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Role of Gateways in MANET Integration Scenarios

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Abstract

Background/Objectives:Mobile Ad Hoc Network, an auto configured wireless network using mobile devices without a predefined infrastructure can be integrated with infrastructure based network to overcome the problems in following networks. **Methods/Statistical analysis**: Integrating two entirely different communication technologies have enormous challenges. The integration process requires an intermediate entity named Gateway for connecting entirely different networks. This paper analyze the role played by gateway in solving issues related with integration using Mobile Ad Hoc Network in various heterogeneous networks and the various phases in communication between two networks using gateways. **Findings:** Recent researches in Green Communication, Machine to Machine Networks, Internet of Things, Device to Device Communication explores the use of Mobile Ad hoc Networks in deploying future wireless networks with less cost and overhead. This paper reviews various categories of networks so far integrated with Mobile Ad- hoc networks, issues discovered in such integration scenarios and importance of different gateways used in integration architectures. Paper also compared different gateway discovery and selection schemes so far adopted in integration scenarios. **Applications/ Improvements:** To support such endeavors paper propose some modification needed in implementation of Mobile Ad hoc Network (MANET) gateways to survive in future wireless networking.

Keywords: Gateways, Gateway discovery, Gateway Selection, Heterogeneous Network, MANET, Next Generation Networks.

1. Introduction

A Mobile Ad hoc Network (MANET) is an infrastructure less, self-configurable wireless network with a set of mobile nodes. Usually, MANET were deployed in areas were infrastructure mode of communication is limited or not available readily. MANET proves to be very useful in disaster areas and in defense activities.[1] Attractive feature of MANET, which makes it useful in such areas are its multi-hop relaying and less deployment cost. In such networks, every node acts as a router to forward packet to next node. However, from the existing network related application scenarios, it is evident that usage of MANET is very rare when compared with other wireless communication technologies. Much recent research works[2-6] focus on integrating MANET with other type of networks to reduce the cost of communication and deployment. Recent research ideas like Green Communication, Machine-To-Machine Networks (M2M), Internet of Things (IoT), Device-to-Device (D2D) communication shows a positive approach towards infrastructure less network like MANET to be included in their architecture.

In[7] reviewed various methods adopted in future Wireless Cellular Network (WCN) for promoting Green Communication. The main aim of such an approach in WCN is to reduce the number of base stations for improving coverage and connectivity that also reduce the amount of carbon emission due to more number of base

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stations. User cooperation is one method suggested for promoting Green communication. In this category, a user mobile can work as a relay node, which can relay packets to and from mobile devices, which do not have cellular coverage. Cooperation between mobile devices happens using multi-hop relaying. Here the Cellular Network could be integrated with MANET to promote Green Communication.[7] In[8] provided more support to use of mobile relaying stations in device–to-device communication using cellular networks. Use of mobile relaying stations improves the coverage of cellular networks and throughput of end users in such scenarios.[9] In[10] also reported the use of integrated networks in promoting Mobile Cloud Communication. Capillary M2M communication that uses MANET setup makes cellular M2M communication more reliable.[11] In the next generation networks, communication can be between device-to-device (D2D) or mobile-to-mobile (M2M) networks. Such networks expect a high rate of concurrently linked devices moving at a higher speed. One of the next generation networks like 5G aims at higher data rate transmission within a limited time and less deployment cost. Researchers in the field of 5G architecture concentrate on the basics of device centric architecture as it gives more importance to device-to-device communication. MANET can play an imperative role in building up a strong foundation for 5G networks.

It is evident from surveys conducted related to recent research works in communication field that MANET can be applied in more scenarios to enhance the day-to-day communication between mobile devices. The aim of future wireless network will be a huge increase in simultaneously connected mobile devices. To maintain connectivity with less cost, only solution is integration of existing wireless technologies. Different integration architectures were proposed to integrate MANET with other networks. Less deployment cost and feasibility to deploy in any infrastructure with dynamic topology, makes MANET a promising technology though such networks have disadvantage like limited battery power and less transmission range.[12, 13]

The complexity of forming a heterogeneous network increases due to the difference in technology used in each network.[14] Different networks participating in integration process use different protocol stack. The routing strategy adopted in one network will be different from another in a heterogeneous environment. The solution to such a scenario is to use a gateway, which can be a special device or a mobile device in any network participating in integration process. Other issues related with integrating are difference in addressing scheme, routing strategies and mobility of nodes in both networks. This paper covers issues related with gateway used in such scenarios.

A gateway is a mobile or stationary communicating device, which works as an interface between different networks to improve their coverage and connectivity.[15] Gateway type, architecture and functionality vary with the different categories of heterogeneous network. Though gateways play a significant role in connecting entirely different networks, lot of issues come up with related to designing or choosing an efficient gateway. Some of the major issues related with gateways are energy management, load balancing, multi-homing, handoffs, providing effective interoperation between neighboring mobile nodes, adapt effectively with dynamic topology and need of effective algorithm for selecting a better gateway node from a subset of qualified nodes. A mobile node has to find an appropriate gateway for improving connectivity. MANET uses different approaches to discover gateways to interact with other networks.[15]

2. MANET Integration Architectures

The future wireless networking field aims at providing ubiquitous network facility to the customers worldwide. In spite of surplus growth in the technologies of wireless telecommunication field, MANET facilitates in creating a reliable and cost less network. MANET comes under the category of infrastructure less network that can be deployed in any area without a proper network connection. Each node in a MANET has the ability to receive and forward the packets to other nodes. The main desirability of MANET is its capacity to transmit packets from source to destination using multi-hop relaying. Scarcity of resources like battery power and less bandwidth of MANET nodes result in coverage and connectivity problems. Integration of MANET with other networks solves the coverage and connectivity problem in both MANET and other networks.

The following section covers the integration of MANET with various categories of wireless networks due to the high demand of such integration in future network scenarios. MANET can be integrated with two different categories of wireless networks like infrastructure based and infrastructure less networks.

2.1 Integration of MANET and Infrastructure Networks

Most of the research works focuses on integrating MANET with infrastructure based networks namely Cellular Networks, Satellite Mobile Network (SMN), Delay Tolerant Networks (DTN), and Internet. Major architectures designed based on integrating Infrastructure networks and MANET are discussed to provide an idea on such systems.

2.1.1 MANET - Cellular Network Integration

Recent research works shows a colossal growth in the telecommunication field mainly in Mobile Cellular Networks (MCN). With the advent of new technologies related with MCN, more users worldwide depend on mobile devices for communication. According to various surveys, by the end of 2020 more than 90% of the communication will be through mobile devices. Major issues that may affect the communication in such areas depend on coverage and connectivity. Handling emergency rescue operations in catastrophic natural disasters or handling situations in army attacks and plane hijacking or communication in remote areas recommends integrating existing MCN with other networks to improve coverage, connectivity and high data rate support. Due to high mobility of users or poor signal strength from base station, mobile devices may encounter problems related with poor connectivity.

