18-759: Wireless Networks
Lecture 16: Wireless and the Internet

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Outline

- Wireless and the Internet
- Mobility: Mobile IP
- Diversity
  - Loss: TCP over wireless
  - Delay: multimedia
  - Devices: WAP

Internet Architecture Assumptions

- Host are (mostly) stationary
  - Address assignment, routing
- Links in the network are fairly homogeneous
  - Transport protocols, applications
- Hosts are fairly powerful
  - End to end principle: push functionality to end points
- Security is an end host issue
  - No security inside the network (architecturally)

Mobility

- Many clients today are mobile
- Mobility inside a subnet is supported
  - E.g. moving across APs that are part of a single EBSS
- Mobility across subnets is harder because the IP address is used as address and identifier
  - Identifier: who you are
  - Address: where you can be found
- Keep IP address: network gets confused
  - Delivers packets to wrong "old" subnet
- New IP address: host gets confused
  - Transport protocols, applications, etc.

Link Heterogeneity

- Original links were basically telephone lines
- Today: huge diversity
  - Optical fiber (wavelengths) … copper … wireless
- Throughput is most visible diverse features
  - Optical links 40 Gbps … Wireless links of Kbps
- But other features are different as well:
  - Error characteristics: higher on wireless
  - Latency: absolute delay and variance in delay
- Mobility adds to diversity
  - E.g. hand off can cause delays and sudden changes in available bandwidth

Device Capabilities

- Originally: mainframes and personal computers
- Today: sensors … supercomputers
- Note: almost any networked device today is more capable than early computers!
  - But our requirements and expectations have increased
  - Anything at or above "PC class" is very capable
- Laptop: view as mobile PC
- PDA: view as 5 year old PC (kind of)
- Cell phone: not even close to a PC
- Sensors: often run as private networks

Security

- Access to the network enables all kinds of attacks
  - » Argues for pushing security inside the network
  - » Firewalls are a very ad hoc way of doing this
- Wireless creates unique challenges
  - » Do not need physical connection to sniff or send
- Discussed (briefly) in the 802.11 lectures
  - » WEP, 802.1x, etc.
- But wireless security needs to be linked into system wide security

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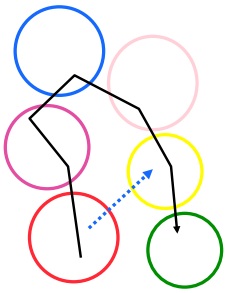
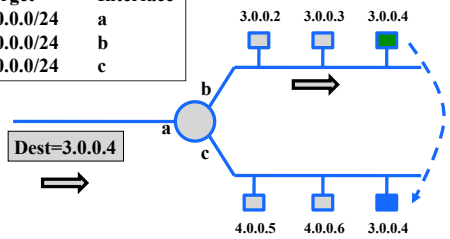
Mobility across IP Subnets

- When moving across IP subnets, different protocols have conflicting requirements
- Network layer wants IP address in current subnet
  - » Needed for routing of packets
- Transport layer want IP address that was used to create connection
  - » Is used to identify the connection
- Applications often do not care but in practice they want to keep the IP address the same
  - » Tied to sockets



Traditional Routing for a Mobile Host

Target	Interface
2.0.0.0/24	a
3.0.0.0/24	b
4.0.0.0/24	c



Mobile IP Goals

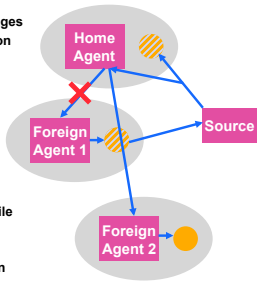
- Communicate with mobile hosts using their "home" IP address
  - » Allows any host to contact mobile host using its "usual" IP address
- Mobility should be transparent to applications and higher level protocols
  - » No need to modify the software
- Minimize changes to host and router software
  - » No changes to communicating host
- Security should not get worse

