A Survey of Security and Privacy Issues in IoT for Smart Cities

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Abstract*— Internet of things (IoT) is collection of smart objects that senses real environment and gives response instantly while connected to a network. IoT and smart cities are implemented in every field of life including home, offices, healthcare centers, agriculture, waste management, transport management and environmental monitoring to make them smart. There are many benefits of implementing IoT in real environment but it raises various issues and challenges including security, privacy and heterogeneous nature of objects. Further, there is not any common communication standard for this purpose. Many traditional approaches are proposed by researchers which do not address these issues completely in a real sense. In this paper, we have presented a survey of existing work focusing on security and privacy issues in applications of IoT in smart cities. Finally, a problem is formulated based on identified issues for our future work.

Keywords*— Smart cities; Internet of things (IoT); Security; Privacy; Critical analysis

I. INTRODUCTION

In the Internet of things (IoT), smart node, appliances, actuators, Smartphone, wearable devices are connected through internet in order to share information among all the nodes to generate results. Although IoT have many benefits but there are its security threats and drawbacks in real time applications to connect them and to secure reliable communication within a network through firewall considering mobility of smart objects. Quantum lifecycle management (QLM) is a standard providing standard interface to all the devices to enable secure communication and transfer data without any security threat which allows real time communication easier, secure and faster [1]. Traditional approach where bottom up technique is used to aggregate and implement is used for smart objects. In [2], author proposed top down Sensing and Actuation as a Service (SAaaS) approach for resources abstraction providing interface to access and communicate with other smart nodes. Author has emphasized on details and considered every aspect of system domain, problems and its solution. The approach is validated and implemented using mobile devices. In most of the existing work in applications of IoT in smart cities, security and privacy are not fully addressed. In this paper, a critical analysis of literature review in this area is done. Weaknesses of existing work are identified. Problem formulation is done for our future work.

Rest of the paper is structured as below. In section II, an introduction and importance IoT is presented. Issues in modeling of smart cities are addressed in section III. Related work is discussed in section IV. Problem for our future work is formulated in section V. Finally, conclusion and future work are given in section VI.

II. INTERNET OF THINGS

The interconnection of smart nodes with the internet in order to share data or to perform some action online is called IoT. IoT is a broad term any appliance or hardware which is connected to the network directly or indirectly in order to share information, communicate with other nodes or to perform some action. IoT is modern form of Wireless Sensor Networks (WSN) which sense data from real environment, interpret, process, and give some output. IoT is automating everything using RFID and WSN low cost hardware and storage capacity and to connect them to the internet. IoT gathers all the information generated by smart objects using internet. As Internet of Things (IoT) is an extension of Wireless Sensor Network and is connected to the physical world therefore it is necessary that smart objects should also be self-secured [3]. Dynamic techniques are used in this paper to provide security to smart objects in which no human interaction is needed rather smart objects secure themselves. All the ideas related to security and to maintain privacy are addressed in this paper.

IoT operations are of three types: data collection phase, transmission phase and utilization phase. Collection phase senses the data from real world and stores it into the database in the network for further processing. Its sensing range is short and covers a limited area. To overcome this problem we need more smart objects within a specific area to get accurate and reliable results. Transmission phase is second operation which sends collected data to the network or to other applications for further processing. In collection phase, useful data is gathered from a bulk of data to get meaningful results or to perform some action. Every device has to pass through these

operations to perform a task over the internet in the domain of IoT.

In [4], it is indicated that how Internet of Things will fit and behave into the existing domain while implemented in a smart environment. All the challenges and opportunities are described by considering socio-technical analysis which shows that how IoT can be developed and implemented into existing environment effectively. In IoT, the most challenging task is the interaction of smart objects with the network and to set communication standard of smart objects. This is called application layer of IoT. The work [5] presents App Execution Platform (AEP), a platform that supports the design, deployment, execution, and management of IoT applications in the domain of smart home, smart car, and smart city that supports dynamic object availability. In [6], authors have focused on availability of recourses based on Internet of Things paradigm including energy, electricity and compatible hardware. The main problem which is addressed in this paper is deployment of distributed applications in order to allocate resources.

