LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Praktikum Mobile und Verteilte Systeme

Outdoor Positioning

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http://www.mobile.ifi.lmu.de
WS 2018/19

Outdoor Postioning

• History of Positioning 1/3

- **Magnetic Compass** (<5th Century in China, then 13th Century in Europe)
- **Octant**, then **Sextant** (18th Century): measurement of height of objects (sun, stars) above horizon, maximum height gives **latitude**
- **Chronometer** (maritime clock) with +/- 1s stability per day (Harrison, 1761), important for **longitude** determination
  – 1 second error means a 450 m longitude error at the equator (caused by the rotation of the earth)
- With **Sextant/Octant** best position accuracy is 1 NM

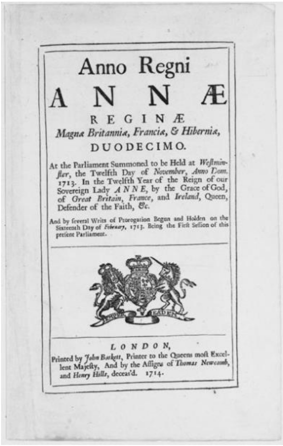
Outdoor Postioning

- History of Positioning 1/3

Outdoor Postioning

• History of Positioning 2/3

- In 1714, following many maritime accidents (including more than 1500 vanished sailors with the loss of the fleet of admiral Clowdisley Shovell in 1707), the British government settled the **longitude act** to offer a 20.000 pounds reward (more than today´s 10 millions €) for a method to determine the longitude.



Anno Regni
ANNÆ
REGINÆ
Magnæ Britanniæ, Franciæ, & Hiberniæ,
DUODECIMO.

At the Parliament Summoned to be Held at *Westminster*, the Twelfth Day of *November*, *Anno Dom.* 1713. In the Twelfth Year of the Reign of our Sovereign Lady *ANNE*, by the Grace of God, of *Great Britain*, *France*, and *Ireland*, Queen, Defender of the Faith, &c.

And by several Writs of Prorogation Begun and Holden on the Sixteenth Day of *February*, 1713. Being the First Session of this present Parliament.

LONDON,
Printed by *John Baskett*, Printer to the Queens most Excellent Majesty, And by the Assigns of *Thomas Newcomb*, and *Henry Hills*, deceas'd. 1714.

- Expected accuracy (drift):
  - Maximum error: **0,5 degrees**
  - 0,5 degrees **= 30 nautical miles** at the equator

    = motion during 2 minutes of earth rotation

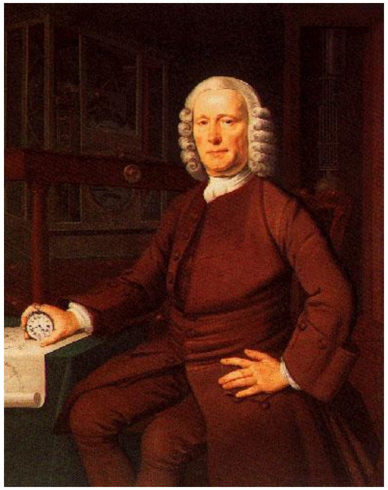
    = 3 seconds per day during 40 days

    (40 days = a 6 week journey from England to the West Indies)

Outdoor Postioning

- History of Positioning 2/2

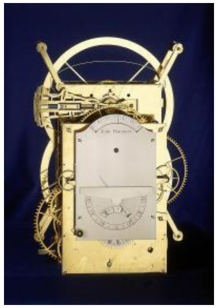
- John Harrison (1693 – 1776)
- Drift on H4 clock: 39.2 seconds after 47 days (4 times better than what was requested)



H1 (1735)
1,2m
34 kg

H2 (1741)

H3 (1757)



H4 (1761)
13cm
1.45 kg

Outdoor Postioning

- Positioning Fundamentals - Components

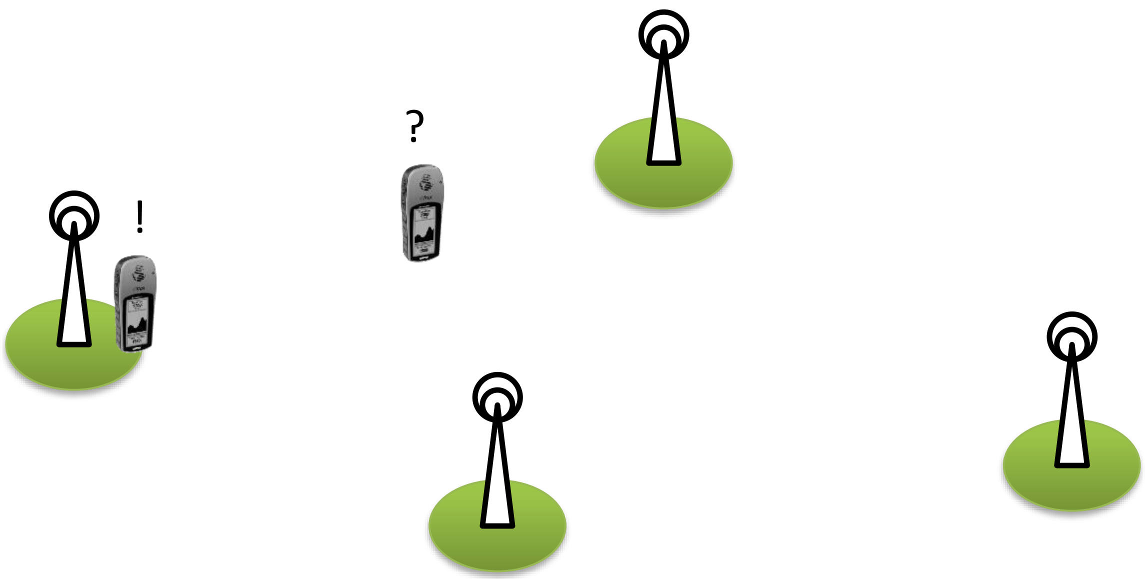
- Positioning is determined by
  - one or **several parameters observed by measurement methods**
  - a positioning method for position calculation
  - a descriptive or spatial reference system
  - an infrastructure
  - protocols and messages for coordinating positioning

Positioning method	Observable	Measured by
Proximity sensing	Cell-ID, coordinates, RSS	Sensing for pilot signals
Lateration	Range or Range difference	**Traveling time** of pilot signals Path loss of pilot signals **Traveling time difference** of pilot signals Path loss difference of pilot signals
Angulation	Angle	Antenna arrays
Dead reckoning	**Position** and **Direction** of motion and **Velocity** and **Distance**	Any **other positioning method** and **sensors**: Gyroscope Accelerometer Odometer
Pattern matching or learning algorithms	Visual images or fingerprints	e.g., via Camera or Received signal strength

Outdoor Postioning

- Positioning Fundamentals – Proximity Sensing

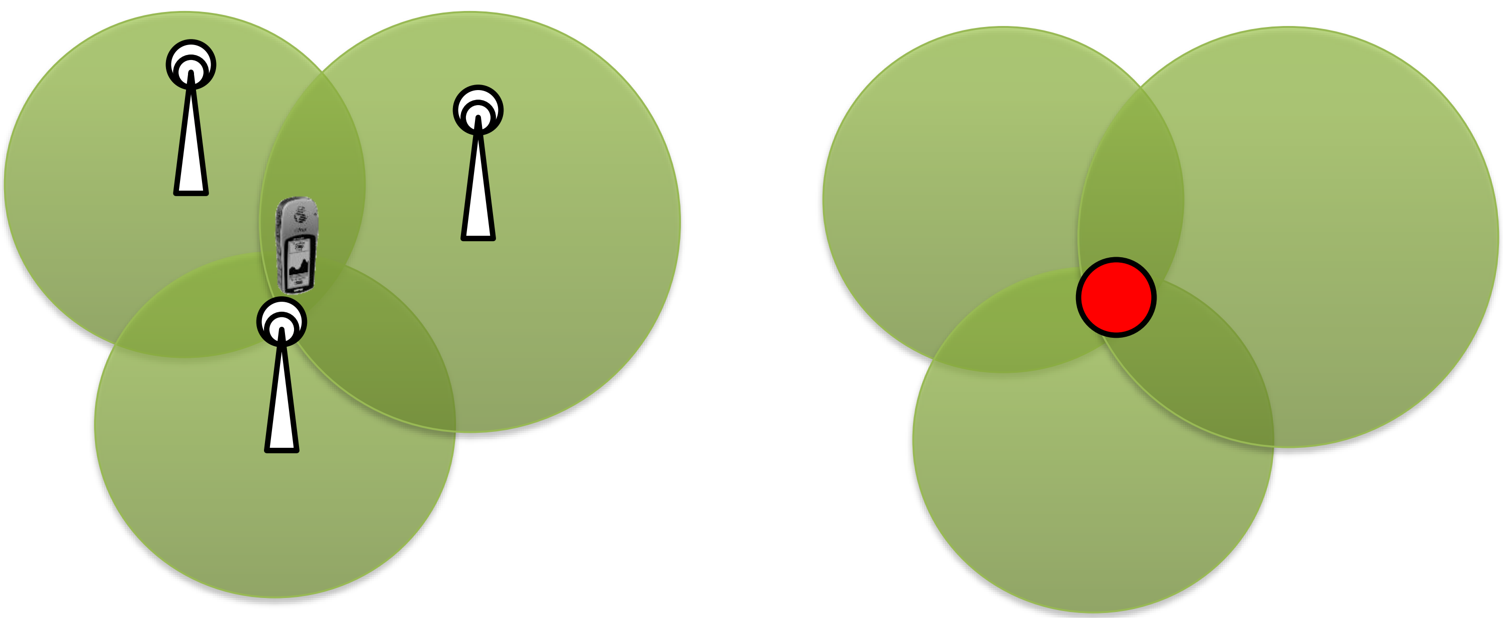
Proximity Sensing by a station using (short) range **pilot signals**:



