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

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http://www.cs.cmu.edu/~prs/wirelessS17/

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
- Gain an understanding of wireless technologies at the physical, MAC, and higher layers
  - » Physical layer essentials for computer systems types
  - » Focus is on the wireless protocol layer
  - » Implications for the higher layers of the protocol stack
- Get 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)
  - » Focus on understanding the impact on higher layers
  - » Not an in-depth course on the communications field!
- 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
- 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?
- 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 treated as separate courses:
- Different questions on the tests
  - » Some questions will be shared
- 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., IMB students

Prerequisites

- This 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 but the course includes introductory material on these topics
- Programming experience
  - » C/C++ programming for the 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!

Grading

Grade distribution:

- Homeworks: 12%
- Project 1: 8%
- Project 2: 25%
- Survey: 10%
- Midterm: 15%
- 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 the material in the book, but slides are detailed
- Web page is primary source for information
  - » Lecture material
  - » Office hours, contact information, …
  - » Dates for quizzes, exams and project deadlines

More Administrative Stuff

- Lectures are Mo/We 2:30-4:30
  - » But lectures will typically be 80 minutes
  - » May go longer, e.g., to make up time for travel
- Recitations are Fr 10:30-noon
  - » There will relatively few recitations, mostly to talk about the projects
  - » May use recitation slot for make up lectures
- This courses does not use blackboard
- Course admin is Ms. Malloy – Gates 9006
  - » Pick up or drop off assignments
- Teaching assistants: TBD

Collaboration

- Traditional rules of collaboration apply
  - » http://dean.pku.edu.cn/notice/content.php?mc=61513&id=1419312543
- You must complete individual assignments and tests by yourself
- You must 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, ..
- Provide proper credit when reusing material
  - » But check with instructor or TAs 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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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
  - » Data communication introduced in ???
- GPS project started in 1973, complete in 1995
- WiFi technology developed in the mid-1990s

Scope of Wireless Covered in the Course

- Wireless in unlicensed band
  - » WiFi, Bluetooth, …
- Cellular technologies in licensed spectrum
  - » Cover all generations with a focus on LTE
- Other wireless communication technologies
  - » RFID/NFC, low-power wireless, satellite, UWB, visible light communication, …
- Localization and sensing
  - » GPS, Wifi for localization and sensing, …
- Wireless deployments
  - » Infrastructure WiFi, ad hoc, sensor networks, vehicular, DTN, ….

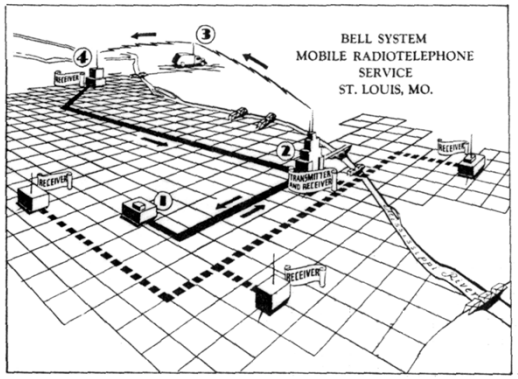
Some topics covered in surveys

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 802.11aq - rates up to several 100 Mps
  - » Very sophisticated technology: OFDM, MIMO, multi-user MIMO, ..

Early WiFi Interfaces

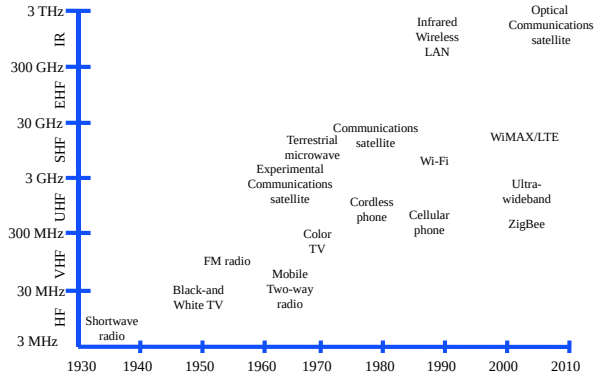
Wavelan at 900MHz
1 Mbps throughput

PCMCIA form factor make Wavelan more portable

Trends in Wireless

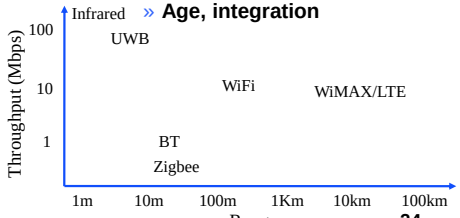
- Early days: specialized applications
  - Broadcast TV and radio, voice calls, data, ..
  - Holds for wireless and wired
- Today: flexible wireless platforms
  - Phones, tables, and laptops all run similar applications
  - Same trend as for wired networks: the internet took over
- Wireless is expanding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

Wireless Technologies



Why so many?

