Research Experiences about Internetworking Mechanisms to Integrate Embedded Wireless Networks into Traditional Networks

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I. Introduction

The aim of this paper is to describe the research experiences of the research group belonging of DIATEL[1] department of the Technical University of Madrid about embedded networks (specifically Wireless Sensor Networks) and mechanisms to integrate them into Internet. Experiences acquired from two research projects are explained. Those projects are i) *Solving Major Problems in MicroSensorial Wireless Networks,* and ii) *Do-it-Yourself Smart Experiences*. For each project, it is included a general description, proof-of-concepts used to prove theorist principles, and lessons learned to be taken into account in future related work.

II. Solving Major Problems in MicroSensorial Wireless Networks (µSWN)

A. Project description

The **FP6 *Solving Major Problems in MicroSensorial Wireless Networks* (µSWN) consortium (STREP Project # IST 034642)** has been working from October, 2006, to November, 2009. The major objectives of µSWN project was to research about generic software and hardware solutions that are common to existent and potential future applications. The research group belonging to the Technical University of Madrid was essentially involved in the design and development of a middleware architecture based on lightweight and reusable component paradigm. This middleware, called Micro Subscriptor Management System (µSMS), implemented an event-driven communication protocol to exchange information between components in the same node (intra-node communication) and different nodes (inter-node communication). The µSMS middleware enabled a generic platform in order to reuse the same physical infrastructure for applications with different aims.

B. Architecture foundations

The proposed µSWN architecture for resource-constraint Wireless Sensor Networks, called µSMS (micro Subscription Management System) was based three main levels, which are illustrated in Fig. 1. In the bottom, a Hardware Abstraction Layer (HAL) was defined, in order to provide a homogeneous abstraction of the physical nodes and its operating systems. Above this, the middleware services are defined. These are divided in several groups, including: (1) Low Level services such as Communications, Resources Management, and Network Configuration; (2) High Level services, offering a added-value to the applications, such as Query, Command, Security, and Reprogramming; (3) Control Services, including a Publish/subscribe core and the middleware Framework, for managing the life-cycle of the middleware components. On the top of the architecture, the Application Layer is defined, were the in-network services are implemented using the agent technology paradigm. Dissemination results of this architecture have been published in [1], [2].

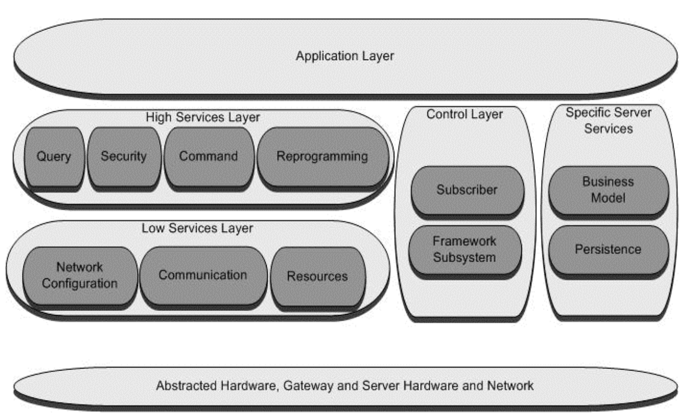

Fig 1. µSWN Architecture.

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C. Proof-of-concepts and prototype deployment

Proof-of-concepts of this project were performed from three Wireless Sensor Network prototype deployments. The prototype deployments were planned according to an incremental prototyped approach from which three versions of the system were generated. The last version of the prototype was deployed in Birstonas, Lithuania. The application scenario, which is illustrated in Fig. 2, was related with healthcare monitoring in a sanatorium achieving three objectives: perimeter surveillance, patient and medical staff multi-tracking, and critical vital signs monitoring. In the three prototypes there was a Gateway interconnecting the components running in WSN's nodes and databases in servers within a traditional LAN. The Gateway was in charge of translating information from WSN encapsulated in events to PDU format which was ready to be processed by the database machine.

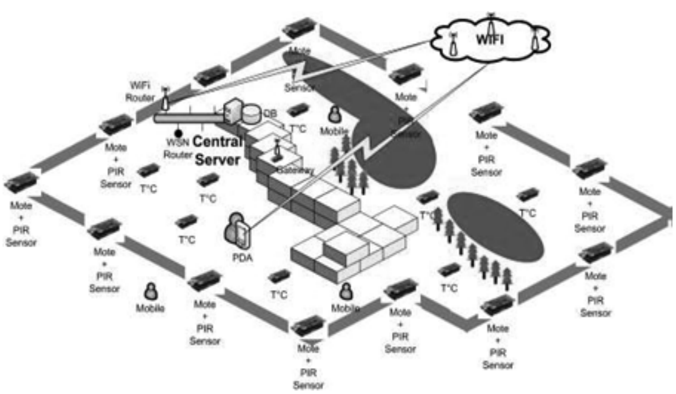

Fig 2. WSN prototype deployment diagram. The three major objectives of the system are shown: surveillance, multi-tracking and critical monitoring.

