**INTRODUCTION**

Initial concept of mobile ad hoc networks (MANET) goes back to 1970s when DARPA’s packet radio project was started with the aim of establishing communication among various wireless terminals in the battlefield. Most of the research in this area is related to routing protocols and performance of isolated ad hoc networks, i.e. where terminals only communicate with some other nodes that belong to the same network. However, the development of new services that require the connection to external networks such as the Internet has extended this idea.

An initial step for the integration is the inclusion of an Access Router that also acts as the interface between the wireless medium and the wired network. However, in the IPv6 context, the introduction of a router is not sufficient as connecting MANET terminals to the exterior requires taking into consideration several technologies. Firstly, the mobile nodes need a global IPv6 address in order to be reachable from external networks. To ensure the Internet hierarchical scheme, an entity must be responsible for providing the necessary information to allow mobile nodes to configure an IPv6 address appropriate to the network topology. This functionality could be associated to a dedicated entity, as in DHCP, which provides the IPv6 global address to all the terminals within a specific domain under its control [1]. Although this strategy has been proposed in several mechanisms, it possesses a principal drawback: its demand for additional equipment (a centralized entity) that restricts the scenarios where MANET could operate [2] [3] [4] [5].

An alternative to DHCP is stateless auto-configuration mechanism where the Access Router periodically notifies all the prefixes that it processes by means of the diffusion of Router Advertisements (RA messages) [6]. Those terminals that need a global IPv6 address concatenate a random value, for example the EUI-64 MAC identifier, to the prefix it is going to use [7]. As this operation does not ensure the uniqueness of the address as in the previous strategy, the mobile nodes should initiate a Duplicate Address Detection (DAD) to confirm that the selected address is unique [8] [9].

The reception of RA messages also allows mobile nodes to know the domain where they are placed. When a terminal detects changes in the RA messages it assumes to be moved to another domain. Consequently, it initiates the correspondent procedures to continue the on-going sessions. In the IPv6 context, the Mobile IPv6 technology specifies the procedures to communicate meanwhile changes in the point of attachment are present [10].

**2. Related Work**

In the IPv6 context, one of the earliest references for Internet connection was due to R. Wakikawa et al. [11]. This mechanism, often called global connectivity, is based on a fixed Gateway attached to each access router that provides globally routable addresses to the ad hoc nodes. Some other authors have provided interesting work based on this mechanism [15] [16].
On the other hand, C. Jelger et al. proposed a mechanism where gateways are responsible for the auto configuration of global addresses by sending periodic messages that inform about its existence as well as the prefix it processes [12]. As multiple gateways may coexist in the same ad hoc network, the nodes may receive multiple autoconfiguration messages originated at different gateways. In order to avoid an excessive load, a mobile node does not forward all of them, but, based on some criteria, it will choose one gateway and it will send its updated message. By this method, mobile nodes can have a continuous path to the Gateway where all of nodes that compose the path share the same prefix.

In the previous solutions Gateways are understood as fixed elements. One of the first mechanisms where mobility is attached to the Gateway was published by H. Ammari and H. El-Rewini [17]. They proposed a three layer implementation. The first layer corresponds to the wired backbone and fixed routers. The middle layer is composed of all the devices that are one hop away from the elements of the first layer and finally, in the third layer the rest of the nodes are included. In the middle layer Gateways may coexist. In this mechanism some of the MANET nodes can act as Gateways. They can move but they are restricted to not leave the coverage area of the access router. Through simulations they show the performance of this mechanism is related to the number of mobile gateways as well as their maximum speed.

Finally, S. Ruffino and P. Stupar have proposed the use of multiple fixed gateways to provide access to the Internet [18]. These elements periodically announce their prefixes through special messages so that nodes receiving this information generate the corresponding IPv6 addresses even if they are not going to use them immediately. As nodes possess IPv6 addresses appropriate to all the gateways in the MANET, they can dynamically change the global address that they utilize for their external communications if, for example, one gateway is not operative any longer.

3. Mobile Multi-Gateway mechanism

The mobile multi-gateway support is intended to simplify the restrictions associated with the integration of MANET into external networks in heterogeneous scenarios. It is based on the transfer of Gateway functionalities to a MANET node, characteristic that avoids the pre-installation of a dedicated Gateway. Therefore, the scenarios where MANETs can operate increase. The mechanism is useful for coverage area extensions in cellular networks where mobile nodes belonging to the same ad hoc network communicate among them without the use of the deployed network.

