Data Descriptor: LoRa Network Performance Analysis in Indoor Buildings

1st Mohamad Moustafa
dept. Sustainable Communication Networks
University of Bremen
Bremen, Germany
mo_mo1@uni-bremen.de

2nd Zouzan Hassaf
dept. Sustainable Communication Networks
University of Bremen
Bremen, Germany
zhassaf@uni-bremen.de

***Abstract*—This paper provides a comprehensive overview of a conducted experiment that explores the performance and feasibility of LoRa (Long Range) technology within indoor building environments. The experiment aimed to evaluate the effectiveness and viability of LoRa communication in multiple locations within an indoor building and evaluate the signal strength and reception ratio of the LoRa communication in different areas and floors of the building. A single LoRa device was used to transmit data, while multiple receivers captured and recorded the received data. The collected dataset underwent meticulous analysis to ensure the reliability of the data. The findings provide insights into the effectiveness of LoRa communication in indoor building scenarios and offer valuable information for optimizing LoRa deployments in similar environments.**

I. Introduction

Internet technologies have permeated practically every element of modern society and changed the way people interact with one another, access information, conduct business, and engage with the outside world. They have facilitated worldwide connectedness, economic growth, knowledge sharing, and cultural interchange, making their significance in contemporary life unquestionable. Utilizing diverse technologies for communication is one of the most significant contemporary technologies that Internet technologies have attained. LoRa (Long Range) is one such technology that has contributed to this progress. LoRa (Long Range) is a low-power wide-area network (LPWAN) technology designed for long-range communication between devices with low bandwidth requirements. It enables long-range communication with low power consumption, making it suitable for battery-operated devices and applications in areas with limited infrastructure. Implementing LoRa in buildings offers numerous benefits, including cost-effective deployment, long battery life for devices, and reliable communication over extended distances. By leveraging the strengths of LoRa technology and considering the specific requirements and characteristics of the building environment, it is possible to create a robust and efficient IoT infrastructure for building automation and monitoring. [1]

II. Experiment Setup:

On Thursday, May 27th, 2023, at 12 o'clock, a comprehensive experiment on LoRa technology was conducted in the NW1 building at the University of Bremen. The experiment utilized a specialized device called the LoRa device, specifically designed for transmitting packets using LoRa technology.

The LoRa device comprises essential components, including a microcontroller, a transceiver, and an antenna. The microcontroller acts as the device's brain, while the transceiver handles the modulation and demodulation of data. The antenna plays a crucial role in transmitting and receiving LoRa signals, enabling wireless communication. This combination empowers the LoRa device to achieve long-distance communication with minimal power consumption, making it an efficient and reliable solution. Refer to Figure 1 for visual representation.

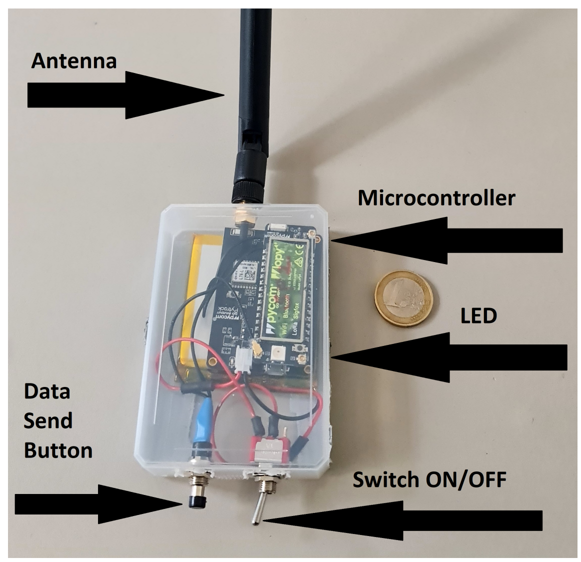

Fig. 1: Picture of the lora device used to send packets

LoRa devices typically operate on battery power, and their status can be understood through LED patterns on top of the device. A blue blinking LED indicates the device is functioning, a green LED signifies an established connection, a yellow blinking LED indicates the completion of transmission, and a red LED indicates an error condition. These LEDs provide valuable feedback on the device's operational status.

By employing the LoRa device, this experiment aimed to investigate the performance and feasibility of LoRa technology within the indoor building environment, specifically the

NW1 building. The following sections detail the experiment's methodology, data collection, and analysis, shedding light on the effectiveness of LoRa communication in this context.

The experiment utilized the LoRa device to send packets from nine different locations within the NW1 building: U, S1, S0, C, N0, N1, H, E, and W. These locations were visually represented in Figure 2.

