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Integrated MANET Routing Scheme for Heterogeneous Networks

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Abstract: Future wireless networks aim in ubiquitous computing that maintains connectivity between mobile units without any constraints on time, place and type of media and connectivity. Connectivity in such networks needs to be maintained with less cost and time. MANET, an infrastructure-less wireless network can be used to maintain connectivity in future networks with the help of Multi MANET Gateway nodes (MMGW). MMGW can be used to connect MANET with any other category of network namely Cellular, WLAN, Satellite, WSN, Internet etc. This paper proposes an integration model, which enable a mobile user to maintain connectivity while mobile. MANET routing protocol AODV is modified to incorporate gateway initialization, discovery and selection procedures. Link stability and path stability are the main two parameters used to find the best gateway and path. A simulation model was developed and performance analysis was done to compare the working of MMGW under different networks.

Key words: MANET · Heterogeneous Network · MANET Gateways · Integration · Global connectivity · Coverage

INTRODUCTION

Future wireless networks aim 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 namely Machine-to-Machine communication, Device to Device networks, Internet of Things, Mobile cloud computing and Green Computing require the cooperation of existing communication technologies [1,2,3,4]. These technical ideas can make a magnificent change in the field of rescue operations, disaster 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 based on various issues that may arise. Issues identified in such scenarios are related to scarcity of available spectrum, increase in deployment cost varying transmission range of communicating devices, the mobility of wireless devices, security and addressing schemes.

MANET, a multi-hop, infrastructure less, the 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 [1,2,3,4]. Most of the existing works focus 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 another network. Proper designing of integration architectures results in the 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.

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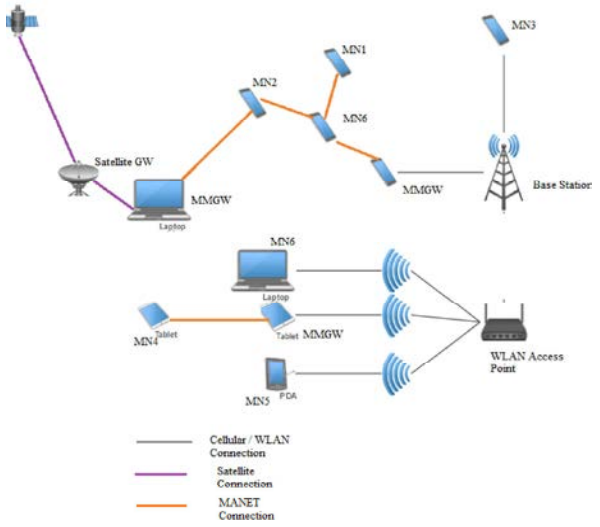

Fig. 1: MANET Integration using MMGW.

MANET seems to be valuable since they may increase the coverage of wireless networks with minor or no cost. Using them, terminals out of range of an access point or a base station, or not having adequate network interfaces, may reach the operator's infrastructure via other terminals. The need for reliable communication between mobile nodes in an integrated environment focuses on a new network model. The design of a new network model varies through the architecture design, protocol stack, routing.

Routing is one of the major issues related to an integrated network model. In such a scenario the major changes need to be incorporated in routing will be gateway discovery and selection. This paper focuses on the implementation of integration process using Multi MANET Gateway Node (MMGW) with new integrated routing solution. Existing Ad Hoc On-Demand Distance Vector (AODV) routing protocol [5] is extended to include gateway initialization, discovery and selection process to route packets to other networks via MMGW.

The proposed approach can be used in a heterogeneous scenario which combines mobile ad hoc networks and other networks. Using the proposed method a mobile node can communicate with the mobile nodes in a cellular network or other networks using multi-hop communication with the help of MMGW. The simulation model and performance analysis also demonstrate the effectiveness of the new approach in different heterogeneous scenarios.

The next section covers a review of some prominent MANET integration scenarios and their scope in future wireless networks followed by some discussion on implementation issues. The proposed model is explained with architecture and the routing solutions adopted. Simulation and performance analysis section gives an overview of the implementation details and performance of the proposed approach in different heterogeneous network scenarios.

