Demo: Chat based Emergency Service via Long Range Wireless Communication (LoRa)

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Abstract—**Internet and mobile communication are the foundation of today's worldwide interaction and connectivity. Recently, several approaches have been introduced in order to add resilience to communication networks mainly by using low cost and commodity hardware by e.g., facilitating smart phones interconnected via LoRa communication. We extend those ideas by introducing a novel and versatile networking architecture for emergency communication in the context of crisis situations (e.g., when cellular coverage is gone) for mobile devices to keep communication overhead low by following an ad hoc and distributed multi-hop networking approach. In this work, we present a demo of our network to handle emergency communication. It features the long-range, wide area communication technique (LoRa), a web-based chat client with a user-friendly interface, a novel data processing approach, as well as a routing algorithm to ensure fast and efficient communication.**

I. INTRODUCTION AND RELATED WORK

It is evident that the rapidly advancing digitalization proportionally increases the dependency on the internet and mobile communications in all areas of life. Considering the increasing occurrence of natural disasters, a breakdown of those communication networks becomes more probable, which would cause enormous damage to the infrastructure and the ordinary life of everyone. Especially communication with emergency services like the police, the fire brigade, and the ambulance has to be kept available in all possible situations.

In terms of long-range and resilient communication networks, *long range communication technique* (LoRa) is providing an established and widely used technique for *Internet of Things* (IoT) applications, however, limited to very low data rates of only up to 50 kBit/s under optimal conditions due to their communication characteristics. *The Things Network* [1], for instance, is spread out over twenty thousand nodes capable of long-range frequency transmission in wide parts of Western Europe, Australia, and the USA. Due to high transmission ranges of up to 2 km in densely developed areas and up to 15 km in open fields, only a few nodes are needed to cover large areas – still they often have to share the same channel resources. Furthermore, the low power consumption and small size simplifies the installation, which contributes to forming LoRa into a suitable solution within a wide scope of applications.

Recent research explored LoRa for emergency communication. Sciullo et al. [2] use *Bluetooth Low Energy* (BLE) in combination with an Android application to send emergency requests via broadcasts using a network of LoRa nodes. Their focus is also to provide a localization protocol (LOCATE) [3] assessed ad hoc emergency networks based on *unmanned aerial vehicles* (UAV) utilizing LoRa communication based on a custom-slotted ALOHA medium access scheme. Works like those from Centelles et al. [4] investigate novel message-forwarding mechanisms to provide reliable communication and study the scalability of such systems. Those novel approaches prove the purpose and success of LoRa-based emergency communication. Further, approaches like Höchst et al. [5] introduce LoRa communication in the context of mobile devices (e.g., smartphones) in order to provide basic messaging services in case of crisis situations. Yet, a deeper investigation from a systems perspective to offer a versatile and user-friendly interface for end devices is still missing in the context of LoRa-based communication systems.

In our work, we fill this gap by following the approach of using commodity hardware equipped with LoRa communication modules to offer a versatile crisis communication service to mobile devices connected via IEEE 802.11 WLAN. In fact, every IEEE 802.11 WLAN-enabled device that is capable of displaying a website is able to use our approach, enabling broad support in case of emergencies without requiring the download and installation of additional applications. In summary, our approach facilitates *(a)* a LoRa-based communication network for efficient communication of emergency messages, *(b)* a web interface operating as a captive portal to allow connected devices to transmit and receive emergency messages, as well as *(c)* a chat application to allow users in case of crisis situations to use basic communication services via the LoRa network.

Our novel solution features a web-based chat client with a user-friendly interface, as well as refined data processing and an efficient routing algorithm to ensure fast and efficient communication. The network consists of several LoRa nodes to handle the physical data transmission, a database to store relevant data, and web servers to host the chat application.

II. OUR NETWORK STRUCTURE

To build a resilient communication system for emergency situations, our approach uses several entities to provide basic communication services. Particularly, the network consists of several nodes equipped with LoRa as well as IEEE 802.11

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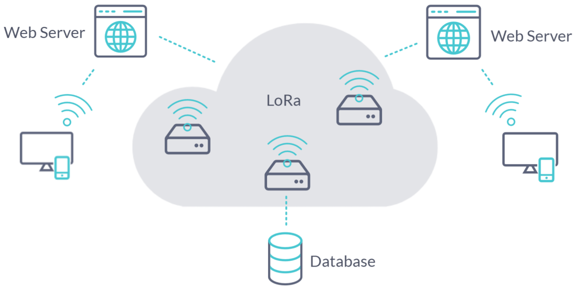


Figure 1. Structure of our network architecture for crisis communication using LoRa. The network can be easily expanded by introducing additional nodes to the network.

