Comparative Analysis of Communication Technologies for an Aerial IoT over Collapsed Structure

Divyasree Mohan Menon, Sai Shibu N B and Sethuraman N Rao

April 24, 2021

Comparative Analysis of Communication Technologies for an Aerial IoT over Collapsed Structures

Divyasree Mohan Menon, Sai Shibu N B, Sethuraman N Rao
Center for Wireless Networks & Applications (WNA)
Amrita Vishwa Vidyapeetham
Amritapuri
India
Email: divyasreemm@am.students.amrita.edu, saishibunb@am.amrita.edu, sethuramanrao@am.amrita.edu

***Abstract*—Coping with natural disasters is one of the central challenges of this century. Many disasters are accompanied by the collapse of buildings and other structures. Since, most of the rescue operations are manually executed, this, in turn, endangers the lives of the responders who are unaware of the situation inside the building. Exact localization of the trapped victims under the debris of collapsed buildings will help streamline the rescue operations. Use of UAVs to set up an aerial IoT to help in this effort is an area of ongoing research. The objective of this paper is to evaluate the various communication technologies that are best suited for such an application of IoT. Experiments were designed and performed under various scenarios to study the propagation effects through the debris, furniture, glass panels, etc. The communication technology alternatives were evaluated based on their coverage range, and throughput through various mediums such as concrete, metal,wood, glass, and air. This paper presents the results obtained and the inferences drawn from them.**

***Index Terms*—Rescuing trapped people, building collapse, IoT, Testbed, Raspberry Pi, LoRa, Waspmote, ESP32.**

I. INTRODUCTION

According to the study of the United Nations Office for Disaster Risk Reduction, billions of people have been affected by disasters from 2005 to 2015 [1]. The exact localization of victims in case of disasters such as earthquake is a major issue. Timely localization of the trapped victims under the debris of collapsed buildings will help streamline the rescue operations [2] [3]. The use of Unmanned Aerial Vehicle (UAV) setup in the field of IoT is an ongoing research area. The focus of this paper is to evaluate the various communication technologies and identify the ones that are best suited for such an IoT application. This paper covers the characterization and evaluation of various design alternatives for an IoT system using a combination of comprehensive survey of the state of the art and experimental evaluation of communication technology options. Experiments were designed and conducted to simulate the various scenarios [4] in collapsed infrastructure involving propagation through the debris. Various communication technology alternatives were evaluated based on their coverage range, throughput, latency, propagation characteristics [5] through various mediums such as concrete, metal, wood, glass and air. The paper is organised as follows: section 2 covers the communication technologies considered, section 3 covers the testbed setup to simulate collapsed infrastructure followed by the discussion of results and conclusion.

978-1-7281-5284-4/20/$31.00

II. COMMUNICATION TECHNOLOGIES CONSIDERED

This section briefly explains different communication technologies considered for the experiment.

A. Wi-Fi Module

Wi-Fi (Wireless Fidelity) is a wireless communication technology which is particularly used where the range is lesser (few meters). It operates in two frequencies i.e., 2.4GHz and 5GHz band and can reach up to 150 feet indoors and 300 feet outdoors [6]. This technology is supported by most of the recent devices such as mobile phones, laptops, DSLR cameras etc. Moreover Wi-Fi technology provides strong security with authentication procedures to allow only the intended users to connect to the network.

B. Long Range Communication Module

Long Range (LoRa) is a low-power wide-area network (LPWAN) technology. It is based on spread spectrum modulation technique derived from the chirp spread spectrum (CSS) technology. It operates at the unlicensed frequency of 868 MHz (Europe) or 915 MHz (Australia and North America). Moreover, under ideal conditions, it provides a range of up to 21.6 kms in LoS (Line of Sight) [7] [8]. Its transmission power can be adjusted to three different values, i.e., 0 dBm (Low Power), 7 dBm (High power) and 14 dBm (Maximum Power) respectively.