Literature Review: Various MANET Integration strategies were reviewed in this section. MANET- satellite hybrid networks were found to be used in disaster management, emergency interactions or activities. Y.N. Lien *et al.* designed an integrated model; P2PNET combined MANET with satellite networks [6]. The main aim of such model was to support temporary group communication through satellite gateway nodes. M. Luglio *et al.*[7] proposed a project named SAVION for using in emergencies. Participating team members in emergency activities will be connected each other through a Savion MANET and in the case of emergencies; these groups were interconnected using satellite gateways.

In a project proposed by K. Kanchanasut *et al.* [8] IPStar geostationary satellite is used as the intermediate link between MANET deployed in disaster areas.

A proposal by A. Oliveira *et al.* [9] connects satellite access points to MANET using MANET nodes having satellite capabilities. MANET -Satellite integration projects were mainly tried in areas, which lack existing telecommunication technologies. The integration process in all the models used a dedicated gateway node or mobile terminals, which have satellite features.

G. K. Tak *et al.*[10] proposed an integration model that combines Cellular network with MANET for reducing the load of the base station. Such an approach also helped in communication of mobile nodes with less signal strength without the help of base station.

Cavalcanti, D *et al.* [11] proposed a self-adaptive method for integrating cellular network with MANET and WLAN. Both reactive and proactive gateway discovery approaches were adopted to choose a best gateway for connecting with WLAN or cellular network.

G. Cardone *et al.* [12] proposed the scope of combining Wireless sensor networks (WSN) and MANET. Many applications like urban data collection in smart cities. This paper discussed how such integration can be effectively done.

P. Bellavista modified the paper proposed in [13] and reported the scope of integrated WSN and MANET as a path towards Internet of Things (IoT). This paper discussed how such integration opens wide applications scenarios ineffective data collection in smart city projects. They also discussed how overlays were used for faster collection of data and its delivery using MANET.

A disaster recovery approach proposed by Y. Gadallah *et al.* [14] points to WSN architecture integrated with MANET. Service discovery in MANET was used in the approach for searching and allocating resource intended for rescue operations.

G. Jisha *et al*. [15] discussed the role of different gateways in different MANET integration architectures. The role played by gateways, gateway discovery and selection methods were also discussed to give a detailed understanding of integrating MANET with other networks in future wireless telecommunication field.

Issues in Integrating Multiple Networks:

Dynamic Network Topology: Major issue identified while integrating multiple networks is related to the change in topology of mobile nodes. Due to the mobility of the participating nodes, the topology of the network changes, this results in finding new routes using different network technologies and gathers neighboring nodes information to maintain connectivity. This may result in high control overhead. So the integration model should be designed to reduce the control overhead [15].

Protocol Stack: Integration of different wireless technologies with MANET demands a modified protocol stack. Protocol stack used in different wireless communication technologies varies from MANET protocol stack. In homogenous networks, all network components utilize same protocol stack. Each layer in such a protocol stack has specific functions and also serves the upper layers. In the case of heterogeneous network protocol stack of different communication, technologies need to be efficiently handled. The protocol stack of a MANET gateway node with multiple interfaces requires a modified structure which can execute different protocols for a given layer to occupy with both MANET and other wireless communication protocols [15].

Handoff: While a mobile node in heterogeneous network moves from one network to another the handoff occurs between gateways to support roaming among mobile users. Normally in such case vertical handoff are considered. Detection period is one constraint under handoff.

Routing and Gateway Discovery and Selection: Routing packets in heterogeneous networks need of gateway node to transfer the packet from one network to another. The best gateway needs to be selected in case of handoff or during initial transfer of data. Various gateway selection and discovery strategies were already considered. In this new model a MANET gateway with multiple interfaces need to be selected as a gateway.

Proposed Model

Architecture: Figure 1 shows an integrated model 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 MANET Gateway node 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 Fig 2. MANET node should have the capability to handle multiple interfaces as well as multiple networks. Such integration architecture can be used to support flexible, costless wireless communication-worldwide.

