

Embedded
Systems
Laboratory



Catedra de Calculatoare

Facultatea de Automatică și Calculatoare



Wireless Sensor Networks

Facultatea de Automatică și Calculatoare
Universitatea Politehnica București

- Pervasive wireless networks and mobile applications
- Challenges facing wireless networks and mobile computing
- Course information

The Future of Computing

“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.”

— Michio Kaku, *Physics of the Future: How Science Will Shape Human Destiny and Our Daily Lives by the Year 2100*

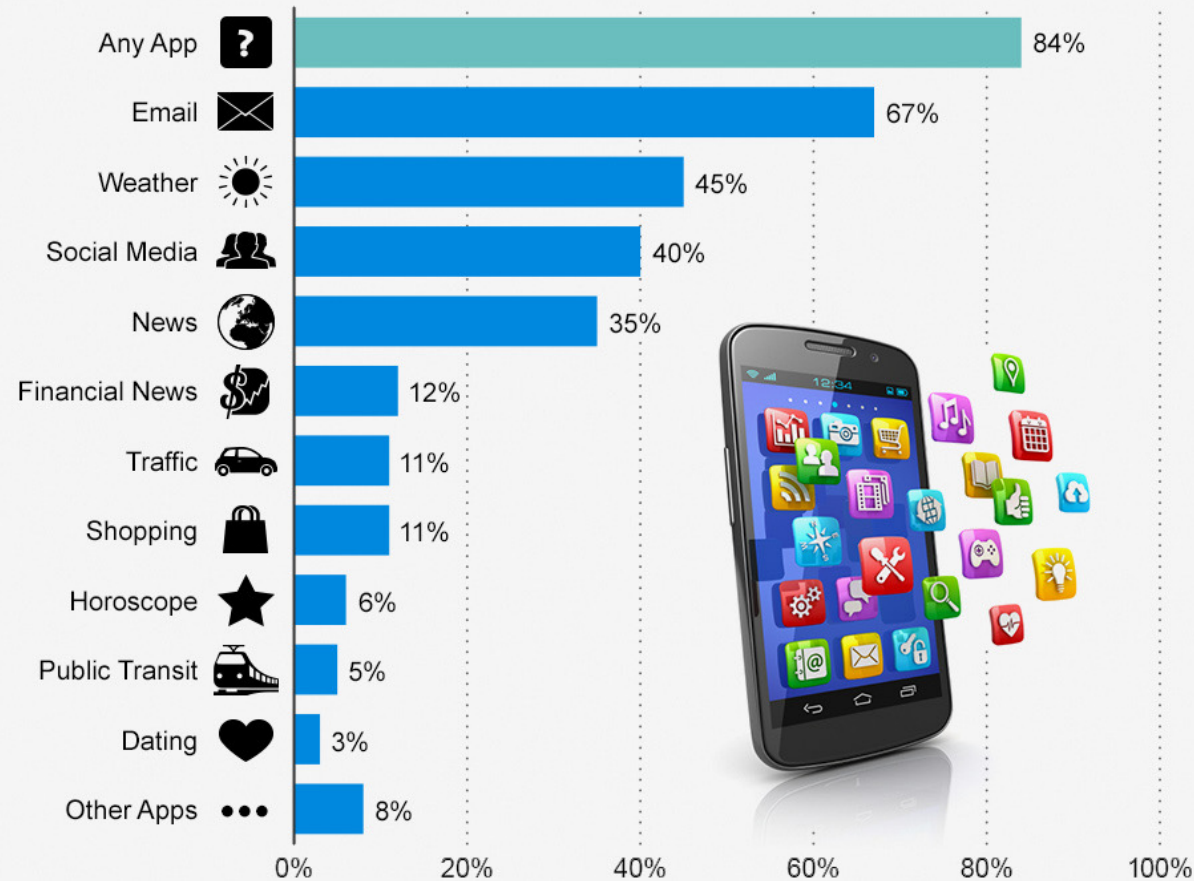
Pervasive Mobile Devices

- “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”

