

Mobile Computing

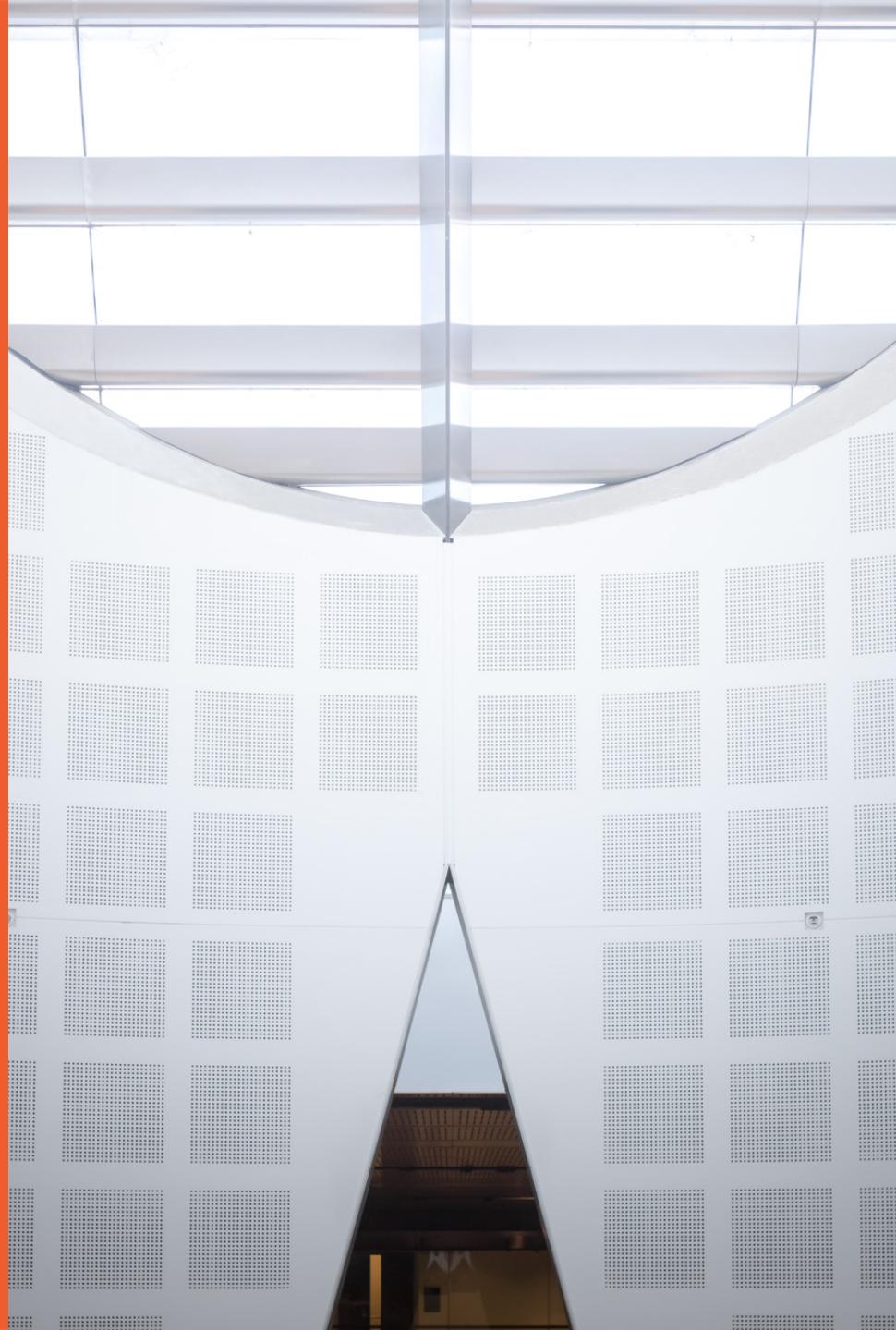
COMP5216

Week 05
Semester 2, 2020

Dr. Kanchana Thilakarathna
School of Computer Science



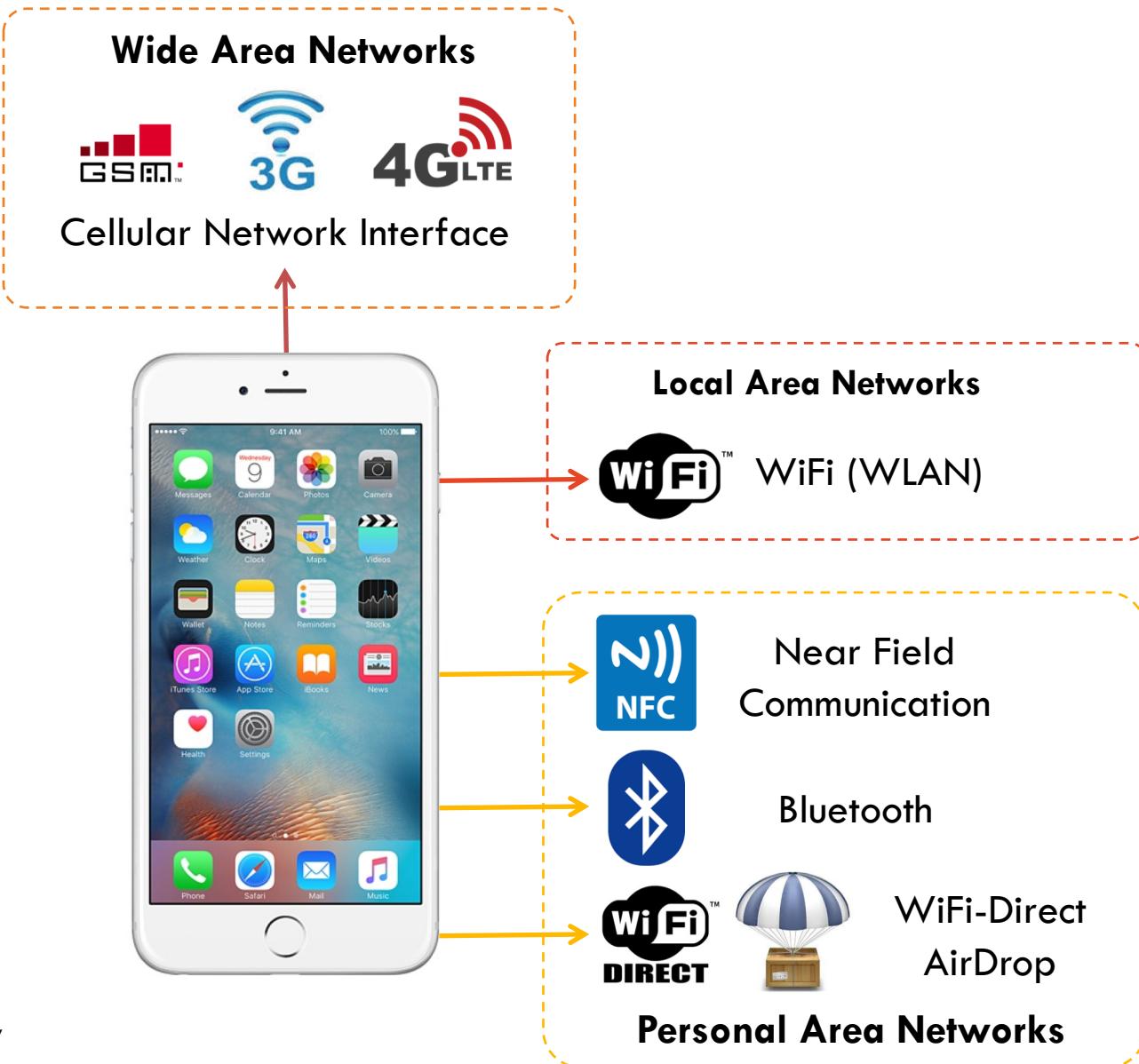
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Outline

- Overview of available networks
 - Cellular, WiFi, Bluetooth, NFC, Ad-Hoc
- What we can do as developers to optimize networking cost ?
 - Selecting the right content
 - Offloading to cheap networks
 - Reduce data usage
 - Reuse data
- Tools for Network Debugging
 - Android Profiler
 - Wireshark

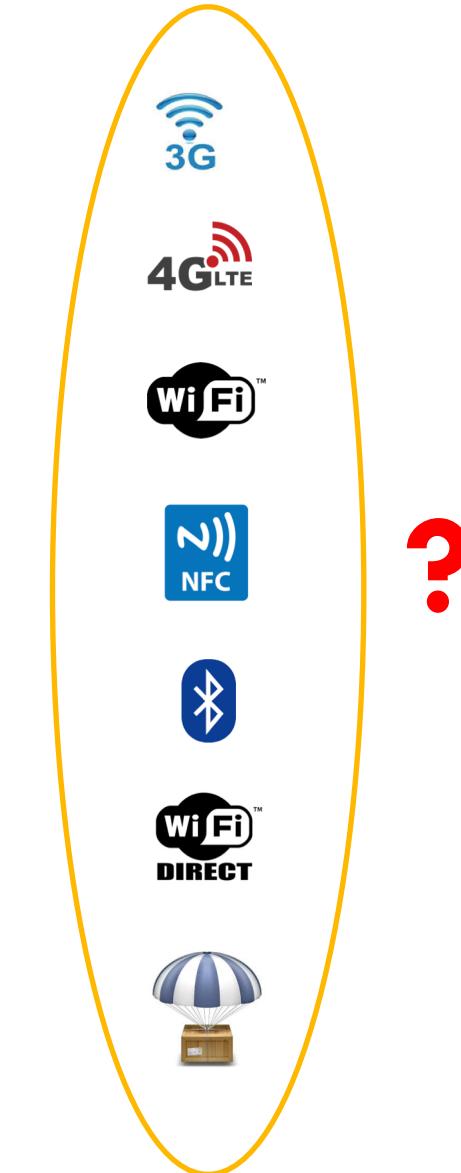
Networking Challenge



Which interface ?

Factors to consider

- **Range**
 - Location of the end hosts
 - Mobility
- **Cost**
 - For the network operator
 - For the consumer
- **Speed**
 - Real time or delay-tolerant
 - User expectations
- **Privacy and Security**
 - Public content or personal data
 - Location of the end hosts
- **Energy**
 - Smartphone energy consumption



E.g. Sharing accelerometer data from smartwatch to smartphone

- What options we have?

