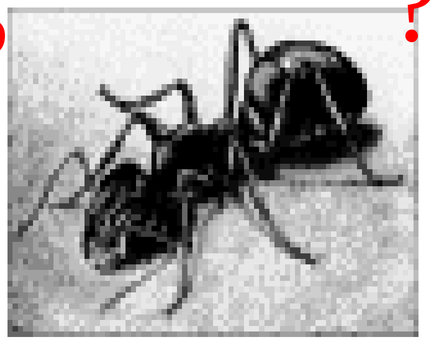
Chapter 3:
Basic Routing Protocols for Ad Hoc Mobile Wireless Networks

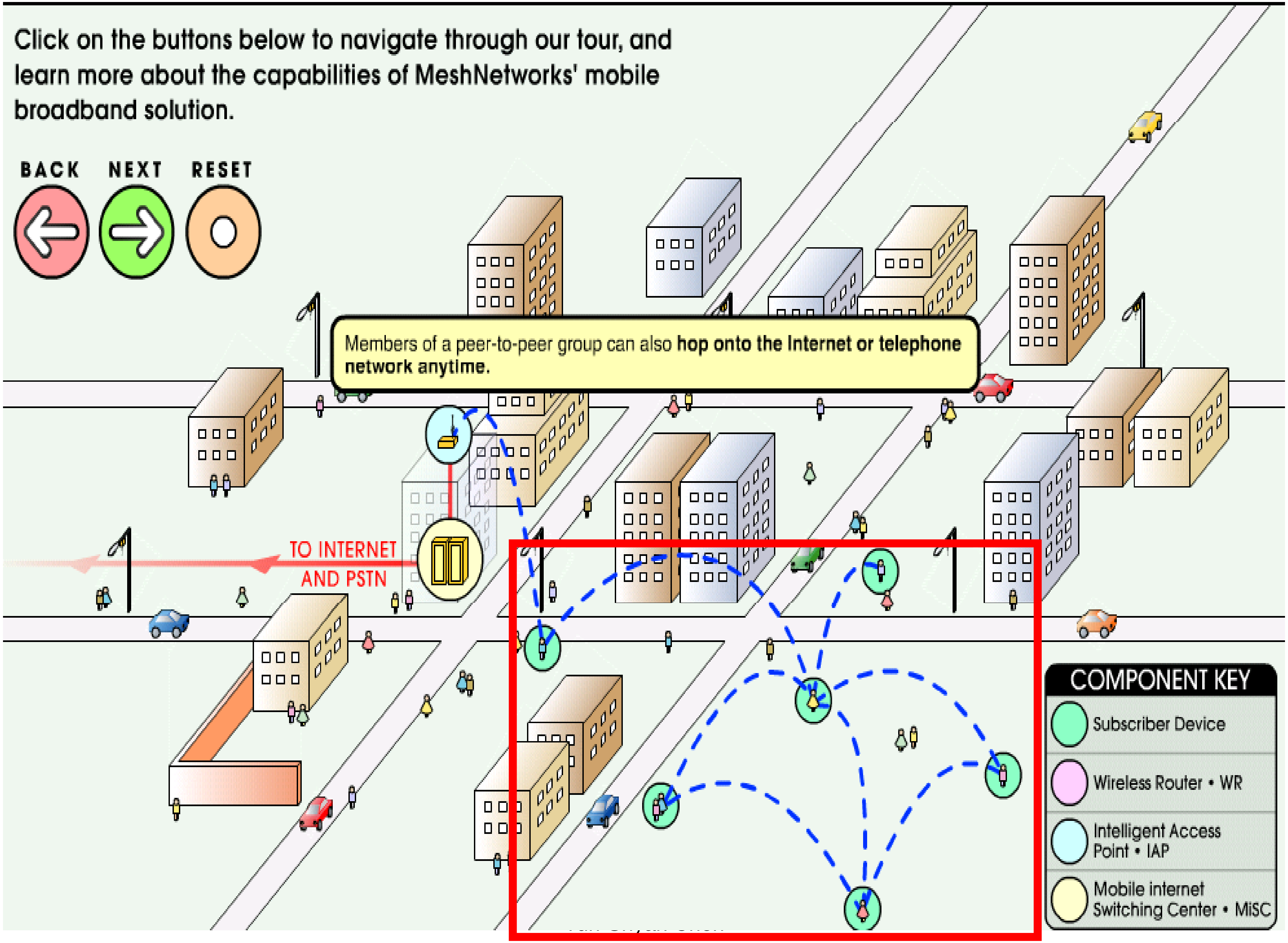
Prof. **Yuh-Shyan Chen**
Department of Computer Science
and Information Engineering
National Taipei University

Outline

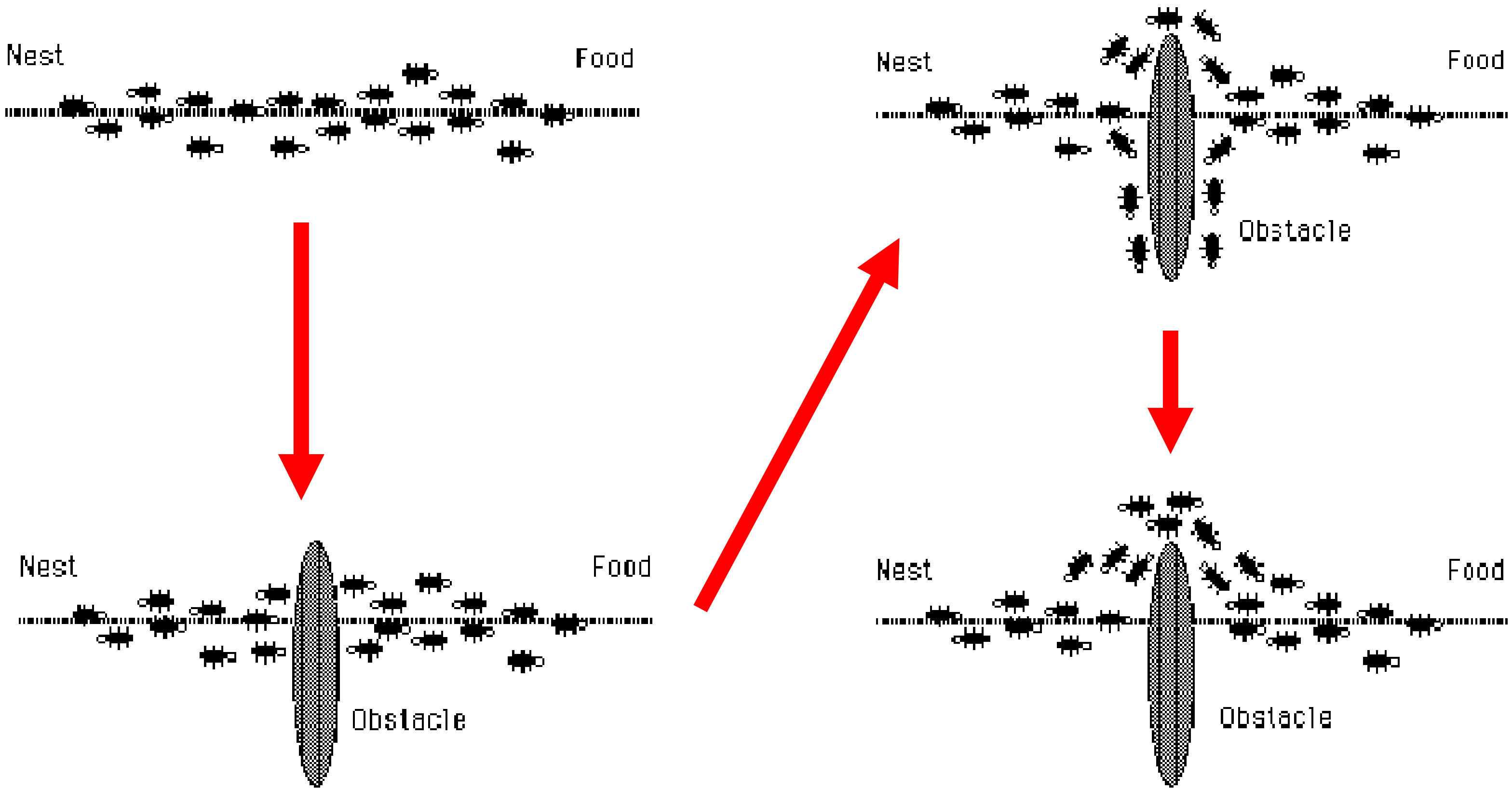
- Routing = Ants Searching for Food
- Introduction to Ad Hoc Wireless Networks
- Can existing internet routing protocols be used for ad hoc ?
- Some Ad-Hoc Routing Protocols (Proactive vs. Reactive)

Routing = Ants Searching for Food




Click on the buttons below to navigate through our tour, and learn more about the capabilities of MeshNetworks' mobile broadband solution.
BACK
NEXT
RESET
Members of a peer-to-peer group can also **hop onto the Internet or telephone network anytime.**
TO INTERNET AND PSTN
COMPONENT KEY
Subscriber Device
Wireless Router • WR
Intelligent Access Point • IAP
Mobile internet Switching Center • MiSC

Example:



Nest
Food
Nest
Food
Obstacle
Nest
Food
Obstacle
Nest
Food
Obstacle

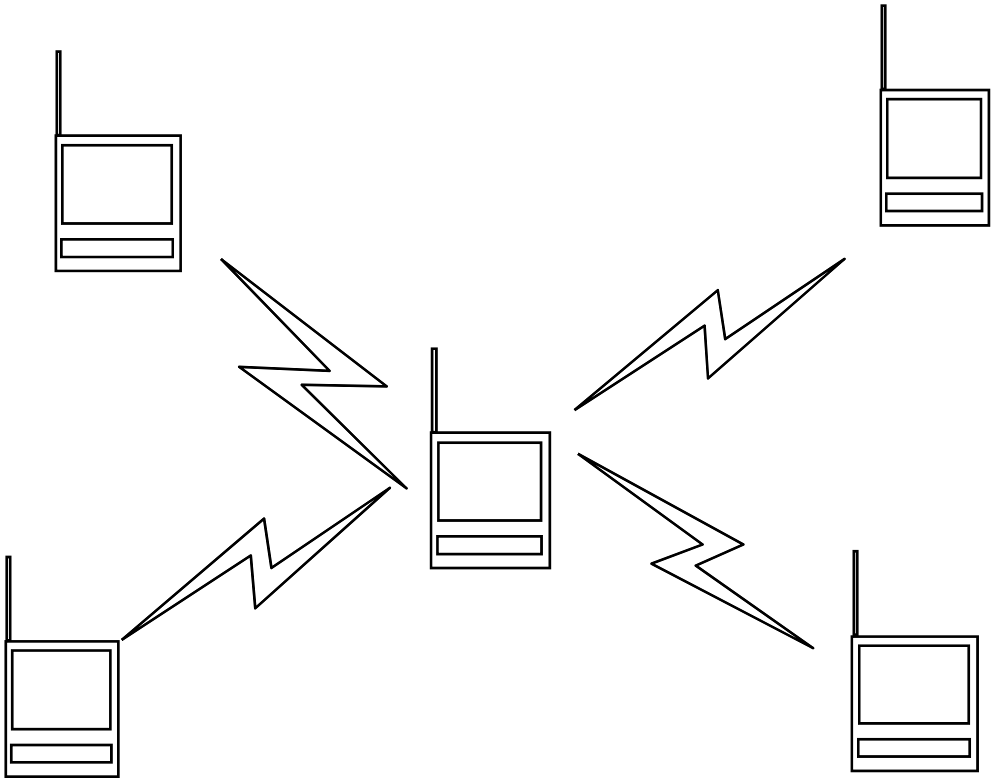
Three Main Issues in Ants' Life

- Route Discovery:
  - Searching for the places with food
- Packet Forwarding:
  - Delivering foods back home
- Route Maintenance:
  - When foods move to new place