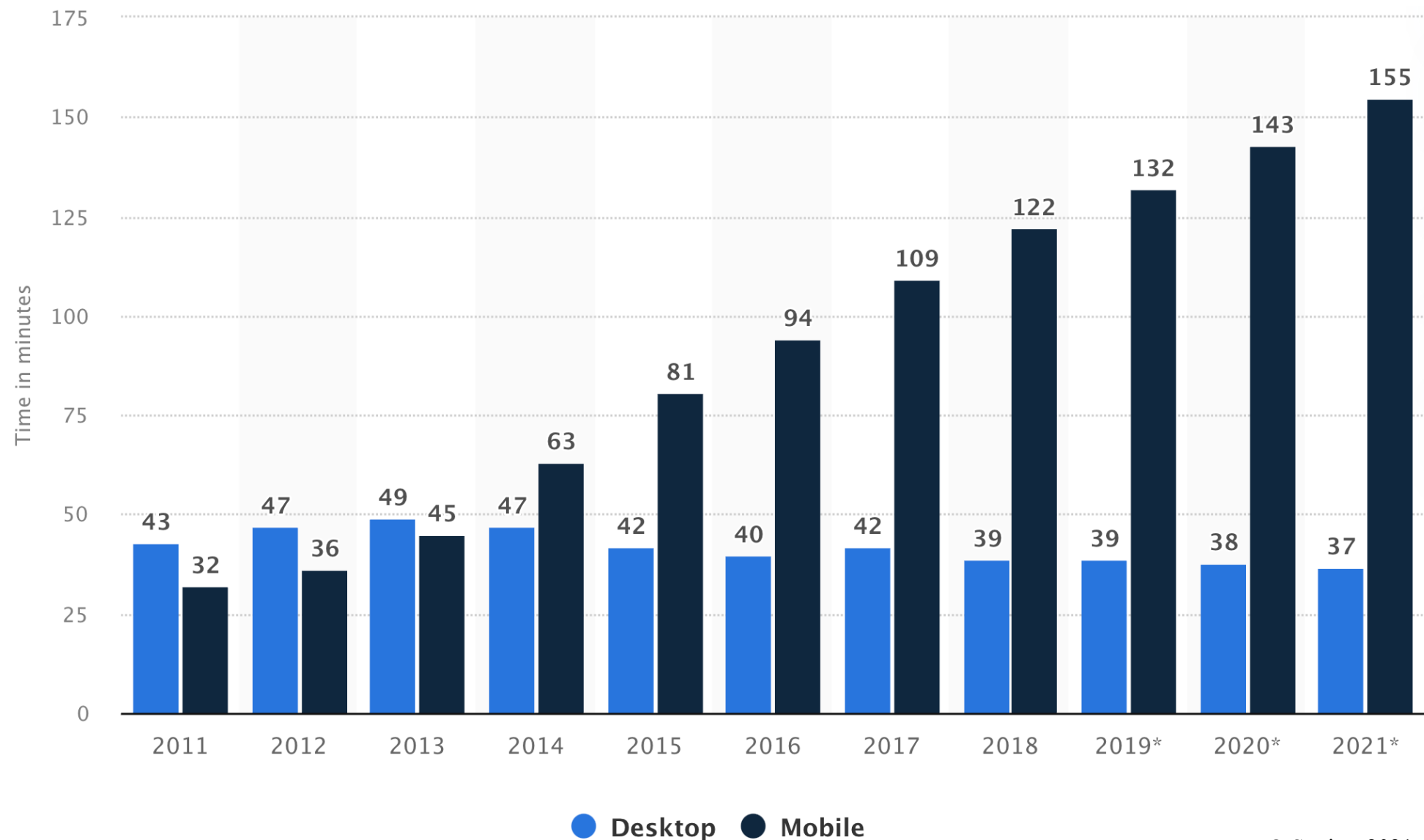
Mobile Device Usage

84% of Smartphone Owners Use Apps During Their Morning Routine

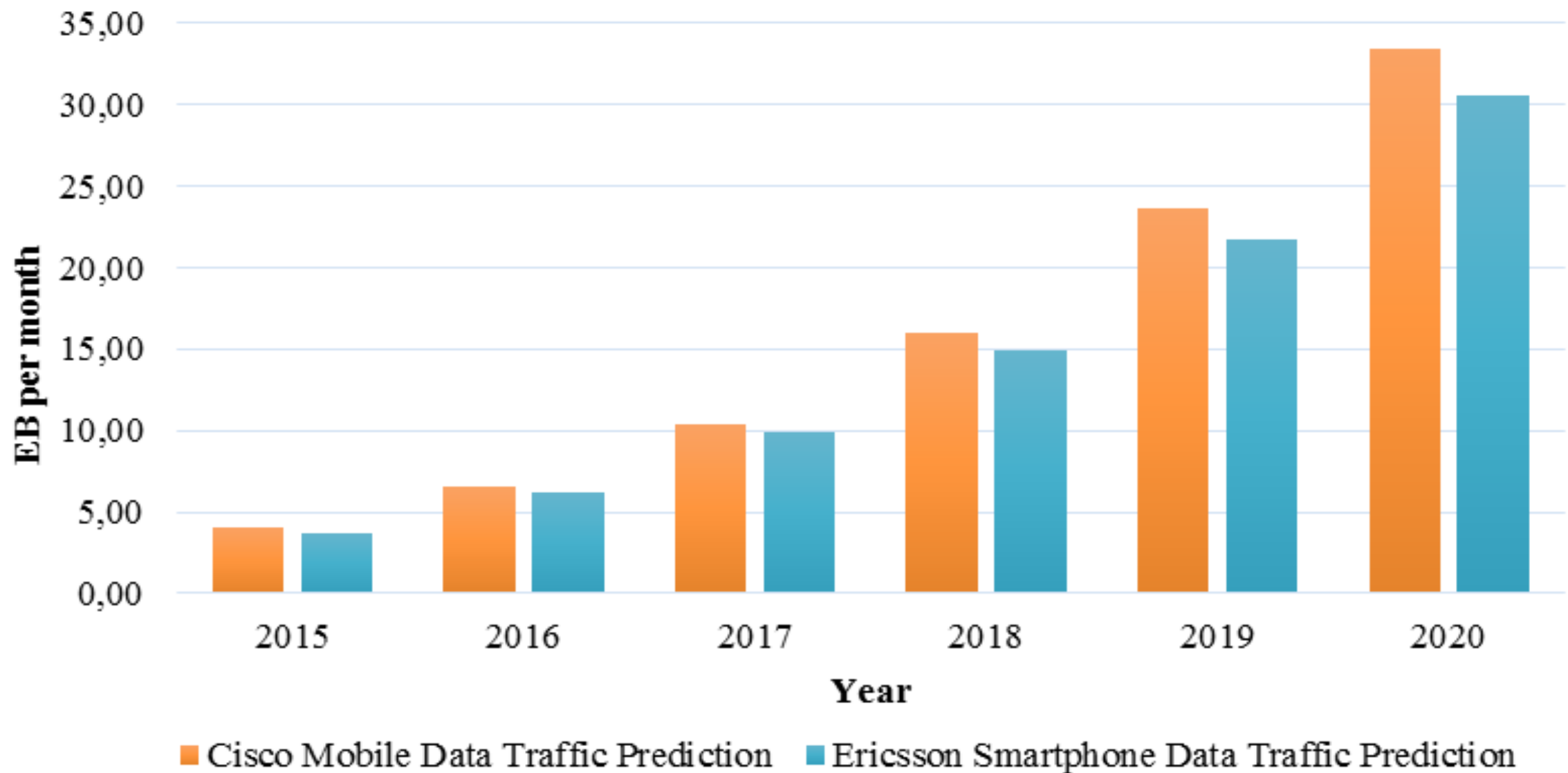
% of U.S. smartphone owners who check the following types of apps first thing in the morning



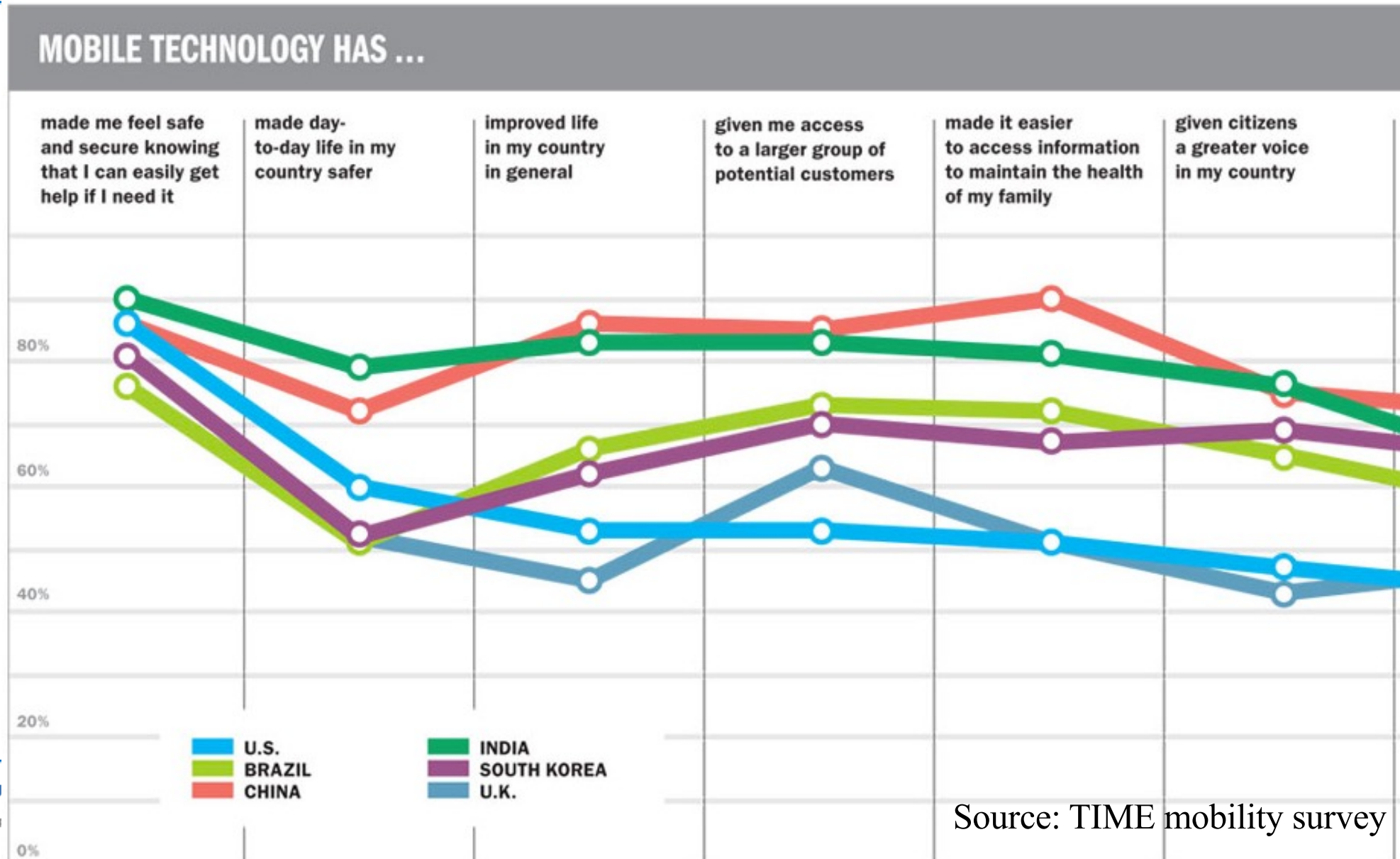
Daily time spent with the internet per capita worldwide from 2011 to 2021, by device



