

Mobile Information Systems

Lecture 02 – Big Issues

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Key issues of MIS (recap)

- Limited power supply
- Limited storage
- Wireless communication channels
- Limited/different I/O capabilities
- Unpredictable usage context
- Privacy & Security
- Sustainability

Key issue: power (1)

Image source (CC): <https://www.flickr.com/photos/intelfreepress/10190082395/>

- Limited power supply
 - Tradeoff: capacity ↔ size/weight/portability
 - Energy consumption becomes important
- Two possible solutions:
 - Increase energy ↔ size/weight ratio
 - Requires chemistry & physics knowledge
 - Out of scope for this course :-)
 - Decrease energy consumption
 - Requires CS/EE knowledge
 - *In scope* for this course

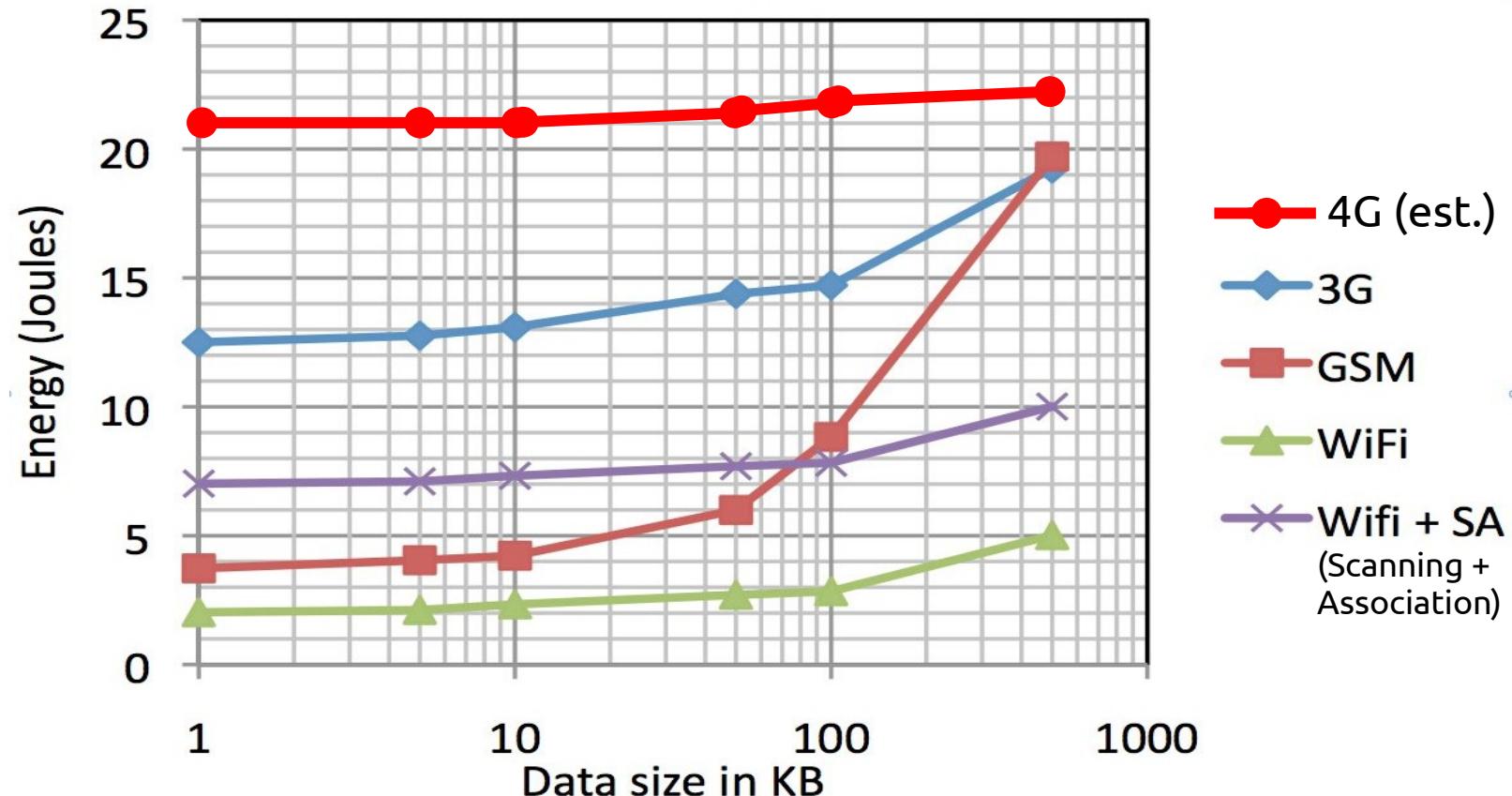


Key issue: power (2)

- Biggest energy consumers (highest first):
 - Display (& backlight)
 - GPS receiver, camera
 - Wireless modules (4G, 3G, WiFi, Bluetooth)
 - Sensors (touchscreen, accelerometer/IMU, ...)
- Energy-saving approaches:
 - Whenever possible, disable unused subdevices
 - Alternative: use lower polling frequency
 - Look for possible tradeoffs, e.g. move computation-intensive tasks to cloud service

Energy demand of wireless transfers

Image source (FU): <http://people.cs.umass.edu/~arun/papers/TailEnder.pdf>



Key issue: storage (1)

