to read:
Krumm, cap 7

Location & Position Services

- principles
- outdoors
  - GPS
  - cellID
- indoors
  - WiFi based
- Google

Where am I?

- Location vs. position
  - Location: symbolic location (building/room)
  - Position: x,y,z, long, lat, alt

- Technologies
  - Look up on the map
  - Dead reckoning
  - Radio
  - Light

- Infrastructure support
  - Instrumented environment
  - Existing infrastructure
  - Independent positioning

- Errors
  - Measurements
  - Clocks, CPUs
  - situation

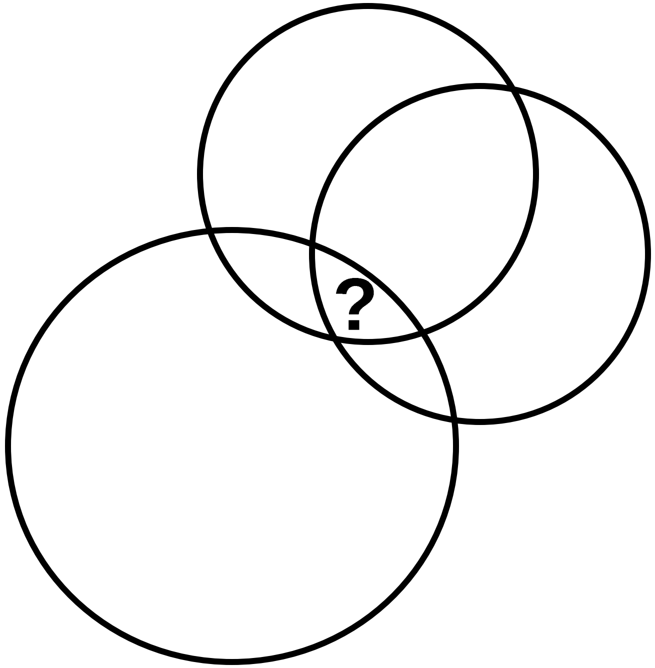
- Accuracy, precision

Principles

1. proximity
2. multilateration
3. multiangulation
4. fingerprinting

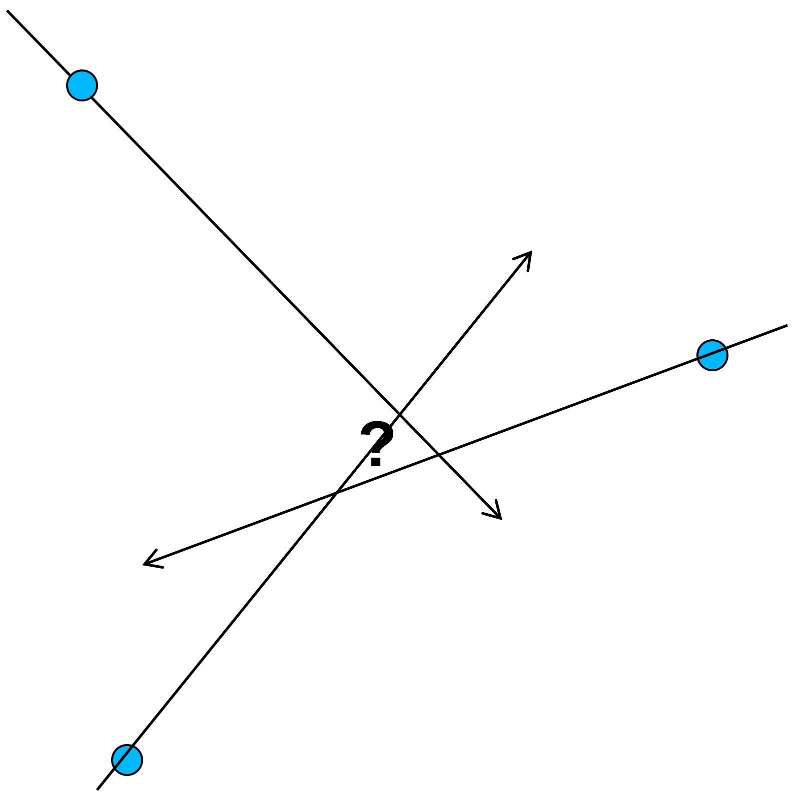
Proximity

- QR code: you are at … (location | position)
- AP MAC
  - Where is the AP?
  - How large is the circle?
- CELL ID
  - Idem
- Solve: intersect circles
- IP geolocation
  - Problem: wide area providers
  - Problem: tunnels



Multiangulation

- **Two known lines**
- **How to find lines?**
  - **Known points**
  - **Measure angles**
  - **Compass?**
- **Not widely used in today's mobiles**



