Ad Hoc Networks: Introduction

Module A.int.1

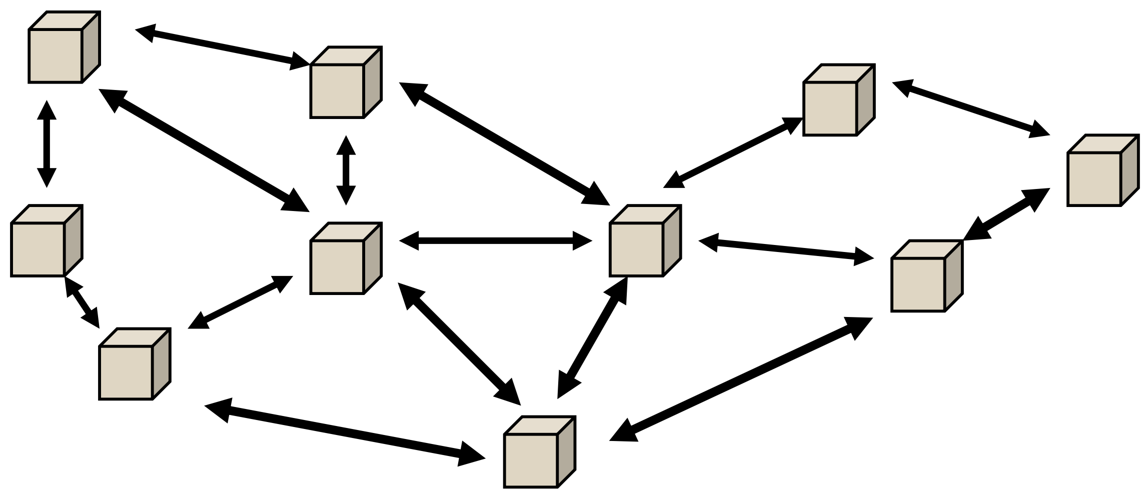
Dr.M.Y.Wu@CSE
Shanghai Jiaotong University
Shanghai, China

Dr.W.Shu@ECE
University of New Mexico
Albuquerque, NM, USA

Ad Hoc networks: introduction

- *Ad Hoc network overview*
- Ad Hoc network types
  - Sensor networks
  - Mesh networks
  - MANETs
- Design issues
  - Link layer and MACs
  - Spectrum reuse
  - Routing
  - Crosslayer design
- End of Module A.int.1

Ad-Hoc networks: overview



- Peer-to-peer communications.
- Virtually fully connected
  - Since media is wireless anyway
  - Quality of link varies a lot!
  - Diagram never can be done accurately

Ad Hoc networks: overview

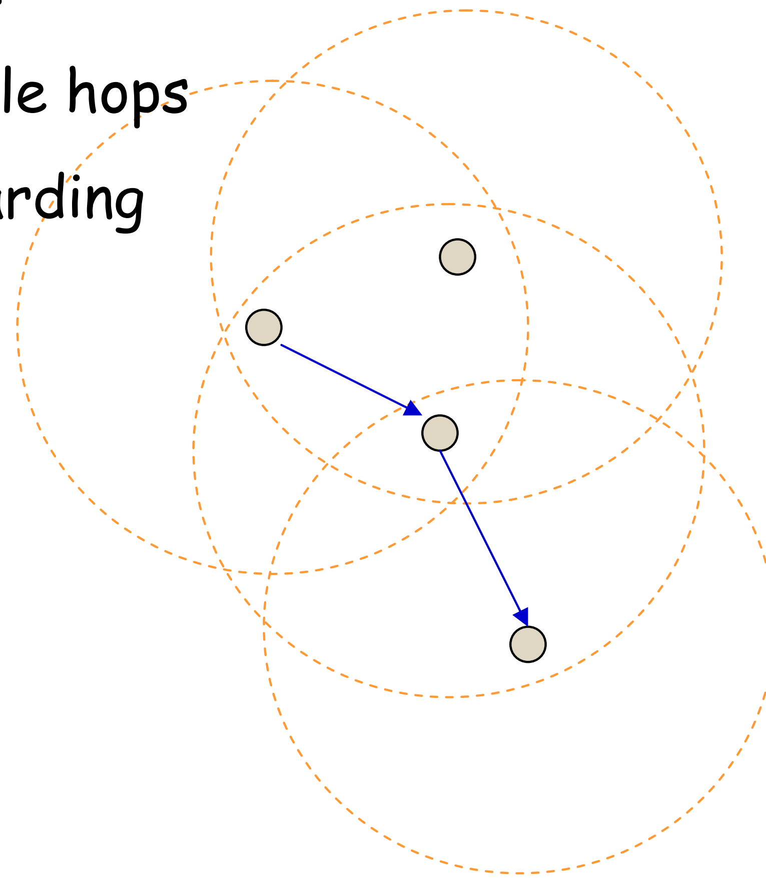
- Characteristics
  - Without using a pre-existing infrastructure
  - Wireless
  - Mobile (partial)
  - Multi-hop
  - Ad hoc deployment
- Benefits
  - Easy and fast deployment
  - Eliminating dependency on infrastructure

