INTEGRATION OF MOBILE-IPV6 AND OLSR FOR INTER-MONET COMMUNICATIONS

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Abstract

Trends in fourth generation (4G) wireless networks are clearly identified by the *full-IP* concept where all traffic (data, control, voice and video services, etc.) will be transported in IP packets. MObile NETwork (MONET) is a group of mobile nodes moving together as a unit. Such groups are common characteristics of the vehicular environments, for example train and buses (which are attractive because of the high concentration of passengers on these vehicles). This paper investigates an ad hoc networking for Inter-MONET communications and interworking between MONETs and the global Internet. We propose a hierarchical architecture: (1) integrating Mobile IPv6 and OLSR, a routing protocol for ad hoc networks, to manage universal mobility; (2) connecting this ad hoc network to Internet. The heterogeneous communication is established with the help of specific access routers, which serve as gateways. We describe the network scenario, its basic protocol architecture and we discuss the different practical approaches for routing. A flat and hierarchical ad hoc routing comparison is studied and performance differentials are analyzed through simulation results using varying network load and mobility.

1. Introduction

With the advances in wireless communication and mobile computing technologies, wireless multihop networking (ad hoc networking) is expected to play an important role in mobile communications beyond fourth generation systems. Because of its independence on pre-existing network infrastructure and its distributed organization, ad hoc networking enables the spontaneous establishment of communication between network-enabled electronic devices (e.g., mobile phones, personal digital assistants). Especially in applications where information must be distributed quickly and is only relevant in the area around the sender, ad hoc communications have major advantages compared to *conventional* wireless systems, such as GSM and UMTS. For example, cars involved in an accident can send warning messages back over a defined number of other vehicles, thus avoiding a motorway pileup [1]. In this vehicular scenario, we can also imagine transmission of information about bad traffic or street conditions (e.g., icy roads, obstacles), or wireless communication of closed user groups (e.g., emergency teams). A mobile ad-hoc network (MANET) [2] is a collection of nodes, which are able to connect on a wireless medium forming an arbitrary and dynamic network with *wireless links*. Implicit in this definition of a network is the fact that links, due to node mobility and other factors, may appear and disappear at any time. This in a MANET implies that the topology may be dynamic and that routing of traffic through a multi-hop path is necessary if all nodes are to be able to communicate.

A MObile NETwork (MONET) [3] is an entire network, moving as a unit, which changes its point of attachment to the Internet and thus its reachability in the topology. A MONET may be composed by one or more IP-subnets and is connected to the global Internet via one or more Mobile Routers (MR). Cases of mobile networks include networks attached to people (Personal Area Network or PAN, i.e., a network composed by all Internet appliances carried by people, like a PDA, a mobile phone, a digital camera, a laptop, etc.) and sensor networks deployed in aircrafts, boats, busses, cars, trains, etc.

This paper addresses the ad hoc networking for Inter-MONETs and interworking between MONETs and Inernet using ad hoc routing, where we restrict our view to IPv6 [4]. The wireless multihop access network is entirely based on IP, uses the optimized Link State Routing protocol (OLSR) [5] and meets the requirements of future *full-IP* wireless networks, such as providing high-rate video, voice and data services.

In the flat routing, the routing information may be maintained regularly (called proactive or table-driven routing) or computed when needed (called reactive or on-demand routing). In the hierarchical routing, the mobile nodes (MN) are clustered into several groups. The routing information is maintained separately within a group and among groups. A typical route can be found in the group-level granularity first and then in the node-level granularity. Extensive simulations are carried out to study performance comparison of flat and hierarchical ad hoc routing for Inter-MONET.

The remainder of this paper is organized as follows: in Section 2, we give an overview of the MONET terminology. We present in Section 3 our proposed architecture for mobility management. Different routing and addressing mechanisms are discussed and compared in Section 4. Performance results are presented in section 5. Finally, Section 6 concludes this paper and defines topics for further research.

2. Mobile Network (MONET)

MONET is a network that changes its Internet access point. It is formed of mobile nodes called MNNs (Mobile Network Nodes) and one or more MRs (Mobile Routers). All these nodes move together as a single unit. The MR takes in charge the handover procedure. It has one or more interfaces and maintains the Internet connectivity for the entire mobile network. It gets access to the Internet through an AR (Access Router) which is an external router. A mobile network is said to be nested when another mobile network is getting attached to it. It is said multihomed when there are more then one active interface connected to the global Internet. The reader can refer to [6] for more details in terminology.

