Mobility and Networking

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

Overview

- 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

\[ \text{dBm} = 10 \log \left( \frac{P_r}{1\text{mW}} \right) \]

- + 40 dBm
- + 10,000 times
- 0 dBm
- - 1,000 times
- -30 dBm

Radio propagation: path loss

- path loss in 2.4 GHz band
  - \( r \leq 8\text{m} \)
  - \( r > 8\text{m} \)
  - \( r \approx 8\text{m} \)
  - \( r \approx 8\text{m} \)
  - \( r \approx 8\text{m} \)
  - \( r \approx 8\text{m} \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( r = \frac{4\pi d^2}{P_s} \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)

- \( P_r = P_s + 10 \log \left( \frac{r^2}{4\pi d^2} \right) \)
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

Time domain
- Fourier transform
- Frequency domain

- 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

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 availability)
  - Carrier provides IP address, but link layer protocols are responsible for ensuring packets are delivered
  - Max data rate of 11 kbps

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 (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.

- 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/R² in free space, 1/R⁴ 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
  - 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
- MAC - layer uses many of the ideas discussed
- RTS/CTS/ACK
- Careful backoff
- Allows two modes
  - Ad-hoc
  - Wired/wireless

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

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
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)

- Correspondent Host (CH)
- Home Agent (HA)
- Mobile Host (MH)
- Internet

Mobile IP (MH Away – Foreign Agent)

- Correspondent Host (CH)
- Home Agent (HA)
- Mobile Host (MH)
- Foreign Agent (FA)

Mobile IP (MH Away - Collocated)

- Correspondent Host (CH)
- Home Agent (HA)
- Mobile Host (MH)
- Internet

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 Query (DNS Lookup)
  - Location Update (Dynamic DNS Update)
- DNS Server
- Connection Initiation
- Connection Migration
- Mobile Host
  - Client Side
  - DNS Client

Shivkumar Kalyanaraman
Rensselaer Polytechnic Institute
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