Routing in MANET

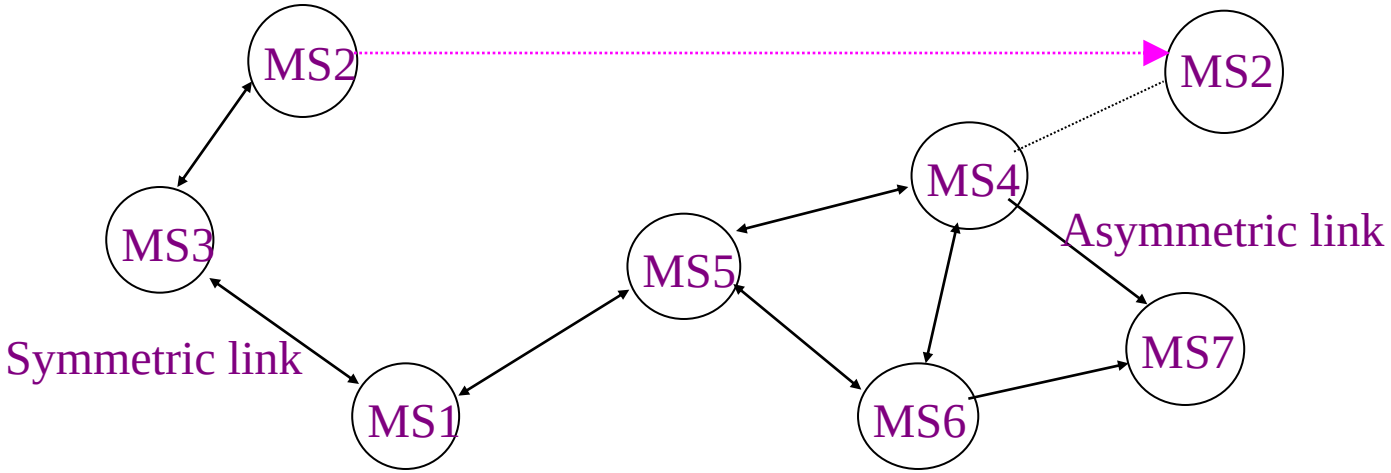
Introduction

- A Mobile Ad hoc Network (MANET) is an autonomous system of nodes (MSs) connected by wireless links.
- A MANET does not necessarily need support from any existing network infrastructure like an Internet gateway or other fixed stations.
- The network's wireless topology may dynamically change in an unpredictable manner since nodes are free to move.
- Information is transmitted in a store-and forward manner using multi hop routing.

Introduction (Cont'd)

- Each node is equipped with a wireless transmitter and a receiver with an appropriate antenna.
- We assume that it is not possible to have all nodes within each other's radio range.
- When the nodes are close-by i.e., within radio range, there are no routing issues to be addressed.
- At a given point in time, wireless connectivity in the form of a random multi-hop graph exists between the nodes.

A Mobile Ad Hoc Network



Characteristics of Ad Hoc Networks

- *Dynamic topologies:* Network topology may change dynamically as the nodes are free to move.
- *Bandwidth-constrained, variable capacity links:* Realized throughput of wireless communication is less than the radio's maximum transmission rate. Collision occurs frequently.
- *Energy-constrained operation*: Some nodes in the ad hoc network may rely on batteries or other exhaustible means for their energy.
- *Limited physical security:* More prone to physical security threats than fixed cable networks.

Applications

- *Virtual navigation*: Data from a remote database is transmitted periodically in small relevant blocks using links present in the path of the automobile. This database may contain the graphical representation of streets, buildings, maps and the latest traffic information, which may be used by the driver to decide on a route.
- *Tele-medicine*: Conference assistance from a surgeon for an emergency intervention.
- *Tele-Geo processing*: Queries regarding location information of the users.
- *Crisis-management*: Natural disasters, where the entire communication infrastructure is in disarray.
- *Education via the internet*

Routing in MANETS - Goals

- Provide the maximum possible reliability - use alternative routes if an intermediate node fails.
- Choose a route with the least cost metric.
- Give the nodes the best possible response time and throughput.
- Route computation must be distributed. Centralized routing in a dynamic network is usually very expensive.
- Routing computation should not involve the maintenance of global state.
- Every node must have quick access to routes on demand.
- Each node must be only concerned about the routes to its destination.
- Broadcasts should be avoided (highly unreliable)
- It is desirable to have a backup route when the primary route has become stale.

Routing Classification

The existing routing protocols can be classified as,

- **Proactive**: when a packet needs to be forwarded, the route is already known.
- **Reactive**: Determine a route only when there is data to send.

Routing protocols may also be categorized as ,

- Table Driven protocols
- Source Initiated (on demand) protocols

Table Driven Routing Protocols

- Each node maintains routing information to all other nodes in the network
- When the topology changes, updates are propagated throughout the network.
- Examples are:
  - *Destination Sequenced Distance Vector routing (DSDV)*
  - *Cluster-head Gateway Switch routing (CGSR)*
  - *Wireless Routing Protocol (WRP)*

Destination Sequenced Distance Vector Routing (DSDV)

- Based on the Bellman-Ford algorithm.
- Each mobile node maintains a routing table in terms of number of hops to each destination.
- Routing table updates are periodically transmitted.
- Each entry in the table is marked by a sequence number which helps to distinguish stale routes from new ones, and thereby avoiding loops.
- To minimize the routing updates, variable sized update packets are used depending on the number of topological changes.

