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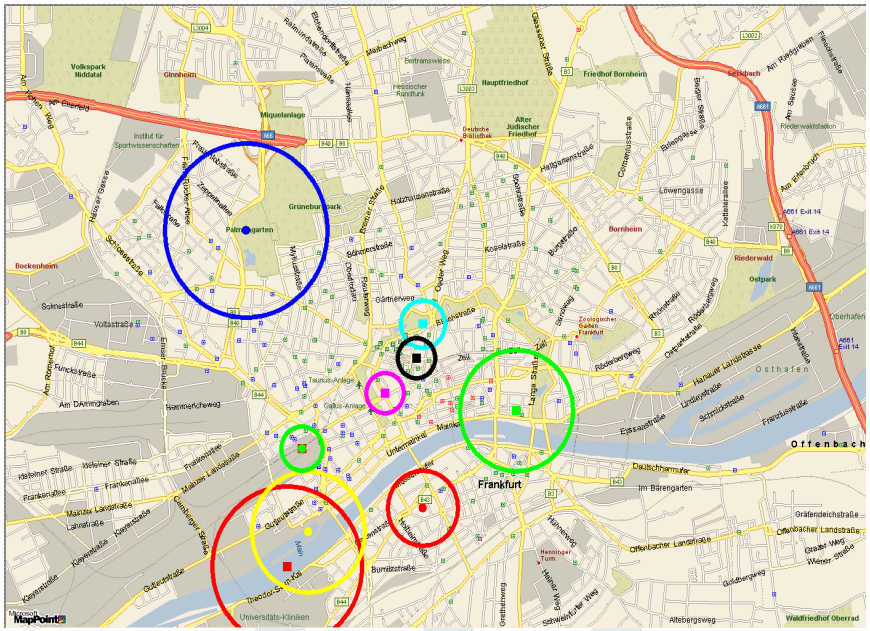
# *Lecture 2*

# Infrastructures for M-Business: Positioning Methods for Location-based Services




Mobile Business II (SS 2020)

Dr. Sebastian Pape

Chair of Mobile Business & Multilateral Security
Goethe-University Frankfurt

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# Agenda

- Introduction to “Location-based Services”
- Positioning Methods
  - Network External Source of Information about Location
  - Network Internal Source of Information about Location
  - Hybrid Solutions
  - Summary

# Definition

- What is a Location-based Service (LBS)?
  - Position information as basis for an application,
  - In most cases one part of the infrastructure is mobile,
  - Data communication is necessary to provide the service.

➲ We consider LBS within the context of wireless data networks
(WLAN, GSM, UMTS, …).

# Purpose of LBS

- Major purposes of LBS are
  - Provision of a useful service (e.g. in e-government), and/or
  - Generate revenues (as commercial provider).
- One needs:
  - Technology basics,
  - An application with a business model,
  - Appropriate business relations,
  - (Compliance with) regulation,
  - …

# Infrastructure for LBS

Usually, we speak of variants of the following infrastructure:

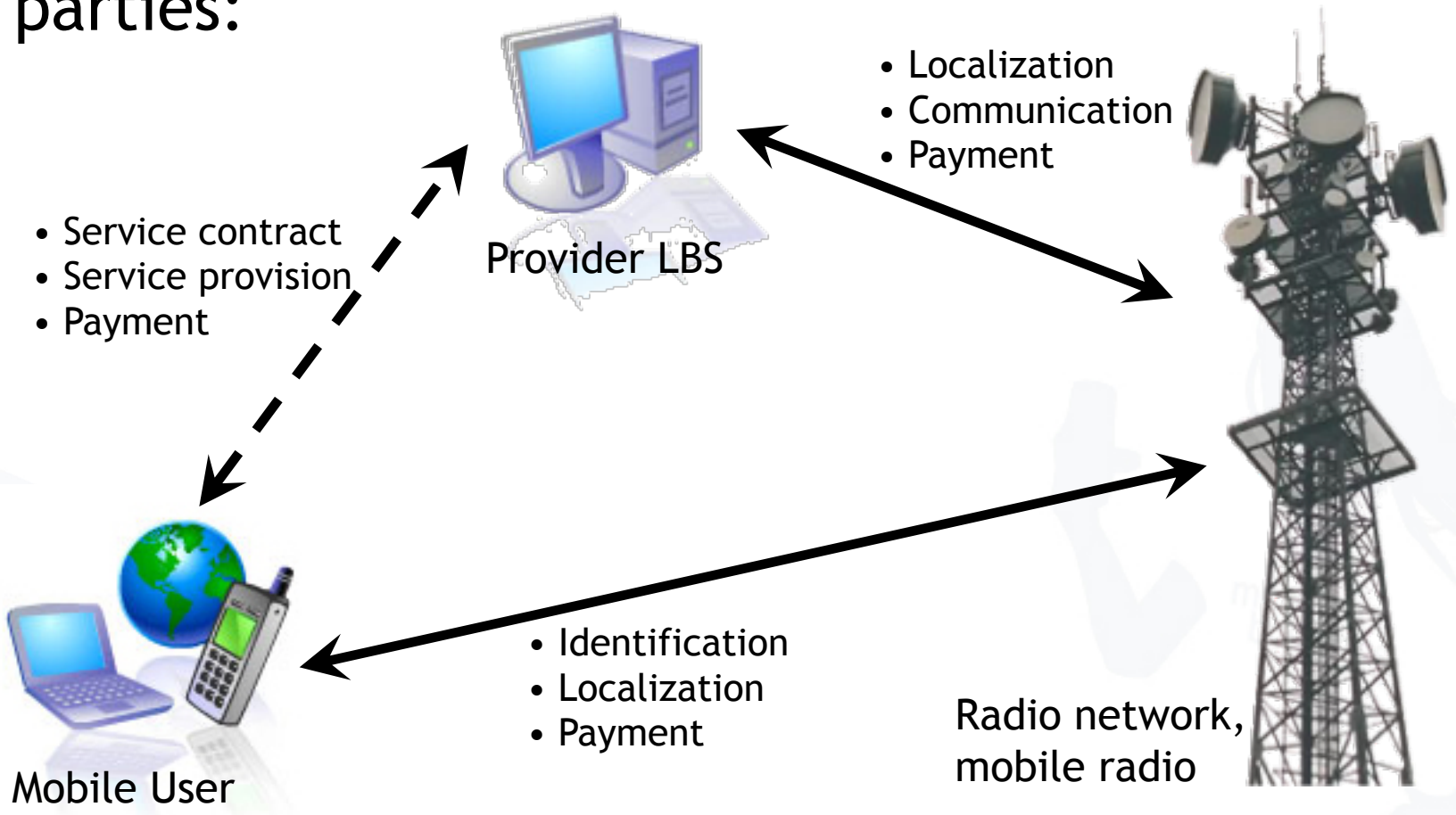
Provider of
a location-based application

Mobile User

Radio network,
mobile radio

# Business Relations

LBS require many relationships among involved parties:



# Business Relations

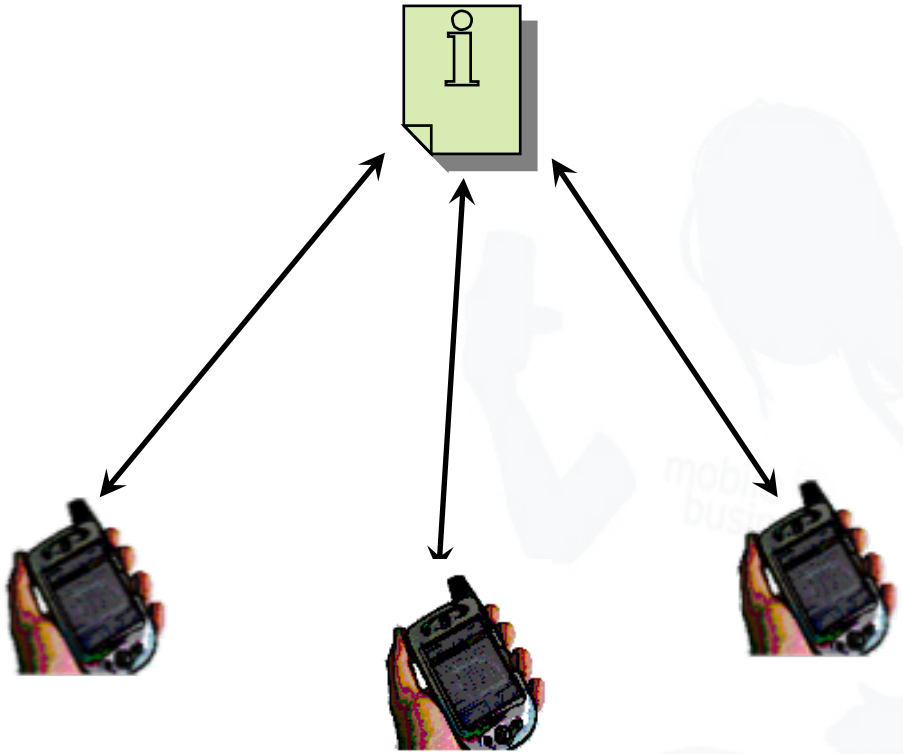
- There may be different business relations:
  - User pays provider and network operator separately.
  - User solely pays via network operator; provider is paid by the network operator.
  - Creation of location information may require investments and operational costs for both the user and the network operator.

# Infrastructure

In special cases one can also think of other options:

- Peer to Peer (P2P)

- Stationary communication



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# Overview Positioning Methods

- Network external source of information about location
  - User input to the device
  - Satellite Systems: GPS (USA), Galileo (EU), GLONASS (Russia)
  - Position sender (Radio, Infrared)
  - WLAN positioning
  - Peer to Peer
- Network internal source of information about location
  - Cell-ID
  - Time Difference of Arrival (TDOA)
  - Enhanced Observed Time Difference (E-OTD)
  - Angle of Arrival (AOA)
  - Signal Attenuation (SA)
- Hybrid solutions
  - Assisted GPS (A-GPS)
- Often the terminal is involved in the positioning
  - Terminal positioning
  - Hybrid positioning

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# Network External Positioning

"Network External" means:

- Positioning system outside of the control of the network operator
- Positioning system is provided by a third party.

