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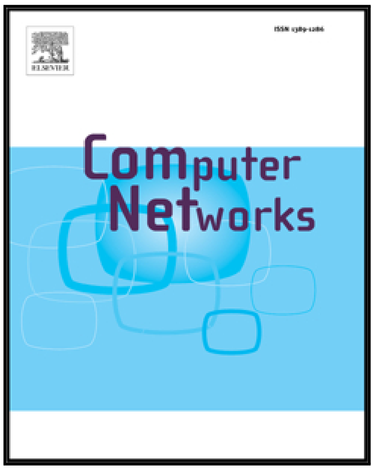

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Urban Planning and Building Smart Cities based on the Internet of Things using Big Data Analytics

M. Mazhar Rathore[1], Anand Paul[2] , Awais Ahmad[3], Suengmin Rho[4]

[1, 2, 3] *The School of Computer Science and Engineering, Kyungpook National University, Daegu, 702-701, Korea*
rathoremazhar@gmail.com, awais.ahmad@live.com, paul.editor@gmail.com
[4] *Department of Multimedia, Sungkyul University, Anyang, Korea,*
smrho@sungkyul.edu

Corresponding Author: paul.editor@gmail.com (Anand Paul)

Abstract— The rapid growth in the population density in urban cities demands tolerable provision of services and infrastructure. To meet the needs of city inhabitants. Thus, increase in the request for embedded devices, such as sensors, actuators, and smartphones, etc., which is providing a great business potential towards the new era of Internet of Things (IoT); in which all the devices are capable of interconnecting and communicating with each other over the Internet. Therefore, the Internet technologies provide a way towards integrating and sharing a common communication medium. Having such knowledge, in this paper, we propose a combined IoT-based system for smart city development and urban planning using Big Data analytics. We proposed a complete system, which consists of various types of sensors deployment including smart home sensors, vehicular networking, weather and water sensors, smart parking sensors, and surveillance objects, etc. A four-tier architecture is proposed which include 1) Bottom Tier-1: which is responsible for IoT sources, data generations, and collections 2) Intermediate Tier-1: That is responsible for all type of communication between sensors, relays, base stations, the internet, etc. 3) Intermediate Tier 2: it is responsible for data management and processing using Hadoop framework, and 4) Top tier: is responsible for application and usage of the data analysis and results generated. The system implementation consists of various steps that start from data generation and collecting, aggregating, filtration, classification, preprocessing, computing and decision making. The proposed system is implemented using Hadoop with Spark, voltDB, Storm or S4 for real time processing of the IoT data to generate results in order to establish the smart city. For urban planning or city future development, the offline historical data is analyzed on Hadoop using MapReduce programming. IoT datasets generated by smart homes, smart parking weather, pollution, and vehicle data sets are used for analysis and evaluation. Such type of system with full functionalities does not exist. Similarly, the results show that the proposed system is more scalable and efficient than the existing systems. Moreover, the system efficiency is measured in term of throughput and processing time.

Index Terms— IoT, Urban planning, Smart city, Big Data.

1. INTRODUCTION

An emergent number of objects are being connected to the Internet at an extraordinary rate comprehending the knowledge of the Internet of Things (IoT). In 2008, CISCO reported that the number of things connected to the Internet surpassed the number of people living on earth, whereas, in 2020, it will touch the limit of 50 billion, resulting in enrichment of the digital world [1]. There is a different domain in which IoT plays a vital role and improve the quality of human life. The people are also now using the capillary devices in IoT for health applications [2]. Similarly, there are a lot of other domains where IoT facilitates the humans in a noteworthy way including healthcare, automation, and transportation, emergency response to man-made and natural disasters where it is hard for the human to make decisions.

IoT empowers object's capabilities of hearing, seeing, listening and communicating them together. Thus, IoT transforms those objects from being traditional toward smart by incorporating its ubiquitous and pervasive computing, embedded devices (e.g., actuators, smartphones, tablets, and other networked-enabled devices), communication technologies, sensor networks, Internet Protocols and applications, revolutionize the way of human beings. The Internet will be no longer considered as the network of computers. However, it will be involved with the billions of smart devices along with the embedded systems. As a result, Internet of Things (IoT) will significantly increase its size and scope, providing a new way of opportunities, as well as challenges [3]. The majority of the countries have put forward longstanding national strategies for the implementations of IoT after completing the intangible stage of service level. For instance, Japan's broadband access is providing the facility of communication between people, people and things, and things and things [4]. Similarly, S. Korea's smart home enables their people to access things remotely [5]. Singapore next generation I-Hub [6] intentions to comprehend the next generation "U" type network through a secure and ubiquitous network [7]. The stated initiatives laid the foundation of IoT [8]. Moreover, the efforts in Tag free activity sensing using RFID [9], evidence theory [10], and mobile ad-hoc social networking [11] leads us towards the advancement in IoT.

Due to that fact that IoT is considered as the next big prospect to the world of Internet. Thus, leading us toward the concept of smart homes where different electronic appliances are interconnected with each other and achieving high-quality two-way interactive multimedia services. In such system, where a large number of devices are communicating with each other, generating a massive volume of data (termed as Big Data). To enrich the smart home technology, the better analytics of Big Data could play a vital role in the advancement of Information and Communications Technologies (ICTs). Such kind of Big Data analysis provides a better understanding and useful information about the future as well as planning and development. Thus, providing us the insight knowledge about the Big Data.

Other than that, to make the IoT more appealing, traditional application can be considered, i.e., the smart home where embedded devices, such as sensors and actuators are self-configurable and can be controlled remotely with the help of the Internet Technology. Such kind of technology is used to enable a large variety of security, as well as monitoring application. A Large number of involved devices senses surrounding's activities and transmit massive amount of data to the remote station where it can be processed, analyzed, and predict or give a response to the user for his/her convenience based on the received data. In the literature, extensive research work has been performed on the Smart home technology [12] has been observed. Such research work focused on individual homes. Similarly, the idea of the smart home is also extended towards the Smart Community where Home Domain, Community Domain, and Service Domain are integrated to provide benefits to the human kind. However, such technology is lacking off various factors, such as how to connect vehicles, roadside units, GPS, and other to the same infrastructure, i.e., the central Web.

It is observed that 70% of the world's population (more than six billion) will live in cities and neighboring regions by 2050 [13]. Having such massive volume of the population, billions of the devices will also communication with each other, this producing overwhelming of Big Data. Hence, analyzing such data based on the user needs and choices, the cities would become even smarter. Thus, powered by the variation of enabling technologies and their data analytics, the IoT has come across out of its early stages and is entering into the era of revolutionizing the traditional network infrastructure into a fully integrated future the internet. Wireless Sensor Network (WSN) and the related technologies flawlessly unified into urban infrastructure establishing a digital skin over it [13]. The massive amount of information generated by the embedded and pervasive devices will be shared across assorted platform and applications to enrich the cities smarter and predict accordingly in term of its planning and development.

Traditionally, for urbanization, it is an utmost important factor to comprehend the demand for service profiling to enhance the efficiency and may bring the recent advancement in the city management. Presently, few organization are on the way with their platforms for live monitoring, planning and gathering urban process parameters. Such activities are followed by the amount of data collected, offline and real-time Big Data processing and analysis, and decision making. Usually, data collection technique is a costly and difficult to achieve. Therefore, there is a need to incorporate smart technology that could efficiently collect the huge and fast data, performed analysis on Big Data, and predict the future for better planning and development [14, 15].

Having understood the feasibility and potential of the IoT and the smart home, in this paper, we propel the concept of the smart home toward the smart city with the notion of urban planning and development based on Big Data analytics. In the paper, we proposed the complete architecture to develop the smart city and does urban planning using IoT-based Big Data analytics. The 4-tier architecture is proposed, which has the capability to analyze the huge amount of IoT datasets generating from various sources of the smart system in the city, such as smart homes, smart car parking, vehicular traffic, etc. In addition, the complete system implementation model is giving, which guides various municipalities to implement the system. Moreover, the analysis is performed on the IoT datasets to make smart city decision using the proposed system. Finally, the system is tested and evaluated with respect to efficiency measures in terms of throughput and processing time.

2. MOTIVATION

As mentioned earlier, smart cities become smarter due to the enrich nature of digital technology, in which smart city is equipped with different electronic equipment utilized by the various application, such as street cameras for the surveillance system, sensors for the transportation system, and so on so forth. Although, there are also initiatives that use objects to provide different value-added services, such as Google street view, global positioning system (GPA), and so on so forth. Furthermore, the enriching nature also grows toward the usage of individual mobile devices, contributing in the said scenario. Have said that, in this heterogeneous environment in term of objects features, contributors, motivations, security rules, etc. different queries arises from a city environment, which need to reciprocate [16]. These are:

- How to tackle uncertainty induced due to the real-time and offline dynamics and ensure the quality of information?
- How to make existing objects smarter? Alternatively, how to design new object smarter based on the user choice?
- How to enable objects to react accordingly with respect to context?
- How to minimize the cost of data collection that is being generated by some devices?
- How to get an insight into the data if data is collected and going to processing stage in a real-time?

Based on the questions mentioned above, the smart city concept utilizes ICT in a way that could help the citizens in a very day life within limited resources. Moreover, various organization aim to develop a system that uses advanced technology by providing the efficient services to their citizens. The majority of these recent technologies consists of advanced sensing capabilities, storage capability for the unprecedented volume of data, and finally, to get an insight into the voluminous data.