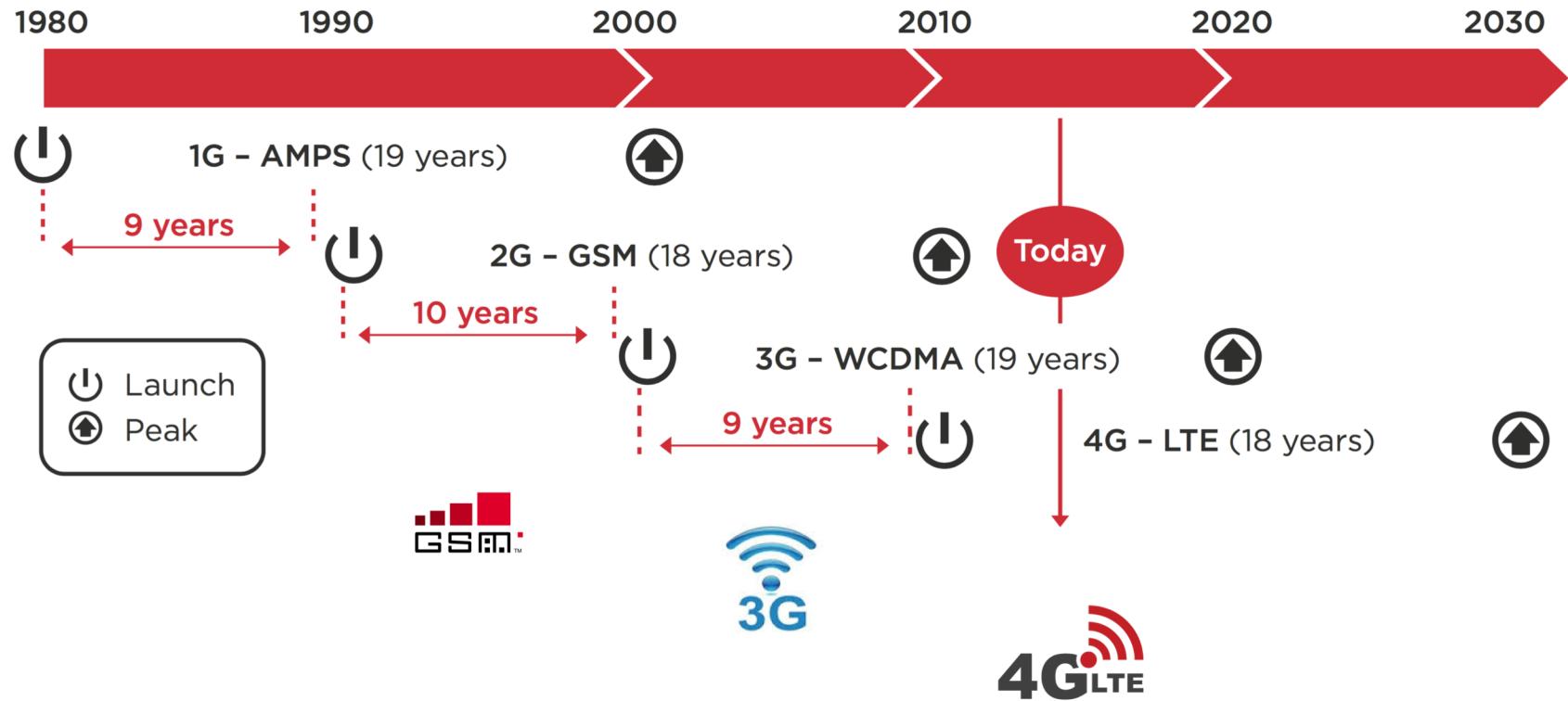


Wide area networks



Wide Area Networks

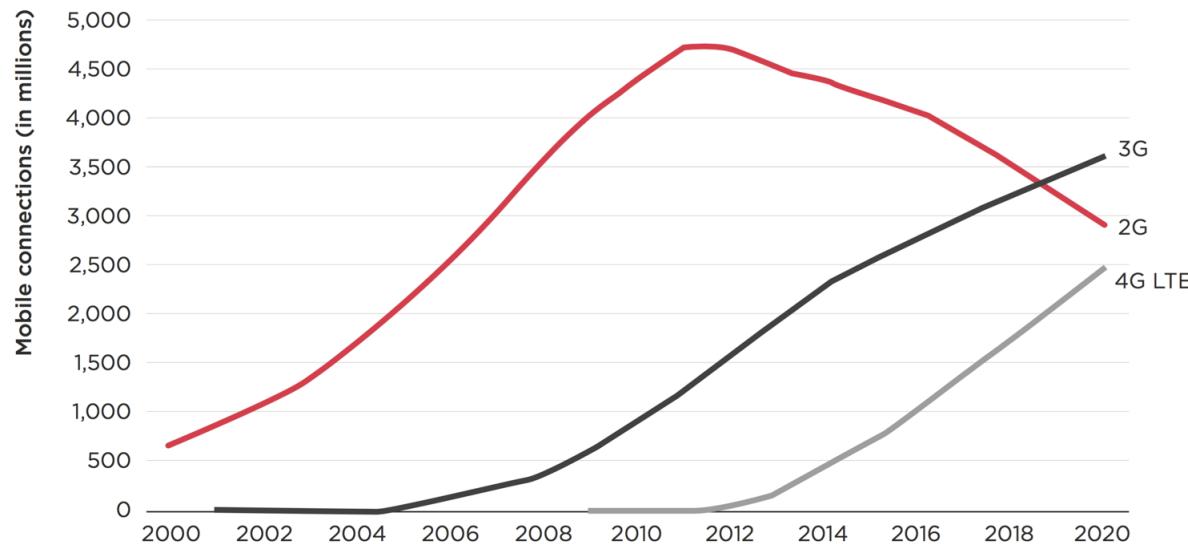
Cellular Networks



- Source: GSMA Intelligence - <https://www.gsma.com>
- Cellular network standards are governed by 3GPP - <http://www.3gpp.org>

Cellular Network Evolution – 2G

- Global System for Mobile Communications (GSM)
 - GSM is originally designed for voice.
 - Introduced **SIM** (Subscriber Identity Module).
 - Mass adoption of mobile phones started with GSM.
 - Even today GSM is the leading mobile communication technology.



Source: GSMA Intelligence

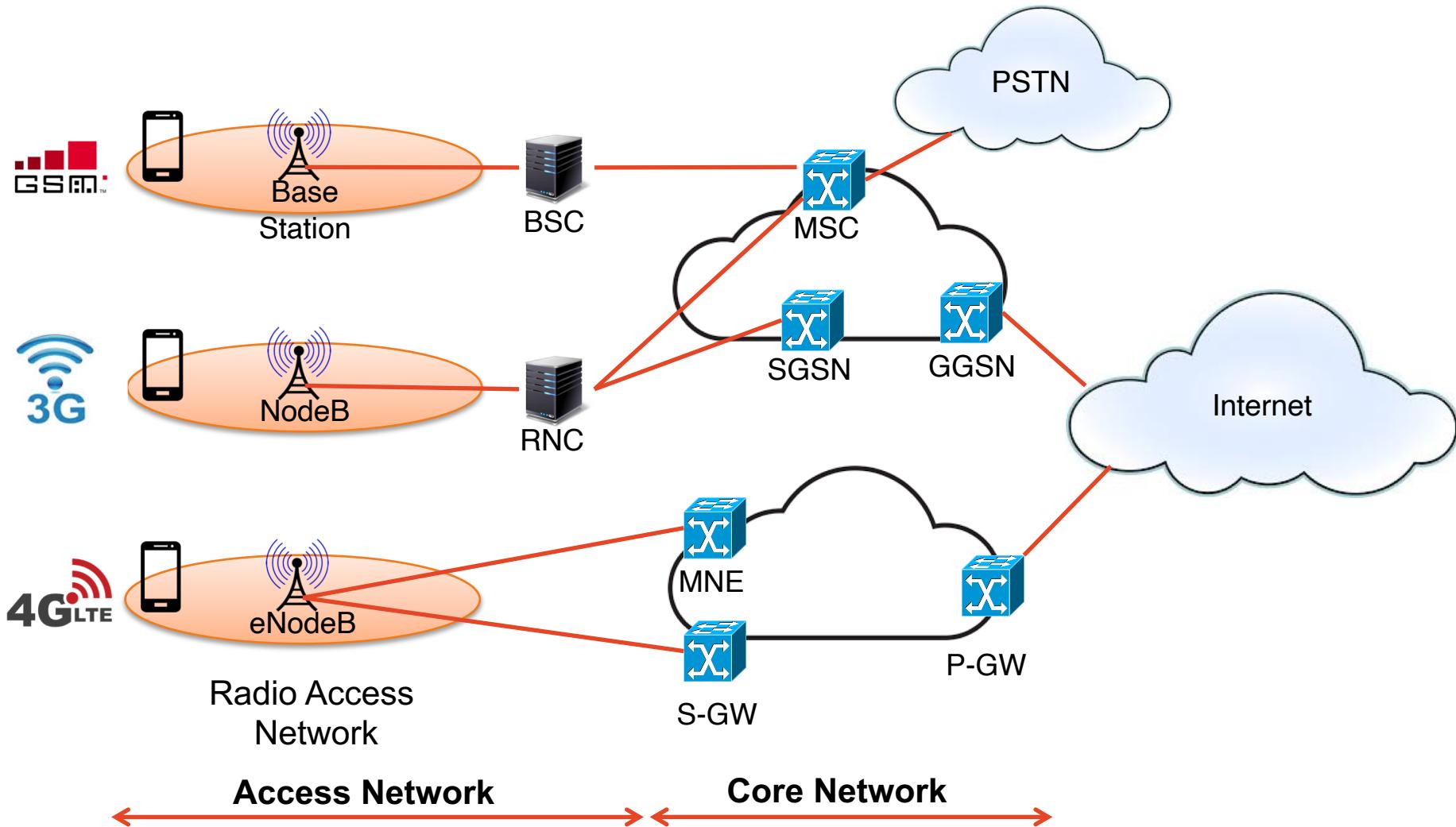
Cellular Network Evolution – 3G

- Two main variants of 3G technologies
- **UMTS** (Universal Mobile Telecommunication Service)
 - W-CDMA, TD-CDMA, and TD-SCDMA (China)
 - HSDPA, HSPA, HSPA+ are Data specific releases.
 - HSPA+ provides data rates up to 56Mbits/s
- **CDMA2000**
 - In North America and South Korea
 - EVDO are Data specific releases.
 - EVDO Rev B provides data rates up to 14.7Mbits/s
- Frequency bands
 - 850, 900, 1900, 2100MHz
- Tied to mobile specific architectures and protocols.

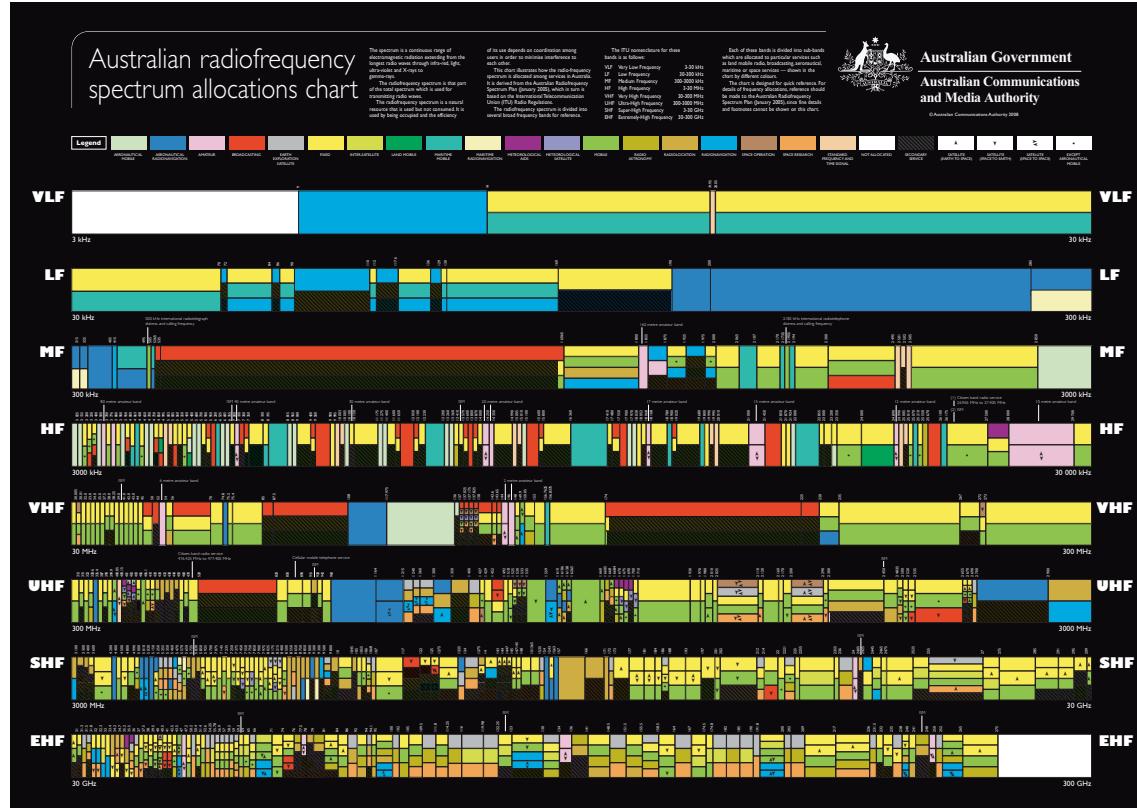
Cellular Network Evolution – 4G

- **LTE Advanced:** 3GPP Long Term Evolution
 - <http://www.3gpp.org/technologies/keywords-acronyms/98-lte>
 - Downlink data rates up to 300Mbit/s
 - Uplink data 75Mbit/s
- E-UTRA (Evolved UMTS Terrestrial Radio Access)
 - High Speed OFDM Packet Access
- Similar frequency bands as 3G.
- **All IP services including voice and messaging**

