Analysis of Coverage in LoRa using secured IoT Systems

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Abstract: Long Range (LoRa) is an unlicensed Low Power Wide Area Network for the application of the Internet of Things (IoT). This LoRa technology is mainly suitable for smart city applications since this technology consumes low power, low cost, and transfer information over a long distance. This technology proposes a new communication standard to tackle discrete IoT applications. This technology works based on Chirp Spread Spectrum (CSS) technique with a larger bandwidth. LoRa deploys the whole channel bandwidth to transmit the signal which results in, to avoid channel noise, Doppler impacts, and fading. This paper mainly focuses on the impact of three parameters namely, Code Rate (CR), Spreading Factor (SF), Bandwidth (BW). Furthermore, analysis the effect of the data rate and transmission time using Code Rate (CR), Spreading Factor (SF), and Bandwidth to extend coverage.

Index Terms: Internet of Things, LPWANs, LoRa, Coverage analysis Methods, IoT.

1 Introduction

The application of the development of Wireless Sensor Networks (WSNs) is industry, science, transportation, civil environment, and safety aspects, etc. In WSNs, includes measuring, computation, and conveying the information into a single small device named a sensor node [1][2]. WSNs contains a huge number of heterogeneous sensor devices and these devices are deployed to process capability, sensors, actuators, an energy source, and this source contains batteries as well as a few power harvesting modules, various kinds of memory, and an RF transceiver. This huge number of Wireless Sensors is closely utilized through a huge field and these sensors are inter-linked with the network and also, combined with the network. These WSNs monitor either physical or ecological conditions and it generates reading and this is fed into sensor node for further processing [2].

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The industry in wireless networks is changing slowly since their significance towards Low Power Wide Area Networks (LPWANs). Technologies which is present in LPWAN such as SigFox, LoRa, Weightless, etc. These technologies are successfully intended for extensive area connectivity from modest to large kilometers for fewer data rates, power, and throughput applications [3]. In the future, the LPWANs market is predicted huge. Almost 30 billion IoT or Machine to Machine (M2M) are presumed to be tied via the internet using LPWAN [4]. In LPWANs, smart cities are one of the largest customers. Hence, the application of smart cities is smart metering, grids, parking, driving, measurement of power radiation, nuclear power station radiation measurements, weather-based street light, management of smart waste, monitoring the structural health, monitoring air pollution, and monitoring the water leakages and these smart cities application structure as shown in Fig. 1.

In WSN, collected of numerous spread wireless nodes, communication is confined by diverse destructions like wireless spread effects, network obstruction, and thermal noise. The signal propagation effects in the wireless channel comprise the reduction of spread signals employing path loss, The signal is blocked because of huge barriers, and received multiple times of the identical broadcasted signal [5]. The network noise is obtained because of cumulating useless signals propagated by other sender systems since either within or exterior of the network and this networking noise is affected to receiver signal in the nodes at receiver network. The thermal interference is affected by the receiver electronics circuits and it can be called Additive White Gaussian Noise (AWGN).

Due to insufficient radio spectrum, WSN is not fully suitable for huge wireless networks to convey information without any noise. At the same time, possibly new broadcasting devices are deployed to transmit the information by using a similar RF band. Therefore, more unwanted signals from noisy transmitters combined with noise-free transmitter's signals. This concept is known as interference. Therefore, it degrades communication networks [6][7]. In this article, see short details about Bluetooth, ZigBee, WiFi, and LoRa. The main intention of the article is to analyze the effect of Code Rate (CR), Spreading Factor (SF), and Bandwidth (BW) in LoRa. Moreover, analysis of the impact of the Data Rate (DR) and Transmission Time by using CR, SF, and BW to enhance LoRa coverage.

The organization of the article includes, section II see brief details about legacy wireless technologies, LoRa's basic details and its basic block diagram in section III, analysis of coverage methods in LoRa will see in section IV, simulation results for this work in section V. Lastly, see the conclusion of the article in section VI.

2 Brief Details about Legacy Wireless Technologies

In WSNs, numerous legacy wireless technologies are utilized. Selection of an exacting technology for an exacting application by investigating essential data rates, energy consumption, and distance is done [8]. Some main traditional wireless technologies deployed unlicensed ISM bands. The comparison of wireless technologies is shown in Table. 1.

