CS6504

Mobile Computing

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Routing Protocols in MANETs – Part II

Outline

- Routing Protocols for Ad hoc Networks
  - DSDV: *Highly Dynamic Destination-Sequenced Distance-Vector Routing*

Introduction

- An example of *table-driven* routing protocols
- Maintain consistent up-to-date routing information from each node to every other node in the network
- Respond to changes in network topology by propagating updates throughout the network
- Based on *classical Bellman-Ford* algorithm (distance vector routing) but with enhancements to ensure freedom from loops in routing tables

Distance Vector Routing

Distance-Vector In distance-vector algorithms, every node i maintains, for each destination x, a set of distances $\{d_{ij}^x\}$ where j ranges over the neighbors of i. Node i treats neighbor k as a next-hop for a packet destined for x if d_{ik}^x equals $min_j\{d_{ij}^x\}$. The succession of next hops chosen in this manner lead to x along the shortest path. In order to keep the distance estimates up-to-date, each node monitors the cost of its outgoing links and periodically broadcasts, to each one its neighbors, its current estimate of the shortest distance to every other node in the network.

Basic Mechanisms 1/5

•Each node stores a routing table which lists all available destinations, and the number of hops to each

•Each route table entry is tagged with a *sequence number* (originated by destination station)

•Each station periodically transmits updates, and immediately when significant new information is available

•Data is maintained about the length of time between arrival of the *first* and the arrival of the *best* route for each particular destination

- ➢A decision is made to delay advertising routes which are about to change soon in order to damp fluctuations of the routing table
- ➢Delay advertisement of routes which may not have stabilized yet

Basic Mechanisms 2/5

•Data broadcast by each node contains its new sequence number *and for each new route*

- Destination address
- Number of hops required to reach the destination
- Sequence number of the information received regarding that destination (as originally stamped by the destination)

•Routes received in broadcasts are advertised by the receiver when subsequently broadcasting its routing information

- The receiver *adds an increment to the metric* before advertising its routes

•When any new or substantially modified route is received, retransmit as soon as possible (subject to damping for route fluctuations)

Basic Mechanisms 3/5

- When a link is broken (might be detected by a layer 2 protocol), describe by a metric of ∞, and assign an updated sequence number
  - ➢Sequence numbers originally generated by nodes are even numbers
  - ➢Metric indicating ∞ is an odd number (real sequence # supersedes ∞)
  - ➢What happens when a node receives a later sequence number with a finite metric (for an ∞ metric)?
- Types of routing information packets
  - Full dump
    - ❑All available routing information
    - ❑Infrequent when no movement is occurring
  - Incremental
    - ❑Only information changed since the last full dump

Basic Mechanisms 4/5

- When new routing information is received
  - Compare to available information
  - Any route with a more recent sequence number is used
  - Routes with older sequence number are discarded
  - A route with a sequence number equal to an existing route is chosen if has a better metric
  - Metrics for chosen routes are incremented by one hop
  - Newly recorded routes scheduled for immediate advertisement
  - Routes showing an improved metric are scheduled for advertisement at a later time depending on the *average settling times* for routes for the particular destination

Basic Mechanisms 5/5

•A node can receive 2 routes to the same destination with a newer sequence number, one after the other (via neighbors) but get the route with the worse metric first (What are the consequences?)

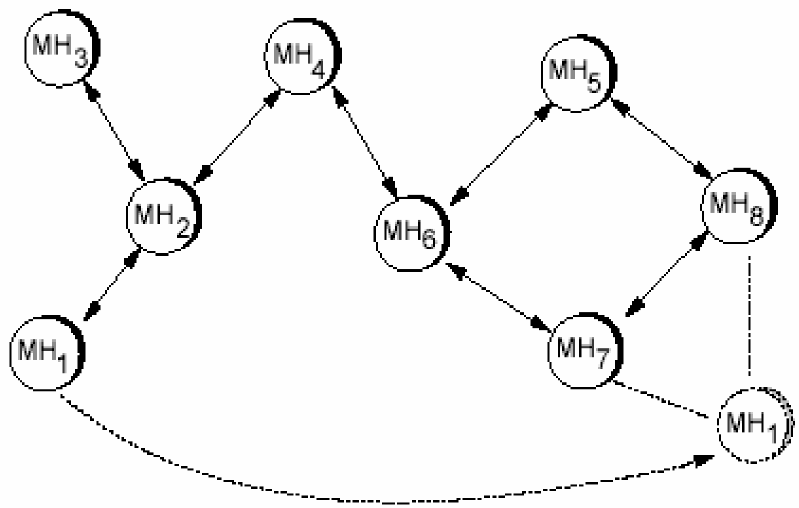
•Solution

- ➢Delay advertisement of route when can determine that a route with a better metric is likely to show up soon
- ➢The route with a later sequence number must be available for use, but does not have to be advertised immediately (unless route to a destination that was previously unreachable)

