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A NOVEL SERVICE-ORIENTED ARCHITECTURE FOR IMPLEMENTING THE SMART CITIES IN TERMS OF COMPLEXITY OF SMART SERVICES

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Master Thesis

Supervisor
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A NOVEL SERVICE-ORIENTED ARCHITECTURE FOR IMPLEMENTING THE SMART CITIES IN TERMS OF COMPLEXITY OF SMART SERVICES

by

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Ramzi Ali Mohamed OUN

DEDICATION

First I would like to Allah Almighty for the power of mind , health, strength , guidance knowledge and skills to complete this study .This thesis is wholeheartedly dedicated to my beloved father, who have been my source of inspiration, he tells me that" every success in your life will be best gift for me". To my mother, who have been supporting me with the kind and pure love.

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ABSTRACT

A NOVEL SERVICE-ORIENTED ARCHITECTURE FOR IMPLEMENTING THE SMART CITIES IN TERMS OF COMPLEXITY OF SMART SERVICES

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The considerable increase of the urban population around the world has been a great challenging to the governments and the existing management of the cities with regards to the high demand of the public services, urban road network, more parking, health services, education, electricity, environment etc. The modern concept of the smart cities is strongly believed as one of the innovation strategies to solve these major issues in the most efficiency and cost-effective way by delivering the smart services faster, more reliable and safer to allow sustainable development and provide the smart living, smart economy and smart environment to the smart citizens. In this thesis , we will provide the general concept stressing on what the definition of the smart cities actually is. Finally, we will describe in the fully detail of the three S-Dimensions used to classify whether the city considered as the smart city or not.

Keywords: Smart cities, S-Dimensions, ICT.

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1. INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The considerable increase of the urban population around the world has been a great challenging to the governments and the existing management of the cities with regards to the high demand of the public services, urban road network, more parking, health services, education, electricity, environment etc. The modern concept of the smart cities is strongly believed as one of the innovation strategies to solve these major issues in the most efficiency and cost-effective way by delivering the smart services faster, more reliable and safer to allow sustainable development and provide the smart living, smart economy and smart environment to the smart citizens.

In general, two main strategies are widely used by the smart city planners in the process of transforming exiting cities into smart cities. The first strategy is by infusing advance technology into the exiting infrastructures to allow the smart operations. This strategy is mostly used by both developing and developed countries such as India, Spain, Korea etc. Another strategy is built the smart cities from the scratch, which is the case of Masdar City in Abu Dhabi in the United Arab Emirates and PlanIT Valley in Portugual. This second strategy is mostly applied by developed counties.

However, most strategies don't provide a detailed view of holistic smart city infrastructure as a roadmap to implement the smart cities. Some smart city planners together with smart city researchers have attempted to build the service-oriented architecture model to develop the smart cities, but some of them are quite complex and not practical in the reality. In this paper, we will bring new insights into the smart city research by uncovering new possibilities of a seven-layered service-oriented reference architecture for implementing the smart cities, starting from a physical infrastructure to a smart participate, and three S-Dimensions to classify a city into a smart city.

1.2 PROBLEM STATEMENT

Turning existing cities into the smart cities integrated fully by advance technology, such as cloud computing, Internet of Things (IOT) etc., and autonomous system etc., is one of the most difficult tasks for the city planners and top management level nowadays. Standardly, we can't simply substitute the existing infrastructure as well as system into the new smarter version. In this research, I am very interested in proposing a service-oriented reference architecture for the smart cities which can tackle these problems.

1.3 RESEARCH OBJECTIVES

The research aims for proposing the new novel concepts of the Smart Cities are:

- To be an innovative mechanism to promote the development of the Smart Cities to achieve Europe 2020 targets at both national and EU-wide levels in order to empower economic recovery, promote employment growth, tackle environment damage and energy, enlarge education as well as Research and Development involvement.
- To propose three S-Dimensions namely the smart technology, the smart government and the smart service to classify whether the city as the Smart City or not.
- To review and analysis the prior research of the Smart City projects in both developed and developing countries.
- To propose the novel service-oriented reference architecture for implementing the Smart Cities encapsulated within seven layers in terms of complexity of smart services and its structure.
- And to constitute a general innovation concept as a roadmap to deal with all types of the European metropolises as well as the global metropolises to implement or study the Smart Cities

1.4 SCOPE AND LIMITATION

The research will focus on three S-Dimensions considered as the attributes to classify the city as the smart city, and the innovation service-oriented reference architecture for implementing the smart cities by detailing in terms of the complexity of smart services and its structure. I also assume that the layer one, physical infrastructure, is facilitated by advances in computing such as Cloud services and Internet of Things (IOT) and data is collected from the layer two, smart devices, to layer three as the big data. This study is not focusing more detail on urban planning, smart mobility, public lighting, emergency, smart environment and e-government.

1.5 THESIS ORGANIZATION

The remaining parts of this thesis are organized as follow. Chapter 2 describes about the definition of the smart cities in general terms and the three S-Dimensions. Chapter 3 conducts the prior researches of the smart city projects in Belgium, USA and Asia. Chapter 4 describes the proposed architecture. This chapter separates into three parts. Firstly, the overview of the proposed architecture is covered. Secondly, to describe each layer of this architecture in more details in terms of the complexity of smart services and its structure.

1.6 TYPES OF CLOUD

- **Public Cloud:** When we talk about public cloud, we mean that the whole computing infrastructure is located on the premises of a cloud computing company that offers the cloud service. The location remains, thus, separate from the customer and he has no physical control over the infrastructure.
  As public clouds use shared resources, they do excel mostly in performance, but are also most vulnerable to various attacks.
  Global Dots offers worldwide Public Cloud service in leading data centres. Our experts will assist you in choosing the right solution for you.

- **Private Cloud:** Private Cloud provides the same benefits of Public Cloud, but uses dedicated, private hardware. Private cloud means using a cloud infrastructure (network) solely by one customer/organization. It is not shared with others, yet it is remotely located. The companies have an option of choosing an on-premise private cloud as well, which is more expensive, but they do have a physical control over the infrastructure.
  The security and control level is highest while using a private network. Yet, the cost reduction can be minimal, if the company needs to invest in an on-premise cloud infrastructure.
  Global Dots offers worldwide private cloud service in leading data centers.
  With our Private Cloud you'll get:
  1. Increased redundancy
  2. Decreased provisioning time for new servers
  3. Saved capital by eliminating hardware support contracts
  4. Quicker expendability compared to hosting your own physical servers
  5. Use of dedicated, private hardware

- **Hybrid Cloud:** Hybrid cloud, of course, means, using both private and public clouds, depending on their purpose.

For example, public cloud can be used to interact with customers, while keeping their data secured through a private cloud.

Most people associate traditional public cloud service with elastic scalability and the ability to handle constant shifts in demand. However, performance issues can arise for certain data-intensive or high-availability workloads.

Global Dots offer combines hybrid cloud with bare-metal and virtualized clouds into a unified environment allowing your business to optimize for scale performance and cost simultaneously.

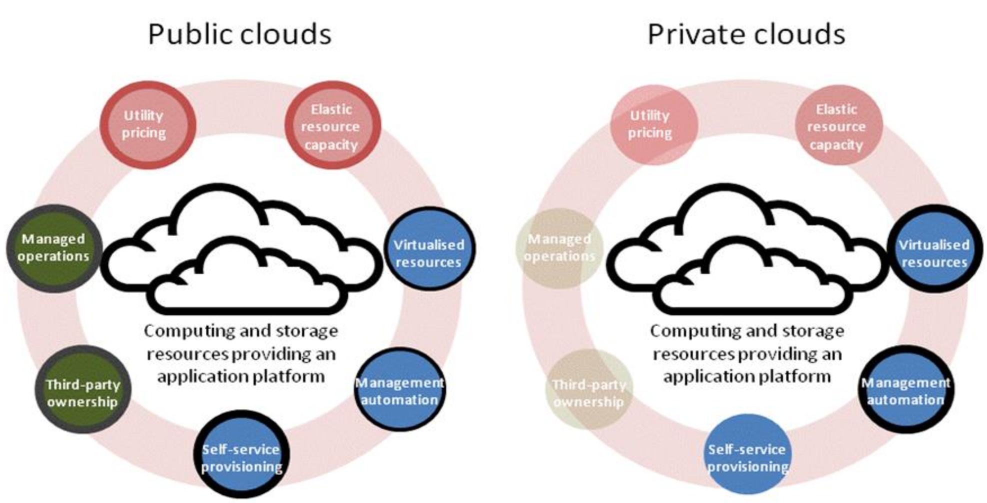

Figure 1.1: Private and Public Cloud Talk Cloud Computing

- **Community cloud:** implies an infrastructure that is shared between organizations, usually with the shared data and data management concerns. For example, a community cloud can belong to a government of a single country. Community clouds can be located both on and off the premises.

1.7 TYPES OF CLOUD COMPUTING SERVICES

The most common and widely adopted cloud computing services are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

What is Infrastructure as a Service (IaaS)?

IaaS is a cloud computing model where virtualized infrastructure is offered to, and managed for, businesses by external cloud providers. With IaaS, companies can outsource for storages, servers, data centre space and cloud networking components connected through the internet, offering similar functionality as that of an on-premises infrastructure. Some examples of the wide usage of IaaS are automated, policy-driven operations such as backup, recovery, monitoring, clustering, internal networking, website hosting, etc.

The service provider is responsible for building the servers and storage, networking firewalls/ security, and the physical data centre. Some key players offering IaaS are Amazon EC2, **Microsoft Azure**, Google Cloud Platform, Go Grid, Rack space, Digital Ocean among others.

What is Platform as a Service (PaaS)?

PaaS builds on IaaS. Here, cloud vendors deliver computing resources, both cloud software and hardware infrastructure components like middleware and operating systems, required to develop and test applications. The PaaS environment enables cloud users (accessing them via a webpage) to install and host data sets, development tools and business analytics applications, apart from building and maintaining necessary hardware. Some key players offering PaaS are Blue mix, Cloud Bees, Salesforce.com, Google App Engine, Heroku, AWS, Microsoft Azure, Open Shift, **Oracle Cloud**, SAP and Open Shift.

What is Software as a Service (SaaS)?

SaaS is special in that it incorporates both IaaS and Paas. Here, the cloud service provider delivers the entire software suite as a pay-per-use model. SaaS lets users easily access software applications -- such as emails -- over the internet. Most common examples of SaaS are Microsoft Office 360, App Dynamics, Adobe Creative Cloud, Google G Suite, Zoho, Sales force, Marketo, Oracle CRM, Pardot Marketing Automation, and SAP Business by Design.

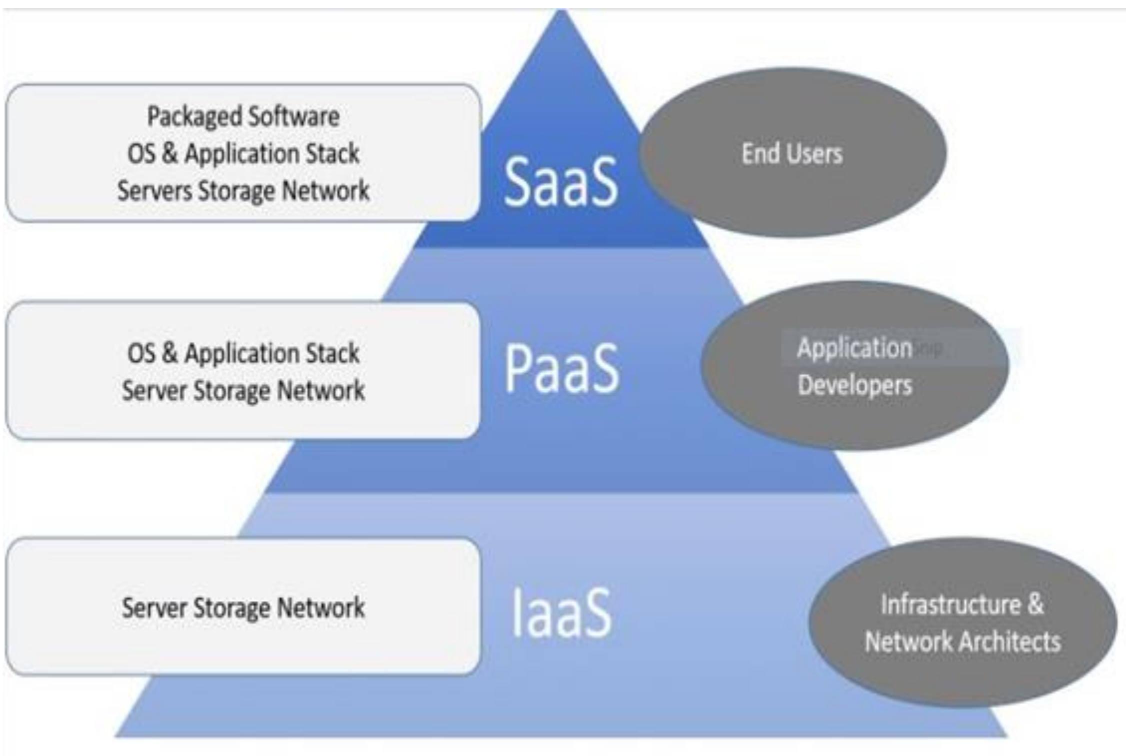

Figure 1.2: Types of Cloud Computing Services

2. SMART CITY

In this chapter, we will provide the general concept stressing on what the definition of the smart cities actually is. Finally, we will describe in the fully detail of the three S-Dimensions used to classify whether the city considered as the smart city or not.

2.1 DEFINITION OF THE SMART CITY

The smart city concept is a recent domain drawn so much attention from both public and private sectors. The Smart City can be also considered as an innovative tool to accomplish the Europe 2020 which is the EU's strategy set on national and EU-wide levels to achieve five key targets including [65]:

- Employment
- Research and Development
- Climate change and Energy
- Education
- Poverty and social exclusion

By providing the smart city servicers, the Smart city initiatives can be widely considered as a useful tool for each city in Europe to accomplish the Europe 2020 targets: 1)- Smart Environment or Smart Mobility can be utilized to solve the Europe 2020 energy target. 2)- Smart Economy as well as Smart People mainly are able to address the employment and education targets by including e-skills development. 3)- Smart Governance and Smart Living are the key solution for poverty and social exclusion by improving the quality of life, focusing on citizen connectivity (such as e-government services) and the use of open data to create citizen service. Finally, other smart city services can be used to support innovative growth and R&D. However, in order to deliver successfully smart city initiatives and visions, the city planners and other stakeholders have to hold a fully understanding of what the definition of the smart cities is along with their key values. On the other hand, there is no formally and universally accepted the definition of the smart cities. Furthermore, the key definitions of the smart cities have widely been differences over the period of time according to the concepts of researchers.

From the perspective of the European Parliament 's Industry Research (ITRE), a smart city is defined as a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnerships [65]. Specifically, the Smart City needs to address one or more of the six characteristics: Smart Governance, Smart People, Smart Living, Smart Mobility, Smart Economy and Smart Environment. The International Business Machines (IBM) gives the definition of the smart city as “connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city” [1]. However, the Ministry of Urban Development (MoUD) in India defines the smart city as “building and promoting cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment, and the application of “smart” solutions.” [2]. Mitchell, Nicola, Martin and Anne define the smart cities as the cities utilizing Information Communication Technologies (ICT) and the internet to address current emerging urban challenges [3]. Caragliu, Del and Nijkamp hold a different view that the city can be defined as ‘smart’ when investments in human and social capital and traditional (transport) and modern (ICT) fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action and engagement [4].

The definition of appropriated meaning of the smart cities we fully consider based on our proposed smart city architecture is “the interconnection among physical infrastructures either ICT or social, smart devices, and smart software to sense, gather, transform and analyze real-world data to yield new intelligently insights driven reliable and efficient decisions or actions to address public issues”. This definition clearly reflected with the most prominent goal of the smart cities is to provide the smart services to the smart participants for their smart living, smart economy and smart environment.

2.2 THREE S-DIMENSIONS OF THE SMART CITY

We have critically identified three key conceptual dimensions that are used to classify whether the city as the smart city or not. The core attributes simply organize into three categories: smart governance (such as innovation strategy and policy), smart technology (such as physical infrastructure, IT infrastructure, the social infrastructure, smart devices, smart software etc.) and smart services (such as smart energy, smart environment etc.). When the first two key dimensions

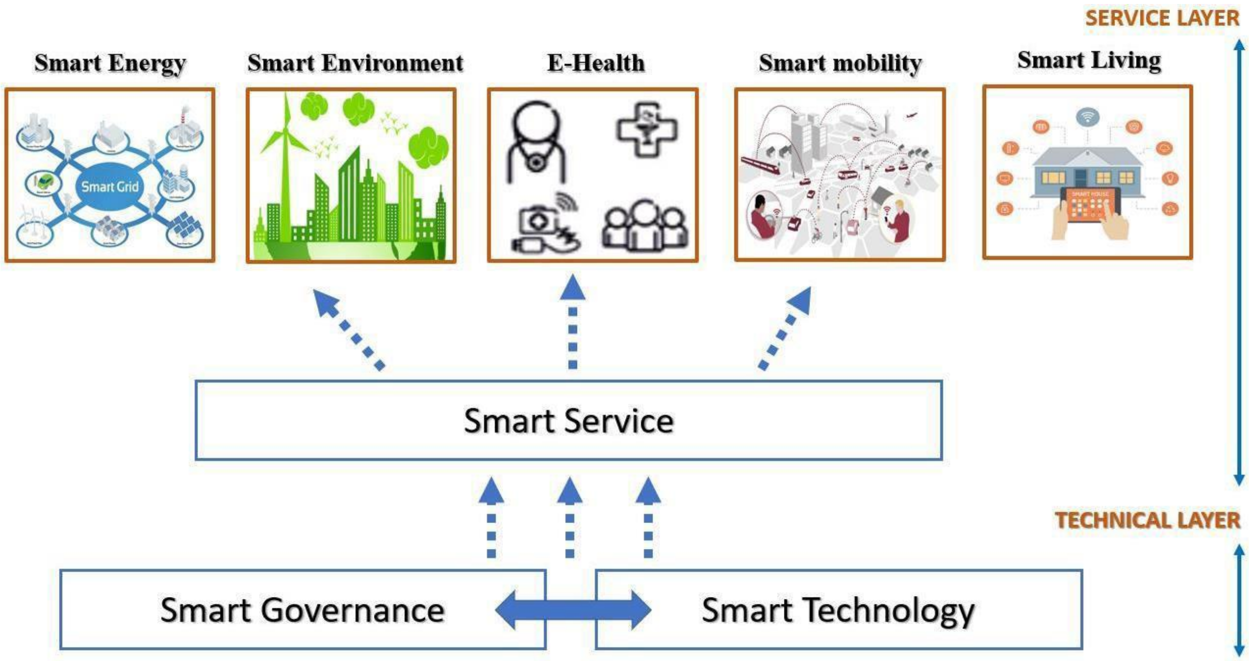

Figure 2.1: Three S-Dimensions of smart city

are connected, a smart platform will be implemented to deliver smart services to smart citizens to develop a sustainable growth and maintain good Quality of Living (QOL) in the smart city.

The main perspective of three core abstract S-Dimensions of the smart city are very simplistic and motivated by two major layers:

- The service layer mainly draws attention on the smart service provision towards the smart participants. The service layer creates the value-proposition directly with the key players in the smart city.
- Th technical layer chiefly emphasizes the combination of smart strategies and policy as well as the smart technology that drive the design and implementation of the structure of the smart city which will produce the smart services.