Normally in Cellular Networks, mobile devices are connected to nearby base stations using single hop relaying method. By Integrating Cellular Networks with MANET, the mobile devices from remote areas can communicate with base station using multi-hop relaying between intermediate mobile nodes. Normally cellular connections lack multi-hop relaying, in such cases a MANET can be setup among the mobile users. Various application scenarios, which facilitate from MANET – Cellular integration are performance enhancement of Cellular Network, mobile communication in pastoral areas with less cost, Green Communication, rescue operations etc. In all the integration scenarios mobile devices can route packets using either single hop relay or multi hop relay.

The integration of latest Cellular Networks with MANET has evolved into an era of All-IP networks, which solves the issues in network layer. A-GSM, ODMA, iCAR, SOPRANO, MADF are some of the existing architectures that highlight how MANET can be integrated with Cellular Networks.

Ad Hoc Global System for Mobile Communication (A-GSM) architecture combines MANET and GSM for extending the coverage, reducing transmission power and increasing the capacity of both networks. In A-GSM, a dual mode terminal having both MANET interface and GSM interface enable multi hop relaying. Such nodes can perform both GSM and MANET handover to reroute the calls using MANET mode incase no direct path can be established using GSM mode. Figure 1 explains how a dual mode terminal enables communication between two different networks. The system throughput of A-GSM shows about 15-percentage improvement when compared with existing GSM architecture.[16] Multi hop relaying used in the system enables reduction in transmission power of base station.

In[17] discussed an architecture that promotes 4G networking by integrating *MANET with UMTS (3G)*. They aim in providing connectivity to mobile users with low infrastructure support. Here intersystem handover happens by connecting a gateway in ad hoc mode with Gateway GPRS Support Node (GGSN). Future enhancements can use multiple gateway support to improve the throughput rate rather than using a single gateway node as suggested in the proposal.

Opportunity Driven Multiple Access (ODMA) architecture uses the concept of multi-hop relaying between the mobile nodes inside the coverage area of base station. This reduces the usage of high transmission power by base station. Every node has the capability to relay packets to its neighboring nodes. The routing decisions are made on basis of signal quality of each node. Unlike A-GSM, it does not support the out-of coverage mobile nodes, as all the mobile nodes should be under the

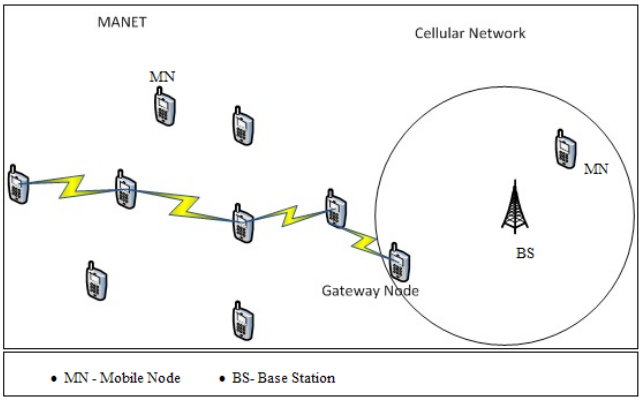

Figure 1. Integration of MANET with Cellular Networks.

coverage of base stations. In this architecture, MANET is formed between mobile nodes under the coverage area of a base station hence gateway does not have any importance in this architecture.[18]

Integrated Cellular and Ad-Hoc Relaying Systems (iCAR) architecture proposed in[19] enhanced the coverage of Cellular Networks using multi- hop relaying. Ad hoc Relaying Stations (ARS) having dual interfaces are deployed in planned locations. Deployed ARS will experience only less mobility. Implementation of iCAR architecture helps in balancing the traffic load in each cell. Relaying packets without using base station of a particular area is explained in Figure 2. The traffic in congested cell could be transferred to an uncongested cell by the use of such architecture.[19]

Mobile Assisted Data Forwarding for Wireless Data Network (MADF) architecture proposed in[20] was mainly designed for balancing load between base stations by sharing the traffic in highly loaded base station with free base stations. Unlike iCAR, MADF use mobile nodes as relaying nodes instead of stationary ad-hoc relay stations. Traffic controlling in base stations depends on packet delay by mobile nodes. Implementation of such architecture does not require a separate device for packet forwarding.

Self Organizing Packet Radio Ad Hoc Network with Overlay (SOPRANO) proposed in[21] was developed to enhance the performance of Cellular Networks. The architecture aimed at offering a high data rate Internet with the help of inexpensive relay stations.

Multi-hop Cellular Networks (MCN) proposed in[22] integrates 3G Cellular Networks with mobile ad-hoc networks. Integration enables the feature of multi-hop relaying in cellular network, which enhance the flexibility of Cellular Networks.

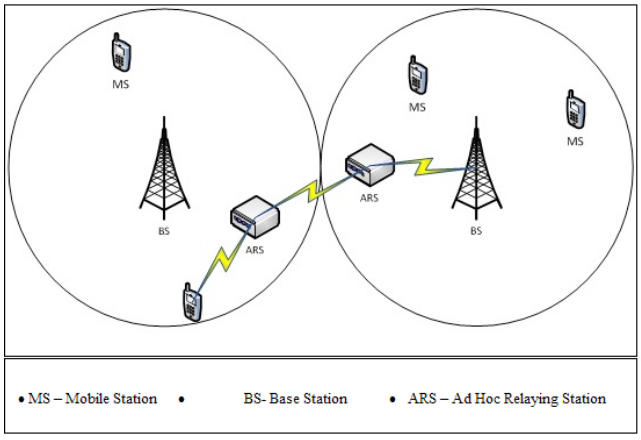

Figure 2. iCAR Architecture.

Study on existing MANET- Cellular architectures highlights the importance of dedicated gateways or dual interface mobile nodes in enhancing the performance of integrated networks. However, some of the architectures like MADF do not depend on a dedicated gateway node.

2.1.2 MANET – Internet Integration

Enhancing the application domain of MANET in future wireless networking requires integrating Internet with MANET. In the current wireless communication scenario, the 4G wireless networks aims at All-IP networks where every user can communicate each other without giving any concern to the location, media or technology used by both networks. Normally, a mobile node under the coverage of access points gets access to Internet services. A mobile node out of coverage of base station or access point can use multi hop routing to reach the access points through other mobile node, which acts as gateway node or through a dedicated gateway like Internet gateway as in Figure 3. A mobile node not under the coverage of access point can get the connection by combining MANET routing protocol and IP mobility protocol. The integration adds more features to both MANET and Internet. Coverage area of MANET can be extended without losing connections and provide mobility support between isolated and merged MANETs using multiple gateways. The integrated architecture helps in reducing number of access points and improving coverage to reach dead spots.

