Integrated Routing Protocol (IRP) for Integration of Cellular IP and Mobile Ad Hoc Networks

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Abstract

Mobile Ad hoc Network (MANET) is a kind of wireless networks architecture, which is an infrastructureless, autonomous, stand-alone network. Therefore, MANET can be flexibly and simply deployed in almost any environment. But it has a limited wireless coverage and limited connectivity that is exclusive to the MANET boundary. The growth of the Internet and its services and applications and the trend in fourth generation (4G) wireless networks toward full-IP networks, lead to an increasing demand for enabling MANET nodes to connect to Internet and use its services and applications. Mobile IP and IP micro-mobility protocols enable the mobile host to access Internet and change points of attachment without losing the connection. So, with the co-operation between MANET routing protocols and IP mobility protocol, Internet connectivity to MANET nodes can be achieved. In this paper, we propose an integrated network architecture to extend the cellular IP access network to multiple MANETs. We also propose an integration routing protocol for connecting MANET to Cellular IP Access network and Internet. The proposed protocol supports mobile nodes mobility between different MANETs.

1. Introduction

Mobile IP[1] is the most widely known IP mobility management proposal that supports host mobility. Mobile IP suffers from many drawbacks, like high handoff delay, which results in a high number of packet losses, especially, in the case of frequent handoff (within the domain). Many solutions have been developed to efficiently support local mobility inside IP wireless networks such as Cellular IP[2][3], Handoff-Aware Wireless Access Internet Infrastructure (HAWAII)[4], Hierarchical Mobile IP (HMIP)[5], which is called IP Micro-mobility protocols. The aim of these micro-mobility protocols is to manage local movement (within domain) of mobile hosts without interaction with the home agents. These lead to decrease the handoff delay and packet loss during handoff and reduce the signaling load experienced by Mobile IP.

The Cellular IP protocol proposal from Columbia University and Ericsson enables routing IP Datagram from/to a mobile host. The protocol intends to provide local mobility (within the domain) and it interworks with Mobile IP to provide macro-mobility support (between domains). The protocol supports fast handoff and paging techniques. Micro-mobility support in a Cellular IP network is more important issue than the other micro-mobility protocols, duo to its simplicity.

MANET [11] is a kind of wireless networks architecture that can be flexibly deployed in almost any environment without the need of network infrastructure or centralized administration.

Integration of the ad hoc network to the fixed infrastructure IP access network provides Internet services and applications for the mobile ad hoc network users. Integration of MANET to Internet extends the coverage area of fixed Cellular infrastructure access network, so that, this integration can provide Internet access beyond the range of fixed Cellular infrastructure.

There has been some research on the problem of integration of MANET to Internet as in [6][7][8]. All of these solutions aim to support MANET with Internet connectivity based on Mobile IP. The integration of MANET with IP micro-mobility protocols is better solution than integration MANET with Mobile IP, because the advantages of IP micro-mobility protocols can be utilized.

In this paper, an integrated network architecture to extend the cellular IP access network to multiple

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MANETs is proposed. An integration protocol for connecting MANETs to Cellular IP Access network and Internet is proposed. The proposed protocol supports mobile nodes mobility between different overlap and none-overlap MANETs with multiple access points.

The rest of this paper is organized as follows. Section 2 presents the proposed integrated network architecture. In Section 3, details of the integrated protocol are presented. Section 4, describes all the routing scenarios. Finally, section 5 concludes the paper.

signal, if it is not interest in Internet connectivity, it simply re-broadcast beacon signal message to its neighbors nodes. If mobile node wants Internet access, it extracts the address of base station and the beacon signal sequence number, and it saves them in a list of base stations. The mobile node should send encapsulated route update and page update messages to base station as in Cellular IP. Every mobile node should re-broadcast beacon signal message to it neighbors nodes and so on. The Time-To-Live (TTL) field should be set to maximum diameter of MANET.

In the proposed protocol, it is assumed that at least one mobile node should be located in the base station coverage area, in order to broadcast the received beacon signal messages to other mobile node in the MANET. The base station IP address and beacon signal sequence number are used for preventing re-processing and re-broadcasting of duplicate beacon signal. It is also used for locating new base stations and creating a default route entry in mobile nodes for the selected base station.

