無線網路多媒體系統
Wireless Multimedia System

Lecture 9: Mobile Ad Hoc Networks

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Observations

Personal Communications have been the dominant paradigm so far, but mobile ad hoc networks open new possibilities, such as the communication between objects

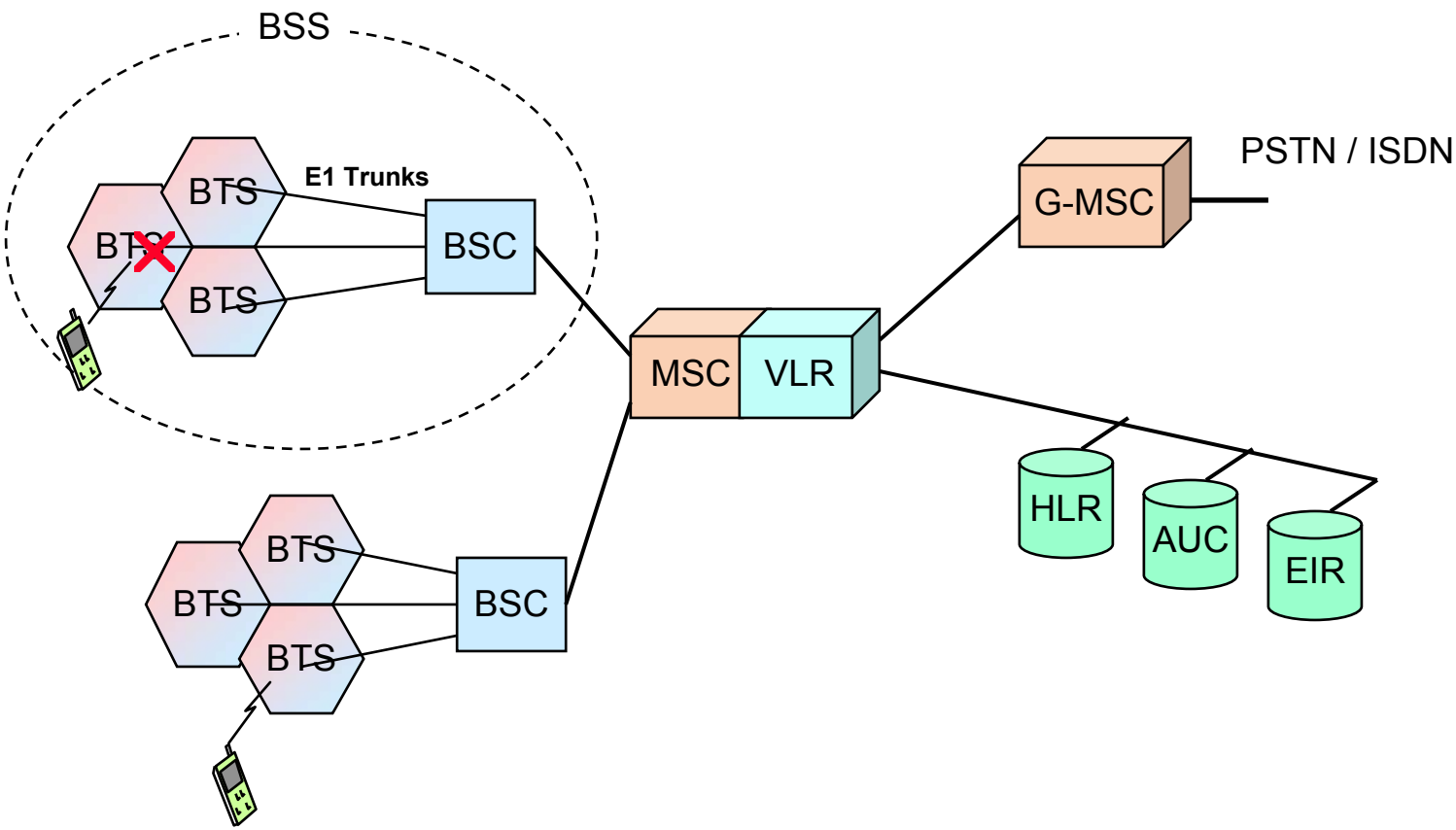
Reading

- [Jean2001] Jean-Pieere Hubaux, Thumas Gross, Jean-Yues Le Boudec, and Martin Vetterli, “Toward Self-Organized Mobile Ad Hoc Networks: The Terminodes Project”

Agenda

- Overview of Mobile Ad Hoc Networks
- Major Technical challenges:
  - Networking
  - Real time services
  - Software
- Long-term Research Project:
  - Terminodes Projects

