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Introduction to Mobile Ad hoc Networks (MANETs)

Advanced Computer Networks

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Outline

- Ad hoc networks – Differences to other networks
- Applications
- Research areas
- Routing
- Other research areas

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Enabling Technologies

- Ubiquitous computing devices with WiFi
  - Laptops
  - PDAs
  - Cameras, MP3-players
- Medium Access Control (MAC)
  - IEEE 802.11x
  - Bluetooth

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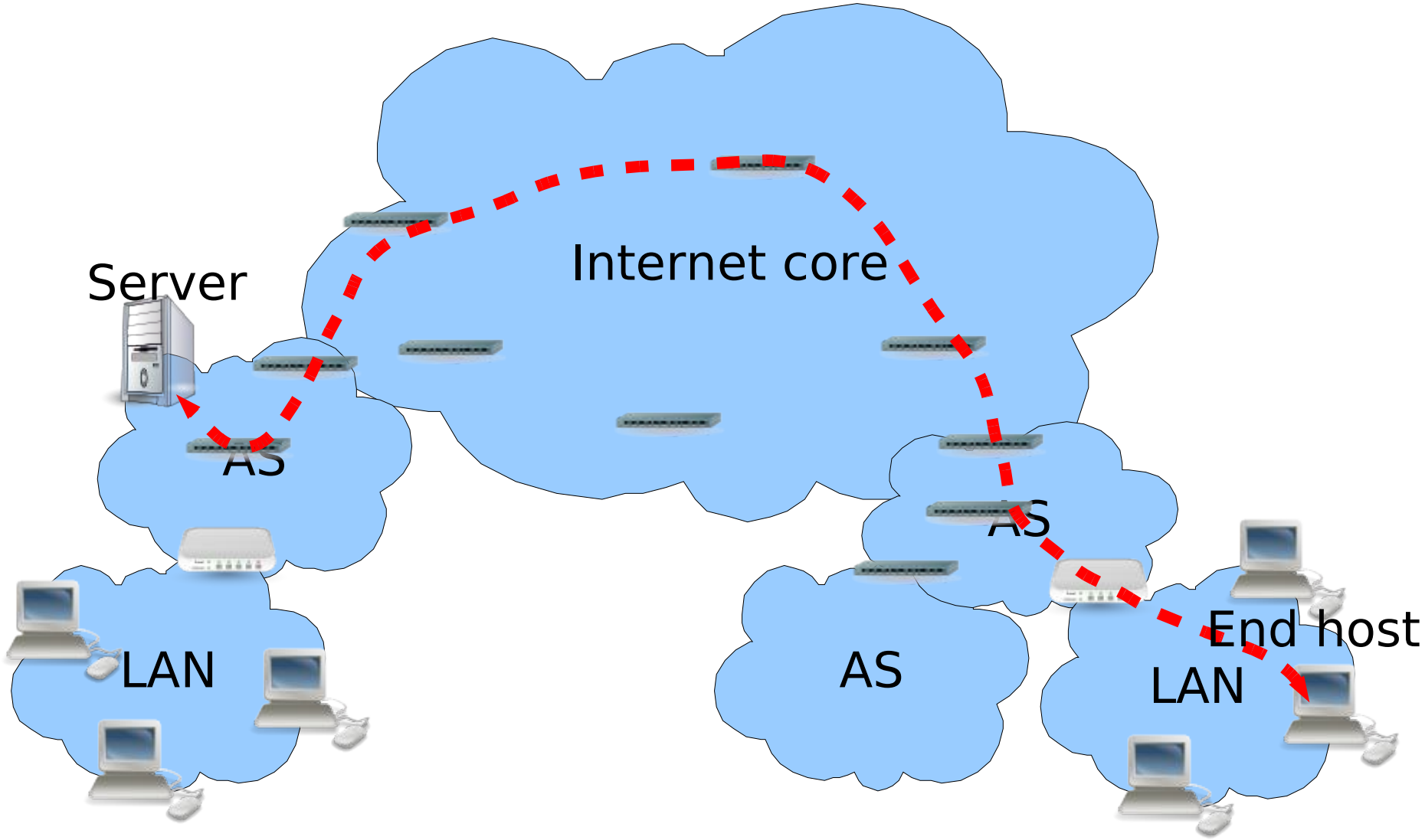
The Internet – A hierarchy of Networks



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How are mobile ad hoc networks different?