In another work, authors proposed Consensus Protocol within distributed networks where all the resources are shared among network nodes homogeneously. This algorithm offers 5% error rate in real scenario that is why it is assumed better. To reduce energy usage Wireless Sensor Network needs secured source of communication. For this purpose multicasting is used in which data is sent from source to multiple destinations in the form of packets by using intermediate nodes at the same time [7]. Heuristic algorithm is used in this work to solve this problem which gives better response while compare to other existing algorithms. Web of Things (WOT) is an open standard for smart objects to connect the web via internet which effects human real life in every aspect of IoT and WOT which effects the human's life by interacting with humans through machines by communicating and sharing the information [8]. Social Web of Things (SWOT) extends IoT by interacting social networks with the smart objects which act as bridge between devices and humans to interact with each other. In this paper, IoT, WOT and SWOT architecture, structure, design, implementation, results and their challenges are described and their solution is proposed for future. In [9], author considered that how to manage all the data that is generated through IoT and smart objects. The management and mining of data to get useful information through making strategy for product is addressed by authors. Data generated through smart objects is used in the context to use for strategic decision making. On behalf of provided data an organization decides which kind of product they have to produce for maximizing their profit. Application development in IoT brings many challenges to the developers about what should be the hardware, where this smart device is to be implemented, what is the functionality of devices in complex environment, how this device will behave, what will be the outcomes, how a device behave within a network addressed [10]? Authors have provided a solution to define different concerns about smart hardware according to its functionality in heterogeneous network and support actions of stakeholder for an application framework. The quality of human life is another focus of IoT especially monitoring and caring of disable people. Authors addressed smart machines which behave like sensing, response, interpret, processing and storage of interpreted data [11]. In order to facilitate disable people a framework is proposed to design smart objects in the case of emergency by using cell phones technology to sense emergency and service oriented response for disable people that is cost effective, efficient and reliable. Author addressed that although IoT has many applications and uses but there are many limitations to smart devices that include limited memory, space, mobility, interaction, usage, implementation and response in the domain of internet of things. The work in [12] emphasizes on life logging system and presents lightweight framework to overcome all the problems of smart objects including energy problem. Traditional view of IoT to connect devices with the internet is overcome by new techniques in opportunistic IoT which represents the close relationship between smart nodes and humans [13]. Authors have addressed reference architecture for opportunistic mobile social networking, marketing, and service provision for the application of opportunistic in internet of things.

III. SMART CITIES

Smart cities are an integration of smart nodes that are interconnected in order to communicate with each other. Smart cities are a collection of smart homes, offices, transportation, waste management, power grid, buildings, etc. Smart cities depend upon the data that is generated from smart nodes within the network. These are implemented through cloud computing to interact with all management systems. Cloud computing model is a collection of different nodes that are interconnected at one place in order to share data, communication and to give a response which is efficient. Cloud computing model is efficient to smart grid for implementing and to providing robust, affordable and secure supply of power [14]. This is because in cloud computing resources are shared to all the network by standard and parallel processing is encouraged and secured. To facilitate reliable network cloud computing is considered better for smart grids. In this paper, architecture of both grid and cloud are described, their flaws, problems, challenges, security and privacy issues are addressed.

In [15], author explains the use of smart objects for interaction of real and digital environment by putting intelligence into everyday objects which results for development and benefit of society to create services by smart objects. From all perspective author have discussed challenges and provided its solution. In [16], all smart devices are connected with IPv4 to the network which may be hacked. Intrusion detection technique SVELTE is designed to reduce routing attacks in IPv4. It is assumed that its evaluation is 100% true positive with limited memory, energy and space.

