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Internet of Things for Smart City

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Abstract - *As a necessary domain in the technology, industry the **Internet of Things (IoT)** has became a topic of interest of many researchers. This recent technology has been spread over wide area in networking signals & systems, sensors etc. It takes advantages of updated technologies in sensors, modern electronics, networking etc. A very large number of people associated with various news, magazines, and journals are discussing the drastic growth in IoT and its probable results for various activities such as security, urban development, and privacy. IoT model is latest research topic that visualizes the near future in which there will be everything connected to the micro controller, sensors, actuators, variety of protocols. It allows interfacing of all these components and with the end user so that each end user can remain connected with the Internet. IoT basically focuses on interfacing and enabling various components with each other so that end user can get benefits out of them. The main objective is to define the generalized architecture for the design of IoT for metropolitan living along with the characteristics and services provided by IoT model for urban IoT. This makes use of the public capital and hence increases the level of the amenities provided to the people with low cost.*

Key Words: Internet of Things, Smart city, Challenges in Smart City, Architecture of Internet of Things.

1. INTRODUCTION

Increasing use of ***Internet of Things (IoT)*** gives assurance to change the way of life every one lives because of increasing IoT based devices for Smart Homes, Smart Watches etc. This recent trend of advancement ensures various benefits for elder people, people with disabilities by providing them new standard of life with improved quality at a reasonable cost and with minimal use of power. Although IoT is capable of changing the living standard of people, it has various issues that should be addressed properly to get added advantage.

A number of researchers observe the IoT as Huge revolution in the technology domain but other sees the IoT as Violators of privacy, security of consumers. Due to various hacking cases of IoT based systems there is a debate on the widespread use of IoT, this all makes IoT troublesome to recognize in real world. However Internet using society accepts IoT as it interfaces various offices, institutions connected also it takes care of their personal, social lives. On the contrary IoT have various challenges to be met across the globe.

In spite of such complicated situation IoT for urban development is remained topic of choice named as "Smart City". There is no official and universally accepted definition of IoT, it can be thought of as, and a microcontroller based system that interfaces various aspects of any particular city to ensure less number of resources so that better quality can be assured to the people at a reasonable cost.

A smart City concept based on IoT can bring various benefits in various domains such as lighting, waste management, traffic management and hence can assure a transparent society to the citizens by gathering large amount of data for analysis. Furthermore, it can spread awareness of people about their responsibilities towards city. It can cause active participation from citizens in maintaining the smart city model as well as inventing new services from IoT for development of city.

1.1 History

Due to multiple technologies such as present wireless communication, machine learning, embedded systems, sensors, and real-time analytics the vision of the Internet of Things has developed gradually (2016). It shows that the traditional fields of technology such as automation, wireless sensor networks, control systems, digital communication all participates in the evolution of Internet of Things.

The basic concept of smart devices as a network was discussed in early 1982, with a modified Coke machine at University. It becomes the first Internet-based device able to report its inventory and whether newly loaded drinks were cold or not. Mark Weiser's seminal 1991 paper on universal i.e. gradually increasing computing, the synchronous vision of IoT was produced by "The Computer of the 21st Century", as well as academic venues such as UbiComp and PerCom. The concept in IEEE Spectrum as "small packets of data to a large set of nodes, so as to integrate and automate everything from home appliances to entire factories" was described by Reza Raji in 1994. Several companies proposed solutions like Microsoft's at Work or Novell's NEST Between 1993 and 1996. Bill Joy visualizes the concept Device to Device (D2D) communication presented at the World Economic Forum at Davos in 1999.

Internet of Things became popular in 1999, through the Auto-ID Center at MIT and market-analysis publications. Kevin Ashton observed Radio-frequency identification (RFID) as a prerequisite for the Internet of things at that point. Ashton used to refer the phrase called as "Internet for Things." Meaning that all objects and

people living in the city can be equipped with computers, sensors, internet could manage them

2. LITERATURE SURVEY

Mark Weiser's made a statement in his influential paper in Scientific American in 1991 as "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it". There is a drastic change in people's daily life as well as in working environments in organizations after the arrival of IT technologies. This is become a well-known concept across many markets through IoT. To represent the future of sensing and communications, and its development The IoT is a technological revolution that depends on technical evolution in a variety of different domains, from wireless sensors networks to nanotechnology. The ability to code and track objects helped companies to become more efficient, increase their speeds, reduce error, and incorporate complex and flexible systems through IoT.

