

In Search of the Lost Nodes in BANs

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Abstract

Communication in Body Area Networks (BANs) involves extremely weak signals because of safety regulations. Human mobility adds one more layer of complexity as it has an effect on path loss depending on the activity. In this paper, we improve the quality of service (QoS) by searching for the lost nodes. Specifically, an Emergency Phase (EP) is added after RAP1 of IEEE 802.15.6-2012 superframe. The connected nodes transmit rescue beacons to reach distressed nodes, i.e. nodes that are disconnected. If a distressed node receives a rescue beacon, it participates in the current EP. The packets are buffered and relayed to the hub by the connected nodes. Our results show that when EP is enabled it is feasible to reach more nodes.

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Abstract

Communication in Body Area Networks (BANs) involves extremely weak signals due to safety regulations. Mobility adds one more layer of complexity as it has an effect on path loss depending on the activity. In this work, we improve the quality of service (QoS) by searching for the lost nodes. Specifically, an Emergency Phase (EP) is added in the superframe. During EP, each connected node to the hub transmits a rescue beacon to reach distressed nodes, i.e. not connected. When a distressed node receives a rescue beacon, it participates in the corresponding EP. Its data packets are buffered and forwarded to the hub by the connected node. This feature is proposed as an enhancement of IEEE Std 802.15.6-2012.

Introduction

The standard for BANs was released back in 2012. It supports a variety of data rates for the communication of the nodes in one-hop star or two-hop extended star topology. The nodes can be on, in or close to the human body. Channel access during the superframe can be random, improvised or scheduled.

- In this work, we propose the use of a special random access phase (RAP) during the superframe, called EP, which takes place after RAP1. We test this feature using a channel model for 2.4 GHz and mobility with real traces from Mocap Database HDM05. Multi-hopping is restricted to two hops. The simulation is implemented using Castalia, a framework of OMNeT++.