C. Zigbee Module

Zigbee is a wireless communication technology developed as an open global standard that fulfills the low-cost, low-power wireless IoT networks requirements. The Zigbee standard operates on the IEEE 802.15.4 physical radio specification

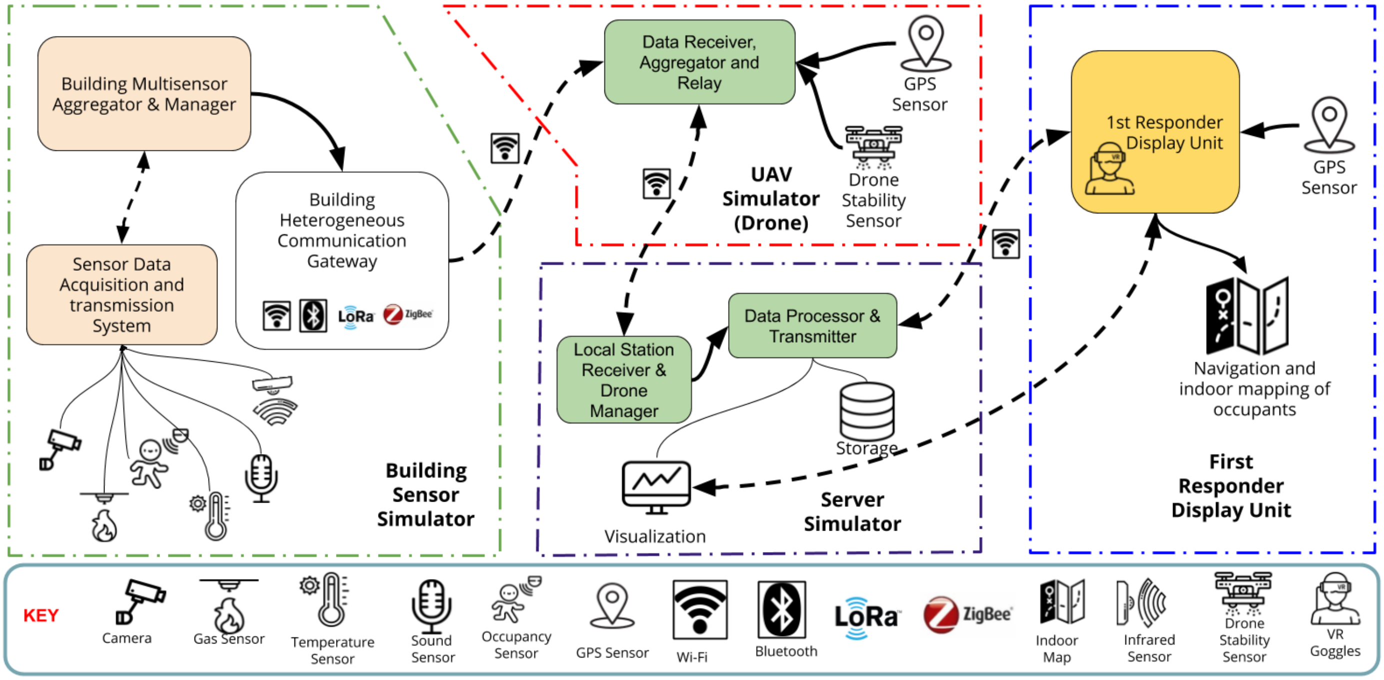


Fig. 1: Overall System Architecture consisting of Building Sensor Simulator, UAV Simulator, Server Simulator, First Responder Display Unit and Keys.

and operates in the unlicensed bands including 868 MHz, 900 MHz and 2.4 GHz [9]. It is a short range communication technology which is best suited for home automation, industrial automation, smart grid monitoring, smart metering etc.

D. *Bluetooth*

Bluetooth is a wireless communication technology which is used for data exchange between two devices over a short distance using short-wavelength Ultra-High Frequency(UHF) radio waves in the ISM band from 2.400 to 2.485 GHz, mostly for creating personal area networks (PANs). Most of the devices have in-built Bluetooth Modules. It generally provides a range of 10-15 meters; hence, it is also known as short range communication technique.

The performance evaluation of all four of the communication technologies under different propagation mediums, i.e., air, wood, glass and concrete pieces have been discussed in the next sections.

III. TESTBED SETUP TO SIMULATE COLLAPSED INFRASTRUCTURE

As shown in the keys of Fig.1, the collapsed infrastructure might consist of some sensors typically in mobiles phones that continuously emit signals in the form of beacons, or some other types of sensors that are expected to send useful information. This sensed data is received by the gateway on the Unmanned Aerial vehicle (UAV) consisting of some processing units along with an efficient communication medium. Further it is expected to transport the semi or fully processed data to the Data Analytics Centre situated at a considerable distance from the UAV for further processing. The processed information is in turn transmitted to the intended responder cum rescue teams.