The rationale behind our intentions is to enrich the vast deployment of ICT resources in developing the entire system. For this very reason, we know that the advancement of recent technology in the embedded system depicts the trends of ICT. Therefore, a system is required that could inhale all of the recent developments in the field of ICT, due to which a remarkable growth can be seen in a near future. The design of this system requires all the capabilities of sensing the environment and analyzing the sensing information. Therefore, various real-time action could be welcomed due to these technological resources. Moreover, it can be seen that integrating a large amount of data to perform the efficient analysis are already performed at their best. However, with large scale environment, it is unavoidable that the huge portion of data is left disjoint. As a result, such data cannot provide us a better understanding of the situation so that we may plan for future. For this reason, urban planning and developing provide a new way to the field of the IoT, in which devices are integrated by means of their geographic location, and they are analyzed by means of a newly designed system for various services in a city.
Due to the fact that urban planning and development applications can be benefited from a smart city IoT capabilities can be grouped into impact areas [13]. This includes the effect on the citizen in terms of health and safety, the transportation system in terms of mobility and pollution, and so on so forth. Different projects related to monitoring of cyclist, cars, public car parking, etc. are undergoing that utilizes sensors services for the collection of specific collection of data. Apparently, different other service domain applications are identified that utilizes smart city IoT infrastructure to provision operations in air, noise, pollution, vehicle mobility, and surveillance system in the cities. The recent research consists of a very few research findings in the field of smart city as well as in urban areas. Similarly, a compact system is not yet built which is more scalable and efficient. The Big Data is used to analyze different aspects of the smart city and then uses the knowledge obtain from the past generated data for the betterment of cities. A similar concept is followed using the IoT paradigm and the Big Data concepts for urban planning. Thus, we tried to come up with a solution that is applicable to be used in the smart city and as well as in the urban areas. The proposed system is implemented and tested on the Hadoop framework with Spark to get the real time effects in the case of real-time smart city decision. Moreover, Hadoop and MapReduce is used for large historical data for urban planning and future enhancements.

3. URBAN PLANNING AND DEVELOPMENT SMART CITIES BASED ON IoT

The key concept of the smart city is to get the right information at the right place and on the right device to make the city related decision with easiness and to facilitate the citizens more quick and fast ways. To develop the IoT-based smart city concept and urban planning system, we deployed several wireless and wired sensors, surveillance cameras, emergency buttons in streets, and other fixed devices. The main challenge in this regard is to achieve smart city system and link IoT information together. We do this by providing relay nodes, aggregation classifiers, etc. Moreover, all sensors generate abundant data with high speed, which is termed as Big Data. To process that data in an efficient way the Hadoop systems is employed. In this section, we provide a complete architecture of how the sensors are deployed and how the sensors is generating data. Similarly, we proposed an IV-Tier architecture and system implementation to clearly show the working of the proposed system.

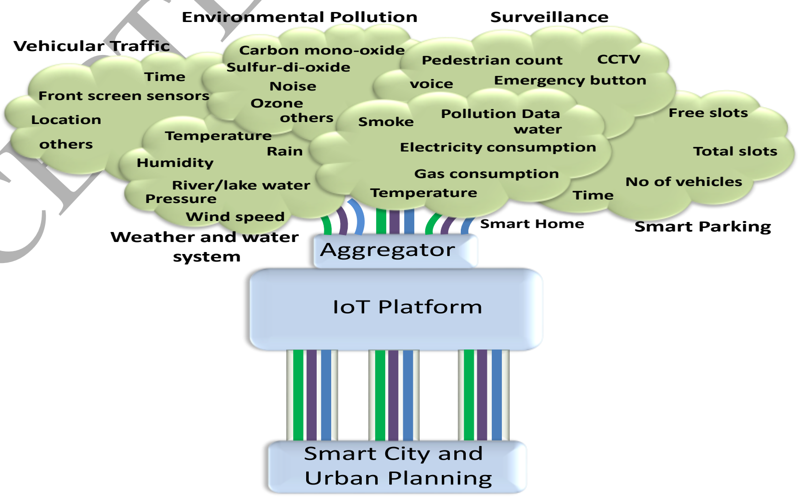

Figure 1. Sensors Deployment

3.1. IoT-based smart city

One of the core challenge and perhaps many people might have the question in the mind that how IoT can be used to established and build a smart city. Thus, we come up with the proper explanation and of course the answer to this question. IoT is called as

the interlinking of heterogeneous devices with each other together over the internet. Since, we are moving towards the digital era, homes, and cities and so on. Therefore, we initiate a thinking that the devices that are available in the homes and the surroundings should be linked to the internet for fast accessibilities. In order to achieve our target, we deployed many sensors at different places to collect the data and analyze that data for better usage. The ultimate goal is to achieve smart homes, smart parking, weather and water systems, vehicular traffic, environment population and surveillance system.
In a smart home, the home is continuously monitored by sending data generated from the sensors measures the smoke and temperature. Similarly, in order to detect fire at the real time, the electricity and gas consumption to effectively manage the power, gas, and water consumption to the houses and different areas of the city. Similarly, monitoring the pollution helps in the health care of the citizens and alert them when the pollution increases than a particular threshold.

The smart parking helps in the checking of vehicles coming and going out of different car parking zones. Thus, a smart car parking can be design or the considering the number of vehicles in a region new car parking can be developed in the areas of more cars. Similarly, the smart car parking data provides lot facilitation of the citizens as well as merchants as being a part of the smart city. The citizens easily get the information of the nearest free slot of parking. Similarly, the citizen can get the information from the smart city about more suitable places to park his/her vehicle. This system reduces the fuel consumption of vehicles. Moreover, other applications may include safety of time wastage and a person can spend more time in a marketplace or other activities.

Weather and water information also increases the efficiency of the smart city by providing the weather related data like temperature, rain, humidity, pressure, wind speed and water levels at rivers, lakes, dams, and other reservoirs. All these information is collected by placing the sensors in water reservoirs and other open places. In the world, most of the flood occur due to the rain and similarly few by snow melting and dam breakage. Therefore, we use rain measuring sensors and snow melting parameters in order to predict the flood earlier. We can also predict about the water reservoirs in advance to meet the need of the water to the citizens.

Vehicular traffic information is the most significant source of a smart city. Through this type of data source and with useful real-time analysis the citizen and as well as government can get more benefits. The citizens can get the destination based on the current intensity of traffic and the average speed of the vehicles. The traffic can be diverse through all the cities, and it will reduce the fuel consumption as well as decreases pollution that occur due to the crowded traffic. Government authorities can also get the real time of information about the blockage of the road due to the accident or other things. They can make necessary action at the real time to manage the traffic. In our smart city system, we are getting the traffic information by GPRS, vehicular sensors, as well as the sensors placed on the front screen of the car. We get the location of each vehicle, the number of vehicles between two pairs of sensors placed at the various location of the city. Moreover, if any accident is happened the front screen will be damage and the sensor will send the alert to the police, traffic authorities, and hospital. Similarly, we can do a lot of other things with real-time to make it more efficient.

Moreover, for people health care conditions, monitoring the environmental pollution and delivering the information to the people is also vital. A city can never be smart with unhealthy citizens. Therefore, while designing smart city, we put a separate module to get environment data which includes gases information, such as particular metals, carbon monoxide sulfur di-oxide, ozone, and noise as well as. These gases are very dangerous to human health that causes liver disordering, coughing, and heart diseases. People should not go outside when these gases are more in the environment. Especially the children, old age people, people for physical exercise, already sick people, should not go outside from their homes when any of the polluted gas is more in the environment. This can only be possible when there is access to all these information to the people at a real time and generate alerts when any of the gas excesses a particular threshold. Moreover, the place where there is more population, the government should reduce the causes of the pollution, like moving industries to other areas, diverting traffic to the other routes, etc.

Last but not least, the most important thing for the people of the smart city is the security concerns. Security is achieved by the proposed system by continuous monitoring the video of the whole city. However, it is very challenging to analyze the video and detect any mishap with anyone at real time by the system. To overcome this limitation, we propose new scenarios that increase the security of the system of the whole city. We put various emergency buttons including microphones at various places of the city with surveillances cameras. When any mishap happens with anyone like robbery, car stolen, purse stolen, fighting, or someone watching some illegal activity. He can just push the emergency button at any near place, and it will send the message to the nearest police station etc. Thus, the police or security agencies can start monitoring the nearby locations through surveillance cameras and can easily locate the imposter. Moreover, the information collected from different sensors can be used to avoid the future security issues. This leads to providing a more secure environment to the citizens of the proposed smart city.

The complete IoT objects deployment is shown in Figure 1. There is one aggregation server that collects and aggregate the data from all smart systems. The data is received with high speed. Therefore, the aggregation process is powerful enough to aggregate the data and send it for analysis through IoT systems.

3.2. IoT-based Urban Planning

For urban planning, the same IoT scenario is considered with same devices and sensors as shown in Figure 1. Only the different in urban planning system is the use of sensors generated data and the purpose of analysis. In a smart city, we do real-time decision making on real-time data on the other hand. In urban planning, we use the previous historical data generated from the same smart city's IoT devices and do planning for future regarding anything related to the city. For example by analyzing the electricity consumption of the previous years, we predict the demand for next year and take necessary action to fulfill the demands.

By smart home generated data government authorities can analyze previous energy consumption data and growing needs and make future places for building new dams to produce more energy. Moreover, they can also analyze the pattern of usage energy at different periods and manages the electricity and gas bills according to facilitates the citizens. They can also make energy plans for various periods of the year accordingly. For smart parking and vehicular traffic generated data, new parking lots needs, new building needs, places to build new roads or extend roads all these things can be planned for future. Based on the increase or decrease in pollution due to the traffic changes is analyzed for identity the causes of pollution increases/decrease and make planning accordingly. Similarly, analyzing the weather and water consumption data sets, we can make plans for agriculture, for prior safety from floods, safety water, etc. Moreover, based on the temperature data and electricity consumption, we can make a better plan for high-temperature seasons to reduce the consumption of electricity. Similarly, from surveillance data sets, we can analyze the number of crime events, more dangerous place, more affected people, which crime is spreading, etc. based on these data, the security places for the next year or even for next month can be prepared.