Ad hoc ≈ “for a particular purpose”, improvised

- No infrastructure – *flat network*
- Radio communication – *shared medium*
- Every computer or device (*node*) is a router as well as end host
- Nodes are in general autonomous
- Mobility – *dynamic topology*
- Limited energy and computing resources

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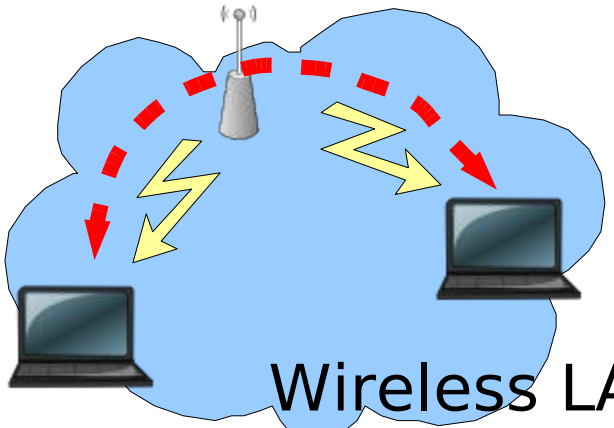
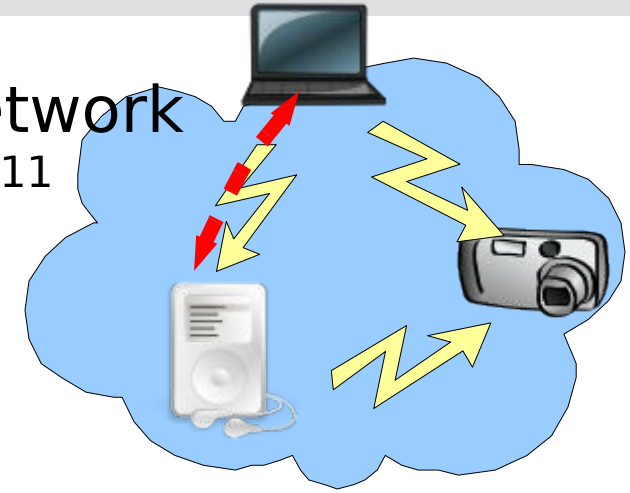
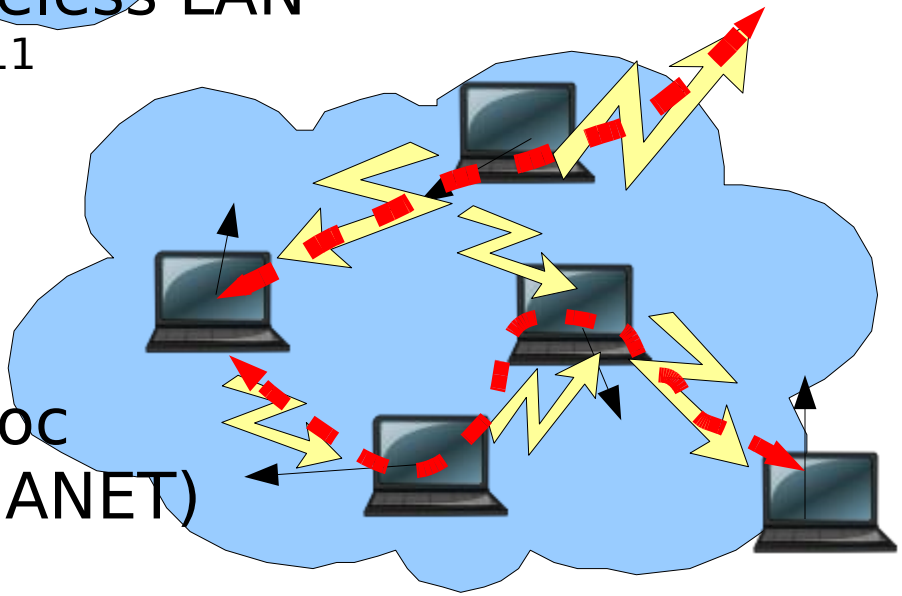
Differences to other Wireless Networks



Wireless LAN
802.11

Ad hoc network
Bluetooth/802.11
Ad hoc mode





Mobile ad hoc network (MANET)
802.11 Multi-hop

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Differences to Wired Networks – Radio (802.11x MAC)