The testbed used for the evaluation of various communication modules consists of Waspmote and Raspberry Pi 3B+ boards embedded with LoRa and ZigBee respectively. For the evaluation of Wi-Fi and Bluetooth, ESP32S is being used as shown in Fig. 2. In addition, various sensors that can be incorporated into the testbed are also shown. The testbed is formed in such a way that it prototypes the Building network and the UAV Platform.

A. *System Architecture:*

1) *Building Sensor Simulator:*

a) Sensor Data Acquisition transmission- The System collects information from the destroyed building and transmits it to the aggregator and manager.
b) Building Multi-sensor Aggregator and Manager- It collects data from sensors in the destroyed building and after some preprocessing manages to send it to the UAV Simulator.
c) Heterogeneous Communication Gateway- The sensed and processed data is being sent to the UAV Simulator through a heterogeneous communication gateway consisting of different modules such as Wi-Fi, LoRa, ZigBee or Bluetooth present in the Building area network.

2) UAV Simulator: The Drone has the capability to receive data from the Building Sensor Simulator and relays it to the Server Simulator using a long range communication module [10]. It has built in sensors such as gyroscopes and GPS location estimators using which it can be automatically or manually steered to the expected location

3) Server Simulator:

a) Local Station Receiver and Drone Manager–The data from the UAV Simulator is received at the local control station and stored onto the database storage which is displayed on the station dashboard after processing for making necessary arrangements and providing instructions to the responders at the earliest. This unit is also responsible for the control and management of Drones.

b) Data processor and Transmitter –The data received from is processed at this unit fed onto the dashboard for making inferences.

4) First Responder Display (FRD): The First Responder Display (FRD) unit is capable of visualising the overall floor plan of the destroyed building so that the responder can have an estimate of the location where exactly people are stuck. The FRD acquires data from the Server and shows the indoor map, location of trapped victims and shortest route to reach them. Single board computers such as Raspberry Pi[11] can be used to build the FRD.

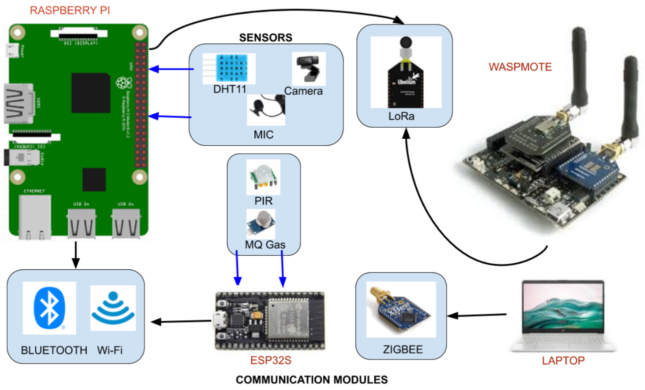


Fig. 2: Testbed Connection

B. Testbed experiments:

The Wi-Fi test setup consists of an on-board Wi-Fi of ESP32S module. The Server and Client Testbeds are kept at a distance of 10 meters during the experimentation. The Server setup is connected to the Laptop so that the Received Signal Strength Indicator (RSSI) value of the packets is visible on the serial monitor. For the test setup of LoRa, Waspmote embedded with LoRA(SX1272) module is used, which is kept at a distance of 15 meters. For the performance analysis of Zigbee, one of the modules is battery powered using a power bank and the other module is connected to the Laptop in which the performance statistics are inferred using XCTU Application. For the performance analysis of Bluetooth, the on-board bluetooth functionality of ESP32 [11] module is used and kept at a distance of 10 meters. The testbeds are set up under different scenarios, such as in LoS, inside a glass chamber, wooden box and a concrete material for acquiring test results in different scenarios.

