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Cost Analysis and Distributed Mobility Management of Sensor-Based PMIPv6 Networks

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***Abstract*: Due to limited resources, the slow progressive development of wireless sensor networks (Wireless Sensor Network) through the development of hardware and power management technology is currently in progress for the development of the latest IP-based IP-WSN. Those with low-power devices on IPv6 can mount the 6LoWPAN (IPv6 over Low power WPAN) this is getting attention. In these IP-based sensor networks, existing IP-based schemes, which were impossible in wireless sensor networks, become possible. 6LoWPAN is based on the IEEE 802.15.4 sensor network and is a technology developed for IPv6 support. The host-based mobility management scheme in IP-WSN is not suitable due to the additional signaling; the network-based mobility management scheme is suitable. In this paper, we propose an enhanced PMIPv6 route optimization, which considers the multi-6LoWPAN network environment. All SLMA (Sensor Local Mobility Anchor) of the domain 6LoWPAN is connected to the SPIG (Sensor Proxy Internetworking Gateway) and perform cross-domain distributed mobility control. All information of SLMA in the 6LoWPAN domain is maintained by SMAG (Sensor Mobile Access Gateway) and route optimization is performed quickly and the route optimization status information from SPIG is stored to SLMA and is supported without additional signaling.Then, we analyze the performance of our proposed scheme in terms of handover latency, handover blocking probability, and packet loss. Through the conducted numerical results, we summarize considerations for handover performance.**

Keywords*:** *Mobile Networks, Distributed Mobility Control, Proxy Mobile IPv6, Wireless Sensor Networks.**

I. Introduction

Wireless sensor networks (WSNs) are collection of autonomous sensors organized into a cooperative network. Each sensor consists of processing capability, may contain multiple types of memory, has a RF module, has a power sources. The WSN consists of node. The node is connected to one or several sensors and communicate wirelessly and often self-organize after being deployed in an ad-hoc fashion. Standardized IP-based 6LoWPAN [1] is IPv6 packets transmission technology at wireless sensor networks over the IEEE 802.15.4 Standard MAC and Physical layer. However, there are existing sensor networks in 6LoWPAN limited resources (low-power, limited storage space, a small packet size, and so on), which will present the same limitations, too. The current IP-WSN is a wireless sensor network and the integration of IPv6 technology is widely recognized as the global sensor network infrastructure and is applied to health care systems, surveillance systems and a variety of applications, such as real-time requirements. Therefore, fast and seamless handover supports are an important 6LoWPAN research issue.

To support mobility in the 6LoWPAN standard mobility protocol, MIPv6, [3] is that IETF 6LoWPAN WG [2] has been proposed, but did not consider the handover. Also, in order to support the Intra-PAN handover for the proposed LoWMo [4] to reduce delays in handover MN for the parent node by estimating the location after the move of the new parent node, information should be transferred to the preset. Mobility management is one of the most important research issues in 6LoWPAN, which is a standardized IP-based WSNs (IP-WSN) protocol.

In this paper, the SPMIPv6 (Sensor Proxy Mobile IPv6) [6] domain managed by SPIG (Sensor Proxy Internetworking Gateway) is separated to manage control between domains. SPMIPv6 domain managing SLMA (Local Mobility Anchor Sensor) and the cost of the SPIG domain is the sum of mobility costs within the existing simple distributed mobility of the PMIPv6 [5] domain. Therefore, our scheme shows the optimized distributed mobility control in the PMIPv6 domain. The rest of the paper is organized as follows. Chapter 2 reviews background data related to PMIPv6, 6LoWPAN and

SPIG. The proposed SPIG architecture, along with its mobility scenarios, sequence diagram and message formats are presented in Chapter 3. Chapter 4 describes performance analysis and evaluation, and finally Chapter 5 concludes the paper.

II. Related Works

A. PMIPv6

The main idea of PMIPv6 is that the mobile node is not involved in any IP layer mobility-related signaling. The Mobile Node is a conventional IP device (that is, it runs the standard protocol stack). The purpose of PMIPv6 is to provide mobility to IP devices without their involvement. This provision is achieved by relocating relevant functions for mobility management from the Mobile Node to the network. PMIPv6 provides mobility support within the PMIPv6 domain. While moving within the PMIPv6 domain, the Mobile Node keeps its IP address, and the network is in charge of tracking its location. PMIPv6 is based on Mobile IPv6 (MIPv6), reusing the Home Agent concept but defining nodes in the network, which must signal the changes in the location of a Mobile Node on its behalf.

Fig. 1 represents the PMIPv6 domain architecture. The functional entities in the PMIPv6 network architecture include the following:

- Mobile Access Gateway (MAG): This entity performs mobility-related signaling on behalf of the Mobile Nodes attached to its access links. The MAG is usually the access router for the Mobile Node, that is, the first-hop router in the Localized Mobility Management infrastructure.
- Local Mobility Anchor (LMA): This entity within the core network maintains a collection of routes for each Mobile Node connected to the LMD. The routes point to the MAGs managing the links where the Mobile Nodes are currently located. Packets sent or received to or from the Mobile Node are routed through tunnels between the LMA and the corresponding MAG.

