Journal of ELECTRICAL ENGINEERING, VOL 71 (2020), NO2, 131–137

sciendo

REVIEW–LETTER-REPORT

Cognitive solution for IoT communication technologies – emphasis on 5G

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The 5G cellular network technology, in collaboration with Internet of Things (IoT), is envisaged to connect the world together through a flawless Internet connection between devices and sensors. The things in IoT term can be of any smart devices or Internet-enabled sensors that can share information in order to perform a task collectively or individually. On the other hand, Cognitive Internet of Things plays a vital role in utilizing available spectrum for 5G networks. Addition of cognitive feature to the things can allow decision making capability, thereby reducing the overall traffic congestion and improving the efficiency of the whole IoT system. Therefore, it is of great concern to develop an intelligent network to address a few challenges such as heterogeneity and volume of devices in 5G. The aim of this article is to provide a critical review of existing IoT communication Technologies and highlight several challenges and their potential solutions associated with Cognitive IoT based 5G networks.

K e y w o r d s: internet of things (IoT), cognitive radio, 5G networks

1 Introduction

The Internet of Things (IoT) paradigm is foreseen to be connecting the physical devices and everyday objects through the Internet, that can communicate and interact with one another to share information, and that can be controlled and monitored remotely. With faster data rates enabled by 5G cellular network, the number of users is predicted to have an exponential growth, nearly 46 billion smart devices by 2020 [1]. Cognitive feature added to this Internet of Things can significantly improve the network performance in contrast to the traditional Internet of Things. Cognition can simply refer to thinking. Hence, Cognitive Internet of Things can relate to things that has the ability to think. While these things are not yet capable of general human-like thoughts, it is seen that they can perform some of the same underlying functions that can be perceived as thinking.

IoT allows communication between heterogeneous devices without human intervention. Business organizations can see the Internet of things as an opportunity to increase the efficiency of their organization by improving decision making capability, with better knowledge of the customer behavior. IoT applications in real-world span numerous verticals, including Enterprise IoT to Consumer IoT and to Industrial IoT (IioT). Smart homes with smart appliances connected through Internet is the most prominent example of Consumer IoT. The devices can be controlled remotely via smart phones within the vicinity or far from the location, through Internet. Wearable devices with sensors can collect and analyze user data, and share information through Internet in order to improve consumer satisfaction. IoT incorporating with 5G, having faster data rate and higher throughput, can enable connecting patients and doctors in remote areas through video call. However, most of the IoT devices are battery powered, which imposes a very big challenge on durability of the devices. Also, these devices are expected to be operated in low data transmission rate owing to saving energy, without sacrificing the Quality of Service (QoS) at the same time. 5G in this case can assist in gaining the goal of efficient and effective interconnection between devices. Although researchers around the world are working on finding solutions to deal with the increasing number of devices and the onslaught of data, establishing a cognitive and scalable network infrastructure must be taken into consideration to deal with the diverse nature of devices and data consumption.

While looking for the emerging technologies related to Internet of Things, it is found that the authors of [2] have provided a comprehensive survey on the potential enablers for future IoT that helps in the upgradation of the previous cellular standards into 5G networks. However, without cognitive capability many IoT objects become meaningless, and the authors in [3] highlighted a few dimensions on how the spectrum related functionalities can be added to achieve a CR-based IoT network. In [4], we get a rigorous discussion on M2M communications inspired by Cognitive radio. In [5], the authors included a survey on several communication technology protocols for IoT. In later sections, some existing 5G networks have been discussed to get an overview of how Cognitive IoT can relate to 5G, including several technologies such as Zigbee for M2M networks, Sigfox, LoRa, RPMA, Dash-7, Weightless, RF-Link, Bluetooth [6–8]. They included the key features of these technologies that gives an overview

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DOI:10.2478/jee-2020–0020, Print (till 2015) ISSN 1335-3632, On-line ISSN 1339-309X

on how to integrate Cognitive IoT in 5G networks. A discussion on Network virtualization and Software Defined Network, which plays an important role in integrating cognition in IoT devices and networks, is included in [1]. Using the limited hardware radio resources by slicing the network in order to support multiple wireless protocols is discussed in [9]. Reconfigurable backhaul network, Radio access network (RAN) where all access points are controlled by one central entity, Software controlled switches for cognitive front-end of a wireless network are explored in [10]. In [11], the authors suggested virtualization in physical layer of the network in terms of spectrum virtualization. Interference mitigation with the help of cloud intelligence is brought to light in [12].

