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MASTER THESIS – Communication Systems Group, Prof. Dr. Burkhard Stiller

Cloud Radio Access Network in LoRa

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Abstract

Das ist die Kurzfassung...

Acknowledgments

Optional

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Chapter 1

Introduction and Motivation

Scalability and improvement of Internet of Things (IoT) devices and protocols are important research questions. Low Power Wide Area Networks (LPWANs) technology offers long-range communication with low poser requirements. Battery powered LPWAN devices can run for years. For instance, a node sending 100B once a day lasts for 17 years [1]. LoRa (short for Long Range) is a spread spectrum modulation technique, a wireless radio frequency technology for long range and low power platforms and has become the de facto technology for IoT networks worldwide [2]. LoRaWAN is the open standard backed by the LoRa Alliance. It is a communication protocol and Medium Access Control (MAC) protocol built on the physical LoRa layer. LoRaWAN is designed from the bottom up to optimize LPWANs for battery lifetime, capacity, range, and cost [3]. There are 142 countries with LoRaWAN deployments, 121 network operators, and 76 LoRa Alliance member operators. Swisscom, Amazon, IBM, CISCO are merely a few of the notables LoRa Alliance members [4]. TTN (The Things Network), also a LoRa Alliance member, provides a worldwide LoRaWAN network for and from the community. Anyone with a LoRa gateway can register their gateway on TTN, thereby extending the networks reach. At the time of writing, TTN has 95'208 members, 9'786 gateways, and is present in 147 countries [5]. As LoRaWAN operates in the unlicensed ISM (Industrial, Scientific and Medical) radio bands. Therefore no government license is required to operate LoRa devices and gateways. This allows hobbyist, enthusiasts, and developers to quickly get started and open networks such as TTN to grow rapidly.
In a typical LoRaWAN use case, an IoT device such as a sensor sends data out over the air. Then a LoRa gateway picks the signal up, decodes it, and forwards it over the Internet to the network server which then can send the packet to the application server. If needed, a response message can scheduled on the network server who then chooses the best gateway to send the response back to the IoT device. LoRa gateways carry the full implementation of the LoRa PHY (the physical layer), the LoRaWAN protocol, as well as the packet forwarder. This architecture of the LoRa gateway can be separated and technological stack on the gateway can be reduced by running the signal processing functions not on the gateway itself but in a cloud environment. Such a Cloud Radio Access Network (CRAN) has been previously shown to be beneficial in the 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) [6]. The gateway then is left with only minimal functionality it has to support. As the decoding does not take place on the gateway

itself, it does not need do have any LoRa specific hardware e.g the SX1276 transceiver chip found on LoRa devices and gateways. Rather, the gateway is equipped with an antenna, an amplifier as well as digital to analog (DAC) and analog to digital (ADC) converters. On the upstream, the gateway receives LoRa radio signals which it converts into Inphase and Quadrature (I/Q) sample stream with the ADC and simply forwards them to the cloud signal processing unit via the internet. On the downstream the cloud unit streams a LoRa signal as I/Q samples to the gateway which converts it with the DAC to an analog signal and propagates it out over the air. Signals are encoded and decoded on the cloud unit, the Radio Cloud Center (RCC). There are many advantages in such a setup but they come at a cost. First advantage is that the gateway can be kept at a much simpler design resulting in significant manufacturing cost reduction. Also, modifications to the LoRa PHY or LoRaWAN are easier to introduce as the physical layer is implemented in software. Gateways that are once deployed do not need to be physically replaced in case of an upgrade as they are agnostic to the underlying protocol and just convert and transceive (transmit and receive) I/Q samples. Updates to the protocol can be realized with just updating the software implementation. A Low Power Network (LPN) provider saves cost by not having to drive out to the deployed gateways throughout the country to upgrade their versions. The disadvantage is the high throughput of the I/Q samples stream between the gateway and the RCC. Streaming the I/Q samples between gateway and RCC has significantly higher bandwidth requirements than just demodulating the signal on the gateway and forwarding the decoded LoRa packet as it is done in the non cloudified setup. Cloudifying the LoRa gateways also brings the advantages of setting the base for Software Defined Networking (SDN) and Network Function Virutalization (NFV) by centralizing the resources in the RCC that were before distributed on the individual gateways. Goal of this work is setting up a CRAN architecture for LoRa by simplifying the gateways as described above and moving the signal processing out of the gateway into a cloud ready environment i.e., Docker.

1.1 Description of Work

This work first gives a general introduction to LoRa, LoRaWAN and its applications, then dives into more details regarding the LoRa physical layer. Then it gives an overview over existing software implementations of the LoRa PHY. There are two main contributions. First, this work implements a CRAN for LoRa, gives an architectural overview as well as the implementation details. It evaluates the architectural and network related requirements. We developed a simple protocol in raw LoRa, meaning not compliant with the LoRaWAN standard, where a hardware IoT device has a queue of packets to transmit then, depending on wether it requires an acknowledgment, waits for a few seconds for a response or just transmit the next packet in the queue in an interval. If the packet required to be acknowledged but no acknowledgment is received, the same packet will put as first item in the queue. We use this protocol to analyze our CRAN for LoRa architecture.
Second, as the LoRa PHY is closed source, there is no official documentation on how the LoRa PHY is implemented. The existing implementations are all reverse engineering attempts with various degree of success. They all focused first on decoding LoRa signals transmitted by a real LoRa hardware. For the CRAN to work, not only is it necessary to

decode signals but also the encoding of downstream LoRa gateway signals is required. In this work we developed a tool allows the generating of downstream signals in software.

1.2 Thesis Outline

Chapter 2

Related Work

2.1 Lora

history, usage iot, smart cities, long range, semtech the things network keys & gateways

2.1.1 LoRa signal

chirps, spreading factors, modulation

2.1.2 LoRa in SDRs

josh blum matt knight pieter robyns

2.2 C-RAN in LTE

advantages graphics

Chapter 3

C-RAN for LoRa

3.1 Goal

3.2 Methods

3.2.1 Sending uplink signals

3.2.2 Sending downlink signals

getting a downlink signal recording from thethingsnetwrok recording from private networks manipualting private gateway offline generation of downlink signal see chapter

3.2.3 Transmission protocol

3.3 Architecture

3.3.1 BBU

3.3.2 RRH

3.3.3 Network

3.4 Implementation

3.5 Results

Chapter 4

Future work

4.1 Limitations

4.2 Improvements

Chapter 5

Summary and Conclusions

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Abbreviations

AAA	Authentication, Authorization, and Accounting

Glossary

Authentication

Authorization Authorization is the decision whether an entity is allowed to perform a particular action or not, e.g. whether a user is allowed to attach to a network or not.

Accounting

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Appendix A

Installation Guidelines

Appendix B

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