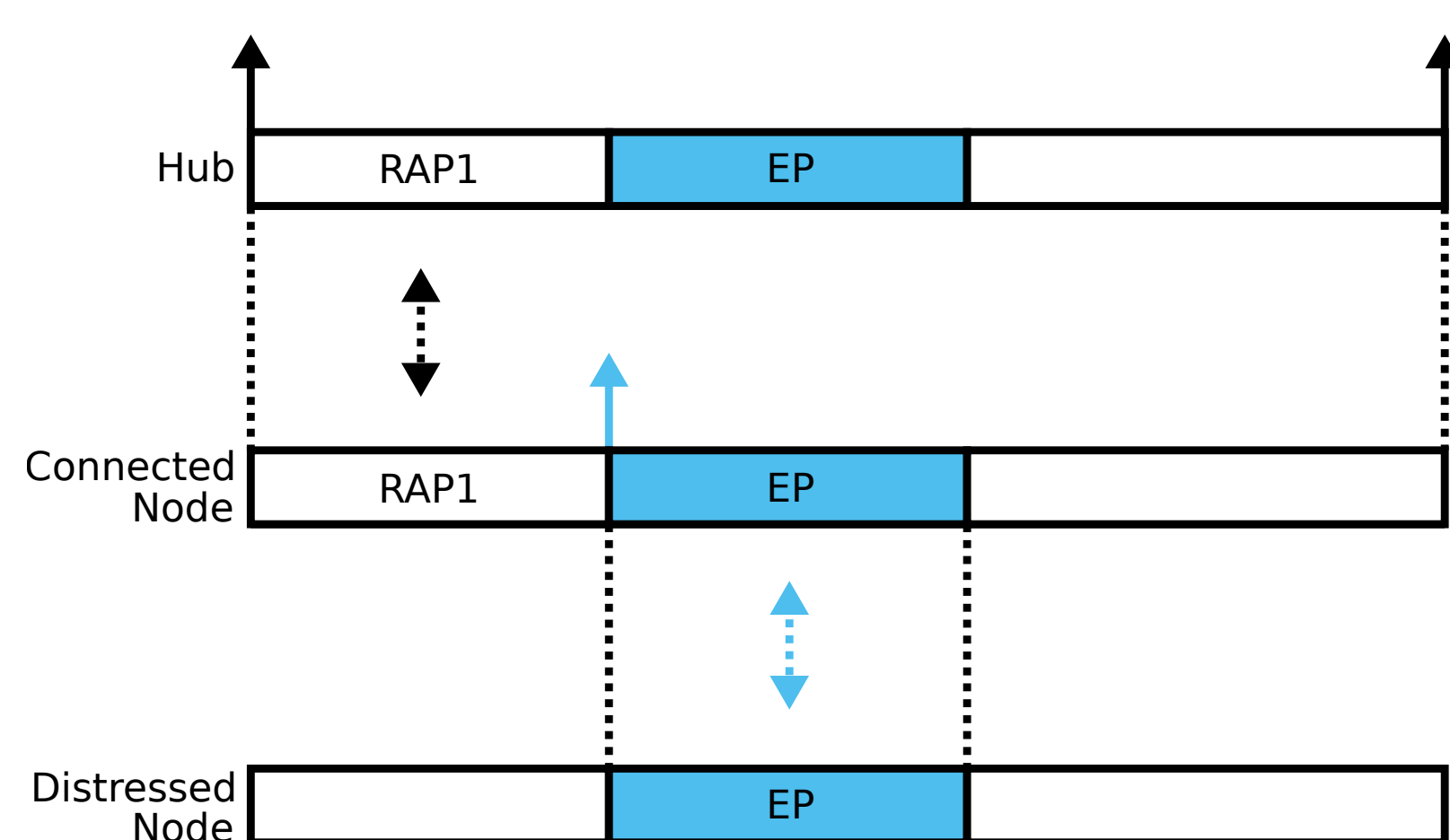


Figure 1: Superframe with enabled EP

MAC

Our MAC protocol is heavily based on Baseline MAC which was implemented by the creators of Castalia as their baseline for IEEE Std 802.15.6-2012. The proposed EP is an additional RAP with the purpose of reaching the distressed nodes and forwarding their packets. The access method is CSMA/CA using the contention windows of the standard.

- During EP, each connected node to the hub can optionally send a rescue beacon to reach any