•Maintain two routing tables

- ➢One for use with forwarding packets
- ➢One advertised via incremental routing information packets
- ➢A node keeps a history of *weighted average time* that routes to a destination fluctuate until the route with the best metric is used (*settling time*)

Examples 1/2



Destination	Metric	Sequence number
MH_1	2	S406_MH_1
MH_2	1	S128_MH_2
MH_3	2	S564_MH_3
MH_4	0	S710_MH_4
MH_5	2	S392_MH_5
MH_6	1	S076_MH_6
MH_7	2	S128_MH_7
MH_8	3	S050_MH_8

Table 2: Advertised route table by MH_4

Destination	NextHop	Metric	Sequence number	Install	Flags	Stable_data
MH_1	MH_2	2	S406_MH_1	T001_MH_4		Ptr1_MH_1
MH_2	MH_2	1	S128_MH_2	T001_MH_4		Ptr1_MH_2
MH_3	MH_2	2	S564_MH_3	T001_MH_4		Ptr1_MH_3
MH_4	MH_4	0	S710_MH_4	T001_MH_4		Ptr1_MH_4
MH_5	MH_6	2	S392_MH_5	T002_MH_4		Ptr1_MH_5
MH_6	MH_6	1	S076_MH_6	T001_MH_4		Ptr1_MH_6
MH_7	MH_6	2	S128_MH_7	T002_MH_4		Ptr1_MH_7
MH_8	MH_6	3	S050_MH_8	T002_MH_4		Ptr1_MH_8

Table 1: Structure of the MH_4 forwarding table

Examples 2/2

- MH_1 moves into vicinity of MH_5 and MH_7

Destination	NextHop	Metric	Sequence number	Install	Flags	Stable_data
MH_1	MH_6	3	S516_MH_1	T810_MH_4	M	Ptr1_MH_1
MH_2	MH_2	1	S238_MH_2	T001_MH_4		Ptr1_MH_2
MH_3	MH_2	2	S674_MH_3	T001_MH_4		Ptr1_MH_3
MH_4	MH_4	0	S820_MH_4	T001_MH_4		Ptr1_MH_4
MH_5	MH_6	2	S502_MH_5	T002_MH_4		Ptr1_MH_5
MH_6	MH_6	1	S186_MH_6	T001_MH_4		Ptr1_MH_6
MH_7	MH_6	2	S238_MH_7	T002_MH_4		Ptr1_MH_7
MH_8	MH_6	3	S160_MH_8	T002_MH_4		Ptr1_MH_8

Table 3: MH_4 forwarding table (updated)

Destination	Metric	Sequence number
MH_4	0	S820_MH_4
MH_1	3	S516_MH_1
MH_2	1	S238_MH_2
MH_3	2	S674_MH_3
MH_5	2	S502_MH_5
MH_6	1	S186_MH_6
MH_7	2	S238_MH_7
MH_8	3	S160_MH_8

Table 4: MH_4 advertised table (updated)

Outline

- Routing Protocols for Ad hoc Networks
- ZRP: *Zone Routing Protocol*

ZRP 1/2

- Proactive Routing
  - ➢Delay before sending a packet is minimal
  - ➢Uses excess bandwidth to maintain routing information
  - ➢Due to mobility, the route updates may be more frequent than route requests
- Reactive Routing
  - ➢Considerable delay in determining route if such information not available in routing tables (long route request delay)
  - ➢May involve significant control traffic due to flooding
- ZRP (a hybrid reactive/proactive routing protocol)
  - ➢Address the problems by combining the best properties of both approaches

ZRP 2/2

- Basic Idea
  - ➢In an ad hoc network, it is assumed largest part of traffic is directed to nearby nodes
  - ➢Reduce proactive scope to a zone centered on each zone (note that zones of neighboring nodes will overlap)
  - ➢Nodes farther away can be reached with reactive routing
  - ➢Categorized as a *flat protocol* (zones overlap, no hierarchical structure)

Architecture 1/4

•Routing zone has a radius ρ expressed in hops

➢The zone includes the nodes whose distance from the node in question is at most ρ hops

ρ = 1?

