Volume 3, Issue 4, April 2013 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Survey of Routing Protocols for Mobile Ad Hoc Networks

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Abstract— Mobile Ad Hoc Network (MANET) is a self organized and self configurable network where the mobile nodes act as routers and connected by wireless link. Routing is a process in which a route from a source to a destination node is identified. Due to mobility involved in the MANET routing becomes an important factor and needs to be improved in terms of communication. There are different factors which are considered for research work like routing, security, synchronization, bandwidth considerations etc. Different routing protocols are proposed for different type of network conditions

Keywords— MANET, Reactive, Proactive, DSDV, WRP, AODV, DSR

I. INTRODUCTION

MANET has gained popularity in last few years and research has been done on different aspects of MANET. Mobile means moving and Ad Hoc means temporary without any fixed infrastructure so Mobile Ad Hoc Network is a temporary network in which nodes have mobility without any fixed infrastructure or centralized administration [1].Designing of an efficient and reliable routing strategy is a challenging task due to limited resources of MANET. An effective routing strategy required to efficiently use the limited resources while at the same time being adaptable to the changing network conditions like traffic density, size of network and network partitioning [2]. MANET is very useful in situations like emergency services, tactical network, education, entertainment, natural disasters etc. The nodes which are in the transmission range of each other communicate directly otherwise communication is done through intermediate nodes which are willing to forward packet hence these networks are also called as multi-hop networks[1].

Figure 1: MANET

Characteristics of MANET

- **Dynamic topology*:*** Topology of the network changes very frequently in comparison of the wired network. Each node can dynamically connect to each other and form the arbitrary network where topology change is generally due to occasional link failure or link re-establishment.
- **Limited Bandwidth**: the bandwidth available for wireless networks is generally low than that of wired networks. The throughput of these networks is generally low due various noises, fading effects.
- **Multi-hop communication**: Mobile nodes that are not in the direct communication range of destination require intermediate nodes for routing the packets
- **Energy constrained nodes**: each node in a wireless ad hoc network operates on battery power and battery energy is a rare resource [3].
- **Lack of security**: Due to mobility of nodes mobile wireless networks are generally more prone to suffer from security threats than wired networks.

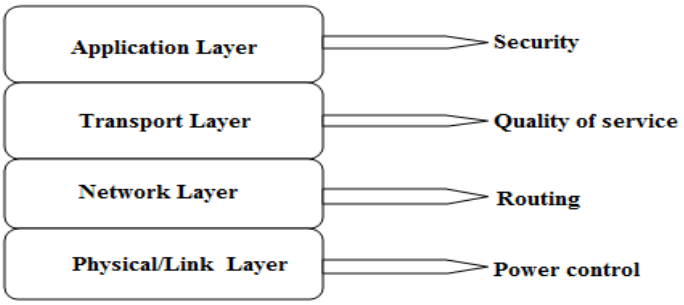

Figure 2: MANET Challenges

Ad Hoc Applications [4]

- Tactical networks : Military Communication automated Battle fields
- Sensor Network : Remote weathers for sensors, earth activities
- Emergency Services: Disaster recovery, earthquakes, crowd control and commando operations
- Educational Applications: Setup virtual class &conference rooms
- Entertainment: Multi-user games, robotics pets.
- Location Aware Services: Automatic Call forwarding, advertise location specific services, Location–dependent travel guide.

Desired Properties of Ad Hoc Routing Protocols [5]

- Distributed implementation
- Efficient utilization of bandwidth
- Efficient consumption of limited battery power
- Optimization of metrices
- Fast route convergence
- Freedom from loops
- Unidirectional link support

Objectives of MANET Routing Protocols [6]

- To maximize network throughput
- To maximize network lifetime
- To minimize delay.

II. CLASSIFICATION

Routing protocols are classified in following categories:

- Proactive (Table Driven) Routing Protocols
- Reactive (On –Demand) Routing Protocols
- Hybrid Routing Protocols

a. Proactive (Table Driven) Routing Protocols:

In proactive routing each node maintain one or more routing tables. Proactive protocols continuously learn the topology of the network by exchanging topological information among the network nodes [6].The differences among the protocols lies in their routing table structure, number of tables, updating frequency, use of control messages and the presence of a central node [7].Whenever there is need for route from source to destination routing information is available instantaneously. Maintenance cost of the network might be high due to frequent exchange of information between the nodes. When communication is needed, the source node has an entry for the route to the destination and there is no need to wait for route discovery phase to prepare and find the path [8].

b. Reactive (On-Demand) Routing Protocol

In this routing protocol routes from source to destination doesn't exist .Whenever route is required each node discover and maintains the route as and when required. In On-Demand routing protocol paths are explored only when needed. When source node has packets to send it initiates the route discovery procedure by broadcasting the control message to all the nodes that are within its range.

