UNIVERSITY OF THE AEGEAN

MASTER THESIS

Security and Privacy Issues in Smart City Infrastructure with Emphasis on Mobility

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Abstract

The increasing boost in urbanization creates more issues including traffic congestion, transportation delays, vehicle pollution emissions, accidents, which affect significantly our lives. A promising solution to challenges of this emerging era, is technological innovations that improved human conditions with a wise management of natural resources. The continuous development of Internet of Things ecosystems will provide an intelligent platform to include technology in our daily lives and offer the chance to strike a balance between economic, environmental, social opportunities that will be delivered through smart city planning, design and construction. Smart city is a demonstration of the Internet of Things, in which the generated data from the sensors can be processed, combined, communicated, integrated and analysed to support some aspects of the city life to function better. In the beginning of a new era, citizens will get used to a new way of living, where everything happens instantly and tailored to their needs. In this thesis, we elucidate the concept of smart city, by defining its essential technologies, key challenges and the major components of a smart city. We present smart mobility projects enabled by the top five smartest cities around the world and we define a framework for security and privacy issues on smart parking, smart traffic control and shared vehicles.

Acknowledgements

This research project would not have been possible without the support of many people. Foremost, I would like to express my gratitude towards my supervisor Panagiotis Rizomiliotis who was very helpful and offered constant support, guidance and assistance. I am also grateful to my parents and my family who supported me.

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List of Abbreviations

GPS	**G**lobal **P**ositioning **S**ystem
IoT	**I**nternet **o**f **T**hings
ICT	**I**nformation **C**ommunication **T**echnology
IEEE	**I**institution **E**lectrical **E**lectronic **E**ngineering
CCTV	**C**losed **C**ircuit **T**elevision
AV	**A**utonomous **V**ehicles
CV	**C**onnected **V**ehicles
EV	**E**lectric **V**ehicles
WSNs	**W**ireless **S**ensor **N**etworks
SDVs	**S**elf **D**riving **V**ehicles
ITS	**I**ntelligent **T**ransport **S**ystem
IPT	**I**ntelligent **P**ublic **T**ransport
M2M	**M**achine **t**o **M**achine
RFID	**R**adio **F**requency **I**dentification
VMS	**V**oice **M**ail **S**ystem
PKI	**P**ublic **K**ey **I**nfrastructure
TPM	**T**rusted **P**latform **M**odule
CCs	**C**onnected **C**ities
SCs	**S**mart **C**ities
RF	**R**adio **F**requency
LTE	**L**ong **T**erm **E**volution
IT	**I**information **T**echnology
SCOOT	**S**plit **C**ycle **O**ffset **O**ptimisation **T**echnique
UTC	**U**rban **T**raffic **C**ontrol

Dedicated to my family…

Chapter 1

Introduction

1.1 Motivation and Background

In the last two decades, urban centres have become the destination of choice for citizens and businesses, leading to a significant increase in global energy consumption, the abandonment of rural areas and rapid population growth. Researchers observe an impressive growth of urbanization, due to the fact that 70 percent of the citizens will live in cities. The rural population of the world is now close to 3.4 billion and is expected to decline to 3.2 billion [17] by 2050. Rural territories have to face desertification, particularly since the industrial revolution when people started to move in populated urban areas due to economic activities. Manufacturing and service industries need suppliers and customers to produce and consume their products and services. Thus, as the world continues to urbanize, sustainable development challenges will be increasingly concentrated in cities, particularly in the countries with lower-middle incomes where the pace of urbanization is fastest.

FIGURE 1.1: Rural areas

On the other side, urban territories have to face a huge demographic pressure and unsustainable urbanization. The increasing demands for energy, water, education, healthcare, housing, transport and public services are testing the limits of city infrastructure. Globally, high urban density brings serious challenges including emission problems, huge congestion, water pollution, inadequate transportation, inefficient bureaucratic processes, more waste, usage of more resources, increases in crime, inequalities and unemployment. Moreover, it generates significant pressure on delivery of services, overwhelming transport and housing systems, health and natural disasters and an expanding informal settlements driven by rural migrants. At the same time, urban centres offer amazing opportunity for economic and social development, market creation and climate change adaptation because of their capacity to attract business and create jobs to drive that growth. This investment will also generate a range of new services focused on improving processes, managing change and building workforce skills related to the expected increase in technology enabled urban management in various city sectors. In addition, cities are increasingly competing with each other on a global basis for investment and business.

FIGURE 1.2: City

More multidisciplinary scholarly communities, study the dynamics and transformation of cities to digital, intelligent, resilient, smart and sustainable entities. Since the beginning of the 21st century, there is an impressive growth of smart cities initiatives worldwide and publications in this field. The smart city concept is a key strategy to tackle poverty and inequality, unemployment and energy management. Also, the city will be automated to enable daily functions to be delivered effectively, without the need of direct human intervention. Smart cities are designed, constructed and maintained by using highly advanced integrated technologies and will provide an intelligent platform to include technology within the society. The main technology is the Internet of Things (IoT), which combines aspects and technologies from ubiquitous computing, wireless sensors networks (WSNs), communication protocols, sensing technologies and embedded devices. However, the huge number of interconnected devices as well as the significant amount of data generated provides various problems including large connectivity, interoperability, security, privacy, safety and legal issues.

FIGURE 1.3: Smart City

As a consequence, all the challenges need to dealt in a smarter approach in order to change human behaviour with the better use of data and innovative technology.

1.2 Scope

With the world's exponential population growth, the 21st century will see more people living in cities than in rural area. The objective of smart cities is to optimize the city in a dynamic way in order to offer a better quality of life to the citizens. It can monitor and integrate status of all their infrastructures, management, governance, people and communities, health, education and natural environment through the application of Information and Communication Technology (ICT). A smart city is a complex concept, including a wide range of issues and at the same time providing better life for its citizens. It involves various services in different components including mobility, communication and critical infrastructure.

FIGURE 1.4: The characteristics of a smart city [22]

The conceptualisation of Smart City varies from city to city and country to country, depending on the level of development, willingness to change and reform, resources and aspirations of the city residents. Building up smart cities requires technological innovations and the development of the right environment for smart solutions to be effectively adopted and used. The development of a smart city requires participation, public-private partnerships, ideas, awareness and expertise from a wide range of stakeholders. But, *how will technology ensure that cities are managed efficiently today, tomorrow and in the future?*

The main contributions of this study include: a repository of the main goals, components and initiatives of a smart city; identification of major challenges that smart cities are facing; the findings from the case study analysis in the smart mobility innovations of the top five smartest cities according to Juniper Research [20]; a framework for defining security and privacy issues on major smart mobility innovations and determining the appropriate requirements. More precisely, we identify the core requirements in smart parking, smart traffic control and shared vehicles in context of information security.

1.3 Outline

This study introduces the notion of Smart City and provides an overview about the security and privacy challenges of smart mobility innovations in smart cities. Furthermore, we analyse smart parking solution being used to cope with security and privacy requirements on deployment and management. We address the main issues related to security and privacy that we should taken into account in the design of a secure and trusted smart parking system. Likewise, we analyse the smart traffic control system and the shared vehicles in the context of security and privacy. More precisely, the dissertation is organized as follows and falls into five main sections:

In Section 2, we give an overview of current situations in modern cities and observations about world's population. Moreover, we identify the main goals of a smart city as well as the various issues that need to be addressed.

In Section 3, we present the smart mobility projects that are used as indicators describing how smart mobility is, in a global context. We describe smart city initiatives and develops them into case studies.

In Section 4, we investigate security threats that many of the smart mobility innovations could encounter. We present the smart parking architecture followed with security analysis by beginning with threat models. Based on the findings from the previous analysis and the projects learnt from the case studies, a framework for defining security and privacy requirements in smart mobility innovations is introduced in this Section. These requirements are used as the constraints for developing an architecture for integrated security awareness. We have analysed it from the perspective of security and privacy.

In Section 5, we develop a threat model in the context of information and privacy security, with the aim of deciding which security functions are required. Based on this, security requirements are defined, with common sense for the three analysed mobility innovations. Finally, we conclude with a piece about the future direction of improvement tactics.

Chapter 2

Smart City

The concept of smart city interconnects different operators and services in order to improve functionalities and the quality of life for its citizens. Have to rely on an Information and Communication Technology architecture to retrieve, process and exchange data. In the research of smart cities will be useful to investigate, what they are and how cities implement their smart city ambitions in practical projects taking into account various issues.

2.1 Modern cities

The aim of this section is to introduce the urbanization trend and discuss some of the urbanization challenges. Today, the growth of modern cities is an unpleasant situation in the history of urbanization. By 2050, more than half of the world's population will soon be living in urban areas according to a recent forecast by the United Nations [17]. But, are cities ready for this evolution? Cities are facing lots of challenges such as security, privacy and legal issues, inadequate transportation, attacks on city infrastructure and public services. Alongside increased pressure on resources from urban migration, the sustainable development seems difficult task due to governance and environmental issues. Moreover, the human migratory pressures from rural areas to urban areas will continue and 70 per cent of the world's population is projected to be urban.

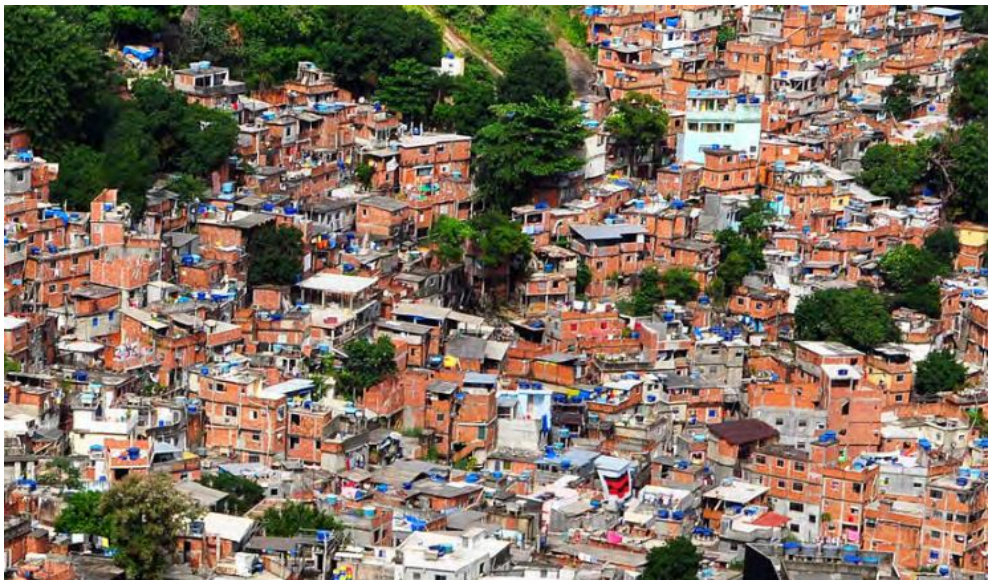

FIGURE 2.1: Urbanization [17]

Digital technologies can help cities to address the problems effectively, improving the planning, design of the whole infrastructure. It is about an evolution of "Connected Cities" (CCs), in which ICT is used to connect field components via data transmission networks with data centres where the data processing happens taking into account mostly the data of the individual operator. CCs are characterized by independent operators that manage one or multiple systems from their own control centre with limited interactions among each other. Smart Cities are an extension of the CCs with data integration and task automation managed by a global decision process. They are characterized by data aggregation connectivity allowing smart processing of data taking into account data of several related operators and stakeholders [15]. The major difference between Connected Cities and Smart Cities is the prevalence of data exchange of the latter at a larger scale.

