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A NEMO-HWSN Solution to Support 6LoWPAN Network Mobility in Hospital Wireless Sensor Network

Mohammadreza Sahebi Shahamabadi[1], Borhanuddin M Ali[1], Nor Kamariah Noordin[1], Mohd Fadlee b. A. Rasid[1], Pooria Varahram[1], and Antonio J. Jara[2]

[1] Faculty of Engineering, Universiti Putra Malaysia,
43400 UPM Serdang, Malaysia
m.saheb.sh@gmail.com, {borhan, nknordin, fadlee, varahram}@upm.edu.my
[2] University of Applied Science Western Switzerland (HES-SO),
Switzerland
jara@ieee.org

Abstract. IPv6 Low-power Personal Area Networks (6LoWPANs) have recently found renewed interest because of the emergence of Internet of Things (IoT). Mobility support in 6LoWPANs for large-scale IP-based sensor technology in future IoT is still in its infancy. The hospital wireless network is one important 6LoWPAN application of the IoT, it keeps continuous monitoring of vital signs of moveing patients. Proper mobility management is needed to maintain connectivity between patient nodes and the hospital network. In this paper, first we survey IPv6 mobility protocols and propose a solution for a hospital architecture based on 6LoWPAN technology. Moreover, we discuss an important metric like signaling overload to optimize the power consumption and how it can be optimized through the mobility management. This metric is more effective on the mobile router as a coordinator in network mobility since a mobile router normally constitutes a bottleneck in such a system. Finally, we present our initial results on a reduction of the mobility signaling cost and the tunneling traffic on the mobile PAN.

Keywords: 6LoWPAN, NEMO, Handoff, Mobility, Wireless Sensor Networks, Healthcare.

1. Introduction

Over the past two decades, communication networks have experienced tremendous growth and expansion all over the world. The explosive growth of many types of mobile devices such as smart phones, variations of tablet computers, and laptops, has fueled the demand for more bandwidth with varying Quality of Service (QoS), with pervasive connectivity and at affordable costs [1]. These mobile devices are generally very powerful in themselves with ever more innovative user interfaces, better information security and privacy, capability for higher end-to-end data transfer rate, streaming or interactive communications, and many other features [2]. Mobile wireless network generally encompasses Wireless Sensor Networks (WSNs), ad-hoc and mesh networks and infrastructure based cellular networks. These groups of networks can service a wide array of application areas such as the ubiquitous broadband access [3], mobile peer-to-peer, WiFi hot-spots, vehicular networks, sensor networks, and many more.

WSNs can be used for a wide range of applications, from environmental monitoring, home and industrial automation, military, to education, transport, healthcare and many more. It has been developed over IEEE 802.15.4 which is a layer_2 standard defined for Personal Area Network (PAN). WSN is designed for infrastructure-less type of networks which does not require an established network to be set up unlike the case with cellular based networks. WSN is also designed to connect to the Internet, this is done via a suitable node called the gateway [4]. However, IEEE 802.15.4 is defined to be of limited capabilities by way of smaller frame sizes, low memory capacity and data rate, respectively. It was primarily designed for short range communications with efficient power management. Eventually it creates a Low-power Personal Area Networks (LoWPANs) that supports a large number of nodes with energy saving capability [5]. The Internet Engineering Task Force (IETF) defines IPv6 Low-power Personal Area Network (6LoWPAN) which is an IPv6-based LoWPAN on the basis of IEEE 802.15.4 for communications with the Internet. With its vast address space, 6LoWPAN allows global connectivity between a large number of IPv6 intelligent devices over large areas. The protocol also enables the nodes to be self-organized i.e. can do self-detection, self-healing, and self-configuring, without human intervention [4].

For the success of IoT in general, and for healthcare in particular, mobility support is essential [6]. Mobility support is required to maintain fault tolerance of the network and full access to information regardless of their locations. In healthcare, some of the main applications for 6LoWPAN are for real-time monitoring of vital signs some examples being ECG (electrocardiogram), heart rate, SPo2, blood pressure, weight and breathing rate of patients. Moreover, it is important that these monitoring could be performed while the patients move around within the hospital [7]. In addition, because of the criticalness of healthcare provisioning mobility protocol needs to be reliable under any conditions, that is, it has to reduce packet loss, end-to-end delay, and network failures. Therefore, among the aims of a portable monitoring system are: firstly to control and monitor the patients in any location, and secondly to store the information as the Knowledge Based System (KBS) in order to study and survey symptoms and predict illness [8].

The design features of 6LoWPAN node like packet size restrictions, energy and power restrictions and delays in the reception of messages, have constrained host-based mobility protocols such as MIPv6 [9], HMIPv6 [10], FMIPv6 [9]. The Mobile Node (MN) which a mobile patient would carry, is involved in most of the mobility management signaling, and this weighs on the MN in the way of power consumption [11]. Hence, Proxy MIPv6 (PMIPv6) [12] is more appropriate in this respect to support 6LoWPAN mobility rather than the host-based solutions, but it has two shortcomings: that it cannot support multi-hop and that it requires 64 bit network prefix to be assigned to each MN [13].

Mobility solutions can give different kinds of efficiency and performance depending on the applications. In order to have a real-time access to the patients' body sensors to control body parameters, the use of Hospital Wireless Sensor Networks (HWSNs) is the best choice. Hence, this paper [14] grantees a reliable continuous and real-time remotely monitoring solution of hospitalized patients in a hospital infirmary based on an HWSN with intra-handover mechanism support. Thus, HWSN based on 6LoWPAN (HWSN6) has been defined for hospitals as smart building, equipped with MNs, Border Routers (BRs) and gateways. Although this mobility solution has been tuned for hospital applications and therefore made more compatible with it, but the energy constraint of mobile patient nodes which comprises a set of sensor nodes as a PAN has not been considered [4]. It also did not consider network mobility especially on the aspect of energy consumption in Mobile Router (MR) this will constrain the PAN lifetime.