Cellular Networks



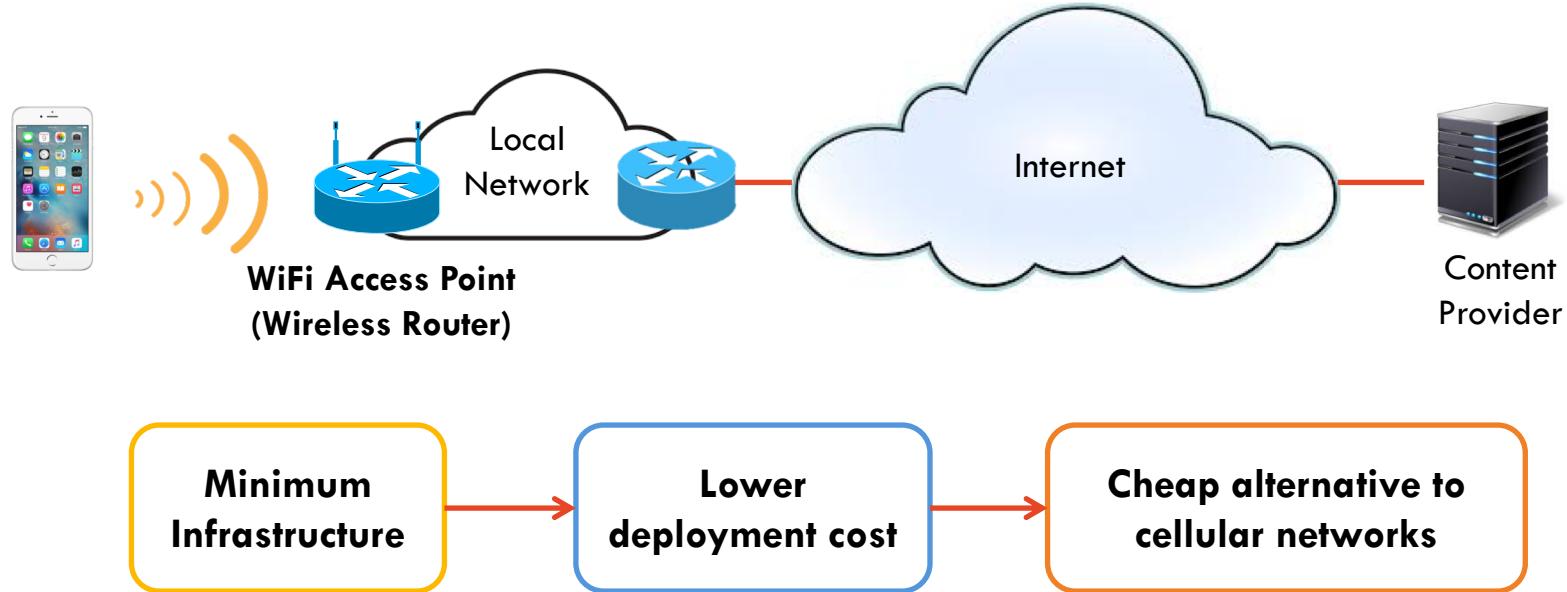
Frequency Usage



<https://www.acma.gov.au>

- Licensed band - Cellular networks
- Unlicensed band - WiFi, Bluetooth, Zigbee, Microwave, etc.

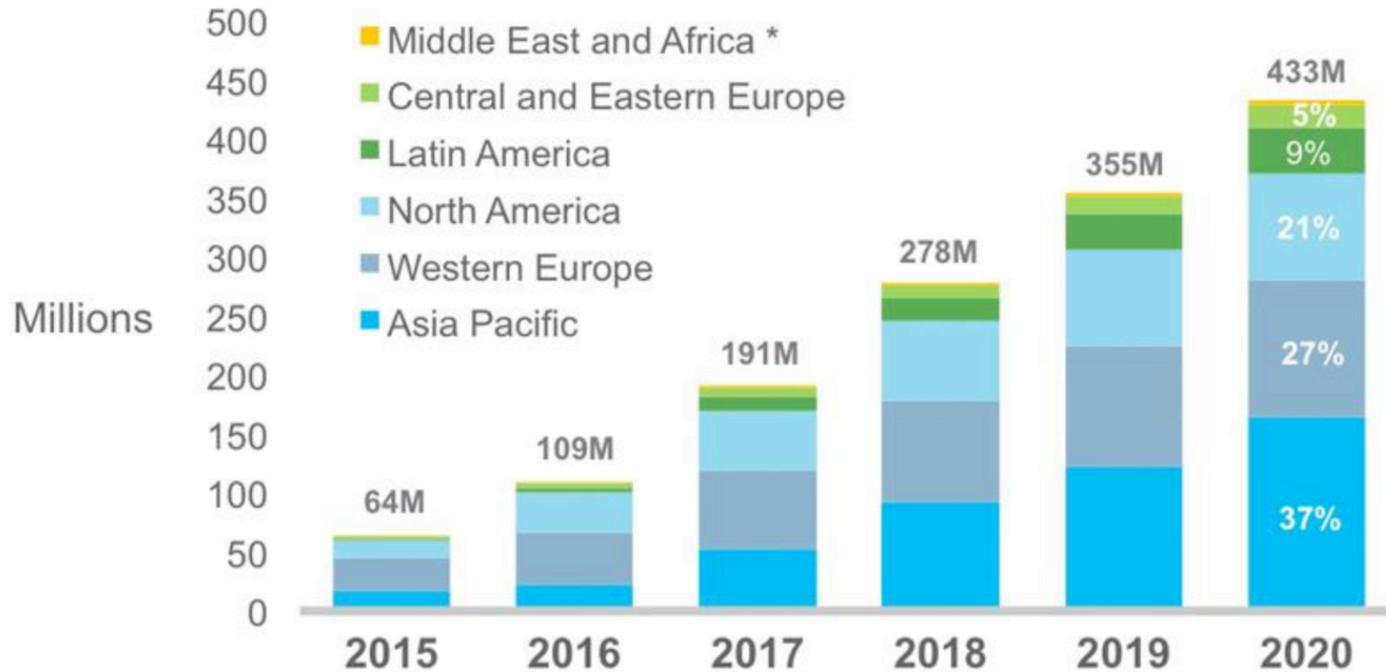
Local Area Network - WiFi



- Current smartphones select WiFi over Cellular for data access by default.

Local Area Networks - WiFi

- WiFi hotspots are everywhere !
 - In Australia - Telstra, Manly Ferry, Westfield, etc.
 - **433 million hotspots worldwide by 2020.**



* Middle East and Africa represents 1 percent of global public Wi-Fi hotspots by 2020.

Source: Maravedis, Cisco VNI Mobile, 2016

WiFi – IEEE 802.11

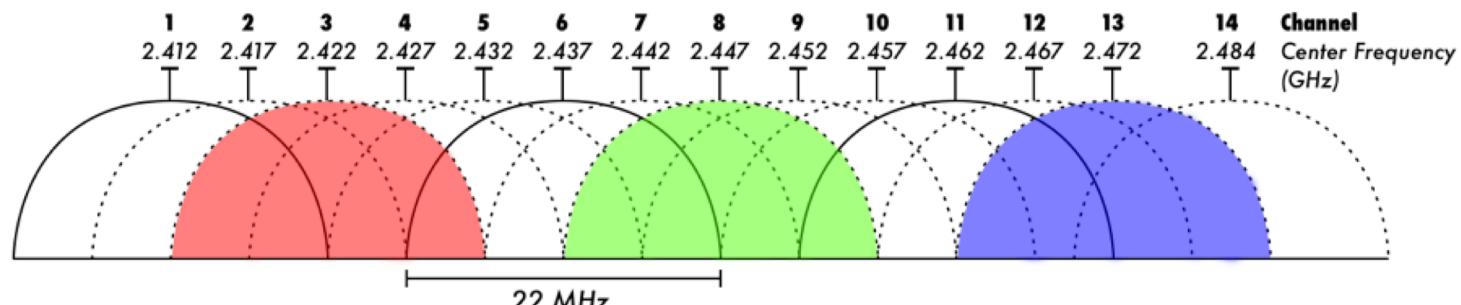
IEEE 802.11 Standards

- First version is released in 1997.
- Often called invented at CSIRO, Australia.
- Wi-Fi Alliance (non-profit) formed in 1999.
- Medium Access Control (MAC) and Physical layer specifications.
 - CSMA/CA- carrier sense multiple access with collision avoidance (recall: Ethernet use CSMA/CD)
- Does not support global mobility
 - 5G heterogeneous networking supports seamless integration with WiFi hotspots.

