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Basics of Mobile Application Development

Hardware

General capabilities

Top existing hardware

iPhone 11 Pro

- 2.65 GHz 6 core SOC
  - 2 High performance cores
  - 4 energy efficieny cores
- +3 cores GPU
- Neural Network Engine
  - Corresponding API
- 6 Gb LPDDR4X RAM

Pixel 3 XL

- 2.5 Ghz 4 cores
- 1.6 Ghz 4 cores
- Dedicated GPU
  - Adreno 630 (multicore)
- AI accelerator chip
  - Parallel processing API
- 4 Gb LPDDR4X RAM

Camera arrays + extra

iPhone X

- Rear: 3 components
  - 12 Mp, multiple lens
  - Uwide, Wide, Telephoto
  - Up to 4K
  - Up to 240 fps
- Front: 12 Mp
  - 4K@30fps
  - HDR
- FaceID
  - 30,000 infrared dots + sensor

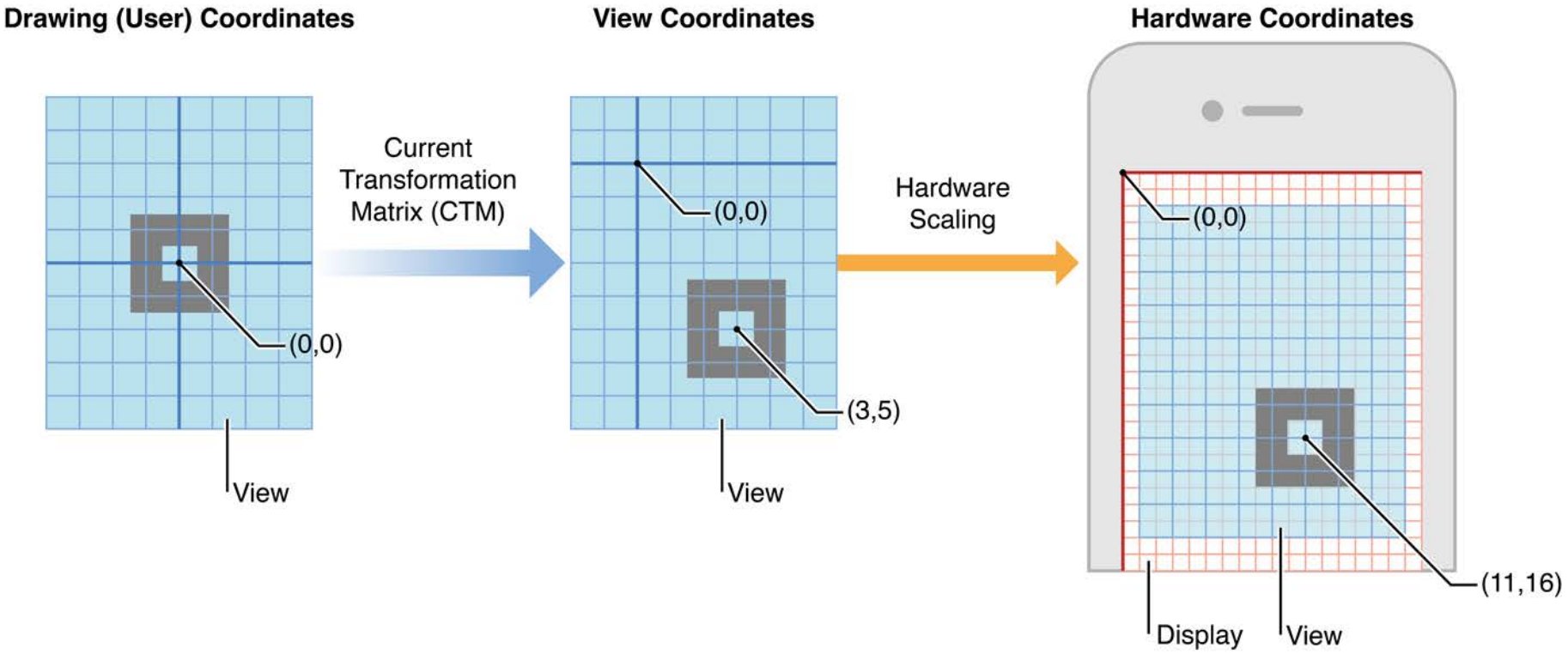
Pixel 3

- Rear: 12.2 Mp
  - Dual Pixel Phase AF
  - HDR+
  - Up to 4K
  - Up to 240 fps
- Front: 8 Mp
  - Two cameras
    - + Wide angle lens
  - Depth sensor
  - 1080p@30fps
- Fingerprint sensor

Sensors systems

Detour – Screen coordinate systems

- In iOS



Detour – Screen coordinate systems

UIKit

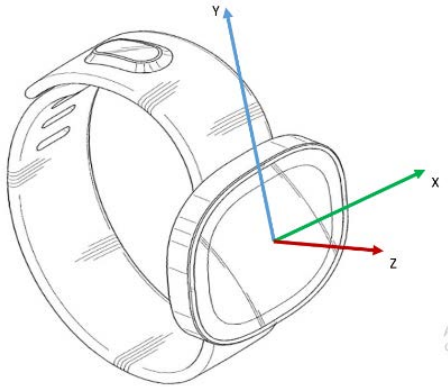
Core Graphics

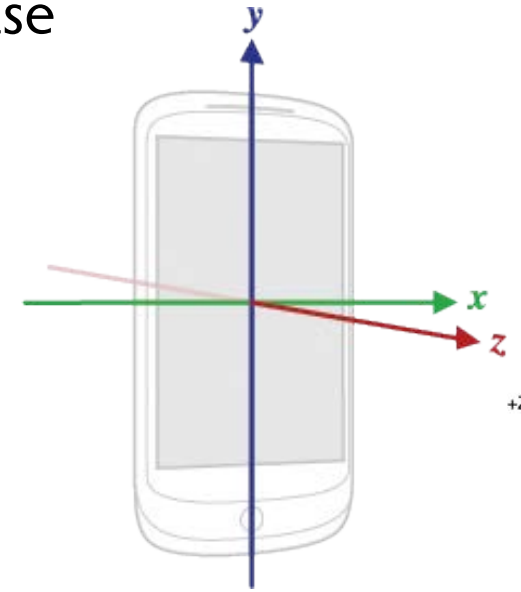
Detour – Screen coordinate systems

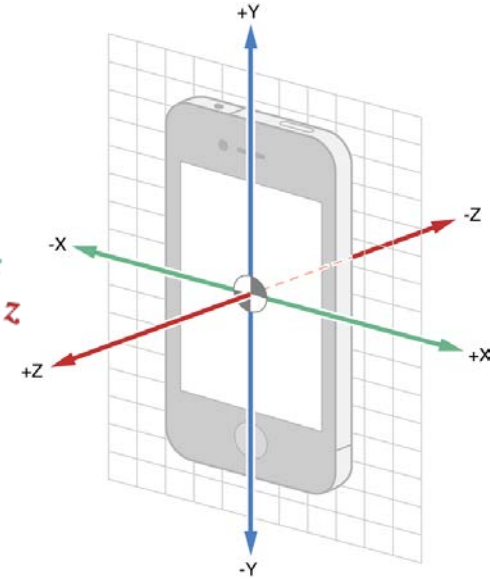
- In Android the top-left point is considered as zero point
  - In any orientation
  - The origin is not an absolute point, it depends on orientation
- 3D graphics introduces the third axis

