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Routing Protocols in Wireless Ad-hoc Networks: A Comparative Study

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Abstract: Ahoc wireless networks are characterized by multihop wireless connectivity, infrastructure less environment and frequently changing topology. As the wireless links are highly error prone and can go down frequently due to mobility of nodes, therefore, stable routing is a very critical task due to highly dynamic environment in adhoc wireless networks. In this paper, behavioral study of different MANET routing protocols viz. Optimized Link State Routing (OLSR), Dynamic Source Routing (DSR), Adhoc On-demand Distance Vector (AODV) and GRP protocols, have been carried out so as to identify which protocol is most suitable for efficient routing over Mobile Adhoc NETwork (MANET). This paper provides an overview of these routing protocols by presenting their overview. The study will be helpful in identifying which protocol is best suitable for MANET and how the performance of that protocol can be further improved.

Index Terms—Adhoc Network, DSR, AODV, MANET, OLSR, GRP

1. Introduction

Ad hoc network is a multi-hop wireless network, which consists of number of mobile nodes. These nodes generate traffic to be forwarded to some other nodes or a group of nodes. Due to a dynamic nature of ad hoc networks, traditional fixed network routing protocols are not viable. Based on that reason several proposals for routing protocols has been presented. Ad hoc radio networks have various implementation areas. Some areas to be mentioned are military, emergency, conferencing and sensor applications. Each of these application areas has their specific requirements for routing protocols. For example in military applications low probability of detection and interception is a key factor such is routing efficiency during fading and disturbed radio channel conditions. At sensor applications low or minimum energy consumption is a precondition for an autonomous operation. All application areas have some features and requirements for protocols in common. The routing protocol overhead traffic is not allowed to drive the network to congestion nor is a local change in link not allowed to cause a massive control traffic storm throughout the network.
The wireless network can be classified into two types:
1) Infrastructured or Infrastructure less.
2) Infrastructured wireless network.

In Infrastructured wireless networks**,** the mobile node can move while communicating, the base stations are fixed and as the node goes out of the range of a base station, it gets into the range of another base station.
In Infrastructure less or Ad Hoc wireless network, the mobile node can move while communicating, there are no fixed base stations and all the nodes in the network act as routers. The mobile nodes in the Ad Hoc network dynamically establish routing among themselves to form their own network ‘on the fly’.

2. A Taxonomy for Routing Protocols

Because of multiple and diverse ad hoc protocols there is an obvious need for a general taxonomy to classify protocols considered. Traditional classification is to divide protocols to table-driven and to source-initiated on-demand driven protocols [7]. Table-driven routing protocols try to maintain consistent, up-to-date routing information from each node to every other node. Network nodes maintain one or many tables for routing information. Nodes respond to network topology changes by propagating route updates throughout the network to maintain a consistent network view. Source-initiated on-demand protocols create routes only when these routes are needed. The need is initiated by the source, as the name suggests. When a node requires a route to a destination, it initiates a route discovery process within the network. This process is completed once a route is found or all possible route permutations have been examined. After that there is a route maintenance procedure to keep up the valid routes and to remove the invalid routes. This classification has though some drawbacks because of its rough granularity. To that classification it is possible to make some modifications (e.g. in [7]). These modifications can make some assumption about if the routing is flat or hierarchical and if any means to obtain global positioning information is in use. One very attractive taxonomy has been introduced by Feeney. This taxonomy is based on to divide protocols according to following criteria, reflecting fundamental design and implementation choices:

- **Communication model.** What is the wireless communication model? Multi or single channel?
- **Structure.** Are all nodes treated uniformly?

How are distinguished nodes selected? Is the addressing hierarchical or flat?

- **State Information.** Is network-scale topology information obtained at each node?
- **Scheduling.** Is route information continually maintained for each destination?

This model does not take an account for if a protocol is unicast, multicast, geocast or broadcast. Also the taxonomy doesn't deal with the question how the link or node related costs are measured. These properties are however worth to be considered in classification and evaluating applicability of protocols.

Based on that lack the taxonomy has been slightly modified by adding such features as

- **type of cast** and **cost function**. Type of cast feature is an upper level classification and so the protocols to be classified must firstly divide by type of cast and after that the more accurate taxonomy can be applied. The above mentioned taxonomy is applied to unicast protocols, while in the context of multicast and geocast protocols a specified taxonomy has been introduced.

The cost function is a classification to be concatenated after presented taxonomy. It is like a remark to be noticed when considering the applicability of the protocol to be chosen.

2.1 Communication Model

Protocols can be divided according to communications model to protocols that are designed for multi-channel or single-channel communications. Multi-channel protocols are routing protocols generally used in TDMA or CDMA-based networks. They combine channel assignment and routing functionality. That kind of protocol is e.g. Cluster head Gateway Switched Routing. Single -channel protocols presume one shared media to be used. They are generally CSMA/CA-oriented, but they have a wide diversity in which extend they rely on specific link-layer behaviors.

