LOCATION IN UBIQUITOUS COMPUTING LOCATION SYSTEMS

By

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OUTLINE

- Introduction
- Location system
- Global Positioning System
  - Active Badge
  - Active Bat
  - Cricket
  - UbiSense
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  - Place Lab
  - PowerLine Positioning
  - ActiveFloor
  - Airbus and Tracking with Cameras

INTRODUCTION

- Localization has been very active and rich research problem in the research comm unity.
- Several characteristics distinguish the different solutions such as
  - IR, RF, load sensing , computer vision, or audition
  - Line of sight requirement
  - Accuracy
  - Cost of scaling over space of No of objects
- Providing a survey of the current systems that have addressed the location trackin g requirement using variety of ways.

TABLE 7.2 Location Tracking Technologies across a Collection of Factors Used to Evaluate a Particular Location System

	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	Multiple cameras	Central	RF for wireless cameras	Passive

CONSIDERATION

- Performance or accuracy of the system and its resolution
  - E.g., low resolution for weather forecast and high resolution for the navigation indoor
- Infrastructure requirement
  - to evaluate the ease and deployment, cost , installation , maintenance

GLOBAL POSITION SYSTEM

Most common outdoor locating system

GLOBAL POSITION SYSTEM

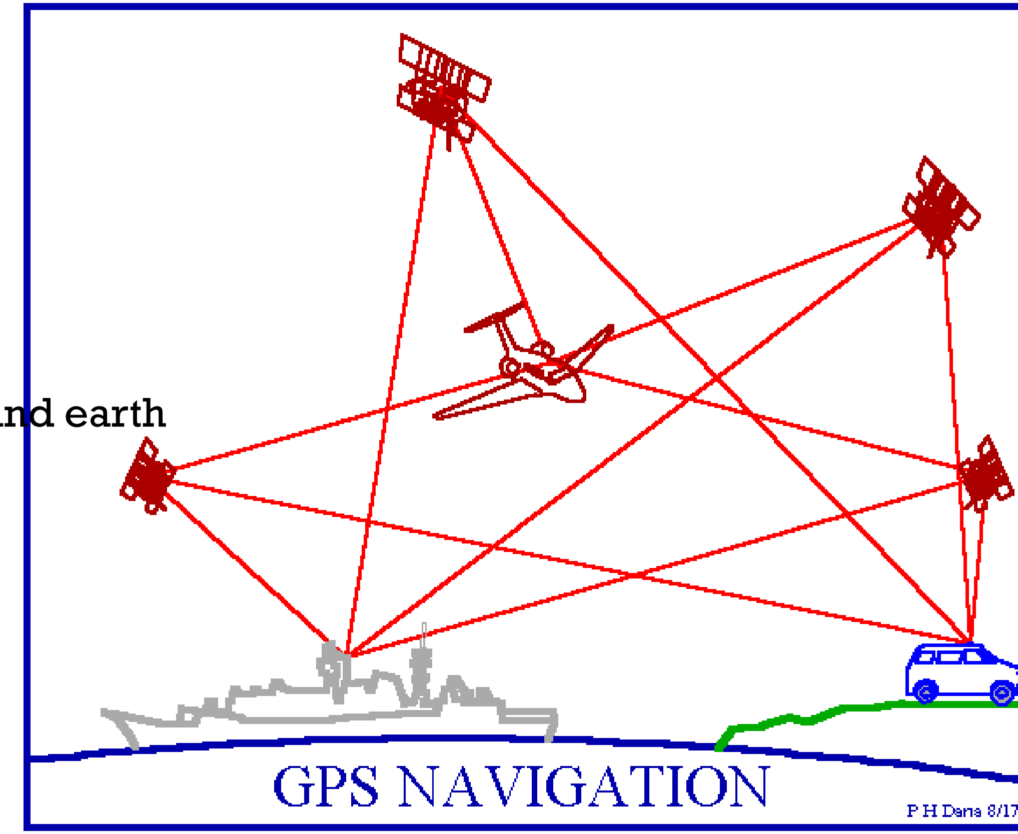
- Was originated for military application but nowadays
  - In-car navigation system, marine navigation , and fleet management system.
- Civilian application of GPS has accuracy of 10 meters
  - Obstructions reduce this accuracy
  - Tall building, large mountains, etc.
- Indoor navigation does not work well
  - because of the occlusion from the satellite

DEFINITION

- The **Global Positioning System** (**GPS**) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. **GPS** was originally intended for military applications, but in the 1980s, the government made the system available for civilian use.

GLOBAL POSITION SYSTEM

- Geosynchronous satellite orbiting
- Minimum satellites to locate successfully
  - Four satellites
- Receivers that passively receive signals
  - From subset of at least 24 satellites orbiting around earth



GLOBAL POSITION SYSTEM

- Each GPS satellite transmits data that contains its location and the current time
- Although the signals transmitted by the satellites are synchronized,
- They arrive at the receiver at different times due to the difference in distance betw een the satellites and the receiver.
  - Thus, the distance to the GPS satellites can be determined by **estimating** the amount of ti me it takes for their signals to reach the receiver.
  - At least four GPS satellites are needed to calculate the position of the receiver.

IS MILITARY GPS MORE ACCURATE TH AN CIVILIAN GPS?

- The accuracy of the GPS signal in space is actually the same for both the civilian G PS service (SPS) and the military GPS service (PPS).
- However, SPS broadcasts on one frequency, while PPS uses two.
- This means military users can perform *ionospheric correction,* a technique that red uces radio degradation caused by the Earth's atmosphere.
  - With less degradation, PPS provides better accuracy than the basic SPS.

GPS ACCURACY

- The actual accuracy users attain depends on factors outside the government's contr ol, including atmospheric effects, sky blockage, and receiver quality.
- Real-world data from the FAA show that their high-quality GPS SPS receivers provid e better than 3.5 meter horizontal accuracy.

GPS FREQUENCIES

- L1 (1575.42 MHz) - Mix of Navigation Message, coarse-acquisition (C/A) code and encrypted precision P(Y) code.
- L2 (1227.60 MHz) - P(Y) code, plus the new L2C code on the Block II R-M and newer satellites.
- L3 (1381.05 MHz) - Used by the Defense Support Program to signal detection of missile launches, nuclear detonations, and other applic ations.

GPS Frequencies

Band	Frequency (MHz)	Phase	Original usage	Modernized usage
L1	1575.42 (10.23×154)	In-phase (I)	Encrypted Precision P(Y) code	
		Quadrature-phase (Q)	Coarse-acquisition (C/A) code	C/A, L1 Civilian (L1C), and Military (M) code
L2	1227.60 (10.23×120)	In-phase (I)	Encrypted Precision P(Y) code	
		Quadrature-phase (Q)	Unmodulated carrier	L2 Civilian (L2C) code and Military (M) code
L3	1381.05 (10.23×135)		Used by Nuclear Detonation (NUDET) Detection System Payload (NDS); signals nuclear detonations/ high-energy infrared events. Used to enforce nuclear test ban treaties.	
L4	1379.913 (10.23×1214/9)		*(No transmission)*	Being studied for additional ionospheric correction
L5	1176.45 (10.23×115)	In-phase (I)	*(No transmission)*	Safety-of-Life (SoL) Data signal
		Quadrature-phase (Q)		Safety-of-Life (SoL) Pilot signal

DEGRADATION FACTORS

- Multipath :
  - Occurs when the GPS signal is reflected off the tall building ,
  - Increase the time-of-flight of the signal
- Visible satellites
  - Obstructions and indoors block GPS
- Atmospheric delay:
  - Signal can slow as they pass through the atmosphere

CORRECTION OF ERRORS

- Predict and model the atmospheric delay and
  - Apply constant correction factor to the received signal
- To increase the number of channels sent by the satellite
  - To enforce the visibility of the satellite(in term of signals)
- Differential GPS(DGPS) uses a network of fixed,
  - ground-based reference stations to broadcast the difference between the positions indic ated by the satellite systems and the known fixed positions
- Phase measurement from existing GPS signals to provide the receiver with real-tim e corrections.
  - Real-time Kinematic GPS

APPLICATIONS – MILITARY

- Military GPS user equipment has been integrated into fighters, bo mbers, tankers, helicopters, ships, submarines, tanks, jeeps, and sol diers' equipment.
- In addition to basic navigation activities, military applications of GP S include target designation of cruise missiles and precision-guide d weapons and close air support.
- To prevent GPS interception by the enemy, the government controls GPS receiver exports
- GPS satellites also can contain nuclear detonation detectors.

APPLICATIONS – CIVILIAN

- Automobiles are often equipped GPS receivers.
  - They show moving maps and information about your position on the ma p, speed you are traveling, buildings, highways, exits etc.
  - Some of the market leaders in this technology are Garmin and TomTom, not to mention the built in GPS navigational systems from automotive ma nufacturers.

APPLICATIONS – CIVILIAN (CONT'D)

- For aircraft, GPS provides
  - Continuous, reliable, and accurate positioning information for all phases of flight on a global basis, freely available to all.
  - Safe, flexible, and fuel-efficient routes for airspace service providers an d airspace users.
  - Potential decommissioning and reduction of expensive ground based na vigation facilities, systems, and services.
  - Increased safety for surface movement operations made possible by sit uational awareness.

APPLICATIONS – CIVILIAN (CONT'D)

- Agriculture
  - GPS provides precision soil sampling, data collection, and data analysis, enable localized variation of chemical applications and planting density to suit specific areas of the field.
  - Ability to work through low visibility field conditions such as rain, dust, f og and darkness increases productivity.
  - Accurately monitored yield data enables future site-specific field prepar ation.

APPLICATIONS – CIVILIAN (CONT'D)

- Disaster Relief
  - Deliver disaster relief to impacted areas faster, saving lives.
  - Provide position information for mapping of disaster regions where little or no mapping information is available.
  - Example, using the precise position information provided by GPS, scient ists can study how strain builds up slowly over time in an attempt to char acterize and possibly anticipate earthquakes in the future.

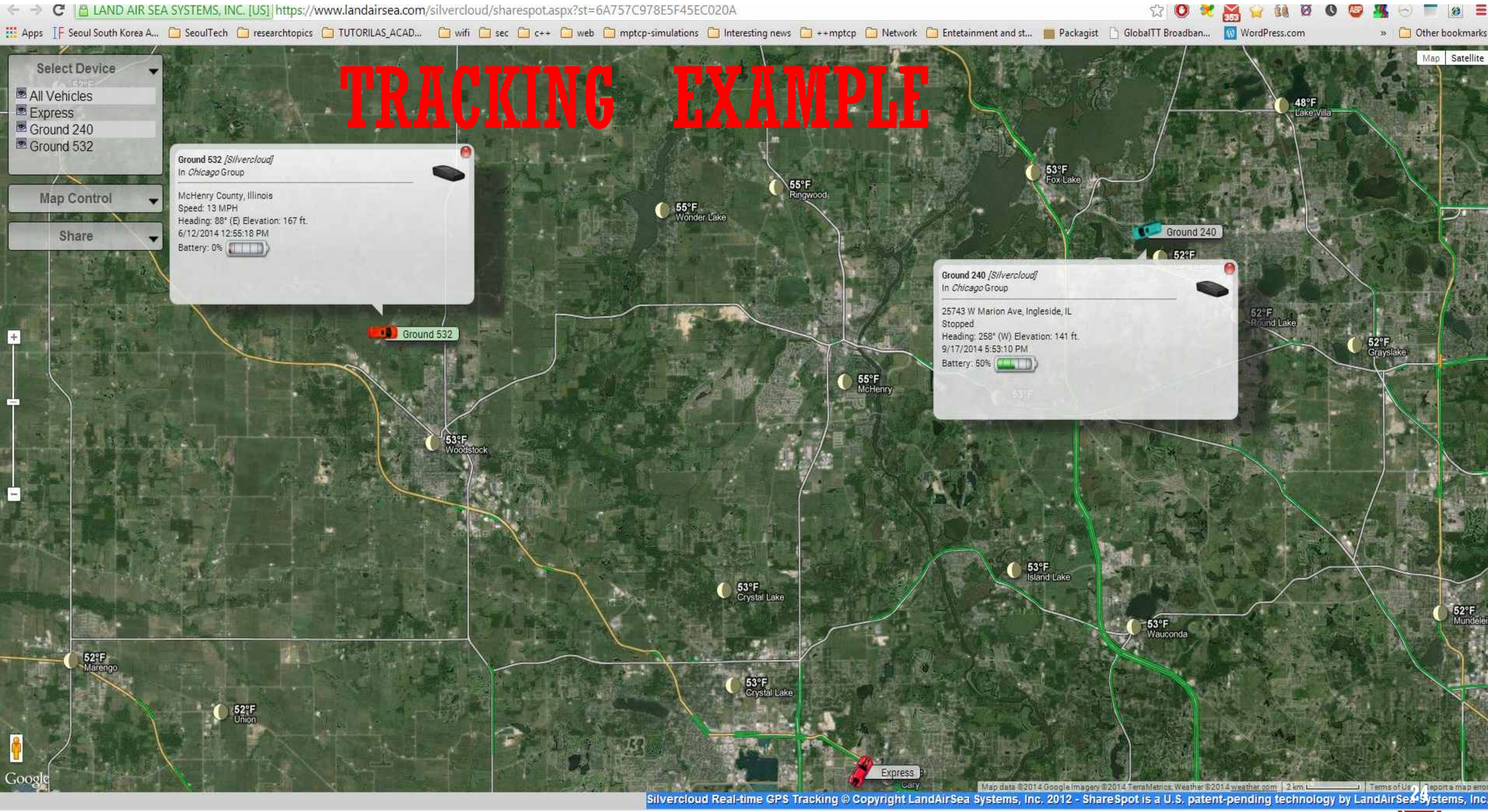
APPLICATIONS – CIVILIAN (CONT'D)

- Marine applications
  - GPS allows access to fast and accurate position, course, and speed infor mation, saving navigators time and fuel through more efficient traffic rou ting.
  - Provides precise navigation information to boaters.
  - Enhances efficiency and economy for container management in port fac ilities.