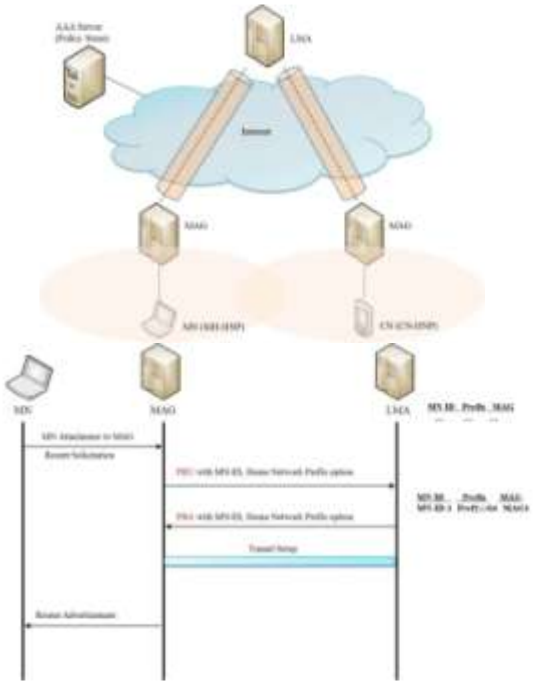

Figure 1. PMIPv6 Domain and Basic Operation

Fig. 1 shows PMIPv6 basic operation. That is as follows. When a Mobile Node enters a PMIPv6 domain, it attaches to an access link provided by a MAG. The MAG proceeds to identify the Mobile Node and checks if it is authorized to use the network-based mobility management service. If it is, The MAG performs mobility signaling on behalf of the Mobile Node. Also, the MAG sends a Proxy Binding Update (PBU) to the LMA associating its own address with the identity of the Mobile Node. Upon receiving this request, the LMA allocates a prefix to the Mobile Node. Then, the LMA sends a Proxy Binding Acknowledgment (PBA) to the MAG including the prefix allocated to the Mobile Node. It also creates a Binding Cache entry and establishes a bidirectional tunnel to the MAG. The MAG sends Router Advertisement messages to the Mobile Node, including the prefix allocated to the Mobile Node, so the Mobile Node can configure an address.

B. 6LoWPAN

The 6LoWPAN working group of the IETF has defined an adaptation layer for sending IPv6 packets over IEEE 802.15.4[7,8]. The goal of 6LoWPAN is to reduce the sizes of IPv6 packets in order to make them fit into 127 byte IEEE 802.15.4 frames. The 6LoWPAN proposal consists of a header compression scheme, a fragmentation scheme, and a method for framing IPv6 link local addresses into IEEE 802.15.4 networks. The proposal also specifies enhanced scalabilities and mobility of sensor networks. The challenge to 6LoWPAN lies in the sizable differences between an IPv6 network and an IEEE 802.15.4 network. The IPv6 network defines a maximum transmission unit as 1,280 bytes, whereas the IEEE 802.15.4 frame size is 127 octets. Therefore, the adaptation layer between the IP layer and the MAC layer must transport IPv6 packets over IEEE 802.15.4 links. The adaptation layer is responsible for fragmentation, reassembly, header compression and decompression, mesh routing, and addressing for packet delivery under the mesh topology. The

6LoWPAN protocol supports a scheme to compress the IPv6 header from 40 bytes to 2 bytes.

C. Sensor Mobility over 6LoWPAN

The network-based mobility management approach, PMIPv6, is more suitable than the host-based approach for supporting the mobility for 6LoWPAN since there are no mobility related signaling messages over the wireless link. Accordingly, the performance of the network-based mobility scheme in terms of energy consumption, signaling costs, and handoff latency can certainly be reduced compared to the host-based mobility scheme. However, the single-hop-based PMIPv6 protocol of the network-based mobility scheme cannot be applied to the multi-hop-based 6LoWPAN.

D. SPMIPv6

To introduce an efficient addressing and routing scheme in our proposed global IP-WSN, we use sensor proxy mobile IPv6 (SPMIPv6) architecture. Fig.3 shows the proposed architecture. That has different functional components. The architecture mainly consists of a sensor network-based localized mobility anchor (SLMA). It also contains a sensor network-based mobile access gateway (SMAG). For end-to-end communications, it contains many full functional devices (FFDs) and reduced functional devices (RFDs).