Ad Hoc networks: overview

- Applications
  - PAN
    - Personal area networking, connecting with cell phones, laptop, wrist watch, etc
  - Military environments
    - Tanks, soldiers, planes, battlefield communications
  - Emergency operations
    - Rescue, fire fighting
    - Surveillance
  - Civilian environments
    - Town hall meeting
    - Gathering, convention

Multi-hop

- From source to destination
  - May need to traverse multiple hops
  - Every node capable of forwarding
  - Require routing algorithms
- Impacts on MAC
  - Multi-hop aware MAC



Assumptions and variations

- Symmetric or asymmetric?
  - All nodes have identical capabilities & responsibilities
  - Or capacity variations in
    - Transmission ranges & bandwidth
    - Battery life
    - Mobility & its speed
    - Processing capacity
  - Or capacity variation in
    - Elected as a leader
    - Routing and forwarding packets
    - Co-exist or co-operate with an infrastructure-based network

Assumptions and variations

- Variation with infrastructures
  - Coexistence with an infrastructure if any
- Variations in traffic characteristics
  - Bit rate
  - Realtime or data oriented
  - Unicast/multicast/geocast
  - Addressing (host, content, capability)
- Variation in mobility
  - link failure/repair due to mobility may have different characteristics than those due to other causes
  - Rate of link failure/repair may be high when nodes move fast

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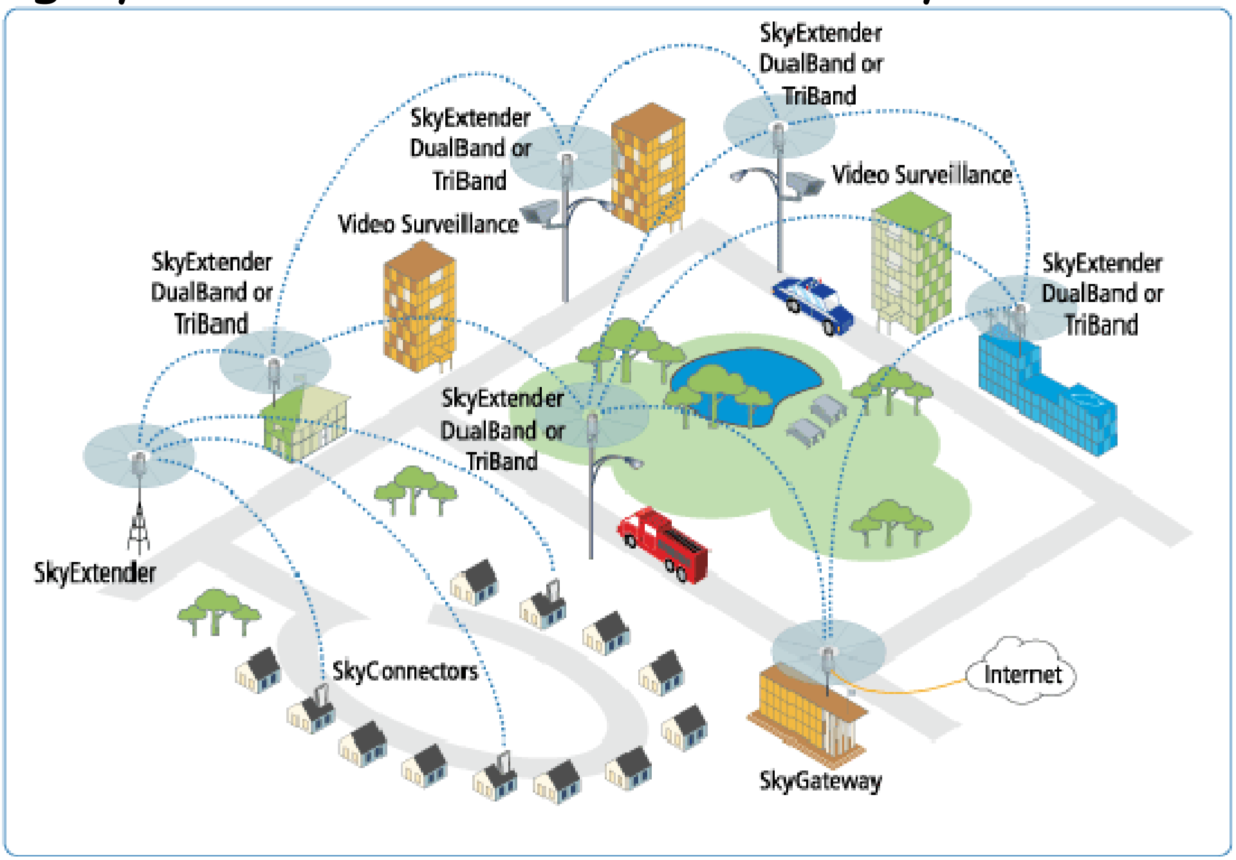
Ad hoc special: sensor networks

- Ad hoc → sensor networks
  - Node equipped with sensing capability
  - Node are severely power constrained
  - Applications are most likely data driven

    → a large collection of tiny sensor devices
- Limited resource with sensors
  - Power, processing, storage, communication
- Deployment in harsh environments
  - Self-organize, self-healing