However, time and space are two major changes in our modern societies, which deeply modify fundamental reality of human lives and are getting nearer to innovation and new technologies. A growing impact of digital technologies in all the sectors of our lives, such as politics, health, economy, culture, transportation systems leads us in the beginning of a new era. To address these challenges, governments are embracing the concept of the smart city and looking for new technological approaches to improve sustainability and quality of life for citizens. Creative industries are transforming many urban areas economically, spatially and socially. The challenges of modern cities are changing rapidly, creating more waste, carbon emissions and other sustainability issues, therefore it is crucial to create new, sustainable and resilient solutions.

2.2 Smart city definition

There is no universally accepted definition, because it means different things to different people in different parts of the world. For us, smart cities are ultra-modern urban areas that address the needs of businesses, institutions and especially citizens. The concept of smart cities is not only in terms that we can automate routine functions serving individual persons, traffic systems, but in ways that enable us to monitor, understand, plan and design the city to improve: (i) sustainability, (ii) efficiency, (iii) quality of life for its citizens in real time. Smart city interconnects different operators and services to improve functionalities. We can achieve it through the application of ICT in order to retrieve, process and exchange data. It is designed, constructed and maintained by using highly advanced integrated technologies, that include sensors, electronics and networks which are linked with computerized systems comprised of databases, tracking and decision-making algorithms.

The main ambitions are:

- Improvement of the functions of the physical and digital infrastructure and service provision of the city through the utilisation of novel technologies and innovative organisational schemes.
- Development of Innovation and Entrepreneurship based on knowledge-intensive and creative activities in order to enhance the local competitiveness. To achieve this, linking knowledge institutions (e.g. universities, research institutes, training bodies) with the productive, cultural and creative sectors is essential.
- Retrofitting of old buildings and reuse of abandoned spaces for hosting new business ventures, creative and cultural activities.

Other goals for further understanding the importance for the development of smart cities are identified: (i) providing smart transportation system, (ii) building smarter economy or finding potentialities for new revenue streams and services, (iii) improving public safety and finding ways of making the knowledge from the information and communication systems useful to ordinary users, (iv) implementing a legal framework for better health and education. To achieve, it is necessary the usage of advanced visualisation and simulation tools, e-Learning platform and knowledge management, ecological systems to satisfy the social and human concerns.

This notion offers an effective way to counter and manage uncertainty, risk dealing with the problems of an ageing population in order to make urban areas energy efficient, comfortable, environmentally-friendly and safe as depicted in Fig. 2.2. It helps with the problems of air pollution, urban growth, natural and manmade disasters, health and contaminated sites.

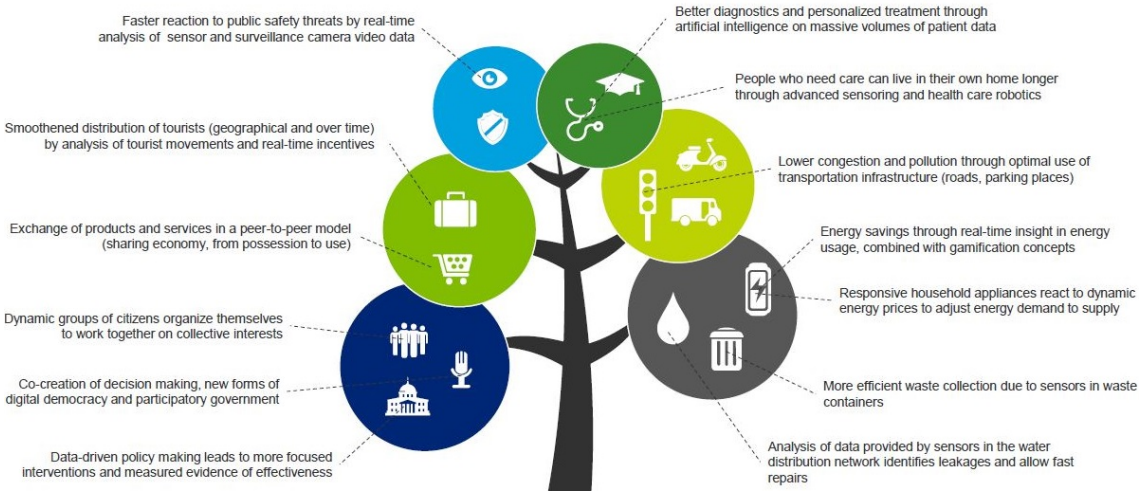

FIGURE 2.2: Potential benefits of the smart city [8]

2.2.1 Essential technologies

Smart city initiatives are solely dependent by a combination of digital technologies in order to leverage data and services, connect city stakeholders and improve citizen involvement. A smart city is an urban development vision that has incorporated ICT and IoT technology within the city facilities. The Institution of Electrical and Electronic Engineering or IEEE, defines the Internet of Things as a network that connects uniquely identifiable things to the Internet. Things refer to every object capable of connecting to the Internet, including smart computational devices, sensors and any other entity that is able to communicate with other connected objects. The interconnected things have physical and virtual representation in the digital world with sensing, actuating and computing capability. Their presentation contain information about the thing identity, location, status or any other relative information.

FIGURE 2.3: Internet-of-Things

This has allowed for continuous data monitoring, data capture using sensors, improved data analytics and the development of business strategies. Summarizing, the interconnected key infrastructure in order to make cities smarter, includes:

- *Networks of sensors:* Installed under roads generating data in huge amounts known as "big data", that are integrated into real objects such as cars, devices in land transport allowing real time insights. For instance, traffic sensors, building management systems, digital utility meters can be used for the control and operation of urban infrastructure.

FIGURE 2.4: Networks of sensors

- *Cloud computing:* Cloud combines virtualisation, automation and IT service management capabilities to revolutionise a company's business operations, making them better, cheaper and faster. It can provide storage for the interconnection of data, things, people and applications.

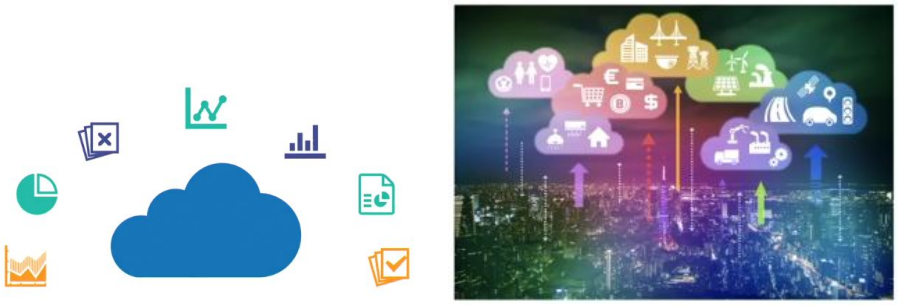

FIGURE 2.5: Cloud Computing

- *Networks of digital communications:* The growing fixed and wireless networks allow sensors and systems to be connected to distributed processing centres in order to exchange information. Once the information is generated, the network allows it to be transported to a server. There are many communication paths facilitating interconnection of sensors and devices through a diversity of protocols and standards. The communication media itself can be fairly diverse (*e.g.*, wireless Internet connection, radio frequency, 4G/LTE).

- *Machine-to-Machine (M2M) solutions:* M2M refers to those solutions that allow communication between devices of the same type and a specific application, through wired or wireless communication networks. It is deployed to achieve productivity gains, reduce costs and increase security for the purposes of monitoring and control or to provide connectivity of remote machine-type devices.

- *Real-time Analytics:* When information from different places on the network has been collected at a central location, it needs to be processed for optimization purposes. Real-time knowledge about the city can be accessed by every person or systems to help achieve their goals, within the context of the overall effective functioning of the city. Analytics will be used, so that this knowledge can be used effectively.

FIGURE 2.6: Analytics

- *Big Data:* The smart cities can extract very important information helping real time analysis and ubiquitous computing provides various opportunities for smarter life. However, it brings challenges of security, privacy, protection and resilience. Challenges include lack of tools for management of big data, third party data sharing, threats in growing public databases, data leakage or concerns on digital security.

- *Data Analysis and Modelling:* The development of data analysis techniques, using models allow the low-level information to be interpreted by processing centres and individuals. For instance, modelling can be useful for mobility and transport behaviour, urban land use transport, urban market transactions and urban supply chains.

- *Artificial Intelligence:* Intelligent machines and software are capable of learning, understanding complex problems and devising solutions. This technology converts the social web into semantic web, where the context-awareness transforms mere information to valuable knowledge. Thus, we can learn more about how people use cities to optimise the use of these resources and to improving public safety in cities.

- *Localization techniques:* The development of localization techniques (*e.g.,* GPS, GSM, WiFi, Bluetooth, RFID) is becoming increasingly important, because traces provide important information on the mobility of the moving objects in a city. It will benefit various applications such as transportation, health, commerce, urban planning and public safety.

- *Blockchain:* This technology is a distributed append-only ledger of transactions maintained by a number of untrusted miners organized in a distributed network. Intermediaries and record keeping will facilitate the transfer of assets and create trust. Blockchains enable novel security mechanisms, because there is no centralized trusted entity and no single point of failure. Thus, it can prevent censorship, facilitate accountability and provide transparency and scalability. Many critical operations of a smart city and an IoT system in particular, can be delegated to blockchains in order to be more secure and resistant against cyber attacks.

These technologies are merged together with city systems to an environment, where the real and digital world meet and interact continuously. The combination of them is even more powerful and creates a better environment to improve both the quality of life and accessibility for their inhabitants. However, citizens should be keep informed on changes and thus interacting and adapting to their needs in real time.