From this brief discourse, it is anticipated that 6LoWPAN will become more popular in the near future. This is primarily because it has a wide address space that is well suited to individually address all objects that are connected to the Internet. Nevertheless, power consumption is a serious issue in 6LoWPAN, hence, mechanisms need to be sought in order to optimize this resource. One example of a busy device is MR; it is a very complex device that manages significant mobility functions [1].

In this paper, we propose a new mobility solution for mobile networks such as mobile patient nodes that comprise of a set of sensor nodes that consitutes a single unit called mobile patient node in HWSN6 scenario [15]. In this scheme, the MR that acts as a coordinator manages the mobility and PAN functions. This mobility solution decreases the amount of message on MR, and prolongs the lifetime of a patient PAN via MR.

This paper is organized as follows: a review of the related works is presented in section 2. A discussion on system architecture is given in section 3. Section 4 presents the HWSN6 mobility scenario. In section 5, our mobility mechanism scheme is evaluated. Finally, simulation results and conclusion are discussed in section 6 and 7 respectively.

2. Related Works

From sensor networks point of view, movement occurs in 6LoWPAN nodes when an MN or a mobile PAN tries to leave its current link and connect to a new point of attachment. 6LoWPAN device/s should do self-configuration and self-detection and automatically introduce themselves in any movement to keep the connectivity. This process usually starts by binding message exchange through Neighbor Discovery (ND), and then establishing a bi-directional tunnel that connects the Home Agent (HA) and the MN. Mobility is categorized into two groups: micro-mobility or macro-mobility and involves two processes roaming and handover. Roaming is moving from the previous 6LoWPAN area to a new PAN and handover is the changing of current point of attachment and data flows to another point of attachment. Micro-mobility or ntra-PAN mobility occurs when an MN leaves its current position and moves to another point of attachment within the same 6LoWPAN network. On the other hand, macro-mobility or inter-PAN is the mobility between network domains where there would be a network address change [11]. Figure 1 displays the possible node mobility movement for supporting IPv6 in WSN 6LoWPAN. When the whole PAN changes its point of attachment similar to NEMO (NEtwork Mobility), this is called WPAN mobility [16].

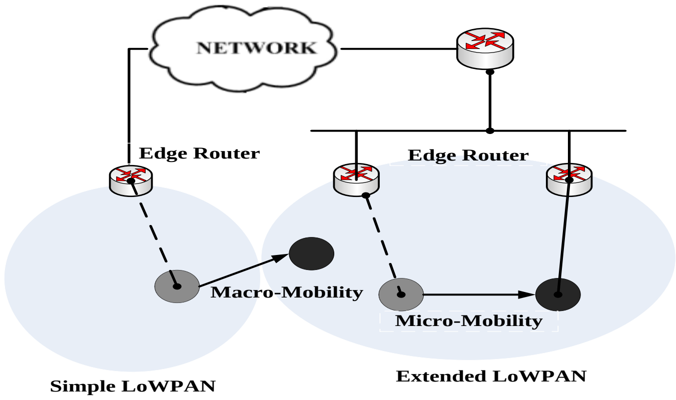

Fig. 1. 6LoWPAN Micro-Mobility and Macro-Mobility

The chart in figure 2 depicts the various mobility protocols and their hierarchies in MIPv6 when an MN changes its point of attachment in the network, it should update its current Care-of Address (CoA) by itself and informs the HA of its CoA using the Binding Update message (BU) [17]. An enhancement to the MIPv6, Hierarchical Mobile IPv6 (HMIPv6) was introduced, whereby it separates global mobility from local mobility [10]. Then, for the optimization of MIPv6, Fast handover for Mobile IPv6 (FMIPv6) was introduced. It reduces handoff delays by performing CoA configuration even before an MN leaves its current network [18]. In [19], they presented an authentication protocol for HMIPv6 roaming service to establish secure communications, when an MN is roaming into a foreign network. In the host-based mobility management protocols, an MN is involved in the processing of mobility and signaling to configure an IP address on a new link management [10]. FMIPv6, HMIPv6 and MIPv6 are of type host-based mobility protocol, but they are not suitable for 6LoWPAN due to its constraints [7].

From figure 2, network-based mobility is more appropriate in low-power sensor nodes because it relieves the MN from participating in any mobility operation, thereby extending its network lifetime [6]. In this respect, the Proxy Mobile IPv6 (PMIPv6) is more suitable as a mobility solution for IPv6 devices as it undertakes the responsibility of performing the handover process from the MN with a single hop. Even through this helps to conserve energy in IPv6 devices but single hop communication is not appropriate for 6LoWPAN devices because this may impose high transmission power to the energy constraint devices in order to reach distant PMIPv6 gateway [12]. Sensor Proxy Mobile IPv6 (SPMIPv6) is an optimization of PMIPv6 which is more suitable for energy constraint devices. It reduces signaling and mobility costs compared with MIPv6 and PMIPv6 [20]. LoWMob has been subsequently introduced for mobile 6LoWPAN nodes based on network-side and intra-mobility. The communication between MNs and gateways with the participant of the 6LoWPAN static nodes is made to be multi-hop rather than a single hop as in the previous protocols. The signaling overhead is reduced through supporting packet format at the adaptation layer [16]. A distributed version of LoWMob referred to as DLoWMob optimizes the mobility process. This is done by way of the following procedures: (i) supporting points to distribute the gateways traffic and to enhance the multi-hop routing path between source and destination nodes, (ii) considering security aspects, (iii) equipping SNs with antennas in order to get the Angle of Arrival (AoA) measurements, and (iv) equipping SNs with a radio-triggered component to manage the sleep state by sending wake up radio signal [16]. Another protocol called Inter-MARIO has been proposed to perform handover based on the pre-configuration mechanism of 6LoWPAN mobility. This solution runs pre-configuration via the partner nodes to save the information on the PAN coordinators in the neighborhood PANs and reduces the mobility handover delay [21].