- 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



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- Goals and structure of the course
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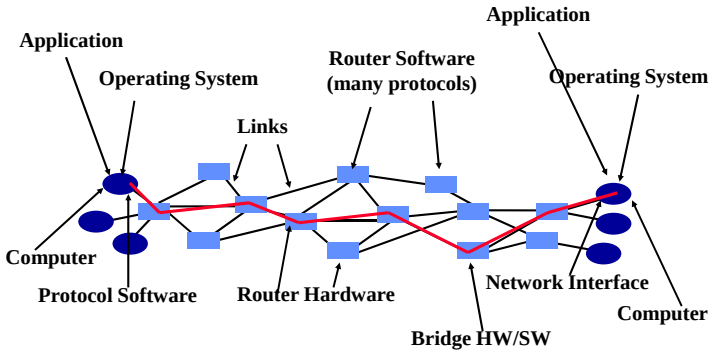
- Building a network
  - » Designing a BIG system
  - » The OSI model
  - » Packet-based communication
  - » Challenges in Wireless Networking

The Internet is Big and Has Many, Many Pieces



How do you design something this complex?

What Do We Definitely Need?

3
- We must have communication hardware and applications
  - » Applications make the network useful and fun

1
- Two "devices" must be able to sent data to each other
  - » When directly connected to each other

2
- The design must allow the network to grow very big and to always be available
  - » We need to be able to expand, fix, and improve the network ….
  - » While it is up and running: you cannot reboot the Internet

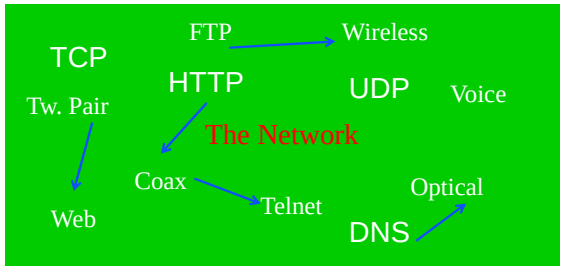
Protocol Enable Communication

- 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?

- No: we need to build a (very big) system
- Need to also deal with significant complexity and scalability
  - » Many, many pieces of components
  - » Many parties involved in building and running the network
  - » Very long life time and the need to evolve
- 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 …

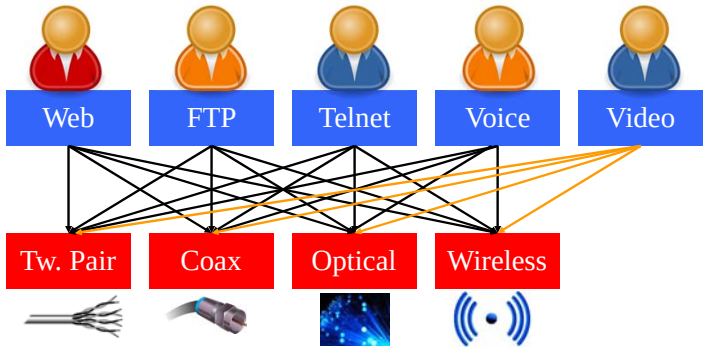
Solution #1



Need to More Add Structure

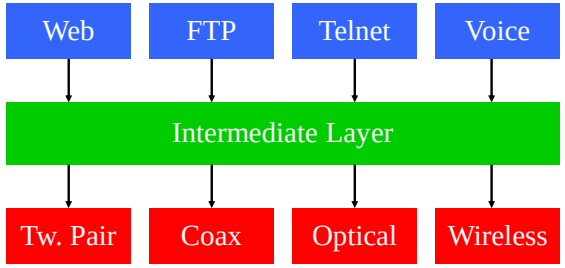
- Adding structure implies that you prevent people from doing arbitrary (≈ silly) things
  - » Can we organize the modules in a certain way?
- What modules do we definitely need in the Internet?
  - » Hardware modules that allow us to send bits around
  - » Applications that make the network useful for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

Solution #2?



Does not scale!

Solution #3

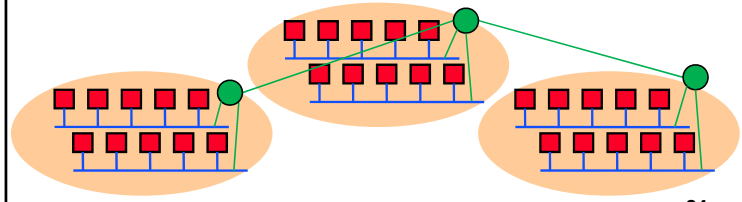


Improves development scalability
But what about heterogeneous deployments?

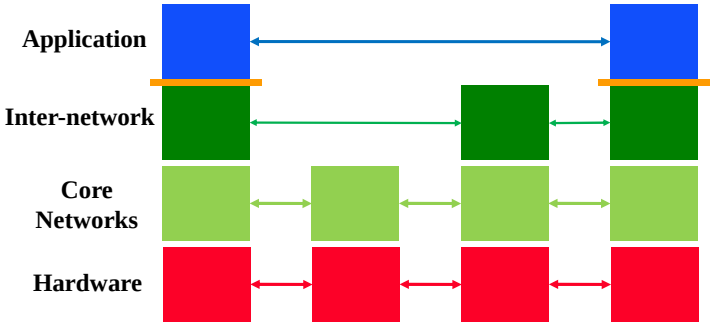
Let Us Try to be More Concrete and Practical

- 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



Protocol and Service Levels



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

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