Extensible Integration of Heterogeneous Wireless Networks with the Internet

Rafi U Zaman, Khaleel Ur Rahman Khan and A. Venugopal Reddy

Abstract--**Wireless networks have been found to be very useful in situations where a wired network cannot be instantly deployed. A lot of research has gone into establishing and maintaining such networks. To extend their usefulness, these wireless networks require connection with the Internet. Many solutions have been proposed which make use of Mobile Gateway to provide Internet connectivity to the wireless network. A problem with such schemes is the single point of failure associated with the Mobile Gateway. This paper proposes a solution for integrating heterogeneous wireless networks with the Internet and at the same time overcoming the problem of single point of failure associated with Mobile Gateway.**

Index Terms--**Cellular IP, Cell Switching, MANET, Mobile Gateway, Mobile IP, Mobile IPv6**.

I. Nomenclature

MANET: Mobile Ad Hoc Network
WLAN: Wireless Local Area Network

II. Introduction

WIRELESS networks are of two types. Infra structured wireless networks are wireless networks that are based on some existing infrastructure, like a base station or access point. The base station or access point acts as a gateway for the nodes in the wireless network. Nodes in an infra structured wireless network connect to a gateway. The gateway acts as a router and communication among the nodes can only take place through the gateway. These networks are usually deployed in historic buildings where the installation of a wired network can endanger the structure of the building.

On the other hand, Infrastructure less wireless networks, also called Mobile Ad Hoc Networks (MANETs) allow wireless mobile users to communicate with each other in the absence of communication infrastructure. They are usually deployed on a temporary basis, especially when installing an infrastructure network is not feasible. Each mobile host in the ad hoc network also serves as a router. They are usually deployed in Military and Emergency situations. Many protocols have been proposed for establishing and maintaining MANETs. A key issue is routing within the MANET. For a representative list of the routing protocols proposed for MANETs, refer [1]. On its own, a wireless network is of limited use. To extend its usefulness, a wireless network needs to be connected to the Internet. Mobile IP [2] is a mechanism which provides one-hop Internet connectivity for wireless nodes. Some of the solutions which work around Mobile IP to provide multi-hop Internet connectivity in MANETs are [3] [4] [5] [6] [7] [8].

A mobile node in a MANET can obtain Internet connectivity through the Foreign Agent (FA) in the Mobile IP in three ways. In the Proactive approach, the FAs periodically broadcast Agent advertisements into the MANET inviting requests for Internet connection. In the absence of Agent advertisements, mobile nodes can send out Agent solicitation messages, to obtain FA information. This is the Reactive approach. Some solutions use a combination of Reactive and Proactive approaches, called Hybrid approach. Unless and otherwise stated, Mobile IP refers to Mobile IPv4.

Several problems have been encountered in Mobile IP, most notable among them being the triangular routing problem and heavy packet loss during a cell switch. Mobile IPv6 [9] is a newer version of Mobile IP, developed to work with the IPv6 Internet and eliminates the triangular routing problem of the original Mobile IP. Some of the solutions that are based on Mobile IPv6 are [10] [11] [12] [13].

While Mobile IPv4 and Mobile IPv6 work at the layer 3 of the TCP/IP [14] protocol stack, Cellular IP [15] works at layer 2. It provides a micro mobility solution and avoids address reconfiguration when the mobile node moves with in the domain.

As shown in Figure1, Mobile IP is used between the Cellular IP Gateway (CIP) and the IPv4 Internet. Every mobile node has to register itself with a Base Station (B). When a mobile node moves from one cell to another, it registers itself with the new cell's base station. Cellular IP follows an elegant self-configuring hierarchical approach. In figure1, it can be observed that if CIP fails, all the base stations registered with it will be unable to forward packets to the Internet. Thus the CIP suffers from the problem of a single point of failure.

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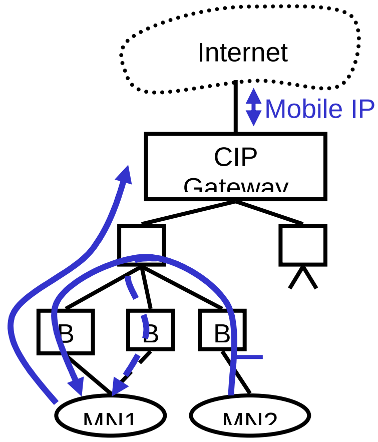

Figure1. Cellular IP.

The focus of this paper is on proposing a strategy that is based on Mobile IPv6 and Cellular IP, which provides a mobile node with the facility of roaming between MANET and WLAN (heterogeneous roaming) seamlessly and which is at the same time robust against a single point of failure.

The rest of the paper is organized as follows. Section III presents some of the related work that has taken place over the years in the area of Integration of MANET and Internet. Section IV presents the network architecture of the proposed scheme. Section V discusses the proposed protocol. Section VI concludes the paper.

III. RELATED WORK

♦ Broch et al [3] proposed a solution to the integration of MANET with Mobile IP. It makes use of Border Gateway with two interfaces. One is configured with the normal IP, which is connected to the Internet. While the other connected to the MANET uses DSR protocol to route packets within MANET.

