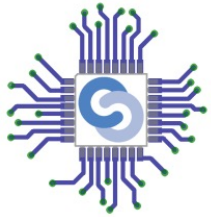


Wireless Sensor Networks

Facultatea de Automatică şi Calculatoare
Universitatea Politehnica Bucureşti

Outline

- 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*

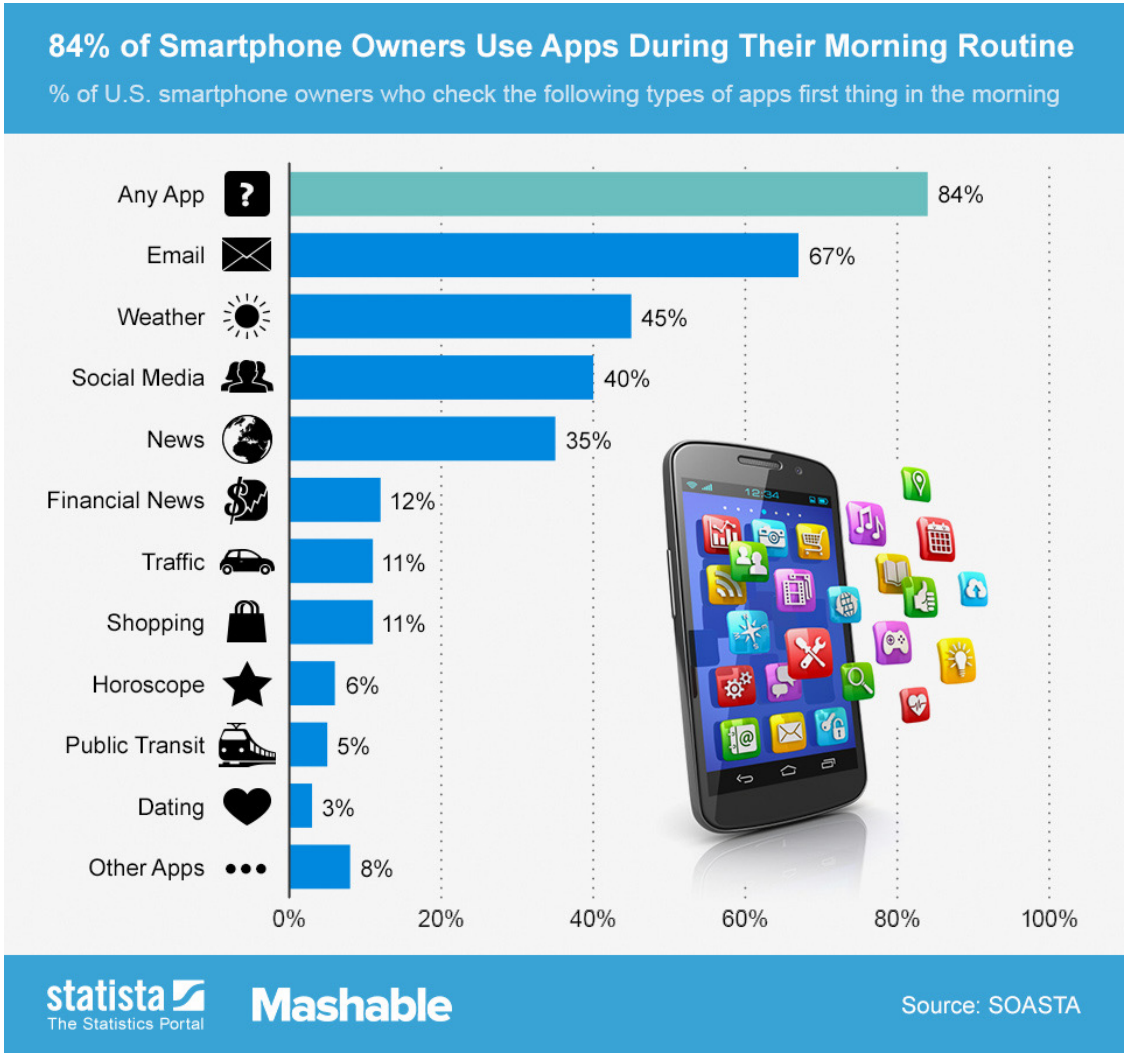
Pervasive Mobile Devices

- "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]

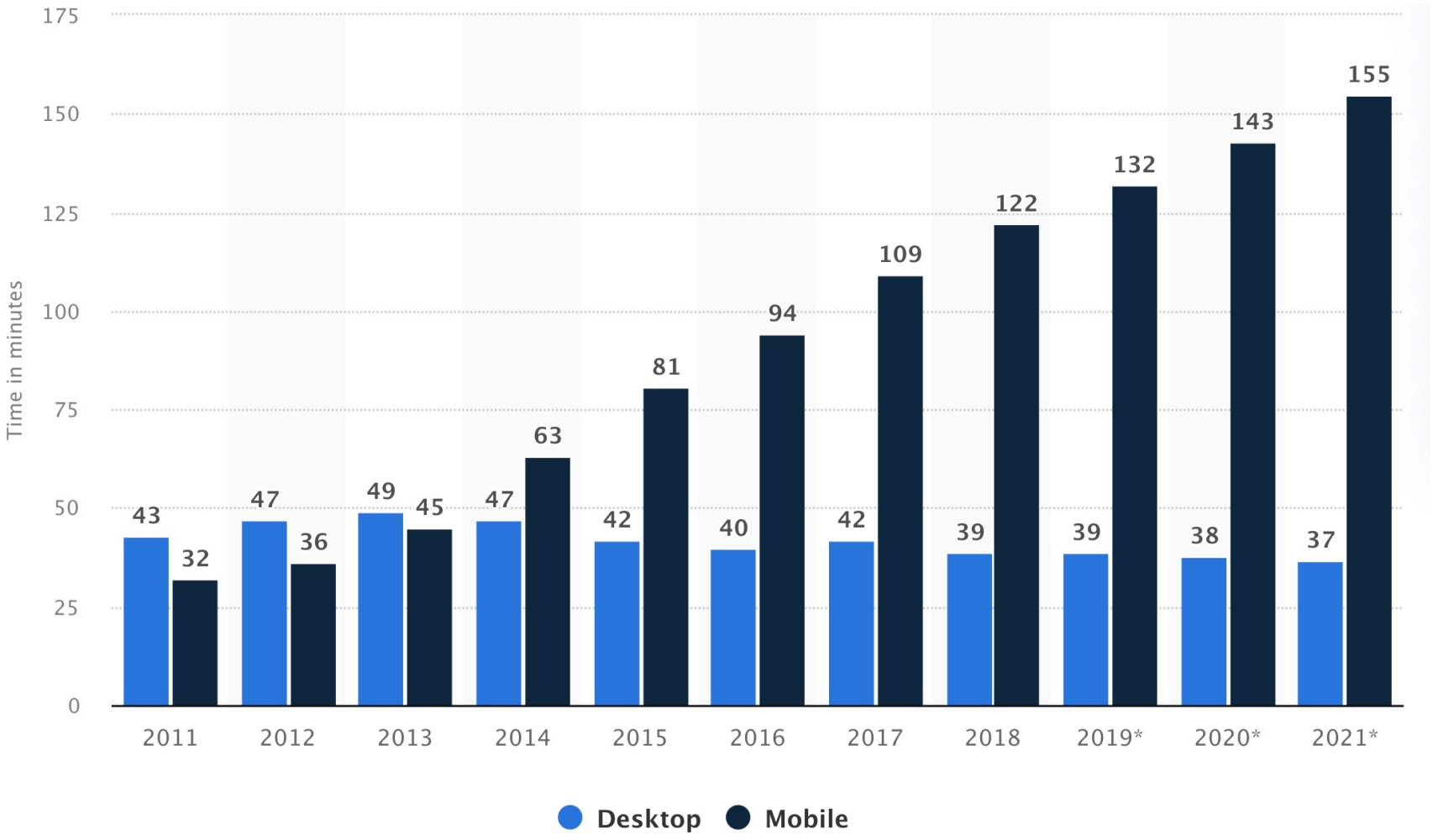
- Many industrial countries reach at least 90% mobile phone subscription penetration rate
  - [see phone penetration rates sheet]

