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The new trends in networking: IoT, 5G, and cognitive radio

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A R T I C L E I N F O

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The domain of networking and wireless communication is rapidly expanding to the point where traditional legacy networks research is nearly complete, and they are supposed to be an elder. IoT, the Internet of Things, and the 5G radio communications are the newest networking advancements. These two technologies fulfill all of the researchers' goals of improving people's quality of life. IoT is a framework that allows everyday devices to become smarter, processing to become more intelligent, and communication to become more relevant. The Internet of Things (IoT) has already made huge progress as a ubiquitous solution platform for the linked world. We also discussed the Radio Cognitive RC, which allows people to connect to networks as secondary users at no cost while the service provided is not as good as that provided to primary users who pay a license to use the network. RC can provide a solution for best-effort IoT applications that do not require constant connectivity and high QoS requirements. This study describes all of these technologies and concludes with a recommendation for using IoT and RC in our further works.

1. Introduction

As a result of its rise throughout the past decade, the telecommunications sector has expanded in importance and prominence way in our modern societies. The "wireless" technology is undoubtedly the most significant advancement in this industry. The ability to be connected provided by the Hertzian waves gives rise to many wireless networks. Communication networks hold a crucial influence in the world we live in because they are constantly used in our daily lives to send and receive messages, make voice calls, and also do more complicated things like remotely controlling cars and homes, which are typical examples of using IoT (Internet of Things) systems (Holler et al., 2014). The 21st-century society is highly associated with new technologies, so the "smart" attribute of smartphones is picked up, and the other things are becoming smart as well, which is the core of the IoT tech. The internet of things is a term that refers to electronic devices that communicate via the internet in order to send and receive data and instructions (Aswale et al., 2019; Mukhopadhyay and Suryadevara, 2014). For example, cars are equipped with a self-driving system; it is known as smart vehicle systems, houses are becoming smart as well, known as smart homes or domotics. According to IHS (Lucero, 2016), the total of smart equipment was predicted to be 15.4 billion in 2015, with 30 to 50 billion devices by 2020 (Dave, 2011). This massive rise in wireless applications has always accompanied steadily higher and more stringent standards in terms of QoS (Quality of Service) and resource control, particularly in the electromagnetic spectrum. Because an IoT system requires a networking platform, we will provide a comprehensive overview of networking protocols utilized in IoT, including LPWAN protocols (Chaudhari and Zennaro, 2020), mobile broadband protocols, and their evolution (Correia, 2010). Indeed, we are now in a situation where the vast majority of the latter has already been allocated to existing systems, leaving no extent or, more accurately, the lack of frequency for the adoption of these new radio technologies complicates the design and implementation of new wireless networks. In this context, the Federal Communications Commission (FCC), the United States spectrum regulatory and management agency, established a think-tank in 2002 to address the scarcity of frequency resources (Kolodzy and Avoidance, 2002). The results of this study highlighted a shortage of spectrum resources while explaining that it is due to the static allocation of resources and not to a saturation of the allocated frequency bands. Indeed, while some bands are intensively used, others are partly used or not at all. Subsequently, the results of

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this study were corroborated by similar studies carried out in other countries confirming an under-exploitation of the spectrum as a function of time and space, and it was the birth of the cognitive radio realm (Mitola and Maguire, 1999).

The rest of the document will be as follows; section 2 presents a detailed study concerning IoT; section 3 is dedicated to the radio communication evolution from 1g to 5G; while in section 4, we will talk about the cognitive radio system. The document concludes with a conclusion.

2. Internet of things

One of the most decisive inventions in the 20 century is, without any doubt the Internet; it provides us with a plethora of advantages that were previously unavailable. People aged sufficient can assert the era when cell phones were not smart; we could only call and text; presently, we can peruse any book, observe any film, or tune in to any music all in our duke. Furthermore, that is to specify a couple of our smartphone's fantastic things. By Googling "what is IoT," we get many responses, and as a non-technical one, we can quote, Internet of Things IoT is a term meaning a million interconnected things around the world, which mean enlarging the influence of the internet further than laptops and smartphone to all the other things (Aswale et al., 2019; Mukhopadhyay and Suryadevara, 2014).

So, great benefits are provided by connecting things to the internet. IoT tries to imitate the advantages that our handsets, computers, and tablets provide and reproduce them for everything else too. Moreover, yes, we do mean everything. A simple definition of the Internet of Things is, connecting all the things in the world to the internet. As a technical definition, according to (Carretero and Garcia, 2014), IoT is described as an auto-structuring capability with an active broad network basis based on interoperable norms and communication protocols; the "things" (virtual and physical) in an IoT system are capable of using intelligent interfaces and being integrated as an information network using because they have identities. For sure, IoT has changed our everyday lives, which is its main strength. Based on the private user point of view, the change impacts the work and the domestic fields. IoT plays a leading role in our daily lives; smart homes, e-health, assisted-living, and smart agriculture are simple examples, among others. From the business user's point of view, automation and manufacturing production, business process management, and adaptive transportation of humans and commodities are visible outcomes of this new era. The rest of this section will be dedicated to giving the general architecture of an IoT system, we will talk about the hardware used, the network protocols, and middleware, and we will give some use cases of the well-known applications, and the section will end by the future challenged facing IoT and some proposing solutions (Holler et al., 2014). Based on Fig. 1, an IoT system contains four fundamental elements:

Thing or devices or the connected objects: Our daily lives object equipped with sensors; the combination of objects and sensors forge the smart objects that can be connected to any network, ideally the internet. These smart devices continually capture data from the environment and communicate it to the next layer. To transmit the data to the end-user, the intelligent things need to be associated with a network. To this end, the smart devices can be linked to different radio networks like Lora, ZigBee, Z-wave, Wi-Fi, Bluetooth, etc. These emerging networks have advantages and drawbacks regarding energy usage, throughput, and global productivity. More details on the wireless protocol for IoT systems can be found later in the following.

The gateway represents the link in which the data is transmitted from the smart devices as a first step; it takes into charge of different network protocols and manages them, and it makes sure the interoperability of the connected devices and sensors. A pre-treatment of the gathered data collected from millions of actuators can be locally performed by configuring the gateways before transmitting it to the next stage. Higher-order encryption algorithms provide a certain amount of security for the network and transmitted data. It is an intermediate layer between the equipment and the cloud protecting the infrastructure against harmful assaults and unlawful access.

Cloud: IoT systems mean a massive amount of data collected from the objects, applications, and users; these data have to be managed efficiently. Different tools are needed for this massive volume of data to be collected, processed, managed, and stored instantly; the IoT cloud offers these tools. The services and the industries remotely access the data stored in the cloud. So, to summarize, the IoT cloud represents a network of servers with high performances optimized to complete a higher data treatment of billions of equipment, traffic control, and precise monitoring. One of the significant vital parts of the IoT cloud is distributed database management.

Analytics: intelligent devices and sensors produce billions of data; the analytic tool converts these data into a useful one that can be understood and used to conduct in-depth research. Smart AI tools are unavoidable for IoT systems for overall system control and evolution. The big enterprises in the world use the analyzed data for their future business opportunities; it helps businesses forecast marketing strategies and plan for effective implementation.

User interface: The apparent and concrete part of the IoT system is that users are reachable. Designers must make a well-designed user interface to facilitate and encourage interaction with the system.