- Varying signal-to-noise ratio
- Different rates = different transmission ranges
- CSMA
- Channel contention
- Obstructions
- Interference, e.g., “hidden terminals”

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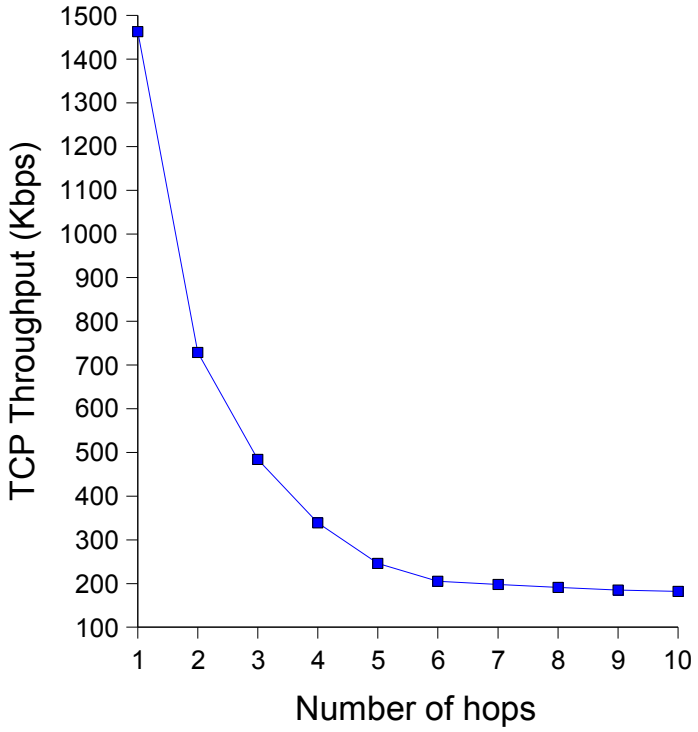
Differences to Wired Networks - The Effect of a Shared Channel

Bandwidth decreases asymptotically with hop count

- Nodes interfere with next hops
- Over longer paths interference is constant



Source:Holland et al. 2002

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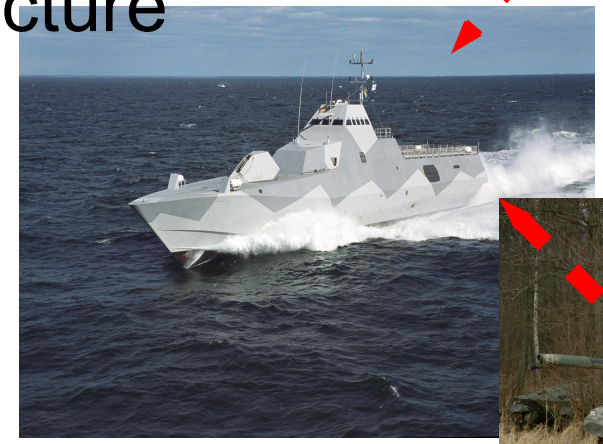
MANET Applications - Military

- Unknown terrain
- Limit the range of communication
  - Directional antennas
- Destroyed infrastructure



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MANET Applications – Disaster Relief

- Disaster relief
  - Earthquakes, tsunamis, hurricanes
  - Wiped out infrastructure
  - Search & rescue

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MANET Applications – Economic & Commercial

- Community Mesh networks
- Access extensions
- Personal Area Networks (PANs)
- Ad hoc Gaming (on subway, cafés, etc)

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MANET Research Areas

- **Routing**
- Path metrics
  - hop count, SNR, RTT, geographical
- Energy conservation
- QoS
- Multicast
- Security
- Self configuration
- Cooperation and Incentive mechanisms

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MANET Routing - Goals

- Finding end-to-end paths/routes
- Scaling
  - minimize overhead
- Loop free
- Route maintenance

So why not just use Internet protocols (OSPF, RIP)?