In MANET- Internet integration the gateways can be categorized into two, planned gateway and unplanned gateways. Planned gateways in many proposals refer to Cellular IP gateways or Internet gateways, which are special type of wireless routers controlled by the service providers. Other category refers to mobile nodes that have dual interface and provides extension to Internet services of a network to other users.[23] The similar concept is also covered in ANWIRE architecture proposed in[24]. In[25] proposed an MANET- Internet integration architecture where MANET nodes namely Mobile Gateways (MG) and MIP foreign agents work as gateway nodes. Major challenges faced in MANET Internet integration is routing between two different networks, which use a combined version of MANET protocol and Mobile IP protocol. Cooperation must be maintained between Mobile IP protocols and MANET protocols to ensure smooth

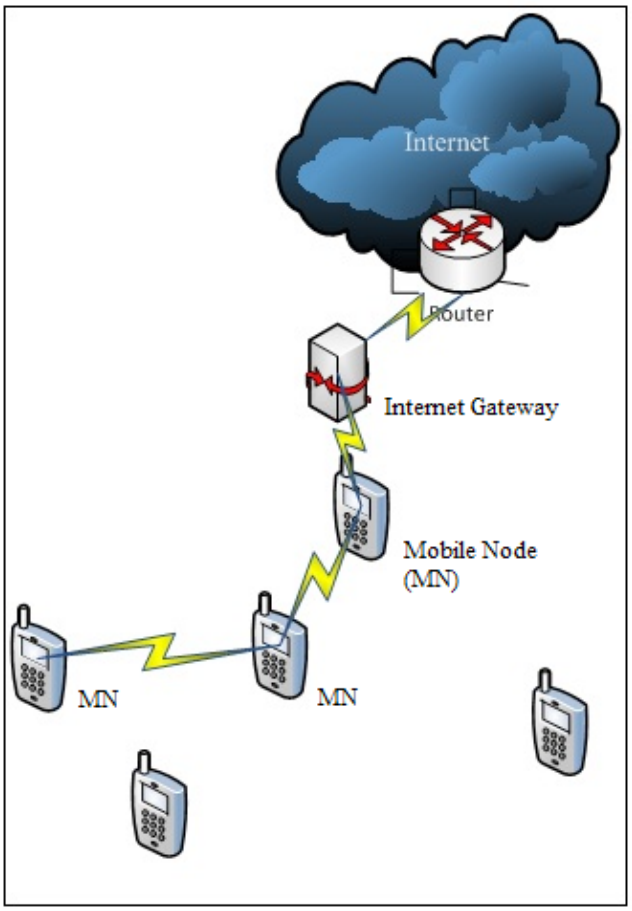

Figure 3. MANET- Internet integration.

transition of services from one network to another. A detailed survey on different integrated routing solutions, categorized as proactive, reactive and hybrid integrated routing were discussed in[26].

Integration strategies can reduce number of base station or access points and maintain connectivity for dead zones. Difference in various integration strategies so far discussed varies with respect to integration solutions, gateway discovery and selection methods, packet transmission methods, addressing scheme suitable for both network and mobility management.[26]

2.1.3 MANET and DTN Integration

Integrating MANET with DTN enables extending the reach of communication in sparsely populated environment. MANET provides end-to-end connectivity using multi-hop facility but such routing scenarios will be affected by link failures. In such occasions, MANET routing protocols fail due to non-availability of path from source to destination, as most of the routing protocols first finds a path and then routes the packet. Latest network model in terminal-to-terminal communication solve such problems by combining MANET and Delay and Disruption Tolerant Network (DTN) routing methods. Transmitting of user data from one mobile node to other will be performed without using any special network resources. The model supports end-to-end communication between terminals without using a base station. The working ability of this model varies according to the change in node density and node mobility. The network model switches between DTN and MANET mode as the node density and mobility varies. A network gateway interconnects two networks. MANET – DTN integration can be achieved by three different methods Store and Forward or Packet Buffering, Select Message Custodian and Message Replication. Though DTN does not work effectively in well-connected networks, when path is not available the integrated routing solution choose any of the three DTN methods to handle the packets from dropping out. On availability of a new path, the packet will be forwarded to destination. Hybrid DTN-MANET Routing Protocol (HYMAD) is a compatible DTN-MANET integration routing protocol which use topological information for modifying the packet delivery according to changing connectivity patterns. Advantage of using DTN in hybrid networks can avoid offloading of cellular networks, provide information and services to users due to disrupted connectivity, support Interplanetary Internet and support emergency response system.[27-31]

2.1.4. MANET and Satellite Mobile Network Integration

Real sense of worldwide communication can be enabled by integrating MANET with Satellite Mobile Networks as in Figure 4. Such an integrated network will help in public protection and disaster management due to their ability to provide both local and global dynamic connectivity. MANET and Satellite technologies are said to be complementary technologies due to their variance in power consumption rate, coverage and capacity. Normally, Satellite Networks are not active inside rooms; in such cases, MANETs can be linked with Satellite Networks to enable network connectivity.[32,33] In[33] explained about MANET Satellite interactions using a system called SAVION, where two types of interfaces are used between MANET and narrow band and broad band satellite

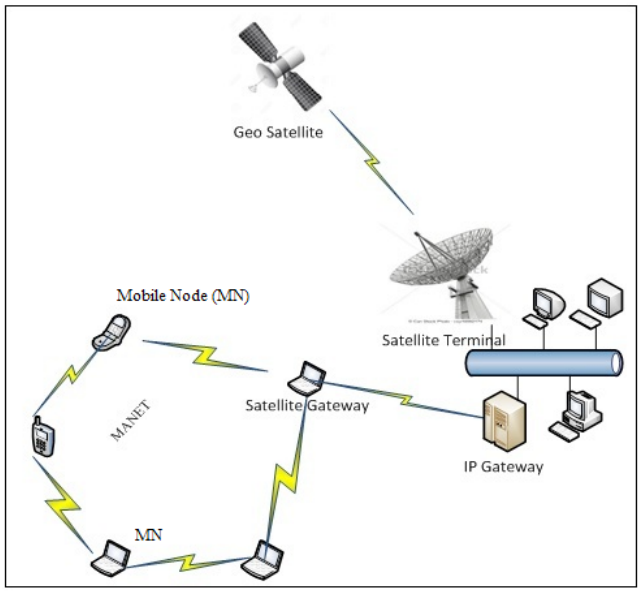

Figure 4. MANET Satellite Integration.

systems. In[34] explained how satellite networks solve the severe impairments experienced by MANETs. This paper also covers the mobility management in MANET using mechanism of clustering.

Satellite Networks can be classified into GEO (Geostationary earth orbit) and NGEO (Non-geostationary earth orbit). NGEO can further be divided as LEO/MEO (Low/medium earth orbit.GEO and NGEO networks are envisaged as range extension networks. Main challenges researchers in this field have to go through are difference in system architecture, overall routing protocol design, mobility management, resource allocation. Need a new architecture, which integrates the cost effective MANET and costly satellite network. Usually a MANET node having satellite and wireless interface becomes the gateway node. Gateway selection is one of the major issues raised by researchers in this field.[34]

2.2 Integration of MANET and Infrastructure Less Networks

Underlying section covers various strategies used for integrating MANET with infrastructure less networks like Wireless Sensor Networks (WSN) and MANET.

2.2.1 MANET- MANET Integration

MANET is an interconnection of mobile nodes using similar technology and protocols. MANET operates differently from other MANET depending on the application requirement.[35] Some application scenarios recommend the combined operation of different homogenous MANETs. Flexible communication between mobile nodes in different MANETs focuses on Inter-MANET communication.

The major issues in the integration of different homogenous MANETS are mainly difference in protocols and radio technologies used by each MANET group. The protocols used in each MANET vary according to the scenarios. Gateway nodes need to be identified for interconnecting MANETs. Any node with specific features like high radio range or higher battery capacity can be set as a gateway node. Gateways in Inter-MANET integration scenarios help in the translation from one protocol to another used in different MANET scenarios.

