LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Praktikum Mobile und Verteilte Systeme

Context-Awareness and Location-based Services

Prof. Dr. Claudia Linnhoff-Popien
Philipp Marcus, Mirco Schönfeld
http://www.mobile.ifi.lmu.de

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Context-Awareness and Location-based Services

Today:

- Context-Awareness
  - What is Context / Context-Awareness?
  - How to sense context?

- LBS
  - What are LBS?
  - Origin and evolution of LBS
  - Classification and role model
  - Position Management in LBS

Next week:

- Concept presentations

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).” (Chen/Kotz 2000)

Defining Context

- **Schilit (1994)**:
  - *Computing context*: connectivity, communication cost, bandwidth, nearby resources (printers, displays, PCs)…
  - *User context*: user profile, location, nearby people, social situation, activity, mood …
  - *Physical context*: temperature, lighting, noise, traffic conditions
  - **Chen/Kotz (2000)** added:
    - *Time context* (time of day, week, month, year…)

- **Dey and Abowd (2000)**: "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 the application themselves."

Sensing Context

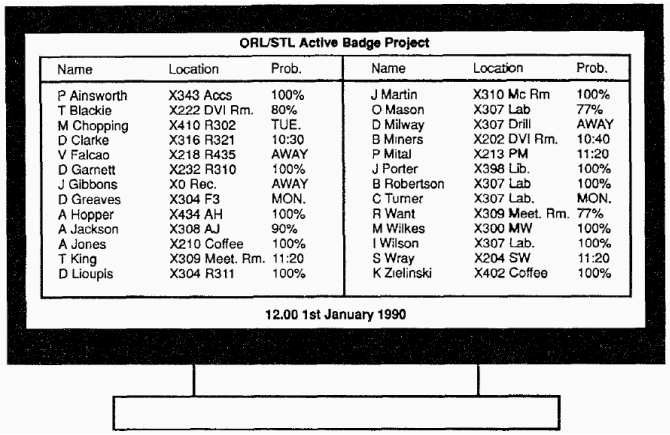
- Sensing location: e.g. GPS (cf. outdoor / indoor positioning)
- Media capturing: e.g. camera, microphone
- Connectivity: mobile network, bluetooth, WLAN, NFC
- Time: e.g. day of week, calendar
- Motion and environmental sensors:
  `TYPE_ACCELEROMETER, TYPE_AMBIENT_TEMPERATURE, TYPE_GRAVITY, TYPE_GYROSCOPE, TYPE_LIGHT, TYPE_LINEAR_ACCELERATION, TYPE_MAGNETIC_FIELD, TYPE_ORIENTATION, TYPE_PRESSURE, TYPE_PROXIMITY, TYPE_RELATIVE_HUMIDITY, TYPE_ROTATION_VECTOR, TYPE_TEMPERATURE`

- Further: active/running apps on device, remaining energy level, …

Example: Active Badge / ParcTab

Active Badge

- From Olivetti Research Lab in 90's
- One of the first context-aware systems
- Office personnel wear badges (IR signal)
- Applications
  - Call Forwarding

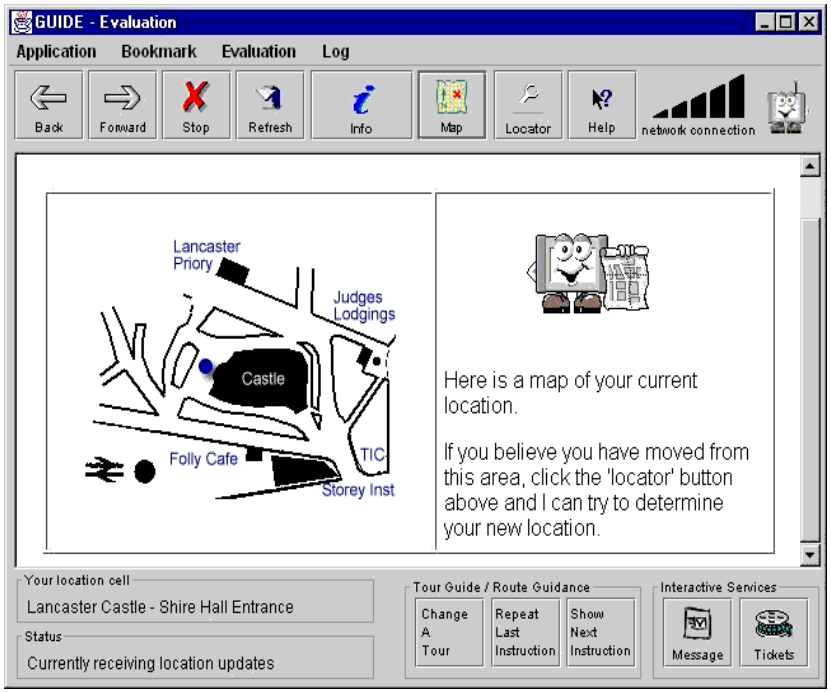


ParcTab

- From Xerox Palo Alto Research Center
- Room-sized IR cells
- Applications
  - Active Map
  - Location information (Room number)
  - Others: Find local resources (e.g. nearest printer), Remote control

Example: GUIDE

- Developed in Lancaster University
  - For Lancaster City visitors
- Using WaveLAN as communication infrastructure
  - A tourist comes to a region(cell), then he receives information of the region.
- Information provided using
  - Fujitsu TeamPad 7600 portable PC
  - Java based http browser



Location-based Services: Definitions

- "[...] services that use the location of the target for **adding value** to the service."

  (GSM Association: Location-based Services. Permanent Reference Document: SE.23; Version 3.1.0, Jan 2003.)

- "[...] service provided either **by teleoperator or a 3rd party service provider** that utilizes the available location information of the terminal."

  3rd Generation Partnership Project: Technical Specification Group Services and System Aspects; Functional stage 2 description of Location Services (LCS) (Release 9) TS 23.271, 2009.

- "Location-based Services (LBSs) are IT services for providing information that has been **created, compiled, selected, or filtered** taking into consideration the **current locations** of the users or those of other persons or mobile devices."

  Küpper, A.: Location-based Services - Fundamentals and Operation. John Wiley and Sons, 2005.

