Localization of mobile devices

Seminar: Mobile Computing

IFW C42

Tuesday, 29th May 2001

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Overview

- Introduction
  - Why
- Technologies
  - Absolute Positioning
  - Relative Positioning
- Selected Systems
  - GPS
  - Positioning in GSM
  - Active Badges
  - Cricket
- Location Models
- Discussion

Why do we need location information?

- Navigation
- Locate resources in the neighborhood
- Stratagies: Logistic

- Additional ideas ?

Location „Technologies“

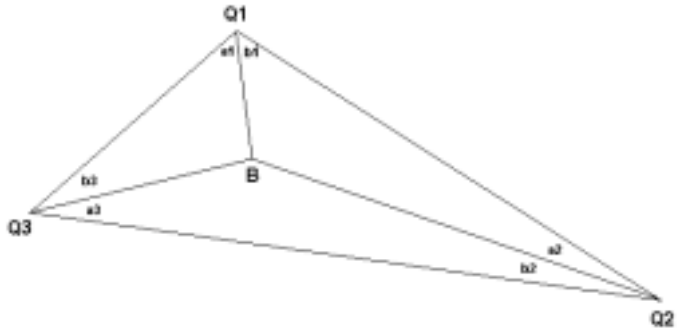
- Tagged
  - locate a marker
- Untagged
  - vision

- Positioning
- Containment
  - check if inside

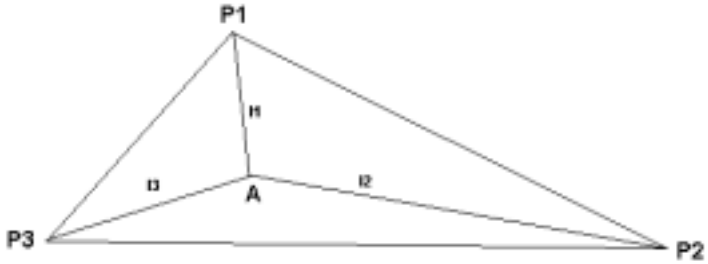
- Absolute Positioning
- Relative Positioning
  - measure movement of object

- Self–positioning
- Remote positioning

Absolute Positioning: Geometry



- Triangulation
  - by measuring the bearings of an object from fixed points

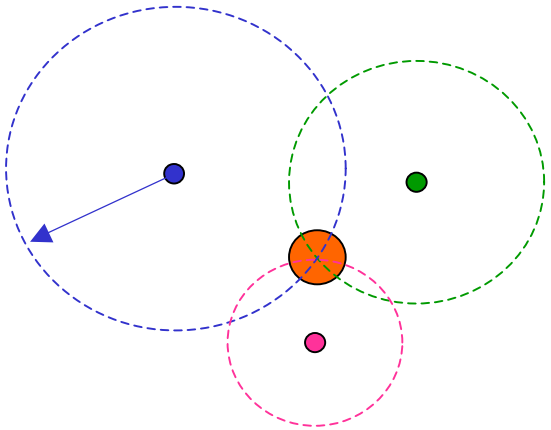


- Trilateration
  - by measuring the distance

- Error
  - Dilution of precision (DOP)
    Position error = DOP * input error

Time of Arrival (TOA)

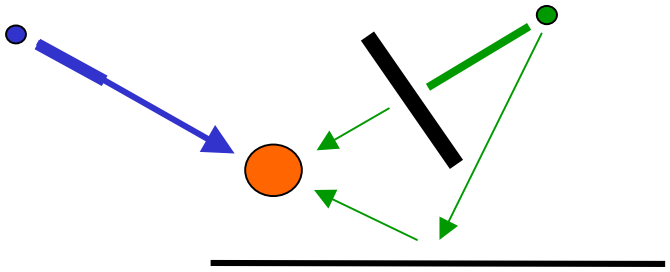
- Propagation time
- Delay between sender and receiver
- one-way time
  - synchronization
    - accurate clocks
    - synchronization with 2 signals having different velocity
    - additional reference
- round-trip time
  - no synchronization



- GPS
- Radar

Signal Strength

- Measuring distance
- Map of signal distribution
  - Calculated
  - Model
- Errors
  - Obstacle
  - Multipath