Coordinate systems

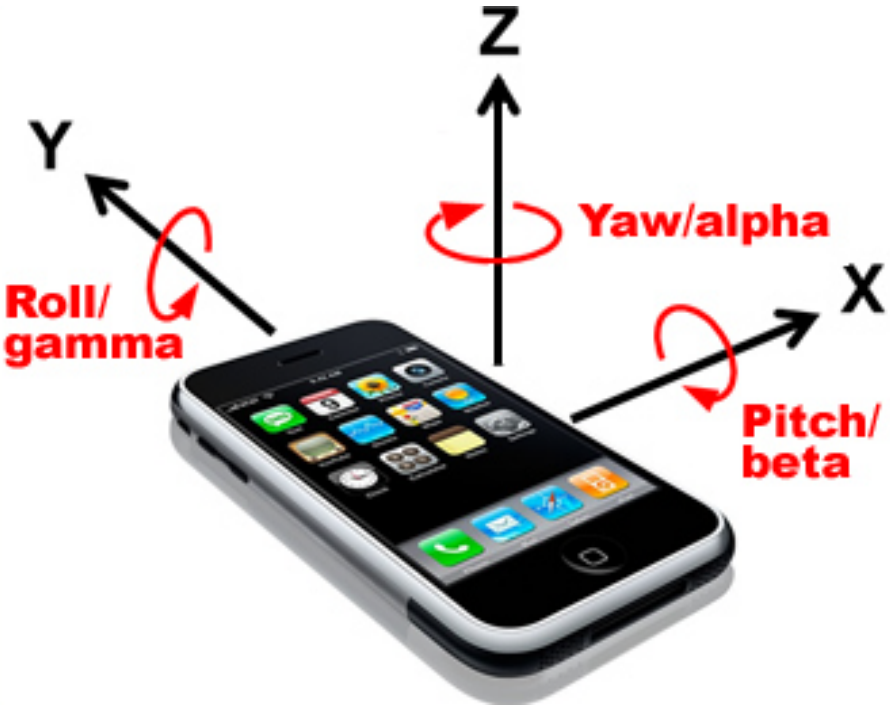
- The tri-axial sensors use the following coordinate system
  - Always the base orientation have to be considered
  - The axes do not change in case of orientation change
  - X-Y plane is the screen itself
- Axis
  - X: short edge, left to right
  - Y: long edge, bottom to up
  - Z: back to front

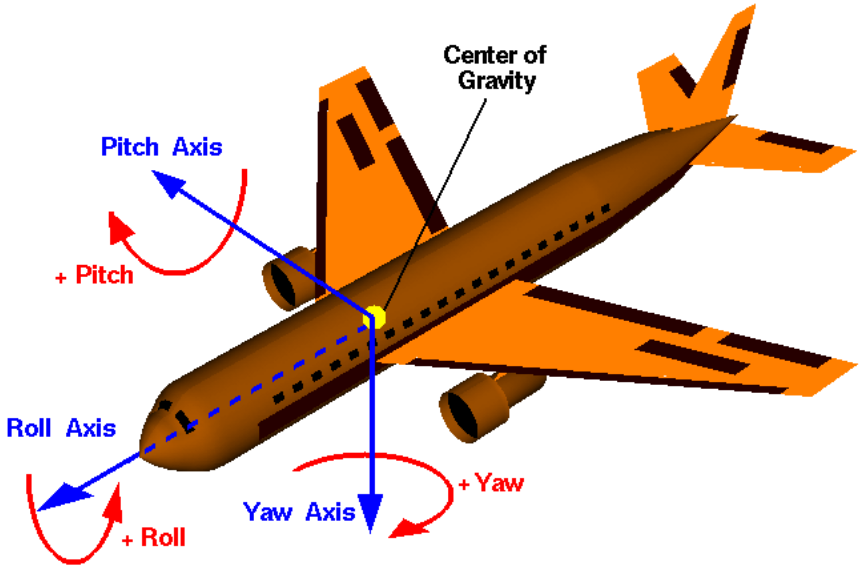






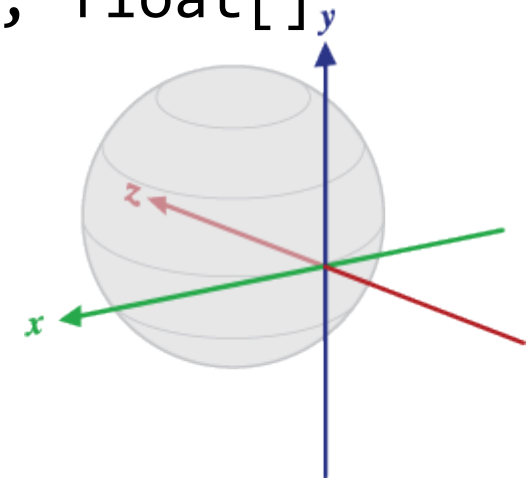
Rotational angles - iOS





Android Orientational coordinates

- Using the inclitation matrix the angle can be calculated
  - `float getInclination (float[] I);`
  - Result in radian
- Using the rotation matrix the orientational angles can be calculated
  - `float[] getOrientation (float[] R, float[] values)`
  - Angels are
    - Around the Z axis (Azimuth)
    - Around the X axis (Roll)
    - Around the Y axis (Pitch)
  - All of them counter clockwise



Sensors in Android API

Sensor	Type	Description	Common Uses
TYPE_ACCELEROMETER	Hardware	Measures the acceleration force in m/s^2 that is applied to a device on all three physical axes (x, y, and z), including the force of gravity.	Motion detection (shake, tilt, etc.).
TYPE_AMBIENT_TEMPERATURE	Hardware	Measures the ambient room temperature in degrees Celsius (°C). See note below.	Monitoring air temperatures.
TYPE_GRAVITY	Software or Hardware	Measures the force of gravity in m/s^2 that is applied to a device on all three physical axes (x, y, z).	Motion detection (shake, tilt, etc.).
TYPE_GYROSCOPE	Hardware	Measures a device's rate of rotation in rad/s around each of the three physical axes (x, y, and z).	Rotation detection (spin, turn, etc.).
TYPE_LIGHT	Hardware	Measures the ambient light level (illumination) in lx.	Controlling screen brightness.
TYPE_LINEAR_ACCELERATION	Software or Hardware	Measures the acceleration force in m/s^2 that is applied to a device on all three physical axes (x, y, and z), excluding the force of gravity.	Monitoring acceleration along a single axis.
TYPE_MAGNETIC_FIELD	Hardware	Measures the ambient geomagnetic field for all three physical axes (x, y, z) in μT.	Creating a compass.

