



# Ad Hoc Network

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# Outline

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- **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

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- 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

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- 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)

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- 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

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





# Challenges

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



# Challenges

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- 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

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## Definition and Challenges

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



# Media Access Problem

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



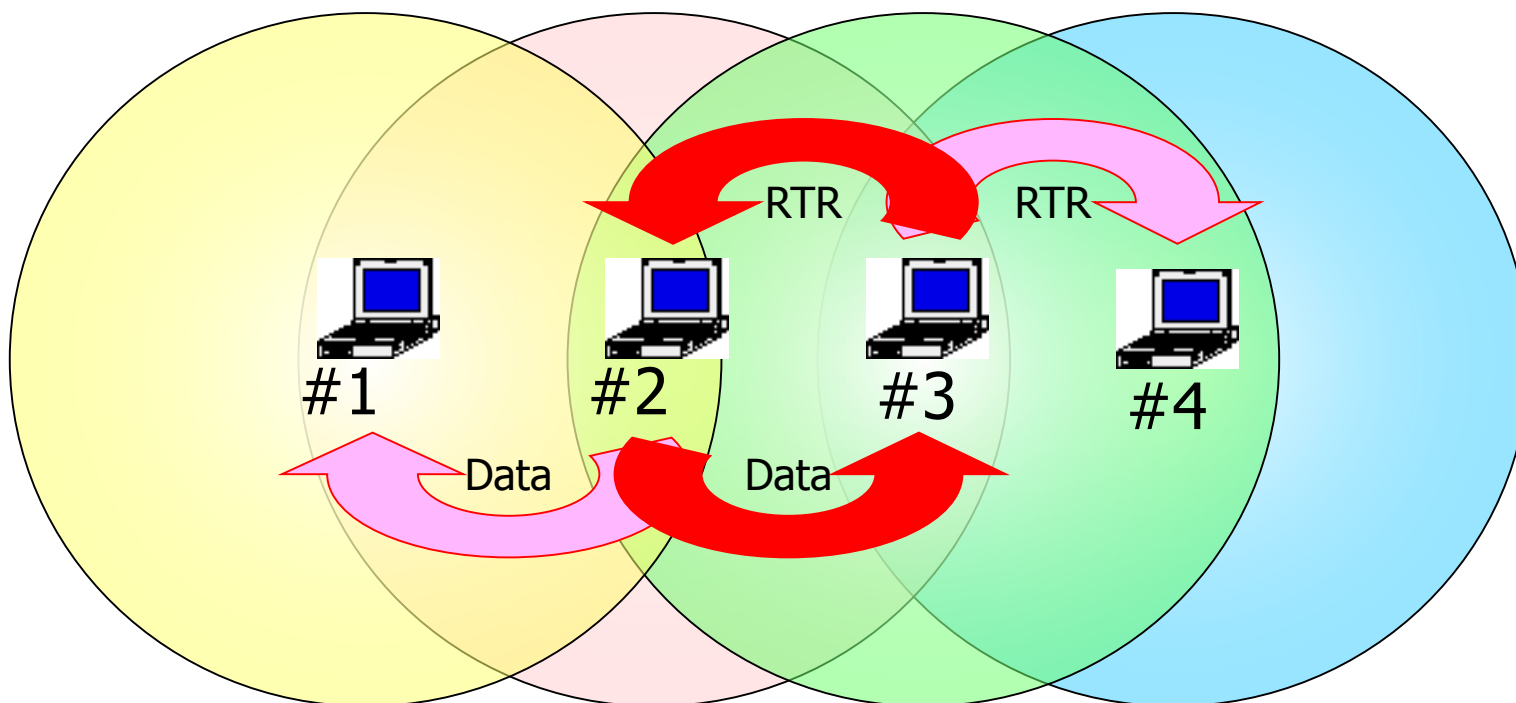
# MAC Protocols

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- 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)

