Toward Digitalization: Accelerating the Adoption of Smart Cities in The Kingdom Saudi Arabia

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***Abstract*— Smart cities, driven by the rapid urbanization of the world, is currently a hot topic among decision makers (mayors, city councilors, economic planners, policy makers) as well as industries (broadband communications providers, Internet of Things (IoT) devices manufacturers, cloud computing providers, big data analytics firms, security providers). This paper discusses recent advances in Information and Communications Technology (ICT), from Telecommunication service providers' point of view, and presents a number of unique value propositions that the Saudi Telecommunication Company (STC) brings to accelerate the adoption of smart cities in the Kingdom of Saudi Arabia.**

Keywords—smart cities; digitalization; vision 2030; broadband connectivity, multi-network approach; Narrowband-Internet of Things (NB-IoT); embedded SIM (eSIM/eUICC); cloud services; end-to-end approach

I. Introduction

The phenomenon of rapid population growth in urban areas, particularly in large cities, has been, and will continue to be, the first and foremost factor driving demand for the development of smart cities. According to the United Nations report, "The World's Cities in 2016" [1]:

- an estimated 54.5% of the world's population lived in urban spaces in 2016. It is projected that, by 2030, 60% of people globally will live in urban areas and 1/3 of people globally will live in cities with at least half a million inhabitants.
- 512 cities with at least 1 million inhabitants existed globally in 2016. By 2030, it is projected that 662 cities will have at least 1 million residents.
- there were 45 cities globally between 5 and 10 million inhabitants in 2016. 63 cities are projected to have between 5 and 10 million residents in 2030.
- 31 megacities (cities with at least 10 million inhabitants) existed globally in 2016. By 2030, the number of megacities is projected to rise to 41 by 2030.

The growing rural-to-urban migration creates opportunities (e.g., for businesses as well as individuals for better educational and employment opportunities) on one hand and poses challenges (e.g., for public sector as well as inhabitants) on the other hand. In fact, public sectors around the globe are facing a number of challenges in many of their areas of responsibilities, such as education, health care, housing, security, emergency services, electricity, water, gas, traffic flow, parking, waste management, and environmental protection.

Recent advances in Information and Communications Technology (ICT) are offering cities the possibility to use technologies to achieve sustainability, citizen wellbeing, and cost reduction. More precisely, the availability of broadband (fixed and mobile) connectivity at a competitive price, a wide range of low-cost real-time sensors, machine-to-machine communication standards, cloud computing, big data analytics, and visualizations tools is helping decision makers (mayors, city councilors, economic planners, policy makers) to embrace the concept of smart cities to address urban challenges.

Although smart cities are still in their infancy, encouraging progress has been made in many cities around the globe. Smart cities are no longer a futuristic vision. They became a reality, at least from a high level perspective. For example, Barcelona, the capital of Catalonia region in northeastern Spain, is using sensors to help monitor and manage traffic. The city is expecting to reduce traffic by 21% by remodeling the flow of traffic. The city also deployed a smart parking system that guides drivers to available parking spaces, thereby reducing congestion, emissions, and parking search time. The city is optimizing waste collection operations through deployment of smart bins that monitor waste levels, so the bins are emptied only when they are full. Further, the city uses smart Light-Emitting Diode (LED) streetlamps, which turn on only when movement is detected, expecting 30% energy savings. Moreover, the city is using sensor technology to enhance irrigation efficiency, which is critical when drought occurs. The sensors monitor rain and humidity to determine the quantity of water needed to irrigate parks [2].

San Francisco, located on the northern California coast and the home to Golden Gate Bridge, has already installed smart water meters for 96% of the city's 178,000 water accounts. Each smart water meter collects the meter reading every hour. The collected data are encrypted and sent wirelessly every 6 hours to a Data Collection Unit (DCU), with each transmission lasting less than 0.1 second. There are a total of 81 DCUs throughout the city. All DCUs sends their data to a data base for billing purpose and possibly other purposes such as data analytics, using mobile data network [3]. The city also rolled out demand-based pricing for 7,000 of the city's metered parking spaces as well as 14 city-managed parking garages. The demand-based pricing increases parking fees when and where demand is highest and reduce parking fees when and where demand is low. This helps decreasing traffic congestion caused by drivers circling the streets for parking, encouraging drivers to park in less crowded areas, and also increasing the parking turnover on popular streets. To reduce energy consumption and contribute positively to environment, the city is replacing approximately 18,500 city-owned high-pressure sodium street light fixtures with smart LEDs [4], and these LEDs will be powered with 100% clean energy.