ρ → ∞?

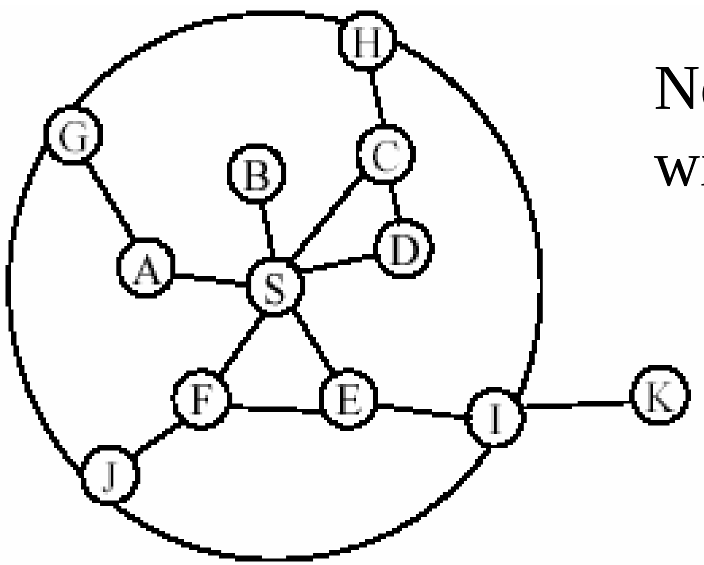


Figure 1: Example routing zone with ρ=2

Node S routing zone with radius = 2

Architecture 2/4

- Nodes of a zone
  - *Peripheral nodes*: Nodes whose minimum distance to central node is exactly = radius (nodes G, J, I, and H)
  - *Interior nodes*: Nodes whose minimum distance less than radius (nodes A and F for example)
  - Can adjust number of nodes in a zones by adjusting transmission power
- IARP: IntrA-zone Routing Protocol (local proactive routing component)
- IERP: IntEr-zone Routing Protocol (global reactive routing component)

Architecture 3/4

- When global route discovery is needed
  - ➢Instead of broadcasting packets, use a *bordercasting* concept
  - ➢Use topology information provided by IARP to direct query request to border of zone
  - ➢Bordercast packet delivery service provided by Bordercast Resolution Protocol (BRP)
    - ✓Uses a map of an extended routing zone to construct bordercast trees for query packets
    - ✓Use source routing based on normal routing zone
    - ✓Employ query control mechanisms to direct route requests away from areas of the network that have already been covered

Architecture 4/4

•To detect new neighbors and link failures rely on a *Neighbor discovery protocol* (NDP) provided by MAC layer

- ➢Transmits HELLO beacons at regular intervals
- ➢If MAC layer does not include a NDP, functionality provided by IARP

