A testbed for long-range LoRa communication

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Author(s):
Trüb, Roman; Da Forno, Reto; Gsell, Tonio; Beutel, Jan; Thiele, Lothar

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Demo Abstract: A Testbed for Long-Range LoRa Communication

Roman Trüb, Reto Da Forno, Tonio Gsell, Jan Beutel, Lothar Thiele
Computer Engineering and Networks Laboratory, ETH Zurich
Zurich, Switzerland
rtrueb@ethz.ch

ABSTRACT

Designing and testing low-power wireless communication protocols often requires experimental deployments on real hardware in realistic settings. Infrastructure testbeds have the advantage that they allow reproducible results using different network configurations. However, most testbeds are either in- or outdoor only and do not span long and short ranges at the same time. In this work, we present an extension to the popular *FlockLab* testbed on a campus-scale in order to better support testing of long-range communciation, for example using the LoRa modulation. Different to existing LoRa test networks where specific protocol layers are fixed, we support custom modification above the physical hardware (above PHY) which allows the development and testing of alternative full custom MAC layers that are not based on LoRaWAN.

CCS CONCEPTS

• **Networks → Wide area networks**; **Sensor networks**.

KEYWORDS

LoRa, long-range, testbed, FlockLab, time synchronization

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1 MOTIVATION

Testbeds for wireless communication protocols are useful when developing and testing protocols since it reduces the effort to deploy test networks repeatedly [10]. Furthermore, such a testbed improves the reproducibility of experiments and allows to share infrastructure [5]. Contrary to many other testbeds, *FlockLab* [2, 6] has always supported a mix of in- and outdoor placements. However, all nodes were located in rather close proximity to each other in and around an office building. This setup has been vastly popular: the *FlockLab* testbed has been operated since 2012, run over 53822 tests by 325 distinct users and reached an average annual utilization of over 55%. In recent years, long-range communication for IoT applications has become increasingly important. Although publicly accessible test networks for long-range protocols exist (e.g. e.g. TheThingsNetwork[3] for LoRa), they are only of limited use for designing and testing on the lower layers since modifications of the fixed MAC layer implementation are typically not possible. To the best of our knowledge, sensor network testbeds that support both long-range communication and and provide the option to monitor and control communication layers above the physical hardware do not exist. Therefore, we are currently extending the existing short baseline distances in *FlockLab* by adding additional nodes on rooftop locations and with significantly larger spacing. The vision is to extend *FlockLab* to span the whole campus (≤ 1 km link distance) or even parts of the city (~5–10 km). Similar efforts have been made for 802.11b/g mesh network research at MIT with the RoofNet [4].

2 FLOCKLAB SYSTEM SETUP

The *FlockLab* testbed consists of observer nodes and a backend server. Each observer node can host 4 targets (devices under test), that are modules with radio and microcontroller chips used for wireless protocol development. The observer provides the infrastructure to power, program, stimulate, log and profile the targets. When running a test on *FlockLab*, the server instructs the observers to setup and start the targets. While the test is running, the observers independently collect profiling data which they aggregate and send to the server once the test is finished. Users can then access all test data which is stored in a database on the server.

Topology: Currently, the extended *FlockLab* testbed consists of 28 nodes located on a single floor inside an office building (75 × 35 m) and 2 rooftop nodes located up to 470 m away (see Figure 1).

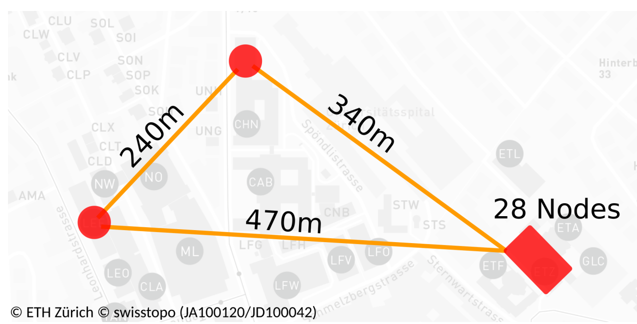

Figure 1: *FlockLab* testbed extension to rooftop nodes.

