

Mobile and Sensor Systems

Lecture 1: Mobile Systems and
Medium Access Control

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About Me

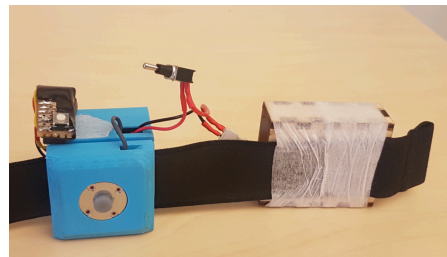
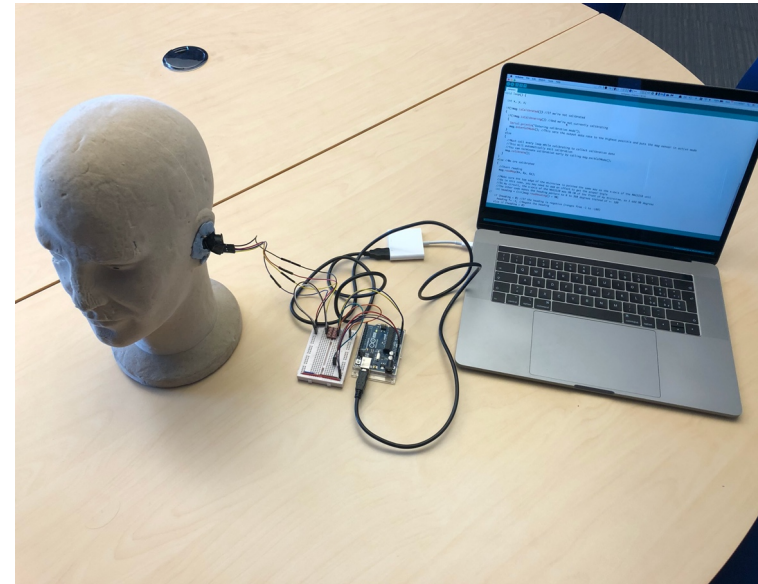


COVID-19 Sounds App

Upload short recordings of cough and breathing and report symptoms to help researchers from the University of Cambridge detect if a person is suffering from COVID-19. Healthy and *non-healthy* participants welcome.



or use the online form



In this course

The course will include aspects related to general understanding of:

- Mobile and ubiquitous systems and networks
- Sensor systems and networks

List of Lectures

- Lecture 1: Intro to Mobile Systems and MAC Layer Concepts.
- Lecture 2: Infrastructure and Opportunistic Mobile Networks.
- Lecture 3: Intro to Sensor Systems, MAC and IoT.
- Lecture 4: Sensor Routing Layer Protocols.
- Lecture 5: Mobile Sensing Machine Learning and Inference
- Lecture 6 Mobile Sensing: Systems Considerations
- Lecture 7: Privacy in Mobile and Sensor Systems
- Lecture 8: Indoor Localization
- Lecture 9: Indoor Localization 2
- Lecture 10: Tracking
- Lecture 11: Mobile Health
- Lecture 12: Mobile Robots

