PROCEEDINGS

4th FREE & OPEN SOURCE SOFTWARE CONFERENCE

(FOSSC'2019-OMAN)

FOSS as Driver for Technology Transfer, Innovation & Entrepreneurship

Organized jointly by

Communication & Information Research Center (CIRC) at Sultan Qaboos University (SQU)

and

Information Technology Authority (ITA)

Held at Sultan Qaboos University

February 11-12, 2019

FOSS as Driver for Technology Transfer, Innovation & Entrepreneurship

The 4th Free and Open Source Software Conference (FOSSC'2019-OMAN) is jointly organized by the Communication and Information Research Center (CIRC) at Sultan Qaboos University (SQU) and the Information Technology Authority (ITA), on Free and Open Source Software (FOSS) to support the national initiative on FOSS. It is a two days' event and aims to promoting awareness and disseminating the use and development of free and open source software for professionals, staff, students, and the community in Oman. The conference is scheduled for every two years. The previous events were on February 2013, February 2015, and February 2017. The main objective was always to promote the open source software. This conference FOSSC'2019-OMAN will be on 11th and 12th February 2019 and its main theme is "FOSS as Driver for Technology Transfer, Innovation & Entrepreneurship". FOSSC'2019-OMAN targets ICT companies and professionals, researchers, faculties, staff and students and the broader FOSS community. In harmony with the conference main theme, the organizing committee has invited a number of well-known experts who are actively involved in building careers, entrepreneurship and job creation, sustainability of open source communities, role and opportunities of FOSS in public administrations, open source for the public sector, scaling applications for global communities, business management, business information systems, e-collaboration, educational Management and other related subjects to talk in the event. FOSSC'2019-OMAN is a good opportunity to discover, discuss and exchange ideas on FOSS in Oman and beyond. The event will also provide the opportunity to network different groups of FOSS users, benefit from insightful lectures delivered at the conference, and share mutual experiences and discuss potential implementations of FOSS. The organizing committee is inviting managers, and individuals who have passion, researchers, educators, students, and experts from companies, public and private organizations to share their successes in the vast array of free and open source software that is transforming information and communication technology across the globe.

Objectives:

- Support the National Free and Open Source Initiative.
- Promote awareness, use, research and development of Free and Open Source Software in Oman and beyond.
- Strengthen communities and enhance the opportunities on Open Source Software for the ICT Industry in Oman.
- Provide an attractive and sustainable environment for networking FOSS users, researchers, developers and experts.
- Share experiences and exchange successful FOSS developments and applications.

Parallel Activities

In parallel with the conference, there is an exhibition to show cases of the national and international open source solutions and products. In addition, a number of workshops tailored with the needs of local communities have been scheduled in parallel sessions within the conference. FOSS experts from Industry and private and government sectors will present these workshops.

Conference Organizations:

About ITA:

The Information Technology Authority (ITA) was set up by Royal Decree No. 52/2006, promulgated on 31 May 2006, as a financially and administratively independent national authority established to lead the implementation of the e.Oman initiative and bear its national vision and objectives. ITA is responsible for implementing national IT infrastructure projects and supervising all the projects related to implementing Digital Oman Strategy while providing professional leadership to various other e.Governance initiatives of the Sultanate. ITA works with a vision to transform the Sultanate of Oman into a sustainable Knowledge Society by leveraging Information and Communication Technologies (ICTs) to enhance government services, enrich businesses and empower individuals.

The FOSS Initiative was launched in March 2010 during the Free and Open Source Software Symposium in Muscat. The broad objective of Free and Open Source Software Initiative (FOSSI) is to encourage innovation, boost software development talent & skills and create the necessary resources and infrastructure to increase commercialization and industry adoption.

About SQU:

Sultan Qaboos University (SQU), the National University of the Sultanate of Oman, provides a wide variety of undergraduate and graduate programs, research and extension activities through its colleges and research centers. The first batch of SQU students were enrolled in 1986 and the University is playing the role of the national house of expertise, and shoulders the responsibility of providing advanced programs, based on knowledge gained from cutting-edge research of national strategic importance. In addition, SQU's central focus is to develop student learning, promote research and enhance faculty and staff professional development. Sultan Qaboos University consists of nine colleges namely, the College of Agricultural and Marine Sciences, Arts and Social Sciences, Economics and Political Sciences, Education, Engineering, Law, Medicine and Health Sciences, Nursing, and Science. These colleges have specific target plans which guide them in designing their programs in their areas of specializations. Each college is comprised of highly qualified faculty members who are actively involved in teaching, research and community service.

Postgraduate teaching and research are supported by well-equipped laboratories and libraries in various colleges. In addition, a number of research centers support the educational needs of postgraduate students. These are Remote Sensing and Geographic Information System Center, Oil and Gas Research Center, Omani Studies Center, Water Research Center, Center for Environmental Studies and Research, Center of Excellence in Marine Biotechnology, Earthquake Monitoring Center, Humanities Research Center, Earth Sciences Research Center, Sustainable Energy Research Center, Nanotechnology Research Center, Medical Research Center, Innovation and Technology Transfer Center and Communication and Information Research Center (CIRC) which is the co-organizer of this event with ITA. The center's mission is focused on contributing to research and consultancy in ICT, capacity building, setting R&D labs, organizing scientific events, building links with different research and industry units, and cooperating with academicians and researchers within and outside SQU. In 2010, the center jointly with ITA have established the first Free and Open Source Software Students Society (Fo3s). The aim of this society is to spread the concept and culture of free and open source on different events in the Sultanate of Oman.

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Message from the Organizing Committee

It is our great pleasure to welcome you to the Fourth Edition of the Free and Open Source Software Conference, FOSSC'2019-OMAN, jointly organized by the Communication and Information Research Center at Sultan Qaboos University (SQU), and the Information Technology Authority (ITA).

The main theme of our event this year is **"FOSS as Driver for Technology Transfer, Innovation & Entrepreneurship"** which is a continuation of the previous conferences efforts in 2013, 2015 and 2017. In this year, the organizing committee has invited a number of well-known worldwide specialists who are actively involved in various FOSS deployments, strategies and cutting-edge applications and developments. This will help to create an important and attractive and sustainable environment for networking FOSS users, industrials, researchers, developers and experts. Our main goal is to assist our local industries, and to support innovation, entrepreneurship and technology transfer through FOSS.

Twelve invited talks on the conference theme are scheduled for the conference. In addition to the main keynote address, ten workshops, and eleven technical and research papers will be presented on both conference days.

The preparation for this event took almost two years, and the organizing Committee is therefore greatly indebted to all invited speakers, workshop presenters, reviewers and all members of various conference committees from SQU and ITA for their great efforts, time spent and quality assistance to make FOSSC'2019-OMAN a successful addition to their activities and to SQU-ITA collaboration and achievements as well.

The committee would like to wish all the success to the scientific and technical presentations, discussions and networking and look forward to meeting you all in the next FOSSC'2021-OMAN event.

Prof. Abdulnasir Hossen

Chairman of Organizing Committee

Committees

Conference Chairs

- **H.E. Dr. Ali Al-Bemani,**
  Vice Chancellor, Sultan Qaboos University (SQU).
- **Dr. Salim Al Ruzaiqi,**
  Chief Executive Officer of Information Technology Authority (ITA).

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- F. Al Saidi, ITA
- K. Al Gheilani, ITA
- K. Al Maawali, ITA
- R. Lakshmi, ITA
- M. Sarrab, CIRC-SQ

Conference Schedule

Day 1: Monday 11 February 2019

08:00-09:00 am	Registration

SESSION 1: Opening Session

09:00-09:10 am	**Opening**
09:10-09:20 am	**SQU Speech,** Dr. Rahma Al Mahrooqi, DVC-PSR, SQU
09:20-09:30 am	**ITA Speech**, Mr. Hassan Al Lawati, GM for DSDD, ITA
09:30-09:40 am	**FOSSC'2019-OMAN Organizing Committee Speech**, Prof. Abdulnasir Hossen, Chairman
09:40-10:00 am	**Keynote Speaker 1**: Gilles Gravier, Director, Senior Advisor Open Source – Blockchain, Wipro Limited **Title**: Open Source: The Engine behind the Third and Fourth Industrial Revolutions.
10:00-10:30 am	**Exhibition and Innovation Hub Opening/Coffee Break**

SESSION 2: Open Source in Critical Industries

10:30-11:00 am	**Keynote Speaker 2:** Prof. Dr. Dirk Riehle, M.B.A, Professor of Open Source Software at the Friedrich-Alexander University of Erlangen-Nürnberg **Title:** How the Oil and Gas, the Tourism, and the Trading Industry can Benefit from Collaboratively Developing Open Source Software.
11:00-11:30 am	**Keynote Speaker 3:** Frank Karlitschek, Managing Director & Founder, Nextcloud **Title:** The Next Steps for Secure Data Handling and Collaboration
11:30-12:00 pm	**Panel Discussion 1**: Gilles Gravier, Prof. Dirk Riehle, Frank Karlitschek **Moderator**: Dr. Qasim Al Maamari, Assistant Dean of Academic Affairs and Scientific Research, College of Applied Science, Sohar.
12:00-12:30 pm	**Coffee Break**

SESSION 3: Open Source as a Bridge for Technology Transfer

12:30-01:00 pm	**Keynote Speaker 4:** Dr. Nasser Al Zidi, Director of the Center for Information Systems at Sultan Qaboos University (SQU) **Title:** FOSS in SQU, Beyond Cost Cutting
01:00-01:30 pm	**Keynote Speaker 5:** Abhas Abhinav, Founder, DeepRoot GNU/Linux **Title:** Applying the Principles of Free Software to Software Procurement, Development, Deployment and Maintenance
01:30-02:00 pm	**Panel Discussion 2:** Dr. Nasser Al Zidi, Abhas Abhinav, Mario Behling and Ms. Dorothy Gordon **Moderator:** Dr. Ahmed Al Maashri, College of Engineering, Sultan Qaboos University
02:00-03:00 pm	**Lunch**

SESSION 4: Papers Presentation

03:00-03:10 pm	Governing University-Specific Open Source ERP: How Open is Open Enough? ***Wisal Al Bulushi, SQU, Oman***
03:10-03:20 pm	A Case for Open Source Powered Parallel Operating System ***Munesh Singh Chauhan, College of Applied Sciences, Ibri, Oman***
03:20-03:30 pm	Free Open Source Software Logisim – A Perfect Tool for Teaching and Learning of Digital Logic Circuit Design Course – Experience and Status ***Sayyid Samir Al Busaidi and Afaq Ahmad, SQU, Oman***
03:30-03:40 pm	The Impacts of Open Source on IoT Solutions Development ***Fatma Al Shohoumi, Mohammed Sarrab, Dawood Al Abri and Abdulla Al Hamadani, SQU, Oman***
03:40-03:50 pm	Open Source Course Equivalency Framework for HEIs in Oman ***Muhammad Azeem Qureshi, Govindasamy Baskar, Sanyo Moosa and Naser Al Hamar Al Katheeri, College of Applied Sciences, Salalah, Oman***
03:50-04:00 pm	Android Application Permission Model Issues and Privacy Violation ***Zainab R. Al Kindi, Mohamed Sarrab and Nasser Al Zidi, SQU, Oman***
04:00-04:10 pm	Proposed Internet Offline Solution for Rural / Village Schools ***Onno W. Purbo, IBI Darmajaya, XECUREIT, Indonesia***
04:10-04:20 pm	User Modeling for Personalized e-Learning Based on Social Collaboration Interaction ***Amal Al Abri, Zuhoor Al Khanjari, Yassine Jamoussi and Naoufel Kraiem, SQU, Oman***
04:20-04:30 pm	The Smart Learning Management System (SLMS) Development ***Iman Al Kindi and Zuhoor Al Khanjari, SQU, Oman***
04:30-04:40 pm	Free Academic Software and Mobile Applications for Technology Transfer in Oman: A Review ***N.R Wilfred Blessing, SK Wasim Haidar and Khalid Abdullah Salim Al-Mashikhi, Salalah College of Technology, Oman***
04:40-04:50 pm	Ready, Set, Pause: Readiness for MOOCs in the Omani Higher Education Institutions ***Aisha Salim Al Harthi, Wajeha Thabit Al Ani and Iman Rashid Al Kindi, SQU, Oman***
04:50-05:00 pm	**Closing Session**

Day 2: Tuesday, 12 February 2019

08:00-09:00 am	Registration

SESSION 5: Open Source for Innovation

09:00-09:30 am	**Keynote Speaker 6:** Dorothy Gordon, Information for All Programme (IFAP) Chair, UNESCO **Title:** Innovation, FOSS and the Platform Economy: Diversity vs. Dominance
09:30-10:00 am	**Keynote Speaker 7:** Robert "Bob" Reyes, Tech Speaker, Mozilla **Title:** Mixed Reality for the Open Web
10:00-10:30 am	**Keynote Speaker 8:** Matthew Treinish, Open Source Developer Advocate, IBM **Title:** Open Source Quantum Computing
10:30-11:00 am	**Panel Discussion 3:** Ms. Dorothy Gordon, Robert "Bob" Reyes and Matthew Treinish **Moderator:** Dr. Taiseera Al Balushi, Assistant Dean for Postgraduate Studies, Sultan Qaboos University**.**
11:00-11:30 pm	**Coffee Break**

SESSION 6: Open Source as Entrepreneurship Driver

11:30-12:00 pm	**Keynote Speaker 9:** Mario Behling, Serial Entrepreneur, Co-Founder of FOSSASIA **Title:** Business Opportunities through Open Technologies
12:00-12:30 pm	**Keynote Speaker 10:** Gilles Gravier, Director, Senior Advisor Open Source – Blockchain, Wipro Limited **Title:** Choosing an Open Source License and Business Model for the Success of your Project
12:30-01:00 pm	**Keynote Speaker 11:** Kiarash Kiazand, Chief Executive Officer (Member of Board), Cloud Acropolis **Title:** Open Source for Cloud Providers
01:00-01:30 pm	**Keynote Speaker 12:** Arun M, Program Head, International Center of Free and Open Source Software. **Title:** Free software as Driver of Innovation: Experiences from India
01:30-02:00 pm	**Panel Discussion 4:** Gilles Gravier, Arun M, Kiarash Kiazand and Mario Behling. **Moderator:** Dr. Mohammed Al Badawi, College of Science, SQU
02:00 pm	**Closing & Lunch**

Parallel Activities & Workshops

Day 1: Monday 11 February 2019

11:00-11:40 am	**Title:** Building a Better Thermostat **Presenter:** Matthew Treinish, Open Source Developer Advocate, IBM
11:40-12:20 pm	**Title**: FOSS of Machine Learning and its Role in Shaping the Future **Presenter**: Younis Al Anqoudi, Head of Applications Development in Oman Airports
12:20–12:40 pm	**Talk Show1 with:** 1. Frank Karlitschek, Managing Director & Founder, Nextcloud 2. Abhas Abhinav, Founder, DeepRoot GNU/Linux **Title:** Security & Privacy in the age of 4IR
12:40-01:20 pm	**Title**: Open Source at the Heart of Oman's Meteorology **Presenter**: Mohammed Jedad, Head Section of Meteorology Devices Maintenance, PACA
01:20-02:00 pm	**Title:** Digital Privacy and Open Source Software **Presenter**: Mohammed Al Ajmi, Telecom Engineer

Day 2: Tuesday 12 February 2019

09:00-09:40 am	**Title:** Ecommerce Open Source Application: Experience and Issues **Presenter:** Ali Al Rubkhi, CEO of Amal Technology Company
09:40-10:20 am	**Title**: Building an IoT solution using Free Software exclusively (and without relying on the proprietary cloud). **Presenter**: Abhas Abhinav Founder, DeepRoot GNU/Linux
10:20-11:00 am	**Title:** How to get started with Machine Learning with Open Source **Presenter:** Alya Al Shanfari, Founder and CEO, Beennova
11:00-11:20 am	**Talk Show2 with:** 1. Gilles Gravier, Director, Senior Advisor Open Source – Blockchain, Wipro Limited 2. Mario Behling, Serial Entrepreneur, Co-Founder of FOSSASIA **Title:** Innovation & Entrepreneurship in the age of 4IR
11:20-12:00 pm	**Title**: Open Source for Cyber Security **Presenter**: Dr. Mohamed Al Fairuz, College of Economics and Political Sciences, Sultan Qaboos University
12:00-12:40 pm	**Title**: FOSS Entrepreneurship (Mazad Oman Experience) **Presenter**: Mazin Al Saadi, Co-Founder and CTO of Mazad Oman
12:40-01:30 pm	**Title**: FOSS Society (Fo3s) Achievements and Future Plans **Presenter**: Sulaiman Al Mazruii, Zeyad Al Gharabi and Rehab Al Jahwari

Invited Speakers

Prof. Dr. Dirk Riehle, M.B.A, Professor of Open Source Software at the Friedrich-Alexander University of Erlangen-Nürnberg.
Title: How The Oil and Gas, The Tourism, and The Trading Industry Can Benefit from Collaboratively Developing Open Source Software.

Abstract: Many industries need a lot of software. Digitalization is only increasing the need for software. The automotive and the energy industry are example of industries, where companies, which are not software companies, joined forces to collaboratively develop the software they need as open source software. Such joint work frees the involved companies from vendor lock-in and innovation blockage. In addition, it supports the local software industries. In this talk, I will discuss the underlying business model that makes such undertaking sustainable. I will use the German openKONSEQUENZ consortium of energy distribution system operators as an example and speculate on how the same model might apply to other industries like tourism, trading, and healthcare.

Gilles Gravier, Director, Senior Advisor Open Source – Blockchain, Wipro Limited
Title1: Open Source: The Engine Behind the Third and Fourth Industrial Revolutions

Abstract: While open source, also known as free software, has been around for several decades already, it has really become prevalent since the last two decades of the previous century. It drove the penetration of computers into homes, but also into the industrial world, through mini computers and client server computing and the digital revolution. It has now taken the lead role in powering the fourth industrial revolution by being the key engine for the development of the new generations of digital technologies that are propelling us into the future. Let's walk along the history of open source and see how all this happened.

Title2: Choosing an Open Source License and Business Model for the Success of Your Project

Abstract: Open source is often misrepresented as being available for free and thus possibly hard to combine with a successful business model. Let's correct this impression by exploring how open source licenses work, what permissions they give, but also what constraints they bring on developers using the code. We will look at how choosing the right license needs a perfect understanding of what business model it will support. We will go over various business models that are particularly well suited to open source software, and even see that venture capitalists today understand the value of investing in open source projects.

Dorothy Gordon
Information for All Programme (IFAP) Chair, UNESCO

Title: Innovation, FOSS and the Platform Economy: Diversity vs. Dominance

Abstract: Prescriptions for economic success in the digital age highlight the importance of innovation. The dominant messaging is that in this world of 'unbounded opportunities' it is possible for entrepreneurs in any geo-location to achieve global dominance as a result of their determined ingenuity. The role that Open Source technologies play in the scope

and velocity of change that characterize the Fourth Industrial Revolution and global innovation is generally acknowledged. However, platform dominance is a reality of the digital innovation ecosystem and new research indicates the existence of real barriers for digital enterprises in the global periphery. The author will explore some of these contradictions and set out some possible policy interventions drawing on feedback from technology entrepreneurs and focusing on the role of Government and in particular technology decision-makers (TDM). Familiar with the challenges of procurement systems, balancing budgets and wise expenditure of tax payers money towards achieving the SDGs, technology decision makers are not always aware of how their decisions impact on their local innovation economy and eventually the openness and diversity of the global innovation system.

Frank Karlitschek, Managing Director & Founder, Nextcloud
Title: The Next Steps for Secure Data Handling and Collaboration

Abstract: Privacy and security on the internet are under attack by hackers and international espionage programs. If we want to use the internet as a free and secure medium again then we have to fix the internet to provide the security and privacy that people deserve.

The Nextcloud community is build an open source and fully federated and distributed network for files and communication. Everyone can run an Nextcloud server at home or somewhere on the internet and collaborate and share with everyone else. Nextcloud can be used to provide file access, syncing, sharing, calendar, contacts and more in a distributed way. Open Source provides a solution for everyone who doesn't want to use the centralized cloud infrastructure hosted in the US.

This talk will cover the current challenges around security and how user, companies and institutions can protect themselves. It will also discuss the big new features around End to End encryption and self-hosted video/voice communication. It also presents a new architecture to bring the scalability of on premise file sync and share solutions to the next level.

Mario Behling, Serial Entrepreneur, Co-Founder of FOSSASIA
Title: Business Opportunities through Open Technologies

Abstract: The emergence of Free and Open Source software (FOSS) unlocked business opportunities for a new generation of entrepreneurs around the world. Big businesses like Facebook, Google, Twitter and Amazon would not have been possible without Linux and FOSS web applications. What opportunities exist today especially for emerging economies? How does the extension of openness to knowledge, data, and hardware enables local production and new local business models? What kind of setting, culture and environment do Open Tech companies need in order to succeed today? In the talk we will look at how OpnTec in Germany and FOSSASIA in Singapore take advantage of this transition to Open Tech in business and new forms of international collaboration. The twin partners develop Open Source software and hardware solutions with a global developer community and organize Open Technology events around the year. FOSSASIA supports its most promising teams through a business incubator and runs coding programs and development contests like Codeheat to grow its developer community. Startup projects include conversational AIs, science applications and event management tools.

Robert "Bob" Reyes, Tech Speaker, Mozilla
Title: Mixed Reality for the Open Web

Abstract: As Mozilla, the global non-profit behind the Firefox web browser announced a new development program for Mixed Reality that will significantly expand its work in Virtual Reality (VR) and Augmented Reality (AR) for the web, focus will be on how to get devices, headsets, frameworks and toolsets to work together, so web developers can choose from a variety of tools and publishing methods to bring new immersive experiences online – and have them work together in a fully functional way.

Dr. Nasser Al Zidi, Director of the Center for Information Systems at Sultan Qaboos University (SQU)
Title: FOSS in SQU, Beyond Cost Cutting

Abstract: Despite its heavy presence in the back end and server sides, SQU has also adopted many FOSS for some of its core business solutions. In many cases the main motive behind this move was cutting down the licenses and subscription fees which in deed enhances the cost of running our IT solutions. Cost cutting, however, was just the start of many features and benefits of adopting FOSS solutions in academic institutions like SQU. Contribution to the international FOSS community was another noble aim of this move where we plan to register SQU as a major contributor to the development of these systems in different aspects including Arabization. Moreover, staff development and avoidance of vendor lock were other important gains from adopting FOSS solutions in SQU.

Kiarash Kiazand, Chief Executive Officer (Member of Board), CloudAcropolis
Title: Open Source for Cloud Providers

Abstract: Today, Cloud is the only way to go forward. It is not cost effective to run IT internally. Also IT is a major cost factor to companies. Fortunately, Open Source communities have been sitting in the driver seat and are enabling "IT as a Service" to users across the world. The "closed" source business that made a huge amount of money during the past 20 years now realizes the move and try (most of the time without success) to get along with open source.

For Cloud Providers, as the number of subscribers are web scale, the old fashion licensing scheme is not suitable. So either they went on to develop their own technology or they started to use open source. In most recent cases, we see a mix.

The good thing is that today, there are many robust, reliable and secure open source technologies that are adequate for cloud providers. However, the manpower cost to implement and support them is quiet high. This means, cloud providers can start with a smaller capex if they have the right knowledge and capability of the business and technology at the same time.

In this presentation, we will describe the open source technologies that are available today to run a commercial cloud company. We only will discuss the robust, performant and secure technologies with an integrated view for enabling such business.

Matthew Treinish, Open Source Developer Advocate, IBM
Title: Open Source Quantum Computing

Abstract: Quantum computers are not just science fiction anymore, with many companies building increasingly more powerful quantum computers. While, concepts in quantum computing have been around for over 30 years, it hasn't been generally accessible until recently. Despite this quantum computing is still very much in its infancy and there are physical limitations preventing them from being generally usable. But the machines that are available today are useful for experimentation and showcasing certain applications where they will be useful in the future. Open source software for quantum computing has started being developed as these new machines are being built. Learning the lessons from the history of developing classical computers, there are already several open source SDKs, languages, and libraries being developed for quantum computers despite the current limitations of quantum computers. This means as the technology matures and becomes more practical there will already be an open source ecosystem for using quantum computing. This talk will provide an introduction to the basics of quantum information theory, look at some of the quantum computers out there, explore the open source tooling available for quantum computing, and show how you can use that to write your own quantum programs and run them on simulators and actual quantum computers.

Arun M, Program Head, International Center of Free and Open Source Software.
Title: Free Software as Driver of Innovation: Experiences from India

Abstract: Building technological capability is essential for development of any region in the planet. For regions lagging behind the world frontier in a technology shall try to catch-up with frontier in capability. Research brings out the fact that this Catch-up is essentially same as innovation, though different from one that happen in frontier. Access to knowledge, learning and entrepreneurship are essential to this catch-up.

In the context of ICT, free software movement is creating an unparalleled opportunity in catch-up. However, appropriate policies are necessary to translate this opportunity into a reality. This presentation looks into some experience from India. In particular, presentation will bring out important role state play in facilitating Catch-up.

Abhas Abhinav Founder, DeepRoot GNU/Linux
Title: The Principles of Free Software to Software Procurement, Development, Deployment and Maintenance.

Abstract: Organizations of all sizes regularly choose Free Software to build their IT systems. These include network, server, desktop and cloud infrastructure. While it is easy to get cost, technology and productivity advantages by choosing Free Software, it takes some more effort and awareness to gain the advantages of the inherent freedom in such solutions. Learning how to use the freedom aspect of Free Software to our advantage will make our implementations scalable, maintainable, transparent, secure, extensible, private and self-sufficient. These are the intangible and long-term benefits of free software and one way to have them is to keep optimizing for freedom and self-hosting. The talk will focus on how to apply the principles of free software to software procurement, development, deployment and maintenance such that it yields the advantages listed above. It will also illustrate (with some examples and case studies) why it is important to do this and the dangers of only focusing on the easy and immediate advantages of employing free software. Finally, the talk will conclude with a road-map of how our awareness, involvement and focus on these aspects can enrich our organizations and enable us to build greater in-house competency and capability.

Workshops

Dr. Mohamed Al Fairuz, College of Economics and Political Sciences, Sultan Qaboos University
Title: Open Source for Cyber Security

Abstract: Cyber security has become an integral part of any information system. In this interconnected world, there are many threats exist, and many anonymous attackers are continuously scanning for vulnerable systems to compromise users' accounts. Therefore, online service providers are required to implement strong authentication to protect their services. The amount of proof a user is required to provide increases or decreases based on the amount of risk associated with the services or resources delivered. This workshop will look on how Open Source utilities help in improving the cyber security of systems in the untrusted Internet world.

Mohammed Jedad, Head Section of Meteorology Devices Maintenance, Public Authority Civil Aviation (PACA)
Title: Open Source at the Heart of Oman's Meteorology

Abstract: The Directorate General of Meteorology in PACA is depending heavily on different Open Source products to operate their weather radars and weather analysis tools and other systems. This workshop will discuss PACA experience with different Open Source products specifically GNU/Linux OS deployments and capacity building efforts around open technologies.

Matthew Treinish, Open Source Developer Advocate, IBM
Title: Building a Better Thermostat

Abstract: After returning from a recent trip that occurred during the middle of a heat wave. Matthew arrived home to find his apartment quite hot, at least 45C inside. Needless to say it wasn't the most comfortable way to come home after 15 days out of town, he decided it was time for him to do something about it to address this so he didn't come home to that unpleasant surprise again. Normally, this problem is solved by having a thermostat which controls the air conditioning. However, his apartment did not have a thermostat. So he decided to build one using open source software!

This workshop will cover how he went about solving his problem using existing software and protocols like home-assistant, MQTT, and also some new software that was created for this. It'll also discuss how by using open software and home automation he was able to solve his issue but also make cooling his apartment smarter.

Abhas Abhinav Founder, DeepRoot GNU/Linux
Title: Building an IoT Solution Using only Free Software

Abstract: This workshop is going to help the participants to become aware different IoT aspects and show them ways of build IoT solutions that are powered by Free Software exclusively and that can even be self-hosted on the local network. This includes examples of the programming environments, build systems, data collection and storage back-ends, the remote control, remote access and networking systems and data analysis and visualization.

Using the pointers provided in the workshop, participants will be able to have more control on their IoT projects and will be able to build products that respect the privacy and freedom of their users.

Mazin Al Saadi, Co-Founder and CTO of Mazad Oman
Title: FOSS in Entrepreneurship (Mazad Oman Experience)

Abstract: FOSS in one of poles of entrepreneurship, most of entrepreneurs start their ideas using FOSS. Mazad Oman is one of those ideas start and still using FOSS toward innovation and successful business model.

Mohammed Al Ajmi, Telecom Engineer
Title: Digital Privacy and Open Source Software

Abstract: Digital privacy is always a hot topic in the scene of digital world booming, especially with not mature mass. This is due to the fact that personal data can be miss-used to affect our reputations, influence our decisions and shape our behaviors on the internet. In addition, the most concern threat here is that personal data can be utilized as a tool to exercise control over us and to cause a great harm! However, this threat can be converted into an opportunity to mitigate the risk associated with our digital privacy while using the internet. This can be achieved by considering the free and open source software as a vital player in protecting our digital privacy. Therefore, the talk will cover this topic by highlighting the important definitions, impact of the digital privacy, unlawful practice of large companies, and the potential of open source software in protecting the digital privacy.

Alya Al Shanfari, Founder and CEO, Beennova
Title: How to Get Started with Machine Learning with Open Source

Abstract: As machine, learning is being adopted to solve more and more interesting — yet more and more challenging — problems, the demand for individuals who can develop machine-learning applications is dramatically increasing. Google has created on open source technologies to allow a faster learning process to be knowledgeable in machine learning. One of the leading project for both machine learning and open source is TensorFlow. TensorFlow is an open source software library created by Google that is used to implement machine learning and deep learning systems.

Ali Al Rubkhi, CEO of Amal Technology Company
Title: ECommerce Open Source Application: Experience and Issues

Abstract: Open Source Software ecosystems have restructured the ways how software-intensive companies develop products and deliver value to customers. Open Source eCommerce projects often face challenges like complex product structures, complex pricing structures, complex availability calculations, thousands of customer groups with specific assortments, highly agile requirements and well documentation of the source files. Therefore, this speaking session we have a clear discussion in e-Commence open source application. The issues, challenges, and experience will be the core main speaking topics.

Younis Al Anqoudi, Head of Applications Development in Oman Airports, PhD researcher in Machine learning at Sultan Qaboos University

Title: FOSS of Machine Learning and its Role in Shaping the Future

Abstract: Artificial intelligence is a dream that industry innovators being living with for a long time and Machine learning there exist promising applications that are making humans life simplified with smart features integrates lots of technologies to serve better human life experience.

Sulaiman Al Mazruii: Junior Student at Electrical and Computer Engineering Department, College of Engineering, Sultan Qaboos University, Chair of Free and Open Source Software Students Society.

Zeyad Al Gharabi: Junior Student at Department of English Language and Literature, The College of Arts and Social Sciences, Sultan Qaboos University, Former Chair of Free and Open Source Software Students Society.