2.2.1 Smart Governance

The provision of the city planners together with the decision makers in terms of the innovation strategies and policies is one of the crucial attributes, which will be used as the descriptive framework for rationalizing the conceptual architecture and specification to implement of the smart cities. Having established a basic understanding that is principally emphasized on a smart service driven approach, the city planners and the decision makers are under obligation to make sure that the descriptive framework aligned with smart technology as well as the requirement of the key participants in order to bring out the smart services to create values for the smart citizens, the enterprises and the governmental agencies.

The smart governance should comprise of four core elements. First, the description of visions, goals, objectives, priorities, promoted activities, resources, innovation strategic plans and critical success factors of the targeted smart services will be defined in the more comprehensive and practical way for stakeholders in order to implement the smart cities, which will operate in full scale mode, harmony, fairness, transparency and high efficiency. This description should also define clearly of the city problems such as environmental issues, traffic congestion, overcrowded etc. and the way to solve those major challenges. Second, the role and collaboration of the key stakeholders are engaged in decision making, implemented and used smart services. A citizen-centric or citizen driven approach is one of the crucial elements of the smart governance since the citizen engagement will make value proposition in the smart cities. Third, the alignment strategy is exactly determined to integrate the innovation strategies and policies, smart technology and requirements of the key players all together. The city planners and the decision makers need to ensure that the smart governance and the smart technology are completely aligned with each other

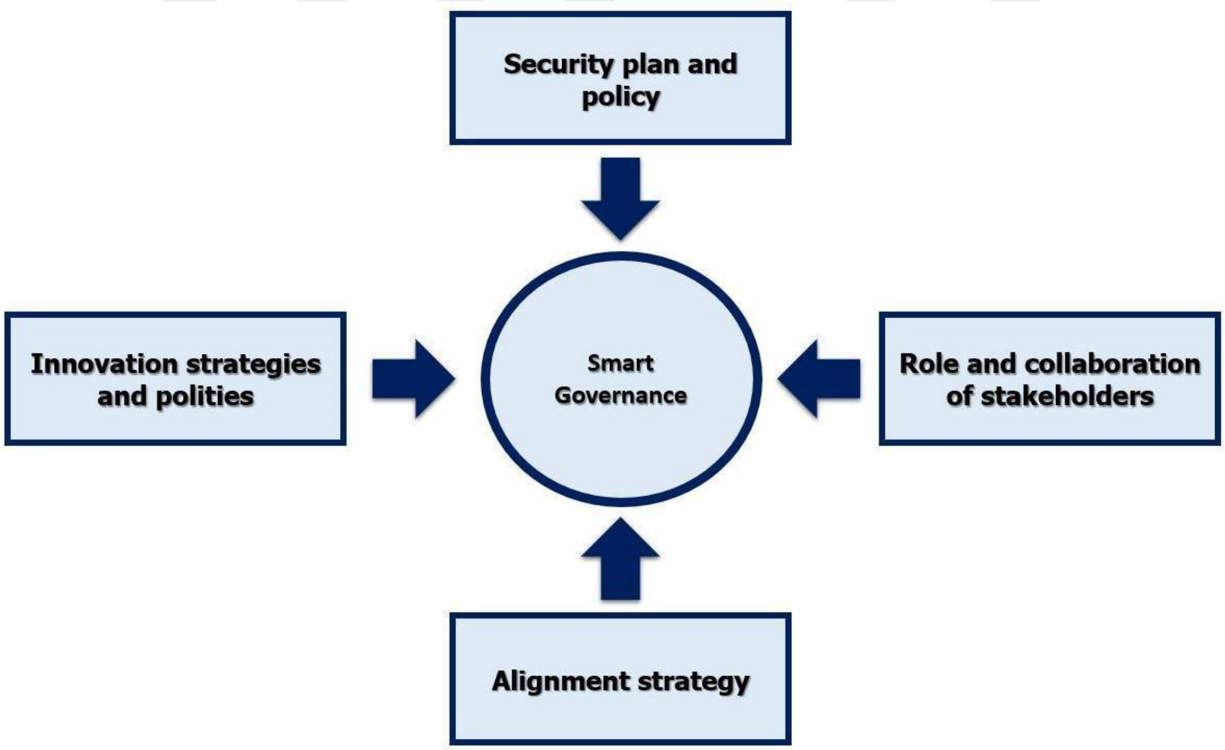

Figure 2.2: Smart Governance

in order to deliver the smart values to the smart citizens, enterprises and government agencies. Forth, the security policy, safety policy and solve method step by step to insure the safety of state secret are used in the smart cities. As the cities adopt the smart initiatives, the security policy and cryptographic security are inevitable to make data security, privacy and public safety.

2.2.2 Smart Technology

Smart technology is one of the key dimensions to completely transform life and work in the city simply to be the smart city. The innovation technology is an intelligent mean to bring the smart city services out by integrating the physical infrastructure, smart devices as well as smart software or application as the smart platform to provide the standard and quality of life for the smart citizens, enterprises and governments.

Smart technology equipped within the smart city should be mainly categorized into three primary categories. First, physical infrastructure is the network of ICT infrastructure, the social infrastructure, physical devices, vehicles, home appliances etc. built as a hardware platform for smart devices and smart software/ application to automatically connect and exchange data. Second, smart devices, for example sensors, actuators etc., are wisely used to sense and gather real-world data remotely across existing physical infrastructure from real-time interaction within the physical environment. Third, the smart software or application has an absolutely well function to transform and analyze real-world data to yield new intelligently insights as the smart services which are driven to the reliable and efficient decisions or actions to address public issues in the smart city.

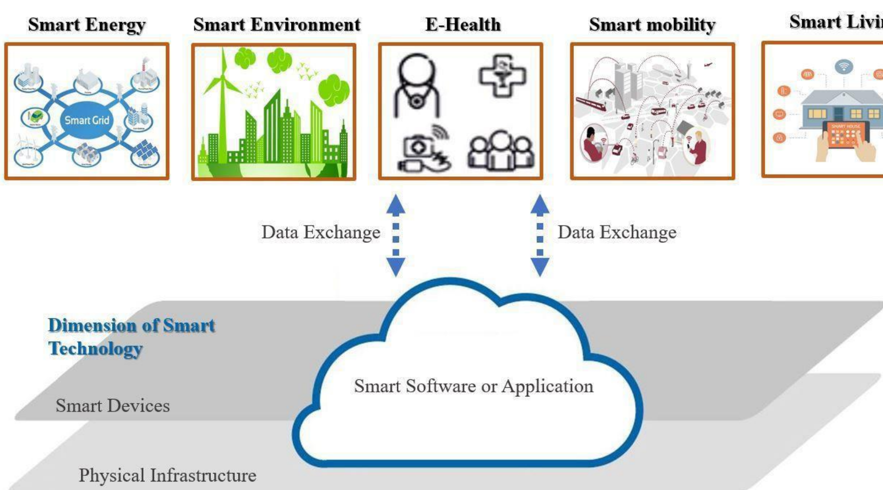

Figure 2.3: Smart Technology

2.2.3 Smart Service

Providing the high-quality smart services in the smart cities is significant for any city planners to solve public needs or issues in the intelligent age. As a result, the smart city services are becoming even more critical for the smart cities to retain and develop the high Quality of Life (QOL) for the smart citizens, enterprises and governments.

We will provide the fresh insight into the smart city service quality dimensions to evaluate the smart services from the perspectives of the city planners or the decision makers as well as the smart users. The proposed smart service quality model mainly contains of six dimensions. Firstly, the usability is wisely defined as the ease of use of the smart services for the smart users included the dominant design and smart functionalities. Second, the reliability refers to the consistency of the performance of the smart services to provide the promised intelligent services accurately. Third, the privacy and safety refer to the degree to which the smart services provide to the smart users in terms of the public safety and protection of their information.

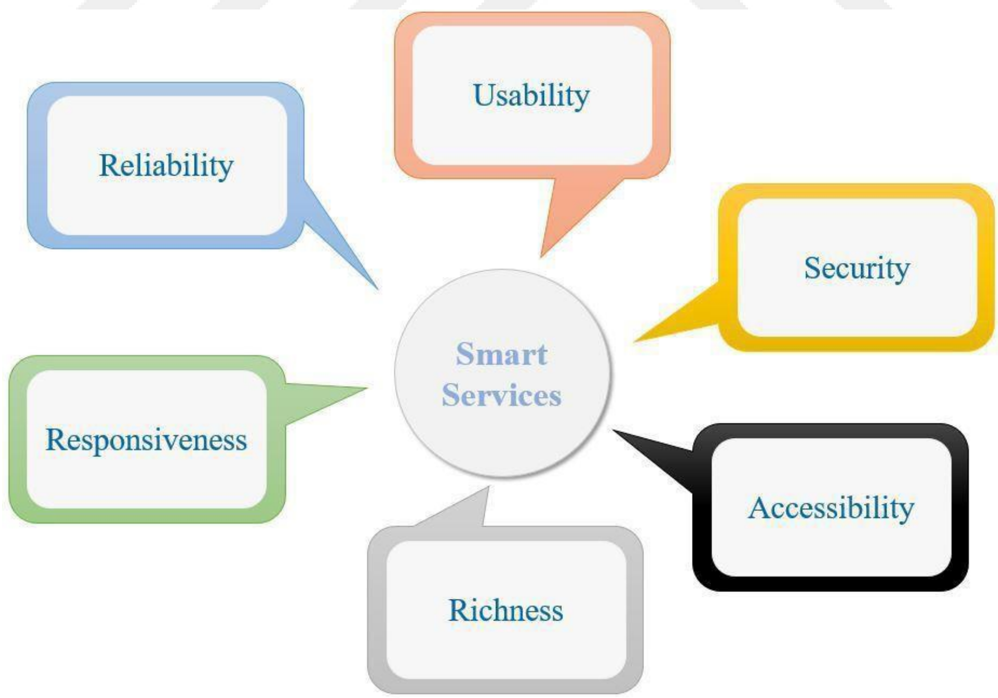

Figure 2.4: The Smart Service Quality Dimensions

Forth, the responsiveness refers to the high flexibility of the effective handling of the real-work interactions from the smart users' commands in the physical world. Fifth, the accessibility refers the ease and convenience of interacting with the smart services anytime and anywhere. Sixth, the richness aims to provide frameworks as indicators to describe the variety of the smart services in the Smart Cities.

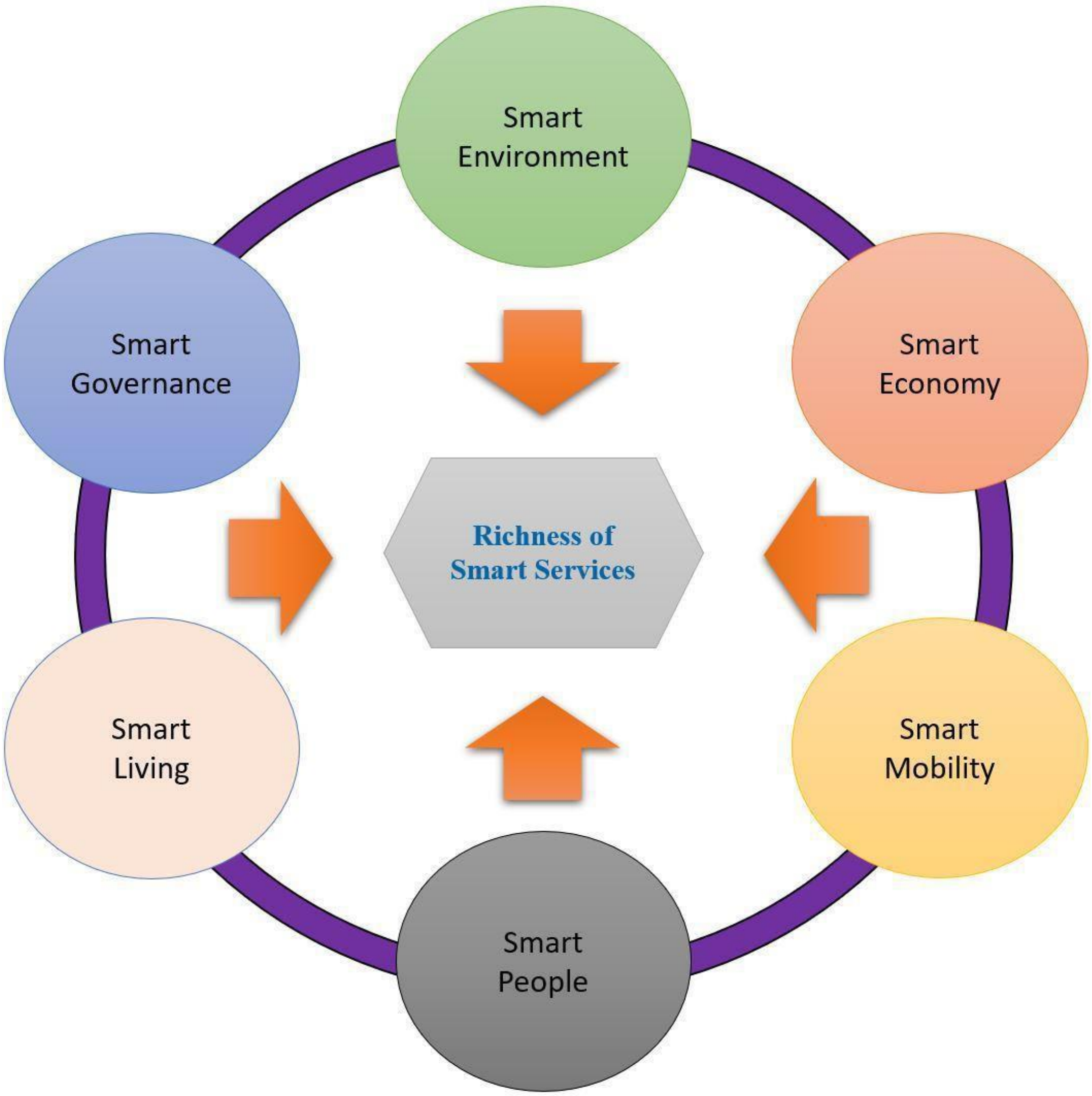

Figure 2.5: The Richness Of The Smart Services

3. RELATED WORK

In this chapter, we will review a few exiting smart city projects within both developed and less-developed countries mainly in United States of America (USA), Belgium as well as India. The focus is on these countries by the reason of the high reflection to the smart cities around the world and the fact that I am conducting this practical research and using the smart services there.

3.1 SMART CITIES IN BELGIUM

Based on the practical study and research of the different case studies of smart cities, we provide an overview of some smart city researches in Belgium.

Anthony Simonofski, Estefanía Serral Asensio, Johannes De Smedt and Monique Snoeck at the faculty of Economics and Business, KU Leuven, Belgium proposed a framework as enablers of the citizen participation in the smart cities [5]. The framework consists of three fundamental categories of the citizen participation specifically citizens as democratic participants, citizens as co-creators and citizen as ICT users. Citizens as democratic participants, the citizens are involved basically with the democratic process of making decision of the smart city's strategy. Citizens as co-creators, the citizens become the providers of experiences, competences, innovation ideas in order to propose the smart city's strategy for the existing challenges or needs in the smart cities. Citizen as ICT users, the citizens can help to collect data by using mobile devices or other technologies in order to make them feel as an integral part of the smart city. The framework is applied to the ongoing smart city design of Namur, Belgium to discovery and improve the degree of the citizen participations. This framework mainly provides three core benefits for the city planners as well as the decision makers in the smart cities. Frist, it is widely usedas an evaluation tool to assess a smart city's strategy. Second, it can be used as either a government tool or guideline for the governments officials or the city planners to implement the citizen-oriented smart city strategy. Finally, it can be used as a creativity tool by enabling comparative analysis of best practices for one criterion or category of criteria across different smart cities by providing new means for designing and implementing the citizen participations in the smart cities.

The three different enablers of the citizen participations from the proposed framework in transforming the traditional city to the smart city context are one of the best practice paradigm by carefully structuring the smart citizens into three different essential roles and involving them into the democratic process of identifying social needs, priorities, strategies, goals etc. within the smart governance which is one of the three dimensions that we have proposed in this research in order to classify weather the city considered as the smart city or not.

S. Latre, P. Leroux, T. Coenen, B. Braem, P. Ballon and P. Demeester proposed "City of things: an integrated and multi-technology testbed for IoT smart city experiments" presenting the City of Things testbed, which is the smart city testbed located in the city of Antwerp, Belgium [7]. The City of Things consists of the highly realistic integrated approach, allowing the setup and validation of new smart city experiments both at a technology and user application level on three different layers namely the networks, data and users.

- **Network level**: Internet of Things infrastructure consists of three different types of infrastructures. Frist, a series of multi-technology gateways is connected to the city' network, which acts as a control network to provide experiment management. Second, a dedicated private LoRa-Based Low Power WAN network mainly intends to ensure a continuous real-time stream of the sensor data and the citywide coverage. Finally, a variety of sensors such as mobile air quality sensors, traffic monitoring sensors, smart parking signs etc. is installed throughout the city to physically collect, analyst and interact with real-time environment.
- **Data level**: Big data analysis, the City of Things data platform provides three main tools, which were previously developed within iMinds. First, DYAMAND (DYnamic, Adaptive Management of Networks and Devices) is running in a private Virtual Machine used for sensor data collection and discovery. Second, Tengu is an experimentation plaform instantiated on GENI (US federation of test beds) and Fed4FIRE (EU federation of test beds) used for sensor data processing and storage. Finally, LimeDS (Lightweight modular environment for Data-oriented Services) is used for data access, service composition and demo prototyping
- **User level**: a large-scale living lab, the Living Lab services are offered in the City of Things classified into two main types of system: IOT-based and not IOT-based. The not-IoT based refers to digital systems, that should be tested in real-life environment to obtain a realistic insight, but not fallen under the IoT moniker such as the Google-maps like application. The IOT-based refers to systems gathering data with the user response in real-world environments such as city games etc.

The three layers proposed in the City of Things testbed look reasonably practical at the first sight especially in the network as well as the data layer; however, it doesn't reveal the further detail of other layers such as the smart services and features (smart energy, smart mobility, smart healthcare etc.) identified as the core value that the smart participants will get. In this paper, we will introduce the holistic smart city architecture from the physical infrastructure to the smart participants, which will provide the complexed structure to implement the smart city projects.

3.2 SMART CITIES IN INDIA

We have conducted an overview study of a few practical researches in India, which can be used to represent the smart city concepts in Asia.