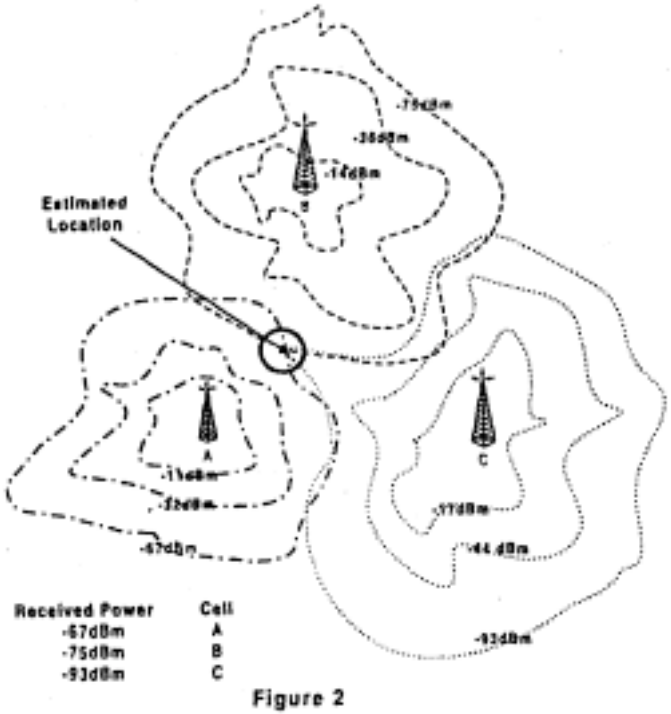
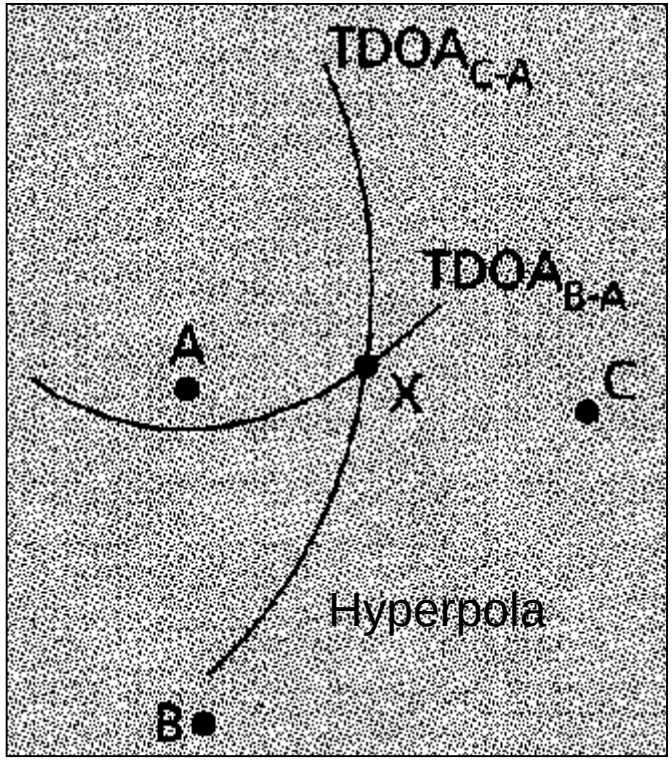


Figure 2

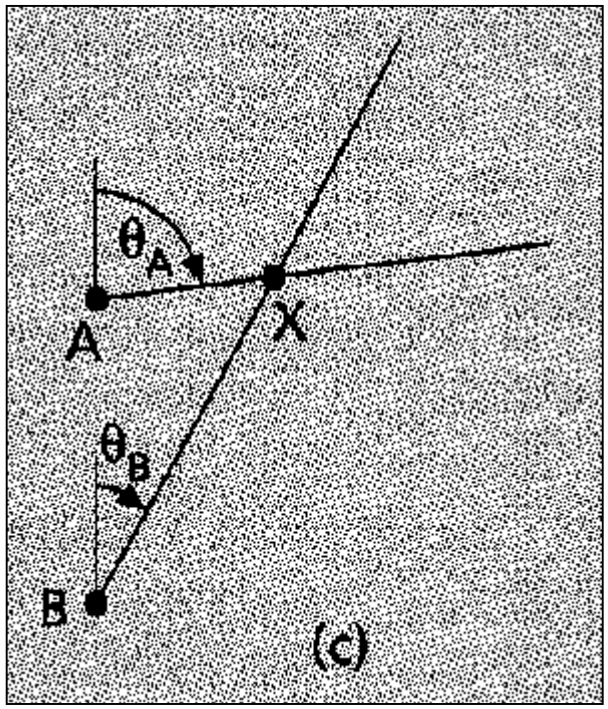
- GSM

Time Difference of Arrival (TDOA)

