CS 294-7: Introduction to Packet Radio Networks

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Packet Radio Networks

- Fixed or mobile nodes that communicate via radios
  - Advantages:
    - » Fast (re)deployment and set-up of network
    - » Ability to support mobile nodes
  - Disadvantage: complications due to
    - » Communications medium
    - » Dynamic nature of the network topology
    - » Half duplex operation
- Single hop vs. multi-hop
- Ad-hoc networks vs. fixed networks

Historical Perspective: ARPA Packet Radio Program

- Program initiated in 1973
  - Geographically distributed network
  - Array of packet radios and minicomputer-based “stations”
  - Deployed in SF Bay Area in 1975
  - Experimental packet radio (EPR)
    - » 100, 400 kbps (128/32 chips per bit respectively)
    - » Use lower data rate in worse multipath environments
    - » Operates in half duplex mode
  - Upgraded packet radio (UPR)
    - » Bit-by-bit PN variability in the waveform
    - » Agile spreading factors to improve LPI/LPJ
    - » Implemented FEC rather than ARQ
  - Low cost packet radio (LPR)
    - » Cost reduced version of UPR (1986)

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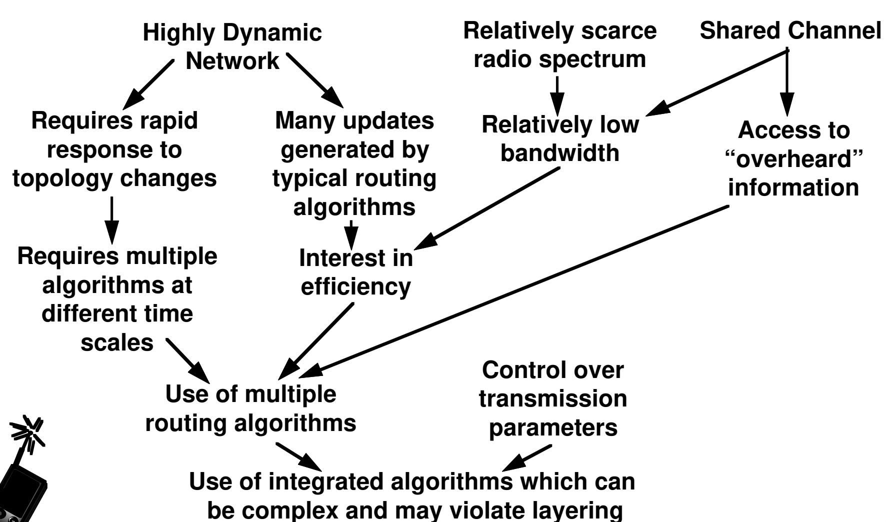
Complexity Issues in Packet Radio Networks



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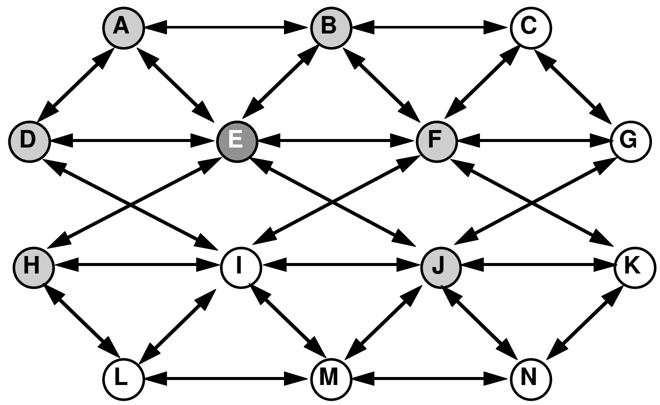
Packet Radio Network Topology



e.g., E can hear transmissions from A, B, F, J, H

Links need not be bidirectional!

