An Introduction to Cognitive Internet of Things: New Perspective of IoT

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***Abstract* — The current trends in information technology have resulted in the need for managing the data in case of applications involving massive data entities. While IoT provides an environment for observing the objects and their properties, sharing that data between the other entities of the network it does not have the intelligence of its own so that the data can be processed and decisions can be made at that stage. Cognitive IoT is introduced which makes the entities to observe the behavior, learn from that aspects seen, undergo the thinking process and then understand the severity of the decision made before incorporating it. The proposed work provides an insight into the several aspects of CIoT, architectural framework and the current trending research issues.**

Keywords – Internet of things, Cognitive IoT, Observe, Orient, Decide, Act, Intelligent systems.

I. INTRODUCTION

In the fast growing era of telecommunication technology, Internet and its usage has seen a fast and constant progression over time. The basic internet versions started with World Wide Web as a collection of html pages, further leading to Web 2.0 and Web 3.0 with much advanced features. The network which started as a mere static html page went on to support the characteristic features of user participation and interaction with the system, social networking services thereby enabling global business issues. Bringing in communication between the peer networks further necessitated the machines making up the network to behave in a more understandable and intelligent manner which led to the use of semantic web. The applications of today are such that they need very less human intervention with the machine being able to process, share and access the data in its own accord. Internet of Things (IoT) is all about building up a network of well-equipped components which are capable of identifying or sensing the data source, communicating it across the network and processing it. IoT has evolved over a period of time where the initial set up included sensor networks, near field communication techniques for communicating with each other. But the current day scenario requires minimal devices and usage of existing technologies. The development of IoT was very much required because of the growing technological needs and expanding networks. The devices constituting the network are used for storing or processing activities and these devices are made accessible in the network by making them active components of the network. IoT in general terms is a collection of well-structured hardware devices, software and components making up the architecture. The hardware devices include personal computers, laptops, servers, desktops and very recently smart phones also. The features of IoT which have made it an emerging field in information technology are its permeating computing support for global network, bringing in context-awareness between the devices and providing an ambient environment for intelligent working of the devices. IoT makes sure that all devices in the network communicate and collaborate with each other based on the status of data that is currently getting transmitted between the devices. The categorization of IoT is based on the very basic constraints like the underlying technology, applications working on or the applications which are using IoT as the fundamental core platform, challenges related to security and privacy and in the implementation of business models. It is all about ―identification, sensing and communication technologies with a vision of anytime, anywhere and any media‖ [2] but the data that is getting communicate is not foreseen and lacks the major decision making characteristic which is an elementary requirement of smart environment, health care and other social applications [3]. The necessitated the introduction of new IoT called as Cognitive IoT (CIoT) for the purpose of greater improvements in performance and bringing in intelligence among the devices of the network. CIoT is specifically used for communication purpose, provided cognitive capability is brought about in each of the end devices being a part of the network. This in turn improves both the computing and communicating capabilities of the network. CIoT is also termed as Brain – empowered Computing [4].

The introduction of IoT was way back in 1999 [5] and it went on to grab attention in very significant applications of which academics and industry are the prominent ones. IoT is defined as the network where both physical and virtual things are interconnected and perform the functionalities similar to that of agents with very less or negligible human intervention. The reason for this is that the devices in the network follow the context – aware, perception – action cycle [6], understanding the current network scenarios, store it based on the semantic knowledge. The decisions are made by employing the resource – efficient decision making mechanism and finally adapting themselves to the alterations coming up each day. CIoT aims at an opportunistic and intellectual usage of resources available in the network. In our work we present a brief introduction to CIoT along with its fundamental framework. Understanding the framework is necessary for the software engineers as it provides a vital platform for the development of several emerging applications.

The organization of the report is as follows: Section II covers the basics of CIoT along with its structure and features. Section III gives a detailed overview of the application trends of CIoT. The research issues associated with CIoT are discussed in Section IV followed by Conclusion in Section V.