The Wireless Routing Protocol (WRP)

- Each node maintains 4 tables:
  -- Distance table
  -- Routing table
  -- Link cost table
  -- Message Retransmission List table (MRL)

  MRL contains the sequence number of the update message, a retransmission counter and a list of updates sent in the update message

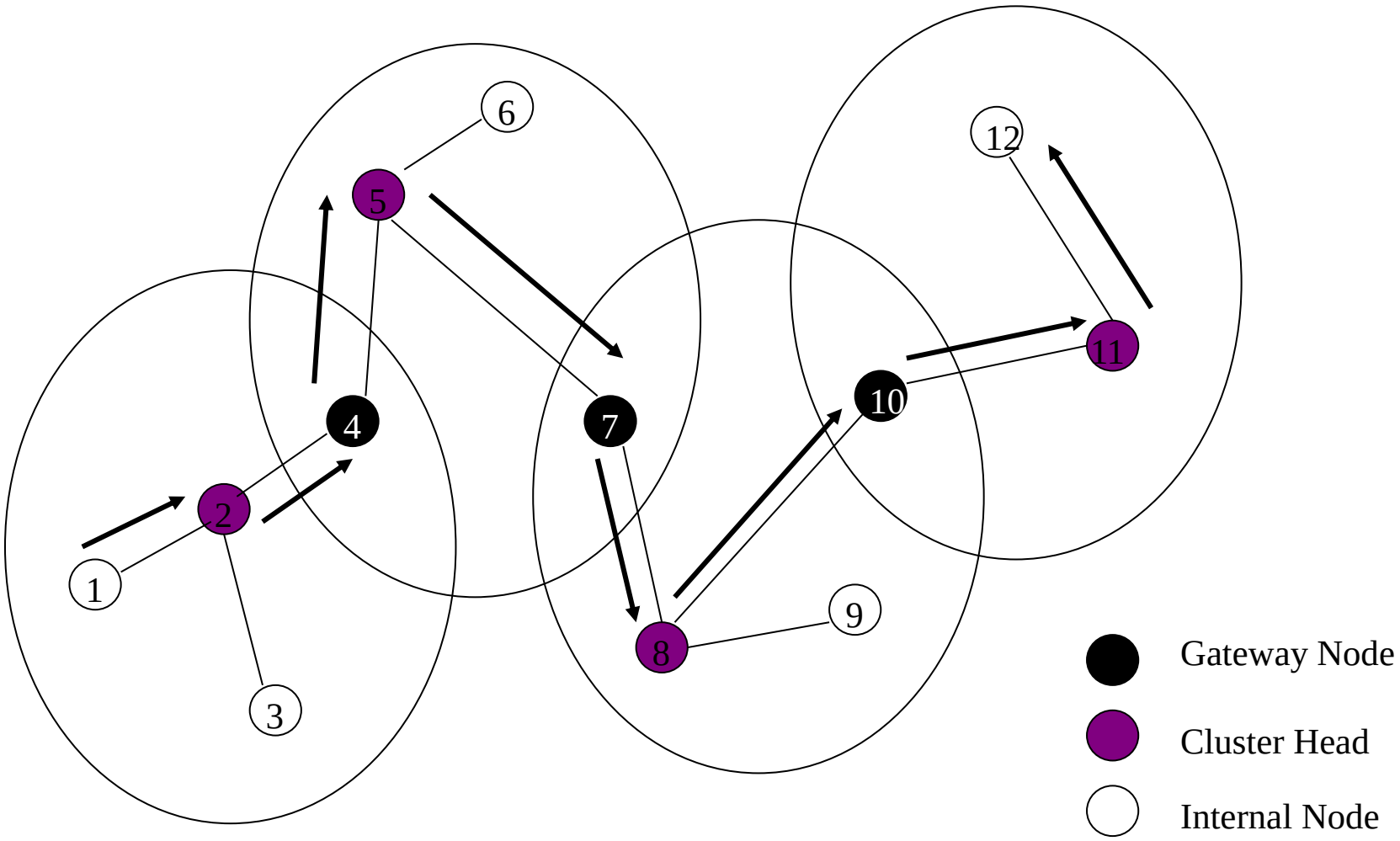
Wireless Routing Protocol (Cont'd)

- Nodes inform each other of link changes using update messages.
- Nodes send update messages after processing updates from their neighbors or after detecting a change in the link.
- If a node is not sending messages, it must send a HELLO message within a specified time to ensure connectivity.
- If the node receives a HELLO message from a new node, that node is added to the table.
- It avoids the "count to infinity" problem.

Cluster-head Gateway Switch Routing (CGSR)

- CGSR is a clustered multi-hop mobile wireless network with several heuristic routing schemes.
- A distributed cluster-head (CH) selection algorithm is used to elect a node as the cluster head.
- It modifies DSDV by using a hierarchical CH to route traffic.
- Gateway nodes serve as *bridge nodes* between two or more clusters.
- A packet sent by a node is first routed to its CH and then the packet is routed from the CH to a gateway of another cluster and then to the CH and so on, until the destination cluster head is reached.
- Frequent changes in the CH may affect the performance of the routing protocol.

CGSR (Cont'd)



Routing in CGSR from node 1 to node 8

Source Tree Adaptive Routing protocol

- Every node broadcasts its source-tree information
- The source tree of a node consists of the wireless links used by the node and in its preferred path to the destinations.
- Each node using its adjacent links and the source tree broadcast by its neighbours builds a partial graph of topology
- During initialization, a node sends an update message to its neighbours.

Source Tree Adaptive Routing protocol

- Each node is required to originate update messages about new destinations, the chances of routing loops and the cost of paths exceeding a given threshold
- The path would be sub optimal