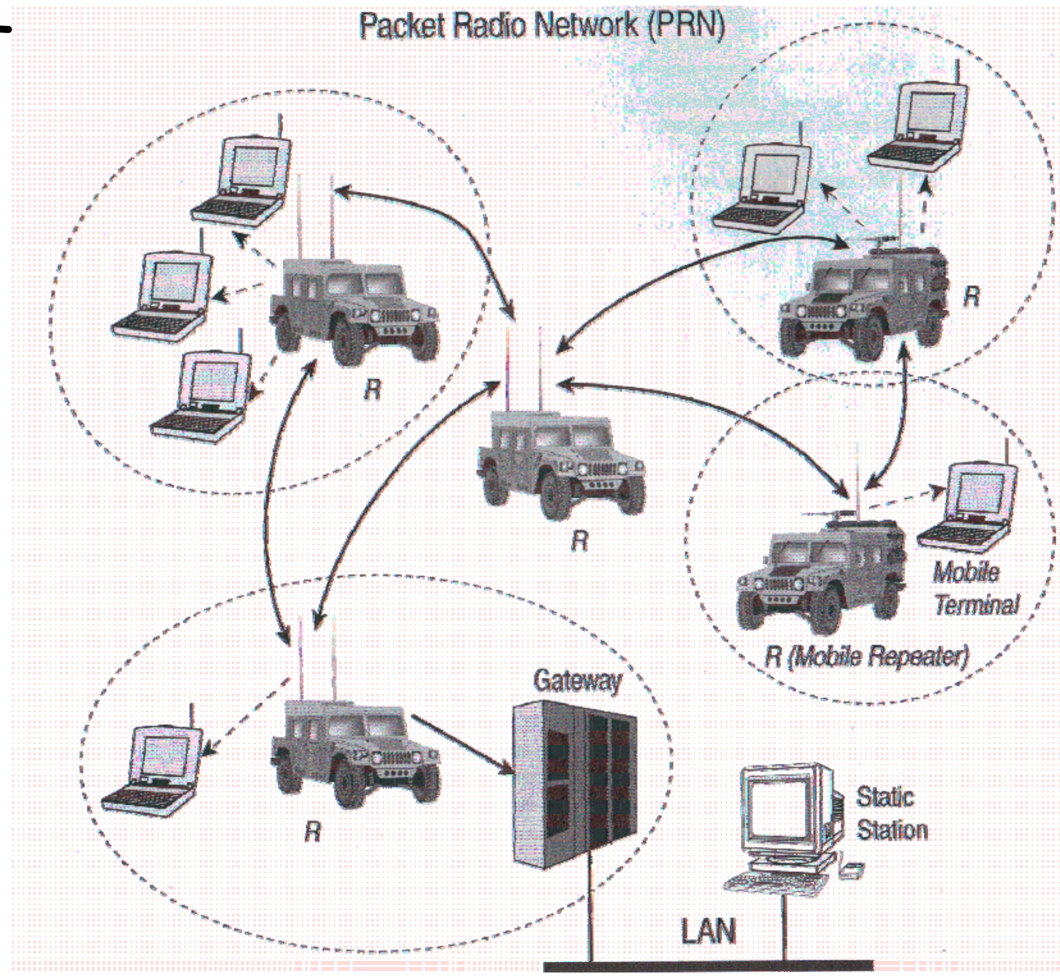
Ad hoc special: mesh networks

- Ad hoc → mesh networks
  - Rapidly deployable wireless infrastructure
  - Largely immobile nodes or stationary nodes



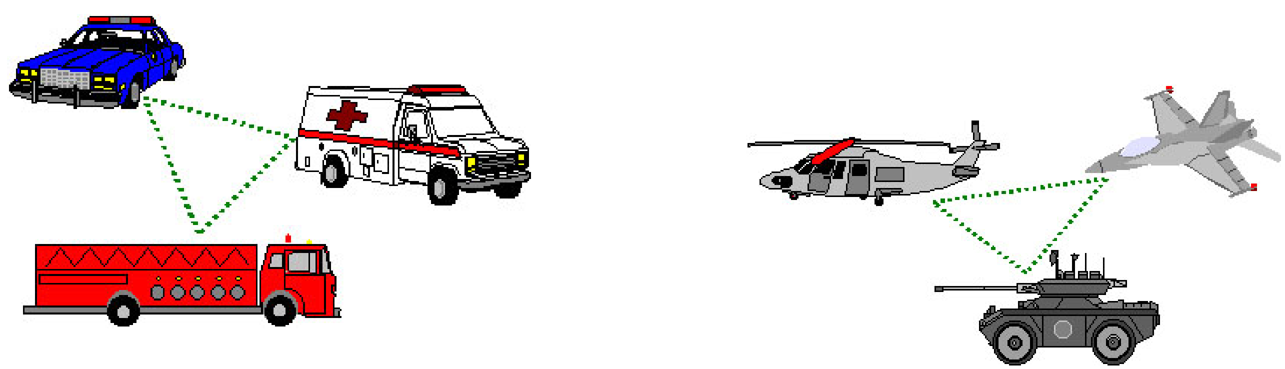
Ad hoc special: MANETs

- Ad hoc → MANET
  - Highly mobile nodes
  - Mobility causes route changes



Ad hoc special: MANETs

- IEFT MANET Working Group
  - to standardize an interdomain unicast routing protocol which provides one or more modes of operation, each mode specialized for efficient operation in a given mobile networking "context", where a context is a predefined set of network characteristics.



