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# Local 5G services on campus premises: scenarios for a make 5G or buy 5G decision

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(Information about the authors can be found at the end of this article.)

**Abstract**

**Purpose** – *The purpose of this paper is to build possible future scenarios for indoor connectivity in a venue such as a university campus and build alternative value network configurations (VNCs) defining different local network deployment options, focused on the Finnish telecom market.*

**Design/methodology/approach** – *In this paper, Schoemaker's scenario planning method (Schoemaker, 1995) is used to construct future scenarios and the VNC method of Casey* et al. *(2010) is used to build alternative VNCs. The paper studies the Aalto University campus network for current end-user data usage demand and the existing technology used in meeting the end-user needs and forecasts the demand for the next five years to understand the need for 5G.*

**Findings** – *This research concludes that with the provision of local spectrum licenses, there is an opportunity for venue owners to take the role of 5G local operator on the venue premises. Furthermore, it enables venue owners to collaborate with the incumbent mobile network operators (MNOs) in a neutral host model and provide venue-specific connectivity services.*

**Research limitations/implications** – *A detailed economic assessment for the network deployment in the campus is considered for future study.*

**Originality/value** – *Considering the provision for local spectrum licenses, this paper has taken a unique attempt in identifying the future scenarios for local 5G network operations. It provides a strategic direction for the venue owners in adopting 5G technology and whether to make 5G or buy 5G from MNOs.*

**Keywords** *5G, Local spectrum license, 5G local operator, University campus, Scenario planning, Value network configurations.*

**Paper type** *Research paper*

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## 1. Introduction

In mobile networks, 5G is considered a leap forward compared to the existing technologies. In addition to the high data rates, emerging use cases such as self-driving vehicles, virtual reality/augmented reality applications and industrial automation require low latency and reliable connectivity. All these service requirements cannot be addressed by using current 4G/long-term evolution (LTE) technology. The new generation of cellular technology called 5G is expected to bridge the gap between legacy technologies (Prasad *et al.*, 2017). 5G technology promises to deliver end-to-end latency of 1 ms for ultra-reliable low latency communication (URLLC), peak data rates of 1 Gbps downlink and 500 Mbps uplink for indoor hotspot environments and 1 million connected devices per sq. km for massive machine-type communications (mMTCs) (3GPP, 2016a). Until now, it has only been possible for mobile network operators (MNOs) to operate mobile communication networks. Venue owners and other stakeholders have been using wireless local area network (WLAN) technology on unlicensed spectrum to provide connectivity services to end-users inside the premises. For formulating a strategic direction for stakeholders, the technical, economic and strategic aspects need to be considered. The scope of this paper is limited to technical and strategic aspects, and a detailed economic assessment is considered for future research.

The local 5G micro operator concept proposed in Matinmikko *et al.* (2017) allows venue owners and other stakeholders to operate their own local mobile networks complementing the traditional MNO offerings and offer venue specific services, serve the MNOs' customers or do both. In this paper, the term 5G local operator is used for the actor operating local 5G networks and put a special focus on the stakeholders managing and operating the local networks. The micro-operator role can be acted by different actors such as MNOs, network equipment vendors and venue owners. In this paper, the local 5G operator role is acted by a venue owner, such as university, over locally issued spectrum license.

According to Ayyash *et al.* (2016), over 80% of mobile traffic was generated indoors, yet majority of the buildings do not offer dedicated cellular network services indoors leading to poor signal quality. So far, majority of the MNOs are extending their coverage indoors using macro base stations, but because of penetration losses, it still leads to poor indoor mobile coverage. Moreover, installing additional macro base stations is not an economically feasible solution. Although small cells play an important role in improving the coverage and capacity indoors, but the costs involved in building the small-cell networks indoors might discourage MNOs. Nevertheless, end-users expect seamless mobile services everywhere, and with majority of the mobile traffic generated indoors, it is pushing MNOs to enter indoors with small cells and serve the demands. Furthermore, the provision of local spectrum license in 5G would enable new business models for venue owners who are seeking alternative small-cell deployment options. In this regard, this paper aims to provide a strategic direction for the venue owners in adopting 5G technology, through possible future scenarios and value network configurations (VNCs) for indoor wireless connectivity.

## 2. Research methodology

The main research question of this paper is to provide a strategic direction for a venue owner on how to provide 5G services in their premises. A venue owner can either buy 5G from MNOs or operate their own local 5G networks. However, there are many uncertainties regarding possible deployment scenarios as well as the relationships between different stakeholders. First, an extensive literature survey is performed covering 5G standardization, local operator concepts, the spectrum situation in Finland, interoperability options between local operators and MNOs, and the supply side as well as regulatory challenges for local network operation. Second, the Aalto University campus network is studied, and usage demand is forecasted for next five years to understand the need for 5G on the campus area. Additionally, interviews are conducted with experts from industry, regulation and from Aalto University to understand the current state of MNOs for indoor connectivity, possible strategies for the university to adopt 5G in the future and the various trends and uncertainties related to local network operation. Next, Schoemaker's scenario planning method (Schoemaker, 1995) is used to construct possible future scenarios for indoor connectivity. The VNC method from Casey *et al.* (2010) is applied to build different VNCs corresponding to different deployment options. The VNCs help to understand how the roles are distributed between important stakeholders in different setups.

## 3. Literature survey

5G is expected to transform future wireless networks in both radio and core network domains as well as provide new services. Densification through millimeter-wave small cells can help achieve extremely high capacity in the access network. Optimal deployment of radio and core network functions, as well as hosting content and services in the edge/local clouds can provide low latency, high reliability and maintain security and privacy for critical data. Decomposition and deployment of network functions independently over distributed datacenters can increase flexibility and scalability. The overall network softwarization, complementing machine learning and analytics further enables a high level of automation in management and orchestration of network services. Network virtualization and use case specific network slicing enable new as-a-service business models (3GPP, 2017a, 2017b; Morgado *et al.*, 2018).

5G is standardized by 3rd generation partnership project (3GPP) in releases. The very first 5G release 15 standards completed in June 2019 specified standalone architecture, which supports pure 5G radio access together with the new 5G core network focusing on enhanced mobile broadband (eMBB) use cases. 3GPP has considered the requirements of vertical domain from release 16 onwards introducing capabilities for industrial use cases such as URLLC in June 2020. The release 17 planned for December 2021 is further targeting mMTC. The 5G non-public network (NPN) architecture for private networks was specified in release 16 (3GPP, 2016b). NPNs are divided into two main types: standalone NPN is a fully isolated complete 5G system, which does not interact with any mobile operator's 5G network, while a public network integrated NPN relies at least partly on mobile operator infrastructure for 5G system functions.

Furthermore, release 16 extends new radio to support 5 GHz and in the future 6 GHz unlicensed bands. All key deployments scenarios are supported: stand-alone operation on unlicensed spectrum, dual-connectivity with the anchor cell on licensed carrier and carrier aggregation with the anchor cell on licensed carrier (3GPP, 2018).