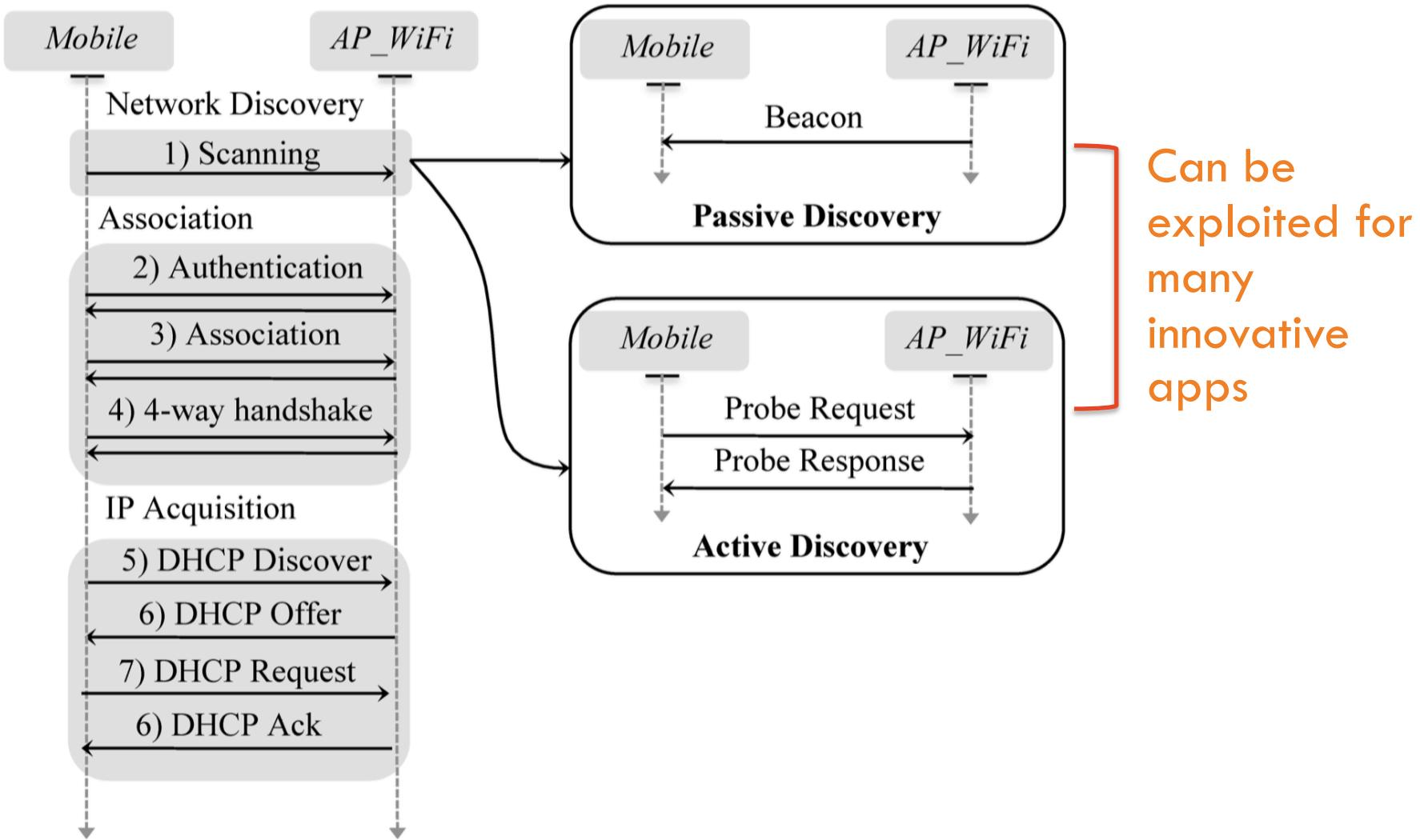
<http://www.ieee802.org/11/>

WiFi

- ISM(industrial, scientific and medical) frequencies.
- **2.4GHz Band**
 - IEEE 802.11b, 802.11g, 802.11n
 - Range \approx 70m
 - 11/14 channels (overlapping)
 - Very crowded frequency band
 - May suffer interference from Bluetooth, microwave oven, etc.
- **5.8GHz Band**
 - IEEE 802.11a, 802.11n, 802.11ac
 - Range lower than 2.4GHz \approx 35m
 - 23 channels (non overlapping)



WiFi



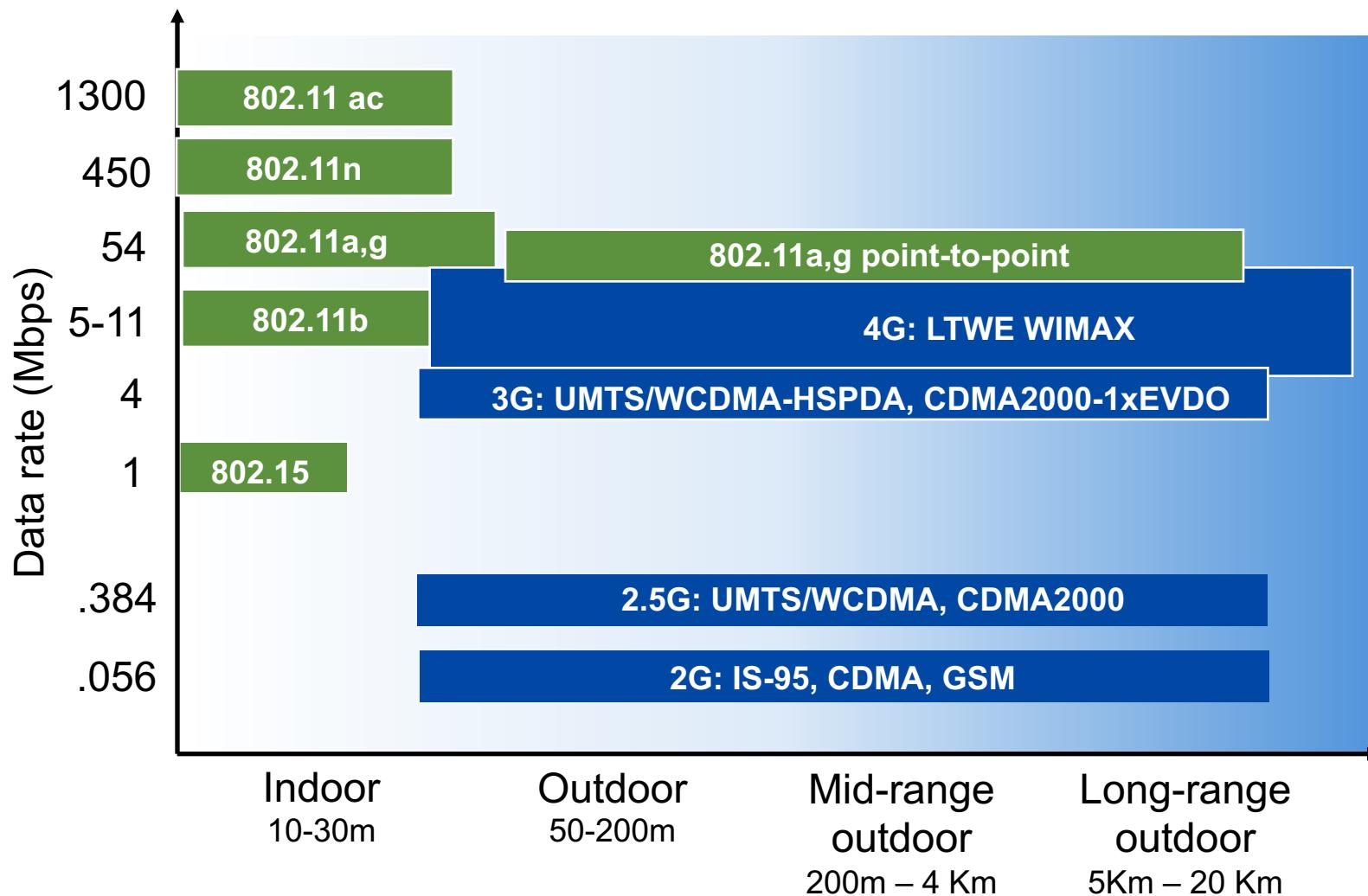
WiFi

- Most of the smartphones supports IEEE 802.11 a/b/g/n/ac

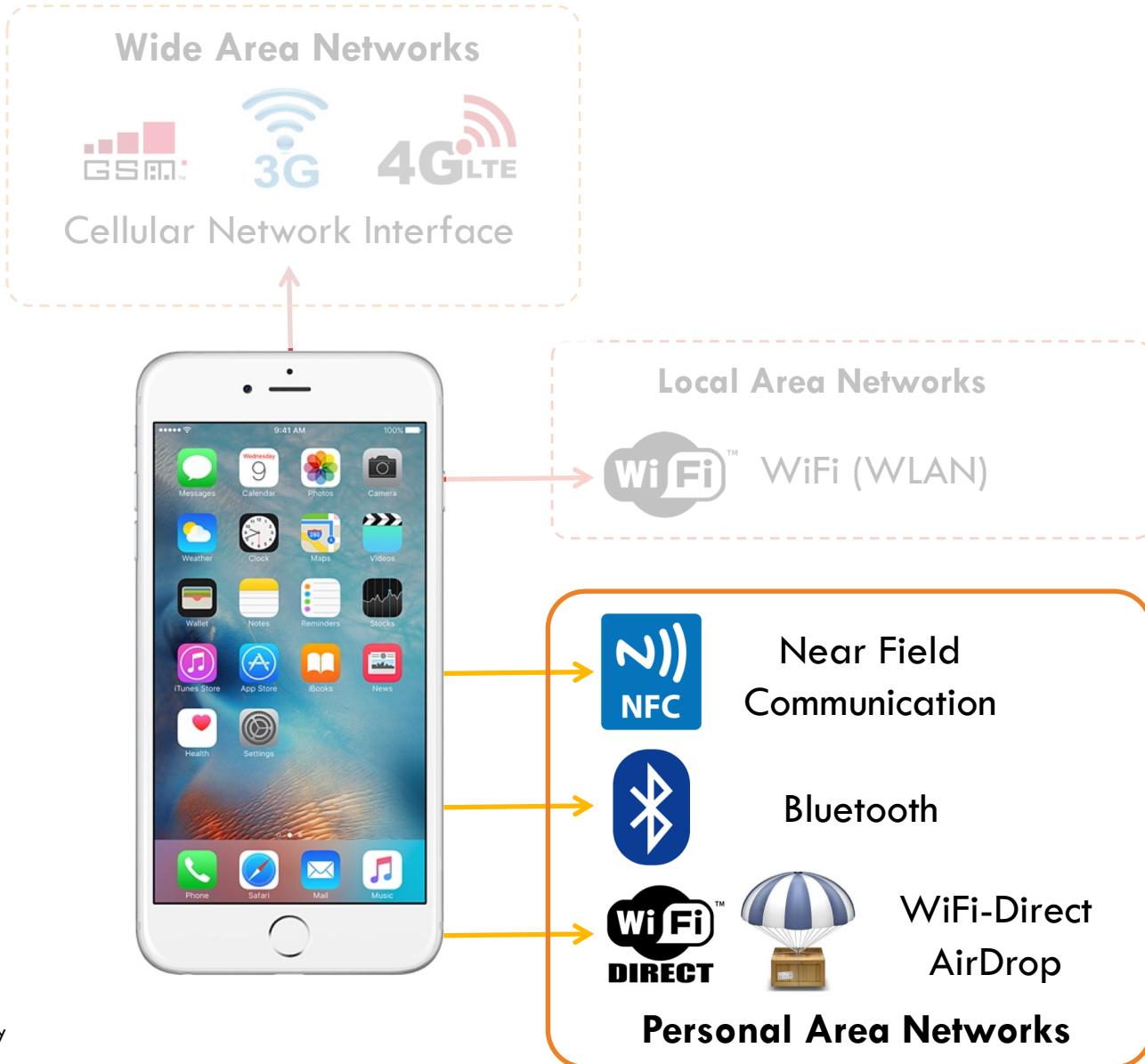
IEEE 802.11	Released date	Frequency band (GHz)	Bandwidth (MHz)	Max Speed (Mbits/s)	Range (m)
a	1999/2012	2.4/5.8	20	54	35
b	2000	2.4	22	11	35
g	2003	2.4	20	54	38
n	2009	2.4/5.8	20/40	72/150	70
ac	2013	5.8	20/40/80/160	96/200/433/866	35

