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Hybrid Mobile Ad hoc Network support for Proxy Mobile IPv6

Hun-Jung Lim, Seon-Ho Park, Young-Ju Han and Tai-Myoung Chung

Abstract— **Supporting for mobile node communications, lots of technologies are researched. They are categorized as infrastructure and infrastructureless : Mobile IP and ad hoc network. Basically, the ad hoc technology is able to the mobile nodes data exchanging within closed group communication. However due to the desire of open network connectivity, the ad hoc networks researches are extended to Internet connective ad hoc networks technology. Existing researches are usually focused on the Internet connective ad hoc with mobile node based mobility support mechanism. On the contrary, the network based mobility support mechanisms with Internet connective ad hoc are rarely researched. In our paper, we will describe problems to Internet connective ad hoc network based on network based mobility support mechanisms. Then, we show the solution using ad hoc network prefix information.**

***Index Terms*—Ad hoc network, Hybrid MANET, MANET_ID, Proxy Mobile IPv6**

I. Introduction

Nowadays, mobile node(MN)s are getting smaller and wireless communication technologies are getting enhanced. Users could work through the service domains without connection interruption. Furthermore, the desire to exchange data in an infrastructureless place is getting stronger for extending radius of movement. A number of technologies have been suggested for supporting network layer mobility. Those technologies can generally be categorized into two parts: infrastructure-based and infrastructureless-based. The infrastructure based technologies focuses on MN's mobility support mechanism. In this mechanism, the MN or the network tracks MN's IP address when the MN performs handoff across domains and also maintains MN's network layer connectivity. According to IP address maintainer, the infrastructure based technologies divide into two parts again: MN based and network based. For a long time, the MN based mobility support mechanism has been researched in the IETF MEXT and MIP4 working group named Mobile IP. They are described in [1], [2] and [3]. Recently, the network based mobility support mechanism has come to the forefront as a mobility support mechanism due to its characteristics and advantages. The IETF NETLMM working group has researched and developed a number of suggestions which is named Proxy Mobile IPv6 (PMIPv6). They are described in [4] and [5]. Whether use the MN based or the network based mechanism, these mechanisms achieve the MN's mobility with infrastructure support. In the Infrastructureless part, the IETF AUTOCONF and MANET working group have researched for IP address allocation and packet routing. They are described in [6] and [7]. By those researches progress, MN could exchange data within a closed group in infrastrutureless place. Nowadays, the researchers begin to study for the next level of the mobile ad hoc networks (MANET) technology. One of the technologies is Internet connective MANET (Hybrid MANET) that overcomes the closed communication restriction. [8] is one of the Hybrid MANET mechanism by perkins. However, to the best of our knowledge, the Hybrid MANET mechanisms are tested and studied on Mobile IP. The question of the PMIPv6 special operations for Hybrid MANET remains unsettled. The PMIPv6 special operations are that the networks hide MN's domain movement detection, remove additional mobility stacks and remove the signaling of MN. However, these operations also bring serious network disconnection problem when adapt to the normal Hybrid MANET mechanism.

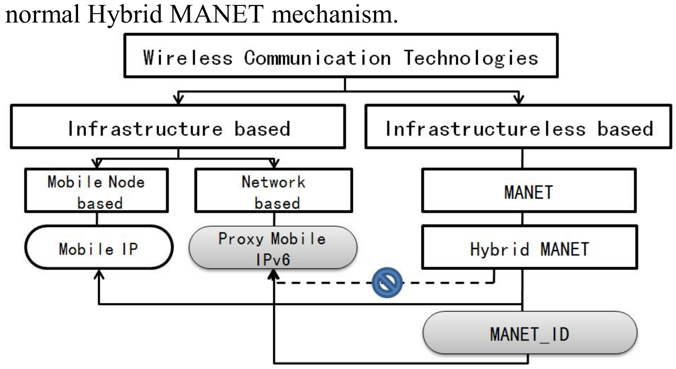

Fig. 1. Wireless communication technologies category and relative works.