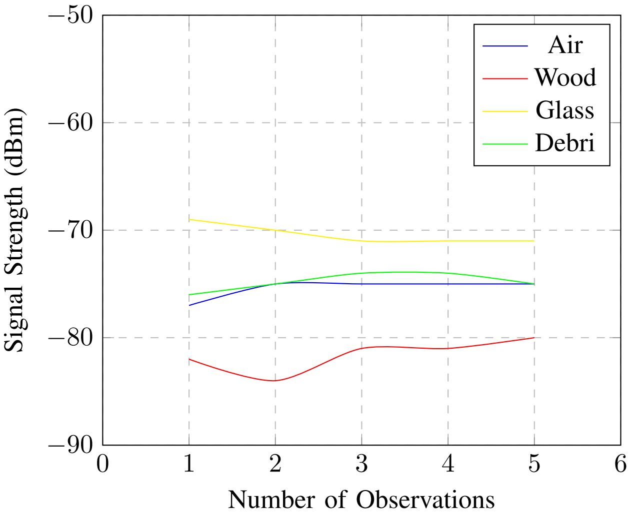


Fig. 3: Plot showing test results of Wi-Fi

IV. DISCUSSION OF RESULTS

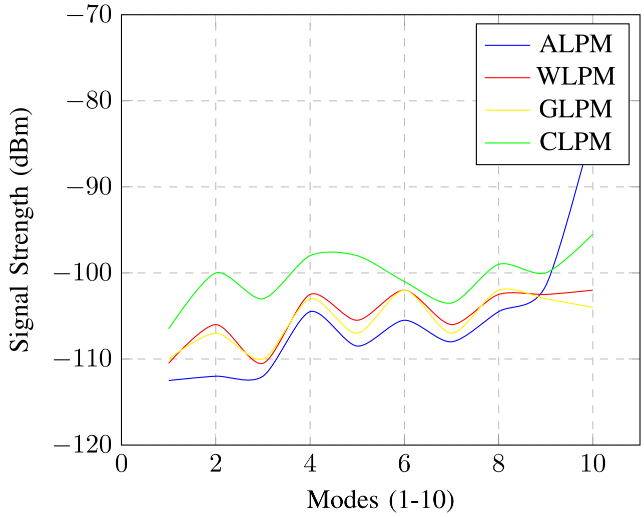
The results of Wi-Fi test setup are shown in Fig. 3 in which the x-axis shows the number of observations taken and the y-axis refers to the RSSI indicated in dBm. Performance evaluation under four different mediums, i.e., air, wood, glass and concrete pieces were performed. As per the plot shown in Fig. 3, the RSSI values for the transmission when kept under the glass was found to be best and is close to -70 dBm. The least performance is shown when the testbed is kept under wooden box. Also, the performance was average when kept inside debris and in Line of Sight (LoS).

The results of the LoRa(SX1272) in the Low, High and Maximum power scenarios for 10 different modes [7] have been shown in Fig. 4.. The x-axis shows the mode number and the y-axis refers to the Signal Strength indicated in dBm. Performance evaluation under four different mediums, i.e., air, wood, glass and concrete pieces have been performed.

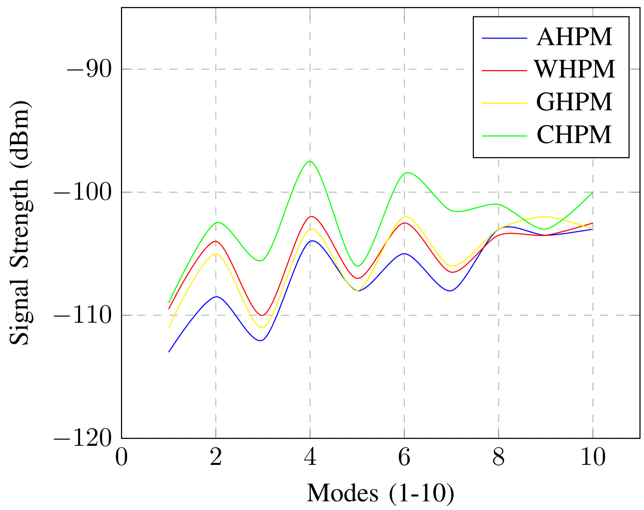
1) LoRa Low Power Mode Analysis - As per the plot shown in Fig. 4.(a), the RSSI values for the transmission when kept under the Debri was found to be better as compared to other mediums and is close to -100dBm. The least performance was shown when the testbed was kept under wooden box and Glass Chamber.
2) LoRa High Power Mode Analysis - As per the plot shown in Fig. 4.(b), the RSSI values for the transmission when kept under the debris was found to be better as compared to other mediums and is close to -100dBm. The least performance was shown when the test setup was kept at Line of Sight(LoS) and an average performance was observed under Glass Chamber and wooden Box.
3) LoRa Maximum Power Mode Analysis - As per the plot shown in Fig. 4.(c), the RSSI values for the transmission when kept under the Concrete pieces, wooden box, Glass Chamber and LoS was found to be almost the same.

