579 and 435 Computing Principles for Mobile Embedded Systems

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Course Goal

- Understand applied computing principles in emerging technologies and applications for embedded systems
- Read and discuss interesting recent work in several areas of emerging computing paradigms
- Be proficient with computing methods by studying the programming aspects in sensor networks and learn how to program with sensor nodes.
- Understand emerging mobile technologies
  - How to determine what is important
  - What is the trend
  - What are the challenges
  - What are the weaknesses

Administrative

- **Course website:**
  - Course syllabus is posted.
  - All the course slides will be posted in Sakai.
    - Class announcements
    - Class schedule

- **How to reach me**
  - **Course meeting time – Once a week**
    - Wednesday 1:40PM – 4:40PM

  - **Email:** yingche@scarletmail.rutgers.edu
  - **Office Hours:** Wednesday 11AM – 1PM or by appointment
  - **Office:** Core 506

Administrative

- **Reference books: (not a requirement to buy)**
  - **Guide to Computing Fundamentals in Cyber-Physical Systems: Concepts, Design Methods, and Applications** by Dietmar P.F. Möller, Publisher: Springer, 2016, ISBN-13: 978-3319251769; ISBN-10: 3319251767.
  - **Fundamentals of Mobile Computing** by Prasant Pattnaik, Rajib Mall, Publisher: Prentice-Hall of India Pvt.Ltd, 2015, ISBN-10: 8120346327; ISBN-13: 978-812034632.
  - **Securing Emerging Wireless Systems** by Yingying Chen, Wenyuan Xu, Wade Trappe, Yanyong Zhang, ISBN:978-0-387-88490-5, Springer, 2009.
- Some knowledge of Java (will teach basics in the class)
- Strong motivation to learn

Main Topics

- Principles of real-time embedded systems
- Wireless sensor networks and mobile sensing applications
- Mobile and smart healthcare
- Wireless localization and location-based services (LBS)
- Methodology of distributed systems and access control computing paradigms
- Vehicular networks computing
- Cyber security and privacy, user authentication
- RFID sensing and systems

Structure

- Flexible and fun
  - Course based on a mixture of lectures, presentation of research papers, and discussions.
    - Background reading from online materials and research papers
  - I will give the lectures on appropriate background for each topic
  - Students are responsible for reading the papers and give the presentations of papers
- Pace
  - Lecture topics
  - Presentation and discussion of 2-3 papers per class
  - Some topics may take more than one class

Requirements

- Paper reading and presentation
  - No regular weekly or bi-weekly homework assignments
  - Each student expects to present 1 paper during the whole semester – treat it as your homework for the whole semester
  - Papers are from different topics.
  - Read and prepare slides before the class
  - Lead the discussion and prepare questions
- Write 1 term paper as mid term exam
  - The same paper that is presented by the student
- Quizzes or online discussion
  - 2-3 times a semester

Requirements

- Course project
  - Participate in 1 project (team project) – 3 to 4 students form a team.
- Final exam
  - Team project presentation
- Participation during classes
  - Active participation and discussion in the class

Grading

- 25% presentations – treat it as your homework
- 15% quizzes and online discussion
- 25% midterm – term paper
- 25% course project and team presentation – treat it as your final exam
- 10% class discussions and participation

Presentations (is your homework)

- Make sure to prepare your presentation well
  - Time: 15 minutes total – 12 minutes presentation, 3 minutes for questions
  - Send me your slides after class
    - Your revised slides based on in-class comments
    - Your slides will be posted in the class website
  - Getting slides from paper authors or other sources is NOT allowed
  - Please do not contact the authors on the questions of the research papers
  - Grading will be based on how well you (a) organize and deliver your presentation, (b) cover the critical points of the paper, and (c) answer questions
- The paper will be assigned to each student after the first week
- Presentations will start in the third week

Key points of presentation

- Practice many times before the class – important!
- Control your time well
- Be very clear about your key message
- Most good speakers average two minutes per slide (not counting title and outline slides.)
- Each theme should be the subject of a small number of slides
- Each slide should have clear heading.
- Make appropriate use of pictures
  - Pictures are usually helpful and can draw attentions
- Each slide should normally contain around 25-35 words
  - Do NOT list everything in a slide. It is distracting – you need to elaborate your points
  - Do NOT copy complete paragraphs from the paper to the slides.

A Generic Talk Outline

- **Title/author/affiliation** (1 slide)
- **Your name and email address (1 slide)**
- **Outline** (1 slide)
  Give talk structure. (Audiences like predictability.)
- **Background**
  - **Motivation and Problem Statement** (4-5 slides)

    (Why should anyone care? Draw attention – important)
- **Approaches and solutions** (4-5 slides)

A Generic Talk Outline

- **Results** (3-4 slides)
  - Present key results and key insights.
    - Do not superficially cover all results; cover key result well.
    - Do not just present numbers; interpret them to give insights.

- **Summary** (1 slide)

- **Related Work** (1 slide)
  - Place into the bigger context and background

- **Future Work** (1-2 slides)
  - Give problems this research opens up
  - Put down your own opinion

- **Backup Slides** (0-3 slides)
  Optionally have a few slides ready (not counted in your talk total) to answer expected questions. (Likely question areas: ideas glossed over, shortcomings of methods or results)

Course Project

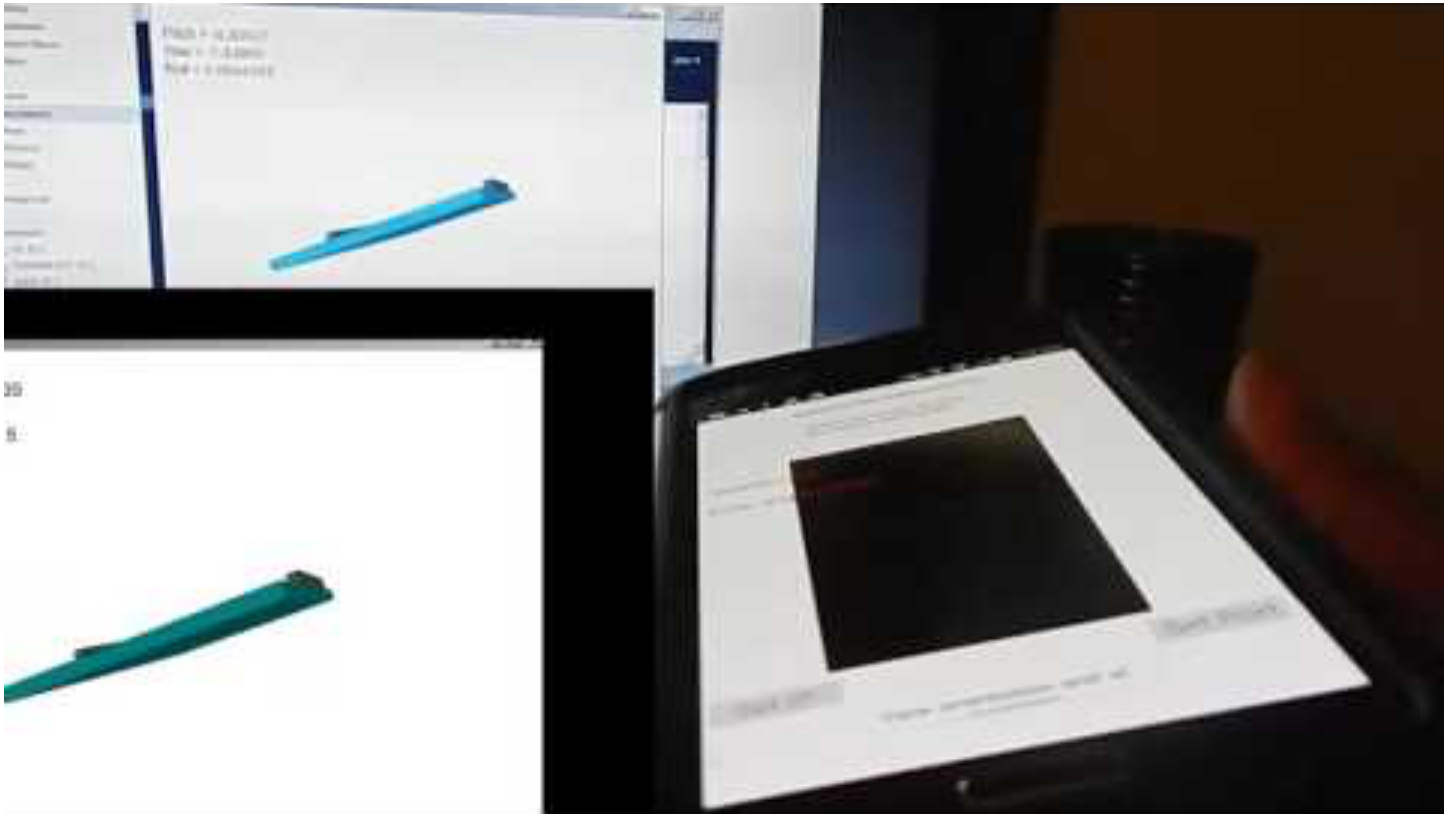
- Learning programming in wireless sensor networks
- What is a sensor network?
  - Formed by multiple sensors
  - Static or mobile?
  - What is the difference between a sensor and a robot?
    - Robots equip with sensors
    - Much cheaper than robots
  - What do they do?
    - Sensing and monitoring
      - E.g., temperature, humidity, spectrum energy, heart beat, blood pressure, and etc.
    - Collect data for analysis
  - Emerging applications
    - Patient monitoring and tracking
    - Animal habitat tracking
    - Emergency rescue and recovery
    - Traffic control and forecast in vehicular networks

