MONASH University

Information Technology

FIT5183: Mobile and Distributed Computing Systems (MDCS)

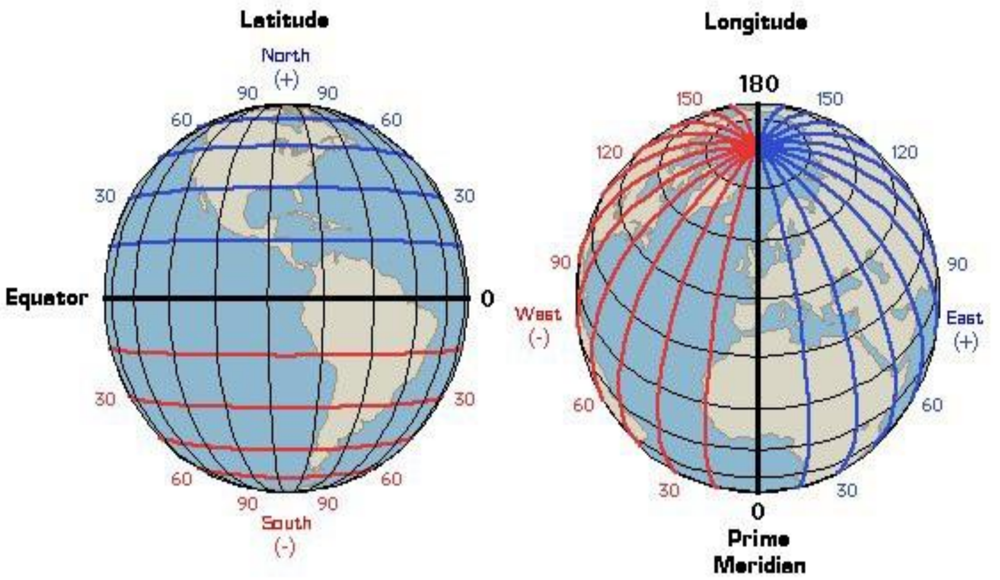
Lecture 11A
Location-Awareness & GPS Technology

Learning Outcomes

1. Define location and its awareness
2. Analyse GPS Technology
3. Synthesize the crowd sensing data/information
4. Apply MEDUSA programming framework to crowd sensing applications

Location

- **A relative location**, meaning the location of one object relative to another
  - usually estimated based on the proximity to some reference points
- **An absolute location** based on the exact location of an object using a specific pairing of **latitude and longitude**
  - **Latitude** is the angular distance measured north and south of the Equator
  - **Longitude** is angular distance measured east and west of the Prime Meridian



Representation

- Latitude and longitude can be represented in:
- **the decimal degree (°)**
  - E.g. (lat, long) -> (-37.876823, 145.045837)
  - e.g. Latitude of -35.789° or 35.789°S
  - One degree is equal to approximately 70 miles
- **Degrees, Minutes, and Seconds (DMS)**
  - e.g. 40° 27' 30" N latitude

Monash University, Caulfield Campus

Latitude	-37.876823
Longitude	145.045837
DMS Lat	37° 52' 36.5628" S
DMS Long	145° 2' 45.0132" E

Convert decimal to DMS:

e.g. **-37.876823**

1) Change degree to minutes

$0.876823 * 1° = 0.876823 * 60$ minutes

$= 52.60938$

*-37° 52**.60938** minutes*

2) Change minute to seconds

$0.60938 * 60 = 36.5628$ seconds

3) -37° degrees 52 minutes 36.5628 seconds

Location Awareness

- Location-aware technologies are used to determine the geographical location of objects
- In many application domains, it is important to know the physical location of objects
  - Tracking and monitoring applications (emergency management, healthcare, shipping, military, and many others)
  - Crowdsensing and crowdsourcing
  - Mobile industry
    - Location-based mobile banner ads
    - Location-based features offered by e.g. Google and FB
    - Location-based search such as Google search

Crowd-Sensing Applications (Medusa)

ABSTRACT

The ubiquity of smartphones and their on-board sensing capabilities motivates crowd-sensing, a capability that harnesses the power of crowds to collect sensor data from a large number of mobile phone users.

[…] crowdsensing poses several novel requirements: **support for humans-in the-loop** to trigger **sensing actions** or review results, the need for incentives, as well as privacy and security. Beyond existing crowdsourcing systems, crowd-sensing exploits sensing and processing capabilities of mobile devices.

Medusa (is) a novel programming framework for crowd-sensing that satisfies these requirements. Medusa provides high-level abstractions for specifying the steps required to complete a crowdsensing task, and employs a **distributed runtime system that coordinates the execution of these tasks between smartphones and a cluster on the cloud**

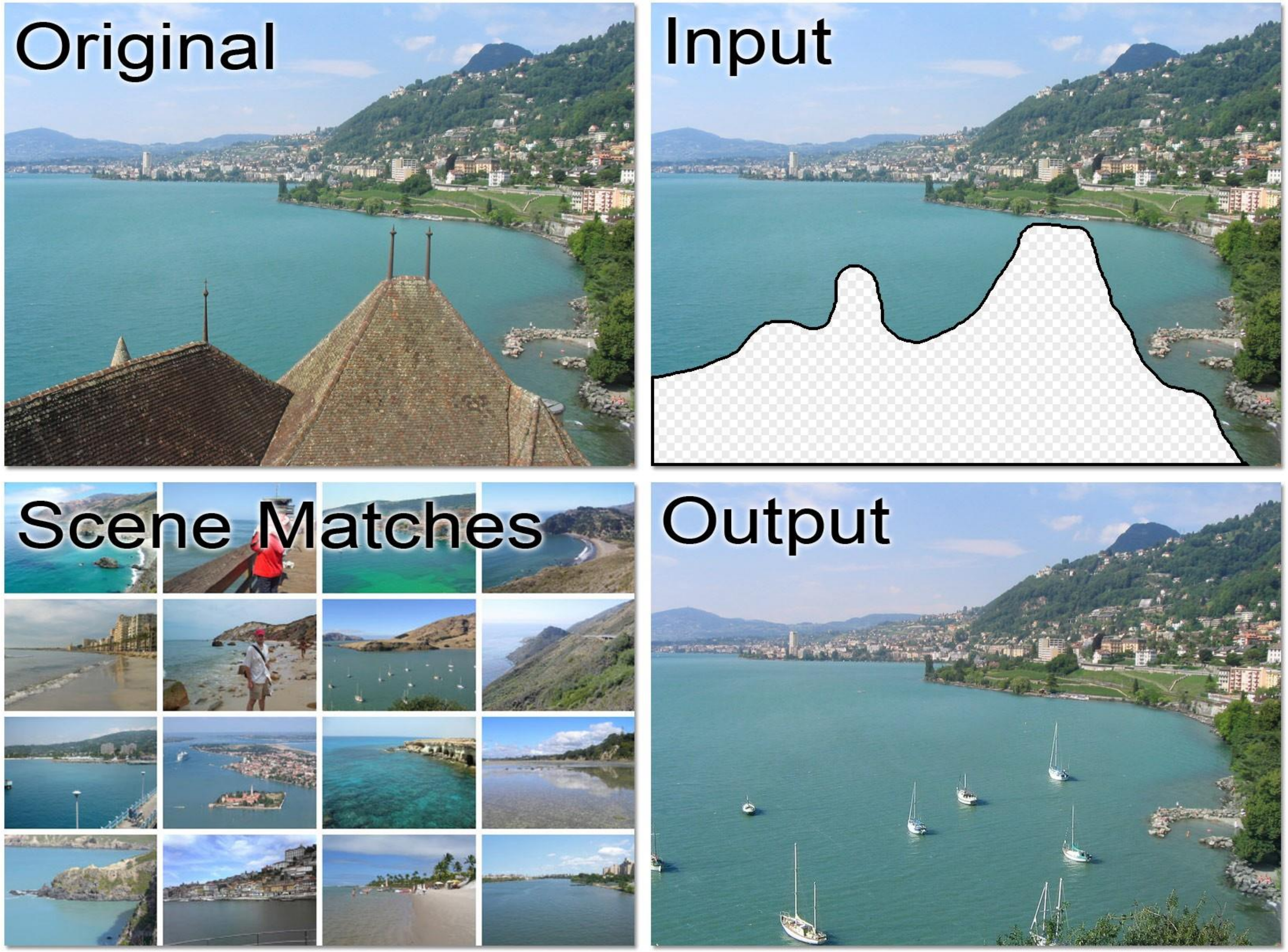
http://www-users.cselabs.umn.edu/classes/Spring-2015/csci8980/papers/TheCrowd/medusa.pdf

Automatic Location Sensing

- Three principal techniques for automatic location-sensing:
  - **Scene analysis**
  - **Proximity**
  - **Lateration** and angulation

Material drawn from: Hightower and Borriello, Location Sensing Techniques, 2001

Scene Analysis

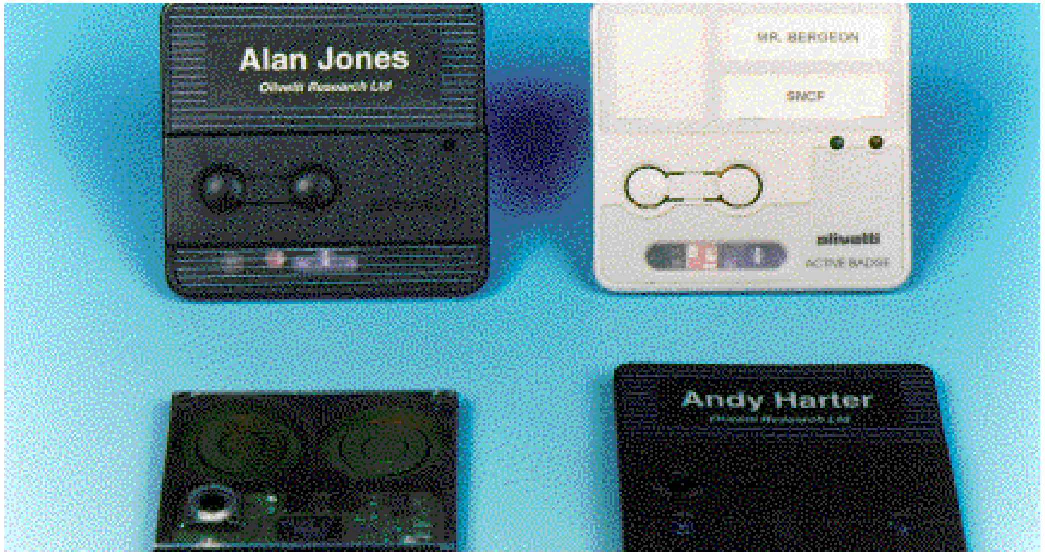


Proximity

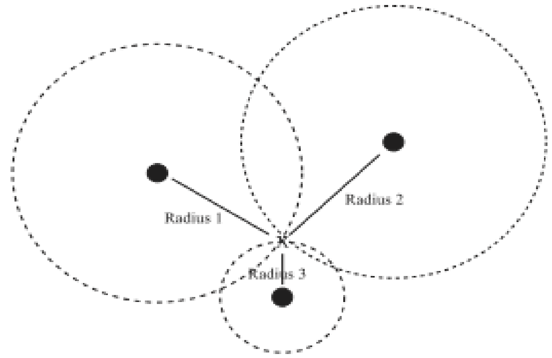
- ❑ Determining when an object is “near" a known location
- ❑ Detecting physical contact with an object (e.g. touch sensors)
- ❑ Using automatic ID systems such as credit cards
- ❑ Using wireless communication technologies
  - Example: Active Badge