2.2.2 Challenges

Our society becomes more vulnerable for cyber threats as much more data is stored digitally and a large number of physical objects becomes connected to the Internet. Main problem with IoT is that the priority has been to make it works and not to makes it work securely. It made it insecure. Even worse, beyond the IoT comes the Internet of everything, including humans, cloud and every computing resource on the planet [16]. Therefore, we present some of the major challenges that we need to address.

- *Interoperability:* Over 300 different IoT platforms and several dozens of standards have deployed. However, the challenge is that many different IoT communication protocols will co-exist and most of the deployed IoT systems are closed due to largely incapable of communicating with other IoT systems.

- *Connectivity:* There is a giant network of connected things, which also includes people, relationships between people to people, people to things and things to things. Smart cities are characterized by large number of data and physical objects with an online connection to the Internet, which increase the possibilities of criminal activities. Interconnections introduce new vulnerabilities, due to the fact that the more we connect things to each other, the more vulnerabilities in one thing affect other things.

- *Large category of applications and protocols within the network:* This will causes vulnerabilities for hacking and as Marc Goodman said "More connections to more devices means more vulnerabilities. If you control the code, you control the world".

- *Security issues:* The goal of information security is to protect the information from attacks, viruses, frauds and many other vicious activities that may cause harm either to the information or the need of information in the technologically embedded smart cities. It is observed the increase in cyber events, due to poorly secured IoT devices and applications. Furthermore, one of the security challenges is the service continuity because lots of devices are designed to be used on a specific scale but the quantity of connection links between these devices is larger. Existing security solutions cannot be directly applied to things due to limited resources. There is no computational power for complex cryptographic operations, things are often exposed physically to malicious users and the remotely connection is not always feasible. However, we need to address the problems because the various Things can collect sensitive and personal information and may control critical aspects of our daily lives.

- *Physical security issues:* Some of the devices are being used in urban areas, where physical security is difficult to establish because makes it easy for attackers to have a direct physical access to the IoT devices.

- *Trust model:* It is necessary a trust framework to enable users of systems to have confidence that the information and services being exchanged is in a secure environment, due to multiple ownership entities. Also, a new trust model is needed to enable the interaction of all devices with little human intervention. To achieve this, we need novel mechanisms for transactions and accountability.

- *Privacy concerns:* The privacy of individuals is a fundamental right that should be guaranteed in a smart city. Data about our purchases, geographic location, movements, health records, photos or the websites we visit is stored somewhere in the digital ecosystem. It is obvious that lots of digital systems could be hacked with unauthorized access to personal data and predicting conclusions from data analytics. Because of the pervasive and invisible aspects of the IoT, information may be collected for a long time before it becomes known and its impact felt. Thus, there are crucial issues about the *storage of personal data in the cloud* or the private data collection from public interactions. Also, a key issue is the lack of opportunity in a smart city environment for the giving of meaningful *consent to processing of personal data*. In Internet of Things systems, we should consider *where data is collected in public-sector activities* e.g. smart roads or smart transport systems to manage the transportation. Another concern identified is *how ordinary users will feel of control* over the processing of their data and whether they will participate enough to help city make smarter. To achieve the privacy of systems, we should gather data and trigger emergency response when needed. The giving of minimum consent to processing of personal data, is essential. Moreover, IoT device manufacturers

need to have a plan during the designing process of the device, to ensure that the device itself has the required privacy layers (privacy-by-design). Another solution could be by cryptographic techniques that enable sensitive data to be stored, processed and shared without having the information content accessible by outside parties.

- *Legal issues:* Smart applications need to have some regulations and protection laws. The compliance is important with national interoperability standards and legal framework.

- *Resilience:* An increasing dependency on digital technologies can cause failures, accidents, attacks by malicious attackers. We need to prepare for and adapt to changing conditions and recover rapidly from unpleasant situations in order to make the digital infrastructure more resilient. Smart solutions consist of ensuring continuity of critical services, incident response and crisis management.

- *Technical challenges:* Making a building intelligent to optimize its energy management does not only consist of connecting it to the Internet. It also means allowing other tools and systems to communicate with such data as frequentation and temperature. This is a technical challenge that all cities must first tackle in order to have an efficient urban planning.

Despite the many issues, a new way of thinking with an emphasis on taking a systems perspective, will be required to address these challenges. It could happen by promoting citizen participation, developing innovative solutions for sustainability, enhancing security, privacy and safety, increasing efficiency, resilience in city systems and adopting a transparent and inclusive governance system [6].

2.3 Major components of a Smart City

The smart city is an "umbrella" term, in which a large number of actors can be involved in smart city fields and can contribute to smart city subsystems. As defined by the European project "Smart City", the smart city is distinguished in six organizational fields.

1. Smart Mobility
2. Smart Governance
3. Smart Environment
4. Smart Economy
5. Smart People
6. Smart Living

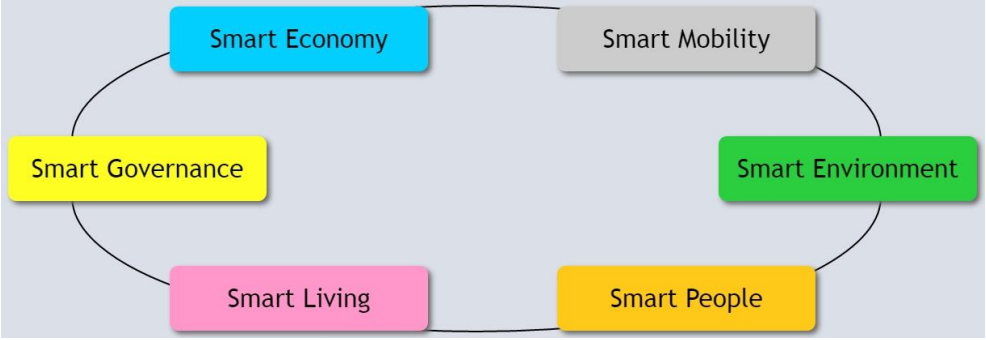

FIGURE 2.7: The European smart city model [9]

As we mentioned above, smart cities focused on enhancing urban life regarding six dimensions: mobility, governance, people, living, economy and environment (Giffinger *et al., 2007*) [9].

2.3.1 Smart Mobility

Smart mobility solutions relates to aspects of availability and accessibility of information and communication technologies and sustainable transport systems, aiming at reducing traffic congestion and providing faster, greener, cheaper transportation options. Due to growing vehicle population and limited land, ITS systems would play an important role to improve mobility for citizens and industries. There are no smart cities without smart mobility. Smart mobility covers how future use and development of the transport system will utilize Information and Communications Technology (ICT) to make the system more efficient, safe and comfortable. The major goals are various from tacking congestion, improving air quality, accessibility to sustainability in cities, by providing better options for urban transport.

Making new services available to citizens, such as real-time guidance on how best use multiple transportation modalities. Most of smart mobility solutions based on innovation, a rethink of public-private sectors cooperation and how to engage citizens more directly in new mobility systems and services. Representative examples are technology-enabled and integrated transport with logistic systems, such as:

- *Sustainable delivery* → It means better deliveries of goods. The popularity of online shopping has led to more delivery trucks visiting residential areas with resulting increases in emissions, noise levels and traffic hazards. Smarter, integrated deliveries will cut overall traffic and provide better information on delivery times, while the use of cleaner vehicles will help to reduce local pollution levels.
- *Smart traffic management* → Improvement in street environment could achieved by a system, where controlled traffic signals and sensors regulate the flow of traffic through the city in response to demand.
- *Alternative fuel driven vehicles* → Today's options for alternative fuel driven vehicles are various, from electric cars and propane vehicles to natural gas-powered buses and trucks.

FIGURE 2.8: Smart mobility

To summarizing, there are some main trends in smart mobility:

1. Connectivity: Smart cities rely on the IoT and networked sensors to solve a variety of local problems. Connected vehicles (CV) need to handle mixed traffic situations and not to slow the connected system.
2. Automation: Self-driving autonomous cars are a rapidly evolving technology with already some advanced prototypes. Also, we should consider how the autonomous vehicles (AV) will help for alleviating traffic congestion.
3. Multimodal vision: It can provide door-to-door paths using most efficient combination of transport modes and mobility as a service.
4. Shared-use modes: The shared use of a vehicle, bicycle or other travel modes is an innovative transportation strategy, that enables users to have short-term access to a mode of transportation. Due to the fact that transportation has to compete for land use against housing, buildings, economic infrastructure or other essential needs.

However, the society is not completely ready for the transport evolution because of the fact that many vehicles are powered by oil, alternative fuels are under-used, public and other transport services are not always well connected. It will require changes in the transport system, operations, mobility behaviour of people and businesses.

2.3.2 Smart Governance

Smart governance compromises aspects of political participation, services for citizens as well as the functioning of the administration [4]. Including flexible governance structure, technology enabled decision mechanisms, smart regulation to connect city laws to new digital realities, and innovation clusters to create jobs and vibrant economies. Smart city governance means long term political vision, cooperation, public-private partnerships, using innovative technical solutions.

Major goal is to show how city managers can collaborate to improve resilience and demands for energy, water, transportation by technology-enabled policy and governance processes via modern day communication channels. The latest enables an open dialogue between citizens and officials, offering fruitful conversations and feedback used by city officials for informed decision processes. Moreover, it tries to address the issues by optimization of public services, direct involvement in public policies and increasing demand for transparency.