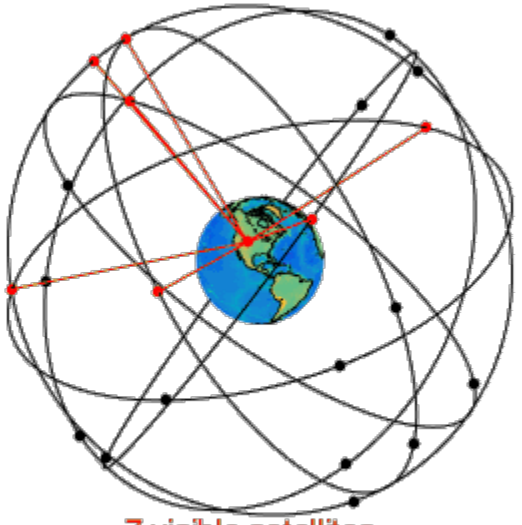
Sensors in Android API

Sensor	Type	Description	Common Uses
TYPE_ORIENTATION	Software	Measures degrees of rotation that a device makes around all three physical axes (x, y, z). As of API level 3 you can obtain the inclination matrix and rotation matrix for a device by using the gravity sensor and the geomagnetic field sensor in conjunction with the getRotationMatrix() method.	Determining device position.
TYPE_PRESSURE	Hardware	Measures the ambient air pressure in hPa or mbar.	Monitoring air pressure changes.
TYPE_PROXIMITY	Hardware	Measures the proximity of an object in cm relative to the view screen of a device. This sensor is typically used to determine whether a handset is being held up to a person's ear.	Phone position during a call.
TYPE_RELATIVE_HUMIDITY	Hardware	Measures the relative ambient humidity in percent (%).	Monitoring dewpoint, absolute, and relative humidity.
TYPE_ROTATION_VECTOR	Software or Hardware	Measures the orientation of a device by providing the three elements of the device's rotation vector.	Motion detection and rotation detection.
TYPE_TEMPERATURE	Hardware	Measures the temperature of the device in degrees Celsius (°C). This sensor implementation varies across devices and this sensor was replaced with the TYPE_AMBIENT_TEMPERATURE sensor in API Level 14	Monitoring temperatures.

Sensors in iOS API

- Core Motion
  - Three dimensional gyroscope
  - Accelerometer
  - Pedometer
  - Magnetic sensor – compass
  - Altitude

Positioning



Positioning systems

System	GPS	GLONASS	BeiDou	Galileo	NAVIC	QZSS
Owner	United States	Russian Federation	China	European Union	India	Japan
Coding	CDMA	FDMA	CDMA	CDMA	CDMA	CDMA
Orbital altitude	20,180 km	19,130 km	21, 500 km	23,222 km	36,000 km	32,600 km - 39,000 km
Precision	5m (no DGPS or WAAS)	4.5m – 7.4m	10m (Public) 0.1m (Encrypted)	1m (Public) 0.01m (Encrypted)	10m (Public) 0.1m (Encrypted)	1m (Public) 0.1m (Encrypted)
Status	Operational	Operational	Basic services operational, To be completed in H1 2020	18 satellites operational, 12 additional satellites 2016-2020	Operational	

Common features

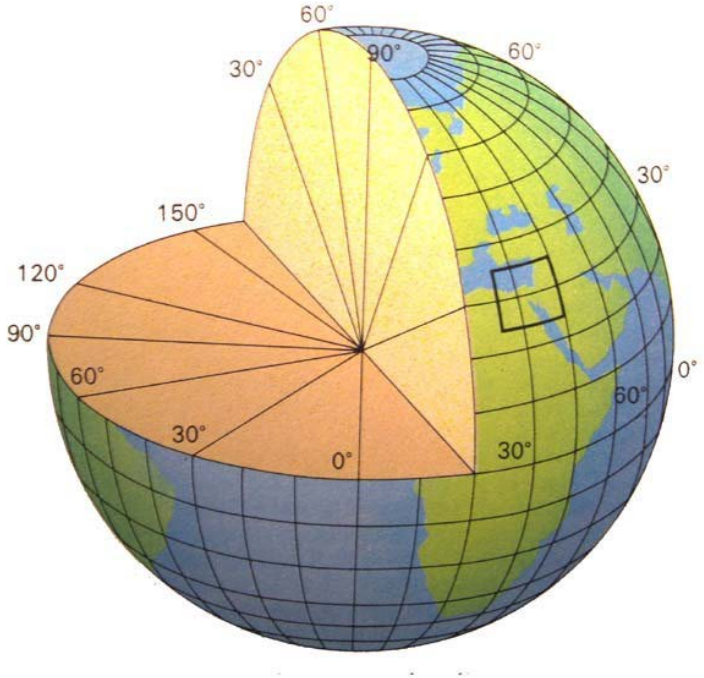
- Satellites in space
  - Influenced by weather conditions
  - All around on Earth, and nearby, in space
  - Mail satellites, and spares
    - Atomic clock inside
  - CDMA coding scheme
- Satellites are broadcasting its positions and time
  - Data from 3+1 satellites is enough to calculate position
- Transmitting on several different frequencies
  - For civilian and military objectives

