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Comparative Study on IoT Technologies - Short & Long Range

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Abstract: *IoT provides extraction of data from things by using sensors & processing it further for decisions or actions. Without connectivity, it is tough to accomplish the same. To establish the connectivity between things and data processing units, IoT technologies play an imperative role. Short & long-range communication technologies support in realizing the goal. Short-range communication technologies (RFID, Bluetooth, Zigbee, wi-fi) use unlicensed spectrum, and Long-range communication technologies use unlicensed (Lora WAN, Sigfox, Weightless) and licensed (LTE, GSM, NB-IoT, 5G) spectrum. This paper provides a comparative study of these technologies in terms of frequency bands, power consumption, range, cost, security, standards & throughput, which help provide competent solutions in the IoT industry. Latest IoT technologies effectively connect with a massive number of devices with reduced power consumption, low cost, easy deployment & extended coverages in rural & urban areas.*

Keywords: *Internet of Things; IoT Technologies; IoT Application LoRa WAN; LoRa*

I. INTRODUCTION

Internet of things (IoT) has significantly changed the thought process of a human being. A human can understand the behavior of things or objects by connecting them to sensors, which send the data through communication technologies to backend processing units. IoT technologies play an important role in bridging between things/objects and backend data processing units. A lot of devices are used to connect for transmitting data by using communication technologies. IoT Technologies uses short-range & long-range communication technologies [1],[2],[5]. For connecting things, short-range technologies are being used. RFID, wi-fi [3], ZigBee, Bluetooth, and Z- Wave use short-range communications technology [5]. Short-range technologies form a mesh network with multiple hops. It allows establishing a connection in a short distance up to 100 m [1]. Therefore, short-range technology has limitations in terms of distance. The range is based on the Parameters like frequency, transmission power, antenna construct, data rate, etc. However, the primary factor in distinguishing range is the frequency in which technology operates. The lesser the frequency more distance will be covered [25]. Short-range technologies use unlicensed spectrum [12]. Therefore, to connect multiple devices across a long distance, long-range technologies are being used. Technologies like Weightless, Lora WAN, Sigfox, Ingenu RPMA, LTE, NB-IoT, GSM are used as long-range technologies [5].

Long-range technologies use unlicensed and licensed spectrum [12],[14]. LPWAN (Low power wide area network) is part of IoT technologies with power efficiency and taking momentum for enabling the IoT network [2],[4],[9].

Combination of short Range & long-range technologies is being used in smart city applications for monitoring health of the building, waste management, environment, smart grid, smart health, smart parking, the navigation system in buses for tracking, autonomous driving, smart metering, home & industrial automation, warehouse logistics, etc. [7],[1],[15]. Technology depends upon parameters like low power, Range, data rate, frequency, cost & security, etc.

There will be exponential growth on smart IoT devices and expected to grow to 75 billion by 2025 [4]. Therefore, multiple devices will be generated simultaneously and sent to a centralized data processing unit. Data generated from personal health devices, home security, logistics monitoring, etc., may have a serious threat to individuals or companies. Leakage of personal data will also be a violation of privacy policy. Controlling or freezing IoT devices by doing illegitimate updates & protecting devices from malwares are some of the IoT network's challenges [28]. Therefore, security plays a paramount role while implementing IoT solutions. Data transmitted by IoT enabled devices in the IoT network can be secured using security algorithms. For robust IoT security encryption algorithm like hash function, AES, WPA, WEP, Snow-3G, A3/A5/A8 are used [6],[16],[20].