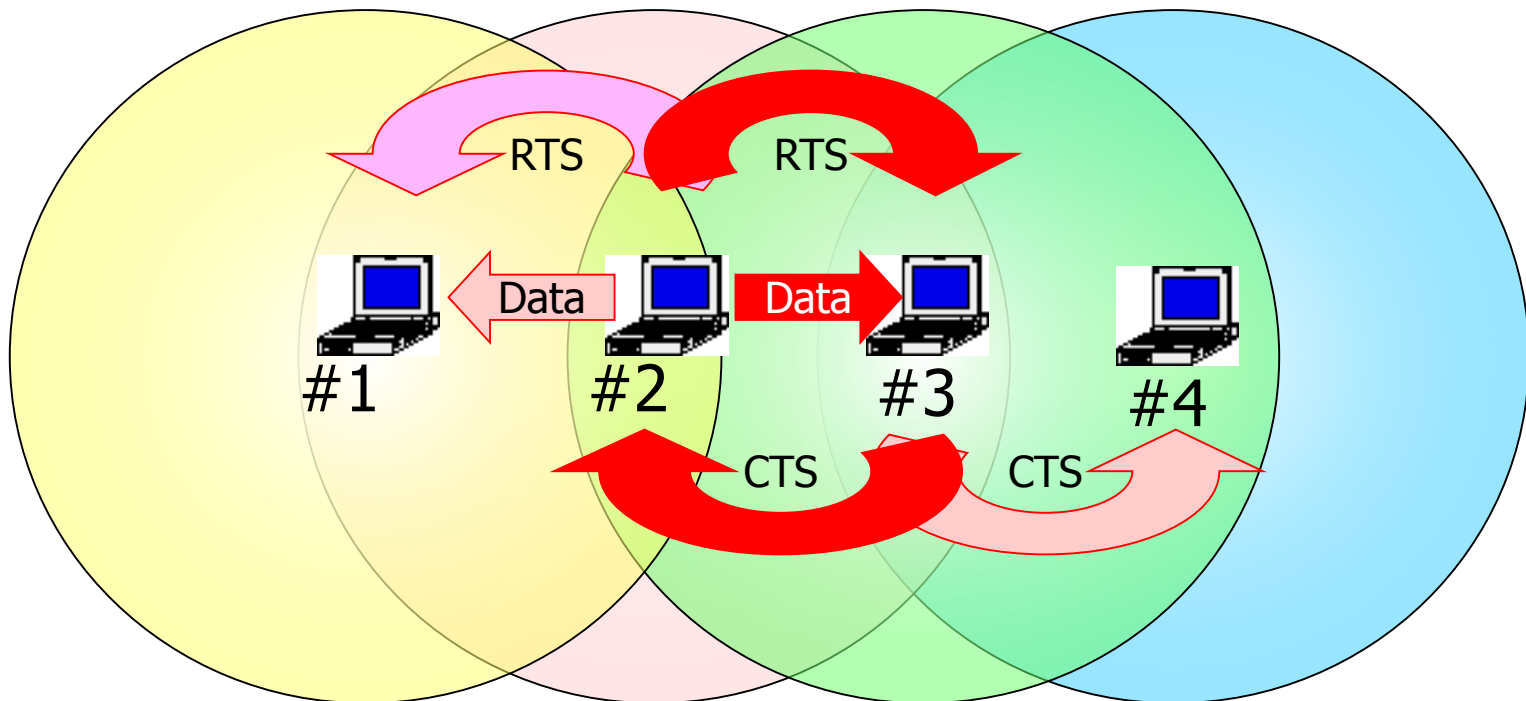


# Receiver-Initiated MAC





# Sender-Initiated MAC





# MAC examples

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- 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

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- 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

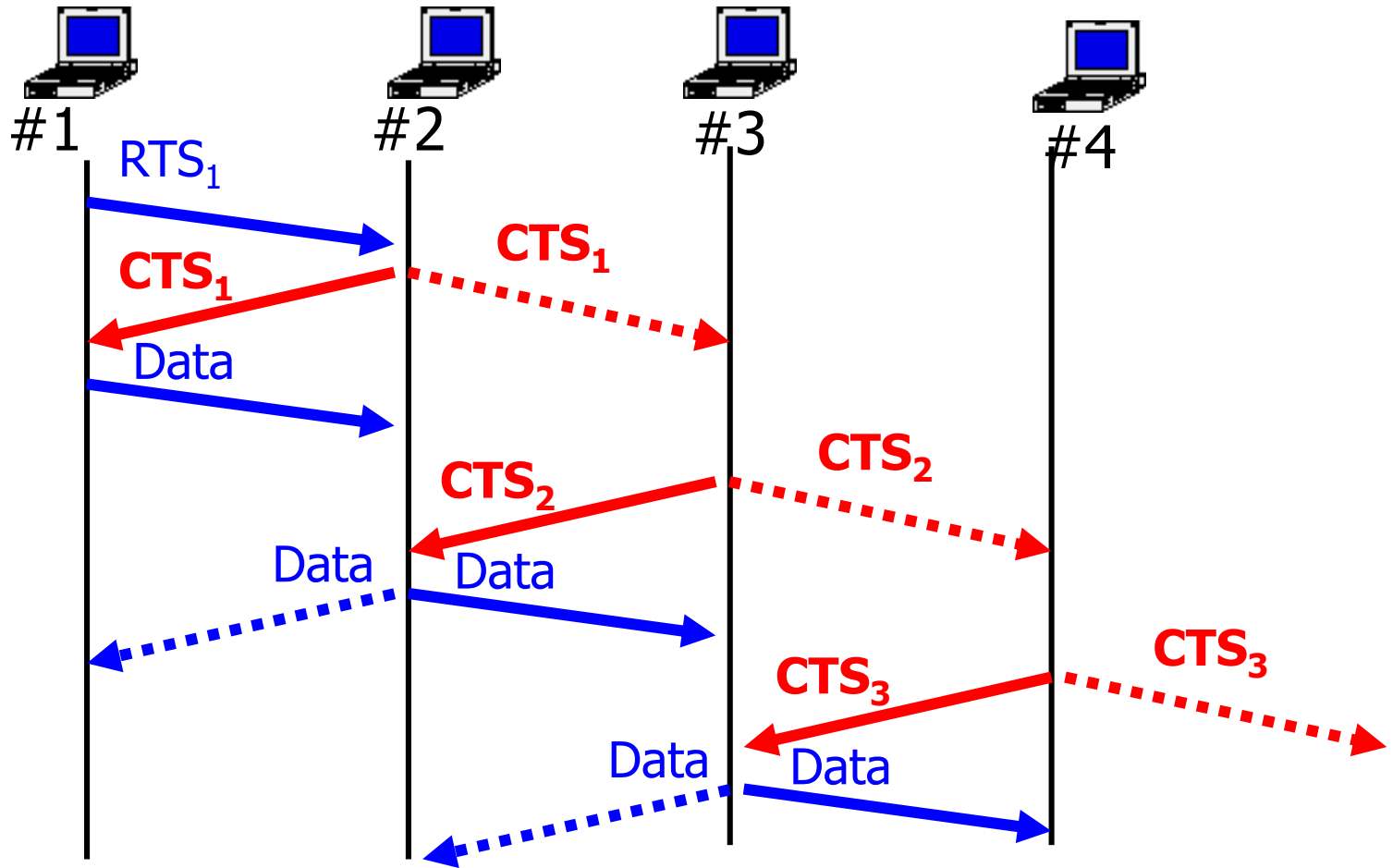
# Media Access with Reduced Handshake (MARCH)



