Journal of Engineering and Applied Sciences 14 (3): 802-811, 2019
ISSN: 1816-949X

Mobile Ad Hoc Networks and Routing Protocols in IoT Enabled Smart Environment: A Review

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Abstract: Mobile Ad Hoc Network (MANET) is an independent, decentralized, highly mobile, self-maintaining, self-repairing, self-configurable wireless network, free to go from one place to another place. These networks do not have any pre-existing infrastructure. Every gadget has freedom to go randomly from one place to another and changes its links to other gadgets usually. Frequent mobility of nodes in MANETs make the establishment of these networks very difficult and challenging in real environment and its design is totally based on routing protocols. Routing protocols are the key factors of MANETs. Such networks have random, rapidly changing, dynamic multi hope topologies which are made up of limited battery power and limited bandwidth with variable capacity links. Their unique property makes it different from traditional networks such as easiness to communicate, mobility, etc. The introduction of MANET in smart environment needs new protocols for connecting devices to the internet. Routing protocols in smart environment must guarantee fairness, quality of service, connectivity among the nodes, both in ad-hoc networks and access points. The quality of service is decided by speed of data delivery and the service quality. Service quality depends upon the routing protocols used for data transmission. Interaction between MANET and IoT (Internet of Things) creates a new MANET-IoT system. These systems provide better mobility for users and reduce implementing costs of the network. Requirements of these networks are increasing in meeting rooms, emergency room, personal area networks, rescue operations, military operations. This study provides an overview of MANETs, relation between MANETs and IoT and its routing protocols by highlighting their functionality, benefits, characteristics, limitations. It also presents comparative analysis of their performance.

Key words: MANET, security, DSR, AODV, OLSR, DSDV, IoT

INTRODUCTION

MANET is a temporary structure it is self-adjustable, random network without any fixed infrastructure or any centralized management. It is a collection of mobile nodes like laptops, mobiles, Notepad, etc. which have limited battery power consumption and bandwidth. Topology frequently changes in these networks so all nodes are free to move randomly anywhere and they established themselves in arbitrary manner. Routing protocols are required for sending data from source to destination. Designing of routing protocols for ad hoc network is difficult or challenging due to the limited resources and mobility conditions of the nodes. The main issue in constructing a mobile network is to enable each device to properly maintain the necessary details/data for traffic. Securing ad hoc routing presents another challenge because every user comes with its own mobile unit via. the network without any centralized policy (Chlamtac *et al*., 2003). In MANET nodes communicate with each other if they are within each other radio range. The introduction of MANET in smart environment needs new protocols for connecting devices to the internet. Routing protocols in smart environment must guarantee fairness, quality of service, connectivity among the nodes, both in ad-hoc networks and access points. The quality of service is decided by speed of data delivery and the service quality. Service quality depends upon the routing protocols used for data transmission. Efficient and effective routing protocols enhance the quality of service. The effectiveness and efficiency of protocol is decided by evaluating different performance parameters. Due to link instability, frequent changing topologies, node mobility, routing becomes important issues in MANET. A suitable routing mechanism helps in successful deployment of MANET in smart environment.

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MANET features

Dynamic topologies: Every node in the network is mobile, hence, free to move in any direction, Topology can change rapidly and randomly any time.

Energy-constrained operation: Nodes have limited processing power, storage and battery life. Hence, fixed number of services and applications can be maintained by the mobile system.

Heterogeneous network: Nodes of MANET have dissimilar radio receiving (upstream) frequencies and radio transmission (downstream) frequencies.

Limited security: Wireless networks are more vulnerable to security and privacy then fixed networks.

Limited radio range: Due to limited transmission power ad hoc network have limited transmission range.

Fast installation: MANET does not require any previous infrastructure or installation, hence, the flexibility level for setting up network is high and thus, they can be built and demolish in small time.

Fault tolerance: Rate of repair/link failure is high when nodes move. MANET support connection failures and routing protocols are designed to maintain these situations.

