# Cloud of Things (CoT) based Smart Cities

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***Abstract*—The promotion of IoT and cloud-based services are a part of the Smart Cities project in which real-world entities like smartphones, sensors, and RFIDs are utilized. In the present scenario, the two most important ICT models are Cloud computing and IoT that will be the major factors in reshaping the future of computers. Both of these components have a big influence on the deployment of smart cities and related applications. Cloud uses the Internet for rendering its services of providing resources over the Internet. On the other side, a new generation of devices that provide free services to the user on the network with a bunch of value-added add-ons is a discipline of IoT. This paper provides a descriptive view of the domain of smart cities implementation. The paper also tells about the smart city framework with an explanation of its working based on the Cloud of Things (CoT).**

***Keywords—cloud computing; IoT; cloud of things; smart cities; smart homes.***

## I. INTRODUCTION

The recent past has encountered some very eye-catching and exceptional enhancements and varied fresh opportunities in the field of Science and Technology. New dimensions have appeared in for the parts of the web- web3. The internet embedded devices have outnumbered the human population on the planet and are still peacefully growing with an assumption of hitting a 24 billion mark [1]. A lend of two giants IoT and Cloud Computing termed as the cloud of Things (CoT) has already started to spread. IoT has its roots in all important aspects of life which are known to all. Summarizing IoT, it simply means a bunch of gadgets fused together in a network that takes services by a backend situated cloud [2]. The other side of the table is Cloud which provides access to its offerings via "Pay-per-Use" policy in form of storage, processing, peripherals, etc. in a distributed environment with anywhere and anytime access [3]. Hence, it can be clearly identified as these two (Cloud and IoT), is the wheels of the future driven Internet, CoT. These can help each other grow and benefit from the capabilities of the counterpart. The research conducted tells about the benefits of the fusion of IoT and Cloud [4].

Accordingly, IoT can repay the favor by enabling Cloud in extending its real-world offerings by increasing its flexibility. The research [5] mentions several positive outcomes of combining Cloud and IoT and the compatibility of using IoT objects with Cloud. The Global Governments are inspired for the welfare of their citizens by the implementation of such technologies in schemes of "Smart Cities". The term Smart City describes the problem of uncontrolled population growth in urban jungles around the globe [6]. Likewise, various schemes and policies are included in smart cities some are illustrated in Fig. 1 [7]. The addresses of these applications can be linked to varied data and domains which lead to issues of interoperability, openness, convergence, etc. [8].

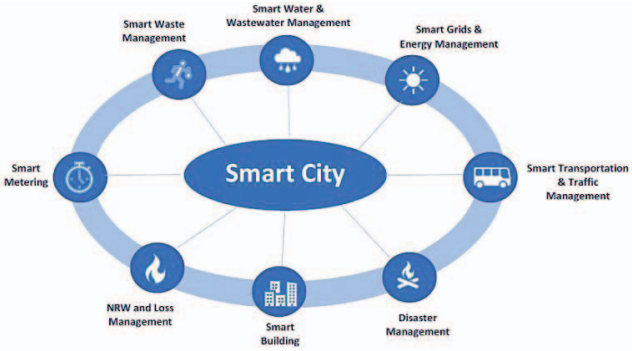



Fig. 1. Application areas of smart cities [7]