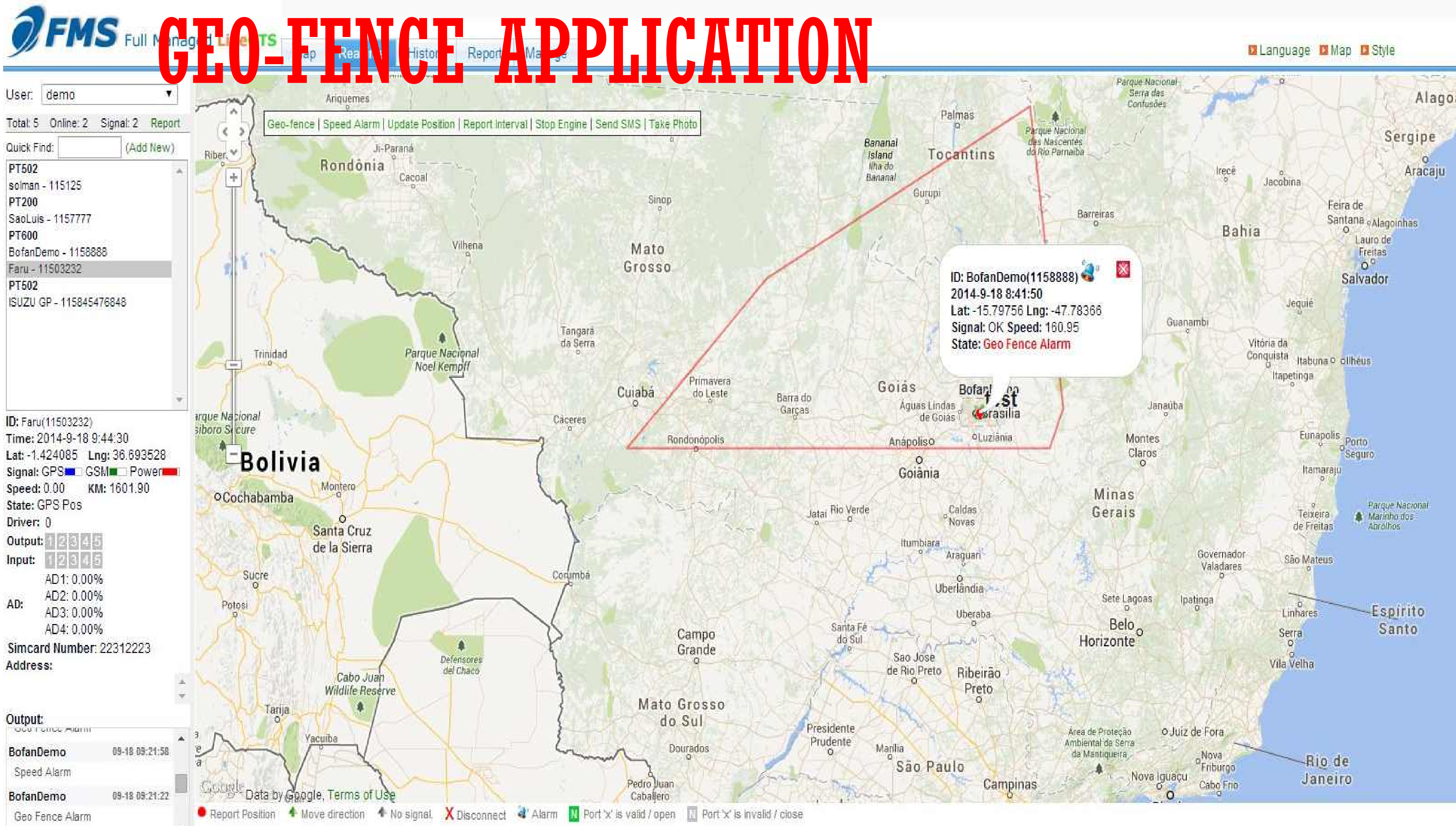
APPLICATIONS – CIVILIAN (CONT'D)

- Other Applications not mentioned here include
  - Railroad systems
  - Recreational activities (returning to the same fishing spot)
  - Heading information – replacing compasses now that the poles are shifti ng
  - Weather Prediction
  - Skydiving – taking into account winds, plane and dropzone location
  - Many more!

TRACKING EXAMPLE



GEO-FENCE APPLICATION



DEMO-

- http://demo.livegts.com/gps_realtime.php

ACTIVE BADGE

First indoor location tracking system (Want et al.,1992)

IR

INTRODUCTION

- Was developed by Cambridge Olivetti Res earch Laboratory in 1992
- Indoor positioning
  - Staffs and visitors
- Sensor networking

INTRODUCTION

- Members of staff wear badges that transmit signals providing information about their location to a centralized location service, through a network of sensors
- The badge transmits a unique code via a pulse-width modulated IR signal to networ ked sensors/receivers deployed throughout a building
- Active Badge uses 48-bit ID codes and is capable of two-way communications
- Updates are sent every 10-15 seconds
  - Updating the sensor data on the central database
  - Central database stores this signal (which sensor and where,.etc)

IR USAGE

- IR-based solution is designed to operate up to 6 meters away from a sensor
- Room wall is the natural boundary to contain the IR signals
  - Allow the receiver to identify the badge within the room
- The number of sensor is depending to the resolution of tracking
  - Multiple senor may be installed in the conference room to detect the activities near the p odium
- IR allows for a low-cost and simple tag and receiver design
  - Irrespective of the line-of-sight disadvantage.

USAGE

- Easy tracking for workers/patients
- In hospitals the tracking of patients and staffs is crucial in providing the essential s ervices during emergencies.
- In office building, Receptionist task would be easy
  - Know every single person existence (there or not)
  - Know their phone
  - Phone the specific employee in the right place at the right time
  - Integration of PBX so 'call forward' and 'call transfer ' beneficially utilized
- Personalized printing
  - Shared printer can only print your page when your badge is close to it.
- Personalized and activating action on PC, et
  - Switch on pc and play my morning music

CHALLENGES

- Privacy
- Integrating motion detection
  - Movement without detecting an Active Badge could alert security personnel to a suspicio us situation.

ACTIVE BAT

Ward et al., 1997

Ultrasonic-based location tracking

GOAL

- Low-power
- wireless
- inexpensive
- fine-grain 3D positioning sensor

DEFINITION

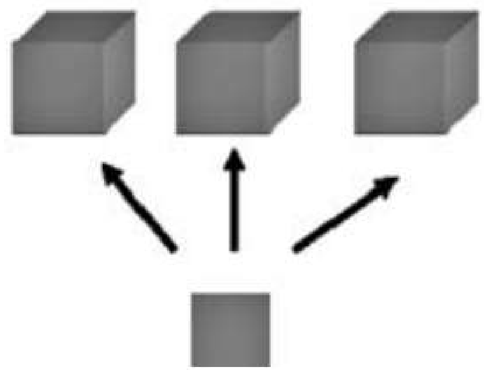
- is an ultrasonic-based location tracking systems consisting of ultrasound receiv ers dispersed in a space and location tags that emit ultrasonic pulses.
- Active Bat tags emit short pulses of ultrasound and are detected by receivers moun ted at known points on the ceiling, which measure the time-of-flight of each pulse.
- Using the speed of sound, the distance from the tag to each receiver is calculated.

DEFINITION

- Given three or more measurements to the receivers, the 3-D position of the tag can be determined using **trilateration**
- RF signal to cue the tag to transmit its ultrasonic pulse.
  - RF cue gives the receivers in the environment a starting point for timing
- the received ultrasonic pulse. Since the speed of light is significantly faster
- than the speed of sound, the RF signal delay is negligible and does not
- need to be considered for calculating the time-of-sight of the acoustical
- signal.

ACTIVE ARCHITECTURE DISADVANTAGE

- Active Bat architecture is its active approach the tag beaconing, as opposed to using a
- passive approach scales better than the active architecture
  - As the location tags increase
  - Because the RF and acoustical channel use independent of the number of tags
- Active mobile architecture require more infrastructure
  - Connecting the deployed receiver to the servers
- Privacy concern is more exploited in the active arch.
  - Since it knows the location of all tags in the system
- Passive architecture allows mobile devices to
  - estimate the location on each tag(cricket)

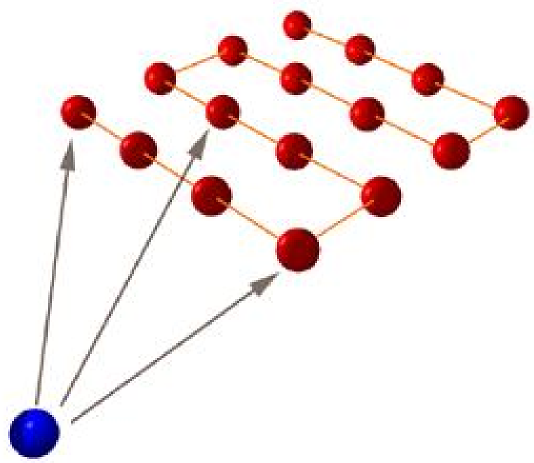


Active mobile device

THEORY

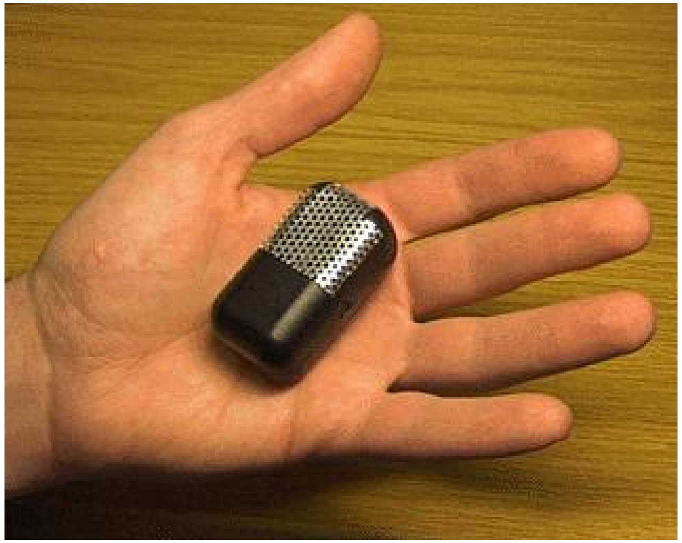
- medium: ultrasonic

- method: triangulation
  - an emitter is attached to an object
  - receivers are mounted on the wall
  - we measure the times-of-flight of the p ulse to the receivers
  - the speed of sound is known
    - given 3 or more distances, we can deter mine the 3D location of the object
  - by keeping track of the 3D locations, w e can determine the orientation and sp eed of the object



TRANSMITTER

- prototype of ultrasonic transmitter:
  - 5.5cm x 3cm x 2.4cm
  - 30 g
  - 3-month life time
  - a unique 16-bit address