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Issues in PR Network Design

- **Physical/Link Layer**
  - Physical Connectivity
    - » Depends on RF propagation charactistics
      - Frequency choice
      - Distance between nodes (LOS vs. OTH)
      - Antenna height and directionality
      - Terrain type
      - Xmit power
      - Interference
  - Bandwidth-Time-Space Management
    - » Frequency, time, code, & spatial reuse of bandwidth resources
  - Channel Access (Narrowband Systems)
    - » Random Access (e.g., Aloha, CSMA schemes)
    - » Reserved Access (e.g., Reservation, Demand Assignment Schemes)

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Issues in PR Network Design

- Physical/Link Layer (cont.)
  - Channel Access (Spread Spectrum Systems)
    - » Code division schemes
      - Common preamble for all transmitters AKA broadcast reception (space-homogeneous preamble code assignment)
      - Receiver-directed preamble code assignment directed towards a specific receiver
      - Similar choices for data portion of packet--once a receiver is locked on to a packet, other overlapping packets do not interfere with correct reception
      - Bit-by-bit code changing--reduces probability of intereference
      - Transmitter directed code assignment--preamble contains information on spreading waveform to be used used to encode the data
    - » Aloha random access versus CSMA schemes with this level of code division schemes

Issues in PR Network Design

- Data Link Control
  - ARQ and FEC techniques needed due to variability in the link quality
  - Especially important with SS systems--possibility of correlated codes is high for at least part of the packet
  - Hop by hop acks in a multihop route
    - » Explicit short acks
      - Priority over data packets
    - » Echo/Passive acks
      - Forwarding on the message is interpreted as an ack to the preceeding sender
      - Delays introduced (forwarding packet placed at bottom of queue)
      - Long packets increase probability of interference
      - Can’t be used in SS systems with received-directed codes

Issues in PR Network Design

- **Network Management**
  - Link determination and control
    - » Centrally collected and redistributed
    - » Locally determined
    - » Use channel measurements:
      - Signal strength, SNR, BER
      - Integrate over packets sent across radio-to-radio links
      - OR simply track packet loss rates per link--delay in discovering loss of link quality?
    - » Balance link parameters (e.g., transmission bandwidth), hop-by-hop FEC/ARQ, end-to-end ARQ
    - » Partitioned networks

Issues in PR Network Design

- **Network Management (cont)**
  - Routing: choosing routes based on link connectivity
    - » Routing schemes:
      - Flooding methods--inefficient utilization, but simple and may be best strategy for rapidly changing network topologies
      - Point-to-Point Routing--sequence of links associated with src-dst pair AKA "connection-oriented" routing
      - Connectionless--no knowledge of connections, local adapative behavior to forward packet on "towards" destination. This is a good approach for dynamic networks.
    - » Spreading routing information
      - Centralized routing server
      - Distributed routing--each node determines routes on its own;
Hop-by-hop decisions or specify full route at source;
Exchange routing tables among neighbors
      - Hierarchical organizations: topology changes more rapidly within clusters than between clusters (centralized "station" within cluster)
  - Packet forwarding
    - » Localized rerouting to fix broken routes: broadcast a packet to any node that can complete the route

Issues in PR Network Design

- Network Management Issues
  - Congestion and flow control
    - » Virtual circuits and resource reservation with rapidly changing topologies
    - » Rate control of packet forwarding based on local congestion
  - Mapping between end nodes and packet radios
    - » Must be able to detach and reattach modem to different end nodes

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Issues in PR Network Design

- Operation and Management
  - Network Deployment
    - » Coverage and capacity requirements
    - » Rapidity of deployment
    - » Software distribution
  - Maintenance and Reliability
    - » Fault detection
    - » Redundancy of coverage
  - Diagnostics and monitoring
    - » Remote/over the air capability

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Issues in PR Network Design

- Connecting to External World
  - Gateways
    - » Network vs. gateway-based routing
  - Network access control
    - » Control typically exercised at the periphery
    - » Complexity when users can attach to the network anywhere within the network
  - Addressing and naming
    - » Internet addressing versus more efficient subnet addressing
  - Security
    - » End-to-end encryption
    - » What about headers?

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Issues in PR Network Design

- Impact on Radio Spectrum
  - Electromagnetic compatibility
  - Electronic counter-countermeasures/noise immunity
    - » link-by-link power control to hide the network
    - » route around nodes being targeted by jammers
  - Efficiency
    - » number of users/bandwidth and or area
    - » performance metrics
      - availability
      - delay
      - priority
      - throughput
      - coverage
      - mobility
      - accuracy
  - Cost

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