## II. LITERATURE REVIEW

A statement by the United Nations states that about two-thirds of the world population will be settled in urban areas by 2050, increasing their population densities to much more than their saturation rates [9].The development of goods, services, and infrastructure by then will not be able to meet the needs of the urban residents [10]. In such a situation the role that will be played by IoT will become unmatched due to its ability to allow objects to interconnect and to interact with humans in their service in a smart and effective way [11].The basic aim of IoT will be to measure, understand, analyses the residence of objects for the betterment of the environment. As per this, many communication science and objects will authorize IoT for its application [12]. Entities that can provide target focus points like Smartphones, related devices, objects like-appliances, monuments, and parks, heritage sites, cultural works, and art [13] will be embedded with IoT. One of the most essential features of IoT is its influence on human life [14]. Apache Storm introduced a scalable structure for home automation [15] and such scalability depends on local reasoning. A number of different designs for Smart-Cities have been introduced till now such as Vlacheas, Giaffreda [16] that purposes a framework for strengthening IoT for its deployment in Smart-Cities, another design-Sanchez, Munoz [17] talks of an experimental architecture of IoT viz. been currently implemented at Santander city, another design named as Lea and Blackstock [18] marks Smart-city as a network of IoT hubs. On the other

hand economic policies, pricing methods and their relationship with IoT along with communication and collection of data were studied by Loung et al. [19].Survey of Smart-Cities architecture was conducted by Da Siva et al while the security parameters were focused on by Ijaz et al [20]. Applications for specific smart cities (Logistic Mobile Application) were proposed by Bourgeois and El-Baz [21]. A brief about the global deployment of smart cities were lined by Pellicer et al. [22]. Another survey that tells about sensors and their use of semantics in the cloud for IoT to cut odd the separation between CoT and IoT was provided by Petroleo et al. [23]. A review of the Electric vehicle charging application was given by Shuai et al. [24] whereas Wang and Sng [25] presented an in-depth learning survey of algorithms that included video analytics too. The application of wireless sensor network was the work of Rashid and Rehmani [26]. The survey is highly diverse because of the data-centric view of the components of Smart Cities. A summary of the study of the data lifecycle for in Traffic Management System deployment in Smart City was given by Djahel et al [27].Various requirements of a Smart City have been briefly discussed by the author and a smart and organized generic reference of the framework for designing an urban Internet of Things has been revealed. The paper also presented an experimental study of PADOVA [28]. Services, Policies, Platforms, Connectivity models, IoT-Infrastructure and related aspects have been discussed by the author [29].The concept of a smart city in the form of a framework and all the important requirements are shown in Fig. 2 [30].

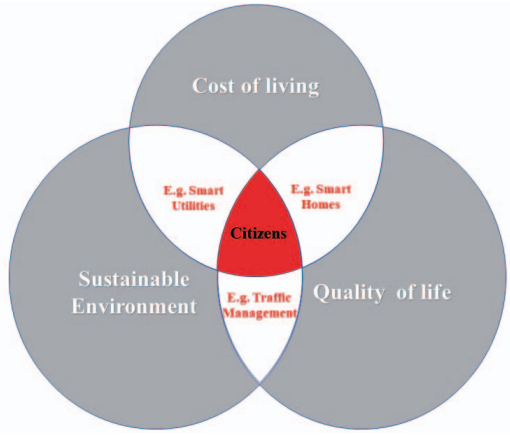



Fig. 2. Essential objects of smart city [30]

Cities can be made smart by the application of IoT and this level of smartness may be further increased by combining IoT with Cloud computing making a new computing paradigm that is CoT [4]. The author has dug deep into the evolution of smart cities and has made a detailed study on it in the last twenty years. Comparisons of smart cities with digital cities, their definitions, which could support all aspects of Performance evaluation a framework and city development strategy has been made [31]. A very clear and unambiguous plus a comprehensive and verified definition of Smart City has been presented by the author. The definition is based on studies of concepts and surveys related to Smart Cities around the globe. Along with it, discussions on various services that can be provided by the smart city has also included [32]. A framework for the design of Smart Cities which includes the utilization of IoT and Cloud along with design requirements have also been proposed in [33].

Table I presentssearch index weight for cloud computing, smart, homes, and smart cities per region of interest over Google [34]. It is notable that Malaysia and Australia are at the top for cloud computing, UK in smart homes and India in smart cities. Major advances in smart homes and cities in the forthcoming years are expected as the former technologies mature.

