Jurva, Risto; Matinmikko-Blue, Marja

Conference Paper

Stakeholder analysis for digital campus development with 5G micro operators

30th European Conference of the International Telecommunications Society (ITS): "Towards a Connected and Automated Society", Helsinki, Finland, 16th-19th June, 2019

Provided in Cooperation with:
International Telecommunications Society (ITS)

Suggested Citation: Jurva, Risto; Matinmikko-Blue, Marja (2019) : Stakeholder analysis for digital campus development with 5G micro operators, 30th European Conference of the International Telecommunications Society (ITS): "Towards a Connected and Automated Society", Helsinki, Finland, 16th-19th June, 2019, International Telecommunications Society (ITS), Calgary

This Version is available at:
https://hdl.handle.net/10419/205186

Stakeholder analysis for digital campus development with 5G micro operators

Risto Jurva, and Marja Matinmikko-Blue

Centre for Wireless Communications (CWC), University of Oulu, Oulu, Finland

Abstract

Assumingly very few sectors of society can avoid the digital transformation, which has been storming in the recent years. Despite of the digitalization being a global mega trend and an essence to survive in the modern world, it seems that many entities are still struggling in initiating the transformation process. Instead of dabbling alone to realize big changes, many actors have noted the strengths of co-development through ecosystems. A digital university campus where education and research of the highest class are conducted together represents an important arena for digitalization. This paper introduces research conducted to constitute an ecosystem to realize a digital university campus that is built on the latest communications infrastructure. To start the change process, it is consequential to recognize the stakeholders to define the requirements and targets of the transformational evolution. An analysis of the internal and external stakeholders of the digital campus is introduced based on interviews and discussions. Considering the 5G, IoT, MEC and cloud technologies to comprise the fundamental base of digital campus, a key topic in this research is to evaluate the model of operating and developing the digital infrastructure and services. Among the traditional actors of IT Administration and mobile network operator (MNO) a novel approach is introduced by examining the recent research outcome, which defines a local micro operator driven ecosystem to provide services through a local 5G network.

1. Introduction

Many vertical operatives like industry plants, health care and education sectors have indicated their dissatisfaction towards mobile communication networks in the past years. Current mobile network operators (MNOs) are often fulfilling deficiently verticals' growing needs for indoor connectivity and tailored service offerings. With all the existing implemented mobile network generations, this feedback is surprising and has generated discussion of telecom market functionality and MNOs' business models [1]-[2]. Indoor connectivity problems have been solved with deploying wireless local area networks (WLAN) and most notably Wi-Fi networks already through years. However, being deployed in license-exempt spectrum bands, these networks are sensitive to interference and result in congestion if the simultaneous number of users in the given location increases. Going towards digitalization through 5G networks, the lack of location specific service delivery has initiated research to find alternative local network deployment models including local licensing of 5G frequencies. To harness all the 5G technology distinctions in full use of digitalization, a dense small cell network topology becomes the most appropriate implementation scenario [3]. In some countries national regulators have already introduced local frequency licensing for local operators, which allows different stakeholders to become vertical specific service providers, also known as micro operators (uO) [1]-[2]. This approach can speed up digitalization and lead to the emergence of unforeseen smart wireless services by allowing the verticals to take an active role in digitalization and implement innovations without direct MNO dependency and involvement.

Education sector is one of the verticals going through a major digitalization leap with transformational change of teaching and learning methods enabled by ICT, IoT, AR/MR and AI technologies [4]. In parallel with physical campus evolvement, high technology has brought global virtual universities with wide selection of courses accessible to students. Moreover, need of life-long learning is growing strongly, which assumes to employ all new ways of studying at workplace, home and underway i.e. independent of location. These trends have raised up discussion on traditional campuses about how to ensure the quality of education and campus attractiveness among students who increasingly want to choose personally what, when and how to study [5] - [7]. Universities may have set specific targets for digitalization to ensure more effective key operations by offering teachers, researchers and other personnel

a modern working environment. Subsequently, many universities are eager to increase interaction with business life and thus aiming to attract enterprises to establish their specific activities like e.g. research functions on campuses. One of the key answers to previously mentioned university challenges is seen in transformation into digital campus [8].

