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 licensed (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
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]

<table>
<thead>
<tr>
<th>Standard</th>
<th>Frequency Bands</th>
<th>Throughput</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wi-Fi a (802.11a)</td>
<td>5 GHz</td>
<td>54Mbit/s</td>
<td>10 m</td>
</tr>
<tr>
<td>Wi-Fi B (802.11b)</td>
<td>2.4 GHz</td>
<td>11Mbit/s</td>
<td>140 m</td>
</tr>
<tr>
<td>Wi-Fi G (802.11g)</td>
<td>2.4 GHz</td>
<td>54Mbit/s</td>
<td>140 m</td>
</tr>
<tr>
<td>Wi-Fi N (802.11n)</td>
<td>2.4 GHz/5 GHz</td>
<td>450Mbit/s</td>
<td>250 m</td>
</tr>
<tr>
<td>IEEE 802.11ah</td>
<td>900 MHz</td>
<td>8 Mbit/s</td>
<td>100 m</td>
</tr>
</tbody>
</table>

Fig 1: Market Size Vs. Technologies [1]
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.

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.

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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Fixed &amp; Short Range Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>RFID</td>
</tr>
<tr>
<td>z-Hz</td>
<td>100kH</td>
</tr>
<tr>
<td>Data Rate</td>
<td>797 b/s</td>
</tr>
<tr>
<td>Range</td>
<td>10 m</td>
</tr>
<tr>
<td>Power Usag e</td>
<td>Low</td>
</tr>
<tr>
<td>Cost</td>
<td>Low</td>
</tr>
</tbody>
</table>
Deployment cost of technology also will be low to energy sector uses GSM, Security Cost Usage Rate Data Frequency Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Weights</th>
<th>LoRaWAN</th>
<th>SigFOX</th>
<th>Ingenu RPMA</th>
<th>LTE-M</th>
<th>NB-IoT</th>
<th>EC-GSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>200 kHz</td>
<td>125 kHz</td>
<td>160 kHz</td>
<td>2.4 GHz</td>
<td>1.4 - 20 MHz</td>
<td>200 kHz</td>
<td>200 kHz</td>
</tr>
<tr>
<td>Data Rate</td>
<td>100 kbps-10M bps</td>
<td>100 kbps</td>
<td>&lt;1 kbps</td>
<td>156-624 kbps</td>
<td>1 Mbps</td>
<td>150 kbps</td>
<td>100 Mbps</td>
</tr>
<tr>
<td>Range</td>
<td>5 km</td>
<td>5-15 km</td>
<td>13 km</td>
<td>13 km</td>
<td>11 km</td>
<td>11 km</td>
<td>15 km</td>
</tr>
<tr>
<td>Power Usage</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Cost</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Standard</td>
<td>Non-3GPP</td>
<td>Non-3GPP</td>
<td>Non-3GPP</td>
<td>Non-3GPP</td>
<td>3GPP</td>
<td>3GPP</td>
<td>3GPP</td>
</tr>
</tbody>
</table>

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]

<table>
<thead>
<tr>
<th>Long Range Technologies</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td>200 Hz to 2.4 GHz.</td>
</tr>
<tr>
<td><strong>Data Rate</strong></td>
<td>From &lt;1 kbps to 100 Mbps based on technology [8].</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>From 5 km to more than 15 km.</td>
</tr>
<tr>
<td><strong>Power Usage</strong></td>
<td>Low to High</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Low to High</td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>Non-3GPP to 3GPP</td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>AES Encryption to A3/A5/A8 Encryption</td>
</tr>
</tbody>
</table>

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]

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

REFERENCES