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A Survey of Hybrid Routing Protocol for Interconnecting Mobile Ad Hoc Network and Internet

G. Ramesh[1*], M. Geetha[2]

[1,2]Dept of Computer Science

[*]*Corresponding Author: phdmangau@gmail.com*

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***Abstract*—** Mobile node is a collection of mobile nodes which forms a temporary network. Some of the nodes in an ad hoc network may want access to an external network, such as internet. Different mechanisms have been proposed to integrate MANETs and the Internet. These mechanisms are differing based on gateway discovery mechanism, and Adhoc routing protocol. When MANET is connected to the Internet, it is important for the mobile nodes to detect an available gateway providing an access to the Internet. The objective of this paper is a survey on the Mobile Ad-hoc Network (MANET) routing protocols used in gateways. This article presents a survey of hybrid solutions for integrating MANETs with the Internet.

***Keywords*—** MANET, AODV, DSDV, Gateway, Routing, Hybrid protocol, OLSR

I. INTRODUCTION

A mobile ad hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure. Some of the nodes in an ad hoc network may want access to an external network, such as Internet.

Ad hoc networks can be connected to an external network such as Internet to facilitate the users with the resources provided by the external network. The routers, or one or more nodes in the ad hoc network, called gateways, connect the rest of network with the external network.

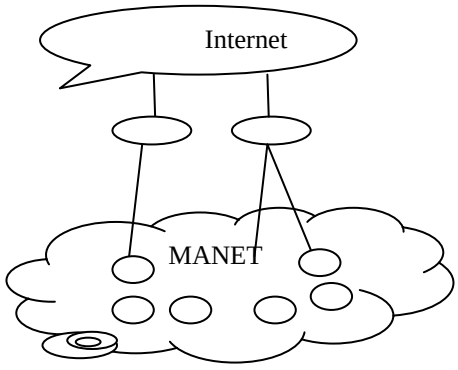


Fig. 1. MANET with Internet Connectivity

Integration of MANETs to the fixed infrastructure IP access network has many usage scenarios, and it provides many advantages for both Infrastructure and MANET networks together. MANET users can access the Internet and access a wide range of Internet services and applications. Because of the limited coverage of MANETs, integration of MANETs with the fixed infrastructure IP access network can increase this coverage.

Integration of MANETs with the fixed infrastructure IP access network based on IP mobility protocols enables MANET nodes movement between different MANETs without losing the connection. It can provide mobility support between different non-overlapping and overlapping MANETs with multiple gateways.

This article presents a survey of hybrid solutions for integrating MANETs with the Internet. The aim of serving as a quick reference for current research issues in Internet connectivity to mobile ad hoc networks based on Mobile IP protocol. A comparison of the solutions for integrating MANETs with the Internet is presented.

A number of gateway routing protocols have been designed for connecting MANET with Internet, and these protocols can be broadly categorized into three classes: proactive routing protocols (e.g. DSDV, OLSR) ,reactive routing protocols (e.g. AODV, DSR) and hybrid routing protocol .

In the proactive solutions, agent advertisement messages are broadcast by gateway nodes and forwarded to the whole ad hoc network. The agent advertisement message is used for gateway discovery, creating default route, movement detection, and handoff decision based on number of hops.

In the reactive solutions, mobile nodes initiate route discovery so as to look for the gateway node. Mobile nodes send a route request message, or an agent request message, to find the gateway node and route to it. It uses invalidate route entry for movement detection and initiates gateway discovery.

In the hybrid solutions, both the proactive and reactive gateway discovery approaches, and a combination of the proactive and reactive approaches, are used. This kind of integration uses flood-periodic agent advertisement messages to announce the presence of the gateway nodes, and uses agent request messages or the agent discovery procedure by mobile nodes to discover the gateway nodes.

In section I overview of the MANET discussed , in section II hybrid routing protocols discussed and in section III the performance of hybrid protocols are evaluated and the section IV shows summary of hybrid routing protocol and in section V conclusion has been derived from the above analysis.