- Limited node capacity
  - Nodes are not dedicated routers
- Higher loss rate
- Links are not binary on/off – varying quality
- Frequent topology changes
- Addressing

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MANET Routing Challenges

- Flat addressing – no hierarchy
  - scaling issues
- Mobility – frequently changing topology
  - adaptability, reactiveness
- Heterogeneity
  - All nodes are not made equal
- Network-to-network connectivity
  - Internet access

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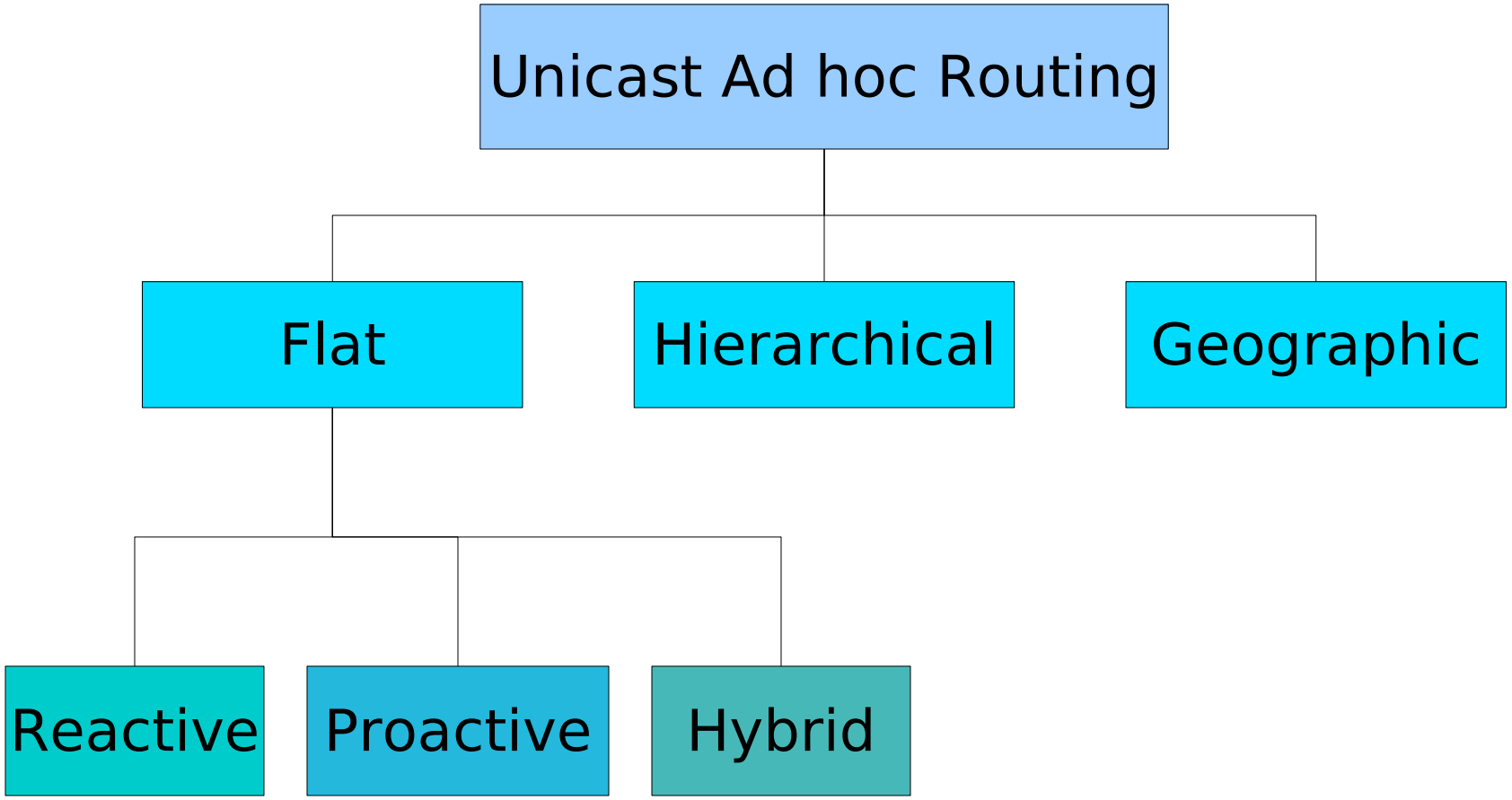
Taxonomy of Ad hoc Routing Protocols



Flat Routing

- Proactive:
  - Global network view
    - Disseminates routing information continuously
    - A route is available when needed
  - Slow convergence
- Reactive:
  - Partial network view
    - Only active (or cached) routes are known
    - Routes discovered when needed
  - Reacts quickly to topology changes
- Hybrid
  - achieves scaling