Active Badge System, AT&T Cambridge

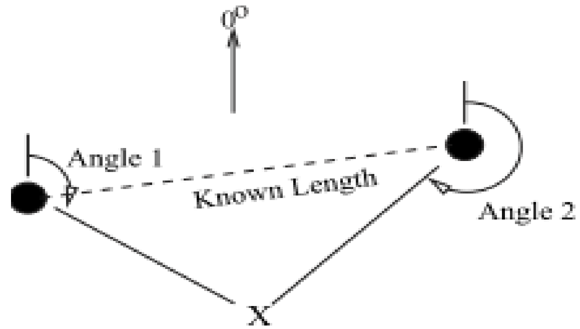
- Badges worn by personnel transmit a unique code/message using infrared signal every 10s
- Each office within a building is equipped with one or more networked sensors which detect these transmissions
- The location of the badge can be determined on the basis of information provided by these sensors



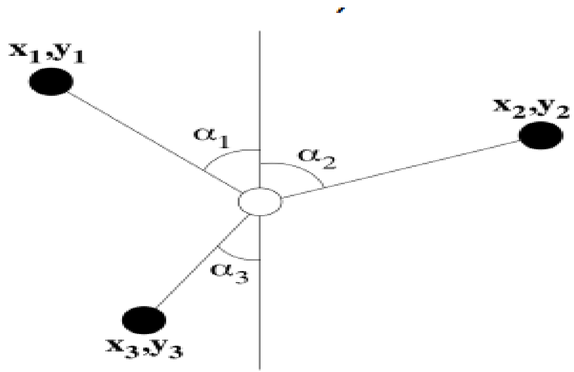
Lateration and Angulation



- **Lateration (Trilateration):** computes the position of an object by measuring its distance from multiple reference positions



- **Angulation:** uses both distance and the angles for determining the position of an object
- **Triangulation:** Uses the geometric properties of triangles



From: Hightower and Borriello, Location Sensing Techniques, 2001

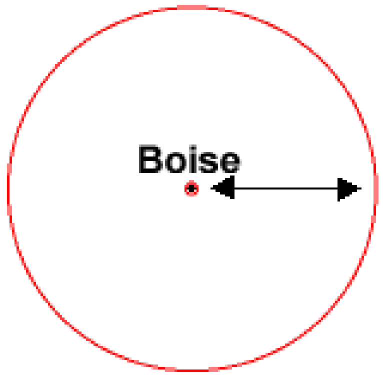
Dargie & Poellabauer (2010) Fundamentals of Wireless Sensor Networks: Theory and Practice

Examples

- Examples from:
  - LUCID (Lehigh university communications internship and development) Summer Workshop 2004

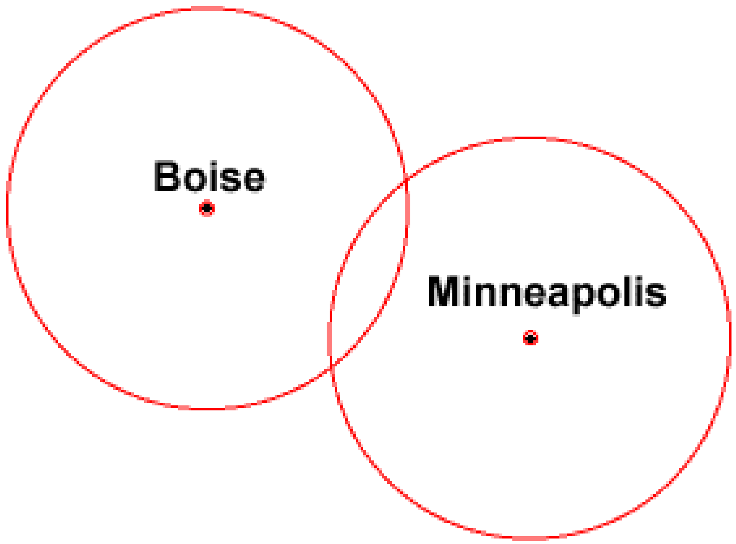
An Example of 2D Trilateration

- Imagine you are somewhere in the United States and you are TOTALLY lost -- for whatever reason, you have absolutely no clue where you are.
- You find a friendly local and ask, "Where am I?" He says, "You are 625 miles from Boise, Idaho."
- This is a nice, hard fact, but it is not particularly useful by itself. You could be anywhere on a circle around Boise that has a radius of 625 miles



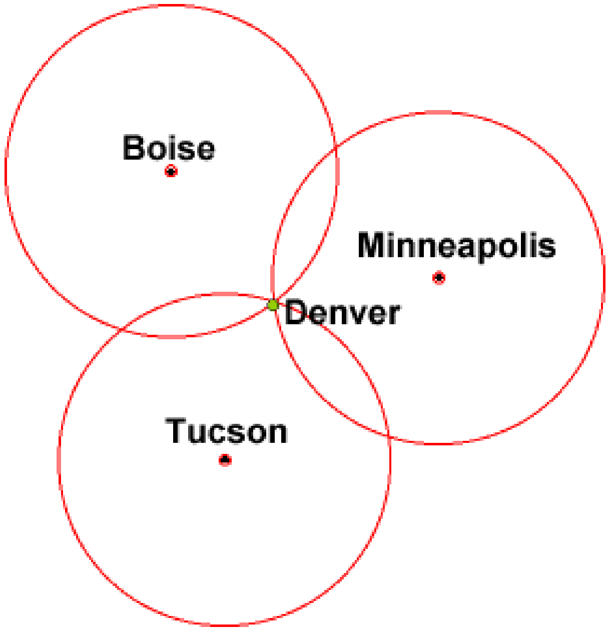
Where in the U.S. am I?

- To pinpoint your location better, you ask somebody else where you are.
- She says, "You are 690 miles from Minneapolis, Minnesota.“ If you combine this information with the Boise information, you have two circles that intersect.



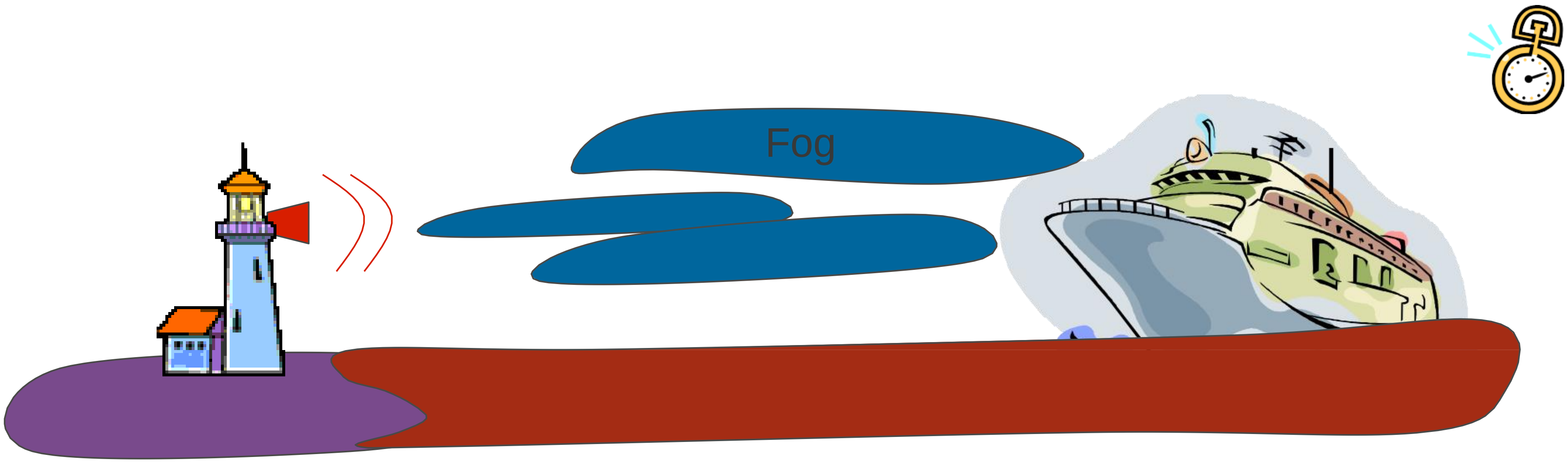
Where in the U.S. am I? (Cont'd)

- If a third person tells you that you are 615 miles from Tucson, Arizona, you can eliminate one of the possibilities, because the third circle will only intersect with one of these points. You now know exactly where you are…
- You are in Denver, Colorado!



