Mobile Network Supported Wireless Sensor Network Services

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1. Introduction

Wireless sensor networking research has been mainly focused on internal wireless sensor network issues such as MAC and routing protocols, energy saving, HW design and to some extent on the architecture of gateways that connect a wireless sensor network with the rest of the world [1]. Wireless sensor networks have been seen as dedicated to one task by one owner.

On the other hand, our research is focused on integration of wireless sensor networks into existing networks, primarily mobile ones, and provision of sensor based and/or enhanced services to remote users [2, 3, 4]. Therefore, we have been working on designing an architecture that utilizes the existing infrastructure to interconnect independent wireless sensor networks and to provide data aggregation and actuator control services. In the proposed architecture, sensor networks (small or large, deployed for any purpose and by anyone) represented by their gateways are treated as leaf nodes hanging off a mobile or fixed network that use these networks to interact with remote and local users. Each gateway exposes the capabilities of its sensors, actuators and the sensor network as a whole. This information is used by sensor services middleware to query/command sensor ecosystems on behalf of applications and remote users interested in sensor measurements or actuator control. The details of the interaction between the gateways and its sensors/actuators are of no interest to the remote users.

Further, we consider the whole wireless sensor networking landscape as an open market where the underlying mobile and fixed networks facilitate the interaction between the sensor networks and the consumers of the information they produce.

Each sensor network is first of all a sensor information provider that offers specific sensor information defined by the type of available sensors and their spatial and temporal conditions to the interested users. Secondly, each sensor network provides actuation services that may potentially affect the information gathered by its sensors. Obviously, in such an environment, where many mobile users are acting as tiny information providers, service discovery, service composition, service provisioning and service authorization are very challenging problems. These problems are addressed in the proposed architecture by introducing a middle layer that aggregates information from all small information providers and provides higher level services to the end users. This layer provides the means to quickly add or remove sensors, actuators, sensor networks, sensor network providers, to modify and enhance the existing or add completely new services utilizing the underlying infrastructure. It could be thought of as a “plug-and-play” functionality for: a) interconnecting different existing sensor networks, b) adding new sensor networks which facilitate the expansion of the entire system, and c) expanding the capability of individual sensor networks.

2. Architecture overview

The objective of the demo is to present concepts and solutions proposed in the new architecture as well as to highlight the flexibility and potential of our proposal using real devices and scenarios. In addition, the experience gained from a real implementation is used to provide feedback to architecture design.

A high level view of the architecture components and subsystems is shown in Figure 1.

An example of a scenario that could take advantage of our architecture is supporting medical personnel in providing help to injured people in emergency
situations, for example after a major disaster like an earthquake. In this case, before the medical personnel arrival at the scene they do not have any a priori knowledge of the locations or health status of the injured people. To find out this context information (location of injured people displayed on a map of the local area, their physiological data, etc.), crucial for the success of their effort, they interact with the middleware layer (Machine to Machine or simply M2M System) via their mobile devices.

The M2M System analyzes high level application requests (for example: *Which zone are the people within the most critical state located in?; What is their current health status?*) and identifies the information it has to receive from the sensors in order to provide an appropriate response. Based on the required information, the M2M System selects the appropriate sensor networks based on the information these sensor networks publish about themselves (for example type of sensors, location, accuracy etc. Price of provided information can be an important variable in some cases, although not in the mentioned disaster scenario) and issues queries to them. The M2M System can in this case be seen as a virtual sensor group that collects information from all available sensors and provides responses to the requests received from the medical personnel. Based on the gathered responses, the medical personnel can decide which people to attend first (those in the most critical state) and which to establish contact with (those not critically injured).

This proxy role of the M2M System enables the application used by the medical personnel to be written independently of the sensor networks and still to be able to interact with and obtain information from a multitude of sensor network implementations. The sensor networks are represented by their gateways. When a sensor network is deployed, the gateway gathers information about all available sensors in its network. The gateway then aggregates that information and publishes it, i.e., forwards a description of the sensor network capabilities to the M2M System. The M2M System stores this information and uses it to select sensor networks that should be queried to provide responses to users’ requests.

In the prototype described in this paper, two types of sensor networks are used: one providing location information and the other one providing electrocardiogram (ECG) measurements of a player.

When a sensor network gateway receives a query it analyzes it, maps it into one or more new queries in the format used by the underlying sensor network and forwards these to the sensors. Once the sensors respond, the gateway processes and aggregates the inputs and forwards a response to the M2M System. The M2M System aggregates responses from all gateways involved in the ongoing task and provides a response to the user application.

![Figure 1: Prototype architecture.](image)

The application, such as the medical application described in the scenario above, uses received information about the people’s or some important object’s location and health status as an input to the application specific logic.

3. Demo implementation

The implementation details of the demo are shown in Figure 2. Two wireless sensor networks are used to provide location information. These are both based on Tmotes communicating over 802.15.4 multi-hop networks and the positioning is based on proximity. Gateways for both networks are implemented on laptops as SIP user agents (SIP UA). These gateways communicate with the M2M System using the SIP protocol with the SIMPLE [5][5] extensions framework for instant messaging and presence information and GEEPRI [6] for localization and positioning information. SIP runs on top of a TCP/IP connection.

A 3-lead custom built device with a Bluetooth interface is used to capture ECG data of a user [7]. The gateway functionality is implemented on a mobile phone as a J2ME MIDlet. Communication between this gateway and the M2M System is based on web services (using JSR 172 API). Bluetooth is used for communication between the gateway and the ECG device using an XML based protocol.
The M2M System is built on top of the SDS (Ericsson Service Development Studio) environment [8] and is completely SIP-based. The M2M web services extension maps information between the SIP and web services domains. The M2M System maps queries received from the application into a set of appropriate commands and forward them to relevant sensor networks.

We will show two applications. The first will demonstrate the positioning functionality by displaying the user in different locations in different rooms. In this application, the application showing the position will be unaware of the fact that two sensor networks are providing data to it. The other application will allow the user to schedule phone calls based on sensor data input. If a pulse is too high, an ECG sensor shows some other kind of irregularity, or if the caller is in a specific place, calls will be setup. This application is also unaware of the actual sensor networks providing this information.

4. Demo requirements

The following are the technical requirements for a demo setup:
- Access to a GPRS/3G network for communication with the physiological sensors
- Access to Internet via a WiFi access point for access to M2M System (installed on a server in our premises)
- Two rooms where location sensors (TMotes) can be positioned.

If Internet access is not available, it is possible to setup the M2M System on a laptop and access it using a local area network.

5. References


Figure 2: Prototype implementation.