Routing Protocols Wireless for Ad Hoc Wireless Networks: Classifications of Protocols and A review of Table Driven Protocols

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Abstract:

Ad Hoc wireless networks have their own unique nature of distributed resources and dynamic topology. This nature introduces very special requirements that should be met by the proposed routing protocols for the Ad Hoc networks. This paper reviews the classification of the Ad Hoc networks routing protocols along with emphasizing on the table-driven class of protocols.

1 - Introduction

For Ad Hoc routing protocols, specific requirements are defined [1]. First of all, such protocols must be distributed. Because depending on a central host to make the routing decisions introduces a bottle neck in the network. Considering the limited resources of the mobile nodes, this central node may be even a single point of failure . Secondly, they must be adaptive to the continuously changing topology due to mobility. Thirdly, they must compute the routes in a fast, loop free, optimal resource usage and up to date fashion. Additionally, they must keep the process of route maintenance, in case of link breaks, as local as possible. Also, they should provide some degree of quality of service (QoS). Finally, they should keep as much helpful information as possible about only the local and stable network topology.

Different Ad Hoc routing protocols have already been proposed. From the view point of the previously defined requirements, each protocol has its own advantages and disadvantages; However, these protocols can be classified based on different criteria. Such classification makes it easier to understand the behavior of the different protocols. Also, this classification is useful for designing hybrid solutions, which combine the advantages of the different classes of these protocols.

In this paper, section 2 reviews the different criteria to classify the different ad hoc routing protocols, along with the classes of protocols according to each criterion. In section 3, the paper focuses on reviewing a group of the already proposed table driven routing protocols.

2 - Classification of Ad Hoc Routing Protocols

Ad Hoc routing protocols can be classified based on different criteria [1]; However, the different classes of protocols are not mutually exclusive. So that, depending on the types of mechanisms employed by a given protocol, it may fall under more than one class.

Routing protocols for Ad Hoc networking can be classified based on four different criteria. They can be classified based on the routing information update mechanism. Another classification can be done based on the use of temporal information for routing. A third option is to classify such protocols based on the routing topology. Finally, they can be also classified based on the utilization of specific resources. The following sub-sections introduce the different classes of the protocols based on these criteria.

2.1- Based on the routing information update mechanism

The mechanism of updating routing information is an essential part of any routing protocol. So that, this criterion is very important [2] for classifying the routing protocols for ad hoc wireless networks.

According to this criterion, there are three classes of routing protocols, they are summarized as follows:

a – <u>Table-driven routing protocols</u>
Based on the periodic exchange of routing information among the network nodes, each node builds its own routing table. A source node uses this table to find a path to a destination. Examples of the protocols of this class are, Destination Sequenced Distance Vector routing protocol (DSDV), Wireless Routing Protocol (WRP), Cluster-Head Gateway Switch Routing protocol and Source Tree Adaptive Routing protocol (STAR). [1, 2]

b - <u>On-demand routing protocols</u>
The nodes of this class do not exchange any routing information in advance. A source node obtains a path to a specific destination only when it needs to send data to it. Examples of the protocols of this class are, Dynamic Source Routing protocol (DSR), Ad Hoc On-Demand Distance-Vector Routing protocol (AODV), and Temporally Ordered Routing Protocol (TORA). [1, 2]

In figure 1, the above introduced two classes are summarized.

c - <u>Hybrid routing protocols</u>
Nodes are grouped into zones based on their geographical locations or distances form each other. Inside a single zone, routing is done based using table-driven mechanisms while an on-demand routing is applied for routing beyond the zone boundaries. A recently introduced example of these protocols is the Tow-Zone Routing Protocol (TZRP). [5]

In [2], a comparison between the table driven routing protocols and on-demand routing protocols is introduced. According to this comparison, the availability of routing information is a key advantage of table driven routing protocols. Consequently, faster routing decisions can be made than those made by the on-demand routing protocols. Which in turn introduces less delay in the route setup process. On the other hand, this important advantage of table driven routing protocols requires periodic routing information updates. By this way, they can maintain up to date routing tables. However, this periodic update process introduces higher routing overhead traffic than the case in the on-demand routing protocols.