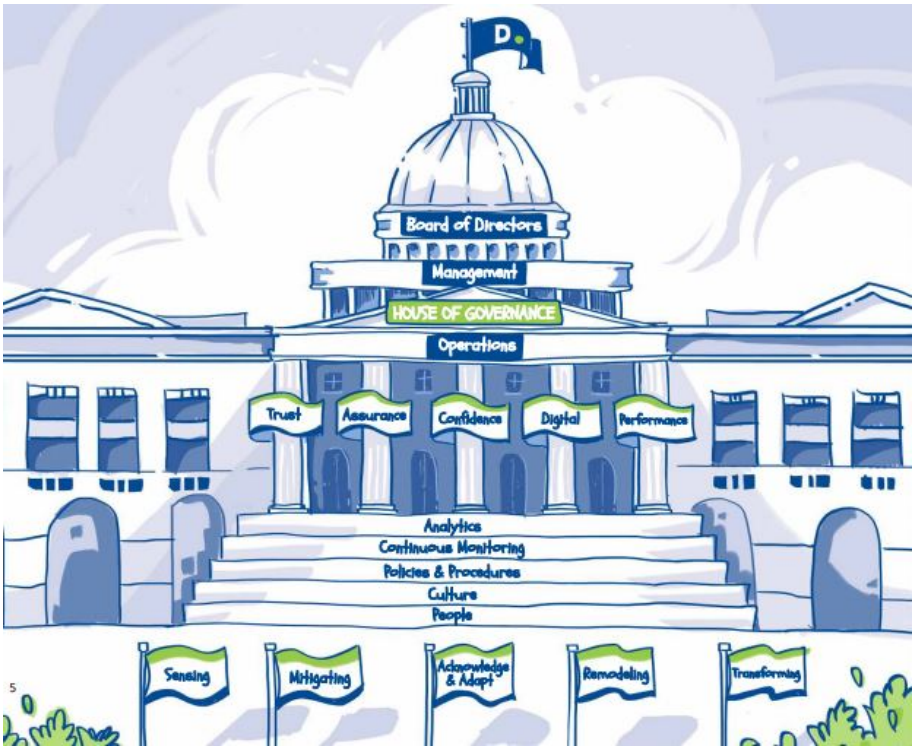

FIGURE 2.9: Smart Governance [25]

2.3.3 Smart Environment

The growth of modern cities leads to the growth of urban environmental problems, which need to address them in order to ensure the the protection of the environment. Smart environment is described by attractive natural conditions (e.g. climate, green space), resource management and can include applications of IoT for the environmental monitoring. More precisely, the goals of this effort are water safety, extreme weather monitoring, species protection and commercial farming. Examples are technology-enabled energy grids, waste management and other initiatives for reducing pollution, the need for energy, the greenhouse gas emissions and emissions of transport.

It is crucial for a city to adopt ecological practices to protect its environment. The application of information technology in smart environment can reduce resource consumption, manage of waste disposal in cleaner ways, maintaining pollution free air, water treatment plants, etc., to provide a cleaner and greener environment to citizens.

FIGURE 2.10: Smart environment

2.3.4 Smart Economy

Due to continuing urbanization, there are many concerns about economic restructuring. Smart economy includes factors around economic competitiveness such as innovation, entrepreneurship, productivity and flexibility of the labour market. Building smart economy, promises smarter economic growth and reduce costs for energy, maintenance, investment in the international market. Examples are technology-enabled production and delivery of products and services to create a city with a healthy, dynamic and responsible economy. Viable and sustainable business opportunities and the presence of innovative enterprises, clubbed with quality education and infrastructure to provide better economic status to the city.

Another solutions is the phenomenon of sharing economy, that has allowed for individuals to be able to borrow or rent assets owned by someone else, through social and online transactions. Uber and Airbnb are prime examples of the sharing economy in action.

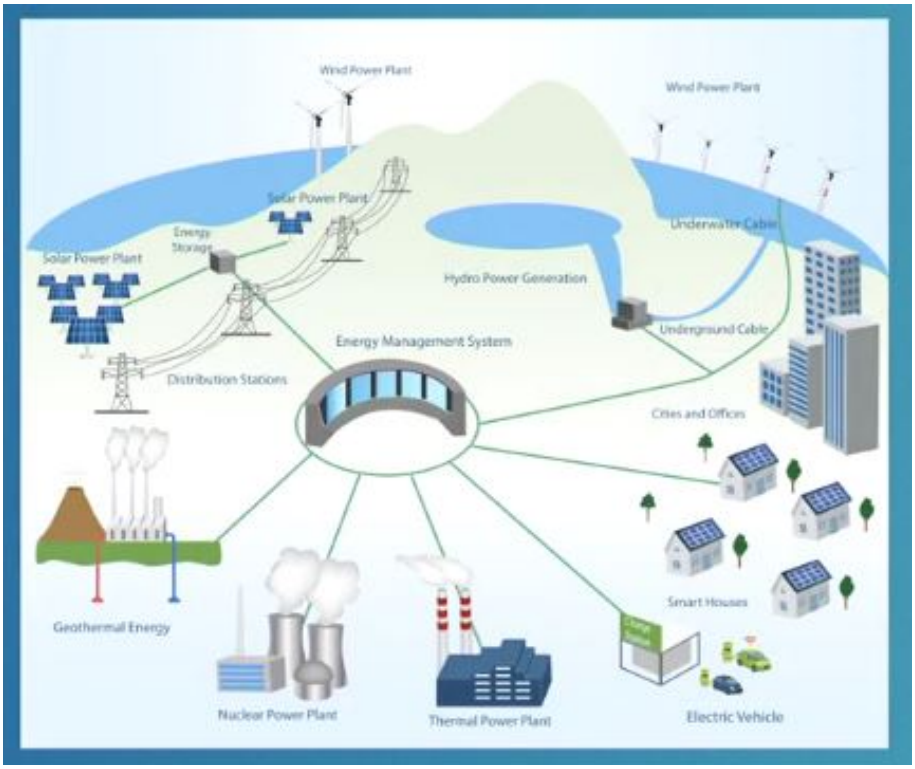

FIGURE 2.11: Smart economy

2.3.5 Smart People

Smart People are not merely described by the level of qualification or education of the citizens, but regarding to quality of social interactions. People will be able to connect to the Internet in innumerable ways. Today, most people connect to the Internet through their use of devices (*e.g.*, PCs, tablets, TVs, smartphones) and social networks (*e.g.,* Facebook, Twitter, Pinterest, LinkedIn). The continual interaction enables citizens to be more open and inclusive, in order to work together effectively.

Smart people can manage the life of the city for their benefit, by creating dynamic communities. Services, notifications, and information to citizens, such as where to find a parking spot or even to monitor air pollution can connect citizens to local government and encourage more direct participation, interaction, and collaboration. Cities will learn from one another, communicate, share experience and information while promoting social inclusion and quality of life for its residents.

FIGURE 2.12: A smart city needs smarter people

2.3.6 Smart Living

Smart Living is a trend encompassing advancements that give people the opportunity to benefit from new ways of living. It involves innovative solutions aimed at making life more efficient comfortable, productive and sustainable. This revolution focus on human lives and the home is the major component for smart living. Moreover, it comprises various aspects of quality of life as culture, health, safety, housing and tourism.

The application of information technology in smart living can improve the utilization of existing infrastructure capacity, improving quality of life and reducing the need for traditional construction projects. Technologies to integrate and analyse massive amounts of data to provide better living to citizens in the form of childcare facilities, community libraries, entertainment modes and hospitals according to area needs.

FIGURE 2.13: Smart home

Chapter 3

The Smartest Cities

According to Juniper Research, that was done in Hampshire and published in the 17th of May 2016, the top 5 Smartest Cities are Singapore, Barcelona, London, San Francisco and Oslo [20]. The below cities are transforming themselves, constructing and testing their smart models. They have already launched some "Smart Cities" projects, creating a more sustainable and efficient environment. But, *how smart cities are changing the way we move?* We provide examples of smart mobility projects from across the world, by exploring case studies of these smart cities.

3.1 Singapore

Singapore was named as "Global Smart City 2016", according to Juniper's Smart City Rankings and the smart city initiatives established by the Smart Nation in 2014. Urban mobility moves to a new level, where ITS systems do not depend on infrastructure, but the emphasis is on data collection, analytics and the availability of useful information on the move. The Smart Nation initiative is coordinated by the Smart Nation and Digital Government Office in the Prime Minister's Office, supported by other government agencies. The vision of Smart Nation is to use technology to solve society problems and address existential challenges. It focuses on five key domains, that will have significant impact on the citizen and society [18]:

1. Transport
2. Home and environment
3. Business productivity
4. Health and enabled ageing
5. Public sector services

Traffic congestion and mobility are almost global issues for cities like Singapore, to address and when they addressed effectively, the results are substantial. The increase in population and in vehicles creates key urban transportation challenges such as land constrains, increased travel, shortage of labor, vehicle pollution. Its smart city strategy aims at making Singapore a well-connected society, which will enhance Singapore's economic competitiveness and enrich people's lives.

FIGURE 3.1: Singapore city

This country in Asia is a world leader in applying smart mobility policies and technology. Representative examples are the following:

– *Smart Mobility 2030:* The ITS strategic plan for Singapore announced at the end of 2014, where Intelligent Transport Systems would play an important role in enhancing transportation services to maintain pleasant mobility experiences. To reduce congestion, all motor vehicles will be fixed with a in-vehicle (IV) unit which will alert drivers of road situations and provide real time traffic information.

FIGURE 3.2: In-vehicle unit

The plan focuses on three key strategies: (i) establish close partnerships and co-creation, (ii) implement innovative and sustainable smart mobility solutions, (iii) develop and adopt ITS standards. Its main objectives are self-driving cars and satellite based road pricing.

- Self-Driving Buses

  The testing of self-driving buses introduced in the second half of 2016 and they will operate on fixed routes and scheduled timings. Its main goals are to provide convenient transport mode within cities, help reduce the dependence on private cars and manpower and give to citizens information about traffic density, nearby road work. It is required the installation of short-range communication beacons to help the vehicles find their way more easily and the usage of CCTV to monitor the network.

FIGURE 3.3: Self-driving buses

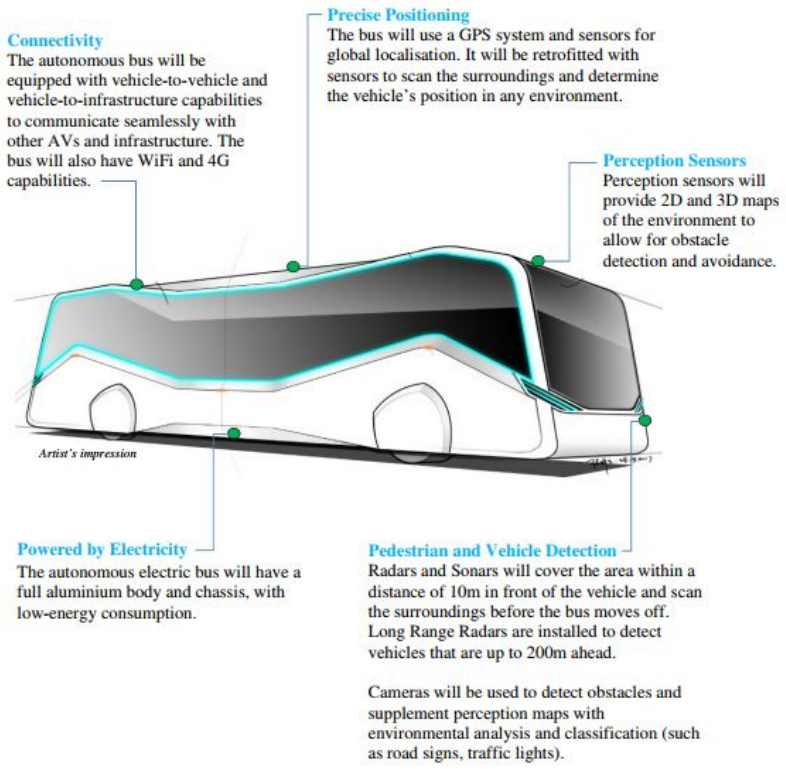

FIGURE 3.4: ST Kinetics' Autonomous Bus Prototype

- Satellite Based Road Pricing

  Building Singapore's next-generation electronic road-pricing (ERP) system, provides the ability to charge for distance travelled. Thus, the implementation will be for all motor vehicles to be fixed with a smartphone sized in-vehicle unit which will be able to alert drivers of priced roads, inform them about charges providing real-time traffic information and automatic payment. All these can reduce congestion on the roads and help drivers to take better decisions (*e.g.*, when to drive, which route to take or leave).

