Smart Cities: Challenges and Opportunities

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ABSTRACT [1]

The concept of smart cities has received a significant interest recently among researchers. United Nations reports that more than half of the world population currently lives in urban environment, and is estimated to increase to about 70% by 2050. This trend needs serious attention by governments to create solutions that will make sure that their citizens will continue to have sustainable and improved quality of life. Smart cities use all the available technologies to achieve that goal and to improve the efficiency of their operations. This massive undertaking of making existing cities smart and building the new smart cities, comes with many opportunities as well as some challenges. Digitization of services, smart operations, and connectivity are essential parts of smart cities. The smart cities will certainly promote cohesive, connected, healthier, and happier communities. This paper elaborates the opportunities and the challenges in moving the smart cities concept forward.

Keywords: Smart Cities, Smart Systems, Opportunities and Challenges.

1. INTRODUCTION

The concept of smart cities has been pursued for several decades. The main goal of a smart city is focused on enhancing the quality of life of its citizens, providing an environment that leads to happiness of citizens and communities, and enhancing efficiency of its operations by utilizing whatever resources are available. The goal makes the smart cities not only livable but also enjoyable for the citizens, and it creates an echo system where citizens of smart cities have opportunities to ascend to the highest level of Maslow's pyramid of human needs. The pyramid starts from the psychological needs at the bottom and adds additional needs of safety and security, love and belonging, self-esteem, and finally self-actualization at the top [1].

The resources needed to develop a smart city include all the available technologies and innovative applications. Information and communication technologies (ICTs) such as Internet of Things (IoT), and artificial intelligence (AI) play a major role. As technologies improve, so do the smart cities with the adoption of the emerging technologies. Internet of Things provide pervasive connectivity and presents itself as an ideal platform to collect data about various aspects of a smart city. The necessary data may be collected for any relevant application, service, and/or operation including healthcare, transportation, energy, environment, waste management, utilities, city architecture/planning, etc. Artificial intelligence can help in processing large volumes of collected data and suggest possible solutions to continuously improve the services provided to the citizens of smart cities. This process has now evolved to a more systematic approach of continuous collection of data, ongoing analysis of collected data, sharing of possible solutions, and implementation of appropriate actions [2].

With the help of available technologies, a smart city can effectively address the following aspects for its citizens:

- Better living conditions
- Better services
- Connected, cohesive, happier, and happier communities
- Enhanced quality of life of citizens
- Better safety and security
- Efficient city operations
- Lower operational costs
- Efficient use of resources
- Sustainable city infrastructure
- Many more …

Development of smart cities has been necessitated by several factors. One of the major factors is the demographic shifts that have been taking place over the past several decades. Growing number of people are choosing to live in bigger cities. A recent report by United Nations [3] indicates that from 2.5 billion in 1950, the

world population is expected to reach 10 billion in 2050. That represents an addition of 7.5 billion (300% increase) within a span of 100 years as shown in Figure 1.

Combined with the rapid rise in the world population, there has been an increased trend of urbanization. A recent study by United Nations [4] indicates that in 1950, only 750 million (30% of the world population) people were living in urban areas. By 2050, this figure is expected to reach 6.9 billion (68% of the world population) as shown in Figure 2. This is another remarkable increase and demographic shift. This factor alone advocates in strongest possible terms, the development of smart cities.
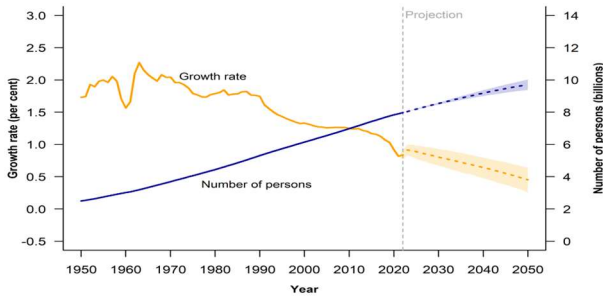

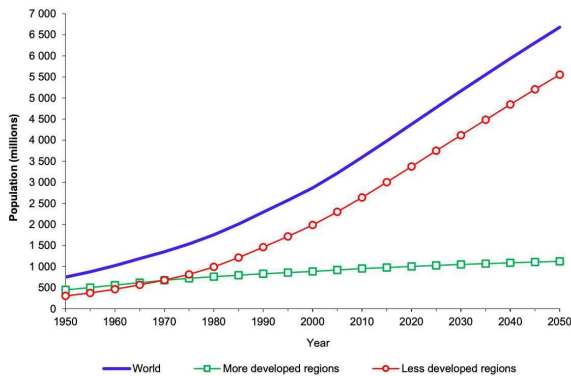Figure 1: World population and its growth rate [3].