This research looks into the digitalization of the education sector towards the realization of a digital campus. This research aims to answer the following research question: What is a digital campus and who are the key stakeholders involved? When considering the implementation and operation of a digital campus with apparently exploding amount of digital systems, there are doubts if traditional MNOs are willing take full responsibility due to their specific business perspective. The university IT Administration is probably not anxious to adopt this role either. Therefore, this paper also aims to answer the following research question: How would a local micro operator driven ecosystem suit to implement and offer services in a digital campus?

This research work is of qualitative nature and uses stakeholder analysis [9] as the major theory element. First, we define the digital campus framework and identify the potential internal and external stakeholders. Then we conduct an extensive interview campaign among the identified stakeholders to gather research data on their expectations on the future digital campus. The data is then analyzed with respect to the framework of a digital campus. The views of the interviewees are compared in order to develop the definition of a digital campus that takes into account different stakeholders' expectations. When considering a campus operator to operate the digital systems, similar research methodology will be applied to discover the role of local uO for the development of the digital campus. Finally, we build a comprehensive view on how to realize the digital campus [9].

2. Defining Digital Campus

This article focuses on the digital campus, where digital infrastructure environment has been under development recently for research purposes. It has initiated discussion about utilizing the infra for digital campus development. When reviewing the literature, it can be noted that there are several terms describing environments, which are advanced and developed. Whether an environment is 'digital' or 'smart', there are numerous definitions existing. Digital environment refers typically deployment of ICT and IoT infrastructure enabling a variety of digital services. Subsequently, when discussing about smart campus or in wider context about smart city, recurrently cited past article [10] published before the actual era of global digitalization trend about benchmarking European cities defines smartness by education level of inhabitants, modern transportation, sustainability or advanced governance of a city. The authors developed a six fields model to characterize a smart city including economy, people, mobility, environment, living and governance. Each of these have specific parameters for more prompt definition. This model they use also in their recent articles [11]. The authors though mention the importance of ICT technology in the framework of a smart city. Furthermore, the authors in [12] have conducted research in benchmarking of six European Universities in the grade of smartness having the approach of Maslow's Pyramid.

Authors in [13] define digital campus and smart campus as two different phases in the development of an advanced environment. In the article the digital environment can be considered as preliminary phase of the smart environment the difference being mainly defined by the grade and utilization of ICT and IoT technology deployment. When the digital environment is mostly composed of basic ICT infrastructure and applications, characteristic for smart environment are on-demand services with quick reaction [13]. Another article [14] introduces additionally the term 'intelligent' and determines smart surroundings to be based on extensive system integration including both the digital systems and the physical to digital systems and continues, that a system can be considered smart, when it can provide what the user needs according to the dynamic needs. According to the paper developing an intelligent campus assumes extensive utilization of data from various sources like learning management, school management, student records, facility management and information security management systems, which defines the level of smartness [14]. Subsequently, when reviewing articles about few realizations of digital or smart campus, it becomes evident that ICT and IoT technology compose the basis of the framework of smart campus [15]-[18].

Even if the focus of this paper is on digital campus considering the existing status of the deployment, depending on various definitions the actual campus environment can be also considered as smart, which is the ultimate target of the development project. The project leans mostly on significant investment of ICT and IoT infrastructure. In the current deployment there are 5G and IoT sensor networks and MEC and could computing with data analytics infrastructure existing. Even if the approach of developing the smart campus is very technological, the human aspects

are emphasized by involving a particular research group specialized in the topic of human-technology interface. In the case of University of Oulu's target to develop smart campus the smartness can be defined as hyper-positioned, context and content specific offering of information and services for each campus individual, device or machine based on their profile and time.

3. Introducing 5G Micro Operators

Research on 5G has predominantly focused on wide-area network deployments by the traditional MNOs. However, the upcoming 5G spectrum bands such as 26 GHz / 28 GHz are specifically suitable for indoor operations as the signals attenuate severely when going through a wall at that frequency. Recently, alternative operator models have emerged to consider the local deployment of 5G networks for vertical specific service delivery especially in indoors [1]. These so called micro operators can deploy local 5G networks in specific buildings, such as campuses, factories, sports arenas, hospitals and shopping malls, and serve a variety of customers. For example, they can serve their own restricted customer sets, act as a neutral host for MNOs' customers or a mix of both. This local 5G operator model is build on top of the technical features of dense indoor small cell network deployments, operation in higher carrier frequencies, and the opening of network architecture to support multi-tenancy and network slicing for serving multiple customer groups with versatile requirements [1].