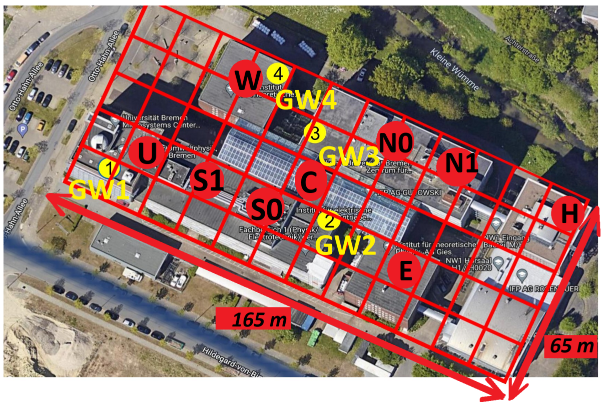

Fig. 2: Picture of the NW1 building: the red circles represent the locations, the yellow circles represent the gateways, length of the building = 165m, width of the building = 65m. [2]

In Figure 2, the red circles indicate the specific locations from which the packets were transmitted during the experiment. These locations represent different points within the NW1 building. On the other hand, the yellow circles represent the placement of the gateways. Specifically, Gateways 1, 2, and 3 are positioned on the second floor, while Gateway 4 is situated on the third floor. Furthermore, Figure 2 provides additional information regarding the dimensions of the NW1 building. The length and width of the building are visually depicted in the figure.

To maintain a systematic and organized approach, the experiment commenced on the ground floor of the building (Floor 0). A starting location (location "U") was selected on the ground floor and the LoRa device was used to transmit a set of four data packets. Once the first set was transmitted, the device was relocated to the next predetermined location on the same floor, where another set of four packets was transmitted. This process was repeated, ensuring coverage of all nine locations on the ground floor.

Once the packet transmission sequence for all locations on the ground floor was completed, the LoRa device was then moved to the subsequent floor of the building. The same sequence and process were meticulously replicated for each floor, including the second, third, and fourth floors. This consistent pattern of relocating the device and transmitting packets ensured comprehensive coverage and data collection throughout the entire building, floor by floor.

In order to maintain a controlled environment and minimize interference, a minimum time gap of one minute was implemented between the start times of two consecutive locations. This deliberate spacing allowed sufficient time for data collection and reduced the likelihood of signal overlap or interference between locations.

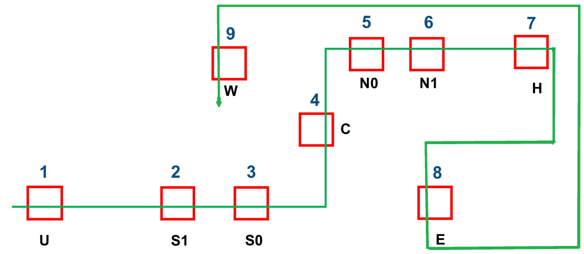

Fig. 3: The followed path (for each floor): the green arrow shows the sequence

Figure 3 provides a visual representation of this sequential movement across the building's floors during the experiment.

Unfortunately, due to ongoing construction work, certain locations within the building were inaccessible during the experiment. Specifically, on floor 0, the location labeled as "N1" and on floor 2, the locations labeled as "S1" and "S0" were unable to be visited. These locations were excluded from the data collection process due to the temporary limitations imposed by the construction activities.

III. Collected Dataset:

During the experiment, the four gateways received the transmitted packets from the LoRa device and forwarded them to a server. The server played a crucial role in processing and storing the received packets. It is responsible for organizing the data in a structured manner. In this case, the dataset was structured as a table in a CSV file format.

A total of 168 packets were sent throughout the experiment, each containing valuable information. The structured table in the dataset includes the following information for each received packet: The location from which the packet was transmitted, the corresponding floor, a unique packet identifier (packet-ID), the date and time when the packet was received, the gateways through which the packet passed, and the received signal strength indication (RSSI) expressed in decibels (dBm). See Figure 4.

	B	C	D	E	F	G	H	I
1	date	time	gw1	gw2	gw3	gw4	floor	location
2	2023, 4, 27	12:34:44	-94	-	-108	-	0	U
3	2023, 4, 27	12:34:53	-97	-	-109	-	0	U
4	2023, 4, 27	12:35:01	-	-	-107	-	0	U
5	2023, 4, 27	12:35:09	-99	-	-108	-	0	U
6	2023, 4, 27	12:40:42	-115	-82	-65	-84	0	S1
7	2023, 4, 27	12:40:52	-115	-79	-66	-83	0	S1
8	2023, 4, 27	12:41:02	-113	-85	-63	-82	0	S1
9	2023, 4, 27	12:41:10	-	-103	-62	-81	0	S1
10	2023, 4, 27	12:42:15	-	-82	-93	-112	0	S0

Fig. 4: A snippet of the dataset, which was structured as a table in a CSV file format

Figure 4 shows The structured table in the dataset includes the following information for each received packet.