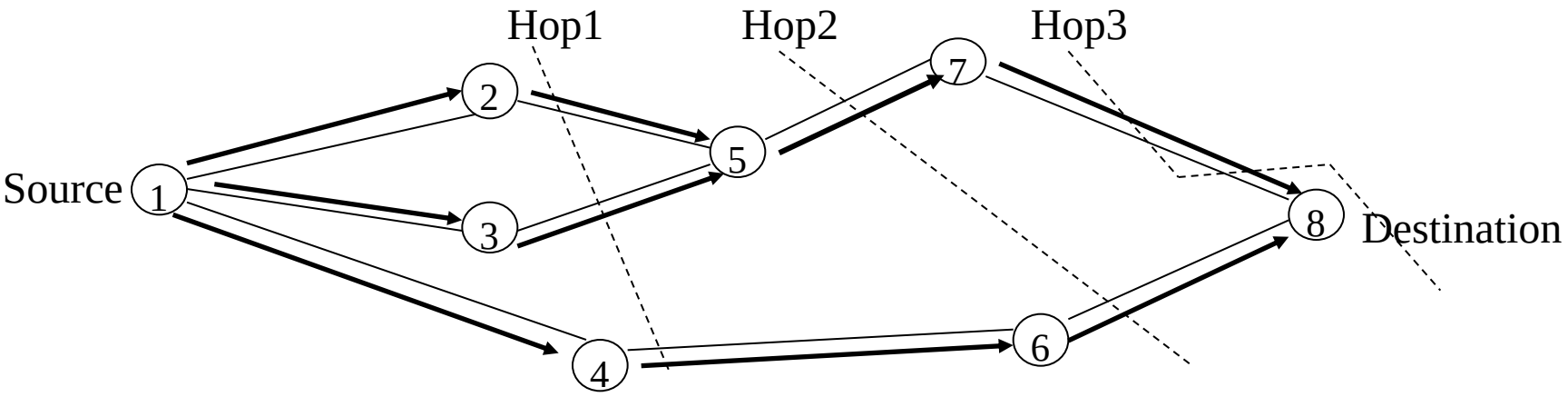
Source-Initiated On-Demand Routing

- Ad hoc On-Demand Distance Vector (AODV).
- Dynamic Source Routing (DSR)
- Temporary Ordered Routing Algorithm (TORA)
- Location aided Routing (LAR)
- Associativity Based Routing (ABR)
- Signal Stability Routing (SSR)
- Flow Oriented Routing Protocol (FOR)

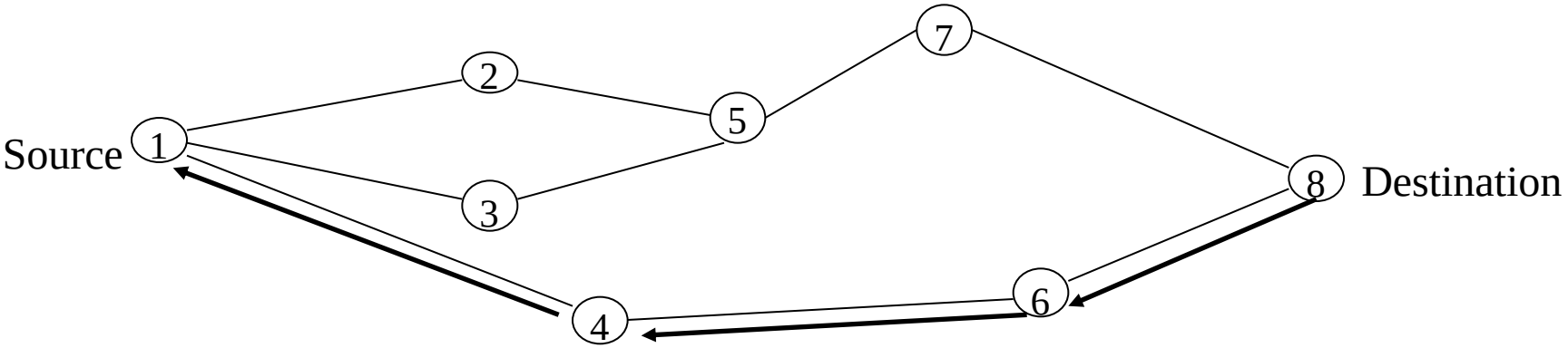
Ad hoc On-Demand Distance vector

- AODV is an improvement over DSDV, which minimizes the number of required broadcasts by creating routes on demand.
- Nodes that are not in a selected path do not maintain routing information or participate in routing table exchanges.
- A source node initiates a path discovery process to locate the other intermediate nodes (and the destination), by broadcasting a Route Request (RREQ) packet to its neighbors.

Route Discovery in AODV Protocol



(a) Propagation of Route Request (RREQ) Packet



(b) Path Taken by the Route Reply (RREP) Packet

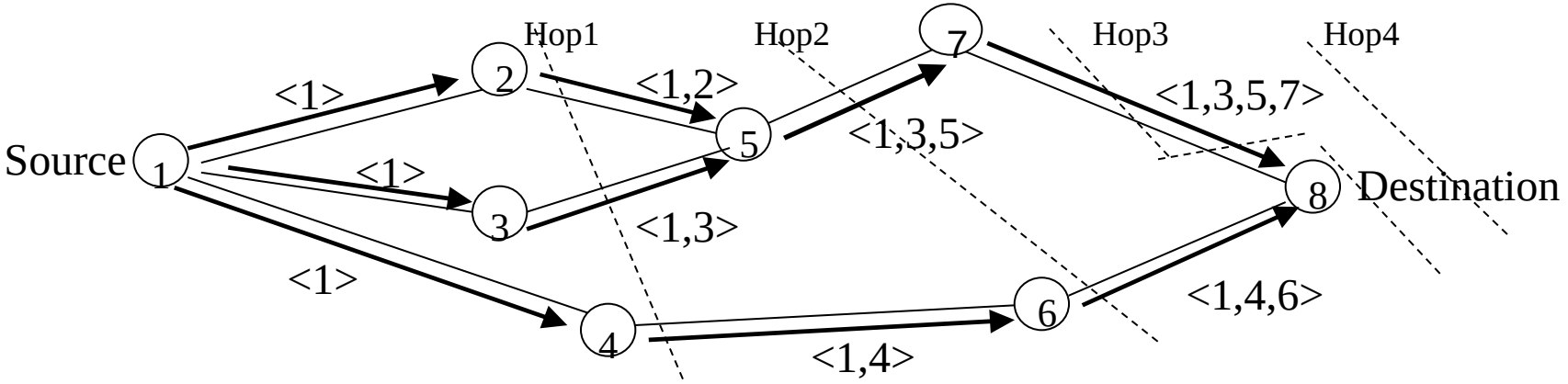
Dynamic Source Routing

- The protocol consists of two major phases: Route Discovery, Route Maintenance.
- When a mobile node has a packet to send to some destination, it first consults its route cache to check whether it has a route to that destination.
- If it is an un-expired route, it will use this route.
- If the node does not have a route, it initiates route discovery by broadcasting a Route Request packet.
- This Route Request contains the address of the destination, along with the source address.

