Wireless Comes of Age

- Marconi invented wireless telegraph in 1895
- First voice transmission over radio made by Fessenden in 1900
- Dec. 1901 Marconi made historic trans-Altantic transmission from St. John, Nfd. to Cornwall, UK.
- Two-way FM mobile police radio first used in 1940
- First communications satellite launched in 1957
- ALOHANET launched at University of Hawaii in 1971
- GSM launched in 1994
- IEEE 802.11 first released in 1997

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Broadband Wireless Technology

- Broadband wireless technologies emerging to support multimedia applications
  - Voice, web browsing, audio, video, images
- 3G cellular at up to 2 Mbps over wide areas
- IEEE 802.11a WLAN at 54 Mbps
- Shares same advantages of all wireless services: convenience and reduced cost
  - Service can be deployed faster than fixed service
  - No cost of cable plant
  - Service is mobile, deployed almost anywhere

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Problems with Wireless

- Insufficient radio frequency spectrum to support popular and broadband services
- Government regulations
- Lack of industry-wide standards
- Device limitations
  - Limited battery power
  - Usability issues: small LCD screens on mobile phones, numerical keypad makes text inputs difficult
- Users and terminals are often mobile
- What are the killer applications?

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Mobile Ad Hoc Networks

- Collection of mobile nodes forming a temporary network
- No centralized administration or standard support services
- Each mobile node also functions as an independent router
- Mobile nodes connected to neighbour nodes by wireless links
- Mobile nodes may join or leave the network at any time
- Applications:
  - Conferences/meetings
  - Search and rescue
  - Disaster recovery
  - E-battlefields
  - Sensor networks

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Issues with MANETS

- Lack of a centralized entity – need distributed control
- Node mobility – network topology changes frequently and unpredictably
- Wireless links – limited bandwidth, bursty and high BER, access contention, hidden/exposed terminal problem
- Portable nodes – battery power limitations
- Security – a matter of trust, i.e., why should I trust that:
  - your traffic will not interfere with proper operation of my node
  - you will properly forward my traffic
- Connectivity – how to reach any destination from any source: **routing, routing, routing ……**

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Wireless Personal Area Networks (WPANs)

- Standards being developed by IEEE 802.15 Working Group
- Wireless connectivity with < 10 m transmission range
- Working groups within IEEE 802.15
  - 802.15.1 – Bluetooth WPAN, standards published in June 2002 802.15.2 – co-existence with WLAN
  - 802.15.3 – high rate (> 20 Mbps) WPAN
  - 802.15.4 – low rate (therefore low power) WPAN
- Focus on the Bluetooth **specifications** that have been adopted as the IEEE 802.15.1 **standards**

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What is Bluetooth?

- A short-range wireless technology
- Designed for several needs Interconnecting a computer and peripherals
- Interconnecting various handheld devices
  - Laptop computer, cell phone, palmtop
  - Preplanning of network is impractical
- Any short-range application where low cost is essential
- Goal: $5 parts cost
- Intended to be embedded in other devices

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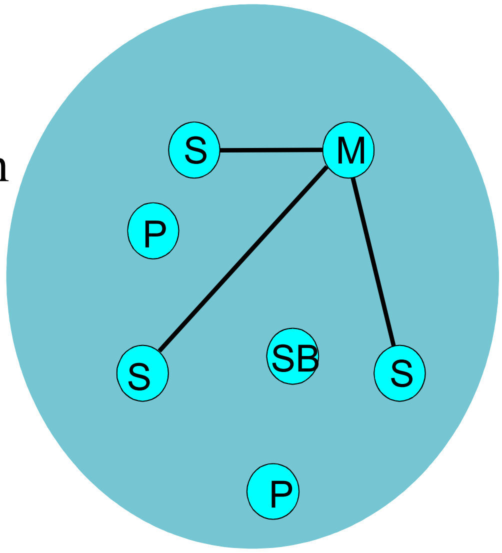
What is a Piconet?