Course Project – Sensing with Smartphone/Raspberry Pi

- Potential applications of smartphone/Raspberry Pi
  - **You are encouraged to have your own ideas!**
  - Sensing with motion sensors
  - Sensing with acoustic signals
  - Sensing with camera
  - Sensing with multiple sensors together

Course Project – Sensing [Motion Sensors]

- **Real time orientation sensing and hand gesture tracking**
  - https://www.youtube.com/watch?v=rUtaqZEidME



Course Project –Sensing [Motion Sensors]

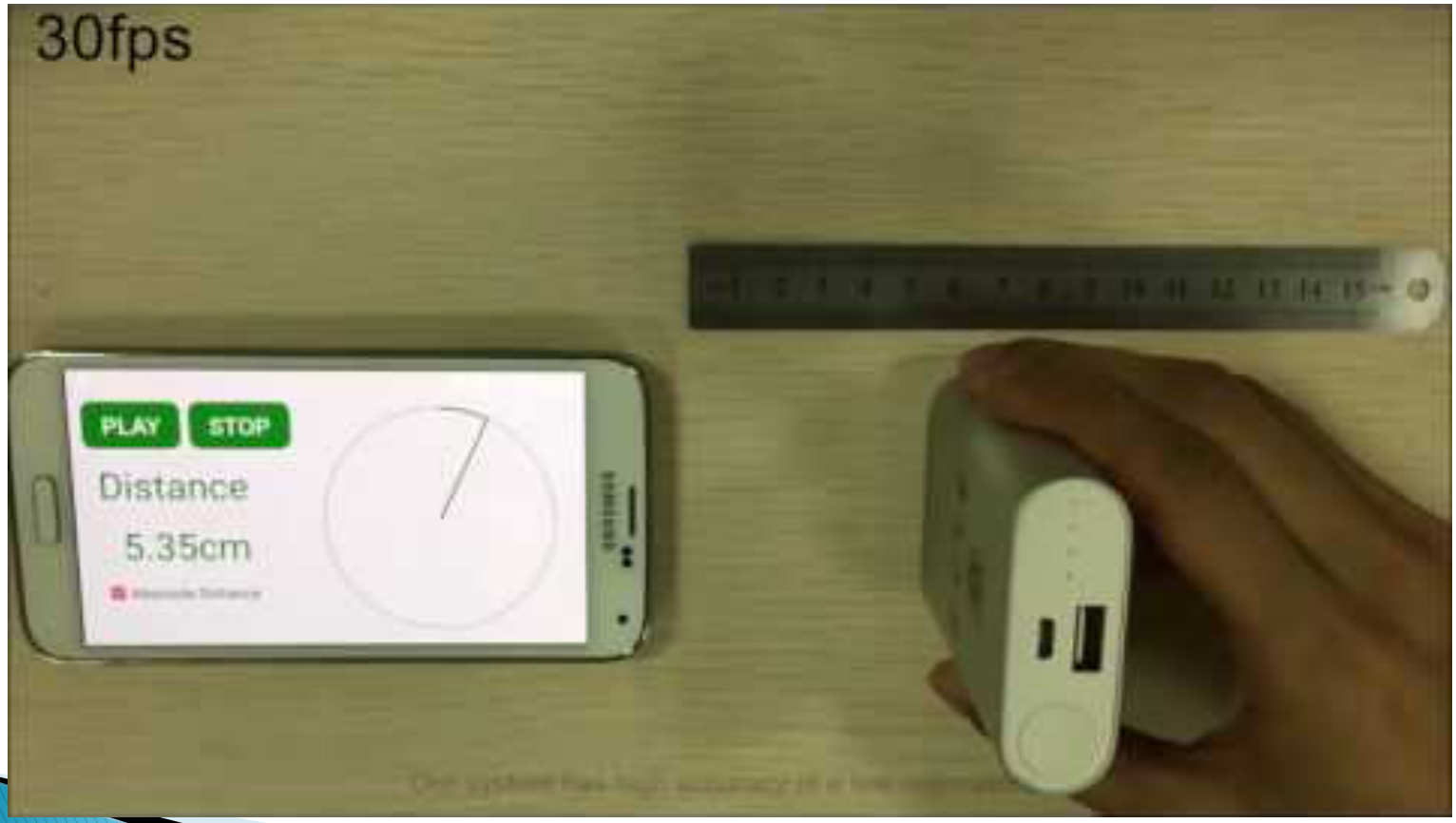
- **I am a Smartwatch and I can Track my User's Arm**

  [ACM MobiSys 2016]

  https://www.youtube.com/watch?v=sLeCW7IUy_s

Course Project –Sensing [Acoustic Signal]

- **Device-Free Gesture Tracking Using Acoustic Signals**
  [ACM MobiCom 2017]
  - https://www.youtube.com/watch?v=gs8wMrOSY80



Course Project – Sensing [Acoustic Signal]

- **Messages Behind the Sound: Real-Time Hidden Acoustic Signal Capture with Smartphones**
  [ACM MobiCom'15] ❖ https://www.youtube.com/watch?v=3aZGZ9RY218

Course Project – Sensing [Acoustic Signal]

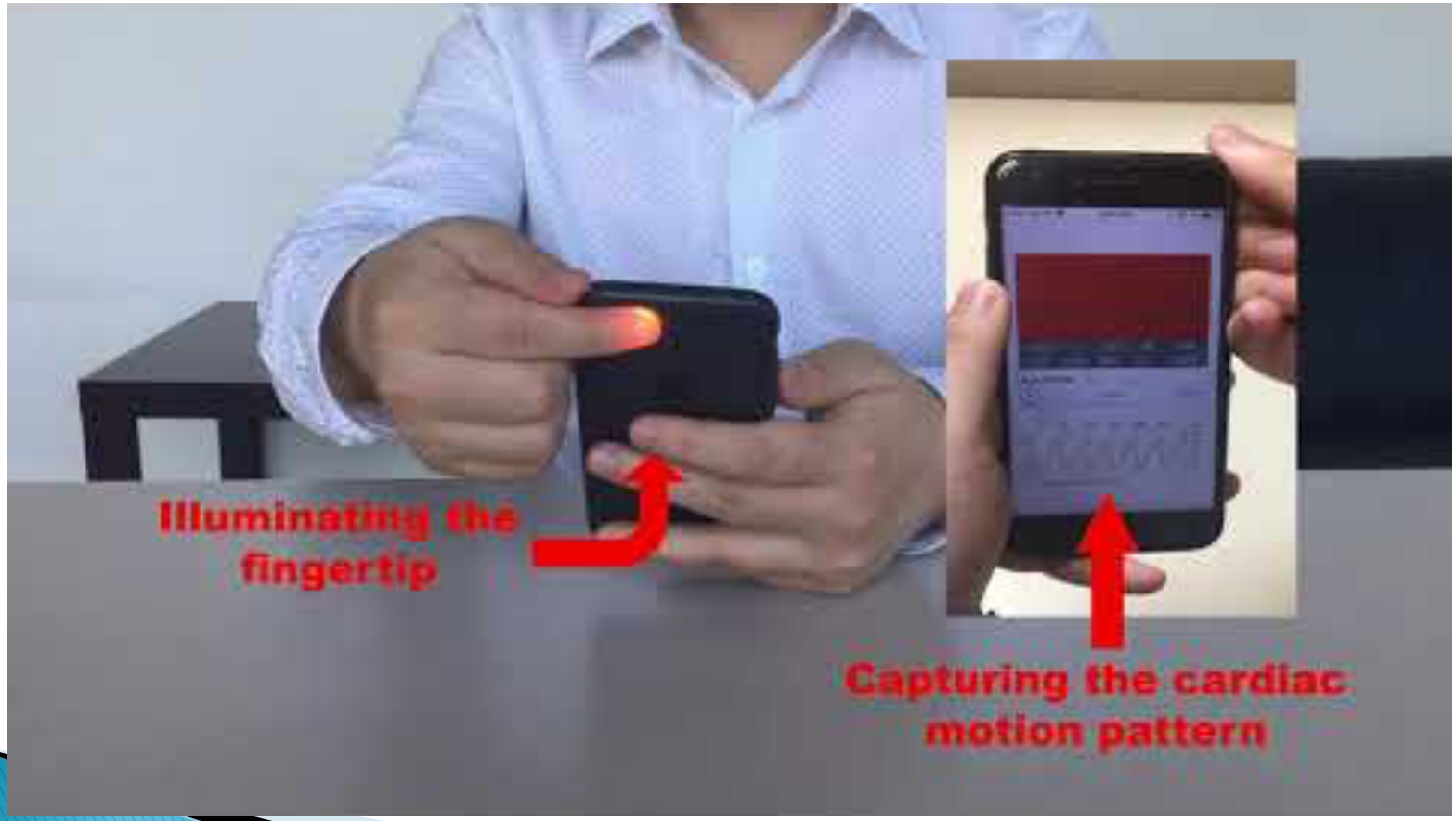
- **EchoTag: Accurate Infrastructure Free Indoor Location Tagging with Smartphones**
  [ACM MobiCom'15]
  - https://www.youtube.com/watch?time_continue=3&v=J_AQkGCD3MU