The philosophy behind NEMO protocol is that it runs Mobile IP and full IPv6 stacks only at MR/edge router, and does not run Mobile IP for attached nodes. This mobility solution fits the 6LoWPAN model perfectly as LoWPAN nodes are not adjustable for dealing with MIPv6 [20]. Lightweight NEMO protocol compresses the packet header to reduce the signaling overhead between MRs and gateways, this is done by using a compressed mobility header to support the 6LoWPAN mobility [11]. Inter-PAN mobility solution proposes an adaptation layer packet format for 6LoWPAN mobility signaling to reduce handover time. It provides extra information about the frequencies of the surrounding PANs at the border nodes [22]. To support mobility in 6LoWPAN sensor nodes, Sensor NEMO (SNEMO) has been introduced, it presents an interoperable architecture between NEMO and 6LoWPAN by way of an extended LOAD routing scheme for MRs [23]. Chai et al. [24] proposed a network architecture that supports the integration of NEMO and 6LoWPAN which shows that the handoff signaling of NEMO is $1/N$ times (N is the number of MNs) smaller than that of MIPv6, hence this means that the consumed energy of NEMO is much smaller than that of MIPv6. However, nodes that are selected as sensor routers consume more energy thus they suggested the use of non-power aware devices as sensor routers or MRs in NEMO.

HWSN6 defines a protocol to carry out intra-WSN mobility to support medical sensor networks based on 6LoWPAN. In this protocol, the mobility management is delegated to Monere system as BR which monitors a mobile patient’s vital data [25]. This mobility scenario looks very similar to the NEMO protocol, in which the mobility of the entire network is viewed as a single unit.

The state of the art in HWSN6 related with high performance solutions includes security and authentication of MN for movements, global IPv6 addressing, intra-mobility among the Monere systems, reduced overload in MNs with respect to Mobile IPv6, distributed storage of the information among all the Monere systems, and mobility control messages to avoid fragmentation. Node authorization and authentication must be supported to offer security capability, integrity and confidentiality of the information, ensure protection of the resources.

In [26], they overview available handover mechanisms used for wireless sensors mobility and proposes a new ubiquitous mobility solutions for Body Sensor Networks (BSNs) in healthcare monitoring. This paper [27] surveys the most recent intra-mobility solutions with special focus on handover approaches that can be used in HWSNs. It proposed open issues that can contribute to improving the performance of handover solutions when applied to hospitalized patients were highlighted.

Although HWSN6 and previous solutions consider mobility issues but the energy consumption optimization of mobile patient node remains an open issue. The adaptation of the current mobility methods to 6LoWPAN remains a serious problem, and the further researches on 6LoWPAN mobility is necessary [7].

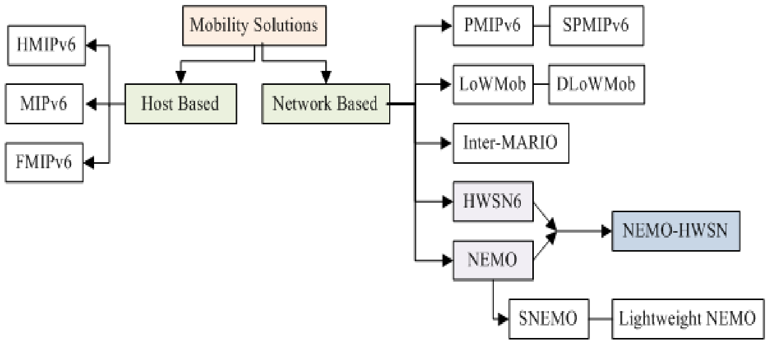

Fig. 2. Summary of IPv6 Mobility Solutions

3. System Architecture

The hospital system architecture is made up of patient nodes (MN with a set of sensors), Monere system (local gateway or BR), Internet gateway, Hospital Information System (HIS), and users (physicians, surgeons and nurses). As shown in figure 3, each part of the hospital such as operating theatre, observation rooms and wards are organised as a PAN which is under network coverage to keep the connectivity among the nodes and the Internet. Each PAN with all the nodes belong to the same domain deployed with a BR to connect to the Internet, HIS, and other PANs via the network backbone [4].

3.1. Gateway and HIS Node

A gateway manages its domain, establishes connections between networks, and interconnects with each other through wireless or wired links. HIS is a system based on Open Services Gateway Initiative (OSGi) technology for the management of all the other systems from the hospital. HIS saves the important monitoring information of all nodes and provides information and services to the other systems belonging to the hospital such as management of alarms from the Monere systems, electronic health record, health status, localization service, and directory service [4].

3.2. Monere System

Monere system [28] is a new BR device that has been suggested to cover each part (domain) of a hospital and also acts as a Mobile Data Collector (MDC) coming from the patient sensors, similar to a sink node in each PAN. It is equipped with several interfaces that establish connections with other networks technologies like Bluetooth, cellular networks, Ethernet and home automation (ZigBee, X10 and EIB) and standards such as CANBus, Ethernet and Serial Interface [29]. The area covered under the interconnected

BRs is referred to as a PAN or domain. 6LoWPAN BR plays two roles: it be identified as an HA responsible for buffering and forwarding packets to the MN, or as a Foreign Agent (FA) which coordinates visited network. Finally, it supports the security requirements like privacy and security that it can cipher the communications with AES-CBC cryptography (256bits key) [4].

