Importance of Internet of Things and Big Data in Building Smart City and What Would Be Its Challenges

Manan Bawa(✉), Dagmar Caganova, Ivan Szilva,
and Daniela Spirkova

Faculty of Materials Science and Technology in Trnava,
Institute of Industrial Engineering and Management, Slovak University
of Technology in Bratislava, Trnava, Slovakia
{manan.bawa,dagmar.caganova,ivan.szilva,
daniela.spirkova}@Stuba.sk

Abstract. Cities are regarded as the backbone of the country's economy and sustainability. To make a city 'smart', we need to build upon the strategies which could mitigate city's current issues and avert future problems which are driven by the urban society and its rapid expansion. According to the UN urbanization report (2011), urban cities occupy 2 % of the earth's total area and still they are responsible for the 70 % of the global energy consumption and emission of greenhouse gases. The cities will need to attend to these global facts and take upon bigger challenges of fulfilling the essential needs of water, food and shelter, providing necessary public services like utility, security, and mobility and importantly managing scare resources. IoT and big data with their innovating techniques and advancing technology provides those critical tools which helps to address these topics and lay down the foundation for next generation smart cities.

Keywords: Smart city · Internet of things (IoT) · Big data · Innovation · Cloud computing

1 Introduction

The world is moving towards extreme urbanization and we need to build our cities around it to sustain the needs and requirements of this urban population. According to UN world urbanization perspective (the 2011 revision), 50 % of the current world population lives in the cities and towns and by 2050 the percentage will rise to 70 %. The word 'city' may not exist from the vantage point of a traditional economist, as they might believe city means higher cost of living, land, goods, etc. Moreover, air and water pollution, toxic emissions due to the greenhouse gases, sewage overflows and different kind of viruses, flu's and diseases floating around are common problems faced by the people living in the city. In 2013, poor air quality shut down the Harbin city in China with population of 11 million and also affected Beijing the capital city of China [1]. However, still 70 % of the world's GDP runs on the economic growth of the cities.

'Smart City' is the term we are going to hear a lot in the coming years. Research at MIT media lab predicted in the future, the modern cities will account for about 80 % of wealth creation and approximately 90 % of global population and the total energy consumption will keep increasing every year. Our objective should be to improve our understanding of the cities and also to develop new and better strategies with the help of innovations and emerging technology for the creation of new cities. Rather than focusing separately on individual functions like – Energy, Transport, Food, Water, Shelter, etc. smart cities should set up a collective approach where a central nervous system with latest technology, using internet of things and big data should be created. This central hub will maintain and sustain all functionalities of public health, food, education, work and even government stability.

The idea behind the smart city initiative is to use innovation in advancing technology and focus on data collection and analysis to make the internet of things and big data a reality into environment where we live in. Every city is a part of complex ecosystem where lot of planning is required for instance to develop data driven systems for transport, efficient energy use and law enforcement to improve the lives of the society. Decision making in most situations may be politically driven, hence the derived data is inevitably human and sometimes analogue. For our purpose we need digital data and with the IoT devices and big data tools we will produce intelligent data which will be able to send and receive information in both direction and be able to interact using smart systems to our smart phones, wearable glasses, watches and other devices and most importantly machines and devices will be able to communicate to each other [2].

2 Smart City

In this digital world our lives are driven by the advancements of computing which has already brought us the social web, the internet, smart phones and more recently internet of things and now we are witnessing this idea of digitalization has started shifting to our cities [4]. We are seeing that tremendous amount of people are moving from rural to urban areas for opportunity to work, to access better education, be part of digital and global economies along with other facilities and services for improved quality of life [5]. Supporting such a movement requires innovative ideas and ways to manage current resources and at the same time think and build upon the future, which has led to the idea of technologically driven interconnected city referred as 'Smart City'.

Figure 1 shows the concept or provides an overview of smart cities, where every key aspect from energy to mobility of the city is integrated together using latest and innovative technologies to make them smart. Figure 2 below, lays out some of the essential terms and tools used for building an advanced next level city. In next couple of sections the authors will discuss the significance of these tools and will also touch upon why and how they need to be interconnected for achieving the goal of structuring a sustainable and a superior smart city.