Mobile Ad Hoc Networks

- Infrastructureless mobile network
- No fixed routers, no base stations
- All nodes can move and be connected dynamically
- All nodes is treated as routers
- Application
  - battlefield, disaster areas

Mobile Ad Hoc Networks



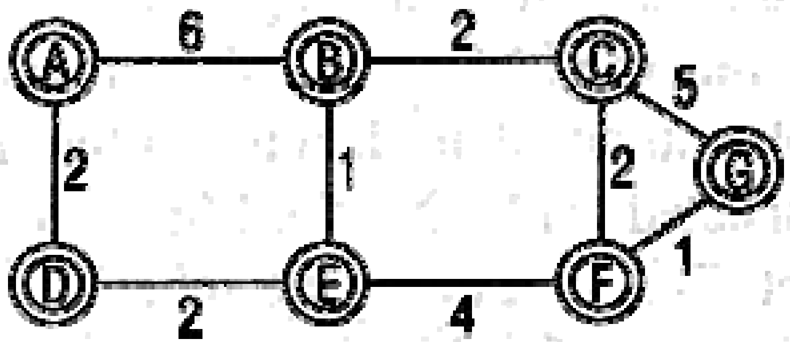
Challenge of Ad Hoc NETs

- No centralized entity
- Host is no longer just an end system
- Acting as an intermediate system
- Changing network topology over time
- Every node can be mobile

Can existing internet routing protocols be used for ad hoc?

- Link-state Routing
- Distance-vector Routing

Link State Routing



Network

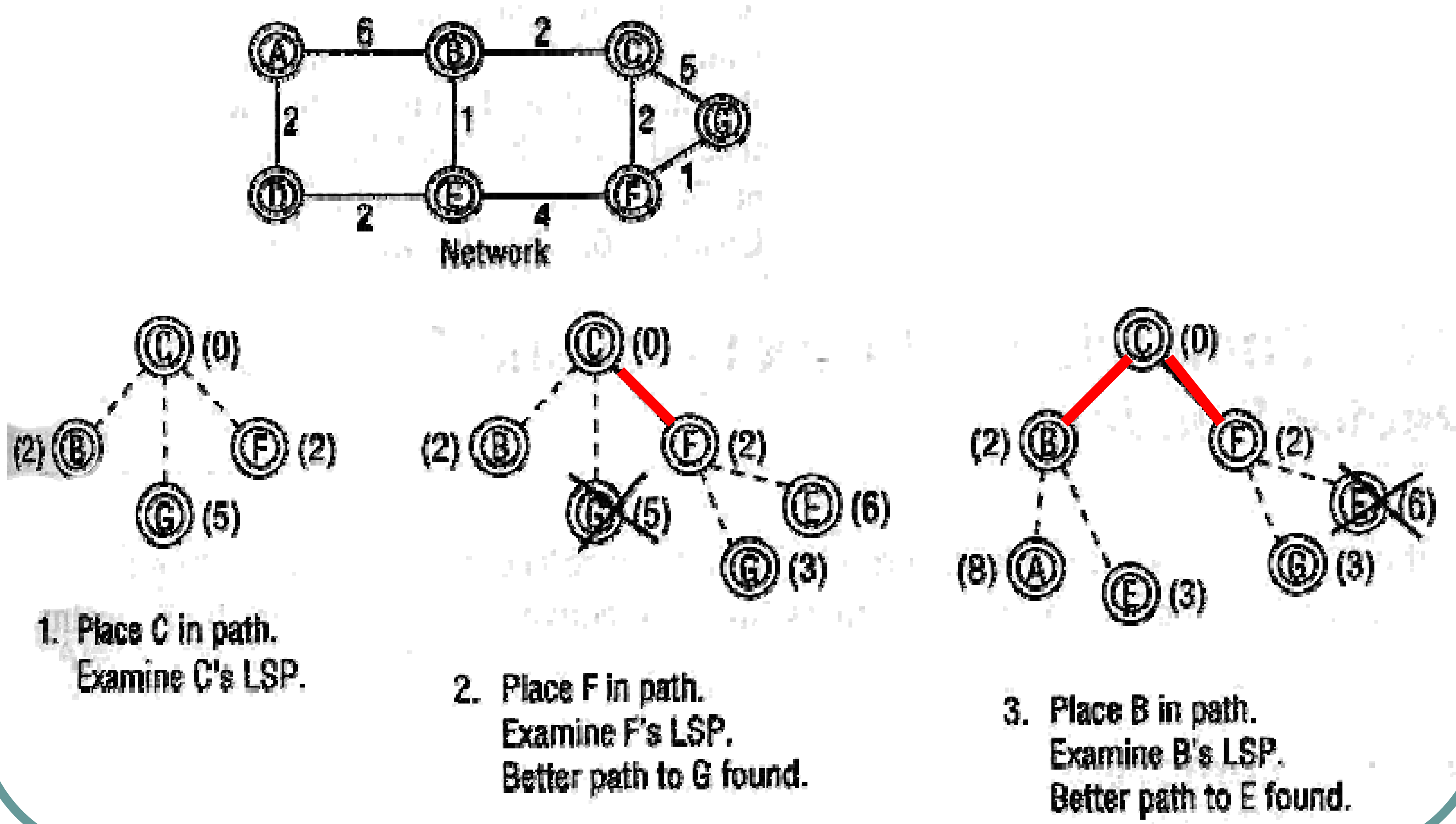
A	B	C	D	E	F	G
B/6	A/6	B/2	A/2	B/1	C/2	C/5
D/2	C/2	F/2	E/2	D/2	E/4	F/1
	E/1	G/5		F/4	G/1	

Link State Database

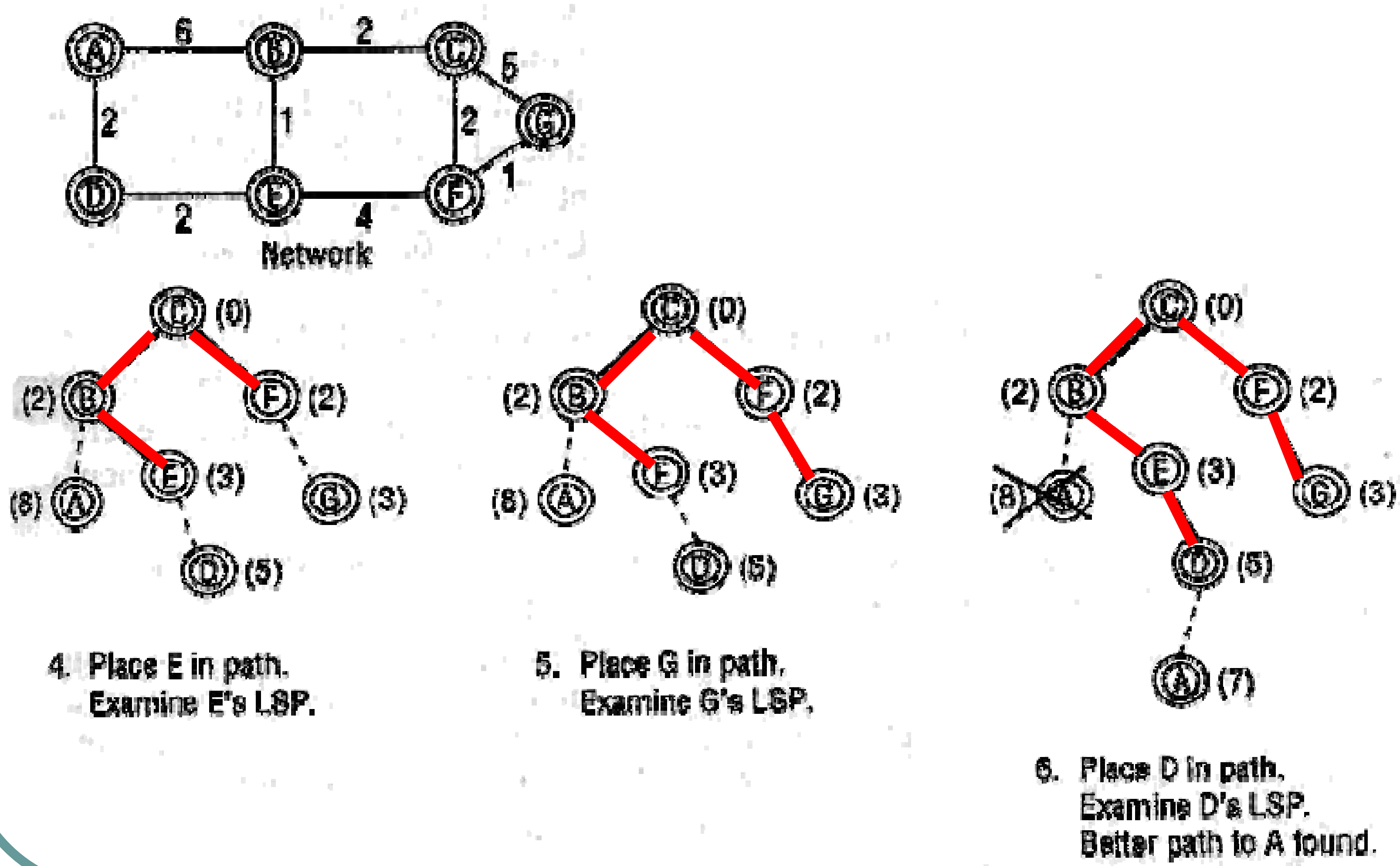
Figure 9.13

Dijkstra computing as done by C

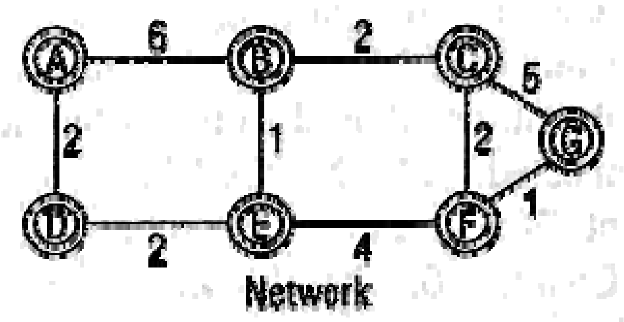
Dijstra's algorithm refers in "Introduction to algorithm" by C, L, & R. pp 527

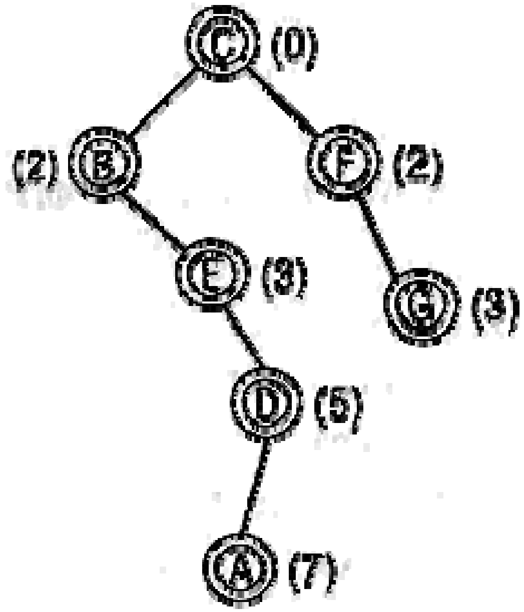


Dijkstra computing (cont.)