### *3.1 Emerging local operator networks*

The local 5G micro-operator is a novel concept to allow a different set of stakeholders to operate local 5G networks and provide venue specific connectivity services, potentially with locally issued spectrum licenses (Matinmikko *et al.*, 2017). So far, it was challenging for new operators to enter the market because of the limited availability of spectrum resources and regulation policies. However, a shift in focus toward local network operators has started to occur and it enables venue owners with new coopetitive business models, ending traditional market MNO dominance. These business models can involve collaboration with MNOs, thereby bringing a change in the MNO business models as well. In Ahokangas *et al.* (2019), the study describes a framework consisting of different business models and the respective ecosystems for local networks.

In Matinmikko-Blue and Latva-aho (2017), possible network operation modes for a micro-operator are presented to support multi-tenancy using network slicing technique. A local operator can operate as a closed network serving its end users and additionally it could operate as a neutral host serving the MNO subscribers as well. The authors in Jurva *et al.* (2020a) propose a micro operator ecosystem to operate and manage 5G on the campus and in Jurva *et al.* (2020b), authors propose a framework for a smart campus use case.

In a neutral host model, multiple MNOs can use the same network infrastructure to provide connectivity services in a specific geographic location. The neutral host model helps venue owners and MNOs to operate local 5G networks by avoiding overlapping infrastructure investments. The role of neutral host can be acted by a venue owner or infrastructure owner or MNOs or a network vendor, or it can be a joint venture of multiple actors, for instance, a venue owner and MNOs.

There can be different deployment models for a neutral host network, depending on different technical approaches and the extent to which participating actors collaborate in sharing the network resources. In regard to this, the study in ATIS (2019) provides an overview of different neutral host solutions. The authors in Forge and Blackman (2017) describe the challenges and uncertainties involved in rolling out 5G networks and the possible actors who would control the 5G market. It also highlights the new entrants to the 5G market in addition to the existing established MNOs. In Schneir *et al.* (2020), the authors provide a cost assessment for a multi-tenant 5G network in an urban area. The results show that total cost of ownership (TCO) reduction was achieved in a multi-tenant setup and it is observed that TCO savings increase with the increase in number of MNOs participating in the scheme.

### *3.2 5G spectrum situation in Finland*

5G network deployments in Europe are targeting a wide range of frequency bands, and MNOs can even reuse their existing spectrum licenses below 3 GHz (Matinmikko-Blue *et al.*, 2018). In Finland, the Ministry of Transport and Communications has assigned 130 MHz spectrum licenses in 3.5 GHz band and 800 MHz spectrum licenses in 26 GHz band to each of the three MNOs in the country through auctions (5GObservatory, 2018; TRAFICOM, 2020). Furthermore, the lower 850 MHz band in 26 GHz is reserved for local private and industrial deployments (5GObservatory, 2020). The 2.3 GHz band is identified for international mobile telecommunications globally and the European regulation exists. However, in Finland and many European countries, the band is used for other services than mobile broadband, and re-farming would be impractical. The licensed shared access concept developed by The European Conference of Postal and Telecommunications Administrations could facilitate shared use. The regulation and standards exist (ECC, 2014), but the public MNOs have not shown their interest in accessing the band. As there are unused spectrum resources, the sub-band 2,300–2,320 MHz is being allocated in Finland to mobile service on a secondary basis and designated to private mobile networks, such as private LTE networks (TRAFICOM, 2019). The specific 20 MHz band may provide the required spectrum for verticals, but its usability still depends on the geographical locations of the incumbent usage, i.e. wireless cameras that need to be protected from harmful interference.

### *3.3 Interoperability between local operators and mobile network operators*

Interoperability mechanisms such as national roaming and mobile virtual network operators (MVNO) provide an opportunity for MNOs and local operators to collaborate and serve users in the indoors of a venue premises. National roaming agreement between local operator and MNO would allow end-users to have a single subscription and access the connectivity services irrespective of their location. MNOs can lease network capacity from local operators and provide mobile services on the premises as a virtual network operator. Multi-homing is a mechanism that enables a device to access connectivity services through multiple access networks. Most of the smartphones are enabled with multi-subscriber identity module (SIM) slots. For a local operator who provides SIM cards to its users to access the network, multi-homing provides an option for end-users to switch between local operator and MNO network based on the availability and performance of the networks.

### *3.4 Regulatory challenges in setting up local 5G network*

As local 5G network is a novel concept, the regulations need to evolve to overcome the possible challenges that local operators could face. Below mentioned are some of these challenges that were discussed with the experts from regulation, academia and industry. There are differences in the regulations in different countries and our study focuses on the situation in Finland.

In a Finnish setup, a venue owner cannot restrict MNOs in setting up their networks inside the premises in terms of constructing network infrastructure inside buildings (Matinmikko-Blue and Latva-aho, 2017). This gives rise to the question: Would it be possible for local operators and MNOs to co-exist considering that it might lead to interference issues?

Another challenge is related to how the local 5G networks could gain access to the outside of their premises leading to the question: Would it be possible for a local operator to arrange national roaming agreements with a specific MNO but not all the MNOs in the country? Similarly, an uncertainty exists over the sharing of network infrastructure resources with the MNOs to help them setup their small cell networks in the venue premises. Third, there is a challenge related to the role of the telecommunication service provider/operator leading to the question: Would it be possible for a venue owner to operate local 5G networks but avoid being a public operator? It remains unclear if the venue owner can avoid being a public operator by providing free network access to the end-users and network infrastructure access for MNOs in setting up their small cell network inside the venue premises.

### *3.5 Supply side challenges in setting up local 5G network*

New 5G releases are being introduced with significant improvements in architecture and support for network virtualization. However, it is important to note that such improvements also come with challenges of building and operating new networks. The 5G radio and core networks need to be complemented with a very dense and high capacity backhaul. Further, as networks evolve toward more distributed processing in local, edge and central clouds, the backhaul needs to evolve in parallel, while maintaining energy efficiency. It is difficult for every base station to be connected using fiber, and as a solution, wireless backhaul approaches also need to be further developed and implemented (Ge *et al.*, 2016). Multiple input multiple output base stations are expected to provide high capacity, but their specific absorption rate (SAR) levels can be hard to evaluate in dense deployments and might lead to additional regulatory roadblocks in local deployments. Thus, novel methods to evaluate and resolve the SAR levels need to be developed (Lin and Chen, 2019). Further, considering the high capital expenditure (CAPEX) infrastructure and high-power demand in operational expenditure (OPEX) required for new 5G deployments, some venue owners might favor network sharing or continue with unlicensed Wi-Fi technologies in their future strategies.

Because of the immaturity of 5G, the stakeholders' maturity level in building and operating a 5G network is also very important for successful commercialization. According to Grijpink *et al.* (2019), large differences in strategic maturity of operators exist around the globe, with most uncertainty in their commercial strategy and business use cases, with many operators expecting network sharing and neutral host models to make a significant portion of 5G deployments. Thus, it is crucial to study such uncertainties and new deployment models.

