INTRODUCTION TO SMART CITIES AND SELECTED LITERATURE REVIEW

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ABSTRACT

Smart City concept is not new but in developing and under developed countries still many people are not familiar with it. Smart City still doesn't have universally accepted definition and many people have defined it with different perspective and views. Sometimes this creates an unnecessary confusion to understand what Smart City is. To have better clarity and to understand Smart City concept well, in this paper an overview of Smart City is provided along with details on Smart City Components and Services. Selected research papers on Smart Cities are also reviewed to identify technology trends and solutions used to design, develop, operate and maintain modern Smart Cities across the globe.

Keywords: Smart City, ICT, IoT, CPS, Simulation

I. INTRODUCTION

Smart City concept is not new in developed countries however many citizens of developing and under developed countries still not much familiar with it and faces challenges in understanding Smart City definition and its necessity in today's world. In reality Smart City doesn't have any standard definition in theory which is accepted by world wide researchers and organization. Many people have explained Smart City concept and proposed different kinds of definitions from different points of view such as technical, social, economical, political, governmental etc. Though these definitions are different from different point of views, researchers and organization however commonly agree to the fact that Smart cities are designed, developed, driven, manged and operated with latest Information Communication and Digital Technologies. Some of the well known definitions of Smart City are listed in table 1 below.

Table 1: Smart City Definitions

Sr. No.	Source	Smart City Definition
1	Techopedia	"A smart city is a designation given to a city that incorporates information and communication technologies (ICT) to enhance the quality and performance of urban services such as energy, transportation and utilities in order to reduce resource consumption, wastage and overall costs."
2	Times Of India	A city equipped with basic infrastructure to give a decent quality of life, a clean and sustainable environment through application of some smart solutions.
3	Wikipedia	A smart city is an urban area that uses different types of electronic Internet of things (IoT) sensors to collect data and then use these data to manage assets and resources efficiently.
4	Smart Cities Council	A smart city is one that has digital technology embedded across all city functions; click on any of the articles below for additional perspectives.

Though well focused and planned development efforts are already going on from last few decades for development of planned cities, however it is realized from last 10 to 15 years that ongoing efforts are not enough and societies are now more demanding and looking for more robust technical solutions for real life problems from residence, infrastructure and commute perspective. I feel that this constant pressure and more demanding nature from societies and city residents to make the life easy and safe must have triggered the thought of digital technology compatible city which is nothing but, in my opinion, a Smart City.

It is not uncommon to expect that Smart City is nothing but one which provides smart services to its citizens to make their life more comfortable, safe and happy. However, it is also about connecting the city residents in reliable and safe way with the government digital governance platform where citizens can consume the services, can give their feedback and improve the services through mutual participation in ongoing basis. And this ultimate aim can not be fulfilled without utilizing the latest technology based solutions specifically from Information Technology(IT), Software Engineering and Information Communication Technologies(ICT).

Smart City is different from traditionally well developed cities and or the way cities were planned and grown. Smart City has brought new trend in setting up and development of cities and applying the governing policies,

rules and regulations through the use of technologies. This enables the citizens to freely access and use digitally available information, various apps providing various digital services related to the city such as various events info, shopping offers, tours and travels related info, tracking and locating address, online admissions to school and colleges etc. Thus Smart City is a place where traditional information networks are replaced with digital services offering more flexibility, more efficient and more sustainable by making the best use of available technologies such as digital and information communication technologies, to improve the overall operations and provide benefits to it's residents. Smart City not only best utilizes the technology to make the citizens life better livable but also cares to reduce harmful impact on environment. Technologies such IOT, Big Data, Geospatial Technology, Artificial Intelligence, Block Chain etc. are making long term impact in smart cities development and operation making them more efficient and more innovative and creative.

In figure 1 below, the typical model representing smart city concept is shown. As shown in the figure, the key ingredients of smart city are shown around the basic residence infrastructure of a city and presented as a collection of paradigms spread among different domains such as people, processes, governance, mobility, environment and better living facilities such as residence buildings, education institutes and medical facilities.