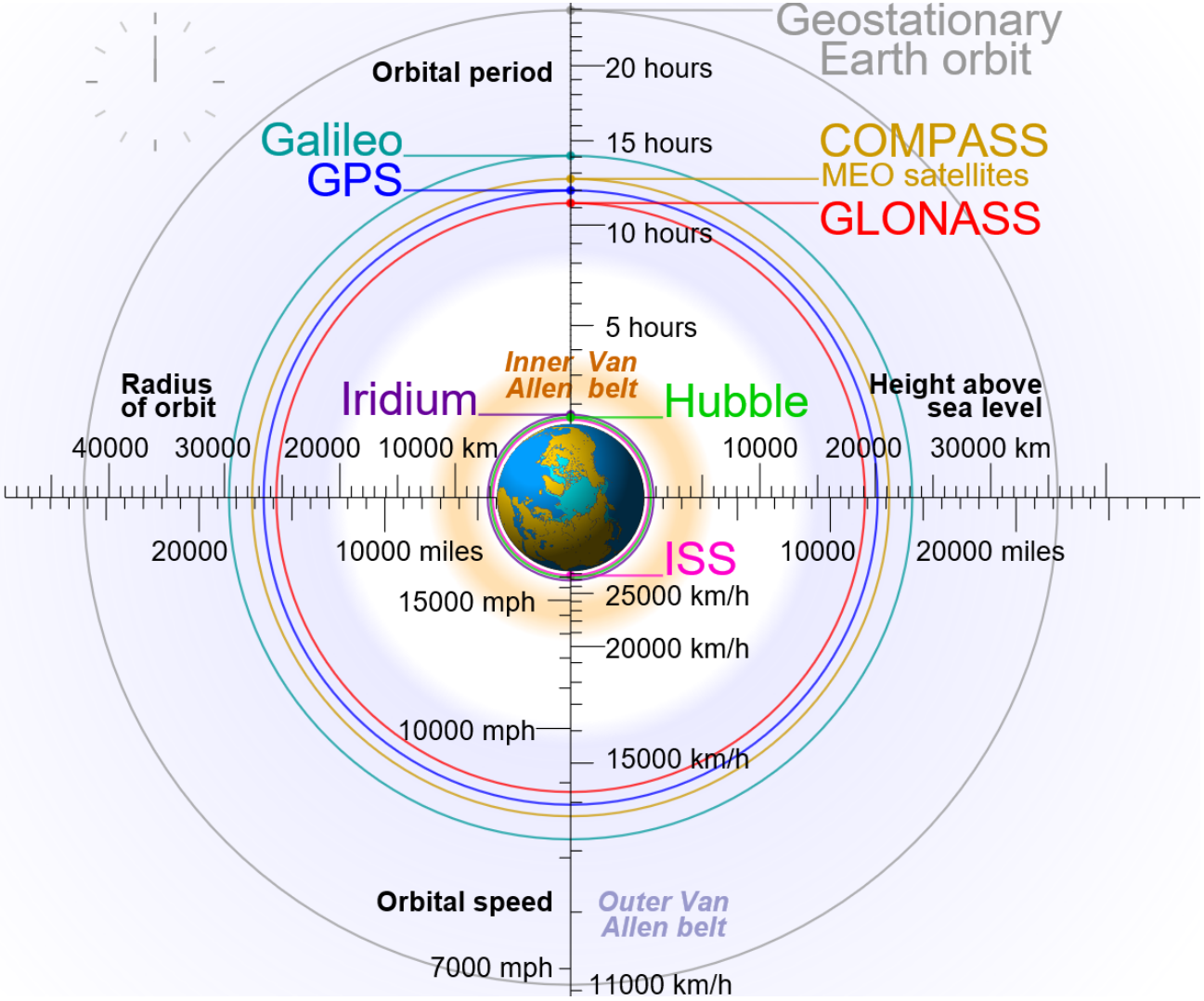
GPS History

- 1978 - 1992
  - 1987: Experimental,
  - 1989: Second generation
- 1993
  - 24 satellites is available
  - 3 channel devices.
  - Positioning requires ~10 minutes
- 1998
  - RDS in Hungary
- 2000
  - 12 channel devices
  - 15-20 seconds enough to calculate position
  - Accuracy in Civilian usage is 20 meters
- 2005
  - Next generation of satellites
  - Secondary signal to increase accuracy
- 2010
  - Second generation of earth control

Coordinate system

- World Geodetic System (WGS)
  - Pole of the system is the mass center of Earth
  - The 0th line of longitude is the IERS reference line
  - Z axis is the rotation axis of the Earth (averaged)
  - Y plane is perpendicular to the rotation axis (the mass center is on the Y plane)




Geostationary
Earth orbit
Orbital period
20 hours
15 hours
10 hours
5 hours
Galileo
GPS
COMPASS
MEO satellites
GLONASS
Inner Van
Allen belt
Iridium
Hubble
Radius
of orbit
Height above
sea level
40000 30000 20000 10000 km
10000 20000 30000 km
20000 10000 miles
10000 20000 miles
ISS
15000 mph
25000 km/h
20000 km/h
10000 mph
15000 km/h
Orbital speed
Outer Van
Allen belt
7000 mph
11000 km/h

Other than GPS

GLONASS

- Russian
  - 17/8 rev / day
  - 24 satellites + spares
  - FDMA
- Finished in 2011, but the system design is older
  - Beginning of development is back to the 70's

Galileo

- EU
  - 17/10 rev / day
  - 26 satellites (spares)
  - CDMA
- Will be completed in 2020

Other than GPS

BeiDou

- Chineese
  - MEO
  - 17/9 rev/day
  - 23 satellites
  - 35 by 2020
- Will be completed by H1 2020

NAVIC/QZSS

- Indian / Japanese
- Both CDMA
- Regional systems
- GEO / GSO

Supported positioning systems

- GPS
  - Almost in all device
- Other systems
  - Number is incresing
- Pixel 3 XL
  - GPS (with A-GPS), GLONASS, BeiDou, GALILEO
- Iphone 11
  - GPS (with A-GPS), GLONASS

Assisted GPS – AGPS

- A system that often significantly improves the startup performance of a GPS satellite-based positioning system
- Assistance falls into two categories
  - Mobile Station Based (MSB): Information used to acquire satellites more quickly.
    - It can supply orbital data or almanac for the GPS satellites to the GPS receiver, enabling the GPS receiver to lock to the satellites more rapidly in some cases.
    - The network can provide precise time.
  - Mobile Station Assisted (MSA): Calculation of position by the server using information from the GPS receiver.
    - The device captures a snapshot of the GPS signal, with approximate time, for the server to later process into a position.
    - The assistance server has a good satellite signal and plentiful computation power, so it can compare fragmentary signals relayed to it.
    - Accurate, surveyed coordinates for the cell site towers allow better knowledge of local ionospheric conditions and other conditions affecting the GPS signal than the GPS receiver alone, enabling more precise calculation of position.

Android Example

```
LocationManager locationManager = (LocationManager)
this.getSystemService(Context.LOCATION_SERVICE);

LocationListener locationListener = new LocationListener() {
    public void onLocationChanged(Location location) {
      makeUseOfNewLocation(location);
    }

    public void onStatusChanged(String provider, int status, Bundle extras)
        {}

    public void onProviderEnabled(String provider)
        {}

    public void onProviderDisabled(String provider)
        {}
  };

locationManager.requestLocationUpdates(
        LocationManager.NETWORK_PROVIDER, 0, 0, locationListener);
```

iOS - Example

- ```
  var locationManager: CLLocationManager!
  locationManager = CLLocationManager();
  locationManager.delegate = self;
  locationManager.desiredAccuracy = kCLLocationAccuracyBest
  locationManager.startUpdatingLocation();
  ```

- ```
  func locationManager(manager: CLLocationManager!,
            didUpdateLocations locations: [AnyObject]!) {
    var location:CLLocation =
            locations[locations.count-1] as CLLocation
    println("locations = \(locations)")
    txtLatitude.text = "\(location.coordinate.latitude)";
    txtLongitude.text = "\(location.coordinate.longitude)";
  }
  ```

Bluetooth

Bluetooth

- History
  - Started in 1994
  - In 1998 the Bluetooth SIG has been formed (Special Interest Group)
    - IBM, Intel, Nokia, Toshiba, Lucent, Microsoft
  - First working ad hoc network
  - Standardized by IEEE: IEEE 802.15
- Properties
  - Easy to implement
    - 1-2 cm size
  - Low power consumption
    - 1-2 % of mobile energy
  - Low cost
    - 5 $

Bluetooth version

- 1.0
  - First version – with bugs
- 1.1
  - IEEE standard
  - RSSI indication, unencripted channel managements
- 1.2
  - Faster
  - Max 721 kbit/s
- 2.0 + EDR
  - Enhanced Data Rate max 3 Mbit/s
  - EDS is optional
- 2.1 + EDR
  - SSP – Secure Simple Pairing
- 3.0 + HS
  - 24 Mbit/s
  - New working methods
  - Advances energy management

Bluetooth version

- 4.0
  - More energy protocols
  - Extension of the Core Specification
- 4.1
  - Mobile Wireless Service Coexistence Signaling
  - Train Nudging and Generalized Interlaced Scanning
  - Low Duty Cycle Directed Advertising
  - L2CAP Connection Oriented and Dedicated Channels with Credit Based Flow Control
  - Dual Mode and Topology
  - LE Link Layer Topology
  - 802.11n PAL
  - Audio Architecture Updates for Wide Band Speech
  - Fast Data Advertising Interval
  - Limited Discovery Time
- 4.2
  - IP over Bluetooth
  - Improvements

Bluetooth version

- 5.0 – 2016
- 5.1 – 2019
  - Angle of Arrival
  - Mesh-based model
  - Many improvements

Protocols

- Not every protocol is supported by all devices / platforms
  - **LMP**
    - The Link Management Protocol (LMP) is used for set-up and control of the radio link between two devices. Implemented on the controller.
  - **L2CAP**
    - The Logical Link Control and Adaptation Protocol (L2CAP) used to multiplex multiple logical connections between two devices using different higher level protocols.
  - **SDP**
    - The Service Discovery Protocol (SDP) allows a device to discover services offered by other devices, and their associated parameters
  - **RFCOMM**
    - Radio Frequency Communications (RFCOMM) is a cable replacement protocol used to generate a virtual serial data stream
  - **BNEP**
    - The Bluetooth Network Encapsulation Protocol (BNEP) is used for transferring another protocol stack's data via an L2CAP channel. Its main purpose is the transmission of IP packets in the Personal Area Networking Profile.