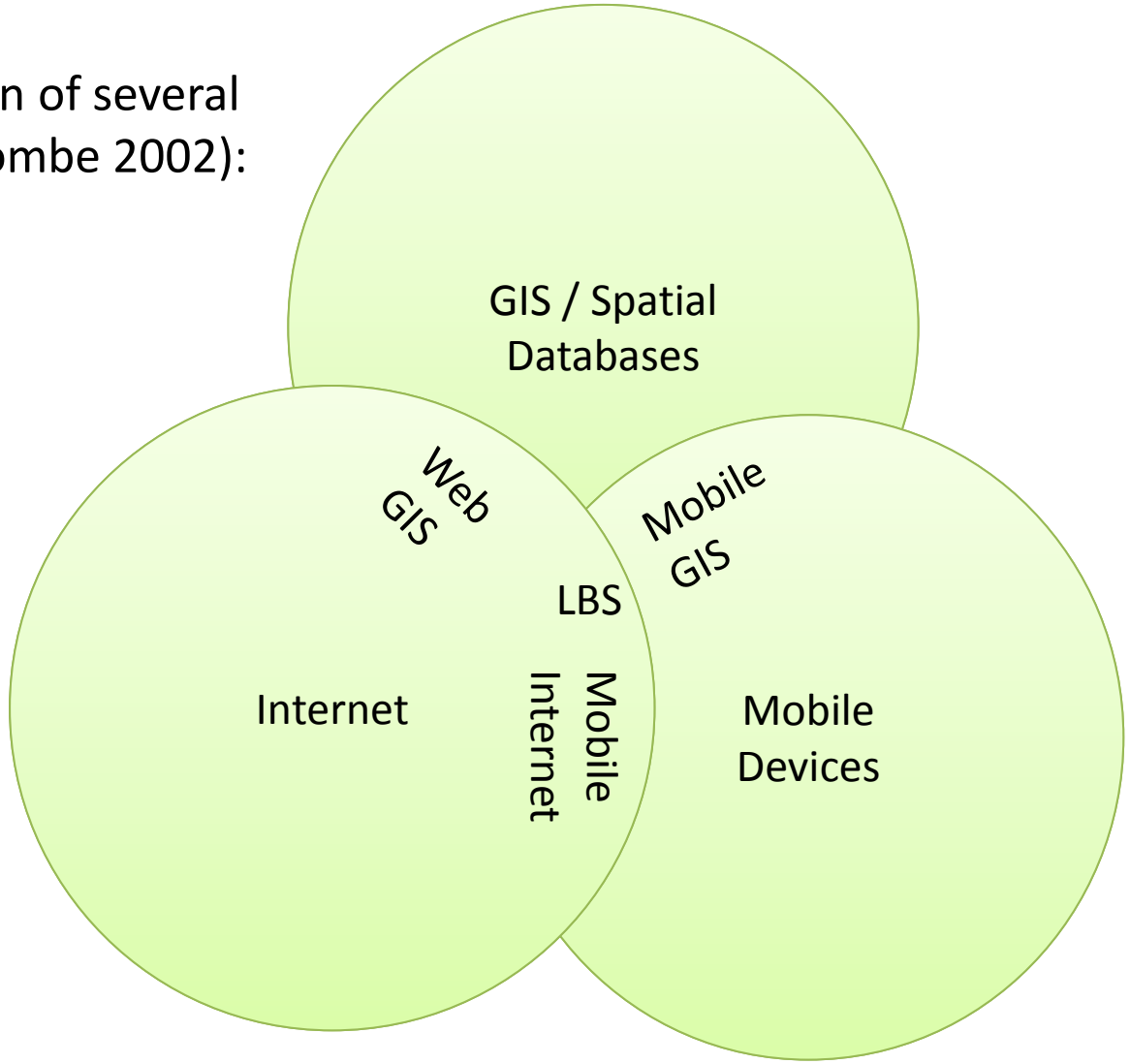
- "A wireless-IP service that uses geographic information **to serve a mobile user**. Any application service that **exploits the position of a mobile terminal**."

  Open Geospatial Consortium Inc. OpenGIS Location Services (OpenLS): Core Services, 2008.