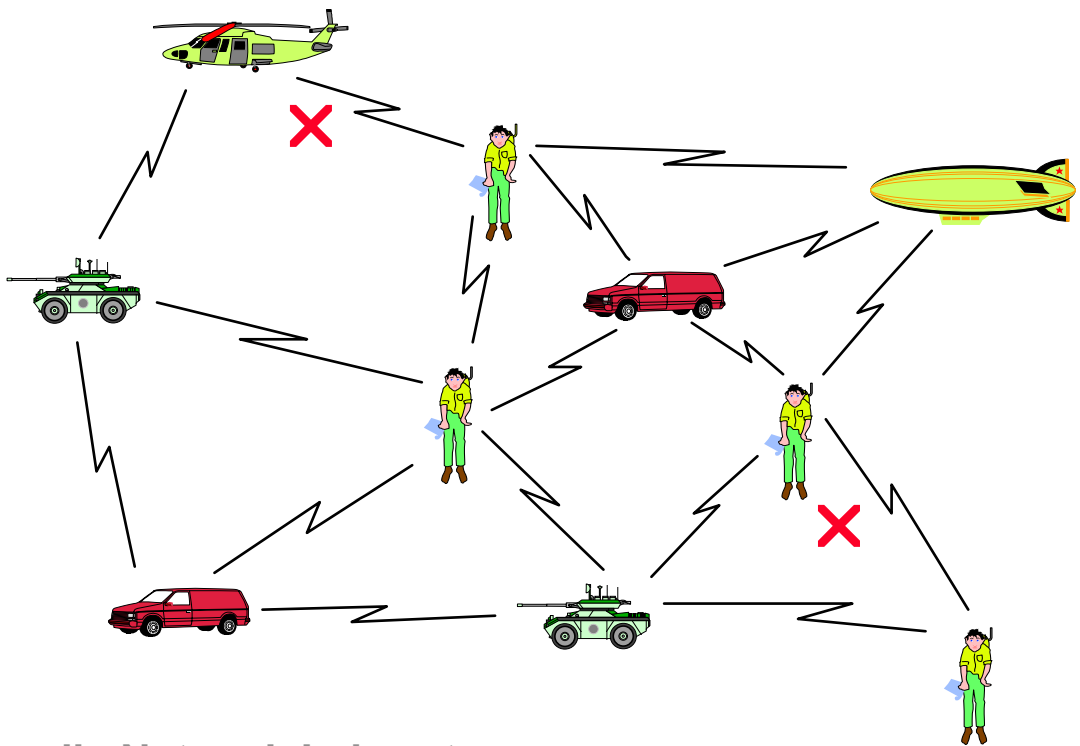
Cellular based

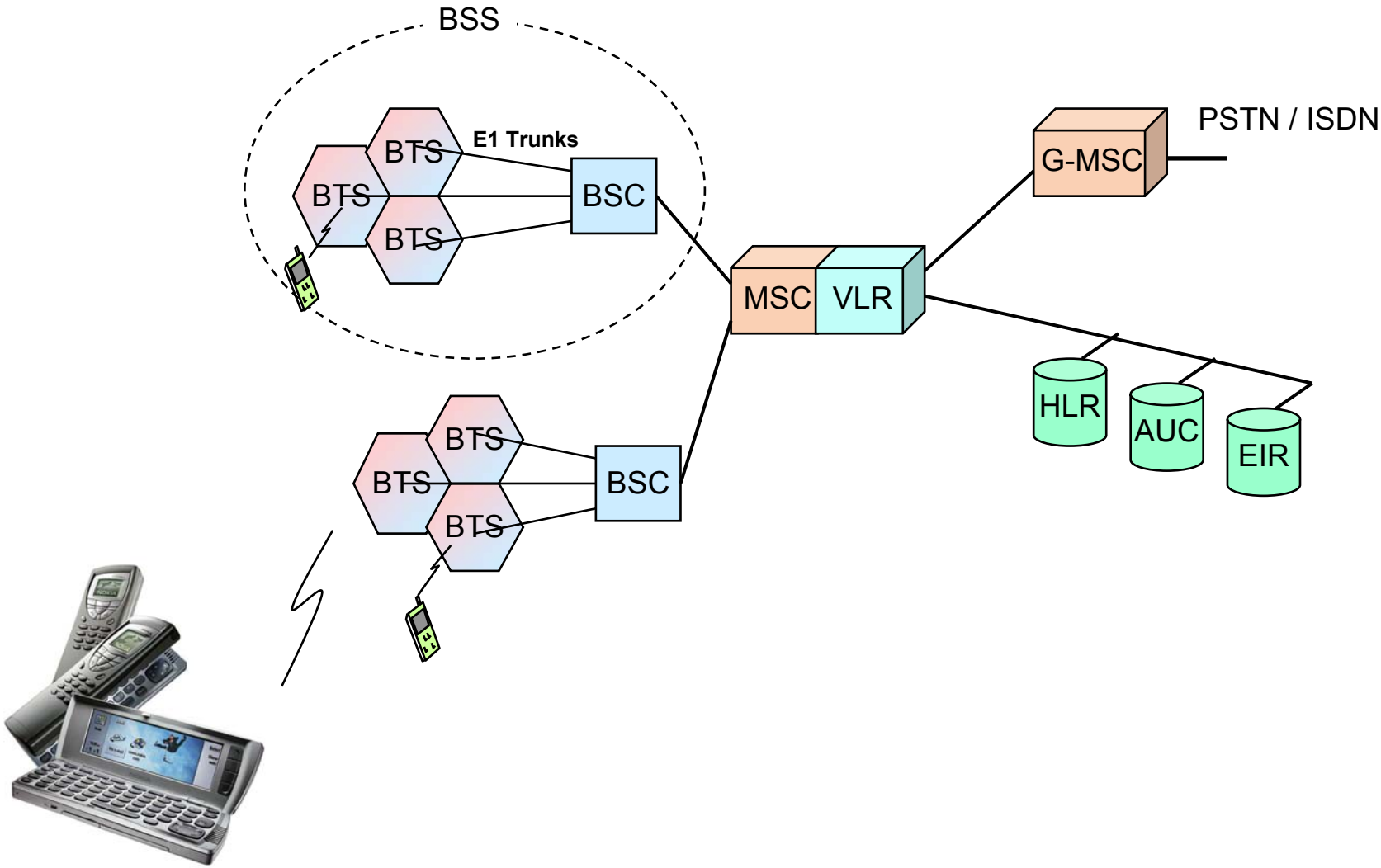


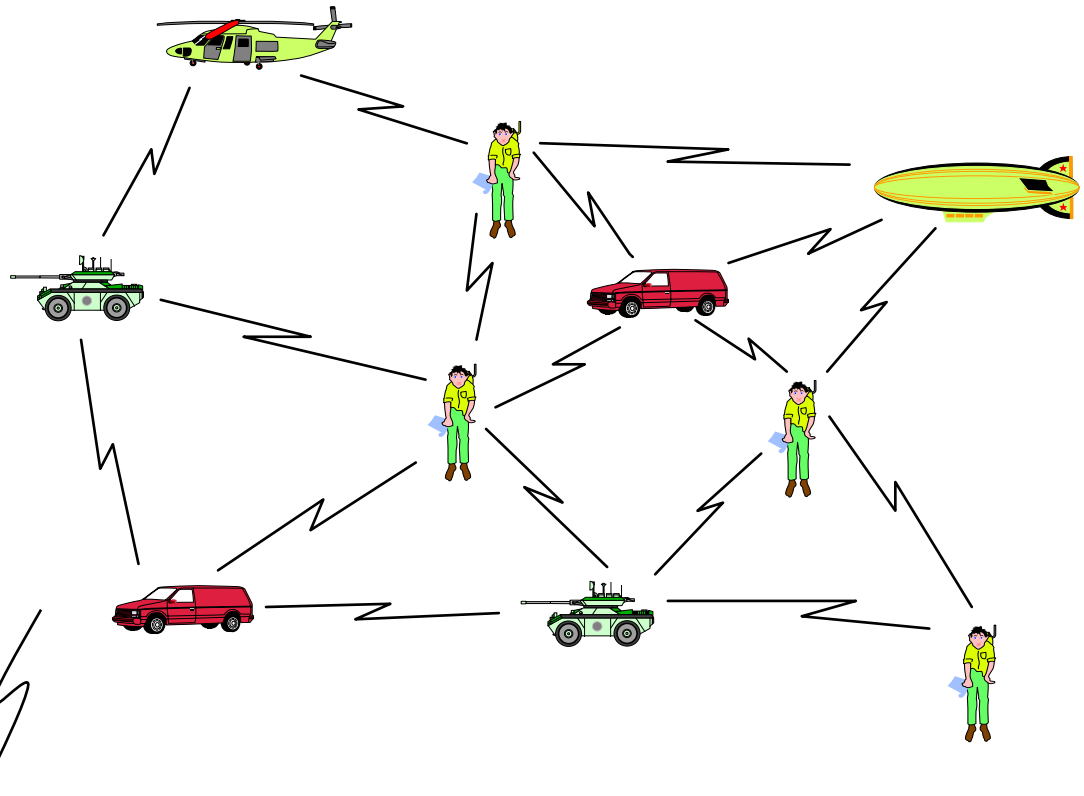
GSM Network Infrastructure

Ad-hoc network

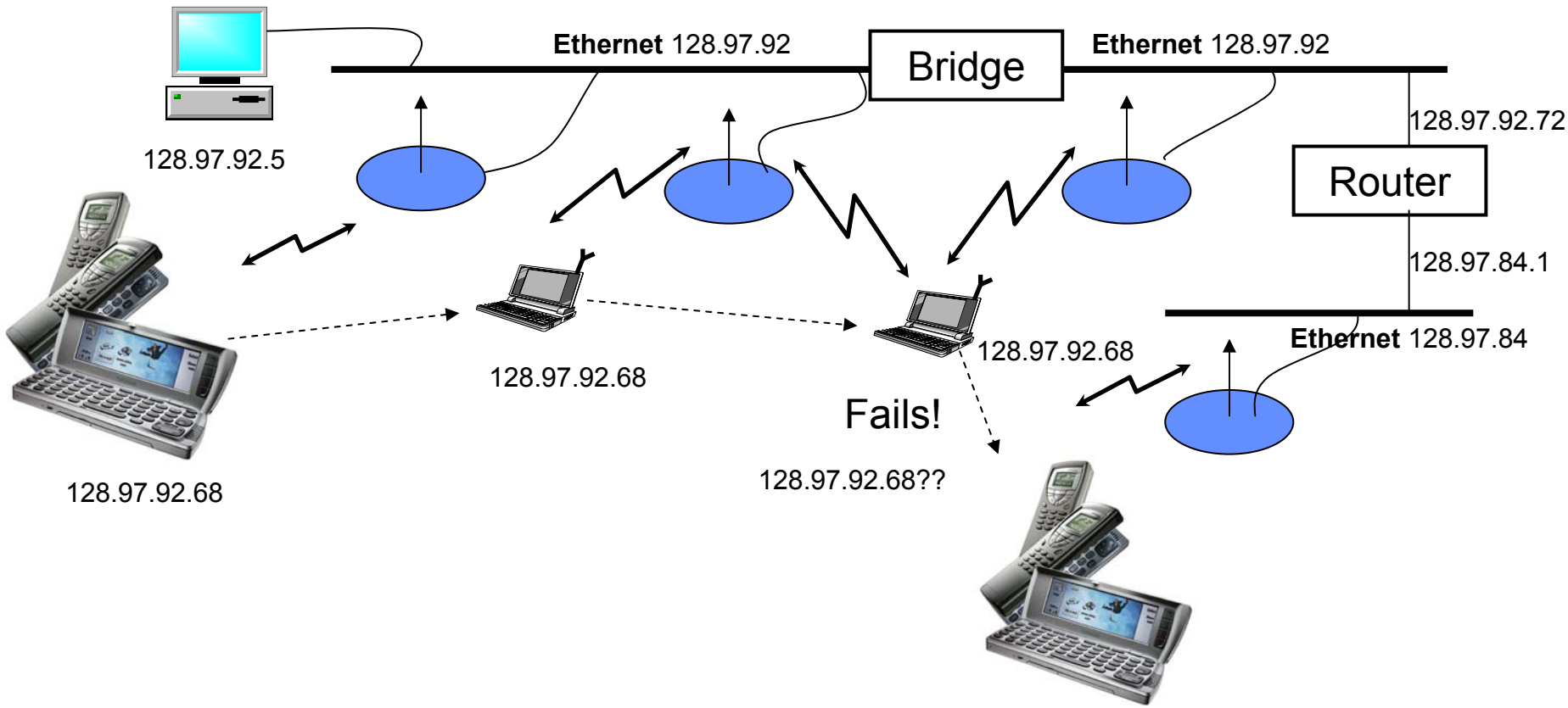
- No centralized controller (base stations)
- No wired inter-connection backbone
- Forwarding function should be provided by mobile nodes