## 4. Case study: Aalto University campus network

Next, the paper proceeds to the case study of Aalto University campus network, starting with an overview, followed by current data demand and a forecast for 2025 on the campus premises.

### *4.1 Overview of Aalto University campus network*

Aalto University campus has more than 1,000 Wi-Fi access points (APs) installed, providing connectivity for users all around the campus. In addition, university also has 4G/LTE and 5G test network, which is used for research purpose. The 5G strategy of Aalto University relies heavily on obtaining a local spectrum license for a production network. Currently, TRAFICOM has granted 60 MHz band from 3,640–3,700 MHz to Aalto University for 5G research and development purposes (University, 2019).

### 4.2 Quantitative analysis of traffic estimates

This section provides an overview of the current end-user data demand on Aalto University Wi-Fi network and forecasts the demand by 2025. The goal is to understand the need for 5G networks on the campus premises because of increase in end-user data demand with the increase in number of users.

The forecasting for Wi-Fi data usage and the number of users on the campus area are carried out based on the data collected from Aalto University. Autoregressive integrated moving average technique is used for forecasting number of users in Aalto University campus.

The maximum number of users is observed during the beginning of the academic year (September to November) and correspondingly the maximum total Wi-Fi traffic on the campus area is observed during the same period. For instance, in the year 2018, 17,578, 17,962 and 17,858 users were observed in September, October and November, respectively. Correspondingly the average data traffic per client was observed to be 3.27 GB, 4.41 GB and 4.22 GB, respectively. Furthermore, the minimum total Wi-Fi data traffic is observed toward the end of the academic year (June and July).

The forecast for the number of users on the campus by 2025 is shown in Figure 1. In 2018, per client, a maximum data usage of 4.41 GB was observed in October 2018. To forecast the demand on Wi-Fi network by 2025, it is assumed that each user has a data usage of 4.41 GB per month. Based on the forecasted data for number of users on the campus in 2025, Figure 2 shows the estimated total traffic per month in 2025. It should be noted that the estimated traffic per month is based on end-user demand, and other emerging use cases of URLLC and mMTC are not included in the scope of analysis.

The forecasted values provide an insight for Aalto University to strategize for future wireless connectivity options, whether to set up its own 5G network or follow the conventional

**Figure 1** Forecast for maximum number of users by 2025 in Aalto University campus

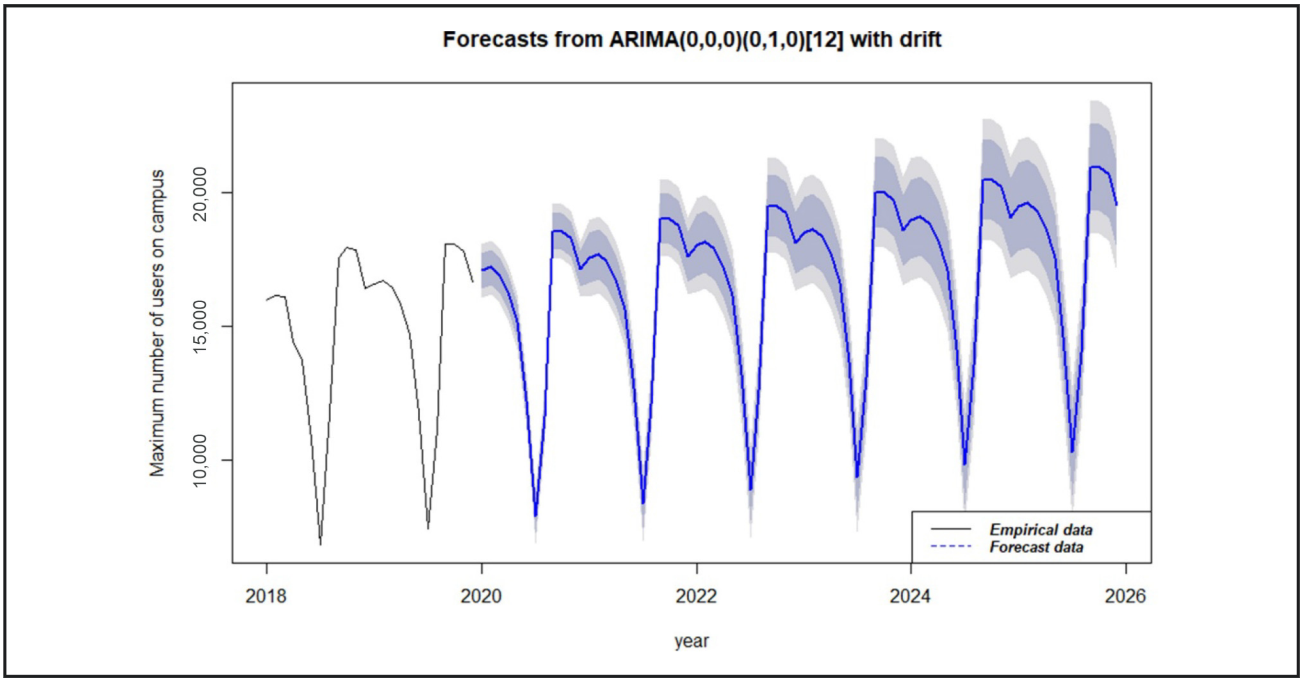
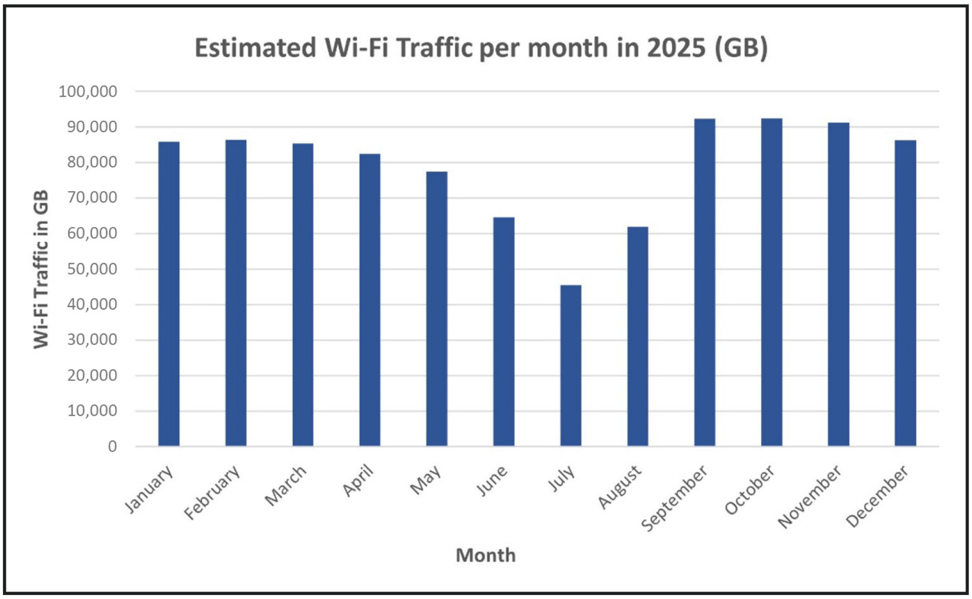


Figure 2 Wi-Fi data usage forecast by 2025 in Aalto University




approach and buy services from MNOs. As reported in TUTELA (2019), in Finland, on average 63% of data usage is delivered over cellular networks (4G and 3G) and 37% over Wi-Fi networks. Assuming a similar trend, in the future, demand on cellular networks on the Aalto University campus would be much higher than Wi-Fi networks.

