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SMART CITY: A REVIEW OF CURRENT DEVELOPMENTS AND IMPLEMENTATION OF SMART GRID TECHNOLOGY

SARA KOSTEVSKA, BILJANA CHITKUSEVA DIMITROVSKA, TODOR CHEKEROVSKI, MARIA CHEKEROVSKA AND SARA SREBRENKOSKA

Abstract. To ensure better living standards for the population, it is necessary to develop smart cities that utilize modern technology and operational efficiency to facilitate daily life. The primary goal of implementing (or creating) a smart city is to maintain, balance and continuously upgrade economic, social, and environmental resources while managing cost. Emphasis is placed on maximizing the use of natural resources through energy conservation (utilizing renewables), efficient water usage, time savings, land optimization, environmental quality, traffic management, and the extensive use of information and communication technology systems and services for effective management and their ongoing enhancement. This paper aims to create improved functionality, smart connections, and better organization among people, while maximizing the use of natural resources, minimizing environmental pollution, and enhancing public awareness.

1. Introduction

The smart city is the "urban center of the future" implemented with complex socio-technical, socio-cybernetic systems and advanced technologies, reliable and safe systems, ecologically green and efficient structures, regardless of whether it is water, transport, or electricity that allows the use of advanced integrated materials, sensors, electronics, and networks which are connected to computerized systems composed of a database and algorithms for monitoring and planning. This system is one of the important application domains of the Internet of Things (IoT), in which smart devices of various types provide advanced and better services to citizens. Apart from being smart, cities should also be self-sustainable in terms of production, management and consumption of resources in an intelligent way. The city should provide access to possible physical, potential and social mobility to different degrees to the users and institutions themselves. We need to use the Internet of Things to create efficient, sustainable cities if we are to live in an efficient, sustainable world. The collection and analysis of large data sets from various sources-including public transportation, public safety, and healthcare enable city administrations to make quick and informed decisions. Cities strive for energy-efficient solutions and reduced greenhouse gas emissions. By adopting renewable energy sources such as solar and wind power, along with smart energy grids, smart cities reduce consumption and distribute energy more efficiently. Smart technologies create new businesses and job opportunities in various industries such as technology, energy, and public transport.

Date: November 11, 2024.
Keywords. Technology, smart grids, renewable energy, mobility, photovoltaic system, battery system.

2. **Definition of Smart City**

There is still no universal and widely accepted definition of a smart city that fully captures the essence of the implemented concept. Based on this, the definition can be divided into several aspects when defining and developing a smart city. One part will focus on technological orientation, specifically the technologies that will connect the city using modern information and communication technology. The work will include another section that defines the smart city in relation to energy production, as well as the future prosperity of the city as an urban center of the future (safe, secure, eco-friendly, and efficient). The multidimensional definition of a smart city indicates that it represents a holistic approach to development, emphasizing its numerous determinants. Three fundamental attributes of a smart city are: technology, human factors, and institutional aspects.

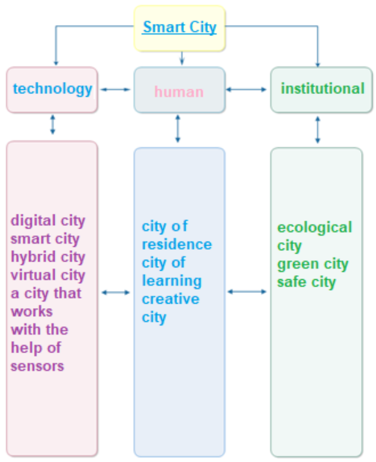

Figure 1. *Attributes of the smart city.*

In Figure 1, the main attributes that illustrate and facilitate the functioning of a smart city are shown, utilizing sensors, actuators, hybrid systems, virtual systems, and ecological and economic approaches that are accessible to both residents and visitors of the city.

