

## ROUTING PROTOCOLS

Challenges and Issues – DSDV – DSR - AODV Protocols - Link Reversal Routing – Properties - Unicast and Multicast Route Establishment - Comparison of Multicast Routing Protocols - Scheduling Techniques - Transmission Scheduling - Medium Access and Sleep Scheduling.

## **NETWORK PROTOCOLS**

### **INTRODUCTION**

Since the ad hoc wireless network consists of a set of mobile nodes (hosts) that are connected by wireless links, the network topology in such a network may keep changing randomly. Hence a variety of routing protocols for ad hoc wireless networks has been proposed.

### **ISSUES IN DESIGNING A ROUTING PROTOCOL FOR AD HOC WIRELESS NETWORKS**

The major challenges that a routing protocol designed for ad hoc wireless networks faces are:

#### **Mobility**

- Network topology is highly dynamic due to movement of nodes. Hence, an ongoing session suffers frequent path breaks.
- Disruption occurs due to the movement of either intermediate nodes in the path or end nodes.
- Wired network routing protocols cannot be used in adhoc wireless networks because the nodes are here are not stationary and the convergence is very slow in wired networks.
- Mobility of nodes results in frequently changing network topologies
- Routing protocols for ad hoc wireless networks must be able to perform efficient and effective mobility management.

#### **Bandwidth Constraint**

- Abundant bandwidth is available in wired networks due to the advent of fiber optics and due to the exploitation of wavelength division multiplexing (WDM) technologies.
- In a wireless network, the radio band is limited, and hence the data rates it can offer are much less than what a wired network can offer.
- This requires that the routing protocols use the bandwidth optimally by keeping the overhead as low as possible.
- The limited bandwidth availability also imposes a constraint on routing protocols in maintaining the topological information.

#### **Error-prone shared broadcast radio channel**

- The broadcast nature of the radio channel poses a unique challenge in ad hoc wireless networks.
- The wireless links have time-varying characteristics in terms of link capacity and link-error probability.
- This requires that the adhoc wireless network routing protocol interact with the MAC layer to find alternate routes through better-quality links.
- Transmissions in ad hoc wireless networks result in collisions of data and control packets.
- Therefore, it is required that ad hoc wireless network routing protocols find paths with less congestion.

#### **Hidden and exposed terminal problems**

- The hidden terminal problem refers to the collision of packets at a receiving node due to the simultaneous transmission of those nodes that are not within the direct transmission range of the receiver, but are within the transmission range of the receiver.
- Collision occurs when both nodes transmit packets at the same time without knowing about the transmission of each other.

Ex: consider figure 3.1. Here, if both node A and node C transmit to node B at the same time, their packets collide at node B. This is due to the fact that both node A and C are hidden from each other, as

## MOBILE ADHOC NETWORKS

they are not within the direct transmission range of each other and hence do not know about the presence of each other.

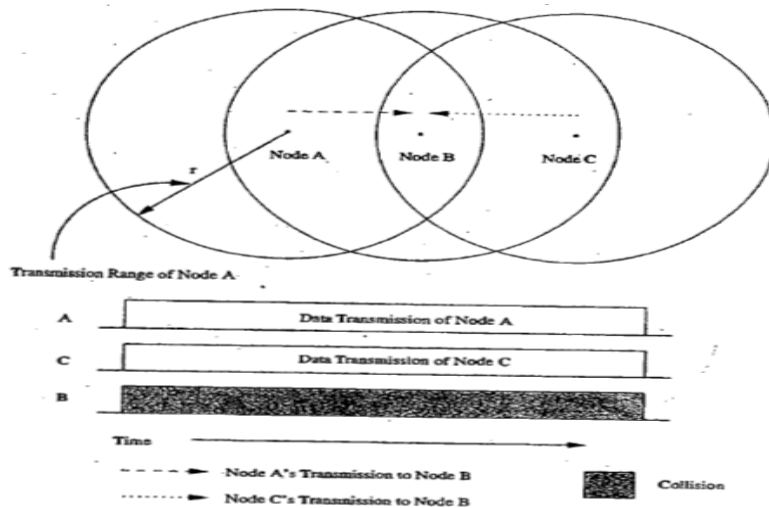


FIG: 3.1 Hidden Terminal Problems

•Solution for this problem include medium access collision avoidance (MACA):

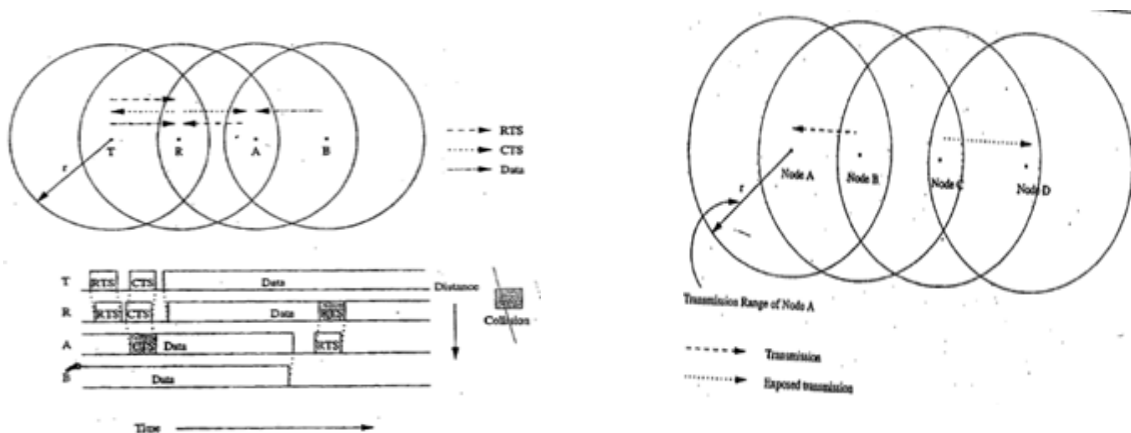
Transmitting node first explicitly notifies all potential hidden nodes about the forthcoming transmission by means of a two way handshake control protocol called RTS-CTS protocol exchange.

❖ This may not solve the problem completely but it reduces the probability of collisions.

•Medium access collision avoidance for wireless (MACAW):

❖ An improved version of MACA protocol.

❖ Introduced to increase the efficiency.



❖ Requires that a receiver acknowledges each successful reception of data packet.

**Figure: 3.2 Hidden Terminal problem with RTS-CTS Terminal Problem**

**Figure: 3.3 Exposed Terminal Problem**

•Successful transmission is a four-way exchange mechanism, RTS-CTS-Data-ACK, as illustrated in figure. Other solutions include floor acquisition multiple access (FAMA) and Dual busy tone multiple access (DBTMA).

•The exposed terminal problem refers to the inability of a node which is blocked due to transmission by a nearby transmitting node to transmit to another node.

•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.

- ❖ 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.

### **TABLE-DRIVEN ROUTING PROTOCOLS**

- 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

•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 ( $\infty$ ) and with a sequence number greater than the stored sequence number for that destination.

•Each node upon receiving an update with weight  $\infty$ , 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.