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



# MARCH





# Outline

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Definition and Challenges



Media Access Control

- **Routing Protocols**
- Research topics



# Issues in Ad Hoc Networks

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





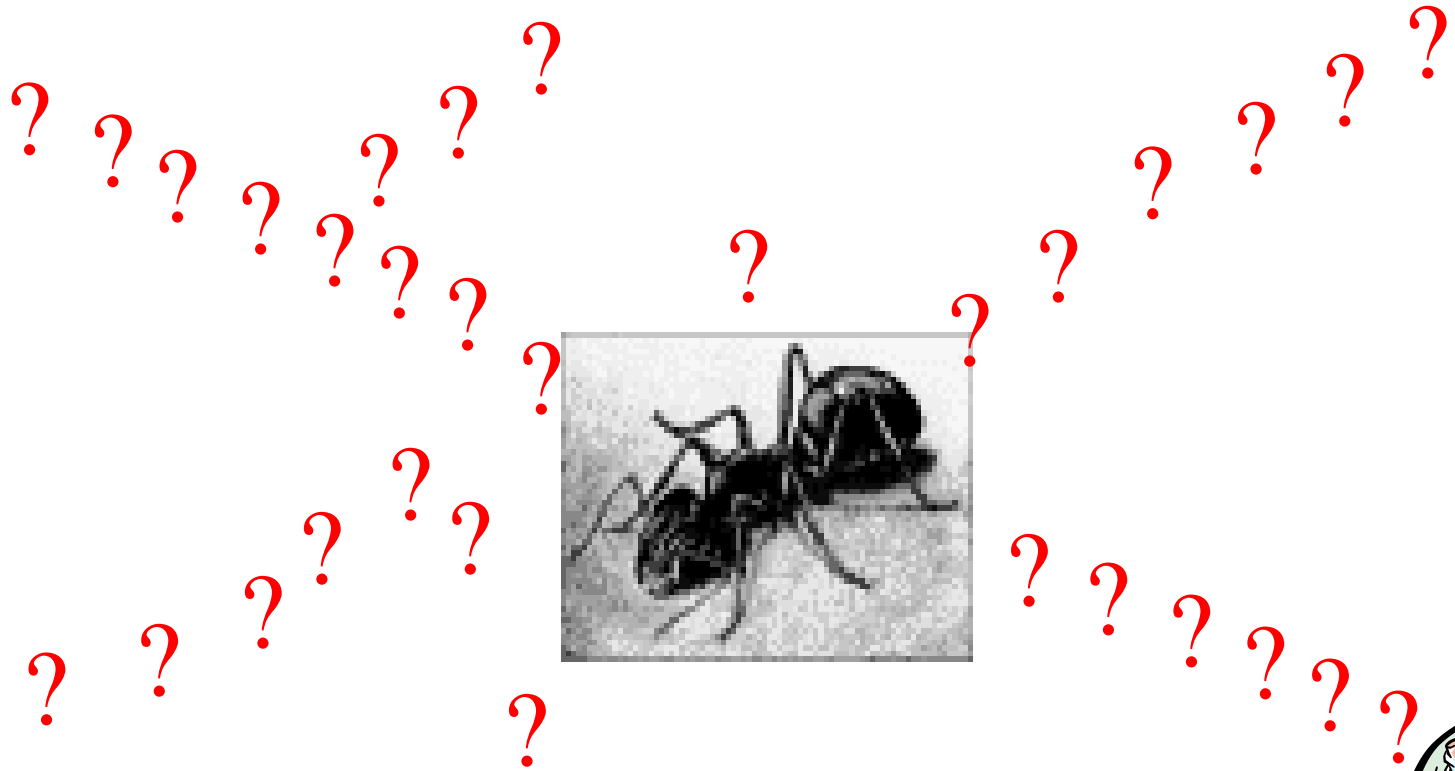
# IEFT MANET Working Group

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- 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