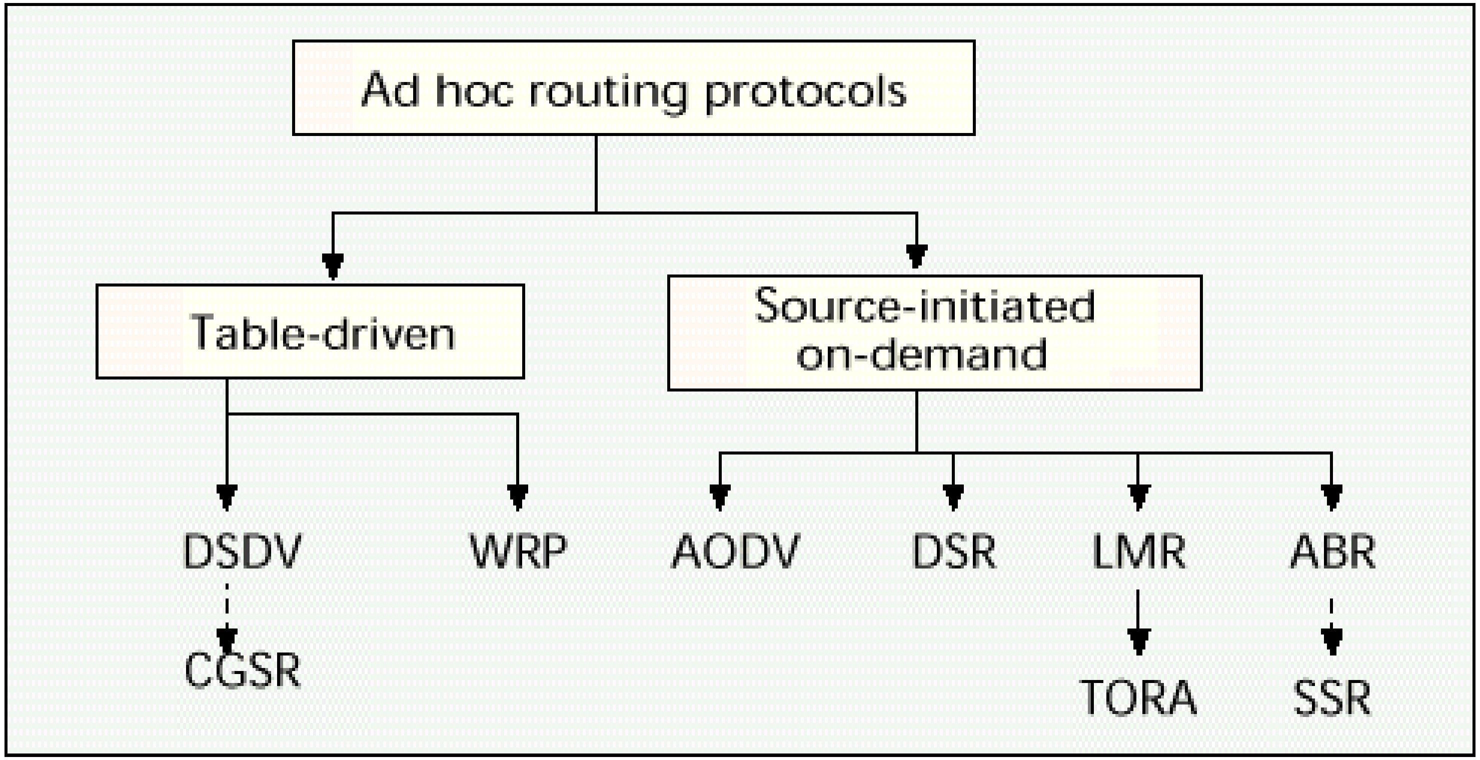
Dijkstra computing (cont.)





7. Place A in path.
   Examine A's LSP.
   No nodes left.
   Terminate.

Overview of current approaches



Proactive vs. Reactive Routing

- Proactive Routing Protocol
  - Continuously evaluate the routes
  - Attempt to maintain consistent, up-to-date routing information
    - When a route is needed, one may be ready immediately
  - When the network topology changes
    - The protocol responds by propagating updates throughout the network to maintain a consistent view
- Reactive Routing Protocol
  - Ex: DSR, AODV

On-demand vs Table-driven

Parameters	*On-demand*	*Table-driven*
Availability of routing information	Available when needed	Always available regardless of need
Routing philosophy	Flat	Mostly flat, except for CGSR
Periodic route updates	Not required	Required
Coping with mobility	Use localized route discovery as in ABR and SSR	Inform other nodes to achieve a consistent routing table
Signaling traffic generated	Grows with increasing mobility of active routes (as in ABR)	Greater than that of on-demand routing
Quality of service support	Few can support QoS, although most support shortest path	Mainly shortest path as the QoS metric

Table-Driven Routing

- DSDV: Destination Sequence Distance Vector
- WRP: Wireless Routing Protocol
- CGSR: Clustered Gateway Switch Routing

DSDV

- Destination Sequenced Distance Vector
  - Table-driven
  - Based on the distributed Bellman-Ford routing algorithm
  - Each node maintains a routing table
    - Routing hops to each destination
    - Sequence number

DSDV

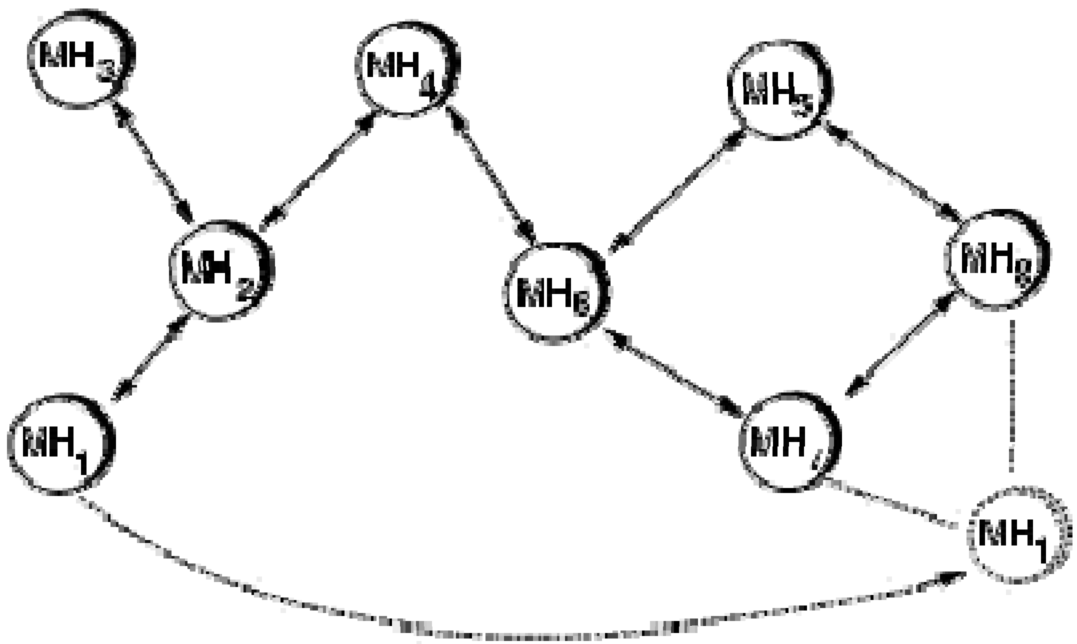


Figure 1: Movement in an ad-hoc network

DSDV(cont.)

Destination	NextHop	Metric	Sequence number	Install	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

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

DSDV(cont.)

Destination	NextHop	Metric	Sequence number	Install	Stable_data
$\mathbf{MH_1}$	$\mathbf{MH_6}$	**3**	**S516_**MH_1	**T810_**MH_4	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)

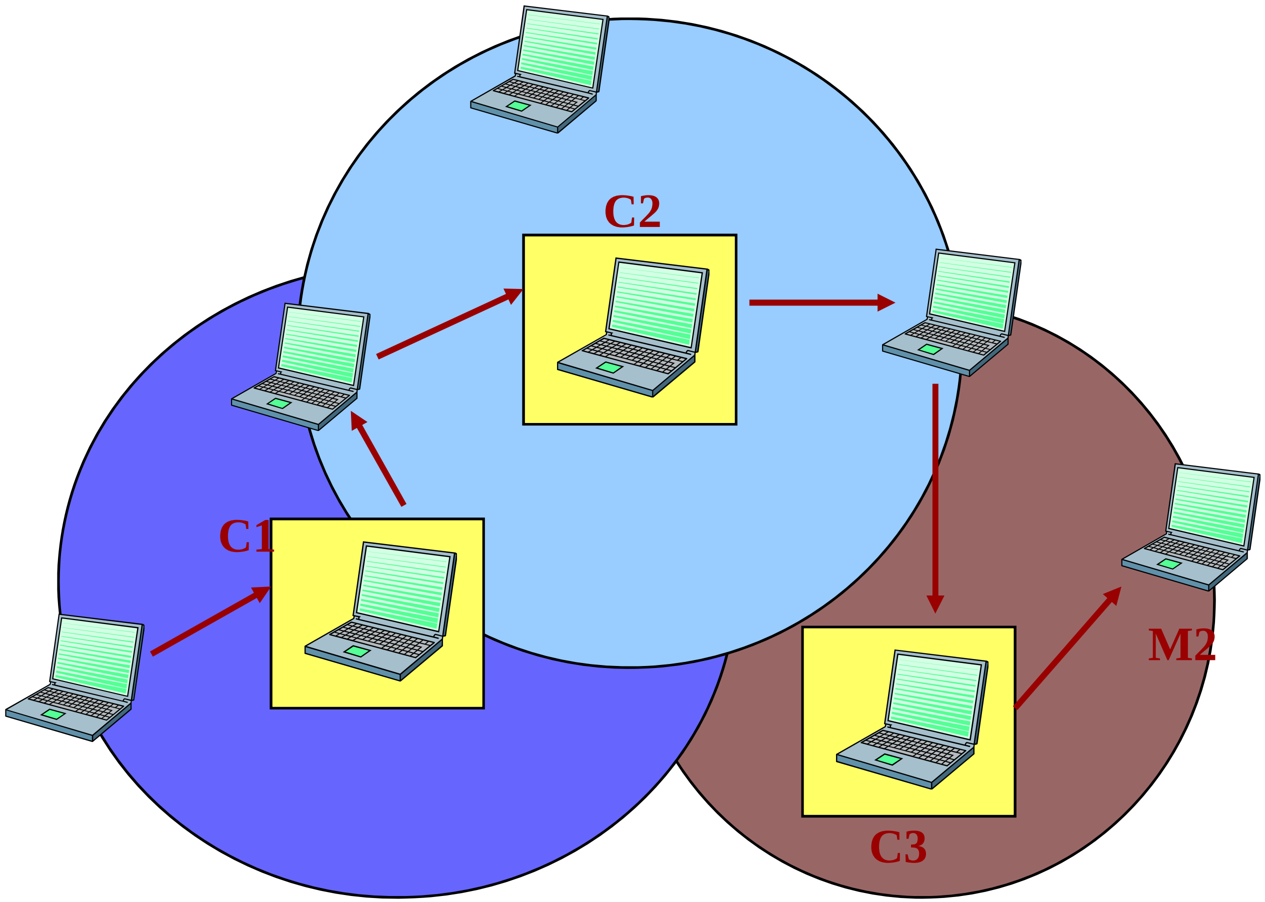
DSDV

- Problem
  - A lot of control traffic in the network
- Solution
  - two types of route update packets
    - Full dump
      - All available routing information
    - Incremental
      - Only information changed since the last full dump