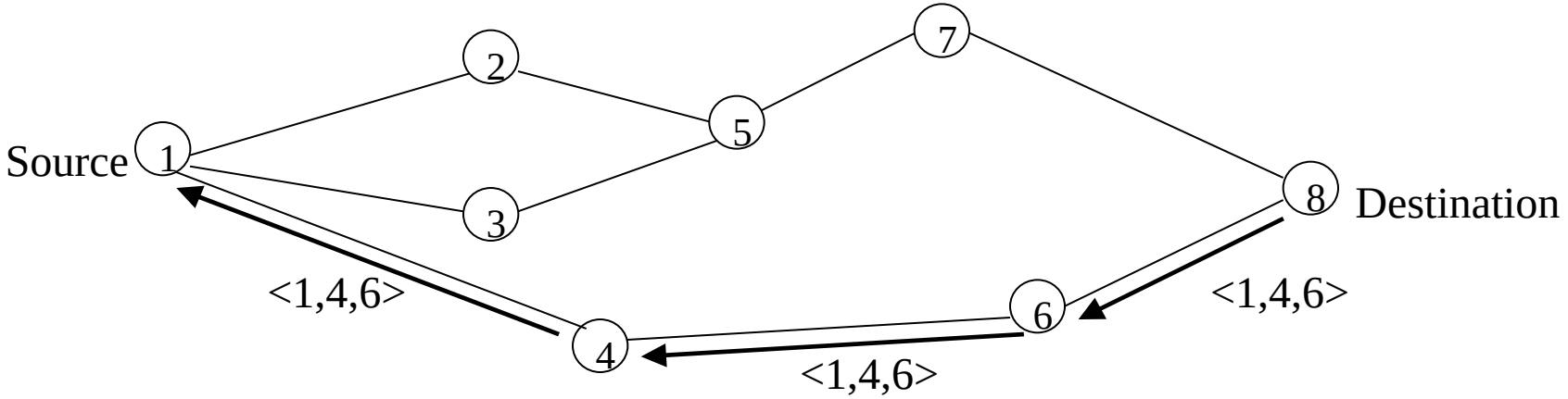
Dynamic Source Request (Cont'd)

- Each node receiving the packet checks to see whether it has a route to the destination. If it does not, it adds its own address to the route record of the packet and forwards it.
- A route reply is generated when the request reaches either the destination itself or an intermediate node that contains in its route cache an un-expired route to that destination.
- If the node generating the route reply is the destination, it places the the route record contained in the route request into the route reply.

Creation of Route Record in DSR



(a) Building Record Route During Route Discovery



(b) Propagation of Route Reply with the Route Record

Temporarily Ordered Routing Algorithm (TORA)

- TORA is a highly adaptive loop-free distributed routing algorithm based on the concept of link reversal.
- TORA decouples the generation of potentially far-reaching control messages from the rate of topological changes.
- The height metric is used to model the routing state of the network.

TORA (Cont'd)

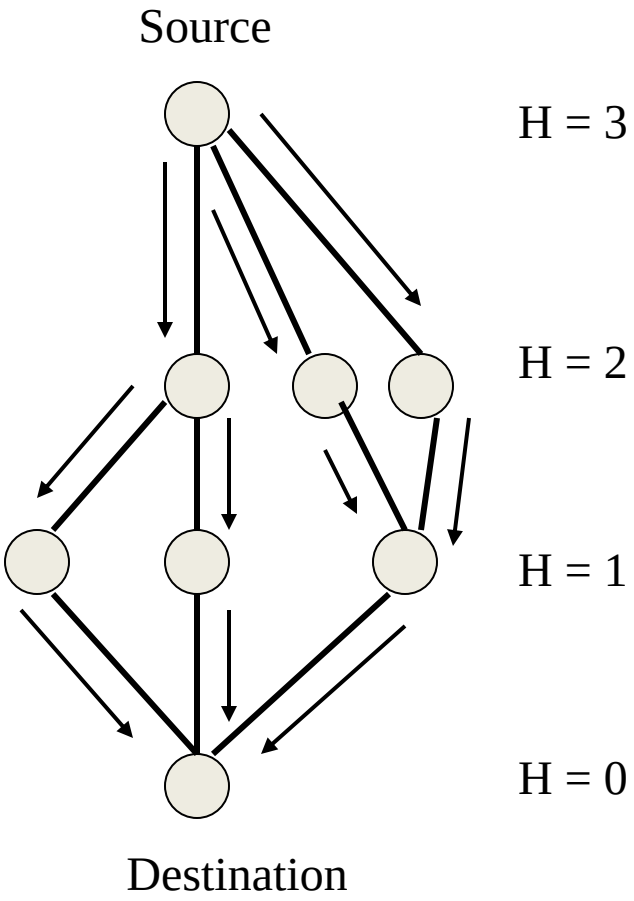


Illustration of Tora height metric

TORA (Cont'd)

- The protocol performs three basic functions: route creation, route maintenance, route erasure.
- During the route creation and maintenance phases nodes use a height metric to establish a Directed Acyclic Graph (DAG) rooted at the destination.
- Thereafter links are assigned a direction based on the relative heights

TORA (Cont'd)