Rehab Al Jahwari: Junior Student at Electrical and Computer Engineering Department, College of Engineering, Sultan Qaboos University, Chair of Publicity Committee at Free and Open Source Software Students Society.

Title: FO3S Achievements and Future Plans

Abstract: Since open source software movement started, a lot of communities started to embrace it due to its openness, cutting cost, and security aspects that it has provided. The open source software value has increased until it became the main part of our daily life in many different applications. That is why we "FO3S" student society at Sultan Qaboos University dedicate efforts to spread awareness about Free and Open Source software movement to contribute in the development and share the benefits of this important field. This workshop will focus on the achievements of our free open source software society FO3S and the future plans at Sultan Qaboos University.

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74-76	Ready, Set, Pause: Readiness for MOOCs in the Omani Higher Education Institutions *Aisha Salim Al Harthi, Wajeha Thabit Al Ani and Iman Rashid Al Kindi, SQU, Oman*

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Governing University-Specific Open Source ERP: How Open is Open Enough?

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***Abstract*— Open source software (OSS) is considered as a solution to the classic build-buy dilemma associated with information technology adoption process in the higher education sector. Adopting and implementing OSS in the higher education sector is regulated through appropriate governance mechanisms that merge OSS concepts with higher education policies. The current literature on OSS governance is dominated by explanations that are focused on infrastructural applications with standard requirements, such as operating systems. This research realizes that OSS has developed and moved towards domain-specific applications that serve particular industries; higher education sector in particular. A case study has been conducted on Kuali, a unique OSS community that is focused on developing and maintaining a university-specific open source ERP system. This research illustrates that governing OSS communities requires balancing between openness and control; i.e. determining "how open is open enough". Governance practices are not fixed; rather they emerge and evolve as the community evolves. In addition, this research redirects the attention of OSS governance scholars towards the promising OSS communities built around domain-specific applications.**

***Index Terms*—Open source software, Open source governance, ERP systems.**

INTRODUCTION

Open source software (OSS) was initially restricted to back-office infrastructural software products. However, today, OSS products are increasingly moving from the invisible, back-office domains towards more visible, front-end, sector-oriented domains [1, 2]. In addition, OSS has grown into a software development approach and a strategic business model. Reputable firms adopt OSS as their business models and place their products into OSS communities to attract innovation [3]. Therefore, numerous studies realized the need to extend the OSS governance literature to cover applications tailored for the need of service organizations [1, 4, 5]. However, governing domain-specific OSS is an overlooked area of research that requires further study [5, 6].

OSS is developed and maintained through the collaborative effort of diverse and geographically distributed individuals and organizations that form an OSS community. The community members utilize shared resources to develop software under OSS license. This type of license allows the source code to be freely available to the public for use, modification, and redistribution [7]. Collaborations between OSS community members are based on concerted rules, values, and norms [7, 8]. However, governance is scattered among different entities and artefacts due to the dispersed nature of the community. Besides, the community lacks a unified formal organizational structure, and thus create challenges to understand OSS governance [5]. The relevant literature provides empirical evidence that following OSS approach is a powerful method to create, maintain, and sustain software [9]. This highlights the significance of understanding how OSS is governed.

Governing OSS communities is defined as the formal and informal means to control and coordinate the collective efforts towards common objectives [10]. The governance structure of OSS communities emerges through collaboration, and thus such communities are described as fluid [11]. Participants, technical artefacts, ideas, resources, and interactions are fluid in the sense that they are reconfigured over time, depending on the overall context. This has raised governance challenges in terms of determining "how open is open enough" [12]. Therefore, in order to govern OSS communities, it is critical to determine whether to open the boundaries to all and risk the quality of the deliverables, or restrict the community to an elite population, which restrains innovative collaboration [13].

In this paper, it is argued that OSS communities are governed by changing the intensity of openness based on the context [14]. Openness refers to the degree of transparency and accessibility of the source code and the technical

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unpredictable scale of the project, and the uncertainty of the outcomes created challenges on selecting suitable mechanisms to govern OSS communities [10, 18].

The topic of OSS governance has attracted the interest of scholars and thus developed a literature of its own that is different from information technology governance [9]. However, current studies failed to provide a clear definition for OSS governance [5]. When explaining OSS governance, the literature mainly focuses on how the community is built [7], and how diverse collaborators share a basis of authority [19] and govern themselves in communities that create and maintain horizontal applications [4]. Horizontal, in this context, refers to the applications that are characterized by standard technical requirements and serve variety of users regardless of their professions, such as operating systems, web servers, and email servers. These applications often attract the interest of developers with non-specific development capabilities. Accordingly, the current literature mainly explains OSS governance as processes that are practiced on loosely coordinated software developers voluntarily contributing to the community, where tasks are self-assigned, and the development process is not restricted to project deadlines or list of deliverables [20, 21].

In general, OSS governance is explained in terms of culture, structure, and process [7]. The cultural perspective describes OSS governance as value-driven practices that are influenced by OSS ethos, such as altruism, reciprocity, and reputation [8]. Scholars that adopt a structural perspective highlight the fluidity of OSS communities. Their studies illustrate that OSS governance structure emerges from the communication patterns between the contributors. Hence, different communities form different governance structures [3]. Finally, the advocates of the process view explain OSS governance as a set of rules and practices, such as control, coordination, membership, and communication processes [9, 22].

The current explanations of OSS governance do not sufficiently realize that the settings of the OSS communities have changed overtime [14]. It is evident that OSS communities are rapidly moving towards sector-oriented applications that are domain specific, created for strategic reasons, and targeting users within a specific domain (i.e. sector or industry). Yet, the literature lacks empirical evidence on governing such communities [6]. Therefore, this research sheds a light in governing Kuali; an open source ERP system. Kuali is considered as a domain-specific OSS community that attracts developers who are experienced and skillful in the higher education sector [4], and provide a different user experience and non-technical processes related to the OSS development [15]. Transparency is about viewing the source code and the associated technical and administrative details, including the discussions among the members and the documentations. Accessibility is about granting the access to change the source code and influence the future direction of the OSS product. Determining the openness of the OSS community becomes more critical when dealing with domain-specific communities. The collaborative effort has to be aligned with the overall objectives of the domain.

Open source enterprise resource planning (ERP) systems built for the higher education sector are examples of domain-specific OSS. Creating an open source ERP community in the higher education sector requires a well-defined IT strategy that aligns the OSS concepts with the objectives of the higher education institutions [16]. This research aims to explain how domain-specific OSS communities govern the collaborative effort. A case study has been conducted on an OSS community called Kuali. Kuali community builds and maintains an open source ERP system that its tailored for universities. The findings illustrate that OSS communities are governed by changing the intensity of openness as the community evolves. This means that the community is governed by changing its boundaries over time through including and excluding resources and rules depending on the context.

LITERATURE REVIEW

OSS communities are considered as special forms of organization that differ from the predictable hierarchal and market structures [17]. Accordingly, they are governed through special governance mechanisms to control and coordinate the diverse resources in order to achieve mutual objectives [10]. This section begins by reviewing the literature with regards to OSS governance in general. Then, it reviews the current studies that highlight the importance of introducing OSS concepts to the development of ERP systems in universities. Finally, it illustrates the importance of having contextualized explanations of OSS governance to cope with the revolution that have occurred to OSS community settings.

OSS Governance

OSS products are developed through the continuous collaboration of geographically dispersed individuals and organizations with multiple interests. Therefore, OSS is considered as a community-driven software development process that requires effective governance mechanisms to ensure the sustainability of the collaborative effort [17]. However, the dispersed community, the diversity of participants, the conflicting interests of contributors, the

ERP system due to the availability of the source code.

The concepts of OSS were introduced to the community of universities since the 1960's. At that time, software development was mainly performed by scientists and engineers in research labs. Freely sharing and exchanging the source code for modifications and improvements was a popular act [7]. Prominent examples of back-end OSS products that were developed in universities are Linux and Apache. They were located in data centers, and used only by specialists [32]. As technology advanced, there was a high demand on involving end users (e.g. students, staff, faculty) in defining business requirements. This was evident in university-specific applications like learning management systems [28]. As a result, the community of universities successfully produced outstanding systems as OSS solutions, such as Moodle and Sakai[1]. This success showed that OSS development practices are more effective when the developers are also users of the software. This has encouraged universities to introduce OSS concepts in the development of enterprise level information systems, such as Kuali; the focus of this paper

Governing Domain-Specific OSS

The transition from back-end to front-end OSS products gave rise to domain-specific OSS. Domain-specific OSS initiated new working practices into the professional software development process [1]. Initially, in typical OSS communities, the software development process is mainly driven by the participants' willingness to contribute [20]. Therefore, the self-governed participants collaborate efficiently despite the absence of formal contracts and managerial authority [21]. However, domain-specific OSS products are maintained by the efforts of selective knowledgeable group of developers (mainly employees) to achieve the objectives of a particular domain [4].

This means that OSS domain-specific community reconfigured the conventional OSS governance practices to meet the requirements of the target domain [1]. For example, the conventional OSS membership process has been reconfigured to invite specific individuals and organizations based on certain criteria [13]. Besides, the produced software is published under a more restrictive OSS license in compliance to the target domain [33]. Moreover, the communications among the community members are performed through secured channels [1]. Most important, domain-specific communities are gated granting specific individuals to contribute to the in comparison to the horizontal voluntarily-based OSS communities [23]. The next section, briefly reviews how open source ERP systems were introduced to the higher education sector.

University-specific Open Source ERP Systems

ERP systems are comprehensive software packages that optimize and integrate the fragmentation of information in business organizations [24, 25]. The main aim of ERP systems is to increase the efficiency of service and product delivery process by facilitating the compatibility between business management and information technology concepts [25]. ERP implementations attract the interest of researchers and practitioners due to their high financial and organizational investments [26, 27]. However, ERP systems are generic solutions [24] that have been developed for manufacturing organizations, overlooking the requirements of service organizations, such as the higher education sector [27]. Although many software vendors started implementing ERP solutions for service sectors, such as SAP and Oracle, their functional modules experience high rate of customization [28].

ERP systems are the largest information system adopted by universities, however less research is conducted with regards to ERP implementations in this particular sector [28]. Similar to other service sectors, the higher education sector was encouraged to adopt ERP solutions with the same objectives of the corporations, such as increasing operational efficiency and decreasing costs, jeopardizing the core functionalities of the service organization. As a result, the higher education section often faces the dilemma of build or buy when adopting, developing, and maintaining ERP systems [29].

The OSS solution has introduced the concept of 'collaboration' to the software development process by merging the benefits of 'build' and 'buy' options [16]. The benefits of adopting an OSS solution goes beyond the absence of licensing costs. The OSS path promotes collaboration and capacity building, and pools resources from multiple organizations to build OSS applications that can be used by everyone [29]. Besides, it separates the software development process from support and maintenance. This separation grants universities the control over the future direction of the software [30]. Most important, ERP implementation is an on-going process because it continuously requires adapting the business processes with the local regulations [31]. Adopting an OSS solution facilitates the adaptability of the

[1] [1]Moodle and Sakai are open source learning management systems used in schools and universities

added various ERP modules, such as the research and student modules. Each module was considered as an OSS project. Moreover, Kuali community invited non-American universities to participate in order to enrich Kuali projects.

With the expansion of scope and the promotion of internationalization, Kuali founders realized that the requirements and work practices of Kuali ERP system varied based on the module and the context of countries. It was necessary to form a foundation to ensure consistent governance practices across different contexts. Accordingly, in 2006, the not-for-profit Kuali Foundation was established to facilitate collaboration between various HE institutes in the development of OSS. The membership of Kuali Foundation was open to any HE institute, i.e. universities, colleges, and research centers. Also, membership was open to for-profit or not-for-profit organizations to provide complementary services to the community, such as data migration, implementation, and supporting services.

During the first decade, the implementation of Kuali ERP system was performed only by university employees and contractors, and according to higher education rules and policies. These restrictions created challenges to cope with the increasing demands and expectations of the stakeholders. As a result, in 2014, Kuali community created a for-profit company called KualiCo to overcome the challenges and sustain Kuali ERP system.

Data Collection and Analysis

The data collection initially started with an in-depth study of Kuali documents in order to gain familiarity with the community settings. These documents include email discussions, Kuali Board meeting minutes, and technical guides. A free Kuali online account was created to obtain access to the archived documents. The data collection also included Kuali official videos that are published on Kuali official YouTube channel. These videos were reviewed and transcribed. The data collection process also involved 16 semi-structured interviews that were conducted via Skype and Google Hangouts applications. The interviewees are categorized into administrators and technicians. They were employee that worked for Kuali Foundation, Kuali commercial affiliates, or the contributing universities.

TABLE 1: SUMMARY OF DATA ANALYSIS

software development process [17]. This is necessary in order to control the future direction of the OSS product.

METHODOLOGY

A single case study was conducted using grounded theory approach to gain an in-depth understanding of governing domain-specific OSS communities. The case, Kuali, has been selected for its uniqueness as it demonstrates features that have not been addressed in the relevant literature. In particular, Kuali community consist of known employees of the contributing universities and companies. The members are they obliged to contribute as it is part of their job responsibility. Besides, Kuali community is gated. Joining, leaving, and contributing to the community are performed according to rules that are set by the higher education sector in USA, as will be further explained in the next section[2].

Organizational Settings

Kuali is an OSS community governed by Kuali Foundation to develop an ERP system for universities by university employees. According to Kuali Foundation [34], Kuali community was initiated in USA by Indiana University (IU) in 2004. At that time, the decision makers in IU decided to replace IU's technically obsolete financial system. However, it was clear from the beginning that they did not want to go through the painful experience of evaluating 'build' and 'buy' options. They took a decision to explore the option of 'collaboration' by looking for strategic alliances interested in developing a shared financial application tailored for the higher education sector in USA. As a result, IU and a group of universities started-off with implementing an open source university-specific financial system that was then named Kuali Financial System (KFS).

The functionalities of KFS were based on the IU's legacy financial application; however, it was built on a more advanced technology. Besides, Kuali community followed a special form of OSS process called the community-source approach. This approach entailed opening-up the OSS code and gating the OSS development process. This gate was done by implementing Kuali-specific framework called Rice to align the OSS development process with the higher education settings in USA.

The success of KFS attracted the interest of the higher education institutes in USA. Accordingly, in 2005, Kuali community decided to expand its scope from finance system only to a full open source ERP suite. Gradually, Kuali community

[2] [2]The case study is based on the author's PhD thesis. The thesis can be found in: http://eprints.nottingham.ac.uk/52074/1/FullThesis-Wisal.pdf

continuous changes in the surrounding context. Table 2 summarizes the three governance phases.

TABLE 2: SUMMARY OF THE FINDINGS

	Creating the Community (2004-2006)	**Balancing Interests (2006-2014)**	**Sustaining the Community (2014-)**
Conditions (Analysis & Design)	Technically obsolete ERP systems in USA universities	Diverse Kuali projects (finance, research, student) Inviting international universities	Inviting international universities.
Governance practices	Controlling the code	Structuring the community, setting properties of OSS code, managing divergent interests, facilitating collaboration	Restructuring the community, reconfiguring coordination and communication
Consequences	-Gated community -Universities are the controllers -Enforce Rice framework -Prompted the need for a full ERP suite	-Tight control -Projects struggle with restrictive Rice -Projects are progressing slowly -Triggered the need to rethink Kuali strategy and spinout KualiCo	-KualiCo is the controller -Kuali transformed from foundation-led to company-led

The first governance phase, "creating the community", refers to the governance practices that were associated with the inception of Kuali community in 2004. The aim was to build a university-specific OSS community to disallow non-universities from influencing the functionalities of the finance system. Therefore, controlling the code was the salient governance practice at that time. Control was practiced through gating the community; i.e. restricting the development to the community of universities only. Control was also practiced by enforcing Rice framework that restricts developers to follow a defined set of development rules.

Sample Concepts	**Categories**	**Governance phases**
Fulfilling HE needs, Gating the community, Selecting resources	Controlling the code	Governance Phase1: Creating the community
Membership and partnership, Assigning roles	Structuring the community	Governance Phase2: Balancing the interests
Who can contribute, How to control contributions	Setting properties of OSS code	
Balancing university and community needs, Means of communication	Facilitating collaborations	
Creating KualiCo, Adjusting community roles	Restructuring the community	Governance Phase3: Sustaining the community
Adjusting technical artefacts, Adjusting means of communication	Reconfiguring coordination and communication	

Following grounded theory approach, data collection and analysis were performed simultaneously and were guided by theoretical sampling [35]. Two main stages of analysis can be identified. The first stage involved a line-by-line reading of the collected data and breaking data into manageable pieces. Then these fragmented data were examined and compared for similarities and differences. The output of this phase is a list of concepts that describe the routines and activities related to governance in Kuali community. These concepts were then aggregated into categories that correspond to governance practices.

The second stage aimed to reassemble the data that was fractured during the previous stage. The categories that have emerged from the first stage of analysis are not standalone [36]. Instead, their properties are connected and can be aggregated in a hierarchal, linear, or recursive form. Given that the categories correspond to governance practices that have changed as Kuali community evolved, the categories were arranged in a chronological order, as shown in table 1. This arrangement illustrates that Kuali community went through three major governance phases. Each phase was triggered by certain conditions, experienced specific set of practices, and produced consequences, as will be further explained in the next section.

FINDINGS AND DISCUSSION

The research findings resonate with the emerging themes in the literature of OSS governance, in particular the changing nature of both the OSS community settings [2] and OSS governance practices [9]. Kuali community went through three governance phases. I have labelled the phases according to the main objectives of the phase. The phases are: creating the community, balancing the interests, and sustaining the community. Each governance phase was triggered by conditions that were identified through a continuous process of analysis and design. Besides, each phase included/excluded various rules, resources, and individuals to cope with the

shown in table 3, the meaning of openness evolved as the context of Kuali changed over time. This contextualized explanation of OSS governance is a response to a growing call to consider the context. For example, Mäenpää, et al. [3], in their recent study, emphasized on the importance of providing empirically-grounded explanations of OSS governance.

Moreover, one of the significant research findings is emphasizing on the role of analysis and design in governing OSS communities. In the software development literature, analysis and design are known to be typical processes in the software development life cycle. However, their importance is overlooked in the OSS literature. These findings are broadly in line with recent studies. For example, Vlas, Robinson, and Vlas [37] that shed a light on the dynamic requirements of complex setting such as OSS communities.

CONCLUSION AND IMPLICATIONS

The research has two main contributions. First, it provides empirical evidence on an overlooked area of OSS research; domain-specific OSS. The current studies are built on taken-for-granted assumptions that neglect the transformations that have occurred to OSS and communities. Current studies focus on autonomous OSS communities where collaborations are not tied to contracts and thus developers are not obliged to contribute. On the other hand, the contributors in Kuali community are employees and their participation to the community is a part of their job responsibility.

Second, although scholars acknowledge that OSS communities are fluid and OSS governance is emergent and adaptive, yet they explain OSS governance using static perspectives. This research provides a dynamic view that acknowledges the versatility of OSS governance. The research showed how the governance practices transformed Kuali community from foundation-led to company-led to determine "how open is open enough" based on the surrounding context. This was essential to ensure the sustainability of the collaborative effort.

This research also has important practical implications, especially in light of the proliferation of OSS communities in various industries. The research findings illustrate that introducing OSS concepts into the higher education sector has impact beyond technology and software development. Universities gained higher control over the future direction of their ERP systems, and thus they were capable of eliminating exorbitant cost incurred by proprietary lock-in. Besides, the findings highlights that governance is inseparable from its context. Therefore, the research findings encourage practitioners to be aware of the

The second governance phase, "balancing the interests", has emerged in 2005 when the community expanded its scope to a full ERP-suite which required inviting new perspectives and resources to the community. This has caused the formation of Kuali Foundation in 2006 to facilitate governance practices. The salient governance practices were structuring the community, setting the properties of the OSS code, managing divergent interests, and facilitating collaborations.

As the community evolved, it faced several administrative and technical challenges to fulfill the needs of the diverse stakeholders. As a result, "sustaining the community" emerged as the third governance phase. The Foundation formed KualiCo company to control the direction of Kuali projects. KualiCo commercialized some of Kuali products and added paid cloud-based services. In other words, Kuali community was transformed to a hybrid form that merges market-based concepts with OSS concepts. Creating a hybrid OSS community has also been discussed in the current literature as a mean to sustain the community; however, it influences the governance practices [3, 22]. This was evident during the third phase of Kuali life were restructuring the community, and reconfiguring coordination and communication emerged as salient governance practices.

As summarized in table2, each governance phase was triggered by conditions that were influenced by the surrounding context in a particular time. Therefore, the governance practices were contextualized. In other words, the governance practices were not fixed. They emerged and evolved based on the context. Besides, table 2 illustrates that the surrounding context was not passive. Instead, governance practices produced consequences that changed the surrounding context. It is evident that the governance practices of Kuali were adapted to the growing complexity of Kuali community.

TABLE 3: MEANING OF OPENNESS CHANGED AS KULAI EVOLVED

Governance Phase	**Degree of Openness**
Phase1: Creating the community	Open-up the OSS code and gate the OSS development process.
Phase2: Balancing the interests	Create configurable & customizable features to satisfy diverse interests
Phase3: Sustaining the community	Merge OSS & market concepts

The research findings illustrate that Kuali was governed by balancing between openness and control. This was achieved by changing the boundaries of the community through time, i.e. including/excluding rules and resources. This means that OSS is not the opposite of closed or proprietary software; rather it refers to the intensity of openness that serves a particular context. As

specificity of the context in governing OSS communities.

REFERENCES

Rolandsson, B., M. Bergquist, and J. Ljungberg, *Open Source In The Firm: Opening Up Professional Practices Of Software Development.* Research Policy, 2011. **40**(4): p. 576-587.

Chauhan, S., et al., *Determinants of Adoption for Open-Source Office Applications: A Plural Investigation.* Information Systems Management, 2018. **35**(2): p. 80-97.

Mäenpää, H., et al., *Organizing for Openness: Six Models for Developer Involvement in Hybrid OSS Projects.* Journal of Internet Services and Applications, 2018. **9**(1): p. 17.

Fitzgerald, B., *The Transformation of Open Source Software.* MIS Quarterly, 2006. **30**(3): p. 587-598.

Crowston, K., et al., *Free/Libre Open-Source Software Development: What We Know and What We Do Not Know.* ACM Computing Surveys, 2012. **44**(2).

Roumani, Y., J.K. Nwankpa, and Y.F. Roumani, *Adopters' Trust in Enterprise Open Source Vendors: An Empirical Examination.* Journal of Systems and Software, 2017. **125**: p. 256-270.

von Krogh, G., et al., *Carrots and Rainbows: Motivation and Social Practice in Open Source Software Development.* MIS Quarterly, 2012. **36**(2): p. 649-676.

Stewart, K.J. and S. Gosain, *The impact of ideology on effectiveness in open source software development teams.* MIS Quarterly, 2006. **30**(2): p. 291-314.

Shaikh, M. and O. Henfridsson, *Governing Open Source Software through Coordination Processes.* Information and Organization, 2017. **27**(2): p. 116-135.

Markus, M.L., *The Governance Of Free/Open Source Software Projects: Monolithic, Multidimensional, Or Configurational?* Journal of Management & Governance, 2007. **11**(2): p. 151-163.

Faraj, S., S.L. Jarvenpaa, and A. Majchrzak, *Knowledge Collaboration in Online Communities.* Organization Science, 2011. **22**(5): p. 1224-1239.

West, J., *How open is open enough? Melding proprietary and open source platform strategies.* Research policy, 2003. **32**(7): p. 1259-1285.

Ferraro, F. and S. O'Mahony, *Managing the Boundaries of an "Open" Project*, in *The Emergence of Organizations and Markets*, J.F. Padgett and W.W. Powell, Editors. 2012, Princeton University Press. p. 545-565.

Curto-Millet, D. and M. Shaikh, *The Emergence of Openness in Open-Source Projects: The Case of OpenEHR.* Journal of Information Technology, 2017: p. 1-19.

West, J. and S. O'Mahony, *The Role of Participation Architecture in Growing Sponsored Open Source Communities.* Industry and Innovation, 2008. **15**(2): p. 145-168.

Wheeler, B., *Aligning IT strategy to open source, partnering, and Web services.* EDUCAUSE Center for Analysis and Research (ECAR), 2003. **2003**(24).

Shah, S.K., *Motivation, Governance, and the Viability of Hybrid Forms in Open Source Software Development.* Management Science, 2006. **52**(7): p. 1000-1014.

Winter, S., et al., *Beyond the Organizational 'Container': Conceptualizing 21st Century Sociotechnical Work.* Information and Organization, 2014. **24**(4): p. 250-269.

O'Mahony, S. and F. Ferraro, *The Emergence of Governance in an Open Source Community.* Academy of Management Journal, 2007. **50**(5): p. 1079-1106.

Howison, J. and K. Crowston, *Collaboration Through Open Superposition: A Theory of the Open Source Way.* MIS Quarterly, 2014. **38**(1): p. 29-50.

Aaltonen, A. and G.F. Lanzara, *Building Governance Capability in Online Social Production: Insights from Wikipedia.* Organization Studies, 2015. **36**(12): p. 1649-1673.

Schaarschmidt, M., G. Walsh, and H.F. von Kortzfleisch, *How Do Firms Influence Open Source Software Communities? A framework and Empirical Analysis of Different Governance Modes.* Information and Organization, 2015. **25**(2): p. 99-114.

Benlian, A. and T. Hess, *Comparing the Relative Importance of Evaluation Criteria in Proprietary and Open-Source Enterprise Application Software Selection–A Conjoint Study of ERP and Office Systems.* Information Systems Journal, 2011. **21**(6): p. 503-525.

Davenport, T.H., *Putting the Enterprise into the Enterprise System.* Harvard Business Review, 1998. **76**(4): p. 121-31.

Al-Mashari, M., A. Al-Mudimigh, and M. Zairi, *Enterprise Resource Planning: A Taxonomy of Critical Factors.* European Journal of Operational Research, 2003. **146**(2): p. 352-364.

Motwani, J., R. Subramanian, and P. Gopalakrishna, *Critical Factors for Successful ERP Implementation: Exploratory Findings from Four Case Studies.* Computers in Industry, 2005. **56**(6): p. 529-544.

Botta-Genoulaz, V. and P.A. Millet, *An Investigation into the Use of ERP Systems in the Service Sector.* International Journal of Production Economics, 2006. **99**(1): p. 202-221.

Chaushi, B.A., A. Chaushi, and F. Ismaili. *ERP Systems in Higher Education Institutions: Review of the Information Systems and ERP Modules*. in *2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*. 2018. IEEE.

Brooks, L. *Considering Open Source: A Framework for Evaluating Software in the New Economy*. EDUCAUSE Center for Analysis and Research (ECAR), 2007.

Wheeler, B. *The Inevitable Unbundling of Software and Support*. 2004.

Serrano, N. and J.M. Sarriegi, *Open Source Software ERPs: A New Alternative for an Old Need.* IEEE software, 2006. **23**(3): p. 94.

Masson, P., *Open Governance in Higher Education: Extending the Past to the Future.* EDUCAUSE Review, 2011. **46**(1): p. 44.

de Laat, P.B., *Governance of Open Source Software: State of the Art.* Journal of Management & Governance, 2007. **11**(2): p. 165-177.

Kuali Foundation. *Kuali Foundation*. 2014 25/03/2015]; Available from: https://www.kuali.org/.

Charmaz, K., *Constructing Grounded Theory*. 2nd ed. 2014: Sage.

Goulding, C., *Grounded Theory: A Practical Guide for Management, Business and Market Researchers*. 2002: Sage.

Vlas, R., W. Robinson, and C. Vlas, *Evolutionary software requirements factors and their effect on open source project attractiveness*, in *Proceedings of the 50th Hawaii International Conference on System Sciences*. 2017.

A Case for Open Source Powered Parallel Operating System

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Abstract— **Open source platform has been a harbinger of major change in the manner software is being used by the industry. Open source software in cutting edge technologies provide a rare opportunity to all of us to experiment and compute at abysmally low costs (both software and hardware). This has led to the proliferation of research and development out from the confines of select high-tech labs to our very homes where we can explore and contribute to the open source community unhindered. Parallel computing is one such domain which once required expensive supercomputers. Now it is a complete reversal of the old setup. GPUs also called Graphical Processor Unit are available in almost all sundry computing devices, hence providing parallel computing opportunities at commodity rates. Nevertheless, despite the cheap parallel hardware, an open source development initiative in this domain is still limited because of many issues and constraints. Our work focuses on this very limitation that has restricted the use of open source in parallel computing sphere. The research work proposes a need for specialized operating systems (OSes) that are inherently parallel and take advantage of the phenomenal computation power of parallel hardware in the form of CPU and multicore GPU. We propose a heterogeneous model of OS that has automatic parallelization capability with modified memory and thread hierarchies. Our parallel OS model supports both fine and coarse grain parallelism thus optimizing the CPU as well as GPU usage.**

Index Terms—**GPU, parallel operating system, multicore computing, multithreading, synchronization, thread hierarchy, shared memory**

I. Introduction

GPU computing at present is being propelled by two major companies: ***Nvidia*** (GeForce, Tesla, etc.) and ***AMD*** (Radeon, etc.). The genesis of GPU also called Graphical Processing Unit lay in the initial days of graphics rendering on old desktop systems. Since the rendering process is itself highly compute-intensive, special processors were designed to deal with it. These graphical processors so called were later explored for other compute intensive tasks of a typical SIMD domain type. This led to the usage of GPUs for tasks [1] other than graphics and led researchers to use these multicore processors for computational finance, bio-engineering, gene-mapping, weather prediction, molecular biology, and artificial neural network to name the few.

There are many open source parallel software frameworks available which have been developed using the open source compiler LLVM [2]. Two of the popular ones are CUDA (Compute Unified Device Architecture) from ***Nvidia Corporation***™ and ROCm [3] from ***AMD***™. Both these platforms are open source by dint of being built on a common open source LLVM compiler framework. Though there exist some proprietary issues related to CUDA but this shall not be delved in detail in this work.

II. Open Source GPU Powered Parallel Operating System

Operating systems are the unsung bedrocks, the very foundation of any application. Applications derive most of their optimized performances from the underlying host OS on which they run and thrive [4]. The efficiency of any application directly depends on two factors. Firstly, the complexity of the algorithm used inside and secondly, the underlying OS/ hardware on which it is run. In the case of the algorithm used in a given application, and especially when an application has high arithmetic intensity, a parallel algorithm is a game changer, provided the underlying hardware supports parallelism. Our work focuses on the system software aspect. The system software in consideration is a parallel GPU-based OS that provides phenomenal computing power by leveraging parallelism over hundreds of multiple cores [5]. As is well known, the majority of the OSes available today do have support for concurrent and multithreaded applications but still fall short of providing a complete parallel package for the embedded multicore GPU hardware. As a result it is pertinent to overhaul the entire OS structure that currently runs on the multicore hardware to provide unfettered parallel computing environment with direct support for the variety of parallel hardware that includes memories as well.