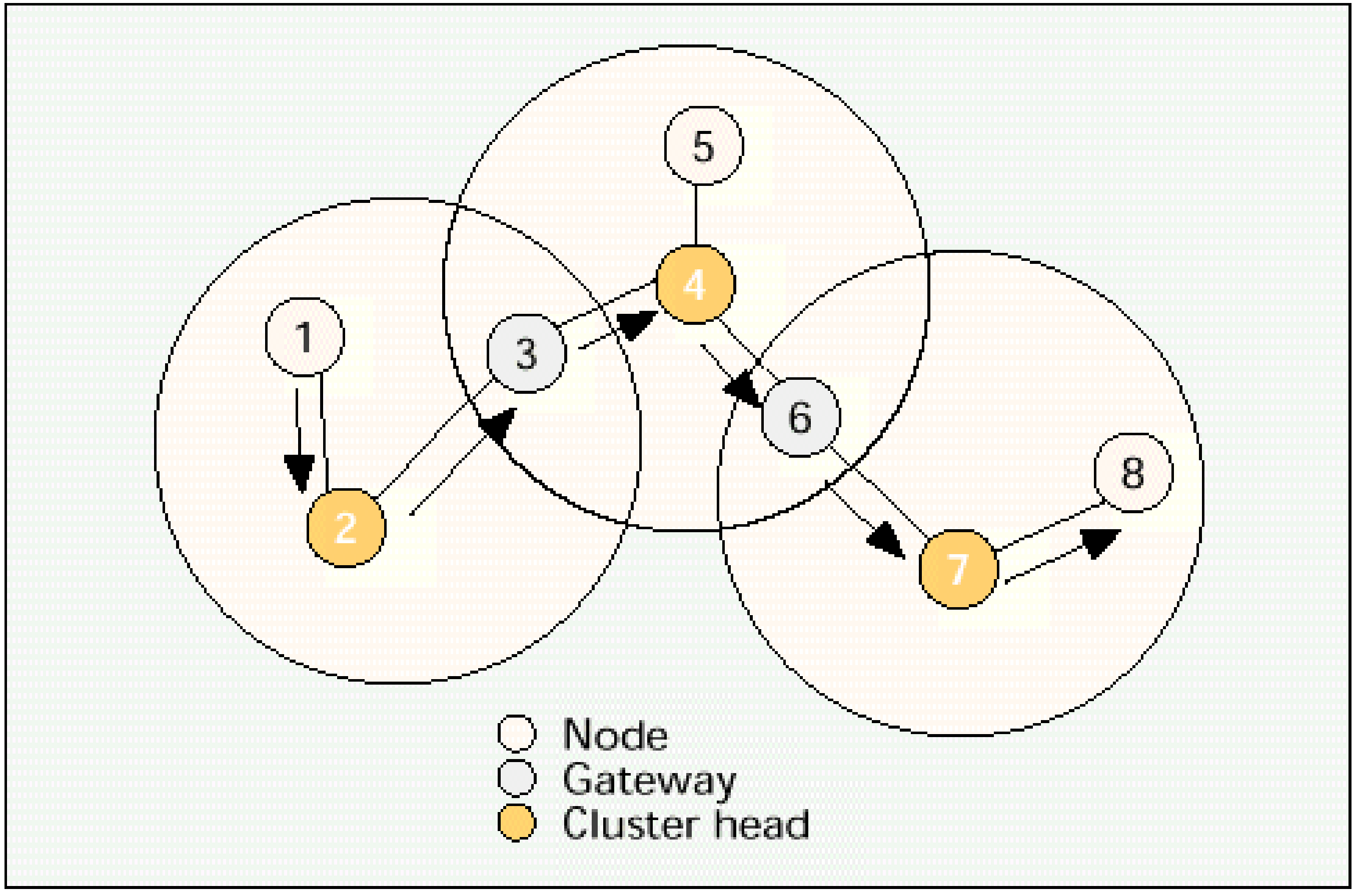
CGSR

- Cluster Gateway Switch Routing
  - Table-driven
  - Uses DSDV as the underlying routing scheme
  - Modification
    - A hierarchical cluster-head-to-gateway routing approach

Example



CGSR (Clustered Gateway Switch Routing)



CGSR(cont.)

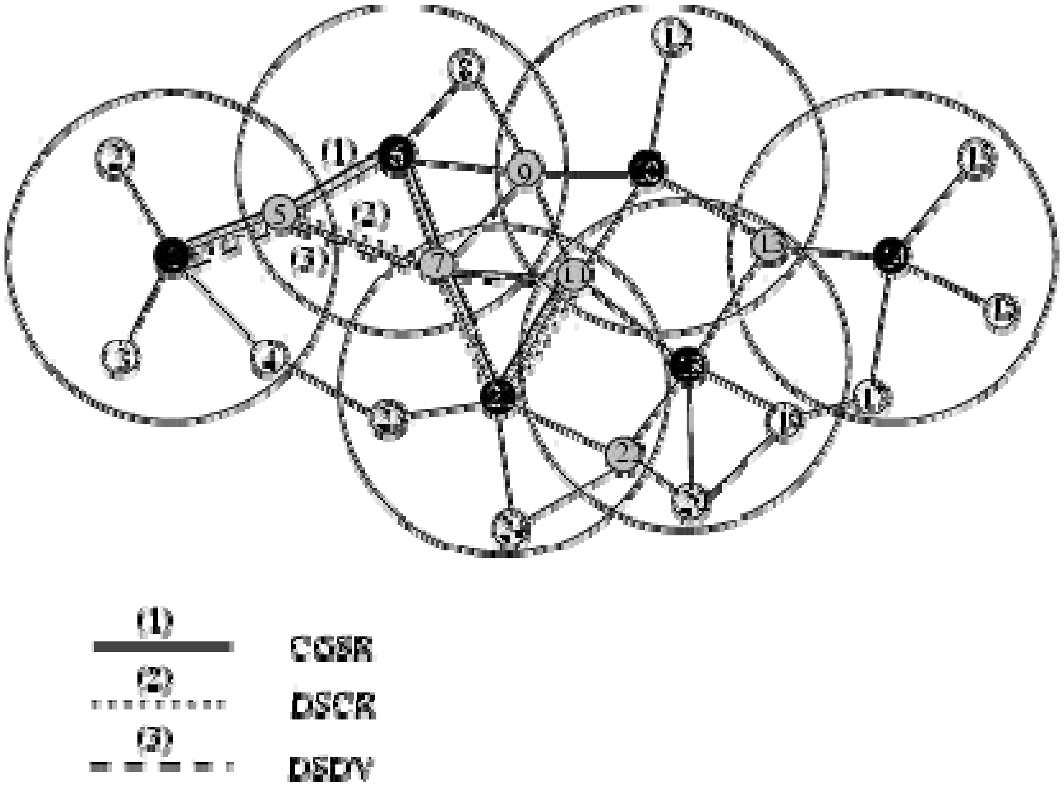


Figure 5: Routing examples (from node 1 to node 11)

CGSR

- Problem
  - A cluster head is changing frequently
- Solution
  - The least cluster change algorithm
    - A cluster only change when
      - Two cluster heads come into contact
      - A node moves out of all other cluster heads

On-Demand Routing

- DSR(Dynamic Source Routing)
- AODV(Ad Hoc On-Demand Distance Vector)
- TORA(Temporally Ordered Routing Algorithm)
  - MER-TORA (micromobility protocol)
    - IP Mobility
    - Support handover solutions
- LAR(Location-Aware Routing)
- ZRP(Zone Routing Protocol)
- SSA(Signal Stability-Based Adaptive Routing)

DSR (Dynamic Source Routing)