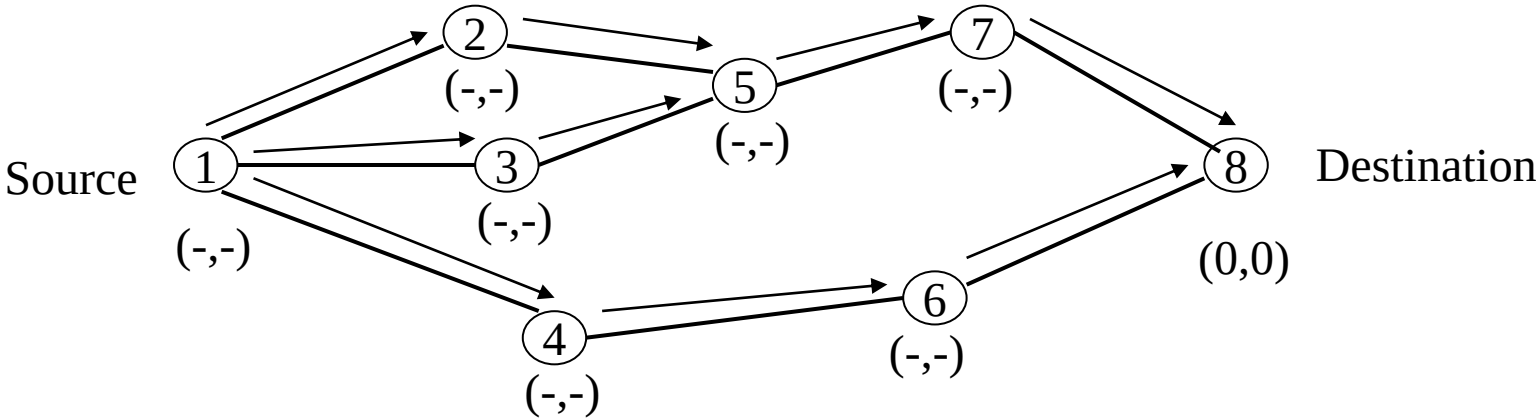
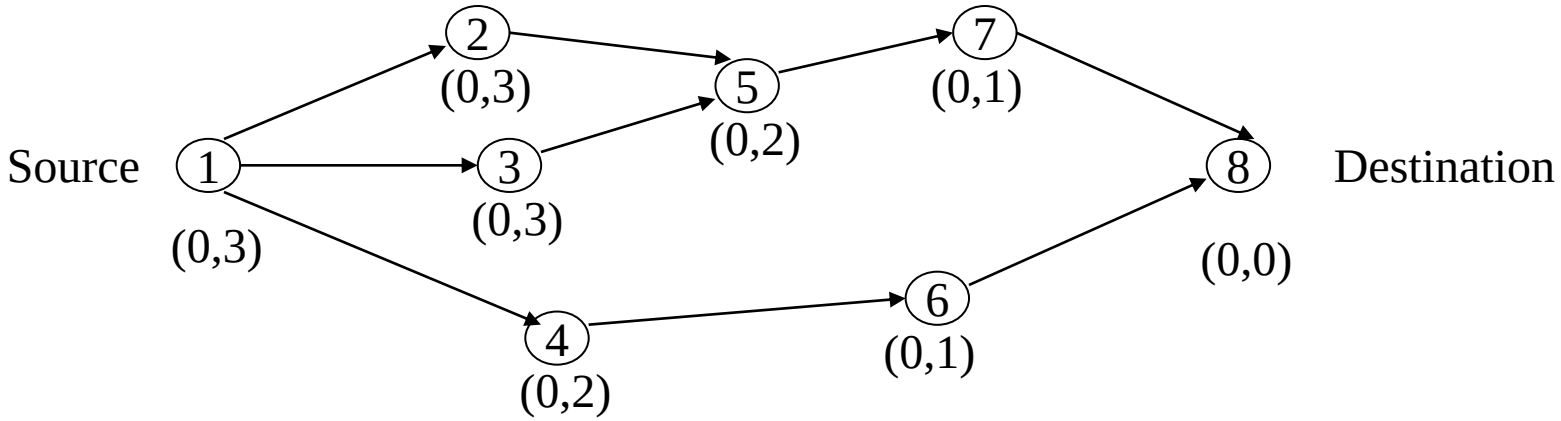