♦ In the proposal of Jönsson et al [4], called MIPMANET provides Internet access to the mobile nodes by making use of Mobile IP with Foreign Agent and reverse tunneling concept. MIPMANET makes use of AODV protocol for routing of packets within the mobile nodes and the Foreign Agent. It makes use of MIPMANET Switching algorithm to decide whether a mobile node should change its Foreign Agent or not.

♦ Sun et al's proposal [5] makes use of AODV [16] and Mobile IP to enable Internet connectivity to Mobile nodes. AODV is used for routing within the MANET, while Mobile IP is used for assigning care of address to the Mobile nodes. Hand off occurs only if a mobile node has not heard for more than one beacon interval.

♦ Ratanchandani and Kravets [6], have given a hybrid scheme to provide Internet connectivity to the MANET nodes, using Mobile IP. The scheme uses techniques such as TTL scoping of agent advertisements, eavesdropping and caching agent advertisements to combine the advantages of proactive and reactive approaches to providing connectivity.

♦ Tseng et al's [7] proposal of the Integration and Implementation is based on IEEE 802.11b wireless LANs. Issues like overlapping of MANETs, dynamic adjustment of mobile agent's service coverage's, support of local broadcast and various communication scenarios are addressed.

♦ Habib Ammari et al's [8], approach of integrating the MANET with Internet is based on the use of mobile gateways. The mobile gateways use Mobile IP when communicating with the Internet and DSDV when they interact with MANET nodes.

♦ Common Gateway Architecture [10] uses a common gateway in the MANET in order to provide a uniform addressing scheme.

♦ The solution by Lamont et al [11] is aimed at providing heterogeneous roaming for a mobile node across MANETs and WLANs.

♦ Bayer et al [12] also provide a solution for heterogeneous roaming by providing each mobile node with two interfaces.

♦ Cabrera et al's [13] solution does not involve a dedicated gateway in the MANET. One of the nodes in the MANET is configured to act as a gateway.

IV. NETWORK ARCHITECTURE

It is observed that among strategies discussed in Section II, those that are based on Mobile IPv4 suffer from the triangular routing problem and of packet loss during cell switching. Among the Mobile IPv6 based strategies, only Lamont et al [11] and Bayer et al [12] allow heterogeneous roaming. The network architecture of Bayer et al [12] is discussed below. The same network architecture is considered in this paper for the proposed protocol.

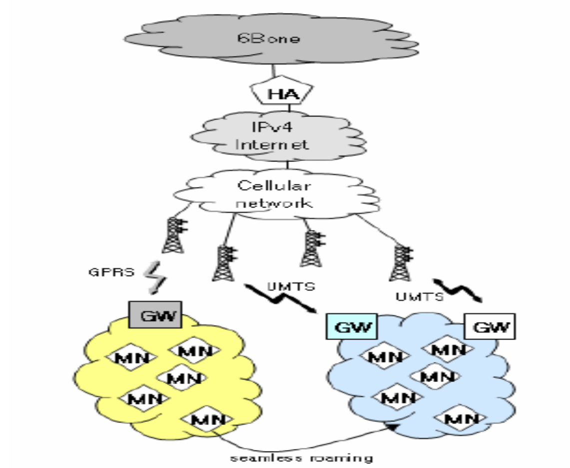

Figure2. Network Architecture of Bayer et al

A mobile gateway connects IPv6 based ad hoc networks over a cellular network with the IPv6 based Internet. The wireless network is IPv6 based. Tunneling is used to send IPv6 packets over the IPv4 infrastructure. Multiple mobile gateways are available within the same ad hoc domain wherein mobile nodes will always use the nearest gateway. Also, the breakdown of one gateway can be handled by switching to another one. This is possible only when the other mobile gateway is within the range of the mobile nodes. The mobility of the gateway offers scope for the entire ad hoc network to be mobile within the coverage area of the cellular network. This is a novel feature of this scheme.

Communication within a MANET is established using the AODV routing protocol. The mobile gateway establishes communication between the ad-hoc network and the cellular network by implementing the protocol stacks of both the networks.

The gateway discovery process can be reactive or proactive. In the reactive approach, an ad hoc node broadcasts the GWSOL (Gateway Solicitation) message into the MANET. When a mobile gateway receives the GWSOL message, it unicasts a GWADV (Gateway Advertisement) message back to the mobile node which contains the gateway information so that the requesting node can set up a route to the gateway. If multiple mobile gateways are available, the mobile node will receive multiple answers. Hop count is used to decide which gateway to use. Once a mobile gateway is selected, the mobile node initiates the address auto-configuration mechanism as per Mobile IPv6 in order to obtain an address with the prefix of the mobile gateway. The above process addresses the issue of roaming in the MANET domain.

