TECHNOLOGY TRENDS AND DIGITAL SOLUTIONS FOR SMART CITIES DEVELOPMENT

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ABSTRACT

Worldwide population is growing and also the overall economic condition. Improving economic conditions are now empowering people to demand for better and better facilities for living. This has automatically increased the living standard of societies and now to meet this improved standard, standard cities are rapidly transforming into Smart Cities. For providing better facilities, Smart Cities are often depending upon the advanced technology enabled solutions and deploying the smart solutions efficiently and effectively. In this paper, latest technology trends and selected solutions for development and operations of Smart Cities are explored. This paper has also discussed in detail smart solutions used in Smart Cities to tackle some of the real life practical problems.

Keywords: IoT, ITMS, SWM, Sensors, Client-Server, Data Security

I. INTRODUCTION

Cities built and operated with sophisticated technologies to make them more livable and to meet the growing demand from its citizens to deliver a better quality of life at sustainable cost are normally known as Smart Cities. This can be a generic definition of any Smart City but, Smart City has much more to offer its citizens to make their life more enjoyable, comfortable and easy going. To achieve this Smart Cities heavily depends upon latest Technologies, tools and solutions.

Worldwide population is growing, and more and more young generation of people are moving to cities from villages. So Smart Cities also needs to accommodate the growing number of population, needs to consider proper shelter for the new migrants, needs to consider their water, food, transportation, schooling, offices, vehicle parking etc. related requirements smoothly and hassle free.
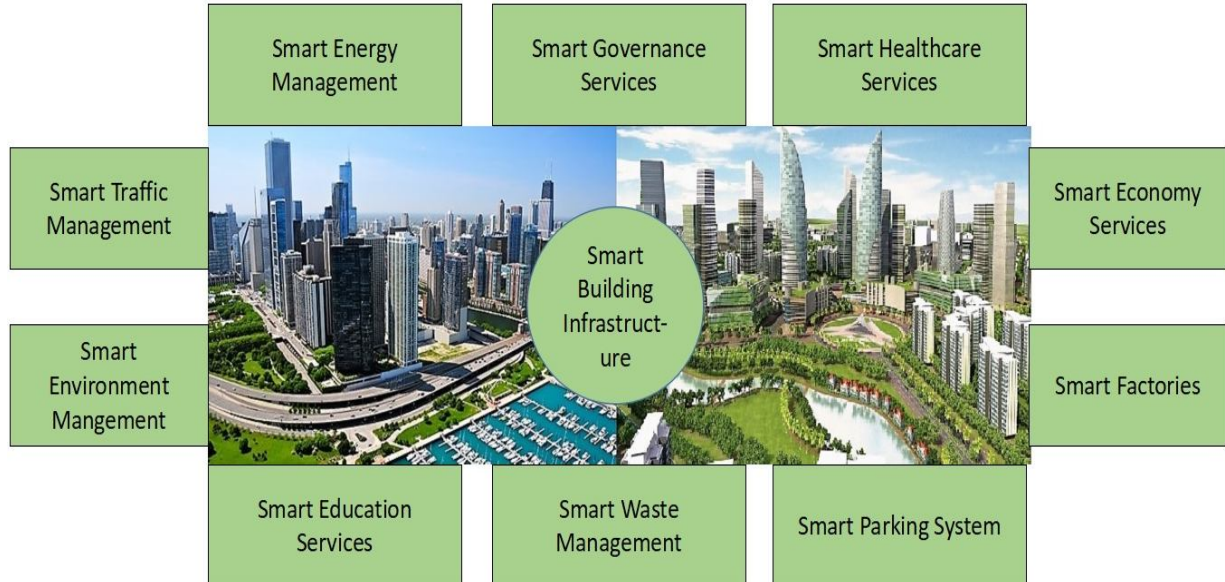

Figure-1: Smart Cities Capabilities

Thus, for any Smart City the biggest challenge is to not only manage the demands from its present citizens but also consider the future expansion, additional load of new citizens and ability to offer the services without any degradation to all its stakeholders.