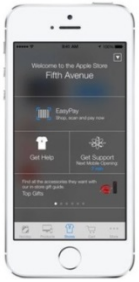
# Examples of Services using Network External Positioning

## User Input (e.g. Local Search)

## Satellite Systems (e.g. GPS Navigation)

NAVIGON

## Position Sender (e.g. In-Store Notifications with iBeacons)



iBeacon

Get In-Store Notifications

## WLAN-Positioning (e.g. Indoor Navigation)

free wifi service

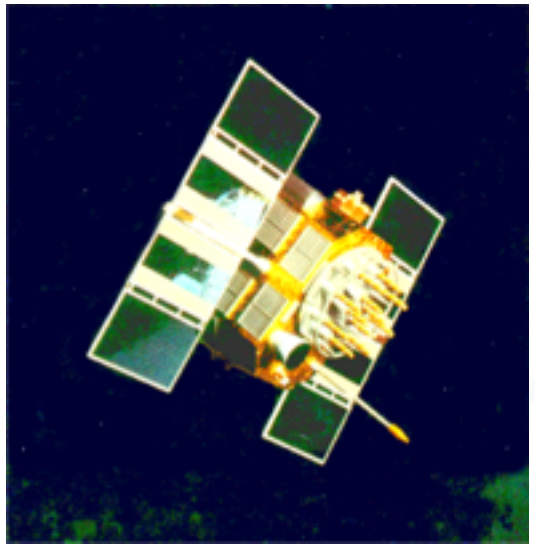
# User Input to the device

Users communicate their location
(e.g. ZIP code, area code, name of regional unit).

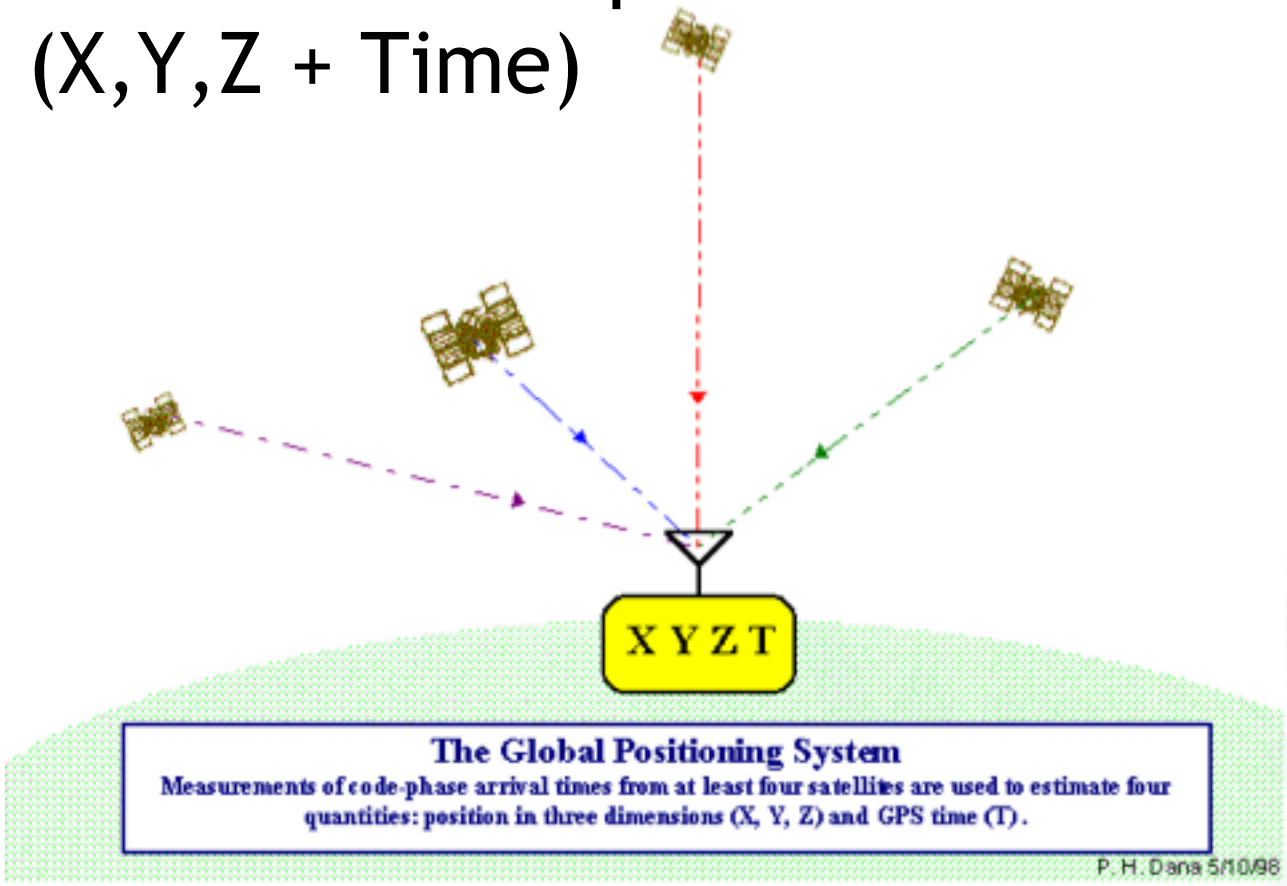
- Advantages:
  - Is possible with almost every terminal,
  - User keeps positioning under control.
- Disadvantages:
  - Only possible for applications where the user knows his whereabouts,
  - Slow and complex position finding (permanently new inputs).

# Global Positioning System (GPS)

- Positioning per terminal via satellites
- Operator: US Department of Defence



# Four Satellites needed for precise positioning (X,Y,Z + Time)



# GPS

- Advantages:
  - Quite precise: 5 - 15 meters,
  - Low cost chip sets, embeddable in terminals,
  - Large choice of standard software for applications available.
- Disadvantages:
  - Works only outdoors,
  - USA can manipulate or disconnect the signals whenever they want,
  - Long initialisation,
  - High power consumption in non-stop operation.

# Galileo

- EU Satellite navigation system “Galileo”:
  - European sovereignty considerations motivated project.
  - More recent technology, higher precision
  - Commercial models planned for the usage (highway toll, logistics).
  - Planning phase is completed.
  - As of February 2016
    - 18 satellites were launched,
    - 14 of them were active.
  - On February 2019, four satellites are launched, making 22 operational satellites.[1]
  - By April 2020, 26 satellites are in orbit, of which 22 are usable for navigation, 2 are in testing modes, and 2 are not usable.[2]
  - At least 6 billion € until 2020 plus 1 billion € operating costs per year[3]
  - Compatible with GPS (so up to 60 satellites)
  - More Information: www.esa.int/esaNA/index.html

[1] https://www.gsa.europa.eu/newsroom/news/latest-batch-galileo-satellites-enters-service
[2] https://www.gsc-europa.eu/system-service-status/constellation-information
[3] http://www.wiwo.de/technologie/vernetzt/galileo-satelliten-europas-navigationssystem-geht-an-den-start/11862908.html

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# GLONASS

- Most expensive program of Russian Federal Space Agency (third of 2010‘s budget)
- Development started 1976
- Numerous rockets launches in 1982, added satellites on the system until the „constellation“ was completed in 1995.
- System consisted of 16 satellites in June 2008 (12 fully operational)
- GLONASS achieved 100% coverage of the russian territory in 2010.
- In October 2011, full global coverage was achieved (24 operational satellites).

# BeiDou

- BeiDou is a Chinese satellite navigation system.
- BeiDou started serving China in 2000, and the Asia-Pacific region in 2012.
- As of January 2018, 9 satellites have been launched.
- On December 2018, BeiDou started to provide global services.
- 33 satellites are operating in orbit for BeiDou.[1]
- Positioning accuracy
  - 10 meters globally
  - 5 meters in the Asia-Pacific region

[1] https://www.livemint.com/Technology/9rkTgLBMCHVottY3rP636J/Chinas-BeiDou-navigation-satellite-rival-to-US-GPS-starts.html

# Position Transmitter

- A terminal can receive location information from transmitters (Infrared, Bluetooth).
  - Terminal detects the transmitter information and runs LBS or transfers location information to the application.
- Usage in M-Business:
  - Exhibition information systems,
  - Museum guides,
  - Tourist guides,
  - Promotion activities.

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# Position Transmitter Bluetooth Low Energy (BLE)

- BLE (also called Bluetooth Smart) is a specification for the Bluetooth radio technology (introduced in 2009)
- It is used to produce modern BLE chipsets for Bluetooth transmitters such as Beacons.
- It requires significantly lower power of the receiver and the sender than traditional Bluetooth.
- The beacons come in different formats, including small coin cell powered devices, USB sticks and software versions.

Bluetooth SMART

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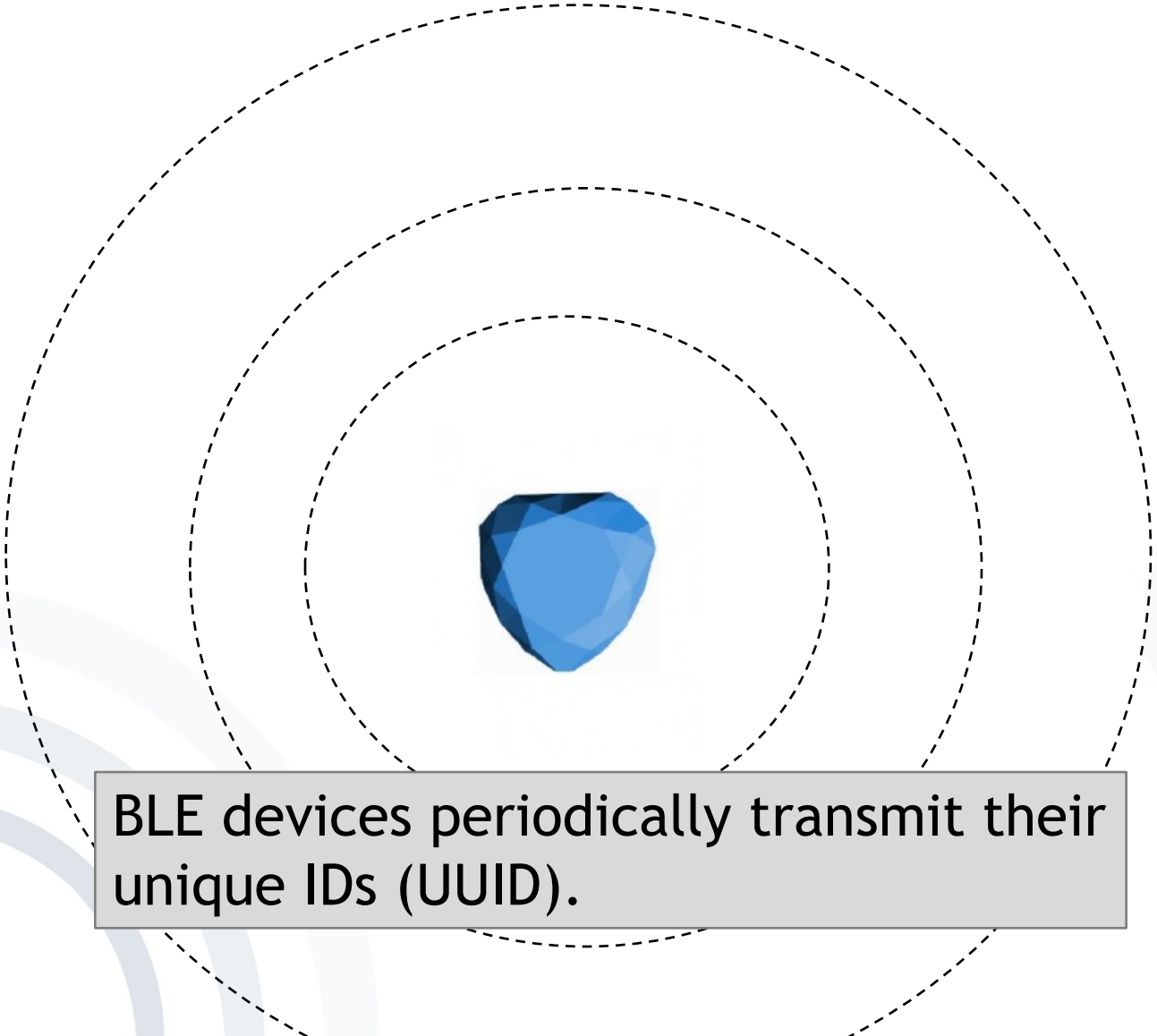
# Position Transmitter iBeacon