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上海交通大学 Shanghai Jiao Tong University

The University of New Mexico

Design issues

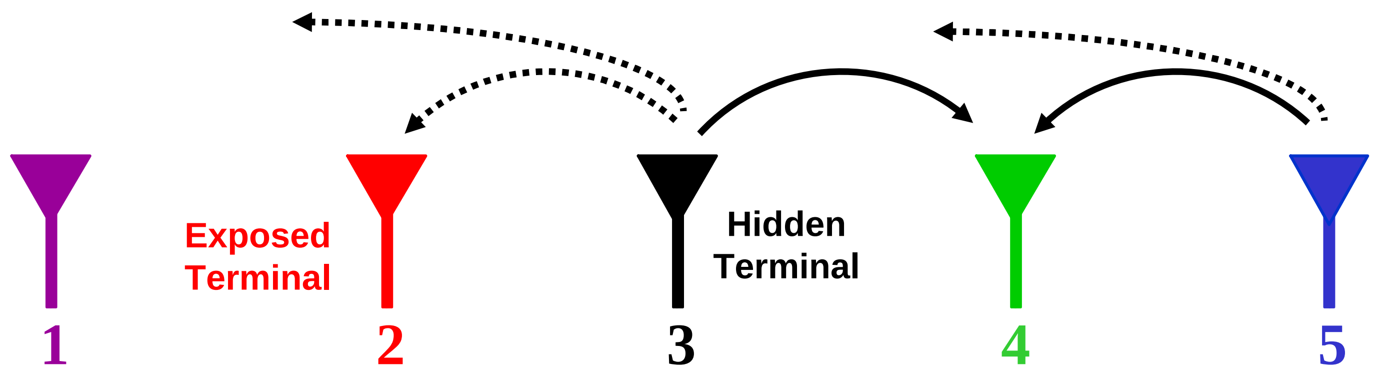
- Link layer design
- Channel access and frequency reuse
- Reliability
- Routing
- Network issues
- Power/energy management

Link layer design

- Modulation and Coding
  - Robustness
  - Rate requirements
  - Performance
  - Adaptive techniques: rate, power, BER, code, framing, etc.
- Power control
- Multiuser Detection
- Antenna design
  - Smart antennas and MIMO.

MAC design

- Nodes need a decentralized channel access method
  - Minimize packet collisions while increasing channel utilization
    - Collisions course significant delay
- Aloha w/ CSMA/CD have hidden/exposed terminals



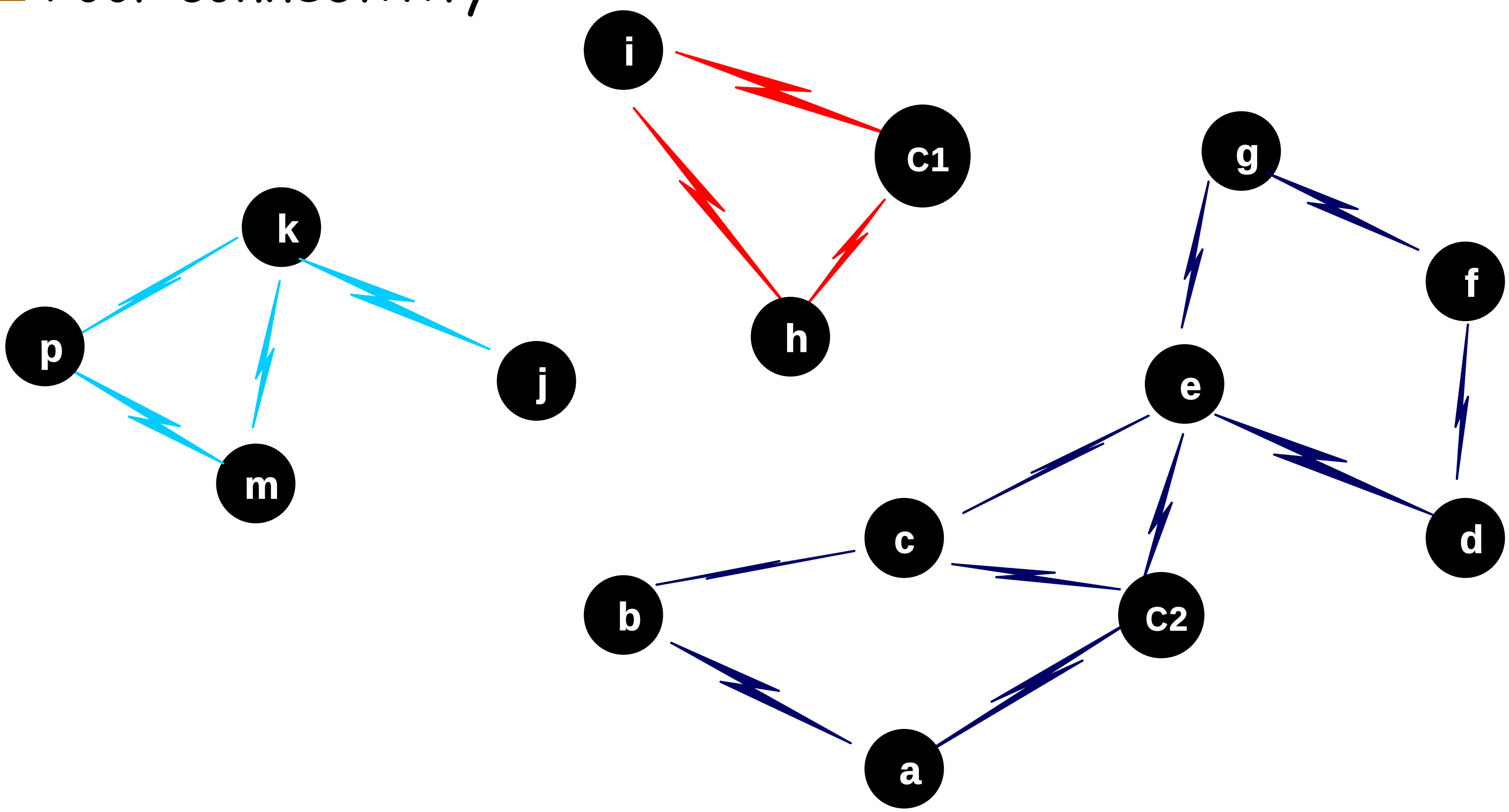
- 802.11 uses four-way handshake
  - Creates inefficiencies, especially in multihop setting