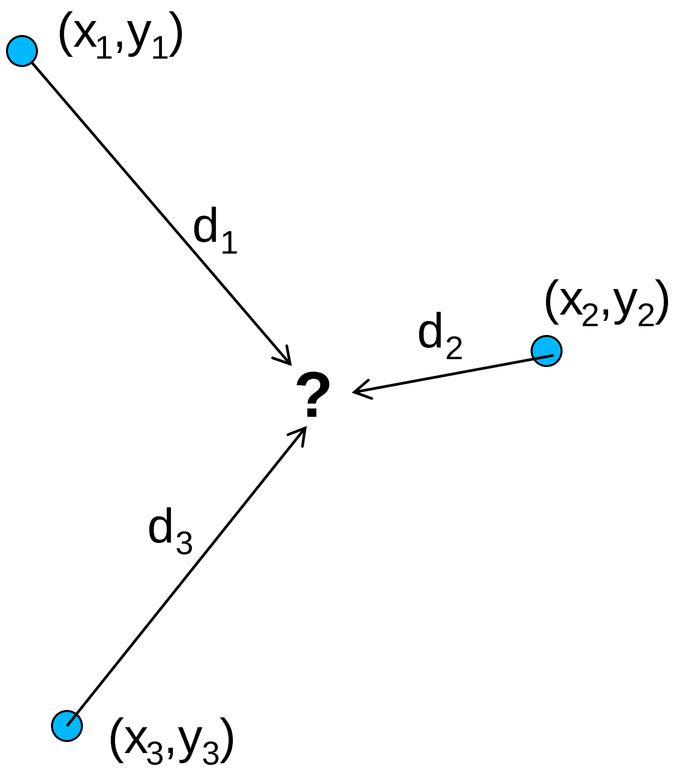
Multilateration

- **Distances to known points:**

$(x-x_1)^2+(y-y_1)^2=d_1^2$

$(x-x_2)^2+(y-y_2)^2=d_2^2$

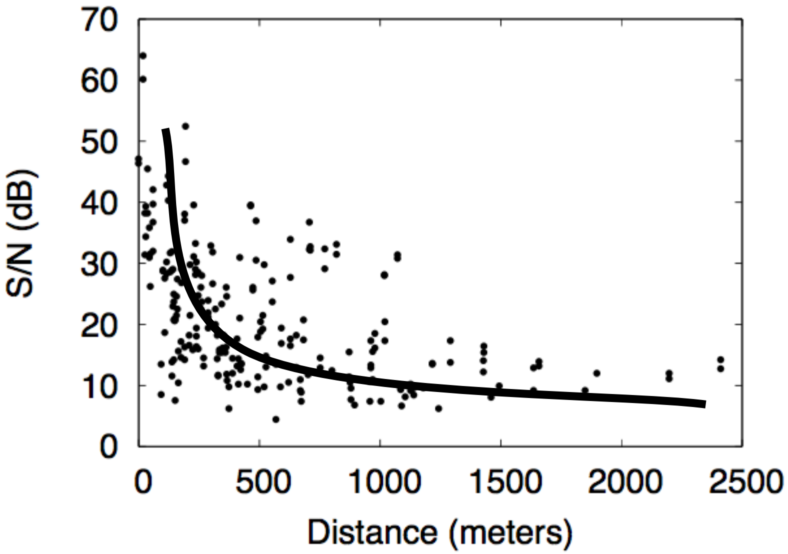
$(x-x_3)^2+(y-y_3)^2=d_3^2$



- **How to**
  - Measure distances?
  - Deal with distance errors?
  - Solve the system?

how to measure distances(ranging)?

1. Signal strength
   - Inaccurate indoor
   - Affected by multipath

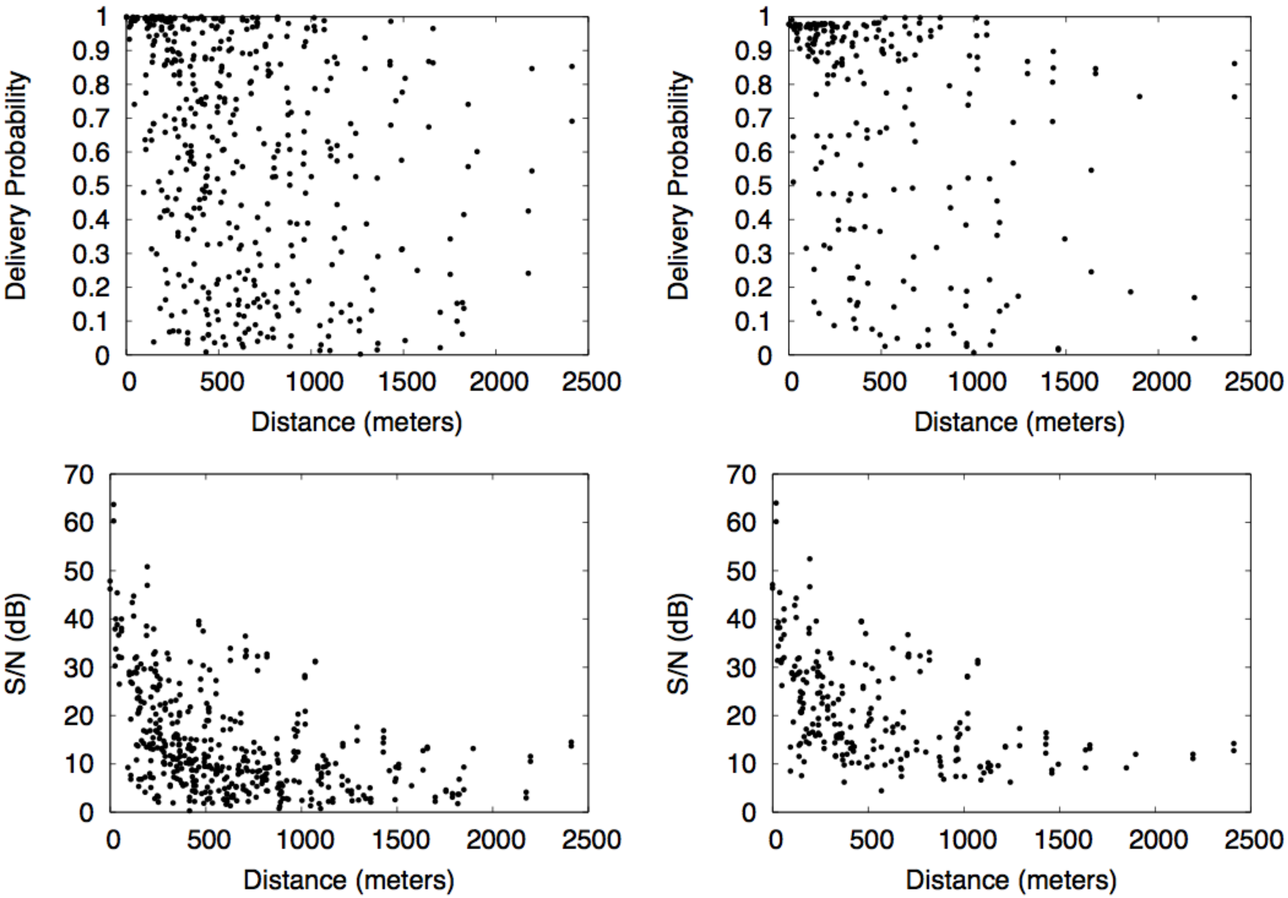


Example: my SNR = 30dB

How far am I?