Literature review: Jeba and Kamala (2016) referred to the problem of IoT (Internet of Things) routing protocols in detail. They have taken various performance metrics like energy consumption, route optimization and latency for comparison analysis of various routing protocols. They discussed that in dense or sparse area the IoT gives interconnectivity among various gadgets and movement models can be used for controlling device movement purpose and hence, stated that routing process is clearly affected by movement of nodes in the network.

Two very important protocols of MANETs (destination-sequenced distance-vector and ad hoc on-demand distance vector routing) have been reviewed by Patil *et al.* (2017). And a comparison between DSDV and AODV has been done by him. By studying his review research, we can choose protocols according to performance and scenarios and we can tell which routing protocol could better perform in particular circumstance.

Alheeti and Al-Ani (2017) presented a novel strategy in which new approach has been brought to the internet of things to save the consumer power of devices. In wireless sensor networks a novel scheme is proposed for managing the sleep of nodes in networks. So that, network connectivity can be kept and energy can be stored for future. The key feature of the scheme is its simplicity. The effectiveness and convenient feature makes this approach more beneficial and this has been successfully applied to many places of the networking.

Ramana and Krishna (2016) proposed a new method for delay tolerant in mobile ad hoc networks. They proposed a new opportunistic adaptive routing protocol. They used a proactive method for routing mechanism and by including a new concept called HUB they had chosen a new route between source and destination. The fitness value of all the nodes in the network has been found by the routing protocols and the nodes having highest fitness value are chosen for the further process.

Nikam and Jadhav (2016) used DSDV (Destination-Sequenced Distance-Vector) protocol to analyze the delay factor in mobile network. The delay was observed in both, low and high conditions by taking various factors like speed pause time, total number of nodes, connection between the nodes, etc.

Das and Seth (2016) reviewed three widely used routing protocols (Dynamic MANET on Demand (DYMO), Dynamic Source Routing (DSR), Ad-Hoc on Demand Distance Vector (AODV)). Evaluation has been done using various factors, e.g., mobility and traffic density.

For the evaluation of two active MANET routing protocols (AODV, DSR) and one proactive routing protocol (DSDV) a mathematical model is presented by Pathak *et al.* (2014) here which research for performance evaluation and presimulation TCL files.

Mechanisms of some widely used existing MANET routing protocols (such as OLSR, DSR, AODV) have been studied by Xin and Yang (2015). And there execution is exploited in internet of things circumstances to find an accurate mechanism of routing for IoT future.

Liu *et al.* (2013) presented B-AODV (improved approach), a new optimized routing protocol. Which was based on the concept of finding the shortest route in network. This study presents key techniques of mobile adhoc network, its basic characteristics and compared it with the mobile communication system.

Chaturvedi *et al.* (2012) presented a study in which energy consumption problem in adhoc network is solved by the proposed algorithm and it also helpful for solving routing problem in network. In static network they also presented energy optimal path algorithm using greedy method. And the proposed algorithm presented better simulation result.

Mohan and Selvakumar (2012) presented a paper in which a modified and enhanced version of AODV protocol is invented and the protocol is modified in such a way that only target node can respond to route request. And this was helpful in reducing control data messages into the networks. Using modified AODV protocol they have presented an adaptive routing concept in mobile network.

Tian and Hou (2010) proposed research shows that, AOMDV-IoT protocol shows better simulation result as compared to AOMDV. A method was designed which used to take function of both network node as well as routing destination.

Espes and Teyssie (2007) presented a research, here, the numbers of control packets were reduced and backbone network was used by an AODV based protocol for minimization of control packets. GPS has given the destination location which was transmitted to the initial node by backbone network.

Naski (2005) presented comprehensive study of various MANET routing protocols and they represented some important features, characteristics. Protocols performance is analyzed and compared using mobile scenario. MANET features are also discussed by Sun (2001).

MANET architecture: MANET's nodes are differentiated by their capabilities. A client or Small Mobile Host (SMH) includes a node with reduced storage communication and power resources while servers, i.e., Large Mobile Host (LMH) is a node with more in same aspects. Larger capacity of LMH occupy the complete DBMS and client quires, data broadcast rely on same. SMH on other hand cache some portions of database with some DBMS query storage and modules. Each node in MANET is confined in area of control where transmissions are heard by other nodes and vice versa. A large area is occupied by LMH due to its more powerful battery. The area of control is reduced as power level decreases because broadcast gets reduced power in that scenario. Three modes are designed to facilitate the reduction in power for network modes are (Jun and Ning, 2010).