The Decision-making process in the retail sector has become more robust based on the data sent by the IoT environment to a cloud platform. Hence smart decision is taken based on the actual data collected [27]. In his paper, Andersson explains only short-range technologies like bluetooth, 802.15.4, wi-fi, NFC & iRDA. Compression is also within short range technologies only with yes or no [1]. B & Petri, in their paper, explains only long-range technologies and provide a broad overview of the LPWAN technologies. Focus is only on LoRa [2]. Alex Makarevich, in his article, covers only theoretical aspects of

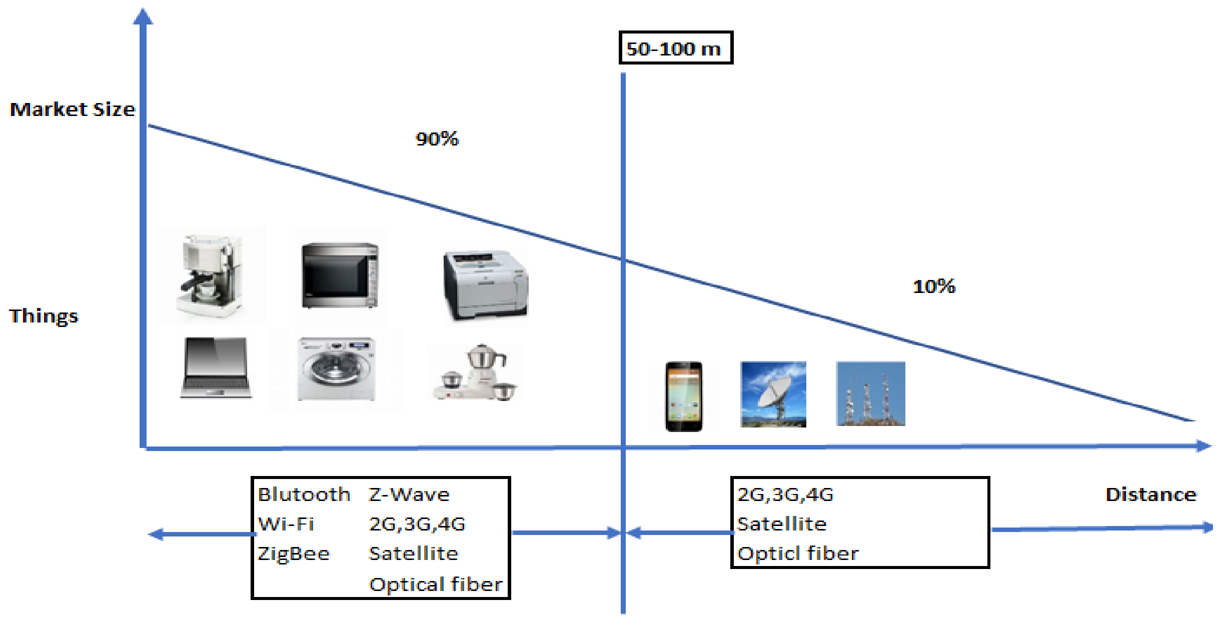


Fig 1: Market Size Vs. Technologies [1]

technologies and talk about the only advantage & disadvantage of wi-fi, Bluetooth, BLE, mesh technologies, LPWAN and 5G only [29].

However, in my paper, the comparison is done on the short-range and long-range technologies with actual values of technical parameters. It covers technical comparison based on frequency, data rate, range, cost power usage, standards & security for technologies like RFID, wi-fi, ZigBee, Bluetooth, Z- Wave, Weightless, Lora WAN, Sigfox, Ingenu RPMA, LTE, NB-IoT, GSM. Also, my paper is recommending the most suitable IoT technologies for related applications.

This paper covers 1) Overview of short- & long-range technologies. 2) Comparative study of short- & long-range technologies based on technical parameters like frequency, data rate, distance, power consumption, cost, standards adopted, and security adhered. 3) Best suited IoT technologies in various fields. 4) Conclusion.

II. SHORT RANGE COMMUNICATION TECHNOLOGIES

The devices beyond the last 100 meters are connected by either home routers (ADSL) or smartphones or GSM/3G/4G routers. However, devices within the range of "last 100 meters" are well not connected [1]. 90% of market size contributes to things in less than 100-meter distance, and only 10 % of the market size contributes to things beyond the 100-meter distance. Short-range communication technologies like Bluetooth, wi-fi, Z-Wave, ZigBee plays a significant role in connecting short distance objects.