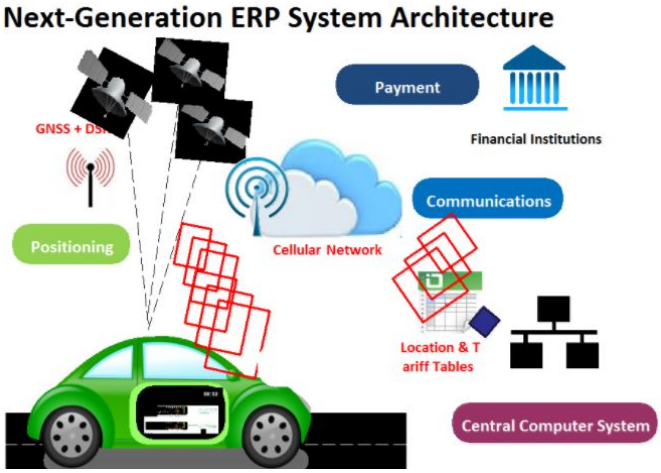

FIGURE 3.5: An illustration of the new ERP system

– *Virtual Singapore:* A dynamic 3D model that enables city planners to run virtual tests for different projects, including 3D maps of Singapore. Virtual Singapore includes semantic 3D modelling, which compromises detailed information such as material representation of geometrical objects, terrain attributes (*e.g.*, transportation infrastructure, water supply systems, vegetations), models of buildings in order to describe the city with the necessary dynamic test-bedding concepts and services.

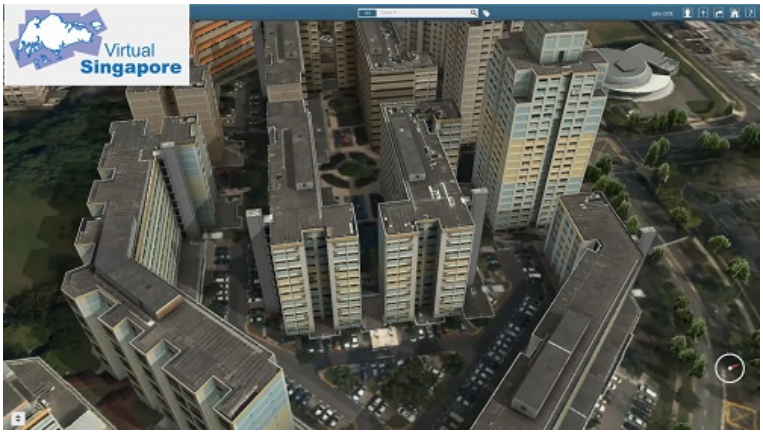

FIGURE 3.6: Virtual Singapore programme

– *Supertrees project:* The implementation of artificial trees 160 feet tall. They are solar-powered trees and operate as temperature moderators, absorbing and dispersing heat due to Singapore's hot climate. They provide lighting and collect rainwater. To generate electricity, 11 of the supertrees are fitted with solar photovoltaic systems that convert sunlight into energy which provides lighting and aids water technology.

FIGURE 3.7: Supertree Grove

– *One Monitoring:* It is a portal for serving all drivers and vehicle owners in Singapore. It can provide online transactions such as traffic fines payment, road tax renewal, selling or buying vehicles and get access to real-time traffic conditions, including accidents, traffic congestion, vehicle breakdowns, parking information. For instance, it is used surveillance cameras to look out for road accidents and warning delivered to drivers through in-vehicle devices in order to prevent some accidents.

– *Transport.SG:* A smartphone application, which provides real time information for passengers about all modes of land transportation. For instance, there are lots of features such as notifications for traffic news, real-time bus arrival, parking availability, search nearby bus stops and other relevant facilities. Moreover, you can personalise your journey using the public transport Journey Planner.

FIGURE 3.8: Transport.SG Mobile

Moreover, Singapore has implemented lots of smart and green transport solutions such as road sensors, smart traffic lights and smart parking. It also has an open data platform related to data collected by sensors. All these include the use of sensors, GPS and cameras to be deployed for tracking purposes, prevention of jams and traffic congestion.

3.2 Barcelona

Barcelona was recently ranked at the top of the list of smart cities, according to the 2015 Juniper Research report. The city is a pioneer in smart city and provides low-carbon solutions. It was among the first in the world to introduce a solar thermal ordinance about a decade ago. However in the context of smart mobility, Smart Barcelona has an Urban Mobility Plan for the period 2013-2018 with the following objectives: (i) Sustainable mobility, (ii) Equitable mobility, (iii) Safe mobility and (iv) Efficient mobility.

FIGURE 3.9: Barcelona city

Representative examples are the following [19]:

– *Metropolitans de Barcelona (TMB):* An application to help the travellers to make one transfer between any two points in Barcelona.

– *Multi-mode transport:* Integration of multi-mode transport for micro distribution of freight, light goods, zero greenhouse gas emissions. Main goal to achieve is to develop an electric mobility system, which will provide alternative fuel driven vehicles by setting up charging infrastructure and refueling facilities for alternative heavy duty fuels. Moreover, smart guiding for fast charging to various fuel stations is needed. The following are examples of some of the modes of transport:

- LIVE(Logistics for Electric Vehicle Implementation)

  The promotion of use of electric vehicles and electric motorbikes as the standard mode of public and private transport. Specific measures include: (i) setting up free charging stations in different locations across the city, (ii) increasing the number of parking spaces with charging facilities, (iii) introducing electric buses and taxis, (iv) enhancing the electric vehicle hiring system to encourage car sharing.

- eBicing

  The Barcelona's city bike system has established 420 bicing stations in the city. It can provide 6000 bicycles for rent by members of the public who have registered online. Using a mobile application, they can access information such as the location of the bicing stations, bicycle availability, rental record, payment status.

- Orthogonal Bus Network

  Trying to reorganising the bus routes into a scheme of vertical, horizontal, diagonal lines according to the configuration of streets in the city. The operation of the entire bus network becomes more efficient, by straighten the bus routes in order to shorten the trip time, avoid the concentration of bus routes along certain streets and alleviating road traffic congestion. Interchange points are set up in the intersections of routes for passengers to change lines for their destinations. Some including systems are smart fleet management system and smart real-time bus stop announcement systems.

- Micro-Platforms for Goods Delivery

  The usage of electric tricycles with 180kg loading capacity for goods delivery in the Old Town can efficiently minimise the impact of conventional lorries on the streets in the Old Town. Goods are delivered from various areas of the city to designated unloading points by lorries and then, they are forwarded to clients in the Old Town by electric tricycles.

- School Pathways

  A programme involving schools, children, parents, community organisations, government departments(police) to encourage school children to walk to school along footpaths. This can promote a healthy lifestyle, by raising their awareness of road safety.

– *Smart traffic lights:* The project in 2014 establishes 1100 lampposts transitioned to LED to reduce energy consumption. Sensors were also installed on these lights to detect when pedestrians are in proximity. When streets are empty, the lights dim to consume less energy. These installations have contributed to over 30% energy savings across the lighting network. When a pedestrian light turns green, a specific sound signal is activated to prompt the blind people to cross the road. Also, when an emergency service vehicle passes by, the traffic light system automatically detects it and synchronises the traffic lights along its route so that they remain green until the vehicle has got through.

– *Smart parking:* A single platform is set up to consolidate information of parking spaces within the same district. Drivers can check the number and locations of available parking spaces in the vicinity through roadside message screens or their own mobile devices.

– *ApparkB:* It is a mobile application for public parking payment, which drivers can tap their mobile devices on the readers fitted alongside the public parking spaces for payment. The system automatically calculates the parking fee according to the type of parking and deducts the appropriate amount from the designated account of the driver.

– *CityOS:* Municipal smart information management system, which is designed to collect and analyse data from various sensors within the city. It can produce simulations and show situations that might affect the city.

– *Smart bus stop:* Using a solar panel to activate a screen that shows arrival time. For sustainable urban mobility, the bus system reduces emissions with hybrid buses.

– *Apps4Bcn:* A collection of applications relating to various information and services for everyday life in Barcelona.

– *App&Town:* Free mobile application about public transport systems (*e.g.*, bus, metro, train, tram) providing people with a variety of information including real-time trip schedule, locations of stops nearby, trip schedule alert and suggested route choices.

3.3 London

The capital of England focuses on four pillars: smart living, smart infrastructure, smart economy and smart governance. The city has used innovative technology to facilitate use of smart phones and also improve health and environmental services. However, London has been well-recognized for its sustainability innovations, by using technology to help in traffic and better, robust transportation system.

FIGURE 3.10: London city

– *London Infrastructure Plan 2050:* The LIP 2050 plan aims at creating a greener and more productive city that is environmentally, socially, financially and economically sustainable through ICT. The future road network will reduce congestion, create new public spaces and encourage more people to walk and cycle [14].

– *Smart Mobility Living Lab:* A real-world urban test bed in a complex public environment, capable of demonstrating and evaluating the use, performance, benefits and security of essential technologies and mobility innovations.

– *Smart London Plan:* It includes innovations in transport using number plate recognition for the congestion charge, Wi-Fi and the intelligent road network management systems.

3.4 San Francisco

San Francisco is another smart city, which has used technology effectively for bringing improvements in fields like transport, energy, water supply and waste management. Many projects focus on public sustainable transportation network by building a smarter, shared and connected transportation system. San Francisco is the innovation capital of the world, which has chosen to lead the way by putting people first in developing safer and innovative solutions to transportation challenges. It is a leader in terms of smart parking with 442.000 publicly available parking spaces, leading to transition of these spaces to parks, pedestrian amenities and affordable housing [11].

FIGURE 3.11: San Francisco city

– *San Francisco Park Initiative:* This initiative was launched in 2011, where a large number of sensors are used to monitor parking spaces.