In [17], smart community management is implemented through cloud computing to interact with society through participation, visibility and transparency to make social life smart. An emerging cloud computing ecosystem will be the

base for other smart components of smart cities as smart home, Offices and health centers. For a recycling center a smart dismantling monitoring system or smart trolley system have been developed in [18]. Every device is equipped with RFID to monitor where it resides and to know what it is doing. Every trolley is filled with useless hardware whenever a trolley get filled it is registered to End of Vehicles (ELV). According to the type of every device it is disposed according to the instructions stored in database displayed in workstation. This system is implemented in South Korea. It gives access to remote stations to dispose or dismantle hardware devices to monitor all the process online.

In [19], authors have emphasized on current situation of universities by analyzing their environment in order to make them smart. That is every components of university are computerized and automated to cope up with the emerging environment and to implement new technologies to make it smart facilitating students, teachers and all others where they can share the knowledge. In [20], by the use of smart technology energy demand greenhouse emissions and radiations are reduced. This paper emphasizes on emerging challenges of using smart objects methodology to analyze its lifecycle and to provide solutions. In [21], the use of Power Line Communication (PLC) for Smart Grid (SG) application is addressed including overview, characteristics, compatibility, usage, implementation and outcomes. PLC challenges and issues are addressed and its old and new solutions are presented. In [22], authors proposed an ARM-compliant IOT security framework and its application on smart buildings scenarios, integrating contextual data as fundamental component to control the building management and security behavior of indoor services effectively. Author has addressed the mobility of smart objects including traffic management, urban dynamics analysis, emergency management and m-health by analyzing them through semantic techniques [23]. To support smarter mobility all the issues and challenges related to the implementation of smart objects are highlighted in this work.

IV. ANALYSIS OF IOT BASED SMART CITIES

The interconnection of IOT and smart objects insures intelligence in hardware. A network composed of smart objects is easier to handle and interpret where there is no human interaction. There are many problems like interconnection different, heterogeneous objects and the generation of applications by beginners creating a problem. For that purpose, [24] presents three solutions: a Domain Specific Language capable of handling application creation problem; a graphic editor that creates interface to DSL and an IOT platform (Midgar) able interconnect many objects together. Using Midger an object can be registered, used, interpreted and generated as DSL model using graphical editor. In [25], a relationship between mobile robots and smart environment is addressed that mobile robots are subset of smart environment. A smart environment needs many appliances, energy, hardware, intelligence, equipment but mobile robots only needs a mobile to operate which minimizes energy usage and decreases the cost of smart nodes. Another work addresses a theoretical framework of qualitative business model analysis involving public actors and city government using IoT [26]. Mobile devices are used in smarter cities in which every indicator is assigned a value to evaluate smart cities performance. Another work [27] gives a detailed overview of IoT in terms of system architecture, enabling technologies, security and privacy issues, and present the integration of fog/edge computing and IoT applications. The relationship between fog/edge computing and IoT is investigated to discuss the issues and challenges faced by IoT in modern era. European commission hires many experts to develop a standard framework for IoT considering issues like legitimacy, transparency, accountability, anti-competitive behavior [28]. IoT is based on heterogeneous technology which is base of every smart technology innovation but there are some constraints to consider such as data confidentiality, privacy, authentication, privacy control, standard communication, flexible infrastructure. In [29], security and open issues related to IoT are addressed and their solution is proposed. Protection of data that is generated through smart nodes is important in IoT as there are heterogeneous networks in which all devices are of different types and there is no common standard to handle them. That becomes a challenge for IoT as described in [30]. For this purpose Model Based Security Toolkit is proposed as solution. That model is applied on smart cities to check their feasibility and working performance. IoT can be implemented through centralized or distributed architecture but this work [31] emphasis on distributed network in dynamic way. In this work, distributed architecture is elaborated in terms of security and privacy. In [32], authors have proposed Advanced Mete Infrastructure (AMI) that reads utility services usage, consuming rate and communicate with the monitoring devices and provides all related information through network.