Services and Time Synchronization: For designing and testing low-power wireless network protocols, *FlockLab* offers the services listed in Table 1. The **GPIO** services provides access to up to 5 GPIO pins of the target. This allows to observe or initiate state changes or measure duty-cycles with high accuracy. The **power profiling** allows to perform fine-grained power measurements. Serial output of the target is logged by the **serial tracing** service. Interaction via the serial interface is supported by the **serial forwarder** service. Both the GPIO and the power profiling services provide high temporal accuracy which is required for developing low-power wireless protocols on the lower layers of the network stack.

The time synchronization of the original *FlockLab* testbed uses a custom wireless time synchronization protocol based on Glossy [7]

FlockLab Service	Max. Rate	Time Sync
GPIO tracing	10 MHz	GlossySync/GPS
GPIO actuation	10 MHz	GlossySync/GPS
Power profiling	28 ksamples/s	GlossySync/GPS
Serial tracing		NTP
Serial forwarding		–

Table 1: *FlockLab* requires tight time synchronization.

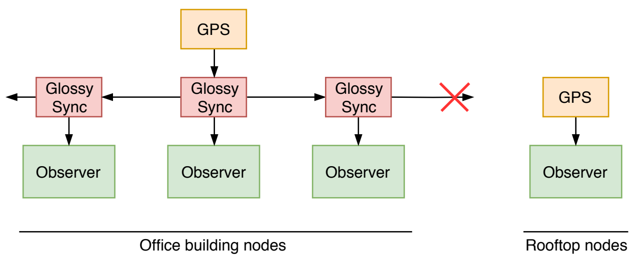

Figure 2: Heterogeneous time synchronization architecture.

	Mean	Std dev.
GlossySync - GlossySync	0.016 µs	0.202 µs
GPS - GlossySync	0.692 µs	0.206 µs
GPS - GPS	0.050 µs	0.115 µs

Table 2: *FlockLab* time synchronization performance.

(GlossySync) referenced to a 1 Pulse-per-second (PPS) signal sourced from a ublox LEA-6T GPS receiver (see left part of Figure 2). This provides an offset between two observers below 1 µs which is sufficient for most applications. However, recent work incorporating the time-of-flight of radio signals has shown that higher accuracy is required [8] and *FlockLab* has been outfitted temporarily with extra GPS receivers in order to perform these tests. This experience and the fact that it is not possible to extend the currently used short-range GlossySync time synchronization required a different approach. The option to use PTP over Ethernet [1] (accuracy <1 µs) has been explored but not implemented since it would require specialized hardware and infrastructure on the networking segment. Therefore, each rooftop node is equipped with a dedicated GPS receiver providing a 1 PPS signal directly to the *FlockLab* observer. Since the used reference timebase (GPS) is the same for both systems, we only need to make sure that the offset between GlossySync and GPS is properly compensated. Measurements of the resulting time difference when timestamping the same GPIO event (hard wired) between two observers using different time synchronization methods are listed in Table 2.

Antenna Options: Since *FlockLab* supports multiple independent target devices on one observer, it is possible to install several instances of the same target hardware using different antennas (low- vs. high-gain) without the need for complex RF switching or cabling. This allows to select different antennas for individual tests.

Figure 3: Rooftop node of *FlockLab* with high-gain antenna.

3 DEMONSTRATION SETUP

In this demonstration, we will show the FlockLab hardware setup (observer with targets) as well as demonstrate running tests on both short-range radio architectures (TinyNode, TmoteSky, DPP2-CC430) as well as long-range radio architectures (DPP2-SX1262). Furthermore, a visualization of the resulting GPIO traces can be observed. The DPP2-CC430 and DPP-SX1262 are based on the Dual Processor Platform (DPP[1]) [9].

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[1] See a separate DPP-related demo submission to IPSN 2019.