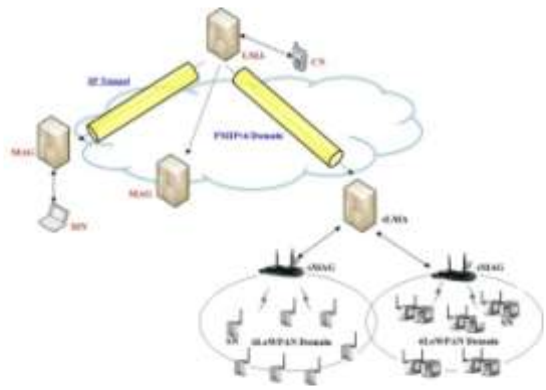

Figure2. Sensor Mobility over 6LoWPAN

III. Proposed SPIG Scheme

The SLMA acts as a topological anchor point for the entire IP-WSN domain. The main role of the SLMA is to maintain accessibility to the sensor node while the node moves in or outside the IP-WSN domain. The SLMA includes a binding cache entry for each sensor node, both encapsulation and decapsulation sections and a SMAG information table. The binding cache entry at the SLMA is used for holding the information of the mobile sensor node. It includes different information such as the sensor node's address, the sensor node's home network prefix, and a flag bit indicating sensor proxy registration. It also acts as the interfacing device between the IP-WSN domain and the Internet domain.

The SMAG acts like a sink node in a traditional sensor network. With regards to the proposed IP-WSN based on SPMIPv6 it acts like an access gateway router with the main function of detecting sensor node movement and initiating mobility-related signaling with the sensor node's SLMA on behalf of the sensor node. It can move with its member sensor node as a SMAG domain within or outside an IP-WSN domain similar to the body sensor network of a patient. It consists of different functional modules such as routing, neighbor discovery, sensor information table, adaptation module and interfacing modules to the sensor node and border router. The routing module performs efficient data transmission among individual sensor nodes and facilitates the end to end communication. The neighbor discovery module performs neighbor discovery and duplicate address detection functionality. The adaptation module performs the task of transmitting IPv6 packets over IEEE 802.15.4 link as mentioned in the 6LoWPAN adaptation layer. The sensor information table provides the up to date information about the sensor nodes to the SLMA.

The IP-WSN domain is comprised of numerous sensor nodes based on IPv6 addresses. We consider the domain as a federated IP sensor domain. There are two types of sensor nodes. One type contains the tiny TCP/IP communication protocol stack with an adaptation layer and an IEEE 802.15.4 interface. This type can forward information to other nodes of similar type as well as information sensing from the environment. Actually, this type of sensor node acts as a mini sensor router and is considered a fully functional device. The other type of sensor node has the protocol stack and environment sensing capability, but can only forward the sensed information to nearby mini sensor router nodes. These types of sensor nodes are considered reduced functional devices. Nevertheless, both types are able to perform end to end communication.

A. SPIG Architecture

Fig. 4 shows the architecture of SPIG including SPIG, SLMA, SMAG and IP sensor node. The SPIG acts as a topological anchor point for the entire SPMIPv6 domain. The main role of the SPIG is to maintain accessibility to the sensor node while the node moves in or out of the SPMIPv6 domain. The SPIG includes a binding cache entry for each sensor node, encapsulation and decapsulation sections and a SLMA information table. The binding cache entry at the SPIG is used for holding the information of the mobile sensor node.

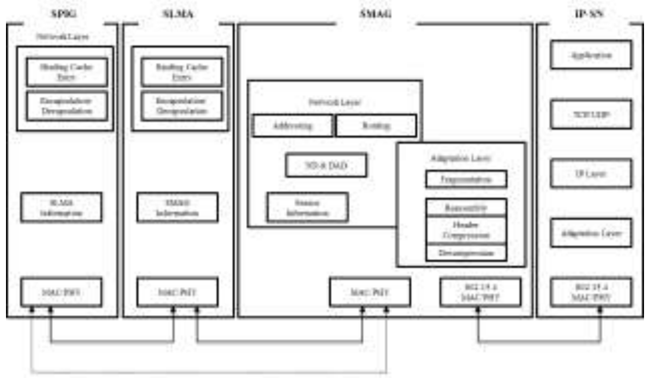

Figure3. Operation Architecture of SPIG

B. SPIG Message Flow

Fig.5 shows message flow in SPIG architecture. All data transfers flow through the SPIG. In the packet delivery, the control operation for the binding query is separated from the data packet delivery. The data passed from CN to IP-WSN includes several stages. First, IP-WSN acquires access to the network and sends a Router Solicitation message to the SMAG. Second, the RS message is received within the SMAG and then the SMAG saves IP-SN information and sends the PBU message to the SLMA. Third, the LBU and LBA message is sent to the SLMA. Fourth, The SLMA will send PBA messages. Fifth, the PBA message received by SMAG was sent to the RA command IP-SN. And then IP-SN can respond CN request. CN is the PMIPv6 network for MAG and LMA, SPIG acquires the information from the IP-SN, and then you may be able to submit data through the SMAG.