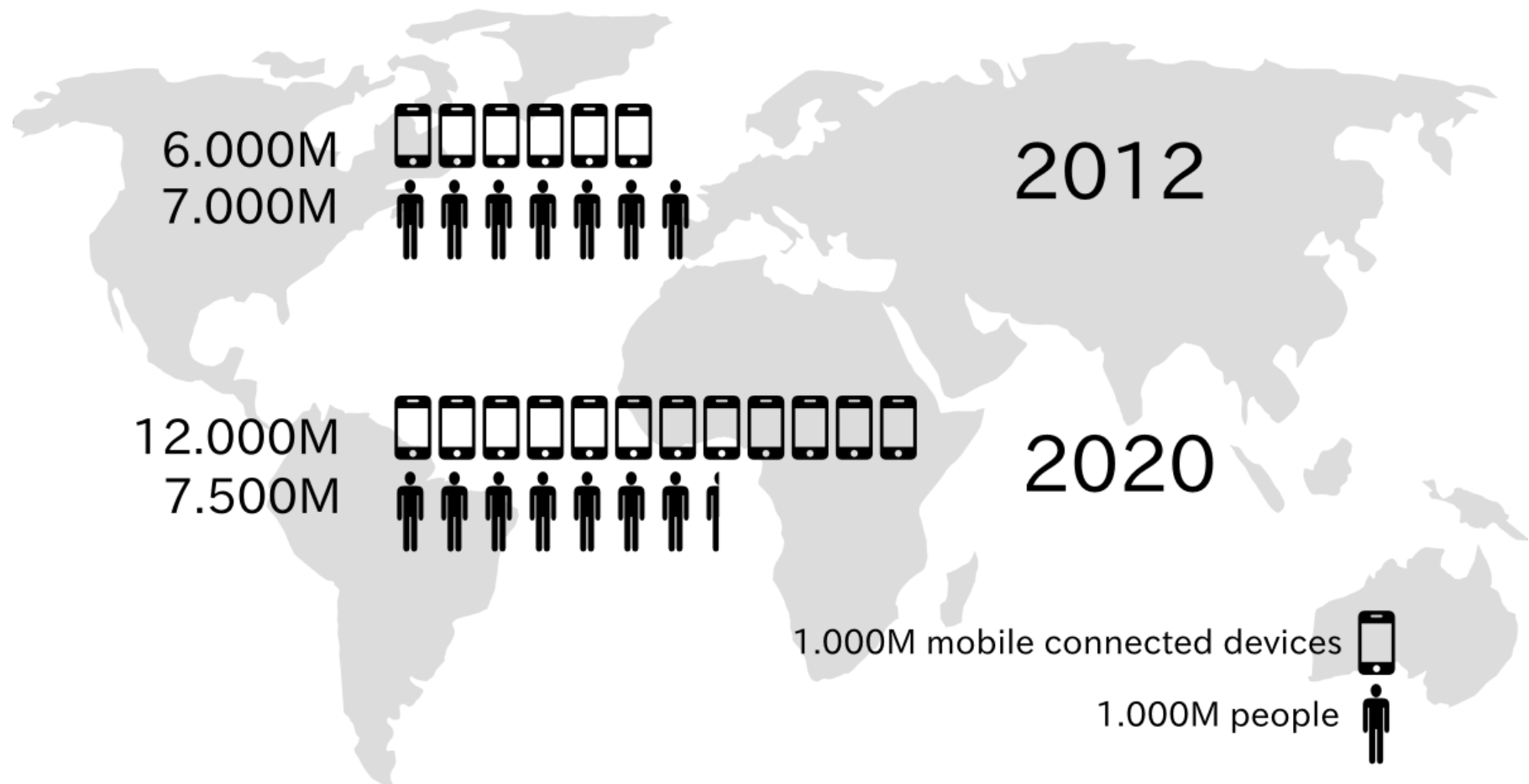
Teaching Material

- Specific lectures will reference research papers which can be used for additional reading.
- No required textbook.
- Some suggested general readings:
 - Schiller, J. (2003). Mobile communications. Pearson (2nd ed.).
 - Karl, H. & Willig, A. (2005). Protocols and architectures for wireless sensor networks. Wiley.
 - Agrawal, D. & Zheng, Q. (2006). Introduction to wireless and mobile systems. Thomson.

In this lecture

- We will describe mobile systems and their applications and challenges.
- We will start talking about wireless networks and medium access layer protocols.