3. **Components of a smart city**

- *Smart people* who socially interact with and connect with public life, higher education, and are open to the world for creating new interactions and achievements.
- *Smart economy* is the interaction and competitiveness of the city in creating innovations, entrepreneurship, productivity, and flexibility, while primarily integrating with the domestic and global market. Information and communication technologies are used to develop e-business and e-commerce, as well as to enhance opportunities related to production, services, delivery, innovations, new products, and business models [1].

- *Smart management (usage)* is associated with the administration and quality of services offered to residents when making decisions about the city. Information and communication technologies are improved and updated using various applications and e-platforms to facilitate the lives and services of the residents in the city.
- *Mobility* refers to the services and information available to the public when accessing and using various technologies that facilitate their lives.
- *Smart environment* refers to an environment that has natural living conditions (green spaces), resource reuse and replacement, efficient waste management and sorting, use of renewable energy sources, and a focus on green urban planning. The main goal of this subsection is the functionality of the city and the infrastructure that dictates the conditions for living and working. The infrastructure should be regularly and systematically modernized (simplified) in accordance with the necessary urban needs.

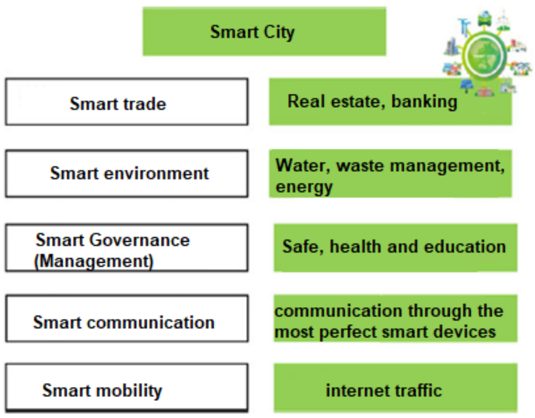

Figure 2. *Components of a smart city [2]*

Figure 2 presents the five main components of a smart city, balancing trade (economy), natural resources (renewable energy, water), waste management and recycling and sorting, technology (mobility), but above all, balance and improvement for better health and education.

4. Smart self-sustaining human cities and communities

This modeled system facilitates simulation through software platforms using coding and the most sophisticated programming languages. The systems themselves achieve self-sustainability by balancing produced, stored, and needed resources. In smaller units, it is characteristic that they are connected to resources, or flows (channels) through which data exchange and communication occur, forming a complete structure or graph. This mechanism is particularly notable because it enables sustainable communication with all other subsystems to ensure continuous sharing and exchange of data. To maintain these levels in relation to each other, a so-called leader will be introduced, who must manage the mechanisms for self-sustainability and the data and work schedules from one level to another. An example that best illustrates the above regarding the organization of cities and communities by levels can be seen in the following: A smart self-sustaining city consists of three buildings, each containing five apartments, while each apartment has a smart photovoltaic system, a smart battery, and a refrigerator that serves as a producer, consumer, and storage. Let's assume this city is organized into three organizational levels:

(1) Apartment level, where each individual apartment is an organizational unit with a battery unit;
(2) Building level;
(3) City level, composed of all three buildings, with the first building acting as the converter.

We can observe that at the city level, the true converter is the battery unit on the ground floor of the first building, which plays a role in the two higher levels. Due to its geographical location, the first building has the best orientation toward the sun, while the photovoltaic panels on the other two buildings are shaded by the first one. As a result, the battery units in the first building charge for longer periods, potentially leading to a situation where no additional electrical energy can be stored. We can say that the battery unit first communicates with the battery units at the same level and receives information that none of the battery units in the other buildings have sufficient electrical energy for sharing.