BSS
BTS
BTS
BTS
E1 Trunks
BSC
BTS
BTS
BTS
BSC
MSC
VLR
G-MSC
PSTN / ISDN
HLR
AUC
EIR



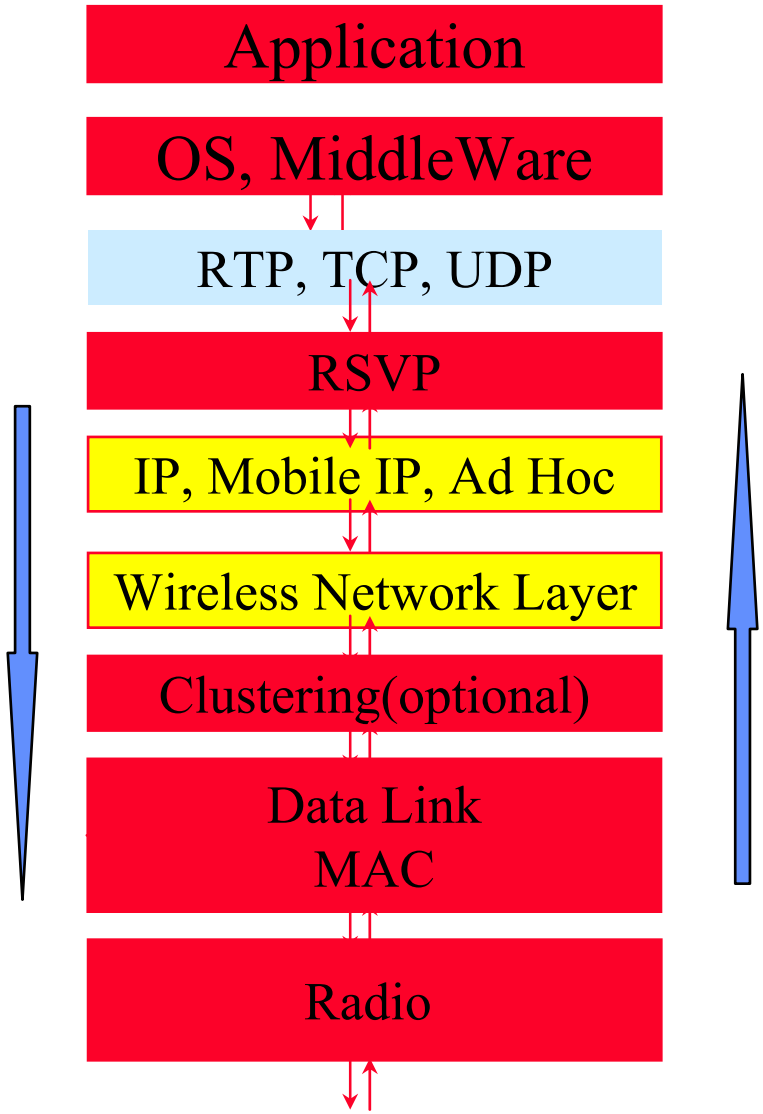
Mobility in Wireless LANs: Mobile IP



QoS and Multimedia Traffic Support

Adaptive Algorithm

by QoS Requirement



Mobility Unpredictable channel

by QoS Information

Introduction

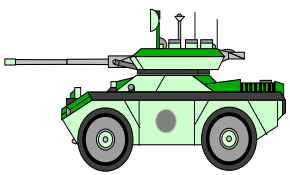
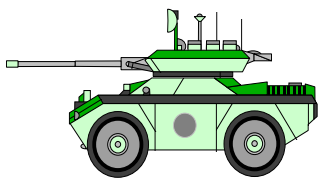
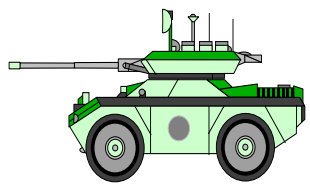
Self-Organized Mobile Ad Hoc Networks

Trend Evolution

- IP success
  - The involvement and level of responsibility of end users have dramatically increased
  - The freedom has fueled creativity
- Infrastructure-less, self-organized networks
  - The network runs solely by operation of end users
  - Progress of electronic integration and wireless communication
  - Complement these infrastructures in cases where cost, constraints, or environment require self-organized solutions
  - Will be interconnected with the Internet and cellular networks

Overview (MANET)

- Packet Radio Networks (’70)
  - Research Results
    - Radio Resource Allocation
    - Network Organization
  - An Individual, handheld device
  - Military application (provide person-to-person communications on the battlefield)

MANET

- Potential Applications:
  - Manmade disasters
  - Relief operation
  - Military applications
  - Car-based networks
  - Sensor networks
  - The Provision of wireless connectivity in remote areas
  - Collaborative Computing, Video Conferences

MANET, Peculiarities

- They can act independent of any provider
- They have to be highly cooperative: The tasks are distributed over the nodes
- Any operation is the result of the collaboration of a group of them
- The nodes rely on batteries for their energy, energy saving
- Power aware: the set of functions offered by a node depends on its available power
- Highly dynamic topology
- Security is difficult to implement

Technical Issues

- Routing
- Mobility Management
- IP Address
- Transport Layer
- Air Interface
- Security
- Power Management
- Standards and Products

Routing

- Ad hoc routing
  - Different from traditional solutions in the Internet or cellular phone networks (relative stable, distributed routing databases)
  - IETF (The Internet Engineering Task Force) MANET address the challenge
  - Distant vector, links state, source routing (table driven, on-demand)
  - Geographic methods: nodes are informed of their own geographic position

Routing Protocol

- Traditional Routing
  - Distance Vector (Bellman Ford)
  - Link State
- Ad Hoc Routing Protocols
  - DSDV
  - DSR
  - AODV
  - TORA

Traditional Routing

- Distance Vector (Table Driven)
  - Each node maintains its own routing table
  - Routing table contains
    - destination node index
    - next hop
    - metric
  - Periodic routing table exchange
- Disadvantage
  - Count-Infinity Problem
  - Convergence Problem

A	B	C
B-A-1	A-B-1 C-B-1	B-C-1
B-B-1 C-B-2	A-B-1 C-B-1	B-B-1 A-B-2
0	1	2
x	1	2
x	3	2
x	3	4
x	5	4
x	∞	∞

Traditional Routing (Cont.)