2.2.2 MANET – Wireless Sensor Networks (WSN) Integration

Disaster and rescue operations were the main application area of MANET at the beginning .Need of communicating or extending the network to disaster free areas required the creation of heterogeneous network by combining different wireless networks. One such network is wireless sensor networks that can be combined with MANET for extending the availability of rescue operations to area outside the disaster area. MANET is meant for wireless communication without any infrastructure, while WSN make sense in gathering sensor related information. Lack of infrastructure and multi-hop relaying support makes WSN and MANET similar. When application area is considered, MANET is more close to users while WSN is more close to environment where such networks are embedded. In MANET, route reconfiguration happens due to node mobility while in WSN it will be due to node failure. MANET can be integrated with WSN to solve problems related to limited bandwidth, extra delivery time and energy efficiency.[36] Sensor networks are formed with a subset of sensor nodes covering the sensor field with unique communication ability. An operator outside the sensor field controls and tracks the changes in each sensor node. Such nodes can be converted as a gateway node in integrating sensor networks with MANET or other networks as in Figure 5.

Latest research works focuses on a new idea on how MANET and WSN convergence help in the development of Internet of Things (IoT) communication. They have

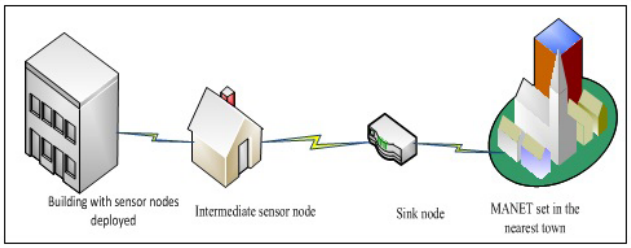

Figure 5. MANET- WSN Integration.

proved that such an approach can support fast collection of urban data from widely dispersed sensors in urban environment.[36-38] Cyber Physical System (CPS) that aims in different forms of human and computer interaction worldwide can effectively use MANET and WSN to nurture the needs of next generation networks. The survey paper[39] highlights various uses of MANET and WSN for CPS.[39] In future wireless networks integration of MANET and WSN can be a useful combination, though they face common issues like less bandwidth, battery power and less resource which were tried to be solved using various approaches.[40]

3. Issues and Challenges in Integration Scenarios

Issues identified by researchers are related with transmitting data between different networks. Problems identified relating to transmission highlights the technology used, need of vertical handoff, transmission range of each interface, co-channel interference, topology discovery, QoS and mobility of nodes.[41] According to the Ericsson mobility report, by the end of 2019 number of smart phones and mobile subscriptions worldwide will exceed 5.6 billion and 9.3 billion. The mobile traffic rate will also increase accordingly due to incredible growth in the usage rate. This section covers issues that may affect the deployment of integrated networks in near future. Various methods used to handle such issues are also mentioned. Issues represented in the section gives a general idea but more researches in this area are required with related to different integration scenarios.

3.1 Mobility

Integrated networks will be the backbone of future wireless communication. About 90% of the subscribers in such networks may be mobile, so mobility management is an issue that needs to be handled properly. Mobility management in such networks is much more different from homogenous networks. Mobility management in heterogeneous network is divided into link layer, network layer, upper layer and cross layer management.

Link layer mobility management is handled below the IP layer and it is specific to the technology used at this level. This type of management provides the mobile terminal to move between different physical points. Normally less consideration is provided to link layer management in case of IP network.

Mobility management in network layer is related with location and handoff management. Management at this layer is classified into two, macro and micro mobility. Micro mobility is considered when a mobile terminal moves within the same network and macro mobility in the case of movement of mobile terminal between different networks. The two main issues in macro mobility are the difference in protocol stack and the wireless interfaces used in different networks.

Upper layer mobility management is usually handled in transport and application layers. TCP- migrate, SCTP (Stream Control Transmission Protocol) supports mobility in transport layer and SIP (Session Initiation Protocol)- based mobility are used in application layer to support mobility. Cross-layer mobility management has investigated the flexibility of combining lower layer mobility management with upper layer schemes. In order to avoid the complexities of mobility management cross layer approach can be a better option that enables the reuse of different architecture used in each layer. Future wireless networks need a better mobility management scheme to integrate all networks, which works on IP core network or linked to such a system.[42,43]

Proper mobility management avoids problems related to packet drop, end-to-end delay, link failure etc.

3.2 Security

Security is another major issue related with integration of MANET with other wireless networks. The security issues of MANET as well as the other networks need to be considered separately for each type of networks participating in integration process or need to design new techniques to avoid or detect attacks in such complex environments. Most of the research work in this area focuses on the attacks in MANET- Internet communication. Most of the infrastructure networks based on IP have a proven set of secure routing protocols. However, due to the infrastructure less and dynamic nature of MANET, security issues are more

in MANET than other networks.[44] The attacks in ad-hoc networks will be more severe than other networks due flexibility in routing strategies used in such networks. This may affect the end-to-end secure data transmission. In an integration scenario, the existing protocols need to be modified or new one need to be designed for secure end-to-end data transmission.

The conversion of all the networks participating in integration process to IP based help in secure data transmission. In an IP based network, most of the existing IP based open standards can be used for secure end-to-end data transmission. IPSec is such a framework that provides secure data transmission in IP based network. It helps secure host-to-host communication.[45]

Features expected from such frameworks are flexibility, secure end-to-end transmission, authentication and confidentiality. The use of such frameworks in modified networks needs extensions of existing routing protocols. The threats faced by integrated networks are modification of routing control messages at different interfaces, falsifying of routing table, rebuffing of service attacks, revealing of security to unauthorized users etc. Some of the existing works related with ad hoc Internet integration are IGAODV, which modifies AODV for secure route creation and transmission of data, modified minimal public based authentication etc.[46]

3.3 Routing

Routing data packets from one network to another suffers from unavailability of exact routing protocols, which works well in heterogeneous networks. Routing protocols in MANET or other networks need to be extended to adapt with heterogeneous networks.[47] While integrating different networks, the existing routing schemes used by each network need to be redefined. The routing protocols in MANET relay packets in a multi-hop manner and aim in low battery usage, less delay, maintaining QoS etc within the limited range of such networks. Different protocols designed based on these criteria are classified into proactive, reactive and hybrid.[48, 49] Most of the infrastructure based network use single hop relaying which need to be replaced for maintaining better connectivity. Maintenance of routing scheme in a large network is a complex task. The position and topology of wireless node change frequently, due to which routing protocols need frequent updating.

Normally, routing in large areas or remote areas with less coverage, need to be restructured for maintaining regular connectivity. Integration architectures can adopt the concept of divide and conquer method to route packets between different types of networks.

In most of the integration scenarios gateways plays the main role in linking very different network to work in a harmony to accomplish the routing procedures smoothly. Table I, gives an overview of integration strategies, their role, the gateways used in each integration architectures and finally the important part in routing, gateway discovery.