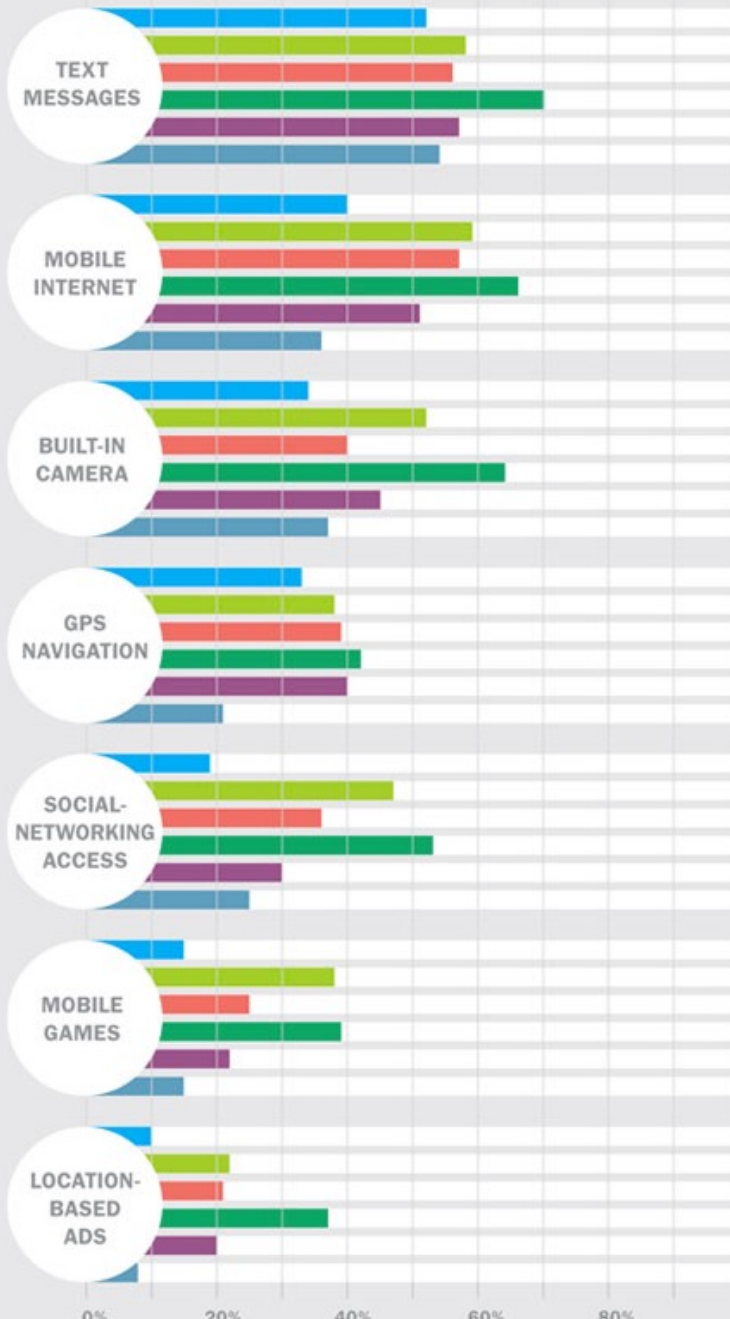
Mobile Traffic Growth



Mobile Computing Changing Our Lives

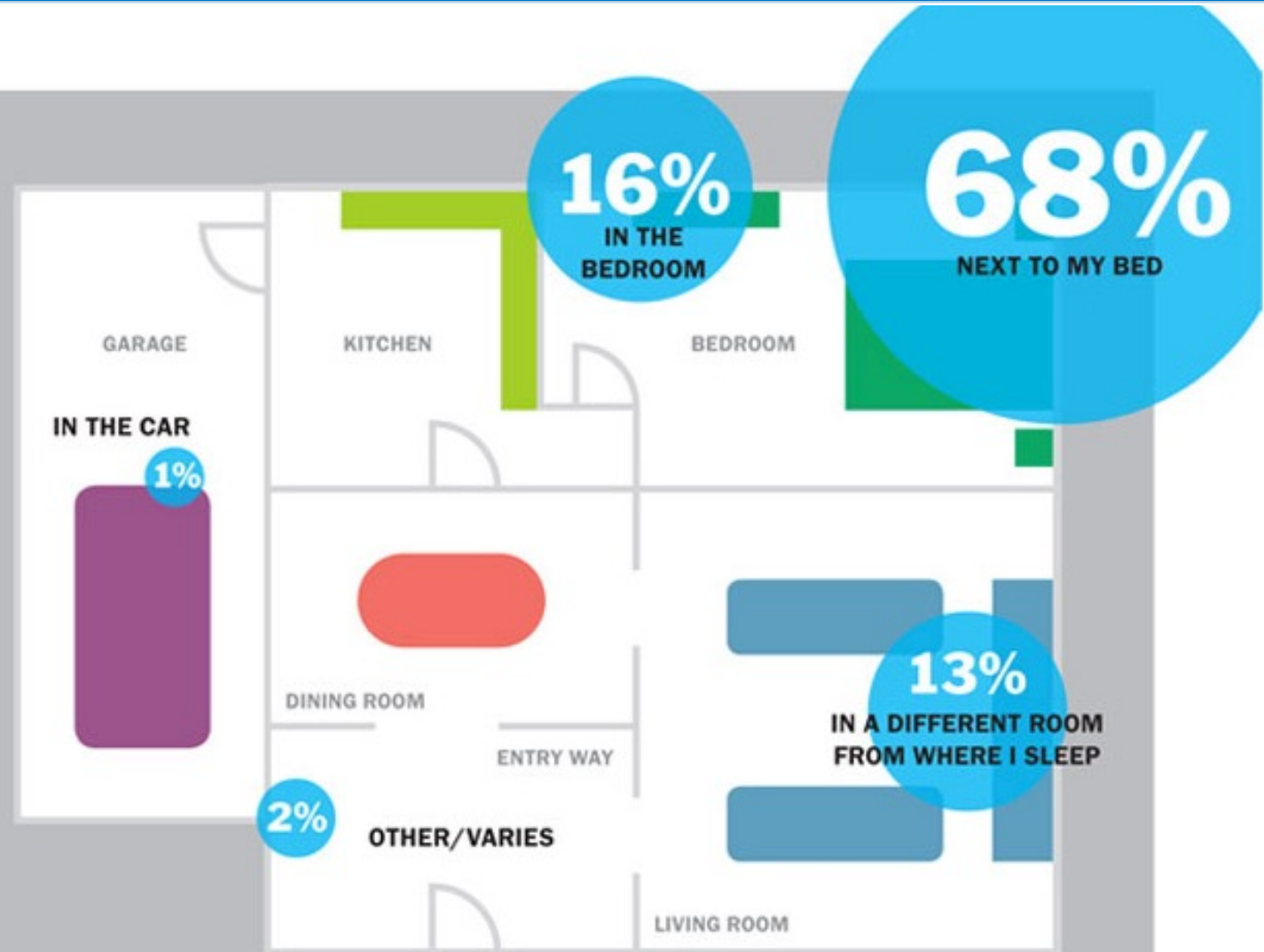


Mobile Computing Features with Larger Effects



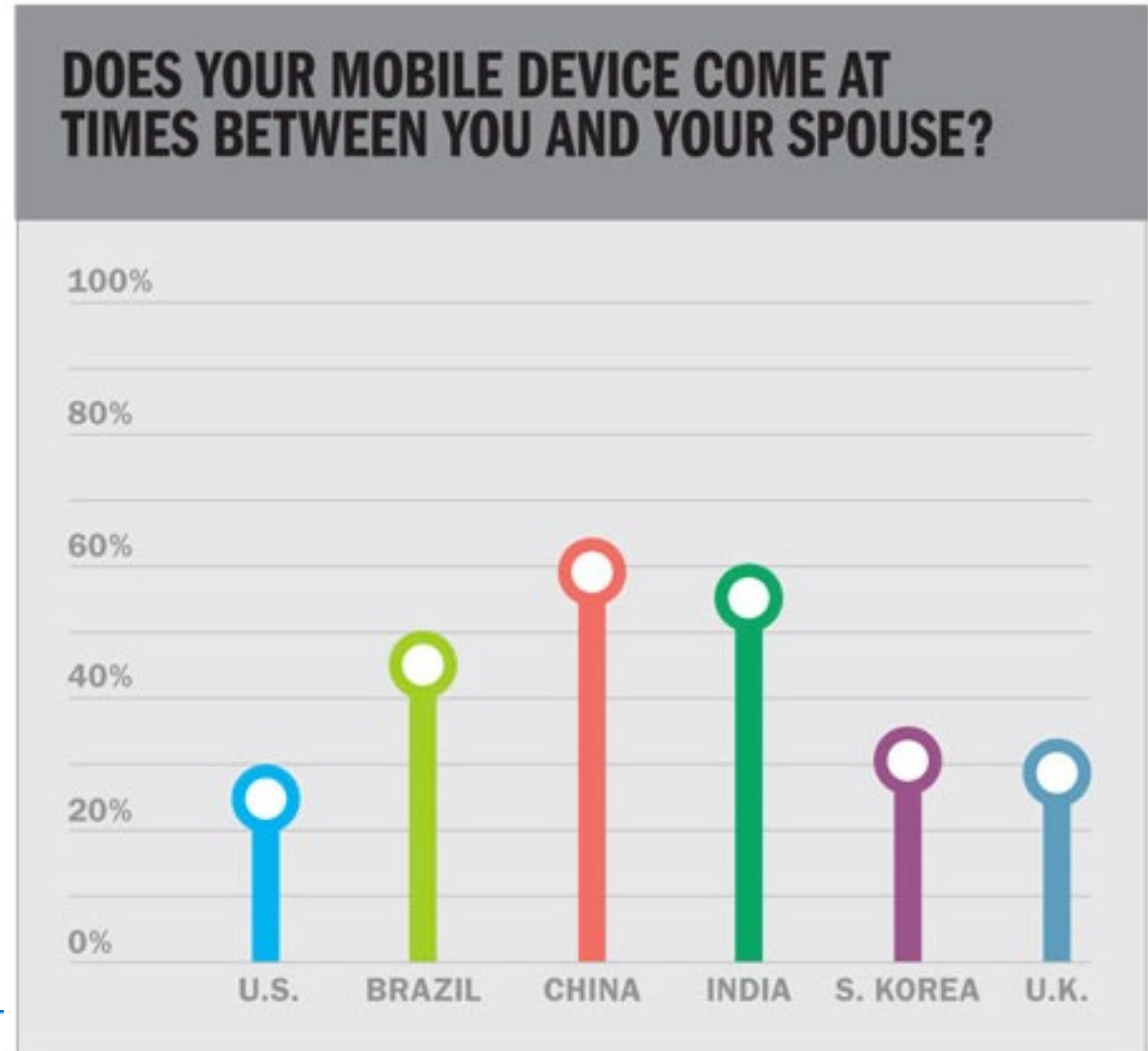
Mobile Computing Changing Our Lives

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