- 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"

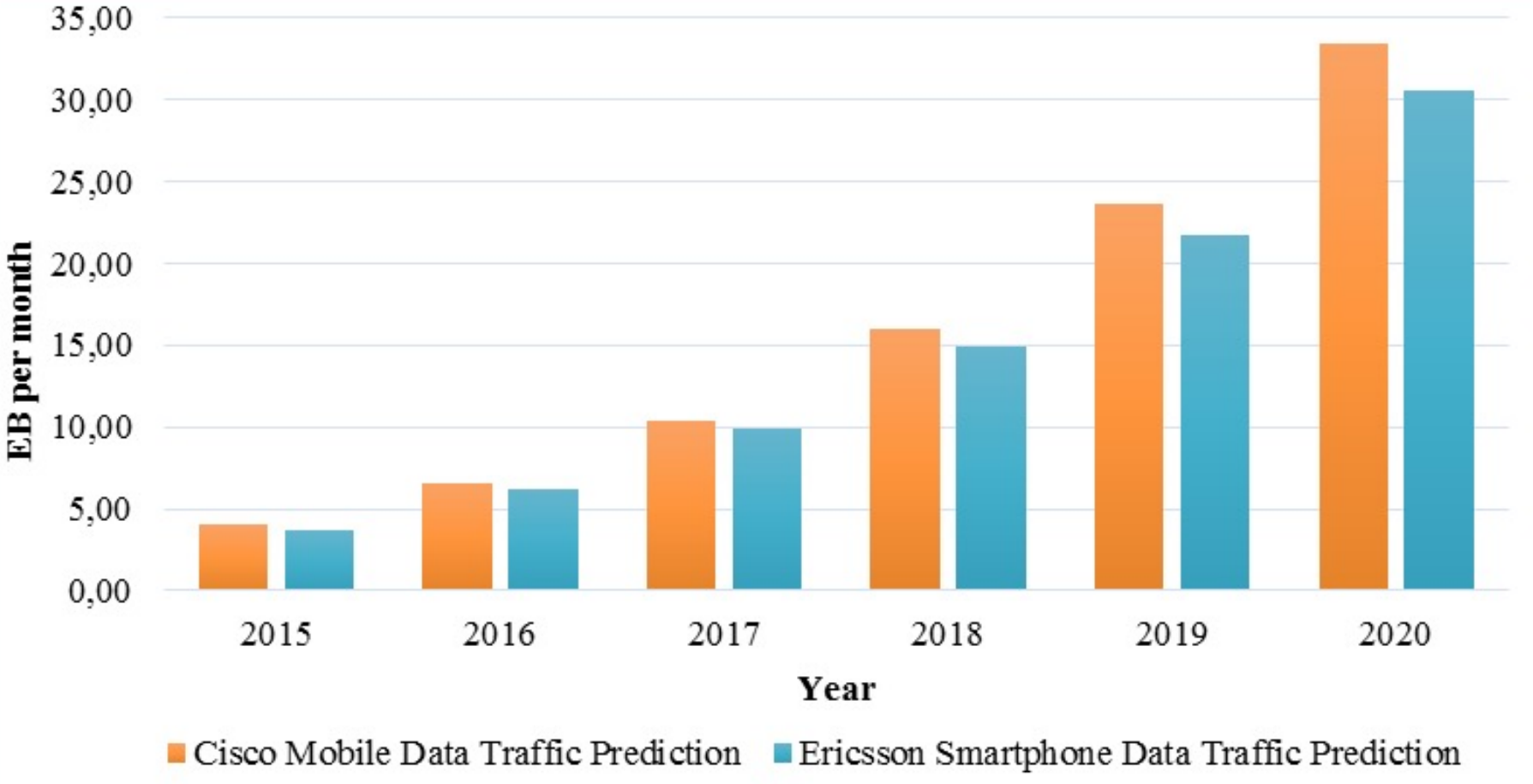
Mobile Device Usage



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

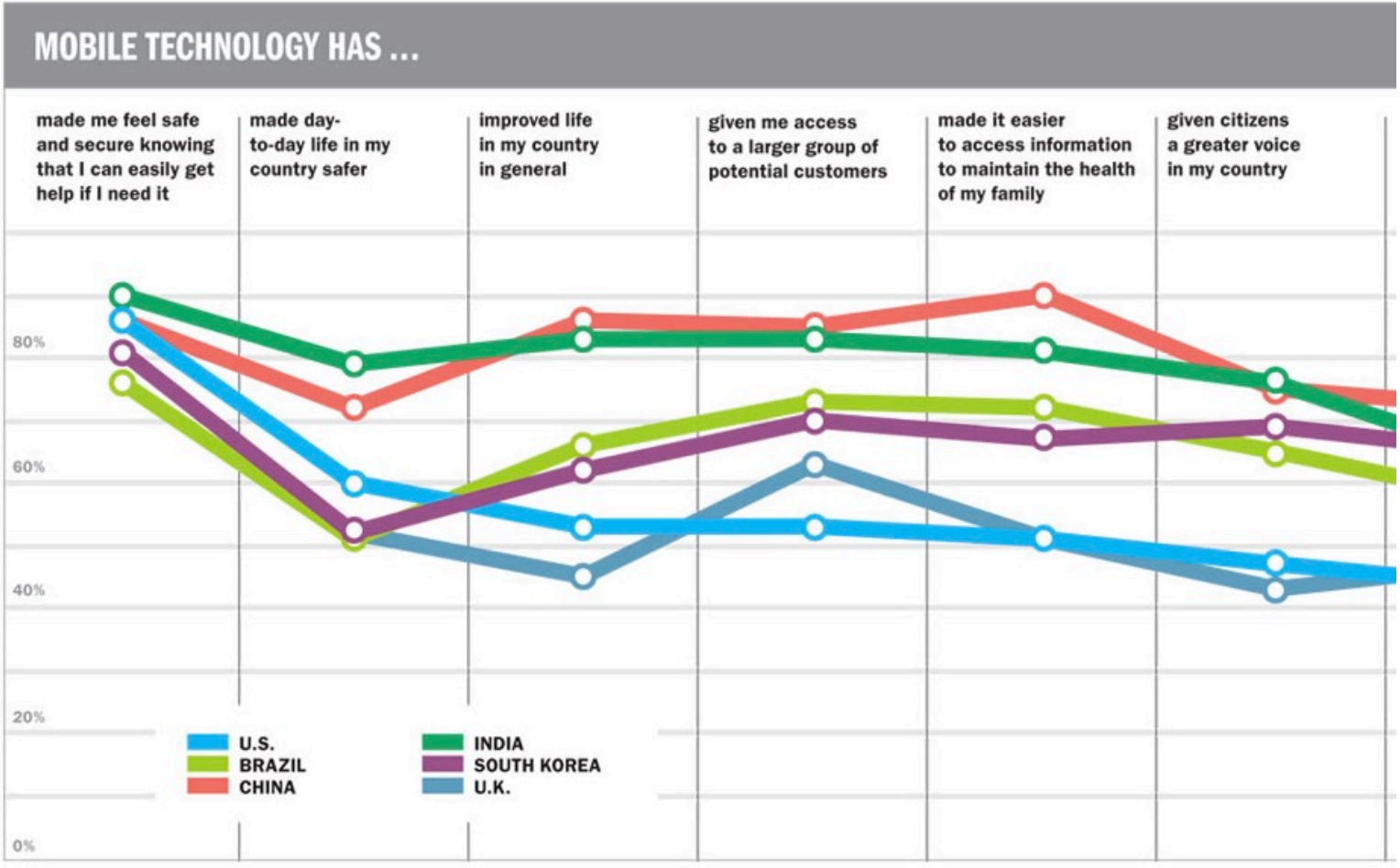


Mobile Traffic Growth

