Wireless Communication Systems
@CS.NCTU

Lecture 1: Introduction to Wireless Networks

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Wireless Courses @ CS, NCTU

- 有線/無線網路技術整合及應用
- 行動無線網路安全
- 無線多媒體網路
- 無線區域網路
- 無線通訊最佳化
- 無線感測網路及射頻識別技術
- 無線網路與行動計算
- 無線網際網路
- 無線隨意及感測網路技術與應用
- 雲端架構之4G/LTE網路和應用
- 行動通訊網路與應用
- 新世代無線網路協定與技術
- ……

What's new here?

Wireless

Use wireless signals




Communication

To communicate or interact

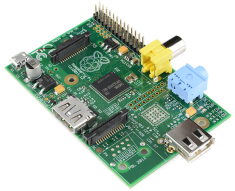
- MIMO, full-duplex, mmWave, localization, action recognition, ….

Systems

Via prototyping or application


Software Defined Radio

Aduino



Pi

iOS App

Main Purposes of This Class

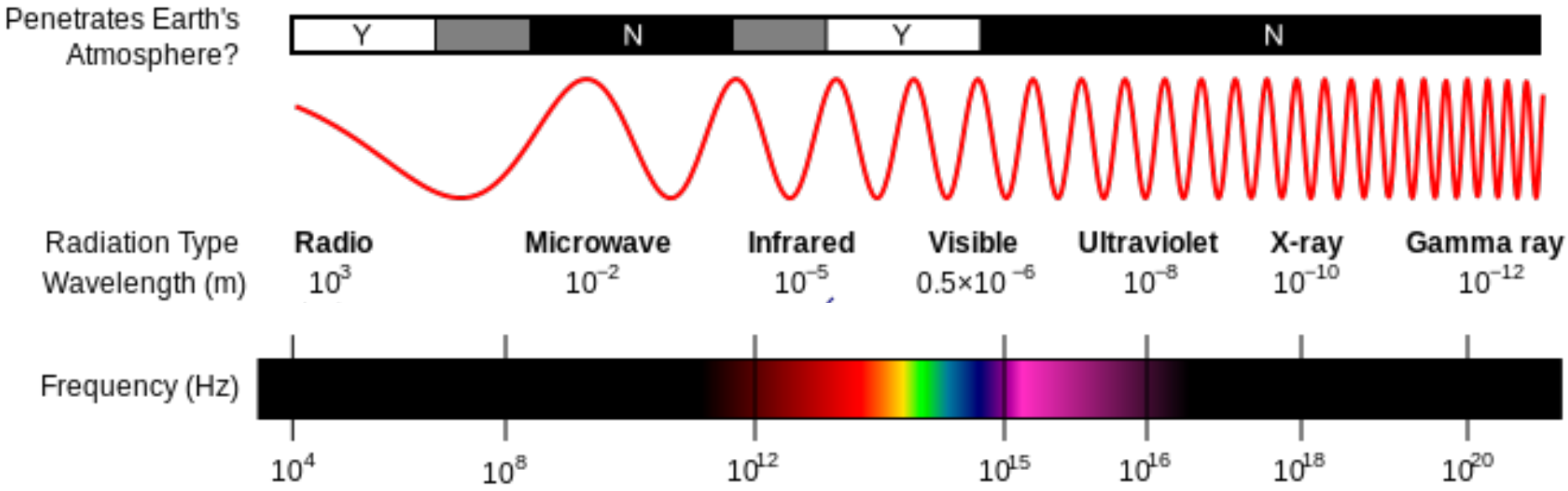
- Train hand-on experiences
  - Three labs
  - One final project
- Broaden your knowledge base for mobile and wireless research
  - Introduce most emerging wireless technologies in recent 5 years
  - Introduce possible applications
- Learn logical thinking
  - Two paper reviews
- Improve your English

Syllabus

- Introduction
- Medium Access Control
- Routing
- Modulation
- Bit-Rate Adaptation
- Soft Information and Error Recovery
- OFDM
- Successive Interference Cancellation
- MIMO 1: Multiplexing, Diversity, and Detection
- MIMO 2: Interference Alignment, Interference Nulling, and Virtual MIMO
- Wireless Localization
- Wireless HCI
- Visible Light Communications
- Full-Duplex Communications
- mmWave

Introduce 1-3 famous papers for each topic!

What wireless signals we can use?



