High Performance Low-power Wireless Network for Water Distribution

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Hinni AG teamed up with CSEM and the Hochschule in Luzern to develop the third generation of the Lorno water monitoring wireless network. The project resulted in the realization of new high value added features such as self-organization, accurate synchronization (+/- 1 ms) for leak localization (+/- 5 m), authentication / encryption and the ability to perform over-the-air firmware updates.

CSEM developed and delivered an industrial grade wireless sensor network (WSN) for the monitoring of a water distribution network. To do so, CSEM relied on more than a decade of expertise in the domain in order to cope with particularly demanding, and sometimes conflicting, system requirements.

The solution implemented by CSEM is a self-organized, multi-hop wireless network. It exhibits state-of-the-art performance in energy conservation (up to 10 years lifetime on a single battery), low latency (alarms transmitted in less than one minute) and adaptability to both very short and long messages (from a few bytes to more than 4 kbytes). Upon request, the network can maintain very tight synchronization (1 ms) between the nodes, despite large temperature gradients. The solution is also secure and the node firmware can be updated over the air. Additionally, the architecture is versatile: depending on how they are combined, the same electronic boards can be used as relays, wireless sensors, cabled or cellular gateways or GPRS/3G sensor nodes in case of isolation from the WSN.

The customer, Hinni AG, is the Swiss market leader in the production, sales and maintenance of water hydrants and associated services. A decade ago, Hinni introduced the Lorno wireless monitoring system for the public water distribution network. The concept uses water hydrants as access points to the underground pipes. They are equipped with wireless sensors capable of measuring the status (opened / closed), temperature and pressure, as well as, a hydrophone for leak detection. The sensor measurements are transmitted to relays installed on street light posts and forwarded to a gateway connected to the internet, as illustrated by Figure 1.

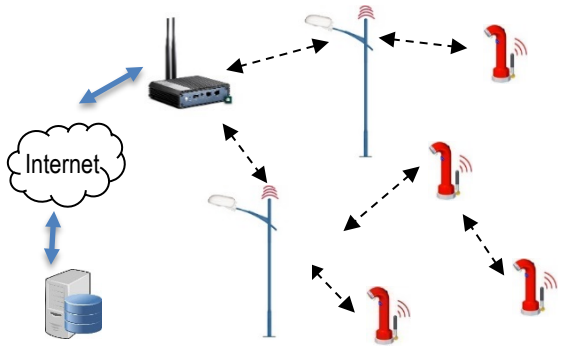

Figure 1: Lorno wireless water distribution network monitoring system.

In 2014, Hinni, CSEM and the Fachhochshule of Luzern teamed up to develop a new generation of the Lorno system aimed at general improvement the performance of the wireless network, implementation of additional features and enabling automatic localization of leaks. CSEM was tasked with the wireless network development, as well as the design of the electronic board.

The network relies upon the CSEM WiseNet solution operating with the ultra-low power WiseMAC medium access protocol. Among the new features, CSEM added a state-of-the-art routing protocol. This protocol enables the network to self-organize, allowing the customer to install or remove nodes without the need for time and resource consuming network planning and manual configuration.

The new system's most innovative and advanced feature is the ability to localize water leaks automatically; whereas, the previous generations were limited to leak detection. The technique relies on the correlation of several hydrophone measurements taken at hydrants connected to the same pipe as the one that detected a leak. For an accurate correlation, it is essential that the measurements at each hydrant start simultaneously with a maximal difference of less than 1 ms (millisecond) between any pair of hydrants. For this purpose, CSEM developed a time synchronisation protocol with clock deviation estimate and compensation. Tests have shown that the clock compensation converges rapidly and that the error is below 1.2 ms in extreme conditions (-25 °C spray cooling). For the leak localization application, this translates into an accuracy of 5% of the length between the measurement points.

As the sensor nodes need to conserve energy, WSNs usually transport small blocks of information at a low data rate. To transport the audiograms recorded for leak localization, which have a significant size (several kbytes), CSEM implemented a transport layer with fragmentation and reassembly over multiple hops, between the sender and the base station. This feature takes advantage of the WiseMAC "more bit", an indication in uplink packets that allows a destination to stay awake for several consecutive packets, which results in a higher throughput without power consumption increase.

Additional enhancements brought by CSEM to the network are over-the-air firmware updates and security. Over the air firmware updates are important in order to reduce the maintenance costs because the transmission devices are not easily accessible, as they are either locked inside hydrants or high up in the light posts. The over-the-air firmware update protocol made by CSEM uses compression based on the difference between the new and the old version and a reliable data dissemination protocol.

Additionally, data authentication and encryption based on AES were added to protect the wireless network against attacks and data corruption. Security is of especially high importance for wireless networks attached to critical resources and infrastructure.

CSEM continues to support Hinni with respect to new product industrialization and certification. Moreover, CSEM is currently developing a compatibility layer that will allow relays of the new Lorno generation to communicate with hydrants equipped with the first and second Lorno generations.