Outdoor Postioning

- Positioning Fundamentals – Laturation

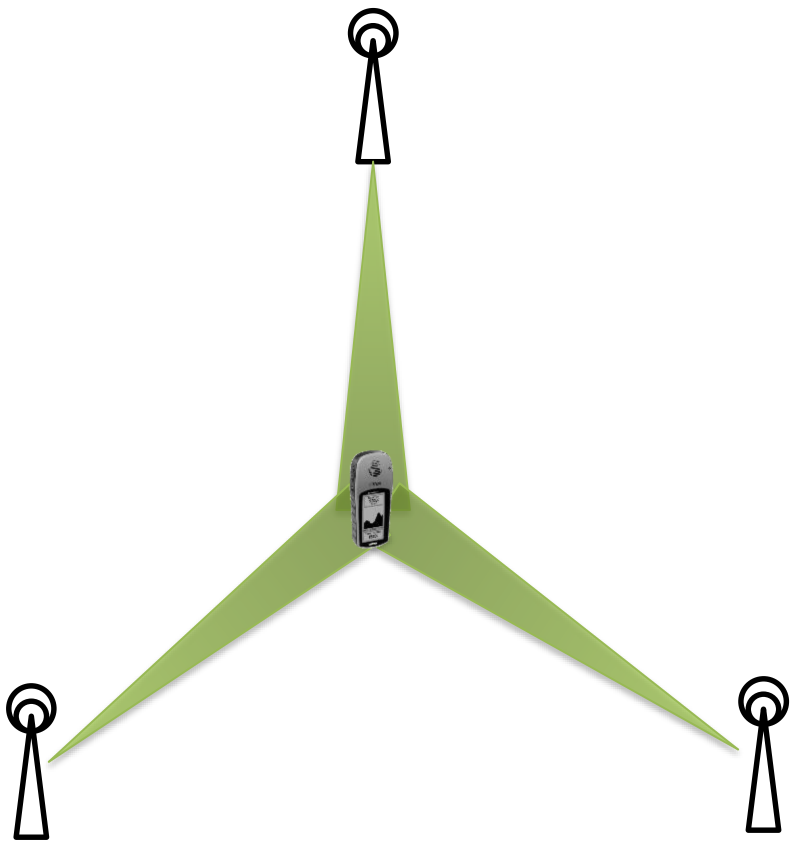
Position is computed by a number of **range measurements** to known **fix-points**:



Outdoor Postioning

• Positioning Fundamentals – Angulation

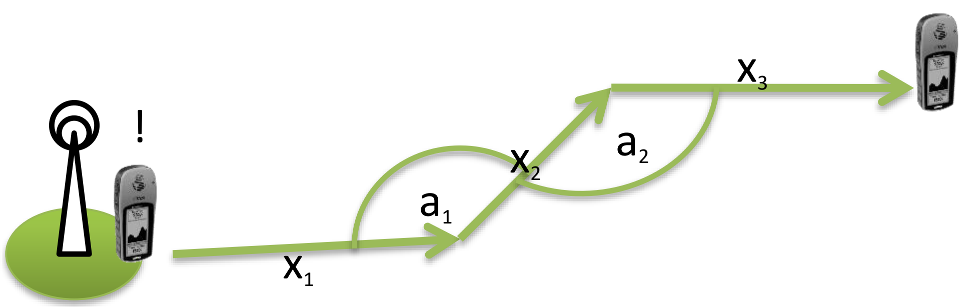
Position is derived by the measured of the **angle of an arriving signal** by multiple stations **at known fix-points**:



Outdoor Postioning

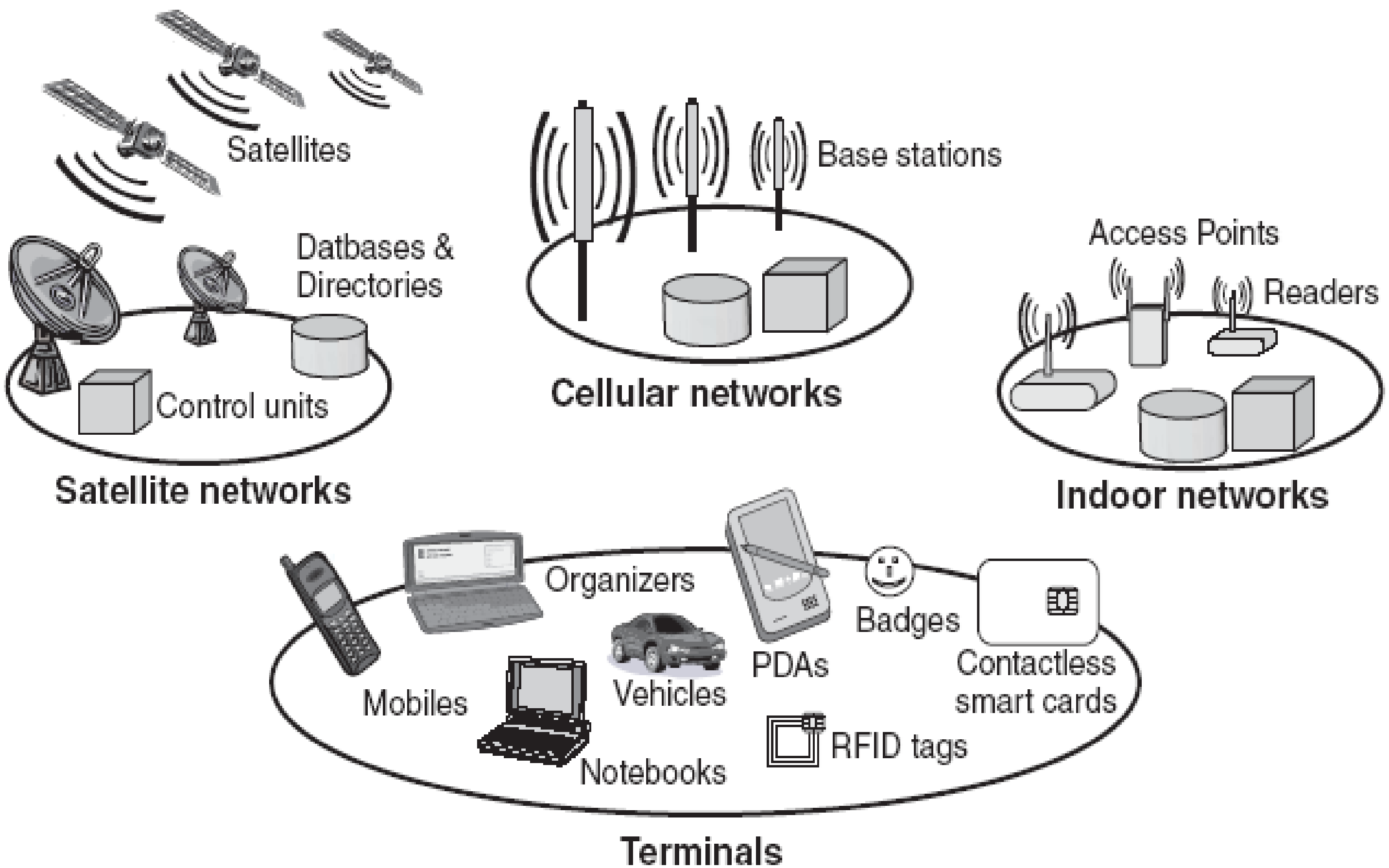
- Positioning Fundamentals – Dead Reckoning

- From a **fixed starting position**, the movement of a mobile device is estimated (e.g., using velocity and direction of movement)
- Position becomes more **inaccurate** with **each estimation**
- **Recalibration** may be necessary



Outdoor Postioning

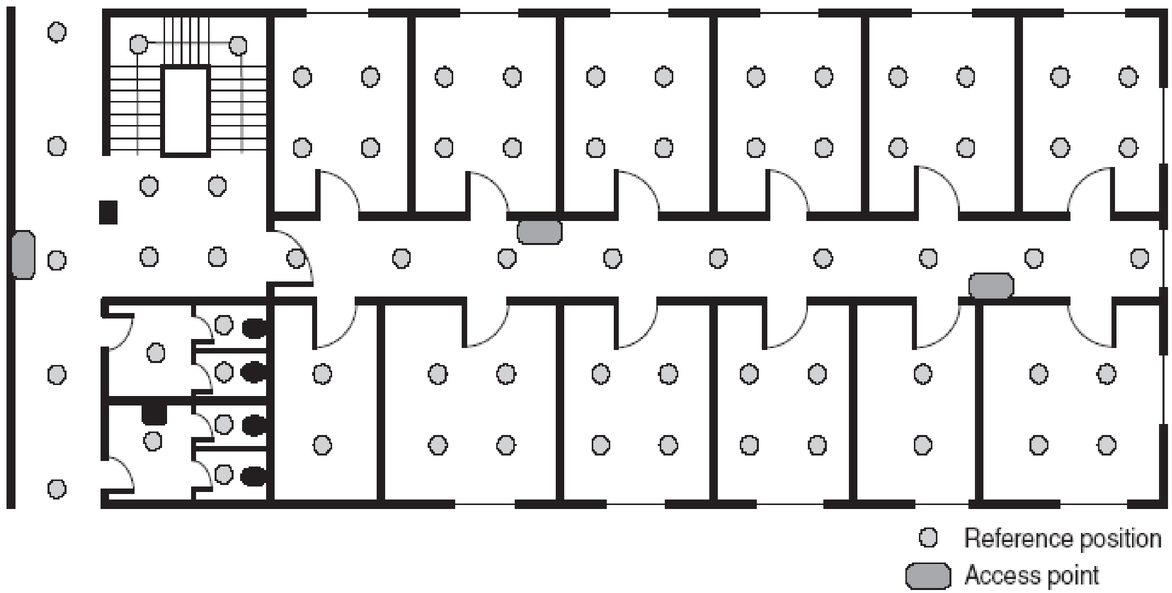
- Positioning Fundamentals – Infrastructures



Outdoor Postioning

- Positioning Fundamentals - Fingerprinting

- Position is derived by the comparison of location dependent online measurements with previously recorded data:



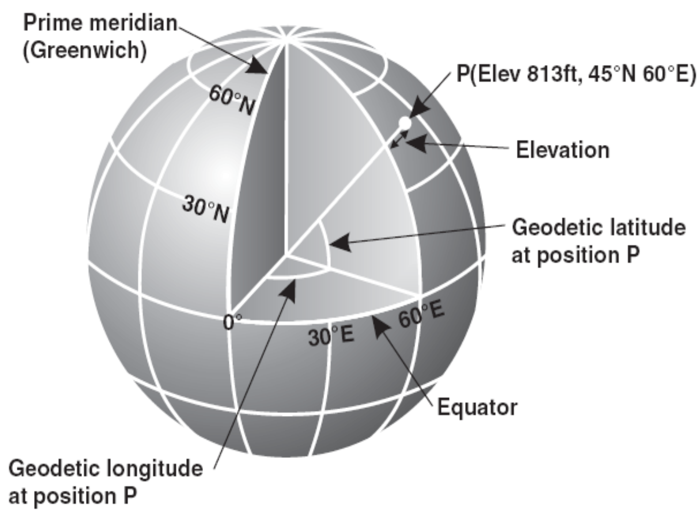
Indoor Navigation / Fingerprinting via:

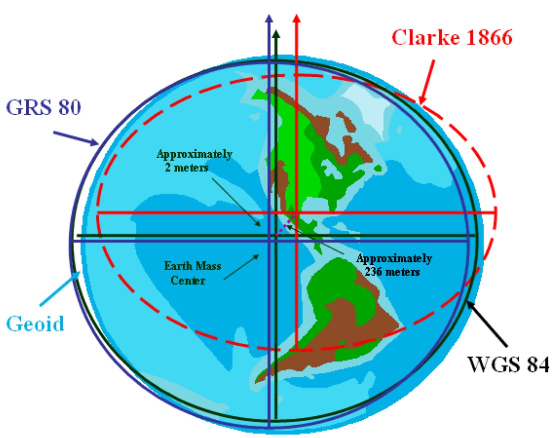
- RSS measurements
- Bluetooth Beacon

Outdoor Postioning

- Positioning Fundamentals – Reference Systems

- Goal of positioning: **derive the geographic position** of a target with respect to a **spatial reference model**
- Spatial reference model
  - Coordinate system (Ellipsoidal/Cartesian)
  - Geodetic datum, e.g., WGS-84
  - Projection (if location is to be represented on a map), e.g., Mercator projection





Outdoor Postioning

• Global satellite Positioning Systems - Past

- Russian satellite **Sputnik** launched in 1957
  - Proof of the ability to **track artificial objects in space** via short wave radio signals
  - **Worldwide triangulation program** (BC-4): simultaneously photographing reflective satellites by several sites separated by some 4000 km
  - **Doppler shift** in the signal broadcast by a satellite could be used to determine exact time of closest approach. Together with the ephemerides this leads to precise positioning anywhere in the world.
- Navy Navigation Satellite System (NNSS), also called **TRANSIT**
  - Predecessor of GPS
  - Six satellites / 1100km altitude
  - Primarily for vessel and aircraft positioning
  - **1m accuracy** if point was **occupied for several days**
  - A satellite passed overhead only **every 90 minutes**

Outdoor Postioning

• GPS – Mission Goals

- Defined by the US Department of Defense (DoD), developed to replace the TRANSIT system and to deliver **not only position**, but also **accurate time and speed**.
- Initial goals
  - User receiver cost < 10.000 $ and „5 bombs in the same hole“
  - Positioning anywhere, continuously & in all weather conditions
- Services
  - **Standard positioning service** (SPS) open to civil users, but single-frequency with **L1 coarse/acquisition signal** 1575.42 MHz, i.e. no ionosphere effect correction, **selective availability**
  - **Precise positioning service** (PPS), dual-frequency, using P(Y) signals in **L1 and L2** (1227.60 MHz) bands, with military control access (key for pseudo-code)

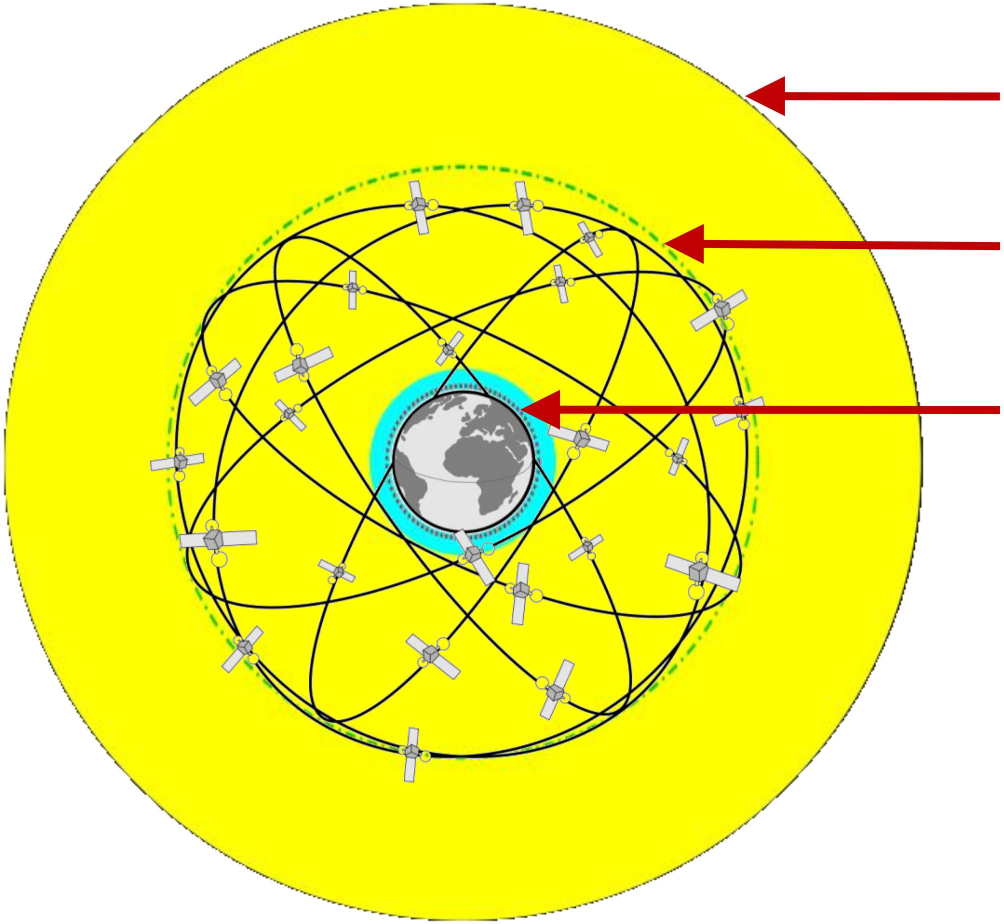
Outdoor Postioning

- GPS – History

1973	Decision to develop satellite navigation system
1978-1985	11 Block-I satellites launched
1989	First Block-II satellite launched
Dec 1993	Initial Operational Capability (IOC)
Mar 1994	Last Block-II satellite
July 1995	Full Operational Capability (FOC)
May 2000	**Deactivation of Selective Availability**
Sep 2005	First IIR-M GPS satellite

Outdoor Postioning

- GPS – Availability & Orbits



Geostationary orbit (ca. 36.000 km)
communication, TV, and meterology

MEO: Medium Earth Orbit
e.g., **GPS satellites** (ca. 20.200 km)

LEO: Low Earth Orbit
e.g., **ISS** (ca. 700 km)

Animated Orbits

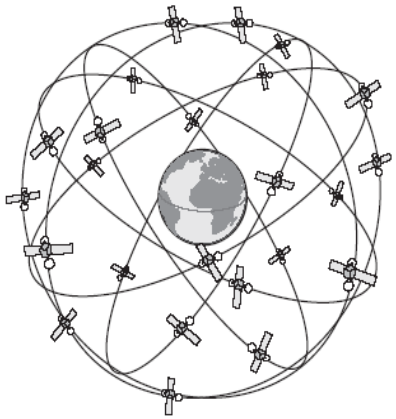
Outdoor Postioning

- GPS – Satellites

- Block-I
  - Weight: 845 kg; Lifespan: **4.5 years**;
  - Energy: Solar panels (400W); Nickel-Cadium batteries
  - Out-of-order since 1996
- Block-II/-IIA
  - Weight: 1500kg; Lifespan: **7.5 years**; Wingspan: 5.1m
  - **Four atomic clocks** (2 rubidium, 2 cesium)
- Block-IIR
  - Weight: 2000kg; Costs: 75 million USD
  - **Three atomic clocks** (all rubidium clocks)
  - **Second civil signal** (L2C)
  - **New military signal with new code**
- Block-IIF
  - **Third frequency for civil use** (L5)

Outdoor Postioning

• GPS – Components



- Space segment
  - **24 satellites** circulating the Earth every 12 sidereal hours on six orbits
  - Each satellite is equipped with onboard atomic clocks
  - Orbits are equally spaced **60° apart from each other** with an inclination angle **of 55° to the equator**
  - Orbit altitude: approx. 20,180 km

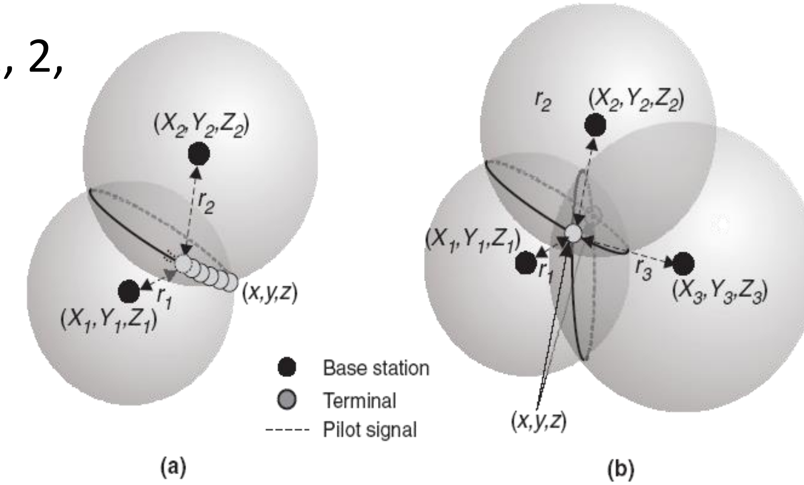
- Control segment
  - Initially: **Five ground** stations for monitoring and controlling the satellites
  - In 2005: **Six additional** monitoring stations
  - **Adjust or synchronize satellites**

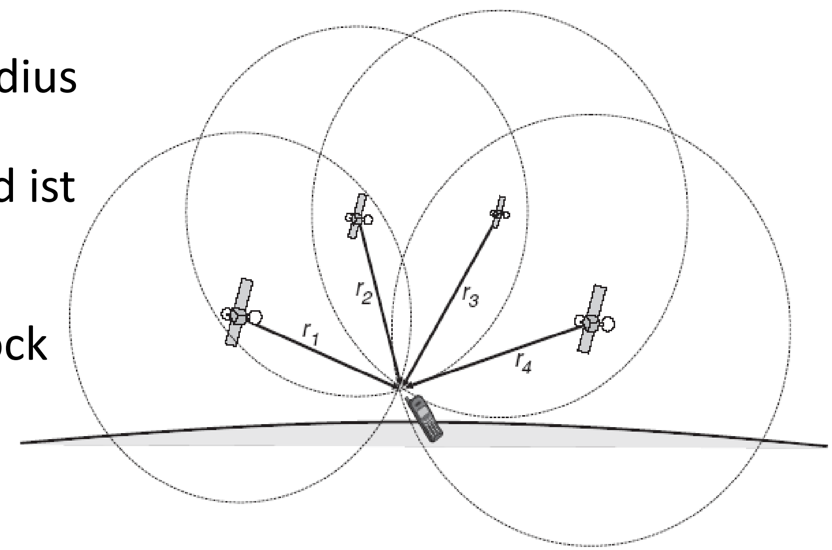
- User Segment
  - GPS receiver
  - Applications: land, sea, and air navigation, as well as military purposes and location-based services

