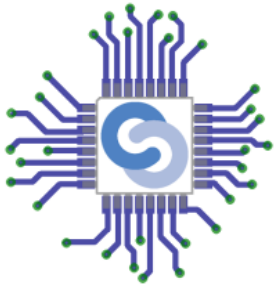




# Wireless Sensor Networks

Facultatea de Automatică și Calculatoare
Universitatea Politehnica București

# Outline

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

# The Future of Computing

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"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

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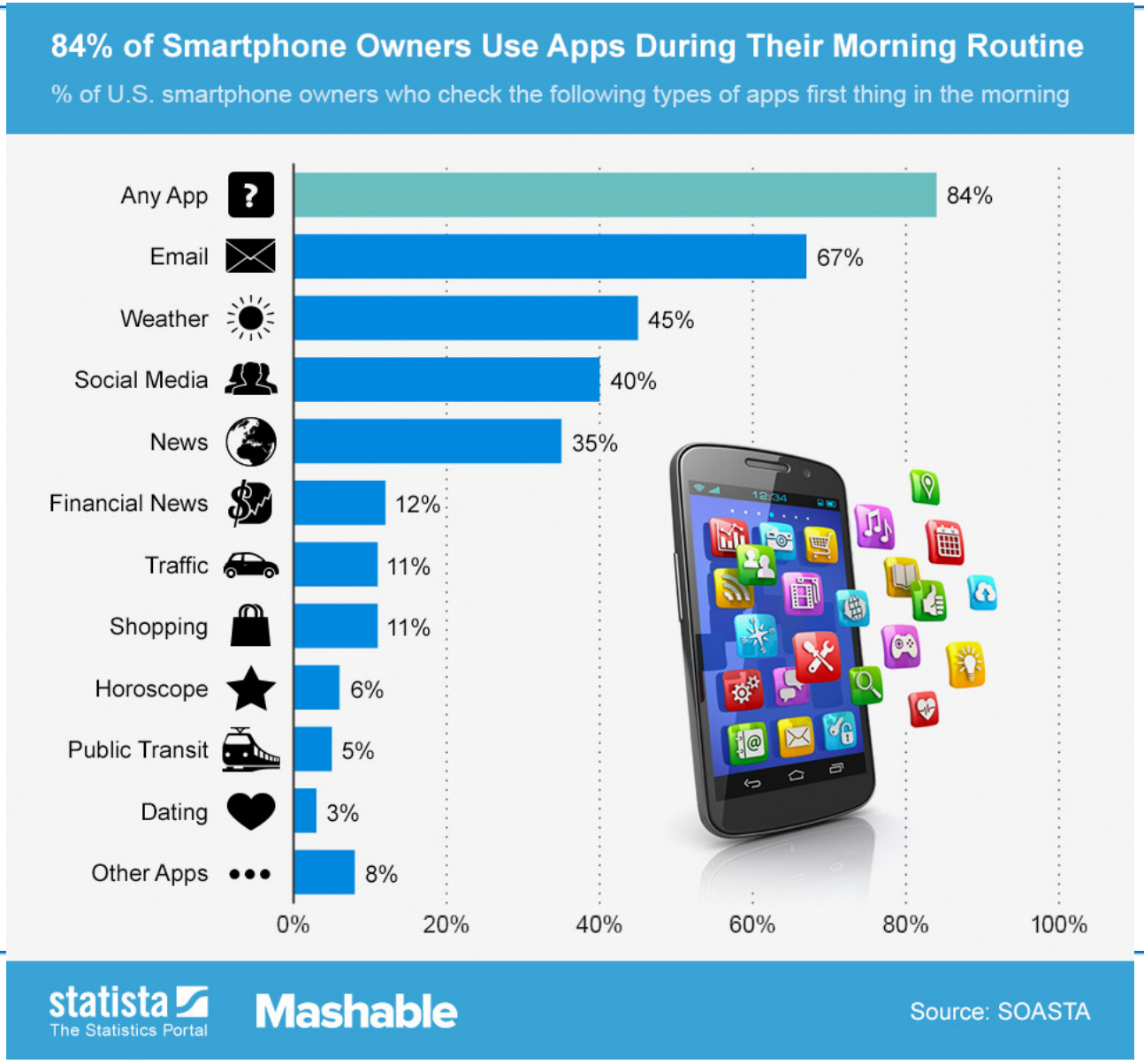
- "In many parts of the world, more people have access to a mobile [wireless] device than to a toilet or running water." [Time Aug. 2012]

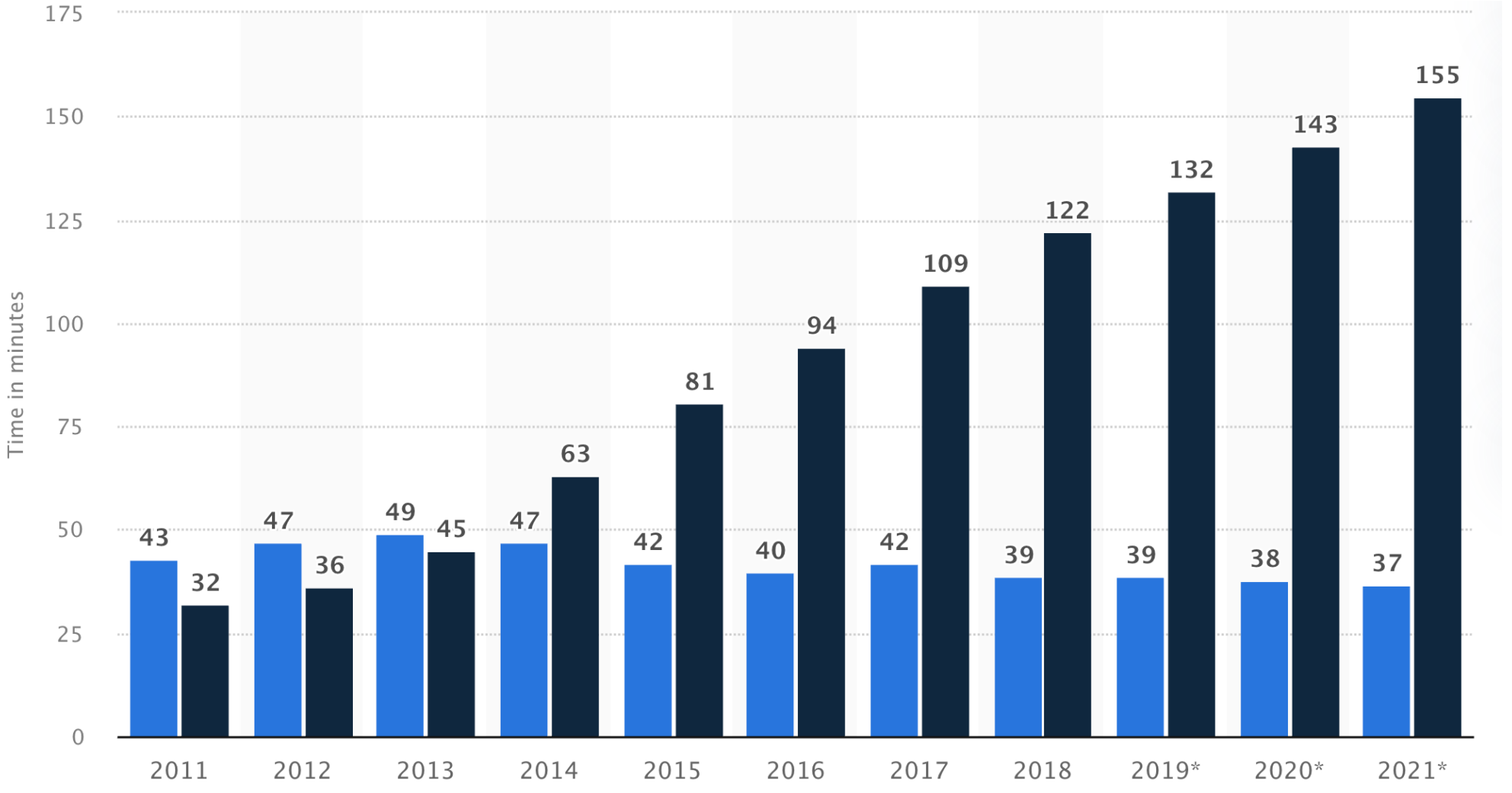
- Many industrial countries reach at least 90% mobile phone subscription penetration rate
  - [see phone penetration rates sheet]