possible distressed node, i.e. not connected. When a distressed node receives a rescue beacon from a connected node, it participates in its EP. When a connected node receives a data packet, it responds with an I-Ack and buffers the packet to transmit it during the next RAP1. If its buffer is full, the packet is dropped. This takes place in every superframe. When a distressed node approaches the hub, it connects and participates in RAP1.

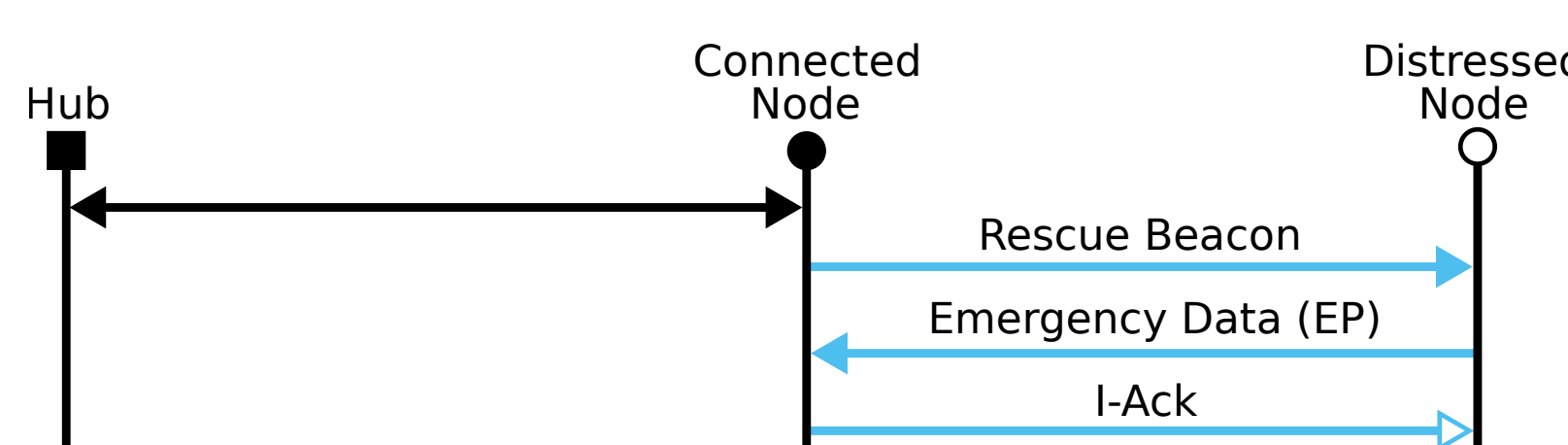
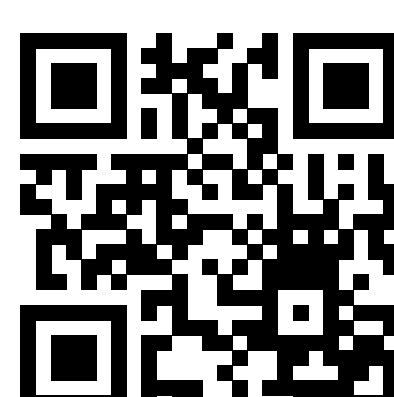


