Deployment Experience with Low Power Lossy Wireless Sensor Networks

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Abstract: Protocols that are to be employed in the context of the Internet of Things (IoT) have to meet a wide variety of application-specific requirements [3] [4] [1] [2]. In this report, we reflect on recent experiences, gained from several real-world deployments in which we have participated, which use low power, embedded networking devices. We discuss the lessons learned from these deployments, with an emphasis on questions affecting the IP layer and, in particular, on the routing protocols for these networks. We point out open issues and possible directions of future work for such routing protocols.

Key-words: Sensor, Ad hoc, Wireless, Network, IETF, Internet, Things, Routing, Deployment

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Quelques Déploiments de Réseaux de Capteurs Tests pour les Normes IETF concernant l'Internet des Objets

Résumé : Ce document rapporte certaines observations à propos de déploiments de réseaux de capteurs dans le contexte de l'Internet des Objets, ayant trait au protocole de routage utilisé dans ce contexte, et notamment la norme en la matière, actuellement en cours de développement à l'IETF.

Mots-clés : Capteurs, Internet, Objets, IETF, Routage, Réseau, Déploiment, Ad Hoc

Protocols that are to be employed in the context of the Internet of Things (IoT) have to meet a wide variety of application-specific requirements [3] [4] [1] [2]. In the following, we reflect on recent experiences, gained from several real-world deployments in which we have participated, which use low power, embedded networking devices. We discuss the lessons learned from these deployments, with an emphasis on questions affecting the IP layer and, in particular, on the routing protocols for these networks. We point out open issues and possible directions of future work for such routing protocols.

1 Deployment Experience

As part of our work on the SensLAB[1] project, we participate in a **large, general-purpose testbed for wireless sensor networks** built by INRIA. SensLAB aims to be an accurate and efficient scientific tool that can be employed for the design, development, tuning, and experimentation of real-world, large-scale sensor network applications. Since 2009, SensLAB has been composed of 1,024 nodes distributed across four sites in France. The SensLAB nodes are based on the Texas Instruments MSP430 micro-controller and employ one of two radio interfaces, one operating in the 868 MHz ISM band and the other at 2.4 GHz, both in compliance with the IEEE 802.15.4 standard. We have conducted experiments on such hardware using various routing protocols including OLSR, and RPL [7] (including the P2P extension [6]) on top of the Contiki operating system [5].

For RPL, we found that the software stack, i.e., Contiki, 6LowPAN, IPv6, RPL (upward routes, no DAOs), and the P2P extension, barely fits into the 48 KB of flash memory available on the MSP430 (current state of the art for such devices), leaving close to no space for any application-specific code. Our experiments showed the Trickle mechanism for establishing upward routes works efficiently and converges within reasonable time. However, the way the RPL specification handles asymmetric links (common in wireless networks) required special attention from our part. Depending on the application requirements, relying on NUD may be inappropriate because a path is required at the time data needs to be sent. In these cases, appropriate link metrics must be used in addition to the RPL specification to continuously monitor link availability. In our experiments, some metrics were functional at small scale (such as ETX), but more work is needed to determine which metrics/signalling are appropriate for larger, denser networks, and that fit the memory/energy limitations on each device.

We also took part in is the OCARI (Optimization of Communications in Ad hoc Industrial Networks)[2] project, started in 2006, with partners including international electricity provider EDF, DCNS, and Telit-RF Technologies. This project targets the **monitoring of industrial equipment or civil engineering constructions using wireless sensor networks**, including performance testing of equipment, radioprotection of site maintenance, and state control of devices. The application requirements in this project include time-bounded

[1] http://www.senslab.info/

[2] http://www.ocari.org/

delays for specific types of traffic, support for nomadic nodes (moving at pedestrian speed) for data collection, energy efficiency to maximize network lifetime, and ease of deployment. Before ROLL was chartered, this project had us design an energy efficient routing protocol, and a node activity scheduling algorithm based on node coloring to save energy by allowing nodes (including routers) to sleep without incurring any data loss.

In the context of the AVS-Extrem[3] project, we have developed a **wireless sensor platform for perimeter surveillance**. The deployment scenario consists of embedded sensor nodes built into the metallic structure of fence elements. These nodes sample acceleration data, use distributed pattern matching algorithms to detect events, and report security-relevant events to a base station. Network traffic in this scenario consists of rare event notification packets sent from sensor nodes to the base station. Reception of these packets needs to be acknowledged by the base station. Due to the widespread deployment of devices along the perimeter of the area under surveillance, a routing protocol needs to operate in a hop-by-hop fashion, i.e., source routing would result in prohibitively large packet headers.

In the context of the ASIST european project (to start in 2011, pending approval), a large deployment is planned, **interconnecting heterogeneous sensor networks** over an IP backbone, targeting airport monitoring. Each individual sensor node will have to be accessible from the Internet, and reliable node-to-node communication across network borders will be required. Furthermore, embedded devices will have to support enumeration and service discovery.

2 Lessons Learned and Position

The deployments described in the previous section are well within the IoT scope. Yet, the requirements they impose on the routing protocol are varied, including some requirements that are not targeted by current RFCs or RFCs-to-be, such as sensor mobility, or traffic patterns requiring paths from the sink to each sensor/actuator in the network. We submit that it is necessary to address these requirements as they are not uncommon.

In order to address these further requirements, we suggest that RPL be complemented with additional extensions. However, we stress that the resource-constrained nature of the targeted devices is a concern for such extensions-to-be-designed, since our experience shows that the RPL specification is already complex, and that available network stacks including an RPL implementation barely fit in the memory of state-of-the-art sensors. Furthermore, the interoperability of the various existing or future extensions and modes of operation should be addressed explicitly in the RPL specification. Finally, we submit that it is important that the basic RPL specification addresses properly the issue of unidirectional links when NUD is not usable.

[3]http://cst.mi.fu-berlin.de/projects/AVS-Extrem/

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