2.1. IoT architecture

IoT architecture contains many sensors, real-world things, cloud services, designers, actuators, communication layers users, and IoT protocols (Al-Qaseemi et al., 2016). Due to the wideness of the IoT realm, different architectures were recommended by different scholars. The consensus between researchers is presented in Fig. 1, which consists of three layers of architecture, composed of perception, network, and application layer, Fig. 1. It is essential to notice that some researchers have added a new layer (which means the IoT architecture contains four layers) labeled the processing layer, sometimes termed the middleware layer; it saves examines and routes an enormous amount of data coming from the transport layer.

2.1.1. Multiple layer model architecture

The consensus between researchers is presented in Fig. 2, which consists of three layers of architecture: the application layer, network layer, and perception layer, Fig. 1. It is crucial to notice that some researchers have added a new layer (which means the IoT architecture contains four layers) labeled the processing layer, sometimes called the middleware layer; the processing layer stores analyses and processes a significant quantity of data coming from the transport layer. It is responsible for being in charge and bringing various offers to the inferior layers (Zhong et al., 2015). It involves several databases, cloud computing, and big data treatment building blocks.

View Layer: Detectors for monitoring and collecting data about the outdoors are included in the physical layer. It recognizes some physical parameters and other intelligent items in the area.

Network layer: her role is to connect the "things" and the servers. Its characteristics are also used in object detection communication and treatment.

The application layer is utilized to deliver implementation services to the user. This layer defines the various applications that can be utilized with the Internet of Things, such as smart homes, smart cities, and smart health.

Other architectures may be found in the literature with more layers, like the transport layer, which connects the perception and the processing layers, and conversely via networks like 4G/5G, WLAN, Bluetooth, LPWAN, NFC, etc.

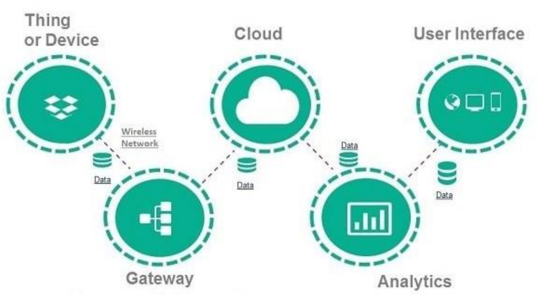

Fig. 1: Key IoT elements

2.1.2. Cloud/fog-based architectures

Recently, other architectures have emerged, the cloud and fog-based architectures for the Internet of Things: Architectures, Protocols, and Applications (Sethi and Sarangi, 2017). Recently, cloud computers have needed data processing effectively; this cloud-based architecture keeps the cloud at the center, applications at the top of the architecture, and the network of intelligent things at the bottom (Omoniwa et al., 2018).

Cloud computing has a huge importance because it offers excellent flexibility and scalability. It offers vital infrastructure, platform, software, and storage services. Designers can utilize the cloud to provide storage, software, data mining, machine learning, and visualization tools to their customers.

A component of the data management and insights is conducted at the sensors and network gateways in the fog-based architecture, which is made up of six layers. The layers from to bottom are as follows:

- Physical layer: the layer where things are analyzed
- Monitor layer: It performs monitoring on resources, power, responses, and services
- Processing layer: the data collected from sensors are filtered, processed, and analyzed
- The storage layer comes with storage features like data copying, dissemination, and archiving.
- Security layer: the encryption/decryption are performed, it ensures data integrity and privacy.
- Transport layer: the communication protocols.

Individuals and businesses are more familiar with the cloud notion because it has become a part of our daily life. Data is saved on numerous servers and can be accessed online from any device using cloud computing, the industry standard for IoT data storage. As a result, instead of saving information on a single computer's local hard drive, users save it to third-party web servers.

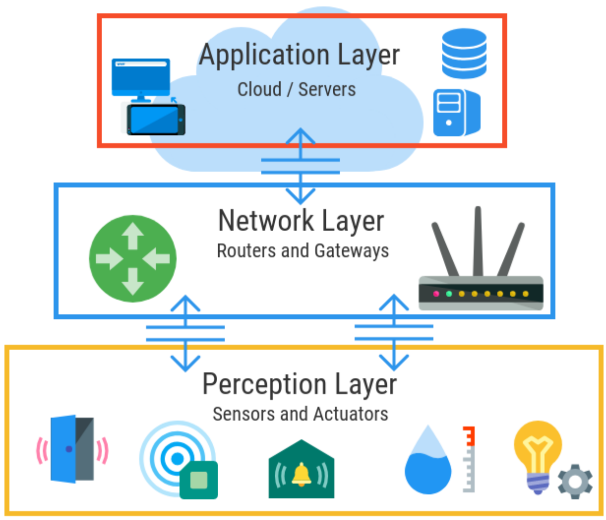

Fig. 2: Three layers architecture of IoT

A user must first create an account with the cloud service to access data. Edge encryption ensures that no one, including service providers, has access to the contents of the user's account. This involves safely storing and managing a large amount of data and having rapid access to it from various devices, anytime and anywhere, for the Internet of Things.

Edge computing and fog computing appear to be equivalent and have several fundamental characteristics. Computation is moved directly to the center of data generation in both Edge and Fog computing systems (Yousefpour et al., 2018). The primary objective is to limit the quantity of data delivered to the cloud. This helps to reduce latency and, as a result, improve system response time, especially in remote strategic applications (Fig. 3).

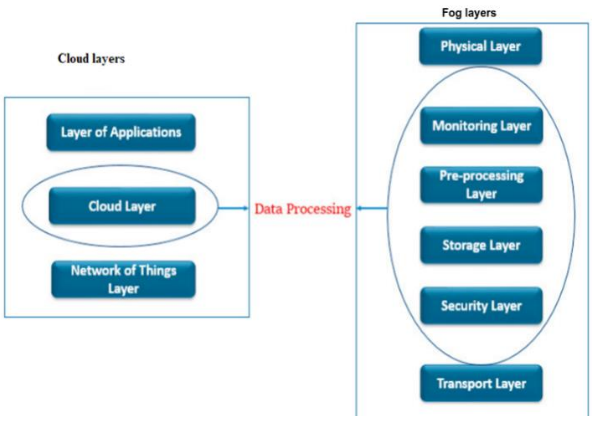

Fig. 3: Cloud and fog based architectures

In a fog environment, cognition is located on the local area network (LAN). This design sends data from extremities to a gateway, which is processed before being sent back to the terminals. Edge computing puts the intellect and processing capability of devices like integrated automation controls in the hands of the users. The differences between these two concepts are summarized in these elements:

- Location of data processing: The essential distinction between cloud and edge computing is where information preparation happens. In cloud-based systems, information is handled on a remote server that is usually distant from the wellspring of data. It happens on cloud services, for example, Amazon E2C occurrences. Edge figuring generally happens straightforwardly on the gadgets to which the sensors are associated or a passage gadget near the sensors. Then again, Fog computing shifts the Edge computing errands to the calculators that are associated with the LAN equipment, so they might be genuinely more far off from the sensors and the actuators.
- Thus, for Edge computing, the information is prepared on the edge elements or end-device itself without moving elsewhere. Conflictingly, in Fog computing, the information is handled inside an IoT entryway or Fog hubs situated in the LAN network.
- Capacity for processing and storing: Cloud computing enables more considerable and more advanced inventive handling capabilities. It can hold more data than Fog computing, with limited processing capability. Similarly, because Edge computing and IoT sensor processing are both done on the device/IoT sensor, the treatment power and capacity capacities are considerably reduced.
- Reason: Cloud computing is most appropriate for long-time top to bottom examination of information. Contrarily, Fog and Edge computing are more reasonable for the immediate investigation needed for the rapid reaction. Likewise, it would be beneficial to specify here that cloud computing needs 24×7 web access, while the other two architectures can work even offline. Hence, they are more adapted for situations where the IoT sensors might not have consistent access to the Internet. Regarding security, Fog and Edge are much more secure. In Fog, the information stays disseminated among hubs.