DSR

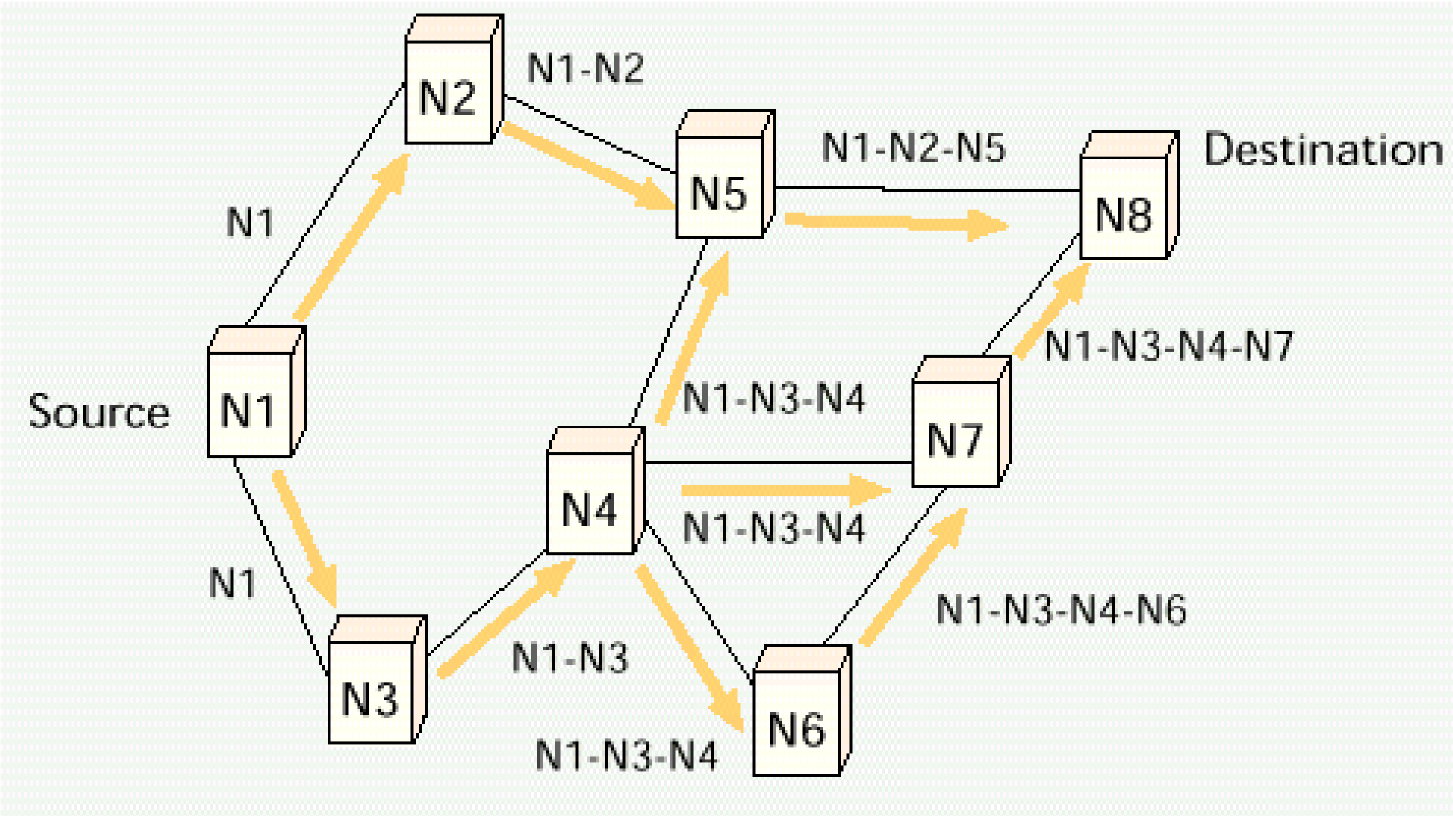
- Dynamic Source Routing [1996]
  - On-demand driven
  - Based on the concept of source routing
  - Required to maintain route caches
  - Two major phases
    - Route discovery
    - Route maintenance
      - A route error packet

Route Discovery of DSR

- When a host has a packet to send, it first consults its route cache.
  - If there is an unexpired route, then it will use it.
  - Otherwise, a route discovery will be performed.

- Route Discovery:
  - A ROUTE_REQUEST packet is sent by flooding.
  - There is a “route record” field in the packet.
    - Each node will append its address to the record.

DSR

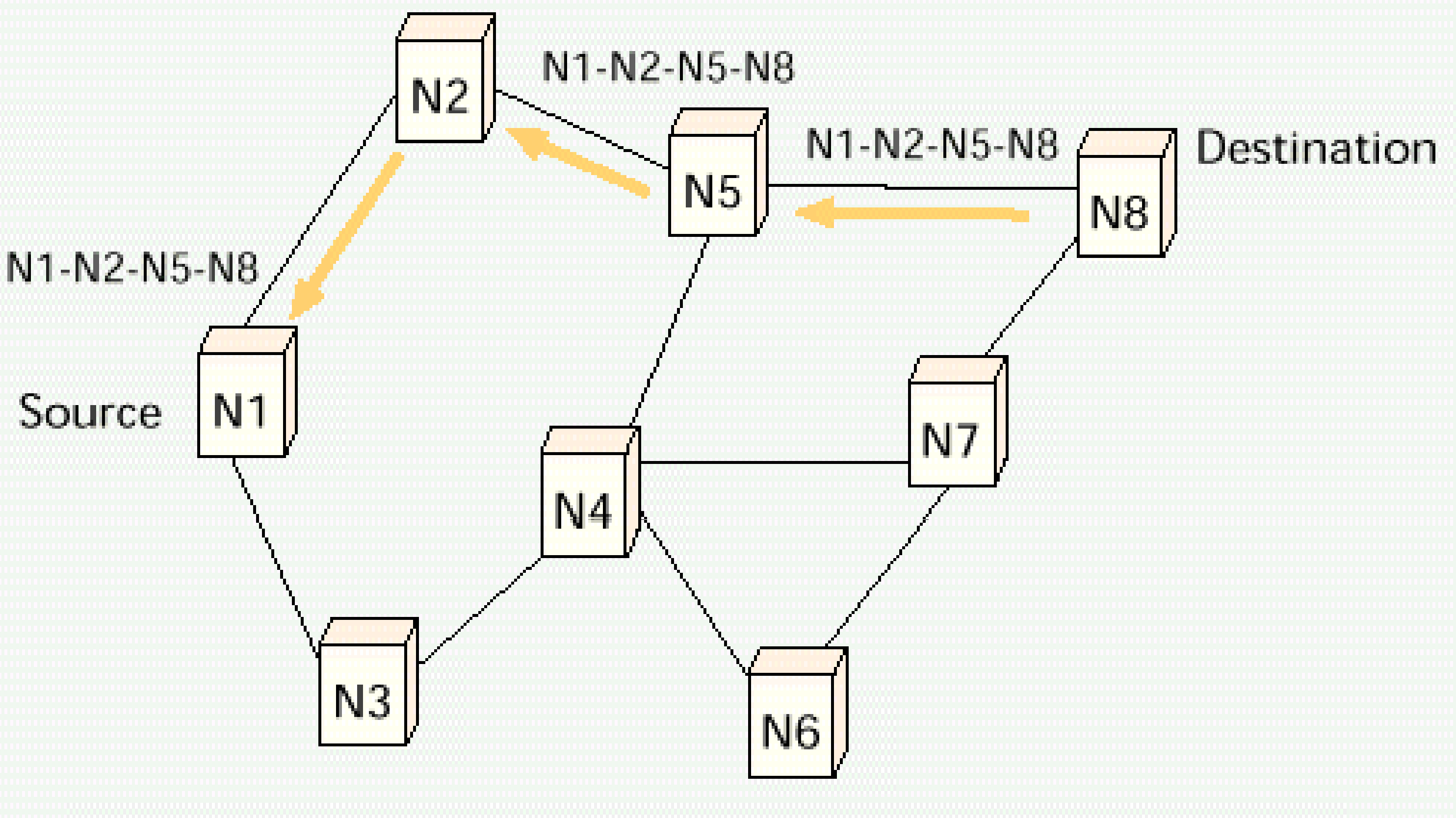


(a) Building of the route record during route discovery

Route Reply of DSR

- A ROUTE_REPLY packet is generated when
  - the route request packet reaches the destination
  - an intermediate host has an "unexpired" route to the destination
- A route is then generated in two manner:
  - from destination:
    - the route traversed by the ROUTE_REQUEST packet
  - from intermediate host:
    - the route traversed by the ROUTE_REQUEST packet concatenated with the route in the intermediate host's route cache

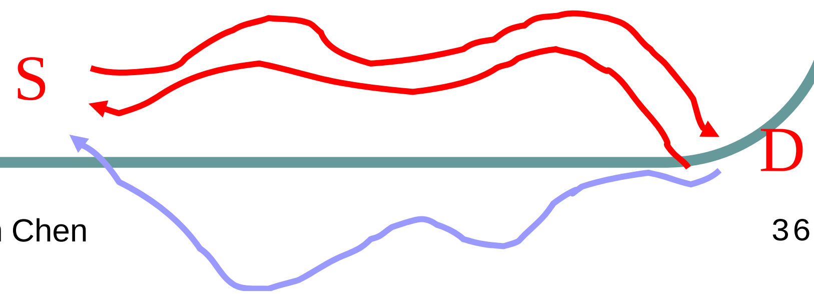
DSR(cont.)



(b) Propagation of the route reply with the route record

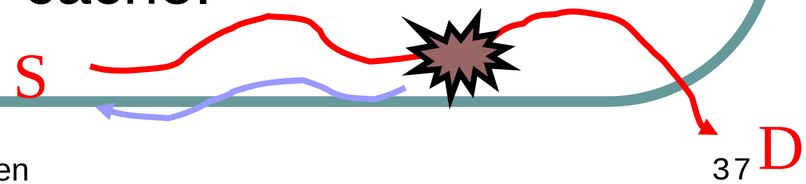
Path of ROUTE_REPLY

- Which way should be taken by the ROUTE_REPLY?
- Two possibilities:
  - symmetric path:
    - follow the same route in the reverse order to reach the source
  - asymmetric path:
    - need to discover a new route to the source by initiating a ROUTE_REQUEST to the source
    - piggyback the discovered route to the ROUTE_REQUEST packet



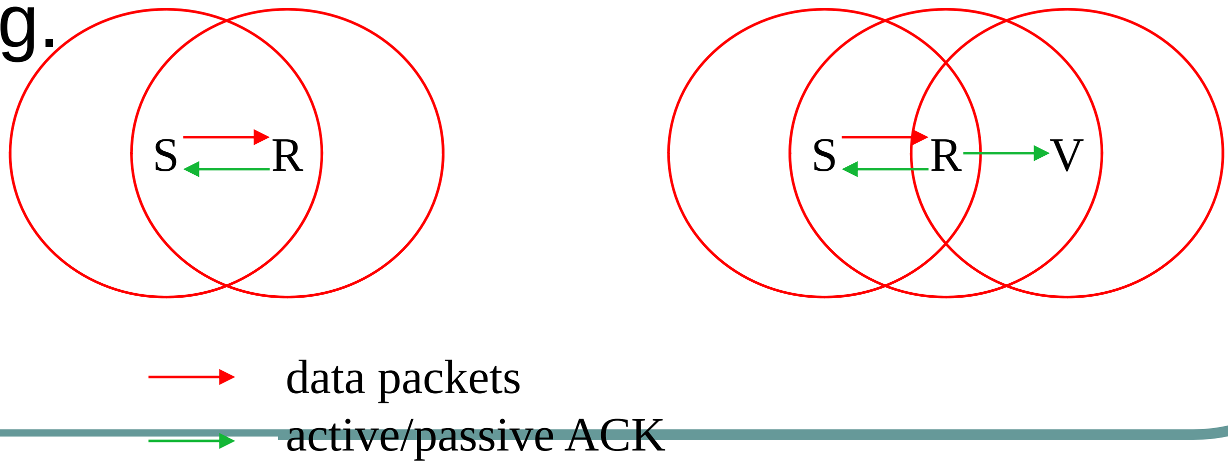
Route Maintenance of DSR

- When the data link layer encounters a link breakage, a ROUTE_ERROR packet will be initiated.
  - The packet will traverse in the backward direction to the source.
  - The source will then initiate another ROUTE_REQUEST.
- Maintenance of route cache:
  - All routes which contain the breakage hop have to be removed from the route cache.



How to Detect a Link Breakage

- Active Acknowledge:
  - The receiver of a packet actively sends an ACK to the sender.
- Passive Acknowledge:
  - The sender passively listen to the receiver's sending.



DSR: Route Request(RREQ)

Type=REQ	Option Length	Idetification	
Target Address			
index1	index2	index3	index4
Address1			
Address2			
Address3			
Address4			

Figure 1: The ROUTE_REQ packet used in DSR. The *option length* field can be used to calculate the number of addresses appended.

