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Review Article
MANET-internet Integration Architecture

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Abstract

Desire to connect various portable devices such as laptops, PDAs, smart phones etc with internet at anytime, anywhere and any how lead to the development of wireless networks. Mobile *ad hoc* networks (MANETs) consists of such devices, which are portable in nature such as laptops, mobile phones or personal digital assistants for initiation of communication. A large number of ongoing research and development in the area of MANET is constrained to the single networks and stand alone. Mobile *ad hoc* networks require the interconnection with internet because a broad range of services and applications rely on wired infrastructure networks now-a-days. Therefore, there is a necessity that *ad hoc* networks should have access to wired networks along with their services. This interconnection of MANET and internet enhance the plasticity of networking and improve the infrastructure network's coverage area. Many solutions have been proposed by researcher for this integration, but which solution among these are comparatively better is still vague. It is mandatory for a node of *ad hoc* network to discover and select the most appropriate internet gateway in order to achieve the access to internet. This study focused on the various issues and challenges of internet integration along with the different proposed solutions on gateway discovery and issues associated with them.

Key words: MANET, *ad hoc* networks, mobile IP, gateway discovery

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INTRODUCTION

MANETs[1] are the combination of mobile nodes that are unable operate in an environment consist of centralized infrastructure or organized connectivity. Each of the mobile node has many component such as battery, radio signal generator interfaces. There are many different ways by which these node can perform mutual communicate together like bluetooth or radio wave signals. Further, topology and diameter of *ad hoc* network changes from static and small to large, mobile and highly dynamic ones. Multiple hops are required to establish a data transmission between source and destination due to limited transmission range of the mobile nodes.

All mobile nodes are operated as routers and should be capable of discovering and meanwhile keep maintaining appropriate paths, to distribute packets correspondingly. Several protocols for routing[2,3] are presented for MANETs. Augmentation in mobile devices and advancement in wireless technology has lead to infrastructure-less networking, getting an attention with the expanding count of various applications. Normally, *ad hoc* network is appropriate in every situations where an interim communications are required or where the deployment of infrastructure network is costly, inconvenient or both. Such kind of network enables the mobile wireless devices to persist association with network therefore, provides flexibility for convenient integration of devices with a network. Many applications for MANETs[2,4] are there: Crisis-management applications, military operations and network based on wireless sensor. Its major drawbacks are the narrow range of applications, its draining and limited battery power, bandwidth and wireless coverage area. Beside these limitation one of the main concern is it's dynamic topology, which needs a greater amount of attention. Wireless system of fourth generation (4G)[5,6] considers global access for users who are willing internet integration via various heterogeneous networks and want to retain global connectivity without aborting or disrupting their current ongoing communications. The connectivity should be maintained independent of their movement from one to another type of network or with the change in routes to the gateways change from where their packets relay. Figure 1 depicts the integration of various networking technologies. In such scenario, connectivity and communication can be maintained with a fixed node on wired network by the mobile users which are able to run all above technologies, independent of node movement. MANET internet integration or IP based network avails a lot of benefits for MANETs and infrastructure networks[7]. Figure 1 depicts the integration of different networks[8].

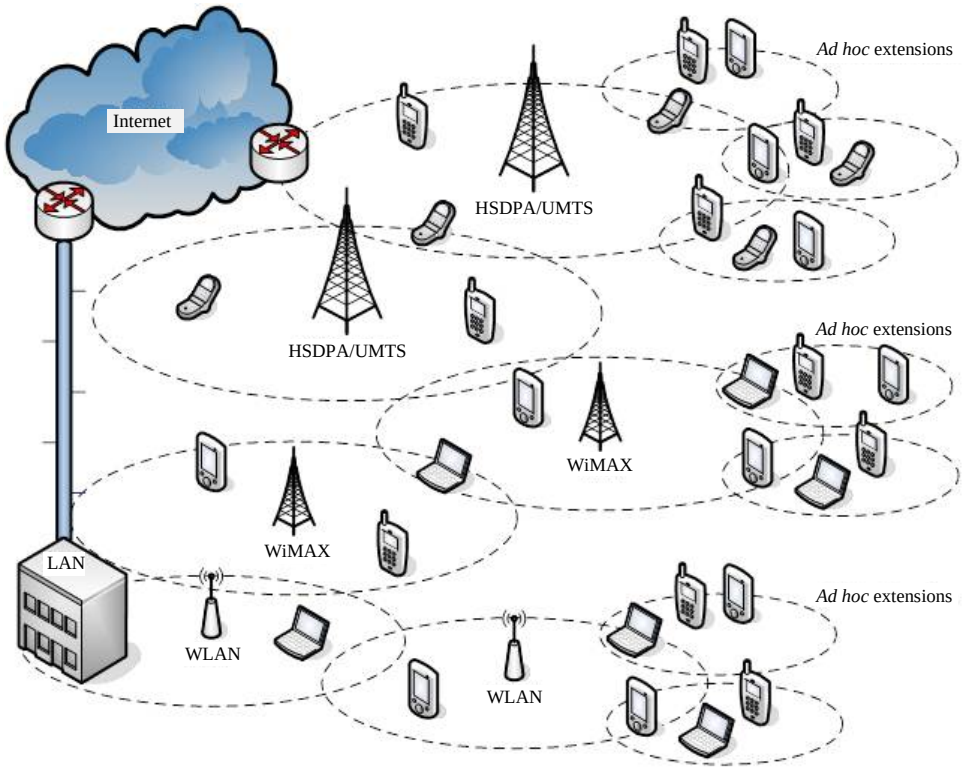

Fig. 1: Integration of MANET with various networks

Users of MANET can gain internet access and a broad variety of application and running on it, improve the wireless coverage area, enables the mobility of mobile nodes among MANETs regardless of break in connectivity and it provide feature for node mobility among different MANETs in presence of multiple gateways.

These kinds of integration of heterogeneous networks is known as hybrid MANET. It could be employed very conveniently. Its applications are wireless interactive classrooms, meeting by conferencing and discussions, vehicular function in roadside, processing of complex and real time information at airport and the trains.

DIFFERENT COMMUNICATION NETWORKS AND UNDERLYING PROTOCOLS

The flexibility and complexity of integration thoroughly depends on the internal mechanism of the various networks. Each network has a different set of protocols for routing and data transmission. Further, the protocols of different wired networks are have some degree of similar but very dissimilar from the wireless protocols and vice-versa. In a wired network, the protocols vary at data link layer and network layer as compared to wireless network. So, due to this heterogeneity of protocol, integration of these networks with MANET can only be done by a networking device called as gateway. A gateway implements the protocols of different types and one to another. Figure 2 shows these networks along with their internal protocol. Figure 2 represents the taxonomy of various networks from which a MANET can be integrated.