- Limited storage
 - Standard is ~ 8 GB in entry-level smartphones
 - Data (partially) stored in „cloud“ services
 - Requires network connection for access
 - Tradeoff: bandwidth ↔ storage
- Reason: flash memory – why?
 - Many related tradeoffs:
price ↔ volume ↔ capacity ↔ power consumption

Key issue: storage (2)

Image source (CC): https://en.wikipedia.org/wiki/Hard_disk_drive#/media/File:Laptop-hard-drive-exposed.jpg

	Hard disk	Flash memory
<i>Price (2023)</i>	~ 15 € / TB	~ 50 € / TB
<i>Density</i>	~ 0.1 GB/mm ³	~ 1.5 GB/mm ³
<i>Power consumption</i>	~ 1 W (idle), 2-3 W (operation)	~ 0.1 W (idle), 0.5W (operation)
<i>Typical capacity</i>	~ 8-12 TB	~ 512 GB



Power/storage: summary

- Primary tradeoff: size/weight \leftrightarrow capacity
- Secondary tradeoffs:
 - Power: conserve power, turn off consumers
 - Storage: “outsourcing” to cloud service
 - Increased traffic due to cloud communication may increase power consumption!

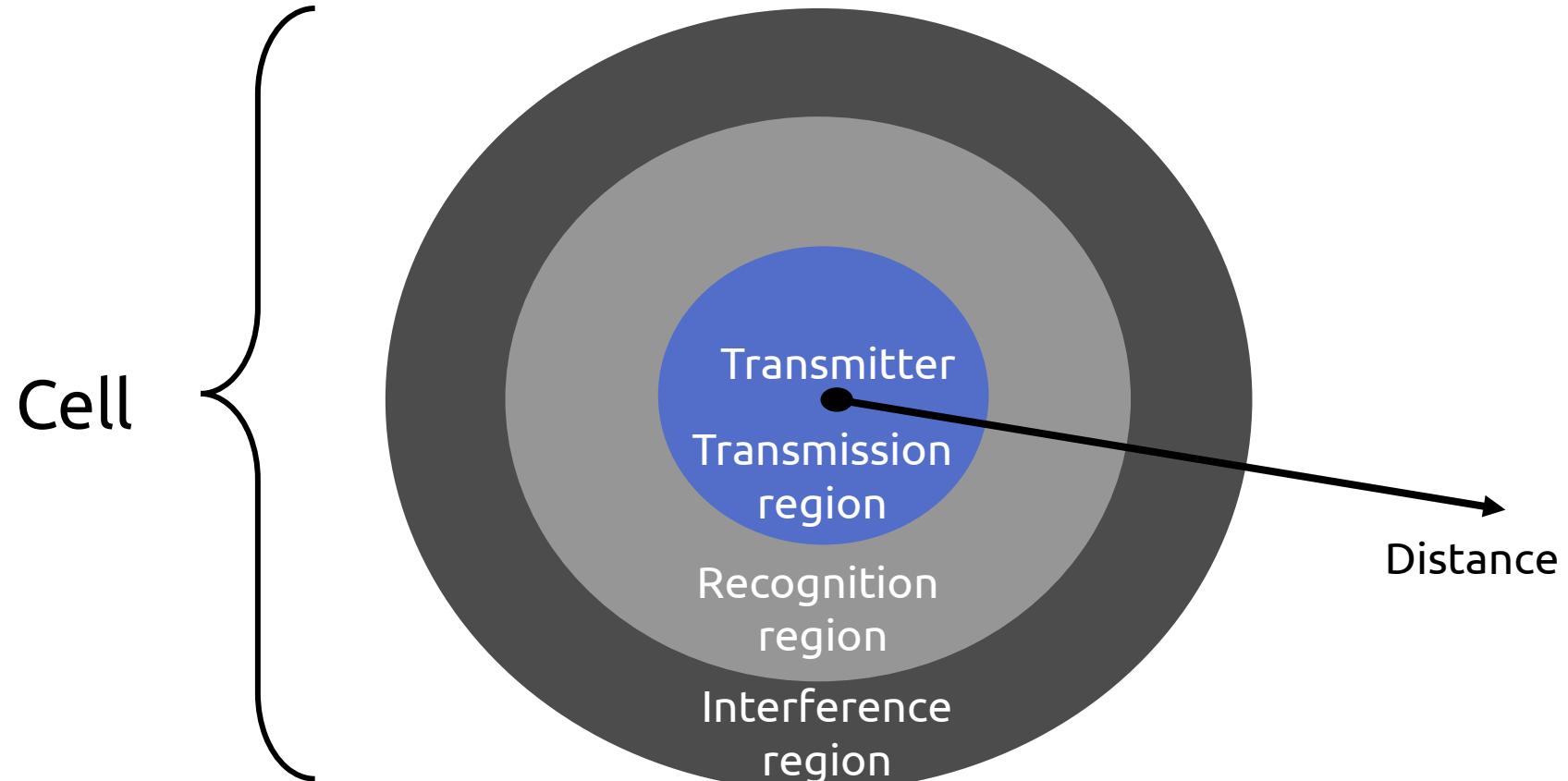
Key issue: wireless

- Wireless communication
 - Unpredictable availability & throughput
 - Tradeoff: bandwidth \leftrightarrow energy consumption
 - Media size growing faster than bandwidth (4K)
 - Abrupt quality-of-service changes
 - Round-trip-time (RTT) may be too high for interactive applications