3.3. Patient Node

This paper proposed the concept of mobile patient node which moves between multiple PANs in a hospital environment. A set of sensors acting as one unit fixed on the patient's body (6LoWPAN MN) measures and collects health data continuously such as heart rate, SpO2, peripheral and core body temperature, glucose etc [25]. From figure 4, two types of sensor nodes have been defined in IEEE 802.15.4: they are Full-Function Device (FFD) and Reduced-Function Device (RFD) respectively. FFDs are designed to support all network functionalities and participate in peer-to-peer topologies with multi-hop communications. On the other hand, RFD devices are limited mainly to perform measurements only of physical parameters and to processing non-complex tasks in star topologies since they do not support multi-hop communications. Normally each PAN coordinator controls a PAN, this is done by way of setting up and maintaining of the PAN. Hence, only a FFD device can assume the role of PAN coordinator [13].Two models are suggested for the patient mobile node: in the first model, there is a main FFD device with one IP address which collects data from a set of RFDs and also manages the patient node area as a coordinator. FFD acts as an MR and connects the BR to the patient through a 6LoWPAN node. All RFDs data are accessible from FFD, and this constitutes a bottleneck in the network. In the second model all 6LoWPAN sensors are considered as FFD devices with their own IPv6 addresses, they send their data directly to BR without any interface such as MR. Thus, it is clear that the second model is more expensive in terms of energy requirement and data exchange during mobility [25].

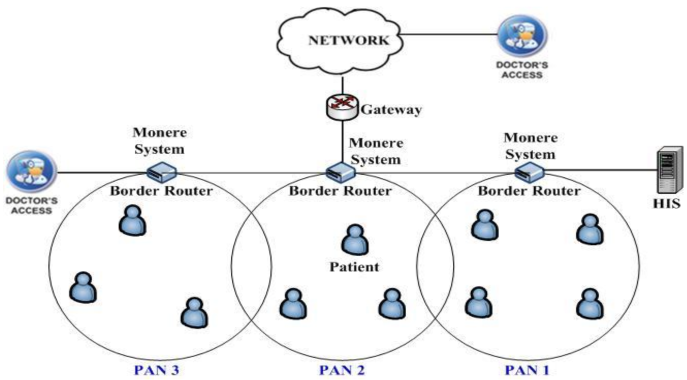

Fig. 3. Hospital Network Architecture

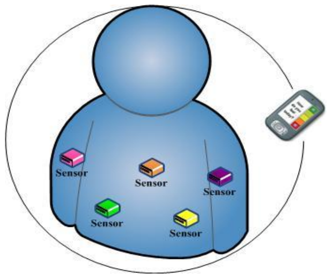

Fig. 4. Patient Node Sample Architecture and Topology

4. The HWSN6 Mobility Scenario

The WSNs mobility protocols proposed a large scope of applicability with the conjunction of the variety of case scenarios make it difficult to generate a standard mobility. To overcome this challenge, a specific scheme in mobility management for hospital WSNs has been proposed. The requirements of this scheme are continuous monitoring, low latency, no packet loss and low signaling. Figure 5 shows a movement scenario of a patient that moves between the home network and visited networks and then returns to base/home network. This kind of scenario is common at hospitals when the patients walk or move to other rooms to do medical tests. Phase 1 shows an initial state of the patient node which is in its home network and exchanges vital signs via the Monere system to maintain a continuous monitoring. In phase 2 and 3, it moves to a visited network and runs mobility protocol and handover mechanism, and finally it returns to the home network in phase 4.

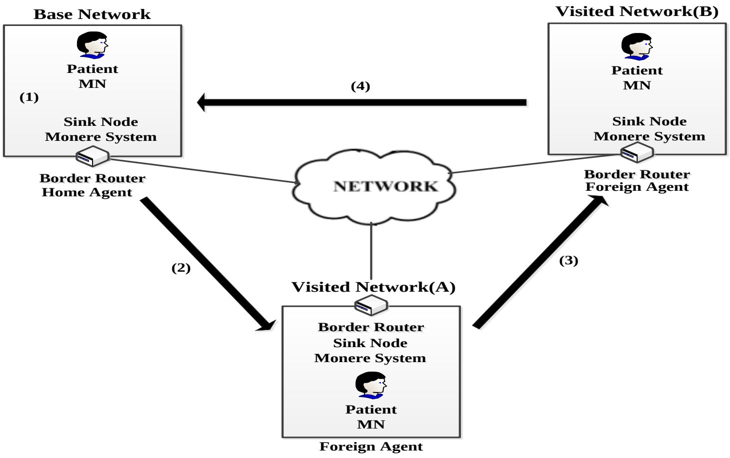

Fig. 5. Mobility Scenario of Mobile Patient Node

Figure 6 shows the HWSN6 mobility diagram with the messages exchanged in each step of mobility scenario as follows:

Exchange of messages *in home network:* The general frames (data, requests, responses and ACK frames) exchanged between sensors such as SPo2 level per each 5 seconds and BR.