The discovery procedure terminates either when a route has been found or no route available after examination for all route permutations. Due to mobility of nodes in Mobile Ad hoc Network active routes may be disconnected so route maintenance is an important operation of reactive protocol. Advantage of reactive protocols is less control overhead as compared to proactive protocols for Mobile Ad Hoc Networks. Thus, reactive routing protocols have better scalability than proactive routing protocols in mobile ad hoc networks. In these protocols, source nodes may suffer from long delays for route discovery before they can forward data [9].

c. Hybrid Routing Protocol

Hybrid routing protocols include the features of proactive and reactive routing protocols. Proactive tactic is used to discover and maintain routes to nearer nodes, while routes for far away nodes are discovered reactively [7]. In an Ad-Hoc

network, a Hybrid RA can be implemented in hierarchical network architecture. The performance of the network depends on the distribution of the proactive/ reactive approaches for each level of the network hierarchy. This type of protocol combines the advantages of proactive and reactive routing [10].

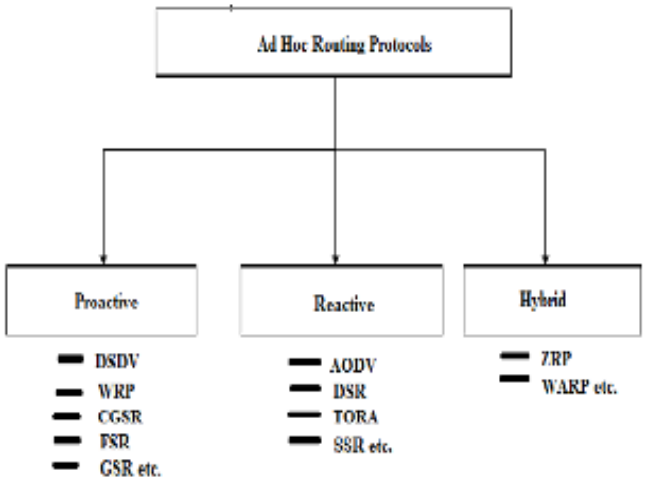

Figure3: Classification of Routing Protocols in MANET

Destination-Sequenced Distance-Vector Routing Protocol (DSDV)

DSDV is proactive routing (table driven) scheme for Ad Hoc Mobile Networks based on the Bellman-Ford Algorithm .This routing protocol resolves the routing loop problem. Each of the routing table contains the list of all available destinations and the number of hops to each. A sequence number is originated by the destination, which is used in DSDV with each table entry. In this protocol each node in the network requires to advertise its own routing table to its current neighbours. The advertisement is done through broadcasting or through multicasting. With the help of advertisements the neighbouring nodes can identify about any change due to the movements of the nodes in the network. Full dump and Incremental update procedure is used for routing updates. The whole routing table is sent to the neighbours in full dump update, where as in case of incremental update, entries that are required to be changed are sent [11]. In DSDV generating and maintaining these routing tables is complex.DSDV requires nodes to periodically transmit routing table updates packets, regardless of network traffic. Every node in the network knows how to reach every other node by these update packets which are broadcasted throughout the network. The major shortcoming of DSDV is that with the increase in number of nodes in the network the size of the routing tables and bandwidth required to update them also increases [12].

Advantages of DSDV [13]

- DSDV protocol provides loop free paths.
- DSDV reduces the Count to infinity problem.
- Incremental updates reduce extra traffic in the network as compared to full dump updates.
- Amount of space is reduced in the routing table by maintaining only the best path instead of maintaining multiple path to every destination .

Disadvantages of DSDV

- Wastage of bandwidth occurs due to needless advertising of routing information if there is node change in the network topology.
- Multi path Routing is not supported in DSDV.
- More bandwidth is required in maintaining the routing table's advertisement for larger network as it requires more bandwidth.