III. Current State of Parallel Operating Systems

Some research initiatives have been made in the parallel OS front, but very little work has been done in systems that are specific to GPU multicores [6]. A typical parallel OS falls in the domain of computer architecture, system software, programming systems, algorithms and synchronization primitives. These are the key focus areas for the researchers to make current operating systems amenable for multithreaded execution on multicores.

With each passing year, the number of installed *SIMD* cores is increasing at rapid rate in various hardware devices. Soon we

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can safely assume that each thread will have the luxury of executing on a single core. This creates an ambience for less contention and greater execution freedom. One thread per core shall be the new defining feature of a typical fine-grained *SIMD* system in the near future. A major effort is ongoing in the field of *invasive computing* [7] that involves automatic resource allocation and subsequent deallocation after use. This style of computing enables optimum use of parallel hardware and also improves the performance, as resources are allocated/ de-allocated on the fly.

A common set of resources identified for flawless parallel output are the different levels (hierarchies) of memories (register, shared, texture, etc.), parallel cores and the communication bandwidth. These resources are critical for any parallel program to run efficiently. The invasive paradigm basically involves the three crucial steps of *invade ()*, *infect ()* and *retreat ()*. Without going into the details, these steps deal with the allocation (claim) and deallocation (reclaim) of the above said resources.

IV. Comparison between parallel operating system and domain specific massively parallel MPSOC

Due to the lack of general purpose parallel operating system, many research works concentrated on a workaround by developing isolated parallel containers called as domain specific applications [8]. Since these applications have specific goals related to the narrow field of interest, it required customized processors that were designed with the prior application functionalities in mind. The major drawback of such an approach is twofold and is outlined below.

Firstly, these domain specific systems need high level of maintenance effort and are not flexible enough to sustain massive changes in the form of new versions.

The second major drawback is that most of the research attention gets diverted to domain specific work instead of concentrating on the development of unified operating system software that caters to and covers all parallel paradigms. Since the domain specific applications have fast developmental timelines, they have been very popular.

In addition, domain specific development has its unique advantages especially in defense and security related sectors where the primary concerns are the security, privacy, and intellectual property right issues [9]. On the other hand, the parallel operating systems create an ecosystem that involves software reuse and push forward general unified frameworks that rely on robust and stable application development. Such systems provide long term parallel solutions with stable support for parallel APIs unlike the domain specific systems that are hardcoded and are not modifiable.

V. Flavors of parallelism

Parallelism can be expressed in a variety of ways. The four different level of parallelism are as under:

1. *Process (thread) level parallelism*. This type of parallelism is very common and is often implemented in conventional CPUs from *Intel™* & *AMD™*. The granularity is often coarser as well as the number of threads are limited from *4* to *20*.
2. *Loop-level parallelism*. This class is often termed as SIMD/ vector parallelism and is evolving at a massive rate. The hardware supporting SIMD parallelism are the multicores and many-cores often called as GPUs.
3. *Instruction-level parallelism*. It is mainly limited to parallel primitives and machine instructions and operate at the kernel level.
4. *Word-level or bit-level parallelism*. It exists at the level of word-size and is prominent at the sub-word level instruction pipeline design [10]. Sub-word level parallelism has applications in embedded systems especially related to media processors.

The above mentioned flavors of diverse parallelism prompts an urgent need for a single unified parallel OS framework that caters to all the above four types. This is advantageous as we can have diverse variety of parallelism embedded in a single application that can be run on a unified parallel OS without any need for any porting or migration.

VI. Proposed heterogeneous operating system architecture

The multicores are now ubiquitous and are part of almost all devices, whether it may be a tablet, cell phone, digital camera or any computing systems in the form of desktops and laptops. Hence these devices require support systems in the form of a parallel OS that is capable of harnessing the computing bandwidth emanating from the multicores inside these devices.

Taking the cue from this massive proliferation of such multicore embedded devices, we propose a ***heterogeneous concurrent operating system*** that caters to the fundamental requirements of these multicore chips in terms of parallelism and synchronization. We divide the proposed system on the following main themes:

1. Memory hierarchy
2. Thread hierarchy and synchronization
3. Branch prediction and handling
4. Input and output streaming
5. Automatic parallelism (on-the- fly execution)
6. Support for parallel data structures and primitives
7. Support for Atomic operations
8. Support for task level (coarse-grain) parallelism
9. Inbuilt support for parallel recursion

We outline below each of the above nine themes in detail on which a new, stable and robust OS can be conceptualized.

A. Memory hierarchy

Memory hierarchy and types play a very critical role in a parallel application execution. There are segments of program

that must be shared among multiple threads and thus different levels of cache memory are desired. Such memories are available in multicore in the form of shared memory [11]. Though these memories are small but are fast especially when random locations of memory are accessed in an un-coalesced manner. At present these memories are small in sizes and future OS can provide faster and wider memory widths by way of support of wide memory bit address. Larger shared memory provides better performance especially when arbitrary memory locations are accessed.

B. Thread hierarchy and synchronization

Multithreading environment needs a major innovation push as it is the main pillar of efficient concurrency. We focus on SIMD level parallelism in which it is important that threads are spawned and run transparently over the available multicore hardware. Yet this has not been entirely accomplished and as such still requires manual intervention from the programmer's end.

Automatic thread allocation is similar to automatic multithreading found in conventional CPUs [12]. But due to large number of threads with very little access to cache memory, the task is complex. Besides, the nature of parallelism varies depending on the data structure and algorithm used in a given application.

For example it is trivial to apply a parallel logic to a million element array for a typical *reduction-sum* operation but it is quite challenging to do a *depth first search* or a *breadth first search* of a large random sparse graph. Hence the allocation of threads entirely depends on the type of application. The research efforts in automatic thread allocation are still in its infancy and no new breakthrough has so far been made.

C. Branch prediction and handling

As the program's control flow proceeds, different threads may take different branch routes depending on the function calls and it is the same for bi-directional statements (such as *if-then-else*). So far the branch prediction and handling is not an automatic process especially with respect to parallel processing [13]. The major bottleneck in branch handling is the issue of *thread diversion*. This happens when an *if-then-else* bi-conditional statement diverge the flow among threads and therefore faster threads have to wait for their slower counterparts to finish execution.

D. Input and output streaming

The biggest challenge with real-time applications is often the presence of input and output streams. These streams may emanate from a CCTV camera feed or some data generating application and are subsequently sent to a parallel machine. Processing gigabits of large I/O data on the fly in real time tend to become an acute computing bottleneck [14]. A properly designed parallel OS that deals with input and output streams efficiently can immensely tilt the scales in the adoption and propagation of use of parallel processing for real-time applications. A major research area in parallel I/O processing involves splitting the incoming data stream into multiple sub-streams and then streaming them over the many cores for fast asynchronous processing. Since the *fork/ join* of data stream are a complex process, very little research has seen the light of the day.

E. Automatic Parallelism

Automatic parallelism implies that a program is scanned for *hotspots* or code segments that can be parallelized and the compiler is instructed to compile and run these hotspots on the fly. At present there exists pre-processor directives (*OpenAcc*) and *DSL* (Domain Specific Language), but a general automation of a given application is still not available [15].

F. Support for parallel data structures & algorithms

Parallel algorithms have been researched for decades as parallelism has been inherent in the form of multithreading facility in many languages such as *C/C++, Haskell* and *Java*. Hence parallel algorithms support has been there in legacy as well contemporary systems for quite some time now [16]. There exist several libraries which have been well adapted into the new parallel OS paradigm (*CuBLAS*, *CuSparse*, etc.).

G. Support for Atomic operations

In parallel systems, synchronization is a prime concern as threads often execute *out-of-order* and thus applications are susceptible to race conditions and destructive updates [17]. *Atomic* operations provide mutually exclusive access to a resource though at the expense of degraded computing performance. Some of the well-known atomic primitives are *TestAndSet (TAS), CompareAndSet (CAS), Exchange (EXCHG),* etc.

H. Support for task level (coarse-grain) parallelism

Coarse grain parallelism has traditionally been an integral part of the past as well as the present-day CPUs. The *hyperthreading* computing model is well supported by various contemporary *Intel™* and *AMD™* processors. Coarse grain *CPU-level* parallelism creates multiple layers of parallelism thus improving performance [18]. Coarse grain parallelism involves division of an application into multiple tasks and then executing them in parallel. A task running on a CPU may further be parallelized using fine-grain parallel primitives by the underlying multicore architecture. Operating systems can deal with this duality in the form of coarse and fine grain by creating a special/ switching logic that segments/ partitions a program on the basis of inherent parallelism.

I. Support for task level (coarse-grain) parallelism

Recursion in parallel systems has very limited support and often the recursive features in a program are converted into iterative equivalents and then sent for execution. This process adds additional overheads and affects the performance [19]. Automatic recursion support is still elusive and remains an unresolved problem for many of the parallel multicore systems. A novel parallel operating system that supports recursion directly or indirectly in the form of *on-the-fly* iterative-

conversion can boost the flexibility and robustness of the entire system.

VII. Conclusion

Hence our work clearly demonstrates the pitfalls in the current OSes especially when it comes to concurrency, and how we can overcome these issues at various levels. We have proposed modifications at the level of memory hierarchy, thread management, automatic parallelism and recursion.

A parallel-aware operating system can be a big boost and significantly enhance the way how computing can be done in future. The parallel OS paradigm will have a widespread disruptive effect in the parallel computing scene. The support for parallel primitives, concurrent algorithms can revolutionize the algorithm design patterns and create more faster, fault-tolerant and robust applications.

References

Michael Feldman, Christopher G. Willard, Addison Snell, HPC application support for GPU computing, Intersect 360 Research, Sponsored research report, Actionable market intelligence for HPC, November 2015.

J. Wu et al., "gpucc: An open-source GPGPU compiler," 2016 IEEE/ACM International Symposium on Code Generation and Optimization (CGO), Barcelona, Spain, 2016, pp. 105-116.

ROCm Documentation, Nov 22, 2018, AMD

Engler, D. R., & Kaashoek, M. F. (1995). Exokernel: An operating system architecture for application-level resource management (Vol. 29, No. 5, pp. 251-266). ACM.

Ryoo, S., Rodrigues, C. I., Baghsorkhi, S. S., Stone, S. S., Kirk, D. B., & Hwu, W. M. W. (2008, February). Optimization principles and application performance evaluation of a multithreaded GPU using CUDA. In Proceedings of the 13th ACM SIGPLAN Symposium on Principles and practice of parallel programming (pp. 73-82). ACM.

Rossbach, C. J., Currey, J., Silberstein, M., Ray, B., & Witchel, E. (2011, October). PTask: operating system abstractions to manage GPUs as compute devices. In Proceedings of the Twenty-Third ACM Symposium on Operating Systems Principles (pp. 233-248). ACM.

Benjamin Oechslein, Jens Schedel, Jürgen Kleinöder, Lars Bauer, Jörg Henkel Daniel Lohmann, Wolfgang Schröder-Preikschat, OctoPOS: A Parallel Operating System for Invasive Computing, Conference: EuroSys 2011 Workshop on Systems for Future Multi-Core Architectures (SFMA), April 2011.

Lee, H., Brown, K., Sujeeth, A., Chafi, H., Rompf, T., Odersky, M., & Olukotun, K. (2011). Implementing domain-specific languages for heterogeneous parallel computing. Ieee Micro, 31(5), 42-53.

Molotov, R. (2017). Use of domain specific API in interactive virtual environments and simulators. UDC 681.518 (04) INTERACTIVE SYSTEMS: Problems of Human-Computer Interaction.–Collection of scientific papers.− Ulyanovsk: USTU, 2017.− 290 p., 219.

Chauhan M.S., Optimization of Media Processor Performance through Sub Word Virtual Register Design, International Conference on Methods and Models in Computer Science, New Delhi, India, December 2010, DOI: 10.1109/ICM2CS.2010.5706724

Xinxin Mei, Xiaowen Chu, Dissecting GPU Memory Hierarchy through Microbenchmarking, IEEE Transactions on Parallel and Distributed Systems (Volume: 28, Issue: 1, Jan. 1 2017)

Unkule, S., Shaltz, C., & Qasem, A. (2012, March). Automatic restructuring of GPU kernels for exploiting inter-thread data locality. In International Conference on Compiler Construction (pp. 21-40). Springer, Berlin, Heidelberg.

He L., Zhang G. (2010) Parallel Branch Prediction on GPU Platform. In: Zhang W., Chen Z., Douglas C.C., Tong W. (eds) High Performance Computing and Applications. Lecture Notes in Computer Science, vol 5938. Springer, Berlin, Heidelberg

Z. Chen, J. Xu, J. Tang, K. A. Kwiat, C. A. Kamhoua and C. Wang, "GPU-Accelerated High-Throughput Online Stream Data Processing," in IEEE Transactions on Big Data, vol. 4, no. 2, pp. 191-202, 1 June 2018.

Jung H., Yi Y., Ha S. (2012) Automatic CUDA Code Synthesis Framework for Multicore CPU and GPU Architectures. In: Wyrzykowski R., Dongarra J., Karczewski K., Waśniewski J. (eds) Parallel Processing and Applied Mathematics. PPAM 2011. Lecture Notes in Computer Science, vol 7203. Springer, Berlin, Heidelberg

P. Misra and M. Chaudhuri, "Performance Evaluation of Concurrent Lock-free Data Structures on GPUs," 2012 IEEE 18th International Conference on Parallel and Distributed Systems, Singapore, 2012, pp. 53-60.

Hermann Schweizer, Maciej Besta, and Torsten Hoefler. 2015. Evaluating the Cost of Atomic Operations on Modern Architectures. In Proceedings of the 2015 International Conference on Parallel Architecture and Compilation (PACT) (PACT '15). IEEE Computer Society, Washington, DC, USA, 445-456. DOI: https://doi.org/10.1109/PACT.2015.24

Albert Cohen. 2015. Streaming Task Parallelism. In Proceedings of the 29th ACM on International Conference on Supercomputing (ICS '15). ACM, New York, NY, USA, 1-1. DOI: https://doi.org/10.1145/2751205.2751208

Xin Huo, Sriram Krishnamoorthy, and Gagan Agrawal. 2013. Efficient scheduling of recursive control flow on GPUs. In Proceedings of the 27th international ACM conference on International conference on supercomputing (ICS '13). ACM, New York, NY, USA, 409-420. DOI: https://doi.org/10.1145/2464996.2479870

The Smart Learning Management System (SLMS)

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***Abstract*— Learning conditions have changed fundamentally in the past couple of decades due to the incorporation of rising Information and Communication Technology (ICT). From the introduction of hardware and software in the education process to a diversity of virtual tools in classrooms. With regards to novelties in the educational atmosphere, researchers put a lot of efforts and creative ideas to assist this kind of learning environments. Besides, instructions in higher education institutions become an integrated process and complex. Consequently, a smart educational atmosphere is required to conform to this change. The idea of smart learning aids to capture approaches to teaching and learning that somehow benefit from the utilization of smart technologies. This paper tackles this concept and show how to enhance the existing Learning Management Systems (LMSs). It shed a light on how to support them with smart facilities through reusing the theoretical features of smart educational atmosphere and existing LMS to become smarter for a long period of time and cover wider space. This new proposed model will focus on learner behavior from which we can collect all data needed to help each learner to answer his/her personal needs.**

***Index Terms*— Smart Learning Environment, Smart Educational Atmosphere, Learner Behavior, LMS, Smart Features**

I. INTRODUCTION

A lot of researchers at the past concentrated on traditional learning and how to improve it. It was clearly noticed the need for the new and smart learning environment. This decade however can be a watershed crossroads in the historical background of higher education at several universities and colleges investigate the capability of online innovation to improve teaching and learning. The learning environment has changed incredibly in the past several years. To answer the needs of different elements (e.g. learner, instructor and learning content) of the educational triad, smart educational atmosphere needs to support important virtual tools. Therefore, smart educational environment is becoming the concentration of the studies meanwhile. Models for educating and learning are developing at an incredible rate. Institutions need to think to improve their way in a manner that will benefit the learners and the entire community.

The emergence of the smart cities and smart technologies raised the urgent need for smart and innovative education and learning process [1] [2]. Smart education atmosphere can be considered as a smart learning environment with the smart and virtual tools to support the learning process [3] [4]. Although smart environment in academic fields is the need for all institutions, it was not given enough attention [5]. The idea behind the smart education environment development is to improve the traditional learning to become smart. In this context, Component Based Software Development (CBSD) has gained popularity in the past era. So, the concept of reusability in CBSD is generally considered as a way to solve the software development crisis. This helped the evolution of a new approach called Component Based Development (CBD). It uses the concept of reusability in application development [6]. The value behind CBSE is to concentrate on reusing a software component rather than inventing the wheel and developing the components from scratch [7]. This will be discussed further in the following sections.

This paper has five sections: Section I introduces the concept of smart educational atmosphere. Section II discusses the emerging field of smart educational environments. Section III presents the literature review. Section IV discusses the proposed solution. Finally, section V provides the conclusion of the paper and the future directions.

II. EMERGING FIELD OF SMART EDUCATIONAL ENVIRONMENTS

An innovative educational atmosphere is considered smart if it supports the environment with smart technologies and includes innovative features to support the classroom learning process. One facet of smart educational environment is to consider the behavior of the learners and treat it in a suitable way to reflect the personalization of the learners. This could be taken care of through adopting an effective educational environment. This involves engaging the learners smartly, effectively and efficiently in the learning process. This should lead to personalizing the learning contents to suit every learner depending on his/her behavior [5]. The smart educational environment needs careful planning of learning process, innovative learning contents and an attractive learning lessons and results.

III. LITERATURE REVIEW

Currently, the literature shows that researchers are investigating on improving this topic which is related to different kinds of learning (e.g. electronic, virtual, web-based learning, ...etc.) The existing investigations cover issues related to learners, LMSs, and contents in general. However, no much literature concentration on the smart issues of learning. This includes investigating on smart features of the learning environment and smart learning management systems, learner behavior and personality, smart virtual tools and smart learning contents [8].

The primary goal of smart educational environment is to create an enhanced learning and teaching environment. Smart learning environments use educational technologies to deliver essential tools for instructors to personalize learning, adapt teaching and assessment, and create suitable learning environments for learners. Smart educational environment should consider adapting the environment to suit the needs and behavior of specific learners. The researchers are involved to frame the smart educational environment. This does not mean to only concentrate on the usage of virtual tools and contents. However, the researchers would like to go further and discuss all aspects and features of smart educational environments [3].

In order to answer the request of each individual learner and instead of developing a new system for smart learning environment from scratch, the authors suggest reusing the available existing systems in a learning environment which are Learning Management Systems (LMSs) to make learning environment inside the LMSs smarter. Furthermore, current LMSs, do not contain smart features as well as they do not have facilities to follow the learner's behavior to enable instructors to come up with new smart learning contents which suit the need of the learners [9]. As a result, using the existing LMS, the features of SLE and the concept of reusability of Component Based Software Development (CBSD) in software engineering field, would enhance the situation and make learning environment smarter and consequently make Smart Learning Management System (SLMS) as shown in Fig.1.

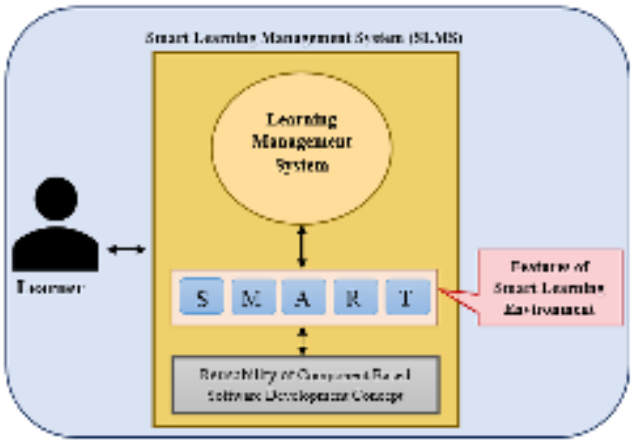

Fig. 1 .The Idea of Smart Learning Management System

IV. PROPOSED SOLUTION

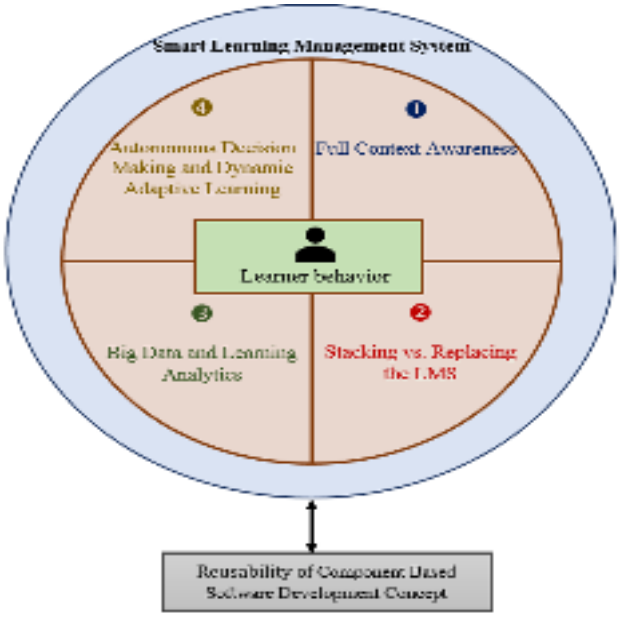

Fig. 2. The Proposed Smart Learning Management System

It should be noted that the suggested solution for the new SLMS will be based on the following parts as illustrated in Fig. 2:

- Learner Behavior
- Features of SLE
- Existing LMS
- Reusability of CBSD

To make the learning environment smart the authors combined all the previous existing parts, each part will complete the other.

The core part of the new proposed environment is the learner's behavior. More in more, smart educational environment should be able to gather learner's behavior from the LMS as an initial step. This should be followed by enhancing the LMS to be able to analyze the learner's behavior in order to know how to manage the learning resources and provide the specific learners with the adjustable and personalized resources [10] [11]. Of course, there are several smart features used to develop the smart learning environments. The smart features, which were introduced theoretically by Nikolov and colleagues [12] have been considered for this

current work of this paper. It is worth mentioning that Nikolov and colleagues [12] did not investigate the practical aspects of these smart features. Therefore, the purpose of using them in the current work of this paper is to explore their benefits practically and also to examine their capability to work or enhance learner's behavior. The smart features proposed by Nikolov and colleagues [12] are:

- **Full Context Awareness:** This feature is used to enhance the existing LMSs to become smart in a way that covers all aspects of Smart Learning Environment. This involves having a smart tool to capture learner's behavior in order to help the instructors to know the suitable learning material for specific learners [12].

- **Stacking vs. Replacing the LMS:** This feature empowers the LMSs by adding layers to the LMSs which should take care of the smart aspects and collaboration with social networks [13]. These layers can include managements aspects layer, regulations layer, feedback layer from different users (e.g. instructors and learners), smart aspects layer [14].

- **Big Data and Learning Analytics:** This feature takes care of the huge amount of data coming from the learners profiles, which could be collected from the LSMs. This kind of data is considered as a big data which should be analyzed to know the behavior of individual learners. Consequently, the analytical data can be used in the other layers of the Smart Learning Environment to know how to prepare the customized learning content for the specific learners [15] [16].

- **Autonomous decision making and Dynamic Adaptive Learning:** This feature is responsible to organize and manage the analyzed data received from the previous smart feature. This data should be provided to the smart and intelligent tools available in the Smart Learning Environment in order to capture the specific learner's behavior in a smart way. This would help the Smart Learning Environment to provide the learners with the appropriate smart material to fulfill their needs [12].

The authors of this paper would like to utilize the previously mentioned features of SLM practically in order to know how each feature could play a vital role in reusing the existing LMS to propose a new SLMS.

Nonetheless, it can be argued that studies on reusing any existing systems for developing smart learning tools and environment are limited. Reusability plays an essential role in CBSD. The primary criterion for evaluating any part of a model is reusability [7]. Using the reusability concepts in proposing the new model will be supposed to extend the functionalities of the LMSs [17] and make them more smart and broader usability as well as increase the learner's performance which will help to enhance the learning material to fulfill the needs of the specific learner depending on their behavior.

V. Discussion

The improvement to smart learning is required to enhance the educational environment in regards to devices, network, contents, learners, instructors, etc. Learning environments of the future will move the educational model from an industrialized instructor-centered statically authoritative prescribed knowledge process to a student-centered, creative, open and global forum [11] Obviously, change inside educational institutions will not happen quickly or easily. However, it is now in advance progress [11]. Information and Communication Technology (ICT) tools will stay offerring easy and exciting ways for learners to associate, express themselves, share and manage information [9].

VI. Conclusion

Higher education institutions need to give tailored learning environment along with customized learning material to fulfill the requirements of various learners. Although Learning Management Systems (LMSs) are important and used to support all types of education being traditional or electronic based [18], they do not contain smart features to make them intelligent. This paper is taking a step forward to enhance the existing LMSs to improve learners behavior and performance. This work would lead to developing Smart Learning Management System (SLMS).

Future work of this paper is to look for a technique or approach to prepare and extend the software tools [19] [20] that are needed to be added to the existing LMS to became smart. One of the solutions could be using the plugin tools [19] in how the student could use the LMS that meet their requirements and aid them in improving their performance. Via this solution, the new tools will be added on the top of the existing LMS and supposed to gather, combine and analyze students profiles to offer them with a suitable and a customized learning environment.

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References

[1] Uskov, VL., Bakken, JP., Heinemann, C., Rachakonda, R., Guduru, VS., Thomas, AB., Bodduluri, DP. in Smart Education and Smart e-Learning.(2017). Building Smart Learning Analytics System

for Smart University, vol 75 (Springer International Publishing, 2017), pp. 191–204. https://doi.org/10.1007/978-3-319-59451-4_19
[2] Roumen, E. S., & Kovatcheva, N. E. (2017). Conceptualising of Smart Education. Online: https://www.researchgate.net/ publication/320623528_Conceptualising_of_Smart_Education. Accessed 06 Feb 2018
[3] Hoel, T., & Mason, J. (2018). Standards for smart education–towards a development framework. Smart Learning Environments, 5(1), 3.
[4] Koper, R. (2014). Conditions for effective smart learning environments. Smart Learning Environments, 1(1), 5.
[5] Spector, J. M. (2014). Conceptualizing the emerging field of smart learning environments. Smart learning environments, 1(1), 2.
[6] Hall, L., Hung, C., Hwang, C., Oyake, A., & Yin, J. (2001). COTS-based OO-component approach for software inter-operability and reuse (software systems engineering methodology). In Aerospace Conference, 2001, IEEE Proceedings. (Vol. 6, pp. 2871-2878). IEEE.
[7] Thakral, S., & Sagar, S. (2014). Vinay. Reusability in Component Based Software Development-A Review. World Applied Sciences Journal, 31(12), 2068-2072.
[8] Lee, J., Zo, H., & Lee, H. (2014). Smart learning adoption in employees and HRD managers. British Journal of educational technology, 45(6), 1082-1096.
[9] Ahmed, N. and Al-Khanjari, Z. 2012. Effect of Moodle on Learning: An Oman Perception. International Journal of Digital Information and Wireless Communications (IJDIWC) 1(4): 782-788 The Society of Digital Information and Wireless Communications. (ISSN 2225-658X). 2012.
[10] Kay, J. (2008, June). Life-long Learning, learner models and augmented cognition. In International Conference on Intelligent Tutoring Systems (pp. 3-5). Springer, Berlin, Heidelberg.
[11] Al-Khanjari, Z., Kutti, N.S. and Dorvlo, A.S. 2011. Promoting On-Line Learning through Learners Vision. ACM Inroads, 2(3), pp. 34-37, September 2011.
[12] Nikolov, R., Shoikova, E., Krumova, M., Kovatcheva, E., Dimitrov, V., & Shikalanov, A. (2016). Learning in a Smart City environment. Journal of Communication and Computer, 13, 338-350.
[13] Jamoussi, Y., Al-Khanjari, Z. and Kraiem, N. 2014. A Framework to Evaluate E-learning Based on Social Networking. International Journal of Current Research and Academic Review (IJCRAR), 2(4), pp. 26-42, 2014.
[14] Hwang, G. J. (2014). Definition, framework and research issues of smart learning environments-a context-aware ubiquitous learning perspective. Smart Learning Environments, 1(1), 4.
[15] Kumar, V. S., Clemens, C., & Harris, S. (2015). Causal models and big data learning analytics. In Ubiquitous Learning Environments and Technologies (pp. 31-53). Springer, Berlin, Heidelberg.

[16] Kumar, V. S., Somasundaram, T. S., Boulanger, D., Seanosky, J., & Vilela, M. F. (2015). Big data learning analytics: a new perpsective. In Ubiquitous Learning Environments and Technologies (pp. 139-158). Springer, Berlin, Heidelberg.
[17] Al-Khanjari, Z., Kutti, N.S. and Hatam, M. 2006. An Extended E-Learning Architecture: Integrating Software Tools Within The E-Learning Portal. International Arab Journal of Information Technology (IAJIT), 3(1), pp. 75-81, January, 2006.
[18] Al-Khanjari, Z., Kutti, N.S. and Ramadhan, H. 2005. E-learning under WebCT. The Journal of Computer Science, 1(4), pp. 487-493, 2005.
[19] Al-Khanjari, Z. and Al-Roshdi, Y. 2014. Extending the Functionality of LMS to Support Computer Science Education Using Plug-in Tools. Journal of Emerging Technologies in Web Intelligence (JETWI), Academy Publisher, 6(2), pp. 220-225, May 2014.
[20] Al-Khanjari, Z., Al-Roshdi, Y. and Kraiem, N. 2014. Virt-Res: Developing Extended Architectural Design for Computer Science Virtual Resources Using SOA, International Journal of Software Engineering and its Applications (IJSEIA), Academy Publisher. 8(9), pp. 125-136, September 2014.

The Impacts of Open Source on IoT Solutions Development

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***Abstract*— Open source software plays a critical role in the development of new technologies such as the internet of things (IoT). The software is considered an essential component of any development and it is used to create innovative products. Undoubtedly, open source software has invaded the new technologies as competitive companies devote huge efforts toward the utilization of open source software. This paper aims to investigate the impact of open source software on IoT development and security. The discussion focuses on the features of employing open source in IoT and clarifies its importance to IoT development. The paper also presents open source tools adopted in IoT such as operating systems, frameworks, hardware, and platforms. In order to inspect the effect of open source on the progress of IoT, the paper compares the widely used open source IoT platforms in terms of supporting features. The results of the comparison between open source platforms indicate that enterprises compete for developing platforms for IoT with great features such as device management, scalability, support of secure protocols for data collection, and data storage and data visualization capabilities. The availability of open source tools for IoT is a good indication that open source software will invade IoT and can be considered as a key driver for IoT development.**

***Index Terms*— IoT, open source, IoT platforms, IoT frameworks, security, IoT Operating Systems.**

I. Introduction

New technologies are emerging and invading the technical world, thus, offering different services and solutions in different fields. These new technologies are increasingly utilizing open source software, which is considered an important transformation in the market for software development and deployment tools. The interest in open source has increased in the past decade and the leading firms have given it a priority in their development [1]. Open source software plays a crucial role in the development of many technologies such as the promising technology of IoT. It is expected that the market will witness a dramatic increase in IoT applications in the next few years, and consequently, the open source software is becoming a fundamental development in IoT technology [1]. Open source plays a major role in IoT development. For instance, open source platform can assist devices to grow in IoT space. The connectivity of devices is a key factor in the success of the IoT market as open source APIs are used to address connectivity obstacles [2]. Moreover, open source APIs can provide a uniform gate for heterogeneous software, hardware, and system for communication purposes [3].