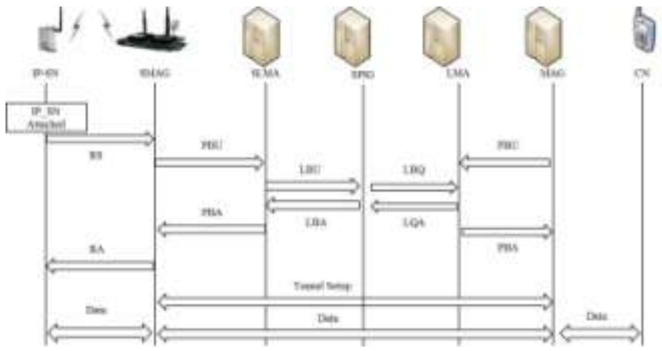

Figure4. SPIG Message Flow

IV. Performance Analysis

A. Network mobility model

Mobility of the IP-sensor node and the SMAG domain network are the major advantages of IP-WSN over the static wireless sensor networks. In this paper, mobility is the key concern in the design and performance analysis of the SPIG. Most wireless network performance studies assume that the coverage areas are configured as a hexagonal or square shape. We assume that IP-WSN networks are to be configured with a square topology. Sensor nodes for an IP-WSN area are assumed to have identical movement patterns within and across IP-WSN. A 2D square shaped random walk mobility model can be used to study the movement pattern of the movable sensor nodes. In this paper, we used a network model subject to some modification for the five-layer personal area network model, with n = 5. In our network model, an IP-WSN consists of a cluster of 2D square shaped sensor nodes, as shown in Fig. 6. Each macro-cell covers n × n micro-cells (n = 5). Each macro-cell coverage area is one location area (LA). Firstly, we can aggregate the states of cells based on their symmetrical positions. Cells belonging to such an aggregated state have the same properties. There are six aggregated states for the 5 × 5 square shaped micro-cell/macro-cells. The corner states (S11, S15, S51 and S55) are grouped into state S1. State S2 consists of (S12, S14, S21, S25, S41, S45, S52 and S54), state S3 consists of (S13, S31, S35 and S53), state S4 consists of (S22, S24, S42 and S44), state S5 consists of (S23, S32, S34 and S43), and state 6 consists of S33. In this figure, aggregate states S1, S2 and S3 are the boundary states. We define asterisk boundary states, S1*, S2* and S3*, which are in the LAs adjacent to the LA under consideration. Fig. 7 also demonstrates the state transition diagram for the Markov chain. Movement into any boundary state indicates inter-IP-WSN mobility, which can be used to study binding update costs[9].

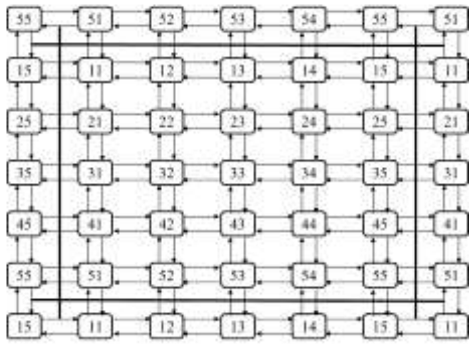

Figure5. Square shaped cell layout of a five-sublayer

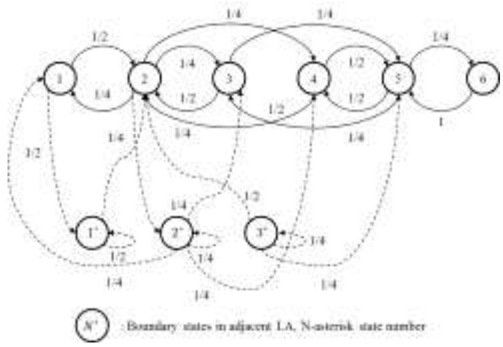

Figure6. State transition diagram for a 5 × 5 square cell model

The state transition diagrams in Fig. 7 demonstrates that there are no transient sets in the model but only a single ergodic set with only one cyclic class, hence the regular Markov chain properties can be applied to analyze the behavior of the proposed model. As long as the SN moves within cells in a location area, SN is in one of the main aggregate state. Let *P* be the regular transition probability matrix, then the steady state probability vector π can be solved by the following equations:

$$\pi P = \pi \ and \ \sum_{i=1}^{m} \pi_i = 1 \tag{1}$$

Where m is the number of states *P*, the fundamental matrix for the regular Markov chain is given by:

$$Z = \left[Z_{ij} \right] = (I - P + A)^{-1} \tag{2}$$

Where *A* is the limiting matrix determined by *P*, and the powers *Pn* approach the probability matrix *A*. Each row of *A* comprises the same probability vector $\pi = \{\pi_1, \pi_2, \ldots, \pi_n\}$, i.e. $A = \xi\pi$, where ξ is column vector with all entries equal to 1. *I* mean the identity matrix. The matrix *Z* can be used to study the behavior of the regular Markov chain and through the use of this matrix one can compute the mean number of times the process is in a particular state. Let $y_j^{(k)}$ be the number of times that a process is in the state S_j in the first *k* steps, then if $M_i\left[y_j^{(k)}\right]$ is the mean number of times the process is in the state S_j starting from the state S_i is given by:

$$M_i\left[y_j^{(k)}\right] \rightarrow \left(Z_{ij} - \pi_j\right) + k\pi_j \quad (3)$$

The total number of boundary updates in *k* steps starting from state S_i can be computed by the total number of times that the process is in the asterisk states (for e.g. 1*, 2* and 3* in Fig.7) starting from state S_i – the initial state. Hence, if U_{A_LA} is the average number of location updates in the analytical model, this is given by:

$$U_{A\_LA} = M_i\left[y_{1*}{}^{(k)}\right] + M_i\left[y_{2*}{}^{(k)}\right] + M_i\left[y_{3*}{}^{(k)}\right] \quad (4)$$