Course Project – Sensing [Acoustic Signal]

- **AIM: Acoustic Imaging on a Mobile**
  [ACM MobiSys'18]
  - https://www.youtube.com/watch?v=AcAteT2Ts5s

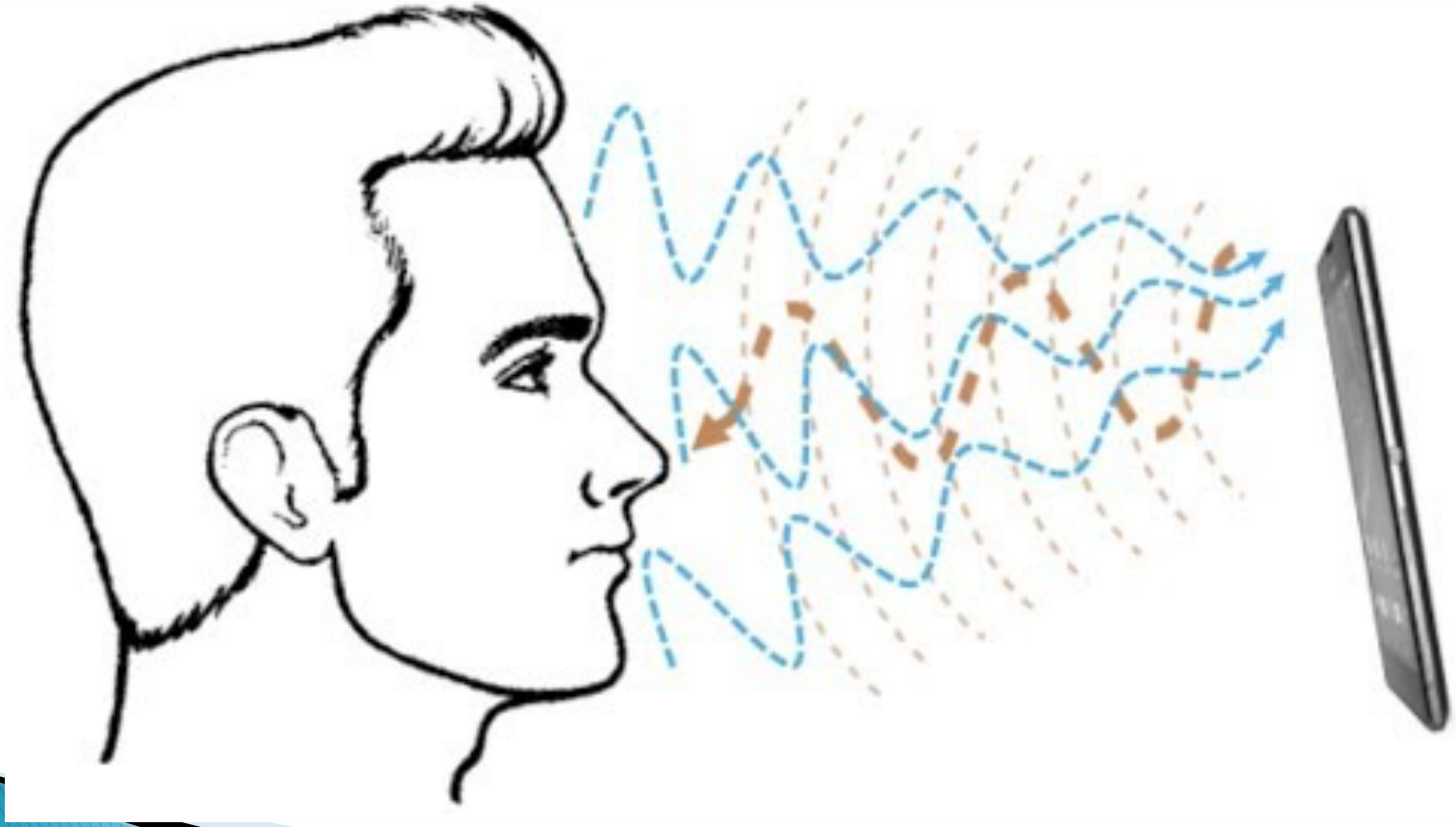
Course Project – Sensing [Camera]

- **CardioCam: Leveraging Camera on Mobile Devices to Verify Users While Their Heart is Pumping [ACM MobiSys 2019]**
  - https://www.youtube.com/watch?v=Wi5iMxq9KDI



Course Project – Sensing [Multiple Sensors: Camera + Acoustic Signals]

- (ACM MobiCom 2018) EchoPrint: Two-factor Authentication using Vision and Acoustics on Smartphones
  - https://www.youtube.com/watch?v=wthUzdKsTZc&feature=youtu.be



Project

- Participation in projects
  - Form a team: 3 –4 people
  - Final exam: project presentation
  - State clearly in the project presentation about who did what – each student's contribution to the project
  - Each student needs to present a part of the final project presentation

Midterm: Term Paper

- Goal:
  - Presents an arguable opinion about an issue/problem in the paper
  - Convince the audience that your opinion is valid and worth listening to.
- How:
  - Use the paper you presented, developing your argument
  - address all sides of the issue
  - take one side of the argument
  - support your argument with evidence
  - address the counterclaims to show that you are well informed about both sides.
- Format: 4 pages, 11 point font, single column, 1 inch margin at each side of the paper.

Student Presentation Example

- Examples will be posted in Sakai.

Email Policies

- **Make sure you put your course (435, 579) in the subject of the message.**

- **Remember that it is not my emergency if you need help at the last minute.**
  - I may check my messages in time to help you make a deadline, but this may not necessarily be the case.

- Ask specific question instead of general question.
  - Bad example: "What course project I should work on?"
  - In general, I will answer quick questions sooner than one that will take a long time to answer

- **In general I will monitor and respond to emails all the time.**

Your Best Strategy

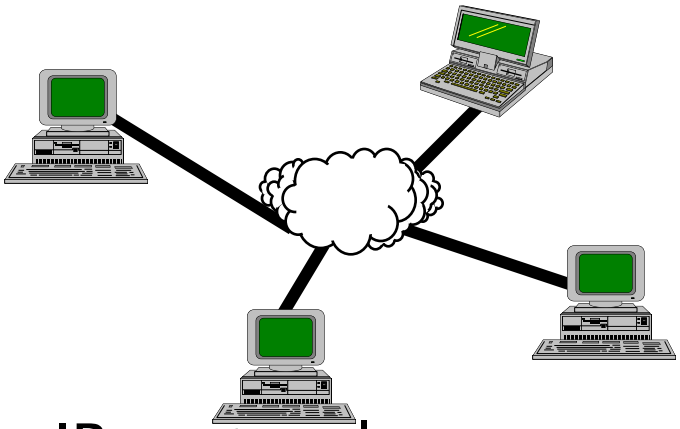
- Come to every lecture
- Read lecture materials
- Read and summarize papers that will be presented
- Participate in the discussion during class!
- Do not wait till last minute to work on the project

Objective for All of Us

- To learn to strive, but not to fail.
- Enjoy the fun!