Transmit mode or active mode: Here, the most of power is used by the nodes. It allows both the reception and transmission of messages.

Receive mode or doze mode: Here, the CPU is capable of processing information and is also able to receive acknowledgement messages from different nodes.

Standby mode or sleep mode: The node remains inactive in this mode and CPU does no processing, the node is not able to receive/send messages. Here, a node turn itself off for some time without requiring power-up or re-initialization. There are two approaches to providing network connectivity in a MANET.

Flat-routed architecture: In this approach, all nodes have same responsibilities and features and all the nodes are identical in terms of responsibility. The advantages of this approach are:

- Reduced use of wireless resources
- Offer different alternate options of routes in the network
- Enhance survivability and reliability due to no single point of failure
- Load balancing property become well
- Optimal routing
- All nodes have one type of equipment

Hierarchical network architecture: This approach comprises the whole network into subnetworks. A dynamically selected node is serves as gateway in each of the sub networks. This results in forming a one tier or multi-tier hierarchy among nodes. The advantages of this approach are:

- Easy mobility management procedures
- Better to manage

MANETS AND INTERNET OF THINGS (IOT) ENABLED SMART ENVIRONMENT

Smart environment provides smart solution and provides a good quality of life to its citizens. It provides a society that is invisibly and richly interwoven with displays, actuators, sensors, embedded seamlessly in everyday things to our life and provides a sustainable and clean environment. Interaction between MANET with IoT (Internet of Things) creates a new MANET-IoT system. These systems provide better mobility for users and reduce implementing costs of the network. But it opens new challenges in networking also. Many methods have been adopted to connect MANETS to internet. Internet may be used to route the packets of nodes having IP addresses in MANETs but the main issue known arises is to find out whether a particular address in MANET exist or not and whether need a gateway or Access Point (AP). Contexts of node being unaware make it difficult to collect/gather IPs of neighboring node. To gather the neighboring information discovery procedure need to be executed. This procedure may lead to time and memory consuming as it may require the nodes to exchange large amount of packets. An AP might be required to enable the

mobile nodes communicates to internet. Due to mobility of nodes the effective position of a gateway could be a challenge design factor. However, the effective placement of gateway could be effective by mobility conditions. This may lead to placement of mobile access point. One solution is to have to two different IPs one to recognize nodes in MANETs and other to communicate through the internet. To make the target gateway challengeable nodes can moves freely. A new IP address should be used in case of nodes switching to another solution by using dynamic address by solving the problem of IP address when nodes are moving. The improving cellular technologies like 4G, 5G, EOLTE enables the nodes to connect to the internet. The users are required to subscribe their unlicensed technologies for services like military application, satellite communications could be used for further research. MANET (Mobile Ad hoc Network) in general is similar to wireless sensor networks, both are multi-hopped and self-organized networks. WSN and MANET, both networks can enable more reliable and effective cross routing in IoT context. MANET's topology is quit more changeable then wireless networks. An ad hoc wireless network provides a way to transmit data in low cost and effective manner in IoT systems. Deployment cost of such networks is very less as compared to wired technology. The connection of Ad hoc network to internet is still a challenging task (Bessis *et al*., 2013). Interaction between IoT and MANET is shown in Fig. 1:

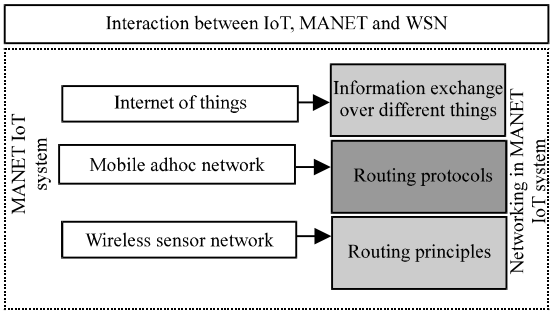

Fig. 1: Interaction between IoT, MANET and WSN

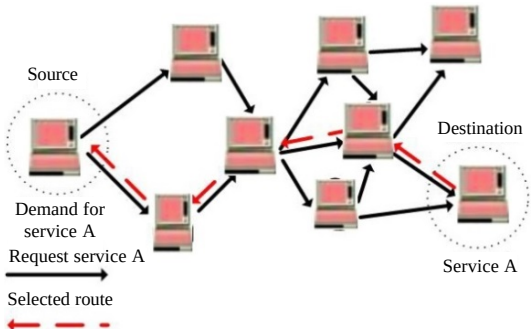

Fig. 2: Routing in MANETs

Routing in mobile ad hoc networks: In such network, routing plays a key role to improve the performance of MANET applications. To achieve efficient routing various protocols have been proposed. Routing protocols are used to find out the route from source to destination. Service quality depends upon the routing protocols used for data transmission. Efficient and effective routing protocols enhance the quality of service. The importance of routing protocols in MANET is shown in Fig. 2.

If source node demands for service A then it generates a discovery process. The discovery process flow is shown by the black arrows. The middle nodes transmit the coming request until any request reaches the target node. The destination node supplies the required service. When routes are found, it is the responsibility of routing protocols to choose the optimized or most accurate route. Some metrics are used to find the routes quality such as end to end delay, hop count distance and throughput. Mobility of nodes can cause changeable dynamic topologies, so, routing protocol must be able to deal with these mobility conditions by applying approaches to re-establish broken communication links. Broadcast storm problem isthe issue in discovery process of routing protocols in ad hoc network. This problem is created due to the repetition of request as shown in Fig. 2. Here, many packets are redundant (Bessis *et al*., 2013). Routing protocols of MANET can be categorized in energy awareness based routing, location based routing and topology based routing.

Service and resource discovery are important for effective performance in ad hoc networks. All services and resources must be known to the nodes. Service and resource discovery approach must work in collaboration with routing protocols. There are two types of architecture for service discovery process, directory less based architecture and directory based architecture. Directory based ask architecture can be divided into two categories, distributed directory and centralized directory. In the directory less based architecture services are reactively requested by the nodes and services are proactively advertised by them. On the other hand, directory based schemes have a directory agent which is responsible for handling and registering services. We can easily distinguish between distributed and centralized directory by observing the number of nodes which implement the agent of directory. This is the responsibility of these nodes to keep the existing directory of service up-to-date in the network. Service and resource discovery

approach is essential for connecting MANETs to smart environment (IoT). Routing protocols in mobile networks are subdivided into three basic classes:

Table driven (proactive) routing protocols: Here, every node contains table which maintains routing information to all other nodes in the network and tables are updated by these nodes at regular intervals and maintain up-to-date and consistent information in network. They maintain the information before it is needed, hence, these are called proactive routing protocols. Various proactive protocols are Destination-Sequenced Distance-Vector routing (DSDV), Optimized Link State Routing protocol (OLSR), etc. (Mohseni *et al*., 2010).

On demand (reactive) routing protocols: Routes are searched when packets have to be sent by the source node, means protocols obtain routes only on demand. Various reactive protocols are Ad Hoc on-Demand Distance Vector routing (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA), etc.

Hybrid routing protocols: Hybrid routing protocols takes the best features of both, reactive and proactive protocols. Example: Zone Routing Protocol (ZRP), etc.