Generalizing,

$$U_{A\_LA} = \sum_{n=1*}^{N*} M_i\left[y_n{}^{(k)}\right] \quad (5)$$

Where 1*, 2* ….N* are the asterisk states in the model. The geometric random variable arises when we count the number *M* for the independent Bernoulli trials until the first occurrence of a success. *M* is called the geometric random variable and it takes on values from the set {1,2, ...}. We found that the *pmf* of *M* is given where $p = P[A]$ as the probability of "success" in each Bernoulli trial. Note that $P[M = k]$ decays geometrically with *k*, and that the ratio of consecutive terms is $\frac{P_{M(k+1)}}{P_{M(k)}} = (1 - p) = q$. As *p* increases, the *pmf* decays more rapidly.

If $M \le k$ can be written,

$$P[M \le k] = \sum_{j=1}^{k} pq^{j-1} = p\sum_{j=0}^{k-1} q^j = p\frac{1-q^k}{1-q} = 1 - q^k \quad (6)$$

From the above expression, we can obtain intra-mobility cost.

$$M_{intra-IP-WSN} = 1 - (1 - \frac{1}{U_{bu}})^k \quad (7)$$

If we get intra-mobility cost, also we get inter-mobility cost. Inter-mobility cost is intra-mobility cost and inter-domain binding update cost.

$$M_{inter-IP-WSN} = 1 - (1 - \frac{1}{U_{bu}})^k \times \frac{1}{U_{bu}} \quad (8)$$

B. Cost Analysis

Fig. 8 shows SPIG architecture over SPMIPv6. SPMIPv6 structure combine intra-Domain Mobility control model and inter-Domain mobility control model. SPMIPv6 of all domains are combined with SPIG, and SPMIPv6 domains oversee the SLMA and are composed of SMAG. Global mobility can control through SPIG.

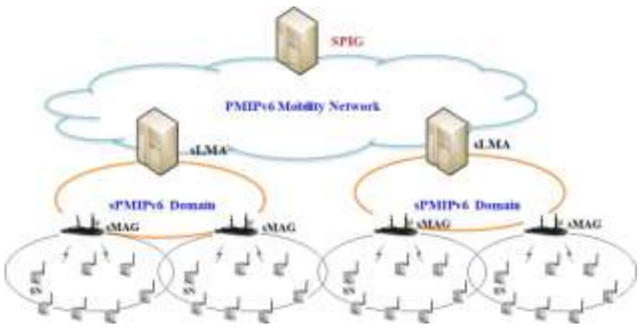

Figure7. SPIG over SPMIPv6

The total cost of IP-WSN in internal move costs and the signaling of IP-WSN are available as the sum of an inter-domain move. Table 1 explains the symbols used.

The PMIP inter-domain binding update operation is done as follows. When IP-SN enters a new SMAG region, IP-SN is in the Router Solicitation SMAG messages. Following this, the IP-SN of the SMAG is the PBU and the PBA control messages, which can be exchanged in the SLMA, and then the SLMA sends a message to IP-SN in the Router Advertisement. As a result, the cost of updating the cross-binding domain of the PMIP can express the following:

$$BUC_{PMIP} = M_{inter-IP-WSN} + S_{CONTROL} \times 2T_{SMAG-SLMA} + P_{SLMA} \quad (9)$$

Thus, the packet delivery cost from CN to IP-SN can be calculated as follows. First, a data packet of CN is passed to the MAG. Then the MAG of CN and LMA exchange PBQ and PQA messages, and then the MAG receives a CoA from IP-SN. The MAG of CN delivers data packets in LMA. LMA of CN is LBQ and LQA messages sent to the SLMA. LMA of CN is delivers packets of data to the SMAG of IP-SN. SLMA of IP-SN delivers packets to the SMAG of IP-SN. Finally, the SMAG of IP-SN delivers data packets to IP-SN. The cost regarding the inter-domain for the PMIP packet forwarding is as follows:

$$\begin{aligned} PDC_{PMIP} = \; & S_{DATA} \times (T_{CN-MAG} + T_{MAG-LMA} + T_{LMA-SLMA} \\ & T_{SLMA-SMAG} + T_{SMAG-SN}) \\ & + S_{CONTROL} \times (2T_{MAG-LMA} + 2T_{LMA-SLMA}) \\ & + P_{LMA} + P_{SLMA} \end{aligned} \quad (10)$$

So, we obtain the total cost of PMIP as follow:

$$TC_{PMIP} = BUC_{PMIP} + PDC_{PMIP} \quad (11)$$

The SPMIPv6 Inter-domain binding update operation is done as follows. When IP-SN enters a new SMAG region, IP-SN is in the Router Solicitation SMAG messages. Following this, the IP-SN of the SMAG is the PBU and the PBA control messages, which can be exchanged in the SLMA, and then the SLMA sends a Router Advertisement message to the IP-SN. As a result, the cost of updating the cross-binding domain of the SPMIP is as follows:

$$BUC_{SPMIP} = M_{inter-IP-WSN} + S_{CONTROL} \times 2T_{SMAG-SLMA} + P_{SLMA} \quad (12)$$