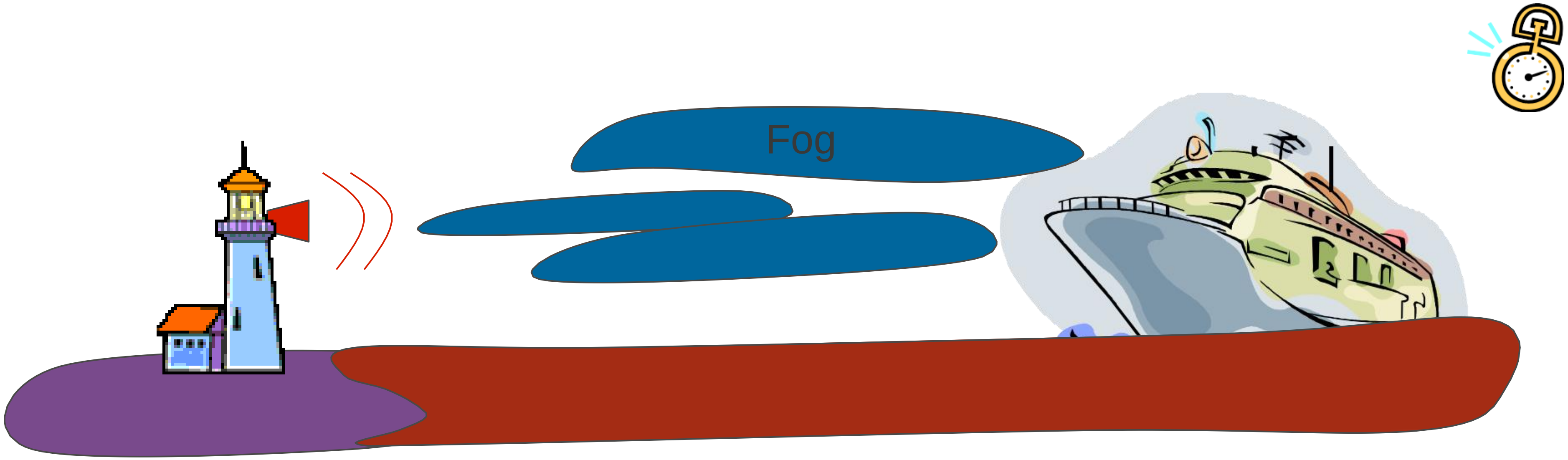
Another 2D Example

- Consider the case of a mariner at sea (receiver) determining his/her position using a siren (transmitter)



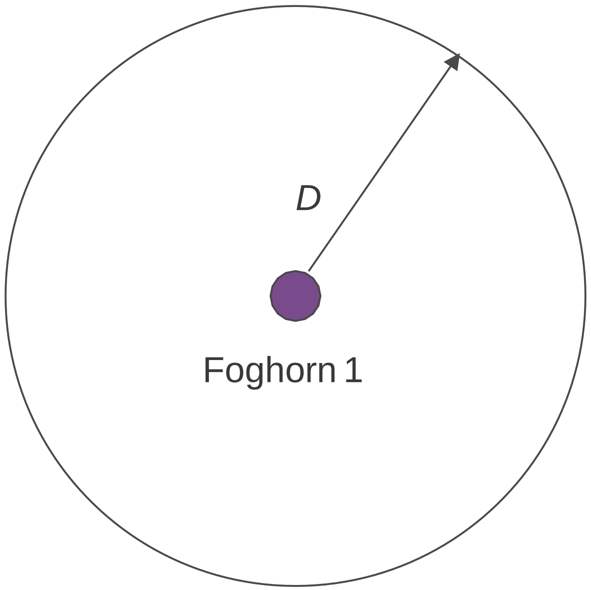
Mariner Example

- The propagation time of the whistle is the time it leaves the foghorn and reached to the mariner’s ear
- The clock of ship and foghorn should be synchronized
- This **propagation time multiplied by** the **speed of sound** is **distance** from siren to the mariner



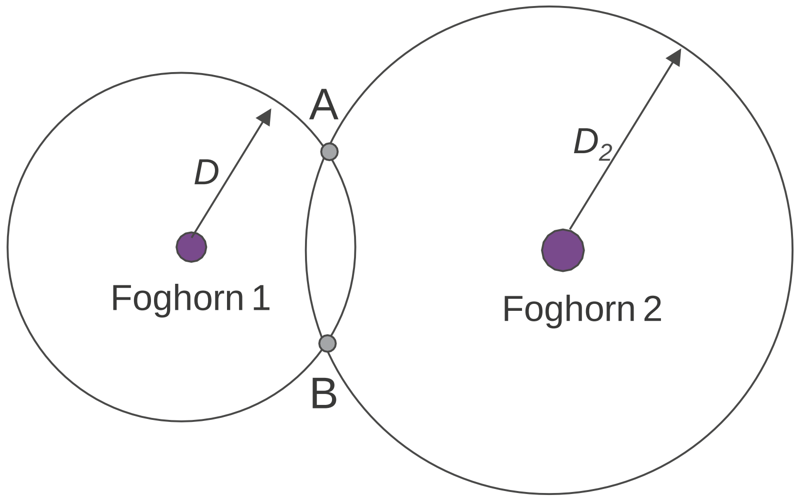
Mariner Example (Cont'd)

- Based on measurement from one such siren, we know mariner's distance (*D*) to siren.
- With measurement from one siren, mariner can be located anywhere on the circle denoted below:



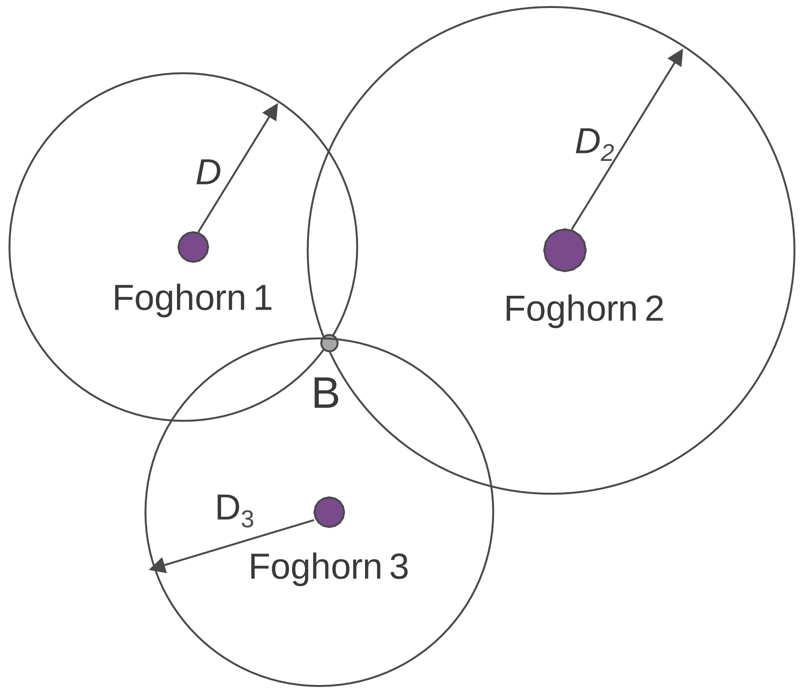
Mariner Example (Cont'd)

- If mariner simultaneously measured time range from 2nd siren in same way.
- Assuming, transmissions synchronized to a common time base and mariner knows the transmission times.
  - Possible Location of Mariner



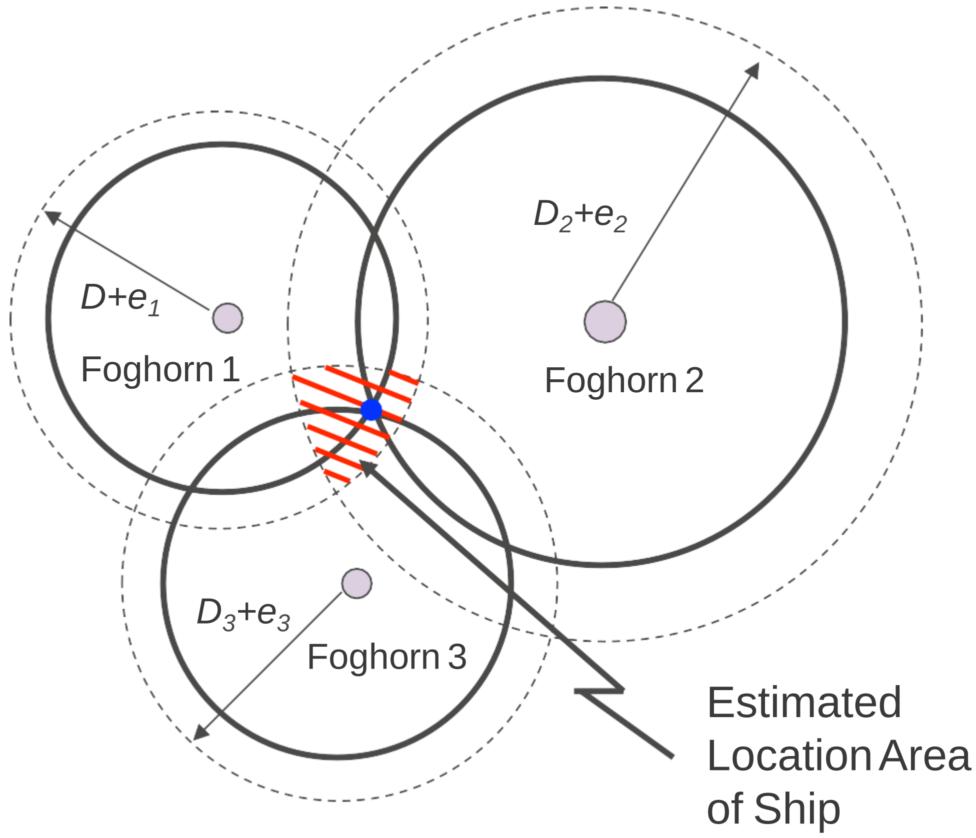
Mariner Example (Cont'd)

- Since mariner has approximate knowledge of ship's location, he/she can resolve the ambiguity between location A and B.
- If not, then measurement from a third siren is needed.



