Poster Abstract: Enabling a Flexible and Sustainable Smart Campus Networking Backbone Using LoRaWAN

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ABSTRACT

Internet-of-Things (IoT) technology is key for smart-campus applications, and the needed IoT infrastructure must be flexible, fault-tolerant, and power-saving to offer a continuous service for such applications. Among Low-Power Wide-Area Network (LPWAN) technologies, LoRaWAN is a promising candidate to meet the requirements. In this paper, we present our on-going research work for a LoRaWAN smart-campus networking architecture. We aim to increase fault tolerance by backing up data between gateways under the LoRaWAN network. At the same time, because now there are multiple gateways, IoT end devices may select appropriate transmission power and spreading factor, to achieve both higher energy efficiency and deployment flexibility.

CCS CONCEPTS

• **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability.

KEYWORDS

Internet of Things, LPWAN, LoRaWAN, Cyber-physical systems

ACM Reference Format:
Cheng-En Yu and Chao Wang. 2021. Poster Abstract: Enabling a Flexible and Sustainable Smart Campus Networking Backbone Using LoRaWAN. In *International Conference on Internet-of-Things Design and Implementation (IoTDI '21), May 18–21, 2021, Charlottesvle, VA, USA.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3450268.3453506

1 INTRODUCTION

In this paper, we report our on-going study of a networking backbone to enable smart campus applications at National Taiwan Normal University (NTNU) in Taiwan. Our vision of a smart campus emphasizes an integration of services that not only makes everyday campus life more convenient and secure, but also reduces the cost of operation and maintenance for campus facilities. At the heart of the smart campus infrastructure is a networking backbone that must be both flexible to support various campus scenarios and sustainable to provide a continuous service at an affordable cost.

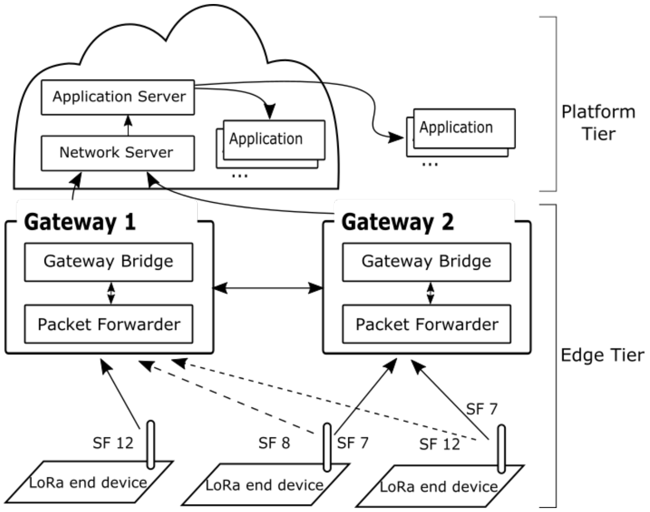

Figure 1: LoRaWAN smart-campus networking backbone.

One of our pilot studies on smart campus applications is for countermeasuring the COVID-19 pandemic. We have been developing and deploying on-campus checkpoints for both body temperature measurement and identity check. We have recognized the following properties for such a service: (1) It should be quick-and-easy to deploy the service at various locations; (2) The networking connectivity should be reliable for on-site embedded modules to save and retrieve data to and from a remote database; (3) Each on-site sensor device only needs to send data at a low rate, and the power-saving of sensor devices is more important than achieving a high throughput, because we can't always replace the battery for each sensor device. For the above reasons, it is appealing to use Low-Power Wide-Area Network (LPWAN) technologies, such as SigFox [6], NB-IoT [7], and LoRa [5]. We chose LoRa because its deployment and operation does not depend on a third party, and because its layer-2 protocol, LoRaWAN, aligns with the reference network architecture of the industrial internet [2].

The key contribution of this paper is a blueprint of using LoRaWAN to build a flexible and sustainable networking backbone to meet the requirements for smart campus applications (Figure 1). In particular, we propose a holistic approach that both tunes the unique SF parameter for each LoRa device and uses multiple LoRaWAN gateways for fault tolerance, better network coverage, and further power saving on the end devices.

IoTDI '21, May 18–21, 2021, Charlottesvle, VA, USA

ACM ISBN 978-1-4503-8354-7/21/05…$15.00
https://doi.org/10.1145/3450268.3453506

2 SYSTEM MODEL AND DESIGN

In the following, we first give a review of related work, and then we describe our networking architecture that integrates the use of LoRa and LoRaWAN for smart campus applications.