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IETF Routing Standardization – The MANET Working Group

http://www.ietf.org/html.charters/manet-charter.html

- Standardizing MANET routing protocols (since 1995)
- Incorporating experiences from previous research on four routing protocols:
  - **OLSR**
  - TBRPF
  - **AODV**
  - **DSR**
- Current candidates:
  - One proactive – OLSRv2
  - One reactive – DYMO (AODVv2)

Classical Routing Approaches

- Distance vector (RIP)
  - Distributed calculation of topology (Bellman-Ford)
  - Routing information aggregated in vectors `<dest, hop count>`
- Link state (OSPF)
  - All nodes propagate their link state to all other nodes
  - Local calculation on complete network graph to find shortest path (Dijkstra)

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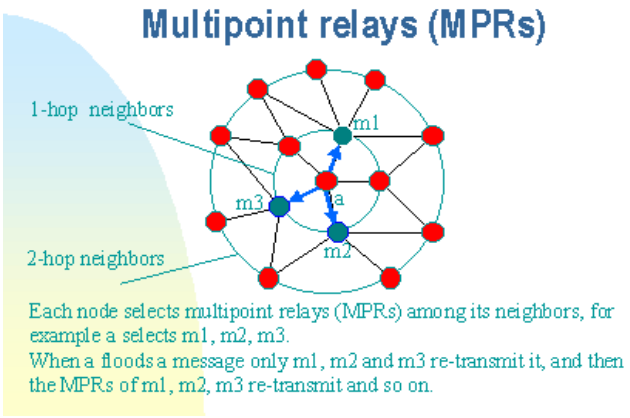
Optimized Link State Routing (OLSR)

- Proactive
- Traditional link state protocol
  - optimized for MANETs
- Multi-Point Relays (MPRs) reduce overhead



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Ad hoc On-demand Distance Vector (AODV)

- Reactive protocol (not really distance vector despite name)
- Route discovery (route request - route reply)
  - Flooding to discover new routes (when needed)
- Route maintenance
  - Only active routes in routing table
- HELLO messages monitor links
- Sequence numbers in control messages to avoid routing loops
- Explicit route error notification (RERR)

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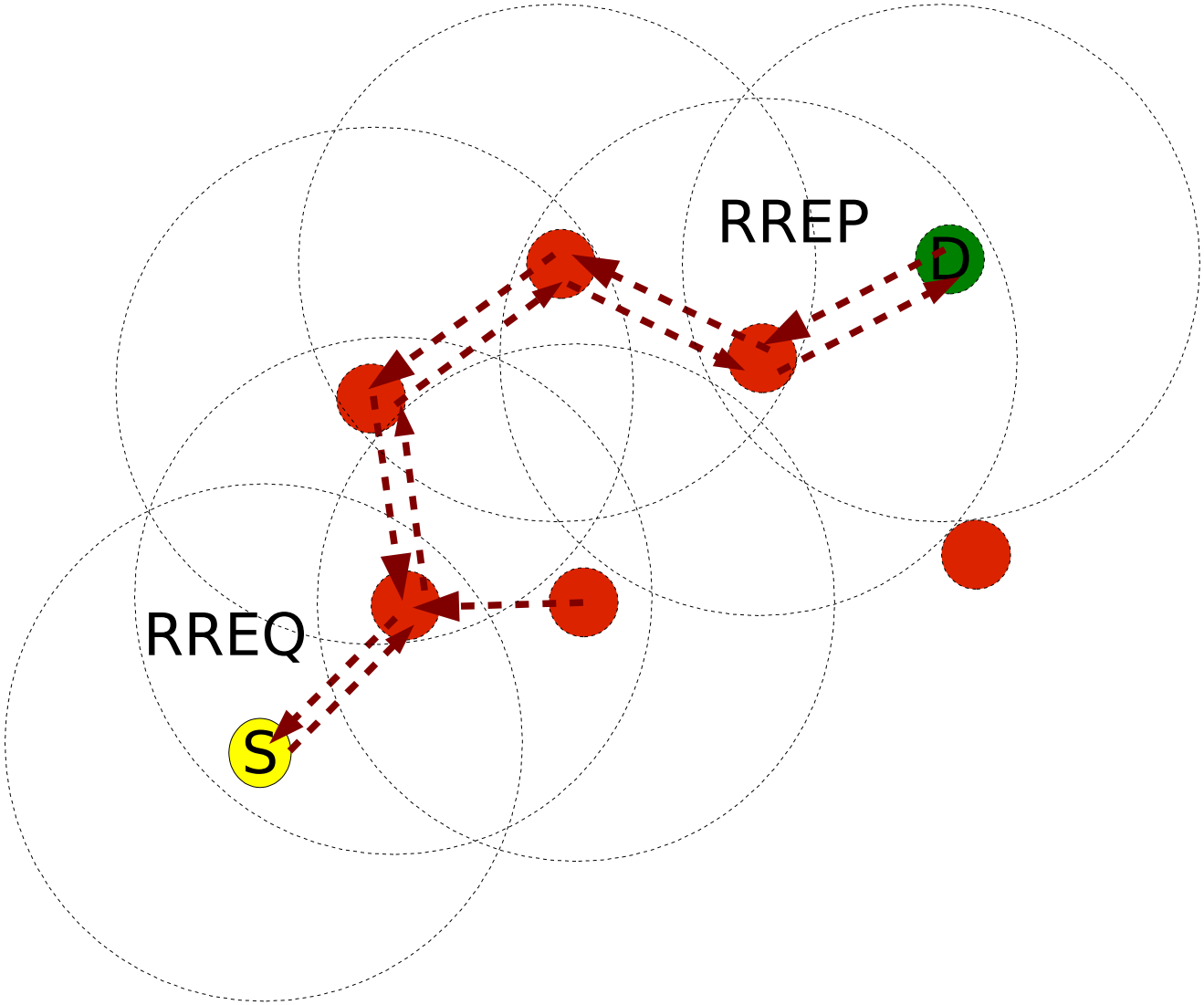
Route Discovery Example (AODV)



