IP Paging in Mobile Multihop Networks

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***Abstract*-- The IP paging architecture in globally-connected mobile ad-hoc network is presented. Motivated by the energy-efficient design requirement in global-connected mobile ad-hoc network context, we design IP paging support in ad-hoc networks that is independent of, and compatible with, existing IP paging architectures. Two IP paging schemes: proactive paging and reactive paging are proposed. The system is implmented and evaluated with Network Simulator-2. In the reactive scheme, the system suffer less in paging delay and paging overhead. On the other hand, it is more energy-efficient in proactive scheme.**

A. INTRODUCTION

There has been considerable research in mobile and wireless networking that emphasizes IP-based, power efficient mobile Internet style systems. Within this domain, two of the most important systems are Mobile IP and mobile *ad-hoc* networks. Research trends demonstrate the practical importance of integrated Mobile IP and *ad-hoc* networks. Handling mobility at the network layer is a natural way to integrate heterogeneous wireless access technologies. Mobile IP provides the global mobility support for the internetworking of heterogeneous wireless and mobile networks. A mobile *ad-hoc* network is composed of distributed mobile nodes, which communicate via wireless multi-hop relay. It makes building mobile networks flexible. Most of the previous *ad-hoc* network research focuses on standing-along ad hoc network. Recently, some research has emphasized the internetworking problem of mobile *ad-hoc* networks and the Internet [Belding-Royer01 Lei97, Lin00, Jonsson00, Wu01, Zadeh02][1]. Clearly, it is important to understand how stand-alone mobile *ad-hoc* networks will be able to internetwork with the mobile Internet.

Energy-efficient design is always an important issue for wireless networks. A paging mechanism is a necessary component in energy-efficient wireless networks. Handling paging mechanisms at the IP layer [Kempf01, Ramjee01, Zhang01] is advantageous for systems that operate over heterogeneous wireless access technologies. It provides energy-saving and reduced signaling overhead over IP-based mobile networks. As the integration of all-IP wireless network and the emerging mobile *ad-hoc* networks proceeds, there are plenty of issues to be investigated in such context. In order to operating battery-driven mobile devices, it's essential to provide energy-efficient mechanism such as paging. Motivated by these two mega-trends, mobile IP and mobile *ad-hoc* networks, the design goal is to provide IP paging support in *ad-hoc* networks that is independent of, and compatible with, existing IP paging architectures.

B. ARCHITECTURE

This paper emphasizes on the paging mechanism in mobile *ad-hoc* networks. The design goal is to provide IP paging support in *ad-hoc* networks that is independent of and compatible with existing IP paging architectures. Different IP paging schemes may have different architectures. Our paging architecture is illustrated within the Mobile IP context. The reference IP paging model is shown in Figure 1.

All incoming packets for mobile nodes are routed through the HA (Home Agent). The Paging Agent initiates the paging message when there is an incoming message for the dormant mobile node. Paging messages are sent to the cellular wireless networks as IP paging and paging messages are also sent to mobile nodes in globally connected *ad-hoc* networks through the Paging Gateway (PG). The PG could choose to send the paging request message to dormant mobile node or to buffer the incoming message waiting for a query.

We focus on the paging issue in the wireless multi-hop networks. It is hard to schedule a specific time slot for mobile nodes in multi-hop network to wake up receiving the paging message. Due to the multi-hop and fast-changing route property, the paging mechanism should be designed accordingly. In this paper we consider both a reactive paging scheme and a proactive paging scheme for paging in *ad-hoc* networks. The mechanism will be described in the next section.

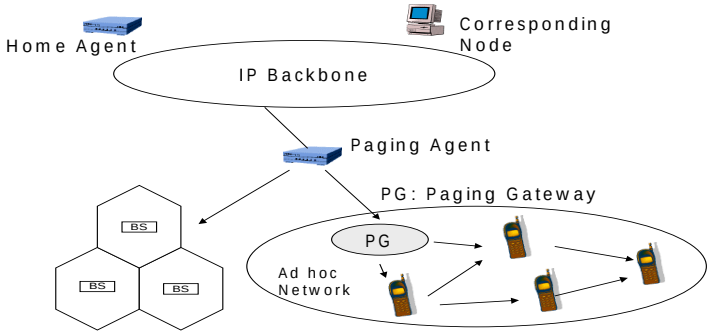

Figure 1 : IP Paging Architecture

C. PAGING PROTOCOL DESIGN

The paging mechanism in the single-hop Mobile IP-based cellular network could be designed as that of [Ramjee01, Zhang01]. Our mechanism design is independent of those existing IP paging protocols, and extends the paging capability to global-connected mobile *ad-hoc* networks. In the following discussion, we assume that IP paging in Mobile IP networks has been taken care of. We will focus on the paging operations in *ad-hoc* networks. We will describe two paging methods: (1) Reactive Paging and (2) Proactive Paging. In reactive paging, mobile networks advertise paging messages, and dormant mobile nodes reactively listen to those paging messages. In proactive paging, mobile networks store paging messages at the edge of access networks. Dormant mobile nodes leave the dormant state periodically to query if there is any paging message.

The packet type profiles, which specify the wake-up criteria of dormant nodes, are stored in the Paging Agent. The profile could include the Voice-over-IP initiation message, SMS (Short

[1] References are attached at the end of the poster material due to the limited space,

Message Service), or, high priority email notification from a mail server. The wake up criteria could be defined by the network, or adaptively specified by mobile user dormant registration. The paging procedure is initiated while there is an incoming packet type that matches the packet type to pull a dormant mobile node from energy-saving mode.