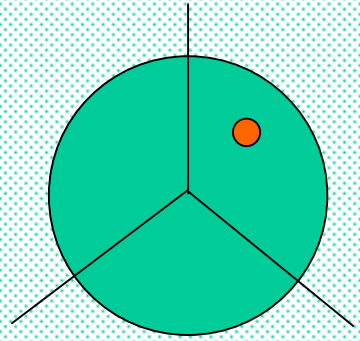


- Synchronization between 2 reference stations required
- In 2D: at least 2 hyperbolas required

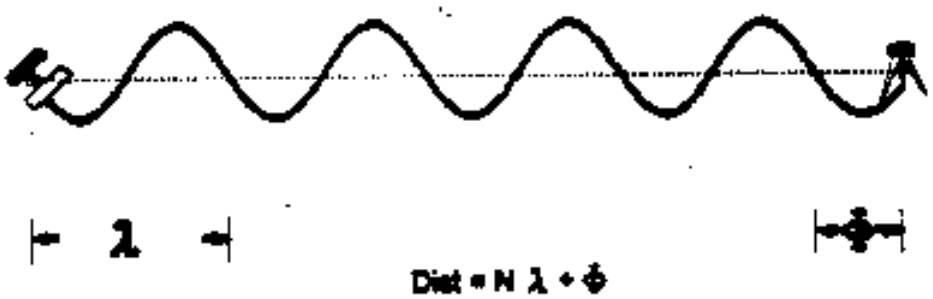
Angle of Arrival (AOA)



- Radar
- VOR
  (VHF Omnidirectional Range)
  used in aviation
- GSM Sector



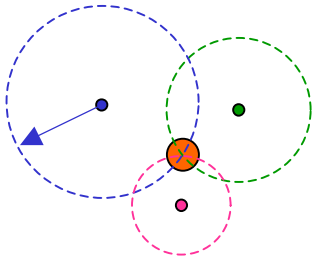
Carrier Phase



- Used for accurate positioning in GPS
- Impossible to measure the number of cycles directly
- Need to maintain a continious lock on the carrier signal