Consequently, it is hard to take control of the information contrasted to the centralized structure of Cloud computing. The information stays on the actual device in Edge computing, making it safer than the three other models. In the cases where security is a significant concern, Fog and Edge are best along these lines. Once more, since the information is disseminated among hubs in Fog computing, the time is insignificant when contrasted with cloud computing, where everything is put away in one location, and on the off chance that anything turns out badly with it, it brings down the entire system. Regardless of whether one hub goes down in fog computing, different hubs stay operational, settling on it the correct decision for the utilization cases that require zero time.

2.2. IoT communication

This section will thoroughly describe each wireless communication protocol (Al-Sarawi et al., 2017). As indicated in Fig. 4, IoT communication protocols can be separated into two categories: long-range and short-range networks protocols.

Fig. 4 categorizes the communication protocols into two wide classes, long-range and short-range networks; more details and explanations are given in the following.

2.2.1. Long-range networks

Long-range networks are classified into two families, LPWAN (Low Power Wide Area Network) and the cellular networks (Sharma and Gondhi, 2018). The LPWAN (Chaudhari and Zennaro, 2020) are famous for their low power consumption and long range; we will give details and examples in the following subsection.

2.2.2. Low power wide area networks

Low-power WAN (LPWAN) is a mobile broadband network solution that connects moderate-bandwidth, battery-limited devices over large distances. LPWANs targeted to machine-to-machine (M2M) and internet of things communications are less expensive and use less energy than typical wireless networks. They can also handle a more considerable number of linked objects over a broader region.

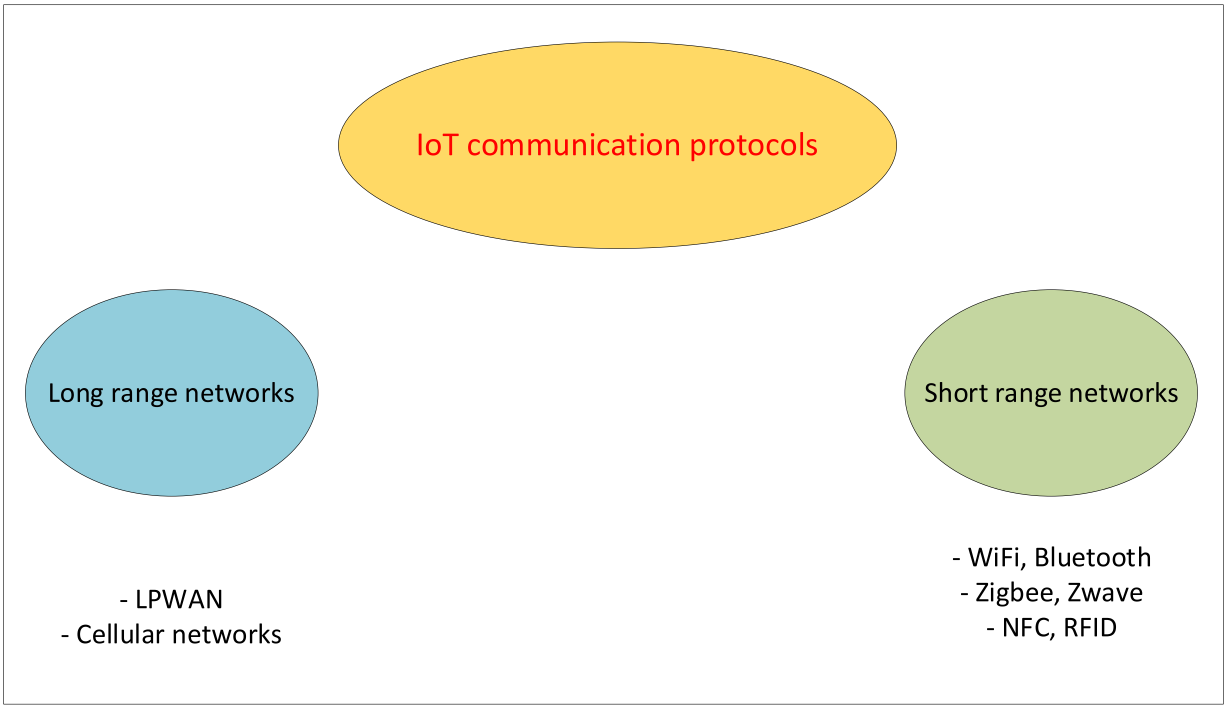

Fig. 4: Communication protocols in IoT

At upstream rates of up to 200 Kbps, LPWANs can accept data traffic ranging from 10 to 1,000 bytes. The long range of an LPWAN depends on the hardware. It can vary from 2 km to 1,000 km. The majority of LPWANs use a star topology, similar to Wi-Fi, in which each terminal links directly to a central transmitter. The famous examples of LPWAN are LoRa and SigFox.

SigFox: SigFox is a convention for high distances (30-50km in natural regions (Lauridsen et al., 2017), 3-10km in metropolitan regions), low throughput (12 bytes for each message, worst-case scenario. 140 messages every day for each end gadget), and low energy activity. SigFox employs the sub-GHz frequency (868MHz in Europe), ultra-narrowband technology, and BPSK alignment. End users who use SigFox technology send data to SigFox cell towers, subsequently sending it to SigFox databases. Until the results are transmitted back to the specified endpoint for viewing, this is where the data is prepared. It infers that SigFox regulates information on its cloud servers. Regardless, the SigFox system is at this point in progress. The company works with gigantic organization administrators all through the planet, even though it continues to introduce and works for its organizations in different provinces, for instance, in the United States and France. SigFox currently has a presence in Spain, Portugal, France, the United Kingdom, and the Netherlands. SigFox is expanding its deployment ambitions in Luxembourg, Denmark, Ireland, Belgium, Italy, Germany, and the United States: in just a half year, the French-based firm wants to enlarge from 10 to 50 metropolitan populations in the United States alone. SigFox does not require a SIM card. The price is determined by the number of messages sent each day and their volume. To maintain a particular end device operational, customers are taxed annually between one and 10 dollars. Fig. 5 depicts the fundamental design of SigFox.

SigFox connects Objects to end-Customer IT through Stations that send the sensors' data to the Cloud. Thanks to a revolutionary approach using Ultra Narrowband technology, SigFox provides a robust, secure, and optimized Low Power Wide Area Network (LPWAN) solution. The protocol operates on Sub-Giga frequency bandwidth, allowing excellent material permeability and autonomy.

LoRa: LoRa (Mekki et al., 2018) is quite comparable to SigFox in that it utilizes the same sub-GHz frequency (868MHz in Europe), has equal transmission distances (up to 15 km), besides it is pretty reliable as a result of its small throughput oscillating between 0.3 to 22 kbps.

Unlike SigFox, LoRa employs the chip spread spectrum technique to balance transmit power and bit rate precisely. The LoRa Alliance was founded in 2015 to normalise and improve LoRa. Apart from the LoRa scientists' Semtech, the LoRa Partnership is represented by several semiconductor and component suppliers, software organisations, and service providers, such as Microchip and STMicroelectronics. The LoRa Foundation charges an annual licence fee of $3,000 to anyone who wants to use LoRa in its ultimate goods. There aren't likely to be any additional fees, because LoRa, like SigFox, doesn't necessitate a SIM card. Concerning the development, the two entrants' situations are somewhat equivalent: The LoRa Foundation is trying hard to expand penetration, principally in Europe and the United States, in vast Russian cities. Each client may help expand the LoRa foundation thanks to the reacting network.