The main idea of 5G micro operators is to allow different stakeholders to take the local operator role specialized for the specific facility, to complement MNOs' traditional offerings. The role and level of involvement of the micro operator is highly dependent on the specific use case and can differ across the different verticals. For example, the facility owner or the tenant could take the operator role within the premises. The deployment of mobile communication networks has so far only been possible for the MNOs while other stakeholders have had to resort to operations in unlicensed bands without quality of service guarantees. The regulators are in the process of making local 5G networks possible in several countries by assigning local spectrum access rights to deploy 5G networks to different vertical stakeholders.

Figure 1 introduces a digital campus framework of possible sectors of university campus digitalization. Additionally, it gives an initial thought of the local operator model to take care of digitalization infra and services. The key operations of a university of include teaching, learning, research and support functions. Internal digital campus services envisaged include events, property management, restaurants, well-being, entertainment and logistics. Additionally, a set of surrounding services are identified including e.g. public and private traffic, living and leisure services, smart city and enterprises.

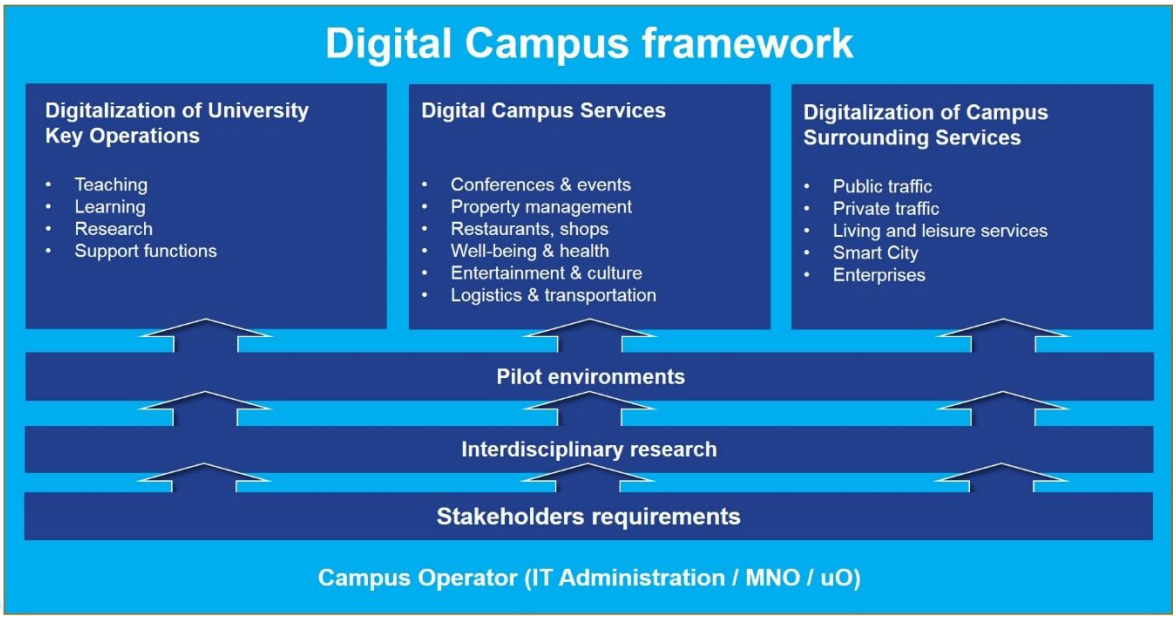

Figure 1. Framework for digital campus with operator model.

4. Identification of Digital Campus Stakeholders

When targeting to develop an advanced digital campus environment to serve and fulfill the needs of the whole campus society it assumes to involve several stakeholders in the evolution. For the success of deployment and wide adoption of the services it is essential that the applications and services are meaningful, supportive, accessible and affordable for all the users. The success can be evaluated e.g. by observing, how largely the campus users are adopting the services and what are their reactions. A key step towards realizing this is the identification of the key digital campus stakeholders and their requirements.