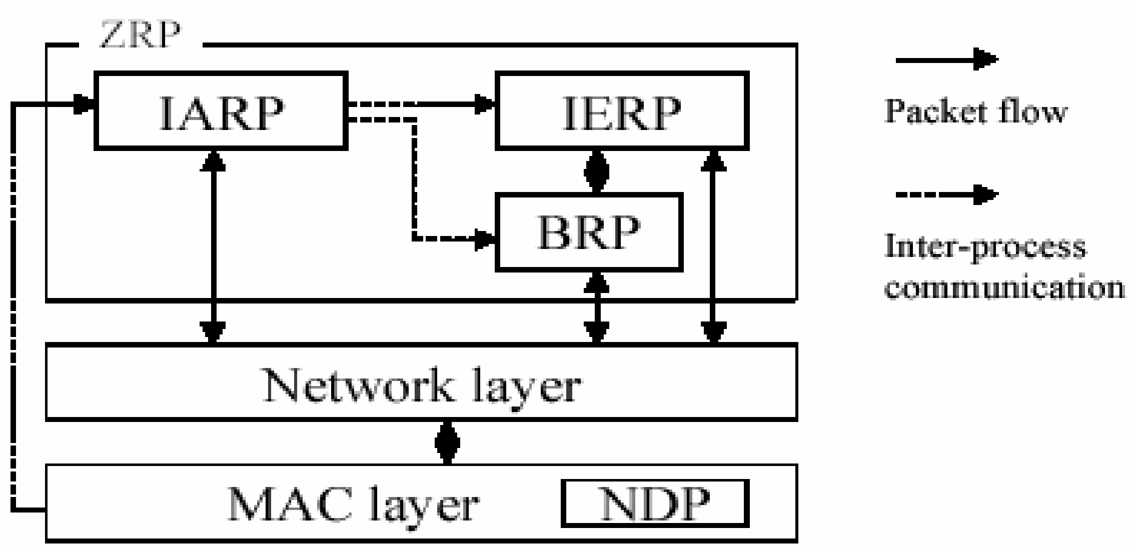


Figure 2: ZRP architecture

Routing 1/4

- When a node has a packet to send
  - ➢Check whether destination is within local zone using routing information provided by IARP (if so, route proactively)
  - ➢If not, reactive routing is used (destination outside zone)
  - ➢Route request phase/ Route reply phase
    - ❑Source sends a route request packet to its peripheral nodes using BRP
    - ❑If receiver knows a route to destination, respond by sending a route reply back to source
    - ❑If not, continue by bordercasting packet
    - ❑If a node receives several copies of same route request packet, discard

Routing 2/4

- How route reply makes it back to source?
- First approach
    - ➢Routing information recorded in route request packet
    - ➢Nodes forwarding a request append their address and relevant node/link metric to packet
    - ➢When packet reaches destination, sequence of addresses is reversed and copied to route reply packet
    - ➢Source will receive complete source route to destination
- Second approach
    - ➢Forwarding nodes record routing information as next-hop addresses (build reverse route to source)

Routing 3/4

- How *bordercasting* is performed?
  - ➢One-to-many transmission, implemented as multicast
- Option1 → Root-directed bordercasting (RDB)
  - ➢Source computes multicast tree and attaches routing instructions to the packets (Disadvantage?)
- Option 2 → Distributed bordercasting (DB)
  - ➢Reconstruct tree at each node
  - ➢Every interior nodes needs to know the topology as seen by the bordercasting node
  - ➢Interior nodes maintain an extended routing zone with radius 2ρ -1
    - ✓An interior node can be up to ρ -1 hops from root
    - ✓In order to construct bordercast tree, need to proactively track topology of $\rho+(\rho-1) = 2\rho-1$ hops