AMI is becoming essential part of smart cities as it is necessary component of smart world ahead. AMI includes smart meters of gas, electricity, water in its architecture which provides a basic infrastructure for smart metering. The work [33] implements the Urban Bus Navigator (UBN) an IoT enabled navigation system into existing real environment to overcome all the problems of transportation system. UBN consists of two components: micro-navigation is a guidance for passenger's journey progress and crowd-aware route recommendation that predicts crowd on buses and recommends less crowded routes to passengers.

According to [34], Smart healthcare systems are helpful in the optimization of healthcare resources and cost-effective. The voice disorder detection system is proposed which works through patient's voice. The accuracy of this system 99.94% and for running speech is 99.75%. As in [35] the number of smart devices is increasing rapidly a large amount of data is also increasing so that it is difficult to find valuable data from bulk data. For this purpose batch processing and event processing is used but these approaches are not sufficient. Authors have proposed hut architecture approach which use historical data sets to do real time analysis. This is

implemented in transportation and energy management. IoT enabled waste management is a collection of waste by smart objects and disposal to an appropriate location.

This work [36] addresses ICT-enabled waste management models that focus on the adoption of smart devices as key enabling technology in waste management. Automated object detection algorithm covers many challenges of urban surveillance systems for IoT. In [37], smart vehicle license plate recognition (VLPR) and vehicle detection are recognized as core research issues of intelligent urban surveillance systems. The proposed model can help to detect object vehicles accurately, but also it reduces big data volume. It is expected that IoT will maintain the stability of future smart devices but there are many issues such as heterogeneity and unreliable nature of objects in complex environment. A cognitive management framework is proposed in [38] which is a preliminary proof of concept and represented in virtualized environment to overcome listed issues. The economics of IoT is discussed in [39] that have great impact on the development of IoT applications. Information economics approach is presented by authors including value and pricing of information. Game theoretical model is proposed to apply information economics on IoT for future implementations of IoT. In [40], authors have analyzed current communication mechanism and proposed future smart communication system named as Smart Ubiquitous Networks (SUN). This article has presented the framework with smart resource management to build smart and ubiquitous communication environment.

V. PROBLEM STATEMENT

There are a lot of issues that arises in smart cities when we use IoT to implement them. The main issues are security and privacy of data in a network but we identified many other issues including waste management, availability of resources, low energy consumption, compatibility of hardware, intrusion detection, routing attacks, limited memory, energy, homogenous nodes, reliable communication, bottom up implementation, cloud computing, robust, affordable, secure supply of power, data mining, management, locate a device, complex environment, storage of interpreted data, standard framework, mobility, interaction, quick response, intelligence in software and hardware, heterogonous objects, green house emissions and radiation, unexpected outcomes, data confidentiality, authentication, standard communication, flexible infrastructure and power consuming rate. We will propose solution to address few important issues as mentioned above focusing on security and privacy by using Formal Methods (FM) and Graph Theory. Formal Methods are mathematical representation of implementing a system or software by using some tools they are used to describe a system mathematically, analyzing its behavior and to address its issues and challenges. These are called formal that they have syntax, their semantics fall within one domain. Formal methods are used to ensure that your system is working well when a system is represented in mathematical form we got proof of its correctness using some tools that have predefined syntax, meaning, logics and compiler. We will use formal methods to gather all requirements of the system and to present these requirements formally and it ensures that the proposed specification is correct syntactically and semantically. Graph theory will be used to represent the given IoT based problem in the form of graphs and trees in order to store the information and solve it efficiently.

VI. CONCLUSION

Internet of Things (IoT) has created high expectations while implemented in smart cities but it raises many issues including security and privacy. We have analyzed such issues and their proposed solutions are identified in this paper. We will focus on solving these highlighted issues by using formal methods and graph theory. This is because formal methods are effective for safety and security critical systems whereas graph theory is useful for modeling any kind of networks. Graph theoretic algorithms will be useful in internet of things as IoT is a special type of network which is extension of wireless sensor and actor networks.

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