Device Location and Location Based Services

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DaimlerChrysler, Telematics Research

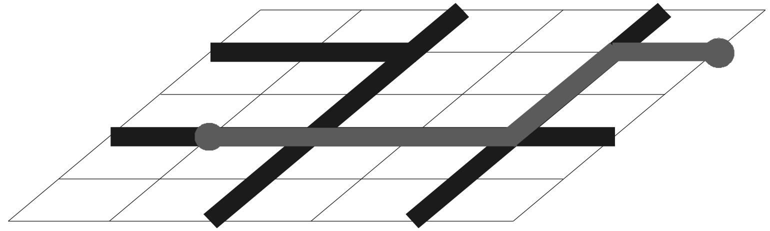
KuVS Summer School “Mobile Computing”, **18.06.2002**

Overview

- Concepts of Location-aware Systems
- Positioning
  - Out-door
  - In-door
- Location-aware Applications
  - Example: Guide

Routing & Navigation: Stationary Destinations

Navigation System



Example: vehicle navigation system

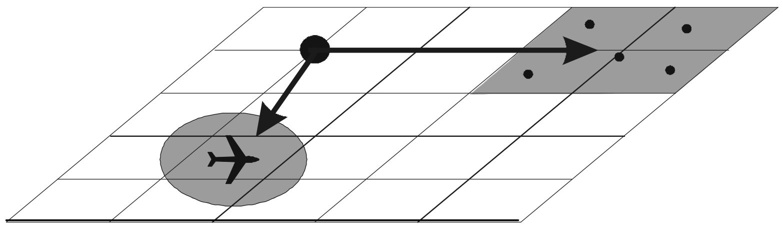
- Model: street map
- Model information replicated in every vehicle
- In future: dynamic download of model information (Hoarding, Infostations)

Only local position information

Routing and Navigation: Mobile Destinations

Example 1: **GeoCast**
(Dataman Rutgers University, Navas97)

- Sending a message to all receivers inside a geographical area
- Area can be stationary or be defined through a mobile object



Example 2: Office application with Active Badges
(AT&T Labs Cambridge, Want92)

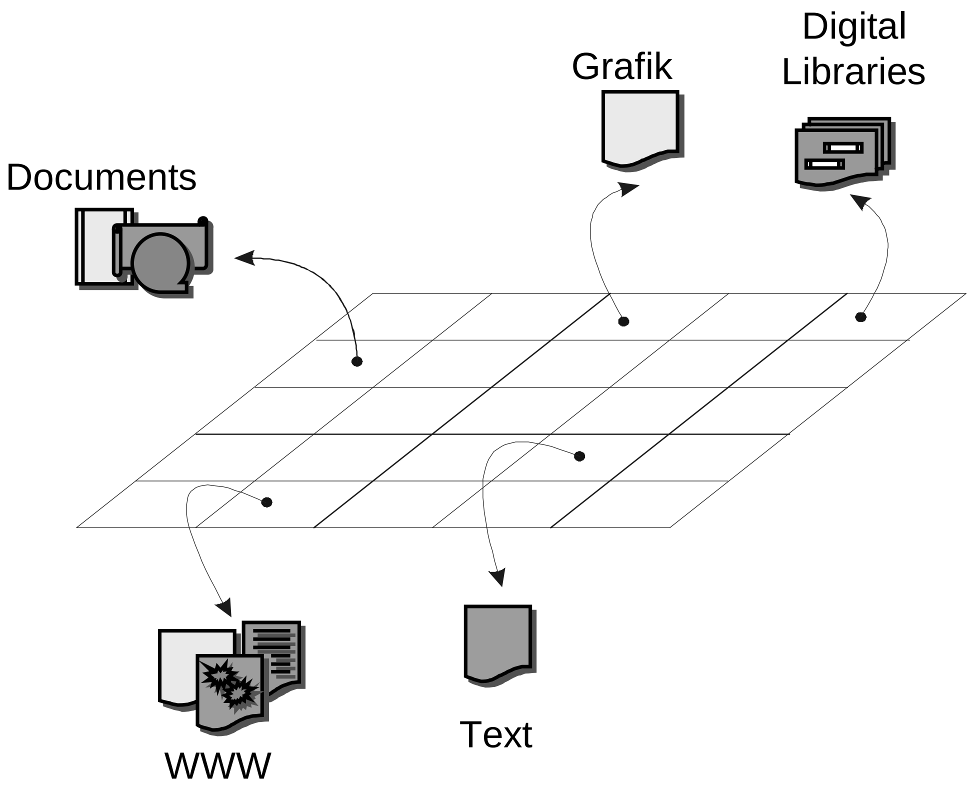
- Routing telephone calls to a user`s current position

Example 3: Location Aided Routing (LAR) in Mobile Ad-hoc Networks

Position information logically centralized

„Situated Information Spaces“

- **Linking physical objects with information or services**
- Using physical objects as a „hint“ to information or services
- Spatial-aware information access
- Spatial queries
- *Metaphors*:
  - Virtual Post-It
  - Virtual Information Towers



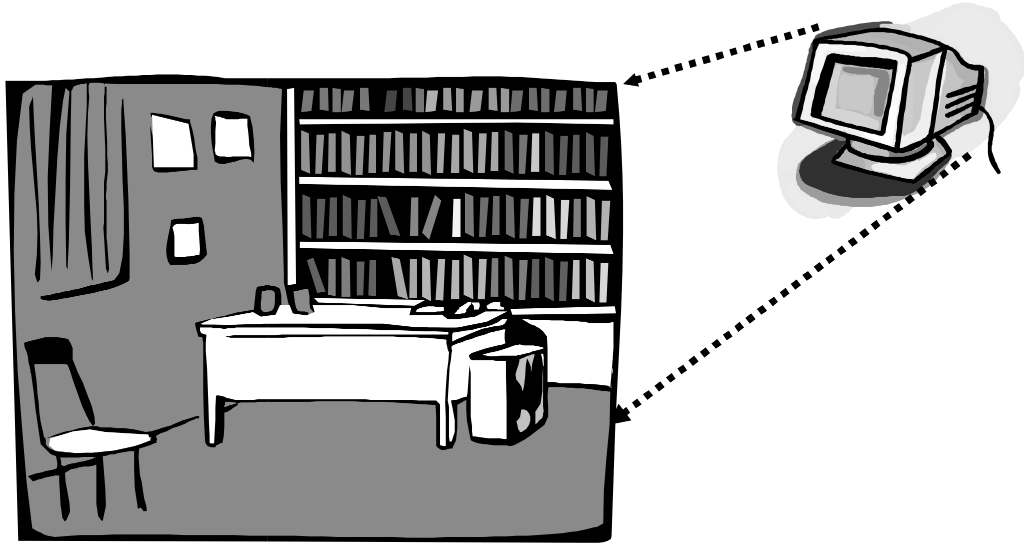
- Example: Location Based Services in Mobile Communication Networks

"Sentient Computing"

„Programming with space“ - interaction with the computer beyond the desktop metaphor

Examples:

- Room reacts to entering user (light, air condition)
- User takes up book or folder from shelf and gets further information (e.g., library information, status)



- ➢ System has to know situation of user and environment
- ➢ Suitable sensor technology required

Using Location Information

- Location as filter
  - Interaction: User-driven
  - Nearest restaurant, cinema, etc.
  - Special offers in walking distance
  - Available parking spaces

- Location as trigger
  - Interaction: System-driven
  - Location based push advertisement
  - Pro active traffic jam warning

- Location as information
  - Interaction: Mainly user-driven
  - Find a friend
  - Fleet tracking

Parameters of a location-aware system

- Scale
  - Number of user‘s
  - Size of service area
- Accuracy
  - Of positioning information
  - Of environmental data (3D model)
- Desired applications
  - Is Alexander currently in the office?
  - Who has painted the picture I am looking at?

⇒ Centralized or distributed system
⇒ Type of positioning system

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  - Out-door
  - In-door
- Location-aware Applications
  - Examples: Guide, Nexus
- (Location Management)

Positioning Systems

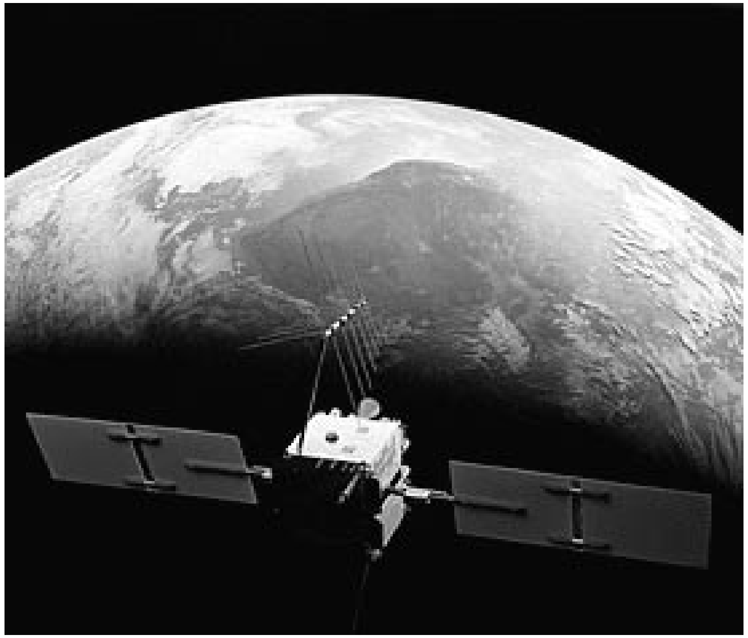
- Out-door
  - Global Positioning System: GPS/DPGS
  - Mobile Communication Networks: A-GPS, EODT
- In-door
  - Infrared-based
  - Ultrasound-based
  - Radio-based (using an existing WLAN)

GPS - Global Positioning System

- Goal: Easy, accurate positioning almost anywhere on Earth
  - $\Rightarrow$ Satellite-based system

- Consists of 3 segments
  - Space segment
  - Control segment
  - User segment

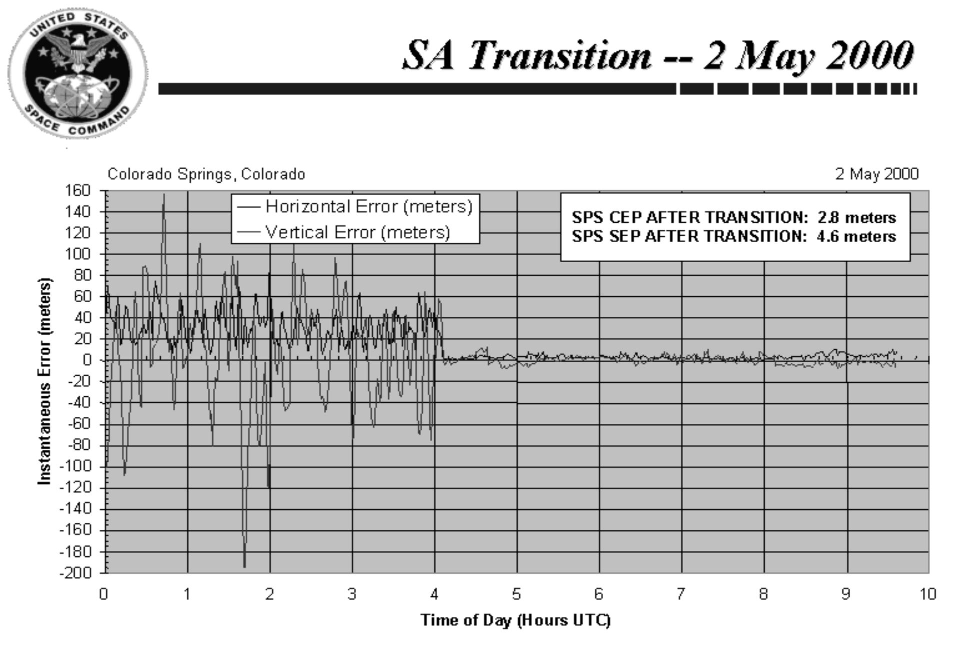
- Financed by American military
- More and more civilian use



GPS: Accuracy (1)

- Civilian use (artifically limited through „Selective Availability“ SA)
  - 100 m horizontal accuracy
  - 156 m vertical accuracy
  - 340 ns temporal accuracy

