COMP90018
Mobile Computing Systems Programming

Prof. Vassilis Kostakos

Introduction to LBS

- Location-based services (LBS)
  - Services that integrate a mobile's device location with other information
  - Available at least since the 1970s (GPS: US military)
- Mobile operators
  - Voice, data (SMS, MMS, Video), location information
- Push versus pull
  - User receives information without an active request
  - User actively pulls information from the network

Applications I

- Infotainment services
  - Driving directions
  - Where is a point of interest (POI): ATM, hotel, restaurant, …
  - Where am I? Location on a map
  - Where are my friends?
- Tracking services
  - Fleet management, taxi monitoring and dispatching
  - Children, elderly people, sick persons
  - Goods and package tracking

Applications II

- Information dissemination services
  - Content delivery wrt. the user's context & profile
  - Advertisement & e-coupons
  - Hazard warnings
- Emergency support systems
  - Police, ambulance, fire brigades
  - Roadside assistance
- Location-sensitive billing
  - Call billing based on vicinity from base/home
  - Toll payment

AT&Ts Find Friend

- User interface
  - User can add friends to a list
  - Send a SMS with a tracking request
- Privacy
  - “Invisible” mode allows to hide from all users
  - Tracking requests always generated an alert
- Services
  - Driving directions or meeting point between friends
  - Search for all friends

Location-based Services

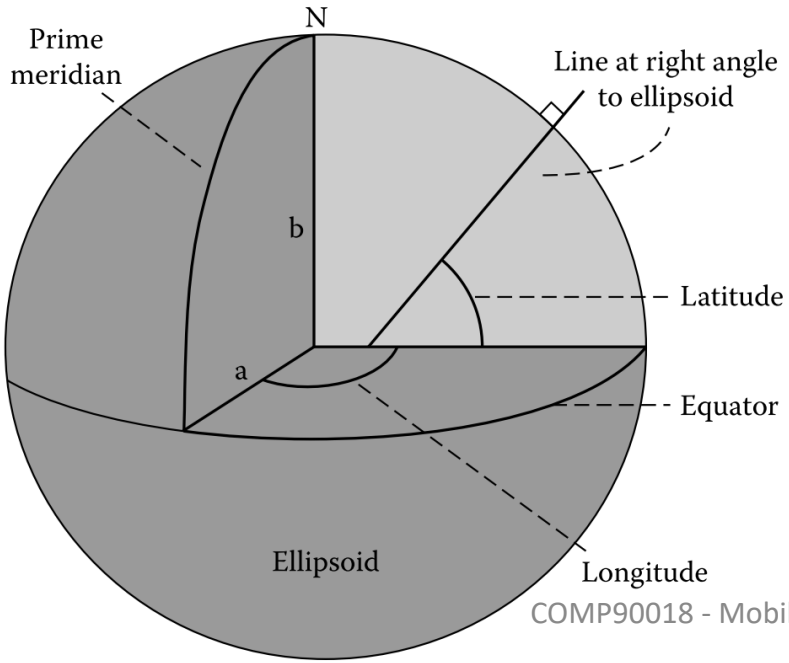
- 1st Generation
  - Manual user input of location information
  - Driving directions, nearby POIs, weather information
- 2nd Generation
  - Location information is acquired automatically within a couple of kilometers
  - Similar services as in 1st generation
- 3rd Generation
  - High position accuracy & automatic initiation of services
  - Asset tracking, street-level routing and positioning, …

Localisation technologies

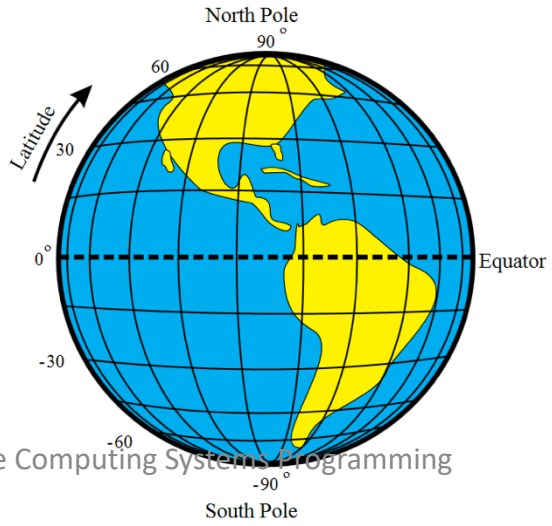
- Location enables a variety of ubicomp applications providing services appropriation to specific location and context
  - Routing phone calls to phone closest to user's current location (Want et al. 1992)
  - Sending printouts to nearest printer, displaying files specific to user's location (Schilit et al. 1999)
- Location is one of the most important components of user context
  - Allows also infering additional pieces of context (user activity, mode of transportation, social relationships)
- No single location technology is accurate, low-cost, easy to deploy and ubiquitous
  - Typically tradeoff between accuracy, coverage and cost

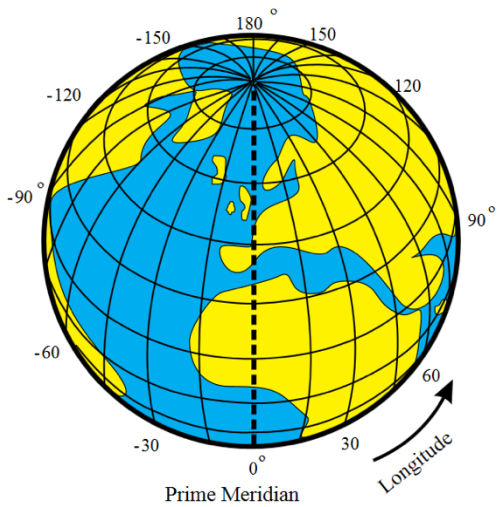
Location representation

- Location can be represented in absolute, relative or symbolic form
  - Absolute: exact position such as address or GPS coordinates
  - Relative: St Kilda is 3 km south of Melbourne
  - Symbolic: home, work, bedroom, beach, etc.
- Geographic coordinates: latitude and longitude



University of Melbourne:
37°47'49.1"S, 144°57'44.5"E



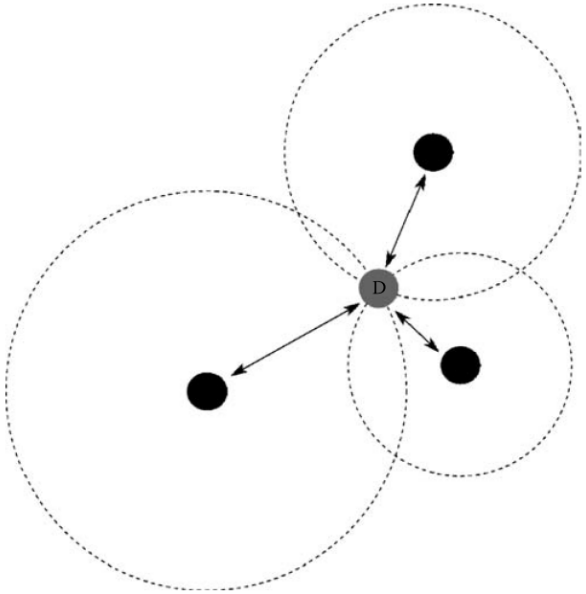


Infrastructure and client-based location systems

- Client-based location system
  - Device computes its own location
  - Example: GPS
  - Main advantage: preserves location privacy of the device
- Network-based location system
  - Network infrastructure calculates position of device
- Network-assisted location system
  - Both device and network infrastructure participate in computing location
  - Example: A-GPS

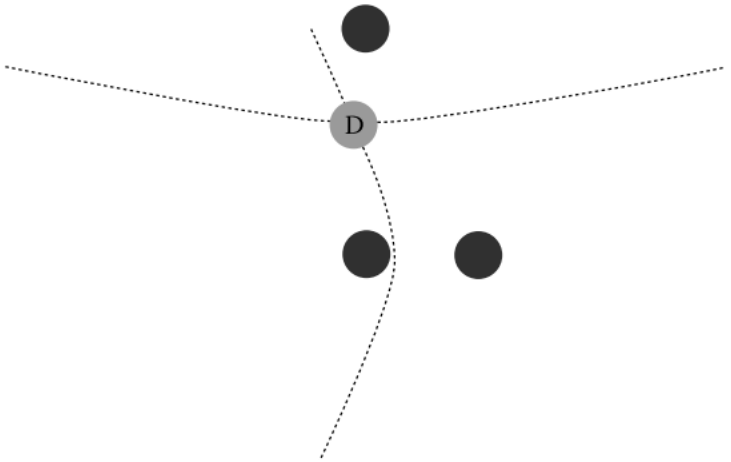
Approaches to determining location (1)

- Proximity
  - Location is estimated from closeness of device to reference point
  - Example: proximity to a wireless AP
- Trilateration
  - Position of device is computed from distances between device and reference points at known locations
    - Number of reference points = number of physical space dimensions + 1
  - Time of flight
    - Requires clock synchronization between reference points
  - Signal strength attenuation
    - Signal attenuation model
    - Subject to complex interactions with physical environment