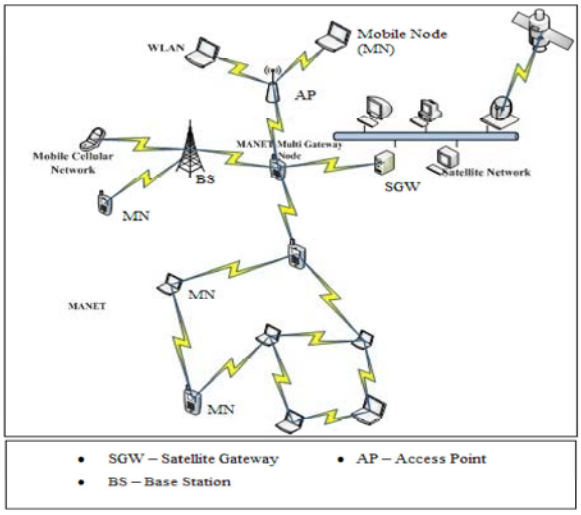

Fig. 2: Multi-MANET-Gateway in MANET integration scenario [15].

Components: The main components included in the integrated structure are provided.

- MANET Multi-Gateway Node: A Multi-interface gateway node with the property of most networks explained. Here an IEEE 802.11u can be used for avoiding preauthorization. MANET node will be given the feature of the multi-interface node.
- Satellite Gateway Node: A gateway node member of the satellite network. It helps in interacting with MANET gateway node to forward the packet to the satellite network and vice versa.
- Access Point (AP): Access point serves as the link with Wireless LAN, WLAN for a MANET node. Normally, a WLAN member gets the facilities of LAN using a single hop connection to AP.

- Base Station (BS): Base station (BS) in the cellular network helps in the interaction of mobile nodes under its coverage area via single-hop communication.
- Mobile Nodes (MN): A mobile can be a member of MANET as well as other networks.

Connectivity Scenarios: Consider two mobile nodes MN1 and MN2 in two different networks. In the case of new integrated model different connectivity, scenarios are possible.

Scenario 1: MN1 and MN2 interact through the cellular interface using BS in single hop mode.
Scenario 2: MN1 and MN2 communicate through WLAN interface where Access point AP provides the single hop communication.
Scenario 3: MN1 and MN2 communicate through Satellite Gateway Node (SGW) using satellite interface.
Scenario 4: MN1 and MN2 communicate through MANET interface using multi-hop communication.
Scenario 5: MN1 and MN2 communicate through WLAN interface via MMGW in ad hoc mode to communicate through multiple hops.
Scenario 6: MN1 and MN2 communicate through Cellular interface via MMGW in ad hoc mode to communicate through multiple hops.
Scenario 7: MN1 and MN2 communicate through Satellite interface via MMGW in ad hoc mode to communicate through multiple hops.

Integrated Routing Scheme for a generic heterogeneous network: A viable integrated routing solution, which supports routing among mobile nodes in an integrated network, is proposed in this section. Routing packets in multi-hop mode may use different interfaces like cellular, satellite, WLAN or MANET. If the nodes are communicating using MANET interface only MANET routing protocol need to be utilized. If it is between any other interfaces like cellular, WLAN or Satellite, IP-based modified routing solution can be used and routing will be through Multi MANET gateway nodes. Multi MANET Gateway Node (MMGN) is the main functioning unit in the integrated scenario. MMGN can interact with other networks namely Satellite, WSN, Cellular, WLAN or Internet using multiple interfaces.

Link stability factor of MANET node with any of the identified gateway nodes (BS/ AP) of external networks are used to initialize a MANET node as an MMGW node. The route discovery process will be handled using AODV routing protocol with modified gateway discovery and selection. Link stability factor is periodically identified by the MANET nodes with neighbor detection using a HELLO message. A mobile device intended to make smart decisions can depend on the link stability between identified multi-gateway node and the gateway node GW node (Access Point, Base Station, Satellite gateway, Internet gateway etc) in another network for forwarding packets.

Link Stability and Path Stability Estimation: Link stability between two nodes in the work is estimated based on signal strength/ transmission power and distance between two nodes. The equation for calculating link stability between MANET node and gateway node of another infrastructure-based network is demonstrated using the approach summarized in by R. Biradar *et al*. [16]. Let SS_{in} be the signal strength between two nodes i and j.