II. COGNITIVE IOT

With the introduction of the word cognition by Joseph Mitola in 1999, the primary concern was to exploit the scarce radio frequencies that were used in a cooperative manner. When the cooperative behavior was further required in improving the network performance by making the components of the network more interactive and intelligent led to the eventual use of cognitive IoT. CIoTs are capable of apperceive the current network status, analyze the network behavior and traits based on the sensed knowledge and perform suitable actions in response to the observation made with the only aim of increasing the performance metrics of the network. But this is not a simple process as the entities making up the network are diversified in nature working towards various domains and to improvise this multi - domain cooperation approach is used. This facilitates in a very quick integration of things across the domains in the network.

The major reason for the introduction of CIoT is to avoid human intervention to the least possible extent by incorporating the cognition process. The network is enhanced by the combination of human level intelligence and system design. Each of the devices composing the network are deployed with sensor nodes in a very agile and efficient manner and with very minimal power consumption. Cognition is necessary to bring in a uniform resource utilization in the network to make sure that all the available resources are homogeneously distributed over all the devices sharing the network. We analyze IoT as the logical arrangement of layers to bring in a coordinated communication. The layers are typically termed as sensing layer, network layer and application layer. Sensing layer is the hardware part of it which is capable of getting configured with respect to the changing software versions it is linked with. Network layer is responsible for providing an integrated social platform. Finally application layer presents with different interaction techniques that takes place between the devices or things making up the network.

The generic architecture of CIoT can be understood in terms of three hypothetical layers namely core and basis of internet, connectivity between the things and lastly the flow of business process. CIoT network is formed by identifying the entities making up the network and grouping them as domains. Each entity grouped in this manner is dependent and loosely coupled with each other. The entities in the network are considered as nodes with transmitting and receiving features accompanied with RFID and GPS, infrared and other type of sensors. Internet is the core requirement of the CIoT without which the concept of data transmission is not happening. The data collected over the entire network is raw data that is to be processed and has no cognitive capability. This data has to be further transmitted to the Server domains where special routines are used for processing. In a majority of cases these server domains act as the intelligent agents or intelligent control terminals. CIoT integrates the human cognition to the system design. The entire network is composed of access router which behaves similar to access points in sensor networks, wireless router for the wireless data transmission and transmission router for data transfer across the network. we can see the presence of cognitive nodes which are self - governing in nature and works towards the best possible scenarios to improve the performance of the network.

CIoT does not follow any standardized underlying architecture but for the convenience of the users CIoT is composed of three planes namely protocol plane, cognitive plane and adjusting plane.

A. Protocol plane

The protocol plane is very much similar to the traditional OSI model with sub layers like Information Perception Layer (IPL), Near Field Interconnection Layer (NFIL) , Network Access Layer (NAL), Network layer (NL) and other layers which are necessary for enabling communication in the network. While the information perception layer aims at gathering of information from different sources, the NFIL manages the transmission and reception of data among the source and destination. The data transmitted over the network is not always of the form of textual data, it can also be a video or an audio. The access to data irrespective of its format must happen the same manner as it carried out the textual message transfer. NAL provides with such a uniform access support.

B. Cognitive plane

The main aim of the cognitive plane is to analyze the network conditions and take up decisions based on the analysis made. The entire cognitive cycle works on the observe - orient - decide - act concept where the nodes first observe the behavior of the nodes, sense the data, collect the data which is not yet processed. The data collected has to be processed before transmitting it and the processing is done by employing the data fusion techniques along with consulting the knowledge database. The status of the fused data decides what action is the be performed next and this becomes the vital characteristic in deciding the nature and behavior of the network. The decision made leads to carrying out the correlated action in the network. In case of CIoT, each entity is programmed to work on the basis of OODA cycle to avoid human intervention to the maximum possible extent.

C. Control plane

The functionality of the control panel is very much similar to that of the application layer where more importance is given to the interaction methodologies that is made available by the system. If any changes are to be brought into the system with respect to the underlying protocols, protocol related parameters, modifications in the logical connectivity of the system, or if in case any protocol has to be reinstated then we use the control panel.