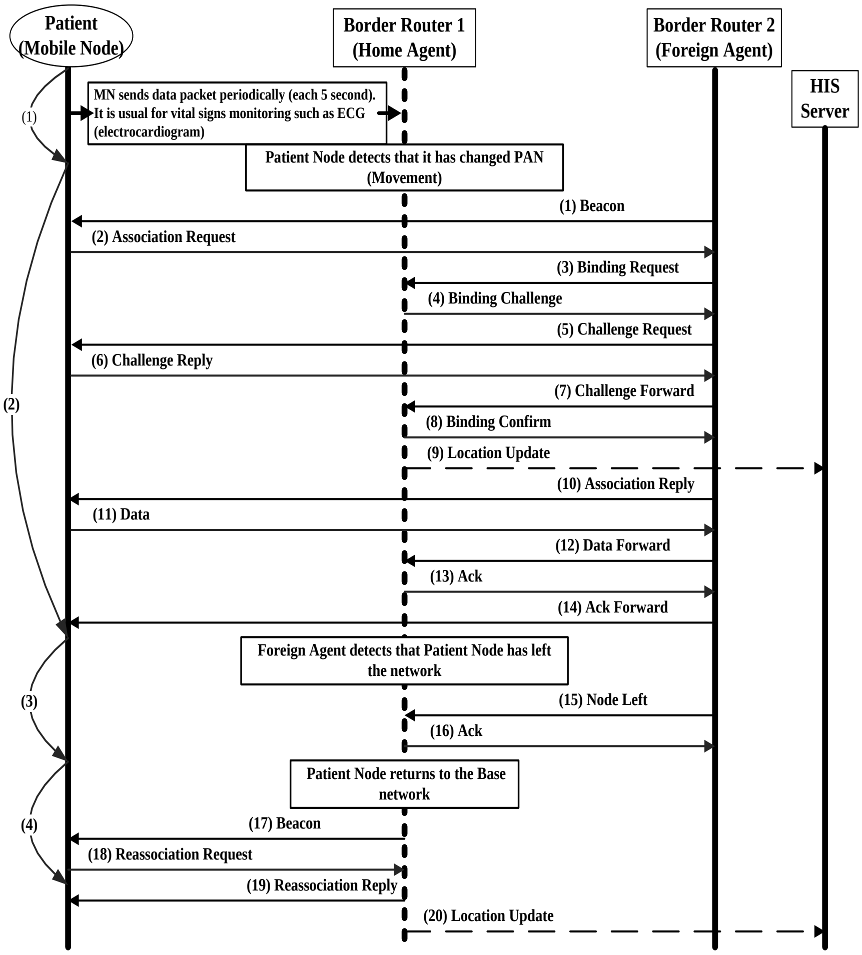

Fig. 6. Message Exchanges in a Mobility Scenario

Movement detection time: When an MN moves, it detects that its link quality has degraded beyond a certain threshold. This means that the existing router is no longer reachable, or a new access router is available [30].

Entering the visited network: Upon the mobile patient node entering the threshold or new network area (PAN), then it receives a Beacon message (message 1) which is broadcasted periodically by 6LoWPAN BR acting as the coordinator (Monere system). Hence it detects the movement and sends Association Request (message 2).

Confirmation of MN in visited network: In order to authenticate the roaming MN, the following messages are exchanged: Binding Request (message 3), Binding Challenge (message 4), Challenge Request (message 5), Challenge Reply (message 6), Challenge Forward (message 7), Binding Confirm (message 8), Location Update (message 9), and Association Reply (message 10) message. These challenge messages are used to confirm that MN is a real node from its network. Patient node ciphers the challenge message and sends it to the FA. FA forwards to the HA. HA checks the challenge, if it is right, it sends a confirm message to the FA. In other case, it sends a deny message to avoid that the unauthenticated patient node receives or sends confidential information. Finally, the proposed mobility protocol supports security and authenticate MN with a challenge based on AES 128 bits when the MN changes its BR.

Interchange of data frames in the visited network: The messages from 11 to 14 show how a data frame and its Ack are exchanged.

Returning to the base network: Finally, as the patient node returns to its base network, it informs HA of its new location by sending a Re-association Request message (messages 17-20).

Movement between visited networks: When a patient node leaves the visited networks, FA informs the HA via Node Left and Ack messages (messages 15 and 16) of the event.

5. NEMO-HWSN Mobility Mechanism Scheme

As mentioned in section 3, the mobile patient node with its attached sensors is considered as a network or PAN that moves between different PANs like NEMO, because when the patient moves, all attached sensor nodes move together. Hence, it looks like the PAN or a group of mobile sensor nodes moves together and they also need a strong power device acting as an MR to coordinate and collect the PAN data. Hence, the partial of mobility cost have close relation to the PAN architecture such as type and number of sensors, message overhead, and the MR as a coordinator which manages the mobility in mobile PAN. The handoff and tunneling costs of patients in the mobility process depend on the number of attached sensors. As a result, the increased number of sensor node increases the complexity of fast handoff detection and decreases its efficiency, and finally increase the energy consumption. Hence, in the following methods, we will survey possible mobility scenarios to show the benefits of our proposed scheme. Figure 7 shows three mobility models that can be applied with mobile patient sensor nodes.

Figure 7 (a) presents the first model in which MR acts as a sink node, it controls, maintains PAN, collects data from body sensors and transmits to BR in the base network or visited network, and finally executes the mobility protocol. Although this model is similar to NEMO and has reduced handoff cost due to the use of MR that only it supports and runs the mobility process. However, the MR presents a bottleneck to the PAN because it should collect all data from attached sensors. This is a serious constraint in 6LoWPAN. As a result, the MR is made to work as a coordinator to handle the mobility and collect data as a sink node. The benefit of this model is that it is less mobility complex and can perform fast handoff detection. The most serious problems are therefore bottleneck at the MR and end-to-end delay in tunneling process.