Figure 1: Smart City Model (Monicaodo - Dreamstime.com)

Smart City thus facilitates and responsible for lot of functionalities under one umbrella including traffic flow analysis and necessary optimization, incident monitoring and reporting, public transportation, utilities monitoring, carbon foot print measurement and monitoring, smart governance, smart power management, best optimized natural resource utilization, smart water management, smart waste management and so on. Please refer figure 2 which has presented the essential capabilities of Smart City. Housing, medical facilities, education, transportation, governance services, citizens safety and security and other such essential services enabled and efficiently operated using advance technology based solutions ensures livability for citizens and also offer economic opportunities for cities to attract and empower citizens of all age groups including senior citizens. Smart City technologies when used wisely and with planning can alter the city infrastructure and the ways the digital services are deployed. These technologies also offer good opportunity to accommodate expectation and desires from ageing communities and disabled communities. All the stakeholders of Smart City thus can ensure that offered services are inclusive.

Figure 2: Smart City Capabilities (Panagiotis Tsarchopoulos, 2017)

II.   SMART CITY ICT COMPONENTS

As cleared from the Smart City introduction, it is confirmed that for deploying all the essential services to make the city residents life more enjoyable and comfortable, Smart City heavily relies upon technology driven solutions. IT, ICT and Digital technologies are playing crucial role in solving real life problems faced by Smart Cities. Let us explore such technology based components for Smart Cities. Refer figure 3 below, which is presenting all the essential components of ICT which directly assist Smart City meeting and fulfilling its many of the objectives. Though the figure has only listed essential ICT Actors, the list in reality is very exhaustive and will continue to grow depending upon the ICT revolution and its implementation across multiple domains. The list is also going to accumulate the new elements in line with industry 4.0 generation.

The smart ways of managing the things required acquiring the relevant data from various sensors, necessary data monitoring and analysis. The relevant data analytics from smart management of various services enables the city governance to make relevant improvements in infrastructure, super asset management and overall effective control on all the relevant resources. For this purpose, a smart city must include key components such as secure centralize server, safe way to access the data through mobile apps or simple secured websites and powerful hardware platforms to drive this IT Infrastructure. With such facilities the citizens can then freely and securely access the systems and subsequently required data and this can happen in two ways where citizens can also upload and update the relevant information in real time. By enabling the relevant controls citizens can contribute in information sharing and can collectively fulfill the combine aim of smart city governance.

Figure 3: Smart City ICT Components (Margaret Rouse, 2017)

III.   How cities can be smart

The systematic definition of Smart City is "a city in which its social, business, and technological aspects are supported by Information and Communication Technologies to improve the experience of the citizen within the city. To achieve that, the city provides public and private services that operate in an integrated, affordable, and sustainable way." Thus, the smart city's basic aim is to have an an integrated as well as collaborated environment to facilitate interoperability, participation and enhancements among city's sub-systems. Making City Smarter is an evolving and ongoing activity and it is necessary that the shared services must be integrated under unified technology infrastructure.
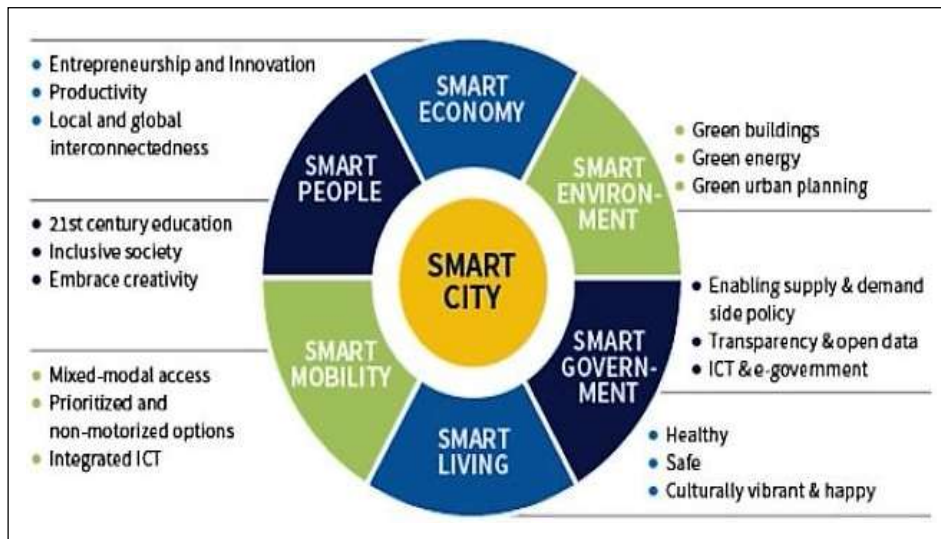