Today's Smart and advance technologies comprising of IoT, Machine to Machine Communication, Data Analytics, Image and Video Processing, Digital Twins, Cyber Security, Artificial Intelligence, Digital Transformation and so on, are helping Smart Cities to meet their present and expected future challenges. Please refer figure 1 which has presented the features and capabilities of modern Smart City which needs to be fulfilled and continuously maintained throughout the sustenance period. We will now deep dive in each of these capabilities and will see how some of the advanced technologies are helping Smart Cities to meet growing demands from its citizens and facilitates better quality of life to its residents.

II. WHAT MAKES CITY SMART?

Smart Cities operates with IT infrastructure and advance technology solutions and software, with an end objective of making its residents life better and better. Smart Cities heavily rely on data which gets generated through their stakeholders and deployed sensors. With the help of technologies like Big Data and Data Analytics, Smart Cities uses proper framework to store and analyze the huge generated data to identify meaningful information from it such as data trend, outliers, data pattern, abnormality, data predictions and so on. With the huge volume of processed and analyzed data, Smart Cities can offer an exact required service to its citizens more effectively and securely. Smart Cities also ensure to have participation of its citizens to run the processes, to form policies and regulation frameworks for better city administration. The Smart City citizens are also facilitated to access records, information, data, applications and other useful stuff including audio and video entertainment contents easily and securely using specially developed Smart City apps available on Smart Phone, Tablet and or Laptop. Users can thus access, use and participate into lot of appropriate applications from anywhere with their own comforts. Smart City also care about green environment and ensures reinforcing appropriate measures to reduce the waste and other harmful products such as dirt, poisonous gases, hazardous material etc. which can have negative impact on the overall environment. Smart Cities care about their citizens and offers better medical services using mobile apps and IoT based sensors which can be body wearable and can provide exact information about user's body condition such as present blood pressure, heart rate, glucose, burn calories etc. in real-time. Smart City focuses on three principles reduce waste, recycle material and reuse the stuff. With this approach Smart Cities always ensure to keep negative impact on the environment at minimum, optimum utilization of available resources and effective utilization of present resources without any loss.

III. TECHNOLOGY DRIVEN SOLUTIONS FOR SMART CITY

Smart Technologies are playing a very critical role in overall development of Smart Cities around the world. Today's technologies are already evolving into next generation technologies and are shaping the world into better place for living. I feel that the biggest contribution of technologies is in Smart Cities development and maintenance which directly or indirectly has touched many of the people lives making it better and better. This is possible by participating, implementing and deploying the technology enabled smart solutions for developing and maintaining Smart Cities around the world. Let us walk through some of the technical solutions which has made it possible for Smart Cities to offer the astonishing capabilities which can't be even think of in normal cities.

- **Smart Traffic Management**

Due to improved economic conditions, number of personal vehicles increased multifold. Also due to efficient business policies many of the heavy commercial vehicles started travelling across the cities and states carrying goods and raw materials. Increase in number of vehicles and the frequent movement of vehicles from one place to other has increased traffic tremendously and put up lot of pressure on traffic monitoring and control system, this in turn increase travelling time. To better deal with the situation Intelligent Traffic Management System (ITMS) is normally used by Smart Cities. ITMS with the help of client server technologies, real time data analytics and with deployed connected sensors on roads, make it possible to monitor and control the traffic in most efficient manner. The major elements in ITMS are as follows.
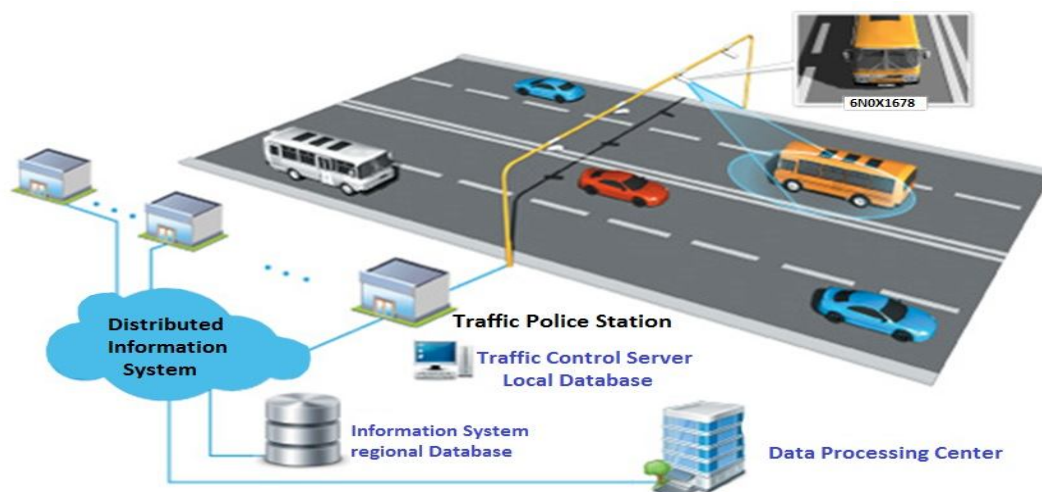