Figure [1] presents the category and relative works. In our paper, we describe adaptation problems and suggest the solution using authors' earlier research MANET_ID [9]. The rest of this paper is organized as follows, In Section 2, we describe background information for reader understating: Proxy Mobile IPv6 and MANET_ID. In Section 3, we present the problems of the Proxy Mobile IPv6 adapted Hybrid MANET mechanism. In Section 4, we show you how our suggested MANET_ID could solve the Section 3 problems.

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The final section gives our conclusions.

II. RELATED WORKS

A. Proxy Mobile IPv6

The existing MN based mobility support mechanism requires additional stacks and signaling for the MN. This could bring overhead such as battery power and computation resource consumption. Network based mobility support mechanism is another approach to solve the problems and support the IP mobility. This is a kind of extended version of Mobile IPv6 [10] and Hierarchal Mobile IPv6 [11]. In the network based mobility support mechanism, MN does not need to install additional stacks and exchange signals. A special mobility agent in the network performs the signaling and does the mobility management on behalf of the MN. The IETF NETLMM working Group has researching under proxy mobile IPv6. There are two main components for the proxy mobile IPv6, a Local Mobility Anchor (LMA) and a Mobile Access Gateway (MAG).

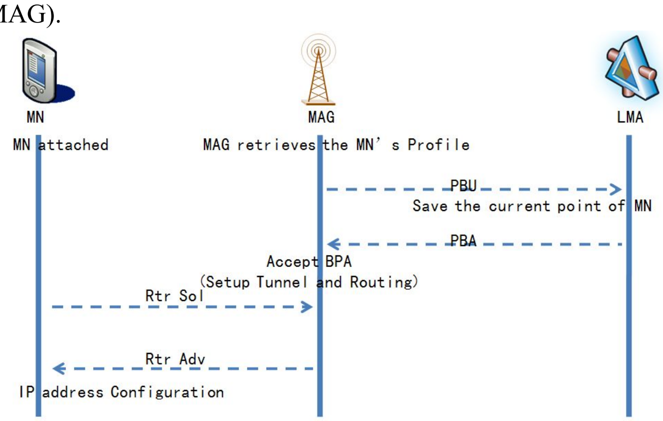

Fig. 2. The basic operation of the Proxy Mobile IPv6.

Figure [2] presents the operation and message flow of the PMIPv6 [12]. The PMIPv6 protocol operation consists of four phases. In the first phase, MAG retrieves the MN's profile using its current identifier. The Binding Update (BU) is the second phase, in which the MAG will send a Proxy BU request to the LMA in order to register the current point of attachment of the MN. Accordingly, a binding cache entry and a tunnel for the MN's home prefix will be created. The third phase will be the MAG emulating the mobile node's home interface on the access interface. Therefore, the MN will always believe it is in the home network. Fourthly, the LMA reply Proxy Bind Acknowledge (PBA) message with the MN's HNP. After receiving the Router Advertise (RA) message, the MN creates its IP address. For packet routing, the LMA will route all received packets over the established tunnel to the MAG. The MAG forwards these packets to the MN. Certainly, the MAG will relay all the received packets over the tunnel to the LMA and then they will be routed towards the CN.

B. MANET_ID

Generally, MANET does not have a access router which broadcast a router advertisement (RA) message for IP address creation. Due to the unusual HNP obtain mechanism, a fundamental rule of network prefixes is not guaranteed: A fixed value and the representation of the network identifier [13]. In our previous work, we propose a MANET identifier (MANET_ID) that could distinguish its network with a fixed value [9]. For the fixed and shared MANET_ID among the MNs, We have designed two main algorithms: MANET_ID creation & negotiation phase.

For the creation phase : When the MN boot up, the MN uses a Neighbor Discovery Protocol (NDP) to detect any existing MNs. NDP transmits a "HELLO" beacon at regular intervals. If no beacon has been received within a specified time, the MN realizes there are no other MNs near its radio range [14]. Then the MN becomes a seed-MN and progresses to the MANET_ID creation phase. The seed-MN uses its MAC address and a timestamp to create the MANET_ID. After create the MANET_ID, the MN set a flag as 'C'. There are three levels of flags: C for creation, N for negotiation and F for fix the MANET_ID.