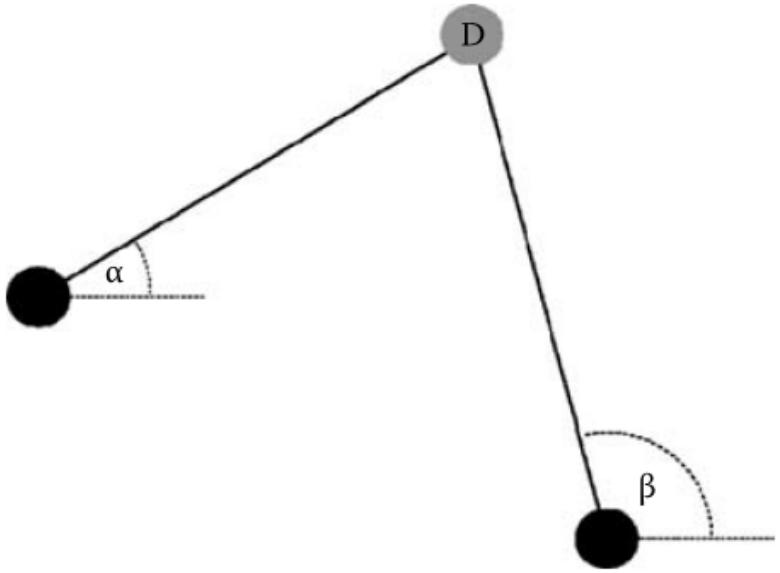


Approaches to determining location (2)

- Hyperbolic lateration
  - Difference between signal arrival times (TDOA) at two reference points defines location of device as hyperbolic line

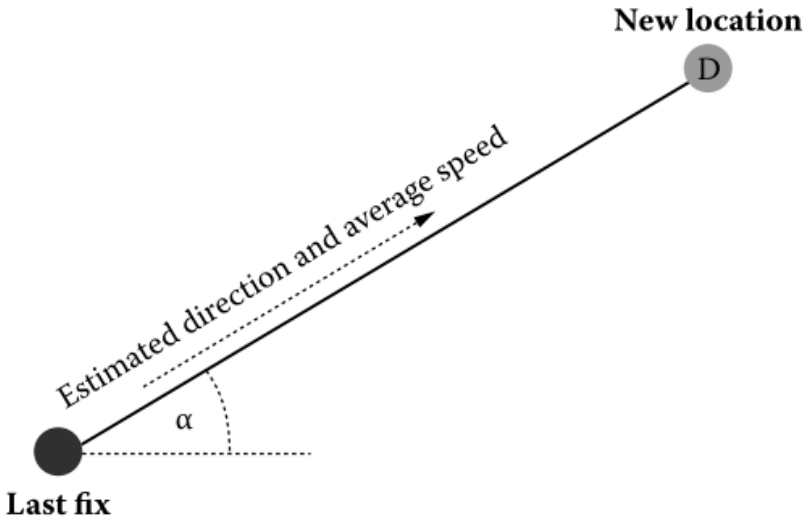


- Triangulation
  - Location is estimated from angle of arrival (AOA) of signals between device and reference points
  - Estimation of AOA requires directional antenna or antenna array, thus AOA is typically measured at reference points (not at device)



Approaches to determining location (3)

- Fingerprinting
  - RF fingerprinting relies on two properties of radio signals: temporal stability and spatial variability
  - In training phase RF measurements (”fingerprint”) are captured from target environment (spatial resolution vs positioning accuracy)
  - Location estimate is obtained by comparing current RF measurement to training measurement
  - Measurements by device, location computations by device or infrastructure
- Dead reckoning
  - Location is computed from previously known
    location (fix), elapsed time, direction and average speed of movement



Error reporting

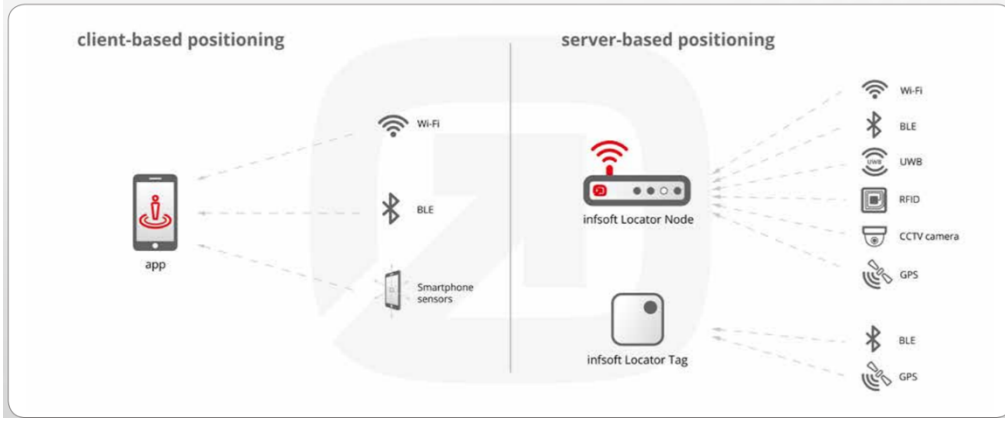
- Sources of errors
  - Incorrect reference point coordinates
  - Ionospheric and tropospheric delay
  - Clock synchronization
  - Multipath propagation
  - Geometry
- Reporting error
  - Symbolic locations: confidence intervals (correct 85% of the time)
  - Absolute locations: cumulative distribution function of location error

Location systems (some obsolete)

	Location Type	Resolution, Accuracy	Infrastructure Requirements	Location Data Storage	Spectral Requirements	Location System Type
Active Badge	Symbolic Indoor	Room level	IR Sensors and customs tag	Central	IR	Custom active tagging
ActiveBat	Absolute Indoor	3 cm, 90%	Ultrasonic (US) receivers and transmitters	Central	30 kHz ultrasound and 900 MHz RF	Custom active tagging
ActiveFloor	Symbolic Indoor	1 m, 91%	Custom floor tiles	Central	Load sensor	Passive
Airbus	Symbolic Indoor	Room level, 88%	Single sensor in HVAC	Central	Pressure sensor	Passive
Cricket	Absolute Indoor	3 cm, 90%	US receivers and transmitters	Local	30 kHz ultrasound and 900 MHz RF	Custom active tagging
GPS	Absolute Outdoor	10 m, 50%	GPS receiver	Local	1500 MHz RF	Custom active tagging
PlaceLab (GSM)	Symbolic Indoor/Outdoor	20 m, 90% 5 m, 50%	Existing GSM towers	Local	900–2000 MHz RF	Active tagging
LaceLab (WiFi)	Symbolic Indoor/Outdoor	20 m, 50%	Existing WiFi APs	Local	2.4 GHz RF	Active tagging
PowerLine Positioning	Symbolic Indoor	2 m, 93% 0.75 m, 50%	2 plug-in module and custom tag	Local or central	300–1600 kHz RF	Custom active tagging
RADAR	Symbolic Indoor	6 m, 90% 2–3 m, 50%	3–5 WiFi APs	Local	2.4 GHz RF	Active tagging
Ubisense	Absolute Indoor/Outdoor	15 cm, 90%	Custom sensors and tags	Central	2.5 GHz and 6–8 Ghz wideband RF	Custom active tagging
Vision	Absolute Indoor/Outdoor	1 m, 50–80% (varies by camera density)	Multiple cameras	Central	RF for wireless cameras	Passive

Example modern positioning system: Infsoft

infsoft Locator Node



comparison of different technologies for server-based indoor positioning

Technology	Accuracy	Range	Suitable for	Tracking	Transmitter power supply	Battery lifetime
Wi-Fi	< 15 m	< 150 m	area detection		or	medium
BLE	< 8 m	< 75 m	area detection			high
UWB	< 30 cm	< 150			or	low to medium
RFID	< 10 cm	< 1			— (passive RFID tag)	— (passive RFID tag)

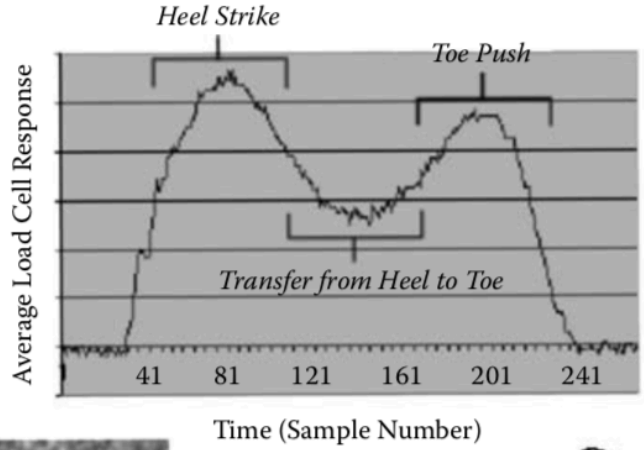
Technology	Accuracy	Range	Cross-Platform
Wi-Fi	5-15 m	< 150 m	
BLE	1-3 m	< 30 m	

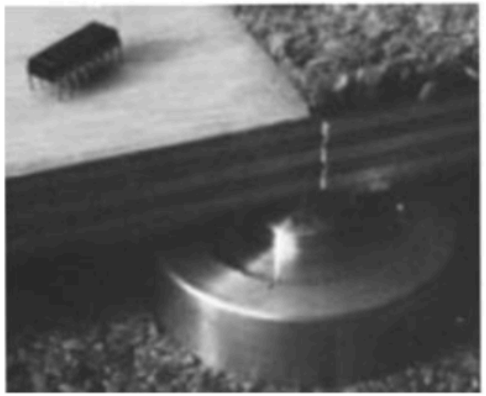
Comparison of Wi-Fi and BLE for client-based indoor positioning