III. APPLICATIONS OF CIOT

The cognitive networks are known for their optimized usage of scare resources because of which they have a very diversified collection of applications including a wide range of devices, networks and embedded technologies. The applications range from medical field, transportation, resource management in huge firms, cellular networks, utility distribution and many other prominent applications where minimal human intervention is required. Some of the real time applications of CIoT have been discussed here:

A. Ready mixed Concrete Transport and Dispatching System

RmCTDS [7] is a system to prepare mixed concrete and then ship it to other places. The preparation of the special building material requires the basic stuff like raw materials, combination ratio based on which they have to be mixed, production flow of the mixed material and its validity because the prepared item has to used with in specific time limits. The complete cycle of events start from the supply of raw materials like sand, gravel, bricks etc to the end points of the system like construction sites, bridges and roads under repair. RmCTDS facilitates in transporting and dispatching the ready concrete to the transport vehicle which maintains the sketch of the entire route i.e. to be transmitted for dispatching the concrete. The transport vehicle must always select an optimal path and make sure that all the destinations are reached in the given span of time. But this is not an easy task as it involves as the traffic and time limits as the real time constraints which have to be taken into consideration. So based on the current status of the source and destination the system incorporates the RMT technique with supported RFID, digital scale reader and travel parameters into account to decide the next destination to be reached and the possible optimal path that can be chosen. The entire system is closely coupled with the GPRS system.

B. Enabling smart cities through a cognitive management framework for IoT

Internet and communication plays a very significant role in the current era of information technology [8]. We often see that a system that is composed of well connected components, performs better than compared to the system of independent components. But not always the connected objects behave in the expected manner because of their diversified backgrounds. Also when the objects are used across several domains, there is a high probability of the object loosing the its identity because of the diversification. To overcome all these issues a cognitive framework for IoT is used which forms a layout like structure supporting all the dynamic traits according to the real world requirements. This further provided a platform for the construction of a smart city and presenting a virtualized environment. The system provided service - level functionality as required by the end users.

C. *Virtualization and Cognitive Management of Real World Objects in the Internet of Things*

This wok proposed by Dimitris Kelaidonis et.al. [9] introduced a virtual framework for identification of real world objects and the management of their virtual components. To bring in a link between the virtual environment and physical objects, the cognitive management is performed such that it enables dynamic creation of smart cities. The virtualization is managed by dividing the existing functionality into modular levels such that the activities of self - learning are incorporated into the system. The framework provides different levels of abstractions so that the system is made reliable and providing all the facilities to the diversified class of stake holders.

IV. RESEARCH ISSUES

CIoT is an emerging technology which can be combined with several other domains such that its functional areas can be expanded not only for technical but social applications also. The major research issues concentrate on the data consolidation as it has the major impact on the decisions made in the network. The data gathered at each of the entity collectively becomes a enormous set of data with heterogeneous characteristics. The complexity of the data is such that it is not separable on the non - linear basis.

The protocols followed for communication between the nodes also has its impact on the type of decisions made i.e. whether it is real time or non - real time in nature, with or without dynamic parameters. Example for such scenarios is the game model system. In gaming applications, the players have to come up with strategies based on the current status of the game, and it is not easy to take decision right when the game is going on as the players would be totally unaware of what the applied strategy would result in. CIoT offers a knowledge - assisted learning technique using which the strategies can be best taken care of and improvement in performance can be identified on a gradual basis.

We are already aware that the data gathered at the sensing stage is the raw data which needs processing, but not all the sensed data is processed. The use of knowledge discovery techniques to identify the semantically related data for further processing. Identification of the knowledge discovery technique that is suitable for the application is the elementary task of researcher. CIoT provides an abstraction that is bridging the gap between the theoretical environment to the practical environment such that the network is made suitable for both generic and specific applications.

The legal framework taken care by the government regarding the CIoT licensing and other issues are not strictly regulated and requires a lot of policing to be done. Also CIoT is not feasible enough for military, defense, literature and business models. The major networking issues that would arise in a CIoT network are the cooperative authentication issues, detection of unreliable nodes, intrusion detection in case of malicious nodes, issues associated to hidden access policies [10].

V. CONCLUSION

The introduction of CIoT in information technology has marked the beginning of a new network archetype with

the primary functionality of balancing the gap between hypothetical and the real world concepts. The main aim of CIoT is to incorporate an intelligent system which avoids the intervention of outside entities with the ability to learn think and understand. The paper presents the transition from IoT to CIoT, highlighting the features of CIoT which have made it useful in a large scale. The architectural framework of CIoT provides the design guidelines for diversified applications. The research problems discussed present the researchers with challenging issues.

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