– *Shared vehicles:* By moving the modes of transportation to a shared model, transportation will belong to everyone and share the benefits. Car sharing means more people can access the same car and less cars are needed, providing more space on streets. Thus, citizens have more choices to get around and will walk much safer throughout the city.

– *Smart traffic management:* Connected vehicles will be able to sense each other and people walking and bicycling, eliminating collisions and traffic fatalities.

3.5 Oslo

The city of Oslo has been granted 225,000 euros by the European Commission for a project on sustainable transport solutions through procurement. The vision for Oslo is to make it a smarter, greener, more inclusive, creative city for all citizens It has a wide range of smart technology projects from testing electrical buses and vehicles, zero-emission construction sites, retrofitting existing buildings to developing circle-based waste management, green energy systems.

FIGURE 3.12: Oslo city

– *Toll ring:* An important tool for traffic reduction, air quality improvement, transition to zero-emission vehicles, reduction of traffic, emissions and finances of public transport. Automated toll stations are located on all entry roads to Oslo. The city uses the toll ring to reduce congestion, by charging people when passing. Revenues are used to facilitate more trips by public transport, bicycle and walking through investing in better infrastructure reducing air pollution and noise. The toll ring as financing model constitutes an important financing framework for public transport investments, improves bicycle infrastructure and promote walking reducing congestion and the number of fatalities. The result is that, between 2005 and 2015, the public transport share increased from 21 to 32%, while the car share decreased from 45 to 34% [24].

– *Electric vehicles:* Over 30% of all new cars sold in Oslo in 2015 and 2016 were electric vehicles (EVs) or plug-in hybrids. Specifically, Norway is today the first mass market for EVs in the world because more than 35,000 EVs are in Oslo region.

– *Ruter mobile app:* For transportation planning and tickets, including buses, trains and metro.

– *Bill i Oslo:* Payment application for parking in the city.

Chapter 4

Security and Privacy on Mobility

4.1 Introduction

The aim of this chapter is to analyse some of the most important technological innovations, establishing by the top smartest cities in context of information security *as shown in chapter 3*. More precisely, we define security and privacy issues on some of the major smart mobility innovations and determining the appropriate requirements. The scope is to build a safe, fair and efficient mobility to minimise the impact on the environment, improve the quality of life and ensure the smooth operation of the public transport systems.

Generally, cyber-threats that target the IoT infrastructure aim at harming its: (i) confidentiality, (ii) integrity, (iii) availability, (iv) authentication, (v) trust and privacy. The most harmful cyber-threats against the IoT are classified as:

- *Malware:* is a malicious software that hijacks the sensor's functions and spreads in the IoT infrastructure in order to gather operational intelligence.
- *Denial of Service:* attacks can cause problems in sensing and querying in urbanization.
- *Botnet:* is a network of infected devices spread across the world and controlled remotely from a master following the client-server architecture.
- *Information Leakage:* causes lots or privacy concerns of citizens of a smart city. For instance, it is important the privacy of systems that gather data and trigger emergency response when needed.
- *Remote Access Tools:* offer remote support and remote management of mobile devices like phones, tablets or PCs from anywhere.
- *Physical Manipulation:* can happen when security devices are installed outdoors and are close to perimeters, leaving them physically accessible.
- *Ransomware:* targets data storage facilities and blocks access to the collected data by encrypting them. A ransom should be paid in order to decrypt them. For instance, ransomware attacks disrupt business

continuity of the IoT infrastructure with few ways out except the ransom's payment.

4.1.1 Smart Mobility Innovations

Smart Mobility innovations aim at reducing traffic congestion and providing faster, greener, cheaper transportation options. The smart mobility provision provides new smart solutions that appeal to real human needs, with changes in human behaviour. More precisely, some new innovative solutions to city management complexity in order to improve sustainability and livability are the following:

- Smart parking
- Smart traffic control
- Self driving vehicles
- Personalized transport information
- Shared self-driving cars

FIGURE 4.1: Smart Mobility

However, smart cities are facing many problems through their development. It is crucial to find them, by sharing information on possible security issues facing smart cities and how these can be addressed or avoided. The more IT is involved in the creation and operation of a smart city, the greater the potential risk. If not addressed early on, the cost and complexity of creating a smart city could make it far more difficult to address security problems further down the line. In the end, the city would be left vulnerable.

4.2 Use Case 1: Smart Parking

4.2.1 Description

The shortage of free parking space in a large city is often difficult. Due to the large number of vehicles on the road and car park facilities are unable to face them, traffic problems are exist, leading to traffic congestion, air pollution, driver frustration. Smart Parking is an intelligent parking system, that (i) enables citizens to find spaces quickly and easily, (ii) improves quality and convenience for the citizens of the city, (iii) optimises parking car space usage, resulting in significant revenue generation, (iv) helps traffic in the city flow and (v) creates better urban environment by reducing the emissions of CO_2 and other pollutants. Furthermore, smart parking would enable intelligent decisions using data, including real-time status applications and historical analytics reports.

To achieve it, sensors that detect variations in magnetic fields generated by parked cars are used to detect whether a parking space is free. More precisely, each parking space is equipped with a sensor that detects whether a car is parked on it or not. This implies M2M technologies. The real time information is used to guide people looking for a car space to the nearest free spaces and their prices. Moreover, new business promotion can be made about on sale prices and fees while payment is made simple.

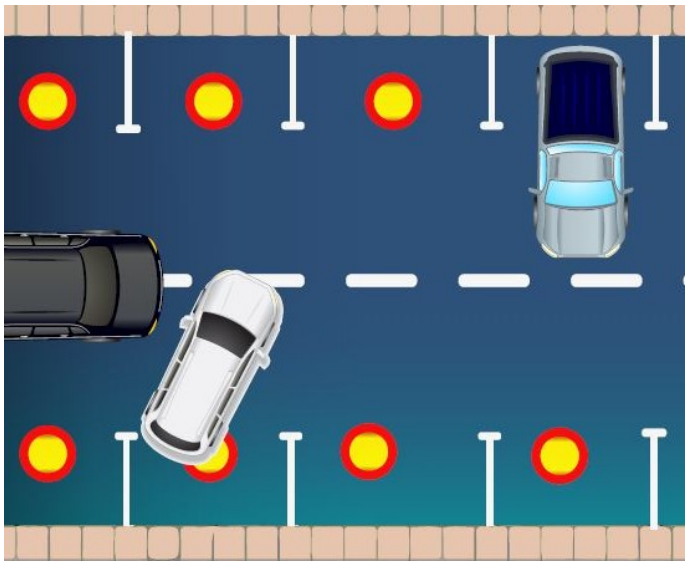

FIGURE 4.2: Sensors installed in each parking space [3]

All the above eliminates the need for driving around looking for a free parking space as a result drivers loss working hours and consume fuel for the searching in parking areas. For instance, if there is no free parking space at all, drivers can decide to change their plans and look for other options. Also, we could take advantage of the privately owned parking spaces of businesses which are often used on working days and during office hours. Outside these hours, there is a great opportunity for making additional parking spaces available through smart solutions, based on an online reservation system. This allows new forms of private-public partnerships by making the parking space of a business available for visitors of a theatre in the weekends.

4.2.2 The smart parking architecture

Figure 2, depicts a general model for smart parking, consisted of entities involved and parking devices. More precisely, we are based on a proposed web application system, named "Park Easy" which use smartphones and sensors monitoring techniques [2]. Searching for parking lots through application is more convenient, because users can determine the availability of spots for parking and then pay for them with their mobile phones simultaneously. The major smart parking infrastructure includes parking sensors, RF connectivity network, smart parking management tool and mobile application.

FIGURE 4.3: Smart parking infrastructure with logistic system

The following model illustrates the entities and the interactions of them. The smart parking system includes many systems, which perform simultaneously in one platform for better performance. The model has the following entities [3]:

- User: A user who drives a vehicle.
- M2M Service Platform: A platform that interacts with M2M Gateways/Devices and M2M Application Service Providers.
- Smartphone: A M2M device acts as a car navigator and a wallet to pay parking fee by connecting parking meters.
- On-street Parking Meter: A M2M device installed near parking slots to charge drivers parking fees.
- In-building Parking Sensor: A M2M device installed near parking slots to charge drivers parking fees.
- Parking Provider: A M2M application service provider who owns parking lots.
- Billing Provider: A M2M application service provider who provides billing service to users such as parking fee.
- Police Centre: A law enforcement authority who charges fine to whom break laws.

The main functions are that the smartphone navigator first sends the car's location to the parking provider. Mobile phones can be used for guidance because of utilization of GPS for vehicle detection. Vehicle detection sensors are commonly installed at entrances, exits and individual parking spaces to detect vehicle occupancy. The M2M service platform checks the parking lots with the parking provider which recommends parking space to the navigator. The occupancy status detected by the in-building parking sensors can either be occupancy of each individual parking space or in terms of vehicles counts in the car park depending on the installation of these sensors. The parking provider gathers and processes the traffic and occupancy information as well as controls the display of information for drivers about parking lots.

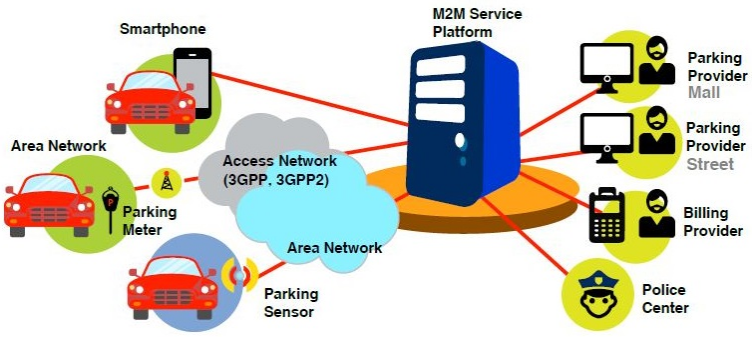

FIGURE 4.4: A generic model of a smart parking system [3]

Then it starts the payment procedure, where the on-street parking meter verifies the vehicle and starts computing. The billing provider provides the smart parking system, which tries to overcome the limitation of the conventional payment methods via parking meters and new technologies. Parking meters incorporates technologies such as having solar power source and wireless connectivity [2]. Thus, it will helps at avoiding additional delays and inconvenience with cash and reducing maintenance and staffing requirements.