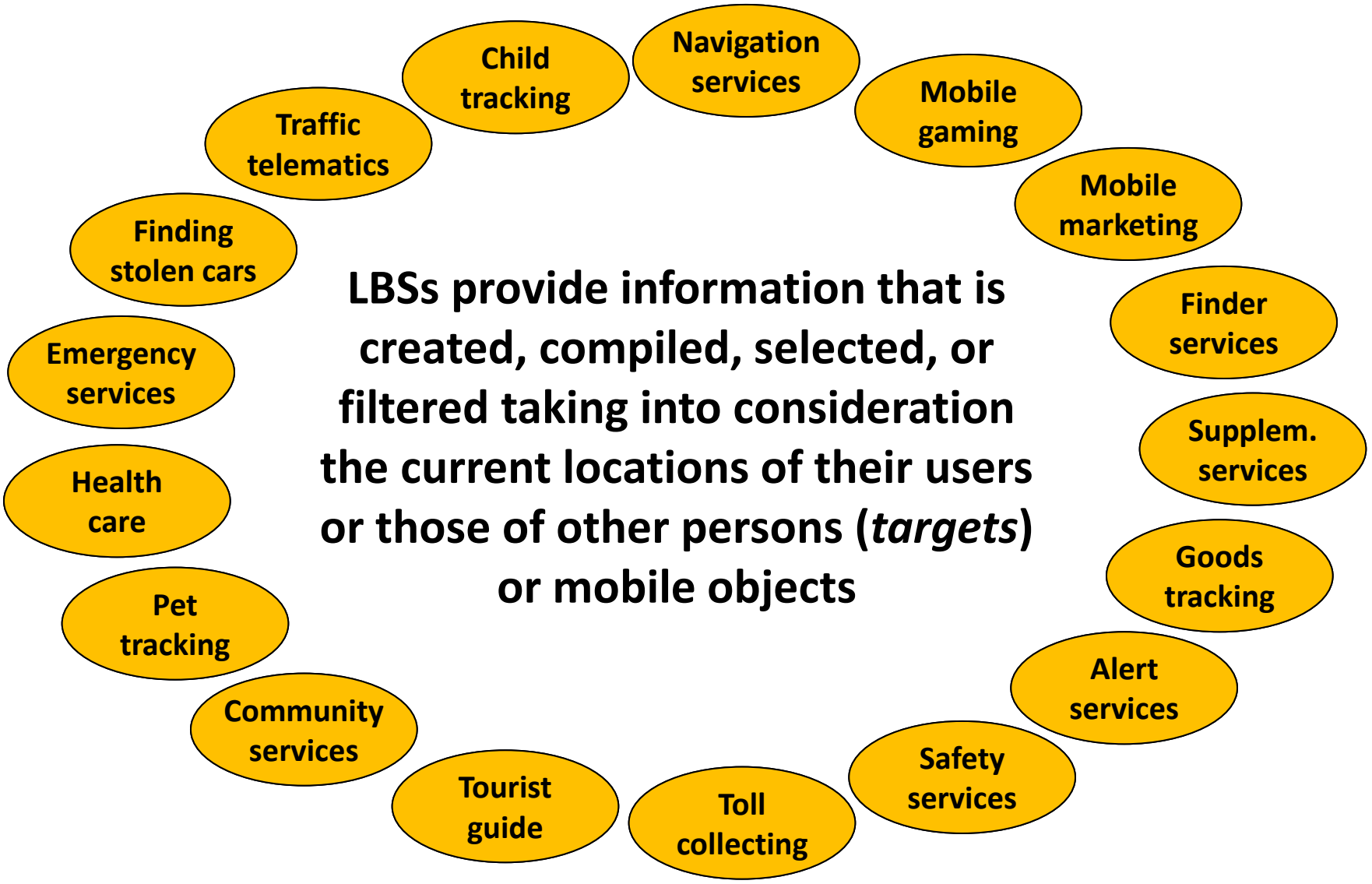
LBS – Relation to Other Areas

LBS as the intersection of several technologies (Brimicombe 2002):

- Internet
- Mobile Devices
- GIS



LBS – Application domains



Background: emergency services

- Persons calling an emergency response agency (e.g., police, fire) are unable to communicate their current location or they simply do not know it
- Address of a caller can be easily determined when made over the fixed telephone network
- But: rescue workers have serious problems locating emergency callers from mobile networks
- emergency calls increasingly originate from mobile networks

Administrations in many countries oblige mobile operators to extend their networks for offering enhanced emergency services

Features of Enhanced Emergency Services

- *Selective routing*: routing of an emergency call to the *Public Safety Answering Point* (PSAP) that serves the geographical area the call originates from

- *Automatic Number Identification* (ANI): delivery and display of the emergency caller's telephone number

- *Automatic Location Identification* (ALI): determines the location (in terms of a street address) of an emergency caller

Examples

- Enhanced 911 (E-911) in the United States
- Enhanced 112 (E-112) in Europe
- Similar activities in Japan and Korea

E-911

- Passed by U.S. *Federal Communications Commission* (FCC) in 1996
- Phase 1
  - Derive a mobile caller's location from the coordinates of the serving cell site from where the emergency call has been made
  - Automatic Number Identification
  - Scheduled to be completed in April 1998
- Phase 2
  - Locate a caller accurately within 50 to 100m in 67% and 150 to 300m in 95% of all emergency calls
  - Required the operators to begin network enhancements not later than October 2001 and to finish them by December 2005
  - Operators were and still are faced with serious problems with the realization of Phase 2

http://www.fcc.gov/911/enhanced/

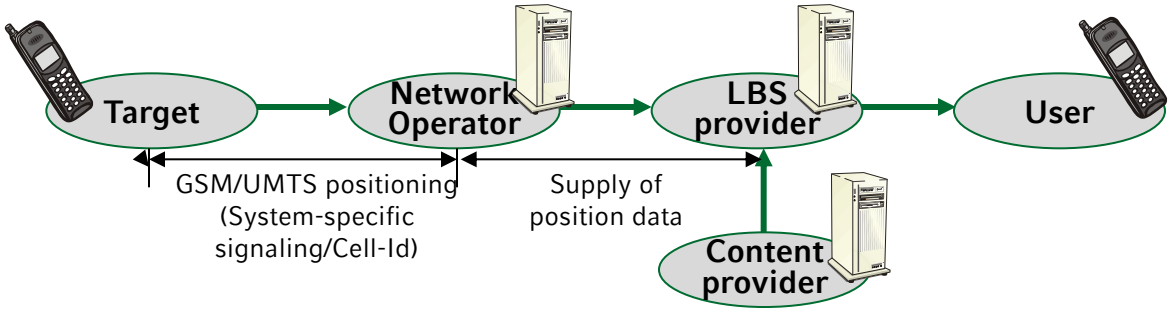
E-112

- Coordinated by the European *Coordination Group on Access to Location Information for Emergency Services* (CGALIES)
- CGALIES investigates and prepares for the introduction of enhanced emergency services in all countries of the EU
- Commitments for operators are less restrictive than in the U.S.
- No mandate, just recommendations defining several features of E-112
- No time schedule
- Operators are urged to locate emergency callers as accurately as possible