Furthermore, customers who do not wish to stand by for better coverage might build up a private network using the LoRa protocol if the application permits. Microchip offers LoRa unit options for European (RN2483) and US markets (RN2903). The microcontroller unit, crystal, EUI-64 Node Identity Serial EEPROM, radio handset having a simple interface, and hardware coordination are all included in the highly integrated modules. The manufacturer provides specific boards and a complete gateway development kit for development. Each LoRa gateway is capable of supporting millions of sensors. Because the transmissions can travel a long-range, fewer assets are necessary, resulting in an economical and rapid system to build. LoRa also has an adjustable throughput algorithm that helps terminals get the most out of their batteries and processing power. LoRa also has an adjustable bit rate algorithm that helps stations get the most out of their batteries and processing power. For secure communications, the LoRa system contains multiple layers, involving encrypting at the network, application, and equipment levels.

Fig. 5: SigFox architecture

Cellular networks: Cellular wireless technology has long held a monopoly in long-range applications that connect a device directly to the Internet without using a gateway (Salva-Garcia et al., 2018). End goods need a SIM card to communicate with the cloud because of the installed infrastructure of radio transmitters worldwide. After practical introduction and enlistment with the network supplier, information may be exchanged. Supplementary improvement of previous mobile wireless solutions for the most part centered on rising information transmission rates. LTE Advanced, for example, presently permits a downstream transmission capacity of up to 3.9 Gbps and an upstream throughput of up to 1.5 Gbps. Be that as it may, most things in the IoT do not communicate such immense quantities of information; most of them require under 100bpm. The focal point of effective communication technology is on long ranges, reliable communication, and low power utilization for broadened battery life. Low data rates positively affect power utilization (Lauridsen et al., 2017). Vast distances, solid correspondence, and short energy utilization for expanded battery life are the focus of successful communication technologies. Low data rates are associated with lower power consumption (Lauridsen et al., 2017).

Cat 0 and Cat 1 LTE are reduced-function variants of LTE designed for low power and low speed to meet the needs of IoT/M2M use cases. Instead of short-range wireless and the Internet, these applications leverage the existing cellular network in the licensed spectrum. With orthogonal frequency-division multiple-access (OFDMA) modulation, Cat 0 and Cat 1 make use of current LTE bandwidths. It is a long-range solution with a range of kilometres. LTE-M and NB-IoT are the most widely used LTE standards.

LTE-M: The LTE-M communication protocol was created by the 3GPP (Third Generation Partnership Project), which is responsible for developing mobile wireless technologies (GSM, UMTS, and LTE) (Lauridsen et al., 2017). LTE-MTC is another name for it (Machine Type Communications). LTE-M operates between 700 and 900 MHz in the approved sub-GHz range. The transmission speeds on the downlink and uplink are both about 1Mbps. The reduced use strategy may help extend the battery capacity of battery-powered end devices to between ten and twenty years. Another feature of LTE-M is its excellent coverage, as LTE-M makes use of mobile network wireless infrastructure. An additional benefit for suppliers is that LTE-M works on well-known registered frequencies. It is, in this way, very protected and robust and perfect for services with great necessities. One drawback of LTE-M is the significant expenses for using authorized mobile wireless networks.

For this situation, each endpoint necessitates its private SIM card which brings about extra setup and support costs. Thus, there are fundamentally higher than those for practically identical advancements. Besides, the current SIM card for LTE-M is relatively tricky. Support might be given later by the eSIM card (inserted SIM card). As the name recommends, it is implanted in the end device and can, while trading supplier, be effectively reconstructed deprived of opening the device. LTE-M employs a 1.4-MHz channel with a 15-kHz more significant and typical LTE resource block. To reach a peak data rate of up to 1 Mb/s; the uplink uses OFDMA and up to 16QAM. SC-FDMA is used for the downlink, with a peak rate of 1 Mb/s. Its low-power modes make it ideal for a wider variety of IoT and M2M applications.

NB-IoT: 3GPP NB-IoT utilizes licensed spectrum and is arranged toward service providers with cell networks set up and need to expand these with long reach (Mekki et al., 2018), low consumption propositions contrasted with 4G LTE, which utilizes more energy at a lot higher transmission capacity. It utilizes a narrow frequency spectrum equal to 200 kHz. Deployments can work independently as a GSM channel, in-band with the LTE resource block, or in an LTE guard band. Service providers will order which will be utilized around their area. NB-IoT works at 250 kbits/s. It has an idleness 1.6 to 10 s. It is equivalent to SigFox and LoRaWAN and features throughput and considerable bandwidth limitations. These restrictions are expected to help many devices while ensuring service to all. It intended to deal with 50,000 pieces of equipment for each cell. It will typically empower out to 40 devices for each home. A designer's decision of which protocol to utilize will rely on various components, and some may force the utilization of one over the other. For instance, engineers should think about how devices and services will be priced. Narrowband IoT, or NB-IoT, is a type of IoT that employs a single resource block of twelve 15-kHz LTE subcarriers. In a 200-kHz channel, it is 180 kHz broad. With modulation of OFDMA downlink and SC-FDMA uplink, data rates peak at 250 kbps uplink and 170-kbps downlink. This streamlined standard allows gadgets to consume extremely little electricity. As a software overlay, NB-IoT may be installed in an LTE network. An NB-IoT resource block can be easily integrated into a conventional LTE channel or a guard band. Table 1 depicts a comparison of the LTE network technologies, namely LTE-M and NB-IoT.

Short-range networks: Short-range wireless communication employs waves that range from limited centimetres to some meters. Short-range networks are also called local and personal wireless area networks; we can cite Bluetooth, WI-FI, Zigbee, Zwave, RFID, and NFC (Fig. 6).