MANET_ID= {seed-MN's MAC address + timestamp}

For the negotiation phase: Each MN periodically sends MANET_ID advertise (MA) messages to inform of its MANET_ID. When the MN receives MA, the MN compares a flag and the MANET_ID. Then the MN changes its MANET_ID into higher flag level's MANET_ID or numerically larger MANET_ID. Finally, every MN in the same network shares the largest MANET_ID.

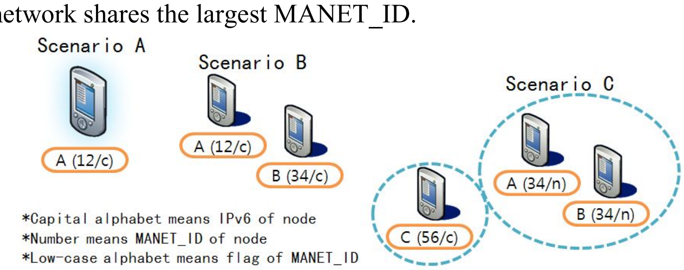

Fig. 3. The basic MANET_IDcreation and negotiation phase.

Figure [3] describes the basic MANET_ID creation and negotiation phase.

In Scenario A, the MN_A boot up and realizes there is no neighbor MNs. Then the MN_A becomes a seed-MN and creates a MANET_ID-12 with a c-flag. MNs or seed-MNs broadcast MA messages periodically to inform of its MANET_ID.

In Scenario B, the MN_A connects to the MN_B. By exchanging MA messages, the MN_A finds that the MN_B has the same flag level 'c'. However, the MN-B's MANET_ID is numerically larger than MN_A's MANET_ID. Then, MN_A changes its MANET_ID into the MANET_ID-34 and its flag into 'n'. Also, MN_B changes its flag into 'n' but MN_B does not need to change its MANET_ID. At this point, MN_A and MN_B are logically connected by MANET_ID-34.

In Scenario C, a new MN_C approaches to the MANET_ID-34 network. MN_C receives the MN_A's or MN_B's MA messages. MN_C realizes it has a lower level of flag. Even though the MN_C has a numerically larger MANET_ID, it changes its MANET_ID into the higher flag MANET' s MANET_ID. Also, it changes its flag level into 'n'.

After negotiation phase, every connected MN has the MANET_ID-34. This shared value used for network distinguisher.

III. PROBLEM STATEMENT

As we describe in the introduction Section, the PMIPv6 has special operations to hide MN's movement detection and to remove mobility signaling. However, these operations also have network layer disconnection problem when adapt to Hybrid MANET. The follow three PMIPv6 features cause the problems.

-- Link-layer connection: Network recognizes MN's identifier by Link-layer signaling.

-- Per-MN-Prefix model: The MN has own unique home network prefix for a management reason.

-- Tunneling: MAG forwards In-and-Out tunnel packets according to its own Binding Update List

A. *Case 1: Link-Layer connection*

In the PMIPv6 mechanism, the MAG needs the MN's MN_ID to allocate HNP of the MN. The MN_ID is transmitted to MAG using link-layer communications. In other word, PMIPv6 requires that every attached MN and MAG have direct link-layer connection. However in the Hybrid MANET, a sender and a receiver is not always connected in the link-layer. They could establish a multi-hop for the connection.

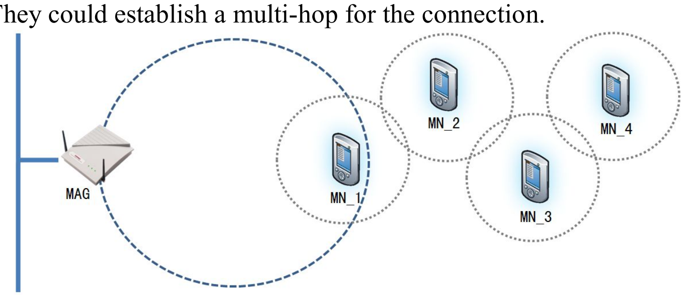

Fig. 4. The Proxy Mobile IPv6 link-layer connection.

Figure [4] describes that the MANET enters a PMIPv6 domain. MN_1 belongs to MAG's radio range and could exchange MN_ID using link-layer communication. Though, MN_2 and MN_3 are connected with the MAG in a multi-hop connection, the MAG could not detect and receive their MN_IDs. Eventually, MN_2 and MN_3 could not obtain a HNP and could not create global IP address. When the MN_1 roles a Internet gateway (IG) of Hybrid MANET technology, this problem could be solved.

