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Demo: Using LoRa Communications and Epidemic Routing in Disaster Rescue Operations

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Abstract: A casualty of disasters is the communication infrastructure. Rescuers, in the aftermath of the disaster, require solutions to maintain communications in order to communicate critical information gathered by them. Despite the numerous solutions proposed, a drawback is the communication range. In this work, we propose a communication system based on LoRa, a long-range, low-power communication technology. We use the commercially available, off-the-shelf LoRa based PyCom LoPy4 platform with opportunistic networking to demonstrate the viability of using LoRa for post-disaster recovery operations.

Keywords: Epidemic Forwarding, LoRa, Pycom LoPy4, Disaster Rescue Operations

1 Introduction

The job of emergency first responders is important in saving as many lives as possible and assisting the affected in the aftermath of disasters. Since disasters destroy communication infrastructure, satellite communications are widely used to provide broadband point-to-point connectivity for devices carried by rescuers. But, satellite communications are expensive due to costly equipment and subscriptions.

Since almost every mobile device these days is equipped with Device-to-Device (D2D) communication technologies (e.g., WiFi, Bluetooth), they are considered a viable solution during rescue operations [GW14, MTN18]. However, the short range of these communication methods makes them inefficient when rescuers are dispersed and operating in debris. LoRa is a low-power wide-area networking (LPWAN) technology with a low data rate and a long range (usually 3 to 30 kilometers), making it an excellent alternative.

Some of the crucial data exchanged during rescue operations are short messages consisting of environmental information such as position coordinates or detected dangers (gas leaks, etc.).Therefore, we propose a solution for rescuers based on a low-cost, commercially available microcontroller platform equipped with LoRa and multiple sensors. This platform, called *PyCom LoPy4*[1], carried by each rescuer, is configured to sense environmental information and

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[1] https://pycom.io

use *Opportunistic Networking (OppNets)* with *Epidemic Forwarding* [VB00] and the *LoRaMAC* mode to disseminate data between rescuers and a disaster management center. In this work, we demonstrate the operation of our solution using a scenario mimicking communication during rescue operations. This work has been evaluated with multiple scenarios previously[2] and the architecture and the performance evaluation have been accepted for publication [DTK+21].

2 Related Work

There are a number of work focusing on using LoRa in disaster communications. An IoT framework based on *LoRaWAN* and WiFi technology for disaster management has been presented in [DDZ+19]. The authors of [CFM+19] suggest a communication scheme for disaster communications. The authors of [HBK+20] describe a firmware that enables users to use LoRaWAN technology via smartphones in post-disaster conditions.

Considering these works, our work is unique in that it is the first time *LoRaMAC* has been deployed in emergency communication applications. LoRaMAC refers to the mode of operation in LoRa for direct, device-to-device (D2D) communications with other devices in a wireless neighborhood. In the LoRaWAN mode, the communications are performed over a deployed gateway. In contrast to [DDZ+19], [HBK+20], and [SFTD18], we employ LoRaMAC and an enhanced version of Epidemic Forwarding [VB00] to disseminate data. Our approach is closely related to the work described in [SFTD18], but the authors propose the use of the LoRaMAC interface as an attachment to a smartphone, thereby limiting their solution to the sensing capabilities offered by the smartphone.

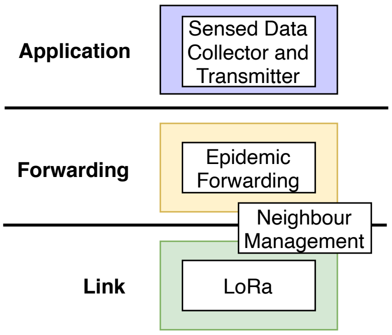
3 System Architecture

The architecture of the system deployed in each PyCom LoPy4 device consists of a 3-layer protocol stack with an additional shim-layer for neighborhood management. The primary purpose of this protocol stack is to exchange sensed data between the devices of the rescuers. The figure 1a shows the Micro-Python programmed protocol stack of a device. Following is a brief description of the protocol stack.

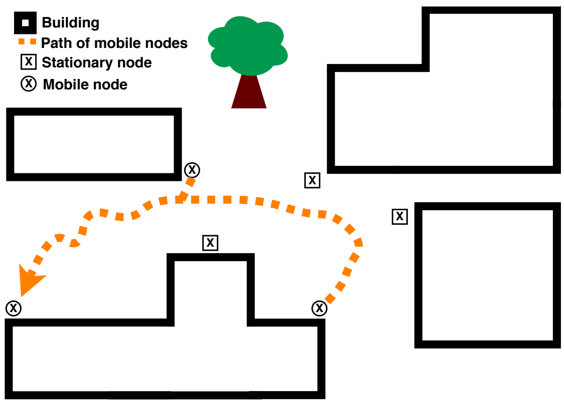
- **Application Layer** is for applications that sense environmental information (e.g., position coordinates) and to use the received data of other rescuers. Currently, we use the *PyTrack* and *PySense* extensions of the PyCom LoPy4 to retrieve the last available localized GPS coordinates, ambient light, pressure, and humidity. This traffic is transmitted periodically and the period of transmitting packets is configurable.

- **Forwarding Layer** is the OppNets forwarding layer where an extended version of Epidemic Forwarding [VB00] is implemented. The extended version consists of anti-entropy sessions based on timeouts to overcome the effects of deadlocks that arise due to the packet losses during transmissions.

[2] https://github.com/ComNets-Bremen/Epidemic-on-PyCom/tree/master/results



(a) The 3-layer protocol stack including the shim-layer



(b) The view of the 6-node scenario demonstrated

Figure 1: Node Architecture and Demonstrated Scenario

- **Link Layer** is realized through LoRa where the LoRaMAC mode is configured at initialization to perform D2D communications. Because LoRa only offers broadcast communications, this module manages unicast operations internally by considering packets that are destined to themselves. The addressing is realized through the unique MAC-like address provided by the LoRa network interface.
- **Neighbor Management** shim-layer is responsible for maintaining the neighbor list of a node using a beaconing mechanism.

There are four different packet types used: *HELLO* message is used by neighbor management to beacon the presence and to know about other devices in its wireless vicinity, *DATA* message carries the sensed data, *REQUEST* and *SUMMARY-VECTOR* messages are used by Epidemic Forwarding to perform the anti-entropy operation [VB00].

4 Demonstration

The focus of our demonstration is to show the dissemination of data to the different devices of rescuers. The figure 1b shows a view of the placement of devices during the demonstration. The demonstration consists of six devices (nodes), three moving (mobile), and three stationary. We have chosen three initial nodes that are responsible for sensing data while all nodes spread the sensed data throughout the network. In this demonstration, we visually show the spread of data throughout the network and at the end, convey how successfully the Epidemic routing protocol disseminated the data throughout the network, and how LoRa enabled this spread to occur.

5 Summary and Future Work

The work presented here for the demonstration focuses on disseminating sensed data of rescuers in the aftermath of a disaster when usual networking infrastructure-based communications are unavailable. The solution we propose uses LoRa and OppNets with Epidemic Forwarding for communications. The solution uses the commercially available off-the-shelf PyCom LoPy4 platform with Micro-Python to implement the functionality. The code and the performance evaluation is available at GitHub[3] and published at [DTK+21]. Though we have an operational version, the performance results show us a number of challenges to address in the future. The primary challenge is the identification of optimal configuration parameters (e.g., the spreading factor). Additionally, we plan to undertake an extensive performance analysis to include evaluations based on realistic post-disaster rescue operations that take into account factors such as node velocity, the distance between nodes, and weather conditions.

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