Smart Campus: a route using 4G and 5G to serve the Smart City

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Smart Campus: a mini Smart City

"Smart City" has become a hot topic in recent years. While still in its infancy, the new and extreme broadband connectivity and computing capacity unleashed by the next generation (5G) mobile networks, is bringing the power of Smart City solutions to our cities. The success is driven by the fact that Smart City and its services have the power to support necessary utility functions in today's cities, and also creating completely new business models and value propositions while enhancing safety and comfort of its users; both citizens and visitors. Based on Deloitte[1], a city is smart when investments in (i) human and social capital, (ii) traditional infrastructure and (iii) disruptive technologies fuel sustainable economic growth and a high quality of life, through sustainable management of natural resources, as well as through participatory governance. They are other definitions for Smart City, however; one can say a smart city is a city with more contented and involved citizens, thanks to the digitalisation of different aspects of their life. During recent years there have been several smart city projects, with different business models and planning. Nevertheless, apart from a high cost of running such projects, one thing common to all of these activities is a "use-case driven" nature of such activities. That means use cases chosen for the smart city project make the foundation of its success and are the essence of a viable business model. So, the ability to choose the best use cases with the best technology solutions- given the circumstances- is the key to the success.

Looking at different Smart City activities, it seems behind most, if not all, is a university working side by side with other stakeholders, if not leading it. Research groups in universities play a significant role in driving innovation, however, the role of campus as a living laboratory - where not only researchers but citizens, city officials, and businesses can experiment with smart technologies that aim to make everyday life more comfortable, enjoyable and sustainable – has been overlooked. Both city and campus have their own goals, challenges, and stakeholders, yet they share a lot of common issues. Citizens' care and wellbeing, estate, energy, transport and mobility, are just a few that can be named. Therefore, campus can be seen as a mini small city - with lesser risks, cost and better mitigation plans- with its own security system, retail outlets, waste collection, sport facilities, car parking, etc. That makes a campus an ideal vehicle to trial smart city initiatives prior to scaling up and get insights about users' behaviour toward this transformation and the effectiveness of different solutions.

Synergy between Smart Campus and Smart City use-cases

Some potential use cases for Smart City which can be scaled up from Smart Campus are listed as follows:

- **Smart transport:** While cities are a complex environment, campus environment can provide a good testbed for testing intelligent transport systems, evaluating their impact on solving density problem and helping users move more quickly, cheaply, and efficiently. Intra-campus mobility can be used to:
  - Test autonomous buses without the official approvals and formal need to have all the sensors and intelligent decision making to adapt to any road traffic situation, but adapted for a restricted but useful case;
  - Trial different operation models to tackle rush-hour problem e.g., demand-based operation using App vs fixed time/fixed route operation, different payment models etc.
  - Explore the idea of moving away from mass transits by introducing and assessing disruptive services such as Mobility-as-a-Service (MaaS) transit, a system which relies on a digital platform that integrates end-to-end trip planning, booking, electronic ticketing, and payment services across all modes of transportation, public or private.

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1 https://www2.deloitte.com/content/dam/Deloitte/tr/Documents/public-sector/deloitte-nl-ps-smart-cities-report.pdf

- **Smart building:** United Nations Environment Program estimated that buildings consume 40 % of global energy[2]. In England alone, annual energy costs for the education sector total more than £200 million, resulting in the release of at least 3 million tonnes of carbon dioxide (CO_2) into the atmosphere. Annual energy costs per institution range from under £200k to over £3 million, and generally account for around 25 % of building-related revenue spend[3]. This is a sizeable portion of any estates budget. It is also potentially one of the most controllable cost. Green Energy Ensemble estimated that smart buildings save 40 % energy and reduce building operational costs up to 30 %[4]. Smart building can help minimise the manual check and maintenance overhead of various systems of the building. This can include fire, smoke, HVAC (heating, ventilation and air condition), elevators, and other facilities which need periodic checks and maintenance. Capabilities such as fine-grained temperature control, auto tinting of windows for optimal lighting, finding empty desk in library or empty class rooms by using location-based services in the buildings, are just a few examples of how smart building could help improve student and employee focus and productivity, while reducing the operation cost and improving the space efficiency. Such solutions can be tested and tuned through series of trials in the campus and then be scaled up.

