18-452/18-750
Wireless Networks and Applications
Lecture 1: Course Organization and Overview

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Fall 2018

http://www.cs.cmu.edu/~prs/wirelessF18/

Outline

- Goals and structure of the course
- Administrative stuff
- A bit of history
- Wireless technologies
- Building a network

- Please ask questions!

Goals of the Course

- Learn about the unique challenges in wireless networking
  - » Starting point is "regular" wired networks
  - » But the physical layer is very different!
- Gain an understanding of wireless technologies at the physical, MAC, and higher layers
  - » Physical layer essentials for computer systems types
  - » Focus of course is on the wireless protocol layer
  - » Implications for the higher layers of the protocol stack
- Get some hands-on experience in working with wireless networks and devices
  - » Measurements of a wireless network
  - » Implementing wireless protocols, algorithms

Lectures

- Introduction
  - » Why are wireless networks so interesting?
  - » A very quick overview of networking
- Physical layer concepts (~5)
  - » Narrow focus: understanding the impact on higher layers
  - » Not an in-depth course on wireless communications!
- LANs and WiFi (~6)
- Cellular networks (~3)
- Other technologies; PAN, RFID, NFC, …. (~5)
- GPS, localization, sensing (~3)
- Deployments: sensor networks, ad hoc, …

Projects

Projects are hands-on, team-based

1. Measurement project to improve your understanding of wireless link properties
   - » Measure signal strength and other signal properties
   - » How do they relate to the physical context?
2. Design, implement and evaluate some wireless protocol, algorithm or system
   - » Needs to deal with the unpredictable nature of wireless links and with mobility
   - » Multi-phase projects: start small and work your way up to larger networks
   - » Define your own project or set project

Survey Presentations

- Present a survey of a particular wireless topic to the class
- Done in small teams
- Survey is based on research papers
  - » Pick from a list of topics or define your own topic
  - » Initial set of papers provided for the list
- Goals are:
  - » Learn about a specific topic in depth
  - » Develop critical thinking skills
  - » Improve your presentation skills

Graduate versus Undergraduate Course Numbers

The course content is the same, but they are separate courses:

- Some different questions on the tests
- Different levels of expectation for projects and surveys, e.g., original versus set project
- Final grades are assigned as separate pools
- The expectation is that students sign up for the course number that matches their status
  - » Talk to the instructor if you want to sign up for the "wrong" course number, e.g., ECE IMB students
- 18-452 is a Software Systems area course
- 18-750 part of Wireless Systems concentration

Prerequisites

- The course assumes you have taken an "Introduction to Computer Systems" course
  - » For example based on the O'Hallaron and Bryant book
- We will also build on basic networking and signals concepts but the course includes introductory material on these topics
- Programming experience needed for project
  - » Often: C/C++ or other language, depending on project
- Course should be accessible to students with a broad range of backgrounds, but …
- I don't know you, so please ask questions when something is not clear!

More Specifically …

- For undergraduates – 18-452
  - » 18-213 or 15-213: Introduction to Computer Systems
- For graduates – 18-750
  - » 15-513/18-600 or …
  - » Equivalent: a basic understanding of how computer systems work both inside the box (CMU, memory, IO, ..) and across boxes (familiarity with communication)
  - » If you have a degree in computer science or computer engineering, you should generally be ok
  - » Talk to me if you have concerns

Grading

Grade distribution:

- Homeworks: 10%
- Project 1: 5%
- Project 2: 25%
- Survey: 10%
- Midterm: 20%
- Final: 30%

Administrative Stuff

- Textbook" "Wireless Communication Networks and Systems", Corry Beard and William Stallings, Pearson, 2015
  - » Best fit for the course
- The course is not based on the book
  - » The book should be used to read about the topics covered in class, e.g., to clarify points or get more depth
  - » Book does not cover all material, but slides are detailed
- Web page is primary source for information
  - » Lecture material
  - » Office hours, contact information, …
  - » Dates for quizzes, exams and project deadlines
- We will use Canvas for assignments

More Administrative Stuff

- Lectures are Tu/Th 4:30-5:50pm/1:30-2:50pm
  - » But lectures will typically be 80 minutes
  - » May go longer, e.g., to make up time for travel
- Recitations are Fr 1:30-2:50pm/10:30-11:50am
  - » Recitations will be used for the project
  - » Only a small number of slots are used (check schedule)
  - » May use recitation slot for make up lectures
  - » Uses Bluejeans for SV students
- Course admin is Ms. Malloy – Gates 9006
  - » Pick up assignments, make appointment, …
- Teaching assistant: Adhishree Jaiprakash

