Smart Cities: Connected Ecosystem of Ecosystems

Narendra Mangra, GlobeNet, nmangra@ieee.org and Alireza Ghasempour, University of Applied Science and Technology, Alireza_ghasempour@yahoo.com

Abstract

The significant growth in the global urban population is expected to drive sustainability, resource conservation, economic and technology development initiatives. Cities will evolve to attract and retain investments, businesses, residents, and visitors. Ecosystems will adapt and drive cross-industry applications such as Connected Vehicles, Smart Grids, Connected Healthcare, and Connected Workforce, etc. The underlying communications infrastructure is critical for smart cities development, economic growth, and quality of life. This paper will describe the smart city ecosystem of ecosystems structure and key fifth generation (5G) communication drivers for Smart Cities.

1. Introduction

Cities rely on several ecosystems to attract and retain investments, businesses, residents, and visitors. These ecosystems may span several sectors such as transportation, energy and utilities, healthcare, public safety, tourism, finance, etc. The growth in the urban population may strain current capabilities as cities adjust to meet growing demands, Technology developments in the Internet of Things (IoT), data analytics, and 5G communications will create both challenges and opportunities.

Smart Cities may be described as an ecosystem of ecosystems where the underlying communications infrastructure is critical for economic growth and quality of life. The Internet of Things and the combined satellite, 5G, and wireless local area network (WLAN) communications will help create new applications and provide greater operational efficiencies for existing applications. Cities may choose to integrate connected services for desired sectors or to create a market based platform to facilitate multiple services across sectors.

2. Industry Trends

There are more urban residents than rural residents across the globe. In 2014, there were 54% of urban residents globally. By 2050, the global urban residents are expected to increase to 66%. This is a reversal of the urban to rural population proportion since the middle of the twentieth century [1].

According to the 2014 United Nations (UN) World Urbanization Prospects:

- North America, Latin America, and the Caribbean have the highest levels of urbanization with at least 80% of their population residing in urban areas.
- Europe is expected to reach an urbanization level of 80% by 2050.
- Asia and Africa are expected to reach an urbanization level of 64% and 56% respectively.

The global market for smart cities technology is estimated to grow from $6.1 billion annually in 2012 to more than $20 billion in 2020 (a compound annual growth rate of 16.2%) which represents a cumulative investment of over $117 billion in smart city technologies between 2012 and 2020 [2].

3. Key Drivers

The high levels of population and urbanization create additional opportunities and challenges for solutions related to renewable energy, precision farming, and sector based applications based on Internet of Things (IoT)/ Network of Things (NoT). Cities will also need to cater to residents, businesses, and visitors to provide solutions where people work, live and play. Key drivers of smart cities global market include [3]:

1. Cities produce 80% of the world's carbon emissions
2. Global urban population increases by 2 people every second
3. Natural resources are exploited and wasted in cities, e.g. 50% of water resources are wasted due to leaky infrastructures, and residential and commercial buildings consume 1/3 of the global energy produced.
4. Sustainable accommodations for more than 7 billion people on the earth.

Cities will also strive to retain a particular image and attract businesses, improve the quality of life for its residents, and attract visitors that may stimulate the local economy.

Venture capital investment tends to be highly concentrated in center cities and walkable suburbs than conventional car-oriented suburbs and exurbs. These investments are influenced by innovation, access to talent, high tech industry clusters, density, wages and income, and openness and diversity [4].

4. Technology Requirements and Link to 5G

Smart Cities may be viewed as a connected ecosystem of ecosystems. Technologies related to Connected Vehicles, Connected Health, Connected Workplace, Public Safety, Utilities, Governance, etc. will need to be upgraded to address the increasing demands of urbanization. During these changes, a robust communications infrastructure is vital in addressing the needs within Smart Cities as well as the addressing the necessary supply chains that may be based in rural areas. The 3rd Generation Partnership Project (3GPP) 5G technology is expected to enable

- Massive Machine Type Communications (MTC) [5] – IoT applications using a massive number of devices such as agricultural, wearables, etc.
- Critical Communications [6] - applications depending on stringent latency, reliability, and availability requirements for drones, mission critical data, etc. [6]
- Enhanced Mobile Broadband [7] - applications such as Augmented Reality (AR)/ Virtual Reality (VR) and high mobility (trains, planes, etc.) that benefit from very high data rates, deployment and coverage density, high user mobility, etc.
- Network Operations [8] - functional system requirements such as network slicing, connectivity and routing, etc.
- Enhancement of Vehicle-to-Everything – autonomous driving, safety and non-safety related vehicle aspects

3GPP describes several use cases that may be applicable to Smart Cities with technical considerations that include data rates, latency, reliability, communications efficiency, traffic density, mobility, position accuracy, etc [9].