Fig. 1. Concept of the smart city [3]

Fig. 2. Smart city and its tools [6]

2.1 Components and Features of Smart City

Population is migrating from rural areas to cities and urban regions at a very high pace as a result city has to grow in every aspect to maintain harmony and to generate socio-economic and environmental balance among the inhabitants. The premier aim of the city to rise to the status of a 'Smart City' is to make the life easier for its people [7]. In doing so, city will have to incorporate certain essential components and establish vital features to its periphery. According to the authors of the paper some of the critical components and features for building a smart city are given below. Figure 3 shows the pictorial representation of the components and the features and Table 1 describes the key areas, benefits and the resources required for building a smart city.

Smart Government – *Information, Communication and Technology Enabled Government* [8]: To succeed with the smart city concept the government first has to enable the smart government tag upon itself, which means adopting the information, communication and technology platform to integrate the various aspects of key government functionalities to the public which is speedy, transparent and accessible to all.
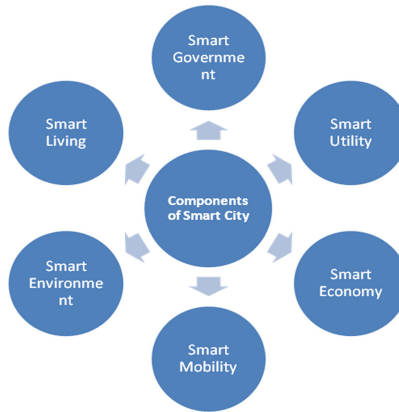
Fig. 3. Components and features for building a smart city [7]

Safety and Security of the Citizen: Safety and security is a very high priority for the government to its citizens and any concerns especially due the alarming and disturbing news on the safety of women and road rages gives sleepless nights to the police. The use of video CCTV cameras in all public areas, man-less verified access, smart centres for surveillance and robot controlled patrolling, and intelligent data to identify the emergency before it happens and at the same time inform the rapid response team to mitigate any emergency situations should be some of the parameters for the government to incorporate.

Participation and Corporation of Citizens to the Government: Government driven mobile applications and web portals should be made responsive to the citizens to participate and help the police and authorities to solve any local issues. A new electoral structure should be carefully designed with the help of latest technologies to enable elections online or to book the voting slots using smart technology.

Smart Utility – *Efficient use of Utilities* [8]: With large amount of population moving to the urban regions, utility becomes a major concern. City will have to clearly look into innovative ways to mitigate the utility scenario by using modern advancements like – smart utility grids, internet powered smart energy meters, buildings running on solar power, efficient usage of energy using sensor enabled technology, using scientific ways for waste disposal and effluent recycling, garbage trucks to be made aware using mobile application to the locality that requires waste collection, use of renewal energy like wind and water and its conservation.

Smart Economy – *Private and Public Partnership:* Healthy and secure economy should be the motto for a smart city, which will require partnerships between private and public sectors. These two sectors working together will not only keep the financials strong but also help in efficient delivery of the agreed services [8].

Highly productive and sustainable economy: Smart economy is about thinking smarter and creating novel and innovating ideas to generate new and successful revenue

Table 1. Key areas, benefits and resources required for a smart city [7]

Smart city – components and features	Key areas	Benefits	Resource requirements
Smart government	Information, communication and technology driven government	Increased safety and security	Government started initiatives – open data, smart city, energy conservation
	Digital presence	Improved and transparent policies	Skills and experience to build and manage smart city (IoT and big data)
	Open communication for everyone	Real time and quick services	
Smart utility	Smart grid	Cleaner, healthier and greener cities	Creating network for managing electricity distribution, water supply, gas distribution and waste management systems via central cloud server
		Solar panels on individual houses and buildings	
	Zero waste and green initiative	Availability of clean water and uninterrupted power	
	Round the clock water & electricity supply	Services available online using technology	
	Using renewable sources of energy – solar power	Recycle and reuse	Smart meters, grids, devices, etc.
	City waste and sanitation management	Improved quality of life	Modern utility to enable a more reliable, efficient and resilient future
Smart economy	New revenue models	Increase in GDP and per capita income	National hubs
	Biggest financial hub		Skill development
	Competitive pricing	Partnership between public and private	Innovation and entrepreneurship
	International and local investments	Greater employment opportunities	Trade centers
Smart mobility	Intelligent transport system	Clean energy	Technological Infrastructure
		Hybrid, solar and electric technology	
	Real time data capture	Cleaner and efficient fuel	
	Big data analysis	Efficient and elegant design	Smart hardware – sensors, cameras, etc.
	Internet of things		Smart software's and tools – mobile applications, designs, web portals