Protocols

- Not every protocol is supported by all devices / platforms
  - **BNEP**
    - The Bluetooth Network Encapsulation Protocol (BNEP) is used for transferring another protocol stack's data via an L2CAP channel. Its main purpose is the transmission of IP packets in the Personal Area Networking Profile.
  - **AVCTP**
    - The Audio/Video Control Transport Protocol (AVCTP) is used by the remote control profile to transfer AV/C commands over an L2CAP channel.
  - **AVDTP**
    - The Audio/Video Distribution Transport Protocol (AVDTP) is used by the advanced audio distribution profile to stream music to stereo headsets over an L2CAP channel.
  - **TCS**
    - The Telephony Control Protocol – Binary (TCS BIN) is the bit-oriented protocol that defines the call control signaling for the establishment of voice and data calls between Bluetooth devices.
  - **Further: PPP, TCP/IP/UDP, OBEX, WAE/WAP**

Bluetooth Profiles

Advanced Audio Distribution Profile (A2DP)
Attribute Profile (ATT)
Audio/Video Remote Control Profile (AVRCP)
Basic Imaging Profile (BIP)
Basic Printing Profile (BPP)
Common ISDN Access Profile (CIP)
Cordless Telephony Profile (CTP)
Device ID Profile (DIP)
Dial-up Networking Profile (DUN)
Fax Profile (FAX)
File Transfer Profile (FTP)
Generic Audio/Video Distribution Profile (GAVDP)
Generic Access Profile (GAP)
Generic Attribute Profile (GATT)
Generic Object Exchange Profile (GOEP)
Hard Copy Cable Replacement Profile (HCRP)
Health Device Profile (HDP)
Hands-Free Profile (HFP)
Human Interface Device Profile (HID)
Headset Profile (HSP)
Intercom Profile (ICP)
LAN Access Profile (LAP)
Message Access Profile (MAP)
OBject EXchange (OBEX)
Object Push Profile (OPP)
Personal Area Networking Profile (PAN)
Phone Book Access Profile (PBAP, PBA)
Proximity Profile (PXP)
Serial Port Profile (SPP)
Service Discovery Application Profile (SDAP)
SIM Access Profile (SAP, SIM, rSAP)
Synchronization Profile (SYNCH)
Synchronisation Mark-up Language Profile (SyncML)
Video Distribution Profile (VDP)
Wireless Application Protocol Bearer (WAPB)

Supported profiles in iOS

Device	Hands-Free Profile (HFP 1.6)	Phone Book Access Profile (PBAP)	Advanced Audio Distribution Profile (A2DP)	Audio/Video Remote Control Profile (AVRCP 1.4)	Personal Area Network Profile (PAN)	Human Interface Device Profile (HID)	Message Access Profile (MAP)
iPhone 4 and later	✓	✓	✓	✓	✓	✓	✓
iPhone 3GS	✓	✓	✓	✓	✓	✓	-
iPhone 3G	✓	✓	✓	✓	✓	-	-
Original iPhone	✓	✓	-	-	-	-	-
iPad 2 and later	✓	-	✓	✓	✓	✓	-
iPad (1st generation)	-	-	✓	✓	✓	✓	-
iPod touch (4th generation and later)	✓	-	✓	✓	✓	✓	-
iPod touch (2nd and 3rd generation)	-	-	✓	✓	✓	✓	-

Supported profiles in Android

Feature		Android version				
Name	Description	6.0	7.0	7.1	7.1.2	8.0
SAP	SIM Access Profile	1.1	1.1	1.1	1.1	1.1
MAP	Message Access Profile for SMS	1.2	1.2	1.2	1.2	1.2
OPP	Object Push Profile	1.1	1.1	1.1	1.1	1.2
OBEX over L2CAP	OBject EXchange over Logical Link Control and Adaptation Protocol	Yes	Yes	Yes	Yes	Yes
HFP Audio Gateway	Hands-Free Profile	1.6	1.6	1.7	1.7	1.7
HSP	Headset Profile	1.2	1.2	1.2	1.2	1.2
A2DP	Advanced Audio Distribution Profile	1.2	1.2	1.2	1.2	1.2
AVRCP	Audio/Video Remote Control Profile	1.3	1.3	1.3	1.3	1.4
HID	Human Interface Device Profile	1.0	1.0	1.0	1.0	1.0

Supported profiles in Android

Feature		Android version				
Name	Description	6.0	7.0	7.1	7.1.2	8.0
HID	Human Interface Device Profile	1.0	1.0	1.0	1.0	1.0
PBAP	Phone Book Access Profile	1.1.1	1.1.1	1.1.1	1.1.1	1.2
HDP	Health Device Profile	1.0	1.0	1.1	1.1	1.1
SPP	Serial Port Profile	1.2	1.2	1.2	1.2	1.2
PAN / BNEP	Personal Area Networking Profile / Bluetooth Network Encapsulation Protocol	1.0	1.0	1.0	1.0	1.0
DIP	Device ID Profile	1.3	1.3	1.3	1.3	1.3
HOGP 1.0	HID over GATT	Yes	Yes	Yes	Yes	Yes
HD Audio[1]	See "Advanced audio codecs" above	No	No	No	No	Yes

GSM-like …

History of mobile services

- 1. generation
  - …
- 2. generation
  - GSM + CSD (circuit switching) (Europe)
  - CDMA based system (IS-54, IS-136, IS-95) (North America)
  - PSH (Far East)
- 2.x generation
  - GSM/3GPP variant
    - HSCSD (57,6 kbps) – analogue with traditional modems
    - GPRS (~80/20 kbps)
    - EGPRS = EDGE ~177,6/118,4 kbps
  - CDMA/3GPP2 variant
    - CDMA2000

History of mobile services

- 3. generation
  - 3GPP variant
    - UMTS (**WCDMA**, TD-CDMA, TD-SCDMA)
    - Beginning of unification of standards
    - Several release
      - R4: EDGE
      - R5: HSDPA – Technology between 1.2 and 14.0 Mbps, most common: 7.2 Mbps
      - R6: HSUPA – 5,76 Mbps
      - R7-R8: Dual cell HSDPA/HSUPA:
  - 3GPP2 variant
    - Further revisions of CDMA2000
- 3.x generation
  - Further releases