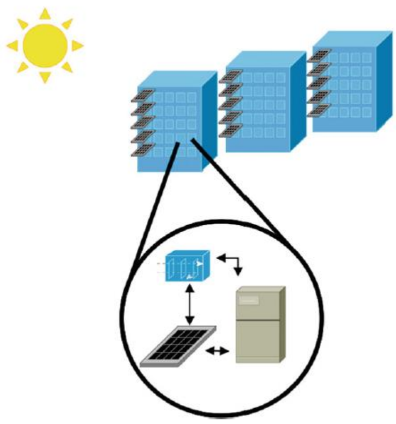

Figure 3. *Example of a Smart Self-Sustaining City and Community [3]*

The example in Figure 3 illustrates a trend in which people should design their daily lives to minimize energy consumption in their homes within communities, economically speaking, while focusing on using renewable energy sources, specifically solar energy. Excess energy will be stored in batteries, which, with the help of a hybrid inverter, will allow for the reuse of energy generated by the photovoltaic panels.

5. **Technology (technological factors)**

Smart cities heavily rely on technology that provides various services to citizens. The Internet of Things (IoT) includes a wide range of smart devices that enable free access to a wealth of information on the most visited online sites and applications. One of the most advanced everyday examples of this smart technology is that smart vehicles can communicate with pedestrians using 5G or Wi-Fi access. They not only communicate with pedestrians but also interact with other institutions in the vicinity. Cyber Attacks*:* There are numerous threats and attacks that complicate the functioning not only of smart networks in the city but also of certain smart devices essential for citizens' daily lives. However, many specialists around the world are working to reduce the frequency of attacks, such as breaching software systems that oversee the entire process from conversion to distribution of exclusively eco-friendly energy, threats via locations, GPS, Wi-Fi, and many others. The Internet of Things (IoT) is the key technology that enables connection and communication between various devices and sensors deployed throughout the city. These sensors collect and analyze vast amounts of data in real time, allowing for intelligent management of infrastructure and resources. For example:

- Traffic sensors are used to optimize traffic lights and manage congestion.
- Air quality sensors monitor pollution levels and allow for immediate action when pollution exceeds certain thresholds.
- Smart parking systems, where sensors detect available parking spaces and direct drivers to them via mobile apps.

The collection, storage, and analysis of large datasets (Big Data) are essential for better managing city resources. Smart cities use this technology too:

- Predict traffic patterns and optimize travel times by analyzing data from mobile phones, GPS sensors, and traffic cameras.
- Plan infrastructure and develop new public services based on analyzed trends and citizens' needs.
- Predict pollution levels and manage pollutants by analyzing atmospheric data from sensors deployed across the city

Artificial Intelligence and Machine Learning are used in smart cities to automate various processes and analyze data. These technologies can:

- Analyze large datasets and predict future events or problems, such as traffic jams or security threats.
- Optimize public transportation using smart systems that adjust bus and train schedules based on demand and weather conditions.
- Automate public services, such as waste management or water quality monitoring.

Geographic Information Systems (GIS) allow for the management and analysis of spatial data to support urban planning, transportation, and resource management.

- Mapping public services and resources such as water supply, waste management, parking, and public transport.
- Integration with IoT and sensors for better monitoring of environmental conditions such as pollution levels, temperature, or infrastructure status.

Cloud computing provides flexibility, scalability, and efficient storage and processing of data. Smart cities use cloud services for:

- Data storage from various systems such as IoT devices, cameras, sensors, and public platforms.
- Real-time data processing, enabling rapid responses to change in urban infrastructure or environmental conditions.

6. **Radio Frequency Identification (RFID)**

Radio Frequency Identification is present and used in various environments, including industry and mobility. This technology is also susceptible to various cybersecurity threats and attacks. The system can operate on two frequency ranges: low frequency (125 kHz, 225 kHz, 13.56 MHz) and high frequency (433 MHz, 915 MHz, 2.45 GHz, 5.8 GHz). RFID is a technology that uses electromagnetic fields to automatically identify, and track tags attached to objects. These tags contain stored information that can be read by RFID readers without the need for direct contact or line of sight. In the context of smart cities, RFID can improve efficiency, reduce costs, and enhance the delivery of services to citizens. RFID can be integrated into sensors for tracking pollution levels, enabling authorities to manage environmental quality proactively.