4.2.3 Security and Privacy

Attackers are attracted by parking as target of attack, due to its features of web-based, connection to the Internet, remote management and complex architecture. Thus, there are lots of security and privacy breaches in "smart" parking management systems. Complex architecture causes certain vulnerabilities, which one discovered would compromise any of the other systems due to the lack of security by design, training, oversight practices and access controls. We analyse potential security problems and security threats imposed on the entities, leading to the specification of a set of security and privacy requirements. These requirements could be used to guide the future design of parking system and help in carrying out the risk assessment of such systems.

4.2.3.1 Threat Model

For the threat analysis, this study focuses on the potential attacks which classified into physical, key, replay and injection attacks. However, attacks aim at defining user location play an important role in the privacy and security of the system. The main goal of attackers is for profit or to spy on parking customers and workers. The latest happens when they can have access in cameras and then, they observe clients' presence and habits. When license plate is detected, warnings could send to them. The result is the existence of several cyber incidents.

- PHYSICAL ATTACKS: Physical damages may happen to assets, including systems, road side units (e.g. CCTV, VMS) which malicious can have a direct physical connection. Manually, attackers could open pay stations and coin boxes. Also, failures could happen due to human threats and to poorly implemented system routines, that likely provide opportunities for exploitation.

- KEY ATTACKS: Because of a large amount of essential information in databases and systems, malicious could steal information that these systems manage, including customers' credit card data. For instance, after obtaining the list of users and their credit card information, the existence of plaintext passwords in database or a weak password policy, make key attacks easier. Furthermore, a publicly accessible folder that contains system backups is an essential vulnerability [12]. So anyone that is able to gain access to the parking management system could control every device it includes, such as the CCTV cameras,

parking's barriers, payment stations, cashier computers.

- REPLAY AND INJECTION ATTACKS: These types of attacks refer to the theft of another entity's identity. In the smart parking management system, some entities can send fake messages on devices regarding payments. For instance, a dishonest user may try to impersonate another user in an attempt to park the car for free. Moreover, malicious can plant malware on cashier and pay stations devices (POS) or with replay techniques they can resell season cards. Using the main application, users are possible to maintain and generate season cards for parking as well as compromising the existing ones. This can happened, because some internal routines of the system such as specific software protocols, may come with some vulnerabilities that can also be exploited.

- USER LOCATION: When user location can being tracked is an example of privacy breaches. Legitimate users may use their privileges to build users' profiles. The question here is who will regulate and manage the database from the sensor network within the smart parking infrastructure, so that individual privacy is not compromised. With a key database identifier such as as credit card number or RFID chip card ID, it becomes easy to track an individual through the sensor network using the transaction data. For example, each smart parking meter in the sensor network has location information and the ability to record, store and transmit transaction data, including video, movements, etc. All these impact privacy in different ways either identity revealing or location tracking.

4.2.3.2 Security Requirements

This Section presents a number or security and privacy requirements motivated by the different types of attacks defined in the previous section. There is the need to identify the core requirements of information security in the technology of smart parking and limitations. The Smart Parking System is already in the circulation of parking areas, but it does not help us to parking the vehicles securely. The main objective of our study is to find the security requirements of a smart parking in order to have not only convenient and efficient systems, but safe and privacy preserved systems. Based on the above threat analysis, we specify these security requirements for a smart parking management system as follows [15]:

- ENTITY AUTHENTICATION:

  One of the most important threat is the impersonation attack, where a vehicle owner deliberately stealing another vehicle's identity. We can prevent this type of attack by storing the vehicle's identity in tamper-resistant hardware, having it properly certified and using modern authentication protocols [13]. To allow the wireless authentication of vehicles, specific authorities must provide each vehicle with a private/public key pair, along with a shared symmetric key and a digital

certificate of its identity and public key. Also, electronic license plates are much more resistant to this type of attack than physical ones.

- CONFIDENTIALITY:

  Smart mobility may cause privacy concerns as personal information and probably account information disclosure could happen in collecting, publishing and utilizing trace data. For instance, some of the smartphone applications that provide services of smart mobility take mobile data and use trace analysis and data mining techniques. More precisely, smart parking system obtain information about available parking spaces in a particular geographic area and process real time to place vehicles at available positions. Optionally, against to eavesdropping confidentiality and authenticity are crucial to the messages that are in transit in the network. The information sent and received from devices used in smart mobility infrastructure may subject to malicious attacks, causing wrong traffic reports in satellite navigation systems. The need to achieve secure information sharing through the technology being used is crucial.

- AVAILABILITY:

  The parking system should be ready to respond to hostile participants, compromised nodes and any other adverse event. Therefore, it is necessary to implement mechanisms and the need for security testing in order to prevent denial of service attacks. In this type of attack, an attacker systematically or selectively jamming the signals that vehicles exchange. There is no purely technical solution to such attacks until now, so this is the reason why a car cannot override its driver in the near future.

- INTEGRITY:

  Data integrity causes many issues like infrastructure or people of the smart city may be harmed. For example, when malicious vehicles cooperate in determining or reporting false locations or distances. They are exposed to malicious attacks, which can alter or damage the whole infrastructure and communication systems. Encryption scheme with a tamper-proof GPS receiver can deal with the issues of data integrity and privacy.

- ACCOUNTABILITY:

  To protect driver's privacy, the broadcast certified identity must be a pseudonym that changes over time because of the fact that the use of radio-transmitted information to track a given car's location and therefore its driver is socially acceptable. Thus, we should trust only the national authorities to be able to determine the relationship between a pseudonym and its real identity in case of cyber events.

To protect a parking management system and more in general, to secure any device exposed online, it is necessary to change factory settings and protect the device with defense systems like firewalls, authentication, self-protected by avoiding defaults options. We advice that all the platforms/services/applications of smart parking system must comply with a predefined set of security and privacy requirements. Moreover, businesses must design their products, services and processes by starting with the end user in mind. They must understand their users deeply, who they are, their needs and values in order to create secure systems, services, products and capture sustainable value.

4.3 Use Case 2: Smart Traffic Control

4.3.1 Description

The observation of what happens on roads is called traffic monitoring, which has a primary purpose of detecting anomalous situations and providing pleasant mobility experiences. Connected vehicles will be able to sense each other and people walking and bicycling in order to eliminate collisions and traffic fatalities. More specifically, sensors that detect the speed and the number of vehicles using public roads are used to detect traffic congestion and suggest drivers to take an alternative route. The data created by these sensors in infrastructure and vehicles, optimise the traffic flow by adjusting traffic lights and other signals.

FIGURE 4.5: Smart Traffic

There are the sensors that collect data about us and our environment: smart thermostats, street and highway sensors and those ubiquitous smartphones with their motion sensors and GPS location receivers. Then, we have to figure out what the data means and what to do about it. This includes all the computer processors on these devices and increasingly in the cloud, as well as the memory that stores all of this information. There are the actuators that affect our environment. The point of a smart thermostat is not to record the temperature, but to control the furnace and the air conditioner.

Smart traffic management can be useful in: (i) travel demand management, (ii) traffic control for passenger vehicles, (iii) movement of goods and (iv) in synchronization of traffic signals to prioritize certain vehicles such as buses, ambulances. Traffic control systems can also be used to guide emergency services like ambulances through the traffic by finding the fastest route, keeping bridges closed and adjusting traffic lights. Moreover, this service is providing routes of vehicles to destinations based on current traffic conditions.

4.3.2 The smart traffic control architecture

Urban traffic management is much about reducing vehicle pollutants and promoting sustainable travel experiences in every mode, including walking, cycling and public transport. Many of these can be effectively delivered through a whole smart traffic control architecture in road networks. One of the established smart traffic management system in London is called Split Cycle and Offset Optimisation Technique (SCOOT) [23, 10]. It is an online urban traffic control system and is used in hundreds of cities throughout Europe, including London, Zurich and Germany. There are four components: (i) traffic lights, (ii) queue detectors buried in the roads, (iii) cameras and (iv) a central control system. The queue detectors tell the control system the state of traffic flow on the main roads in the city. The control system controls the lights to maintain a free flow of traffic within the city. Also, it can use data from vehicle detectors to optimise traffic signals. Traffic signal control is a tool that typically separates conflicting movements at an individual junction. This has enabled the development of features such as prioritisation of public transport or emergency vehicles.

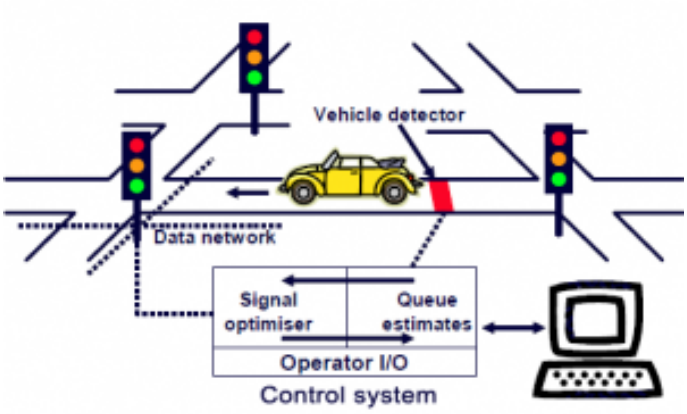

FIGURE 4.6: Basic SCOOT traffic control system [21]

SCOOT has proved to be an effective and efficient tool for controlling traffic on road networks. But, this software would be set up with knowledge of the road network and trained to respond appropriately to a wide range of questions, including traffic incidents, disruptions.

4.3.3 Security and Privacy

In this Section, we analyse the factors that are taken under consideration in order to identify the issues in information security in a smart traffic control architecture. Our study develops a threat model in the context of information and privacy security, with the aim of deciding which security requirements are required.

4.3.3.1 Threat Model

Cybercriminals are well organised and have plenty of resources, as a result they can improve their attack techniques continuously. We define an approach of threat modelling, which combines a set of potential attacks relevant in the context of smart traffic management and control [15].

- PHYSICAL ATTACKS: Thefts or physical damages may happen to assets of traffic control system, including physical destruction and tampering that can be used to corrupt transmitted data. In the physical destruction, sensor nodes are destroyed completely, so that sensing operation becomes unavailable.

- KEY ATTACKS: In this type of attacks, it is possible to have vehicle management manipulation by an unauthorised remote control. Attackers can access and modify internal structure of the assets and get information, without physically accessing the sensors. The information might be essential, because malicious can learn about traffic flows, traffic data and driver's behaviours.

- REPLAY AND INJECTION ATTACKS: These attacks cause threats to vehicle's users regarding to the availability of the smart control architecture. More precisely, attackers could cause Denial of Service (DoS) attacks due to the fact that SCOOT is an online signal timing optimizer. Data corruption is one of the major security threats to Wireless Sensor Networks (WSNs) and it can be resulted from both kind of attacks, cyber and physical. It can also place fake sensors nodes to inject false data, causing confusion in the whole network [22].