## 5. Scenario planning

In this paper, possible future scenarios for indoor connectivity options in a university campus are constructed using Schoemaker's scenario planning method (Schoemaker, 1995). The process involves defining the scope and time frame of the analysis, identifying major stakeholders, key trends and uncertainties. The key trends and uncertainties are identified based on literature review and interviews with experts from industry and academic experts at Aalto University. The interviews/discussions with Aalto University academic experts were focused on understanding the existing technology used in providing connectivity services on the campus premises and to understand the possible strategies in enabling 5G networks on the campus area. The interviews/discussions with industry experts were focused on understanding MNO strategy in deploying 5G networks inside the venue premises, specifically in mmWave spectrum bands with small cells.

### *5.1 Scope, timeframe and stakeholders*

The scope of this paper is a university campus. The time frame is set for five years until 2025 considering that the 5G small cells will be deployed by the year 2025 inside the venue premises.

Major stakeholders for a university campus are university, MNOs, MVNOs, telecom equipment vendors, application service providers and cloud service providers. Depending on the different scenarios constructed, the roles of these major stakeholders would vary accordingly. While the analysis is focused on university campus, the constructed scenarios could be used as a reference for other venues, such as shopping malls and sports arena, as most of the stakeholders and expected costs and benefits would remain the same across different venues.

### 5.2 Key trends and uncertainties

Several technological, political, social, regulatory, industry and economic trends and uncertainties influence long-term strategies for organizations. While the key trends impact the current strategy and provide a general direction for the future with expected outcomes, the key uncertainties significantly impact the future direction of decision-making for an organization, with their uncertain alternative outcomes. The trends and uncertainties are listed in Table 1.

### 5.3 Scenario construction and assessment

For constructing future scenarios, two most important uncertainties are selected based on expert interviews. As the scope of the study is focused on building strategy for wireless connectivity options in a university campus, the term venue/venue owner is interchangeably used with university. The two uncertainties selected are described below:

*5.3.1 Uncertainty 1: mobile network operator indoor coverage – macro base stations or small cells.* MNOs have been relying on installing more outdoor macro base stations to extend their coverage indoors. However, problems with indoor network coverage, congestion and quality still exist. Further, with the move to higher frequency bands in 5G, it would be even more challenging for MNOs to address such indoor connectivity issues. Small cells are considered an ideal solution for building future indoor networks, but MNOs will need to establish agreements with venue owners and regulatory authorities need to set up a framework to overcome associated challenges and enable new deployment scenarios for indoor networks. Thus, it is uncertain if MNOs would continue to extend indoor coverage with deploying more outdoor macro base stations or deploy indoor small cells.

*5.3.2 Uncertainty 2: university network operation – licensed spectrum or unlicensed spectrum.* 5G enables allocation of local spectrum licenses, making it possible for venue owners to build and operate local 5G networks. A venue owner operating as a local operator can better address venue specific needs, in addition to traditional Wi-Fi services over unlicensed spectrum. However, acquiring a spectrum license, building and operating a local small cell network will require more investments and lack of experience in managing 3GPP networks will require higher management effort from the venue owners. Thus, it is uncertain whether venue owners will acquire local spectrum licenses or continue with Wi-Fi.

Next, these two uncertainties are crossed to construct four quadrants on a scenario matrix with the uncertainty 1 as the horizontal axis and uncertainty 2 as the vertical axis as shown in Figure 3. The ends of each axis represent the extremes of each uncertainty and the four quadrants represent four alternate future scenarios as described further.

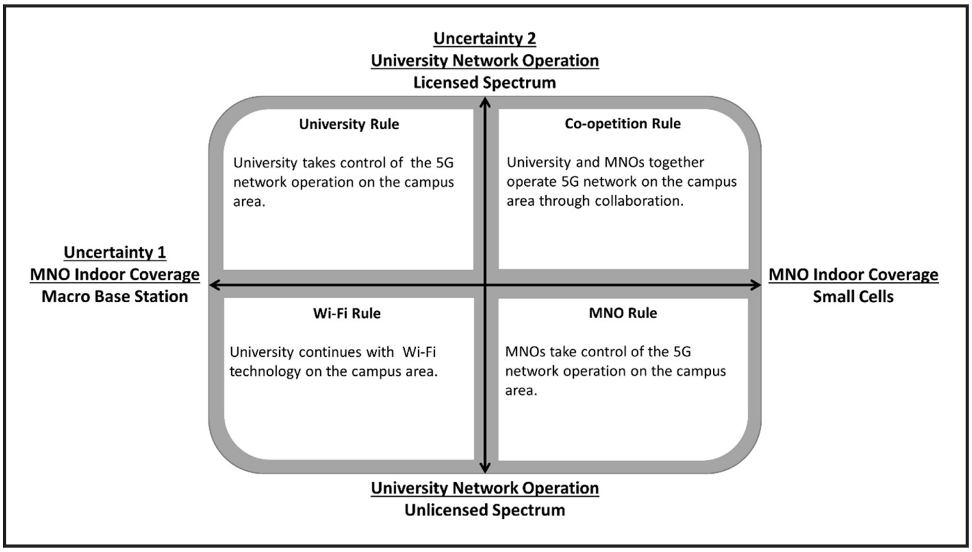
*5.3.3 Scenario 1: university rule.* The university obtains a local spectrum license and builds an indoor small cell network on the campus, while MNOs decide not to build an indoor network and continue with macro base stations outdoors. This leads to the venue owner taking full control of the indoor network services using both institute of electrical and electronics

**Table 1** Key trends and uncertainties

| *Key trends* | *Key uncertainties* |
|---|---|
| Increase in indoor data usage | MNO indoor coverage – macro base stations or small cells |
| Increase in number of subscriptions | Venue network operation – licensed spectrum or unlicensed spectrum |
| Increase in IoT/M2M traffic | Indoor networks technology – IEEE or 3GPP |
| Emergence of local operator networks | Interoperability among incumbents and emerging local operators |
| Spectrum licenses allocation in higher frequencies | Competition because of new entrants |
| Increase in adoption of eSIM | Life cycles of deployed networks – long term or short term |
| Emergence of eMBB, URLLC and mMTC use cases | Data usage demands – increasing or saturated |
| Digitalization of venues | 5G subscription charges |

**Note:** M2M = Machine-to-machine

Figure 3 Scenario matrix for future indoor connectivity in a university campus




engineers (IEEE) and 3GPP technologies, being independent of incumbent MNOs. This also leads to splitting the mobile operator market into indoor and outdoor, increasing the dominance of venue owners and reducing MNOs share of mobile traffic as a significant amount of mobile data traffic is generated indoors.