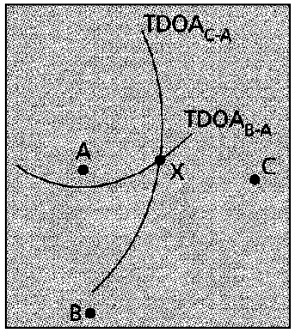
Absolute Positioning Methods

TOA - time of arrival

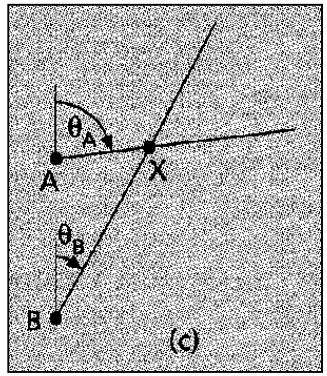


TDOA

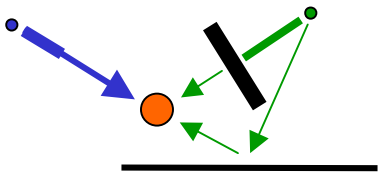
time difference of arrival



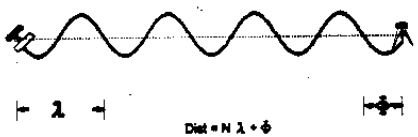
AOA - angle of arrival



Signal strength



Carrier Phase



Relative Positioning

Distance

- Distance itself (weehlsensor)
- Velocity
- Acceleration

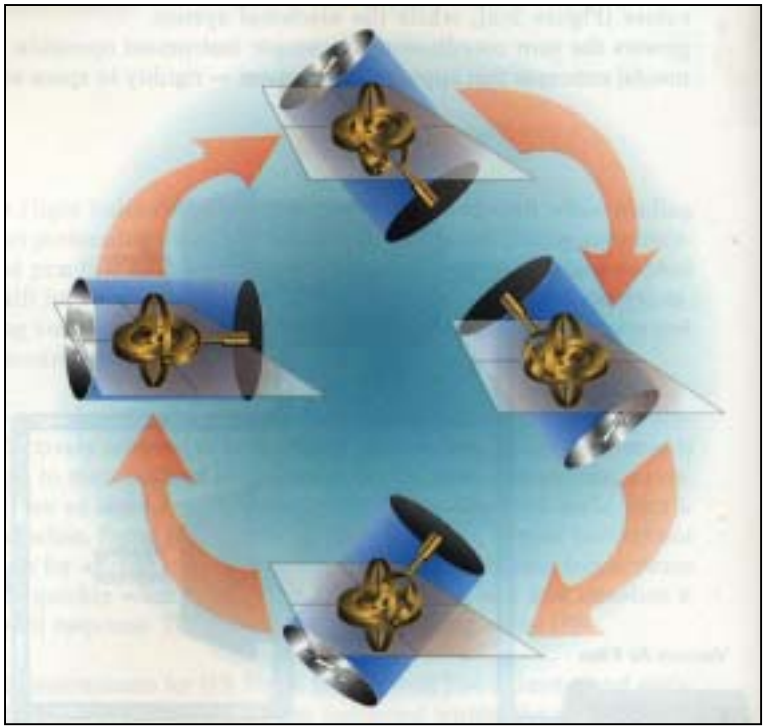
$$x = \iint a(t)\,dtdt$$

- Height (Barometer)

- Inertial Navigation System (INS) used in aviation
- Car navigation

Orientation in space

- Gyroscope (rigid in space)



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  - Positioning in GSM
  - Active Badges
  - Cricket
- Location Models
- Discussion

Timeline of electronic location systems

- 1935 : Radar
- WW2: LORAN-A [TOA]
- 1950 : LORAN-C [TDOA]

LORAN-C

- 1970 : First satellite system
- 1990 : Active Badge - indoor location
- 1994 : GPS
- 1996 : GSM
- Positioning with Ultrasonic, RFID, etc.

GPS

- Tagged
  - locate a marker
- Untagged
  - vision

- Positioning
- Containment
  - check if inside

- Absolute Positioning
- Relative Positioning
  - measure movement of object

- Self–positioning
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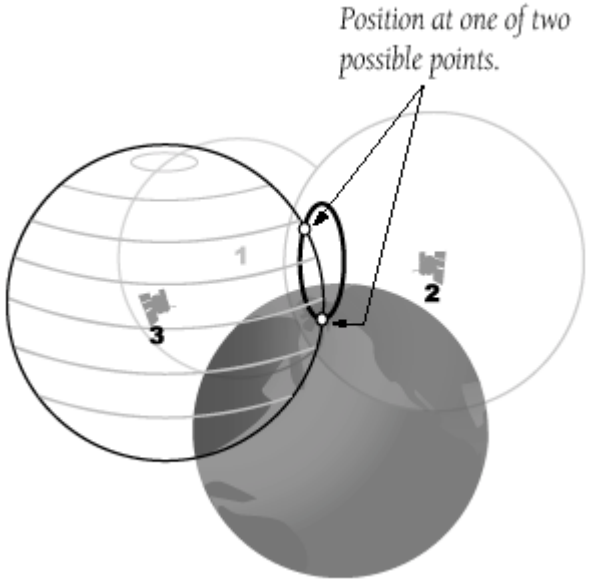
GPS

- Who & When: U.S. Department of Defense
  1973 start, 1978-1994 test, assembly - 13 Mrd $
- 24 satelliten in 6 orbital planes, 20‘200 km, 12h period
- Transmitting with CDMA (code devision multiple access)
  - 1575.42 MHz civil
  - 1227.60 MHz military
  - 50 Watt