(*Continued*)

Table 1. (*Continued*)

Smart city – components and features	Key areas	Benefits	Resource requirements
Smart environment	Green and clean environment	Technology and network enabled houses	Government initiatives – greener public transportation system, cycle paths, etc.
		Efficient urban planning	
	Use of renewable and recyclable materials	Control over energy consumption	
	Smart homes and buildings	Reduction of waste generation	Central hub for all urban planning – energy distribution, waste disposal, transportation, etc.
Smart living	Intelligent devices	Increased safety	Advancement in technology
	Automation systems	Improved health	
	Education facilities for everyone	Increase in life expectancy	Smart data analysis using big data and its features
	Wi-Fi and internet availability everywhere	Better education to all	Creating networked world with sensors using IoT and controlled by cloud servers

models. Smart means producing improved products and services at a competitive price and the aim would be to influence government to implement a range of policies to make the economy more dynamic.

Smart Mobility – *Urban Transportation:* Big data and internet of things can capture real time data and help manage the road traffic using the video cameras and sensors. Social media and mobile applications can help avoid road blocks by updating information about accidents or potential traffic jams. Concept behind smart mobility is to use latest techniques and innovate designs developed by vehicle manufacturers like electric and hybrid cars, solar powered cars with solar cells on the rooftop, highly efficient and intelligent vehicles etc.

Smart Environment – *Green Transportation:* Use of urban public transport system which contains all different mode of transportation's schedules which links even to the remotest location and is connected to the cloud network, minimizing the use of private vehicles, changing the fuel technology to use electric or hybrid techniques and build bicycle paths and promote cycling are some of the features for smart environment.

Renewable and recycle: Thoughtful measurements should be taken by the government for creating an habitable environment for its citizens like smart tags can be implemented on the products which are recyclable by the manufacturers and by default it highlights itself as a mandatory recyclable item, thinking of innovative ideas in the field of biodegradable packaging, using sensors and internet of things which connects to the central server in the cloud to notify the nearest garbage pickup truck when the bins are full.

Smart Living – *Intelligent Living:* Modern homes equipped with intelligent devices and automation systems are the key to smart living. With internet of things a network of devices like washing machines and refrigerator and systems like central heating, air conditioners and home theatre can all be connected together via a cloud and they all can interact and communicate with each other and can be controlled with a mobile application by the owner [9].

3   Internet of Things

The internet of things can be defined as a system where all the machines and devices are connected to a network and have a central server or a cloud server, which has the capability to monitor and control everything on the network [10]. All these gadgets will have their own unique internet protocol (IP) addresses and all of them can see, communicate and exchange information among each other [11]. With IoT traditional systems which used to work independently like in the case of home and industry automation such as fire alarm system, motion detection and access control, surveillance system, HVAC and energy management system, etc. can all work, interact and talk with each other using propriety protocols and standards over a network. IoT is the foundation for a smart city, as all the equipment can sense the complexity of the environment and they can communicate and exchange information as required.

It is very hard to estimate the exact size of IoT as numerous embedded devices like machines, automation devices, sensors, radio frequency identification tags, and many more other devices are all linked together on to a network. It is believed that with this tremendous rate of growth of internet of things, it will soon exceed the size of the internet (in terms of number of nodes) and it will keep growing at a rate of billions of devices per city.

Two crucial features of IoT includes sensor networks and cloud computing. A sensor network is a web of sensors which are used for monitoring, transmitting, analyzing and recording different conditions [12]. Sensor detects via a sensor node and each node consists of a specialized transducer, microcontroller, transceiver, and a power supply [11]. Transducer converts physical sensations for example pressure, vibrations, humidity, temperature, vital body functions, etc. to an electrical signal and microcontroller at the same time processes and stores these signal [12]. The transceiver, acts both as a transmitter and receiver and when it receives a command from the central computer, it transmits the stored output to the computer for analyzing. Power is required for the sensor to operate which is usually supplied by the grid or it has a battery onboard.