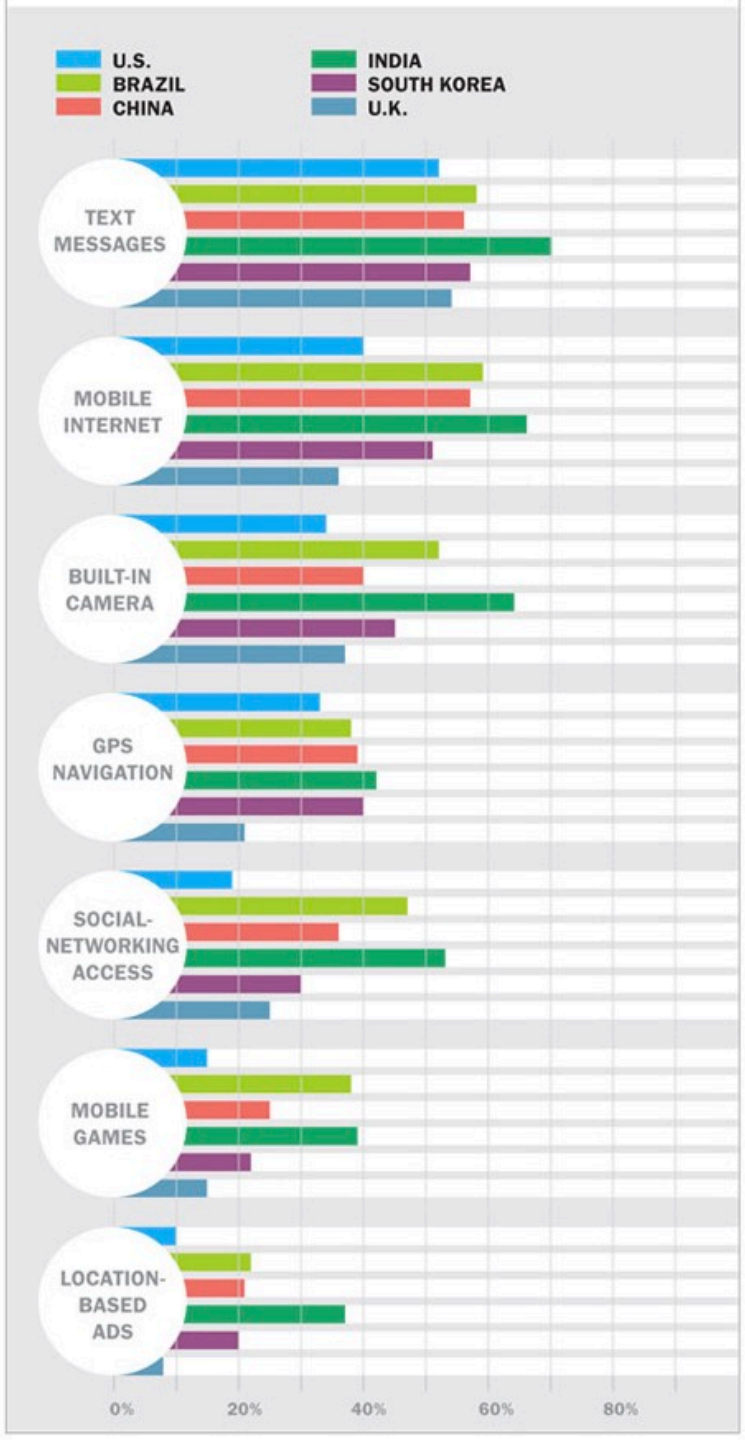


Source: Cisco&Ericsson

Mobile Computing Changing Our Lives



Source: TIME mobility survey



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Mobile Computing Features with Larger Effects