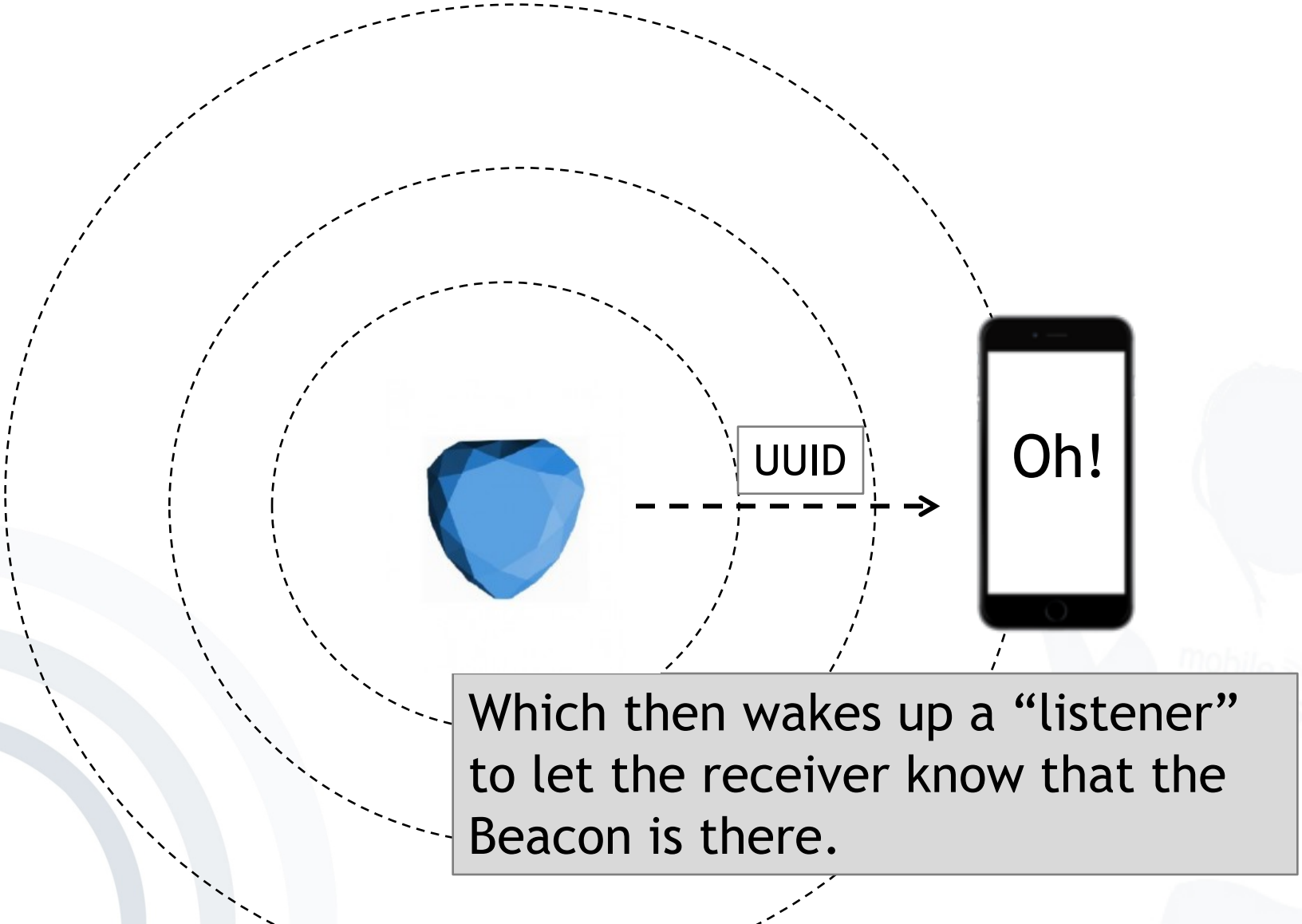
- iBeacon is Apple's term for an ordinary Beacon. The physical Beacon itself has not changed. But how the iOS software deals with Beacons is different from other systems (e.g. Android).
- Now the 'listening' happens within the OS instead of within the app itself. The IDs of iBeacons are registered against an application with Apple.
- iOS tracks the beacons it encounters and queries Apple's UUID database to see what app the beacon is associated to, then alerts the app (if installed on the iPhone or iPad) that a relevant beacon has been found.
- The app then uses that UUID to figure out a course of action.
- For example, a museum may designate a specific Beacon's UUID to indicate a beacon in the tyrannosaurus exhibit, so the museum app can pull up pictures, videos, audio descriptions, and so forth about that dinosaur.
- No further development and support from Apple so far [The Montley fool]

# Position Transmitter iBeacon



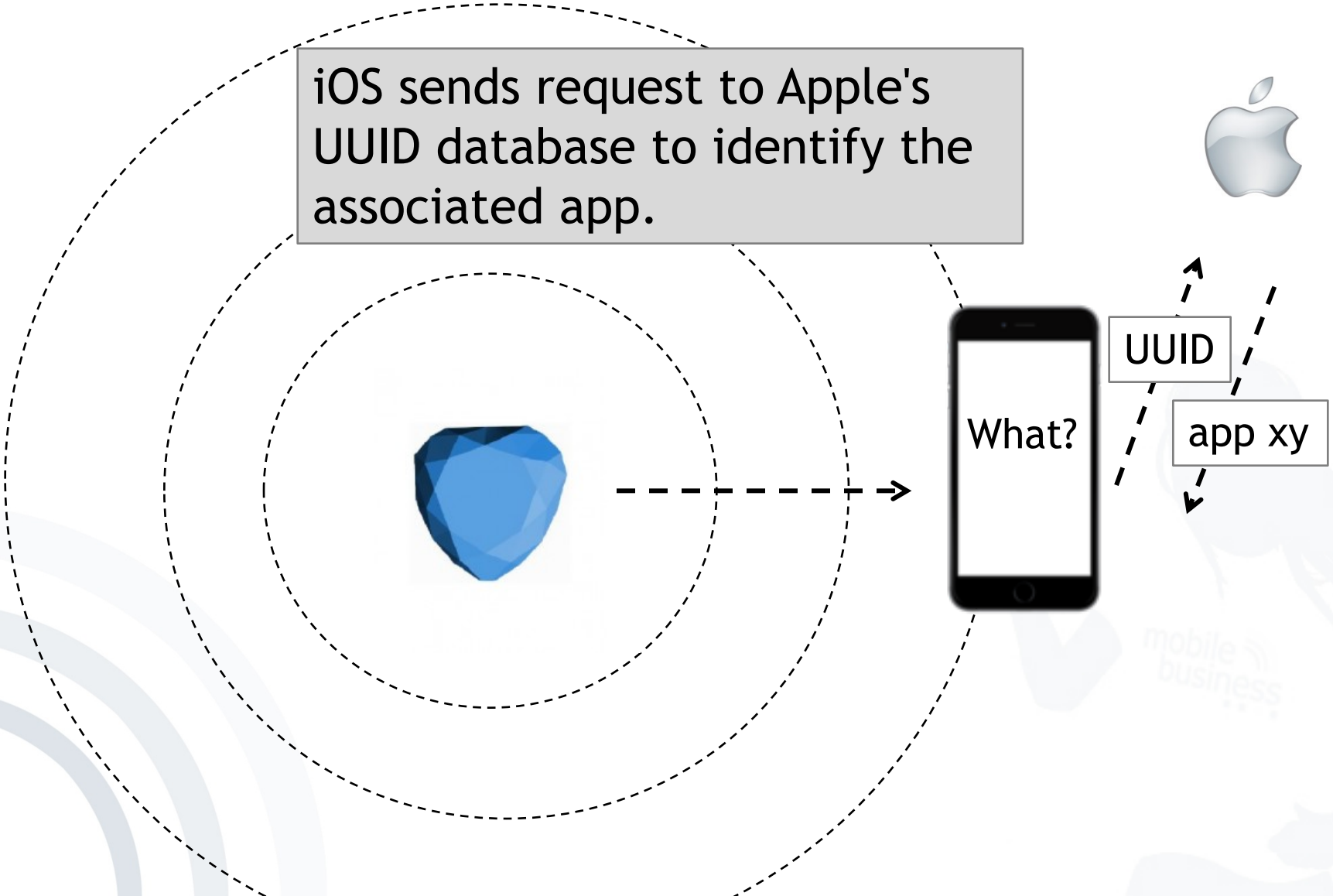
BLE devices periodically transmit their unique IDs (UUID).

# Position Transmitter iBeacon




Which then wakes up a “listener” to let the receiver know that the Beacon is there.