2. Time of flight (TOF)
   - Range = $c(t^R - t^S)$
   - Needs clock synchronization

SS vs distance, PDR vs distance

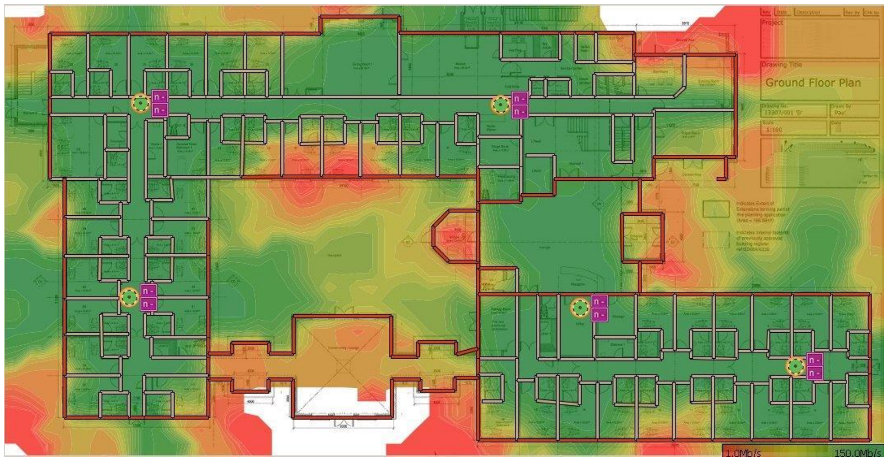


802.11b 1Mbps **802.11b 11Mbps**

Signal is highly variable indoors

fingerprinting

- SS = P/d² is only idealized outdoors
- Indoors:



- Radio fingerprint of a point (x,y)
  - SS_1 to AP_1
  - SS_2 to AP_2
  - …

  (roughly unique)

- Training phase

X	Y	APA	APB	APC
x_1	y_1	SS_1^A	SS_1^B	SS_1^C
x_2	y_2	SS_2^A	SS_2^B	SS_2^C
x_3	y_3	SS_3^A	SS_3^B	SS_3^C
x_4	y_4	SS_4^A	SS_4^B	SS_4^C

- Online phase:

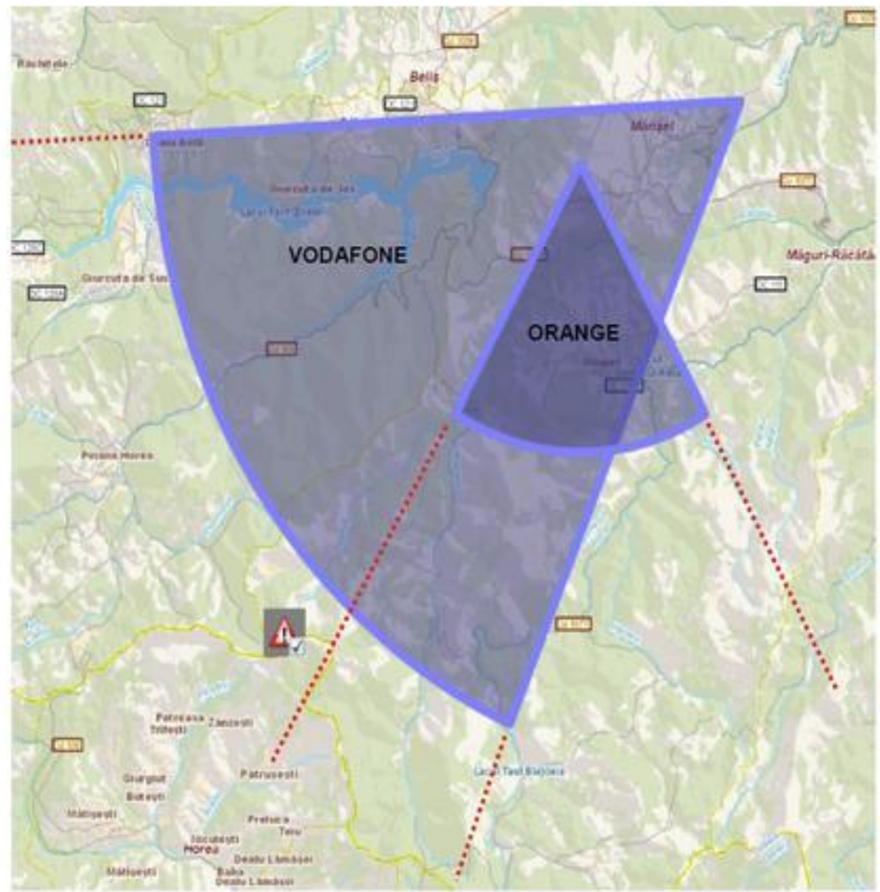
I see (SS_0^A, SS_0^B, SS_0^C),

Where am I ?

GSM/UMTS based positioning

- From user – cell-id
- From operator
  - Sector + time advance (GSM)
  - Multiple cells (UMTS)

SUPRAPUNERE IMAGINI LOCALIZARE
APELURI VODAFONE / ORANGE



S.T.S. – NU DETINE ALTE MIJLOACE DE LOCALIZARE, CF. LEGII

Accidentul din Apuseni (2014):

LOCALIZAREA APELULUI 112

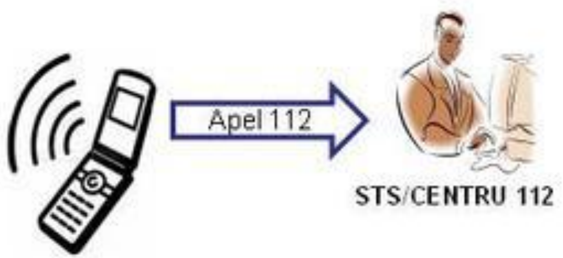
INFORMAȚIA DE LOCALIZARE - datele care indică **poziția geografică** în care se află echipamentul terminal al unui utilizator de telefonie mobilă sau **adresa fizică** de instalare a punctului terminal pentru o rețea de telefonie fixă. (OUG 34/2008, aprobată prin Legea 160/2008, art. 3, alin. n)

ANCOM - stabilește conținutul și formatul datelor în baza cărora este obținută automat informația de localizare a apelantului. (Decizia ANCOM nr. 1023/2008, art. 27 la 32)