Figure 2: Communication with enabled EP

Mobility model

After several tests, we realised that the way to implement human mobility accurately is to use empirical data instead of random mobility models. Trace based mobility is possible because there is a great amount of motion capture data available online.



- Our model uses a dataset of real traces of human body parts for an everyday activity from HDM05. You can watch an animated clip of it on YouTube by scanning the QR code.

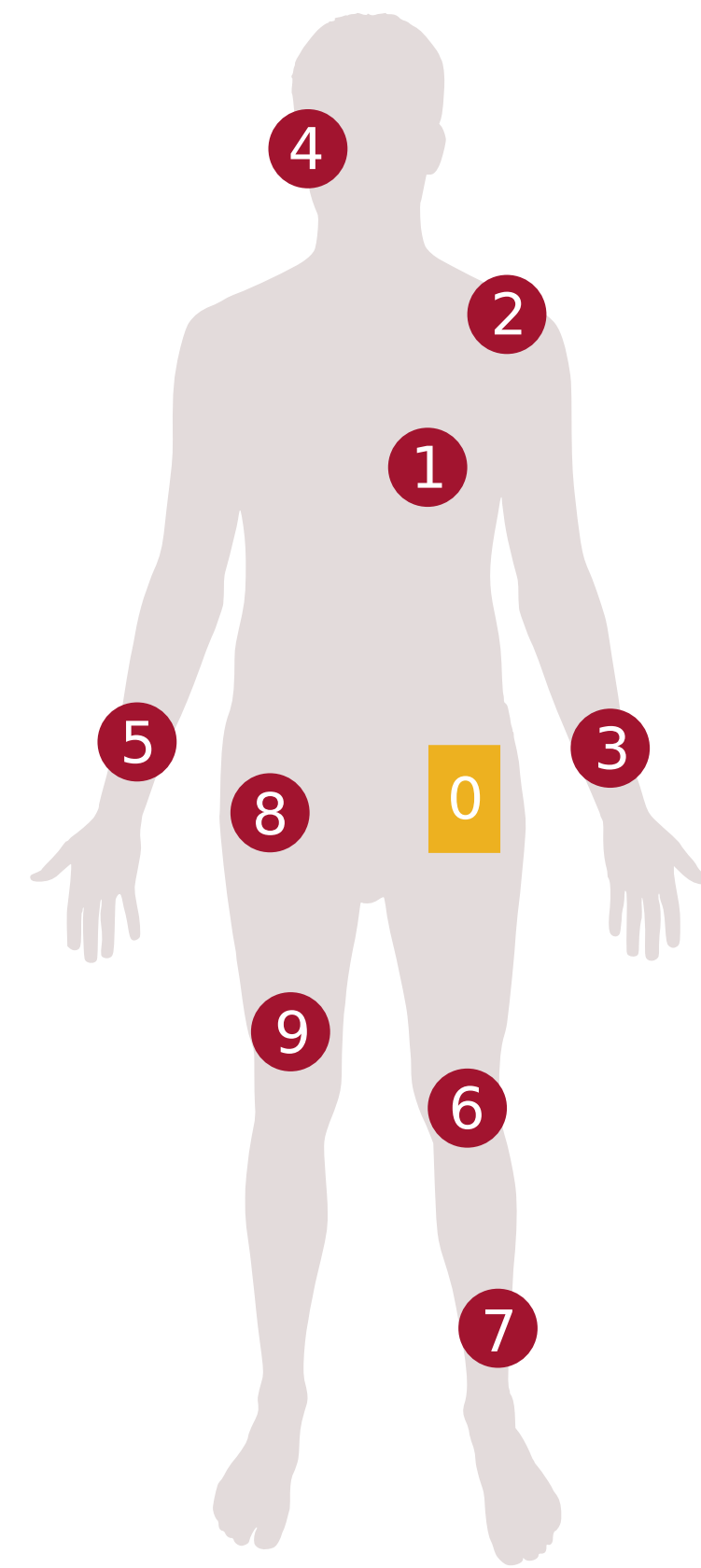


Figure 3: Node placement ~ Simulation

Simulation

Parameter	Value
Time	60 s
Nodes	9 + Hub
Application	Throughput
Payload	100 bytes
Packet rate	20 packets/s
TX power	-10 dBm
RX sensitivity	-87 dBm
Carrier frequency	2.4 GHz
MAC	Baseline MAC + EP
Superframe length	32 slots
RAP1 length	16 slots
EP length	16 slots
MAC buffer size	48 packets
Channel model	CM3A (hospital room)
Mobility model	Object placement

Table 1: System model

- To implement our system model, we modified and extended Castalia. The extra features can be configured using the NED language of OMNeT++. The simulation runs for 60s, while the human subject walks and places objects in a small room. The 9 nodes are placed on body surface according to Figure 3 and send data packets to the hub. Some packets may travel through a two-hop route to reach the hub. Our metric is the number of transmitted and received packets.

Channel model

The quality of a signal in the area of the human body is subject to the typical causes of degradation: fading, path loss and shadowing. Path loss can be modeled as a function of distance between two nodes. The model for the communication of the devices placed on body surface for 2.4 GHz according to IEEE 802.15 Working Group is

$$PL(d)_{dB} = a \log_{10} d + b + X(\mu, \sigma^2), \quad (1)$$

where $a = 6.6$ and $b = 36.1$ are coefficients of linear fitting and d is the distance between two nodes in mm. X is a normally distributed variable with $\mu = 0$ and $\sigma = 3.8$.