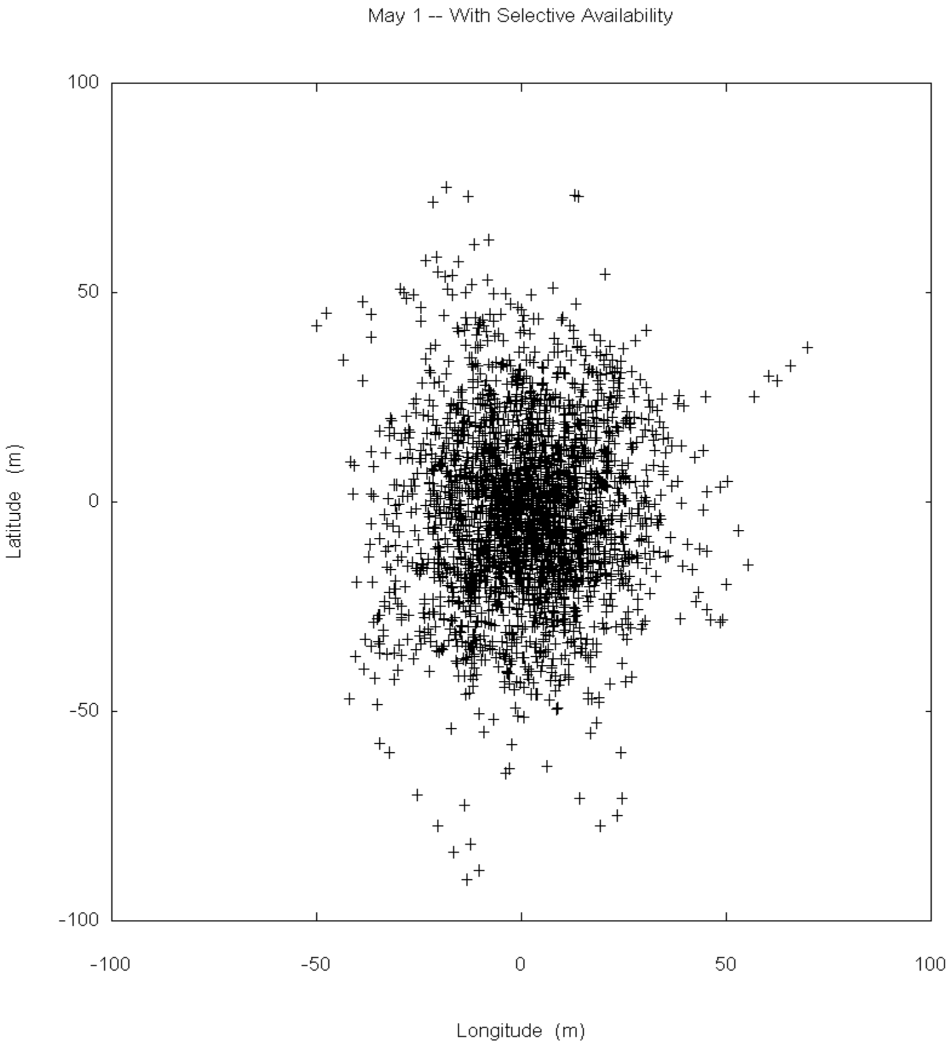
- Military use
  - 22 m horizontal accuracy
  - 27,7 m vertical accuracy
  - 200 ns temporal accuracy

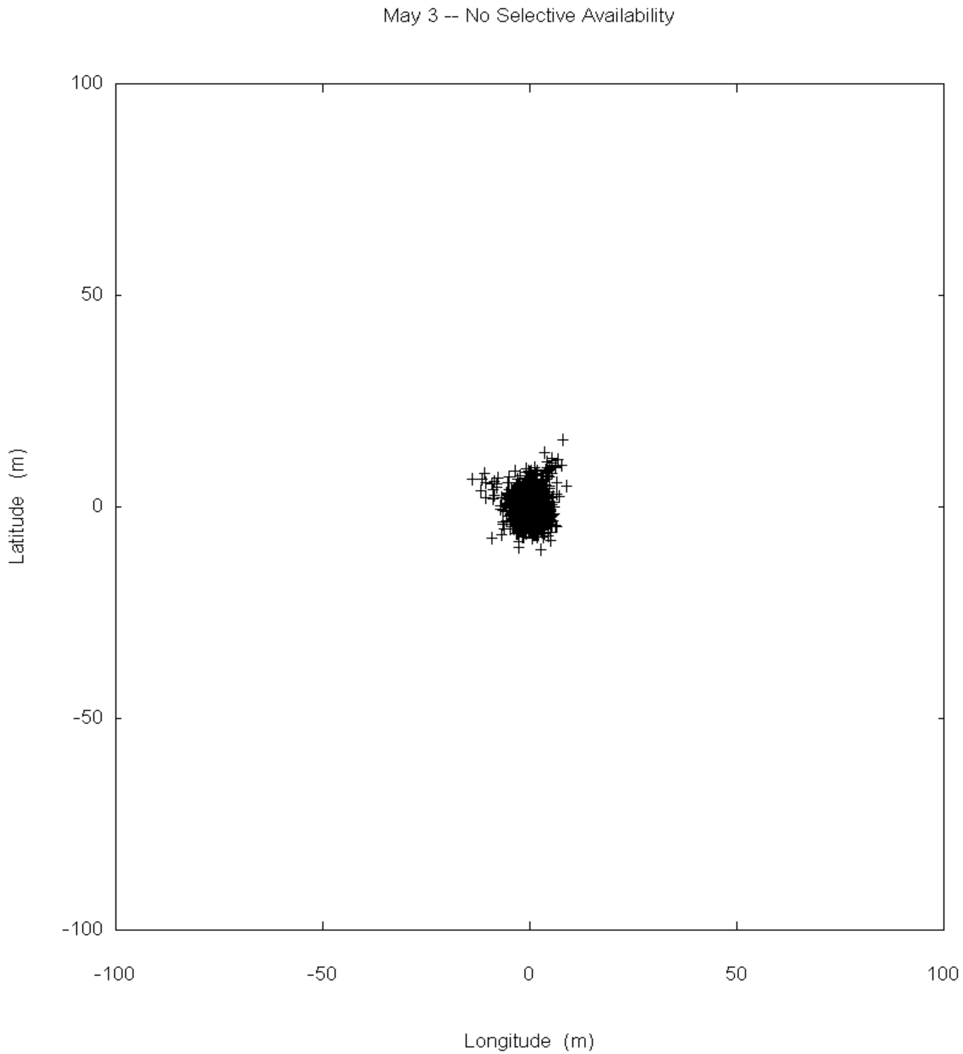


Since May 2nd, 2000 „Selective Availability“ has been shut off

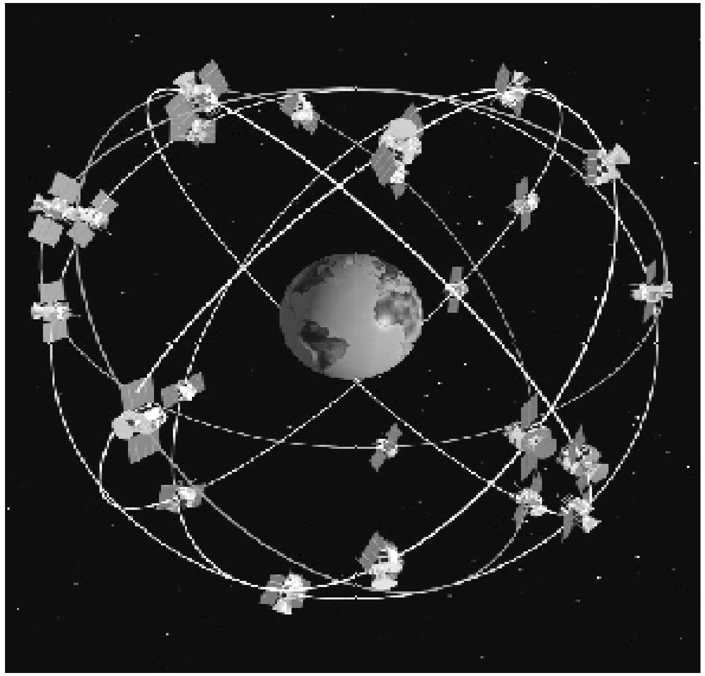
$\Rightarrow$ Military accuracy is globally available

GPS: Accuracy (2)

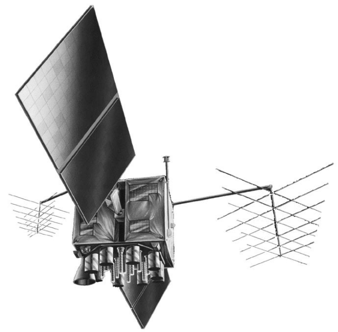




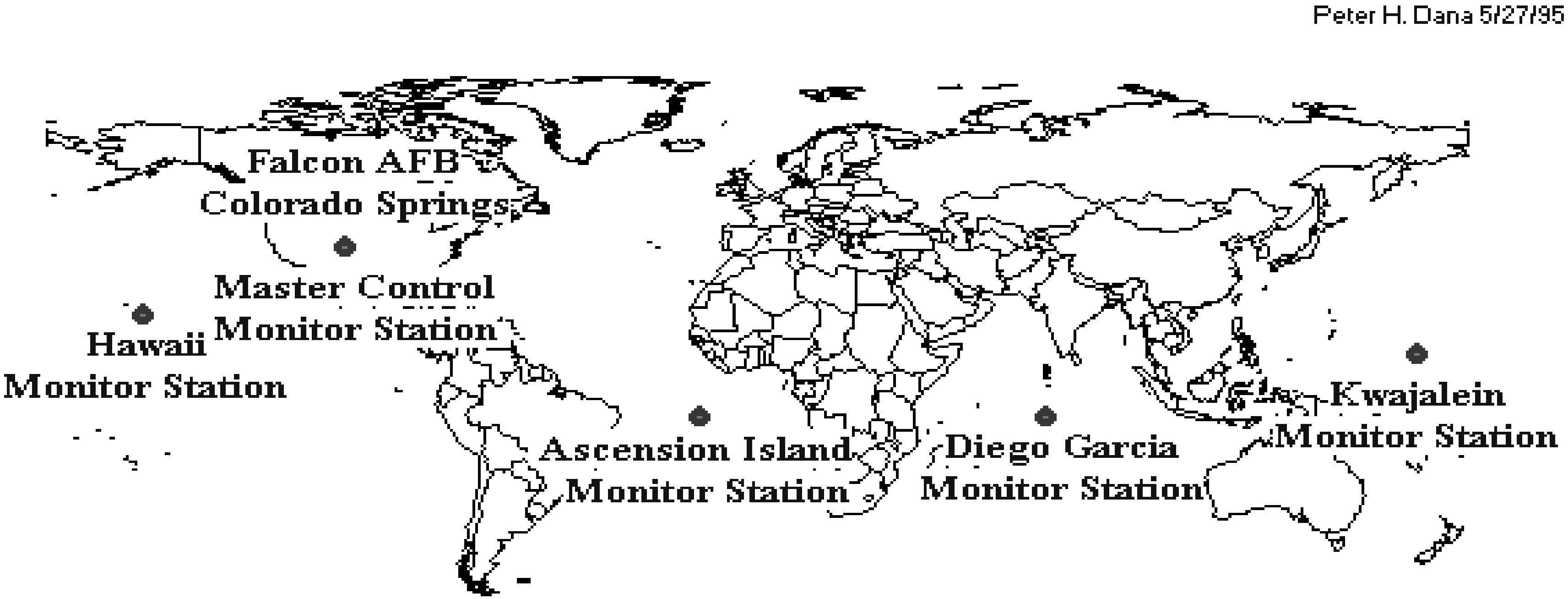
GPS: Space segment



- 24 satellites
- Almost circular orbit in a height of about 20200 km
- At least 4 satellites (a maximum of 8) are simultaneously visible with a view angle of ~ 15°
- Holes in coverage at the poles
- Time of orbit: about 12 hour
- Satellites broadcast information:
  - Identification
  - Position (every 30 seconds)
  - Almanach-information of all satellites (every 12.5 minutes)



GPS: Control Segment



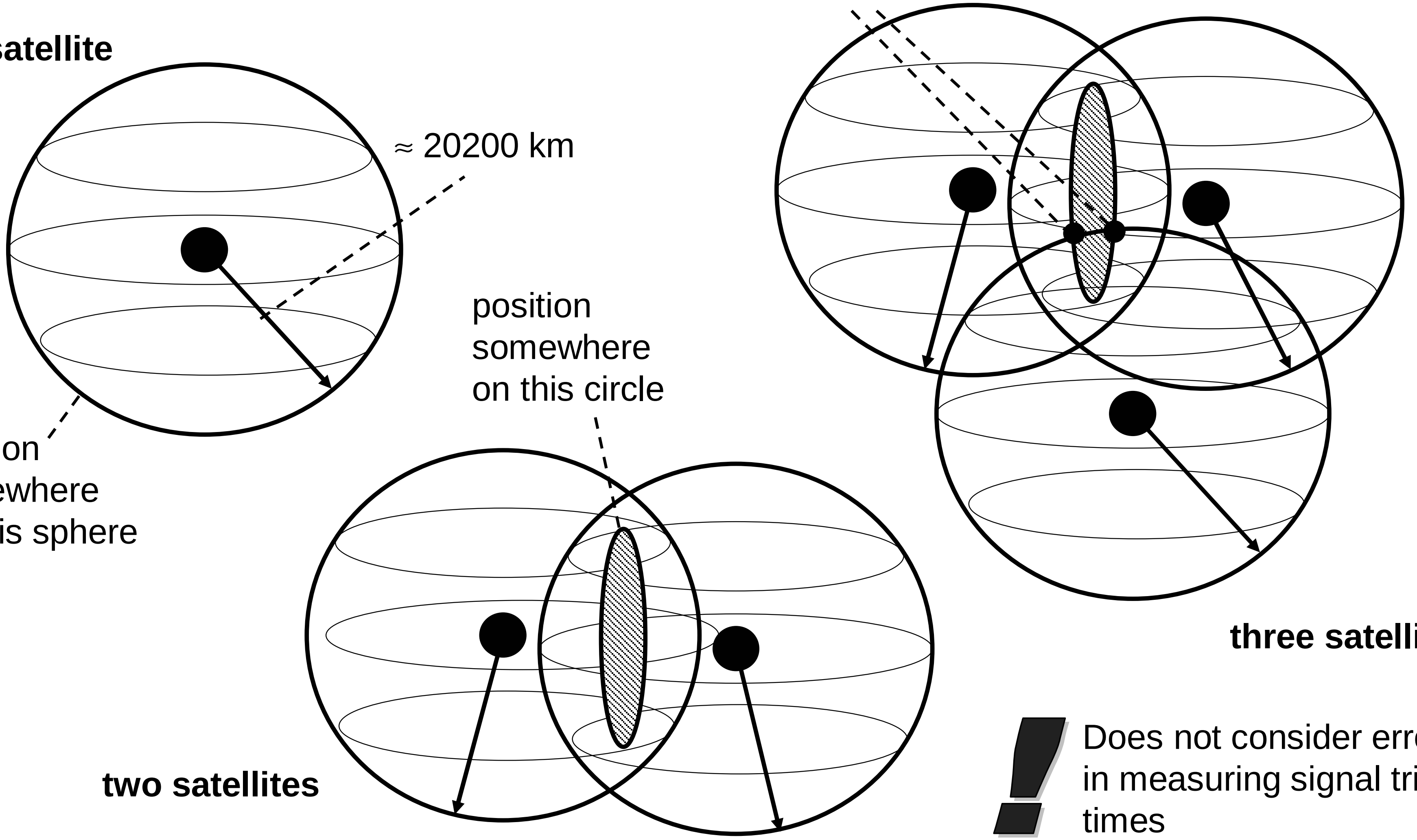
Global Positioning System (GPS) Master Control and Monitor Station Network