- IEEE 802.11ad (60GHz) is coming...!
 - Supports ~7Gbps data rate
 - But, requires line-of-sight → Point-to-Point connections

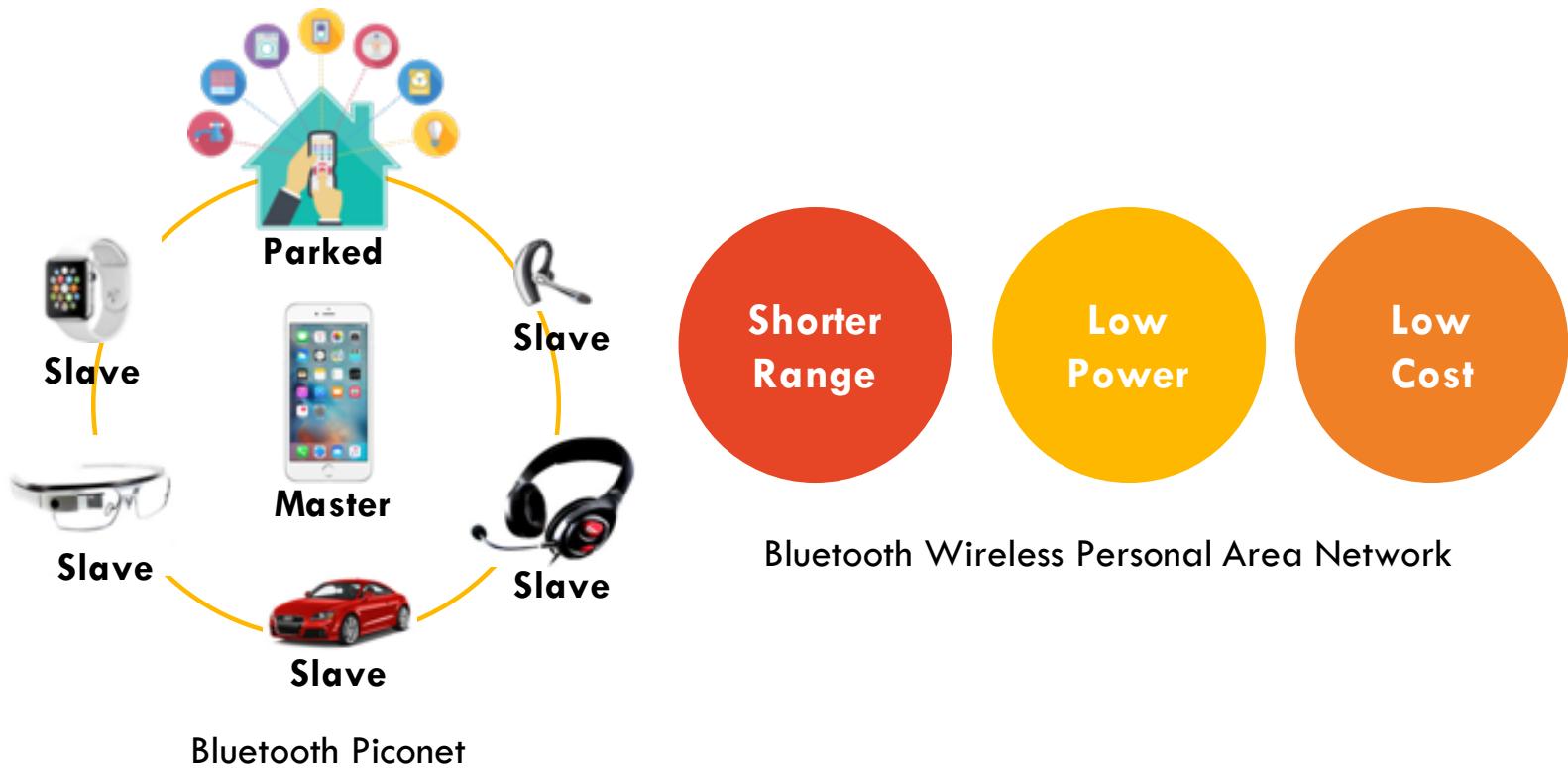
Summary – WiFi vs Cellular



Personal Area Networks



Personal Area Networks (1) Bluetooth



- IEEE 802.15.1 - now maintained by Bluetooth SIG¹
- ISM band - 2.4GHz

¹<https://www.bluetooth.com>

Bluetooth

- Bluetooth device in discoverable mode transmits the following info on demand:
 - Device name, Device class, List of services, Some Technical information (e.g: device features, manufacturer, Bluetooth specification)
- Traditional pairing:
 - Needs user interaction.
 - If not, PINs are hardcoded in the device.
- **Secure Simple Pairing (SSP)**
 - Since Bluetooth v2.1
 - Works without user interaction.
 - Use other technologies such as NFC to bootstrap the authentication.
- Establish a shared secret key and if both device store the same key, they are paired after that.

Bluetooth

- Infrastructure-less network → self-organized
- Time Division Multiple (TDM) access with random channel hopping - $625\mu\text{s}$ timeslot.
- 40 channels with 37 data channels and 3 advertising channels.
- Master – Slave approach
 - **Up to 8 slave devices**
 - Up to 255 parked devices (not actively transmitting data)



Bluetooth v5

– Bluetooth v5

- **2x Speed, 4x Range, 8x Data** and less interference
- Only available in new hardware iPhone 8, iPhone X, Galaxy S8
- https://3pl46c46ctx02p7rzdsvsg21-wpengine.netdna-ssl.com/wp-content/uploads/2019/03/Bluetooth_5-FINAL.pdf
- 3 PHY Layers to select

	Bluetooth v4.0	Bluetooth v5		
	LE 1M	LE Coded S=2	LE Coded S=8	LE 2M
Symbol Rate	1 Ms/s	1 Ms/s	1 Ms/s	2 Ms/s
Data Rate	1 Mbit/s	500 Kbit/s	125 Kbit/s	2 Mbit/s
Error Detection	CRC	CRC	CRC	CRC
Error Correction	NONE	FEC	FEC	NONE
Range Multiplier (approx.)	1	2	4	0.8
Bluetooth 5 Requirement	Mandatory	Optional	Optional	Optional

- LE Coded S=8
 - Higher range
 - Low speed
- LE Coded S=2
 - Low range
 - Higher speed

Personal Area Networks (2) NFC



- **Range $\approx 4\text{cm}$** of each other.
- ISM band - 13.56MHz
- **Data rates $\approx 106\text{-}424\text{kbps}$**
- Multiple standardization organizations
 - ISO/IEC, GSMA, NFC Forum¹
- NFC is based on **RFID (Radio Frequency IDentification)**
 - Use magnetic field induction in close proximity

¹<http://nfc-forum.org>

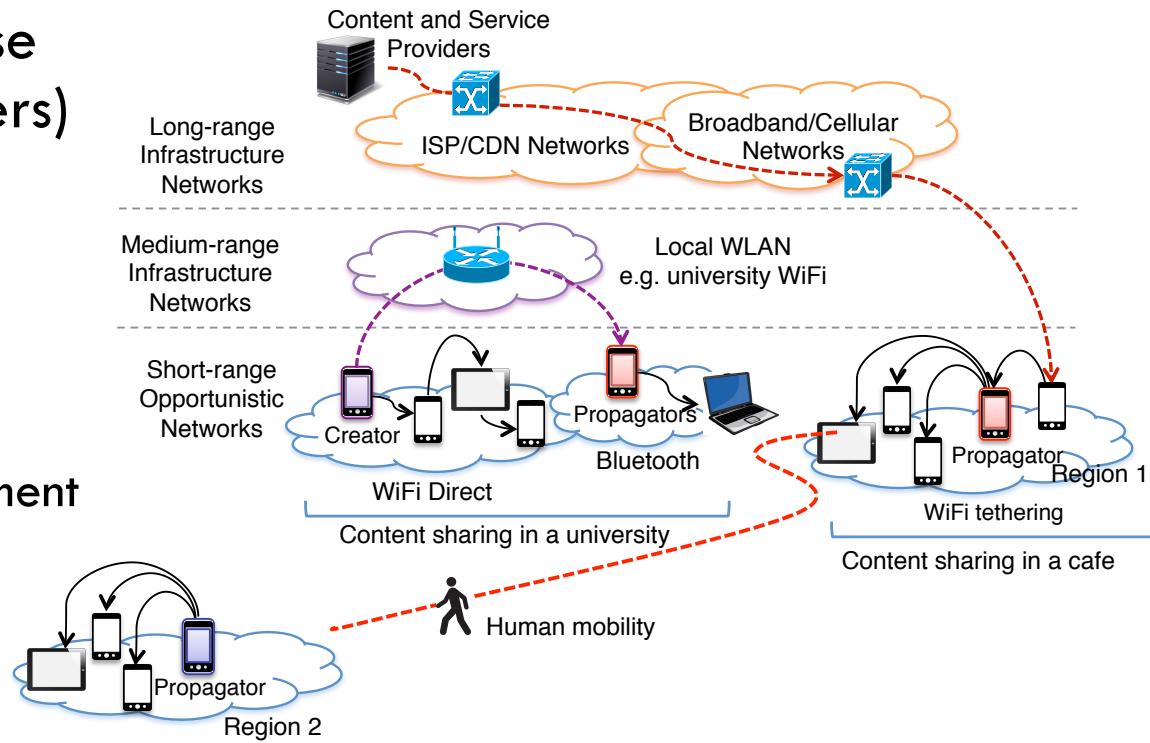
Personal Area Networks (3) WiFi Variants

- Use WiFi networking interface: Range and Data rates are similar to WiFi.
- **WiFi-Direct**
 - Activates Software AP within the device.
 - Specifications are administered by WiFi Alliance¹
- **AirDrop** by Apple
- **WiFi-Tethering (Mobile Hotspot)**
 - Some network operators block WiFi-Tethering
 - Can only connect up to 8-9 devices

¹<http://www.wi-fi.org/discover-wi-fi/wi-fi-direct>

Ad-Hoc Networking

- No Infrastructure (base stations, routers, servers)
- Devices organize themselves
- **Device to device communication**
 - E.g. disaster management



Ad-Hoc Networking - Android

- Network Service Discovery (NSD) API to discover available services/devices nearby
- WiFi P2P API to setup wireless connections

- Devices that support NSD includes;
 - Printers, Webcams, HTTP servers, Smartphones

- Allows fast data transfer within the local network.
 - Low latency
 - No bandwidth cost
 - Useful in range of P2P applications
 - E.g. chatting, file sharing and multi-player games

