Demo Abstract: Self-configuring and IP-enabled Low Rate Wireless Personal Area Networks based on 6LoWPAN and IEEE 802.15.4

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***Abstract*—Low rate and low power personal area networks (LR-WPANs) which use IEEE 802.15.4 physical and MAC layers at the lower layers of the protocol stack, have been conceived for sensor network applications for their inner characteristic of reduced size, power saving and proximity coverage range. In these application scenarios, the ZigBee protocol stack is often used to create closed, ad hoc environments. However, we can also imagine new application scenarios where IEEE 802.15.4 devices, thanks to their small size, can be integrated into smart/mobile phones and could greatly benefit from built-in IP support. Goal of this work is to present a test-bed where a protocol stack including IEEE 802.15.4, IPv6 support and self-configuring capabilities runs on Secure Digital Input/Output (SDIO) cards and consequently on mobile phones and PDAs. The IPv6 connectivity support is made possible by the inclusion in the stack of 6LoWPAN solution, defined by the homonomous IETF working group to enable the transmission/reception of IPv6 packets in IEEE 802.15.4 nodes[1].**

I. Introduction

Low rate and low power personal area networks (LR-WPANs) are more and more often considered the ideal candidate for sensor-based applications such as home automation, industrial control, medical assistance and remote control ad monitoring. The main reason lies in the small size and low cost of the supported devices. The most important and currently available reference standard for LR-WPANs is IEEE 802.15.4 [1], which defines the physical layer and the medium access control (MAC) sub-layer. The first attempt to define the upper part of the IEEE 802.15.4 protocol stack is due to the ZigBee Alliance, which has defined the network and the application layers [2]. Despite its diffusion, unless complex and stateful gateways are used, the ZigBee network layer is not compatible with the IP network layer. However, thanks to their small size, IEEE 802.15.4 nodes can be hardware-integrated in devices such as SIM [3] or Secure Digital Input/Output (SDIO) cards, and in a futuristic vision, they can play a key role in the Internet of Things vision [4]. Clearly, in these scenarios, a built-in interoperability with IP networks would be desirable. Goal of this work is to present a test-bed where the 802.15.4 technology is brought on mobile nodes, enabling both small, self-configuring, IP-enabled nodes. This test-bed takes advantage from and integrates the so called 6LoWPAN adaptation layer [5], a solution for the transmission/reception of IPv6 packets defined by the homonomous IETF working group.

[1]This work has been carried out in cooperation with and with funding from Telecom Italia.

II. System Architecture

The system architecture implemented in the test-bed is composed by two kinds of entities: node and 6LoWPAN/IPv6 gateway.

Each node implements the protocol stack depicted in figure 1.

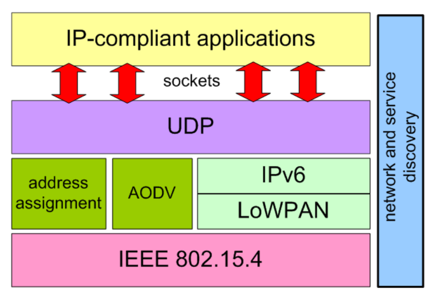

Fig. 1. High level overview of the proposed protocol stack.

The IEEE 802.15.4 standard is used at physical and MAC layers. The LoWPAN adaptation layer is located between IEEE 802.15.4 MAC and IPv6 layers, and it provides services such as fragmentation or header compression. Since 6LoWPAN specification requires that each node is equipped with a proper layer 2 routing table to support multi-hop forwarding, but it does not mention how to fill such layer 2 routing tables, the protocol stack includes AODV for the multihop routing. In addition, since 16-bit short addresses are highly desirable for the sake of compression, the protocol stack includes a module for the 16-bit layer 2 short address auto-assignment[2].

[2]The specification of how the PAN coordinator assigns 16-bit short addresses is out of the scope of the IEEE 802.15.4 standard, which leaves the responsibility of such assignment to upper layer protocols. However, the 6LoWPAN IETF working group does not specify how 16-bit layer 2 short addresses are generated and assigned.

The availability of IPv6 at network layer allows to use any IP-compliant transport protocol. Nevertheless, due to the limited hardware resources of a node, we consider UDP more suitable than other transport services. Finally, we include a module for network and service discovery, because IEEE 802.15.4 beacons carry only information about PAN identifiers, logical channel and network capability to accept joining requests, but lack a way to announce which networks are available and what are the services they offer.

The above protocol stack has been implemented in a custom SDIO with an embedded System-on-Chip. We used the TI's CC2430 SoC, that includes the 2.4 Ghz IEEE 802.15.4 transceiver, an 8051 microcontroller and the flash memory. SDIOs are used inside PDAs.