B. *Case 2: Per-MN-Prefix model*

One of the PMIPv6 features is that the network could hide the MN's movement by advertising the same HNP wherever the MN attached. For this management reason, LMA maintains MN_ID and HNP mapping table in a special entity such as an AAA server or LMA it-self. By this Per-MN-Prefix model, even the MNs are belonging to the same network, they receive different HNP according to their MN_ID. The problem is the IG's operation in the Hybrid MANET. By the basic I.G operations, the IG-MN receive a RA message from the MAG and broadcast the RA message, named IG advertisement message, to the sub-ad hoc nodes. This conflict brings two main problems. First, except IG, every MN allocates its global IP address not using its MN_ID mapping HNP but using IG's HNP. This breaks the PMIPv6's basic rule: Per-MN-Prefix model. Second, every Hybrid MANET MN has mobility nature. When IG is changed to the other MN, this brings all sub-ad hoc nodes IP address change.

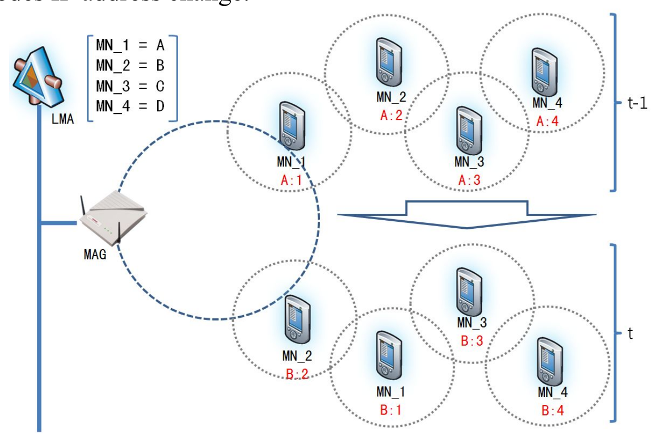

Fig. 5. The Per-MN-Prefix model problem.

Figure [5] describes the Per-MN-Prefix model problems. In a figure, notation *ALPHABET :NUMBER* means IP address of the MN where *ALPHABET* indicates the HNP and a *NUMBER* indicates MN_ID. In a case t-1, a MN_1 becomes an IG. The MAG receives MN_A's HNP 'A' from the mapping table and sends it to the MN_1. After IG broadcasts this HNP 'A' to all sub-ad hoc nodes, each sub-ad hoc node creates their global IP address like A:1, A:2, A:3, and A:4. Notice that in a basic PMIPv6 mechanism, their IP address must be A:1, B:2. C:3 and D:4. In a case t, a MN_2 becomes an IG. Then the MAG receives a MN_B's HNP 'B' from the mapping table. The other operations are the same as the previous operations. Each sub-ad hoc nodes change their IP address like B:1, B:2, B:3, and B:4. As a result, every time another MN becomes the IG, every sub-ad hoc node creates new IP address and establishes new connection with correspond node (CN).

C. *Case 3: Tunneling*

Another feature of the Hybrid MANET is that the closed network overcomes group communication and extends its connectivity to Internet using a special entity: Internet Gateway. A number of mechanisms have been suggested for the Internet connection. Most of these mechanisms use the IG as a default gateway and every packet from sub-ad hoc nodes have to path through this entity. In the PMIPv6 part, another feature of the PMIPv6 is that the two main entities, MAG and LMA, establish a tunnel and participate packet delivery. They maintain data structure, binding update list (BUL), and refer it for the routing.

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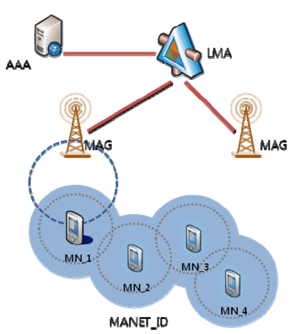
When two technologies are merged, they cause a network disconnection problem. In a case of sending a packet form sub-ad hoc node to CN through IG, the MAG must check on BUL that there is an established binding for that MN with its LMA [5]. However, the binding could establish only with the IG which finishes the MN_ID exchange. In a case of receiving a packet form a CN to sub-ad hoc node through tunnel, the MAG must use the destination address of the inner packet for forwarding it on the interface where the destination network prefix is hosted [5]. There will be interface information about IG, however there will be no interface information about sub-ad hoc node. According to the PMIPv6 specification, the MAG must silently drop the packet.