Mariner Example: Consider Effect of Errors

- Errors in TOA (Time of Arrival) measurements can occur
- If we make a fourth measurement, we can remove this uncertainty



Location Sensing

- GPS
  - A widely used technology is the GPS (Global Positioning System)
    - the navigation system using a network of satellites
  - In 2013, over 770 million GPS-enabled smartphones
  - However, GPS suffers from degraded accuracy indoors
- Indoor positioning
  - Wireless technologies such as: infrared (IR), Bluetooth, ultra sonic, radio signals (WiFi) or visible light

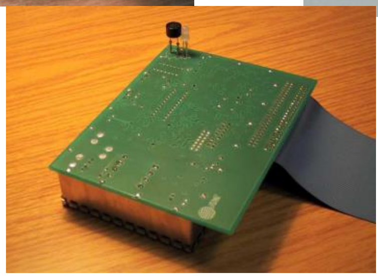
Positioning Techniques

- Time of Arrival (ToA): the travel time of a signal between the transmitter and the receiver
- Angle of Arrival (AoA): the direction of signals sent from a transmitter is determined
- Received Signal Strength (RSS): the signal strength values indicate the distance between the transmitter and the receiver
- Fingerprinting: comparing the received signals values in particular location with previous stored values in a database
  - RSS is widely used in fingerprinting positioning systems
- WiFi is available in many indoor environments
  - WiFi fingerprinting
  - WiFi trilateration: by calculating distances between access points (AP) and mobile device based on signal strength values

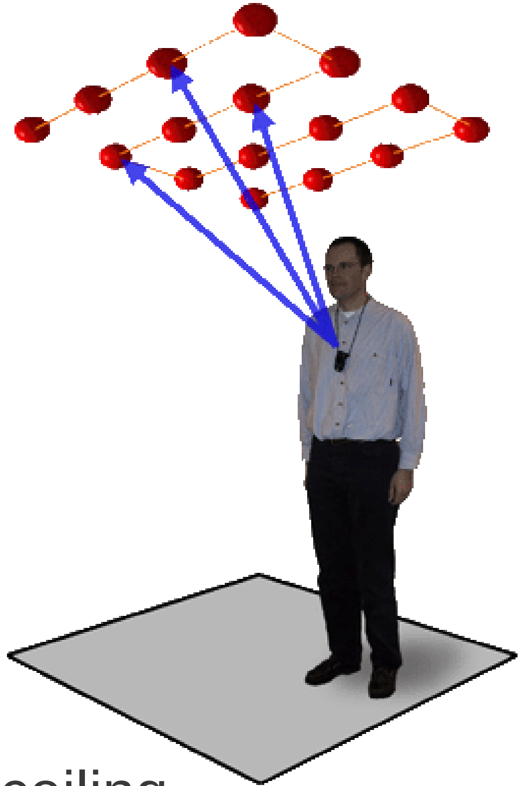
Location Aware Systems

- Indoor technologies:
  - Active Badge
  - Active Bat
  - Cricket
  - Microsoft Radar

Active Bat System, AT&T Cambridge



Ultrasonic receiver

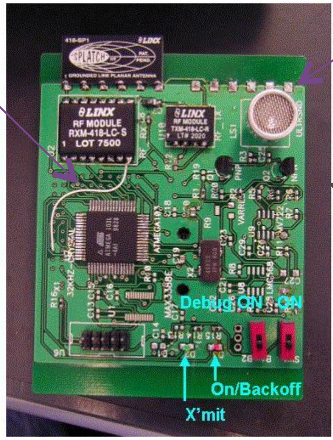


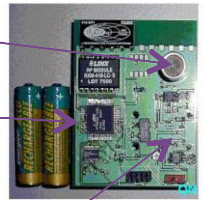
- ❑ Bat sends ultrasonic pulses to receivers on the ceiling
- ❑ The travel time of a pulse is measured
- ❑ Considering 3 or more distances, the location of person can be then determined based on the principle of trilateration

Cricket System, MIT

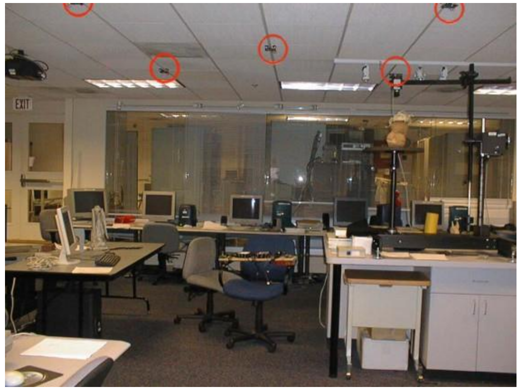
RF module

RF antenna





Ultrasonic sensor

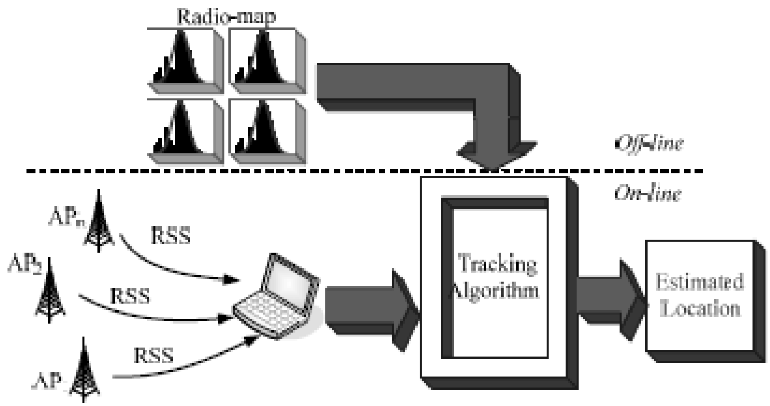


- ❑ Ceiling-mounted beacons publish information as RF signals and ultrasonic pulses
- ❑ The listeners on mobile devices receive RF signals (speed of light) and then ultrasonic pulses (speed of sound)
- ❑ The listeners estimate the distance of the corresponding beacon based on the difference in propagation speeds between RF and ultrasound

http://cricket.csail.mit.edu/

RADAR, Microsoft

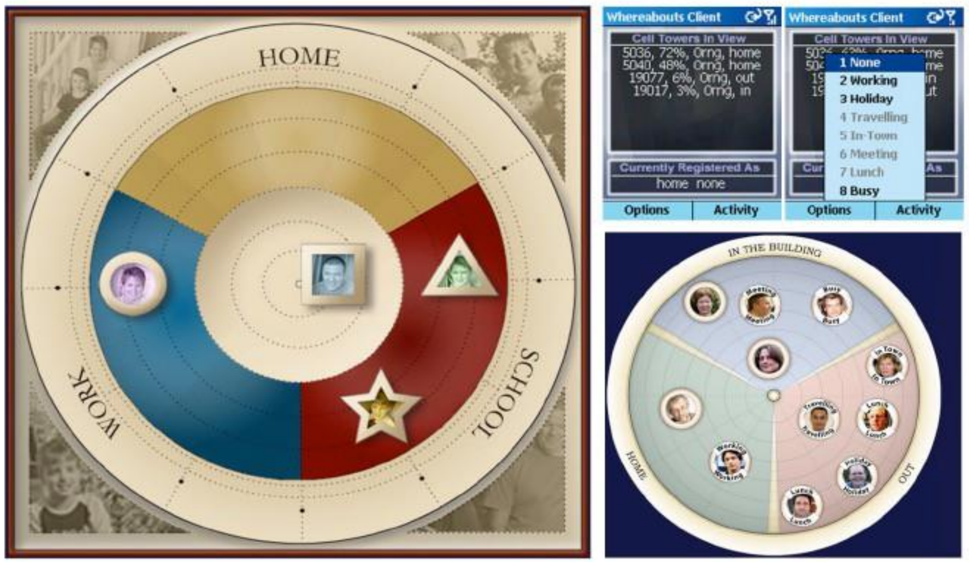
- The world's first Wi-Fi signal-strength based indoor positioning system
- Uses RF fingerprinting
- First stage: creating a radio map, i.e. a database of previously collected signal strength information at multiple locations and orientations
- A mobile user can perform a radio scan (measure the signal strength from APs within the range)
- It searches the radio map to determine the signal strength entry that best matches the measured signal strength



Xu, Liu, Ma and Peng (2010)

Location-Aware Clock

- ❑ Whereabouts Clock (Brown et al., 2007)
  - – The Clock displays family members’ current location
  - – It uses GSM cell ID available on cell phones to provide the location data



Location sensing technologies

- ❑ Wi-Fi fingerprinting and trilateration
- ❑ Bluetooth similar to Wi-Fi
- ❑ Cell ID: Whereabouts Clock
- ❑ Internal sensors: smartphones with a compass, accelerometer, and gyroscope
- ❑ Synthetic GPS uses computing power to forecast satellites' locations days/weeks in advance
- ❑ Barometer: improves indoor sensing (determining which floor) by measuring atmospheric pressure
- ❑ Terrestrial transmitters: the same principle as GPS but are stationary, ground-based transmitters that cover a chosen area with strong radio-positioning signals

Lawson (April, 2012) Ten Ways Your Smartphone Knows Where You Are, PC Magazine,
http://www.pcworld.com/article/253354/ten_ways_your_smartphone_knows_where_you_are.html

GPS Technology

GPS (Global Positioning System)

- Provides location and time information anywhere
- Free access using a GPS receiver
- The receiver can estimate its position based on latitude, longitude, and altitude
- GPS is generally an outdoor positioning system
- GPS signals are already very weak when they arrive at the Earth’s surface and even harder to determine the location in areas obstructed by buildings

GPS Architecture

- ❑ GPS satellites
- ❑ GPS receivers
- ❑ Ground stations
  - Track and monitor the GPS satellites and their transmissions, perform analyses, and update clocks and satellite orbit