Next, we proceed to the identification of the key campus stakeholders in our case study of a digital university campus. When focusing specifically on multidisciplinary university campus case we expect to receive varying opinions about digital campus from both internal and external stakeholders. Additionally, inside the university the different faculties present diverse views on digital campus. Technical faculties obviously handle the framework from very technological aspect e.g. by defining systems that obviously should be accommodated in digital campus. Faculty of education may bring up modern educational methods utilizing digital systems, which are seen essential part of the framework. Faculty of humanities may want to emphasize the importance of digital systems usability meaning that systems are easy to take in use and to utilize daily. IT Administration will probably discuss about their digitalization strategy for the coming years. Compared to industry or hospital verticals university campus differs from those.

4.1 Internal Campus Stakeholders

The audience in campus is used to digital life and therefore may expect high quality of services and transformational applications. On the other hand, they are also friendly-users giving constructive feedback and innovative to develop applications and services themselves. This paper introduces the research where the campus main stakeholders were first identified, after which some of them were invited for an interview and discussion about expectations and initiatives. The campus society is composed of professors, researchers, teachers, students and personnel taking care of functions like management, administration, finance, human resources, communications, strategy, IT administration and other supporting functions. For the interviews, discussions and meetings were involved more than 25 persons including university management, IT administration, professors, researchers, project managers and library representatives. In addition to the discussions in the campus, several meetings and presentations with external stakeholders like facility owner, city officials and partnering enterprises were conducted. Finally, a public introductory event including a workshop with approximately 30 participants was arranged to initiate open discussion about digital campus and to invite the society into the co-creation process of digital campus. Subsequently, it was speculated how to largely engage the students to innovate around the topic in addition to those numerous students working in the research groups. It was concluded that interviews or meetings were not the most appropriate means to receive a comprehensive feedback. Therefore, it was envisaged that a specific student workshop, questionnaire or hackathon would be most effective manners to aggregate the ideas from the student society. This was agreed to be left as future activity.

Discussion with the university management were addressing the strategical dimension of developing the digital campus. The university strategy determines as one of the key research areas to be digital solutions in sensing and interactions with the focus areas of sensing and ubiquitous wireless sensor systems, wireless communication and other new services and systems. Subsequently, the target is in future information infrastructures having the aspect of technology perception by individuals and groups. Implementing and operating of research infrastructures supports the world-class research and will be harnessed to the evolution of state-of-the-art service platforms to serve the campus society and visitors. One of the strategical aims is to develop interdisciplinary research between the faculties, which can be advanced through the infrastructure and digitalization. Additionally, in the increasing global competition the university need to stay attractive among students, who more willingly want to choose when, where and how to study, which has increased the popularity of virtual universities in the recent years [5], [6]. To stay competitive among students the university strategy defines the need to offer modern, digitalized and inspiring learning environment. Moreover, lifelong learning is a growing trend and assumes the universities to launch modern methods to educate people and to offer a tempting setting for enterprises [7]. From the perspective of co-operation with the business life both through projects and through providing the premises to attract the enterprises to establish their presence in the campus, the deployment of digital and smart campus environment is essential. Reflecting the discussion with the university management, they expect digital campus to support in reaching the strategical goals. The mandate for developing the digital campus assumes further discussion to nominate the responsible actor for the deployment and operation.

Typically, the IT administration creates the strategy of the university digital infrastructure development including e.g. computers, servers, applications, terminals and connectivity. In the discussions with the IT personnel a strategy review was made to trigger brainstorming about the campus future. In several negotiations a common understanding of the digital campus framework was found and in large scale the evolutionary views were similar. There were several development projects ongoing by the IT team to develop the campus services. The most immediate expectation towards the digital campus by the IT administration was defined to be the implementation of positioning infrastructure to enable location-based services in the campus. Another expectation by them was a practical issue to arrange the system management and operations. Even being an existing challenge but latest by time, when the campus develops, it is obvious that the digital infrastructure with the devices, machines and robots grows manifold from the present. This necessitates, that a responsible stakeholder needs to emerge to manage and operate the digital infrastructure. With the current setup the IT administration is not capable to adopt the responsibility and therefore this concern has to be raised in discussion. The operational aspect was agreed as a common issue to be solved.