- A collection of devices connected in an ad hoc fashion
- One unit acts as master and the others as slaves for the duration of the piconet connection
- Master sets the clock and hopping pattern for all devices
- Each piconet has a unique hopping pattern/ID
- Each master can connect to 7 simultaneous slaves per piconet
- Standby devices are not part of any piconets



M=Master P=Parked
S=Slave SB=Standby

3-bit Active Member Address (AMA)
7-bit Parked Member Address (PMA)

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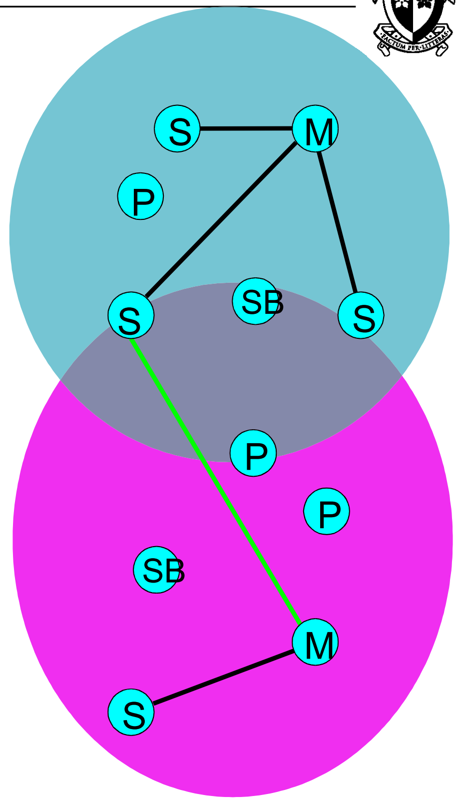
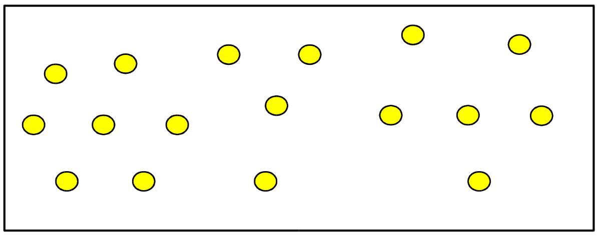
What is a Scatternet?

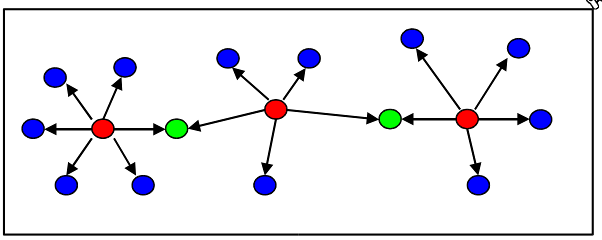
- A Scatternet is the linking of multiple co-located piconets through the sharing of common master or slave devices known as bridges
- A bridge can be a master on one piconet and a slave on another piconet, or a slave on both piconets
- Bluetooth radio at bridge device must timeshare between the two piconets, leading to possible traffic bottleneck



M=Master P=Parked
S=Slave SB=Standby

Scatternet Formation Algorithms





- Given a set of Bluetooth devices, a scatternet formation algorithm is necessary to:
  - create the topology of piconet or scatternet
  - Assign role of each device (master, slave, bridge)

Design Guidelines

- Resulting scatternet is fully connected.
- Minimize the number of piconets in a scatternet.
- Only one bridge node is shared between two piconets.
- Minimize number of piconets that a bridge node can connect to.

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Mobility Support at IP Layer

- Rationale for mobility support at IP (network) layer:
  - Network layer present in all Internet nodes
  - Network layer responsible for routing packets to the proper location
  - Network layer mobility support transparent to applications
- Design considerations: Support mobility across the entire Internet, even over different physical medium, wired or wireless
  - No modifications to existing routing infrastructure
  - No modifications to existing protocols
  - Independence of wireless technology
  - Scalable to large number of nodes