Figure-2: Intelligent Traffic Management System [1]

➤ IP Cameras: These are the network connected various types of cameras, chosen based on the traffic area to be monitored. It can contain day and night vision cameras as well as thermal cameras. Some of the cameras may also have Pan, Tilt and Zoom (PTZ) capability. These cameras act as eyes of traffic monitoring controller and carries out responsibility of feeding real time live footage of the traffic at steady rate to the traffic controller Server. These cameras are typically mounted on Traffic Indicator Poles or standalone poles in such a way that it can cover maximum field of view with best resolution.

➤ Traffic Central Server: This is the brain of the ITMS and responsible for taking the decisions such as traffic diversion, traffic incidents handling, traffic light controls, traffic congestion predictions and corrections, data analysis and reporting. It operates with an application software responsible for taking traffic control related decisions based on the inbuilt real time data analytic engine. It also maintains the data through interfaced database maintaining the record of traffic incidents and decisions and exporting of the relevant data in the required format for offline reporting and record. Traffic Central Server receives various data from various other network devices deployed in each traffic zone such as selected IP Cameras, Traffic Monitor Server, Traffic Power Manager, Incident Management Server etc.

➤ Traffic Monitor Server: This is a deputy controller for an ITMS which has the main responsibility of maintaining the video footage received from various IP Cameras belonging to specific traffic region. The traffic Monitor Server is responsible to report accidents related incidents, traffic jam, traffic real time condition to Traffic Central Server which in turn reports the incidents to Incidents Management Server. There are more than one Traffic Monitor Server deployed for each specific region which is responsible for monitoring the traffic belongs to that specific region.

➤ Traffic Light Controller: Traffic Light Controller runs the special Traffic control algorithm and based on the specified time duration controls the on-off duration of the Green, Red and Yellow Indicators. The Traffic Light Controller also can alter the on-off duration of the specified Traffic indicators based on the recommendations from Traffic Central Server as well as Traffic Monitor Server belongs to that region.

➤ Traffic Light Power Manager: This is one of the most critical components of ITMS. Keeping in mind the Green Power and Green environment related policies of the Smart Cities, the Traffic Power Manager, ensure providing appropriate power to all the elements of an ITMS. It drives the power mainly from Solar Panel and or Electrical Mains or diesel generator as per the availability of power source and ensures providing uninterrupted clean and smooth power supply to all the network devices.

➤ Traffic Address System: Due to accidents, rallies, large convoys and other relevant incidents, sometimes the traffic gets jammed and it is not possible to remove the jam automatically. In such cases it becomes necessary to provide oral instructions to drivers to control the traffic flow. Public Address System facilitates addressing the drivers by providing relevant instructions over loud speakers installed at regular intervals along the road and or through designated Radio Channels operating at relevant frequency range kept reserved for communicating traffic related information.

➤ Incident Management Server: This server receives the instructions from Traffic Central Server about various incidents such as Emergency Alert Situation, Accident, Medical Emergency, special convoy movement etc. The Traffic Incident Management Server has pre-defined work instructions to react based upon the type of incident. For example, it must inform Ambulance Services in case of any accidents at a particular spot on road or in case of Fire due to accident, it must call Fire Brigade etc. In case ITMS is responsible for covering large area of City then there is a possibility of having more than one Incident Management Server as per applicable area and to share the work load.