In spite of these clear differences between these two classes of protocols, we can not come to absolute conclusions about the

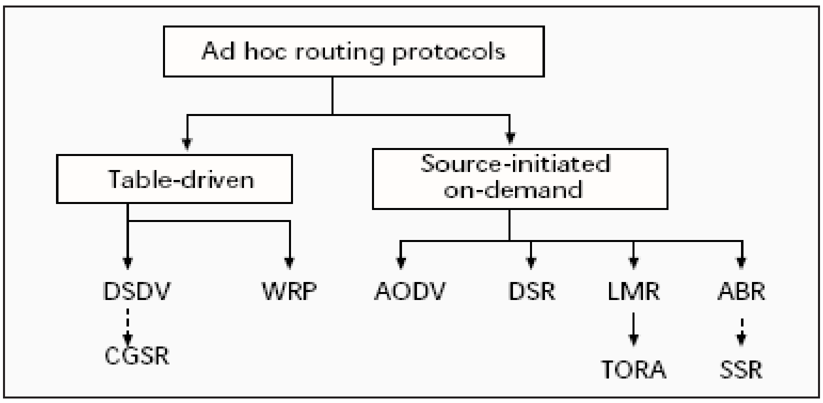

Figure 1 . The two main classes of the Ad Hoc wireless networks routing protocols based on the routing information update mechanism. [2]

preference of one class to another. And such preference conclusions should be done at the protocols level, and not at the class level. This is because, each protocol still has its own very specific features.

To explain the above, consider Table.1, which summarizes the performance study in [3]. In this study, different measurements were studied. The simulation was applied to DSDV, a table driven routing protocol, and other on-demand routing protocols, viz. AODV, DSR, and TORA. The study also considers the impact of the mobility of nodes on the performance of the protocols. The study assigns 1 for the best performance, while it assigns 4 for the worst performance.

Having an aggregate view of table.1, from the view point of almost all the considered performance measures, DSDV and AODV form a group, while DSR and TORA form another. By this way, we can see the similarity between two different protocols from two different classes along with the differences between inside the same class. This is mainly due to the specific features of each protocol and the non mutual exclusive nature of the different classification criteria.

The second part of this paper focuses on the table driven routing protocols, so that appropriate explanations and different types of comparisons are addressed later in details.

Protocols / Metrics	AODV	DSR	TORA	DSDV
Delay	2	4	3	1
Jitter	1	4	3	2
Loss ratio	1	3	4	2
Throughput	1	3	4	2
Routing load	3	2	1	4
Scalability	3	2	1	4
Connectivity	1	2	4	3
Supporting Multicast	YES	NO	NO *	NO

Table 1. Performance comparison of AODV, DSR, TORA and DSDV. [3]

2.2 - <u>Based on the use of temporal information for routing</u>

The routing protocols for the ad hoc wireless networks should consider the dynamically changing topology of such networks. They also should consider the life time of the wireless links due to nodes mobility and the limited resources of the nodes (e.g. according to battery status). So that, the usage of temporal information for making routing decisions is a key feature of such protocols. However, these protocols differ in the way they use such information. These differences introduce a very important criterion for classifying these protocols. According to this criterion, there are two classes of routing protocols, they are summarized as follows:

a - <u>Using past temporal information</u>

This protocols of this class use information about the current status of the links at the time of making the routing decision. Consequently, the unpredicted link breaks enforce path reconfigurations, which may be resource-wise expensive. DSDV is an example of such protocols.

b - <u>Using future temporal information</u>

The protocols of this class predict the future status of the links and the life time of nodes (e.g. according to battery status). Then, they make approximate routing decisions considering this predicted future status. A very important example of this class is Flow Oriented Routing Protocol (FORP). [6] This protocol predicts the future time of the breaks of the links in the networks. Consequently, for a path which is composite path of these links, it can predict the future time of its break It utilizes mobility information about the nodes in the network. This information includes, the locations of the nodes, their moments directions and velocities, and their ranges of wireless coverage. Using these predictions, FORP can ,in advance, establish alternative connections before the path breaks.

In figure 2, the simulation results in [6] are shown. According to this study, the routing overhead of DSDV increases as the mobility of nodes increases, while the routing overhead of FORP is almost constant. This is mainly because FORP is using future temporal information to avoid link breaks. Consequently FORP avoids a large portion of the required traffic for reporting breaks and re-establishing them. This could be the most important advantage of using future temporal information.