Outdoor Postioning

• GPS – Circular Lateration

- **Known:**
  - Position $p_i = (x_i, y_i, z_i)$ for satellites i ϵ {1, 2, 3, 4} at time t_i
  - Inaccurate reception time tr_i
  - Speed of light c
- **Unknown:**
  - Position p
- **Calculation:**
  - $r_i = (tr_i – t_i)*c$ for i = **1,2,3**
  - Estimate position p_{est} : intersection of spheres (centered on satellite i with radius $r_{i)}$
  - p_{est} contains the coordinates (x,y,z) and ist determined on basis of the signals 1,2, and 3
  - p_{est} is **not accurate** due to different clock times at the satellites and the receiver
  - Signal 4 is now used to determine the corrected reception time ***t***

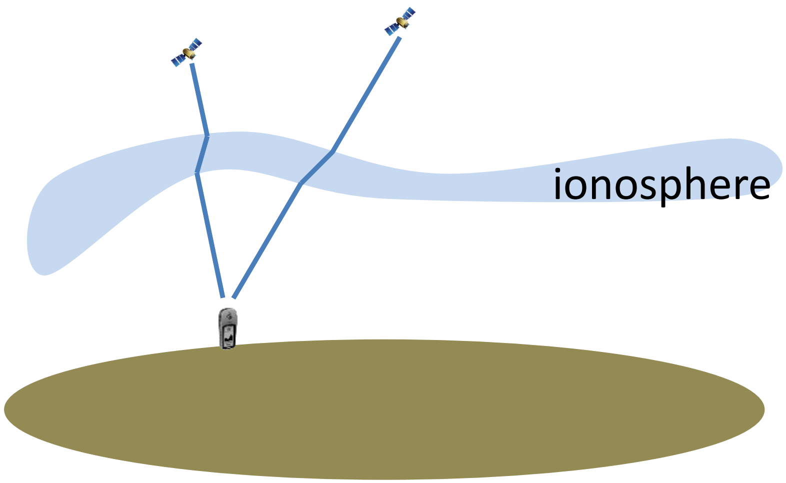




Outdoor Postioning

- GPS – Possible Errors

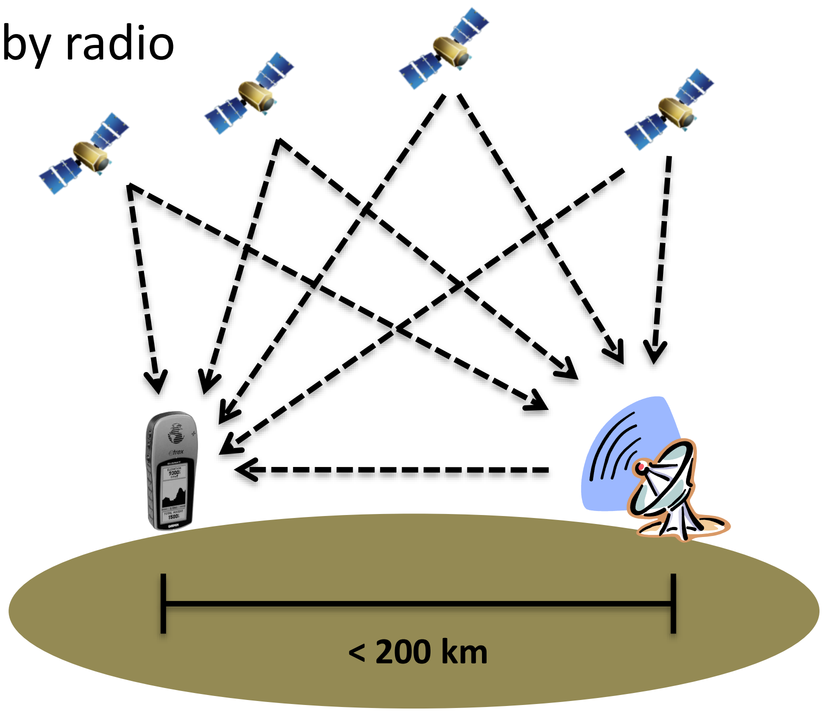
- **Satellite clocks** (although four highly accurate atomic clocks) can cause **time error** of 10ns
- **Satellite position** is only known up to approx. 1-5m
- **Receiver** has only limited accuracy
- **Multipath propagation**
- **Satellite geometry** (Dilution Of Precision, DOP)
- Signal (speed of light) **slow down** when crossing **ionosphere** and **troposphere**



Outdoor Postioning

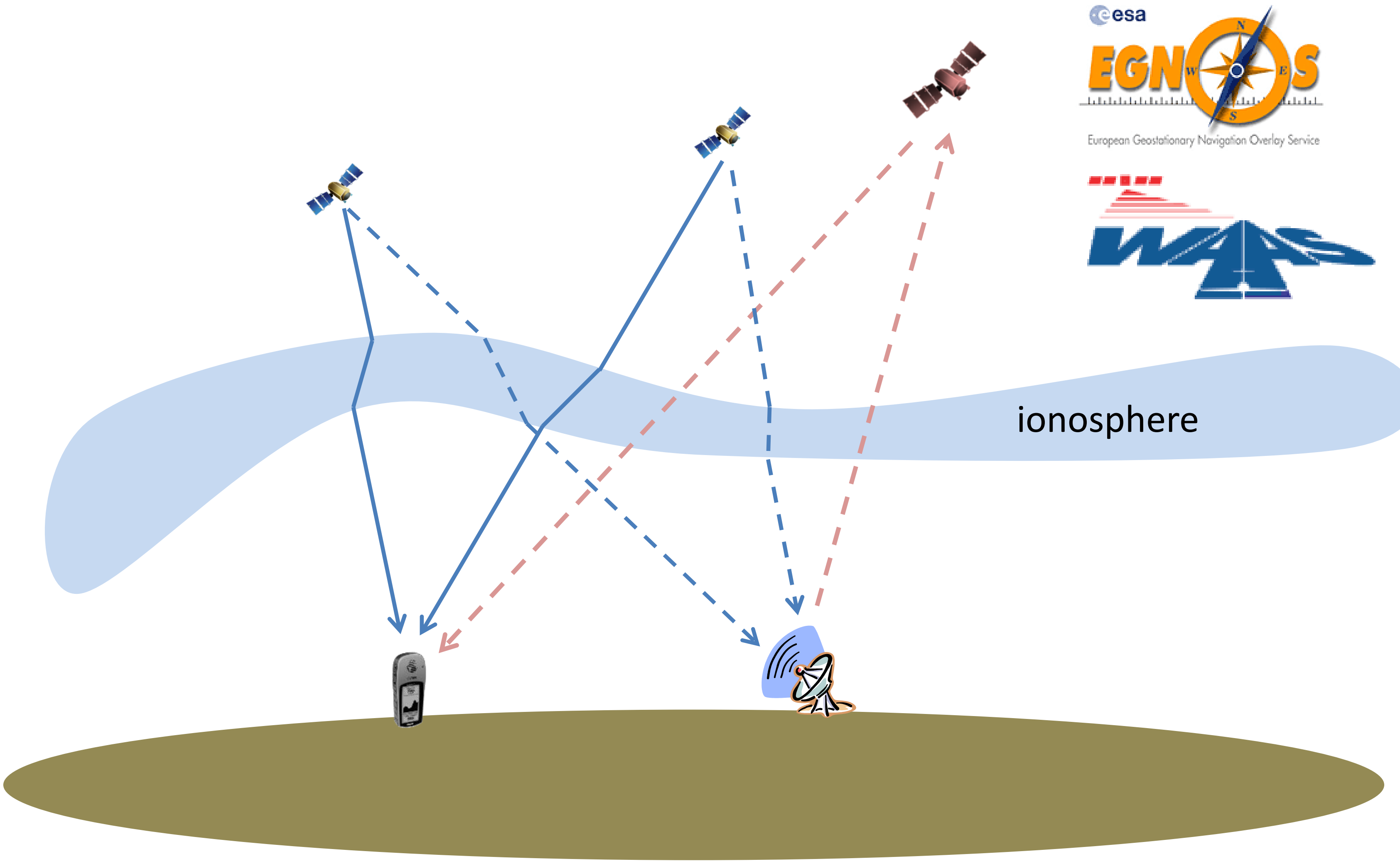
- GPS – Components

- **Reference station** (RS) located at a **known and accurately surveyed point**
- RS determines its GPS position using four or more satellites
- Deviation of the measured position to the actual position can be calculated
- Variations are valid for all the GPS receivers around the RS
- Runtime corrections are transmitted by radio



Outdoor Postioning

- GPS – Augmentation Systems



Outdoor Postioning
• GPS – Galileo

- European GNSS
- Publicly available since December 2016
- Independence of other systems
- **More services**: Open, Commercial, Safety of Life, Public Regulated, Search and Rescue
- Advantages
  - **Precision**: Combination of GPS and Galileo in dual receivers is about to lead to higher precision
  - **Availability**: Higher number of satellites to improve the availability.
  - **Coverage**: Galileo aims to provide a better coverage at high latitudes due to the location and inclination of the satellites.

Outdoor Postioning

- GPS – Galileo Services

- **Open Service**
  - basic signal provided free-of-charge
- **Safety-of-Life Service**
  - Enhanced signal including an **integrity function** that will **warn** the user within a few seconds in case of a **malfunction**. This service will be offered to the safety-critical transport community, aviation, etc.
- **Commercial Service**
  - combination of two encrypted signals for higher data throughput rate and higher accuracy authenticated data;
- **Public Regulated Service**
  - two encrypted signals with controlled access for specific users like governmental bodies; security against manipulation, availability garanties
- **Search And Rescue Service**
  - Galileo will contribute to the international COSPAS-SARSAT cooperative system for humanitarian search and rescue activities. Each satellite will be equipped with a transponder transferring the distress signal from the user to the Rescue Coordination Centre and informing him that his situation has been detected.

