Wireless Networks
Lecture 2: Networking Overview and Wireless Challenges

Peter Steenkiste

CS and ECE, Carnegie Mellon University

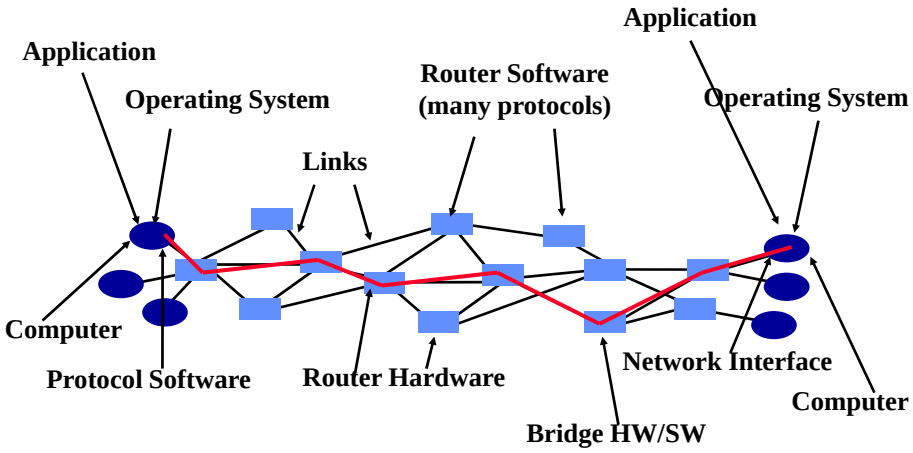
Peking University, Summer 2016

Schedule for Today

- Designing a BIG system
- The OSI model
- Packet-based communication
- Challenges in Wireless Networking

- Please ask questions!

The Internet is Big and Has Many, Many Pieces



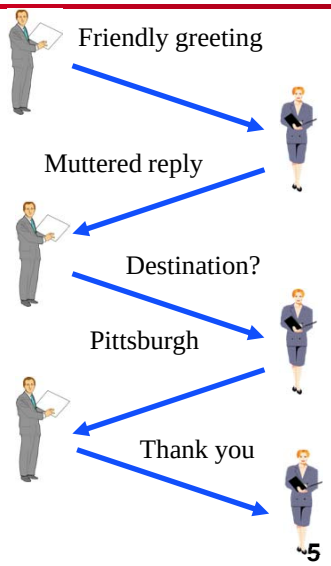
How do you design something this complex?

What Do We Definitely Need?

- We must have communication hardware and applications
- Two "devices" must be able to sent data to each other
- Applications are what make the network useful and fun
- We also need to design the network so it can grow very big and is always available
  - » We need to be able to expand, fix, and improve the network ….
  - » While it is up and running: you cannot reboot the Internet

Protocol Enable Communication

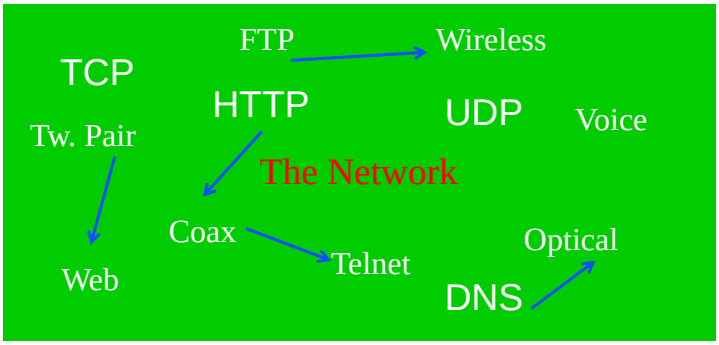
- An agreement between parties on how communication should take place.
- Protocols may have to define many aspects of the communication.
- Syntax:
  - » Data encoding, language, etc.
- Semantics:
  - » Error handling, termination, ordering of requests, etc.
- Protocols at hardware, software, *all* levels!
- Example: Buying airline ticket by typing.
- Syntax: English, ascii, lines delimited by "\n"



Do We Only Need Protocols?