3. Proposed architecture for mobility management

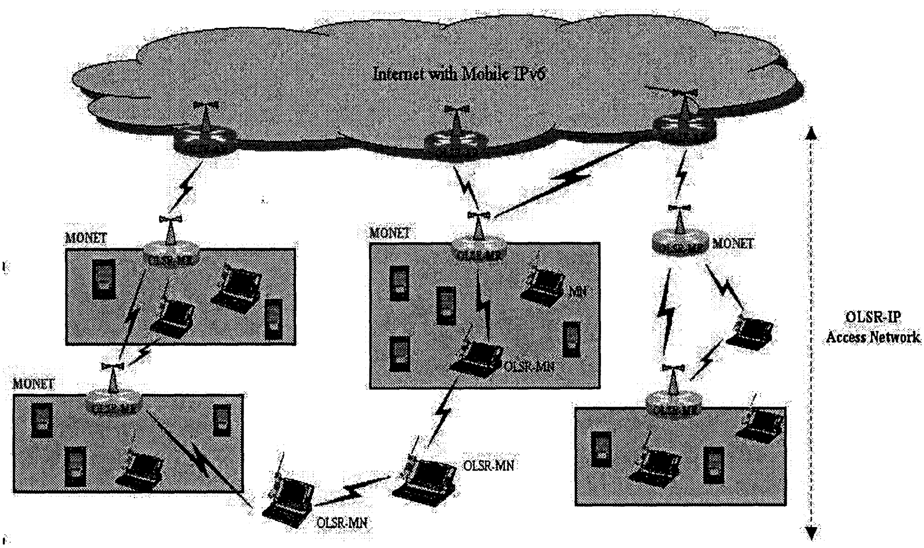

Figure 1. Hierarchical mobility management

The proposed architecture is depicted in Figure 1. An OLSR-IP access network constitutes an IP subnetwork and its interconnected to the Internet via an OLSR Access Router (OLSR-AR). The motion of a Mobile Router (MR) inside an OLSR-IP access network is managed by the OLSR protocol and the Mobile Node (MN) inside the MONET by a wireless LAN. Mobility between different OLSR-IP access networks or IP subnetworks is managed by Mobile-IPv6.

An OLSR-IP access network consists of a random topology of ad hoc moving networks. In our MONET, an OLSR Mobile Router (OLSR-MR) provides connectivity between MONETs and OLSR-ARs. We can find more then one OLSR-MR per MONET.

The architecture is composed of several functional entities:

- ☞ Home Agent (HA): a Router in the MN's home network.
- ☞ OLSR Mobile Router (OLSR-MR): a router which changes its point of attachment to the Internet. The OLSR-MR has one or more egress interface(s) and one or more ingress interface(s) and acts as the gateway between the mobile network and the rest of the Internet. The OLSR-MR implements the OLSR protocol.
- ☞ OLSR Access Router (OLSR-AR): any subsequent point of attachment of the OLSR-MR at the network layer. Basically, a router on the home link or the foreign link. It can also implement the role of a HA if the OLSR-IP access network is the home network. Furthermore, OLSR-AR implements the OLSR protocol.
- ☞ Mobile Node (MN): A node, either a host or a router located within the MONET. A MN could be any of OLSR-MR.
- ☞ OLSR Mobile Node (OLSR-MN): a MN that can implement the OLSR protocol.
- ☞ Ad hoc Mobile Node (ad hoc MNs): an OLSR-MR or OLSR-MN.
- ☞ Correspondent Node (CN): any node that is communicating with one or more MN.

In our architecture, OLSR-ARs and OLSR-MNs form an ad hoc network and use the OLSR routing protocol. MNs in the MONET implement a wireless LAN, and connected to the global Internet via its OLSR-MR. Some of MNs which are the OLSR-MNs implement the OLSR protocol and have a routing table. An OLSR-MR can exchange information directly with its OLSR-MRs neighbors. If an ad hoc MN has no OLSR-AR and OLSR-MR as neighbor, it can connect to the Internet by an OLSR-MN. Any OLSR-MN that belongs to the MONET, connects to its OLSR-MR using the OLSR protocol.

4. Routing and addressing in OLSR-IP access network

This section describes and compares different approaches for flat and hierarchical routing in our heterogeneous scenario.