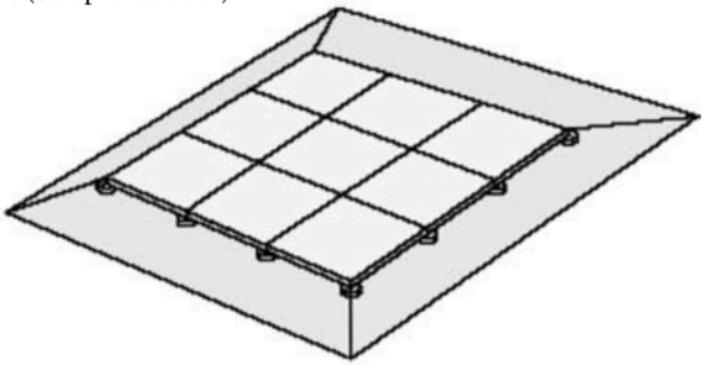
Comparison of indoor positioning systems (Batistic & Tomic, 2018)

IPS	Technology	Accuracy	Cost (installation/ unit)	Advantages	Disadvantages	Complexity
RADAR	WiFi	2-3 m	L/L	Low price, existing infrastructure	Low accuracy, complex system	Medium
Ekahau	WiFi	1-3 m	H/L	Existing infrastructure, good mapping software	Expensive mapping software	Low
LANDMARC	RFID	2 m	H/L	Very cheap user units	Locating delay 7.5 s	Medium
Active Bat	Ultrasound	3 cm	H/L	Cheap user units, very precise	Requires a lot of beacons, medium battery life	High
Lok8	Ultrasound	10 cm	L/L	Smartphone user units, precise	Requires new infrastructure in every room	Medium
Topaz	Bluetooth	2 m	L/L	Low price	Locating delay 15-30 s	Medium
iBeacon	Bluetooth	0.5-3 m	H/L	Smartphone user units, ease of access	Requires a lot of beacons for better precision	Low
Beauregard et al.	Inertial	0.74-2.5 m	L/L	Cheap, map can be added post-hoc	Requires a detailed map for better precision	Medium
Ubisense	Ultra-wideband	15 cm	H/H	Very precise, very robust	Expensive installation and units	High
Leppäkoski et al.	Inertial +WiFi	3 m	L/L	Cheap, could work on smartphone	Low accuracy, time consuming installation	Medium
Cricket	Ultrasound + RF	10 cm	H/L	Cheap user units, provides privacy, precise	complex installation, low battery life	High
Han Zou et al.	Inertial +WiFi +Bluetooth	0.59 m	L/L	Cheap, precise	Requires detailed mapping	Medium

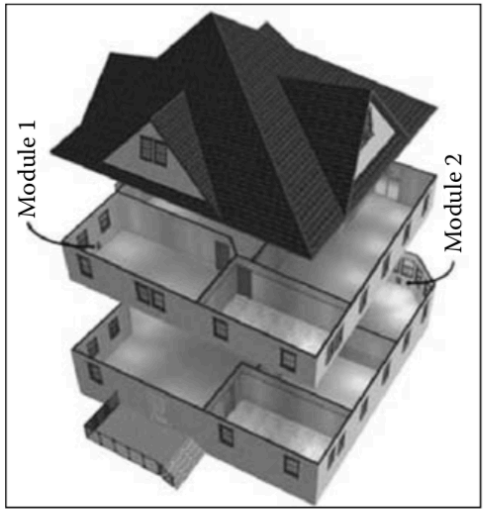
Smart floor

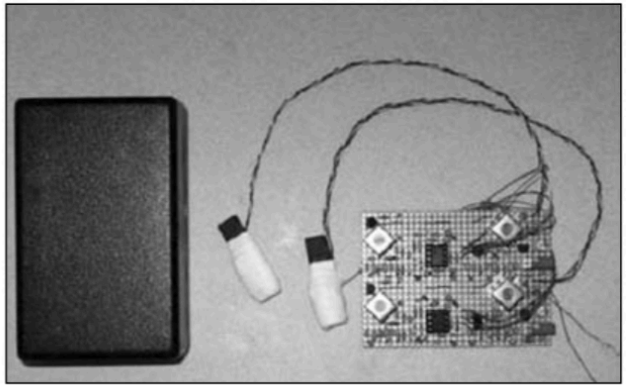

Heel Strike
Toe Push
Transfer from Heel to Toe
Average Load Cell Response
41
81
121
161
201
241
Time (Sample Number)



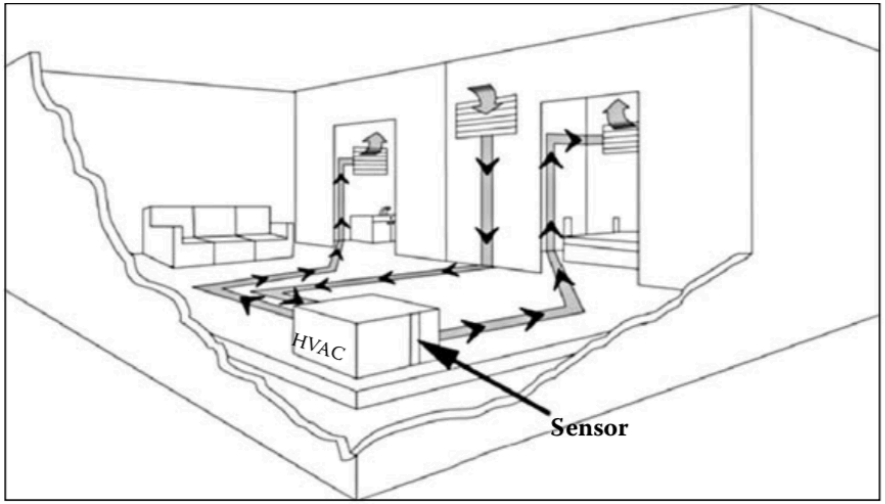


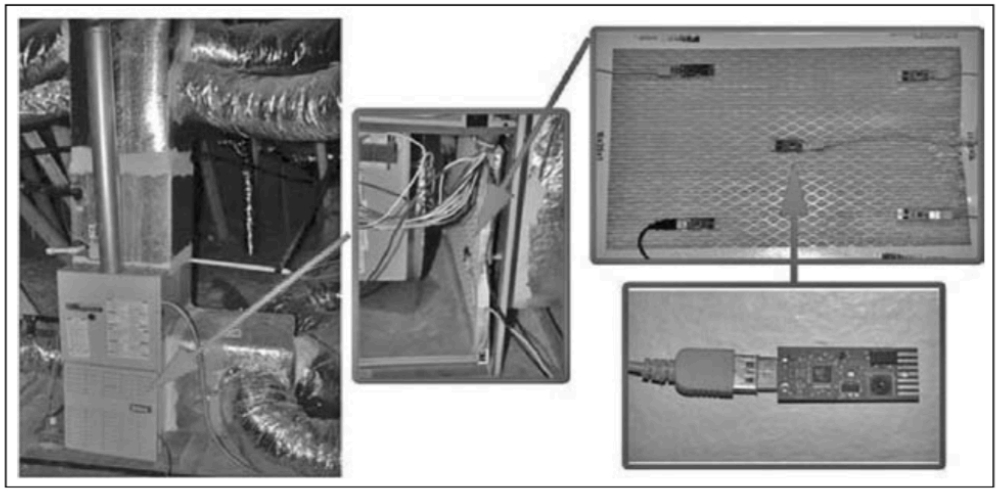
In-home localisation





Sensing via air pressure





Break! – 15 min

- During the break, please complete the questionnaire at:

- http://go.unimelb.edu.au/jb8r

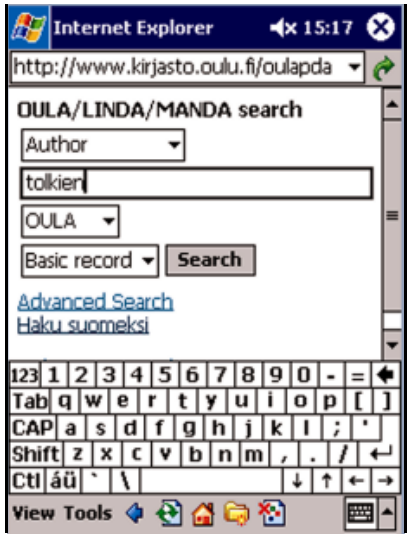
Selected examples of research on location-aware systems

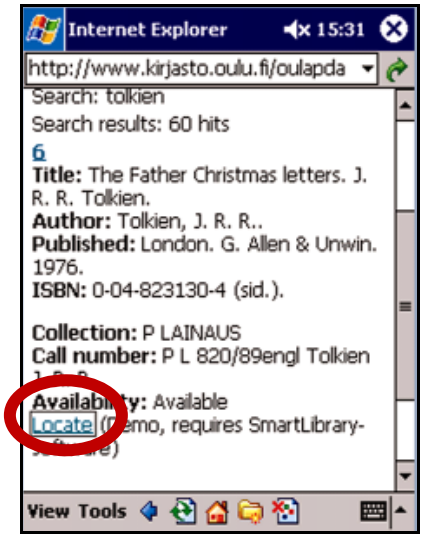
SmartLibrary (2003)

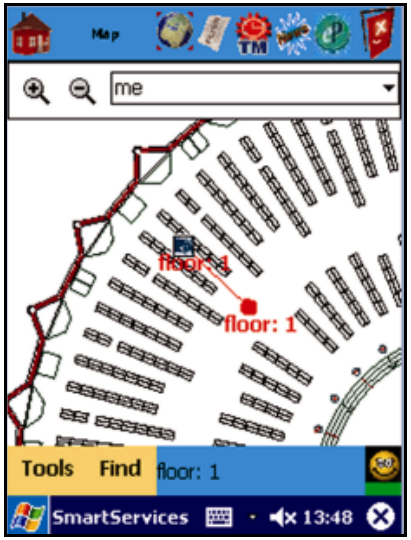
- One of the first examples
  - Adaptation of existing service for various mobile devices
    - Automatic UI adaptation based on HTTP user agent
  - Optional map-based guidance
    - WLAN positioning of the device based on RF fingerprint
- Motivation
  - To provide mobile access to library database
  - To assist library users in finding books by themselves
    - Users not familiar with the shelf classification system overload the library staff with their requests for guidance