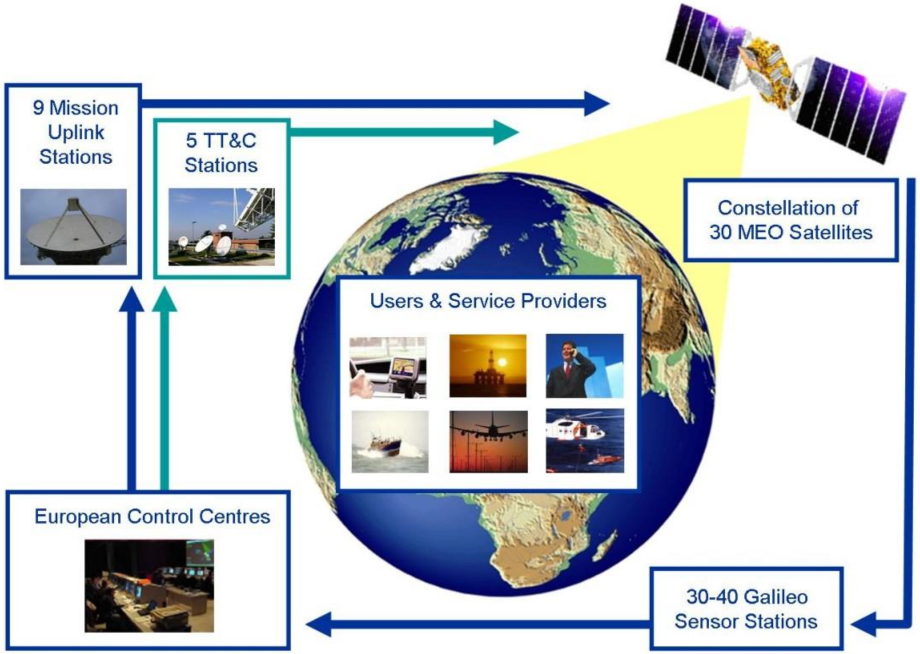
Outdoor Postioning
• GPS – Galileo Operations

- Galileo programme structured in two phases
  - **In-Orbit Validation (IOV) phase**
    - **Qualifiying and validating** the systems through in-orbit tests
    - Two experimental satellites: Dec 2005, Apr 2008
    - Four operational satellites: Q3/4 2011, Q1/2 2012
  - **Full Operational Capability (FOC) phase**
    - Deployment of remaining ground and space infrastructure
    - Intermediate initial **operational capability: 18 satellites** in operation
    - **Full system: 30 satellites**, control centers located in Europe and a network of **sensor stations** and **uplink stations** installed around the globe

Outdoor Postioning

- GPS – Galileo Architecture

- 30 satellites in MEO: Each satellite will contain
  - a navigation payload
  - search and rescue transponder
- 30-40 sensor stations
- 3 control centers
- 9 Mission Uplink stations
- 5 TT&C stations.



http://ec.europa.eu/enterprise/policies/satnav/galileo/programme/index_en.htm

Outdoor Postioning

- GPS – Other GNSS

- Global Navigation Satellite System (**GLONASS**)
  - Program started in 1982
  - System currently operated by the Russian Defense Ministry
  - 24 planned satellites
  - 3 orbital levels
  - Orbital altitude of 19,100 km
  - Full operation since 1996

- Compass Navigation Satellite System (CNSS)
  - China's second-generation satellite navigation system (also known as **BeiDou 2**)
  - Long-term goal: Development of as system **similar to the GPS and GLONASS**
  - 25~35 satellites: **4 GEO satellites** and **MEO satellites**
  - Two levels of positioning service: **Open** and **restricted** (military)
  - **Coverage**: Initially only neighboring countries, later on extension to global navigation satellite system.
  - Launches: 1 MEO (Apr 07) and 3 GEO (Apr 09 – June 10)

Outdoor Postioning

- GPS – Summary

Praktikum Mobile und Verteilte Systeme

Location-based Services in Android

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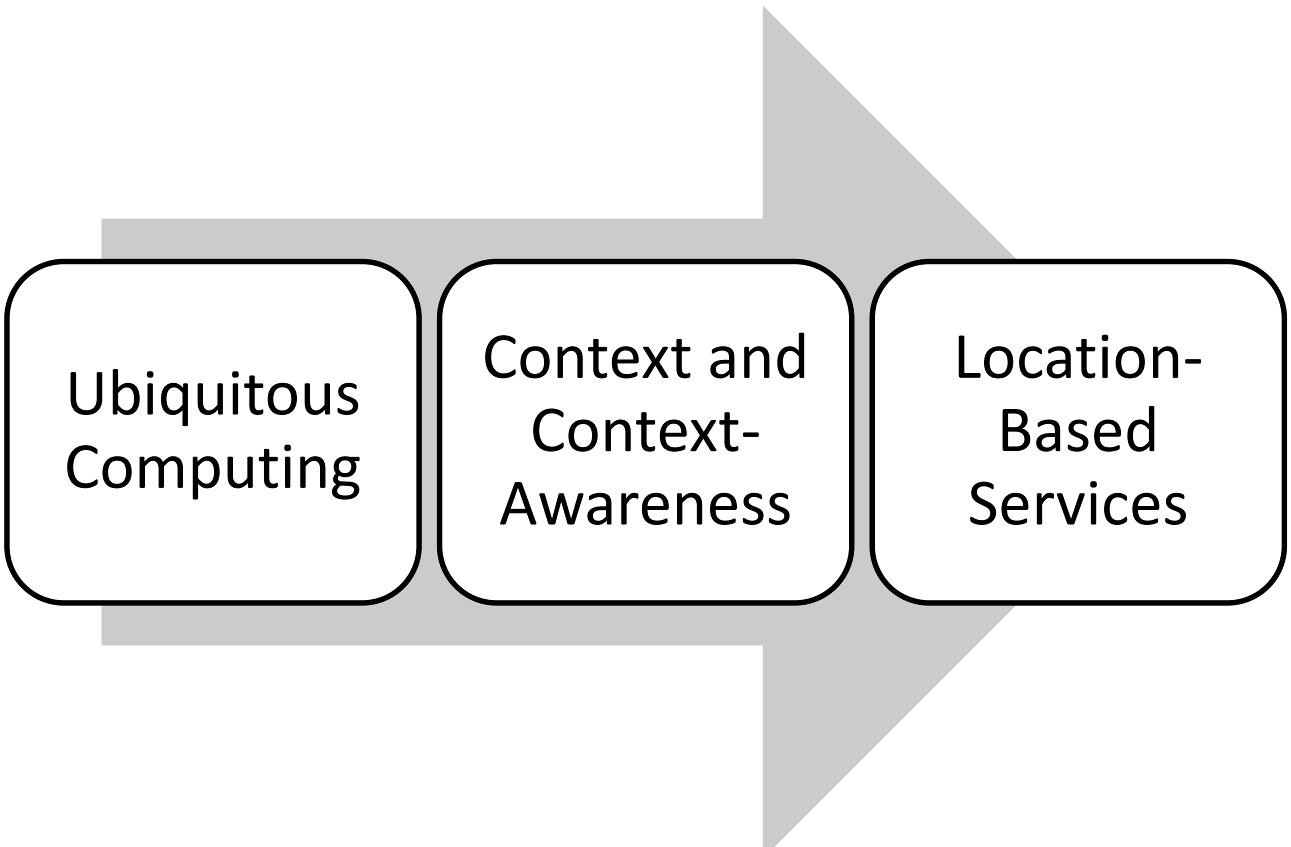
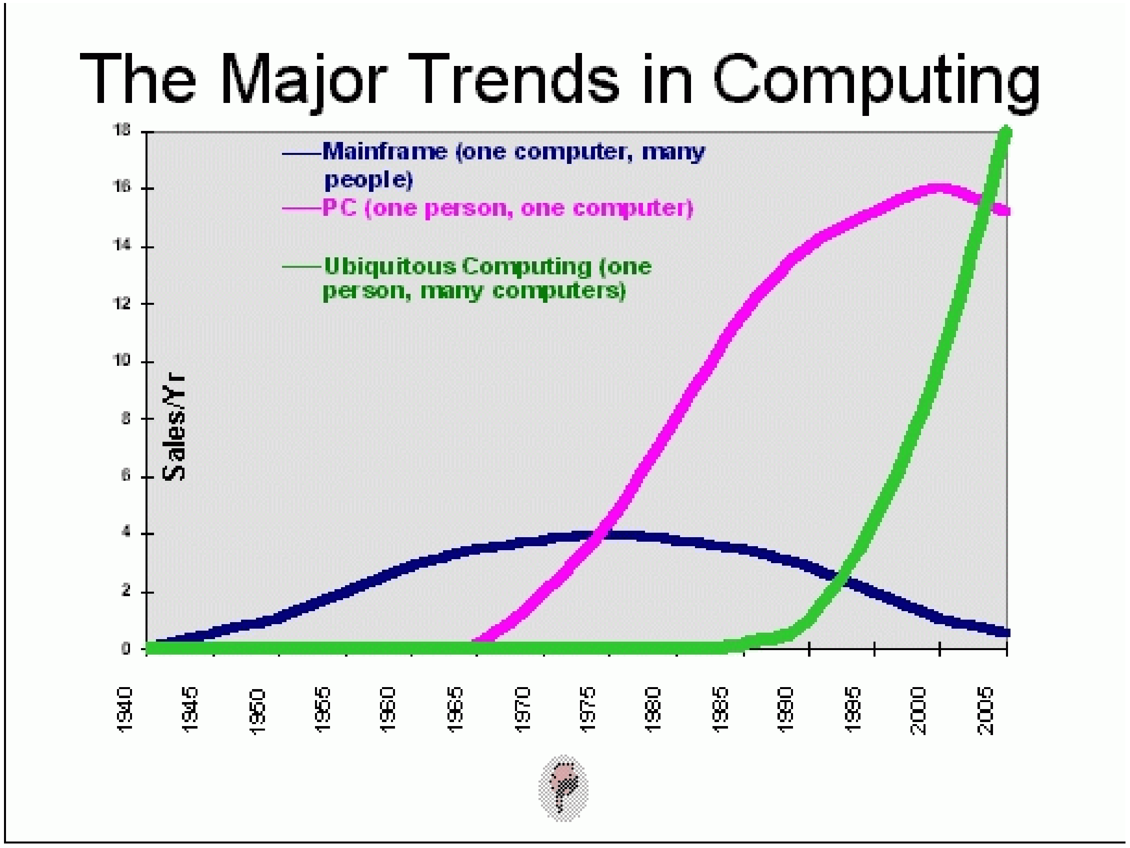
Location-Based Services

- Historical Outline



Location-Based Services
• Ubiquitous Computing

- Mark Weiser, Xerox PARC
- “Nomadic Issues in Ubiquitous Computing”
- Talk at Nomadic ‘96



Location-Based Services
- Context & Context Awareness

Context is **any information** that can be used to characterize the **situation** of an **entity**. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.