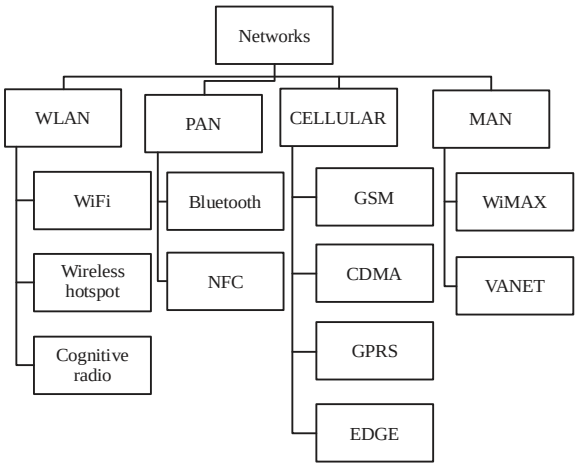

Fig. 2: Classification of various networks

Further, the protocols used by these network for routing and communication are also discussed. Table 1 lists these networks along with protocol implemented by them. As one can interpret that these networks have almost dissimilar protocol stacks than the MANET protocol stack. So this heterogeneity between them is a major issue in MANET-internet integration. To make enable a network to communicate with another one with different set of protocol, these networks have to connect through a specialized device called gateway[9].

INTERNET INTEGRATION OF MANET: BASIC PROVOCATIONS AND COMPETENCE

Achieving internet integration of MANETs are not possible without difficulties and complications[7,10]. So, to evaluate its performance, unification of *ad hoc* network with the internet should be attentively analyzed. The major challenges in this integration are: Routing, mobility, gateway discovery and selection, addressing, packet forwarding, handover and security. Figure 3 lists the various issues along with challenges for internet connectivity.

MANET and internet routing

Internet on routing: Internet routing is the task of figuring out the appropriate routes through which the network packets transmitted in a network. Architecture of the internet is based on the TCP/IP protocol suit.

Table 1: Protocols used by different wireless network

Network types	Protocol
Wireless fidelity (Wi-Fi)	IEEE 802.11
Wireless hot-spot (WSP)	IEEE 802.11u
Cognitive Radio (CR)	MSCRP
Bluetooth	LMP, L2CAP, SDP
Near Field Communication (NFC)	NFCIP, MiFARE ultralight, Topaz protocol
Global system for mobile communication (G.M.)	LAP-D, LAP-Dm, DTAP, BSSMAP, SCCP
Code Division Multiple Access (CDMA)	DTAP, BSMAP
General Packet Radio Service (GPRS)	SNDCP, IP, UDP, GTP
Enhanced data rates for GSM evolution (EDGE)	SNDCP, IP GTP,
Worldwide interoperability for microwave access (WiMAX)	IEEE 802.16
Vehicular *ad hoc* Network (VANET)	FSR, AODV, GPSR, GSR, VADD, GeDTN+Nav

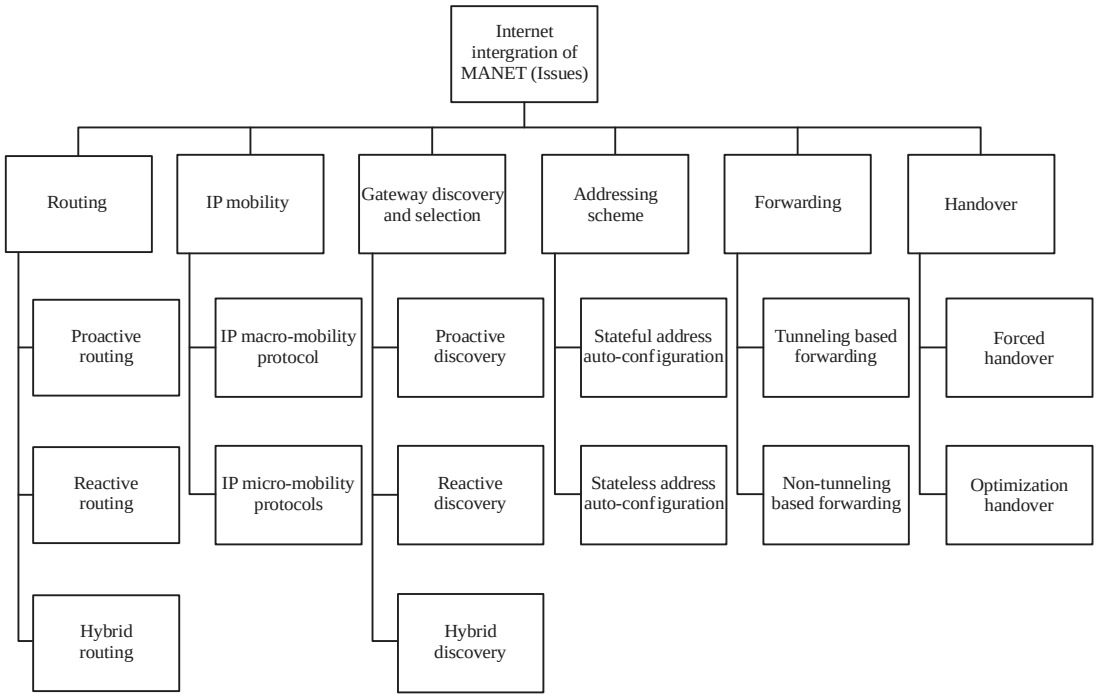

Fig. 3: Issues in MANET internet integration

Functionality of routing in the internet is the responsibility of network layer and based on IP address. Each IP address can be divided into two part, first is the network ID part, second is the host ID part. Routers are responsible for taking the decisions regarding packet routing depend on the network ID part of target IP address. So, within same network the IP addresses of various mobile nodes share common network ID, however, the host ID part of an IP-address identifies a specific host or node in that network.

MANET routing: The MANET routing has become a popular research topic in wireless *ad hoc* networks, gaining wide interest from researchers now a days[11,12,5]. In MANETs, the network topology may change dynamically because the mobile nodes are free to move anywhere. Consequently, in MANETs the task of routing prone to very difficult and complex. These *ad hoc* network routing protocols must be able to tackle frequent network changes therefore, routing protocols of conventional wired network are inoperable. Meanwhile, mobile radio interfaces provide limited bandwidth, so it's essential that measure of control traffic initiated by the protocols is stay as low as possible. These protocols, work dissimilarly than the traditional internet routing protocols because there is no involvement of central router. To solve the problem of routing, many MANET routing protocols[13] have been proposed in this field. According to their characteristics, these protocols are classified into three classes: Proactive i.e., table driven protocols, reactive i.e., on demand protocols[14] and hybrid protocols. In proactive routing protocols each node has at least one or more routing tables. These routing tables store many information related to routing regarding other mobile nodes in network. The main aim of these protocols to update information which belongs to routing table whether a certain time period or as a result of topological change in network for maintaining the consistency and updated information of routing. Each routing protocol implements unequal number of routing table along with various methods for broadcasting the routing updates and updating routing tables. The delay in updating routing table depends on how many such tables are associated to a node. The major benefit that these protocols have is that when an originator needs to initiate communication with another node they do not require a path discovery process to discover a path to desired destination, which is a reason of extra delay in initiating a connection. Information of paths towards destination is available by routing tables of nodes. One of the main pitfalls that these routing protocols have managing up-to-date, consistent and valid routing table needs significant overhead of control messages, which ingest battery power along with bandwidth and drops network throughput, especially when there is significant count of mobile nodes with high-mobility are present.

In the reactive routing protocols whenever initiator node contains packets of data to transmit to a target node, the initiator node initiates discovery of route to uncover the route for particular target. Once the route is located, a mechanism for maintenance of route is initiated to sustain previously uncovered route till the route obsolescence or target become unreachable. Less messaging overhead is the major advantage of these protocols. The drawbacks of these protocols are when two nodes willing to have communication with one another they encounters a delay in discovering a new path to destination node.