World Population vs Devices

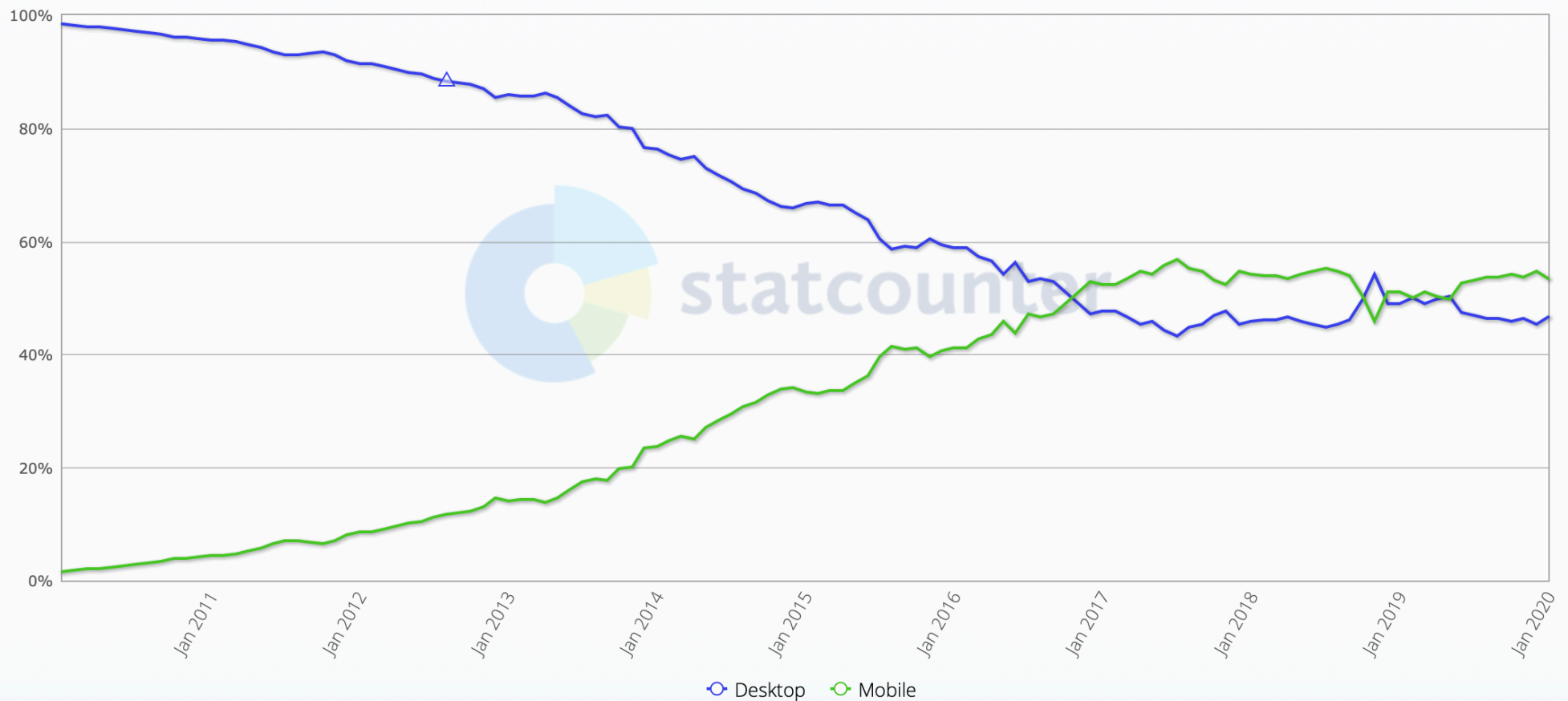


Desktops vs Mobile

Desktop vs Mobile Market Share Worldwide

Jan 2010 - Jan 2020

Statcounter Statistics



For many, a mobile device is the only way to access the Internet

**Mobile-Only
Internet Users**

Country

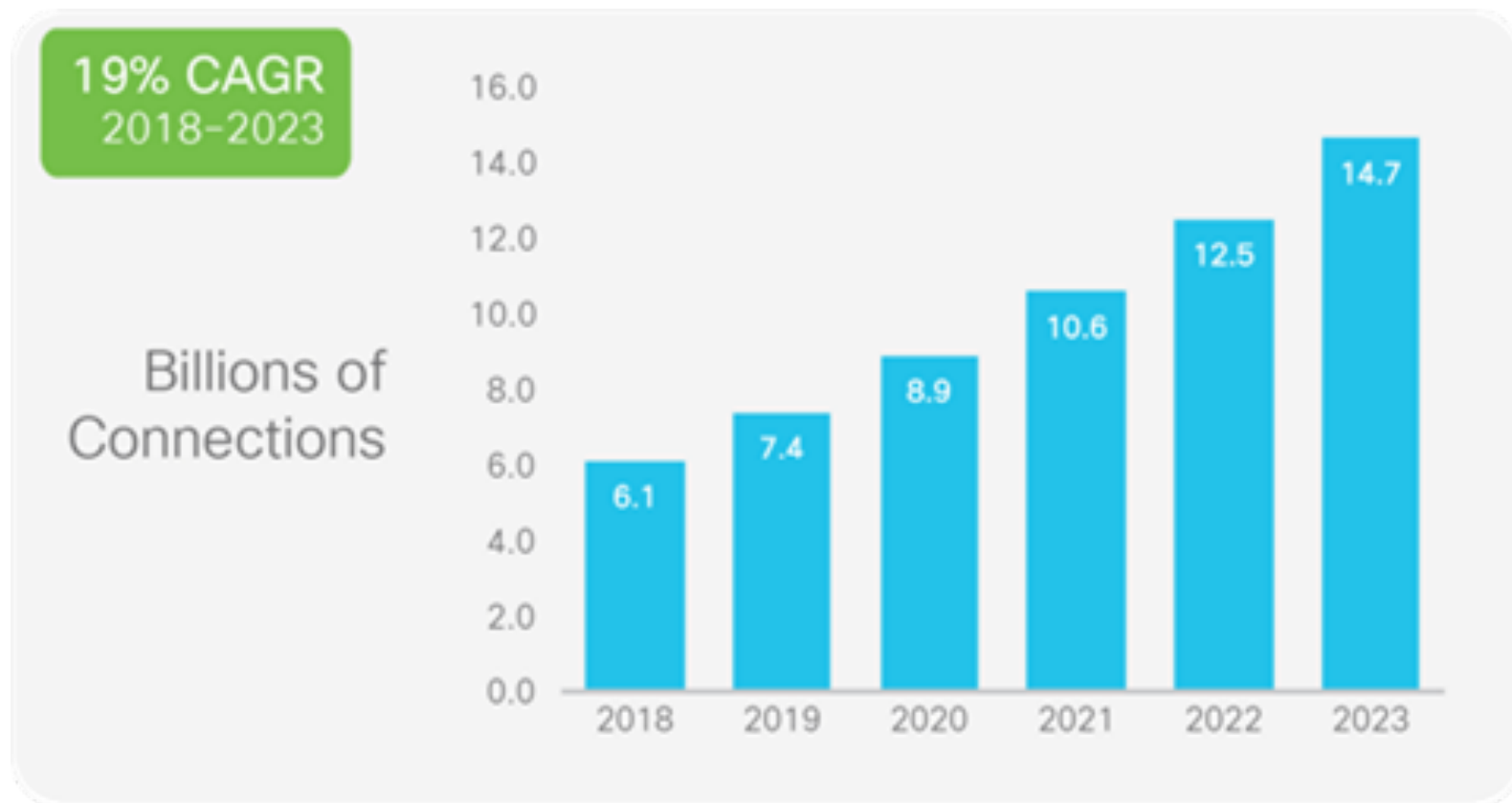
Egypt	70%
India	59%
South Africa	57%
Indonesia	44%
United States	25%