SmartLibrary version 1

- Separate client application for WLAN positioning of the PDA
- "Raw" graphics
- In user evaluation map-based guidance to books proved useful, especially to novice library patrons
  - Usefulness of dynamic relative user positioning remained doubtful



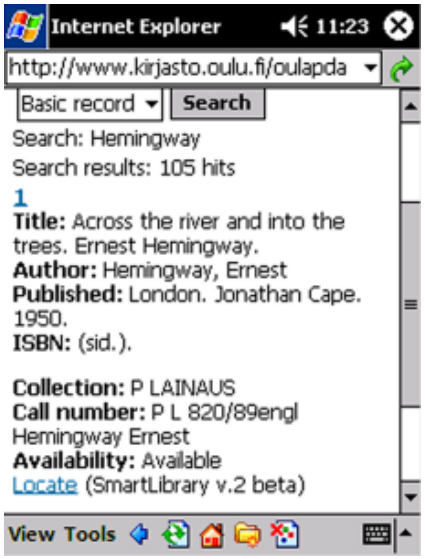


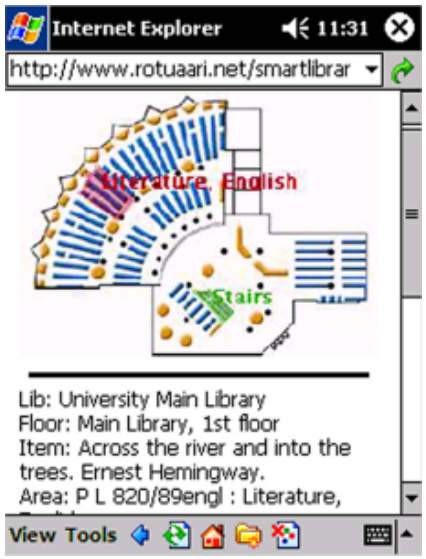


Aittola M, Ryhänen T & Ojala T (2003) **SmartLibrary - Location-aware mobile library service**. Proc. Mobile HCI 2003, Udine, Italy, 411-416.

SmartLibrary version 2

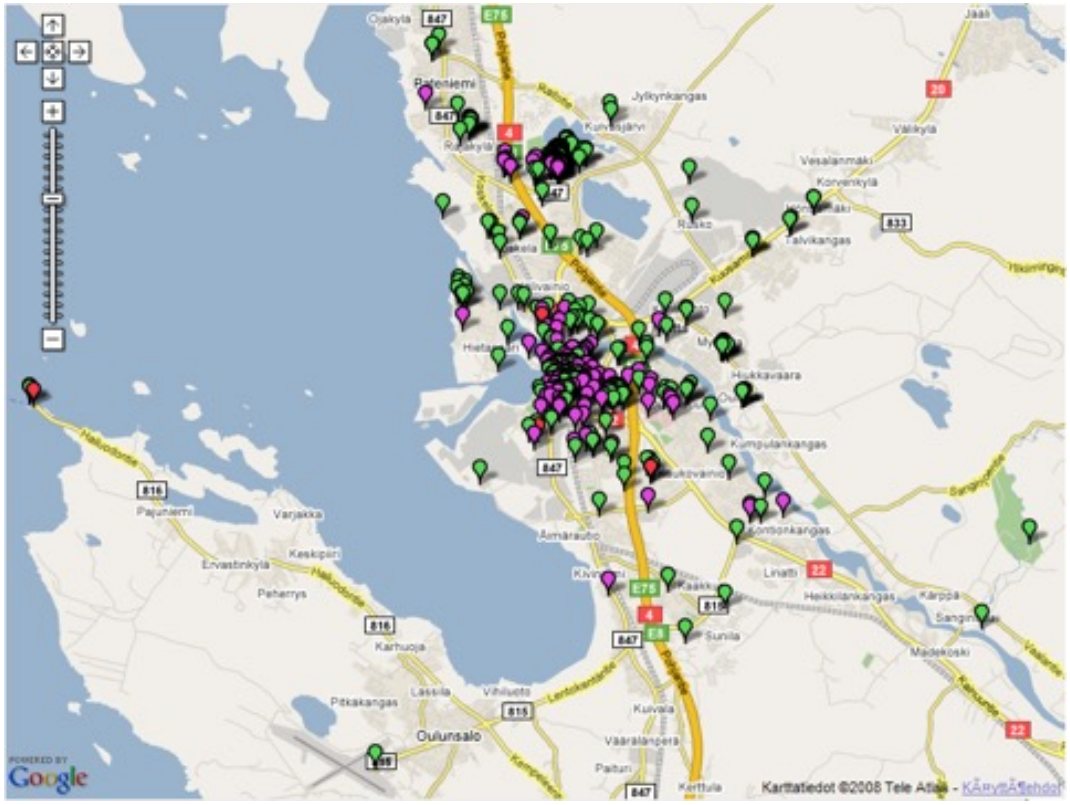
- Pure web-based (XHTML) browsing UI
- Web CPI (Content Provider Interface) for content management
  - Other library resources included, in addition to books
- Improved graphics
  - Had to create floorplans for the whole university :)



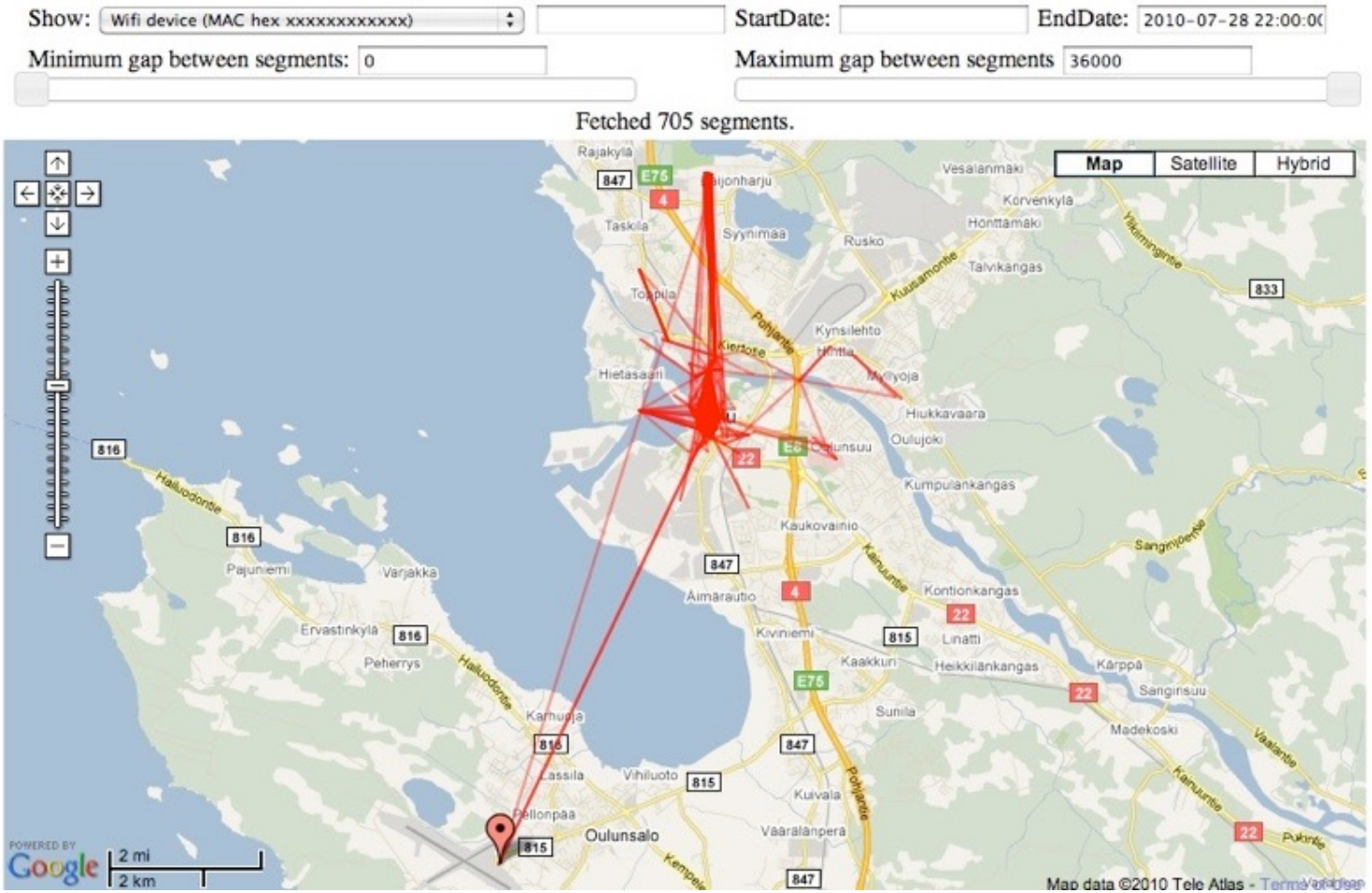


Aittola M, Parhi P, Vieruaho M & Ojala T (2004) **Comparison of mobile and fixed use of SmartLibrary**. Proc. MobileHCI 2004, Glasgow, Scotland, 383-387.