- **Smart parking:** Both cities and campuses are suffering from the lack of enough parking spaces, leading to an ever-pressing demand of reducing inefficiency in parking systems and payment. In a campus, available solutions can be benchmarked, new features can be tested and their impacts can be evaluated in a small scale. Features such as multi-tier users e.g., showing last available spaces only to staff rather than students, can be tested and refined in a campus before being rolled out in a city.

- **Smart water:** Water system is one of a city's most important parts of critical infrastructure, yet one of the oldest ones. Providing effective and economical solutions for measuring the water quality, water loss management, leakage detection, and predictive maintenance planning are just a few examples of how camps can serve as a cost-effective testbed for this purpose.

- **Big data analytics:** Data, the lifeblood of smart solutions, is the "oil" of the 21st century, and is considered as a viable asset within and beyond the actual smart city opportunity. The challenge is how to use the power of data to create smart solutions that meet real needs of city users. And for that, big data analytics has, undeniably, a very important role in having a sustainable smart city/campus. In smart campus/city data is created from people, systems and things, and comes from various environments such as traffic, transport, water and sewage, energy, and buildings, with minimal or no coordination. While data is a big asset, its heterogeneity makes it challenging to discover, combine, organise, interpret, consume and publish information. Campus, as a mini city, can provide a living laboratory to try novel and sophisticated techniques and test their effectiveness.

- **User education:** The transformation from today's cities to smart ones doesn't just happen overnight. Smart solutions should address needs of their users, be utilised in their full potential and be perceived as useful. Only this way can they be adapted naturally and stimulate changes in users' behaviour. And that is the key for success of Smart environment. Education of smart city users and raising awareness can start from campuses. Students, as the most technology-friendly citizens, can act as early adapters and a good advocate for smart services. They can then educate their family and friends and raise awareness among them.

2 http://www.unep.org/sbci/AboutSBCI/Background.asp
3 http://www.cibse.org/getmedia/f944f3e0-e047-4c62-af85-43f02533f2de/ECG54-Energy-Use-in-Further-Higher-Education-Buildings.pdf
4 http://energyensemble.com/news_details.php?%20news_id=240

- **Smart people:** Disruptive technology and big data are gaining huge attention due to their role in developing Smart City. However, they are just two out of three pillars of any smart environment. The third one, and the most important one, is "smart people". These people are essential for a constant renewal of the economic infrastructure through creative destruction and innovation. Education is critical for development of talent that is motivated and enabled to drive innovation. Tomorrow's resources are in today's classroom. Therefore, providing them with an experience of living in a smart environment is a start of laying the foundation for new initiatives, start-ups and a climate in which innovation can flourish.

- **Crowd management:** Crowd management - the ability to monitor/support and, where necessary, direct a group of people to ensure their safety- is one of ever growing needs in today's societies, with some similar challenges found in campuses. Enabling technologies can be assessed in campus to see how they help move people to their destination more efficiently. The aggregated and anonymous geo-location data, available through monitoring and analysing crowds, can be used to identify how they move, how environments can be planned around them, how to get some insights about crowd densities, travel patterns and the group profile of the crowds travelling. It also can be used to identify the source of any issue or unusual behaviour and try new features based on that. For instance, new features to detect and localise an abnormal behaviour in crowd scenes, such as detecting violent in a stadium, can be tested in campus environment before being scaled up.