Several discussions have been conducted with the professors, researchers and project managers and students working in the research groups . The research groups have proposed several crucial issues for the development of digital campus. Commonly, the research units expect that the digital campus acts as research infrastructure and it is also supposed to advance the interdisciplinary research. Both of these topics are in line with the university strategy. The research units have specific research areas like wireless technologies, sensor technology, ubiquitous computing, data analytics, artificial intelligence, education technology, human-technology co-evolution, health technology, property management and digital traffic. Thus, the ICT and IoT technologies are seen essentials parts of digital campus. To collect data it presumes to deploy comprehensive sensor network including fixed, mobile and wearable sensors to generate data from the campus environment. In addition to data generated in the campus, open data provided by various stakeholders will be utilized when appropriate. For data transmission it is assumed that the terminals, sensors, and devices have good quality connectivity. To ensure this, various wireless technologies need to be deployed for research purposes both indoors and outdoors. Subsequently, for the research of data management and refinement and AI algorithms the researchers propose to employ both powerful edge computing and cloud computing infrastructure to evolve sophisticated services. To complete the infrastructure it is expected that specific actuators, devices, machines, vehicles and robots as research outcomes will be included in the digital campus deployment to develop state-of-art services e.g. for property management, premises management, air quality optimization, guidance, energy consumption, lightning control, digital health, traffic and other services for the campus audience. Based on above, the digital campus is expected to offer wide support for research projects.

4.2 External Campus Stakeholders

Concerning the external stakeholders of the digital campus, consultation was carried out with the university facility owner, city development officials and enterprises co-operating with university. Each of the external stakeholder has an innovative attitude towards the development of digital campus. The expectations and visions of the facility owner are ambitious and digital campus evolvement is desired to support to reach the targets. This has resulted in their participation and contribution in particular research projects. To respond to the challenge of the disruption of education, it could be enhanced through piloting and co-creation of various stakeholders. Realizing the expectations, the facility owner proposes the university transition to a service platform for students, enterprises and society and to set the key focus in the value creation by enhancing learning. Possibly the final concept could be duplicated globally. A concern annotated by the facility owner is, that who is the stakeholder capable of maintaining and operating the digital campus infrastructure and services. A discussion was initiated also with the city officials developing smart city. Many of the challenges are common and digital campus is seen to be a crucial part of smart city. The smart city developers expect intensive co-operation to develop compatible and interoperable platforms to ensure seamless smart services offered by the city and university. Many of the smart city services are based on commercial solutions, which can be complemented by piloting of university research outcomes in the context of city environment. A concrete co-operation has been initiated with the city officials to develop the framework of private and public smart traffic including also pedestrian and cycle paths.

An application developer was interviewed to listen thoughts about end-user mobile services. Currently there are a variety of personal and campus specific information available like study records, schedule and information about restaurants, career, timetables etc.. In the digital campus framework it is though possibly to develop applications with highly location specific services, which the 5G technology will enable. The application provider is looking for co-operation in the evolution of digital campus. Another discussion was started with a research partner company developing mobile SIM card functionalities. The solution will potentially enable to access a variety of campus

specific services by changing the mobile network when entering service area of a local service provider in the campus. It is expected that the co-operation with this particular enterprise may result in significant evolution in service provisioning of local networks.

What comes to mobile network operators (MNO), research co-operation and discussions have been completed with some of those. The MNOs have indicated to have motivation to deploy and operate local vertical specific networks. Due to the high requirements of business specific expertise and sometimes high investments in network deployments there are though discussions if the MNOs have capability and business interest to operate local networks. These statements have been agreed by some giant MNOs. Therefore, a research project has been conducted to find alternative options to provide services for verticals [1]-[2]. The outcome of the project is introduced in Chapter 'Digital Campus Operator'.