# Position Transmitter iBeacon



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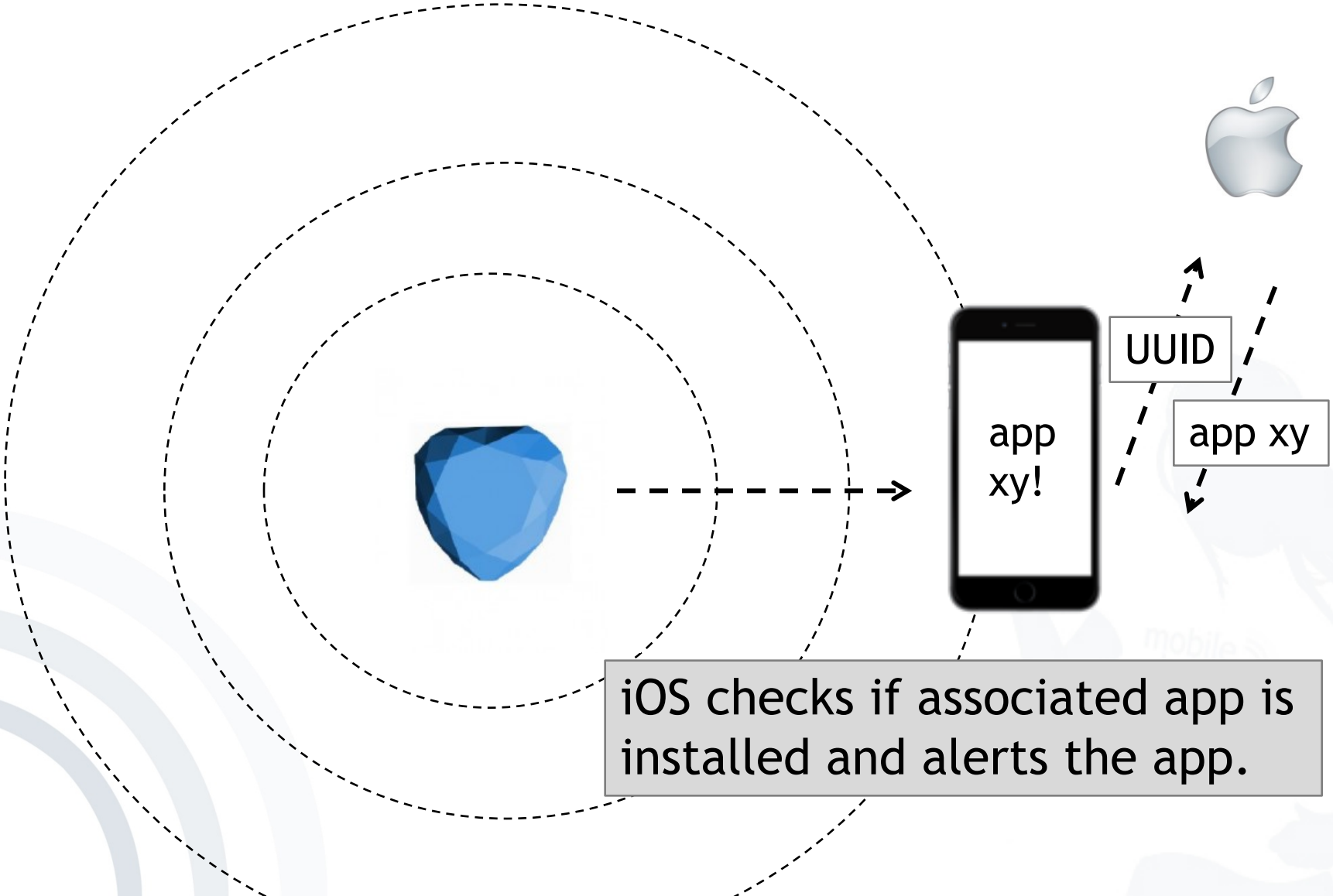
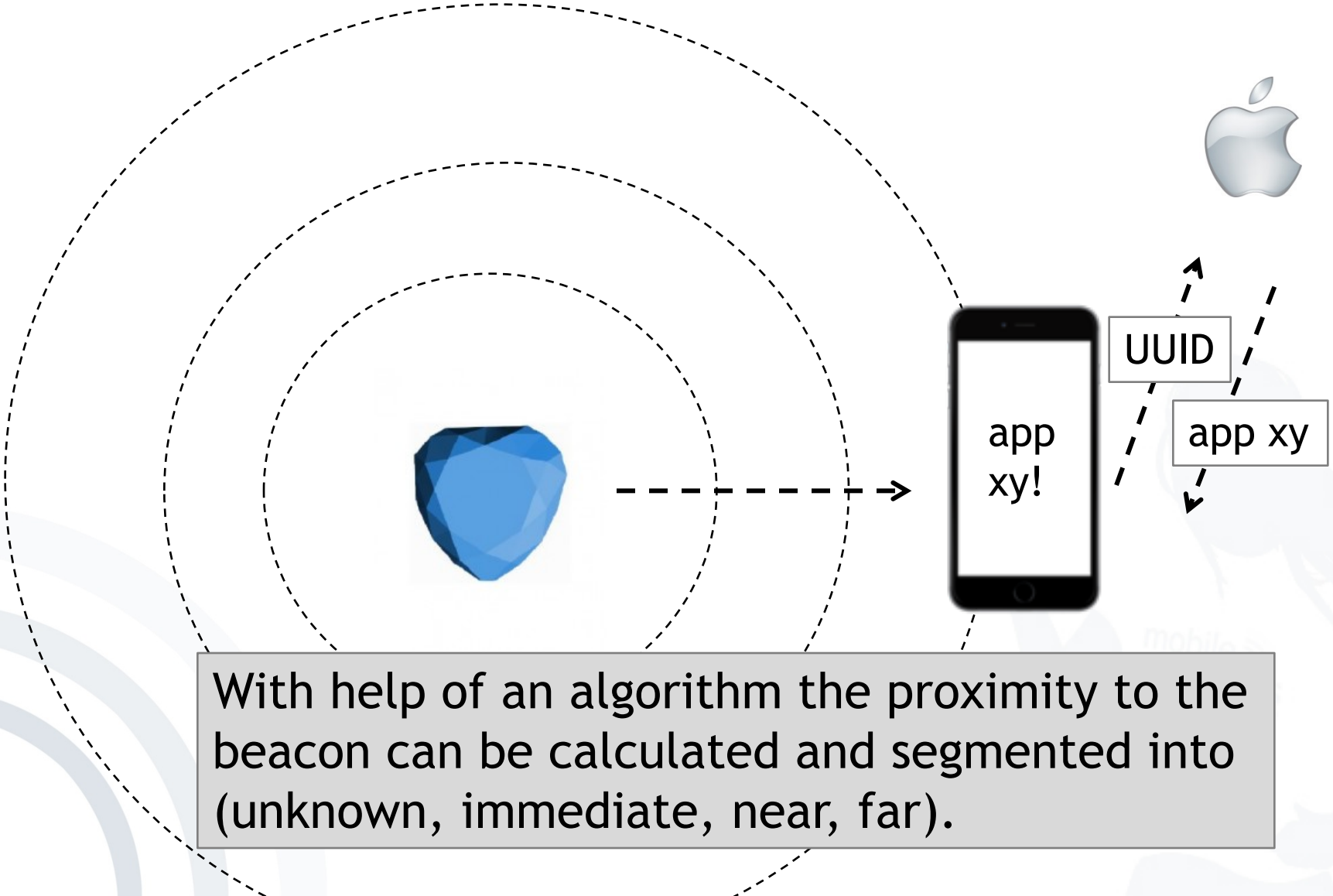
# Position Transmitter iBeacon



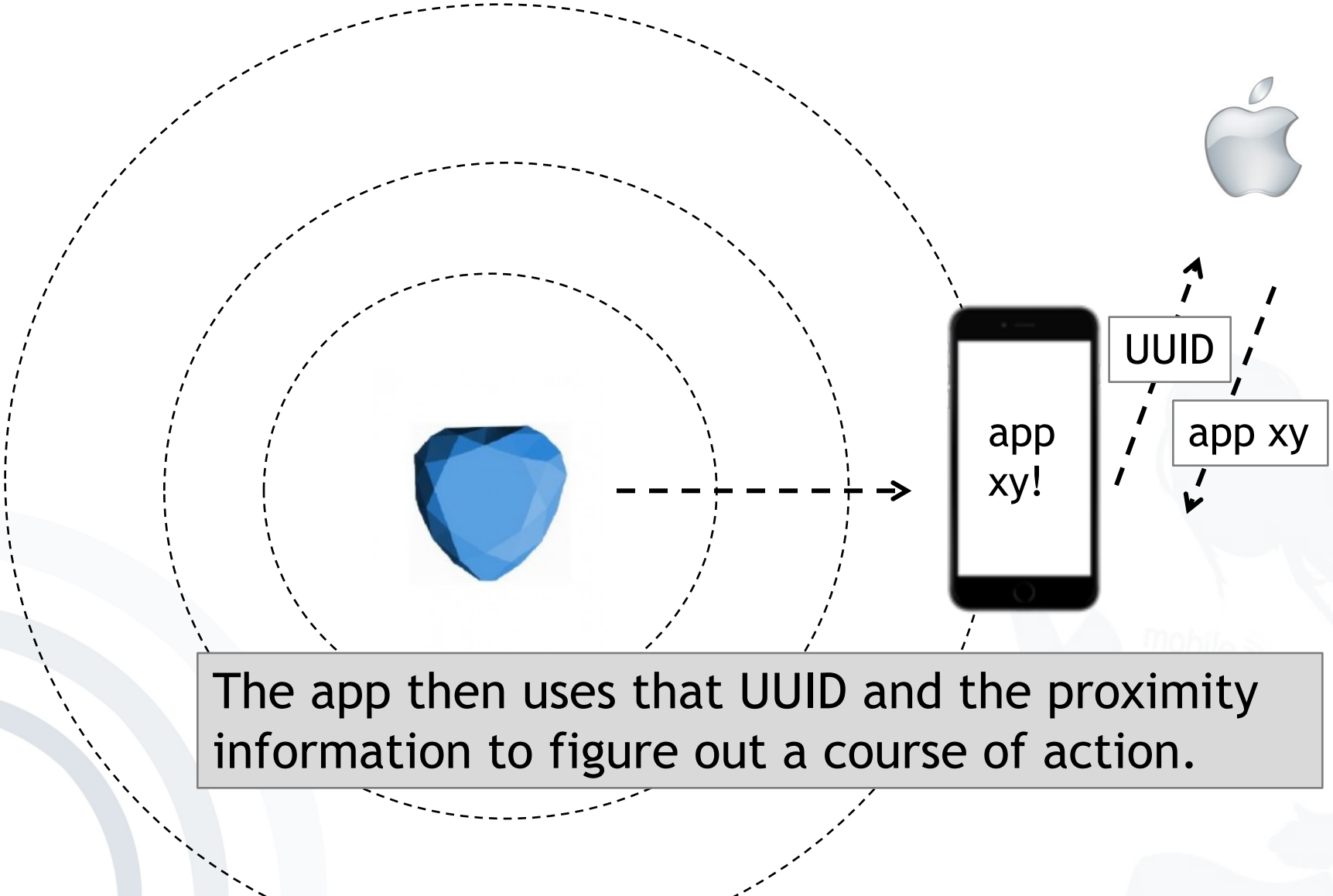

iOS checks if associated app is installed and alerts the app.