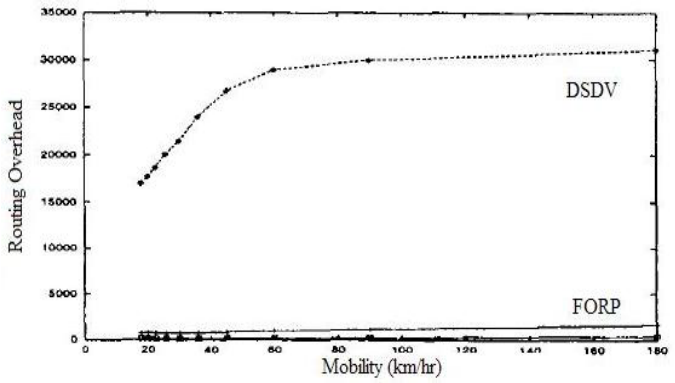

Figure 2. Routing Overhead vs. Mobility, Comparing DSDV vs. FORP.

[4] , with modification for better view

2.3 - Based on the routing topology

Ad Hoc networks do not use central infrastructure. Additionally , they have no fixed topologies. So that, routing protocols should be designed in a very flexible fashion to adapt with a dynamically changing topology [7]. On the other hand, because ad hoc networks are relatively small in size, they can make use of a flat topology. And as the size of the network increases, they can even apply a hierarchical topology [1]. These two alternatives introduce another criterion for classifying the routing protocols of the ad hoc wireless networks. According to this criterion, there are two classes of routing protocols, they are summarized as follows:

a – Flat topology routing

Most of the proposed ad hoc routing protocols fall in this class [7]. For a flat topology, each node has its own unique global address. This is called a flat addressing scheme. So that all nodes are considered as peers. Examples of protocols in this class: DSR and AODV.[1]

b – Hierarchical topology routing

A hierarchical control structure is employed by the protocols which fall in this class [7]. The nodes located in a common scope in the network are grouped together into a cluster. The scope of the cluster can be defined using some metric, e.g. the distance between each pair of nodes. By this way, the network is defined as clusters. This clustering can be extended to a multi level hierarchy. For addressing the nodes in the network, a hierarchical addressing scheme is applied.

For a cluster, the nodes elect a node as a cluster head. This node coordinates the work between the different nodes in the cluster. A very important example of this class is Cluster-Head Gateway Switch Routing Protocol (CGSR).[1]

Flat topology routing is suitable for small ad hoc network. However, as the size of a network is relatively increasing, hierarchical routing is better. High level and relatively stable routing information are exchanged among the cluster heads. In turn, this reduces the long distance routing overhead. Additionally, it enables an efficient on-demand routing between the different clusters. On the other hand, table-driven routing can be applied between the nodes in the same cluster where complete topology information are not resource-wise expensive to exchange. [8]

However, because the continuous process of electing the cluster heads of different clusters, the hierarchical topology routing may suffer from instability during high mobility. [1]

2.4 - Based on the utilization of specific resources:

For this criterion, the classification of the routing protocols of the ad hoc wireless networks does not have very well defined classes. This classification focuses on the very specific features of specific protocols.

Such protocols may make routing be aware of very specific resources e.g. the battery power. So that, they make routing decisions which optimally utilize such resources.

Other protocols may utilize some unique resources to make routing decisions. For example, GPS is used be some protocols to make routing decisions based on the location and the movement information of the nodes.

The following part of the paper focuses on the table driven routing protocols in more details.

3 – Table Driven Routing Protocols For Wireless Ad Hoc Networks

As mentioned before, the mechanism of updating routing information is an essential part of any routing protocol. And this is why this criterion is a almost the main one for classifying and studying the routing protocols of the ad hoc wireless networks. According to this criterion, table driven protocols form an entire class. The following subsections introduce four examples of the protocols of this class.

3.1 Destination Sequenced Distance-Vector Routing Protocol (DSDV)

DSDV [1, 9] depends on the periodic exchanging of routing information updates. The updates can be incremental ones or exchanges of full dumps of the entire routing tables. The periods of exchanging these updates should be short enough to adapt with the dynamically changing topology of and connectivity conditions of the network. Also, DSDV allows the exchange of the updates when some significant change in topology or connectivity occurs. Additionally, DSDV allows a node to send routing information updates in response to a request from other nodes in the network.

Routing information updates are advertised by either multicasting or broadcasting. This process may use the MAC addresses or the network addresses of the nodes. Each destination node initiates its own routing information update messages combined with sequence numbers, which indicate the freshness of the updates from it as a destination.