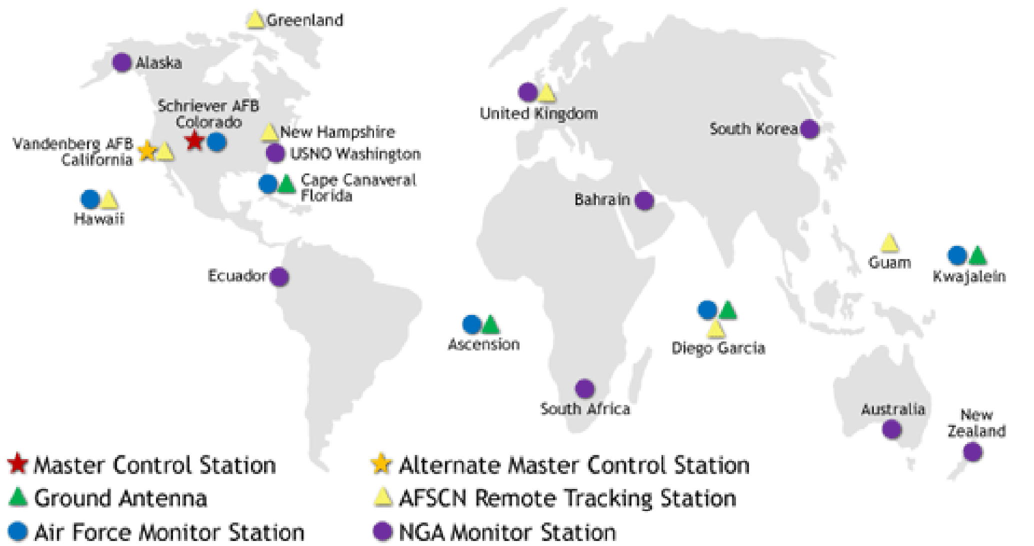


Figure source: http://www.gps.gov/systems/gps/control/

GPS Satellites

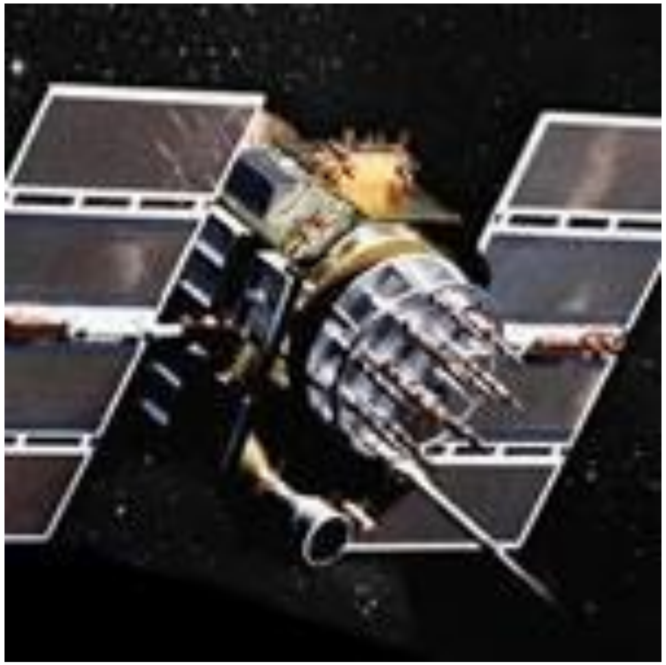
- The first operational GPS satellite (Navstar 1) was launched in 1978
  - NAVSTAR (NAVigation Satellite Timing And Ranging)
- Devised by the U.S. Department of Defense
- They soon opened it up to everybody else
- Maintained by the US government
- Operated by the US Air Force
- GPS Satellites Blocks/Groups
  - Blocks I, II, IIA, IIR, IIF and III

GPS Satellites Blocks (technicalities)

- **Block I/Group I** satellites: SVNs (Space Vehicle Numbers) 1-11, and were launched between 1978 to 1985
  - **Launch vehicle:** Delta II

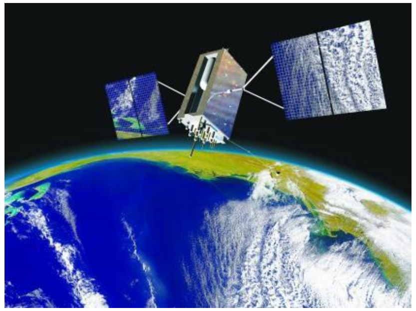
Rockwell International

- **Block II and IIA** satellites:
  - **Block II** was the first full scale operational, SVNs from 13-21, launched from 1989-1990
  - **Block IIA** satellites: SVNs 22-40 were launched from 1990 to 1997



GPS Satellites Blocks (cont'd)

- **Block IIR** satellites (3rd generation): SVNs 41-61developed by Lockheed Martin, 1997-2004
- **Block IIR(M)** satellites: Upgraded from IIR series, SVN 48-50, 52, 53, 55, 57, 58, from 2005 to 2009
- **Block IIF** satellites (4th Generation): SVNs 62-73 with improved capabilities, developed by Boeing, 2010 to 2016, 12 year lifespan
  - On August 1, 2014, the Air Force launched the 7th GPS IIF satellite into orbit
- **Block III** satellites: SVNs 74-81 and up by Lockheed Martin, span of life of 15 years, more powerful signals, enhanced accuracy and reliability
  - In production, begins launching in 2016



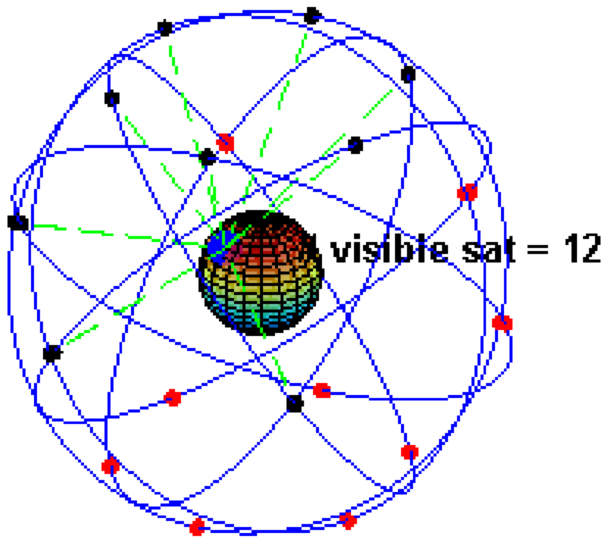
Global Navigation Satellite System (GNSS)

- **GPS** specific to the United States
- GPS satellite visibility limited in some areas
- **GNSS** provides geo-spatial positioning with global coverage:
  - Russia's satellite navigation network (**GLONASS**)
  - The European Union (EU)'s satellite navigation network (**Galileo**)
  - China's **BeiDou** Navigation **Satellite** System (**BDS**)
- **GNS = GPS+S**= other additional systems
- GNSS-enabled devices can use navigational satellites from other networks
- More satellites to track increases accuracy and reliability

GPS

GPS receives signals from multiple satellites

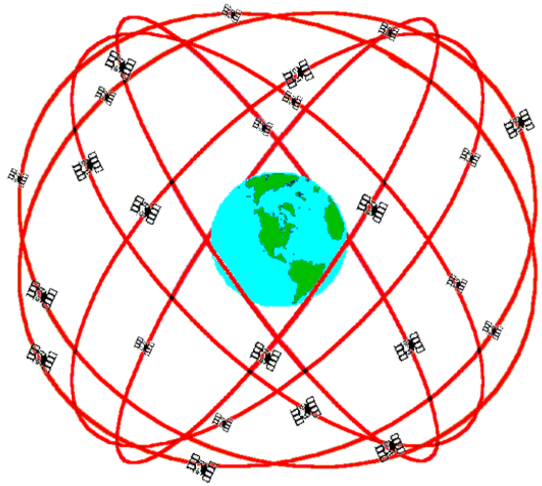
- A constellation of at least 24 earth-orbiting satellites
- It basically employs trilateration to determine physical locations
- GPS uses these “man-made stars” as reference points to calculate positions accurate to a matter of inches



From: Wikipedia

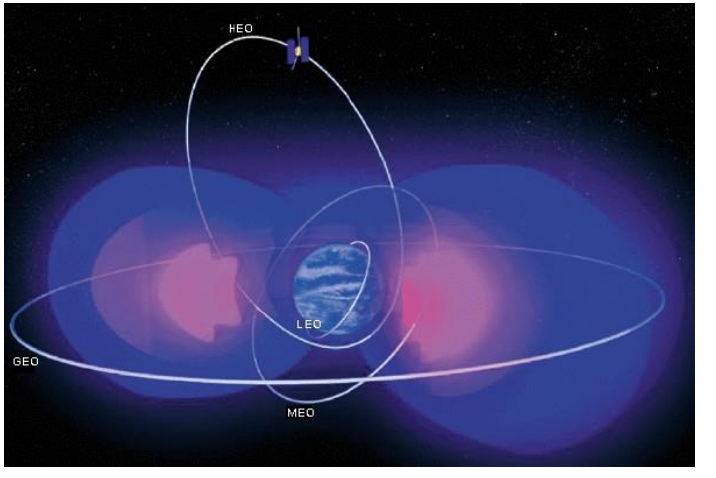
The Arrangement

- GPS satellites positioned in **MEO**
- Each satellite orbits the Earth **twice a day**
- The satellites in the GPS constellation are arranged into **6** equally-spaced **orbital planes** surrounding the Earth, each with **4 satellites**
- This 24-slot arrangement ensures there are **at least four satellites** in view from virtually any point on the planet



Types of Satellites

- LEO (Low Earth Orbit)
  - at 500-1500 kms above earth
  - used in telecommunication and data communication
- MEO (Medium Earth Orbit)
  - at 6000-20000 kms above earth
  - navigation satellites
- GEO (Geostationary Earth Orbit)
  - at 36,000 kms above the earth
  - commercial and military communications satellites
- HEO (Highly Elliptical Orbit)
  - communication satellites for regions near the North Pole



Satellite Facts (as of 2013)

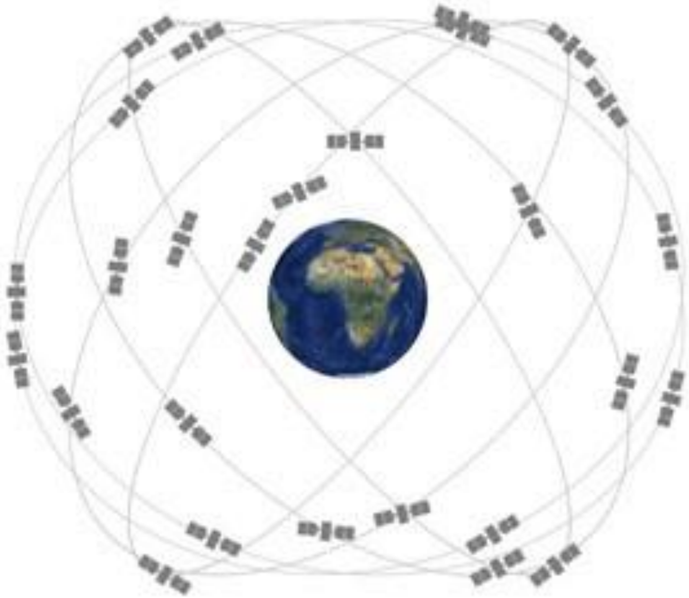
- More than 1000 operational satellites currently in orbit around Earth

Satellite Quick Facts			
Total number of operating satellites: 1071			
LEO: 523	MEO: 75	Elliptical: 38	GEO: 435
United States: 459	Russia: 110	China: 105	
Total number of U.S. Satellites: 459			
Civil: 7	Commercial: 204	Government: 117	Military: 131

includes launches through 5/31/2013

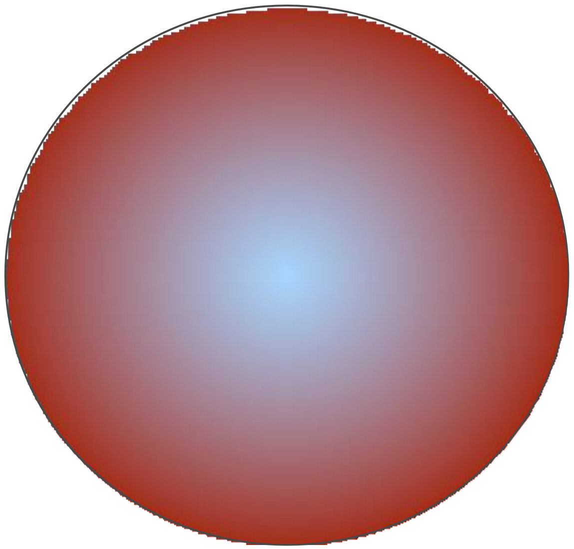
Satellite Constellation

- In June 2011, the Air Force successfully completed a GPS constellation expansion known as the "Expandable 24" (or 24+3)
- Existing satellites were repositioned, so that three of the extra satellites became part of the constellation baseline
- GPS now effectively operates **as a 27-slot constellation**



