THE PROPOSED IMPROVEMENT 3-LAYER MOBILITY MANAGEMENT SCHEME FOR WIRELESS MESH NETWORKS USING IP PREFIX MECHANISM

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***Abstract* — After the great deployment and success of the Wireless Local Area Networks based on access points, which communicate by using wired links, the wireless world saw the birth of new technologies like Ad Hoc networks and Wireless Mesh Networks (WMN), which permit the flexibility, easy deployment and low cost. The first objective of these networks is to offer a seamless connectivity to mobile users. Nevertheless, wired mobility management protocols perform poorly with these new technologies. In fact, traditional protocols do not permit to have a realistic snap-shot of the network; moreover, we need to propose new approaches to detect clients' movements.**

In this paper, we investigate mobility problems in WMN and propose a new efficient solution with high performances. Specifically, we present a new mobility management scheme for WMNs, 3-layer mobility management scheme. It utilizes some WMN's features and uses IP Prefix in mobility management to reduce the signaling cost as well as to shorten the handoff latency. Our analysis shows that significant benefits can be achieved from this scheme.

We provide the following contributions. First, we talk about some routing protocols at layer 3. After that we propose a 3-layer mobility management scheme in order to reduce the signaling cost and shorten the handoff latency. We focus on our experiment in using IP Prefix in detecting client movement.

***Keywords* — Mobility Management, 3-layer mobility management scheme, IP Prefix, Wireless Mesh Networks, Routing Protocols.**

I. Introduction

Mobility becomes a very important issue in current networking, because users are more and more mobile due to the widespread of wireless technology. We are often confronted with the adaptation of network to the unceasingly increasing mobility of its users. Like mobile phones, computers are also increasingly mobile. This new tendency of clients who want to move during communications with no constraint of connectivity, no additional software to install, and where the changes of network are completely transparent, had induced the researchers to think about new architectures. As an example, we can quote Ad Hoc networks or Wireless Mesh Networks, which are network architectures that propose free mobility to their clients.

In this context, the challenge is to preserve client's connections whatever the type of displacement.

Mobility management is made up of two parts: localization and handover management. If we have a good mechanism of detection and localization, easily and in an efficient manner we can manage the handover. Handover, or in some cases handoff, means the change of access point due to client's displacement. The main objective of researchers is to minimize the handover latency and reduce the signaling cost.

Unlike Ad Hoc networks, which are not able to guarantee the connectivity of nodes, Wireless Mesh Networks offer connectivity to end-users and form a stable self-organized wireless backbone.

In this paper, we propose a mobility management scheme in WMN, called 3-layer mobility management, to reduce the signaling cost and the handoff latency**.** Some features of WMNs, such as multi-hop, mesh topology, continuous coverage and especially IP Prefix have been taken into consideration to better support the IP micro-mobility in WMNs. In this paper, we also discuss and do some simulations to compare the two protocols AODV and DSDV in some aspects such as throughput, packet loss rate and delay to choose the best protocol for our scheme.

The rest of this paper is organized as follows. Section II discusses some related works. Section III compares some routing protocols in order to choose the best protocol for our scheme. Section IV describes the proposed scheme. Conclusion is given at the end.

II. Related works

In this paper, we focus on the mobility management within one network. First, we briefly review the most popular ad hoc routing protocols that are the direct candidates for the routing protocol in wireless mesh networks. Then, we analyze their characteristics and propose a routing protocol suitable for small/normal-scale wireless mesh networks. After that, we propose a 3-layer mobility management scheme for wireless mesh networks.

Not many related works of mobility management can be found in the literature of WMNs. Ganguly et al. [12] mentioned the mobility management issue in their comprehensive work. The experiment results confirm that handoff latency using a tunneling scheme is much longer than that using flat routing. However, since mobility management is not the focus of this paper, the authors discuss only the feasibility of mobility support and do not include detailed analysis. In SMesh [4], multiple APs monitor the moving mobile clients to achieve seamless handoff. This scheme eliminates the handoff latency at the price of high signaling cost.