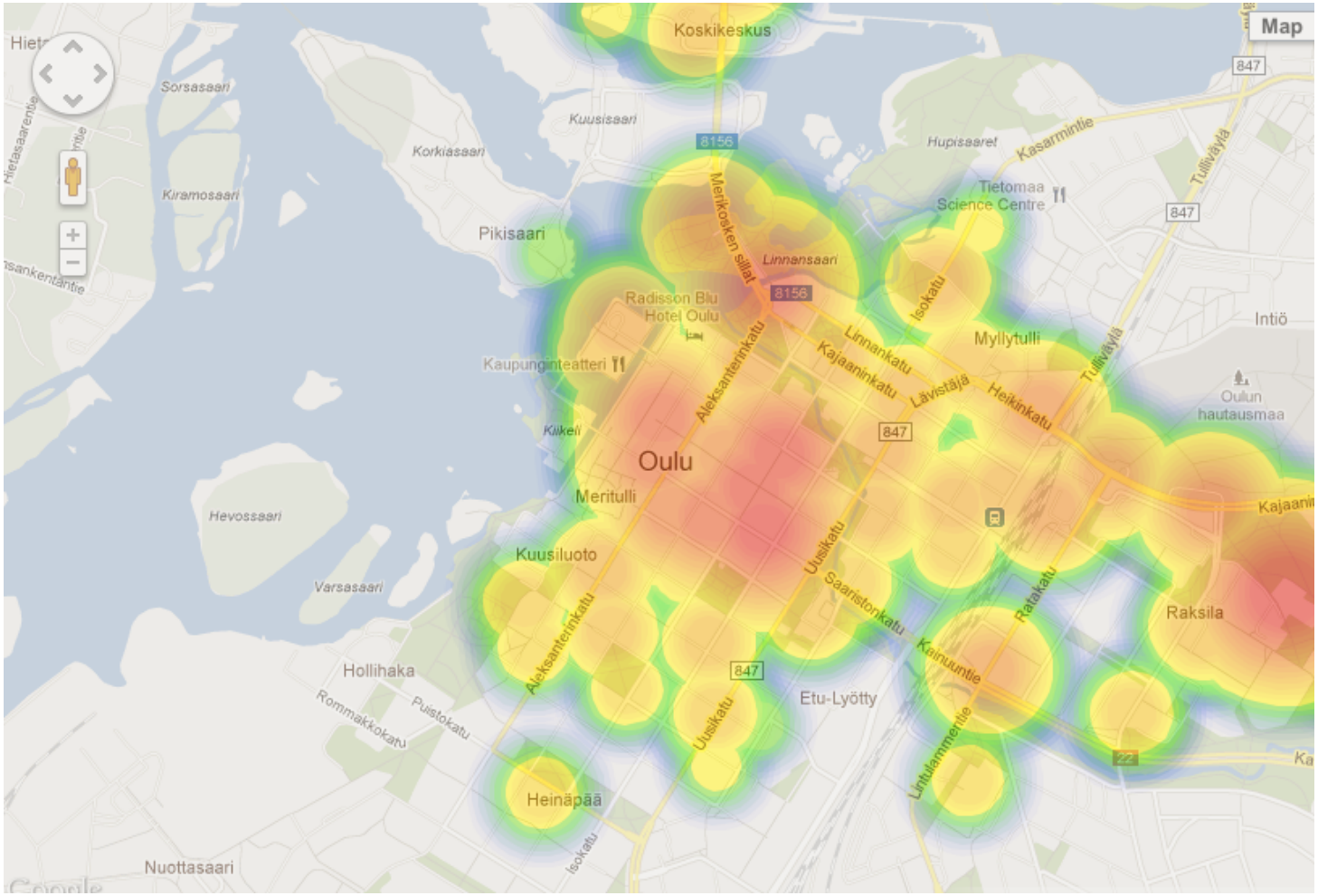
panOulu WiFi



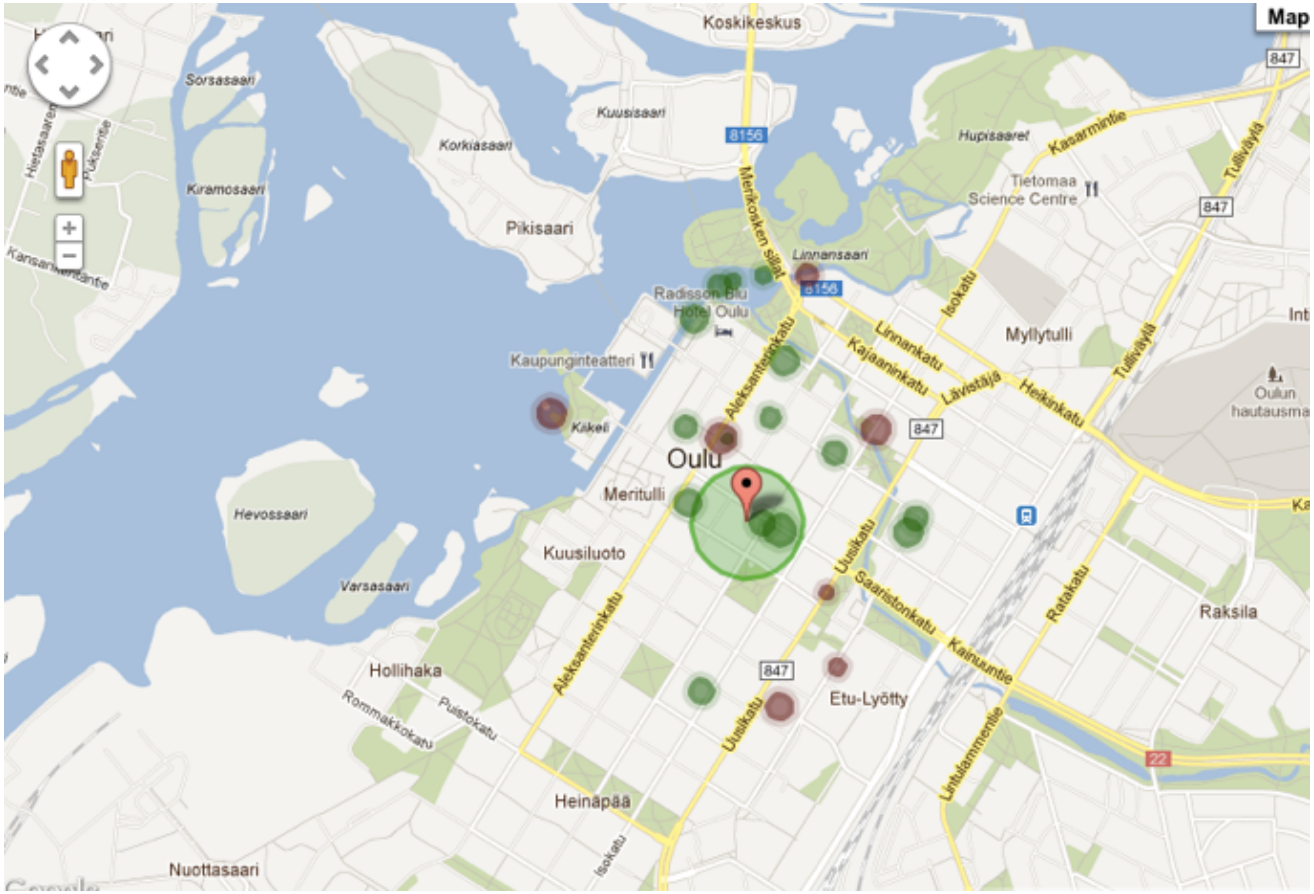
Reconstructing movement



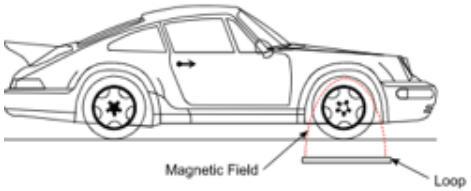
Where is it busy now?