- **Localizarea apelului din rețele mobile de telefonie**

IDENTIFICATOR CELULA SAU SECTOR
Decizie ANCOM 1023-2008, art 27

Localizare aplicată în cazul accidentului aviatic

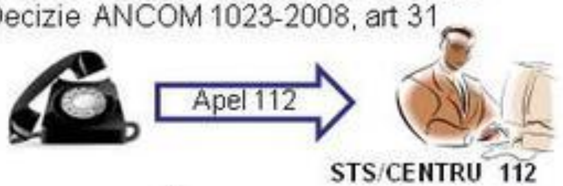


Date transmise de operator: 1,2,3 si 4

Figura desenata de STS pe baza datelor de la operator

- **Localizarea apelului din rețele fixe de telefonie**

ADRESA FIZICĂ: oraș, stradă, adresă
Decizie ANCOM 1023-2008, art 31



Furnizate de operatori ca liste

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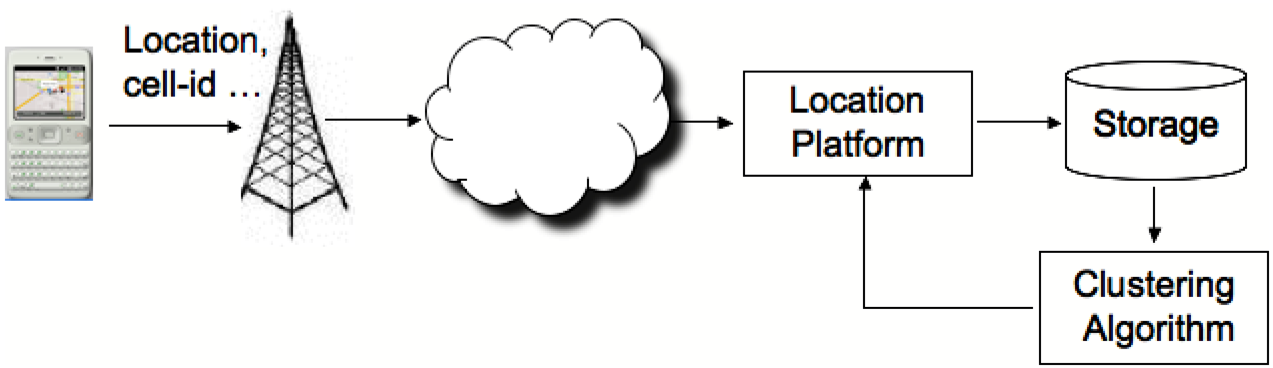
Google

- API looksup fingerprint (WiFi+Cell)
- Google car
- + involuntary crowdsourcing
  - Cell id + GPS
  - WiFi MAC + GPS
    - Every 45s (NetworkLocationProvider.java)
    - Submitted even when not running any Google app



https://support.google.com/gmm/answer/81873

http://googlemobile.blogspot.ro/2008/06/google-enables-location-aware.html

GPS

Slides borrowed from Richard Y. Yang @ Yale

GPS Basics

Simply stated: The GPS satellites are nothing more than a set of wireless base stations in the sky @20000 Km

- The satellites simultaneously broadcast beacon messages (called navigation messages)
- A GPS receiver measures time of arrival to the satellites, and then uses "trilateration" to determine its position

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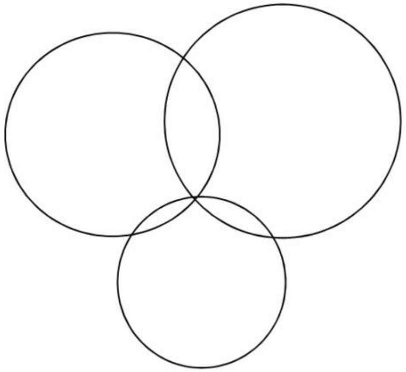
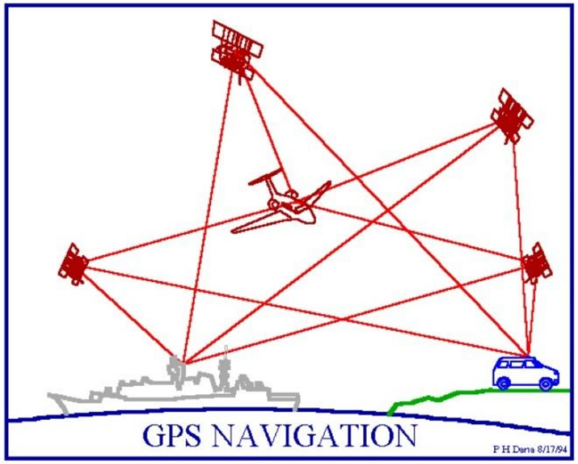
GPS Basics: Trilateration

- Measurement: $$t^{R1} = t^{S} + \frac{\|p - p_1\|}{c}$$

Computes distance $\|p - p_1\| = c(t^{R1} - t^{S})$ + error





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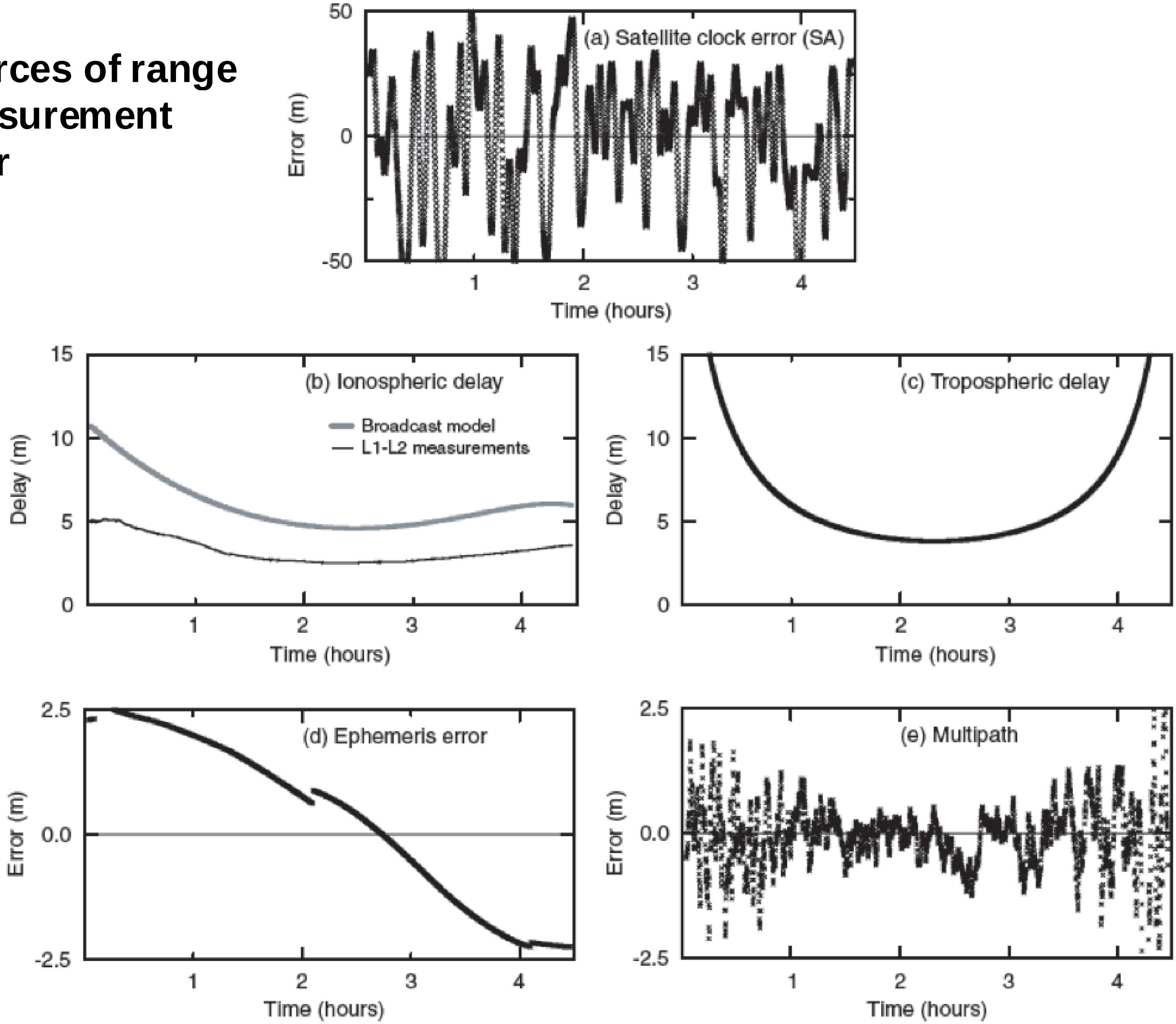
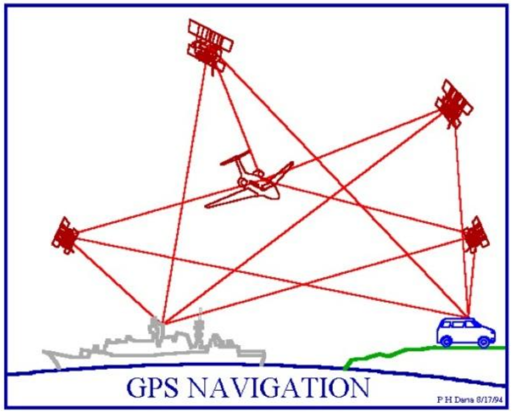
Sources of range measurement error