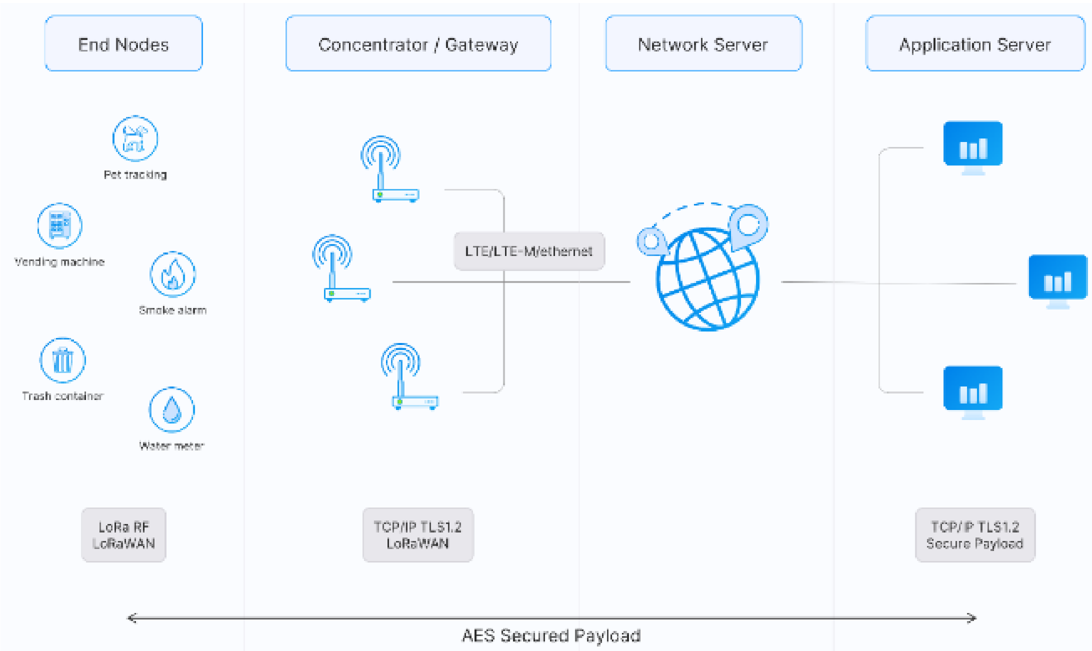

Fig. 6: Lora architecture

WI-FI Wireless Fidelity: WiFi, also known as 802.11 (Wilhelmsson et al., 2017), is a radio technology developed to replace Ethernet with radio transmissions over unlicensed frequencies. Its goal was to provide off-the-shelf, easy-to-install, easy-to-use short-distance radio access with bridge compatibility. WiFi is an undeniable option for IoT networks because in-building WiFi coverage is practically universal; however, it is not forever the suitable decision. The advantages of employing standard 802.11a/b/g/n/ac for IoT include inexpensive facility and equipment costs, high reliability; however, the disadvantages include high energy consumption, limited range, and frequency saturation (Wilhelmsson et al., 2017). While being the undeniable decision for IoT, Standard WiFi has limits in both reached range and energy effectiveness. The IEEE tended to these weaknesses by publishing specifications for 802.11ah (HaLow) and 802.11ax:

- Wi-Fi HaLow 802.11ah: Wi-Fi HaLow (Bednarczyk, 2018) is built on the IEEE802.11ah specification, approved in October 2016. It was created definitely to overcome the IoT's distances and energy issues. 802.11ah uses the 900 MHz ISM license-free spectrum to increase range while reducing power consumption. Energy use is additionally upgraded by utilizing fixed wake/doze periods and extending throughout one kilometre. It considers station gathering to limit conflict and hand-off to expand the range. In any case, 802.11ah will necessitate specialized wireless access and subscriber devices. Regardless that the standard was authorized in October 2016, chip suppliers have shown little interest in Wi-Fi HaLow.
- HEW 802.11ax: Many IoT-friendly characteristics are also included in the future High-Efficiency Wireless (IEEE802.11ax) (Bellalta, 2016) standard. It concentrates on the waking time and station collecting characteristics of 802.11ah to allow consumers to save energy and avoid collisions. Moreover, the uplink multi-user MIMO capacities joined with the smallest (78.125 kHz) channel spacing allows up to eighteen users can exchange

packets in a 40 MHz channel subcarrier simultaneously.

The selection of 802.11ax in IoT relies upon the expense of the 802.11ax customers and how quickly the customers and the APs hit the market.

Bluetooth and BLE: Categorized in the Wireless Personal Area Networks (Wilhelmsson et al., 2017), Bluetooth is a short-range communication technique robust from the customer point of view. Legacy Bluetooth was initially desired for point-to-point or point-to-multipoint (up to seven slave hubs) data trade between clients' devices. Improved power utilization, Bluetooth Low-Energy was subsequently released to address small IoT applications.

BLE-empowered devices are generally utilized in association with electronic devices, consistently smartphones that fill in as a support for communicating data to the cloud. Nowadays, BLE is generally merged into fitness and integrated medical devices (for example, smart-watches, glucose meters, beat oximeters) in domotics (for instance, door locks) — where content is usefully communicated to and seen on mobile phones. Bluetooth Mesh's description in 2017 expects to empower a more scalable installation of BLE devices, especially in retail settings. Given adaptable indoor localization characteristics, BLE beacon networks have been used to provide additional help features such as in-store navigation, customizable features, and content delivery.

Zigbee: Zigbee (Ramya et al., 2011) is a reducing-power, short-range wireless standard (IEEE 802.15.4), commonly set up in a mesh network to extend the distance by sending sensor data across multiple sensor hubs. Compared to LPWAN, Zigbee provides better data rates while consuming much less energy due to the mesh design. As a result of their actual short-range (< 100m), Zigbee and alike mesh protocol (for example, Z-Wave) are most appropriate for moderate IoT applications with an even spreading of hubs in closeness. Usually, Zigbee is an ideal supplement to Wi-Fi for different domotics use cases like intelligent lighting, air conditioning, HVAC controls (Heating, Ventilation, and Air Conditioning), security and energy management, etc.

Radio Frequency Identifier RFID: RFID systems comprise a scanner and a minuscule wireless radio microchip known as an RF tag. This tag is digitally implanted with single data connected from distantly. RFID tag solutions are classified into active reader tag systems and passive reader tag systems (Coskun et al., 2013). Active tags are battery-rechargeable, expensive, and run at an upper wavelength, whereas passive tags operate at lower spectrums and lack a power source.

Table 1: LTE-M vs NB-IoT

		LTE-M			NB-IoT
		Cat-1	Cat-0	Cat-M	
Standardization		3GPP Rel.8	3GPP Rel.12	3GPP Rel.13 (1Q 2016)	3GPP Rel 13 (2Q 2016)
Bandwidth		20MHZ	20MHZ	1.4MHZ	200KHZ
Data rate	DL	~10Mbs	~1Mbs	~1Mbs	~100kbs
	UL	~5Mbs	~1Mbs	~1Mbs	~100kbs
Max UE Tx power		23dBm	23dBm	20dBm	23dBm
Battery usage		-	~10 years	~10 years	~10 years
Features		-	Half-duplex (375 KBS) PSM	Low power eDRX	Narrow Bandwidth Extended coverage

RFID data cannot be utilized directly for measurement or debugging since it is fixed and should be encoded into the tag. Intelligent retail, health care, homeland security, and agriculture are some IoT applications that use RFID. P2P network topologies can be supported using RFID.

Near Field Communication NFC: NFC is a small distance wireless communication technology that allows network connectivity between devices, simply contacting them together or moving them within a few centimetres of each other. RFID technology concepts are similar to those used in NFC (Coskun et al., 2013). Therefore, it is employed for more complex communication and identification. NFC has a tag that can store a tiny bit of information. This tag can be read-only (like RFID tags for identifying) or rewritable and edited later by the device. NFC operates in card emulation mode (passive mode), reader/writer mode (active mode), and peer-to-peer mode. Mobile phones, industrial applications, and wireless money transfers all make substantial use of NFC technology. Likewise, NFC simplifies the connection, commissioning, and management of IoT equipment in various settings such as households, industries, and workplaces. NFC supports P2P network topology.

3. 5G radio communication

During the 2G time, there were various significant technologies, like GSM (Global Systems for Mobile Communication), which allow data transmission at speeds that would make us laugh today (30-35 kbps), and GPRS (General Packet Radio Service), which worked on technology like that utilized by GSM, yet with slightly higher rates (110 kbps) (Lauridsen et al., 2017). With the launch of EDGE (Enhanced Data rates for GSM Evolution) in 2003, we entered a new domain. EDGE addressed a significant technological headway, offering data rates up to 135 kbps, and it established the framework for what was to be known as 3G. With 3G, which offered speeds of up to 2mbps, we could now send and get significant emails and messages, peruse the Web, appreciate video in real-time, and above all, security is enhanced. 3G generally depended on EDGE and CDMA2000 (Code-division Various Access) techniques, and that CDMA2000 worked on ideas like EDGE. It additionally empowered numerous channels to impart all the while4G introduced the period of mobile Web and set a few necessities for the mobile network, including forcing the utilization of Internet Protocol (IP) for data traffic, and appreciated least data rates of 100 Mbps. It extended the 3G world with more transmission capacity and services. Presently it is 5G's turn, and keeping in mind that somehow or another, its presentation can be viewed as 'the subsequent stage' regarding the wireless network, as a general rule, it is the subsequent stage in digitization.