DSR: Route Reply(RREP)

<table>
<tr><td>Type=REPLY</td><td>Option Length</td><td>R</td><td>F</td><td>Reserved</td></tr>
<tr><td colspan="5">Target Address</td></tr>
<tr><td>Index1</td><td>Index2</td><td>Index3</td><td colspan="2">Index4</td></tr>
<tr><td colspan="5">Address1</td></tr>
<tr><td colspan="5">Address2</td></tr>
<tr><td colspan="5">Address3</td></tr>
<tr><td colspan="5">Address4</td></tr>
</table>

Figure 2: The ROUTE_REPLY packet used in DSR.

DSR: Data Packet

R	Option Length	Idetification	
index1	index2	index3	index4
Address1			
Address2			
Address3			
Address4			

Figure 3: Format of data packet header in DSR. Duplicating the index and address fields, if necessary, can increase the route length by 4.

DSR: Error Packet

Type=ERROR	Option Length	Index
Originator Address		
From Hop Address		
Next Hop Address		

Figure 4: The ERROR packet used in DSR. The *originator address* field indicates the source of the data packet experiencing error, and the *from hop* and *next hop* addresses identify the two end nodes of the broken link.

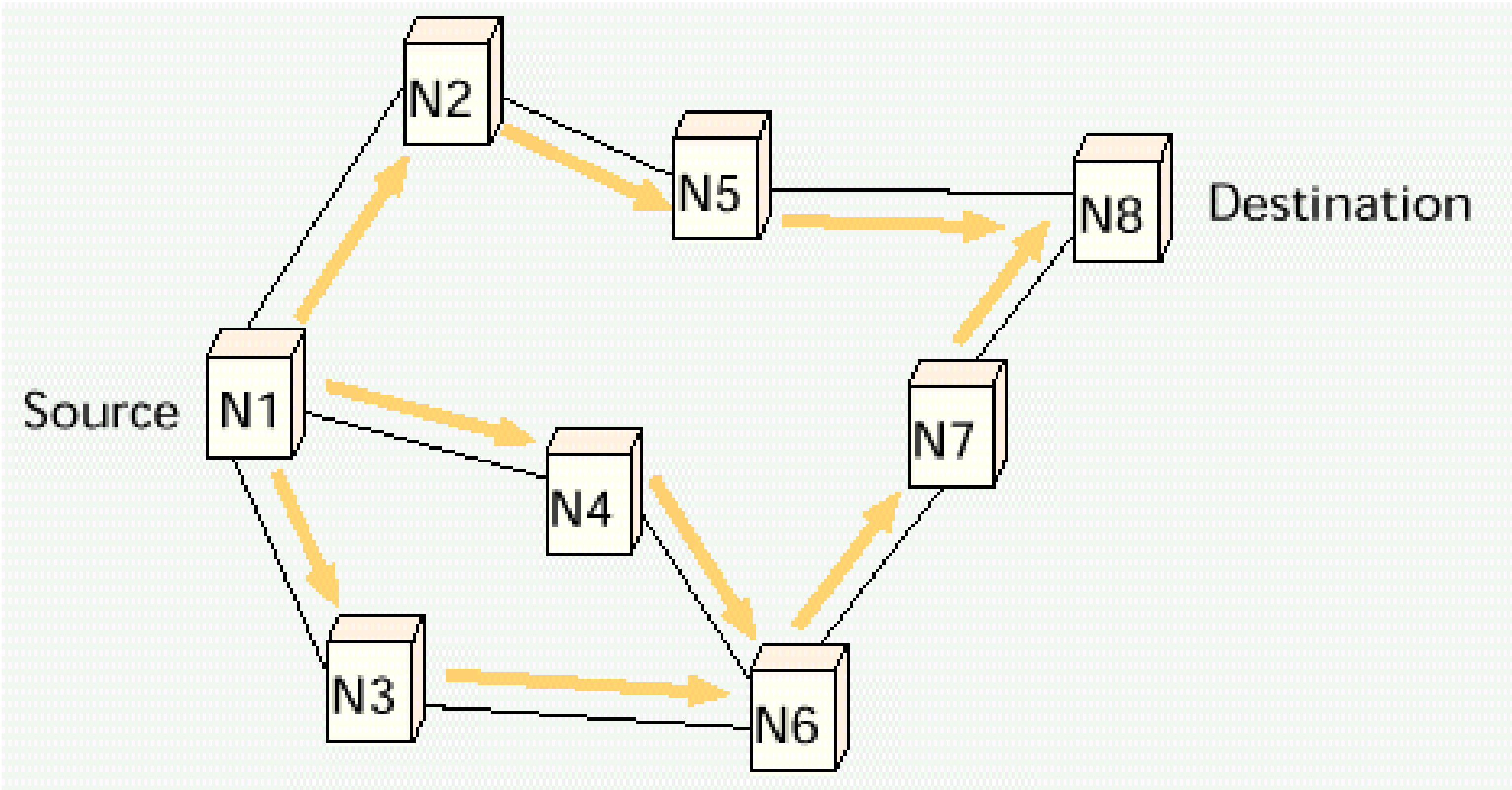
AODV(Ad Hoc On-Demand Distance Vector)

MAODV (Multicast AODV)

AODV

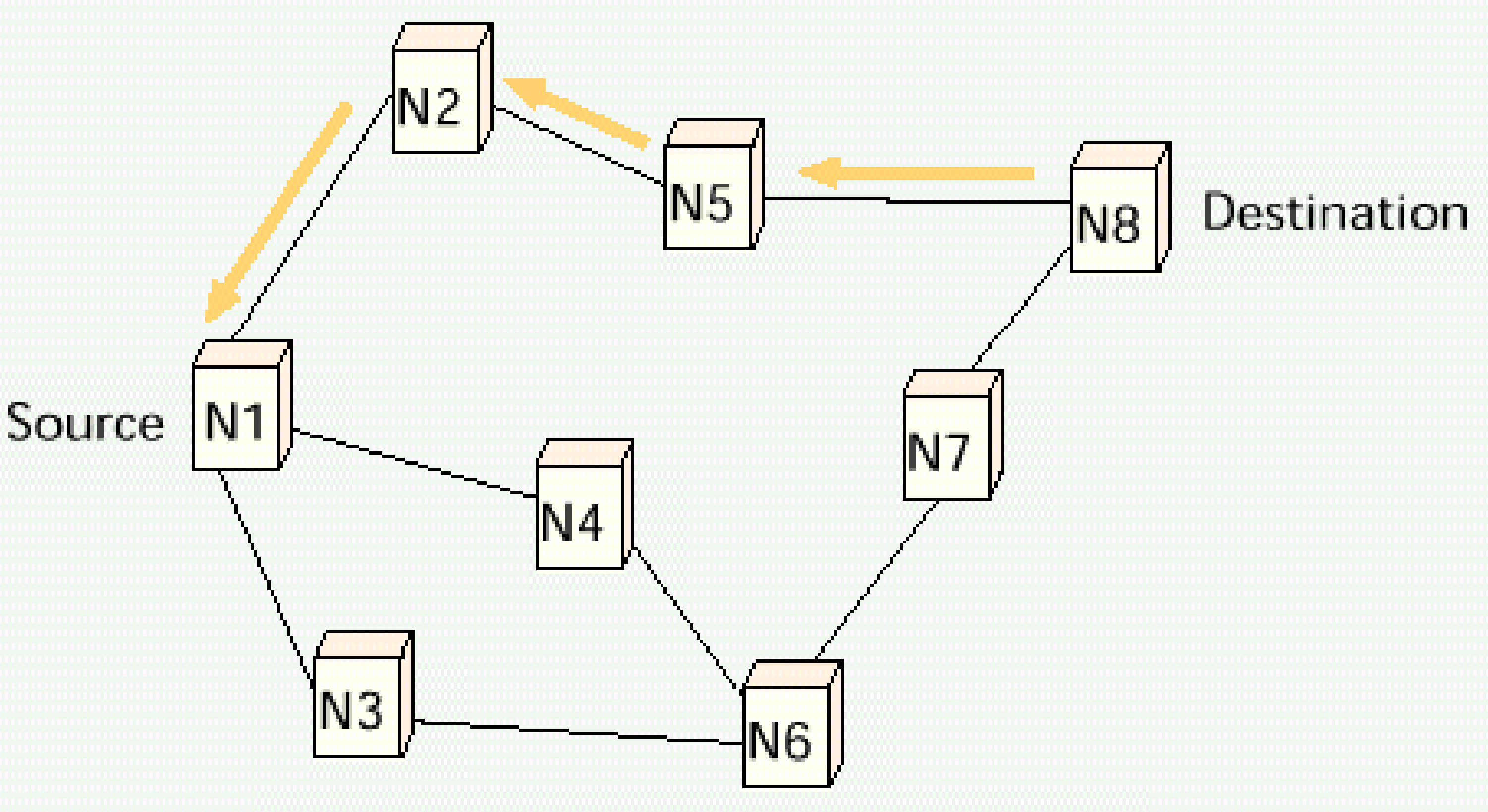
- Ad hoc On-demand Distance Vector
  - On-demand driven
  - Nodes that are not on the selected path do not maintain routing information
  - Route discovery
    - The source node broadcasts a route request packet (RREQ)
    - The destination or an intermediate node with "fresh enough" route to the destination replies a route reply packet (RREP)

AODV



(a) Propagation of the RREQ

AODV (cont.)



(b) Path of the RREP to the source

AODV: Route Request

Type	Reserved	Hop Count
Broadcast ID		
Destination IP address		
Destination Sequence Number		
Source IP address		
Source Sequence Number		

Figure 8: The ROUTE_REQ packet useds in AODV.

AODV: Route Reply

<table>
<tr><td>Type</td><td>L</td><td>Reserved</td><td>Hop Count</td></tr>
<tr><td colspan="4">Destination IP address</td></tr>
<tr><td colspan="4">Destination Sequence Number</td></tr>
<tr><td colspan="4">Lifetime</td></tr>
</table>

Figure 9: The ROUTE_REPLY packet used in AODV.