- **Smart Education Services**

Smart Education concept came into picture to cater the modern needs of large population of students staying in Smart Cities. Since Smart Cities heavily depends upon IT Infrastructure and cloud computing platforms, it is obvious that while delivering the educational services to its students Smart Cities encourages and promotes online education using IT Infrastructure. Today's students are technology savvy and believes in practically fast education without any physical boundaries imposed by conventional schooling. Keeping in mind this prime objective, Smart Education offers online education through virtual classroom which resembles real classroom like environment facilitating students to ask queries to the teacher, participates in group discussion, notes sharing and recording of the sessions, notes storing, annotation over the boards etc. Advantage of such online education system is that instead of limited students, education can be reached to large number of students who can take up the online classes without any major infrastructure requirements and that is too at their own pace

and sitting at their home with their own comfort. Refer fig.3 which has shown the high-level architecture of Smart Education Services for Smart Cities.
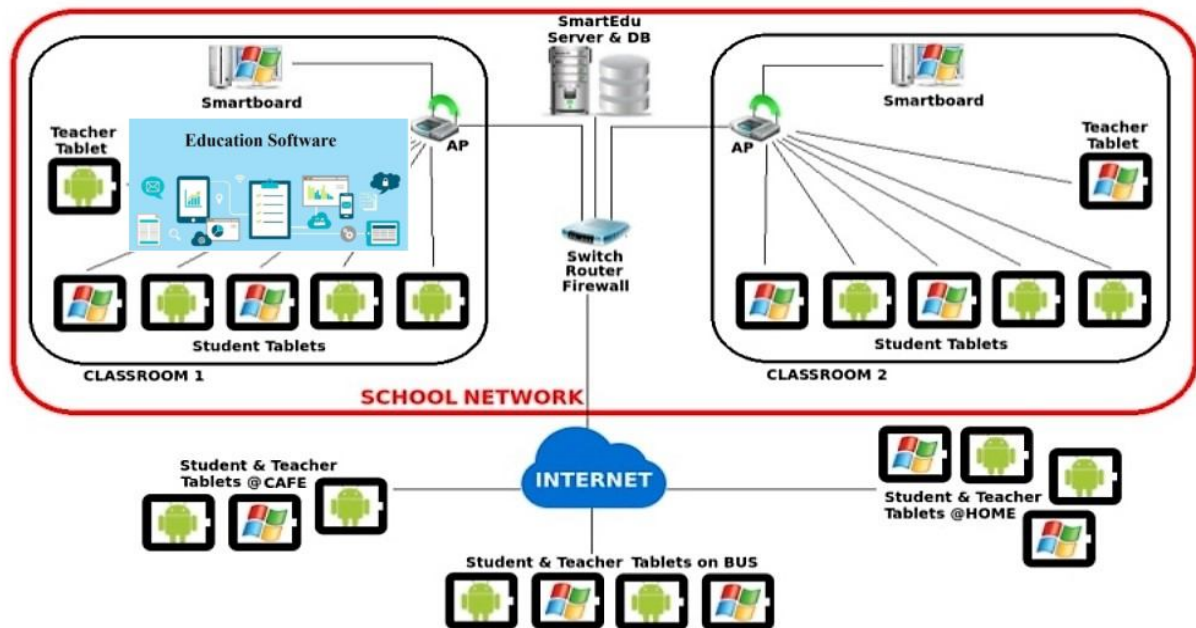

Fig-3: Smart Education Management System [3]

Figure 3: Smart Education Service High Level Architecture [2]

Smart Education Services connects students directly with teachers through internet web services, Mobile Apps and Standalone Virtual Classroom System. This has made possible for large number of students to enrol for the courses of their choice. Also, it is possible for teachers to reach to the large number of students instead of limited classroom students. Students can access the recorded class room sessions as well and appear for online examinations as per requirements. Since the answer sheet evaluation can as well possible through software, it ensures the standard evaluation and less errors in results. As shown in fig. 3, the Smart Education Services consists of major elements such as

- Smart Education Server

- Educational Material Database

- Live Video Recording Cameras

- Digital interactive boards

- Smart Phone Digital App

- Distance Education Application

- Virtual Classroom Application

- Examination Server

Students can access the teaching material, and online classes through their Smartphone, Laptops or Tablets installed with Smart Education Application Software. Smart Education Services also promotes Virtual Universities where students from any place can enrol and take education online through secured Net. It should be noted that Smart Education Services doesn't mean to avoid physical classroom teaching and or to minimize face to face interactions between students and teachers rather it is a collaborative platform which assist teachers and students to interact with each other online at larger scale and in convenient way.