- 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




© Statista 2021

# Mobile Traffic Growth

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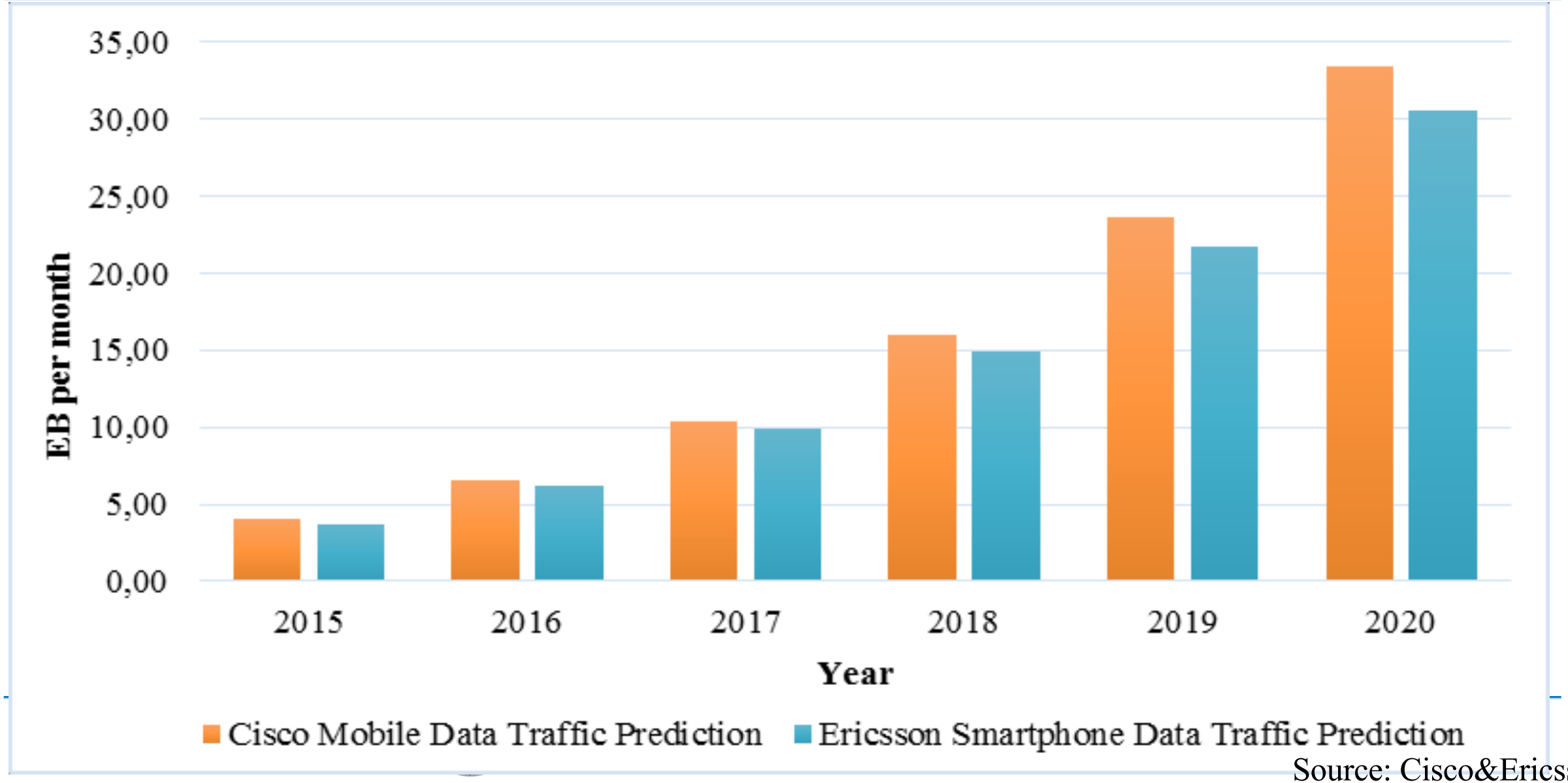
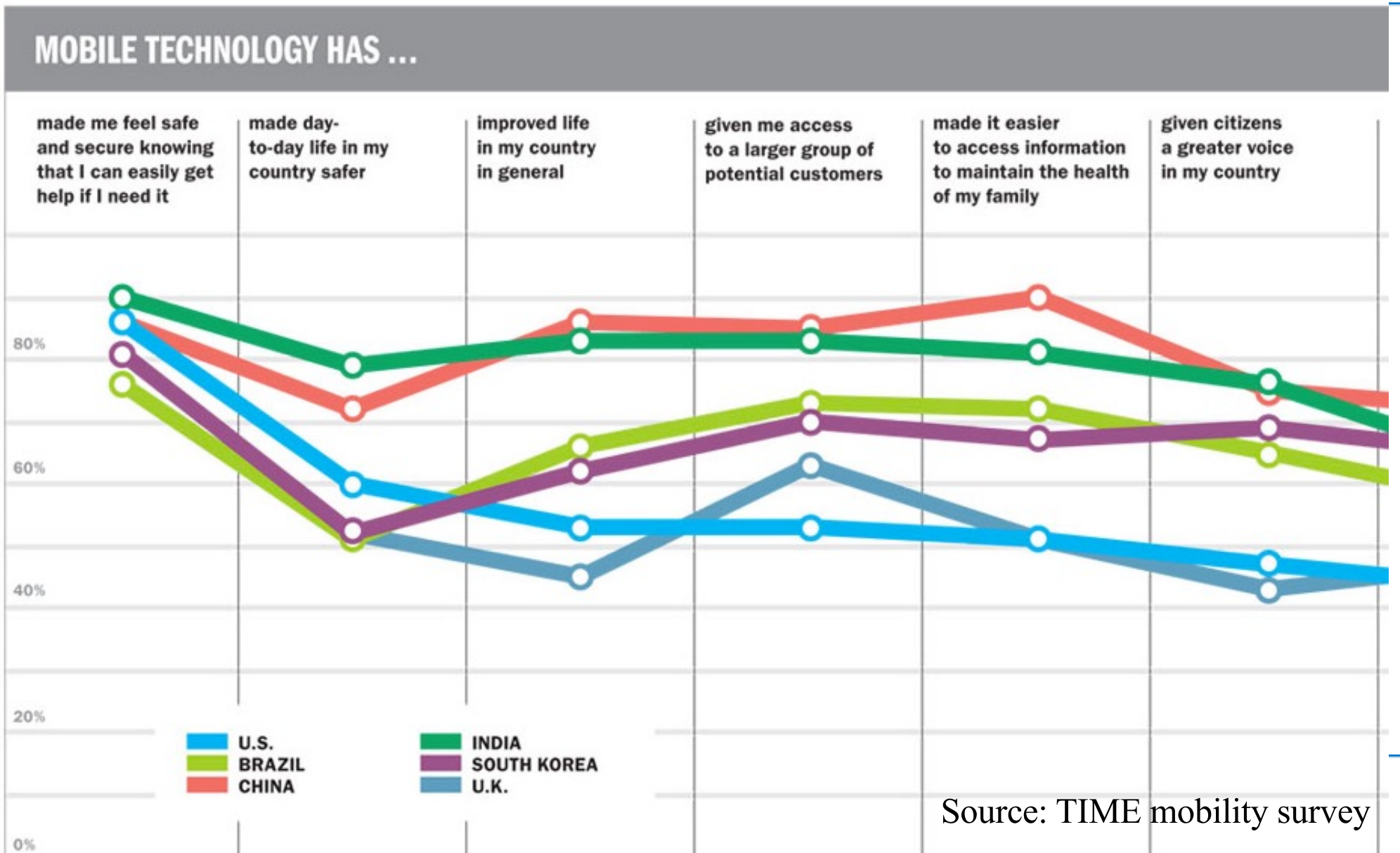
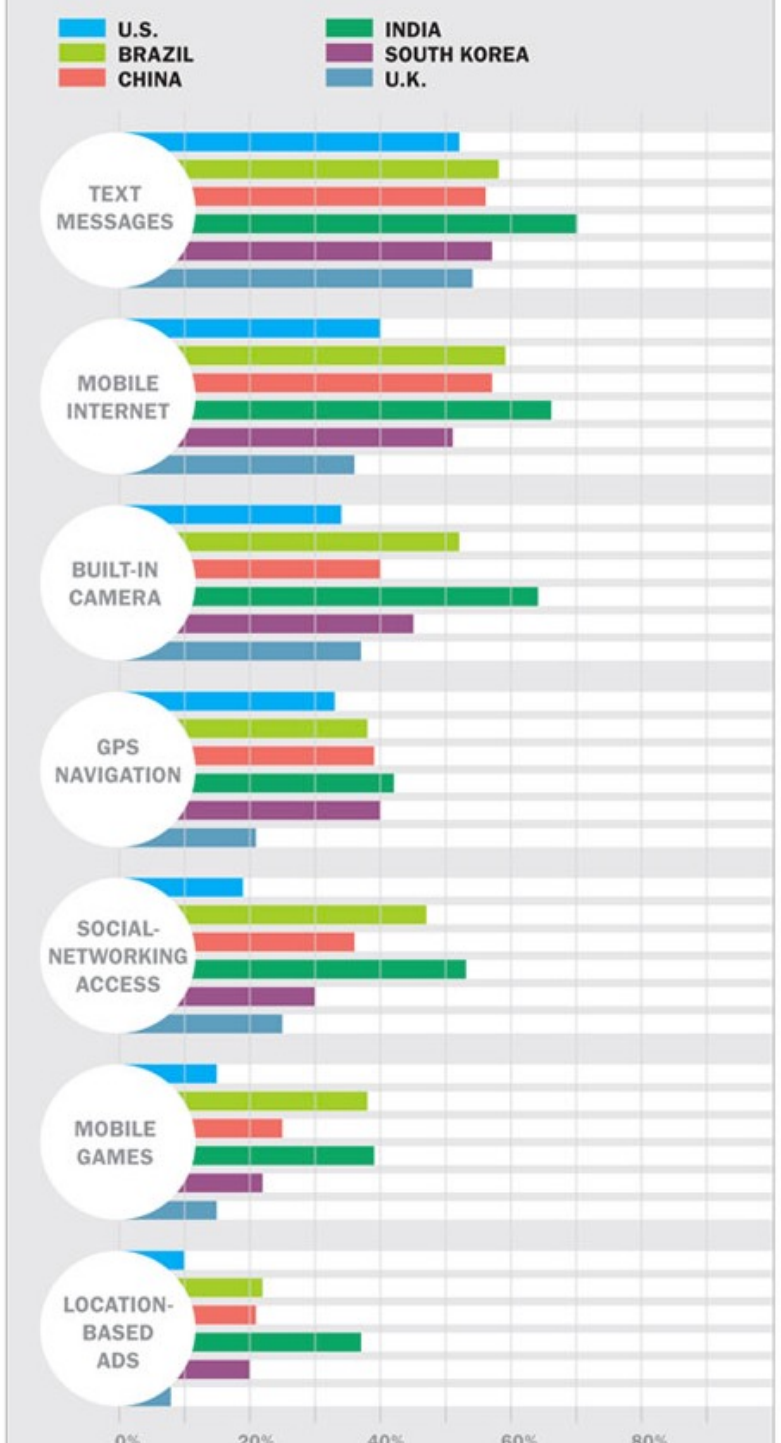