The fifth-generation mobile networks will not simply improve how we connect; they will carry extraordinary advantages to interconnect and control machines, objects, and devices while conveying higher rates, lower delay, and better security. It has been intended to meet today's high development in data and connectivity while likewise keeping an eye on the upcoming advancements. It will first operate into the existing 4G networks before developing completely independent systems. 5G-IoT achieves unexpected features; data transmission in the proposed 5G-IoT potentially near to 20 Gbps, leading to quick response times.

A 1G network costs 8 million times less than a 5G network (Lauridsen et al., 2017). It will also be feasible to send data in instantly with 5G. It signifies that 100 billion mobile equipment will be connected at the exact moment around the world. To put it another way, an interconnection intensity of one million devices each square kilometer. Similarly, emerging technologies increase reliability in high mobility cases. It means that link performance will be significantly more consistent up to 500 km/h, which will have huge benefits, particularly for rail passengers. In other areas of application, regardless of cell phones, rising volumes of information are unavoidable. Therefore, 5G-IoT will turn into the future leading technique of communication.

The 5G of cellular networks will pay special attention to and treat those above: three main perspectives:

User-centered by connecting devices all the day, continuous communication services, and a high-level user experience.

Provider-centric, including networked intelligent transportation systems, commercial wayside services, detectors, perilous duty, and tracing operations.

Network-operator-centric services provide well-organized, accessible, small prices, uniformly-monitored, customizable, and protected connecting services organization.

As a result, 5G networks are thought to have the following three primary characteristics.

Pervasive connectivity: In the forthcoming, various types of gadgets will link to each other and provide a continuous user experience. In reality, pervasive connectivity will enable a user-centric perspective.

Zero-latency: Vital systems, instantaneous apps, and services will all be supported by 5G networks with zero delay tolerance. Thus, 5G networks are projected to achieve zero delays or exceedingly low latency on the order of 1 millisecond (Fettweis, 2014; NGMN, 2015). The zero-latency will, therefore, actualize the service-provider-centric view.

High-speed Gigabit connection: A high throughput connectivity (in Gbps) that allows rapid data transfer to people and devices could be used to achieve zero latency (NGMN, 2015).

A few other significant characteristics of 5G networks are described and liken to cellular networks of the fourth generation (4G) (GSMA, 2014; Aziz et al., 2015):

- A 10-100x increase in the number of connected devices.
- A 1000x increase in mobile throughput per area.
- A 10-100x increase in data rate.
- A 1-millisecond delay.
- Compared to 2010, the amount of energy consumed has decreased ten times.
- Information processing and transfer in real-time.
- Decrease of operating costs for network management.
- Modern wireless technologies are seamlessly integrated.

3.1. Requirements of 5G networks

A considerable number of UEs and a significant increase in bandwidth requirements for massive data transfer necessitate a revolutionary upgrade to current technology. The requirements of future 5G networks are highlighted in the following.

Due to the rapid expansion of device scalability in the forthcoming exponential expansion of smartphones, it is estimated that the development of gaming systems, HD TVs, cameras, domestic appliances, workstations, connected rail networks, recording devices, drones, monitors, and wearable devices (smartwatches and eyewear) would accelerate. Because of this, 5G networks are projected to accommodate many linked devices. (Wang et al., 2014; Agyapong et al., 2014)

Massive amounts of data are being streamed at a high rate. A massive surge in the Of course, an increase in the number of electronic connections will outcome in a 100-fold increase in data exchange (e.g., movies, songs, Web surfing, Data from social networking, videogames, and instant signals, photographs, bursty data, and multimedia) in 2014, overburdening the current network. As a result, comparable data transport capabilities are required about new structures, methodologies, capabilities, as well as network configuration for interior and exterior users (Agyapong et al., 2014; Hong et al., 2014).

The use of the spectrum. From the band's standpoint, the two separate subcarriers (one for the upside UL and another for the downside DL) appear to be duplicated (Hong et al., 2014). Furthermore, considerable chunks of the already allocated spectrums are underutilized. As a result, an admission control system that can improve the frequency of use must be developed. Furthermore, spectrum efficiency and usage have already been pushed to their limits. It will undoubtedly necessitate spectrum broadening (beyond 3 GHz) and unique spectrum usage strategies (Cai et al., 2014).

Omnipresent connectivity. Because of the world's different functioning frequencies, ubiquitous connection necessitates UEs supporting a range of frequencies, networks, and spectrum. Furthermore, the significant industry is divided into time division duplex (China, India) and frequency division duplex (e.g., the United States and Europe), so UEs must offer both duplex choices. So, 5G systems are expected to provide a continuous connection for users over heterogeneous networks (Wu, 2011).

Zero delays. Upcoming mobile-cellular networks are estimated to improve many zero-delay-applications, web browsing, and services with different types of quality of service (QoS) (in terms of delay,

throughput, delay variation, packet loss) and quality of experience (QoE) related to the user and the network provider service satisfaction versus feedback). It leads to, 5G networks are expected to deliver instant and latency-limited services with the highest QoS and QoE (Agyapong et al., 2014; Nam et al., 2014).

3.2. 5G development challenges

The 5G network strategy is not easy to realize. In such context, there are numerous issues to be addressed; some are listed below:

Improvement of data throughput and network capacity while reducing energy consumption. The organization of more base stations in a geographic zone and the usage of progressive frequency bands and connection improvements may help enable network size growth, billions of users, high throughput, large volumes of data, and resourceful backhaul data transmission to the core network. Yet, in terms of cost and energy consumption. As a result, network capacity must be significantly enhanced while energy usage and costs are strictly controlled.

To do that, Small-cell deployment (Wang et al., 2014; Agyapong et al., 2014), cognitive radio networks CRNs (Akyildiz et al., 2009), mMIMO (Larsson et al., 2014), energy-efficient architectures (Hu and Qian, 2014), full duplex radios (Bharadia et al., 2013), NFV, and SDN-based designs.

Flexibility and scalability. These are the primary distinguishing characteristics of future mobile communication. HetNets must be designed into future cellular infrastructures and techniques. Furthermore, a substantial number of potential users seek a set of services simultaneously. As a result, 5G networks must support scalable user demand throughout the coverage region.

NFV- and SDN-based architectures are solutions to do that.

For both UL and DL, a single channel is used. A full-duplex wireless radio (Bharadia et al., 2013). exchanges signal simultaneously and frequency on a single channel. As a result, a full-duplex system achieves the same performance as a system with different UL and DL channels, resulting in increased link capacity, spectrum savings, and cost savings. On the other hand, complete duplex systems are not simple to implement because they require complicated protocols for the physical and data connection layers and techniques to reduce the effects of interference (Hong et al., 2014).

Interference management. In wireless communication, interference between transmitting equipment is a big problem. Interference will increase in 5G networks as the different users, technologies (such as heterogeneous networks, CRNs, full-duplex transmission, and D2D connectivity), services grow, and the current modern method might underperform on modern mobile networks (Hossain et al., 2014). In 5G networks, several macro cell towers, various mobile users, and small-cell base stations can interfere with users. Consequently, an effective (in regards to eluding network congestion) and responsible (in terms of flawless interference identification and processing) interference management system for resource reservation, power management, cell connection, and network management is required.