A good example of IoT platform is Netbeast which aims to offer APIs that work with all IoT smart home devices, regardless of the specifications [3]. Furthermore, open source projects such as the Linux Foundation's Iotivity are developing an open standard specification and certifications program for IoT smart devices. Thus, they provide developers with an access to an IoT framework that consists of a range of devices [3]. Additionally, developers can build products that have secure interoperability across different operating systems such as Android, IOS, Windows, Linux etc. Furthermore, an open source IoT framework can infuse unique features such as innovation and agility, which are not provided by the propriety model, into software development lifecycle. The unique features provided by IoT frameworks prevent the process of reinventing the new products. Consequently, developers can reuse the available resources to develop products more rapidly. These features enable a reduction in the time and cost of software lifecycle [2] [3]. Accordingly, with no obstacles in the cost and with the free use of different IoT frameworks, developers can adopt IoT with no hesitation [2].

By utilizing open source IoT frameworks, developers can use tools to customize the IoT platform in order to meet the company's needs. Open source IoT frameworks offer a set of libraries, SDKs and open source hardware such as Raspberry Pi and Arduino [2]. In addition, the developers' skills can be improved by collaborating with the open source community, which is a fertile environment for support and knowledge sharing [3] [2].

II. Reasons for using Open Source Solutions in IoT

The use of open source solution in IoT is distinctive since its features aim to guarantee efficiency and innovation by unifying technology stack. First, open source solutions ensure the connectivity of billions of IoT devices by providing a standard

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platform to connect them all together. In Open source software, the source code is subject to a degree of permissions on how it can be used by developers. The source code is scanned easily with no restriction [4]. Additionally, open source solutions offer a feature of low-risk innovation where the process of searching for a new killer is accelerated. Furthermore, open source software empowers new technology with small financial commitments and minimal fear over intellectual property lawsuit [5]. In addition to these features, there are economic advantages to using an open source solution in IoT. First, it enhances the quality of solutions and support due to knowledge sharing among the community of developers. Second, it ensures efficiency by cutting development time and cost, and through collaboration and interoperability. Third, it guarantees affordable scaling to tens of billions of devices. Fourth, it provides control over connected devices [5].

There are many reasons why it is recommended to use open source software in IoT. First, statistics showed that about a third of IoT developers use open source projects because they think that the improvements they receive from the community advance technology. Second, direct collaboration and support (developer-to-developer) among the community members are more preferred than vendors' support in proprietary software. Developers can gain more experience from other developers and, in fact, become more convert once they discover community support. Third, statistics indicated that a fifth of IoT developers prefer and choose open source solution because it is both attractive and new. Fourth, open source provides developers with a good opportunity to learn new technologies and build their skills [5].

As mentioned in [5], about 91% of IoT developers use open source software, open hardware and open data in at least one part of their development stack. In contrast, less than 1 in 10 IoT developers never choose open source as an option for developing IoT. According to a study conducted in 2018 [5], 64% of IoT developers use open source for developing embedded OS such as TinyOS, Contiki, and FreeRTOS, etc. The study also reports that 71% of IoT developers use open source in the IoT frameworks, software components, and libraries such as thingbox project and the Eclipse IoT, etc. A survey which involved 253 IT decision makers in 2018 concluded that open source tools for the development of IoT solutions are more widely used than proprietary tools [1]. Moreover, the results of the survey indicated that the leaders in IoT solutions prefer the use of open source [1].

III. EXISTING OPEN SOURCE SOLUTIONS FOR IOT

Open source solutions have been used in IoT extensively. There are many open source tools which are used in IoT development such as operating systems, frameworks, platforms, and hardware, etc. This section presents the frequently used open source IoT tools such as IoT OSes, IoT frameworks, and IoT hardware, and compares the best and most commonly used open source IoT platforms in term of their supporting features.

A. Open Source IoT OS

As IoT devices are resource-constrained, conventional operating systems such as Linux, and windows, etc. are incompatible with the IoT environment in which IoT devices do not have adequate resources to run them [6]. The operating systems developed for the IoT environment require special specifications such as constrained memory size (few kilobytes of RAM) and low power consumption [7][8]. Unlike regular OS'es such as Mac OS and Windows OS, IoT OS'es include features related to communication, networking, and security, as they are built-in with several pre-installed applications, drivers, and other protocols. Furthermore, they employ various unique security measures for the purpose of improving IoT infrastructure [8].

Many open source OS'es are developed and placed on top of IoT applications, such as wearable IoT devices and automobiles such as Contiki, RIOT, google Brillo OS, and Zephyr, which are considered the top four open source operating systems for IoT devices [7]. Table I presents a comparison of these top open source IoT OS'es in terms of minimum memory requirement.

TABLE IV: COMPARISON OF TOP OPEN SOURCE IOT OS IN TERMS OF MINIMUM MEMORY REQUIREMENTS

Open Source OS Name	Year	Minimum Memory Requirements
Contiki	2002	3KB of RAM and ROM
RIOT	2013	1.5Kb RAM and 5Kb of ROM
Google Brillo	2015	At least 128MB of ROM and 32MB of RAM
Zephyr	2016	The memory size of 8KB

As Table I shows, the specification of the memory size of open source OSes for IoT improves gradually across the years as IoT evolves.

B. Open Source IoT Frameworks

The purpose of IoT frameworks is to achieve integration and interoperability and to cater for standardization in IoT [9] [10]. To achieve this purpose, IoT frameworks should adopt a minimal set of measures such as contract decoupling, scalability, ease of testing, ease of development, fault tolerance, lightweight implementation, and service coordination [10].

Many Open Source IoT frameworks are available. The top 3 open source IoT frameworks are Kura, Node-RED, and Flogo [11]. Each of these platforms has its distinctive features to ease the interoperability in IoT. Table II presents a comparison between these top 3 open source IoT frameworks.

TABLE V: FEATURES OF TOP OPEN SOURCE IOT PLATFORMS

IoT Framework Name	Features
Kura	– Most used IoT framework – Designed for a developer familiar with Apache Camel and it uses the eclipse 1.0 public license – Developers can write their own source code without a visual designer.

	– Provides a web user interface for managing protocols configurations and device connections – Offers the use of data and cloud services
Node-RED	– Differs from Kura – Has a visual tool specified for writing IoT connections and for the integration among devices – Built on JavaScript and Node.js
Flogo	– Has a lightweight edge application – Has a visual tool and uses a BSD style license – Easy to install

As shown in Table II, each IoT framework is designed for a specific purpose and provides different services for developers.

C. Open Source IoT Hardware

Open source hardware is expected to play a significant role in IoT development in the coming years due to the success of Raspberry Pi and Arduino. With the growth of open source hardware, IoT products such as wearable products and connected appliances are all predicted to rise rapidly. Open source hardware plays a vital role in building a smart city infrastructure [12]. Raspberry Pi, which was introduced in 2010, can be defined as a small board that is cheap and powerful. It is similar to PC in operation [13]. Raspberry pi differs from Arduino as it is a general-purpose computer which uses Linux OS and can run multiple programs. On the other hand, Arduino is a microcontroller board that can run one program at a time. Raspberry Pi is more complicated than Arduino [14]. Table III provides a comparison between the two IoT open source hardware[15] [16].

TABLE VI: COMPARISON BETWEEN IOT HARDWARE SPECIFICATIONS

IoT Hardware	Specifications
Arduino	– Microcontroller with CPU, EEPROM, lots of input/output port – Supports custom operating system stored in EEPROM – Get power from USB – Used to make hardware projects – Suited for LED controller, alarm systems, robots, weather station
Raspberry Pi	– Minicomputer with CPU, GPU, RAM, and some input/output port – Support Linux operating system stored in SD – Used to make software projects – Suited for NAS server, web server, game emulator

As Table III indicates, each open source IoT hardware has specific technical specifications to be used for specific applications.

D. Open Source IoT Platforms

IoT platforms can be defined as a set of components which are used for the deployment of applications that can control the connected devices. They mainly collect and manage data from connected devices [17]. A platform can combine both a hardware and software to deploy applications. It provides a set of functionalities to be used for building IoT applications. More specifically, it offers services like development, deployment, maintenance, analytics, and capabilities of intelligent decision making to IoT applications [18].

Many IoT platforms exist to facilitate the development of IoT applications. Some of these IoT platforms are proprietary and open source platforms. The Azure IoT Suite is an example of top used proprietary IoT platforms. It can be described as a collection of services that allow connectivity, data analysis and visualization, and presentation. It provides scalability and offers great features such as data collection from devices, in-motion data stream analysis, huge data set storage and querying, real-time and historical data visualization, back-office system integration, and device management [17]. Azure IoT addresses many challenges such as security, infrastructure incompatibility, and scaling IoT applications or solutions. Through the Azure platform, millions of devices, software and services can be connected, and terabytes of data can be processed and stored. The deployment can be on edge, in the cloud, or anywhere in between. It solves security in IoT by securing IoT data, managing risks, and protecting information. Furthermore, it can ensure the safety of sensitive data across devices, software, applications, and cloud services [19].

Generally, the platforms can be considered as the key to the development of IoT applications. The main components of IoT platforms are device management, device connectivity and protocols, secure access management, data processing and action management, data visualization, data storage, and connection to third-party services [20]. The major differences between open source solutions and closed or proprietary source solutions are price, security, support, availability of source code, and usability [4]. More specifically, open source software is free of charge. Moreover, the source code is available and, therefore, anyone can fix, upgrade and test a broken code or a code that has any vulnerability issues. Open source software provides quality support in forums, blogs, and even in hiring experts [4]. Such differences can also be utilized in IoT open source tools such as IoT platforms. Six open source IoT platforms have been selected as the best and most largely used by developers as mentioned in [21] [23]. The table below (Table IV) presents a comparison between these platforms in terms of their purpose as well as supported features such as devices management, scalability, protocols used for data collection, data storage, and data visualization and security.

TABLE VII: COMPARISON BETWEEN TOP OPEN SOURCE IOT PLATFORMS

Platform	Purpose	Supported Features					
		IoT Device Management	Scalability level	Connectivity Protocols	Data Storage	Data Visualization	Security
Kaa	Provides useful features that allow developers to develop advanced IoT application for smart products easier than before [24]	Yes	Supports scalability	Uses lightweight protocol for data collection such as MQTT and CoAP	Allows sending data to various databases or data analytics systems such as MongoDB, Cassandra, Hadoop, Oracle NoSQL	Supports data visualization which comprises a rich set of widgets, such as gauges, charts, maps, tables, etc	Communication with IoT devices is secured through TLS or DTLS. Kaa server supports a variety of methods for device authentication.
SiteWhere	Used to build IoT applications scaled to targeted businesses [25]	Yes	Scalable	Supports numerous protocols such as MQTT, JSON, AMQP, XMPP, Stomp, JMS, and WebSockets, while providing published APIs	The default database is MongoDB, but other databases such as HBase, InfluxDB are used for data storage	Grafana (analytics platform) for data visualization	-
ThingSpeak	Provides free web service that helps to collect data from sensors and store it in the cloud, used to develop IoT apps [26]	Yes	Supports building scalable commercial solutions [27]	Supports RESTful and MQTT APIs	Collected data is stored in private channels by default, uses a MySQL database	Uses MATLAB for analyzing and visualizing data	Data can be secured through connection with APIs. [28]
DeviceHive	A platform for data collection, processing and analysis, visualizations with a wide range of integration options [29]	Yes	Builds with high scalability [30]	Connects any device via REST API, WebSockets or MQTT	Supports big data solutions through Elastic Search, Apache Spark, Cassandra and Kafka for real-time and batch processing, uses PostgreSQL, SAP Hana DB	Provides Visualization dashboard as customer's need	keeps things safe and secure, Apps application and device connectivity secured through TLS, access for users, networks, and devices is role-based [31]
Zetta	A platform for building IoT servers that can run across geo-distributed computers and the cloud [32]	Yes	Operates at scale in the physical world (e.g. home automation, smart transportation, wearable computing) and wherever your imagination leads	Combines REST APIs, WebSockets, and reactive programming	Unknown Registry	Supports analytic platform of Splunk for stream data.	-
Thingsboard	A platform for device management, data collection, and processing, visualization for IoT solutions [33]	Yes	Combines scalability	Supports transport encryption for both MQTT and HTTP(s) protocols	Cassandra database	Supports Real-time data visualization and remote device control, provides 30 customizable widgets for custom dashboard	provides, monitors and controls your IoT entities in a secure way using rich server-side APIs

Table VIII shows that there is a variety of open source platforms for IoT. The comparison indicates that the purpose of open source IoT platforms is to build and develop IoT applications or solutions that can collect, process, analyze and visualize the data gathered by IoT devices. These platforms offer great features related to IoT devices management, which are used to manage the collected data and support scalability in the sense that they can scale to fit many numbers of IoT devices. There is a major difference in supporting integration protocols which are mainly used for communication. As Table IV shows, MQTT protocol is used primarily by the mentioned open source

IoT platforms. MQTT protocol is used for IoT connectivity mostly to ensure communication and message delivery in resource-constrained devices. It is a lightweight, simple and easy to use for communication in IoT [34]. Most of the above-discussed platforms support data visualization which is considered a main part of IoT. Data visualization is conceptualized as tools used for analyzing and presenting the data collected by IoT sensors on visual language that helps in making accurate decisions [35]. However, each platform uses different analytics for this purpose. Data storage in each of the afore-mentioned platforms differs considerably. Data security is carefully considered by open source platforms and this is vital for IoT as a new technology where security can maintain trust among IoT users. In some of the above-mentioned open source IoT platforms, application programming interface (APIs) are used for the purpose of providing security. APIs help to control data by allowing applications to request data from each other [36]. Thus, these competitive features indicate that open source IoT platforms help in accelerating the development of IoT applications due to the pricing policy, quality of support, availability of code, and consideration of security.

IV. Discussion: The Impact of OSS on IoT Development

Open source software offers 4 freedoms to users. Freedom 0 is that it provides the developer with the permission to run the source code for any purpose. Freedom 1 gives the developer a chance to analyze the code, to check how it flows and how it operates, and he/she can make changes to it. Freedom 2 allows the developer to redistribute the source code to any other developer. Freedom 3 gives the developer the permission to share the source code so others can benefit from his/her changes [37] [38]. Regardless of the type of development, whether it is IoT or any other technology, these four freedoms offered by open source software help to accelerate the development process, produce innovative products, improve the developers' skills and enhance their creativity, and help to make immediate changes to the source code which ensures quick fixes in case of malfunction [37].

Nowadays, open source software plays a critical role in IoT development. The impact of open source in IoT development is clearly apparent in the availability of open source tools that are dedicated for IoT development stacks such as open source operating systems, open source platforms, open source hardware and open source frameworks which are discussed in section 3. In 2017, a worldwide IoT innovation survey was conducted to investigate the impact of open source on IoT development [1]. In the survey, respondents were asked about the software development tools which they used in developing IoT solutions. The survey findings showed that 39% of the enterprises were using open source software, 36% were using proprietary software, while 24% of them were using both technologies. This result emphasizes the impact of open source on IoT development, which has become clear and noticeable [1]. Furthermore, according to the survey findings, many vendors considered themselves as leaders of open source tools of IoT development. The findings indicated that the top five leaders of open source tools of IoT development are Red Hat, Google, Microsoft, Oracle, and IBM. This confirms that open source technology impacts on IoT development on a large scale [1]. Therefore, the market, nowadays, has witnessed an important transformation to open source software considering the great characteristics of open source technology. As mentioned above, open source solution is by large a software developed by the developer to the developer, which creates an innovative environment that leads to the acceleration of development and achievement of goals. Customer satisfaction can also reach its peak, and many issues related to their security and privacy will be resolved when collaboration among developers exists. An open source license gives anyone the permission to use the open source code and edit it [37]. Furthermore, once it is used in IoT, an open source will ensure that IoT devices can connect to each other in a proper way, and thus, open source will play a significantly important role in device connection. Open source software is combined with open source standards that act as a benchmark that is responsible for updating and managing codes. Such standards are useful in providing communication among IoT devices [39].

As discussed in section 3, a variety of open source platforms for IoT exist including Kaa, SiteWhere, ThingSpeak, Thingboard.io, DeviceHive, and Zetta which are currently used for developing IoT applications and solutions. As shown in the comparison among these platforms, it is obvious that enterprises are competing for developing open source platforms for IoT with different supporting features such as device management, supporting protocols for data collection, data storage tools, data visualization tools, scaling ability, and security support. This competition among enterprises indicates that open source platforms influence the development of IoT. Likewise, the comparison shows that a rich set of tools are integrated into open source IoT platforms to perform several IoT services such as data collection, data storage and processing, data visualization, and data protection.

Furthermore, open source impacts on security in IoT. The security in IoT has been compromised in several attacks that targeted IoT devices [40]. For instance, tea kettle IoT was used to launch a distributed denial of service attack and other attacks were launched to access the webcam and other IoT devices [41]. Researchers and developers are trying to identify better techniques to protect IoT devices. The security of IoT must be studied from different perspectives starting with the sensors that collect the data and ending with the presentation of data to machine or people. Open source can be used to solve various security issues in IoT. Open source software code can be accessed by thousands of developers which helps in engineering a more robust code instead of waiting for the organization in proprietary software. Moreover, any bugs in the code can be fixed immediately. Making the code open to developers helps in increasing the quality and usability of the code because large numbers of developers will focus their attention on the code development. Furthermore, the code can be tested by many developers who are, then, capable of verifying that it is free from any kind of vulnerabilities. Accordingly, security flaws can be fixed within minutes. In addition, the open source community can share new solutions on securing the promising technology

of IoT. Secure tools can be developed for IoT advancement via open source [42]. The full control over the source code can help in mitigating any kind of risk and vulnerabilities can be patched immediately once they are identified [41].

Certifying embedded software can be a challenge when the source code is closed. To certify any software, the source code must be studied. Therefore, making the source code readily available to security experts who will be enabled to deal directly with the source code and will try to uncover any kind of vulnerabilities and then deal with them properly helps to maintain the security of the devices. Moreover, the security patches will be applied to devices easily [43]. A security audit by IoT developers and cybersecurity can be conducted for the purpose of systematic review of the source code in order to detect any vulnerabilities or threats [39]. Therefore, open source software is going to play a vital role in the security of IoT.

Undoubtedly, there is an important need to combine open source with IoT development. Open source is an effective leader for IoT wave. It offers high-speed development, mitigates risks, reduces development cost, and ensures control over code [37]. IoT platforms are available with important features that help develop IoT applications with strong capacities and characteristics.

V. Benefits of an Open Source Adaption in IoT Application Enablement

The nature of open source can enhance the richness of the IoT application in which it can gain success in the market more than the commercial systems. Open source can be considered the best in class security which constitutes the most important benefit from this adaption [44]. Security auditing is crucial to ensure the quality and security of the code. In open source, developers, quality assurance team, and researchers can conduct a security audit and test the open source code at different levels. Such auditing can assist a deep and thorough analysis of potential threats or vulnerabilities and thus provide a certain level of transparency from a security standpoint. Furthermore, once the vulnerabilities have been identified by the community of developers, they can be patched rapidly. Full control over the source code can help to mitigate risks without spending time waiting for a vendor to identify risk and issue a fix as in proprietary software [4]. Another benefit of open source is that it can offer extraordinary flexibility. In this regard, the open source platform provides great flexibility to deploy software that can satisfy or meet the business needs. Moreover, open source can provide the ability to future proof. Adaption to the changing requirements and to the market needs is provided by open source platforms through robust techniques. Additionally, contrary to the proprietary system, migration to the newer application is easier in open source. The most valuable benefit of open source in IoT is that there is no cost for the software or its upgrade [41].

VI. Conclusion

The world has witnessed a new wave in technology that is called internet of things (IoT) that contributes to making an object interact with people or other objects via the internet. Many vendors in the market started adopting this new technology through the development of IoT devices that have embedded applications and are supported by sensors and communication technologies. However, combining IoT technology with other technologies such as open source software constitutes a great transformation. This paper discussed the impact of open source in IoT development and IoT security. The discussion involved an analysis of the key features of using open source in IoT, and comparisons of the best and most widely used open source platforms for IoT. The discussion showed that open source solutions for IoT such as platforms, frameworks, operating systems, and hardware are available in the market. The availability of these solutions accelerates the development of IoT applications, helps in improving the experiences of IoT developers, offers secure platforms for IoT, addresses many security issues and protects user privacy since the source code is on hand. The open source also contributes to enriching the world with new ideas that result from community collaboration. Moreover, reusing the source code can reduce the development time and cost. In addition, the results of the comparison made between open source IoT platforms showed that enterprises are competing for the development of open source IoT platforms with great capabilities and useful features such as device management, scalability, connectivity protocols, data storage, data visualization, and security that allows for robust IoT development. Overall, open source impacts largely on the development of IoT and it can be considered as a critical driver for development. The research can be extended to adopt open source tools in IoT architecture to enhance its security and privacy.

Research Direction

Many IoT architectures are available. However, a standard architecture for IoT is yet to exist. The existing IoT architecture lacks consideration of privacy and security in IoT architecture layers. Consequently, adapting open source in IoT architecture can enhance two major aspects, namely security and privacy. Therefore, research that utilizes open source solutions to support IoT architecture with security and privacy mechanisms is definitely needed.

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References

[1] S. Hendrick, "The Impact of Open Source Software on Developing IoT Solutions - RTInsights," 2018. [Online]. Available: https://www.rtinsights.com/the-impact-of-open-source-software-on-developing-iot-solutions/. [Accessed: 24-Jul-2018].

[2] V. Ratan, "The Role of Open Source in IoT - Open Source For You," 2017. [Online]. Available: https://opensourceforu.com/2017/07/open-source-role-in-iot/. [Accessed: 26-Jun-2018].

[3] P. Johnson, "Open Source's Role in the Internet of Things," 2016. [Online]. Available: https://resources.whitesourcesoftware.com/blog-whitesource/open-source-s-role-in-the-internet-of-things. [Accessed: 24-Jun-2018].

[4] K. Oliinyk, "5 Differences Between Open Source and Closed Source Software - API2Cart - Unified Shopping Cart Data Interface," *API2CART*, 2018. [Online]. Available: https://api2cart.com/business/5-differences-between-open-source-and-closed-source-software/. [Accessed: 23-Sep-2018].

[5] VisionMobile, "The Essential Guide to Open Source in IoT," 2016.

[6] E. Baccelli et al., "RIOT: An Open Source Operating System for Low-End Embedded Devices in the IoT," *IEEE Internet Things J.*, vol. 4662, no. c, pp. 1–12, 2018.

[7] A. Kumar, "Top 5 Open Source Operating Systems for IoT Devices," 2018. [Online]. Available: https://www.technotification.com/2018/05/open-source-iot-operating-systems.html. [Accessed: 10-Jul-2018].

[8] T. Borgohain, U. Kumar, and S. Sanyal, "Survey of Operating Systems for the IoT Environment," April 2015.

[9] B. Katole, M. Sivapala, and V. Suresh, "Principle Elements and Framework of the Internet of Things," *Int. J. Eng. Sci.*, vol. 3, no. 5, pp. 24–29, 2013.

[10] O. Uviase and G. Kotonya, "IoT Architectural Framework: Connection and Integration Framework for IoT Systems," *Electron. Proc. Theor. Comput. Sci.*, vol. 264, pp. 1–17, 2018.

[11] R. Bhagat, "3 Best IoT Frameworks for Beginners - DZone IoT," *Dzone*, 2018. [Online]. Available: https://dzone.com/articles/3-best-iot-frameworks-for-beginners. [Accessed: 10-Jul-2018].

[12] C. Thumar, "Reach New Heights in IoT with Open Source Technology - JAXenter," *jaxenter*, 2018. [Online]. Available: https://jaxenter.com/open-source-140701.html. [Accessed: 10-Jul-2018].

[13] M. Maksimovic, V. Vujovic, N. Davidović, V. Milosevic, and B. Perisic, "Raspberry Pi as the Internet of Things Hardware: Performances and Constraints." 2014.

[14] P. Di Justo, "Raspberry Pi or Arduino Uno? One Simple Rule to Choose the Right Board," *magazine*, 2015. [Online]. Available: https://makezine.com/2015/12/04/admittedly-simplistic-guide-raspberry-pi-vs-arduino/. [Accessed: 10-Jul-2018].

[15] P. Justo, "Raspberry Pi vs Arduino," *December 4, 2015*, p. 1, 2015.

[16] A. Rogers, "Arduino vs Raspberry Pi - A Comparison - Codeduino," 2018. [Online]. Available: https://codeduino.com/tutorials/arduino-vs-raspberry-pi/. [Accessed: 20-Sep-2018].

[17] S. Kumar, "5 Platforms for IoT Application Development - DZone IoT," DZone, 2018. [Online]. Available: https://dzone.com/articles/5-platforms-for-iot-application-development. [Accessed: 09-Jul-2018].

[18] B. Nakhuva and T. Champaneria, "Study of the Various Internet of Things Platforms," *Int. J. Comput. Sci. Eng. Surv.*, vol. 6, no. 6, pp. 61–74, 2015.

[19] Microsoft, "Azure Internet of Things (IoT) Introduction | Microsoft Docs," *Microsoft*, 2018. [Online]. Available: https://docs.microsoft.com/en-us/azure/iot-fundamentals/iot-introduction. [Accessed: 09-Jul-2018].

[20] BaseApp, "Top IoT Platforms of 2018," *https://www.baseapp.com/iot/top-iot-platforms/*, 2018. [Online]. Available: https://www.baseapp.com/iot/top-iot-platforms/. [Accessed: 09-Sep-2018].

[21] Techtic Administrator, "Top 10 Open Source IoT Frameworks By Techtic Solutions," *Techtic Solutions*, 2018. [Online]. Available: https://www.techtic.com/blog/top-10-open-source-iot-frameworks. [Accessed: 23-Sep-2018].

[22] H. Media Team, "9 Best & Top Open source IoT Platforms to Develop the IOT Projects |H2S Media," 2017. [Online]. Available: https://www.how2shout.com/tools/best-opensource-iot-platforms-develop-iot-projects.html. [Accessed: 23-Sep-2018].

[23] Bitnine, "TOP 9 IoT Open Source Platforms - Bitnine Global Inc.," *bitnine*, 2016. [Online]. Available: https://bitnine.net/blog-useful-information/top-9-iot-open-source-platforms/. [Accessed: 23-Sep-2018].

[24] "Technical Capabilities and IoT Architecture of Kaa," *kaaproject.org*, 2018. [Online]. Available: https://www.kaaproject.org/platform/. [Accessed: 12-Sep-2018].

[25] "SiteWhere | The Open Platform for the Internet of Things," *sitewhere.org*, 2016. [Online]. Available: http://www.sitewhere.org/. [Accessed: 12-Sep-2018].

[26] "ThingSpeak Documentation," 2018. [Online]. Available: https://www.mathworks.com/help/thingspeak/. [Accessed: 12-Sep-2018].

[27] H. Scharler, "ThingSpeak Adds Paid Options to Its IoT Analytics Service » Hans on IoT - MATLAB & Simulink," *MathWorks.com*, 2016. [Online]. Available: https://blogs.mathworks.com/iot/2016/12/05/thingspeak-adds-paid-options-to-its-iot-analytics-service/. [Accessed: 11-Sep-2018].

[28] ThingSpeak Community, "SSL and Security | ThingSpeak API," 2016. [Online]. Available: https://community.thingspeak.com/forum/thingspeak-api/ssl-and-security/. [Accessed: 10-Sep-2018].

[29] "DeviceHive - Open Source IoT Data Platform with a Wide Range of Integration Options.," *devicehive.com*, 2018. [Online]. Available: https://devicehive.com/#home. [Accessed: 12-Sep-2018].

[30] "DeviceHive Microservices Architecture," 2018. [Online]. Available: https://docs.devicehive.com/docs/devicehive-

architecture. [Accessed: 12-Sep-2018].

[31] "Security in DeviceHive," *devicehive.com*, 2018. [Online]. Available: https://docs.devicehive.com/docs/security-in-devicehive. [Accessed: 12-Sep-2018].

[32] "Zetta - An API-First Internet of Things (IoT) Platform - Free and Open Source Software," *zettajs.org*, 2018. [Online]. Available: http://www.zettajs.org/. [Accessed: 12-Sep-2018].

[33] "ThingsBoard - Open-Source IoT Platform," *thingsboard.io*, 2018. [Online]. Available: https://thingsboard.io/. [Accessed: 12-Sep-2018].

[34] S. Manandhar, "MQTT Based Communication in IoT,". May 2017.

[35] "Internet of Things and Data Visualization — Exastax," *exastax.com*, 2017. [Online]. Available: https://www.exastax.com/big-data/internet-things-data-visualization/. [Accessed: 25-Sep-2018].

[36] W. Ashford, "APIs Key to the Security of the Internet of Things, Says Axway," *computerweekly.com*, 2013. [Online]. Available: https://www.computerweekly.com/news/2240209213/APIs-key-to-security-of-internet-of-things-says-Axway. [Accessed: 24-Sep-2018].

[37] G. Gravier, "Open Source as a Driver of the Internet of Things," *InfoQ*, 2016. [Online]. Available: https://www.infoq.com/articles/open-source-as-a-driver-of-internet-of-things. [Accessed: 11-Jul-2018].

[38] L. Rosen, "Freedom and Open Source," *Open source License. - Softw. Free. Intellect. Prop.*, pp. 1–12, 2004.

[39] N. Cranford, "The Role of Open Source Software in the IoT | Enterprise IoT Insights," 2017. [Online]. Available: https://enterpriseiotinsights.com/20170623/uncategorized/the-role-of-open-source-software-in-iot-tag27-tag99. [Accessed: 27-Jun-2018].

[40] D. Eidenskog and F. Kamrani, "Internet of Things : An IT Security Nightmare," *Strategy. Outlook*, vol. 7, no. November 2017.

[41] D. Tokar, "Benefits of an Open Source Approach to IoT Application Anablement - IoT Agenda," 2017. [Online]. Available: https://internetofthingsagenda.techtarget.com/blog/IoT-Agenda/Benefits-of-an-open-source-approach-to-IoT-application-enablement. [Accessed: 28-Jun-2018].

[42] A. Swift, "Improving Security in the Internet of Things | ITProPortal," *ITproPortal*, 2016. [Online]. Available: https://www.itproportal.com/2016/03/20/the-internet-of-things-improving-its-security/. [Accessed: 11-Jul-2018].

[43] C. Hall, "Secure IoT Through Oversight, Open Source, and Open Standards," 2016. [Online]. Available: http://www.itprotoday.com/security/secure-iot-through-oversight-open-source-and-open-standards. [Accessed: 27-Jun-2018].