Wireless basics

- Basics of signal theory
- Signal transmission & interference
- Classification of wireless networks
- ISO/OSI model, TCP/IP stack

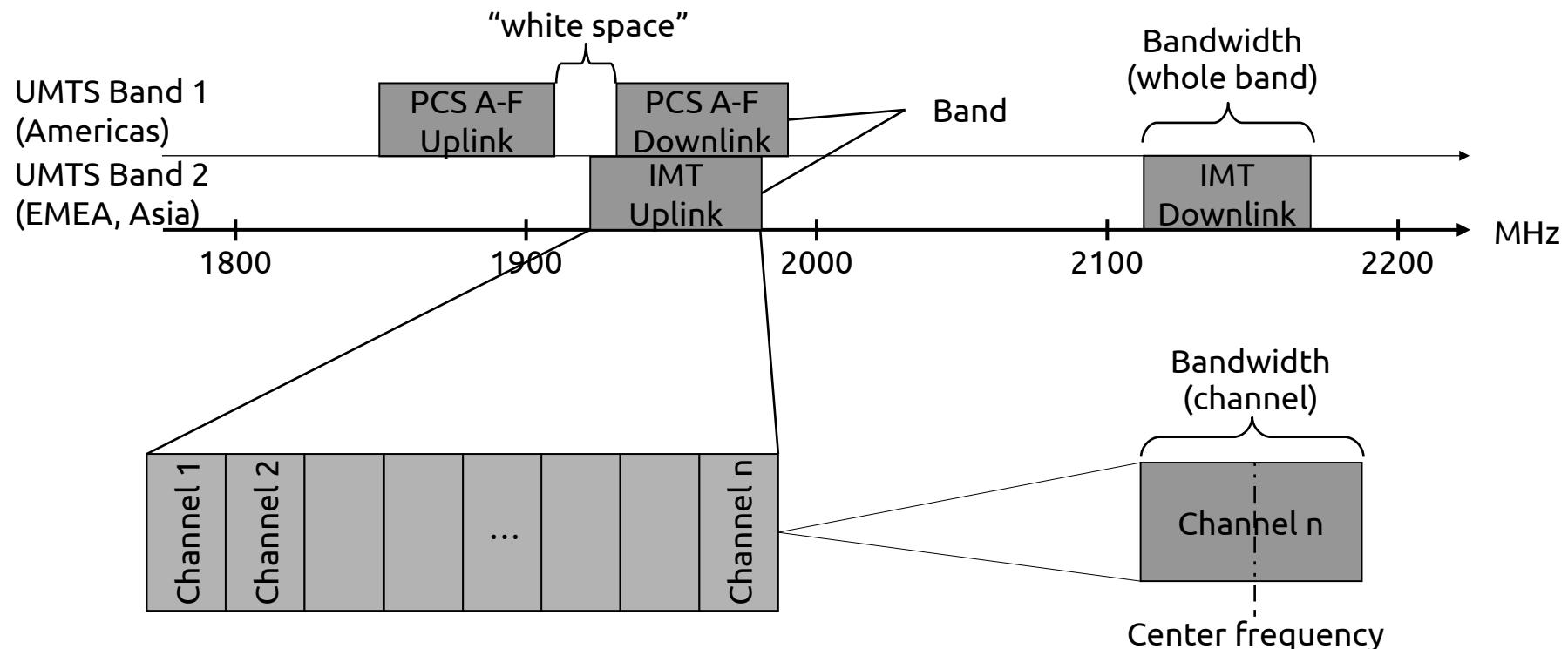
Wireless basics: signal transmission



Wireless basics: signal theory (1)

- Communication with electromagnetic waves
 - Frequency $\sim 0.5 - 5$ GHz \rightarrow no line-of-sight required
- Channel capacity/throughput depends on:
 - Channel bandwidth
 - Given in MHz (e.g. 60 MHz for common UMTS bands)
 - Limited by hardware/cost as well as regulations
 - Modulation method
 - Encodes data on the carrier wave ("center frequency")
 - Analog (AM/FM, known from radio) or digital (usually QAM, quadrature amplitude modulation)

Wireless basics: signal theory (1)



US Frequency Allocation Chart 2011

Image source (PD): https://en.wikipedia.org/...The_Radio_Spectrum.pdf

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM



ALLOCATION USAGE DESIGNATION

Primary	Secondary	Other
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U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management
August 2011

FCC NIST NTIA



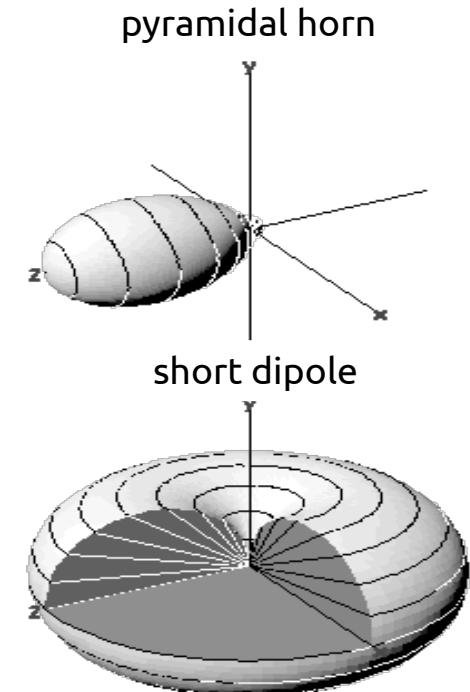
Wireless basics: signal theory (2)