- **Smart Waste Management**
Collecting and disposing the waste in rightful manner keeping in mind the impact on environment is the biggest issue of concern. Smart Cities also face this challenge and address it using the smartest technologies available, the whole solution is known as Smart Waste Management (SWM). SWM monitors, controls and effectively dispose waste as per regulatory guidelines. The whole process it manages right from the inception of waste to waste disposal.
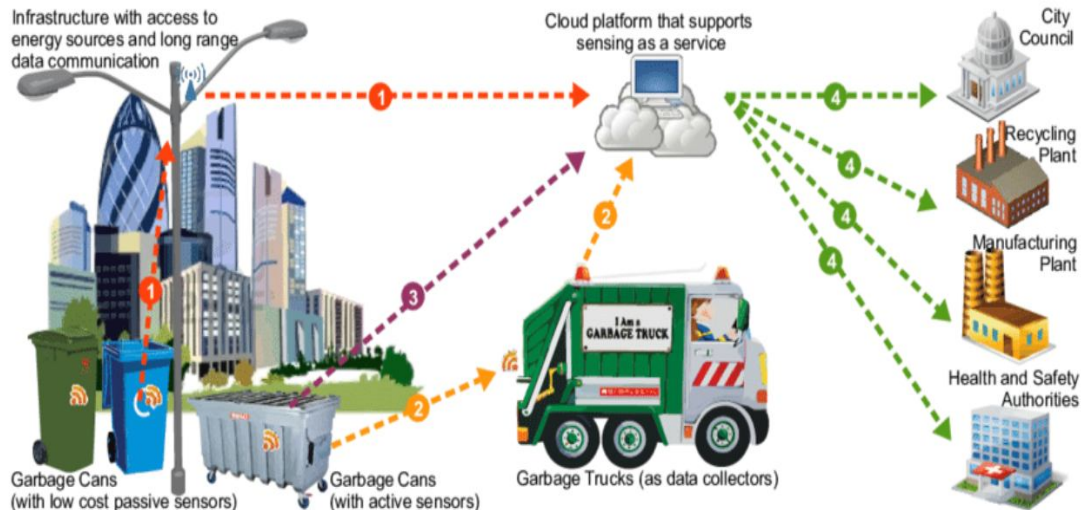
Figure-4: Smart Waste Management System [3]

SWM operates on 3 principles

- Reduce

- Recycle and

- Reuse

Waste can be in any form such as solid, liquid, gaseous and can be hard or soft. It can be generated from the household, industries, plants, constructions and can be dangerous to human beings as well as for the environment. SWM therefore is a very important process and plays a very critical role in Smart City development and operations. SWM focuses on reducing the waste and then wherever possible recycling it, that is processing the waste and transforming it into some useful form. For example, the paper waste can be recycled and can be transformed into new paper. And finally reuse the recycled material.

SWM relies upon Cloud Server Technology Platform, wireless and or networked communication Sensors including RFID, ultrasonic, PPR, CCTV Cameras, GPS etc. Even the waste Bins some time used as Smart Bins fitted with Sensors to detect if the Bin is filled or not. Refer fig. 4 above which has presented the SWM Process and its main elements.