3.4 Gateway Discovery

Integrating MANET with other networks require the use of gateway nodes. Gateway node in an integrated scenario may be either dedicated gateway node or MANET nodes with dual interface. Through a gateway node, other MANET nodes get connectivity to Internet or Satellite network or Cellular network or Sensor Networks. Thus, a gateway node helps in the transition of communication between two networks. The source node will discover one or more gateway nodes. According to various metrics like hop count, traffic load, mobility rate, residual energy etc an optimal gateway need to be selected. One major issue related with integration is finding gateway discovery and selection methods with minimum delay and overhead.[15, 50]

3.5 Difference in protocol stack

One of the major issues related with integration of different networks focuses on the need of modified protocol stack for the gateway node. Dissimilarities in the protocol stack of two networks need to be solved for the efficient working of integrated architecture. The network layer can hide the dissimilarities of higher layer up to an extent. Researches in this field mainly focus on new techniques for relaying packets from one mobile node to other using different networks. To provide integrated, visible and self-configurable services, an access point, a base station, or a mobile node with dual interface can be elected as a gateway node in MANET-Cellular integration. A gateway node should have the capability to understand the difference in the protocol stack of both networks as mentioned in Figure 6. The protocol stack of a dual mode MN integrates the features of both networks.

The network layer in the newly devised protocol stack links the lower layers of network like physical, MAC and Link layer with the transport and application layer. Continuous researches are going on in the routing

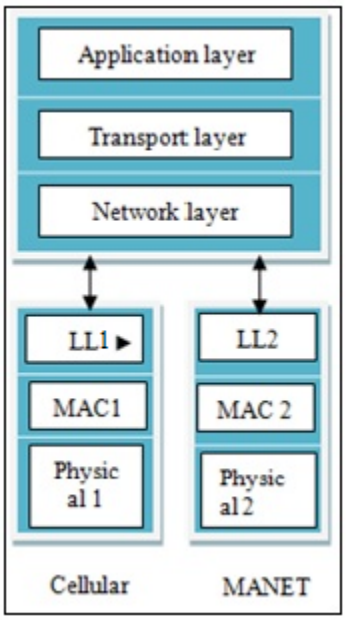

Figure 6. Protocol Stack of a multi interface node.

protocols that support all communication alternatives in heterogeneous routing.

4. Role of Gateways In MANET Integration Scenarios

Gateways play a main role in integrating two or more different network architectures. Gateway acts as a service provider in one network, to access the service of other network. Gateway node can be a dedicated node or a mobile node in MANET having multiple interfaces.

Features of a gateway node

- Help external network to route packets back to internal network by providing internal route.
- Gateway nodes can provide security to MANET network by restricting the traffic from and to the network.
- Provide controlled access to external networks.

The number of gateway categories used in an integration network depends on the number of networks used in the integration process. In case of MANET-Internet integration, the gateway used will be Internet gateway. While in case of integrated network formed using cellular, satellite and MANET integration minimum two gateways namely satellite gateway and terrestrial gateway are required. Normally, the minimum number of gateways in an integration network comprising of n network will be n-1 gateways.

Gateways used in different integration architectures are classified into single and multiple gateways. Single and multiple gateways can be either fixed or mobile. A fixed gateway will be deployed at particular locations planned by the service providers. Gateway can be connected to other infrastructure network using a wired or wireless interface. Figure 7 gives a brief idea of different categories of gateway identified by various researchers.

Routing in integrated scenarios combines MANET routing and routing in external networks. Since gateway nodes are just another MANET node, the most efficient design would be to integrate the gateway discovery phase with path resolution phase of a MANET routing protocol. Gateway nodes route packets to and from MANET using existing MANET routing protocols using wireless interface. For communicating with external networks, gateways use cellular/ radio/ wireless/ wired interface along with routing schemes in external network like Cellular IP or Mobile IP. The existing routing methods in MANET require modification to incorporate gateway discovery and selection strategies to find a path from source node to destination node to route packets.

MANET routing protocols can be categorized as Proactive, Reactive and Hybrid.[51-53]

In Proactive routing methods, every node in the MANET maintains one or more routing table to maintain information about other nodes. Tables are updated based on the topological change. In this category, delay encountered for route discovery is comparatively less. Common proactive routing protocols used in different scenarios are Destination Sequenced Distance Vector (DSDV), Cluster head Gateway Switch Routing (CGSR) and Wireless Routing Protocol (WRP).[51-53]

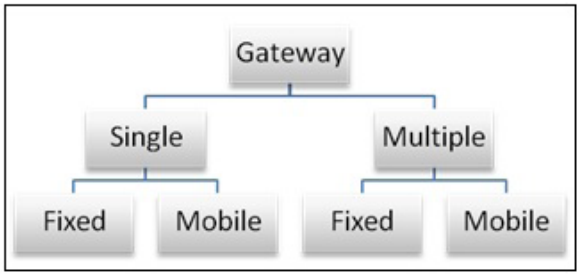

Figure 7. Gateway Classifications.

Reactive routing protocol computes route from source to destination only on request from source node. Once discovered route is maintained until route expiry. This category saves the time needed for frequent modification of routes. Ad hoc on Demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR), and Temporally Ordered Routing Algorithm (TORA) are some of the common on-demand or reactive routing protocols.[51-53]

Hybrid routing protocol combines the proactive and reactive routing protocol. When the network size increase the MANET could be divided into different zones or clusters. Inside each zone a proactive routing protocol handles the route request and routing while outside the zone reactive routing approach is used. Zone Routing Protocol (ZRP), a hybrid routing protocol is most commonly used protocol in this category.[51-53]

Recent researches concentrate on solving issues in routing mainly routing overhead, energy consumption and security.[54,55]

For routing packets to external networks, existing routing methods can be further extended to external networks through a node called gateway node. The category of gateway node varies depending on the type of external networks to which a MANET node is connected.

Cellular Gateway: In Integration between MANET and Cellular Networks, mobile router or a MANET node with dual interface becomes a gateway node. A gateway node in this scenario has two interfaces, cellular interface that connects the gateway node to Cellular Network and the wireless interface (IEEE 802.11) that connects to other nodes in MANET using any of the MANET routing protocol. In architectures like i-CAR, gateways are deployed in planned locations, in A-GSM architecture Ad hoc Relaying Station (ARS) works as gateway nodes.

Internet Gateway: While integrating MANET and Internet, an Internet Gateway (IGW) node is identified by the MANET nodes to access the Internet. Internet gateway combines existing MANET routing protocols mainly AODV, DSR, and DSDV with Mobile IP protocol to facilitate the integration procedures. MANET-Internet integration scenario is more popular compared to other integration category. Most of the research works focus on integrating MANET protocols with mobile IPv4/ IPv6 as initiative towards supporting All-IP networks.

Satellite Gateway: Satellite Gateway connects the local MANET with Mobile Satellite network. Gateway node helps in remote communication and data transfer with remote areas. In existing works IP gateway that converts the information from satellite network to IP format, enable communication with remote MANET network.

Sensor Gateway (Sink): Wireless Sensor Networks (WSN) gets connected to MANET network via sink nodes for information sharing and modification. In WSN-MANET integrated scenario, information recorded due to change in environmental conditions, temperature, sound, vibration, pressure etc needed to be communicated using MANET . All information will be collected at sink nodes and transferred from sink nodes to other network. Gateway used must have the capability to store and forward information from WSN. The information gathered from WSN must be translated to format compatible with MANET. In most of the existing research works, the gateway node, which is the interface point between two different networks, facilitates the translation of data to a form understandable by the other network. Gateway node must be able to support different type of physical world data.