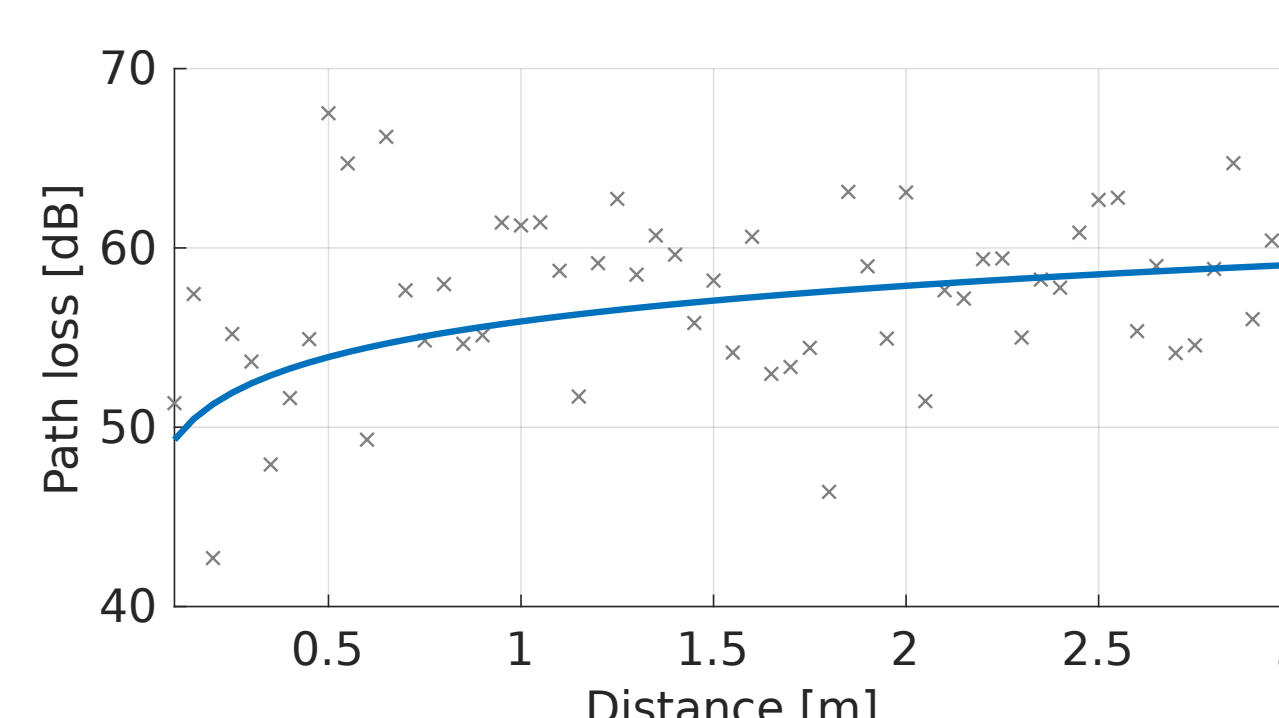


Figure 4: Channel model for 2.4 GHz (CM3A)

- This channel model indicates that we must expect high values for path loss even for distances less than 1 m.

- Nodes placed on human body surface are often disconnected from the network due to very weak signals and high mobility
- We propose a low-level store and forward mechanism in the two-hop area of the body as an enhancement of the standard
- The results show that it is feasible to reach more nodes and receive more data packets