Mobile IP

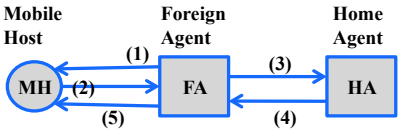
- Home network has a home agent that is responsible for intercepting packets and forwarding them to the mobile host.
  - » E.g. router at the edge of the home network
  - » Forwarding is done using tunneling
- Remote network has a foreign agent that manages communication with mobile host.
  - » Point of contact for the mobile host
- Binding ties IP address of mobile host to a "care of" address.
  - » binding = (IP address, foreign agent address)
  - » binding includes time stamp

Mobile IP Operation

- Agents advertise their presence.
  - Using ICMP or mobile IP control messages
  - Mobile host can solicit agent information
  - Mobile host can determine where it is
- Registration process: mobile host registers with home and foreign agent.
  - Set up binding valid for *registration lifetime*
- Tunneling
  - forward packets to foreign agent
  - foreign agent forwards packets to mobile host
- Supporting mobility
  - invalidating old caches in a lazy fashion



Registration via Foreign Agent

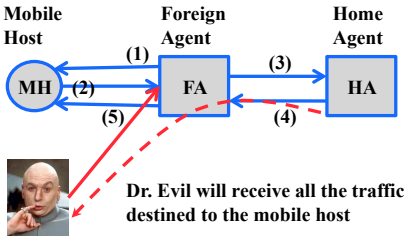


1. FA advertizes service
2. MH requests service
3. FA relays request to HA
4. HA accepts (or denies) request and replies
5. FA relays reply to MH

Optimizations

- Mobile host can be its own the foreign agent.
  - Mobile host acquires local IP address
  - performs tasks of the mobile agent
- Short circuit the home location by going directly to the foreign agent.
  - Routers in the network store cache bindings and intercept and tunnel packets before they the mobile host's home network
  - Need a protocol to update/invalidate caches
  - Raises many security questions and is not in the standard

Authentication



Dr. Evil will receive all the traffic destined to the mobile host

Mobile IP Authentication

- Without security, a "bad guy" on any network with a FA could issue a registration request for a host on any network (with a HA)
  - HA would begin to forward datagrams to the bad guy
- So, registration messages between a mobile host and its home agent must be authenticated
  - Uses mobile-home authentication extension
- Mobile hosts, home agents, and foreign agents must maintain a mobility security association for mobile hosts, indexed by…
  - Security Parameter Index (SPI)
  - IP address (home address for mobile host)

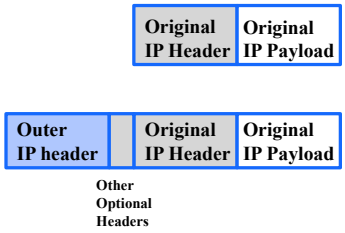
Mobile IP Authentication (cntd)

- The identification field in the registration request changes with each new registration to prevent replaying request.
- The identification field in reply is based on the identification field in the request.

Security Considerations

- Authentication of mobile host, home agent
  - avoid invalid interception of traffic
- Authentication of mobile host, foreign agent
  - Desirable, but more difficult, so not required
- Use encryption for sensitive data
- Replay of registration messages.
  - standard problem
  - use standard solutions, e.g. timestamps, nonce, ..
- Dealing with the firewalls at the foreign site.
  - most easily sent directly to destination
  - but has a "strange" IP network address in source field
  - reverse tunneling by foreign agent or mobile host
  - Can replace tunnels by UDP for NATs

Tunneling – IP-in-IP encapsulation



Discussion

- Mobile IP not used in practice
- Was not designed for truly mobile users
  - I.e. for continuous operation across subnets
  - Switching between subnets is heavy weight
- Was designed for nomadic users
  - I.e. visitors are a remote site
- Value for nomadic is limited to:
  - Mobile user is contacted using home IP address
  - User maintains connections between subnets
  - Neither of them are very likely or common
  - Laptops are mostly used for accessing servers

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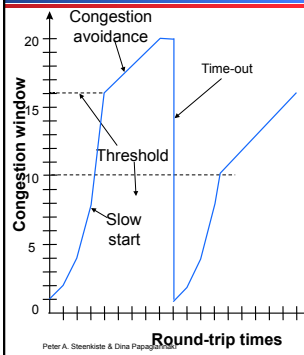
TCP Congestion Control