# Position Transmitter iBeacon




With help of an algorithm the proximity to the beacon can be calculated and segmented into (unknown, immediate, near, far).

# Position Transmitter iBeacon




The app then uses that UUID and the proximity information to figure out a course of action.

# Position Transmitter Bluetooth Beacons

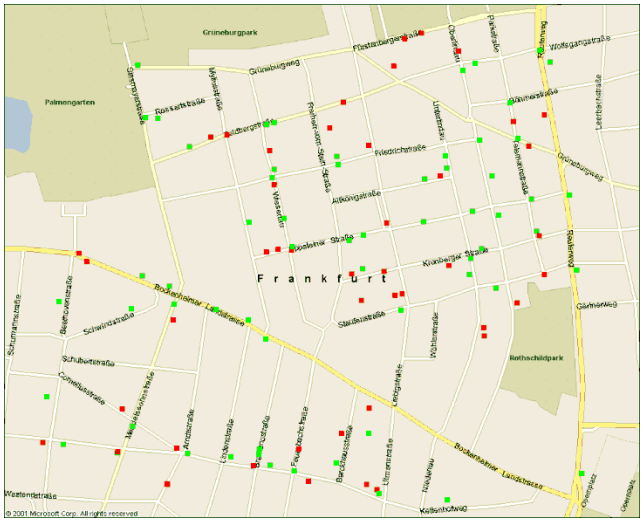
- Advantages:
  - Inexpensive ($20-$30 / beacon)
  - Up to 100 meters reach
  - Low power consumption (does not drain smartphone battery)
  - Modern mobile operating systems natively support BLE
  - Smartphone can also act as transmitter.

- Disadvantages:
  - Transmitter does not transmit data.
  - Receiver software (app) has to be installed.
  - Transmitters have to cover area.
  - Proximity is vague (unknown, immediate, near, far)

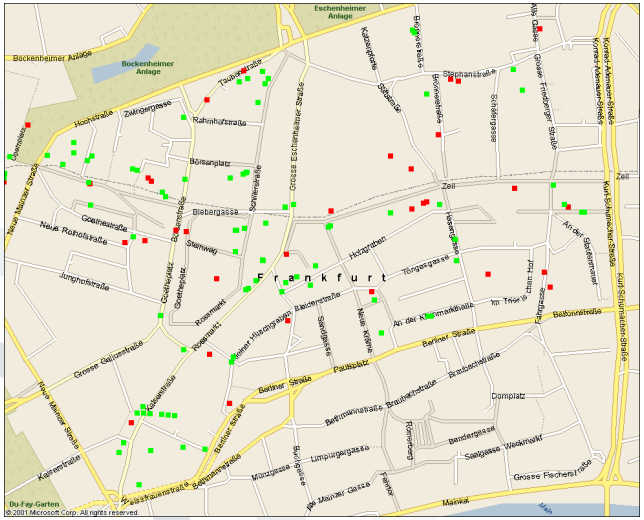
# LBS with Wireless LAN

- Strong increase of WLAN Access-Points in urban areas
- Offers from e.g. Telekom, Swisscom, Skype WiFi
- Idea: use Access Points as a source for location information
  - Diploma thesis from Th. Lindner Chair for M-Commerce in the period from 4/2003 - 8/2003:
    *„Geschäftsmodelle für situationsbezogene Mehrwertdienste in drahtlosen Netzwerkinfrastrukturen mit stationären Zugangspunkten“*
  - *Lindner, T. (2003) Geschäftsmodelle für situationsbezogene Mehrwertdienste in drahtlosen Netzwerkinfrastrukturen mit stationären Zugangspunkten, Frankfurt am Main.*
    Objective: Measuring, to document changes in the positions and amount of Access-Points, develop a business model.

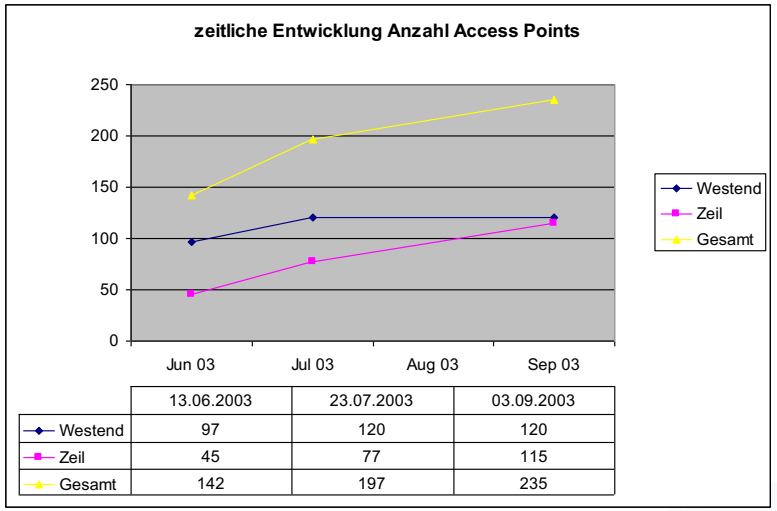
# LBS with Wireless LAN



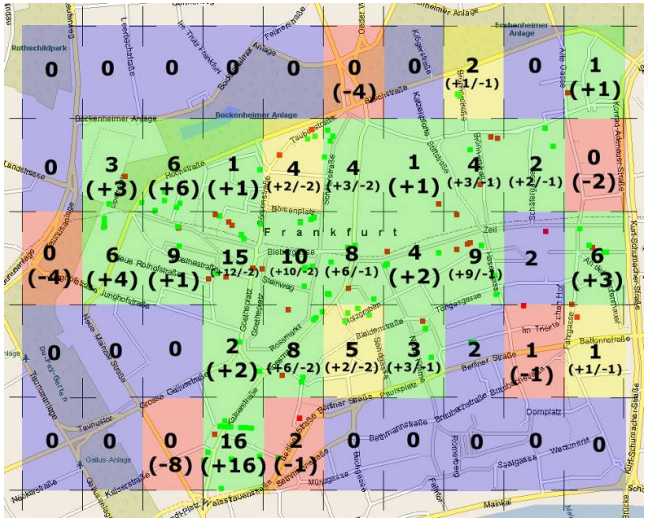

Infrastructure Westend Status 03. September 2003 (120 Access Points)




Infrastructure Zeil Status 03. September 2003 (115 Access Points)




| | 13.06.2003 | 23.07.2003 | 03.09.2003 |
|---|---|---|---|
| Westend | 97 | 120 | 120 |
| Zeil | 45 | 77 | 115 |
| Gesamt | 142 | 197 | 235 |




Changes in the density of WLAN in the area „Zeil“ from June-September 2003
Green increase, Yellow: Changes with const. number, Red: decrease

Origin: T.Lindner

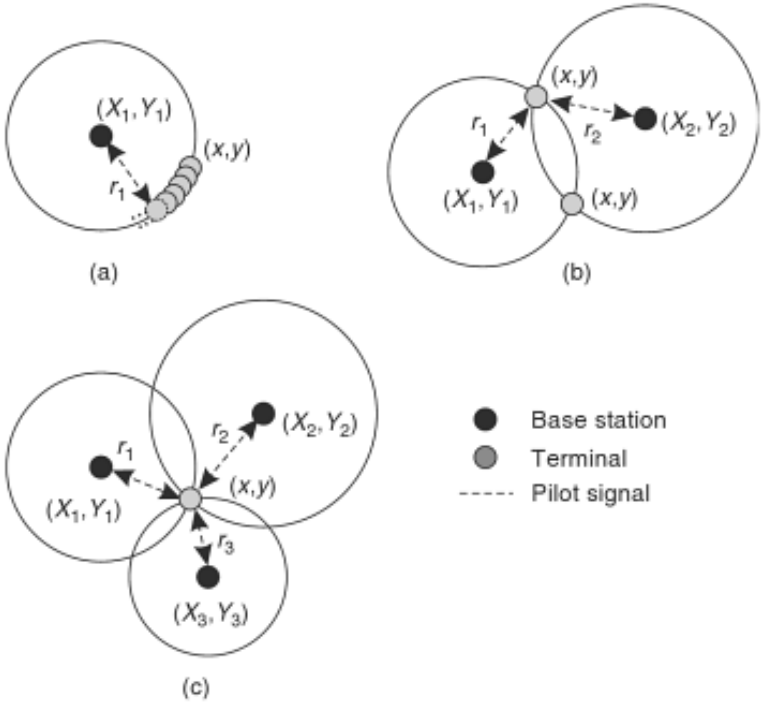
# LBS with Wireless LAN

- Mobile Device sends a request to a WLAN Database for information (like SSID, IP Address etc.) of the WLAN Access Point
- Based on the provided information, the coordinates of the respective WLAN Access Point will be returned to the Mobile Device.

# LBS with Wireless LAN

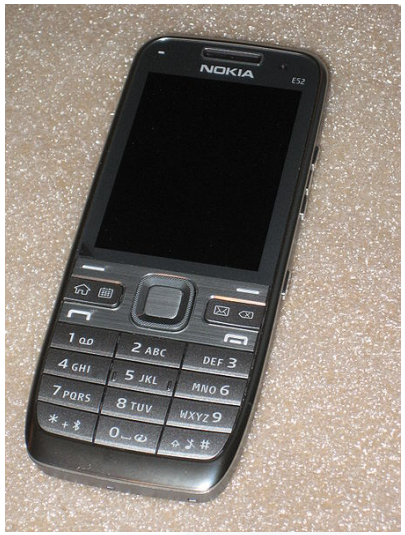
- Available WLAN Databases
  - Freely available:
    - NodeDB.com
    - hotspot-locations.com
    - ...
  - Commercial and chargeable:
    - Apple Database
    - Google Database
    - ...
  - Database update via terminals (Mobile Devices)

# Indoor navigation with Trilateration (WLAN or Beacons)




The gray circles (terminal) provide a possible position of the smartphone. The dashed line is the distance between Terminal and base station.