C.1 Reactive Scheme

The message flows of the reactive paging scheme is shown in Figure2. First, the application initiation message is sent from Corresponding Node (CN) to Mobile IP Home Agent (HA). The incoming packet type is examined to see if it meets the criteria to initial the IP paging procedure. It depends on the IP paging architecture type which node is the paging initiator. It can be Home Agent Paging, Foreign Agent Paging, or Domain Paging [Ramjee01]. However, the location of the paging initiator doesn't affect the paging mechanism in mobile ad hoc network. The paging process starts from the Paging Agent (PA). Paging Agent sends paging request messages to all base stations and Paging Gateways (PG) in its paging area. After that, Paging Gateway initiates the paging process in the multi-hop ad hoc networks.

Paging Gateway broadcasts the paging request message if Paging Gateway does not have a valid route to the mobile node. While the dormant mobile node receives the paging request message, it enters the active mode and starts the registration process. After the Mobile IP registration process completes, it starts the application.

C.2 Proactive Scheme

Similar to the message flow described before, the application initiation message comes from CN to HA, and then to PA (Paging Agent). PA receives the incoming message for MN and buffers it. After that, PA sends paging request message to PG (Paging Gateway). Unlike the reactive scheme, PG updates the paged node's status information in Paging Status Cache. Dormant mobile nodes will query the PG the paging status by sending paging query message periodically. PG replies the paging status stored in the Paging Status Cache with paging query reply message. Once the dormant node receives the paging query reply message indicating that there is an incoming paging message cached at the Paging Gateway, it enters active state and starts the Mobile IP registration.

Unlike dormant mobile nodes keep listening for incoming paging messages in reactive scheme, dormant mobile node turns off the radio interface for a time period $\tau_{DORMANET}$ in reactive scheme. It enters the query state periodically.The mobile node sends paging query message toward Paging Gateway. Then it keeps listening to the channel for paging query reply message for a time period τ_{QUERY}. During the query period, if the mobile node receives paging query reply message and the paging status field indicates there is an incoming paging message buffered in the Paging Gateway, the mobile node enters active mode. Otherwise, it goes back to the dormant mode and turns off the radio interface. If the mobile node does not receive the paging query reply message during τ_{QUERY}, it returns to dormant mode at the end of the query period.

D. PERFORMANCE EVALUATION

We implement and simulated the system within *ns-2*. Ad Hoc On-Demand Distance Vector (AODV) is used for ad hoc routing. IEEE 802.11 Distributed Coordination Function (DCF) is used in MAC layer. The Paging Gateway locates at the center of the rectangular space. Constant Bit Rate UDP traffic sources are used when mobile nodes are in active state. Some simulation results are shown in poster draft.

Reactive scheme is power inefficient but with small paging delay and with less paging overhead. In proactive scheme, the paging delay depends on the frequency of paging query. The more frequent mobile nodes query the Paging Gateway, the sooner mobile nodes get the paging message. However, frequent paging query results in heavy paging overhead. In proactive scheme, the query/dormant time needs to be carefully chosen. Choosing the parameter is an important implementation issue and it depends on the network topology, mobility model, and application requirements.

E. CONCLUSION

We proposed an IP-paging architecture for mobile *ad-hoc* networks. Two paging schemes: a proactive and a reactive scheme were presented and their performance was evaluated. In the reactive scheme, the Paging Gateway broadcasts paging messages, while in the proactive scheme, mobile devices query the Paging Gateway to see if any paging message is cached. The paging performance has been evaluated in terms of paging delay, paging overhead, and power consumption. We demonstrated that the paging delay and paging overhead are less in reactive scheme. On the other hand, the proactive scheme is more power efficient. In conclusion, a foundation has been established to architect energy-efficient Internet-connected wireless multi-hop networks.

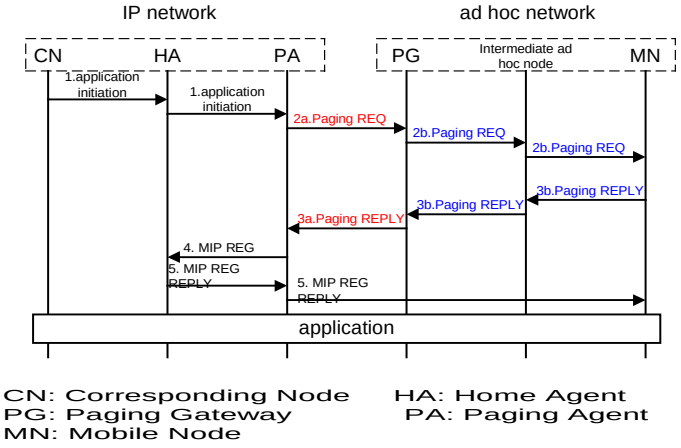

Figure 2: Message flow in Reactive Paging

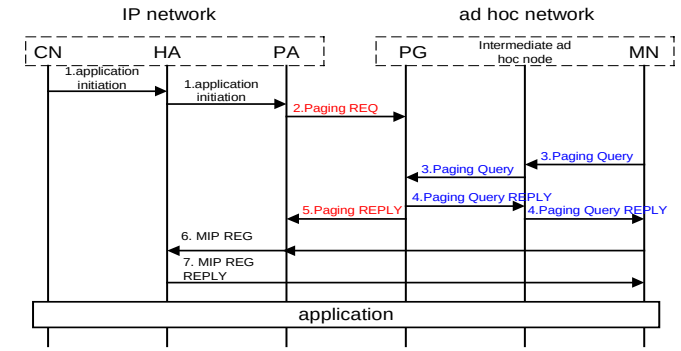

Figure 3: Message Flow in Proactive Paging