A. RFID

In 1945, RFID (Radio Frequency Identifications) came into existence. The RFID tag is a microchip attached to the object. RFID reader communicates with RFID tag, collects the data, and share with backend data processing units. RFID works on radio frequency from 100 kHz to 10 GHz.

B. Bluetooth

Bluetooth is a wireless technology and consumes low power. It operates on a 2.4 GHz radiofrequency. It creates PAN (Personal area network). Bluetooth supports a data rate of 1 Mb/s. It has a range of 1-100 meters. This short-range technology is low cost & easy to implement.

C. Wi-fi

Wi-fi is a wireless technology, and it is alternate to wired technology. The standard used by wi-fi is IEEE 802.11. In 1997 first version of IEEE 802.11 was released. It ranges from 10 m to 100 M. wi-fi is used to automate homes & buildings, smart energy, safety & security, and M2M communications using wi-fi infrastructure. To identify the geolocation of the device, the wi-fi hotspot position is being used. This technology also helps in establishing connectivity within the city. In 2004, Mysore became the first wi-fi enabled city in India [3].

Table 1: wi-fi frequency bands, throughput, range [5]

Standard	Frequency Bands	Through put	Range
Wi-Fi a (802.11a)	5 GHz	54Mbit/s	10 m
Wi-Fi B (802.11b)	2.4 GHz	11Mbit/s	140 m
Wi-Fi G (802.11g)	2.4 GHz	54Mbit/s	140 m
Wi-Fi N (802.11n)	2.4 GHz/5 GHz	450Mbit/s	250 m
IEEE 802.11ah	900 MHz	8 Mbit/s	100

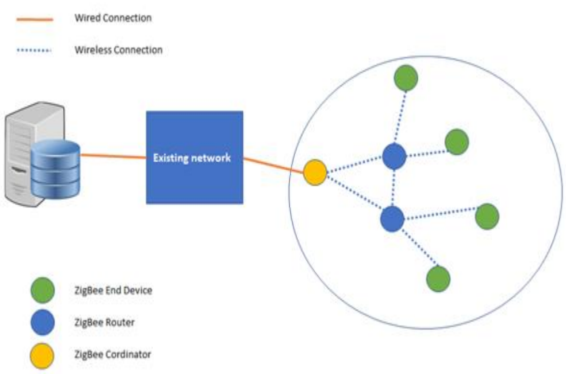
D. Zig Bee

ZigBee uses a mesh network, having low deployment cost & consumes low power. This technology is built on IEEE standards (802.15.4). IEEE-802.15.4 specifications were approved in 2004 and are known as ZigBee 2004 specifications. ZigBee is used for home, building & industrial automation, medical data collection, smoke & intruder warning. ZigBee end devices are connected to things or objects and transmit the data to Zigbee routers in a wireless network. Zigbee routers are further connected with ZigBee coordinators, which are connected through the wired network to backend processing units in the exiting network [3],[5],[19].

Fig 2: ZigBee Network

III. 'LONG RANGE 'COMMUNICATION TECHNOLOGIES'

Long' range' communication' technologies use either 3GPP standards or Non-3GPP standards. Non-3GPP standard technologies consume less power compare to 3GPP



standard-based technologies. Technologies under non-3GPP standards are also known as LPWAN (Low power wide area network) technologies.

A. Non-3GPP Technologies (LPWAN)

LoRa, SigFox, Weightless, Ingenu RPMA are family of LPWAN and fall into the unlicensed band category. Consumes low power, low cost, and easy to deploy.

a) LoRa

LoRa (Long Range) association was created in 2015 to support Lora WAN protocol and interoperability of LoRa products [5],[13]. It uses a channel bandwidth of 125kHz and has a range of up to 15km. Has strong indoor penetration up to 20dB. Inhabits the entire bandwidth of the channel to broadcast signals. The spreading factor is inversely proportionate to throughput. By increasing the spreading factor, throughput decreases, but the connection is preserved.