Let q_{ij} be the link quality between two nodes i and j and calculated as the reciprocal of bit error ratio.

Let d_{ij} be the distance between nodes i and j and calculated using the Euclidean distance formula

$$D_{ij} = v\,(x_j - x_i)^2 + (y_j - y_i)^2 \quad (1)$$

The LS_{ij} that represent link stability is calculated as

$$LS_{ij} = SS_{ij} * q_{ij} / d_{ij} \quad (2)$$

Path stability is taken as the average of link stability between each pair of nodes in a given path.

Let PS represent the path stability.

Let P1, P2, P3,..,Pn be the link stability between each pair of nodes in the path from S to D.

$$PS(S, D) = \frac{\sum_{i=1}^{n} Pi}{n} \quad (3)$$

Initializing a MMGW Node: A MANET node under the coverage of BS/AP (GW node) will be chosen as the MMGW. A reliable MMGW node is selected based on link stability estimated using equation (2) between the MANET node and GW node. It is calculated when the distance between the two nodes is less than the transmission range R. In order to find the link stability, the

MANET node can use periodic HELLO messages to acquire the information related to signal strength and position of each neighboring node.

Table 1: Fields identified in HELLO packet

Field	Function
NID	ID used to identify a mobile node
NLOC	Location information
SS	Signal Strength

Based on the signal strength of the neighboring node, the MANET node's table is updated with the value as in table 2. Initially, the value of the table will be set as zero. The source node can further use this value to send data to the corresponding network.

Table 2: Service indication value stored in MMGW

Gateway Type	Value
Satellite Gateway	1
Cellular Gateway	2
Internet Gateway	3
WLAN Access Point	4
WSN BS	5

Gateway Discovery and Selection: Gateway discovery in integrated scenarios is divided into three categories namely proactive, reactive and hybrid. In proactive approach gateway nodes periodically broadcast the information to other nodes in MANET. In reactive approach source node sends GWSOL, a solicitation message to gateway nodes. On receiving the solicitation message the gateway node reply with its information to the source node. In the case of hybrid gateway discovery, both proactive and reactive approaches are combined to find nearby gateway nodes [17].

In the proposed routing scheme, the initial phase in the routing is related with finding the best MMGW connected to an external network. The proposed routing strategy uses a reactive gateway discovery approach in finding available MMGW for transmitting messages to other network using multi-hop communication path. The source sends a GWSOL message to the neighboring nodes announcing its need for service from other networks. Available MMGN replies with its information and service mode it offers to the source node. The mode indicates the type of external networks connected to a particular MMGW. The source node on receiving the information about multiple MMGWs use equation (3) and the service indication value send by the multiple MMGW for finding MMGW with the stable path.

Routing: A modified version of Ad Hoc on Demand Vector (AODV) routing protocol is used to design the whole routing scheme, which includes gateway discovery, selection and routing. If the destination node is a member of MANET, an RREQ message is forwarded to neighboring nodes from the source node S to destination node D. If the destination address denotes a mobile node outside the MANET, it requires the service of a gateway node. In such case, GW-RREQ is forwarded to find a gateway node.GW-RREP format is changed to incorporate the details regarding MMGW node. On receiving multiple GW-RREPs regarding the same MMGW, the best path towards D will be chosen based on the path stability.

The packet is forwarded through the selected path to selected MMGW, which further forwards the packet to GW node of the external network.

Advantages of New Integrated Routing Scheme:

- Helps routing in heterogeneous environment
- Path reliability is given more importance.
- Enables cost effective communication in disaster areas, emergencies, conferences etc where existing telecommunication facilities fail.
- MANET node with multiple interfaces used to connect with other external networks.
- Every node in MANET can be connected to any other mobile device using different communication technology.