A. Overview of Mobile Ad hoc Network (MANET):-

A mobile ad hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure. A mobile ad-hoc network (MANET) is a self-configuring network of mobile routers connected by wireless links.

Some of the main features of MANET are

a) MANET can be formed without any preexisting infrastructure.

b) It follows dynamic topology where nodes may join and leave the network at any time and the multi-hop routing may keep changing as nodes join and depart from the network.

c) It does have very limited physical security, and thus increasing security is a major concern.

d) Every node in the MANET can assist in routing of packets in the network.

e) Limited Bandwidth & Limited Power.

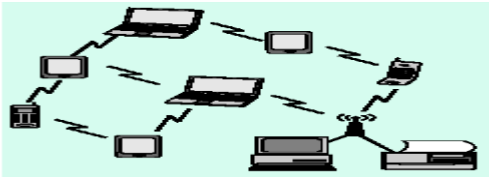


Fig. 2. Mobile Ad hoc Network (MANET)

II. OVERVIEW OF HYBRID ROUTING PROTOCOL

In the hybrid solutions, both the proactive and reactive gateway discovery approaches, and a combination of the proactive and reactive approaches, are used. This kind of integration uses flood-periodic agent advertisement messages to announce the presence of the gateway nodes, and uses agent request messages or the agent discovery procedure by mobile nodes to discover the gateway nodes.

B. Ad Hoc Networking with Mobile IP(ANETMIP):-

This enables mobile computers to communicate with each other and access the Internet. An adaptation for Mobile IP protocol is proposed. The proposed adaptation makes the FA to serve a mobile node, which is out of communication range. A modified Routing Information Protocol is used to handle the routing inside the ad hoc network. A Mobile IP Protocol is used to handle the routing outside the ad hoc network.

Mobile IP was designed to have foreign agent and the visiting node on the same link. When Mobile ad hoc networks have link-layer connectivity, packets to the visiting node are forwarded by the foreign agent using the link-layer address to the visiting node. In an ad hoc network, the foreign agent visiting node might not have link-layer connectivity, but instead have to use multi hop communication. Thus, when applied to an ad hoc network, Mobile IP must rely on the network routing protocol used in the ad hoc network for routing packets between the foreign agent and the mobile node.

Advantage Of ANETMIP :-

This protocol use RIP protocol for routing the information with in the ad hoc network. The main advantage of RIP protocol is preventing the routing loops between the nodes.

Disadvantage of ANETMIP:-

RIP routers do not support the ability to variably subnet the network using different mask lengths. This greatly limits the ability to conserve IP addressing space within a network.

2. Mobile IP for Mobile Ad Hoc Networks (MIPMANET)

In "MIPMANET — Mobile IP for Mobile Ad Hoc Networks" a solution for integrating ad hoc networks to the Internet based on Mobile IP is proposed. This solution is proposed to provide mobile nodes in ad hoc networks with access to the Internet and the mobility service of Mobile IP. The FA is used as an access point to the Internet. The AODV routing protocol is used to route packets between the FA and the ad hoc nodes. When a new node wants to access the Internet, it registers with the FA using its home address. The mobile nodes in the ad hoc network tunnel the packets to the FA in order to send them to the Internet.

The FA simply sends any packet coming from the Internet to the mobile node in the ad hoc network. Routing the packet inside the ad hoc network is based on the ad hoc routing protocol used, which in this case is AODV. MIPMANET uses the route discovery mechanism of the AODV routing protocol to search for the destination. If the route to destination is not found within the ad hoc network, the

mobile node establishes a tunnel to the FA according to the FA default route the mobile node registers with.

Advantage of MIPMANET:-
Mobile node selects the foreign agents based on minimum hop count. So it reduces the delay time between the node and foreign agent.

Disadvantage of MIPMANET:-
With in the ad hoc network the AODV protocol use single path between the nodes. So it creates the overhead problem.