- Channel capacity/throughput (continued):
 - Channel sharing (time/frequency slots)
 - Multiple simultaneous transmissions on same frequency will cause interference (sometimes also on adjacent channels)
 - Arbitration scheme required, either time-domain (round-robin) or frequency-domain (sub-channels)
 - Signal-to-noise ratio (SNR) at receiver
 - Signal: energy of the data I want to receive
 - Noise: energy of everything else (thermal noise, other transmitters, cosmic radiation, ...)

Wireless basics: antennas

Image source (PD): https://en.wikipedia.org/wiki/Radiation_pattern#/media/File:Radiation-patterns-v.png

- Antennas: multiple characteristics
 - Gain (~ efficiency)
 - Radiation pattern (horn/dipole →)
- Ideal omnidirectional antenna:
 - Does not exist in reality
 - Can be “simulated” through multiple real antennas
- Antenna selection can help improve SNR



Wireless basics: negative effects (1)

- Refraction
 - Varying densities of the transmission media disrupt/redirect electromagnetic (EM) waves
- Reflection
 - Material smooth in the same size range as the EM wavelength (cf. RADAR dish, microwave oven door)
- Absorption
 - EM energy is absorbed by matter
- Diffraction
 - EM waves bend around small obstacles

Wireless basics: negative effects (2)

- Interference
 - Multiple transmitters on the same frequency band/ channel or reflections of a single transmitter
 - Can lead to crosstalk and areas without signal
- Multipath scattering
 - Multiple different transmission paths between sender and receiver
 - Can be used as advantage by MIMO systems with multiple antennas

Wireless basics: classification (1)

- Wireless local area networks (WLAN)
 - Replacement for wired LAN (e.g. Ethernet)
 - 802.11x protocol family (currently x = a/g/n/ac/x)
 - up to ~ 800 Mbit/s (in theory), 20-50 m indoor range
- Wireless personal area networks (WPAN)
 - Short-range communication between peripherals
 - 2-10 m range, ~ 3 Mbit/s, Bluetooth protocol family
- WiGig (802.11ad)
 - WLAN in 60 GHz band → very high data rate (up to DisplayPort), but needs line-of-sight, low range

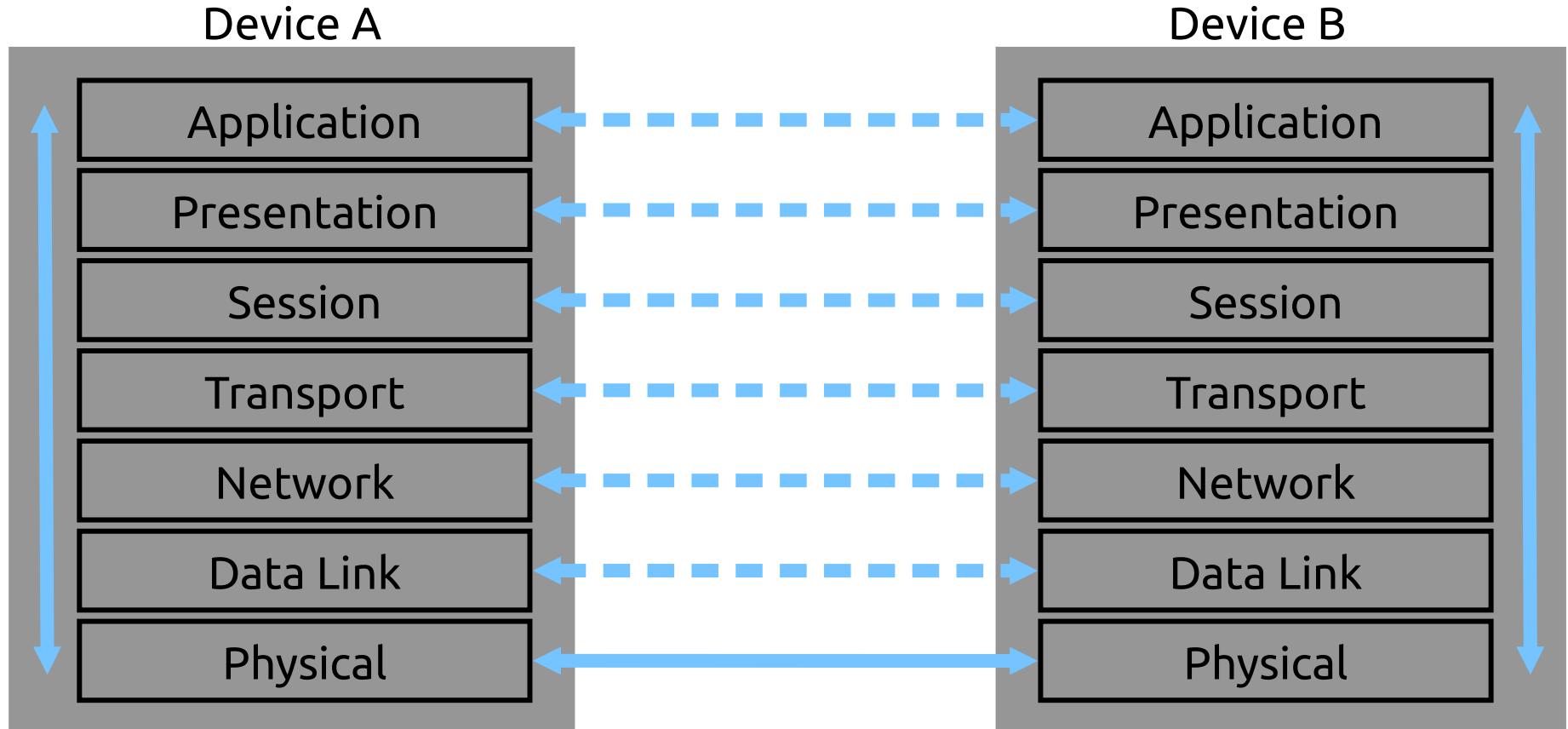
Wireless basics: classification (2)