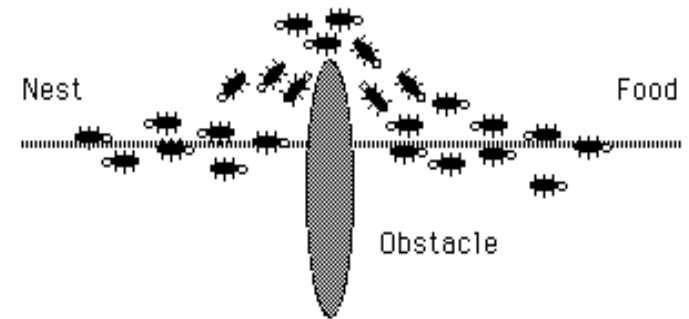
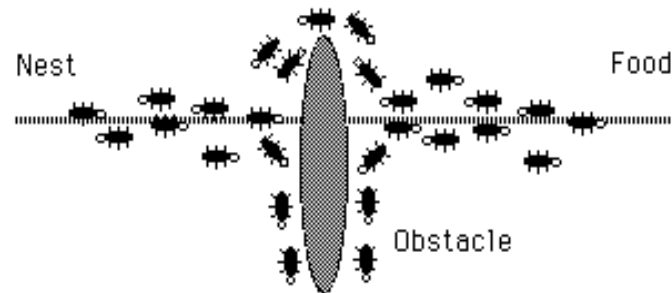
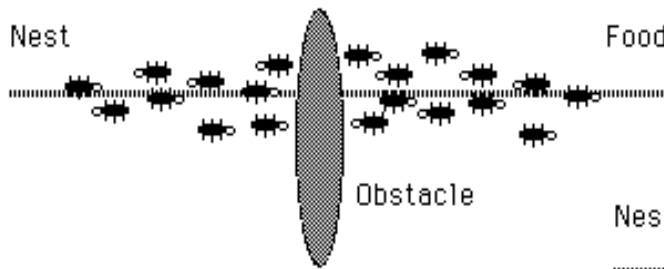


**Ants Searching for Food**





# Routing (Ants' scenario)





# Three Main Issues in Ants' Life

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- Route Discovery:
  - searching for the places with food
- Packet Forwarding:
  - delivering foods back home
- Route Maintenance:
  - when foods move to new place



# Routing Protocols

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- 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

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- 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

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- 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

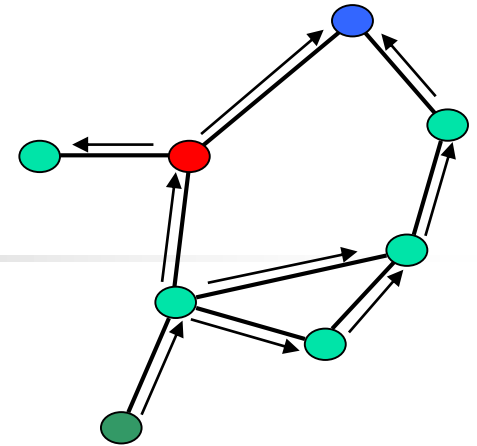
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- Zone routing protocol (ZRP)
- Zone-based hierarchical link state (ZHLS)
- Distributed spanning trees (DST)
- Distributed dynamic routing (DDR)
- Scalable location update routing pro. (SLURP)





# 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

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- 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

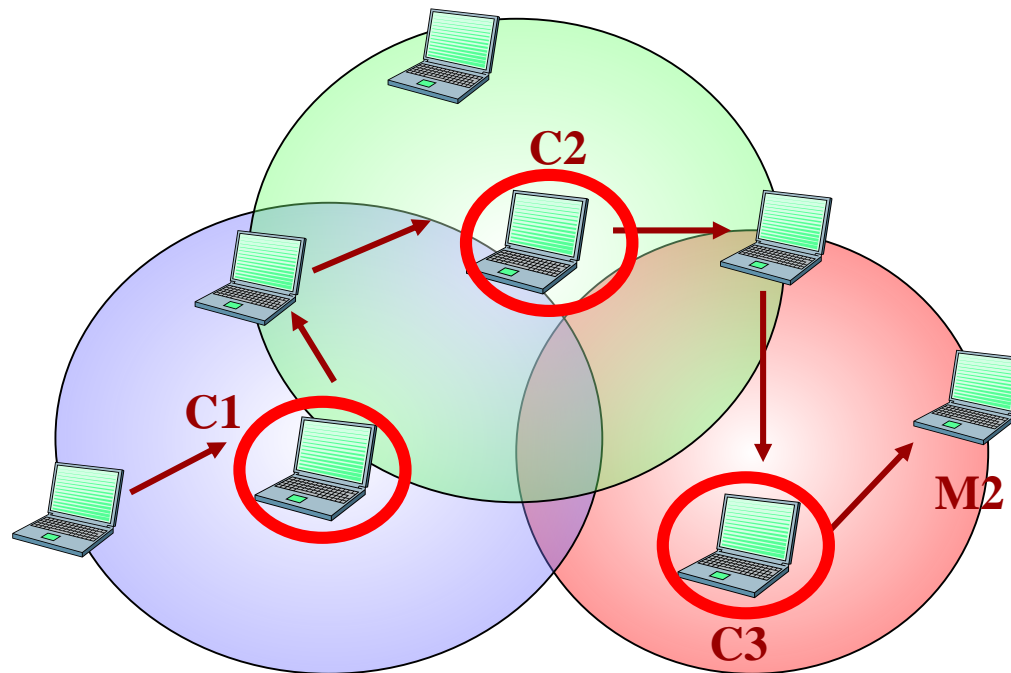
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- Problem
  - a lot of control traffic in the network
- Solution: two types of route update packets
  - full dump (All available routing info)
  - incremental (Only changed info)