Source: TIME survey

Mobile Computing Changing Our Lives

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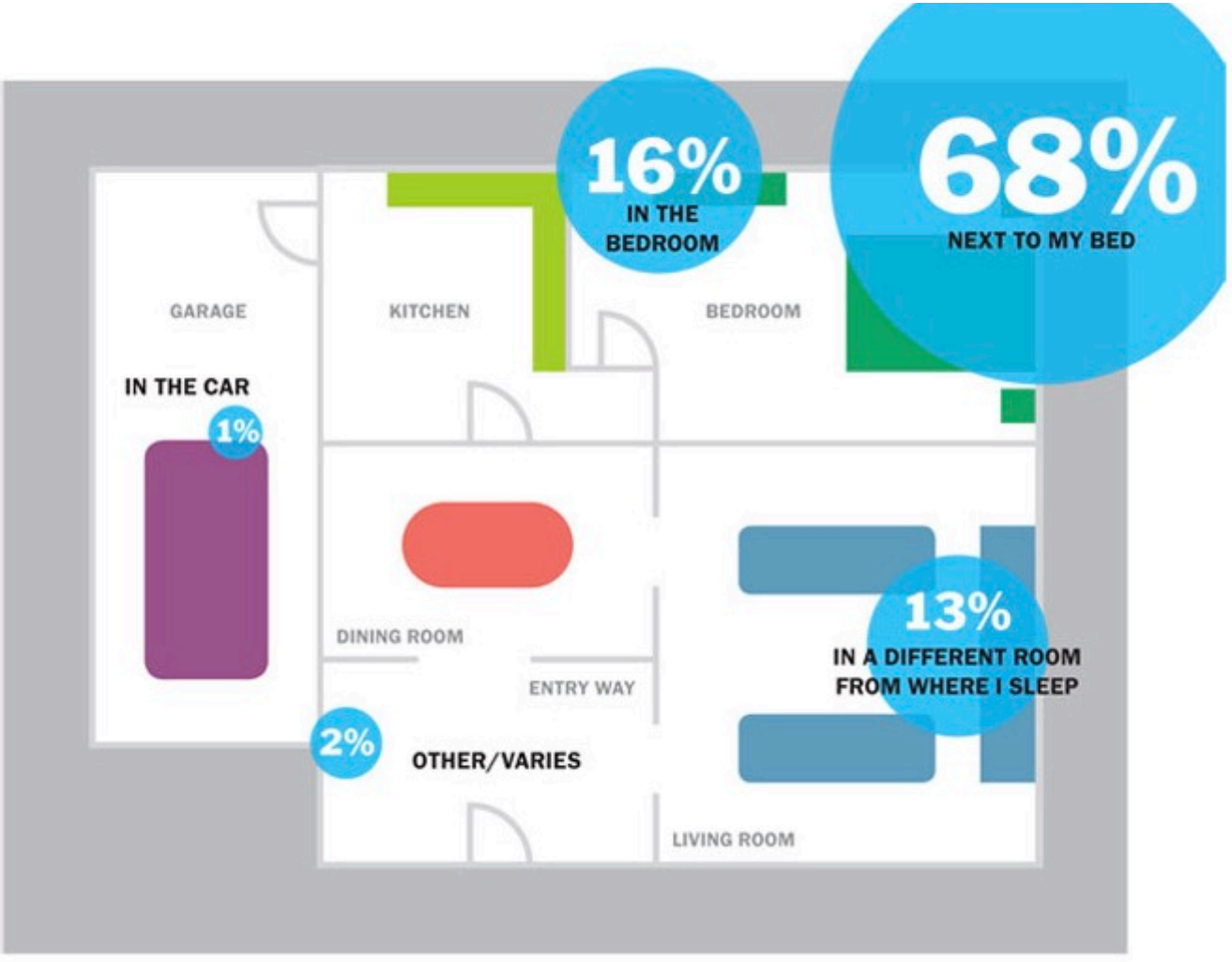
Where do you place your mobile device while sleeping at night?



Source: TIME survey

Mobile Computing Changing Our Lives

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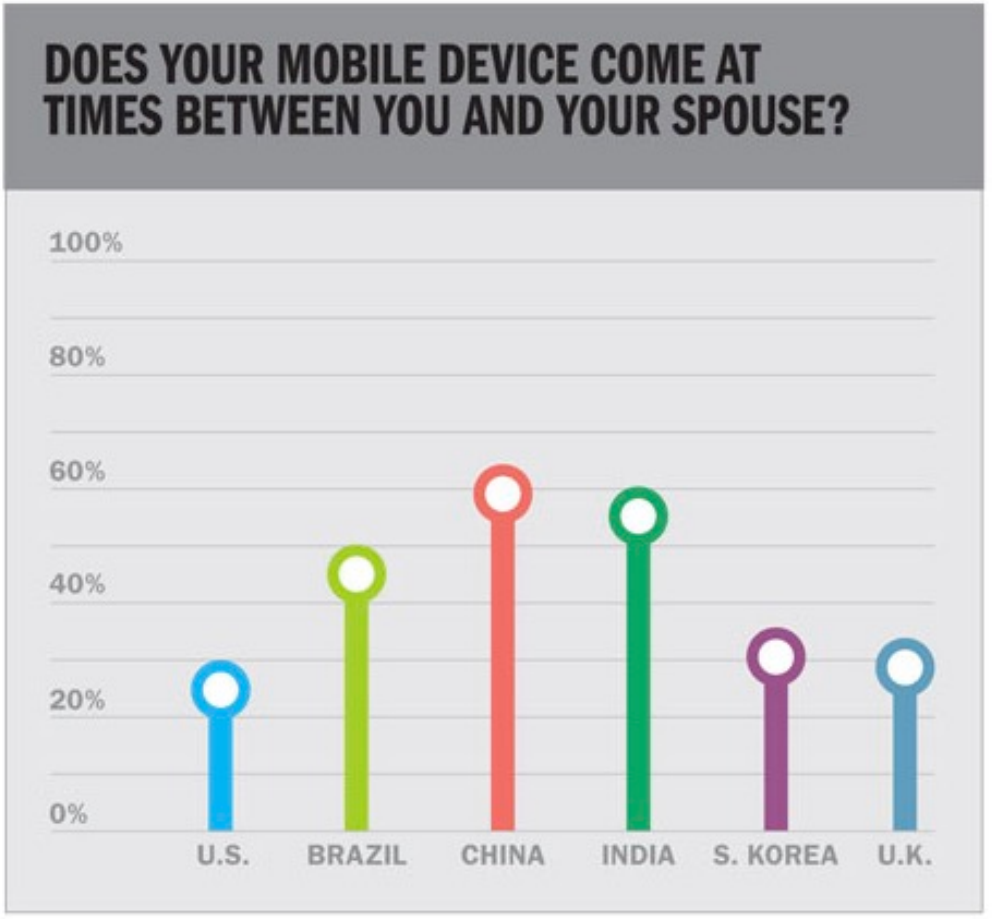
AGE	FLIRT WITH SOMEONE?	SEND SUGGESTIVE PICTURES?	COORDINATE OR COMMIT ADULTERY?
18–24	73%	48%	32%
25–29	76%	55%	36%
30–34	68%	52%	30%
35–44	54%	42%	24%
45–54	44%	26%	19%
55–64	22%	10%	13%
65+	16%	7%	3%

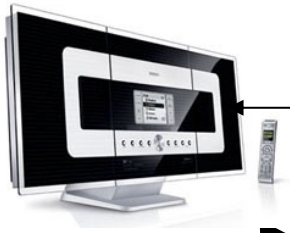
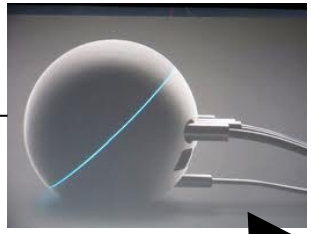
Source: TIME survey



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

Use Case: Home Networks





satellite

WiFi
802.11g/n
WiFi
Bluetooth
NFC
WiFi

UWB




bluetooth

WiFi


cellular


Use Case: Mesh Networks

Urban Mesh Networks

Use Case: Mesh Network for Disaster Recovery/Military

- 9/11, Tsunami, Hurricane Katrina, South Asian earthquake …
- 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

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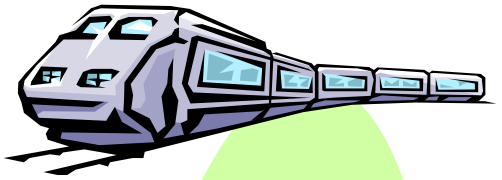
LAN, WLAN
780 kbit/s