- **Safe campus:** The cornerstone of all smart developments is security. While data leakage from different smart services used can cause serious concerns, smart safe campus/city is not just about IT (information technology) and cyber security. It is also about how security and emergency situations can be organised and dealt in a smart way. Today's technology can provide users with an app that can inform authorities of an alert as and when needed. Using an intelligent work flow, authorities can process an incident based on different priority levels and provide voice and/or video communication with users i.e., a victim or witness with one click. Depending on the incident category and location, the system can automatically recommend the dispatch units to assign based on their skill sets, location, availability, current work load, available assets and traffic conditions to the person in need. Such services can be very effective in big campus, with the ability to subsequently serve vulnerable citizens, elderly people, etc., in big cities.

- **Wayfinding and Digital Signage:** One of primarily outcomes of smart city/campus is to improve communication with users. The ability to change all signs through the central platform, not only can provide better user experience, it can immensely help authorities in a case of security and emergency events. Possibility of updating relevant signs based on path closures, events on a day, emergency incidents etc., and providing what users need to know at the given time and location can have a very positive impact on users' day to day life.

- **Experimenting the future of SIM:** The arrival of embedded SIM (eSIM)- or more accurately eUICC- will add a new level of flexibility to mobile access. eSIM will remove the physical SIM and replace it with an embedded chip on the phone. This will enable users to download and store different mobile operator profiles on their phone and select the one they want to use without the need to change out the SIM – although they can only use one profile at a time. This will enable smaller devices such as smart watches, fitness bands and small IoT devices to be freed up of a physical SIM and make connectivity of these devices much simpler. With eSIM, new opportunities for the use of SIM cards and mobile devices arise, allowing MNOs to customise their products for different customer groups. One example of such opportunities is to install private business applications on the SIM. For example, adding building access control, or cooperate Wi-Fi profile, are just few examples of such applications. eSIM will also support access to a Neutral Host Network in a stadium, event, campus or any location where a Neutral Host Network is provided. A university site would be a good test bed for this use case where only registered students could access the network and access rights for entry to buildings, photocopying, and student services was managed by eSIM. After testing in campus, the concept can be tailored for other communities, e.g., Heath services or facilities

- **Heterogeneous connectivity:** Similar to smart city solutions, smart campus solutions contain usually both the "service" and "connectivity" parts, two domains that need to be bridged based on the requirement of each service. As the range of services and their connectivity requirements is very broad, there is no one-fit-all solution. Smart Campus/City connectivity may come through a cluster of cellular4G and 5G, Wi-Fi, and LPWA networks sites and all wireless technologies will continue to evolve to meet the full needs of the smart city and smart users. A Smart Campus can therefore provide a good testbed to try different combinations before implementing them in a city-wide application.

Business case for 5G smart cities

One of the key questions around smart cities is the business case, and specifically, where does the revenue come from to support the investment needed to build out the city-wide 5G network. There are multiple service suggestions, but what is ideally needed is a main use case that goes some way to answering the business base revenue question and then a range of adjunct services that contribute to the overall business case. If this could be established, there is no reason that a business proposition could not be developed to stimulate investments and a suitable commercial vehicle established to deliver on the smart city vision. What then could be the key use cases?

It is generally agreed that areas such as traffic management and road traffic flow are a key benefit of smart cities, but would drivers pay extra to avoid congestion and a faster less stressful journey? One option is to not offer a choice. A congestion or pollution zone charging scheme, already used in many cities around the world, could indeed be applied to the Smart Cities that adopt a 5G infrastructure. Vehicles could be charged a variable daily rate for entering the city area, the cost dependent on time of day and type of vehicle – electric vehicles could be subject to reduced fees to enter the city for example – and high polluting vehicles charged more. The smart city app in the vehicle's built-in 5G system or on the driver's smart phone would suggest available parking, and even reserve a spot for premium app users. Public car parks could be automatic, based on number plate recognition, charging only for the time parked, etc.

This level of "city smartness" would require extensive video coverage from networked cameras. As an only candid, this can be achieved over 5G – with AI and machine learning to reduce the need for massive human intervention and the associated costs. Once this video coverage is established, a number of supporting smart city services become apparent.