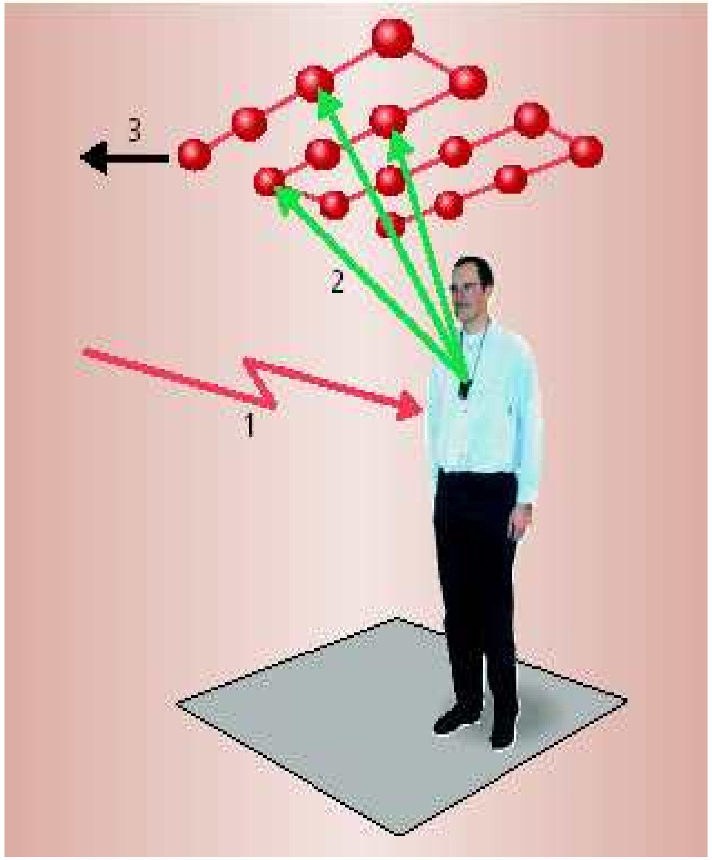
RECEIVERS

- mounted on the wall
- Distance from each tag is calculated
- Central server controls all the bats

APPLICATIONS

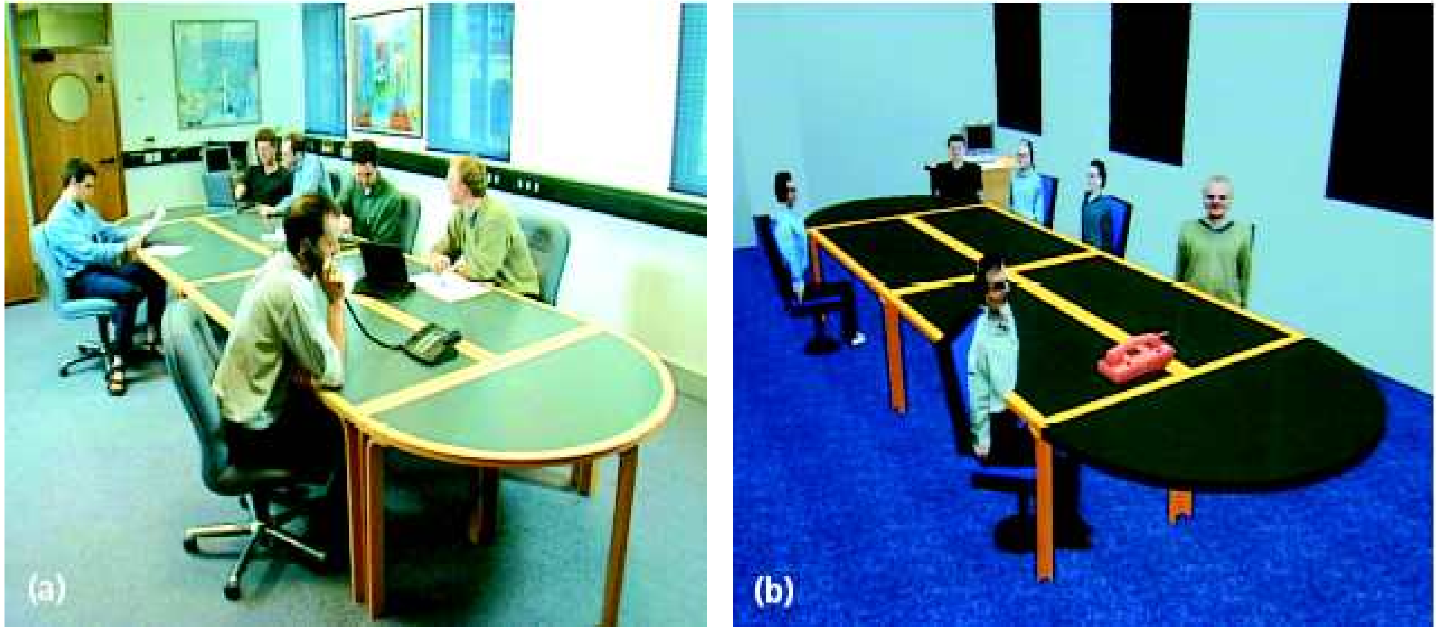
- Sentient computing system
  - AT&T Lab, Cambridge.
  - Personnel carry wireless devices – Bats.
  - Sensors locates on the ceiling.
  - Functions
    - Spatial monitor (for browsing on the Web)
    - Follow-me systems
    - Data creation, storage, and retrieval

APPLICATIONS



1. trigger
2. emit signals
3. positioning by TOA

APPLICATIONS

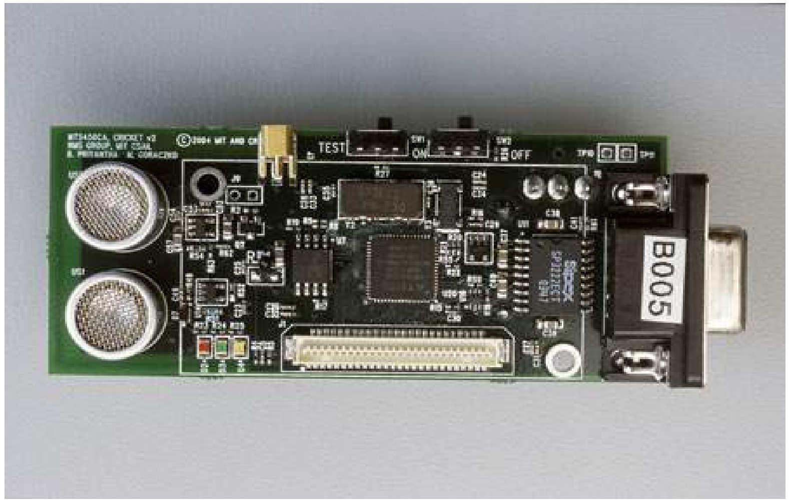


CRICKET

Indoor ultrasound positioning system

INTRODUCTION

- Location system
- Project started in 2000 by the MIT
- Other groups of researchers in private companies
- Small, cheap, easy to use



Cricket node v2.0

5 SPECIFIC GOALS

- User privacy
  - location-support system, not location-tracking system
  - position known only by the user
- Decentralized administration
  - easier for a scalable system
  - each space (e.g. a room) owned by a beacon
- Network heterogeneity
  - need to decouple the system from other data communication protocols (e.g. Ethernet, WLAN)
- Cost
  - less than U.S. $10 per node
- Room-sized granularity
  - regions determined within one or two square feet

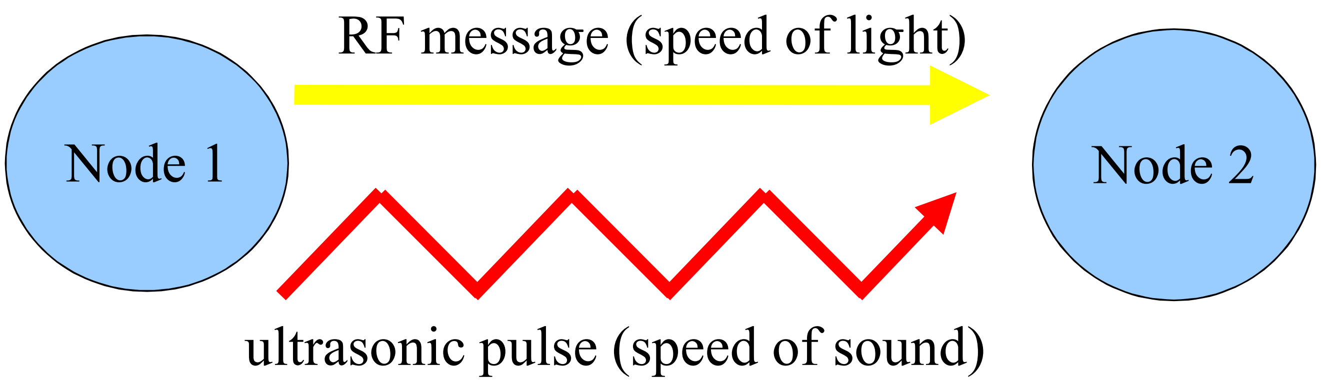
DETERMINATION OF THE DISTANCE

- First version
  - purely RF-based system
  - problems due to RF propagation within buildings
- Second version
  - combination of RF and ultrasound hardware
  - measure of the one-way propagation time of the ultrasonic signals emitted by a node
  - main idea : information about the space periodically broadcasted concurrently over RF, together with an ultrasonic pulse
  - speed of sound in air : about 340 m/s
  - speed of light : about 300 000 000 m/s

DETERMINATION OF THE DISTANCE

1. The first node sends a RF message and an ultrasonic pulse at the same time.

2. nd activates its ultrasound The second node receives the RF message first, at t_{RF} areceiver.



3. A short instant later, called $t_{ultrasonic}$, it receives the ultrasonic pulse.

4. Finally, the distance can be obtained using t_{RF}, $t_{ultrasonic}$, and the speed of sound in air.

DIFFICULTIES

- Collisions
  - no implementation of a full-edged carrier-sense-style channel-access protocol to maintain simplicity and reduce overall energy consumption
  - use of a decentralized randomized transmission algorithm to minimize collisions
- Physical layer
  - decoding algorithm to overcome the effects of ultrasound multipath and RF interferences
- Tracking to improve accuracy
  - a least-squares minimization (LSQ)
  - an extended Kalman filter (EKF)
  - outlier rejection

DEPLOYMENT

At the MIT lab : on the ceiling

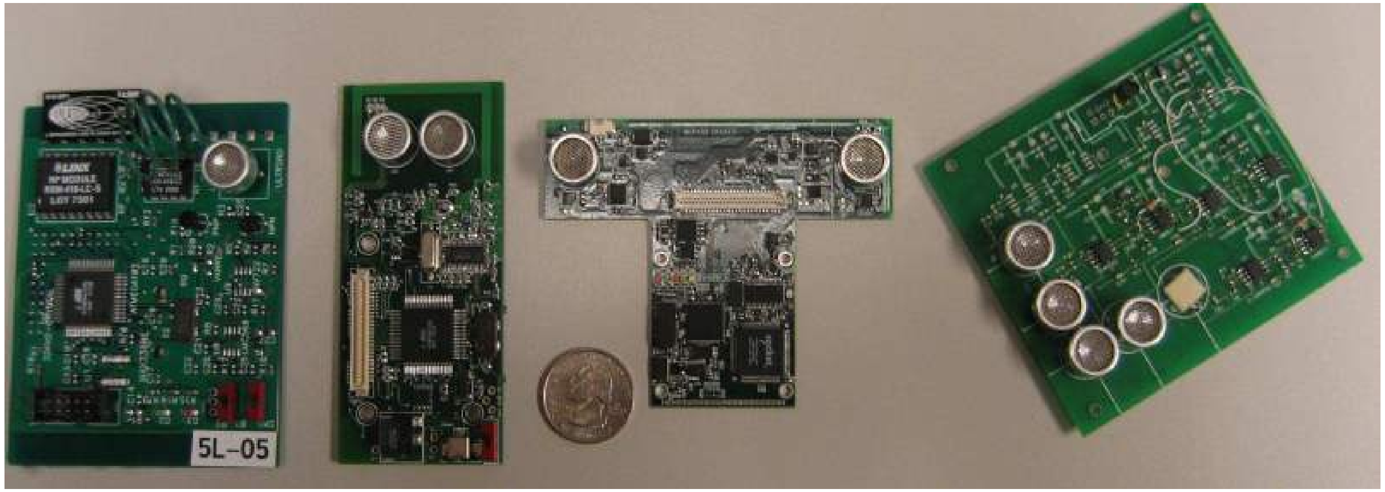
Ref. [1]

DIFFERENT ROLES

A Cricket device can have one of these roles

- Beacon
  - small device attached to a geographic space
  - space identifier and position
  - periodically broadcast its position
- Listener
  - attached to a portable device (e.g. laptop, PDA)
  - receives messages from the beacons and computes its position
- Beacon and listener (symetric Cricket-based system)

CRICKET VERSIONS

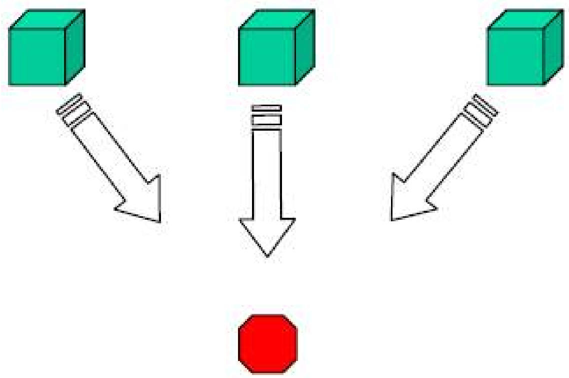


Ref. [5]

From left to right: v1, v2, v2 done jointly with Crossbow,
and a compass daughter board.