Introduction to Internet

Internet & Networks



- What is an internet?
  - Network of networks
- What is the Internet?
  - A global internet based on the IP protocol
- To what does “Internet technology” refer?
  - Architecture
  - Services

Protocols

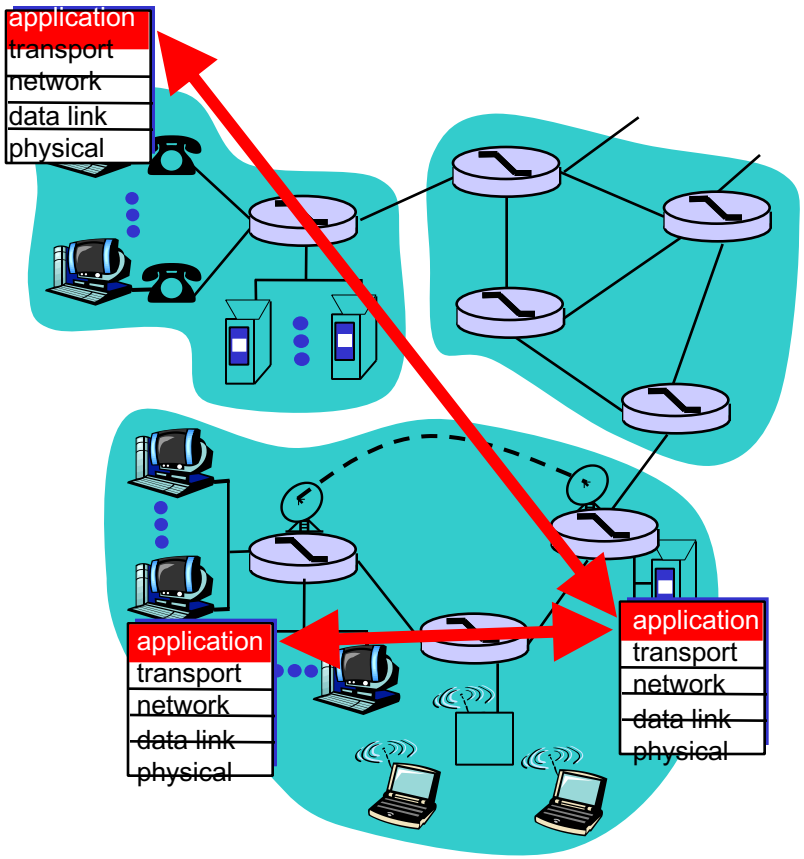
What are network applications?

Programs that

- run on different end systems and
- communicate over a network.
- e.g., Web: Web server software communicates with browser software

little software written for devices in network core

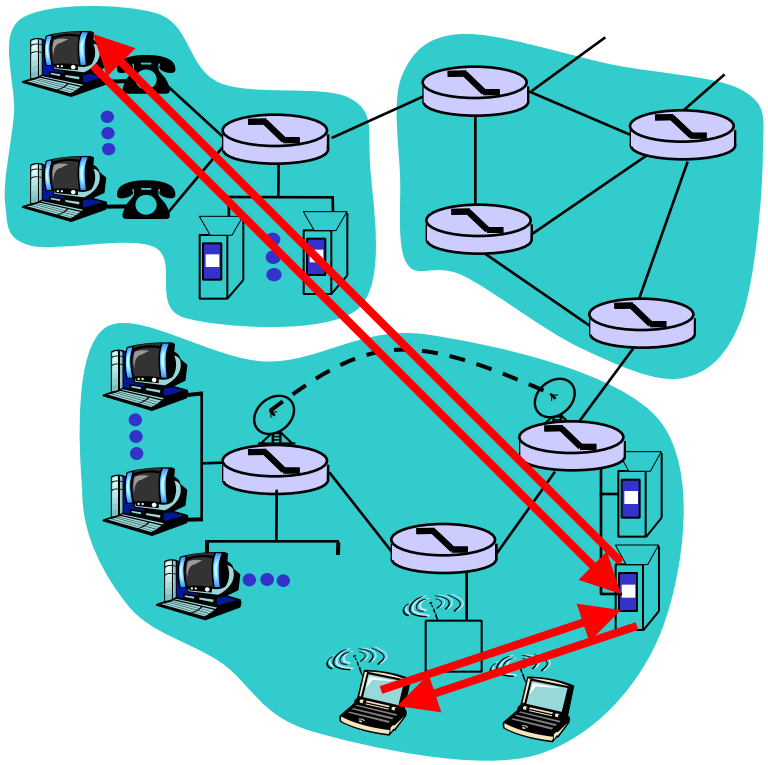
- network core devices do not run user application code



Some Existing and New Apps

- E-mail
- Web
- Instant messaging
- Remote login
- P2P file sharing
- Multi-user network games
- Streaming stored video clips
- Internet telephone
- Real-time video conference
- Massive parallel computing

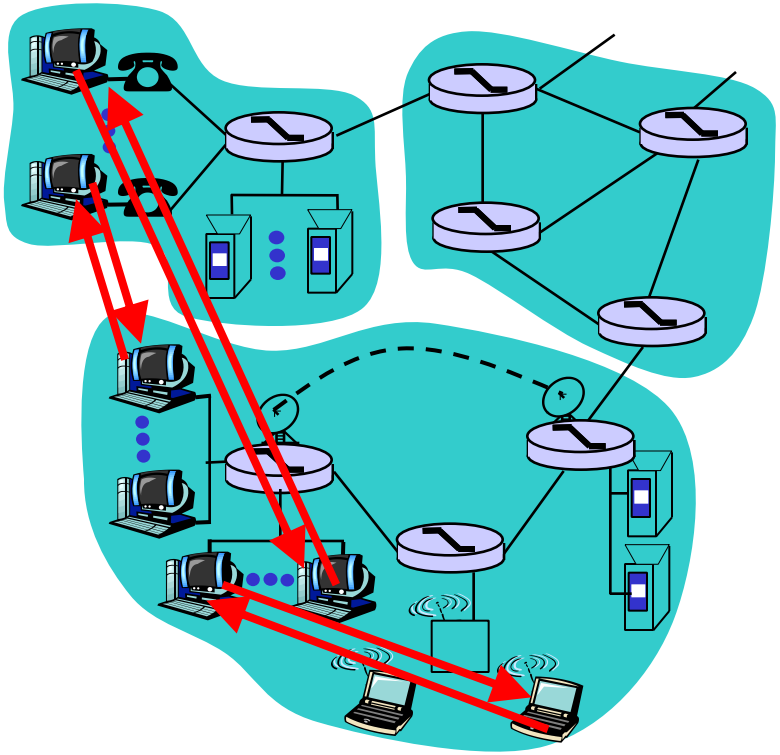
Client-server architecture



- server:
  - always-on host
  - permanent IP address
  - server farms for scaling
- clients:
  - communicate with server
  - may be intermittently connected
  - may have dynamic IP addresses
  - do not communicate directly with each other

Pure P2P architecture

- no always-on server
- arbitrary end systems directly communicate
- peers are intermittently connected and change IP addresses
- example: Gnutella