3. Global Connectivity For Ipv4 Mobile Ad Hoc Networks (GCIPV4MANET):-
In this protocol the Ad hoc On-Demand Distance Vector (AODV) Routing protocol can cooperate with the Mobile IP protocol such that mobile nodes within an ad hoc network, which are out of direct transmission range of a foreign agent, can obtain a care-of address and register with the foreign agent to obtain Internet connectivity. Mobile IP is used for mobile node registrations with a foreign agent, while AODV is used for routing within the ad hoc network and for obtaining routes to the foreign agent.

Once a MANET node has a care-of address, it may send data packets to destinations in the Internet by routing through the foreign agent Global connectivity is required for mobile nodes to communicate with the fixed Internet. However, routing protocols for ad hoc networks typically only maintain routes within the ad hoc network, and hence do not provide a way to utilize an access point to the wired network when one is available. In particular, mobile nodes that are multiple hops away from a foreign agent are unable to utilize that foreign agent for obtaining a care-of address and global connectivity.

Advantage of GCIPV4MANET :-
It enables the MANET to obtain Internet connectivity. In this a mobile node outside the FA transmission range can get a COA and connect with the Internet through other hops in the MANET. It can roam to another MANET subnet without disconnection using Mobile IP.

Disadvantage of GCIPV4MANET:-
This protocol use AODV protocol for transferring the packet with in the ad hoc network. In this protocol route discovery within the ad hoc network is accomplished through AODV's route request/route reply discovery cycle. So it will create overhead problem.

4. Internet Connectivity for Ad Hoc Mobile Networks (ICAMANET):-
This protocol enables the nodes within an ad hoc network to obtain Internet connectivity when one or more nodes within the direct transmission range of an Internet gateway. In this protocol, the Mobile IP and AODV routing protocols can cooperate to discover multi hop paths between mobile nodes and foreign agents. These paths allow nodes that are multiple hops from a foreign agent to gain Internet connectivity.
In addition, it describes a method for duplicate address detection, whereby a node can obtain a unique co-located care-of address when a foreign agent is not available for the assignment of care-of addresses.

Advantage of ICAMANET:-
To enable multi hop Internet connectivity, the proposed method utilizes the AODV routing protocol for the discovery and maintenance of routes within the ad hoc network. The mobile node in the ad hoc network can obtain Internet connectivity through Access point instead of Gateway.

Disadvantage of ICAMANET:-
Flooding the message between the node create the overhead. With high node mobility, route changes happen more frequently, and hence there are more route discoveries for the foreign agent within the ad hoc network.

5. Mobile IP And Ad Hoc Networks: An Integration And Implementation Experience (MIPANETIIE):-
In integration of a MANET with the Internet is proposed. In this integration, one-hop wireless networks are extended to multiple MANETs. Every MANET is served by an FA (access point), and it represents a subnet of the Internet. The proposed architecture consists of multiple MANETs connected to the Internet using different access points called gateways.

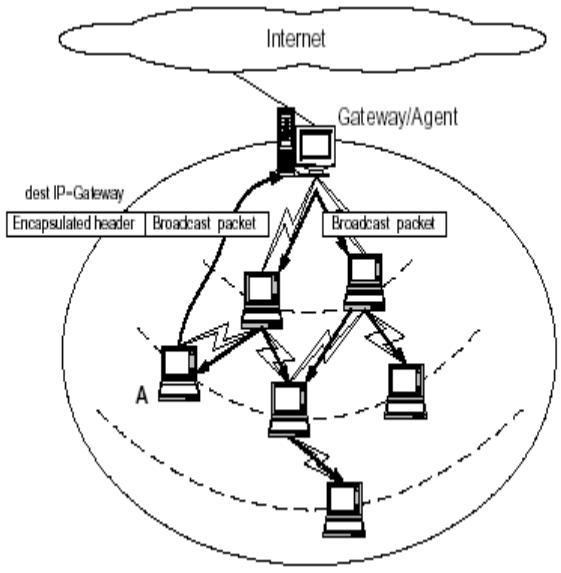


Fig 3. Intra- and inter-MANET routing
The Intra MANET communications are supported by DSDV. In the DSDV protocol, hosts will exchange routing

information periodically and compute the next hop to reach the destination with the least metric (such as hop count). Proper route entries will be written into the kernel routing table by system calls. So whenever a route entry leading to the destination is found, the packet is directly forwarded to the next hop.