Simulation Model: The integrated routing strategy is tested in a simulated model developed using NS2. The heterogeneous network is simulated with wireless nodes ranging from 10 to 50. Three categories of GW nodes with varying features are used to represent Bases stations in the cellular network and Access Points in WLAN. Each MANET node is assigned three wireless interfaces. Multiple interface support is incorporated in NS2 to add multiple interfaces to each mobile node.One interface are used for a wireless link between two MANET nodes. The second interface represents the wireless link for MANET node and Base station (home gateway); Third interface represents the wireless link between MANET node and Access point (home gateway). The simulation area is set as 2000 X 2000 m2 area. Duration of each simulation is set as 1000 seconds. Free space propagation model is assumed. Mobility model used is the random way- point model. Traffic model used is constant bit rate. Exponential traffic generators are also used as application [18-20].

Analysis: Network behavior is analyzed based on following performance metrics.

Packet Delivery Ratio: It is defined as the sum of a number of packets received at each GW nodes to the product of a number of packets sent from the source node and a number of GW nodes.

Average End to end delay: It is defined as ratio between the sum of time interval between data packet sent time and the time all packets are received at each node and sum of data packets received by all nodes

Performance Analysis: In the performance evaluations working of three categories of gateway nodes are analyzed. The simulation scenario analyzed working of gateway nodes connected to access points, base stations and satellite gateways. In the case of packet delivery ratio analysis from the figure 3, best performance is shown by MMGW node connected to WLAN access points when compared to cellular gateways and satellite gateways. The Average end to end delay as in figure 4 shows improvement in the case of WLAN gateway connection compared to Cellular and Satellite connection [11-20].

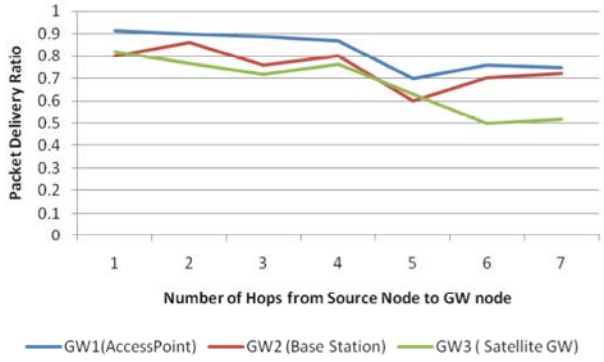

Fig. 3: Packet Delivery Ratio with related to different categories of Gateway nodes.

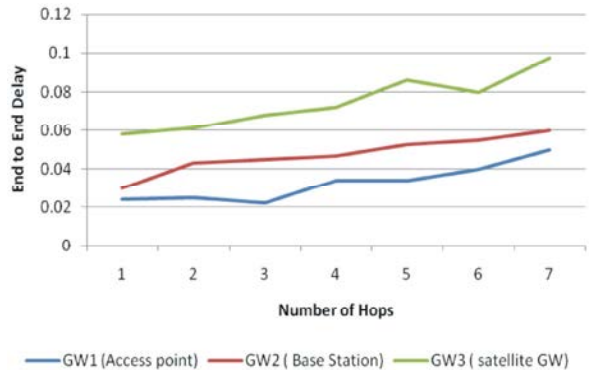

Fig. 4: Avg End to End delay experienced in different gateway categories.

CONCLUSION

An integrated routing solution has been proposed in this paper, which helps in integrating MANET with other category networks like cellular, WLAN, Satellite, WSN etc. In the proposed model, MANET nodes with multiple interfaces will work as Multi MANET Gateway node (MMGW) which helps in interconnecting with other networks. The work includes gateway initialization, discovery and selection followed by routing. Existing AODV protocol is modified to include gateway initialization, discovery and selection. Gateway initialization is done based on link stability between MMGW and gateway of other networks. A reactive gateway discovery approach is used and gateway selection procedure depends on path stability from the source node to MMGW. Packet Delivery Ratio and delay parameters were considered to check the efficiency of routing strategy with related to different networks connected to MMGW. Most of the other works focus either on integrating MANET with any one network namely Cellular or WSN or Internet or Satellite. In this integration model, more than one network can be connected using same MMGW node. By integrating different networks coverage and connectivity of next generation networks can be improved. Such endeavors can also help in molding new models which will be useful in developing latest technologies like Iota which support MANET-WSN integration, Device to Device (D2D) communication which supports MANET Cellular and Green Communication which all aim in the availability of telecommunication facility which is faster, cost less and available anytime and anywhere.

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