Hybrid protocols amalgamate convenience of reactive and proactive protocols. These protocols behaves as proactive protocol inside a limited area and as reactive protocol outside this zone.

Researchers of this field have coined a broad category routing protocols[3]. The fundamental motivation behind these protocols are for improving performance like maximize network throughput along with minimum loss of packet, overhead of control messages and battery power consumption.

Internet MANET routing: The mobile node is barely competent of managing mutual communication to the other side of the frontier in middle of MANET and internet because MANET nodes cannot acquire the parameter of routing beyond the boundary of MANET. So, interoperability among IP routing protocols and wireless *ad hoc* routing protocols necessitates attention[7,10]. Every interaction among MANET nodes and node inside the internet is done through a specialized networking device knows as internet gateways (IGWs). An IGW can acts as a bridge among various heterogeneous networks and provides mapping among there protocols. In order to bridge the dissimilarity between MANET protocols and internet protocols, gateways have to provide implementation of the MANET routing protocol suit and the TCP/IP protocol suite. Implementation of the both protocols, xed infrastructure internet and the dynamic MANET is provides by IGWs. It runs usual TCP/IP protocol suit on the internet side and it transmit packets using a MANET routing protocol on the MANET side, which assist them in acknowledging whether incoming packets though anyone interfaces should forwarded to the interface on other side or should stay local on incoming interface. Integrated connectivity utilizing reactive protocols have proven more challenging respect to proactive. This is due to the reason that reactive protocol neither keep entire routing information of complete network, as proactive protocol do, nor always have updated information. Whenever a mobile node willing to initiate communication process to wired node, it looks-up entire routing table to figure out a possible route information in direction of the target. Communication can be initiated if the desired route is available otherwise, initiator node perform a route discovery procedure.

IP mobility: The MANET have dynamic topology because all nodes have mobility in nature. This mobility of node can be divided into two levels, namely micro mobility and macro mobility based on whether the movement is intra-subnet within domain or inter-domains. A mobile node may be deprived of routing related information about an IGW from which it was initially connected, at any instance of time due to its movement. Therefore, in such scenario, progress communication associated with the roaming node with fixed node or with corresponding node belongs to internet, would be intervened. The IP mobility management protocols[15,16] may be utilized for integrating MANETs and internet together and facilitate intra domain or inter domain support for mobility to mobile nodes. Classification of these mobility protocols can be done in two classes: First is IP macro-mobility protocols, second is IP micro-mobility protocols. Figure 4 shows the architecture of IP mobility.

IP macro mobility protocols: The term macro mobility is stand for the node which can roam among two or more subnets in two heterogeneously dissimilar domains. These protocols were developed to tackle with the roaming of mobile node among disjoint domains and not losing the connectivity and disrupting ongoing communication. These IP macro-mobility protocols coupled along with IP packet routing mechanism to interconnect wired and wireless mobile networks which a basic property of these macro-mobility protocols. One of the best popular standard for IP mobility is mobile IP[1]. It is the most appropriate, thoroughly accepted and the quickly accepted method for macro-mobility support. The mobility protocols were introduced by Internet Engineering Task Force (IETF) for allowing the mobile node interact with corresponding node and roam independently among various subnets and still not suffers from disconnection. There are following two version of mobile IP namely, mobile IPv4 and mobile IPv6. Mobile IPv4[17] is contemporary approach to provide mobility for IP node in network based on IPv4. The each network which have mobile nodes and is based on IPv4 protocol is made up of three component:

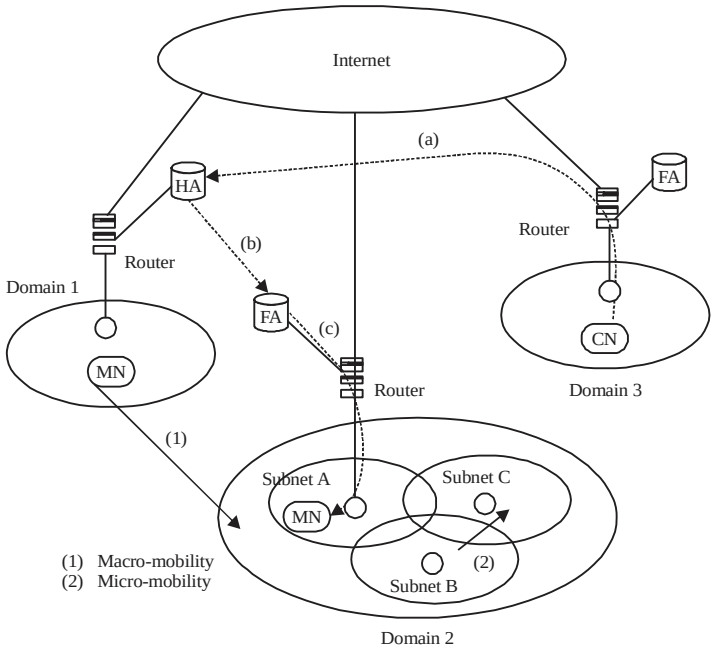

Fig. 4: Representation of IP mobility

- **Mobile Node (MN):** The term mobile node is used for a network router or host, which used to alter base station or access point in between two or more subnets but no any change in IP address which it was having at its home site
- **Home Agent (HA):** Each servers or routers located on the home network of mobile node normally termed as home agent. These agents get the entire packets which is designated to the home IP address of the mobile node and also, send them to the present point of connection even if the mobile node moves out of boundary
- **Foreign Agent (FA):** Outsider (foreign) network contains the router is called as foreign agent. Mobile node is seeing a particular FA and may dispense a network router for mobile node to convey information across a mobile node and home agent

Figure 5 shows the working of MIPv4. In this the roaming of a mobile node is represented from one subnet called A to another subnet called B. This architecture also shows packets routing. Further, an advertisement message from home agent and foreign agent broadcasted periodically. A node figure out its position that whether it is inside its home or has roamed into a different subnet due to its movement, with the assistance of advertisements of various agents. In case when a node required to discover an agent it can do it by sending a solicitation to agent. To start the handoff to the new subnet these nodes employ three mechanism for detection of movement (MDM)[1,17], Lazy Cell Switching (LCS), Eager Cell Switching (ECS) and Matching Prefix (PM). Whenever there is node roaming into a non-previous agent of mobility, roamed node achieves care-of-address inside the current roamed network either by utilizing centralized external entity for allocating care-of-address such as DHCP and this address is called centralized CoA or derive a CoA from the periodic advertisement by the agents. After this, a unique and special message is send by mobile node to HA, called request for registration, for registering new CoA for it. The information of mobile node is updated by HA through association of node's IP address with its CoA. After this, a message called reply for registration is send to the mobile node from home agent. This reply can be send either directly or via FA, depending upon the mechanism of acquiring CoA. Based on binding information, binding of CoA along with packet of tunnels together FA of mobile node is done by HA, which is established using registration process.