Thus, the packet delivery cost from CN to IP-SN can be calculated as follows. First, a data packet of CN is passed to the MAG. Then the MAG of CN and LMA exchange PBQ and PQA messages, and then the MAG receives a CoA from IP-SN. The MAG of CN delivers data packets in LMA. LMA of CN is LBQ and LQA messages sent to SLMA. LMA of CN delivers packets of data to the SMAG of IP-SN. Finally, the SMAG of IP-SN delivers data packets to IP-SN. The cost regarding the inter-domain of the SPMIP packet forwarding is as follows:

$$\begin{aligned} PDC_{SPMIP} = {} & S_{DATA} \times (T_{CN-MAG} + T_{MAG-LMA} + T_{LMA-SMAG} \\ & + T_{SMAG-SN}) \\ & + S_{CONTROL} \times (2T_{MAG-LMA} + 2T_{LMA-SLMA}) \\ & + P_{LMA} + P_{SLMA} \end{aligned} \quad (13)$$

So, we obtain the total cost of SPMIP as follow:

$$TC_{SPMIP} = BUC_{SPMIP} + PDC_{SPMIP} \quad (14)$$

The SPIG inter-domain binding update operation is done as follows. When IP-SN enters a new SMAG area, IP-SN is in the Router Solicitation SMAG messages. Following this, the IP-SN of SMAG is the PBU and the PBA control messages, which can be exchanged in the SLMA, and then the SLMA sends a Router Advertisement message to the IP-SN. The SLMA send LBU message to SPIG, and then SLMA can update SPIG latest information. SPIG is the LBA control messages sent to the SLMA. As a result, the cost of updating the cross-binding domain of the SPIG is as follows:

$$BUC_{SPIG} = M_{inter-IP-WSN} + S_{CONTROL} \times 2T_{SMAG-SLMA} + P_{SLMA} \quad (15)$$

The packet delivery cost from CN to IP-SN can be calculated as follows. First, a data packet from CN is passed to the MAG. The MAG of CN and the LMA of CN exchange PBQ and PQA messages. The LMA of CN receives IP-SN information of the SLMA from SPIG. SPIG sends an LQA message to the LMA of CN then the LMA of CN receives the SLMA of IP-SN information. The MAG of CN sends a PBQ message to the SLMA of IP-SN. Then, the SLMA of IP-SN sends a PQA message to the MAG of CN. The MAG of CN is as a data packet should pass IP-SN of SMAG. Finally, IP-SN as the IP-SN of the SMAG delivers data packets. SPMIPv6 the cost of packet forwarding cross-domain as follows:

$$\begin{aligned} PDC_{SPIG} = {} & S_{DATA} \times (T_{CN-MAG} + T_{MAG-SMAG} + T_{SMAG-SN}) \\ & + S_{CONTROL} \times (2T_{MAG-LMA} + 2T_{LMA-SPIG}) \\ & + P_{LMA} + P_{SLMA} \end{aligned} \quad (16)$$

So, we obtain the total cost of SPIG as follow:

$$TC_{SPIG} = BUC_{SPIG} + PDC_{SPIG} \quad (17)$$

C. Handover Blocking Probability

In order to analyze the handover failure for each proposed scheme, the handover blocking probability presented in [10], [11], [12] is used here. The handover for an IP-SN (IP Sensor Node) can fail for several reasons such as unacceptably high handover latency, signal-to-noise deterioration, unavailable wireless channel resource, etc. Suppose $L_{HO}^{(\cdot)}$ denotes the handover latency for a specific mobility management protocol developed in the previous subsections. Note $\cdot$ is used as a protocol indicator. Let $E\left[L_{HO}^{(\cdot)}\right]$ be the mean value of $L_{HO}^{(\cdot)}$. Suppose T_R is the residence time in the network with its probability densityfunction $f_R(t)$. For the sake of simplicity, $L_{HO}^{(\cdot)}$ is also assumed to be exponentially distributed with the cumulative function $F_T^{(\cdot)}(t)$ .Then, assuming that $L_{HO}^{(\cdot)}$ is the only handover blocking factor, the handover blocking probability p_b is expressed as follows:

$$\begin{aligned} p_b &= P_\gamma\left(L_{HO}^{(\cdot)}\right) > T_R \\ &= \int_0^\infty \left(1 - F_T^{(\cdot)}(u)\, f_R(u)\, du\right) \\ &= \frac{\mu_c E\left[L_{HO}^{(\cdot)}\right]}{1 + \mu_c E\left[L_{HO}^{(\cdot)}\right]} \end{aligned} \quad (18)$$

where μ_c is the border crossing rate for the IP-SN. Assuming that the sLMA's coverage area is circular, then μ_c is calculated as follows [13], [14], [15]:

$$\mu_c = \frac{2\upsilon}{\pi R} \quad (19)$$

where υ is the average velocity of the IP-SN and R is the radius of the sLMA's coverage area.