However, and according to the range limits of the wireless connections, these information are supposed to be received by only the neighbors of the sending node. So that, DSDV depends on forwarding fresh routing information updates among the nodes. By this way, the updates are propagated across the network. And ever node has the full information about the current status of the network.

When a neighbor node receives a routing information update, it compares the freshness of the update to the currently used routing information. Particularly, it compares their associated sequence numbers. Then, if the update information has a higher sequence number than that of the currently used information, the node will use the update information to modify its routing table. However, if the sequence numbers of the update and the used information are the same, the node will update its routing table only if only if the update information contains better routes the currently used ones. DSDV applies some metrics (e.g. number of hops) to make such selections .

Alternatively, the receiver of the routing information update message may wait for some time until it receives another update message about the same destination. Then, if this new message has better routes than that of the already used ones, it may use it instead.

If a node detects a link break to a destination node D ,using a link layer mechanism, it will initiate a link break update message. This message defines the cost to the destination D as ∞. This is the only situation in which some node other than the destination is allowed to initiate an update message about the routing information of this destination. To differentiate the two update messages, odd sequence numbers are used for link break update messages, while even sequence numbers are used for the destination initiated update messages.

Upon receiving the link break update message, each node updates its routing table to reflect the effects of the break. Then it broadcasts the message again to its own neighbors. Consequently this message is propagated across the whole network.

Afterwards, when a neighbor node to D receives the periodic update message from D across some other link (if any), this update message also propagates across the whole network and all the nodes in the network update their own routing tables to reflect the new route to D.

3.2 Wireless Routing Protocol (WRP)

WRP is designed to adapt with the unreliability of the wireless links. Also, it provides faster convergence in case of link breaks than the case in DSDV. This two features of WRP are the results of two unique mechanisms of WRP, which are summarized as follows.

The first mechanism is using acknowledged routing information update messages. So that, WRP can retransmit the unacknowledged update messages. This explains how WRP adapts with the unreliable nature of the wireless links.

The second mechanism is storing information about the routes used by the neighbor nodes to all nodes in the network. Additionally, for each of these routes, it stores information about the predecessor node to the destination node. And this is the key piece of information which is used by WRP for fast convergence after link breaks.

To apply the above mentioned two mechanisms, WRP uses four types of tables viz. the distance table (DT), the routing table (RT), the link cost table (LCT) and the message retransmission list (MRL). Each node in the network maintains the four types of tables. DT is where a node saves the network views of the neighbors. RT is the routing table of the node itself. LCT contains the costs of the links form the node to the neighbors. MRL is a list of the update messages along with the state about if they have been already acknowledged or not yet.

WRP, as a table driven protocol, depends on the periodic exchange of routing information. For each routing information update message, there is an entry ,in the MRL, for each expected receiver . The sender of the message expects an acknowledgment from these receivers before the expiry of a counter. When the counter expires the update message is retransmitted. According to [10], this retransmission process can be done for unlimited number of times; however it can be limited by any mean.

In case of a link break, the two end nodes of the link send an update message to their neighbors with the cost of this as ∞. Upon receiving the message, each node updates its RT, so that any routes across this link will not be used any more for the moment.

Then the node consults its DT to find any alternative routes to the destination nodes through any other predecessor node than those who reported the link breaks. Afterwards for those nodes which find alternative routes , they propagate their updates to their neighbors. A node updates its already valid route to a destination only if a new proposed route is better the currently used one, in terms of some defined metric.

3.3 Cluster Head Gateway Switch Routing Protocol (CGSR)

The key feature of this protocol is that it applies a hierarchical scheme in contrast to the flat scheme applied by the other table driven protocols. Nodes are grouped into clusters. For each cluster a node acts as a cluster head. This cluster head is elected using the Least Cluster Change (LLC) algorithm [11]. The cluster head node provides some level of coordination among the nodes in the cluster. At the same time, the nodes located in the intersection areas between two clusters, can act as gateways between the two clusters. All the routing traffic goes through the cluster heads and the gateways. A simple example of routing traffic in CGSR is shown in figure 3.