The major drawback of mobile IPv4 is that it suffers from handoff delay and overhead in task of signaling. Consequently, due to the above reason it is unsuitable to tackle the environment of micro-mobility. In order to overcome the drawbacks of mobile IPv4 several improvements have been proposed by researchers, for example, mobile IPv6[16] and MIPv4-RO[18]. Mobile IPv6 is an improvement for IPv6[19]. It enables IPv6 address based node to

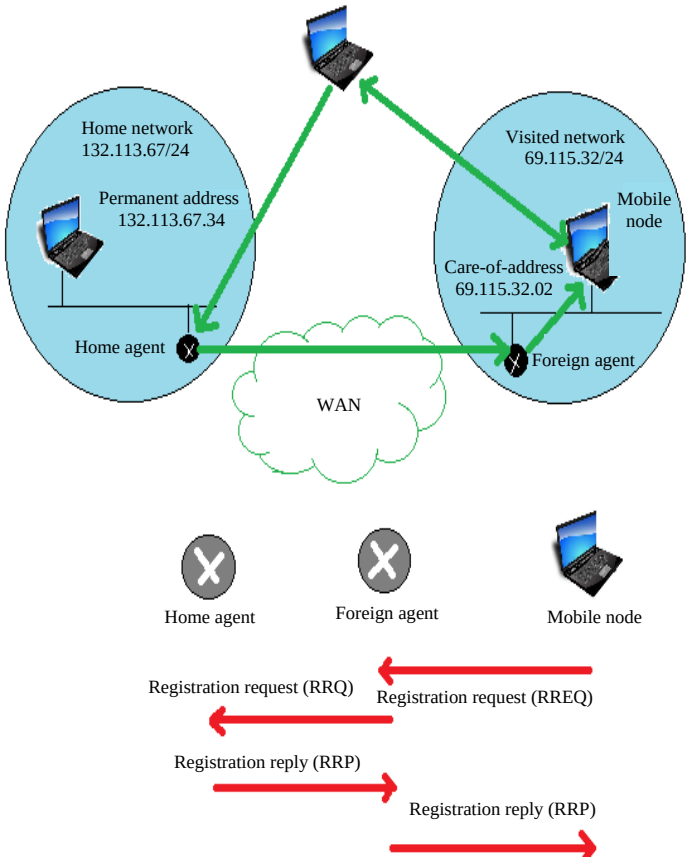

Fig. 5: Mobile IPv4 architecture

move from one IPv6 subnet to another without any change in its IPv6 address. It is developed on the basis of same architecture of mobile IPv4 along with the feature of IPv6. In mobile IPv6, uses IPv6 stateless address auto-configuration scheme or state full address auto-configuration such as DHCPv6[20] or PPPv6[21] for allocating the address to mobile nodes. This care-of-address has the network ID of the foreign subnet, so there is no requirement of a foreign agent in this case. Further MIPv6 defines two new option for IPv6 destination for establishing a connection by binding in the mobile node's HA and fixed or wired node. First IPv6 option is known as binding update option and second is binding acknowledgment option.

IP micro-mobility protocols: Within same domain, the roaming of the mobility of the mobile node among many subnets is termed as micro-mobility[15,22]. Standard mobile IP does not work in case where the changes is quit frequent, because of the too much overhead caused by its mechanism. Micro-mobility mechanisms is a convenient effort to minimize the handover delay, signaling and refrain communication with distant access points or servers. Different solutions in this area are provided which all work in an environment where a mobile node's access point is changed in the same network to access periodically and IP micro-mobility protocols deals with the roaming and provide fast and continuous handoff. Some of the example of such protocols is such as HMIP[4], EMA[17], HAWAII[23,3], TelMIP[24], cellular IP[25,26] etc.

Discovery and selection of gateway: In order to integrate a MANET node with internet it have to discover and select an appropriate internet gateways along with the lesser consumption of the too little network resources like bandwidth, battery power[27,28] etc. The delay in IGW discovery, control messages generated and handover hold-up have great influence on the performance metrics like, routing overhead, packet delay and throughput.

Discovering the internet gateway: The conventional MANET routing protocols only provides the feature of packet routing within the MANET and restrain from the functionality of discovering the internet gateways. Thus these protocols need

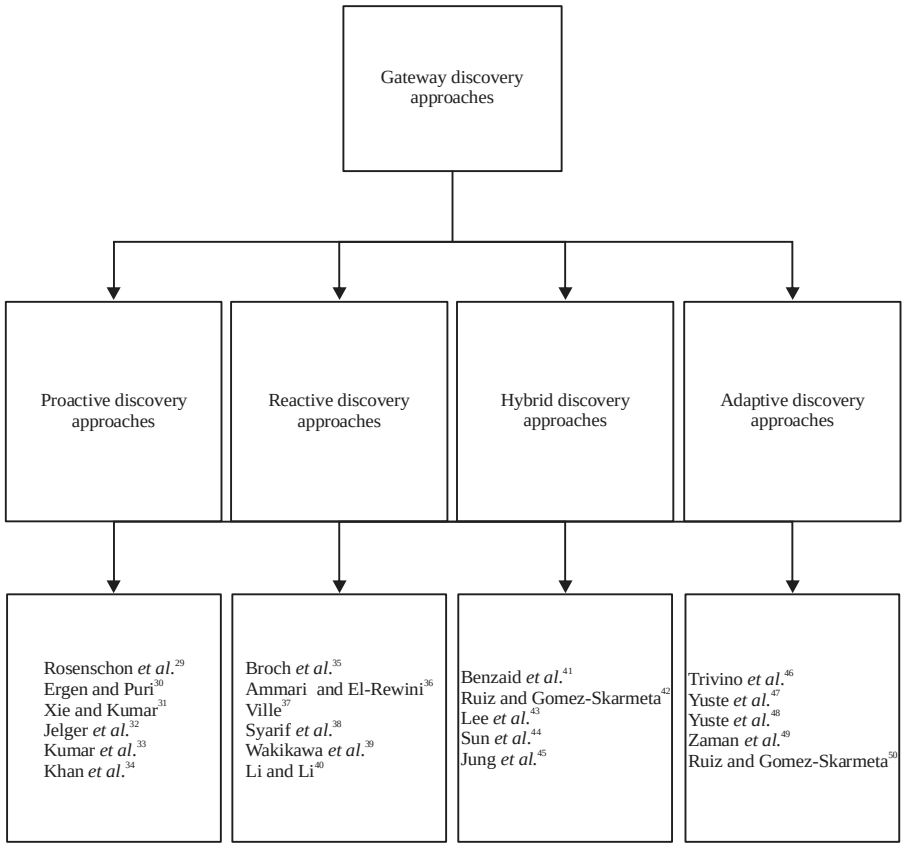

Fig. 6: Gateway discovery approaches

to get extended by adding extra procedures to support discovery process. These routing protocols can be extended by applying three methods to discover IGWs[20]. Figure 6 shows all types of discovery approaches is listed:

