



Ad Hoc Network

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Outline

- **Definition and Challenges**
- Media Access Control
- Routing Protocols
- Research topics



Ad Hoc Network

- Meaning
 - form / deform
 - temporary
 - mobile
- 2 or more devices
 - Within radio range – they communicate
 - Outside communication range – need relay node



Ad Hoc Network Node

- Diversity of mobile devices
 - Notebook, PDA, phone, badge, etc.
- Heterogeneous / Homogeneous
- Fixed transmission range
- Limited battery
- Unrestricted movement
- No collision detection



Ad Hoc Network Topology

- Self-organizing
- Adaptive (dynamic) topology
 - join and leave the network at any time
 - no predefined structure
 - no global topology info



Ad Hoc Network Key Points

- Shared transmission medium
- Each node responds for forwarding data packets for others
- Network partitions can occur
- Collision avoidance (no collision detection)



Mobile Ad Hoc Network (MANET)

- Set of mobile nodes
 - communicate with each other
 - roam around at will
- No supporting base stations
- No guarantee of direct connection
 - single-hop
- Use intermediate nodes to relay packets
 - multi-hop



MANET Applications

- Immediate network deployment
 - Battlefields
 - Major disaster areas
 - Sensor networks
- Areas without base stations
- Areas where fixed network structures are unavailable



Challenges

- Spectrum Allocation (ISM Band)
- Media Access
 - No centralized : TDMA cannot be used
 - Mobility
 - Access without collision
- Routing
 - Link break often
 - Topology change



Challenges

- Multicasting
 - Tree formation might not work?
- Energy Efficiency
 - battery
 - Packet forwarding
- TCP Performance
 - Connection oriented assumes node to be static
 - Packet loss and long RTT
- Service Location
- Security and Privacy



Outline



Definition and Challenges

- **Media Access Control**
- Routing Protocols
- Research topics



Media Access Problem

- Hidden terminal problem
 - contention-based protocol
 - CSMA, IEEE 802.11
 - RTS/CTS (incompleteness)
- Exposed node problem
 - overhearing from neighbor
 - separate control channels
 - directional antennas

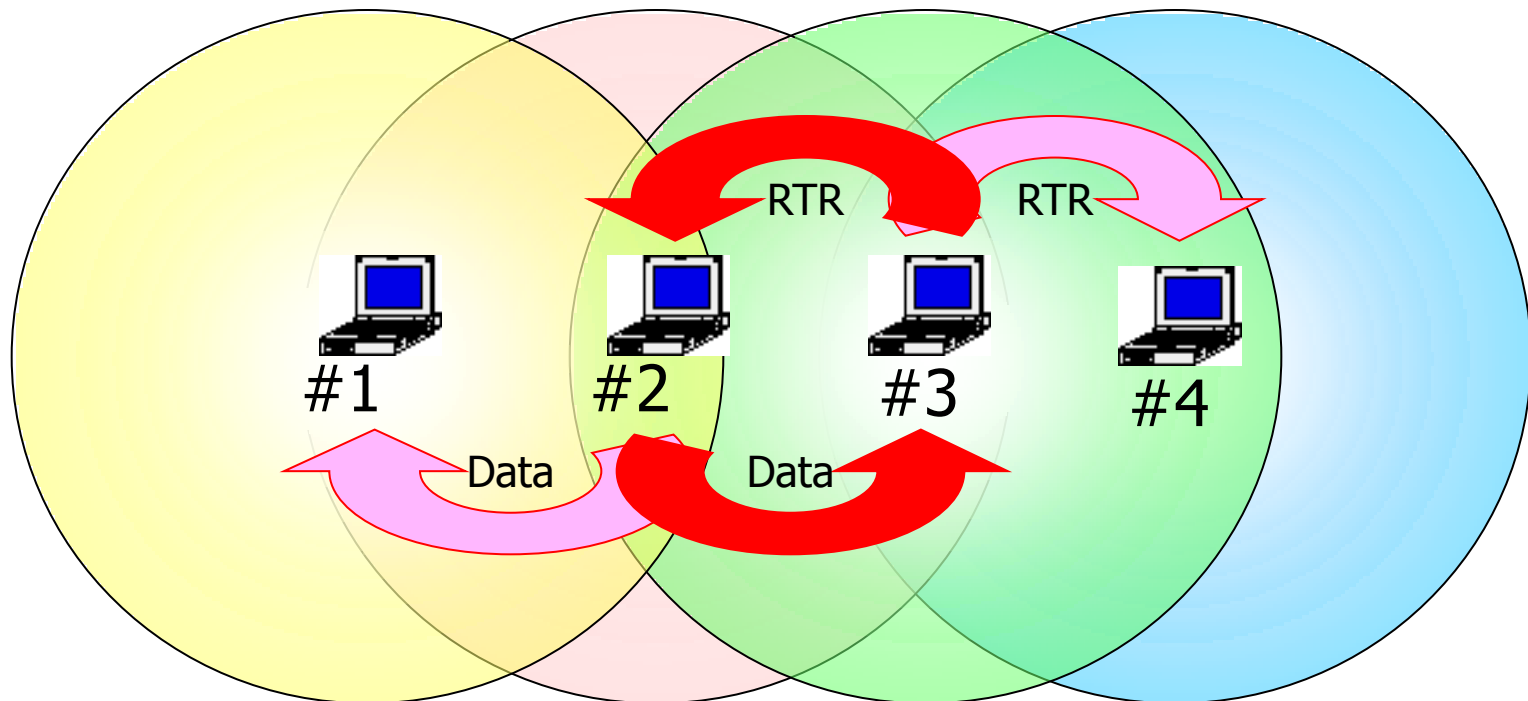


MAC Protocols

- Receiver-Initiated
 - receiver informs sender (ready to receive)
 - only one control message (no RTS/CTS)
 - Multiple access with collision avoidance – By Invitation (MACA-BI)
- Sender-Initiated
 - sender informs receiver (has data for receiver)
 - MACA
 - MACA with ack (MACAW)