Source: OnDevice Research



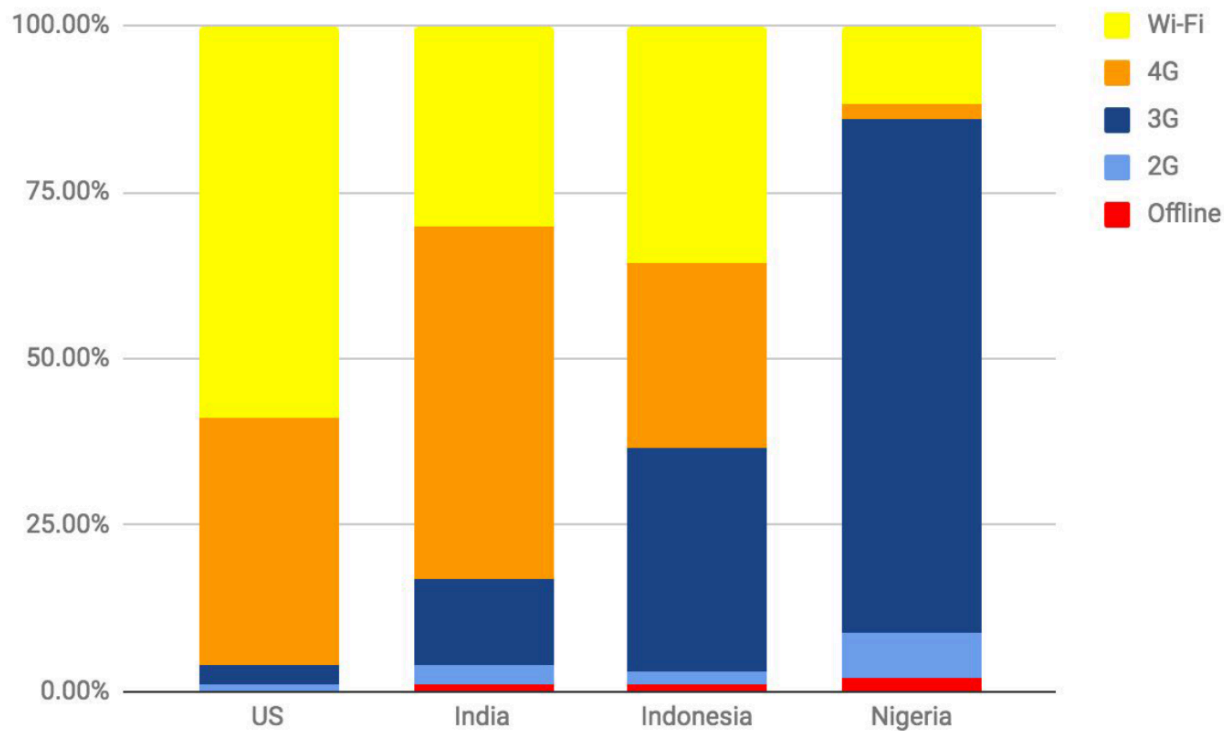
[flickr.com/photos/43560604@N03/6845754798/](https://www.flickr.com/photos/43560604@N03/6845754798/)

