Poster abstract: CLOVES: A Large-scale Ultra-wideband Testbed

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ABSTRACT

Research advances in low-power wireless systems have greatly benefited from the availability of public testbeds. However, none is currently available for the increasingly popular ultra-wideband (UWB) radios enabling communication and localization. We present CLOVES, the first public large-scale testbed supporting UWB.

CCS CONCEPTS

• **Networks → Network experimentation**.

KEYWORDS

ultra-wideband (UWB), experimental testbed

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1 MOTIVATION AND GOALS

Ultra-wideband (UWB) radios offer low-power communication and accurate distance estimation (ranging), a combination seeing a surge of interest in many applications. Nonetheless, the lack of public testbeds pushed experimental studies to small-scale, custom setups, limiting generalizability, replicability, and stifling the development of UWB multi-hop networking protocols and localization schemes.

Inspired by the impact public testbeds had on research in, e.g., wireless sensor networks, we present CLOVES (Communication and Localization Testbed for Validation of Embedded Systems) a large-scale, publicly accessible UWB testbed. CLOVES consists of 130 nodes deployed in three distinct areas of the University of Trento (Italy) for a total of 7250 m^2. Narrowband IEEE 802.15.4 devices are also deployed alongside UWB ones on the same nodes. All devices are remotely accessible for firmware upload and collection of experiment logs (§2). The different characteristics of the indoor testbed areas (e.g., narrow corridors vs. wide halls) cater to different types of studies concerning communication and localization (§3). As a conclusion (§4), we outline current plans to expand CLOVES and exploit it to contribute to research on UWB.

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2 INFRASTRUCTURE

Type and number of devices. All 130 nodes in CLOVES host a Qorvo EVB1000 board with a DW1000 UWB radio controlled by an STM32F105RC (ARM Cortex-M3 MCU). However, the infrastructure supports multiple platforms at once. Several nodes host also a Qorvo DWM1001-DEV board, where the DW1000 is paired with an nRF52832 SoC integrating an ARM Cortex-M4 MCU with a BLE radio. Finally, all nodes also host a Zolertia Firefly equipped with the CC2538 SoC integrating a Cortex-M3 MCU and a 2.4 GHz IEEE 802.15.4 narrowband radio. This platform is a popular choice in research on low-power wireless. Therefore, CLOVES is a larger-scale alternative to existing IEEE 802.15.4 narrowband testbeds, while offering a one-of-a-kind opportunity for direct comparison of narrowband vs. UWB network stacks in the same conditions.
Node placement and testbed architecture. The devices are contained in a box along with the ST-LINK V2 programmer necessary to upload firmware on the EVB1000, all connected via USB to a Raspberry Pi 3 (RPi) through which they can be reprogrammed and controlled, and experiment logs are collected. All of the above constitutes a CLOVES node, attached to wooden tiles in the drop ceiling (Figure 1), simplifying installation and maintenance. Cables run through the tile holes, hidden from sight, including those powering the RPi (and attached devices) and the Ethernet cable enabling remote access via the testbed server.
Remote access. The CLOVES workflow is managed entirely via a Web interface or a Python client. The user can schedule experiments of fixed duration, program devices with any custom firmware, and download the logs. Further, the devices participating in the experiment can be selected and operated upon at once, via pre-defined groups, or individually, e.g., to obtain specific topologies or manage their different firmware. Additional features under development support the safe execution of custom scripts and MQTT as a higher-level means to configure a device or retrieve its logs.

3 ENVIRONMENT AND COMMUNICATION

Environment. CLOVES offers three separate areas (Figure 2).

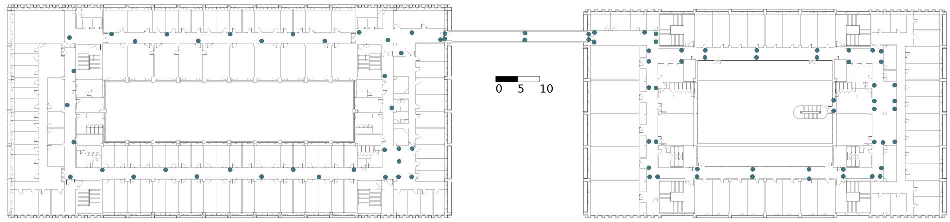
DEPT (91 nodes, 6382 m^2) spans the entire Dept. of Information Engineering and Computer Science (DISI); two floors in nearby buildings, connected by a suspended passageway. Nodes are mostly deployed on the corridors among offices, laboratories, and meeting rooms. Their narrow (2.4–3.2 m) and long (up to 134 m) dimensions likely induce strong signal reflections, exacerbated in the passageway by its narrower width (1.72 m) and metallic frame. However, wider areas are also present, overall yielding a realistic environment with mixed geometrical and signal propagation characteristics.