- Link State Routing
- Procedures
  - Neighbor Discovery
  - Routing Information Broadcast
  - Shortest Path Finding (e.g. Dijkstra's algorithm)
- Disadvantage
  - short-live looping problem

	0	1	2	3	4	5	6	7	8	9	10	11	12
0			X										
1			X										
2	X	X		X									
3			X		X			X			X		
4				X		X	X						
5					X								
6					X								
7				X					X	X			
8								X					
9								X					
10				X								X	X
11											X		
12											X		

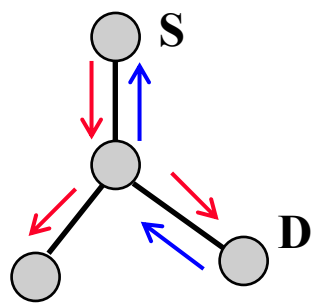
adjacency matrix

Ad Hoc Routing - DSDV

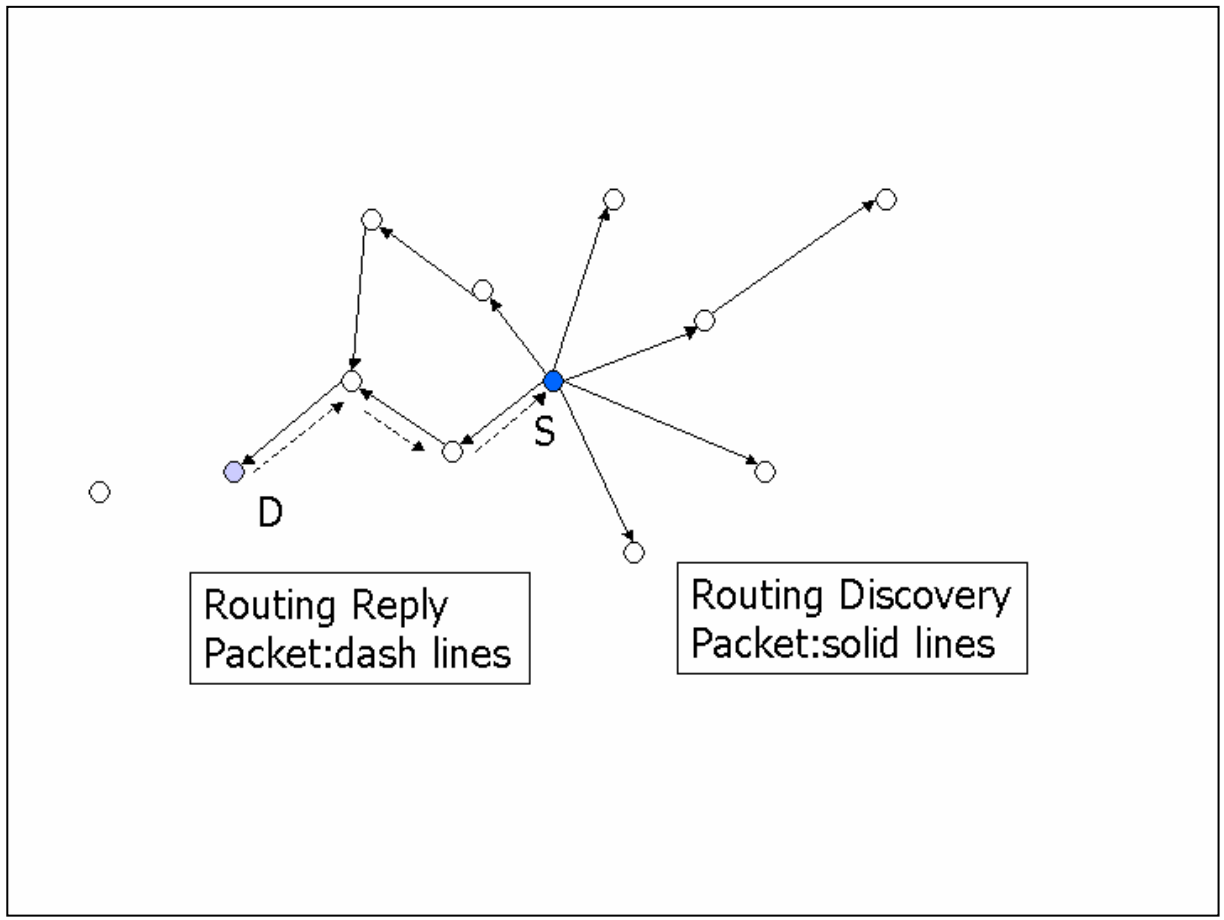
- DSDV
  - Destination Sequence Distance Vector Routing
  - Each route information is labeled with a increasing sequence number
    - Route info. with greatest number will be update
  - Route info. of broken link is broadcast with odd sequence one greater than the original sequence number
- Contribution
  - Main contribution of DSDV is freedom-loop guarantee
- Disadvantage
  - The periodic broadcast adds the overhead into the network

Ad Hoc Routing - DSR

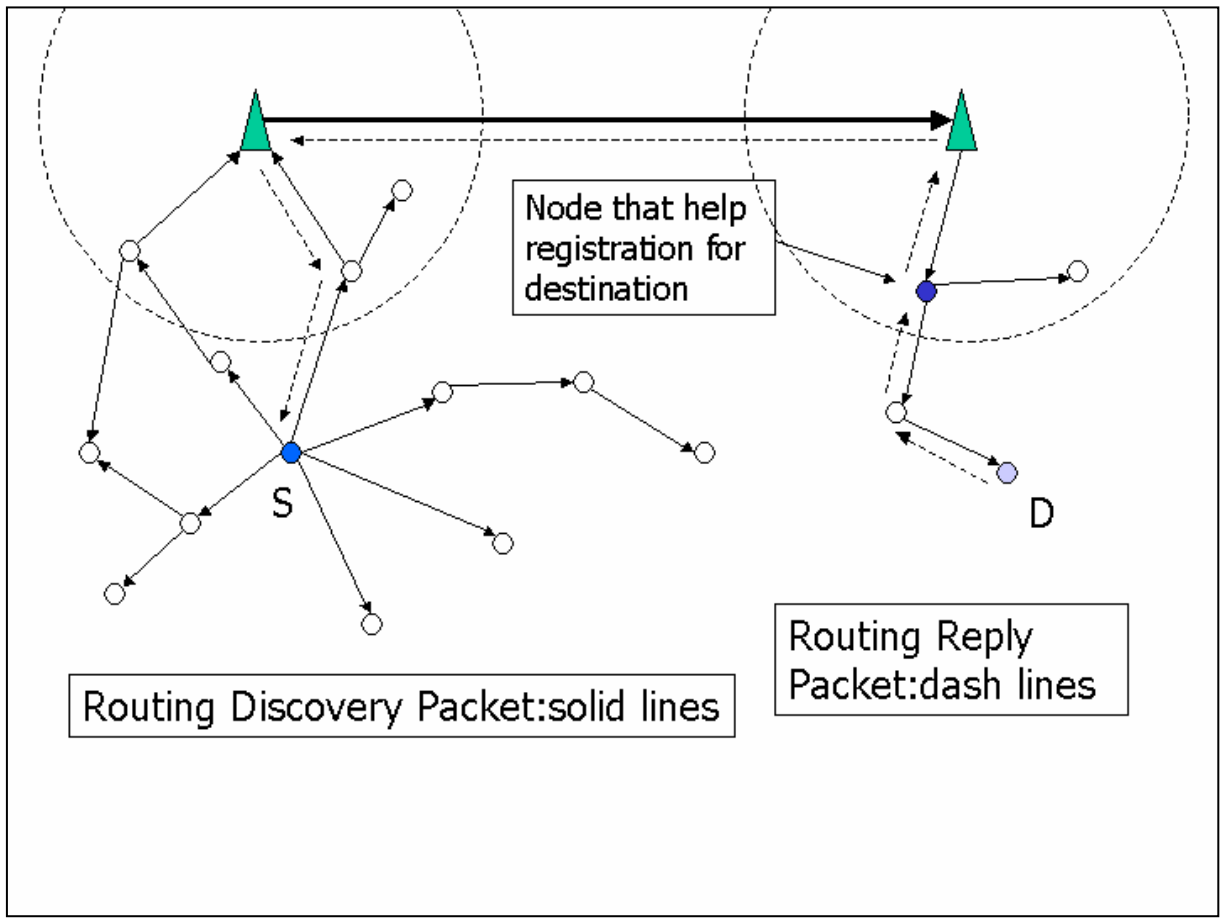
- DSR
  - Dynamic Source Routing
  - Route Discovery
    - Source node flooding routing request (RREQ) packet
    - Destination (inter-node) node reply RREP packet that piggybacks the route info.
    - Source node caches the route info
  - Route Maintenance
    - The route info. will be remove after receiving RERR packet
- Advantage
  - Requires no periodical routing exchange
- Disadvantage
  - packet is larger because of carrying route info.