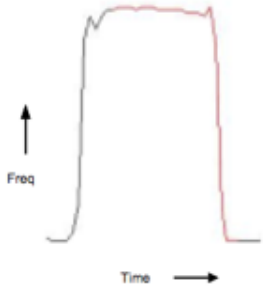


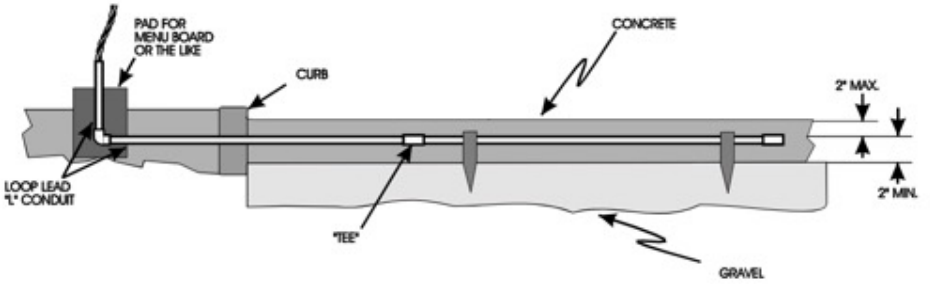
Catchment areas

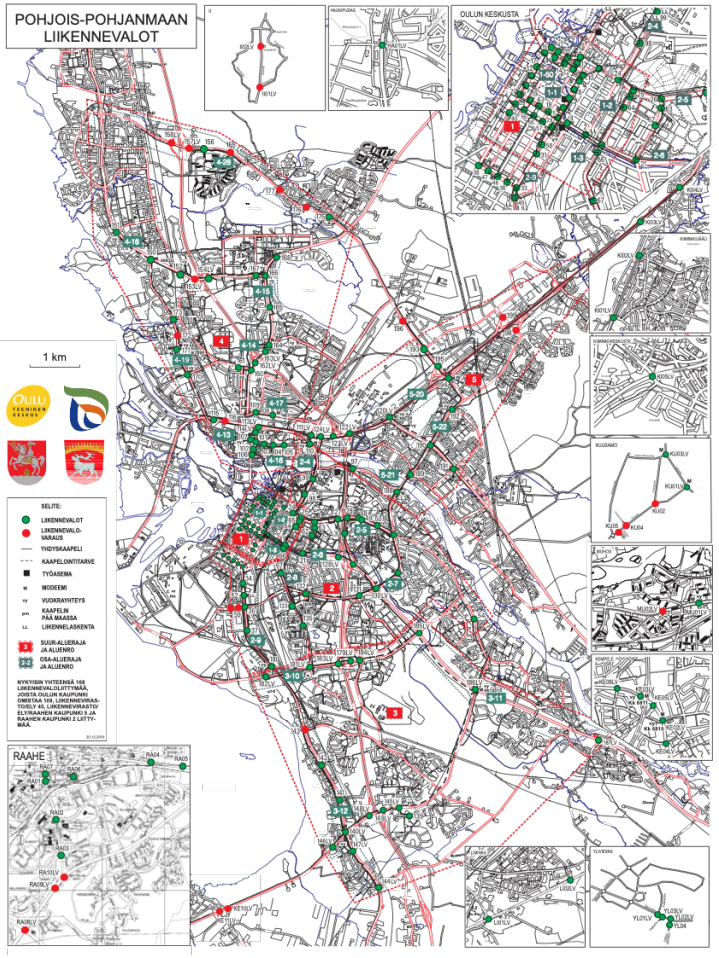


Induction loops

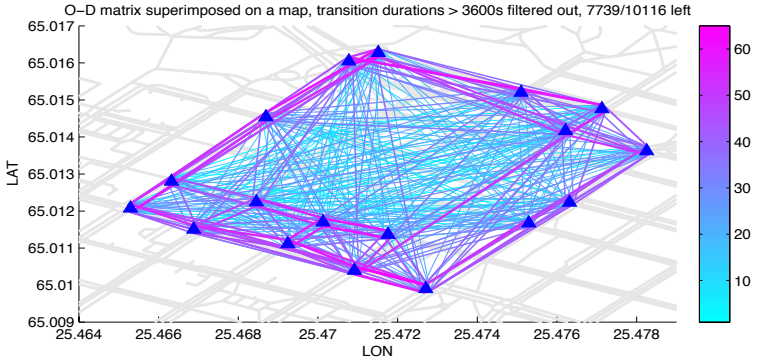


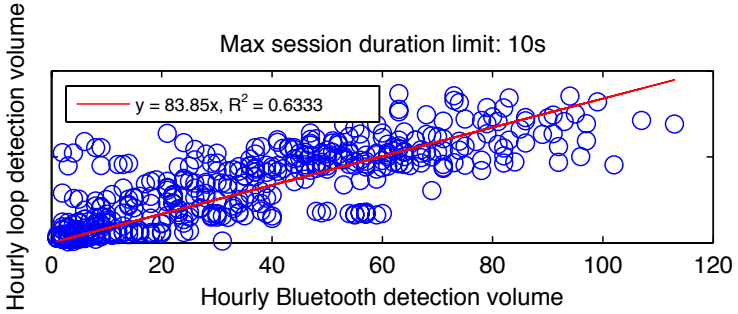






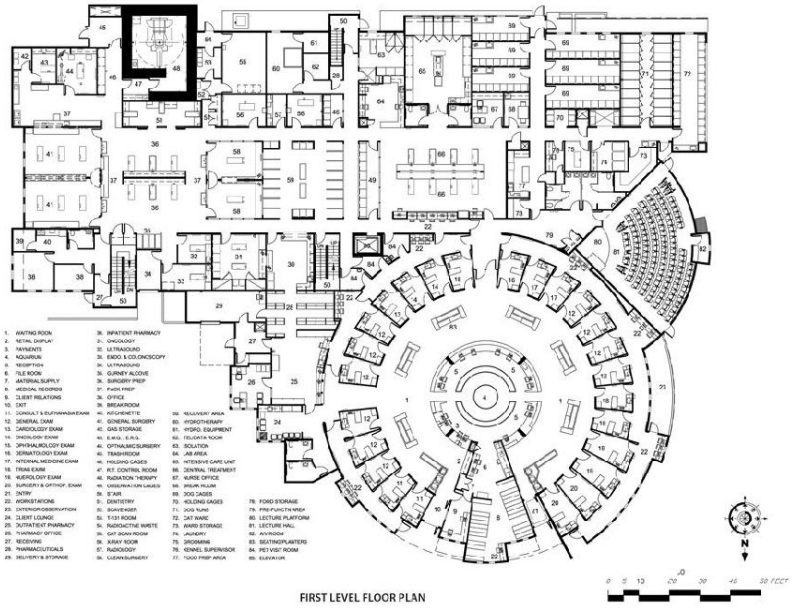
Smarter traffic lights

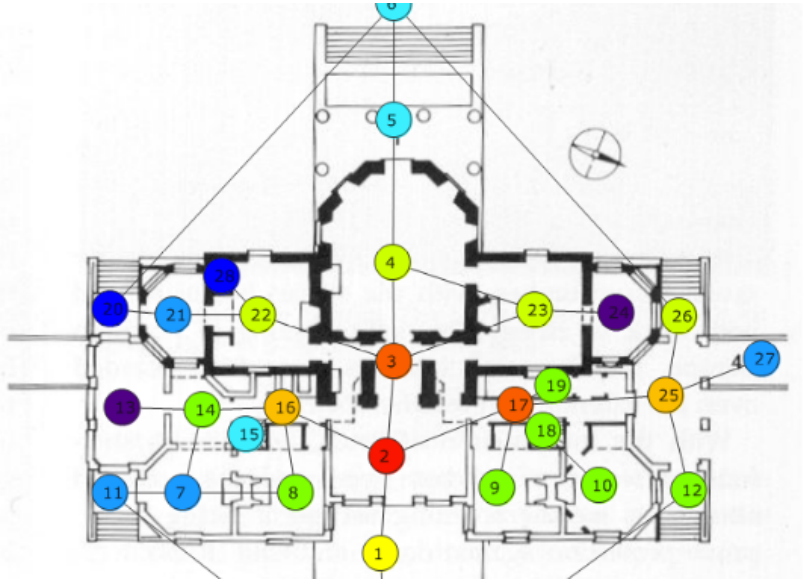




Operating theatre tracking

Track patients/staff in & out of operating theatres



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NP Airway T Bag
Combine Large &
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SUCTION
OXYGEN