2.2 Structure

Structure of a network can be classified according to node uniformity. Some protocols treat all the nodes uniformly, other make distinctions between different nodes. In **uniform protocols** there is no hierarchy in network, all nodes send and respond to routing control messages at the same manner.

In **non-uniform protocols** there is an effort to reduce

the control traffic burden by separating nodes in dealing with routing information. Non-uniform protocols fall into two categories: protocols in which each node focuses routing activity on a subset of its neighbors and protocols in which the network is topologically partitioned. These two different methods for non uniformity are called **neighbor selection** and **partitioning** respectively.

With neighbor selection mechanism, every node has its own criteria to classify network nodes to near or to remote nodes. In partitioning protocols that differentiation is to use hierarchical node separation. Hierarchical protocols have some upper-level and lower level nodes and certain information difference between them.

2.3 State Information

Protocols may be described in terms of the state information obtained at each node and / or exchanged among nodes. **Topology-based protocols** use the principle that every node in a network maintains large scale topology information. This principle is just the same as link-state protocols use.

Destination-based protocols do not maintain large-scale topology information. They only may maintain topology information needed to know the nearest neighbors. The best known such protocols are distance-vector protocols, which maintain a distance and a vector to a destination (hop count or other metric and next hop).

2.4 Scheduling

The way to obtain route information can be a continuous or a regular procedure or it can be trigged only by on demand. On that basis the protocols can be classified to proactive and on-demand protocols. Proactive protocols, which are also know as table-driven protocols, maintain all the time routing information for all known destinations at every source. In these protocols nodes exchange route information periodically and / or in response to topology change. In on-demand i.e. in reactive protocols the route is only calculated on demand basis. That means that there is no unnecessary routing information maintained. The route calculation process is divided to a route discovery and a route ma intenance phase. The route discovery process is initiated when a source needs a route to a destination.

The route maintenance process deletes failed routes and re-initiates route discovery in the case of topology change.

2.5 Type of Cast

Protocols can be assumed to operate at unicast, multicast, geocast or broadcast situations. In unicast protocols one source transmits messages or data packets to one destination. That is the most normal operation in any network. The unicast protocols are also the most common in ad hoc environment to be developed and they are the basis on which it is a possibility to construct other type of protocols. Unicast protocols have thought some lacks when there is a need to send same message or stream of data to multiple destinations. So there is an evitable need for multicast protocols.

Multicast routing protocols try to construct a desirable routing tree or a mesh from one source to several destinations. These protocols have also to keep up with information of joins and leave ups to a multicast group. The purpose of geocast protocols are to deliver data packets for a group of nodes which are situated on at specified geographical area. That kind of protocol can also help to alleviate the routing procedure by providing location information for route acquisition.

2.6 Cost Function

When making routing decisions in ad hoc environments, it is normally not enough to take only considerations to hop count. In ad hoc networks there is a wide variety of issues to consider such as link capacity, which can vary in large scale, latency, link utilization percentage and terminal energy issues to mention a few most relevant. That is why there is a need to adapt cost functions to route calculations. Rough classification of protocols according to cost function can be based on hop count approach (no special cost function applied) and to bandwidth or energy based cost functions. Also quite a different approach to routing metrics is used by Associativity Based Routing (ABR) protocol, which uses degree of
association stability for a metric to decide for a route. That means that presumably more permanent routes are pref

3. Overview of Selected Routing Protocols

Routing protocols are broadly classified as distance vector and link state routing. Distance vector routing is a decentralized routing algorithm.

- **Optimized Link State Routing (OLSR) Protocol**

OLSR is the proactive routing protocol. OLSR achieved RFC status in 2003 (T. Clausen (Ed.), and P. Jacquet (Ed.) Oct. 2003). Basically OLSR is an optimization of the classical link state algorithm adapted for the use in wireless ad hoc networks. In OLSR, three levels of optimization are achieved. First, few nodes are selected as Multi Point Relays (MPRs) to broadcast the messages during the flooding process. This is in contrast to what is done in classical flooding mechanism, where every node broadcasts the messages and generates too much overhead traffic. Second level of optimization is achieved by using only MPRs to generate link state information. This results in minimizing the “number” of control messages flooded in the network. As a final level of optimization, an MPR can chose to report only links between itself and those nodes which have selected it as their MPR. This results in the distribution of partial link state information in the network. OLSR periodically exchanges topology information with other nodes at regular intervals. MPRs play a major role in the functionality of the protocol. Every node selects a subset of its one hop neighbor nodes as MPR. MRPs periodically announce in the network that it has reach ability to the nodes which have selected it as an MPR. Nodes which are not selected as MRP by any node, will not broadcast information received from it. The functionality of OLSR lies in the exchange of HELLO and TC messages. The periodic dissemination of HELLO packets also enables a node to know whether a node or a set of nodes have selected it as MPR. This information is known as ‘Multipoint Relay Selector Set’, and is critical to determine whether to broadcast forward the information received from a node(s) or not. In a dynamic and rapidly changing environment, this set of nodes can change over the time. HELLO messages are also used for link sensing and neighborhood detection. TC messages are used to provide every node enough link-state information for the calculation of routes. Basically, a TC message is sent by a node to advertise a set of links, which includes the links to all nodes of its MPR selector set. TC message is only broadcast forwarded by MRPs and offers controlled flooding of the topology information into the whole network. OLSR is designed to support large and dense wireless networks. The levels of optimization discussed above, make it better suited for such networks. OLSR is tailored for networks where the traffic is random and sporadic between large number of nodes. It is also suitable for scenarios, where the communicating pairs change over time. Once the communicating pair changes, a route to new pair is readily available, and no control traffic or route discovery process is needed as in the case of reactive protocols. This can be beneficial for situations where time critical or safety related data needs to be delivered with minimum possible delay. [6]