The performance graph of Zigbee is shown in Fig.5. The x-axis shows the channel number(1-16) and the y-axis refers to the Signal Strength indicated in dBm. Performance evaluation

(a) LoRa in Low Power Mode



(b) LoRa in High Power Mode



(c) LoRa in Maximum Power Mode

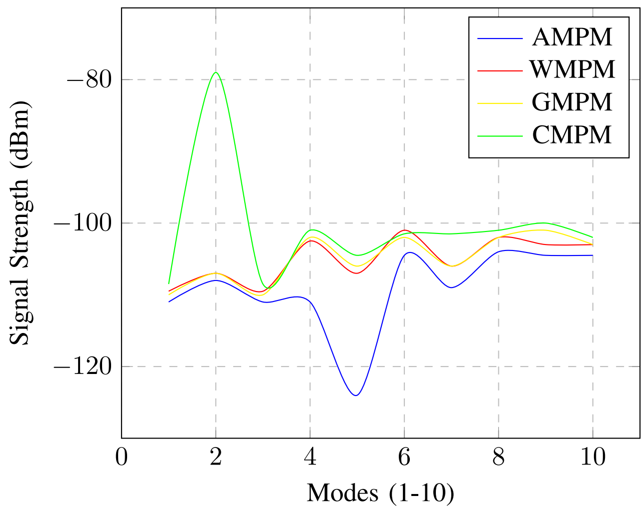


Fig. 4: Plot showing test results of LoRa in Air, Wood, Glass and Debri at low, high and maximum power modes respectively.

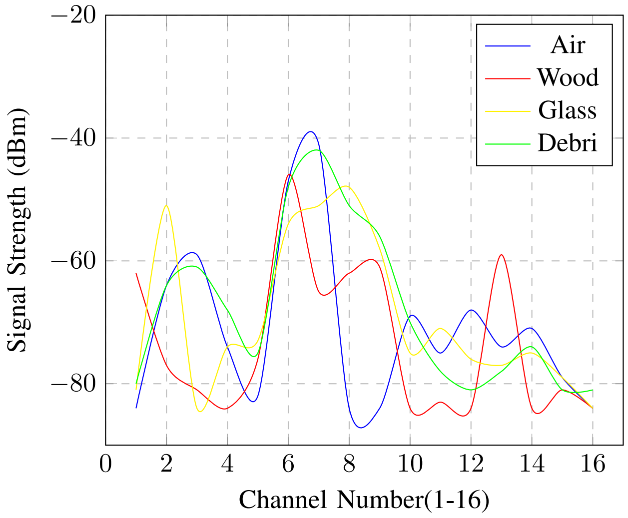


Fig. 5: Plot showing test results of Zigbee

under four different mediums i.e. air, wood, glass and concrete pieces were performed.

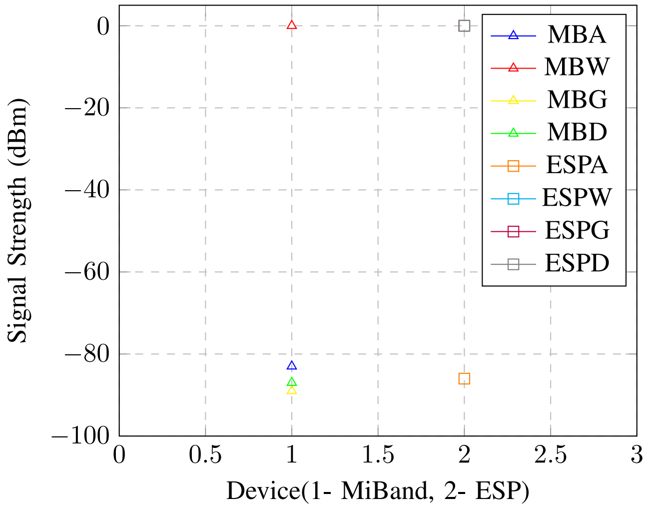


Fig. 6: Plot showing test results of Bluetooth; Abbreviations used: MBA, MBW, MBG, MBD: Mi Band in Air, Wood, Glass and Debris respectively; ESPA, ESPW, ESPG, ESPD: EP32 in Air, Wood, Glass and Debris respectively