*5.3.4 Scenario 2: co-opetition rule.* The university obtains a local spectrum license, and both the university and MNOs decide to participate in indoor small cells deployment. This provides the venue owner, MNOs and other stakeholders an opportunity to share the infrastructure as well as the roles in service provisioning, for example, using a neutral host model. The venue owner can provide venue specific services, while the MNOs can extend their existing services indoors. The scenario involves cooperation and competition, and requires additional commercial agreements for national roaming, network slicing and infrastructure sharing. Further, venue owners that lack experience in 3GPP technologies can let MNOs take up operation and management roles and both can enjoy cost savings through infrastructure sharing.

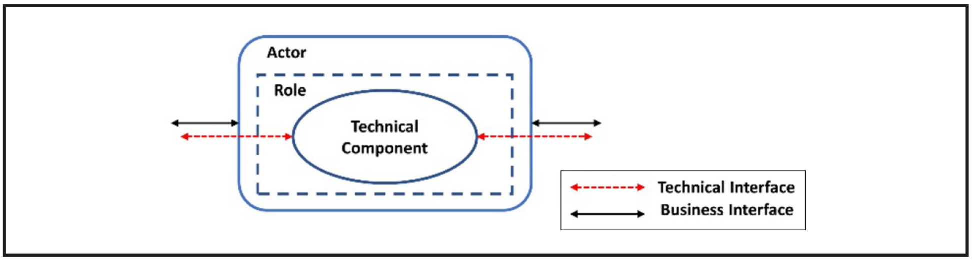
*5.3.5 Scenario 3: mobile network operator rule.* The university does not obtain a local spectrum license, and MNOs deploy small cells inside the university buildings. So far, incumbent MNOs have dominated the wide-area network operations, and in this scenario, the dominance of MNOs continues with the local area (LA) networks. Considering the experience in operating wide area networks and installed base of LTE networks for non-standalone support, MNOs are better placed in taking control of the LA network operations.

*5.3.6 Scenario 4: Wi-Fi rule.* The university does not obtain a local spectrum license and MNOs do not deploy small cell networks on the campus area and continue with macro base stations. The scenario closely depicts the current scenario with MNOs trying to provide indoor coverage through macro base stations and university offering connectivity services over Wi-Fi networks. The university continues with Wi-Fi technology and can upgrade to the latest Wi-Fi 6 for higher data rates.

## 6. Value network configurations

Next, the VNCs are derived for the developed scenarios. In local 5G networks, uncertainty exists over the roles of different stakeholders and their relationship in different future scenarios. Furthermore, they can take up different set of roles and collaborate to co-produce value, leading to different deployment models. In this paper, the VNC framework with the notation shown in Figure 4 is used to study alternative configurations of local

**Figure 4** VNC blocks with interfaces




network deployment (Casey *et al.*, 2010). A VNC consists of a set of technical components, technical interfaces connecting the technical components and interlinked business actors performing specific set of roles co-producing value through offered products and services.

Table 2 summarizes the technical components, role and business actors involved in providing connectivity solutions in a university campus and Figure 5 shows the university LA network architecture with generic roles. For consistency, the technical components in the VNCs, specifically, the indoor Wi-Fi APs, outdoor cellular macro base stations and indoor cellular small cell base stations, are labelled as “Campus IEEE Local Area APs,” “Campus 3GPP Wide Area Access Network on 3.5GHz” and “Campus 3GPP Local Area Access Network on 3.5GHz/26 GHz” respectively.

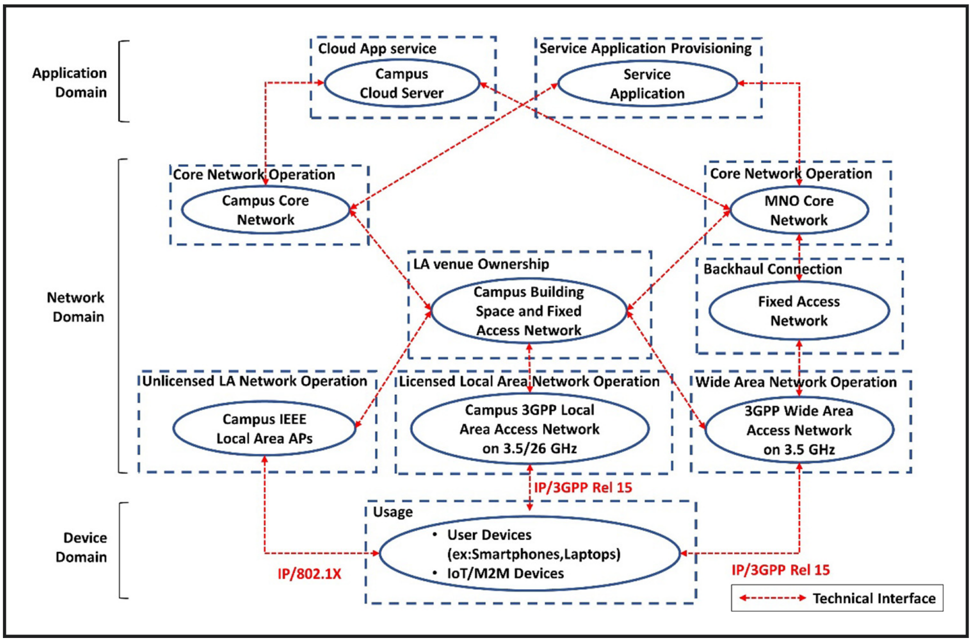
### *6.1 Value network configuration analysis*

This section describes five different VNCs and will be driven by a dominant actor that exerts more control than other actors in value creation. Certainly, in a real-world scenario, there could be more than five different configurations that a local network could shape into, but this paper tries to capture the extreme cases. It is assumed that university will allow MNOs to access the university owned infrastructure on the campus premises. Hence, in most of the VNCs, a technical interface is shown with MNOs accessing the university cloud servers and fiber for macro base stations and small cells.