GSM/EDGE 135 kbit/s,
WLAN 780 kbit/s

GSM 53 kbit/s
Bluetooth 500 kbit/s

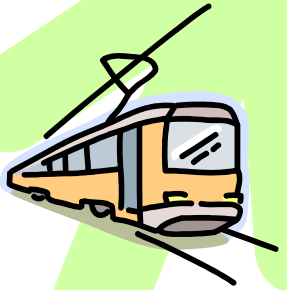
GSM 115 kbit/s,
WLAN 11 Mbit/s

UMTS Rel. 5
400 kbit/s



UMTS Rel. 6
400 kbit/s

LAN
100 Mbit/s,
WLAN
54 Mbit/s



UMTS,
DECT
2 Mbit/s

Use Case: Traffic Signal Advisor

http://www.princeton.edu/~ekoukoum/SignalGuru.html

Use Case: Vehicular Networks

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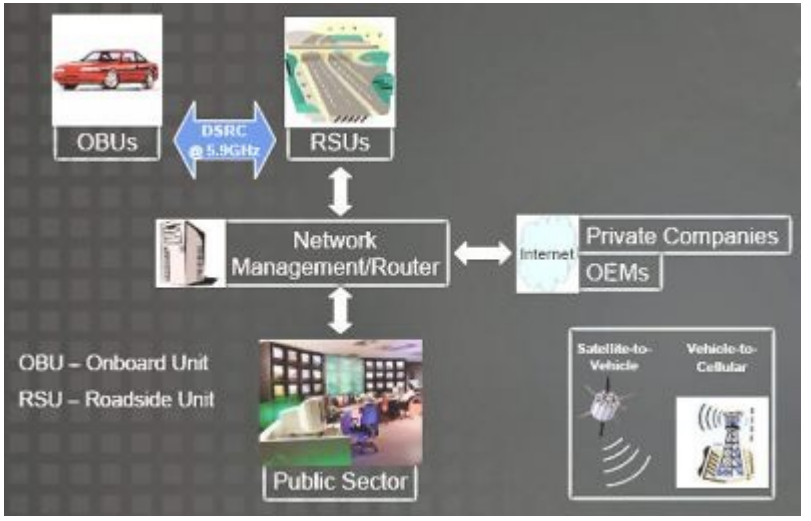
- Traffic crashes resulted in more than 41,000 lives lost/year

- 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

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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

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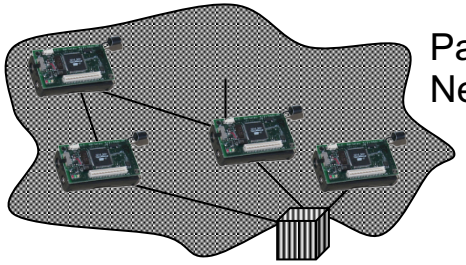
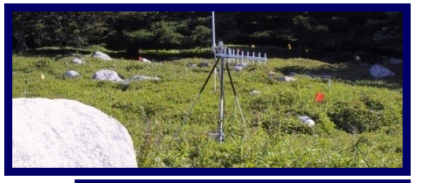
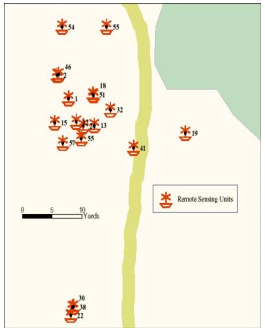
A 15-minute human visit leads to 20% petrel offspring mortality







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

Enabling Infrastructures

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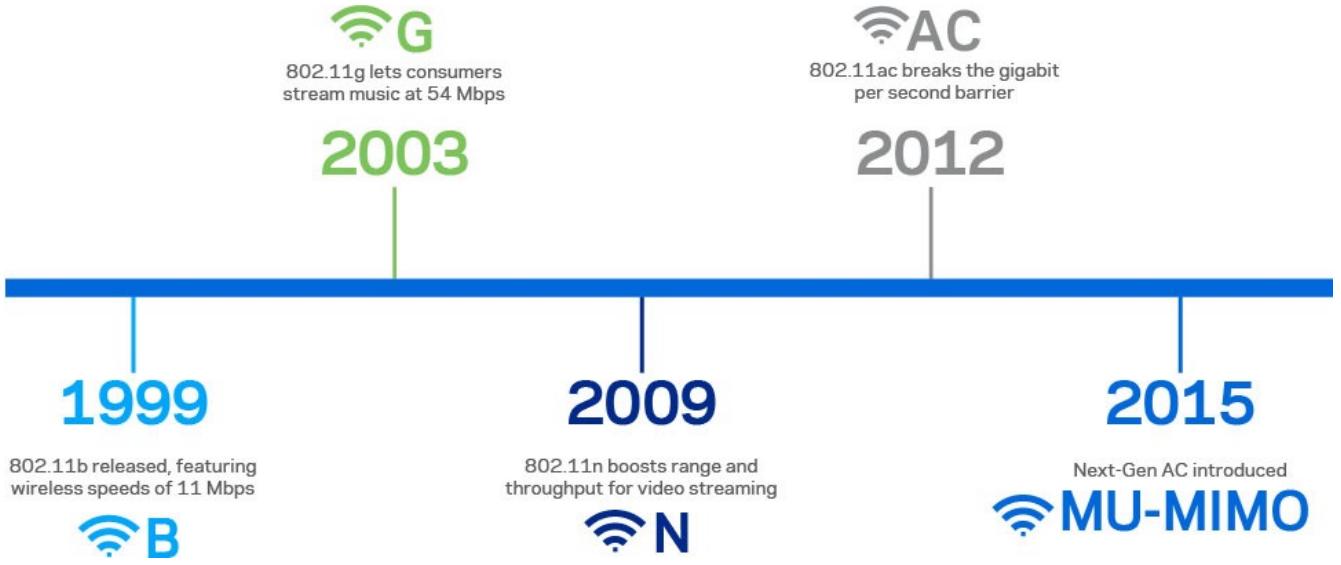
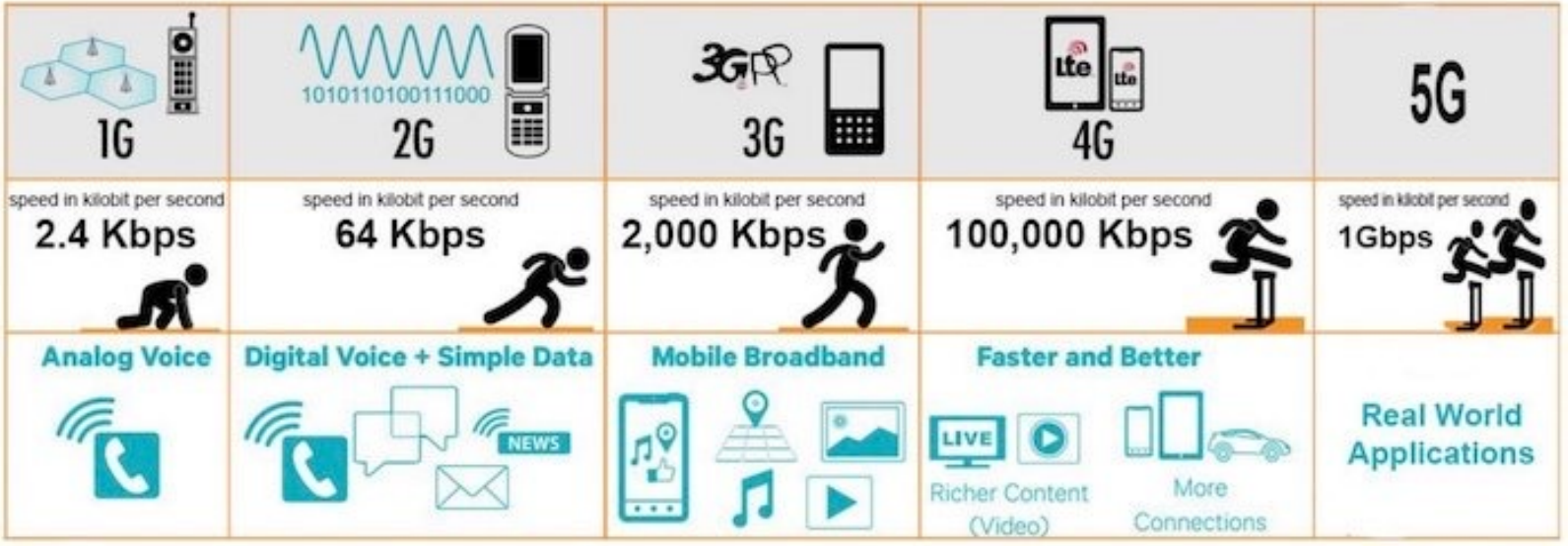
- Development and deployment of wireless infrastructures
  - networking: in-room, in-building, on-campus, in-the-field, MAN, WAN
- Development and deployment of localization infrastructures
  - location: GPS, AGPS, …
- Development and deployment of sensor networks

