Wireless Connections
And ad-hoc Networking

How to link up appliances to the wired infrastructure
- the "last meter" problem

Are you linking to the nearest wire via a base station,
Or forming truly "ad-hoc" networks, peer-to-peer?

Possible media:
- Home wiring (X-10, Intel,…) -- tricky, hard to bound
- IR – now standardized by IRDA
  - Low bandwidth, line of sight, serial link
  - successful in organizers as a "beaming" function
  - network, diffuse versions never accepted although
    - 1 Mbps demonstrated
- Radio – the generic solution everybody loves
  - Cell size is the critical parameter
    - (power decreases as R^3-4 except with directional antennas)
    - cell phones and "mobile radio" 10 km → 1 km
    - 802.11b: 100 m range
    - Bluetooth and ultra low power research systems
      - 10 → 1 m
  - Spectrum bands available:
    - 902 – 928 MHz (mostly used in N America)
    - 2400 – 2484 MHz (world-wide – almost)
    - 5725 – 5850 MHz (world-wide)
    - UWM research proposals
      - ultra low power over 1-10 GHz
      - → 100 Mbps, < 200 uW
    - Berkeley "picoradio" targets
      - < $0.50, < 1 cm^3, < 100 uW

What's different about Wireless?

Communications comes in layers:
- Physical
- Data link
- Network layer (includes MAC)
- Transport
- Application

Issues special to wireless occur first in physical and MAC layers
- The "mobile IP problem"
- 802.11 addresses this
  - 802.11b: 2.4 GHz, 5-10 Mbps, 100 mW
    - support 3 full speed sessions in 100 m radius
  - 802.11a: 5 GHz, 54 Mbps max, 12 sessions in 50 m
- other physical media:
  - Home RF – now abandoned
  - Bluetooth (802.15) 2.4 GHz, .7 Mbps, 10 sessions in 10 m
  - UWM
  - Pico-radio

Trend is to lower power, smaller cells, but each physical layer solution is different. For example, 802.11 and Bluetooth degrade each other's performance as both use 2.4 GHz ISM band.

Bluetooth
- 1998 consortium of Ericsson, IBM, Intel, Nokia, Toshiba…
  - royalty-free, achieving IEEE backing as 802.15
- began with usage models:
  - 3-in-1 phone
  - the "briefcase trick"
  - auto synch for organizers
  - (note – all these are ad hoc wire, not network)
- physical layer:
  - fast frequency hopping over 79 1 MHz subbands
  - roughly one packet transmitted per hop, 1600 hops/sec
  - transmit/receive on alternate hops
  - first unit is master, others slave. Master provides clocking
  - once asleep, listen only every 1-3 sec (like pager)
  - both circuit-like voice and packet data protocols offered

MAC layer issues

How to take turns on a link.

ALOHA (earliest CSMA style – "collision sense")

Send anytime the mood strikes you, backoff random amount and repeat if collision occurs. Easy to analyze:

Expected rate = G exp(-2G), max = 0.18 of packets get through

Slotted ALOHA – add a clock, initiate transmission at frame start only

This halves the collision rate, expected throughput is G exp(-G), With max of 0.37.

All methods that get above 50% utilization require that you listen before sending, and use some clocking to allocate times for contention, transmission. Finally, CSMA/CD requires halting transmission as soon as "collision detected".

What goes wrong with wireless networks?

"hidden terminal" problem: A hears base station but not B, base station hears both. Both A and B can try to transmit without detecting collision.

"open terminal" problem: with more than one base station available, can't tell if other senders which you overhear are using the same base station that you want to use.

Standard resolution of this is CA – collision avoidance, with the aid of the base station:

A sends RTS packet

Base station sends back "A – CTS" and everyone not A is silent

After A transmits, base station sends out ACK.

Stations close to A hear the RTS of A

Stations close to base station hear the CTS and ACK.

Note: CDMA finesses much of this, because multiple units transmit without interference at same time. Ref: A. Viterbi, "CDMA Principles of Spread Specturm Communications.