Routing 4/4

Comparison between RDB and DB

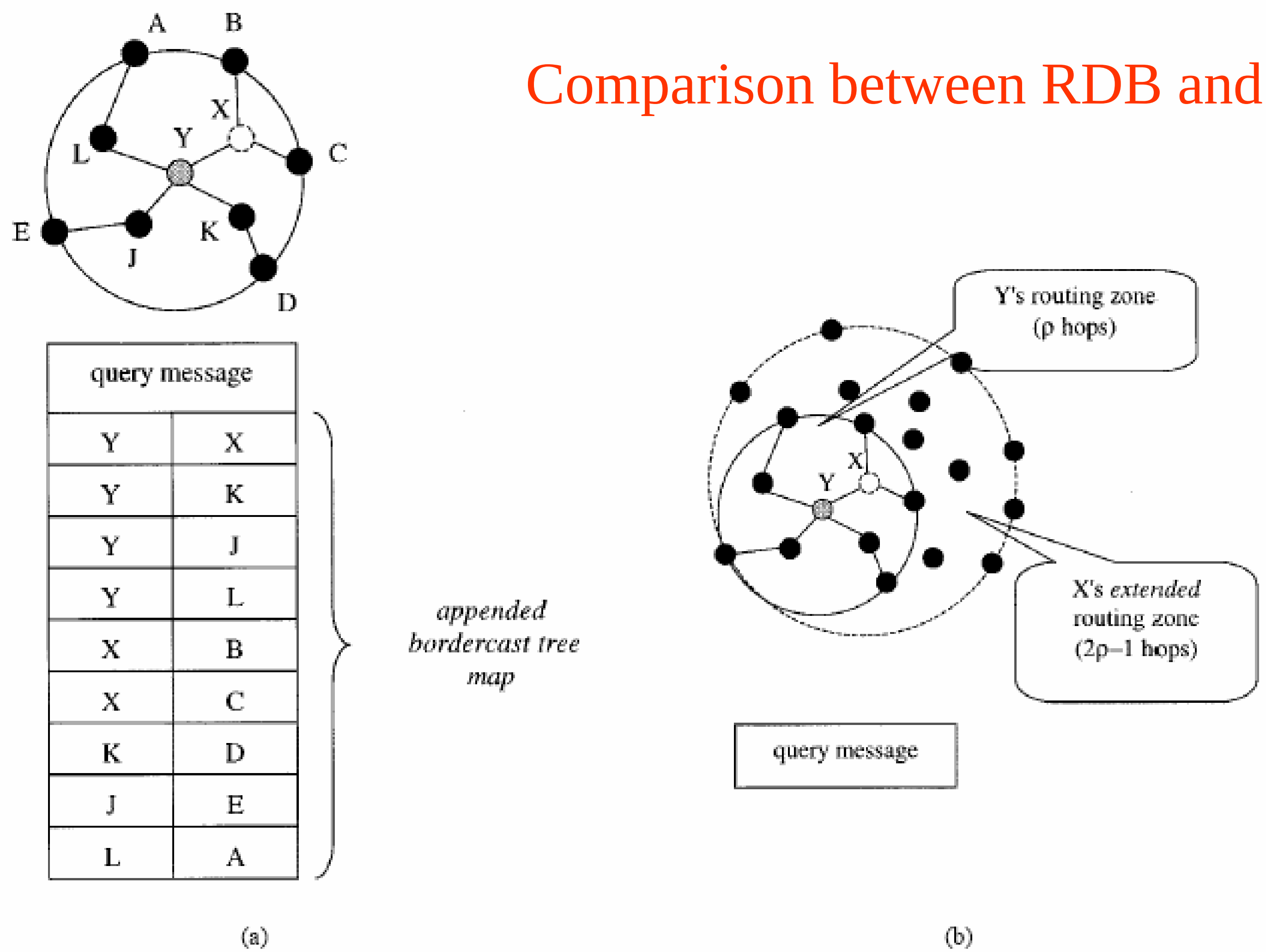


Fig. 3. (a) RDB. (b) DB.