The Inter-MANET communication (with Mobile IP): A MH may roam away from its home network. In this case, Mobile IP will be involved to forward packets between MANETs. In the transmission from CH to D in Fig. 3, packets will arrive at G4 by IP routing. These packets will be encapsulated and tunneled, by Mobile IP, to G3, which will then forward them to D by DSDV. To support such scenario, MHs have to monitor any existing AGENT ADVERTISEMENT. Registration and deregistration procedures in Mobile IP should be followed. The routing of these packets will be supported by DSDV. HAs should maintain the current locations of its MHs. FAs should maintain the visiting MHs in their MANETs. HAs should execute proxy ARP for roaming MHs.

Advantage of MIPANETIIE:-
With in the MANET the DSDV protocol is used. No node in MANET sends any Request information. So it reduces the overhead between the nodes.

Disadvantage of MIPANETIIE:-
It use single path between the nodes. It also use single gateway for interconnecting MANET and INTERNET.

6.Global Connectivity For Ipv6 Mobile Ad Hoc Networks (GCIPV6MANET):-
This method enables MANET nodes to communicate with the fixed Internet. The connection between the MANET nodes and the Internet is through nodes called Internet-gateways, which are connected to the Internet using a wired interface and connected to MANET using a wireless interface. This protocol has two methods to enable MANET nodes to find the Internet gateway and obtain the global prefix information, so that the MANET node can generate a global IPv6 address, which is used for sending/receiving packets from/to the Internet.

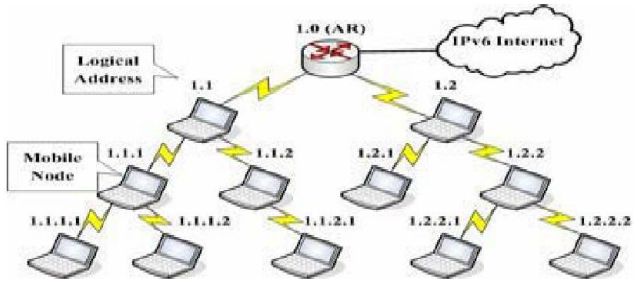


fig 4. IPv6-based MANET framework with global connectivity

Advantage of GCIPV6MANET:-
IPv6 is supported on MANET such that each mobile node automatically configures its global IPv6 address and connects to the global Internet via an access router.

7.A Hybrid Approach To Internet Connectivity For Mobile Ad Hoc Networks (HASICMANET):-
It enables the MANET nodes to obtain Internet connectivity using Mobile IP. The FA periodically broadcasts agent advertisement messages. The agent advertisement messages are flooded in the MANET in an n-hop neighbor. Any node, n hops far from the FA, can receive up-to-date information about the FA. Mobile nodes more than n hops away from the FA and wanting Internet connectivity broadcast a request message to discover the FA. The intermediate node, which receives a fresh agent advertisement message and has a correct route to the FA, can reply to the mobile node with a unicast advertisement.

Advantage of HASICMANET:-
To reduce flooding overhead due to Request, the Expanding Ring Search Method is used.

Disadvantage of HASICMANET:-
The Number of Registered Nodes increase means the overhead is also increases. Because of unicast.

8.Dynamic Mobile IP Routers In Ad Hoc Networks(DMIPRANET):-
The basic idea in the integration is using Mobile routers as a gateway between the HA and ad hoc mobile nodes. It is assumed that gateways (mobile routers) in the ad hoc network are multi-interfaced. One interface is connected to the cellular system and the other connected to the ad hoc network using the ad hoc routing protocol. The mobile router sets up tunnels to every mobile node for which it is serving as gateway, and another tunnel to the HA using second interface.

