Smart Middleware for Wireless Sensor Networks

Frieder Ganz

Year 1 PhD Student, C.C.S.R., e-mail: F.Ganz@surrey.ac.uk

Abstract

Sensors will play an important role in our future daily life. Ongoing research areas such as Smart Homes, Healthcare and the Future Internet leverage the use of sensors in combination with Web data and services. Large scale networks can produce a large variety of information related to human users and their environment. Utilising and integrating this information are the key issues to enable future environment and user aware networks and applications. We introduce a middleware design which addresses the emerging issues by constructing a homogeneous framework to connect heterogeneous sensor networks and providing decision making mechanism to optimise and utilising resource constrained wireless sensor networks.

Key words: Wireless Sensor Network, Middleware, LTE Gateway, Sensor data and query processing

1. Introduction

In the next few years sensors become increasingly important in our daily life. Sensors and actuators monitor and control physical objects and their interaction to provide machine-readable information. There are several ongoing research areas trying to introduce sensors into our everyday life. In the area of medical healthcare, sensors are used to transmit health information measured by sensors attached to the body to medical staff. Another emerging area is the smart home initiative which can exploit sensors measuring the energy consumption to recommend saving opportunities or provide mechanism to control and/or interact with different objects and devices in homes. The current efforts in the wireless sensor and application/service areas lead to interconnected networks of devices, sensors and physical and logical world objects called the Internet of Things (IoT) [1]. The sensors and actuators and the gained information and processed knowledge is made accessible to the end-user or consumer applications and services in an IoT platform.

The heterogeneity of the sensors used and the variability of the information gained from different scenarios demands a homogeneous way to retrieve and exploit the observation and measurement data captured by these devices.

In this paper we introduce a middleware component which abstracts the underlying low-level networks and provides a unified access layer to the sensors and the information they provide. We will focus on the emerging challenges which arise by connecting sensors and especially wireless sensor networks (WSN) to a higher level network (e.g. IP-based) and discuss the possible solutions and mechanisms to address those.

2. Challenges and Design Principles

To design a successful middleware solution, challenges and issues related to WSN characteristics and high-level applications must be addressed [2]. Sensors often have different purposes and therefore are based on different hardware and software protocols [4]. IEEE 802.15.4, Bluetooth, ZigBee and 6loWPAN are just some used standards in industry and research. To address the problem of the heterogeneity the middleware has to provide a **unified connectivity layer** to all different sensor islands [5]. This connectivity layer which acts as a **gateway** bridges the gap between underlying sensor networks and higher-level applications. The middleware has the overview and control over the whole network and is therefore responsible to distribute incoming queries over the network. **Query Processing and Distribution** is a difficult topic in WSN as sensors are energy- and processing-constrained devices and not available all the time or not capable to satisfy an incoming query due to limited hardware. The middleware has to select sensors which are capable to satisfy a query. Context information such as location, energy-status, available capabilities, Routing and Radio information from each connected sensor node has to be used to satisfy the incoming queries. If nodes are not available or data freshness is not needed , caches can be consulted to save energy and response time. Another way to compensate faulty nodes is to query similar nodes in the same spatial area with the same capabilities. A query processing mechanism and/or language has to be developed which is aware of the WSN characteristics and introduce parameters such as data freshness, quality and priority. Data freshness represents the need of data served directly by the sensor. Is no freshness required the data can be provided by a cache. If the query can not satisfied by a particular node and a similar node has to be consulted the quality of the provided information decreases if the compensation node has less specific capabilities or the spatial area does not exactly match the demanded one. Priority parameters declare how fast a query has to be answered. As the heterogeneous network contains less-capable and higher-capable devices, middleware functionality could be transferred to higher capable devices to aggregate or process queries. The overall **architecture** has to be **lightweight**, if high-capable nodes join the network, middleware should balance the

overall stability and quality of the network by transferring functionality to different nodes.

3. Middleware for Wireless Sensor Networks

The different challenges from Section 2 will be addressed in our architecture in different layers which are shown in Figure 1. The **Connectivity Layer** tries to establish a connection between different sensor platforms. On each sensor, a management module is introduced which connects sensors via multi-hop connections to the sink node which acts as a base station. The management module on the sensor side is implemented either in the Operating system or in the protocol stack of the node. This allows a zero-configuration like management of nodes which is in large WSN environments mandatory required and often not provided by other middleware solutions. The **Information Processing Layer** manages the overall network. Incoming queries will be distributed over the underlying sensor networks and nearby middleware units which manage sensor islands in a different spatial area. Defect and not available nodes will be compensated by either introducing caching techniques or the discovery of similar capable nodes in the near spatial area. Information which is not available at the queried middleware unit will be relayed to other connected units via peer to peer or hierarchical connections. The **Service Layer** provides the knowledge gained from the network and introduces connectivity to RESTful and WS-* based Web services [3].