http://europa.eu/

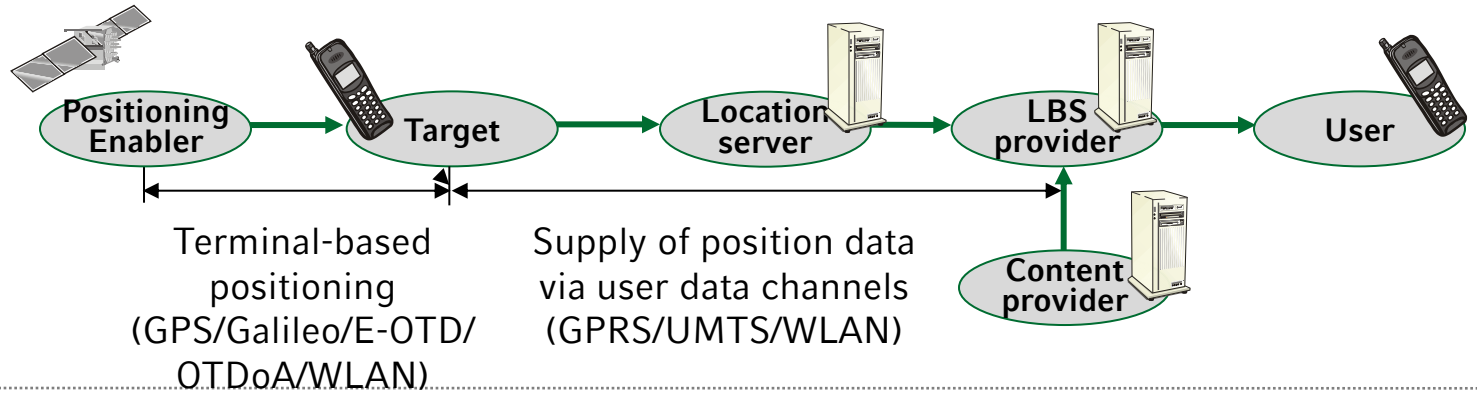
Role models

Classical approach, 1. Generation



Often: reactive, self-referencing, single-target, focus on outdoor applications, e.g. “Points of interest”

Terminal-centric approach



Classification Of Location-based Services

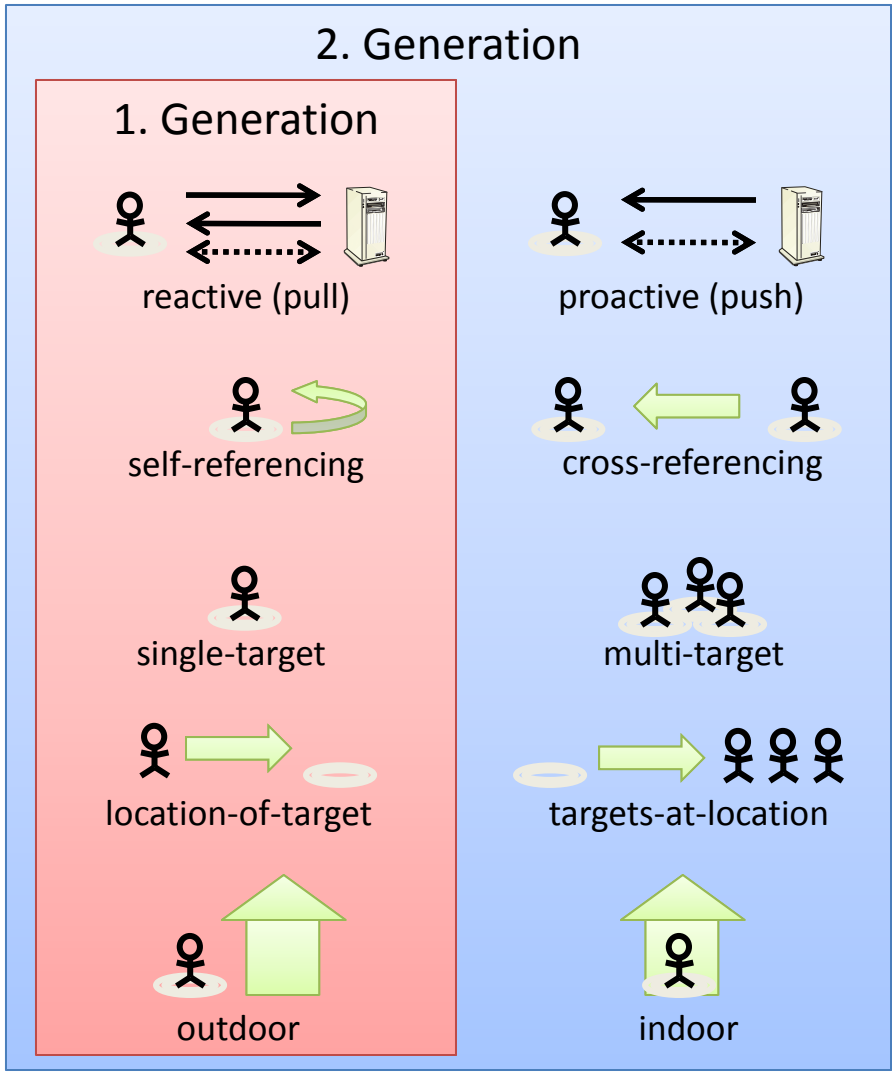
User/service-interaction:

User/target relationship:

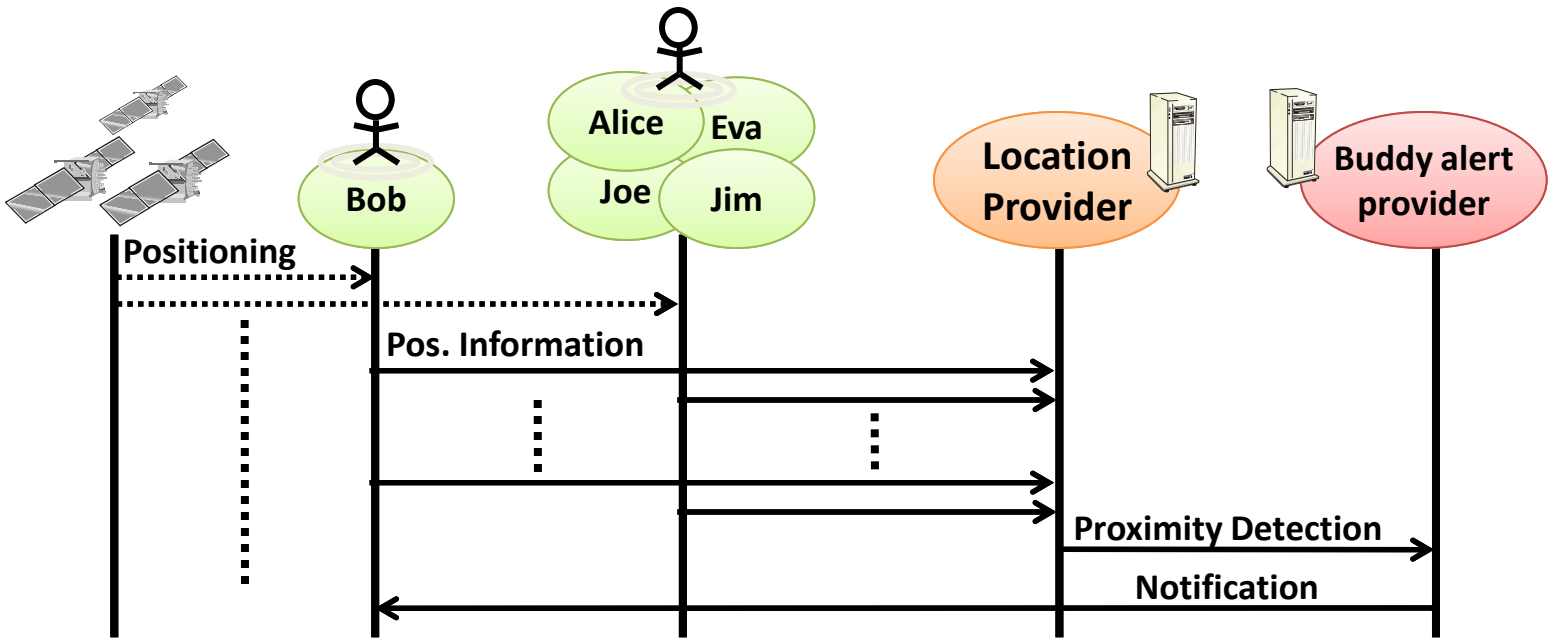
Target/target relationship:

Direction of mapping:

Environment:



Terminal-centric approach



Positioning

- Outdoor: GPS or A-GPS
- Indoor: WLAN-Fingerprinting or Indoor-GPS
- Mainly terminal-based

Target of Positioning

- "Location Sharing" between different persons
- Central or Peer-to-Peer

User/Service-Interaction

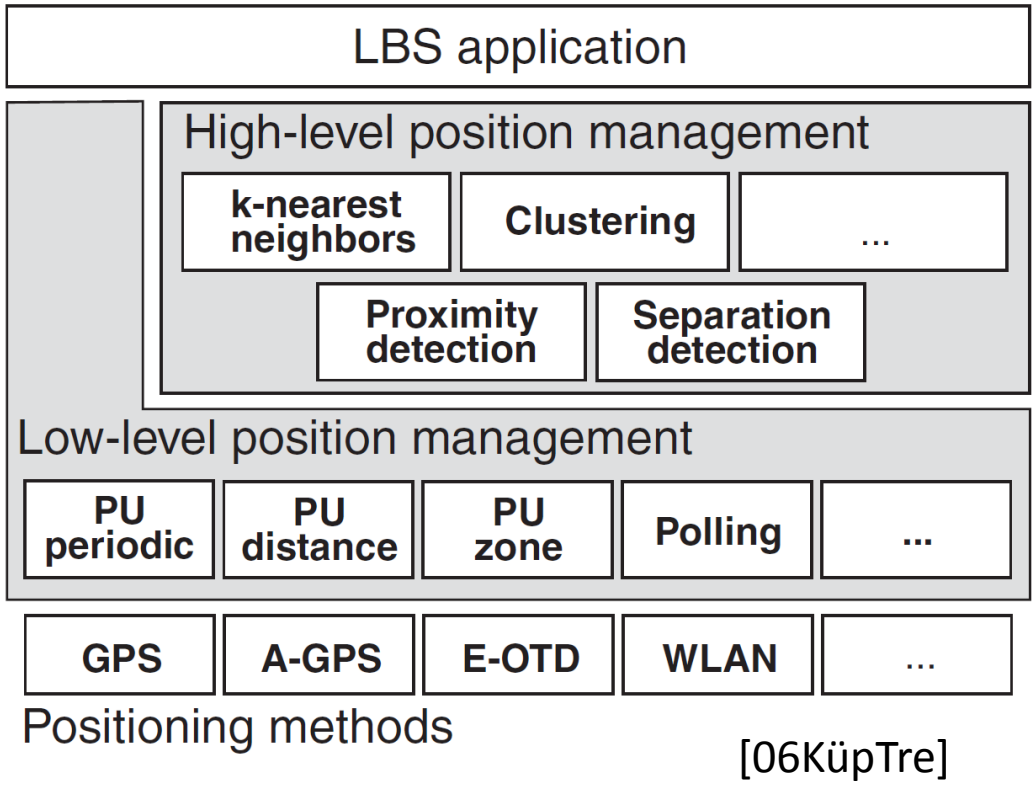
- Proactive und asynchronous (e.g. Actions on entering certain zones)
- Tracking of targets necessary

➔ Terminal-based + Location Sharing + Proactivity

➔ Management of positions necessary

Position Management - Overview

- Location-based services are built upon *low-level* and *high-level* services
- *Low-level* functions are based directly on the positioning layer
- *High-level* functions have access to *low-level* functions. They are strategies to use low-level functions
- The application has access to all levels