Advantage of DMIPRANET:-
This protocol allows mobility of gateway router and multiple gateway routers. The Mobile router set up the bidirectional tunnel to the mobile nodes. It eliminates looping between the mobile nodes using tunneling process.

Disadvantage of DMIPRANET:-
Each node is connected to each Mobile Router. So it requires more Mobile Router.

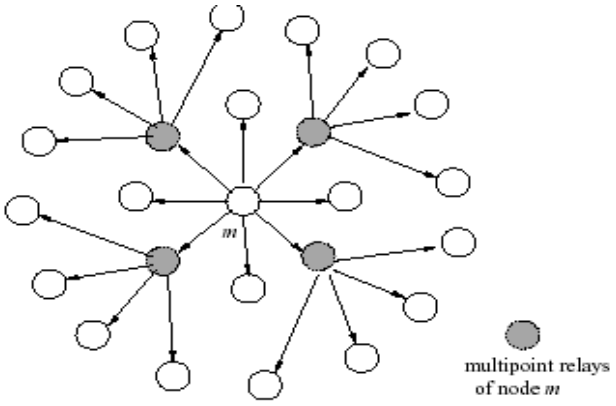
9. Integration Of Mobile-IP And OLSR For Universal Mobility(INTMIPOLSR):-
Hierarchical mobility management architecture is proposed and used to interconnect MANET nodes to the Internet. The access network of the proposed integrated network architecture is called OLSRIP access network. This

optimization is based on the concept of multipoint relays (MPRs) .First, using multipoint relays reduces the size of the control messages: rather than declaring all links, a node declares only the set of links with its neighbors that are its "multipoint relays". The use of multipoint relays also minimizes flooding of control traffic. Indeed only the MPRs of a node forward control messages received from this node. This technique significantly reduces the number of retransmissions of broadcast control messages OLSR is characterized by two types of control messages: neighborhood and topology messages, called respectively Hello messages and Topology Control (TC) messages. Indeed OLSR provides two main functionalities: Neighbor Discovery and Topology Dissemination.

Advantage of INTMIPOLSR:-

MULTIPOINT RELAYS:-

A node N selects an arbitrary subset of its 1-hop symmetric neighbors to forward data traffic. This subset, referred to as MPR set, covers all the nodes that are two hops away. The MPR set is calculated from information about the node's symmetric one hop and two hop neighbors. This information is extracted from HELLO messages. Similar to the MPR set, a MPR Selectors set is maintained at each node. A MPR Selector set is the set of neighbors that have chosen the node as a MPR. Upon receiving a packet, a node checks its MPR Selector set to see if the sender has chosen the node as a MPR. If so, the packet is forwarded, else the packet is processed and discarded.



Multipoint relays of node m.

Disadvantage of INTMIPOLSR:-

The information about the entire network need to be maintained at all times, OLSR requires relatively much storage complexity and usage. Hence, there is a greater demand for storage capacity of nodes in such networks. Also, the control overhead adds to the necessary processing in each node, hence increasing the battery depletion time. Another downside to OLSR is that it must maintain information about routes that may never be used.

III. PERFORMANCE OF HYBRID ROUTING PROTOCOL:-

The performance of hybrid protocol is evaluated based on gateway discovery method, packet transmission and addressing.

1. Gateway Discovery :-

ANETMIP uses two methods for gateway discovery. ANETMIP discovers the gateway either by listening for agent advertisement broadcast by the FA, or by sending an agent solicitations message. We can observe that the ANETMIP gateway discovery methods are a modification to the mobile IP agent discovery methods, such that the agent advertisement message or the agent solicitation message can travel more than one hop to reach the mobile node or the FA.

