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LoRa: A Proposed Connectivity Technology for Internet of Things Applications in the Kurdistan Region of Iraq

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ABSTRACT

The Internet of Things (IoT) has become one of the most important trends of this century. Recent advances in many different communication technologies and protocols, and access to low-cost and low-power microcontrollers and sensors have made it more prevalent. Globally, most IoT adoption comes from developed countries such as the United States, United Kingdom, Western Europe, and East Asia, as these countries have a well-established nationwide IoT infrastructure. In contrast, the IoT application in developing countries such as Kurdistan Region of Iraq (KRI) remains restricted as deployment faces main challenges. On the one hand, selecting the right technology for IoT applications can be complicated with so many IoT connectivity technologies such as Cellular, Wi-Fi, Low Power Wide Area Network (LPWAN), Bluetooth, and ZigBee on the market. On the other hand, the main impediment seems to be the lack of IoT infrastructure technologies in developing countries.

In this paper, a comparative study on the main LPWAN technologies has been carried out in terms of cost and coverage of the network and range to become connectivity technology for IoT applications in the KRI. Based on the study, LoRa technology has been presented and proposed as the optimal connectivity technology to establish an IoT infrastructure for the KRI. The proposed network enables the deployment of IoT applications easier and faster. In addition, various LoRa based IoT applications have been proposed that benefit many sectors. To show case the significance of the new infrastructure, a LoRa-based weather monitoring station has been proposed as a case study.

The proposed LoRaWAN infrastructure can accommodate a vast range of applications and will revolutionize IoT applications in the KRI as it enables data transmission over a long distance while using extremely low power.

1. INTRODUCTION

The Internet of Things (IoT) is among the newly emerging communication frameworks extending the world wide web and allowing Machine to Machine (M2M) communications. Until quite recently, humans fully controlled Internet-connected devices, which consisted mainly of tablets, laptops, and smart phones. However, the IoT will allow any kind of gadget to connect to the Internet, such as smart tags and sensors [1].

Smart houses and smart cities are examples of the use-cases of the IoT, which is becoming increasingly popular. As a consequence, the network scale and density is increased. According to Ericsson's mobility report [2], the connected IoT device population will grow from seven billion in 2017 to twenty billion in 2023, which translates to a 19% annual growth rate. Gadgets with sensing abilities that can interact with the environment, other equipment, and people to make smart decisions are used widely in the IoT. Wireless networks are necessary to link IoT devices while maintaining high reliability and energy efficiency. Batteries power the majority of the IoT end gadgets. They are typically expected to operate between five and 10 years without the need for repair or maintenance. Additionally, these IoT end-nodes should span a large geographic area.For instance, forest monitoring projects deploy end-nodes all over the forest. These devices then communicate smaller payload data between each other over a wide distance to send valuable data such as temperature, humidity, and other essential parameters [2][3].

Globally, the vast majority of IoT adoption comes from developed countries. Each of the following factors contributes to the growth and development of IoT: government efficiency, local infrastructures such as networks and cloud infrastructure, accessible resources, and a favorable environment for innovation and investment. Economic concerns undoubtedly play a part as well [4].

International Data Corporation (IDC), a market intelligence company specializing in information technology, telecommunications, and consumer technology; has released a rating of countries' capability for Internet of Things (IoT) development (the G20 Internet of Things Development Opportunity Index Ranking) utilizing thirteen criteria. According to the study, the United States, South Korea, and the United Kingdom are the three nations most prepared to create and profit from the IoT. The United States performed incredibly well on ease of doing business, government effectiveness, creativity, cloud infrastructure, and GDP and technology expenditure as a percentage of GDP. Despite its small GDP, South Korea performed very well in IoT-related spending and has a corporate climate that encourages development and encourages attractive investment possibilities. Similarly, the United Kingdom scored well on criteria of business ease, government effectiveness, institutional quality, start-up processes, creativity, and broadband penetration [5]. Australia emerged as the ranking's standout nation, scoring exceptionally high on ease of doing business and start-up processes, government effectiveness and institutional quality, as well as creativity and education. Australia's results indicate that the nation has the essential elements for an IoT-ready corporate environment.

Beyond the countries outside the G20, there are undoubtedly nations with a high level of maturity in terms of the IoT and significant deployments. For example, in the Netherlands, two rival LPWAN technologies, LoRaWAN and Sigfox, provide countrywide IoT coverage [6]. The nation boasts a robust cloud infrastructure and many IoT installations, which are often highlighted. Additionally, the country has The Things Network (TTN), which intends to build LoRaWAN networks in every city on the planet. The network establishes a global infrastructure to enable a global IoT [7].