However, previous works on IP micro-mobility are possible to be applied to WMNs, since WMN can be treated as one type of mobile IP networks. We now review some IP micromobility protocols.

In Cellular IP [13], mobile clients use the gateway's IP address as their CoA and each router in this domain use the home addresses of the mobile clients to route the downstream packets. The default routes for each router to the gateway are used to direct the upstream packets.

HAWAII is another important framework of IP micromobility [10]. The CoA of each mobile client in HAWAII is a unique IP address allocated by the gateway of the domain. Different from the Cellular IP, HAWAII uses the CoA of each mobile client to route the downstream packets. This difference makes HAWAII less coupled with Mobile IP protocol and also enables the per-flow QoS support in the backbone network.

In both schemes, each domain is identified by a single gateway and the entire domain is constructed to a tree-like structure. Both schemes require each router to maintain a routing entry for each mobile client in the downstream APs' coverage. When handoff occurs, the corresponding routing entries will be updated in all the routers involved from the new AP to the crossover router which is shared by the new AP and old AP. The invalid routing entries in the routers of the old path need to be removed. Due to the major feature of per-host routing, this type of schemes is called mobile-specific routing approach [5].

Another important type of IP micro-mobility protocols is the hierarchical tunneling approach [5], an example of which is Mobile IP Regional Registration (MIP-RR) [6]. Hsieh et al. [7] proposed another scheme, namely, Hierarchical Mobile IPv6. This type of schemes replaces the mobile-specific routing by introducing the tunneling technique. Through the hierarchical registration procedure, the higher-level FA knows the location information (ID of the lower-level FA) of the mobile clients and encapsulates the data packets with the destination address of this lower-level FA. Per-host routing entry is not required for the routers in these schemes while per-host location information is still stored in FAs. Due to the extra processing of encapsulation and decapsulation as in Mobile IP [9], larger delay is introduced to each flow. Additional cost of this type of schemes is that two or more CoAs have to be used. When handoff takes place, the registration with a different CoA also adds extra delay. The intuitive idea of this approach is to extend the Mobile IP mechanism to local movements.

III. Routing Protocols

First we briefly review the most popular ad hoc routing protocols those are the direct candidates for the routing protocol in wireless mesh networks, and then analyze their characteristics and propose a routing protocol suitable for small/normal-scale wireless mesh networks.

Traditional ad hoc routings can be divided into two categories: on-demand (or reactive) and table-driven (or proactive) protocols. In reactive protocols, a route path is established only when a node has data packets to send. Some of the best known on-demand protocols are Ad-hoc On-demand Distance Vector routing (AODV), Dynamic Source Routing (DSR) and Temporary Ordered Routing Algorithm (TORA). In contrast to the on-demand routings, proactive routing protocols continuously update regardless the traffic activity in the network. Normally, each node generates control messages periodically and/or in response topology changes. Some popular proactive routings include Optimized Link State Routing Protocol (OLSR), Destination Sequence Distance Vector routing protocol (DSDV), Wireless Routing Protocol (WRP) and Cluster-head Gateway Switch Routing (CGSR) are the most popular table-driven protocols for mobile ad hoc networks. However, all these routing protocols do not scale well because they periodically propagate routing information of all nodes throughout the whole network. Moreover, there is another kind of routing protocol which is called geographic Routing. With this scheme, packets are forwarded by only using the position information of nodes in the vicinity and the destination node. Thus, topology change has less impact on the geographic routing than other routing protocols. It is more scalable since it only demands local states for communication without end-to-end path setup. However, geographic routing relies on the existence of GPS or similar positioning technologies, which increase cost and complexity of wireless mesh networks. Meanwhile, it needs the Geo-location service for the destination. All these issues increase the complexity of devices and routing protocol. Therefore, we do not consider the geographic routing in the paper.