Source: Cisco&Ericsson

# Mobile Computing Changing Our Lives




Source: TIME mobility survey

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# Mobile Computing Features with Larger Effects



Source: TIME

# Mobile Computing Changing Our Lives

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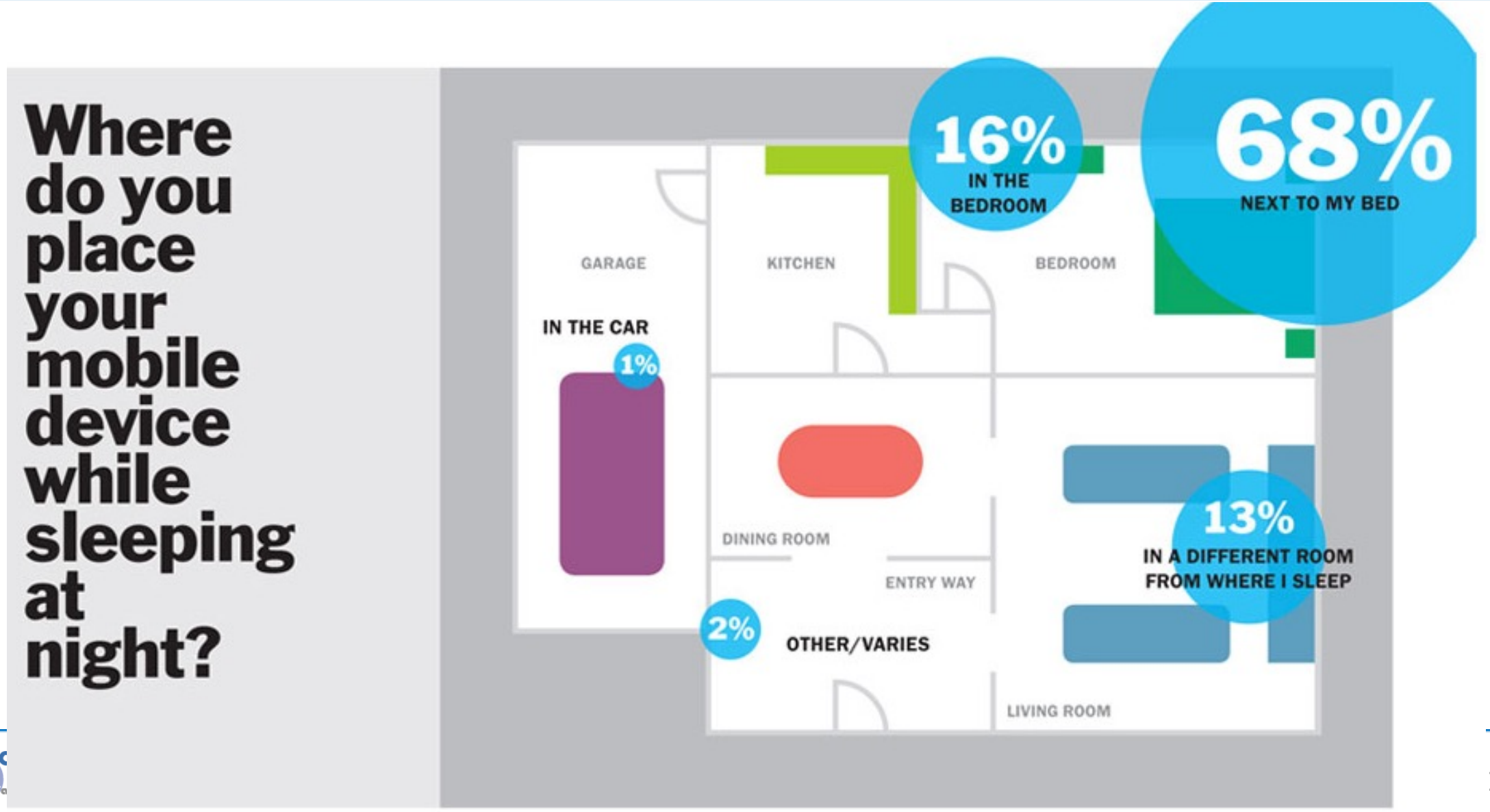
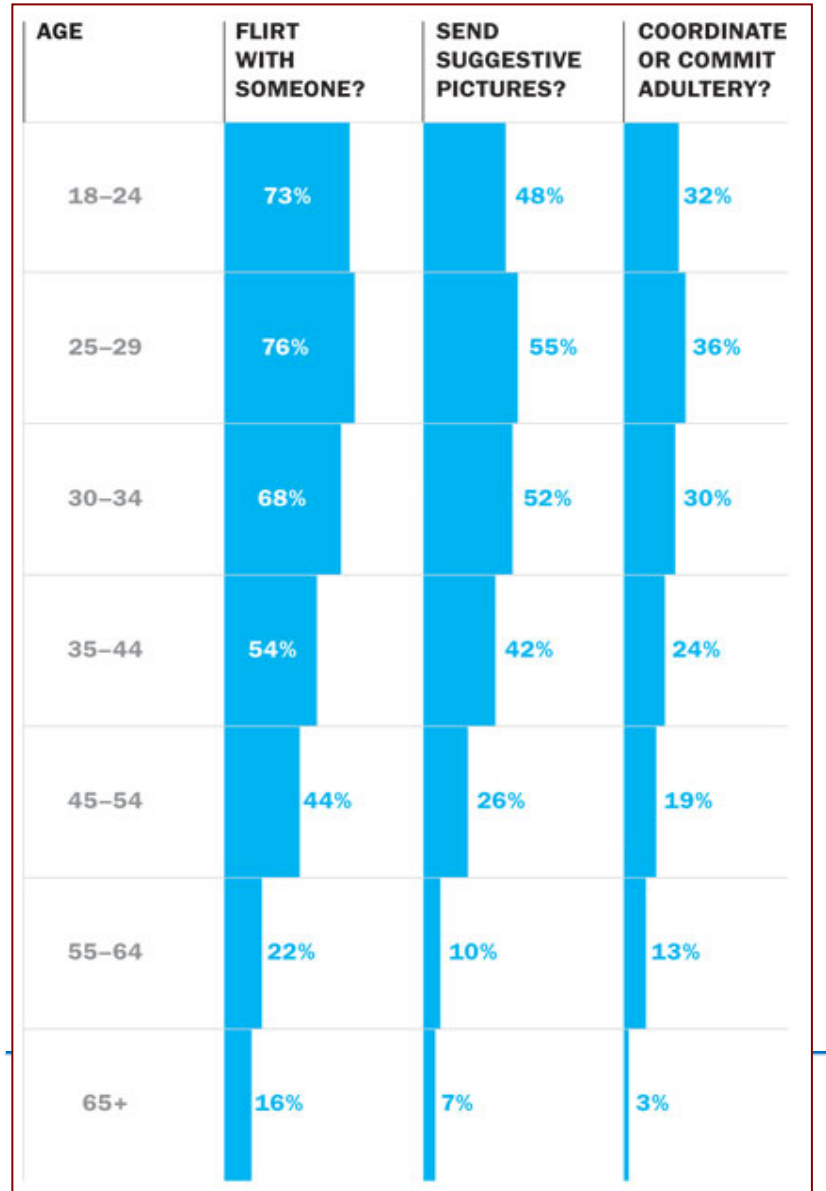
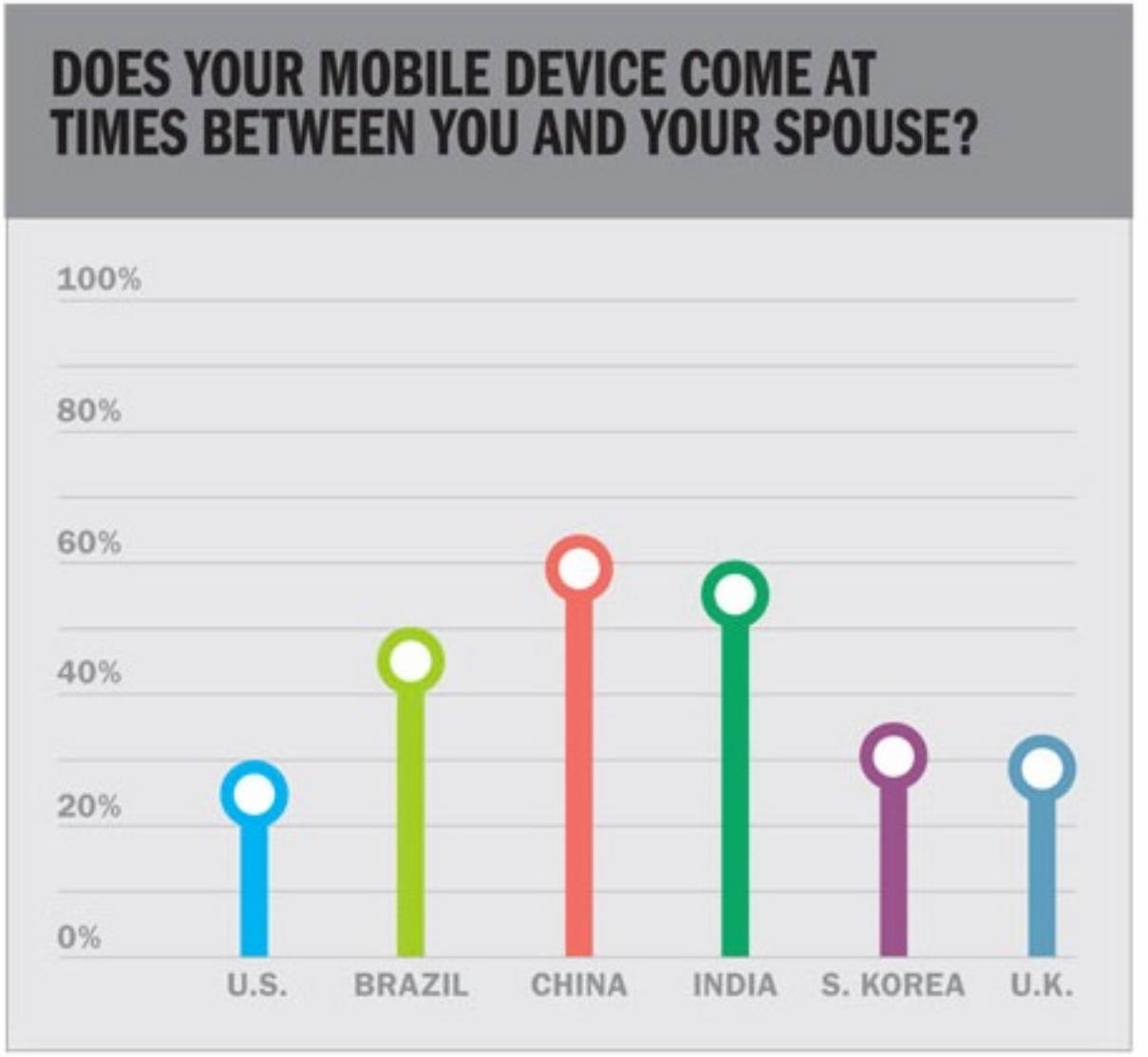