Mobile Data



Breakdown for some states of type of connectivity

Fraction of browsing sessions on each network technology



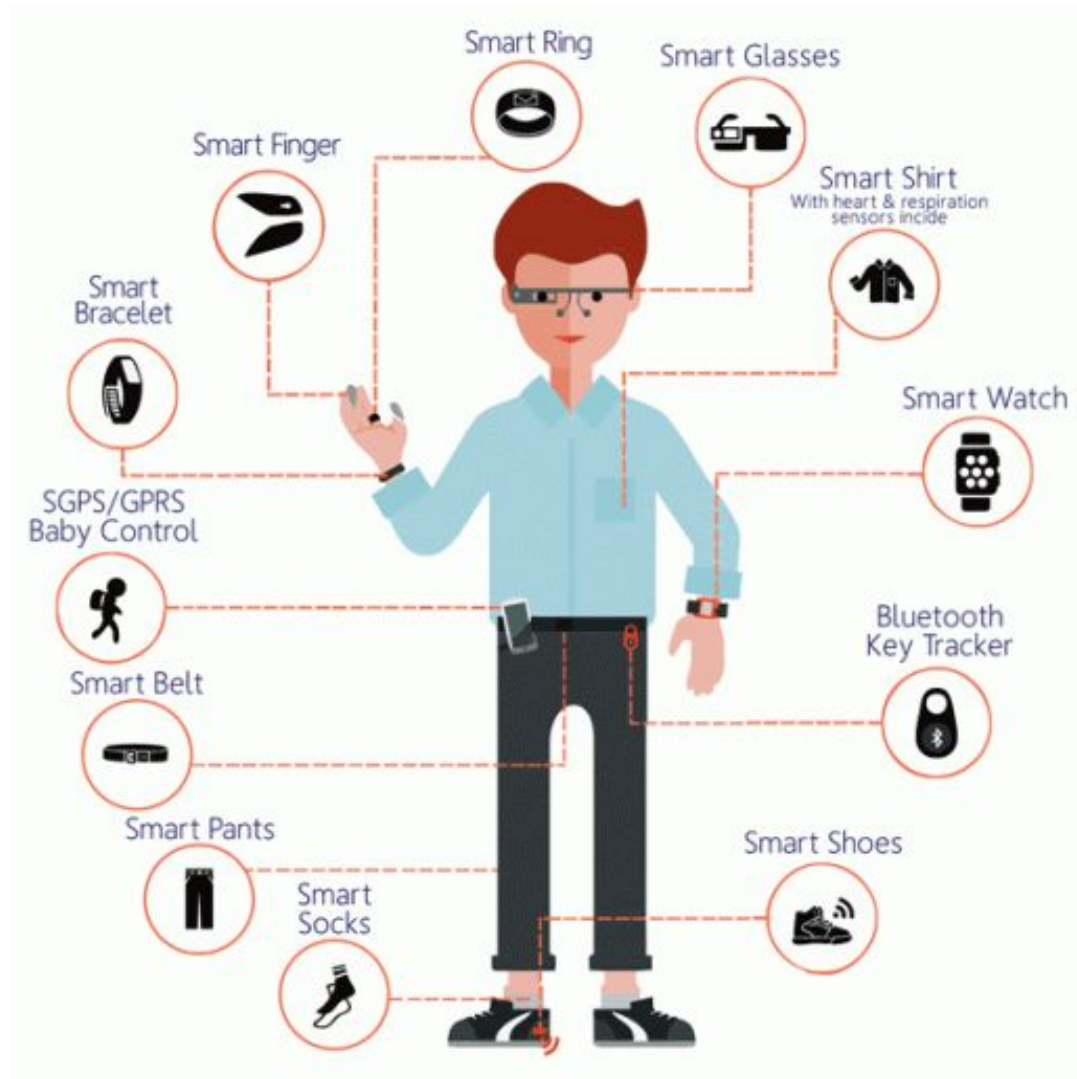
Source: Chrome logs

Phone Sensors and Radios

Various sensors: IMU, GPS, Cameras,
Proximity Sensor, Microphone(s)
Radios: Wifi, Cellular, BLE,..
Processors: CPU, GPU, Coprocessor(s)



Wearables!



Fundamental Challenges in Mobile Computing

- Mobile devices can be resource-constrained.
- Mobile connectivity is highly variable in performance and reliability.
- Mobile devices are inherently less secure.

Mobile Devices are Inherently Resource Constrained

- Mobile devices rely on batteries.
- Energy consumption due to:
 - Computation (CPU, GPU, co-processors)
 - Display
 - Communication
 - Sensing
- Energy-efficient algorithms are needed.

Mobile Connectivity is Highly Variable in Performance and Reliability

- Various types of connectivity:
 - Cellular (3G, 4G, 5G, etc.)
 - WiFi
 - Bluetooth
 - Near Field Communication (NFC)
 - ...
- Constraints related to:
 - Coverage issues
 - Trade-offs: energy consumption, throughput, costs

Mobile Devices are Inherently Less Secure

- Wireless not wired communication:
 - Eavesdropping.
 - Need for encrypted communication.
- Devices can be stolen:
 - Devices might also be accessible by everyone
- Devices sense very “personal” aspects of our lives...

Issues in Designing Mobile Computing Systems

- Distributed systems issues:
 - Remote communication
 - Fault tolerance
 - Remote information access
 - Distributed security
- Networking issues:
 - Wireless communication
 - Transport layer for wireless channel

Issues in Designing Mobile Computing Systems

- Databases issues:
 - Disconnected operations
 - Weak consistency
- Energy issues:
 - Adaptation in terms of communication
 - Intelligent uploading of data
 - Hardware aspects