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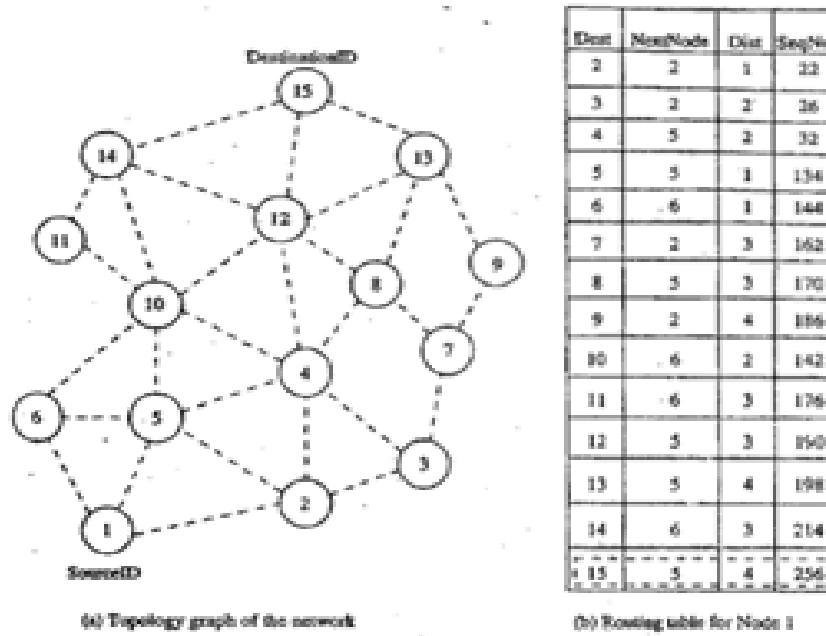


Figure: 3.4 Route establishment in DSDV

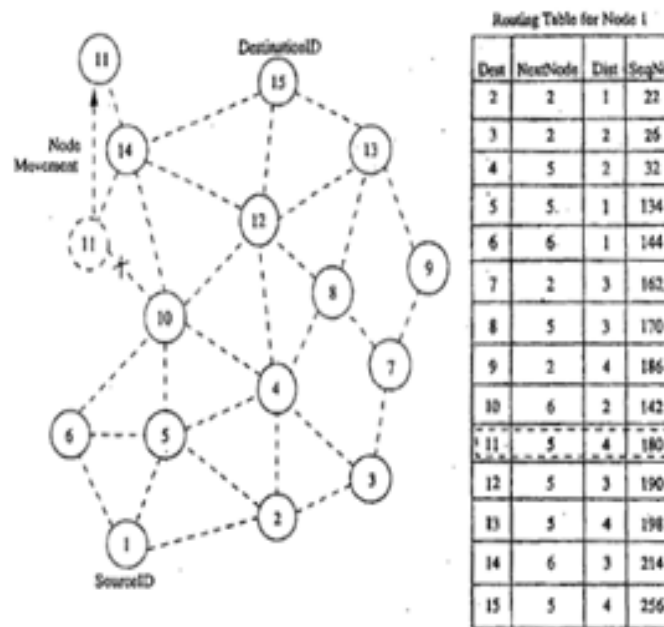


Figure: 3.5 Route maintenance in DSDV

### **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  $\infty$ . 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  $\infty$ . 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.



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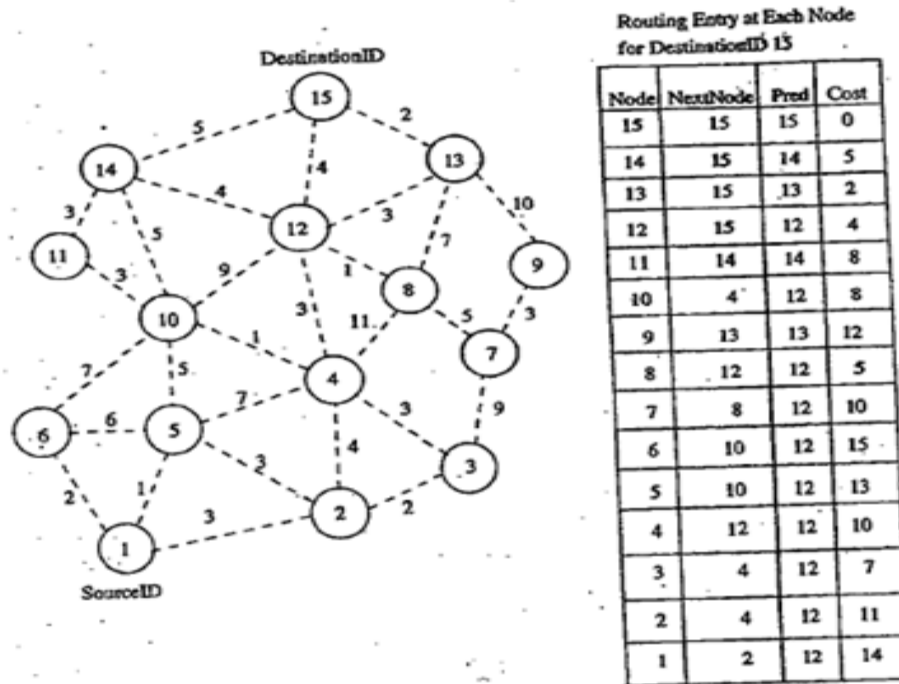


Figure: 3.6 Route establishments in WRP

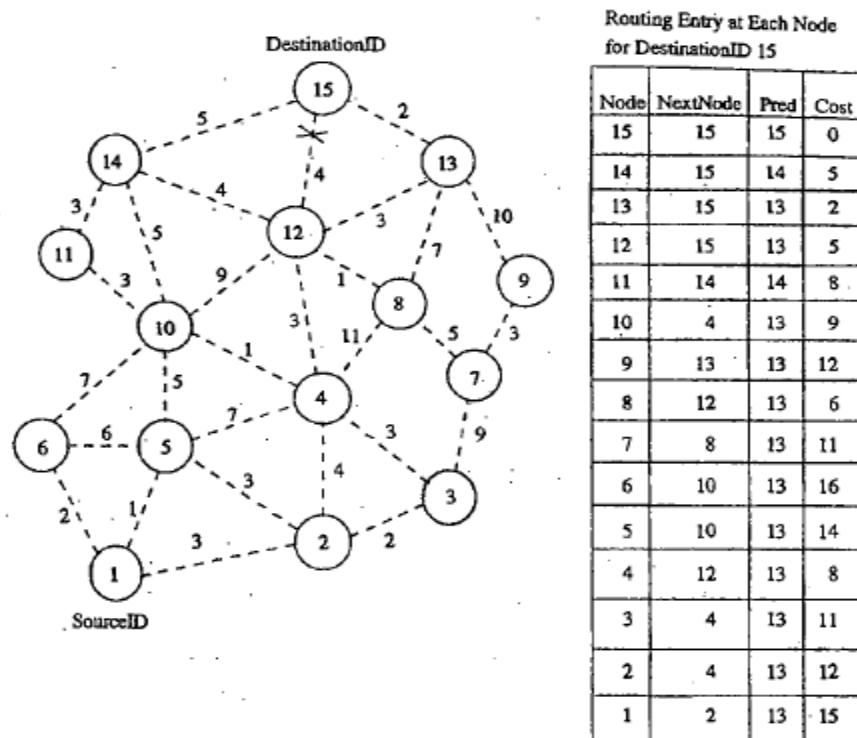


Figure: 3.7 Route maintenance in WRP



### **ON-DEMAND ROUTING PROTOCOLS**

They execute the path-finding process and exchange routing information only when a path is required by a node to communicate with a destination