However, the communication with external host requires the use of a MANET node acting as the Gateway that is not controlled by the telecommunication operator. On the other hand this support is also appropriate for automotive scenarios where a vehicle temporally connects to a petrol station or to an UMTS access and it performs the Gateway functionalities for some other vehicles [19]. In both situations the gateway can freely move. The method of selecting the node to operate as Gateway as well as the treatment associated to its mobility is the main characteristics of this mechanism. In the following section these procedures will be described. It is worth noting that the implementation of the mechanism shows the lack of certain specifications in the IETF Draft. In order to overcome it, several changes are proposed along the following explanation.

4. Analysis of Different Internet Connectivity Proposals for MANETs

When the Ad Hoc network is interconnected to an IP network, mobile nodes in the Ad Hoc network need global addresses to communicate with the Internet and node mobility should be properly dealt with [21,22]. Especially, when mobile nodes move to another area, their subnet changes and a new IP address must be obtained. Several solutions have been proposed to deal with the integration of MANETs to the Internet. Most of the proposed solutions require the addition of gateways and differ in the design and functionality of the gateways, number of occurrences, and the routing protocols used within the Ad Hoc network. Since Internet gateways have two interfaces they are part of the Internet and the Ad Hoc network simultaneously. They understand the Internet protocol (IP) as well as a MANET routing protocol (e.g. AODV).

Mostly, the existing approaches consider only fixed gateways to connect MANET nodes to the wired Internet. We briefly discuss solutions for both fixed Internet gateways and mobile Internet gateways [28].

4.1 Fixed Internet Gateway Approaches

Bin et al. [23] proposed an adaptive gateway discovery scheme that can dynamically adjust the TTL value of Agent Advertisements (GWADV messages) according to the mobile nodes to Internet traffic and the related position of mobile nodes from Internet gateway with which they registered. This protocol provides Internet access to MANET mobile nodes using mobile IP [14,31]. The protocol uses foreign agents to track and forward packets to and from mobile nodes. Foreign agent periodically calculates the average hops conveyed by RREQI message or registration request sent by mobile nodes requesting Internet connectivity. So the broadcast radius of Agent Advertisements can be adjusted dynamically according to real time demand for the Internet access and the factual network conditions.

Ratanchandani et al. [24] proposed a hybrid gateway discovery approach to discover gateways that limits the effects of broadcast overhead. AODV and two Mobile IP [14,31] foreign agents are used to interconnect MANET and the Internet. However, the TTL of the foreign agent’s advertisements is limited to only a few hops. Thus, only mobile nodes that are close to one of the foreign agents receive the agent advertisements. Nodes that are further away have to solicit advertisements reactively. Intermediate nodes are allowed to reply on a solicitation with agent advertisements and to eavesdrop and cache agent advertisement information that is sent by unicast to the requesting mobile node. The performance of this approach depends on the Time-To-Live (TTL) value, which is set for a particular scenario and network condition under considerations. In order to switch between foreign agents, the MIPMANET Cell Switching algorithm [21] is used.

Hamidian et al. [27] gave a solution, which provides Internet connectivity to Ad Hoc networks by modifying the AODV routing protocol. An “I” flag is added as an extension to AODV RREQ and RREP to locate the fixed node. If after one network-wide search without receiving any corresponding route replies, the mobile node assumes that the destination is a fixed node, which is located in the Internet and thus delivers the packets through a gateway.
Three methods of gateway discovery for a mobile node to access the Internet are provided: proactive, reactive and hybrid approach. All of them are based on the number of physical hops to gateway as the metric for the gateway selection. Rosenschon et al. [13] proposed a proactive gateway discovery method in which gateway periodically sends HELLO messages that contain a special option called PROAGW option. This option has all information about the gateway that is needed to set up a route to it. All Ad Hoc nodes that have received the PROAGW option can add the option to their own hello messages. If multiple gateways are available, then mobile node receives multiple answers. The Ad Hoc node has to decide which gateway it should use. For selection of best Internet gateway, parameters that can be considered are hop count, congestion, overload, available bandwidth, delay etc. In both approaches, the MANET is flooded with routing messages. Sun et al. [25] discussed the performance of the integration of the Ad Hoc On-Demand Distance Vector (AODV) routing protocol and Mobile IP [14,31]. It presents a method for enabling nodes within an Ad Hoc network to obtain Internet connectivity when one or more nodes is within direct transmission range of a foreign agent or more specifically an Internet Gateway/Access Router. In their approach, an Ad Hoc network is connected to a foreign agent, which basically has the same functionality as an Internet gateway (IGW). Internet Gateway assigns a global prefix for the Ad Hoc network, which makes it possible for mobile nodes in Ad Hoc network to communicate with Internet. While AODV is used for route discovery and maintenance within MANET, Mobile IP [14,31] provides mobile nodes with care-of addresses.