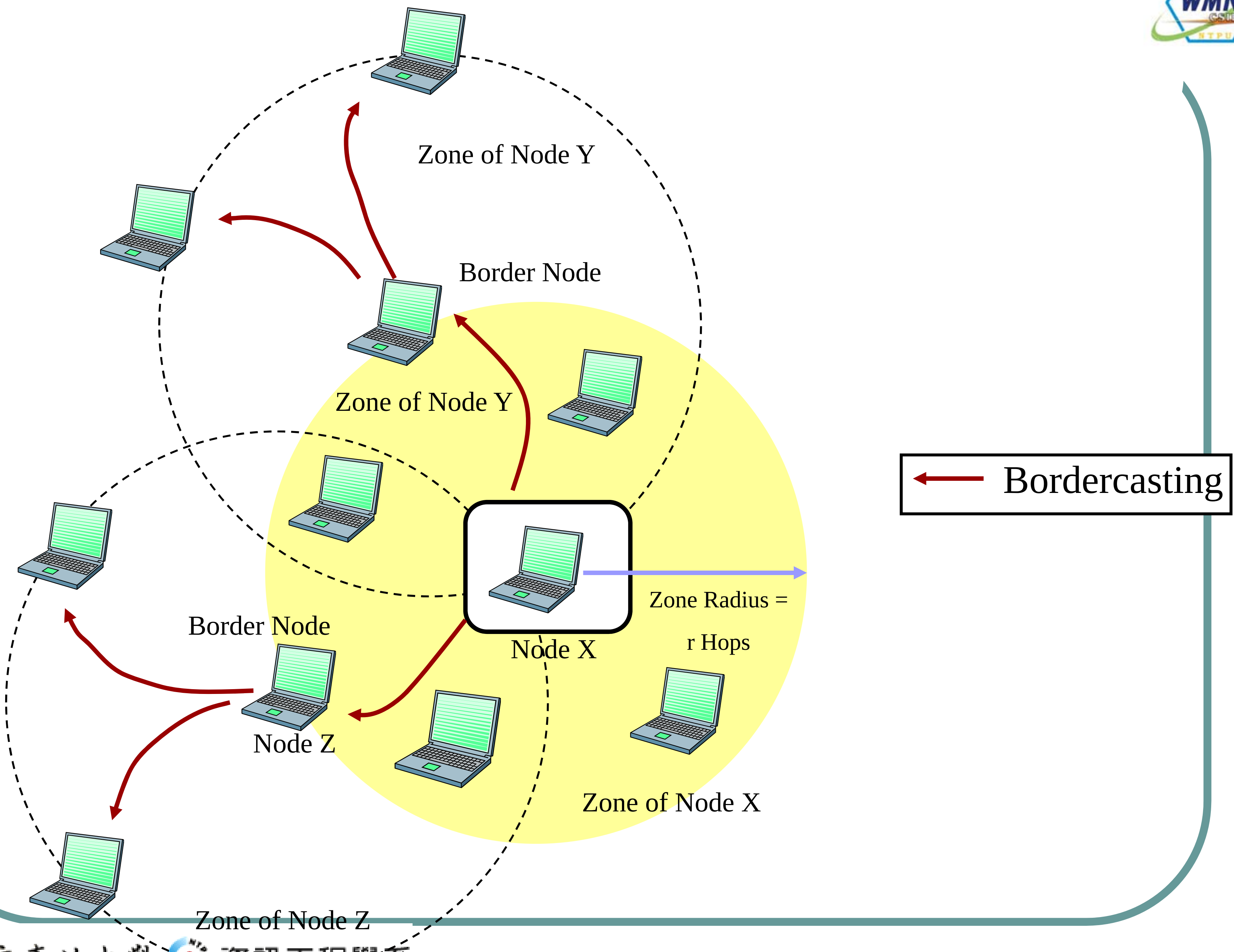
AODV

- Problem
  - A node along the route moves
- Solution
  - Upstream neighbor notices the move
  - Propagates a link failure notification message to each of its active upstream neighbors
  - The source node receives the message and re-initiate route discovery

ZRP (Zone Routing Protocol)-
Combining Pro-active and Reactive

ZRP

- Zone Routing Protocol
  - Hybrid protocol
    - On-demand
    - Proactive
  - ZRP has three sub-protocols
    - Intrazone Routing Protocol (IARP)
    - Interzone Routing Protocol (IERP)
    - Bordercast Resolution Protocol (BRP)


Zone of Node Y
Border Node
Zone of Node Y
Border Node
Node X
Zone Radius =
r Hops
Node Z
Zone of Node X
Zone of Node Z
Bordercasting

ZRP

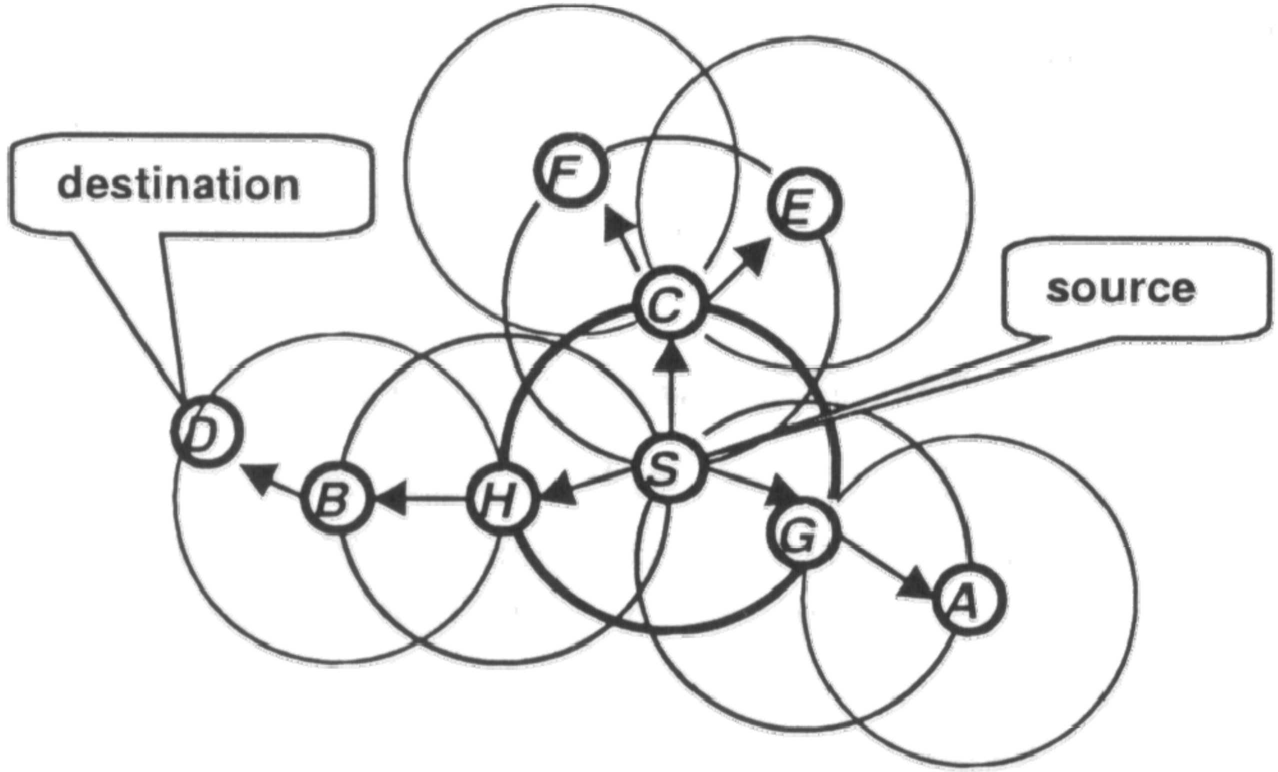


Figure 3: An example of the ZRP protocol

Location-Aware Routing

(1) LAR (Mobicom'98)
(2) DREAM
(3) GRID
(Yu-Chee Tseng *et al.*, Telecommunication Systems (2001))

Location-Aware Routing

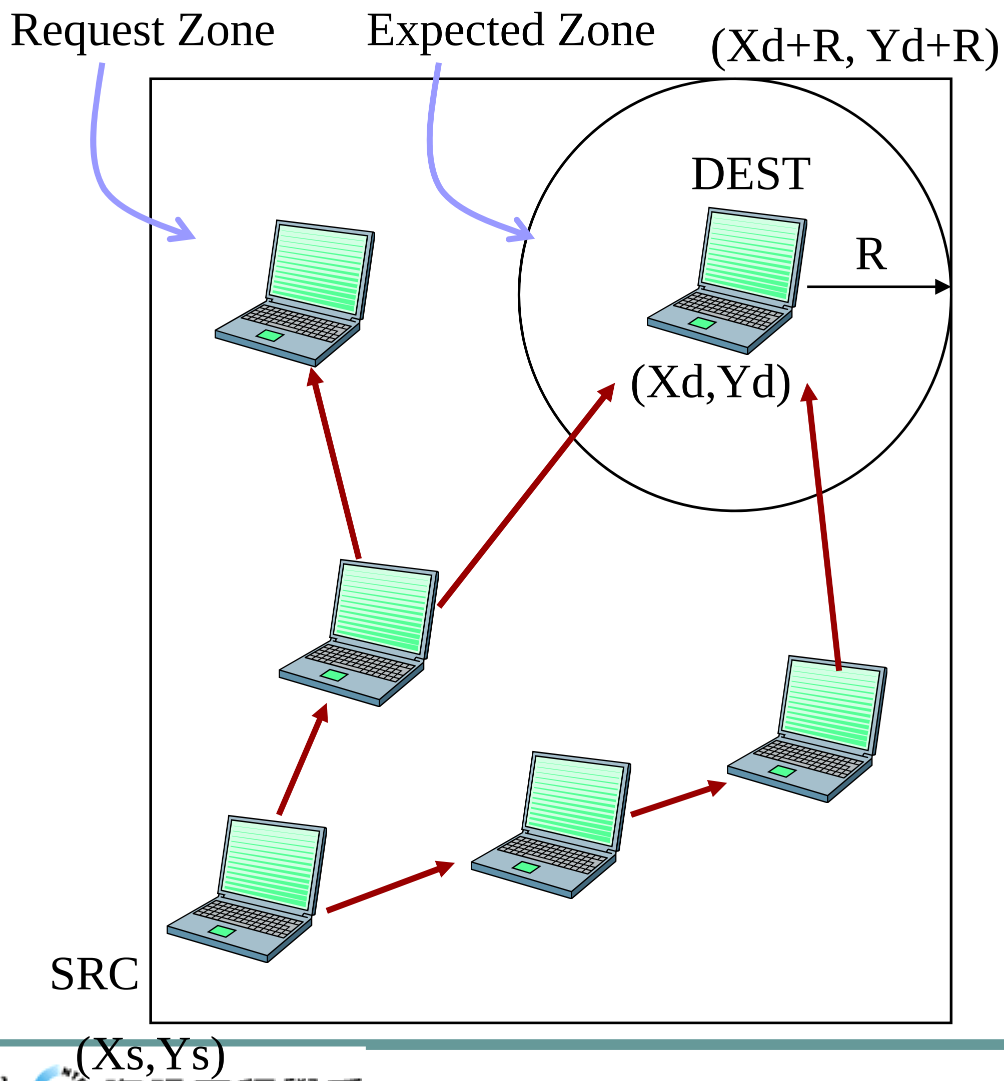
- LAR
  - Mobicom'98
- DREAM
- GRID
  - Yu-Chee Tseng *et al.*, Telecommunication Systems (2001)