TABLE I. SEARCH INDEX WEIGHT FOR CLOUD COMPUTING, SMART, HOMES, AND SMART CITIES PER REGION OF INTEREST OVER THE GOOGLE

| Cloud Computing | | Smart Homes | | Smart Cities | |
|---|---|---|---|---|---|
| | Google search index | | Google search index | | Google search index |
| Malaysia | 19 | UK | 100 | India | 100 |
| Australia | 16 | USA | 41 | Spain | 41 |
| UK | 14 | | | UK | 11 |
| USA | 14 | | | USA | 7 |
| Canada | 11 | | | | |
| Indonesia | 8 | | | | |
| Germany | 8 | | | | |

## III. REQUIREMENTS OF SMART CITIES

The implementation of the majority of the smart cities is over a centralized model wherein, a very dense jungle of peripheral devices is deployed along the physical area having varied forms of data. It is then delivered for performing data storage and processing in a control station viacommunication technologies. Therefore, the capability of integration of varied technologies via an existing communication model thereby supporting the evolution of CoT is a must-have for CoT infrastructure. This capability of CoT leads to the realization of novel functionalities and services, as depicted in Fig. 3.

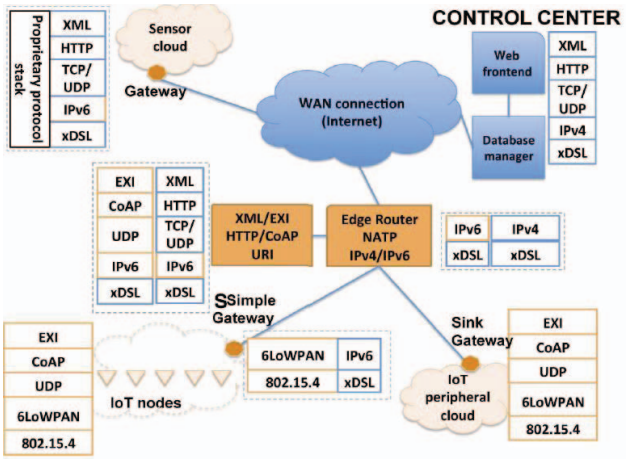



Fig. 3. Conceptual representation of a CoT based web service approach in smart cities

Support of heterogeneity of services, infrastructure, devices, platforms, and connectivity has been the requirement of technology supporting smart cities [1] [5]. Likewise, to provide us with a number of services is the most essential requirement of a smart city. For the resident of a smart city, services act as content providers [27]. This content has a decisive role in the preservation and optimal utilization of available resources and future policies of a smart city. Air quality monitoring, waste management, energy consumption, traffic congestion, monument, and heritage welfare, etc. are the common services of a smart city [4]. To manage hardware and transmission of data, we need IoT. Slice the volume of data to be transmitted and the density of devices involved in CoT, the management of this data and related services are a challenge. For serving this purpose, many infrastructures have been proposed having some set of advantages and disadvantages.The summary of the requirements of a smart city is shown in Table II.

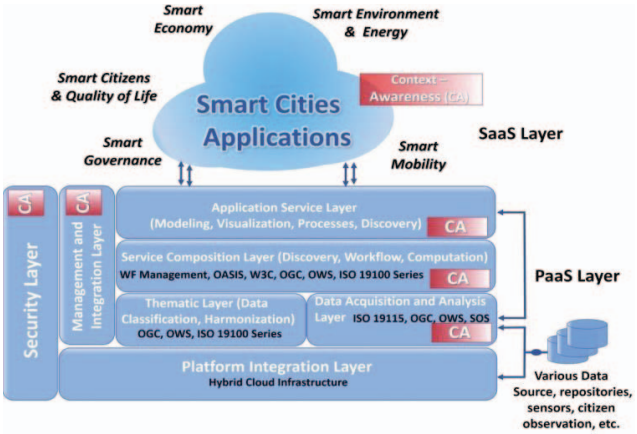
TABLE II. BASIC REQUIREMENTS OF SMART CITIES

