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Development of a Framework to Support Network-based Mobility of 6LoWPAN Sensor Device for Mobile Healthcare System

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***Abstract*--In this paper, we focus on the scheme which supports mobility for 6LoWPAN sensor devices. We adopt Proxy Mobile IPv6 protocol to provide mobility for low power 6LoWPAN sensor devices. We also implement a testbed of the mobile healthcare system using our proposed mechanism.**

I. INTRODUCTION

IPv6 over Low power WPAN (6LoWPAN) [1][2] is a simple low-cost communication protocol that allows wireless connectivity in applications with limited power. The 6LoWPAN adopts the IPv6 stack for seamless connectivity between IEEE 802.15.4 multi-hop based sensor networks and IPv6 based infrastructure. In this paper, we focus on the scheme which supports mobility to each 6LoWPAN sensor device. To provide mobility to the low power 6LoWPAN sensor devices, an efficient mobility management protocol is needed to maintain the connectivity. If the concept of network-based mobility, which is specified in RFC 5213 [3] as Proxy Mobile IPv6 (PMIPv6), is applied in the 6LoWPAN, the 6LoWPAN sensor device itself does not require exchange of any mobility-related signaling messages. The reason is that special proxy agents such as 6LoWPAN Gateway (GW) are responsible for managing mobility-related functions on behalf of the 6LoWAPN sensor devices. Therefore, the network-based mobility approach can be the best solution in terms of low-energy consumption to support mobility for the 6LoWPAN sensor devices. However, the conventional PMIPv6 protocol supports only single-hop based IPv6 access network. It cannot be applied to multi-hop based 6LoWPAN sensor networks because the 6LoWPAN GW cannot directly detect PAN attachment of the 6LoWPAN sensor devices. To solve this problem, we propose a PAN attachment detection mechanism of the 6LoWPAN sensor devices using Router Solicitation (RS) and Router Advertisement (RA) messages. Also, we present the design and implementation of our mechanism to develop a mobile healthcare system. According to the best of our knowledge, our work is the first proposal that includes the implementation and testbed construction for interworking between 6LoWPAN and PMIPv6.

II. PROPOSED MECHANISM

In this section, we describe the proposed interoperable architecture between 6LoWPAN and PMIPv6 for supporting multi-hop based 6LoWPAN sensor network. Figure 1 shows overall mobility-related messages when a 6LoWPAN sensor device moves to away from PAN#1 to PAN#2.

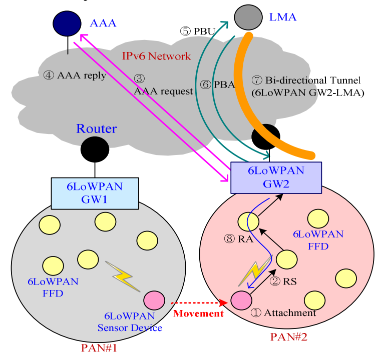

Figure 1. Mobility-related message exchange scenario of the 6LoWPAN sensor device mobility

The following describes the overall movement procedure of the 6LoWPAN sensor device. The 6LoWPAN sensor device can detect whether it is still in the same PAN area or has moved to another new PAN area by comparing the current PAN ID with the previous PAN ID in the beacon message. If the 6LoWPAN sensor device detaches from PAN#1 area and attaches on PAN#2 area, it sends a RS message to the 6LoWPAN GW to notify the PAN attachment. The destination address of the RS message is set to the unicast address to avoid broadcast. The RS message includes MN_ID option that needs to be set to identify the 6LoWPAN sensor device. The 6LoWPAN GW can recognize the 6LoWPAN sensor device's 64-bit MAC address and link-local address of IP header from MAC header of the RS message. Upon receipt of the RS message from the 6LoWPAN sensor device, the 6LoWPAN GW sends AAA Request message to the AAA Server including the 6LoWPAN sensor device's MN_ID to obtain the 6LoWPAN sensor device's profile such as the Home Network Prefix (HNP) and its Local Mobility Anchor (LMA) address. The AAA Server in response sends AAA Reply message, which includes the 6LoWPAN sensor device's profile, to the 6LoWPAN GW. If the 6LoWPAN GW receives the AAA Reply message, it can be aware of the 6LoWPAN sensor device's HNP and its LMA address. And then, the 6LoWPAN GW sends a PBU message to the LMA for the binding registration on behalf of the 6LoWPAN sensor device. After that, the LMA completes the steps to create or update the binding cache entry for the 6LoWPAN sensor device, and it sends a PBA message to the 6LoWPAN GW. At the same time, a bi-directional tunnel is established between the 6LoWPAN GW and the LMA. The 6LoWPAN GW assigns a 16-bit address to the 6LoWPAN sensor device and it manages a list of all the 6LoWPAN sensor devices with 16-bit

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addresses which can only be used within PAN area. Therefore, the 6LoWPAN GW does not require the 16-bit address collision avoidance mechanism. Upon receipt of PBA message the 6LoWPAN GW sends a RA message to the 6LoWPAN sensor device which is in the PAN#2 area. The RA message contains the 6LoWPAN sensor device's 16-bit address, which is assigned by the 6LoWPAN GW, and its HNP information. The RA message is delivered directly to the 6LoWPAN sensor device because both the source and destination of the RA message are set to unicast link-local addresses. The 6LoWPAN sensor device always can obtain its HNP anywhere in the PAN area by receiving the RA message with HNP option. This means that the 6LoWPAN GW emulates the home PAN on its access PAN area. Therefore, the 6LoWPAN GW can ensure that the 6LoWPAN sensor device believes it is at its home PAN area.