- Need to also deal with
  - » Many, many pieces of functionality
  - » Complexity
  - » Many parties involved building and running the network
  - » Very long life time
- The solution for dealing with complexity is modularity: break up the Internet "system" in a set of modules with well-defined interfaces
  - » Each module performs specific functions
  - » Can build a large complex system from modules implemented by many parties
- Let us start with multiple protocols …

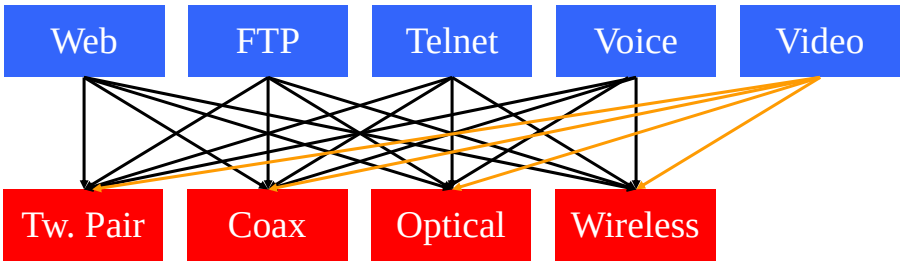
Solution #1



Need to More Add Structure

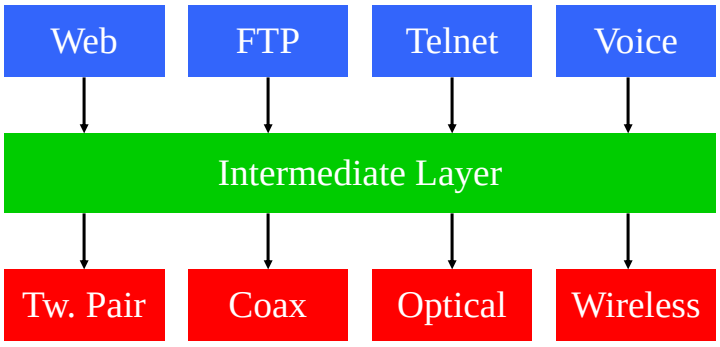
- **Adding structure implies that you prevent people from doing arbitrary (≈ silly) things**
  - » **Can we organize the modules in a certain way?**
- **What modules do we definitely need in the Internet?**
  - » **Hardware modules that allow us to send bits around**
  - » **Applications that make the network useful for users**
- **Do we need additional modules "in between" the applications and the hardware?**

Solution #2?

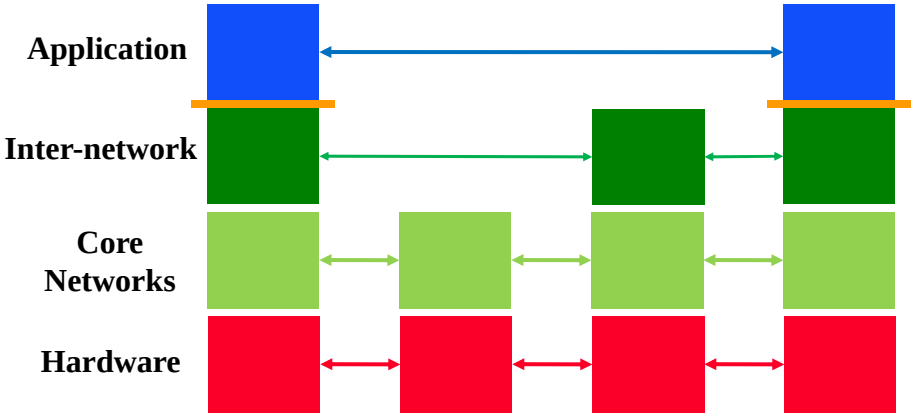


Does not scale!

Solution #3



Protocol and Service Levels



- Having two different types of protocols helps with scalability and network management

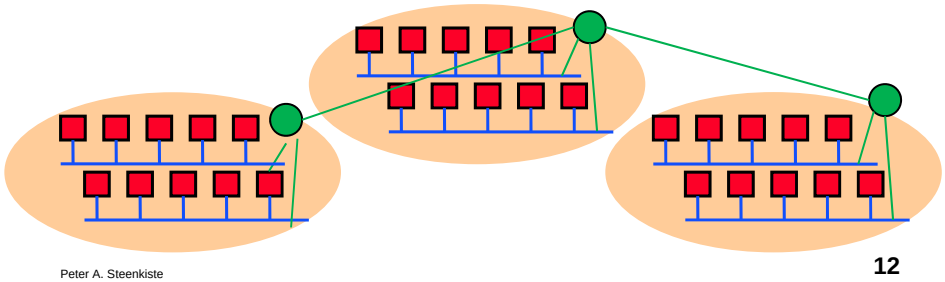
Let Us Try Again, a Bit More Systematically