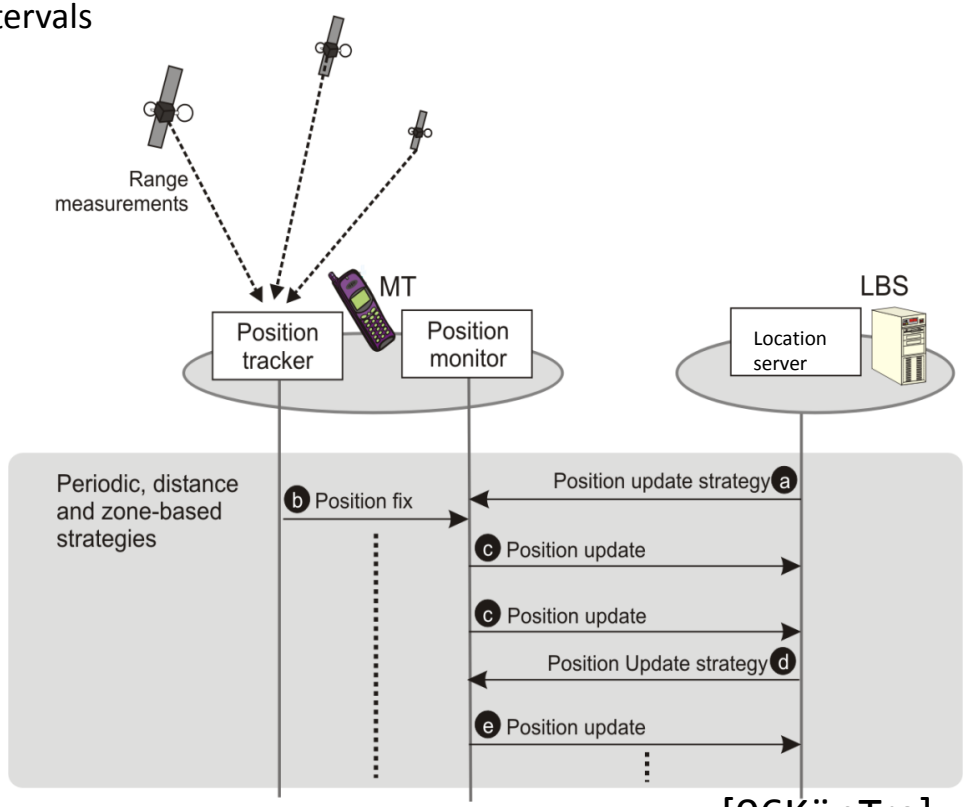


[06KüpTre]

Position Management II

Architecture for Exchanging Position Updates (PUs) measured at a Mobile Terminal (MT)

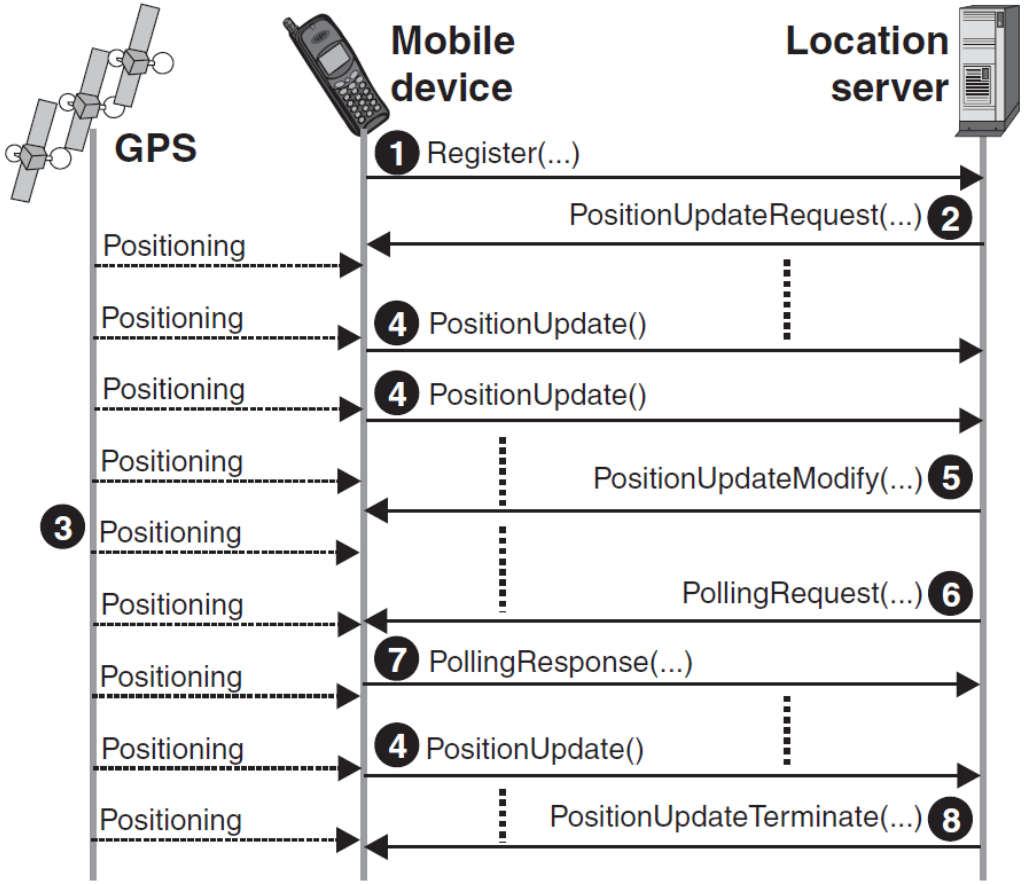
- Position Tracker
  - Terminal-based positioning in short intervals
- Location Server
  - Configuration of the PU-Strategies
  - Polling of Position-information
- Position Monitor
  - Tracking and PUs following
    - … a periodic method
    - ….a distance-based method
    - ….a zone-based method
  - Reply to poll-queries
- Communication over mobile network



[06KüpTre]

Position Management – Example Scenario

- Example represents generation 2 LBS
- The Location server acts as an intermediary between the mobile device and a LBS provider
- Mobile device receives instructions about the low-level position management function to apply
- Strategy is determined by the high-level functions



[06KüpTre]

Position Management – Low-level functions (1)

Low-level functions are strategies to transmit position updates to the location server…

Basic position queries are provide by this layer:

- **Polling:** The location server *polls* the current location from the mobile device. Can be performed periodic, on behalf of the application or on the location server.

- **Periodic position update:** The device triggers the updates after a certain time interval elapsed after the last position update.

- **Distance-based postion update:** The mobile devices sends a position update if it has moved further away than a given threshold.

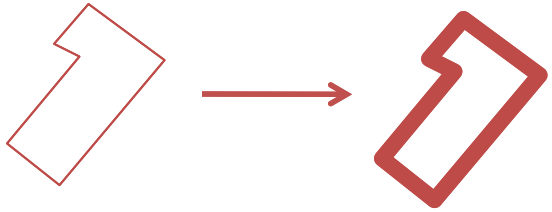
- **Zone-based position update:** Mobile devices sends a position update if it enters or leaves a predefined *update zone* (Polygon, Circle…)

Zone-based Update Jobs

- Objective:
  - Alert user when MTs enter or leave pre-defined zones

- Applications:
  - e.g. child tracking

- Efficiently monitor position on mobile terminal
- Definition of bounding polygon depends on used positioning technology (borderline tolerance)



Position Management – High-level functions

High-level functions are strategies on how to use the low-level functions...