# Electronic Compass (Magnetometer)




- First device on the market was Nokia E52 in Q1 2009.
- Today magnetometers are integrated into many devices and enable compass functions, e.g.
  - Android
  - Since iPhone 3GS
  - Several Nokia Devices

[de.wikipedia.org]

# Agenda

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# Cell-ID

- Cell-of-Origin (COO) within the network or Cell-ID on terminal
- Most common method for positioning (USA Phase 1 911, D1, D2, 02)
- No „positioning“, but „looking-up“ in the VLR (Visitor Location Register)

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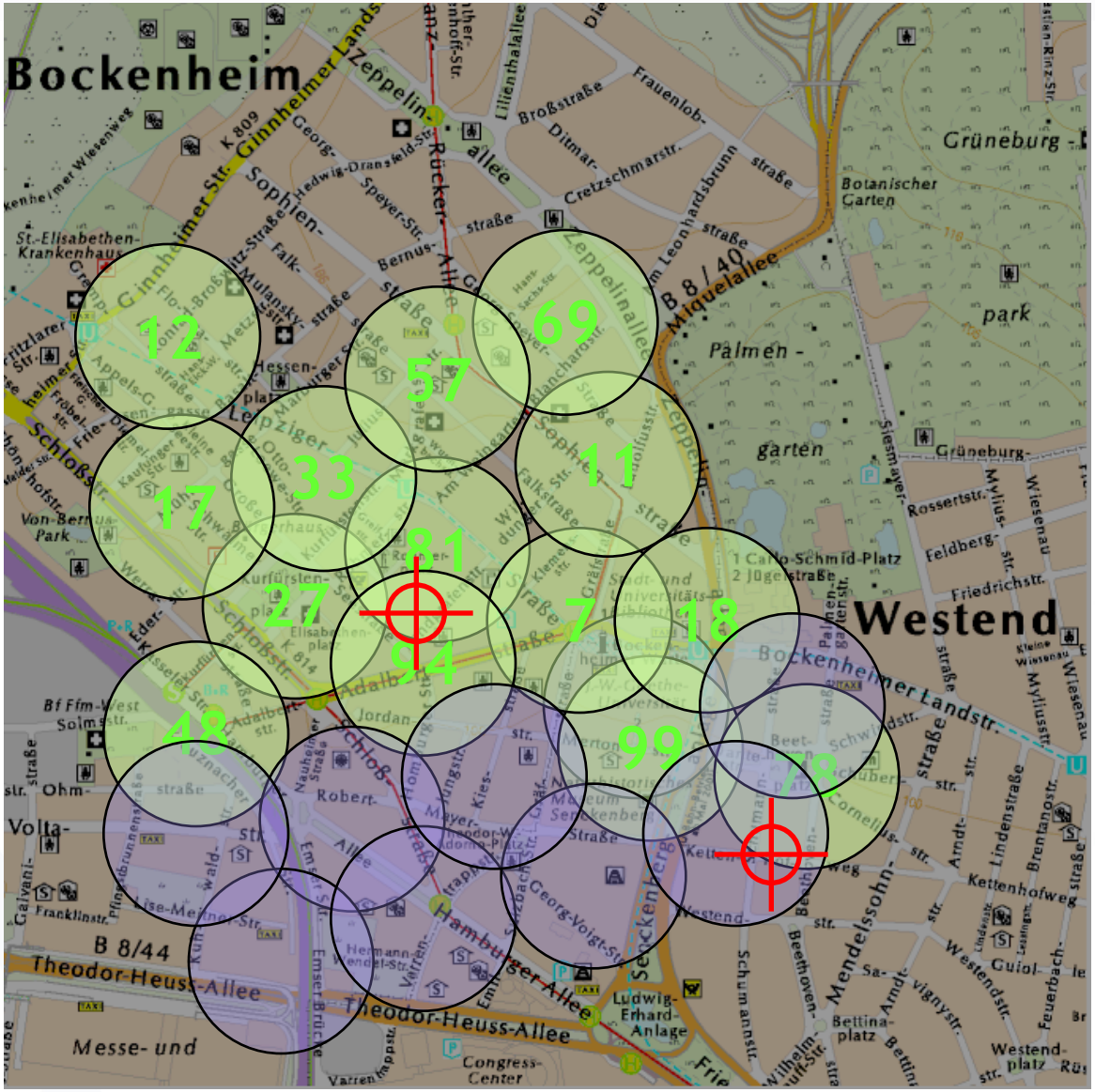
# Cell-ID



# Cell-ID

## Usage in M-Business:

- Accuracy = Depending on size of the cell
  - In city centres: approximately 300 metres
  - In rural areas: much larger cells up to approximately 30 km
- Very fast positioning is possible
  - Average response time < 3 seconds
- No hardware-upgrade necessary
- But: A data base with cell location and cell sizes is needed.

# Data retention of cell-based location data

[https://www.zeit.de/datenschutz/malte-spitz-data-retention]

# Time Difference of Arrival – TDOA

## Time Difference of Arrival (TDOA)

- Measuring of time intervals
- Using the “uplink-data” (data, that are sent out from the terminal)
- TDOA supports legacy-terminals:
  All base stations have to be equipped with “Monitoring Software”.

# TDOA

- Advantages:
  - Slightly more precise than Cell-ID (50-125 m)
  - No modification of the software on the terminal
- Disadvantages:
  - Slower response time than Cell-ID (< 10 seconds)
  - High costs due to the needed upgrade of the network,
  - Relocation of the “intelligence” into the network.
  - The customer has no control over his location information anymore.

# Enhanced Observed Time Difference – E-OTD

- Terminal (Mobile Station, MS) observes the time difference of the arrival of signals from two different base stations (Observed Time Difference (OTD)).
- However the clocks of the base stations may not be synchronized, so OTD may be imprecise.
- A Location Measurement Unit (LMU) with a fixed location estimates the transmission time offset between the two base stations (Real Time Difference (RTD)).
- OTD – RTD = Geometric Time Difference (GTD)
- To locate the terminal, one needs two BTS.

# E-OTD

## Usage in M-Business:

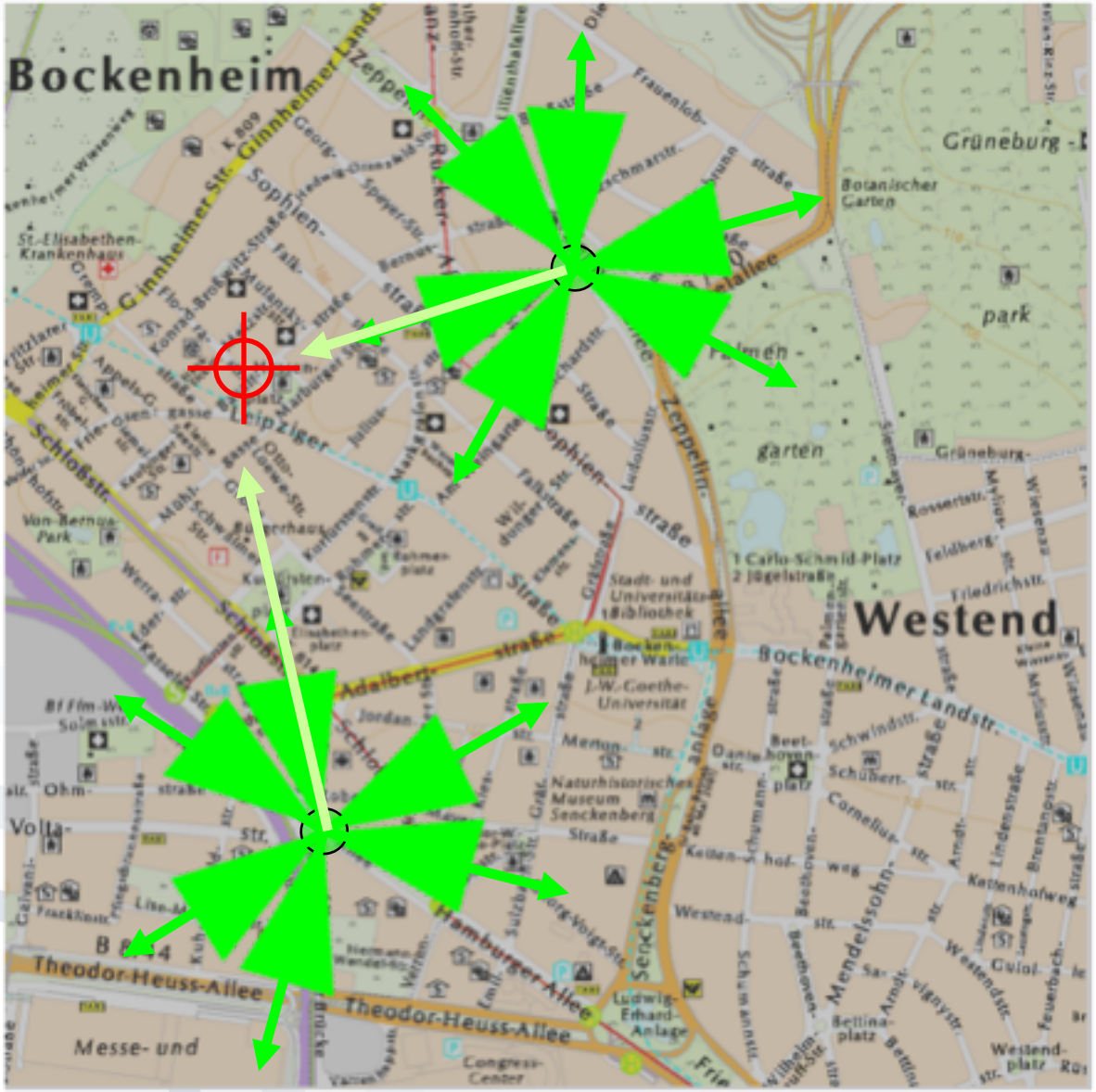
- Advantages:
  - Slightly more precise than Cell-ID (50-125 m)
- Disadvantages:
  - Modification of the software on the terminal
  - A bit slower response time than Cell-ID (< 5 seconds)

# Angle of Arrival – AOA

## Angle of Arrival (AOA)

- Bearing with beam antennas
- Was used in analogue systems (still used today in the USA)
- Set up of an antennae system; then calculation of the angles to the network
- At least two antennae necessary
- Use is difficult in digital systems (channel-division and changes of cells)

# Angle of Arrival – AOA



Mast with 6 sectors

[Source: www.nobbi.com]

# Angle of Arrival – AOA

- Advantages:
  - No modification of the terminal
- Disadvantages:
  - The „beam antenna“-trait of the whole network has to be measured.