Example 1/2

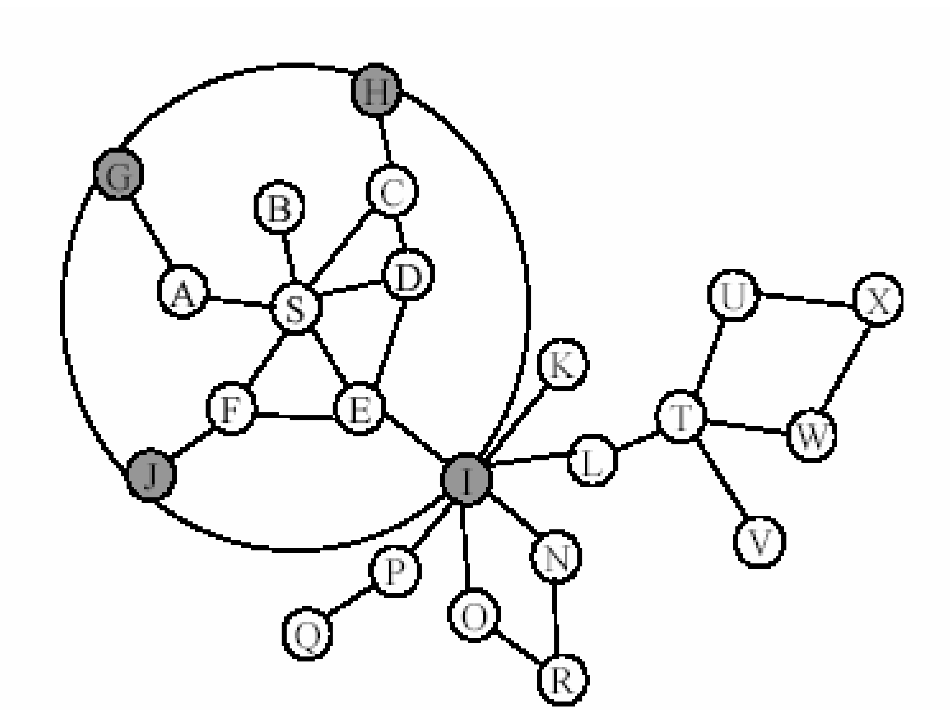


Figure 3: The routing zone of node S

Node S has a packet to send to X

Zone radius = 2

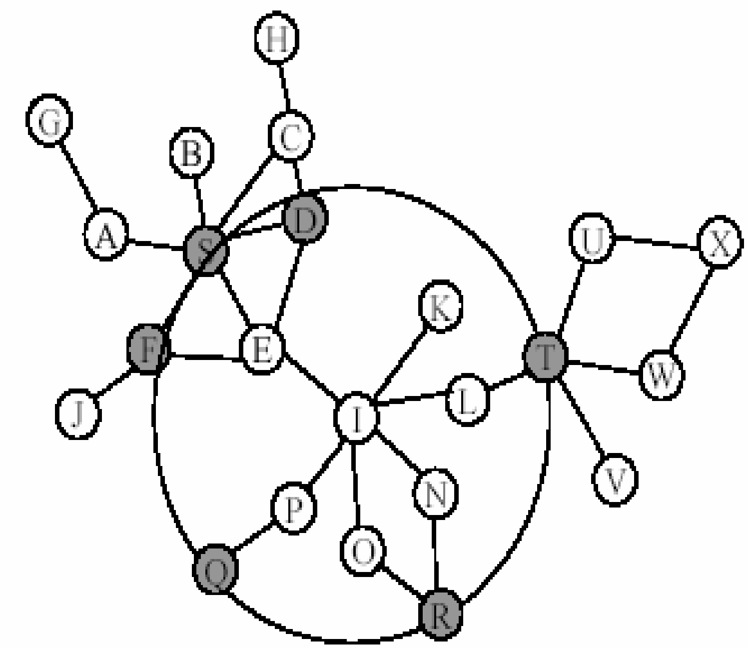


Figure 4: The routing zone of node I

Due to query control mechanisms, query not sent back to D, S, and F

Example 2/2

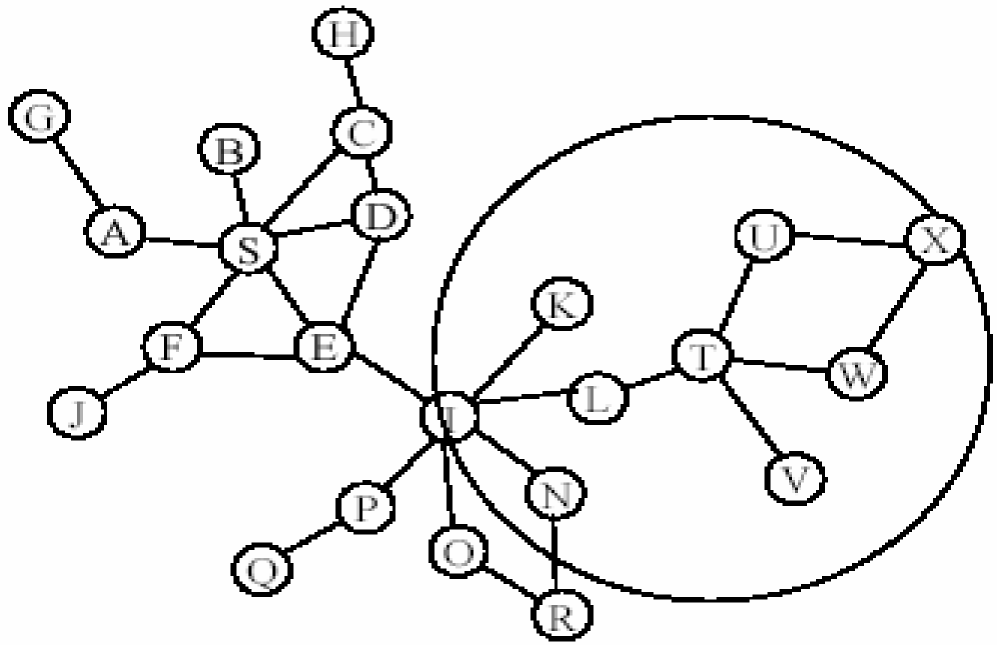


Figure 5: The routing zone of node T

- Node T can find destination in its routing zone
- Append path from itself to X to the path in route request and generate a route reply