**Table 2** Technical components, roles, role description and respective business actors

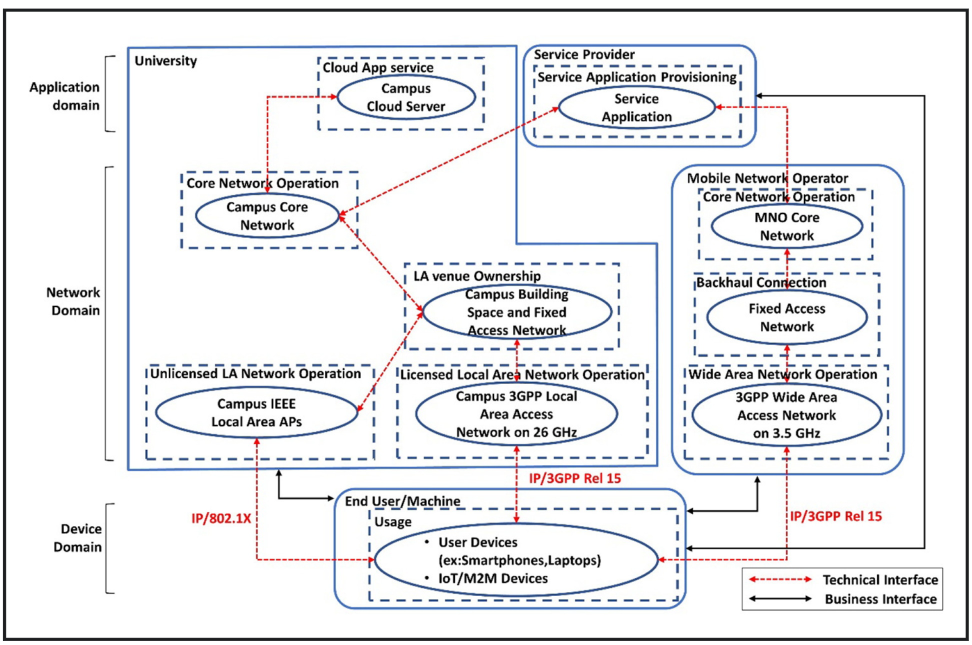
| *Technical component* | *Role* | *Role description* | *Business actor* |
|---|---|---|---|
| User devices, IoT/ M2M devices | Usage | A component that uses network connectivity and hosts device applications | End-user/machine |
| Campus IEEE LA APs | Unlicensed LA network operation | Includes providing connectivity services over Wi-Fi using unlicensed spectrum | University |
| Campus 3GPP LA access network | Licensed LA network operation | Includes providing 5G connectivity services in campus area using small cells in licensed spectrum | University/MNO |
| 3GPP wide area access network | Wide area network operation | Includes providing wide area connectivity services using macro base stations | MNO |
| Campus building and fixed access network | LA venue ownership | Includes owning of building space, optical fiber, network switches, power supply, etc. which could be leased to MNOs | University |
| Campus/MNO core network | Core network operation | Includes operation of core network | University/MNO/ MVNO |
| Campus cloud server | Cloud app service | Includes data management, providing security for the stored information and application integration on the campus area | University |
| Service application | Service application provisioning | Includes enabling of services offered by service providers | Service providers such as over the top service providers |

**Figure 5** University campus network architecture with generic roles




*6.1.1 University-driven value network configuration (multi-homing based).* The university obtains 26 GHz local spectrum license and builds small cell network on the campus to provide indoor connectivity as well as university-specific services, as shown in Figure 6. The university provides its users with SIM cards for local network access. The devices with dual SIM capability enjoy enduser multi-homing, thus being able to switch between university network and their existing MNO network based on their location and network availability.

**Figure 6** University-driven VNC



The two networks (university and MNO) being independent increases venue owner's dominance in indoor network access using both existing IEEE and new 3GPP technologies, while MNOs continue extending their indoor coverage using outdoor macro base stations over 3.5GHz band.

*6.1.2 Single mobile network operator-driven value network configuration.* The university does not obtain local spectrum license and does not invest in building 5G local network but rather outsources 5G deployment to one of the MNOs as shown in Figure 7. Thus, one MNO takes full control of local 3GPP network operations on the campus and the university simply buys 5G connectivity for university specific services from this MNO. Here the venue owner buys and provisions the additional SIMs from the partnered MNO to its users. Existing users of the partnered MNO will not require the additional SIMs. Alternatively, the university can be assumed to be operating as a virtual network operator using the network infrastructure of the partnered MNO. However, other MNOs can also deploy their 5G small cells indoors for extending their existing services, but university will provide 5G services with one of the partnered MNOs. The *campus core network* and *campus cloud server* represent the test network setup used for research purposes in the campus area. Considering the complexities involved in renting space for different MNOs in setting up their small cell network on the campus area and the associated interference issues, a single MNO-driven campus 5G network appears to be a viable option for the university.

*6.1.3 Multi-mobile network operator-driven value network configuration.* The university continues to provide connectivity services on Wi-Fi technology and all the incumbent MNOs set up their small cell network on the campus premises as shown in Figure 8. To provide 5G services over 26 GHz spectrum in a large campus area, it needs dense deployment with large number of small cells. With all the MNOs willing to exploit the mmWave spectrum band, radio planning plays an important role both from technical and economical point of view. MNOs could end up deploying small cells in close proximity to each other, leading to a complex setup. In addition, as per Finnish setup (Matinmikko-Blue and Latva-aho, 2017),

**Figure 7** Single MNO-driven VNC

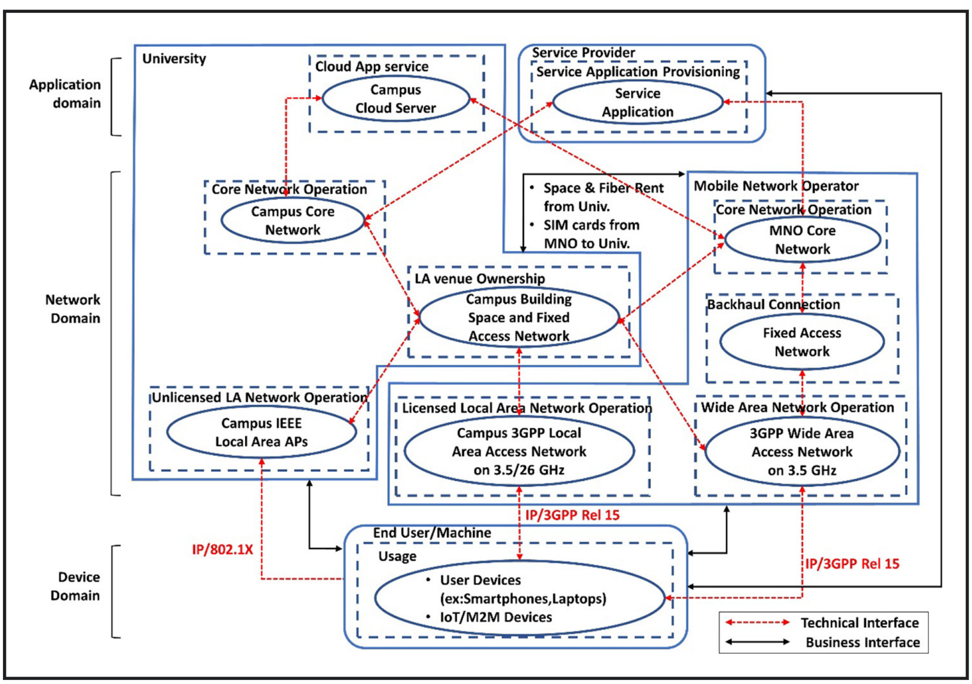
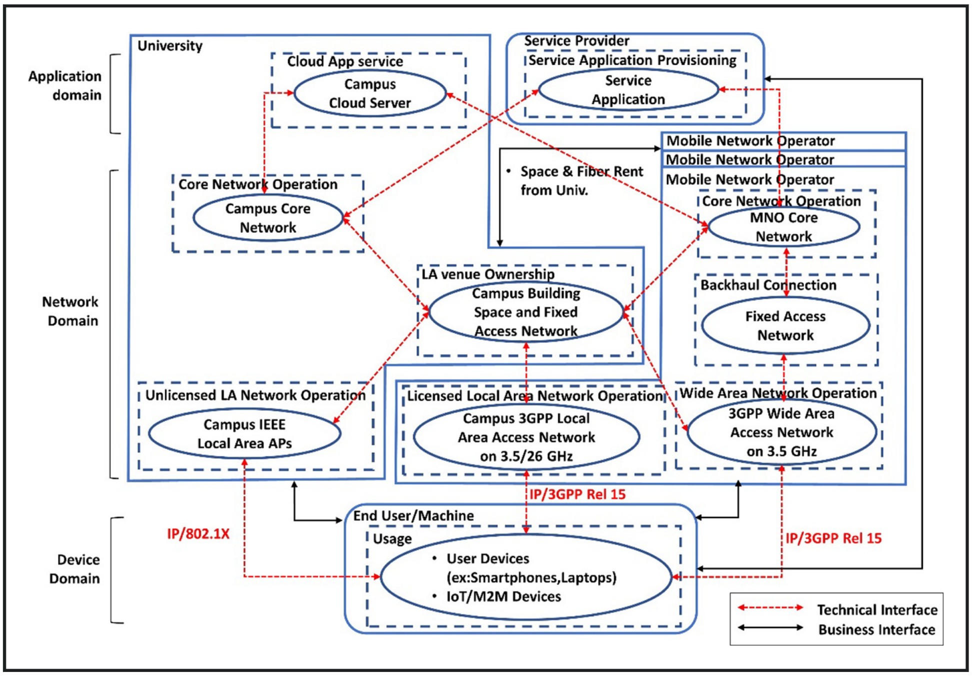