Figure 13.6(a) – Propagation of the query message

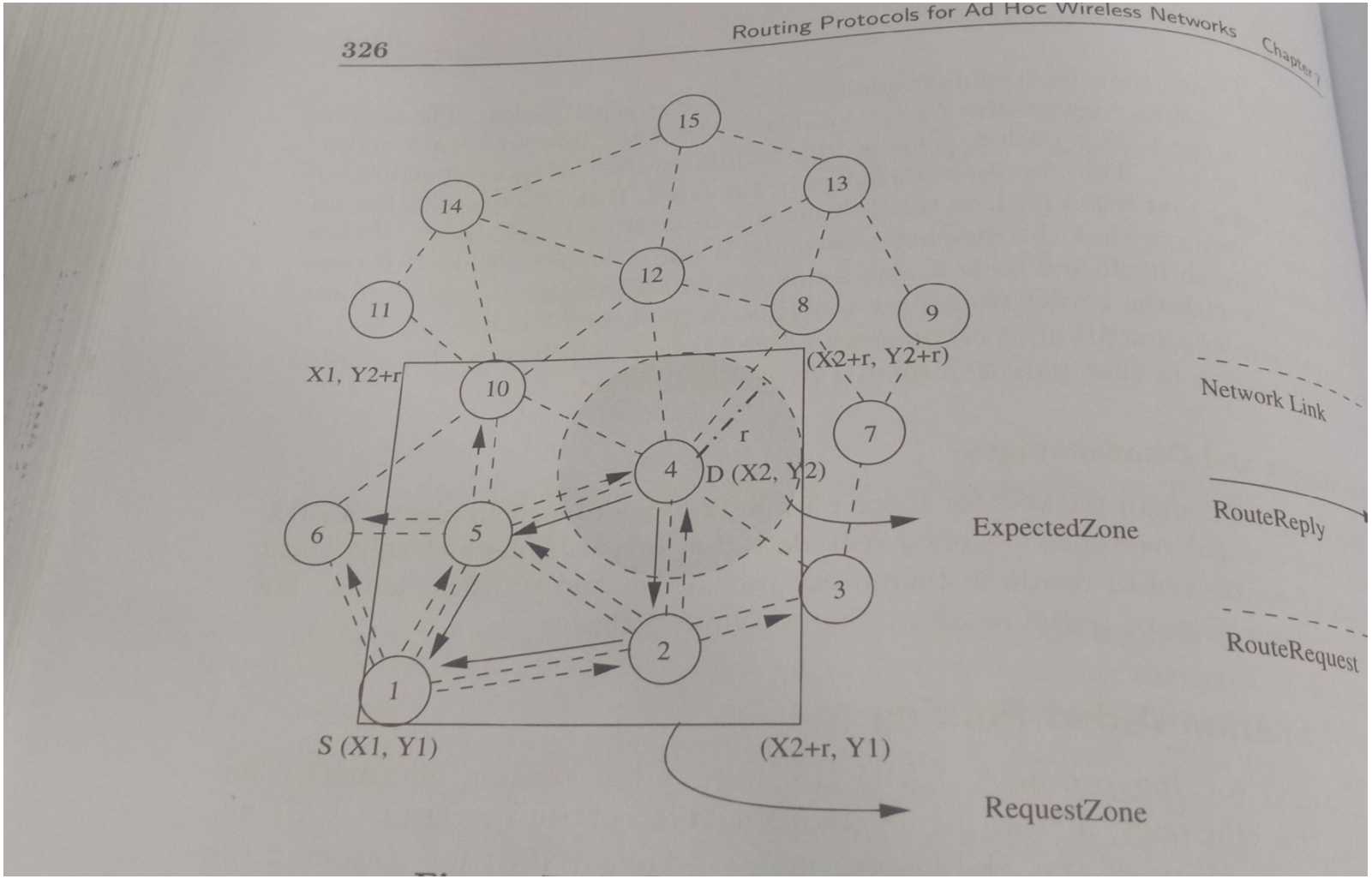


Node's height updated as a result of the update message

Location Aided Routing

- Utilizes the location information for improving the efficiency of routing by reducing the control overhead.
- Presence of GPS for obtaining the location information
- Expected Zone: Region in which the destination node is expected to be present, when its past location information and its mobility information is available
- Request Zone: Geographical region within which the path finding control packets are permitted to be propagated.
- Path finding control packets are forwarded by nodes present in Request zone and discarded by nodes outside the zone

Location Aided Routing



Location Aided Routing

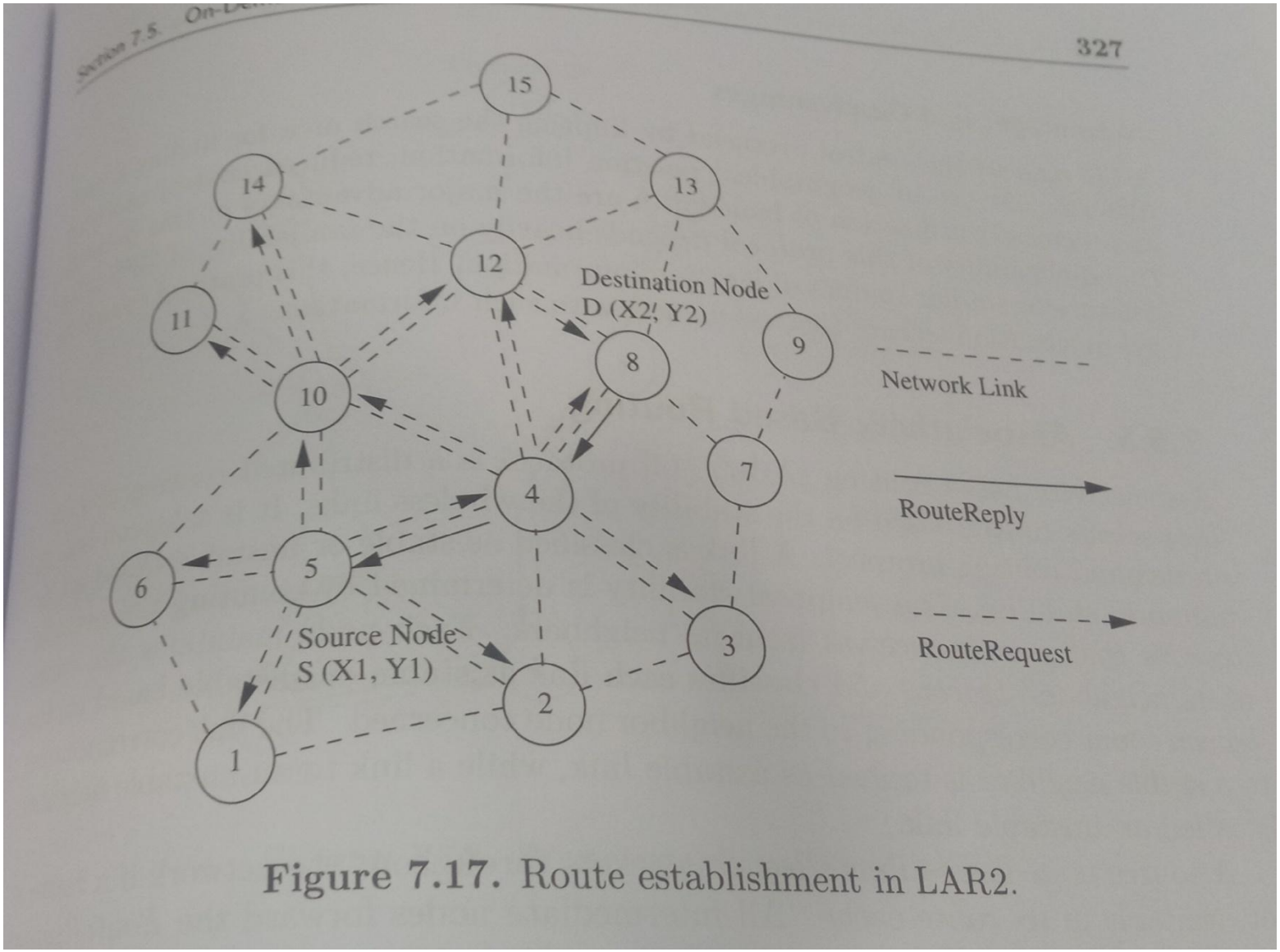


Figure 7.17. Route establishment in LAR2.

Associativity Based Routing (ABR)

- The three phases of ABR are: route discovery, route reconstruction, route deletion.
- In ABR a route is selected based on the degree of stability associated with mobile nodes.
- Association stability is defined by connection stability of one node with respect to another node over time and space.
- Each node generates a beacon to signify its existence.
- When received by neighboring nodes, the beacon causes their associativity tables to be updated.
- The route discovery is accomplished by a Broadcast Query- Reply (BQ-REPLY) cycle.
- When a discovered route is no longer desired, the source node initiates a Route Delete broadcast so that all the nodes along the route update their routing tables.