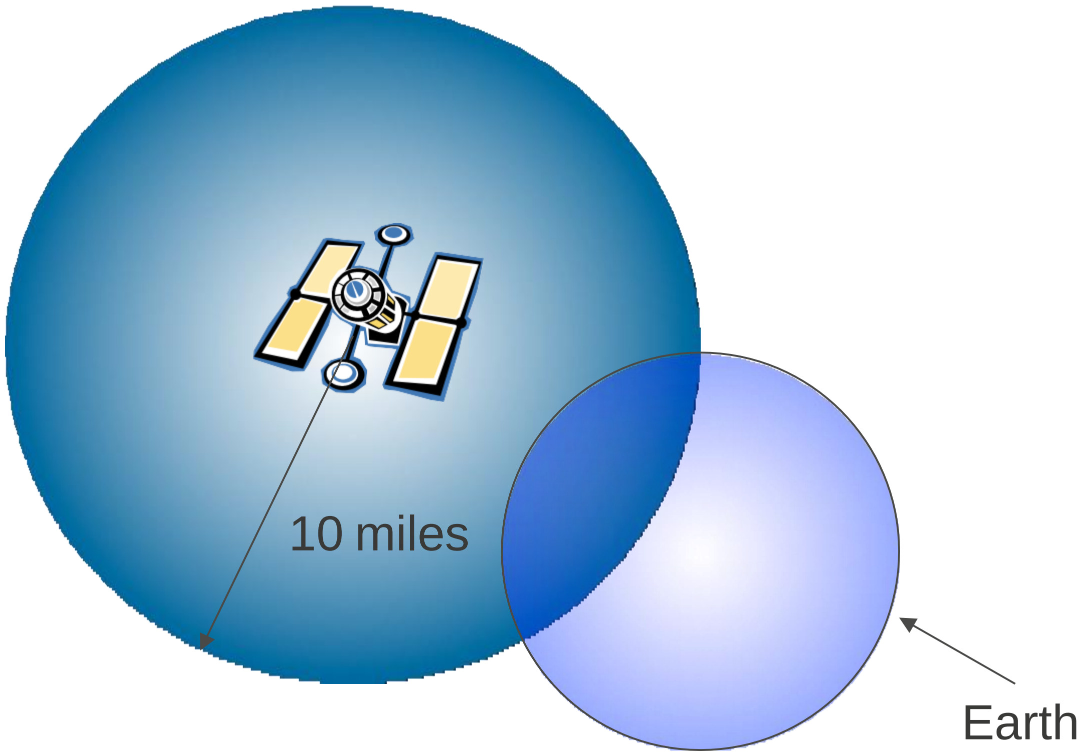
3D Trilateration

- 3D trilateration is not much different from 2D trilateration, but it's a little trickier to visualize
- Imagine the radii from the examples in the last section going off in all directions. So instead of a series of circles, you get a series of spheres.



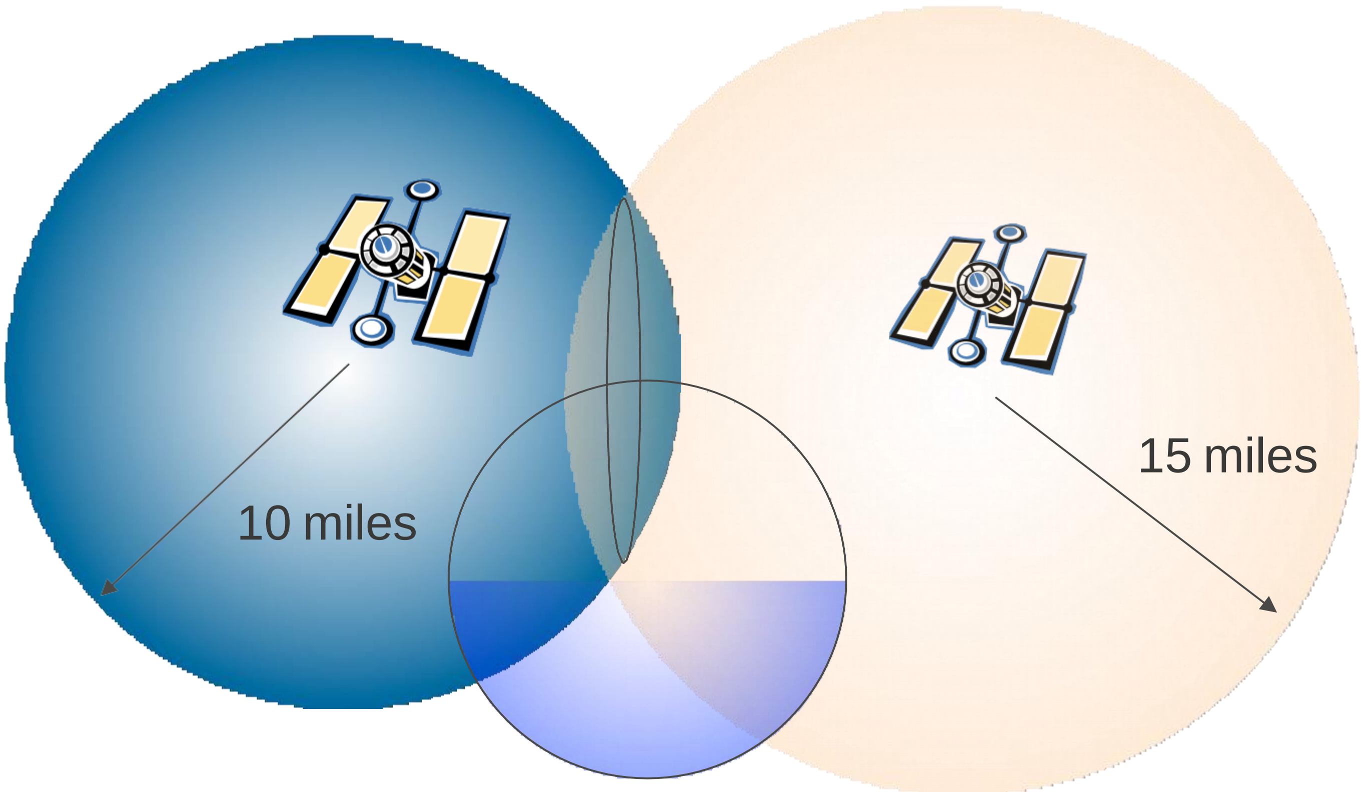
GPS Trilateration

- If you know you are 10 miles from satellite A in the sky, you could be anywhere on the surface of a huge, imaginary sphere with a 10-mile radius.



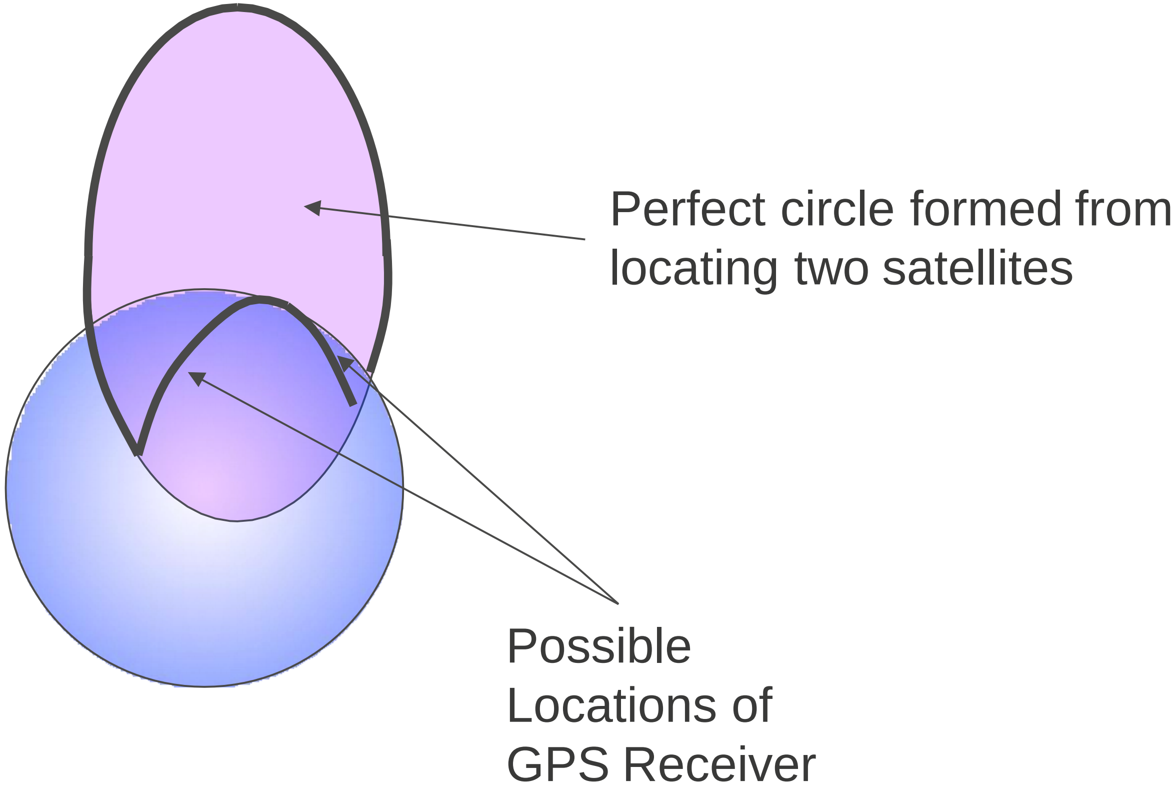
GPS Trilateration (Cont'd)

- If you also know you are 15 miles from satellite B, you can overlap the first sphere with another, larger sphere. The spheres intersect is a perfect circle.