**Figure 8** Multi-MNO-driven VNC




venue owners cannot restrict MNOs from installing small cells inside the venue premises which paves the way for the development of multi-MNO driven VNC.

The university buys 5G services from the MNOs and can provide access to its users buying access to network slices from each of the MNOs. The capacity required by the university will depend on the MNOs customers accessing university slices. While this VNC leads to a complex setup as compared to the single MNO-driven and university-driven VNCs, this VNC has an advantage as the university does not need to buy and provide SIMs from the MNOs as customers from different MNOs already have their respective SIMs and receive 5G services both indoor and outdoor without multi-homing. The *campus core network* and *campus cloud server* represent the test network setup used for research purposes in the campus area.

*6.1.4 Neutral host-driven value network configuration (network slicing based).* The university obtains local 5G spectrum license and builds small cell network in collaboration with MNOs as shown in Figure 9. The MNOs are inclined to use university deployed small cell to avoid hefty investments to build overlapping infrastructure. The MNOs and university can pool network infrastructure and spectrum resources to provide a wide range of services with different service requirements over different network slices. For instance, the 26 GHz will be used for indoor hot spots for high speed connectivity while 3.5GHz will be used for campus wide deployment. The university will provide network slices to MNOs/MVNOs to service their customers indoors, thus, acting as a neutral host. Alternatively, the neutral host role can be taken up by one of the MNOs, a joint venture or a third party.

*6.1.5 Neutral host-driven value network configuration (national roaming based).* The university builds small cell network on 26 GHz license spectrum and serves the MNO customers on the campus area through national roaming agreements as shown in Figure 10. Unlike the previous VNC, it does not involve the pooling of spectrum resources rather services are provisioned on the spectrum license obtained by the university. It is also possible for the university to take the role of the neutral host operator without any assistance from the MNOs. MNOs will make national roaming contract with the university, enabling seamless mobility for their customers on the campus area. It would also mean that MNO customers can have a

Figure 9 Neutral host-driven VNC (network slicing based)

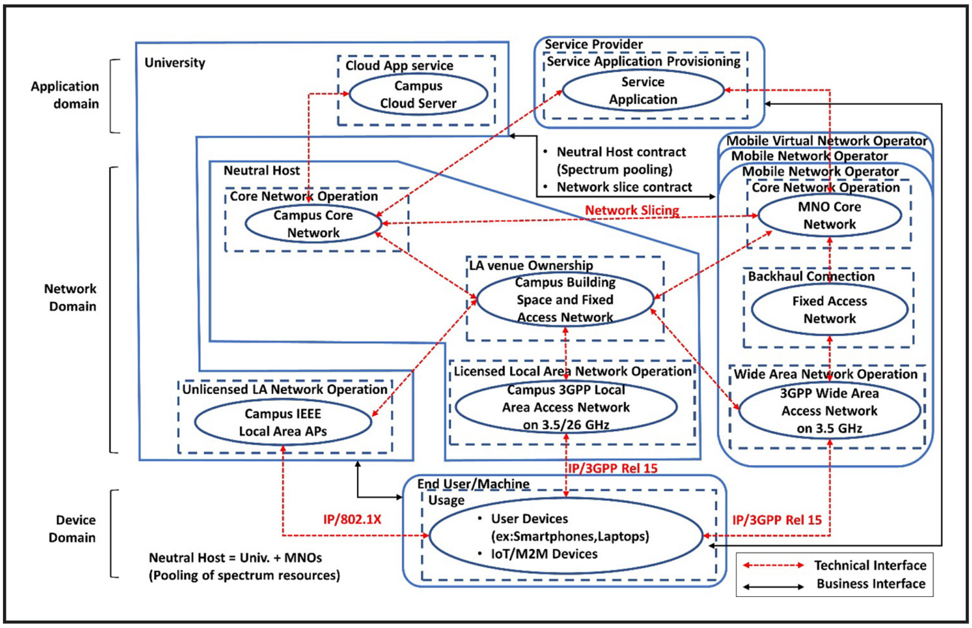
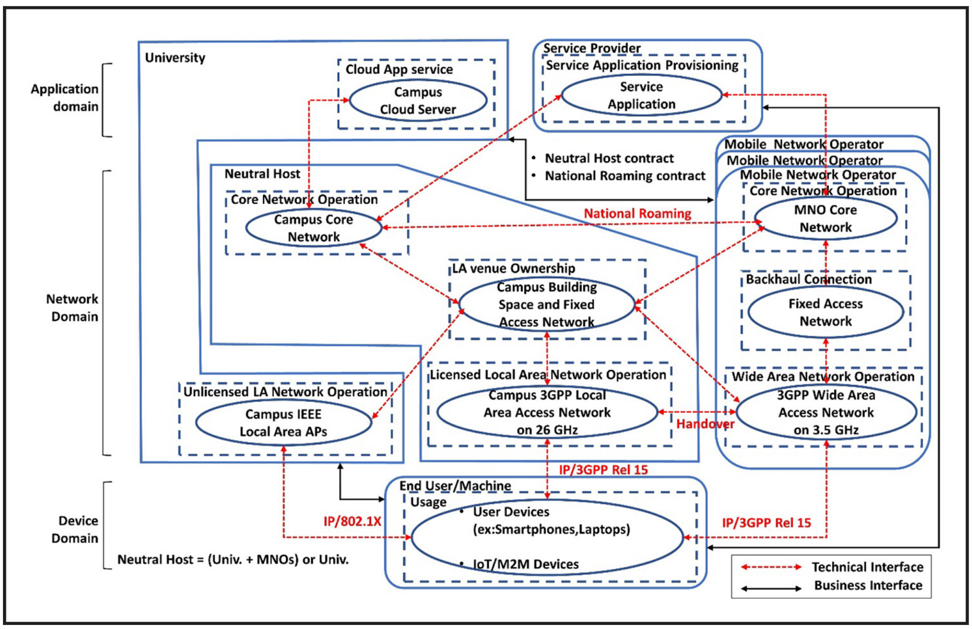