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

- Designed to restrict the bandwidth consumed by control packets in adhoc wireless networks by eliminating the periodic table update messages
- It is beacon-less and does not require periodic hello packet transmissions
- Basic approach
  - to establish a route by flooding RouteRequest packets in the network
- Destination node responds by sending a RouteReply packet back to the source
- Each RouteRequest carries a sequence number generated by the source node and the path it has traversed
- A node checks the sequence number on the packet before forwarding it
- The packet is forwarded only if it is not a duplicate RouteRequest
- The sequence number on the packet is used to prevent loop formations and to avoid multiple transmissions
- Thus, all nodes except the destination forward a RouteRequest packet during the route construction phase
- In figure 3.8, source node 1 initiates a RouteRequest packet to obtain a path for destination node 15
- This protocol uses a route cache that stores all possible information extracted from the source route contained in a data packet
- During network partitions, the affected nodes initiate RouteRequest packets
- DSR also allows piggy-backing of a data packet on the RouteRequest
- As a part of optimizations, if the intermediate nodes are also allowed to originate RouteReply packets, then a source node may receive multiple replies from intermediate nodes
- In fig 3.9, if the intermediate node 10 has a route to the destination via node 14, it also sends the RouteReply to the source node
- The source node selects the latest and best route and uses that for sending data packets
- Each data packet carries the complete path to its destination
- If a link breaks, source node again initiates the route discovery process

#### **Advantages**

- ✓ Uses a reactive approach which eliminates the need to periodically flood the network with table update messages
- ✓ Route is established only when required
- ✓ Reduce control overhead

#### **Disadvantages**

- Route maintenance mechanism does not locally repair a broken link
- Stale route cache information could result in inconsistencies during route construction phase
- Connection set up delay is higher
- Performance degrades rapidly with increasing mobility
- Routing overhead is more & directly proportional to path length

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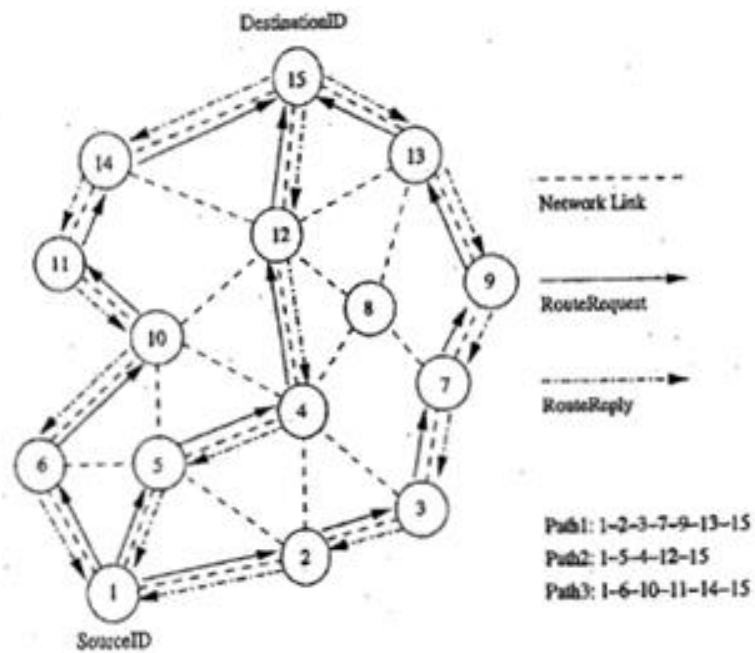


Figure: 3.7 Route establishment in DSR

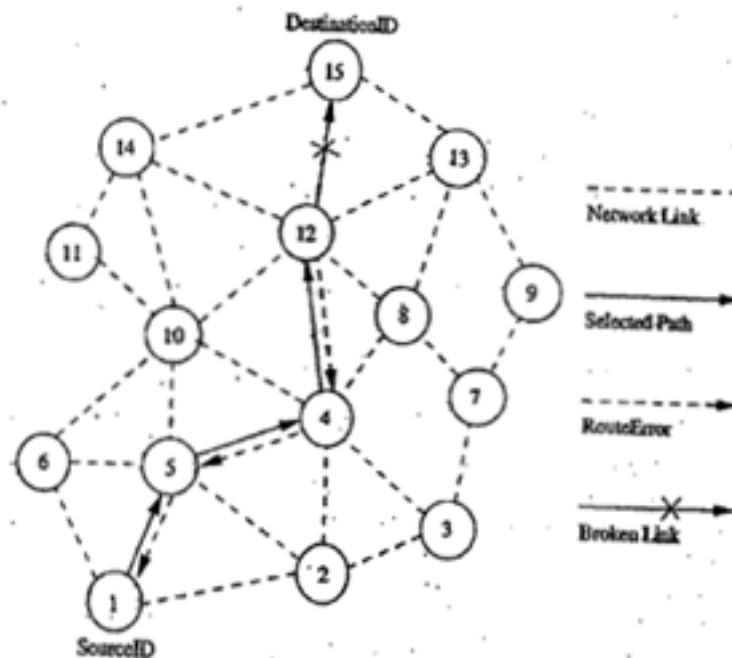


Figure: 3.7 Route maintenance in DSR

## Ad Hoc On-Demand Distance Vector Routing Protocol (AODV)

- Route is established only when it is required by a source node for transmitting data packets
- It employs destination sequence numbers to identify the most recent path
- Source node and intermediate nodes store the next hop information corresponding to each flow for data packet transmission
- Uses DestSeqNum to determine an up-to-date path to the destination
- A RouteRequest carries the source identifier, the destination identifier, the source sequence number, the destination sequence number, the broadcast identifier and the time to live field
- DestSeqNum indicates the freshness of the route that is accepted by the source
- When an intermediate node receives a RouteRequest, it either forwards it or prepares a RouteReply if it has a valid route to the destination
- The validity of the intermediate node is determined by comparing the sequence numbers
- If a RouteRequest is received multiple times, then duplicate copies are discarded
- Every intermediate node enters the previous node address and its BcastID
- A timer is used to delete this entry in case a RouteReply packet is not received
- AODV does not repair a broken path locally
- When a link breaks, the end nodes are notified
- Source node re-establishes the route to the destination if required