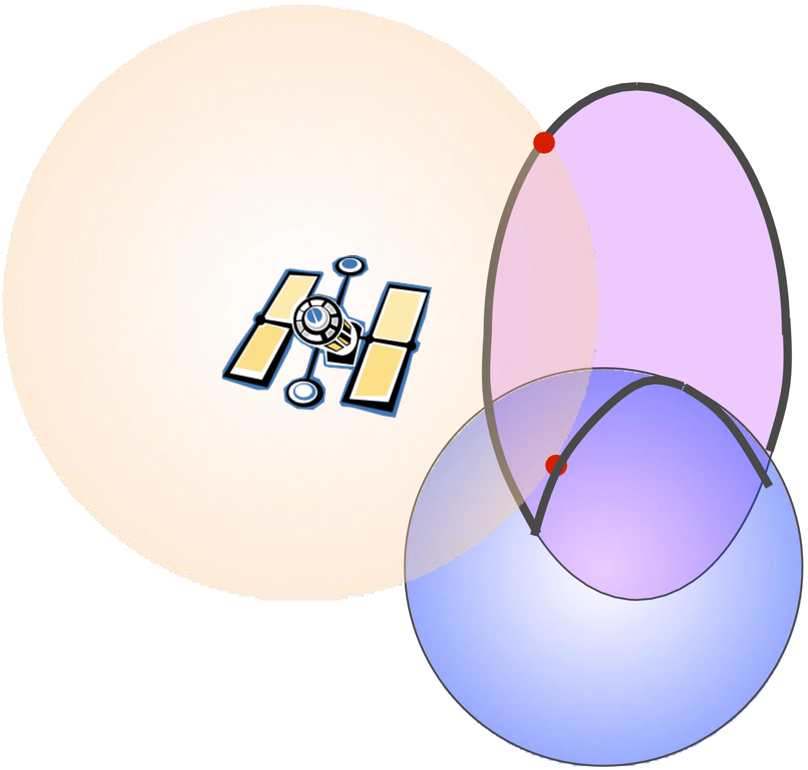
GPS Trilateration (Cont'd)

- The circle intersection implies that the GPS receiver lies somewhere in a partial ring on the earth.



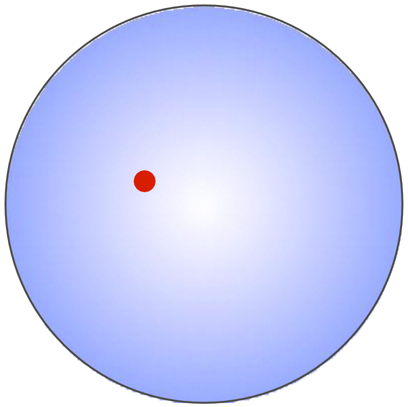
GPS Trilateration (Cont'd)

- If you know the distance to a third satellite, you get a third sphere, which intersects with this circle at two points.



GPS Trilateration (Cont'd)

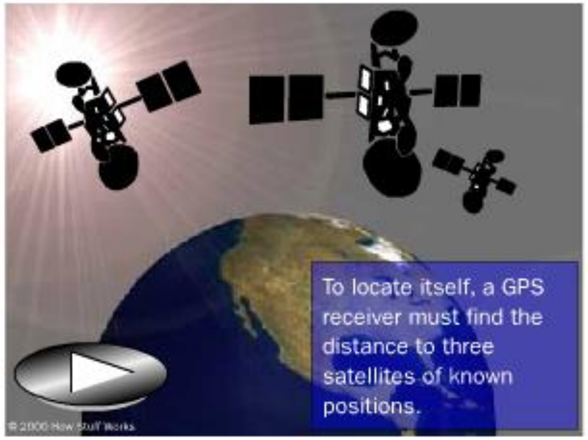
- The Earth itself can act as a fourth sphere -- only one of the two possible points will actually be on the surface of the planet, so you can eliminate the one in space.



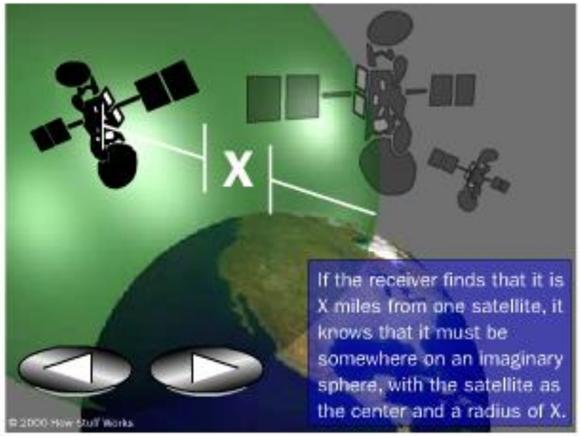
- Receivers generally look to **four (or more) satellites** to improve accuracy and provide precise altitude information.

GPS

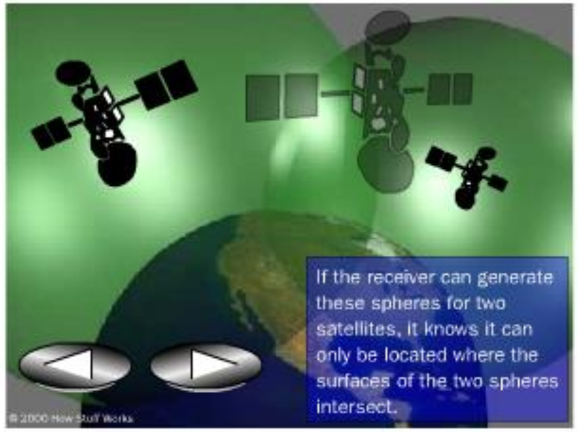
3-D Trilateration



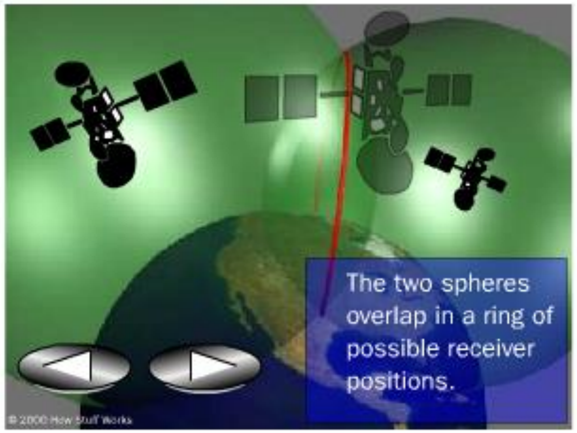
3-D Trilateration



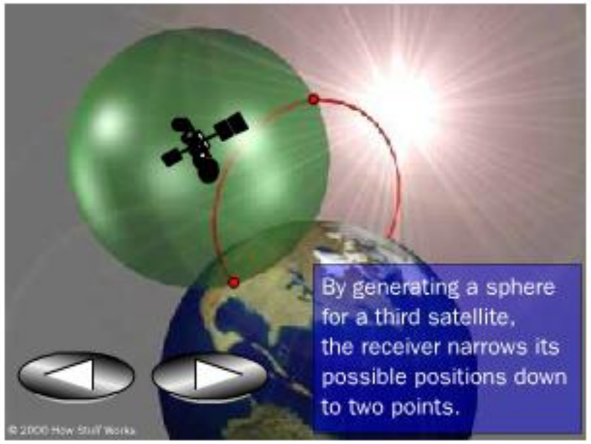
3-D Trilateration



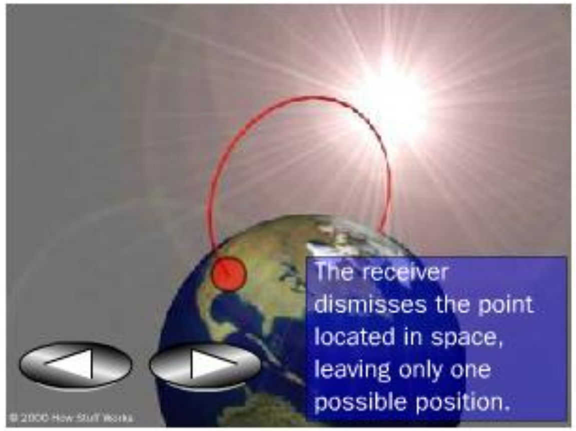
3-D Trilateration



3-D Trilateration

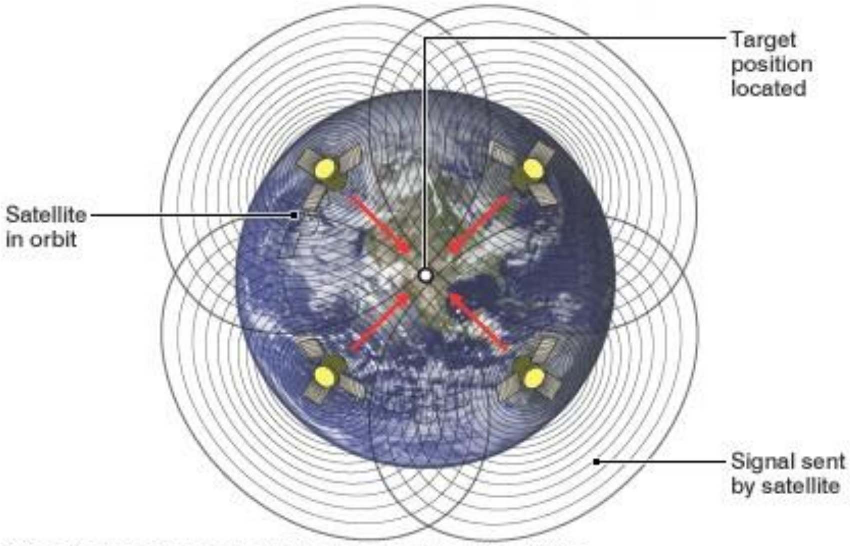


3-D Trilateration



GPS Receivers

- In order to determine the location, GPS need to know three things:
  - Orbit position and the location of four or more satellites above you
  - Time of Arrival of signals: requires accurate satellite and receiver clocks and time synchronization
  - The distance between you and each of those satellites



When the receiver has locked onto a number of satellites, it can accurately determine the position of the subject