Ad Hoc on-Demand Distance Vector routing (AODV): AODV protocol is a mixture of DSDV and DSR protocols. When a source node has to send data to the destination and it does not have a fresh or valid route, then it initiate the route discovery process. A Route Request packet (RREQ) is broadcasted by it to its neighbors and they forward this request to their neighbors and so on. Until either the middle node or destination node with fresh enough route to the destination node is find out. If within some time limit the node does not get the RREP message, it again broadcast route request message to the network or its assume route is not present. It uses the sequence number for fresh route and maintains the table entries for fresh route information. Every node has its own broadcast ID and sequence number. With every RREQ message, broadcast ID is incremented. The most recent or current sequence number for the target node is included by the source node in the route request packet along with its on broadcast ID and sequence number. A reply is given by middle node if they have fresh way to the target node. Routing table maintain all information and provide help for creating reverse route. For local connectivity hello messages are used in the network. After Receiving Route Request message (RREQ), the intermediate or destination node response with Route Reply message

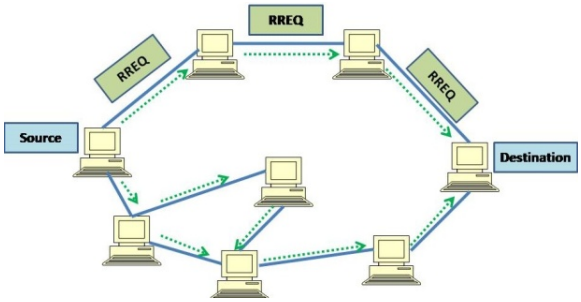

Fig. 3: Route Request (RREQ)

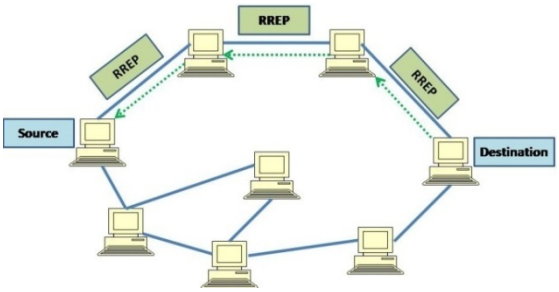

Fig. 4: Route Reply (RREP)

(RREP) back to the neighbors nodes. Figure 3 and 4 show the route request and route reply process, respectively (Mohapatra and Kanungo, 2012).

Once a route request message received by the intermediate or destination node, route reply message is sent back (rivers path). The nodes along the reverse route maintain their tables with forward route entries which indicate the node from which the route reply has come.

Characteristics of AODV: Some of characteristics of AODV are as follows:

- Multicast, broadcast and unicast communication
- Route establish when demanded by the source node
- Sequence number provides loop free routes
- Active routes links breakage is efficiently repaired
- Take care of just next hop rather than the whole route
- It is adaptive to highly dynamic topology
- If the sequence numbers are very old they can cause inconsistent routes and can have stale entries

Destination-Sequenced Distance-Vector Routing (DSDV): DSDV gets the idea of on distance vector routing protocol with certain enhancements/ improvements. Here, each node contains a routing table that includes all possible targets and expected number of hopes to reach the destination. DSDV keeps the sequence number to distinguish the old path from new one and hence, formation of loop is avoided. To maintain