- <https://developer.android.com/training/connect-devices-wirelessly/>

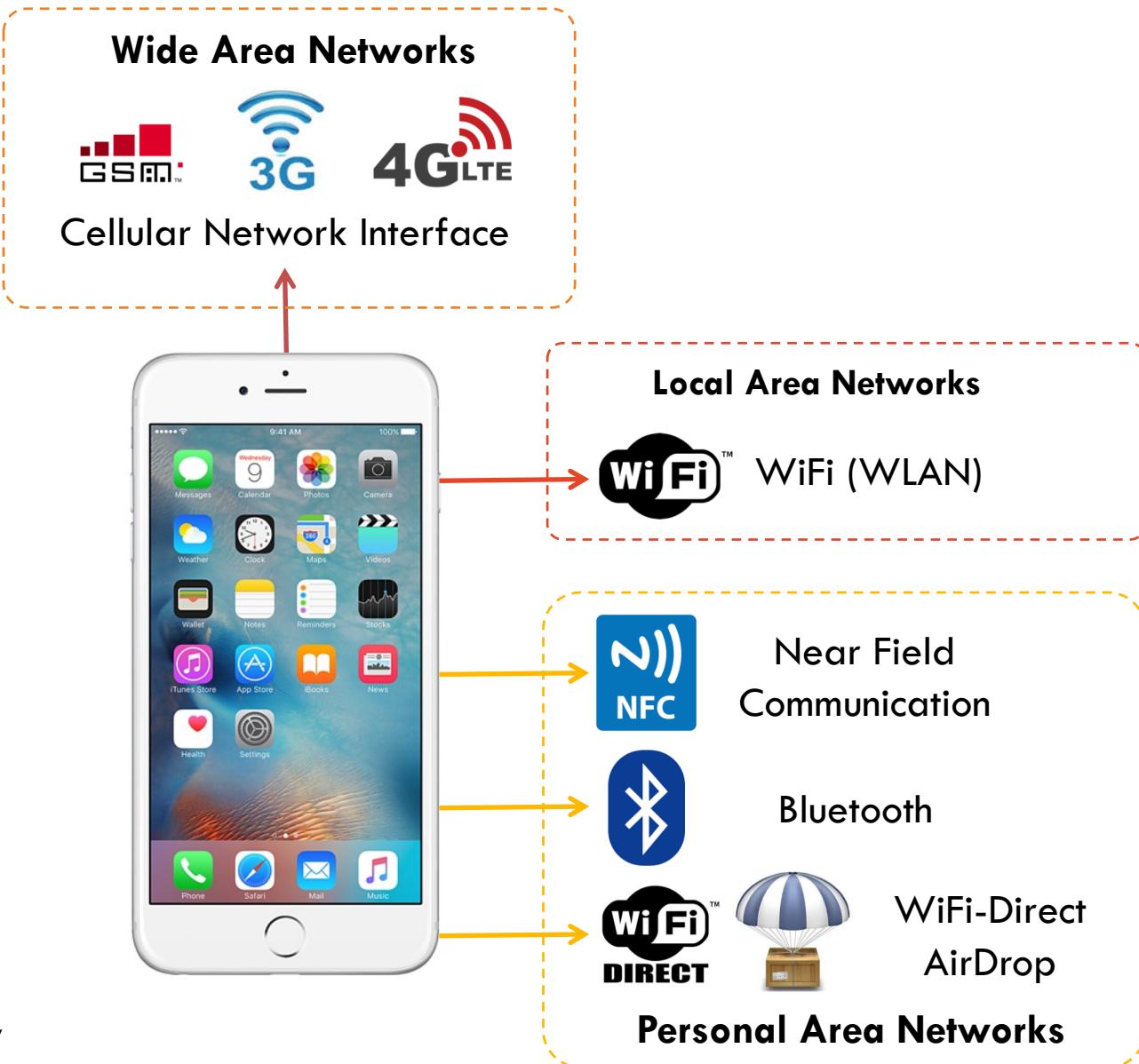
NSD

- Rely on DNS-based Service Discovery (**DNS_SD**) protocol
 - Allows your app to request services by specifying;
 - A type of service, and
 - The name of a device instance that provides the desired type of service
- What is DNS (Domain Name System) ?
 - Map between human readable addresses (google.com) and its IP address
 - For Internet there are 14 Root DNS servers.
- Multicast DNS is distributed (no central server)
 - Hostnames ending with **.local**
 - All devices in the same sub-net creates a directory of service exchanging IP multicast messages
 - i.e. NSD will not work if multicast traffic is blocked on the local network
- DNS-SD extends Multicast-DNS including service information
- You can register your service name at;
 - <https://www.iana.org/form/ports-services>

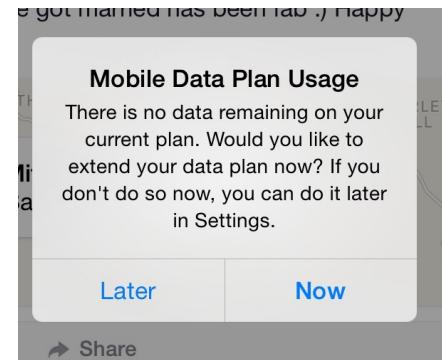
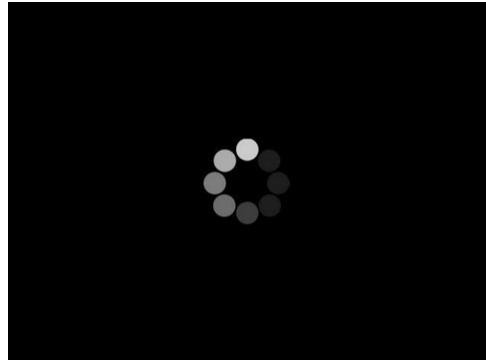
WiFi P2P

- Allows apps to connect nearby device without a network or hotspot support
 - <https://developer.android.com/training/connect-devices-wirelessly/wifi-direct>
- Provides WPA2 encryption
- Steps:
 1. Ask for the correct permissions.
 2. Set-up a broadcast receiver & P2P manager.
 3. Peer Discovery & Fetch list of peers
 4. Connect to a peer
- WiFi P2P can also be used to discover services nearby
 - Recall NSD requires devices to be on the same WiFi network
- A higher level API for adhoc connections combining WiFi and Bluetooth –
NearBy API
 - <https://developers.google.com/nearby/connections/android/discover-devices>

Networking Challenge



What to avoid ?



Best Practices for Mobile Networking

What can we (developers) do ?

Do you really need this data ? Yes

1. Select the right content for the device, the user and adapt dynamically
2. Offloading cellular (default) to alternative networks
3. Reduce the amount of data
4. Reuse the data as much as possible
 - Secure networking [Week 6]
 - Energy efficient networking [Week 8]

(1) Selecting the right content

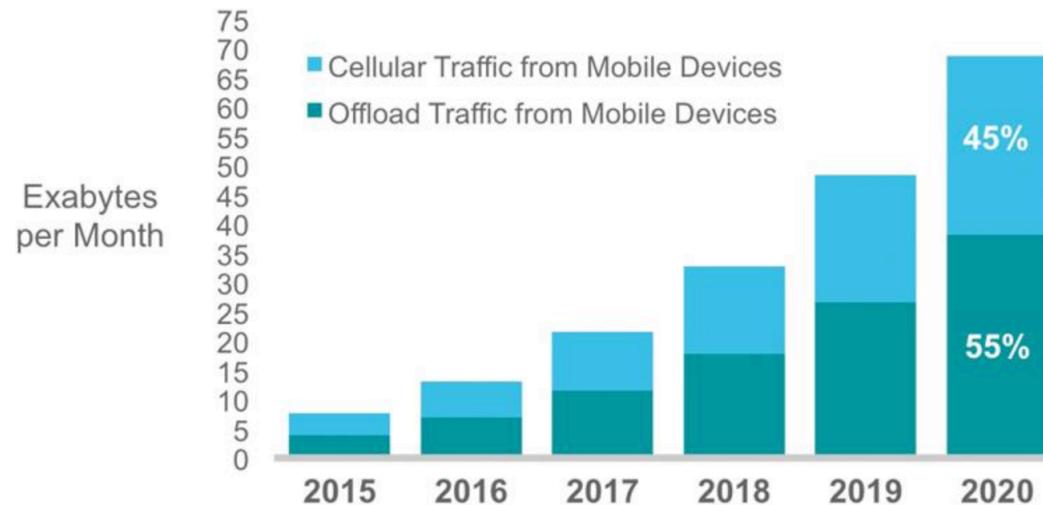
- User expectation dependent on context;
 - Users' activity, e.g. running or sitting in the living room.
 - Time of the day.
- Request appropriate content
- Examples for bad practices?

(1) Adapting to the conditions

- Check before downloading/uploading
 - User activity
 - Connected network type
 - Available network bandwidth
 - Location
 - Time of the day
- Slow connection → Download lower resolution media
- DASH Video Players (Dynamic Adaptive Streaming over HTTPS)
 - E.g. YouTube – Varying video quality according to the available network bandwidth

(2) Offloading

- Reactive offloading
 - Offload to another network when it is available.
 - Cellular to WiFi, WiFi to Bluetooth, Bluetooth to USB
- **55% of global cellular traffic will be offloaded to WiFi by 2020.**



Offload pertains to traffic from dual-mode devices (excluding laptops) over Wi-Fi or small-cell networks.

Source: Cisco VNI Mobile, 2016

(2) Offloading

- All most all current smartphones automatically prioritise WiFi networks over Cellular (3G/4G) networks

Benefits of WiFi offloading

- Faster connections (depends on the location)
- Lower cost
- Lesser battery drain
- Overall improved quality of user experience
- Reduces cellular network capacity issues

(2) Offloading - Reactive

- To automatically connect to WiFi, the available WiFi network has to be **in the previously connected list of networks.**
- **Reactive WiFi offloading practices**
 - Wait until the device is connected to WiFi to transfer;
 - Large files
 - Delay tolerant content, e.g. software updates.
 - Push notifications to the user to connect to WiFi (after a timeout)
 - Scan the available WiFi networks and offer the user option the switch to WiFi

(2) Offloading - Predictive

- **Predict** near future WiFi availability and **delay** the transmission.
- Only works for **non-real time content** (delay-tolerant content)
 - Social networking content.
 - Software updates.
 - Environmental monitoring, data collection.
- **Predict** future demand and effectively **pre-load** the content when the user is connected to WiFi.
 - News
 - YouTube, Facebook videos

(2) Offloading - Predictive

- Regular behavioural patterns of users
 - Users have regular weekly patterns, e.g. 9:00am -5:00pm work hours.
- Long-tail content popularity
 - 10% of content accounts for 80% of views
- User and location targeted content delivery
 - Location based advertisement distribution
 - User targeted content, e.g. Facebook videos

(3) Reduce Data

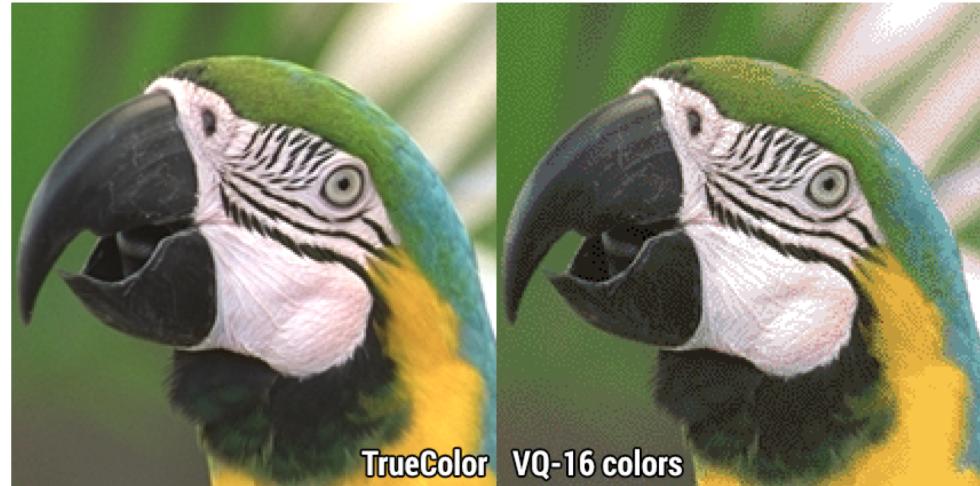
- Download only essentials
- Don't upload everything collected