Wireless Routing Protocol (WRP)

The Wireless Routing Protocol (WRP) is table driven routing protocol for MANET. In this protocol enhanced Bellman-Ford Distance Vector routing algorithm [14] is used. For each four tables are maintained i.e. distance table, link-cost table, routing table and message retransmission list (MRL) table [12]. Routing table contains the distance to a destination node, the ancestor and the descendant along the paths to the destination, and state identification, tag field. The main drawback of distance vector algorithm i.e. routing loops and count to infinity problem is detect with the help of routing table. In link-cost table a mobile node creates an entry for each neighbour. In WRP, using update messages, mobile nodes exchange routing tables with their neighbours. The update messages can be sent either periodically or whenever link state changes happen. The MRL provides the information about which neighbour has not acknowledged an update message. A Hello message is send by the node to ensure its connectivity. When a node receives an update message, according to the updated information distance table of the node is modified .A node checks the reliability of its neighbours after identifying any link change.

Advantages

- It has faster convergence
- Fewer table updates are involved
- Algorithm is simple in functionality.

Disadvantage

- Bandwidth usage is increased due to the complexity of maintenance of multiple tables demands a larger memory and throughout the entire network [14].

Dynamic Source Routing (DSR)

Source routing is the main feature of **the** DSR protocol .In this protocol the sender knows the complete hop-by-hop route to the destination. Route cache is used to store these routes; this is in disparity to AODV which uses traditional routing tables, one entry per destination. For each destination DSR can maintain multiple route cache entries. DSR works on two procedures

- Route Discovery
- Route Maintenance

Route Discovery

Route discovery works in two sub phases: Route Request (RREQ) and Route Replay (RREP). Source node initiates the route discovery procedure to discover a route to a destination. To discover new routes, a node uses a special packet called Route Request (RREQ), which includes its own identification, the destination required and the ID-request.

After receiving that packet, a node can ensue in two different ways:

- If it knows how to reach the destination, path is taken from its route cache table and sends back the whole path using a Route Replay (RREP) packet.
- Otherwise, it forwards to its neighbors the packet generated by the source, attaching its own address to the route record.

These two situations are managed by each node that receives a RREQ. Finally, when that packet arrives at the destination node, the destination is able to know which nodes forwarded that request of the source. Now path is discovered, and using a RREP is sent back to the source.

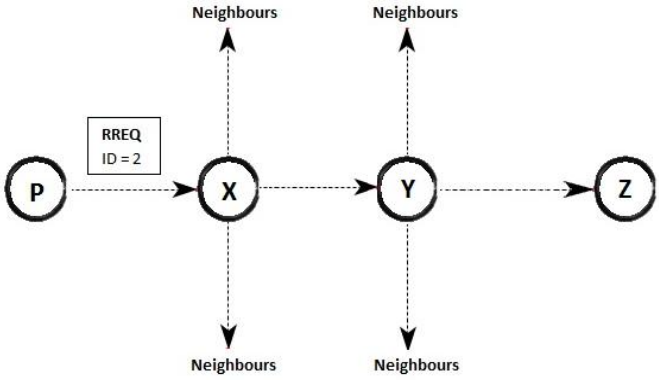

Figure3: Path discovery with RREQ

Route maintenance

Mobility is an important feature of MANETs. By route maintenance mechanism a node is able to detect any change in the network topology. When a node detects a broken link, sends a route error message to each node that has sent packets over that link and removes the link from its cache. After receiving RERR by the source node, a new the route discovery mechanism by sending a new RREQ message is initiated if the route is still required or stop sending the packets[15][16][17].

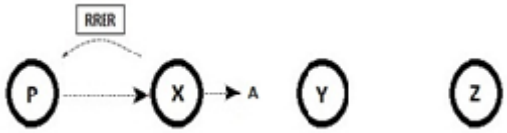

Figure4: Route maintenance with RERR

Advantages

- Nodes that need to communicate. Routes sustained only between nodes who need to communicate which reduces the overhead of route maintenance
- Route discovery overhead is reduced by route caching
- Multiple routes to the destination exist by single route discovery phase.

Disadvantages [18]

- Due to source routing packet header size grows with route length
- Care must be taken to avoid collisions between route requests propagated by neighboring node. insertion of random delays before forwarding RREQ
- Increased contention if too many route replies come back due to nodes replying using their local cache.