The aim of this article is to present the recent progress in IoT technology to make it 5G enabled cognitive IoT. It also depicts the gradual evolution that are taking place in the communication sector for the advancement of network system, incorporating the cognitive feature in the IoT and 5G network. It is hoped that the cognitive solution leads to notable contribution in the overall performance of IoT based 5G networks.

The article has been organized as follows: Section 2 provides an overview of the Cognitive IoT communication. Section 3 brings forth the enabling technologies that are useful for Cognitive IoT based 5G Network whereas Section 4 presents the major challenges that comes in the way with their most-likely solutions. Lastly, Section 5 concludes the article with future research direction.

2 Overview of cognitive IoT communication technology

Internet of Things (IoT) refers to the real-time information sharing between smart devices and sensory nodes, whereas, Cognitive Internet of Things (CioT) refers to the intelligent sharing of the information. Cognition essentially means the capability to think. Addition of the cognitive feature to the IoT can optimize the available resources. Many potential network technologies are currently on the field that are being used rigorously by the IoT devices, but a definite solution for the CioT devices network technology is yet to be found. Therefore, long range, short range and cellular technology, all are under consideration for the communication technology of CioT. Here all the communication standards either connect through the cellular IoT or the Low Power Wide Area Networks (LPWAN) for attaining the Massive IoT and Critical IoT connection. These are suitable for their exceptional features like energy efficiency, wide area coverage, data rate, channel bandwidth, power consumption, *etc.*

Long range networks mainly use the LPWA technology for its low power and long range capability. Some of the popular long range networks are: LoRa, Sigfox, Ingenu, DASH7 and Weightless which are discussed in Tab. 1. These network technologies can connect the sensors and controllers without the help of cellular network or the traditional WiFi. Massive IoT devices mainly use these networks.

2.1 Unlicensed long range technology

Unlicensed Short Range network covers wireless connectivity according to their typical reach or coverage (Tab. 2). This range can be from millimeters to few hundreds of meters, depending on the type of information to be shared. For Short Range communication, Wireless Local Area Networks (WLAN), Wireless Personal Area Networks (WPAN), Radio-Frequency Identification (RFID) and Wireless Sensor Networks (WSN) are the most commonly used approaches, where WLAN and WPAN are leading ones. Technologies like Bluetooth, WiFi, Zigbee provides widespread wireless network to smart devices. They can provide multiple types of radio network which included point to point, tree, point to multipoint connection. Bluetooth and WiFi is the most common network used for the very basic communication between phones, laptops, gadgets, industrial equipment *etc.* Bluetooth Low Energy is used for medical purposes. For flexible and reliable IoT network, with lots of devices connected, Bluetooth mesh can be used. Zigbee has the ability of building up the large mesh network for sensor monitoring, handling up to 65000 nodes. It can be used in home automation, industrial control, and machine to machine connection and IoT applications. Another technology is the Near Field Communications (NFC) which can provide a small range of maximum 20 cm for the security of connection because the customers can just use their cell phone as a credit card instead of using cash.

2.2 Cellular technology

It is well known that 3G delivered improved broadband connectivity, and 4G LTE improved the wireless connectivity. However, a common ground between these two connectivity solutions is foreseen to be the main catalyst in developing the worldwide Internet of Things (IoT). Comparatively, 5G makes a huge difference by allowing high density of devices in smaller areas without sacrificing the Quality of Service (QoS). 5G can assist in gaining the goal of efficient and effective interconnection between devices. One of the biggest opportunities of 5G is that it allows multiple technologies to co-exist which includes high data rates, low latency, less battery consumption, integration of different platforms and gadgets [13]. In addition, it is of great concern to integrate IoT with 5G communication technologies in an intelligent and optimized manner to improve the scalability of Cognitive IoT based 5G Networks. It goes without saying, the lightning fast speed of 5G is going to allow new services in the context of IoT that are now unimaginable with the existing communication technologies.

3 Enabling technologies for cognitive IoT

The recent paradigm shift in communication technologies introduce the Cognitive feature in IoT devices and network. Multiple devices such as mobile phones, house appliances, vehicles in a Smart city are interconnected through Machine Type and Device to Device Communication using Heterogeneous network. In order to establish real-time exchange, storage and analytics of information among these devices, Big Data, Cloud Computing, SDN and NV technologies should be utilized.