S. Madakam and R. Ramaswamy proposed "100 New smart cities (India's smart vision)" by mainly focusing on the six dimensions of the smart cities, the smart city enablers comprising of Internet of Things and the prerequisite consideration "How to set up 100 New Smart Cities in India" [9]. The characteristics of the smart cities are identified into six main dimensions based on traditional regional and neoclassical theories of urban growth and development: smart economy,

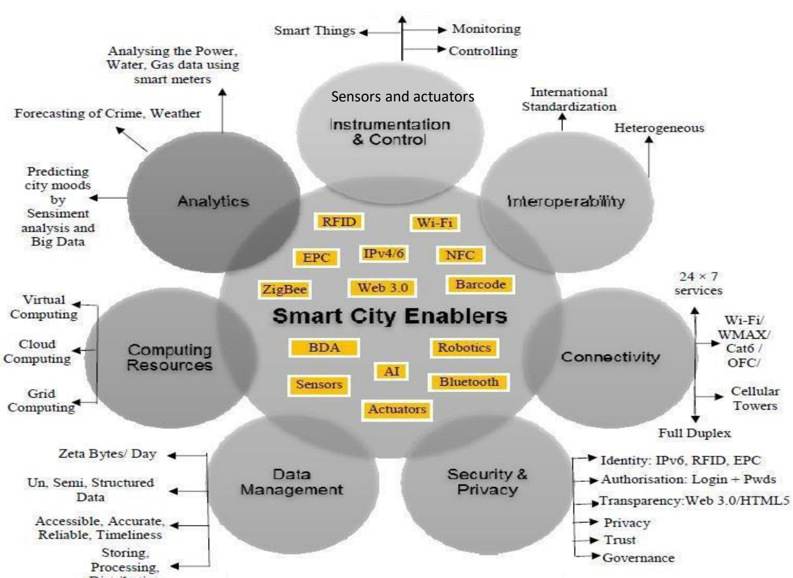

Figure 3. 1: Model Diagram: IoT technologies in Smart Cities

Smart Mobility , Smart Environment, Smart People, Smart Living and Smart Governance. The enablers of the smart cities can radically improve through the power of Internet of Things (IoT) technologies categorized into seven categories: Instrumentation and Control, Interoperability, Connectivity, Security and Privacy, Data Management, Computing Resources and Analytics.

Nowadays, India is setting up 100 new smart city projects across the nation in cooperation with multinational companies under Public Private People Partnerships (PPPP) model by using two ways. Firstly, the government converts the existing cities into the smart cities by deploying technologies into the existing infrastructure and the system of the city. Secondly, the government constructs the entire new smart cities from the scratch. However, the six dimensions of the smart cities are fairly completed and oversimplified when we come to the deep understanding. The smart mobility, smart living, smart economy as well as smart environment should be either smart services or the yield of the smart services produced. The smart people should involve with the smart governance as the citizen engagement to implement the smart strategy, solutions, vision etc. to build the smart cities. Furthermore, the model diagram of IoT technologies for building the smart cities are revealed separately without giving an interpretation the supportive level for one another.

P. Datta and B. Sharma in New Delhi, India conducted “A survey on IoT architectures, protocols, security and smart city based applications” [10]. The basic architecture of IoT consists of five core layers: perception, network, middleware, application and business layers. Firstly, the perception layer consists of sensor devices viz, RFID, ZigBee, Quick Response (QR) code, etc. with the functions of the device management and collecting information. Secondly, the network layer forwards information from the perception layer to the upper layers. Thirdly, the middleware layer is the service management and stores information into the database. Forthly, the application layer manages IoT applications. Finally, the business layer covers the entire IoT applications and services management.

The IoT data protocols are used to interact with the IoT gateway such MQTT, XMPP, CoAP, AMQP etc. Message Queuing Telemetry Transport (MQTT) protocol runs over TCP/TP as the lossless connections to deliver message with minimized transport overhead, and to ensue message delivered according to availability of the operating environment and exactly once. Extensible Messaging and Presence Protocol (XMPP) is a protocol for real time communication for voice, video calls etc. The IoT security measures are used in the smart cities like ZigBee, RFID etc. ZigBee is one of the IoT security measures developed by ZigBee Alliance for personal area networks (PAN) and two-ways wireless communication standard with low cost, low power and reliable communication between smart devices and gateway.

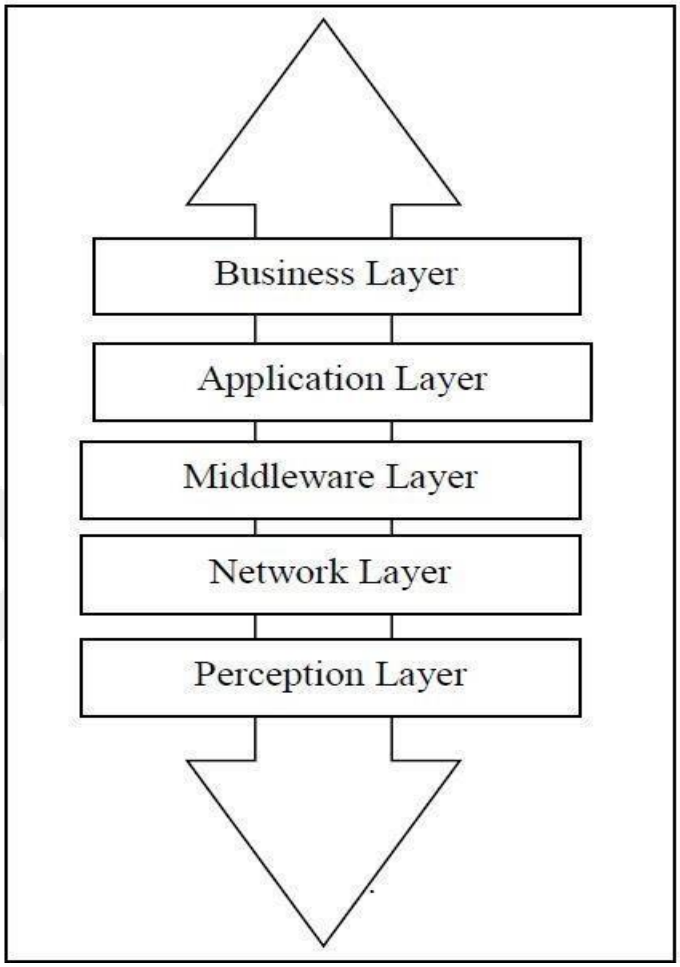

Figure 3.2: IoT Basic Layered Architecture

The basic architecture of IoT consisting of five layers doesn't appears to the right orders, dependencies and functionalities. The network layer should be in the position of the lowest layer that mainly provides the physical infrastructure with the function of wire and/ or wireless communication with the layer of sensors. Furthermore, the middle layer shouldn't have two functionalities. This layer should be responsible for only the big data management. Finally, the fourth and fifth layer seems to have the same roles and functions.

3.3 SMART CITIES IN UNITED STATES OF AMERICA

N. Mohamed, S. Lazarova-Molnar and J. Al-Jaroodi at Pennsylvania, United States of America (USA) proposed "Cloud of Things: Optimizing smart city services" by using the Cloud of Things as a powerful platform for implementing and operating the smart city services with the enhancement from Fog Computing to extra value-added features for the smart city services [11]. The architecture of the proposed model has four core layers: perception and action, the Internet of Things (IoT) network and Cloud Infrastructure, the Cloud of Things (CoT) platform as a service, and the smart city services. At the IoT network layer, all objects of the smart cities such as people, vehicles, streets, buildings, hospitals, energy etc. are interconnected through the IoT, which is integrated with cloud computing systems as the physical infrastructure. The CoT platform as service layer links the IoT and the CC infrastructure and services to provide the services to implement and operate the optimization application for the smart city services, which is the powerful cloud platforms to run the smart city services as can be seen in Figure 3.3.1.

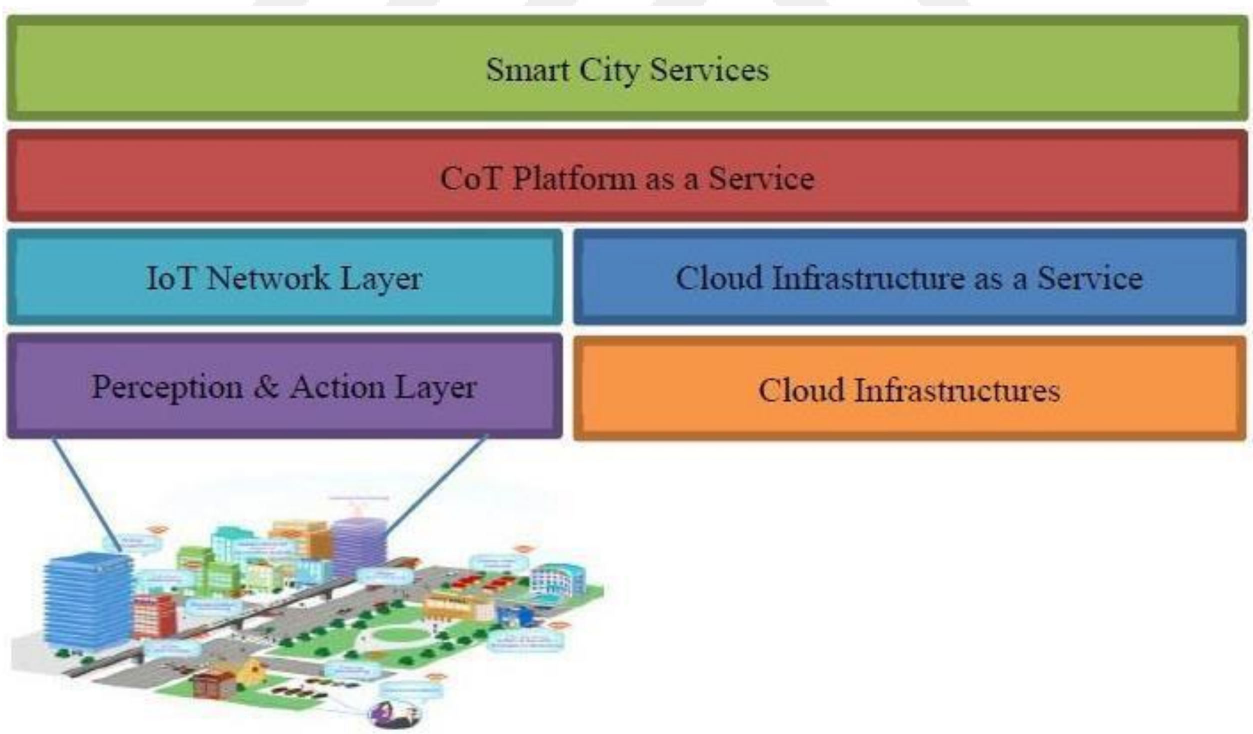

Figure 3.3: The Cot layers for smart cities

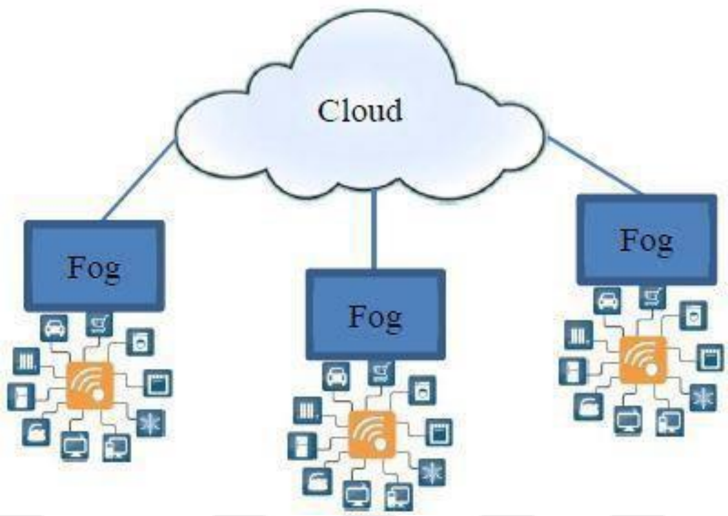

Figure 3.4: Integrating Fog Computing and the CoT for smart cities

The Fog computing can enhance the CoT paradigm by providing the small platforms located at the network edges in the smart cities, which is the fast control mechanisms and service available geographically for the areas of the IoT application. The architecture included the Fog computing into the CoT for the smart cities is shown in the Figure 3.3.2; the fog provides more localized real time monitoring, control, and optimization for the smart city applications while the cloud provides global monitoring, control, optimization, and future planning for the smart city applications. On the other hand, there are some issues with the proposed architecture. In the reality, it is hard to integrated between IoT network layer and Cloud infrastructure as a service to provide the physical infrastructure for perception and action layer to collect real-time data and for CoT platform as a service for implement the smart city services. Furthermore, the architecture doesn't detail the complexity of the smart city services on the layer four.

Amany Alnahdi at Kent State University and Shih-His Liu at California State University, USA proposed "Mobile Internet of Things (MIoT) and its applications for Smart Environments" by allowing fully mobility hardware and software devices of the IoT technology within the smart IoT environments [64]. The smart IoT environment can be the cities or the buildings that are built, rebuilt or improved by using the MIoT model, and the Mobile Internet of Things (MIoT) is an IoT system that is moved and reused within the smart IOT environment. The MIoT model is composed of three main components including MIoT stakeholders (human resources), software as well as hardware. Firstly, the MIoT stakeholders are people who work on the building and maintain tge MIoT systems. They can be MIoT experts, MIoT programmers as well as MIoT system supports.

Secondly, the MIoT software mainly consists of services, Operating systems, scheduling services, auditing services and feedback services. The scheduling services will be enable the business owners and the system users to find available time to lend and utilize the system or to move the system to another location. Furthermore, the feedback services will allow the business owners and the system users to understand their customers' requirement and enhance their services for the future business by communicating directly with their customers. Finally, the hardware isincluded sensors and mobility devices.

The MIoT system could be fully utilized in multiple domains including smart cities, smart health environment, smart entertainment cities, smart homes, smart educational system and smart marketing systems by providing the benefits such as sharing technology system resources which lead to the efficient and effective utilization of these resources from the perspective of the business owners and providing a fast way when the business owners develop new systems for the customers. On the other hand, the MIoT model proposed with three layers doesn't reveal the further detail of each layer such as hardware (which hardware is used in the smart cities) etc. Furthermore, the smart services and features doesn't mention within this research.

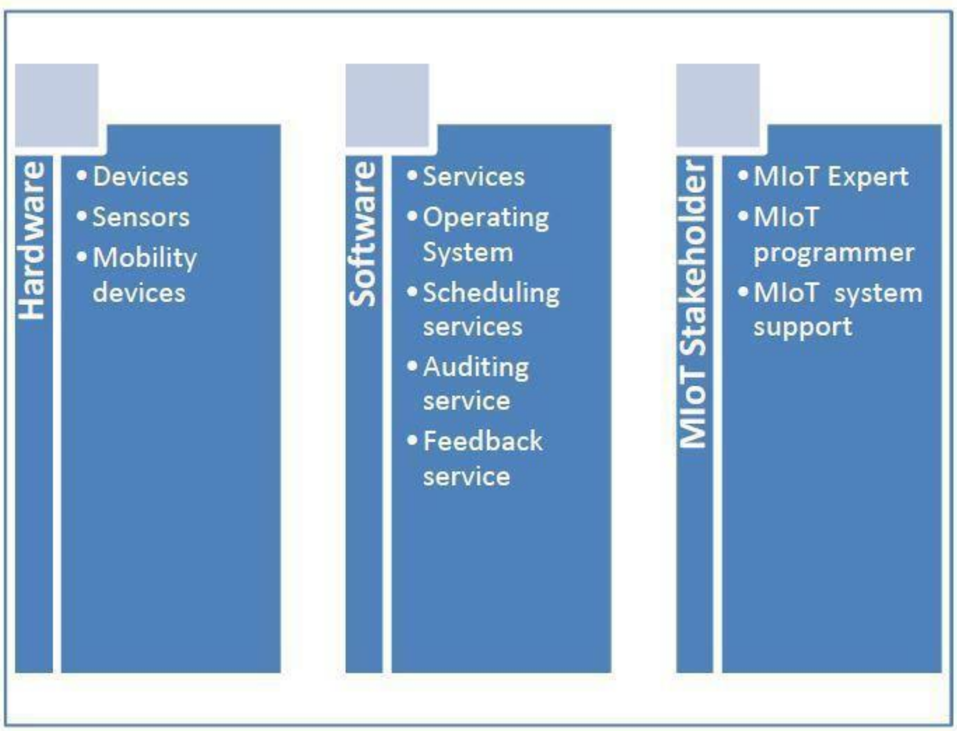

Figure 3.5: Components of MIoT system

4. THE COMPLEX SERVICE AND STRUCTURE OF SMART CITY

4.1 OVERVIEW

In this academic paper, we propose a new complexity of smart services and architecture of the smart city. We are motivated by the idea that the smart city can be built either from exiting physical city infrastructure or Information Communication Technology (ICT) infrastructure. My unique architecture of the smart cities provides an integrated approach to do both network, data as well as producing the smart services. It is based on the topological assumption that either the physical city infrastructure or the ICT infrastructure, there allow pluggable smart devices to build on and interact with the physical world and the smart participants to collect real-time data and contribute to the intelligent services for the smart participants in terms of entertainment, transportation, education, energy, environment etc. The proposed architecture consists of seven core layers. In the first layer: physical layer, the physical infrastructure of the smart cities is built from either exiting physical city infrastructure (transport infrastructure, wet infrastructure, energy infrastructure, public space etc.) or the ICT infrastructure (hardware and software) to provide an innovation physical platform for the smart cities. In the second layer: the smart devices, after building the physical infrastructure, the smart devices including sensors, actuators, cameras, GPS, other Internet of Things (IoT) etc. are plugged on and scattered around the smart cities, allowing to quickly interact, surveillance and faster collect real-time data from the physical environment and the smart participants. At the data management layer, it consists of a myriad of wireless technologies and cloud computing, providing the innovation technological capacity for faster data clearing, transformation and loading data to data warehouses (OLAP). At the fourth layer, the smart application and software performs data analysis as well as predict certain actions toprovide specific smart intelligences. In fifth layer, the smart services including open/ close, notify/ call, monitor/ control etc. are the functionalities or commands of the smart applications to perform specific actions. In the sixth layer: the smart features layer, it serves as the GUI/ window for the smart participants to directly access the smart services. In the final layer of the smart city architecture, there are the smart participants. The smart participants can be either smart citizens, smart government officers, as well as smart enterprises to utilize the smart services. The proposed architecture of the smart cities consists of seven core layers as can be seen in Figure 4.1.1.