Routing in ad hoc network environment only



Routing in heterogeneous environment



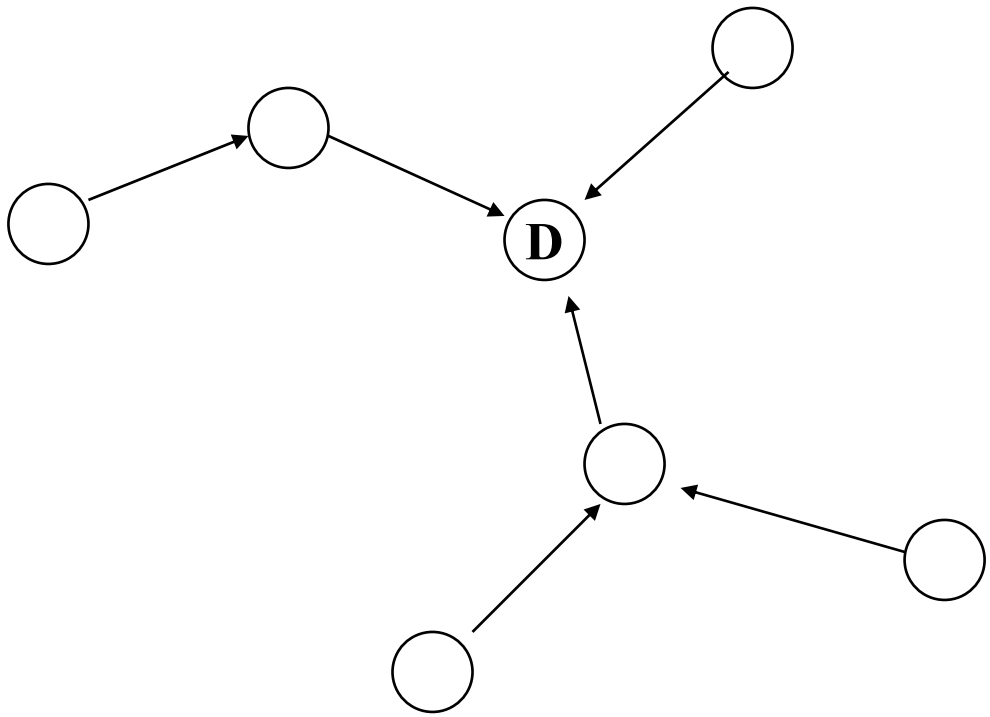
Ad Hoc Routing - AODV

- AODV
  - Ad-hoc On-demand Distance Vector
  - Shares the advantages of DSR and distance vector
  - Route Discovery
    - Similar to DSR
  - Route Maintenance - Table Entry
    - Destination IP, Destination Sequence, Hop Count, Next Hop, Life Time
  - The route info. Is invalid if
    - Life Time is expired
    - Receive RERR packet

Ad Hoc Routing - TORA

- TORA
  - Temporally-Ordered Routing Algorithm
  - Routing procedures
    - Flood QUERY packet
    - UPDATE packet will be broadcast from destination or inter-node
    - HEIGHT info. is appended to UPDATE packet
    - the node receives UPDATE packet set its height and the forwarding UPDATE packet's height to a value one greater than original one
  - Source node send data to the destination via neighbor that have lower height with respect to the destination
- Advantage
  - Minimizes the reaction due to changes of network topology
- Disadvantage
  - Depend on Internet MANET encapsulation Protocol, the overhead is large

Ad Hoc Routing - TORA (Cont.)



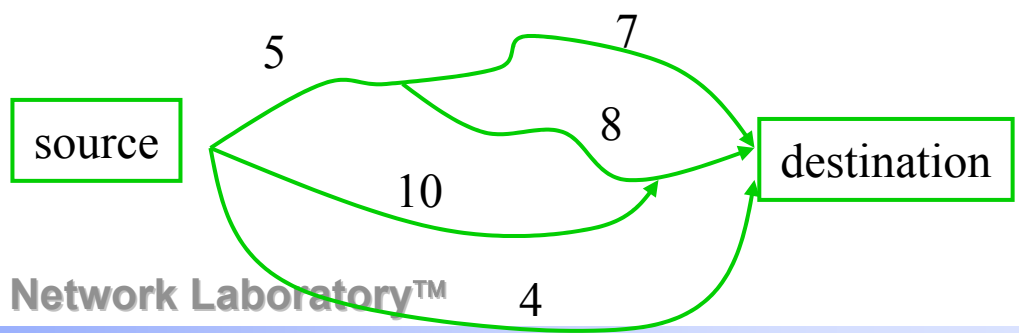
Directed acyclic graph rooted at destination

ABR (Associativity-Based Routing)

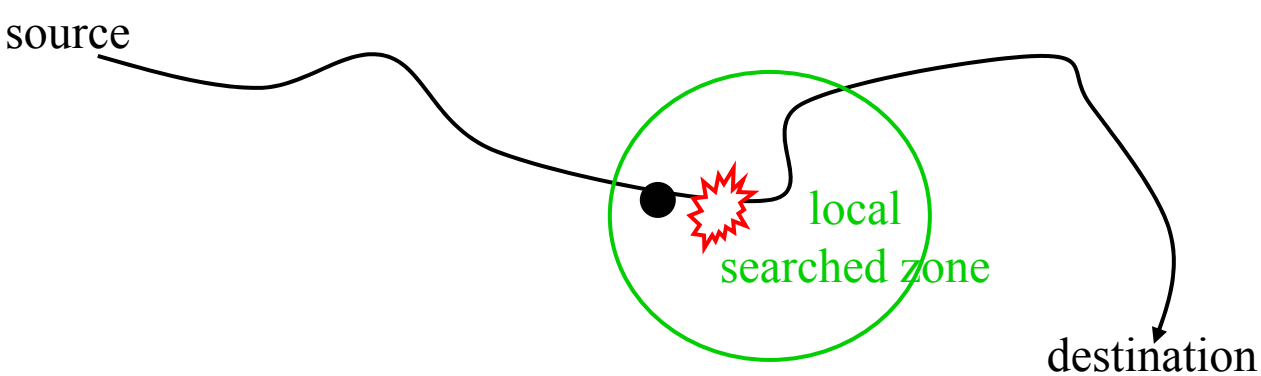
- ABR considers the stability of a link.
  - The metric is called degree of association stability.
- Basic Idea:
  - Each node periodically generates a beacon to signify its existence.
  - On receipt of the beacon, a neighboring node will increase the "tick" of the sender by 1.
    - A higher degree of association stability (i.e., ticks) may indicate a low mobility of that node.
    - A low degree of association stability may indicate a high mobility of that node.
  - When a link becomes broken, the node will set the tick of the other node to 0.

ABR Outline

- Route Discovery:
  - (similar to DSR)
    - On needing a route, a host will broadcast a ROUTE_REQUEST packet.
    - Each receiving host will append its address to the packet.
  - The association stability (represented by “ticks”) is also appended in the ROUTE_REQUEST packet.
  - The destination node will select the best route (in terms of association stability), and then respond a packet to the source.

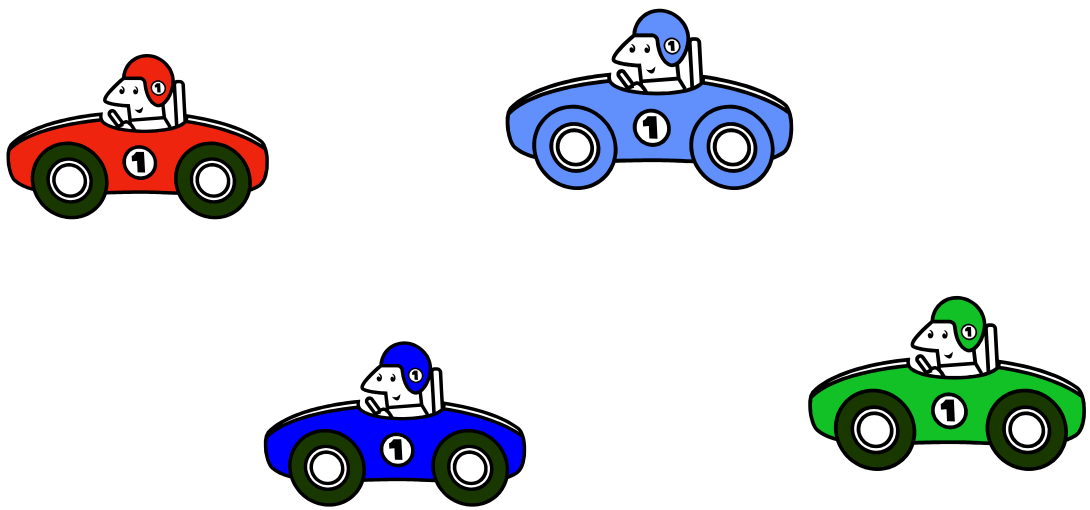


- Route Reconstruction:
  - On route error, a node will perform a local search in hope of rebuild the path.
  - If the local search fails, a ROUTE_ERROR will be reported to the source.