In order to provide seamless mobility when a mobile node wants to roam from a MANET into a WLAN or vice versa, as depicted in Figure 3, the mobile node is equipped with two WLAN interfaces instead of one. At a certain instance, the mobile node can communicate over one of the two interfaces. The signal strength of the communication interface is continuously monitored. If it falls below a preset threshold, the other interface is set into scanning mode, in order to find other appropriate networks for a possible switchover. A new address for the second interface is configured using the address auto-configuration mechanism as soon as the first router advertisement from the new network is received. While the second interface is being configured, the mobile node can keep receiving packets over the first interface, at the same time ignoring router advertisements over this interface. Binding updates are sent to the home agent and correspondent node informing about the change in IPv6 address. After the binding updates are successful, the packets are sent to the mobile node over the second interface. The first interface is set to idle mode.

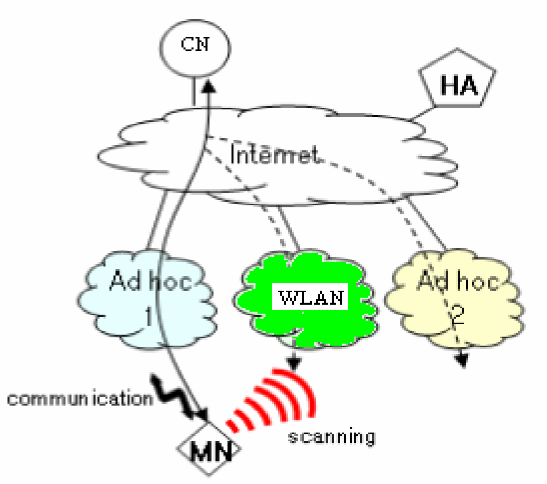

Figure3. Seamless Roaming Scenario in Bayer et al.

V. EXTENSIBLE HETEROGENEOUS INTEGRATION PROTOCOL

Consider a situation in figure2, wherein, the mobile gateway of the yellow cloud is unable to forward packets into the Internet due to the loss of signal. It is still available to service the MANET nodes registered with it, but cannot do so due to the signal loss. The MANET nodes can broadcast GWSOL messages to see if they are within range of another mobile gateway. If they receive GWADV from another mobile gateway, they have to again register with this new mobile gateway and send binding updates to their respective home agents, which results in unnecessary overhead. On the other hand, if the mobile nodes do not receive a GWADV, there is no way they can obtain Internet connectivity. This situation depicts a classic case of single point of failure of a mobile gateway.

In our proposed approach, the mobile gateway which is available but unable to forward packets into the Internet due to the signal loss is called the Disconnected Mobile Gateway (DMG). Once a mobile gateway realizes that it has become a DMG, it broadcasts a GWSOLGW (Gateway Solicits Gateway) message. This scenario is depicted in figure4. When a MANET node receives a GWSOLGW message, it simply discards the message. Only those mobile gateways that are connected to the Internet can process GWSOLGW messages. When a mobile gateway which is connected to the Internet receives a GWSOLGW message, it unicasts a GWADVGW (Gateway Advertisement for Gateway) message back to the DMG, so that the DMG can setup a route to the newly discovered mobile gateway. This newly discovered mobile gateway is called a Connected Mobile Gateway (CMG), since it is connected to the Internet. The restriction in the above scheme is that the DMG and CMG should be only one hop away. The DMG registers with the CMG.
Now, for each mobile node that was registered with the DMG, the DMG obtains a new address from the CMG. In effect, the nodes which were under the DMG become the logical members of the CMG. The mobile nodes send binding updates to their respective home agents. Therefore, from now onwards, the DMG acts as a proxy mobile gateway for its mobile nodes.

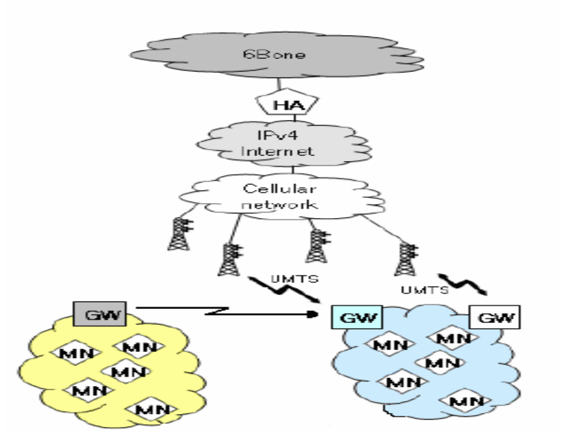

Figure4. GWSOLGW Message.

After the address configuration is successful, the mobile nodes under the DMG can send and receive packets through the DMG and CMG. In this way, the functionality of CMG is extended to the disconnected MANET under the DMG, hence the Extensible Heterogeneous Integration Protocol.

VI. CONCLUSION

In this paper, a simple scheme for overcoming the single point of failure associated with a Mobile Gateway has been proposed. Future work can consist of simulating the proposed protocol to observe the overhead associated with the implementation of this scheme in the network architecture of Bayer et al.

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VIII. BIOGRAPHIES

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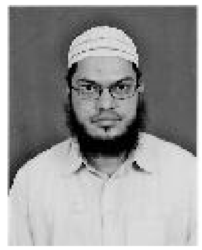

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