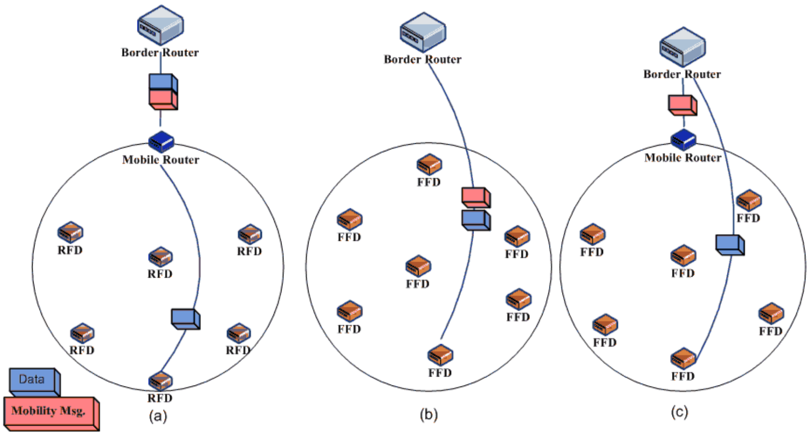

Fig. 7. The Messages Scheduling of Three Models. (a) RFD Devices with MR, (b) FFD Devices without MR, (c) FFD Devices with MR

Figure 7 (b) shows the second model in which all body sensors are FFD devices without any coordinator that attend to the mobility process. Accordingly, all FFDs repeat and execute the mobility scenario such as coordinator node (in previous model) and send their mobility messages to BR directly. This model is similar to individual mobile node that runs mobility scenario; it means the mobility protocol is supported with each individual node separately. The disadvantage with this model is that the handoff process will be increased based on the number of nodes, therefore the handoff complexity also will be increased [25]. With the benefit of this model is that each sensor node can leave its PAN and run mobility scenario separately and hence there is no bottleneck compared with the previous model. Finally, the MNNs send their data frames directly, thus the end-to-end delay in tunneling process will be optimized compared with previous method.

Table 1. Benefits of NEMO-HWSN Scheme

Mobility Issues	NEMO	HWSN6	NEMO-HWSN
End-to-End Delay	High	Low	Low
Bottleneck Node	MR Node	No	Optimized
Mobility Complexity	Low	High	Low

NEMO-HWSN [15] is our mobility management solution which is designed to solve the serious challenges of previous mobility models to apply for group mobility in 6LoWPAN. We present a new scheme with low handoff cost like NEMO and light traffic on MR to optimize the PAN lifetime. Figure 7 (c) illustrates the proposed architecture which comprises of FFDs as sensor nodes with an MR as the coordinator. In this model, the MR as a coordinator just runs the mobility process based on mobility diagram (Figure 6) to exchange the handover messages in movement situation; but data from sensors or MNNs are transmitted to BR directly. Consequently, the end-to-end delay in tunneling will be reduced due to remove one hop (MR node) in the direction of tunneling process. Hence, the duty of sensing data transmission is eliminated from MR, thus it leads to longer lifetime of MR during the tunneling process and sensor nodes can be located behind the MR without mobility message support. Finally, the MR registers all FFDs in the BR as an FA in order to create a connection with a new FA and transmit their data frames into networks. By way of this technique, we provide the best handoff cost and mobility scenario for MR. Hence, any increase in the number of FFD will not increase the cost of handoff during mobility. As a result, FFDs as members of patients' node send their data frames directly and the MR is set free of congestion at tunneling time. Thus, the bottleneck problem will be overcome by this scheme. Table 1 shows the previous challenges that are solved in NEMO-HWSN.

Figure 8, 9, and 10 show a comparison of the mobility diagram in terms of mobility and data messages scenario in three models. The dotted lines show handoff messages direction, when the MR or Mobile Network Nodes (MNNs) as mobile sensors run the mobility scenario which exchanges the handoff messages to follow the mobility process. The bold lines present the case when the tunneling scenario happens to exchange the sensing data from MNNs to destination like HA or CN. As shown in figure 10, the total signaling cost of our proposed scheme is better than the two previous mobility models. The NEMO-HWSN scheme that the MR mobility overhead is optimized by way of reduction in the MR traffic and the amount of mobility messages. As has been pointed out, the mobility cost is related to handoff and tunneling process time. Both of them have been surveyed by way of NEMO-HWSN solution through scheduling and managing the mobility functions of the MR.