3.3. The Big Data Analytical Architecture and Implementation Model

Based on the needs of the smart city and urban planning, we proposed a 4-tier architecture to analyze IoT Big Data in order to establish smart cities. The complete architecture is shown in Figure 2; the 1st tier is the bottom tier, two intermediate tiers, and finally the top tier. Functionality of each tier is described below:

Tier 1. Bottom Tier: this layer handles data generation through various IoT sources and then collecting and aggregating that data. Since there are a lot of IoT sensors participating in the generation of data, therefore a lot of heterogeneous data is produced with varying format, a different point of origin and periodicity. Moreover, various data have security, privacy, and quality requirements. Also, in sensor data, the Metadata is always greater than the actual measure. Therefore early registration and filtration technique are applied at this layer, which filters the unnecessary Metadata, as well as repeated data, is also discarded.

Tier-II; Intermediate Tier-I: This tier is responsible for the communication between sensors, from sensors to relay node through ZigBee technology, and rely to GW or base station and then on the internet using various communication technologies, such as Wi-Fi, WiMAX, LTE, 3G, etc. At the analysis sides between various analysis servers, Ethernet is used.

Tier-III: Intermediate Tier-II: This layer is the main layer of the whole analytical system, which is responsible fo the processing of data. Since we need real-time analysis for the smart system, therefore, we need a third party real-time tool to combine with Hadoop to provide a real-time implementation. To provide real-time implementation, Strom, Spark, VoltDb could also be used. However, for system evaluation, we implemented the system by using Spark. At lower layer of Hadoop, same structure of MapReduce and HDFS is used. With this system, we can also use HIVE, HBASE, and SQL for managing Database (in-memory or Offline) to store historical information. For urban planning, since we do not care about the real-time results. Therefore, we use Hadoop with the MapReduce programming.

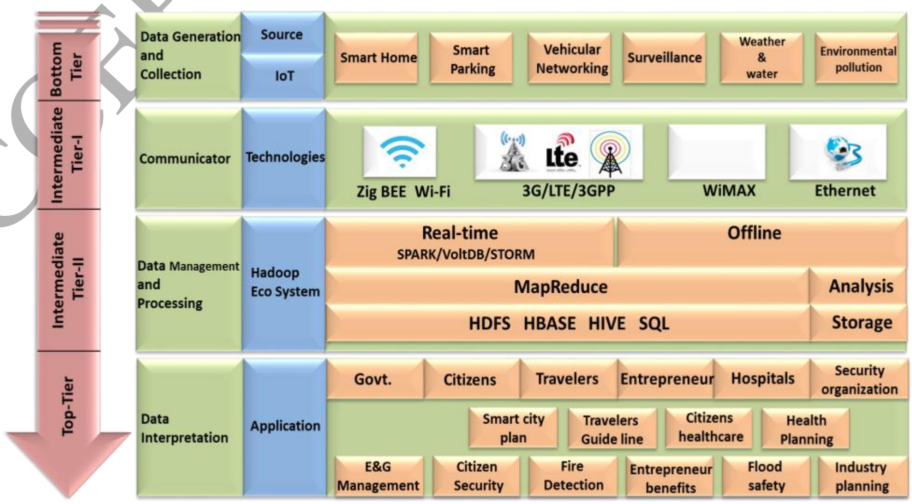

Figure 2. IV-Tier Architecture for IoT Big Data analytics for remote smart city and urban planning

All the data is be stored at Hadoop using HDFS and analysis are performed at intermediate tier-II. The last tier is the interpretation tier, which is the usage of the results of analyzed data and then generating reports. Here, the generator results are announced and used by many applications, such as flood detection, security, and city planning.

We also design implementation model of the system, which is shown in Figure 3. It shows the complete details of all the steps performed while implementing the system. Initially, every system generates their data, such as smart hoe generated data, vehicular data, smart parking data, etc. At every system, there is relay node, which is responsible for collection data from all the sensors in the system. It uses ZigBee technology to communicate with the sensors. The relay handles collecting data from all sensors and then sending to the analytical system through GW and Internet. As the sensors have a lot of Metadata. Therefore, all the unnecessary Metadata and redundant data are discarded. Moreover, the data is classified by the message type and the identifier. After classification, the classified data is converted to the form, i.e., understandable to the Hadoop ecosystem, such as sequence file.

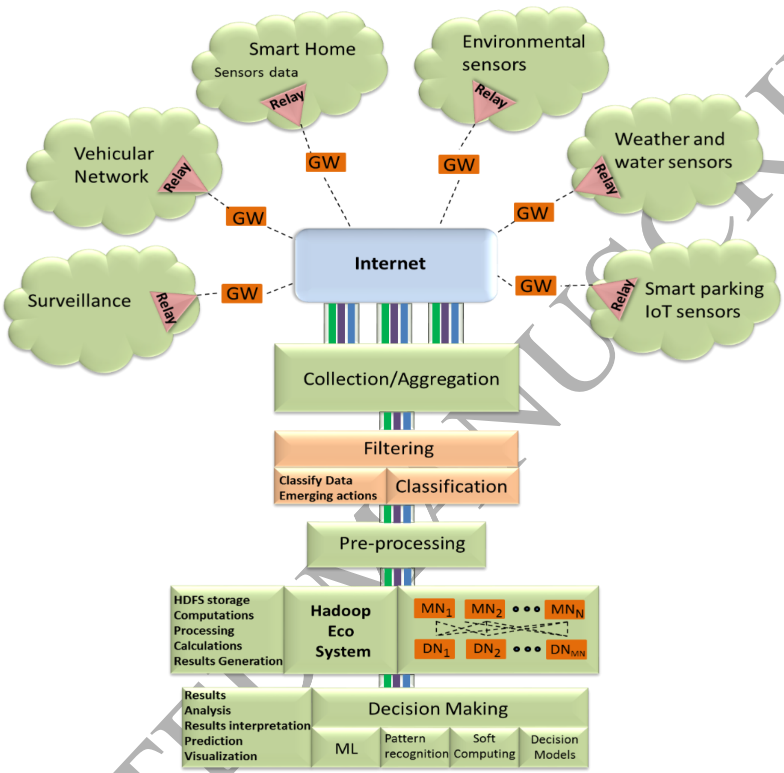

Figure 3. Implementation Model.

Since we are dealing with a large amount of data (termed as Big Data). Therefore, we need a system that could efficiently process a large set of huge datasets. To meet these requirements, we used Hadoop ecosystem, which contains Master nodes, and various data nodes under the Master node. The Hadoop ecosystem has HDFS file storage, which divides the data into an equal amount of chunks and stored them on various data nodes. Later, the parallel processing is performed on these chunks using MapReduce system. All the processing calculations, results generation are done at Hadoop ecosystem. Finally, the decision making is performed based on the results generated by Hadoop ecosystem. The decision-making approach uses machine learning, pattern recognition, soft computing and decision models.

4. URBAN DATA ANALYSIS AND DISCUSSION

To perform the feasibility study, and understand the importance of the system, the detailed analysis are performed on various IoT datasets. The analysis is performed to show that how the smart city can be built by using the proposed system, how the deployment of sensors matters for building a smart city, and also how we can use the historic sensors data to perform Big Data analytics for urban planning. This section also illustrates how we can use the same IoT generated data for both real-time decision making to make your city smarter as well as performing offline analysis on historical data to perform urban planning. In this section, we describe the details of the datasets used for analysis as well as for evaluation purpose and also the discussion on the analysis make to establish the smart city and perform useful urban planning for future.

4.1. Datasets description

We take real large size IoT generated datasets from various reliable resources. The datasets includes 1) the data of flood occur in all over the world, 2) the smart home temperature collected dataset including the water usage of each house, , etc., 3) the vehicular datasets including all the details of the vehicles traveling between many pairs of source and destination points at various places of the city, 4) parking places datasets including the current status of number of vehicles in the parking area, 5) pollution datasets including various gases and noise pollution, 6) social media datasets, such as Twitter including daily tweets record, 7) weather datasets including continuous measurement of temperature, humidity, rain, etc., outside as well as inside the home, 8) other data common city datasets, such as cultural events, library events, etc. the complete datasets details including the datasets size, the number of parameters, and the source is given in Table 1.

Table 1. Datasets details

S#	Datasets	Size	No. of parameters	Source
1	Floods	16 MB	30	[17]
2	Water Usage	5 MB	11	[18]
3	Madrid Highway vehicular traffic	450 MB	5	[19]
4	Vehicular Mobility Traces	4.03 GB	5	[20-22]
5	Parking lots	294 KB	7	[23-25]
6	pollution	32 GB + 570 MB	8	[23-25]
7	Social Network (twitter)	8 +8 MB	7	[23-25]
8	Aarhus city traffic	33 GB	9	[23-25]
9	Weather	3 MB	7	[23-25]

G.R.Brakenridge [17] generated the flood data set by collecting the news from official and TV news channel of the flooded country. The data contains the date of flood, area of flood, damage, intensity, death, etc.