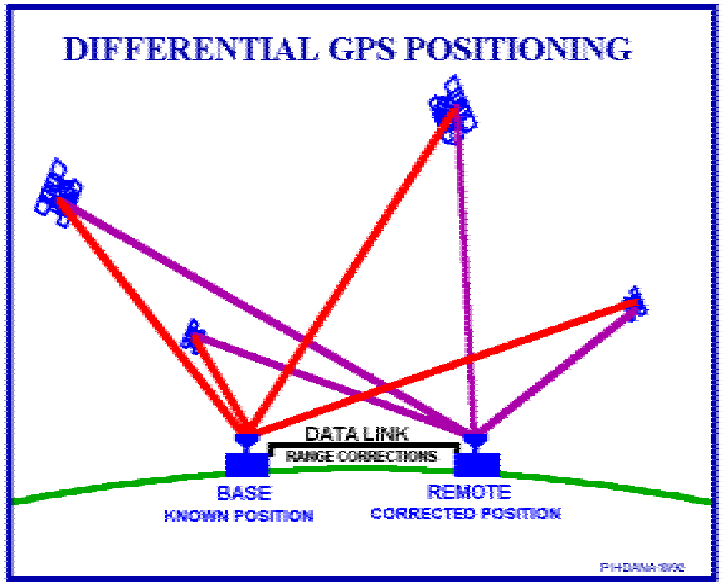
GPS

- Position calculation:
  - Trilateration (distance measuring)
  - In 3D with at least 4 satellites
  - Almanac & ephemeris data



GPS

- Accuracy: since May 2000 ~15m
- Errors:
  - Visibility
  - DOP - geometry
  - Ionosphere + Troposphere
  - Multipath
  - Receiver clock errors
  - Orbital errors
  - Intentional degradation
- Optimization:
  - DGPS (Differential)
  - Carrier phase
- Russian version: GLONASS



GPS

Simulation

Postioning with GSM

- Tagged
  - locate a marker
- Untagged
  - vision

- Positioning
- Containment
  - check if inside

- Absolute Positioning
- Relative Positioning
  - measure movement of object

- Self–positioning
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Positioning GSM Telephones

- Reason
  - Location-Sensitive Billing (e.g. Genion)
  - Increased Safety (E911)
  - Location-Dependent Content (e.g. Swisscom)
  - Enhanced Network Performance
- Positioning using GSM features
  - Time of Arrival (TOA)
  - Time distance of Arrival (TDOA)
  - AOA (Angel of Arrival)
  - Signal power

Positioning GSM Telephones

- Who & When: UT Sidney, 1998
- TOA (Time of Arrival)
  - GSM uses *timing advance* due to time multiplexing [554m]
  - Problem:
    - network synchronization
    - multipath is not rejected but combined
    - DOP
- TDOA (Time Difference of Arrival)
  - for improving handovers: *observed time differences* [554m]
  - same Problems
- AOA (Angel of Arrival)
  - use sector information
- Accuracy: 150m

Positioning in GSM using WAP

- Who & When: Chinese Uni. of Hong Kong, 2000
- Cell shape based mobile positioning
  - measure signal power
  - compare with cell shape database
- Accuracy: 300m