In contrast, the IoT application generally in the developing countries and particularly in the KRI1 are minimal and facing main challenges [8][9][10]. The factors that significantly impede IoT adoption are relevant to the KRI, lack of modern infrastructure, lack of research in the field, and unstable power resources. Despite some recent efforts by some universities to hold conferences and workshops by some mobile operators relevant to IoT [11][12][13], challenges still exist, and IoT applications remain minimal. To date, to the best of the author's knowledge, unfortunately, it seems to be very difficult for researchers to find a significant IoT project or application in the KRI, even though there is a very small number of IoT projects at undergraduate levels at some universities. These projects are based on a basic level of microcontrollers and sensors and are not suitable for real IoT applications.
There are also difficulties in selecting the right IoT connectivity technologies. Several IoT technologies on the market include Wi-Fi, Cellular, LPWAN, Bluetooth, and ZigBee. Although. The KRI does not have any IoT network, but it has an excellent Internet infrastructure that can be utilized as a backbone for any future IoT network. For instance, three mobile operators, Asiacell, Korek and Zain, provide excellent cellular coverage in 2G, 3G and 4G LTE for voice and internet access. In addition, several internet providers are using 4G LTE coverage, such as Fastlink and Tishknet [14]. Figure 1 shows the internet coverage of Fastlink in the Region [15].

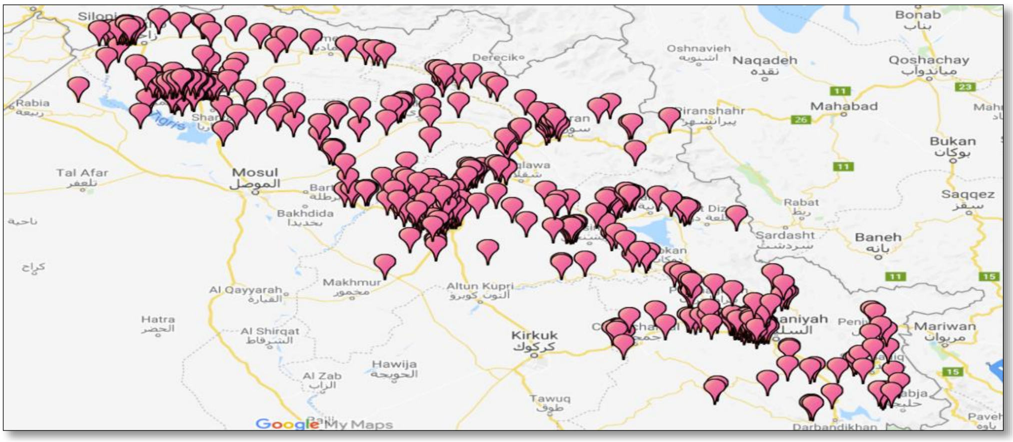

Figure 1: Fastlink internet coverage [15].

Also, many companies provide an excellent fiber-optic infrastructure in the main cities and towns, such as IQ net and others [16].
As the IoT networks require internet connectivity using either Ethernet, Wi-Fi or cellular, an IoT network can be established based on this wide internet coverage. But IoT use cases need more advanced technologies to operate in a cost-effective, low-power manner along with low-complexity end devices that can cover long-distance communications wirelessly. Because most IoT end nodes are sensors supplied by batteries, the power consumption profile will be similar to those devices should be carefully configured to maximize battery life. Since end devices are dispersed around a wide area of service, communication ranges must go from a few hundred meters to several kilometres.
The remaining part of the paper proceeds as follows: Section 2 reviews the leading LPWAN IoT connectivity technologies that can become the infrastructure for IoT networks, emphasizing on LoRa. In Section 3, various LoRa based IoT applications has been proposed that benefit many areas., A focus on a case study in Section 3.4 is provided to showcase the

[1] The Kurdistan Region of Iraq (KRI) is a relatively new autonomous region in Northern Iraq. It borders the Kurdish regions of Iran to the east, Turkey to the north, and Syria to the west, along with the rest of Iraq to the south. The regional capital is Erbil, known. The region is officially governed by the Kurdistan Regional Government (KRG).

significance of the new infrastructure. Finally, Sections 4 and 5 present the discussion and conclusion.

2. IOT CONNECTIVITY TECHNOLOGIES

IoT wireless technologies allow different objects to communicate with one another, resulting in smart applications. This section presents the leading IoT technologies. As many papers review various IoT technologies, this section focuses only on the main players with the potential to build a wide range of infrastructure networks. There are mainly three network technology categories for IoT applications: standard wireless technologies, cellular-based LPWAN and proprietary LPWAN. The suitability of each type to become connectivity technology has been evaluated in terms of cost, network coverage, and range.

2.1 Standard Wireless Technologies

The main internet access technologies such as Wi-Fi and cellular networks (2G, 3G, 4G/LTE, 5G) play the primary role in connecting many consumer gadgets to the Internet worldwide. There are already many IoT devices that use these technologies.

2.1.2 Wi-Fi

Wi-Fi is a collection of solutions for WLAN. Unlike Bluetooth and ZigBee, which offer inter-device networking, Wi-Fi offers last mile wireless connectivity for gadgets to the world wide web with greater distances and Data Rates (DR) [17]. In reality, Wi-Fi has undergone many iterations of development to achieve better connections. In particular, IEEE 802.11a and IEEE 802.11b were launched in 1999, with IEEE 802.11a supporting DR up to 54 Mbps in 5 GHz and IEEE 802.11b supporting 11 Mbps in 2.4 GHz. IEEE 802.11g was launched in 2003, and it offered DR of up to 54 Mbps at 2.4 GHz. Although, because of the low connectivity and capability, IEEE 802.11a/b/g models could not satisfy the high demand for hypermedia apps through WLANs. As a result, in 2008 and 2014, new iterations of WLANs, namely IEEE 802.11n and IEEE 802.11ac, were launched. These modern generations utilized dense modulation and Multiple Input Multiple Output (MIMO) technology to provide higher DR of up to 600 Mbps in IEEE 802.11n and 7 Gbps in IEEE 802.11ac, which offered a much broader connection distance than the other generations of IEEE 802.11a/b/g. IEEE 802.11ah, also known as Wi-Fi HaLow, launched in 2017 so that IoT gets expanded connection distance and low-energy usage. It works under the unlicensed sub 1 GHz connection bands, except white space bands of TV, and occupies only 1MHz of bandwidth on average.