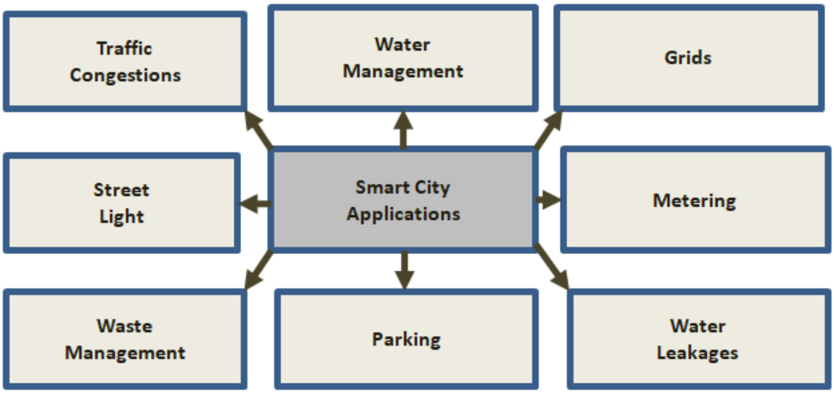

Fig. 1. Application of Smart City

Table 1. Comparison of Traditional Wireless Technologies

	IEEE 802.15.1	IEEE 802.15.4	IEEE 802.11
Maximum UEs	255	> 64000	Based on No. of IP Address
Peak Value of Current Consumption	30 mA	30 mA	100 mA
Distance	10m	10-100m	100m
Throughput	1Mbps	Till 250 kbps	Between 11 Mbps and 54 Mbps
Cost of Devices	Low	Low	Moderate
Deployed Topology	Star	Star and Mesh	Star and Point to Point
The technique utilized in Transmission	FHSS	DSSS	OFDM

2.1 Bluetooth (IEEE 802.15.1)

This is one of the Wireless Personal Area Network (WPAN) technologies. It is introduced by Ericesson in the year 1994. It deployed an unlicensed spectrum 2.4 GHz band with till 1 MHz channel band. It uses Frequency Hopping Spread Spectrum (FHSS) technique and utilizes data rate till 1 Mbps. In traditional Bluetooth, connect 8 Nodes to every new with 7 slave nodes with one master node. Bluetooth network is used from one end to the other end based on the master-slave method. In every communication network, the energy consumption is powerfully based on the range from a transmitter node to a receiver node. Hence, the chosen energy is retained employing signal and then this important signal data is exchanged between transmitter node and receiver node. The Bluetooth network is deployed to exchange all kinds of data such as multimedia, text, etc. [9].

Another technology of the Bluetooth called Bluetooth Low Energy (BLE) for the past Bluetooth versions 1.0, 2.0, and 3.0. This BLE provides low energy for the standard Bluetooth. Both Bluetooth and BLE are deployed for diverse scenarios. Traditional Bluetooth can hold nearly all kinds of data since it needs large energy and the cost of the technology is high, BLE technology is applicable for low throughput and hence the battery life is highly similar to standard Bluetooth. Also, BLE deploys unlicensed ISM bandwidth and it contains 40 diverse channels. Out of 40 channels, three channels are used for advertising purposes and the rest of the channels are used for data for sharing data information between sender and receiver after the connection is given [9].

2.2 Zigbee

The ZigBee is commonly referred to as IEEE 802.15.4. This is one of the popular low throughput Wireless Personal Area Networks (WPANs) and Wireless Sensor Networks. It contains Physical (PHY) and MAC layers. These two layers are under the characteristics of ZigBee. This ZigBee also contains Network and Application Layer. These two layers are under the specification of ZigBee. The MAC layer permits to access the wireless physical channel, association with wireless node, validate the data frame, and is applicable for security purposes in the case of wireless networks. As per the requirement of the ZigBee application, ZigBee Networks are utilized in a centralized or decentralized manner [10].

ZigBee deploys star topology or peer-peer topology. This star topology recommends both argument and non-argument-based wireless channels and this channel is used to access their elements nodes. Nodes are used to communicate the information with other nodes surrounded by RF distance in the case of peer-peer topology. The peer-peer wireless network topology sustains based on contention slotted free carrier sense multiple access to avoid a collision which is present in CSMA/CA without wire Medium Access Control (MAC) protocol. To access and share the information in the wireless medium, the CSMA/CA protocol nodes are struggling with everyone. ZigBee connects larger than 64000 nodes and each node requires to assign a task. ZigBee deploys Direct Spread Spectrum Sequence (DSSS) technique with a 250 kbps data rate for a 2.4 GHz band [11][12]. This DSSS technique is applicable for enhancing the bandwidth (BW). The phase of DSSS shifts the sine wave in a pseudo-random manner by using chips. These chips are also called as Pseudo-Noise (PN) code symbols. These PN code symbols are used to enhance the signal energy, reduce the intrusion since the effect of the received signal, permit to share the spectrum between various users, and resist the proposed signal blocking. The sequence of PN is identified between transmitter and receiver. The ZigBee consumes low energy and the cost of the module is low. Hence, it is suitable for Wireless Sensor Networks (WSNs) [13].