Another important feature of IoT is that all information or the data from the embedded devices gets stored on to a central cloud server. Users can access the information from anywhere from the world using their smart phones, tablets, laptops, smart watches, etc. from the cloud in a form of an application which is usually hosted as software as a service (SaaS) [13]. Cloud computing also acts as a service for storing, sharing, computing, and analyzing the data.

A very vital component for the IoT network is the software design, as it brings life to the hardware and completes the whole network cycle. The software architecture is

divided into three functional layers namely – data format, application/transport layer and network layer [14]. Figure 4 shows the internet of things protocol used for each functional layer for constrained nodes and for constrained networks.
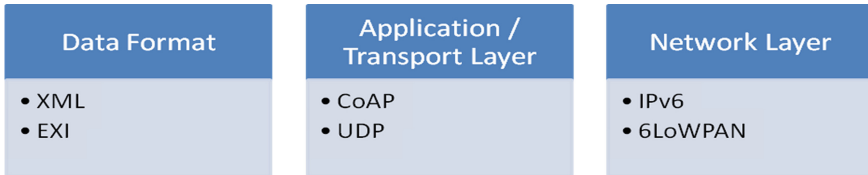
Data Format	Application / Transport Layer	Network Layer
• XML • EXI	• CoAP • UDP	• IPv6 • 6LoWPAN

Fig. 4. IoT protocols for each functional layer [14]

Data Format: With internet of thing there are specific data requirements for generating and supporting messages for all the devices embedded in its network. The common languages for data exchange are extensible mark-up language (XML) and efficient XML interchange (EXI). The size of the XML files can become too large and with limited capacity for the devices onboard to handle such large data, the complexity can increase [15]. These issues are resolved when use EXI format and that's why authors of the paper proposes to use EXI format, additionally all constrained devices can interpret EXI format hence making the devices a multipurpose IoT node [16].

Application/Transport Layers: Internet traffic is mostly transported at the application layer by hypertext transfer protocol (HTTP) over transmission control protocol (TCP) protocol, however the complexity of HTTP and no scalability of the TCP protocol with the constrained devices make it unsuitable for IoT environment [14]. The constrained application protocol (CoAP) transported over user datagram protocol (UDP) helps overcome the above mentioned problem and provides a reliable solution [17] and they can be easily interoperate with HTTP.

Network Layer: World wide web consortium (W3C), has recently declared the internet protocol version 4 (IPv4) standard, which is the most popular addressing technology has exhausted all its address blocks [14], however we have internet protocol version 6 (IPv6) standard which provides 128 bit address field and helps assigns a unique address to all possible nodes in the IoT network [18]. The issue with using IPv6 it is not fully compatible with the capabilities of all the constrained nodes [14], therefore the authors of this paper recommends adopting IPv6 over low power wireless personal area network (6LoWPAN) standard which is derived from the IPv6 and UDP header which works over low power constrained networks [19, 20] ideal for IoT.

4   Big Data

Data plays a vital role in the concept of smart city as massive amount of data is streamed though different kinds of network and even with IoT's cloud technology for storing, analysing and processing the data, it is still very complicated to convert the

data into useful or intelligent form [11]. Big data with its innovative approach which aims for creating data driven processes and its leveraging advancements in data analysis and technology offers some promises.

Big data can be defined as a medium for collection and storage of data so humongous and complex that it is not possible to use traditional data and management tools for processing and analyzing of the data. There are three V's to the concept of big data – volume, variety and velocity, as shown in Fig. 5 below. City generates large **volume** of data with a vast range and **variety** and the decisions needs to be made at a very high **velocity** [21]. It is a challenge for the smart city to collect, store, process, analyze, share and visualize huge amount of data coming from all different sources and convert the information into useful and meaningful form. More than 80 % of data is unstructured, variable in nature and come in many formats – documents, emails, images, videos, GPS coordinates, sensor data, etc. however it is also predicted by the data scientists that with smart city, sensor data will hit the crossover point with the unstructured data from the social media [22]. These data streams are all in real time and changes very constantly and rapidly.
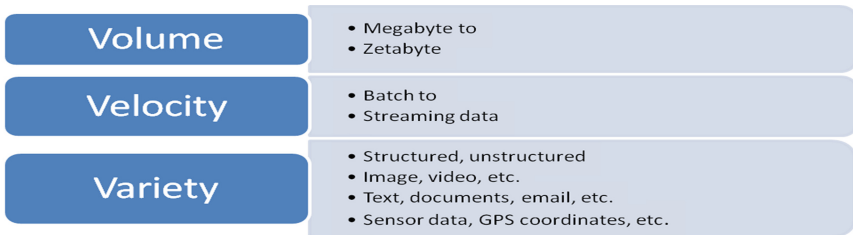
Volume	• Megabyte to • Zetabyte
Velocity	• Batch to • Streaming data
Variety	• Structured, unstructured • Image, video, etc. • Text, documents, email, etc. • Sensor data, GPS coordinates, etc.