Some Changes in Schedule

- Tuesday/Thursday lectures are a problem for travel
  - » Will lose a bunch of Thursday lectures
- Plan is to use the recitation slot for a few makeup lectures
  - » Guest lectures for the others
- I will give makeup lectures early in the semester
  - » Reduced class schedule later in the semester
  - » Helps a bit in picking survey and project topics
  - » Current plan: Friday lectures in weeks 1, 3, and 5

Collaboration

- Traditional rules of collaboration apply
  - » https://www.cmu.edu/policies/student-and-student-life/academic-integrity.html
- You must complete individual assignments and tests by yourself
- You are expected to collaborate with your partner in the team-based projects
- It is acceptable and encouraged to help fellow students with generic problems
  - » E.g. where to find documentation, use of tools, ..
- You must give proper credit when reusing material
  - » But check with the instructors first

Course Material

- Most slides were prepared by the course instructor
- Some slides contain material from other sources
  - » Previous co-instructors have contributed slides
  - » Some figures are taken from the textbook
  - » Some lectures contain material from other sources

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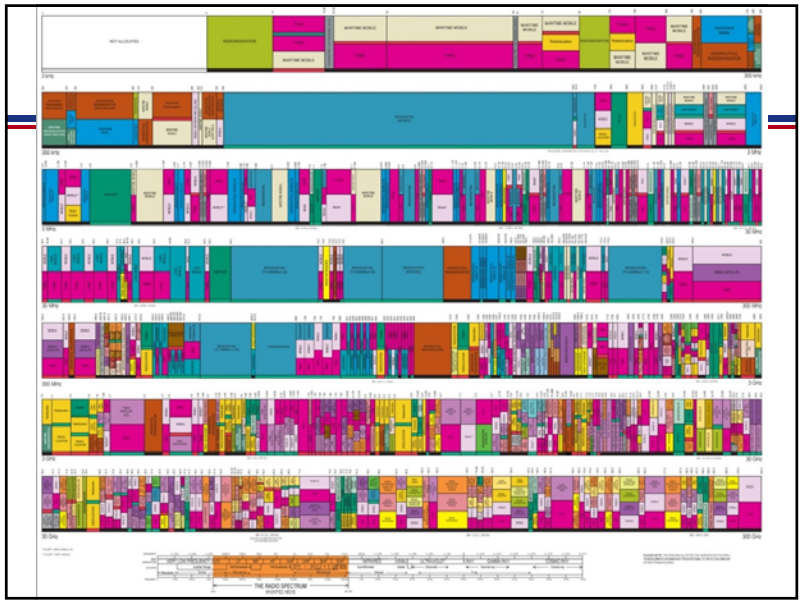
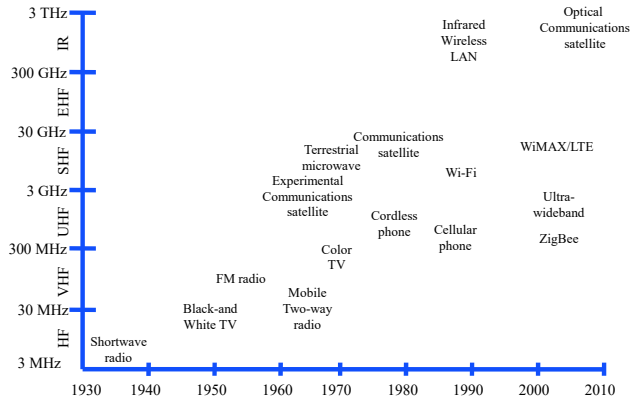


Spectrum Shared by Many Users

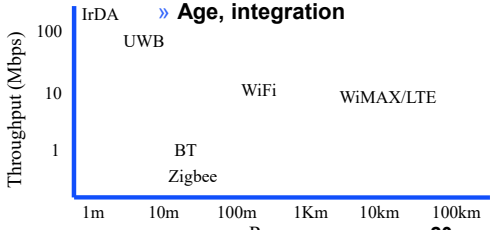
- Spectrum allocated by FCC and NTIA
- Two types of spectrum bands:
  1. Licensed spectrum: exclusive access to an organization
     - Federal agencies, broadcast TV, first responders, …
     - Commercial, e.g., cellular operators
  2. Unlicensed spectrum: everyone can use it with appropriate equipment, e.g., WiFi, zigbee, …
- Other trends:
  - » Technology improvements have allowed us to use higher frequency bands over time
  - » Many bands have low utilization
  - » Older bands often use very inefficient technologies

Wireless Technologies



Why so many Technologies?