→ Number of required position updates (*low-level* function calls) should be **minimized** (transmission costs energy and bandwidth)

Possible *high-level* functions are:

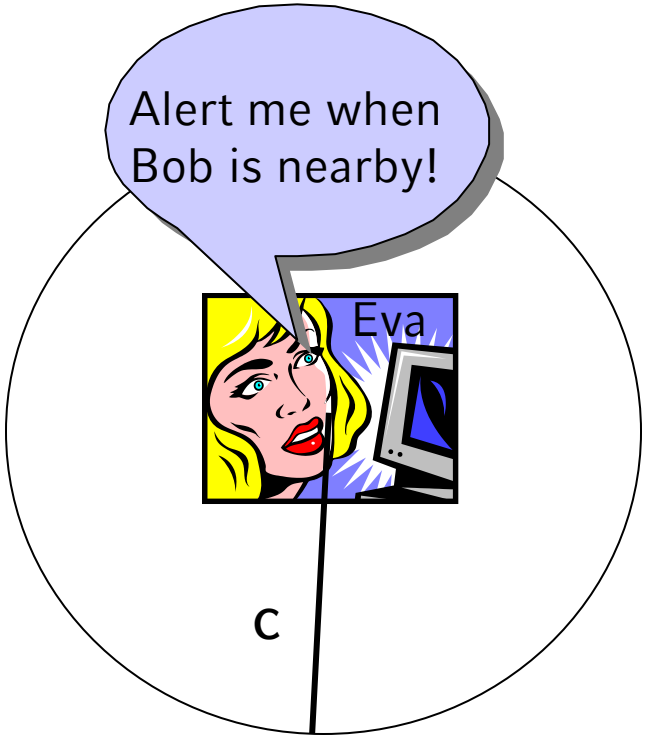
- **Proximity detection:** Detect if a pair of mobile devices in a group approaches each other closer than a predefined *proximity distance.* Thus each mobile devices has a set proximate mobile devices.

- **Separation detection:** Detect automatically if two mobile devices in a given set have a larger distance than a predefined *separation distance*.

- **k-nearest neighbors:** Retrieve the *k* nearest other mobile devices
- **Clustering:** Is there a cluster of k targets within a certain area?

High-level functions – Proximity Detection (1)

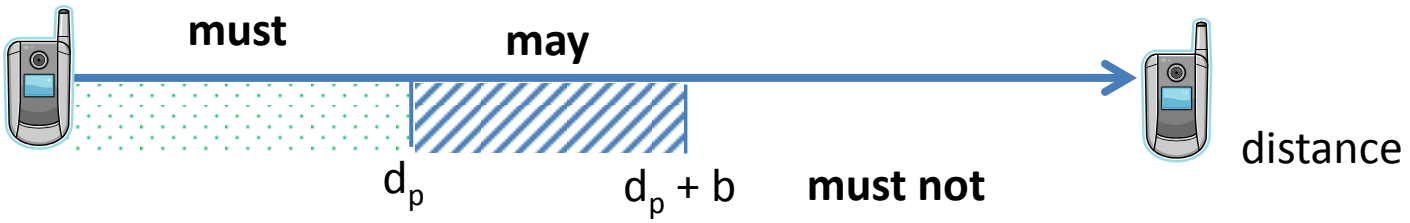
- Objective:
  - Alert user when distance among MTs of targets gets below distance threshold C
- Applications:
  - Buddy Tracking, Mobile Gaming, Dating Services, Fleet Management,…



- How to track Bob and Eva without exchanging to many messages over the air-interface?

High-level functions – Proximity Detection (2)

- Let *dist*(t_i,t_j) denote the geographic distance between t_i and t_j
- Proximity detection is implemented using the predefined constants:
  - Proximity distance d_p: Proximity for devices closer than d_p *must* be detected
  - borderline distance b: Proximity for devices closer than d_p+b *may* be detected



- Requirements for proximity detection:
  - If *dist*(t_i,t_j) < d_p: Proximity **must** be detected
  - If $d_p \leq$ *dist*(t_i,t_j) $\leq d_p$ + b: Proximity **may** be detected
  - If d_p + b < *dist*(t_i,t_j): Proximity **must not** be detected

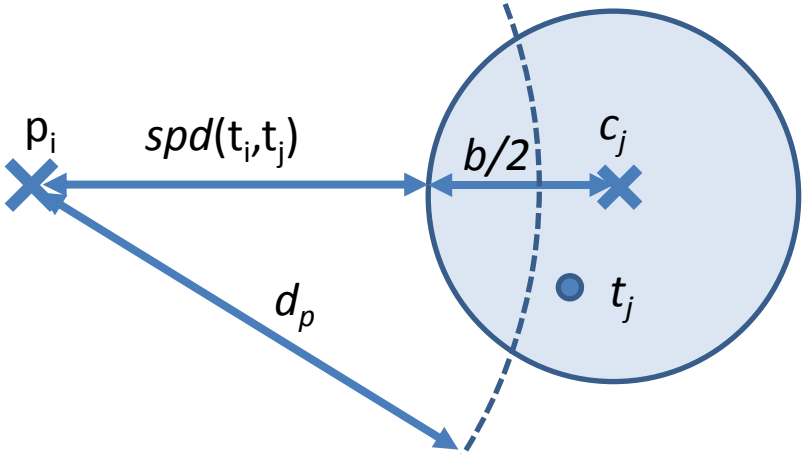
High-level functions – Proximity Detection (3)

Proximitiy Detection with the **Static Circles Strategy**:

- The location server stores the last position fix c_i for each device i
- For each c_i a circle with radius b/2 is defined
- The mobile devices performs a **zone-based position update** if it leaves this circle
- *spd*(t_i, t_n) = *dist*(t_i,t_j) – r_i – r_j: smallest possible distance
- Non-proximate devices for a given device i are stored in the set $T_{p,i}$
- Algorithm if a mobile device t_i provides a fresh position fix p_i:

```
for n in T_p,i:
        if spd(t_i, t_n) < d_p then
                p_n ← PositionUpdateRequest(n)
                        if dist(p_i,p_n) < d_p then
                                raise proximity_alert
                                T_p,i ← T_p,i – n
        else
                continue
```

High-level functions – Proximity Detection (4)



- The smallest possible distance would suffice for a classification as proximate devices…
- … but after the position update from p_j we know they are not close enough
- **Question:** Which size should the new detection circle have?