- **Smart city lighting:** Using city video surveillance and motion detection it would be possible to intelligently manage street lighting and traffic lights. There can be long periods of time when street lighting is not needed – during the night for instance – and street lighting could be dimmed or turned off by location based on need. Traffic lights could automatically engage based on approaching traffic reducing energy costs for the city. These services are predominantly night-time based and the 5G mobile network would be less busy during these periods so gaining maximum use out of the network at minimal cost.
    - A smart campus could also utilise the same smart lighting solution to reduce energy costs.
- **City road tax:** An alternative to a congestion or pollution zone charge could be a city road tax to cover the cost of maintaining the smart city network and supplement the maintenance of highways. Vehicles, including electric cars – which may not pay fuel tax – could be charged for the distance travelled in the Smart City. Different rates could be applied to different types of vehicles, with the least polluting vehicles being charged the least per km travelled.
- **Night time security:** An out of hours surveillance service could monitor movements – people or vehicles – and if certain pre-defined criteria were met, video of the area could be packaged up and sent to a central control centre for human analysis and action as required. A mechanical digger entering the city at 2am for instance would trigger the surveillance system since this would be an unusual event for this time of night and could be an intended smash and grab – theft of a cashpoint for instance. The cost of this service could

be added to the business rates of those in the city area protected and should actually have a positive impact on business insurance rates so potentially negating the cost to any business.

  o A smart campus solution would probably be focused late at night covering people's movements and also consider noise – identifying a scream for instance – as part of the incident monitoring criteria.

- **City road block:** Following on from the above surveillance service if a vehicle was used to smash into a store and drive off late at night, bollards could be raised across access streets trapping the vehicle in a defined zone.

- **Parking compliance:** Illegal parking can be a major headache for cities where a vehicle like a delivery truck is parked outside of the agreed time period for deliveries. This inconsiderate parking can cause traffic to back up. If a vehicle is illegally parked a tiered parking fine can be instantly raised based on vehicle number recognition and its owner can be informed via text, asking them to remove the vehicle to avoid further charges. The service revenue here is quite clear.

  o A smart campus could also implement the same parking compliance service without the need for expensive human monitoring and intervention.

- **Residential security:** The smart city video surveillance service could be expanded to cover residential areas of the city providing a percentage of the street signed up to an annual service contract. This would supplement any private house CCTV and again could positively impact the cost of insurance.

Compliance was one of the interesting business case proposals that came out of Mobile World Congress 2018 to fund the cost of smart cities. Whether it is charging for travelled distance, excessive speeding, jumping red lights, vandalism, graffiti or ant-social behaviour, using smart city video surveillance to instantly spot the infringement and deliver an appropriate fine was suggested as a viable revenue source.

Delivering the smart city solution ideally needs a commercial partner, potentially via a private public partnership or a standard commercial agreement with a private enterprise building the network and sharing any revenue generated with the city.

A smart city video surveillance services should not be viewed as big brother in current times of increased security threats and the rise in petty crimes that often go unpunished due to a lack of policing resources. Technology, including 5G and AI can improve city life considerably. The key issue is the vast amount of video data that would be collected. The solution is to use AI to only save information that meets specific incident criteria and then automatically save the video file as evidence of the event for future use if needed – question over a speeding fine for instance. Urgent incidents would be instantly brought to the attention of those that needed to take any action.

Smart city business case conclusion

The business case for smart cities can be challenging and identifying how these networks will be funded has delayed the wide introduction of smart city networks. Traffic congestion and air pollution reduction could be central to the smart city revenue plan with additional less profitable services complementing this revenue stream. Now could be the time for those enterprises with the vision to recognise the business potential of smart cities and the benefits such services can deliver to engage with the broad smart city ecosystem to make this a reality and take benefit of using smart campuses as a living laboratory for their ideas, if applicable.