20–20kHz

Audio signal

20kHz – GHZ

Ultrasound

3kHz – 300GHZ

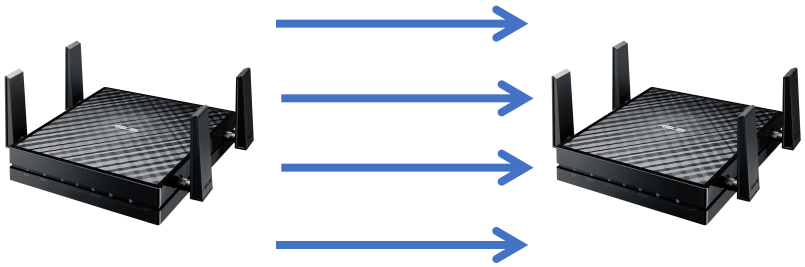
Radio frequency (WiFi, LTE, Bluetooth, RFID)

430–770 THz

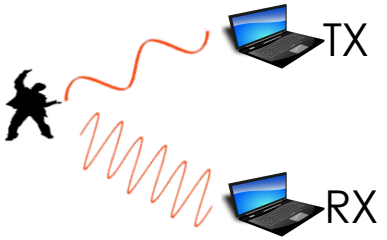
Visible light

What topics we will cover?

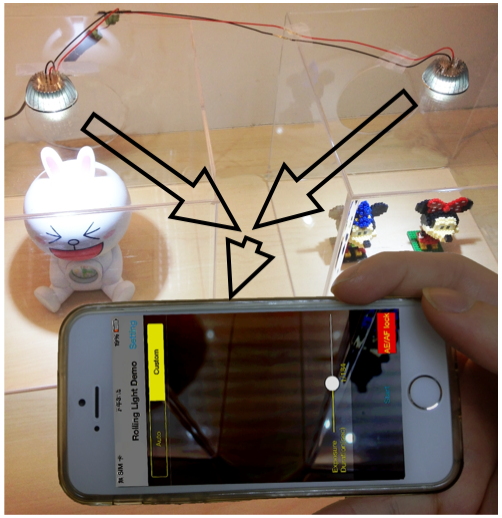
Multi-antenna (MIMO) systems



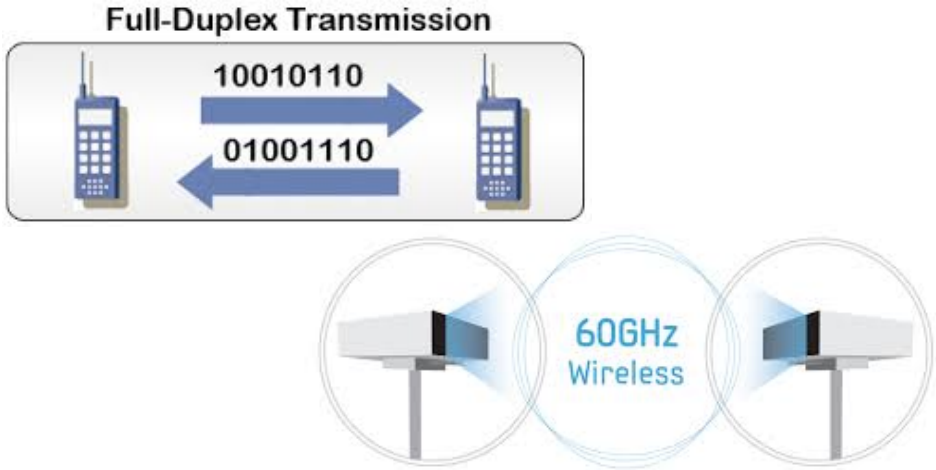
Device-free / wearable localization and action recognition



Visible light applications



Next-generation communications (5G)



Syllabus

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- Full-Duplex Communications
- mmWave

What you will NOT learn from this class?

- Standards, such as 3GPP, 802.11ac, ZigBee
- Top-down or bottom-up network design
- Optimization and algorithm designs
  - Advanced algorithm, combinatorial optimization, etc
- Performance modeling and analysis
  - Random process, queueing theory, etc
- Simulation

What you WILL learn from this class?