In 1999, the term "Internet of Things" (IoT) was first used by British technology pioneer Kevin Ashton to describe a system in which objects in the physical world could be connected to the Internet by sensors. Now-a-days IoT has become topic of interest due to its internet connectivity and computing capacity which can be used to enhance the performance of components such as various devices, sensors, actuators etc. Since the IoT is relatively new technology there is large probability of remaining the concepts such as networking to monitor the devices and sensors for a long time period.

In 1990, up gradations in wireless technology permit "machine–to–machine" (M2M) communication solutions for operating and monitoring the devices to become global. Older versions of M2M solutions were based on old technologies and were designed particularly to meet industrial standards rather than Internet Protocols (IP) and internet connectivity.

In 1990, the first "device" based on the Internet i.e. an IP–enabled toaster was developed having its boot operation based on internet, was presented at an Internet conference. After that over 16 years the other things were developed which were based on Internet Protocol (IP) soda machine, coffee pot at Carnegie mellon University and the Trojan Room at the University of Cambridge in the UK respectively. Due to such unusual developments and heavy research into the smart networking forms the base for latest Internet of Things (IoT). One of the most important and necessary goal of developing the internet of things at global level is to reconfigure the daily life. With the help of IoT the ability of person's interaction with the various device can be altered remotely depending upon requirements. The best example of IoT is S-Parking system [2]-[3].

3. SMART CITY CONCEPT

The smart city concept has estimated to be of billions of dollars by 2020 as per the pike research. It is a market based research that gives level of city based on cleanliness and other related factors. The smart city concept is upgrading over the different types of domains such as Smart Utilities, Smart Buildings, and Smart Environment etc. This domain is one of the standards that are considered in European countries to decide the criterion of their level of smartness of countries in the Europe.

In spite of having large number of merits, the smart city concept is not really accepted due to various factors such as politics, technical etc. as follows:

- **Political factors:**

As there are various parties, there is categorization of decision making rights to each of the team member hence it causes drawback to the developments of IoT systems. One of the possible ways to minimize this drawback is to divide the entire decision making procedure into a single, specific department in a particular city so that decision making can be done according to strategies.

- **Technical factors:**

One of the most important factors from technical side is non-cooperative working environment for various technologies currently being used for development of cities. IoT can be used to co-ordinate all these activities so that, pre-emptive working can be achieved.

- **Financial Factors:**

It is generally a last factor, dealing with improper business model causing threats to the development of IoT systems. Also a Global economic situation such as recession heavily affects the systems and hence makes them difficult for becoming realistic in physical world.

3.1 Smart City Services

There are various categories of services offered by urban IoT model which increases quality of services provided to citizen of any particular city. These services also reduce the cost of quality services. These services are as follows

- **Structural monitoring of Buildings:**

Ancient structures need to be maintained well. This maintenance requires testing of impact on whole area and hence continuous monitoring of areas subjecting to more impact external entities. IoT based system can provide complete information about the stresses acting on building so that proper monitoring can be done for maintenance of building. This complete information about stresses minimizes the need of continuous human intervention.

- **Traffic overcrowding**

Now-a-days many cities have camera surveillance on the traffic issues but it is not proving to be an effective solution. To provide a strong source of monitoring and information low-power and wide range mode of communication is required. By using various available

sensors, protocols and GPS based systems various issues related to traffic can be addressed. This system can solve the problems of people.

- **Garbage Management**

Due to lack of enough space for the storage of garbage in many cities causes various diseases. The cost of proper management and maintenance of garbage is comparatively high, hence it is becoming an essential issue to be addressed by IoT. IoT can be proven very economic as well as eco-friendly solution for such problems. The IoT based solutions may contain smart water storage solutions; it can indicate the level and hence can be useful for optimization of water usage, cost minimization. To make all things real IoT has to connect the end entities such as smart garbage collectors so that proper utilization of the resources can be achieved.

- **Purity of Air**

An IoT can also be useful to detect the level of impurities in air in crowded parts of the city, parks, and other public places. IoT can also provide medium of communication to the joggers. Hence by using IoT, people can opt healthiest way for their activities and can remain connected to their initial location. This requires various pollution sensors and air quality sensors and hence IoT can provide healthiest air to the citizens.

