Open-M3: Smart Space with COTS Devices

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ABSTRACT
Support of legacy devices and services is crucial for the adoption of new smart space technologies. We present two technologies which enable the formation of local ad-hoc smart spaces with commercial off-the-shelf (COTS) devices. First of these technologies is NoTA, which is a service oriented architecture enabling networks of devices with different physical transports. Second one is Smart-M3, which is a semantic information sharing architecture for smart spaces. It aims at opening physical world information for the use of services and applications in the information world, thus enabling new types of mash-up applications. In our demonstration - Open-M3 - we show how these technologies are used to build a small, yet extendable smart space for sensor monitoring using COTS devices.

Author Keywords
Smart Spaces, COTS, middleware

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Experimentation, Verification.

INTRODUCTION
The on-going evolution in ICT has led to estimates that 1000 networked devices exist per person by the year 2017 [11]. For this amount of devices to be interoperable requires scalable and portable communication solutions along with a feasible way of sharing information between objects in a network. These networks can be described as smart spaces. Smart spaces share similar ideas and features as ubiquitous or pervasive computing, ambient intelligence and internet of things [1,2,4,8]. In this work we present on the experiences of porting, modifying and enhancing the two interoperability solutions – NoTA and Smart-M3 – for the use of COTS devices. Our demonstrator shows that a vast number of commercial devices are able to be used with Smart-M3 and NoTA based smart spaces. In the following chapter we present the interoperability of smart spaces and NoTA and Smart-M3 solutions in more detail. Later we present our COTS case study application and finally summarize our work with conclusions.

NOTA SERVICE ORIENTED ARCHITECTURE
NoTA device interconnect protocol is an open source technology enabling multi-transport, modular service oriented architecture (SOA) between devices [6]. It is usable for communication between services both inside and between devices. On the top level it consists of application nodes (AN) and service nodes (SN). ANs can communicate with SNs with a BSD socket-like API through a Device Interconnect Protocol (DIP) stack. Nodes are transport agnostic. NoTA networks can include gateways, which can seamlessly relay data between devices without a common transport – thus enabling heterogeneous networking. NoTA is written in C and is portable for various platforms such as Linux, Mac OS X and T-Kernel. Currently supported transport layers are TCP, Bluetooth and USB.

SMART-M3 INFORMATION SHARING PLATFORM
Smart-M3 is an open source semantic information sharing architecture for devices and services utilizing an ontology oriented design and RDF based representation of information [9]. It is a publish-subscribe architecture for semantic information level interoperability. It is a device, domain, vendor and use case independent platform. Three components are integral for all Smart-M3 implementations: Semantic Information Broker (SIB), one or more Knowledge Processors (KP) and Smart Space Access Protocol (SSAP).

SIB is the database for information shared by the KP in the Smart Space. Along storing information, SIB can also incorporate a number of different query languages such as Wilbur Query Language (WQL) [5] or SPARQL [10] for semantic reasoning of ontology based information. Smart-M3 uses a RDF triple format to describe the data thus enabling the usage of queries similar to the Semantic Web.

KP is responsible for producing, consuming or aggregating information stored in the SIB. Their role is not limited – they can be for example actuators, sensors, or even Internet connected services interacting with a local SIB. KPs share information with each other form a smart space application. KPs can be joined to several SIBs at the same time. KPs can be implemented with ANSI C, Java, Qt and Python making Smart-M3 usable even for embedded devices.

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ACM 978-1-60558-843-8/10/09.
SSAP is a protocol between a SIB and a KP. It includes the following operations: join, leave, query, insert, remove, update, subscribe and unsubscribe.

Smart-M3 supports either TCP or NoTA transports. The link between NoTA and Smart-M3 is simple: SIB can act as a NoTA service node and KPs can act as an application node. The main advantage of using NoTA instead of TCP is the multi-transport feature which enables adding devices with different transport layers to the same smart space. Another advantage is the service discovery provided by NoTA.

CASE STUDY: WIRELESS SENSOR MONITORING

As a case study we implemented a wireless sensor monitoring application for mobile devices. The application is an example of loosely coupled interoperability as all information is exchanged through the SIB. This enables modular extensions to the smart space. Commercial off-the-shelf devices were used in this case study. The reference implementation of Smart-M3 and NoTA are not optimized for the embedded or mobile domain so we wanted to empirically study the portability and feasibility of these open source technologies with COTS equipment.

Application description

The application and device setup of the case study is in Figure 1. Two Crossbow IRIS sensor motes [3] provide raw measurement data of temperature, humidity, acceleration, air pressure and luminosity. These battery operated devices are connected wirelessly to a Crossbow Stargate Netbridge gateway device with a proprietary protocol. A KP on the gateway reads the sensor information and updates it periodically to the SIB which is located in an Asus WLAN router with OpenWRT [7] firmware.

A simple custom sensor ontology was used for describing the sensor information shared by the devices in the smart space. One sensor mote is mapped as a living room sensor and one a wine cellar sensor. Alarm features were built for the iPhone and N810 sensor applications. Smart-M3 is modular, so new KPs using existing information in the SIB can be added to smart spaces even during run-time – if they use the same ontology as the existing application.

CONCLUSIONS

Our case study showed how commercial off-the-shelf devices and open source architectures can be used to build a fully functional smart space for sensor applications as long as an ANSI C programming environment exists for these devices. NoTA and Smart-M3 technologies provide smart environment solutions, which are usable with the devices used in our case study. We proved that these technologies are portable and usable in embedded Linux, Maemo Linux, Mac OS X and Symbian S60 environments and were able to create easy interoperability between devices from various different vendors.

REFERENCES