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Elements of Mobile IP

- Mobile Node (MN) – can visit foreign networks
- Mobility support nodes (mobility agents):
  - Home Agent (HA) – at MN's home network
  - Foreign Agent (FA) – at foreign network visited by MN
- Care-of-address (COA) – address acquired by MN at visited network (e.g., by DHCP, or simply FA's address)
- Registration – MN registers its COA with HA via FA
- Authentication – HA authenticates MN's identity
- Binding – of MN's home address (MNA) and COA established in HA and FA
- Packet delivery – datagrams for MN arriving at home network are intercepted by HA and tunneled to COA at FA for delivery to MN
- Tunneling – IP-over-IP encapsulation/decapsulation

Coping with Mobility

- MN looks for mobility agent advertisements to identify HA at home or FA at visited network
- Binding has limited lifetime – reregistration required when binding expires
- MN moving to visited network discovers FA and registers with HA
- MN moving to different visited network finds new FA and renew registration with HA; binding at old FA times out
- MN moving back home notifies HA directly
- Many proposals for micro-mobility support: HA needs not be informed of movements within visited domain even though FA has changed, e.g., Cellular IP

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Route Optimization

- Triangular routing:
  - Datagrams routed from MN to CN directly
  - Datagrams routed from CN to MN via HA and FA
- Triangular routing is inefficient in use of network bandwidth and introduces additional delays
- Route optimization 1: HA informs CN of current binding and CN tunnels datagram directly to MN's COA; works only if CN can handle tunneling
- When MN attached to a new FA, it takes time before CN informed of new binding
- Route optimization 2: new FA informs old FA about change of binding; old FA tunnels datagrams to new COA
- If old FA's binding has expired and no new binding information received, FA tunnels datagrams back to HA

Mobility Models

- Needed for performance evaluations in research on mobility management
- Traditional models: random motion
  - Random change of direction at random way point or cell boundary
  - Constant velocity chosen from some distribution between change of directions
  - Time between change of direction either randomly generated from some distribution or depend on cell boundary
  - Further abstraction: equal likelihood in moving into any adjacent cell after a random cell residence time generated from some distribution
- Individual user-based models:
  - Markovian model: cell transition depends on history
  - Activity-based model: e.g., commuting, working, attending classes

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Mobile IP in IPv6

- IPv6 mainly increases IP address space from 32 bits to 128 bits
- Mobile IP much better supported by additional IPv6 features
- Tunneling is universally supported using address extensions
- COA can be self-generated by MN by neighbour discovery and auto-configuration
- MN can use “destination option” to send binding to CN
- Strong encryption is build in through IPsec

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TCP Performance over Wireless/Mobile

- Many applications on the networks run on top of the transmission control protocol (TCP)
- TCP used on the mobile network, it will encounter packet loss unrelated to congestion. However, these packet losses will trigger congestion control procedures at the fixed host that could result in significant degrading performance.

