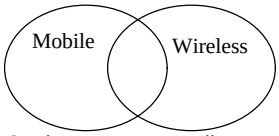
Mobility and Networking

Shivkumar Kalyanaraman
Rensselaer Polytechnic Institute
shivkuma@ecse.rpi.edu
http://www.ecse.rpi.edu/Homepages/shivkuma

Based in part on slides of Hari Balakrishnan, Srini Seshan, Pravin Bhagwat

- Wireless: Introduction
  - 802.11, Bluetooth, CDPD
- Mobility: IP Addresses and location
- Solutions: Mobile IP, TCP Migrate
- Service discovery, Configuration: current work
  - iNAT, zero-conf

Mobile vs Wireless

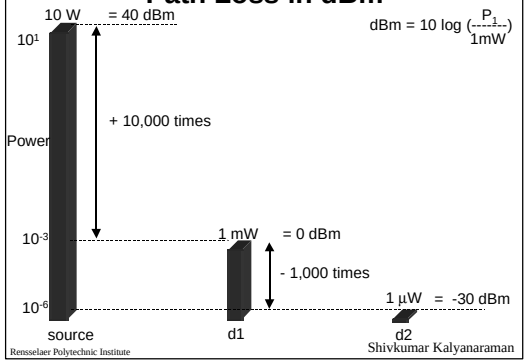


- Mobile vs Stationary vs Nomadic
- Wireless vs Wired
- Wireless ⇒ media sharing issues
- Mobile ⇒ routing, location, addressing issues
- Nomadic => terminate existing communications before leaving point-of-attachment. Later, reconnect.

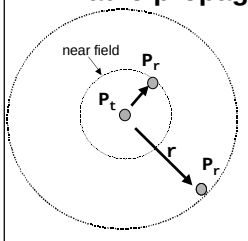
Wireless Challenges

- Force us to rethink many assumptions
- Need to share airwaves rather than wire
  - Don't know what hosts are involved
  - Host may not be using same link technology
- Other characteristics of wireless
  - Noisy → lots of losses
  - Slow
  - Interaction of multiple transmitters at receiver
    - Collisions, capture, interference
  - Multipath interference

Path Loss in dBm



Radio propagation: path loss



path loss in 2.4 Ghz band

$r \leq 8m$ | $r > 8m$

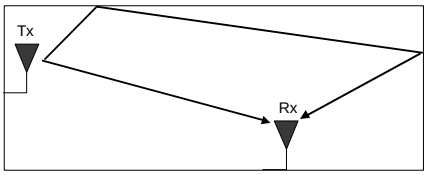
near field $\propto r^2$ | far field $\propto r^{3.3}$

path loss = $10 \log (4\pi r^2/\lambda)$ $r \leq 8m$

= $58.3 + 10 \log (r^{3.3}/8)$ $r > 8m$

Fading and multipath

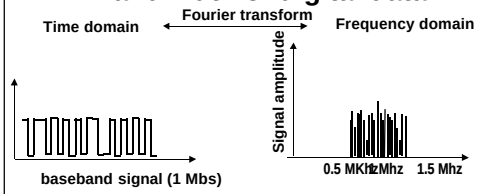
Fading: rapid fluctuation of the amplitude of a radio signal over a short period of time or travel distance



Effects of multipath

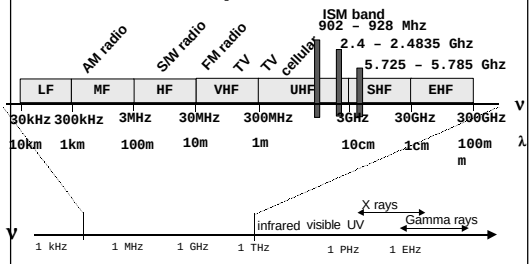
- **Fading**
- **Varying doppler shifts on different multipath signals**
- **Time dispersion (causing inter symbol interference)**

Bandwidth of digital data



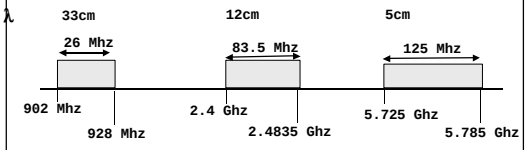
- **Baseband signal cannot directly be transmitted on the wireless medium**
- **Need to translate the baseband signal to a new frequency so that it can be transmitted easily and accurately over a communication channel**