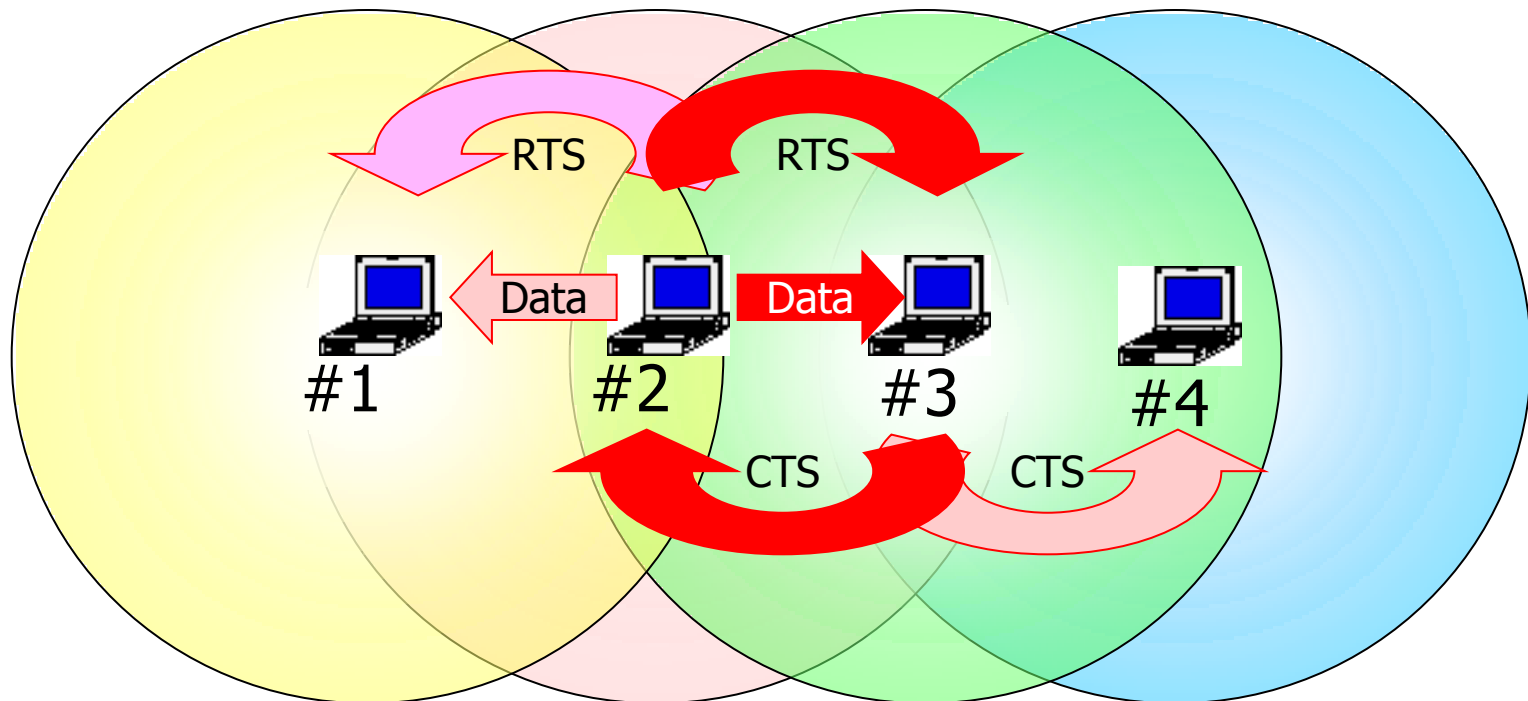


Receiver-Initiated MAC





Sender-Initiated MAC





MAC examples

- Multiple access with collision avoidance (MACA)
- Multiple access with collision avoidance by Invitation (MACA-BI)
- Power-Aware Multi-Access Protocol with Signaling (PAMAS)
- Dual Busy Tone Multiple Access (DBTMA)
- Media Access with Reduced Handshake (MARCH)



MACA

- Amateur packet radio network (Phil Karn)
- Single frequency network
- Aim to solve
 - hidden node / exposed node problems
- 3-way handshake
 - RTS-CTS-Data
 - no carrier sense
- Power control features
 - adjust power according to receiver



MACA-BI (by invitation)

- Fabrizio Talucci
- 2-way handshake
 - RTR-Data (no RTS, CTS → RTR)
 - cannot tx if not receive RTR
- Receiver guesses (predict) the arrival rate (by queue length)
- Performance
 - Good for constant bit rate (CBR)
 - Same as MACA for bursty data

Power-Aware Multi-Access Protocol with Signaling (PAMAS)



- Based on MACA
- Add separate signaling channel
 - for RTS-CTS
- Selectively power off not active (no Tx Rx)
- Operations
 - Sender → RTS
 - Receiver → CTS
 - Receiver → busy tone on signaling channel
- Others power off
 - Others transmit
 - node has no data to send/receive
 - probing to detect when should power up

Dual Busy Tone Multiple Access (DBTMA)



- BTMA (by Fouad Tobagi)
 - aim to solve hidden terminal problem
 - relay on last-hop architecture
 - centralize nodes for others
- DBTMA (by Zygmunt Haas)
 - two out-of-band busy tones
 - different frequencies