- **Monitoring of unwanted quantities (Noise)**

Noise is acoustic pollution for air. Various authorities in cities have issued several laws regarding the factors generating noise in particular hours. An IoT for noise monitoring can be used for complete monitoring of amount and factors causing noise in a specific time given by designer.

- **Energy Consumption Issues**

IoT also provides a service for monitoring a energy consumption of a particular city for a specified time period. Because of monitoring of energy, citizens of a city can predict the requirement of energy for the whole city for various operations such as lights. In short, an IoT based system can be used to predict the overall power consumption of a city.

- **Parking using IoT**

IoT also provides solution for management of traffic in modern cities. IoT uses road sensors for managing traffic. One of the most important advantages of this service is faster allocation of space for car and hence less harmful emissions. , less traffic congestion can be observed by deploying this service. This service can be integrated into the modern city infrastructure.

- **Lighting using IoT**

This service basically deals with reduction of power consumption by managing intensity of light especially street lights according to the time of the day number of people in particular area and whether. This system can also connect homes to WiFi so that interconnected network can be increased.

- **Automation of public Buildings**

Another important service provided by IoT is the complete automation of the Buildings (government offices, schools, hospitals etc.) using various types of sensors such as temperature sensors, humidity sensors. By monitoring all these parameters it is possible to give quality services to the people living in such buildings.

4. URBAN IoT ARCHITECTURE

As described earlier all the services provided by IoT requires distributed architecture where different set of devices performs the action of data collection which can be delivered to a central location where it is processed as per the requirements. There are various characteristics of the IoT which are abilities of IoT to integrate different technologies by seeking their merits to support particular service and its easy access to the citizen so that they can make use of quality services and hence evolution of IoT can be achieved and social awareness can be spread by using IoT.

Different components of IoT are described in this chapter. Fig.1 shows the various components of IoT. There are various approaches to describe the IoT. First we will discuss with the web service approach which requires different protocols to be deployed at different parts of the network as shown in the Fig -1. Secondly we will discuss link layer technologies which are used to connect different elements of the IoT. Lastly we will discuss the set of devices which forms the basic IoT.

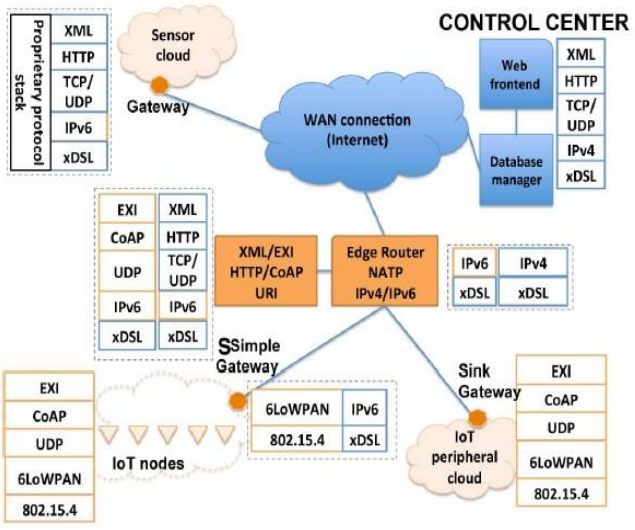

Fig -1: Conceptual representation of an urban IoT network based on the web Service approach [1]

- **Web Service Approach**

There are various standards which are trying to be the official one. We will discuss the Internet Engineering Task Force (IETF) standard as it is open and based on internet practices and used over wide range of community. IETF standard holds the complete web service approach which

is used widely for literatures and it is flexible too. Basically web services approach allows realizing the basic fundamental and flexible IoT architecture for IoT nodes though Representational State Transfer (ReST).

IoT services provided with the ReST are very close to the services provided by traditional IoT model hence becomes advantageous to both i.e. end users as well as developers and hence allows reuse of information provided by IoT.

Web services approach is also encouraged by various standardization bodies such as IETF, ETSI, W3C as well as IoT-A, SmartSantander

Reference protocol architecture for the IoT for Smart City is shown in the Fig -2. That contains both an unconstrained and constrained protocols as shown. The first consists of the protocols that are commonly used by regular Internet hosts, such as XML, HTTP, and IPv4. These protocols are represented as the constrained protocol stack by their low complexity forms which are the Efficient XML Interchange (EXI), the Constrained Application Protocol (CoAP), and 6LoWPAN, which give services to the constrained devices. The conversion of unconstrained and constrained protocols shown in the Fig -2 is done in low complexity and standard way. As a result of that easy access to the IoT nodes becomes possible. The systems that do not considers the EXI/CoAP/6LoWPAN protocol stack can also be included in the Smart City IoT system but the condition is that they should provide interfacing with all the layers of protocol shown in the Fig -2.