- Diverse application requirements
  - » Energy consumption
  - » Range
  - » Bandwidth
  - » Mobility
  - » Cost
- Diverse deployments
  - » Licensed versus unlicensed
  - » Provisioned or not
- Technologies have different
  - » Signal penetration
  - » Frequency use
  - » Cost
  - » Market size
  - » Age, integration



Application Trends in Wireless

- Early days: specialized applications
  - » Broadcast TV and radio, voice calls, data, ..
  - » Holds for wireless and wired
- Today: flexible wireless platforms
  - » Phones, tables, and laptops all run similar applications
  - » Same trend as for wired networks: the internet took over
- Wireless is expanding in new domains
  - » Sensor networks, body area networks, …
  - » Edge of the internet is increasingly wireless
  - » Many of these applications are unique to wireless
- Future?

Scope of Wireless Covered in the Course

- Significant depth on two technologies:
  - » Wireless in unlicensed band: WiFi
  - » Wireless in licensed spectrum: cellular
  - » Focus is on optimizing performance with limited spectrum
  - » Sophisticated protocols to fight challenging physical layer
- Other wireless communication technologies
  - » RFID/NFC, low-power, satellite, UWB, visible light, …
- Localization and sensing
  - » GPS, Wifi for localization and sensing, …
- Wireless deployments
  - » Infrastructure WiFi, ad hoc, sensor networks, vehicular, DTN, visible light, ..
  - » Some topics covered in the surveys

Some History…

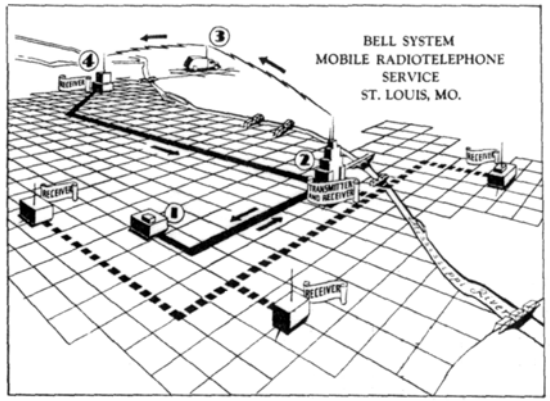
- Tesla credited with first radio communication in 1893
- Wireless telegraph invented by Guglielmo Marconi in 1896
- First telegraphic signal traveled across the Atlantic ocean in 1901
- First “cell phone” concept developed in 1946
  - » But only voice – data took another 50+ years
- GPS project started in 1973, complete in 1995
- WiFi technology developed in the mid-1990s

The origin of mobile phone

- America’s mobile phone age started in 1946 with MTS
- First mobile phones bulky, expensive and hardly portable, let alone mobile
  - » Phones weighed 40 Kg~
- Operator assisted with 250 maximum users

The MTS network

http://www.privateline.com/PCS/images/SaintLouis2.gif



Cell Phones Today

Some statistics for the US:

- **Two hundred trillion text messages/day**
  - » Average US teens sends 3339 texts per month
  - » 42% of teens can text while blind folded
  - » No 2 use of cellphones (what is No 1?)
- **People use their phones for lots of things**
  - » Take pictures (83%), play music (60%) and games (46%)
  - » Exchange videos (32%), access the web (27%) and social networks (23%)
  - » Only was of accessing the Internet for many people
- **It is a big business**
  - » Dollars spent on mobile devices: 42.8 M$ (2010) versus 1.8 B$ (2015)

Short History of WiFi

- **In 1985, the FCC opened up the 900 Mhz, 2.4 GHz and 5.8 Ghz bands for unlicensed devices**
- **NCR and AT&T developed a WiFi predecessor called "Wavelan" starting in 1988**
  - » NCR wanted to connect cashier registers wirelessly
  - » Originally used the 900 MHz band and ran at 1 Mbps
- **Standardization started in early 90s and led to 802.11b (1999) and 802.11a (2000)**
  - » Pre-standard products were available earlier
- **Today –many standards!**
  - » Working on 802.11ba - rates up to several Gps
  - » Very sophisticated technology: OFDM, MIMO, multi-user MIMO, ..