- Monitor stations
  - Measure satellite signals
  - Check orbit data
  - Correct satellite clocks, ...
- Results are transmitted daily to all GPS satellites

GPS: User Segment

- Consists of GPS receivers
- Responsible for determining:
  - Signal trip times
  - Exact time
  - Position of satellites
- Considering possible errors
- GPS receivers have become more accurate (12 channel receivers), cheaper and smaller

GPS: Positioning (1)

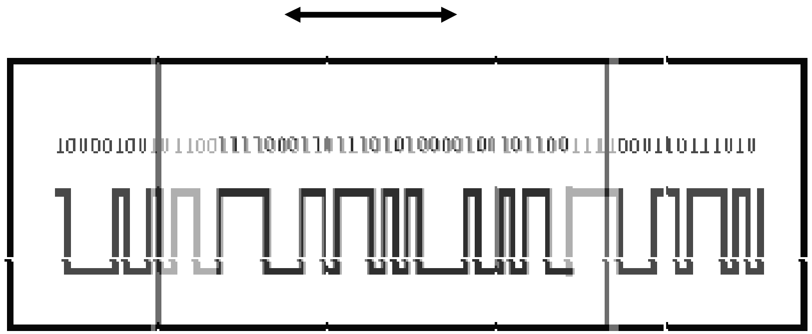


Does not consider errors in measuring signal trip times

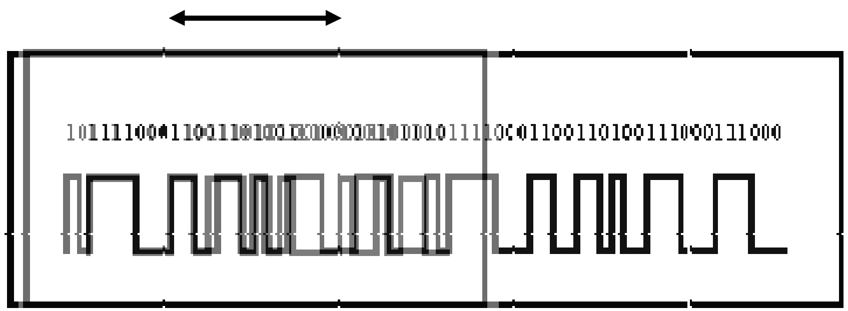
GPS: Positioning (2)

Measuring signal trip time:

- Satellite and receiver generate identical PRC (Pseudo Random Code) at exactly the same time
- Receiver compares generated signal with received signal
- The time difference measured at the receiver corresponds to the signal trip time
- Distance to satellite is calculated from signal trip time
- Exact clocks are required to be able to measure trip times
- Exact position of satellites have to be known



Full Correlation (Code-Phase Lock) of Receiver and Satellite PRN Codes



No Correlation with a Different PRN Code

GPS: Time Synchronization (1)

- Satellites
  - Atomic clocks
  - Exact and identical clock information (monitored by control segment)

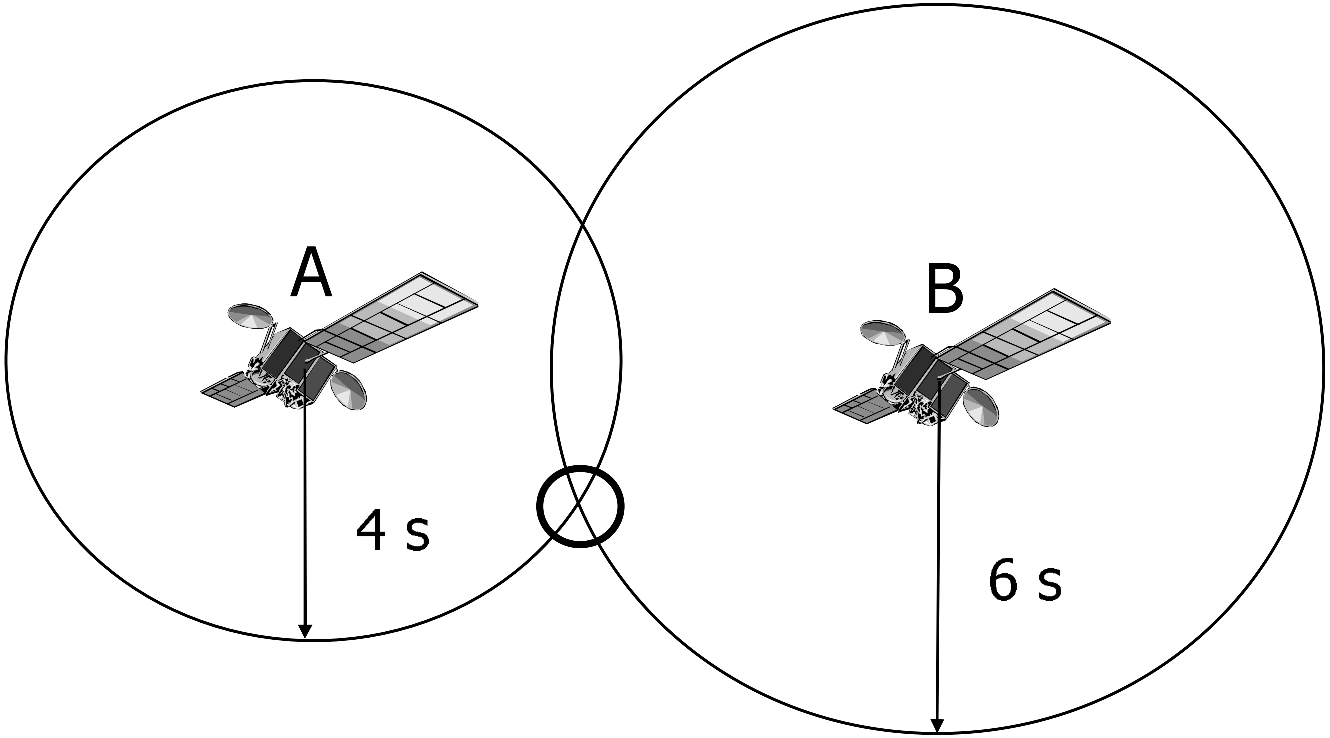
- GPS receiver
  - needs cheaper and smaller clocks
  - less accurate clock information

- Exact clock information required for positioning
  - not possible with clocks in receivers

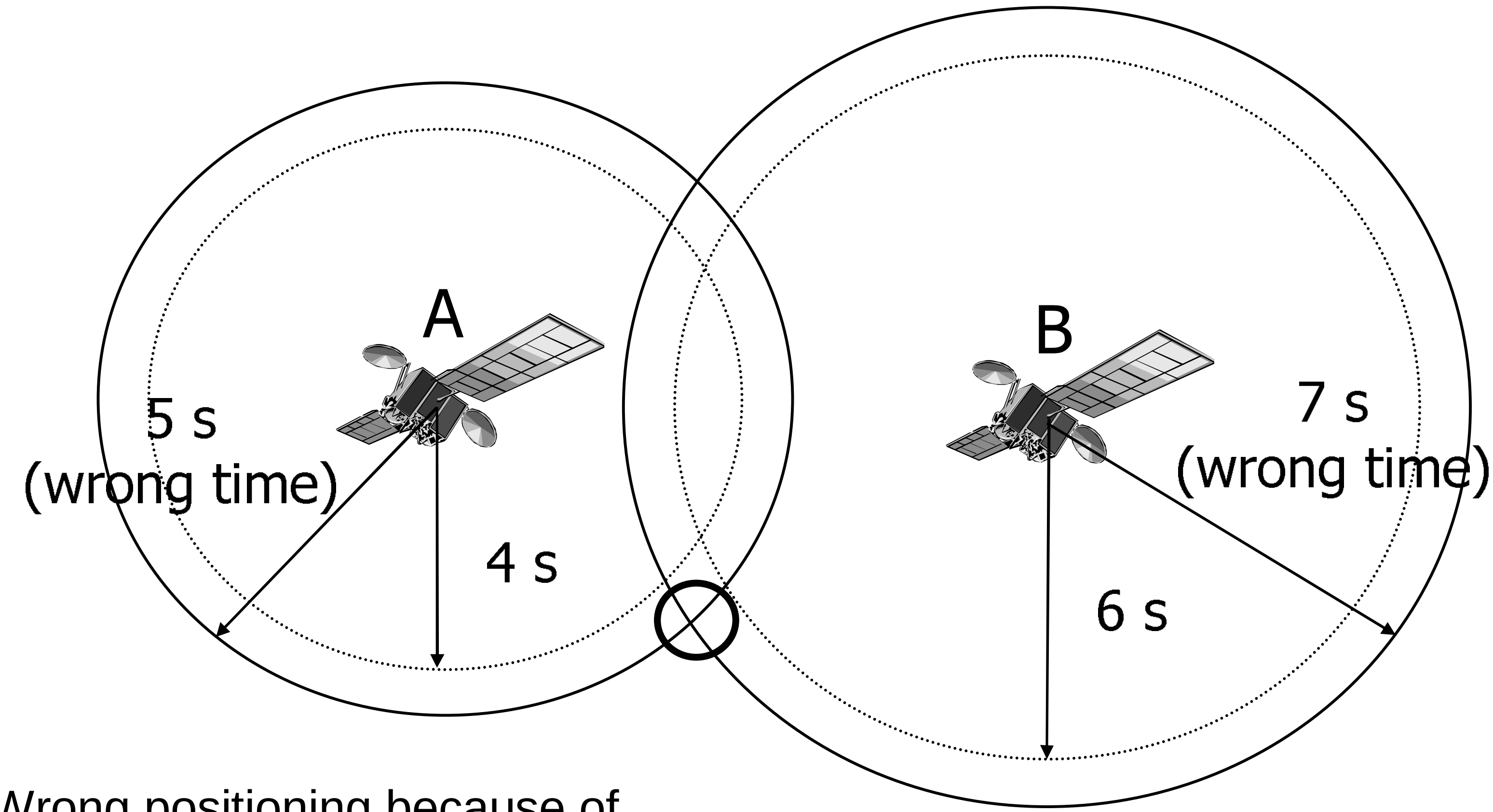
  ⇒ Time synchronization required

GPS: Time Synchronization (2)

- Reduced to 2D

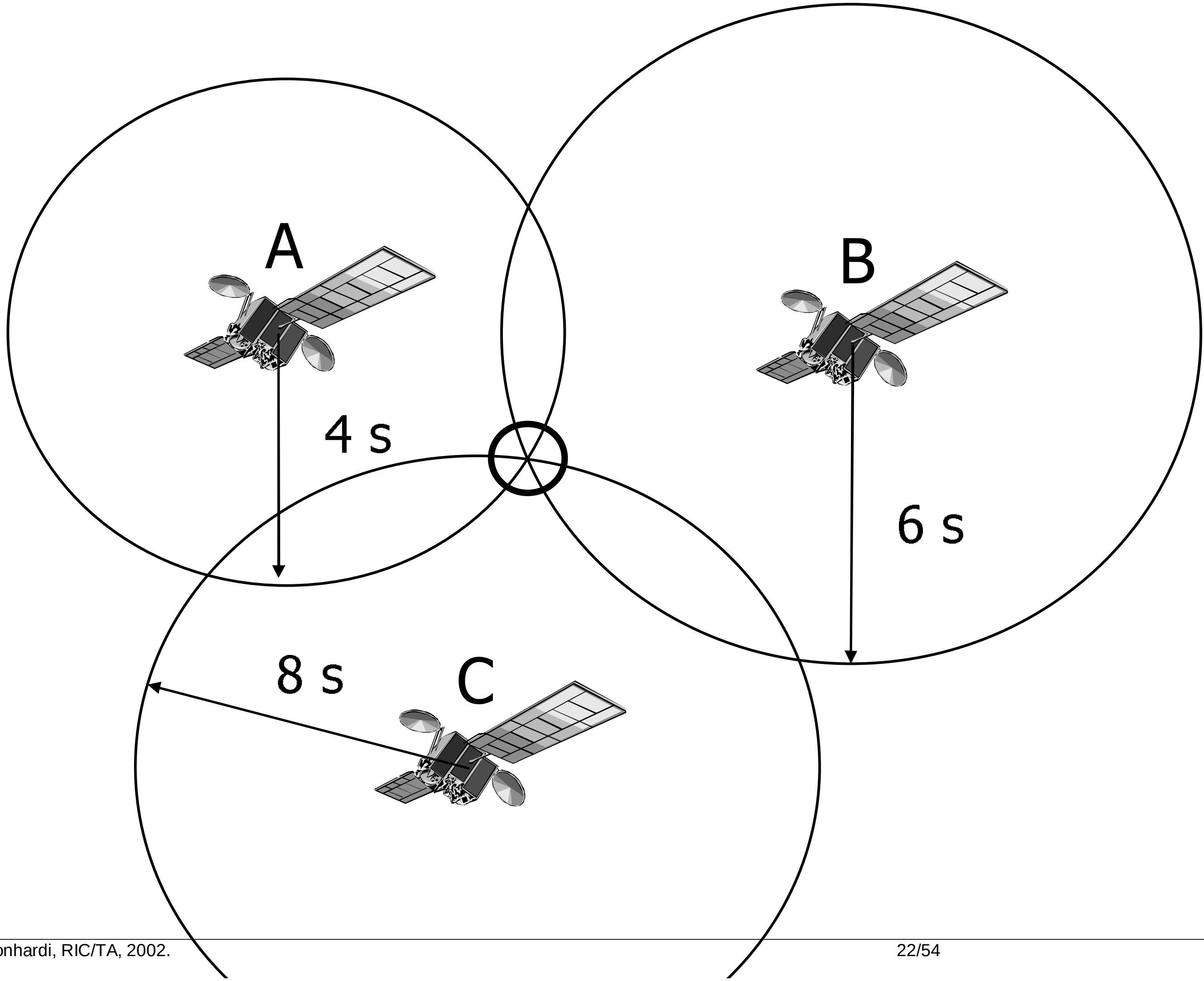


GPS: Time Synchronization (3)