In this paper, we investigate the impact of reactive routing protocol AODV and proactive routing protocol OLSR in wireless mesh networks. We choose the two algorithms due to the fact that these two routing schemes have the dominant role in the ad hoc networks, and the working group IEEE 802.11s is currently focusing on these two protocols, or variation of them, to understand the advantages of both the strategies in the mesh environments. In the following we review the two protocols.

As reactive routing protocol, AODV reacts relatively quickly to the topological changes in a network and updates only hosts that may be affected by the change. However, AODV tends to cause heavy overhead due to the flood search triggered by link failures.

As a result, AODV does not perform well in heavy load or mobile networks.

Optimized Link State Protocol (OLSR) is a proactive routing protocol that is an optimized version of a pure link state protocol by applying Multipoint Relays (MPR) concept. The idea of MPR is to reduce flooding of broadcast packets by shrinking the number of nodes that retransmit the packets.

In wireless mesh networks, Mesh Points (MPs) usually have minimal mobility, while STAs can be stationary or mobile. If a STA moves into another Mesh AP and AODV is used as the routing protocol, the STA needs to flood the network again to discover a new path. Therefore, AODV will incur excessive routing overhead. In contrast, with proactive routing protocols, the host can find the path immediately without finding a new route after moving into another mesh router's coverage. Thus, in the paper we propose to adopt the OLSR. In addition, to overcome the drawback of the scalability problem of OLSR, we enhance OLSR protocol with Fisheye (FSR) concept.

The OLSR operates as a table driven and proactive protocol regularly exchanging topology information with other nodes of the network. The key concept used in the protocol is that of multipoint relays (MPRs). OLSR is based on MPR flooding technique to reduce the number of retransmissions of topology broadcast packets as compared to classical flooding mechanisms, where each node forwards all received non-duplicate packets. In OLSR, a node (selector) independently chooses a minimal subset of its 1-hop neighbors to cover all its 2-hop neighbors to act as multipoint relaying nodes. The process is based on information acquired through HELLO messages which are containing lists of it neighbors' links. When a node sends/forwards a broadcast Topology Control (TC) message, containing the topology information necessary to build the routing tables, only its MPR nodes forward the message reducing duplicate retransmissions.

OLSR protocol is proactive or table driven in nature, hence it favors the networking context where this all-time-kept information is used more and more, and where route requests for new destination frequently. The protocol also goes in favor of the applications which do not allow long delay in transmitting data packets. OLSR protocol is adapted to the network which is dense, and where the communication is assumed to occur frequently between a large number of nodes.

A. Simulation

We conduct simulation experiments using the network simulator ns2 [8]. In our experiments, the maximum speed is varied from 0m/s to 100m/s. The transmission range is 200m and channel rate is 2 Mbps. Traffic sources are CBR. For each CBR session, the packet size is 512 bytes and rate is 600 Kb/s.

AP and MAP are both Access Points, form a backbone network, all the other nodes are client nodes. Each client node will be administered by one AP. When the client node moves, it will communicate with other nodes through new AP.

B. Wireless Mesh Network

We shall compare the two protocols AODV and OLSR in some aspects such as throughput, packet loss rate and delay. Fig. 2, Fig. 3 and Fig. 4 show us the simulation results:

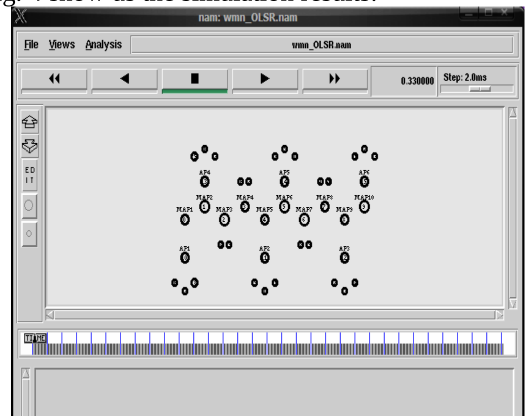

Figure 1: Simulation Topology

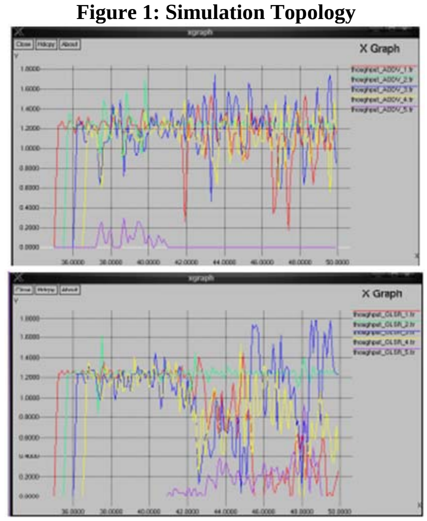

Figure 2: Compare the two protocols AODV and OLSR on throughput

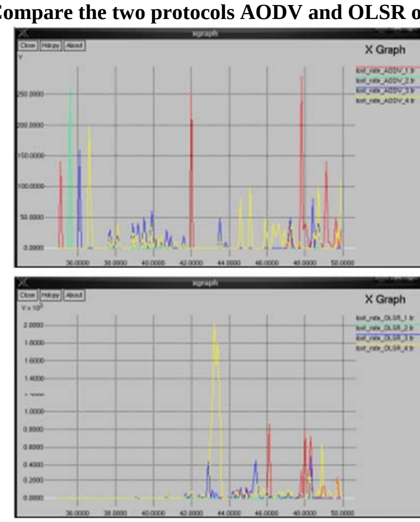

Figure 3: Compare the two protocols AODV and OLSR on packet loss rate

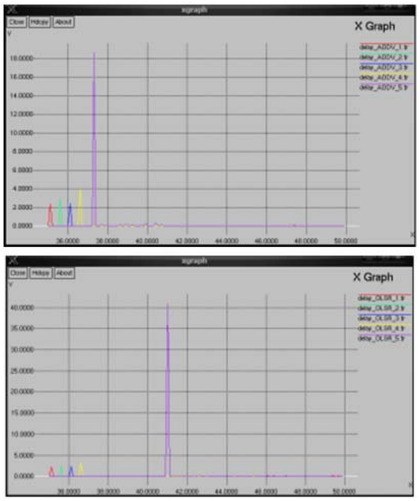

Figure 4: Compare the two protocols AODV and OLSR on delay

According to the simulation results above, we can realize that the protocol OLSR is better than AODV. In Fig. 2, the throughput of both two protocols is very high. However, if we pay more attention to that result, we can realize that OLSR is better than AODV in providing throughput for the data flows. In Fig. 3, we can see the packet loss rate of OLSR is lower than AODV. According to the simulation result in Fig. 4, we can see that the delay of OLSR is also lower than AODV.

IV. 3-level mobility management scheme

A. Model Description

Proposed model is a 3-level one including one gateway that connects to the Internet, some superior routers which connect to that gateway, all the rest APs are in peer-to-peer status.

The three APs connecting have superior status than their downstream nodes. They are required to collect the location information of the mobile clients in the cells of the subordinate APs. We named these APs "superior router (SR)". SRs act as the delegates of the gateway and share the signaling traffic. In small-scale network, if the gateway is not the bottom neck, we can converse the above structure into 2-level structure by removing the Superior Routers.

The gateway is required to assign a unique IP address in its domain to a mobile client when it is powered up. This unique IP address of a mobile client can be the Care-of-Address when mobile IP is provided for the inter-domain roaming. The foreign agent (FA) and home agent can be resided in the gateway.