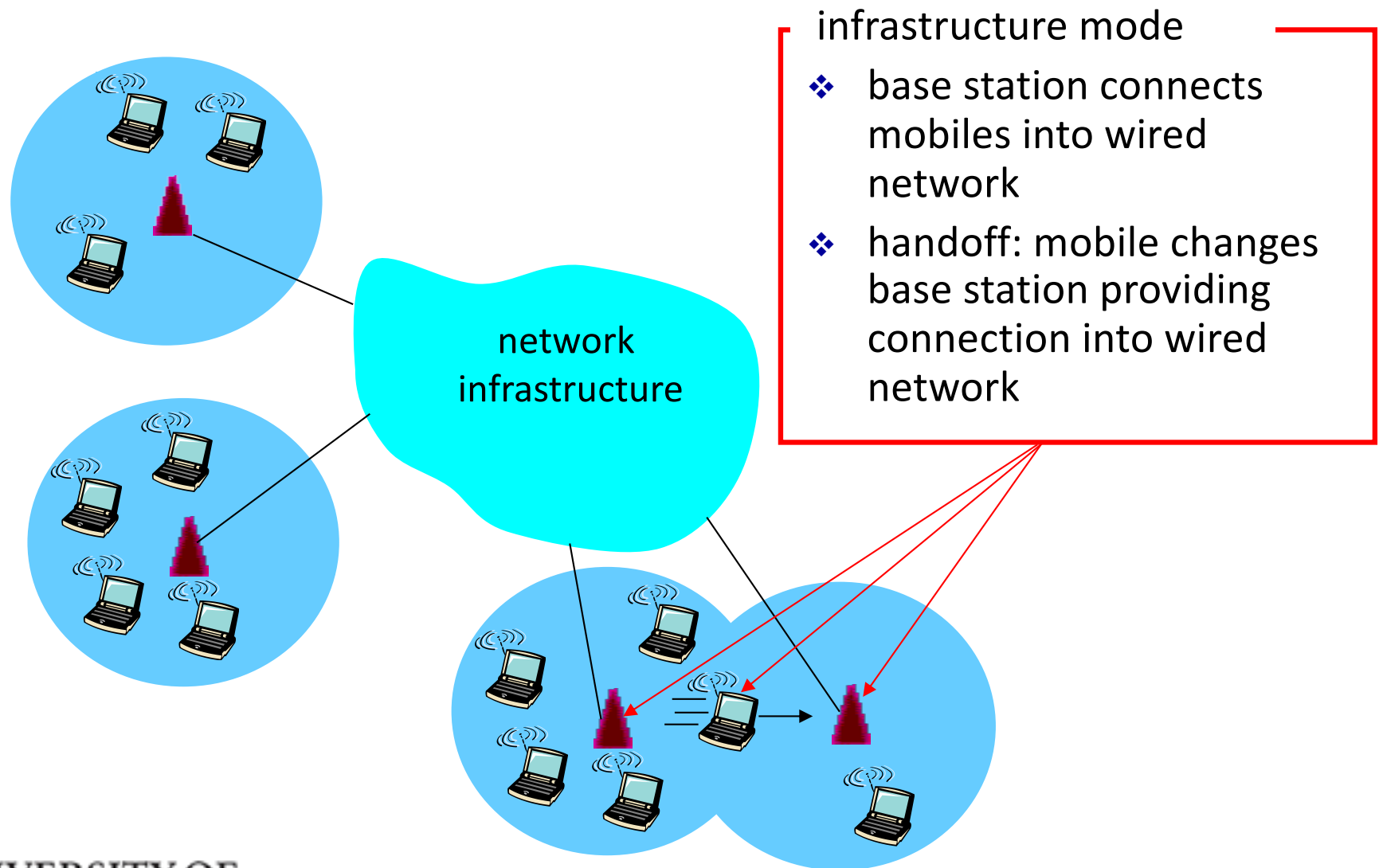
Issues in Designing Mobile Computing Systems

- HCI issues:
 - Limited interface
 - Interaction with the devices (input, etc.)
 - Ergonomics
- Privacy issues:
 - Location sharing
 - Activity recognition
- Security issues:
 - Encrypted communication

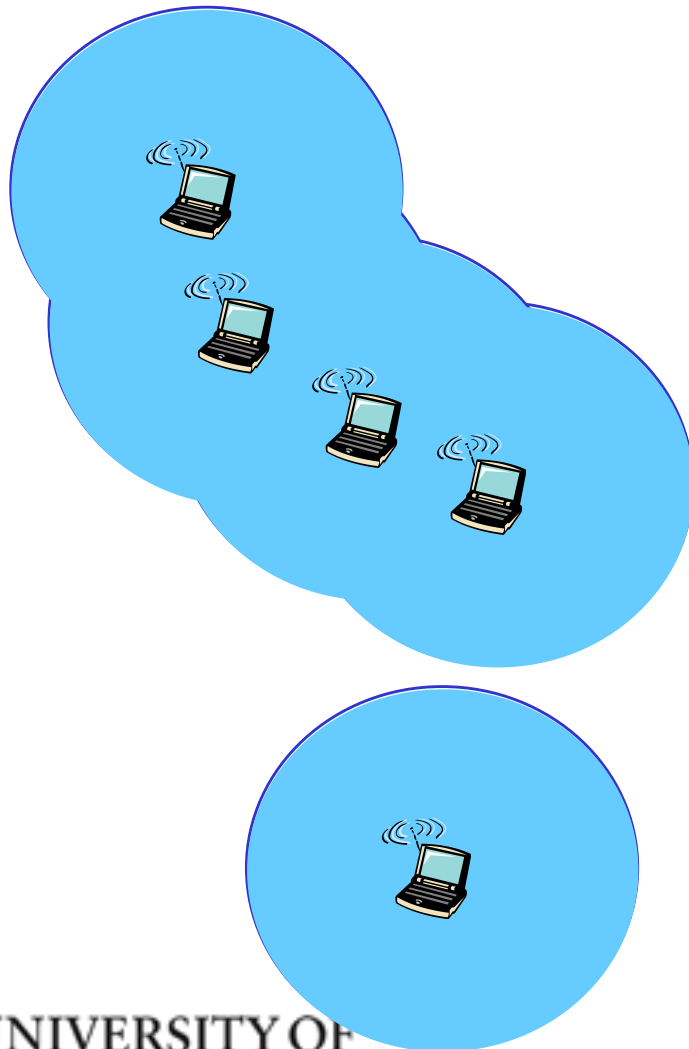
Infrastructure-based vs Ad-hoc

- Wireless communication can be organized in two different fashions:
 - This might depend on the application and on the network set up.