The 6LoWPAN/IPv6 gateway enables the transmission of IPv6 datagrams towards the public Internet and vice versa. It is made-up by an IEEE 802.15.4 node connected to a Linux Box through a serial line. The node is responsible for the interaction between the gateway and the 802.15.4 6loWPAN network. Besides the role of simple IP router, the 6loWPAN/IPv6 gateway just performs compression/decompression operations on headers. Thus, the gateway is totally stateless.

III. Description of the implemented test-bed

We conceived the application scenario depicted in figure 2.

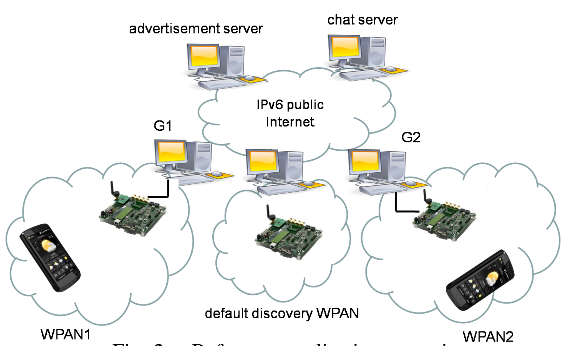

Fig. 2. Reference application scenario.

In a shopping center there are two different IEEE 802.15.4 LR-WPANs, denoted as WPAN1 and WPAN2, whose IPv6/6LoWPAN gateways are denoted as G1 and G2. There is also a special WPAN, specifically conceived for service discovery, and denoted as "default discovery WPAN". We used PDAs equipped with SDIO cards, where the implemented protocol stack runs. In such a way, we were able to fully exploit the PDAs equipment (display, keypad, etc.) and to develop applications based on the IPv6/6LowPAN capabilities of the proposed protocol stack.

To allow the interaction between the SDIO and the applications, we provide PDAs with Berkley-like APIs. A wrapper converts the calls to these APIs into tasks for the SDIO firmware. More precisely, we implemented an application that interacts with the firmware loaded on the SDIO cards and allows users i) to visualize on the PDA displays the available WPANs and information about the offered services, ii) to chat with other users, even if connected to different WPANs, iii) to receive context-based advertisement messages. Figure 3 shows three different screenshots of this application.

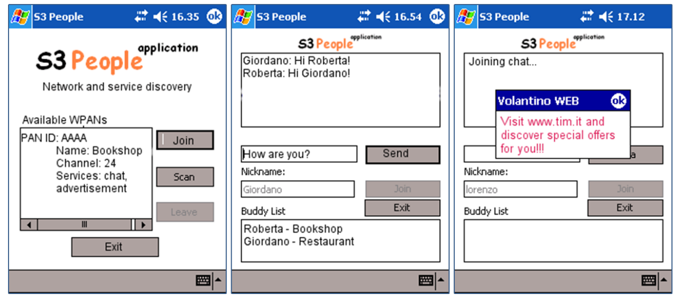

Fig. 3. Screenshots of the service discovery, chat and context-based advertisement messages service.

In more detail, nodes in the commercial center, perform a WPAN scanning using the IEEE 802.15.4 facility to find the list of WPANs in their coverage range. Then they connect to a default discovery WPAN to acquire information about services available in the WPANs they found. That gateway derives these information from DNS-SD/mDNS [6] messages that WPANs' gateways have previously transmitted through the public Internet. As regards the chat function, we developed a single room client-server chat. The remote chat server depicted in figure 2 manages user connections and disconnections, buddy lists, and it allows buddy users to discover each other. In addition, in case of users connected to different WPANs, the chat server makes possible the communication by receiving messages from the IPv6/6LoWPAN gateway of the source WPAN and forwarding messages to the IPv6/6LoWPAN gateway of the destination WPAN. As regards the advertisement server, it interacts with the IPv6/6LoWPAN gateways to send advertisements and promotional messages, that PDAs receive in form of pop-up messages. These messages can also contain URLs that users can access through the default web browser by using the GSM/UMTS and/or Wi-Fi connectivity.

IV. Conclusion and future work

We presented in this work a test-bed where a protocol stack including IEEE 802.15.4, IPv6 support and self-configuring capabilities runs on SDIO cards and consequently on mobile phones and PDAs. As future work, we will address the issue of IEEE 802.15.4 nodes going temporarily down during the sleeping mode. In doing this, we will focus only on applications and services that are based on asynchronous data exchanges and we will assume the availability of a publish/subscribe infrastructure for data exchanges. With such reference scenario in mind, we will investigate and design an innovative routing mechanism, which integrates both Mobile Ad-hoc NETworks (MANETs) routing functionalities and Delay Tolerant Networks (DTNs) routing functionalities.

References

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