2.3 WiFi

Even though Bluetooth and ZigBee are consumed low energy and low complexity devices in wireless sensor technologies, however, these technologies are contained some drawbacks like low throughput, covers less distance, and penetrating the information is less across the barriers with advanced wireless and System on Chip (SoC) fields, based on WiFi sensor SoC numbers are developed in the case of low energy sensor applications in the wireless environment [14]. This WiFi is commonly called IEEE 802.11 and this technology is under Wireless Local Area Network (WLAN). The IEEE 802.11 standard offers some specifications in MAC and PHY layer for employing WLAN in a wireless environment in the spectrum bandwidth 900 MHz, 2.4 GHz, 3.6 GHz, 5 GHz, and 60 GHz [15]. 2.4 GHz Spectrum bandwidth is commonly used in IEEE 802.11 standard extensions employing 14 diverse channels. Based on the Wi-Fi network, WSNs are centered network and it contains a huge number of low energy nodes and it distributes over a long distance.

WiFi provides from 11 Mbps to 54 Mbps data rate using 100-meter transmission distance. In the network, the Node numbers are depending on IP address numbers. The alternate OFDM technique is called as Multi-Carrier Modulation and it is implemented in various IEEE WLAN standards such as IEEE 802.11a, IEEE 802.11g. OFDM technique also deploys IEEE 802.11n and IEEE 802.11ac since this OFDM is combined with MIMO [16].

3 Basic Details and Block diagram of LoRa

This LoRa technology is an unlicensed LPWAN and it is introduced by Semtech [17]. The LoRa deploys star topology because the User Equipment (UEs) communicate directly by a small number of gateways using a single hop technique to reduce the complexity of the LoRa Network. Gateways are used to forward the received data from UEs to the cloud as shown in Fig. 2. Gateways and UEs are communicated together by using diverse spectrum channels and throughputs, where the exacting throughput selection offers an exchange between distance and time duration of the message.

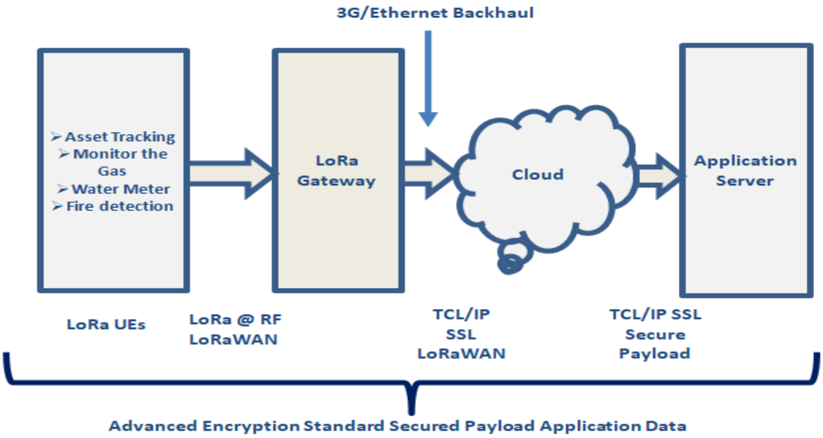

Fig. 2 Basic Block Diagram of LoRa (Long Range)

In the latest years, LoRa is an important licensed free LPWAN since it provides high throughputs for powerfully used in communication distance. Also, it is applicable for IoT in urban areas. The specification of the Semtech mentioned three components in LoRa called, (i) The Physical (PHY) layer, the Link layer, and the architecture of the Network [18].

3.1 Physical Layer

LoRa provides Chirp Spread Spectrum (CSS) with combined Forward Error Correction (FEC) [19]. LoRa UEs are deploying diverse throughputs and this is not disturbed with everyone due to the above design. Moreover, it activates more channels to enhance the network capacity. The networks of the LoRa activate in licensed free ISM bandwidth. In particular, from 902 to 928 MHz are deployed in North America employing the middle spectrum in the range of 915 MHz. As per the specification of the LoRa, identify 64 wireless channels in 125 kHz band varies between 902.3 and 914.9 MHz in the spectrum 200 kHz enhancements using 915 MHz bandwidth. Further eight 500 kHz uplink transmission channels are there in 1.6 MHz enhancements between 903 MHz and 914.9 MHz. This carries a total of 72 uplink transmission channels; even though the eight channels with 500 kHz spectrum are not being separated by the rest of the 64 channels. It contains 8 channels in downlink and each channel contains a 500 kHz length between 923.3 MHz and 927.5 MHz.

The Federal Communication Commission (FCC) permits a larger crest of 1 Wh (30 dBm) power if the channel band is as a minimum of 500 kHz. The LoRa UE provides Frequency Hopping (FH) employing a maximum 400 ms settle time for each channel in case of lesser bandwidths. Hence, this formulates the lowest throughput of the LoRa is not utilizable; the packet of preamble gets greater than 400 ms only during transmission.