5. Connected Ecosystems

The 3GPP, 3GPP2, and Institute of Electrical and Electronics Engineers (IEEE) family of communication technologies provide a diverse set of technologies that span 2G, 3G, 4G, 5G, and WLAN wireless communications that may be used to provide the underlying communications infrastructure to directly or indirectly support Smart Cities. These applications include:

- Healthcare – Continuum of Care with health based technologies such as Electronic Health Record (EHR), mHealth, and telehealth
- Utilities – mesh or narrowband radio communications

    - Waste Management / Sanitation - trash can monitoring, coordinated pickups
    - Electricity – Advanced Metering Infrastructure (AMI), transmission and distribution networks (e.g. smart grids), renewable energies (e.g. wind, solar), storage (e.g. batteries, fuel cells)
    - Water – AMI, pipe monitoring, etc.
    - Gas – AMI
- Transportation Modes (public / private) – Dedicated Short Range Communications (DSRC), Long-Term Evolution (LTE) Vehicle to Vehicle (V2V), etc.
    - Roads – autonomous vehicles, connected vehicles
        - Trails for pedestrians and bicycles
    - Rails – light and heavy rail, Communications Based Train Control (CBTC), Positive Train Control (PTC)
    - Waterways – small craft, ferries
    - Air Travel – commuter planes, long haul
- Quality of Life and Economic Growth – Connected Workplace, Smart Buildings, AR/VR, parking applications, etc.
    - Commerce Areas
    - Restaurant / Entertainment Areas
    - Points of Interest including tourist attractions (includes AR/VR tourism applications)
    - Residential Areas
    - Recreational Areas, e.g. parks, amusement parks
- Safety and Governance – 5G, Land mobile radio system (LMRS), WLAN for fleet management, emergency response, etc.
    - Public Safety – Police, Fire, Emergency Medical System (EMS) emergency response
    - Municipal Services – residential and business services, public works, etc.
    - Environment – energy and resource conservation enabling policies and technologies such as smart street lights, parking availability applications, etc.
    - Safety – sensors and detectors to detect gunshots, chemicals, etc.
- Supporting Services – IoT to support information visibility and inspection stations
    - Agricultural Supply Chain Management – food safety inspections

6. Smart Cities Ecosystem Structure

The implementation of Smart Cities may vary depending on the needs and available resources. Cities may choose to act as an integrator to maintain control, coordinate with selected suppliers, and provide quality control. However, this centralized approach may not be flexible to new developments. Cities may alternative choose to create platforms for marked based services that are provided by participating firms. This approach may provide a variety of services that may easily adapt to changing needs. However, the quality may vary amongst the different services. It is imperative that cities have a long-term vision and choose an ecosystem that best suits their needs. Cities may also use an orchestrator approach to switch between the centralized integrator approach and the market based platform approach to adjust to the changing landscape [10].

7. Major Challenges

Cities will need to address each major vertical listed above to address the demands from their constituents. Furthermore, these technologies will to be interoperable within each vertical (e.g. intermodal transportation coordination between connected vehicles and railroad crossings) and across major verticals (e.g. electric vehicle charging and impact to smart grid). This will require extensive planning to align the different verticals to maximize the overall Smart City system benefits. In addition, there will also be privacy and security concerns related to the collection of personal or sensitive data.

Cities will also need to assess whether they will be direct or an indirect provider of services. Cities may provide direct services as an integrator of inputs and services from suppliers for the final service delivery. This will include selecting supplier selection, inputs and services procurement, service integration, and service delivery within their jurisdiction. Cities may provide services indirectly by providing a platform for third parties to provide market based services within their jurisdiction. This

service may include platform hub development to align service demand, service delivery, and economic transactions.

8. Conclusion

Smart Cities presents both opportunities and challenges to address sustainability, resource conservation, economic and technology development initiatives. The evolution to smart cities may create competition to attract and retain key stakeholders as cities focus on the deployment Connected Vehicles, Connected Care, Smart Grids, Public Safety Communications, etc. with retaining its strategic advantage. The implementation of these services may require coordination among to different sectors as cities strive to become a connected ecosystem of ecosystems.

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Narendra Mangra is a multi-disciplinary telecommunications advisor, consultant and educator at GlobeNet. He has over 20 years experience with the mobile telecommunications, public safety, IT, government, and higher education sectors. He has held pivotal leadership roles within the end-to-end mobile wireless ecosystem and network deployment lifecycle phases. His areas of interest include strategy development, wireless engineering, project management, business & operational support systems (BSS/OSS), wireless education, Smart Cities, IoT, ITS / Connected Vehicle, Connected Health, and Smart Grids. Narendra is also an Adjunct Professor at the George Mason University where he currently teaches telecommunications project management with a focus on smart cities

Alireza Ghasempour has been a faculty member in Information and Communications Technology department at the University of Applied Science and Technology for more than 10 years. He has over 14 years research experience and 8 years of experience in executive positions. His areas of interest include smart grids, wireless sensor and ad hoc networks, Internet of Things, cognitive radio networks, device-to-device communications, optimization techniaues, machine-to-machine communications, wireless heterogeneous networks, and 5G mobile networks. He has published several papers in these areas in peer-reviewed journals and IEEE conferences.