The water usage data for each household of Surrey city of Canada is taken for household analysis. Total 61263 houses water meter readings are measured. It contains the complete address and water usage of the house. The 3rd dataset that we have analyzed for the smart city and urban planning is Madrid Highway vehicular traffic. This dataset is more important for the smart city to facilitate the people as well as for urban planning in constructing new roads building, etc. it contains the location of the each vehicle between two edge points of Madrid highway as well as the speed of the vehicle. We also tested the vehicular mobility dataset that is generated by Institute of Transportation Systems, German Aerospace Center (ITS-DLR) as TAPASCologne project. It contains the mobility of all the cars in Cologne city of Germany. It covers the area of 400 square km in 24 hours with 700 cars. Next all other datasets are covering the Aarhus city of Denmark. Parking lot dataset covers the continuous monitoring of eight parking lots of the city with respect to the usage. It contains the data from May 22, 2014, to Nov 4, 2014, by capturing data through 55 points. The pollution datasets and Aarhus city vehicular datasets are generated by placing sensors at the same location at the same timing to find the effects to traffic on the environment. Both of datasets contains the various periods of data of 2014. They generate the data by placing 449 sensors at different locations in the city. For vehicular data generation, they placed source and destination pair sensor in different locations to estimate the traffic between two points. It contains various information about the average speed of vehicles between two points, the average speed, and time to reach the 2nd point. The pollution data has various measures including Ozone, Nitrogen dioxide, nitrogen oxide, particle matters, carbon dioxide, etc. Moreover, social network data is also important for smart city real-time decisions and urban planning as well. So we take twitter data which includes tweets from many peoples of the city, their location, time, etc. Twitter data contains the information of 13674 tweets from September 23, 2013, to December 17, 2013. Finally, the weather data consisting of temperature, humidity, rain, pressure, wind, etc., are also considered for analysis and evaluation, which covers the period of Feb to June and August to September 2014.

4.2. Analysis and Discussion

The main challenge in the smart city development is the analysis of real-time data to make an urgent action. Enabling smart cities not only give benefits to the government authorities but the citizens can also take benefit from it, such as it helps citizens to save their fuels by efficiently managing the route to reach the destination, as well as to protect themselves from environmental pollution when it's more in the air. Here, we are analyzing various kinds of data and give directions to the authorities how they can use IoT technologies and the Big Data generated from IoT for Smart cities and urban planning. We mainly presented the analysis of vehicular traffic, parking lots, smart home taking the use of water by each house in the city of Aarhus, flood, and pollution.

4.2.1. Vehicular traffic analysis

As a use case scenario, we use publically available traffic data of Aarhus, Denmark, which contains the information of geographical location, timestamp, and traffic intensity, such as average speed and vehicle count. Moreover, we also used the vehicular datasets of Madrid City as we mention earlier. The analysis of Aarhus city traffic is presented only by the data taken from the two sensors placed at 1 Km distance in "A rhusvej" street of Hinnerup.

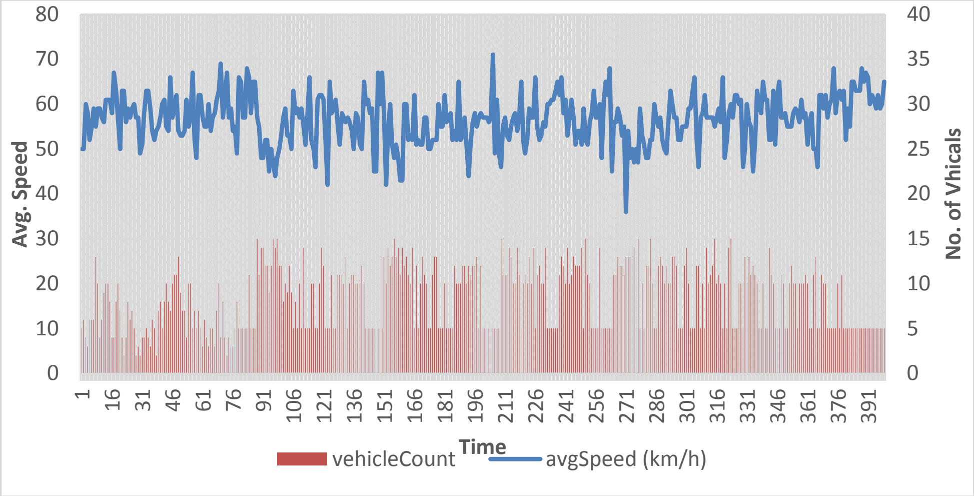

Figure 4. The speed of vehicles at low intensity of traffic between two points.

The number of vehicles in a particular area plays a vital role in society. For instance, during the on hours, the traffic intensity at particular roads are higher than off times. Similarly, the road management system can be affected by the number of vehicles in a particular time and on a particular road. In Figure 4 and 5, we carefully analyzed the traffic intensity on different roads in a society. For instance, if the vehicle speed is low on some roads than this means that the intensity of the cars is high on that roads. Moreover, in Figure 4, when the number of vehicles is higher for example 106 and 121, the vehicle speed is less 45 and 42. Therefore, keeping this relation between vehicle and vehicle speed, we can design roads for better vehicular management. Similarly, in Figure 5, the number of vehicles are taken between 25 and 35, by considering this number as high-intensity traffic. We can see that when the number of vehicles is high for example 37, the vehicle speed decreases to 18. Thus, the statistics in Figure 4 and Figure 5 can be used to design wide roads where the intensity of vehicle is high and vice versa while planning for future.

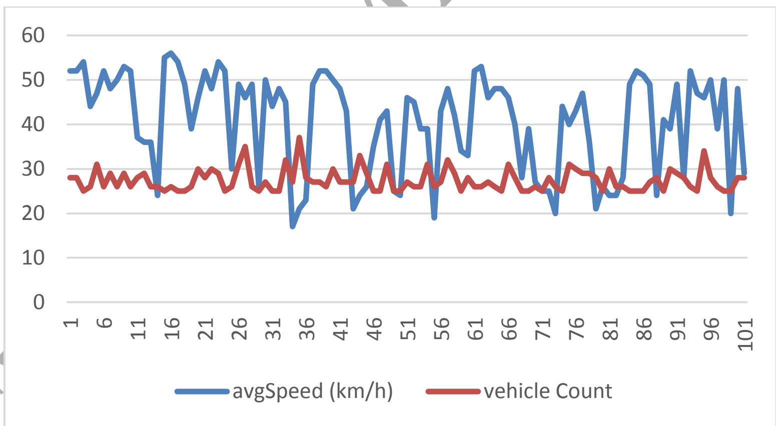

Figure 5. Speed of vehicles at high intensity of traffic between two points.

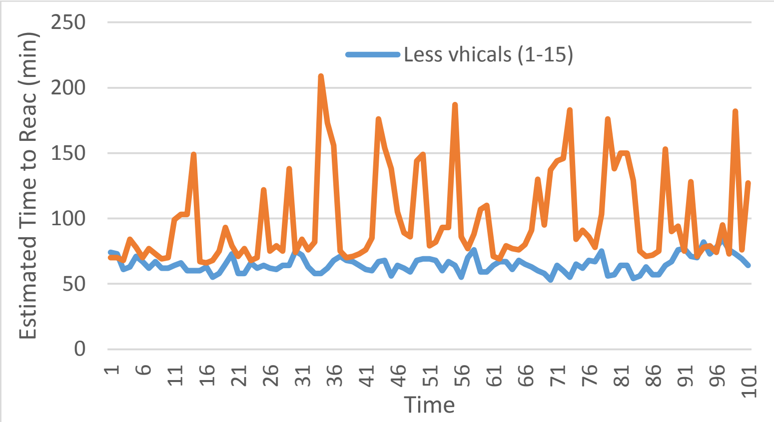

Figure 6. Estimated time to reach the destination depending on the traffic intensity

In Figure 6, two types of traffic classes are used, i.e., 1~15 and 25~35 cars. We performed an experiment of reaching moving between two points. We start assuming a car is moving from point A to point B on the road with the number of cars between 1 ~15. The Figure shows that the time required for the car to reach its destination is less comparing to the same road with cars between 25 and 35. This estimation is taken at a real time average speeds of the cars running on the roads. Thus, we can design wider roads in those areas where the intensity of car is high. For example, if on a road the number of schools, colleges, universities, etc. is high, then using statistics, a wider road is considered. Similarly, the area where the number of buildings is less than the roads can be designed with less number of lanes. However, we are avoiding the scalability option for now, and we will consider it in our future work.

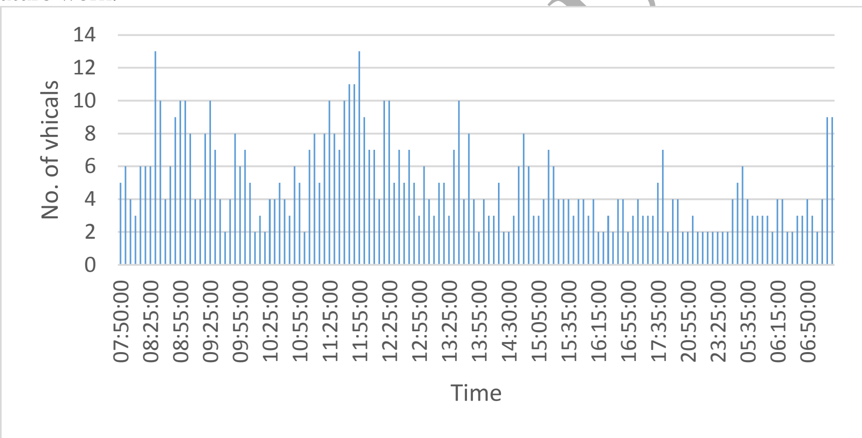

Figure 7. No. of vehicles between sources and destination pairs at the various time of the day.

In Figure 7, we check the intensity of the vehicle along a road in a different duration of time. For example, we can see from the graph, during 08:25 and 11:55, the number of vehicles are very high in number i.e. >12. Thus, an efficient road system can design that can dynamically change the routes during the rush hour time. Similarly, the sensors can be installed at different locations that can communicate with the vehicles in the case of accidents and congestion on the roads. Thus, the various conclusion can be drawn from the statistics of Figure 7. For example, the engineer can be provided with better information about the road designing and construction.