As can be seen, although Wi-Fi offers high-throughput data transfer for both company and home-based environments. Significant scalability, coverage, and power consumption constraints render the technology unsuitable for IoT applications, especially vast networks of battery-powered IoT sensors. However, as most buildings have internal Wi-Fi and Ethernet coverage-connected via fibre, ADSL, 4G LTE or a wireless link, the technology can become an excellent backhaul for IoT networks. Most of the IoT gateway devices have Ethernet or Wi-Fi backhaul connectivity [18].

2.1.3 Cellular (2G, 3G, 4G/LTE, 5G)

Cellular networks connect physical things such as sensors to the Internet using the same network for mobile communications. The network is best-suited for IoT solutions that require long-distance data transfers combined with low latency [19]. With the deployment of the latest generations, such as 4G and 5G, that data transfer increased, and the latency decreased.

3G, 4G/LTE, and 5G cellular networking systems are some of the very appropriate and efficient standards for precision agriculture, where a significant volume of fast data must be exchanged and calculated. For example, in LTE-Advanced Release 10, the downlink DR can go as high as 3 Gbps, and the uplink DR can go as high as 500 Mbps, with a delay of no more than ten milliseconds [20]. Furthermore, 5G is supposed to support high-speed end-to-end communication, allowing for car parking. Moreover, a lot of gadgets could be assisted in a kilometer-square radius. In contrast to LTE, the new 5G can operate on high-frequency bands, allowing for broader channel bandwidths. 5G technology, which offers high DR and wider connections ranges by appealing to the ideal of high-speed connections or real-time connections, can allow new capabilities on farm equipment, particularly in rural areas. Nevertheless, the presence of cellular networks and the economic viability of 5G in farms remains a challenge [21].

Hardware, maintenance, monthly charges for rates and data plans, and power usage are all factors to consider. pose new challenges to this solution for many IoT applications. In some developing countries, the new generations have more challenges. For instance, in the KRI, 4G was deployed in 2020 [22], and Zain was the first telecommunications company in Iraq to provide 4G-LTE services in a "test phase" after meeting all licensing requirements. Mobile operators will profit from 4G infrastructure. In contrast, 5G has already been deployed in many developed countries [23]. To that end, cellular networks can provide an excellent choice as backhaul for an LPWAN system.

2.2 Cellular-based LPWAN

To provide IoT further expansion and evolution, the mobile industry has developed and standardized these technologies. In cellular IoT, also known as mobile IoT, devices and sensors connect to the Internet by utilizing mobile networks. The existing telecommunication network operators support these LPWAN technologies. The standards are inside the licensed spectrum and developed and governed by the 3rd Generation Partnership Project (3GPP) and GSMA [24]. The cellular IoT applications use various technologies like LTE-M, NB-IoT and EC-GSM-IoT. The main features are longer battery life, better coverage, and lower costs. However, for building a network that covers a wide area Numerous cost considerations should be made, including spectrum (licensing) fees, installation costs, and terminal prices. In this regard, cellular-based LPWAN costs more than proprietary LPWAN technologies such as Sigfox and LoRa as they are built on the existing cellular network [25].

2.2.1 NB-IoT

The Narrow Band IoT, also known as NB-IoT, is a narrow-band communication type of protocol that uses 180 kHz of bandwidth in IoT applications [26]. The downlink communication rate of this technology is 250 kbps, while the uplink communication rate is 20 kbps per second. Another problem is the implementation of NB-IoT, which necessitates a hardware upgrade of the current LTE framework. Moreover, NB-IoT can only be implemented via a carrier provider's communication service. As a result, it is costly and does not provide the transparency that other IoT technologies do [27]. In-band, guard-band LTE, and standalone modes are all possible modes that can be used with NB-IoT. While the In-band mode uses the LTE connection band, standalone utilizes an exclusive variety such as GSM connection bands, guard-band mode uses the unused portion of the LTE band. Since this technology does not allow hand-over, it is not viable for mobile IoT use cases. This technology is already implemented in some places and is currently being implemented in others. Nevertheless, unlike LoRa and Sigfox, this technology includes a hardware update of the current LTE model, making it more challenging to deploy [26].