Infrastructure-based



Ad-hoc



ad hoc mode

- ❖ no base stations
- ❖ nodes can only transmit to other nodes within link coverage
- ❖ nodes organize themselves into a network: route among themselves

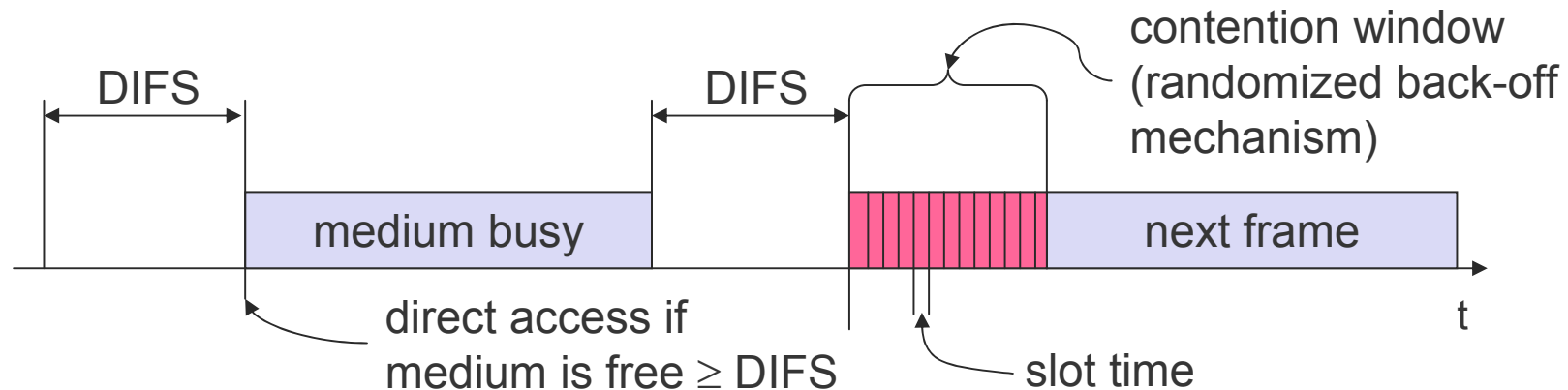
Wireless Medium as Shared Medium

- The access to the wireless needs to be shared among the various transmitters.
- How?
 - Multiplexing the medium:
 - Time (fixed or dynamic)
 - Space
 - Frequency
 - Code

Limitations of multiplexing

- Multiplexing is one way to share the medium through the definition of “channels”.
- Once channels are established, packets will be sent through that:
 - Might be a bit rigid as a method; for example, frequency division multiplexing would have issues with large numbers of users.
 - Also depending on traffic and time some users might want to send more or less;
- More ad hoc approaches exist which allow channels to be shared in a “statistical” way.

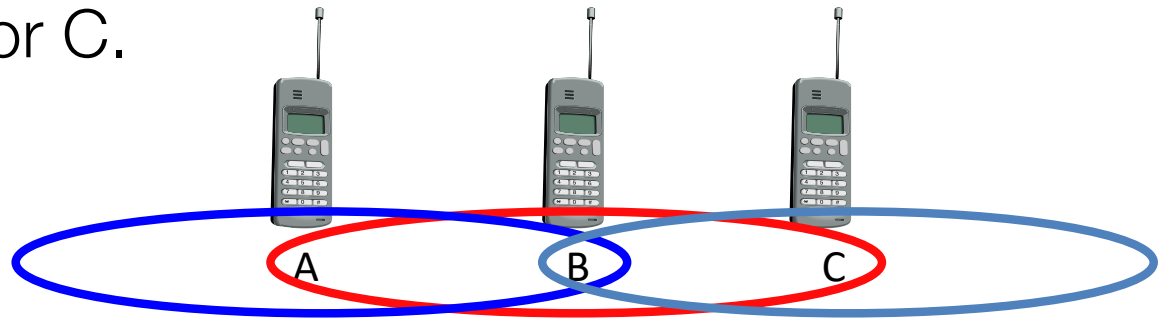
CSMA/CA: Carrier Sensing Multiple Access Protocol with Collision Avoidance



CSMA/CA: sense medium. If free transmit (although this might generate collision at the receiver). If not, wait with a back off strategy. Transmit when medium is sensed free.

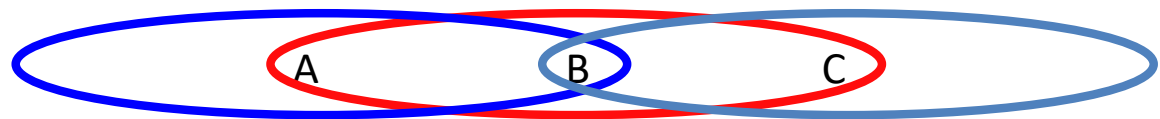
Hidden Terminal

- Hidden terminals:
 - A sends to B, C cannot receive from A.
 - C wants to send to B, C senses a “free” medium (CS fails).
 - Collision at B, A cannot receive the collision (CD fails).
 - A is “hidden” for C.