Table. 1 Expectations and contribution of digital campus stakeholders

Stakeholder	**Requirement/expectation to digital campus**	**Contribution/ Interaction**
University management	Support to strategical targets: - Interdiscipline research infrastructure including human-technology aspect, - Digital solutions in sensing and interactions with the key focus areas modern - Digitalized and inspiring learning environment	- Strategy, premises
Research personnel: Professors, researchers, project managers, students	- Research infrastructure to advance the interdisciplinary research - Support to develop co-operation with enterprises - Showcasing of research outcomes	- Requirements, funding
IT Administration	- Co-development with IT strategy - Interoperability of systems -Actor to be defined to operate the digital infrastructure	- Co-development
Facility owner	- University transition to a service platform for students, enterprises and society - Set the key focus in the value creation by enhancing learning. - Actor to be defined to operate the digital infrastructure and services	- Contribution trough research projects - Co-development
City Developers	- Co-operation to develop compatible and interoperable platforms to ensure seamless smart services offered by the city and university - Research outcomes piloting in the context of city environment	- Co-development
Enterprises: MNOs. developers, suppliers	- Platform for piloting products and services	- Co-development, funding

The digital campus workshop was introducing the digital campus concept and inviting the audience to converse about campus development. The participants were composed of university management, professors, researchers, project managers, IT personnel and students. The topics for the group work were digital campus from the following aspects: education, research and support functions. Concerning the education various ideas were highlighted to be involved in digital campus. One of the mentioned by the work group was that the digital campus should be evolved as a platform of education. It has potential to offer specific functionality like courses, mentoring and study records. This is highly potential topic for further discursion though assuming a prompt definition. An issue proposed for campus development by students was to arrange a hackathon, which will surely bring up fresh ideas from students and could produce e.g. applications, software and devices. Moreover, it was highlighted that co-operation between campuses should be developed in parallel with digital campus. This could offer more possibilities for education in national and global level. Rest of the ideas raised in terms of education were multidiscipline and international studying in digital campus. The working group revolving the digital campus from research point of view highlighted the importance of interdisciplinary research and co-development with the enterprises and also suggested, that the research units should be made more visible. Additionally, the group proposed that different research unit should define a specific target to develop the digital campus. This could support to develop the campus versatility. The university support functions were revised by the third working group. They were concentrating on the data utilization for various functions like IT, HR, property management and education services and emphasized the importance to define the data ownership. Moreover, the working group heightened, that a specific actor need to emerge to operate the digital campus. The expectations and contribution of stakeholders are presented in Table 1.

5. Digital Campus Operator

The digital campus realization consists of significant amount ICT and IoT infrastructure with a variety of devices, robots and vehicles compared to the existing campus. A justifiable discussion has been raised about the management and operation of digital campus infrastructure and services. The university IT Administration has indicated the existing IT infrastructure maintenance and development to require high effort from the personnel. Subsequently, the digital campus may yield operational systems for new types of entities like e.g. property management or traffic probably assuming particular skill profiles to be employed. The MNOs have probably favourable attitude for deploying and operating the digital campus ICT and IoT networks but the infrastructure will though consist of a variety of devices, machines and vehicles requiring such expertize to manage which the MNOs potentially do not have. Moreover, to develop hyper-local context oriented services it assumes that the developer is familiar with the practices, processes and environment in question. Therefore, the MNOs are not primarily seen as appropriate actor to operate the digital campus. A specific research project was conducted to study alternative options to operate local networks for verticals and the project was resulting a model of micro operator [1]-[2]. The micro operator is based on ecosystemic model, where various stakeholders have specific roles according to their expertise. There can be diverse stakeholders depending on the vertical's domain.

Campus Operator	**Pros**	**Cons**
IT Administration	- Experience about operation of university IT infra - Strategy includes new digital services to support digital campus evolution	- Requires strong development of IT function; resources and competence - Not willing to adopt campus operator role
Mobile network operator	- Long experience of operating mobile networks - Willing to act as micro operator - Frequency license existing	- Running digital campus infrastructure requires experience of high education domain - Low business motivation
Micro operator	-Based on ecosystemic model with experienced stakeholders - Knowledge of hige education domain - Technical expertize exists	-No earlier experience of operating digital infrastructure

With the growing requirements of verticals, the ecosystemic operator model can be considered the most appropriate for the deployment of local 5G networks. For the digital campus the following stakeholders have been identified. In the following the digital campus stakeholders are presented in the micro operator ecosystem. The developed micro operator model is introduced in the Figure 2.