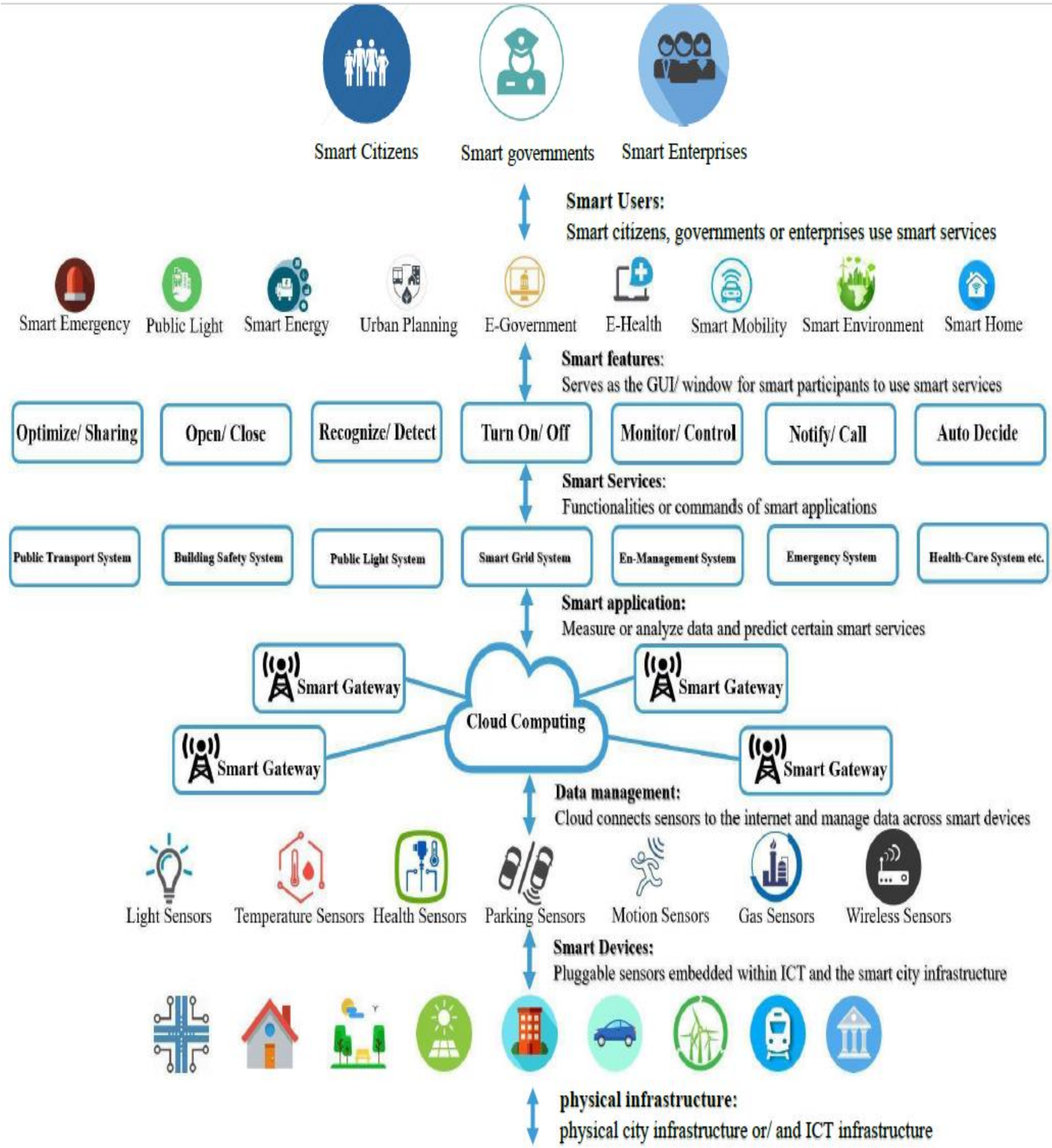

Figure 4.1: the proposed architecture of smart cities

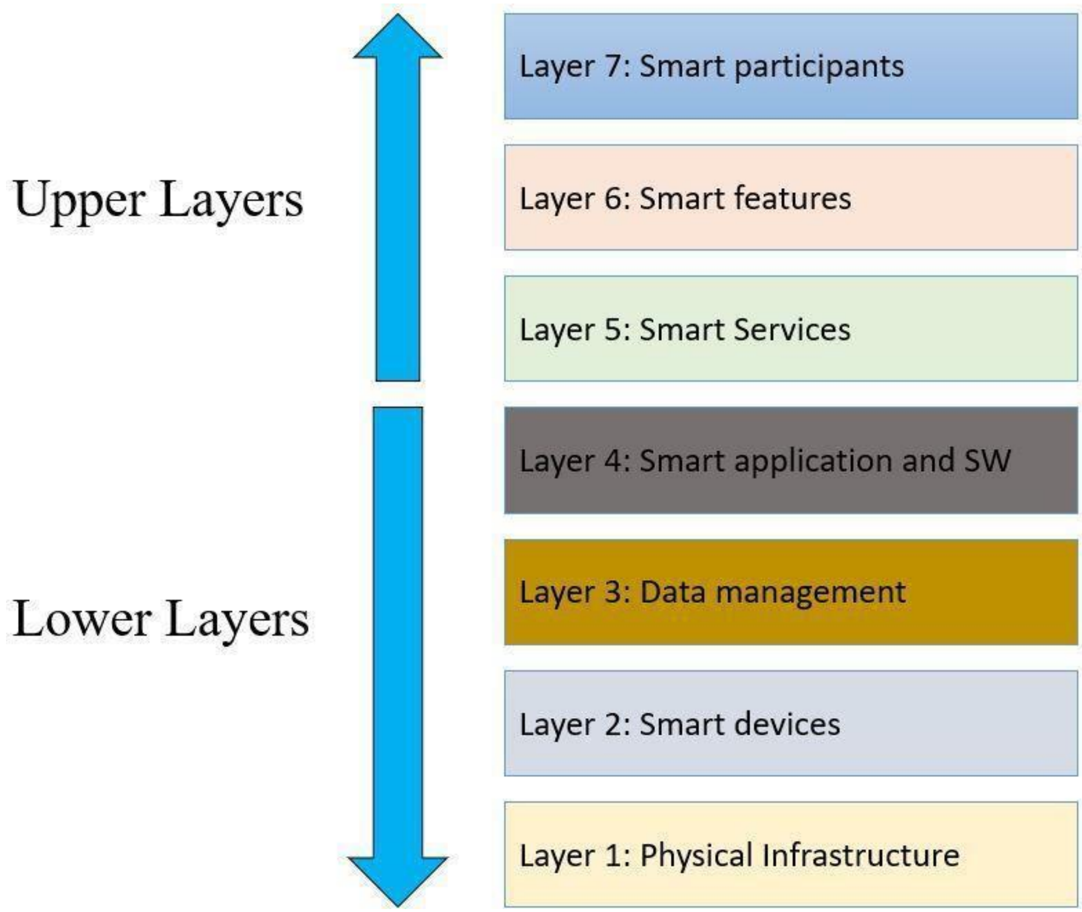

Figure 4. 2: the proposed architecture of smart cities

Let us consider above Figure 4.1.2 of the proposed architecture. The proposed architecture of the smart cities consists of seven core layers. Typically, the physical infrastructure is known as either exiting physical city infrastructure and/ or physical ICT infrastructure which provide as the physical platform to build the smart cities. In the second layer, smart devices are plugged into the physical infrastructure and scattered around the city to sense and collect real-time data from the physical world and users. In the third layer, data management has a myriad of wireless technologies and cloud computing. This layer consists of three processes: data clearing, transformation and loading data into data warehouses (OLAP), which acts as the centralized OLAP to share data across the smart cities. In the fourth layer, smart applications analyze data and produce certain smart intelligences. In the fifth layer, smart services are the functionalities or commands from the layer four. In the sixth layer, smart feature has a main role of connecting between smart services, layer five, and smart users, layer seven, by allowing smart users directly access to smart services. In the seventh layer, smart participants are the people utilizing the smart intelligences of the smart cities.

4.2 LAYER ONE: PHYSICAL INFRASTRUCTURE

In the layer one, the physical infrastructure is generally known either as the exiting physical city infrastructure or/ and the ICT infrastructure, which is widely considered as the City as a Platform used as one of the smart enablers to transform the traditional cities into the smart cities around the world. The exiting physical objects including home appliances, buildings, parks, traffic roads, social facilities, vehicles, portable devices, gadgets etc. used in daily life are being equipped with the electronic smart devices such as sensors, actuators, GPS, Camera etc. to be able to sense, collect, exchange, analyze and produce the intelligent services for the smart users through connecting to cloud computing to inter-operate within the exiting ICT infrastructure [14], [15] and [16]. On the other hand, using the right exiting physical city infrastructure or/ and the ICT infrastructure for the smart city solution is essential to design and implement the smart city projects and initiatives. With the emergence of innovation technology such as Internet of Things (IoT) [31], we can connect any exiting physical objects around us with the intelligent devices to the internet to enable these objects to connect, exchange data and control remotely [12] and [13]. The Internet of Things (IoT) is defined as a concept and a paradigm considering pervasive presence in the environment of a variety of things/ objects that wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach the common goals [17] and [18]. The main goal of the Internet of Things is to enable the exiting physical objects to be connected anytime, anyplace, with anything and anyone ideally using any network and any service by transforming the traditional cities into the smart cities that make energy, transport, health, education, public services and many other areas more intelligent or in short, the Internet extends into the real world embracing everyday objects. Integrated networking, information processing, sensing and actuation capabilities allow the exiting physical devices/ objects to operate in the dynamic/ changing environments with tightly interconnection and coordination with or without the human in the loop.

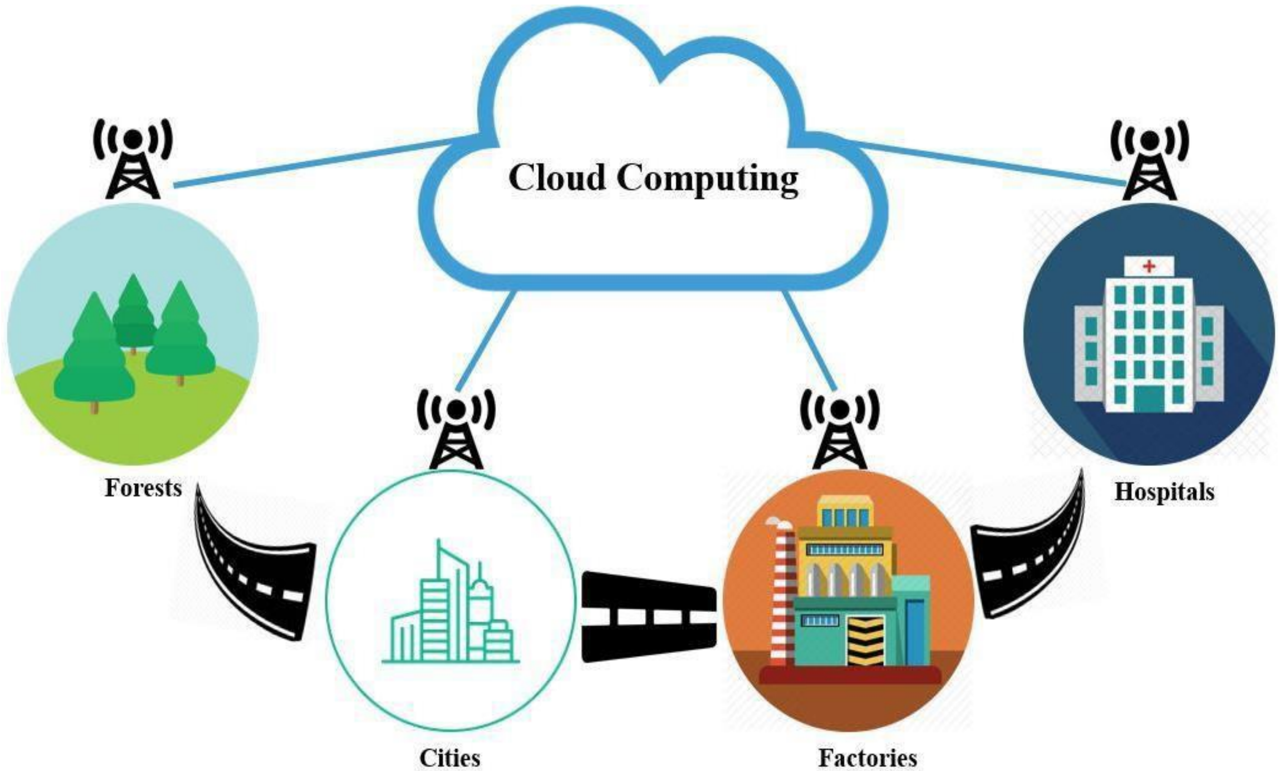

Figure 4.3: the exiting physical city infrastructure and/ or ICT infrastructure

Let us consider above Figure 4.2.1: the exiting physical city infrastructure and/ or ICT infrastructure. The exiting physical city infrastructure and/ or ICT infrastructure, for example: forests, cities, factories as well as hospitals, are embedded with the intelligent devices in order to be able to sense and collect real-time data from the physical world and the smart participants. Data is transmitted, cleared, transformed and loaded into the data warehouses via a myriad of wireless technologies in the form of gateways/ hubs and cloud computing which will be utilized to produce certain smart services by the smart application or software.

4.3 LAYER TWO: SMART DEVICES

In the layer two, the smart devices are enabling technology devices, modules or subsystems such as sensors, actuators, Radio Frequency Identification (RFID), ZigBee, Quick Response (QR) code, GPRS, Camera etc. which enable “physical objects/ things” to sense, acquire, control or change in its dynamic environment and send real-time contextual information to other electronic intelligent devices across the smart cities [20], [21] and [22]. The majority types of the smart devices are widely embedded in the exiting physical infrastructures across the cities to make the city smarter and smarter to optimize resources, reduce traffic congestion, address the emerging challenges of public health, aging population, environmental protection and climate change, enhance safety and security, contribute the economic growth and provide more and more services for daily activities [18] and [19]. The smart devices are moving from “smart” to “intelligent”. For example, the sensors in the home will control the lights by turning them off periodically when there are no movement or people in the rooms. The Home Area Network enables unitalities to be controlled when the home appliances are used by giving the users to determine when they exactly want to use electricity, and at what price. Furthermore, the development of the smart implantable chips can monitor and report the smart citizens’ health status periodically to their doctors. There are the number of the smart sensors used nowadays to sense and gather the real-time data to accommodate the smart participants in the smart cities:

- Motion sensors and brightness sensors are used in the smart street lights of the urban planning to detect as well as to gather data regarding of pedestrians’ movement and vehicles’ movement. The data is collected through these sensors used to determine when to turn a street light on or off in order to minimizing the energy consumption. It is also used to adjust the current ambient light level (bright/ dark etc.).
- Wireless traffic monitoring sensors are installed at the traffic bottleneck in the smart city to monitor traffic level, traffic routing and over speeding detection etc.
- Smart stick-on sensors are the low-cost as well as self-powered sensors to monitor different parameters in the smart grid [40].

- Smart emergency sensors for the smart emergency are used to sense and collect real-time data from the surrounding physical environment to deduce anemergency such as trespassers, fire, earthquake etc.
- Chemical sensors are used to detect infections around biomedical implants in the smart health.
- Waste management sensors, air pollution sensors, water pollution sensors, land management sensors etc. are used in the smart environment
- Mobile air quality sensors measure gas levels as well as temperature
- Parking sensors measure parking spot occupancy
- Smart parking signs temporarily prohibit parking in a zone. The signs contain an accelerometer and GPS sensor to monitor movement and their location
- Proximity sensors detect the presence of nearby objects etc.

To connect the smart devices to the Cloud Computing/ Internet, there are multiple wireless technologies available nowadays, but each wireless technology has their own strengths and weaknesses in terms of range, data rates and power utilization. We can mainly use two major types of the innovation technology used to deliver data collected by the intelligent devices to the Cloud Computing, which can be used for big data analysis in the layer three: 1) – Multi-technology gateways and 2) –LoRa-based Low Power WAN network [23], [24], [25] [26] and [27].

4.3.1 Multi-Technology Gateways

The multi-technology gateways are mainly scattered across the smart cities. Each gateway generally acts as a control network or an access point wirelessly connecting the smart devices to the Cloud Computing/ Internet. In addition, it can act as an ad-hoc peer-to-peer mode by connecting the gateways with each other to form the multi-technology wireless network to allow the smart devices exchanging data among each other. These gateways have a wide range of wireless technologies available following radios on-board as dedicated systems on Chip: IEEE 802.1ac on 2.4 and 5 Ghz, DASH7 on 433 and 868 Mhz, Bluetooth (Low Energy), IEEE 802.15.4, IEEE 802.15.4g, LoRa and 3G/ 4G/ 5G Cellular. This allows connecting to the high/ low bitrate smart sensors. With the wide range of the radios available, virtually any kind of sensors can be connected.

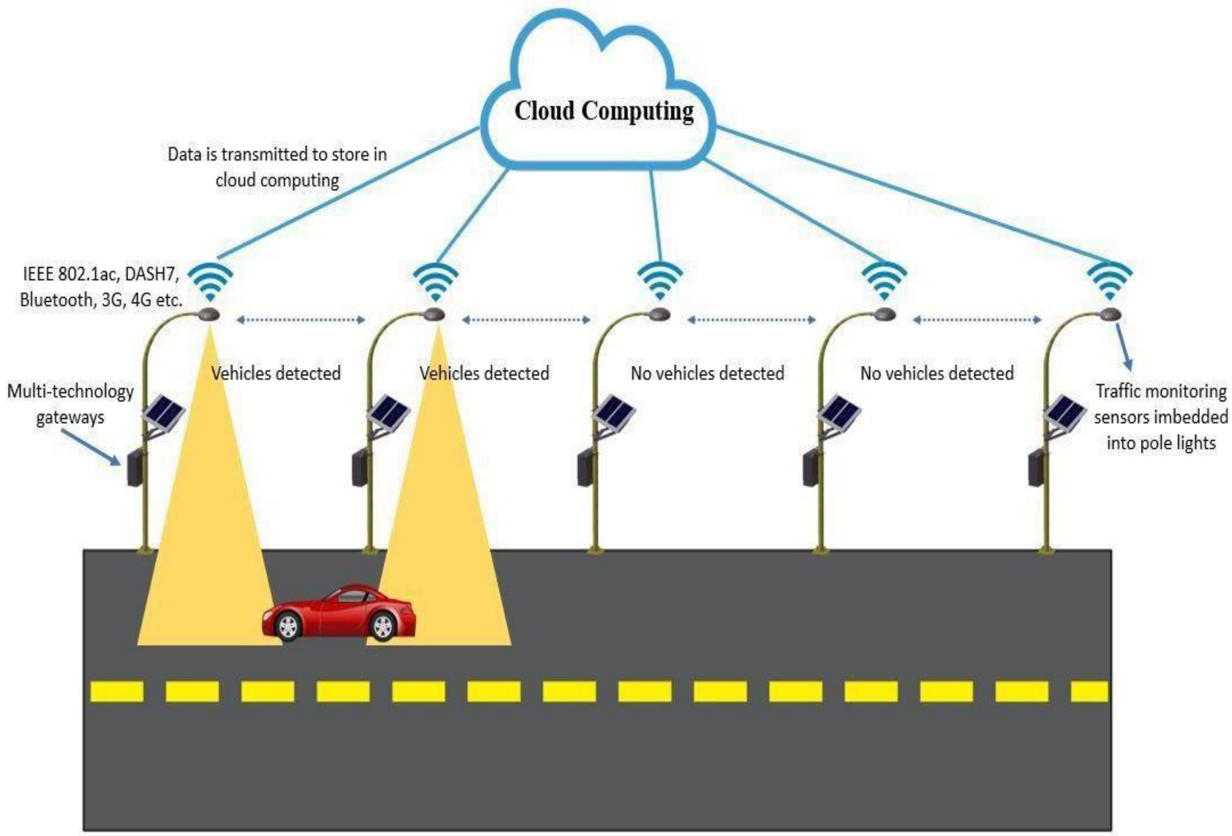

Figure 4.4: Smart lights with multiple- technology gateways

Let us consider Figure 4.3.1.1: Smart lights with multiple-technology gateways. In this scenario, hundreds of the traffic monitoring sensors are embedded into the street pole lights at various traffic intersections, motorway entries as well as city entrances to manage the traffic volume, road occupancy, vehicle speed as well as queue length during the busy time. The traffic monitoring sensors detect and gather data per vehicle which will send to the multiple-technology gateways via IEEE 802.1ac, DASH7, Bluetooth (Low Energy), IEEE 802.15.4, IEEE 802.15.4g etc. The sensor data is transmitted into the cloud computing for processing and storing into the OLAP databases, which is used by the smart applications later. Therefore, the traffic authority may use the sensor data to actuate the traffic lights, manage the traffic congestion, the road accidents or the special festivals in the smart cities.