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Dynamic Source Routing (DSR)

- A “reactive link state protocol”
- Route discovery similar to that in AODV
  - accumulates source route during discovery
- Source routing (really source forwarding)
  - No hop-by-hop forwarding state in nodes
  - Append full route to all data packets
- Promiscuous operation
  - Cache routing information (link state)
  - Automatic route shortening
- Packet salvaging

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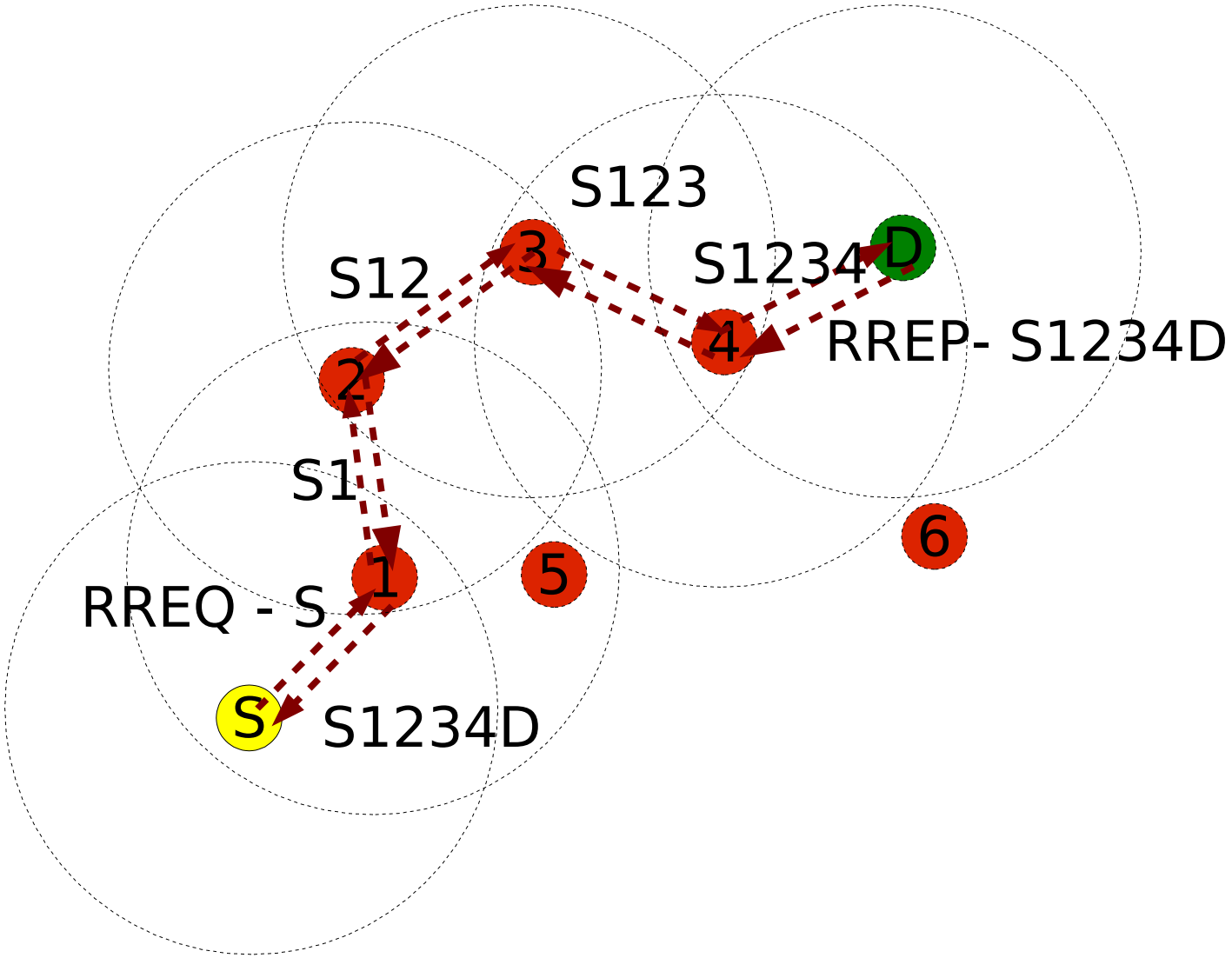
Route Discovery Example (DSR)