| Requirements | Definitions | Variabilities / Variability Problems |
|---|---|---|
| Services | The beneficial contents that are provided to the receivers. | Variability: Waste, Air, Noise, Traffic, Energy, Parking, Historical |
| Platforms | The foundation that is establish, organize and manage the smart city components and services | Variability: Government, Enterprises, Business |
| IoT-Infrastructure | The way by which the hardware components and the transmitted data is being managed | Variability: Network, Cloud, Data |
| Devices | The type, operating system, machine language of the involved devices in the smart city infrastructure. | Variability: Sensors, Mobile, Data portals |
| Enabling Technologies | | Problems: Scalability, Privacy, Access, Testbeds |
| Connectivity Models | The way by which the devices and technologies are connected to each other | Variability: Ubiquitous, Autonomic |
| Connectivity Features | | Variability: Coverage, Reliability, Responsiveness |

Optimization of utilization and organization of available resources and data is a requirement of any CoT model. Three CoT infrastructures: cloud, data-centric and network are widely used for the implementation of the smart city [10].

## IV. PROPOSED ARCHITECTURE OF COT BASED SMART CITIES

CoT enables the Internet to work along with modern gadgets in harmony to generate optimum utilization of resources. Regarding this, all the required devices must be first connected to the Internet for the fulfillment of this purpose - for collection of data deployment of sensors, actuators, cloud, data science, communication technologies. The proposed architecture, shown in Fig. 4, has five horizontal and a couple of vertical layers. The generic data generation is carried out by Thematic, Data Acquisition and Analysis layer. This generic data can be altered according to smart city application needs in the top three layers of the design. In order to continually coordinate the vertical flow of data and to retain contextual information, context-aware components are placed at different layers of the architecture. Cross-platform accessibility of data is ensured by a hybrid cloud environment placed at the Platform integration layer. This is a representation of a cyber-infrastructure. Environmental data is accessed at the data acquisition layer from varied sources that include remote database repository, sensor nets, and citizens' observations. Necessary data organization, data cleaning and quality of data acquired is checked by this layer. A context-aware component filters out irrelevant data and performs a quality check of only related data. Data is distributed to specific applications by the thematic layer and it also carries out data organization and updates regarding data/service for future utilization. Workflow designs, identification of data sources, and link necessary processing are done by the composition layer.




In addition to this, analysis of workflow outputs, check on the source of data and pacific processes is carried out here which can help in expert analysis too. To utilize contextually related services for workflow composition ad information generation again a context-aware component is added in this layer. The application service layer enjoys services from the composition layer to perform contextual analysis for decision making using tools like simulations and visual maps. This layer supports the development of fresh applications at the SaaS level using existing tools to satisfy the needs of the end-user. Automation of the flow of filtered data and information in the horizontal layers is the function of the Management and Integration layer. It checks for the correct transmission of results between the layers. It is also responsible to tackle change management taking place at the various layers of the architecture and to reduce the amount of transmission to prevent data overhead in the layers. All the major aspects of security, naming a few- authentication, authorization, and auditing for the use of data and services is controlled by the security layer. It also ensures the security of individual profiles, personalization of the end-user for the required operations on information from a CoT infrastructure.

## V. CONCLUSION

There are numerous smart city designs that have been proposed based on different network architectures including different features. Each smart city application is based on certain architecture therefore issues like-interoperability, transparency and convergence arise. The ever-changing IoT environment regarding smart cities hence requires the adoption of new gadgets and technologies. Different Smart City designs provide different levels of services, interpretation, access, supported devices, user-friendliness, privacy, reliability, etc. The mechanism through which IoT and Cloud can be collaborated, that is the cloud of things used for the implementation of smart cities is the significance of this study.

A cloud-based framework for smart cities, the required component working for the correct optimization of the technology was covered in the paper.

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