# Cluster Gateway Switch Routing (CGSR)



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



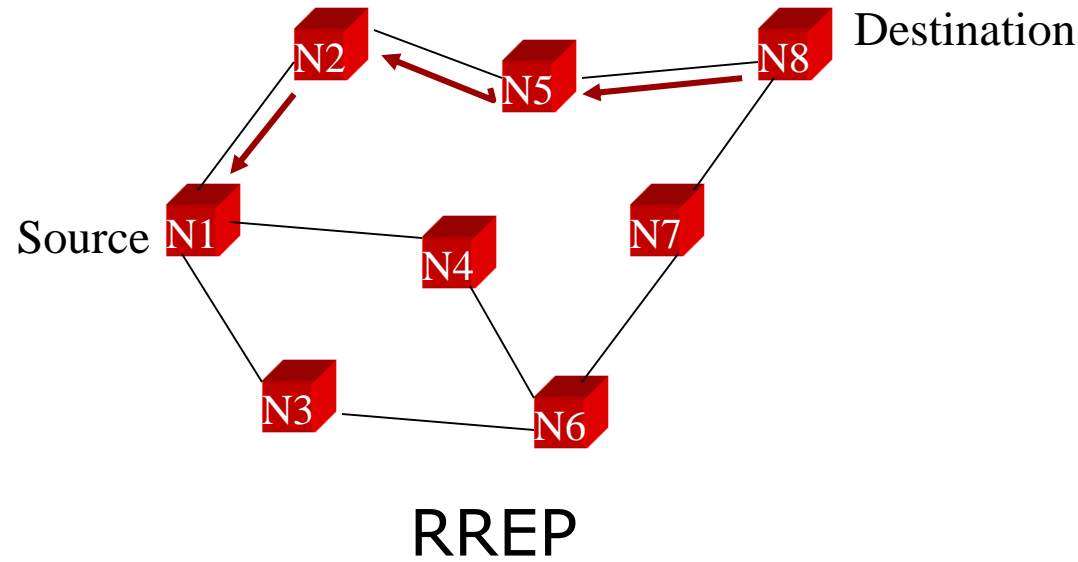
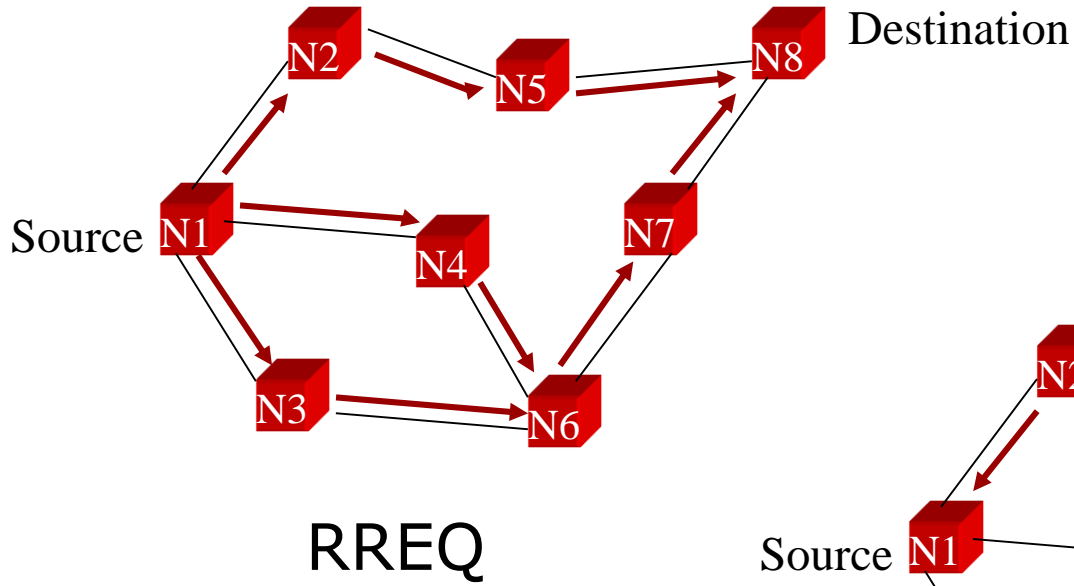
# Ad hoc On-demand Distance Vector (AODV)



- 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

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- 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