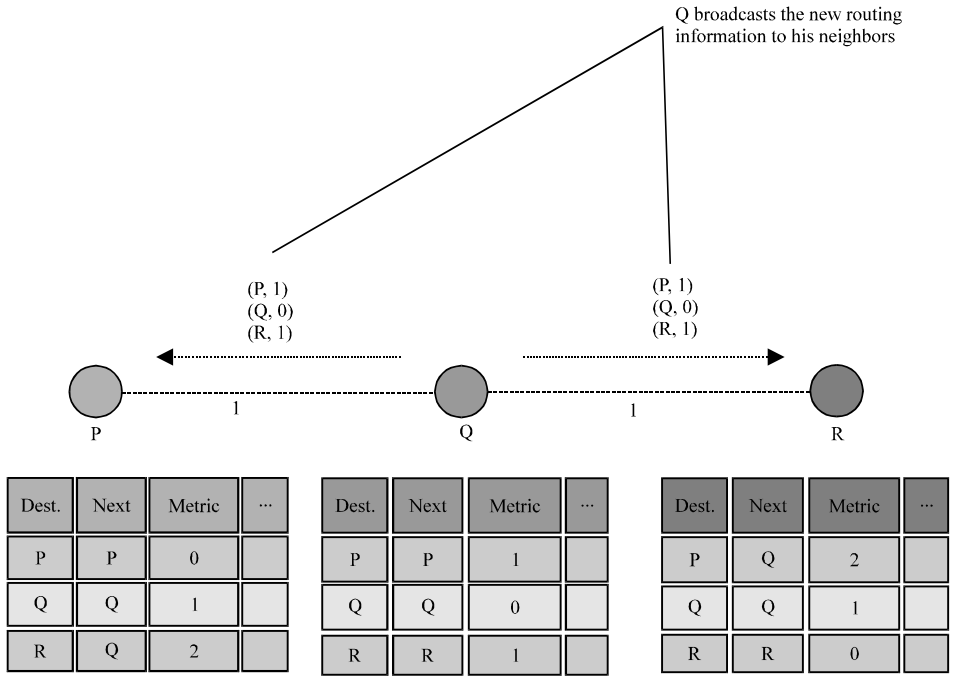

Fig. 5: Exchange of routing table and hello messages

consistency in the routing table updates are periodically transmitted through the network. Routing updates can be sent through two ways: incremental update and full dump type. In incremental update only those entries are sent from the routing table which leads to metric changes, since, the last update. In full dump type packet the whole routing tables is sent to neighbors and can span many packets. The DSDV required addressing the following two issues:

- Message overhead problem
- As each node in the network require maintaining a complete list of routes, hence, large memory and bandwidth is required

This routing protocol node uses "Hello" messages to present them. In Fig. 5, hello messages will be sent by PQR nodes. Node Q has pand R neighbor, node Pand R will introduce Q as a neighbor. Hop count is shown by the metric field in table of each node. Each node will send whole routing table to its neighbor. By this method node P reach to node R through node Q in two hops (Dass *et al*., 2015).

In Fig. 6, when a new node S comes, it will send a hello message, node R will accept hello message and add node S as new neighbor. Now, node R will send an advertisement about node S and also update its neighbor. Then node Q will insert node S to its routing table and do the same as node R. In last new node S is added by all the nodes to their routing table.

If in some case as shown in Fig. 7, node S moves away from node R and R can't reach it anymore, then R must send an advertisement to the entire network that it can't reach node S anymore, so that all nodes update their routing table (Dass *et al*., 2015).

Characteristics of DSDV: Some of characteristics of DSDV are as follows:

- Updates are periodically transmitted by each node (includes its own sequence number, routing table updates)
- Routing table updates are sent by nodes for important link changes
- When two routes to target node receive from two different neighbors
- Select the route which has greatest sequence number, if same, select the smaller hop count
- DSDV gives its best performance under no mobility (high delivery rate, fails to coverage for increased mobility)

Dynamic Source Routing (DSR): When source node wants to send packets to target node it initiates the route