Figure 10 Neutral host-driven VNC (national roaming based)




single subscription and use the university network services. If permitted by the regulatory authority, the university can arrange two-way national roaming contracts with the MNOs, which would allow users with university-offered SIM cards to avail services outside the campus area.

## *6.2 Comparison of value network configurations*

Table 3 presents a comparison of the developed VNC describing their priorities for the university/venue owner as well as pros and cons for major stakeholders.

**Table 3** VNC comparison

| VNC type | Priority | Pros | Cons |
|---|---|---|---|
| University driven | Medium | 1. Can deploy small cells co-located with Wi-Fi APs<br>2. Enables university-specific services<br>3. Helps addressing data privacy issue as data stay within the university with the local network setup | 1. Small cell CAPEX/OPEX is high<br>2. Unavailability of non-standalone support for 5G<br>3. Lack of experience in operating 3GPP networks and university might outsource some of the network operations<br>4. Customers need to have multiple SIMs (university provided and existing MNO SIM) |
| Single MNO driven | Medium | 1. Less complexity in renting space to a single MNO<br>2. MNO experience and non-standalone support | Monopoly of a single MNO in the campus area |
| Multi-MNO driven | Low | 1. Maintains competition among MNOs<br>2. Presence of all MNOs on the campus<br>3. Customers can continue to use their existing MNO SIMs in campus | 1. Overlapping infrastructure investment<br>2. University needs to provide space for all the MNOs, which might impact the aesthetics of the building<br>3. Interference problems |
| Neutral host driven (network slicing) | High | 1. Reduced CAPEX/OPEX<br>2. Enables different deployment models<br>3. Efficient utilization of resources | Challenge in ownership and strategic control of the network |
| Neutral host driven (national roaming) | Medium | End-users can have a single subscription | Increased complexity and load on campus network |

## 7. Findings: Make 5G or buy 5G?

For a venue owner like Aalto University to operate as a 5G local operator on the campus premises, it becomes fundamental to obtain a local spectrum license. In addition to spectrum licensing, the related regulatory, supply side and venue-specific demand side challenges can affect the venue owner's decisions. The maturity of the technology itself and that of the stakeholders' can often limit the future scenarios. Furthermore, economic challenges exist in the form of large investments needed for the supporting network infrastructure such as optical fiber, small cells and the experience of operating mobile networks. Irrespective of whether a venue owner would be motivated to obtain a spectrum license and setup their own 5G network, MNOs will be entering the indoors of venues to setup their small cell network and exploit the mmWave spectrum resources. Considering all these aspects, the make 5G and buy 5G scenarios are described below:

### *7.1 Make 5G*

If the required supporting infrastructure is available, then the venue owner should consider applying for the local spectrum license and operate as a local operator on the venue area. The local operator might still have to outsource some of the network operations to MNOs/ network vendors or any other service company because of lack of experience in operating 3GPP mobile networks. A venue owner can also approach MNOs with the neutral host models, and if an interested MNO decides to participate, it can lead to a cost-efficient solution for all the involved stakeholders. In other words, it is possible that a venue owner can start off as a local operator by outsourcing some of the operational expertise and later, if MNOs join the proposed neutral host platform, then the venue owner-driven 5G network would eventually transform into a neutral host-driven 5G network.

### *7.2 Buy 5G*

A venue owner can continue with Wi-Fi technology in the future if the increase in data demand could be addressed by installing additional Wi-Fi APs wherever needed. However, to meet the service requirements of emerging use cases such as URLLC, mMTC and eMBB, venue owner would still need 5G services. If the venue owner chooses not to obtain a local spectrum license because of high costs or complexities involved in setting up, managing and operating 5G networks, then the venue owner can follow the conventional approach and buy 5G services from MNOs. If multiple MNOs show an interest in setting up independent small cell network, it gives an option for the venue owners to buy 5G services (network slices) from different MNOs depending on the service requirements on the venue premises.

Furthermore, university can also buy 5G network management and orchestration and operations as a service not only from MNOs but from a service company or technology vendors.

## 8. Conclusions

The paper has created a deep and broad insight for venue owners in terms of whether to make 5G or buy 5G. A venue owner needs to plan for the future connectivity options apart from strengthening the existing WLAN setup to meet the service requirements of evolving and emerging use cases. The case study of Aalto University campus network provided a practical insight into a university campus network. The quantitative analysis performed on the Aalto University campus provided an overview on the current data demand and the forecasted data help the university to plan and strategize for the future. As a part of future study, detailed economic assessment such as total cost of ownership for different scenarios should be conducted. In local 5G networks, there will be many interested stakeholders apart from traditional MNOs who can participate in local network operations. Uncertainty exists over the roles of different actors and the corresponding relationship between the participating actors in different scenarios. These uncertainties have been addressed in this paper by presenting different future scenarios and VNCs. The presented VNCs define the possible configurations for local 5G networks and different actors that will be driving each of these VNCs.

The VNCs covered extreme cases ranging from university operating as a local operator and making 5G, buying 5G services from MNOs and lastly collaborating with MNOs and other stakeholders in a neutral host model. This paper has presented different possible scenarios and VNCs for local 5G networks in a university campus. However, looking at the bigger picture, some of the structural results may apply for other campuses as well. For instance, a telecom vendor would be able to operate 5G networks in their venue premises which follow the venue-driven VNC. Additionally, in a harbor and sports arena environment, there could be multiple stakeholders interested in operating 5G networks and the deployment could shape into any of the presented VNCs in this paper. The make 5G strategy enables venue owners to independently offer venue specific connectivity services. However, the venue owner might still have to outsource some of the network operations to MNOs/network vendors/third party because of lack of experience. The buy 5G strategy follows the conventional approach of buying connectivity services from the incumbent service providers but it remains uncertain whether the MNOs would be able to offer venue specific services considering that the MNO business is focused on wide area networks. The comparison of different VNCs helps the venue owners to evaluate the different VNCs and choose the feasible option depending on the venue requirements.

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