PASSIVE MOBILE ARCHITECTURE

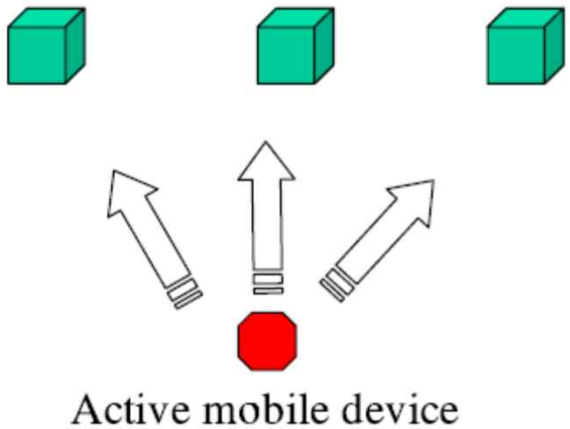
In a passive mobile architecture, fixed nodes at known positions periodically transmit their location (or identity) on a wireless channel, and passive receivers on mobile devices listen to each beacon.



Ref. [4]

ACTIVE MOBILE ARCHITECTURE

In an active mobile architecture, an active transmitter on each mobile device periodically broadcasts a message on a wireless channel.



Ref. [4]

SUMMARY

	Pros	Cons
Passive Mobile Architecture	-privacy -scalability -decentralization	-weak accuracy at higher sp eed
Active Mobile Architecture	-accuracy	-privacy concern -reduced scalability -required network infrastruct ure

UBI-SENSE

Commercial location tracking system using UWB for localization

DEFINITION

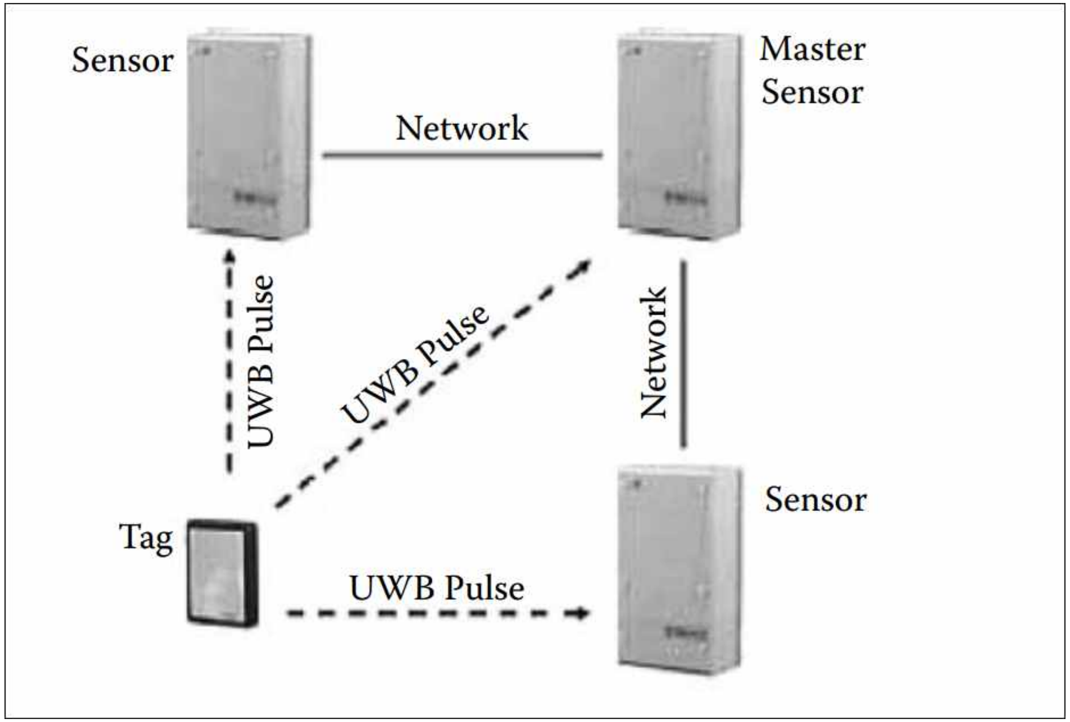
- Is a commercial location tracking system using a UWB signal for localization
- Offers high precision at about 15cm by triangulating the active tags(Ubitag) locatio n from the collections of network sensors (ubisensors)
- Incorporates conventional RF radio (2.4 GH) and UWB 6-
- Conventional radio is used to coordinate and schedule when a particular Ubitag sh ould transmit .
- A"er a tag is queried to transmit its UWB pulse, the Ubisense system
- uses TDOA and AOA to triangulate the location of the tag. !us, at least
- two Ubisensors are needed to calculate the 3-D position of a Ubitag. !e
- TDOA information is computed from sensors connected together with
- a physical timing cable.

ADVANTAGE

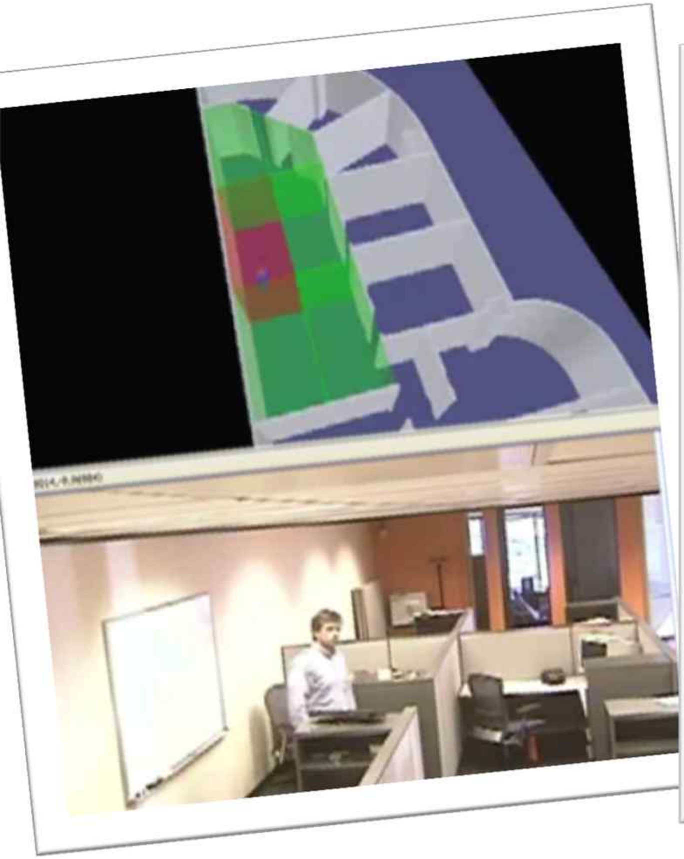
- It is easier to filter multipath signals
  - So it can endure some occlusion
- Does not require the line of sight operation for the optimal performance

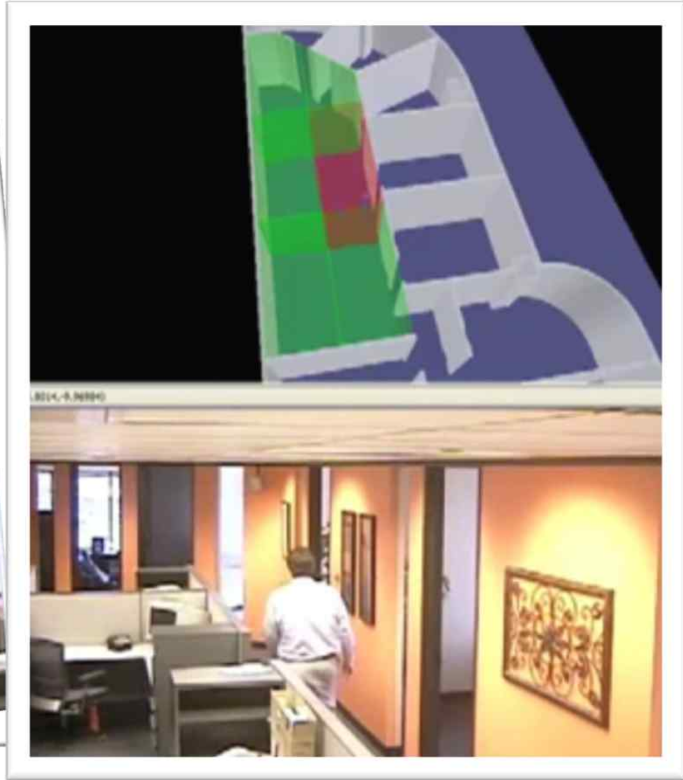
ARCHITECTURE

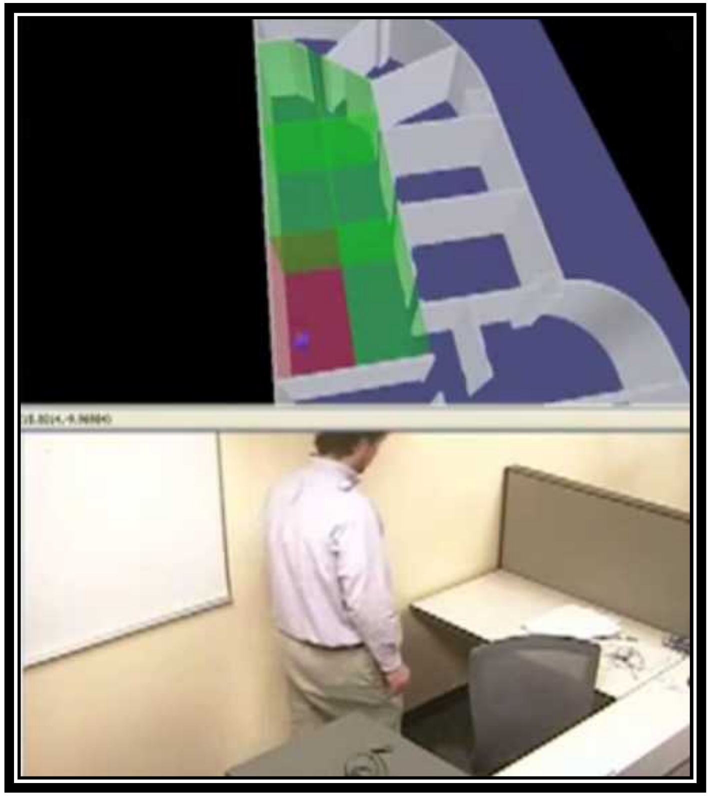
- To the right is the network architecture



EXAMPLE OF UBI-SENSE POSITIONING







User movement is sensed according to user's current location

RADAR

Indoor wifi based location system

BACKGROUND

- RADAR system implements the location services using the information from the already existing WIFI networks.
- RADAR Uses the RF signal strength as an indicator of the distance between the AP and the receiver
- The major advantage is that the costumer need not to buy new dedicated hardware
- Cost and effort of installation of the necessary infrastructure drawback
  - Using the existing infrastructure to ease the cost of installing new one.