From the above IoT-based network traffic analysis, we can predict the estimated time to reach from one point to the other point. Smart City analyzes vehicular traffic data at a real time and facilitates citizens to find how much time it will take them to reach the destination by following alternative routes depending on the current intensity of the traffic. It gives the updated information about all the travelers so that they can make their plan to reach the destination by following the convenient route. Moreover, it also helps the government traffic authorities to control traffic and make an optimized plan at a run time when the intensity of traffic becomes higher, or the road is blocked due to any mishaps happens on the road like an accident, strike, any damage, etc. This traffic management not only helps the citizen and government while providing fuel saving but also provide safety from pollution that is generated by abundant of traffic at a single point. So smart city helps the diversion of traffic from busy roads to free roads to get the equal usage of all alternative roads.

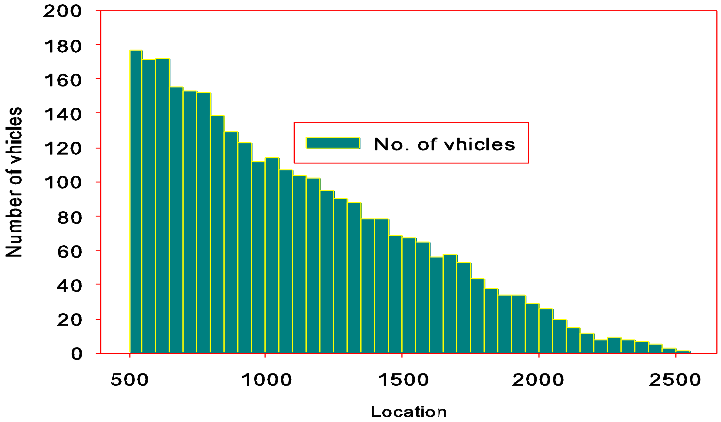

Figure 8. Intensity of traffic on various Location on Madrid highway

Next phase of vehicular traffic analysis, a slightly different dataset covering Madrid is taken. We show the traffic intensity of first 2500 locations for a particular time in Figure 8. The figure shows the congested location where the intensity of the traffic is more. We can easily observe that at starting position there are more vehicles, and when we go forward, the number of vehicles start reducing. It shows that the location 500 is the central location, where most of the vehicles are passing through. On the other hand, the location 2500 is very far from the city, where very fewer cars are moving. Therefore, on the basis of this analysis, we can plan for the road by building more lanes where the traffic is more. Moreover, we can also assume that at location 2500, the number of people living or the number of houses, shops, and building are less. Therefore, we can plan to build more houses and buildings there to reduce the traffic burden, pollution, and crown.

For the Madrid traffic data, we also analyze the speed of the vehicles at the highway. The average speed of the vehicle is 90 km/h. On the basis of speed measure, we can estimate the condition of the road by identifying the regions where the speed of the vehicles goes lower, such as the poor structure of the road or the damage of the road. Similarly, in a smart city, we can identify the speed violations of the vehicles at the run time and charge challan on the violation. We identified the regions, where most of the vehicles crosses the maximum limit of speed, as shown in Figure 9. On Madrid highway, most of the vehicles cross the maximum limit from location 5000 to 1100. Most of the violations occurs at Lane three (most extreme lane) of the highway. These violations might be due to the less number of vehicles on the road. This can be stopped by notifying through sign boards or placing speed barkers at that place, which is suitable for that location. This can also be a better option towards the smart city and urban planning as well. Moreover, in the smart city, the accident ratio is also monitored with respect to the area speed and violation data.

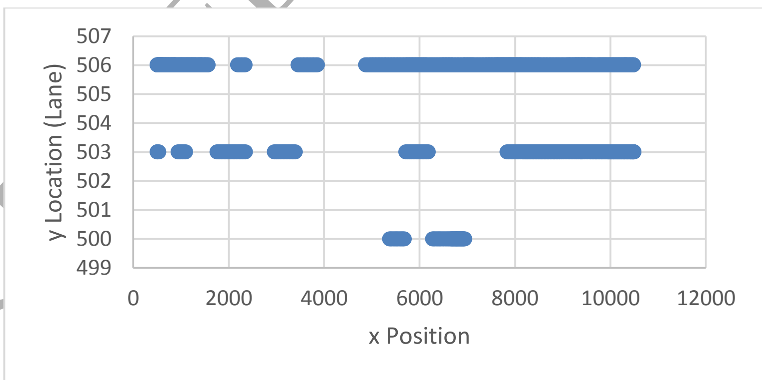

Figure 9. Location of Speed Violation on Madrid highway

4.2.2. Use of Parking Lots Data Analysis

By analyzing the parking lots current usage, citizens are updated to select the best suitable parking lot near their location. Figure 10 shows the number free spaces at various parking garages in Aarhus city and Figure 11 shows the current use of parking garages. By this studies, the users are updated about the free car parking at a run time. He can save his fuel without manual searching the free car garage. Moreover, it also makes profit equilibrium between the sellers in the city by giving benefit to the shop owners who are getting less profit. Generally, citizens prefer to go the un-congested place for shopping where the number of people is not that much and where they can easily get the parking, resultantly encouraging all sellers. The parking study analysis also gives direction to the government authorities for the urban planning to build more parking areas near the places where most of the people go. In Figure 11, it is obvious that the Bruuns is a huge parking with the capability of parking 931 cards but still you cannot find the parking place few times. This shows the need for more parking lots at that location to facilitate the user. Similarly, the same result we get by the analysis of selling the garage.

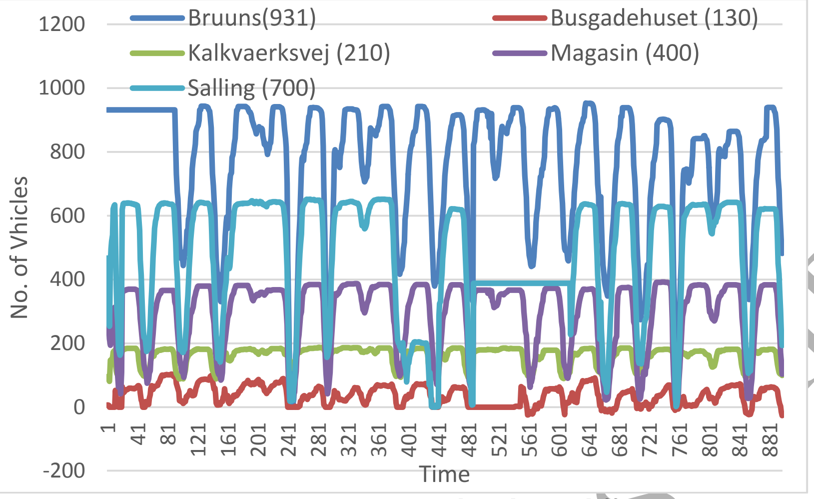

Figure 10. Free Spaces at various parking lots at different times

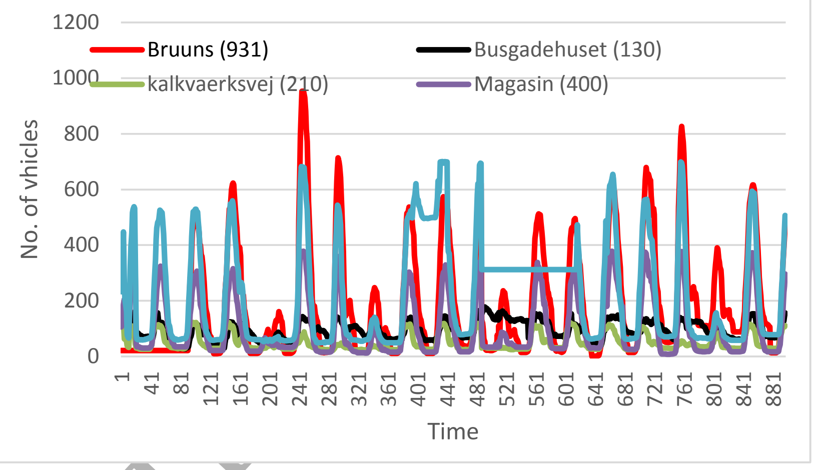

Figure11. Usage of various parking lots at different times

4.2.3. *Smart Home Data Analysis*

While analyzing the smart home Data, one use case is taken to analyze the current usage of water consumption in each house. The helps smart cities to manage the water resource with respect to the current usage of data. The next year need of water can also be predict. Moreover, the flow of water to various area depending on the need of the area can also be controlled. The water consumption of each house of the Surrey city of Canada is analyzed for that purpose. Figure 12 shows the histogram of the usage of water in the cubic meter at all houses of the city. It shows more than 6000 houses consume water more than 8000-9000 cubic meter. This shows the normal use of the water at maximum houses. This study can help the authorities to decide the water billing rates based on normal use of water.