Figure 4: Smart City Features (Boyd Cohen)

A more sensible way to make this reality is with a well-thought of and designed, robust software platform providing the essential infrastructure for dealing with huge volumes of data, a wide variety of software devices, platforms and applications, interoperable systems, and other issues related to Smart City environments.

Refer figure 4 above which has shown the 6 essential features any smart city must have. The smart city is built on the smart combinations of enabling these features. For smart and sustainable growth of a city, it is important to promote a more efficient use of available resources, reliable data analysis, robust technical infrastructure, a competitive economy and continuous innovation. For better performance, smart city depends upon advancements in software engineering field and uses digital and information communication technologies to enhance quality of the offered services to make citizens lives better. All the stakeholders of Smart City including administration and management officials are provided with better technology driven ways to connect with each other and take rapid action as and when required. Continuous small steps are being taken towards the final goal, Smart City, by providing & continuously improving on the Smart Living aspect of it.

IV.   Literature review of selected research papers

Worldwide scientists, research scholars, Industry SMEs have put lot of efforts in proposing and implementing various innovative solutions to address the real life challenges faced in developing Smart Cities. Lot of good research papers, white papers, presentations, thesis and books are available online as well as in printed form elaborating in detail the Smart City concept, systematic steps in implementing and maintaining Smart City infrastructure and solutions based on advanced technologies to meet specific features and functionalities Smart City needs to fulfill. Following are some selected research papers reviewed to gather more information about Smart Cities, its technology trends, Smart City Services, its challenges and Solutions.

[1] Agatha: Predicting Daily Activities from Place Visit History for Activity-Aware Mobile Services in Smart Cities by Byoungjip Kim et al (2015)

For any Smart City to smartly function, many digital services are used such as city planning, transportation, administration, location mapping and so on. Number of digital services are increasing day by day according to the larger requirements of Smart Cities. In this paper Authors have shared details of new digital service for citizens of Smart Cities that is place-history-based activity prediction system called as Agatha. This service will be mobile app based. While people moves around city the GPS enabled Smartphone installed with Agatha Service App will collect location coordinates of the place visited by the user, time stamp the event for In and

OUT information. This data will be then processed, and the system will extract the place visit history of the user and on that can predict the user's likely activities in and around city using machine learning techniques. Authors have claim that this new service of place-history-based activity prediction can be very useful for Mobile Advertising and for recommending the users specific other services and information such as best dining out nearby or entertainment event happening nearby or even information related to forth coming events in such places where user is expected to visit in nearby future.

[2] Analysis and assessment of a knowledge based smart city architecture providing service APIs by C. Badii et al (2017)

Smart City development faces many of the issues and challenges where one of the main challenge is related to collecting data generated from various services, analyzing it and generating meaningful conclusion out of it. Also, Smart City service effectiveness depends upon its capability of collecting the relevant data and passing it to its stakeholders reliably and accurately. To meet this challenge, authors have proposed a robust solution for data aggregation and for Smart City API. This work was performed by the authors in the context of Sii-Mobility smart city project on developing the smart city architecture addressing huge data processing requirements. The authors proposed solution by aggregating and re-conciliating all types of generated data including real time, static, openly available as well as private services data by using smart algorithms for enabling Smart City API sophisticated service delivery.