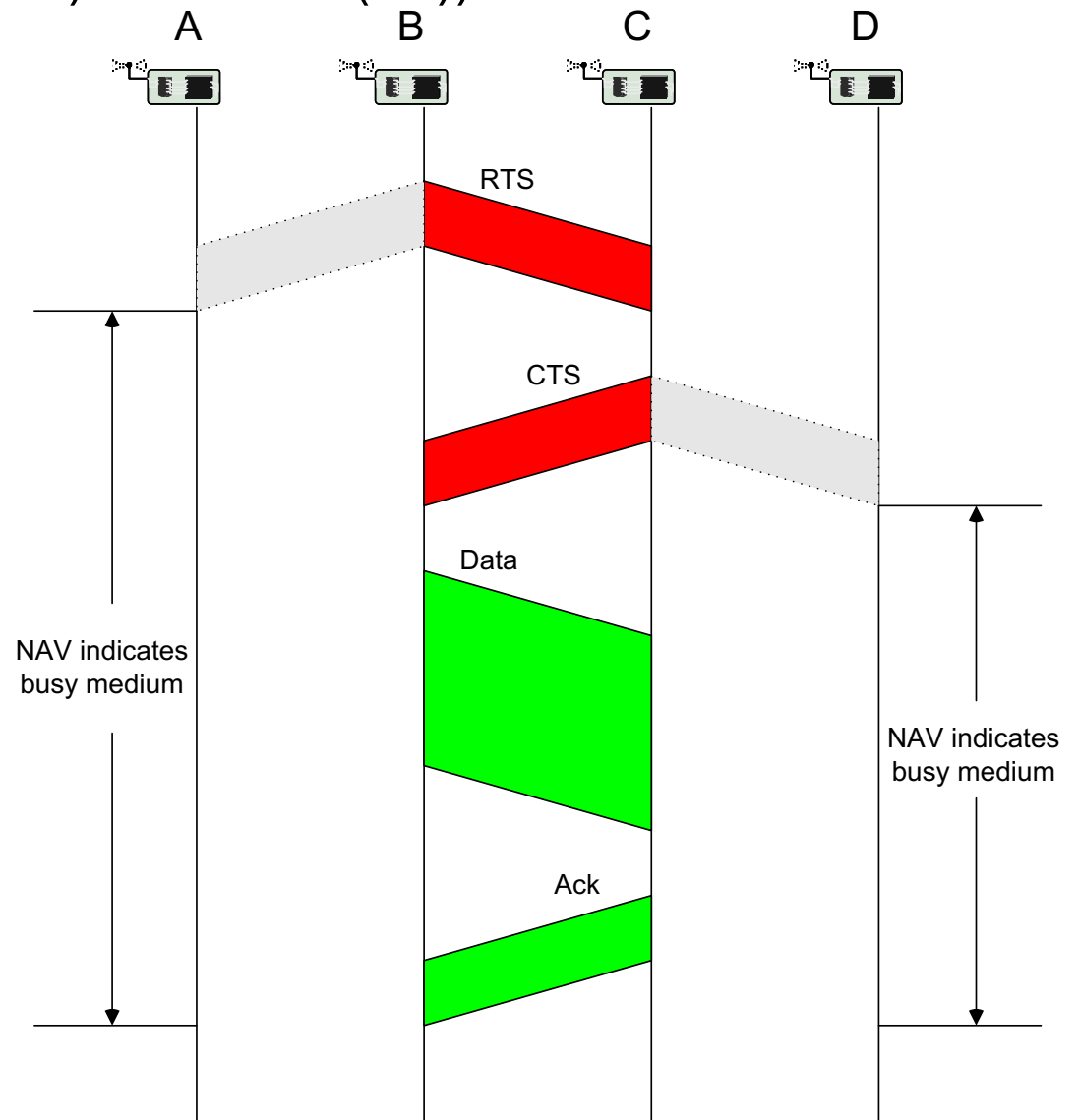
Exposed Terminal

- Exposed terminals:
 - B sends to A, C wants to send to another terminal (not A or B).
 - C has to wait, CS signals a medium in use.
 - but A is outside the radio range of C, therefore waiting is not necessary.
 - C is “exposed” to B.



Multiple Access with Collision Avoidance (for Wireless): MACA(W)

- Sender B asks receiver C whether C is able to receive a transmission *Request to Send (RTS)*.
- Receiver C agrees, sends out a *Clear to Send (CTS)*.
- Potential interferers overhear either RTS or CTS and know about impending transmission and for how long it will last.
 - Store this information in a *Network Allocation Vector*.
- B sends, C acks:
! *MACA(W) protocol* (used e.g. in *IEEE 802.11*).



Summary

- We have introduced Mobile (and Wearable) Systems, its peculiarities and challenges.
- We have talked about medium access control for mobile communication.

Suggested Readings

- Mark Weiser. The Computer for the 21th Century. Scientific American. September 1991.
- Mark Weiser. Some Computer Issues in Ubiquitous Computing. Communications of the ACM. Vol. 36. Issue 7. July 1993.
- M. Satyanarayanan. Pervasive Computing: Vision and Challenges. IEEE Personal Communications. Vol. 8 Issue 4. August 2001.
- Chapter 6 of James F. Kurose and Keith W. Ross Computer Networking. A Top Down Approach. 6th Edition. Pearson 2012.