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

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	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

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Why is the Field Challenging?

Challenge 1: Unreliable and Unpredictable Wireless Coverage

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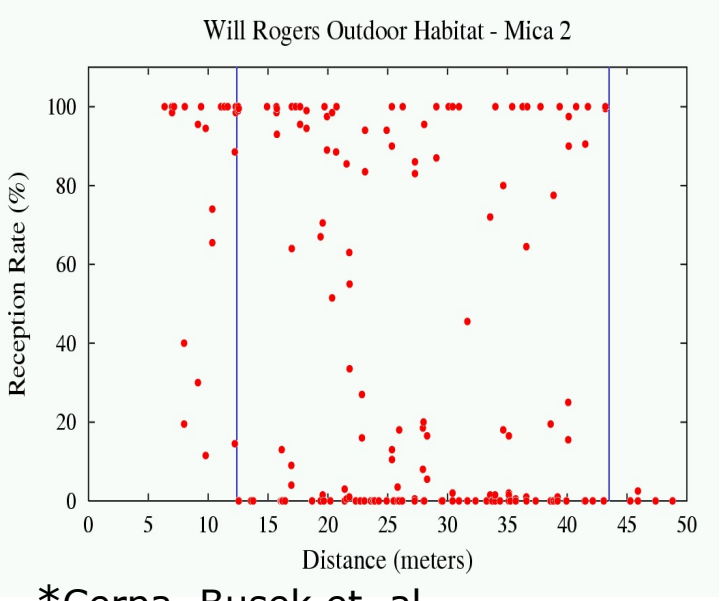
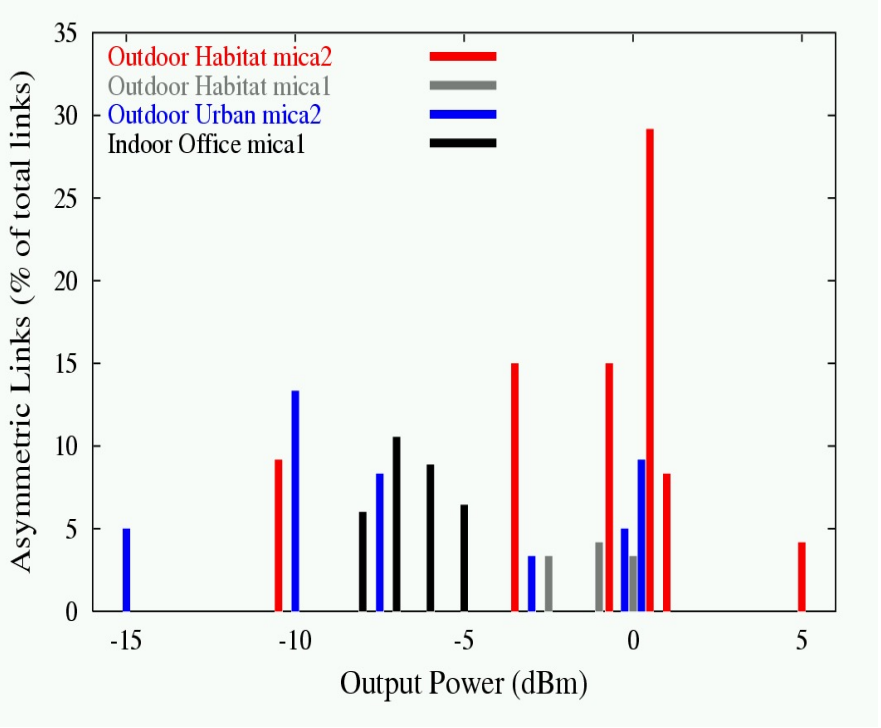
Wireless links are not reliable: they may vary over time and space

Reception v. Distance



*Cerpa, Busek et. al

Reception vs. Power



Challenge 2: Open Wireless Medium

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- Wireless interference

Challenge 2: Open Wireless Medium

Embedded Systems Laboratory

- Wireless interference

- Hidden terminals

Challenge 2: Open Wireless Medium

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- Wireless interference

- Hidden terminals

- Exposed terminal

Challenge 2: Open Wireless Medium

Embedded Systems Laboratory

- Wireless interference

- Hidden terminals

- Exposed terminal

- Wireless security
  - eavesdropping, denial of service, …

Challenge 3: Mobility

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- 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

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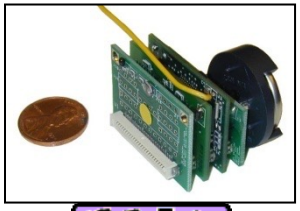
- Limited battery power
- Limited processing, display and storage