However, handoff occurs only if a mobile node has not heard from its foreign agent for more than one beacon interval, which is the time between two successive agent advertisements, or its route to a foreign agent has become invalid. Broch et al. [26] proposed a solution for the integration of MANET with Mobile IP [14,31] using a source routing protocol. They introduced a border router, which has two interfaces. Routing on Internet gateway’s interface internal to the Ad Hoc network is accomplished using dynamic source routing (DSR) protocol, while its interface connected to the Internet is configured to use normal IP routing mechanisms. Mobile nodes in an Ad Hoc network are assigned home addresses from a single network. The nodes within range of the foreign agent act as gateways between the Ad Hoc network and the Internet.

As a reactive approach, foreign agent discovery is only done when required. Traditional IP routing is used on the Internet side while within MANET DSR protocol is used. Foreign agents are responsible for connecting the Ad Hoc network with the Internet.

4.2 Mobile Internet Gateway Approaches

In [30], Ammari et al. proposed a mobile gateway based on three-layer approach using both Mobile IP protocol and DSDV Ad Hoc routing protocol (Fig. 7). The first layer contains Mobile IP foreign agents; the second layer includes mobile gateways and mobile Internet nodes, which are one-hop away from Mobile IP foreign agents; the third layer has all MANET nodes and visiting mobile Internet nodes that are at least one-hop away from mobile gateways. The second layer is to provide Internet connectivity to MANET nodes and, thus, to help establish interaction between MANET nodes and the Internet. Mobile gateways are powerful MANET nodes and are designed in a way to use both Mobile IP protocol when they communicate with the Internet. The DSDV protocol is used for routing within the MANET. The integration framework considers using some border MANET nodes to connect the rest of MANET nodes to the Internet. These MANET nodes are referred as mobile gateways. A mobile gateway selects a closest and/or a least loaded foreign agent based on the distance and the load criteria. MANET nodes select a closest and/or least loaded mobile gateway.

Khan et al. [20] proposed a new approach for integrating MANET with the Internet by devising a protocol named Efficient DSDV (Eff-DSDV). The proposed framework uses one of the Ad Hoc mobile nodes as a Mobile Internet Gateway (MIG), which acts as a bridge between the two networks. The MIG runs the EffDSDV protocol and takes care of the addressing mechanisms to ensure the transfer of packets between MANET and Internet. This strategy does not require the flooding of the gateway advertisements for registration of mobile nodes with MIG. Ad Hoc routing protocol EFFDSDV and Mobile IP coordinate with each other to provide the connectivity. EFFDSDV follows the conventional DSDV, however it reduces the packet loss due to broken links.

Fig 7. Three layered mobile gateway based architecture

CONCLUSIONS AND FUTURE WORKS

In this paper, we analyzed Internet connectivity of MANETs via fixed and mobile Internet gateways and pointed out limitations in the existing approaches. It provides a good insight to the research community for further modification and review.

There are many challenges in the integration of MANETs and the Internet such as mismatches regarding their infrastructure, topology and mobility management mechanisms. Based on the results of this work, we believe that an interesting future research topic is the work on adaptive and mobile Internet gateway discovery mechanism.

In this paper we have given the critical review of various key techniques existing so far for MANETInternet interconnectivity and Internet gateway discovery. The gaps in the existing works have been identified and highlighted as and where needed.

REFERENCES

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