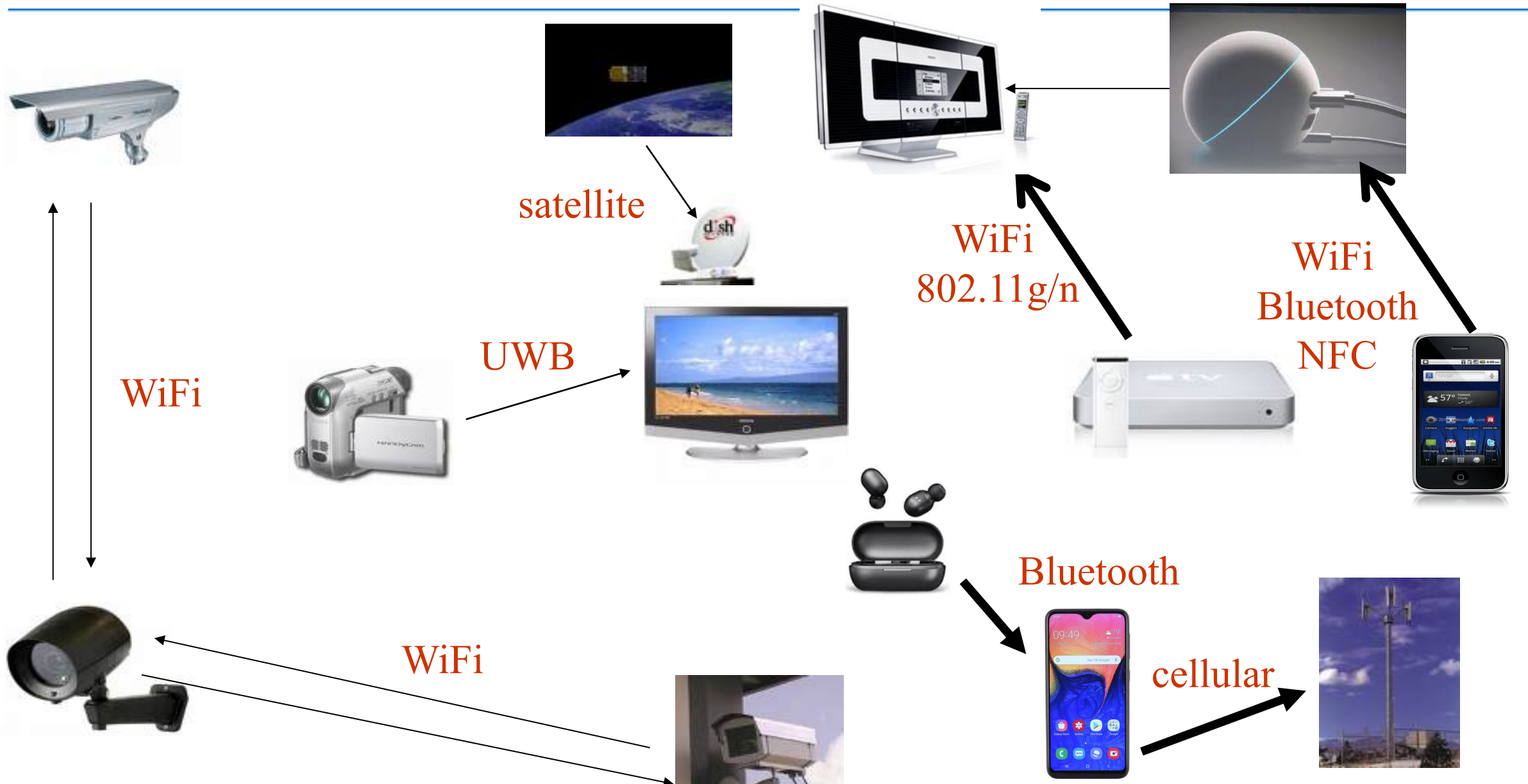


Mobile Computing Changing Our Lives

AGE	FLIRT WITH SOMEONE?	SEND SUGGESTIVE PICTURES?	COORDINATE OR COMMIT ADULTERY?
18-24	73%	48%	32%
25-29	76%	55%	36%
30-34	68%	52%	30%
35-44	54%	42%	24%
45-54	44%	26%	19%
55-64	22%	10%	13%
65+	16%	7%	3%



