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A survey on mobility management protocols in Wireless Sensor Networks based on 6LoWPAN technology

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ABSTRACT

Mobility has the advantage of enlarging the WSN applications of the Internet of Things. However, proposing a mobility support protocol in Wireless Sensor Networks (WSNs) represents a significant challenge. In this paper, we proposed a survey on mobility management protocols in WSNs based on 6LoWPAN technology. This technology enables to connect IP sensor devices to other IP networks without any need for gateways. We highlighted the advantages and drawbacks with performances issues of each studied solution. Then, in order to select a typical classification of mobility management protocols in WSNs, we provided some classification criteria and approaches on which these protocols are based. Finally, we presented a comparative study of the existing protocols in terms of the required performances for this network type.

1. Introduction

Traditional Wireless Sensor Networks (WSNs) are developed using static nodes (SNs) [1–4]. These networks can be applied in numerous applications such as healthcare [5,6], military, industry, monitoring, tracking based on multimedia sensor [7] among others [8–10]. Hence, a lot of researches and propositions are made for static scenarios. Nevertheless, the advanced technology in the Internet of Things [11,12] involves applying more complex applications, which require mobility of their nodes [13]. Mobility of nodes can enlarge WSN applications [14]. It can also prolong the nodes lifetime, since data transfer between two nodes does not usually use the same relayed nodes in the path route. In addition, it serves to increase connectivity between nodes, since mobile nodes (MNs) can help the communication between two isolated nodes [15]. It also helps to extend area of coverage interest [16,17]. However, mobility can cause some problems, like disconnection of nodes during the handover process, which causes data loss and a negative impact on the applications performances. Other issues related to mobility are resource management, topology control, routing protocol, quality of services and security.

In this paper, we focused on mobility management protocols in WSNs based on 6LowPAN technology [13,18,19]. This technology was proposed by IETF Working Group in order to introduce IPv6 over IEEE 802.15.4 [20–23], since IPv6 is considered as one of the candidate technologies for the Internet oh Things [24]. Using IPv6 packets instead of IPv4 packets offered a more important address space, that helps to deploy an important number of nodes and satisfy scalability performance. Hence, introducing IPv6 over IEEE 802.15.4 made data accessible at any-time and from anywhere through the Internet. Therefore, 6LoWPAN offers the possibility to establish a direct connectivity between devices based on the IP address. Unlike ZigBee technology [25], each external communication from a WSN requires a Zigbee coordinator (ZC) or a gateway (GW) as an intermediate node which centralizes this kind of communication [26].

The aim of mobility support protocols is to keep nodes reachable and connected during the handover process, without any connectivity interruption [13]. Thus, when a node moves away from its neighbor's coverage, the protocol must rapidly provide an alternative router and ensure the configuration of a new interface for the MN.

The contribution of this paper is summarized as follows:

–Review of the state-of-the-art of mobility management protocols in WSNs based on 6LoWPAN technology. The advantages and drawbacks with performance issues of each studied solution are highlighted.

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–An attempt of mobility management protocols classification in WSN is proposed, after studying different criteria and approaches.
–A comparative study of existing mobility support protocols in WSN is proposed and analyzed.

The remainder of this paper was organized as follows: Section 2 discussed the challenges to provide and design a protocol of mobility management. Section 3 focused on the classification criteria of existing mobility support protocols proposed for wireless networks, to select the best criteria which might be applied in 6LoWPAN Networks. Then, in Section 4, we presented our comparative study considering the limited constraints of 6LoWPAN Networks. Section 5 discussed the future directions to be considered for the design of a mobility support protocol in the 6LoWPAN Networks. Finally, in Section 6, we drew our conclusions and suggested some perspectives.

2. Mobility management, challenges and design issues

Mobility is the act of a node changing its attachment point due to the topology change. Before studying solutions dealing with mobility, we should understand its causes to be able to point out the appropriate challenge. In WSN based on 6LoWPAN technology, a topology change is caused by some reasons such as physical movement, failure of some routers, using aggressive sleep, radio channel conditions since the radio propagation is affected by any environmental change. Other possible reasons can be the network performances like the delay, the packet loss and the low signal [13].

The change of the attachment point requires the disconnection of the MNs. This disconnection causes significant problems of data loss and affects the proper functioning of applications. For these reasons, it is crucial to elaborate a mobility support protocol that tackles the encountered problems with mobility. The principal operations of this protocol follow some steps as shown in Fig. 1. The first step is the detection of the movement of nodes (or network). In the second step, the Mobile Node (MN) performs a new address configuration called Care of Address (CoA), and then performs the Duplicate Address Detection (DAD). The third step is the registration in the Home Agent, which is carried out by sending a Binding Update (BU) with the new address to the Home Agent. The final step is performed by the Home Agent (HA), which maintains the bond between the two addresses (HoA and CoA) after receiving the binding update. Then, it buffers and forwards traffic between the mobile node and its correspondent.