# Mobile Computing Changing Our Lives




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

# Use Case: Home Networks

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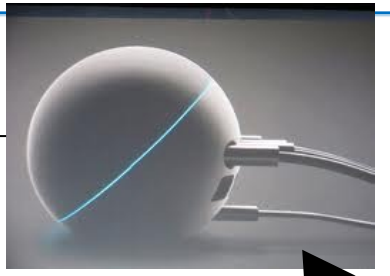
satellite



WiFi
802.11g/n

WiFi
Bluetooth
NFC

WiFi

UWB

Bluetooth

WiFi

cellular

# 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

# Use Case: Mesh Network for Disaster Recovery/Military

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- 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

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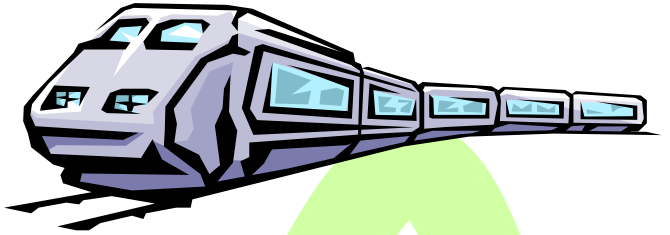
LAN, WLAN
Low Datarate

LTE
Bluetooth

LTE 4G, WiFi

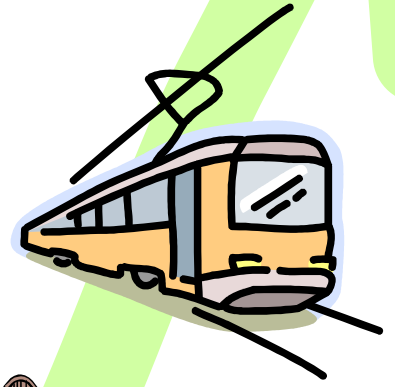


LAN,
WLAN, LTE,
Satellite

LTE or WLAN

LTE & WiFi

LTE 5G, WiFi



LTE 5G

# Use Case: Traffic Signal Advisor

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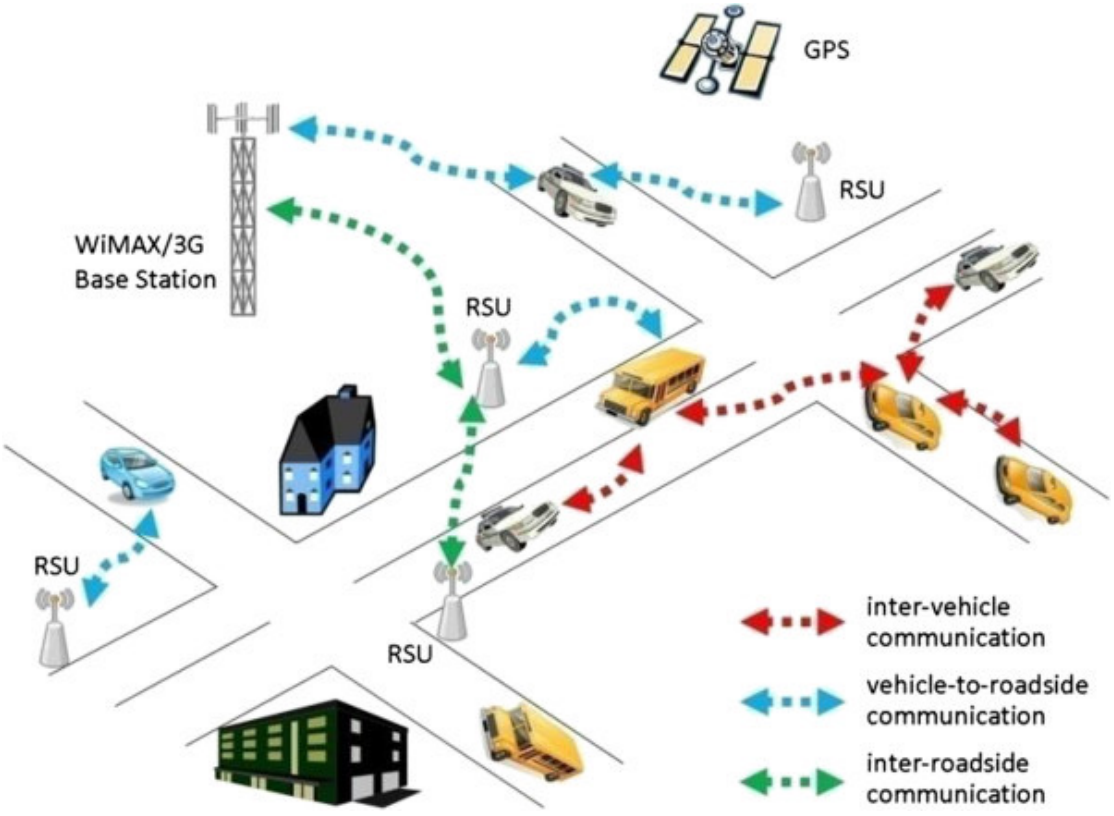
http://www.princeton.edu/~ekoukoum/SignalGuru.html