4.3.2 Lora-Based Low Power WAN Network

The multi-technology gateways allow for rapid wireless connection to the smart sensors; however, this technology alone can't provide full wireless coverage to connect all smart sensors throughout the smart cities. The LoRa-based Low Power WAN network is an alternative option or additional option on the multi-technology gateways mainly intended for ensuring a continuous real-time stream of the sensor data and the citywide coverage. The LoRaWAN is the novel Low Power WAN technology, specifically for battery powered machine to machine communication. One single base station provides an actual range of kilometers and supports data rates of up to 50 kbps in Europe and 100 kbps in USA. The LoRa-based Low Power WAN architecture can be seen in Figure. 4.3.2.1 [28].

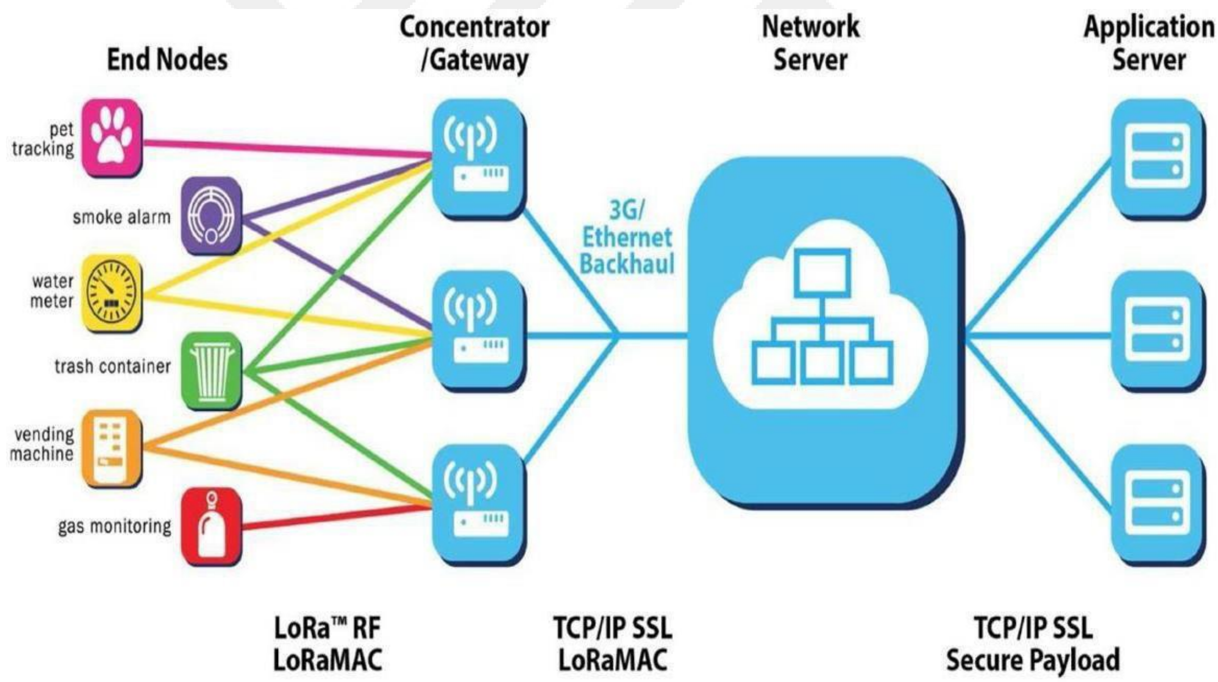

Figure 4.5: LoRa-based Low Power WAN architecture [28]

4.4 LAYER THREE: DATA MANAGEMENT

One of the key innovation technologies nowadays supporting data management and smart applications in the smart cities is the Cloud Computing [30]. The cloud computing provides the powerful independent platform for transformation, clearing and storage big data collecting from the smart devices into the virtual data warehouse databases for utilization by the smart applications, and implement and operate multiple types of the smart city services. The more challenges for the data management are the dynamic and characteristics of the big data such as volume, velocity, variety and volatility, heterogeneity and complexity [32] and [33].

The OpenIoT platform is an open-source cloud-based IoT middleware using a three- layered service-based architecture to support the smart city paradigm by enabling the integration of the smart sensor data and facilitating the large-scale smart applications and software [34] and [35]. The OpenIoT can be deployed on any Cloud Computing such as NeCTAR cloud, the Cloud of Things (CoT) [36] etc. In the data management, OpenIoT involves with the virtual and/ or physical sensors, X-GSN, LSM and Virtuoso database (data warehouse DB).

- Sensor Middleware: the sensor middleware gathers, filters, transform and combines the sensor data from both virtual sensors and physical sensors. It uses Extended Global Sensor Network (X-GSN) as the gateway between the smart devices and the Cloud Computing. X-GSN abstracts all physical smart sensors as the virtual smart sensors and register every virtual sensor with Linked Stream Middleware Light (LSM-Light) so that each physical smart sensor can get a unique sensor ID. The sensor ID helps in sensor discovery, sensor data update and read bydifferent smart participants. Then it streams data from the physical smart sensors into the wrapper (NGINX) and publishing the sensor data in parallel into LSM-Light before storing to the data warehouse databases (Virtuoso DB). It also supports the semantic annotation of sensor data and metadata.
- Cloud Data Storage: the OpenIoT uses the Linked Stream Middle Light (LSM-Light) for the sensor registration and discovery, data visualization and analyze, as well as storage and management of the sensor data streams and metadata received from the sensor middleware before projection into the data warehouse databases (Virtuoso DB). The LSM-Light uses the W3C standard SSN (Semantic Sensor

Network) ontology [37] to widely publish the smart sensor data in the form of Resource Description Format (RDF) triple and store this triple in the Open Link Virtuoso database [38].

- Security Management: the OpenIoT uses the Single Sign-On solution based on Central Authentication Services (CAS) [39] where multiple CAS enabled web services can be assessed by issuing and validating the tickets/ tokens to CAS clients like X-GSN or third-party applications when storing and retrieving the sensor data.

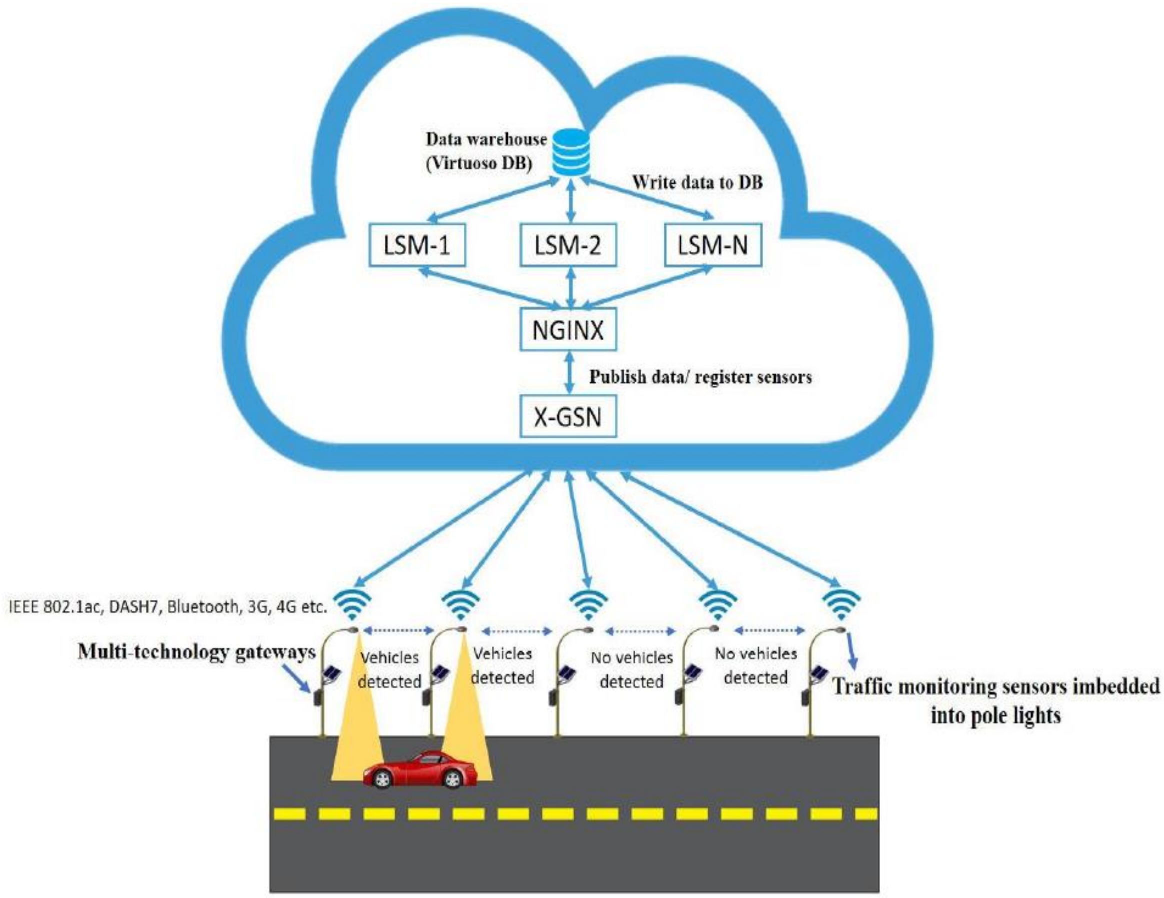

Figure 4.6: OpenIoT deploys on the Cloud of Things (Data center)

4.5 LAYER FOUR: SMART APPLICATION AND SOFTWARE

Smart application and software are a rapidly developing area in the smart cities nowadays. Majority of the smart city applications together with researches have been done by the universities, enterprises as well as government sectors. The smart city applications contain the main functions of analyzing the sensor data and producing certain smart intelligent services to provide the new and efficient ways to optimize or improve energy consumption, environment, health-care, public transportation, public services etc. in order to reduce operational cost, save time and human safety. In the layer four, we will discuss some smart city applications as bellow:

4.5.1 Smart Street Light Systems

By using smart street light systems, the smart city can reduce the environmental pollution and save the dramatical energy consumption by monitoring the exiting traditional street lights remotely like turning on/ off lights or adjusting its brightness depending on the time of day, the location and traffic/ pedestrian activities. Veena et al. [41] proposes the smart street light system which takes the video as an input to detect movement of the vehicles and human beings to switch on the street lights ahead and switch off the lights at the back to save the energy utilization. Veena et al. uses the Object Level Frame (OLF) comparison methodology to process the image of an approaching object and then send a control message to the street light block to switch on/ off the light. Sheu et al. [42] develops a Light Emitting Diode (LED) street light system by using multi-color LED, power driving IC and image processing. The system is used to monitor the road status. In case the serious fog or heavy raining is detected, the system will instruct the power IC to drive multi-color LEDS for generating the lower color temperature light to improve the road visibility for pedestrians and drivers. Jain and Nagarajan [43] implement the smart light system with the LED array and the micro-controller powered by many solar panels and battery packs. Every day, the micro-controller estimates the sunrise and sunset times based on the Real-Time Clock (RTC) to dim the lights or switch on/ off the lights.

Let us consider the Figure 4.5.1.1: Smart street light systems. After the sensor data is gathered and written into data warehouse DBs (Virtuoso DB), the smart street light systems read that sensor data to perform analysis based on their imbedded algorithms to produce certain smart city services responding real-time physical environment like turning on/ off the street lights.

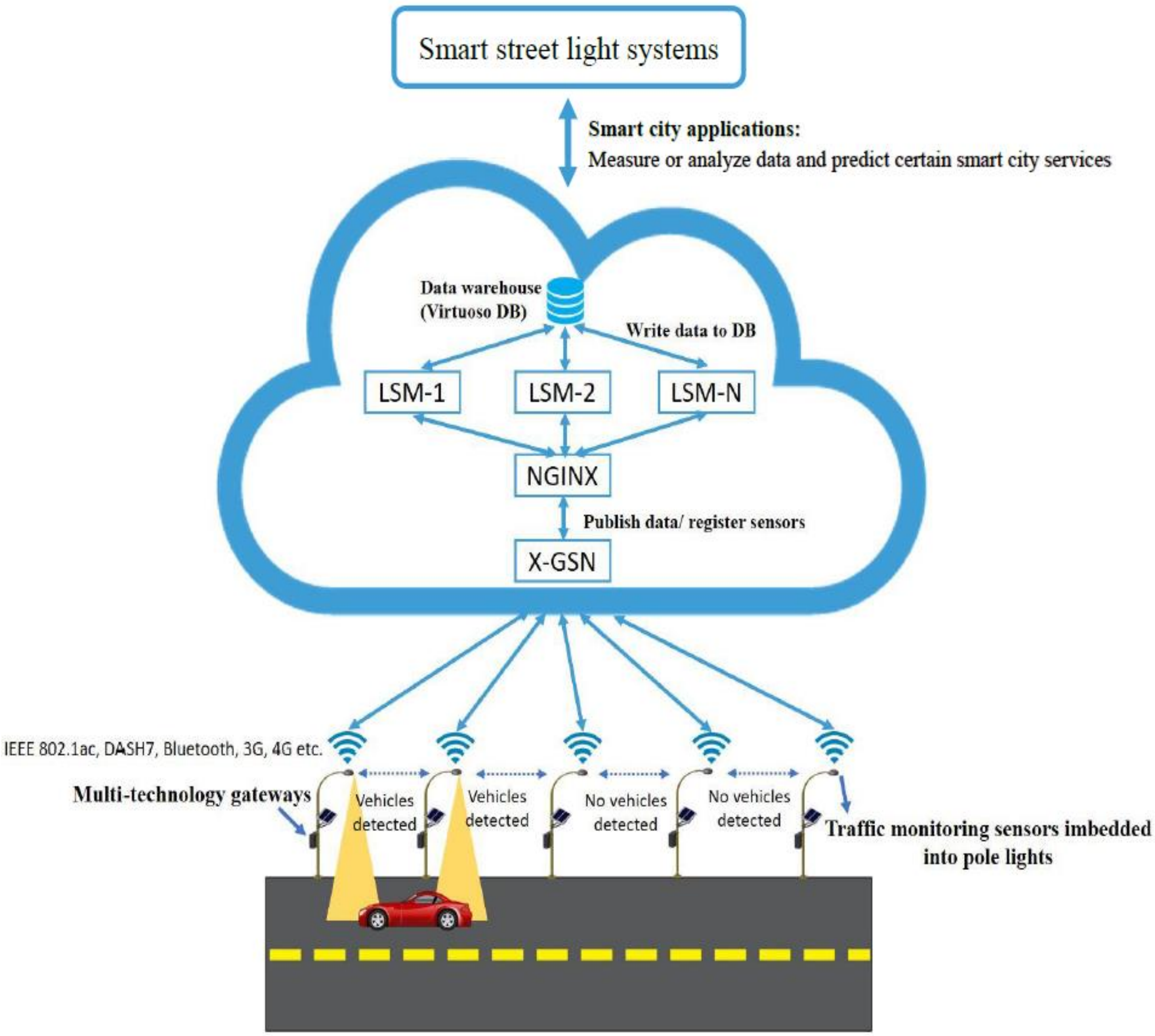

Figure 4.7: Smart street light systems

4.5.2 Smart Emergency System

Smart emergency systems can be used for detecting crime and preventing with accidents and natural disasters to promote safety and security for the citizens in the smart cities [44] and [45]. The smart emergency systems need to analyze the sensor data quickly and to response smart services accurately to the proper rescuing agencies. The physical infrastructure such as emergency cars, CCTV cameras, buildings etc. can be embedded with smart sensors to collect real-time data.

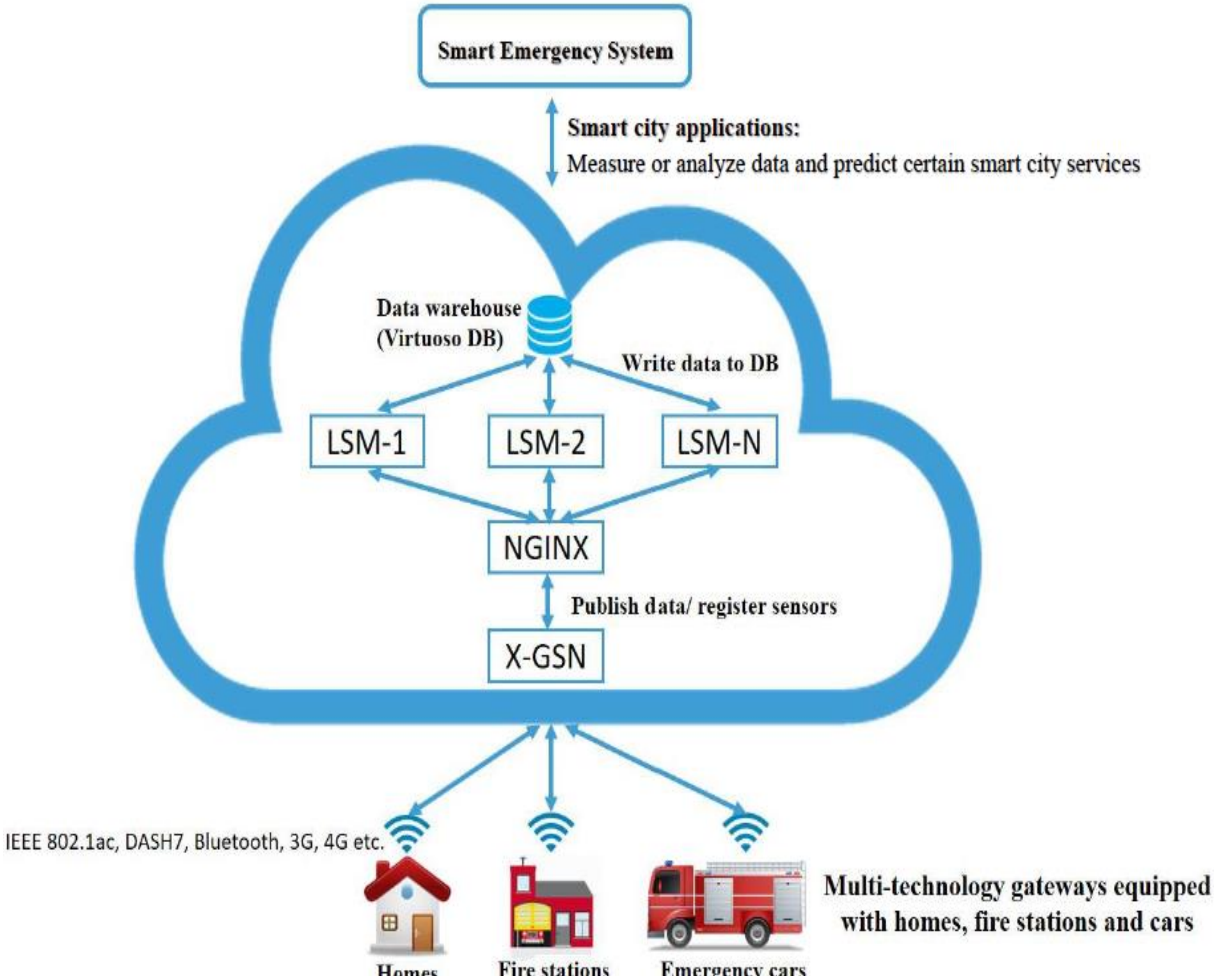

Figure 4.8: Smart emergency systems

Based on Figure 4.5.2.1 Smart emergency systems, when the fire alarm sensors detect or sense the fire in the homes, it will quickly gather fire data and transmit into the Cloud Computing. Then, the smart emergency systems will analyze the sensor data critically and quickly notify to the fire stations and the emergency cars mostly nearby the homes in order to take proper actions as soon as possible.