III. IMPLEMENTATION AND TEST

We implement a testbed of the mobile healthcare system using our proposed mechanism as shown in figure 2. The 6LoWPAN sensor device can be attached to a patient for sensing patient's vital signs such as heart rate and blood oxygen saturation information. The sensed data is sent to Healthcare Server periodically. As the patient can move from one place to another, we require a seamless mobility support to avoid any casualty. Our system ensures the seamless mobility of sensing devices with low overhead and also allows for monitoring patient's health at any given time.

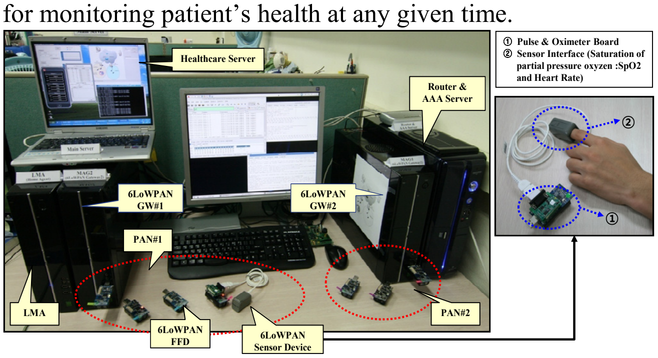

Figure 2. Testbed for 6LoWPAN sensor device mobility

Figure 3 shows the proposed interworking architecture between 6LoWPAN and PMIPv6. To accomplish our mechanism, we develop two major protocol stacks: TinyOS 2.0 [4] based 6LoWPAN protocol and PMIPv6 Daemon for supporting the 6LoWPAN sensor device mobility based on PMIPv6. We enhance the 6LoWPAN protocol stack using nesC, a component based programming language for embedded environments, in the TinyOS 2.0 framework. We test on the Telos motes hardware platforms which are equipped with the MSP430 processor having 10KB of RAM and 48KB of ROM. We add the following new features: a lightweight neighbor discovery protocol to handle proposed RS and RA messages for the 6LoWPAN sensor device's PAN attachment detection, and a mesh routing protocol to handle the mesh header in 6LoWPAN networks for the multi-hop communication within PAN areas. PMIPv6 Daemon is developed for the 6LoWPAN GW and LMA which are implemented in Linux kernel 2.6.11 using modified NEPL (Network Mobility Platform for Linux).

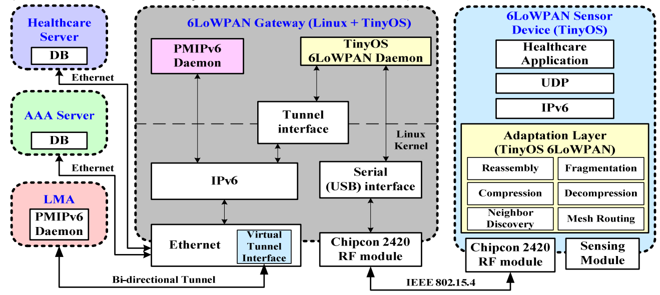

Figure 3. The proposed functional architecture

Figure 4 shows the user interface of monitoring application for the Healthcare Server. On receipt of the sensing data from the 6LoWPAN sensor device, the Healthcare Server stores its value in database. A real-time graph is plotted for the sensed data. Also, this monitoring application displays history of sensing values and relevant personal information in detail. We verify that the 6LoWPAN sensor device can maintain the connectivity even though it has the freedom of moving between PANs without mobility protocol stack.

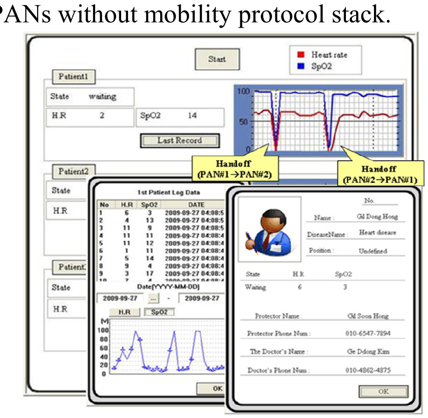

Figure 4. The user interface of monitoring application for Healthcare Server

IV. CONCLUSION

In this paper, we propose a scheme which supports mobility for 6LoWPAN sensor devices based on PMIPv6. Also, we present the design and implementation of our mechanism for the mobile healthcare system. We verify that the 6LoWPAN sensor device can maintain the connectivity while on the move between PANs without mobility protocol stack.

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