FEATURES

- Initially the system used a trilateration on RSSI
  - But the problem of multipath
  - Led to the use of mapping or fingerprinting approach for localization
- The mapping between location and the singal strength emanating from nearby WiFi AP
- To determine the position of the WiFi-enabled device, the receiver
- measures the signal strength of each of the APs and then searches through
- the signal map to determine the signal strength values that best matches
- the signal strengths seen in the past. An NN approach is used to $nd the
- closest signal values and then the system estimates the location associated
- with the best-matching signal strengths

PERFROMANCE

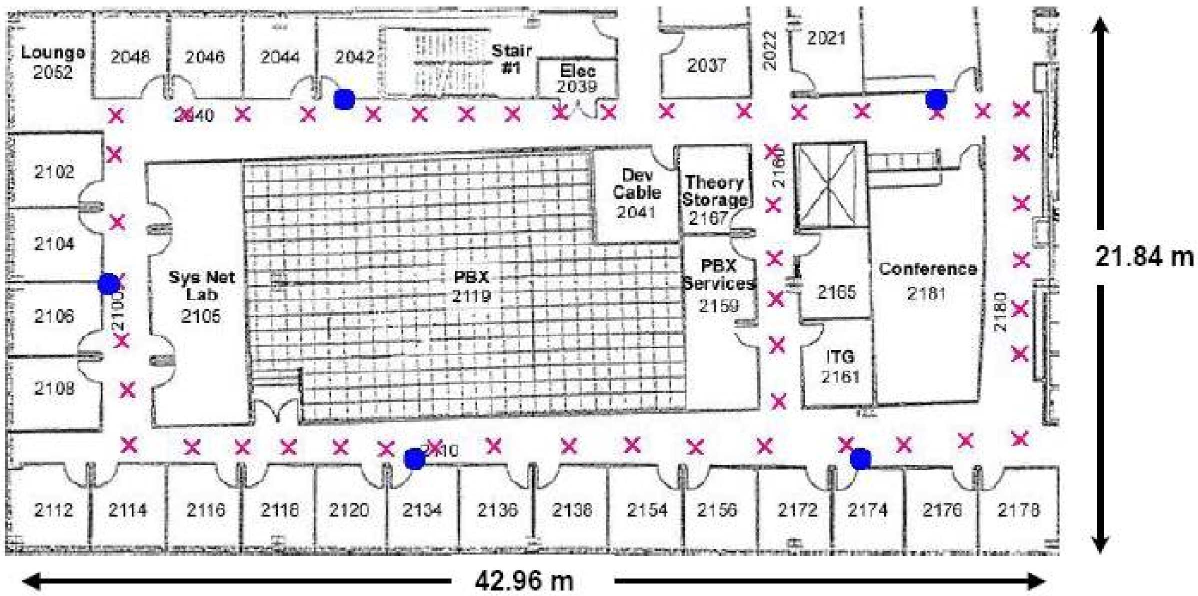
- median position error of about 3 meters and 90 percentile resolution of 6 meters.
- 3 AP are needed for effective localization
  - Problem might occur when furniture is moved from one place to another
  - New survey is needed if such change happens

GSM LOCALIZATION -VARSHAVSKY 2007

- Unlike the technologies used in most of the indoor localization are short range signals
- Contrary to popular belief, an indoor localization system based on wide-area GSM fingerprints can achieve high accuracy, and is in fact comparable to an 802.11-based implementation
- The key idea that makes accurate GSM-based indoor localization possible is the use of wide signal-strength fingerprints. The wide fingerprint includes the 6-strongest GSM cells and readings of up to 29 additional GSM channels, most of which are strong enough to be detected, but too weak to be used for efficient communication. The higher dimensionality introduced by the additional channels dramatically increases localization accuracy.

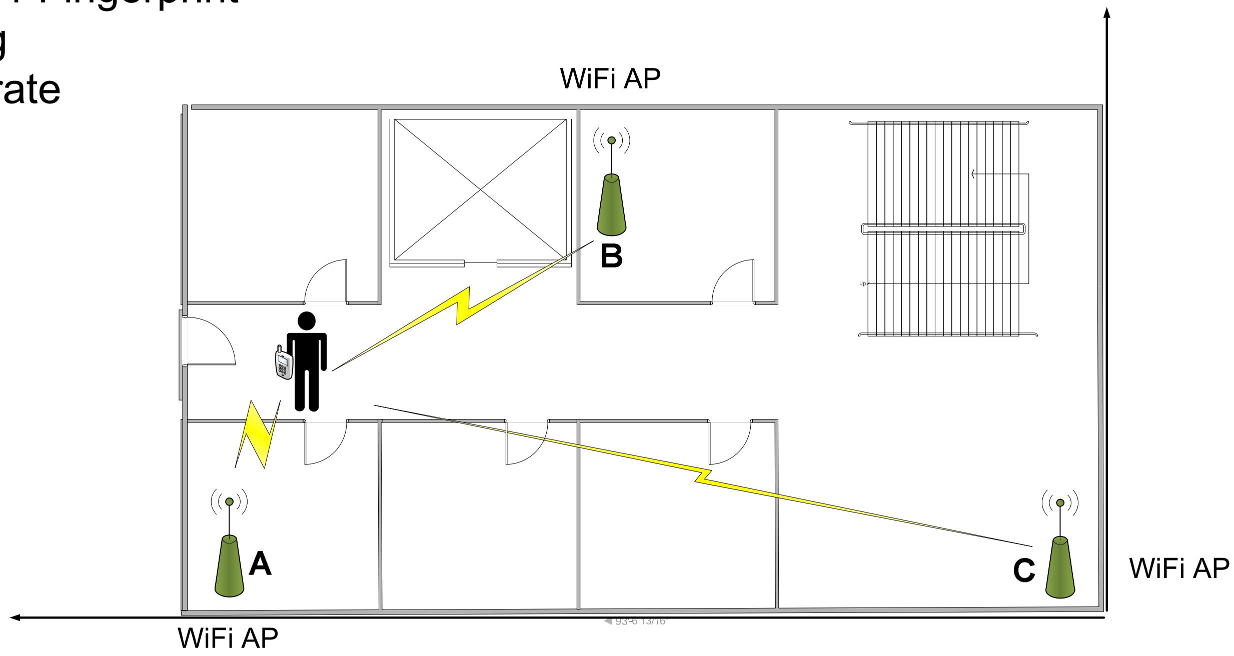
RADAR

- WiFi-based localization
- Reduce need for new infrastructure
- Fingerprinting



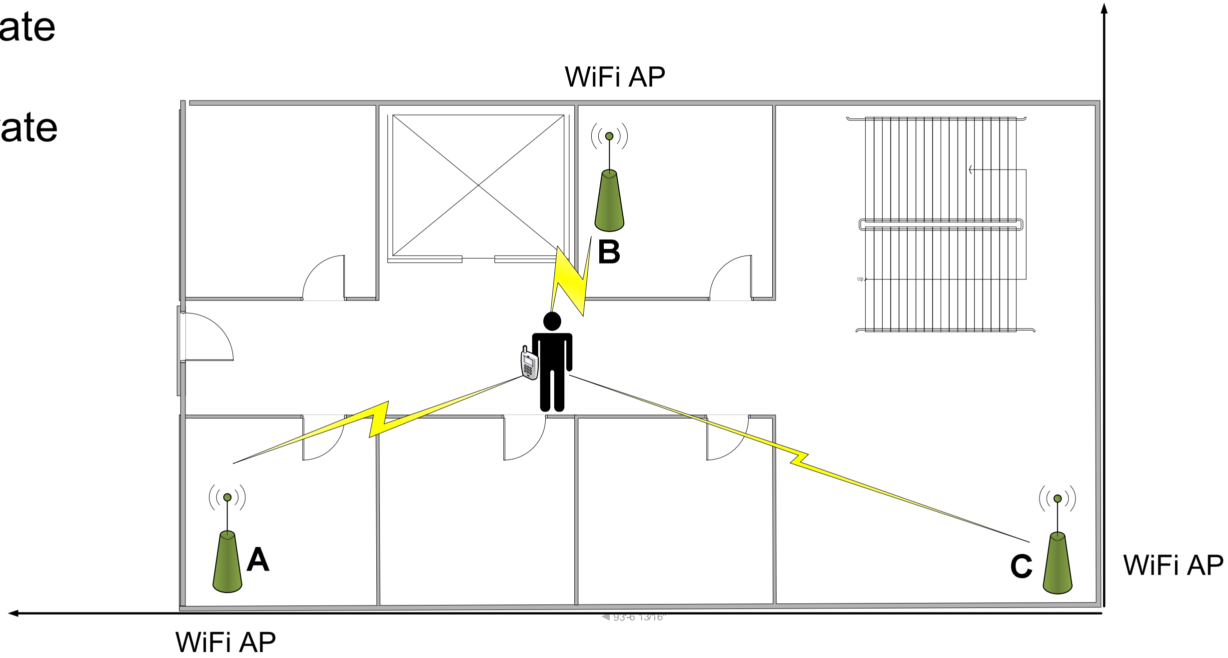
FINGERPRINTING WITH WIFI OR GSM

Location 1 Fingerprint
A: Strong
B: Moderate
C: Weak



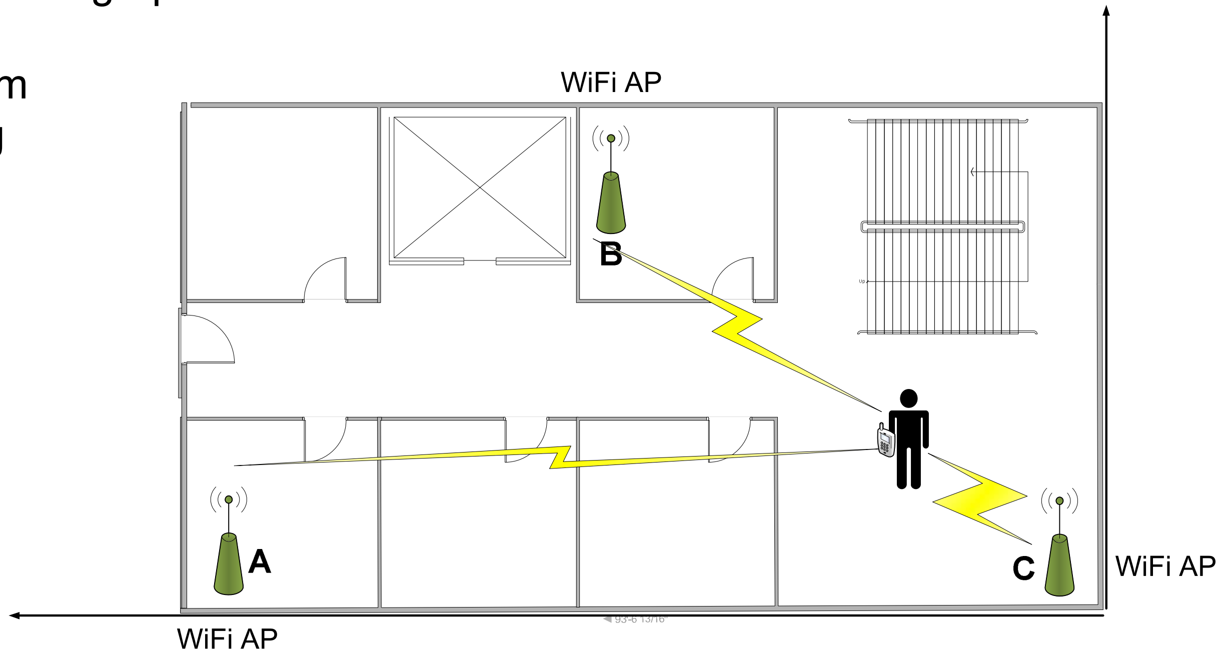
FINGERPRINTING WITH WIFI OR GSM

Location 2 Fingerprint
A: Moderate
B: Strong
C: Moderate



FINGERPRINTING WITH WIFI OR GSM

Location 3 Fingerprint
A: Weak
B: Medium
C: Strong



PLACE LAB

Indoor/outdoor

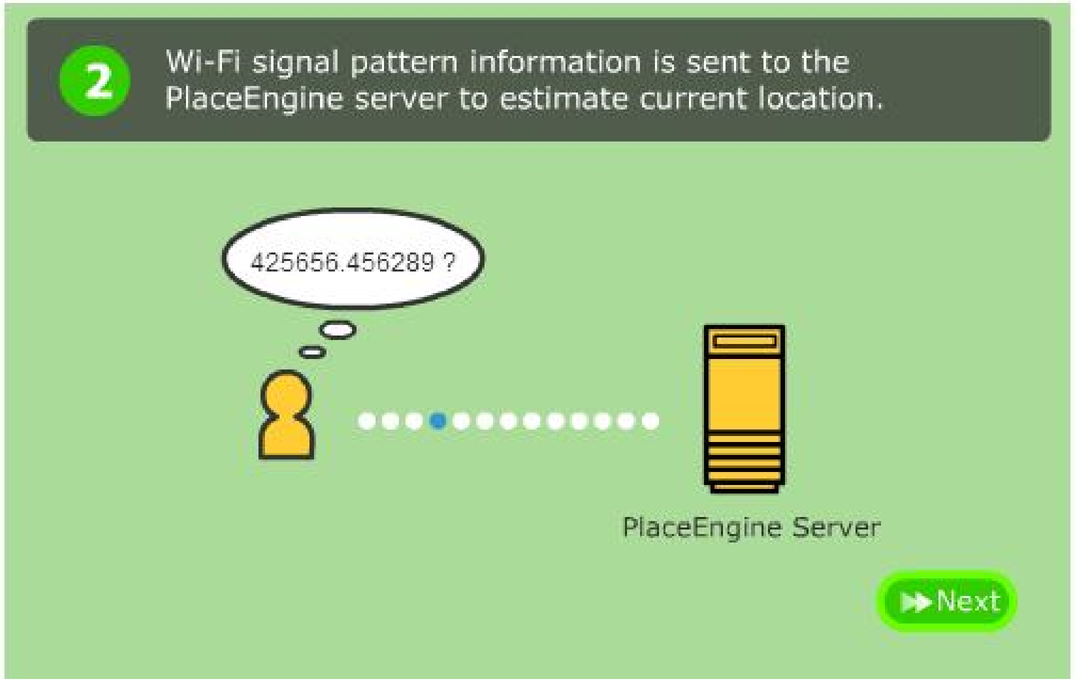
PLACE LAB

- "Beacons in the wild"
  - WiFi, Bluetooth, GSM, etc
- User's privacy is intact because the user does not have to reveal an ything to a central server.
- Clients running Place Lab software