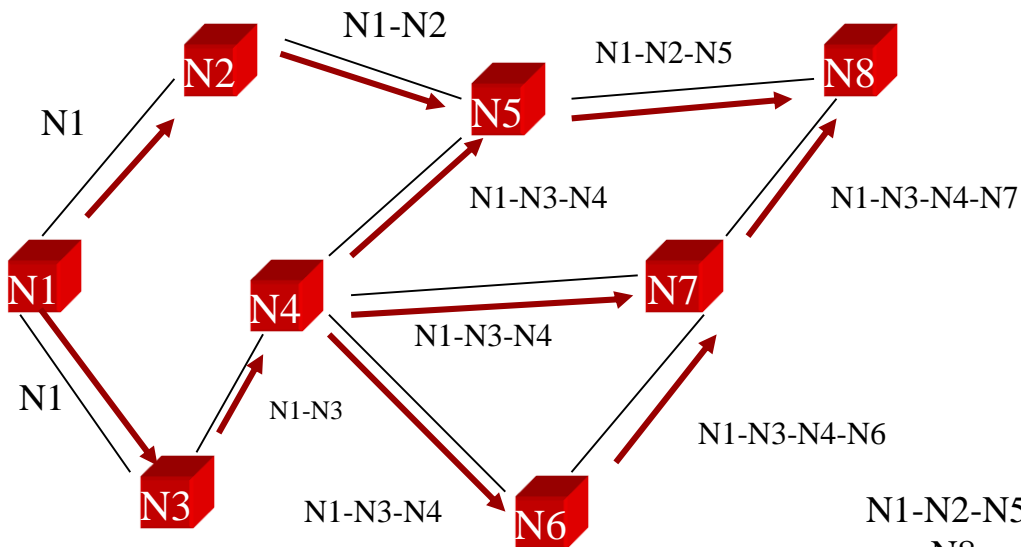
# Dynamic Source Routing (DSR)



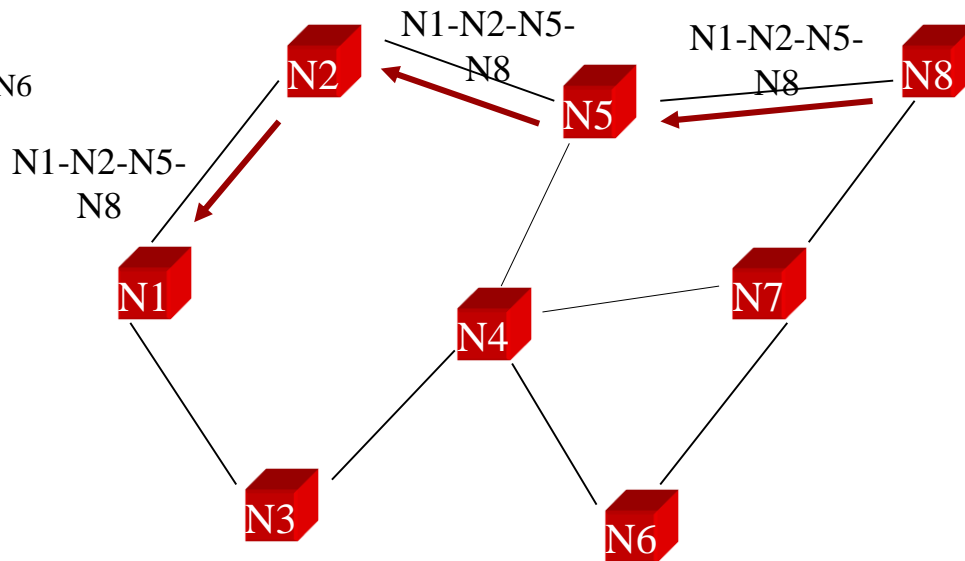
- On-demand driven
- Based on the concept of source routing
- Required to maintain route caches
- Two major phases
  - Route discovery (flooding)
  - Route maintenance
    - A route error packet



# DSR



Route Discovery



Route Reply



# Modified DSR

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



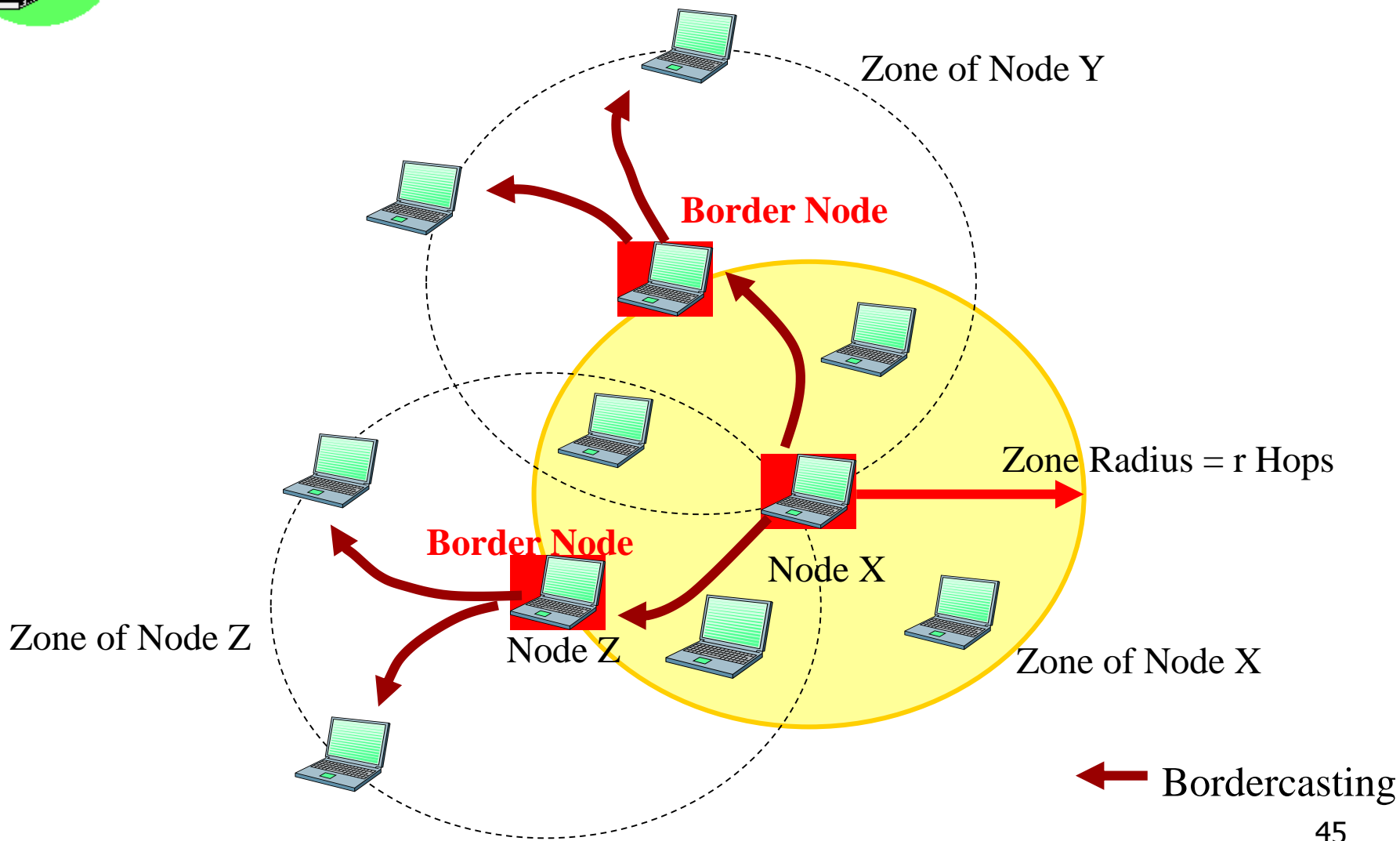
# Zone Routing Protocol (ZRP)