- Two or more hosts talk over a wire
- Groups of hosts can talk at two levels
  - » Hosts talk in a network is homogeneous in terms of administration and technology
  - » Hosts talk across networks that have different administrators and my use different technology
- We run some applications over that

Physical

Datalink

Internet



A Bit More Detail

- Physical layer delivers bits between the two endpoints of a "link"
  - » Copper, fiber, wireless, visible light, …
- Datalink layer delivers packets between two hosts in a local area network
  - » Ethernet, WiFi, cellular, …
  - » Best effort service: should expect a modest loss rate
  - » "Boxes" that connect links are called bridges or switches
- Network layer connects multiple networks
  - » The Inter-net protocol (IP)
  - » Also offers best effort service
  - » Boxes that forward packets are called routers

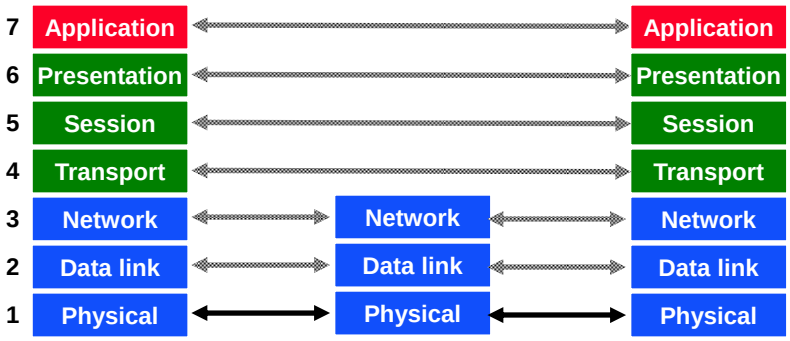
Schedule for Today

- Designing a BIG system
- The OSI model
- Packet-based communication
- Challenges in Wireless Networking

- Please ask questions!

Networking 101
Layer Network Model

The Open Systems Interconnection (OSI) Model.



OSI Motivation

- **Standard approach of breaking up a system in a set of components with well defined interfaces, but components are organized as a set of layers.**
  - » **Only horizontal and vertical communication**
  - » **Components/layers can be implemented and modified in isolation without affecting the other components**
- **Each layer offers a service to the higher layer, using the services of the lower layer.**
- **"Peer" layers on different systems communicate via a protocol.**
  - » **higher level protocols (e.g. TCP/IP, Appletalk) can run on multiple lower layers**
  - » **multiple higher level protocols can share a single physical network**

Interfaces

- A protocol defines an interface between two protocol modules in the same layer
  - » Uses the lower layers to communicate
  - » Syntax: format of messages exchanged
  - » Semantics: what actions to modules take and when
- Each protocol offers an interface to its users in the higher layer, and expects one from the layers on which it builds
  - » Protocols build on each other to provide increasingly richer communication services
  - » Syntax: specify the format of data
  - » Semantics: what service does each module provide to the next layer

OSI Functions

- (1) Physical: transmission of a bit stream.
- (2) Data link: flow control, framing, error detection.
- (3) Network: switching and routing.
- (4) Transport: reliable end to end delivery.
- (5) Session: managing logical connections.
- (6) Presentation: data transformations.
- (7) Application: specific uses, e.g. mail, file transfer, telnet, network management.

Benefits of Layered Architecture

- Significantly reduces the complexity of building and maintaining the system.
  - » Effort is 7 x N instead of N^7 for N versions per layer
- The implementation of a layer can be replaced easily as long as its interfaces are respected
  - » Does not impact the other components in the system
  - » Different implementation versus different protocols

True For Wireless?