Use Case: Home Networks



Use Case: Mesh Networks



SMART CITY CONTROL CENTER

Internet of Things
Platforms

SMART
SECURITY

SMART
INDUSTRY

SMART
METERING

SMART
HOME

SMART
BUILDINGS

SMART
TRAFFIC

SMART
XXX



Science



Security



Gas
Metering



Health



Water
Metering



Mobility



Thermal
Energy
Metering



Living



Electricity
Metering



Government



Services



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

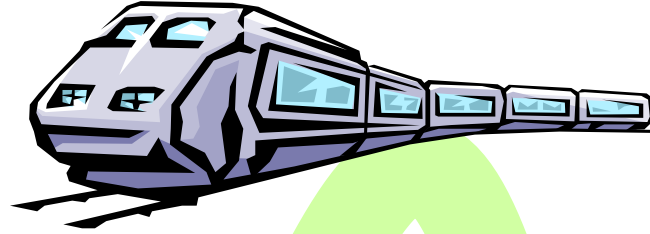
LAN, WLAN
Low Datarate



LTE
Bluetooth



LTE 4G, WiFi



LAN,
WLAN, LTE,
Satellite



LTE or WLAN



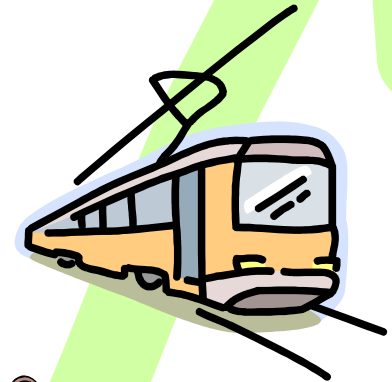
LTE & WiFi



LTE 5G, WiFi



LTE 5G

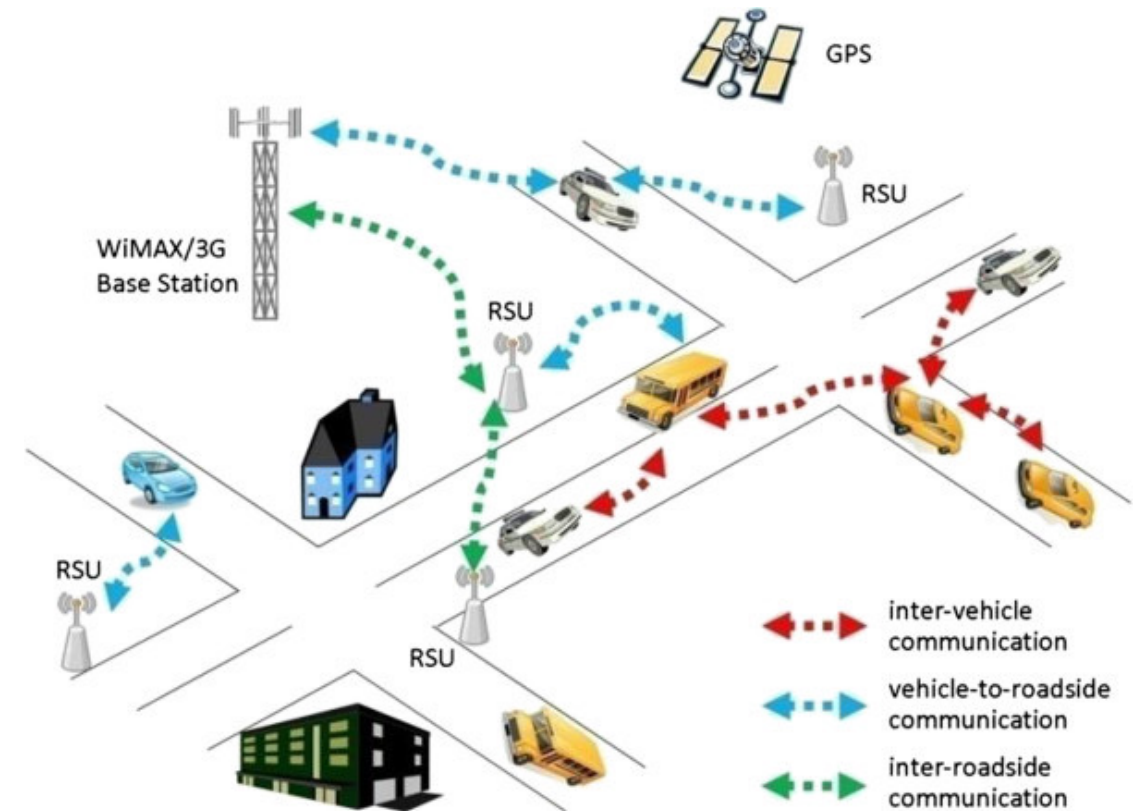


Use Case: Traffic Signal Advisor



Use Case: Vehicular Networks

- Traffic crashes resulted in more than 41,000 lives lost/year
- Establishing
 - vehicle-to-vehicle (V2V), vehicle-to-infrastructure (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



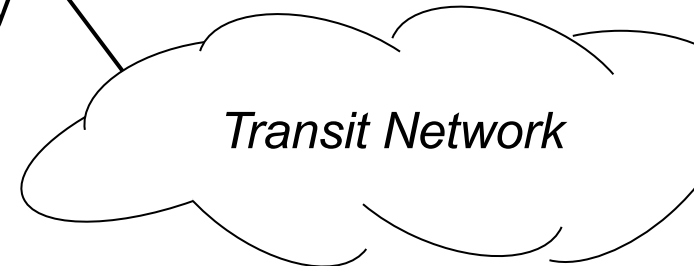
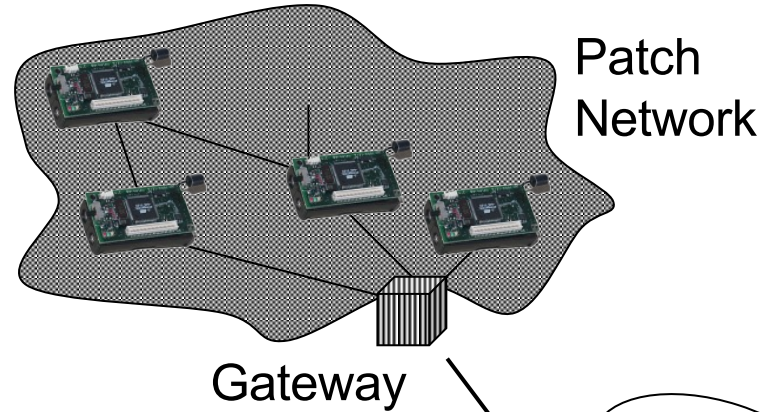
GLASS ENTERPRISE EDITION

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

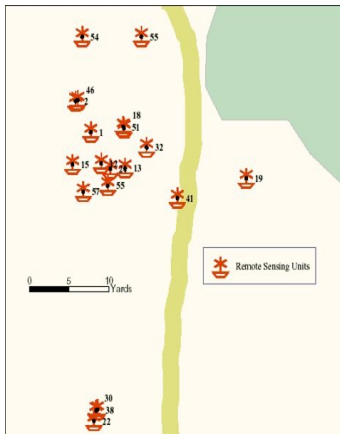
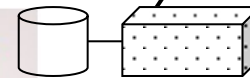


Use Case: Habitat Monitoring

A 15-minute human visit leads to 20%
petrel offspring mortality



Basestation

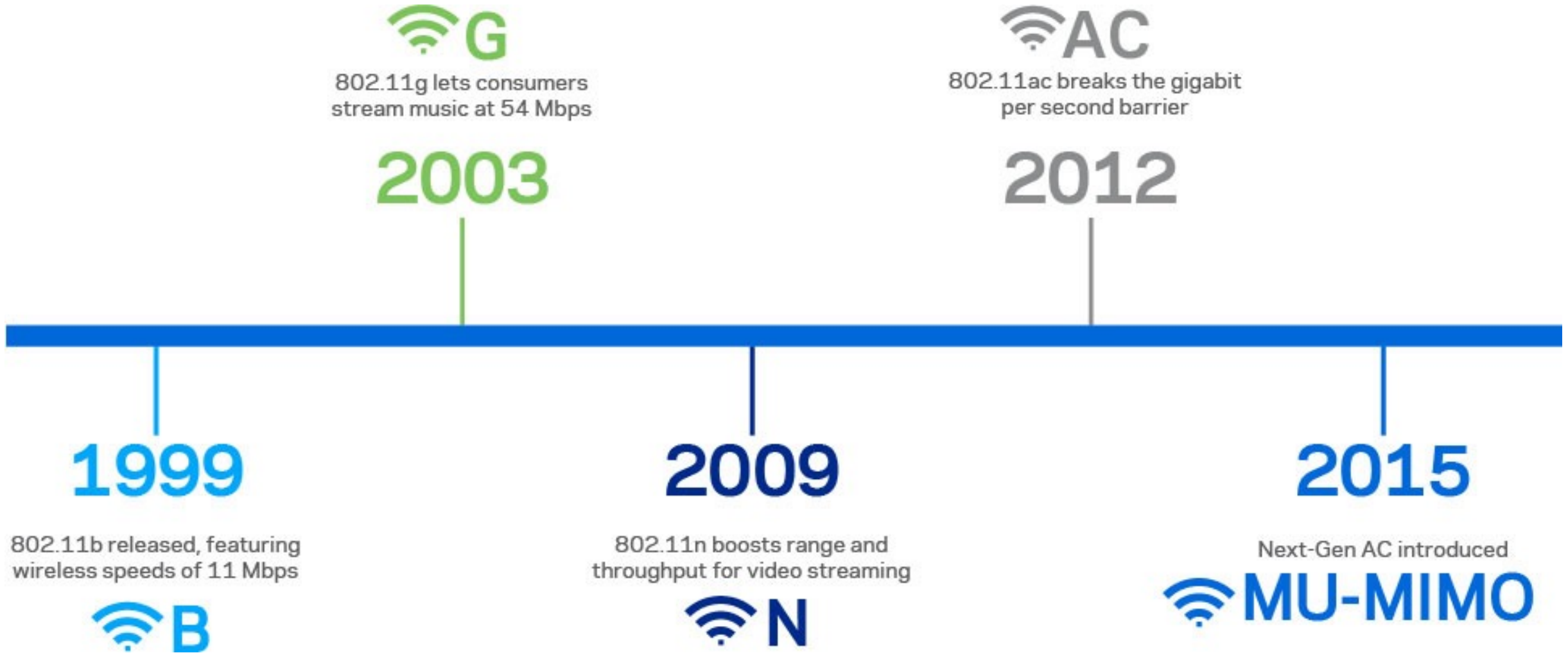


- Driven by technology and vision
 - Mobile device capabilities and platforms
 - Global communication infrastructures
- The field is moving fast