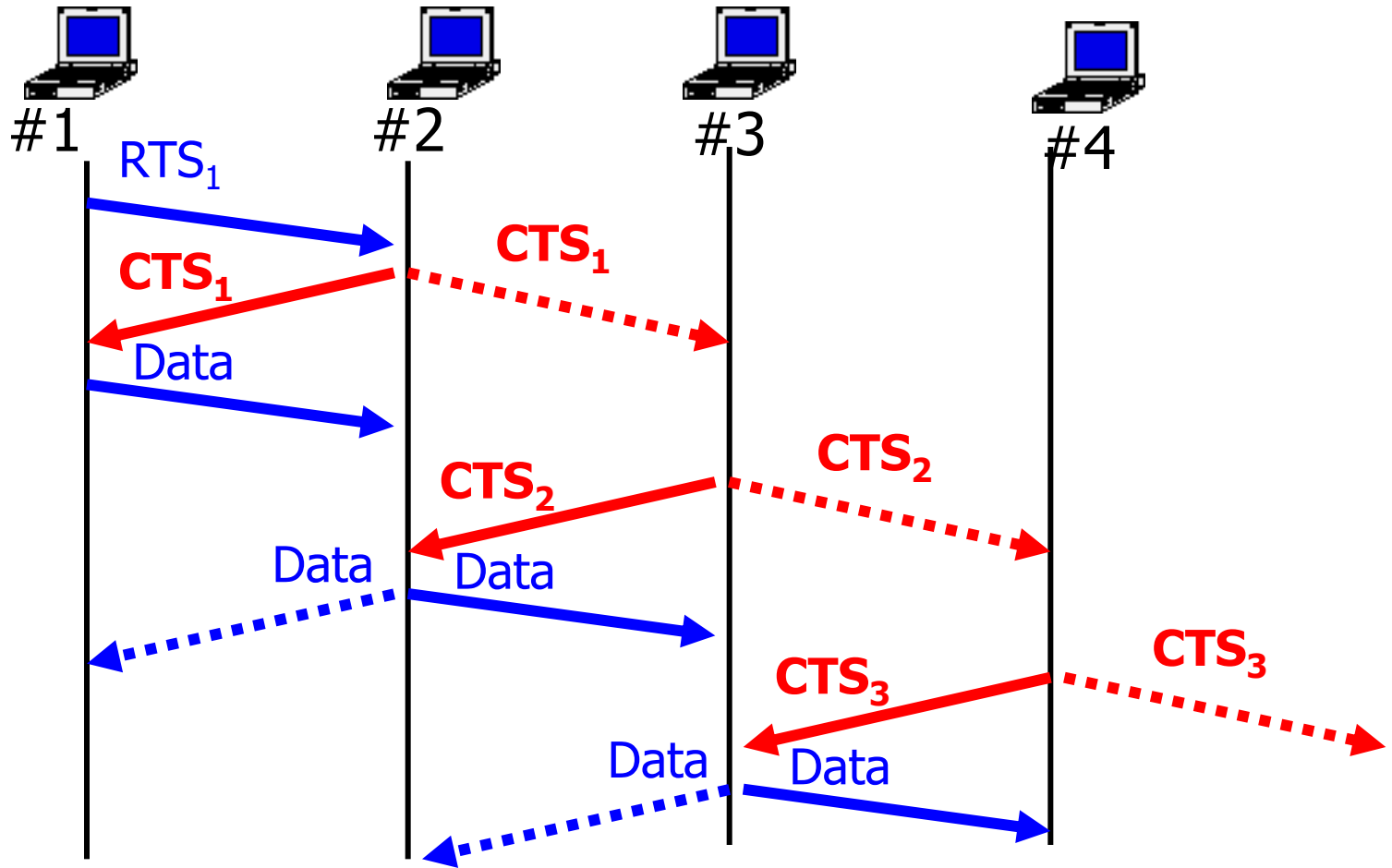
Media Access with Reduced Handshake (MARCH)



- Multi-hop ad hoc network
- Reduce control overhead
- Utilize overheard CTS
 - for invitation to relay node
 - reduce RTS packets



MARCH





Outline



Definition and Challenges



Media Access Control

- **Routing Protocols**
- Research topics



Issues in Ad Hoc Networks

- Communication in mobility environment
 - connection initialization
 - path selection
 - path reliability
- Energy consumption vs. latency
- Throughput
- Scalability
- Incompatibility standards