4.5.3 Smart Healthcare Systems

The smart healthcare systems can provide the high-quality and low-cost healthcare services to help any kind of the patients with higher demand for the healthcare services in the smart cities. With the smart sensors such as wearable smart sensors, emerging on-body sensors etc. the patient's health conditions can be measured and notified to doctors or hospitals anytime and anywhere.

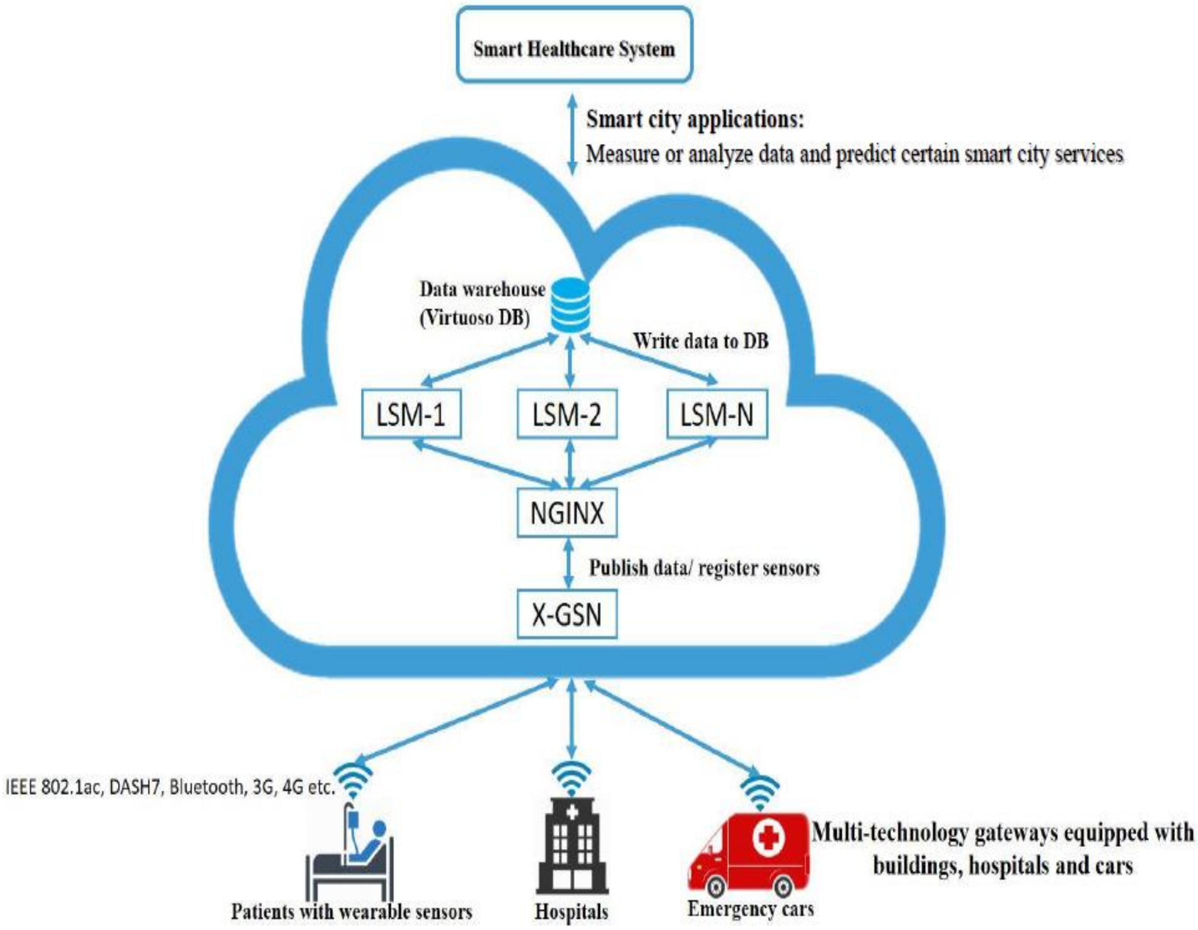

Figure 4.9: Smart Healthcare Systems

Let us consider Figure 4.9:

The patients use the wearable sensors in order to measure their health condition or status. In case, the patients have physiological sings or health problems such as blood flow, blood pressure, respiratory rate, heart rate, body temperature etc. The wearable sensors will detect and transfer the health data into the smart healthcare system in order to analyze and notify to their doctors or hospitals. On the other hand, the wearable sensors need to be light, small and highly energy efficiency.

4.5.4 Smart Environment Systems

Smart environment systems can be used to perform real-time data analysis from multiple physical environments and produce the smart services to solve many environmental issues such as

Air pollution, water pollution, waste overload, flood, landslides, illegal animal hunting etc. The environments must be properly equipped with the intelligent devices such as waste management sensors, air pollution sensors, water pollution sensors etc. in order to sense, gather and measure the environment status and condition and inform the related agencies.

4.5.5 Smart Building Systems

Smart building systems can fulfill users' demands effectively and efficiently in their daily living and activities to create the more sustainable, comfortable and productive work and living environment [46] and [46]. The smart building systems can sense and analyze the insights from the building's environment as well as the users' commands, and then perform specific smart services such as monitoring building appliances, turning off/ on the windows, controlling or scheduling the temperature in the room (heating, cooling etc.), notifying any kind of emergency events etc. It can reduce the utility costs and energy consumption.

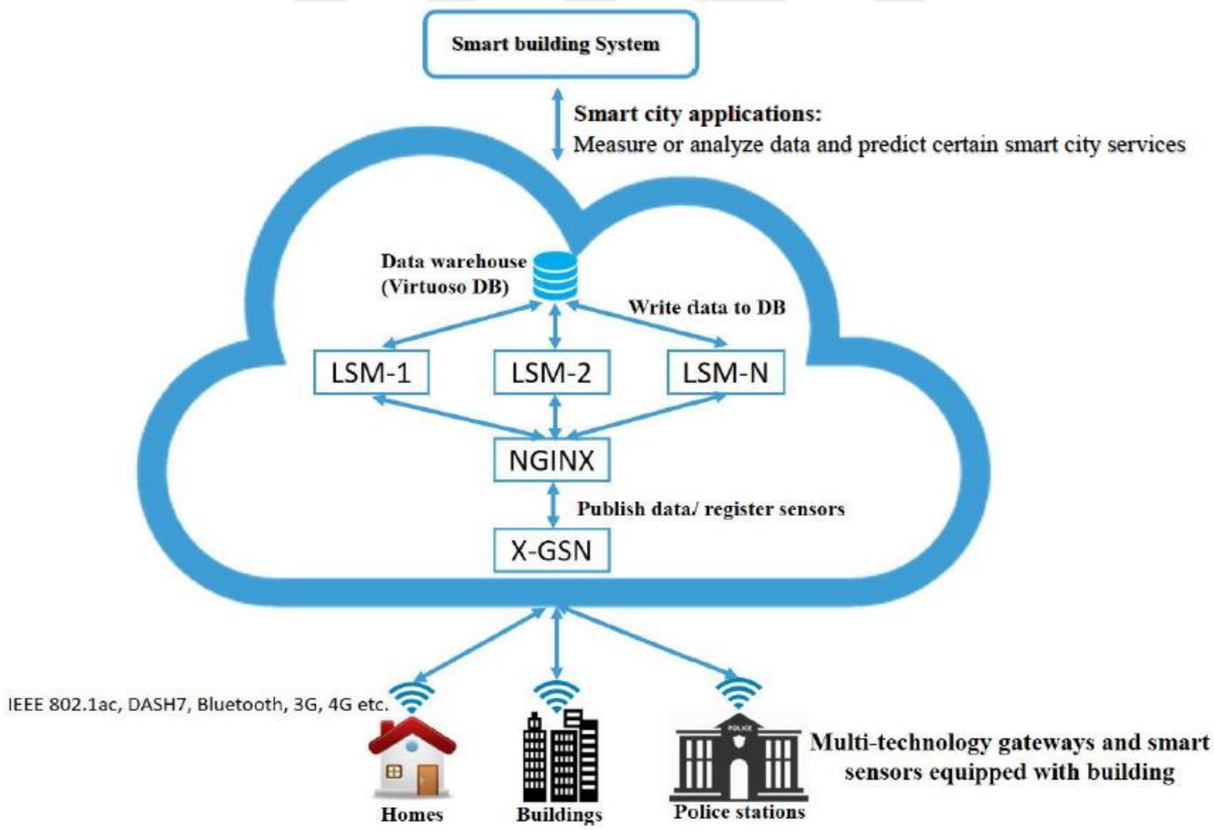

Figure 4.10: Smart building systems

4.6 LAYER FIVE: SMART SERVICES

Smart services are primarily produced by layer four, the smart city applications, based on analyzing the sensor data either from the smart user commands or the physical real-time environment to provide certain actions or services. These smart services allow the smart users to monitor or control the smart devices by using smart phone application, voice command, schedule, automatic decision etc. These smart services are classified into general principally functions as following:

- Open/ close
- Recognize/ detect
- Turn on/ off
- Optimize/ sharing
- Notify/ call
- Monitor/ control
- Automatic decision etc.

Let us consider Figure 4.6.1: Smart traffic light control systems. Every vehicle on a road can be detected by the smart devices such as smart street light sensors, road sensors, vehicle sensors, cameras etc. to model the traffic patterns or observe the status of the traffic by adjusting the traffic lights in an urban area in the smart cities. The sensor data of each vehicle gathered through the smart devices in regular periods will transferred into the Cloud Computing for writing into the data warehouse DBs (Virtuoso DB). The smart traffic light control systems read that sensor data to perform an analysis by using learning and adaptation algorithms [48], [49] and [50] to make optimizing decisions about specific traffic lights. The intelligent services produced by the smart traffic light control systems can be utilized for decreasing the traffic delays, prioritizing emergency traffic, route optimization, traffic monitoring, and driving style control during the peak hours. In addition, the smart data of each vehicle stored in the Cloud Computing can be used to organize multiple traffic lights equipped with the intelligent traffic light sensors within a short distance at a significant street in the smart cities for shorter traffic delays, route optimization, informing the smart users about the status of traffic etc. With highly intelligent services produced by the smart traffic light control systems, it will be able to help the smart users to travel comfortably and efficiently by saving their time, money and effort across the smart cities.

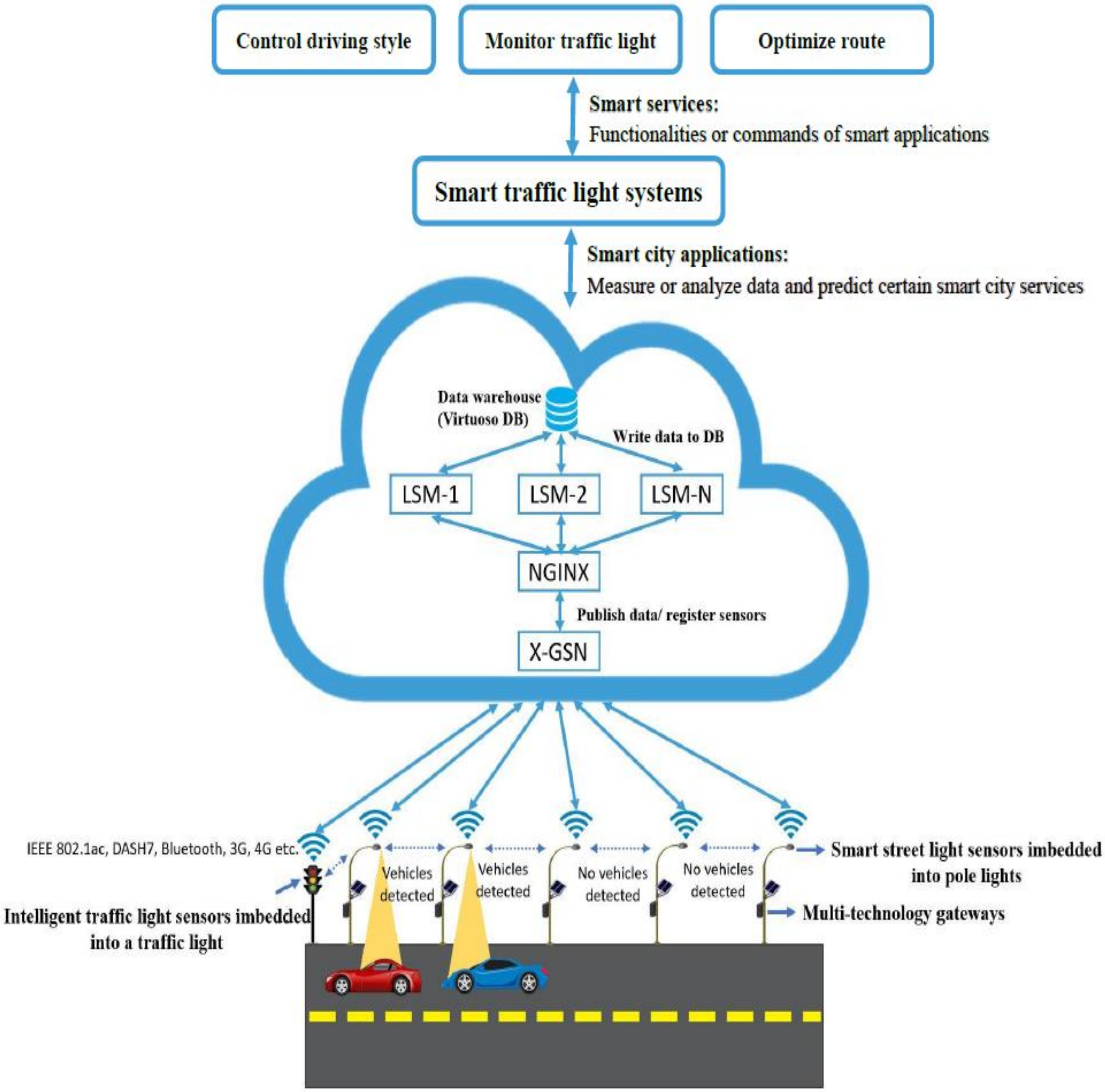

Figure 4.11: Smart traffic light control systems

4.7 LAYER SIX: SMART FEATURES

At layer six of the proposed service-oriented reference architecture of smart cities, the smart features are a gateway or interface, which enables the smart users to utilize as well as manage directly the set of the smart city services produced by layer four, the smart applications and software via manual command, voice command, schedule etc. The smart features bring the core value of smart cities directly to the smart citizens, smart enterprises as well as smart governments. The smart features should be:

- User friendly
- Cross-platform
- Highly responsive
- Highly adaptive and intelligent by learning user's interests and preferences
- Easy to use
- Consistent
- Meet smart users' requirements etc.

Let us consider Figure 4.7.1: Smart Buildings bellow. The smart buildings are widely known as the buildings with the intelligent features, which have ability to sense, measure and analyze the sensor data from either the physical real-time environment of the buildings and/ or the smart user commands to produce certain smart actions or services for monitoring or enhancing the buildings' performance. There are multiple Building Management Systems (BMS) using in the urban areas in the smart cities nowadays:

- **Health of buildings**: properly maintain and assess the conditions of the building by periodically send the radio signal of the suitable amplitude and phase characteristic to inform about the structure's status to the smart users [51]. The smart devices are embedded within a concrete structure of the building to sense, measure and analyze the building's state.
- **Thermostat systems**: periodically monitor the temperature in the room and control the thermostat by allowing the smart users to schedule, utilize voice command, automatic decide about smart actions etc. [52].

- **Building safety systems**: automatic monitor and detect the physical safety of the building such as calling police by burglary, adjusting indoor air quality, detecting leaking gas, controlling emergency etc. [53].

The smart building features are mostly utilized to optimize energy consumption, enhance buildings' performance, provide the quality of security services and improve the quality of life for the smart participants.

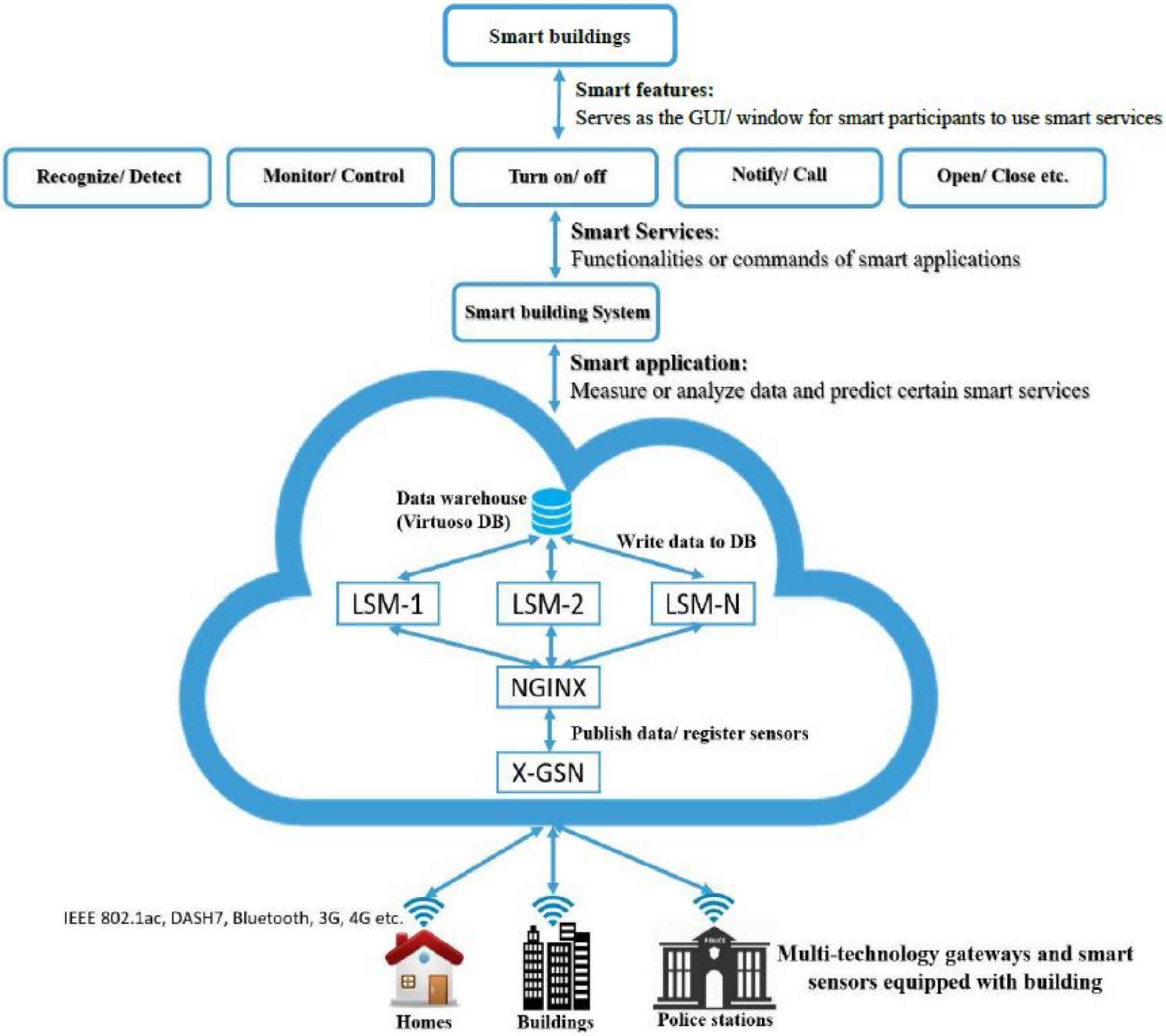

Figure 4.12: Smart Buildings

4.8 LAYER SEVEN: SMART PARTICIPANTS

Layer seven, the smart participants play an important role as one of the enablers to transform the traditional city into the smart city by being participated in the democratic process either from co-creating the strategic planning of the smart city projects, proactively utilizing the smart city services and/ or evaluation of the smart city services. In smart city research area, the participation of the smart users such as smart citizens, smart enterprises or smart governments in the strategic planning of the smart cities is widely considered as an essential factor for the smart city service quality to deliver the innovation solutions in the domains of the smart mobility, smart environment, smart economy, smart governance, quality of life as well as smart education. There is always a key challenge in coordination with the smart users since the smart users are not properly involved in the strategic planning, usage smart services or evaluation of the smart cities.