Sensors, embedded controllers



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

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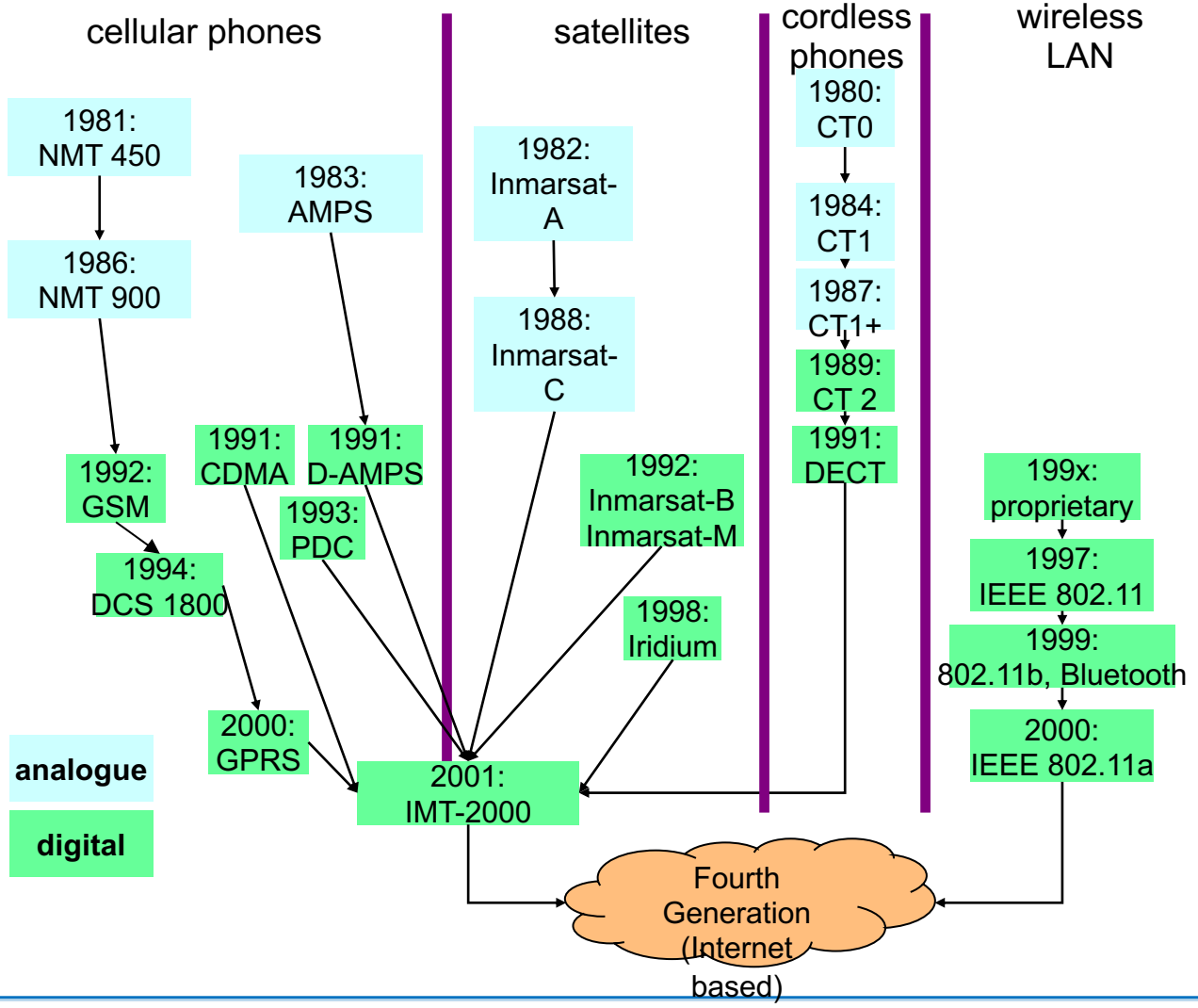
Challenge 5: Changing Regulation and Multiple Communication Standards



Wireless Communication Standards

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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

https://en.wikipedia.org/wiki/Mobile_telephony

What Will We Cover?