Early WiFi Interfaces

Wavelan at 900MHz
1 Mbps throughput

PCMCIA form factor make Wavelan more portable

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- Goals and structure of the course
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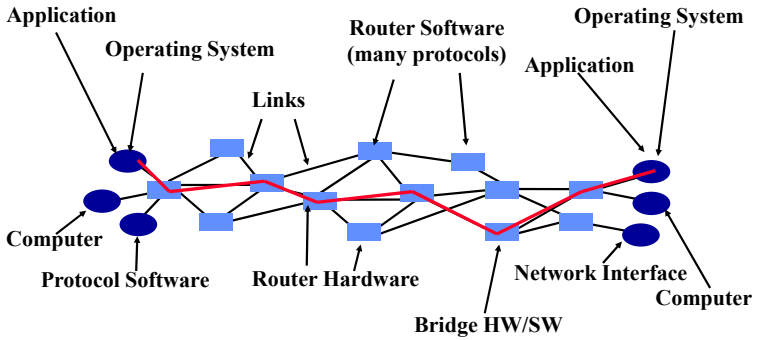
- Wireless technologies
- Building a network
  - » What pieces do we need
  - » The OSI model
  - » Packet-based communication
  - » Challenges in Wireless Networking

The Internet is Big and Has Many, Many Pieces

How do you design something this complex?



What Pieces Do We Need?

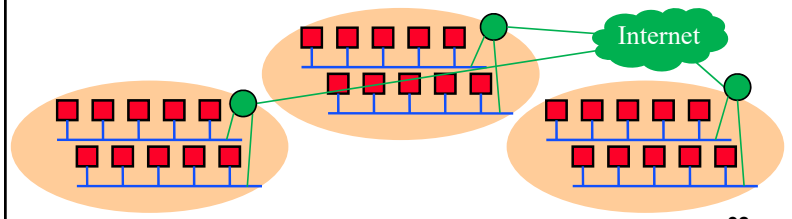
Module:

- We need to be able to send bits — **Physical**
  - » Over wired and wireless links
  - » Based on analog signals
- We really want to send packets — **Datalink Network**
  - » Statistical multiplexing: users can share link
  - » Need addresses to deliver packets correctly
- But network may not be reliable — **Transport**
  - » Bit errors, lost packets, …
  - » Must recover from these errors end-to-end
- You need applications and services — **Application**
  - » Otherwise: who cares?

Hosts Exchanging Packets can be Easy or Hard

Scaling up

- Two or more hosts talk over a wire (bits) — Physical
- Groups of hosts can talk at two levels — Datalink
  - » Hosts talk in a network is homogeneous in terms of administration and technology
  - » Hosts talk across networks that have different administrators and technologies — Internet
- Differ in physical and admin properties, scale

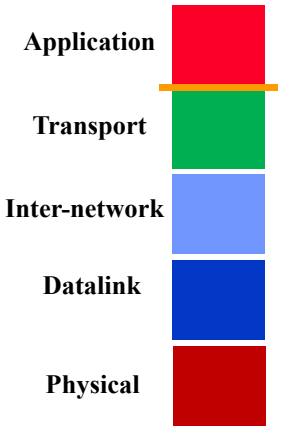


A Bit More Detail

- 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

Scaling up the network

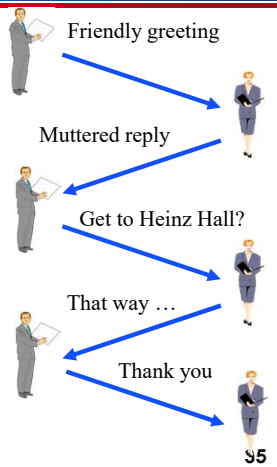
Our Internet So Far



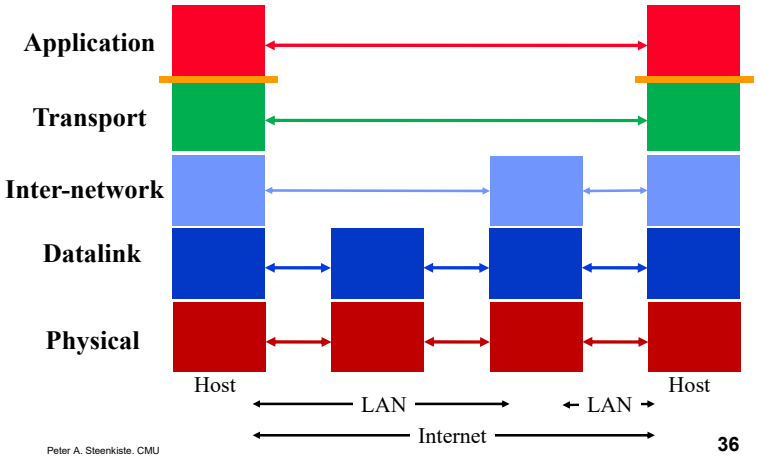
- The Internet as five modules that are stacked as a set of layers
  - » More on this later
- Five layers is nice, but …
  - » Each module is still huge!
  - » What about communication?
- We need protocols!
- Protocol modules within each layer on different devices allow the devices communicate