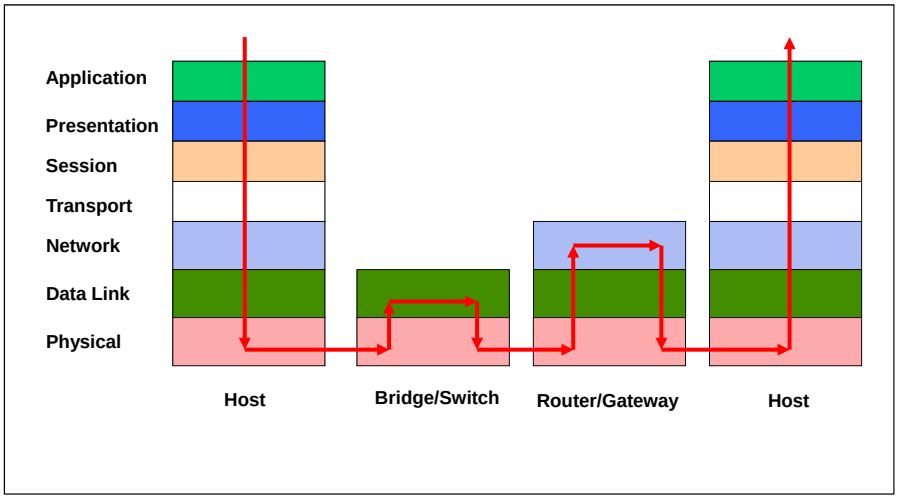
- In practice: most significant evolution and diversity at the top and bottom:
  - » Applications: web, peer-to-peer, video streaming, ..
  - » Physical layers: optical, wireless, new types of copper
  - » Only the Internet Protocol in the "middle" layer

Schedule for Today

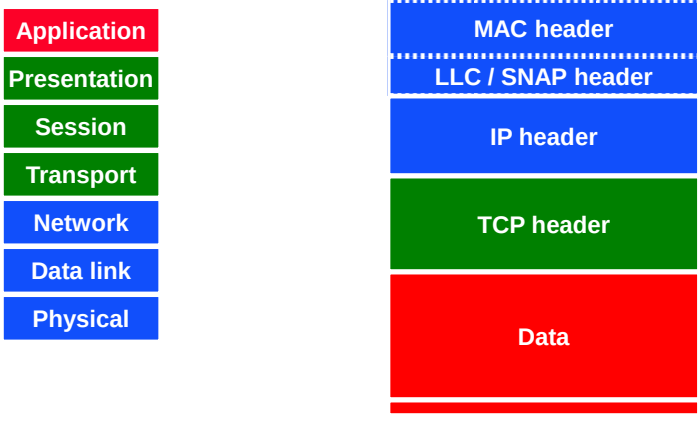
- Designing a BIG system
- The OSI model
- Packet-based communication
- Challenges in Wireless Networking

- Please ask questions!

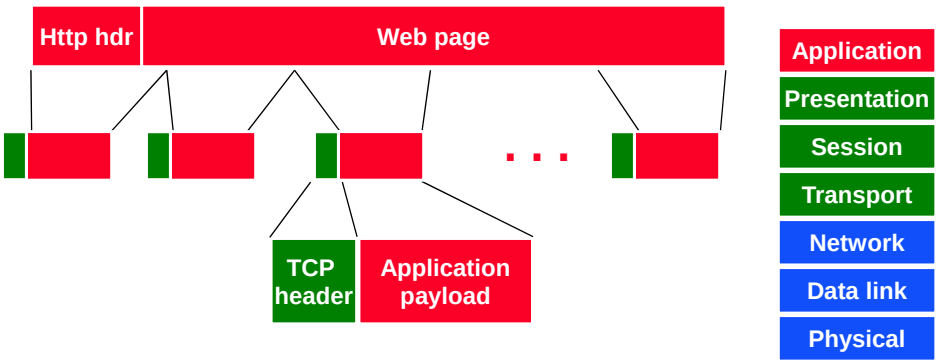
Life of Packet



A TCP / IP / 802.11 Packet



Example: Sending a Web Page



Schedule for Today

- Designing a BIG system
- The OSI model
- Packet-based communication
- Challenges in Wireless Networking

- Please ask questions!

Why Use Wireless?

There are no wires!