- **Proactive discovery approach:** In this discovery method, throughout the MANET, every IGW broadcasts advertisement periodically which is called the Modified Router Advertisement (MRA) messages. It contain the pre x address of IP. Mobile node which urge to communicate over the internet with fixed host traces this packet and the route entry is updated in the routing table for the internet gateway and then the message is rebroadcasted to all its single hop neighbor. The MRA periodicity must be select optimally so that the network is not saturated unnecessarily with the MRA messages. Low delay and good connectivity is achieved by the proactive discovery of gateway mechanism. Because this approach try to have updated routes to IGW all the time it incurs high communication overhead
- **Reactive discovery approach:** In on-demand or reactive IGW discovery a mobile node starts the discover process for an IGW when necessary. In this, the mobile node sends a Modified Router Solicitation (MRS) message which need to be forwarded via multiple hops by intermediary nodes until it reach IGW. Response to the solicitation message is send on receiving the MRS, the internet gateway unicast a route reply message to the source node of MRS its services along with address of IP pre x, so that mobile node which is requesting may configure route to the IGW and initiate the communication with corresponding node
- **Hybrid discovery approach:** This discovery approach utilizes the advantages of both previous internet gateway discovery methods. The mobile nodes in a particular radius[28] (also called advertisement or proactive zone) surrounding internet gateway with a definite value of time to live (TTL) uses the proactive internet gateway discovery method, but for all the mobile node staying away from this range uses the reactive internet gateway discovery approach to get details regarding IGW for discovering, connecting and communicating with it. The hybrid approach amalgamates the balance of the delay and control overhead in internet integration

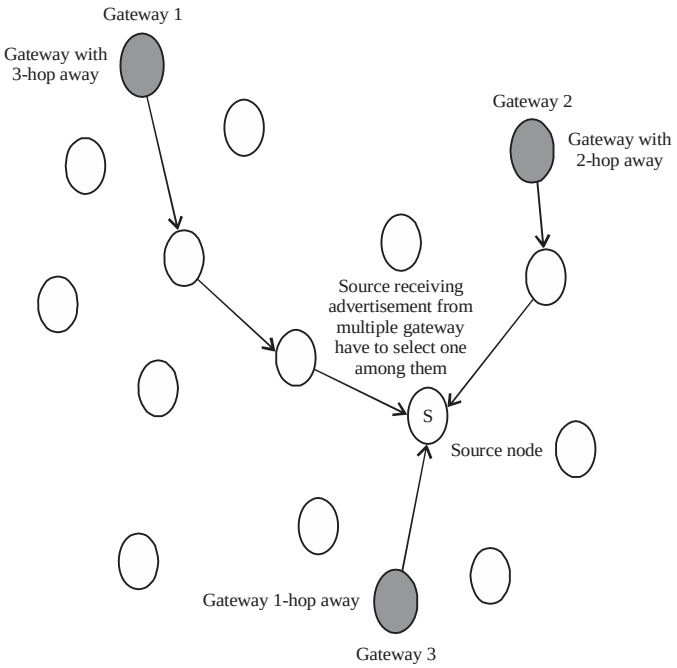

Fig. 7: Gateway selection scenario

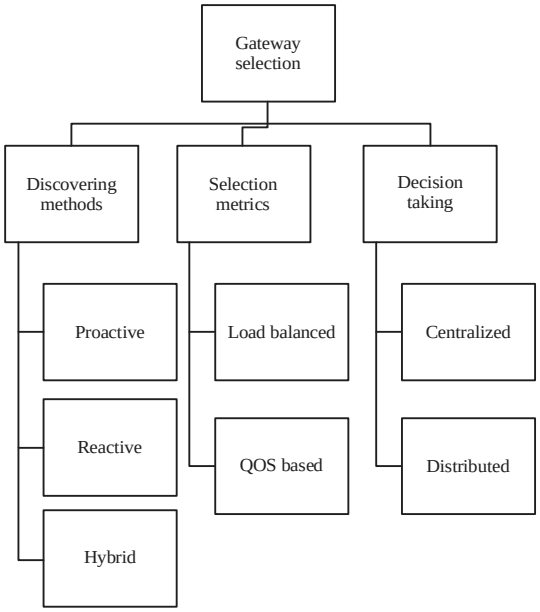

Fig. 8: Taxonomy of gateway selection protocols

Gateway selection: Selection of gateway comes into play where multiple IGWs are available to select[21,51]. Selection can happen either at the internet gateways level or the mobile nodes. Whenever a mobile node receives MRA from more than one IGW, it initiates the selection process and select the gateway with better quality of service. In the proxy approach[52], internet gateways can selectively reply depending on specific policies to route requests, such as, the announcement of the gateway parameters and services to each mobile node is not performed by the network operator, or when load on it crosses a predefined threshold value, the gateway might stop responding. In case where mobile nodes make decision regarding the selection of IGW, a direct approach is applied to choose the IGW which has the least hop count towards the IGW. To choose the most appropriate gateway, we can use other parameters along with hop count, like the traffic load recommended by gateway. It also might be case that mobile node selects a set of internet gateway for multi-homing or load-balancing[53,54]. Therefore, the method should aid forwarding to various IGWs singly. Figure 7 depicts the gateway selection scenario. Figure 8 shows the gateway selection method is classified based on different parameters.

Addressing: Allocation of IP addresses of mobile node is huge influence on MANET internet integration. It has a completely at addressing model unlike in the internet which uses fully hierarchical addressing scheme. This flat addressing approach makes the task of grouping the mobile node under a similar network prefix very difficult and making more complicates entry process of routing table.

After the IGW selection process, registration with the chosen internet gateway, sent all packet to this IGW require a SA with the exactly similar network pre x as once selected by the IGW. In order to configure an address which routable globally and topological correct, a mobile node requires a mechanism of address auto-configuration. For this purpose, IPv6 describes two basic methods for auto-configuration[19,55]. Stateful address auto-configuration and stateless address auto-configuration. Stateful auto-configuration has a pivot entity that is the server called Dynamic Host Configuration Protocol (DHCP) in the IGW, designate the IP address to the mobile nodes. Automatically, it allocates addresses to the requesting mobile nodes and handles their address space in a way such that each mobile node has a unique IP address. However, centralized approaches are not appropriate for MANETs because there might be partitions in network. In stateless address auto-configuration, every mobile node sets a global and unique IP address by itself. In this approach, the IGW announce a network pre x in its control messages to mobile node by which an IP address is derived. Including the information of auto-configuration to the internet gateway discovery messages reduced the extra overhead notably. Stateless auto-configuration has risk of allocation of identical addresses to mobile node within a particular network. A technique is used to detect these duplications known as Duplicate Address Detection (DAD)[37,44]. This can be performed by requesting the IP address of all mobile nodes within the network to check whether an address used already or not. The node get messages requesting derived IP address, then the reply is send to the initial node to inform about the duplicity and that it requires a stateless address which is new. Repeating the DAD procedure periodically avoid the duplications in the address spatially when a MANET with partition splits or merges. The control overhead is the major disadvantage of using this technique in MANET.