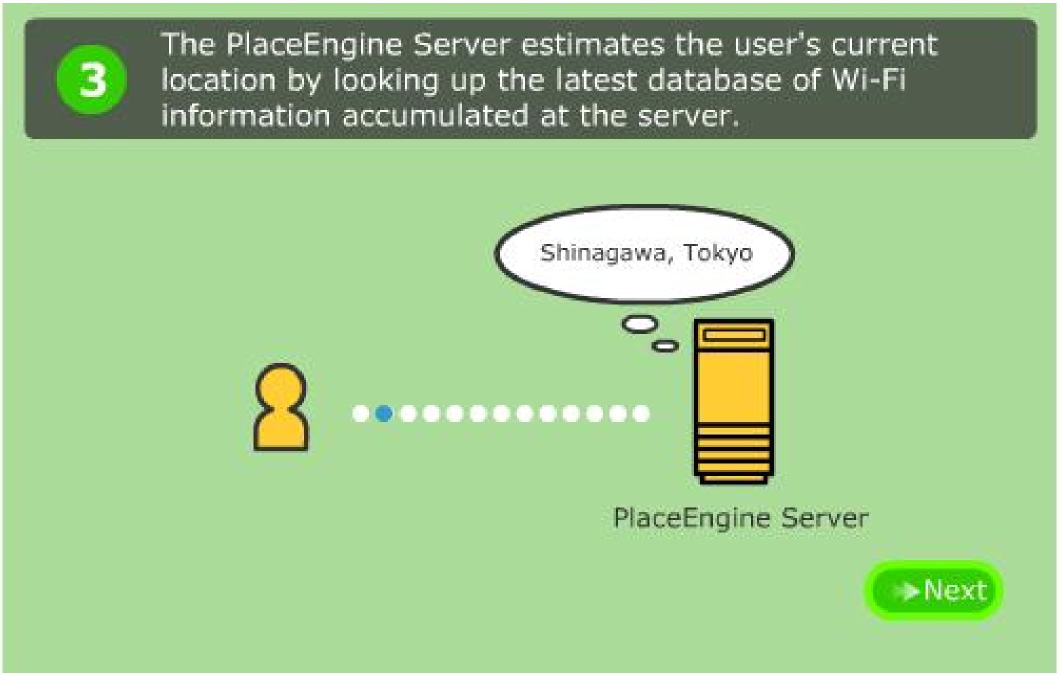
MAIN FEATURES

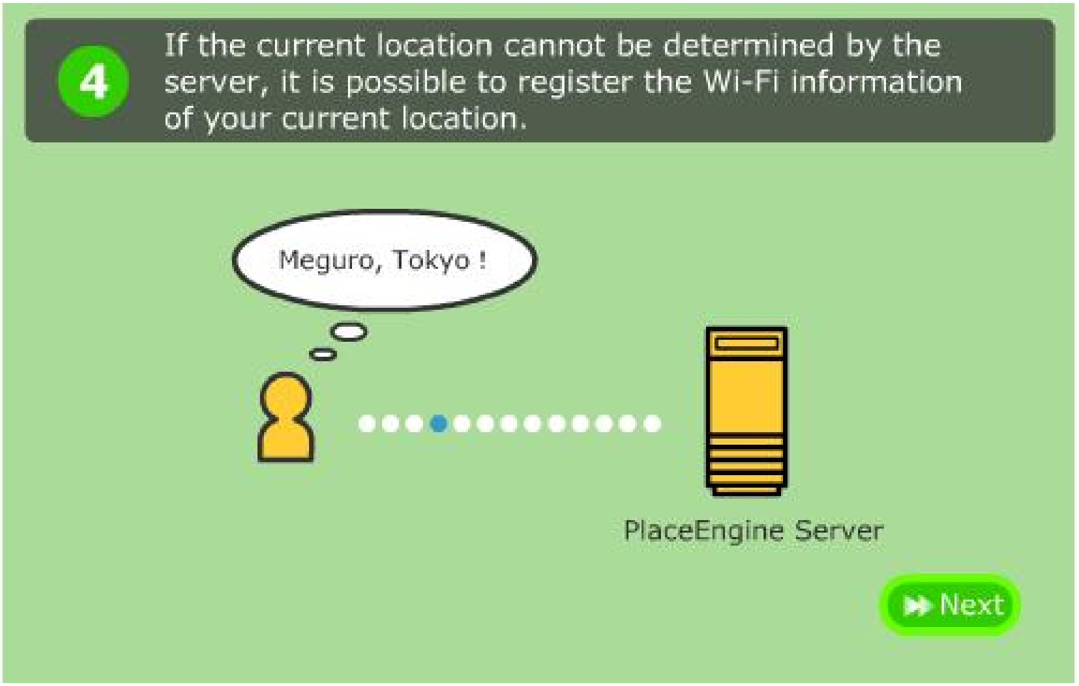
- Is a software based indoor and outdoor localization system developed by Intel reseac h. It runs on notebook,PDA,
- A user could locate their devices by the broadcasted ID and the reference on his devi ce map.
- It is similar to RADAR, but is different in term of scalability(more Areas are covered)
- Place Engine from Sony Computer science called PlacedEngine

