Demo: LoRa Mesh network experimentation in a city-wide testbed

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ABSTRACT

LoRa is a low-power long-range Internet of Things (IoT) standard that offers remarkable performance, especially in remote rural areas. However the single-hop nature of current LoRa networks, poses significant challenges for urban setups and complex network environments, where several gateways with network access need to be deployed to offer the required connectivity. Towards overcoming the connectivity inefficiency of LoRa in relevant environments, the application of mesh networking has been identified as a candidate solution with rich potential. In this work, we present a LoRa based mesh-networking tool for LoRa mesh experimentation. that is currently applied in testbed of 10 LoRa mesh capable devices across the city area of Volos, Greece.

KEYWORDS

LoRa Technology, Testbed Experimentation, LoRa Performance Evaluation, Multi-hop Network

1 INTRODUCTION

In recent years, *Low-Power Wide-Area Networks* (*LPWANs*) have gathered a lot of interest in both academic studies and industrial developments. LoRa [1] is a prominent technology of this type, employing a specific radio layer based on the *Chirp Spread Spectrum* (*CSSs*) modulation. Despite the remarkable performance of the LoRa specification in rural environments, its biggest disadvantage is the single-hop nature that results in low coverage, especially in urban areas where

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line of sight links are degraded mainly due to big obstacles (e.g. buildings, walls, floors). The ability of LoRa nodes to perform direct *Device-to-Device* (*D2D*) communications lead to the ability to create LoRa mesh networks, where relay nodes forward packets to the destination gateway. Several works, study the performance of LoRa mesh networking in urban and rural environments [2–4] and some others in theoretical basis [5], providing some first results in the behavior of this technology.

Over the past decades, significant research efforts have focused on routing for multi-hop wireless networks, and specifically for networks with dynamic topology, such as *IoT* networks. Mobile ad-hoc routing protocols are divided into three main categories, proactive, reactive and hybrid protocols, based on the information that they use for the route discovery procedure. A detailed analysis of representative protocols per category is presented in [6].

The specific characteristics of LoRa technology, along with the well-defined restrictions, such as the 1% duty cycle limitation, constitute a complex setup where network performance highly depends on the employed multi-hop routing protocol. Considering LoRa bandwidth limitations, it is made clear that proactive protocols are not well-suited for relevant deployments, due the continuous exchange of information for discovering and maintaining the network routes. On the other hand, reactive protocols require topology information only when a new route is required or when a route fails, consisting them ideal candidates for a LoRa mesh networking. In [2], the Ad-hoc On-Demand Distance Vector Routing (AODV), which is probably the best-known reactive routing protocol for MANETs, and the Hybrid Wireless Mesh Protocol (HWMP) used in 802.11s mesh networks, are presented as the ideal routing protocols for LoRa mesh applications.

In this work, we present a LoRa wireless mesh networking set of tools, offering a wide range of experimentation options and performance evaluation tools that have been specifically designed for analyzing the performance of LoRa mesh networking in urban setups. The tool is directly deployed on a city-scale testbed presented in our previous works [7, 8].

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(a) Testbed topology

(b) Edge device

(c) Mesh topology presentation

Figure 1: Testbed topology and devices

2 SYSTEM ARCHITECTURE

The testbed consists of a single LoRa Gateway (GW) that is deployed on the rooftop of the University premises and ten edge nodes that are scattered across the city of Volos, Greece. Fig. 1(a) illustrates the testbed topology. Both type of nodes are custom built based on the SX1272 [9] chipset manufactured by Semtech and the MK20DX128VLH5 [10] micro-processor that is a 32-bit ARM Cortex-M4 CPU. The edge nodes periodically receive custom data messages describing the configurations that will be employed in the upcoming transmission period, while the GW collects uplink data frames and evaluates the LoRa-link performance metrics. Fig.1(b) presents one end device attached with four gas concentration probes at the top and a dust particle concentration module attached inside the box in the right side, while the host micro-controller board is illustrated in the middle of the enclosure interfaced with the LoRa SX1272 transceiver.

3 TOOLKIT FUNCTIONALITY

The overall procedure is orchestrated at the GW level, which periodically polls the edge nodes that continuously remain in receive mode. Polling is executed in a Round-robin fashion, instructing edge nodes to transmit data frames under specific configurations. Upon receiving a request for experiment, each edge node transmits consecutive packets under the settings that been determined by the GW. Mesh routing relies on our AODV implementation that has been ported in Arduino code through the RadioHead library [11].

Transmission Mode (*BW*, *SF*, *CR*), Power, Frequency and Network Topology (Star or Mesh) are the core configuration options supported by the toolkit. The performance evaluation and visualization tools include the ping application to measure latency, iperf application to measure throughput and visualization of network connectivity.

4 DEMONSTRATION SCENARIO

In the actual demonstration, we will showcase how different LoRa protocol parameters (e.g. transmission power) affect the network topology, under both star and mesh topologies. The tool will also visualize in real-time the resulting network connectivity and the measured performance. In Fig.1(c), we present an indicative network topology in Mesh mode, where green nodes are single-hop, yellow are relays and red are multi-hop nodes.

5 CONCLUSIONS & FUTURE WORK

In this demo paper, we presented a tool that enables gathering measurments in a city-wide LoRa wireless network. In particular, experimenters can configure a variety of LoRa parameters to perform performance evaluation tests under various network parameters and network performance metrics. Currently, we are in the process of extending our tool to support additional mesh-routing protocols, including the HWMP protocol.

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