- **Disadvantage:** Very distant devices perform a zone-based position update if they leave their circle
- **Possible Optimization:** Choose circles with a radius that corresponds to

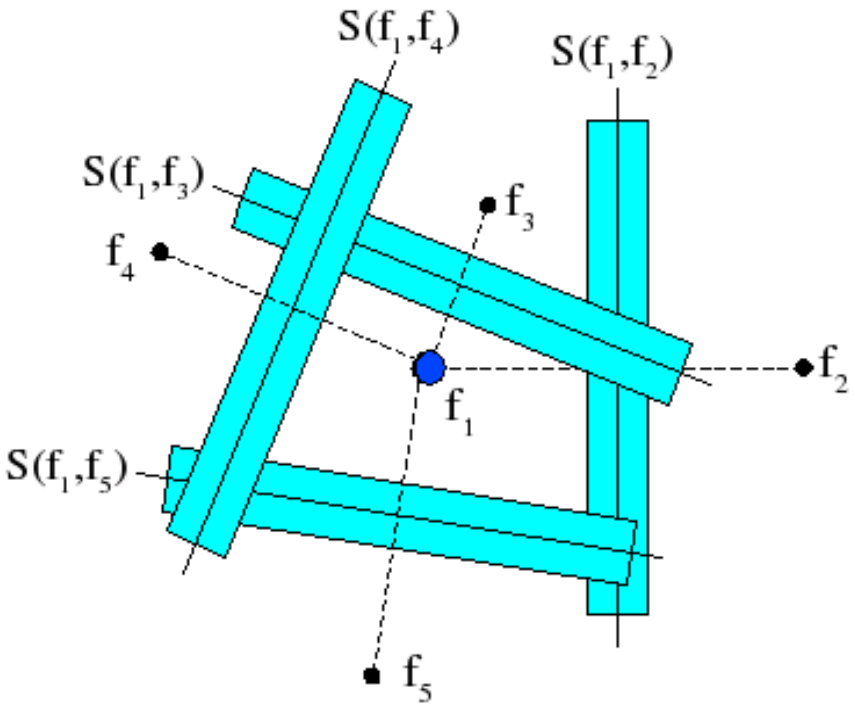
  $spd(t_i, t_n) - d_p = r_i$ (Assumes that $d_p < spd(t_i, t_n)$)

  ➔Both circles are separated by a distance of d_p which guarantees that proximity is detected!

High-level functions – Proximity Detection (5)

Proximitiy Detection with the **Stripes Strategy (zone based updating)**:

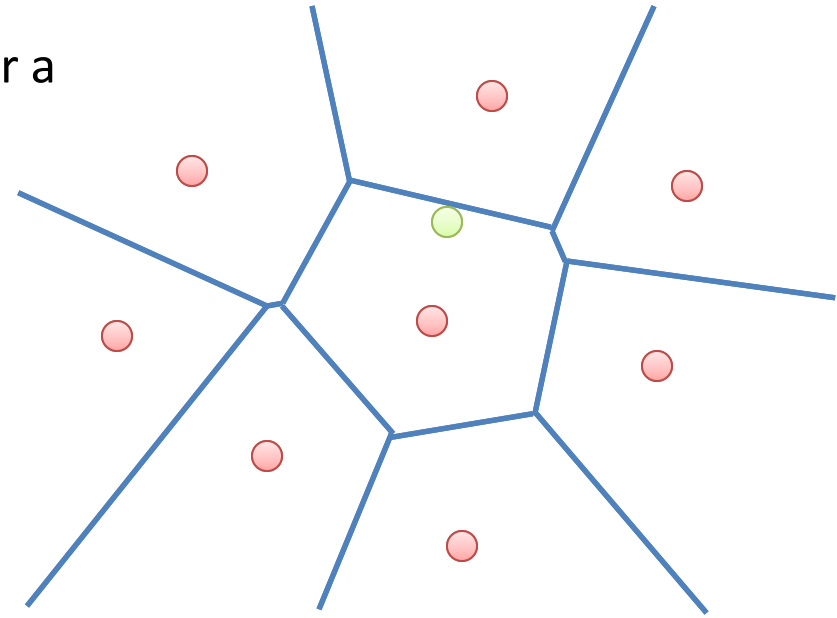
- Establish a stripe of infinite length between two targets
- Width corresponds to the proximity distance threshold d_p
- If one target crosses the stripe a PU is performed by both targets
- Number of globally needed stripes is n*(n-1)/2
- Could lead to a scalability problem



Amir et al 2004

High-level functions – Proactive k-Nearest-Neighbors

- Objective:
  - Efficiently find k nearest neighbors for a given MT



- Simple approach:
  - Continuous position updates
  - Calculate distance between point i and all other points j (j != i)

- Better approach:
  - Use voronoi diagrams
  - Send position update only when entering / leaving a voronoi cell

- For k > 1: Higher order voronoi diagrams

Challenges for future LBS

- Positioning
  - Higher availability of positioning services
  - Standardized technologies for indoor positioning
  - Positioning handover
- LBS Middleware
  - Low level position management: exchange of position data between GPS device and server
  - High level position management: correlation of position data of several targets
- Privacy protection
  - Anonymization
  - Privacy policies
  - Mechanisms for reducing peer-group pressure

References

This slides are based on the following publications:

- [05Küp] – Axel Küpper: **Location-based Services - Fundamentals and Operation**
- [06KüpTre] - Axel Küpper Georg Treu: **Efficient Proximity and Separation Detection among Mobile Targets for Supporting Location based Community Services**
- [06KüpTreLin] - *Axel Küpper, Georg Treu, and Claudia Linnhoff-Popien:* **TraX: A Device-Centric Middleware Framework for Location-Based Services**
- [08BelKüpHel] - Paolo Bellavista, Axel Küpper, and Sumi Helal: **Location-Based Services: Back to the Future**
- [08TreKüpNeu] - Georg Treu, Axel Küpper, Oliver Neukum, and Claudia Linnhoff-Popien: **Efficient Clique Detection among Mobile Targets**