Query Control Mechanisms 1/6

- Routing zones of neighboring nodes overlap
- Each node may forward route requests several times (more traffic than in flooding)
- Excess traffic is a result from queries returning to covered zones instead of covered nodes as in traditional flooding
- Query control mechanisms are needed to direct queries away from covered zones, and terminate query packets before they are delivered to peripheral nodes in regions already covered by the query
  - Query detection
  - Early termination
  - Random query-processing delay

Query Control Mechanisms 2/6

•Query detection

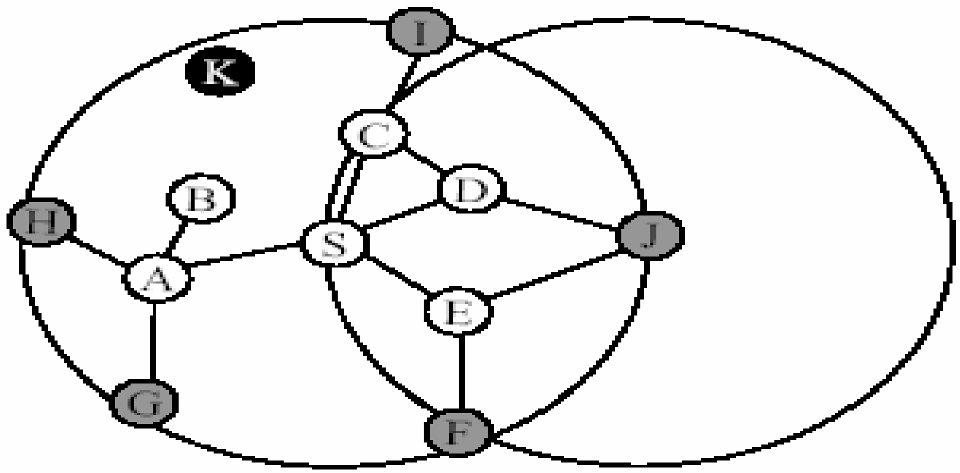


Figure 6: Query detection example

•S bordercasts to F-J (query relayed by nodes D and E)

•Node J continues bordercasting to nodes C, S, and F (peripheral nodes in J's routing zone)

•Query again relayed by nodes D and E and is redundant

Query Control Mechanisms 3/6

- Query detection (use a query detection table)
- QD1 (bordercast relay)
  - Nodes that relay the query are able to detect the query
- QD2 (eavesdropping)
  - Possible to listen to traffic by other nodes within radio coverage (promiscuous mode)

