Wireless Networking

- wireless media: slow and error-prone
- mobility issues
  - how to find hosts
  - impact of losses on TCP congestion control
- other mobile computing issues
  - energy conservation
  - disconnected operation
  - ubiquitous computing

Wireless Networking: Issues

- low bandwidth
  - 2 Mbps vs. 100 Mbps
- high error rate
  - 10^{-6} vs. 10^{-12} bit error rate
- variable error rate
  - noise and multipath interference
  - deep fade regions cause long burst errors
  - out-of-range hosts

Wireless Networking: Issues

- mobility
  - hosts move between data transfers
  - hosts moving during data transfers
- connectivity
  - bandwidth is scarce, hence expensive
- energy conservation
  - transmitting takes energy
  - other energy issues: processing, spinning disk

Adapting to Wireless Media

- bandwidth efficiency more important
  - compress headers and data
  - selective retransmit
- error control more important
  - adaptive error control
  - hop-by-hop vs. end-to-end error control
- media access control is harder
  - hidden terminals
  - asymmetric bandwidth needs

Cellular Networking

- divide space into cells
  - often hexagonal
  - sometimes cells overlap
- limit broadcast power so signals don't travel between cells
  - except neighboring cells
- assign radio frequencies to each cell
  - no duplication of frequencies between neighboring cells

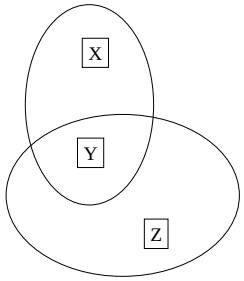
Cellular Networking

- base station for each cell
  - connected to central office via radio or wires
- each mobile station talks to nearest base station
- base stations track location of mobile stations so traffic can be routed to mobile stations

Cells

- wireless LANs
  - cells a few meters in diameter, overlapping
- advantages of small cells
  - higher aggregate bandwidth
  - lower power
  - accurate location info
- disadvantages of small cells
  - need many base stations
  - frequent handoffs

Hidden Terminals

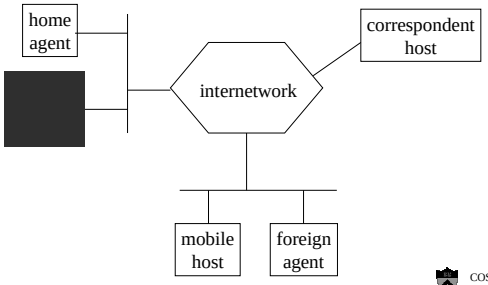


- Y can hear X and Z, but X and Z can't hear each other
- result: X and Z may transmit at same time
- solution
  - X sends small "request to send" (RTS)
  - Y responds with "clear to send" (CTS)

Mobility and the Network Layer

- names, addresses, and routes
  - name: what it is
  - address: where it is
  - route: how to get there
- traditionally
  - name maps to a single address
  - address encodes a location
- What happens when hosts move?

Mobility Support in IP



Naming, Addressing, Routing

- mobile host
  - has name and address on home network
  - gets care-of adress from foreign agent
  - tells home agent the care-of-address
- correspondent agent
  - send to home address, just like normal
- home agent intercepts packets and forwards to foreign agent through IP tunnel
- foreign agent forwards to mobile host

Issues

- performance
  - all traffic goes via homes, even if corresponding hosts are in the same room
- caching location state
  - after host moves, traffic goes to old location
- finding foreign agents
- whether to trust foreign agents

Performance

- goal: transparency for traditional hosts
  - host that doesn't know about mobility can communicate with mobile host
- optimizations
  - mobile host sends packets directly to correspondent
  - correspondent is smarter and figures out to send packets directly
- still a topic of discussion

Wireless Handoffs

- each cell has a base station (BS)
- BSs broadcast periodic "beacon" signals
- host decides to switch based on strength of beacon signal
- switch requires careful "handoff" protocol to avoid disrupting communication
  - some out-of-contact time necessary unless cells overlap

Handoff Protocol

- host greets new base station
- host changes its routing tables
- new BS changes its routing tables
- host tells new BS identity of old BS
- new BS tells old BS about handoff
- old BS changes its routing tables
- new BS acknowledges handoff to host

Impact of Mobility on TCP

- sources of packet loss
  - cell transitions
  - routing inconsistencies during handoff
  - transmission errors
- TCP reacts badly to packet loss
  - assume loss is due to congestion
  - backs off and slows down
    - » backoff causes 0.8 second freeze
    - » slow-start causes another second or so of slowdown

A Good Solution

- signal TCP when handoff is done
- retransmit immediately after handout, without waiting for timeout
- drop TCP congestion window to minimum and initiate slow-start
  - like starting a new connection
  - avoids congesting the new cell
  - requires support from end hosts only, not from network

Other Mobile Computing Issues

- security
  - really the same problem as on normal networks
    - » just a bit more urgent
  - solution: encrypt and sign everything
- power conservation
  - reduce transmissions
  - reduce disk power consumption
  - reduce CPU power consumption

Disk Spin-Down

- disk states
  - active uses 1.5 watts
  - idle but spinning uses 0.6 watts
  - spun-down (stopped) uses no power
- transition from spun-down to spinning
  - takes a few seconds
  - uses 2.2 watts
- when to spin down?

Spin-Down Strategies

- optimal strategy (but unrealizable)
  - spin down if next disk access will be more than 3.5 seconds from now
- fixed threshold
  - spin down after N seconds of inactivity
    - » typically N = 1minute or so
    - » N = 2 seconds best for power consumption
- adaptive

Adaptive Strategy

- after the fact, know whether we should have spun down
- if spin-down was better, decrease threshold
- if spin-down was worse, increase threshold
  - but not past 3.5 seconds
- complicated analysis and proof of competitive property
- outperforms fixed threshold in practice

CPU Power Conservation

- observation: energy used per clock cycle goes up quadratically as machines get faster
- consequence: can save energy by slowing down CPU when full speed isn't needed
- example: 50 ms of work to do in 100 ms
  - choice A: full speed for 50 ms, idle for 50ms
  - choice B: half speed for the whole 100 ms
    - » uses half as much total power

CPU Power Conservation

- approach: run slower when there isn't much work to do
- try to predict future workload, and run just fast enough to do work promptly
- complications
  - "busy work" daemons
  - interactive response: how fast does it really have to be?

Ubiquitous Computing

- project at Xerox PARC
  - computers everywhere
  - computer in your book to tell you where it is, which pages still need to read
  - computer in your pencil, to tell you when it is getting dull and is near a sharpener
  - active badges
- the wired house
  - open or closed network?