In ICAMNET and GCIPv4MANET , two methods are used for discovering the gateway. In the first, the mobile node can learn the FA and its IP address from the periodic agent advertisement messages. In the second, the mobile node issues a route request of the AODV for the "All Mobility Agents" multicast group address. We can observe that the first method is a modification of mobile IP and the second method is a modification of the AODV routing protocol.

MMTHWMN uses a reactive approach for gateway discovery. The mobile node sends AODV route request with an IPv6 multicast address ALL-BS and, based on the protocol operation mode, the base station's response to the route request along with beacon packet.

MIPANETIIE uses the same gateway discovery procedures used in ANETMIP ,but in MIPANETIIE , the mobile node sets the destination field to the all-routers multicast address 224.0.0.2 in the multicasts agent solicitation in order to find a nearby mobile agent. MIPMANET uses the same methods used in ANETMIP for gateway discovery, which are a modification to mobile IP agent discovery methods.

In HAICMANET , three methods are used for discovering the gateway, either by monitoring any agent advertisement message and recording the address of the FA, or by broadcasting agent solicitation to discover an FA, or a combination of the first and second.

In IntMIPOLSR two methods are used for discovering the gateway, either by receiving a periodic agent advertisement message from OLSR-GW, or by sending agent solicitation message. The IntMIPOLSR uses the OLSR routing protocol to handle the broadcasting of agent advertisement and agent solicitation messages inside the access networks, so that the gateway discovery broadcast overhead is less than that of other proposals. DMIPRANET uses two methods for gateway discovery, either through sending a solicitation message requesting agent (gateway) services, and then

receiving the agent advertisement message, or by waiting for the periodic agent advertisement message.

In ICFIANET , the gateway discovery is totally based on the modification to the MANET routing protocol , a host broadcasts DSDV advertisement to its neighbors, in order to establish routing table, so that a mobile node and an FA automatically know each other's presence via routing update of EDSDV protocol.

In GCIPv6MANET , two methods for gateway discovery are used. The first uses an extended route discovery messaging of on-demand routing, and the second uses an extended router solicitation and advertisement of the Neighbor Discovery Protocol (NDP). In CGAMANET, the gateway address is preconfigured in mobile nodes. Another method uses AODV with any of the gateway discovery procedures.

2.PACKETS TRANSMISSION:-

In MIPMANET , the mobile node lets the route discovery mechanism of the ad hoc routing protocol search for the destination before it can decide whether or not the destination is within the ad hoc network. Then it simply tunnels packets to the FA.

In GCIPv4MANET ,the mobile node discovers the route to external destination either by using route created using FA_RREP from the gateway node, or if the route to destination is not discovered within the MANET, the mobile node uses path created using agent advertisement message.

In MMTHWMN , the mobile node uses AODVv6 route discovery to search for the destination; if it is not found, it initiates route discovery and sends RREQ with an IPv6 multicast address ALL-BS. When the base station receives the RREQ packet, it replies with the RREP packet, which establishes the route from the mobile node to the base station or to the Cellular IPv6 gateway. The mobile node utilizes the IPv6 routing header for sending data packets.

In ICFIANET , the mobile node checks its routing table. If the route entry is found, packets will be forwarded inside the ad hoc network. If the route entry is not found, the mobile node checks the route to the FA. If the route to the FA is found, packets will be forwarded to the FA gateway towards the Internet; otherwise, the packets will be discarded.

In HAICMANET, the same procedure as in MIPMANET and ICFIANET is used. If no route reply is received except FA_RREP, the mobile node discovers that the destination is located outside the MANET. Then, the packets are encapsulated and routed to the FA. Also, the agent advertisement message is used to set up the reverse route to the mobile node.

In MIPANETIIE, if the destination address is not listed in the kernel routing table, the packets will be forwarded to the gateway.

In DMIPRANET, if the destination address cannot be reached using ad hoc routing, the packets will be forwarded using tunneling to the mobile router. It can be observed that MIPMANET , HAICMANET , and DMIPRANET use the idea of tunneling for data packets transmission inside MANET toward the external destination. In IntMIPOLSR ,routes to each node are immediately available for all destinations in the access network, and these routes are computed with Dijkstra's shortest path algorithm.