Protocol Enable Communication

- An agreement between parties on how communication should take place.
- Protocols must 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"

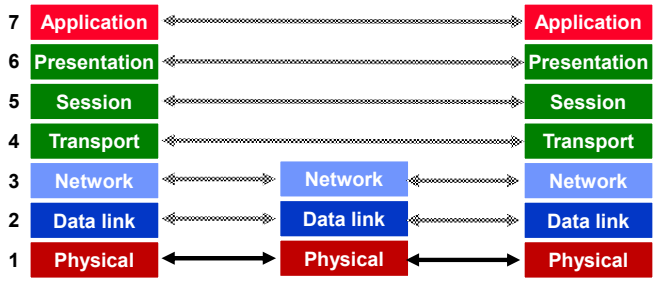


Protocol and Service Levels



The ISO Layered Network Model

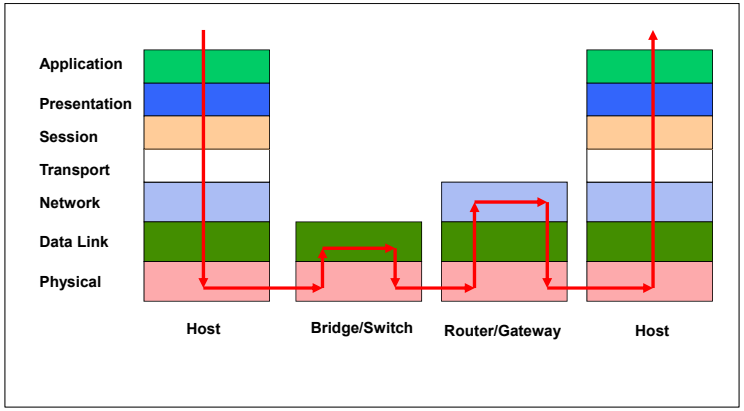
The Open Systems Interconnection (OSI) Model.



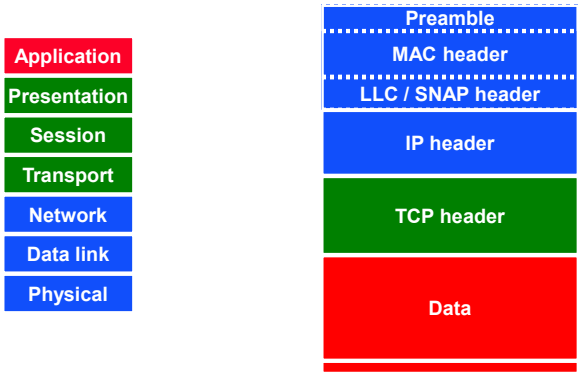
OSI Functions

- (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.

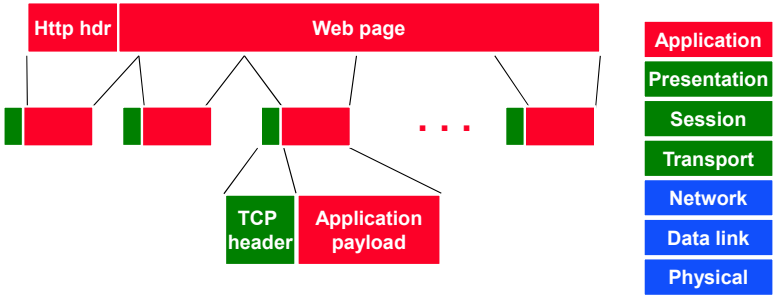
Life of Packet



A TCP / IP / 802.11 Packet



Example: Sending a Web Page



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

Benefits of Layered Architecture

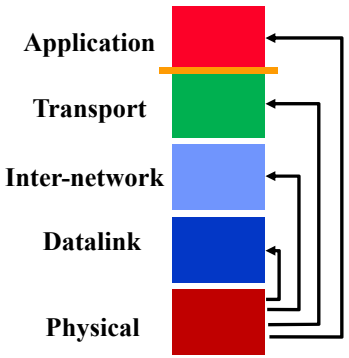
- Significantly reduces the complexity of building and maintaining the system.
  - » Effort is 7 x N instead of N^7 for N versions per layer
- The implementation of a layer can be replaced easily as long as its interfaces are respected
  - » Does not impact the other components in the system
  - » Different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

Impact of the Physical Layer

- Wireless PHY: error prone, variable
  - » Wires: very reliable and predictable



- Disconnections, unpredictable performance
- Packet losses and variable delay and bandwidth
- Mobility: IP addresses change
- Must manage complex PHY to perform error control
- Sophisticated modulation & coding, bit rate adaptation