By organizing the data in this structured format, it becomes easier to analyze and draw insights from the experiment, as it provides a comprehensive overview of the received packets and their associated details.

IV. Analyzing Dataset:

When analyzing the data collected from the LoRa experiment, several key metrics can be considered to show the performance of LoRa technology. In addition to that, multiple expectations can be defined based on the characteristics of LoRa technology and the specific experiment setup.

The packet reception ratio stands out as a crucial metric for evaluating the performance of LoRa technology. This metric measures the proportion of packets successfully received by the gateways compared to the total number of packets sent. It serves as an indicator of the quality and reliability of data transmission. Since the packets were sent from different locations and floors, it is expected to see variations in the reception ratio across different areas.

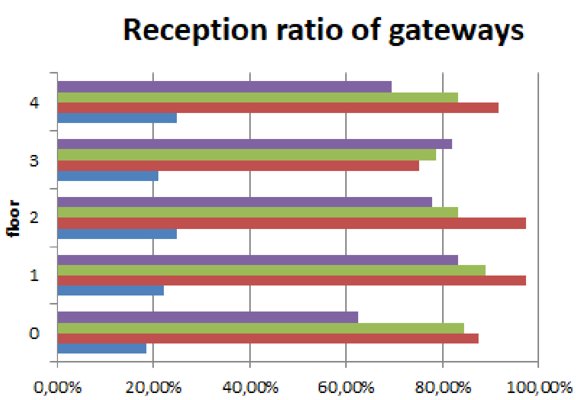

Fig. 5: The reception ratios observed for the four gateways of all five floors

Figure 5 offers valuable insights into the reception ratios observed for the four gateways positioned on each floor of the building. Gateways 2 and 3 notably demonstrate the highest reception ratios among the gateways. This can be attributed to their strategic placement near the middle of the building, as depicted in Figure 2. The central positioning of these gateways allows for improved reception by minimizing the impact of walls, objects, and physical obstacles that may attenuate the signal strength. Consequently, Gateways 2 and 3 consistently exhibit strong reception ratios across all floors, indicating their effectiveness in capturing transmitted packets.

In contrast, Gateway 1 displays the lowest reception ratio among the gateways, with a reception rate of below 50%. This lower reception ratio can be attributed to its positioning at a greater distance from most of the transmitting locations within the building. This distance creates challenges in signal propagation, resulting in weaker signal reception and subsequently a lower reception ratio for Gateway 1.

Considering this consistent low reception ratio across all floors, it may be advisable to evaluate the viability of Gateway 1 for potential removal or relocation to a more optimal position within the building.

Moreover, it is worth noting that certain locations, such as ”H” on the third and fourth floors, exhibit lower reception ratios (50% reception rate) even with the presence of gateways. To address this issue and improve overall performance, it is recommended to consider the addition of a new gateway or relocating Gateway 1 to a more strategic position within that specific area. These measures can potentially enhance signal reception and improve the reception ratios at these challenging locations.

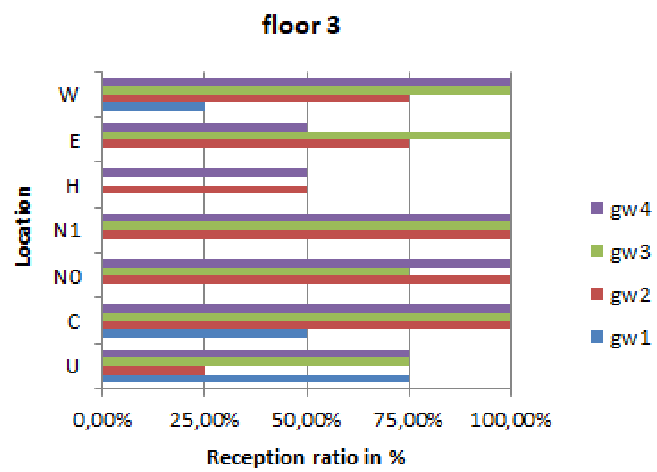

Fig. 6: The reception ratio of floor 3, which shows the lower reception ratio (50%) for Location ”H”

Figure 6 highlights the lower reception ratio (50%) for Location ”H” on the third floor.