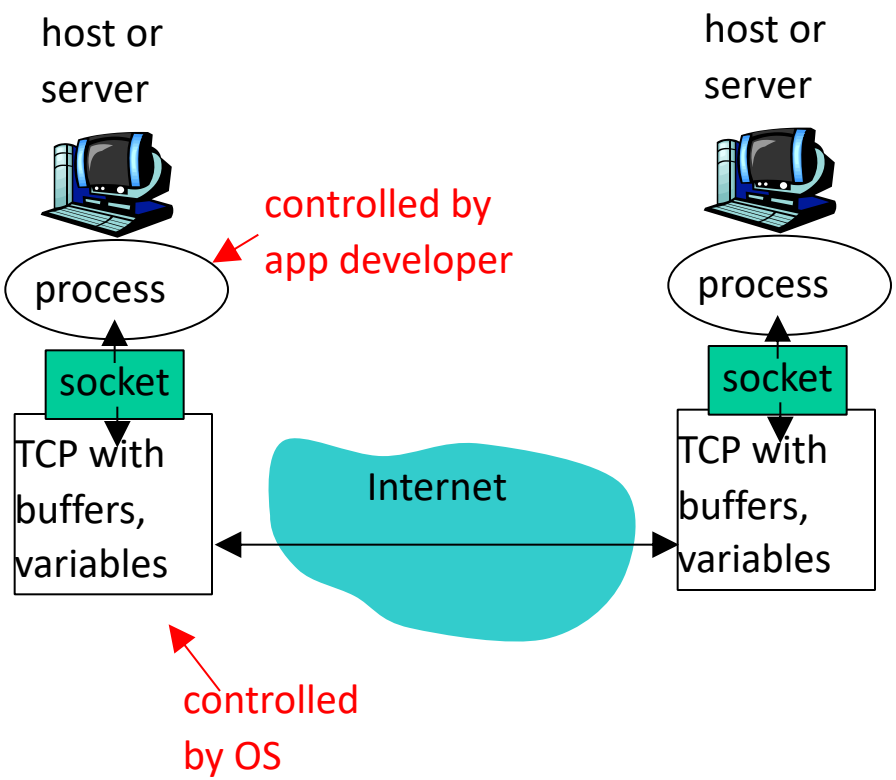
Highly scalable but difficult to manage

Hybrid of client-server and P2P

- Skype
  - Internet telephony app
  - Finding address of remote party: centralized server(s)
  - Client-client connection is direct (not through server)
- Instant messaging
  - Chatting between two users is P2P
  - Presence detection/location centralized:
    - User registers its IP address with central server when it comes online
    - User contacts central server to find IP addresses of buddies

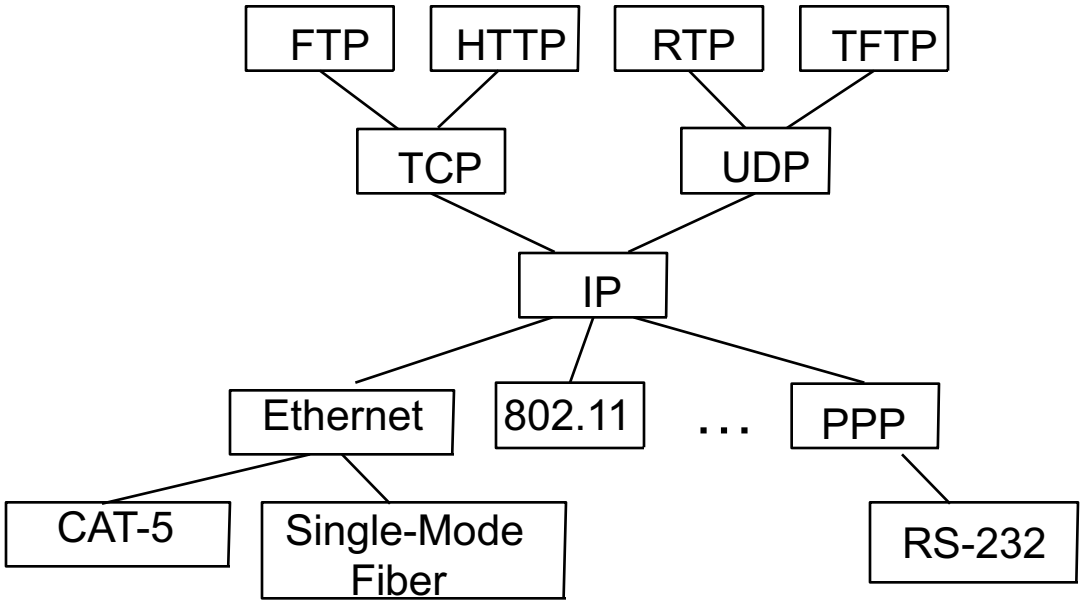
Sockets

- Process sends/receives messages to/from its socket
- Socket analogous to door
  - Sending process shoves message out door
  - Sending process relies on transport infrastructure on other side of door which brings message to socket at receiving process



Protocols

- **Protocol**
  - Architecture → Service
  - Rules of communication



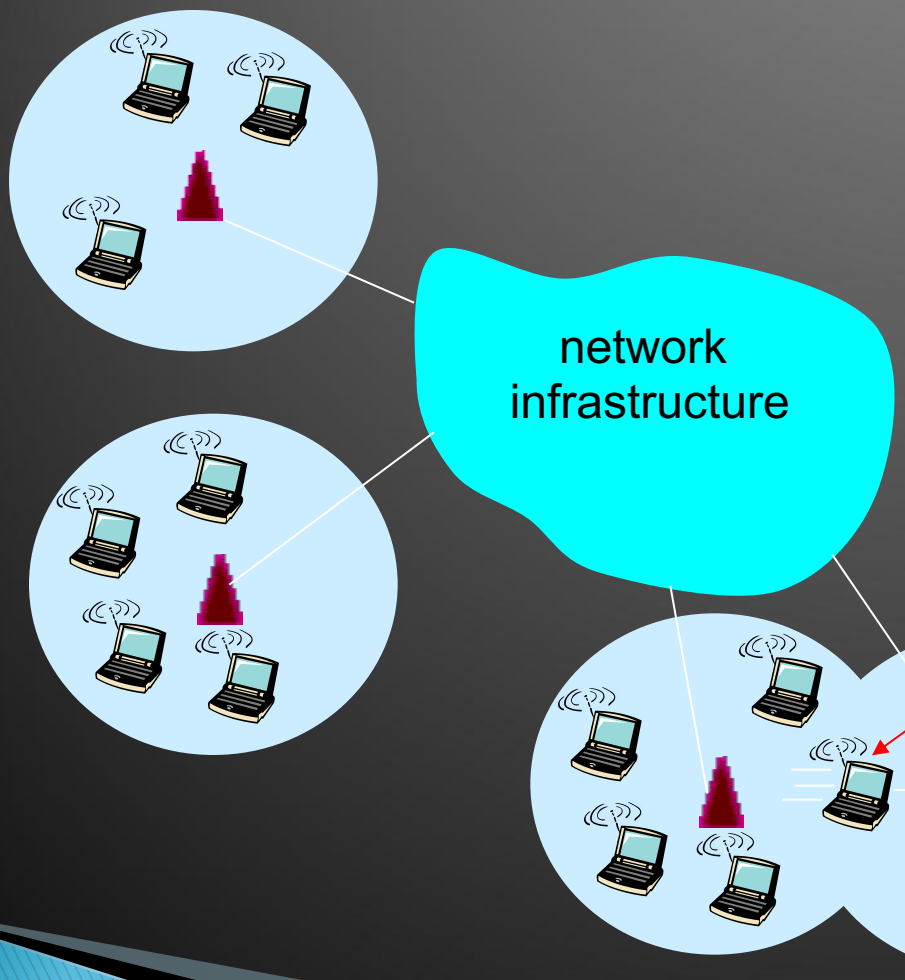
Introduction to Wireless Networks

Wireless and Mobile Networks

Background:

- # wireless (mobile) phone subscribers now exceeds # wired phone subscribers!
- computer nets: laptops, palmtops, PDAs, Internet-enabled phone – promise anytime untethered Internet access
- two important (but different) challenges
  - communication over wireless link
  - handling mobile user who changes point of attachment to network