- Cellular networks (WWAN, ... wide area ...)
 - Terrain-based – 2G (GSM), 3G (UMTS), 4G (LTE), 5G
 - Satellite-based – Globalstar, Iridium
 - Asymmetric bandwidth allocation (mostly downstream, to device)
- Mesh networks
 - No central access point, peer-to-peer network
 - Used for low-power sensors, “Freifunk” networks
 - Can be based on WLAN, Bluetooth, Zigbee, ...
- 5G: has substandards for WLAN, WWAN, ...

Wireless basics: ISM bands

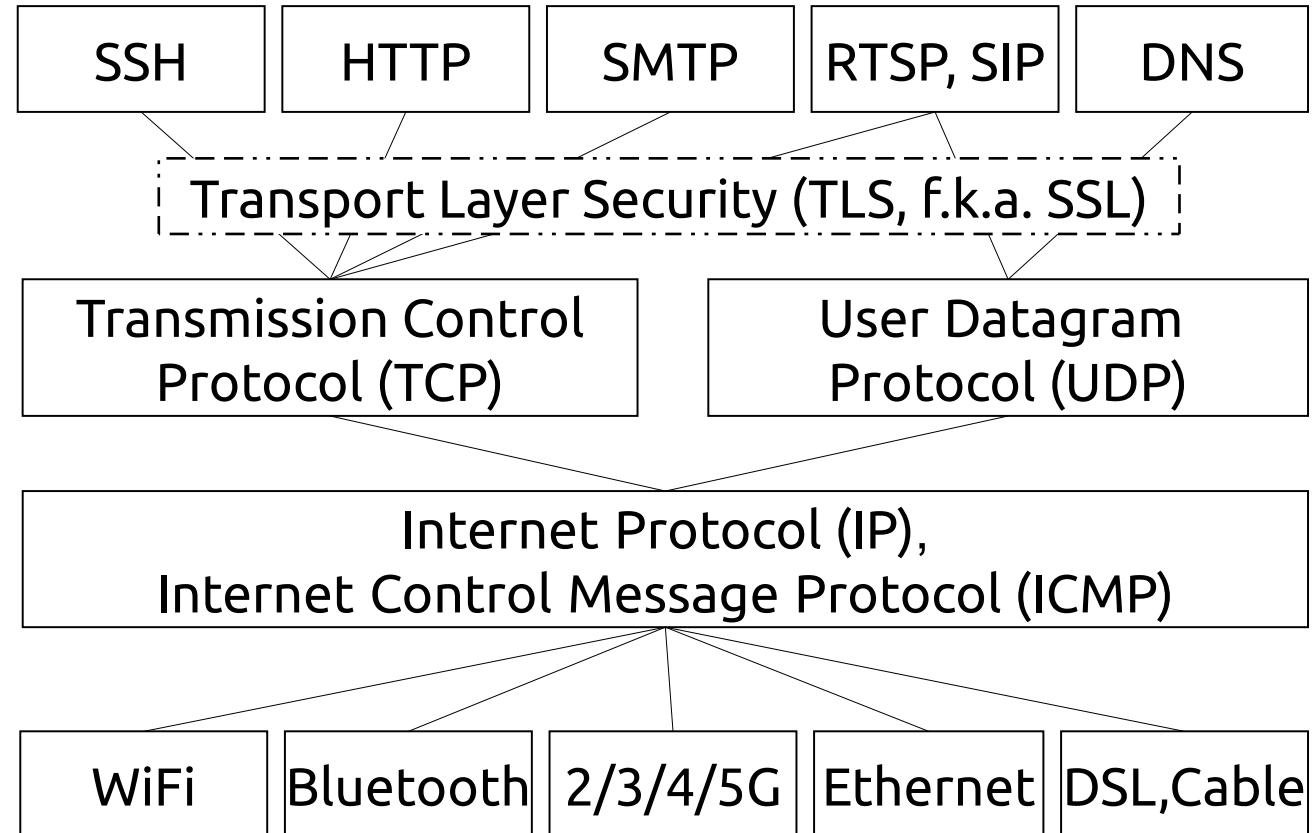
- ISM = Industrial/Scientific/Medical
 - Bands designated for unlicensed use, commonly 434 MHz/915 MHz (US/EMEA), 2.45 GHz, 5.8 GHz
- Any equipment may transmit on these bands:
 - Microwave ovens (commonly 2.4 GHz)
 - Industrial processes (e.g. plastic welding)
 - Tumor treatment (also with microwaves)
- Also allowed for communications devices
 - E.g. WLAN & Bluetooth in 2.45 GHz band, must be able to deal with ISM device interference