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- 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)

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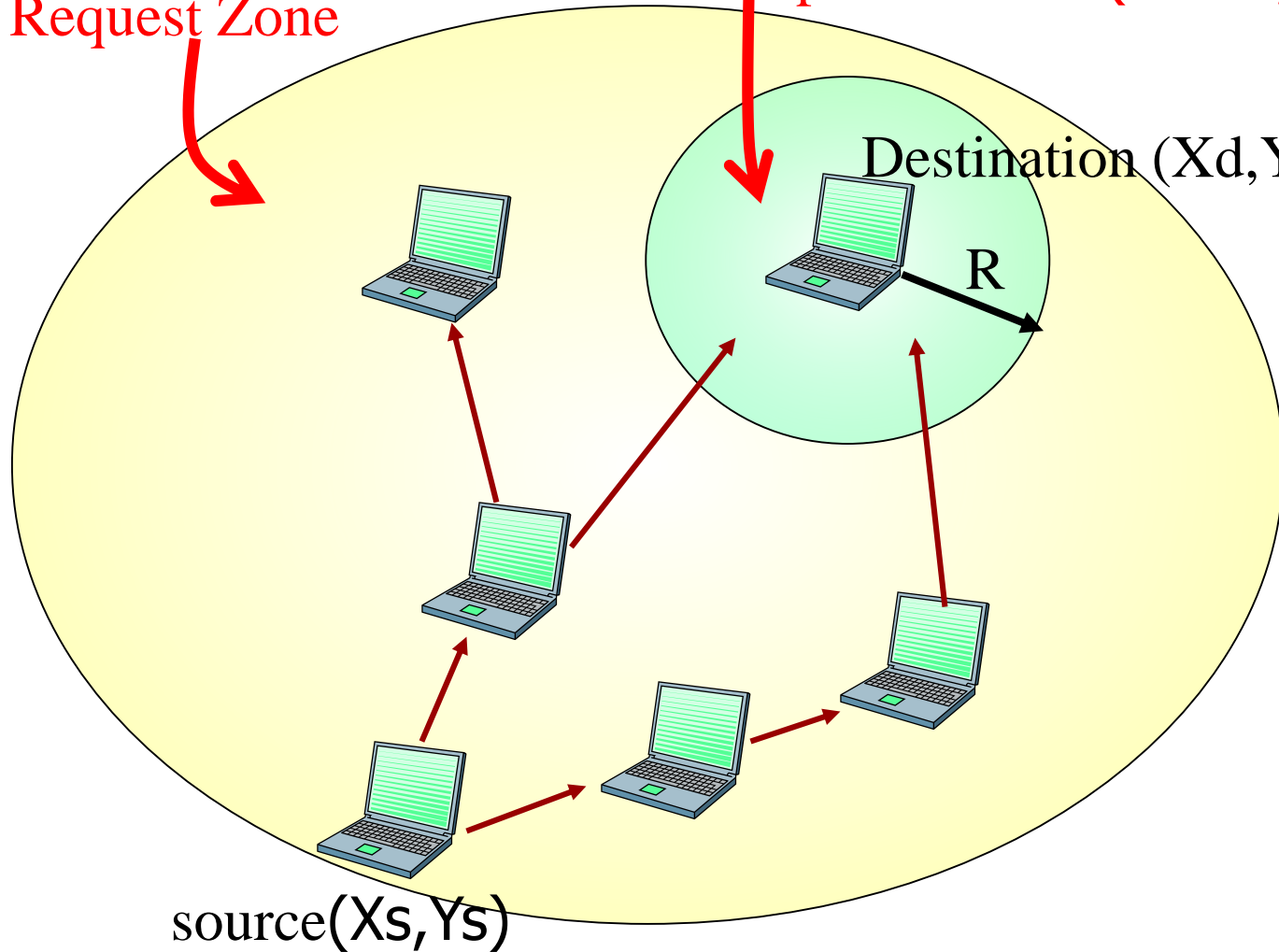
- Location information via GPS
- Shortcoming (*maybe not anymore 2005*)
  - GPS availability is not yet worldwide
  - Position information come with deviation