# 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

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## Stalled vehicle warning

## Blind spots

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

# Google Glass

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**GLASS ENTERPRISE EDITION**

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

# Use Case: Habitat Monitoring

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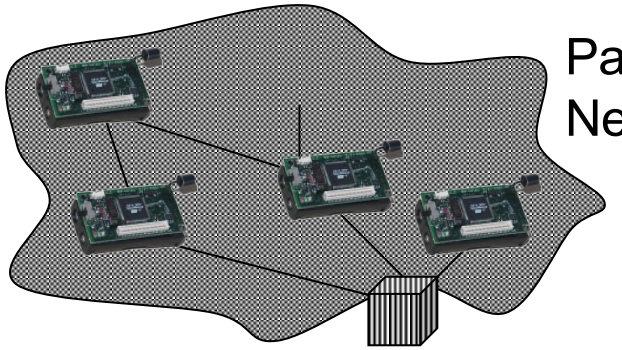
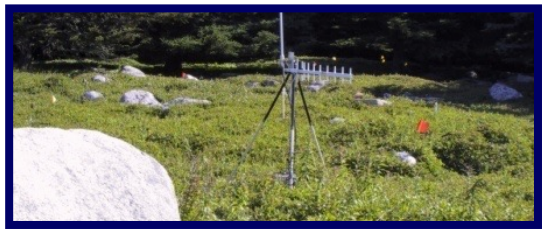
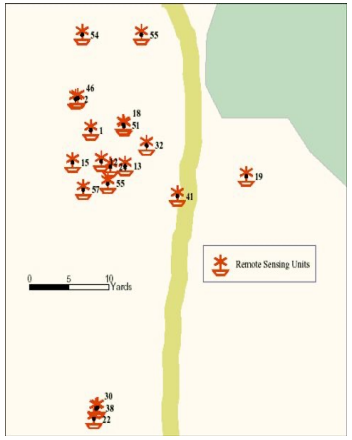
A 15-minute human visit leads to 20% petrel offspring mortality






# Wireless and Mobile Computing

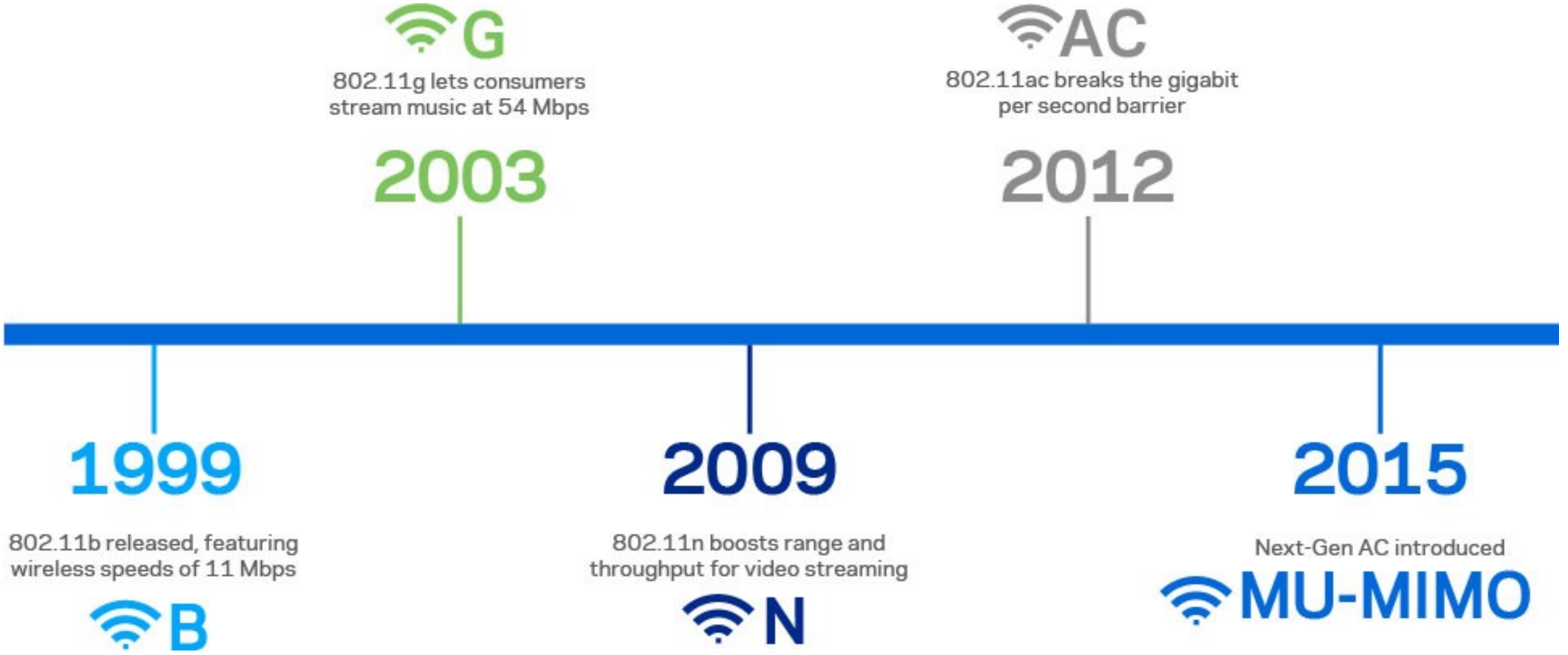


- Driven by technology and vision
  - Mobile device capabilities and platforms
  - Global communication infrastructures
- The field is moving fast

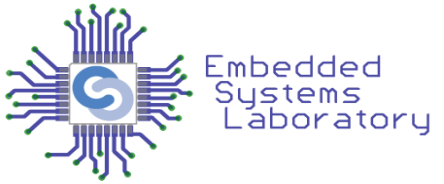
# Enabling Infrastructures

- 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

| | $\alpha_u$ (mW/Mbps) | $\alpha_d$ (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