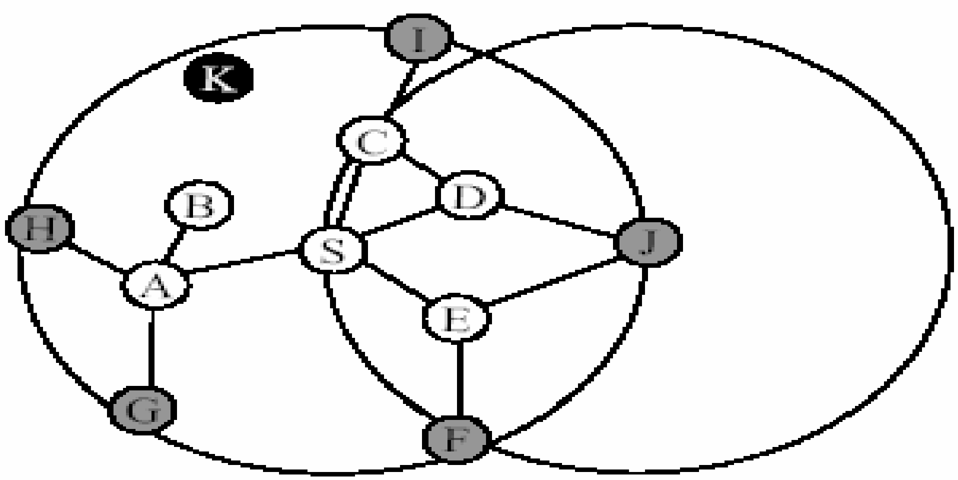


Figure 6: Query detection example

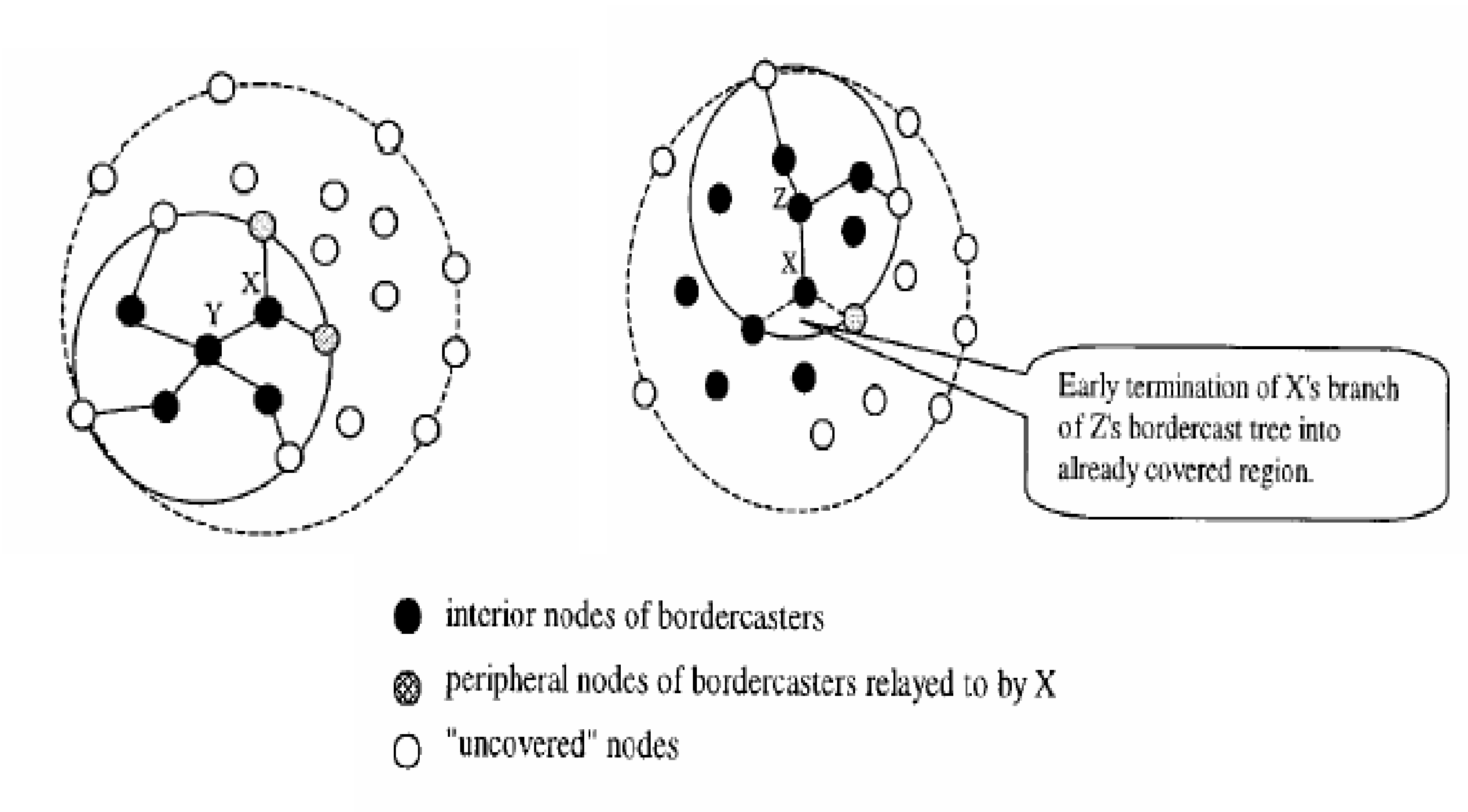
- All nodes except node B relay S's query (use QD1)
- Node B overhears the relayed query and can use QD2
- Node K does not overhear the query and is unaware that S's zone is covered

Query Control Mechanisms 4/6

- Early Termination
- Prevent a route request from entering already covered regions
- Combine information obtained through query detection with the local topology knowledge to
  - prune branches (interior nodes) leading to peripheral nodes inside covered regions
  - Prune peripheral nodes if have already relayed a query to that node
- Local topology knowledge consists of
  - Extended routing zone in case of DB
  - Standard routing zone and cached bordercast trees in RDB

Query Control Mechanisms 5/6

- Early Termination



Query Control Mechanisms 6/6

•Random query-processing delay (RQPD)

•A node may propagate same request in the time it takes a query to propagate along bordercast tree and detected through detection mechanisms

•A RQPD can be used

•Each bordercasting node waits a random time before the construction of the bordercasting tree and Early termination