The protocol layers shown in the Fig -2 can be categorized into three functional layers which are (i) Data, (ii) Application/ Transport, and (iii) Network, these functional layers requires special entities for intermediate conversions. In the next part we will discuss these three functional layers and their roles at different points of the IoT system.

4.1 Data Format

The requirements specified by the IoT are in the form of data access. In this approach data transfer is typically done by the languages, from which the eXtensible Markup Language (XML) is most widely used language. The size of the XML message is generally large .The text nature of XML use CPU operated devices for parsing which is complicated than binary formats. Because of this problems the World Wide Web Consortium (W3C) has initiate the EXI format(Efficient XML Interchange),by which constrained devices can also interface with and can generate message which are supported by XML.

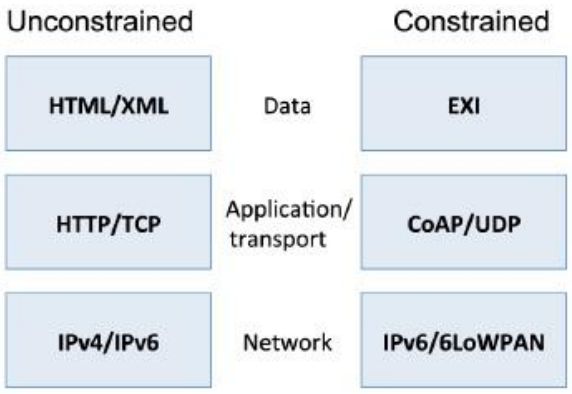

Fig -2: Protocol stacks for unconstrained (left) and constrained (right) IoT nodes. [1]

EXI has two categories of encoding which are schema-less and schema-informed. Schema-less encoding generates directly from XML and decoded by any EXI entity without prior information about the data whereas on the other hand schema-informed encoding considers two EXI processes which share same XML schema before actual operation starts.

4.2 Applications and Transport Layers

Most of the traffic through the internet uses the application layer formed by HTTP (Hypertext Transfer Protocol) rather than TCP. Since the HTTP requires more words for its messages, it becomes complex and hence becomes less suitable for IoT devices. Hence for these reasons human readable formats of HTTP are used. It can be one of the limiting factor due to large amount of redundant data. HTTP basically depends on TCP (Transfer Control Protocol) which is not suited for scaling of constrained devices and hence gives bad performance along with noise. These difficulties are minimized by CoAP (Constrained Application Protocol) by initializing binary format over UDP (User Datagram Protocol) as it adjusts the transmissions and retransmissions which are mandatory to provide reliable service. Moreover, CoAP can be easily used with the HTTP because of following:

- It gives the Representational state transfer methods of HTTP,
- There is proper compatibility between these two protocols.
- Various modes of CoAP support the HTTP.

4.3 Network Layer

Internet Protocol Version 4 (IPv4) is the fourth revision of the IP and a widely used protocol in data communication over different kinds of networks. IPv4 is a connectionless protocol used in packet-switched layer networks, such as Ethernet. IPv4 is widely used protocol supported by

internet. IPv4 has exhaustion of nodes and IoT networks require billions of nodes to be incorporated together. This problem can be solved y using IPv6. IPv6 gives 128-bit address and hence it is possible to assign unique address to any node from billions of nodes in the IoT network.

As IPv6 resolves the problems of addressing each node from huge network but on the other hand it is not possible with the IPv6 to meet all the capabilities of constrained nodes. To solve this problem 6LooWPAN is used. Basically 6LoWPAN is the compressed version of IPv6. The conversion between IPv6 and 6LoWPAN is performed by a border router by transferring a IPv6 packet to the particular 6LoWPAN header format and replica of this operation for opposite reverse direction. Border router is only solving the problem of IPv6 but the issue of addressing of IPv6 using IPv4 remains as it is. To resolve this problem there are different approaches which are discussed below.