2.1 An Overview of LoRa and LoRaWAN

The LoRa technology is based on the spread spectrum modulation technique with a parameter called the *spreading factor* (SF). The SF value (from 7 to 12) can be changed on-the-fly to tradeoff throughput, noise resilience, and energy efficiency. Energy efficiency is defined as the number of bits that can be transferred per unit of energy. A smaller SF value will permit a higher throughput and thus will improve the energy efficiency. But a smaller SF value will lead to a higher demodulation floor in terms of signal-to-noise ratio (SNR), causing a reduction on the transmission range. On the NTNU campus, we observed that for the same transmission power, SF 12 will permit a transmission range up to 400 meters (line-of-sight) while SF 7 will permit a range up to 100 meters.

The LoRa Alliance [4] defines the LoRaWAN network architecture to be a star of stars. LoRaWAN gateways relay messages between end devices and a central network server. The LoRaWAN specifies a mechanism called Adaptive Data Rate (ADR) to optimize data rates, airtime, and energy consumption for end devices. It searches for the minimal SF value and then tries to reduce the transmission power to save energy. A related work, DyLoRa [3], shows that ADR tends to select a larger SF value and transmission power, and there exists a gap between the energy efficiency of ADR and an achievable optimal energy efficiency. DyLoRa tries to optimize SF value and transmission power to achieve better energy efficiency in a single-gateway network. In contrast, we consider the presence of multiple gateways and integrate the choice of SF values along with the data replication performed between gateways.

In our previous work [8], we have shown that with a moderate rate of transmissions from data publishers, adaptive data replication performed between IoT gateways will not cause a large overhead to the system. In our current work described in this paper, we apply and implement the idea to a LoRaWAN network.

2.2 The Proposed Networking Architecture

Figure 1 shows our networking architecture. In smart campus scenarios, wireless transmissions to a LoRaWAN gateway may be blocked by campus buildings. Using multiple gateways may solve this problem and at the same time have the following advantages: (1) The gateways may backup data for each other to avoid a single-point-of-failure; (2) The network coverage may be extended; (3) IoT end devices may be within the coverage of multiple gateways, and therefore the system may configure them to use a lower SF to transmit data and save energy consumption measured by power monitor. For example, in Figure 1 both the LoRa end devices at the middle and to the right may use SF 7 to send data to Gateway 2.

In our design proposal, each end device should determine a set of smallest SF values, one per each gateway, for data communication. Then the end device should use the smallest SF value to send data to at least one of the gateways. A gateway should determine when and how to replicate the received data to a backup gateway. When a gateway crashed, the backup gateway should upload the backup data, and all the data flows that were previously routed through the broken gateway should be transferred to some other still-alive gateways. This may be done by having each affected end device increase its SF value to the next level in the predetermined set. In some smart-campus scenarios, new or mobile gateways may be deployed and the network should be able to reconfigure accordingly.

Currently, we have set up our test-bed using ChirpStack [1], a collection of open-source components for a LoRaWAN network. The ChirpStack components map to each part of our architecture shown in Figure 1. The Gateway Bridge translates the data format used by the edge-tier components (e.g., the Semtech UDP Packet Forwarder protocol) into a data format used by the platform-tier components (e.g., MQTT). We are implementing our data replication approach and SF-tuning strategy as a lightweight substrate in the Gateway Bridge. The Network Server will forward data to the ChirpStack Application Server, which provides a web interface and APIs for management of users, organizations, applications, gateways, and devices.

We have conducted a micro benchmark on the NTNU campus to investigate the performance for uplink transmission from LoRa end devices to LoRaWAN gateways. These end devices use our test-bed to transmit data every 10 seconds to a LoRaWAN application server via the gateways. We found that when there is no building between the sensor device and the gateway, the transmission distance can be up to 400 meters; when there is a building between the sensor device and the gateway, the transmission distance will be greatly shortened. We also found that when we use multiple gateways, not every gateway can receive data from all end devices. Both the locations of gateways and of end devices are very important.

3 FUTURE WORK

We have been implementing the proposed network architecture. We will run some selected smart-campus applications on our test-bed to see how much we may extend the lifetime of IoT end devices and, should a gateway crash, how efficient the backup gateways and the end devices may cooperate to provide a continuous service.

ACKNOWLEDGMENTS

This work is supported by MOST grant 109-2222-E-003-001-MY3. We would like to thank reviewers for helping improve this work.

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