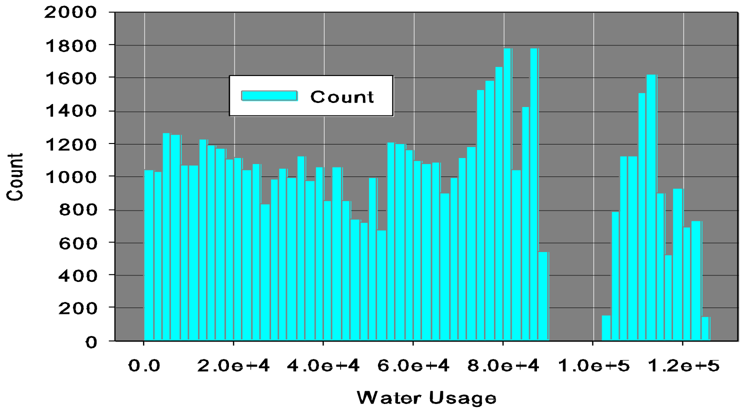

Figure 12. Total water usage counts for the Surrey City

In general, every city and each street or home in a city used a different amount of water. The consumption of water directly depends on the number of people present in a city. Similarly, some of the cities provide fewer services, such as industries, hospitals, universities, schools, etc. therefore, the population of these cities is fewer comparative to the other cities. Therefore, the statistics present in Figure 12 for the Surrey homes helps us in designing the water usage system for the houses within a city. Similarly, the fresh water consumption can be maintained, for example if a house needs more fresh water and another needs less than a balance relation can be drawn among the houses. Moreover, it also helps the authorities to control the water resources depending on their reservoirs. For instance, if you have more water reservoir, then you can only store the required amount of water by finding the smart city overall water consumption parameter. Likewise, if you have a scarcity of water reservoir, then you can predict the need for water before and then consume the water accordingly.

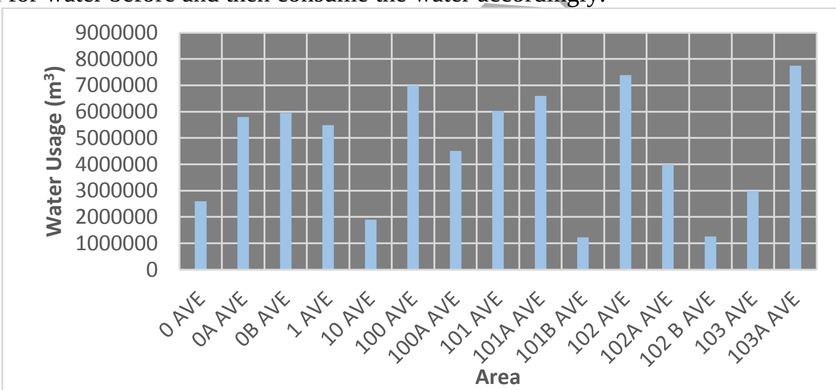

Figure 13. Water usage of various areas of Surrey City

We also noticed that the water usage in some areas like cities and industrial zones is more than the water usage in the residential area. In Figure 13, we show the average water consumption in different areas. For instance, in area 101B and 102B, the average water consumption is very short. Similarly, in area 102 and 103A, the average water consumption is very high. This helps us in designing a system by increasing or decreasing the flow and level of water in different areas. Similarly, an efficient drainage system can designs while keeping the above statistics in mind. Thus, we can draw a conclusion on the basis of water consumption in a particular city by planning a billing system of water usage. To check the authenticity of the statistics regarding water usage and predict for future need, we use the skewness measure. It Univariate usage of water consumption W1, W2, W3 . . . WN by the following formula of skewness.

$$\text{Sk} = \sum_{i=1}^{N} \frac{1(Wi-W^{-})3/N}{s^3} \tag{1}$$

Where W¯ is the mean, s is the standard deviation, and N is the number of data points. While computing the skewness, the s is computed with N, rather than N-1.

We observed that in total 61263 houses, the average consumption of the house is 57877.937. However, 50% of the citizens consume less than 58186 cubic water (find out by Median analysis), 25 % citizen use less than 26893 cubic water. While the 75 % of the people use less than 81983 cubic water. The data is positively skewed, which means more than 50% use more than average consumption of water. By this analysis of water consumption, smart authorities manage the billing system by choosing a limit for less fixed bill payments and for charging extra amount to those people who consume more amount of water as compared to most of the users.

By this management of water, similarly, we can manage energy, such as electricity and gas as well.

4.2.4. Flood Data Analysis:

The flood due to rainwater normally happens more and intensive as compared to another type of floods, such as flood due to snow melting, storm, etc. In Table 2, we examine different types of floods, resulting that the rain water produces high chances of the flood following by snow. The M represent the magnitude of the flood, which is calculated as, log (duration x severity *x* area affected).For example, if the M value is greater than 4, it means the flood is of a higher intensity. Around 50250 floods have been experienced with higher intensity at the various area of the world. Similarly, if the value of M is greater than 6, the intensity of the flood is dangerous. 13751 floods have been recorded of this intensity. The flood ratio in the case of both these magnitude is greater in the event of rain. We can see that 35% of floods have been happening due to the rain following by snow of 1.5%. Thus, we can design a society with predefined thresholds of rain. For instance, if rain in an area crosses a predefined threshold then a warning signal or alert can be broadcasted to the public. The society can be made safer by installing high diameter drainage pipe in an area where the rain level is high. Moreover, the rain measure also used to manage the water reservoir in a smart city. Similarly, the snow melting is also a cause of flood but it is not that much. This can also be saved by placing snow melting sensors at the hilly station.

Table 2. World Flood Report from 1985-2014

Flood Type	Total Floods	Duration	Total Deaths	Total (M>4)	Total (M>6)	%age of total floods
Avalanche	3	11	33	14.02157794	0	0.005970149
Rain	3657	41637	190426	17830.89731	6539.589962	35.48437276
Snow	134	2404	851	776.500426	416.4602809	1.54527448
Storm	83	981	6320	473.2605046	229.0867418	0.941811949
Dam Break	54	568	3600	163.5712257	44.54054417	0.325514877
Typhoon	5	38	1486	28.63278646	12.34100746	0.05698067

4.2.5. Environmental Data Analysis for Pollution

Transportation is the main daily activity of the Europeans. Each citizen travels at least one hour per day [26]. Therefore, a lot of transportation means, such as buses, trains, cars, etc. exists in cities. This means of transport cause the emission of 12 % Co_2 [27]. Moreover, road population is more than twice as deadly as traffic accidents [28] and car pollution also damaged the youth health and increased the risk of earlier deaths [29]. This shows how much the awareness and safety of pollution are important. The more important gasses in the air that affect the human health are ozone (O_3), carbon monoxide, sulfur dioxide (SO_2), nitrogen oxide, and particulate matter. The Environmental existence of these gasses is analyzed to deliver the current intensity of those gasses in the air so that more people protect themselves from these gasses.

Ozone (O_3) is made with three oxygen items joint together. It is too dangerous for the living tissues of the human when it contacts to them, such as, it can harm your lungs, effect to a sunburn inside your lungs, a cough, an irritated throat, or an uncomfortable feeling in your chest, Worsened Asthma, emphysema and bronchitis, and may reduce the body's ability to fight infections in the respiratory system. It is made by the reaction of volatile organic compounds (VOC), Nitrogen oxide (NO), and Nitrogen Dioxide (NO_2). Therefore, nitrogen dioxide is also dangerous. As more VOC's and NO_2 cause more ozone. Sunny weather, less wind, crowded traffic cause increase in ozone. Sulfur dioxide (SO_2) adverse respiratory effects including bronchoconstriction and increased asthma symptoms. "Particulate matter" is a complex fusion of extremely small particles and liquid droplets. The particle can be made by acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles. These are so small that they can get deep into the lungs and cause serious health problems.

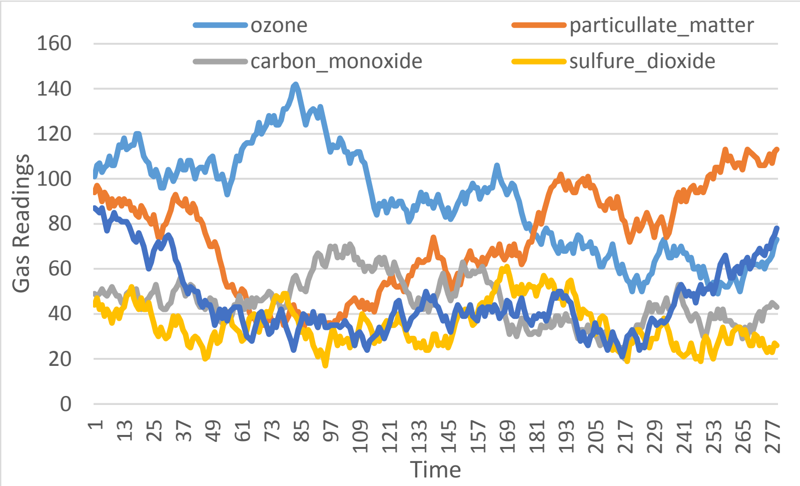

Figure 14. Pollution level at different time of the day

For the analysis purpose to keep the gasses value within a limit, the calculations of gas values are a little bit modified [23-25]. However, it will not affect the analysis and reality and effect of the gasses. The values of carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and ozone index levels gases values are calculated as:

- Initially assigned a value between 25 and 100. Every 5 minutes, the values is updated as follows:
- If the value were below 20 before, it would now be the last value + random integer between 1 and 10
- If the value were higher than 210, it would now be the last value - random integer between 1 and 10
- Else the value is the last value + a random integer between -5 and 5.

These gasses are dangerous when their values are greater, such as shown in Figure 14, the pollution data of Aarhus city is depicted. The maxima values of all gases, as shown as ozone value at time 70 to 90, particulate matters value at time 185-215 and also at more than 245, Nitrogen dioxide at start and end of the time interval, and carbon mono oxide at 90-115, are all dangerous for health. Therefore, everyone should not allow the children to spend more time outdoors. Moreover, adults should not exercise outdoor at that time as healthy persons engaged in physical activity breathe faster and more deeply. Which cause flowing ozone into the lungs. The people with the respiratory disease should also care when ozone value is higher, as Ozone can further damage the lungs of the person who already has the disease of the lung.