Table 1 gives an overview of the existing MANET integrated architecture and type of gateways used.

5. Service Discovery using Gateways

Proper deployment of MANET integrated networks enables mobile ad -hoc users to access services from outside world. With the advent of 4G networks mostly all the networks shift to the concept of All-IP network. The benefit of 4G networks ensures users the accessibility of services of other networks with maximum flexibility and less usage rate. Gateway acts as a service provider in one network, to access the service of other network. In the next generation wireless, network eighty percentages of the communication devices are expected to be mobile. Switching from one mode to other or extending the accessibility of a mobile node requires gateway node. The communication between mobiles node in such an environment can be either using single hop or multi hop routing. In order to achieve better performance in multi hop terminal-to-terminal communication, the routing strategies need to be modified by including gateways. MANET routing protocols are used to route packets between mobile nodes in a MANET. To extend the routing technique to other wireless technologies the route must be set to gateway nodes which act as an interface between MANET and other wireless technologies.

Table 1. MANET Integration Architecture- Related Works

Integration Strategies	(Architectures /Protocol) Existing Works	Goal	Type of Gateways	Gateway Discovery approaches
MANET-MANET	Inter-MANET (Lee et.al, 2010)	Enhance the coverage and improve deployment opportunities	MANET nodes	Multi hop
MANET-CELLULAR	iCAR (Cavalcanti et.al, 2005,Hu et.al, 2001)	Base Station load balancing	GW nodes at specific positions	Single hop gateway discovery
	ODMA (Rouse et.al, 2001)	Transmission power reduction	No gateways	Routing based on signal capacity
	A-GSM (Aggelou, Tafazoli, 2001)	Extending the coverage and connectivity in dead spot areas.	GSM dual mode MS	Proactive
	MADF (Wu et.al, 2002)	Base Station load balancing without any special device	MS between loaded and free cells acts GW nodes	Proactive
	SOPRANO (Zadeh,2002)	Increase the capacity of cellular networks-bandwidth, traffic control		Reactive- energy based
MANET-Internet	MIPMANET(Abduljalil, Bodhe, 2007)	Extends the coverage of Internet and MANET users	Internet gateway	Hybrid
MANET-DTN	(Kawamoto et.al, 2013, Raffelsberger et.al, 2013, Whitbeck, Conan, 2010) SF-BATMAN, STAR, DT-DYMO, CAR, HYMAD	Can shift between DTN and MANET depending on node density and mobility.	Network Gateway	Store & forward method, Message replication, Probabilistic custodian
MANET-WSN	(Chiti et.al, 2008)	Extending the rescue operations to more areas. i. e, extending the coverage	Sink	Reactive
MANET-Satellite Mobile Networks	MONET, (Mose et.al, 2007)	Helps Pc ,laptops etc that does not have a satellite interface to connect to satellite mobile network	Satellite gateways	Reactive

The routing strategies used in such environment can be categorized into MANET and Non-MANET routing strategies.

MANET routing is used to find best path between source node and destination node to route the packets in a MANET. Non-MANET routing is used for routing packets outside MANET. A MANET node with multiple interface helps in routing packets from MANET to infrastructure network. The routing strategies in MANET need extension for accommodating a path to gateway node for interacting with other networks. The categories of gateway node vary depending on the type of external networks to which a MANET is connected. The different categories of gateways identified in section 4 are satellite gateways, Internet gateways, cellular gateways, sensor gateways, DTN gateway.

Service discovery in integrated MANET network consists of different stages. Two main sections in service discovery are Gateway Discovery and Gateway selection.

The following section surveys various gateway discovery methods and selection schemes adopted in different integration scenarios where MANET was an active member.

5.1 Gateway Discovery Adopted in Integrated Scenarios

Gateway Discovery is a process of identifying a set of nodes that has multiple interfaces or employs the features

of a gateway node. It can be either a MANET node or a special gateway node mentioned in integrated networks. There can be more than one gateway nodes that are identified after the gateway discovery procedure. Gateway Selection procedure selects a best gateway from identified set of gateways taking into account the parameters like hop count, load and QoS Parameters. Gateway with optimal path will be selected based on the metrics used for selecting the gateway. The gateway discovery procedure should focus on discovering optimal paths to gateway nodes in minimum amount of time and with less overhead.

Gateway discovery methods are broadly classified into three based on the initiator of the discovery process. The classified approaches are listed as:

- Proactive gateway discovery
- Reactive gateway discovery
- Hybrid gateway discovery

The following section gives an overview of three different gateway discovery methods and lists their advantages and disadvantages.

5.1.1 Proactive Gateway Discovery

In a proactive gateway discovery, a mobile node depends on the existing routes available in its routing table to forward packets to gateway node. Proactive gateway discovery is initiated by the gateway. A gateway floods a gateway advertisement message (GWADV) throughout the network to announce its presence to its neighboring nodes. A gateway node starts sending GWADV on periodic time intervals or a mobile node gets access to multiple interfaces. On receiving a GWADV by a neighboring node, an entry is created in its routing table and it forwards the GWADV with a unique ID to its neighboring nodes. Through multi hop, routing in MANET the GWADV is forwarded to all nodes in the network.

Advantage

- Good connectivity between the mobile nodes and Gateway
- Predefined routes to the gateway nodes are available which result in fast routing.
- Minimum end-to-end delay in sending packet to an optimal gateway.

Disadvantage

- Increased overhead due to periodic flooding of GWADV messages.
- Increase in node density directly influences the routing overhead.

5.1.2 Reactive Gateway Discovery

In reactive gateway discovery method, if a mobile node need to connect to other network it is the responsibility of the mobile node to discover an optimal path to a gateway node. A mobile node in the MANET initiates reactive gateway discovery. A mobile node that wants to send a packet through gateway to other network sends a request to all available gateway nodes inside the MANET.

In reactive approach a mobile node that requires a path to gateway broadcast a gateway solicitation (GWSOL) message to gateway multicast address. In most of the integration strategies MANET routing protocols like AODV and DSDV are modified to in co operate GWSOL messages. RREQ is modified to forward such messages to IP address of groups of gateways linked with MANET. RREP is used by gateways to send back reply. Intermediate nodes on receiving the GWSOL forward it to nearby mobile nodes. Gateways on receiving the solicitation message replies with a GWADV message to the mobile node.[15,50]

Advantage

- Control messages are generated only on demand.
- Reduced overhead.
- Avoid periodic flooding of GWADV messages.
- Provides better connectivity.
- Messages are delivered with less delay.

Disadvantage

- Load on neighboring mobile nodes close to gateway node increases.
- Message delivery time increases.
- Cannot make a fast handoff decision in case of node mobility.