[44] C. Serrão, D. Neves, and P. Trezentos, "Open Source Security Analysis," no. February 2002.

Open Source Course Equivalency Framework for HEIs in Oman

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***Abstract*— Sultanate of Oman is one of the fastest growing nations in Middle East with the majority of its youth population. To utilize its young generation as knowledge worker in the economy, the role of higher education is imminent. Oman's higher education institutions are providing a flexible learning environment to students with different specializations according to the need of the market. During the studies, students are permitted to shift from one institute to another. This process of migration having considerable compatibility issues of the courses and programme. At present, higher education institutions (HEIs) are manually analyzing applications and matching it with their offered courses to accommodate transfer students. This process of acceptance of credits and courses needs to review each application manually; requires ample amount of time and resources. We have proposed a framework that can be executed simultaneously at multiple institutions. The framework will result in saving time and cost. This work will facilitate all participating academic bodies to take advantage from each other's efforts. This framework can help in academic benching marking of courses and programs in large.**

***Index Terms* — Course Equivalency, Academic Benchmarking, Open Standard, XML, Higher Education Information Standardization, Electronic Data Standard.**

I. Introduction

Higher education is a key pillar of any economy in modern world. Higher education institutions in Sultanate of Oman are committed to provide quality education and services to community.

Any Information processing requires time and resources to manage and process so that it become useful. Information processing requires human resource to execute it and it surely involves direct or indirect cost. That's why information is also considered as organizational asset. Modern world businesses are investing time and resources to ensure the availability of their required information to support and meet their organizational goals. This helps them to improve their work on time with less dependency on other information sources.

Student transfer is an ongoing process among higher education institutions. Students may take transfer from one institution to another upon acceptance of formalities such as matching credits, course outcomes, and required grades. This process of accepting student has to meet several requirements which require sufficient time for each application to complete. To simply say, this process of course exemption has to look each one of the completed courses, their description, or objectives to match with the equivalent courses offered in host institution. The connections of course equivalencies among institutions are n x n in practice which is a difficult scenario to accomplish, as all HEI's are having less or more variation in their course outcomes. We have applied a concept of information processing efficiently through our framework to map the scenario of course equivalency and transfer cases.

The framework will facilitate all the HEIs to identify the matching courses and compare them at once and reuse this information for any upcoming applications. In a case of any newly received application, the host institute can easily see the corresponding course with the percentage of matching contents already recorded earlier.

I. Problem Statement

When students is migrating from one institute to another, such transfers especially with incomplete programs, brings lot of background work to be done manually by the receiving institutions. These transfers lead to delays in registration process due to scrutiny of transcripts [7]. Such evaluation of transcript includes verification of courses completed in required grades with matching outcomes by specialized faculty. Once they are evaluated then only they are accepted in host institution.

It was also stated that "Problems are further aggravated when the student need course equivalencies in another

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college, where the QA manual and bylaws in colleges/universities state that courses need to be matched and equivalencies-weightages need to be ascertained before granting admission to students."[5][6]

All these obstacles are faced in absence of benchmarking among HEIs especially in courses and programs areas. To avoid the said delays and improve the efficiency of this transfer process we have proposed an open source framework. That said framework can be freely adopted and it will be useful in benchmarking of the courses and programs offered in different HEIs. Further, it will reduce paper work and make this process efficient and less time consuming.

II. FRAMEWORK

Oman Standard Classification of Education Framework (OSCED) classifies programs, fields of study and specializations [6]. It also highlights courses under specializations with outlines.

The open source course equivalency framework illustrates five core phases namely select specialization, identify course, compare course outline, store equivalency result, and report generation. The last process is generation of course equivalency report as shown below in Fig. 1.

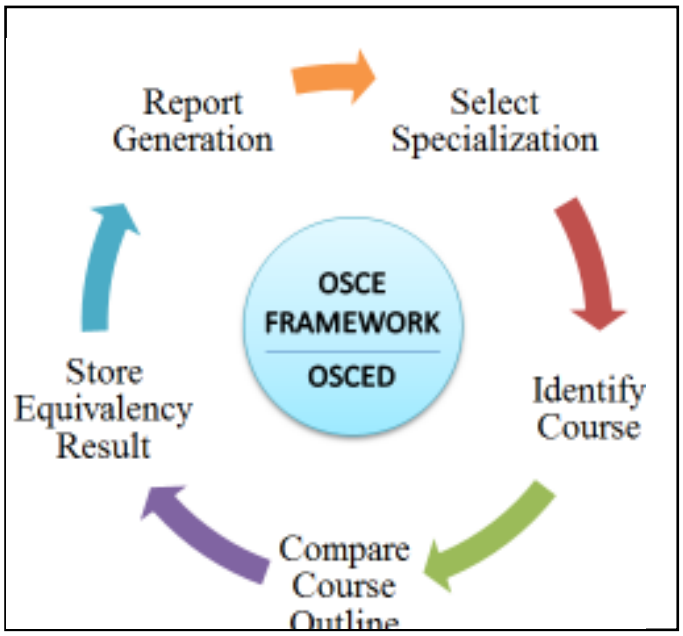

Fig. 1: Open Source Course Equivalency Framework

The framework is based on OSCED standard document. The framework is implemented in an open source structured document which will take care of each specialization and its courses.

The standard document will incorporate not only courses information but also course equivalency information which can be modified and utilized by all others. The structure and data of xml document is shown in Fig. 2.

```
<?xml version="1.0"?>
<!-- Information Systems Courses -->
- <courses>
    <stream>OAAA - Information Systems</stream>
  - <course>
      <code>020305</code>
      <title>Systems Analysis and Design </title>
      <credits>3</credits>
      <description> Systems Analysis and Design is the stu
        of analysing the information needs of the user a
        designing or modifying a system to meet these
        needs. </description>
    - <outline>
        <content> data and process modelling </content>
        <content>identifying system components </conte
        <content>general systems theory</content>
        <content>systems software engineering</conten
        <content>systems design</content>
        <content>systems development lifecycle</conten
      </outline>
    - <equivalencies>
      - <institute>
          <iname>CoT</iname>
          <ccode>ITDB2101</ccode>
          <ctitle>System Analysis and Design</ctitle>
          <match>80</match>
        </institute>
      - <institute>
          <iname>CaS</iname>
          <ccode>SFDV3003</ccode>
          <ctitle>Systems Analysis and Design </ctitle>
          <match>85</match>
        </institute>
      </equivalencies>
  </course>
</courses>
```

The xml document contains basic programme and courses information like their descriptions, outlines, credits and matching percentage with corresponding courses of all accredited HEIs.

The xml file given in this example is containing information of "Information Systems" stream's courses as given in OSCED document [6]. It includes information of related courses. A single course 'Systems Analysis and Design' is shown along with its code, credits, description, and outline. Each institution can compare available courses from standard document with their courses of existing programs and identify and write the percentage of its matching contents. It will also help them to do equivalency with any other institution having similar course.

The file shown above in Fig. 2 can contain several courses information and may be long enough depending on the size of courses and related information in it.

To process and get desired information an XSLT processor is responsible for applying the rules defined in the style sheet to the input XML document as shown in Fig. 3. [1]

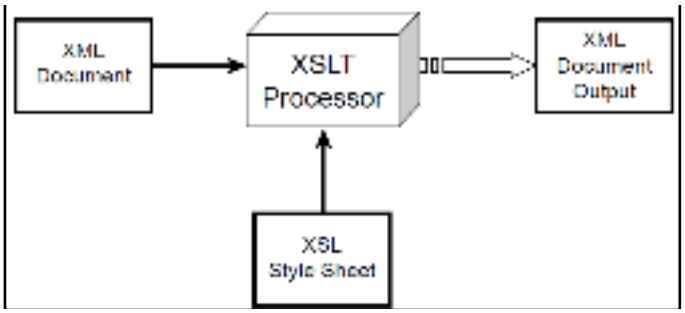

Fig. 3: Sending Data to XSLT Processor [1]

In this process of XSL transformation the real xml document which contains structure of program and courses data will not be effected and keep secure at its place. The XSLT process will generate a new document. That new result document can be in any supported format whether xml, xhtml, or html [2] [3] [4]. After XSL transformation the equivalency report of selected course can be generated as shown in Fig. 4.

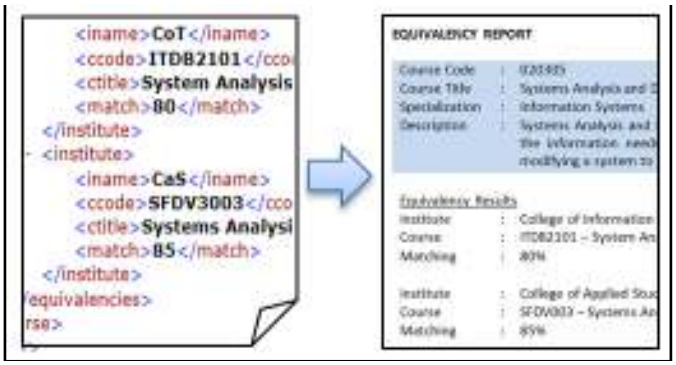

Fig. 4: Equivalency report after XSL transformation

The equivalency report is displaying selected institutions percentage of matching contents from source document. This report can be used for equivalency purposes.

III. DISCUSSION

The framework we have proposed is simple and effective solution for course equivalency process to meet the existing and future requirements of higher education institutes within Sultanate of Oman. The framework is working with open source technology and can be implemented with minimal investment.

Further enhancement can be done to use xml structure and data as a data source for applications to process it more conveniently. Simple interfaces can be easily developed to access and maintain information in any modern programming tool.

The information of academic programs will be aligned centrally with OAAA. It will help to streamline and standardize the process of equivalency and will help in benchmarking in future. This effort will also be useful for competent authorities to utilize information for planning and decision making without any delays.

IV. CONCLUSION

The proposed framework will transform the existing practice of manual processing to information processing. It can also be used for the purpose of standardization of academic courses and programs. The implementation of the framework will bring radical changes in process and improve the institutional information exchange.

REFERENCES

Ron Schmelzer, Travis Vandersypen, Jason Bloomberg, Madhu Siddalingaiah, Sam Hunting, Michael D. Qualls, David Houlding, Chad Darby, Diane Kennedy, "XML and Web Services Unleashed", Sams Publishing, pp. 348, 2002.

Extensible Markup Language (XML) 1.1 W3C available at https://www.w3.org/TR/xml11/ last accessed on 14 Oct 18.

Extensible Markup Language (XML) 1.1 W3C Recommendation online article-edited 15 April 2004 available at https://www.w3.org/TR/2004/REC-xml11-20040204/#sec-prolog-dtd last accessed on 14 Oct 18.

XML Technical Specification for Higher Education http://xml.coverpages.org/PESC-DraftTechSpec.pdf last accessed on 3 Oct 18.

Quality Assurance Manual, Salalah College of Technology, Ministry of Manpower, Sultanate of Oman, Version 8, April 2014.

Oman Standard Classification of Education Framework (OSCED) available from http://www.oac.gov.om/frameworks/osced/ last accessed on 21 Oct 18.

Qureshi et. al., "Open Standard Data Exchange Model for Higher Education Institutions in Oman", Free and Open Source Software Conference (FOSSC-17), Feb 18-19, 2017

Android Application Permission Model

Issues and Privacy Violation

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***Abstract*— Smart devices have been developed to dominate the market as a communication channel that supports various online services for a wide range of end users. Android architecture introduces a built-in security and privacy mechanism called the permission model, which confines access to private phone resources. In this security model, mobile applications must have declarations for all the permissions required to access sensitive mobile resources. The Android developer must define the matching permissions in an application-launched file (manifest). Nevertheless, a regular user does not consume much time to recognize more about the requested permissions by the applications, and some of the users do not have technical skills about Android permissions and their impacts. Thus, there are many opportunities for malicious to gain access to private resources, data and personal information. This paper investigates the effects of using a permission model in Android mobile applications. The authors contributed to realize the relationship between the permission mechanism and users' private data. In addition, this paper highlights the main permissions that are required by various Android applications and discusses the user's abilities to control these permissions and their impact on protecting user privacy.**

***Index Terms*— Android Security, Android Permission Model, User Privacy.**

I. INTRODUCTION

Android, as an open source platform, highly dominates the Mobile market, which has witnessed a sharp growth in recent years. Gartner reported that Google's operating system holds 81.7 percent of the market share during 2016 [1]. The number of apps available for users has also grown tremendously. There are over 3.3 million apps hosted in Google Play in the first quarter of 2018 [2], whereas the Apple App Store remained the second-largest app store that hosts 2 million apps [2]. With an increase in users and available applications in different app stores, it is predictable that many of these apps will compromise users' private information and steal or damage their personal data. Along with malicious apps, there are many other applications that could be considered greyware because they ask users for over-privileges access, or they may have indirect access to private resources in a user's mobile device [3]. In that direction, the adversary may gain access to the private resources from an over-privileged app and leak users' private data.

In the Android platform, the security mechanism has been implemented in different Android software stack layers. In the kernel level, the isolation process separates users' resources from one another, so that it acts as a multiuser operating system. In the applications layer, Google introduced the permission mechanism as an access control model for restricting access to sensitive resources [3,4,5,6]. In this mechanism, to access sensitive APIs (e.g. GPS, Camera, Contact Numbers etc.), users must accept the granting of permissions. The permissions are proposed to offer a limited access to device resources and to reduce privacy threats toward end-users.

Android does not offer any capability to users for dynamically enabling, modifying, and configuring the permissions [3,6,7,8]. The only method available to users is to revoke the app permissions or non-revoke them from the device setting.

According to the official Google developer website, the permission model is divided into different levels; the normal level, which is automatically granted to apps when requested and secures the API calls that may impact the user data. The second level is the dangerous level, which is granted based on users' approval and it enables an application to do harmful operations (e.g., recording audio/video). The last level is the signature level, which is granted to apps signed with the same certificate as the one that states the permission, and it can control access to very dangerous privileges (e.g., clear users' data) [9,10].

The main drawback of Android permission architecture is that there is no technique that allows an App developer to recognize the most significant permissions needed by the app functionality. The developer will then request more privileged ones according to some check and stability criteria, which protect the privacy of the user. Thus, it leads to have many malicious applications and other online services that negatively impact the reliability of user private resources, or they may also affect the mobile device itself [3,11,12,13,14,15].

Th rest of the paper is organized as follows; section II presents the previous research that mentioned Android security stack, Android permission and user privacy. Section III provides the research discussion and data analysis. Finally, section IV provides the research recommendations and conclusions.

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II. Related work

Before the app gains access to users' private data (e.g. contact number, location, credit cards and photos), it should declare a list of required permissions in the *AndroidManifest.xml* file. Some of these permissions may have side effects for the user private data (Over-privileges). The user is only alerted when the app requests dangerous permissions. This warning only notifies the user about the type of the permission being requested, however, it does not provide information on how the app is going to use this type of permission.

Researchers have been trying to address the issue of privacy leakage in Android applications using different methodologies. Several studies have addressed different types of potential attacks and privacy leakages in Android systems.

In [16], the authors showed a side-channel attack by tracking changes in an application's memory footprint. A user may use web browsers as an application target (hybrid app), which permits unprivileged apps, malicious apps and attackers to infer the page browsed. Moreover, vulnerabilities were recognized in the Android Sandboxing mechanism that allows applications to gain the resource-access of other applications [17]. AppIntent is an approach that focuses on detecting a user's information privacy leakage. It provides a sequence of GUI manipulations matching the sequence of events that lead to data transmission. The tracing mechanism performed by GUI allows an analyst to determine if the data transmission is user intended or not [18]. In 2017, Dar proposed a runtime detection and prevention system, which provides a second level of security by locking the apps that try to access the resources of the device without users' prior knowledge [19]. Many static and dynamic analysis detection of privacy leakage tools have been published in order to provide effective Android application tracing [18][20][21].

To secure users' privacy, Google has introduced a technique by which the developers of each app have to assign the appropriate declaration of the required privacy policy when submitting the apps to Google play store. The developers should specify why they need to access the sensitive resources (e.g. recording audio and camera) [22]. Previous studies have discussed the importance of giving users clarifications on why Android permissions are needed while using Android apps. For instance, Kelley et.al [23] stated that explaining the purpose of requiring permissions to access users' information is an effective way to comfort customers' privacy concerns [23]. In the current Android market (google play), an app is published without providing the permission justification on app download pages.

The authors in [8] reviewed the issue that occurs when users try to understand the permission models and their impact while accessing their private data. Privacy can be accessed via dangerous permissions, ads and operations that are used by many apps to access sensitive resources, collect private data and share these data with a third party. Authors have proposed a privacy-based notification framework that allows a user to keep on tracking each app permission while requesting access to sensitive resources [8].

Researchers in [24] discussed the privacy issues of an Android system by explaining the Android applications that exploit the end users' privacy including social media apps, location-based apps, and government apps [24]. In addition, [25] realized that the privacy settings of an app can be modified during the run-time without causing an application to crash and without user control. Thus, the authors developed a Privacy Management Platform (PMP) which is a fine-grained technique to allow users to track the potential data access and protect any sensitive resources suitably.

User privacy can be hacked through the permission models. Attackers use many methods to access sensitive user data. The authors in [26] found that app permissions disclose the private user resources which lead to serious privacy threats, and users need to be aware of privacy violation. In 2017, Fu et al. discussed a number of ways that can expose users' privacy. For example, MobileAppTracking, ad network and location tracking apps are used by at least 100 authorized apps, and they present a real hazard for users. These apps do not access the data unless users confirmed the permissions, thus, all users should carefully read the description of permissions before agreeing on the list and understand the implications of disclosing the information as well [26].

Researchers in [27] declared that video surveillance and camera functions that are used in different areas including home surveillance, baby monitoring, surveillance on workers and camera apps can be used to violate users' privacy without prior notification. The attackers may misuse the details of these media in web servers to obtain other user sensitive information [27].

In [5], authors stated that the application developers can take advantage of an existing permission verification to obtain users' consent for all of the requested permissions in order to use the application. They can also apply other not-related permissions to gain sensitive information without using appropriate permissions (over-privilege). Moreover, [28] found that user privacy can be hacked via the app ads e.g. social networking ads and e-commerce ads, which activate hazardous mechanisms to fetch and run codes from the Internet and trigger additional security risks to mobile users. Therefore, providing users with control over information disclosure and enhancing their ads awareness before installation efficiently support them to recover the privacy decisions, increase their likelihood of installing an app, and expand their perceptions of the app.

Furthermore, in [29] researchers discussed that third-party libraries can gain access to user privacy e.g. google Admob library that requires access to user location to deliver the targeted advertisement. In contrast, users cannot distinguish between harm libraries and useful once.

III. DISCUSSIONS AND DATA ANALYSIS

This section examines the different types of apps available at Google app store, the number of permissions requested, the types of these permissions and the degree in which users can revoke or control these permissions. Google play store categorizes its apps into 15 sub-categories which are Comics, Communication, Entertainment, Finance, Health, Lifestyle,

Productivity, Multimedia, News and Weather, Shopping, Social, Sports, Travel, Demo, Transportation, Food and Drinks, House and Home, and Software libraries.

A research was done by [30] that shows the statistics of the most popular and top-rated app of the main categories. The frequency of the permission requested by each app, the type of the permissions that are used in each app and the possibility of user privacy leakage were observed and selected based on the statistics of [30]. Table 1 illustrates the categories of the apps, the type of permissions used and the number of revocable/non-revocable permissions.

GOOGLE PLAY STORE CATEGORIES, APPS AND PERMISSIONS.

Google Play Store Category	*Selected Apps*	*Types of permissions Used*	*No. of Revocable Permissions*	*No.of Non-Revocable Permissions*
Education	Coursera	Calendar, Camera, Contacts, Storage	4	11
Entertainment	Subway	Network	0	9
Business	ROP-Royal Oman Police	Camera, Storage, Location, Telephone, SMS	5	7
Lifestyle	Tinder	Location, Storage	2	13
Tools	VPN Free Betternet	Storage	1	10
Personalization	CM Launcher 3D-Personalized	Device & app Identity, Calendar, Contact, Location, SMS, Phone, Photos/Media/Files,	13	15+
Music & Audio	Smule	Camera, Contacts, Storage, Location, Microphone	5	8
Books & Reference	Webnovel	Camera, Storage, Location	3	9
Travel & Local	Booking	Camera, Contacts, Storage, Location	4	13
Shopping	Namshi	Contacts, Location, Telephone, Storage	4	6
Health & Fitness	Calorie Counter	Camera, Contacts, Storage, Location,	4	13
Social	Snapchat	Camera, Contacts, Storage, Location, Microphone, Telephone, SMS	7	14
Communication	Whatsapp	Camera, Contacts, Storage, Location, Microphone, Telephone, SMS	7	15+
Sports app	MLB At Bat	Location, Microphone, Telephone	3	8
Maps & Navigation	Karta GPS	Contacts, Storage, Location, Telephone	4	10

As shown in Android google play store [31], all the dangerous permissions are placed in a special group called permission group, which may also contain normal permissions. The user is only notified when the app requires access to dangerous permissions. The notification is only about the type of the permission being requested, but no information is provided on how the app is going to use this kind of permission. As shown in Table I, these types of permissions are called revocable permission. In android 6.0 and above, users can control (accept/grant/ switch off) the permissions that are classified as dangerous permissions (revocable permission). It can be controlled through the revocation mechanism. For example, Table II lists dangerous permissions that are requested from users during app installation.

DANGEROUS PERMISSIONS GROUP

Dangerous permissions Group	Permission Functionality	Controlled by User
Camera	Camera	√
Contacts	Read, write, get account, modify contact	√
Storage	Read, Write	√
Microphone	Record audio	√
Location	Access fine location, access coarse location	√
Telephone	Read phone state, call, read call log, write call log, add voice mail, Use_SIP, Process outgoing calls	√
SMS	Send, receive, read, receive wap push, receive MMS	√
Calendar	Read, write	√

All Android applications consider dangerous permissions as more hazardous because user privacy can be harmed easily. However, the normal permissions (Non-revocable permissions) can cause privacy issues for the user sensitive data. For instance, WhatsApp mobile application, which is considered at the top of the communication apps category in Google play store, requests around 7 dangerous permissions where users can revoke them based on their own specification. On the other hand, it requires more than 15 normal permissions, which causes a side effect to user privacy. They cause privacy concerns for the user by tracking location, installing packages and shortcuts, sending data without notification, retrieving running apps, reading and writing call logs, giving permission to run at startup, using system settings etc. Moreover, these permissions cannot be controlled by users, which complicates the issue and allows the malware to leak the user privacy without notifying the user. Figure 1 shows the WhatsApp permissions.

Fig. 1. Example WhatsApp main permissions

In addition, Facebook social networking app has been considered as one of the disclosure apps that expose user privacy [35]. Facebook can share users' data with a third-party by giving the app permissions to access different sensitive resources. For this reason, users are put at risk where their private data are disclosed to these applications. Malicious applications can collect and use users' private data for undesirable purposes because most of the users do not take the privacy seriously and prefer to keep the default setting of privacy while using the social networking apps. Moreover, many users use Virtual Private Network (VPN) apps to access luck services. [32] illustrated that 67% of the identified VPN Android apps offer services to improve online privacy and security. However, 75% of these VPN tools use third-party tracking libraries and 82% request permissions to access private resources e.g. user accounts and text messages [32].

IV. CONCLUSION

The Android operating system supports users' privacy using apps permission technique that puts restrictions on all apps with regard to accessing a user's private data. Each app requires a list of permissions, which are determined by the app developer and accepted by the user during the app installation time. The ability to avoid granting dangerous permissions is delegated to the end-user, who is expected to understand what permissions have been accepted. Android does not provide tools to analyze and trace the possible interactions between apps. This work has analyzed the most popular Android apps and discussed numerous privacy concerns associated with the permission grants required by these apps, especially in the context of communications and social media apps. The authors note that most of the mobile apps use over-privileges permissions and misuse users' private data. It is often unclear to end users how apps are accessing resources and personal information on their devices. Furthermore, most of these applications request over-privileges permissions, which cannot be handled by the user, although new versions of Android platform are available. Permission techniques are not effective enough to protect the user privacy, as they can be attacked in different ways e.g. Ads libraries, social networking ads and e-commerce channels. Therefore, providing users with a mechanism to trace, control and configure their data and privacy is very critical.

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REFERENCES

[1] C. Miller, 'Latest Gartner data shows Apple edge out Samsung in market share during Q4 2016', *https://9to5mac.com/2017/02/15/samsung-loses-market-share-to-apple-in-q4-2016/*. 2016.

[2] © Statista 2018, 'App stores_ number of apps in leading app stores 2018 _ Statista', © *Statista 2018*, 2018. [Online]. Available: https://www.statista.com/statistics/276623/number-of-apps-available-in-leading-app-stores/. [Accessed: 24-Jun-2018].

[3] J. Gu, Y. Calvin, H. Xu, C. Zhang, and H. Ling, 'Privacy concerns for mobile app download : An elaboration likelihood model perspective', *Decis. Support Syst.*, vol. 94, pp. 19–28, 2017.

[4] B. Li, Y. Zhang, J. Li, W. Yang, and D. Gu, 'The Journal of Systems and Software AppSpear : Automating the hidden-code extraction and reassembling of packed android malware', *J. Syst. Softw.*, vol. 140, pp. 3–16, 2018.

[5] N. K. Thanigaivelan, A. Hakkala, S. Virtanen, and J. Isoaho, 'CoDRA : Context-based dynamically recon fi gurable access control system for android', vol. 101, no. April 2017, pp. 1–17, 2018.

[6] C. Lyvas, C. Lambrinoudakis, and D. Geneiatakis, 'Dypermin : Dynamic permission mining', *Comput. Secur.*, vol. 77, pp. 472–487, 2018.

[7] S. E. E. Profile, 'Malware Analysis and Detection on Android: The Big Challenge', in *Smartphones from an Applied Research Perspective*, no. November, 2017, pp. 198-211.

[8] A. Khatoon, G. S. Member, and P. Corcoran, 'Android permission system and user privacy- A review of concept and approaches', no. December, 2017.

[9] A. P. Felt, H. J. Wang, A. Moshchuk, S. Hanna, and E. Chin, 'Permission Re-Delegation : Attacks and Defenses', in *Proceedings of the eighth symposium on usable privacy and security*, 2011.

[10] L. Xing, X. Pan, R. Wang, K. Yuan, and X. Wang, 'Upgrading Your Android , Elevating My Malware : Privilege Escalation Through Mobile OS Updating', 2014.

[11] R. Mahmood, N. Esfahani, T. Kacem, N. Mirzaei, S. Malek, and A. Stavrou, 'A whitebox approach for automated security testing of Android applications on the cloud', in *Proceedings of the 7th International Workshop on Automation of Software Test*, 2012, pp. 22-28.

[12] J. Ren, A. Rao, M. Lindorfer, A. Legout, and D. Choffnes, 'ReCon: Revealing and Controlling PII Leaks in Mobile Network Traffic', *Proc. 14th Annu. Int. Conf. Mob. Syst. Appl. Serv. (MobiSys '16)*, pp. 361-374, 2016.

[13] R. Neisse, G. Steri, D. Geneiatakis, and I. Nai Fovino, 'A privacy enforcing framework for Android applications', *Comput. Secur.*, vol. 62, pp. 257-277, 2016.

[14] S. Bezobrazov, A. Sachenko, M. Komar, and V. Rubanau, 'The Methods of Artificial Intelligence for Malicious Applications Detection In Android OS', *Int. J. Comput.*, vol. 15, no. 3, pp. 184-190, 2016.

[15] A. Alshehri, A. Hewins, M. Mcculley, H. Alshahrani, H. Fu, and Y. Zhu, 'Risks behind Device Information Permissions in Android OS', *Commun. Netw.*, vol. 9, pp. 219–234, 2017.

[16] S. Jana and V. Shmatikov, 'Memento : Learning Secrets from Process Footprints', in *IEEE symposium on security and privacy.*, 2012, pp. 143–57.

[17] Z. Yang, M. Yang, Y. Zhang, G. Gu, P. Ning, and X. S. Wang, 'AppIntent: analyzing sensitive data transmission in android for privacy leakage detection', *Proc. 2013 ACM SIGSAC Conf. Comput. Commun. Secur. - CCS '13*, pp. 1043-1054, 2013.

[18] Z. Yang, M. Yang, Y. Zhang, G. Gu, P. Ning, and X. S. Wang, 'AppIntent: analyzing sensitive data transmission in android for privacy leakage detection', in *Proceedings of the 2013*

ACM SIGSAC conference on Computer & communications security - CCS '13, 2013, pp. 1043-1054.

[19] M. A. Dar, 'A Novel Approach to Enhance the Security of Android based Smart phones', in *International Conference on Innovations in information, Embedded and Communication Systems (ICIIECS)*, 2017, pp. 1-5.

[20] M. Xia, L. Gong, Y. Lyu, Z. Qi, and X. Liu, 'Effective real-time android application auditing', *Proc. - IEEE Symp. Secur. Priv.*, vol. 2015-July, pp. 899-914, 2015.

[21] A. P. Fuchs, A. Chaudhuri, and J. Foster, 'SCanDroid : Automated Security Certification of Android Applications', *Read*, vol. 10, no. November, p. 328, 2010.

[22] google, 'Developer Policy Center', *google*, 2018. [Online]. Available: https://play.google.com/intl/en-GB/about/privacy-security-deception/permissions/index.html. [Accessed: 08-Jul-2018].

[23] P. G. Kelley, J. Bresee, L. F. Cranor, and R. W. Reeder, 'A Nutrition Label for Privacy', in *Proceedings of the 5th Symposium on Usable Privacy and Security*, 2009.

[24] A. Khatoon and P. Corcoran, 'Privacy Concerns on Android Devices', in *IEEE International Conference on Consumer Electronics (ICCE)*, 2017, pp. 1-4.

[25] C. Stach, 'How to Assure Privacy on Android Phones and Devices ?', in *14th IEEE International Conference on Mobile Data Management*, 2013, pp. 1–4.

[26] H. Fu, D. Ph, B. Sangeorzan, and D. Ph, 'Relationship Between User Privacy And Application Permissions In Smartphone Platforms', Oakland University, 2017.

[27] A. D. Kelec and D. R. Vukovic, 'Privacy threats on Android devices - Big brother is watching you', *2015 23rd Telecommun. Forum, TELFOR 2015*, vol. 7, pp. 926–929, 2016.

[28] N. Wang, B. Zhang, B. Liu, and H. Jin, 'Investigating Effects of Control and Ads Awareness on Android Users ' Privacy Behaviors and Perceptions', *Acm*, pp. 373–382, 2015.

[29] S. Chitkara, N. Gothoskar, S. Harish, J. I. Hong, and Y. Agarwal, 'Does this App Really Need My Location ? Context-Aware Privacy Management for Smartphones', *IEEE Trans. Dependable Secur. Comput.*, vol. 12, no. 2, pp. 150–163, 2017.

[30] Sensor Tower., 'Google Play: most popular app categories by downloads 2017 | Statistic', *https://www.statista.com/statistics/279286/google-play-android-app-categories/*, 2018. [Online]. Available: https://www.statista.com/statistics/256772/most-popular-app-categories-in-the-google-play-store/. [Accessed: 24-Jul-2018].