Table 2: Type of LoRa Devices [5]

Device Classes	Description	Latency Constraint	Examples of Services
A (all)	Module listen only after end device transmission	No	Fire Detection Earthquake early Detection
B (beacon)	Module listens at a regular adjustable frequency	Few seconds	Smart metering Temperature rise
C (continuous)	Module always listening	Less than one second	Fleet management Real-Time Traffic management

b) SigFox

SigFox is the first PLWAN technology and uses an ultra-narrow wireless band of 160 Hz with a throughput of <1 kbps. It has ranged between 10 km to 50 km. It supports 140 massages per day per device and has roaming capability. Sigfox is present in 70 + countries covering an area of 5.7 Million Km^2 & connecting 1.3 billion devices [17].

Fig 3: Sigfox Current Implementation

c) Weightless

Weightless is a low-cost technology. A special interest group was created in 2012 for managing weightless technology. This technology is used where interference cannot be detected and need to overcome. It operates in a narrow band with a frequency of 200 Hz and can manage large numbers of terminals proficiently. It has a range up to 5+ km with a data range up to 10 Mbps.

d) Ingenu' RPMA

RPMA ('Random Phase Multiple Access') uses low power' & exclusively used for M2M communication. RPMA was developed to enable connectivity within the oil & gas sector. However, the technology's name changed to Ingenu after this technology started supporting IoT & M2M. It works on 2.4 GHz frequency and has a range of up to 13 km.

e) Z-Wave

Low power, mesh network technology with frequency 908 MHz (US) & 868 MHz (Europe) with throughput up to 40 kbps, range up to 50 m.

B. 3GPP Technologies

a) LTE-M
LTE -M is a narrow-band frequency network up to 20 MHz, throughput up to 1 Mbps. It has a range of up to 13 km. It is a licensed network.

b) NBT-IoT
NBT-IoT is an ultra-narrow band frequency network up to 200 kHz, with a throughput of up to 150 kbps. It has a range of up to 13 km. It is a licensed network.

c) EC-GSM

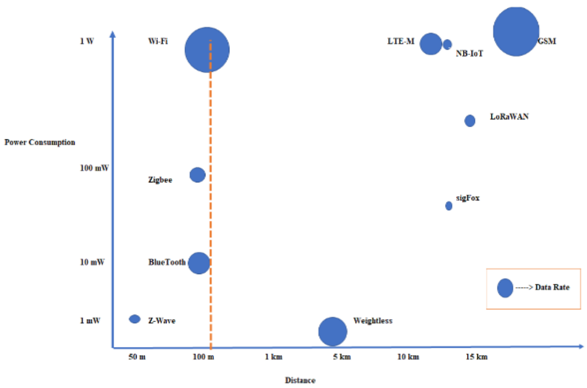


Fig 4: IoT Technologies comparisons based on Distance Vs. Power Vs. Data Rate [1],[8]

EC-GSM is a narrow-band frequency network up to 200 kHz, with a throughput of up to 10 kbps. It has a range of up to 15 km. It is a licensed network. This technology is used to leverage the 2G infrastructure to deliver adequate and consistent IoT connectivity.

IV. COMPARITIVE STUDY
Short- & Long-range technologies are compared based on various parameters like frequency, data rate, range, power consumption, cost, security & standards adopted. Based on these parameters, technologies are being used in various areas like home automation, smart energy, industrial automation, warehouses for logistics management, smart cities, etc. Furthermore, smart technologies like artificial intelligence [24], business intelligence [22], and marketing intelligence [23] are aiding IoT in smart business transformations.