EM Spectrum



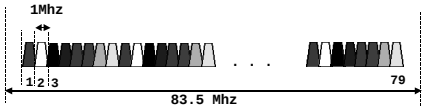
Propagation characteristics are different in each frequency band

Unlicensed Radio Spectrum



cordless phones	**802.11**	**unused**
baby monitors	**Bluetooth**	
Wireless LANs	**Microwave oven**	

Bluetooth radio link



- Frequency hopping spread spectrum
  - 2.402 GHz + k MHz, k=0, …, 78
  - 1,600 hops per second
- GFSK modulation
  - 1 Mb/s symbol rate
- transmit power
  - 0 dbm (up to 20dbm with power control)

Wireless link layers

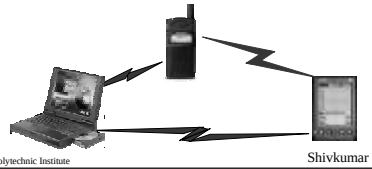
- Cellular Digital Packet Data (CDPD):
  - **Send *IP packets over unoccupied radio channels* within the analog cellular-telephone systems**
  - **Not circuit switched => no per-call/call-duration charges**
  - **Usage-based billing (contract w/ CDPD providers who have roaming agreements w/ other providers) => a wide area mobility solution (limited by availablility)**
  - **Carrier provides IP address, but link layer protocols are responsible for ensuring packets are delivered**
  - **Max data rate of 11 kbps**

Wireless link layers (contd)

- **IEEE 802.11**
  - Wireless LANs: 2 or 11 Mbps.
  - Defines a set of transceivers which interface between wireless/wired
  - Link layer protocols make entire network of transceivers appear as one link at network layer => mobility within 802.11 invisible to IP
  - Changing router boundaries => interrupts communications.

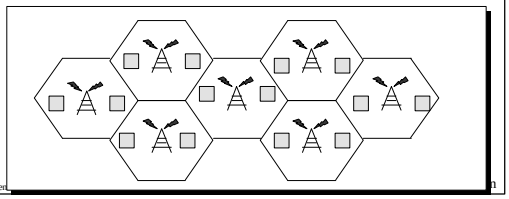
Wireless link layers (contd)

- **Bluetooth:**
  - **A cable replacement technology**
  - **1 Mb/s symbol rate; Range 10+ meters**
  - **Single chip radio + baseband**
  - **Target: low power & low price point**



Ideas: Cellular Reuse

- Transmissions decay over distance
  - Spectrum can be reused in different areas
  - Different "LANs" and "forwarding mechanisms"
  - Decay is $1/R^2$ in free space, $1/R^4$ in some situations

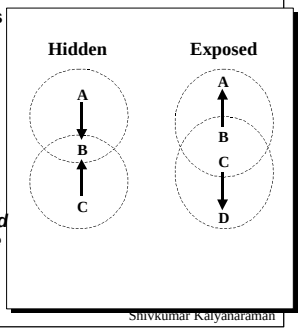


Multiple Access

- **TDMA, FDMA like wired networks**
- **CDMA (code division multiple access)**
  - **Multiple senders at a time (like FDMA)**
    - **Senders cause interference to each other**
  - **Each sender has unique code known to receiver**
    - **Codes chosen to be distinguishable, even when multiple sent at same time**
    - **Code "spreads" actual transmission**
  - **Codes can be applied in different ways**
    - **Direct sequence – controls transmitted bits**
    - **Frequency hopping – controls hopping sequence**

CSMA/CD Does Not Work

- **Carrier sense problems**
  - **Relevant contention at the receiver, not sender**
  - ***Hidden* terminal**
  - ***Exposed* terminal**
- **Collision detection problems**
  - ***Hard to build a radio that can transmit and receive at same time***