GPS Basics: Triangulation

- In reality, receiver clock is not sync'd with satellites
- Thus need to estimate clock

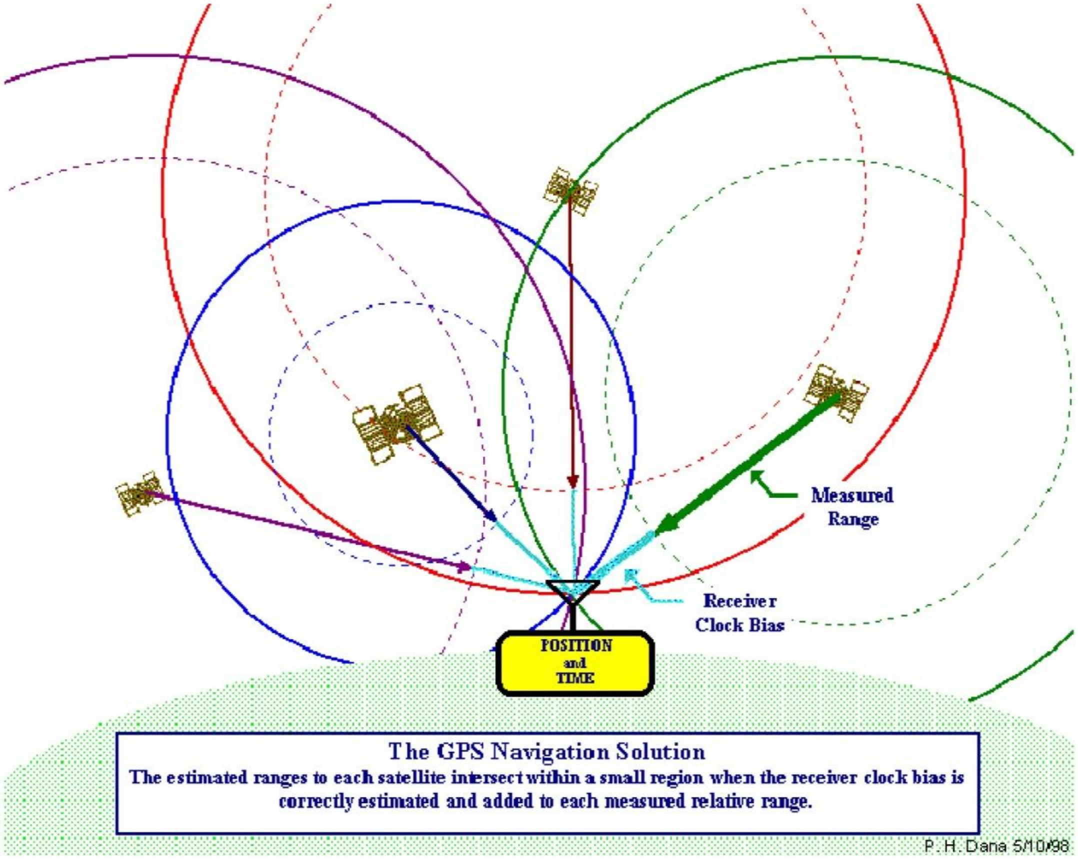


$$t^{R1} = t^S + \frac{d_1}{c} + \delta_{clock-drift} \longrightarrow \|p - p_1\| = c(t^{R1} - t^S - \delta_{clock-drift})$$

$$= c(t^{R1} - t^S) - c\,\delta_{clock-drift}$$

called pseudo range

Why Do I Need To See 4 Satellites?



