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Department of Information Engineering

Bachelor thesis in
Computer Engineering

An LPWAN MAC protocol for agricutural applications

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Abstract

Insert abstract here

Ideas for abstract: - There's a high demand of LPWAN networks, especially in agriculture - Low power usage means smaller devices and less maintenance (e.g.: battery swapping) - A simple and cost effective solution could help a lot

Glossary

GSM Acronym for "Global System for Mobile Communications", it's a 2nd generation mobile communication standard, see [1] for more information.

LTE Acronym for "Long Term Evolution", it's a 4th generation mobile communication standard, see [2] for more information.

FTP Acronym for "File Transfer Protocol", built on top of TCP, see [3] for more information.

VHF Acronym for "Very High Frequency", it refers to the radio frequency band between 30 and 300 MHz.

PHY Stands for physical layer protcol specification.

Contents

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Introduction

Place introduction here

Chapter 2

Bacco protocol

The goal of this chapter is to give a description of the *Bacco* protocol and to discuss the implementation choices that were made in order to deploy it. This is achieved using a top-down ordering for the level of detail, meaning that the overview of the network is presented before its specifics.

2.1 Overview

The network is built upon 3 fundamental categories of devices:

- Sender node - collects data and sends it to the gateway using LoRa
- Repeater node - listens to the incoming LoRa messages form Senders and sends them to a Gateway [1]
- Gateway node - collects data coming from the sender nodes and sends it to the web server using the FTP protocol over a mobile network such as GSM or LTE.. This node has also the role of coorinating and syncronizing Sender nodes. It can be optionally configured to perform pre-processing operations (e.g. filtering, smoothing, interpolation ...) on the incoming data
- Web server - receives data coming from the gateways through FTP, elaborates it and makes it available through a self-hosted web application

[1] The use of Repeaters where physical obstacles compromise the integrity of the signals is of very high relevance in agricultural contexts, since natural barriers such as hills can easily block VHF radio signals.

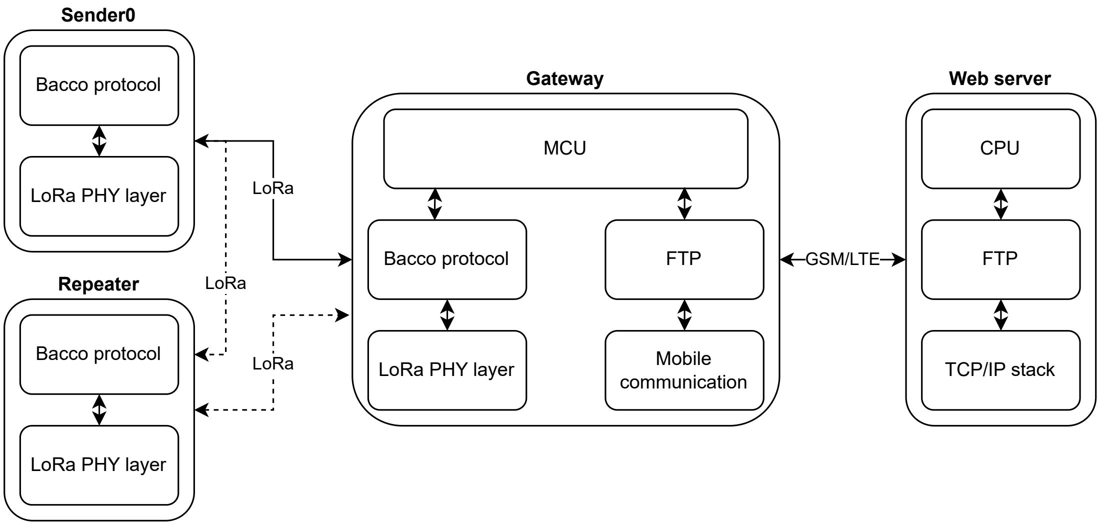

Figure 2.1: Schematic representation of the protocols involved

2.2 Topology

The network has a star-of-stars topology, in which the zeroth level is occupied by the Web server, the first level by the Gateways and Repeaters, and the second level contains the Senders. Figure 2.2 shows the type of devices that are involved and their communication schema.
The structure is equivalent to a tree, hence we can define a hierarchy of nodes. The root node is the central web server and its children nodes are the Gateways. All sender nodes are children of either a Gateway or a Repeater and have to chlidren, so they correspond to the leaves of the tree.