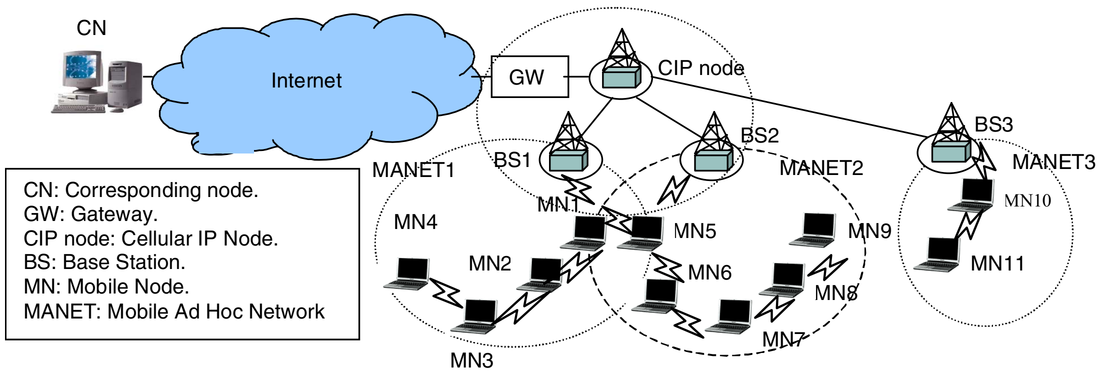

Figure1: Integrated network architecture.

2. Network Architecture

The proposed Integrated Network architecture is depicted in Figure 1. It consists of: (1) multiple overlaid and non-overlaid MANETs. (2) Access points, which are Cellular IP base stations (BSs) that run AODV routing protocol on the wireless interface and connected using wire link to other CIP nodes and CIP gateway. (3) Cellular IP nodes (CIPN) and Cellular IP gateway (GN), which are used to establish forwarding entries for mobile nodes and forward data packet from/to Internet. (4) Mobile nodes (MNs), which use its IP home address for all communication with Internet. AODV routing protocol is selected for routing inside the MANET.

3. Protocol Design

3.1. Periodic Beacon Signal Message

Base stations periodically announce their presence on the MANET through broadcasting beacon signal messages. When a mobile host receives a beacon

3.2. Route Discovery and Transmission of Packets

It is assumed that, mobile nodes in an ad hoc network that want Internet access use their home address for all communication with base station and gateway node in cellular IP access network. The base station should run AODV routing protocol in its wireless interface. When a mobile node wants to send data packets to a destination address, it use a route discovery procedure of AODV routing protocol to search for that destination address. If the destination found in the ad hoc network, the mobile host sends data packet according to AODV routing protocol. If the destination address is not found, Mobile node

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performs a routing table lookup for the IP address of base station according to default route entry and tunnels data packets to base station. The base station de-capsulates these packets and sends them to uplink port toward gateway node. Then, the gateway node sends packets to destination node.

3.3. Route Update and Page Update messages

Mobile nodes in the integrated protocol use the same routing update and page update procedures used in the ordinary Cellular IP protocol to establish the routing entries in the routing cache of each cellular IP node in the path from base station to gateway node with the exception that the route update messages and page update messages may have to traverse multiple hops before reaching to base station. The Integrated protocol uses tunneling to forward route update and page update messages to base station.

3.4. Movement detection and multiple base stations

In the integrated protocol, there can be multiple hops between a mobile node and base station. The MANETs can be overlapped, such that no clear boundary between these MANETs, and the mobile node can receive beacon signal messages from more than one base station. So that, the movement detection used in the ordinary Cellular IP becomes not applicable in the proposed protocol. So, the movement detection algorithm used in the proposed protocol is based on the hop count from base station to the mobile node, such that the mobile node can decide whether to change its base station or not. The mobile node should change its base station and initiates handoff to new base station if the number of hops to the new base station is less than number of hops to old base station or the mobile node misses 2 consecutive beacon signal intervals form current base station or the route to old base station becomes invalid due to mobility or route expiration.