# Signal Attenuation – SA

## Signal Attenuation (SA)

- Measuring whether a terminal moves away from a base station or towards it.
- If one knew the signal strength, one could calculate the distance of the device from the base station.

# Signal Attenuation – SA

Usage in M-Business:

- Measuring the signal strength is technically very complex
  - change of the frequency,
  - obstacles like e.g. walls,
  - environmental influences like e.g. the weather,
  - radiation of buildings, ...
- Simply observable by taking a look at the “power beam” on a mobile phone, also when one does not move.

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# A-GPS

## Assisted GPS (A-GPS)

- Completed via other methods:
  - Coupling of efficient GPS receiver in handset with location server in the network
  - Combination of GPS reception & cell / base station location data in one service
- Use in M-Business
  - Usual application area: navigation applications, logistics
  - Recently: Games like Geocaching
  - Additional hardware needed, connectivity of handset
  - For network operators: enhanced control over location applications

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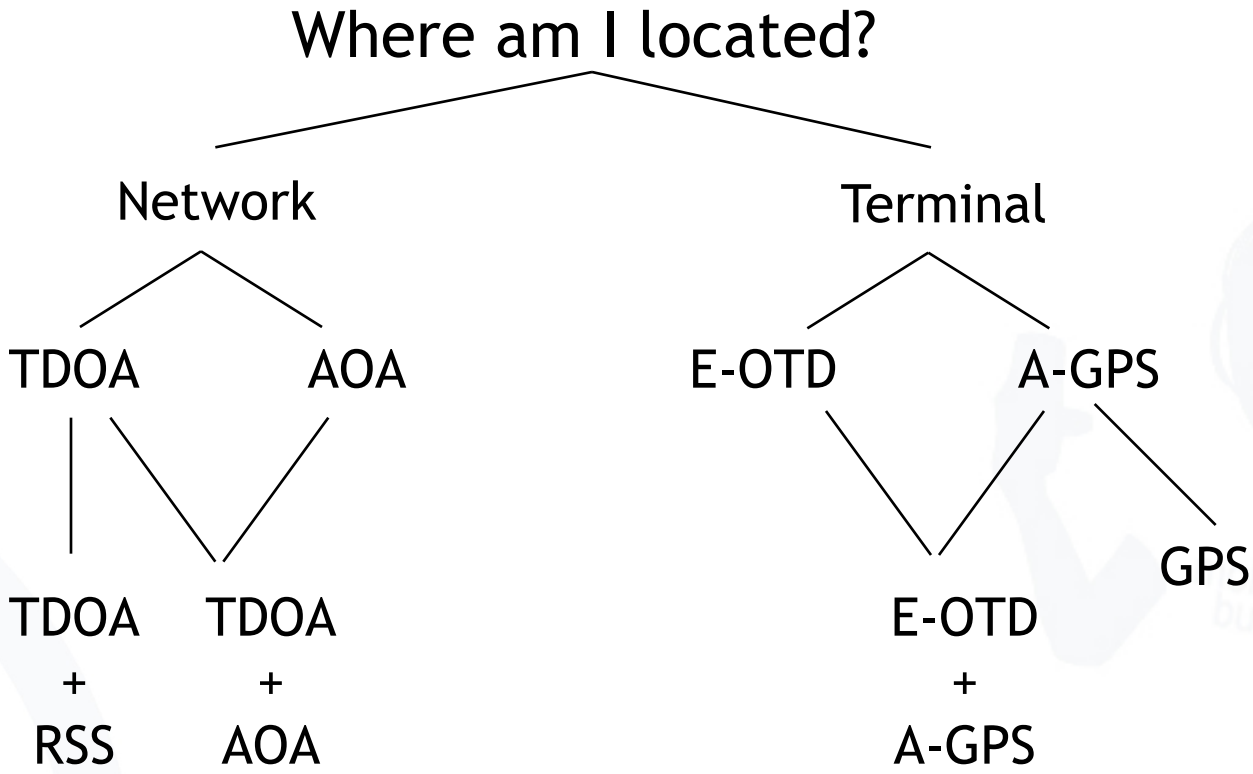
# Summary: Positioning-“tree“




[Source: Motorola]

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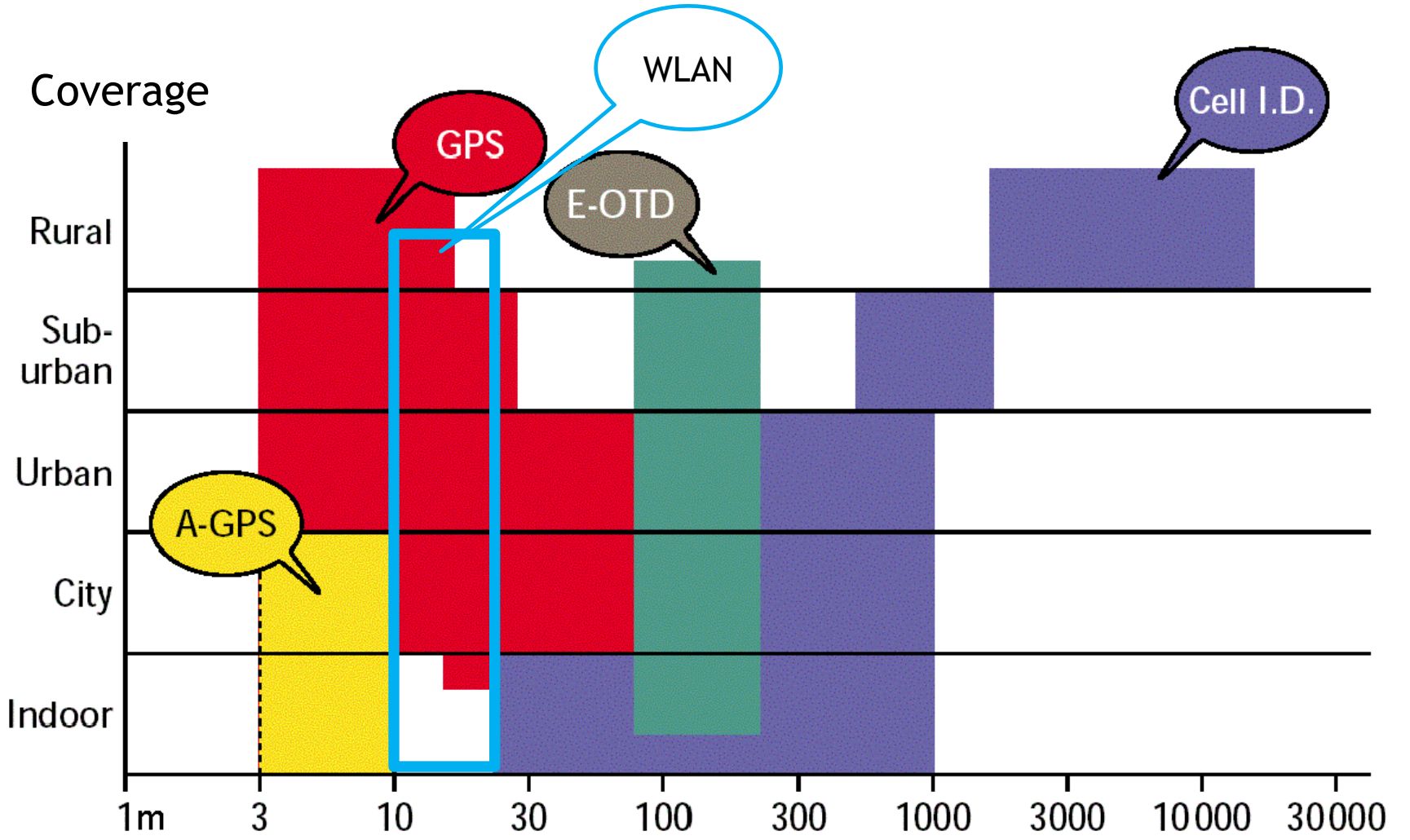
# Precision of positioning




[Source: based on Nokia]

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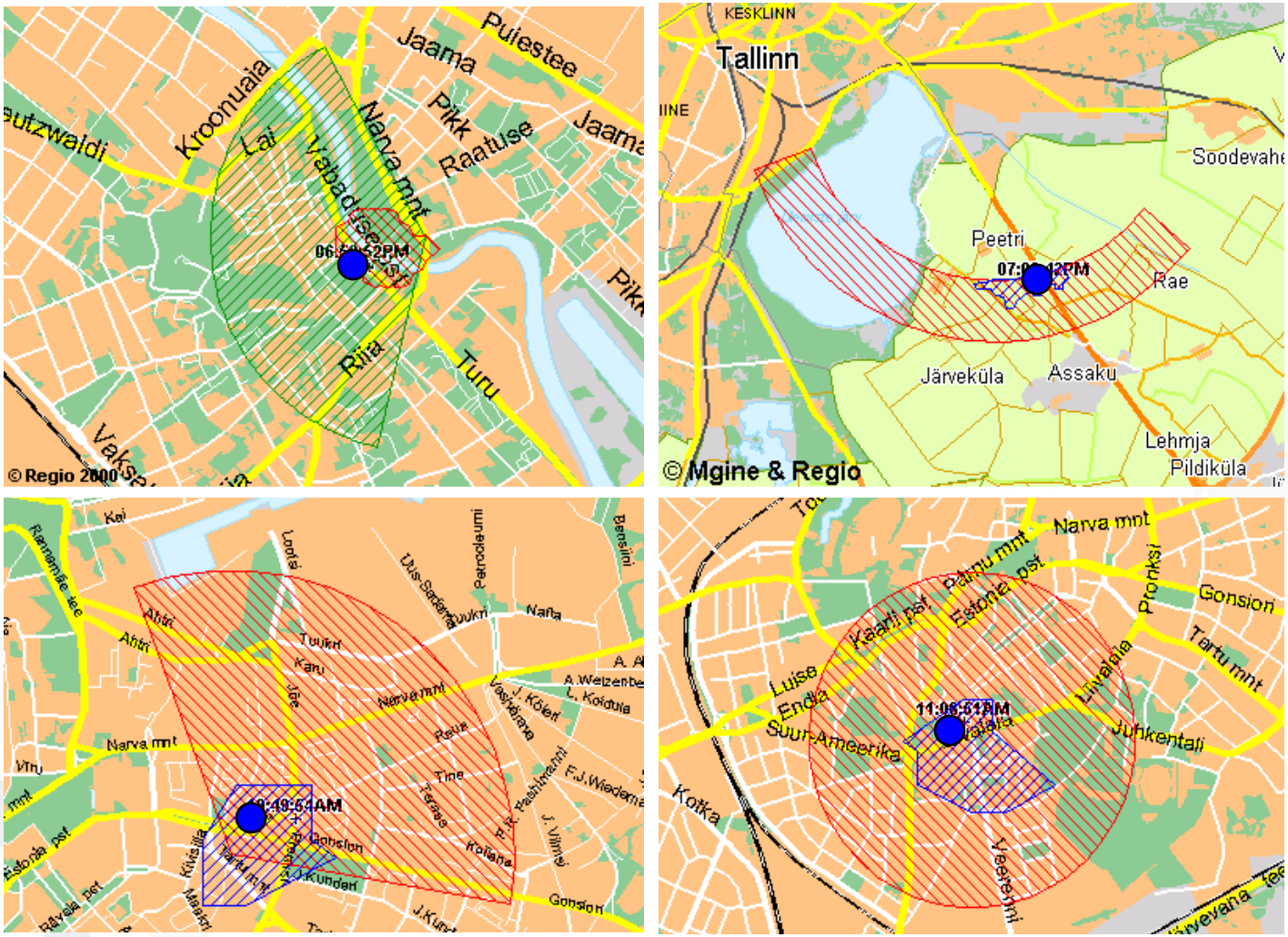
# Positioning examples