It can be inferred from the Fig. 5 that in Channel 5 - 8, the performance is good as compared to other channels when the module is kept inside a wooden box and glass. The results are shown in Fig.6 in which the x-axis shows the different Bluetooth devices (1- Mi Band 3 and 2-ESP32S module) and the y-axis refers to the Signal Strength indicated in dBm. Performance evaluation under four different mediums i.e. air, wood, glass and concrete pieces were performed. From the Fig.68, it can be inferred that the Mi Band 3 and the ESP32 (Bluetooth enabled) were the only devices that got localized with a poor Received Signal Strength Indicator (RSSI) value and the rest of the devices were not detected.

V. CONCLUSION

The inefficiency of the traditional methods to localize victims stuck inside a collapsed debris is a matter of concern, hence a system capable of localizing the victims efficiently is a pressing need. In order to form such a system, various design alternatives were evaluated based on their performance in different media. The communication modules chosen for the analysis were Wi-Fi, Zigbee, LoRa and Bluetooth. The testbed was created for the analysis of the various communication technologies which analogously creates a disaster scenario and results were inferred from the same. From the results, it can be inferred that a single communication technology might not serve all the requirements hence, a heterogeneous platform consisting of various modules has to be set up. As future work, the identified communication module will be integrated into a platform such that it servers the purpose of an IoT system capable of localizing trapped victims inside a collapsed infrastructure.

VI. ACKNOWLEDGEMENT

I extend my sincere thanks to the Chancellor of my institution, Shri Mata Amritanandamayi Devi, faculty,reviewers, each and every person who has helped me to improve the quality of this paper.

REFERENCES

[1] "What is disaster risk reduction?" [Online]. Available: https://www.unisdr.org/who-we-are/what-is-drr

[2] M. V. Ramesh, "Design, development, and deployment of a wireless sensor network for detection of landslides," *Ad Hoc Networks*, vol. 13, p. 2–18, 2014.

[3] A. T. Kunnath, P. Pradeep, and M. V. Ramesh, "Locating and monitoring emergency responder using a wearable device," *Proceedings of the International Conference on Advances in Computing, Communications and Informatics - ICACCI 12*, 2012.

[4] V. S. Anusha, G. K. Nithya, and S. N. Rao, "A comprehensive survey of electromagnetic propagation models," in *2017 International Conference on Communication and Signal Processing (ICCSP)*, April 2017, pp. 1457–1462.

[5] "Waspmote - wireless sensor networks open source platform." [Online]. Available: https://www.cooking-hacks.com/documentation/tutorials/waspmote

[6] B. Mitchell, "How far will your wi-fi reach?" Nov 2019. [Online]. Available: http://www.lifewire.com/range-of-typical-wifi-network-816564

[7] "Introduction to waspmote." [Online]. Available: http://www.libelium.com/development/waspmote/documentation/waspmote-lora-868mhz-915mhz-sx1272-networking-guide/

[8] H. Lee and K. Ke, "Monitoring of large-area iot sensors using a lora wireless mesh network system: Design and evaluation," *IEEE Transactions on Instrumentation and Measurement*, vol. 67, no. 9, pp. 2177–2187, Sep. 2018.

[9] Tarun, A. Baig, D. Shanker, and et al., "What is zigbee technology, architecture and its applications?" Nov 2018. [Online]. Available: http://www.elprocus.com/what-is-zigbee-technology-architecture-and-its-applications

[10] S. N. Rao, D. Raj, V. Parthasarathy, S. Aiswarya, M. V. Ramesh, and V. Rangan, "A novel solution for high speed internet over the oceans," in *IEEE INFOCOM 2018 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*, April 2018, pp. 906–912.

[11] "Esp32 overview: Espressif systems." [Online]. Available: https://www.espressif.com/en/products/hardware/esp32/overview