Another important metric is the Received Signal Strength Indication (RSSI), which is a metric used to measure the strength or power level of a received radio signal. In the context of LoRa, the RSSI provides information about the signal strength of LoRa transmissions received by a LoRa receiver or gateway. The RSSI value, typically measured in decibels (dBm), ranges from 0 to -130 dBm, encompassing plausible signal strength values. [3]

Plotting RSSI values against distance is a crucial step in understanding how the signal strength behaves as the distance between the transmitting locations and gateways increases.To create a graph showing the RSSI values over distance, the distances between the transmitting locations and the receiving gateways for each packet were determined using the dimensions of the building provided in Figure 3. Then the RSSI values and their corresponding distances from the dataset were extracted. The duplicate values were removed to avoid redundancy in the graph. See Figure 7.

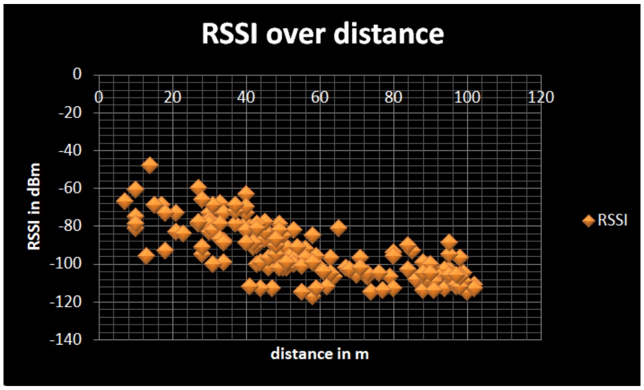

Fig. 7: RSSI values over distance

Figure 7 demonstrates how the RSSI values decrease as the distance between the LoRa device (transmitter) and the gateways (receivers) increases. This decreasing trend is expected behavior, as signals generally weaken over longer distances due to attenuation and other factors. Additionally, the graph shows that the RSSI values never drop below -130 dBm. This suggests that even at the maximum distance tested in the experiment, the received signal strength remains above the lower limit of -130 dBm. The fact that the RSSI values do not go below -130 dBm is significant because it indicates that the LoRa communication system maintains a minimum level of signal reception even at the farthest points within the building.

Based on the analysis, there is potential for improving the deployment. By addressing the gaps in coverage, optimizing gateway placement, and considering the specific characteristics of the building, the overall performance of the LoRa network can be enhanced.

V. Outliers:

It is noteworthy that a few transmitted packets were not received by any of the four gateways. There are a couple of possible explanations for this. Firstly, it is possible that these packets were picked up by other gateways that were not part of the experiment. This could occur if there were additional gateways within the vicinity that unintentionally captured the packets. Alternatively, technical difficulties with either the LoRa device or the gateways themselves might have caused these packets to go unrecorded. Such technical issues could have temporarily disrupted the reception process, resulting in the failure to receive these specific packets.

Additionally, it is important to mention that some received packets did not come with an accompanying Received Signal Strength Indication (RSSI) value. This absence of an RSSI value could be attributed to technical limitations or issues encountered during the packet reception process. It is possible that certain circumstances during the experiment hindered the accurate measurement or recording of the RSSI value for these particular packets. These issues might have been temporary or intermittent, affecting only a subset of the received packets.

Furthermore, it should be acknowledged that certain locations within the building were inaccessible during the experiment due to ongoing construction work. As a result, these locations were not included in the data collection process. The presence of construction activities might have restricted access to certain areas, making it impractical or unsafe to deploy the LoRa devices or gateways in those specific locations. Therefore, it is important to recognize this limitation when considering the overall coverage and representation of the data collected during the experiment.

VI. Conclusion:

This study aimed to evaluate the performance and practicality of LoRa (Long Range) technology in the NW1 building at University Bermen. The experiment involved transmitting data from a single LoRa device, while multiple receivers (gateways) captured and recorded the received packets. By analyzing the dataset consisting of 168 packets, the experiment effectively assessed the performance of LoRa technology.

The analysis primarily focused on two important aspects: the reception ratio and the Received Signal Strength Indication (RSSI). The findings revealed a notable relationship between the proximity to the gateways and the strength of the RSSI values, indicating the quality of signal reception. Locations situated closer to the gateways exhibited stronger RSSI values, while those farther away experienced weaker signals. This correlation aligns with the expected behavior of LoRa technology, as increased distance or physical obstacles can diminish the signal strength.

The results of this experiment significantly contribute to the understanding of LoRa communication within indoor building environments, offering valuable insights for similar scenarios. LoRa's reliable long-range communication capabilities make it an appealing technology for applications such as building automation and monitoring.

Overall, this study sheds light on the performance characteristics of LoRa technology and highlights its potential for indoor building environments. It emphasizes the significance of LoRa as a viable solution for long-range communication in various indoor settings.

References

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