[31] Android Developers, 'Permissions overview | Android Developers', *developer.android.com*, 2018. [Online]. Available: https://developer.android.com/guide/topics/permissions/overview#normal-dangerous. [Accessed: 20-Sep-2018].

[32] M. Ikram, N. Vallina-Rodriguez, S. Seneviratne, M. A. Kaafar, and V. Paxson, 'An Analysis of the Privacy and Security Risks of Android VPN Permission-enabled Apps', in *Proceedings of the 2016 ACM on Internet Measurement Conference - IMC '16*, 2016, pp. 349–364.

Internet Offline Solution for Rural / Village Schools

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***Abstract* — Close to the end of 2018, the Indonesian Ministry of Education seems to be interested to re-include ICT class into school curriculum named Informatics class. Unfortunately, access to the Internet is rare especially in rural / villages. In addition, there are not many initiatives in the world in providing offline knowledge / content that can be accessed offline in rural and villages. This work tries to enable rural communities to gain similar knowledge as those in cities. In this work, we report on the possibility to provide inexpensive solutions for schools in village / rural areas. Using the proposed solution, the students in village / rural areas will be able to get the required information and knowledge by accessing the needed information on the Internet while OFFLINE. The main contribution of this work is (1) To provide simple and low cost, less then US$100, Offline Internet server solution, (2) able to run without main electricity power, such as phone power bank or solar cell, (3) copied the required online information on the Internet to local offline Internet server, and (4) acting as Offline Internet to locally provide the required information and knowledge at rural / village schools.**

Thus, rural students will be able to gain the required information / knowledge needed for educational purposes similar to Internet for schools in the cities. No Internet is required to access the information / knowledge as it is locally available.

***Index Terms*—Open Source, Internet Offline, RaspberryPi, Rural School, Village Schools.**

I. *ICT Class re-inclusion into School Curriculum*

Alhamdulillah, the Indonesian Ministry of Education seems to be thinking on re-inclusion of ICT as part of school curriculum. The consequences to be considered are (1) the Indonesian need to prepare a good Informatics curriculum to build a good basic foundation for elementary, middle and high school students in maximizing the use of ICT. This includes topics on computational thinking, basic programming, robotics, 3D printing, internet in addition to traditional office skill which in the past was prioritized, (2) Prepare the required ICT teachers. There are currently around 240,000 schools in Indonesia, it requires 500,000 new ICT teachers for the schools. Not to mention, the required knowledge, such as computational thinking, robotics, 3D printing, are currently not thought in most of the available educational faculties. It is becoming a huge task for the ministry of education. Thus, the Indonesian needs setup a strategic policy to prepare the needed ICT educational resources in a short time, and (3) Indonesia need to prepare infrastructure, laboratories, networks and these must be low cost, have to consume very low electricity / energy as it is very difficult to get a good supply of electricity power. And no less important is that it must be able to operate without having to depend on the Internet. Thus, all materials, such as multimedia files video, audio, photos as well as web copy from the Internet sites, including wikipedia, to low cost local server. The focus of this work is to contribute to third concern.

This work will not focus on the curriculum and educational policy, we will focus on providing the infrastructure solution especially for village and rural schools. The price range that seems to acceptable for rural / village needs is under US$100 per unit for a school. This is not include the electrical installation, and power bank and assume smartphone may be used by students. These financial and budget constraints require a deeper research by correlating the needed budget to operate and maintain the system.

II. Internet Offline Solution for Rural and Village

Efforts to create an Internet offline access may not new, since the early development of the Internet, some have been looking for solution on how to read Internet content while offline. Some may fullfil by backing up emails, SMS, WA, to more complex activities such as downloading songs, movies, files, PDFs, ebooks etc.

In this study, focus is given to educational content to be accessed offline. This effort is not very new, there are a number of effort seem to be done in the world from the initiatives of several state institutions and non-governmental organizations supported by various technologies that support offline Internet. Thus, there are some activities on Internet offline initiatives but not much. Only a handful of institutions / researches in the world are trying to provide solutions for areas with scarce Internet access. Let's review the ongoing effort.

A. Institutional Level Initiatives

At institutional level, both non-governmental organizations (NGOs) and state institutions, some of these initiatives are: (1) ICT Centre Uganda https://sites.google.com/site/ictcentreuganda/ - The ICT Center of Uganda strives to create a system so that schools can access content on the Internet offline. It seems that there are several similar effort, especially in Africa, to create / copy Internet content so that it can be accessed offline [1], (2) EduAir - EduAir (Formerly Kwiizi) from Cameroon is the concept name to offer a better education via digital with or without the internet. Their work focuses on the design of portable and open media libraries

in the form of Boxes with solar energy giving access to millions of educational content and offering an integrated communication system where learners can make video calls within the local network deployed by the Box http://www.eduairbox.com [2], and, (3) Project Tawasol Tunisia - IEEE Sight in Tunisia developed Raspberry Pi operated devices with hard disks that can be updated periodically with relevant content such as Wikipedia pages, TED Talks and other educational content from the Internet. They are capable of automatically updating content when connected to Wi-Fi or 3G networks [3].

No detailed information on the technology is described in the above information. Our work is using RaspberryPi, seems to be similar with Project Tawasol Tunisia. We are unable to compare the technology as no detail technology is described.

B. Patents

Indeed, not many patents have been produced to make the Internet Offline technology, some of which are (1) Jay F. McLain, "Offline viewing of internet content with a mobile device", Assignee Microsoft Technology Licensing LLC, US Grant US6493758B1, 1998 [6], (2) Robert Shaver, William Clogston, "Systems and methods for providing a similar offline viewing experience of online web-site content", Assignee University of Texas System, Oath Inc, US Grant US8001471B2, 2006 [7], and (3) Robert Shaver, William Clogston, "Systems and methods for a single development tool of unified online and offline content providing a similar viewing experience", Assignee Oath Inc, US Grant US8015491B2, 2006 [8]. This work is not using any patented technology.

C. Open Source Technology

In terms of technology, there are quite a number of technologies developed that we can use to make Internet content offline, a glimpse of these technologies include (1) SolarSpell - SolarSpell - Library powered by Raspberry Pi, with Wifi access point http://solarspell.org/ [4], and (2) Kiwix - is a free app that allows you to search and read Wikipedia without an Internet connection. Available for Android, iOS, Windows, MacOS and Linux http://www.kiwix.org/ [5]. This work uses Kiwix to provide offline Wikipedia content.

To synchronize content needed to provide offline content, we use mainly the following commands: (1) rsync - Server apps to synchronize content, and (2) wget - Server apps to partially copy or copy the entire web content. Scripts for rsync and wget is developed to suite the require needs.

To deliver the content to the user, several services are installed in the server, such as,

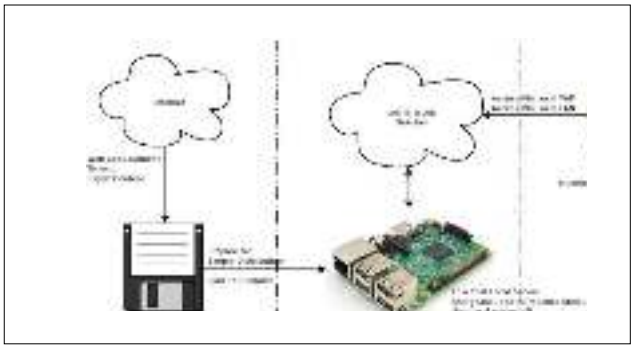
1- Kiwix - apps to display an offline wiki.
2- Apache, MySQL, PHP - Server apps to provide web services
3- Samba - Server apps to provide file sharing, streaming videos.
4- BIND – Server apps to spoof the hostname and redirect to the local virtual hosting in RaspberryPi.
5- DHCP – to provide IP address to clients.

On the client side, the technology needed to access the Offline Internet is fairly similar to the tools to access normal Internet. Thus, the users does not have to know that the actual content is located on the local server in their school.

III. Offline Internet Framework

The Offline Internet Framework was developed for the first time and presented on youtube on the OnnoCenter Channel at https://www.youtube.com/watch?v=cKuiRIQMZFE entitled "Offline Internet Concept for Schools" dated 1/10/2018.

In general, as shown in Fig. 1, there are three (3) functions / sections, namely, (1) content controller and accumulator, (2) Operation of Offline Internet facilities at school, and (3) students / teachers who are accessing the content using smartphones / computers.



Offline Internet Block Diagram

The content collection section may be centralized and performed by an authoritative body. The content collected in an SD / microsd card. It includes the operating system and required services ready to be inserted in a RaspberryPi. Copy of the microsd card is distributed to schools, and installed on a local RaspberryPi server. Teachers and students can access through local network facilities such as LAN and WiFi. The Newer RaspberryPi has a built-in WiFi that can be used as HotSpot access point to create a small local network for distributing the local Internet content.

IV. Preliminary Development

Initial development has been self-financially started by the author. Moreover, the results are freely released online and, thus, the Indonesian may immediately received the benefit from the technology.

In general, there are three (3) functions of Internet Offline System that must be considered, and developed, namely, (1) content collector / controller / accumulator, as well as distributor to schools, (2) offline Internet infrastructure at schools, and (3) users mostly students / teachers who access the content via smartphones / computers.

Some of the tasks and limitations in content collector / controller / accumulator are as follows:

- Determine which content / web need to retrieved based on the school's curriculum.
- Content will be limited to the size of microsd. The average affordable microsd has around 8-16 Gbyte space, which be used for a lot of text content. But not much lots of video content.
- Content should be adjusted to the school's curriculum. This is a bit difficult as content for grade 1 will definitely be different from other classes. Hence, more research is needed to do in depth content analysis.
- Content should be adjusted to the teaching methods. As far as the author's knowledge, in Indonesia, there is currently no standard on the teaching materials / methods on using online materials. Not many education faculties provide practical method to maximize online teaching material in the learning process. Thus, teacher's creativity is required to maximize the benefits of existing content.
- Technologically, the process of copying material to make it available offline is relatively simple, even the Wikipedia community has provided kiwix for these purposes.

In the operation of Internet Offline facilities at schools, some of the tasks are as follows:

- Prepare the the offline Internet server using embedded system, such as raspberrypi or orangepi.
- The technical aspects are written in more detailed in the wiki http://onnocenter.or.id/wiki/index.php/Internet_offline [9]
- The Raspberrypi server is prepared to act as a stand alone server with Web server, DHCP server, file sharing server, name server so that it can function as an Offline Internet server.
- The BIND name server is set according to the machine domain that is copied to redirect traffic not to the Internet but to the local server.
- Apache Web server is set to be a virtual hosting server that is capable of handling HTTP and HTTPS traffic.
- Kiwix is used to display copy of Indonesian wikipedia and wikitionary copies. Users may access it via the Web.

Students / teachers may access the content via smartphone / computer. Some of the challenge face in providing a large number of gadget at schools are:

- Smartphones, tablets, laptops may be used to access available teaching materials. A single WiFi Access Point will only effective for a maximum of ten (10) simultaneous devices. To be able to be simultaneously accessed by the whole school, many WiFi access points with many channels that are different from each other (orthogonal channel) are needed. We need to provide additional WiFi Access Points and LAN cables.
- The biggest challenge is to provide electrical power to keep smartphones, tablets and laptops running for a long period of time.

V. SUMMARY

The main contribution of the paper is in proposing low cost Offline Internet solution for rural and village schools using local server at the school. The required Internet content is copied to Raspberrypi based local server, and, thus, may be view offline by the students. The solution to overcome the knowledge scarcity in rural and villages areas due to lack of Internet access.

Open Source technology is used and detailed how to has been posted on the web and wiki [9]. The major technical issue is in providing electric power to many devices in the school for a long period of time. Alternative electric resources such as solar cells that are integrated with the power bank may be of interest.

The most difficult and the time consuming work is in preparing the teaching materials to be copied to the offline Internet server. From the hardware side, we will face the limitation of microsd storage size. It thus limits the scenario and methods in providing the educational material to the students. With very limited space in the microsd, we need to focus on what material need to be copied to microsd so that it is sufficient for teaching processes. From the content side, we need to develop method to do automatic educational content collection from the Internet.

Another advantage of Internet Offline Solution for schools is that teacher no longer have to worry about pornographic, in appropriate contents, cyberbully, spam, hoax and many unproductive content from the Internet. Thus, the schools can be focused on positive content for teaching only.

This research is still in the early stage. It is our hope to be able to produce a practical solution for schools in rural / village areas. Further work, especially in preparing content in sync with the teaching method is needed.

REFERENCES

An ICT Centre for the people of Kisozi. (n.d.). Retrieved 2018, October 20, from https://sites.google.com/site/ictcentreuganda/

EduAir. (n.d.). Retrieved 2018, October 20, from http://www.eduairbox.com/

Project Tawasol - Connecting Primary Schools to Create an Internet - Empowered Next Generation in Tunisia. (n.d.). Retrieved 2018, October 20, from http://1worldconnected.org/wp-content/uploads/2018/02/Project-Tawasol-Tunisia.pdf

SolarSPELL is a Solar Powered Educational Learning Library. (n.d.). Retrieved 2018, October 20, from http://solarspell.org/

Kiwix: Read Wikipedia Offline. (n.d.). Retrieved 2018, October 20, from http://www.kiwix.org/

Jay F. McLain, "Offline viewing of internet content with a mobile device", Assignee Microsoft Technology Licensing LLC, US Grant US6493758B1, 1998.

Robert Shaver, William Clogston, "Systems and methods for providing a similar offline viewing experience of online web-site content", Assignee University of Texas System, Oath Inc, US Grant US8001471B2, 2006.

Robert Shaver, William Clogston, "Systems and methods for a single development tool of unified online and offline content providing a similar viewing experience", Assignee Oath Inc, US Grant US8015491B2, 2006.

Internet Offline Experimental Notes. (n.d.). Retrieved 2018, October 20, from http://onnocenter.or.id/wiki/index.php/Internet_offline

User Modeling for Personalized e-Learning Based on Social Collaboration Interaction

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***Abstract*— Modeling user for personalization purpose is a very important and challenging task. The challenging part came from the fact that we have to consider and model different characteristics at the same time. It is even more complicated when the source of data is unstructured, not a structured user profile as commonly used. Such data requires a couple of tasks to be cleaned and analyzed to extract the required information. In this paper, the user-generated data during collaborative learning activity has been used to extract the information for modeling the user. Data mining techniques are being implemented to clean the collected data and extract the required information. Knowledge level and learning style features have been determined for user modeling purpose.**

***Index Terms* —Collaborative learning, Personalized e-learning, user modeling**

I. INTRODUCTION

The users of an e-learning environment, referring to the main users (learners), are different. They are different in background and knowledge obtained on a subject, different in preferences, learning style, goals and interests [1], [2]. Thus, it is crucial to personalize the delivery of the learning materials in the e-learning environment according to each individual needs.

Personalized e-learning means providing users with learning package based on their needs. Therefore, it is very important to know what their needs are and how to model them. User modeling refers to the process of constructing, updating, modifying and exploiting the user model [1].

User modeling plays an important role in an adaptive educational system like adaptive hypermedia (AH). AH is the most common web-based system developed to support personalized e-learning environments [3]. The basic concept of AH is an adaptation by changing the system's behavior according to the learner's characteristics stored in the user model [4]. The user model is the representation of the system's beliefs about the user as described by [1].

In an e-learning environment where the adoption of collaborative learning methodology is the base, it is very important to consider the implicit identification of learner's characteristics. These characteristics expressed via user-generated content and opinions via comments, tags, .etc. Focusing on this area, this paper is providing an overview of the methodologies used to model the learner model from the data generated during interaction within a collaborative learning environment.

When it comes to the social web, the targeted information for the user modeling focus on user profile attributes not user model [5]–[7]. To differentiate the two, let's say simply user profile is all about learner's general information and it may contain features related to interest, learning styles, and preferences [8]. Such a profile can be found in most applications like LMS, social media and other Web 2.0 applications. However, the user model is built based on the user profile focusing on features related to learning process like the knowledge level. Therefore, the user model is more specific for an educational perspective. In order to enrich the user model using the social web interaction and collaboration tools, the focus should be on the social context including the linguistic content and nonlinguistic social signals [9] not only the profile attributes.

According to [10] adaptive and dynamic E-learning perform as follows (refer to Fig. 1);

1. Recognizes the characteristics of the learner through pedagogy principles which are the process of collecting the data about the learners.
2. Adapts the learner with the current status of the system by processing the collected data to learn about learner's characteristics and build up the user model.
3. Changes the system behavior dynamically and presents the learning concepts according to the user model.

User modeling generally extracts user information related to knowledge and learning style via a questionnaire or test, and observation of learner's behavior during the learning process. In our approach, the source of the collected data is user-generated content during discussions in the collaborative learning environment.

Fig. 1. General view of user modeling and adaptation in adaptive systems As presented in [11]

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This paper is organized as follows: Section 2 discusses some works carried out by other researchers in the field of user modeling. Section 3 discusses briefly the learner characteristics. Section 4 explains the modeling structure and approaches in the user model for the knowledge level and learning style. The modeling representation is provided in section 5 and the paper concluded in section 6.

II. Related Work

Many researchers had an interest in modeling user either based on e-learning environment or web 2.0 tools.

The authors in [12] proposed a user modeling system (UMS). The aim of this system is to discrete the user modeling process from adaptive learning application. The system targeted the domain-dependent features for adaptation. To do so, the authors propose "Triangular Learner Model (TLM)" which contains three main learners' characteristics: knowledge, learning style, and learning history. The UMS (Zebra) builds up and manipulates TLM. To model the knowledge, the author used an overlay method and Bayesian network combined together. Modeling the learning style accomplished using Hidden Markov Model (HMM). The learning history is responsible for storing and manipulating all learners' actions within the learning management system. This may include learning materials access, duration of computer use, doing exercise, taking an examination, doing the test, communicating with teachers or classmates. Despite the promising functionalities of this model, there is no consideration for social interaction using external web 2.0 platforms.

Aiming at presenting a comprehensive user model especially tailored to the needs of the Social Web, Plumbaum [7] presented a Social Web User Model (SWUM). The model utilizes the available distributed personal information on the social web application (user profile). SWUM covers user characteristics like Personal information, Interests, Knowledge and Behavior, Needs and Goals and Context (Social Context, Location). This model aims to support the sharing and aggregation of user information to enhance personalization. However, this model focuses only on the user profile data where there is so much to model from the social contest when targeting the social dialogue within the social context.

The learner model proposed by [13] incorporates the information perception dimension of the Felder-Silverman model of learning style and also knowledge level. A wide variety of learner characteristics, including knowledge, learning style, affective state, goals, motivation, skills, and context, can be integrated into the learner model. The presented framework supports both static and dynamic learner modeling. Static learner models can be initiated by completing a questionnaire to identify the learning style and by a pre-test to construct the knowledge model at the beginning of the interaction with the system. A dynamic approach to learner modeling continually monitors learner system interactions to maintain a running update of the learner characteristics in the learner model. This model also lacks the incorporation of social interaction and depends on questionnaires and pretest to extract the initial learner features.

As it has been noticed, the user profile available in most applications is not providing adequate information to provide personalized and adaptive learning. Besides, modeling the user based on one feature like knowledge level is not sufficient to give a professional view of other features. As [12] stated, "there is no modeling method fit all characteristics". To overcome these issues, we are providing a user model to represent four learner characteristics as follows:

- Personal information: personal information like name, age, e-mail, etc., are extracted from LMS.
- Preferences: this feature is extracted from the opinions expressed via comments (positive, natural, negative) and likes related to shared learning objects in social media tools.
- Learning style: modeling learning style is based on the Felder-Silverman Learning Style Model according to the preferences of learning objects.
- Knowledge level: the enrichment of user-generated content by each learner can identify the level of knowledge s/he has on a specific concept or domain.

In our approach we followed three steps to process the user modeling which are; identify the nature of the represented information (What learner characteristics to include?), the approach to structure the information (What structure and approaches used for modeling?), and the representation of information (what specification used to represent the user model?).

III. Learner Characteristics

Personalization is performed based on the characteristics of each learner. These characteristics identify the information which is represented in the user model. According to [2], the most popular and useful features which can distinguish the learner as an individual are; the learner's knowledge, interests, goals, background, preferences, and individual traits like (cognitive style and learning style).

The modeling of information related to the learner's characteristics can be divided into two categories; Domain Dependent Information (DDI) and Domain-Independent Information (DII) [14]. DDI is related to the representation of information referring to a specific knowledge corresponding to the domain model. The DII is representing information related to the learner personal information and individual traits.

Considering the collaborative learning environment, learners are using different social media (SM) platforms for discussion [15]. The generated data during the discussion (contents, comments, actions, and opinions) can be a source for extracting the learner's features. Thus enhance personalization process.

In our approach, the user modeling will use the characteristics; personal information, knowledge level based on learning activity, preferences, and learning style (see Fig. 2). The whole conversation during collaborative learning could be considered as a social context which requires

particular analysis to recognize the level of engagement of a particular learner.

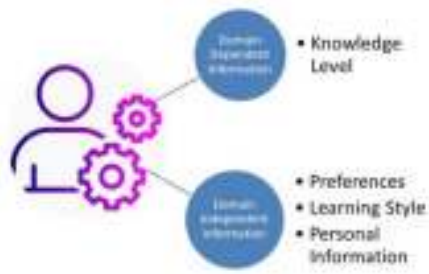

Fig. 2. The Nature of Learner characteristics

IV. Modeling Structure and Approaches

Learner modeling should be based on the characteristics of the learner. As discussed before, the main characteristics used in our approach are knowledge level based on learning activity as a DDI and learning style based on preferable content (learning object) as a DII. It is also worth mentioning that these characteristics are extracted from the discussion which takes place during collaborative learning.

The aim of this approach is mainly to build/update the user model by estimating the knowledge level of the learner and identifying the learning style. The modeling of the user is a combination of overlay and stereotype approaches. The knowledge level based on the domain model is represented in the overlay approach and learning style is represented in Stereotype. The user modeling process is shown in a triangular format in Fig. 3.

Considering the collaborative learning methodology involved during the learning activity execution, the generated data during the interactions is the main source for extracting the required information for modeling the user model. During collaborative learning, learners are sharing their knowledge on the discussed topic either by comments or learning contents which can be used to identify their knowledge level. Besides, learners also expressing their opinions on the shared content/learning object which can be used to identify their learning style. Without failing to address the noisiness and unstructured nature of the generated data, it is very important to apply data mining approach to clean the data [16]. This approach involves four main tasks to be carried out. These can be summarized as follows:

- Collecting Chat Messages
- Text Mining
- Transforming and domain ontology building
- Collaborative filtering

The discussion of these tasks is not the scope of this paper as it is focusing on user modeling which is considering the output of the collaborative filtering task. The details of these tasks are discussed in our previous published paper [16].

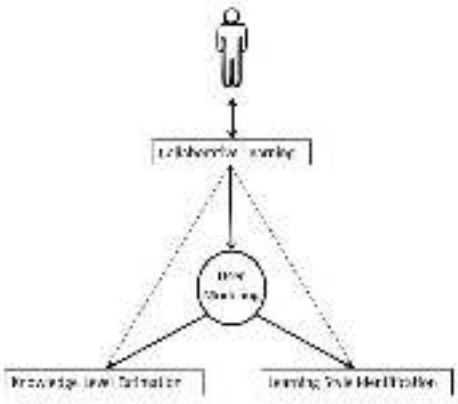

Fig. 3. Triangular learning model

The text mining approach applied will help to clean the data and structure them to be ready for further analysis like collaborative filtering. The collaborative filtering task is responsible for estimating the knowledge level and identifying the learning style of each learner. The forming of the knowledge level and learning style, as well as personal information allocation, are discussed below.

A. Knowledge Level

In our approach, the Knowledge Level modeling imitates the structure of the domain model. The overlay modeling approach is used for modeling student knowledge based on domain model which is constructed as Domain knowledge ontology. For each domain concept, an overlay model stores estimated the level of knowledge. Overlay Modeling: describe user characteristics, e.g. "knowledge of a user" with respect to "ideal" characteristics.

In our approach, the domain model is structured as a domain model ontology representing the learning activity to be performed by learners and the related term of concepts belong to each activity. As Fig. 4. depicts, the target concept or domain is the learning activity (LA). This learning activity has a list of vocabularies representing terms or concepts related to the LA. This relation called HasPart, which means that the term/concept is-part-of the LA. These concepts/terms can also be related to each other using the IsRequiredBy relation. Another connection is the HasResource relation where each concept/term connect to a learning object (LO) using the HasResource relation. To identify these concepts and relations, concept extraction and relationship discovery will be used. The proposed approach builds on top of [17] suggestion.

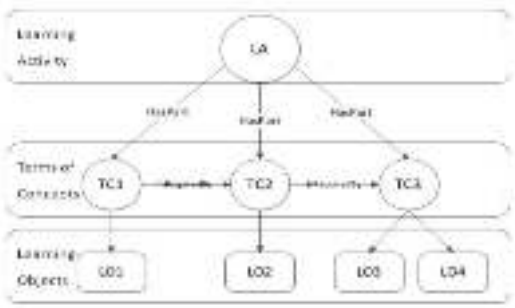

Fig. 4. Semantic Relations in Learning Activity model (Domain model)

For the purpose of estimating the knowledge level of the learner, the focus will be on the user-generated content related to the topic of the activity (domain model) which can identify the engagement of the learner. This engagement can identify how active the learner is in the discussion through the number of shared messages and how relevant these messages to the topic/concept under discussion. Consequently, help to identify the knowledge level. The measure of knowledge level can be obtained by calculating how rich the content shared by a particular learner. The richness of the content is calculated in terms of the total number of related words can be found in each message. In this study, the authors adopt the same measure concept used by [18] to define the content richness score which identifies the knowledge level (KL) for each learner (s).

- $KL_S = \frac{\sum_{i=1}^{n} mci}{n * max(mc)}$

- **s** represents the student, **mci** represents the value/weight of the content in the **message i** (relatedness to the concept) as described in Table 1.

TABLE 1. THE WEIGHTING OF THE MESSAGE CONTENT

Weight	Meaning	Description
0	Not related	No words related to the concept found in the message.
1	Related	1 to 2 words related to the concept found in the message
2	Very related	More than 2 words related to the concept found in the message.

- **n** is the total number of messages on a particular topic shared by s,
- **max(mc)** represents the maximum possible value of message content quality.
- **KL** score can range from 0 to 1.
  - 0 indicates a low level of knowledge since no contribution by that learner/student on the specific topic.
  - 1 means a high level of knowledge and excellent engagement by that learner.

For example, if there is an activity related to the waterfall concept, the construction of the domain model from the discussion will generate a domain ontology (see Fig. 5)

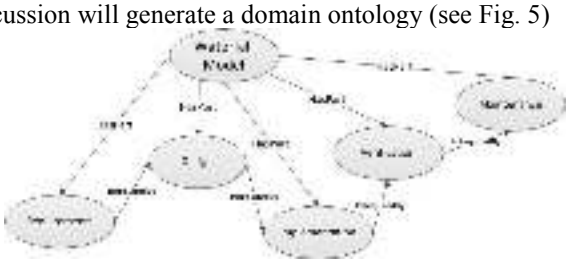

Fig. 5. Sample graph representation for learning activity

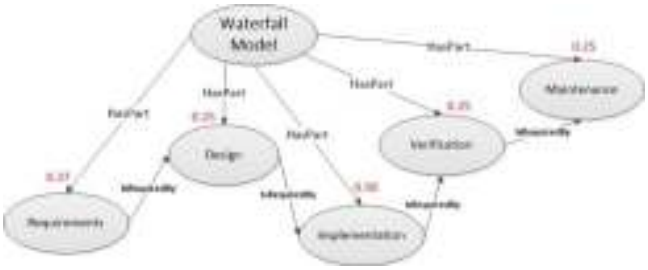

Fig. 6. graphical representation of knowledge level estimation

After estimating the knowledge level related to each term of concept using the above-mentioned method. The graphical representation will be similar to the one in Fig. 6.

B. Learning Style based on Preferences

The identification of learning style is identifying the learning style (LS) of each learner based on the learning object (LO) preferences gathered in the previous stages. Felder-Silverman Learning Style Model (FSEL) [19], has been adopted. Dynamic Bayesian Network (DBN) technique is used to model the learning style identification as discussed in our previous paper [20]. The DBN is a model to describe a scheme that is dynamically changing or evolving over time. This model enables users to monitor and update the system as time proceeds.

We consider that the student preferences (student opinion on learning object and level of interaction with the Learning Object) influence the identification of learning style. Besides, the current preferences of the learning object are accumulated from the previous preferred LO to determine the most accurate LS.

To determine the LS of any student, there is a need to extract information related to the learner's preferable format of learning objects as they have a direct relationship with the LS identification. The identification mainly utilizes the data extracted from chat conversation during the collaborative learning activity. Based on the preferable learning objects, the learning style can be identified. For example, if the learner likes to view audio and video media, then this is an indication that he/she belongs to verbal learning style. Then the learners will be categorized based on their learning style into three groups using stereotype approach as illustrated in Fig. 7.

The grouping of learners in our approach is by considering the social dimension and interaction concepts [21] [22]. Based on this dimension, the learners will be categorized into three groups (participatory, collaborative, and independent). These three groups are reflecting the learning styles which are identified based on the characteristics of each group. The grouping dimensions of the learners according to the identified learning style are defined as follow:

- Participatory: {Visual, Sensory}
  In this group, chat application is part of the preferable learning object along with other learning objects which address the identified learning style.
- Collaborative: {Active, Global}
  In this group, the chat application is the preferable learning object.

- Independent: {Verbal, Intuitive, Reflective, Sequential}
  In this group, chat application is not part of the preferable learning object. The identified learning objects are addressing the identified learning style.

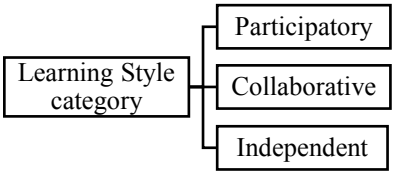

Fig. 7. Stereotype grouping based on learning style categories

C. Personal Information

Normally personal information describes the learner natural features and demographic data as part of the DII. The basic information collected in this element are name, e-mail, gender, etc. It could also include an identification feature like id. Generally, this information can be obtained from the user profile in the LMS.

V. Modeling Representation

To represent the user model in a structure supporting the reuse and interoperability features, there is a need to use one of the common learner modeling standards.

TABLE 2. THE REPRESENTATION OF USER MODEL ELEMENTS USING THE ISM LIP SPECIFICATION

User Model Element	IMS LIP Element	Description
Knowledge Level	Activity/learningactivityref/ sourcedid	The global identifier for the learning activity being referenced.
	Activity/evaluation/result/ interpretscore	Information used to describe the context of the scoring data e.g. maximum possible score.
	Activity/evaluation/result/ score	The scoring data itself.
Media Preferences	AccessForAll/context/ content	The modality of media preferences (audio, text, image, etc).
Learning Style	Accessibility/preference/ typename/tyvalue	The textual entry for the selected type.
	Accessibility/preference/ prefcode	The coding assigned to the preference.
Personal Information	Identification/name/partname/text	The name itself
	Identification/contactinfo/ email	Email address.
	Identification/demographics/uid	An identifier assigned to the learner e.g. social security number.
	Identification/demographics/ gender	The gender of the learner

The proposed user model is structured according to Information Management Systems Learner Information Package specifications (IMS LIP). As our modeling based on the learning activity domain, the IMS LIP package [23] is incorporating the important activity element and learner´s features related to the proposed theme.