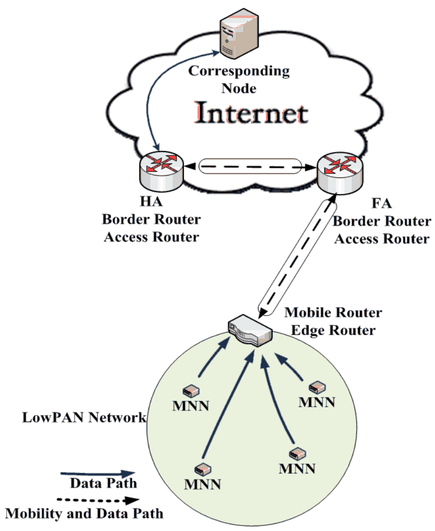

Fig. 8. Network Mobility Mechanism

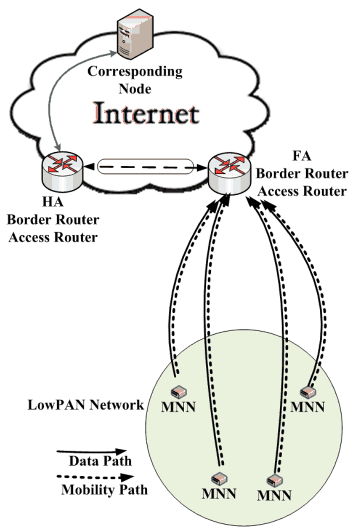

Fig. 9. Node Mobility for all MNNs

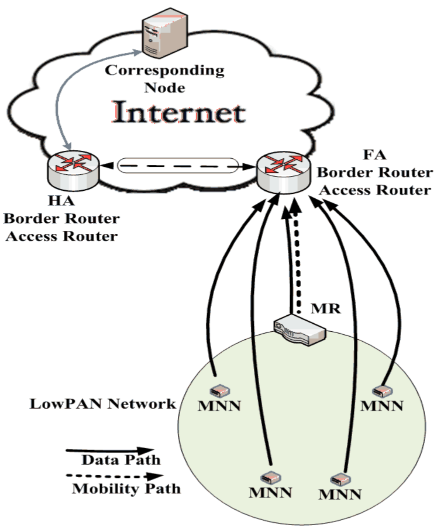

Fig. 10. NEMO-HWSN Mobility Mechanism

6. Simulation Results

To simulate our proposed scheme, we used OMNet++ simulator and the HWSN6 message diagram (Figure 6) which including binding update, challenging messages and etc. that exchange between MNNs, MR, HA, and FA in during the mobility scenario. In this scenario, the patient node consists of the five MNNs as mobile sensor nodes (attached sensors) to generate the sensing data and one MR node as a coordinator to manage the mobility mechanism.

The results from figure 11 shows the total mobility cost for tunneling and handoff process of the patient node with five attached sensor nodes (MNNs), i.e., the messages to exchange the data frames periodically from MNNs to HIS. It compares the total signaling cost of the NEMO-HWSN solution against that of the first model (NEMO) and the second model (node mobility) of the previous schemes. The graphs show that the total signaling cost in the NEMO-HWSN is very small in comparison to the second model (node mobility) and slightly smaller than NEMO protocol at minimum level. As mentioned before in figure 10, the proposed scheme (NEMO-HWSN) minimizes the handoff signaling of the MR; thus its total handoff cost is optimized as well as the NEMO protocol (first model). Consequently, the handoff signaling of NEMO-HWSN and NEMO are 1/N times (N is the number of MNNs) smaller than HWSN as node mobility. The graph shows the total signaling cost between NEMO-HWSN and NEMO is not very high, due to we exchange the low amount of data frames in tunneling process. In other words, the data frames start from MNNs are exchanged between MR and HA or HIS (as a CN in this scenario) without MR involvement in the tunneling direction.

Figure 12 compares the end-to-end delay between two network mobility models (HWSN6 and NEMO-HWSN). The end-to-end is optimized in our proposed scheme because it transfers MNNs data frames to HA without MR involvement in tunneling process. The NEMO-HWSN does not impose heavy traffic on the MR, and hence the bottleneck traffic is optimized. Therefore, the PAN lifetime is prolonged in mobility scenario process.

Finally, our proposed scheme reduces the mobility overhead of MR through reduction the tunneling messages to help extend the lifetime of PAN. This type of scenario is suitable for 6LoWPAN network mobility such as NEMO, which suffers from energy challenges such as energy constraint, limited battery or accessing to energy resources.

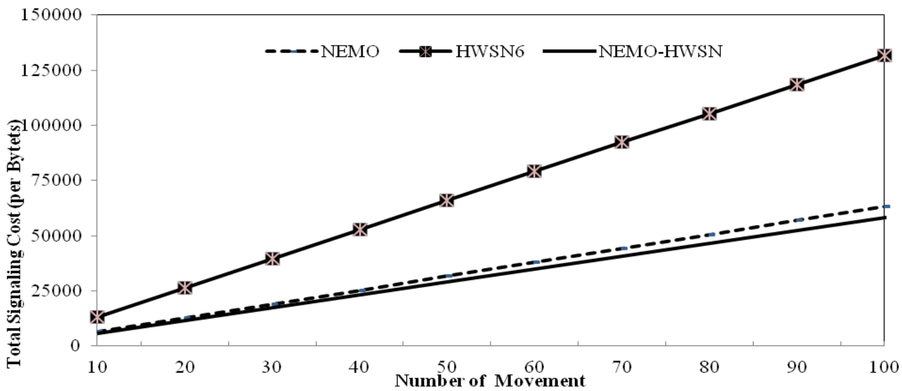

Fig. 11. Comparison of the Total Signaling Cost in Three Models

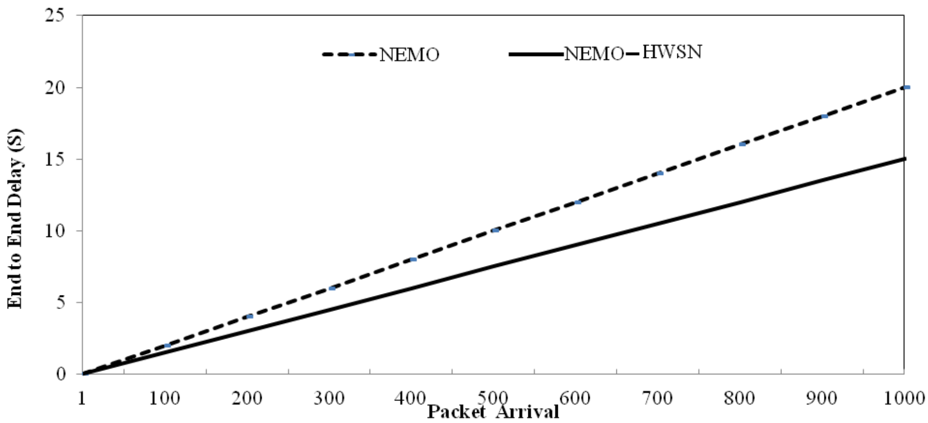

Fig. 12. Comparison of the End-to-End Delay in Two Group Mobility Models

7. Conclusion

This paper described a mobility solution for a group of 6LoWPAN mobile sensors like patient node with attached sensors in hospital settings to maintain the continuous connectivity between the patient nodes and hospital area network as a smart building. This solution considers the hospital architecture in order to define a solution that reduces the amount of messages exchanged between the mobile patient node and 6LoWPAN hospital network through the MR. This means that the signaling overload is decreased and also the lifetime of the MR is optimized due to the reduction in the total amount of mobility messages. The patient node should not run a costly configuration for new topology that causes the MR dies early due to congestion. Finally, it is shown that this scheme provides the low tunneling cost and light traffic on MR and BR regardless of the number of sensors attached to a patient node. Hence, the NEMO-HWSN mobility protocol for hospital architecture should be more feasible in a 6LoWPAN topology.