The Kingdom of Saudi Arabia, represented by the Royal Commission for Jubail and Yanbu, is also making good progress in smart cities. Yanbu, industrial and port city on the red sea coast of western Saudi Arabia with average handling capacity of 1.3 million barrels of crude oil per day [5], has deployed a smart parking management system that uses geomagnetic and infrared sensors installed on the parking space to determine parking space occupancy in real time. The system allows residents to enjoy most of the parking lots free of charge and applies parking fees for parking lots in popular places. The city also deployed a smart heavy vehicle management system that monitors speed and weight to assess penalties for overloading and speeding vehicles. This is important to reduce damages and maintenance costs caused by overloading and speeding vehicles. Further, the city of Yanbu put in place a smart waste management system that uses capacity sensors, powered by solar energy, that report in real time the fill-level of a garbage bin, enabling the administrator to optimize the driving routes of garbage vehicles, thereby improving the garbage collection efficiency. To reduce energy consumption, the city has replaced the high-pressure sodium lamps with smart LEDs, which feature low energy consumption, can be automatically switched on and off as per need, and can have brightness adjusted according to the environmental conditions. Moreover, for more energy savings, the city has deployed smart energy sensors in office buildings, which allow remote shutdown of air conditioners and lighting devices if they are left switched on unnecessarily during non-working hours. The city of Yanbu is cultivating the fruits of this engagement: 30% increase in utilization of public parking spaces, 20% reduction in road maintenance cost, 50% increase in garbage clearing efficiency, and 30% reduction in overall cost of the public lighting system [6].

As part of the National Transformation Program 2020 and the Vision 2030, the Ministry of Municipal and Rural Affairs of Saudi Arabia announced the adaption of five smart initiatives for smart cities, including smart parking, smart lighting systems, smart solid waste disposal, smart cameras, and environment pollution monitoring [7]. The ministry is currently conducting field studies, for 17 major cities whose population counts for nearly 72% of the country’s total population, to determine the readiness of these cities for transformation into smart cities.

II. CHALLENGES

Smart cities adoption is still very limited due to a number of challenges. The magnitude of challenges varies from country to country and also varies within the same country. This section discusses key challenges facing the global adoption of smart cities [8][9][10].

A. Infrastructure

Given the rapid development and availability of smart solutions for cities, every city can (at least theoretically) become smarter. A key challenge, though, is the availability of proper communications infrastructure as it is an important component in smart city development. This is because such infrastructure is necessarily to transfer data, collected by sensors and the like, to their destinations and also to transfer commands sent to sensors and the like. The communications infrastructure is expected to offer broadband connectivity, mobility, security, reliability, coverage, scalability, and quality of service (QoS) at affordable price. Thus, municipalities need to work closely with Telecommunications Service Providers to guarantee the availability of adequate communications infrastructure throughout their cities.

B. Fund

The creation of a smart city takes time and tends to require huge fund because of the cost associated with huge number of sensors, end-to-end connectivity, tools and applications, as well as operation and maintenance. Unfortunately, in many countries, municipalities do not have enough funds for smart cities. Thus, there will be a need to have private investors on board, which is not an easy task unless there is a clear business model that ensures private investors adequate returns. This is why most existing smart city projects focus on low-hanging fruits that are guaranteed to generate revenue or reduce operational cost such as smart lightning, smart water, smart waste management, smart parking, and smart transportation.

C. Skills

Smart cities require also smart skills at municipality level. It is not just about investing in smart technology; it is also about investing in smart people. This is because smart city projects can be complex, risky, and long term undertakings that involve many stakeholders and a wide range of new technologies. Thus, municipalities need to hire new professionals with special management skills (e.g., risk assessment, dealing with a diverse set of stakeholders, cross-departmental coordination and alignment) as well as technical skills (e.g., communications infrastructure, cyber security, cloud environments, data analytics and visualization, programming languages). Hence, each municipality is required to conduct its own analysis of skill deficits and find out how to address these deficits.

D. Silos

Most smart cities use physically isolated vertical solutions to address a very specific issue such as car parking or waste management. Further, these solutions are controlled by different administrative entities. This is an expensive approach as each vertical will have a separate platform with separate hardware configurations and software instances. Also, if the data collected from each vertical, are stored and processed separately, the cross-correlation between various data sets is impossible, which prevent the city from making best use of the collected data. A city cannot be truly smart if each smart solution operates in silos across the city, which will likely remain the case as long as there are silos across different administrative entities.