4.1 Flat Routing

Let us first consider the case in which a flat routing protocol is used in our architecture (Figure 3). Such protocol regards the ad hoc network as a number of nodes without subnet partitioning. The communication in this environment can be categorized into two scenarios: (1) routing between an Internet host and a MN and (2) routing between two MNs with the same OLSR-AR or with different OLSR-ARs.

With the OLSR protocol, an ad hoc MN (OLSR-MR or OLSR-MN) senders should have an entry for the destination in its routing table, which is either a route in ad hoc network or a link to the default OLSR-AR if the destination is not reachable through the ad hoc network.

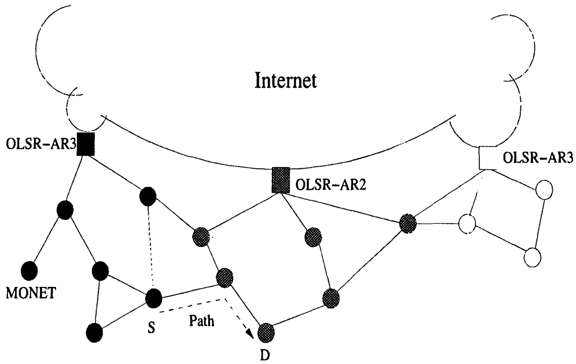

Figure 2. Flat routing in the OLSR-IP access network

Communication btw. An ad hoc MN and Internet host. After obtaining a route to the destination, an ad hoc MN can tunnel IPv6 packets through the ad hoc network to the OLSR-AR, which then forwards them to the Internet host. There are two methods to realize this tunneling. One method is that the ad hoc MN encapsulates each IPv6 packet (i.e., they add an ad hoc header with the OLSR-AR as destination). Another method is possible, the sending ad hoc MN uses the IPv6 extension header. The routing extension of this header contains the final destination address, i.e., the address of the Internet host, and the destination field of the IPv6 header contains the final destination the OLSR-AR address. Only an ad hoc MN with an IP address mentioned in the destination field of the IPv6 header of an IPv6 packet can examine the routing header of this packet [4]. The home destination option of Mobile IPv6 is used to inform the correspondent IP host about the home address of the ad hoc MN. The OLSR-AR decapsulates the incoming packets from the ad hoc MN, or it reads the routing header and puts the address of the IP host into the destination field of the IPv6 header. The resulting packet is then routed through the Internet to the IP host.

We now consider traffic from the CN to the ad hoc MN. If the CN knows the care-of address of the ad hoc MN, it puts ad hoc MN's care-of address in the IPv6 destination address field and the ad hoc MN's home address in the routing header of the routing IP packet. If the CN has no binding information about the ad hoc MN, it sends a usual IPv6 packet the ad hoc MN's home address. The home agent intercepts this packet and must tunnel it to the ad hoc MN's current care-of address using IPv6 encapsulation. In the remaining routing process, we can distinguish two design options:

- All ad hoc MNs of a single subnet have been assigned the same care-of address from the OLSR-AR, e.g., by stateful autocongiguration. The OLSR-AR possesses two IP addresses: a home address the identifies the OLSR-AR uniquely and a second address that is given as care-of address to the ad hoc MNs. Both addresses have the same prefix. With this address assignment, incoming IP packets that are addressed to an MN's care-of address can be processed by the OLSR-AR, i.e., the OLSR-AR can decapsulate packets or examine the routing header, respectively. The home address of the MNs is used in routing, i.e., the OLSR-AR uses the MN's home address as the destination address.
- Each ad hoc MN has been assigned a different care-of address with the prefix of the corresponding OLSR-AR using stateful or stateless auto-configuration (this is in our case). This address or the home address can be used in ad hoc routing, where the location information of the care-of address is not used. The content of packets from the ad hoc MN to an IP host (outgoing traffic) is the same as in the previous case. In case of incoming traffic, the OLSR-AR does not decapsulate packets or examines routing headers that are addressed to the care-of address of ad hoc MNs.

Communication btw. Ad hoc MNs. In order to send an IPv6 packet to another ad hoc MN in the ad hoc network, the ad hoc MN originates an IPv6 packet with the address the destination ad hoc MN in the IPv6 header. No IPv6 routing header is required in this case.