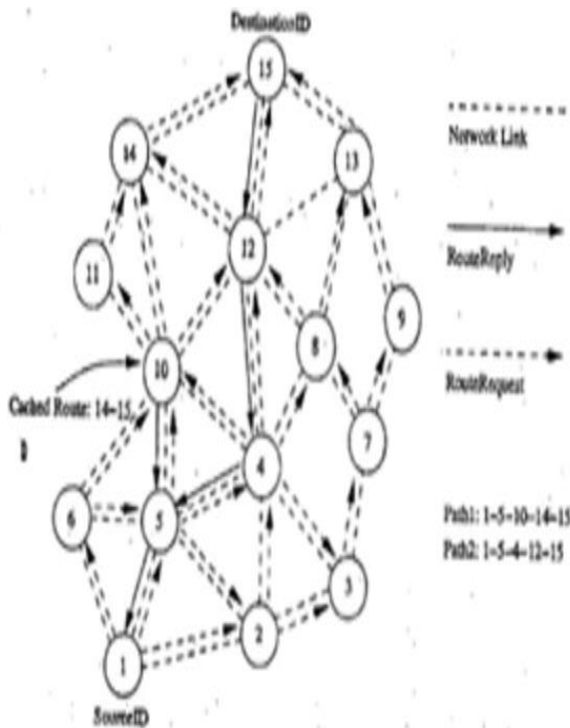


Figure: 3.10 Route establishment in AODV

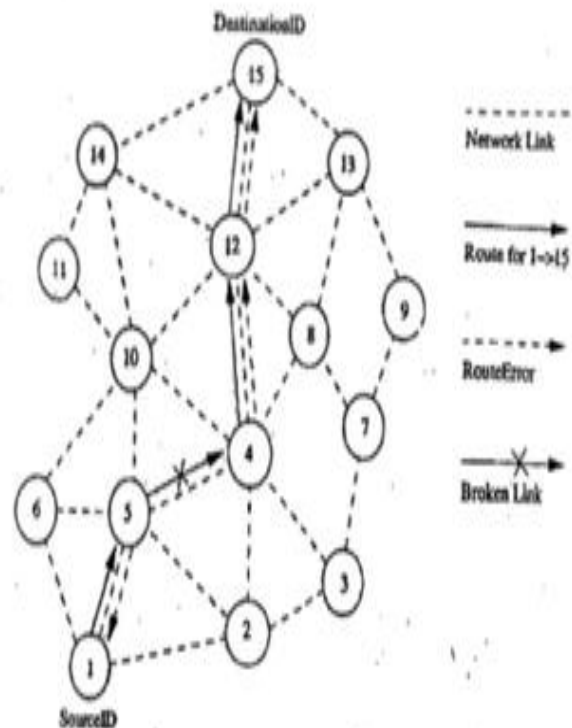


Figure: 3.11 Route maintenance in AODV

### Advantage

- ✓ Routes are established on demand and DestSeqNum are used to find latest route to the destination
- ✓ Connection setup delay is less

### Disadvantages

- Intermediate nodes can lead to inconsistent routes if the source sequence number is very old
- Multiple RouteReply packets to single RouteRequest packet can lead to heavy control overhead
- Periodic beaconing leads to unnecessary bandwidth consumption

### Temporally Ordered Routing Algorithm (TORA)

- Source-initiated on-demand routing protocol
- Uses a link reversal algorithm
- Provides loop free multi path routes to the destination
- Each node maintains its one-loop local topology information
- Has capability to detect partitions
- Unique property • limiting the control packets to a small region during the reconfiguration process initiated by a path break
- TORA has 3 main functions: establishing, maintaining and erasing routes
- The route establishment function is performed only when a node requires a path to a destination but does not have any directed link
- This process establishes a destination-oriented directed acyclic graph using a query/update mechanism
- Once the path to the destination is obtained, it is considered to exist as long as the path is available, irrespective of the path length changes due to the re-configurations that may take place during the course of data transfer session
- If the node detects a partition; it originated a clear message, which erases the existing path information in that partition related to the destination

### Advantages

- ✓ Incur less control overhead
- ✓ Concurrent detection of partitions
- ✓ Subsequent deletion of routes

### Disadvantages

- Temporary oscillations and transient loops
- Local reconfiguration of paths result in non-optimal routes