Handover decision by movement detection: The handover is performed by a mobile node if node alters its gateway while interfacing with corresponding node over internet due to mobility of the node. The decision of handover can be done by methods of detection of movement of mobile node. Handover schemes based on multiple hop can be classified into two categories:

- **Forced handover:** MANET is highly dynamic, so link breakage or failure is a general possibility. In such environment losing single communication link belongs to a multiple hop path to the internet gateway will initiate a process of handover to discover the paths towards new internet gateway. Since there are multiple routes from the starting mobile node to the selected internet gateway is a technique to avoid unnecessary handovers so that when a route is not linked, it uses the secondary route
- **Optimization based handover:** Whenever a mobile node detects an IGW with better quality of services than one from which it previously registered with, they starts handover process to new gateway[56]

Forwarding: This scheme for IGW in the MANET has vital role in the flexibility in connectivity of internet. Forwarding can be categorized into two types based on mechanism used in tunneling[7,57]: Tunneling is the first one and non-tunneling based are second integrated routing solutions which are as follows:

- **Tunneling based integrated routing:** In this method, the packets are routed for the nodes that are wrapped in an external IP header and sends to the internet gateway. Then, the IGW takes it out and using standard IP forwarding technique, packets are sent to its destination node. Inclusion of extra header leads to the notable overhead and this is the major drawback of this approach.
- **Non-tunneling based integrated routing:** The smallest path/route available is used in this approach. A route or path is considered as short route which minimizes some parameters like count of hops or delay in transmission. For performing the forwarding process two main approaches are there:
  - **Forwarding by host route:** From the source to the destination, the host route has the forwarding state which is distributed over the mobile node. A host route is normally a route within the MANET and until the destination resides the approach works well. In case, where internet is destination, the IGW may be included or excluded just like the other intermediary node towards the route. Thus, unless IGW itself is the destination it is impossible for last points to impose which traverses the host route IGW. This approach require a new route request for each internet destination and can find various IGWs for every destination of internet
  - **Forwarding by default route:** An entry in routing table referring to an internet gateway integrated with the internet is called as default route. It provides aggregation of routes and can to avoid making unnecessary route discoveries it reuse an existing default route when the determination of locality can be done directly

DISCUSSION ON VARIOUS MANET'S PROPOSALS

This study presents underlying characteristics of proposals for this internet integration. These proposals are categorized among three categories: Proactive IGW discovery, reactive IGW discovery and hybrid IGW discovery, respectively. Further, these presented approaches are classified based on previously discussed issues.

Proactive gateway discovery approach: Rosenschon *et al*.[29] proposed an approach for discovering gateway which is the modification in AODV protocol. In AODV HELLO packet is used the find the IGW. This approach used a modified HELLO message format. This also deals with the selection of the gateway in case when multiple gateways are broadcasting the advertisement or responding to solicitation message. For selecting the appropriate gateway among them mobile node use the hop count parameter as quality of service. This modified HELLO procedure has better performance in term of discovery time and messaging overhead but performance degraded sharply in case of handover.

Ergen and Puri[30] presented a solution for internet connectivity which is mobile enriched. It is based on wireless local area network architecture. This solution is an improvement to the mobile IP based solutions to MANETs. There are two different protocols called MEWLANA-TD and MEWLANA-RD, respectively. They utilizes the table driven and the route driven protocol of routing. For transmission of data packets from mobile node and foreign agent DSDV is used by MEWLANA-TD. The MEWLANA-RD utilizes the Tree Based Bidirectional Routing (TBBR) protocol. It is a special routing protocol where the routing table formed with the agent advertisement and the registration request messages and repeated on renewal of each registration. However, TBBR provides the low overhead at the cost of degradation in performance. The approach summed up that the MEWLANA-TD is appropriate for MANETs of small size and more internal traffic and MEWLANA-RD is appropriate for MANETs of huge in size and less internal traffic.

Xie and Kumar[31] proposed a modification in conventional DSDV protocol. This improved protocol provide obsolete link solution. This modification solves the problem, in case of high mobility of mobile node and increase the performance. This improved and modified protocol is called as enhanced DSDV (EDSDV) for MANETs. In proposed protocol, a short timed route is established messages which are only single hop and known as path request and path acknowledgment. The feature of internet connectivity is provided by this protocol. It amalgamate mobile IP with DSDV to provide bi-directional connectivity to internet. In term of performance is better than others by providing high enough throughput and low delay.

Jelger *et al*.[32] proposed an approach including the forward propagation of information, behavior of nodes and underlying format of message. These parameters combined to find the gateway and IP prefix for generating a globally unique IPv6 address for each mobile node in MANET. Further if it is necessary that the discovered route has to be maintained it use a default route to gateway so to internet. This approach has another advantage that it can deal with the more than one gateway even when they are broadcasting totally different IP prefix. Connectivity provided by this protocol is better than other ones but it has less scalability and more overhead.

Kumar *et al*.[33] proposed a proactive load-aware IGW discovery mechanism by analyzing existing load-aware routing protocols. This approach considered traditional min hop count and size of interface queue for the gateway selection. An efficient hand-off mechanism from one gateway to another has given. A protocol was suggested that converts the number of packets into the equivalent hop count without proper justification that may not provide exact traffic related information [N1].

Khan *et al*.[34] suggested an extended DSDV protocol, named as efficient DSDV (Eff-DSDV) for providing bi-directional connectivity between internet and mobile nodes[40]. A gateway used to integrate mobile nodes to the internet. Although this mechanism does not supports flooding of the gateway advertisement (GWADV) for registration of mobile nodes with gateway. Since in DSDV, with the exchange of routing tables complete topology information is available to every node in network and hence the gateway and the mobile nodes learn about their presence. This strategy outperforms over certain metrics like packet delivery ratio, routing overhead and end to end delay. Since only one IGW manages the MANET, if mobile node situated away from IGW then it has long latency communication. Along with this issue internet gateway can be overloaded with serving all mobile nodes. All mobile nodes are required to register with the internet gateway whether they use it or not. Due to topology change once a mobile node loses connectivity with the gateway then it cannot react adaptively. Over utilization of network resources due to continuously updation of routing table and flooding of internet gateway advertisement (GA).

Reactive gateway discovery approaches: Broch *et al.*[35] proposed a method in a multi-hop MANET which utilizes mobile IP and dynamic source routing protocol for heterogeneous network interface support. A real *ad hoc* network testbed is used for implementation and validation of this technique. Along with it, how this technique could be used to more general scenarios was also discussed. However, this approach is only suitable in a case where for detecting a mobile node that moves to the MANET for the first time. A mobile node cannot be reactively triggered to solicit a new IGW if it within the MANET loses the connectivity with the IGW from which it is registered currently. Also, only a single IGW is supported by its architecture in a MANET IP subnet and for internal and external destination distinguishing mechanism when moving nodes exist within the MANET is not considered. Additionally, they have not specified the procedure of mobile IP registration and the propagation of mobile IP signaling messages through multi-hops.

Ammari and El-Rewini[36] proposed a layered approach based on three-layer and utilizes both mobile IP and Destination Sequenced Distance Vector (DSDV) for the internet integration. In this, the first layer have mobile IP FAs, the second layer contains mobile internet nodes, which are single hop away from the mobile IP FAs and Mobile Gateways (MGs) and last layer has all MANET nodes and visiting mobile internet nodes that are at least single-hop away from mobile gateways. Mobile gateways increase the transmission range of the mobile IP FAs, consequently increase their availability and accessibility. The major disadvantage of this architecture is that it introduces unnecessary mediators among MNs and FAs.

Ville[37] proposed an approach for integration between cellular IPv6 along with AODVv6. It enables mobile node eligible to establish a communication with cellular IPv6 network. Operating mode of this approach is divided in two separate modes: First is proxy-enabled, which utilizes the traditional proxy mechanism of the internet to decrease the signaling amount and improve handover performance. Second is the proxy-disabled, which provides a more conservative approach. It allows each node to completely control all ongoing operations carried out of them. In this, AODV runs on base station and works like an access point for the mobile node. The mobile node starts a route a procedure for discovery procedure and cellular IP registration and controls the handover mechanism by sending a route update packet to the gateway of cellular IPv6 through the new base station. Integration of such type can be useful merely in small or medium size places.