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Performance Evaluation

- Simulation
  - Idealized environment, simplified models
- Emulation
  - Reduce impact of radio, emulate mobility
- Real world experiments
  - Repeatability issues

MANET Research at Uppsala University

- Experimental approach
- Implementing routing protocols
  - AODV-UU
  - DSR-UU
  - LUNAR
- Making ad hoc work in the real world
  - Communication gray zones
- Real world Experiments
  - APE Testbed
  - Comparison to simulation and evaluation

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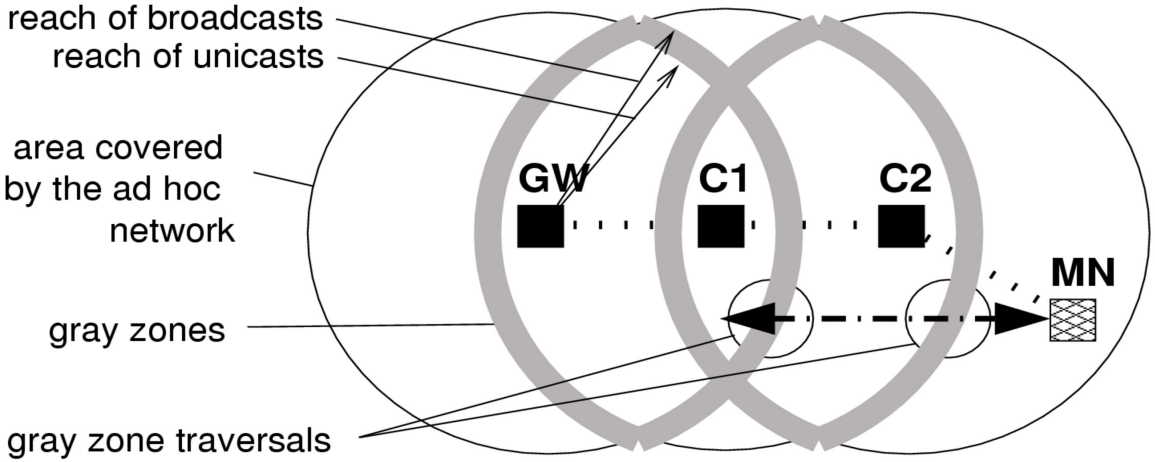
Differences Between Simulation and Real World

Communication Gray zones



- Broadcast and unicast TX ranges are different
- Broadcast HELLO messages give false connectivity