IV. Suggested Solution

In the Section 3, we describe the problems of integrating PMIPv6 with Hybrid MAMET: Link-layer connection, Per-MN-Prefix model and Tunneling. The central problem of integration is that the MAG only could manage the one-hop MNs. In our paper, we suggest a method to manage whole sub-ad hoc nodes using a logical identifier value: MANET_ID. This identifier helps PMIPv6 to overcome one-hop management limitation. For adaptation, we require three entities' modifications: MN, MAG, and LMA.



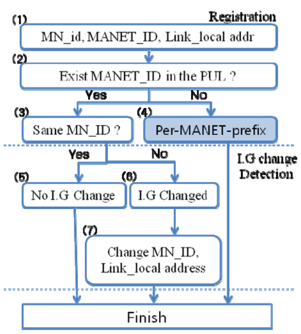


Fig. 6 The modification of the MN for MANET_ID.
Fig. 7 The modification of the MAG for IG change detection.

A. MN : Able to Create and negotiate MANET_ID

Figure [6] presents a topology of PMIPv6 and Hybrid MANET using MANET_ID. By MN modification, every MN in the same MANET share the equal value called MANET_ID. MAG could connect to MN_2,3,4 logically with MANET_ID.

B. MAG : Able to detect IG change

Figure [7] presents a modified operation of the MAG. The biggest modification is that the MAG checks the MANET_ID too. The basic operations are as follow. When MAG detects MN and receives MN-ID.

1) First MAG checks the role of the MN first. If the MN is IG, MAG will receive the MANET_ID.
2) Second, MAG searches the BUL and figure out whether the MANET_ID is already recorded or not.
3) If there is, then checks the MN_ID.
4) If there is not, MAG procedure Per-MANET-Prefix model which will introduce soon.
5) If there is the MANET_ID and its related MN_ID is not changed, MAG regard as the existing MN still work as IG and no more procedure progresses.
6) If there is the MANET_ID and its related MN_ID has changed, MAG regard as the IG has changed too.
7) Therefore, MAG modifies the MN_ID and Link-local address in the BUL.

C. LMA : Able to handle the Per-MANET-Prefix model

By LMA modification, LMA could handle the Per-MANET-Prefix model. When MAG detects new MN with new MANET_ID, MAG sends the PBU message to the LMA with the MANET_ID. Then, LMA award that the MN is the IG and marks the IG flag in the prefix mapping table.

D. The suggested solution

Figure [8] describes the message flow of the suggested solution. In the examination, extension header based IG mechanism is used [8].

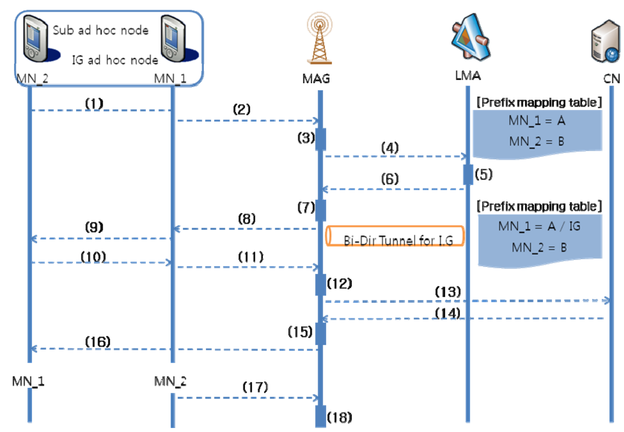


Fig. 8 The message flow of the suggested solution.