2.3 Proprietary LPWAN

2.3.1 Sigfox

Sigfox is an LPWAN framework that provides a complete IoT networking service based on its patented features [28]. Sigfox uses an IP-based network to link its exclusive base stations to the back-end servers, configured with innovative software adjusted radios. Moreover, Binary Phase Shift Keying, commonly known as BPSK modulation, is used to link the end devices to these base stations via a sub-GHz ISM band frequency with a specific range of 100 Hz. Unlicensed ISM bands in North America, Europe, and Asia include 915 MHz, 868 MHz, and 433 MHz, consequently, which Sigfox utilizes. Sigfox uses a very narrow band to use the frequency bandwidth effectively. At the same time, they are experiencing a minimal amount of noise, resulting in low energy usage, high recipient sensitivity, and cheap antenna models that are possible at the cost of a maximum throughput of just 100 bps. The framework Sigfox began as an uplink-only system but later developed into a bidirectional system with significant connection asymmetry.

Downlink communication can only occur after an uplink communication, for example, information from the base stations to the end-nodes. Each day, the maximum quantity of message data sent via the up-link is restricted to 140 messages. And the size of every up-link message can have a maximum payload length of 12 bytes [25]. Nevertheless, the amount of message data sent over the downlink is restricted to 4 messages daily, which implies that every up-link message will not be acknowledged. Each downlink message can have a maximum payload length of eight bytes. The effectiveness of the up-link connection is protected by using frequency and temporal diversity, as well as signal to duplicate when recognitions are inadequate. Every end-device message data is sent out many times, usually three times on various frequency channels. Because of this, in Europe, the frequencies band between 868.180 MHz and 868.220 MHz are divided into four-hundred orthogonal 100-hertz channels, which amidst them forty channels are not utilized. Since the base stations can accept message data on every track simultaneously, the end-node can select a channel frequency randomly to send their message data. This further disentangle the end-system model and makes the gadget.

2.3.2 LoRa

LoRa is an RF-based modulation technique that is optimized for LPWANs [25]. The name LoRa refers to the capability of the technology to establish extremely long-range communication systems. LoRa, which Semtech developed to standardize LPWANs, allows long-range connections of more than 5 kilometres in city areas and up to 15 kilometres in farm areas considering the distance between the points. The ultra-low power consumption of systems using LoRa is one of its key features that allow the development of battery-reliant gadgets that can work for ten years. A network architecture based on the open-source LoRaWAN protocol and implemented in a star network topology is suitable for applications that need long-range or deep mortar-and-brick connections. amidst a massive number of low power consuming gadgets that collect and communicate small amounts of data. The chirp-spread-spectrum, also known as CSS modulation, diffuses a narrow-band connection over more channel bandwidth and obtains bidirectional communication [29].

LoRa, similar to Sigfox, operates on unlicensed ISM-bands, which include 868 MHz in Europe, 433 MHz in Asia, and 915 MHz in America. Figure 2 shows an infographic of the latest LoRaWAN implementation around the world. The ability to implement LoRa base stations by regular users to expand the connection is another advantage of using LoRa. To enforce the data rate and range advantage, LoRa employs six diffusing factors from Spread Factor SF7 to SF12. A wider range at the expense of a lower data rate is possible with a higher spreading factor, and vice-versa. Based on the diffusing factor and bandwidth of the channel, the LoRa data rate ranges from 300 to 50 kbps.

Furthermore, messages sent with different diffusing factors can also be received by LoRa base stations at the same time [30][25]. The LoRaWAN sets the network's connection protocol and framework design, while the physical-layer of LoRa enables for the network's long-range connection link. The network and protocol architecture have the most significant impact on a node's battery life, Quality of Service, network bandwidth, security, and the range application range that can be supported by the network[31].

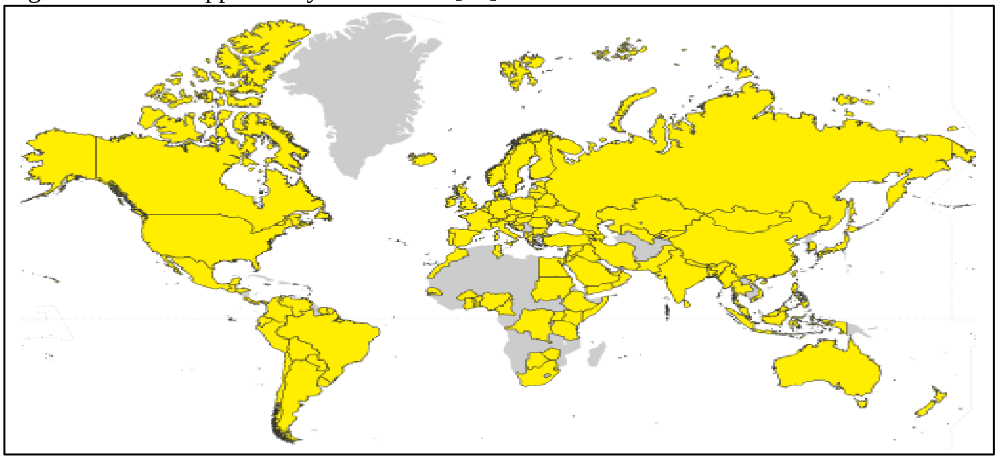

Figure 2: Deployment of LoRaWAN in the world countries [29]

2.3.2.1 Architecture

A mesh network architecture is used in many currently deployed networks. Individual end-nodes in a mesh network relay other node information to extend the network's contact range and cell size. Although this improves coverage, it also adds complexity and decreases the network bandwidth while shortening battery life since nodes accept and relay data from other end-nodes that are possibly meaningless to them. Long-range networking is possible through long-range star architecture that makes the most sense for maintaining battery life. Figure 3 shows the architecture of LoRaWAN.