The SWM actively uses various sensors deployed at various locations to collect the relevant data. The passive and active sensors mounted on waste bins provides information about the waste bin filling status. The CCTV camera provides the direct video footage of Waste Bin condition. The GPS provides the location coordinates of garbage collection trucks as well as the location of waste bins. The deployed active sensors can communicate via existing Smart City wi-fi network. The Cloud computing Server receives data from the deployed active sensors along with location coordinates and time stamp. The Server application collects the whole data received from various sensors, process it suitably and analyse it to identify following information

- Waste Bins which needs to be empty immediately

- Waste Bins which are about to getting full

- Waste collection Truck real time waste collection status

- Status of waste delivery to processing plants

- Amount of waste recycled

- Waste recycled material collection status

- Generation of overall waste analysis report (amount of waste generated, types of waste, days wise waste collection, days wise recycled waste, waste bin maintenance status, waste disposal status etc.)

The cloud platform Server for SWM also connects with other Servers of Smart City over the existing secured network provided by Smart City and exchanges the real time information about waste analysis as and when required by other services of Smart City.

- **Smart Medical Services**

Availability of right Medical services (Doctor's consultations, medicines, surgical operations etc.) at right time is a crucial need. Many times, patients could not survive due to delay in availability of medical treatment. Smart Cities are more concern about wellbeing and health of their citizens and uses Smart Healthcare Services to systematically tackle the medical issues of their citizens.

Smart Healthcare is a technology driven medical service that ensures better treatment for patients, better diagnostic tools, medical specialist consultation at right time, facility to securely maintain medical records and disease history for patients and enhance quality of lives. For providing health care support remotely a dedicated Telemedicine service is there which is basically an Electronic Health Service which offers the medical consultation, analysis the trends in medicine usage and making this information available to the authorized specialist as and when required.
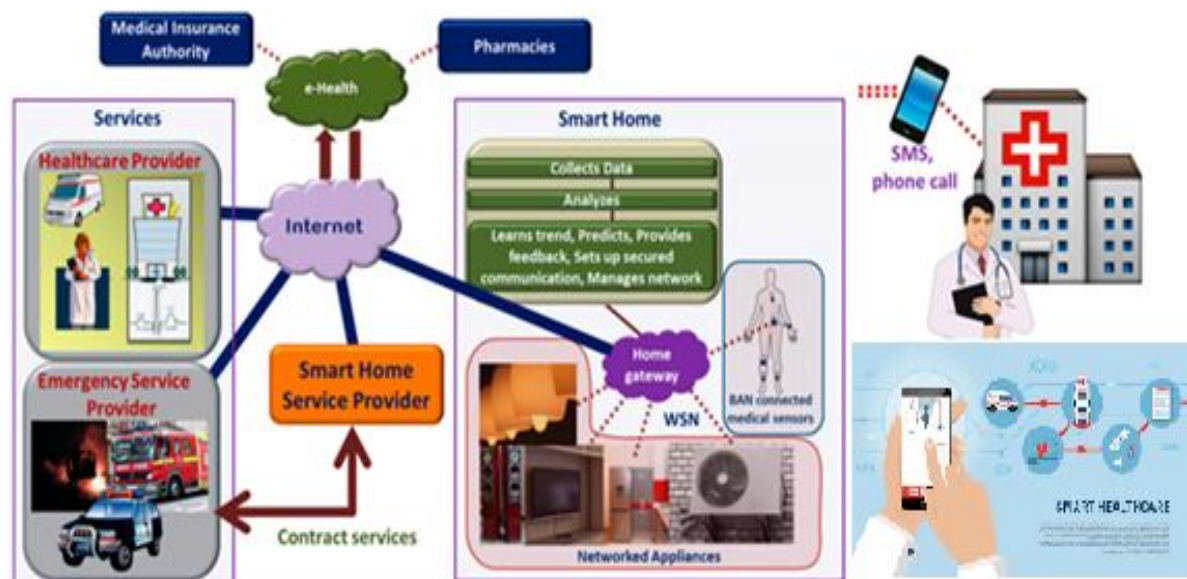

Figure-5: Smart Healthcare Services

As shown in fig.5 above, Smart Healthcare Services relies upon following some of the core technologies and components to offer the medical services to its stakeholders at full extent.