University Management: The management is responsible of defining and executing the university strategy, which is supported by the digital campus set up.

Research personnel: Professors, researchers, project managers and students of various research groups define the requirements from research point of view and expecting the digital campus to act as research infrastructure.

IT Administration: The digital campus strategy is defined in co-operation with the IT personnel for ensuring that itiis in line with IT infrastructure strategy.

Facility owner: The digital campus facility owner acts actively in the research projects and grants permissions for infrastructure deployment.

City developers: The co-development with the smart city developers ensures that the digital campus platforms, infrastructure and services are compatible and interoperable with the smart city solutions.

Enterprises: Including e.g. MNOs, application developers and suppliers the enterprises have a significant role in realizing the digital campus. Additionally, many of them are contributing the research projects.

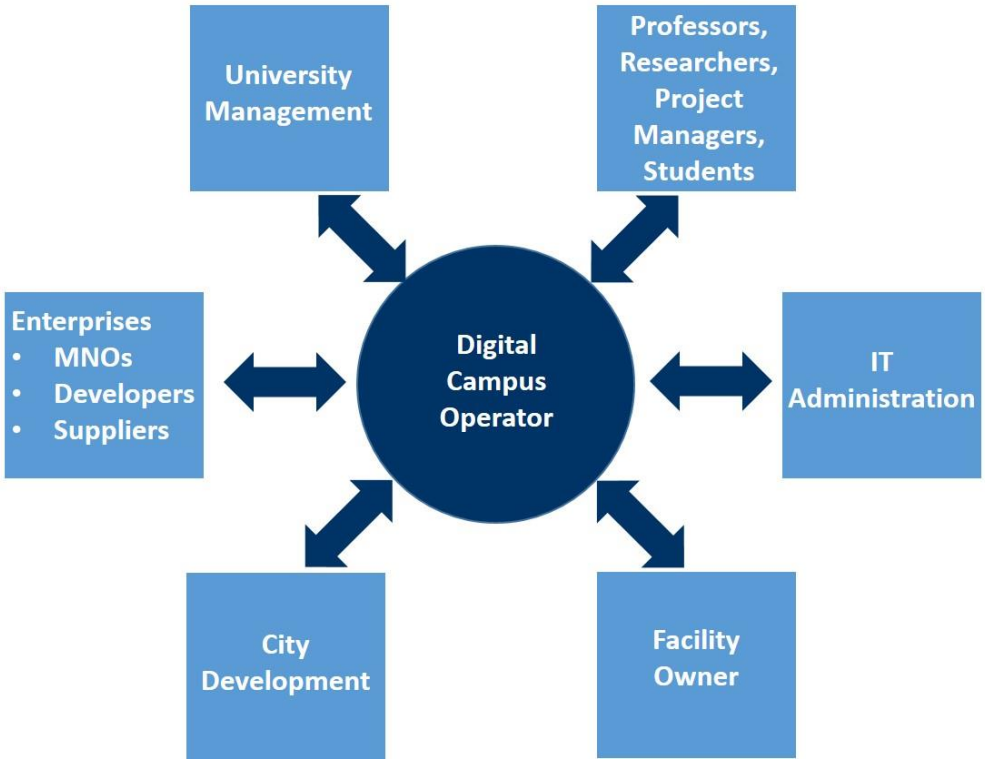

Figure 2. Micro operator ecosystem model for digital campus

Finally, to realize the digital campus with local 5G micro operator deployment model co-operation of stakeholders needs to be initiated for agreeing the high level targets, roles, responsibilities and timetables. At the first phase it is presumed to compile the requirements, which can be based on the interviews and discussions with the campus stakeholders. Additionally, it requires a licensing procedure with the regulator for receiving the frequency license to operate the local 5G network. The permitting process need to be carried out with the facility owner and evaluation of network vendors, application and content providers and suppliers are to be completed. Moreover, successful deployment of the digital campus presumes extensive service development and business modelling, although campus environment serves an optimal research infrastructure also from services and business development aspects.