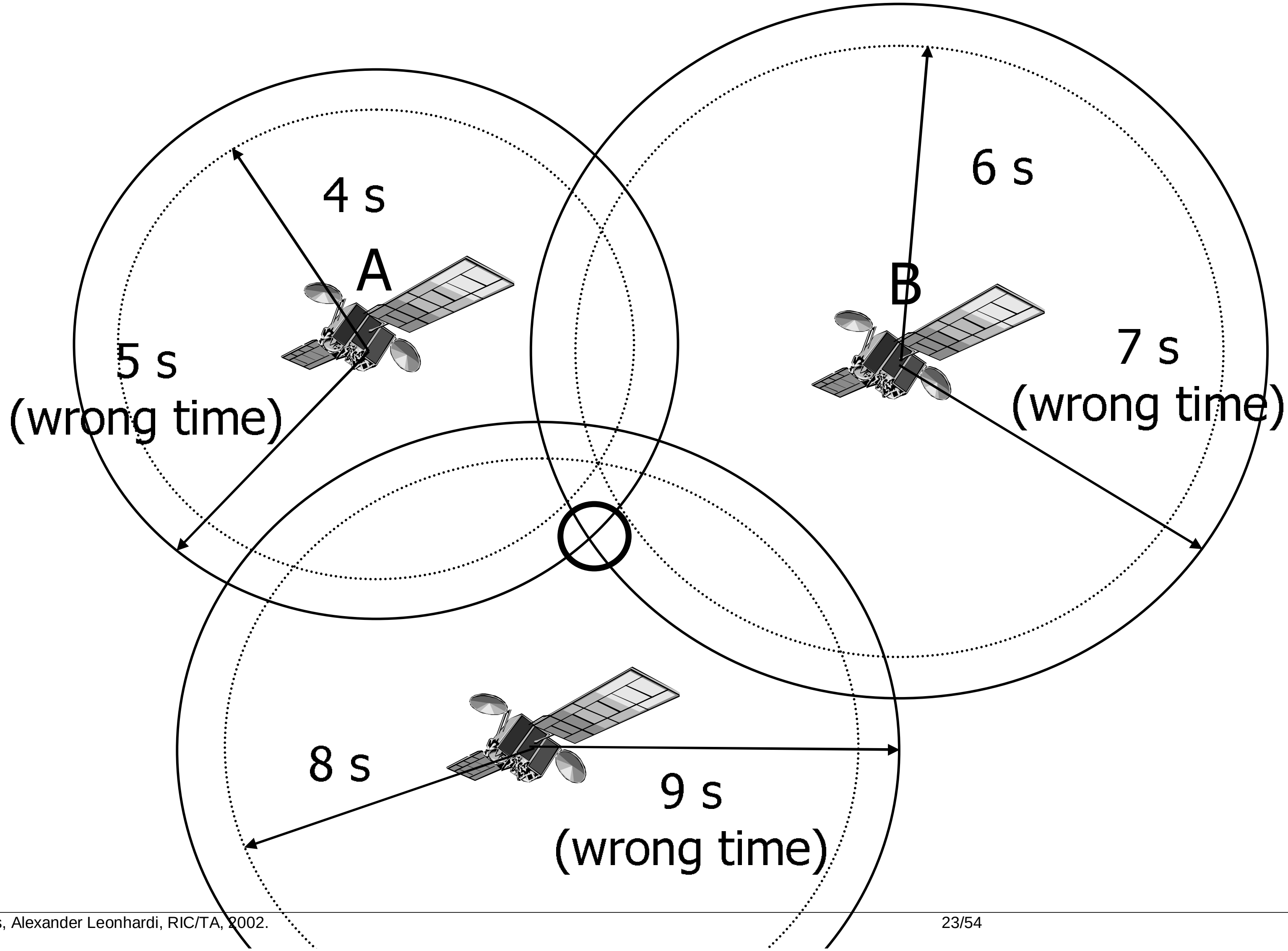


Wrong positioning because of clock deviations

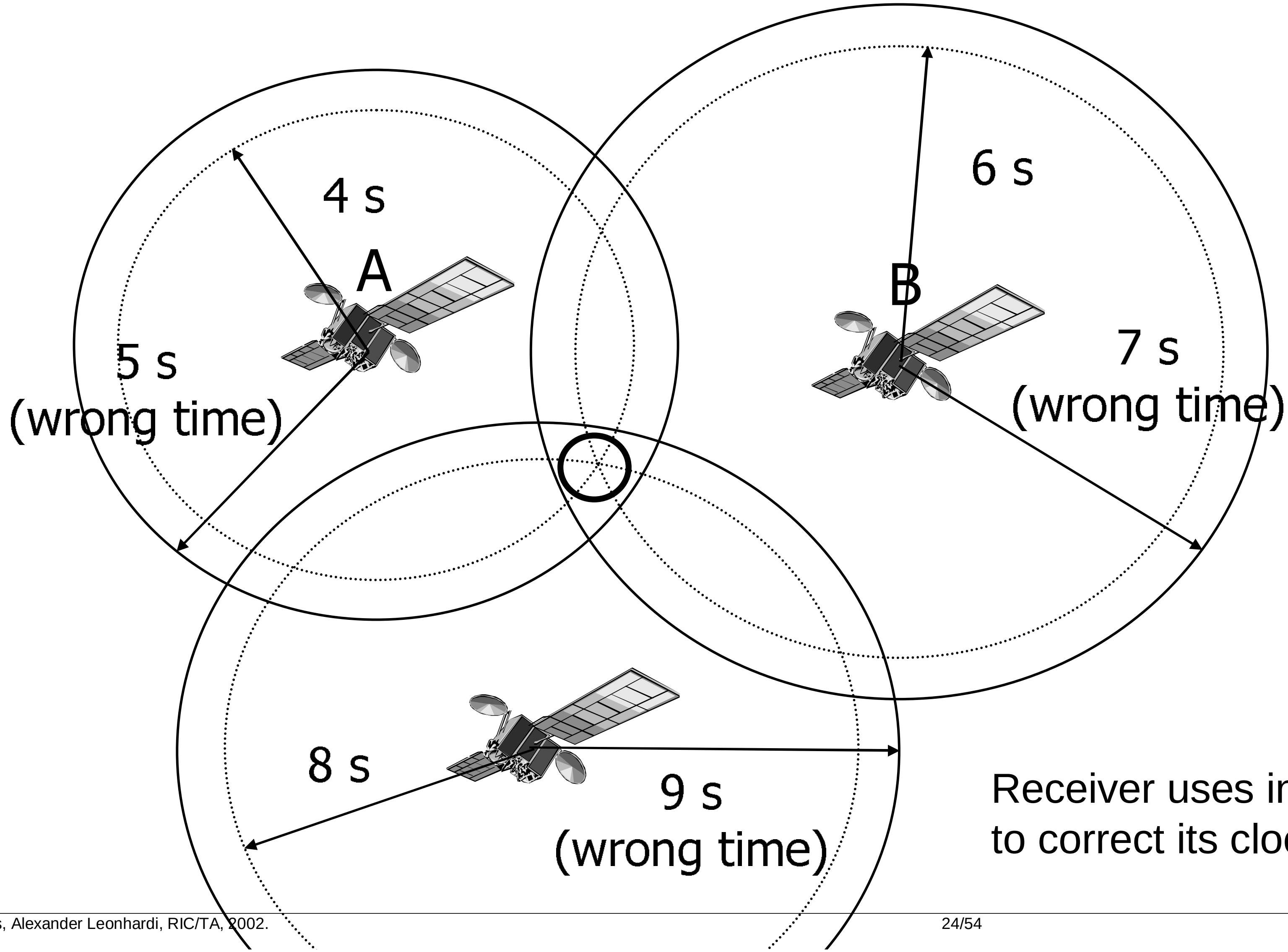
GPS: Time Synchronization (4)



GPS: Time Synchronization (5)



GPS: Time Synchronization (6)

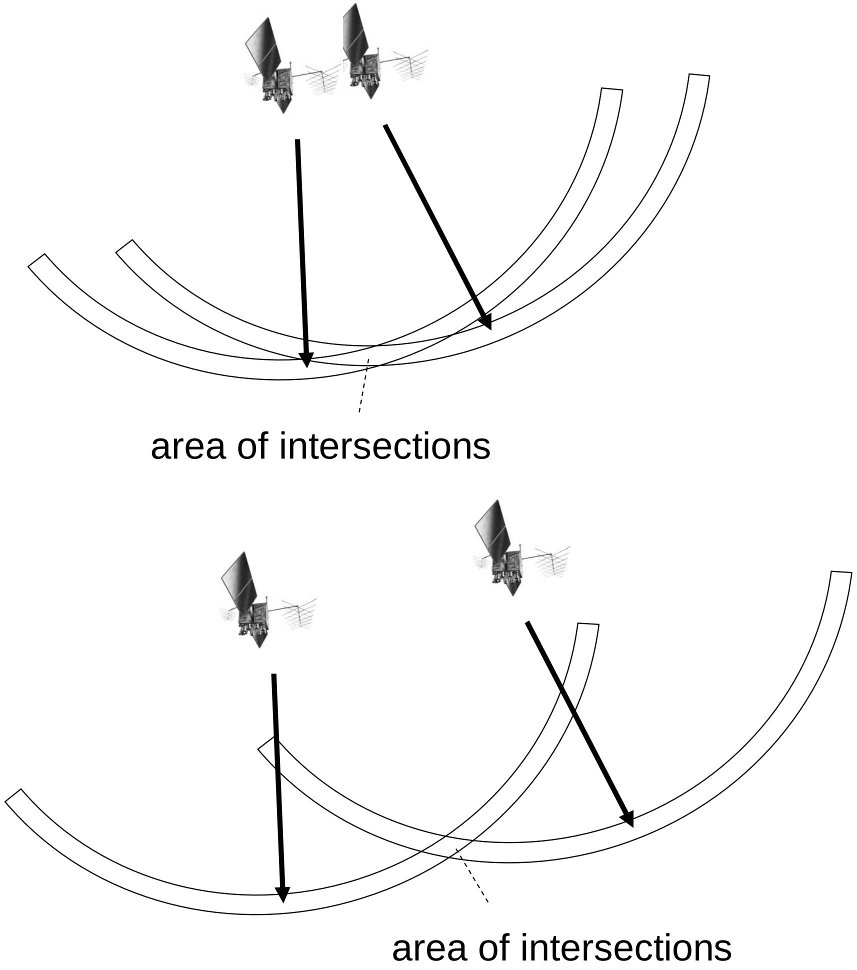


Receiver uses information to correct its clock

GPS: Causes of Errors

- Deviations in satellite orbits (~ 2.5 m)
- Atmospheric influences (~ 5.5 m)
- Atomic clock of satellites (~ 1.5 m)
- Reflections
  - Trees, Hills
  - Buildings
- GDOP (Geometric Dilution of Precision)
- Bad visibility

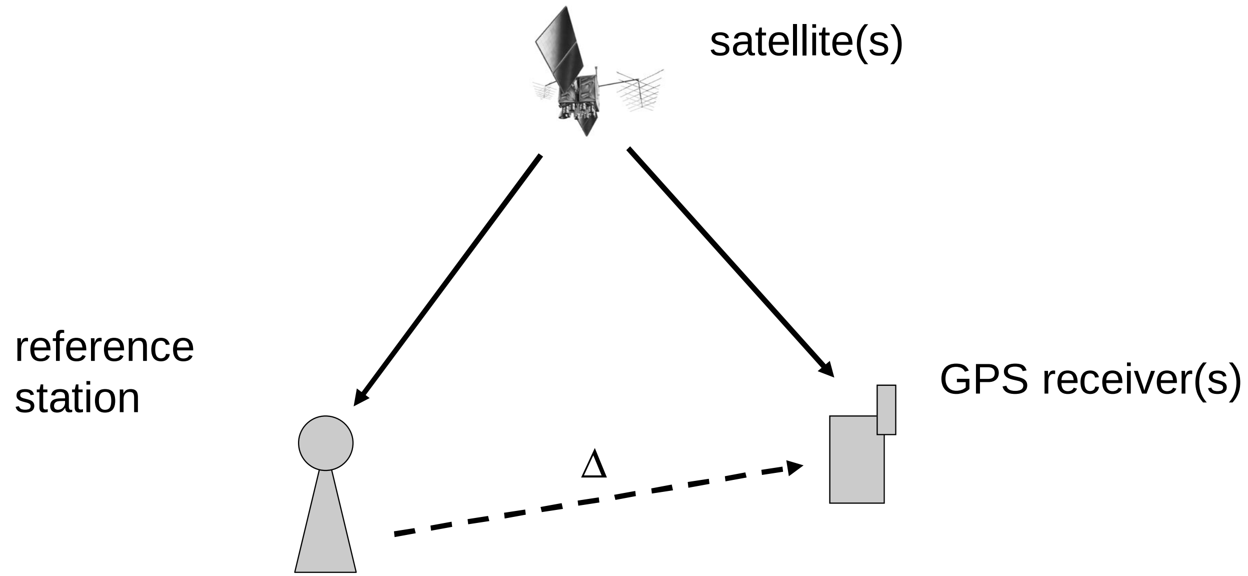
Example for GDOP:



DGPS: Differential GPS

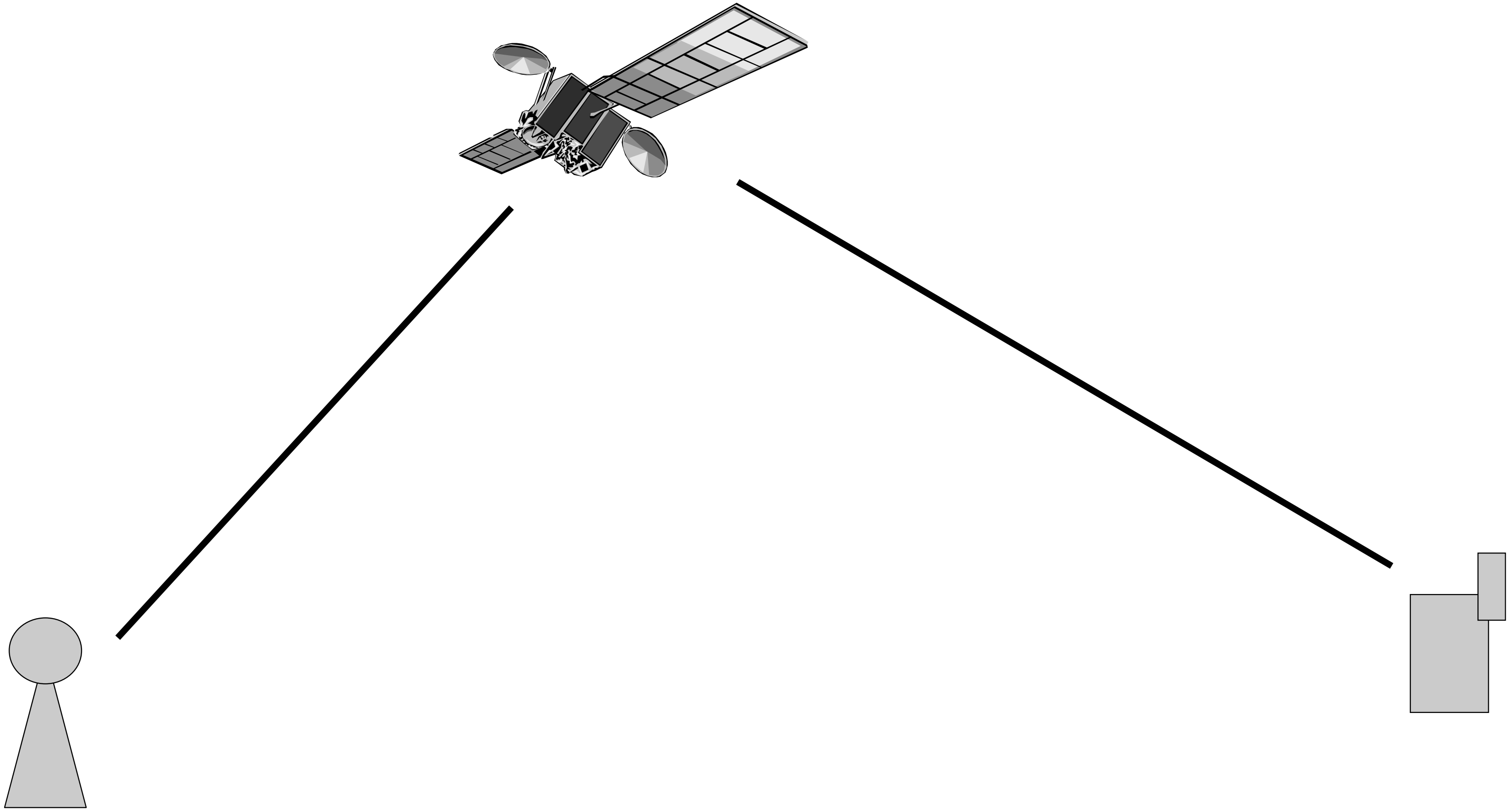
- Idea: Using a stationary reference station, whose position is known

  ⇒ Errors are similar for GPS receivers and reference station



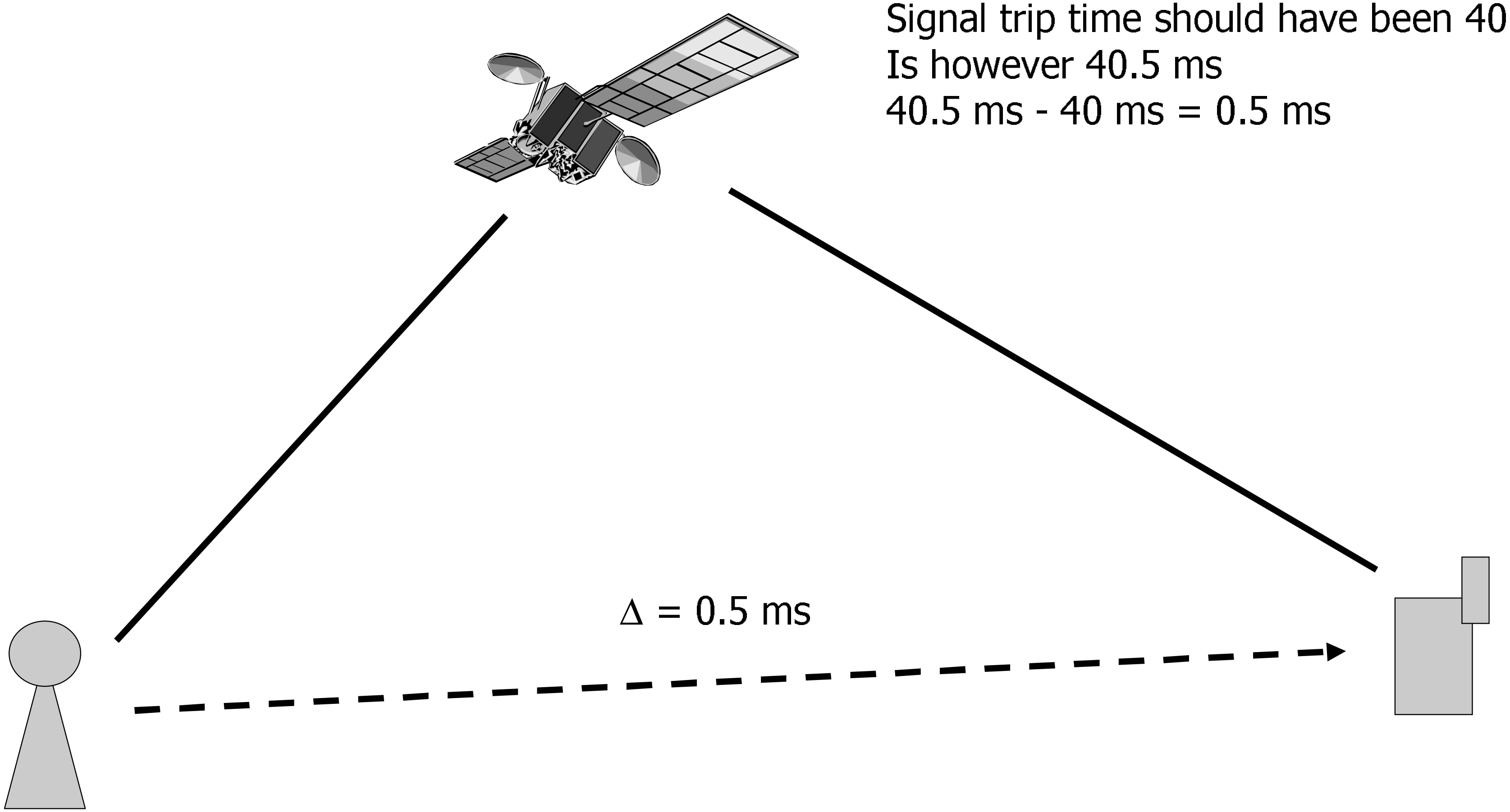
- Requirement: Reference station and receivers have to be reasonably close to another (< 200 km)

DGPS: Improving GPS Positioning (1)

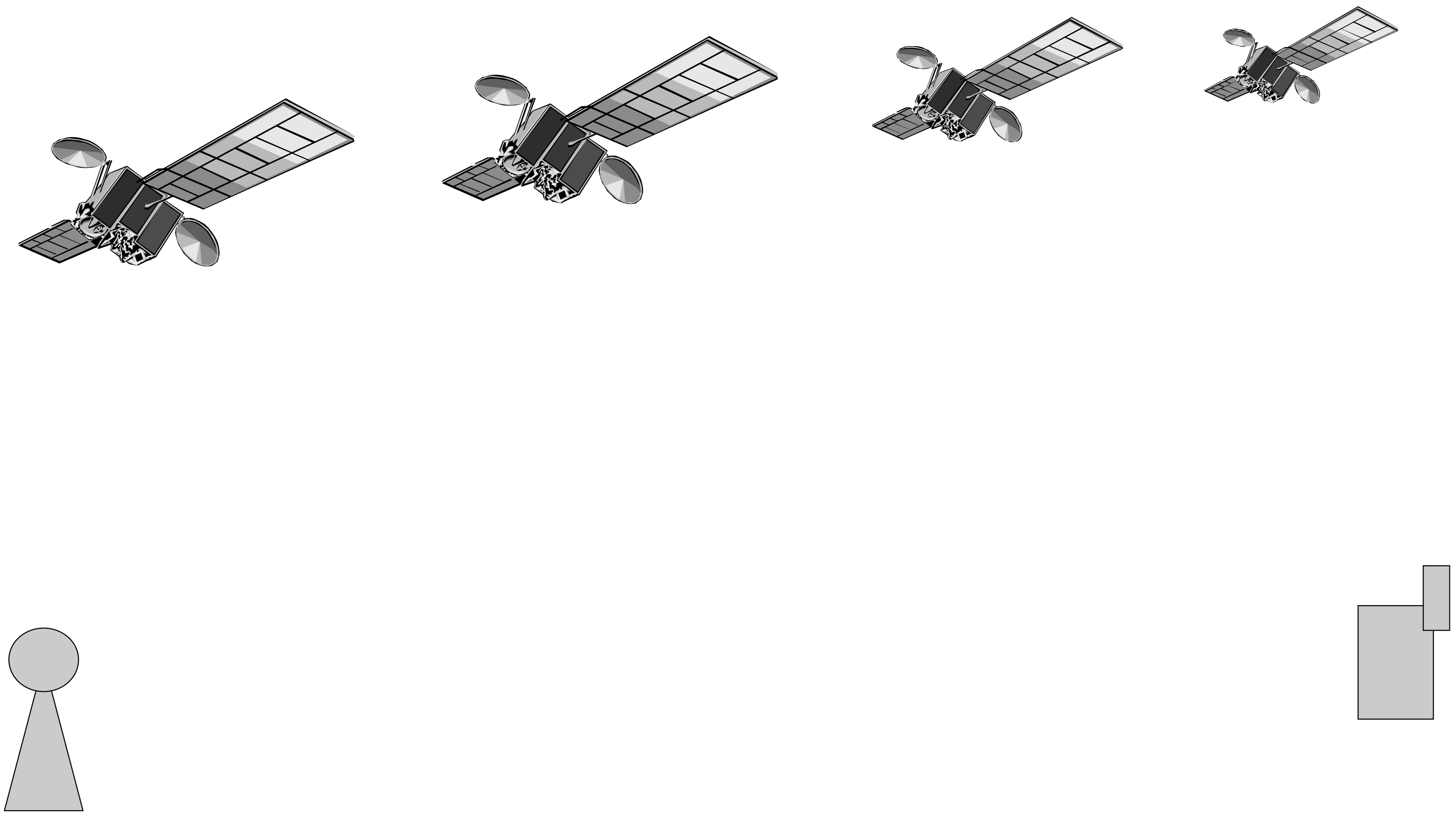


DGPS: Improving GPS Positioning (2)

Signal trip time should have been 40 ms
Is however 40.5 ms
40.5 ms - 40 ms = 0.5 ms



DGPS: Improving GPS Positioning (3)