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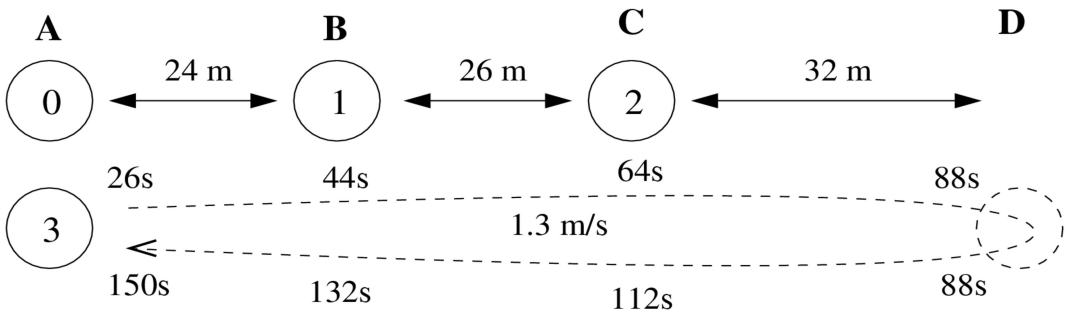
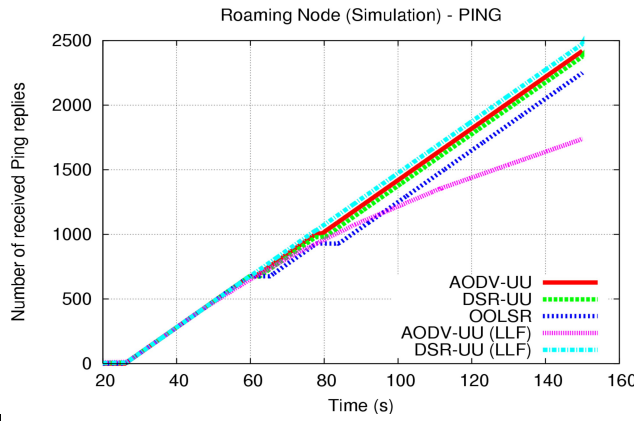
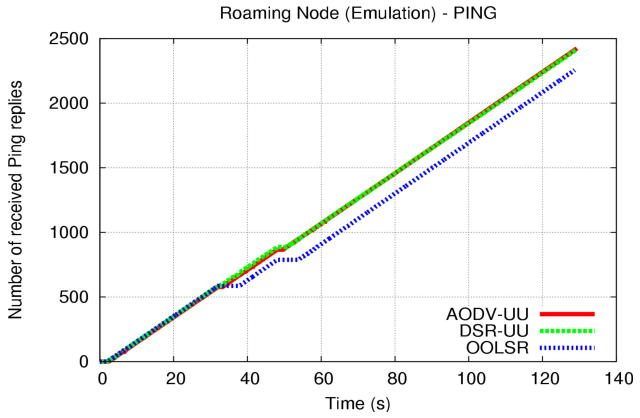
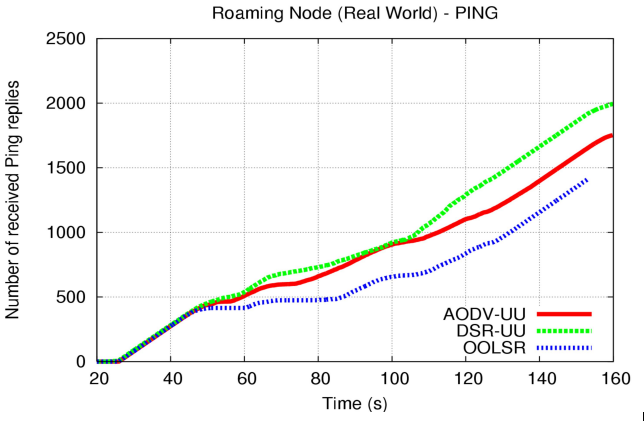
Simulation vs. Emulation vs. Real World

Roaming Node Scenario – Ping Traffic









Some Security Issues in MANETs

- Passive eavesdropping
- Denial of Service (DoS)
  - black holes
- Signaling attacks
- Flow disruption
- Resource depletion
- Data integrity attacks

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Incentive Mechanisms

- Why should I forward someone else's packets?
  - Drains battery
  - Reduces bandwidth
  - Consumes CPU
- Approaches
  - Game Theory models
  - Economical models

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Internet Connectivity

- How to interface with the Internet?
  - Addressing problems, flat vs. hierarchical
  - Multiple gateways
  - Home vs foreign networks
  - Mobile IP Integration
  - Gateway discovery/selection

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Internet Connectivity - Example