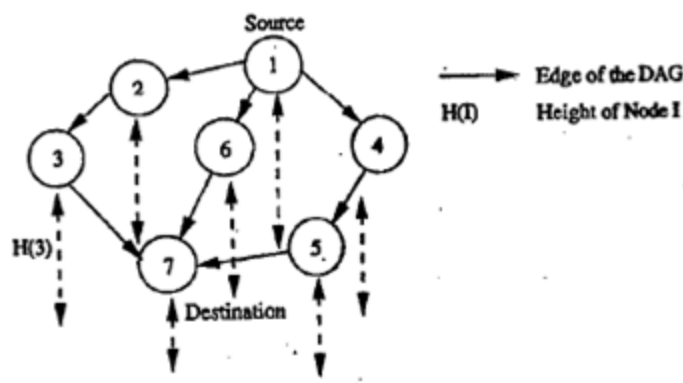


Figure: 3.12. Illustration of temporal ordering in TORA

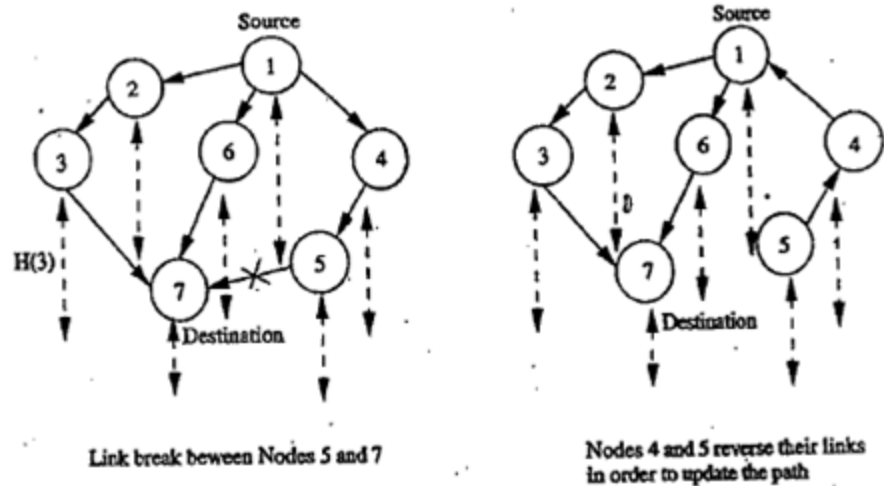


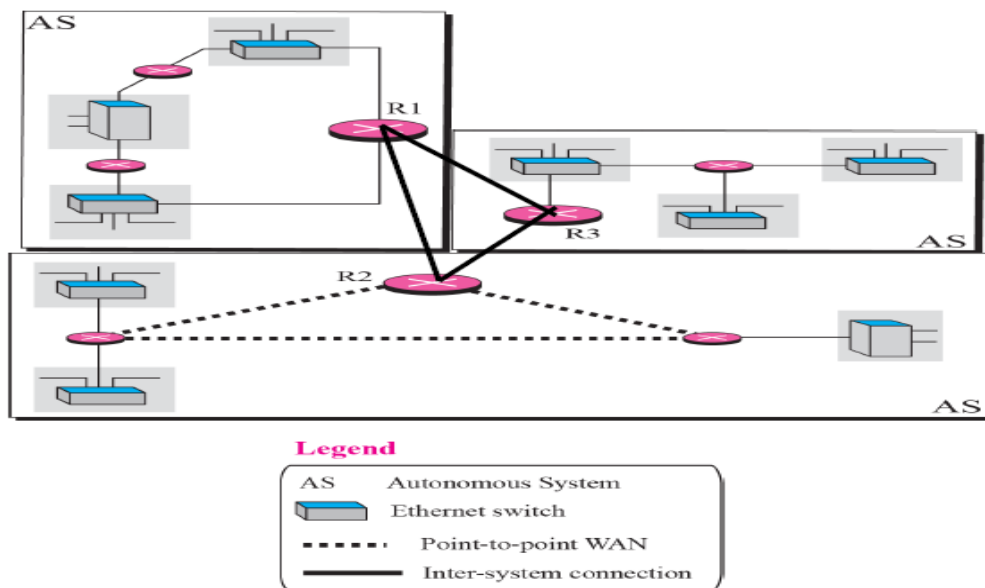
Figure: 3.13 Route maintenance in TORA

## Unicast routing algorithms

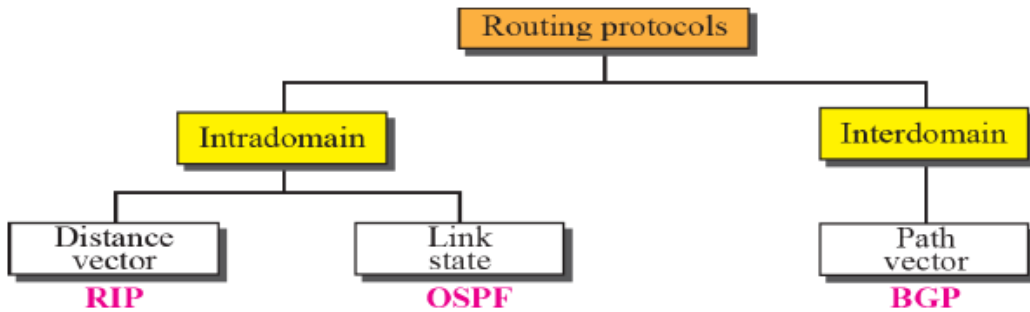
An internet is a combination of networks connected by routers. When a datagram goes from a source to a destination, it will probably pass through many routers until it reaches the router attached to the destination network.

### INTER- AND INTRA-DOMAIN ROUTING

An internet can be so large that one routing protocol cannot handle the task of updating the routing tables of all routers. For this reason, an internet is divided into autonomous systems. An autonomous system (AS) is a group of networks and routers under the authority of a single administration. Routing inside an autonomous system is called intra-domain routing. Routing between autonomous systems is called inter-domain routing.



## Popular routing protocols

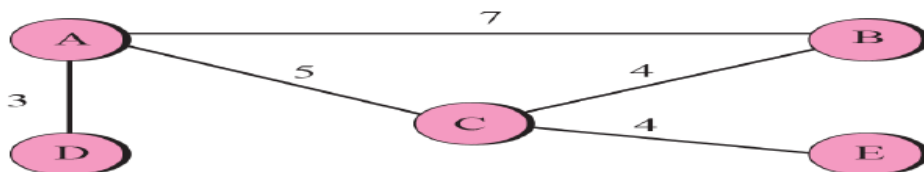


## DISTANCE VECTOR ROUTING

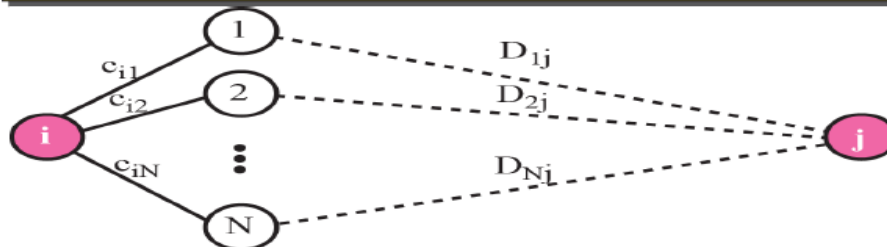
Distance vector and link state routing are both interior routing protocols. They can be used inside an autonomous system. Both of these routing protocols become intractable when the domain of operation becomes large. Distance vector routing is subject to instability if there is more than a few hops in the domain of operation. Link state routing needs a huge amount of resources to calculate routing tables. It also creates heavy traffic because of flooding. There is a need for a third routing protocol which we call path vector routing.

- Bellman-Ford Algorithm
- Distance Vector Routing Algorithm
- Count to Infinity

## A graph for Bellman-Ford algorithm



$$D_{ij} = \text{minimum} \{ (c_{i1} + D_{1j}), (c_{i2} + D_{2j}), \dots, (c_{iN} + D_{Nj}) \}$$



### Legend

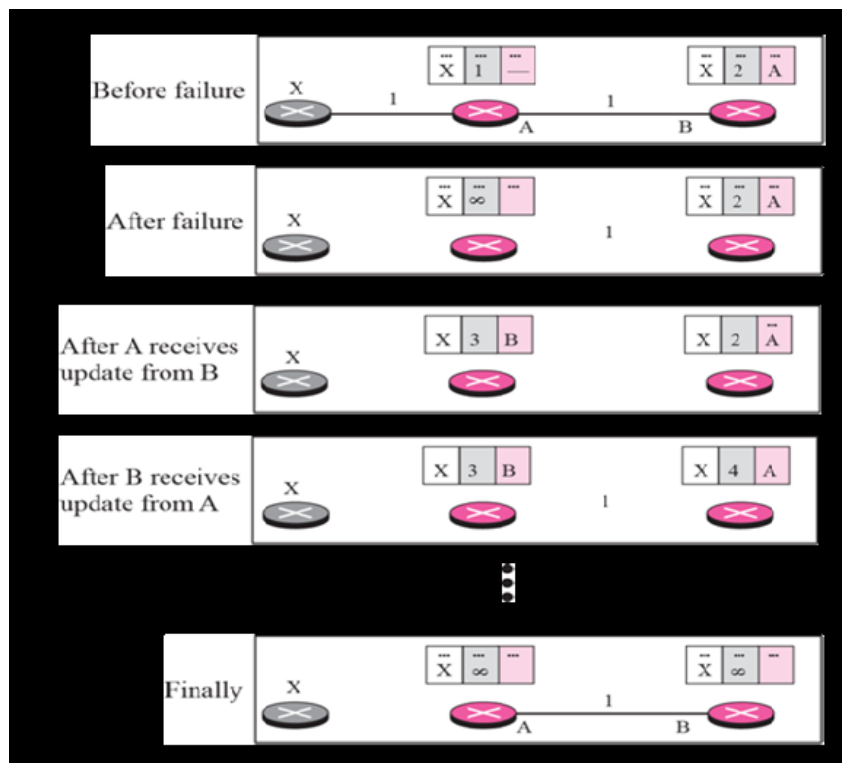
$D_{ij}$  Shortest distance between  $i$  and  $j$   
 $c_{ij}$  Cost between  $i$  and  $j$   
 $N$  Number of nodes

### Updating Routing Table

- If the next-node entry is different
  - The receiving node chooses the row with the smaller cost
  - If there is a tie, the old one is kept
- If the next-node entry is the same
  - i.e. the sender of the new row is the provider of the old entry
  - The receiving node chooses the new row, even though the new value is infinity.
- Periodic Update
  - A node sends its routing table, normally 30 seconds, in a periodic update
- Triggered Update
  - A node sends its routing table to its neighbors any time when there is a change in its routing table
- After updating its routing table, or
- Detects some failure in the neighboring links

### Two-Node Instability

- Defining Infinity
  - Most implementations define 16 as infinity
- Split Horizon
  - Instead of flooding the table through each interface, each node sends only part of its table through each interface
  - E.g. node B thinks that the optimum routes to reach X is via A, it does not need to advertise this piece of information to A