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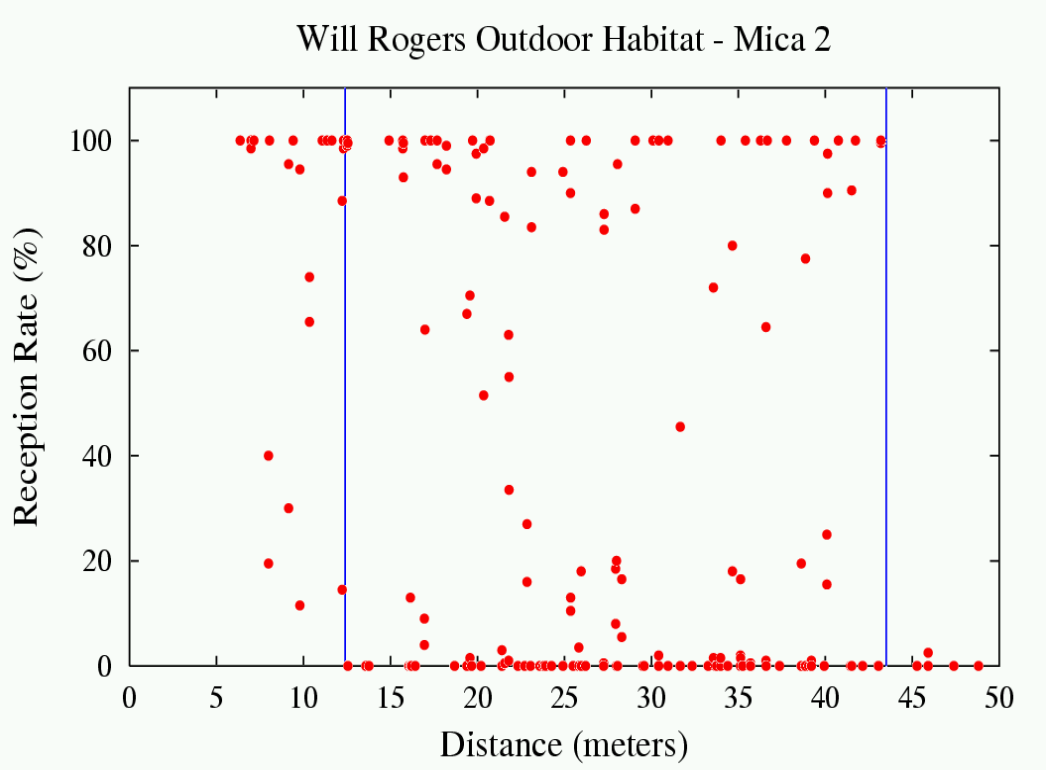
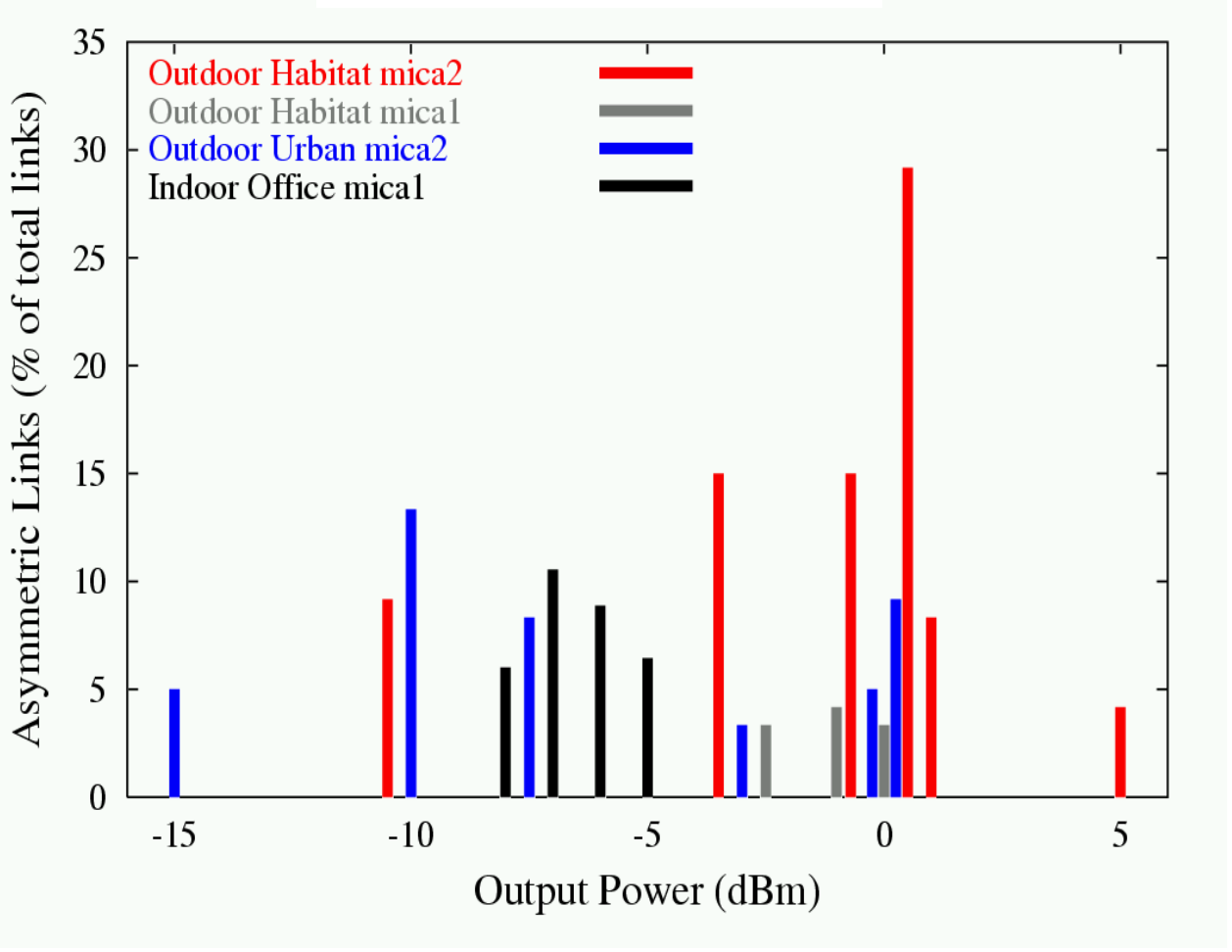
Wireless links are not reliable: they may vary over time and space