Results

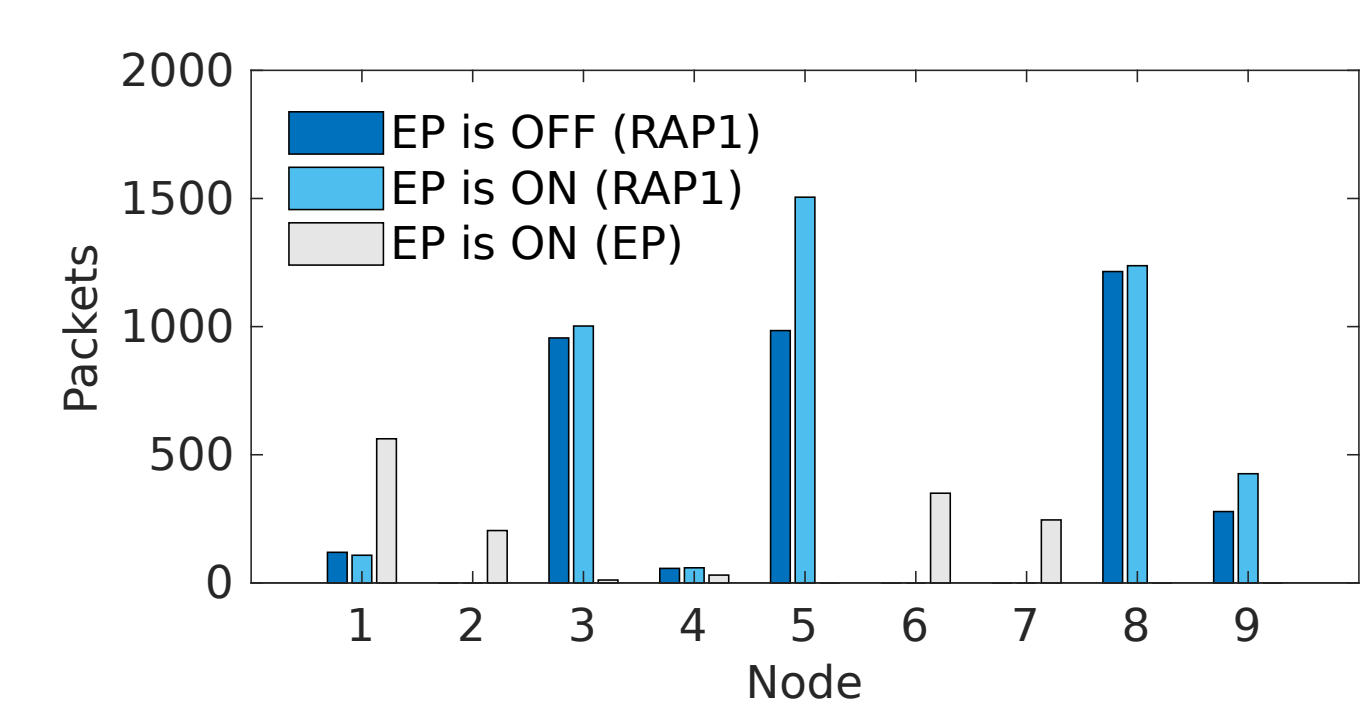


Figure 5: Transmitted data packets

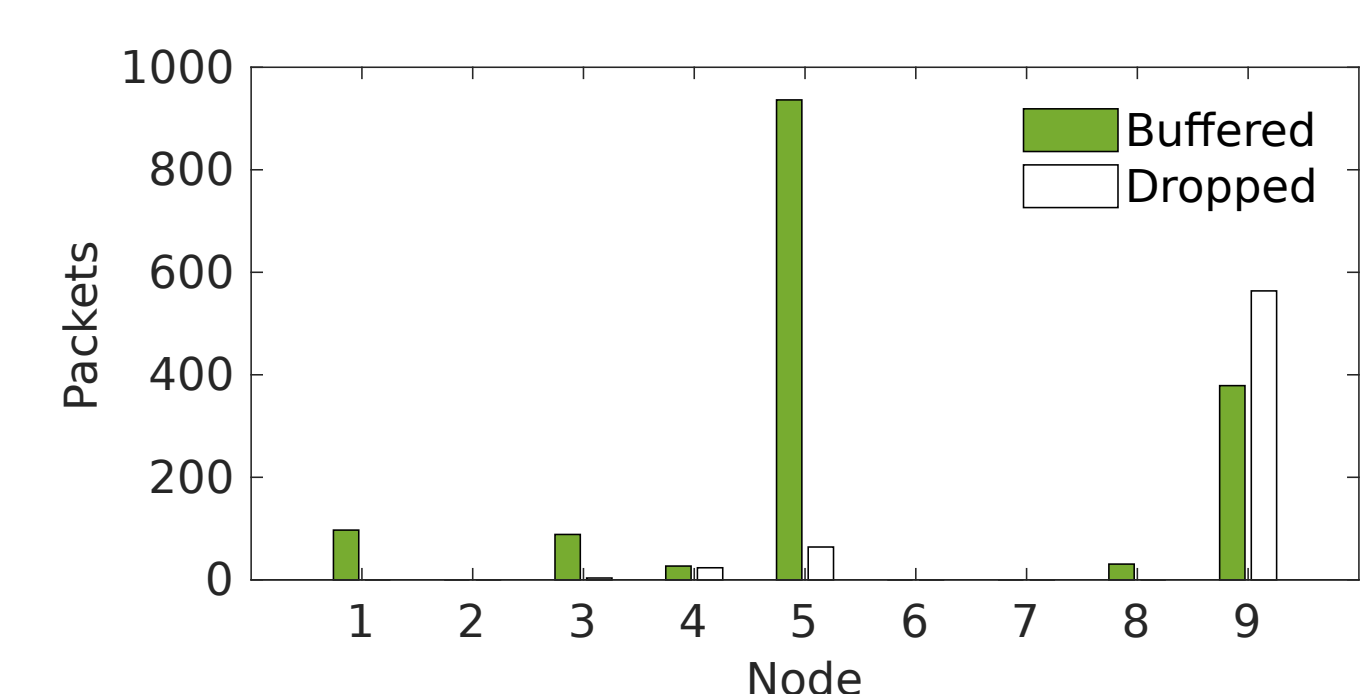


Figure 6: Buffered and Dropped data packets during EP

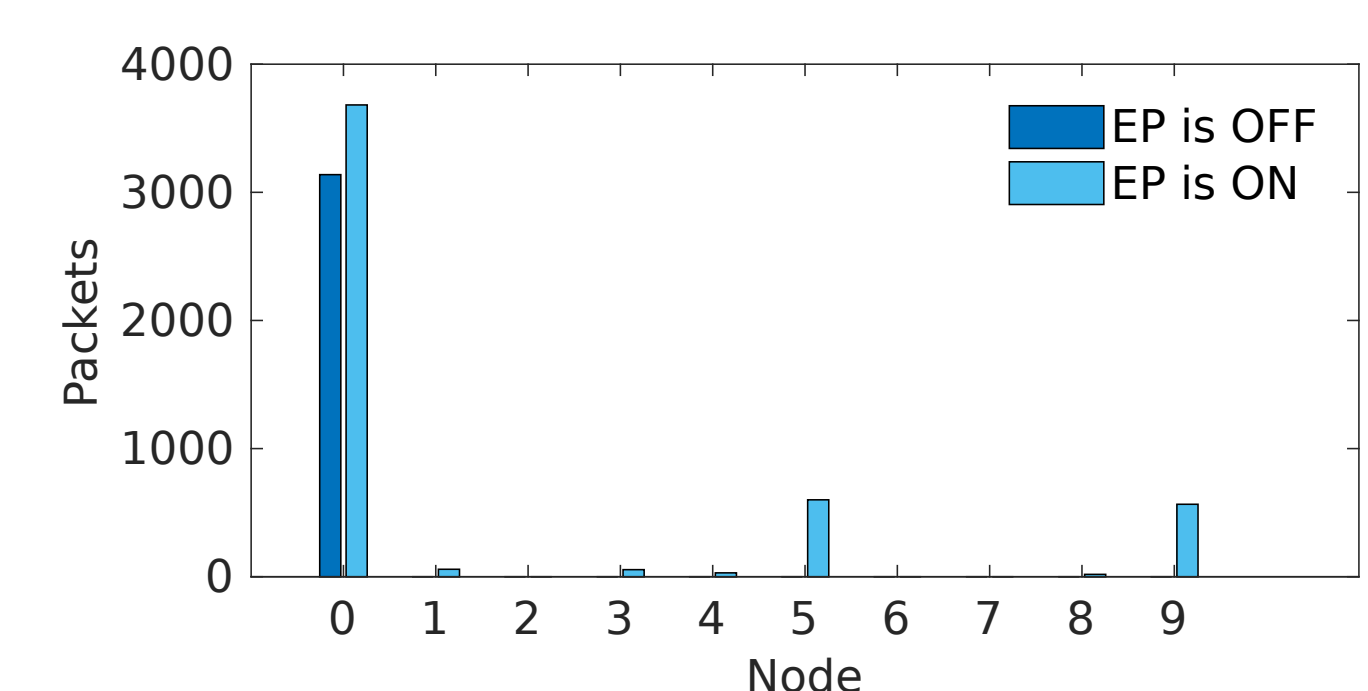


Figure 7: Received data packets

- The results show that when EP is enabled it is feasible to reach distressed nodes and receive more data packets. However, the delivery of each packet to the hub depends on the condition of the corresponding connected node.

Conclusion and Work in Progress

The concept of relaying works well for BANs and seems to be necessary for the devices with the current sensitivity and low signal levels. The effectiveness of the proposed feature must be validated for more channel and mobility models in order to reach a conclusion. Despite the fact that this work is oriented towards QoS, the quantification of the energy benefit is planned for future work as well.

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