D. Lessons learned

This first research on the WSN area was much enriched experience about how to proceed when treating with reduced functional devices. Technologies to bridge WSN and Internet (as 6LowPan or Web services) were not used. However, we got much knowledge about in-network architectures. We used the TelosB mote platform to perform the deployments describe in previous section. The main features of this platform are: 48Kb of ROM and 16 Kb of RAM, and 2xAA batteries as energy supplier. Lessons learned during µSWN project were focused on two points. Firstly, we learnt that it is essential to carry out lightweight designs to reduce the footprint in sensor nodes. The complete software architecture in µSWN project was made up by a network protocol, a Hardware Abstraction Layer, a Middleware (µSMS), and several agents (3 or 4 depending on the node's role) running on it, fit in only 48 Kb. Secondly, we observed that energy consumption is critical factor in resource-constraint devices as sensor nodes. Regarding this issue, our best result about network lifetime was a month and a half of duration. Other lessons learned were related to deployment issues to reach objectives in specific scenarios (surveillance and multi-tracking). Furthermore, the number of sink nodes as well its situation had to be planned in order to avoid bottlenecks generated from traffic in the network.

III. Do-it-Yourself Smart Experiences (DiYSE)

A. Project description

The **ITEA2 DiYSE *Do-it-Yourself Smart Experiences* (DiYSE) consortium (code: 08005)** is focused on providing both technical and non-technical users the possibility to create, by themselves, Ambient Intelligence (AmI) ecosystems using their everyday objects, sensors, devices and media therein. This Internet of Things approach will lead to a highly personalized meaningful communication/interaction experience that can span the home and city domains. The project aims to create a sustainable marketplace for user-generated application (components) for an Internet-of-Things world, in which non-technically-skilled people can participate, (re-) using well-abstracted components, capabilities and devices. As such, it goes beyond Web, mobile or multimedia applications. To achieve it, service-oriented and semantic architectures have been defined and implemented for both full functionality devices and reduced functionality devices.

B. Architecture foundations

The proposed architecture for the wireless sensor devices, which has been called nSOM (nano Service-Oriented Middleware) is illustrated in Fig. 3. This architecture defined a full-SOA framework for virtual sensor service description, composition and orchestration in reduced functionality devices. In the bottom of the architecture, the operating system, and the networking stack are defined. Over this, the service-oriented middleware is defined, over a device Abstraction Layer (DAL). The middleware offers a set of Low Level, High Level, Cross-Layer and Control services. Above this, the Pervasive Service Platform is deployed, where the simple agent-based in-network services are implemented in application nContainers, personalizing its execution environment. For the service description, discovery, and invocations, a lightweight language, called nSOL (nano Semantic Ontology Language) has been implemented, using SMD (Service Mapping Description) over JSON (JavaScript Object Notation), with RDF (Resource Description Framework) Notation3, in order to get a lightweight, powerful tool for developing AmI ecosystems. Dissemination results of this architecture have been published in [3].

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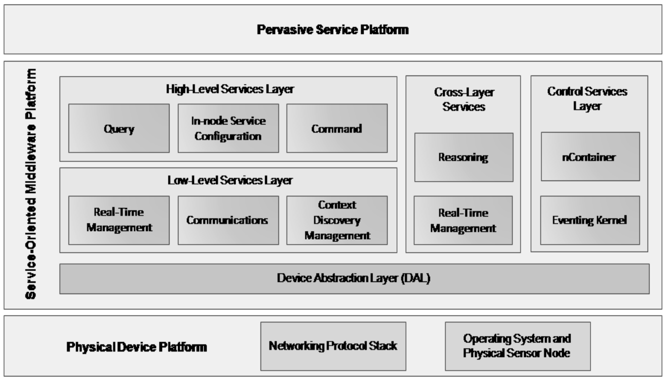

Fig 3. nSOM Architecture.

C. *Proof-of-concepts and prototype deployment*

The first pilot experience of this project has been carried out building a Smart Dining Hall University Space, in a physical deployment of the Universidad de Alcalá de Henares, Madrid (Spain). The schematic of it is illustrated in Fig. 4.

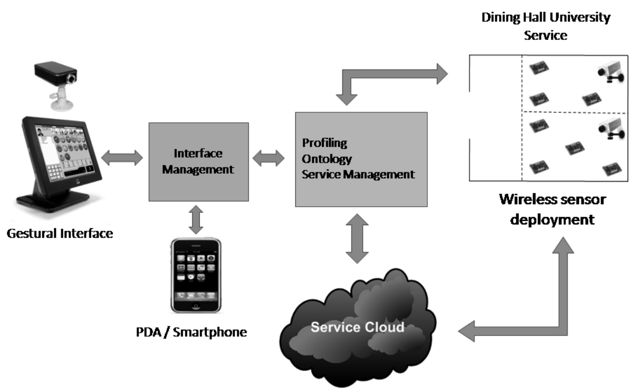

Fig. 4. Smart Dining Hall University Space in the DiYSE Project.

D. *Lessons learned*

Regarding the lessons learned from the deployment and integration of embedded computing devices in service cloud architectures, these are organized in three main axes. First, it is necessary to define Service-Oriented Architectures for sensors devices, leading to build autonomous service entities, operating system and platform independent. The development such frameworks will also allow fast development, evolvable, interoperable, and easy assembly application components. Second, discovery and service request mechanisms based on XML for embedded devices are not efficient. The usage of this standard in low-capacity devices produces a considerable energetic cost, given the redundancy of language. In our best knowledge, the use of emerging proposals, such as SMD/JSON offer a more efficient hardware resource management of the nodes, and therefore improving its autonomy. Third, the creation of Ambient Intelligence (AmI) ecosystems is a key element in the Internet of Things paradigm, and its development through sensor networks and low-capacity devices can be improved by developing virtual sensor services that groups several heterogeneous physical sensors. To this end, the use of lightweight standards, such as RDF Notation3, for the semantic description of services, and their subsequent composition and orchestration, can benefit significantly the end-user experience.

REFERENCES

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