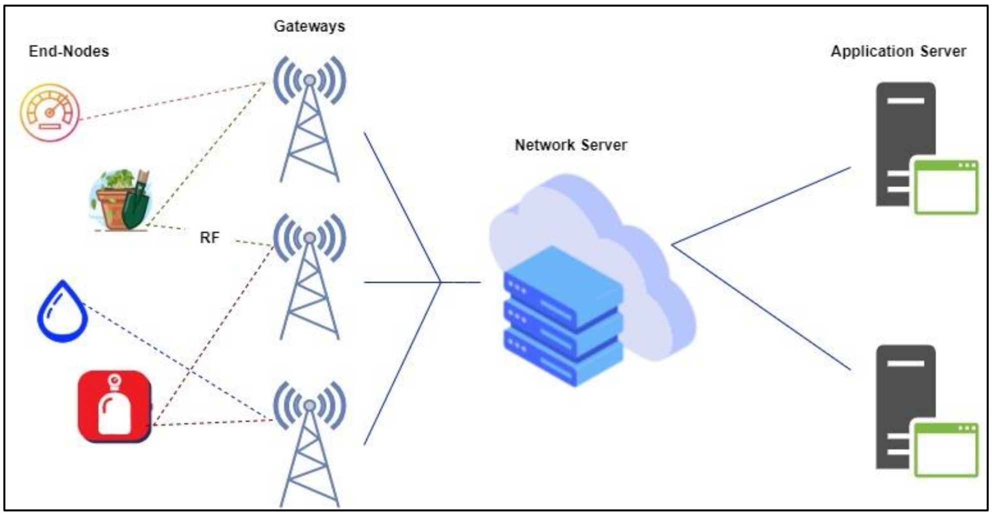

Figure 3: LoRaWAN architecture

A sensor or actuator that supports LoRaWAN and is remotely connected to a LoRaWAN system by using radio gateways utilizing the RF Modulation of LoRa is known as a LoRaWAN-enabled end device.

A Gateway of LoRaWAN accepts LoRa Adjusted RF message data from every end-device within listening range and transmits them to a Network Server (NS) linked to the Internet through an IP structure. The connection between an end system and a specific gateway is not fixed. Rather than, several gateways located across the area may service the same sensor. As shown in Figure 3, every uplink-generated packet relayed by the end-node is accepted by all of the gateways in range with LoRaWAN. Due to the high probability that one gateway would receive the messages, this configuration significantly reduces packet error rates. It also reduces battery use for mobile and nomadic sensors while allowing cheap geolocation, considering that the utilized gateways are capable of geolocation. Wi-Fi manually wired Ethernet can all be used to backhaul IP signals that are coming from a gateway to a network back-end. The NS controls every aspect of the network. It simultaneously controls connection variables to adjust the network to the constantly unstable variables. It uses 128-bit AES links for security in the communication of user device to device information, meaning that it transports it from the LoRaWAN system to the devices. This dynamic similar to the application in the cloud system, along with traffic control from LoRaWAN server to the NS, which returns the cycle afterward. The network system confirms the validity of any data collector on the system as well as every message's legitimacy.

On the other hand, the network server is unable to view or access the data of platform. Sensor device data must be safely handled, interpreted, and managed by application servers. They also produce all software downlink data for linked end devices [31].

2.3.2.2 LoRa Physical layer

LoRa modulation builds on conventional diffusing spectrum concepts to lower the power needed to send data through channels. Bit rate (R_b) in available connections could be calculated from the bandwidth BW, the coding rate CR, and the Spreading Factor SF as in (1) [31]:

$$R_b = SF * \frac{BW}{2^{SF}} * CR \qquad (1) \; [32]$$

In terms of interference management, LoRa modulation outperforms Frequency Hopping techniques. With a decrease in sensitivity of less than 6 dB, the configuration can withstand disturbances of variable energy such as 30% in terms of symbol length. SF is the most critical parameter in determining service reliability. Data Rate (DR) is a lot, and the corresponding period is concise since it uses the lower range of spreading-factor numbers. The higher the SF, the wider the coverage. However, it lowers the service reliability. Spreading factors that range from severe to twelve can use orthogonal connections; for example, different systems could communicate simultaneously using the exact frequency band-connections with no disturbance [33].

2.3.2.3 LoRaWAN MAC layer

LoRaWAN, a MAC-layer that controls intermediate-usage for nodes that use many frequencies, LoRa Alliance developed and maintained the LoRaWAN open standard. As shown in Figure 4, there are three key access groups: A and B and C, which are present for various energy use schematics. This protocol assumes every message sent from a node should be handled by the accepting gateway to prevent unwanted messaging. The receive windows can be used to manage acknowledgement messages, but the ACK mechanism was not one of the protocol's key concerns when it was designed.