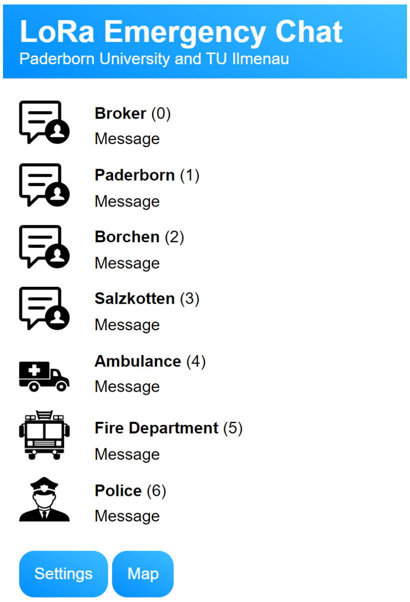
WLAN communication technology to allow end devices (e.g., smartphones) to access the LoRa network via a web server running on those nodes. Further, those nodes are responsible to build and maintain a multi-hop routing scheme in order to scale the network over larger distances. Additionally, the network consists of a dedicated broker including a database to store data of the communication and help bootstrapping and maintaining the multi-hop network. This dedicated broker, however, could reside on a normal LoRa/WLAN node as well.

A. Emergency Message Communication

In order to provide full flexibility for the protocol design of our communication approach and keeping networking overhead low (as needed by LoRa), we employ a custom Link Layer for communication between the devices in the LoRa network. To allow flexibility in terms of our hardware architecture, we use dedicated LoRa communication modules on each node which are connected via serial communication (UART), see Section III for details. This is hardware specific and can be easily interchanged based on the requirements of the used hardware architecture. A self-designed framing procedure enhances the interface between the node and the LoRa module to allow sending and receiving frames over the LoRa interface. Another challenge of our communication system is caused by the very low data rates offered by LoRa, which we overcome by serializing every message into an efficient bit string using Google's Protocol Buffer library. The resulting message structure provides a unique identification number, information about the sending and the receiving node, the message type, the content of the message, as well as additional information about the routing path. We use three different message types, namely *broadcast-msg*, *setup-msg*, and *chat-msg* to specify the purpose of the message, which we outline in the following subsections.

B. Routing

The general routing concept of our approach is divided into two different phases. Initially, every node gets assigned a fixed unique ID, which is used for addressing in the context of our routing approach. This could be achieved by, e.g., deriving this ID from the MAC address of the IEEE 802.11 WLAN module in the node. Once a new node is joining the network, it has to notify the broker about its presence. This message is transmitted as a one-hop broadcast and is forwarded by neighboring nodes up until it reaches the broker. In each forwarded message, the ID of the forwarding node is appended, such that the broker knows the traversed path of each packet – similar to the Dynamic Source Routing approach in the context of sensor networks. In our approach, we assume that the first message arriving at the broker has the best route – however, alternative approaches for selecting suitable routes can be employed here. The traveled route from this first message is then reversed and saved in a routing table in the connected database on the broker. To confirm the successful setup, the broker replies with a *setup-msg* containing a list of addresses of every available node.


LoRa Emergency Chat
Paderborn University and TU Ilmenau

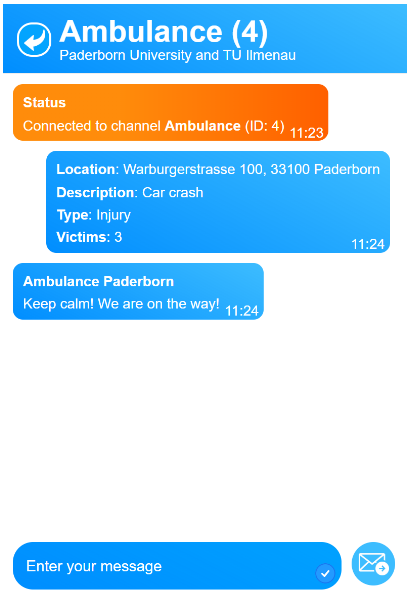
Broker (0)
Message
Paderborn (1)
Message
Borchen (2)
Message
Salzkotten (3)
Message
Ambulance (4)
Message
Fire Department (5)
Message
Police (6)
Message

Figure 2. Example of our chat system which lists all currently available chat channels on the website of the captive portal accessed by the end devices, e.g., smartphones.

Any following communication underlies fixed-path routing. Therefore, messages are sent accordingly to a fixed path throughout the network, which thereby allows a more efficient routing than the broadcast method, e.g., avoiding broadcast storms, and networking overhead. In order to avoid the high local storage requirements of every node, the extensive routing table is only stored in the database on the broker. On the contrary, a node only stores the shortest path to the broker. Despite being a possible bottleneck of overall communication, using a central distributor allows an easy overview and control of the network's traffic. We want to highlight that this approach can easily be extended by having multiple broker nodes in the network, and applying clustering schemes to connect networking nodes to the nearest broker.