Figure 2: Trends and projections of urban population [4].

Urbanization of this scale is expected to lead to very densely populated cities with unique needs to better serve the citizens. It is important to recognize the citizens' needs early and develop a plan to address these. The needs may include the following:

- Housing needs and better living conditions
- Educational needs and opportunities
- Adequate food supply to meet the increased demand
- Clean environment
- Better security, safety, and law enforcement
- Efficient city governance
- Services such as healthcare, transportation, utilities etc.

Smart cities are being viewed as a possible solution for the rise in urbanization and to effectively address the challenges of densely populated cities. The smartness in smart cities comes from the use of emerging technologies including IoT and AI. These technologies lead to automation of many services and tasks. As mentioned earlier, the automation in decision making uses data-driven process. This process augments the human abilities, improves the efficiency of operations, and improves the quality of life of citizens.

The next section of this paper discusses the characteristics of smart cities. Section 3 discusses the roles of IoT and AI in smart cities. In section 4, we discuss the challenges and opportunities in smart cities. Finally, section 5 presents a summary and conclusions of the paper.

2. CHARACTERISTICS OF A SMART CITY

As discussed earlier, a smart city, by definition, must deploy smart systems with a goal of enhancing quality of life of its citizens. To achieve this goal, smart cities require the use of emerging technologies such as Internet of Things (IoT), artificial intelligence (AI), and others. The smart systems use data collected by IoT through its pervasive connectivity. The data is analyzed by AI environment to make some decisions, communicating the appropriate decisions to IoT devices, and implementing these decisions using actuators. This cycle of data collection and implementation of decisions continues and essentially makes the foundation of smart systems. In turn, smart systems lead to autonomous operations [5,6]. This is one of the most fundamental characteristics of smart systems and thus of smart cities. Figure 3 shows a typical depiction of components of a smart city [7].

Figure 3: Typical depiction of smart city components [7].

Smart systems are essential for smart cities. Applications of smart systems in smart cities are dynamic and endless. They are dynamic because they keep adjusting with the

changing needs and availability of emerging new technologies. Smart cities must be flexible enough to adapt to the new circumstances, conditions, and technologies.

Every smart city has a unique set of needs and, therefore, must have a unique set of applications to meet those needs. However, there are some features and characteristics that are common in all smart cities. Following is a partial list of characteristics that each smart city should have:

- Smart healthcare
- Smart transportation/mobility
- Smart energy/utilities
- Smart environment
- Smart city architecture / city planning
- Smart buildings
- Smart security/law enforcement
- Smart city governance
- Many other smart aspects

For centuries, humans have been interested in automation and doing things fast. Finally, the time has come for the use of emerging information and communication technologies in conjunction with artificial intelligence, and it is possible to have widespread automation to serve the needs of the citizens of the smart cities.

Development of a smart city requires a visionary leadership with open mind, necessary resources to implement the vision, commitment for greater collaboration among different agencies, and a task force focused on development of a smart city. Some of the examples of smart cities include New York, Barcelona, London, Singapore, and Tokyo.

3. ROLE OF IoT AND AI

Both, Internet of Things (IoT) and artificial intelligence (AI) play a major role in smart cities. IoT and AI work together to support smart applications. Some of the experts feel that IoT and AI need each other for their existence. IoT provides a platform to collect data, AI uses this data to make some decisions, these decisions are communicated using IoT, and that leads to a need of collecting more data. This cycle of interdependence has coined a new term AIoT or artificial Internet of Things.

Role of IoT
Internet of Things (IoT) represents a connected system where almost every object or device that we can think of, is connected, is uniquely identifiable, is accessible, and can communicate with other objects from anywhere and at any time. Some of these objects could be trivial in their capabilities but are still connected. Examples of these objects include thermostats, doorbells, children's toys, utensils, lightbulbs, furniture etc. Nonetheless, each object connected to the Internet of Things is capable of collecting and/or sensing information, processing it, and communicating it. Therefore, each object must have a communication protocol stack to handle its communication needs. In addition, each IoT connected object must have adequate processing power to perform its basic operations.