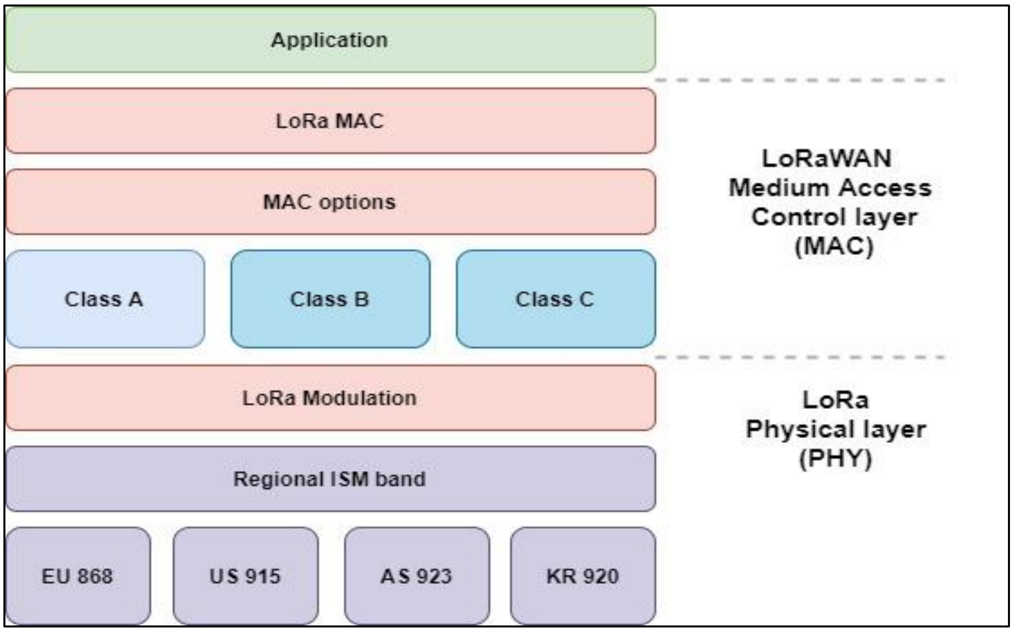

Figure 4: LoRa physical and LoRaWAN MAC layer

The device's class is determined by how the receive windows are managed. Class-A devices only allow the accepting windows two following a message-data that has been sent. As a result of this approach, Class-A devices use power very efficiently. A receiving window is opened by Class B devices regularly. Beacons are used to synchronize these windows. To minimize downlink latency, Class-C devices eventually hear the network constantly. These devices are the most energy-intensive and need a reliable power supply. The Adaptive Data Rate (ADR) mechanism is used to control the DR of the connection between end-devices and gateways. The data rate varies depending on the distance between 0.3 and 50 kbps. The ADR scheme optimizes the DR of each individual device. Moreover, DR controls the range and power usage of devices. The higher the power consumed through transmitting a byte, the lower the data rate, but the greater the connection range.

Greater DR uses power more efficiently in energy expenditure by each transmitted byte. However, the range is smaller, and packet-drop rates are more prevalent. The LoRaWAN configuration uses the system work with the biggest possible DR. An activation method is needed to join a LoRa network. The standard model defines two methods for activation includes Activation By Personalization (ABP) and Over-The-Air Activation (OTAA). ABP configures nodes to operate in a particular LoRaWAN system. As a result, the Network and Application sessions are pre-installed on the devices. OTAA, on the other hand, requires devices to submit a joining message to a particular LoRa system to get an address for the device and an authorization token . OTAA activation works with dynamic network-keys and roaming [33].

3. LORA BASED IOT APPLICATIONS

LoRaWAN supports a broad range of IoT applications applicable to a wide variety of markets. Recently, a significant amount of research has proposed and implemented IoT-based monitoring solutions in many different areas. This section discusses and offers several potential applications for the KRI where LoRa-WAN can significantly impact and be utilized effectively.

3.1 Water Resources

Water is regarded as the most important and valuable natural resource on our planet and plays a crucial role in developing the most economic and agricultural sectors. The KRI primary water sources are groundwater, rivers, dams, ponds, wells, and springs [34]. In addition, from 2009 to 2017, Kurdistan's population grew at an incredible rate [35]. This necessitates an increase in irrigation and drinking water capacity. Therefore, an adequate water resource management system is required. For instance, displaying the water level in dams and the level measurement with a LoRaWAN-based system will keep the area safe from severe issues like water crises. Additionally, the system assists in making an informed decision, such as developing a water management plan to reduce use or consulting a professional evaluation. By adopting a water level monitoring solution, users can better understand the situation from anywhere and at any time.

3.2 Agriculture

IoT applications enable efficiencies that reduce environmental impact, protect resources, and minimize expenses in this sector. Additionally, the applications can provide significant improvements, such as water reduction for farms. The IoT is becoming increasingly apparent in the field of smart farming and agriculture. The goal of these applications is to collect and monitor agricultural data at the same time.

3.3 Smart Energy Metering

Traditional utility operations are performed with many labor forces by sending personnel to the field, which is costly. A LoRa based application can easily collect data remotely and manage the billing system. As this field has many challenges and is not yet regulated in the KRI, LoRa technology can benefit significantly.