- **Dynamic Source Routing (DSR) Protocol**

The Dynamic Source Routing (DSR) is a reactive unicast routing protocol that utilizes source routing algorithm. In source routing algorithm, each data packet contains complete routing information to reach its dissemination. [6] Additionally, in DSR each node uses caching technology to maintain route information that it has learnt. There are two major phases in DSR, The Route Discovery Phase and The Route Maintenance Phase. When a source node wants to send a packet, it firstly consults its route cache. If the required route is available, the source node includes the routing information inside the data packet before sending it. Otherwise, the source node initiates a route discovery operation by broadcasting route request packets. A route request packet contains addresses of both the source and the destination and a unique number to identify the request. Receiving a route request packet, a node checks its route cache. If the node doesn’t have routing information for the requested destination, it appends its own address to the route record field of the route request packet. Then, the request packet is forwarded to its neighbors. To limit the communication overhead of route request packets, a node processes route request packets that both it has not seen before and its address is not presented in the route record field. If the route request packet reaches the destination or an intermediate node has routing information to the destination, a route reply packet is generated. When the route reply packet is generated by the destination, it comprises addresses of nodes that have been traversed by the route request packet. Otherwise, the route reply packet comprises the addresses of nodes the route request packet has traversed concatenated with the route in the intermediate node’s route cache.

- **Ad-hoc On-demand Distance Vector –AODV**

The Ad Hoc On-demand Distance Vector [4] routing protocol shares DSR‟s on-demand characteristics in that it also discovers routes on an "as needed" basis via a similar route discovery process. However, AODV adopts a very different mechanism to maintain routing information. It uses traditional routing tables, with one entry per destination. This is a departure from DSR, which can maintain multiple route cache entries for each destination. Without source routing, AODV relies on routing table entries to propagate a route reply back to the source and, subsequently, to route data packets to the destination. AODV uses sequence numbers maintained at each destination to determine freshness of routing information and to prevent routing loops. These sequence numbers are carried by all routing packets. When a route is needed, a node broadcasts a route request message. The response message is then echoed back once the request message reaches the destination or an intermediate node finds a fresh route to the destination. For each route, a node also maintains a list of those neighbors actively using the route. A link breakage causes immediate link failure notifications to be sent to the affected neighbors. Similar to DSDV, each route table entry is tagged with a destination sequence number to avoid loop formation. Moreover, nodes are not required to maintain routes that are not active. Thus, wireless resources can be effectively utilized. However, because flooding is used for route search, communication overhead for route search is not scalable for large networks. As route maintenance considers only the link breakage and ignores the link creation, the route may become non optimal when network topology changes. Subsequent global route search is needed when the route is broken.

- **Gathering-based Routing Protocol (GRP)**

Gathering-based Routing Protocol combines the advantages of Proactive Routing Protocol (PRP) and of Reactive Routing protocol (RRP). PRP are suitable for supporting the delay sensitive data such as voice and video but it consumes a great portion of the network capacity. While RRP is not suitable for real-time communication, the advantage of this approach is it can dramatically reduce routing overhead when a network is relatively static and the active traffic is light. However, the source node has to wait until a route to the destination can be discovered, increasing the response time. The function of Gathering-based Routing Protocol (GRP) for mobile ad hoc network is to gather network information rapidly at a source node without spending a large amount of overheads. It offers an efficient framework that can simultaneously draw on the strengths of Proactive routing protocol (PRP) and reactive routing protocol (RRP) collects network information at a source node at an expense of a s mall amount of control overheads. The source node can equip promising routes on the basis of the collected information, thereby continuously transmitting data packets even if the current route is disconnected, its results in achieving fast (packet) transfer delay without unduly compromising on (control) overhead performance.

4. Conclusions

In this paper, two categories of routing protocols for ad hoc Wireless ad-hoc Networks have been described, i.e distance vector and link state routing. Distance vector routing is a decentralized routing algorithm. Each node that participates in routing exchanges its estimated least cost path to its directly connected neighbors to all other nodes in the network. Link state routing is a global routing algorithm in which each node computes the shortest path to every other node in the network using global knowledge about the network.

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