7. Smart Grids

The smart grid consists of various energy sources (renewable or conventional), smart meters, operational control mechanisms, load balancing mechanisms, and fault-tolerant systems for efficient and secure delivery of energy to the end user from different energy sources. These components represent sensors and communication channels through which the necessary energy flows and is distributed [4]. One of the most well-known hybrid networks is VANET-WSN, enhanced by the deployment of wireless nodes along roads, especially on highways. The sensors primarily act to monitor and control real-time traffic flow. The goal of this network is to improve transportation and facilitate communication between smart devices and people. This network can also communicate with other technologies, such as 5G, LTE, and others. In smart grids, the speed of data collection can vary from a few seconds (e.g., the status infrastructure and transformers) to several minutes (smart meters) [4]. The collected data must be transmitted within a specified period (time value of information) and synchronized to a specific voltage and frequency without fluctuations [4]. Smart energy measurement is a crucial part of a smart city, simplifying the time required for users to record their energy consumption. Nowadays, lithium-ion batteries or fuel cells are used to store excess energy, providing efficient storage and delivery over extended periods.

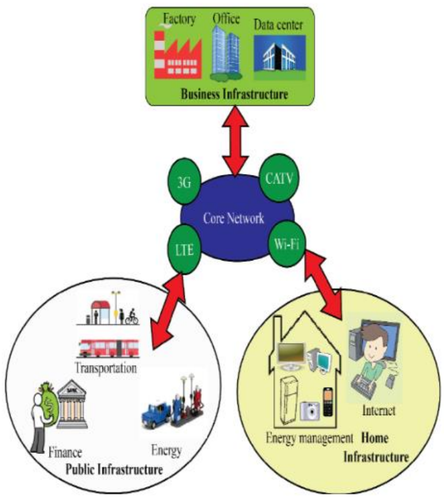

Figure 4. *Smart Infrastructure* [5]

In Figure 4, the smart infrastructure is shown, which serves as the fundamental foundation for the construction and implementation of a smart city. The infrastructure enables communication through Wi-Fi networks. All components of the infrastructure are processed and supplemented through a common software platform. The information needed by the infrastructure components is quickly accessible through this software. Figure 4 shows the connection of a family in the city with different institutions and platforms through different mobile smart networks and applications. Energy sources are diverse, including solar, fossil fuels, gas, electricity, and batteries. Energy cannot be created or destroyed; it can only be transformed from one form to another [5]. In recent years, alongside traditional energy forms, many other terms have emerged, including clean energy, green energy, sustainable energy, renewable energy, and smart energy [5]. Consumers (households and industries) will increasingly generate their own electricity. All powered units will operate entirely on green (renewable) energy. Backup capacities serve to ensure a reliable supply of electricity while also responding to demand, managing load, and controlling the electrical grid. Households can generally be referred to as prosumers, as they will produce and store electricity in the grid using bi-directional electrical systems. Many producers or several small local power units can connect and integrate into balanced energy supply systems based on market demand. Excess energy can be stored in battery systems, which will develop over time and become more commercially viable, enabling thermal storage to be available in the future. Various producers, storage systems, and network equipment consumers will be interconnected and managed through smart communication grids. Smart grids will be implemented to coordinate universally installed meters to generate vast amounts of data.

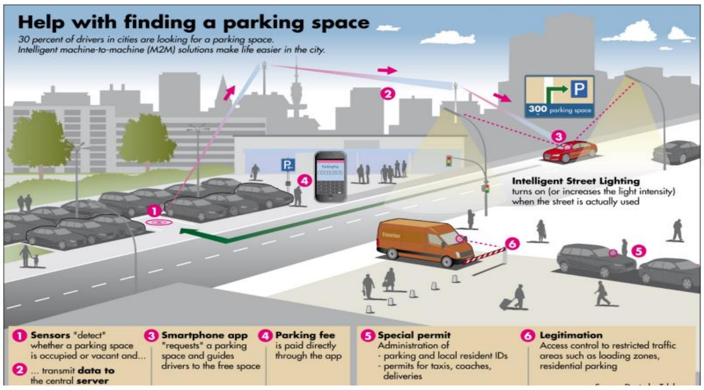

Figure 5. *Smart Parking*[1]