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

All units are Mbps

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

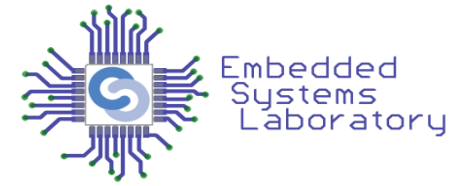
Sensing Capabilities

*Regular Smartphone



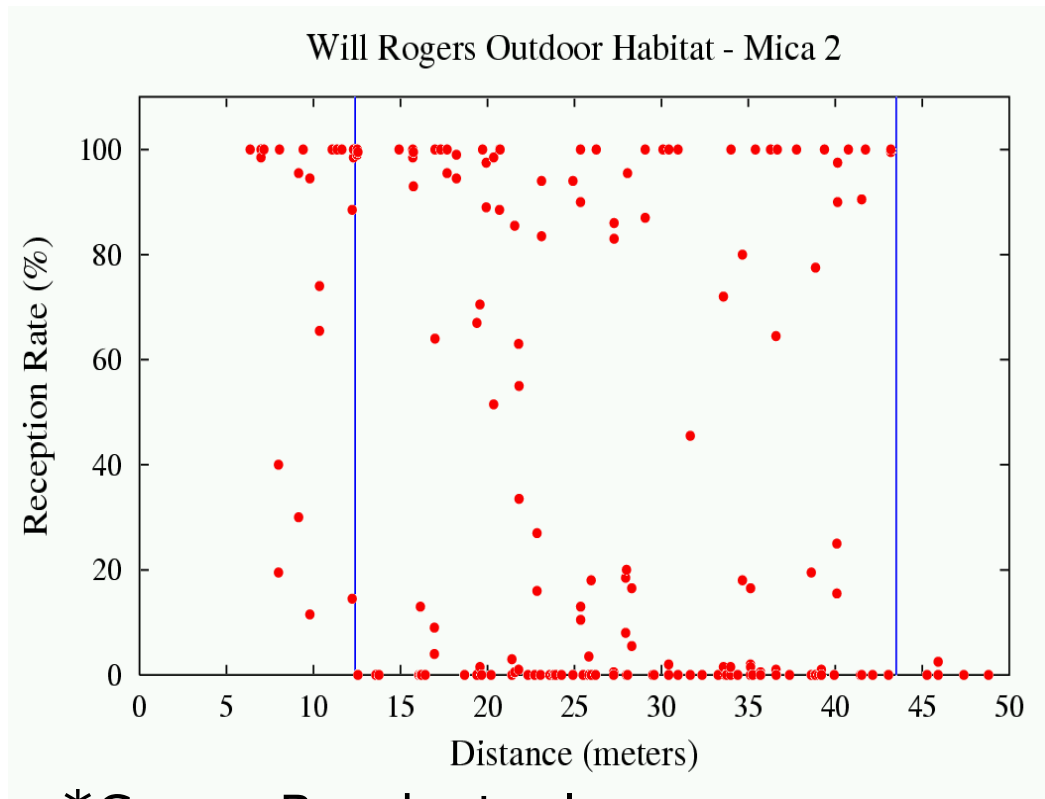
Why is the Field Challenging?

Challenge 1: Unreliable and Unpredictable Wireless Coverage



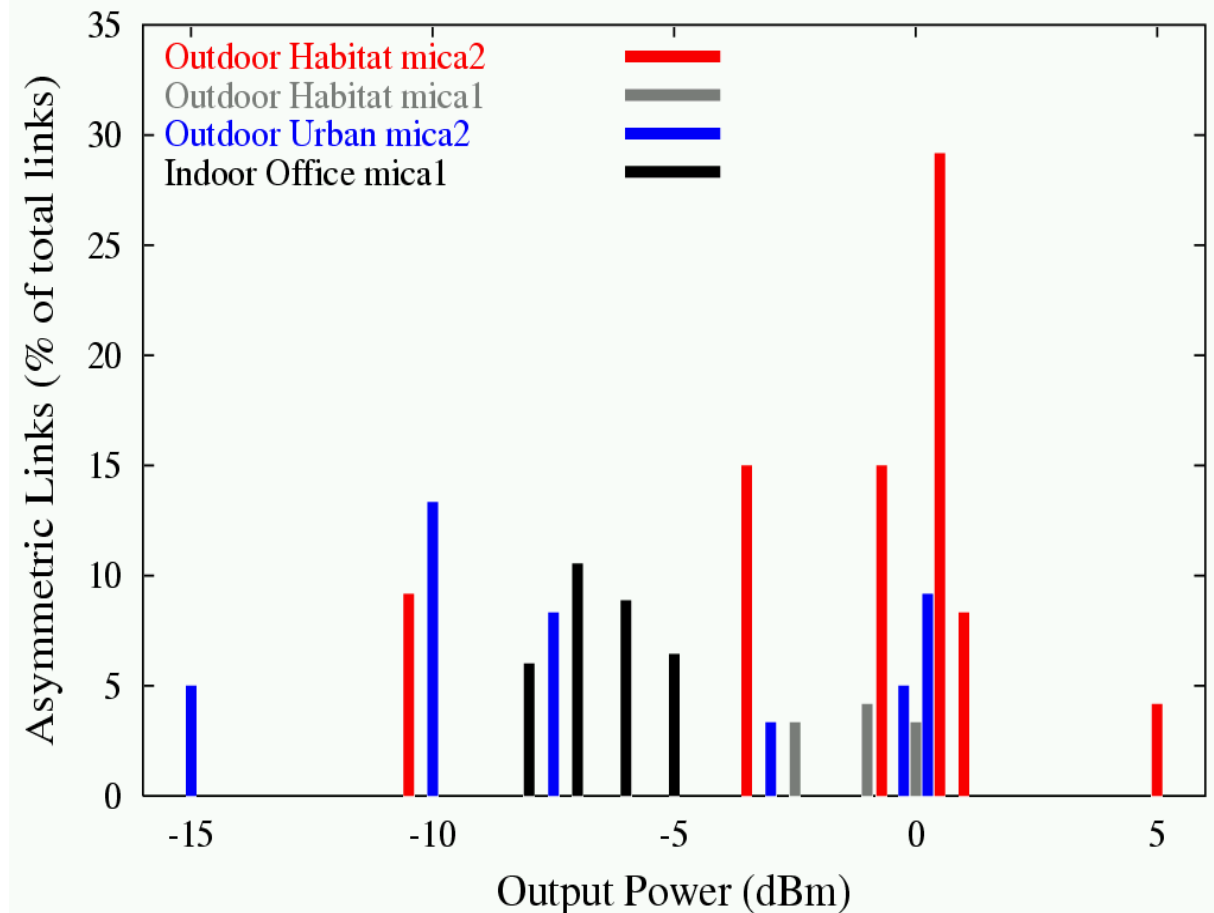
Wireless links are not reliable: they may vary over time and space

Reception v. Distance



*Cerpa, Busek et. al

Reception vs. Power



Challenge 2: Open Wireless Medium

- Wireless interference



- Hidden terminals



- Exposed terminal



- 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

Wearables
IoT devices



Mobile phones

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

Smart phone

- data
- small graphical displays
- 802.11/3G



Tablet/Laptop



Performance/Weight/Power Consumption

Challenge 5: Changing Regulation and Multiple Communication Standards

AT&T 3G network m... x

www.techeye.net/internet/att-3g-network-mysteriously-upgrades-to-4g

yry links | lans | yryang | GR | GCal | GMail | GIO | PODS'10 keynote | Netflix | RFC 2629 - Writi... | Other bookmarks

"In theory, there is no difference between theory and practice. But in practice, there is" - Yogi Berra

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Sunday 9 Jan 2011



Learn More

AT&T 3G network mysteriously upgrades to 4G

Marketing department weave some magic

06 Jan 2011 11:45 | by Matthew Finnegan in London | posted in Internet

1 Comment | SHARE



The term **4G** plunged to new depths of meaninglessness yesterday as America's second largest wireless carrier, AT&T, suddenly decided that what was once a 3G network has evolved all by itself into a 4G network.

It was just in September that the firm was labelling its HSPA-plus network as third generation, though now it seems that the AT&T marketing department has succumbed to the prevailing outlandish claims of competitors by declaring that its own network has joined the 4G club, announcing that it has "the nation's fastest mobile broadband network" rather the fastest 3G network.

Fourth generation wireless technology is said to promise mobile internet speeds that are considerably faster than what current networks can offer, meaning quick downloads of massive files and super-fast video streaming.