D. Packet Loss

While an IP-WSN experiences its handover, data packets destined for the IP-SN will be lost if any buffer management at network sides does not exist. The amount of packet loss $\varphi_p^{(\cdot)}$ during a handover is defined as the sum of all lost data packets sent from a CN of the IP-SN. Then it is expressed as follows:

$$\varphi_p^{(\cdot)} = \lambda_S E(S) L_{HO}^{(\cdot)} \quad (20)$$

where λ_S is the average session arrival rate at the IP-WSN's wireless interface and $E(S)$ is the average session length in packets. As presented upper, $\varphi_p^{(\cdot)}$ is directly proportionate to $L_{HO}^{(\cdot)}$.

E. Numerical Analysis Results and Discussions

Fig. 9 shows the cost with respect to the number of nodes in the IP-WSN in term of the PMIPv6, SPMIPv6 and SPIG. PMIPv6 and SPMIPv6 compared with SPIG showed to be more cost effective.

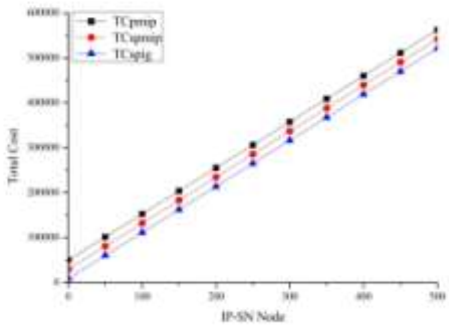

Figure8. Number of IP-WSN Node

Fig. 10 is the hop count to reach the destination nodes according to the cost analysis number. The maximum hop count is 15. The increase in the number of hop count cost in accordance with the methodology proposed increased linearly and SPMIPv6 compared to PMIPv6 demonstrated good performance.

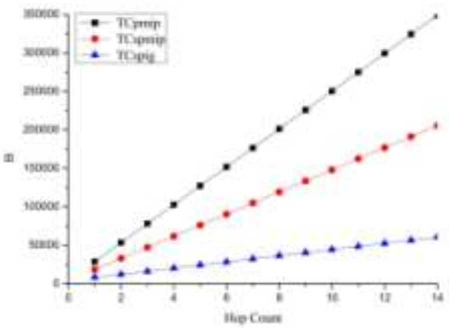

Figure9. Number of Hop Count

Fig. 11 and Fig. 12 are the binding updates and show the sum of the cost lookup behavior. All techniques shown in the picture are almost unaffected. This is the total cost of the binding update and lookup behavior is an important, you might find that does not affect.

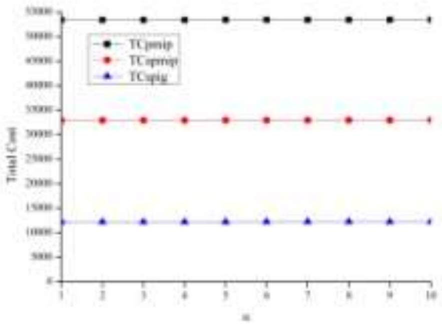

Figure10. Cost Analysis as Binding Update

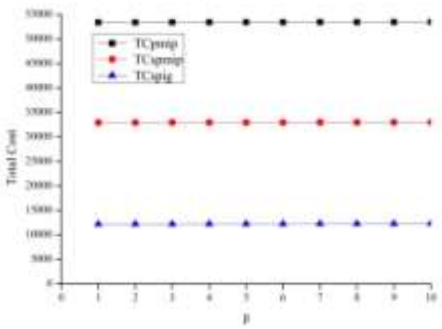

Figure11. Cost Analysis as Lookup

Fig. 13 is the number of hosts contained in the MAG, and the total cost of the analysis. As shown in comparison to host MAG count, almost all the schemes do not affect.

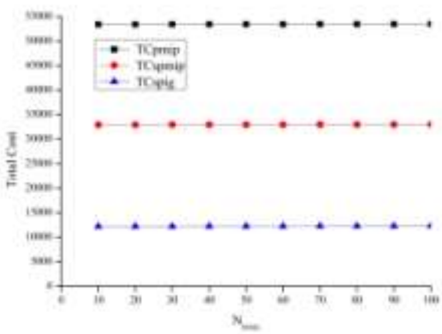

Figure12. Number of MAG vs. Total Cost

Looking at all of the results of the analysis, the expansion of the existing domain distributed mobility control, and apply the techniques suggested in this paper than the techniques in the analysis showed that the performance of all cost effective. In particular, signal distributed control technique SPIG full figured most effectively in terms of cost.

Also, We analyze and compare in terms of handover latency, handover blocking probability, and packet loss in our proposed scheme. Let p_f varies from 0 to 0.7 with a step value of 0.05. Fig.13 shows the handover latency against p_f. A higher value of p_f increases the probability of the erroneous packet transmission over the wireless link. Accordingly, the number of mobility signaling retransmissions is increased and results in increased handover latency. In order words, as presented in Fig. 13, the handover latency for each proposed scheme is relative to p_f .