- How to ***design*** a wireless system/application using
  - Existing signal processing skills
  - Cross-layer designs
  - Various wireless spectrum, such as radio frequency (RFID, WiFi, mmWave, etc), ultrasound and visible light
- How to ***build*** a wireless system/application using
  - Software designed radio, such as USRP and WARP
  - Commodity NIC with the modified driver
  - Development board, such as Arduino and Raspberry pi
  - Mobile applications, such as iOS and andriod
- How to ***evaluate*** your wireless system, using
  - Well known performance metrics
  - Testbed experiments

General Information

- http://people.cs.nctu.edu.tw/~katelin/courses/wcs16/
- Other information
  - Facebook group: NCTU WCS
  - Mendeley: https://www.mendeley.com/groups/4710311/wcs/
- Instructor
  - Kate Ching-Ju Lin (林靖茹), EC-538
  - Office hours: Thu. after class
- TA
  - 張威竣, EC-522, wcchang1115@cs.nctu.edu.tw
  - 魏佑霖 (Wally Wei), weiwally@gmail.com
- Schedule
  - 10:10 — 12:00, Tue. (Fundamental knowledge)
  - 15:30 — 16:20, Thu. (Related papers)

Course Details

- Materials
  - Mainly research papers
  - Additional tutorials/notes/slides
- Reference textbook
  - David Tse and Pramod Viswanath. 2005. Fundamentals of Wireless Communication. Cambridge University Press, New York, NY, USA. https://people.eecs.berkeley.edu/~dtse/book.html
  - Andrea Goldsmith. 2005. Wireless Communications. Cambridge University Press, New York, NY, USA.
- Prerequisites
  - Undergraduate network class
  - Basic math: probability, Fourier, shortest path algo., …
  - Programming required in wireless labs and projects (Python, C and Matlab)

Grading

- Project 30%
- Three Labs 45%
  - Use USRP software defined radios
  - Develop in UHD (USRP hardware driver, written in C)
- Presentation 5% (Can bring your notes)
  - Elevator pitch
  - Each one is in charge of a short introduction of the next reading assignment in each Tue. Class
- Mini-Assignment 10%
  - Summarize any two paper reading (after the lecture)
- Quiz 10%
  - Participation, 10 out of 18 lectures
- Bonus
  - Ask questions and shortly remark your questions in the quiz sheet

Elevator Pitch

From Wikipedia:

It should be possible to deliver the summary in the time span of an elevator ride

- ~5 minutes summary of a paper
- Quickly summarize
  - Motivation
  - Key features
  - High-level ideas
  - (Take home messages)

Two Mini-Assignments

- One paper note
  - Motivation
  - Problem definition
  - Methods
  - Results
  - Take home messages
- One paper review
  - Summary (short but concrete)
  - Strength of the paper (about 3—5 bullets)
  - Weakness of the paper (about 3—5 bullets)
  - Detailed comments
    - Can be as many as possible
    - But, should be constructive, instead of nitpicking (e.g., typo, grammar errors)

Labs and Projects

- 2-4 students per group

- Projects
  - Build a wireless system or mobile applications using ANY wireless signals
    - Will provide a list of candidate projects
  - Proposal (around mid-term)
    - Discussion in the office hour
    - Slide
    - Presentation (similar to the poster session)
  - Final presentation
  - Project report

In this class, you will

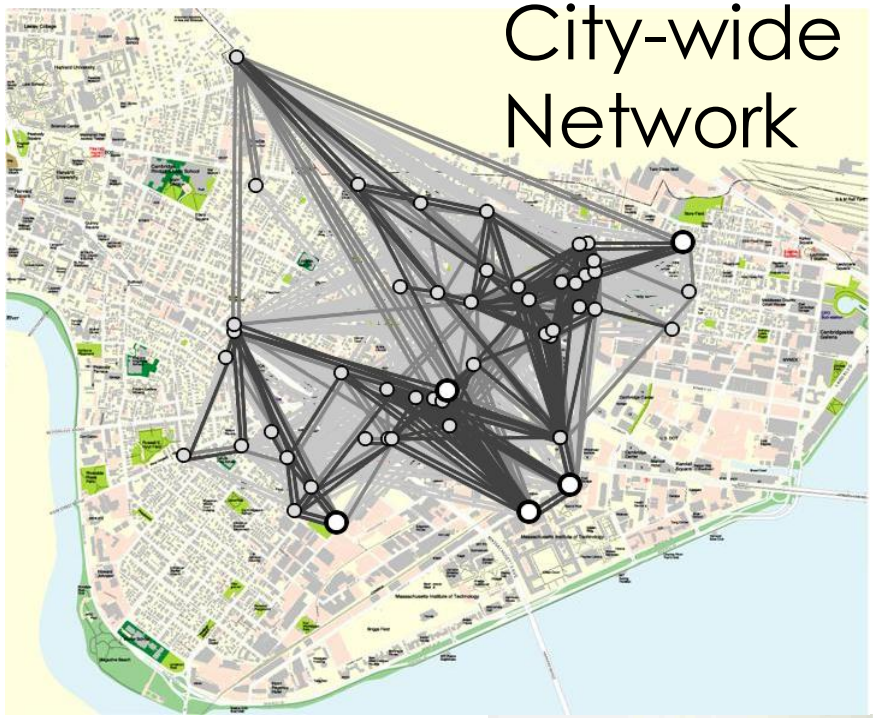
- Learn how the interaction between PHY and MAC can improves network performance
- Leverage wireless signals to develop potential applications
  - Localization
  - Human interaction
  - Smart home
  - Visible light communications
- Learn how to do networking research
  - Paper reading
  - Logical thinking
  - Prototyping and evaluation