- USER LOCATION: There are some possibilities for attackers to deploy fake network to collect sensitive information about drivers. This is a threat in the privacy of drivers, because they can derived essential information from traffic data.

4.3.3.2 Security Requirements

- AVAILABILITY:

  The SCOOT model is online that the predictions of delay are recalculated every few seconds from the latest measurements of traffic behaviours. Thus, attackers might aim at disrupting services and making network resources unavailable. Leaders did not test security controls sufficiently to determine that they were operating as intended. Therefore, it is necessary to implement mechanisms and run security testing by applying penetration tests in city systems and networks.

- INTEGRITY:

  Data integrity is a fundamental requirement of the traffic control system, because the system functionalities rely on the data that are initially captured from sensors. Unauthorised access to restricted information can cause loss, manipulation or corruption of transmitted information. Attackers could manipulate the vehicle behaviour in terms of requesting or sending informations to other vehicles without the user's knowledge.

- AUTHENTICATION:

  Authentication attacks might happen, due to the fact that traffic control system has the ability to send, receive and replay various types of messages. Cryptographic will be used for entity authentication and access control services to limit unauthorised access.

- CONFIDENTIALITY:

  In WSNs, it is necessary the symmetric cryptography to prevent communications from unauthorised sensor nodes. Another security requirement is the privacy due to the illicit collection of data through eavesdropping or the analysis of messages traffic. Data from vehicle detectors are analysed by an online computer which contains programs that calculate traffic flows and predicted queues. Thus, malicious users can gain from potential network vulnerabilities and learn information about driver's traffic data.

- ACCOUNTABILITY:

  To ensure that nobody can deny that particular messages were sent or received, regular auditing and maintenance of activity logs is important in case of incidents.

4.4 Use Case 3: Shared Vehicles

4.4.1 Description

The shared use of vehicles is an innovative transportation strategy, that enables users to have short-term access to this mode of transportation. It is a shared model, in which transportation will belong to everyone, providing lots of benefits. Some of the major benefits are the following:

- less cars are needed, because more people can access to the same car
- provide more space on streets
- citizens have more choices to get around
- reduce congestion
- citizens will walk safer throughout the city
- reduce energy consumption and traffic emissions
- increase efficiency of the transport system

Shared-use vehicle systems consist of a fleet of vehicles that are used by several different individuals throughout the day. In most cases of car sharing, a member reserves a vehicle, then picks it up at a designed location and returns the vehicle to the same location.

FIGURE 4.7: Car sharing

4.4.2 The shared vehicle architecture

Generally, there are three basic shared-use vehicle system models: (i) traditional, (ii) peer-to-peer and (iii) one-way. The traditional model refers to the car share organisations, that own and maintain a fleet of vehicles. A representative round-trip example of car sharing is Zipcar. Another alternative traditional model is peer-to-peer, in which allow individuals to rent their privately-owned vehicles to other members. One-way car sharing allows members to pick up a vehicle, make a trip and leave the shared vehicle at a different location anywhere within a predefined area [1, 5].

The station car system is illustrated in Figure 4.8 and includes a fleet of vehicles that are used by several different individuals throughout the day. Firstly, you can apply online to access your desired vehicle and then find a Zipcar spot near you to reserve it. The keys are inside the car and you can unlock, it using your Zipcard. There is option to extend the time you reserved the car, with mobile application or by text message.

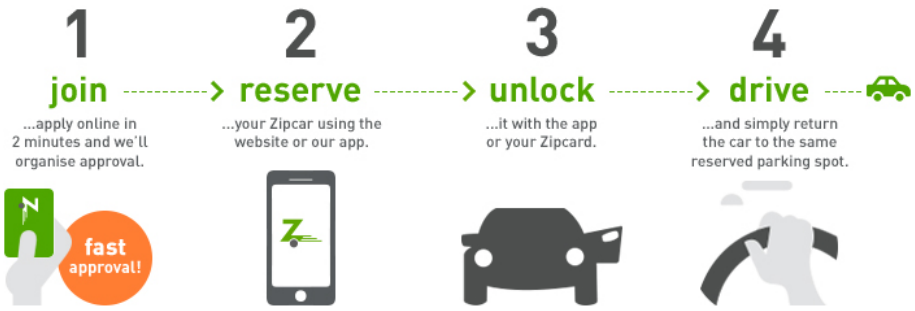

FIGURE 4.8: Car sharing with Zipcar [7]

4.4.3 Security and Privacy

The security analysis can give us understanding of causes and impacts of cyber security incidents. Similarly, we investigate potential threats that car sharing architecture could encounter. Based on this, security requirements are mapped to the architecture of car sharing.

4.4.3.1 Threat Model

- PHYSICAL ATTACKS: Thefts or physical damages may happen to car stations, leading to the termination of their functionalities. Attacks on car stations can result in damage to physical infrastructure elements such as electronic devices, electrical machines and transportation facilities. Therefore, alarm systems and periodic maintenance are required.

- KEY ATTACKS: To reserve a car you should have a card in order to unlock and lock the shared vehicle. However, malicious could steal essential information that these cards manage, including customers'

credit card data. Thus, attackers can accomplish data leakages, where a compromised device can be used to steal confidential and financial information. Moreover, they can deploy fake cards to achieve an unauthorised access to car stations.

- REPLAY AND INJECTION ATTACKS: Altering information about charges, returning, extending can significantly affect the user via several means. Moreover, replay attacks in the form of false messages can be sent to the network and deceive users to make them believe that another node/station was responsible for sending these messages.

- USER LOCATION: To know the destinations and stops of the shared vehicle will be an important security and privacy issue for its driver.

4.4.3.2 Security Requirements

- AUTHENTICATION:

  Authenticity attacks might happen, due to the fact that car stations have the ability to send, receive and replay various types of messages. Cryptographic will be used for entity authentication and access control services Policy related techniques will also be used to monitor and grant users access as well as the information within the reservation card.

- INTEGRITY:

  Data integrity is a fundamental requirement of the car sharing system, thus we need strong access control policies and encryption scheme with a tamper-proof GPS receiver.

- ACCOUNTABILITY:

  Alarm systems with CCTV cameras need to act in an accountability manner. It requires actions with log files leading to the reporting of malicious events. The maintenance of backups and regular auditing can provide a good indicator of what happened and how a threat managed effectively.

- PRIVACY: Tracking content sharing and usage for illicit purposes could affect significantly the safety of users. The protection of personal data, including traffic data, movements, transaction data is needed.

Chapter 5

Conclusion

In this dissertation, we introduce the notion of smart city and investigate the major components based on existing European smart city model. Furthermore, we analyse the essential technologies and major challenges of smart cities. A smart city is a complex concept, including a wide range of issues and at the same time providing better life for its citizens. In fact, smart cities are not so smart if the concerns in security and privacy are not properly catered. The need to achieve security requirements through the technology being being used is crucial, thus we specified in defining a framework for threats and requirements on smart mobility. More precisely, we examined the security and privacy of the smart parking, smart traffic control and shared vehicles and we identified some common points in threats and requirements.

Finally, our goal is to make recommendations of the required trust, privacy and security issues for the benefits of consumers of the major smart mobility solutions. We analysed *in chapter 4* the three following smart mobility innovations, because they were a reference point for the top five smartest cities:

1. *Smart Parking*, which enables citizens to find spaces quickly and easily.
2. *Smart Traffic Control*, where controlled traffic signals and sensors regulate the traffic flow through the city in response to demand.
3. *Shared Vehicles* enable users to have short-term access to a mode of transportation and will cut overall traffic, helping to reduce local pollution levels.

These recommendations are essential input for the processes of establishing of these technologies in cities. This study is designed to help stakeholders identify threats and select appropriate controls to mitigate the risks identified in the preceding steps. The following factors should be considered to achieve privacy and security by design in the smart mobility innovations:

Privacy Category	Description
Privacy of person	Lack of opportunity for the giving of meaningful consent to processing of personal data. Revealing identity. • Who will regulate and manage the database from the sensor network, so that individual privacy is not compromised?
Privacy of behavior and action	An extension of the privacy of person focus on preferences, personal activities in public and private space. Impact on the associated individuals. • The use of CCTV to catch drivers who commit traffic violations.
Privacy of communication	The protection of the ways in which individuals communicate with others in the network. • Concerns about deployment of fake network and communications to collect essential information from traffic data. • The use of communication interception tools that copy communications without letting users know.
Privacy of data and image	The protection of personal data is needed in all forms, including traffic data, movements, transaction data, geographic locations and information about our purchases and the websites we visited. • Where data is collected in public-sector activities? • Concerns about storage of personal data in the cloud.
Privacy of location	Tracking user location to build users' profiles. Knowledge of routes, destinations, stops of vehicles.

FIGURE 5.1: Privacy concerns in smart mobility solutions

Security Category	Description
Key Attacks	Because of a large amount of information in databases and systems, malicious could steal it, including customers' credit card data. • Retrieving essential information • Unauthorized remote control • Data loss • Existence of plaintext passwords • Publicly accessible folders
Physical Attacks	Physical damages may happen to assets, including systems, road side units, pay stations, sensor nodes, car stations transportation facilities. • theft/loss of devices, vehicles • no device authentication
Replay and Injection Attacks	Theft of another entity's identity • Denial of service • Leverage the wireless connectivity of the target • Eavesdropping to extract essential information • Plant malware on devices

FIGURE 5.2: Security concerns in smart mobility solutions

However, most of threats could encountered and we provide a list of recommendations that can be followed by the users to keep their data stored in a secured way.

- Gather data and trigger emergency responses when needed.
- The giving the minimum consent to processing of personal data.
- Plan for IoT device manufacturers during the designing processes of the devices. Including privacy layers to achieve privacy by design.
- Encryption is the only way to protect sensitive data. It is required cryptographic techniques, that enable sensitive data to be stored, processed and shared without having the information content accessible by outside parties.
- User authentication with proper authentication mechanisms, preventing devices from unauthorised people.
- Strong access control mechanisms to maintain the confidentiality of the personal data.
- Installation of antivirus and firewall on the devices
- Awareness raising campaigns
- Alarm systems and periodic maintenance are required
- International standards and policies development

However, citizens are not the only factors to consider in the development of smart cities, because governmental and commercial entities play increasingly important roles in implementation of essential technologies. Sustainable urban development requires changes in political, social, economic and physical backgrounds. Education is a major key, by using information sharing for promoting the benefits of a smart city beyond the challenges. In summary, this work contributes to a deeper understanding of innovation projects in the context of smart mobility and provides basic recommendations, that all stakeholders should take into account.

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