[3] Thinking about smart cities by Amy Glasmeiera and Susan Christopherson (2015)

In this paper, author went through the various definitions of Smart City and came forward with different perspective about Smart City keeping in mind the two essential attributes. These two essential attributes are: technology driven and living experience in urban places with new reality. Author has discussed about the various expectations from citizen about Smart City and elaborated their thoughts throwing light on following

➢ Better equipped infrastructure of Smart City for smarter Cities

➢ Are Smart City resident real beneficiary from Smart Cities?

➢ Can Smart City movement fulfills the better urban living expectation from its citizens

Authors feel that the Smart City Development process should be well thought of and conducted through collaborative research. While doing so following questions shall be answered
➢ The capabilities and constraints of technologies used in development of Smart Cities

➢ Application deployment conditions such as scale, market size, density and proximity and finally

➢ Applications marketability

Authors have also raised concerns stating that many of the smart cities will need to be developed from scratch considering the possibility that many of the people will move from rural areas to Urban for exploring better employment opportunities and better liveable experience. In such cases it is extremely important to consider essential resources requirements such as water, transportation, waste management, electricity, housing, medical facilities, education facilities etc.

[4] Smart Cities as Cyber-Physical Social Systems by Christos G. Cassandras (2016)

The Smart City network infrastructure consists of network of sensors and actuators embedded throughout the urban terrain and Smart City services, interacting with smart phones, tablets and laptops. All these devices and or nodes are finally interacting with cloud services offered via internet. In this paper authors have correlated the smart city architecture with Cyber Physical Systems (CPS). Authors have successfully argued that the data collected and flowed through various network nodes in Smart City may involve data related to traffic signals information, traffic flow information, parking availability information, vehicles monitoring and location coordinates, water and air quality related information, emergency related information. Under such conditions data reliability, accuracy and availability of information is key requirement which demands a robust CPS infrastructure equipped with new software platforms adhering to strict standards of mobility, safety, security and data privacy. In this paper authors have discussed key characteristics of Smart City and discussed following lessons learned by viewing Smart City as CPS.

➢ Smart City CPS shall treat Smart City as close loop system and not just the architecture data collecting and distributing among various digital services

➢ Instead of numerous applications, implementing a user-friendly platform for accumulating and data distribution can have major impact

➢ Just technology alone cannot transform any city into Smart City. Participation and involvement of human beings in managing and running Smart Cities is more important and essential and hence in developing any CPS human being behaviour and role should also be considered.

[5] Algorhythmic governance: Regulating the 'heartbeat' of a city using the Internet of Things by Claudio Coletta and Rob Kitchin (2017)

In this Paper, authors have discussed how the IOT infrastructure with its associated network of sensors and actuators can be used to regulate, measure and monitor the polymorphic temporal rhythms of urban city life. Authors have developed a concept of 'algorhythmic governance' by employing rhythmanalysis in conjunction with Miyazaki's notion of 'algorhythm' and nascent work on algorimic governance. Authors have also successfully demonstrated the concept of 'algorhythmic governance' through two case studies on Traffic Management System and Sound Monitoring and Modelling. Through this study and discussion authors analysis has revealed following

➢ Various distinct forms of algorhythmic governance

➢ Practical applications and working style of algorhythmic governance works in practice   and

➢ How Smart City technologies perform, computationally rhythmanalysis and undertake rhythm-making that intervenes in space-time processes

[6] Simulation Game as a Reference to Smart City Management by David Wiselia et al (2017)

In this paper authors have proposed simulating the Smart City aspects such as related to Citizen, Environment, Traffic, Welfare, Economy, Technology etc. and its associated problems in game fashion to make Smart City stakeholders aware of and understand the problem-solving techniques and solutions in efficient manner. Authors have discussed in detail the influence on the stakeholders from playing a game for City Management skills acquiring and better planning on what needs to be done first and in what order. Authors have claimed that by simulating real life practical problems associate in Smart City management and administration and providing relevant sandbox style of simulated solutions to tackle such problems can offer the game players i.e. Smart City stakeholders better skills, training and learning experience to handle similar kind of challenges in real life. Authors have successfully demonstrated how Smart City aspects can be simulated into game and it can positively influence the people playing this game to take appropriate actions for similar kind of situations in real life while managing the Smart Cities. Authors have concluded that simulation game can be used a successful teaching method by implementing problem and solutions of city management into a game and by allowing the player to solve it.