[1] Dey, Abowd, 1999

Towards a Better Understanding of Context and Context-Awareness

Anind K. Dey and Gregory D. Abowd

Graphics, Visualization and Usability Center and College of Computing,
Georgia Institute of Technology, Atlanta, GA, USA 30332-0280
{anind, abowd}@cc.gatech.edu

Location-Based Services

- Context & Context Awareness

Context-aware computing is a mobile computing paradigm in which applications can **discover and take advantage** of **contextual information** (such as **user location**, time of day, nearby people and devices, and user activity).

[2] Chen, Kotz, 2000

A Survey of Context-Aware Mobile Computing Research

Guanling Chen and David Kotz
Department of Computer Science
Dartmouth College

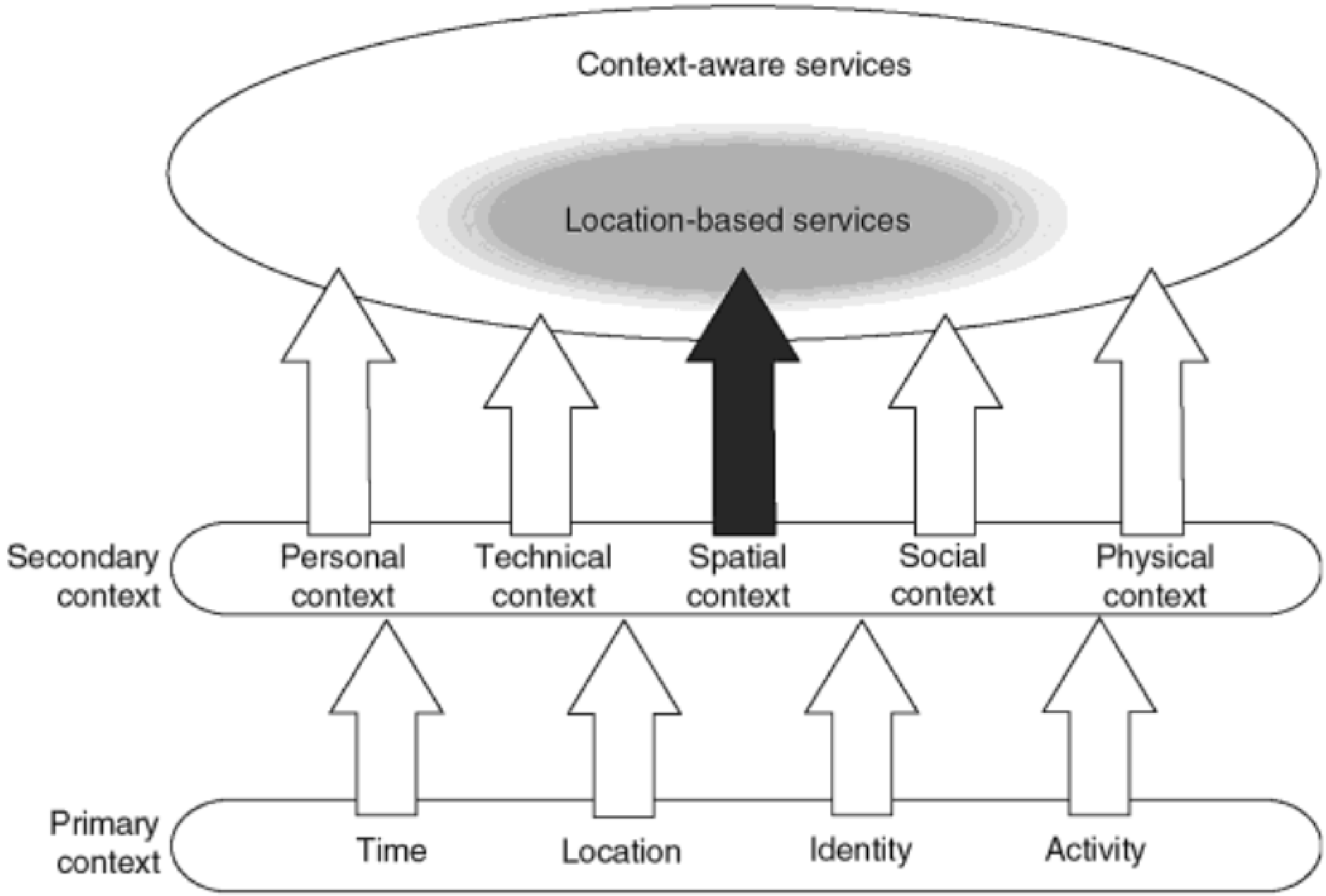
Dartmouth Computer Science Technical Report TR2000-381

Location-Based Services
• Sensing Context

- Sensing location
  - E.g. GPS (outdoor / indoor positioning)
- Media capturing
  - E.g. camera, microphone
- Connectivity
  - Mobile network, Bluetooth, WLAN, NFC
- Time
  - Day of week, calendar, Daytime
- Motion and environmental sensors
  - Accelerometer, ambient temperature, gravity, gyroscope, light, linear acceleration, magnetic field, orientation, pressure, proximity, relative humidity, rotation vector, temperature
- Further
  - Active/running apps on device, remaining energy level, …
  - Semantic Meaning

Location-Based Services

- Definition of LBS

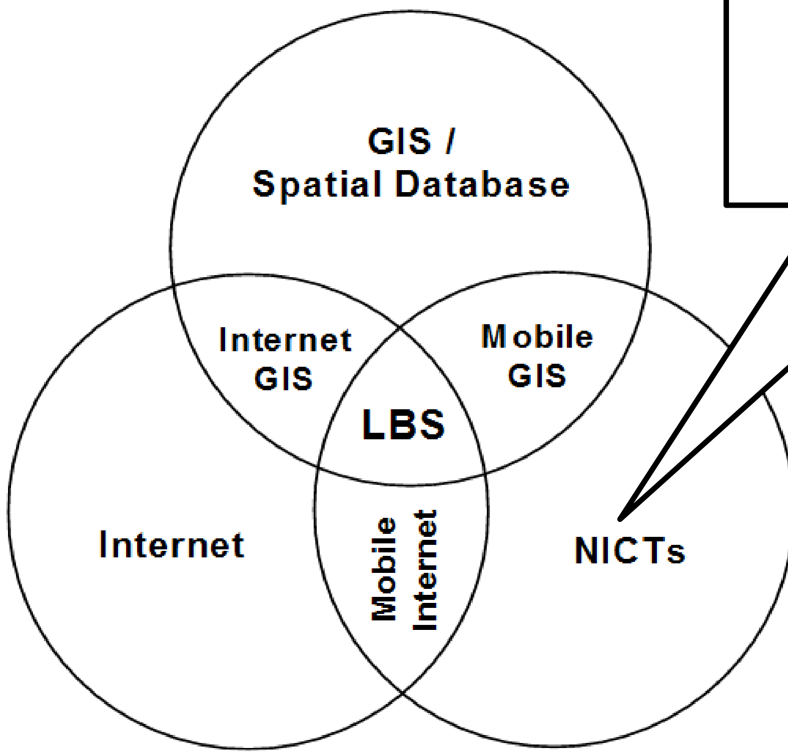


[3] Küpper, 2005

Location-Based Services
- Convergence of Technologies

LBS as the **intersection of several technologies**

New information and communication technologies (→ "smartphones")

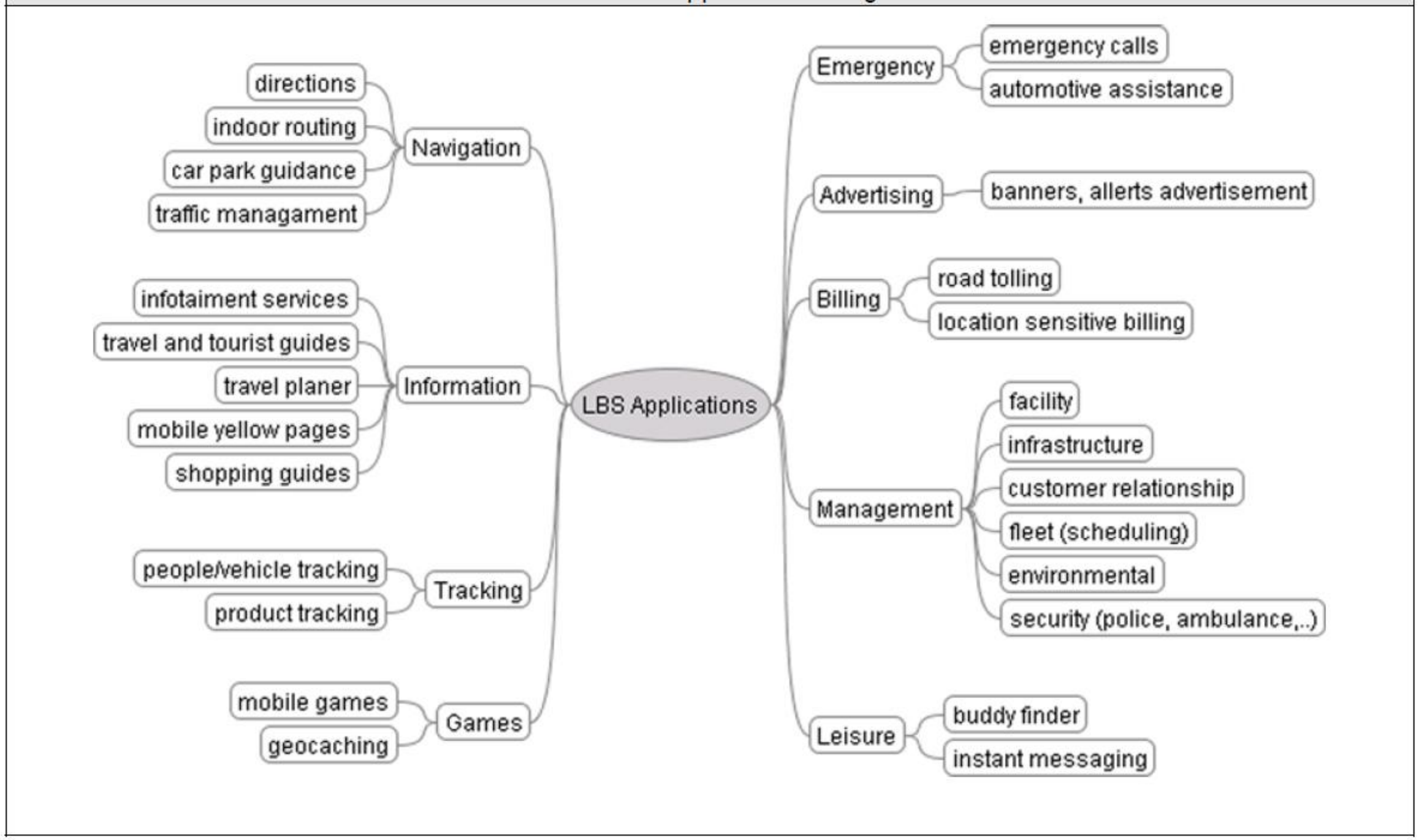


[4] Brimicombe, 2002

Location-Based Services

- Application Categories

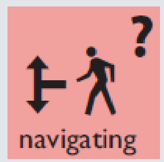
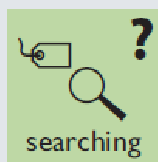
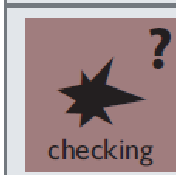
Table 2a - LBS application categories