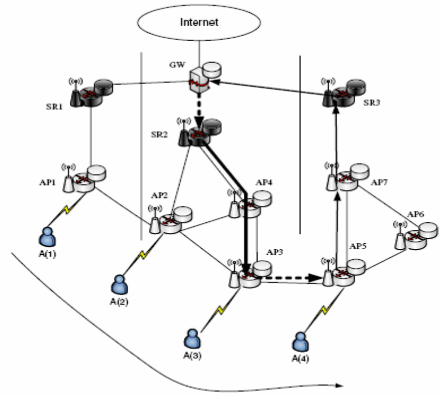

Figure 5: 3-layer mobility management scheme

A WMN can be constructed in a tree-like structure. Each router has its only parent node and may have some children nodes. Tree-like structure shows its limitation in routing process. So, this new structure will allow the routing process between APs which are not in the same branch to get the optimal result.

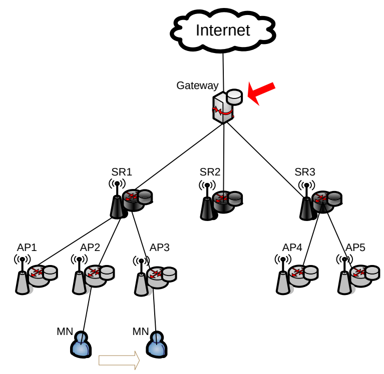

Figure 6: A tree-like structure

We assume that the routing in the backbone (APs, SRs and the gateway) has been set up. Since the backbone nodes in WMNs are mostly stationary, this assumption is reasonable. The remaining problem is on ensuring a mobile client to move around in this area without incurring high packet loss, long latency and high signaling cost to the system.

In this paper we suggest a new solution for this problem.

B. Proposed Solution

1) Power-up: For a mobile client, the subscriber information includes AAA information (Authentication, Authorization, Accounting) and QoS profiles. If every AP in a domain maintains a copy of all the mobile clients' subscriber information from the gateway, we will meet some difficulties in network management and expansion. For this reason, in our scheme, when a mobile client is powered up, the authentication procedure should be fulfilled before an IP address is allocated to this client according to the subscriber information in the gateway.

If the authentication is successful, the gateway then activates the record of this mobile client and records the location information hereafter. The APs also keep a copy of the subscriber information to avoid frequent visiting the database in the gateway. The database of each AP only contains information about the current clients which are being active in their domain. The database of each superior additionally contains location information of all the mobile clients residing in the subordinate APs' cells. All these AP are administered by the SR.

We assume that routing in the backbone (AP, SR and gateway) is established. We also consider that all backbone nodes in WMN are almost fixed.

Each AP will administer mobile clients by using an IP Prefix which is already assigned to that AP. When mobile client moves to a new domain of another AP, new AP will check the client's IP address to know which AP administers that client. Then, the new AP will contact with the old one to forward all the information about that client to the new AP. Before talking about this process, we introduce NDP (Neighbor Discovery Protocol) for IPv6, the protocol which determines the relations between the neighbors. It replaces the Address Resolution Protocol (ARP) used with IPv4. Clients use this protocol to find neighbor routers, to discover addresses and configuration parameters. Generally, nodes use it to detect changed Ethernet addresses and to maintain a track of neighbors' reachability. There are five different Neighbor Discovery packet types, and all are ICMP packets: Router Solicitation, Router Advertisement, Neighbor Solicitation, Neighbor Advertisement and Redirect.

Now, the process of "how to get CoA when the mobile client moves to a new domain" will be described below:

- When client A connects to WMR1 for the first time, it may send out a Router Solicitation that requests WMR1 to generate Router Advertisement immediately rather than at their next scheduled time.
- WMR1 advertises its presence together with various link and Internet parameters either periodically, or in response to a Router Solicitation message. Router Advertisement contains prefix that are used for on-link determination and/or address configuration, a suggested hop limit value, etc. Suppose that the client is on the home network, it will combine IP Prefix of WMR1 with its MAC address to get a Home Address (HoA).
- When the client moves from WMR1 to WMR2, it will receive a Router Advertisement which is generated periodically. If no RA is generated, the client will then send out a RS to request WMR2 to send RA. When the client receives RA, it will check the IP Prefix immediately to find out whether it is on the home network or foreign network. If it is on the foreign network, it will register a CoA with WMR2. There are 2 ways to get a CoA: stateless (it combines IP Prefix of AP with its MAC address to make a new address) or stateful (use DHCPv6 to get a dynamic address).