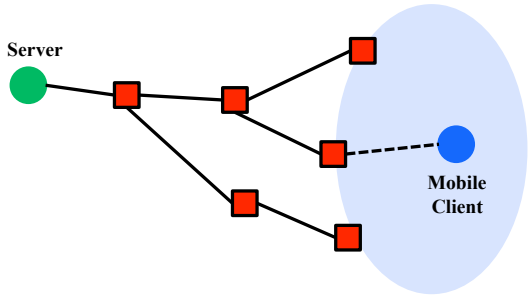


- Congestion detection based on lost packets:
  - Timeout or
  - Receipt of duplicate ACKs
- Packet loss results in cutting window in half
  - To reduce congestion in network
- Assumes all (or most) packet losses are due to queue overflow
  - I.e. two are equivalent
- TCP also estimates roundtrip time
  - Used to set timeout value

Challenges in Wireless

- Wireless network may drop packet due to link errors
  - Will be interpreted as congestion losses by TCP sender
  - Will result in backoff and loss of throughput
  - TCP tends to perform poorly when error rates go above 1%
- High variability of properties wireless links could also confuse TCP
  - TCP likes nice predictable paths
- Roundtrip time can be variable
  - Due to wireless retransmissions, handoff, …
- Available bandwidth can fluctuate
  - Rate adaptation, interference, handoff, …

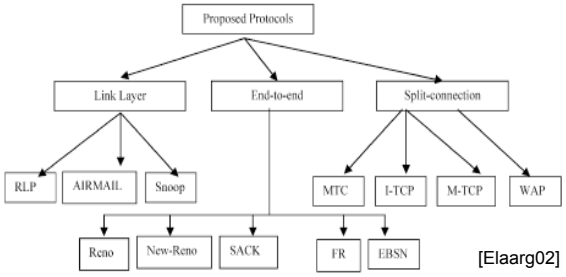
Solution Ideas?



Solution Space

- Modify TCP for wireless paths
  - Would maintain status quo for wired paths
  - What would wireless TCP look like?
  - Difficult to do: there are many Internet hosts
  - Traditionally, hosts have no information about path properties
- Modify TCP for all paths
  - Not clear what that modification would be!
  - Similar problems: need to modify many hosts
- Modify TCP only on the mobile host
  - Interesting idea – kind of what WAP does in an extreme way
- Keep end hosts the same but tweak things at the wireless gateway
  - Keep end-end TCP happy despite wireless links

Possible Classification of Solutions

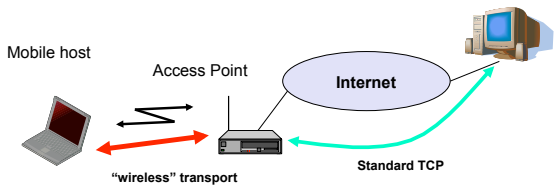


[Elaarg02]

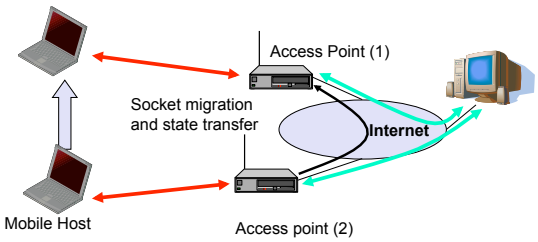
Connection Split: Indirect TCP or I-TCP

- Do not change TCP on the wire-line part
- Split the TCP connection at the wireless gateway into two parts
  - One optimized for the wireless link
  - The second for the wire-line communication (TCP)
- No real transport-layer end-to-end connection
  - Although host on wired network does not know this
- Wired host should not notice the characteristics of the wireless part
  - This is a challenge since wireless gateway is limited in what it can send and when, e.g. cannot prematurely acknowledge data
  - Certain things cannot be hidden: delay, dramatic throughput variations