In addition to the above concept, the Spreading Factor (SF) and Coding Rate (CR) are must be deployed by LoRa UEs. These SF and CR are significant for strength to intrusion and transmission time during transmission. The LoRa deploys orthogonal SFs that permit numerous packets with diverse SFs are to be sent through a similar channel in a parallel manner which results in enhancing network efficiency and data rate. The SF is from 7 to 12 in the case of European operations but the SF is from 7 to 10 in case of North American conditions, if we send the packet then the transmission time will be affected.

Moreover, LoRa provides FEC which allows for the recovery of the information during errors obtained in the transmission. For the application of the FEC, needs extra Coding data is comprised in every packet during transmission which results in, the coding data amount being calculated by CR. Based on the selection of CR, one can accomplish an extra strength during interference. Hence the availability of CR is (4/5, 4/6, 4/7, 4/8).

The physical packet structure of LoRa contains a preamble, the data payload, and a header (optional).

Preamble: Deployed to match the transmitter with the receiver system

Header (optional): Includes length of the payload (Bytes) and it is protected by the lowest CR 4/8 of FEC always.

The data payload: It contains FEC Code Rate and CRC header.

3.2 Link Layer

The LoRa link-layer networks are commonly called Long Range Wide Area Network (LoRaWAN). In LoRaWAN specifications, the MAC layer activates the LoRa physical layer at the top. It differentiates three LoRa UEs called Class A, Class B, and Class C. Here Class B and C UEs are needed to well match with Class A UE. Optimize the energy consumption in the case of Class A UE which results in, receive the downlink information without any delay after completing the uplink transmission, by releasing two small receive windows. In addition with Class A UEs are contain two receive windows, Class B UEs release another receive window during downlink at planned times that times are matched by transmitted beacons via a gateway. Class C UEs are continuously held to receive windows under open conditions otherwise the window will be closed during transmission.

The mechanism of the channel access in LoRaWAN is untainted ALOHA which results in, LoRa UE being used to the channel exclusive of the channel sensing for the current communications. To extend the battery lifetime of the LoRa UE in the wireless channel, to control energy consumption in UEs.

3.3 Network Architecture

The networks of the LoRaWAN are organized by Star-topology by every gateway getting information's directly from various UEs. Gateways are deployed to connect the cloud with TCP/IP protocols to convey the information to the cloud. Every UE may change its throughput by utilizing Adaptive Data Rate (ADR) [20]. The cloud provides ADR and calculates the most favorable throughput used by every UE because UEs transmit their information and the similar information accepted by various gateways and also, this gateway is used to send the information to the cloud which results in the overlapping information's being cleaned. Lastly, the cloud for this architecture is answerable for safety, analysis, and acceptance purposes [20].

3.4 Coverage Analysis Methods in LoRa

In the wireless communication industry, the LPWAN is one of the growing technologies. This LPWAN consumes low power, conveys the information over a long distance. Hence, Semtech introduces the LPWAN technology called LoRa. This is one of the licenses free LPWAN with the advanced version of spread spectrum technique utilization when compared to traditional wireless technologies such as Bluetooth, WiFi, ZigBee, etc. This LoRa technology is used to enhance the link budgets and also, to avoid network noise interferences. The LoRa permits the Bandwidth to be 125 kHz, 250 kHz, and 500 kHz [21]. In LoRa, Chirp Spread Spectrum (CSS) modulation is utilized and this CSS is the sub-division of Direct Spread Spectrum Sequence (DSSS). It permits to convey 1 bit per every chirp. It occupies a much greater Bandwidth during transmission compared to the bandwidth needed by data rate.

The modulation of the LoRa characteristics is based on three factors called Code Rate (CR), Spreading Factor (SF), and Bandwidth (BW).

Code Rate (CR): To enhance the sensitivity of the receiver deploys Forward Error Correction (FEC) technique in LoRa. CR is used to define the FEC amount. LoRa permits the CR values from 0 to 4 which means if CR equals 0 then there is no FEC. LoRa utilizes CRs are 4 equals 5, 2 equals 3, 4 equals 7, and 1 equals 2 shown in Table. 2. Hence, if the CR is mentioned as K = N where K indicates valuable information and N indicates the Number of yield in bits. Therefore, $\mathbf{N - K}$ will mention as redundant information in bits. The function of redundancy is used to permit the receiver to sense and correct the error in the information however it reduces the throughput also.

Table. 2 LoRa Code Rates

Value in CR	**1**	**2**	**3**	**4**
Number of Overlapping bits	1	2	3	4
Numerical value in Coding Rate	4/5	2/3	4/7	1/2

The Data Rate (DR) or bit rate in LoRa is given by

$$R_b(bps) = SF_n.\frac{BW_n}{2^{SF_n}}.\frac{4}{4+CR_n} \qquad (1)$$

Where LoRa Bandwidth (BW_n) are 125 kHz, 250 kHz, and 500 kHz, SF_n is the number of Spreading Factor and these values are 7, 8, 9, 10, 11, and 12 in LoRa, CR_n are Code Rate and these values are 0, 1, 2, 3, and 4 in LoRa.