HALL-A (25 nodes, 666 m^2) is an L-shaped area on the ground floor of one the buildings (Figure 2b). The top sub-area (10×24.5 m) is the entrance; the bottom one (57.7×7.3 m), connected by a sliding

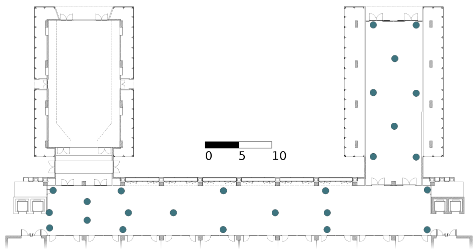
Figure 1: Testbed nodes.

	PRR	#link/NLOS	neighbors
CH4	any	1410/487	15.55
	>90%	1214/386	13.35
CH5	any	834/178	9.12
	>90%	648/116	7.12

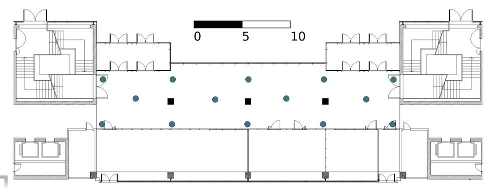
Table 1: Communication in DEPT.



(a) DEPT.



(b) HALL-A.



(c) HALL-B.

Figure 2: Testbed areas.

door, has office accesses on one side and student tables on the other. All nodes in a sub-area are in line of sight (LOS); communication across sub-areas is often in non-line-of-sight (NLOS). HALL-B (14 nodes, 205 m^2) is the entrance to the other building, smaller in size and with several columns yielding NLOS conditions.

We envision the different characteristics of these areas to support different types of studies. The geometry and features of DEPT suit experiments focusing on multi-hop communication, by exploiting the great diversity of link conditions, as well as ascertaining the effect of strong multipath on both communication and ranging. However, the linear geometry limits localization. This is instead supported by the other two areas that, besides offering very different geometry and features, host nodes properly placed to serve as anchors. Moreover, the peculiarity of HALL-B is the presence of NLOS, a hot topic in UWB research that can also be studied in the different conditions provided by HALL-A and DEPT. Also, the sub-areas present in both of these can be used separately or together, enabling experiments with different scale. Finally, although mobile devices are currently not available in CLOVES, users can emulate them to some extent. For instance, devices can be configured to turn off and on at designated times, emulating their (dis)appearance to create dynamic conditions useful, e.g., to study device discovery or the impact of faults. Similarly, some nodes can be configured as localization targets and others as anchors; by changing the role allocation, the quality of localization can be tested in different geometric and/or communication conditions.

A glimpse at communication features. We focus on DEPT, the largest area and explore two common UWB configurations for long range (CH4, 1024-symbol preamble) and short range (CH5, 64-symbol preamble), with 6.8 Mbps data rate and 64 MHz pulse repetition frequency (PRF). Table 1 shows the total number of links vs. those in NLOS and the average number of neighbors based on the packet reception rate (*PRR*), using the common 90% reliability threshold. A few key observations can be made. The number of links is huge, enabling statistically-significant experiments. Further, a significant fraction is in NLOS, supporting research on this link condition. Finally, the impact of different configurations is evident, exemplifying one of the aspects quantifiable at scale with CLOVES.

4 CONCLUSIONS AND OUTLOOK

CLOVES (`https://iottestbed.disi.unitn.it/cloves`) is a large-scale public testbed, the first for UWB. Examples of its exploitation can be found in our own efforts concerning UWB communication [1, 2] and localization [4] as well as narrowband [3], also supported. We plan to increase the value of CLOVES for the research community along two directions. First, we will deploy the newer Qorvo DW3000 radios, and possibly other UWB-based ones, to enable direct comparisons. Further, 16 mmWave devices (Mikrotik IEEE 802.11ad 60 GHz) being deployed in HALL-A will offer another communication and localization option. Second, a characterization of UWB communication and ranging in CLOVES is ongoing. We argue that the findings obtained at scale, along with associated datasets, hold the potential to significantly advance the body of knowledge related to UWB.

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