Design issues

- Scalability issues
- Tradeoff
  - energy consumption vs. latency
- Standard issues
  - protocol deployment and incompatibility standards
- Security issues

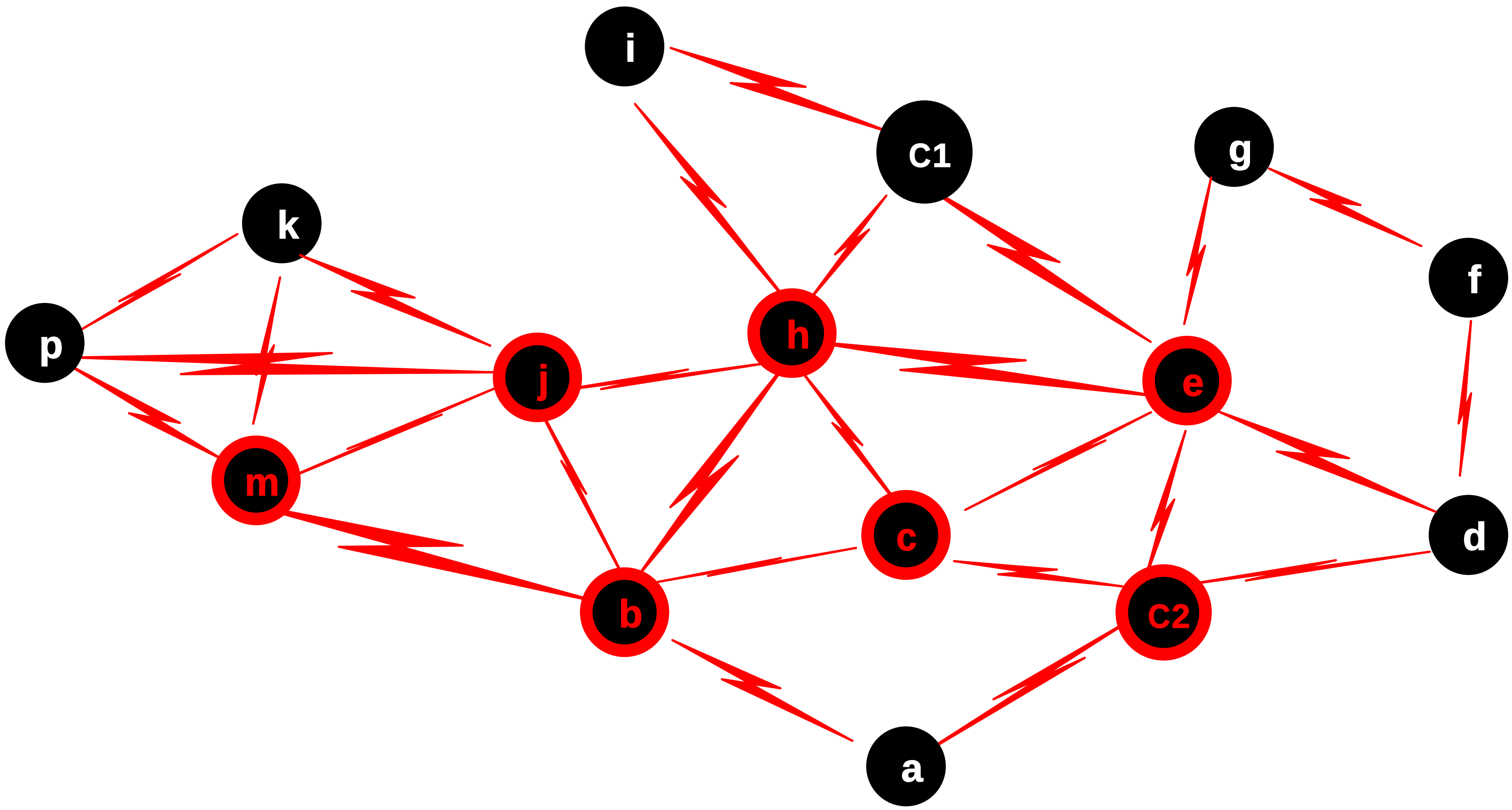