Associativity Based Routing (ABR)

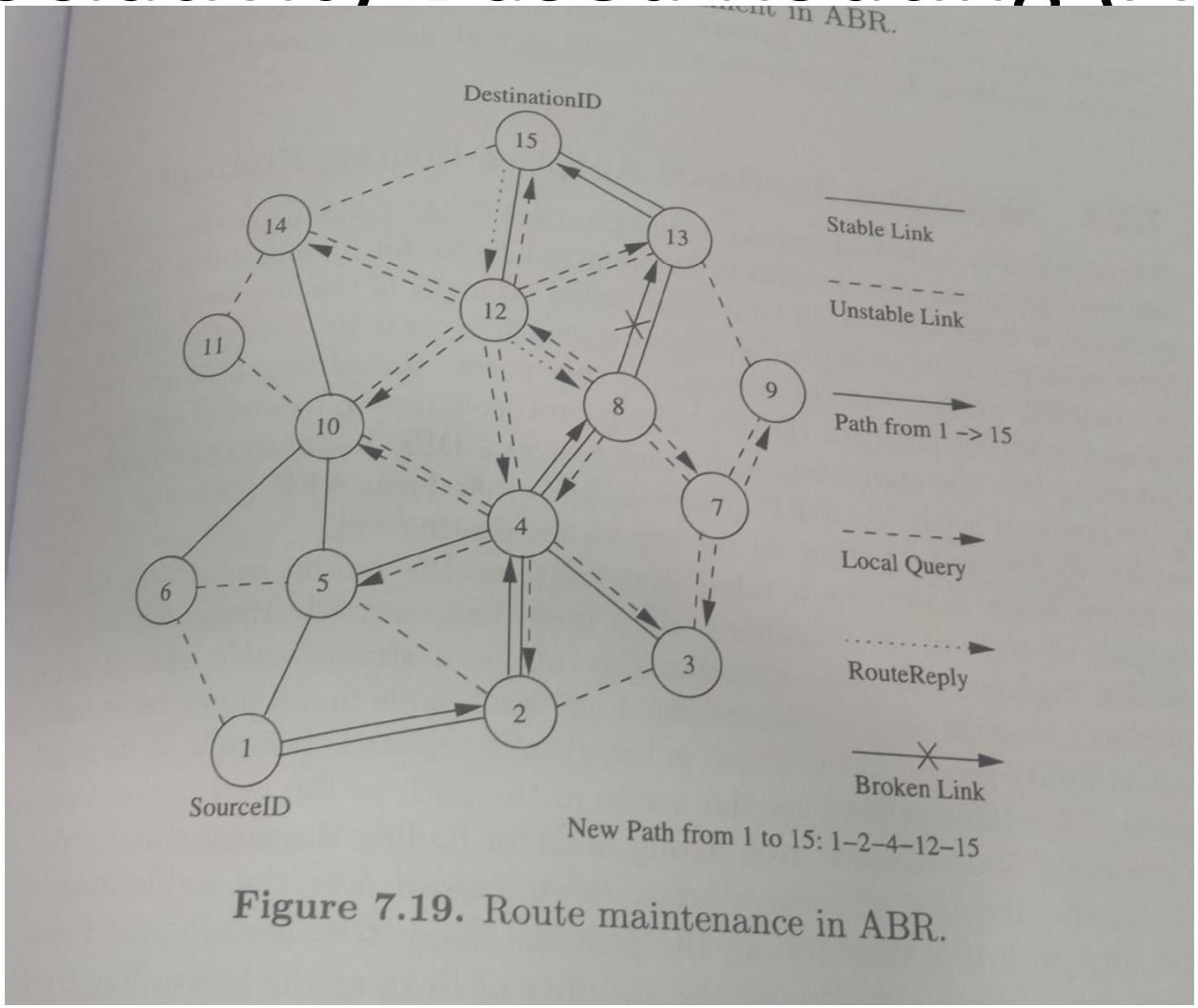


Figure 7.19. Route maintenance in ABR.

Signal Stability Routing (SSR)

- SSR selects a route based on the signal strength between nodes and a node's location stability.
- This route selection criteria has the effect of choosing routes that have a better link connectivity.

Hybrid protocols

- **Zone Routing Protocol** (ZRP): a node proactively maintains routes to destinations within a local neighborhood. The construction of a routing zone requires a node to first know who its neighbor, which is implemented through a MAC layer Neighbor Discovery Protocol.
- **Fisheye State Routing** (FSR): There are multi-level fisheye scopes to reduce routing update overhead in large networks. It helps to make a routing protocol scalable by gathering data on the topology, which may be needed soon.
- **Landmark Routing** (LANMAR): Uses a landmark to keep track of a logical subnet. The LANMAR routing table includes only those nodes within the scope and the landmark nodes themselves.

Hybrid protocols (Cont'd)

- **Distance Routing Effect Algorithm for Mobility** (DREAM) : It is based on the distance effect and a node's mobility rate. Each node can optimize the frequency at which it sends updates to the networks and correspondingly reduce the bandwidth and energy used.
- **Relative Distance Micro-discovery Ad Hoc Routing** (RDMAR): This is based on the calculated relative distance between two terminals. The query flood is localized to a limited region centered at the source node.
- **Power Aware Routing**: power-aware metrics are used for determining routes. It reduces the cost, ensures that the mean time to node failure is increased, without any further delay in packet delivery.