Calculating Distance

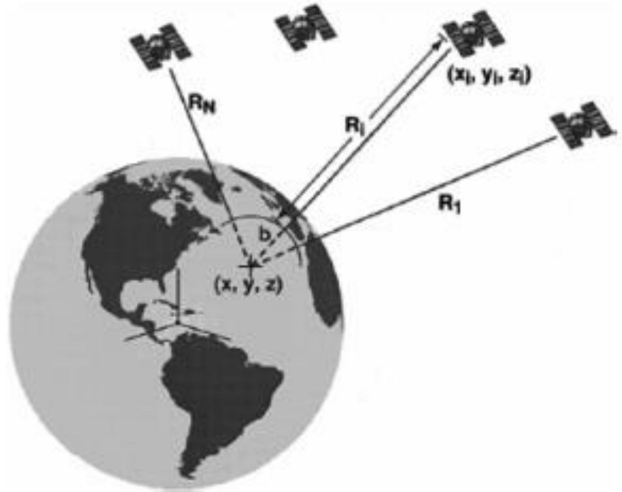
- Radio waves travel at the speed of light (about 300,000 km per second in a vacuum)
- The receiver can determine how far the signal has traveled by timing how long it took the signal to arrive (Similar to siren example)
  - GPS satellites broadcasting the time of transmission of signals

Distance = (the time the satellite transmitted signals – the time the receiver received signals) * speed of light)

Location Estimation

A GPS receiver's job is:

- ❑ to locate four or more of the satellites,
- ❑ figure out the distance to each by measuring the transit time of the signal between the satellite and the receiver and multiplying by the speed of light
- ❑ and use this information to determine the location based on mathematical principle of **trilateration**
- ❑ However it is important to calculate and consider the receiver's clock bias



Source http://pooh.poly.asu.edu/Mobile/ClassNotes/Papers/Location/LocationSystemsAnIntroToTechLocationAwareness.pdf

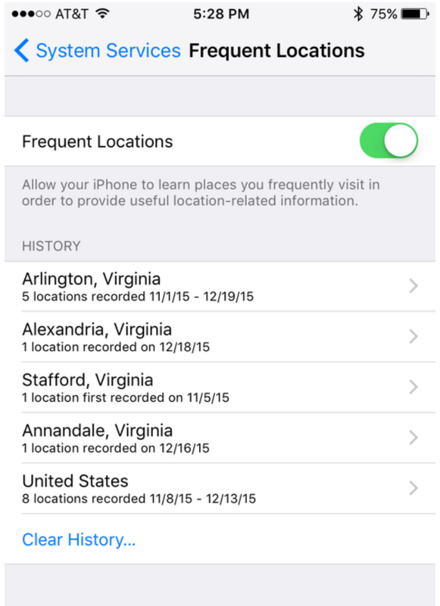
Geofencing

- ❑ It combines the information about the user's current location with the information about the user's proximity to locations of interest
- ❑ Geofence = location (lat and long) + proximity (radius)
- ❑ There can be multiple active geofences for one user device
- ❑ Each geofence can use Location Services to send the information whether you entering or exiting (or include a duration within the area to wait/dwell)
- ❑ A geofence can have an expiration duration

Geofencing in Marketing

- It enables to send mobile phone users advertisements, special offers messages, alerts, coupons or other information
- Accesses Location Services on your device (your location data and history)

https://www.tatango.com/blog/top-10-most-commonly-asked-location-based-mobile-marketing-questions/



Sourcehttps://www.mac4n6.com/blog/2015/12/20/parsing-the-ios-frequent-locations

Location Aware Computing Challenges

- Absolute versus relative location
- Accuracy (how close are readings to real values)
- Precision (how consistent are readings)
- Indoor positioning
  - Identifying the floor level
- Energy management
- Privacy and security issues
  - Policies for sharing location information
- Integration of multiple location sensing technologies
  - E.g. GPS, Cell ID and Wi-Fi

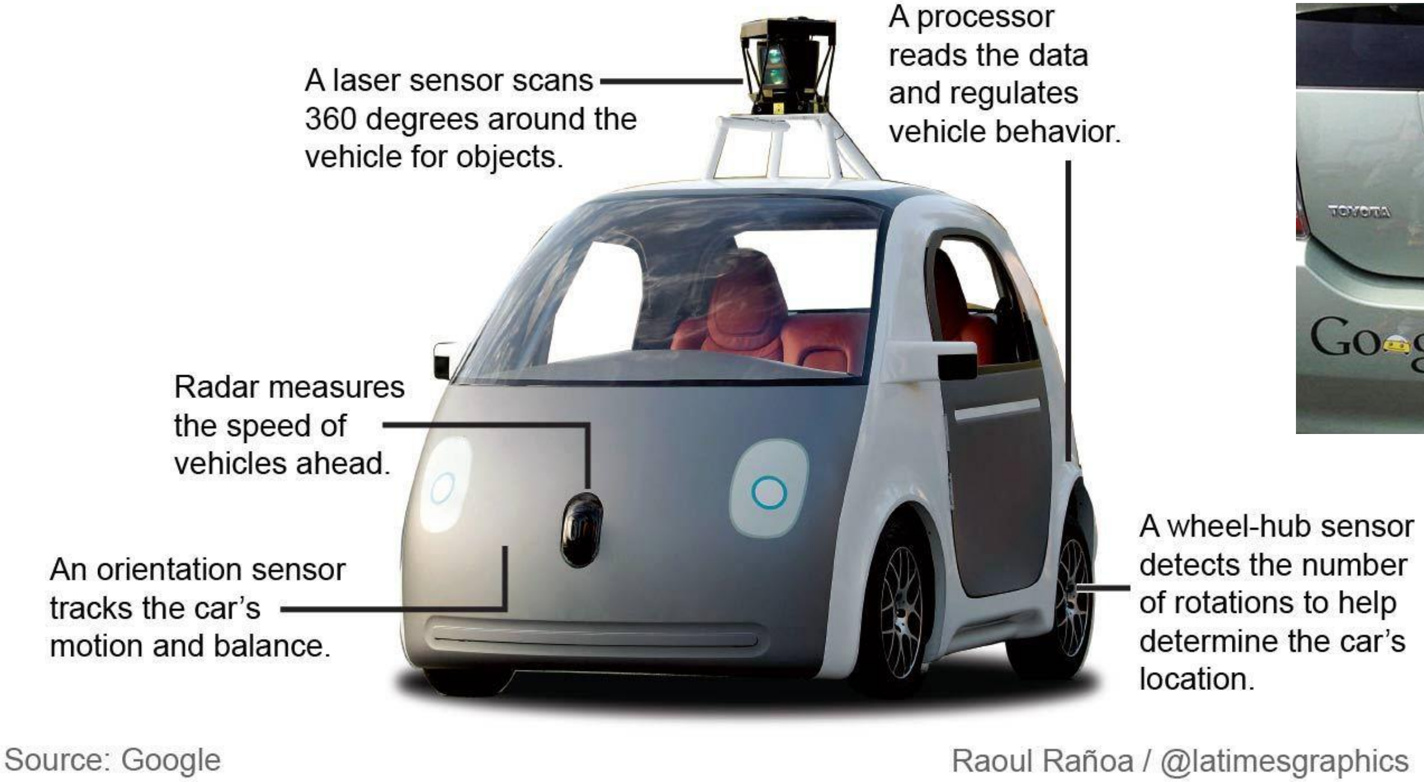
Location Sensing Apps

- WAZE
  - Waze is one of the world's largest community-based traffic and navigation apps
- Google Latitude
  - Google Latitude was retired on August 9th, 2013
  - Instead, sharing your location with your friends on Google+ using the Google+ Android app

A Current Example

[Google self-driving car]

"AU-001" is a historic license plate, the first one ever issued in the United States to an autonomous vehicle



http://spectrum.ieee.org/transportation/advanced-cars/plate-and-switch-googles-selfdriving-car-is-a-transformer-too

References

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- Paramvir Bahl and Venkata N. Padmanabhan (2000), RADAR: An In-Building RF-based User Location and Tracking System,
- Firas Alsehly, Tughrul Arslan and Zankar Sevak () Indoor Positioning with floor determination in Multi Story Buildings
- Xu, Liu, Ma and Peng (2010), WLAN Indoor Tracking Method via Improved Particle Filter Algorithm
- Hakan Koyuncu, Shuang Hua Yang (2010) A Survey of Indoor Positioning and Object Locating Systems

Exam Structure (Proposed)

Assessment Weighting: 50% **Total Marks available: 100**
Reading Time: 30 Minutes **Exam Duration: 2 Hours**

Part A: 10(20) Multiple Choice Questions (20 Marks)

Part B: 8 Short Answer Questions (64 Marks)

Part C: 1 Long Answer Question (16 Marks)

Or

Part A: 15(30) Multiple Choice Questions (30 Marks)

Part B: 5 Short Answer Questions (40 Marks)

Part C: 2 Long Answer Question (30 Marks)

Or

Part A: 18(36) Multiple Choice Questions (36 Marks)

Part B: 6 Short Answer Questions (48 Marks)

Part C: 1 Long Answer Question (16 Marks)

Sample Exam questions – Part A

Question 1. Which of the following REST's architectural constraints reduces the number of client-server interactions?

A. Cacheable.
B. Code on Demand.
B. Stateless.
C. Uniform interface.

Question 2. Which of the following statements is not TRUE?

A. A bundle can be used to start an activity.
B. A bundle is a mapping from String keys to various Parcelable values.
B. The putExtra() method allows adding a bundle to the intent.
C. A bundle enables carrying data between activities.

Sample Exam questions – Part A (cont'd)

Question 3. Which of the following statement is NOT true for situation-aware computing?

A. Aggregation and fusion of multiple context attributes.
B. Inferring current situations based on multiple context attributes.
B. Focusing on individual pieces of context.
C. Providing a more abstract view of the environment.

Question 4. Which of the following mobile technologies is commonly used in biosensors and wearables such as a blood pressure monitor?

A. Bluetooth
B. WiMAX
C. ZigBee
D. NFC

Sample Exam questions – Part B

Question 1. Compare fingerprinting and trilateration in location-aware computing.

Question 2. Briefly explain the purpose of AsyncTask in Android and how it is related to the UI Thread

Question 3. How does fog computing relate to cloud computing? Explain.

Question 4. Describe how Client and Server Side Stubs are generated using WSDL files

Sample Exam questions – Part C

Will not look at actual example here, however you could expect a design problem drawing upon experience gained throughout the tutorials and assignments.

This could start with a detailed specification of a problem scenario to be solved through the use of a Mobile and Distributed Computing System. The question would be comprised of different components, for example:

- A question to outline an overall system to meet the requirements based on the client-server (or related) architecture, including how the processes would be divided between tiers
- A question to describe Web Service methods (including input and output parameters) to be used at the server side – pseudo code only
- Description of screens, activities and UI features in an Android font end (client)

Another type of long answer question could relate to other major concepts covered in the course such as: (i) the evolution of middleware, RESTful web services and related MDCS architectures; (ii) comparison of suitability of different mobile and wireless technologies, (iii) the future of pervasive and ubiquitous computing.