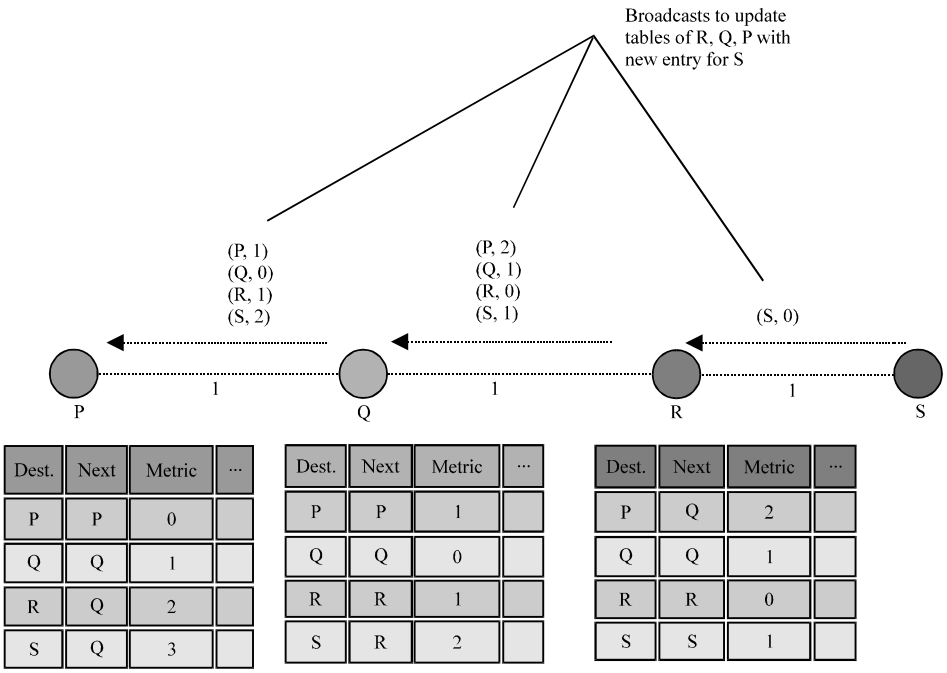

Fig. 6: New node arrive to the network

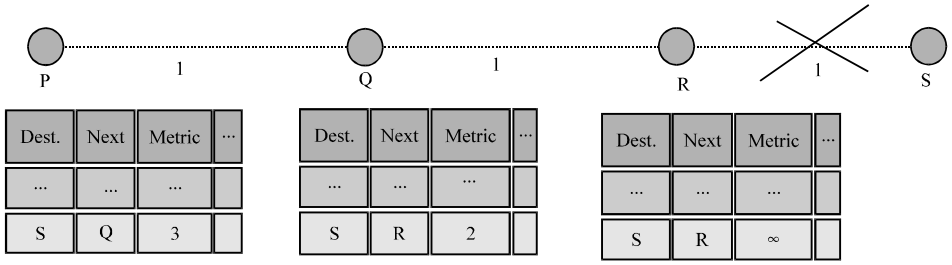

Fig. 7: New node arrive to the network

discovery process. The node checks its route cache to see if there is a route to destination already. If an unexpired route to the destination is found by it then this way is used for sending packets. If it doesn't find any route, it initiates route discovery process. A Route Request (RREQ) is broadcasted by the source node in the network. Route request maintain unique identification number, destination address and source address. A route to destination is checked by every node which receives route request packet. If node doesn't find any route to destination it attaches its own address to packets route record. Packets are sent to its neighbor's node. And if it find a way it send a Route Reply (RREP) packet having the optimal path information to the source node using shortcut route. If a node has a route request message it will not accept the same route request message which already has its address in its route record and hence limit the number of route request propagated. The route record is formed by the route request propagated message (Johnson *et al*., 2001). Dynamic source routing protocol needs each transmitted message to carry the complete address from source to target/destination. Due to this process DSR not perform properly in large network as the size of message increases continuously the amount of overhead carried is also increases and large amount of bandwidth is consumed by it.

DSR protocol is able to adapt according to topology changes. It does not require any central administrative system for controlling the routing process. Congestion and collision problem may also occur here. Invalid routed nodes can mislead other. It is possible that a valid route has expired. Reasonable expiration time is difficult to determine because the nodes consists of mobility and the source of sending rates can vary widely and can be changed randomly and dynamically from node to node. It has scalability problem (Mohseni *et al*., 2010). DSR is vulnerable to different types of attacks (Marina and Das, 2001).

Optimized Link State Routing Protocol (OLSR): Optimized Link State Routing (OLSR) (Tian and Hou, 2010) is a table driven protocol. This protocol uses Topology Control (TC) and hello messages to identify and then spread link state information within network. It gets idea of traditional link state method and it is a point to point routing protocol. For forwarding control traffic, it uses Multipoint Relays (MPR) concept into the network. To control the protocol overhead it uses various parameters like TC redundancy parameter, MPR coverage parameter, TC interval parameter, hello-interval parameter, etc. By using multipoint relays (selected nodes) it reduces the control traffic overhead into the network. It reduces the number of repetitions expected to disseminate a message to all nodes in in network. Updated topology information is periodically sent by OLSR throughout the whole network. The throughput is better when compared to other protocol (DSDV). Congestion control factor is not supported by this protocol. Multipoint relay concept is used for efficient flooding of control traffic. OLSR minimizes the rebroadcasting nodes and reduces the size of control messages. OLSR supports three mechanisms: sufficient topology information, efficient flooding of control traffic and neighbor sensing.