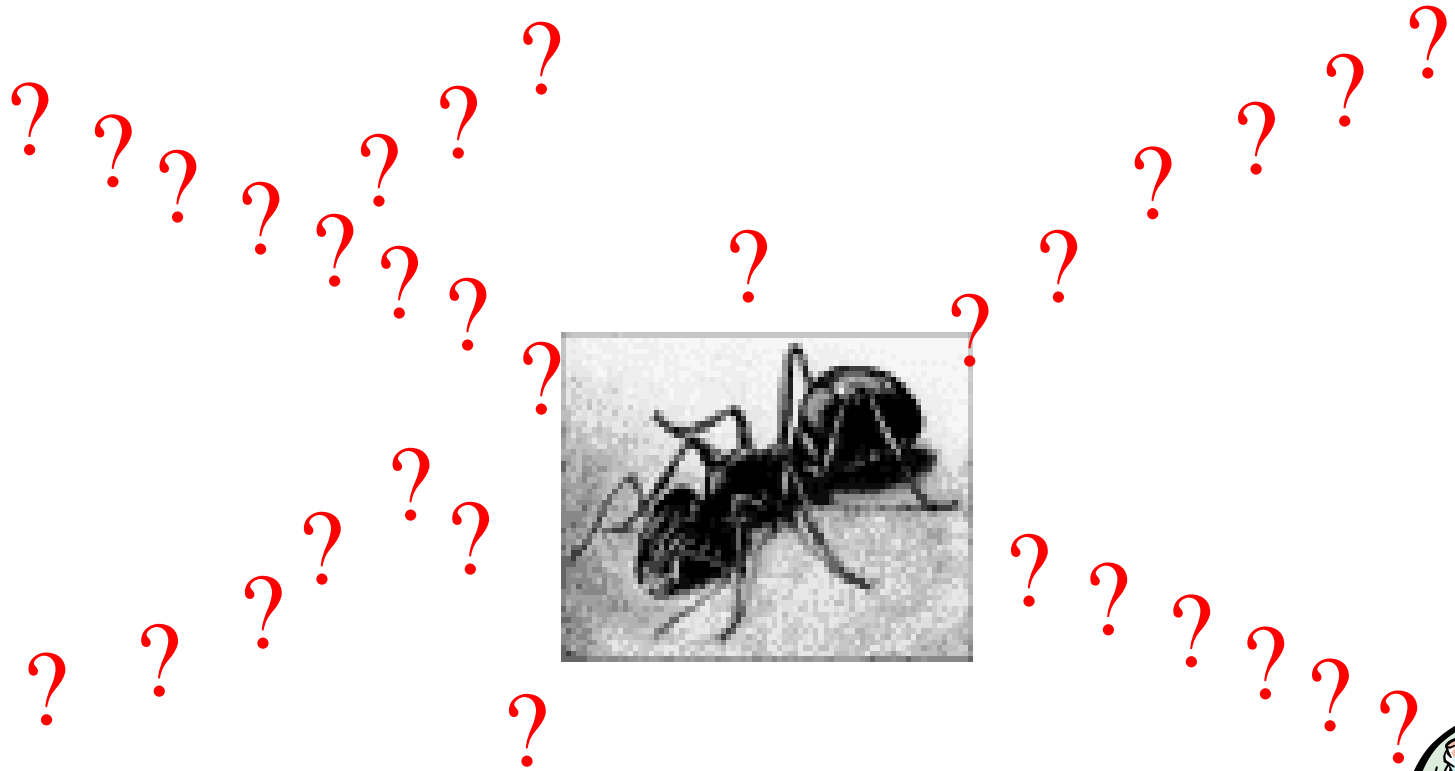


IEFT MANET Working Group

- Goals
 - standardize an interdomain unicast (IP) routing protocol
 - define modes of efficient operation
 - support both static and dynamic topologies
- A dozen candidate routing protocols have been proposed



Routing

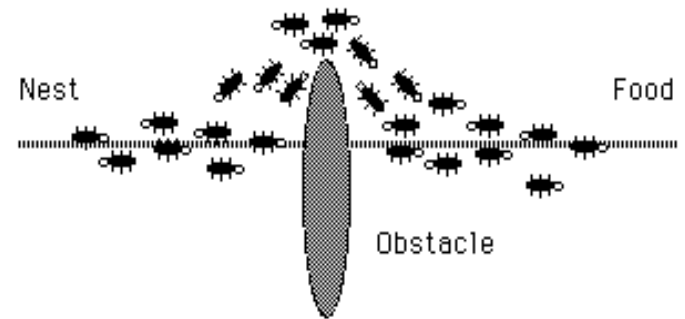
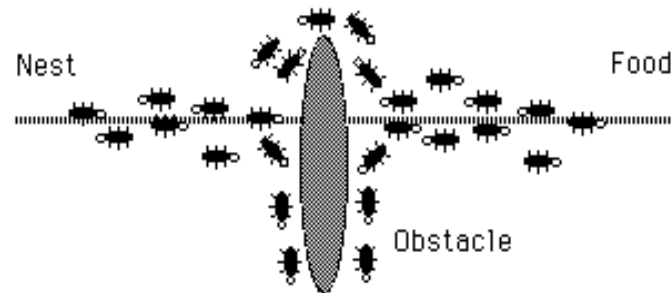
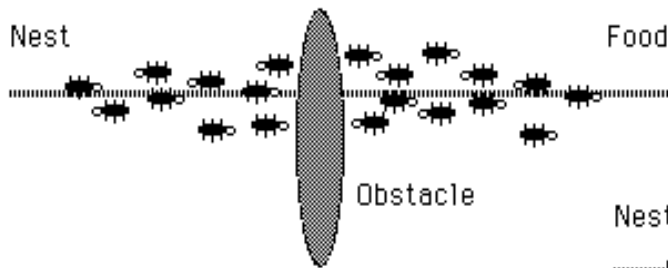


Ants Searching for Food





Routing (Ants' scenario)





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



Routing Protocols

- Proactive (Global/Table Driven)
 - route determination at startup
 - maintain using periodic update
- Reactive (On-demand)
 - route determination as needed
 - route discovery process
- Hybrid
 - combination of proactive and reactive



Proactive

- Destination-sequenced distance vector (DSDV)
- Wireless routing protocol (WRP)
- Global state routing (GSR)
- Fisheye state routing (FSR)
- Source-tree adaptive routing (STAR)
- Distance routing algorithm for mobility (DREAM)
- Cluster-head gateway switch routing (CGSR)



Reactive

- Associativity-base routing (ABR)
- Dynamic source routing (DSR)
- Ad hoc on-demand distance vector (AODV)
- Temporally ordered routing algorithm (TORA)
- Routing on-demand acyclic multi-path (ROAM)
- Light-weight mobile routing (LMR)
- Signal stability adaptive (SSA)
- Cluster-based routing protocol (CBRP)

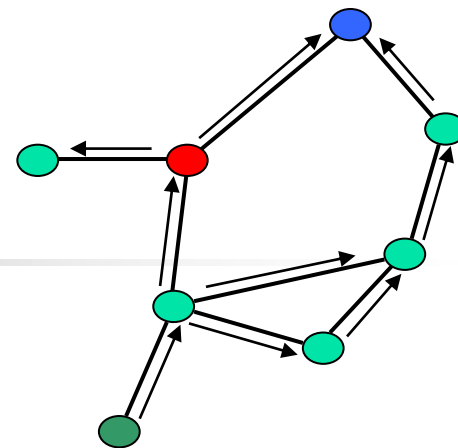


Hybrid

- Zone routing protocol (ZRP)
- Zone-based hierarchical link state (ZHLS)
- Distributed spanning trees (DST)
- Distributed dynamic routing (DDR)
- Scalable location update routing pro. (SLURP)



Flooding



- Simplest of all routing protocols
- Send all info to everybody
 - If data not for you, send to all neighbors
- Robust
 - destination is guaranteed to receive data
- Resource Intensive
 - unnecessary traffic
 - load increases, network performance drops quickly



Routing Examples

- Destination Sequenced Distance Vector (DSDV)
- Cluster Gateway Switch Routing (CGSR)
- Ad hoc On-demand Distance Vector (AODV)
- Dynamic Source Routing (DSR)
- Zone Routing Protocol (ZRP)
- Location-Aided Routing (LAR)
- Distance Routing effect Algorithm for mobility (DREAM)
- Power-Aware Routing (PAR)

Destination Sequenced Distance Vector (DSDV)