Reception v. Distance




*Cerpa, Busek et. al

Reception vs. Power



# Challenge 2: Open Wireless Medium

- 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

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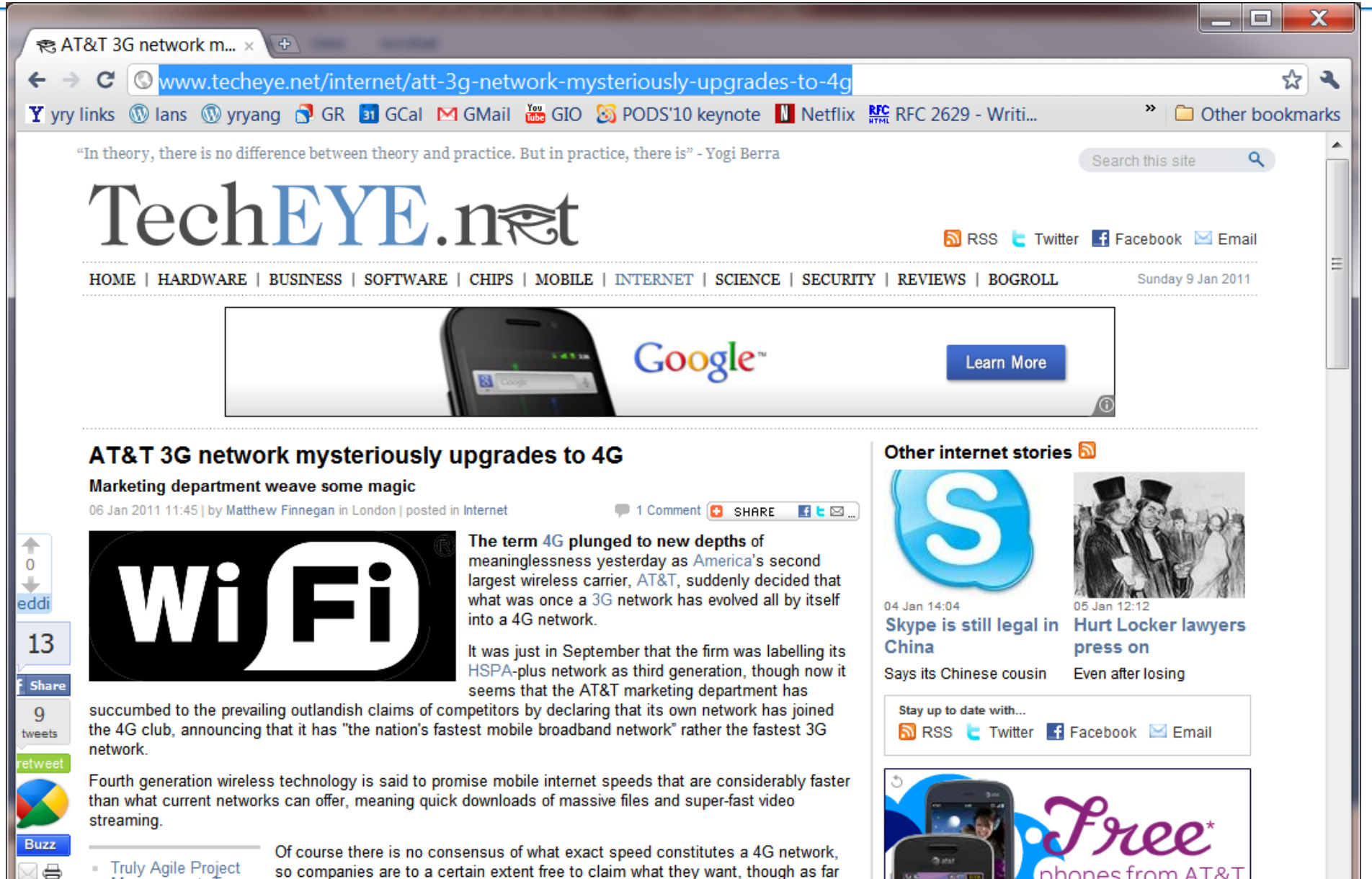
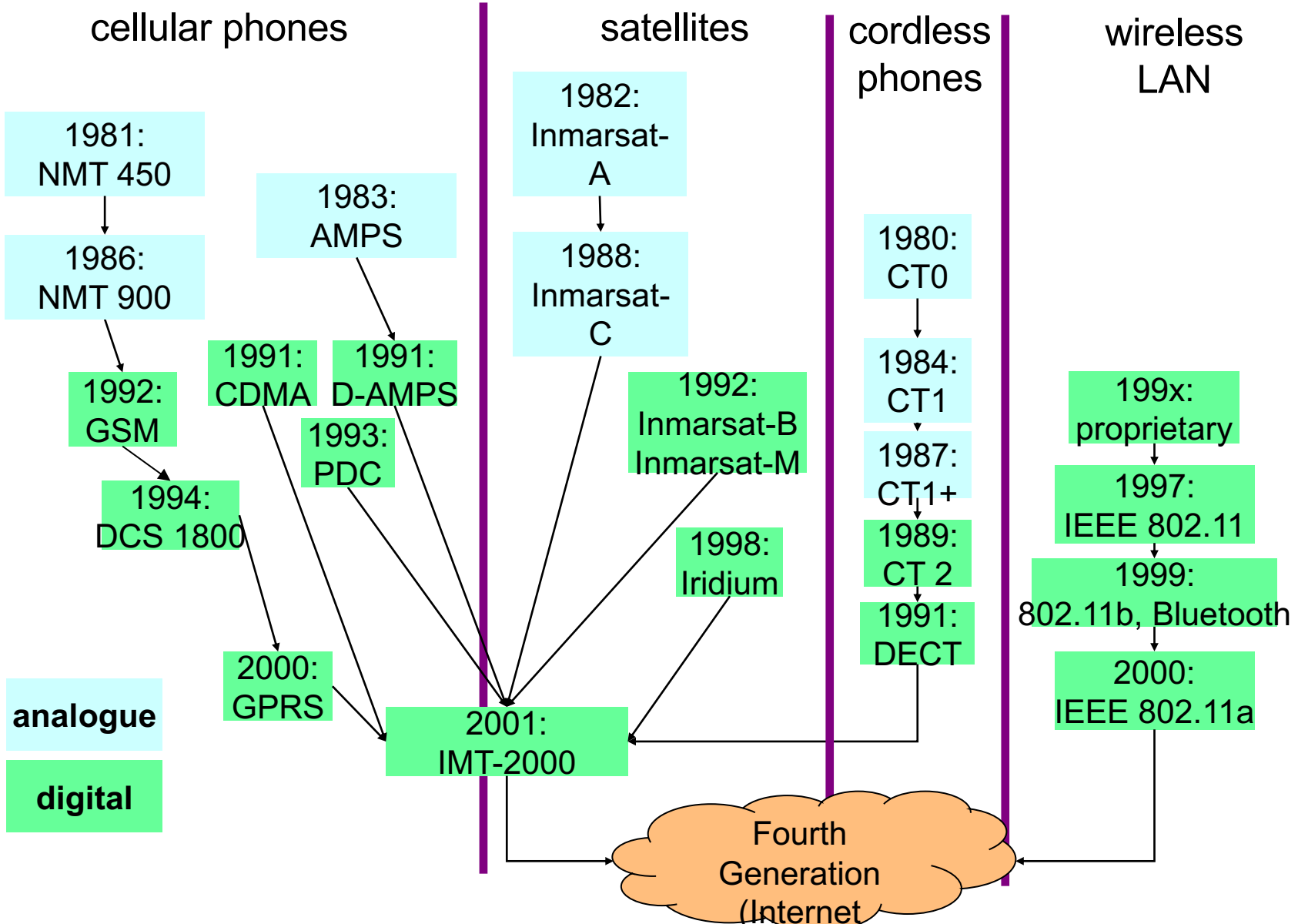


# Challenge 5: Changing Regulation and Multiple Communication Standards



# 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

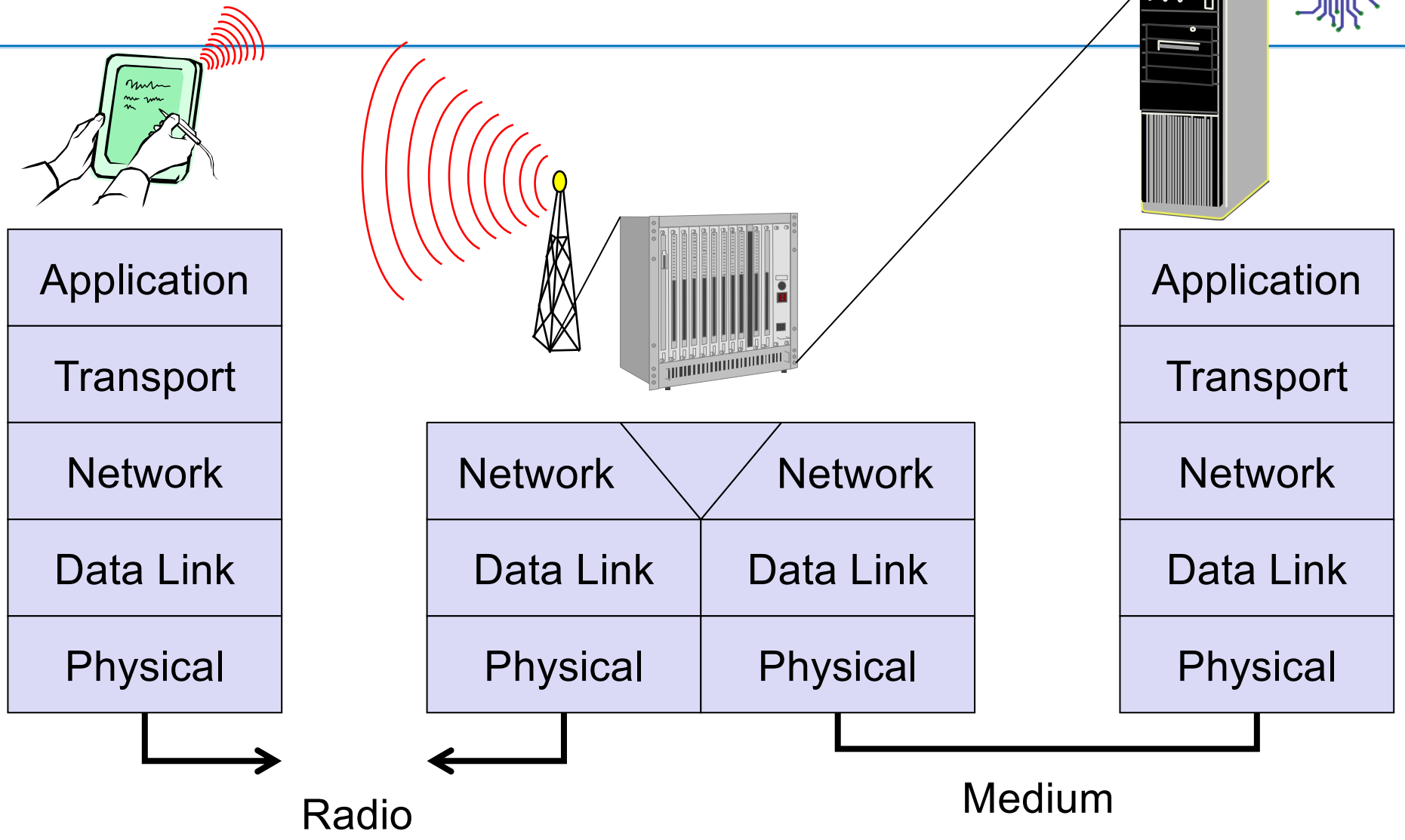
https://en.wikipedia.org/wiki/Mobile_telephony

