





Wireless Sensor Networks

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• Pervasive wireless networks and mobile applications

 Challenges facing wireless networks and mobile computing

• Course information





- "By 2100, our destiny is to become like the gods we once worshipped and feared. But our tools will not be magic wands and potions but the science of computers, nanotechnology, artificial intelligence, biotechnology, and most of all, the quantum theory."
 - <u>Michio Kaku, Physics of the Future: How Science Will</u> <u>Shape Human Destiny and Our Daily Lives by the Year</u> <u>2100</u>



Pervasive Mobile Devices



- "In many parts of the world, more people have access to a mobile [wireless] device than to a toilet or running water." [Time Aug. 2012]
- Many industrial countries reach at least 90% mobile phone subscription penetration rate
 - [see phone penetration rates sheet]
- PEW Internet and American Life Project:
 - "The mobile device will be the primary connection tool to the Internet for most people in the world in 2020"

Mobile Device Usage

84% of Smartphone Owners Use Apps During Their Morning Routine

% of U.S. smartphone owners who check the following types of apps first thing in the morning

Computer Science & Engineering Department

statista Mashable

Source: SOASTA

Daily time spent with the internet per capita worldwide from 2011 to 2021, by device

~ ~

🔵 Desktop 🛛 🔵 Mobile

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Mobile Traffic Growth

Mobile Computing Changing Our Lives

Embedded Systems Laboratory

Mobile Computing Features with Larger Effects

9

Mobile Computing Changing Our Lives

Where do you place your mobile device while sleeping at night?

Mobile Computing Changing Our Lives

DOES YOUR MOBILE DEVICE COME AT TIMES BETWEEN YOU AND YOUR SPOUSE?

http://www.time.com/time/interactive/0,31813,2122187,00.html

Use Case: Home Networks

Use Case: Mesh Networks

Use Case: Mesh Network for Disaster Recovery/Military

- 9/11, Tsunami, Hurricane, Ukraine War...
- Wireless communication and mobile computing capability can make a difference between life and death !
 - rapid deployment
 - efficient resource and energy usage
 - flexible: unicast, broadcast, multicast, anycast
 - resilient: survive in unfavorable and untrusted environments

http://www.att.com/ndr/

Use Case: Seamless Handoff--Always Best Connected

Use Case: Traffic Signal Advisor

http://www.princeton.eau/~ekoukoum/SignalGuru.ntmi

Use Case: Vehicular Networks

- Traffic crashes resulted in more than 41,000 lives lost/year
- Establishing
 - vehicle-to-vehicle (V2V), vehicle-toinfrastructure (V2I) and
 - vehicle-to-hand-held-devices (V2D) communications

More info: http://www.its.dot.gov/intellidrive/index.htm

Collision Avoidance : V2V Networks

Stalled vehicle warning Blind spots

http://www.gm.com/company/gmability/safety/news_issues/releases/sixthsense_102405.html

Google Glass

GLASS ENTERPRISE EDITION

A hands-free device for smarter and faster hands-on work.

Use Case: Habitat Monitoring

- Driven by technology and vision
 - Mobile device capabilities and platforms
 - Global communication infrastructures

• The field is moving fast

Enabling Infrastructures

- Development and deployment of wireless infrastructures
 - networking: in-room, in-building, on-campus, in-the-field, MAN, WAN
- Development and deployment of localization infrastructures
 - location: GPS, AGPS, ...
- Development and deployment of sensor networks

Wireless Bit Rates

Enabling Infrastructure: Networks

Standard	Peak Downlink	Peak Uplink	Tech
GSM GPRS Class 10	0.0856	0.0428	
GSM EDGE Evolution	1.6	0.5	TDMA/FDD
CDMA EV-DO Rev. 0	2.458	0.1536	CDMA/FDD
CDMA EV-DO Rev. A	3.1	1.8	CDMA/FDD
CDMA EV-DO Rev. B	4.9	1.8	CDMA/FDD
WiFi: 802.11b	11	11	DSSS
Flash-OFDM: Flash-OFDM	15.9	5.4	Flash-OFDM
WiFi: 802.11g	54	54	OFDM
WiFi: 802.11a	54	54	OFDM
LTE	300	75	OFDMA/MIMO
WiMAX: 802.16m	365	376	MIMO/SOFDMA
WiFi: 802.11n	600	600	OFDM/MIMO
HSPA+	672	168	CDMA/FDD/MIMO
LTE Advanced (Cat 8)	2998.6	1497.8	MIMO
WiFi: 802.11ac (8aAP; 4a ST)	3470	3470	MU-MIMO