The value of D_{wl} also contributes the handover latency. For instance, the handover latency is dramatically increased as the value of p_f is increased with a higher value of D_{wl} . An IP-SN in PMIPv6 is locally managed and mobility signaling is exchanged by the sLMA and sMAG. It means that mobility signaling over the wireless is not occurred so that the effects of p_f and D_{wl} are minimized in the performance of SPIG.

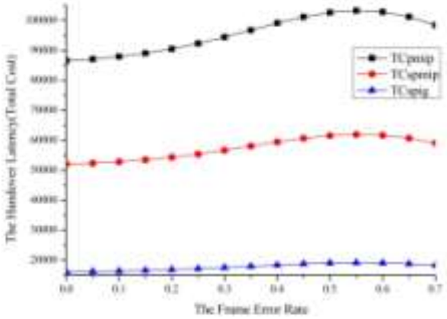

Figure 13. Handover Latency versus p_f with D_{wl} = 10 ms

Here, υ and R are set as 20 m/s and 500 m, respectively. Then, D_{wl} is fixed as 10 ms, while p_f is varied from 0 to 0.7 with a step value of 0.05. Fig. 14 shows the handover blocking probability for each proposed scheme. Recall that the conducted analysis for handover blocking probability only considers the handover latency as a blocking factor. Similar to the results presented in Fig. 13, the handover blocking probability is increased as the value of p_f is increased. Now, p_f and R are set as 0.2 and 500 m. Then, υ is varied from 0 to 30 m/s. Fig.14 shows the handover blocking probability against υ . As υ is increasing, the IP-SN quickly changes its point of attachments. It means that the IP-SN with the high value of υ is required to complete its handover in a shorter time than the IP-SN with the low value of υ . Accordingly, as the value of υ is increased, the handover blocking probability for each proposed scheme is also increased. In the given analysis environment, only SPIG provide good performance in terms of the handover blocking probability that is less than 0.05 even if υ is increased until 30 m/s. As shown in Fig.14, most of proposed scheme is under the influence of R.

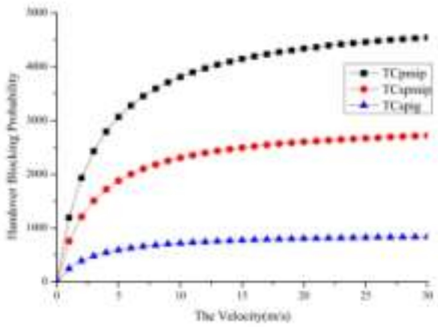

Figure 14. Handover Blocking Probability versus p_f

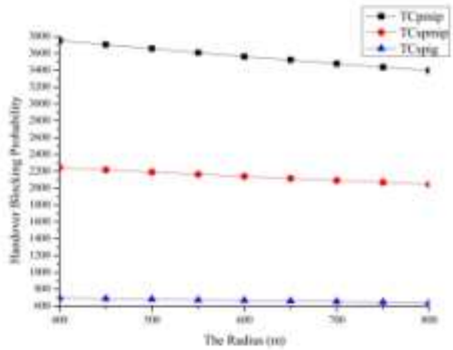

Figure 15. Handover Blocking Probability versus R

Without any buffering mechanism, data packets sent from the CN to the IP-SN will be lost while the IP-SN performs its handover. Fig. 16 demonstrate the packet loss during a handover. Here, λ_s and E(S) are set as 1 and 10, respectively. Then, p_f is varied from 0 to 0.7 with different values of D_{wl} In Fig. 16, D_{wl} is set as 10 ms. According to the results presented in Fig.16, it is seen that p_f with the higher value of D_{wl} has more impact of packet loss.

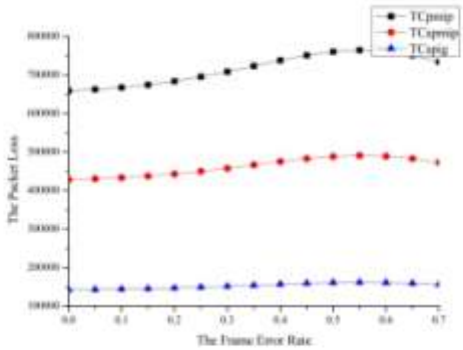

Figure 16. Packet Loss versus p_f with D_{wl} = 40 ms

V. Conclusions

In this paper we proposed new scheme SPIG. SPIG was proposed in order to resolve the issue regarding IP-SN hand-over excessive signal transport problems and delays, recent 6LoWPAN within a domain, for efficient data processing and distributed control study. This paper discusses recent research in the PMIPv6 domain regarding the mobility of IP-SN and the SPMIPv6 techniques presented in this paper are applied rather than a separate hand-over procedure, even if they are not for LMA and SLMA information is included in the SPIG has continuous network. If you look at the cost side, by the analysis of the existing SPMIPv6 techniques using distributed control techniques than SPIG performance will prove to be excellent. We have been analyzed and compared in terms of handover latency, handover blocking probability and packet loss. From the conducted analysis results, PMIPv6 and SPMIPv6 show poor handover performance, but SPIG shows good handover performance.

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