Data Compression

- Specially for text based files. e.g. HTML, JavaScript, CSS, .txt
 - Files less than 1KB do not benefit from compression.
- The compression and decompression have to be supported by the end-points.
 - Common algorithms - GZIP, DEFLATE

(3) Reduce Data - Image compression

- Trade size and color
 - More colors → larger size



- Adjust quality to around 75
 - Significantly smaller image size for insignificant visual difference
- **WebP** provides better compression than JPEG and PNG
 - <https://developers.google.com/speed/webp/>
 - WebP lossless images are 26% smaller compared to PNGs

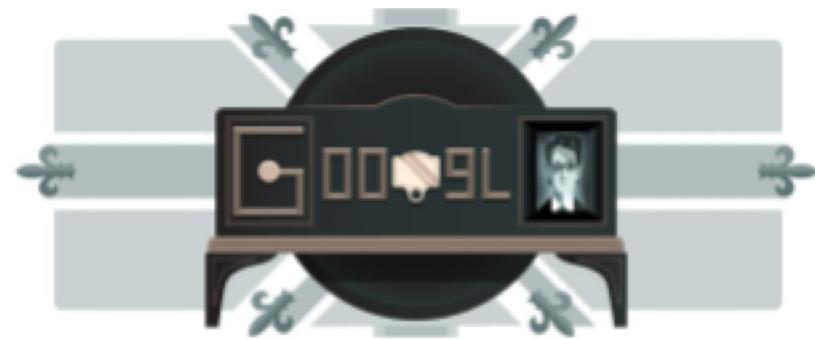
(3) Reduce Data - Image compression

- Use WebP whenever possible
- If not, use;
 - PNG – if image needs transparency or image is simple in color and structure
 - JPG – if image is complex



JPG : 201 k

PNG : 636 k



JPG : 82 k

PNG : 50 k

Same color better compression with PNG

(3) Reduce Data - Other forms of data reductions

- **Minification** of JS, CSS and HTML
 - Remove unnecessary characters
 - JS – e.g. UglifyJS [<https://github.com/mishoo/UglifyJS2>]
 - CSS – e.g. CSSNano [<https://github.com/ben-eb/cssnano>]
 - HTML – HTMLminifier [<https://github.com/kangax/html-minifier>]
 - General minification tools. e.g. eMinifier
 - Compress: GZIP compression on server
 - Offline compression using Zopfli or 7-Zip.
- **Serialization**
 - JSON, XML are serialization methods, but bulky and slow
 - Use customized structure to minimize data
 - FlatBuffers - an efficient cross platform serialization library
 - <https://google.github.io/flatbuffers/>

(3) Reduce Data - Data Compression

- Samsung Max App (Previously Opera Max)



Samsung Max - Data Savings & Privacy Protection

Max apps Tools

★★★★★ 329,864

3+

Contains Ads

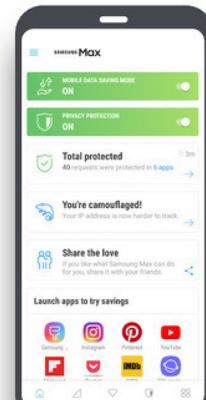
⚠ You don't have any devices.

Add to Wishlist

Install

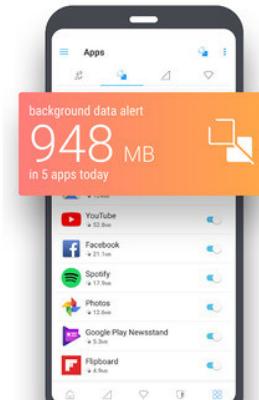
Take Control

Save your data, protect your privacy



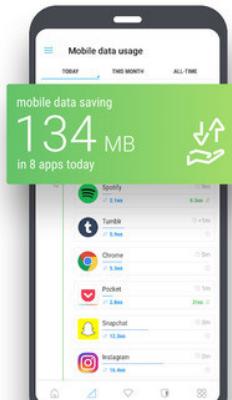
Data Management

Manage background data usage



Data Savings

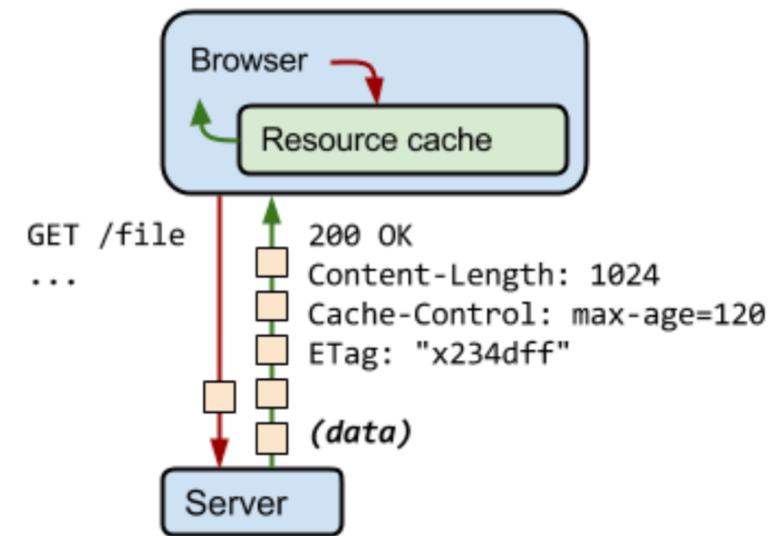
Save data and extend your data plan



(4) Reuse Data

- Design the app and the communication protocol to reuse data, if you control both the client and the server.
 - **Static content** – Cache until updated
 - **Dynamic content** – Cache until expires

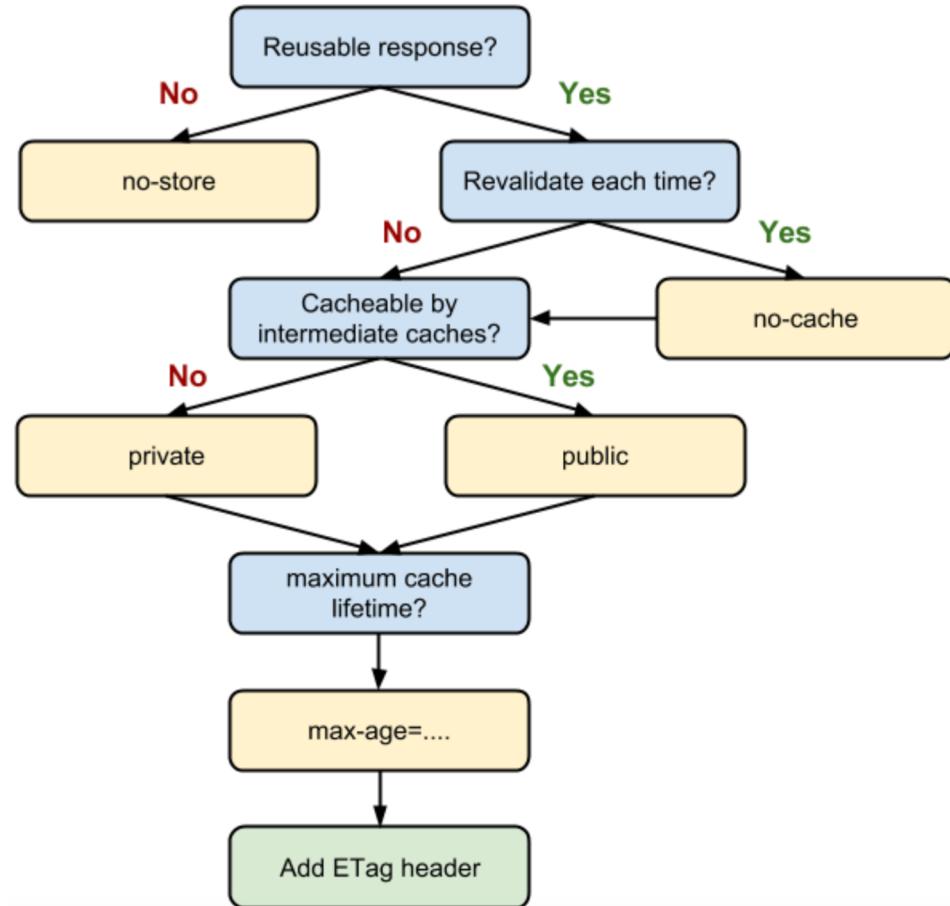
- For web-content, HTTP provides number of flexible cache-control parameters.



- <https://developers.google.com/web/fundamentals/performance/optimizing-content-efficiency/http-caching>

(4) Reuse Data - HTTP Caching

- HTTP Header cache-control directives:
 - **no-store**- can not cache the content
 - **no-cache**- can not use unless checking with the server
 - **public**- can be cached
 - **private**- can be cached for only one user
 - **max-age**- maximum time in seconds that the cached content can be used
 - **ETag** – use to check saved version at the client is still valid



(4) Reuse Data - Cache Replacement Policies

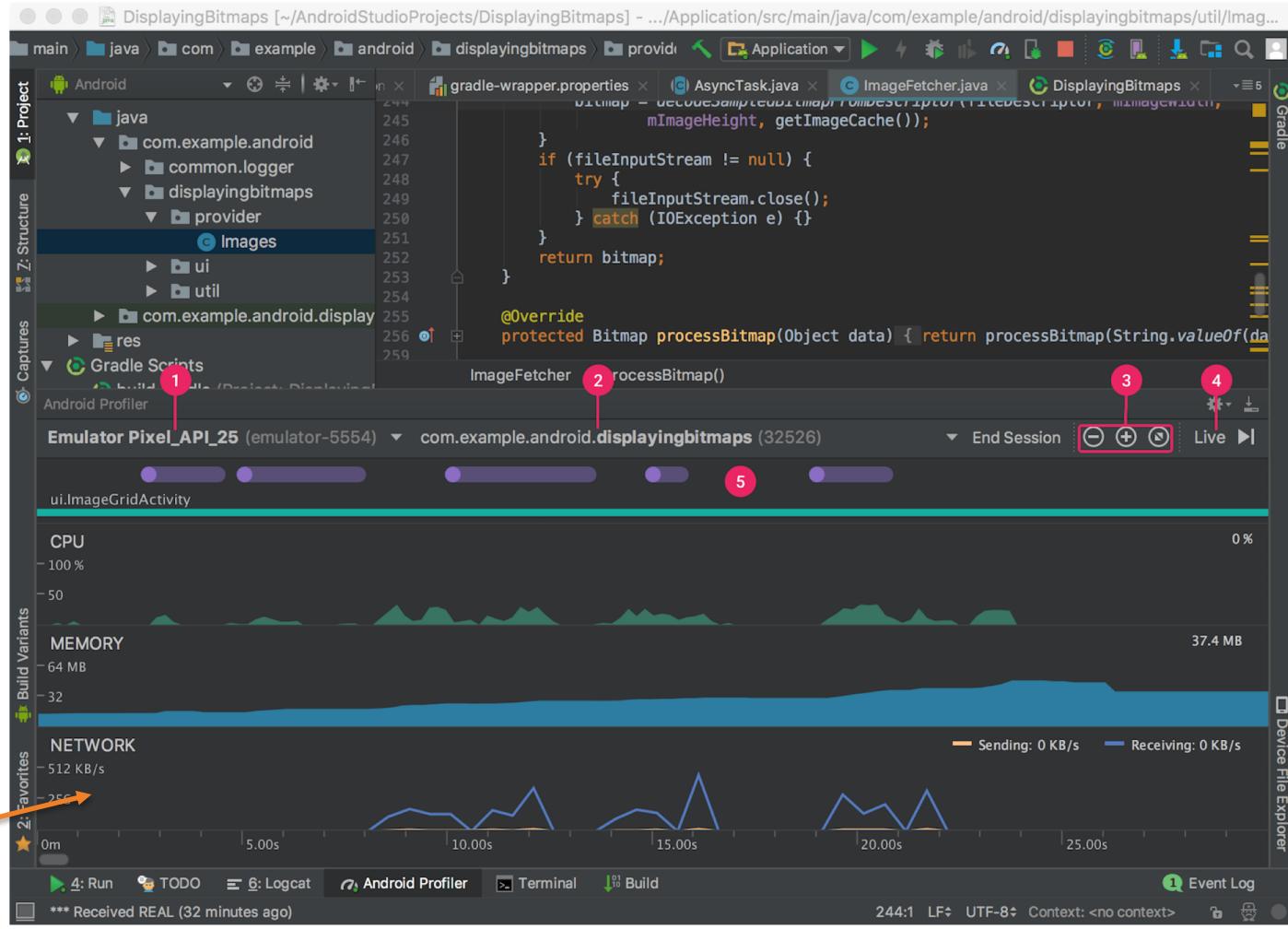
- Storage is not unlimited, **not possible to cache everything...!**
- Memory cache vs Disk cache
- Use the most suitable cache replacement policy for the app.
 - FIFO - First In First Out
 - Largest Evict
 - **LRU - Least Recently Used**
 - **LFU - Least Frequently Used**
- Android Caching support
 - <https://developer.android.com/reference/android/net/http/HttpResponseCache>
 - <https://developer.android.com/reference/android/util/LruCache>
 - <https://developer.android.com/topic/performance/graphics/cache-bitmap>
- Image caching/loading libraries
 - Glide - <https://github.com/bumptech/glide>
 - Picasso - <http://square.github.io/picasso/>