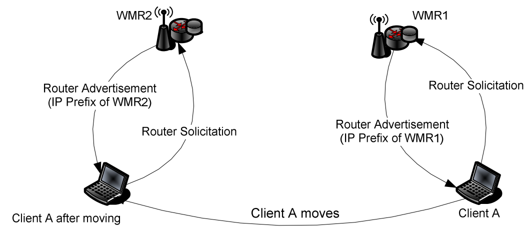

Figure 7: How to get CoA when the mobile client moves to a new domain

By using different IP Prefix, all the APs will identify clients quickly and minimize the handoff latency.

2) Handling Downstream Packets: The downstream packets, in which the destination address is not the AP's address, cannot be routed by the intermediate superior router and APs without routing entries. In this scheme, tunneling technique is used to forward the downstream packets. These packets are attached with extra IP headers in which the destination address is the destination AP's address. Upon receiving these tunneled packets, the destination APs decapsulate and forward them to the addressed mobile clients in the cells. In Fig. 5, the bold lines illustrate the downstream process, with the dashed lines and solid lines indicating the routing part and the tunneling part, respectively. From the gateway (GW) to the SRs, the packets are routed according to the location information.

3) Handling Upstream Packets: For the upstream packets, the tunneling is not needed. The APs can use the default routes to forward packets to the gateway.

4) Handling Handoff: Handoff occurs when the mobile client moves to a new AP's cell. Upon receiving a handoff request message from the moving client indicating the former AP's ID, the new AP sends a handoff request message to the former AP. The former AP sends back the corresponding subscriber information to the new AP after receiving the handoff request message. Meanwhile, it adds a temporary entry in its routing table with the destination address of this mobile client. A timer with length T_r is started. If the downstream packets are decapsulated by the former AP but the addressed mobile client is not found in the cell, these packets are routed to the new AP using the temporary routing entry. This process just happens when the clients that the mobile node is communicating with haven't updated the information about the Binding Update of that mobile node yet. After updating the Binding Update, the timer expires, and then the routing entry and the corresponding subscriber information will be removed from the former AP.

5) Binding Update: The clients have to send the update messages about their current location to the other mobile client which is communicating with them. The APs have to update their database and gateway's database.

We use the idea of route optimization in FMIPv6 [17] to express this process. Route optimization enables to use the shortest communications path between CN and MN by routing packets directly to the MN's care-of-address. This eliminates congestion at the MN's home agent and home network. In addition, the impact of any possible failure of the home agent or networks on the path to or from it is reduced.

In order to do so, route optimization requires the MN to register its current mobility binding at the CN. This means that the MN sends a binding update to every CN, telling it about its current care-of-address. The CNs are then able to create a mobility binding between the MN's home address and the MN's care-of-address in their mobility binding cache. When sending a packet to any IPv6 destination, a CN checks its cached mobility bindings for an entry for the packet's destination IP address. If a cached mobility binding is found, the CN will use a new IPv6 extension header to route the packet to the MN by using the care-of-address indicated in this mobility binding. The main purpose of the extension header is to carry the MN's home address and replace the packet's destination IP address with the home address, once the packet has arrived at the MN. Vice versa, the MN adds a new IPv6 destination option to every packet it sends to a CN. This new option is called the home address option and it is used to inform the CN of the MN's home address. The inclusion of the MN's home address in these packets allows a transparent use of the care-of-address above the network layer.

MN has not changed its home address and it still uses the home address of its home network. The IPv6 packets from the MN to the CN are extended with the home address option.

V. Conclusion

3-layer mobility management scheme is proposed to meet the requirement of lower signaling cost and shorter handoff latency. Moreover, by using different IP Prefix, all the APs will identify clients quickly and minimize the handoff latency. Consequently, this scheme mitigates the shortcomings and achieves the advantages of both.

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