Wireless basics: ISO/OSI model



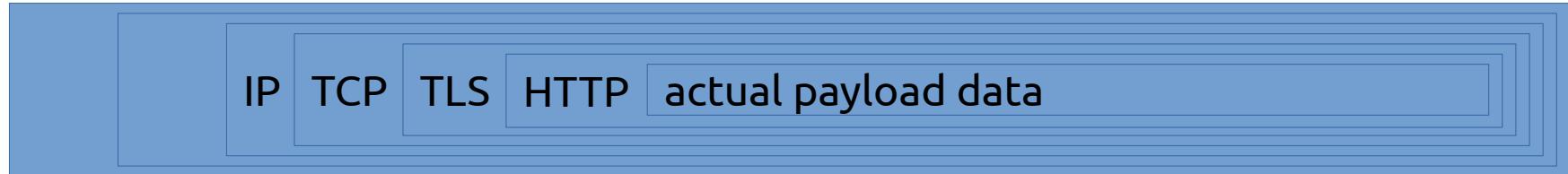
Wireless basics: TCP/IP stack

Application
Layer



Recap: network stack protocols

- Layered protocols → nested data packets
- Packets consist of header + payload
- Payload of protocol 1 = packet of protocol 2



Wireless: summary

- Many physical issues (refraction, absorption, antenna geometry, power limits ...)
- Wireless spectrum is highly contested
 - Many sources of interference
 - Limited bandwidth available
- Complex interleaved HW/SW stack

Key issue: I/O

Image source (FU): The Simpsons (S21E11), Fox Broadcasting Company

- Different I/O capabilities
 - Small screens, often no physical keyboard
 - Text entry/precision work much slower (“Fat finger problem”)
 - Less room for displaying data (cf. InfoVis)
 - Use other channels ...
 - For input: touch, gestures, motion, camera, location, ...
 - For output: vibration, sound, speech, notification LED, ...
 - Tradeoff: size/weight ↔ I/O features?



I/O issues: touch (1)

Image source (FU): <http://tactustechnology.com/wp-content/uploads/2014/08/White-Paper-New-Tagged-PDF.pdf>

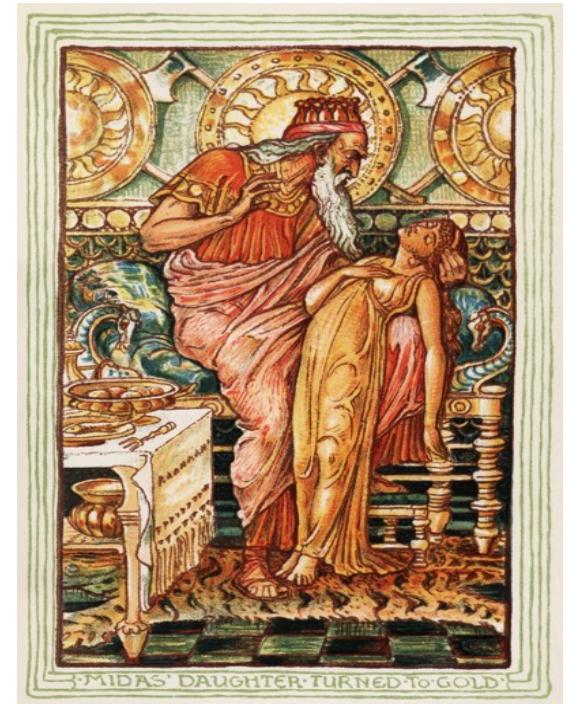
- No haptic feedback (unlike keyboards)
 - “Phorm” overlay by Tactus
- Occlusion
 - Hand/fingers covers part of display
 - Choose suitable screen layout in advance
- Precision
 - finger hits multiple pixels at once & covers target
 - Use handles, menus with offset



I/O issues: touch (2)

Image source (PD): https://en.wikipedia.org/wiki/Midas#/media/File:Midas_gold2.jpg

- No “hover” state (unlike mouse)
 - Every touch immediately triggers an action
 - “Midas Touch Problem”
 - Everything touched turns to gold
 - Problems with food, relatives etc.
 - Also in eye-tracking
 - (Partial) solution: wait with action until touch lifted off



I/O issues: gestures

- Discoverability
 - How do I know which gestures are available?
 - Even more difficult for complex gestures
- “Natural” interaction
 - What's a natural gesture?
 - Strong personal & cultural preferences
- No standards
 - E.g. tap-and-hold, swipe, double tap can have very different meanings depending on app/OS
 - Exception: pinch-zoom

I/O issues: bimanual interaction

Image source (CC): https://en.wikipedia.org/wiki/Text_messaging#/media/File:Texting.jpg

- Symmetric
 - Both hands have same role, e.g. typing with both thumbs
- Asymmetric
 - Hands have different roles, e.g. one hand holds device, other hand types
- Often not possible:
 - One hand may be required for other tasks
 - Thumb-only usage sometimes difficult



I/O issues: speech

- Speech input
 - Mostly used for hands-free dialing (in car)
 - Siri, Cortana, Google Now: more complex speech recognition offloaded to cloud service
 - Apparently not widely used (have you ever seen someone talk to Siri like in the commercial?)
- Speech output
 - Mostly used for car navigation
 - Again, not widely used otherwise
- Cultural differences (e.g. US vs. Europe)?