[7] Software Platforms for Smart Cities: Concepts, Requirements, Challenges, and a Unified Reference Architecture by Eduardo Felipe Zambom Santana et al (2017)

In this paper authors have surveyed the current research on software platforms for Smart Cities and tried to investigate the most relevant requirements to facilitate the development, integration, testing and deployment of Smart City Applications. Based on the analysis and investigations done to explore the highly reliable, effective and scalable Software Platform for efficient running of Software Applications/Services for Smart City, authors proposed a unified reference architecture supporting this prime objective. The paper has provided all the relevant information to help software developers and Smart City stakeholders to handle the non-functional and functional requirements to be fulfilled by software Platform for Smart Cities, classifying them into four categories: IoT, Big Data, Cyber-Physical Systems, and Cloud Computing.

[8] SMArc: A Proposal for a Smart, Semantic Middleware Architecture Focused on Smart City Energy Management BY Jesús Rodríguez-Molina et al (2013)

In this paper authors have argued that among other various functionalities of Smart City, improved energy management is also one of the important functionalities to be analyzed, monitored and fulfilled. To do so, authors feel that Smart Grid Energy management is the best suitable solution since it provides two-way information flow between consumer and provider and this mechanism can boost the energy management enhancement. However, authors also suggested that to use all the generated information effectively a middleware layer is also needed in the architecture which will be responsible for collection and distribution of data among various nodes. To meet this requirement, authors have proposed a Semantic Middleware Architecture named as SMArc. The SMArc layer basically takes care of any changes happens at lower layer of

architecture and insulates applications from complex metering facilities. Authors have also provided the computational and functional analyses to prove the successful functioning of SMArc. Authors have claimed that the SMArc layer can be easily integrated in a Smart Grid without need to be ported or adapted from other contexts.

[9] Securing Smart Cities Using Blockchain Technology by Kamanashis Biswas and Vallipuram Muthukkumarasamy (2016)

In this paper, authors have proposed a Blockchain technology-based security framework for Smart City Architecture to have a secure communication Platform. As the Smart City network is becoming more and more complicated where millions of IOT devices are supposed to be an integral part of Smart City architecture and going to generate huge messages for exchanging among various nodes, in such case safety and security aspects for data communication is an essential aspect to look after. The Blockchain Technology supports crypto currency and is basically peer to peer distributed ledger technology which can record any kind of transactions such as contracts, agreements, sales etc. and it doesn't need any intermediary. The benefit of Blockchain Technology as security framework is that an attacker can't penetrate the system unless 51% of the system is compromised, which is as good as impractical. Also, such penetration attempts can catch the attention of security measures the moment first access layer is compromised. Thus, using Blockchain technology to secure the Smart City Architecture can offer high secured robust security framework which is practically secured to deal with any kind of virtual attack. Authors have proposed security framework via four different layers i.e. Physical Layer, Communication Layer, Database Layer and Interface Layer. Authors have claimed that using Blockchain based security framework can create a common platform which can enable secure data communication in a Smart City and can offer multiple advantages including better fault tolerance capability, improved scalability, faster and efficient operation, better reliability etc.