Spectrum reuse

- Static channel allocation, multiple channels
  - Poor connectivity



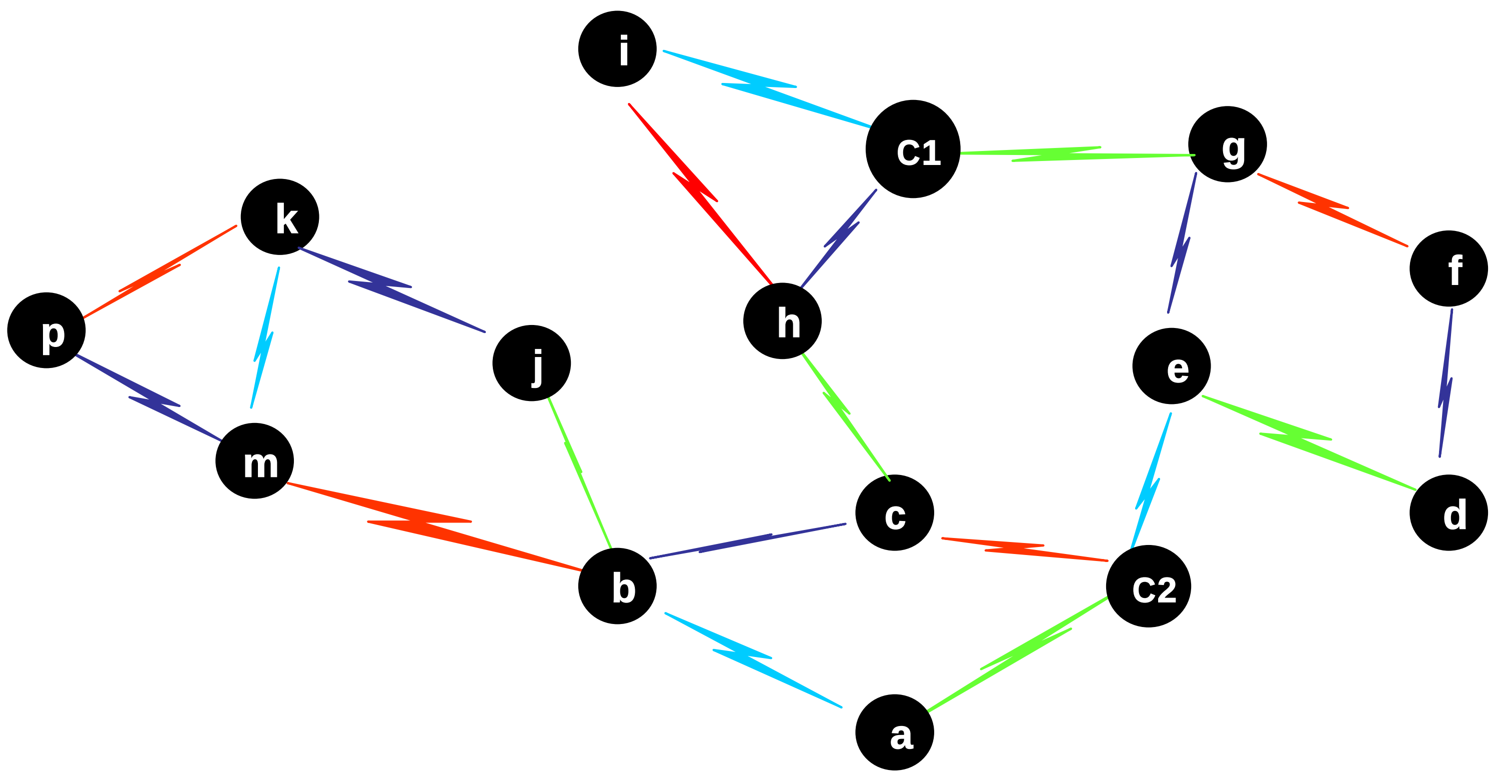
Spectrum reuse

- Static channel allocation, single channel