I/O issues: motion

- Motion as output
 - Mostly vibration alerts (binary channel, sometimes with patterns)
 - Moving/shape-changing phones exist as concepts
(cf. <http://www.fabianhemmert.com/projects>)
- Motion as input
 - Accelerometer, inertial measurement unit (IMU)
 - Can only sense *relative* position, not absolute
 - Needs combination with GPS, marker tracking, ...
 - Sensitive to interference (magnetic fields)
 - Use secondary device, e.g. smartwatch?

I/O issues: vision

- Vision as input (camera)
 - Input of barcodes/QR codes, text recognition (OCR), 3D structure reconstruction (SLAM)
 - Computer vision needs to deal with wildly different lighting conditions (indoor/outdoor)
- Vision as output: display
 - Size/resolution: very high information density, suitable information visualization required
 - Brightness/contrast: readable in sunlight?
- Combination: augmented reality

I/O issues: other channels

- Bio sensors
 - Fingerprint, heart rate, skin conductivity
 - Privacy issues?
- Miscellaneous
 - Back-of-device touch sensors
 - Notification LEDs and sounds
 - Location sensors (GPS etc.)
 - Buttons
- Spoilt for choice? Too “exotic” for user?

I/O: summary

- Wide variety of very different I/O channels
 - Primary: touch input, visual output
 - Secondary: motion, camera, audio, ...
- Not necessarily limited by size, other tradeoffs (e.g. features ↔ learning curve)

Key issue: context

- Unpredictable usage context
 - Environment
 - Location/position
 - Social context
 - Activity context
 - Context recognition?

Context: environment

Image source (CC): https://en.wikipedia.org/.../File:Cell_phone_use_while_driving.jpg

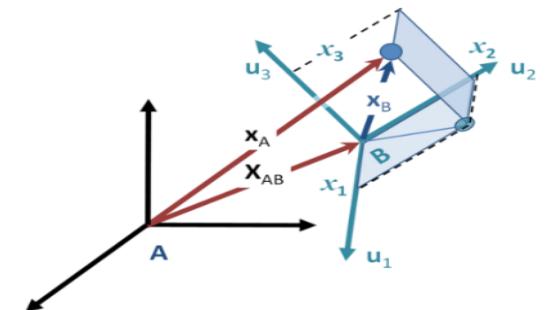
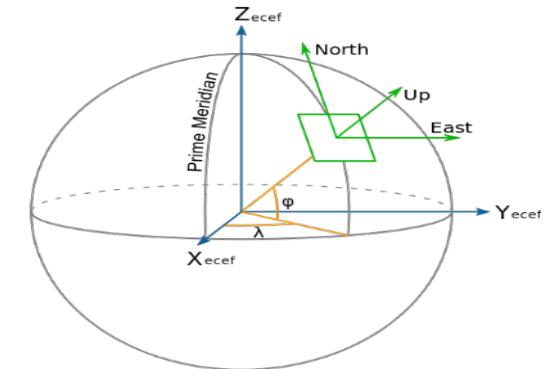
- Motion
 - User moving on their own
 - User being moved (bus, car)?
- Sound
 - Noisy or quiet?
 - Should remain quiet (concert)?
- Light
 - Bright or dark?
 - Should remain dark (movie theatre)?



Context: geometric

Image source (CC): [ECEF_ENU_Longitude_Latitude_relationships.svg](#), [Moving_coordinate_system.PNG](#)

- Geographic context
 - Moves with the user
 - Absolute location (~ 3DOF)
 - Use GPS/compass
- User/device context
 - Moves relative to the user
 - Relative location/orientation (6DOF)
 - Often more difficult to determine
 - Higher precision required?



Context: social

Image source (CC0): http://pixabay.com/p-193357/?no_redirect

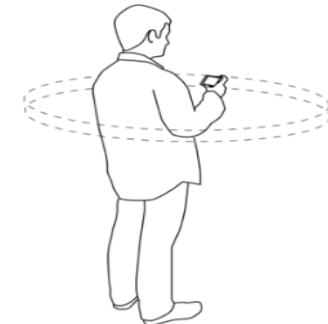
- Expected user base?
 - “Techies”, grannies, “normal” users, ...
- Acceptable behaviour?
 - Talking loudly, taking pictures, ...
 - Depends on location: subway car or church?
- Privacy
 - “Shoulder surfers” snooping on passwords
 - Temporary sharing with other persons (e.g. map)



Context: activities

Image source (FU): LMU lecture by J. Wagner

- Physical activities of the user
 - Walking, standing, sitting at a table, ...
 - Influences available precision & attention
- “Virtual” activities
 - Taking pictures, looking at maps, using social networks, reading website, ...
 - Quick access to related activities
- Seamless context switching?
 - Continuing activities in different context, e.g. on desktop computer?