3.3.1 Electricity Metering

New innovative power metering solutions are an attractive alternative to other connection options for IoT networks and smart grid applications, thanks to the emergence of LPWAN technology. Cost and resource savings result from better monitoring. For example, Lar. Tech[36], a Russian intelligent technology innovator and member of the LoRa Alliance, provides a module that can be used with energy meters to gather data remotely in broad urban areas—using meters that integrate LoRa. Lar. Tech has also developed an automated meter reading (AMR) solution for the power grid industry. Following a successful trial in 2017, Lar. Tech began rolling out 50,000 smart energy meters to install 1 million by the end of 2023 [37].

3.3.2 Water Metering

Utility providers may effectively gather data and analys it in real-time by installing a smart metering system composed of sensors and gateways that use the LoRaWAN standard, simplifying operations and saving expenses. For instance, Birdz [6], a Nova Veolia subsidiary and a global pioneer in resource optimization, used LoRaWAN technologies to help clients manage their energy more efficiently. Customers use these solutions to reduce non-revenue water and promptly discover problems in their water distribution network, including major municipal utility providers. Birdz runs approximately 400,000 end devices in the city of Lyon, France, as an example. Since its implementation, over 1,200 leaks have been discovered, saving about one million cubic meters of water each year. In addition, Lyon's water network efficiency has increased by 8%, from 77 percent in 2015 to 85.2 percent in 2019 [37].

3.3.3 Gas Metering

Meters used in a gas utility application must be capable of operating for long periods of time and communicating data on a regular basis. Gas utilities may increase safety and economy by integrating smart metering technology with sensors for intelligent valves, gas pressure monitoring, and gas leak detection on the same network. Cavagna Group [38], a leading supplier of intelligent solutions and equipment for regulating and controlling compressed gases, has created a line of advanced smart meters based on LoRa devices and the LoRaWAN protocol. To link the meters to cloud platforms, smart meters use LoRa devices embedded in them. Using Cavagna Group's platform or a third-party application, utility companies may access and analyze meter data. To that end, it has allowed utilities to develop new billing methods that benefit utility customers while also monitoring real-time, accurate gas use. Customers can make energy-saving modifications to their behaviors using data given by these billing models [37].

3.4 Case Study: LoRa-based Weather Monitoring Station

The weather monitoring system is primarily used to track the change in climatic and meteorological conditions in specified regions by collecting various data like air temperature and relative humidity, pressure, wind speed and direction, and rainfall rate. In the KRI, weather stations are traditional, and most of the works are performed manually. In addition, due to the cost, additional stations can not be easily deployed in other places whenever required.

In a visit to the Sulaimany directorate of Meteorology and Seismology, a governmental department responsible for monitoring the weather and concerned with earthquakes and related phenomena in the city, it has been noted that most of the works are performed manually. For example, they take weather parameters like air temperature, humidity, barometric pressure, dew point, wind speed and direction, etc., every ten minutes. Then, all data are sent to the meteorological center in Erbil every three hours through the Viber communication network. Based on the analysis, the authors proposed a LoRa-based weather monitoring system to this department.

3.4.1 Proposed Weather System Architecture

Figure 5 illustrates a proposed weather station architecture using LoRaWAN protocol to transmit sensor data. The end-node comprises weather sensors like air temperature, pressure, relative humidity, wind speed and direction. All sensors are directly connected to the microcontroller (MCU) that is responsible for dada acquisition. After measuring, the LoRa module transmits the collected data to the getaway and then to a Network Server (NS). Finally, the collected data can be analysed and visualized on IoT platform.

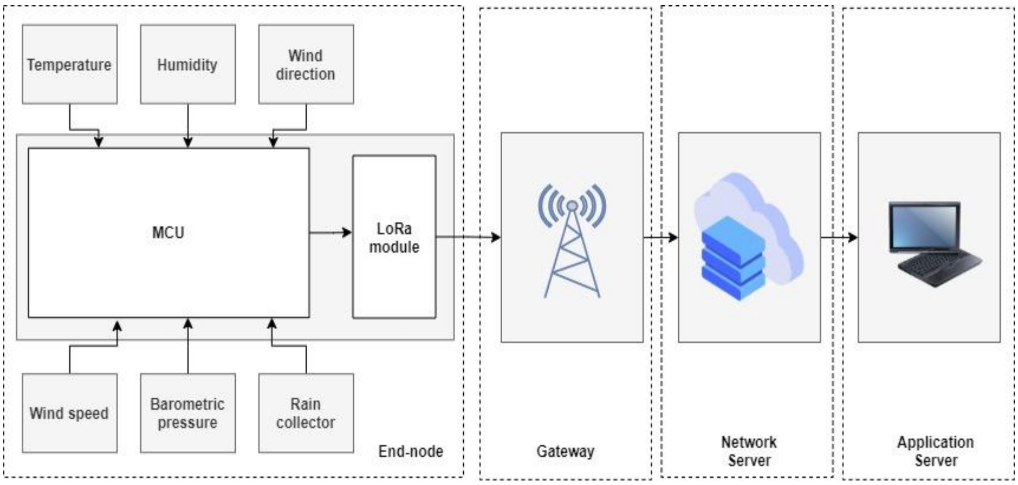

Figure 5: Proposed Weather System Architecture

4. DISCUSSION

Table 1 summarizes the main characteristics of LPWAN technologies alongside Wi-Fi and cellular.

