•Ex: consider the figure 3.3. Here, if a transmission from node B to another node A is already in progress, node C cannot transmit to node D, as it concludes that its neighbor node B, is in transmitting mode and hence should not interfere with the on-going transmission. Thus, reusability of the radio spectrum is affected.

Resource Constraints

•Two essential and limited resources are battery life and processing power.

•Devices used in adhoc wireless networks require portability, and hence they also have size and weight constraints along with the restrictions on the power source.

•Increasing the battery power and processing ability makes the nodes bulky and less portable.

Characteristics of an Ideal Routing Protocol for ad hoc wireless networks

A routing protocol for ad hoc wireless networks should have the following characteristics:

•It must be fully distributed as centralized routing involves high control overhead and hence is not scalable.

•It must be adaptive to frequent topology changes caused by the mobility of nodes.

•Route computation and maintenance must involve a minimum number of nodes. Each node in the network must have quick access to routes, that is, minimum connection setup time is desired.

•It must be localized, as global state maintenance involves a huge state propagation control overhead.

•It must be loop-free and free from state routes.

•The number of packet collisions must be kept to a minimum by limiting the number of broadcasts made by each node. The transmissions should be reliable to reduce message loss and to prevent the occurrence of state routes.

•It must converge to optimal routes once the network topology becomes stable. The convergence must be quick.

•It must optimally use scarce resources such as bandwidth, computing power, memory, and battery power.

•Every node in the network should try to store information regarding the stable local topology only. Changes in remote parts of the network must not cause updates in the topology information maintained by the node.

•It should be able to provide a certain level of quality of service (QoS) as demanded by the applications, and should also offer support for time-sensitive traffic.

CLASSIFICATIONS OF ROUTING PROTOCOLS

A classification tree is shown below:

The routing protocol for adhoc wireless networks can be broadly classified into 4 categories based on

- ❖ Routing information update mechanism
- ❖ Use of temporal information for routing
- ❖ Routing topology
- ❖ Utilization of specific resources

Based on the routing information update mechanism

Ad hoc wireless network routing protocols can be classified into 3 major categories based on the routing information update mechanism. They are:

•Proactive or table-driven routing protocols:

- ❖ Every node maintains the network topology information in the form of routing tables by periodically exchanging routing information.

▪Ex: Destination sequenced distance vector routing protocol (DSDV), wireless routing protocol (WRP), source-tree adaptive routing protocol (STAR) and cluster-head gateway switch routing protocol (CGSR).

Destination sequenced distance-vector routing protocol (DSDV)

▪It is an enhanced version of the distributed Bellman -Ford algorithm where each node maintains a table that contains the shortest distance and the first node on the shortest path to every other node in the network.
▪It incorporates table updates with increasing sequence number tags to prevent loops, to counter the count-to-infinity problem, and for faster convergence.
▪As it is a table-driven routing protocol, routes to all destinations are readily available at every node at all times.
▪The tables are exchanged between neighbors at regular intervals to keep an up -to-date view of the network topology.

▪The table updates are of two types:

Incremental updates: Takes a single network data packet unit (NDPU). These are used when a node does not observe significant changes in the local topology.

Full dumps: Takes multiple NDPUs. It is done either when the local topology changes significantly or when an incremental update requires more than a single NDPU.