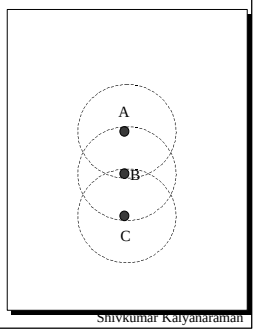


RTS/CTS Approach

- Before sending data, send Ready-to-Send (RTS)
- Target responds with Clear-to-Send (CTS)
- Others who hear defer transmission
  - Packet length in RTS and CTS messages
- If CTS is not heard, or RTS collides
  - Retransmit RTS after *binary exponential backoff*

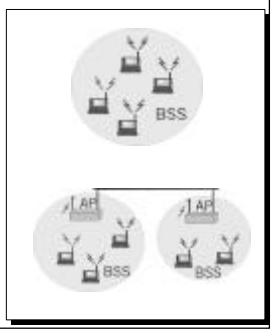
Adding Reliability

- Noise can corrupt packets
- Add an ACK after DATA transmission
  - If ACK not received, sender restarts RTS/CTS again
  - If ACK was lost, receiver sends ACK instead of CTS

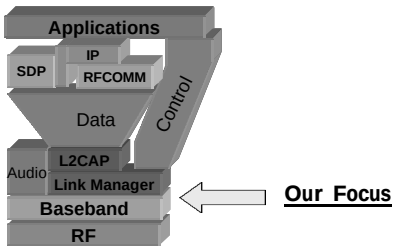


IEEE 802.11

- Standard for wireless communication
- MAC-layer uses many of the ideas discussed
  - RTS/CTS/ACK
  - Careful backoff
- Allows two modes
  - Ad-hoc
  - Wired/wireless



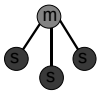
Bluetooth Protocols



Bluetooth Physical link

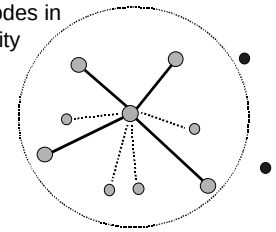
- **Point to point link**
  - master - slave relationship
  - radios can function as masters or slaves

- **Piconet**
  - Master can connect to 7 slaves
  - Each piconet has max capacity (1 Mbps)
  - hopping pattern is determined by the master



Piconet formation

- Page - scan protocol
  - to establish links with nodes in proximity

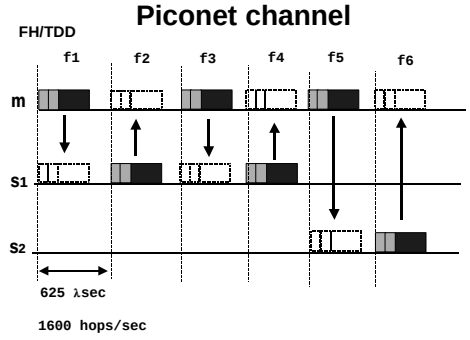


Master
Active Slave
Parked Slave
Standby

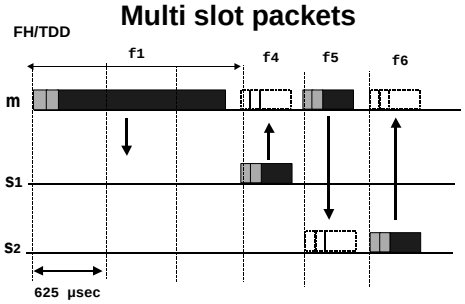
Addressing

- Bluetooth device address (BD_ADDR)
  - 48 bit IEEE MAC address
- Active Member address (AM_ADDR)
  - 3 bits active slave address
  - all zero broadcast address
- Parked Member address (PM_ADDR)
  - 8 bit parked slave address

Piconet channel



Multi slot packets



Data rate depends on type of packet

Mobility at IP, Transport Layers

- **Mobile IP:** independent of link layer technology
  - **Mobility-aware routing: home/foreign agent**
  - **Transparent to end hosts ("seamless")**
  - **Often inefficient packet routes**
- **TCP Migrate:** new MIT proposal
  - **Locate hosts through existing DNS**
  - **Secure, dynamic DNS is currently deployed and widely available (*RFC 2137*)**
  - **Maintains standard IP addressing model**
  - **Seamless connectivity thru connection migration**
  - **No home agent or foreign agents: "end-to-end"**

Mobile IP drivers

- IP Address is used for two purposes:
  - **To identify an endpoint**
  - **To help route the packet**
- *Move from subnet* ("link") => need to *change address* to allow routing
- Problem 1: How to route packets to this node at its new link ?
- Problem 2: Can we avoid changing the addresses seen by higher layer protocols ?
  - **Several protocols affected by address change: DNS, TCP, UDP.**

How to Handle Mobile Nodes?