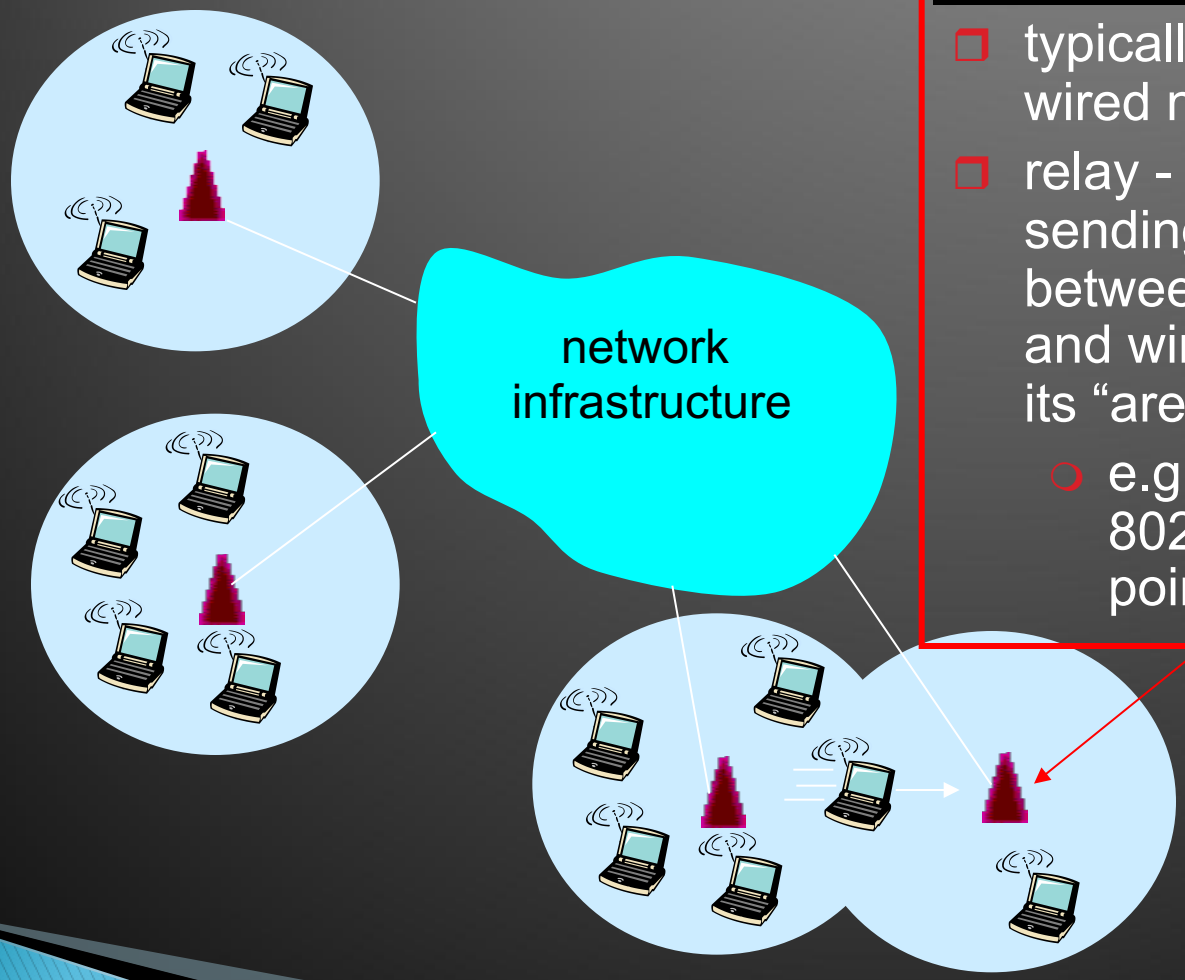
Elements of a wireless network



wireless hosts

- laptop, PDA, IP phone
- run applications
- may be stationary (non-mobile) or mobile
  - wireless does *not* always mean mobility

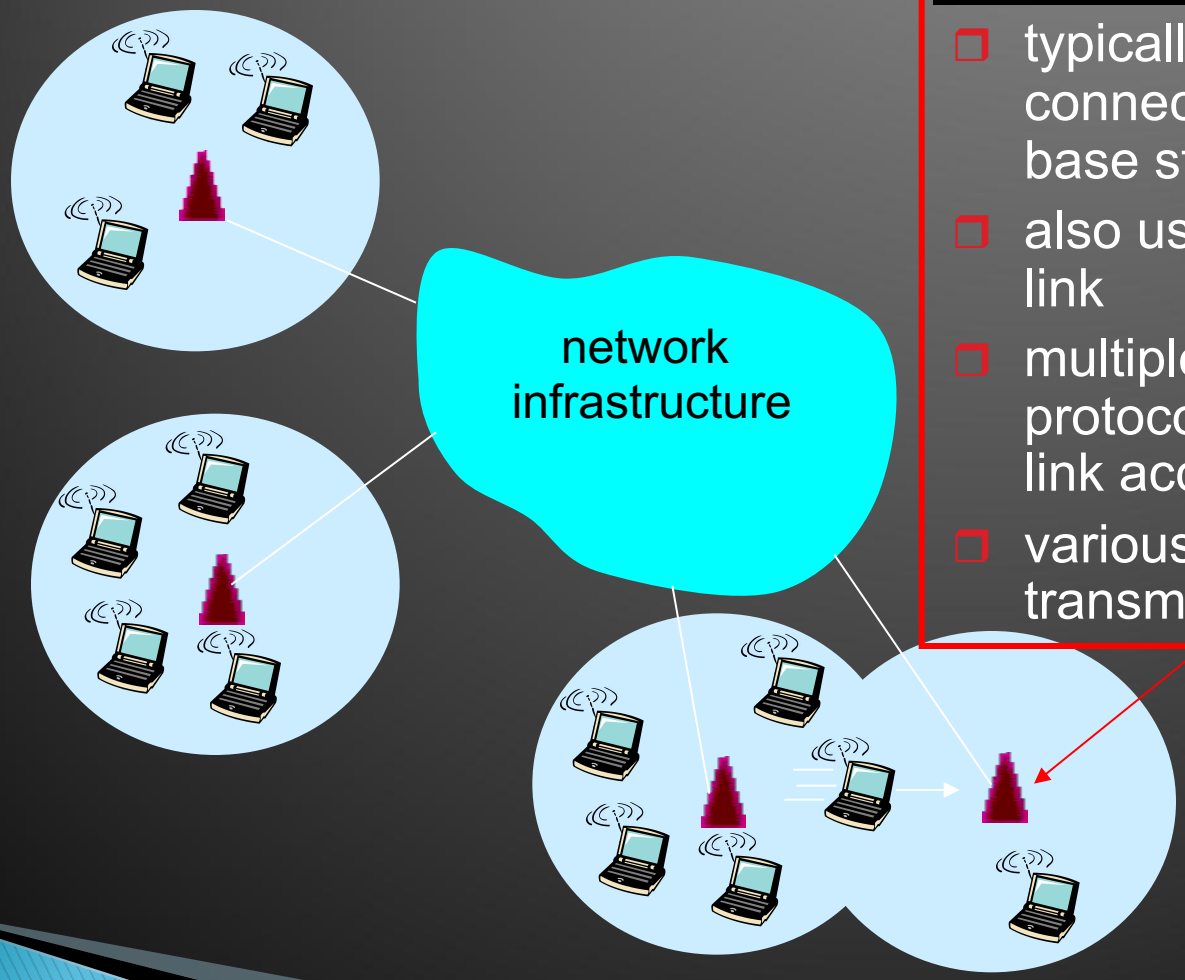
Elements of a wireless network



base station

- typically connected to wired network
- relay - responsible for sending packets between wired network and wireless host(s) in its “area”
  - e.g., cell towers 802.11 access points