[5] Steiniger et al., 2011

Location-Based Services

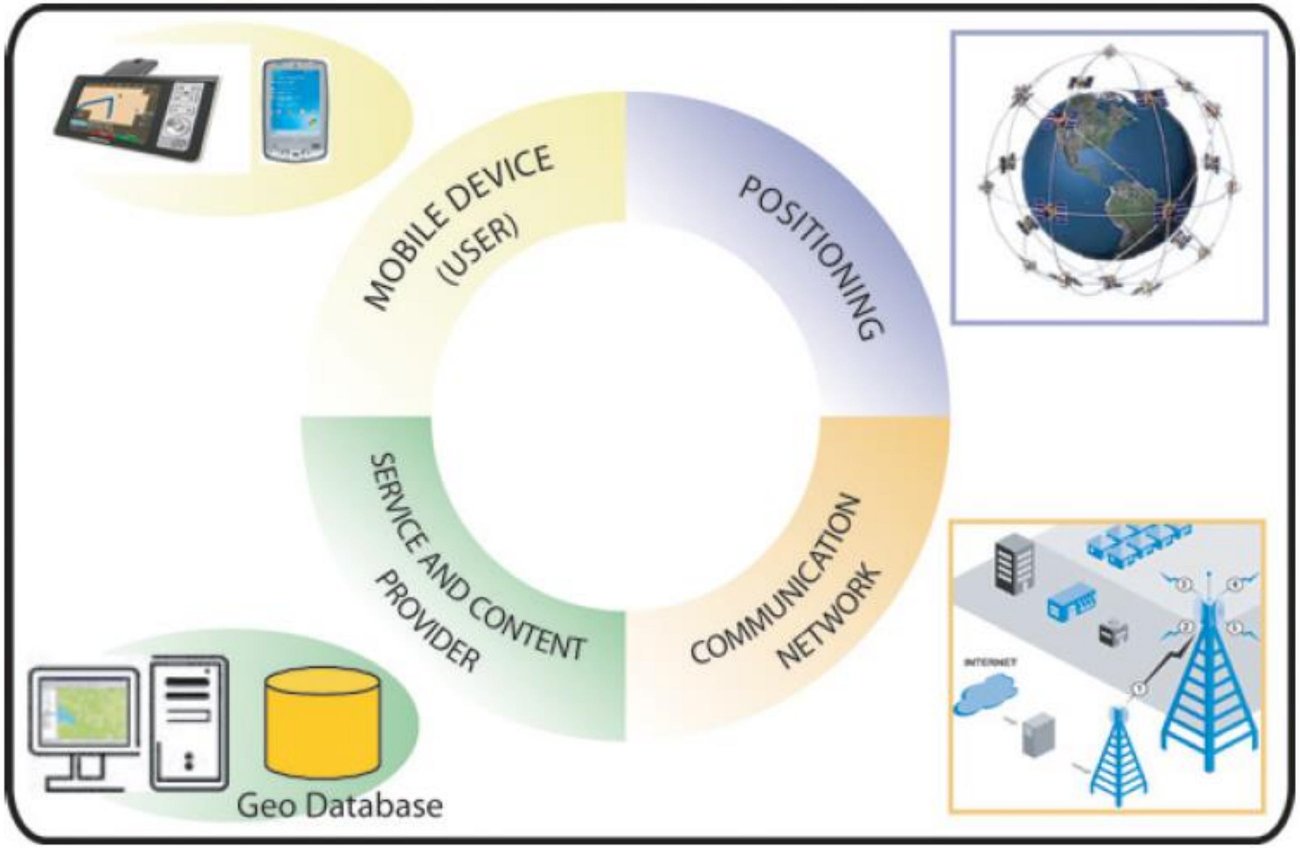
- Demarcation – Elementary Spatial User Actions

action		questions	objective
	**orientation & localisation** locating	where am I? where is {person| object}?	localise people and objects
	**navigation** navigatingthrough space, planning a route	how do I get to {place name| address| xy}?	find the way to a destination
	**search** searching for people and objects	where is the {nearest| most relevant| &} {person| object}?	searching for people and objects meeting the search criteria
	**identification** identifying and recognising persons or objects	{what| who| how much} is {here| there}?	identify people and objects; quantify objects
	**event check** checking for events; determining the state of objects	what happens {here| there}?	knowing what happens; knowing the state of objects

[6] Reichenbacher, 2004

Location-Based Services

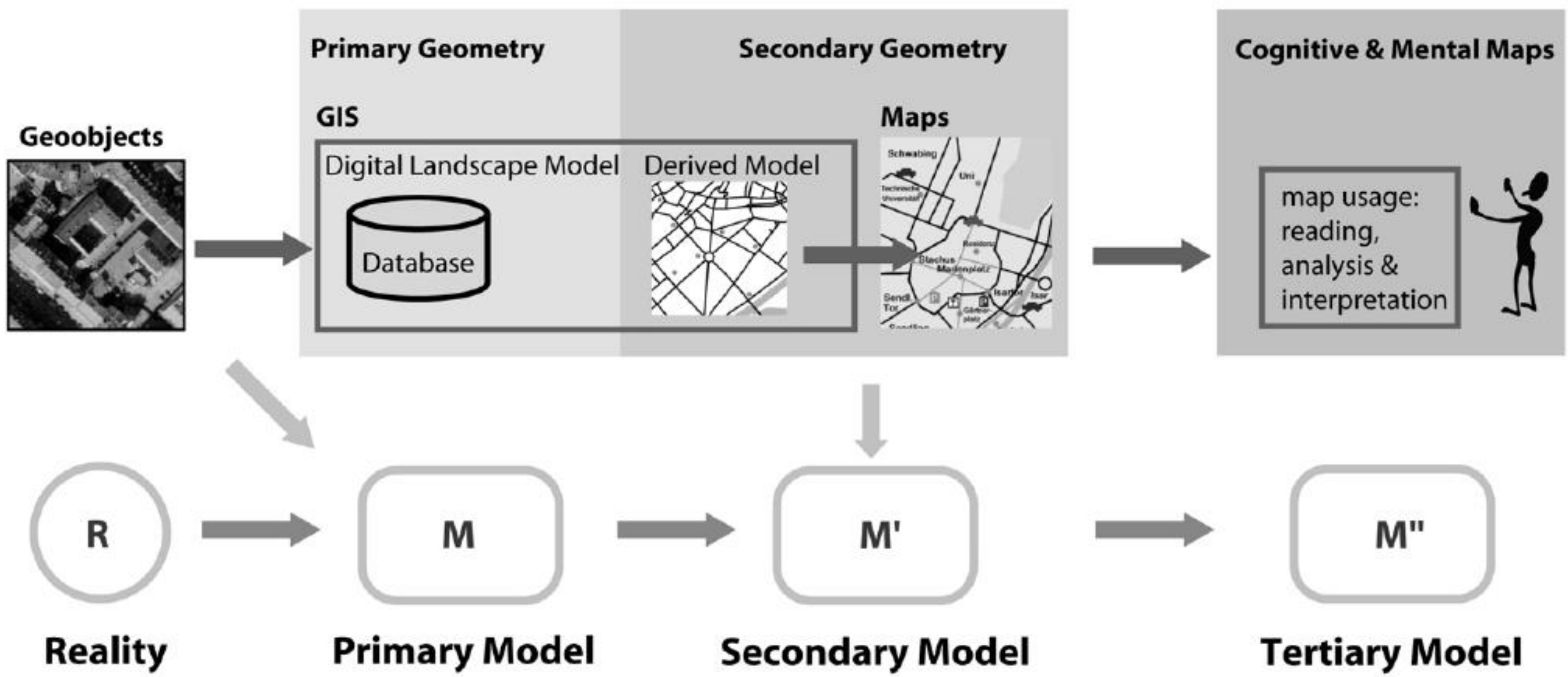
- Demarcation



[7] Steiniger et al.,2011

Location-Based Services

- Demarcation



[8] Reichenbacher, 2004

References 1/2

[1] Abowd, Gregory D., et al. "Towards a better understanding of context and context-awareness." *International symposium on handheld and ubiquitous computing*. Springer, Berlin, Heidelberg, 1999.

[2] Chen, Guanling, and David Kotz. A survey of context-aware mobile computing research. Vol. 1. No. 2.1. Technical Report TR2000-381, Dept. of Computer Science, Dartmouth College, 2000.

[3] Küpper, Axel. Location-based services: fundamentals and operation. John Wiley & Sons, 2005.

[4] Brimicombe, Allan J. "GIS-Where are the frontiers now." Proceedings GIS 2002. 2002.

[5] Steiniger, Stefan, Moritz Neun, and Alistair Edwardes. "Foundations of Location Based Services Lesson 1 CartouCHe 1-Lecture Notes on LBS, V. 1.0." (2011).

[6] Reichenbacher, Tumasch. Mobile cartography: adaptive visualisation of geographic information on mobile devices. München: Verlag Dr. Hut, 2004.