I-TCP



I-TCP and Mobility



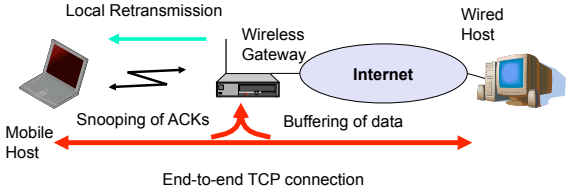
I-TCP Discussion

- **I-TCP Advantages**
  - No changes in the fixed network or hosts (TCP protocol), all current TCP optimizations still work
  - Wireless transmission errors do not "propagate" to the wire-line network
  - Simple, effective (in the best case)
- **I-TCP Disadvantages**
  - End-to-end semantics become less clear, e.g. what happens if the wireless gateway crashes
  - Higher end-to-end delays due to buffering and forwarding to the gateway

Snooping TCP

- "Transparent" extension of TCP within the wireless gateway
  - End hosts are not modified
- Hides wireless losses from wired host
  - Buffer packets sent to the mobile host
  - Local retransmission: Lost packets on the wireless link, for both directions, are retransmitted immediately by the mobile host or foreign agent
- Wireless gateway "snoops" the packet flow so it can cover up signs of packet loss
  - E.g. recognizes acknowledgements in both directions and suppresses duplicate ACKs

Snooping TCP



Snooping TCP Discussion

- Data transfer to the mobile host
  - FA buffers data until it receives ACK from the MH
  - FA detects packet loss via duplicated ACKs or time-out
- Data transfer from the mobile host
  - FA detects packet loss on the wireless link via sequence numbers
  - FA answers directly with a NACK to the MH
  - MH can now retransmit data with only a very short delay
- Integration of the MAC layer
  - MAC layer often has similar mechanisms to those of TCP
- Problems
  - Snooping TCP does not isolate the wireless (as I-TCP)
  - Snooping might be useless if encryption is used

How about Mobility?

- Split connection approach
  - Hard state at access point must be moved to new base station
- Snoop approach
  - Soft state need not be moved
  - While the new access point builds new state, packet losses may not be recovered locally
- Frequent handoffs remain a problem
  - Hard state should not be lost
  - Soft state needs to be recreated for performance

Mobile TCP

- Handling of long and frequent disconnections
- M-TCP splits connection as I-TCP does
- Wireless gateway monitors all packets but
  - Does no caching, no retransmission
  - If it detects a disconnection
    - It sets the sender's window size to 0
    - Sender automatically goes into "persist" mode
- Advantages
  - ETE semantics are maintained, no buffer forwarding
- Disadvantage
  - Wireless link loss propagates to the wire-line network

An Internet Style Approach

- Use aggressive retransmission in the wireless network to hide retransmission losses
  - » Most deployed wireless network in fact do that already
  - » Would sell few products if they did not
- Wireless losses are translated into increased delay
  - » But TCP roundtrip time estimation is very conservative, e.g. increases if variance is high
- Also: persistent high loss rate results in reduced available bandwidth -> congestion response is appropriate and needed
- Works remarkably well!

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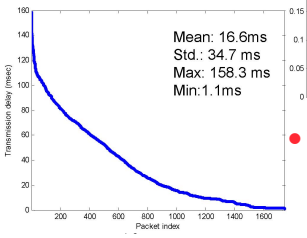
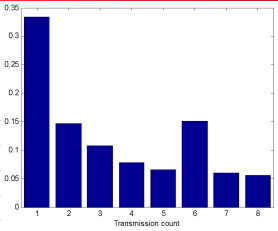
Variable Latency in Wireless Networks

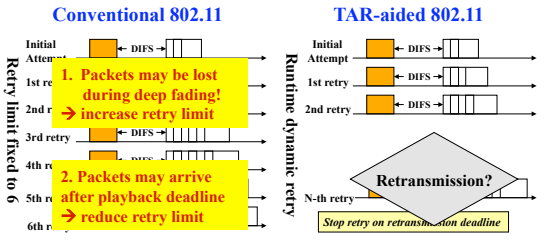
- Retransmissions in 802.11 results in variable e-e latency
  - » 100 msec or more