However, each operation can be performed in different ways depending on the network type requirements. Thus, it is interesting to clarify the requirements and specifications of our networks. Indeed, as we previously noted, WSNs based on 6LoWPAN technology provide the possibility to introduce IPv6 packets over the IEEE 802.15.4 to offer more advantages for the internet of things applications. Thus a problem of disproportion of IPv6 packets size (1280 bytes) compared to IEEE 802.15.4 frames size (127 bytes) is present [27,28]. To tackle this problem, the 6LoWPAN technology proposed an adaptation layer between the MAC and network layers. The main aim of this layer is to carry out two main functions: packet fragmentation/reassembly and header compression/decompression. Moreover, 6LoWPAN technology is based on the Neighbor Discovery concept to provide some tasks -with the help of RS/RA messages- such as interfaces auto-configuration, IPv6 address resolution, router availability checking and mapping between IPv6 and MAC addresses. In addition, this technology supports a stronger density than traditional WSNs [29]. Furthermore, the overall application performed in the Internet of Things with 6LoWPAN technology involves a strong mobility of nodes, which need more resources, and thus increases the risk of attack in the network and impacts the connectivity and the routing path.

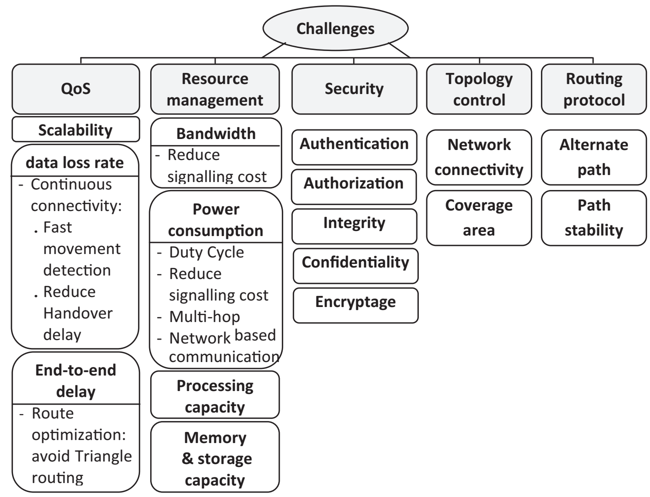

Fig. 2. Challenge of mobility management for WSNs based on 6LoWPAN.

On the one side, the concept of 6LoWPAN technology needs more overhead, memory and power consumption. And, on the other side, WSN devices are characterized by limited resources in terms of power, data rate, bandwidth, processing and storage capacities. The IEEE 802.15.4 standard enabled to reduce power consumption in WSNs using a periodic sleep/wake-up process [30]. Therefore, WSNs based on 6LoWPAN technology require more resources consumption than a traditional WSN or IPv6 Network.

Considering that the WSNs with 6LoWPAN technology imposes some delicate constraints and requirements [17], it has become urgent to discuss potential challenges to deal with these encountered problems as illustrated in Fig. 2.

In WSN with 6LoWPAN technology, the greatest challenge consists in providing a suitable "*Quality-of-Service*" (QoS) with different constraints consideration. For instance, mobility management must be efficient with an important density of nodes (i.e. ensure "*scalability*"). Moreover, mobility support protocol must mitigate the data loss rate. This problem occurs when the MN is disconnected during the handover process. Thus, it is important to reduce the handover delay in order to limit the disconnection time and ensure a continuous connectivity. Furthermore, after the handover process, mobility management must keep the same end-to-end delay as used before this process. Hence, in 6LoWPAN technology, protocol must avoid the triangle routing[1] (as illustrated in Fig. 3) which might enlarge the needed delay to communicate between the MN and its CN, as used in "*Hospital WSNs*" (HWSN6) [31–33], Inter-PAN [34,35] and "*Low Mobility*" (LoWMob) [36].

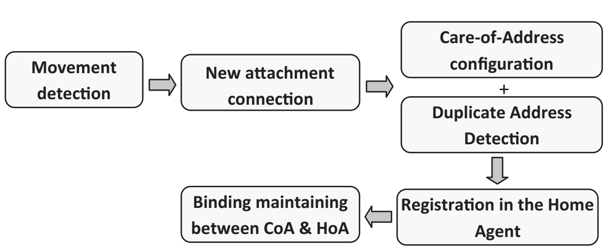

Fig. 1. Operations of mobility support protocol for mobile Networks.

[1] Communication between a MN and its CN: Packet from a CN is forwarded to the HA, then, to the Foreign Agent and finishes at the MN.