[7] Steiniger, Stefan, Moritz Neun, and Alistair Edwardes. "Foundations of Location Based Services Lesson 1 CartouCHe 1-Lecture Notes on LBS, V. 1.0." (2011).

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[8] Reichenbacher, Tumasch. Mobile cartography: adaptive visualisation of geographic information on mobile devices. München: Verlag Dr. Hut, 2004.

[9]

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Praktikum Mobile und Verteilte Systeme

Location Management in Android

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Location Management in Android

- Positioning Challenges on mobile Devices

- Sources: **GPS**, **Cell-ID**, and **Wi-Fi**

- Trade of in **accuracy**, **speed**, and **battery-efficiency** and **trust**.

- Re-estimating user location due to frequent and non-linear movement.

- **Varying accuracy** and **non-consistent localization**:

  Older positions from one source might be more accurate than a newer location from another or same source.

Location Management in Android

- Google Location Services

Android Location Manager

- locationManager = getSystemService(Context.LOCATION_SERVICE) as LocationManager

// Register the listener with the Location Manager
locationManager.requestLocationUpdates(LocationManager.NETWORK_PROVIDER, 0, 0f,locationListener)

Location Management in Android

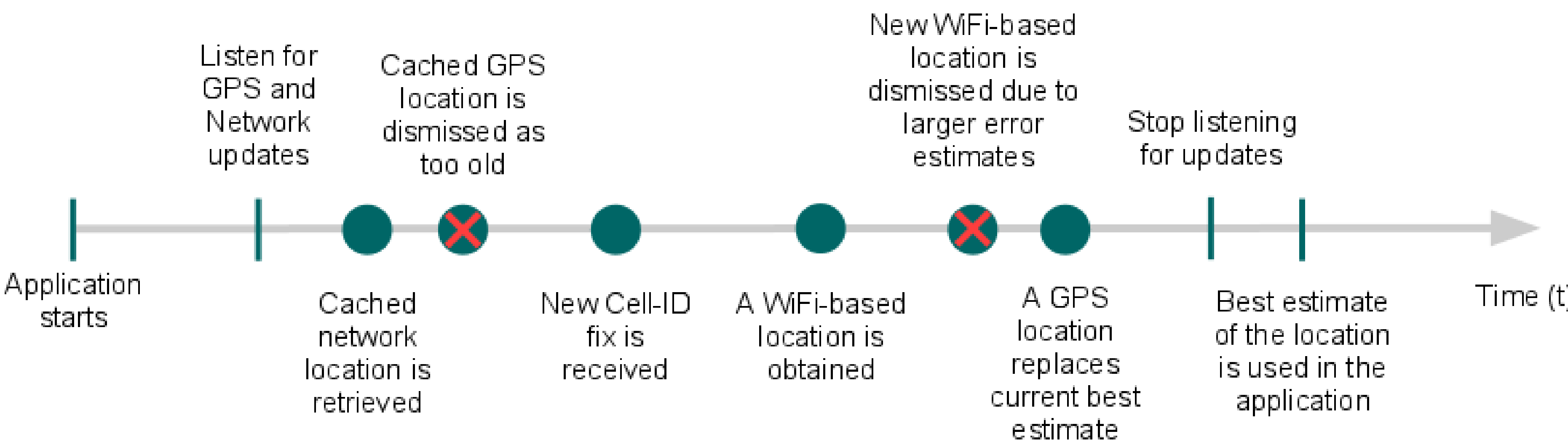
- Localization strategies on mobile

```
// Define a listener that responds to location updates
val locationListener = object : LocationListener {

    override fun onLocationChanged(location: Location) {

            makeUseOfNewLocation(location)
    }

    override fun onStatusChanged(provider: String, status: Int, extras: Bundle) {
    }

    override fun onProviderEnabled(provider: String) {
    }

    override fun onProviderDisabled(provider: String) {
    }
```

Location Management in Android

- Localization strategies on mobile

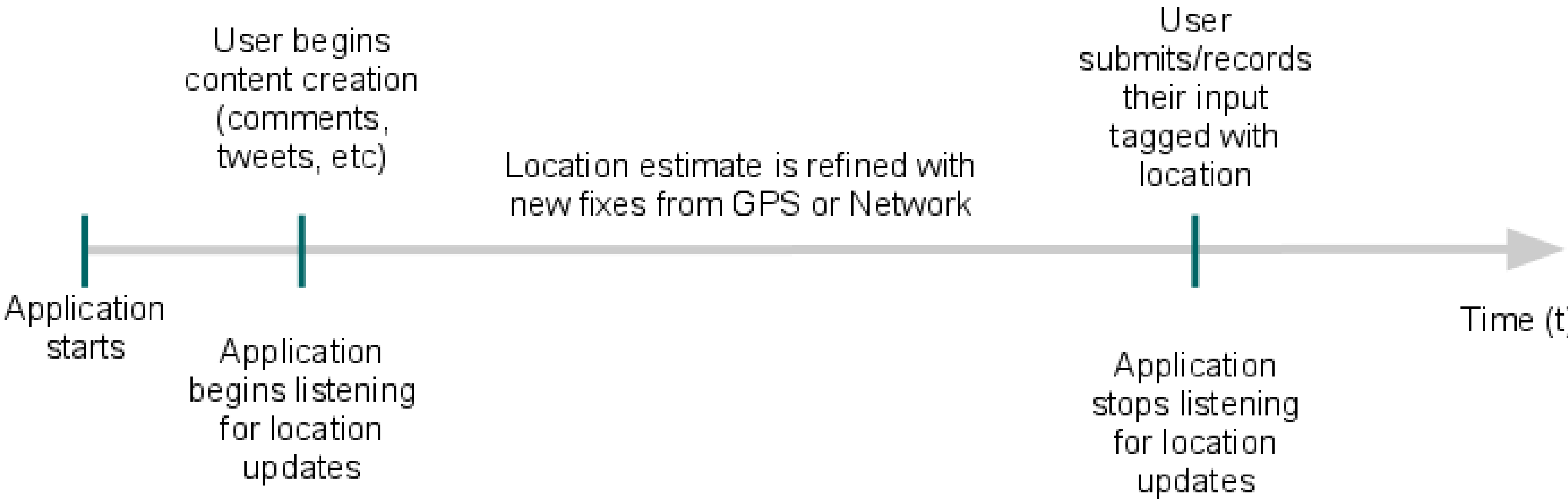
1. Start application
2. Start Listening for updates from desired location providers
3. Maintain a "current best estimate" of location by filtering outlow accuracy samples
4. Stop listening for location updates
5. Take advantage of the last best location estimate.



Location Management in Android

- Location Updates & User Interaction

- Context based location updates.
- Location update strategies may depend on User Interaction.
- Most of the time, users don't want to wait to get a high accuracy location (Apart from navigation task e.g.)

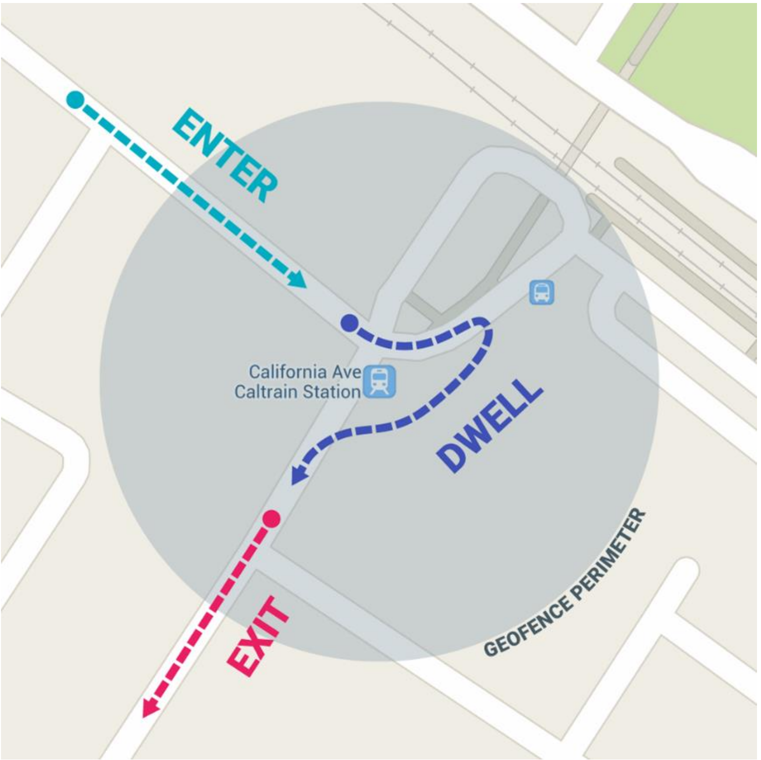


Location Management in Android

- Geofences: Trigger Events

- Geofences are geometric shapes
- Its vertices are geopositions as WGS84 coordinates

- Events that can be triggered :
  - Entering a Fence Region
  - Leaving a Fence Region
  - "Dwelling" in a Fenced Region
    - Stay of specified Length
    - Less triggering friendly



Location Management in Android

- Geofences: Android Librarys & Usage

Android Geofencing Client:

- geofencingClient = LocationServices.getGeofencingClient(this)

- geofenceList.add(Geofence.Builder()
- .setRequestId(entry.key)

- // Set the circular region of this geofence.
- .setCircularRegion(entry.value.latitude, entry.value.longitude,
- Constants.GEOFENCE_RADIUS_IN_METERS)

- // Set the expiration duration of the geofence .setExpirationDuration(Constants.GEOFENCE_EXPIRATION_IN_MILLISECONDS)

- // Set the transition types of interest. Alerts are only generated for these transition. .setTransitionTypes(Geofence.GEOFENCE_TRANSITION_ENTER or Geofence.GEOFENCE_TRANSITION_EXIT)

- // Create the geofence.
- .build())

Location Management in Android

- Geofences: Android Librarys & Usage

```
geofencePendingIntent: PendingIntent by lazy {
        intent = Intent(this, GeofenceTransitionsIntentService::class.java)
PendingIntent.getService(this, 0, intent,
PendingIntent.FLAG_UPDATE_CURRENT)
```

```
geofencingClient?.addGeofences(getGeofencingRequest(),
geofencePendingIntent)?
```

https://developer.android.com/training/location/geofencing

Location Management in Android

- Tips for Development and Debugging

Use the geo command in the emulator console to mock a Geo Location

Connect to the emulator console:

- telnet localhost <console-port>
- geo fix -121.45356 46.51119 4392
- $GPRMC,081836,A,3751.65,S,14507.36,E,000.0,360.0,130998,011.3,E*62