5.1.3 Hybrid Gateway Discovery

Hybrid gateway discovery is a combined approach that uses both proactive and reactive methods to discover a gateway node. Mobile nodes nearby gateway nodes use proactive approach while the far away nodes depend on reactive method for gateway discovery. In most hybrid approaches periodic updating of gateway information are done in mobile nodes that come under the advertisement zone. The message or advertisements end by the gateway to nearby nodes are called flood-periodic agent advertisements.[15,50]

Advantage

- Reduce the overheads needed for route / gateway discovery.
- Provide better connectivity.
- Reduces end to end delay

Disadvantage

- Difficulties in identifying the advertisement zone.

The hybrid gateway discovery approaches use different methods to send GWADV message to nearby nodes. Depending on the different methodologies used, the proactive area in this combined approach can be modified.

The main classifications of hybrid gateway discovery are shown in figure 8.

General approach use a fixed proactive area, the size of proactive area does not change with node movement. The performance of this approach decreases as the node mobility increases.

Adaptive gateway discovery guarantees the easy delivery of gateway information to the mobile nodes depending on various scenarios.

Different metrics were used in different proposals like hop count of mobile nodes from gateway, load of a gateway node, number of traffic source, artificial intelligence etc. Several adaptive gateway discovery approaches are compared.[56] One of the main factors, which affect the integration process, is security. If security parameters are include in gateway discovery procedure security problem related with routing to a network outside MANET can be solved.

A secure gateway discovery process mentioned in[57] uses TTL to limit the GWADV within a particular hop limit from the gateway. The intermediate node forwards the GWADV messages only on checking the security parameters for ensuring the identity of sender. In this category, the proactive area can be adjusted dynamically.

QoS aware gateway discovery focuses on transmitting real time multimedia flows. The proactive area in QoS approach is fixed which may affect the performance.[58]

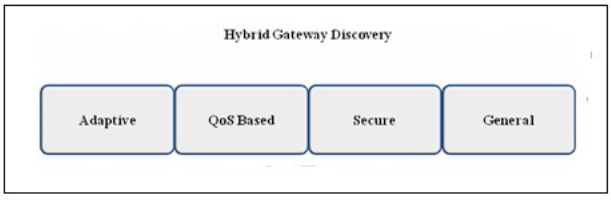

Figure 8. Hybrid Gateway Discovery categories.

5.2 Gateway Selection in MANET Integration Scenarios

Gateway selection schemes adopted by different integration architectures helps to select the optimal gateway from the gateways listed out in the gateway discovery phase. Normally gateway selection procedures are incorporated in existing routing protocols used by the mobile ad hoc network depending on a single or multiple metrics. The problems related with network overhead can be reduced using a good gateway selection algorithm.

If proactive approach is used the routing table of a mobile node may contain multiple gateway entries. In reactive approach, the gateway solicitation broadcasted by the MN will get reply from multiple gateways. In such cases a selection criteria need to be adopted for choosing a better and reliable gateway.

Different selection schemes adopted in integration strategies are categorized based on

- Hop Count.
- Traffic load of gateway node.
- Congestion and contention level linked with hop count
- Multiple metric scheme using hop count or load.

Selection schemes can be categorized mainly into two, one using hop count and other using hop count and metrics explained above. Some schemes use only traffic load of a gateway node to identify the best gateway. This scheme uses a reactive method.

Other combined schemes use adaptive methods to select the optimal gateway. The transmission of packets through gateways selected using adaptive methods provide less transmission delay and improves packet delivery ratio.[59]

When a node in the mobile ad hoc network desires to connect to another network it seeks the assistance of a gateway node. A best gateway node is selected based on the gateway selection strategies adopted by different integration architectures. Gateway Selection scheme varies with metrics used to find out the optimal path from the set of multiple gateways discovered. In this paper, we categorize the selection schemes into two, single metric and multiple metric gateway selection based on the number of metrics used to select gateway. The gateway selection schemes were widely been used in heterogeneous MANET and other network integration scenarios. Most of the researches focus on the gateway selections in MANET-Internet integration

scenarios. Some of the latest works related with various integration scenarios are listed.

A review on gateway selection approaches adopted in MANET, NEMO integration was provided in[59].

In heterogeneous mobile ad hoc networks which consist of MANETs using different routing protocols, dynamic gateway node selection is adopted to endure the mobility of nodes. A new scheme based on autonomous clustering was proposed in[60] for using in heterogeneous MANET to dynamically select gateway nodes. In this proposal ATR (Ad hoc Traversal Routing) protocol is installed in some nodes of each network. These nodes act as gateway nodes in each cluster. Usually in a gateway node with more number of neighboring nodes from other networks are selected as an optimal gateway node in such networks. A trust based gateway selection scheme in MANET –Internet integration scenario was proposed in[61] which use security metrics like node trust, route trust, hop count and residual load capacity to select an optimal gateway node. In this scheme, rather than selecting an optimal gateway node the emphasis is given to select an optimal or secure path with trusted nodes from gateway node to sender nodes.

In[62] proposed an efficient secure gateway selection and authentication scheme in MANET. This research work enables the secure transfer of confidential data between MANET and Internet. Apart from the work mentioned above this work aims at finding an authenticated, trusted secure gateway node that can be linked with the source node via a trusted and uncongested route with trusted nodes.

Gateway selection scheme proposed in[63] computes the weight of a gateway node using a Simple Additive Weighting (SAW) method depending on three metrics like number of hops, mobility or speed and remaining energy of MANET.

In[64] discussed an optimum Internet gateway selection scheme based on mixed integer linear program. The performance of gateway selected using the proposed method overwhelms the gateway selected using conventional multi metric gateway selection schemes.

In[65] discussed a QoS aware adaptive Internet gateway selection based on selection method using QoS attributes such as hop-count and residual capacity. This scheme selects an adaptive gateway and attains better load balancing and performance.

In[66] proposed a gateway selection scheme which uses multiple end to end QoS parameters to select a potential node. The proposed scheme aims at improving the overall network performance rather than performance depending on a single QoS parameter or multiple non QoS parameter than the approach described in[65]. This scheme considers multiple parameters like route availability period, route capacity and route latency. Before maintaining a route between the mobile node in MANET and Internet, a gateway node need to be discovered and selected as optimal one to help in communication with other network. The gateway selection is an important step prior to routing data from one network to other.

A gateway selection scheme can be categorized initially based on the number of metrics used for selection algorithm or technique. Considering the number of metrics the selection scheme can be categorized into single metric or multiple metric. Most of the prominent research proposals were based on multiple metrics. Multiple metric gateway selection schemes have the ability to find an optimal gateway node according to different scenarios. Single metric gateway selection has been proposed by many researches mostly in the field of MANET and Internet integration. Table 2 gives an overview of different gateway selection schemes used in different MANET integration scenarios.