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[1] https://erticonetwork.com/pisa-and-deutsche-telekom-launch-6-month-smart-city-pilot-project-to-optimize-city-parking/

Smart parking is an essential part of the smart city concept, using IoT and other advanced technologies to provide a more efficient and convenient experience for drivers, reducing the stress of parking and improving urban mobility. These technologies not only optimize the use of parking spaces but also reduce the impact of traffic and pollution in cities. Smart parking systems use various types of sensors (such as ultrasonic, magnetic, or infrared sensors) installed on or above parking spaces. These sensors can detect whether a parking space is occupied or free and send this information to the central system. Mobile apps play an important role in smart parking systems, providing drivers with an easy way to:

- Search for and reserve parking spots: Drivers can use apps to find the nearest available parking spaces and reserve them without needing to drive around the area.
- Pay for parking fees: Smart parking apps enable quick and contactless payments for parking through mobile devices. Platforms can also offer different billing options, such as hourly, daily, or monthly rates.
- Real-time information: Apps can show real-time data on available parking spaces as well as any disruptions or events affecting parking availability.

Figure 6. *Smart street lighting*[2]

Smart Street Lighting is a critical element of smart cities that leverages Internet of Things (IoT), sensor technology, and data analytics to enhance urban lighting systems. These advanced street lighting solutions improve energy efficiency, reduce operational

[2] https://www.linkedin.com/pulse/smart-street-lighting-connectivity-technologies-market-singh-

costs, and increase safety and security within cities. Smart street lighting systems automatically adjust to environmental conditions, optimize energy use, and can be remotely monitored and controlled. Smart street lighting systems allow cities to remotely manage and monitor streetlights using cloud-based platforms and IoT sensors. Sensors within the lighting units can detect faults, like a burned-out bulb, and send automatic alerts to the maintenance team, reducing the response time and ensuring quicker repairs. By utilizing energy-efficient LED bulbs and dynamically controlling their intensity, cities can lower electricity bills and maintenance costs. Streetlights can communicate with traffic signals to improve the flow of traffic, reducing congestion. Integrated sensors can monitor environmental factors such as air quality, temperature, and humidity, providing valuable data for city planning and sustainability efforts. Some smart streetlights are equipped with Wi-Fi hotspots, providing free internet access to residents and visitors. Through smart lighting systems, citizens can be involved in discussions about energy usage, sustainability, and urban development.

8. **Conclusion**

Key aspects for defining the concept of a smart city primarily include IoT and cyber-physical systems, which play a significant role in the infrastructure of technology, informatics, and, more importantly, communication technology. The need for the development and implementation of smart cities is increasing daily, in parallel with the continuous advancement of new technologies. Demand-side management will play a crucial role in reducing peak loads in smart cities. In the near future, it is believed that the services offered by smart cities will become indispensable.

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Sara Kostevska
University Goce Delcev, Stip
Faculty of Electrical Engineering
R.N.Macedonia
Email: sara.kostevska@ugd.edu.mk

Biljana Chitkuseva Dimitrovska
University Goce Delcev, Stip
Faculty of Electrical Engineering
R.N.Macedonia
Email: biljana.citkuseva@ugd.edu.mk

Todor Chekerovski
University Goce Delcev, Stip
Faculty of Electrical Engineering
R.N.Macedonia
Email: todor.cekerovski@ugd.edu.mk

Marija Chekerovska
University Goce Delcev, Stip
Faculty of Mechanical Engineering
R.N.Macedonia
Email: marija.cekerovska@ugd.edu.mk

Sara Srebrenkoska
University Goce Delcev, Stip
Faculty of Mechanical Engineering
R.N.Macedonia
Email: sara.srebrenkoska@ugd.edu.mk