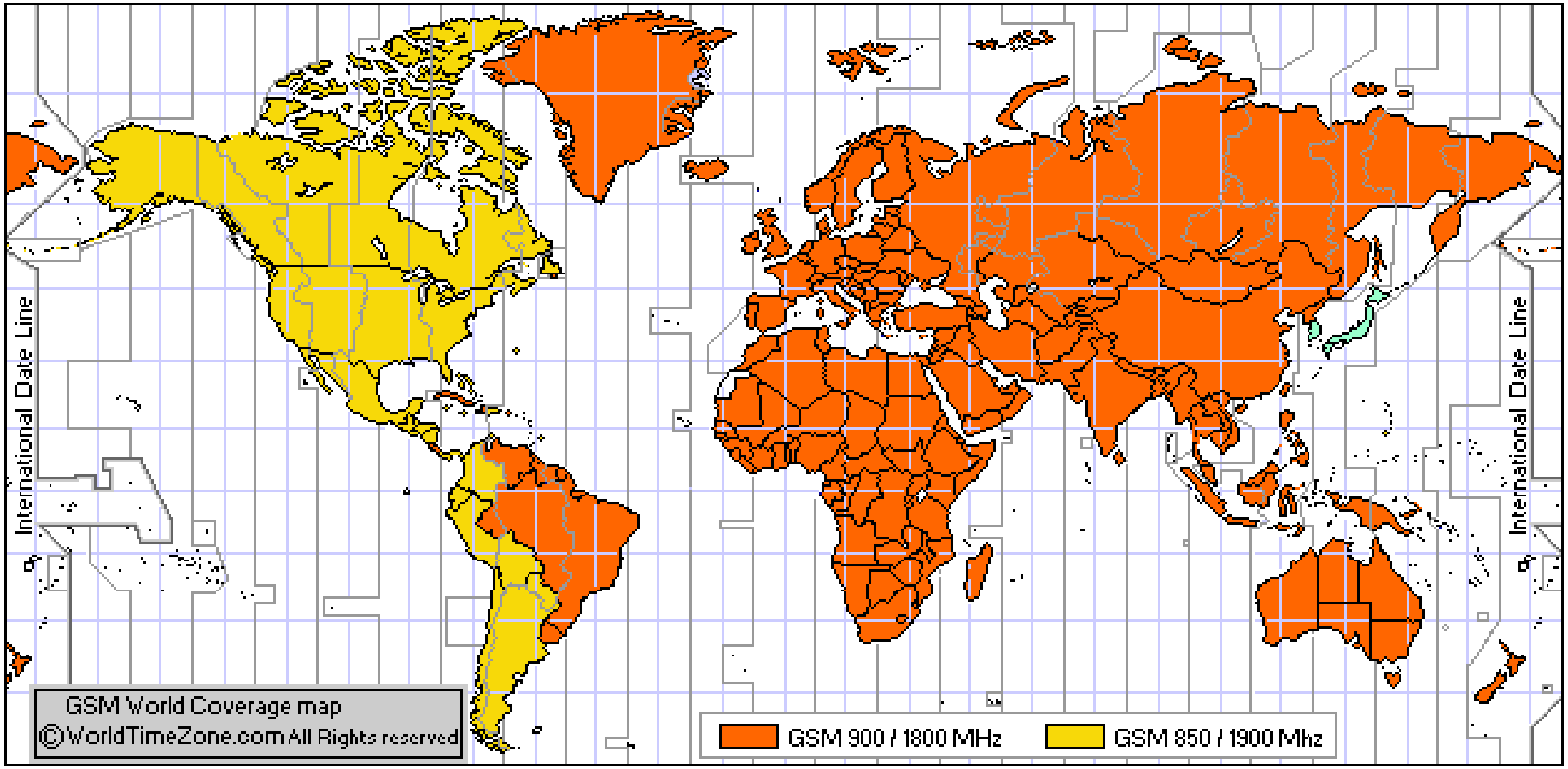
History of mobile services

- 3.9
  - LTE
- 4. generation (4G, 4.5G, 4.9G)
  - LTE – Advanced – All-in-one
  - Several Release and Category, different frequency band in different countries
- 5. generation

VoLTE

- Voice over LTE (VoLTE) is a standard for high-speed wireless communication for mobile phones and data terminals
- VoLTE has up to three times more voice and data capacity than 3G UMTS and up to six times more than 2G GSM.

GSM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GSM World Coverage map
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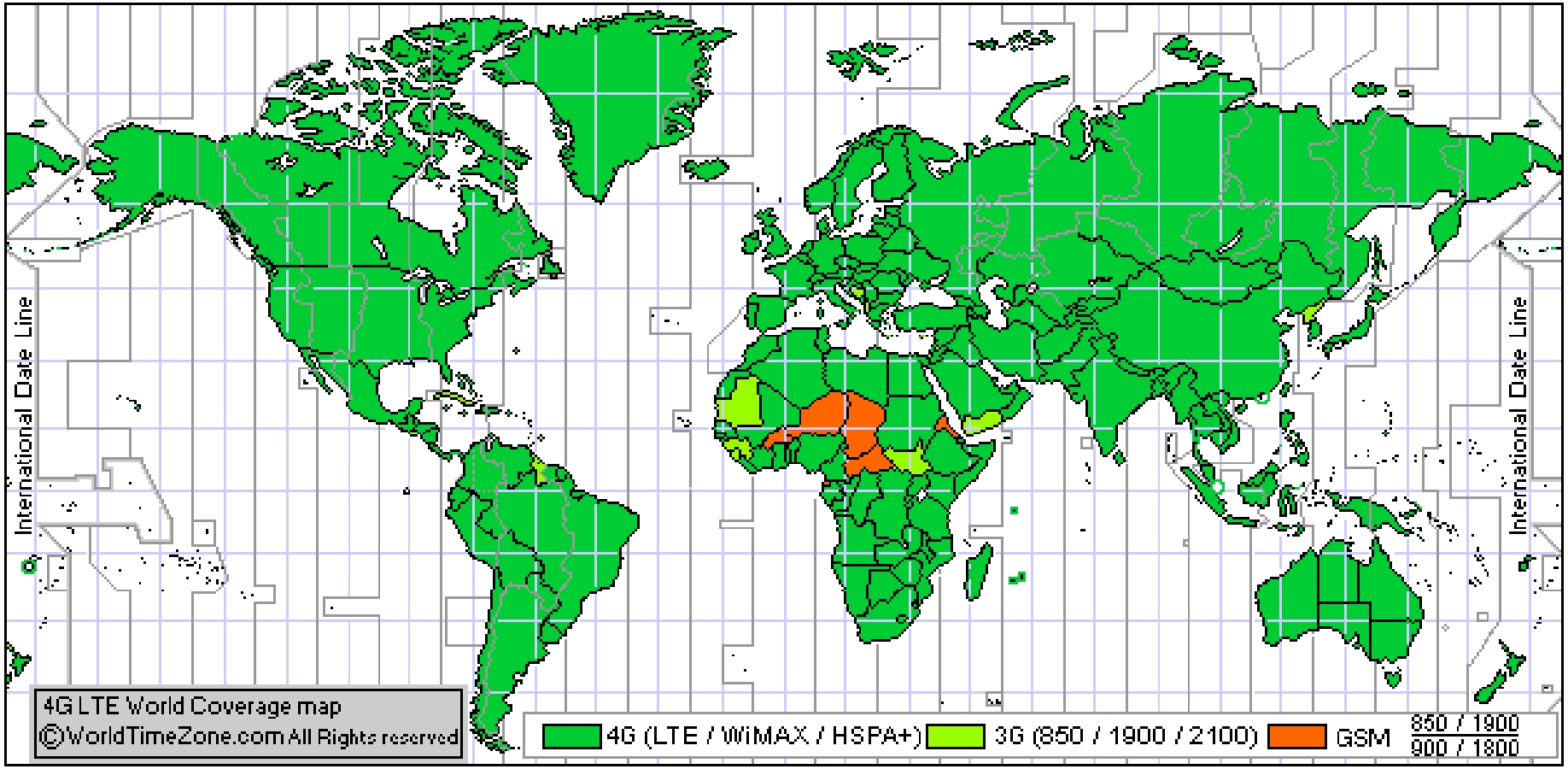
GSM 900 / 1800 MHz
GSM 850 / 1900 Mhz