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



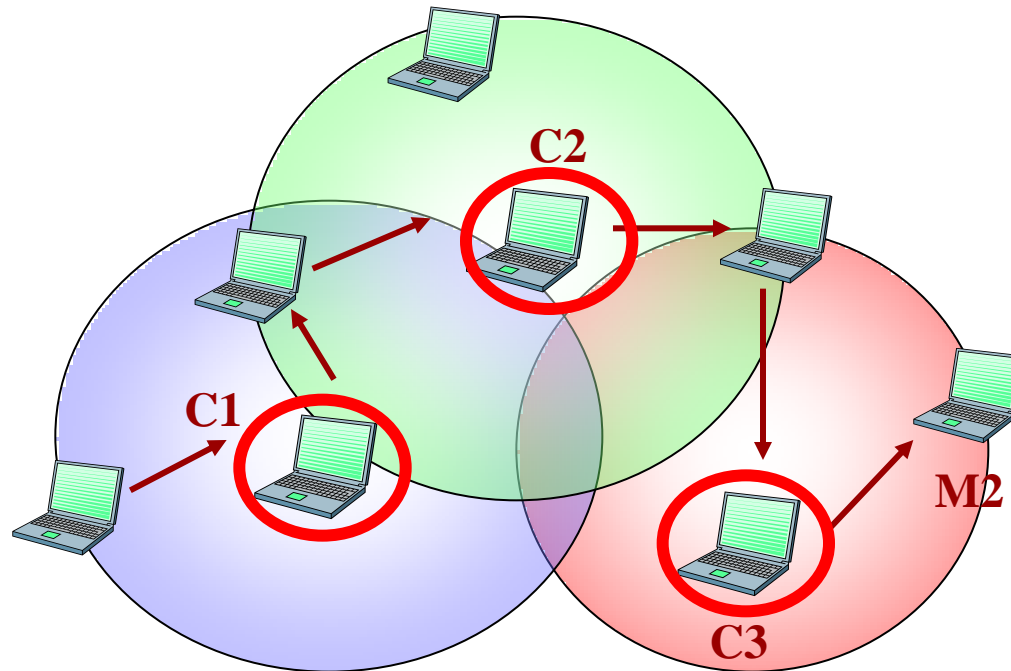
DSDV

- Problem
 - a lot of control traffic in the network
- Solution: two types of route update packets
 - full dump (All available routing info)
 - incremental (Only changed info)

Cluster Gateway Switch Routing (CGSR)



- Table-driven for inter-cluster routing
- Uses DSDV for intra-cluster routing



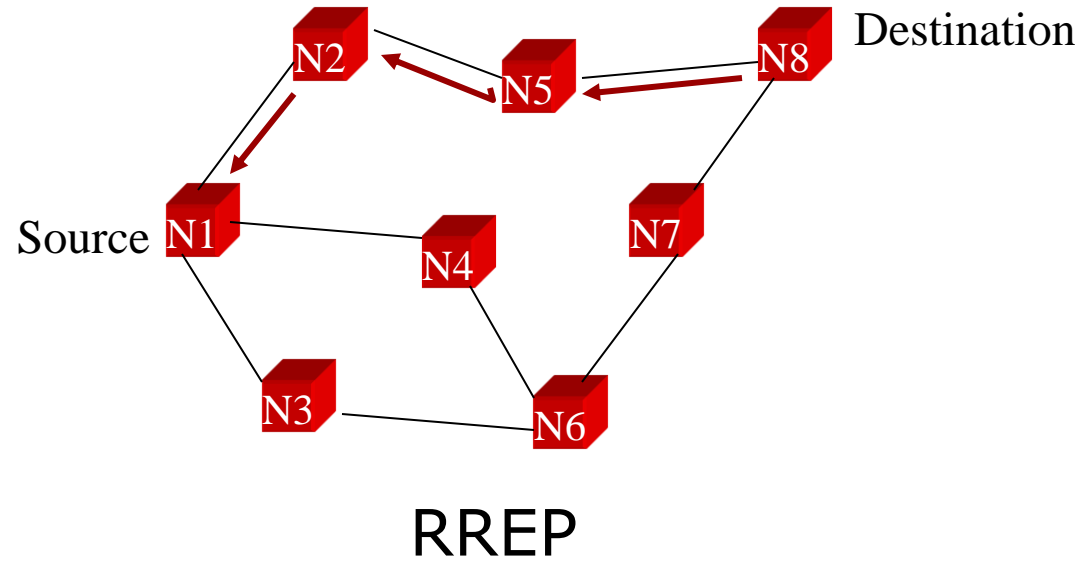
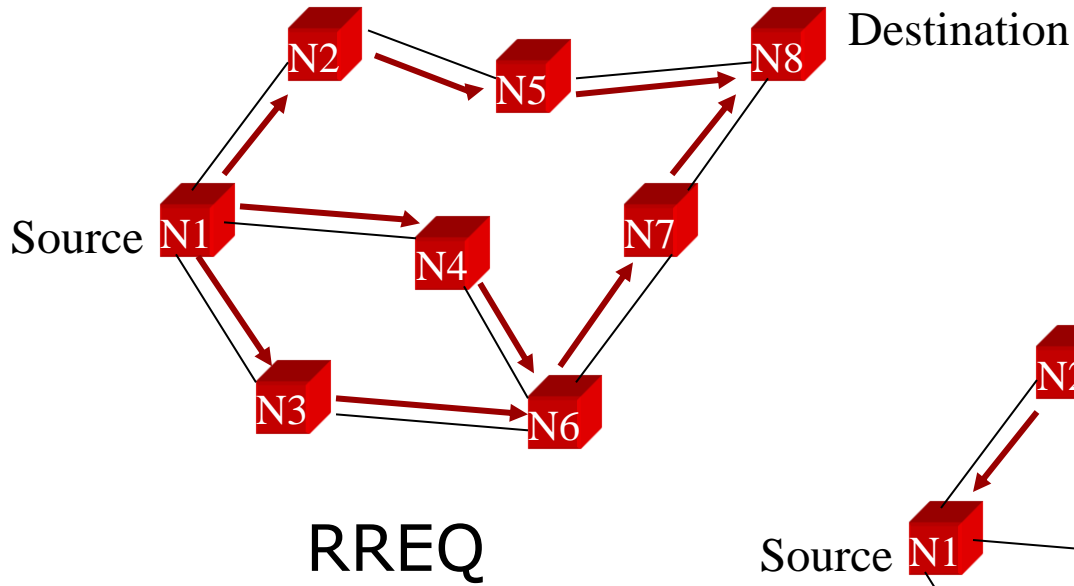
Ad hoc On-demand Distance Vector (AODV)