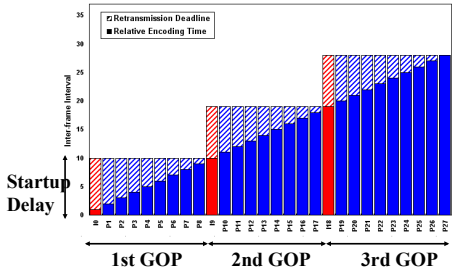
- Variability is increased by
  - » Use of exponential backoff
  - » Freezing of backoff counter when the medium is busy

Time Aware Adaptive Retry



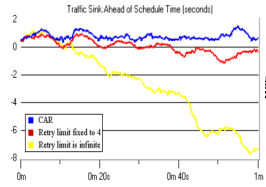
- 802.11 retransmission takes a fixed try limit for every packet (count based)
- CAR dynamically determines retry limit for each packet using its "retransmission deadline"

TAR: Retransmission Deadline

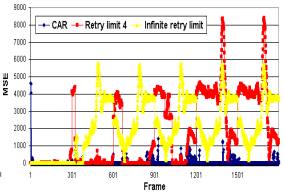


Comparison of Visual Quality

Results of the Ahead of Schedule Time



Mean Square Error of the Y Component



Packets with a value smaller than zero is behind its playback schedule

$$MSE = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} [x(i,j) - \hat{x}(i,j)]^2$$

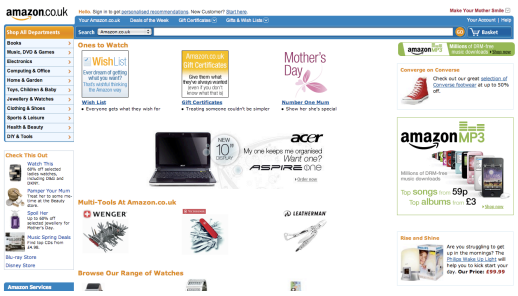
What About Cell Phones?

- **Cell phones have very limited capabilities:**
  - Low bandwidth
  - Small display and limited "keyboard"
  - Small memory and processing capabilities
- **Raises issues at different layers:**
  - HTML is too rich for cell phone I/O capabilities
  - General purpose protocol likely to be too inefficient, big, and unresponsive
- **Result: define a completely new stack and glue it to the IP stack using a gateway**
  - Ugly but practical

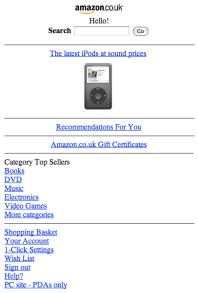
Wireless Access Protocol (WAP)

- **Protocol stack for small low-powered devices**
  - E.g. cell phones
- **Layered Protocol, like IP stack**
  - Two versions of protocol stack
    - WAP1.x Protocol Stack
    - WAP2.0 Protocol Stack
  - Based on some older, proprietary protocols
  - Provide security
- **Connects WAP devices with a WAP gateway**
- **Gateways translate wireless protocols into Internet protocols**
  - Located near Mobile Telephone Exchange

The WEB …



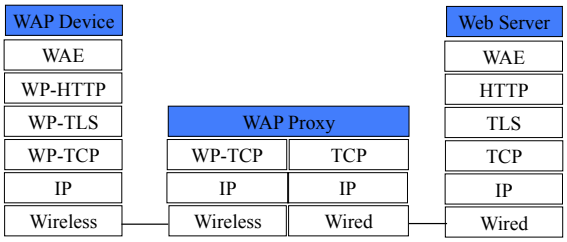
And the WAP



WAP 2.x Protocol Stack

WAP Device	
WAE	Wireless Application Environment
WP-HTTP	Wireless Profiled HTTP
WP-TLS	Wireless Profiled TLS (SSL)
WP-TCP	Wireless Profiled TCP
IP	Internet Protocol
Wireless	2.5G and 3G

WAP 2.0 Proxy



Wireless Markup Language

- **Very specialized for cell phones**
  - **Needs to be compact**
- **Window has limited size**
  - **Server needs to optimize for specific devices**
  - **Standards ways of chaining windows and window layout**
- **Keyboard is limited**
  - **Supports concise ways of using standard buttons on cells phones**

WAP emulator toolkits and SDKs

- **Available by most handset manufacturers**

References

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