Spreading Factor (SF): The LoRa deploys various Spreading Factors from 7 to 12. SF offers an exchange between data rate and range. If the SF enhances, then the range increases and reduces the data rate and vice versa. Every symbol are spreading by using spreading code length 2^{SF_n} chips. The length of the spreading code is sub-category into length codes as $2^{SF_n} = SF$. After that, every symbol bit is spreading by using sub coding technique as shown in Fig. 3. Hence, it offers 2^{SF_n} chips for one symbol spreading i.e $SF(bits). 2^{SF_n} = SF$ shown in Table.3. This technique is already known by the receiver side. This one symbol substitutes in multiple information chips which results in, the SF manipulating the efficient data rate directly [19].

Table. 3 **SFs and its Chip Length in LoRa**

SF_n	**Length of Chip (2^{SF_n})**
7	128
8	256
9	512
10	1024
11	2048
12	4096

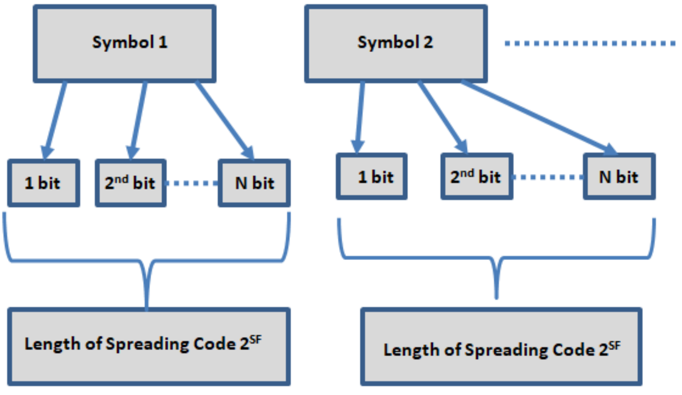

Fig. 3 Spreading Structure of Symbol in LoRa

To renew the excitation data, the code of the spreading is multiplied by the acceptance bits by the receiver side.

Bandwidth (BW): LoRa offers three BW are 125 kHz, 250 kHz, and 500 kHz shown in Fig.. 4. The transmitter is used to convey the spreading data by using chip rate and chip rate is equal to the bandwidth of the system (cps/Hz). Hence, the LoRa BW 125 kHz is equal to 125 kcps. Here, cps represents chips per second.

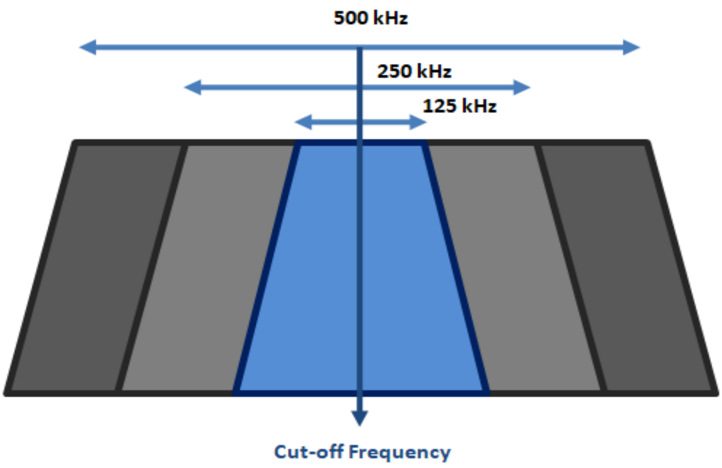

Fig. 4. The Bandwidth of the LoRa relates to the dual-sided broadcast frequency.

3.5 Structure of LoRa Packet

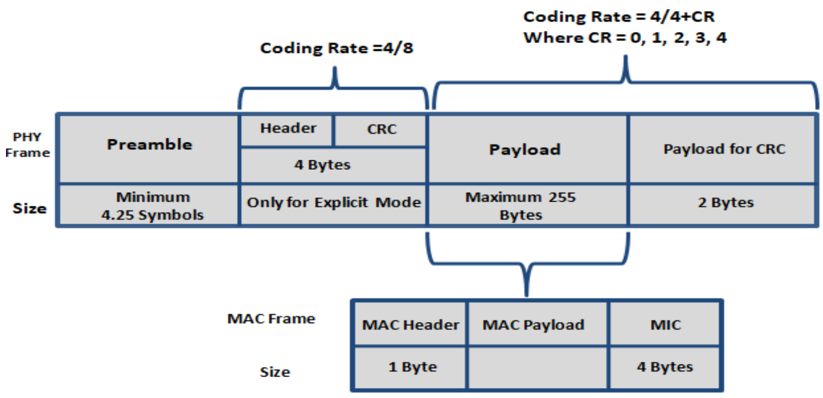

Fig. 5 Structure of LoRa Packet

Fig. 5 indicates the structure of the LoRa packet and it provides 256 bytes in maximum packet size. The detailed LoRa packet [20] is given by

Preamble: It is mainly utilized for synchronization and the receiver section is synchronized with the acceptance information.