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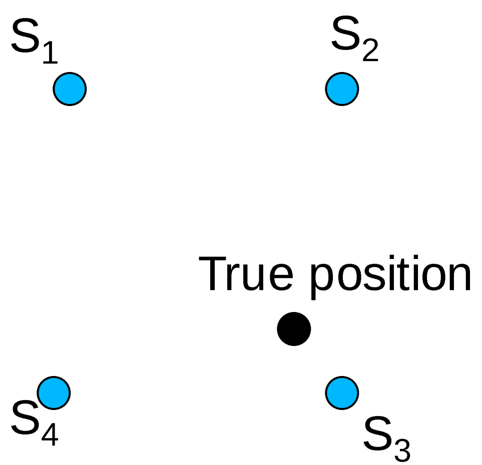
GPS – solving for position

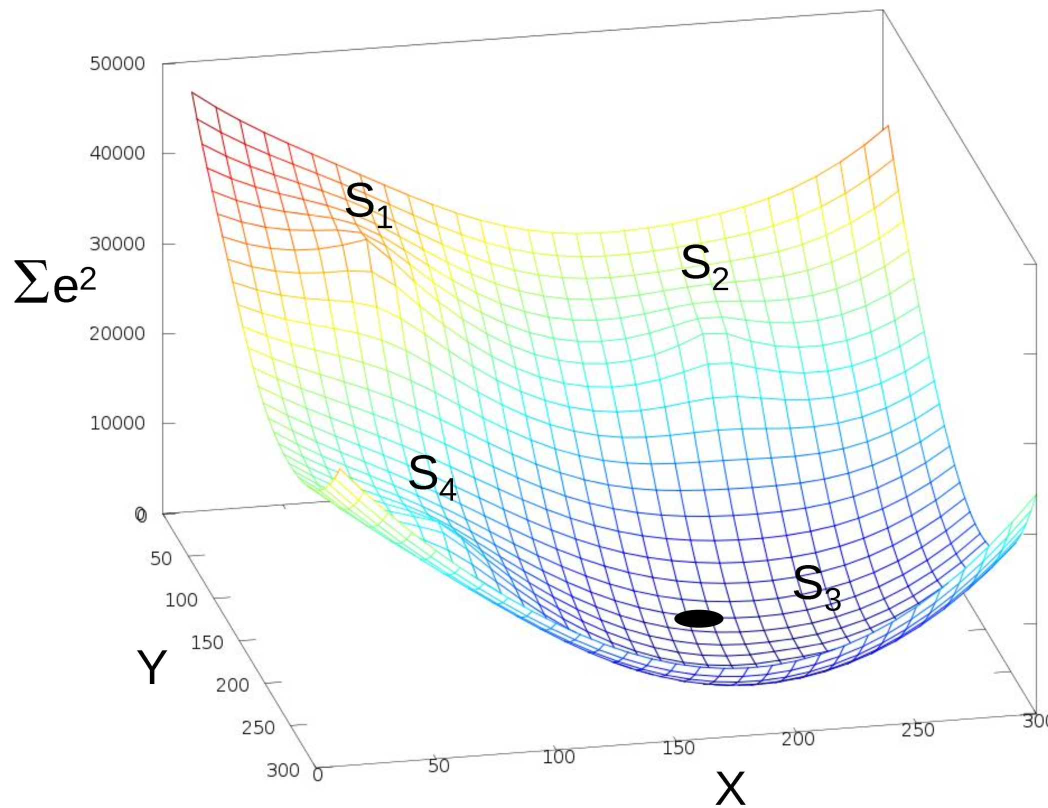
- Why do we need min. 4 satellites?
  - clock drift: the fourth unknown besides x,y,z
- System solving implies minimizing error
  - Needs a starting candidate
    - Recent fix, A-GPS
    - Time to first fix => no candidate, needs many ‘good’ satellites
  - Refine the candidate to reduce the error
- System needs to be ‘well conditioned’
  - Worst case: all satellites on one side
    - possibly huge errors => receiver refuses to fix
    - GDOP = geometric dilution of precision
  - Best case => satellites around mobile

GPS – favorable position

Plane example:

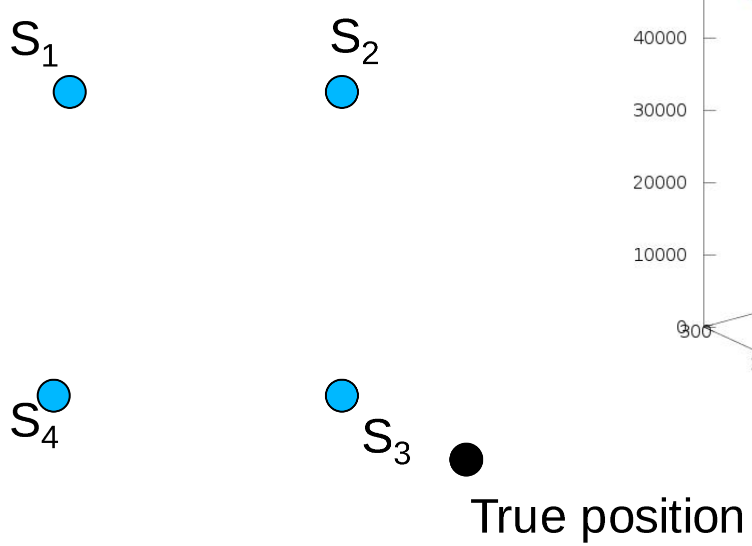
1. ranges have errors (not shown)
2. start with a candidate – any on the surface
3. go towards lower error
4. leads towards the 'right' minimum

