Principles of Wireless Communications

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Wireless Communications: Long History

Early development based on visible light

Smoke

Torches

Signal Lamps

Still used today!

Wireless Communications: Long History

First radio (EM wave) was built by Marconi

Marconi, 1901
First telegraph sent across the Atlantic Ocean wirelessly

- Since then, various wireless technology developed:
  - AM/FM radio; Analog TV broadcast; Paging system
  - Digital TV
  - Wireless LAN; Bluetooth; ultra-wideband (UWB)
  - Cellular systems

History of Cellular Systems

Generation	Time	Technology	Features
0G	1947	**Mobile Telephone Service (MTS)** by AT&T	Analog Heavy (36 kg) ~5000 customers
1G	1983 (NTT had an earlier deployment in 1979)	**Advanced Mobile Phone System (AMPS)**	Analog FDMA Voice
2G	1991	**Global System for Mobile Communication (GSM)** in Europe (Finland)	Digital FDMA Voice
3G	2001	**WCDMA** **CDMA2000 1xEV-DO** **HSDPA**	Digital CDMA Broadband Data
4G	2010	**WiMax** **LTE**	Digital OFDMA Data, IP network

Reason for the Success

- Explosive increase in mobile users and data rate:

$$\approx 0 \text{ cellular phones in mid 90's} \longrightarrow \approx 6 \times 10^9 \text{ mobile devices now}$$

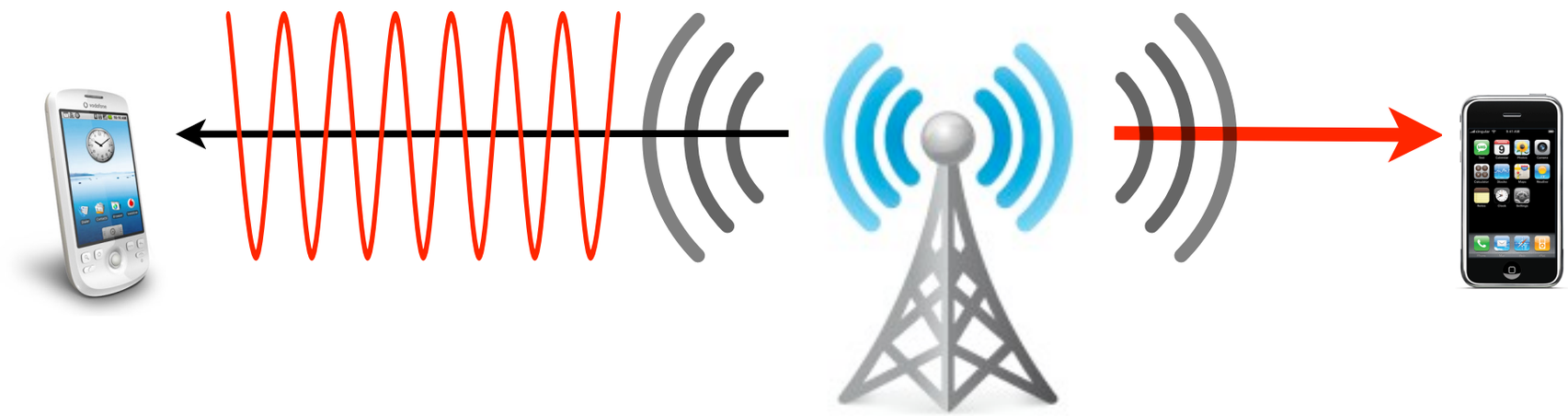
$$\text{low-rate voice} \longrightarrow \text{high-rate data}$$

OSI 7계층 Layer 1

- Advances in physical layer communication techniques play a key role
  - 10 to 15-fold increase in spectral efficiency from 2G to 4G