  - Poor interference



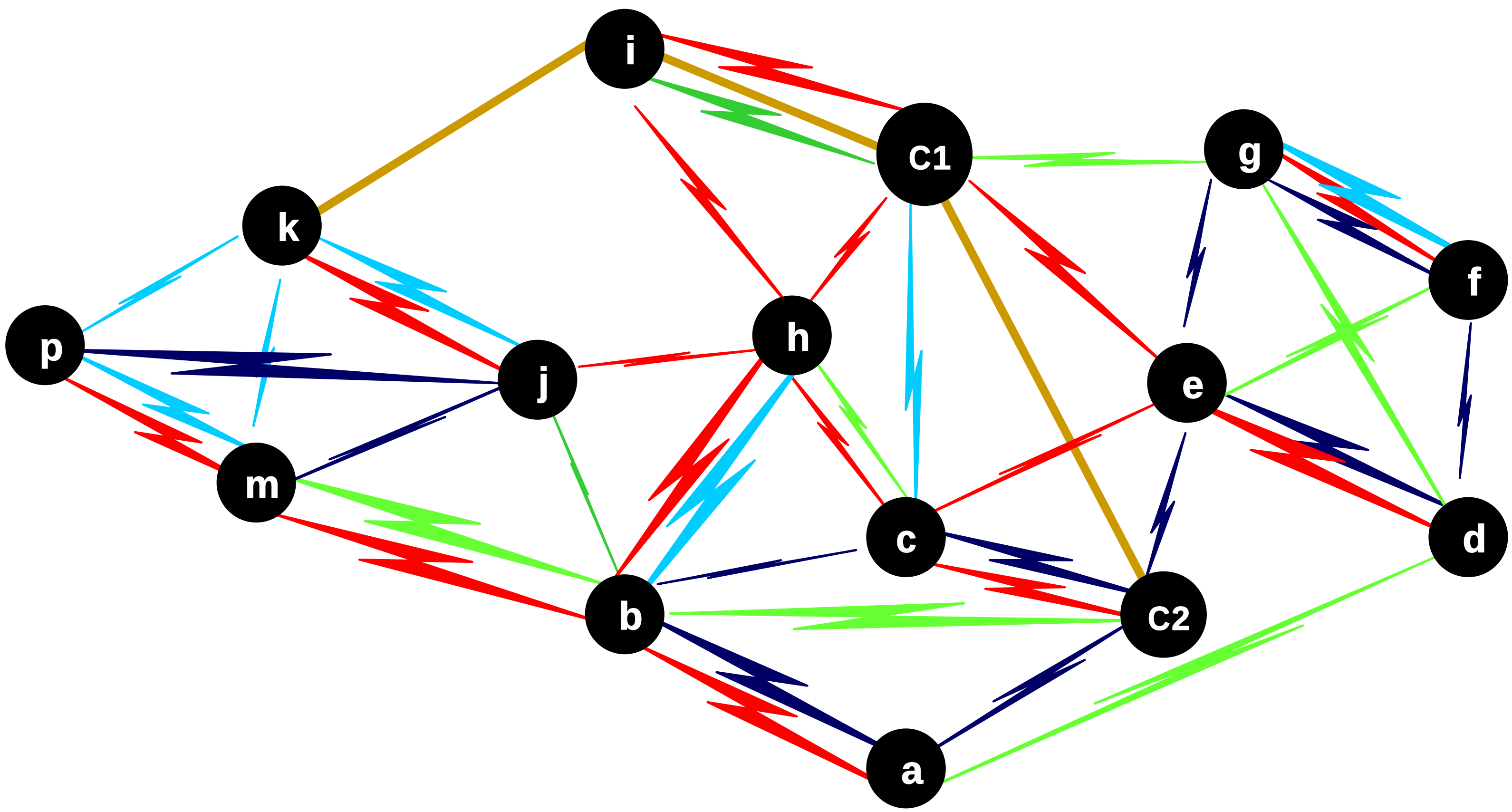
Spectrum reuse

- Dynamic channel allocation, single interface
  - Good Connectivity and Controlled Interference