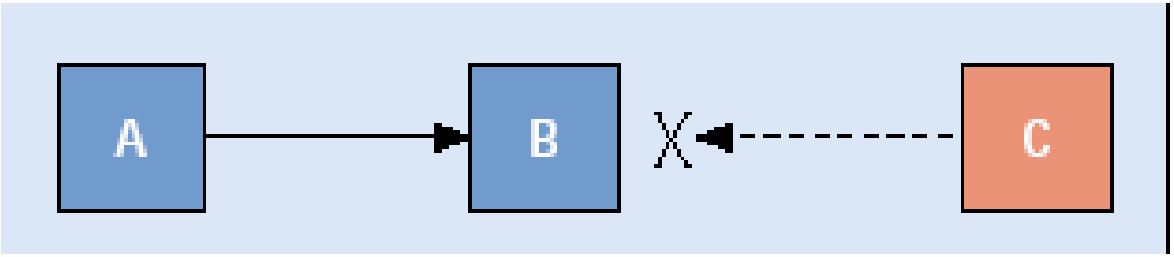
Mobility Management

- Broadcasting a paging message the whole network: won't scale well
- Different from centralized servers (either HLR in GSM), location must be distributed among the nodes
- Prediction of the future locations



Radio Interface

- CSMA/CA: hidden terminal



- Defining master and slaves roles:
  Bluetooth

Simulation Models

- Simulation Languages:
  - MAISIE Language
- Integrating Simulation with Prototyping
- Parallel Model Execution
- Hybrid Models

MACA/PR

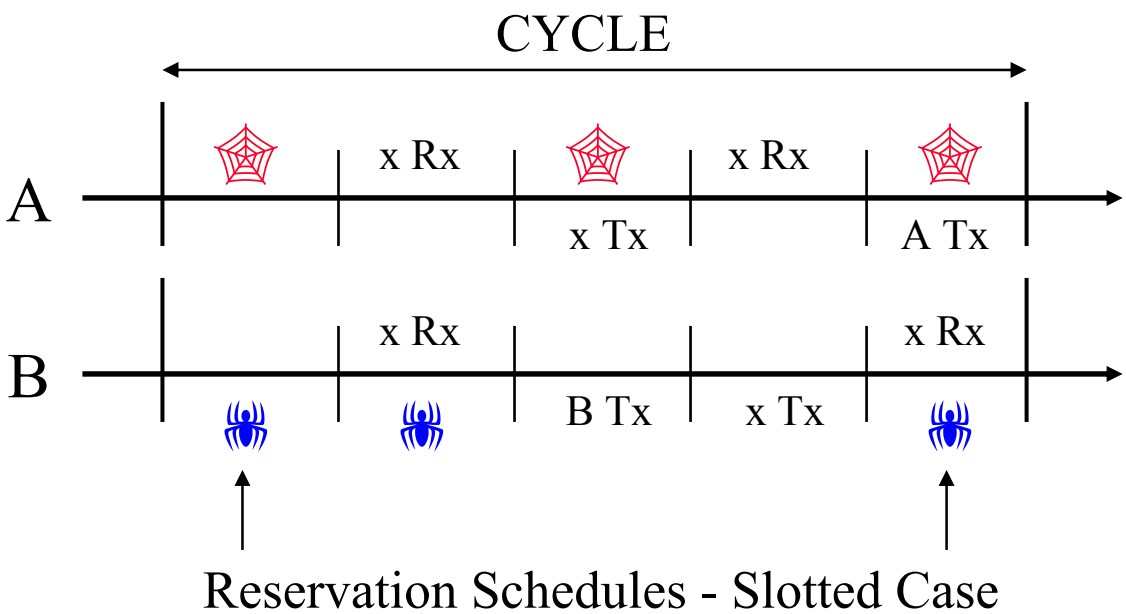
- The key component
  - the MAC protocol for data transmission
  - Reservation scheme for real-time connection setup
  - QoS Routing algorithm

MACA/PR - MAC

- Data-gram Traffic
  - RTS - CTS - PKT - ACK
  - <RTS,CTS> for hidden terminal avoidance, ACK for retransmission
- Real-Time Traffic
  - < RTS - CTS > - PKT - ACK
  - <RTS,CTS> used for first time transmission to set up the reservation
  - ACK for renewing the reservation, not recovery

MACA/PR - Reservation/QoS Routing

- CYCLE is the max. interval allowed between two real-time packets
- Each node maintains its own reservation table
- DSDV routing is employed
- Bandwidth info. can be easily obtained via reservation table



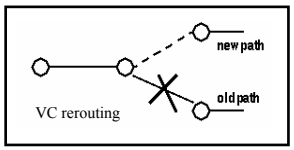
MACA/PR - Properties

- Asynchronous approach
- Low latency, low packet loss rate
  - Hidden Terminal Problem is solve automatically
- Fair bandwidth sharing
- Good mobility handling
  - Maintain secondary routing path
- Low implementation costs

MAISIE Simulation Modules

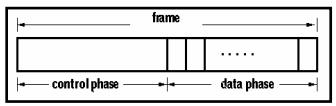
Algorithms/ Protocols

Mobile IP/Nomadic Router

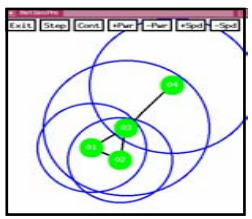


Network Layer: VC support ← "Soft state" fast VC setup

Network Layer: routing ← Loop-free QOS routing (DSDV)



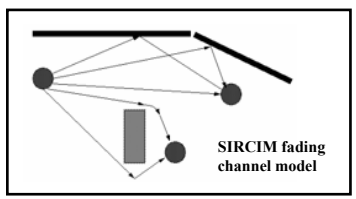
Link Layer ← Acks, backpressure, priority



Mac Layer ← TDMA, CDMA, MACA, TOKEN

Clustering ←

Connectivity Management ← Adaptive power control
Distributed clusterhead election:

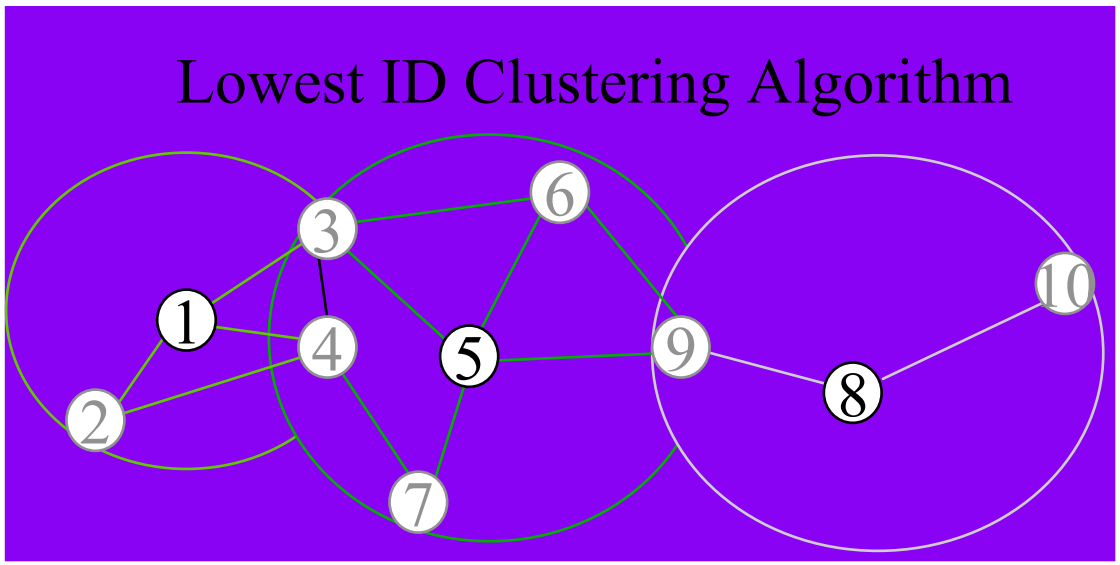


Radio Channel ← DS-SS;channel encoding

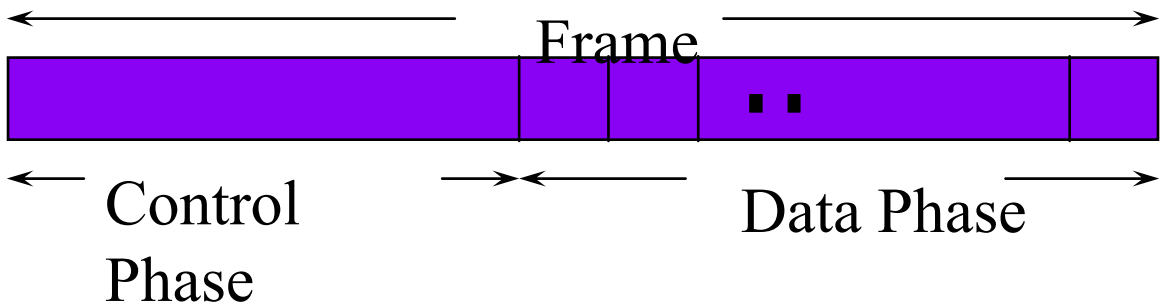
Network Architecture Models

PRNET | Cluster TDMA | MACA/PR | Cluster MACA

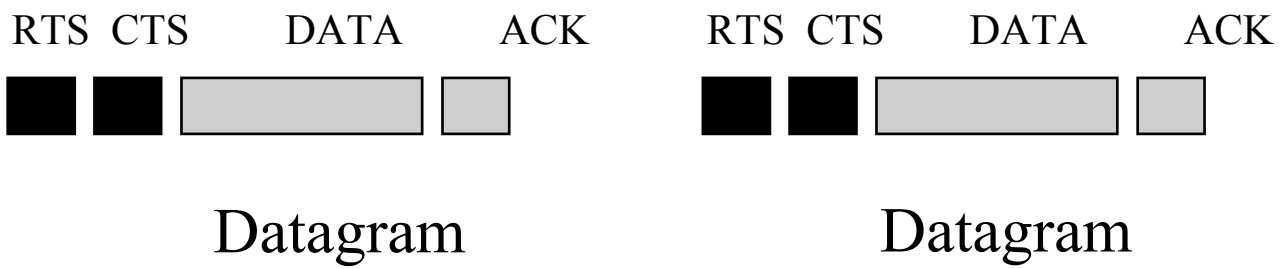
Cluster TDMA

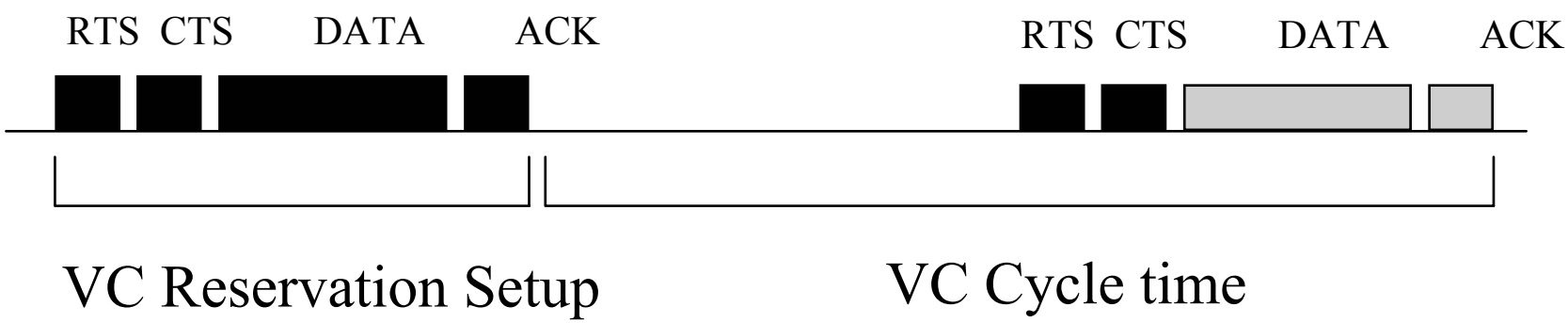


Within each cluster: time-slotted frame



Cluster MACA





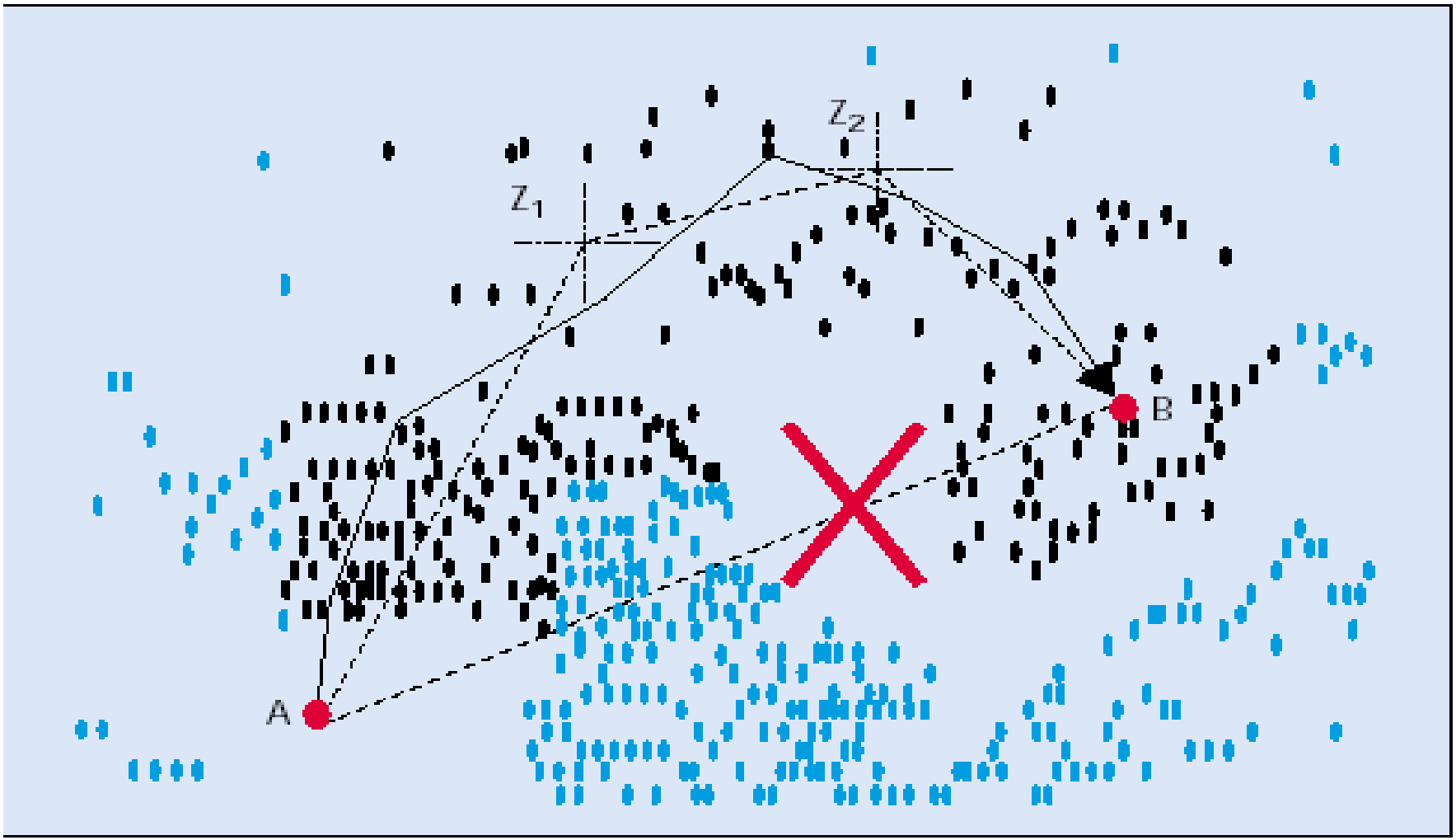
The Paradigm Shift and Some Open Research Questions