A. Comparison based on Distance, Power & Data Rate
Short- & long-range technologies are being used based on coverage, power consumption & data rate supported by the technologies. Applications with long Range, GSM, NB-IoT, LTE-M, Lora WAN, Weightless, Ingenu RPMA are considered. However, for fixed & short-range requirements, wi-fi, Bluetooth, Z-wave, Zigbee are given preference. Graphical view based on distance, power consumption & data rate illustrates a very clear view of technology uses [1],[11].

B. Technical parameter comparison
IoT Technologies can be compared based on technical parameters like frequency, data rate, Range, power usage, cost, standard & security [18].

a) Fixed & Short-Range
RFID, Bluetooth, Z-Wave, Zigbee & wi-fi can be compared based on technical parameters: -

1) Frequency
RFID operates on frequency 100kHz to 10GHZ. Z-wave uses 868MhZ in Europe & 908 MHZ in the US. Bluetooth & Zigbee works on 2.4Ghz, while wi-fi operates on a higher frequency like 2.4GhZ, 5Ghz & 900 Mhz.

2) Data Rate
Data rate denotes the data transmission speed. It varies from 797 bps to 54 Mbps based on technology [8].

3) Range
Range denotes the coverage supported by technologies. Within short-range technologies, communication range varies from 10 m to 100 m.

4) Power Usages
Power usages by short-range technologies will be low, and hence battery life will be more.

5) Cost
The deployment cost of technology also will be low to medium [8].

6) Standard
Short-range technologies are nonstandard (Non-3GPP).

7) Security
Encryption is used in security for the protection of data. RFID uses the Hash function and while the rest of the short-range technologies uses AES encryption for security.

Table 3: IoT Technologies comparisons based on technical parameters [1],[8],[26]

	Fixed & Short Range Technologies				
Parameters	**RFID**	**Z-Wave**	**Bluetooth/BLE**	**ZigBee**	**Wi-fi**
Frequency	100kHz-10 GHz	868 MHz(Eur) 908MHz(US)	2.4GHz	2.4Ghz	2.4Ghz, 5Ghz,900 MHz
Data Rate	797 b/s	9-40 kbps	1 Mbps	250k bps	0.1-54 Mbps
Range	10 m	50 m	100 m	100 m	100 m
Power Usage	Low	Low	Low	Low	Medium
Cost	Low	Medium	Low	Medi	Low

				um	
Standard	Non-3GPP	Non-3GPP	Non-3GPP	Non-3GPP	Non-3GPP
Security	Cryptographic hash function	AES Encryption	AES Encryption	AES Encryption	WPA, WEP

B. Long Range

Lora WAN, Sigfox, Weightless, Ingenu RPMA, GSM, LTE-M & NB-IoT can be compared based on technical parameters: -

Table 4: IoT Technologies comparisons based on technical parameters [1],[2],[26]

	Long Range Technologies						
Parameters	**Weightless**	**LoRaWAN**	**SigFox**	**Ingenu RPMA**	**LTE-M**	**NB-IoT**	**EC-GSM**
Frequency	200 Hz	125 kHz	160 Hz	2.4 GHz	1.4 - 20 MHz	200 kHz	200 kHz
Data Rate	100 kbps-10Mbps	100 kb/s	<1 kbps	156-624 kb/s	1 Mbps	150 kbps	100 Mbps
Range	5 km	5-15 km	13 km	13 km	11 km	11 km	15 km
Power Usage	Low	Low	Low	Low	Medium	Medium	High
Cost	Low	Medium	Medium	Low	High	High	High
Standard	Non 3GPP	Non 3GPP	Non 3GPP	Non 3GPP	3GPP	3GPP	3GPP
Security	AES Encryption	AES Encryption	AES Encryption	AES Encryption	SNOW-3G Encryption	SNOW-3G Encryption	A3/ A5/ A8 Encryption

a) Frequency

The frequency for long-range technologies varies from 200 Hz to 2.4 GHz.

