Demo Abstract: Adaptive Lighting in Road Tunnels Using Wireless Sensor Networks

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1. MOTIVATION

Tunnels are an integral component of the road infrastructure in almost all European countries. Their operation is a concern for most local authorities, as it affects the drivers' safety, and it involves significant energy expenditures due to lighting and ventilation. To address these issues, the Province of Trento, Italy (PAT) is funding a 3-year research and development project[1] called TRITon (Trentino Research and Innovation for Tunnel Monitoring, `triton.disi.unitn.it`), involving the local university and research centers, as well as industry partners. The ultimate goal is to deploy some of the solutions designed in the project in four *operational* road tunnels near Trento to improve safety and reduce energy costs.

To address the latter issue, TRITon is investigating *adaptive lighting* in road tunnels. The light intensity is currently regulated based on fixed design parameters and coarse-grained time information, e.g., the current season. Nevertheless, this occurs regardless of the current environmental conditions, e.g., sunlight vs. rain at the entrance, which determines a potential waste of energy and a safety hazard. Leveraging the ease of deployment of WSNs, we use motes to sense the current light conditions inside the tunnel and report this information to a control station. This performs fine-grained adaptation of light intensity in the different tunnel sectors.

2. WSN-BASED ADAPTIVE LIGHTING

Hardware. We use TMote-like devices manufactured by a local SME (`www.tretec.it`) along with a custom board built in TRITon, featuring 4 temperature-compensated Intersil ISL29004 digital light sensors. Node and board, along with a package containing 4 size D batteries, are contained in a $14 \times 17 \times 9.5$ cm^3 plastic box, shown in Figure 1(a), that according to the regulations must be fire-proof and at least IP65-compliant. As WSN gateway we employ a Gumstix device (`www.gusmtix.net`), a Linux-based embedded PC which also provides local data logging. The Gumstix communicates sensed data over Ethernet to a PLC (Programmable Logic Controller) in the tunnel control station. The PLC performs the required tuning by controlling actuators connected to lights inside the tunnel.

Software. Our software architecture, shown in Figure 2, is entirely implemented atop TeenyLIME [2], a WSN middleware designed and implemented by some TRITon partners. Using TeenyLIME, we realize mechanisms ranging from data collection to security, the latter being required by the critical operation of the system. The middleware sits on top of the TinyOS operating system, making use of the CC2420 Active Message stack for communication. In particular, we leverage off the Packet Link functionality for reliability and the Low Power Listening layer to prolong the system lifetime.

(a) Node packaging. (b) Doss Trento tunnel.

Figure 1: Experimental deployment.

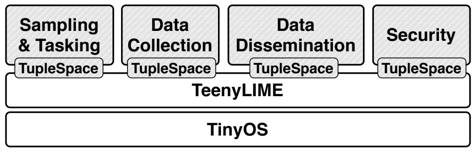

Figure 2: Software architecture.

3. DEMONSTRATION HIGHLIGHTS

We are currently testing our WSN inside Doss Trento, a non-operational tunnel made available by PAT, shown in Figure 1(b). The early results are promising, in that we achieve a delivery ratio >99% at the gateway and an expected lifetime over a year. During the demonstration, we replicate the setting in Doss Trento with some of our TRITon nodes reporting light readings to a Gumstix node. To showcase the adaptation functionality, we implement our control algorithms on the Gumstix and make it control a dimmer connected to a light bulb.

Attendees will see how the light intensity is adjusted based on sensed data, with increasing intensity for lower light readings and vice versa. A laptop connected to the Gumstix will display information on the current system status, e.g., routing topology and current sensor values. We will also bring some samples of our node packaging to discuss with the interested people the logistical issues we are addressing in such a real-world, operational scenario. Our demonstration requires a medium-size table and two power plugs.

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[2]P. Costa et al., "Programming Wireless Sensor Networks with the TeenyLIME Middleware". In ACM/USENIX Middleware Conference, 2007.