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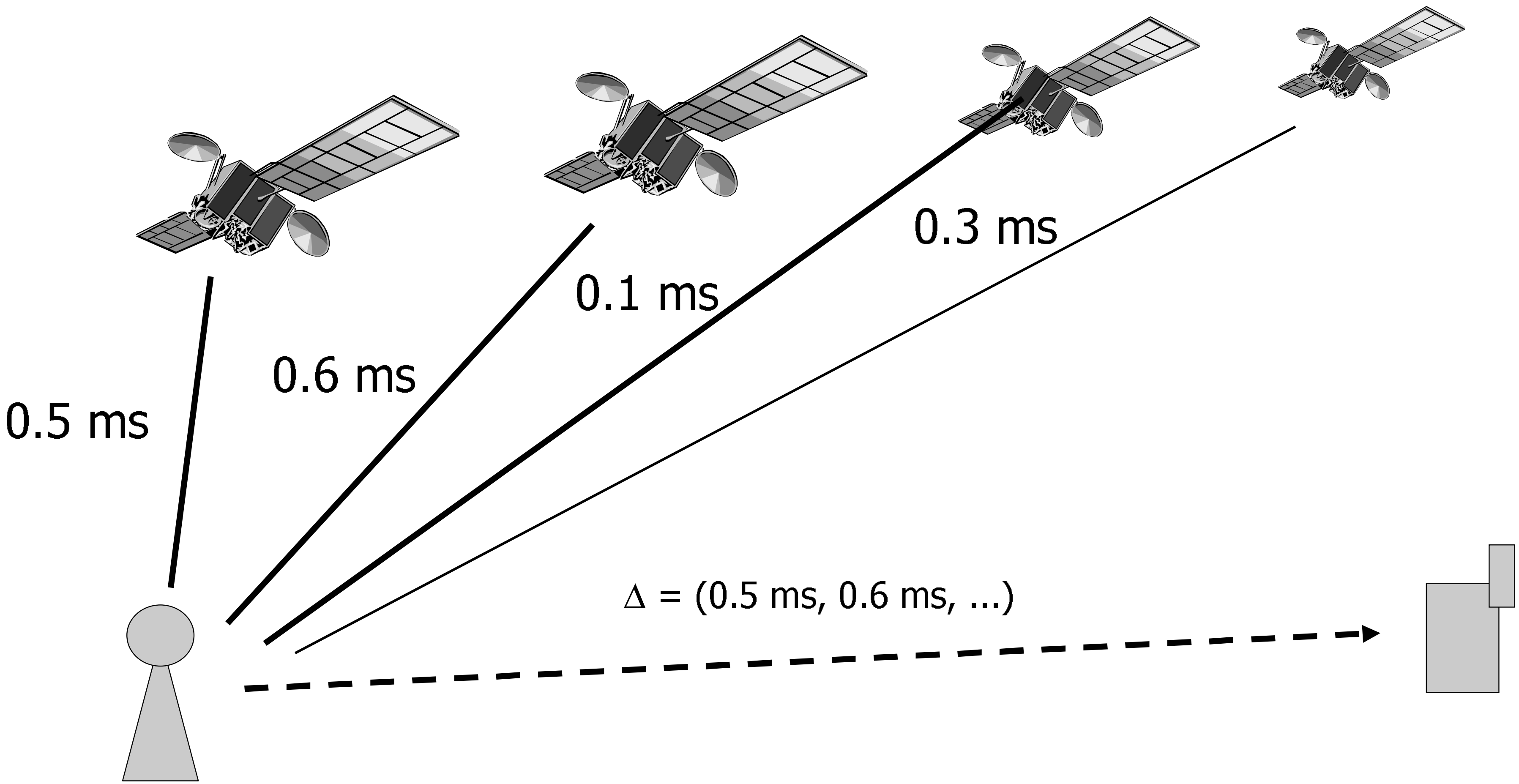
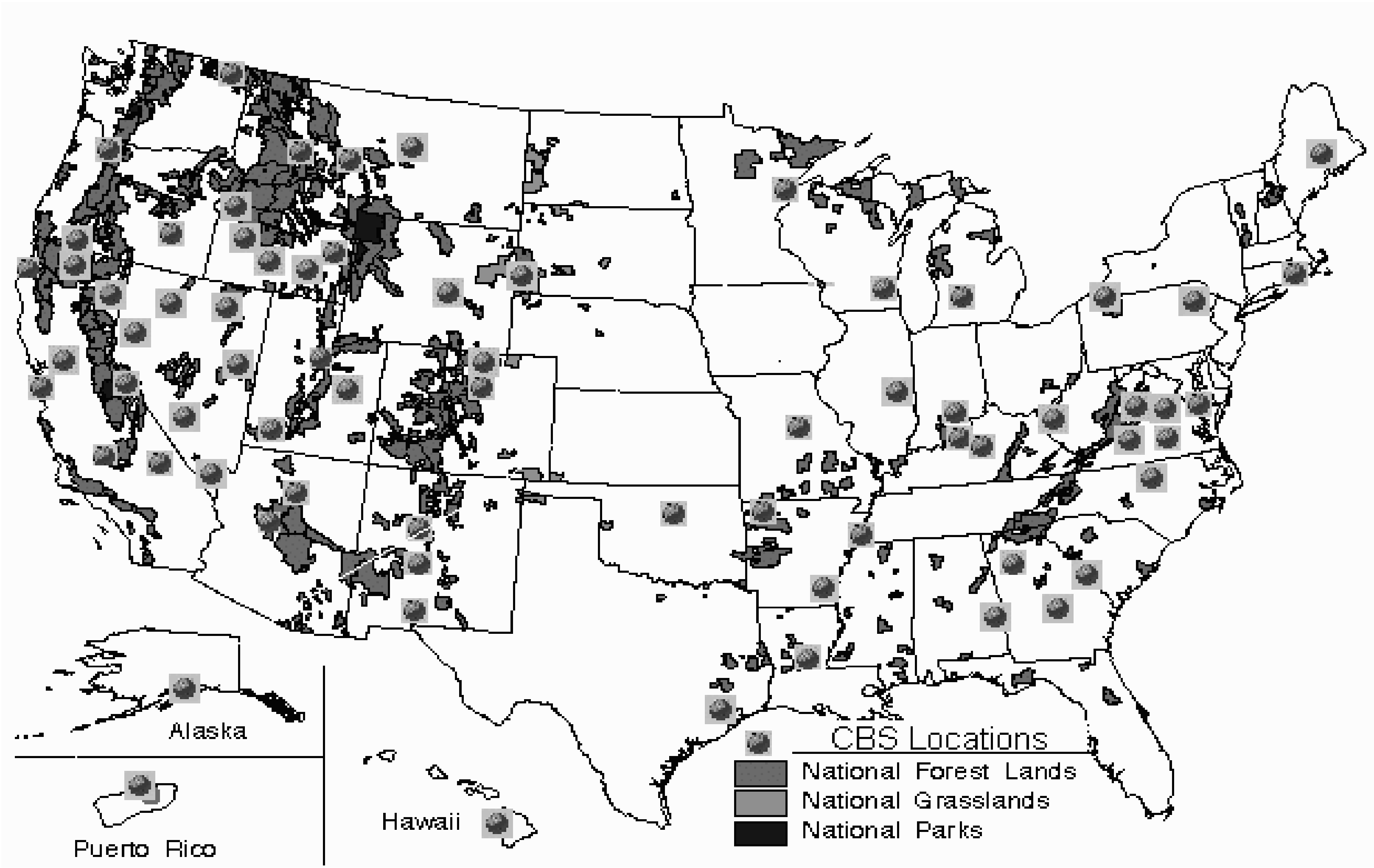


DGPS: Reference Stations in USA



Positioning in Mobile Communication Networks

- Positioning in Mobile Communication Networks
  - Location Based Services
  - Emergency calls (required by US legislation)
- Soluting: Integrating a GPS receiver into a mobile phone
- Problems:
  - GPS receiver would add to cost, weight and complexity
  - GPS receiver has a rather long time to acquire a first fix
- Idea: Use existing infrastructure for positioning

Assisted GPS (A-GPS)

- Integrating GPS in mobile phones
  - is complex
  - GPS takes a long time to achieve a first fix
- Fixed GPS receivers placed at regular intervals (every 200 to 400 km)
- Fetch data to complement readings on phone
- Phone can make timing measurements without having to decode messages
- Reduces time to determine location
- First fix in 1-8 seconds

- A-GPS requires
  - extensive hardware and software modifications
  - likely an additional antenna
- Accuracy
  - less than 50 m

Enhanced Observed Time Difference (E-OTD)

- Similar to GPS using base stations of Mobile Communications Network
- Measures signal trip times to surrounding base stations
- Used to calculate the distance to these base stations
- Requires the base stations positions to be known
- Calculations are usually done in infrastructure

- E-OTD requires:
  - Changes to infrastructure
  - Extensive changes to mobile phone
- Accuracy:
  - About 125 m
  - Will become better with smaller cell sizes in 3G

- Commercial system: Cursor (promised accuracy: 50 m)

GSM: Comparison of Positioning Technologies

	System Accuracy	Commercial Availability on GSM	User Controlled Privacy	Speed of Response	Mobile Network Upgrade Cost
E-OTD	15m to 150m	2000	Yes	Less than 10 seconds	Medium
Cell ID	Variable 250m to 30km	1999	No	Less than 10 seconds	Minimal (MSC Interface)
Cell ID / Timing Advance	150m to 30km	1999	No	Less than 10 seconds	Minimal
Assisted GPS	Generally better than 50m if available	2002	Yes	Less than 10 seconds to 1 minute	Medium (standards-compliant)
Time of arrival	Difficult to achieve better than 150m	2002 (non-standards compliant)	No	Less than 10 seconds	High
Angle of Arrival	Unlikely to achieve 150m	No known commercial solution	No	Less than 10 seconds	High

Overview

- Concepts of Location-aware Systems
- Positioning
  - Out-door
  - In-door
- Location-aware Applications
  - Examples: Guide, Nexus
- (Location Management)

In-door Positioning

Problem: GPS signal can not (or only badly) be received inside of a building

$\Rightarrow$ Satellite system not possible

Requirements:

- Availability
- Costs
- Accuracy
- Robustness
- Few installation efforts

In-door Positioning (2)

- Positionierung mit Infrarottechnologien
  - Relatively cheap
  - Large-scale installations problematic
  - Low interference problems (confined to one room)
- Ultrasound-based Positioning
  - Very accurate
  - Very expensive
  - Large-scale installations not possible
- Radio-based Positioning
  - Using existing infrastructure
  - Suitable for
  - Prone to interference

Infrared-based Positioning

2 basic solutions:

System-centered

- Mobile (small) senders
- Fixed installed receivers
- Sender emits unique code identifying a mobile object (e.g., the user's PDA)
- Receivers report sightings to the infrastructure

Device-centered

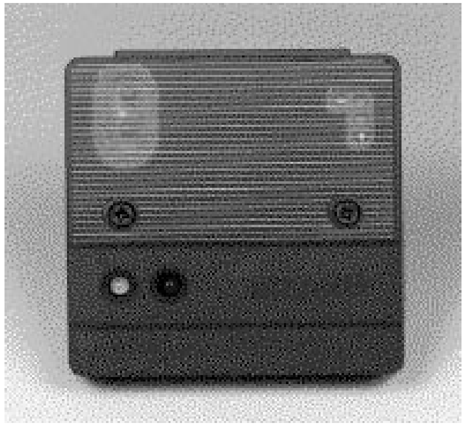
- Fixed installed senders
- Mobile receivers attached to (or integrated in) PDA or notebook
- Sender emit unique code identifying a location (for example a room)
- Mobile receiver identifies location locally

Infrared-based Positioning: Active Badges (1)

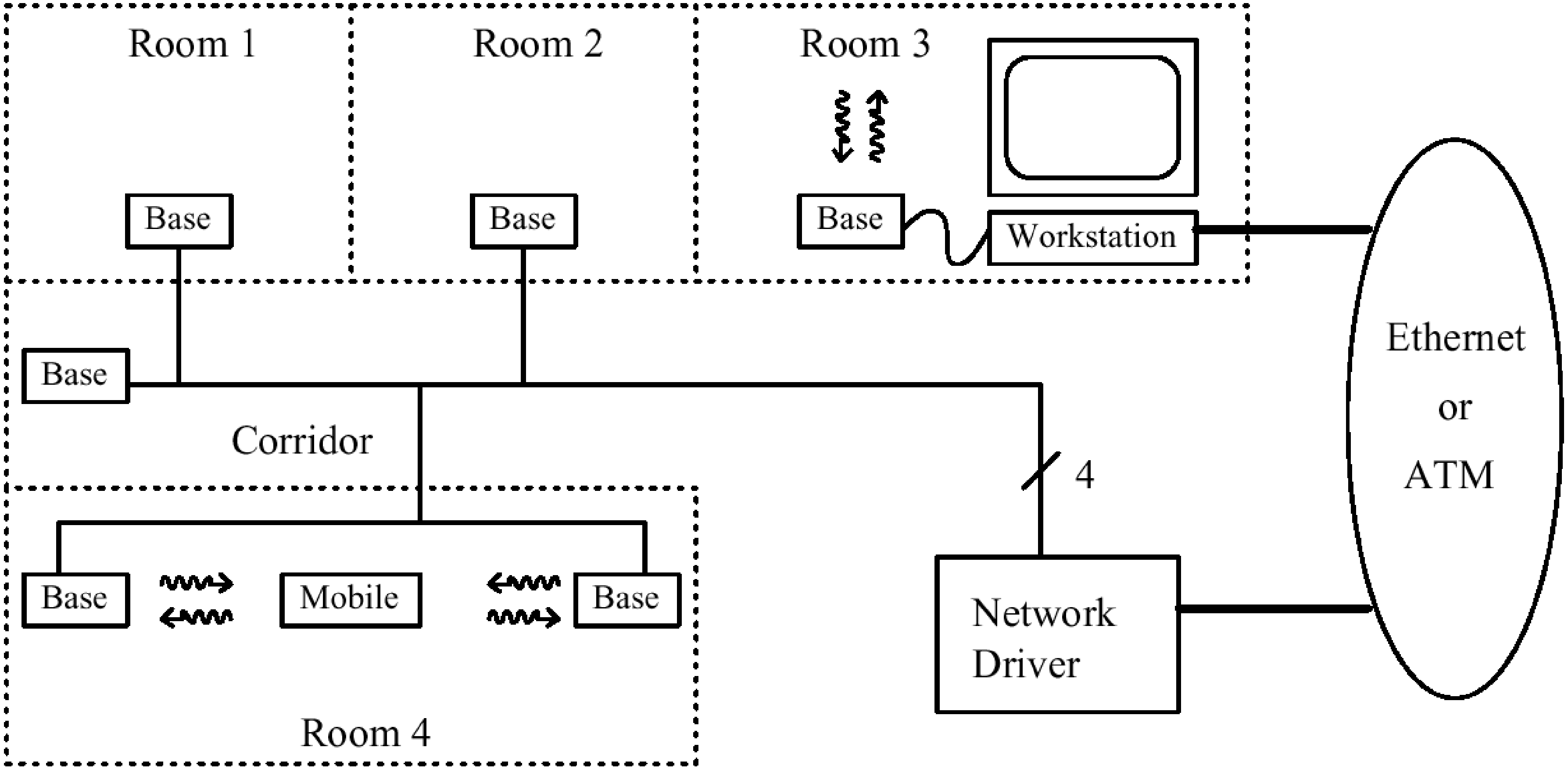
- Developed at the Olivetti Research Laboratories (now AT&T) together with the University of Cambridge
- Started research on location-awareness: in use since 1992
- Mobile transmitters
- Fixed receivers connected to a central server
- Location information is managed on central server
- Variants are commercially available