6. MANET Gateways in Future Wireless Communication

Future networks aims in ubiquitous computing worldwide, where a mobile user can communicate with any device regardless of the location, time, communication media and technology. Existing standalone communication technologies are not sufficient to support such an endeavor. New technologies Machine-to-Machine communication, Device to Device networks, Internet of Things, Mobile cloud computing and Green Computing require cooperation of existing communication technologies. These technical ideas can make a magnificent change in the field of rescue operations, disaster avoidance and management, communication during military attacks, smart city implementation etc. In such scenarios, more than one category of networks will be employed in gathering and processing the information. An integrated architecture which supports more than one network must be designed based on various issues that may arise. Issues identified in such scenarios are related to scarcity of available spectrum, increase in deployment cost,

Table 2. Overview of Different Gateway Selection Schemes

Proposed Architecture	Integration Scenario	Metrics Used	Criteria adopted	Metric category	Evaluating Parameters
(Park et.al 2006)	Ad hoc wireless Internet Access networks	Hop Count, Residual Capacity	Redirect Selection Method (Coverage)	Multiple Metric	Average Delay, Packet loss, Packet delivery ratio.
F.P. Setiawan (Setiawan, Sasase, 2009)	MANET and Infrastructure network	Residual energy, mobility/speed, Number of hops in MANET	Weight Based	Multiple Metrics	Gateway Lifetime, Packet delivery ratio, Throughput
F. Hoffmann (Hofmann, Medina, 2009)	Ad Hoc and Internet	Min Max Node utilization	Mixed Integer linear program	Single Metric	PDR, Delay ,LBI
(Bouk, Sasase, 2009)	MANET- Internet	Route availability period, Residual load Capacity, Route latency.	End to End QoS Based	Multiple Metric	Throughput, Packet delivery ratio, Success rate, End to end delay, Average energy consumption
Manoharan, Mohanalakshmi, 2011	MANET-Internet	Node trust, Route trust, Hop Count, Residual load capacity	Trust Based	Multiple Metrics	Delivery Ratio, Control Overhead, Attack Success rate
K. Okano et.al (Okano, 2012)	MANET Heterogeneous Networks	Topology	Clustering	Single metric	Network gateway node ratio, Number of hops, PDR
A. K. Gupta (Gupta et.al, 2014)	MANET- Internet	Node trust, Residual Energy, Residual Load Capacity.	Security Based	Multiple metrics	Network trust

varying transmission range of communicating devices, mobility of wireless devices, security and addressing schemes.

MANET, a multi-hop, infrastructure less, self-organized and packet-based network can effectively be used along with the latest technologies for providing flexible networking capability among the mobile users. Multi-hop capabilities of MANET have opened a wide range of opportunity in D2D, M2M, Green communications etc. Most of the existing works focuses on integrating MANET with any one of the existing networks like Satellite Networks, Mobile Cellular Networks, WSN, VANET etc. MANET has the ability to work as an access point to other network. Proper designing of integration architectures results in reduction of deployment time and cost, enhancing the coverage of participating networks, reliability and automatic connectivity, availability of high data rate, reduce the transmission rate of wireless devices, effective utilization of available spectrum and supporting IP based networking.

Instead of using network specific gateways or dedicated gateways to interact with other networks, MANET can train its own node to behave as a gateway node. When a MANET node comes under the coverage of more than one network, the specified MANET node could work as a gateway node. Usually such nodes should have the capability to interact with other mobile terminals using multiple interfaces and multiple connections. The feature of next generation mobile devices should be modified to incorporate the support of multiple interfaces. Figure 9 shows an integrated architecture which shows the presence of multiple networks like Satellite, WLAN, Mobile Cellular Network and MANET. In this architecture, a MANET node can act as a multi gateway as it comes under the coverage of more than one network. In such cases, MANET node can become the access point for other networks like mobile cellular, satellite, WLAN and MANET as in figure 10. MANET node should be modified with capability to handle multiple interfaces as well as multiple networks. Such a scenario can be a starting to flexible, costless wireless communication worldwide.

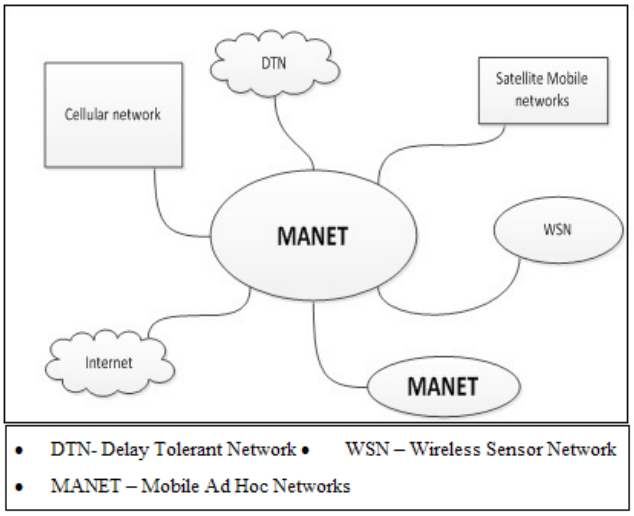

Figure 9. MANET Integration with different networks.

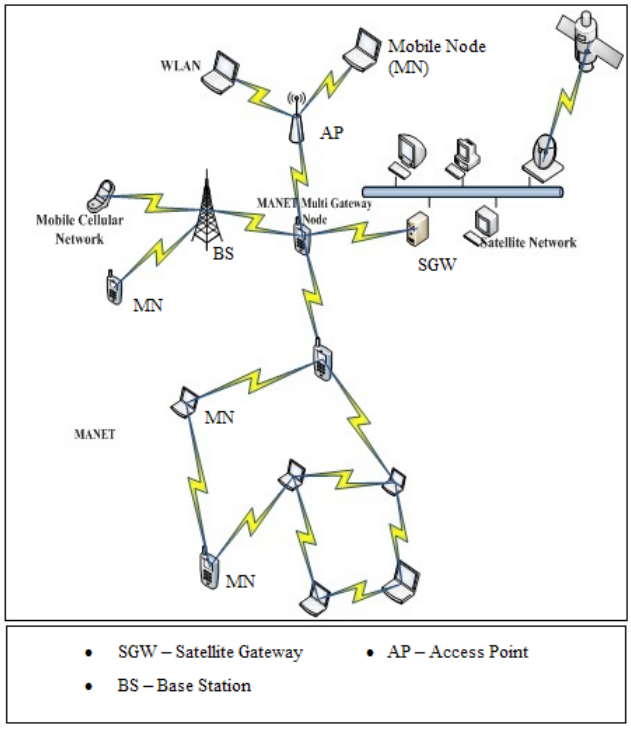

Figure 10. Multi-MANET-Gateway in MANET integration scenario.

7. Conclusion

Mobile Ad hoc Network an infrastructure less, self-organized network has proved to be a successful entity in future wireless communication. Integration of MANET and other networks focuses on ubiquitous computing around the world. Gateway nodes have gained more importance in the field of integration, which acts as an interface between participating networks. Such integration strategies can help in effective data transmission, effectively handle spectrum scarcity, reduce energy wastage and finally provide connectivity with limited cost.

Various integration strategies discussed in this paper will provide a detail idea about integration of MANET with Cellular Network, Satellite Networks, DTN, WSN, MANET, Internet etc. A brief overview of different integration architecture is discussed. Various issues are addressed, related with integration process such as gateway discovery, load balancing, security, location discovery, addressing and routing. The paper highlights the role of gateways in integrated environment. Discussion gives an idea about advantage of using different categories of gateways in integrated scenarios. The major phases in service discovery namely gateway discovery and gateway selection are analyzed based on existing works in various integration architectures are explained.

Last section explores an idea on how to effectively use MANET gateway nodes in future wireless networks. The research areas in such a scenario are opened to incorporate MANET, a costless network to be effectively used in next generation wireless networks.

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