Tools for Network Debugging

Android Profiler

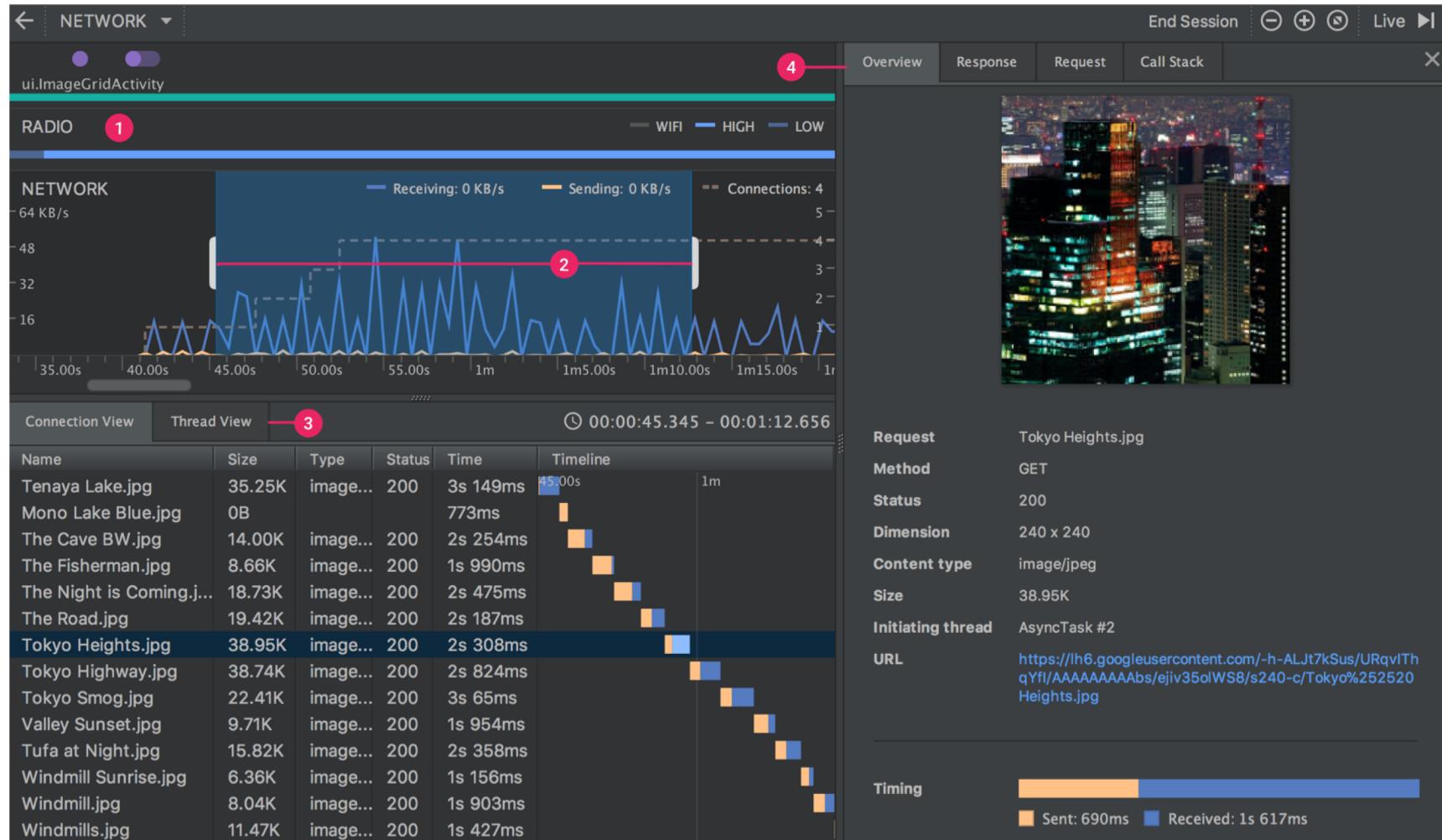
- Available from Android Studio 3.0
 - **View > Tool Windows > Android Profiler**
- Great tool to ensure efficient/in-efficient usage of resources of your app
 - CPU Profiler
 - Memory Profiler
 - **Network Profiler**
- Enable Advanced Profiling
 - **Run > Edit Configurations > Profiling > Enable advanced profiling**

Android Profiler



Clicking here opens Network Profiler

Network Profiler

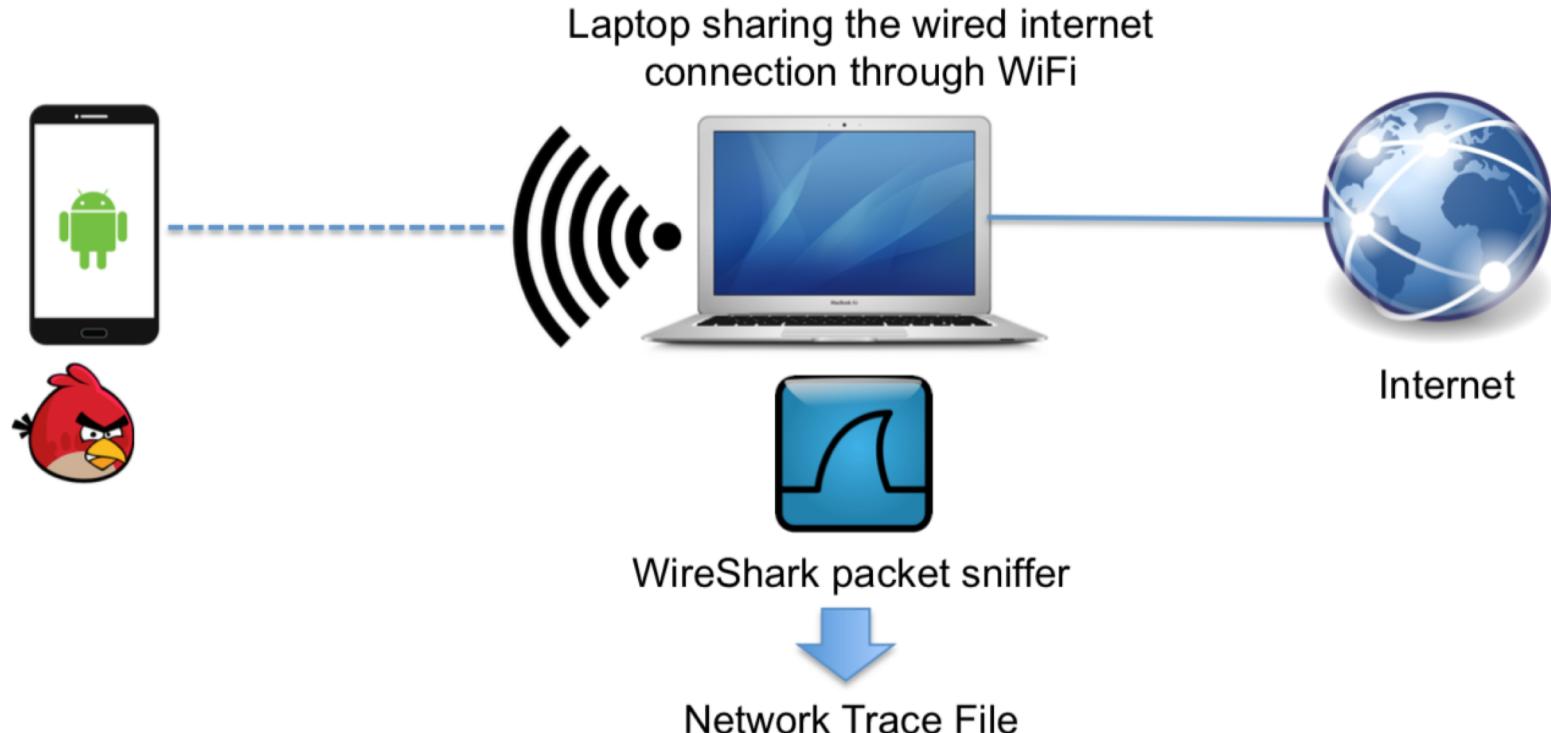


Network Profiler

- Click on the network timeline to open Network Profiler
- **Connection view**
 - List both sent and received files including the size, type, status, etc.
- **Thread view**
 - Display activities of each thread
- Currently supports [HttpURLConnection](#) and [OkHttp](#) libraries
- Can not profile other application traffic to answer questions like;
 - What happened to all of my data?
 - Why my battery drains so fast?
 - Is my data safe?

Wireshark for passive network measurements

- Wireshark Packet Sniffer
 - Download - <https://www.wireshark.org>



Resources

- Android Developer Documentation
 - <https://developer.android.com/guide/topics/connectivity/>
- Computer Network Fundamentals
 - **Computer Networking: A Top Down Approach, 7th Edition, Jim Kurose, Keith Ross**
- Mobile networking best practices
 - **AT&T Video Optimizer Best Practices**
 - <https://developer.att.com/video-optimizer/docs/best-practices>

What's Next?

- Assignment 2 released today.
- Media access tutorial today, which provides the basis for Assignment 2.
- **Project Proposal due next week.**
- Submit a PDF via Canvas by the deadline
- Next week
 - Mobile Privacy and Security