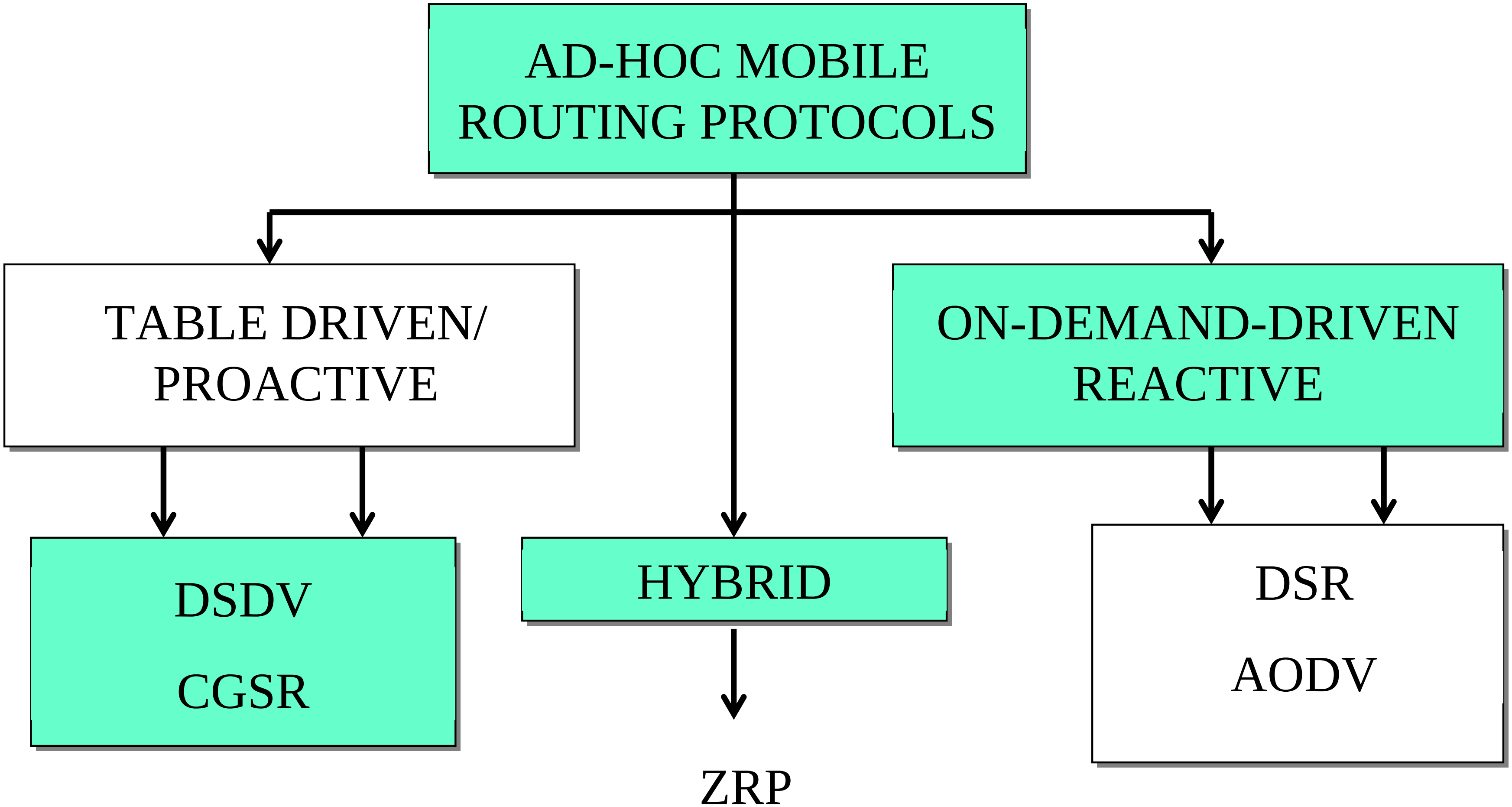


Spectrum reuse

- Dynamic channel allocation, mulitple interfaces
  - Complicated control



Ad hoc routing



Ad hoc routing

- Flooding, broadcast-based
  - Inefficient
  - Robust for fast changing topologies.
  - Little explicit overhead
- Point-to-point routing
  - Routes follow a sequence of links
  - Connection-oriented
    - Explicit end-to-end connection
    - Less overhead/less randomness
    - Hard to maintain under rapid dynamics.
  - Connectionless
    - Packets forwarded towards destination
    - Local adaptation

Ad hoc routing

- Table-driven
  - Destination-sequenced distance-vector
  - Clusterhead gateway switch routing
  - Wireless routing protocol
- On-Demand Routing
  - On-demand distance vector routing
  - Dynamic source routing
  - Temporally ordered routing
  - Associativity-based routing
  - Signal stability routing

Ad hoc 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:
  - on-demand
  - Ex: DSR, AODV

Ad hoc route dissemination

- Route computed at centralized node
  - Most efficient route computation.
  - Can't adapt to fast topology changes.
  - BW required to collect and disseminate information
- Distributed route computation
  - Nodes send connectivity information to local nodes.
  - Nodes determine routes based on this local information.
  - Adapts locally but not globally.
- Nodes exchange local routing tables
  - Node determines next hop based on some metric.
  - Deals well with connectivity dynamics.
  - Routing loops common.

Reliability

- Packet acknowledgements needed
  - May be lost on reverse link
  - Need negative ACKs?
- Combined ARQ and coding
  - Retransmissions cause delay
  - Coding may reduce data rate
- Hop-by-hop acknowledgements
  - Explicit ACKs
  - Echo ACKs
    - Transmitter listens for forwarded packet
    - More likely to experience collisions than a short ACK.
  - Hop-by-hop or end-to-end or both.

Crosslayer design

- Application
- Network
- Access
- Link/MAC
- Hardware

Delay Constraints
Rate Requirements
Energy Constraints
Mobility

Optimize and adapt across design layers
Provide robustness to uncertainty

Crosslayer design?

- The technical challenges of future mobile networks cannot be met with a layered design approach.
- QoS cannot be provided unless it is supported across all layers of the network.
  - The application must adapt to the underlying channel and network characteristics.
  - The network and link must be application aware
- Interactions across network layers must be understood and exploited.

Summary

- Ad-hoc networks provide a flexible network infrastructure for many emerging applications
- Advances in communication techniques should be incorporated into ad-hoc network design
- Design issues traverse all layers of the protocol stack, and cross layer designs are needed
  - Protocol design in one layer can have unexpected interactions with protocols at other layers.
- Many new issues to be addressed

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