The article offers important insights for further studies on healthcare monitoring by using 6LoWPAN MNs as a part of IoT in movement. In the future, we will present the analytical model and real implementation to carry out a real test for performance evaluation in order to obtain the optimum handover solution along the mobility process.

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Mohammadreza Sahebi Shahamabadi has received his bachelor degree in Computer Hardware Engineering from the Islamic Azad University, Maybod, Iran in 2001. Later, he received the Master degrees from the Islamic Azad University, Arak, Iran in 2008. He has started the Ph.D degree in wireless senseor networks in Universiti Putra Malaysia since 2010.

Borhanuddin M Ali received his PhD from the University of Wales (Cardiff) in 1985 and subsequently became a lecturer in Universiti Pertanian Malaysia (now renamed Universiti Putra Malaysia) since 1985. He served the university as a lecturer and various administrative positions -- Director of the Institute of Multimedia and Software; Director of Institute of Advanced Technology UPM (ITMA), and presently Director of the National Centre of Excellence in Sensor Technology (NEST), besides being the Head of Department twice. In 1996 he helped to realize the formation of Teman project a precursor to MYREN (a national research network), and later was made the Chairman of the MYREN Research Community till 2006. He is a Chartered Electrical Engineer and a member of IET and Senior Member of IEEE. He was Chair of IEEE Malaysia Section 2002-2004, and ComSoc Chapter twice, 1999-2002, and 2006-2008, and various portfolios in ComSoc AP Board culminating as Vice Director (2014-2016) and conference coordinator IEEE Region 10 in 2013. His research interest spans wireless communications in particular wireless sensor networks and broadband communications. He has authored and co authored some 100 journal papers and 200 conference papers under those areas of interests.

Nor Kamariah Noordin received her PhD at Universiti Putra Malaysia. She then became a lecturer in 1991 at the same department where she was later appointed as the Head from year 2000 to 2002. After that, she is assigned as a Deputy Dean (Academic, Student Affairs and Alumni) of the Faculty. Currently, she is the manager of Corporate Planning Division in Universiti Putra Malaysia. During her more than 15 years at the department, she has been actively involved in teaching, research, and administrative activities. She has supervised a number of undergraduate students as well as postgraduate students in the area of wireless communications, which led to receiving some national and UPM research awards. Her research work also led her to publish more than 100 papers in journals and in conferences.

Mohd Fadlee A. Rasid is currently the deputy director for National Centre of Excellence for Sensor Technology (NEST) in Universiti Putra Malaysia (UPM). He received a Ph.D. in electronic and electrical engineering (mobile communications) from Loughborough University, U.K. He directs research activities within the Wireless Sensor Network (WSN) group and his work on wireless medical sensors is gaining importance in health care applications involving mobile telemedicine and has had worldwide publicity, including BBC news. He was a research consultant for a British Council UKIERI project on wireless medical sensors project. He was also part of the French Government STIC Asia Project on ICT-ADI: Toward a human-friendly assistive environment for Aging, Disability & Independence. He currently leads a few research projects on WSN, particularly for medical and agriculture applications. He is currently involved with a project under Qatar National Research Fund by Qatar Foundations on Ubiquitous Healthcare. He was nominated for IEE J A Lodge Award for Outstanding Work in Field of Medical Engineering, London, 2005 and was the proud recipient of State of Selangor Young Scientist Award 2006.

Pooria Varahram has obtained his bachelor degree in Electrical, Electronics Engineering from the Khaje Nasir University, Tehran, Iran in 2002. Later, he received the Master and Ph.D degrees in Wireless Communications from Tarbiat Modares, Tehran, Iran and Universiti Putra Malaysia, in 2005 and 2010. He is a member of IEEE since 2010. He has more than 5 years of experience in designing and developing a range of electronic and telecommunication related projects. He is currently senior lecturer in UPM.

Antonio J. Jara; Assistant Prof. PostDoc at University of Applied Sciences Western Switzerland (HES-SO) from Switzerland, vice-chair of the IEEE Communications Society Internet of Things Technical Committee, CTO and founder of the Wearable Computing and Personal Area Networks company HOP Ubiquitous S.L., CTO and co-founder of the Smart Cities company viBrain Solutions. He did his PhD (Cum Laude) at the Intelligent Systems and Telematics Research Group of the University of Murcia (UMU) from Spain. He was associated with the Department of Information and Communication Engineering, UMU, since 2007, where he has been working on several projects related to IPv6, WSNs. and RFID applications in building automation and healthcare. He is especially focused on the design and development of new protocols for security and mobility for Future Internet of things, which was the topic of his Ph.D. Nowadays, he continues working on IPv6 technologies for the Internet of Things in projects such as IoT6, and also Big Data and Knowledge Engineering for Smart Cities in collaboration with projects such as SmartSantander. He has also carried out a Master in Business Administration (MBA). He has published over 100 international papers, As well, he holds one patent. Finally, he participates in several Projects about the IPv6, Internet of Things, Smart Cities, and mobile healthcare.

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