Elements of a wireless network

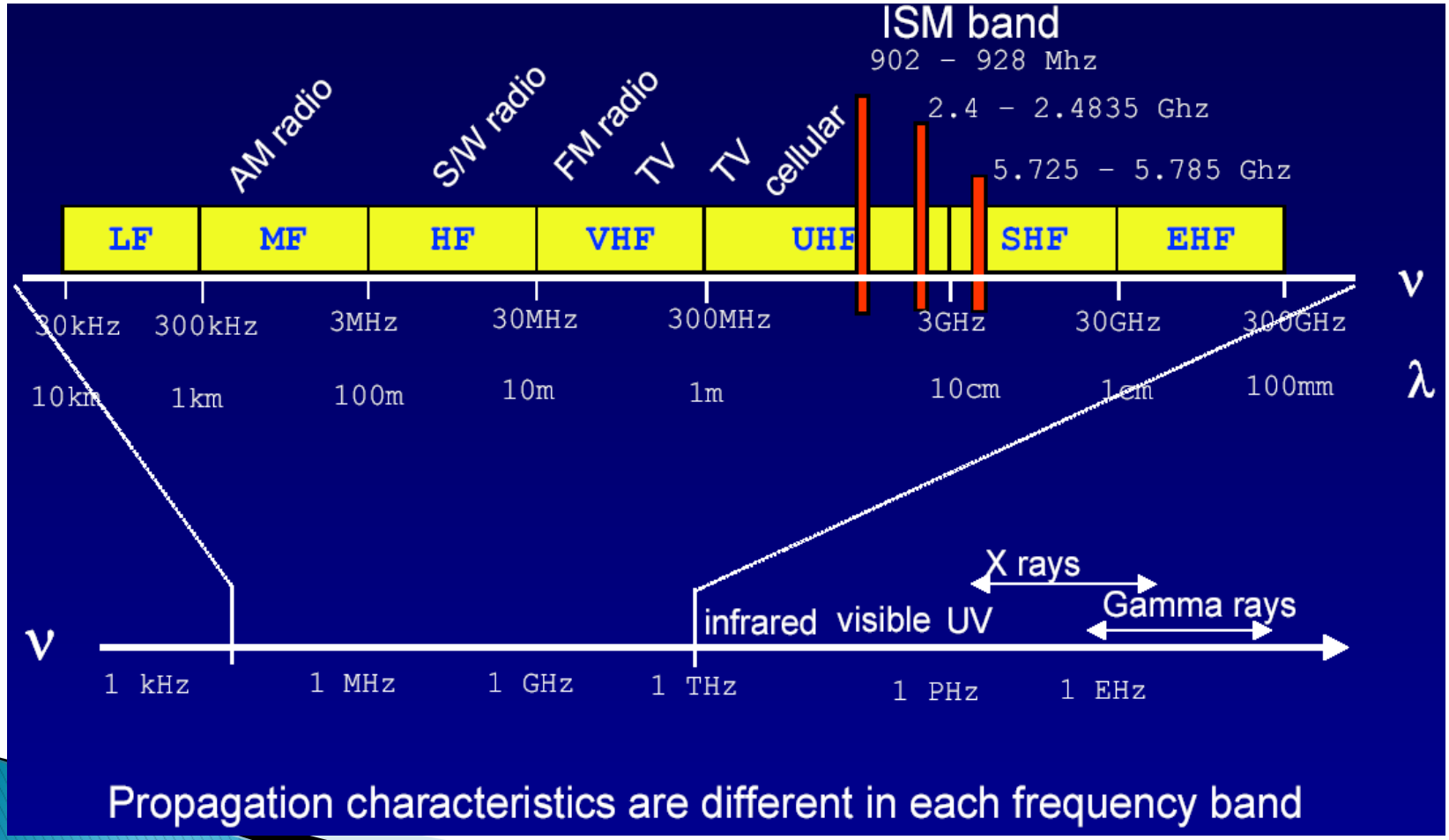


wireless link

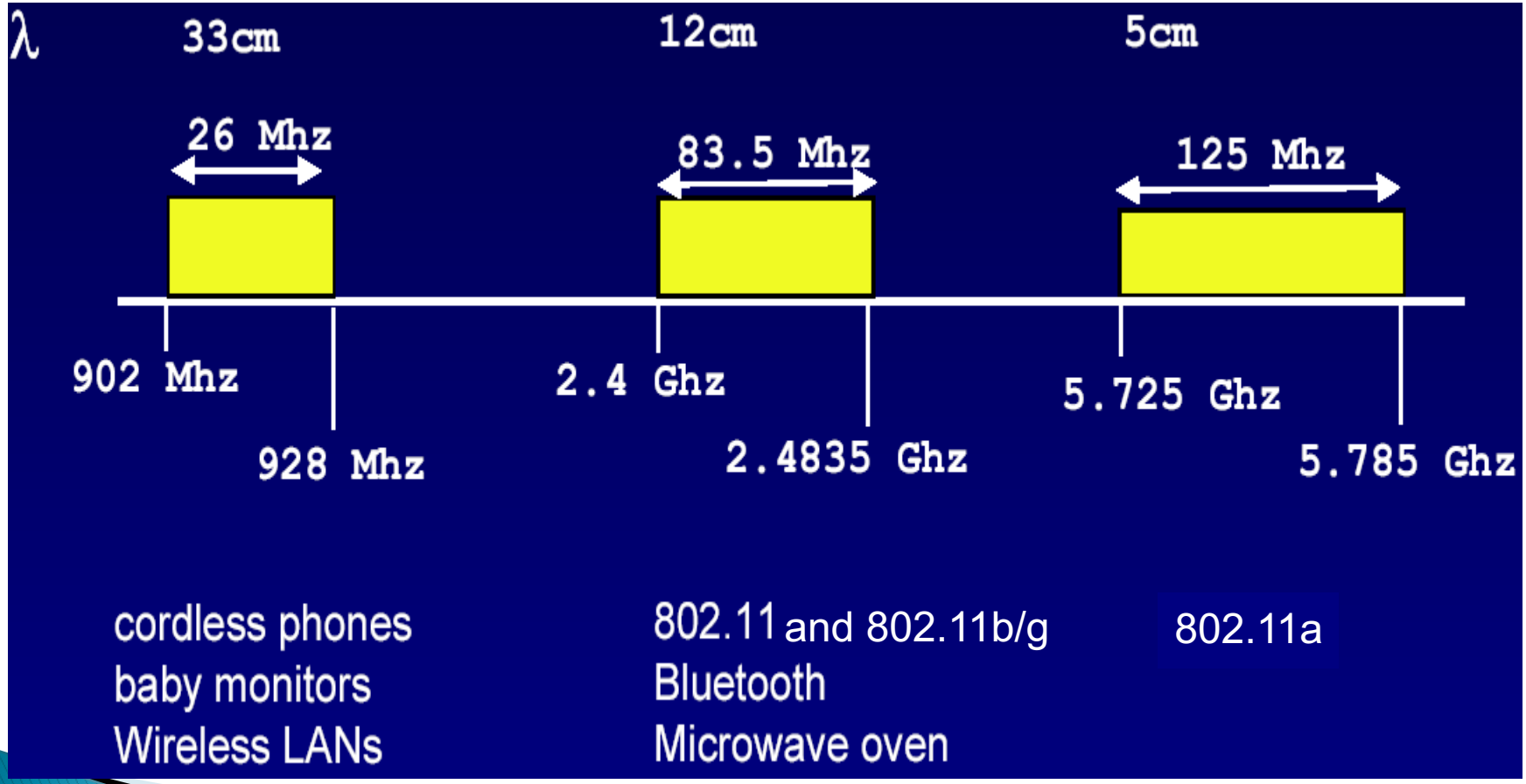
- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance

ISM: Industry, Science, Medicine

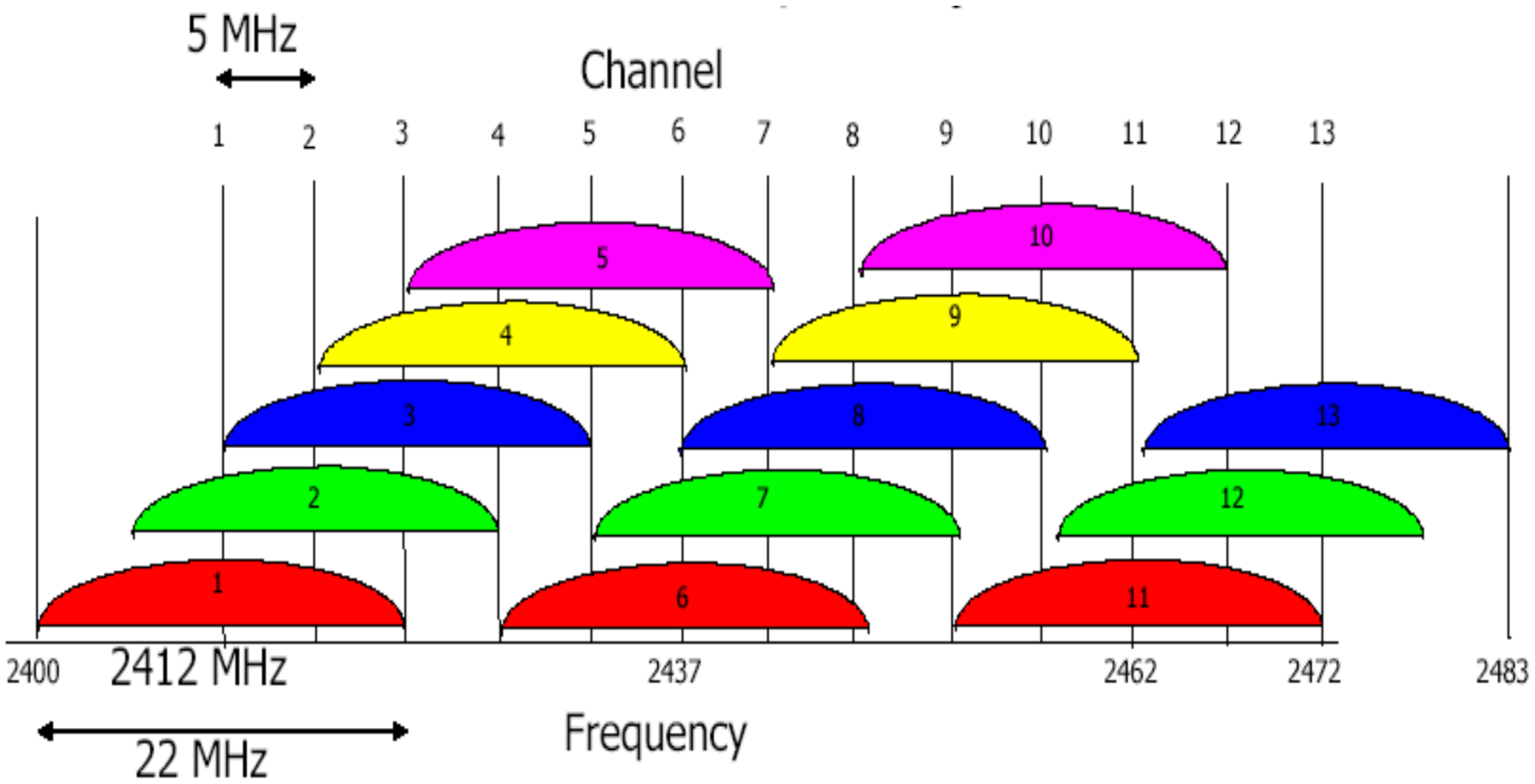
unlicensed frequency spectrum: 900Mhz, 2.4Ghz, 5.1Ghz, 5.7Ghz