Ad hoc on-demand distance vector (AODV)

The AODV is based on DSDV and DSR algorithm. It uses sequence numbering and periodic beaconing procedure of DSDV and a similar route discovery procedure as in DSR But there are two major differences between DSR and AODV. Firstly, in DSR full routing information is carried by each packet, whereas in AODV the packets carry the destination address. Hence, more routing overheads in DSR as compared to AODV. The next difference is that in DSR route replies carry the address of every node along the route, while in AODV the route replies contain only the sequence number and destination IP address.

Advantage

- AODV is adaptable to highly dynamic networks.

Disadvantage

- A node may experience large delays during route construction, and another route discovery may be initiated by link failure, which introduces extra delays and consumes more bandwidth as the size of the network increases [19].

III. Power Efficient Ad Hoc Routing

To minimize the total power consumption to route packets on the network and maximize the lifetime of all nodes routing algorithms must select the best path.

Low Power Routing Protocols

There has been some study on power aware routing protocols for MANETs. Presented below is a brief review of some of them .This routing algorithm based on minimizing the amount of power (or energy per bit) required to get a packet from source to destination. More precisely, the problem is stated as to minimize

$$\sum_{i \in P} T(i, i+1)$$

Where *T(i,i+1)* denotes the power expended for transmitting (and receiving) between two consecutive nodes, i and i+1(a.k.a. link cost), in the route. *P*.

For link cost two cases are defined:

- For fixed transmit power is
- For dynamically varying transmit power which is function of the distance between the transmitter and receiver.

For the first case, energy for each operation (receive, transmit, broadcast, discard, etc.) on a packet is given by

E (packet) =b*packet_size*c

Where *b* and *c* are the appropriate coefficients for each operation. Coefficient *b* denotes the packet size-dependent energy consumption whereas *c* is a fixed cost that accounts for acquiring the channel and for MAC layer control negotiation. Route selection depends on the packet size; hence in case of variable packet size transmission many routes should be selected. The second case is more involved. Reference proposes a local routing algorithm for this case. The authors assume that the power needed for transmission and reception is a linear function of d^{α} where d is distance between the two neighboring nodes and α is a parameter that depends on the physical environment. They make use of the GPS position information to transmit packets with the minimum required transmit energy. The major requirement of this technique is that the relative positions of nodes are available to all nodes. However, this information may not be easy readily available. The GPS-based routing algorithm has two drawbacks .One is that GPS cannot provide the nodes much information about the physical environment and the second is the power dissipation overhead of the GPS device is additional [20].

Battery-Cost-Aware Routing

The main disadvantage of the problem formulation of the previous approach (1) is that it always selects the least-power cost routes. As a result, nodes along these routes tend to "die" soon because of the battery energy exhaustion. This is doubly harmful since the nodes that die early are precisely the ones that are needed most to maintain the network connectivity (and hence useful service life). Therefore, it is better to use a higher power cost route if it avoids using nodes that have a small amount of remaining battery energy. This observation has given rise to a number of "*battery cost-aware routing*" algorithms as described next.

- Minimum battery cost routing algorithm minimizes the total cost of the route..
- Min-Max battery cost routing algorithm is a modification of minimum battery cost routing. This metric always tries to avoid the route with nodes having the least battery capacity among all nodes in all possible routes. Thereby, it results in fair use of the battery of each node.
- Conditional Max-Min battery capacity routing algorithm: This algorithm chooses the route with minimal total transmission power if all nodes in the route have remaining battery capacities higher than a threshold; otherwise routes including nodes with the lowest remaining battery capacities are avoided. Several experiments have been done in [to compare different battery cost-aware routing in terms of the network lifetime. The result showed that the first node in "Shortest Path routing" metric died sooner than all the battery -cost-aware routing but most of the other nodes had longer expiration time. In that result Minimum battery cost routing showed better performance than Min-Max routing in terms of expiration time of all nodes. Conditional Max-Min routing showed different behavior that depended on the value of chosen threshold [21]

IV. Conclusion

This paper presents an overview of various routing protocols in MANET with their advantages and disadvantages Different routing protocols are used under different network conditions. Due to dynamically changing topology power awareness and security are difficult to attain in Mobile Ad Hoc Networks .Future work on routing protocols will be such that to make them secure and power aware/energy efficient. The field of Mobile Ad Hoc networks is very vast and there are various challenges that need to b met, so these networks are going to have widespread use in future.

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