Syarif *et al.*[38] proposed a new reactive gateway discovery protocol. This protocol is a modification in most efficient routing protocol AODV. This extended protocol is called R-AODV. It merge the two version of modified AODV together R-AODV[58] and AODV, introduced by Srivastava and Kumar[9]. In R-AODV protocol, a new message called reverse request for route replaces the conventional route reply message to forward back to source and all its neighboring node. Therefore, It generates multiple number of valid routes in direction of the source node. Availability of multiple route is very convenient in case where topology is highly dynamic and changing due to mobility. It minimizes the failed and broken link by using alternative links to source. This solution provides the mechanism of gateway discovery but the limitation is that it does not provide the other aspects of the internet integration.

Wakikawa *et al.*[39] illustrated the working set of AODV that can be used for integrating MANET and IPv6 based internet. The whole idea is based on detection of internet gateway that can distribute a global routable prefix for the MANET. However, only one gateway is available thus several mobile nodes use it simultaneously due to which heavy traffic congestion would occur near gateway. Researchers didn't perform movement detection and handover decision procedure.

It has drawback such that there is one IGW presents and hence heavy traffic may cause due to simultaneous use of the internet gateway. Along with this issue they have not considered handover decision technique and movement detection mechanism.

A dynamic gateway adaptive selection (MRBDAS) is presented by Li and Li[40]. The basic idea used by authors is group decision making approach which implements the methods of multipath and query localization based on old path information to maintain adaptive routing. It considers gateways load degree, connecting degree, residual energy and movement rate synthetically. Candidate gateway nodes are basically MANET nodes and also called dynamic gateway nodes when they have chosen for executing gateway function. Another node which is a decision node is a special internet node that is able to select suitable gateways and routes. Calculation of node speed imposes additional cost which may limit the applicability of the work. The main drawback in the proposal of Li and Li[40] is that obtaining the speed of a node imposes additional cost which can limit the work applicability.

Hybrid gateway discovery approaches: Benzaid *et al.*[41] proposed an architecture for providing an extension in

mobility. This architecture is hierarchical in nature and integrates protocols for micro-mobility management with the MANET. Further, this architecture is interconnected with the networks based on infrastructure and internet. One of the good feature of this solution that it provides multi-hop wireless connection with this architecture relies on the IP. It uses OLSR protocol for this integration because OSLR along with the proposed architecture fulfill the requirement of a network based on full IP which is the one of future requirement. But this protocol is used in case where only one gateway is available for mobile node and their range and cannot deal with the multiple gateways. Another issue with it is if mobile nodes are located far away from the gateway in terms of hop count, they suffer from long latency.

Ruiz and Gomez-Skarmeta[42] proposed the modelling of gateway discovery analytically. Further they used the model for presenting a solution which is hybrid of this approaches called hybrid discovery of gateway in hybrid *ad hoc* networks. Their hybrid solution considers a hybrid topology based network along with a reactive routing protocol AODV for connecting with internet. In proposed analytical model, they evaluated the other discovery approaches and conclude that most of the previously presented solution are poor in performance as the number of active node, which are willing to connect with internet increases and not provide better performance. In this a new gateway discovery approach which is adaptive in nature is proposed by them. This algorithm is known as "Maximal benefit coverage". This approach provides modification in to parameter on which the discovery time depends. It has adjusted the advertisement periodicity along with the TTL value in a way that determined by the network scenario. So, this provides better internet connectivity and keeps it maintain even if the topology changes. However, the observing the changes in topology is based on some assumption so it is not possible to measure network changes very accurately and sometime it seem not feasible to measure these changes. This solution has an overhead of continuously evaluating change in topology and become inefficient when node are too many hops away from the internet gateway.

Lee *et al.*[43] proposed a gateway discovery approach. This approach utilizes the best of the proactive and reactive discovery approaches called hybrid gateway discovery. Comparison of this solution is done with the some reactive discovery approaches. For this purpose, proposed solution uses a protocol based on routing by source DSR in MANET. Sending of advertisement depends upon the topology of MANET and a new advertisement have to send whenever a change in topology is detected by gateway. Further, the advertisement messages are not simply broadcast advertisement to all the nodes, it only considers the node which are moved due to mobility and connected to internet. This is an adaptive approach because advertisement timer adjusted with the change in active source and forwarded advertisement ratio. The problem is that, it is based on a routing protocol with is source oriented and this limits the scalability of use.

Sun *et al.*[44] presented an approach in which they make possible to interconnect the mobility protocol which is mobile IP and a reactive routing protocol AODV. This solution provides internet connectivity for those node which are not in range of foreign agent and cannot achieve the advertisement message. It also deals with the duplication of IP addresses while working in a stateless addressing scheme and also suggest the use of DAD for allocating unique CoA when FA is not present and advertisement message has the information of routing. So, when a mobile node get the advertisement message, along with it node achieves the route to FA. But in this approach they have not discussed that how the information related to routing can be piggybacked inside the advertisement message. Another problem in this approach due to high mobility it is difficult and not always possible to detect the duplicated address by applying DAD repeatedly.

Jung *et al.*[45] proposed a dynamic agent advertisement method using AODV protocol and mobile IP which provides a better connectivity and reduce overhead for achievement of good performance when a mobile node moves from one subnet to another[45]. The approach support a scheme in which the mobility agent is located at the boundary of the two subnets or MANET and a fixed network advertises its information to MANET with two different advertisement scope and lifetimes. This suffers from few drawbacks. Although, this approach was given for overhead reduction but the outcome was totally different when the entire mobile node in the MANET wants to connect to the internet and when the entire route to the mobile node is frequently changing. The above condition when meet out then the overhead will be higher. It also lacks in some clear explanation of the concept given if a deep analysis is done.

Adaptive gateway discovery approaches based on fuzzy logic: The mechanism proposed by Trivino *et al.*[46] is based on the approach that a gateway send Modified Router Advertisement (MRA) messages at fixed interval of time T_1. A modified router advertisement message is gateway advertisement message. This message is distributed in predefined zone closer to gateway i.e., zone of pro-activeness. The zone is created with help of value of TTL. Solicitation generates by MN in area of reactiveness is called Modified

Router Solicitation (MRS), that is also known as gateway solicitation messages. The optimal values for T_1 and TTL depend on load of the network. Theme of the proposal was to determine the advantage of automatically updating the T_1 and TTL in a hybrid technique. This technique is lies on getting the number of MRS messages given by the MN in an interval of time called MRSCOUNT or T_1. On the basis of T_1 messages received, the gateway get prediction of number of MRS requests it would receive in the next T_1 interval. Here maximum source coverage algorithm is used.

Yuste *et al.*[47] proposed a gateway discovery approach. In this scheme, they consider a different way of optimizing the discovery process. This solution does not make any change in advertisement time or we can say in this advertisement value of MRA message is not depends on the topology change. Further this also not make any adjustment in TTL value of the MRA message. Author presented a way to find the optimal route to internet gateway in their discovery process. This optimal route further used for the any communication from the gateway. If one optimal route is break down then other optimal route have to be determined. For implementing this approach they utilized the concepts of fuzzy logic. This approach is termed as type-2 fuzzy system and it uses Mamdani's fuzzy inference system with one extra component called as 'Type reducer' which is used between inference system and defuzzifier units. In this, along with the calculating the optimal route authors take care of route breakage. In case where optimal route is lost the discovery of the other optimal route initiated by the system. It considers the probability that whether the local link exist between the node and gateway or not. Link life time is supposed to has lognormal distribution in this solution.