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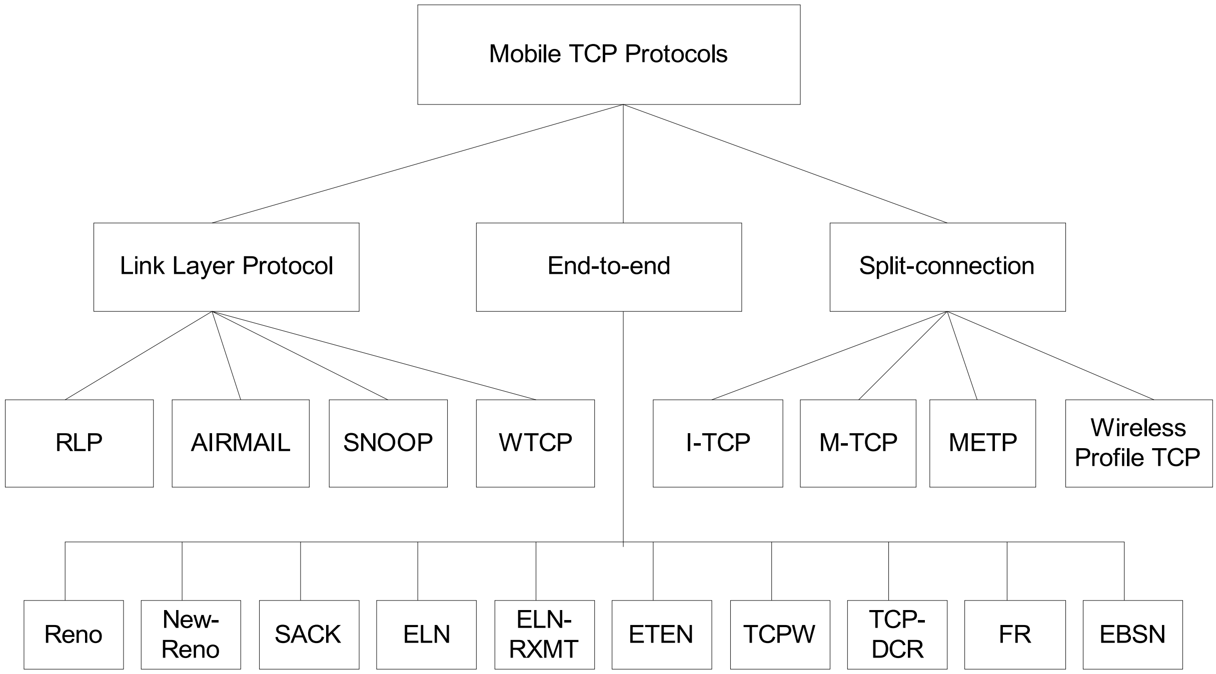
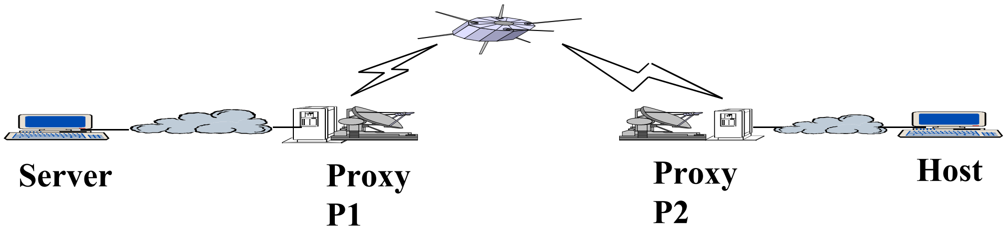
Enhanced TCP protocols



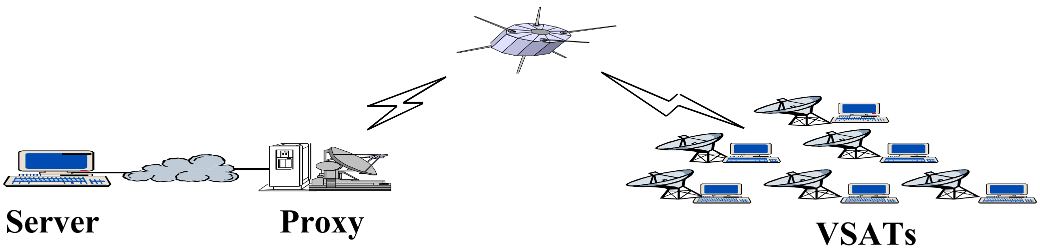
Why Satellite

- Cost-effective way for providing Internet Access
  - Appeal to geographically dispersed/remote users
  - A rapidly deployable communication infrastructure
- Match the asymmetric Internet Traffic Pattern
- Inherent broadcast capability
- Support mobility

Satellite Architectures



❖ Two gateways are located at edges of the satellite network



❖A number of VSATs, which employ a MAC protocol to access a shared satellite uplink, are located at the customer premises.

❖The gateway is granted fixed bandwidth in a dedicated channel.

Performance Enhancement over Satellite

- Improve end-to-end transport performance over all-satellite architecture
- Deploy split connection proxies to deal with specific characteristics of satellite channels
- Apply dynamic congestion control scheme
  - Uncouple flow control and error recovery schemes, which benefits error-prone links
  - Allow immediate congestion feedback from the underlying layer, which benefits long-delay links