Internet of Things has witnessed tremendous growth over the past few decades. Its growth trajectory is expected to continue for the foreseeable future. The number of devices connected to IoT in 2016 was estimated to be 6.4 billion. This number is estimated to be 50 billion by year 2050. More than 80% of senior corporate executives feel that IoT is critical for their businesses [8,9].

For smart systems' operations to work efficiently, they need relevant data to make decisions. Based on its broad, diverse, and pervasive connectivity, IoT can serve as an ideal platform for collecting data relevant to smart applications. That applies to smart cities as well with a broad set of applications including healthcare, transportation, energy, environment, and governance etc. The collected data can be used by artificial intelligence to analyze, extract useful contents, and make decisions. These decisions can be communicated to appropriate IoT devices for implementation. After the decisions have been implemented, system operations will adjust accordingly, and new data will be available for collection. So, IoT plays a crucial and central role in bidirectional flow of data that makes smart operations possible for all smart systems including smart cities.

Role of AI
By its nature, artificial intelligence (AI), uses data from different applications to train devices (as well as systems) and makes them look smart. Devices associated with the systems can use the collected data and machine learning tools to train. These devices can quickly process large volumes of data leading to autonomous decision-making. Thus, AI is expected to play an effective role in all smart systems including smart cities. Furthermore, the role of AI in smart systems is expected to continue an upward trend due to the other technical advances such as faster computational devices, faster data communication, and availability of massive data storage capacity. These trends are expected to transform every aspect of our daily life and daily activities [10].

As smart cities continue their development process, a larger number of their operations become smart. Some of the major smart operations in a smart city include smart healthcare, smart transportation, smart energy, smart city architecture, smart city architecture, smart law enforcement, smart governance and many more. The process of making all these operations smart is essentially the same. All these smart operations depend on relevant data and artificial intelligence tools to process that data,

and start making smart decisions. For instance, smart healthcare will need to collect data from all components of healthcare sector including patients, healthcare professionals, diagnostic equipment, medications, treatment equipment etc. This data, when analyzed and used by artificial intelligence tools, enhances the overall efficiency of healthcare operations. Similarly, for smart city architecture, relevant data can be collected over a span of time including transportation data, city temperature data, city energy consumption data, location of public parks, data about the services for elderly population and many more. This data can be analyzed, and artificial intelligence tools can suggest some options regarding architectural changes to the city for enhancing the efficiency of city operations. The same approach and the same process applies to transportation sector, energy sector, law enforcement sector and all other aspects of smart cities. In summary, artificial intelligence is expected to play a high impact role in all aspects of smart cities [11].

Another emerging role of artificial intelligence (AI) in smart cities would be what is being referred to as augmented intelligence (AuI). In many situations, we do not feel totally comfortable with artificial intelligence making critical and personal decisions for us which such as healthcare. In such cases, AI can be used to suggest some of the suitable options based on the relevant data analysis. Healthcare professionals can review those options and make a final decision according to their best judgement. Such a process essentially combines human intelligence and artificial intelligence – thus using augmented intelligence – to come up with the best possible healthcare options [12].

4. CHALLENGES AND OPPORTUNITIES

There is a consensus that smart cities will bring many benefits to their communities and improve quality of life of their citizens. With rapid proliferation of emerging technologies, new and almost endless opportunities will become available leading to the development of new applications. Major opportunities to address various aspects of smart cities include:

- Enhanced services for citizens
- Efficient operations
- Better education
- Economic growth
- Better safety and security
- Happier citizens
- Data-driven decisions
- Many more such opportunities

Innovative and creative approaches are essential to make the best use of emerging technologies. As the new applications are implemented to better serve the citizens of smart cities, additional needs will surface. These new needs will need new technology-based solutions leading to even more new applications. This cycle is essential part of the process of growing with technologies. It is important for the leadership of smart cities to adapt to these opportunities and continuously improve their services.