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



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
 - source receives the message and re-initiate route discovery

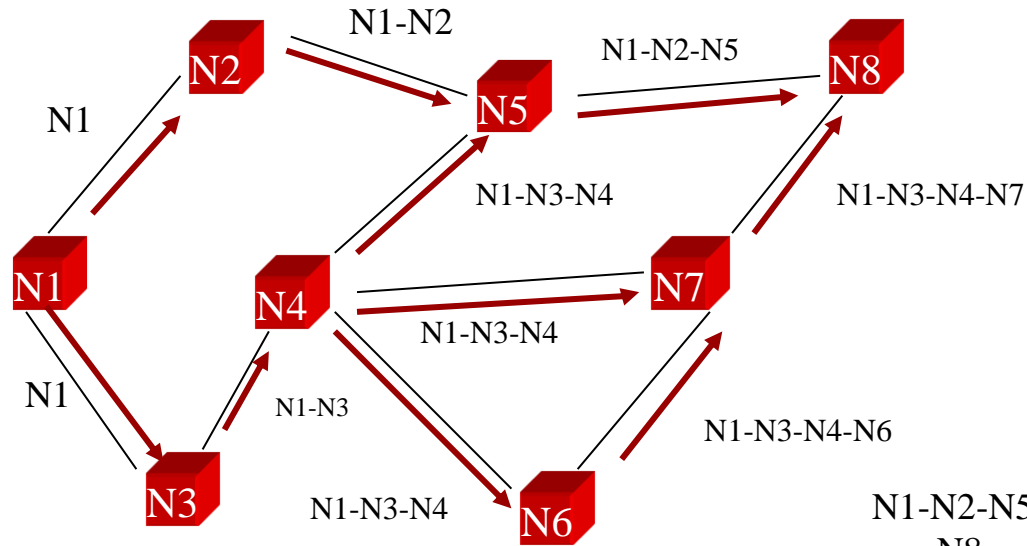
Dynamic Source Routing (DSR)



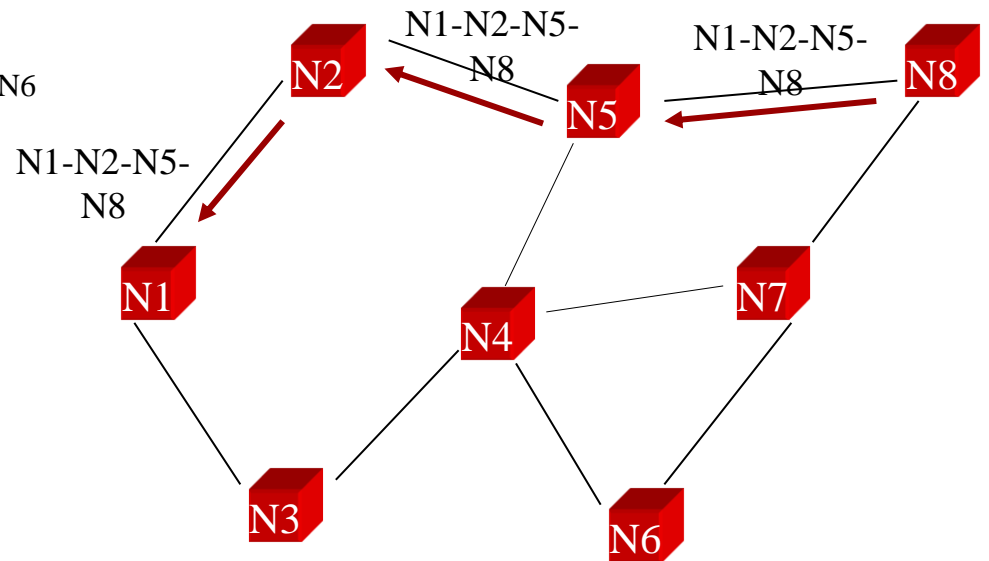
- On-demand driven
- Based on the concept of source routing
- Required to maintain route caches
- Two major phases
 - Route discovery (flooding)
 - Route maintenance
 - A route error packet



DSR



Route Discovery



Route Reply



Modified DSR

- Route information determined by the current network conditions
 - number of hops
 - congestion
 - node energy
- Other considerations
 - fairness
 - number of route requests