Notebook + GPS

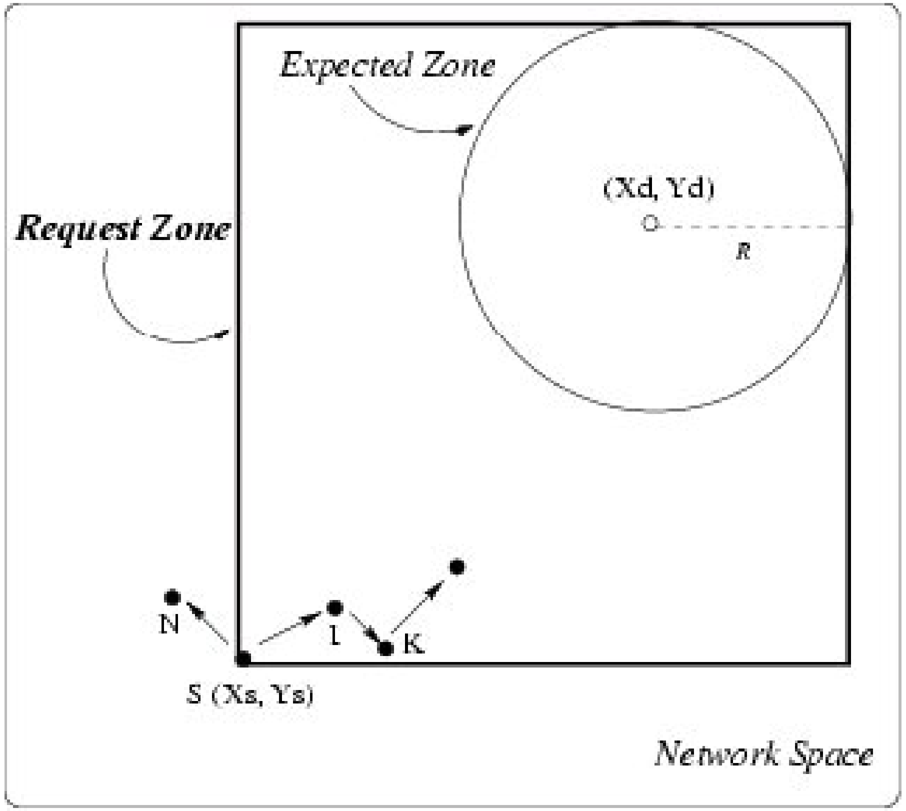
LAR

- Location-Aided Routing [Mobicom'98 best paper]
  - Location information via GPS
  - Shortcoming
    - GPS availability is not yet worldwide
    - Position information come with deviation

Reduce the flooding area

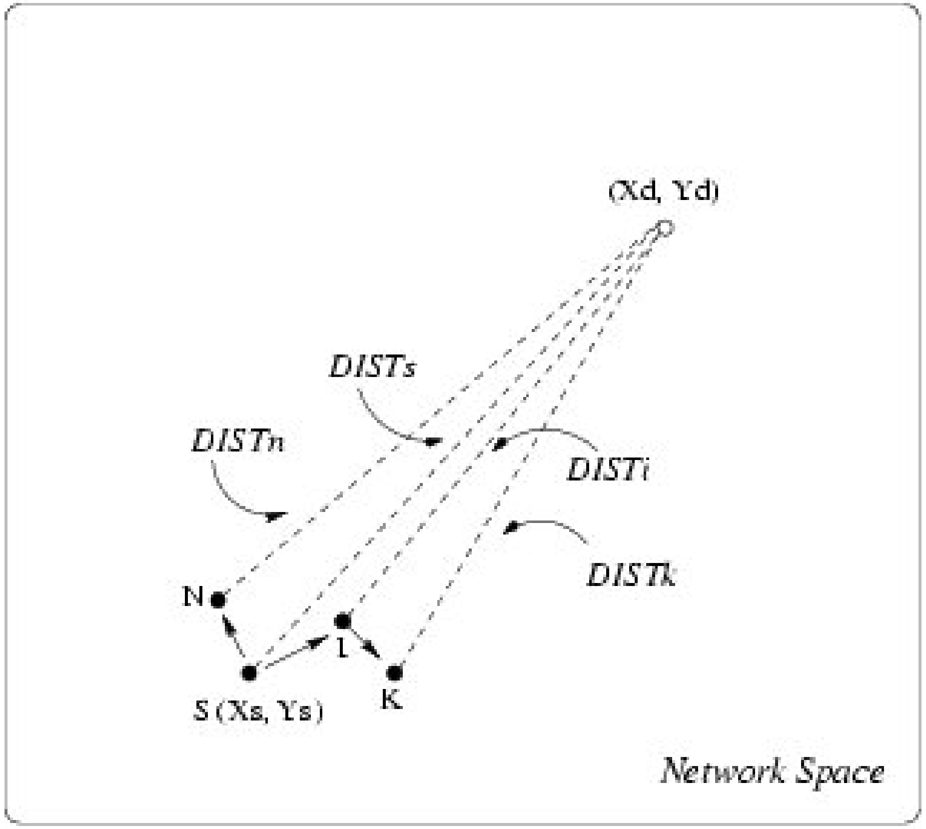


LAR



(a) LAR scheme 1

LAR(cont.)



(b) LAR scheme 2

DREAM

- Distance Routing effect Algorithm for mobility
  - Position-based
  - Each node
    - maintains a position database
    - Regularly floods packets to update the position
      - Temporal resolution
      - Spatial resolution

SSA (Signal Stability-Based Adaptive Routing)

SSA

Host	Signal Strength	Last	Clicks	Set
Y				
Z				

Table 2: The Signal Stability Table (SST)

Destination	Next Hop
Y	
Z	

Table 3: The Routing Table (RT)

SSA(cont.)

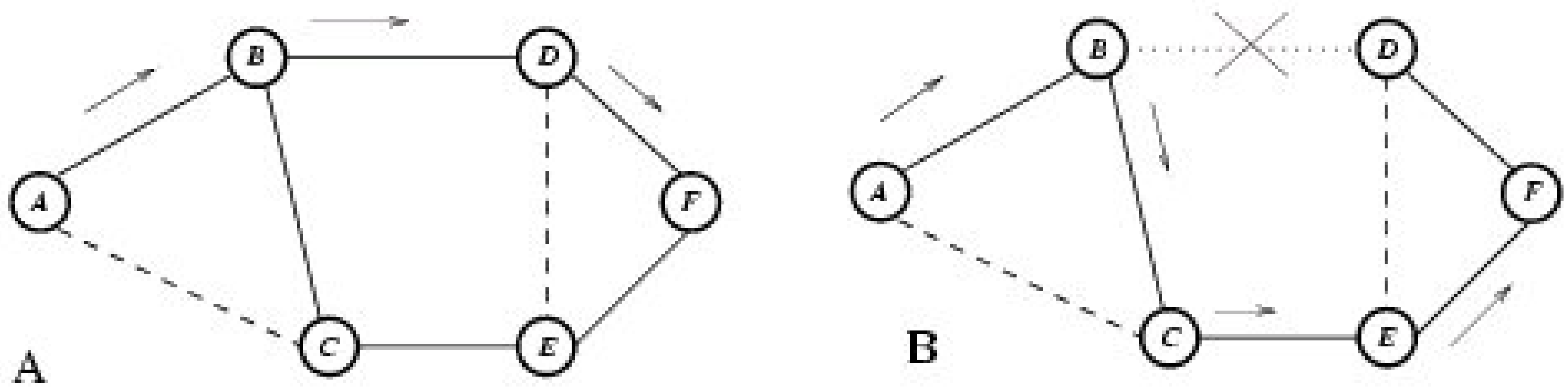
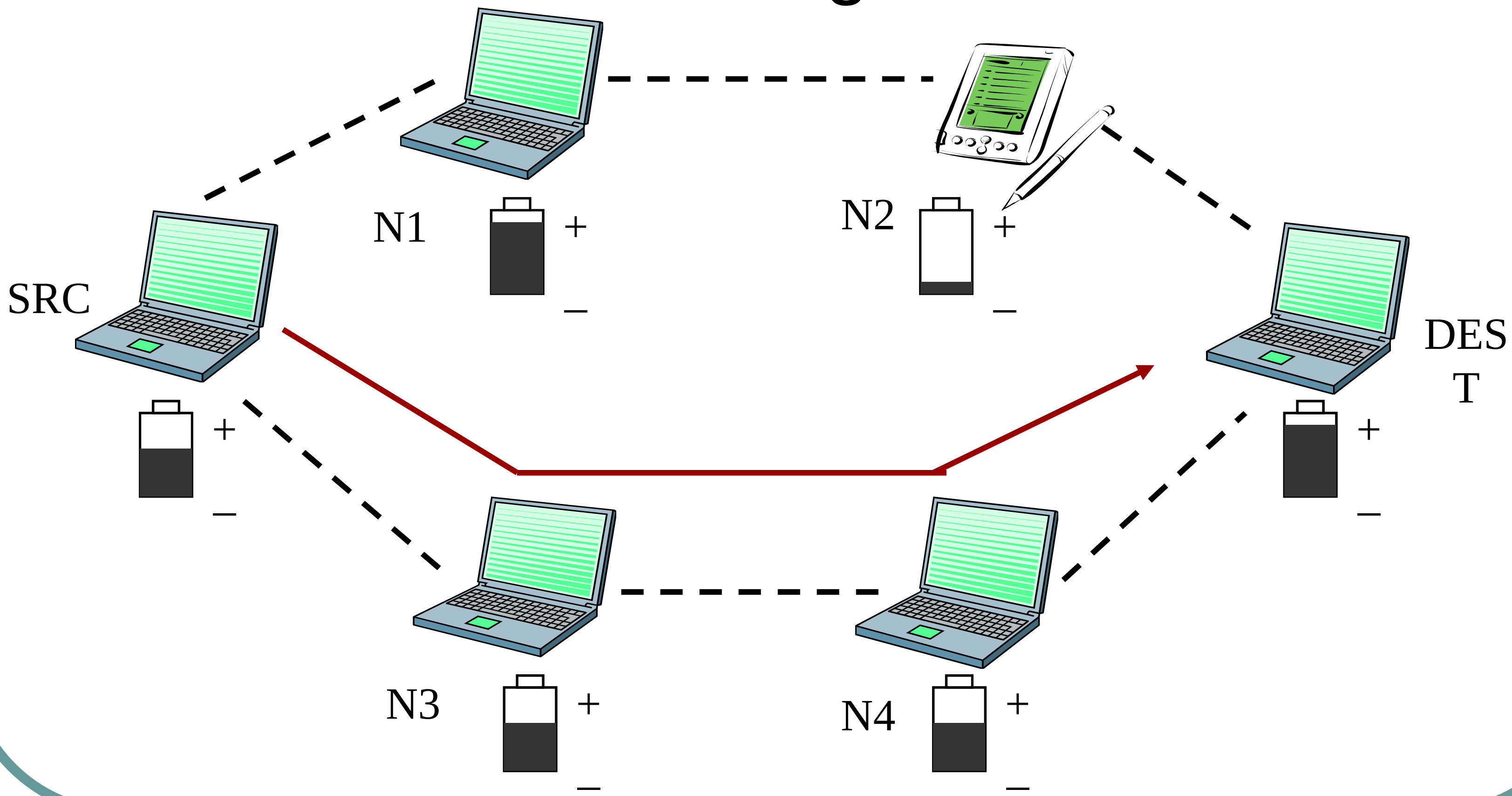


Figure 1: An Example Network

Power-Aware Routing

PAR

- Power-Aware Routing



Homework #3:

- What's difference of proactive and reactive routing protocols in MANETs ?
- What's difference of DSR and AODV protocols ?
- What's the location-aware routing protocol in MANET ?
- What's power-aware routing protocol ?