3.1 Millimeter wave (mm Wave) communication

Due to the increasing number of smart devices around the world, frequency bands below 6 GHz have been saturated. As a result, mm Wave frequency ranging from 24 GHz to 28 GHz band is considered to be the most suitable for future applications related to 5G and IoT [14, 15]. However, owing to attenuation over this frequency range, it can only be used in short range communications. Moreover, its efficiency is significantly affected by humidity, rain, even gases in the atmosphere. But one very important advantage of this technology, surpassing its drawbacks is that, frequency can be reused within short ranges, thereby supporting massive number of devices [16].

3.2 Machine-type Communication (MTC)

One of the main features of 5G Cellular system is to provide connectivity for MTC devices. MTC and IoT innovation demands shift in overall architecture of 5G networks to cognitive networks [17]. Despite being the most popular communication techniques nowadays, 3GPP and LTE (4G) networks cannot support the MTC communications [18, 19]. Machine to machine communication technology is envisaged to form the foundation of next-to-come 5G IoT network, enabling automated and remote monitoring of smart devices and sensors [20].

3.3 Device to device communication (D2D)

This technology assists communication in shorter ranges with a very low consumption of power and better QoS for the users. It has the advantages of low latency and higher spectral efficiency. It can be employed in licensed spectrum bands and unlicensed bands without traversing the Core network, thereby offloading the complication from the network. Several communication technologies can be used for enabling Direct D2D in IoT applications which includes WiFi Direct, NFC, Zigbee, RFID and Bluetooth. Since D2D communication is now an important technology for the heterogeneous devices, it has the potential to fulfill the IoT requirements in 5G network.

3.4 Heterogeneous networks (Het–Net)

Heterogeneous networks (HetNet) is useful in the case of resource constrained devices, where data transmission rates vary depending on the demand. Heterogeneous network, as the name refers, is a network where different cell types and several different protocols are used to connect all the devices in the network. Also, there are different kinds of base stations in this paradigm, using high power and low power transmitters and receivers, and utilizing different kinds of network topologies [21]. WiFi offloading and Context aware HetNet can be adopted in order to integrate HetNet with IoT network [22]. The 5G-IoT together with Het-Net connection, can provide on demand information transmission to and from, massive number of resource constrained devices.

3.5 Cloud computing

Cloud Computing simply refers to the on-demand remote access of data storages and processing the data over the Internet [23]. It is essentially a metaphor for the Internet. The hardware and software resources associated with this Cloud can be accessed at any time from any place. On the other hand, IoT is going to introduce a large amount of data that needs to be stored and processed to extract useful information. Integrating IoT with Cloud Computing can give meaning to the raw data. Addition of 5G to these technologies will allow having the features of faster and on-demand access to the stored data. It removes significant burden on the edge devices and thus improves the Quality of Experience (QoE) at the user end.

3.6 SDN and NV technology

Some elementary changes are required in the communication industry that will virtualize the network by reducing its complexity of network management. SDN and NV are responsible communication technologies that can create flexible logical networks, by which it can support 5G network communication with scalability, ultra low latency, ultra high capacity and huge number of users and Internet of things or devices. The network infrastructure based on SDN will be such that it can establish communication between applications and services in the cloud and users mobile terminal. The latest network requires flexibility and easy troubleshooting. SDN manages this by using the centralized network control [24], hence, manage the real-time network and status simultaneously.

3.7 Data analytics and Big data

As the development of IoT progresses, the need for an effective technology to extract information from the massive amount of data generated by these IoT devices have become the center of concern. The concept of Data analytics analyses the information extracted from devices in order to generate a pattern that best describes the consumers. On the other hand, Big Data includes a large number of datasets that may not be analyzed by the traditional computing tools. The technologies like Big data or Data analytics create the opportunity for a lot of industries that can get the human behavior information through the internet of devices and sensors.

4 Major challenges in CIoT based 5G

Deployment of 5G Cellular Networks is itself a very big challenge in establishing a worldwide Internet of Things network. On top of that, onslaught of data with massive number of devices, the interoperability between heterogeneous networks and devices, the limitation of available frequency bands, and most importantly, the security and privacy of the network impose numerous challenges on the development of Cognitive IoT based 5G network. This section highlights the major challenges in CIoT based 5G.