Fig. 5. The three V's of big data [23]

Big data provides flexible model to store, analyze and process data of any shape and size. It can receive data from number of channels and offers innovative tools and latest techniques to explore and convert the incoming data into intelligent and meaningful form. The most sophisticated tools out in the current market which can handle big data are Hadoop and NoSQL technologies. Also there are other open source solutions available which fulfil the requirements of big data. These tools are secure and they can work with any size, variety and scale of data. NoSQL technology has gained high popularity in the world of big data and it has four different varieties – key value, document store, wide column and graph database [23]. It can process complex and multiple data arriving from social media, sensor, linked data, etc. along with its relationships. Big data has some challenging software requirements for its processes, here are few of the requirements –

- The data storage should be redundant, reliable, and could store data for very long time
- Data processing and analyzing should be fast
- Tool should share the information in real time and with multiple locations

- Should have fast response and allows the users to navigate through the information with no delays
- It should be scalable to the needs for the user and the society.

5   Challenges

In coming days the country's economic progress and status would be measured by the sustainable development of their smart cities. The cities will be filled with IoT devices and big data technology – smart and urban mobility, smart buildings running smart meter, monitoring security, running elevators, etc., smart traffic, use and tracking renewable items, etc. Therefore, it will be safe to say that we exist in a networked world, and so do our cities.

However, there are many challenges to reach to the goal of creating a smart city and it can create a havoc situation for the people, society, government, and even for the country's growth and economy. According to the authors of the paper, few of the critical challenges which needs to be addressed now are discussed below –

- A smart city will be full of IoT enabled devices and different systems which run on various platforms and at the same time the data generated by these devices and systems will come in the form of different variety, velocity and volume over different networks. The greatest challenge would be to integrate the either city to a network.
- The biggest of all challenge for smart city concept, which ties mainly to internet of things and big data is the concerns over security, the IoT devices contains lot of data and of various kinds and when they get connected to a network the data gets communicated to the central server (cloud), which increases its vulnerability to the next level. As the amount and value of data increases with time, the targets for the attacks also get multiplied with the same number [24]. The attackers and the hackers can steal all the private information, may be they can also manipulate information and even can damage its integrity.
- The lack of standards in the field of internet of things and big data are another set of challenges for the progress of smart city. There are lot of concepts out there however not many of them are designated to form a standard yet. Therefore, there are no real standards to follow for some of the critical functionalities in terms of IoT and big data like – how to handle data, how to adapt to the real values, and how to transmit, store, analyze and most importantly secure the information.

6   Conclusion

Smart city is a great initiative and making it a reality requires development of all the components and sectors associated with and around it. Many key features and requirements of smart city including smart government, smart mobility, smart living, smart utility and others, all play a very critical part in the designing, planning and

development of a city. It provides enormous benefits to the people and the society and even though intelligent city has very contingent resource requirements. The big players and the government understands the importance of urban city and are putting the right step forward to implement it and this can seen from the fact that it is estimated by the industry analysts that smart city will represent around USD 40 billion in the market by the year 2016.

Internet of things is the brains of the smart city concept as it provides all the essential hardware and software to manage the city efficiently and improve the quality of life. Big data is the heart of the smart city as it promises to generate intelligence from the data collected from IoT enabled devices and other data streams. There are still lot of unknowns and challenges like security, privacy, data management and analysis that needs to be addressed and attended too, however if the city needs to be smarter, show progress, be more competitive and have sustainable development they need to leverage to the advancements of IoT and innovative techniques of big data to succeed towards their goal of building smart city.

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