IMS LIP package is structured in eleven categories which are: Identification, Goal, QCL (Qualifications, Certification, and Licenses), Accessibility, Activity, Competence, Interest, Affiliation, Security Key, and Relationship. Based on the user model elements include in our scheme, the mapping with the ISM LIP elements is shown in Table 2.

The modeled information will be used to provide a personalized e-learning package mainly based on the knowledge level and learning style. The learning package is supporting the learner with suitable contents to be presented based on his/her learning style and knowledge level in relation to the domain model.

VI. Conclusion and Future Work

This paper presented a user modeling approach to build/update a user model for personalization purpose based on four learner characteristics. The source of information is the social interaction during the performance of learning activity. Applying data mining technique to clean and extract useful information is implemented to process the collected information from interactions. To model the user, three steps have been followed. First, identifying the learner characteristics to be included in the model. In our case, knowledge level, preferences, learning style, and personal information are identified. Second, deciding on the structures and approaches for representing the characteristics. Overlay approach has been used to represent the knowledge level as a representation of the obtained knowledge in relation to the concepts in the domain model. To represent the learning style, stereotype approach has been applied to model the learning style categories for the processing of information based on the preferable learning objects. Third, representing the user model based on suitable learner information standards. IMS-LIP specification elements have been mapped with the proposed user model elements to represent the user model. After building the learners' models, the next issue to consider is their storage and retrieval. one of the most effective database tools for storing and managing the learner model is XML database: Apache Xindice which is tagged as the future work for this work.

Acknowledgments

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References

[1] N. P. de Koch, "Software Engineering for Adaptive Hypermedia Systems," PhD Thesis, no. August 2015, 2000.

[2] P. Brusilovsky and E. Millán, "User Models for Adaptive Hypermedia and Adaptive Educational Systems," Adapt. Web, pp. 3–53, 2007.

[3] L. Nguyen and P. Do, "Learner Model in Adaptive Learning," World Acad. Sci. Eng. Technol., vol. 45, no. November, pp. 395–400, 2008.

[4] P. De Bra and J.-P. Ruiter, "Aha! adaptive hypermedia for all," Proc. AACE WebNet Conf., no. DECEMBER 2001, pp. 262–268, 2001.

[5] F. Abel et al., "A Framework for Flexible User Profile Mashups," pp. 1–10, 2009.

[6] N. Henze, P. Dolog, and W. Nejdl, "Reasoning and ontologies for personalized e-Learning in the Semantic Web," Educ. Technol. Soc., vol. 7, no. 4, pp. 82–97, 2004.

[7] T. Plumbaum, "User Modeling in the Social Web," 2015.

[8] C. Froschl, "User modeling and user profiling in Adaptive E-learning Systems," 2005.

[9] A. Pentland, "Socially aware computation and communication," Computer (Long. Beach. Calif)., vol. 38, no. 3, pp. 33–40, 2005.

[10] H. M. Ghadirli and M. Rastgarpour, "A web-based adaptive and intelligent tutor by expert systems," Adv. Intell. Syst. Comput., vol. 177 AISC, no. VOL. 2, pp. 87–95, 2013.

[11] P. Brusilovsky, "Methods and techniques of adaptive hypermedia," User Model. User Adapt. Interact., vol. 6, no. 2–3, pp. 87–129, 1996.

[12] L. Nguyen, "ZEBRA: A new User Modeling System for Triangular Model of Learners' Characteristics," AIED 2009 14th Conf. Artif. Intell. Educ. Proc. Work. "Enabling Creat. Learn. Des. how HCI, User Model. Hum. Factors Help., pp. 42–51, 2009.

[13] M. ALSHAMMARI, "Adaptation Based on Learning Style and Knowledge Level in E-Learning Systems," no. March, 2016.

[14] A. C. Martins, L. Faria, C. Vaz de Carvalho, and E. Carrapatoso, "User modeling in adaptive hypermedia educational systems," J. Educ. Technol. Soc., vol. 11, no. 1, pp. 194–207, 2008.

[15] A. Al-Abri, Y. Jamoussi, N. Kraiem, and Z. Al-Khanjari, "Comprehensive classification of collaboration approaches in E-learning," Telemat. Informatics, vol. 34, no. 6, pp. 878–893, 2017.

[16] A. Al-Abri, Z. Al-Khanjari, N. Kraiem, and Y. Jamoussi, "A scheme for extracting information from collaborative social interaction tools for personalized educational environments," in Proceedings of the IEEE International Conference on Computing, Networking and Informatics, ICCNI 2017, 2017, vol. 2017–Janua.

[17] C. De Maio, G. Fenza, M. Gaeta, V. Loia, F. Orciuoli, and S. Senatore, "RSS-based e-learning recommendations exploiting fuzzy FCA for Knowledge Modeling," Appl. Soft Comput. J., vol. 12, no. 1, pp. 113–124, 2012.

[18] W. C. Paredes and K. S. K. Chung, "Modelling learning & performance," Proc. 2nd Int. Conf. Learn. Anal. Knowl. - LAK '12, no. May, p. 34, 2012.

[19] R. Felder and L. Silverman, "Learning and teaching styles in engineering education," Eng. Educ., vol. 78, no. June, pp. 674–681, 1988.

[20] A. Al-Abri, Z. AlKhanjari, Y. Jamoussi, and N. Kraiem, "Identifying Learning Styles from Chat Conversation using Ontology-Based Dynamic Bayesian Network Model," in 2018 8th International Conference on Computer Science and Information Technology (CSIT), 2018, pp. 77–84.

[21] V. Balakrishnan and C. L. Gan, "Students' learning styles and their effects on the use of social media technology for learning," Telematics. Informatics, vol. 33, no. 3, pp. 808–821, 2016.

[22] A. Laks, "Focusing On Learners," Epsilon Learning Systems, 2017. [Online]. Available: http://epsilonlearning.com/learners.html. [Accessed: 21-Nov-2017].

[23] IMS Global, "IMS Learner Information Packaging Information Model Specification." 2001.

Free Open Source Software Logisim – A Perfect Tool for Teaching and Learning of Digital Logic Circuit Design Course – Experience and Status

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***Abstract*— Logisim – a Free Open Source Software (FOSS) has been in continuous advancement since early 2001. Today, Logisim is used in many schools, colleges and universities for teaching and learning of a core program course "Digital Logic Design (DLD)" and beyond. Many universities extended the application of Logisim to support the teaching and learning of many other courses of Computer Science and Engineering programs. This paper is written with the aim to share the authors experience and to talk about the status of using the Logisim and its extended applications. With the long shared experience of using Logisim, authors make their firm opinion that it is high time to generate an awareness and inculcate the keen interests amongst the individual enthusiastic users, teachers and students of schools, colleges and universities of Sultanate of Oman for an appropriate use of Logisim version. Undoubtedly, Logisim – FOSS can be a booster towards technology transfer, innovation and entrepreneurship in the age fast growing electronics and short product life.**

***Index Terms*— FOSS, Logisim, Digital Logic Design, Boolean, Software.**

V. INTRODUCTION

THE free software movement was started in 1983 by computer scientist Richard M. Stallman, when he launched a project called GNU, which stands for "GNU is Not UNIX", to provide a replacement for the UNIX operating system. In 1985, Richard M. Stallman established Free Software Foundation. With a set of code of ethics, this nonprofit organization is marching forward with the mission of advocating and educating on behalf of computer users around the world since 1985. Today, with more than 5,100 individual programs and tools the organization is serving Millions of people around the world — including entire governments [1] – [4].

Logisim – a Free Open Source Software (FOSS), which run on the Windows, Macintosh and Linux operating systems. This Java powered tool 'Logisim', that provides a popular interactive platform for electrical designing and simulating of digital logic circuits ranging from a brief unit on logic in courses general-education computer science surveys, to computer organization courses, to full-semester [1] courses on computer architecture and digital logic design.

[2] Today, Logisim that has been used in many schools, colleges and universities for teaching and learning of many courses is the work of Carl Burch, who initiated and developed to its peak [5], [6]. On October 11, 2014, Burch announced the suspension of the development of Logisim indefinitely [6]

At present, the Logisim is being hosted through SourceForge.net [7].

VI. LOGISIM DEVELOPMENT PHASE HISTORY [7], [8]

A. Version 0.3 and Later

Logisim versions 0.3 and 1.0 were released in April and July 27, 2001 respectively. The Logisim versions of 1.01 and 1.02 were made available with effect from 2001 September 10, 11 respectively. The other versions and their release date are listed as below.

Versions 1.03 [15 September 2001]; 1.04 [27 September 2001]; 1.05 [5 February 2002]; 1.06 [29 September 2002]; 1.07 [7 October 2002]; 1.08 [8 November 2002]; 1.09 [14 December 2002] and 1.09c [13 October 2003].

B. Version 2.0 Beta Phase

1) Beta 1:

This version was released on April 11, 2005 by rewriting the code from scratch by more than doubling in size to previous software version. This version brought many new features and removed many bugs.

2) Beta 2

By adding, the features Clear, Load, and Save options to the RAM component's menu and fixing the bugs for Select tool that did not permit moving text up or to the left Version *2.0 Beta 2* was released on April 11, 2005.

3) Beta 3

By release of this version on May 1, 2005 one could save a project that imported from other Logisim files, could properly merge wires when it is moved or removed, could undo the deletion of items and could save the Multi-bit constant values. The release brought some new features like attributes for the component, wire's current value, sub-circuit's name and control of the brightness.

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In Beta phase development the Logisim was improved till Beta 24. It is out of scope to discuss the about the removal of "Bugs" and adding and or improving of "Feature". The interested readers can get this information via [7], [8]. However, the date of release of versions are as below.
Beta 4 and 5 [4 May 2005]; Beta 6 and 7 [5 May 2005]; Beta 8 [7 May 2005]; Beta 9 and 10 [9 May 2005]; Beta 11 [10 May 2005]; Beta 12 [11 May 2005]; Beta 13 [12 May 2005]; Beta 14 [13 May 2005]; Beta 15 [10 June 2005]; Beta 16 [29 June 2005]; Beta 17 [6 July 2005]; Beta 18 [11 July 2005]; Beta 19 [14 July 2005]; Beta 20 [19 July 2005]; Beta 21 [25 July 2005]; Beta 22 [12 October July 2005]; Beta 23 [16 October July 2005]; and Beta 22 [24 October July 2005] followed by the Logisim release of Version 2.0.0 on October 31.

Logisim versions 2.0.1 to 2.0.6 were released during November 1, 2005 - April 26, 2006. Another series of developmental phase of Logisim were carried out during May 11, 2006 – February 8, 2009 and released in the forms of versions 2.1.0 – 2.1.8. During period May 20, 2009 - July 30, 2010 the Logisim attained more maturity in the forms of its releases of versions 2.2.0 – 2.4.0. The developmental phase of Logisim were carried during August 30, 2010 – December 23, 2010 as a result to release Logisim versions of 2.5.0 – 2.6.2.

VII. LOGISIM DEVELOPMENT 2.7 AND BEYOND

Logisim versions opened gates for learning and teaching of Digital Logic Design. The version 2.7 and 2.71 released within gap of a week period. This is much stable.

The authors provide below an updated study of Library reference of components of Logisim versions making Logisim 2.7.1 (released on 21 March 2011) as a benchmark.

Library Reference:

1) *Wiring Library:*

The Table 1 shows the symbol, name and induction in Logisim version for each of the components of the Wiring library.

Table 1: Components of the Wiring library

Symbol	Name	Introduced
	Splitter	2.0 Beta 1 Base Library
	Pin	2.0 Beta 1 Base Library
	Probe	2.0.3 Base Library
	Tunnel	2.5.0 Base Library
	Pull Resistor	2.5.0 Base Library
	Clock	2.0 Beta 13 Base Library
	Constant	2.0 Beta 1 Base Library
	Power/Ground	2.7.0
	Transistor	2.7.0
	Transmission Gate	2.7.0
	Bit Extender	2.5.0 Base Library

2) *Gate Library:*

The Gate library consists of the following gates listed in Table 2. All the Gates of this library were inducted in Logisim version 2.0 Beta 1 except XNOR Gate which was introduced in version 2.0 Beta 6

1) *Arithmetic Library:*

The Table 3 shows the symbol, name and induction in Logisim version for each of the components of the Arithmetic library.

Table 2: Components of the Gate library

NOT Gate
Buffer
AND/OR/NAND/NOR Gate
XOR/XNOR/Even/Odd Gate
Controlled Buffer/Inverter

Table 3: Components of the Arithmetic library

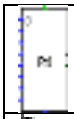
Symbol	Name	Introduced
	Adder	2.0 Beta 11
	Subtractor	2.0 Beta 11
	Multiplier	2.0 Beta 20
	Divider	2.0 Beta 22
	Negator	2.0 Beta 22
	Comparator	2.0 Beta 22
	Shifter	2.3.0
	Bit Adder	2.6.0
	Bit Finder	2.6.1

3) *Plexers Library:*

The Table 4 shows the symbol, name and induction in Logisim version for each of the components of the Plexer library.

Table 4: Components of the Plexers library

Symbol	Name	Introduced
	Multiplexer	2.0 Beta 11
	Demultiplexer	2.0 Beta 11
	Decoder	2.0 Beta 11

	Priority Encoder	2.3.0
	Bit Selector	2.0.5

4) *Memory Library:*

Memory library consists of following components listed in Table 5. All the components of this library were inducted in Logisim version 2.0 Beta 1 except components Counters, Shift Registers and Random which were introduced in version 2.3.0.

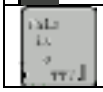
Table 5: Components of the Memory library

D/T/J-K/S-R Flip-Flop
Register
Counter
Shift Register
Random
RAM
ROM

5) *Input/output Library:*

The Table 6 shows the symbol, name and induction in Logisim version for each of the components of the Input/output library.

Table 6: Components of the Input/output library

Symbol	Name	Introduced
	Button	2.1.3
	Joystick	2.2.0
	Keyboard	2.2.0
	LED	2.1.3
	7-Segment Display	2.1.3
	Hex Digit Display	2.2.0
	LED Matrix	2.2.0
	TTY	2.6.0

6) *Base Library:*

Base library consists of following components listed in Table 6. All the components of this library were inducted in Logisim version 2.0 Beta 1 except Edit Tool which was introduced in version 2.3.0.

Table 6: Components of the Base library

Poke Tool
Edit Tool
Select Tool
Wiring Tool
Text Tool
Menu Tool
Text

VIII. MORE GUIDANCE

Logisim Interface:

The main body of the Logisim working space is shown in Fig. 1. In the Figure the Logisim Canvas, Explorer, Tools, Menus are demarcated. The six menus reference provided in Logisim window are as below.

- The File menu
- The Edit menu
- The Project menu
- The Simulate menu
- The Window and Help menus

Figure 2 shows about Attribute window of the Logisim.

Sub-circuits:

Sub-circuits can be added to Logisim library by having the following processes.

- Creating circuits
- Using sub-circuits
- Editing sub-circuit appearance
- Debugging sub-circuits
- Logisim libraries

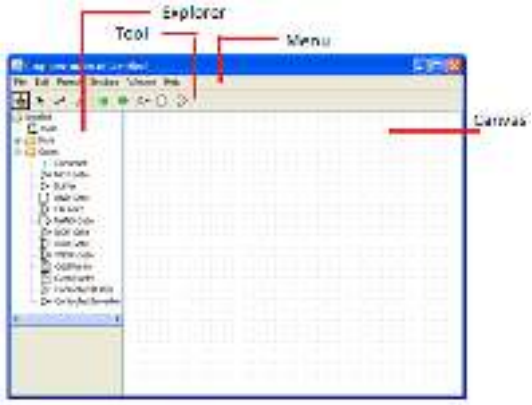


Fig. 1 Logisim Interface Area.

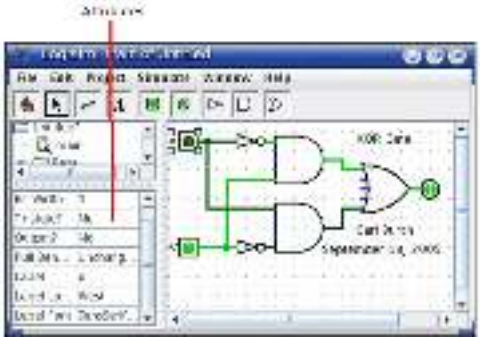


Fig. 2 Interfacing Components Attributes Window

Figure 3 shows about creating a 2-to-1 Multiplexer named "2:1 MUX" as sub-circuit. After adding the circuit, Logisim Interface area will look like as given in the Fig. 3. In the explorer pane, it can be seen that the project now contains two circuits, "main", and "2:1 MUX." Logisim draws a magnifying glass over the icon of the circuit currently being viewed; the current circuit name also appears in the window's

title bar. Further, using sub-circuit is demonstrated through Fig. 4.

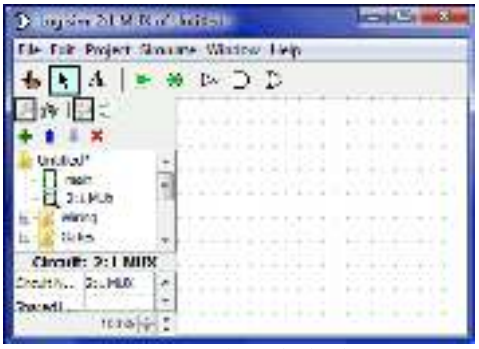


Fig. 3 Creating Sub-circuit

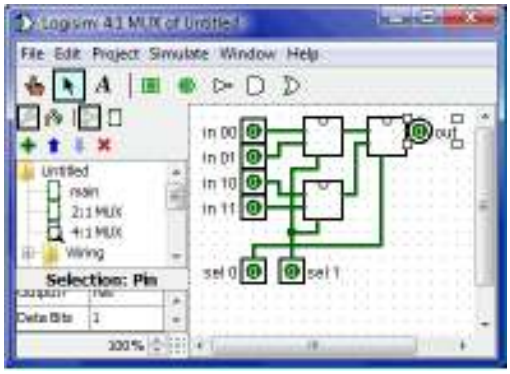


Fig. 4 Using Sub-circuit

Creating Bundles:

The below screen shot shown in Fig. 5 illustrates a simple circuit for finding the bitwise AND of two three-bit inputs; each pin has its Bit width attribute customized for dealing with three-bit data, as with the pictured AND gate attributes.

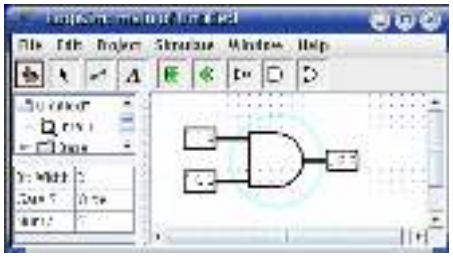


Fig. 5 Using Sub-circuit

Splitters:

The Base library's splitter tool facilitates working with multi-bit values. To demonstrate this Fig. 6, show the splitter actually split an incoming value into multiple outgoing values. But splitters can also combine multiple values into a single value.

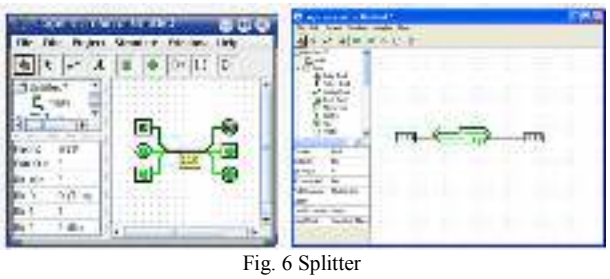


Fig. 6 Splitter

Wire colors:

There are wire with seven colors, a rain bow's colors. Figure 7 shows these wire colors. The functionality of each wire colors are described as below.

- Gray: The wire's bit width is unknown. The color appears when the wire has no connectivity.
- Blue: The wire carries a one-bit value, but nothing is driving a specific value onto the wire. This is like x or z input variables of Verilog HDL.
- Dark green: The wire is carrying a one-bit 0 value.
- Bright green: The wire is carrying a one-bit 1 value.
- Black: The wire is carrying a multi-bit value. Some or all of the bits may not be specified.
- Red: The wire is carrying an error value.
- Orange: The components attached to the wire are incompatible.

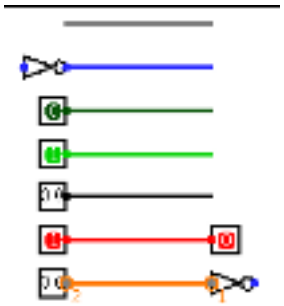


Fig. 7 Wire colors

Combinational Analysis:

The Logisim Combinational Analysis provision makes it incredibly simple to create truth tables, which is a key step in the design of combinational logic systems. The following options are available in the Logisim Combinational Analysis tool.

- Opening Combinational Analysis
- Editing the truth table
- Creating expressions
- Generating a circuit

To illustrate the process, let to generate a truth table for the digital logic circuit shown in Fig. 8.

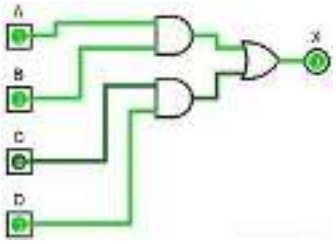


Fig. 8 A 4-input and 1-output circuit.

The Boolean expression for the above circuit is described through Equation (1).

$$X = A\,B + C\,D \quad (1)$$

The step one is to open the Combinational Analysis tool by selecting the Window > Combinational Analysis menu option. Click on the Inputs tab and enter the four input variables, A, B, C and D. Next click on the Outputs tab and add the intermediate outputs A B plus C D, as well as the main output X – in that order.

The result of clicking on the Table; a truth table with its four inputs and three outputs is generated. Although the outputs will initially be shown as a series of 'x's or don't care states. Click on each output to cycle through the possible values (0, 1, X) entering the appropriate values based on the desired Boolean expression for each column.

The category of combinational circuits is the simpler of the two. Digital logic designers and practitioners need either truth table or Boolean expression or logic circuit or summarizing the behavior of the design problem. The Combinational Analysis module of Logisim allows to convert between these three major representations in all directions. Some of the screen shots of in action Combinational Analysis module of Logisim are given through Figures 9-11.

Fig. 9 Assignments of input variables

Fig. 10 Use of Boolean expression

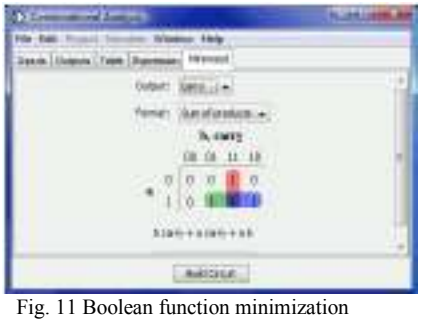


Fig. 11 Boolean function minimization

IX. USE OF LOGISIM AT SULTAN QABOOS UNIVERSITY

At Sultan Qaboos University in sultanate of Oman, the development of teaching tools and use of FOSS educational tools have been in practice since 2001 [9] – [20]. In this process the Logisim-FOSS was inducted to support the teaching of Digital Logic Design (ECCE3206) course. The first author of this paper added a complete set of ICs (IC0V6) in the Logisim library. Figure 12 provides a glimpse the added library. The double click to the IC furnishes the gate connections through pins.

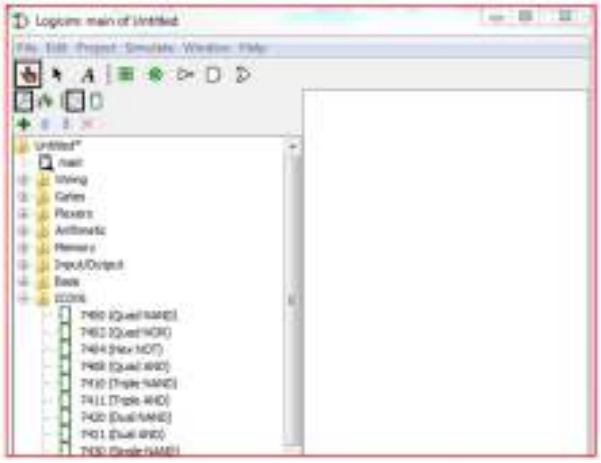


Fig. 12 Induction of Library IC0V6

X. A CASE STUDY

We present a case study where Experiment number 3 of the course Digital Logic Design (ECCE3206) conducted in offering of Fall semester of 2018 is considered as a sample. The homework tasks of this experiment are as below:

Pre-Lab

Notes:

- Without a successful simulation you will not be authorized to implement your circuit.
- You have to prepare your circuits in Logisim, test it to make sure it is functioning correctly, and then demonstrate them in the lab for instructor or any lab staff.
- Once design is approved, only, then you may start the physical (H/W) implementation of your design.

Deliverables:

You should submit the following before you start the lab.

• A LOGISIM simulations for all parts.

• A LOGISIM IC circuit printout [to be used for physical implementation]

Part I: Simulation ONLY

Half-Adder:

Task 1. Fill the truth table for half-adder.

Task 2. Draw the half-adder circuit using two gates only.

Task 3. Simulate the logic gates level half adder circuits (with inputs and outputs labeled).

Task 4. Build a sub-circuit for the half adder and give it the label HA.

[Hint: a PDF file and a video posted on SQU e-learning web site (in LogiSim folder) to show you how.]

Full-Adder:

- Task 5: Design a full-adder using two HA sub-circuits and one more logic gate.
- Task 6: Build a sub-circuit for the full adder and call it FA.

Adder/Subtractor Unit:

- Task 7: Design and simulate an Adder/Subtractor unit that has two numbers as inputs A, B (2-bit each) and one number S as an output result containing 2-bits. Two more input bits are needed to be added namely; a carry-in bit and a mode bit that is when 0, the unit will add the two numbers, otherwise, the second number B will be subtracted from A. In addition, the unit should generate a carry-out bit as well as an overflow bit.
- Task 8: Make a sub-circuit for the above 2-Bit Add/Sub unit.
- Task 9: Cascade two sub-circuits from 8 to build a 4-bit Adder/Subtractor unit.

Part II: Simulation & Implementation

Combinational Circuit Design:

Design a combinational circuit that has 3 inputs and 3 outputs as follows:

$$FF_1(X, Y, Z) = X\,Y\,Z + X\,Y\,\bar{Z} \quad (2)$$

$$FF_2(X, Y, Z) = Y\,(X + \bar{Z} + Z) \quad (3)$$

$$FF_3(X, Y, Z) = X\,Y\,\bar{Z} + X\,Z \quad (4)$$

- Task 10: Use K-map and find the minimized expressions for the Boolean functions given in Equations (2) – (4).
- Task 11: Draw the Logic Gate Circuit below and simulate it in LogiSim at logic gate level.
- Task 12: Redesign the above Circuit using a 3-8 Decoder (NAND Implementation) and one other type of logic gates (NAND). Compare the output with the one of the completed work of Task 11.
- Task 13: Simulate the chip-level circuit for the completed work of Task 12.

Experiment In-Lab

Implement the decoder based combinational circuit for the completed work of Task 13 using IC 74138.

Note that 74138 is a 3-8 Decoder with NAND implementation, which means that the selected output generates 0 while all other unselected output lines will generate 1.

[Show the lab instructor a printout of your simulated circuit with pin numbers labeled before you proceed with the practical session.]

Case Study Analysis:

As the tasks 1-13 of the Experiment number 3 were assigned as prelab using Logisim educational software tool hence, their sequential completion facilitated the students better understanding of the theoretical background of the module in particular and course in general. Performing the hardware part of the experiment takes on average 25-30 minutes only to complete. This is due to students' better understanding, the availability connection diagram and their practice of simulations made them able to generate logic circuits quickly and accurately. Further, the tool is capable to coach students to discover and correct their mistakes in design of logical circuits of the experiment and possibility to experiment with different values of input signals using hand tool of the software. The tool enabled the students to visualize circuit design concepts in more tangible ways. An added attribute of Logisim software tool is that it enables the students to make their database of their stored of individual work.

XI. CONCLUSION

The authors want to share the experience of induction and practicing of Logisim – FOSS as the teaching and learning tool for the course of Digital Logic Design. The first and most important gain by this induction is that every student has equal opportunity of owning and using of Logisim – FOSS, no economic hurdle. It provides students to complete the pre-lab tasks at home. Using Logisim, the students simulate and test their designs on gates and ICs levels. In the lab session, the students implement their designs on breadboard as their assigned hardware lab tasks. Students use this software in completing their homework assignments and mini-projects. The students also use Logisim in the tasks of their senior undergraduate and mini-projects of the other courses.

As instructors that due to Logisim upgraded versions we have been revising the experiments and mini-projects' with objectives of solving more complex problems and designing circuits with greater realistic scenarios. Further. The use of Logisim have been saving the significant amount of the lab running cost.

It is recommended that the induction of Logisim – FOSS in schools will give an opportunity to students of understanding a design process, problem solving approach and awareness of constraints. Hence, undoubtedly, Logisim – FOSS can be a booster towards technology transfer, innovation and entrepreneurship in the age fast growing electronics and short product life.

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REFERENCES

https://en.wikipedia.org/wiki/Richard_Stallman; Richard Stallman; Retrieved 27 October 2018.

Stallman R. M., GNU Emacs Manual. Boston, Massachusetts: GNU Press, 2002, ISBN 1-882114-85-X.

Stallman, R. M., McGrath R. and Smith P. D., *GNU Make: A Program for Directed Compilation*. Boston, Massachusetts: GNU Press, 2004, ISBN 1-882114-83-3

Stallman R. M., Free Software, Free Society: Selected Essays of Richard M. Stallman (PDF) (Third Ed.). Boston, Massachusetts: GNU Press, 2015, ISBN 978-0-9831592-5-4.

https://www.hendrix.edu/research/default.aspx?id=55783; HENDRIX College; Retrieved 30 October 2018.

https://en.wikipedia.org/wiki/Logisim; Logisim; Retrieved 30 October 2018.

https://sourceforge.net/; The Complete Open-Source Software Platform; Retrieved 30 October 2018.

http://www.cburch.com/logisim/history.html; Logisim History; Retrieved 30 October 2018.

Ahmad A., Al-Musharafi, M. J., and Al-Busaidi, S., Study and implementation of properties of m-sequences in MATLAB-SIMULINK – A pass / fail test tool for designs of random generators, Journal of Scientific Research – Science and Technology, vol. 7, part 1, pp. 147 – 156, 2002, (ISSN 1027-524X).

Ahmad, A., Al-Maashri, A. and Arshad A. M., Development of software tool for diagnostic AND/OR conceptual based teaching, Proceedings International Educational Technology Conference (ETEX – 03), Oman, October 20 – 22, 2003, pp. 1 -11.