4.1 Resource constraints

With the exponential growth in the number of smart devices and systems in 5G, the need for an intelligent network that can utilize the available radio spectrum. In order to establish effective communication between devices, the concept of Cognitive Radio (CR) comes into the picture [25]. CR is an adaptive network technology that can automatically detect available channels in a wireless spectrum, consequently controlling the network congestion and interference. Spectrum sensing is a paradigm related to cognitive radio that checks if a specific frequency band is occupied by primary user, maintaining a specific time interval. This helps secondary users to opportunistically use the channels in order to reuse the frequency band. This cognitive feature in radio spectrum carries a great significance in developing Cognitive Internet of Things. Spectrum management is another important issue because we know that spectrums are limited and are getting crowded day by day. Bringing in new bands of spectrum is very difficult as well as extremely time consuming. So we must know how to share this with the maximum level of efficiency.

4.2 Device and data management

Efficient management of huge number of connected devices and the data sharing among them highlights the paramount challenge in establishing interconnected networks that constantly exchange huge bulk of information without human intervention. Mobile Edge Computing (MEC) in 5G-IoT will vastly increase computation related applications like Virtual Reality (VR) or Augmented Reality (AR). Available computer resources can be efficiently used if this intelligent feature is taken into consideration while developing Cognitive IoT. Cognition at the edge essentially means sending just the useful data to the data centers instead of all sorts of data collected from the user. Machine learning technology can be rigorously used to group the useful data; useful is in the sense of extracting consumer behavior. Most of the IoT devices are going to be connected through 5G network, hence it enables cognition at the sources of generated data that can significantly reduce the burden on network.

4.3 Interoperability

Most of the IoT applications are now closed systems. Breaking this barrier, the system will allow semantic interchange of information between devices to have an IoT ecosystem. Interoperability must be established between heterogeneous things and many different IoT platforms to explore the full potential of IoT applications whether it is a direct device to device communication or machine type communication, There have been significant attempts in bridging the gap of interoperability, but a unified solution is yet to be discovered. IoT Middlewares can be the key solutions to address the lack of interoperability. IoT Middlewares are basically software defined platforms that bridge the communication gap between IoT devices. The SiteWhere is the best IoT Middleware to date among few open-source Middlewares such as DeviceHive, Inatelplat etc. But, one major disadvantage of the existing Middlewares is that they are application-specific. However, cognitive Middlewares for IoT will account for a holistic solution to the lack of interoperability. Cognitive gateway will sense the incoming data and initiate the required communication protocol to deliver the data, thus making the information semantic at the receiving end.

4.4 Scalability

The increasing number of users and heterogeneity of devices impose some challenges in effective management of the limited network resources. SDN and NV are two emerging technologies that are envisaged to provide cognition in IoT devices. The basic concept behind SDN is that it separates the control plane of the network from the data plane. Control plane is where the networking protocols are executed, and packets are delivered through the fastest route in data plane. This way, intelligent routing of the onslaught of traffic can lessen the burden on limited networking infrastructure. On the other hand, Network virtualization is a technology that allows the sharing of physical network infrastructure by creating multiple virtual networks. This technology refers to the virtualization of the network resources such as routers, database, links *etc.* These resources can be viewed wirelessly and as an individual network infrastructure by different vendors, despite sharing the same physical infrastructure. Subsequently, application specific service requirements can be fulfilled by limited physical resources. These network can work as a supplementary to the 5G-IoT technology simplifying the deployment of IoT functionalities. For virtualization of the whole network, NV can be the best supplimentation for easy deployment of 5G-IoT [26]. It can add the programmability attribute to the network, thereby creating the provision for a scalable network. While it is foreseen to have a data and user onslaught in near future, scalability of the network is of great concern which can easily be solved by this NV technology. Cognitive Internet of Thing (CIoT) paradigm can be enabled by combining the technologies SDN and NV [1].

Table 1. Long range networks

Name	Lora	Sigfox	Ingenu	Dash-7
Communication Network Standard	IEEE 802.15.4	SIGFOX	Ingenu (Formerly Onramp)	ISO/IEC 18000 standard
Communication Range	Rural- 10 km Urban- 2-5 km	Rural- 30-50 km Urban- 3 10 km	>500Km LoS	0 – 5 km
Data rate	27 kbps	UPLINK: Eu: 100 bps USA 600 bps DOWNLINK 600 bps	624 kbps	167 kbps
Spectrum	ISM band Unlicensed spectrum 433– 868 MHz 915 MHz	ISM band Unlicensed spectrum 868 MHz (Europe) 915MHz (US) 433MHz (Asia)	ISM band Unlicensed Spectrum 2.4 GHz	Sub-GHz ISM band Unlicensed spectrum 433 MHz, 868 MHz and 915 MHz
Key features	-Uses CSS (Chirp spread spectrum) -uses more BW but gives extended range -cost effective in deployment	-uses UNB (Ultra narrowband) -Downlink: GFSK -Uplink: DBPSK -higher spectral efficiency -better mitigation the noise -very practical	-Used mainly in M2M communication Downlink: CDMA -Uplink: RPMA and DSSS -well known network for its capacity, range and robustness - also provides bi-directional communication	-Uses RFID technique -Direct communication between devices -can also be used for non-RFID devices