In ANETMIP ,the mobile node searches its kernel routing table. The kernel IP code looks up the matching route entry. If the selected route entry carries an RTF_INDIRECT flag, the IP will have to do another look up for the indirect gateway returned in first look up. The second look up returns the link-layer address of next hop, which is used for packets transmission.

In GCIPv6MANET , if mobile node does not have a route to the destination host, it sends a route request for the destination. If a reply is not received and a default route exists, the node uses the default route for packet transmission to the destination.

In ICAMNET, there are two ways for destination route discovery and packets transmission, either using the route created from FA_RREP, or if the route to destination is not discovered within the MANET, the mobile node transmits packets to the FA using the path created by using the agent advertisement message.

In CGAMANET, the mobile node has the ability to distinguish external address from the internal address. Then, it broadcasts the route request to establish the route to gateway using standard AODV operation.

3. ADDRESSING:-

In GCIPv4MANET , the mobile node uses its home IP address in its home network as in Mobile IP, and it gets a globally routable IP address CoA on the visited network. The CoA in GCIPv4MANET can be obtained in one of the following three ways:

- From an agent advertisement message
- By issuing an agent solicitation message
- By acquiring a collocated CoA

But in HAICMANET , every node has an arbitrary address, which is used within the MANET, and it uses the CoA acquired from the FA for external communication.

In MIPMANET , the mobile node that wants Internet access has a home IP address that is valid on the Internet, and this home address can be used on the ad hoc network as well. In

MMTHWMN , a mobile node uses a collocated CoA that it is formed from network prefix in the Cellular IPv6 beacon.
In MIPANETIIE , every node should have two address: a home IP address and a CoA as in Mobile IP. IntMIP OLSR uses the same addressing as in MIPANETIIE .The every mobile node has two IP addresses, a home IP address and a CoA. The CoA is the IP address of OLSR-GW.
In DMIPRANET , a mobile router connects to the Internet using a global IP address, and the mobile node uses a collocated CoA that it acquires for use on their WAN interface and uses its home address in the ad hoc network. For ICFIANET every node should have a routable IP address, a home IP address that is used for routing inside MANET, and an FA address that is used as a CoA for every visited mobile node.
In ANETMIP, every node has a home IP address, which is used for communication with a host in the Internet or a host inside MANET, as in Mobile IP. In GCIPv6MANET , the mobile node gets the global prefix information of the Internet-gateway and uses it for configuring a routable IPv6 address.

IV. SUMMARY OF HYBRID ROUTING PROTOCOL

A summary of the Hybrid Integration Routing Solutions characteristics and design issues is given in Table 1 and Table 2.

Table 1. Summary of the hybrid integration approaches.

Hybrid Approaches	ANETMIP	MIPMANET	GCIPv4 MANET	ICAMNET	MIPANETIIE
1. Micro-Mobility support	No	No	No	No	Yes
2. Gateway Discovery	2 Method	2 Method	2 Method	2 Method	2 Method
3. Tunneling	No	Yes	No	No	No
4. Movement Detection	Receiving Agent advr. from new FA.	MIPMANET Cell switching Algorithm	As in MIPv4	Receive agent adv. from new FA	As in MIP
5. Handoff decision	Shortest distance	MIPMANET Cell switching Algorithm	As in MIPv4	If MN has not received agent Adv. From registered FA.	Shortest distance
6. Ad hoc Routing	Modified RIP	AODV	AODV	AODV	DSDV
7. Routing between MANET nodes and Gateway	According to a modified RIP	Using tunneling	Normal IP forwarding	Standard IP	forwarding Based on DSDV routing

V. CONCULSION

This survey reflects advantage and disadvantage of possible hybrid gateway routing protocols. The reviewed protocol has some merits and demerits depend on the user approach. The user can able to choose and use the required protocol based on their requirements. In future the hybrid routing is evaluated based on several metrics.

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