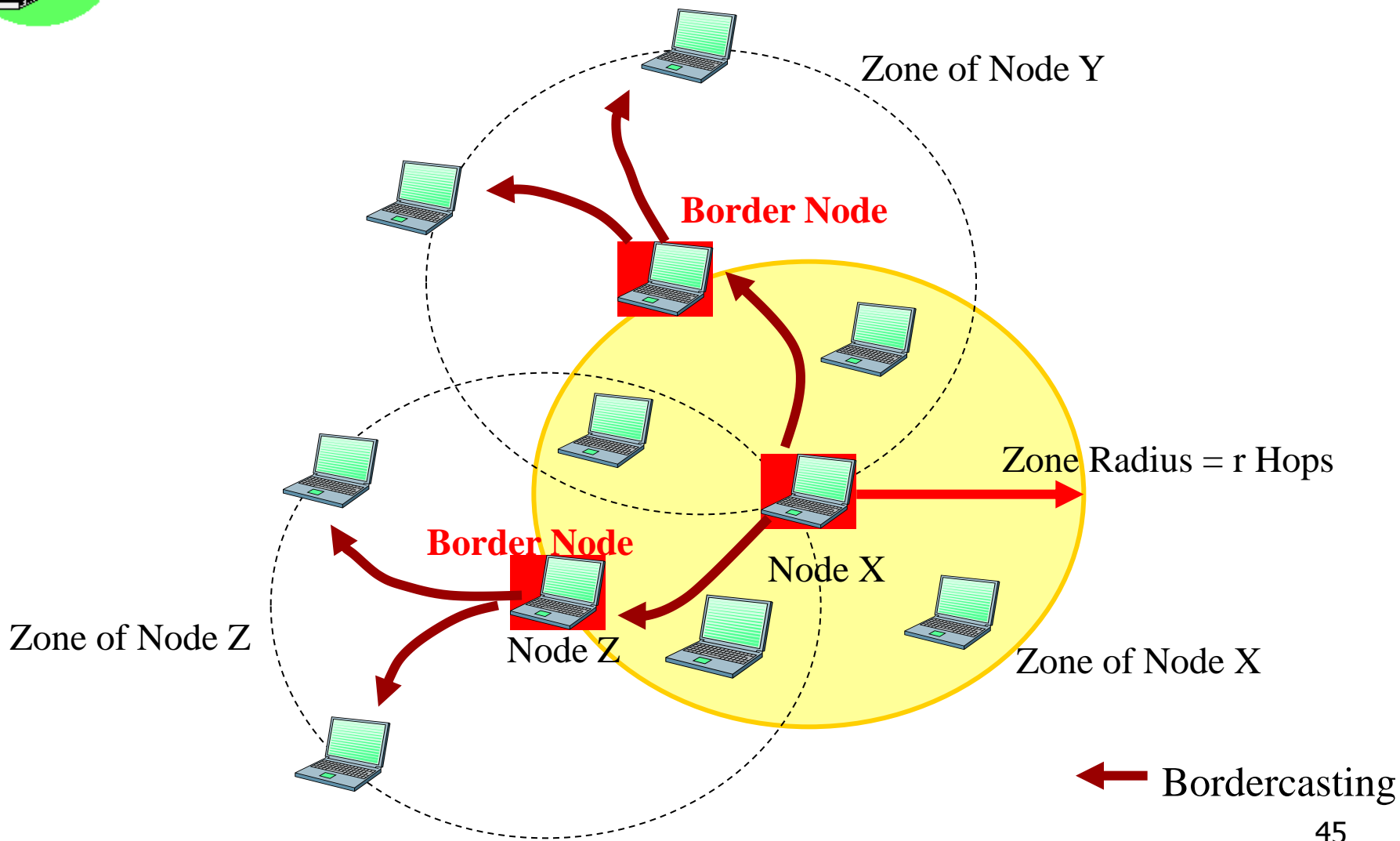


Zone Routing Protocol (ZRP)

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



Zone Routing Protocol (ZRP)





Location-Aided Routing (LAR)

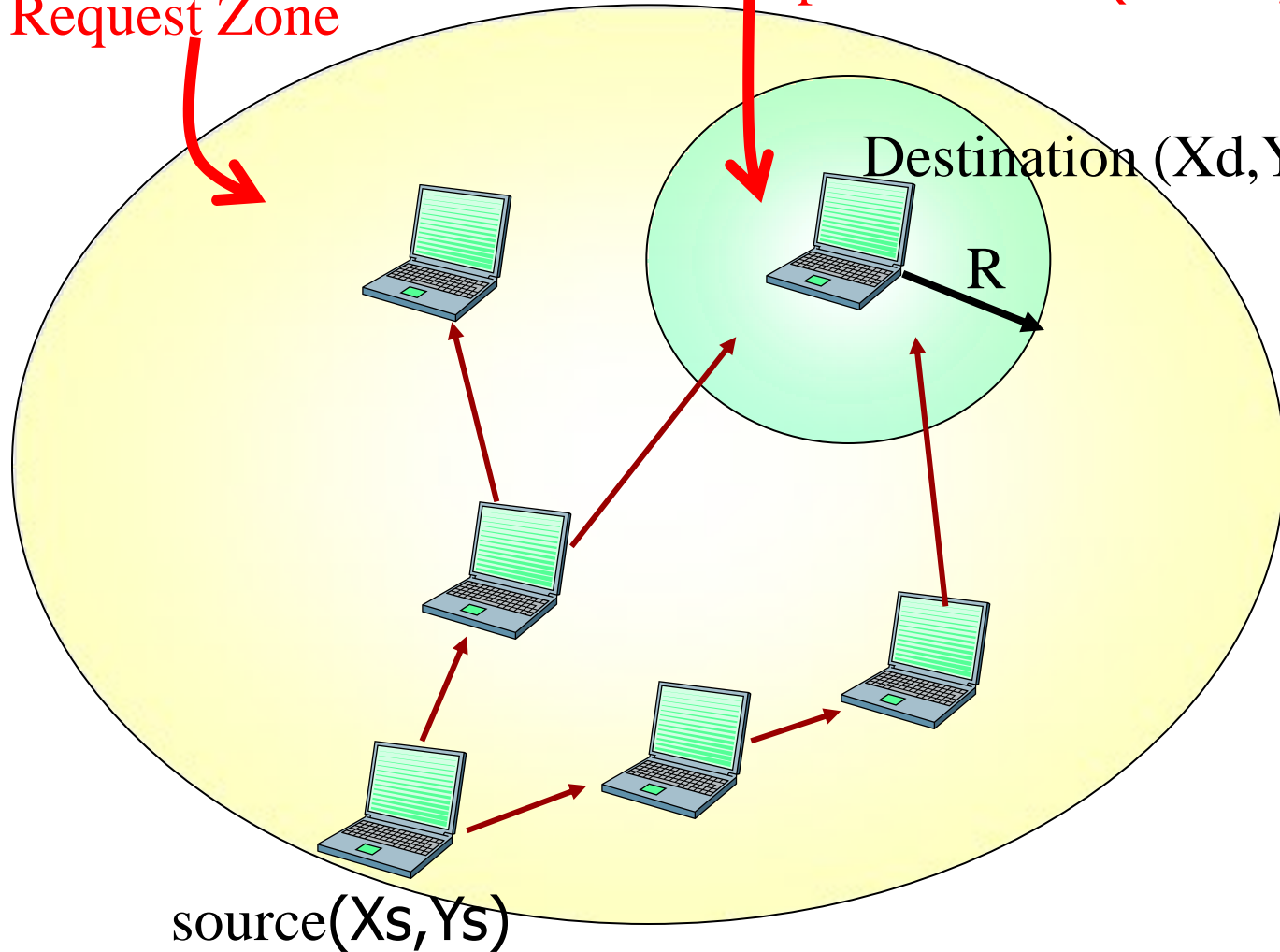
- Location information via GPS
- Shortcoming (*maybe not anymore 2005*)
 - GPS availability is not yet worldwide
 - Position information come with deviation



