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

amr ergawy
aergawy@cc.hu.fi

Abstract:
Ad Hoc wireless networks have their own unique nature of distributed resources and dynamic topology. This introduces very special requirements that should be met by the proposed routing protocols for the Ad Hoc networks. This paper summarizes 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 or even to a single point of failure considering the limited resources of the mobile nodes. 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 as local as possible. Finally, they should provide some degree of quality of service (QoS) and 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 easy to understand and may be designing hybrid solutions to get combined advantages.

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 routing mechanisms employed by a given protocol, it may fall under more than one class.

Routing protocols for Ad Hoc networking can be classified into four categories viz. based on the routing information update mechanism, the use of temporal information for routing, routing topology, and utilization of specific resources. The following sub-sections summarize the descriptions of each class.

2.1- Based on the routing information update routing 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 ah 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 periodically exchanging of routing information between the different nodes, each node builds its own routing table which it can use 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]

b - <u>On-demand routing protocols</u>:
The nodes do not exchange any routing information. A source node obtains a path to a specific destination only when it needs to send some 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).

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.

In [2], a comparison between the table driven routing protocols and on-demand routing protocols is introduced. This comparison defines the main differences between the two classes of protocols. Mainly, the availability of routing information is a key advantage of table driven routing protocols, because faster routing decisions – and consequently less delay in route setup process- can be made than in the case of on-demand routing protocols. On the other hand, this important advantage of table driven routing protocols requires periodic routing updates keep the routing tables up to date, which in turn costs higher signalling traffic than the required for on-demand routing protocols.

However, for other functions like path reconfiguration after link failures, there are variations between the protocols of each class. For example, both DSR and TORA are on-demand routing protocols. At the same time, DSR uses global route maintenance schemes while TORA uses a local one which reduced signalling overhead.

From the above, it is important to understand that we can not come to absolute conclusions about the preference of some class than the other, and such preference conclusions should be done at the protocols level, and not at the class level. This applies to all classification criteria.

Additionally, from the studies in [3, 4] and because the non mutual exclusive relationship between the different classification criteria, performance evaluation studies are also done at the protocols level and their results are very specific to each protocol regardless of the class it belongs to.

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

2.2 - Based on the use of temporal information for routing:

To cope with the dynamically changing topology of the ad hoc networks and regarding the life time of the wireless links, this category of protocols uses temporal information for routing. According to this criterion, there are two classes of routing protocols, they are summarized as follows

a - Using past temporal information:

This category of protocols uses information about the current status of the links at the time of making the routing decision. The unpredicted breaks in links enforces path reconfiguration which may be resource-wise expensive. DSDV is an example of such protocols.

b - Using future temporal information:

The protocols of this category make predictions about the expected future status of the links and the life time of nodes (e.g. according to battery status), and then it makes approximate routing decisions regarding the expected future state. A very important example of this class is Flow Oriented Routing Protocol (FORP). This protocol predicts the future disconnection time so that it can in advance establish alternative connections before the path breaks.

According to simulation results in [6], we can notice that the usage FORP introduces less routing overhead than that introduced by DSDV. This is mainly because FORP is using future temporal information to avoid link breaks and consequently avoiding the required traffic for reporting breaks and re-establishing them. This could be the most important advantage of using future temporal information.

2.3 - Based on the routing topology:

Ad Hoc networks do not have central infrastructure which introduces the lack of fixed topologies. So that, routing protocols should be designed in a very flexible fashion to work in 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 or a hierarchical topology [1]. 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]. The general assumption [1] about the applied addressing scheme for a flat topology is that each node has its own unique global address so that all nodes are peers. Examples of protocols in this class: DSR and AODV.

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 (may be defined by their distances to each other) in the network are grouped together into a cluster, so that the network is defined as clusters. The nodes of a specific cluster elect a cluster head who coordinates the work between the different nodes in the cluster. This clustering can be extended to a multi level hierarchy. A very important example of this class is Cluster-Head Gateway Switch Routing Protocol (CGSR). A hierarchical addressing scheme is required [1].

Fat topology routing is suitable for small ah hoc network, but 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 leading to reduce the long distance routing overhead and enabling an efficient on-demand routing between the different clusters. At the same time 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 selecting the cluster heads of different clusters, the hierarchical topology routing may suffer from instability during high mobility. [1]

3 – Table Driven Routing Protocols for wireless ad hoc networks:

3.1 Destination Sequenced Distance-Vector Routing Protocol (DSDV): [1, 9]

DSDV depends on the periodic exchanging of incremental routing updates or even the entire routing tables among the nodes in the ad hoc network. The periods of advertising these updates should be short enough to adopt with the dynamically changing topology and connectivity conditions of the network. Also, it may allow the exchange of the updates when some significant change in topology or connectivity occurs. Additionally, routing information could be exchanged in response to requests from other nodes.

Routing information updates are advertised either by multicasting or broadcasting, either using the MAC addresses or the network addresses of the nodes in the network. However, and according to the range limits of the wireless connections, these information are supposed to be received by only the neighbours of the sending node. 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.

When a neighbour node receives a routing information update, it compares the freshness of the update to the currently used routing information by comparing the associated sequence numbers, and the most recent information is used to update its routing table. However, if the sequence numbers of the new and the old information are the same, it selects the better routing information according to an applied metric (it can number of hops).

Alternatively, the receiver of the routing information update message may wait for some time until it receives another update message about the same destination, and if this new message has a better metric value than that of the already received one, it may use it instead.