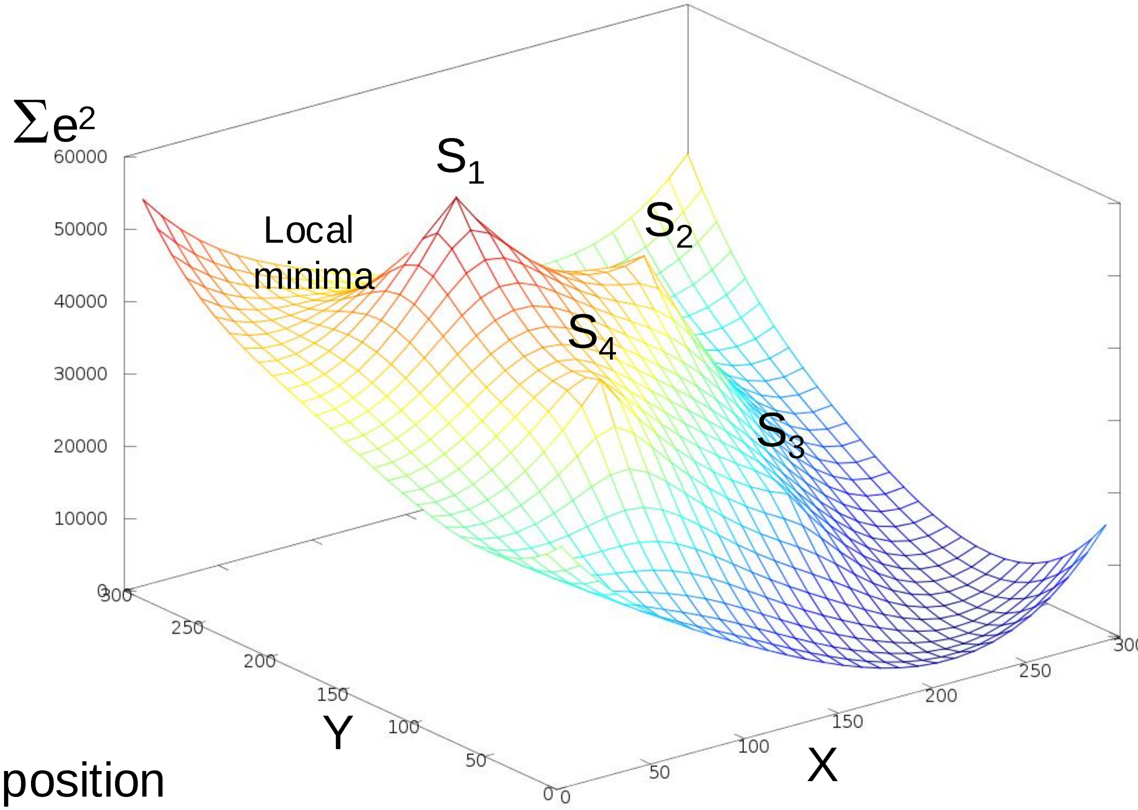




GPS – bad GDOP position

1. ranges have errors (not shown)
2. start with a candidate – now it matters which
3. go towards lower error
4. some <u>might lead to local minima</u>





GPS Design/Operation

- Segments (components)
  - user segment: users with receivers
  - control segment: control the satellites
  - space segment:
    - the constellation of satellites
    - transmission scheme

Control Segment

Master Control Station is located at the Consolidated Space Operations Center (CSOC) at Flacon Air Force Station near Colorado Springs

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

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CSOC

- Track the satellites for orbit and clock determination
- Time synchronization
- Upload the Navigation Message
- Manage Denial Of Availability (DOA)

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Space Segment: Constellation

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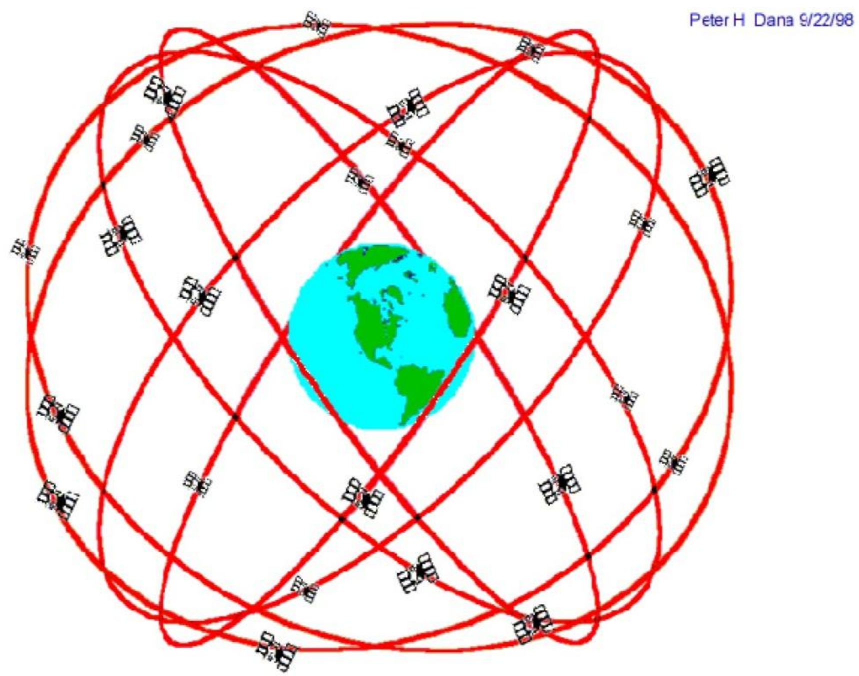
Space Segment: Constellation

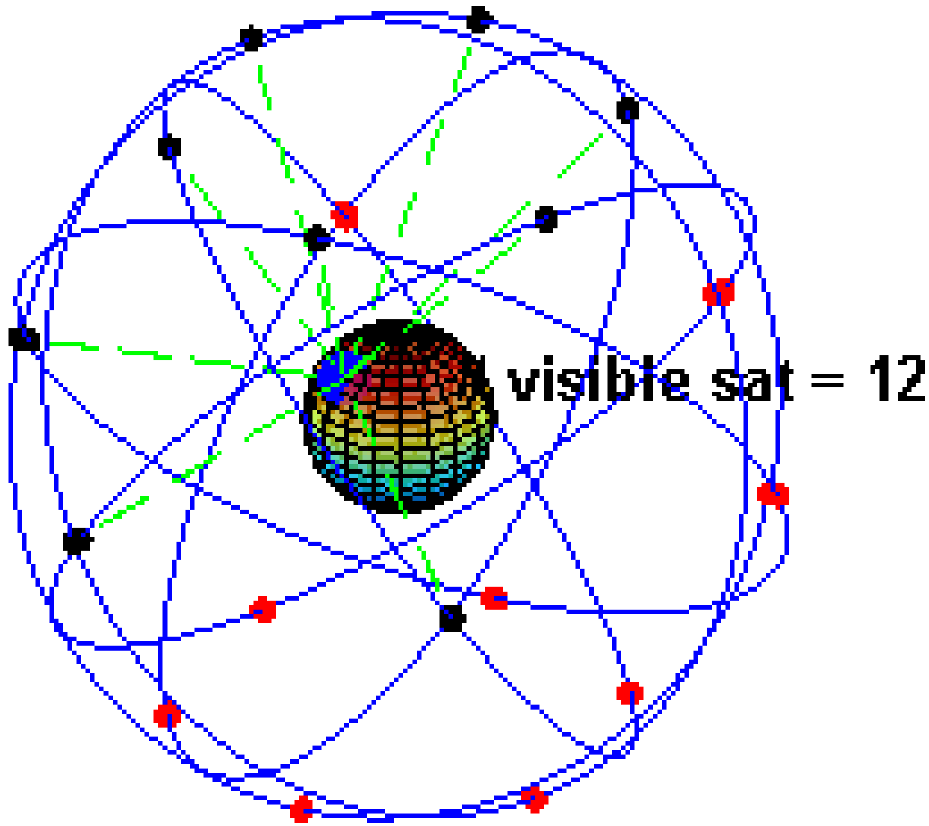
- System consists of 32 satellites in the operational mode: 31 in use and 1 spares