4.2 Hierarchical Routing with Care-of address

Using hierarchical routing, the ad hoc network is logically separated into subnets (i.e., cluster) (Figure 4). When an ad hoc MN receives a packet, it checks the destination address. If itself is the destination, it processes the packet for further operation. If the ad hoc MN is not the destination and the prefix of the source is different than its own prefix, the ad hoc MN ignores this packet. Inter-subnet information exchange is only possible via the OLSR-AR. In this case, a hierarchical address structure is also needed for routing in the ad hoc network, and therefore an ad hoc MN's care-of address is the right choice for addressing in the ad hoc routing protocol, since it contains the prefix of the OLSR-AR that a node is registered with. It is required that each ad hoc MN obtains a unique care-of address.

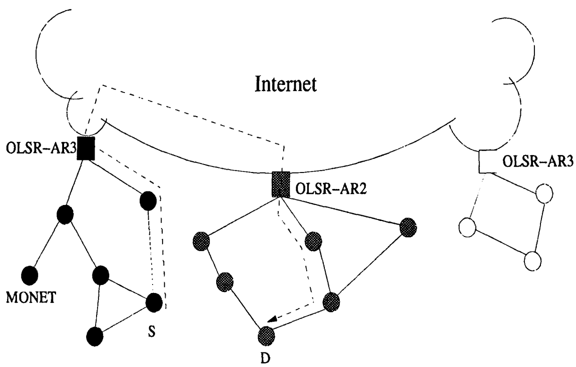

Figure 3. Hierarchical routing in the OLSR-IP access network

If an ad hoc MN wants to send data packet to an Internet host, it knows from the prefix of the destination address that his host does not belong to its own subnet. Thus, it sends the data packets to the OLSR-AR using the OLSR protocol. Once the OLSR-AR receives the data packets, it forwards them to the Internet host.

Communication btw. Ad hoc MNs in same subnet. if an ad hoc MN wants to communicate with another ad hoc MN that has attached to the same OLSR-AR, the ending ad hoc MN learns from the prefix of the destination's care-of address, that the destination is located in the same IP subnet (from the routing table). If the sender knows only the home address of the destination, packets will be routed to the home agent of the destination.

Communication btw. Ad hoc MNs in different subnets. The sender learns from the IP prefix, that the destination is located in a different IP subnet. Thus, the packets are routed toward its serving OLSR-AR, and the source OLSR-AR routes the packets to the destination OLSR-AR via the fixed IP network. The destination OLSR-AR forwards the packets to the destination using the OLSR protocol.

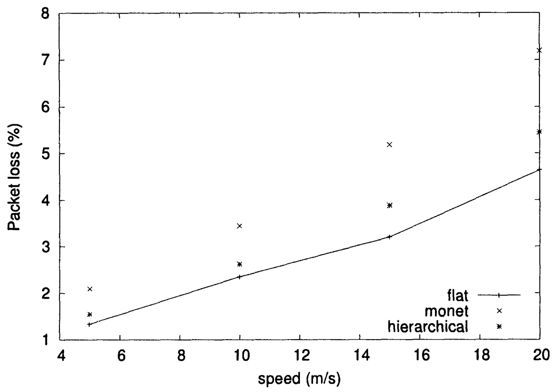

Figure 4. Loss data packets versus mobility with 200ms as interarrival

5. Simulation results

Figure 4 shows the results of our simulation in which the data packets sent and lost plotted against the increasing speed. The OLSR-MR's speed is increased from $5m/second$ $(18Km/hr)$ up to $20m/second$ $(72Km/hr)$.

In this simulation, 5 OLSR-MRs move in the same direction using our mobility model. All the 5 OLSR-MRs are packet-generating sources using $200ms$ as interarrival and. Each OLSR-MR source selects randomly one of the remaining OLSR-MR as a destination. The OLSR-AR range is a uniform value between $1000m$ and $2000m$, the OLSR-MR area range is $200m$. Each OLSR-MR node selects its speed and direction which remains valid for next $60seconds$. We can see that when the mobility (or speed) increases, the number of packet loss increases. This can be explained by the fact that when a node moves, it goes out of the neighborhood (OLSR-AR in MONET or OLSR-MR in MANET) of a node which may be sending it the data packets. There are about 2.1% of packets lost for monet classical routing at a mobility of $5meters/second$ (1.5% for hierarchical routing and 1.3% for flat routing). At a mobility of $20meters/second$, 7.2% of packets are lost for monet classical routing (5.4% for hierarchical routing and 4.6% for flat routing). The data packets are lost during the handover and Access router discovery latency. Flat routing has the highest packets delivered because during the OLSR-MR handover process, packets to this OLSR-MR are forwarded by one of its OLSR-MR neighbor. In Flat and Hierarchical routing mechanisms, the data packets are lost because the next-hop node is unreachable. A node keeps an entry about its neighbor in its neighbor table for about 6 seconds. If a neighbor moves which is the next-hop node in a route, the node continues to forward it the data packets considering it as a neighbor. Also, the next-hop is unreachable if there are interferences.