Transmitter:

Receiver:



Infrared-based Positioning: Active Badges (2)



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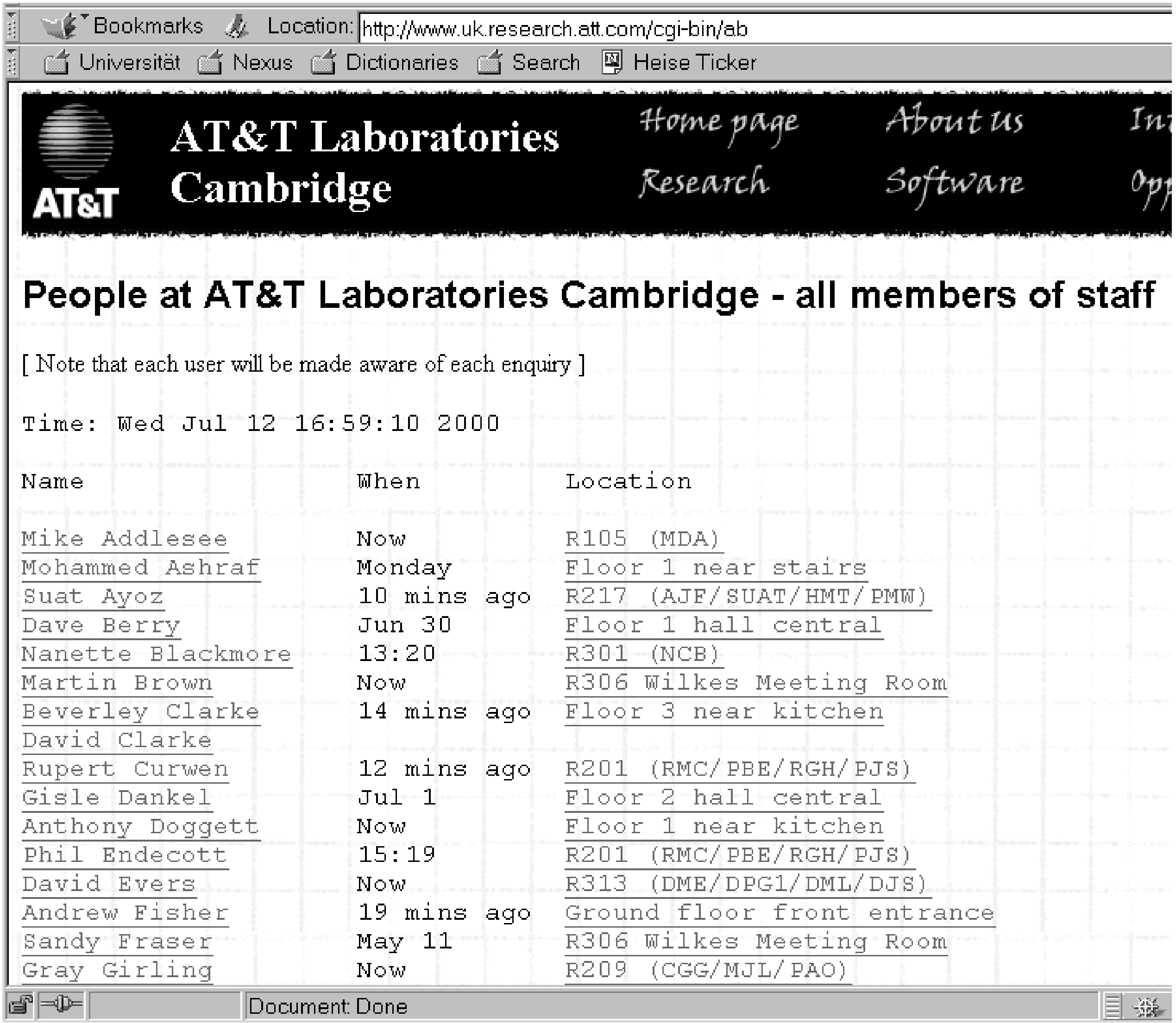


People at AT&T Laboratories Cambridge - all members of staff

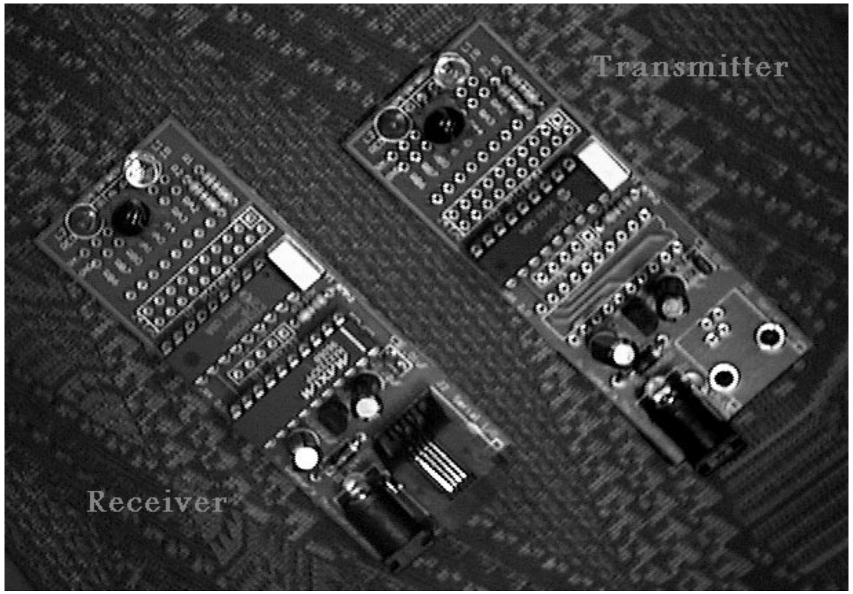
[Note that each user will be made aware of each enquiry]

Time: Wed Jul 12 16:59:10 2000

Name	When	Location
Mike Addlesee	Now	R105 (MDA)
Mohammed Ashraf	Monday	Floor 1 near stairs
Suat Ayoz	10 mins ago	R217 (AJF/SUAT/HMT/PMW)
Dave Berry	Jun 30	Floor 1 hall central
Nanette Blackmore	13:20	R301 (NCB)
Martin Brown	Now	R306 Wilkes Meeting Room
Beverley Clarke	14 mins ago	Floor 3 near kitchen
David Clarke		
Rupert Curwen	12 mins ago	R201 (RMC/PBE/RGH/PJS)
Gisle Dankel	Jul 1	Floor 2 hall central
Anthony Doggett	Now	Floor 1 near kitchen
Phil Endecott	15:19	R201 (RMC/PBE/RGH/PJS)
David Evers	Now	R313 (DME/DPG1/DML/DJS)
Andrew Fisher	19 mins ago	Ground floor front entrance
Sandy Fraser	May 11	R306 Wilkes Meeting Room
Gray Girling	Now	R209 (CGG/MJL/PAO)

Infrared: Locust Swarm

- Developed at the MIT Media Lab (Wearable Computing department)
- Fixed transmitters (emitting room number)
- Mobile receiver attached to PDA or Notebook
- Identical hardware for transmitters and receivers
- Experimental system
- Extension by radio module

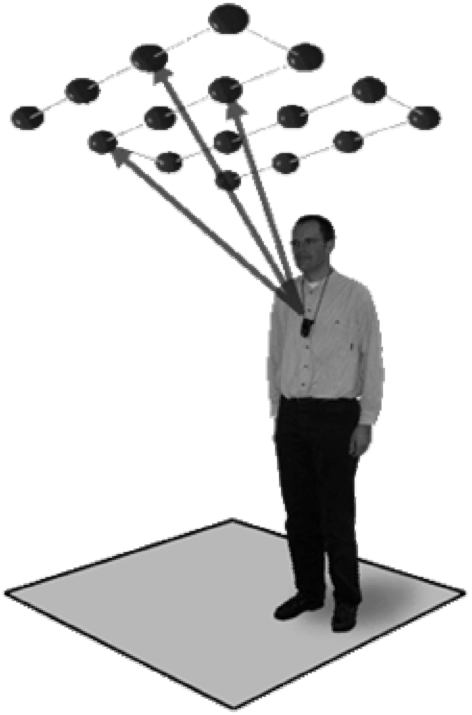


Infrared-based Positioning: IRREAL System

- Developed at the University of the Saarland
- Fixed IR transmitter
- Receivers are standard Palm Pilots
- Information is broadcasted periodically
- More important information (index) is transmitted more frequently
- Information (transmitter-specific) is accumulated over time

Ultrasound-based Positioning: Active Bat System

- Developed at the Olivetti Research Laboratories (now AT&T) together with the University of Cambridge
- Successor of Active Badges



- Grid of ultrasound receivers placed with in a grid 1.2 m apart on the ceiling
- Installation: about 720 receivers for 1000m²
- Bats have radio link
- Central receiver controls receivers and bats

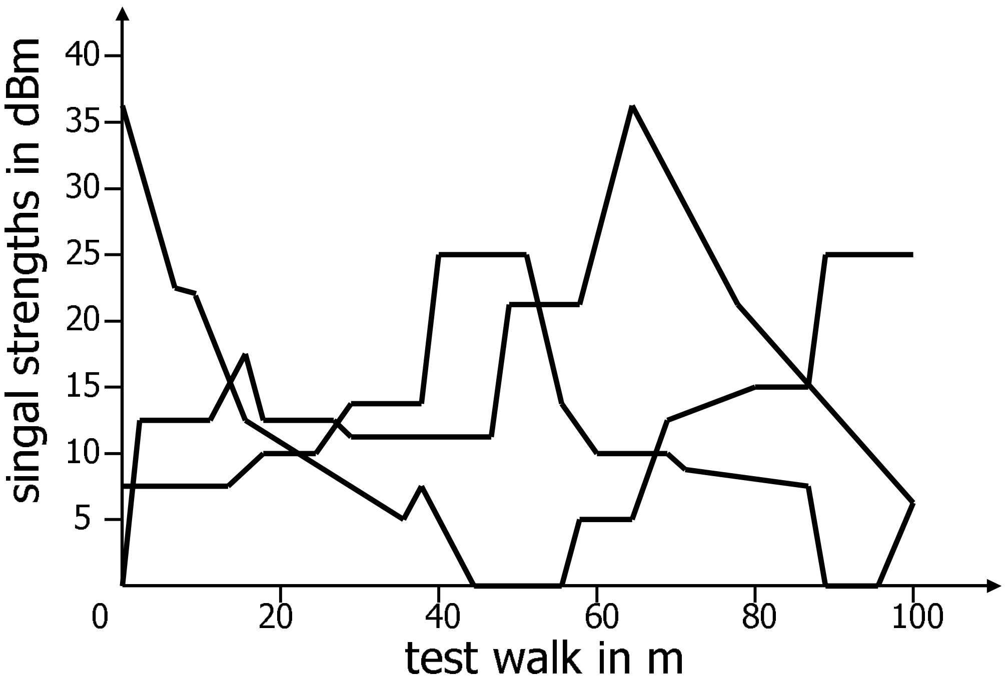
- Accuracy: 3 cm
- Direction measurement by using more than one bat