Ali Al-Lawati and Ahmad, A., Realization of a simplified controllability computation procedure – A MATLAB-SIMULINK based tool, Sultan Qaboos University Journal for Scientific Research - Science and Technology, Oman, vol. 8, pp. 131 – 143, 2004, (ISSN: 1027-524X).

Ahmad A., Al-Lawati, A. M. J. and Ahmed M. Al-Naamany, Identification of test point insertion location via comprehensive knowledge of digital system's nodal controllability through a simulated tool, Asian Journal of Information Technology (AJIT), vol. 3, no. 3, pp. 142 – 147, 2004, (ISSN 1682-3915).

Ahmad, A., D. Al-Abri and M. M. Al-Ramhi, Design of an E-Learning Process in the Area of Digital System Testing, Proceedings International Conference on Distance Education (ICODE2006), Oman, March 27 – 31, 2006, pp. 174 -184.

Ahmad, A., Dawood Al-Abri, Design of an Optimal Test Simulator for Built-In Self-Test Environment, Journal of Engineering Research, vol. 7, no. 2, pp. 69 – 79, 2010, (ISSN:1726-6009).

Al Busaidi S. S., Complementing digital logic design with Logisim, Journal of Engineering Research, vol. 11, no. 1, pp. 69-76, 2013.

Ahmad, A., Al-Abri, D. and Bait-Shiginah, F., Software Testing Education – A Required Knowledge for Software Systems' Developers and Managers, Free and Open Source Software Conference (FOSSC-13), held at Muscat, Oman, February 18-19, 2013, pp. 29-33.

Ahmad, A. and Ruelens, D., Development of digital logic design teaching tool using MATLAB & SIMULINK, IEEE Technology and Engineering Education (ITEE), vol. 8, no. 1, pp. 7-11, 2013 (ISSN 1558-7908).

Kordestani, M. A., Ahmad, A. and Bourdoucen, H., (2015): "A review of CRC mechanisms and FOSS algorithms", The Free and Open Source Software Conference (FOSSC Oman), held at Sultan Qaboos University, Muscat, Oman, Feb. 18 – 19, 2015, pp. 73-77.

Ahmad, A., Jamil, T. Ahmad, S. Abdulghani, A. A., About a FOSS for the Teaching of FORTRAN Programming Language Course, The Free and Open Source Software Conference (FOSSC Oman), held at Sultan Qaboos University, Muscat, Oman, Feb. 18 – 19, 2015, pp. 78 – 81.

Free Academic Software and Mobile Applications for Technology Transfer in Oman: A Review

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***Abstract*—The concept open source refers to the software products or computer programs that are publicly available where the designs could be shared and modified when required. Open exchange and community oriented sharing are the ultimate goal of any open source systems. The feature of open source includes inspections, enhancements and modifications. On the other hand, the student community wonders to manage the educational expenses including the course materials, reference books and the required computing resources such as laptop, tablet or mobile phone. In addition, meeting the expenses for software license for the educational software would be challenging task for the young student community. Students in Oman can enhance their academic skills when free software and provided and also they can download and use or can access from play store or apple store from their personal digital assistants. Consequently, this research review can provide enough awareness to use the academic tools for technology transfer. Therefore, students can use the limited versions of software from any places either at their home or college. In this paper, the open source software tools based on communication, multimedia, collaboration, scheduling, document analysis and management tools are reviewed and explored.**

***Index Terms*—open source, collaboration tools, free open source software, academic skills, and technology transfer**

I. Introduction

Free Open Source Software (FOSS) made tremendous changes in the field of software and mobile applications in the recent days [1]. FOSS in today is an esteemed option reinforced by Government agencies, businesses and educational institutions as well as the society in the earth [2].

In 1985, Richard Stallman an ex-MIT academician established the Free Software Foundation (FSF) [3] a non-profitable agent devoted to the production of free software. The FSF oversee the GNU Project, hold the copyright in the software fashioned for it and impose the licenses. The basic concept of Free Open Source Software includes the following:

- Free software offers the right to use the software-tool for any purpose.
- Independence to learn the program flow and anybody can use it according their needs.
- No restriction to re-issue/share the copies of modules amongst student community, professors and societies.
- Any individuals or organizations can update or modify the existing free software and re-issue the improved version to help the students, organization and societies.

FOSS can create and enhance value for effectual, fiscal, secured and quality facilities to Information and Communication Technology (ICT). Free system software including Linux and Ubuntu operating systems creates a massive awareness in technology transfer among different computer laboratories. Programming languages such as Java, php, Perl and database tools such as MySQL, mongoDB are creating good changes in educational institutions.

The primary visions of FOSS can be the following:

- Decreasing vendor lock-in
- Decreasing the cost of ownership
- Reducing digital divisions
- Increasing progress of knowledge based society
- Increasing progress of FOSS developer
- Increasing growth of FOSS user community
- Boosting growth of ICT industry
- Aggregating freedom of choice of software use

Here are the primary features of few open source tools: Thunderbird 3.1 is an adaptable messaging and email suite available for Windows, Linux and Mac OS. Free web-based collaboration and scheduling tool named GanttProject is an open source desktop tool for project management and scheduling. Another scheduling tool named TimetoMeet is used to work on college course assignments and course projects which synchronize automatically with the calendar. Free document editing and management tool named EditGrid is an online spreadsheet tool which works similar to Microsoft's Excel. GoogleDocs is also a free word processing product that gives free forms and presentations to students. PDFCreator is a free program that allows us to create PDF files from any platforms.

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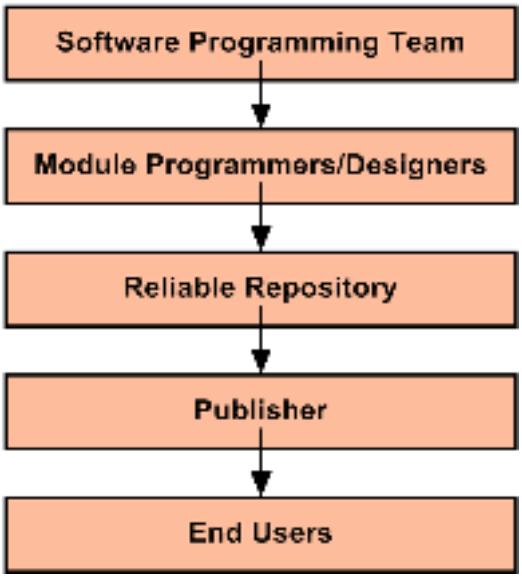
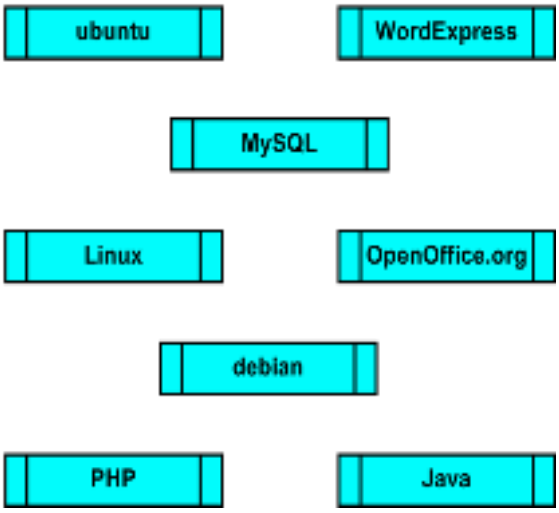
Dropbox is a cloud based storage service which allows us to store and share large data within a community. ZohoWriter is another online word processor and collaboration tool which supports for group work and documentations that supports for student centered learning. Gmail's web mail service supports to access the large storage services. Another famous mail service is Opera mail which provides similar applications. Meebo messenger integrates a number of online communication channels into one service [4].

WordPress, Apache, Mozilla Firefox, fedora, blender, OpenOffice, debian, NetBeans, Exlipse, VirtualBox, OpenLDAP, Audacity, thunderbird, LibreOffice, GODOT, kdenlive, git, openSUSE are other primary tools widely used by institutions and students for their academic performance. Open source image manipulation software named GIMP (GNU Image Manipulation Program) and related free software such as Inkscape, Jing, Moodle, .LRN, Dokeos, Sakai creates good outputs for student community [5]. Fig. 1 shows the clear steps for the development of FOSS and Fig. 2 explores the samples.



FOSS development model



Sample FOSS tools used by students in colleges

II. Analysis on Primary Tools meant for ICT Education

In the field of ICT education, computer science and engineering faculties, information technology department's curriculum multiple types of academic software are used to develop the student creativity and technological awareness. However, technology transfer is the ultimate intension of any academic institution [6]. The authors suggest and review a good number of open source tool which can be used in educational institutions and mainly in the following domains.

- Virtual universities
- Online courses
- Education portals/Moodles
- Courseware

A. ClickChart

It is freeware software with user friendly interface [6] and it is used to create pictorial representation of a process, organization, and projects. It is also used to design the software by charting the flow in different structural designs, program which requires lot of symbols, shapes, and colors to incorporate in a particular design. After finishing the work the users can save the file in their convenient format like .pdf, .jpg, .png and in many more. From the students and faculty prospective they can use the ClickChart during their course project to design Entity Relationship Diagram (ERD), Data Flow Diagram (DFD), Unified Modeling Language (UML) and general flow diagram of their course project in diploma, bachelors or in master's level. The principal features of ClickChart are given below:

- Use to design flow chart to arrange and display the steps in a process.
- Use seamless sheet overlapping feature to print the large diagram.
- To design Unified Modeling Language (UML).
- By ClickChart the users can edit multiple diagrams simultaneously.

- Colors and images can be added to the pictorial representations of any design or diagrams.

B. NetBeans IDE

NetBeans is an Integrated Development Environment (IDE) that support java 8.0 with its editors, code analyzers and converters [7]. Using this feature and facility anyone can upgrade their application. The latest version of the NetBeans IDE is 9.0. It is a platform independent IDE, which can be installed on any operating systems that support Java language. Because NetBeans IDE itself written in Java language. It can also support many programming languages including Java, C, C++, Extensible Markup Language (XML), Hypertext Preprocessor (PHP), Java Server Pages (JSP), Java Script and more. From the students prospective it is very beneficial IDE to write the java program, in that after creating the new project it can append all the required packages automatically. In addition, it is very easy to debug the program by adding breakpoint in the code and running the debugger.

C. Bracket

Bracket [7] is open source software under the MIT license and it is primarily made for the web development and it is written in JavaScript, HTML and Cascading Style Sheets (CSS), and Graphics. Bracket editor is very attractive that attract the new programmers, it can run on Mac operating system, windows and Linux too. Bracket is very good software for front end developers and projects user interfaces. Its support the other programming languages as well including C, C++, JavaScript, python, PHP and more.

D. Jmeter

It is an open source load testing tool and used by thousands of developers [8]. It is mainly used as a load testing tool for analyzing performance of the project principally focused on web application. The advantages of Jmeter are given below:

- Open source license
- User friendly GUI
- It is platform independent
- Full support of multithreading framework
- Easily visualize the test results
- Installation process is very easy
- It has unlimited testing capabilities
- It support multi-protocol
- Shows number of binding connection

Jmeter working way:

- First it sends the request to target server
- Second get the analysis report of the target server
- Third produce the test report in different format.

E. Wamp Server

It is free software and is meant to develop a windows web application using apache, php and MySQL [8]. Once wamp server is installed, then no need to perform any further clarification. Just initiate or start the programming without changing in configuration file. The default port of wamp server is 8080, but if the user faces any troubles with this default port or if there is any chance of clashes in the port with other application, in such case there is a configuration file "wampmanager.conf" to be utilized. In that the user can simply change the port and restart the wamp server to make effect of new port.

To run an application on wamp server, the user need to maintain www folder within wamp and the user can check the log of wamp and as well as Mysql in log folder within wamp. The user can also enable the query log, general log in mysql, but better to avoid enabling the general log on production server it may overhead the user. While processing a problematic query, the user can check in slow log, same way the user can also enable the application log as well. For wamp server, there are two types of .exe (extension) files including 64 bit and 32 bit. The developer can install according to the compatibility of the corresponding operating system.

F. Scratch

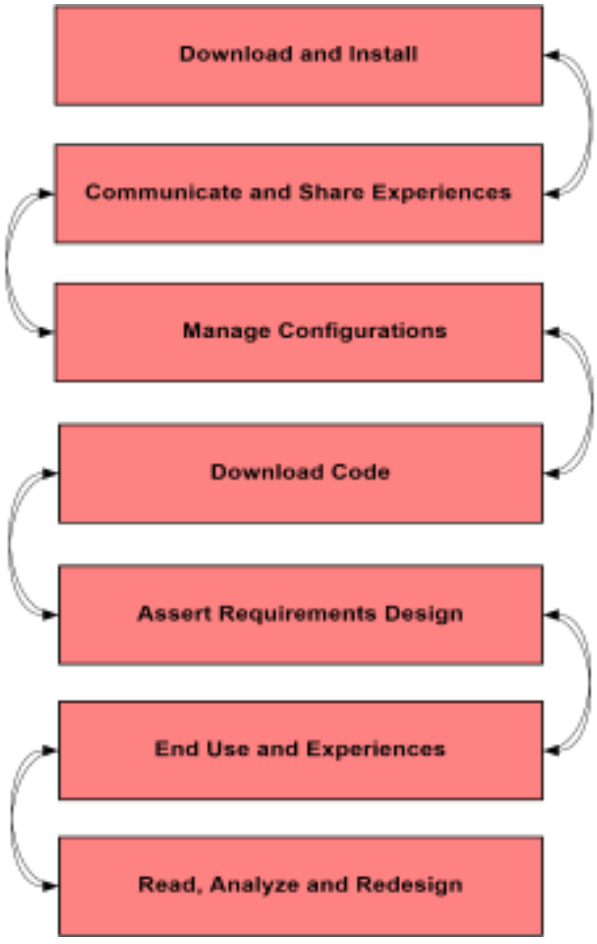
Scratch [9] is a cartoon and animation making free software application which can also run in online without any installations. Scratch is open source applications programming language and online society where the users can generate his/her own interactive animations, cartoons, games and stories [9]. The software Scratch is also called as a visual programming language targeting a young student community to practice the creativity online [10].

The students can create online based projects and also it act as an offline editor by means of a block-like interfacing technique. This tool was developed by MIT media laboratory and this tool was especially available in more than seventy languages including Arabic and English. The student community can share their projects with other users. They can also register and comment on other projects. In addition it support to create own studios. It can provides rich user interfaces using the options such as motion, sound, looks, pen, data, events, sensing, control, blocks and operators [10].

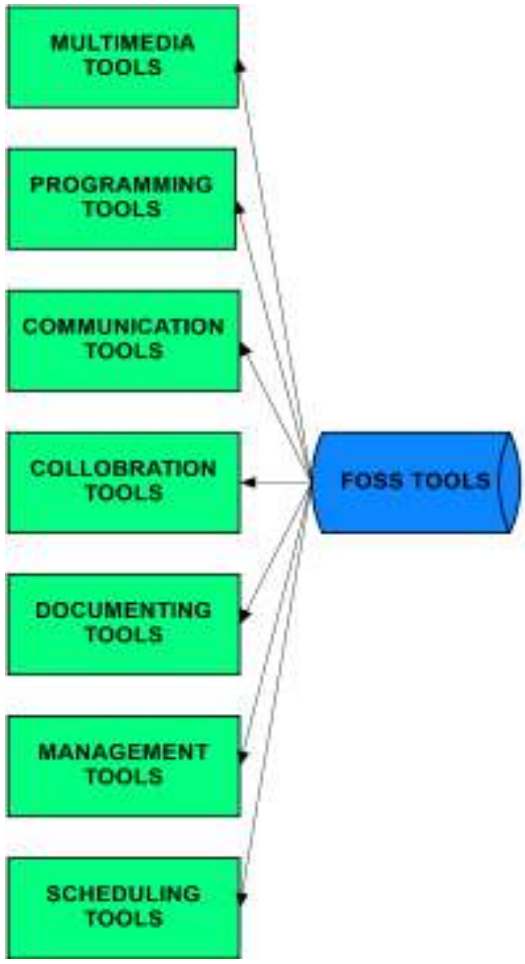
Downloading and installing as offline editor would be the efficient method to deal with. The students can use the pictures or images or photos from the scratch library. In addition they are able to use live pictures or download the required images from search engines. Similarly, the audio files and sound files can be added whenever necessary. Once the project is completed the project can be shared within the community. Subsequently, the projects can be imported and exported accordingly. Thousands of animation projects are shared [10], which is considered as a motivating factor for students for technology transfer and access to open access tools.

III. Project Management Tactics

Project Management (PM) is commonly distinct as bringing a specific project within an granted time-period and within a static financial plan. To accomplish this end-to-end process, the project typically follows a organized life cycle course with diverse phases. Software Engineering (SE) is also a methodical style to execute a given problem in to multiple processes. An ultimate purpose of software engineering is to bring a system that must inter-operate symphonically, which, in turn, necessitates an efficient and repeatable progression for scheming, mounting, and employing the system. From a operational viewpoint, PM and SE are orderly tactics to build a Software [11]. This cohesion can surmise that either PM has its origin in systems engineering, vice versa or some other association may be existing. Here the authors explains challenges and relationships to highlight the interconnectivity of PM and SE. These concepts are organized to focus a short historic look at PM and systems engineering views. This is trailed by a conversation on how the two processes are knotted [12]. The primary role of researchers to identify the challenges associated with the systematic approach in the composite project procedures and suggests the essential requirements for a systems PM prototype, and paradigm shift.



FOSS cycle process and procedures



Types of FOSS tools

Fig. 3 focus the FOSS cycle process and Fig. 4 focuses the various types of FOSS tools such as scheduling tools, management tools, documenting tools, communication tools, collaboration tools, multimedia tools and programming tools. In this survey, it has been strongly identified the availability of free mobile applications for the benefit of student community. Few of the applications are released both in software mode and also in mobile application model.

IV. Challenges & Conclusions

Some of the open source applications are limited for use. The owners provide limited period of time for free access and later they will change it in to pay and use type where original license is required to use the software tool for the further use. Consequently, it is found that few of the open source materials are not up-to the standard. For example, free online tools which are available for checking the plagiarism are failing to produce the similar results of licensed products which are purchased by the academic educational institutions and colleges for a huge financial budget. Humanitarian and societal based products [13] shall be available freely for public use. Environmental quality software [13], [14] can make a high impact when the researchers

initiate to publish freely for the public use and also to redesign. In another viewpoint, the young student community shall realize the availability of n-number of free software to upgrade their creativity skills, technical skills, programming skills and innovative skills. The educational institutions in Oman shall initiate and provide necessary awareness in respect to the free open source software that are available in online libraries and mobile play stores.

In India, some institutions handle Information Technology (IT) department examinations and IT competitions using FOSS tools [15]. It is noted that IT practical examination, 4.5 million students are evaluated every year using FOSS platform [15]. A report states that "The State Council of Educational Research and Training (SCRET)" provide strategies and procedures to assess the IT practical examinations. The examination was conducted using a FOSS tool named "soft exam" [15]. In addition, the departments conduct online competitions such as digital painting, multimedia presentation, programming, IT project developments, and quizzes using FOSS tools. Similar approaches could be suitable for Oman institutions and Omani students for an expected technology transfer and up-gradation.

USEFUL OPEN SOURCE APPLICATIONS

Sl. No.	*Open Source Software*	*Open Source Mobile Apps*
1	feKara	Dictionary.com
2	RedNotebook	coursera
3	ownCloud	Google Classroom
4	Fedena	Brain Gym
5	MoodleCloud	Cam Scanner
6	FocusWriter	Dropbox
7	Brackets	GoogleDocs
8	Gibbon	Wikepedia
9	OpenSIS Open Source	Duolingo
10	SchoolTime	Curiosity
11	SchoolTool	Mathletics Student
12	TS School	ClassDojo

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REFERENCES

S. Babu, "FOSS as a tool for development: The Kerala experience", 2011 IEEE Global Humanitarian Technology Conference, 30 Oct.-1 Nov. 2011.

A. Herrera, T. Prowse, "IEEE's humanitarian open source", Standardization and Innovation in Information Technology (SIIT) 2015 IEEE 9th International Conference on, pp. 1-4, 2015.

Free Software Foundation, URL: https://www.fsf.org (accessed on September 9, 2018)

Webopedia, URL: https://www.webopedia.com/quick_ref/free-web-and-open-source-software-for-students.html (accessed on September 12, 2018)

Open Educational Resources, URL: https://fitchburgstate.libguides.com/c.php?g=468797&p=3204457 (accessed on September 10, 2018)

W.Z. Khan, Yang Xiang, M.Y Aalsalem and Q. arshad, "Mobile phone sensing systems: A survey", Communications Surveys and Tutorials, IEEE, vol. 15, 2012, pp.402-407.

M. Aberdour, "Achieving quality in open-source software", IEEE Software, IEEE, vol. 24, no. 1, pp. 58-64, 2007.

J. Coffin, "Analysis of open source principles in diverse collaborative communities", Proceedings of the second Monday conference, pp. 1995-2018, May 2006, Chicago.

M.L Jesus, G. Robles, "Dr. Scratch: a Web Tool to Automatically Evaluate Scratch Projects", WiPSCE '15 Proceedings of the Workshop in Primary and Secondary Computing Education, At London, UK, October 2015.

MIT Scratch, URL: https://scratch.mit.edu (accessed on October 1, 2018)

S. Blom, M. Book, V. Gruhn, and R. Hrushchak, "Write once, run anywhere a survey of mobile runtime environments", Grid and Pervasive Computing Workshops, 2008. GPC Workshops '08. The 3rd International Conference, IEEE, 2008, pp.402-427.

M.E. Marwan, A.R. Madar, and N. Fuad, "An overview of mobile application in learning for student of kolej poly-tech mara (kptm) by using mobile phone", Journal of Asia and Scientific Research, vol. 3, 2013, pp. 527-537.

N.R.W. Blessing, and S. Benedict, "AquaScope: An online-based distributed WQ analysis methodology using agents", 14th Middle Eastern Simulation and Modelling Multiconference, MESM 2014 - 4th GAMEON-ARABIA Conference, pp. 10–14, Muscat, 2014.

N.R.W. Blessing, and S. Benedict, "Extensive survey on software tools and systems destined for WQ", International Journal of Applied Engineering Research, Vol. 9, No. 22, pp. 12991-13008, 2014.

B. Thankachan, and D.R Moore, "Challenges of Implementing Free and Open Source Software (FOSS): Evidence from the Indian Educational Setting", International Review of Research in Open and Distributed Learning, Vol. 18, No. 6, 2017.

Ready, Set, Pause: Readiness for MOOCs in the Omani Higher Education Institutions

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***Abstract*— This study used a qualitative research design to investigate the level of awareness and readiness in the Omani higher education institutions to offer Massive Open Online Courses (MOOCs). The reported sample in this paper includes only three higher education institutions. Data was collected using semi-structured interviews with 14 policy makers. A SWOT (Strengths- Weaknesses- Opportunities- Threats) analysis was conducted on the transcripts from the interviews to classify the responses into strengths and weaknesses in the internal environment and opportunities and threats in the external environment. One of the main conclusions of the study is the need for the Omani higher education to extend its vision to include innovative forms of education such as MOOCs. This will help to expand its role to meet the needs of the Omani society and to educate its digital citizens.**

***Index Terms*— MOOCs, Oman, higher education, SWOT**

I. INTRODUCTION

Massive Open Online Course (MOOC) brought closer the promise of universities to open up quality education for all. MOOCs as online courses are designed for large numbers of learners that can be accessed by anybody and in any place as long as they have an internet connection, available to everybody without the need for any qualifications and provide a complete online course for free in some cases [1].

Within the framework of the theory of disruptive innovation of Bower and Christensen [2-5] higher educational institutions (HEIs) can either view MOOCs as either "disruptive" innovation or "sustained" innovation. Viewing MOOCs as a "disruptive" innovation suggests the potential of changing the business model of higher education by replacing the traditional, expensive, face-to-face model to higher education with this new business model. As a disruptive innovation, MOOCs covert complex, expensive university courses designed for tuition-paying traditional students to simple, free courses designed for non-traditional students with different needs. HEIs that perceive MOOCs this way fear that the "appearance of MOOCs signals the demise of higher education as we know it" (p. 258) [6] and the appearance of new start-ups such as Udacity and Coursera platforms targeting new markets and different needs of students [3-5].

HEIs that perceive MOOCs as a "sustaining" innovation look into extending their strengths through experimenting with MOOCs. Examples of these institutions are universities like MIT and Harvard in the edX network that extend their on-campus teaching to other groups of learners with the purpose of extending their brand and improving their current performance. This started in 2012 when MIT offered a course with 120,000 students enrolled in it [3-5].

Given the previous views of higher education institutions about MOOCs, it seems there is an agreement on the benefits from offering MOOCs in different formats. These reasons as summarized by the UK Department for Business, Innovation and Skills [4] as "brand extension, recruitment, educational innovation and revenue (or cost reduction) opportunity" (p.12).

II. CONTEXT OF THE STUDY

According to Class Central in 2017 [7], there were 81 million learners taking 9,400 MOOCs from more than 800 universities around the world. As this shows the MOOC market has grown substantially in the past few years, and was extended beyond higher education to include school students and training courses.

They grew from single courses to full degrees and certificates. However, their growth in the Middle East is still at the infancy stage with a few platforms such as Edraak and Egymoocs and with other platforms that offer training courses such as Nadrus. In Oman, some platforms appeared in the past few years to offer open content but no full MOOCs were offered by higher education institutions, as far as we know. The most mature experience in this area in Oman is the one in the College of Shari'a Sciences, which offeres completely online degrees,

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with still some face to face requirements such as proctering of exams. They offer an online degree to tuition paying students only. At other Omani HEIs, there is an increase in using blended courses and providing more electronic content and communication to students. Therefore, this paper aims to concretely examine the awareness and readiness of Omani higher education institutions to offer online courses such as MOOCs.

III. METHODOLOGY

This study used a qualitative research design to investigate the level of awareness and readiness in Omani higher education institutions to offer massive open online courses. The sample of the study included ten higher education institutions in Oman representing both the private and public sectors, multiple specializations (scientific versus humanities), and diverse geographic location. The results reported in this paper only cover three institutions, as data is still being gathered from other institutions. The study used semi-structured interviews with policy makers who were in various administrative positions such as a vice chancellor, a dean, and an assistant dean, and department head. Interview questions specifically targeted institutional practices in using technologies in teaching and learning in higher education and the possibility of providing MOOCs. The sample reported here include fourteen policy makers from the three institutions.

A SWOT (Strengths- Weaknesses- Opportunities- Threats) analysis was conducted on the transcripts from the interviews to classify the responses into strengths and weaknesses in the internal environment and opportunities and threats in the external environment.

IV. RESULTS

Strengths (S):

There is a positive trend in using educational technology in HEIs. However, the three HEIs interviewed were at different levels of using technology: one has its own fully developed online education program; one was working on providing completely online courses and another using only blended learning in a few courses. Overall policy makers expressed a high level of readiness to technology in teaching and learning from "traditional" technologies like MS programs to more advanced uses like virtual labs, smart boards, electronic assessments, open source LMS programs and creating content for YouTube. Practices like reducing face to face attendance were starting to appear. In addition, many agree that the technology infrastructure is ready to offer online courses. This readiness is also reflected in students and teachers' positive attitude towards online education, and willingness to try it. Two institutions reported the availability of trained staff to handle issues related to technology use in education, for example instructional designer and technicians. They also reported that technological infrastructure is ready to handle online education such as MOOCs.

Weaknesses (W):

It was evident from the interviews from the three HEIs that there is no clear vision of the use of MOOCs, and in fact only five out of the fourteen individuals interviewed had an accurate idea of the nature of MOOCs and their uses in higher education.

In these institutions, no clear policy is available for the use of MOOCs in these institutions, in addition to the lack of strategic planning to move towards electronic modes of delivery. The available policies also do not explain issues related to delivery of online courses such as student attendance, faculty rights and loads, contribution credit for offering these courses, incentives, promotion, time allocation, and course design. Financial support for developing and offering online courses is not clearly allocated in all three institutions. Additionally, the role of online education is not well understood by faculty members. For example, some faculty members fear such transformation to the online mode may result in replacing them. Some policy makers see a need to be invested to upgrade the level of faculty skills to be able to offer online courses.

Opportunities (O):

All policy makers believe online education provides an opportunity to expand higher education in Oman through offering course to other segments in the Omani community such as those who cannot pass through the traditional doors of higher education, at a lower cost. Many realize that this type of expansions will not need additional buildings or human resources. The Omani market is still young in accommodating this type of education. Thus, opportunities to establish new online platforms, for example, is widely open. There are already some initiatives in this area such as the collaboration between the College of Engineering at SQU and the National College of Automotive Technology. Other opportunities include virtual labs and open resources. The unique location and geography of Oman makes it attractive to offer MOOCs in topics that could only be studied and observed in Oman. Courses from Oman in cultural-specific areas will also be attractive to a wide international population such as teaching Arabic for non-native speakers. The interviews reflected the opportunity for collaboration among HEIs to offer similar courses such as the ones in the foundation program, and other similar specialization courses. This could reduce national resources on developing these courses for all higher education institutions. The newly

established National Open Resource Center could host open resources from different HEIs and can play an active role in collaboration initiatives. In addition, policy makers see a tremendous benefit to attract specialized experts in many disciplines from around the world without having to host them in Oman.

Threats (T):

National threats were identified in terms of the need for technical, financial, legal and political requirements to be able to offer online course such as MOOCs, and online education in general. Technological threats include weakness in the technological infrastructure and network availably in all Omani regions. Many areas still do not have broad band internet, and the remote areas in Oman are still suffering from simple network coverage.

Financial threats are associated with the fragile economy dependence on oil and the fluctuation of oil prices in this regard makes for unstable and dependable government funding. Legal threats are mitigated by the lack of clarity in terms of a legal framework, and specific regulations for online education systems. Political issues reflected in the lack of clear national vision and strategy to accommodate new forms of education, and political will to make provision for it not only in terms of funding but also in terms of positioning it as an option for higher education.

V. CONCLUSION

As explained in the SWOT analysis, a new strategy is needed to use MOOCs as a policy tool to change the Omani higher education system. It seems from our analysis that a great Omani HEIs are at a good position in terms of their readiness to offer online education such as MOOCs, as they have the capacity to do so. In addition, their opportunities to do so are wide open with a number of initiatives already starting at this point. Although the financial resources can weaken efforts in this area, we believe the need for vision and policy is a more important factor to push HEIs' efforts towards online education and MOOCs. This need for a national strategic vision that can be adopted by the Omani Education Council will clear many doubts regarding the legal and political issues and could provide seed initiatives with technical and financial support. Extending the vision of the Omani higher education to MOOCs can greatly expand its role to meet the needs of the Omani society and educate its digital citizens. We believe that Omani HEIs are "Ready" and can be "Set" quite easily to take on the adventure of providing online education, including MOOCs, however, the "Go" button is complicated by the lack of clarity and vision in this area. As suggested by Ossiannilsson, Altinay, and Altinay [8], MOOCs are here to stay and change the learning landscape in higher education. Therefore, HEIs can