# LAR

Request Zone

Expected Zone ( $X_d+R, Y_d+R$ )



# Distance Routing effect Algorithm for mobility (DREAM)

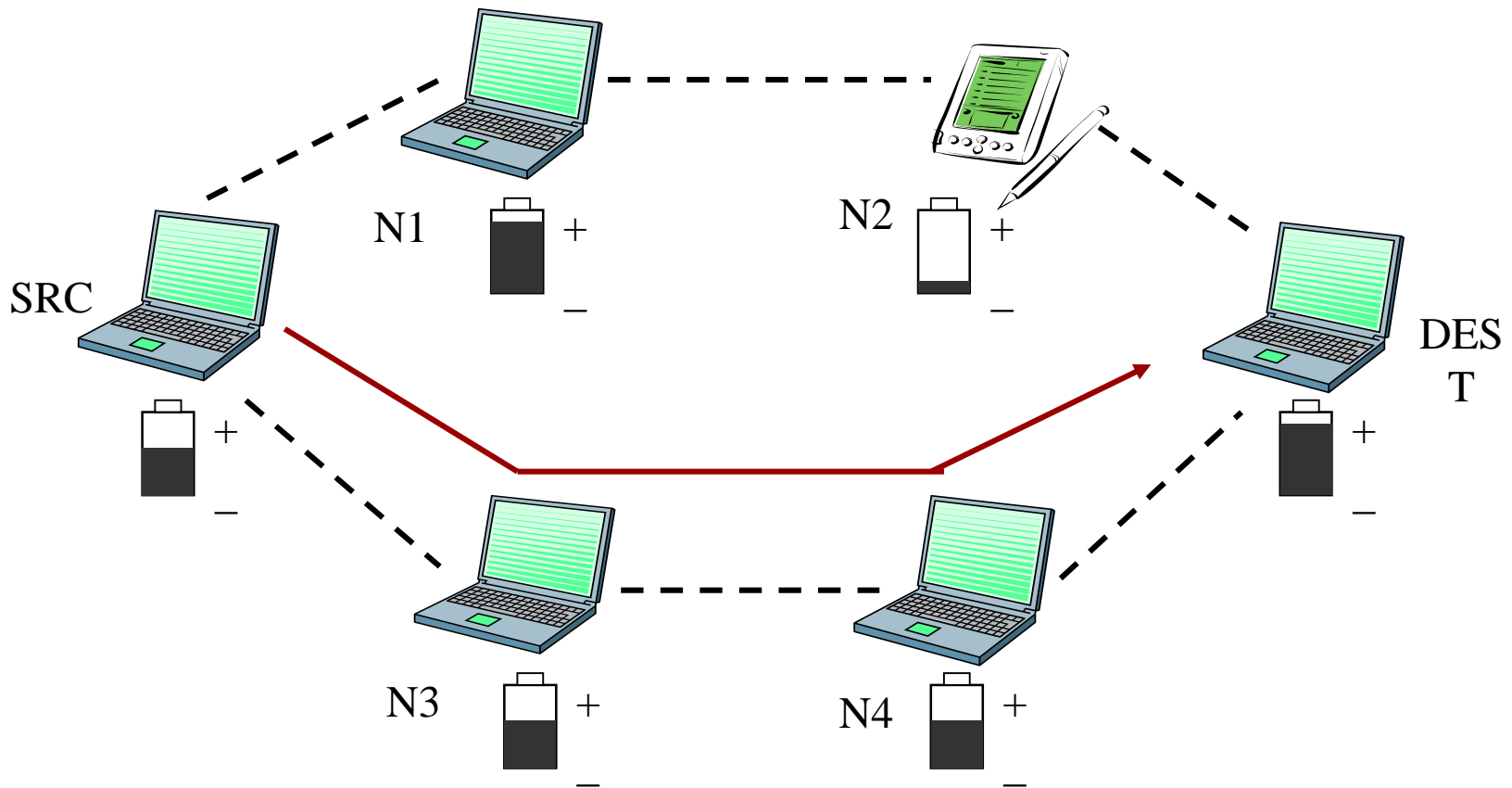


- Position-based
- Each node
  - maintains a position database
  - regularly floods packets to update the position
    - Temporal resolution
    - Spatial resolution





# Power-Aware Routing (PAR)





# Outline

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Definition and Challenges



Media Access Control



Routing Protocols

- **Research Topics**



# Current routing protocols

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- 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

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- 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

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- 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

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



# References

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- 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