C. Database

The access to the database is exclusively reserved for the broker to guarantee easy use and data reliability. The database itself consists of two tables. The *routing table* stores every


Ambulance (4)
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Status
Connected to channel **Ambulance** (ID: 4) 11:23

Location: Warburgerstrasse 100, 33100 Paderborn
Description: Car crash
Type: Injury
Victims: 3
11:24

Ambulance Paderborn
Keep calm! We are on the way! 11:24

Figure 3. Example of the fill-in form for emergency use cases.

node's address and shortest path. The table is updated with every new joining node and is used to inform nodes so they can route every chat message through the network. Further, in the database, all received and transmitted messages are stored.

D. Web Server and Website

To allow end devices (e.g., but not limited to smartphones) easy access to the emergency network, a web-based chat client is used to overview all chat channels as well as write and receive messages. When a chat message arrives at its end receiver via LoRa communication, it is forwarded to the web server running on that particular node. An open local access point (Captive Portal) for IEEE 802.11 WLAN is deployed by the node. Subsequently, almost every device with IEEE 802.11 WLAN capability is able to connect to the web server, which allows the user to easily access and use the emergency chat.

The website itself offers a clear, user-friendly interface and features an overview of all chat channels, a separate message history per channel, and several user settings, as portrayed in Figures 2 and 3. With every new visit, a configuration window opens up first to set the user's name and layout properties. Browser cookies allow users to load their previous settings when reopening the chat. The channel overview not only shows every available chat partner but also indicates the three emergency services. As an example for our scenario, we made channels available for the police, the fire department, and the ambulance, each using a dedicated chat. After selecting a channel, the chat history opens up, where new messages can be sent and received. On the contrary, when selecting an emergency service, a form to collect all relevant data about the emergency case pops up first. The entries are then formatted into a clear, structured text and sent on to the dedicated service to ensure that the emergency service receives all relevant information first. Subsequently, a chat as featured in the other channels follows. Particularly, this form allows the collection of important information, avoids missing information, and keeps message sizes small as only relevant information will be transmitted.

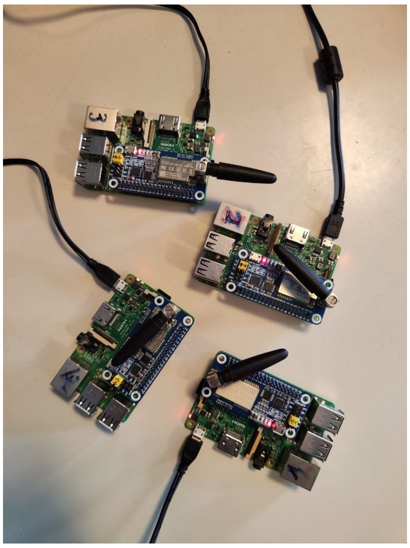

Figure 4. Several nodes (Raspberry PIs) equipped with LoRa HATs.

III. DEMONSTRATION

We use several Raspberry Pi nodes of model 3B extended with SX1262 868M LORA HATs, which provide the technical fundamentals to use the LoRa communication technology. Further, every node hosts a web server and a local access point for IEEE 802.11 WLAN. Our implementation takes advantage of additional software, e.g., *node.js*, *zeromq*, *socket.io*, *MariaDB*, *DNSmasq*, *hostapd*, and of course *GNU/Linux*.

IV. CONCLUSION

We presented an emergency chat system based on LoRa communication for crisis situations. It intends to keep emergency communication available and offers a simple and fast way to enable messaging over a wide area while keeping hardware costs and deployment complexity low as we are targeting commodity hardware architectures.

REFERENCES

[1] T. T. I. B.V., *The things network*. [Online]. Available: https://www.thethingsnetwork.org/ (visited on 05/12/2023).

[2] L. Sciullo, A. Trotta, and M. Di Felice, "Design and performance evaluation of a LoRa-based mobile emergency management system (LOCATE)," *Ad Hoc Networks*, vol. 96, p. 101 993, 2020.

[3] M. Pan, C. Chen, X. Yin, and Z. Huang, "UAV-aided emergency environmental monitoring in infrastructure-less areas: LoRa mesh networking approach," *IEEE Internet of Things Journal*, vol. 9, no. 4, pp. 2918–2932, 2021.

[4] R. P. Centelles, R. Meseguer, F. Freitag, L. Navarro, S. F. Ochoa, and R. M. Santos, "LoRaMoto: A communication system to provide safety awareness among civilians after an earthquake," *Future Generation Computer Systems*, vol. 115, pp. 150–170, 2021.

[5] J. Höchst, L. Baumgärtner, F. Kuntke, et al., "Mobile Device-to-Device Communication for Crisis Scenarios Using Low-Cost LoRa Modems," in *Disaster Management and Information Technology: Professional Response and Recovery Management in the Age of Disasters*, Springer, 2023, pp. 235–268.