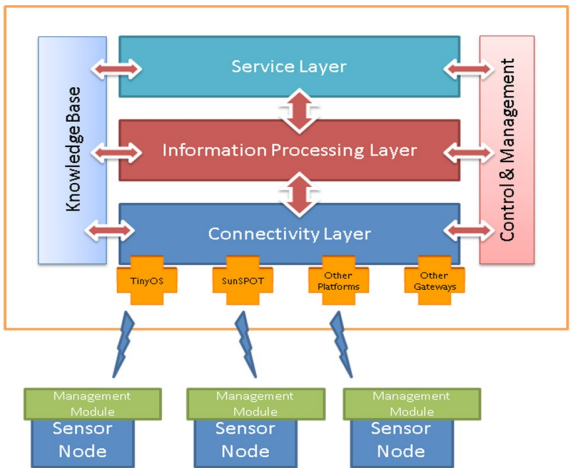

Fig 1: Middleware Architecture

The layers are mapped to its counterpart in the OSI Layer model. The connectivity layer in our middleware connects devices from physical, data link and network layer to a unified access layer. The current stage of work contains the connectivity for IEEE 802.15.4 capable nodes which either have the support in the Operating system (SunSpot) or in the protocol stack (TinyOs, 6loWPAN). Modified Session enabled protocol can be designed here to support M2M communication over different networks such as LTE. Incoming Queries will be processed in the Information Processing Layer, either they will be distributed to the attached underlying sensor network or relayed to other middleware units in other spatial areas.

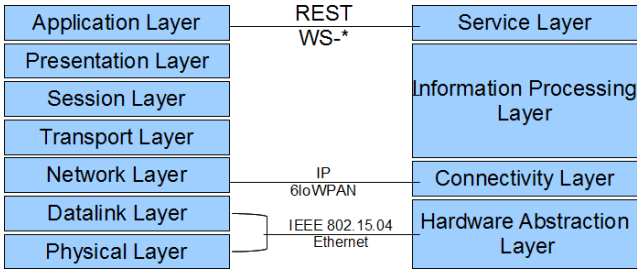

Fig 2: OSI model and mapping to different layers

The Application Layer is represented in the Service Layer. Interfaces are provided to connect high-level applications to the underlying networks. Web services such as the WS-* stack can be used to represent the sensor network and orchestrate and integrate network into existing applications which are capable of the standards.

4. Conclusions, Future Work and Impact

In this paper we introduced an initial architecture to connect heterogeneous sensor networks to a unified framework. In the future work, query distribution and processing in an heterogeneous environment has to be examined. Prediction mechanisms have to be researched. Prediction not in the sense of forecasting data, but how the network could change or what other nodes and events can be checked to efficiently address the upcoming queries. Another issues is orchestration and communication between different gateway (middleware components); how different data can be retrieved from them and how queries have to be forwarded in the overall set-up. The goal is to have one platform connecting different sensor nodes connected to spatial distributed middleware components to integrate into the future internet.

Key References

[1] V. Tsiatsis, A. Gluhak, T. Bauge, and F. Montagut, "The SENSEI real world internet architecture," in *Towards the future internet : emerging trends from European research*. Amsterdam ;;Washington DC: IOS Press, 2010.

[2] D. Bimschas, H. Hellbrueck, R. Mietz, D. Pfisterer, K. Roemer, and T. Teubler, "Middleware for smart gateways connecting sensornets to the internet," in *Proceedings of the 5th International Workshop on Middleware Tools, Services and Run-Time Support for Sensor Networks*, 2010, p. 814.

[3] H. Abangar, P. Barnaghi, K. Moessner, A. Nnaemego, K. Balaskandan, and R. Tafazolli, "A service oriented middleware architecture for wireless sensor networks," in *Proceedings of the Future Network & MobileSummit 2010 Conference*, 2010.

[4] L. Mottola and G. P. Picco, "Programming wireless sensor networks: Fundamental concepts and state of the art," *ACM Computing Surveys*, 2010

[5] P. Schramm, E. Naroska, P. Resch, and others, "A service gateway for networked sensor systems," *IEEE Pervasive computing*, 2004, pp. 66–74.