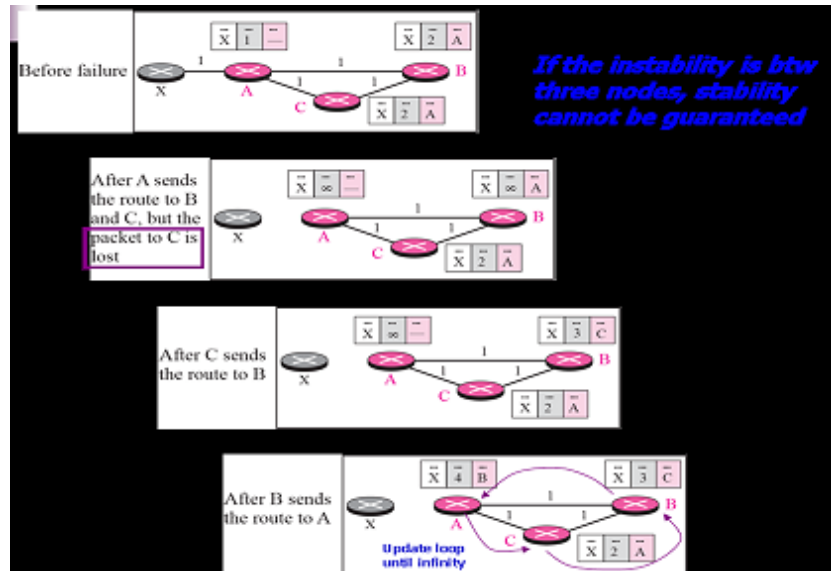


- Split Horizon and Poison Reverse
  - One drawback of Split Horizon



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- Normally, the DV protocol uses a timer and if there is no news about a route, the node deletes the route from its table
- In the previous e.g., node A cannot guess that this is due to split horizon or because B has not received any news about X recently
  - Poison Reverse
- Node B can still advertise the value for X, but if the source of information is A, it can replace the distance with infinity as a warning



### RIP

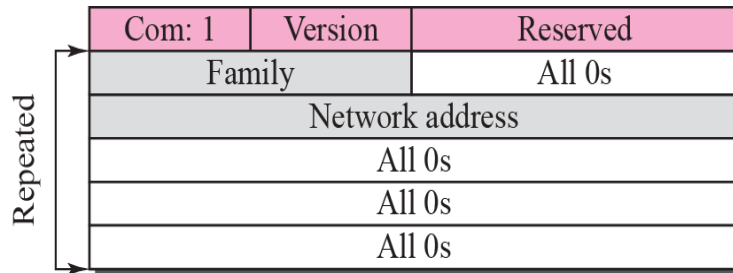
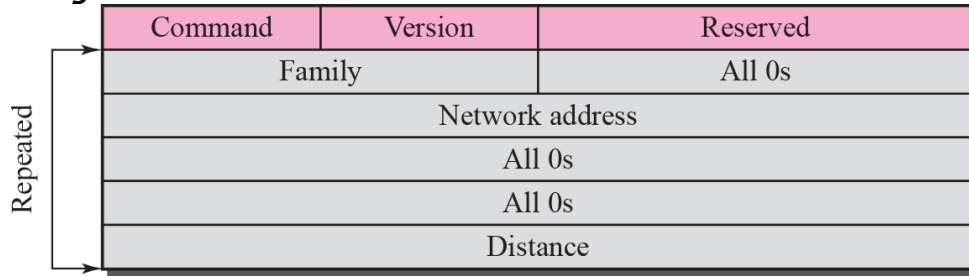
The Routing Information Protocol (RIP) is an intra-domain (interior) routing protocol used inside an autonomous system. It is a very simple protocol based on distance vector routing. RIP implements distance vector routing directly with some considerations.

- RIP Message Format
- Request and Response
- Timers in RIP
- RIP Version 2
- Encapsulation

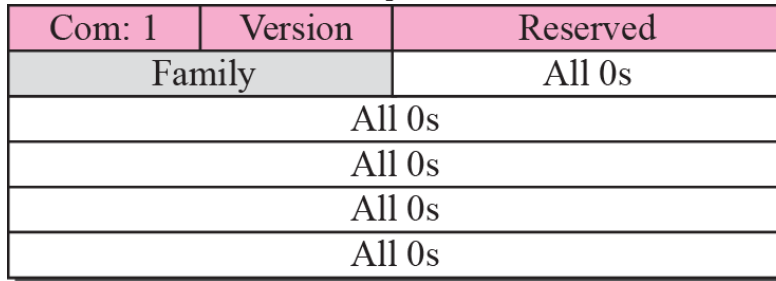
#### RIP messages

- Request
  - A request message is sent by a router that has just come up or by a router that has some-time-out entries
  - A request can ask about specific entries or all entries
- Response
  - A response can be either solicited or unsolicited (30s or when there is a change in the routing table)

**RIP message format**  
**Request messages**



a. Request for some



b. Request for all

**RIP Timers**

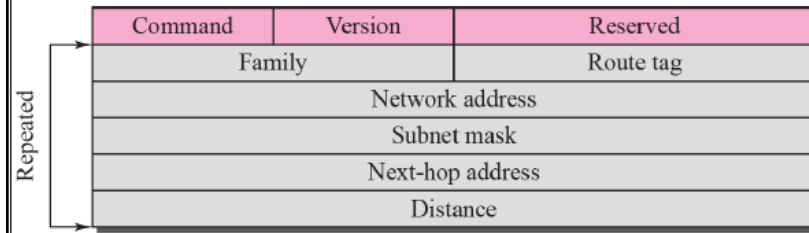
- Periodic timer
  - It controls the advertising of regular update message (25 ~ 30 sec)
- Expiration timer
  - It governs the validity of a route (180 sec)
  - The route is considered expired and the hop count of the route is set to 16
- Garbage collection timer
  - A invalid route is not purged from the routing table until this timer expires (120 sec)

**RIPv2 vs. RIPv1**

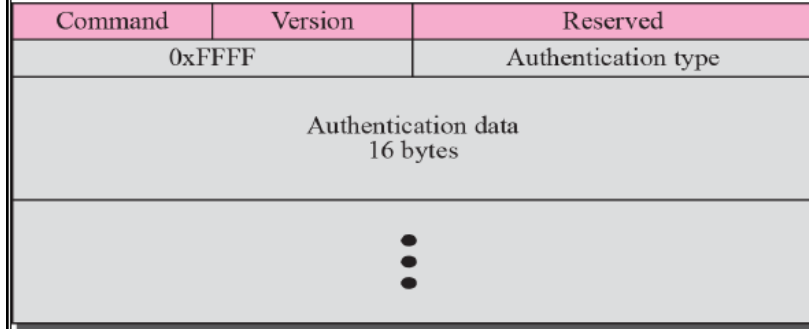
- Classless Addressing
- Authentication
- Multicasting
  - RIPv1 uses broadcasting to send RIP messages to every neighbors. Routers as well as hosts receive the packets
  - RIPv2 uses the all-router multicast address to send the RIP messages only to RIP routers in the network