Table 1. Summary of IoT Connectivity Technologies [19][27]

	Sigfox	NB-IoT	LoRaWAN	Wi--Fi	Cellular (2G, 3G, 4G/LTE , 5G)
Frequency band	Sub-GHz ISM: EU (868 MHz), US (902 MHz)	Licensed 700–900 MHz	Sub-GHz ISM: EU (433 MHz, 868 MHz), US (915 MHz), Asia (430 MHz)	2.4-60 GHz	900MHz , 2100MHz, 2600MHz, 3-90GHz
Channel-Bandwidth	100 kHz	200 kHz	125 kHz	20 or 40 MHz	364 kbps, 3 Mbps, 100 Mbps, 10 Gbps
Modulation	DBPSK, GFSK	QPSK	CSS	DSSC	GMSK, QPSK, QPSK and QAM
Range	10 Km in urban, 40 km in rural area	1 Km in urban, 10 km in rural area	5 km in urban, 15 km in rural area	100m	50 miles, 35 miles, 10 miles, 1,000 miles
Payload size	12 B (UL), 8 B (DL)	125-B (UL), 85-B (DL)	243 B	1500 B	Unknown
Data rate	100 bps (UL), 600 bps (DL)	158.5 kbps (UL), 106 kbps (DL)	03–37.5 kbps (LoRa), 50 kbps (FSK)	Maximum 54mbps-12Gbps	64 kbps, 144 kbps-2 Mbps, 100 Mbps-1Gbps, 1 Gbps<
Bidirectional	Mostly unidirectional and limited half-duplex	Yes/Half-duplex	Yes/half-duplex	Yes/full-duplex	Yes/full-duplex
Battery Life	5-10 yr	5-10 yr	5-10 yr	Hours	Continius power
Cost of Building a Network	4000€/ base station	15000€/ base station	100€/ gateway >1000€/base station	300-500€	>15000€ / base station
Reliability	Yes	Yes	Yes	Yes	Yes

Table 2 summarises the IoT applications with connectivity technologies based on the requirements of selected IoT applications.

Table 2. Connectivity technologies for IoT applications[25][39]

Requirements	IoT applications	Communication technologies
Data rates	Video camera streaming	Wi-Fi, 4G-LTE, 5G
	System for cooking	ZigBee, Bluetooth, Wi-Fi
	Water meter and Energy	NB-IoT, Sigfox, LoRa, ZigBee
Latency	Self-driving, wellbing sensors	Wi-Fi, 5G, LoRa, Sigfox
	Sensors for waste management	NB-IoT, ZigBee, Sigfox, LoRa
Coverage	Sensors for smart farming	Wi-Fi, 4G-LTE, 5G, LoRa, Sigfox, NB-IoT,
	Appliances for the smart house	Wi-Fi, Bluetooth, ZigBee,
Power	Tracking, smart-retail	Wi-Fi, Bluetooth, ZigBee, 5G,
	Pollution monitoring	LoRa, Sigfox, NB-IoT
Reliability	Patient monitoring in real time	5G, LoRa
	Smart-farming	LoRa, Sigfox, NB-IoT
Mobility	Autonomous vehicles	5G
	Smart traffic-lights	LoRa, Sigfox, NB-IoT, ZigBee

For various IoT applications, short-range, medium-range, and long-range technologies are utilized. For instance, short-range technologies such as Bluetooth can be used to support innovative home IoT applications. For medium-range technologies such as ZigBee and Wi-Fi, more data rates and coverage can also be used for high data rates and low delay indoor use cases. Long-range technologies are needed to be utilized in a loT of gadgets distributed in a broad region. LTE and 5G can efficiently serve multi-media and apps very reliably with low delay in terms of connectivity. Generally, LoRaWAN and Sigfox networks give connectivity distance, cost-effective implementation, fewer linking problems, and a solid device and battery lifespan. NB-IoT and other cellular technologies are best suited for higher-value IoT applications.

From the features, LoRaWAN seems to be the optimal candidate for building an infrastructure for IoT applications in the KRI, as the cost of building a network is inexpensive compared to other technologies, and no licence is required for LoRa as it operates in the unlicensed ISM radio band which is available worldwide.

5. CONCLUSION

The IoT market is projected to grow exponentially in the years to come. This growth offers potential opportunities to individuals and businesses alike. With many IoT connectivity technologies on the market, selecting the right technology for IoT applications can be complicated, particularly in developing countries. The paper set out to review various IoT connectivity technologies in the KRI. The study has identified and proposed LoRa connectivity as the optimal connectivity technology that enables the deployment of IoT applications easier and faster. The LoRa's main features of wide range coverage, low power requirement, and relative cost of the required hardware make this technology the primary candidate. The proposed LoRaWAN infrastructure can accommodate a wide range of applications and revolutionise IoT applications in the Region.

In the KRI, establishing a LoRa-based network infrastructure is more effective and achievable by individuals and institutions. LoRaWAN networks can be built as public, private or enterprise networks; this enables a region like the KRI to befit significantly from this technology to establish its own IoT infrastructure. In addition, various LoRa-based IoT applications have been proposed that benefit many sectors. A potential application has been set out as a case study to showcase the significance of the new technology.

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