High reliability and low latency Message delivery through drones managing patients, life safety features, cloud-based videogames, nuclear power stations, detectors, cruise missiles, and networked rail networks, to name a few applications, all necessitate low latency and high consistency. Therefore, obtaining relatively low delay and reliable data transmission across a vast network while increasing network equipment costs is challenging, as it involves the design of features that enable speedy connections, quick handoffs, and high data transmission speeds. As suggested proposals, VLC, caching methods, fast handover techniques, mmWave, mMIMO.

QoS: The challenges of ensuring QoS in 5G networks are numerous, including users velocity, communication over several hops, resource distribution, and a lack of central control. Furthermore, a large volume of bursty and multimedia data, multi-RATs, and low latency bound for various applications and services are essential obstacles in achieving the needed QoS in 5G networks. As a result, designing quick and capable algorithms to ensure QoS is devoid of congesting a base station instantly (Zhou et al., 2014).

It is suggested to use Delay-bound QoS, mobility, and handoff management to do that. The 5G wireless

UEs are designed to maintain an active service connection while moving between cells or from one RAT (e.g., 3G, 4G, 5G, WiFi, Bluetooth, and WLAN). Although a user inside a speeding vehicle is traveling rapidly, mobile service mobility adaptability should not be slowed. Furthermore, various users travel from one location to another throughout time, coming to workplaces from houses, for instance, in the morning. Thus, 5G networks are expected to make the most spectrum use while also keeping up with the rapid speed of device movement.

To do that, multi-RATs handoff and securing mechanisms.

The networks' and UEs' security and privacy: The promised features of 5G networks provide complex problems in the design of 5G networks with a focus on confidentiality and protection Threats such as imitation, denial-of-service (DoS), replay, spying, man-in-the-middle, and repudiation, for example, might be launched by a plethora of different types of social (ever attached) equipment. Furthermore, transferring a large amount of data securely and quickly while avoiding harmful files from infiltrating is crucial. Furthermore, network densification must be safe, and UEs must be handed off quickly and securely.

To do that, Supervision, physical layer security, secret dynamic frequency hopping, encoded communications, and policy-based communications.

3.3. 5G and IoT

From academic and business perspectives, several research activities focused on surveys research in many IoT and 5G systems (Cisco, 2017; Levanen et al., 2014). The goal is to provide a forum for new advancements in the 5G concept, technology, regulation, and deployment in IoT (IoT) applications. Remarkable work on 5G-IoT has been done in the last few years (Cisco, 2017). Verizon, Cisco, and Intel have collaborated on a 5G wireless studies effort to expose a revolutionary conventional of "IA-based algorithms" that adjust user experience to meet the needs of the people's sight, meaning that wireless networks will include human intelligence (Levanen et al., 2014).

By linking billions of intelligent devices to establish true gigantic IoT, in which intelligent devices mutually communicate and share data without human help, 5G can make substantial contributions to the future IoT (Xu and Li, 2012). Currently, a heterogeneous area of systems makes it difficult for IoT to determine if equipment will guarantee application requirements (Xu and Li, 2012).

Current IoT structures mainly employ particular applications such as Bluetooth Low Energy (BLE), ZigBee, and others. WiFi, LPWA networks, and cellular communications (e.g., MTC using 3GPP, 4G (LTE), etc.) are examples of other technologies. The Internet of Things is continually and rapidly growing, with new technologies being proposed and present ones expanding into innovative application domains.

Nowadays, IoT tech aims to increase the worth of daily life, involving the links of intelligent home equipment and intelligent buildings, and even intelligent towns. Industry IoT (IIoT) is expanding and experiencing several obstacles, including new product and solution needs and changing business models (Schaich and Wild, 2014). The IIoT is still confronting various method issues in some essential industry systems, such as traffic, machines with consistency, permanency, and the vigor of link

The present 3GPP and LTE networks are the most attractive communication strategies in IoT technology (Astely et al., 2013), providing IoT systems with extensive penetration, lower installation costs, high security, connectivity to reserved frequencies, and easy setup (Palattella et al., 2016). On the other side, conventional cellular networks are incapable of supporting MTC communications, as is the situation in IoT. In this case, the following 5G networks might be a potential solution. In contrast, to present 4G networks, 5G can offer the most significant cellular network throughput with almost zero delays and improved penetration for MTC communication, enabling the most intensive IoT applications. Indeed, M2M communication allows the concept of a connected society by enabling massive numbers of intelligent devices.

The 5G-IoT is planned to give applications with zero delay, on-demand, all online, reconfigurable, and sociable experiences, which means the 5G-IoT architecture must be able to coordinate end-to-end during each step. The 5G-IoT designs are projected to bring the following benefits:

Build a conceptually independent network based on application requirements;

Rebuild radio access networks (RANs) using cloud-based radio access networks (CloudRANs) to provide enormous connections across different norms and achieve the on-demand organization of RAN capabilities needed in 5G.

Facilitate basic network architecture to enable network function arrangement on demand.

In general, the prospective architecture of international mobile telecommunications (IMT), in which 5G networks will provide: (1) enhanced mobile broadband (eMBB), (2) ultra-reliable and low-latency communications (uRLLC), and (3) massive machine-type communications (mMTC).

4. Cognitive radio

Thanks to the work of Joseph Mitola within the Royal Institute of Technology in Stockholm, Sweden, as part of his Ph.D. thesis (Iii, 2000), the concept and the term of cognitive radio appeared for the first time in his article "Cognitive radio: making software radios more personal" in 1999 (Mitola and Maguire, 1999). According to a definition given by Mitola, "A cognitive radio can know, perceive and learn from its environment and then act to simplify the user's life"

(Iii, 2000). Based on this definition and linking with the functionalities offered by software-defined radio, we can say that cognitive radio is software-based radio equipped with intelligence allowing it to become aware of its environment and adapt to it by modifying its operational parameters. The objective is to offer the user, in a completely transparent way at a given time and place, the desired service with the best possible quality of service (Quality of Service, QoS) without causing the slightest disruption to primary users holding operating licenses.

So, since most of the spectrum is already assigned, the biggest challenge is to share the licensed spectrum. Cognitive radio allows the use of a temporally unused spectrum, referred to as a spectrum gap or white space. If an authorized user still uses this band, the RC offers movement to another white space, changing its transmitting power level or modulation arrangement to avoid interference. From this vision, two elements are omnipresent in every cognitive radio communication.

So, we can say that the two main characteristics of cognitive radio are: Re-configurability and cognitive capacity (Haykin, 2005).

A) Re-configurability: This feature allows the radio to adjust parameters relating to the signal transmission without any hardware modification to adapt to a continuously dynamic environment. According to the guidelines of the regulatory authority the FCC; the parameters that could be adjusted are:

- Transmission frequency: Cognitive radio must be able to transmit on any frequency in order to choose the most adequate, based on the information collected on the environment.
- Modulation: This parameter directly influences the quality of service (QoS) and is important for multimedia applications such as video conferencing or applications sensitive to error. By adjusting this parameter, Cognitive Radio can guarantee an acceptable QoS for the user.
- Signal strength: Remember that the signal strength must, in no case, exceed the thresholds imposed by the regulatory authorities and that these thresholds differ from one frequency to another. A cognitive radio must have the ability to adjust its transmission power dynamically so that it can exploit the different spectral holes.