Class Policy

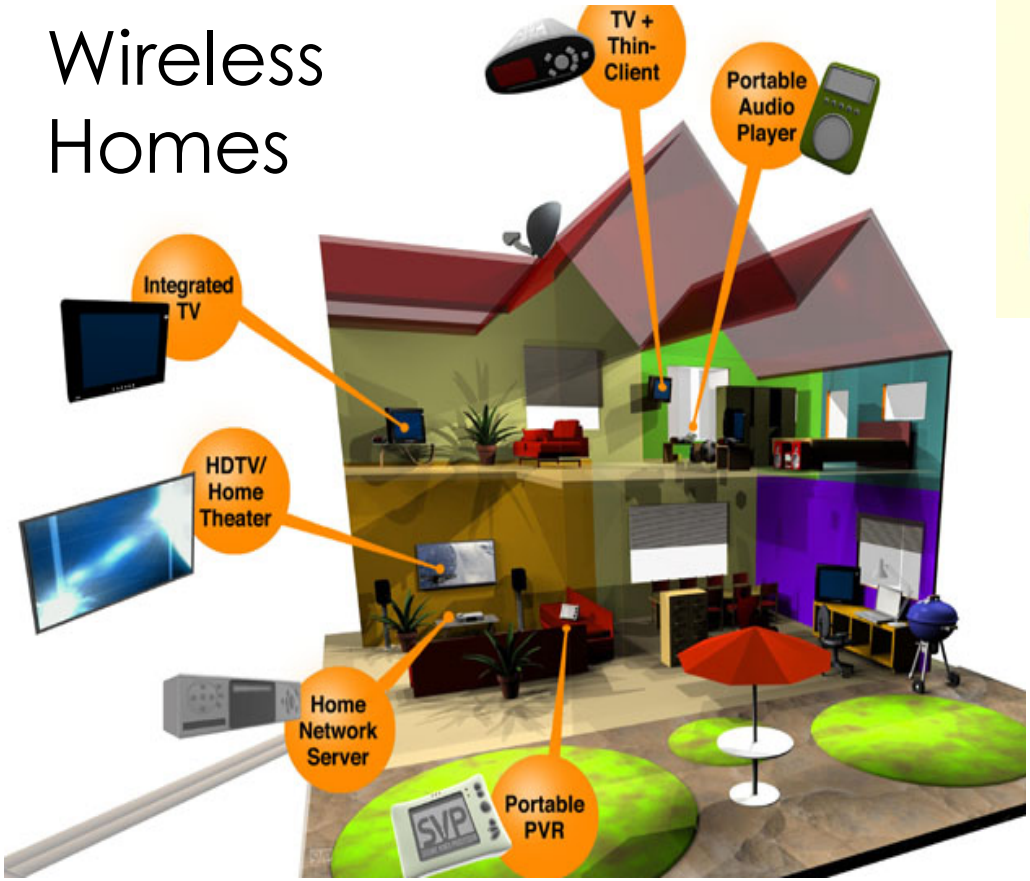
- Don't be shy!
- Feel free to stop me if you have ANY question
- Feel free to ask (partially) in Chinese
- Feel free to request for repeating again if you didn't get it
- Feel free to discuss offline (office hour, e-mail, facebook)
- Engage even if the assignments are group-based
- Correct me if I said anything wrong

Introduction to Wireless Networks

Wireless networks are increasingly prevalent



Wireless Homes



IOT devices

Introduction to Wireless Networks

- Wireless networks provide advantages
  - Mobility
  - Eliminate wires at home and office

- But wireless networks present different challenges
  - The medium is shared
    - Nearby transmitters can interfere
    - Need medium access protocols
    - Throughput is relative low particularly in a dense environment
  - Channel quality could be bad and/or unpredictable
    - High bit errors which could result in dead spots