Context: recognition

Image source (FU): <http://www.gettyimages.com/gi-resources/ub/unfinishedbusiness/index.html>

- Example: automatic meeting detection
 - Disable audible notifications, send all calls to voicemail
- Problem: what if it fails?
 - False positive: user misses important call
 - False negative: phone plays embarrassing ringtone in meeting
- Must be very, very accurate to earn user trust



Context: summary

- Very broad range of possible usage contexts
 - Consequently, automatic classification is hard
 - Influence on possible/allowed user actions
- Related issues: safety, privacy, security

Key issue: security/privacy (1)

- Huge amounts of private & personal data on mobile devices
 - Contact information, messages & e-mails
 - Visited websites, pictures
 - PIN/TAN codes
- Many people want access to that data
 - Google, Facebook, Microsoft (for selling ads)
 - NSA, GCHQ, BND etc. (for catching criminals)
 - Hackers (for stealing/extorting your money)



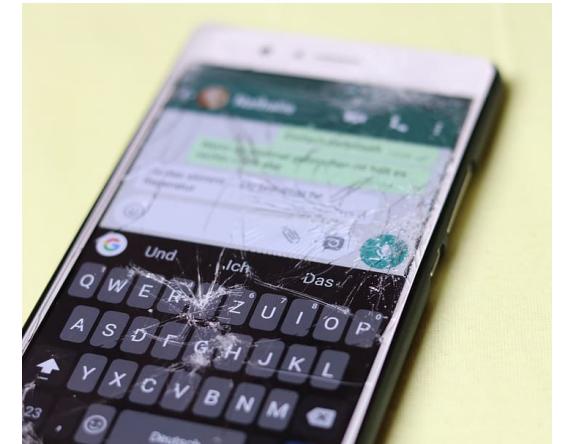
Key issue: security/privacy (2)

- Problem 1: no pervasive encryption
 - Strong opposition from government snoopers (up to demanding “key escrow”, cf. WhatsApp)
 - Lost/found phones often trivial to access
- Problem 2: voluntary use of cloud services
 - Reasons discussed earlier (storage, processing)
 - Requires trusting at least one, usually several 3rd parties (outsourcing)



Key issue: sustainability (1)

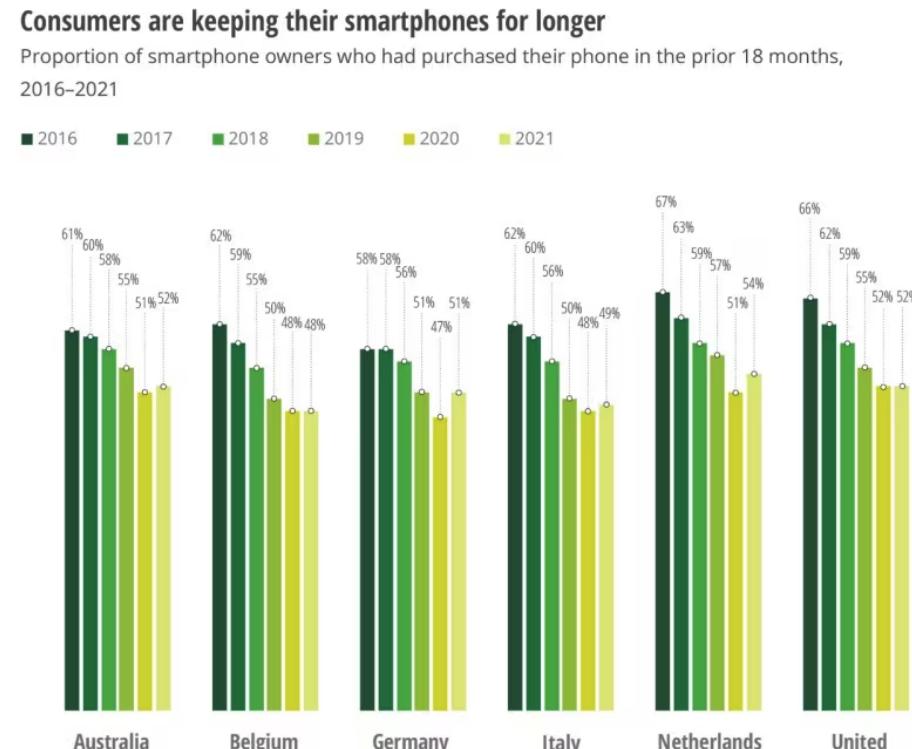
- Current: ~ 2 year lifecycle of mobile phones
- Fundamental feature set hasn't changed since ~ 2015
 - Touchscreen, camera, NFC, Bluetooth, WiFi, fingerprint
- Mostly due to lack of software updates (on Android)
- **LineageOS** offers longer-term support
 - Volunteer-driven, still unpredictable
 - Installation requires tech skills



Key issue: sustainability (2)

Image source (FU): <https://www2.deloitte.com/.../environmental-impact-smartphones.html>

- ~ 85 kg of CO₂ equivalents per phone (**iPhone 12, Pixel 5**)
- similar to a flight Berlin – Paris
- Phone market slowing down →
- Alternatives:
 - EU “Right to Repair” laws
 - **FairPhone** (more modular)



The End