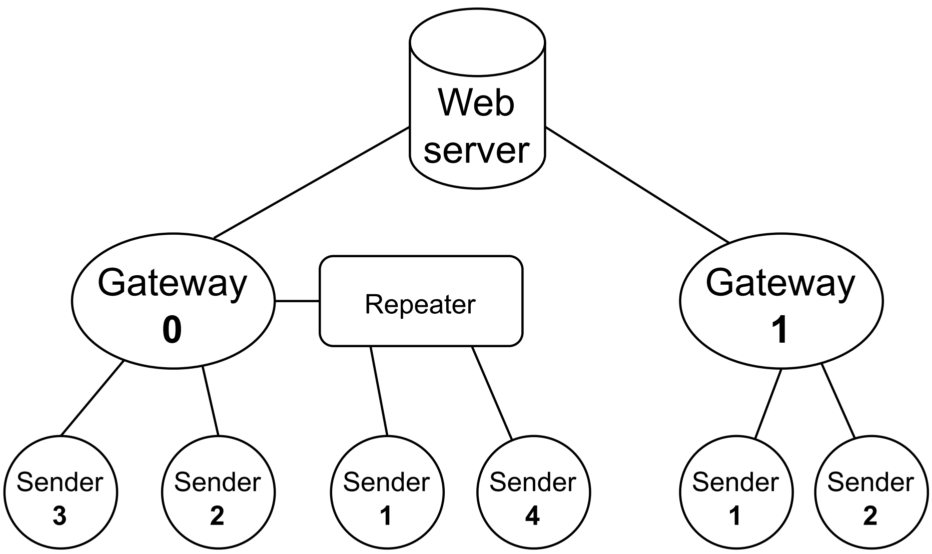

Figure 2.2: Network topology

2.3 Addressing

The addressing scheme follows from the hierarchical structure of the network. A first description of the addressing algorithm is given in the case where there's a fixed number of nodes connected to the network. Later the procedure will be extended in order to achieve the addition or removal of nodes from the network. Note that since repeaters do not modify the repeated message (see **DESCRIZIONE DEI RIPETITORI** for a detailed desription), they are transparent to the other nodes ad thus they will be treated as straight edges by the addressing algoritm. Note also that since there is only one central Web Server, it is redundant to assign it an identifier.

2.3.1 Static addressing

In order to uniquely identify each node in a static network represented as a tree, we can apply the following procedure:

- May T be a tree and may r be its root node
- May $\{T_i\}$ be a forest of substrees with cardinality of I, where T_i is a subtree rooted in the child node i of r, and I is equal to the degree of r
- For each root node i, assing it an identifier that is unique among the other is. In particular the integers contained in the interval $[1, I]$ will be used to represent each node
- For each T_i apply the same procedure from the first step in a recursive way
- After applying this algorithm to every possible subtree down to the leaves, each node will have a unique identifier among its sibiling nodes
- Now, to get a unique identifier among all the network for every node, we can concatenate the identifiers generated by the algorithm for each ancestors of the node, starting from the root and traversing the tree form parent to child

Each Gateway is manually given a static and unique identifier based on its physical location in the range $[0, 65535]$. The maximun number of Sender nodes connected to a single Gateway is limited to 256 [2].

[2] This choice is influenced by the current Italian regulations**CITAZIONE PARAGRAFO REGOLAME** [4] on duty cycle for the 868MHz band and the fact that most agricultural contexts do not require a huge amount of sensors

2.4 Distribution of transmission activity

The LoRa PHY protocol does not cover the matter of sharing the communication link between multiple connected deivices, thus it is necessary to define a method for doing so, in order to minimize interference and achieve a realiable exchange of information. Many techniques can be applied in the domain of both time and frequency.

The Bacco protocol distributes the activity on the channel over time using slots reserved for each Sender, using a concept that was first introduced by the AlohaNet[5] protocol. The slots are equally distributed between the Senders, and the start of the frame is function of the identifier. The time delay between transmissions of each Sender is a constant value and it is called a cycle. At the end of each cycle, a slot is reserved for the Gateway to upload the data received from the Sender nodes to the Web Server.

To make this possible, a

2.4.1 Dynamic addressing

Dynamic addressing is achieved through the

Addressing of Sender nodes can be managed dynamically by the corresponding Gateway in order to seamlessly integrate new sensors into the network.