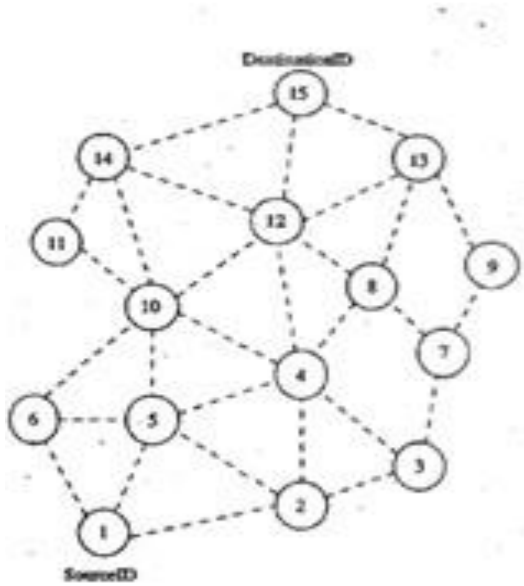
▪Table updates are initiated by a destination with a new sequence number which is always greater than the previous one.
Consider the example as shown in figure 3.4(a). Here node 1 is the source node and node 15 is the destination. As all the nodes maintain global topology information, the route is already available as shown in figure 3.4 (b). Here the routing table node 1 indicates that the shortest route to the destination node is available through node 5 and the distance to it is 4 hops, as depicted in figure 3.4(b)
▪The reconfiguration of a path used by an on-going data transfer session is handled by the protocol in the following way.
▪The end node of the broken link initiates a table update message with the broken link's weight assigned to infinity (∞) and with a sequence number greater than the stored sequence number for that destination.
▪Each node upon receiving an update with weight ∞, quickly disseminates it to its neighbors in order to propagate the broken-link information to the whole network.
▪A node always assigns an odd number to the link break update to differentiate it from the even sequence number generated by the destination.
▪Figure 3.5 shows the case when node 11 moves from its current position.

Advantages

- ✓ Less delay involved in the route setup process.
- ✓ Mechanism of incremental update with sequence number tags makes the existing wired network protocols adaptable to ad hoc wireless networks.
- ✓ The updates are propagated throughout the network in order to maintain an up-to-date view of the network topology at all nodes.

Disadvantages

- ➢ The updates due to broken links lead to a heavy control overhead during high mobility.
- ➢ Even a small network with high mobility or a large network with low mobility can completely choke the available bandwidth.
- ➢ It suffers from excessive control overhead.
- ➢ In order to obtain information about a particular destination node, a node has to wait for a table update message initiated by the same destination node.
- ➢ This delay could result in state routing information at nodes.

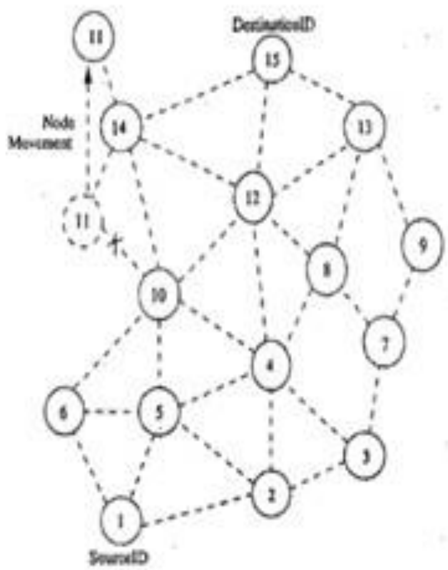


(a) Topology graph of the network

Dest	NextNode	Dist	SeqNo
2	2	1	22
3	2	2	26
4	5	2	32
5	5	1	134
6	6	1	144
7	2	3	162
8	5	3	170
9	2	4	186
10	6	2	142
11	6	3	176
12	5	3	190
13	5	4	198
14	6	3	214
15	5	4	256

(b) Routing table for Node 1

Figure: 3.4 Route establishment in DSDV



Routing Table for Node 1

Dest	NextNode	Dist	SeqNo
2	2	1	22
3	2	2	26
4	5	2	32
5	5	1	134
6	6	1	144
7	2	3	162
8	5	3	170
9	2	4	186
10	6	2	142
11	5	4	180
12	5	3	190
13	5	4	198
14	6	3	214
15	5	4	256

Figure: 3.5 Route maintenance in DSDV

Wireless Routing Protocol (WRP)

·WRP is similar to DSDV; it inherits the properties of the distributed bellman-ford algorithm.
·To counter the count-to-infinity problem and to enable faster convergence, it employs a unique method of maintaining information regarding the shortest distance to every destination node in the network and penultimate hop node on the path to every destination node.
·Maintains an up-to-date view of the network, every node has a readily available route to every destination node in the network.
·It differs from DSDV in table maintenance and in the update procedures.
·While DSDV maintains only one topology table, WRP uses a set of tables to maintain more accurate information.
·The table that are maintained by a node are:

- Distance table (DT): contains the network view of the neighbors of a node. It contains a matrix where each element contains the distance and the penultimate node reported by the neighbor for a particular destination.
- Routing table (RT): contains the up-to-date view of the network for all known destinations. It keeps the shortest distance, the predecessor/penultimate node, the successor node, and a flag indicating the status of the path. The path status may be a simplest (correct) path or a loop (error), or destination node not marked (null).
- Link cost table (LCT): contains the cost of relaying messages through each link. The cost of broken link is ∞.it also contains the number of update periods passed since the last successful update was received from that link.
- Message retransmission list (MRL): contains an entry for every update message that is to be retransmitted and maintains a counter for each entry.

·After receiving the update message, a node not only updates the distance for transmitted neighbors but also checks the other neighbors' distance, hence convergence is much faster than DSDV.
·Consider the example shown in figure below, where the source of the route is node 1 and destination is node 15. As WRP proactively maintains the route to all destinations, the route to any destination node is readily available at the source node.
·From the routing table shown, the route from node 1 to node 15 has the next node as node 2. The predecessor node of 15 corresponding to this route is route 12. The predecessor information helps WRP to converge quickly during link breaks.
·When a node detects a link break; it sends an update message to its neighbors with the link cost of the broken link set to ∞. After receiving the update message; all affected nodes update their minimum distances to the corresponding nodes. The node that initiated the update message then finds an alternative route, if available from its DT. Figure 3.6 shows route maintenance in WRP.

Advantages

- ✓ WRP has the same advantages as that of DSDV.
- ✓ It has faster convergence and involves fewer table updates.

Disadvantages

- The complexity of maintenance of multiple tables demands a larger memory and greater processing power from nodes in the adhoc wireless network.
- It is not suitable for highly dynamic and also for very large ad hoc wireless networks.

- ❖ Routing information is generally flooded in the whole network.
- ❖ Whenever a node requires a path to a destination, it runs an appropriate path-finding algorithm on the topology information it maintains.

▪Reactive or on-demand routing protocols:

- ❖ Do not maintain the network topology information.
- ❖ Obtain the necessary path when it is required, by using a connection establishment process.

▪Hybrid routing protocols:

- ❖ Combine the best features of the above two categories.
- ❖ Nodes within a certain distance from the node concerned, or within a particular geographical region, are said to be within the routing zone of the given node.
- ❖ For routing within this zone, a table-driven approach is used.
- ❖ For nodes that are located beyond this zone, an on-demand approach is used.

Based on the use of temporal information for routing

The protocols that fall under this category can be further classified into two types:

▪Routing protocols using past temporal information:

Use information about the past status of the links or the status of links at the time of routing to make routing decisions.

▪Routing protocols that use future temporal information:

Use information about the about the expected future status of the wireless links to make approximate routing decisions.

Apart from the lifetime of wireless links, the future status information also includes information regarding the lifetime of the node, prediction of location, and prediction of link availability.

Based on the routing topology

Ad hoc wireless networks, due to their relatively smaller number of nodes, can make use of either a flat topology or a hierarchical topology for routing.

▪Flat topology routing protocols:

Make use of a flat addressing scheme similar to the one used in IEEE 802.3 LANs.

It assumes the presence of a globally unique addressing mechanism for nodes in an ad hoc wireless network.

▪Hierarchical topology routing protocols:

Make use of a logical hierarchy in the network and an associated addressing scheme.

The hierarchy could be based on geographical information or it could be based on hop distance.

Based on the utilization of specific resources

▪Power-aware routing:

Aims at minimizing the consumption of a very important resource in the ad hoc wireless networks such as battery power

The routing decisions are based on minimizing the power consumption either logically or globally in the network.

▪Geographical information assisted routing:

Improves the performance of routing and reduces the control overhead by effectively utilizing the geographical information available.

<u>TABLE-DRIVEN ROUTING PROTOCOLS</u>

▪These protocols are extensions of the wired network routing protocols
▪They maintain the global topology information in the form of tables at every node
▪Tables are updated frequently in order to maintain consistent and accurate network state information