6. Conclusions

This paper has outlined a digital campus and identified its key internal and external stakeholders in the case of a university campus. These stakeholders include the university management, research personnel, students, IT Administration, facility owner, city development personnel and enterprises, which all have different requirements for the digital campus. Interviews and negotiations have been conducted to gather the requirements for digital campus evolution. Many of the stakeholders expect the digital campus to function as a development platform for research, education or services and to support interdisciplinary research. Some stakeholders raised the concern about the digital infrastructure and services operation and development. The perspectives of emerging a specific actor to operate the digital campus were discussed. This is supported by the recent research project, which resulted a concept of vertical specific service provider to operate local 5G network. Finally, this paper introduced the aspects of digital campus realization by listing the required actions for initiating the deployment of digital campus, Further study and piloting will be required to develop services and business models to motivate the users and stakeholders in the campus as well as to develop the architecture of the local communications infrastructure.

Acknowledgements

This research has been financially supported by Business Finland in MOSSAF project and Academy of Finland in 6Genesis Flagship (grant 318927)

References

[1] M. Matinmikko, M. Latva-aho, P. Ahokangas, S. Yrjölä & T. Koivumäki. Micro-operators to boost local service delivery in 5G. Wireless Personal Communications, May 2017.

[2] M. Matinmikko-Blue & M. Latva-aho. Micro Operators Accelerating 5G Deployment. 12th IEEE International Conference on Industrial and Information Systems (IEEE ICIIS) 2017

[3] M. Agiwal, A. Roy & N. Saxena. Next generation 5G wireless networks: A comprehensive survey. IEEE Communications Surveys & Tutorials, 2016.

[4] TechVision Group of Frost & Sullivan. Technologies Impacting the Future of Education. AI, Mixed Reality, XaaS, Wearables Will Shape the Classroom of the Future, 2017.

[5] B. Hirsch, J.W.P. Ng. Education Beyond the Cloud: Anytime-anywhere learning in a smart campus environment. 6th International Conference on Internet Technology and Secured Transactions, 2011.

[6] A. A. Sejzi, B. Aris, N. Yahya. The Phenomenon of Virtual University in New Age: Trends and Changes. International Conference on Teaching and Learning in Higher Education (ICTLHE 2012) in conjunction with RCEE & RHED, 2012

[7] M. Laal. Key necessities for lifelong learning. 2nd World Conference on Educational Technology Researches – WCETR2012, 2012.

[8] F.-L. Wang. Research on the Application of Smart Campus Construction under the Background of Big Data, 2017. 2nd International Conference on Computer, Network Security and Communication Engineering (CNSCE 2017)

[9] R. E. Freeman. Strategic management: A stakeholder approach. Cambridge university press, 2010.

[10] R. Giffinger, C. Fertner, H. Kramar, R. Kalasek, N. Pichler-Milanović, E. Meijers. Smart cities: Ranking of European medium-sized cities, 2007.

[11] R. Giffinger, H. Kramar, N. Pichler-Milanović, F. Strohmayer. Smart City Profiles, PLEEC Project, 2014.

[12] C. Giovannella, D. Andone, M. Dascalu, E. Popescu. Smartness of Learning Ecosystems and its bottom-up emergence in six European Campuses, 2015.

[13] X. Nie. Constructing Smart Campus Based on the Cloud Computing Platform and the Internet of Things. Proceedings of the 2nd International Conference on Computer Science and Electronics Engineering (ICCSEE), 2013.

[14] L. Kwok. A vision for the development of i-campus, 2015

[15] C. Chen, C. Chen, S.-H. Lu, C.-C. Tseng. Role-based Campus Network Slicing. IEEE 24th International Conference on Network Protocols (ICNP) Workshop on COntrol, Operation and appLication in SDN protocols, 2016.

[16] F. Wang. Research on the Application of Smart Campus Construction under the Background of Big Data. 2nd International Conference on Computer, Network Security and Communication Engineering CNSCE, 2017.
[17] D. Van Merode, G. Tabunshchyk, K. Patrakhalko, G. Yuriy. Flexible Technologies for Smart Campus. 13th International Conference on Remote Engineering and Virtual Instrumentation (REV), 2016.
[18] A. Adamkó, T. Kádek, M. Kósa. Intelligent and Adaptive Services for a Smart Campus - Visions, concepts and applications. CogInfoCom, 5th IEEE International Conference on Cognitive Infocommunications, 2014.