PLACE ENGINE

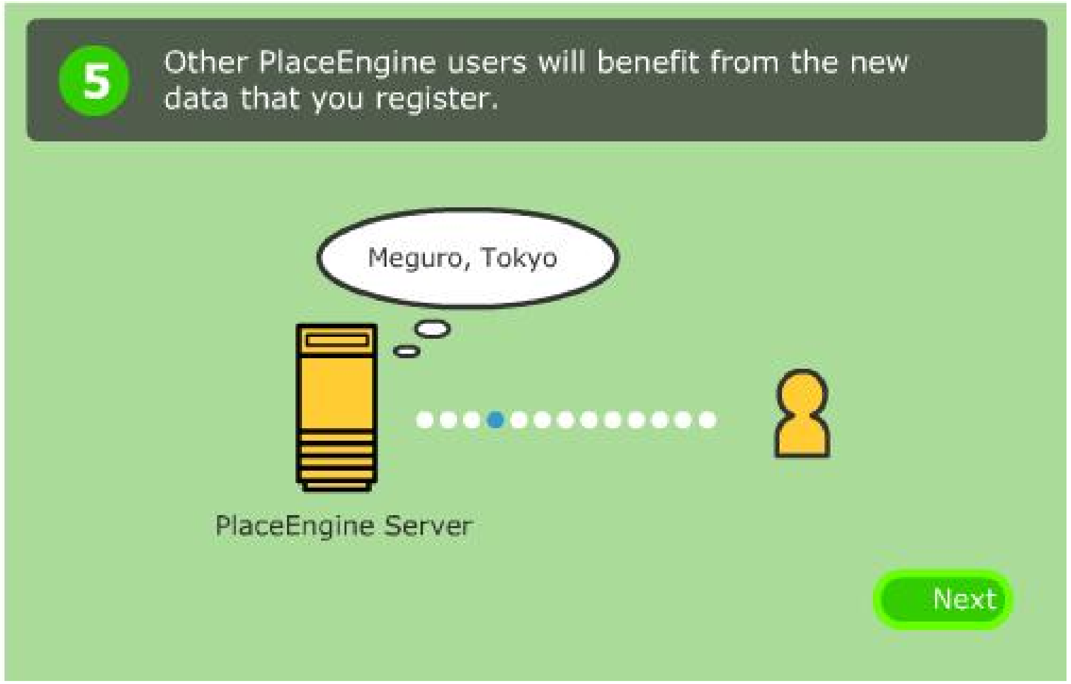


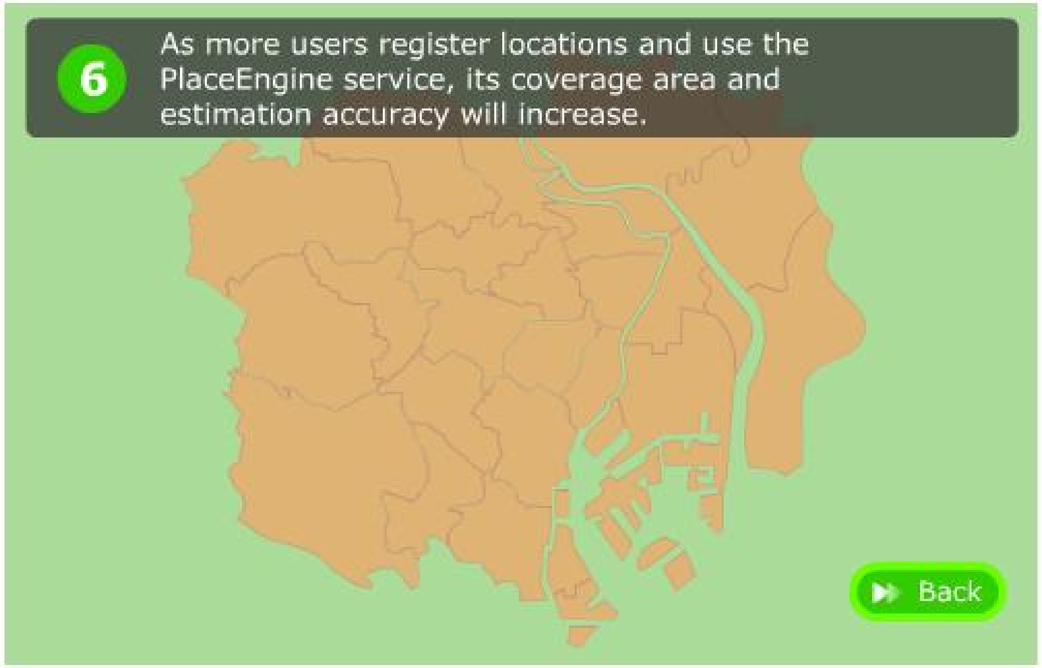
PLACE ENGINE



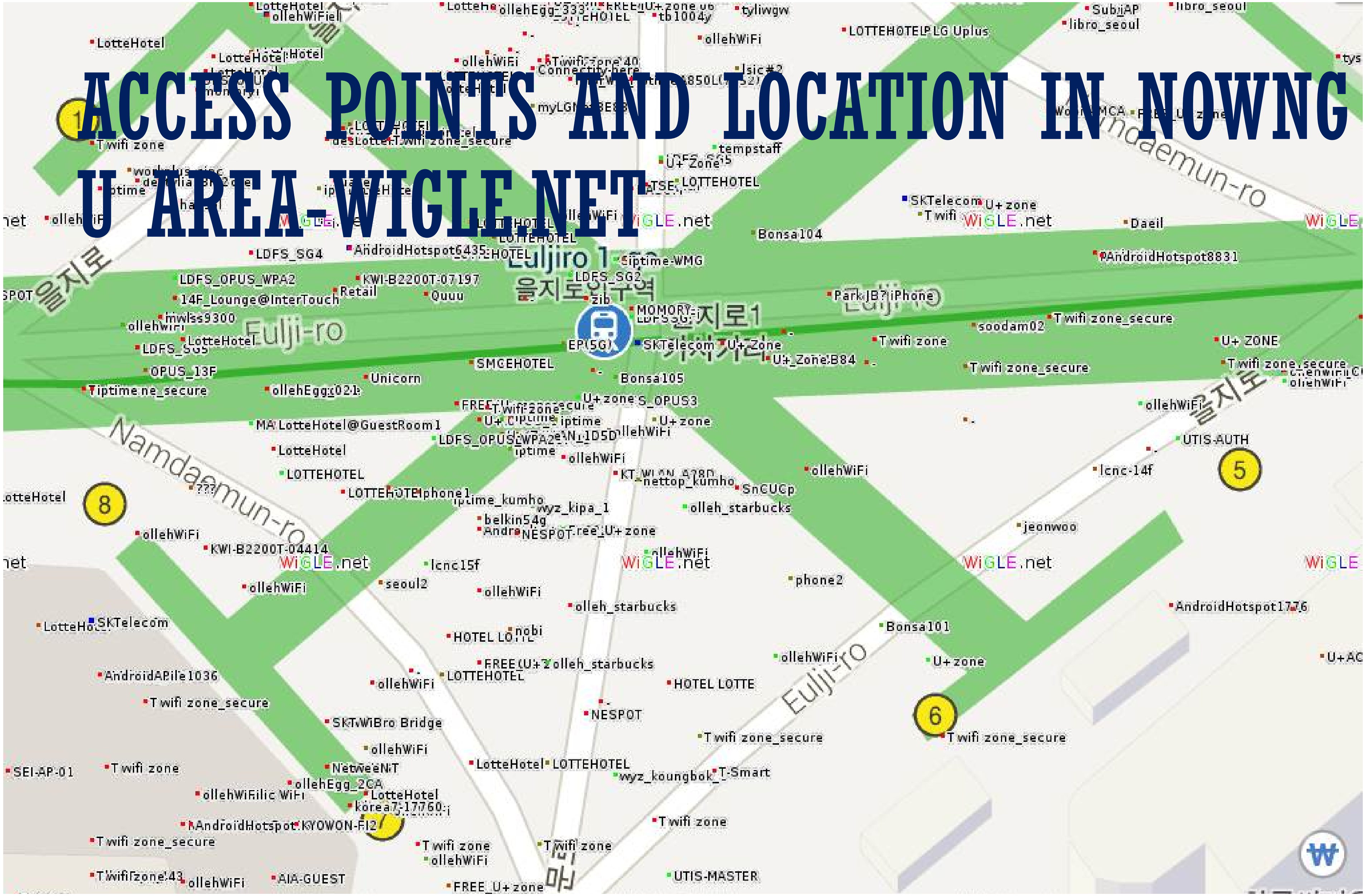


PLACE ENGINE





ACCESS POINTS AND LOCATION IN NOWNGU AREA-WIGLE.NET



POWER LINE POSITIONING

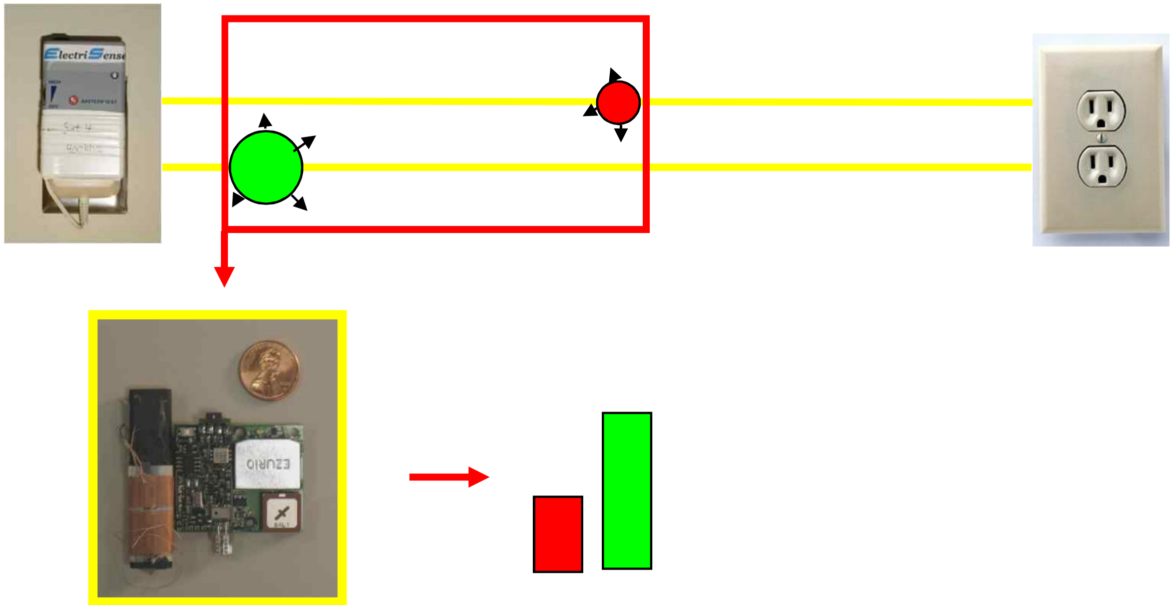
Indoor positioning using electrical system

POWERLINE POSITIONING

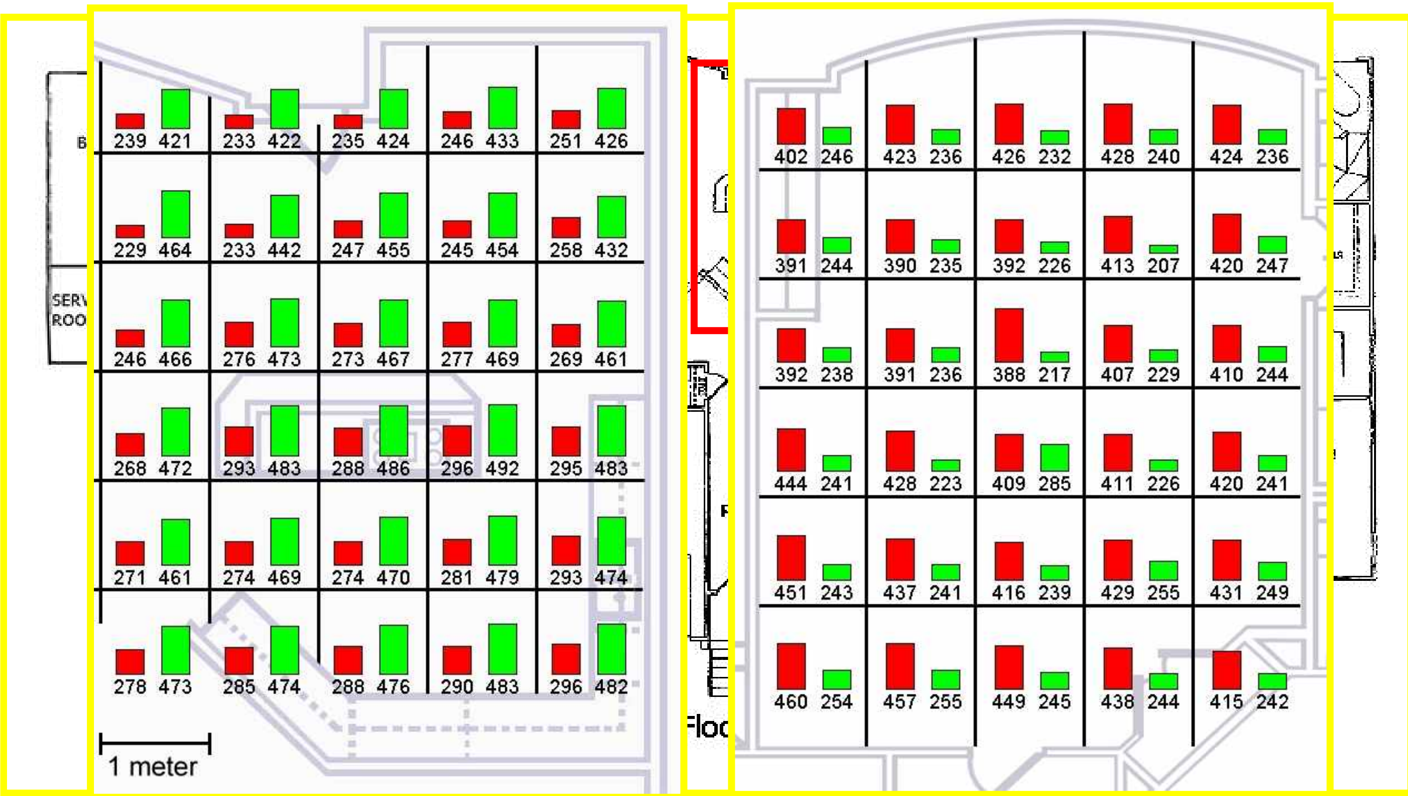
- Indoor localization using standard household pow er lines

SIGNAL DETECTION

- A tag detects these signals radiating from the elec trical wiring at a given location

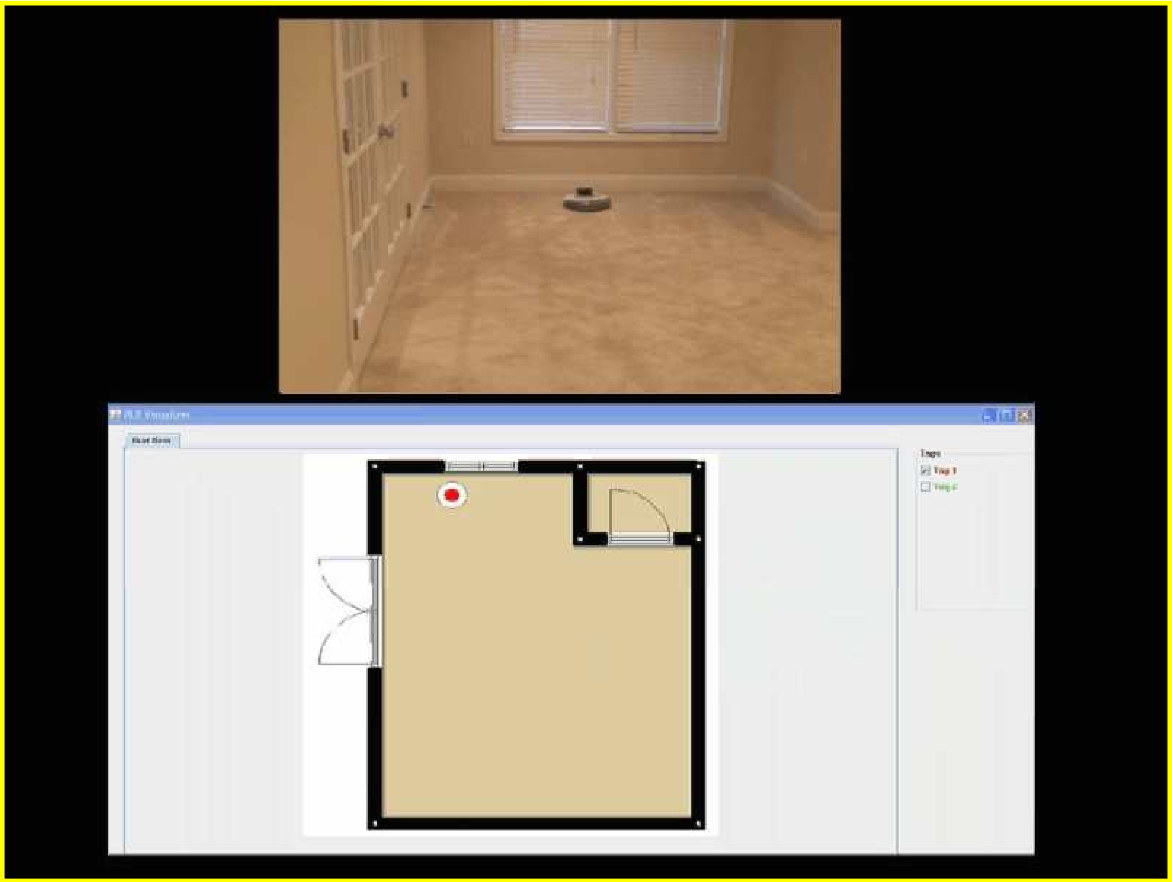


SIGNAL MAP



1st Floor 2nd Floor

EXAMPLE

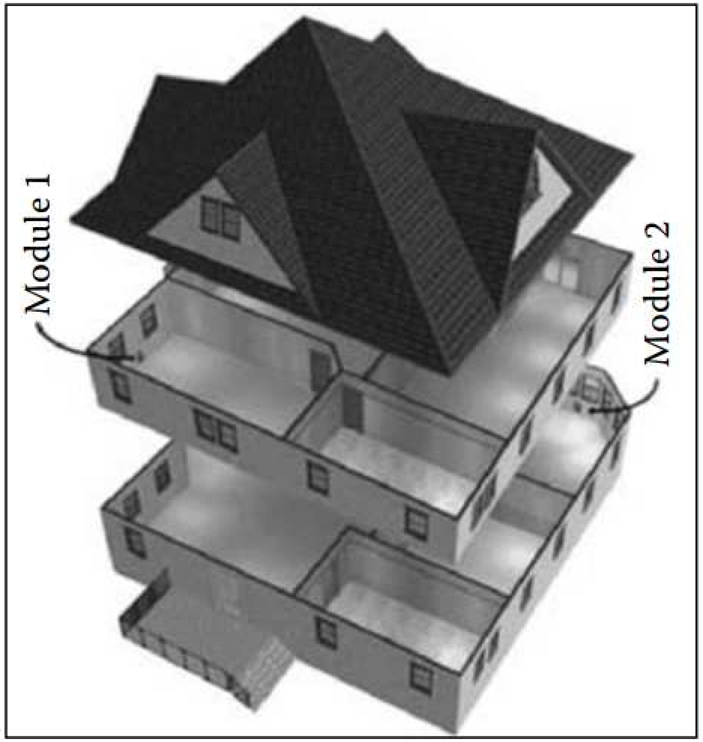


PASSIVE LOCATION TRACKING

- No need to carry a tag or device
  - Hard to determine the identity of the person
- Requires more infrastructure (potentially)