Header: It contains two modes namely, explicit and implicit operation modes. In explicit mode, the header field indicates the FEC code rate (Bytes), the length of the payload, and CRC. In Implicit mode, the frame of the Coding rate and payload are constant and also, this mode does not have any frame which results reduce the transmission time. The header also occupies two bytes for CRC which is used to deactivate the packets. Besides with header field, CRC is 4 bytes length and this CRC is encoded with Coding Rate (1=2) and the rest of the Coding Rate indicates Physical header. The first byte of the PHY header indicates the length of the payload.

Payload: The value of the payload between 2 and 255 bytes. This payload contains the following fields given by

- **(i)** **MAC Header:** This header indicates the type of frame. This field also indicates the version of the protocol and their direction either uplink transmission or downlink reception.
- **(ii)** **MAC Payload:** This field includes real data
- **(iii)** **MIC field:** This field is deployed as the signature which presents in the digital payload
- **(iv)** **CRC Field:** This is one of the optional fields and includes Cyclic Redundancy Check Code in bytes to detect the error at the receiver side and it contains 2 bytes length.

3.6 Transmission Time in LoRa

The transmission time during transmission of the packet in LoRa is given by

$$\boldsymbol{\tau}_{\mathbf{T_{XN}}} = \boldsymbol{\tau}_{\mathbf{Preamble}} + \boldsymbol{\tau}_{\mathbf{Payload}} \qquad (2)$$

Where $\boldsymbol{\tau}_{\mathbf{T_{XN}}}$ Transmission time during transmission in LoRa, $\boldsymbol{\tau}_{\mathbf{Preamble}}$ is the duration of the Preamble, and $\boldsymbol{\tau}_{\mathbf{Payload}}$ is the duration of the Payload

$\boldsymbol{\tau}_{\mathbf{Preamble}}$ is given by

$$\boldsymbol{\tau}_{\mathbf{Preamble}} = (\mathbf{l}_{\mathbf{Preamble}} + \mathbf{4.25}).\boldsymbol{\tau}_{\mathbf{S}} \qquad (3)$$

Where $\mathbf{l}_{\mathbf{Preamble}}$ is the length of the preamble and $\boldsymbol{\tau}_{\mathbf{S}}$ is the duration of the symbol rate and is given by

$$\boldsymbol{\tau}_{\mathbf{S}} = \frac{\mathbf{1}}{\mathbf{r}_{\mathbf{S}}} \qquad (4)$$

Where $\mathbf{r}_{\mathbf{S}}$ is the Symbol rate and is defined by

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$$\mathbf{r_S = \frac{BW_{LoRa}}{2^{SF_n}}} \qquad (5)$$

Where $\mathbf{BW_{LoRa}}$ is the Bandwidth in LoRa and this BW is are 125 kHz, 250 kHz, and 500 kHz, $\mathbf{SF_n}$ is the number of Spreading Factors in LoRa and these values are 7, 8, 9, 10, 11, and 12.

The duration of the payload in LoRa is followed as

$$\mathbf{\tau_{Payload} = N_{Payload}S.\tau_S} \qquad (6)$$

Where $\mathbf{N_{Payload}}$ is the number of Payload

$$\mathbf{N_{Payload}S = 8 + MAX\left(Rounded\ off\left(\frac{(8.N_{Payload} - 4.SF_n + 28 + 16.CRC_n + 20.h)}{4(SF_n - 2.D_E)}\right).(CR_n + 4), 0\right)}$$

Where $\mathbf{N_{Payload}}$ is the number of Payload, $\mathbf{SF_n}$ is the Spreading Factor numbers, $\mathbf{CRC_n}$ is the number of Cyclic Redundancy Check Code and this value is 4 bytes, h is the header and if h is 0 then the header is activated otherwise it is deactivated, $\mathbf{CR_n}$ are the Code Rate number and this value is 0, 1, 2, 3, and 4. Lastly, $\mathbf{D_E}$ is enabling the Data rate. If $\mathbf{D_E}$ is 1, then activated for low data rate otherwise it is deactivated

Finally, the total transmission time in LoRa UEs are calculated by using the equations (2), (3), and (6) is given by

$$\mathbf{\tau_{T_{XN}} = \tau_S(l_{Preamble} + N_{Payload}S + 4.25)} \qquad (7)$$