Has several significant advantages:

- Supports mobile users
  - » Move around office, campus, city, … - users get hooked
  - » Remote control devices (TV, garage door, ..)
  - » Cordless phones, cell phones, ..
  - » WiFi, GPRS, Bluetooth, …
- No need to install and maintain wires
  - » Reduces cost – important in offices, hotels, …
  - » Simplifies deployment – important in homes, hotspots, …

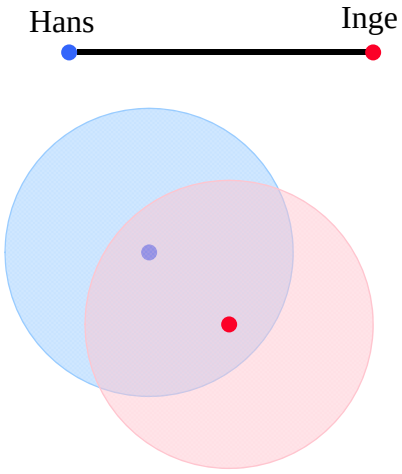
What is Hard about Wireless?

There are no wires!

- In wired networks links are constant, reliable and physically isolated
  - » A 100 Mbs Ethernet always has the same properties
  - » This is definitely not true for “54 Mbs” 802.11a
- In wireless networks links are variable, error-prone and share the ether with each other and other external, uncontrolled sources
  - » Link properties can be extremely dynamic

Wireless is a shared medium

- In wired communication, signals are contained in a conductor
  - » Copper or fiber
  - » Guides energy to destination
  - » Protects signal from external signals
- Wireless communication uses broadcasting over the shared ether
  - » Energy is distributed in space
  - » Signal must compete with many other signals in same frequency band

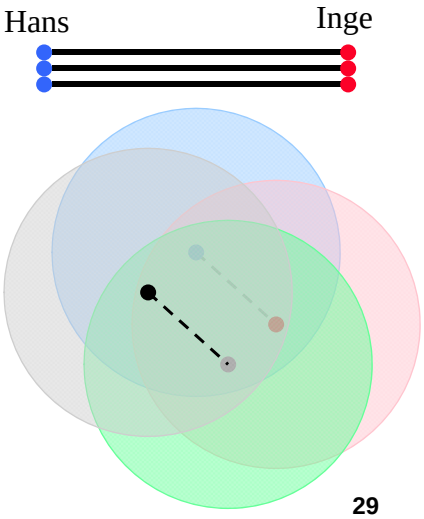


Attenuation and Errors

- In wired networks error rate 10^{-10} or less
  - » Wireless networks are far from that target
- Signal attenuates with distance and is affected by noise and competing signals
- Obstacles further attenuate the signal
- Probability of a successful reception depends on the "signal to interference and noise ratio" - the SINR
- More details later in the course

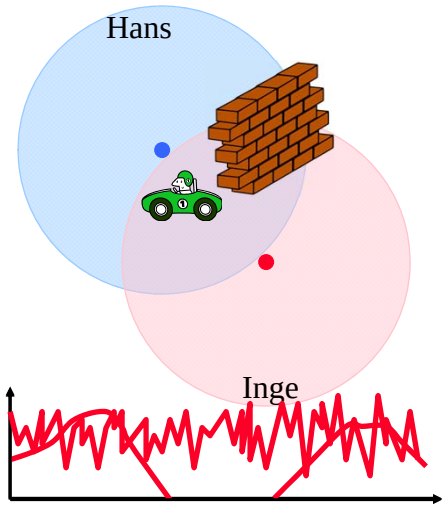
How Do We Increase Network Capacity?

- Easy to do in wired networks: simply add wires
  - » Fiber is especially attractive
- Adding wireless "links" increases interference.
  - » Frequency reuse can help … subject to spatial limitations
  - » Or use different frequencies … subject to frequency limitations
- The capacity of the wireless network is fundamentally limited.



Mobility Affects the Link Throughput

- Quality of the transmission depends on distance and obstacles blocking the "line of sight" (LOS)
  - » "Slow fading" – the signal strength changes slowly
- Reflections off obstacles combined with mobility can cause "fast fading"
  - » Very rapid changes in the signal
  - » More on this later
- Hard to predict signal!



How is Wireless Different?

Wired	Wireless
• Physical link properties are fixed and known during standardization	• Physical link properties can change a lot rapidly in unpredictable ways
• Designed for low error rates and throughput is fixed and known	• Error rates vary a lot and throughput is very dynamic
• Datalink layer is simple and optimized for the physical layer	• How do you design an efficient datalink protocol?
• Internet was designed assuming wires	• How well will higher layer protocols work?

The physical layer is the key!