4G LTE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4G LTE World Coverage map
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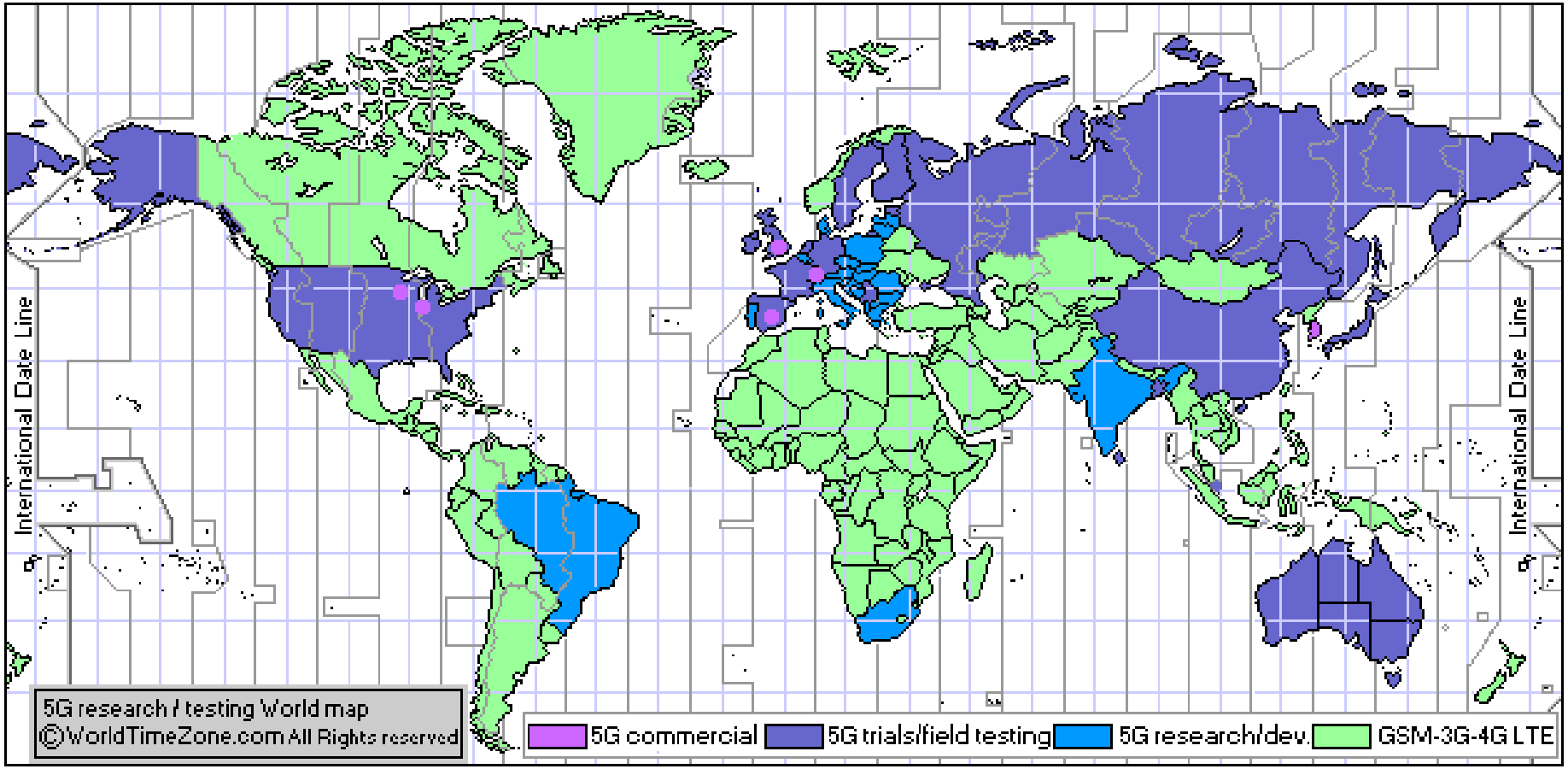
4G (LTE / WiMAX / HSPA+)
3G (850 / 1900 / 2100)
GSM
850 / 1900
900 / 1800

5G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5G commercial
5G trials/field testing
5G research/dev.
GSM-3G-4G LTE

LTE

1	South Korea	97.5%
2	Japan	96.3%
3	Norway	95.5%
4	Hong Kong	94.1%
5	United States	93%
6	Netherlands	92.8%
7	Taiwan	92.8%
8	Hungary	91.4%
9	Sweden	91.1%
10	India	90.9%

LTE / LTE Advanced

Category 0	1.0 Mbit/s	1	1.0 Mbit/s	Release 12
Category 1	10.3 Mbit/s	1	5.2 Mbit/s	Release 8
Category 2	*51.0 Mbit/s*	*2*	*25.5 Mbit/s*	*Release 8*
Category 3	102.0 Mbit/s	2	51.0 Mbit/s	Release 8
Category 4	150.8 Mbit/s	2	51.0 Mbit/s	Release 8
Category 5	299.6 Mbit/s	4	75.4 Mbit/s	Release 8
Category 6	301.5 Mbit/s	2 or 4	51.0 Mbit/s	Release 10
Category 7	301.5 Mbit/s	2 or 4	102.0 Mbit/s	Release 10
Category 8	2,998.6 Mbit/s	8	1,497.8 Mbit/s	Release 10
Category 9	452.2 Mbit/s	2 or 4	51.0 Mbit/s	Release 11
Category 10	452.2 Mbit/s	2 or 4	102.0 Mbit/s	Release 11
Category 11	603.0 Mbit/s	2 or 4	51.0 Mbit/s	Release 11
Category 12	603.0 Mbit/s	2 or 4	102.0 Mbit/s	Release 11
Category 13	391.7 Mbit/s	2 or 4	150.8 Mbit/s	Release 12
Category 14	3,917 Mbit/s	8	N/A	Release 12
Category 15	750 Mbit/s	2 or 4	N/A	Release 12
Category 16	979 Mbit/s	2 or 4	N/A	Release 12

44 LTE channel

- **Networks on LTE-bands 1, 3, 7, 28 (FDD-LTE) or 38, 40 (TDD-LTE) are suitable for future global roaming in ITU Regions 1, 2 and 3.**
- Networks on LTE-band 8 (FDD-LTE) may allow global roaming in the future (ITU Regions 1, 2 and 3) (Long-term perspective).
- Networks on LTE-band 20 (FDD-LTE) are suitable for roaming in ITU Region 1 (EMEA) only.
- Networks on LTE-bands 2 and 4 (FDD-LTE) are suitable for roaming in ITU Region 2 (Americas) only.