MANET

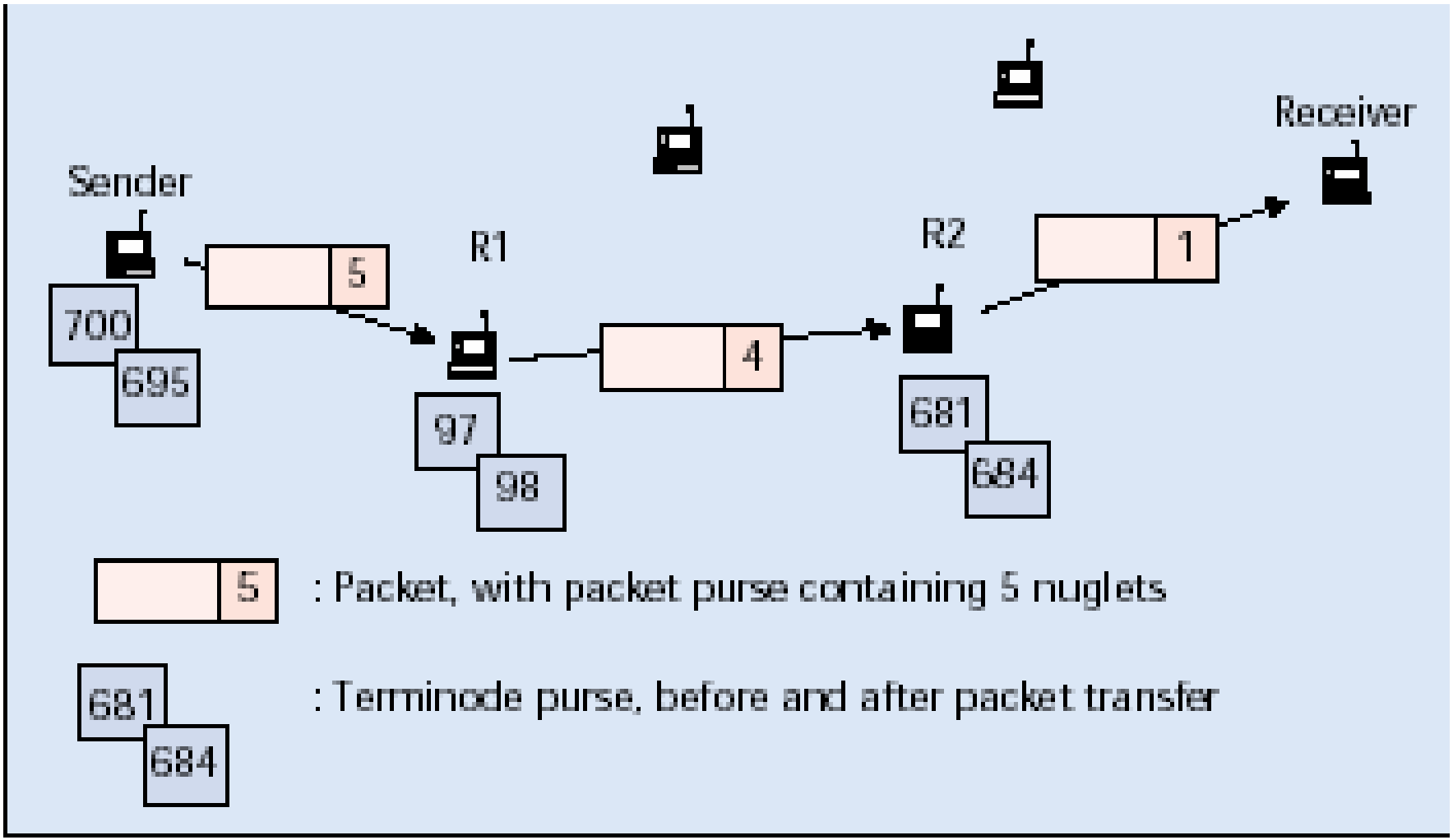
Terminodes Projects

- Large scale self-organized mobile ad hoc networks
- All layers and interlay interactions
  - From physical layer up to software architecture and applications
- Try to capture the business and societal potential
- Three levels:
  - Technical challenges
  - Intellectual fantasy
  - Societal/political vision

Networking Issues



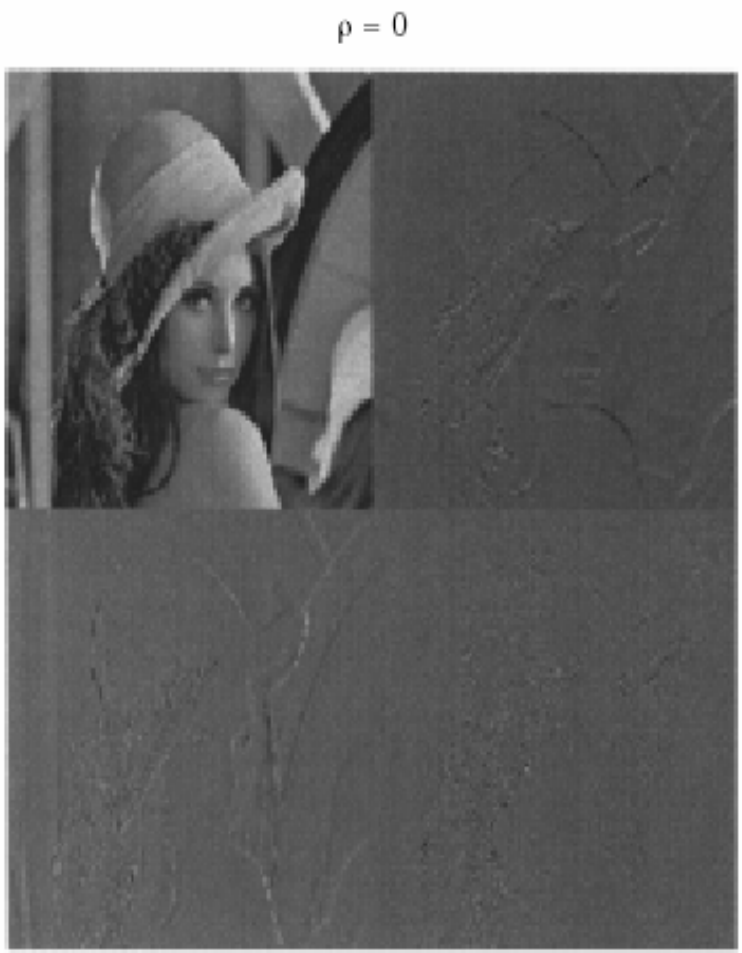
Networking Issues



Real-Time Services over Ad hoc Networks

- Real-Time Services
  - Voice or video over ad hoc networks
  - Unreliable <-> stringent delay
  - Large error , node failure
- Redundancy, error correction codes over parallel connections

Multiple description coding



Software Aspects

- Software implementations:
  - Base software: Routing algorithms, accounting system and security system
  - Application software: Software that makes a collection of terminodes useful for a client
  - Flexible software architectures
- Resource Allocations
  - Contract
  - Loader
  - Dynamic checks

Discussions

- Three Networks:
  - Telecom networks
  - The Internet
  - Self-Organized Mobile Ad Hoc Networks

Network	Infrastructure	Security	Applications
Telecom networks	Telcos	Telcos	Telcos (IN)
Internet	ISPs + telcos	ISPs + users (PGP)	Users
Self-org. ad hoc NW	Users + vendors	Users + vendors	Users