- **v4/v6 Port Address Translation (v4/v6 PAT)**

This technique basically allocates the random pair of IPv4 addresses to the IPv6 addresses and similarly TCP and UDP ports to the corresponding TCP/UDP ports. This technique also provides internet access to the different hosts by sharing common IPv4 address. This same technique can be used for multiple mapping of IPv6 addresses into a single IPv4 address. But this gives rise to scalability problems as multiple mapping of addresses into a single IPv4 address.

- **v4/v6 Domain Name Conversion**

This method allows more than one website to run on a single server which shares the same IPv4 address. This method also provides services related to DNS (Domain Name System) servers The DNS helps to make cross proxy of nodes to be connected to the single IoT node by returning the IPv4 address.

- **URI mapping**

This technique is URI mapping technique i.e. Universal Resource Identifier technique. This technique is basically used for the reverse cross proxy. This cross proxy acts as being a final server to the client device and acts as a original client to the server. The purpose of IPv6 protocol is to provide direct access to the end nodes of IoT.

A. Link Layer Technologies

As the extent of the IoT is increasing with faster rate and hence for large are, IoT requires various Link layer technologies to cover large geographical area required for set up of IoT model. Due to link layer technologies various small data flows can be managed for wide spread areas. Link layer technologies are divided into two types which are unconstrained and constrained technologies.

Unconstrained technologies have high reliability, high throughput capability, support for high data rates. Unconstrained link layer technologies includes basic network topologies such as LAN, MAN, WAN, Ethernet, WiFi, Cellular technologies etc. Due to complex nature and power consumption these technologies are not well suited for IoT nodes.

Constrained link layer technologies have low energy and power consumption but they provide low data rates. Constrained link layer technologies includes IEEE 802.15.4 Bluetooth, IEEE802.11.These technologies have higher latencies as compared to that of unconstrained technologies because first, low transmission rate at physical layer and second, these technologies provides power saving modes so that power can be used optimally.

B. Devices

IoT requires various types of devices for their deployments and they resides at the different locations in the whole IoT network. In this section we will discuss the various devices and their relative positions in the complete IoT network.

- **Backend Servers**

Backend servers are not necessary for the IoT based systems for their operation but still these servers acts as basic building block of IoT as they can provide easy access to the services provided by IoT. Backend servers are positioned in the control center where the basic data manipulation operation such as collection, storage and processing of data takes place.

Backend servers are used for interfacing of data with the following systems.

- **Database management systems:**

These systems stores large amount of data collected by the various sensors for the IoT system. Depending on the type of the data various categories of data can be made for easy access of information.

- **Web sites:**

Web site is basically a collection of different web pages including multimedia content can be identified by using domain name.web sites can be used to spread huge amount of information to the various parts of globe.

- **Enterprise resource planning systems:**

Enterprise recourse planning system is basically used to manage the course of information in the complex systems. Incorporating the ERP system with the database management system allows organizing the large amount of data collected by IoT and hence new services can be initialized.

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4.4 Gateways

Gateways are located at the boundary of the basic IoT system. They are used to connect end user devices to the core infrastructure of the IoT model. As shown in the fig.2 gateways are required for conversion of protocols and mapping of them according to the requirements of the system.

As the protocol conversion is necessary for the proper interaction among the different protocols it is not mandatory to use a single gateway for entire conversion. A set of distributed gateways can also be used for protocol conversion. Gateways are also used to provide mode of interconnection among the various unconstrained and constrained link layer technologies.

4.4 IoT Peripheral Nodes

There are devices positioned at the boundary of the IoT architecture which generates the data that is to be delivered to the control center for further processing, these devices are known as IoT peripheral nodes. The initial expenses for these devices are very less, but it can vary depending upon type of the device. These nodes can be categorized based on various factors such as sensors, actuators used, power modes technologies used etc.

Portable devices such as cell phones, laptops etc. can acts as very important sections of the IoT system as they use internet for almost all the activities for which they are designed. These portable devices can have access to the IoT in different ways hence it is possible to invent new services using such portable devices for the particular IoT system.

5. CONCLUSION

In this paper, the analysis of the uses of IoT its advantages, disadvantages have been discussed in detail. Also the Internet of Things architecture for smart city is discussed with the consideration of each and every component. Also stated that there are small number of protocols are present for such a huge and wide-spreading concept. The discussions on the services that are provided by IoT have been given.

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