1) Authenticate & MANET_ID : MNs authenticate each other and share the MANET_ID.
2) MN_1 attached event [MANET_ID, MN_ID, Profile] : When MN_1 is attached to MAG, it first became IG and sends MANET_ID, MN_ID and Profile to MAG for obtaining HNP.
3) Per-MANET-prefix model : MAG performs modified MAG operation which is described in figure[7]. Then, MAG awards that the Per-MANET-Prefix needed for the new IG.
4) Proxdy Binding Update [MANET_ID, MN_ID, Profile]: MAG sends a PBU message to the LMA. At this point, LMA have a Per-MN-Prefix mapping table for the management reason.
5) Set MN_1 = A / IG : When LMA receives PBU with a MANET_ID, LMA awards that the MN play an IG role in the network. Then the LMA set the MN_1 as the IG.
6) Proxy Binding Ack.[MANET-HNP] : LMA sends a PBA message to the MAG with the per-MANET-prefix.
7) Update BUL : MAG updates the BUL for MN_1 and establishes a bi-direct tunnel between the LMA and the IG.

8) Rtl Adv [MANET-HNP] : MN_1 receives RA message and creates its IP address for Internet communication.
9) IG Adv [MANET-HNP] : Every sub-ad hoc nodes also receive IG advertisement message and create its IP address using the MANET_HNP.
10) Send a packet to CN [CN, (MN_2, MN_1)] : To communicate with CN, sub-ad hoc node sends a packet to the IG using the extension header option.
11) Send a packet to CN [MN_1, (MN_2, CN)] : IG swaps the destination address to the next router in the list and forward to the MAG.
12) Check MANET_ID : MAG checks the BUL for the suitable tunnel interface for MN_2 using the MANET_ID. The PerMN-Prefix model does not work in this point because MN_2 is not registered to LMA directly. Even if the MN_ID is not registered, the MANET_ID is registered subsidiary.
13) Send a packet to CN [MN_1, (MN_2, CN)] : The packet reaches the CN through the LMA.
14) Receive a packet from CN [MAG, LMA, (MN_2, CN)] : To communicate with MN_2, CN just sends a packet to the MN_2. The prefix leads the packet to the LMA. LMA encapsulates the packet and forward the packet to the correspond MAG.
15) Check MANET_ID : MAG checks the BUL for the suitable interface for MN_2 using the MANET_ID. The Per-MN-Prefix model does not work in this point because MN_2 is not recorded in BUL. The MANET_ID indicates related IG's interfaces then, forward to the IG.
16) Receive a packet from CN [MN_2, CN] : IG receives the packet and forwards it to the sub-ad hoc node.
17) MN_2 attached event [MANET_ID, MN_ID, Profile] : Due to the MN's mobility, MN_1 and MN_2 change their geographical position. This means the MN_1 no longer belong to the MAG radio range and the MN_2 will become new IG.
18) IG change detection : When the MAG receives MN_2's MANET_ID and MN_ID, it performs modified MAG operation.

By observing the same MANET_ID and the different MN_ID, MAG award that the IG has changed. MAG just updates its BUL to new MN_ID and Link-local address. By this operation, all sub-ad hoc nodes keep unchanged IP address and keep the communication.

V. Conclusion

Lots of communication technologies are invented in nowadays. Those technologies show great enhancement and performance when they are working individually. However for the better mobility communication, the integrating of these deserves careful attention. In Chapter 3, we present the Hybrid MANET problems when integrate with PMIPv6. In Chapter 4, we suggest the solution using the shared network identifier among the same MANET nodes and show the full operation using the MANET_ID in figure [8]. We could conclude those problems and solutions as follow. Please refer the solution numbers in figure [8] steps.

--Link-Layer information: Unable to allocate HNP, Unable to synchronize mapping table, Step 1~7

--Per-MN-prefix: Limited IP address allocation, rapidle IP address change, step 9, 17~18

--Tunneling: Unable to forward data, step 7,15

The solution, MANET_ID, shows extension and enhancement of the basic MANET functionality in previous paper [9]. Furthermore, it also shows the interaction and solution for the PMIPv6. Even if there exist the traffic exchanging overhead for the MANET_ID negotiation, this overhead could be take into consideration for the solution of the PMIPv6 and Hybrid MANET integrate problems. For future work, we plan to authenticate algorithm for all MANET_ID shared MNs using asymmetric encryption or a public key encryption scheme.

Acknowledgment

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