B) Cognitive capacity: The cognitive capability allows the radio to become aware of its continuously dynamic environment and extract relevant and valuable information from it in order to select the most appropriate operating parameters at a given time. Cognitive capacity is concretely implemented mainly through four main functions, namely:

- Spectrum sensing: detect the available (free) spectrum areas.
- Spectrum selection: choose the most acceptable accessible frequency
- Spectrum sharing entails coordinating channel access with other users.
- Spectrum mobility: when the principal user is spotted, depart the channel.

These four functions are known in the literature as the cognitive cycle.

4.1. Dynamic access spectrum

Dynamic spectrum allocation is employed in future wireless networks to address the spectrum shortage problem. Full duplex operation on a radio node, which allows it to transmit and receive on the same radio channel, improves the usage of available spectrum resources. Increased link capacity, wireless virtualization, improved physical layer security, reduced end-end and feedback delays, and improved spectrum utilization efficiency are all advantages of full-duplex operation in wireless systems, which allow simultaneous sensing and transmission, as well as simultaneous transmission and reception. Three-dimensional (3D) beamforming, Massive MIMO, and mmWave Communication are additional ways to increase the capacity of future wireless networks. Because Visible Light Communications can support both low data rate and high data rate applications, such as location or asset tracking, it can improve the capacity, efficiency, and security envisioned in 5G (NetWorld2020 ETP, 2014). Smart antennas' beamforming idea is critical in CR to improve spectral efficiency. 3G and 4G technologies primarily target mobile broadband consumers, delivering increased system capacity and incredible data speeds. Services like video will drive by services future 5G technology, which will allow increased system capacity and offer better data rates.

Any node or entity that might benefit from connected must have wireless access in future wireless networks. As a result, the 5G network is more than just improvements to "traditional" mobile broadband technologies. The goal of 5G is to improve support for "machine to machine communication" or "machine-centric communications," which is also known as the Internet of Things.

The concept of dynamic spectrum access is quite simply to allow secondary users to exploit gaps in the spectrum without disrupting the communications of primary users, where:

- Primary users: The traditional system users with a license can operate on a specific frequency band. The license gives its owner the right to communicate at any time and freely on the frequency band dedicated to him. The only restrictions on this freedom are those of the license.

- Secondary users: Secondary users, for their part, access the spectrum opportunistically. In return, they must be careful not to interfere with primary users who remain a priority. The functioning and the design of the primary users must not be affected by the presence of the secondary users. These must take full responsibility for never causing interference to primary users. Furthermore, to do so, they must integrate additional functionality (software and hardware) compared to traditional radios. On the other hand, primary users (traditional radios) must not undergo any modification either at the hardware level or at the software level.
- The spectrum hole: This term was first defined by "Haykin" as "a band of frequencies allocated to a primary user. However, for a particular time and at a specific geographic location, the band is not used by that primary user (Haykin, 2005). Dynamic spectrum access has only been permitted very recently. The FCC led the way in 2003 in (Kolodzy, 2006). The problem with this kind of access is that wireless communications systems were designed to operate on dedicated frequency bands and therefore cannot benefit from this flexibility.

4.2. 5G and cognitive radio

Since some frequency given to a legitimate user in a mobile network is often idle, CR can improve the utilization of overloaded radio in cellular networks (Yang and Zhang, 2015). Auxiliary systems can use CR to obtain entry to frequency bands that have been assigned to an effective system, providing for further flexible and innovative spectrum access (Sachs et al., 2010). The secondary system discovers and utilizes frequency gaps or white spectrum spaces for a specific time that the primary system has left unused without interfering with the primary user. To designate white areas, spectrum sensing (Yucek and Arslan, 2009; Tandra et al., 2009) or geolocation combined with access to a spectrum use database might be employed.

In CR approaches, the secondary and licensed systems can share spectrum bands on an interference-free or interference-tolerant basis. Aggressive spectrum reuse, the excessive density of base stations and wireless devices, and the integration of numerous communication technologies are all features of 5G cellular networks, which must support tremendous data traffic. The physical layer of the CR architecture is responsible for various spectrum sensing methods. The link-layer handles the radio environment characterization and power control. The network layer is in charge of spectrum aware routing, whereas the transport layer is in charge of spectrum handoff. The application layer is responsible for user utility and quality of service needs.

5G Cognitive Terminals: Key Requirements and Challenges: Till we can understand the specific objectives and obstacles for cognitively capable 5G equipment, we must first establish a more comprehensive understanding and expectations for the first deployment of a 5G device. 5G devices will need many qualities to provide end-users with energy-efficient and high-speed connectivity while also being multi-utilized.

Interoperability: 5G devices must be able to connect to and interact with each other and with various wireless technologies; they will rely on CR's interoperability capabilities to do so. They should determine the optimal network connectivity based on their position and outdoor radio circumstances.

Context-awareness: 5G equipment ought to collect data from the wireless environment and adjust their radio characteristics consequently, among other things, to enable energy-efficient connection and other applications

Ability to learn: The 5G devices must be capable of transmitting data intelligently with both machines and individuals; therefore, the terminal must enable a variety of machine learning techniques.

Self-optimization: On 5G terminals, innovative optimization algorithms based on environmental information and designated wireless technology should be used to save energy-wasting and increase wireless spectrum use while maintaining necessary QoE. Since roaming will be an essential component of 5G networks, practical proposals for smooth, high-quality access, effective routing adaptation, location awareness, self-coexistence, and real-time optimization should be provided.

Dynamic frequencies are controlling: 5G devices ought to monitor a broad area of the wireless frequencies and utilize unlicensed or unlicensed spectrum bands. They will use a variety of processes within the DSA architecture to gather enough spectrums for communication.

Self-healing: it will be included in 5G devices to help users and networks overcome the issues of QoE deterioration caused by mobility, switching activities, and frequency grouping.

In this work, the authors discussed the new trends in networking, primarily the IoT domain, and the future technology. The leading research in networking focuses on IoT and 5G systems discussed in this paper. For IoT systems, there is a quiet consent between researchers on the architecture (cloud, fog, and edge). However, the communication part is still a work camp. The competition involves LPWAN, cellular, and personal/local wireless protocols. Each of them presents its pros to capture more applications. In the previous sections, we have discussed in detail each of them. 5G radio communication is a promising technology that will outperform all the former technologies; we must combine the best of LPWAN and cellular (low power consumption and high range). The last point is the cognitive radio; this technique is so essential nowadays that we all know that the radio spectrum is scarce. So, why not combine IoT systems with radio cognitive to release more spectrums and communicate as secondary users. It helps to liberate the spectrum, especially for IoT applications' best effort. In our future works, we will combine IoT and RC to liberate more spectrums for applications that do not need severe communication constraints. Like that, we can apply IoT apps on a large scale in our society.

5. Conclusion

In this paper, we tried to present detailed work on the new trends in networking, especially IoT, wireless radio communication protocols, and cognitive radio systems. We gave the fundamental architecture of an IoT system, namely cloud, edge, and fog computing; we also talked about the communication protocol involved. 5G radio communications seem to be a revolutionary technology, and researchers are working on using IoT, and 5G, 5G must take advantage of LPWAN and cellular networks. Finally, we give an overview of radio cognitive and dynamic spectrum access. To conclude this paper, we consider combining radio cognitive and IoT for best-effort application for two reasons: liberate more spectrums for other utilisation, and trying to force the society to use IoT application because this later uses only the free spectrum with no costs; we will try to concretize this idea in the following paper.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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