These technological advances and developments come with some challenges as well. Our discussion has been about two main technologies that are playing a central role in smart cities. These technologies are Internet of Things (IoT) and artificial intelligence (AI). IoT provides an ideal platform to collect data from various applications, and AI analyzes this data to introduce smartness, data-driven decision-making, and automation [13,14]. There are three types of challenges that can be attributed to smart cities:

- Challenges and concerns faced by the citizens of smart cities
- Challenges associated with the emerging technologies used in smart cities
- Challenges associated with the development of smart cities

With the massive amount of data being collected and communicated through IoT, there is always a concern that the data (some of it may be of personal natures or healthcare-related) may fall in the hands of some misguided individuals. Similarly, while AI has tremendous benefits in automating applications, the society does have some concerns about its potential impact. The biggest concern stems from the fear of unknown territories that these technologies are steering the society into. However, it is also true that historically such fears gradually fade away.

Privacy and security of information is another challenge that citizens of smart cities are concerned about. That is a valid concern because IoT connects some of the devices which are very small such as thermostats, coffee makers, toys, door locks, small appliances etc. Such devices do not have sophisticated protections and are vulnerable. The concerns are valid, and it is a major challenge to secure IoT environment. However, there are serious efforts to provide robust security for IoT environment and to protect the information. Concerns such as privacy and security of information impact citizens' trust in the use of widespread technologies such as in smart cities. With time, however, such concerns become less worrisome, and the level of trust improves [15].

Another lesser known but major concern that impacts the trust is about the use of artificial intelligence in growing number of applications such as autonomous vehicles and healthcare [16,17]. AI is providing tremendous benefits to various segments of our society and in many sectors. However, the concern is that there is less attention being given to hidden biases embedded in AI infrastructure and in its process of decision making. In all AI environments,

devices are trained based on some known datasets (with known inputs and outputs) and AI algorithms make decisions based on that training. The decisions made by AI are as good as the datasets used for its training. These datasets used are generally produced by expert professionals and may have unintentional biases. In such cases, AI will produce results or make decisions that are inherently impacted by the opinions or expertise of the professionals producing those datasets. However, we also know that the AI environments continue to learn beyond initial training and improve their decision-making process. Therefore, with time these biases will gradually have less impact on autonomous decisions.

Development of smart cities requires robust infrastructure, adequate resources, visionary leadership, and focused taskforce. Lack of resources and short-term mindsets will pose a serious challenge to the development of smart cities. It is important to have a clear vision, allocate enough resources, and have dedicated effort to achieve the goals of smart cities and to reap its benefits.

One more challenge attributed to AI is different than the challenges posed by other technologies. As mentioned earlier, emerging AI trends lead to continuous improvement of decision-making process and its outcomes. Where will the future use of AI take us with better and more sophisticated emerging technologies such as quantum computing? Future projections indicate that by 2050, a $1000 laptop will have more processing power than that of a human brain. In that case, what will the coexistence of humans and AI machines mean? What will the future bring, remains unknown at this stage and the fears of unknown are legitimate.

At this stage, the best we can do is to use these technologies to better serve our society such as in healthcare [18]. Combining human intelligence and AI is being referred to augmented intelligence and that can really serve the humanity better and should be a part of all the smart cities [19,20].

5. SUMMARY AND CONCLUSIONS

This paper discusses the role of emerging technologies in development of smart cities. The paper also discusses the associated opportunities and challenges. Recently significant research efforts have been directed to the concept of smart cities. Recent trends in demographic shifts of the world population show that more and more people prefer to live in urban environment. It is estimated that 70% of the world population will be in larger cities by the year 2050. This trend needs serious attention by governments to create solutions that will make sure that their citizens will continue to have sustainable better quality of life. Smart cities use all the available technologies to achieve that goal and improve the efficiency of operations. This massive undertaking of making existing cities smart and building new smart cities, comes with many opportunities as well as some challenges. Digitization of services, smart operations, and connectivity are essential parts of smart cities. The smart cities will certainly promote cohesive, connected, healthier, and happier communities. Two technologies are expected to play a major and impactful role in the development of smart cities. These technologies are Internet of Things and artificial intelligence. Associated with the use and implementation of any technology, are many opportunities and challenges. Smart cities are no exception. Smart cities provide tremendous opportunities to provide better services and improve the quality of life of their citizens. At the same time, there are many challenges that need to be addressed. Some of the major challenges are related to privacy and security of personal information, fears of unknown that emerging technologies may bring, and level of trust that citizens of smart cities may have in dealing with these technologies. This paper elaborates the opportunities and the challenges in moving the smart cities concept forward.

6. ACKNOWLEDGMENT

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