LAR

Request Zone

Expected Zone (X_d+R, Y_d+R)



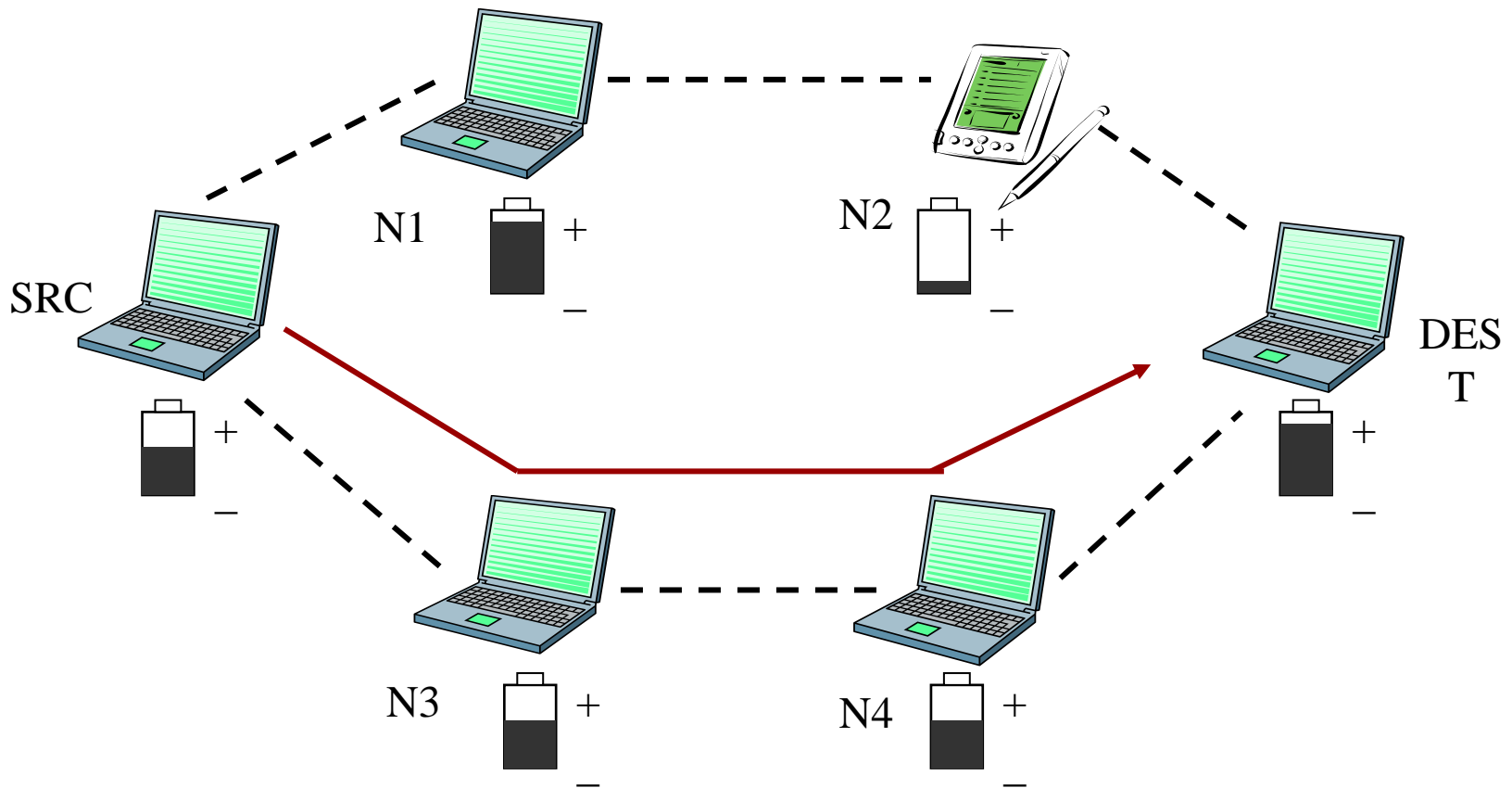
Distance Routing effect Algorithm for mobility (DREAM)



- Position-based
- Each node
 - maintains a position database
 - regularly floods packets to update the position
 - Temporal resolution
 - Spatial resolution



Power-Aware Routing (PAR)





Outline



Definition and Challenges



Media Access Control



Routing Protocols

- **Research Topics**



Current routing protocols

- Many do not consider energy conservation
 - lead to partitions
 - shorten network life
 - fairness to intermediate nodes not incorporated
 - fail to work well in both sparse and dense networks



Interesting Research Topics

- Energy Awareness Routing
- Multipath Routing
 - more paths used to send information, more reliable the transmission
- Clustering (Hierarchical Routing)
 - dynamic management of subnetworks



More Research Topics

- Topology Control
 - adjustment of transmission power to simplify routing
- Internetworking
 - managing wired and wireless networks
- Heterogeneous Networks
 - Different devices on the network have different capabilities
- Content Aware Networks
 - Location of services within the network (Printers)



More Research Topics

- Delay-Tolerant Network (DTN)
- Vehicular ad-hoc network (VANET)



References

- Ad Hoc Mobile Wireless Networks – Protocols and System, C-K Toh, Prentice Hall, 2002, ISBN: 0-13-007817-4
- “Introduction to Ad Hoc Networking”, Prof. Yu-Chee Tseng