- Smart Wearable Devices/ Sensors for Health Monitoring

- Mobile Healthcare Apps

- Cloud Computing Healthcare Platform

- Data Analytics for data processing and predictive analysis of patient's medical records

- IoT Sensors and Devices for Medical Data acquisition and communication

The IoT technology is playing a crucial role here by connecting the body wearable devices and sensors with Cloud Computing Platform running with Healthcare Medical Services. The data collected from body wearable sensors is properly analyzed, processed and stored in medical record of respective patient. The Data analytics engine running with Healthcare Application Software, also carries out predictive diagnostics on patient's data base and identifies the relevant possible diseases patient may suffered with. Such suggestions and data diagnostics report are shared with specialist and team of doctors electronically for further recommendations and decisions. Smart Healthcare Services also facilitates interaction of Patient and doctors through Video Call for discussion of firsthand information generated through Healthcare Application and to discuss the recommended actions on it. Based on the recommendations from doctors, patients may choose to take up an appointment of relevant Specialist/ Surgeon for physical treatment. Such Appointments can be booked online and necessarily follow up through SMS/WhatsApp can be possible. Since the Healthcare Application maintains the medical record of its user, sufficient capacity secured database, complying the safety and security practices related to information security management system, is typically used. The biggest advantage of Smart Healthcare Services is that the users of such system are always appraised with latest information related to their health and can get necessary medical support well in advance as per the predictive diagnostics results applicable for them. So, we can say that Smart Healthcare Systems can minimize the risk of unexpected medical emergency for its users.

- **Smart Governance**

Smart City offers its services to its stakeholders through the IT Infrastructure where facility to be available 24x7 for the service of the stakeholders, information security and maintaining transparency is key to success. The Smart Governance operates exactly on same model and principles. Smart Governance is the process of utilizing modern technologies and ICT to create a collaborative, communication-based, transparent, and sustainable environment for the citizens and government. Traditional governance model basically suffers from restrictions on data sharing, poor data transparency, limited public involvement in policies formation which makes it ineffective in implementing and executing mutual beneficial policies and framework for governments and its stakeholders. Whereas Smart Governance backed with robust IT Infrastructure encourages and facilitates governance related data sharing to all the stakeholders in reliable and effective manner. Due to this it is possible to have more involvement of all its stakeholders in executing and implementing policies and procedures for all concerns including government bodies, societies, administration staff, corporations, municipalities and all stakeholders. This boosts people confidence in administration authorities and can create a cooperative and healthy environment for Citizens and Smart City Administration Authorities. And thus, principles of good Governance can be applied more rigorously with the help of Smart Governance.

Smart governance covers various stakeholder's expectations by having relevant policies and procedures in place. It can operate in any of the following 4 engagement models as the case may be

- Government to Citizens Engagement Model: Cater communications/interactions between Citizens and Government Authorities

- Government to Business Engagement Model: Cater communications/interactions between Business bodies and Governance Authorities

- Government to Government Engagement Model: Cater communications/interactions among Government organizations, agencies and departments

- Government to Employee Engagement Model: Cater communications/interactions among Government Authorities and its employees
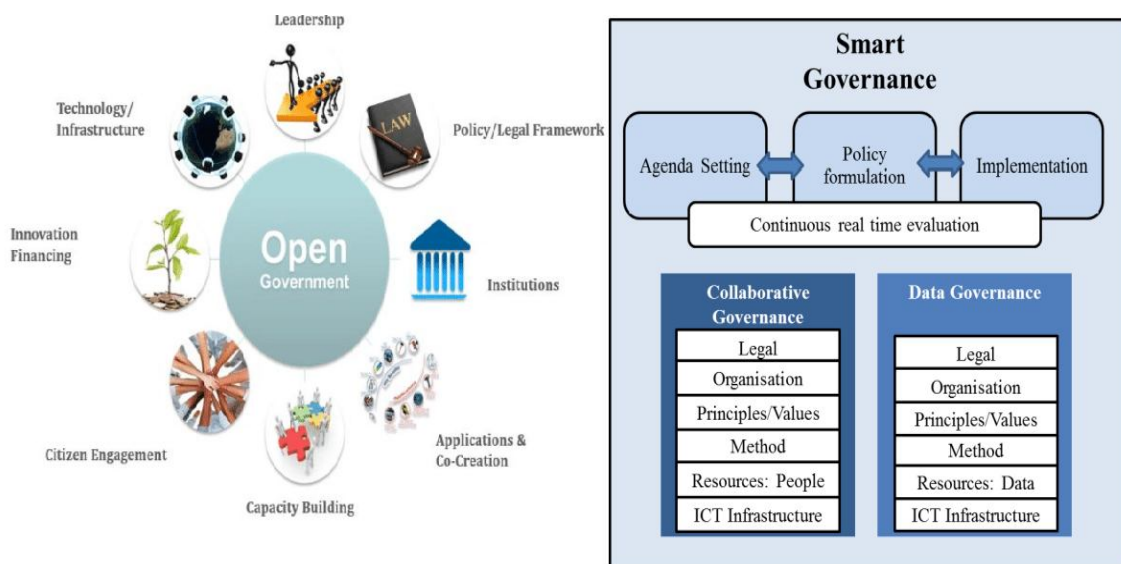