[Source: EMT, PinPoint LBS]

# Data retention of cell-based location data

[https://www.zeit.de/datenschutz/malte-spitz-data-retention]

# LBS in 2G vs. 3G

- UMTS and LBS:
  - UMTS has higher frequency (shorter range) than GSM.
  - Are more cells a trigger for LBS with Cell-ID?

# Altitude and Direction

- What is missing in mobile communication based methods presented so far?
  - Measuring of the line of sight
  - Measuring of the altitude
  - Direction of a movement
- Solutions
  - Infrared beacons
  - Electrical compasses
- Some technical solutions are very complex.

# Open Questions concerning Infrastructure

- What does positioning cost?
  - In the terminal?
  - In the network?
  - As protocol overhead?
- How can roaming work?
- How are LBS accounted in a privacy-friendly manner?

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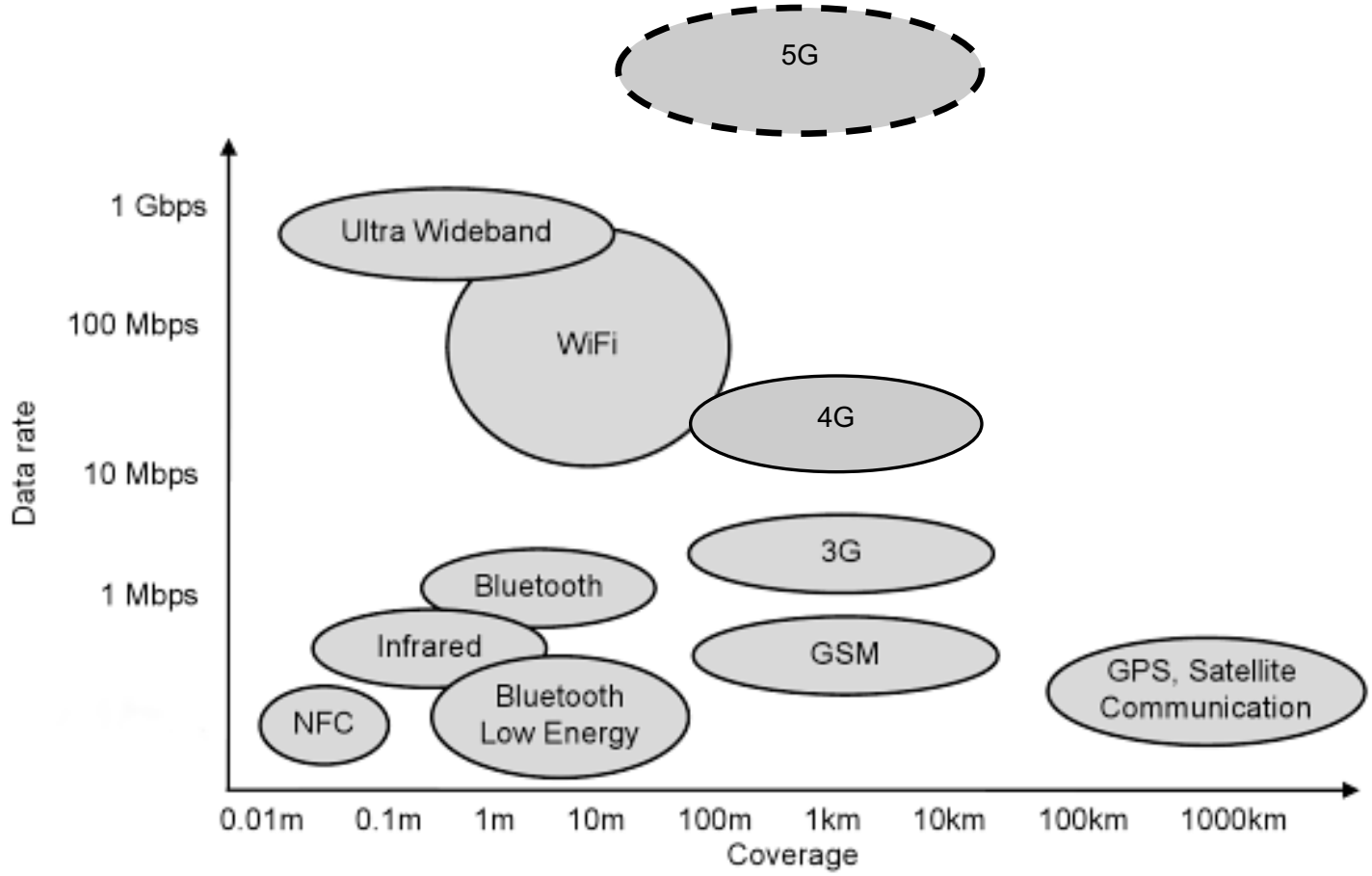
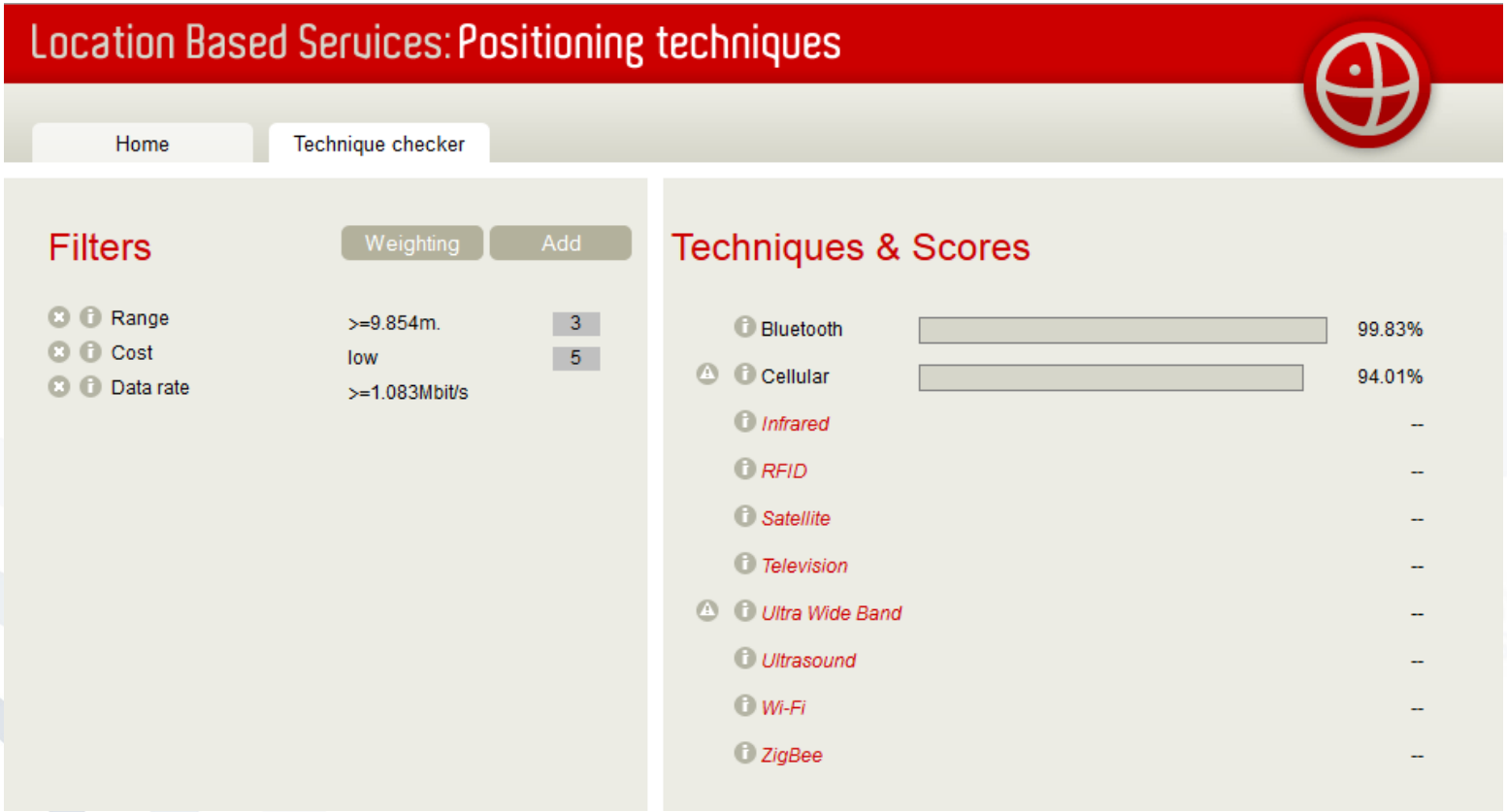
# Overview of the data transfer rate and range of wireless technologies




[Source] Based on GUPTA, N. C. (2013). *Inside Bluetooth Low Energy*.

# Which Positioning Method for which circumstance?

- Technique Checker:
  - ➔ http://www.positioningtechniques.eu/lbs_technique_checker.asp



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