- Main focus of this course

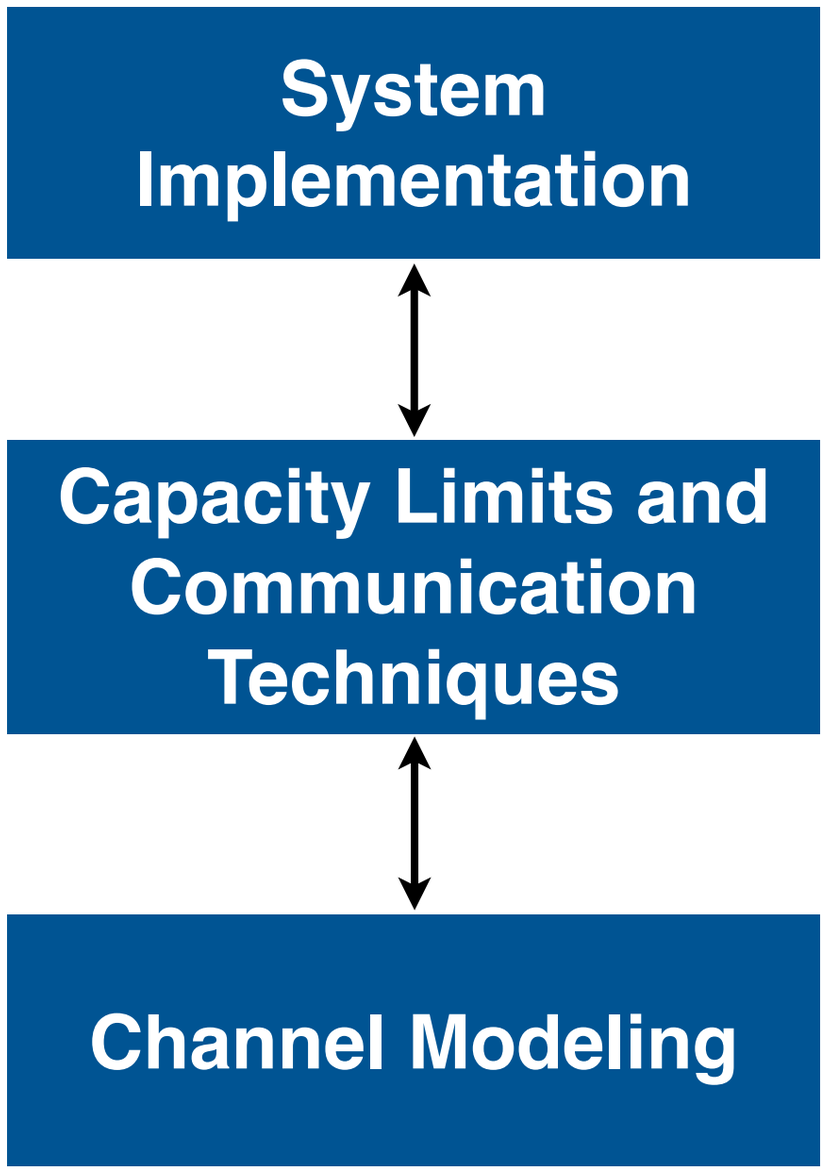
Key Challenges



To establish a reliable system, there are some challenges

- Variable channel quality (Fading)
- Broadcast nature of wireless medium (Interference)

In this Course



Logistics

- Lecturer: I-Hsiang Wang
  - Email: ihwang@ntu.edu.tw
  - Office: MD-524 (明達館524室)
  - Office hours: Tues. Wed. 17:30 – 18:30

- Lecture Time: Thursday 14:20 – 17:20 (678)
- Lecture Location: EE2-104 (subject to change)
- Textbook:

  [TV] D. Tse and P. Viswanath, Fundamentals of Wireless Communication, Cambridge University Press, 2005

- Course Website:

  http://homepage.ntu.edu.tw/~ihwang/Teaching/Sp14/Wireless.html

Grading Policy

- Grading:
  - Exam (40%), Homework (30%), Project (30%)

- Exam:
  - There will be one exam

- Homework:
  - Roughly one per month
  - Late homework = 0 point

Project

- Team: 2 people per team

- Topic:
  - A list of potential topics will be announced
  - Meeting with the instructor to decide the topic
  - Write a proposal before the spring break

- Presentation
  - Oral or poster (depending on how many groups)

- Report
  - One report for each team (more info to be announced later)

Course Outline

- Basics:
  - *Wireless channel* – physical models, input/output channel models, time and frequency coherence, statistical channel models, fading
  - *Point-to-point communications 1* – detection in fading channels, diversity (time, frequency, antenna)
  - *Cellular Systems* – multiple access, interference management, narrowband systems, wideband CDMA, wideband OFDMA
  - *Point-to-point communications 2* – capacity of point-to-point fading channels
  - *MIMO 1* – channel modeling, spatial multiplexing, space diversity
  - *MIMO 2* – space-time codes, capacity of MIMO channels, diversity-multiplexing tradeoff

Course Outline

- Advanced:
  - *Multi-user Communications 1* – single-cell: capacity of uplink fading channels and downlink fading channels, multi-user diversity, opportunistic communications
  - *Multi-user Communications 2* – single-cell: multi-user MIMO
  - *Multi-user Communications 3* – multiple-cell: interference management revisited, capacity of interference channels, interference alignment, open questions
  - *Multi-user Communication 4* – relay networks: capacity of relay channels, cooperative diversity, general multi-hop relay networks, open questions

Tentative Schedule

Week	Date	Content	Reading	Remark
1	2/20	Introduction Wireless channel	[TV] Ch 1, 2	
2	2/27	Wireless channel Point-to-point comm. 1	[TV] Ch 2, 3	
3	3/6	Point-to-point comm. 1	[TV] Ch 3	HW1
4	3/13	Cellular systems	[TV] Ch 4	Project topics announced
5	3/20	Cellular systems Point-to-point comm. 2	[TV] Ch 4, 5	
6	3/27	Point-to-point comm. 2	[TV] Ch 5	HW2
7	4/3	**No lecture**		
8	4/10	MIMO 1	[TV] Ch 7	**Project proposal due**
9	4/17	MIMO 1 MIMO 2	[TV] Ch 7, 8	

Tentative Schedule

Week	Date	Content	Reading	Remark
10	4/24	MIMO 2	[TV] Ch 8	HW3
11	5/1	**Exam**		
12	5/8	Multi-user comm. 1	[TV] Ch 6	
13	5/15	Multi-user comm. 1 Multi-user comm. 2	[TV] Ch 6, 10	
14	5/22	Multi-user comm. 2	[TV] Ch 10	HW4
15	5/29	Multi-user comm. 3		
16	6/5	Multi-user comm. 3 Multi-user comm. 4		
17	6/12	Multi-user comm. 4		
18	6/19	**Project Presentation**		**Final Report Due: 6/22**