For daily based pollution analysis, as we did, we guided the people about the intensity of the pollution and suggested them not to go outside and also do not allow children, deceased persons, and old age people to go out when the intensity of any of the gas is higher. Authorities can also take actions and make alert and announced public when the pollution goes beyond the limit. The government can also do urban planning by analyzing the history and change behaviors of the pollution in different seasons and month. Overall year analysis, and plan for traffic, city and industrial building and shifting to other places. They can shift industries outside the cities or build new industries at far from cities when these pollution gasses start increasing.

5. SYSTEM IMPLEMENTATION

Based on the datasets collected, the analysis made, and the proposed system architecture, the system is developed using Hadoop single node at Ubuntu 14.04 LTS with 3.2 GHz x 4 processors and 4 GB memory. The PCaP format traffic is processed by Hadoop-pcap-lib, Hadoop-pcap-scr-de libraries. These traffic data are then converted into sequence file to make it capable of processing on Hadoop. The system is implemented by two major modules i.e. smart city and urban planning. These two modules further have other sub-modules for various functionalities.

5.1 .Smart city implementation

The input source remains the same as described previously as shown in Figure 15 with circles outside the boundary of the system i.e. smart home, parking, etc. Each facility of the smart city is implemented as a separated class or sub-module that takes data from various sources. Traffic information measurements take data from the vehicular traffic and parking. Security management module takes data from surveillance, smart home, and vehicular traffic. It takes data from vehicular traffic, in the case of government needs to monitor stolen vehicles. Flood and water management module take water usage data from smart home rain, ice storm data from weather and predict flood at run time. Similarly, energy consumption management also takes electricity and gas data from smart home and dam and water-related data weather and water. This module manages and saves extra energy, which is not used by the several homes. It also distributes the energy to various areas according to their needs. Similarly, early fire management program performs fire detection. Finally, the health management makes a decision on pollution data. Citizens have limited access to the results of these modules, and the government has full access to them. The complete flow of data, modules, actors, is shown in Figure 15

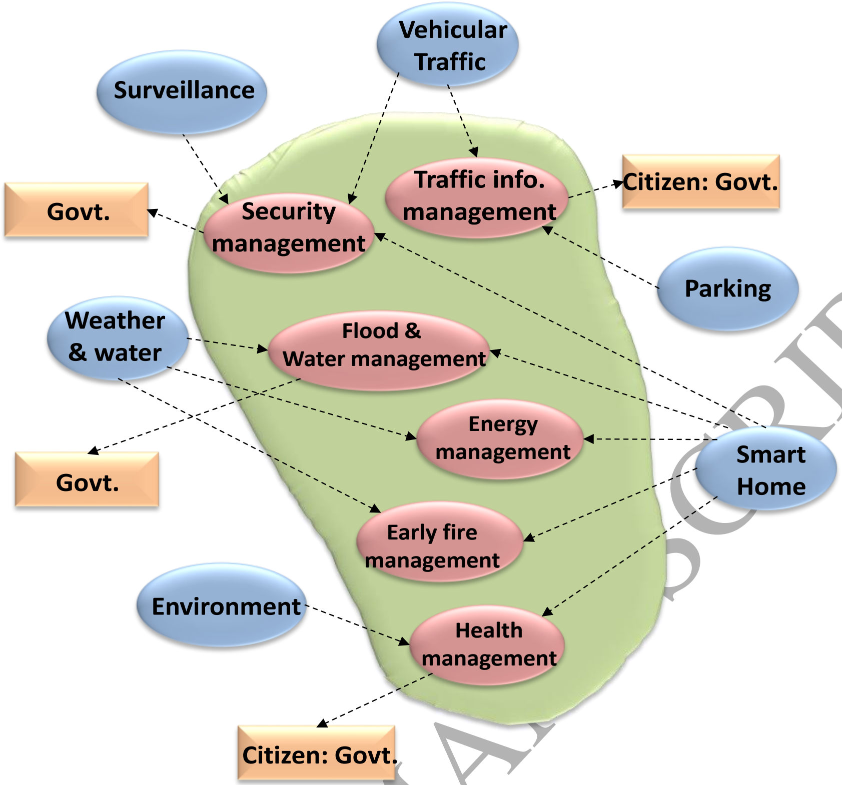

Figure 15. Smart city system implementation scenario

5.2. Urban Planning system Implementation

Urban planning system implementation is done at three levels i.e. physical level, intermediate level and upper level as shown in Figure 16. Physical level is called storage level, which is based on Hadoop HTFS system. All the historical data is stored in physical level. Each data set given a number in the figure, such as vehicular data at number 1, energy data as number 2, and so on. The intermediate level is the second level, which is also called processing level. All the processing is done at this level by taking the data stored on the physical level. At this level, statistical calculation, computation, graph analysis, and other computations are performed. The third level is the upper level, which is also called decision level. The decision regarding the urban planning is made at this level. The decision level has various modules for each type of planning, for example, road planning, building planning, and so on. The number written under the planning module is the number of data set from which the module takes the data for input.

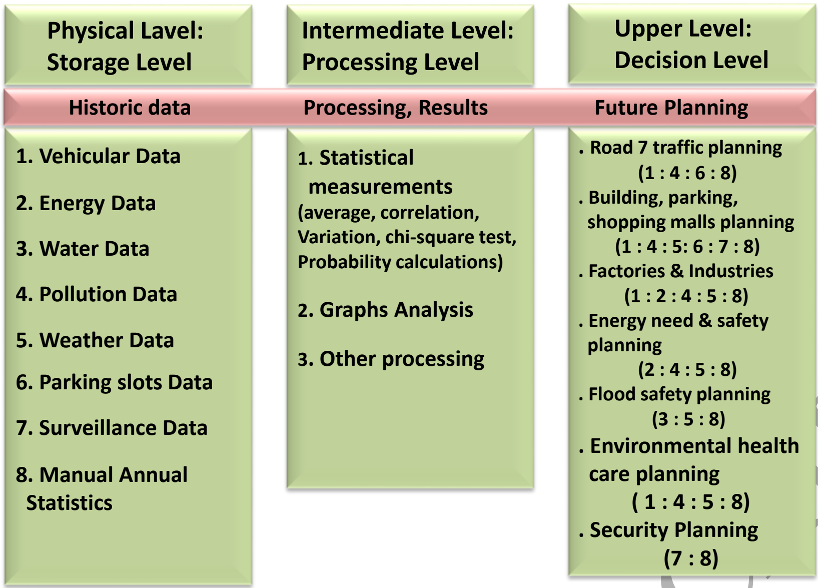

Figure 16. Urban planning system implementation scenario

6. SYSTEM EVALUATION

The proposed algorithm is implemented using Hadoop single node setup on UBUNTU 14.04 LTS coreTMi5 machine with 3.2 GHz processor and 4 GB memory. For real-time traffic, we generated Pcap packets by Wireshark libraries and retransmitted them using other systems to the developed the system. Hadoop-pcap-lib, Hadoop-pcap-serde, and Hadoop Pcap Input libraries are used for network packets processing and generating Hadoop Readable for (sequence file) at collection and aggregation unit so that Spark can process it. MapReduce programming is used for performing offline analysis for urban planning. The Dataset mentions in section IV are used to perform the efficiency evaluation of the system.

Figure 17. Processing time of various size vehicular datasets

Since the system is based on Big Data analytics, the system is evaluated with respect to the efficiency and response time. The System performance is measured various size dataset by considering the processing time (in milliseconds) and throughput (in megabytes/sec Mbps). The processing time results are shown in Figure 17, and the throughput analysis result is shown in Figure 18. It is obvious in the graph that when the data size is increased the processing time proportionally increased, both data size and processing time are directly proportional to each other. However, we can examine the processing at higher (larger) dataset i.e. 5345MB, the processing time for this dataset is just 300000 which is far better than other systems. Moreover, when we analyze the throughput corresponding to the data size. We identified that the throughput was also directly proportional to data size because of the parallel processing nature of Hadoop system. This is the major achievement of the system that with an increase in data size the throughput is also increased.

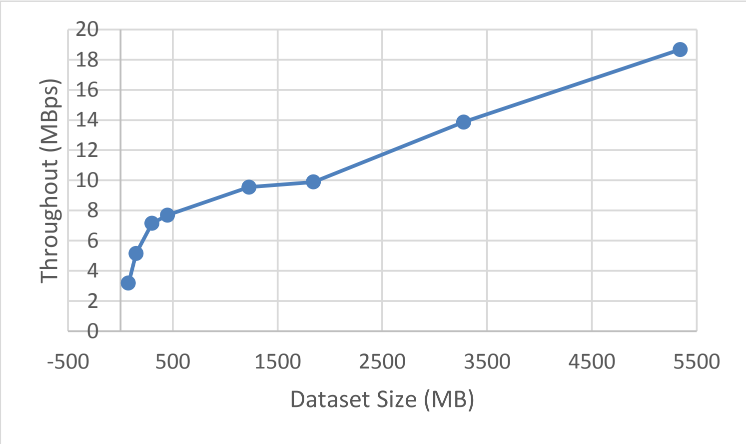

Figure 18. Throughput of datasets depending on the size of data

We also check the performance of the system by increasing the number of sensors for a single record. We keep the data size as constant i.ie. 2 GB and raise the number of sensors per record, we came to know that with the increase in the number of sensors, the throughput is decreased. This is because when we increase the sensors, it takes a lot of time in classification filtrations and processing, as a lot of comparisons due to a large number of sensors in a single record. The throughput of the system with respect to the number of sensors is shown in Figure 19.