# What Will We Cover?

# Class Goals

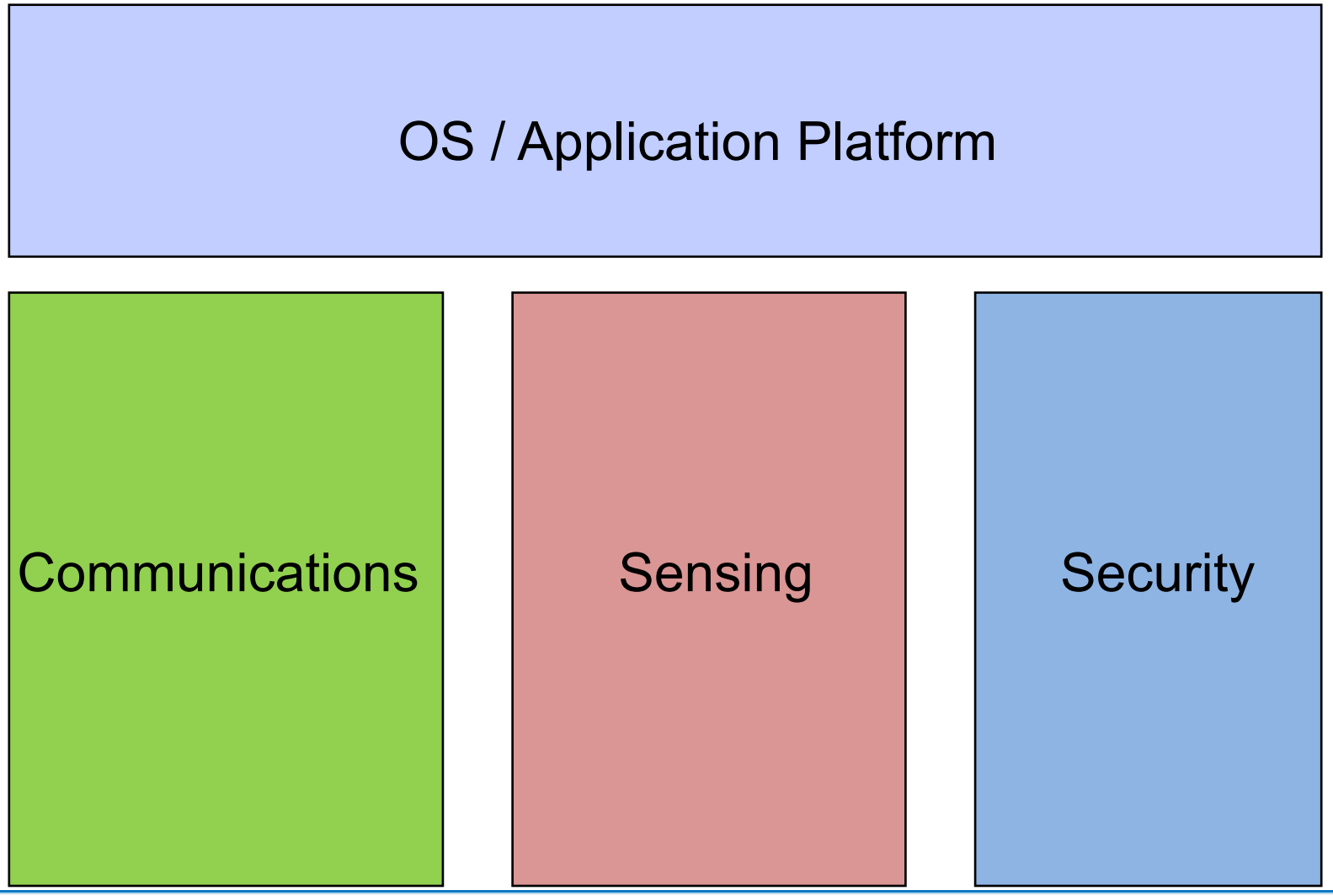
- Learn both fundamentals and applications of wireless networking and mobile computing
- Obtain hands-on experiences on developing on wireless, mobile devices
  - wireless networking, sensor nodes
- Discuss challenges and opportunities in wireless networking and mobile computing

# The Layered Reference Model




Often we need to implement a function across multiple layers.

# Course Topics



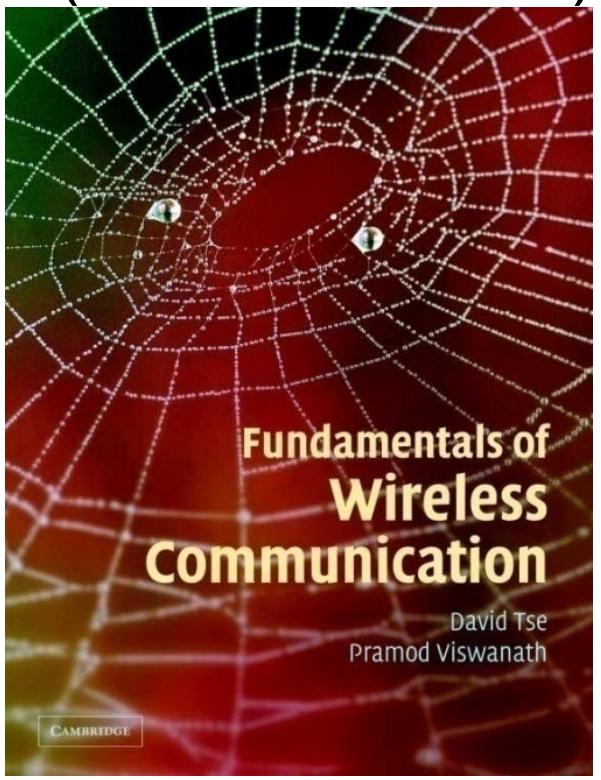
# Class Materials

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

# Suggested Reference Books

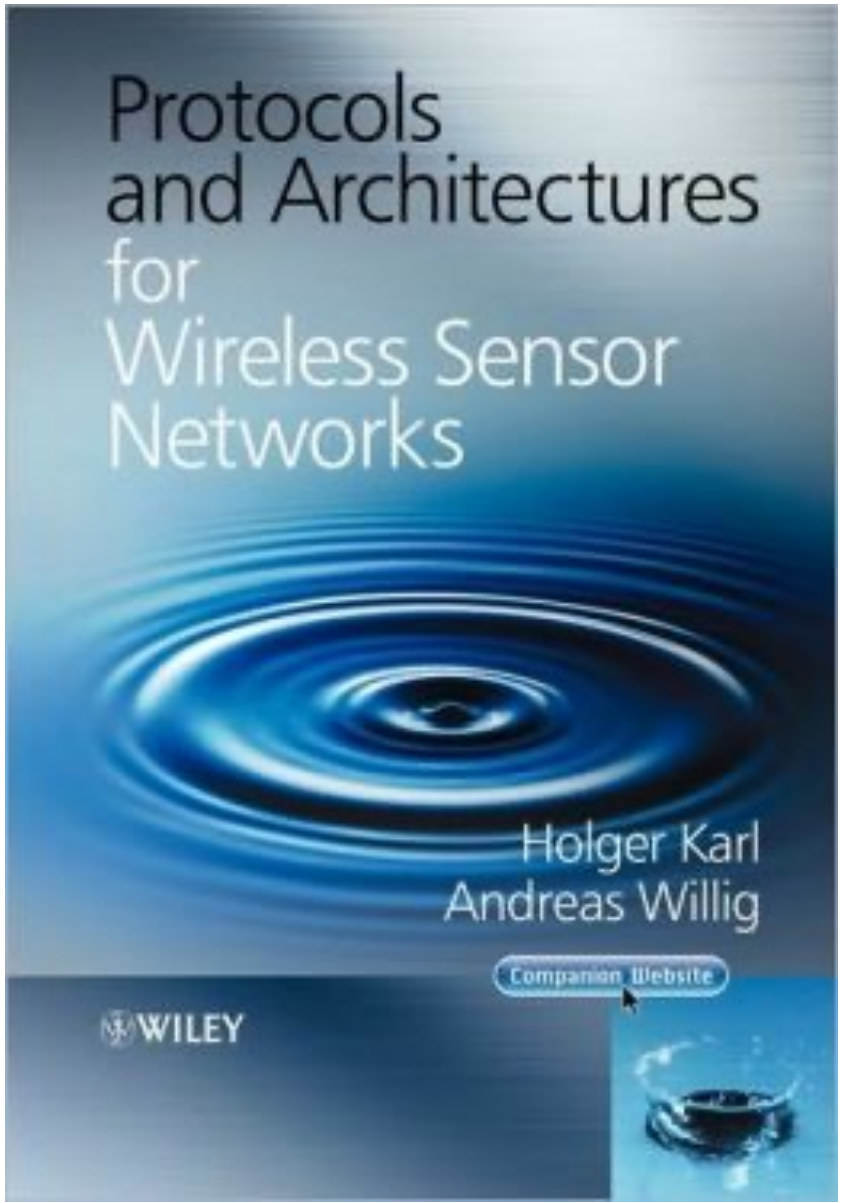
Embedded Systems Laboratory

"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

- 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 build / learn than the grades!