Performance metrics: Many factors can be considered as the performance metrics of routing protocols and the major concern factors are as follows:

Routing overhead: This explains how many routing packets are needed to be sent to route discovery and route maintenance, so that, data packets can be propagated.

Throughput: It can be defined as the total amount of data that the recipient actually received from the sender divided by the time it took to receive the last packet.

Average delay: It measure in seconds. Average end to end delay is represented by this metric and it represents how long it took for a packet to go from source pointto destination point.

Packet delivery ratio: The ratio of the packets of incoming data and packets of received data.

Media access delay: Time taken by a node to access media to initiate packet transmission is known as media access delay. Delay is recorded for each packet.

Energy consumption: It indicates the energy consumption level from starting to destination in message transmission.

Latency: It shows the delay time for sending packets from starting point to destination point.

Route optimization: Difference between the route taken by the packets and the best route for sending packets. An optimal or best route should be selected for packet transmission.

Redundancy elimination: It indicates how many duplicate/redundant packets eliminate by routing protocols.

Loop free: Provides loop free path in the network.

Reliability: It shows the error rate.

Scalability: It defines the ability of a network to scale.

Load balancing: It shows the amount of network traffic.

PERFORMANCE COMPARISON ANALYSIS OF VARIOUS PROTOCOLS

In this study, a summary of comparison of four main routing protocols is given on the basis of following parameters as shown in Table 1.

Proactive protocols use flat and hierarchical both type of routing structure but reactive protocols mostly uses flat structure for routing. Proactive protocols always have availability of routes but in reactive protocols routes are determined when needed. Reactive protocols have lower control traffic volume than proactive protocols. Proactive contains more control overhead as compare to reactive protocols and they required more bandwidth and power as compare to reactive protocols, delay level of reactive protocols is higher. It is important to improve the performance of routing protocols because they have many limitations. For example, packet loss due to transmission errors, short battery lifetime, controlling message overhead, frequent disconnection, adaption issue, delay issue in networks, connectivity problem, power or energy consumption problem, security problem, problem in quick establishment of routes, etc. Most of the mobile adhoc networks protocols are designed and implemented in small area and there performance decreases as the network increases, hence, the enhancement in routing protocol is required.

Table 1: Here, comparison analysis is done by taking different parameters

Parameters	AODV	DSDV	DSR	OLSR
Routing approach	Reactive	Proactive	Reactive	Proactive
Routing structure	Flat structure	Flat structure	Flat structure	Flat structure
Hello messages	Yes	Yes	No	Yes
Route selection	Updated and shortest path	Link state	Shortest path or next available	Link state
Multiple routes	Yes	No	Yes	Yes
Energy consumption	High	High	High	High
Latency	Low	Low	Medium	High
Route optimization	Medium	High	High	High
Redundancy elimination	High	High	Medium	Medium
Loop free	Yes	Yes	Yes	Yes
Reliability	Yes	Yes	Yes	Yes
Scalability	No	No	No	No
Load balancing	No	No	No	No
Route maintenance	Routing table	Routing table	Routing cache	Routing table
Advantages	Low overhead, higher bandwidth efficiency, loop free, adaptable to high dynamic topology	Loop free, shortest route to every destination is selected	Support multipath routing, promiscuous overhead, loop free	Reduced control overhead and contention, good transmission quality
Disadvantages	Takes more time to build the routing tables, scalability problem	High overhead	Flooding and source routing creates scalability problems, high route discovery latency	Two hop neighbor knowledge required

CONCLUSION

This study provides an overview of MANETs and its routing protocols by highlighting their functionality, benefits, characteristics and limitations. MANETs and IoT enabled smart environment is also discussed here. The introduction of MANET in smart environment needs new protocols for connecting devices to the internet. Comparative study of various protocols has been also done. It is difficult to achieve power and security awareness across these networks due to dynamically changing topology and infrastructure less features. Therefore, the power awareness mechanism and security facilities for all kinds of applications in ad hoc network should be built.

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