4 Analysis of Simulation Results

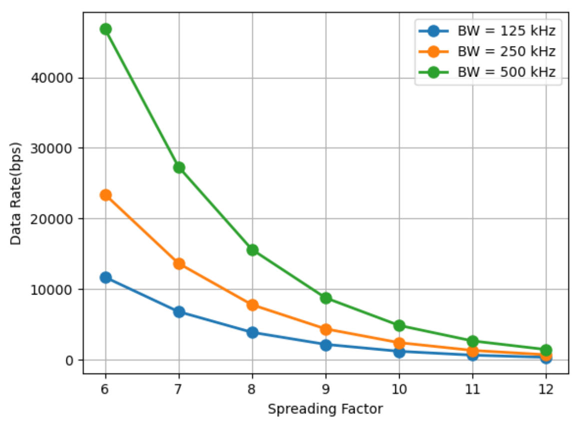

Fig. 6 Data Rate for Spreading Factor with diverse LoRa Bandwidth.

In Fig. 6, when the LoRa Spreading Factor (SF) enhances, the data rate is decreased with different LoRa bandwidths. For example, if SF is 8, then the data rate is 4076 (bps) at 125 kHz LoRa Bandwidth, if SF is 7, then the data rate is 6856 (bps) at 125 kHz. Similarly, if SF is 7, then the data rate is 27289 (bps) at 500 kHz, if SF is 8, then the data rate is 15752 (bps). From the graph, we inferred that, if the SFs are enhanced, then the coverage is enhanced which results in, the data rate in LoRa being reduced at diverse bandwidth.

From Fig. 7, when the Code Rate (CR) enhances, the data rate is reduced with different bandwidths. For example, if CR is 1, then the data rate is 5469(bps) at 125 kHz bandwidth, if CR is 3, then the data rate is 4039 (bps) at 125 kHz. Similarly, if CR is 1, the data rate is 10904 (bps) at 250 kHz, if CR is 3, the data rate is 7829 (bps) at 250 kHz.

In Fig. 8, if the Spreading Factor (SF) is increased, then the transmission time also enhances with different payloads. For example, if SF is 10, then the transmission time is 0.376 (seconds), if SF is 12, then the transmission time is 1.334 (sec) at 20 (Bytes) payload. Likewise, if SF is 10, then the transmission time is 0.528 (sec) at 40 (Bytes) payload, if SF is 12, then the transmission time is 1.857 (sec) at 40(bytes) payload. From Fig. 8, we inferred that the SFs are enhanced, the transmission time in LoRa is also enhanced with diverse payloads which means the coverage of the LoRa is enhanced.

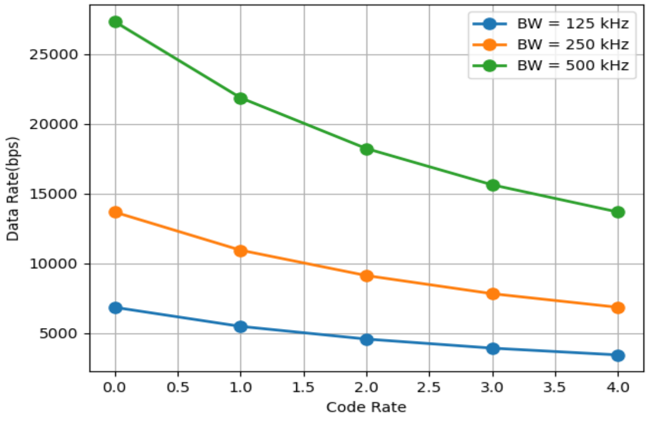

Fig. 7 Impact of Data Rate with Code Rate at different Bandwidth

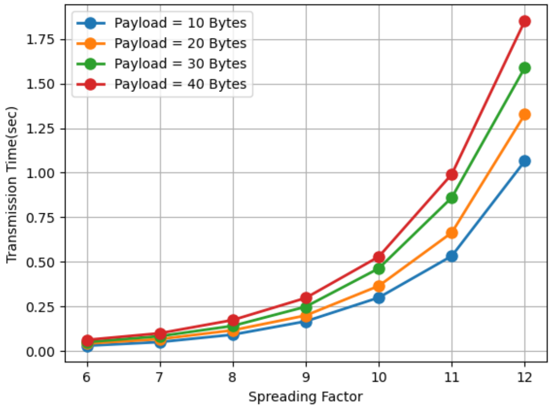

Fig. 8 The Spreading Factors with Transmission Time at diverse payload in LoRa

In Fig. 8, if the Spreading Factor (SF) is increased, then the transmission time also enhances with different payloads. For example, if SF is 10, then the transmission time is 0.376 (seconds), if SF is 12, then the transmission time is 1.334 (sec) at 20 (Bytes) payload. Likewise, if SF is 10, then the transmission time is 0.528 (sec) at 40 (Bytes) payload, if SF is 12, then the transmission time is 1.857 (sec) at 40(bytes) payload. From Fig. 8, we inferred that the SFs are enhanced, the transmission time in LoRa is also enhanced with diverse payloads which means the coverage of the LoRa is enhanced.