Of course there is no consensus of what exact speed constitutes a 4G network, so companies are to a certain extent free to claim what they want, though as far

Other internet stories



04 Jan 14:04
Skype is still legal in China
Says its Chinese cousin



05 Jan 12:12
Hurt Locker lawyers press on
Even after losing

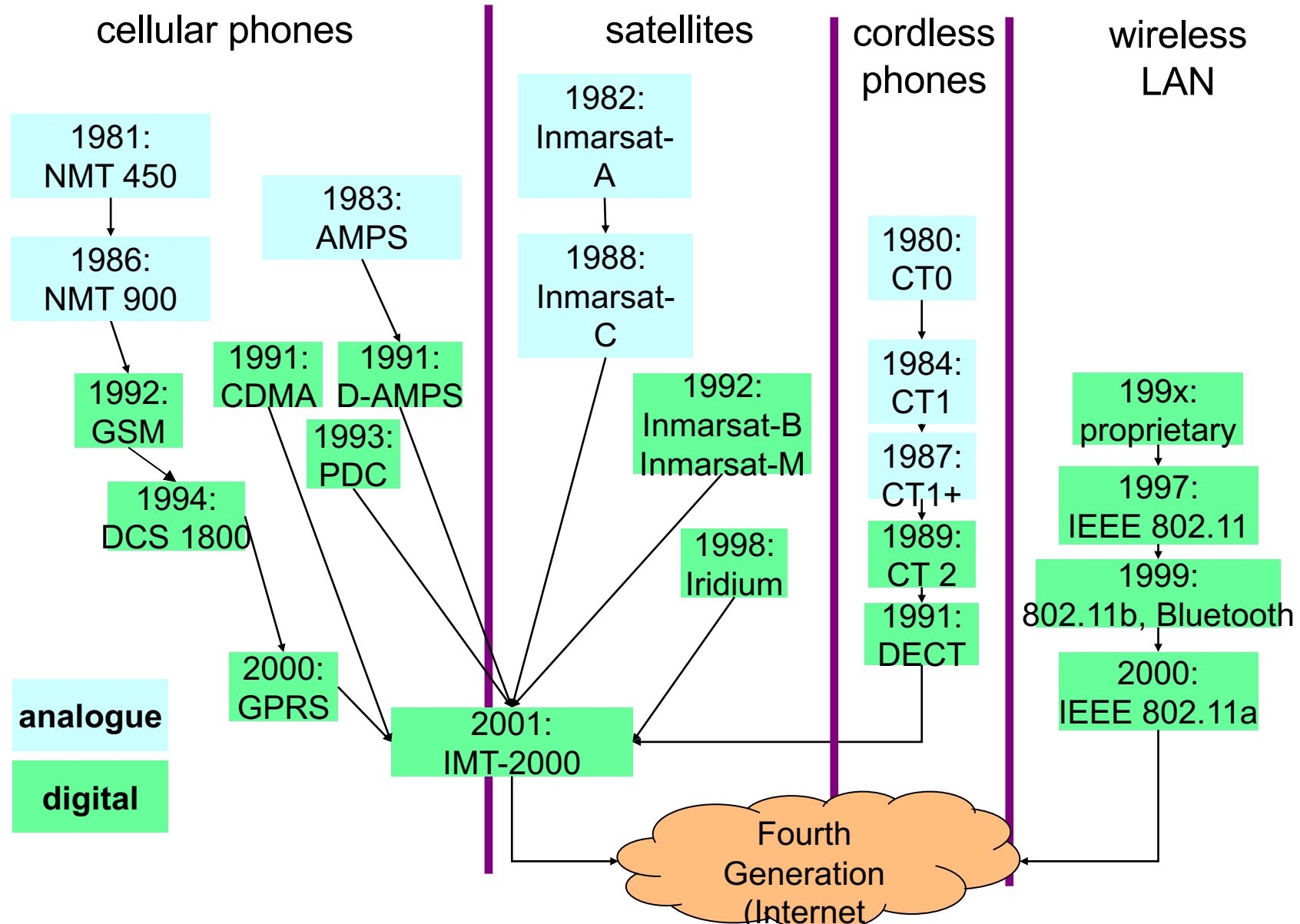
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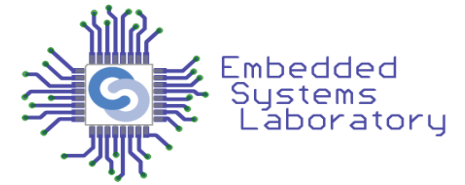


Free*
phones from AT&T

Challenge 5: Changing Regulation and Multiple Communication Standards



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:

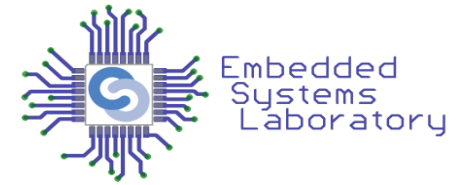
- LTE (TD-LTE)
- LTE Advanced
- LTE Advanced Pro
- WiMAX
- WiMAX-Advanced
- Ultra Mobile Broadband

5G networks:

- 5G NR

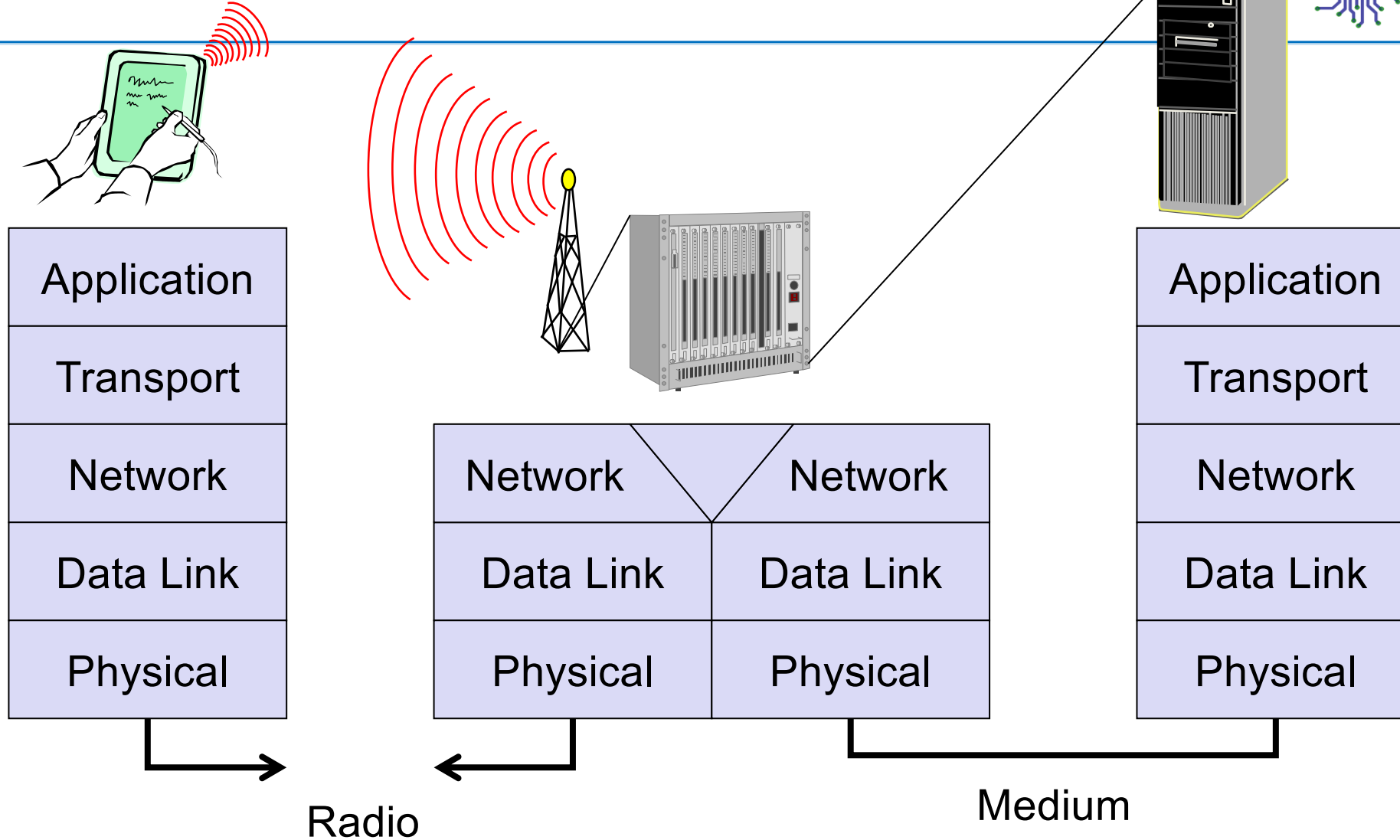
What Will We Cover?