## MOBILE ADHOC NETWORKS

### RIP version 2 format



### Authentication

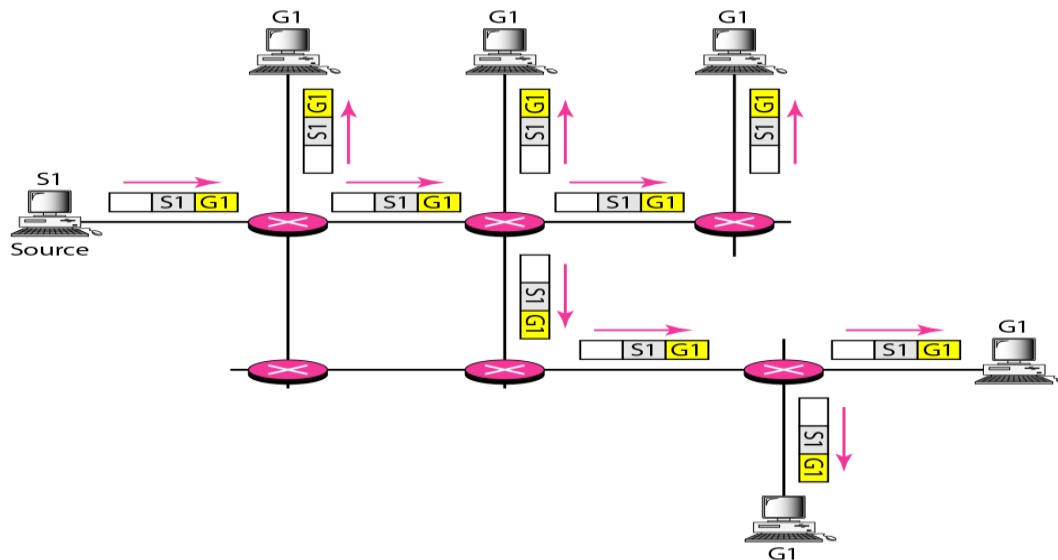


### Multicast routing algorithms

A multicast address is a destination address for a group of hosts that have joined a multicast group. A packet that uses a multicast address as a destination can reach all members of the group unless there is some filtering restriction by the receiver.

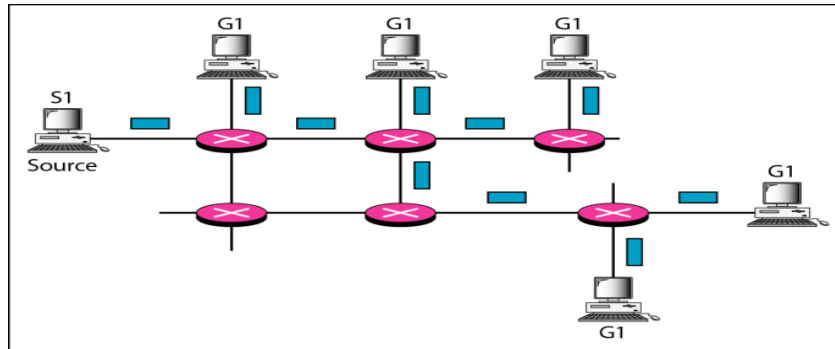
### Multicasting

- In multicast routing, the router may forward the received packet through several of its interfaces.
- Broadcasting is a special case of multicasting

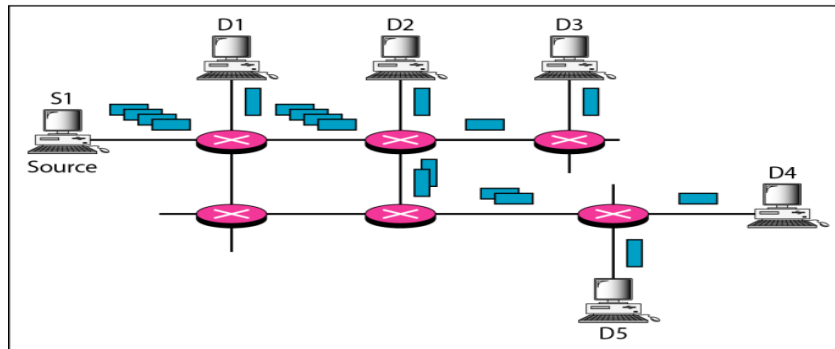


### Multicasting vs. Multiple Unicasting

- Emulation of multicasting through multiple unicasting is not efficient and may create long delays, particularly with a large group



a. Multicasting



b. Multiple unicasting

### Multicasting Applications

- Access to distributed databases
- Information dissemination
- Dissemination of news
- Teleconferencing
- Distance learning

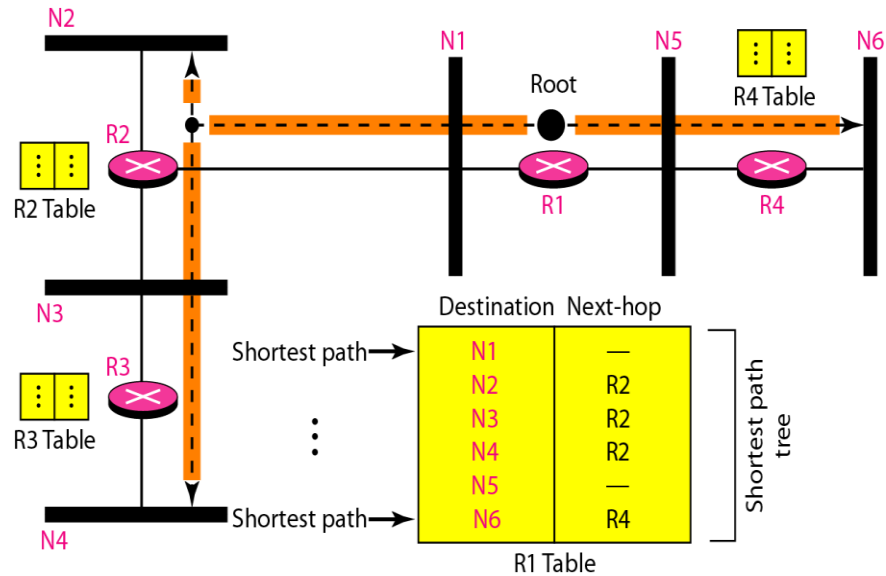
### Multicast tree

- Objectives of multicasting:
  - Every member of the group should receive one, and only one, copy of the multicast packet.
  - Nonmember must not receive a copy
  - There must be no loops in routing
  - The path traveled from source to each destination must be optimal
- In a source-based tree approach, the combination of source and group determines the tree (DVMRP, MOSPF, PIM-DM)
- In the group-shared tree approach, the group determines the tree (CBT, PIM-SM)

### Multicast Routing

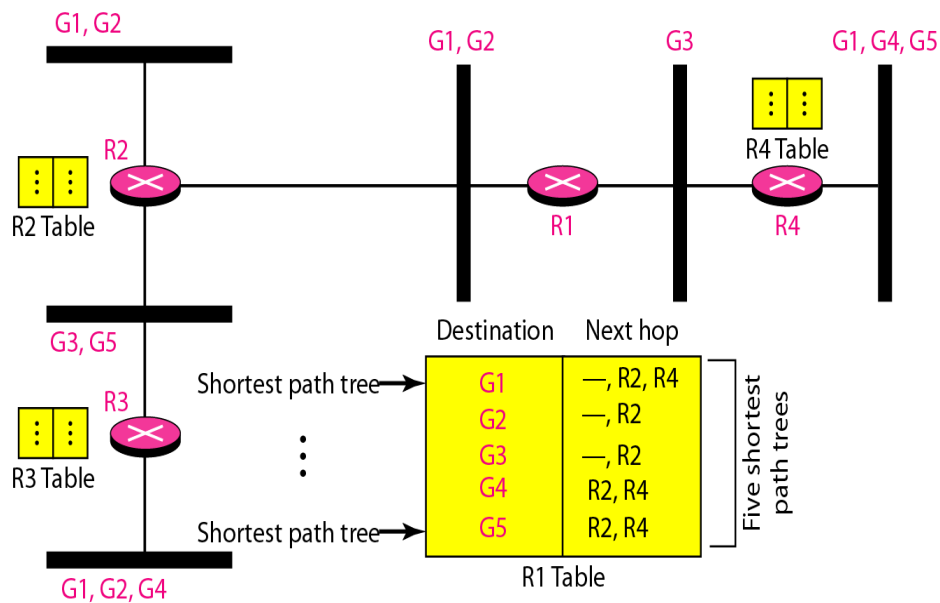
- Optimal routing: Shortest path trees
- *Unicast Routing*
  - Each router in the domain has a table that defines a shortest path tree to possible destinations