OR 3
THE UNIVERSITY OF MELBOURNE
DO NOT UNPLUG!
Project: Reliable Operating Rooms (ROR)
In collaboration with The University of Melbourne
For more information contact:
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vassilis.kostakos@unimelb.edu.au
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OR 1
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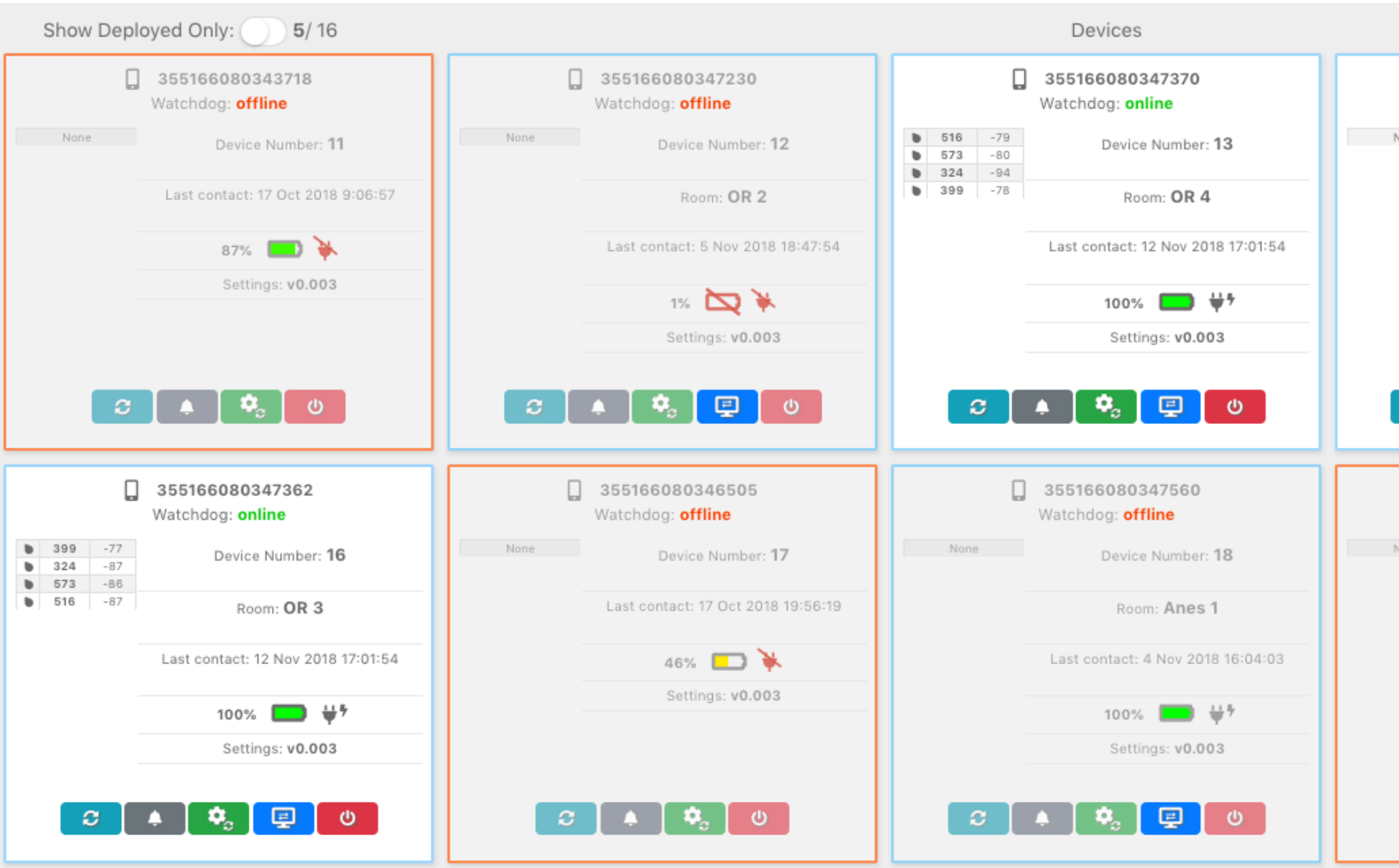
Show Deployed Only:
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Watchdog: offline
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Device Number: 11
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Settings: v0.003
355166080347230
Watchdog: offline
None
Device Number: 12
Room: OR 2
Last contact: 5 Nov 2018 18:47:54
1%
Settings: v0.003
355166080347370
Watchdog: online
516 -79
573 -80
324 -94
399 -78
Device Number: 13
Room: OR 4
Last contact: 12 Nov 2018 17:01:54
100%
Settings: v0.003
355166080347362
Watchdog: online
399 -77
324 -87
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Device Number: 16
Room: OR 3
Last contact: 12 Nov 2018 17:01:54
100%
Settings: v0.003
355166080346505
Watchdog: offline
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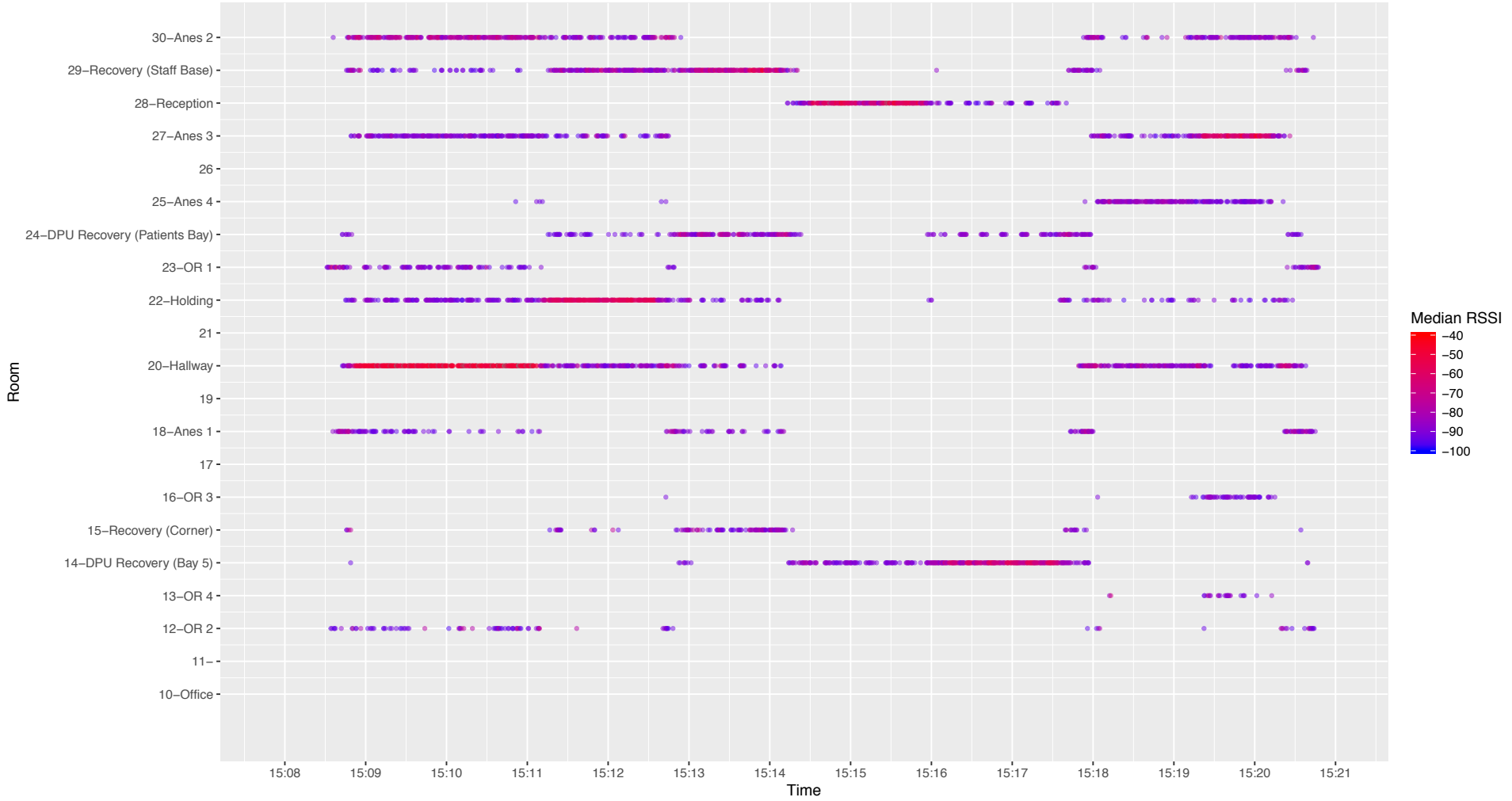
Device Number: 17
Last contact: 17 Oct 2018 19:56:19
46%
Settings: v0.003
355166080347560
Watchdog: offline
None
Device Number: 18
Room: Anes 1
Last contact: 4 Nov 2018 16:04:03
100%
Settings: v0.003