E. Inclusive

Smart cities must be inclusive in terms of providing benefits to all its residents and ensuring that no particular groups are left behind, regardless of any potential cost impacts to the city. Old and disabled people are part of the human experience and therefore they have the right to be offered smart solutions that address their needs. Although most businesses in slums in developing countries are seldom under government taxation, this should not deprive slums inhabitants of the benefits of smart cities they bitterly need and deserve. Unfortunately, slams are often marginalized and completely left out. Smart cities must be inclusive to all and must engage aging communities and those living with disabilities or in slums in the planning of smart cities to ensure these people get solutions they need.

III. ARCHITECTURE

Although the term “smart cities” has been used for several years by both academics and practitioners and it is moving fast from trend to mainstream, there is still no agreement among academics about a clear-cut definition of “smart cities”. In line with what is common in most definition, we agree with the definition used by authors of [11], namely “Smart City” is the term for the use of ICT and other new technologies to improve the sustainability, efficiency and quality of public services and improve the standard of living for citizens. This is because ICT and new technologies, such as Big Data Analytics and Artificial Intelligent (AI), are key elements for the success of smart-cities. This section discusses the main layers of smart-cities infrastructure, namely, sensors, communication, data platforms, applications, and security [11][12].

A. Snesors

This layer is one of the most important pieces of the smart cities’ puzzle and vendors and standard bodies are heavily working on it. This layer consists of sensors that are spread across an urban area to collect data that were previously too complex or time-consuming to collect. Sensors also allow data to be collected and analyzed in real time, which was difficult and expensive in the past. There are many use cases for sensors such as monitoring of energy and water usage, environment conditions, and traffic flow patterns. Sensors come in many variations and are divided into two main categories:

- <u>Constrained</u>: characterized by low-power consumption, low processing power, and low data-transfer rate.
- <u>Unconstrained</u>: no constraints in terms of power consumption, processing power, and data-transfer rate.

B. Communication

This layer, also called connectivity layer, is responsible for receiving and sending data from and to sensors. This layer is where communication network elements reside such as equipment and broadband infrastructure (e.g., fibre, copper, coax, and microwave radios) that make it possible for sensors to transmit and receive data in various formats and according to different standards. Due to the different characteristics and use cases of sensors, this layer is required to have both fixed and mobile broadband networks as well as technologies that are compatible with both constrained and unconstrained sensors. The availability of mobile networks is crucial not only because it is very costly and practically impossible to link all sensors via fixed connection, but also because there are use cases that require mobility such as tracking of moving objects. The communication network is expected to provide coverage, reliability, scalability, security, QoS, and efficient use of unlicensed spectrum at affordable price.

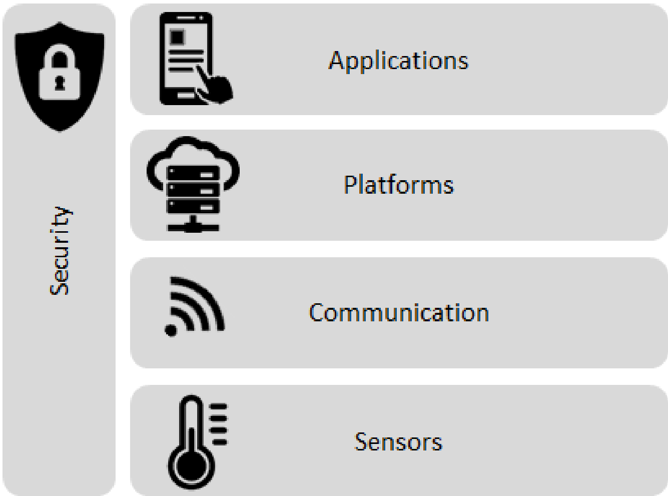

Fig. 1: A typical smart-cities architecture

C. Platforms

The role of the platforms layer is to receive, store, process, and expose information to the applications layer. It is also responsible for device/sensor management. As there will be a huge number of sensors in smart cities, vast quantities of data will be collected and pushed to the platforms layer. Thus, this layer must be able to accommodate and manage large volume of data (big data) using established standards and regulations. Also, this layer is required to have data analytic tools that are capable of processing the big data to extract useful insights out of the collected raw data. Further, this layer must be able to expose application program interfaces (APIs) that allow various applications to connect and interact with this layer. This layer can be cloud-based or operated and managed by the city itself. In case of cloud-based layer, it is extremely important to specify clearly in the contract who own the data, the city itself and/or other actors. Ideally, the city owns the data otherwise it cannot monetize it and make some money along the way.