Spectrum considerations for the Smart City/Campus

Mobile network operators (NMO) are usually the focus for providing a smart city network since they usually have spectrum that would support efficient and affordable 4G or 5G technologies for the services envisaged and have the core network available to manage the connectivity to multiple smart city devices or end points. Their ability to deliver an Internet of Things (IoT) solution also suggests MNOs are ideally positioned to deliver on the smart city/campus initiative.

However, if the main underlying revenue solution driving smart cities is video surveillance that could require high quality imaging and massive bandwidth, new spectrum and a 5G radio link along with massive MIMO may be the only solution. MNOs could acquire new 5G spectrum as could other agencies who wanted to focus on the 5G smart city opportunity.

The advantage of using current mobile spectrum, sub-6 GHz, is that the propagation is generally good and the cell size results in fewer sites. Sub-1 GHz bands are even better for demanding coverage requirements, but there is less bandwidth impacting the peak data rates and the capacity at these lower mobile frequencies; so high bandwidth video is probably not a use case for this band.

Considering the need for extreme throughput and the amount of data that could be needed for smart city video it will also be necessary to consider the expected 26 – 28 GHz and 37 – 43.5 GHz ranges for smart city connectivity.

The main advantage is the large amounts of bandwidth that is available – well in excess of 1 GHz in the early stages of 5G deployments.

In a campus situation large cells may not be an issue and this could be an ideal proving ground for these bands.

When considering the design of a smart city network and what devices need to initially be connected – video cameras, lighting and traffic lights for instance – many of these are in what could be referred to as city canyons with clear line of sight to required service points (CCTV cameras). Servicing these connections with a fixed wireless access (FWA) point to multipoint 5G network in the mmWave bands using MIMO antennas would potentially support the capacity requirements for smart city video.

Further considerations

- Smart city/campus is, in its nature, use-case driven. Having use-cases with perceivable values is the foundation for its success and key to viable business model. That makes the transformation toward smart environment evolutionary rather than revolutionary; change will not occur overnight. Different use cases need to be identified, their impacts on different parts should be assessed, people should be educated and involved and their feedbacks need to loop back in from very early stage of project.

- Sharing the ownership of a Smart City project with different stakeholders not only can provide a unique aspect into issues, it can open to new ideas and increase the likelihood of success. As different parties feel being part of the project, they will try their best to avoid failure. Involving universities can also help stimulate start-ups by providing incubators where new ideas can be shared, and problems can be solved through collaboration between entrepreneurs and students.

- While the foundation is the same, every city has its own priorities and challenges. Attracting and retaining high-tech and creative talents who are familiar with Smart City environment is very crucial to its existence. Today's students equipped with the experience of smart environment can be the best resource for tomorrow's need.

- NREN[5] (National Research and Education Network) can play a significant role in involving universities. NREN is a specialised Internet service provider dedicated to supporting the needs of research and education communities within a country and usually has peering with mobile operators and service providers. It is usually distinguished by support for a high-speed backbone network, often offering dedicated channels for individual research projects. Apart from connectivity, most NRENs offer digital services to their members in pursuit of the vision of having a digitally advanced education and research community. Involving NRENs in smart campus/smart city activities can:

  - Provide the best platform to raise awareness among Education sector by disseminating Smart Campus project's outcomes through case studies, conference presentations, workshop, etc. It also helps to explore and identify the best possible use cases;

  - Help to utilise the concept of Network Slicing to meet the need of different Smart Campus data traffic through having totally independent and isolated virtual networks within NREN infrastructure, and providing different level of latency, reliability, availability and security for each use case.

  - Facilitate an inter-country collaboration. Different NRENs across Europe are interconnected with each other via GÉANT[6]. Together, GÉANT connects over 50 million users at 10,000 institutions across Europe. Operating at speeds of up to 500Gbps, and offering unrivalled geographical coverage, GÉANT is considered the most advanced research network in the world. Apart from connectivity, GEANT Associations opens a door for a Pan-European deployment of successful services through other NRENs, enabling collaboration on projects over dedicated infrastructure.

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5 National Research and Education Network
6 https://www.geant.org/