Figure-6: Smart Governance Building Blocks [4]

The Fig.6 above has presented the activities and basic building blocks of Smart Governance. As it is clear from the figure that Smart Governance is empowered to play role in overall administration of Smart City and that is too expecting a transparent process in line with the one which is jointly formed by the governance authorities and citizens. While executing its work Smart Governance fully utilizes the existing IT Infrastructure of Smart Cities as backbone to execute the governance process. The Key IT components and technologies which plays a crucial role in the whole gamut of Smart Governance Services are as follows

- Cloud Computing Platform: It typically host applications for different governance processes commonly comes under umbrella of E-Seva Services (in India)

- Smartphone Apps: These are client end applications which provide a secure user interface connecting user directly to the Server hosted on cloud running with various E-Seva Services

- Secured Database: A huge secured database which can have multiple instances and backups as required. It is used to store the user's information who are stakeholders of governance services

- Big Data: The huge data stored in the database needs proper processing in real-time to get the relevant results as per the queries and to sort the information, analyze the data, finding out trends, outliers and for generating various records as per stakeholder's requirements

- IoT: IoT technology is useful for collecting user's information through various sensors connected to the Internet. This information can be useful for authenticating the user while carrying out financial transactions or for identifying the User during any application process. Example of Sensors can be Cameras, Retina Scanner, Biometric Finger Impression Scanner etc.

Overall Smart Governance offers plenty of advantages as compared to traditional governance processes. Some of the key benefits offered by Smart Governance are as follows.

- Secure access to all the relevant information as per requirements

- Complete transparency in engagement activities and offered services

- Enhanced participation of all the stakeholders in implementing and managing governance policies and framework

- Inclusion of larger population in running the governance policies and operations

- Increases interests of citizens

- Better productivity due to efficient and speedy execution of all the processes

IV. CONCLUSION
In present paper, Smart City concept and overview is presented and some of the technology-based solutions to implement some of the Services of Smart Cities are discussed in detail. Based on the information collected, analyzed and discussed here, it is concluded that Smart Cities are heavily relying on latest technologies such as IoT, Big Data, Image Processing, Embedded Software Engineering, Client Server Technologies, Cyber Security and IT Infrastructure to run and maintain the overall operations. World's population is growing and thereby number of Smart Cities worldwide. It is sure that all the relevant technologies of Industry 4.0 are going to be utilized heavily in building and maintaining Smart Cities over the period. This will also put pressure on worldwide researchers to offer more accurate, fast and reliable solutions to the practical problems faced by the upcoming Smart Cities.

V. FUTURE WORK
Due to time and space constraint it could not become possible to cover the details of all the Services of Smart Cities. Also, it could not become possible to discuss the implementation solutions for left out services such as Smart Parking System, Smart Energy Management, Smart Factories etc. In future, it is decided to cover details of rest of the services of Smart Cities along with its basic building blocks and implementation details through separate research paper. It will be also good to develop the Proof of Concept (PoC) and laboratory prototypes for some of the Services of Smart Cities for better concept demonstration and to analyze the feasibility of further improvements and its suitability to larger group of stakeholders. A separate research paper covering implementation details of such PoCs and or laboratory prototypes for each selected service of Smart Cities is considered as future work and will be undertaken as a next stage of research.

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