IEEE 802.11 Frequency Band



802.11b/g Channels

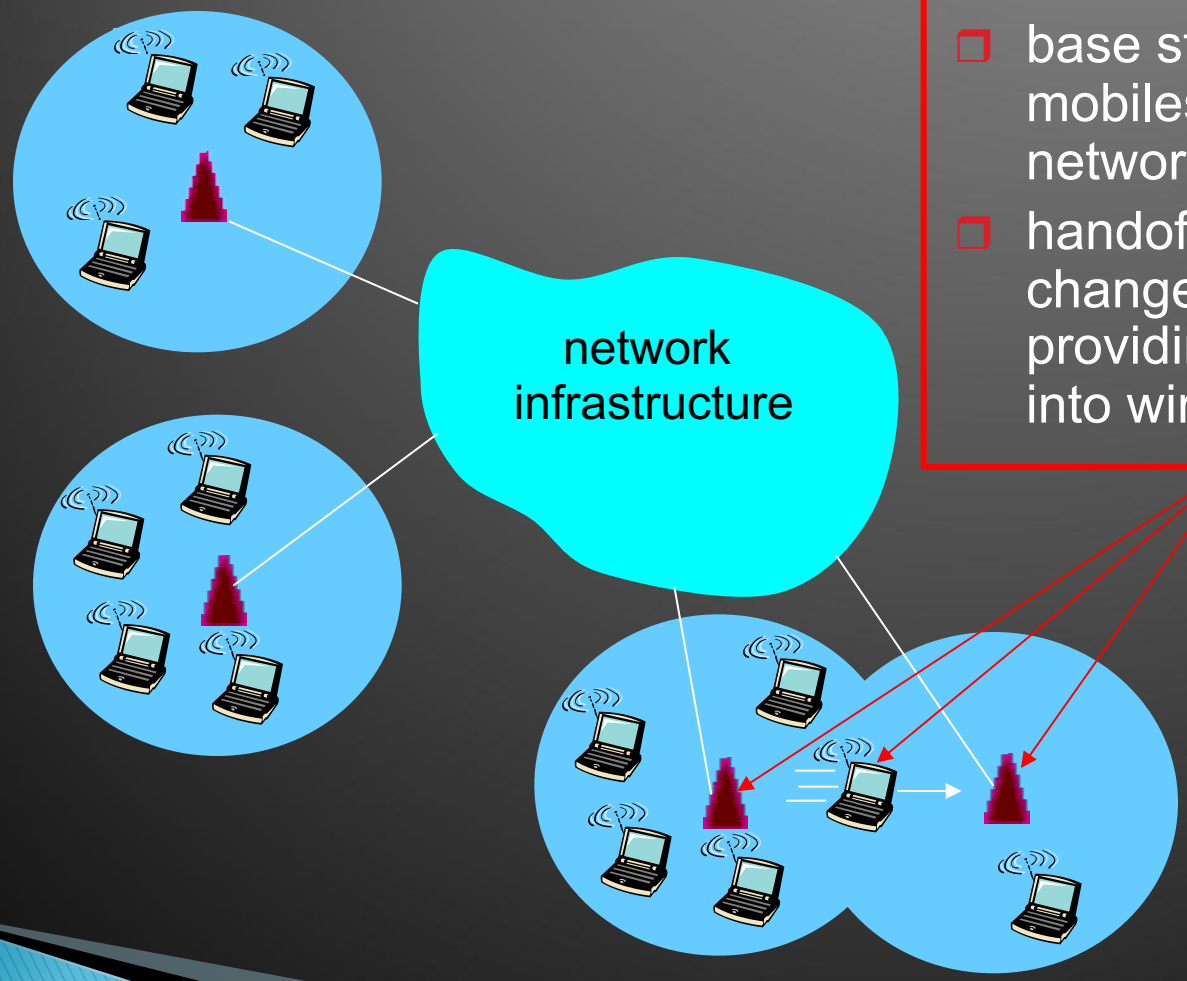


IEEE 802.11 variants

	802.11a	802.11b	802.11g	802.11
Standard approved	Sep. 1999	Sep. 1999	June 2003	July 1997
Available bandwidth	300 MHZ	83.5 MHZ	83.5 MHZ	83.5 MHZ
freq. of operation	5.15-5.35G 5.725-5.825G	2.4-2.4835G	2.4-2.4835G	2.4-2.4835G
No. of non-overlapping Ch.	4	3	3	3
Rate per channel (Mbps)	6,12,24,36,48,54	1, 2, 5.5, 11	1, 2, 5.5, 11, 6, 9, 12, 18, 24, 36, 48, 54	1, 2
Range	~150 feet (indoor) 225 (outdoor)	~225 feet	~225 feet	??
Modulation	OFDM	DSSS/CCK	DSSS/CCK; DSSS/OFDM	DSSS, FHSS

FHSS: frequency hopping spread spectrum DSSS: direct sequence spread spectrum
OFDM: orthogonal frequency division multiplexing

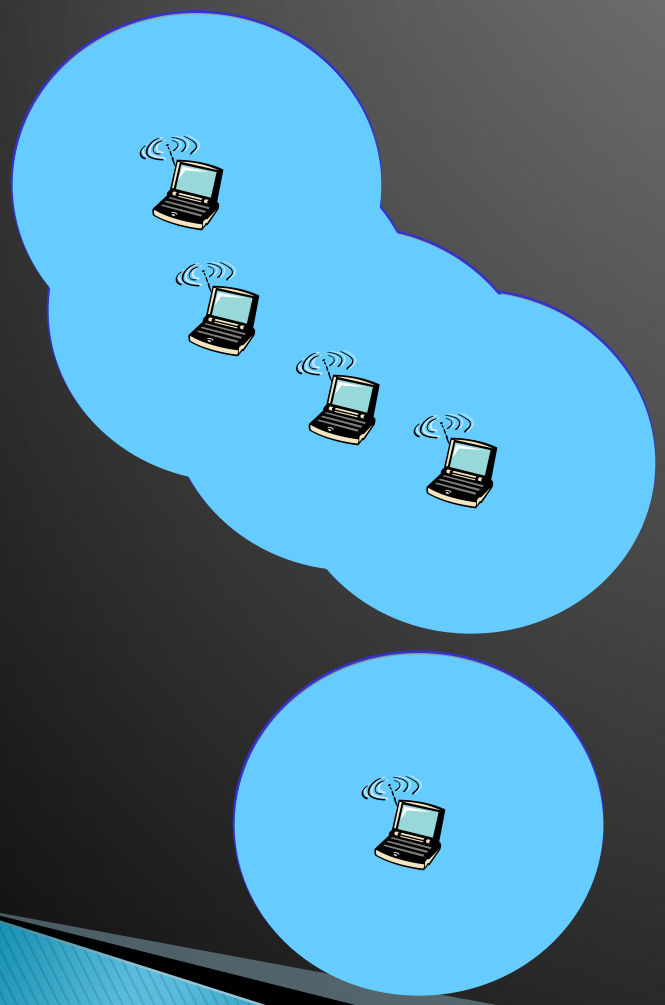
Elements of a wireless network



infrastructure mode

- base station connects mobiles into wired network
- handoff: mobile changes base station providing connection into wired network

Elements of a wireless network



Ad hoc mode

- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network: route among themselves