  3 other satellites are used for testing
- Altitude: 20,200 Km with periods of 12 hr.
- Current Satellites: Block IIR- $25,000,000 2000 KG
- Hydrogen maser atomic clocks
  - these clocks lose one second every 2,739,000 million years

GPS Orbits



GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination


visible sat = 12

GPS Satellite Transmission Scheme: Navigation Message

- To compute position one must know the positions of the satellites

- Navigation message consists of:

  - satellite status to allow calculating pos

  - clock info

- Navigation Message at 50 bps
  - each frame is 1500 bits

  - ephemeris (precise orbit, from each satellite): 6sec
  - almanac (coarse orbits, all satellites): 12.5 min

More detail: see http://home.tiscali.nl/~samsvl/nav2eu.htm

GPS Satellite Transmission Scheme: Requirements

- All 24 GPS satellites transmit Navigation Messages on the same frequencies
- Resistant to jamming
- Resistant to spoofing
- Allows military control of access (selected availability)

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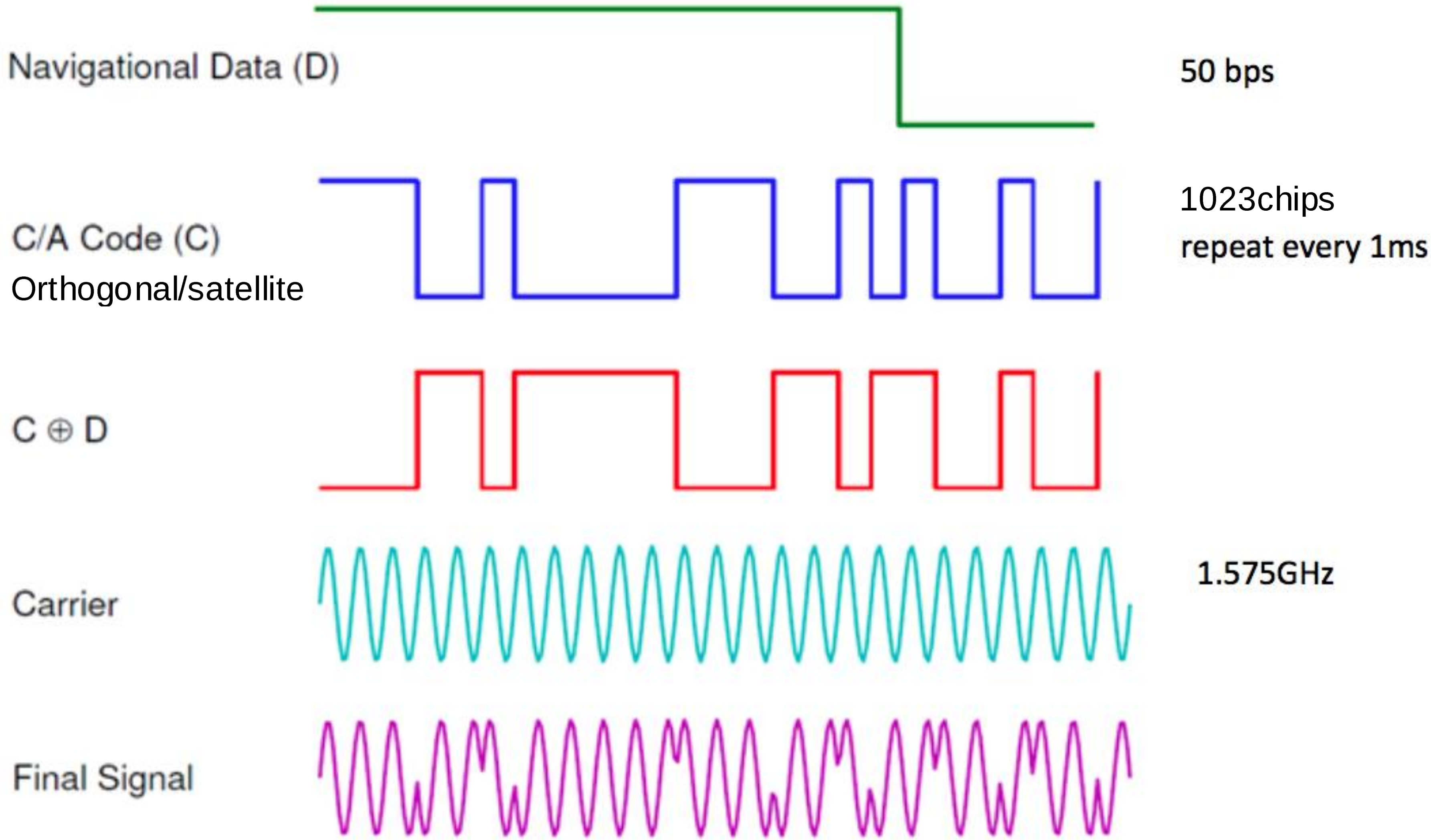
GPS As a Communication Infrastructure

- All 24 GPS satellites transmit on the same frequencies BUT use different codes
  - i.e., Direct Sequence Spread Spectrum (DSSS), and
  - Code Division Multiple Access (CDMA)
  - Using BPSK to encode bits


Navigational Data (D)
50 bps
C/A Code (C)
Orthogonal/satellite
1023chips
repeat every 1ms
C ⊕ D
Carrier
1.575GHz
Final Signal

GPS acquisition

- Cold start:
  - No previous knowledge
  - Needs almanac: 12.5 min
  - Brute force 30+ frequency bins x 8000+ phases / satellite

Doppler code phase

- Warm start < 30sec
  - Search around previous code phase, Doppler
- Hot start < 1sec
  - Directly tracking
- A-GPS
  - Up to date ephemeris from GSM basestation

GPS power consumption

- Low link speed 50bps
- Ephemeris (precise orbit, from each satellite): 6sec
- Almanac (coarse orbits, all satellites): 12.5 min
- Continuous tracking for clock sync, frequency shifts
  - Substantial signal processing
  - Doppler: sat may fly @ 800ms
  - code phase: where inside the CDMA code
  - least squares: solve system
- Cheap to track (update Doppler, phase)
- Expensive to start (after 30s)
- Example: 25s@462mW

Extensions to GPS

- Differential GPS
  - ground stations with known positions calculate positions using GPS
  - the difference (fix) transmitted using FM radio
  - used to improve accuracy

- Assisted GPS
  - put a server on the ground to help a GPS receivers
  - reduces GPS search time from minutes to seconds