CS 294-7: Introduction to Packet Radio Networks

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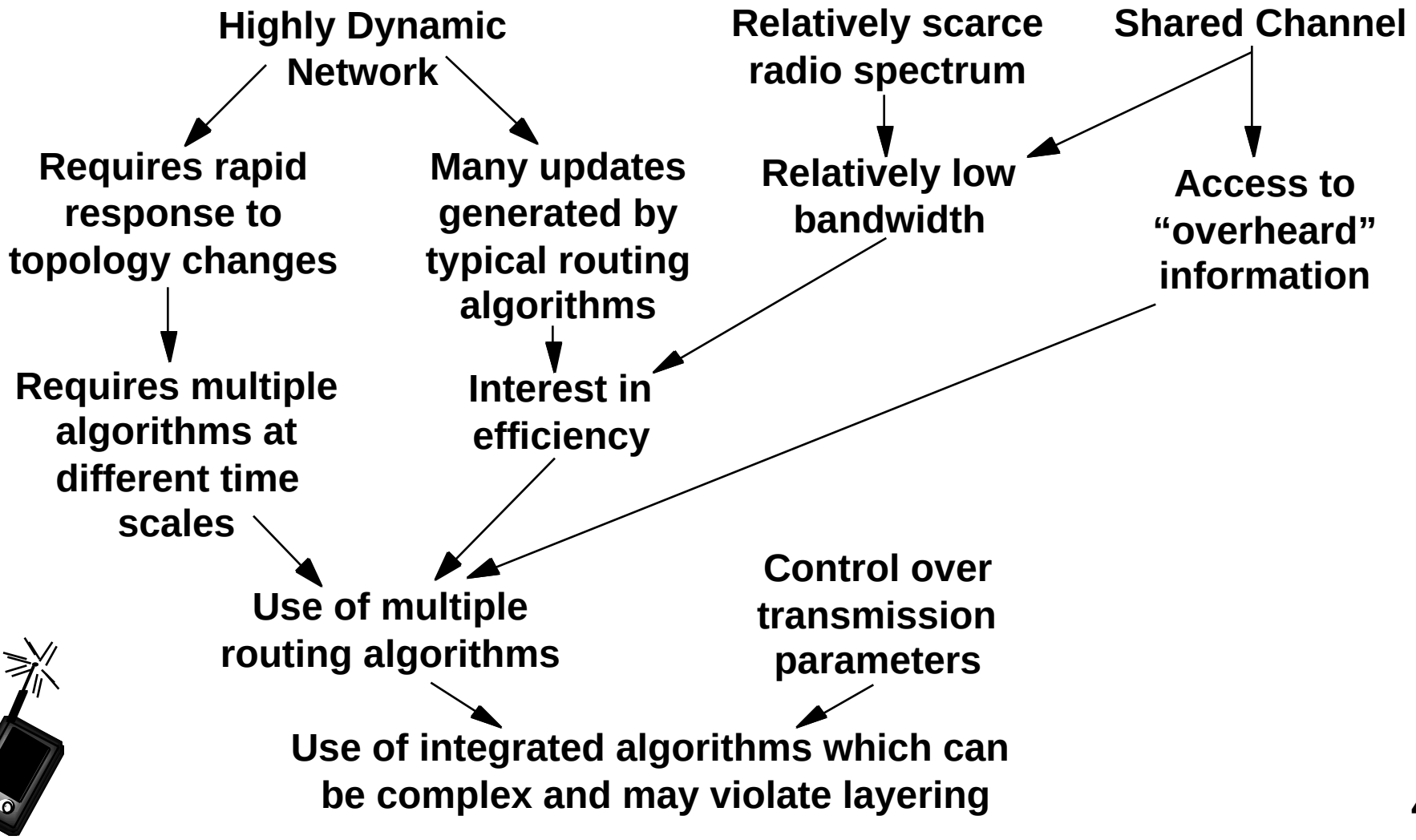
Packet Radio Networks

- **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**

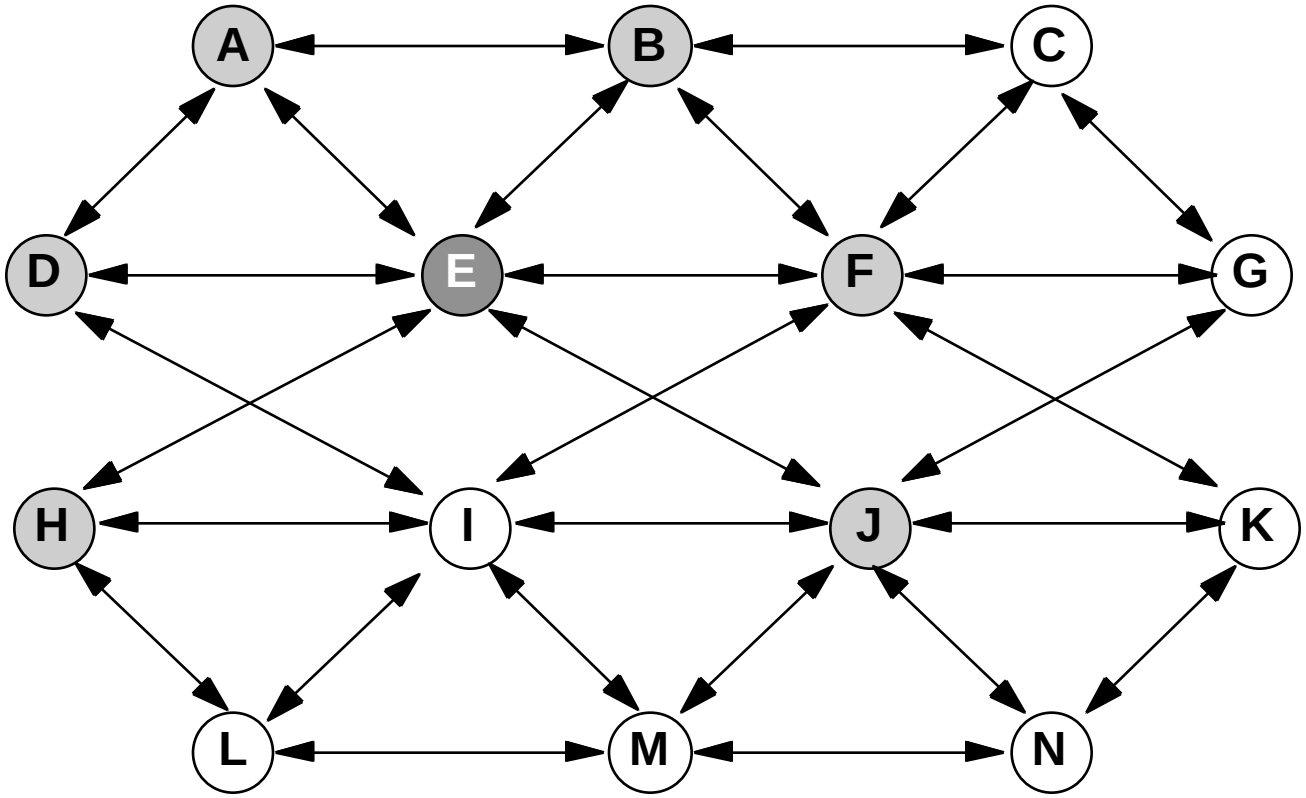
Historical Perspective: ARPA Packet Radio Program

- **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)**

Complexity Issues in Packet Radio Networks



Packet Radio Network Topology



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

Links need not be bidirectional!

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)**

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**

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**

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?**

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**