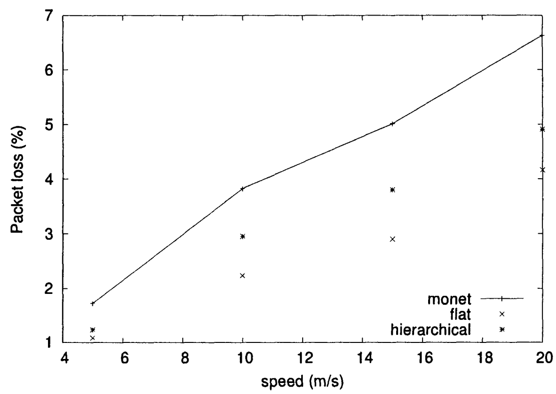

Figure 5. Loss data packets versus mobility with 400ms as interarrival

In Figure 5, we show the packet loss versus the increasing speed. We modify only the packet arrival rate using $400ms$ as interarrival parameter. The loss packet has the same behavior as that of Figure 4. However, it is clear that the packet loss in figure 5 is less than that the figure 4 (packet arrival rate used to obtain Figure 5 is less than that the figure 4).

Fig. 6 depicts end-to-end delay for both flat and hierarchical routing. Flat routing has an average delay about 130 ms. However, hierarchical routing has 300 ms. This can be explained by the fact that in flat network, the hop count number between any two ad hoc MNs is less than in hierarchical network. A low variation can be detected with increasing interarrival and speed due to the high number of ad hoc MNs.

6. Conclusions

In this paper, we considered the Internet access of mobile devices in a wireless ad hoc network via specific access routers. We have described problems and our solution approach for access router discovery and routing. A new architecture is proposed to manage the MONET mobility using OLSR protocol. An OLSR-IP access network consists of a random topology of ad hoc moving networks. OLSR-ARs and OLSR-MNs form an ad hoc network and use the OLSR rouring protocol. Simulations are carried out using an efficient simulation model to study the performance of our proposed architecture. We have shown that flat routing achieves less data packet loss and end-to-end average delay.

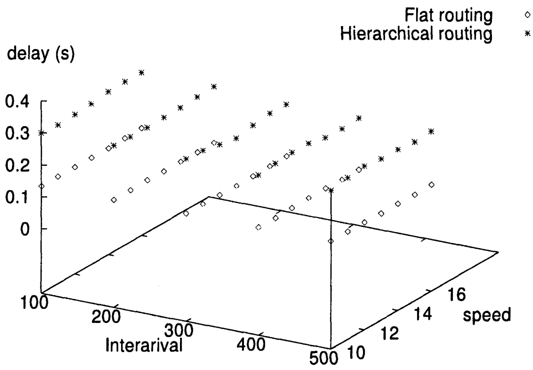

Figure 6. Delay versus mobility and interarrival for flat and hierarchical routing

Topics for further research include the investigation of proper methods for access router selection. Furthermore, *location updating* and *multihop handover* schemes must be designed and evaluated. Also, we will propose a smooth handover with reduced packet losses.

References

[1] AW. Kellerer, C. Bettstetter, C. Schwingenschlogl, P. Sties, K.E. Steinberg and H.J. Vogel. "(Auto)Mobile communication in a heterogeneous & converged world," IEEE Personal Comm., 2001.

[2] http://www.ietf.org/html.charters/manet-charter.html.

[3] V. Devarapalli, R. Wakikawa, A. Petrescu and P. Thubert. "Network Mobility (NEMO) Basic Support Protocol," RFC 3963, 2005.

[4] S. Deering and R. Hinden. "IPv6 Specification," RFC 2460, 1998.

[5] T. Clausen and P. Jacquet. "Optimized Link State Routing Protocol," RFC 3626, 2003.

[6] T. Ernst and H. Y. Lach. "Network Mobility Support Terminology," Internet Draft, 2002.