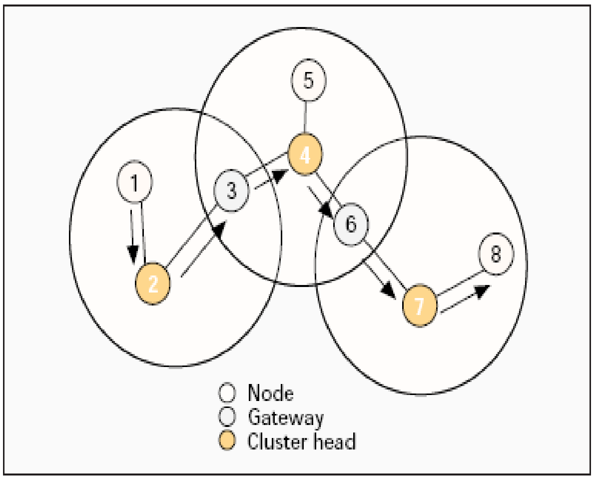

Figure 3. CGSR routing from node 1 to node 8. [2]

The main role of the cluster head is t provide some level of coordination among the nodes in its cluster. This coordination can be utilized to achieve an efficient allocation of the wireless bandwidth among the different clusters. Each cluster may use its own spread code, and cluster heads can schedule a token based scheme to organize the transmission process among the nodes inside its cluster.

It is recommended that the gateway nodes can listen to the spreading codes of more than one cluster. This is why such nodes may have more than one interface to listen to more than one spreading code at the same time. By this way, these nodes can avoid the conflict between the received tokens from two different clusters at the same time. Generally speaking the performance of the CGSR depends mainly on the code scheduling and the token scheduling which are influenced by the cluster heads and the gateways.

In [11], the CGSR is considered to be an improvement to another protocol namely, the Cluster Hierarchical Routing Protocol. For both of them, each node in a cluster maintains a cluster member table which it uses to map the address of a destination node in the network to the address of the cluster head of the cluster of this node. The updates of the information in the cluster member table are exchanged periodically in the same fashion as in DSDV.

For the cluster hierarchical routing protocol, the nodes use another table, namely a routing table. This table is used by a source node to find the next hop inside its own cluster to forward a packet to the cluster head of a destination node. However, the nodes in CGSR forward the packets directly to their own cluster head which forwards it to the appropriate gateway to the cluster head of the addressed destination. Consequently, CGSR introduces higher speedup in packet delivery than that the case in the cluster hierarchical routing protocol. Moreover, both are better than DSDV from this point of view. [11]

In case of link breaks with the cluster head, the Least Cluster Change (LLC) algorithm is used to elect a new cluster head. However, for link breaks among other nodes in the cluster, routing table updates and route maintenance mechanisms similar to those in DSDV are applied.

3.4 Source Tree Adaptive Routing Protocol (STAR)

The key feature of this protocol is applying a Least Overhead Routing Approach (LORA). This completely the opposite to the Optimum Routing Approach (ORA) which is followed by the previously described protocols.

Consequently, the nodes running LORA send updates only when it is necessary to and not periodically. In particular, each node sends routing information updates only when it detects new nodes, when it loses all paths to a particular destination, or when it detects some loops introducing topology changes. [12]

In STAR, the nodes send the updates in the form of a source tree, which contains its own preferred paths to all destinations. Upon receiving the source trees from neighbors, a node aggregate these source trees with its own information about its adjacent links. Then, the node produces a partial topology graph of the network. The combination of this topology graph and its own source tree produces its new source tree. Then a node can use this source tree for the routing process. By this way every node in the network should have a path to every destination.

If a node does not have a path to a particular destination which the node wants to send packets to it [1], the node triggers a path absence message to its neighbors. A neighbor which has a path to this destination sends its own source tree in response. Otherwise, a neighbor forwards the absence message to its neighbors. The forwarding of this absence message continues until some alternate path is replied. This is considered as the link break maintenance mechanism of STAR.

4 - Summary And Conclusion

The unique nature of the wireless ad hoc networks imposes its own requirements on the proposed routing protocols. They should consider many factors including the dynamically changing topology, the limited resources of the nodes, the limited transmission medium, and even more. Many routing protocols have been already proposed. They can be classified according to specific criteria of how they behave; However, the classes of the protocols are not mutually exclusive. The classification according to the way the nodes exchange updates of routing information is considered as a key classification method. According to it the protocols are classified as either table driven routing protocols or on-demand routing protocols. The table driven protocols vary in the way they maintain and update their routing tables, which directly affect the efficiency of each protocol. However, all the table driven protocols share their common advantage of the immediately available routes to the reachable destinations, along with the disadvantage of the introduced routing information update overhead.

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