Class Goals

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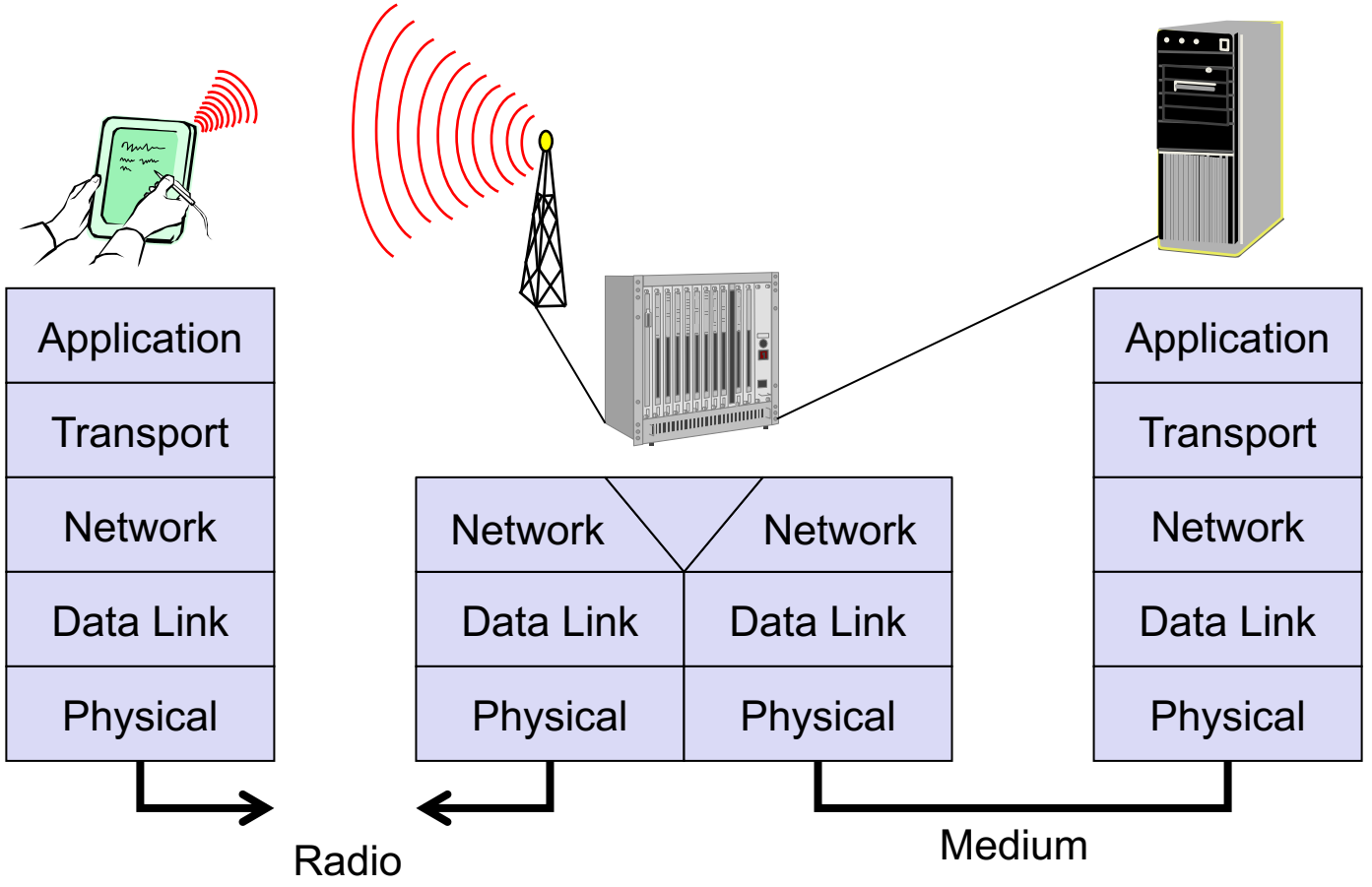
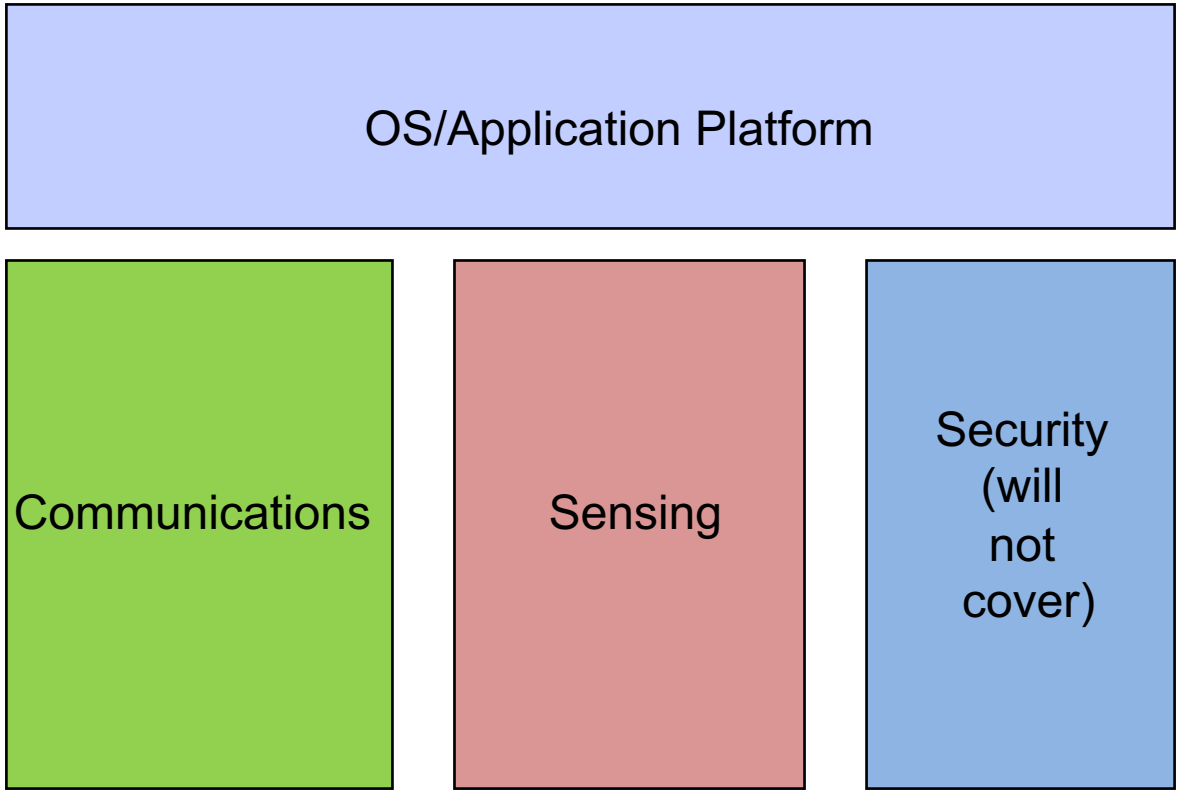
- Learn both fundamentals and applications of wireless networking and mobile computing
- Obtain hands-on experiences on developing on wireless, mobile devices
  - wireless networking, sensor nodes
- Discuss challenges and opportunities in wireless networking and mobile computing

The Layered Reference Model



Often we need to implement a function across multiple layers.

Course Topics



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

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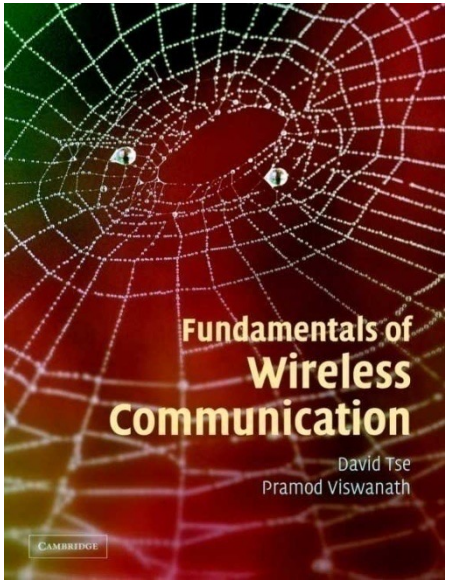
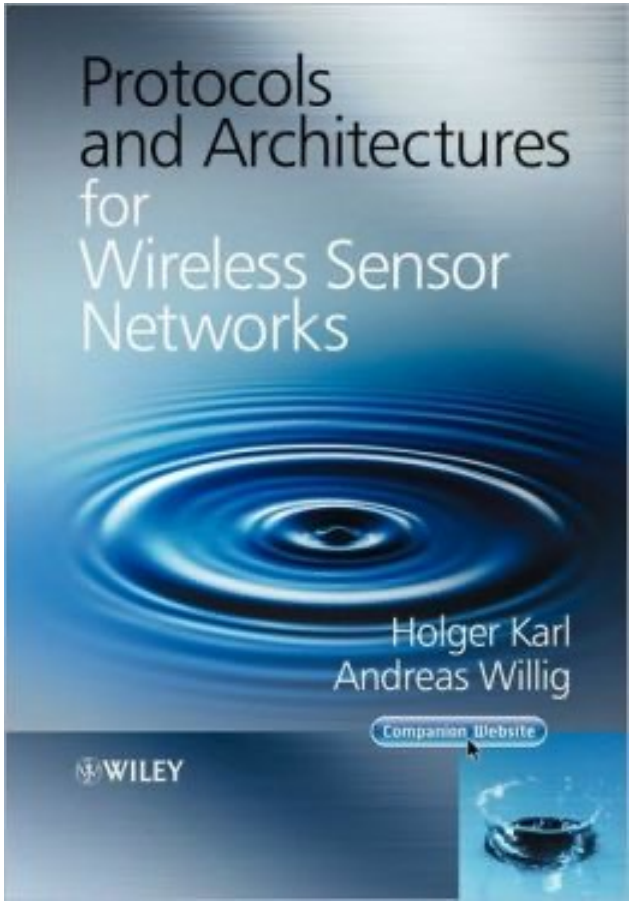
"Fundamentals of Wireless Communication", by David Tse and Pramod Viswanath, Cambridge University Press (available online)



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

THE Book



Protocols and Architectures for Wireless Sensor Networks

Holger Karl, Andreas Willig

Class Project

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- 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

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

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