[10] Video big data in smart city: Background construction and optimization for surveillance video processing by Ling Tian et al (2018)

In this paper authors have proposed new scheme for Video Compression based on block-level boundary matching (BBM) algorithm to support long-term reference structure for efficient surveillance video coding. As the Smart City Architecture is going to use more and more IOT enabled sensors for better surveillance and city administration, it is obvious that huge amount of text and video data is going to get generated and needs to be processed in time bound manner. As video data is bulky, if it is not compressed while transmission from one place to other can seriously pose data processing and data loss challenges. To deal with such issues, authors feels that better compression technique for Video Data is an essential requirement rather than just necessity. Authors have also developed a rate–distortion optimization for surveillance source (SRDO) algorithm to improve coding performance. Authors have further proposed to collaborate the BBM Video Compression technique with rate–distortion optimization for surveillance source (SRDO) algorithm (SRDO) for further improving the video compression performance. Authors have recommended using this newly developed BBM and SRDO algorithms in Video Compression for surveillance video data of Smart City and have also claimed that this technique would require less storage requirement for video data and can offer efficient video data processing for any video applications required in Smart City.

Table 2: Summary of reviewed papers

Paper	Summary
[1]	Agatha is a new Digital Service App for place history based activity prediction system which records users place visit history and recommends them the relevant offers, advertises as per their places of visits.
[2]	Smart City API based solution for data aggregation and reliable analysis for the data generated by various Smart City Services
[3]	Smart City definition considering two essential attributes : technology driven and living experience in urban places with new reality.
[4]	Smart City architecture correlated with Cyber Physical System. The data collected from Smart City Services would require robust CPS infrastructure for data processing and for adhering to strict standards of mobility, safety, security and data privacy.
[5]	The IOT infrastructure with its associated network of sensors and actuators can

	be used to regulate, measure and monitor the polymorphic temporal rhythms of Smart City life.
[6]	Simulation of various aspects of Smart City related related to Citizen, Environment, Traffic, Welfare, Economy, Technology etc. and its associated problems in game fashion can enhance Smart City administration staff's City Management, planning and problem solving skills.
[7]	IoT, Big Data, Cyber-Physical Systems, and Cloud Computing based Software Platform can easily facilitate Smart City stakeholders to handle all including the non-functional and functional requirements for Smart Cities.
[8]	Energy Management is an important functional requirement for any Smart City to fulfill. Authors have proposed a Semantic Middleware Architecture named as SMArc which basically takes care of any changes happens at lower layer of Smart Grid Management architecture and insulates applications from complex metering facilities.
[9]	Blockchain based security framework can create a common platform which can enable secure data communication in a Smart City and can offer multiple advantages including better fault tolerance capability, improved scalability, faster and efficient operation, better reliability etc.
[10]	BBM) and SRDO algorithms can offer better video compression techniques and would be very much useful for Smart City Video Surveillance data compression, transmission over internet and facilitates less storage requirement for video data and efficient video data processing for any video applications required in Smart City.

V. CONCLUSION

In today's world, Smart Cities are emerging as an essential requirement and solution to the problems faced by urban cities. Across the globe the population is growing and this growing population doesn't just need the basic essential infrastructure to support for living rather they are demanding better facilities to make their life more enjoyable and comfortable. Smart Cities with the help of latest technologies based on IT, ICT, IoT, Big Data, Block Chain, Cyber Security, Artificial Intelligence, Image Processing, Machine Learning etc. are able to provide the better facilities to their citizens and can offer smart services such as Smart Economy, Smart Mobility, Smart Environment, Smart Governance, Smart Living, Smart Parking, Smart Education, Smart Medicare etc. Such Smart Services are based on latest technologies and with the help of such services, Smart Cities ensure that their citizens not only just gets better facilities and comfortable life but also an opportunity to participate in running and managing Smart Cities as well give feedback on quality of services offered and improvements needed in Smart City facilities. It is clear that world wide Smart Cities are going to be established at larger scale and larger population is going to get benefited by the Smart Cities.

VI. FUTURE WORK

In present paper Smart City introduction is covered along with review of selected research papers. Due to time and space constraints, more literature available on Smart Cities could not be reviewed. In future, more research papers are needed to be reviewed to explore latest technology based solutions which are used in solving the problems faced by newly established Smart Cities. It is also necessary to analyze and categorize the solutions based on the technologies to understand which technology is being used more often in Smart City development, operation and maintenance. A separate research paper would be required to cover this topic in detail. This is considered as future work and would be undertaken in next stage of research.

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