Protocol Characteristics (1/2)

Routing Protocol	Route Acquisition	Flood for Route Discovery	Delay for Route Discovery	Multipath Capability	Effect of Route Failure
DSDV	Computed a priori	No	No	No	Updates the routing tables of all nodes
WRP	Computed a priori	No	No	No	Ultimately, updates the routing tables of all nodes by exchanging MRL between neighbors
DSR	On-demand, only when needed	Yes. Aggressive use of caching may reduce flood	Yes	Not explicitly. The technique of salvaging may quickly restore a route	Route error propagated up to the source to erase invalid path

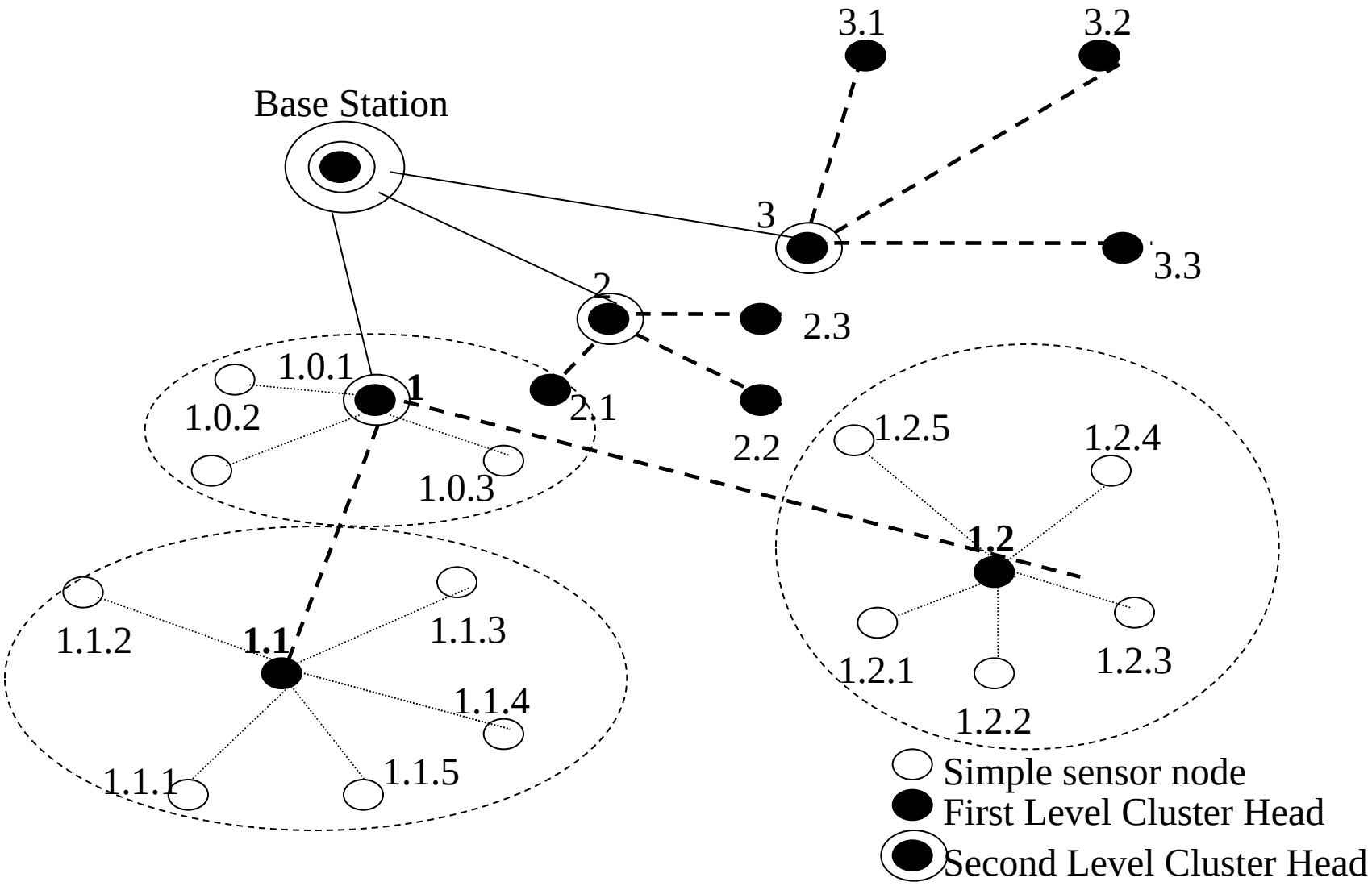
Protocol Characteristics (2/2)

Routing Protocol	Route Acquisition	Flood for Route Discovery	Delay for Route Discovery	Multipath Capability	Effect of Route Failure
AODV	On-demand, only when needed	Yes. Controlled use of cache to reduce flood	Yes	No, although recent research indicate viability	Route error propagated up to the source to erase invalid path
TORA	On-demand, only when needed	Basically one for initial route discovery	Yes. Once the DAG is constructed, multiple paths are found	Yes	Error is recovered locally
LAR	On-demand, only when needed	Reduced by using location information	Yes	No	Route error propagated up to the source
ZRP	Hybrid	Only outside a source's zone	Only if the destination is outside the source's zone	No	Hybrid of updating nodes' tables within a zone and propagating route error to the source

Hierarchical Routing in ad hoc Networks

- Hierarchical clustering schemes are the most suitable for wireless sensor networks.
- The network consists of a Base Station (BS), away from the nodes, through which the end user can access data from the sensor network.
- BS can transmit with high power.
- Nodes cannot reply directly to the BS due to their low power constraints, resulting in asymmetric communication.

Hierarchical Routing (Cont'd)



Cluster Based Routing Protocol

Cluster Based Routing Protocol (CBRP)

- Here the cluster members just send the data to the cluster head (CH).
- The CH routes the data to the destination.
- Not suitable for a highly mobile environment, as a lot of HELLO messages are sent to maintain the cluster.

Fisheye State Routing Protocol

- Fisheye state routing protocol is implemented based on link state routing protocol and global state routing protocol.
- The FSR protocol is the descendent of GSR.
- FSR reduces the size of the update messages in GSR by updating the network information for nearby nodes at a higher frequency than for the remote nodes, which lie outside the fisheye scope.

Fisheye State Routing Protocol

- This makes FSR more scalable to large networks
- Scalability comes at the price of reduced accuracy.
- This is because as mobility increases the routes to remote destination become less accurate.
- This can be overcome by increasing the frequency at which updates are sent to remote destinations proportional to the level of mobility.

Power aware/energy aware routing

- Power aware routing metrics are used for routing
- Minimum Energy Consumption per packet
- Maximize network connectivity
- Minimum variance in Node power levels
- Minimum cost per packet
- Minimize Maximum node cost