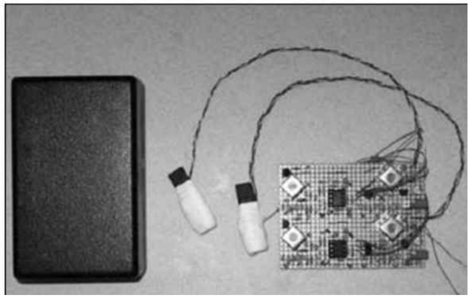
PLP INSTALLATION EXAMPLE

- Two signal generating modules



- Signal generator plugin

- Prototype of PLP tag



ACTIVE FLOOR

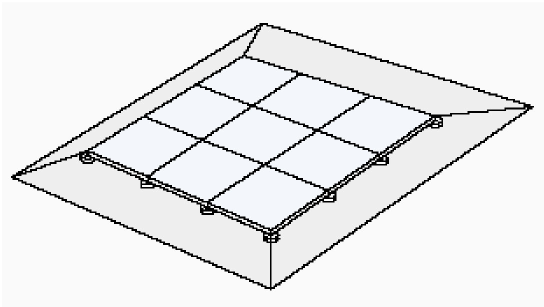
Locating without carrying tags

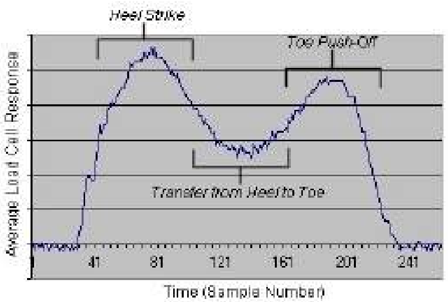
BACKGROUND

- Most positioning system require attachment of tags, Line of sight, and Network that connect the tag to the database
- Active Floor, is to alleviate the need for such burden.
- Utilizes weight

ACTIVE FLOOR

- Instrument floor with load sensors
- Footsteps and gait detection





AIRBUS

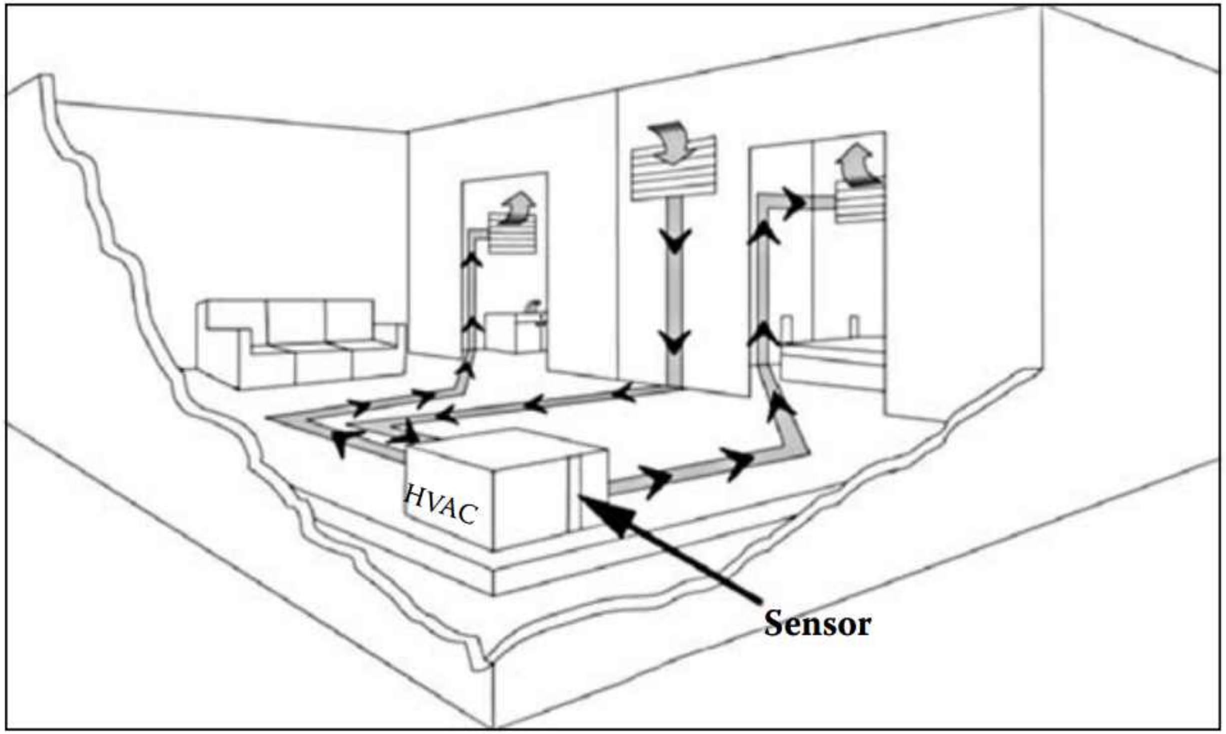
Indoor position using HVAC

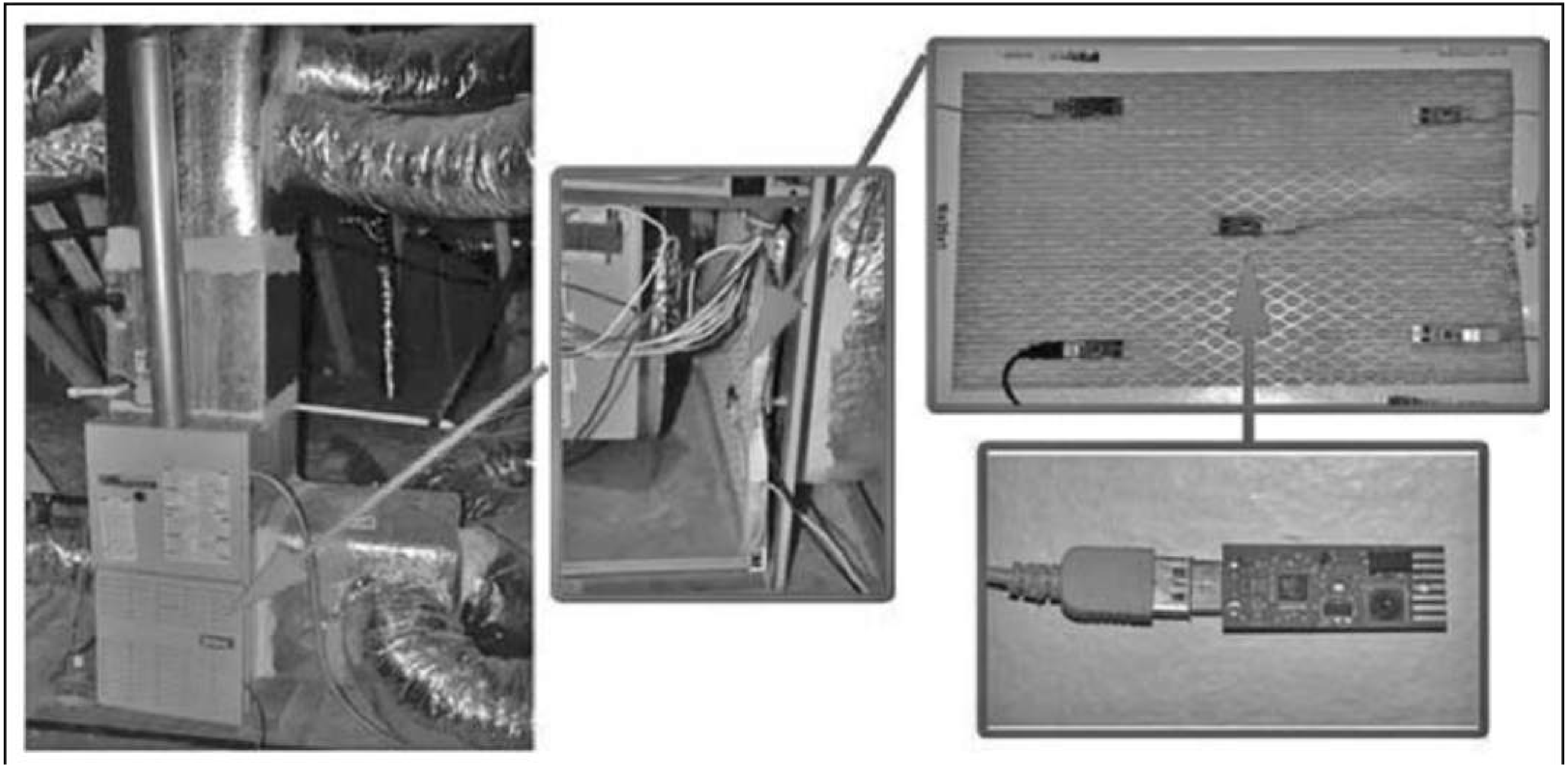
BACKGROUND

- Similar to active floor since use does not have to carry any tag
- The system can detect human movement by sensing air pressure

- Airbus is more appropriate for applications that need to know people's presence, such as for smart heating and cooling or lighting control.
- So we can customize and optimize energy and user's comfort
- The system fails to identify the identity of the person in the building

AIR FLOW FROM RETURN AND SUPPLY DUCTING IN A HOME





- An alternative strategy might be to install a collection of motion detectors in a spac e to directly sense the presence of a person to determine the path of a person
- More accurate than airbus

MOTION DETECTORS

- Low-cost
- Low-resolution

TRACKING WITH CAMERAS

Cameras/computer vision for indoor and outdoor positionin
g

COMPUTER VISION

- Leverage existing infrastructure
- Requires significant communication and computational resources
- CCTV
- User does not have to carry any tag
  - The camera inferred the position of identified object

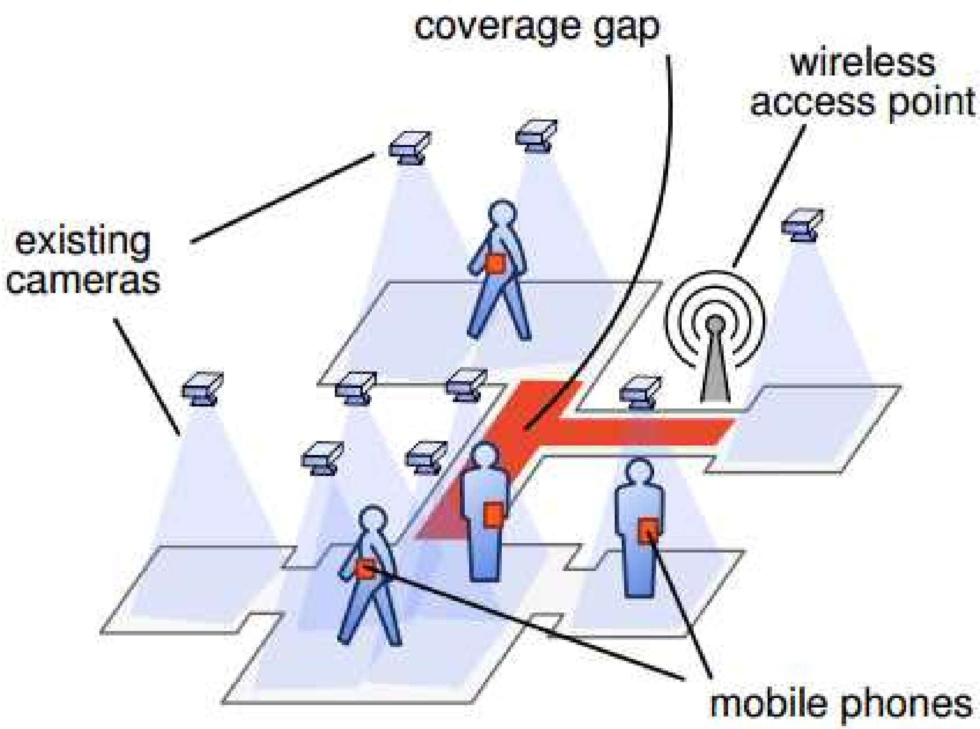


Figure 1. System overview: a network of overhead cameras is used to detect and localize people, and inertial sensors on people's mobile phones are used to identify them.

CONSIDERATIONS

- Location type
- Resolution/Accuracy
- Infrastructure requirements
- Data storage (local or central)
- System type (active, passive)
- Signaling system

REFERENCE

- Deak, G., Curran, K., & Condell, J. (2012). A survey of active and passive indoor loca lisation systems. *Computer Communications*, *35*(16), 1939-1954.
- J. Krumm**Ubiquitous Computing Fundamentals.**CRC Press (2009)