There is a framework to compare and evaluate the user participation as the enablers in the smart cities [5]. Figure 4.8.1: Citizen participation evaluation framework descripts briefly the three categories of criteria of the citizen participation, their main sub-categories and their reflection into criteria. This framework can be used in three different ways. Firstly, it can be used as an evaluation tool to assess the smart city strategy as the means to ensure the smart users' participation. Secondly, it can be used as the governance tool for the government officials to invest in the citizen-oriented smart city strategy considered guidelines for implementation. Finally, it can be used as the creatively tool by enabling comparative analysis of best practices for one criterion or category of criteria across the different smart cities to get new means for smart citizen participation involved in designing and implementation. Here are the three elements of this evaluation framework:

4.8.1 Citizens as Democratic Participants

Smart citizens as democratic participants can help prioritize the smart city projects to meet the budget limitations and reduce the chance for litigation or unhelpful smart city services unused by the public. Furthermore, there are mutiple benefits from the smart citizens as democratic participants [54]. The smart citizens can deeply understand the difficulty of technical issues and become experts in matters of the public relevancy or services. The government administrators also learn from the smart citizens about the unpopular strategic plans of the smart cities and find out the compromised smart city plans.

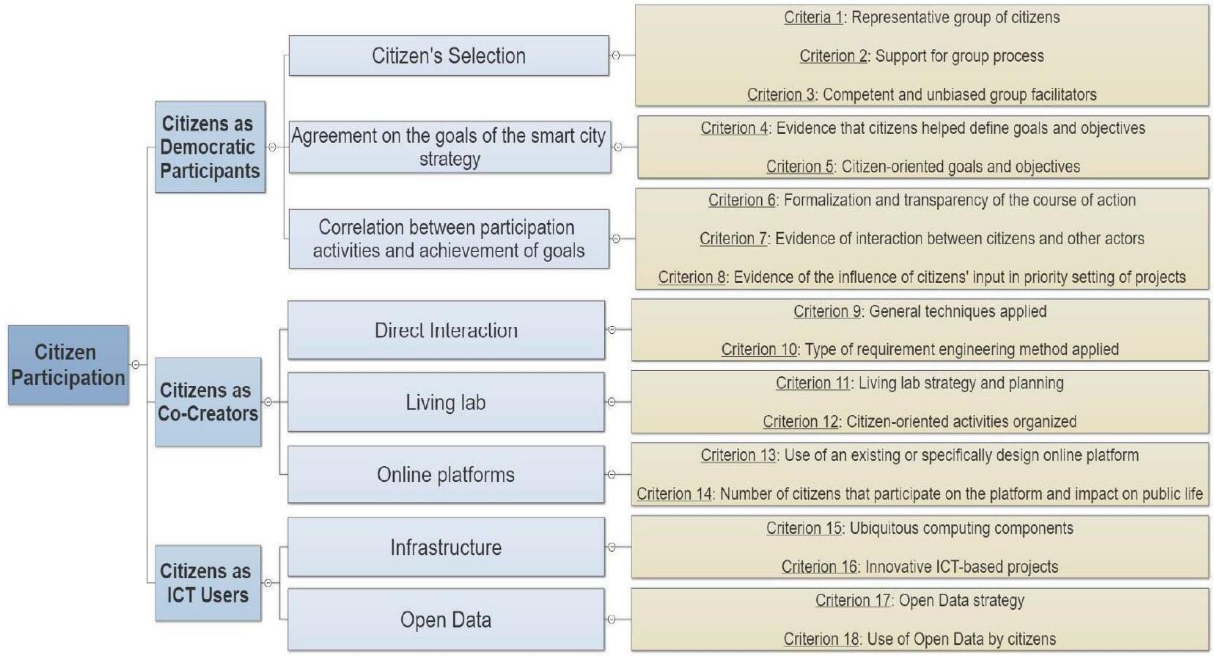

Figure 4.13: Citizen Participation evaluation framework [5]

4.8.1.1 Citizens' selection

There are three main criteria to choose smart citizens as the democratic participants. Firstly, the group of smart citizens participated in the process of the smart city projects must be sufficiently population and have the good profits to avoid overrepresentation of the certain class, gender etc. Secondly, the criterion "Support for group process" are used to support the smart citizens during the decision-making process through finance or social rewards to motivate them and reduce their own money and time. Finally, the criterion "Competent and unbiased group facilitators" is added to check the participation activities are handled by the competent and unbiased group facilitators ensure the voice of the smart citizens heard.

4.8.1.2 Agreement on the goals of smart city strategy

The goal of the smart citizen participation could be to "involve the citizens in the planning, implementation and reporting phase of the smart city", to "develop a citizen oriented smart city strategy with transparency, participation and collaboration" or to develop the smart city to meet at best the citizens' expectations. There are two main criterions. Firstly, the criterion "Evidence that citizens helped define goals and objectives" checks the smart citizens contribute the definition of the smart city's goals. Secondly, the criterion "Citizen-oriented goals and objectives" checks the smart city's goals are citizen-oriented and consider the human resources in that smart city into account.

4.8.1.3 Correlation between participation activities and achievement of goals

Two main criteria ensure the correlation between participation activities and achievement of goals [55]. First, the criterion "Formalization and transparency of the course of action" checks that participantion actions have been formalized and transparent to get the clearly decision-making process for all smart citizens involved. Secondly, the criterion "Evidence of the influence of citizens' input in priority setting of the projects" ensures that the citizens, their quality of life and participation are at the core of the smart city strategic plans.

4.8.2 Citizens as co-creators

Co-creating a smart city refers to the active participation of smart citizens in the variety of stages in the smart city process [56] and [57].

4.8.2.1 Direct interaction

Direct interaction focuses on the widespread techniques to collect smart citizens' opinions such as interviews, meetings, testing, real-time comments etc. There are two mainly criteria of the direct interaction. Firstly, the criterion "General Techniques applied" checks these techniques are used to gather smart citizens' opinions. Secondly, the criterion "Type of requirement engineering method applied" checks the smart citizen involvement in the requirement engineering method.

4.8.2.2 Living lab

Living lab is a technique of citizens co-creators, which implies that the smart users are participated in the development process of the smart cities by primarily analyzing the needs and brainstorming about ideas. Then the panel of the smart users test the prototypes of the smart cities from these ideas. The main goal is to achieve the smart users' expectation as well as to tests how these innovation prototypes are suited with the smart users' environment [58] and [59]. There are two main criteria. Firstly, the criterion "Living lab strategy and planning" checks the living lab puts the smart users at the center of its implementation. This criterion takes account of the citizen-oriented activities to explore ideas for the smart cities, innovation technology etc. Secondly, the criterion "Citizen-oriented activities organized" checks that the living lab is built to enhance the smart citizens' participation in the smart city.

4.8.2.3 Online platforms

The internet such as the centralized platforms (voting system) and the social media analysis (crowdsourcing platforms, collaboration tools, social networking, questioning tools etc.) is another method of the citizens as co-creators in the planning phase of the smart city to reduce/ remove time or space constraints from the traditional methods in the living lab [60], [61] and [62]. There are two criteria. Firstly, the criterion “Use of an existing or specifically designed online platform” verifies that the online platforms used by the smart city for the citizens as co-creators are described. Secondly, the criterion “Number of citizens that participate on the platform and impact on public life” checks that the platform has a real-life setting by monitoring the number of the smart citizens’ participant and their ideas or complaints.

4.8.3 Citizens as ICT Users

4.8.3.1 Infrastructure

The criterion “Ubiquitous computing components” describes all computing elements that increase the smart citizen participation. This criterion puts the innovation technology as the services of the smart citizens. The criterion “Innovative ICT-based project” verifies that the new citizen-oriented applications are clearly mapped to the proposed framework. These citizen-oriented applications support and motivate the smart citizens to engage in the smart city services.

4.8.3.2 Open data

Open data is all publicly produced data diffused without restrictions [63]. Open data is involved multiple smart city domains like traffic, weather, public, tourist etc. The criterion “Open Data strategy” checks the smart city policy which focuses on the availability of the public data by listing all datasets available and their techniques. The criterion “Use of Open Data by citizens” lists all the means by which the available datasets are used by the smart city citizens.

Let us consider Figure 4.8.2: Smart Buildings. The smart users are widely known as the smart citizens, smart governments or smart enterprises, who gain the critical value of the smart city services directly by co-creating the strategic planning of the smart buildings, proactively utilizing the smart city services or evaluation of the smart city services of the smart buildings.

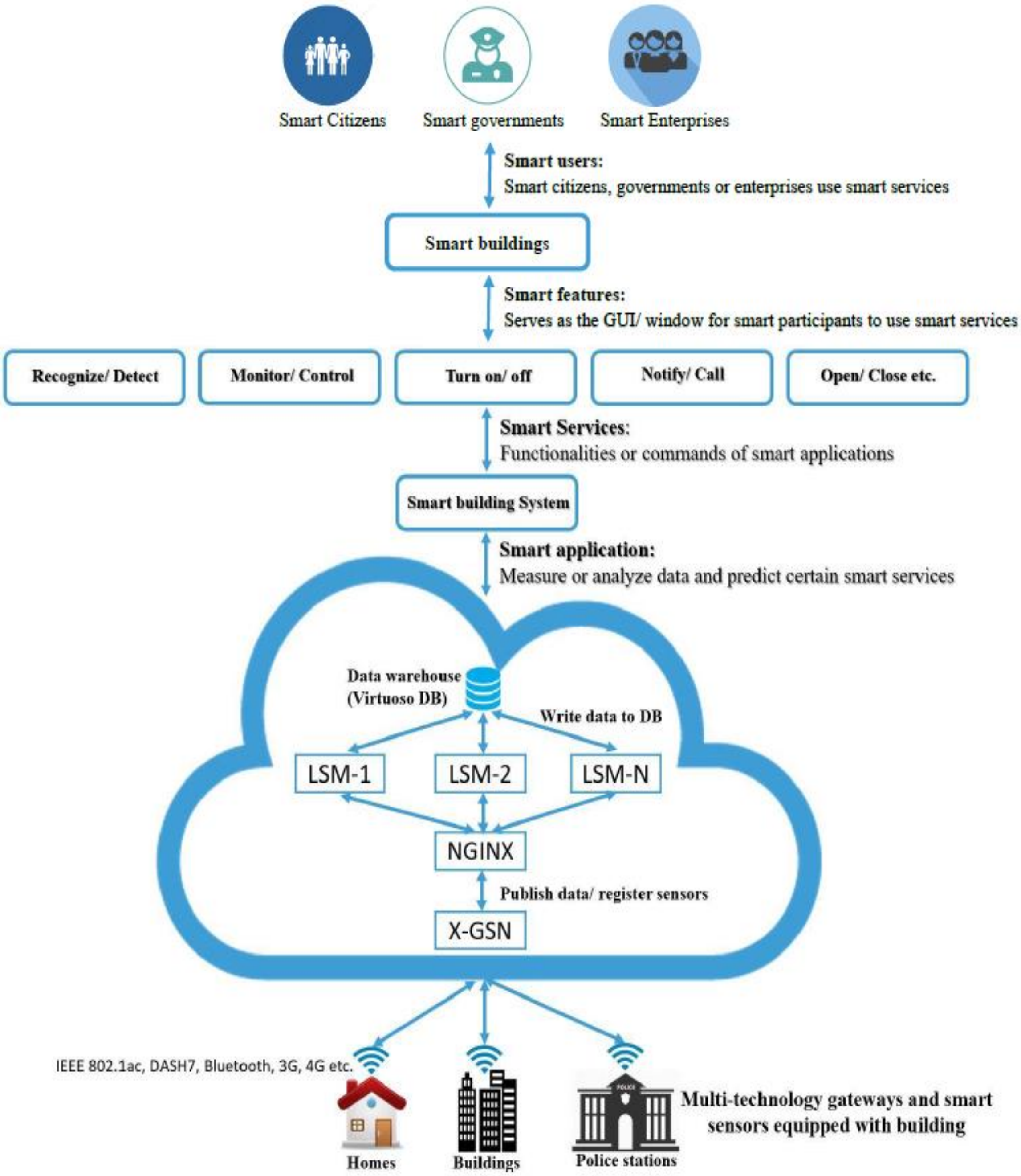

Figure 4.14: Smart Buildings

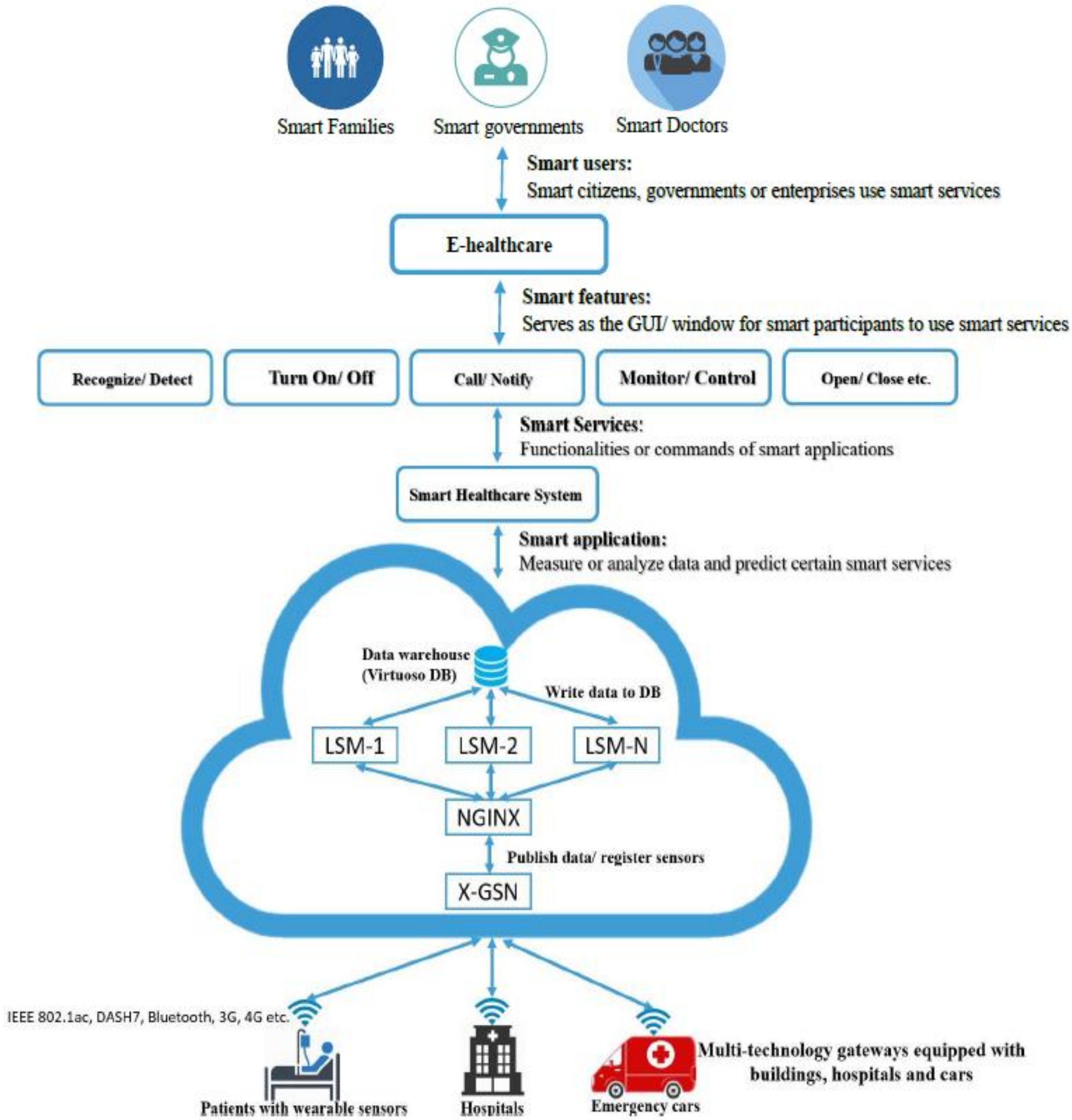

Figure 4.15: Smart Healthcare

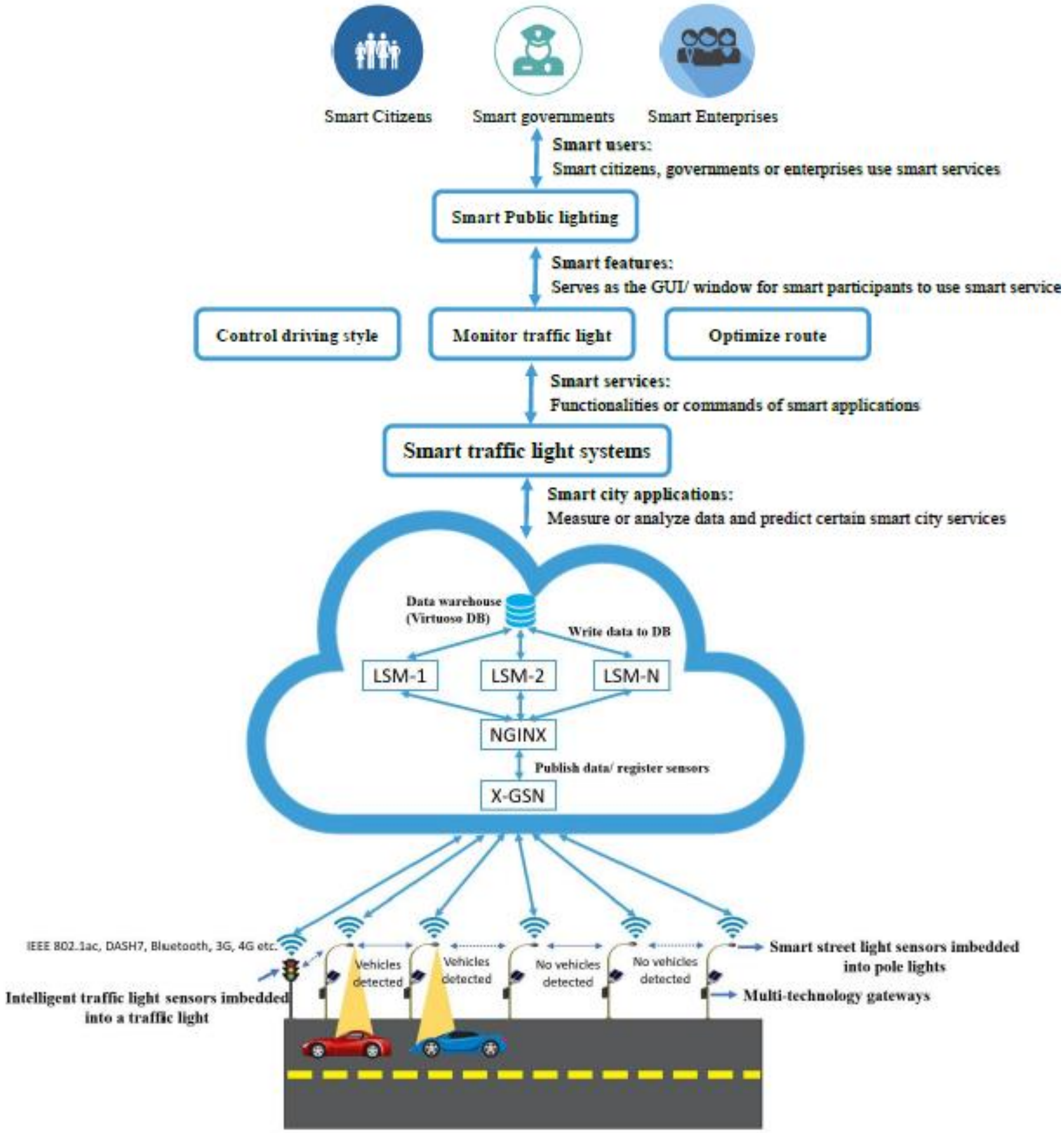

Figure 4.16: Smart Lights

5. CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

In this thesis, we propose the new smart city concept and the original three S-Dimensions which can be used to evaluate the city classified into the smart city or not based our proposed smart city architecture. These three core S-Dimensions are the valuable factors to create and analyze the smart city services to build the sustainable smart economy, smart living and smart environment. Furthermore, we have conducted the practical research of smart city projects in both developed and developing countries namely Belgium, United States of America and Asia with concerning on the complexity of services and its structure of the smart cities.