2.5 Interference mitigation techniques

- CAD - IQ inversion

delta time is 51.6ms and total energy is 21.3mJ

delta time is 71.8ms and total energy is 30.8mJ

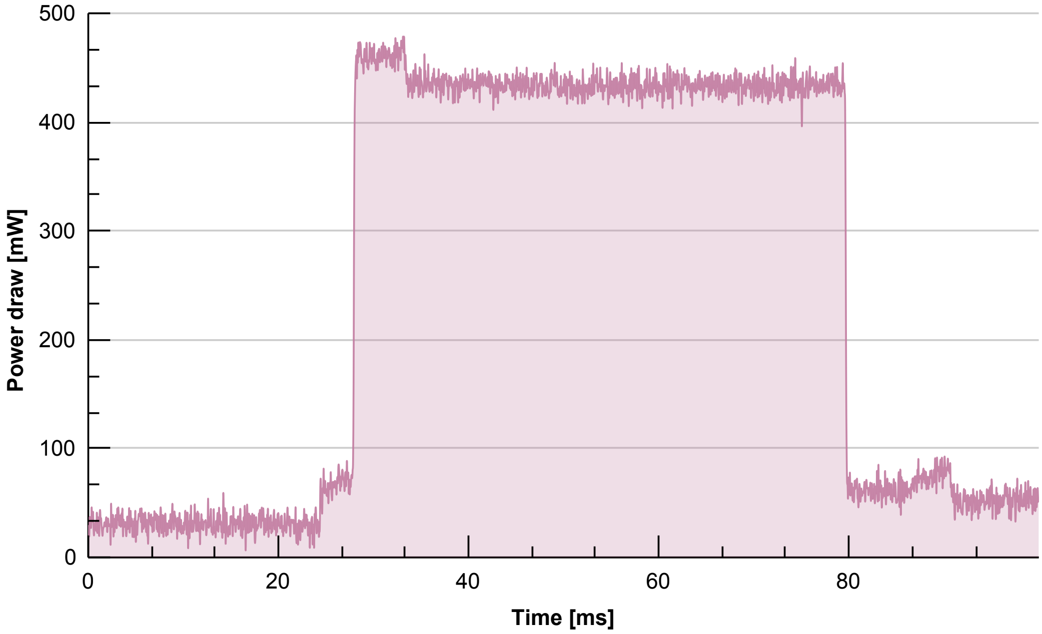

Figure 2.3: Power draw during transmission of a Bacco packet with payload size of 15 bytes, using SF7, 14dBm, 125kHz bandwidth

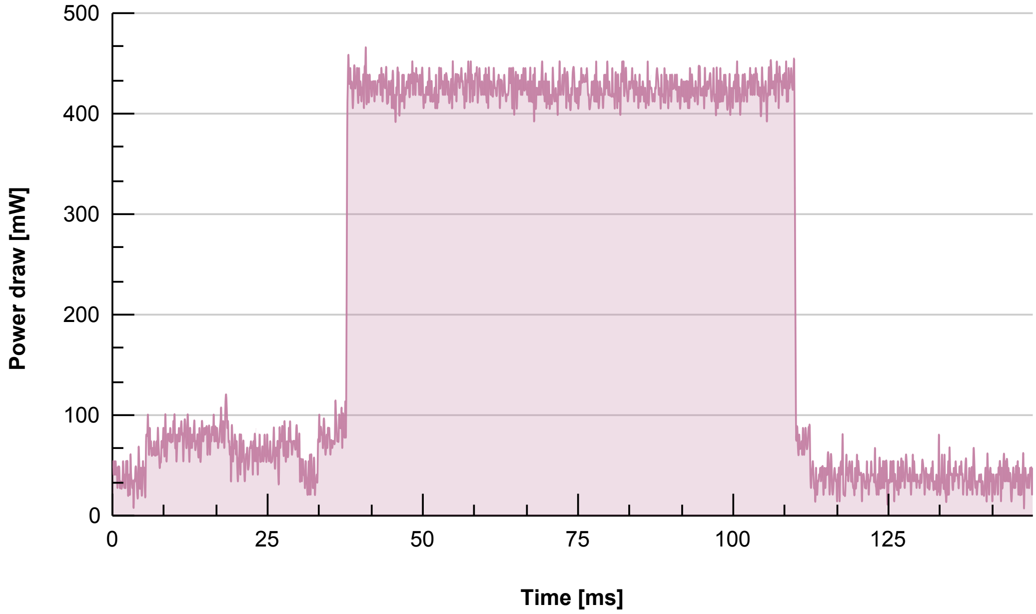

Figure 2.4: Power draw during transmission of a LoRaWAN packet with payload size of 15 bytes, using SF7, 14dBm, 125kHz bandwidth

Bibliography

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