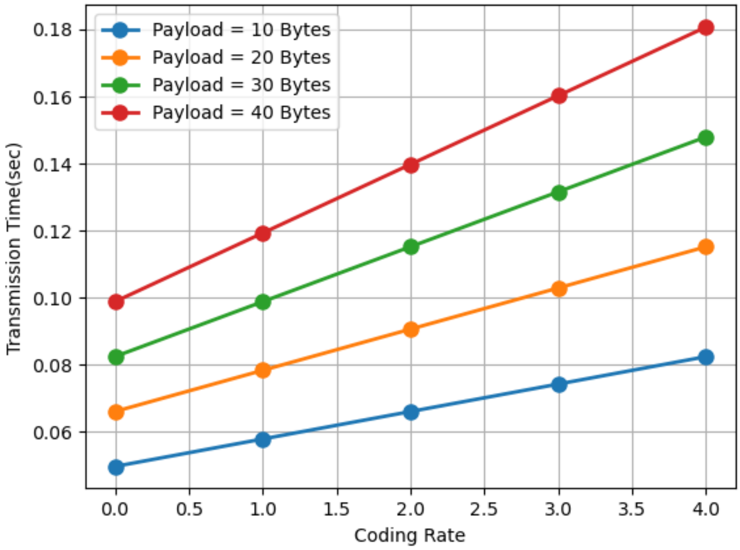

Fig. 9 Coding Rate relates with Transmission Time at different Payloads

In Fig. 9, when the Coding Rate (CR) of the LoRa is increased, the transmission time is enhanced with different payloads. Let us consider, if CR is 1, the transmission time is 0.0581(Seconds) at 10 payloads in bytes, if CR is 3, the transmission time is 0.0746 (Sec) at 10 payloads in bytes. Similarly, if CR is 1, the transmission time is 0.1 (Sec) at 30 bytes, if CR is 3, the transmission time is 0.132(Sec) at 30 payloads in bytes. Hence, we inferred that, if the payload size is reduced, then the transmission time is reduced with the enhancement of the Coding Rate.

In Fig. 10, when the bandwidth is enhanced, the transmission time is reduced at different payloads. For example, if the BW is 200 kHz, then the transmission time is 0.0309 (seconds) at 10 payloads in bytes, if the BW is 350 kHz, then the transmission time is 0.01763 (seconds) at 10 payloads in bytes. Likewise, if the BW is 200 kHz, then the transmission time is 0.0621 (seconds) at 40 payloads in bytes, similarly, if the BW is 350 kHz, then the transmission time is 0.035556 (seconds) at 40 payloads in bytes. From Fig. 10, we inferred that the transmission time is reduced at larger Bandwidth with diverse payloads.

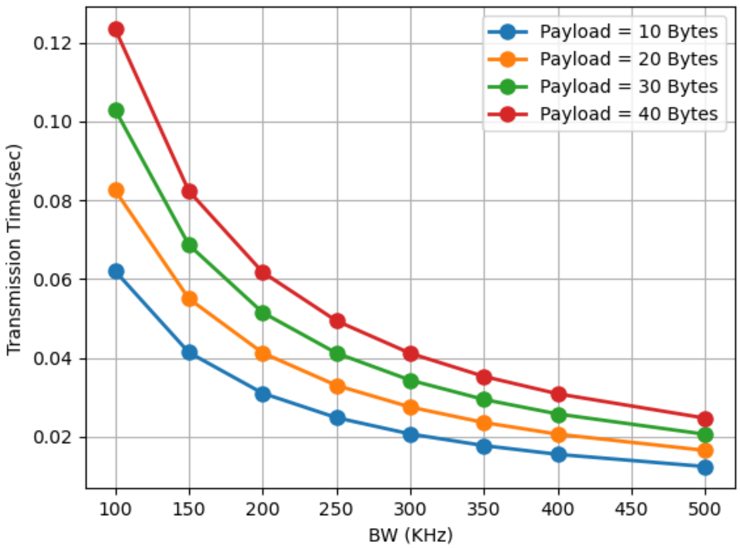

Fig. 10 The Bandwidth with the transmission time at the diverse payload

5 Conclusion

In this article, we have discussed the basic detail of the traditional wireless technologies and also, studied the basic concept and basic block diagram of the LoRa in detail. Mainly, analyzed the coverage methods of the LoRa in detail. In particular, analyzed the impact of the Coding Rate, Spreading Factor, and Bandwidth of the LoRa. Furthermore, discussed the effect of the transmission time based on the Spreading Factor, Coding Rate, and Bandwidth at diverse payload lengths in LoRa. Lastly, the Spreading Factors are enhanced, the Data rate is reduced and the transmission time is increased which results in, the coverage of the LoRa being enhanced.

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