- Dynamic Host Configuration (DHCP)
  - Host gets new IP address in new locations
  - Problems
    - Host does not have constant name/address → how do others contact host
    - What happens to active transport connections?
- Naming
  - Use DHCP and update name-address mapping whenever host changes address
  - *Fixes contact problem but not broken transport connections*

Basic Solution to Mobile Routing

- Add a level of indirection!
- Keep some part of the network *informed about current location*
  - Need technique to route packets through this location (interception)
- Need to forward packets from this location to mobile host (delivery)
- TCP connections not broken!
  - Remote hosts just use the home address in their socket pair

Interception

- **Somewhere along normal forwarding path**
  - **At source**
  - **Any router along path**
  - **Router to home network**
  - **Machine on home network (masquerading as mobile host)**
- **Clever tricks to force packet to particular destination**
  - **"Mobile subnet" – assign mobiles a special address range and have special node advertise route**

Delivery

- Need to get packet to mobile's current location
- Tunnels
  - Tunnel endpoint = current location
  - Tunnel contents = original packets
- Source routing
  - Loose source route through mobile current location

Mobile IP (RFC 2290)

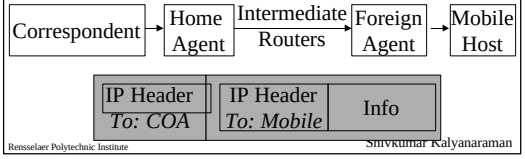
- Interception
  - Typically home agent – hosts on home network
- Delivery
  - Typically IP-in-IP tunneling
  - Endpoint – either temporary mobile address or foreign agent
- Terminology
  - Mobile host (MH), correspondent host (CH), home agent (HA), foreign agent (FA)
  - Care-of-address (CoA), home address

Mobile IP model

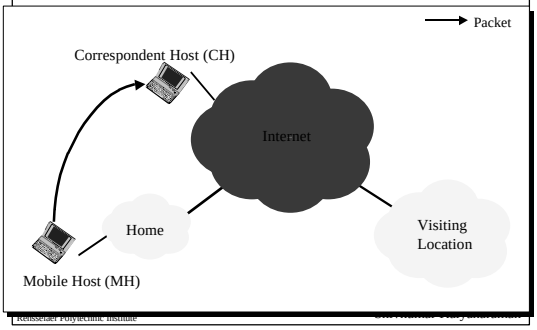
- ***Two-level addressing:***
  - **Home address: fixed (permanent) address used by other nodes to communicate with the mobile node.**
  - **Care-of-address: address on a (foreign) link to which the mobile is currently attached.**
- ***Home agent:***
  - **Tracks care-of-address of mobile**
  - **Re-addresses packets destined to home address and tunnels them to the care-of-address**
- ***Foreign agent:***
  - **Gives mobile node its care-of-address. Optimizes IP address use.Terminates tunnel from home agent**
  - **Default router for packets from mobile node**

Encapsulation/Tunneling

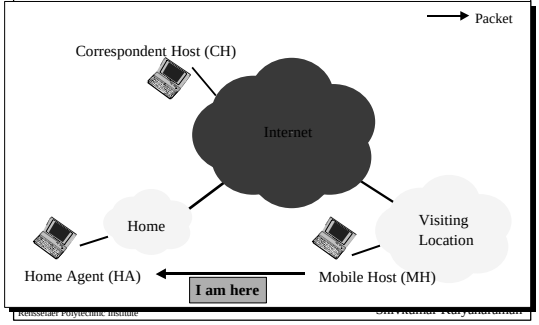
- **Home agent intercepts mobile node's datagrams (using proxy ARP) and forwards them to care-of-address through a tunneling mechanism**
- **Decapsulation: Extracted datagram sent to mobile node**