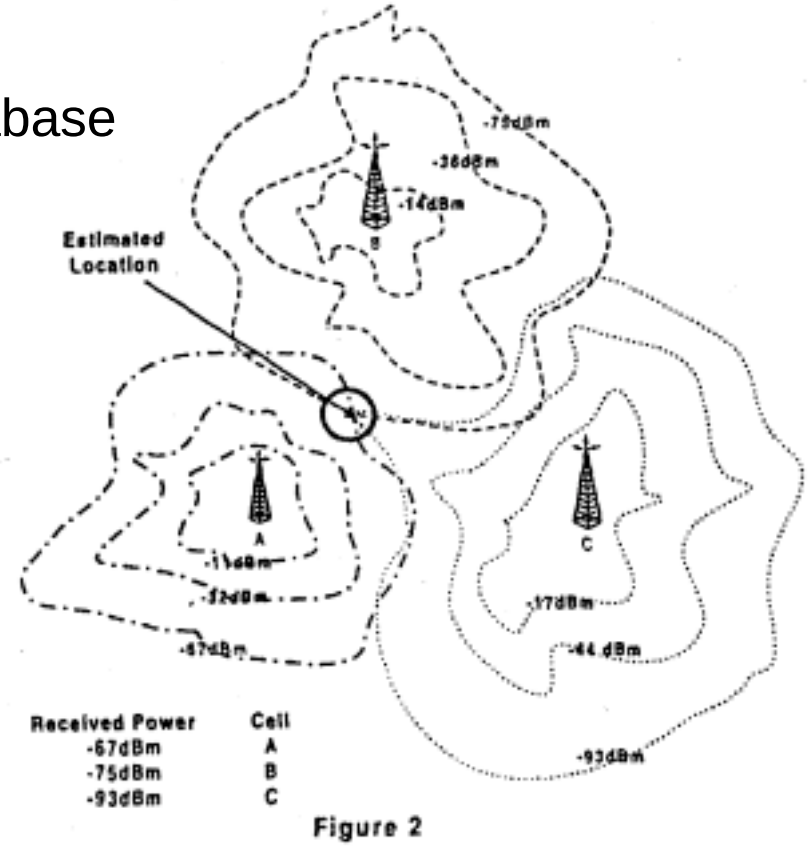

Figure 2

Active Badges

- Tagged
  - locate a marker
- Untagged
  - vision

- Positioning
- Containment
  - check if inside

- Absolute Positioning
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  - measure movement of object

- Self–positioning
- Remote positioning

Active Badge Location System

- Who & When: Olivetti Research (AT&T), 1990
- Containment based, in-building system
- Active Badge
  - emits unique code every ~15s via IR
  - battery life: 1 year
- Network of sensors, centralized
- The Application
  - location information with probability
  - find(name), with(name), look(location), notify/setalarm(name), history(name)
- Privacy ?

Cricket

- Tagged
  - locate a marker
- Untagged
  - vision

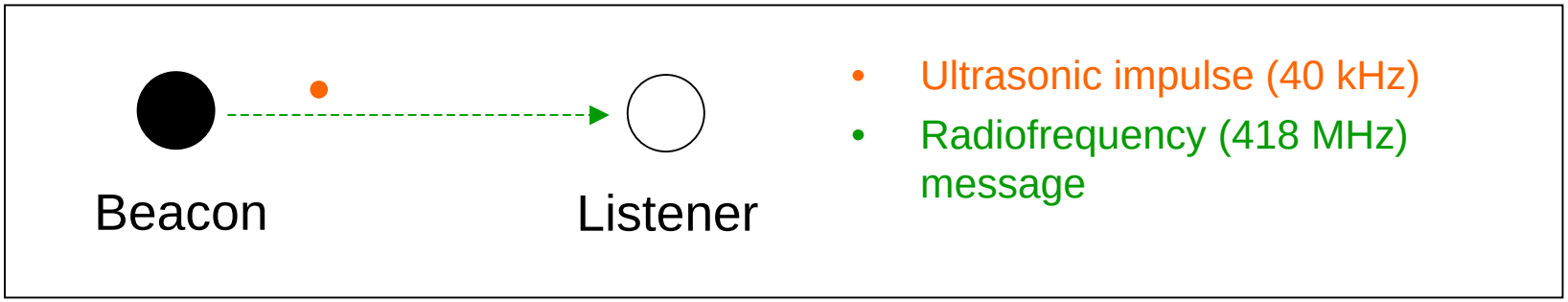
- Positioning
- Containment
  - check if inside