D. Applications

This layer is basically a user interface and the associated software (e.g., web application or a mobile application) that connect to the platforms layer and provide information to customers in well-defined formats such as tables, graphs, and reports. This way, customers can get high-quality smart services that meet their needs (e.g., smart parking, smart water metering, smart traffic monitoring). This layer as well as the sensors layer get the most attention. This is because user can download and install an application that makes life easier (e.g., finding an empty parking slot). Also, people can see (and touch in some cases) sensors that are deployed in smart cities.

E. Security

All layers are vulnerable if not protected properly. This is because (a) sensors, due to cost considerations, often do not have enough computing power required for sophisticated security implementation so they can be hacked to produce false data, (b) communication can be compromised by man-in-the-middle attacks (i.e., traffic flow from point A to point B will go through the fraudster X who can sniff login details for future use), and (c) platforms contain data that can be breached by unauthorized parties. Thus, the security layer is extremely crucial and lies vertically across all other layers (from sensors to application). The security layer consists of technical mechanisms and policies to protect, sensors, communication network, data, and application from unauthorized outside access and manipulation.

IV. STC's Unique Value Propositions

Saudi Telecom Company (STC) is Saudi Arabia's pioneer telecommunications services provider and a leading telecom operator in the Middle East and North Africa (MENA) region. In line with the Kingdom's Vision 2030, STC is driving a process of transformation with the goal of becoming the cutting-edge leader in digitalization within the kingdom's ICT sector. STC is fueling the digitalization engine with outstanding network infrastructure (both fixed and mobile), state-of-the-art cloud services, IoT solutions, data analytics, user-friendly web applications, and talented professionals.

When it comes to smart cities, there are hundreds of companies (from sensors manufacturers to software vendors) that offer specialized solutions for a wide range of verticals (e.g., utilities, transportation, and environment). However, Telecommunications Service Providers have a unique combination of competencies that set them apart from other solution providers. For instance, STC has a strong value proposition for smart cities not only because it has already deployed cutting-edge technologies and own state-of-the art network infrastructure across the Kingdom, but also because it has already a rich experience in providing Machine to Machine (M2M) solutions for both enterprises and consumers. Examples of these M2M solutions are: mobile Point of Sale (PoS), Mobile ATM, and fleet control services that was introduced early 2015 and offer alert management, vehicle record history, maintenance management, and more. Below are some of STC's unique value propositions for smart cities in the Kingdom.

A. Multi-network Approach

Multi-network approach is in the fabric of STC Heritage. This is extremely important for the success of smart cities because it allows for pairing of network technology with different vertical solutions, each has special requirements as it is dedicated to a specific segment of smart cities. This multi-network approach provides the flexibility and agility required to accelerate the development of smart cities in an optimized and cost effective manner. In nutshell, STC is committed to take the heavy lifting away from the municipalities across the Kingdom by providing them access to the right network at the right time.

Mobile connectivity and excellent coverage are provided through STC's mobile networks: 2G, 3G, and 4G. STC has positioned itself as the mobile broadband operator of choice in the Kingdom through the acquisition of large amounts of expensive spectrum, state-of-the-art technologies, and customer-centric services. STC has re-affirmed its commitment to remaining the leader through recent acquisition of additional 2×15 MHz blocks in the 700 MHz band (well suited to IoT solutions, including smart cities) and 2x8 MHz blocks in the 1800MHz band for 2.507 billion SAR as well as the boost of LTE network capability through the commercial launch of LTE Advanced Carrier Aggregation of two component carriers (each of 20 MHz LTE TDD). In addition STC has already engaged in 5G activities and plan to be the first operator to launch 5G in the Kingdom. This is important because the full potential of smart cities will be unlocked by 5G network as it can by default support massive IoT connections, very low latency, ultra-high speed broadband, energy-efficient connected objects, and network slicing (i.e., creation of end-to-end virtual network, on top of a common shared physical infrastructure, that is granularly configured and optimized for a certain business purpose or a customer).

Fixed connectivity is provided through STC's fixed line network, which is the best one in the Kingdom in terms of customer base, geographical spread, and revenue. STC's fixed line network uses copper (twisted pair) cables and optical fibre cables to provide broadband connectivity to homes, businesses, and public spaces throughout the Kingdom. Free public WiFi access is a key enabler for the success of smart cities because it helps connecting local residents as well as visitors to general resources (e.g., bus timetables, weather forecast, maps, hospitals, etc.), commercial businesses (e.g., restaurants, malls, stores, banks, etc), and tourism attractions (e.g. museums, cultural attractions, historical places, etc). In this regard, STC is well prepared to serve municipalities because 1) it has already deployed more than 10,000 public WiFi sites throughout the Kingdom and can deploy more WiFi sites and make all of them offer free public WiFi access and 2) it is also the major player in the "high-speed fibre-optic broadband initiative" to expend fibre-optic broadband access (at speed not less than 100 Mbps) to additional 2.3 million houses in all urban areas across the Kingdom from 2017 to 2020, as part of the National Transformation Program 2020 and the Vision 2030.