3.5. Handoff

A modification to the ordinary Cellular IP handoff schemes is proposed for the proposed protocol. Modified Hard handoff is used when a mobile node moves from one MANET to another one and these MANETs are not overlapped. Also hard handoff can be used, when mobile node loses the connection with the old base station or the route to old base station become invalid. Modified Semi-soft handoff is used when a mobile node moves between an overlapped MANETs and the hop count to new base station is less than the hop count to old base station

4. Routing Scenarios

Based on the above architecture, all the possible combinations and routing scenarios between the Cellular IP access network and MANETs are presented.

4.1. Intra-MANET Routing

Intra-MANET routing happens between a MN in MANET and another MN in the same MANET. In such routing scenario, the routing between source and destination node is maintained by AODV routing protocol.

4.2. Inter-MANET Routing and Intra-domain Routing:

In this scenario, two MNs located in different non-overlaid MANETs served by different BSs in the same Cellular IP access network domain, and they want to communicate. The source MN encapsulates data packets and sends them to its default BS. When BS receives encapsulated data packets, it de-capsulates them and sends them uplink toward gateway node (GW). Gateway node checks its visitor list and routing and paging cache and forwards data packet downlink toward destination MN based on routing cache entries in every Cellular IP node. Then, the destination MN's BS uses AODV routing protocol to route data packet to destination MN.

4.3. Inter-domain Routing

Inter-domain Routing occurs when a MN in the MANET wants to send data packets to a node in Internet (CN) or a node in Internet (CN) wants to send data packets to a mobile node in the MANET. If the MN wants to send data packets to CN (host in Internet), MN should tunnels data packets to its default BS. Then, BS de-capsulates data packets and sends them uplink toward the gateway node according to Cellular IP protocol. Then, Gateway sends data packets to CN in Internet. The Internet node (CN) sends data packets to gateway node based on standard IP routing or Mobile IP. The gateway node checks its visitor list and routing table and then sends data packets downlink toward BS as in Cellular IP protocol. Then BS sends data packets to destination MN based on AODV routing protocol.

4.4. Inter-domain Routing (with handoff): Micro-Mobility.

In this type of routing, the MN, who is currently in communication with CN in the Internet, may move between different MANETs served by different BSs. Figure 1 shows this routing scenario. When MN moves from MANET3 served by BS3 to MANET2 served by BS2, a modified hard handoff is used in this case. When MN moves from MANET2 to MANET1 served by BS1, a modified semi-soft handoff is used.

4.5. Inter-MANET Routing in overlaid MANETs:

In this scenario, two MNs located in different overlaid MANETs (served by different BSs) and connected to each other. AODV route discovery can search for destination node in both MANETs. Based on the destination node default route and the number of hops obtained from route discovery procedure, the source MN decides to route data packets either through fixed infrastructure Cellular IP access network or direct communication between the two MANETs .

4.6. Inetr-MANET Routing in overlaid MANETs (with handoff)

In this routing scenario, a MN is in communication with another MN both of them are located in different non-overlaid MANETs in the same Cellular IP access network domain. Then one of these MNs moves to a new MANET, which is overlaid with the other MN's MANET. If this MN is the source of data packets, then it may decide to use direct routing with other MN or to use routing through Cellular IP access network, based on route discovery procedure and beacon signal from new BS. If the MN is the destination of data packets, it will initiate a modified hard handoff, such that data packets will be routed toward new BS.

5. Conclusion

In this paper, we proposed an integrated network architecture to extend the Cellular IP access network to multiple MANETs. We also proposed an integration protocol for connecting MANETs to Cellular IP access network and Internet, and support MANET nodes mobility between different MANETs. Based on the proposed Integrated network Architecture, we present all possible routing scenarios between MANETs nodes and between MANETs nodes and nodes in Internet. Integrating Cellular IP Access network with MANETs gives many advantages for both Infrastructure and MANET networks. The MANET nodes can access Internet and get a wide range of Internet services. MANET nodes can move to different MANETs with out losing the connection. Cellular IP access network can be extended to include dead zones and cover long areas. The number of base stations (access points) can be decreased. We are currently working in implementing and evaluation the proposed integrated routing protocol using network simulator ns2 and Columbia IP micro-mobility software (CIMS) [10].

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