Class Goals



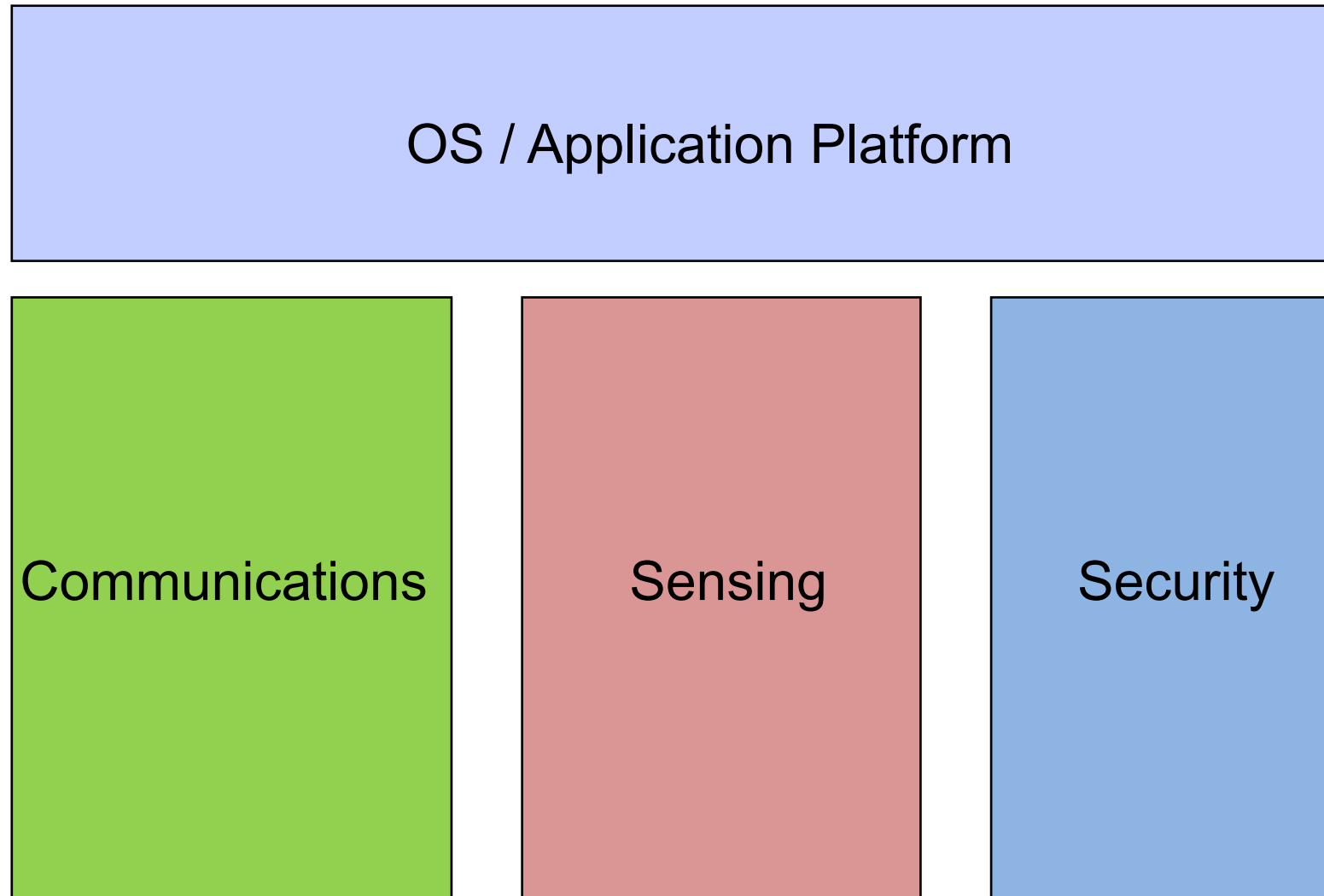
- Learn both fundamentals and applications of wireless networking and mobile computing
- Obtain hands-on experiences on developing on wireless, mobile devices
 - wireless networking, sensor nodes
- Discuss challenges and opportunities in wireless networking and mobile computing

The Layered Reference Model



Often we need to implement a function across multiple layers.

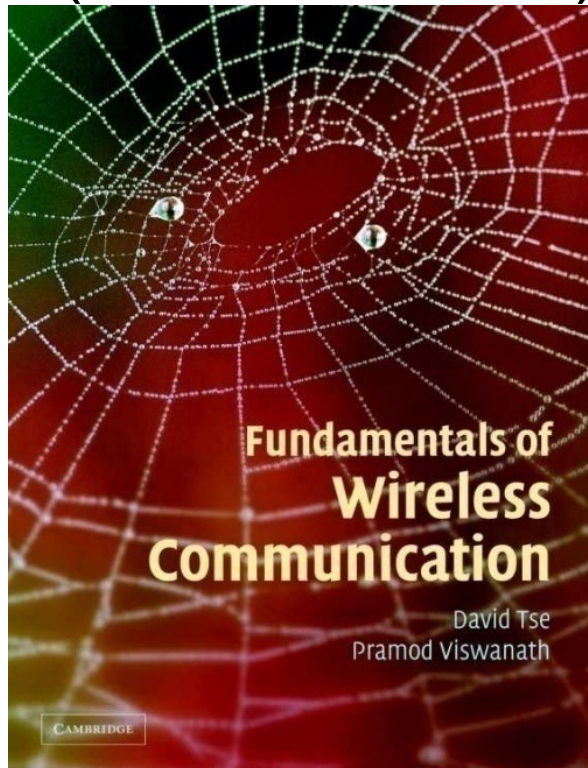
Course Topics



- Chapters of reference books
- Selected conference and journal papers
- Other resources
 - MOBICOM, SIGCOMM, Mobisys proceedings
 - IEEE Network, Communications, Pervasive magazines

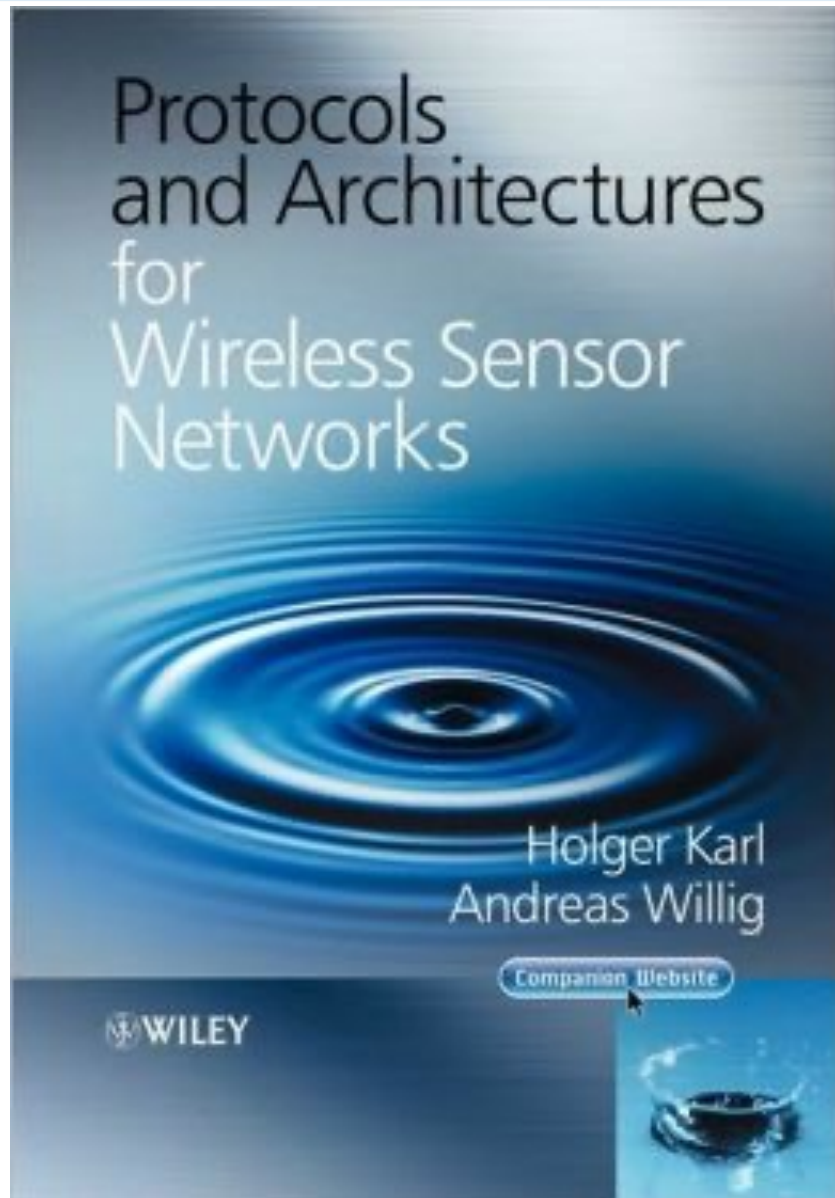
Suggested Reference Books

“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)





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

Grading

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

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