## MOBILE ADHOC NETWORKS



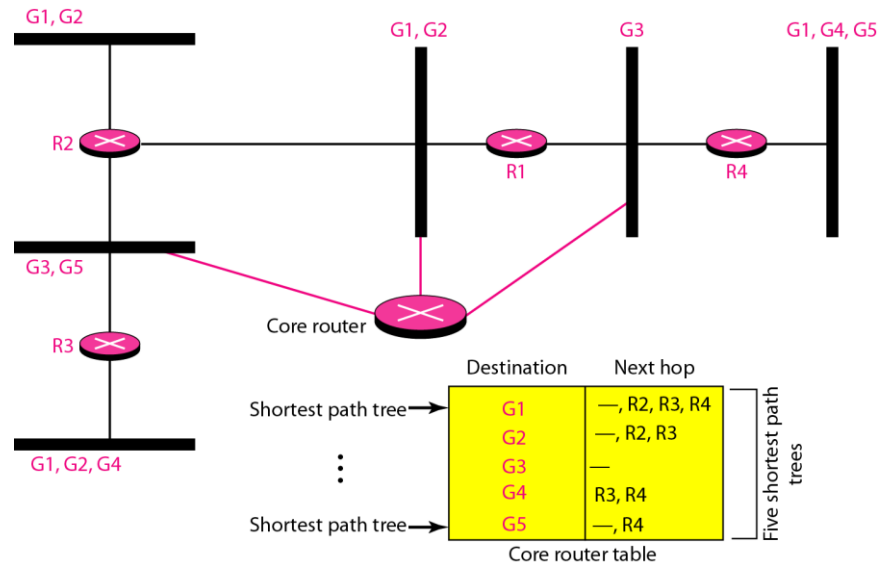
### Shortest Path Tree

- Multicast Routing
  - Each involved router needs to construct a shortest path tree for each group
- *Source-Based Tree* and *Group-Shared Tree*
- In the source-based tree approach, each router needs to have one shortest path tree for each group

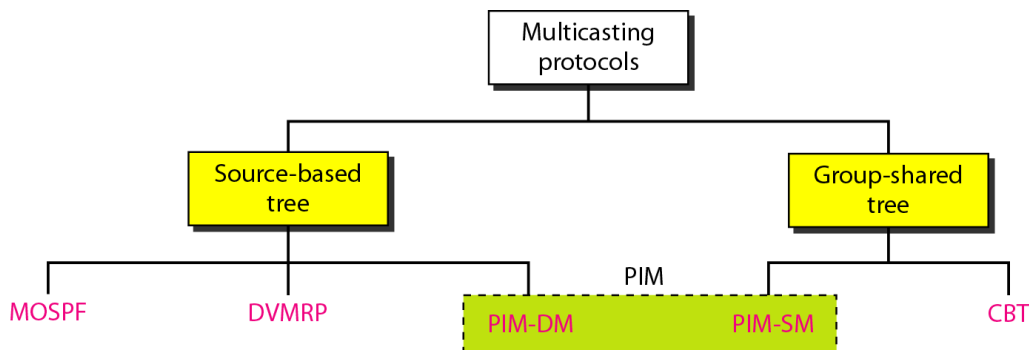


- In the group-shared tree approach, only the core router, which has a shortest path tree for each group, is involved in multicasting

## MOBILE ADHOC NETWORKS



### MULTICASTING PROTOCOLS:



#### Multicast Link State Routing: MOSPF

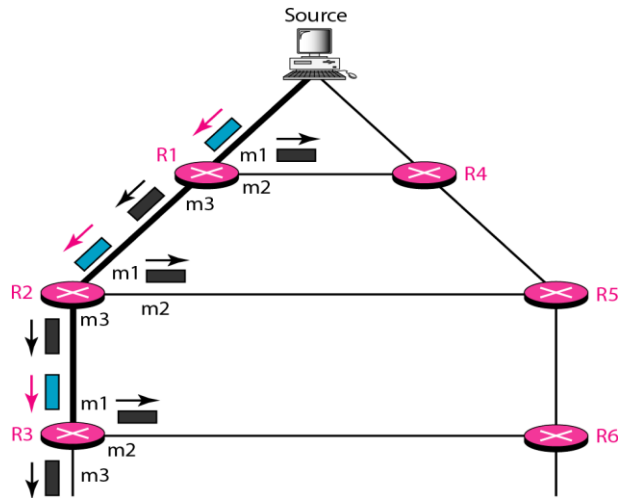
- Multicast link state routing uses the source-based tree approach
- n (the number of group) topologies and n shortest path trees made
- Each router has a routing table that represents as many shortest path trees as there are groups
- MOSPF is an extension of the OSPF protocol that uses multicast link state routing to create source based trees
- MOSPF requires a new link state update packet to associate the unicast address of a host with the group address or addresses the host is sponsoring
- MOSPF is a data-driven protocol; the first time an MOSPF router see a datagram with a given source and group address, the router constructs the Dijkstra shortest path tree

#### Multicast Distance Vector: DVMRP

- Multicast distance vector routing uses the source-based trees, but the router never actually makes a routing table
- Multicast routing does not allow a router to send its routing table to its neighbors. The idea is to create a table from scratch by using the information from the unicast distance vector tables
- Process based on four decision-making strategies. Each strategy is built on its predecessor
  - Flooding
  - Reverse Path Forwarding (RPF)
  - Reverse Path Broadcasting (RPB)
  - Reverse Path Multicasting (RPM)

### DVMRP: Strategies

- *Flooding* broadcasts packets, but creates loops in the systems
- *Reverse path forwarding*: RPF eliminates the loop in the flooding process
- *Reverse path broadcasting*: RPB creates a shortest path broadcast tree from the source to each destination. It guarantees that each destination receives one and only one copy of the packet
- Problem with RPF



### Part A Questions

1. What is hidden terminal problem?
2. What are the responsibilities of routing protocol?
3. What are the major challenges in designing routing protocols?
4. Differentiate proactive and reactive protocols. Write examples for each.
5. List the characteristics of a routing protocol for ad hoc wireless networks.
6. List the major classification of routing protocol for ad hoc wireless network.
7. Based on routing information update mechanism how the routing protocols are classified?
8. How does energy aware routing work?
9. List the classification of routing protocols based on the routing information update mechanism.
10. List the advantages and disadvantages of DSDV routing protocols.
11. What is hybrid routing protocol?
12. List some examples of table driven routing protocols.
13. List the types of on-demand routing protocols
14. What do you mean by time to live (TTL)?
15. What are the advantages and disadvantages of dynamic source routing protocol?
16. Give the difference between Ad hoc on demand Distance vector routing protocol (AODV) and dynamic sequence routing protocol (DSR)

### Part B Questions

1. Explain on demand routing protocol in detail.
2. Explain the major challenges that a routing protocol designed for ad hoc wireless networks face.
3. List the characteristics of ideal routing protocol for ad hoc wireless network.
4. Discuss table driven protocols with examples.
5. Explain multicast routing algorithms in detail.
6. Explain the scheduling table update mechanism in distributed priority scheduling.