Radio-based Positioning: Using a Wirless LAN

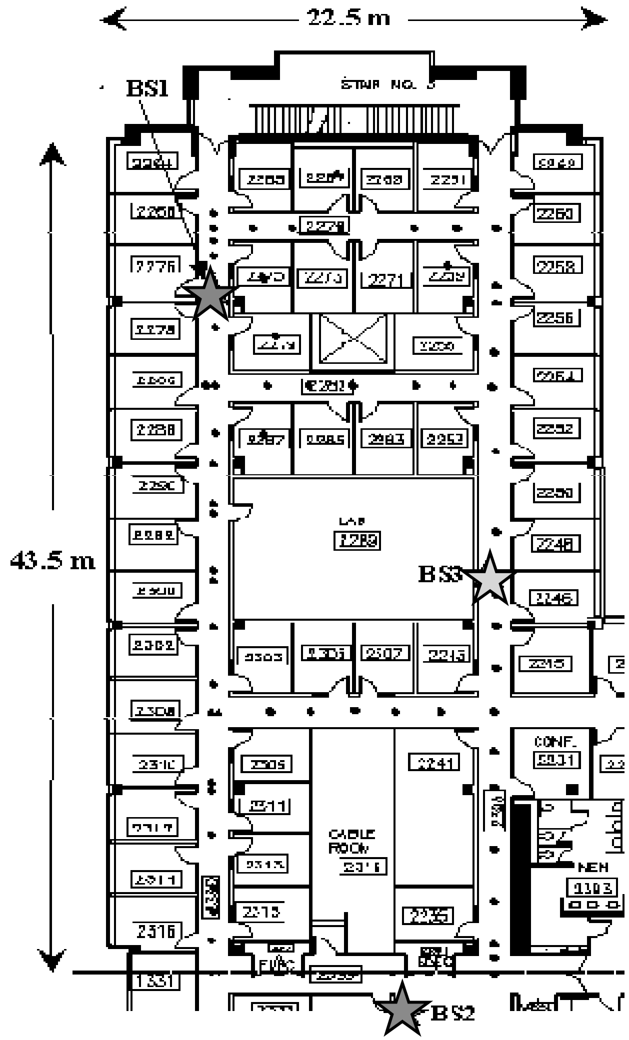
- Idea: Determining position based on the signal strength of an existing WLAN infrastructure
- Values for signal strengths needs to be known
  - Setting up DB with signal strengths before-hand
  - Using a radio propagation model
  - Using history information to improve positioning
- General problems:
  - Changes in signal strength, for example through closed/opened doors
  - Interference through electronic devices (computers)

Radio-based Positioning: RADAR System

- Developed by Microsoft Research
- Average accuracy: 3 to 4.3 m (50%)



BS1
BS2
BS3



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Applications: Location-aware City Guides

- Cyberguide
  - Georgia Institute of Technology
  - Early interactive city guide for Atlanta
  - www.cc.gatech.edu/fce/cyberguide

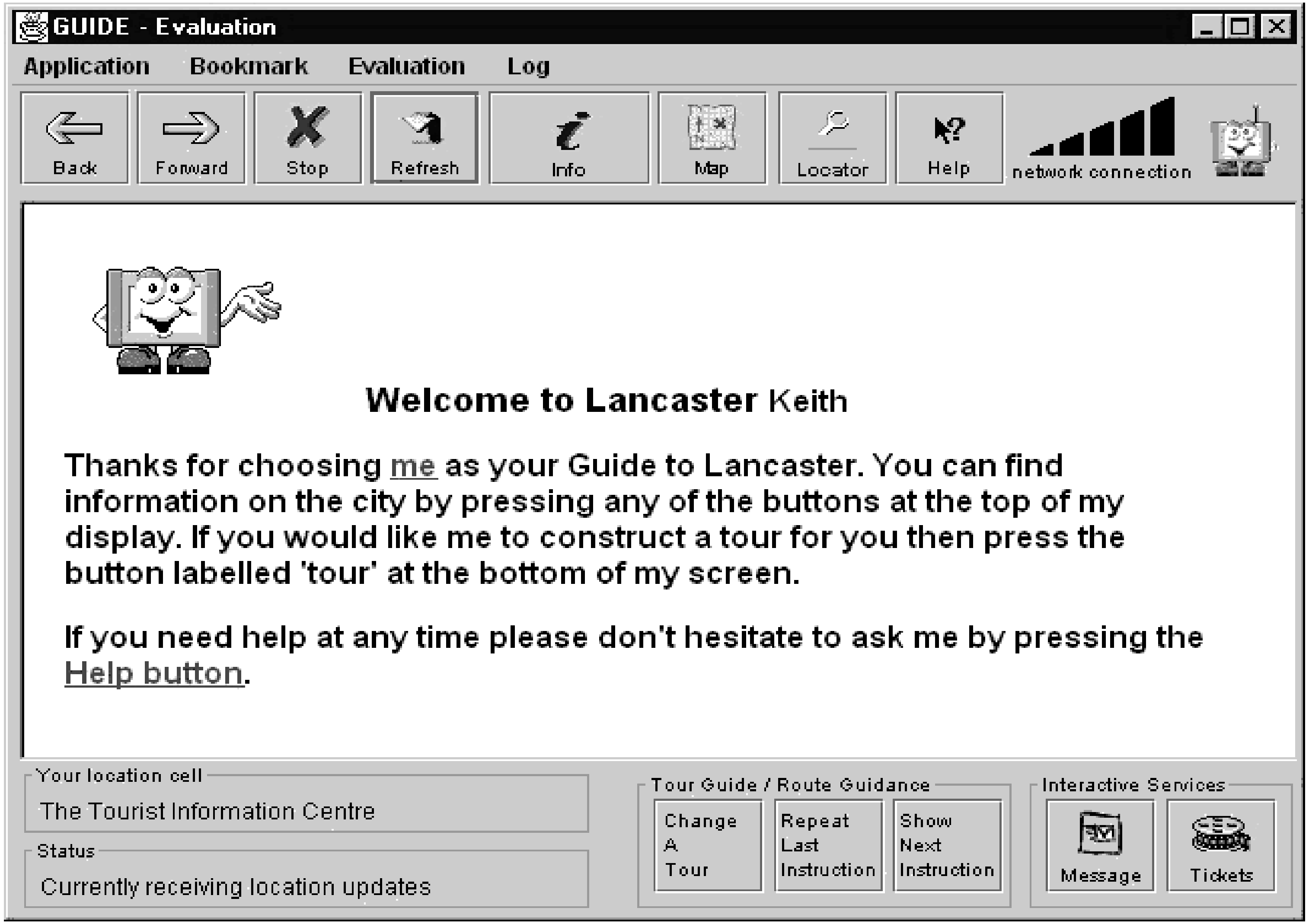
- Deep Map
  - European Media Lab EML, Heidelberg
  - Interactive city guide for Heidelberg
  - using high resolution 3D information

- GUIDE
  - University of Lancaster
  - Interactive multi-media city guide for Lancaster
  - http://www.guide.lancs.ac.uk/

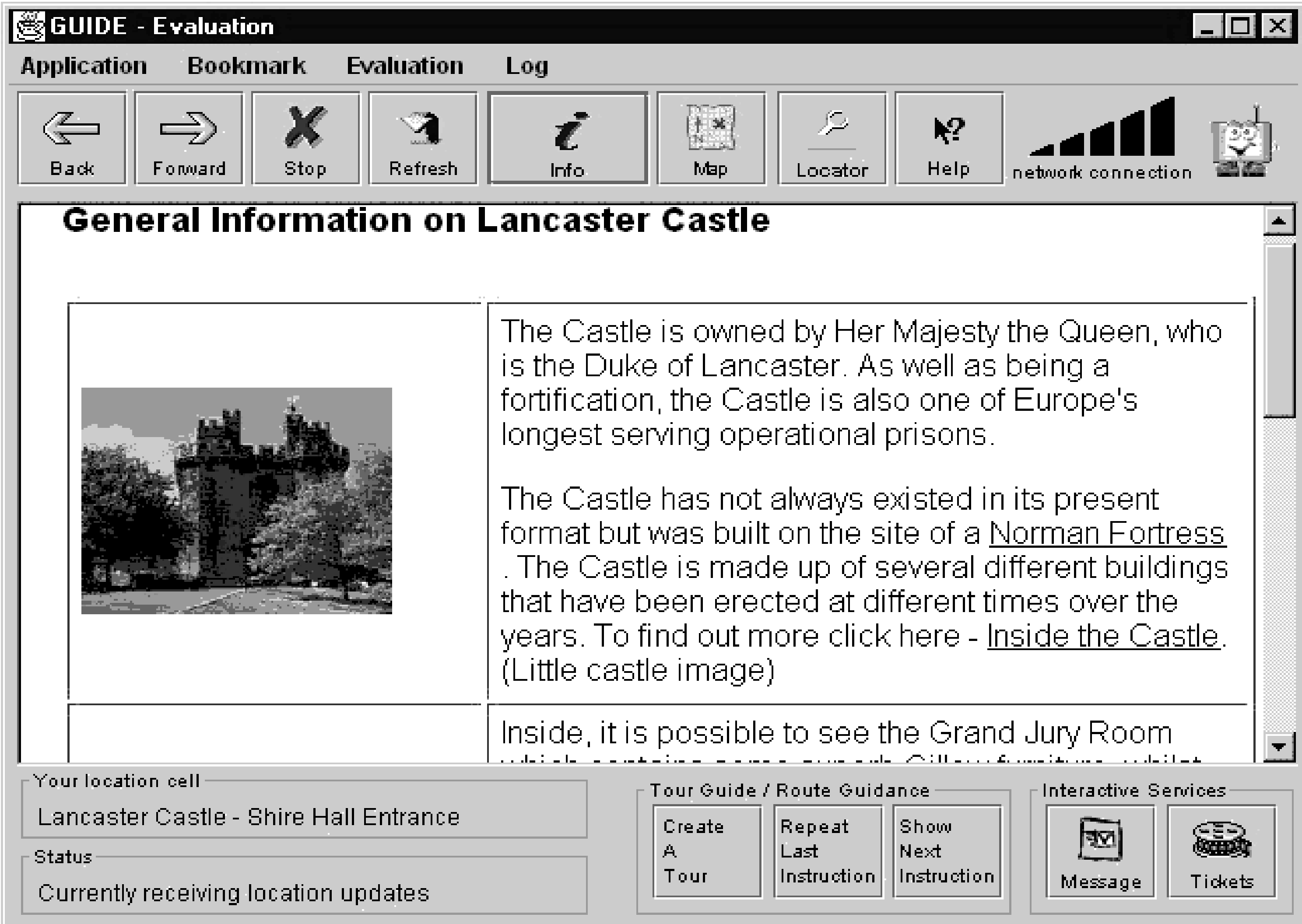
Further Applications

- Stick-e Notes (University of Kent)
  - Virtual „Post-Its“
- Context Toolkit (Georgia-Tech)
  - Context Widgets
- Context-aware medicine shelf (Anderson Consulting Research)
- Context-aware coffee cup (TeCo, Karlsruhe)

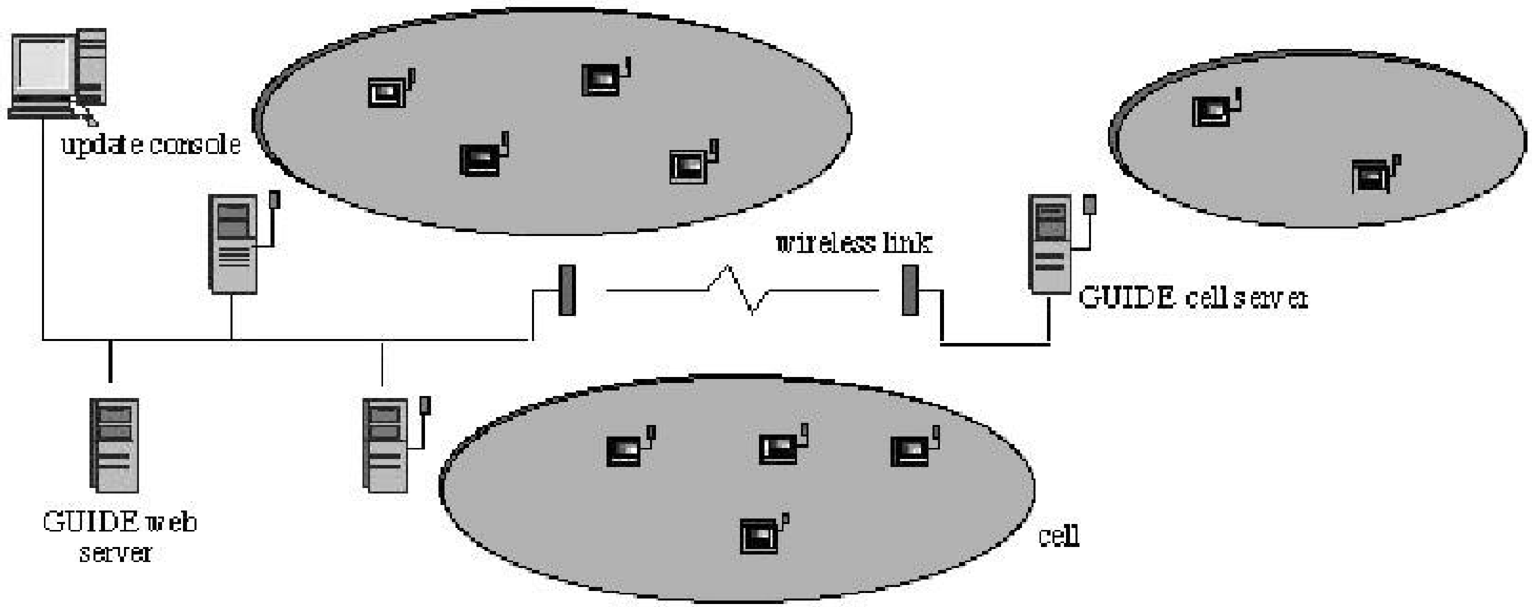
GUIDE: User Interface



GUIDE: Location-aware Information



GUIDE: System Architecture



Questions?

Thank you very much for your attention!

Contact: Alexander.Leonhardi@daimlerchrysler.com