Yuste *et al.*[48] proposed an adaptive discovery of gateway approach. In this they use fuzzy inference system to generate an optimal value of the advertisement periodicity. In this researchers first find out the parameters, link changes, number of MRA message and change in time to live value, these parameters further used as input to fuzzy system and an output is generated by the system is the value of advertisement timer. This approach only make change in advertisement time not in TTL value. So this approach is a single parameter adaptive approach.

Zaman *et al.*[49] proposed a soft computing based approach. The concept for fuzzy logic has been utilized in this approach. In this study researcher suggested that how fuzzy logic provide better mathematical association among parameters. This solution has make adjustment in advertisement timer of the gateway. This adjustment in advertisement timer is done the network scenario. First this approach figured out the parameters on which the advertisement time value should depends. After predicting such parameters they use fuzzy inference system to use these parameters as input and generate output. They considers the gateway load balancing along with Hop Count (HC), aggregate routing table entries (ARE) and Aggregate Queue Length (AQL) as there parameters. Further this solution use a method for calculating optimal route to gateway and merge this solution with adaptive discovery of gateway approach. Further, the fuzzy inference engine of the inference system provides inference on fuzzified parameters and generate output based on rule base. In this they also perform adjustment in TTL value.

Ruiz and Gomez-Skarmeta[50] emphasized on dynamic change in TTL value. An active mobile node is register with gateway and sends data to a correspondent node. In this methodology, location of active node is keeps on tracking by gateway. It is easier for the gateway to do as entire data packets of MN register with same gateway. To obtain TTL value for next advertisement message maximal source coverage algorithm is utilized. For this condition TTL should be equal to maximum hop count. The proposed approach conveys that the gateways keep tracking on the hop count at which its active sources are residing. By only viewing IP header one can extract the information. The metrics which was formed is updated periodically so that duplicate entries may be restricted. While going to the second stage is the problem associated with selection of heuristic technique for getting optimal TTL value for next GA_AV. The maximum source coverage algorithm gives the gateway send the later GW_AV with TTL has value equal to maximum hop count for its entire mobile nodes. This shows that the above approach uses heuristics proactively. The above methodology is the adaptive gateway discovery approaches which emphasized on auto-modification in TTL, but it did not focus on problem of periodicity. There are several other suggestions given by researchers like other than maximum source coverage, there exit average source and minimal source.

COMPARATIVE ANALYSIS OF GATEWAY DISCOVERY APPROACHES

A comparative analysis of various existing approaches is presented in Table 2 on the basic of some set of parameters. Parameters are approaches that implements, whether multiple gateway support exists, which IP mobility protocol is used, which MANET routing is used and how the internet MANET integration is performed.

Table 2: Comparison of various gateway discovery approach

Scheme	Approach implemented	Multiple gateway suppose	IP mobility protocol	MANET routing	Internet-MANET routing
Proactive gateway discovery approaches					
Rosenschon *et al.*[29]	Based on Hello message of AODV	Yes	N/A	AODV	Route established by Hello packet
Ergen and Puri[30]	Mobile IP with DSDV and TBBR	No	MIPv4	DSDV and TBBR	Establishment of route by agent advertisement
Xie and Kumar[31]	Modified the mobile IP to work with EDSDV	No	MIPv4	EDSDV	According to EDSDV
Jelger *et al.*[32]	Global addressing combined with IGW discovery protocol	Yes	MIPv6	Any proactive or reactive	According to the selected protocol
Kumar *et al.*[33]	Load aware gateway discovery	Yes	MIPv4	AODV	Based on the load on gateway, discovery perform
Khan *et al.*[34]	Bi-directional connectivity by modified DSDV	No	MIPv4	Eff-DSDV	using Eff-DSDV protocol
Reactive gateway discovery approaches					
Broch *et al.*[35]	Interfacing network by DSR and mobile IP	No	MIPv6	DSR	Normal IP routing
Ammari and El-Rewini[36]	Layered approach uses DSDV and MIP	Yes	MIPv4	DSDV	Single hop away FA of multiple gateways
Ville[37]	AODV and cellular IP combined in IPv6 space	Yes	Cellular IP mobility	AODVv6	Based on AODVv6 and MIPv6
Syarif *et al.*[38]	AODV+ with R-AODV	Yes	N/A	R-AODV	Using reverse method (R-AODV +)
Wakikawa *et al.*[39]	AODV and IPv6 combined for providing global IP prefix	No	MIPv6	AODV	Modified AODV
Li and Li[40]	MRBDAS access	Yes	Not applicable	Any	Based on MRBDAS
Hybrid gateway discovery approaches					
Benzaid *et al.*[41]	Modified OSLR to support micro-mobility	No	MIPv4	OLSR	OLSR routing
Ruiz and Gomez-Skarmeta[42]	IGW discovery coverage with adaptive maximum benefit	Yes	MIPv6	AODV	AODV with normal IP forwarding
Lee *et al.*[43]	MIP with DSR	Yes	MIPv4	DSR	Based on MIPv4 and DSR
Sun *et al.*[44]	Adjusting MIP with AODV	Yes	MIPv4	AODV	IP forwarding
Jung *et al.*[45]	Integrating MIP, AODV	Yes	MIPv4	AODV	e-RREQ broadcasting

CONCLUSION

In this study, various existing study show that MANET-internet integration have been described by taking various metrics and also their pros and cons have be stated. Shortcomings which were identified leads to building future scope that provides untouched portion of these existing scenarios. Along with this, taxonomy is presented regarding gateway discovery approaches. All the issues and challenges which are associated with the integration such as routing, mobility, gateway discovery and selection, addressing, forwarding are discussed in this study. The MANET usage is drastically increased among current trends due to its infrastructure less architecture, stand-alone employability, self-configuring behavior and cost-effective nature. Its limitation is available bandwidth, dynamic topology and limited power. The range of services and application provided by it to user of MANET is limited as compared to internet. Therefore, the need of providing internet connectivity to MANET has come into researchers thinking during some previous years, connectivity to internet become a primary concern of almost every mobile user. Reason behind is that now-a-days, most of the services is based on the internet compatible applications. Many of the researcher have predicted that the future belongs to wireless and mobile computing. So, there would be a need of various internet integration mechanisms which can efficiently handle the connectivity among heterogeneous protocol based network. Whenever advancement in internet technology and its underlying protocol occurs, there would be need to modify the integration mechanism. So, work in this field is dependent on above fact and need upgradation according to that.

SIGNIFICANCE STATEMENTS

This study presents a state-of-the-art review on various methodologies for the integration of MANET and internet. A broad classification of important research works is presented along with their shortcomings and contributions. A comparative analysis in tabular form of various gateway discovery approaches has also been given. Future scopes motivate researchers to proceed further in devising newer efficient gateway discovery algorithms/protocols. This study is very helpful for those who want to buildup a level of understanding in the area of MANET-internet integration based solutions.

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