30–Anes 2
29–Recovery (Staff Base)
28–Reception
27–Anes 3
26
25–Anes 4
24–DPU Recovery (Patients Bay)
23–OR 1
22–Holding
21
20–Hallway
19
18–Anes 1
17
16–OR 3
15–Recovery (Corner)
14–DPU Recovery (Bay 5)
13–OR 4
12–OR 2
11–
10–Office
Room
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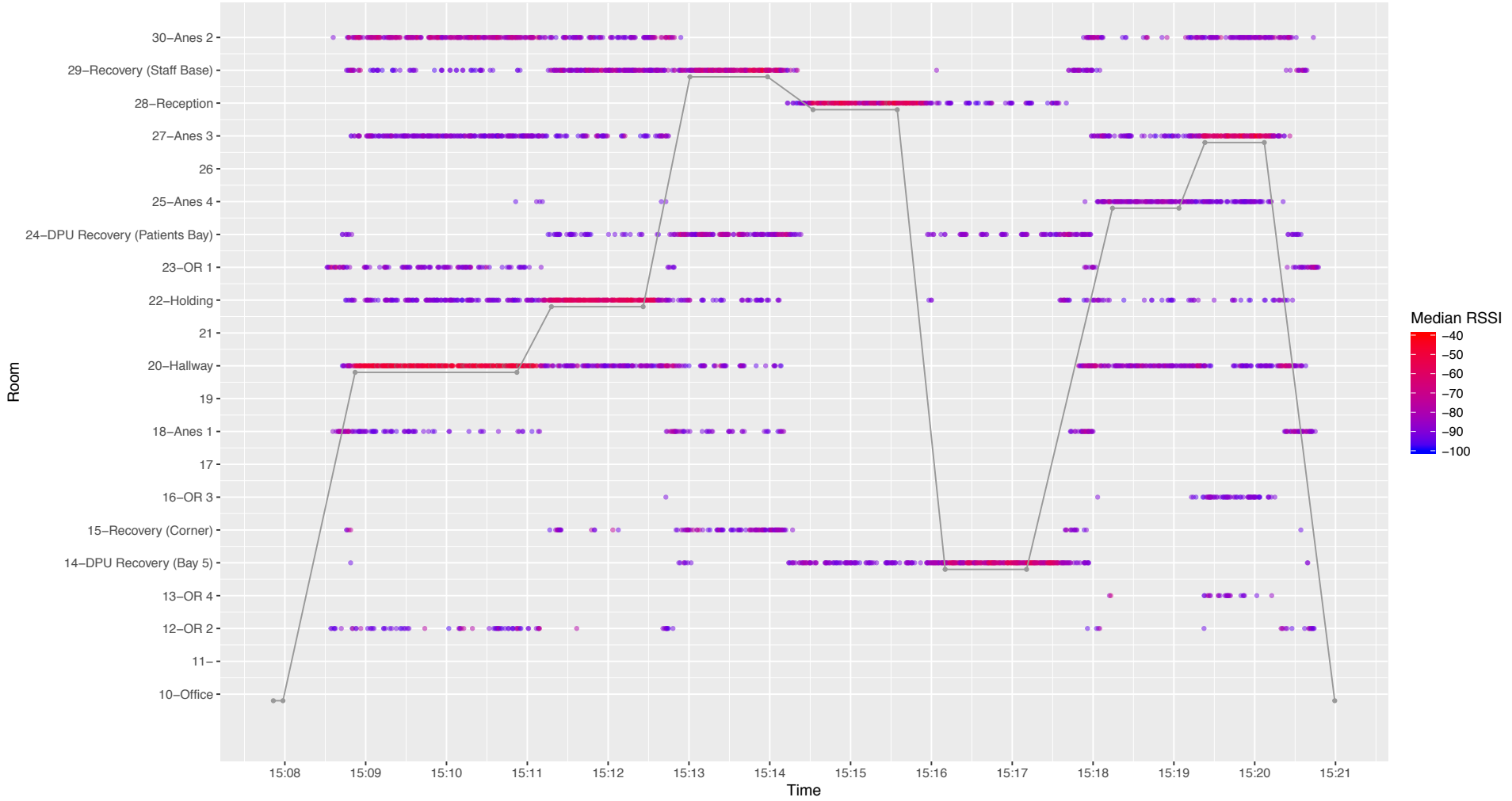
30–Anes 2
29–Recovery (Staff Base)
28–Reception
27–Anes 3
26
25–Anes 4
24–DPU Recovery (Patients Bay)
23–OR 1
22–Holding
21
20–Hallway
19
18–Anes 1
17
16–OR 3
15–Recovery (Corner)
14–DPU Recovery (Bay 5)
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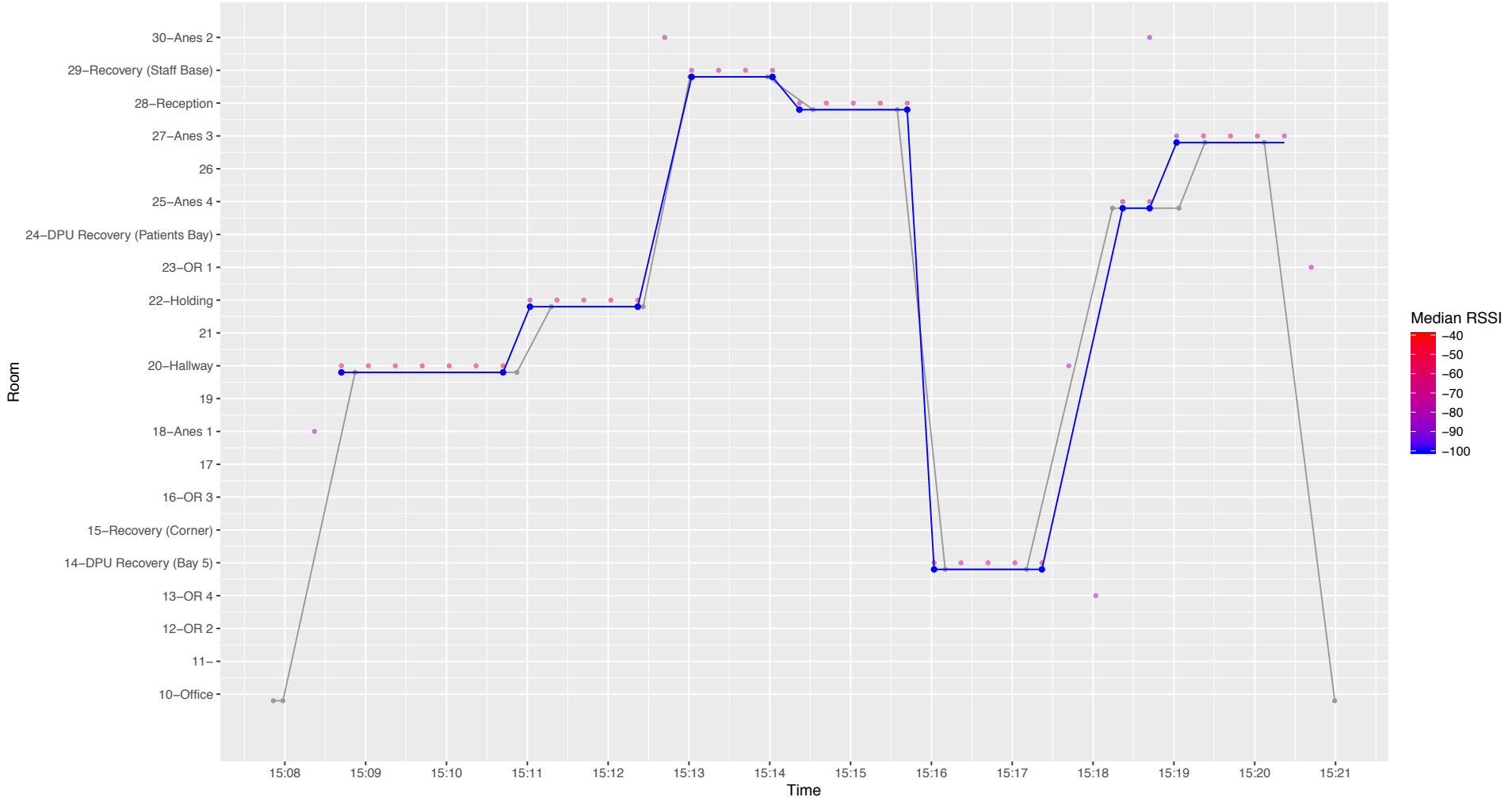
30–Anes 2
29–Recovery (Staff Base)
28–Reception
27–Anes 3
26
25–Anes 4
24–DPU Recovery (Patients Bay)
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16–OR 3
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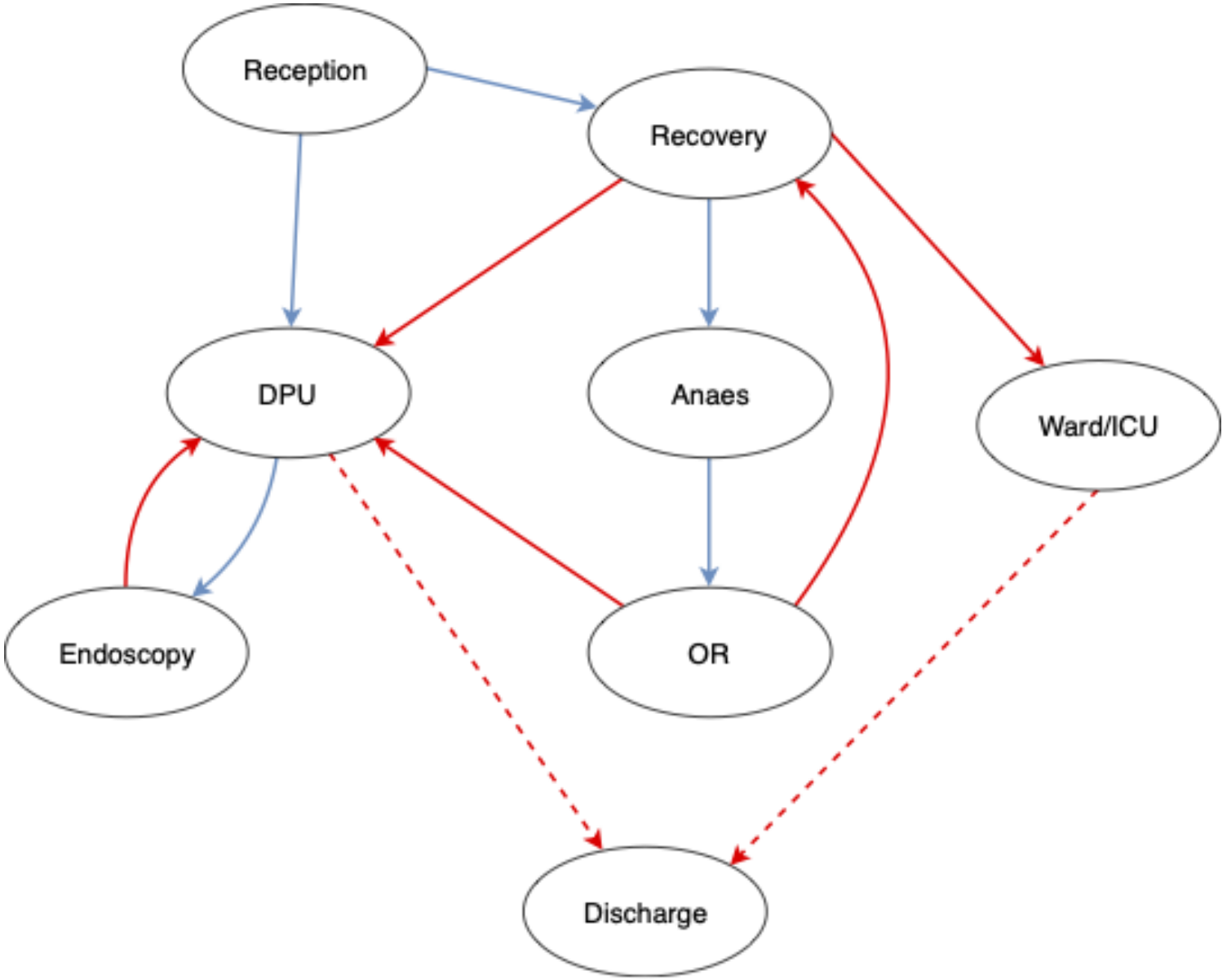
Reception
Recovery
DPU
Anaes
Ward/ICU
Endoscopy
OR
Discharge

Summary

- Characterizing location technologies
  - Location representation
  - Infrastructure and client-based location systems
  - Approaches to determining location
  - Error reporting

- Location systems