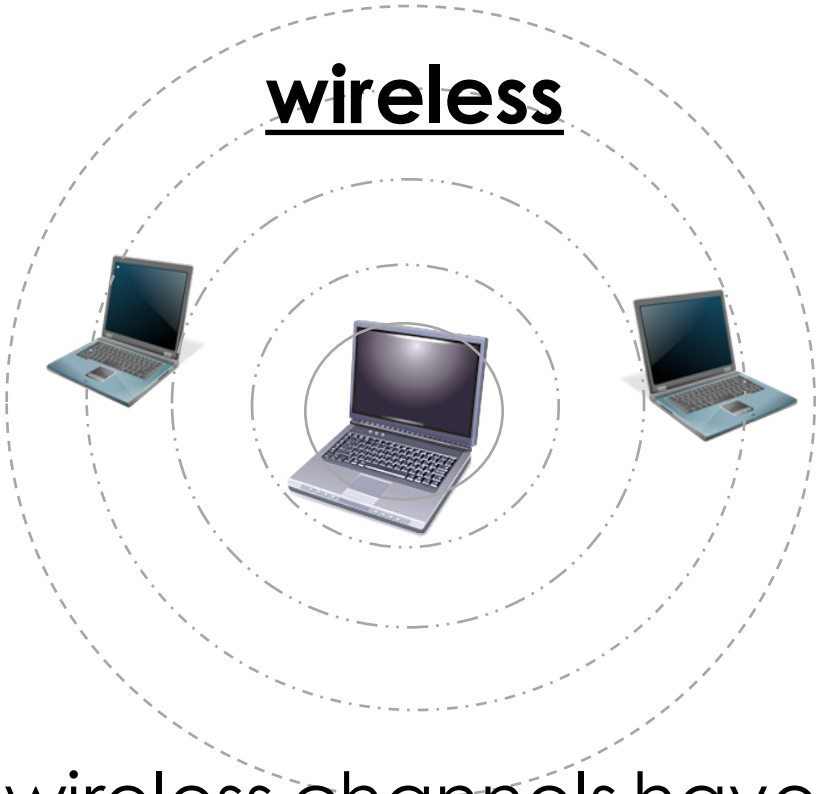
Traditional Design of Wireless Networks

- Traditional design of wireless networks mimics wired networks

wired

assume links are point-to-point

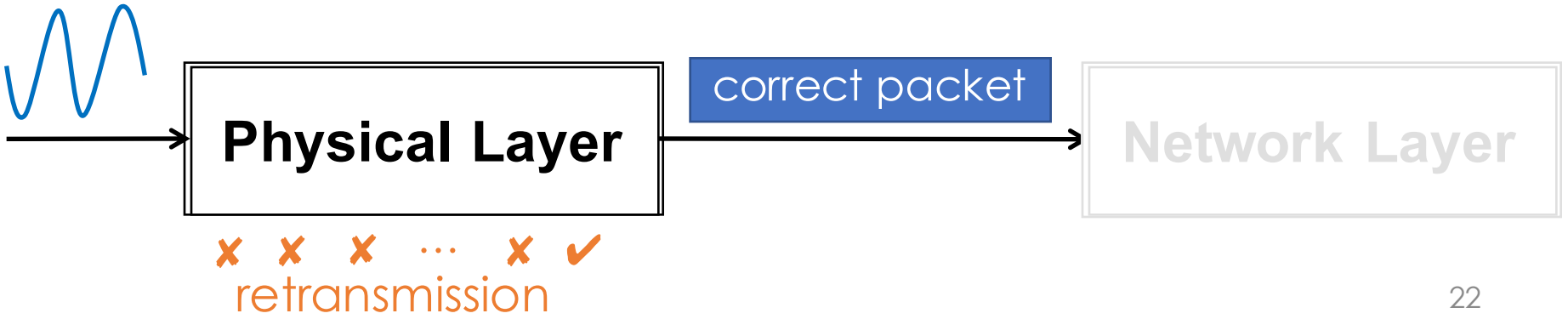
wireless



wireless channels have a broadcast nature

Traditional Design of Wireless Networks

- Traditional design of wireless networks mimics wired networks
  - Divide the network stack into separate layers
  - But separation reduces spectrum efficiency because one can optimize only within a layer, without considering the properties of other layers
  - E.g., assumes the PHY and lower layers deliver fully correct packets, but the errors in wireless channel are high and PHY keeps retransmitting until succeed



Cross-layer Design