Name	Dash-7		Weightless	
Communication Network Standard	ISO/IEC 18000 standard	Weightless	Weightless	Weightless
Communication Range	0 5 km	3 km (urban)	2 km (urban)	5 km (urban)
Data rate	167 kbps	100 bps	200 bps to 100 kbps	1 kbps-10 Mbps
Spectrum	Sub-GHz ISM band Unlicensed spectrum 433 MHz, 868 MHz and 915 MHz	Sub-1 GHz ISM	Sub-1 GHz ISM	400-800 MHz (TV Whitespace) Uses operation,
Key features	-Uses RFID technique -Direct communication between devices -can also be used for non-RFID devices	-uses DBPSK -extremely large area of coverage instead of high data rates -Limited to one way communications for UNB standard -Weightless-N supports more range and less power consumption than Weightless-P	- Uses GMSK and QPSK modulation -Allows operation from coin-cell batteries - highest performance of all three categories - Control transmit power to maintain reduced interference and highest capacity	- Time-division duplex Differential BPSK and 16-QAM

Table 2. Short range networks

Name	RF link	Bluetooth	Bluetooth 4.0 Low Energy	Zigbee	Wifi
Communication Range	100 – 1000 m (depending On transmission power and antenna)	100 m	More than 100 m	1020 meters (approx)	50m depending on router
Data rate	1-2 Mbps	1-3 Mbps	25 Mbps	20 kb/s to 250 kb/s	250 Mbps
Spectrum	916.5 MHz	2-3.5 MHz	2.4 GHz	868 MHz to 2.4 GHz depending on region	2.4 GHz Unlicensed (ISM) band But designed To operate Between 1 to 7 GHz
Power consumption	Less than 1 mW	1 W	0.01-0.5 W	Very low	Very low
Latency and Battery life	-	100 ms and 0.625 ms	6 ms and 3 ms	Low latency	Low latency
Key featurres	-Uses FSK technique -Low cost	-Uses GFSK technique -important for	-Uses FHSS technique -User	-Uses O-QPSK -Low power	-Uses radio waves to establish networks

4.5 Security

With the rapid growth of the heterogeneous IoT devices within a system, the security issues need to be in consideration in a great margin. The issues may include threats like malicious code attacks, inability to receive security patches, hacking into smart meters and Denial of Services (DOS) [2]. Therefore, the system requires security to protect each layer from unwanted interference through valid data security, authorization, authentication, confidentiality and trust. To ensure security in the IoT devices, the architectural layers must include individual secure administration. Currently, the main target is to control the access control protocol and authentication issues, but new networking protocols like Ipv6 and 5G are essential to be incorporated for the upcoming technological revolution. The basic challenges in 5G will include mandated security in the network, flash network traffic, security of radio interfaces, user plane integrity, roaming security, signaling storms, DOS attacks on the end devices and the infrastructure [27]. Massive connectivity, cost issues and device flexibilities can be met with the help of Cognitive solutions such as Cloud computing, SDN and NV. However, privacy concern comes to light when Cognitive IoT is integrated with 5G. Hence, we need to go for artificial intelligence and context awareness which will enable proactive programmability and network forensics. The inability of incorporating shared infrastructure retains major issues such as mismatch in global policies and standards, access control and end to end security which impose a research challenge issue for future researches.

5 Conclusion

Internet of Things (IoT) with cognition capability is a great inclusion to the development of an interconnected world, where every thing can share information [28]. 5G on the other hand is an add-on to this development with improved data rate and low latency. 5G and cognitive based IoT together can enable sensory nodes or massive devices connecting in real-time through smart decisions while sharing information. This article provides technical aspects associated with Cognitive solutions for IoT based 5G networks. It also highlights the challenges in Cognitive IoT based 5G reported in the literature.

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Received 12 February 2020

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