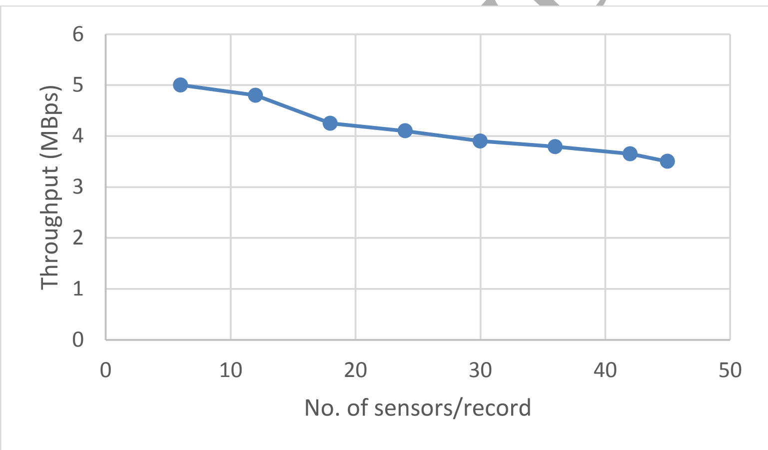

Figure 19, Throughput of the system by increasing the number of sensors per record for 1GB of data

7. ConCLUSION

Smart cities and urban planning leave a major impact on the development of the nations. It increases the decision power of the societies by making an intelligent and effective decision at the appropriate time. In this paper, we propose a system for smart cities and urban planning by using IoT generated Big Data analysis. The proposed architecture consists of four tier, which have the functionalities of the collection, aggregation, communication, processing, and interpretation. The complete system is developed using Hadoop technologies with Spark to achieve real-time processing. The simple IoT-based smart city data sets, such as vehicular network, smart parking, smart home, weather, pollution, surveillance, etc. data sets are analyzed for making the smart city as well as urban planning decisions. The proposed system not only beneficial to the citizens but also the authorities while providing them the facilities to make intelligent and fast decisions. The system is finally tested based on the efficiency performance by considering processing time and throughput. The system gives efficient results even on larger data sets. The system throughput is increased with the rise in data size.

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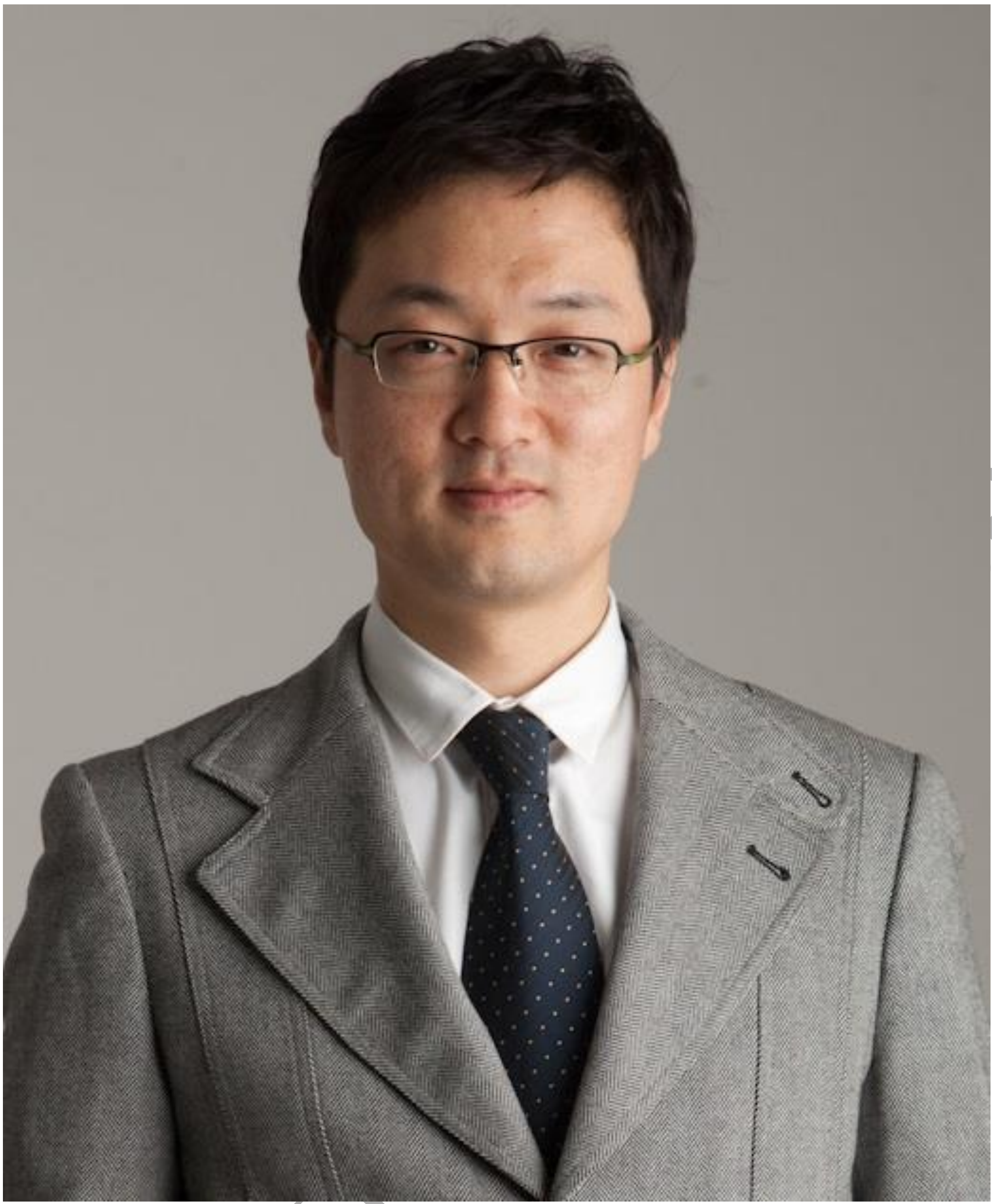
Muhammad Mazhar Ullah Rathore received the Master's degree in computer and communication security from the National University of Sciences and Technology, Islamabad, Pakistan, in 2012, and is currently pursuing the Ph.D. degree at Kyungpook National University, Daegu, Korea. His research interests include Big Data analytics, network traffic analysis and monitoring, intrusion detection, and computer and network security.

Anand Paul (SM'15) received the Ph.D. degree in electrical engineering from the National Cheng Kung University, Tainan, Taiwan, in 2010. He is currently working as an Associate Professor with the School of Computer Science and Engineering, Kyungpook National University, Daegu, Korea. He is a delegate representing Korea for M2M focus group and for MPEG. His
research interests include algorithm and architecture reconfigurable embedded computing. Prof. Paul has Guest Edited various international journals and he is also part of Editorial Team for *Journal of Platform Technology* and *Cyber Physical Systems*. He serves as a Reviewer for various IEEE/IET journals. He is the track Chair for smart human computer interaction in ACMSAC 2015, 2014. He was the recipient of the Outstanding International Student Scholarship Award in 2004–2010, the Best Paper Award in National Computer Symposium, Taipei, Taiwan, in 2009, and International Conference on Softcomputing and Network Security, India, in 2015.

Awais Ahmad (S'14) received the B.S. degree (CS) from the University of Peshawar, Peshawar, Pakistan, and the M.S. degree (telecommunication and networking) from Bahria University, Islamabad, Pakistan, in 2008 and 2010, respectively. Currently,
he is pursuing the Ph.D. degree at Kyungpook National University, Daegu, Korea. During his research work, he worked on energy efficient congestion control schemes in Mobile Wireless Sensor Networks (WSN). There he got research experience on Big Data analytics, machineto- machine communication, and wireless sensor network. Mr. Ahmad was the recipient of three prestigious awards: 1) Research Award from President of Bahria University Islamabad, Pakistan in 2011, 2) Best Paper Nomination Award in WCECS 2011 at UCLA, USA, and 3) Best Paper Award in 1st Symposium on CS&E, Moju Resort, Korea, in 2013.



Dr. Seungmin Rho, Ph.D. is a faculty of Department of Multimedia at Sungkyul University in Korea. In 2012, he was an assistant professor at Division of Information and Communication in Baekseok University. In 2009-2011, he had been working as a Research Professor at School of Electrical Engineering in Korea University. In 2008-2009, he was a Postdoctoral Research Fellow at the Computer Music Lab of the School of Computer Science in Carnegie Mellon University. He gained his B.Science. (2001) in Computer Science from Ajou University, Korea (South), M.Science. (2003) and Ph.D. (2008) in Information and Communication Technology from the Graduate School of Information and Communication at Ajou University. He visited Multimedia Systems and Networking Lab. in Univ. of Texas at Dallas from Dec. 2003 to March 2004. Before he joined the Computer Sciences Department of Ajou University, he spent two years in industry. His current research interests include database, big data analysis, music retrieval, multimedia systems, machine learning, knowledge management as well as computational intelligence.

He has published more than 180 papers in refereed journals and conference proceedings in these areas. He has been involved in more than 20 conferences and workshops as various chairs and more than 30 conferences/workshops as a program committee member.

He has been appointed as an Editor-in-Chief in Journal of Platform Technology (JPT) since 2013. He has edited a number of international journal special issues as a guest editor, such as Enterprise Information Systems, Multimedia Systems, Information Fusion, ACM Transactions on Embedded Computing, Journal of Real-Time Image Processing, Future Generation Computer Systems, Engineering Applications of Artificial Intelligence, New Review of Hypermedia and Multimedia, Multimedia Tools and Applications, Personal and Ubiquitous Computing, Telecommunication Systems, Ad Hoc & Sensor Wireless Networks and etc.

He has received a few awards including Who's Who in America, Who's Who in Science and Engineering, and Who's Who in the World in 2007 and 2008, respectively.