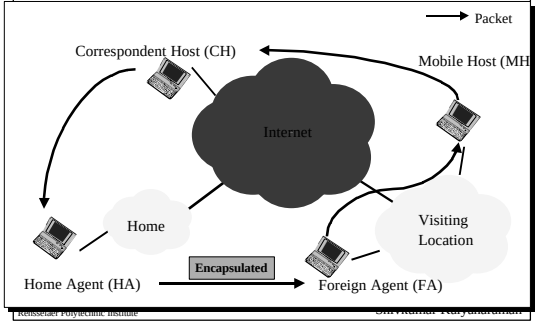
Mobile IP (MH at Home)



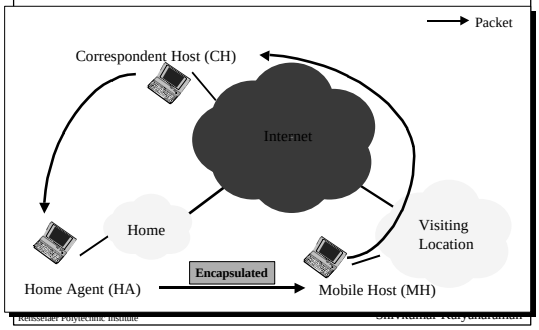
Mobile IP (MH Moving)



Mobile IP (MH Away – Foreign Agent)



Mobile IP (MH Away - Collocated)



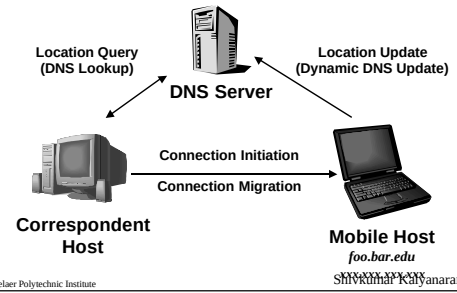
Other Mobile IP Issues

- Route optimality
  - Resulting paths can be sub-optimal
  - Can be improved with route optimization
    - Unsolicited binding cache update to sender
- Authentication
  - Registration messages
  - Binding cache updates
- Must send updates across network
  - Handoffs can be slow
- Problems with basic solution
  - *Triangle routing*
  - *Reverse path check for security*

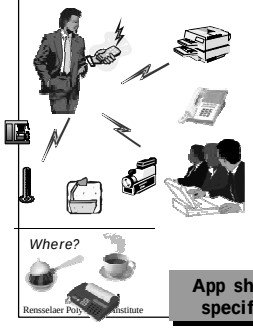
TCP Migrate Approach

- Locate hosts through existing DNS
  - Secure, dynamic DNS is currently deployed and widely available (*RFC 2137*)
  - Maintains standard IP addressing model
    - IP address are topological addresses, not Ids
    - Fundamental to Internet scaling properties
- Ensure seamless connectivity through connection migration
  - Notify only the current set of correspondent hosts
  - Follows from the end-to-end argument

Migrate Architecture



Location-dependent wireless services



- **Spontaneous networking**
- **Automatically obtain map of region & discover devices, services and people there**
- **Access, control services, communicate with them**
- **Handle mobility & group communication**
- **Locate other useful services (e.g., nearest café)**

App should be able to conveniently specify a resource and access it

Resource discovery

- Why is this hard?
  - Dynamic environment (mobility, performance changes, etc.)
  - No pre-configured support, no centralized servers
  - Must be easy to deploy ("ZERO" manual configuration)
  - Heterogeneous services & devices
- Approach: a new naming system & resolution architecture

iNAT: Design goals

Expressiveness	**Names must be descriptive, signifying application intent**
Responsiveness	**Name resolvers must track rapid changes**
Robustness	**System must overcome resolver and service failure**
Easy configuration	**Name resolvers must self-configure**

Intentional Naming System (INS) principles

- Names are intentional, based on attributes
  - Apps know WHAT they want, not WHERE
- INS integrates resolution and forwarding
  - *Late binding* of names to nodes
- INS resolvers replicate and cooperate
  - Soft-state name exchange protocol with periodic refreshes
- INS resolvers self-configure
  - Form an application-level overlay network

Summary

- Wireless: Introduction
  - 802.11, Bluetooth, CDPD
- Mobility: IP Addresses and location
- Solutions: Mobile IP, TCP Migrate
- Open areas: new directions...
  - iNAT, zero-conf