If a node detects a link break to a destination node D (using a link layer mechanism), it initiates a link break update message, which defines the cost to the destination as ∞. This is the only situation in which some node other than the destination is allowed to initiate an update message about its routing information. So that, odd sequence numbers are used for link break update messages, while the destination initiated update messages include even sequence numbers.

Upon receiving the link break update message, each node update its routing table to indicate that that the cost to the destination is ∞, and then it broadcasts the message again to its own neighbours. Consequently this message propagates across the whole network. Afterwards, when a neighbour 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): [1, 10]

WRP is designed to adopt with the unreliability of the wireless links and provides faster convergence in case of link breaks than the case in DSDV. These two features of WRP are the result of the way the nodes exchange routing information updates, the way they maintain routing information in their tables, and the scheme WRP uses for route maintenance after link breaks.

Particularly, the above two key features of WRP can be explained by applying the following two mechanisms. The first one is the acknowledged routing information update messages with the retransmission option for unacknowledged messages. This explains how WRP adopts with the unreliable nature of the wireless links. The second is storing the routes used by the neighbour nodes to all nodes in the network along with knowing the predecessor node to each destination node reachable by each neighbour. And this is the key piece of information which is used by WRP for fast convergence after link breaks.

WRP uses four 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 neighbours. RT is the routing table of the node itself. LCT contains the costs of the links form the node to the neighbours. MRL is the table which contains list of the update messages along with the state if they have been already acknowledged or not.

WRP, as a table driven protocol, depends on the periodic exchange of routing information. For each routing update information message, there is an entry for each expected receiver in the MRL. The transmitter of the message expects an acknowledgment from the receivers before the expiry of a counter. When the counter expires the acknowledgement is retransmitted. In [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 neighbours with the cost of this as ∞. Upon receiving the message, each node updates its RT, and consults its DT to find any alternative routes to the destination nodes through any predecessor other than those who reported the link beaks. Afterwards the nodes who find alternative route simply propagate their updates. A node updates its already valid route to a destination only if the new proposed routes are better in terms of some defined metric.

3.3 Cluster Head Gateway Switch Routing Protocol (CGSR): [1, 11]

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 protocol. 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 head and the gateways.

The main role of the cluster provides some level 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. While each cluster can listen to a different spread code other than the one used by the others, cluster heads can organize a token based scheme to organize the transmission process among the nodes inside the cluster.

The gateway nodes can listen to the spreading codes of more than one cluster. So that, it is recommended that the a gateway has more than one interface to listen to more than one spreading code at the same time, and to avoid the conflict between the tokens form 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 (DSCR). 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 this node. The updates of the information in the cluster member table are exchanged periodically in the same fashion as in DSDV.

For DSCR, 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 addressed destination cluster head. Consequently, CGSR introduces higher speedup in packet delivery than that in DSCR, and both are better than DSDV from this point of view [11].

In case of link breaks with the cluster head, the LLC algorithm is used to elect a new one. 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): [1, 12]

The key feature of this protocol is that it applies Least Overhead Routing Approach (LORA) rather than the optimum routing approach (ORA) which is followed by the previously described protocols. Consequently, the nodes running TORA send updates only when ii necessary and not periodically. Particularly, each node sends routing information updates only when it detects new nodes, when it loses all paths to a particular destination, or when detects some topology changes which may lead into routing loops. [12]

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 neighbours, a node aggregate these source trees with its information about its adjacent links to produce a partial topology graph. The combination of this topology graph and its own source tree produces its new source tree. Then the node can use this source tree for the routing process. 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 neighbours. A neighbour which has a path to this destination sends its own source tree in response. Otherwise, a neighbour forwards the message to its neighbours and so on until some alternate path is replied. This is considered as the link break maintenance mechanism in STAR.

Summery 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 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 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 required routing information update overhead.

References:

[1] C. Siva Ram Murthy and B.S. Manoj. Ad Hoc Wireless Networks: Architectures and Protocols.

[2] E. M. Royer, C. Toh, *"A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks*", IEEE, April 1999.

[3] Azzedine Boukerche, "*Performance evaluation of routing protocols for ad hoc wireless networks*", ACM, 2004.

[4] YUAN Peiyan, LI Layuan, *"Performance Evaluation and Simulations of Routing Protocols in Ad Hoc Networks"*, ACM 2006.

[5] Lan Wang and Stephan Olariu, "*A Two-Zone Hybrid Routing Protocol for Mobile Ad Hoc Networks*", IEEE 2004.

[6] William Su, Mario Gerla *"IPv6 Flow Handoff In Ad Hoc Wireless Networks Using Mobility Prediction"*, ACM 1999.

[7] Rajmohan Rajaraman, *"Topology Control and Routing in Ad hoc Networks: A Survey"* ACM June 2002

[8] Xukai Zou, Byrav Ramamurthy and Spyros Magliveras, *"Routing Techniques in Wireless Ad Hoc Networks Classification and Comparison*" Proceedings of the SCI 2002/ISAS 2002

[9] Perkins and P. Bhagwat, *"Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for mobile computers"*. ACM 1994.

[10] Shree Murthy and J.J. Garcia-Luna-Aceves, *"An Efficient Routing Protocol for Wireless Networks"*. ACM 1999.

[11] Ching-Chuan Chiang, Hsiao-Kuang Wu, Winston Liu, Mario Gerla, *"Routing In Clustered Multihop, Mobile Wirelessnetworks with fading channel"*. IEEE 1997.

[12] J.J.Garcia-Luna-Aceves and M. Spohn, *"Source-Tree Routing in Wireless Networks"*, IEEE Oct 1999.