NFC

NFC

- Short distance communication standards
  - Communication between mobile devices
  - Touch to start communication
- NFC communication with passive „tags".
  - Passive side has no power source
  - The information can be read by an active device
- The spread of NFC enabled devices is slow (iPhone 6)
  - Other methods: NFC integrated into SIM cards
- Wireless payment methods (credit cards) are also based on NFC

NFC vs. Bluetooth

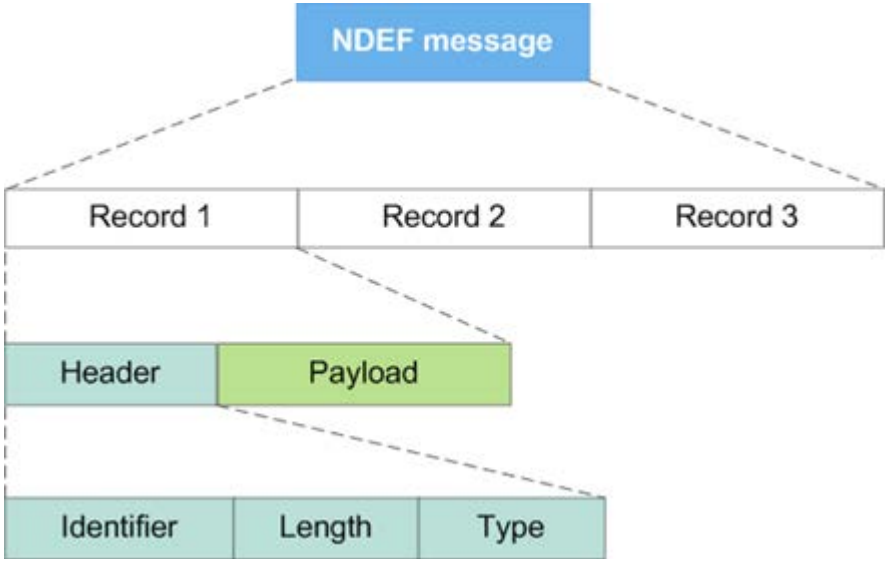
	NFC	Bluetooth	Bluetooth Low Energy
Tag requires power	No	Yes	Yes
Cost of Tag	10c	$5	$5
RFID compatible	ISO 18000-3	active	active
Standardisation body	ISO/IEC	Bluetooth SIG	Bluetooth SIG
Network Standard	ISO 13157 etc.	IEEE 802.15.1	IEEE 802.15.1
Network Type	Point-to-point	WPAN	WPAN
Cryptography	not with RFID	available	available
Range	< 0.2 m	~100 m (class 1)	~50 m
Frequency	13.56 MHz	2.4–2.5 GHz	2.4–2.5 GHz
Bit rate	424 kbit/s	2.1 Mbit/s	1 Mbit/s
Set-up time	< 0.1 s	< 6 s	< 0.006 s
Current consumption	< 15mA (read)	varies with class	< 15 mA (read and transmit)

NFC modes

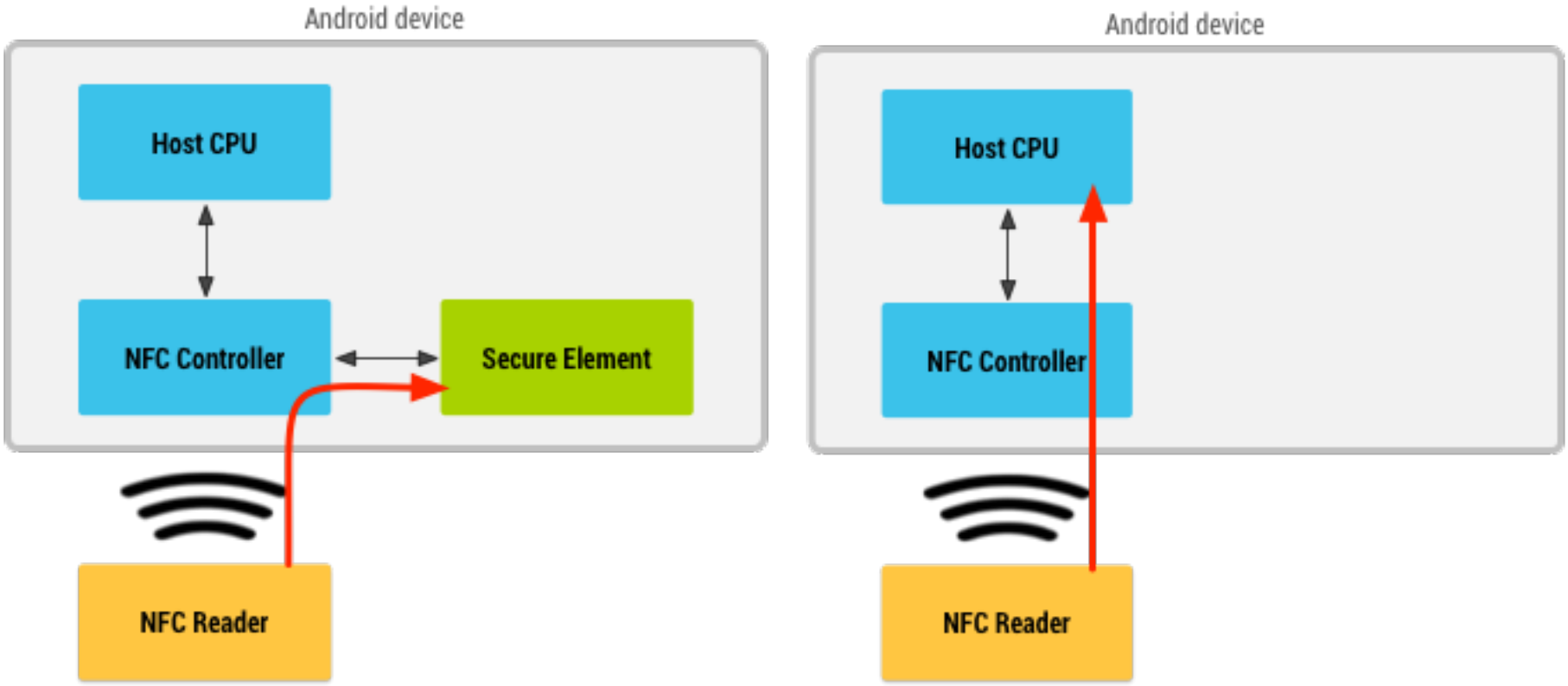
- **Reader/writer mode**, allowing the NFC device to read and/or write passive NFC tags and stickers.
- **P2P mode**, allowing the NFC device to exchange data with other NFC peers
  - This operation mode is used by Android Beam.
- **Card emulation mode**, allowing the NFC device itself to act as an NFC card.
  - The emulated NFC card can then be accessed by an external NFC reader, such as an NFC point-of-sale terminal.

NFC data structure

- NDEF message
- ID = TNF (3 bit)
  - URI: 0x0003
  - Empty: 0x0000
  - External: 0x0004
  - MIME: 0x0002
  - Well Known RTD 0x0001
  - Unknown 0x0005
  - Unchanged 0x0006
- RTD
  - URI, TEXT, Smart Poster, …



Card Emulation



Additional devices

Apple

- iPod, iPad
  - Running the same system
  - Different screen size
  - Some of the features are missing
- Watch
  - WatchOS
  - Gen 4:
    - Cellular, Wifi, Bluetooth, GPS/GLONASS, Storage, etc.
- AppleTV

Google

- Auto
  - „External Display" for Android
  - App support
- Watch
  - Basically the same OS
  - Some of the functions are missing
    - Depending on the manufacturer
- Embedded
  - FireTV
    - Based on the open Android source
  - Other (TV) devices
- ChromeCast

Review of basic programming techniques and definitions

Next week