Improving Infrastructure: Power Efficiency

	α_u (mW/Mbps)	α_d (mW/Mbps)
LTE	438.39	51.97
3G	868.98	122.12
WiFi	283.17	137.01

Source: A Close Examination of Performance and Power Characteristics of 4G LTE; Mobisys'12

Sensing Capabilities *Regular Smartphone

Why is the Field Challenging?

Challenge 1: Unreliable and Unpredictable Wireless Coverage

Reception v. Distance

5

Wireless links are not reliable: they may vary over time and

space

Reception vs. Power

Challenge 2: Open Wireless Medium

Wireless interference

• Hidden terminals

$$S1 \longrightarrow R1 \longleftarrow R2$$

Exposed terminal

$$R1 \longleftarrow S1 \qquad S2 \longrightarrow R2$$

- Wireless security
 - eavesdropping, denial of service, ...

Challenge 3: Mobility

• Mobility causes poor-quality wireless links

- Mobility causes intermittent connection
 - under intermittent connected networks,
 traditional routing, TCP, applications all break

• Mobility changes context, e.g., location

Challenge 4: Portability

- Limited battery power
- Limited processing, display and storage

Mobile phones

- voice, data
- simple graphical displays
- GSM/3G/4G/5G

- data
- small graphical displays
- 802.11/3G

Tablet/Laptop

Performance/Weight/Power Consumption

Challenge 5: Changing Regulation and Multiple Communication Standards

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Wireless Communication Standards

- 0G (mobile radio telephone)
- 1G networks (analog networks)
- 2G networks (the first digital networks):
 - GSM
 - Digital AMPS
 - cdmaOne
 - GPRS
 - EDGE(IMT-SC)
 - Evolved EDGE

3G networks:

• UMTS

- W-CDMA (air interface)
- TD-CDMA (air interface)
- TD-SCDMA (air interface)
 - HSPA
 - HSDPA
 - HSPA+
- CDMA2000
 - OFDMA (air interface)
 - EVDO
 - SVDO

4G networks:

- LTE (TD-LTE)
- LTE Advanced
- LTE Advanced Pro
- WiMAX
- WiMAX-Advanced
- Ultra Mobile Broadband
- 5G networks:
 - 5G NR

What Will We Cover?

- Learn both fundamentals and applications of wireless networking and mobile computing
- Obtain hands-on experiences on developing on wireless, mobile devices
 - wireless networking, sensor nodes
- Discuss challenges and opportunities in wireless networking and mobile computing

Often we need to implement a function across multiple layers.

Course Topics

Class Materials

• Chapters of reference books

• Selected conference and journal papers

- Other resources
 - MOBICOM, SIGCOMM, Mobisys proceedings
 - IEEE Network, Communications, Pervasive magazines

Suggested Reference Books

"Fundamentals of Wireless Communication", by David Tse and Pramod Viswanath, Cambridge University Press (available online)

"802.11 Wireless Networks: the Definitive Guide" by Matthew Gast, O' Reilly (available online)

THE Book

Protocols and Architectures for Wireless Sensor Networks

Protocols and Architectures for Wireless Sensor Networks Holger Karl, Andreas Willig

Class Project

- Goal: obtain hands-on experience
- I'll suggest potential topics
- You may also choose your own topic
- Initial proposal + midterm progress report + final report + [presentation]
- We provide help in obtaining
 - Mobile devices
 - Sensor Nodes

Project	50%
Exam	50%
Mandatory Class/Lab Participation	10%

More important is what you build / learn than the grades!