- Absolute Positioning
- Relative Positioning
  - measure movement of object

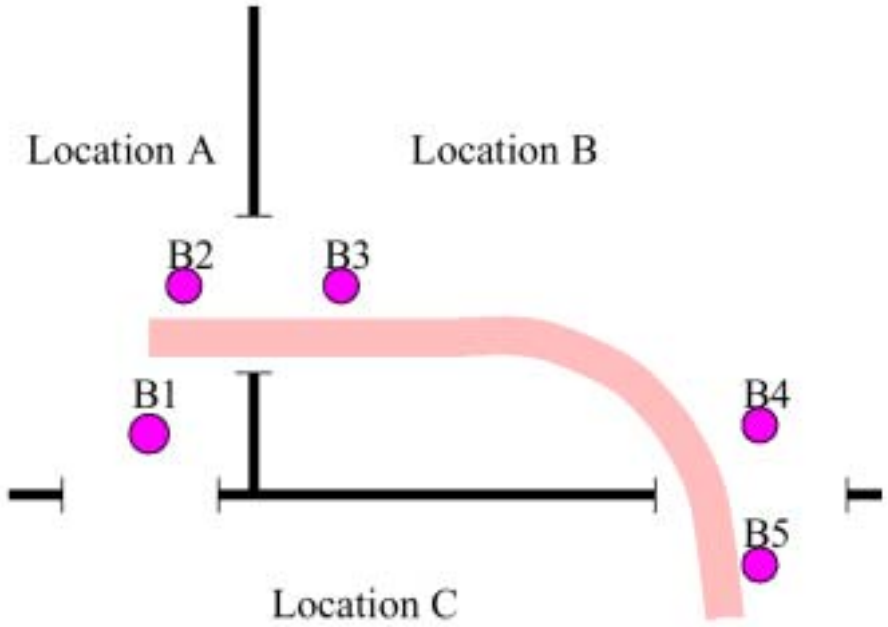
- Self–positioning
- Remote positioning

Cricket Location-Support System

- Who & When: MIT, 2000
- Containment based, in-building system
- Beacon
  - sends name of space
  - randomized transmission times in a given intervall
- Listener
  - calculates nearest beacon
- smallest space: ~1.2 m^2 , precision: ~30 cm

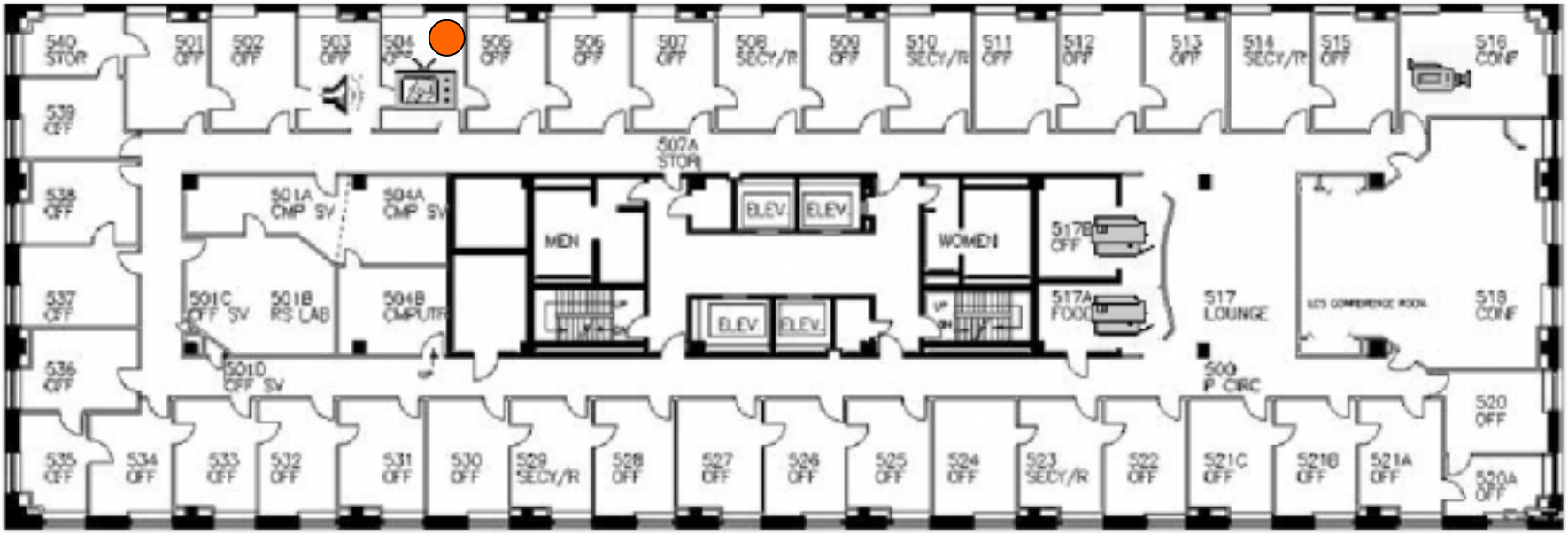


Cricket Location-Support System



- decentralized
- keeps user privacy, no tracking
- low cost, „off the shelf“ hardware
- scalable

Cricket Location-Support System



Location Space Models

- Geometric: n-dim. Coordinate system
  - WGS84:(09.53 E, 46.32 N, 0)
- Symbolic: set of symbols (names) with relationship
  - CH/Zurich/ETH/IFW/C42
- Combined