Mission-critical communications are provided to public safety agencies as well as industrial and business critical customers through a dedicated network that is operated by the company

STC Specialized (formerly known as Bravo), the critical communications arm of STC. To create smart cities that are safe, mission-critical communications network is required so that public safety agencies (e.g., law enforcement, fire, and emergency medical services, etc) remain connected in situations like natural disasters or major emergencies. In this respect, STC offer a wide range of services such as "Push-to-Talk" service (to allow for instant communication among a group of individual users or between multiple groups) and “Data Transfer” services (to allow staff in the field to transmit data either through internet or internal network).

B. Low-Power Wide-Area (LPWA) Technology

LPWA Technology suits well to many verticals of smart cities because it offers low power consumption (sensor/device battery can last up to 10 years, thereby reducing operational cost associated with replacing batteries of hundreds of thousands of sensors/devices, some of them are in places that are hard to reach), massive connections (tens of thousands of sensors/devices per base station), long range (about 5 km in dense urban areas and about 50 km in rural area), good signal penetration (can reach elevators inside buildings as well as basement and underground car parks), low device cost (less than 5 US$ per module so that mass deployment of sensors is possible at reasonable cost), and low connectivity cost (few dollars per year). Further, LPWA is breaking down smart city silos because it can be used by many verticals of smart cities (e.g., smart electricity meters, smart water meters, smart energy sensors in office buildings, etc). This means a single system can be used by many verticals, thereby reducing both capital expenditure (CAPEX) and the operating expenditure (OPEX). A single system also helps the city to easily cross correlate data sets from different verticals to get more insight into relationships between these verticals. In this regard, STC Network supports Narrowband Internet of Things (NB-IoT), which is a secure, reliable, and efficient type of LPWA technology that was standardized by 3GPP in Release 13 [13] and uses licensed spectrum. Also, STC has already tested Long range Radio (LoRa) for different verticals of smart cities and ready to engage with municipalities across the Kingdom. LoRa is a LPWA technology that uses unlicensed spectrum in the Industrial, Scientific and Medical (ISM) bands.

C. embedded SIM (eSIM) Technology

When deploying hundreds of thousands of devices that transmit their data using mobile network, it is important to think about operational cost. For example, traditionally, SIMs are inserted into these devices and each SIM is dedicated for a specific mobile network (i.e., changing the mobile operator means replacing the exiting SIM with another SIM). Imagine that, for some reasons, all exiting SIMs (can be hundreds of thousands) must be replaced. This means large manpower is required to do the SIMs replacement. An alternative approach is to deploy only devices that use eSIM technology, which allows the download and activation of eSIM profiles over the air in a seamless, secure, and convenient way, using Remote SIM Provisioning (RSP) Platform. In this respect, STC has already tested successfully the eSIM technology and in the process of launching RSP platform this year (2018).

D. Cloud Services

Cloud services offers agility, scalability, and efficiency at a reasonable cost, making them an attractive option for smart cities. STC, represented through its subsidiary company STC Solutions, offers a wide range of cloud services through a number of certified Tier III and IV data centers spread across the Kingdom. These services include Virtual Machines (VMs) on Linux or Windows operating system, software licenses, block storage, object storage, network bandwidth, Oracle database 12c, backup as a service (Baas), disaster recovery as a service (DRaaS), VOOST analytics, and Vormetric transparent encryption.

E. End-to-end Approach

To ease the burden on municipalities and let them focus on their core business (e.g., drinking water, sewage, social care, emergency management, future strategies), it is highly recommended that municipalities adopt end-to-end solution(s) from a single provider. STC takes an end-to-end approach including sensors, network, applications, analytics, and management to deliver smart cities solutions. STC is well-equipped to provide a wide range of end-to-end solutions across many different verticals as it has a strong network infrastructure, a large number of talented professionals with in-depth expertise in technology selection and implementation, and a good network of partners.

V. CONCLUSIONS

The key driver for the development of smart cities and examples of smart cities in Europe, North America, and MENA region are discussed. Key challenges facing the global adoption of smart cities as well as smart-cities architecture are highlighted. A number of STC’s unique value propositions are presented, including multi-network approach (mobile, fixed, and mission-critical), cutting-edge technologies (NB-IoT and eSIM), cloud services, and end-to-end approach.

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