Our strategic vision is to propose the new service-oriented reference architecture of the smart cities, which will help the city planners and the top-level decision makers in both private and public sectors for implementing the smart cities to provide the smart values to their smart participants. This abstract architecture is encapsulated within the seven layers namely physical infrastructure, smart devices, data management, smart application and software, smart services, smart features as well as smart participants in the main areas of urban planning, smart energy, smart mobility, public lighting, emergency, smart environment and e-government. The physical infrastructure is either the exiting physical city infrastructure or ICT infrastructure to provide an innovation physical platform for the smart cities. The smart devices are included with sensors, actuators, cameras, GPS, other Internet of Things (IoT) etc. are plugged on and scattered around the smart cities, allowing to quickly interact, surveillance and faster collect real-time data from the physical environment and the smart participants. The data management layer mainly consists a myriad of wireless technologies and cloud computing, providing the innovation technological capacity for faster data clearing, transformation and loading data to data warehouses (OLAP). The smart application and software layer performs data analysis as well as predict certain actions to provide specific smart intelligences. The smart city service is widely known as the functionalities or commands of the smart applications to perform specific smart actions including open/ close, notify/ call, monitor/ control etc. The smart features layer is used as the GUI/ window for smart participants to directly access the smart city services. In the final layer of the smart city architecture, there are smart participants. Smart participants can be either smart citizens, smart government officers, as well as smart enterprises to utilize the smart services.

5.2 FUTURE WORK

We strongly believe that there will be a possible implementation of the smart city projects in the near future based on our key findings by:

- ❖ Utilizing the three S-Dimensions to evaluate the smart cities.
- ❖ The proposed service-oriented reference smart city architecture as the guideline for the design and implementation.

Furthermore, we also consider to develop the smart city application on the layer four by using JAVA or C++ platform to performs data analysis as well as predict certain actions to provide specific smart intelligences for the smart participants in the near future.

We have set the strategic visions to conduct the practical research on “the complexity of smart services and structure of the smart city”, and now we have successfully achieved it with the valuable outcome. We strongly believe that this practical research will enable other researchers and the city planners for further research and planning, designing and implementing the smart city projects, which will bring the valuable smart city services into the smart participates around the world.

REFERENCES

[1] C. Harrison, B. Eckman, R. Hamilton, P. Hartswick, J. Kalagnanam, J. Paraszczak, and P. Williams, “Foundations for smarter cities,” IBM Journal of Research and Development, vol. 54, no. 4, pp. 1–16, 2010.

[2] Dániel Tokody, Imre János Mezei, "Creating smart sustainable and safe cities", Intelligent Systems and Informatics (SISY) 2017 IEEE 15th International Symposium on, pp. 000141-000146, 2017, ISSN 1949-0488.

[3] S. Mitchell, V. Nicola, S. W. Martin, and L. Anne. The Internet of everything for cities, 2013. Available: www.cisco.com/web/strategy/docs/gov/everything-for-cities.pdf.

[4] A. Caragliu, B. Del, and C. Nijkamp. Smart Cities in Europe. 2009.

[5] Anthony Simonofski, Estefanía Serral Asensio, Johannes De Smedt and Monique Snoeck," Citizen Participation in Smart Cities", 2017 IEEE 19th Conference on Business Informatics.

[6] Danielle Griego, Varin Buff, Eric Hayoz, Izabela Moise, Evangelos Pournaras, "Sensing and Mining Urban Qualities in Smart Cities", Advanced Information Networking and Applications (AINA) 2017 IEEE 31st International Conference on, pp. 1004-1011, 2017, ISSN 1550-445X.

[7] S. Latre, P. Leroux, T. Coenen, B. Braem, P. Ballon and P. Demeester, "City of things: An integrated and multi-technology testbed for IoT smart city experiments," 2016 IEEE International Smart Cities Conference (ISC2), Trento, 2016, pp. 1-8.

[8] Stefano Rinaldi, Paolo Ferrari, Alessandra Flammini, "Analisys of modular bridge platform for heterogeneous software defined networking in smart city applications", Instrumentation and Measurement Technology Conference (I2MTC) 2017 IEEE International, pp. 1-6, 2017.

[9] S. Madakam and R. Ramaswamy, "100 New smart cities (India's smart vision)," 2015 5th National Symposium on Information Technology: Towards New Smart World (NSITNSW),Riyadh, 2015, pp. 1-6. doi: 10.1109/NSITNSW.2015.7176407

[10] P. Datta and B. Sharma, "A survey on IoT architectures, protocols, security and smart city

based applications," 2017 8th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Delhi, India, 2017, pp. 1-5.

[11] N. Mohamed, S. Lazarova-Molnar and J. Al-Jaroodi, "Cloud of Things: Optimizing smart city services," 2017 7th International Conference on Modeling, Simulation, and Applied Optimization (ICMSAO), Sharjah, 2017, pp. 1-5. doi: 10.1109/ICMSAO.2017.7934875

[12] S. Kraijak and P. Tuwanut, “A Survey on IoT Architectures, Protocols, Applications, Security, Privacy, Real-World Implementation and Future Trends”, 16th International Conference on Communication Technology (ICCT), 2015.

[13] P. Datta and B. Sharma, "A survey on IoT architectures, protocols, security and smart city based applications," 2017 8th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Delhi, 2017, pp. 1-5.

[14] Brown, Eric (13 September 2016). "Who Needs the Internet of Things?". Linux.com. Retrieved 23 October 2016; https://www.linux.com/news/who-needs-internet-things

[15] Brown, Eric (20 September 2016). "21 Open Source Projects for IoT". Linux.com. Retrieved 23 October 2019; https://www.linux.com/NEWS/21-OPEN-SOURCE-PROJECTS-IOT

[16] ICT4SDG, "Internet of Things Global Standards Initiative". ITU. Retrieved 26 June 2019 https://www.itu.int/en/ITU-T/gsi/iot/Pages/default.aspx

[17] Vermesan, Ovidiu; Friess, Peter (2013). Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems. Aalborg, Denmark: River Publishers. ISBN 978-87-92982-96-4

[19] Mattern, Friedemann; Floerkemeier, Christian. "From the Internet of Computers to the Internet of Things". ETH Zurich. Retrieved 23 October 2019.

[20] M. Kretschmar and S. Welsby (2005), Capacitive and Inductive Displacement Sensors, in Sensor Technology Handbook, J. Wilson editor, Newnes: Burlington, MA.

[21] C. A. Grimes, E. C. Dickey, and M. V. Pishko (2006), Encyclopedia of Sensors (10-Volume Set), American Scientific Publishers. ISBN 1-58883-056-X

[22] Blaauw, F.J., Schenk, H.M., Jeronimus, B.F., van der Krieke, L., de Jonge, P., Aiello, M., Emerencia, A.C. (2016). Let's get Physiqual – An intuitive and generic method to combine sensor technology with ecological momentary assessments. Journal of Biomedical Informatics, vol. 63, page 141-149.

[23] T. Wauters, B. Vermeulen, W. Vandenberghe, P. Demeester, S. Taylor, L. Baron, M. Smirnov, Y. Al-Hazmi, A. Willner, M. Sawyer et al., "Federation of internet experimentation facilities: architecture and implementation," in European Conference on Networks and Communications (EuCNC 2014), 2014, pp. 1–5.

[24] A. C. Hume, Y. Al-Hazmi, B. Belter, K. Campowsky, L. M. Carril, G. Carrozzo, V. Engen, D. Garc´ıa-P´erez, J. J. Ponsat´ı, R. K˝ubert et al., "Bonfire: A multi-cloud test facility for internet of services experimentation," in Testbeds and Research Infrastructure. Development of Networks and Communities. Springer, 2012, pp. 81–96.

[25] L. Sanchez, L. Mu˜noz, J. A. Galache, P. Sotres, J. R. Santana, V. Gutierrez, R. Ramdhany, A. Gluhak, S. Krco, E. Theodoridis et al., "Smartsantander: Iot experimentation over a smart city testbed," Computer Networks, vol. 61, pp. 217–238, 2014.

[26] S. Latre, P. Leroux, T. Coenen, B. Braem, P. Ballon and P. Demeester, "City of things: An integrated and multi-technology testbed for IoT smart city experiments," 2016 IEEE International Smart Cities Conference (ISC2), Trento, 2016, pp. 1-8.

[27] Y. S. Chou et al., "i-Car system: A LoRa-based low power wide area networks vehicle diagnostic system for driving safety," 2017 International Conference on Applied System Innovation (ICASI), Sapporo, 2017, pp. 789-791. doi: 10.1109/ICASI.2017.7988549

[28] CNXSOFT: 'Comparison table of low power WAN standards for industrial applications', 2015.Available athttp://www.cnx-software.com/2015/09/21/comparison-table-of-low-power-wan-standards-for-industrial-applications/

[29] Christie, D.: 'Iot standards, Why so many?', 2019. Available at https:// www.linkedin.com/ pulse/iot-standards-why-so-many-damian-christie

[30] Suciu, G., Vulpe, A., Halunga, S., Fratu, O., Todoran, G. and Suciu, V.: Smart cities built on resilient cloud computing and secure internet of things. In Control Systems and Computer

Science (CSCS), IEEE 19th International Conference, 513-518, (2013)

[31] Gubbi, J., Buyya, R., Marusic, S. and Palaniswami, M.: Internet of Things (IoT): A vision, architectural elements, and future directions. Future generation computer systems, 29(7), 1645-1660, (2013)

[32] Geng, Hwaiyu (Ed.): Internet of Things and Data Analytics Handbook. John Wiley & Sons, (2016).

[33] Ranjan, R., Wang, L., Jayaraman, P. P., Mitra, K., & Georgakopoulos, D.: Special issue on Big Data and Cloud of Things (CoT). Software: Practice and Experience, 47(3), 345-347, (2017).

[34] Ngu, A. H., Gutierrez, M., Metsis, V., Nepal, S., Sheng, M. Z.: IoT Middleware: A Survey on Issues and Enabling technologies. IEEE Internet of Things Journal, (2016).

[35] Ray, P. P.: A survey of IoT cloud platforms. Future Computing and Informatics Journal, 1(1-2), 35-46, (2016).

[36] P. Parwekar, "From internet of things towards cloud of things," In 2nd International Conference on Computer and Communication Technology (ICCCT), pp. 329-333, IEEE, 2011.

[37] Ngu, A. H., Gutierrez, M., Metsis, V., Nepal, S., Sheng, M. Z.: IoT Middleware: A Survey on Issues and Enabling technologies. IEEE Internet of Things Journal, (2016).

[38] Geng, Hwaiyu (Ed.): Internet of Things and Data Analytics Handbook. John Wiley & Sons, (2016).

[39] Ranjan, R., Wang, L., Jayaraman, P. P., Mitra, K., & Georgakopoulos, D.: Special issue on Big Data and Cloud of Things (CoT). Software: Practice and Experience, 47(3), 345-347, (2017).

[40] R. Moghe, F. C. Lambert, and D. Divan, "Smart 'stick-on' sensors for the smart grid," IEEE Trans. Smart Grid, vol. 3, no. 1, pp. 241–252, Mar. 2012.

[41] P. C. Veena et al., “Smart street light system based on image processing,” in Proc. Int. Conf. Circuit Power Comput. Technol. (ICCPCT), Nagercoil, India, Mar. 2016, pp. 1–5.

[42] M. H. Sheu, L. H. Chang, S. C. Hsia, and C.-C. Sun, “Intelligent system design for variable color temperature LED street light,” in Proc. IEEE Int. Conf. Consum. Electron. Taiwan (ICCE TW), May 2016, pp. 1–2.

[43] A. Jain and C. Nagarajan, “Efficient control algorithm for a smart solar street light,” in Proc. 9th Int. Conf. Next Gener. Mobile Appl. Services Technol., Cambridge, U.K., 2015, pp. 376–381.

[44] K. Finch and O. Tene, “Welcome to the metropolitan: Protecting privacy in a hyperconnected town,” Fordham Urb. LJ, vol. 41, no. 5, p. 1581, 2013.

[45] Bhubaneswar’s Smart Safety City Surveillance Project Powered by Honeywell Technologies, Honeywell, Morris Plains, NJ, USA, Accessed on Sep. 2019. [Online]. Available: http://www.honeywell.com/newsroom/news/2015/05/bhubaneswarssmart-safety-city-surveillance-project-powered-by-honeywelltechnologies

[46] CHEN, Xuxu; ZHENG, Yu; CHEN, Yubiao; JIN, Qiwei; SUN, Weiwei; CHANG, Eric; MA,Wei-ying. Indoor Air Quality Monitoring System for Smart Buildings. 2014, pp. 2–6. ISBN 9781450329682.

[47] PAN, Gang; QI, Guande; ZHANG,Wangsheng; LI, Shijian; WU, Zhaohui. Trace Analysis and Mining for Smart Cities: Issues, Methods, and Applications. 2013, no. June, pp. 120–126.

[48] A. Salkham, R. Cunningham, A. Garg, and V. Cahill, “A collaborative reinforcement learning approach to urban traffic control optimization” in Proc. IEEE/WIC/ACM Int. Conf. Web Intell. Intell. Agent Technol., vol. 2. Dec. 2008, pp. 560-566.

[49] I. Arel, C. Liu, T. Urbanik, and A. G. Kohls, ``Reinforcement learning based multi-agent system for network traffic signal control," IET Intell. Transp. Syst., vol. 4, no. 2, pp. 128-135, 2010.

[50] S. El-Tantawy, B. Abdulhai, and H. Abdelgawad, “Multiagent reinforcement learning for

integrated network of adaptive traffic signal controllers (MARLIN-ATSC): Methodology and large-scale application on downtown Toronto” IEEE Trans. Intel. Transp. Syst., vol. 14, no. 3, pp. 1140-1150, Sep. 2013.

[51] Jin, J., Gubbi, J., Marusic, S., et al.: ‘An information framework for creating a smart city through Internet of things’, IEEE Internet Things J., 2014, 1, (2), pp. 112–121

[52] ANTHOPOULOS, Leonidas; JANSSEN, Marijn. Smart Service Portfolios: Do the Cities Follow Standards-1895, pp. 357–362. ISBN 9781450341448

[53] CHEN, Xuxu; ZHENG, Yu; CHEN, Yubiao; JIN, Qiwei; SUN, Weiwei; CHANG, Eric; MA,Wei-ying. Indoor Air Quality Monitoring System for Smart Buildings. 2014, pp. 2–6. ISBN 9781450329682.

[54] R. A. Irvin and J. Stansbury, “Citizen participation in decision making: Is it worth the effort?,” Public Adm. Rev., vol. 64, no. 1, pp. 55–65, 2004.

[55] J. B. Rosener, “Citizen Participations: Can We Measure Its Effectiveness?” Public Adm. Rev., vol. 38, no. 5, pp. 457–463, 1978.

[56] P. Lombardi, S. Giordano, H. Farouh, and W. Yousef, “Modelling the smart city performance,” Innov. Eur. J. Soc. Sci. Res., vol. 25, no. 2, pp. 137–149, 2012.

[57] W. H. Voorberg, V. J. J. M. Bekkers, and L. G. Tummers, “A Systematic Review of Co-Creation and Co-Production: Embarking on the social innovation journey,” Public Management. Rev., no. July 2014, pp. 1–25, 2014.

[58] European Commission, “Living Labs for user-driven open innovation,” 2009. [Online]. Available: http://bookshop.europa.eu/is-bin/INTERSHOP.enfinity/WFS/EUBookshop- Site/en_GB/-/EUR/ViewPublication-Start?PublicationKey=KK3008803. [Accessed: 26-Nov-2019].

[59] M. Pallot, B. Trousse, B. Senach, and D. Scapin, “Living Lab Research Landscape: From User Centred Design and User Experience towards User Cocreation,” Technol. Innov. Manag. Rev., vol. 1, pp. 19–25, 2010.

[60] M. Batty, K. W. Axhausen, F. Giannotti, A. Pozdnoukhov, A. Bazzani, M. Wachowicz, G. Ouzounis, and Y. Portugali, “Smart cities of the future,” Eur. Phys. J. Spec. Top., vol. 214, no. 1, pp. 481–518, 2012.

[61] L. Berntzen and M. R. Johannessen, “The Role of Citizen Participation in Municipal Smart City Projects: Lessons Learned from Norway,” in Smarter as the New Urban Agenda, Switzerland: Springer International Publishing, 2016, pp. 299–314.

[62] J. I. Criado, R. Sandoval-Almazan, and J. R. Gil-Garcia, “Government innovation through social media,” Gov. Inf. Q., vol. 30, no. 4, pp. 319–326, 2013.

[63] M. Janssen, Y. Charalabidis, and A. Zuiderwijk, “Benefits, Adoption Barriers and Myths of Open Data and Open Government,” Inf. Syst. Manag., vol. 29, no. 4, pp. 258–268, 2012.

[64] A. Alnahdi and S. H. Liu, "Mobile Internet of Things (MIoT) and Its Applications for Smart Environments: A Positional Overview," 2017 IEEE International Congress on Internet of Things (ICIOT), Honolulu, HI, 2017, pp. 151-154. doi: 10.1109/IEEE.ICIOT.2017.26

[65] Catriona MANVILLE, Gavin COCHRANE, Jonathan CAVE, Jeremy MILLARD, Jimmy Kevin PEDERSON, Rasmus Kåre THAARUP, Andrea LIEBE, Matthias WISSNER, Roel MASSINK, Bas KOTTERINK (2014). Mapping Smart Cities in the EU, PE 507.480.