b) Data Rate

Data rate denotes the data transmission speed. It varies from <1 kbps to 100 Mbps based on technology [8].

c) range

Range denotes the coverage supported by technologies. Within long-range technologies, communication range varies from 5 km to more than 15 km.

d) Power Usages

Power usages by long-range technologies will vary from low, medium & high. Low & medium usage technologies will have better battery life.

e) Cost

The deployment cost of technology also will be low to high [8].

f) Standard

Long-range technologies are nonstandard (Non-3GPP) & 3GPP supported. LTE-M, NB-IoT, EC-GSM will follow 3GPP standards While weightless, Lora WAN, Sigfox, Ingenu RPMA will follow non-3GPP standards

g) Security

Weightless, Lora WAN, Sigfox, Ingenu RPMA uses the AES encryption method while LTE-M & NB- IoT uses SNOW-3G encryption. GSM follows A3, A5, A8 encryption for security.

V. APPLICATION VS IoT TECHNOLOGIES

Mobile operators are using the M2M communication network to support IoT-based applications and create new verticals for generating revenue. IoT technology has been used in various sectors like home automation, industries, health, transport & warehouses, energy, security, etc. [10]. Based on the requirement, fixed or short- or long-range technologies are being used. GSM, LTE-M, NB-IoT, and Satellite are suitable for sectors to need more mobility and applications like connected cars, fleet management, and remote health monitoring. The energy sector uses GSM, LTE-M, NB-IoT, Ingenu RPMA, Sigfox, LoRa, Weightless for smart metering & parking. Wi-fi, RFID, Sigfox are being used for tracking hospital assets, warehouse logistics. Short-range technologies like Zigbee, wi-fi, Z-Wave are used for automation in industry & home sectors [21]. At the same time, Bluetooth is used to track personal activities like motoring blood pressure, heart rate, pulse, steps, etc., and for local object tracking.

Table 5: Application Vs. suitable network [26]

Application	Suitable Network
Connected Car, Fleet Management Remote Health Monitoring	GSM, LTE-M, NB-IoT, Satellite
Smart Metering, Parking	GSM, LTE-M, NB-IoT, Ingenu RPMA, Sigfox, Lora, Weightless
Hospital Assets Tracking, Warehouse Logistics	Wi-fi, RFID, Sigfox
Industrial Automation, Home Automation	Z-Wave, Zigbee, wi-fi
Local object tracking, Personal activity tracking	Bluetooth

VI. CONCLUSION

Fixed, short & long-range IoT technologies have a significant role in connecting things through the internet and generating a mammoth volume of data. Short-range technologies like RFID, wi-fi, Bluetooth, Z-wave are suitable up to 100m range and consume low power & low-cost comparative to long-range technologies like weightless, Lora WAN, Ingenu RPMA, LTE, NB-IoT, GSM. Security is paramount important in IoT networks. Technologies are compared based on the encryption algorithm used. Based on technical parameters like range, frequency, data usage, power consumption, cost & security, short & long-range IoT technologies are being used.

For applications like personal health monitoring, asset tracking in the warehouse, home & industrial automation, short-range technologies (Bluetooth, RFID, wi-fi, Z-Wave) are most suitable. However, for smart metering, smart parking, monitoring connected cars, fleet management, where more mobility is required, long-range technologies (Weightless, Sigfox, LoRA WAN, NB-IoT, LTE, GSM) are the most suitable technologies

Data collected from smart devices are used to make smart decisions, design new products, monitor health & asset, home & industrial automation, smart metering, etc. By seeing the use of IoT applications in day to day life, we can certainly conclude that IoT technologies have enriched human life quality. This paper's finding is based on the literature review, which has led to creating the IoT technology comparison matrix and suggesting the most suitable IoT network for applications. By seeing the security challenges, security is the prime parameter for implementing any technology. Hence in future research, security challenges related to IoT technologies & their mitigation approach can be researched.

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