Energy Efficient GPS

Silvan Egli

Motivation


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Ha Long Bay
Khe Cá
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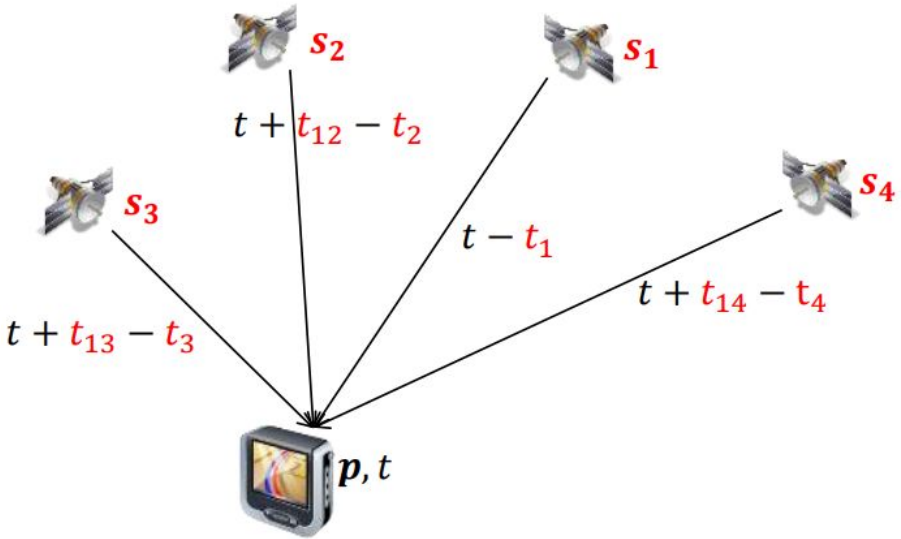
H.Vụng Hà

GPS - Localization

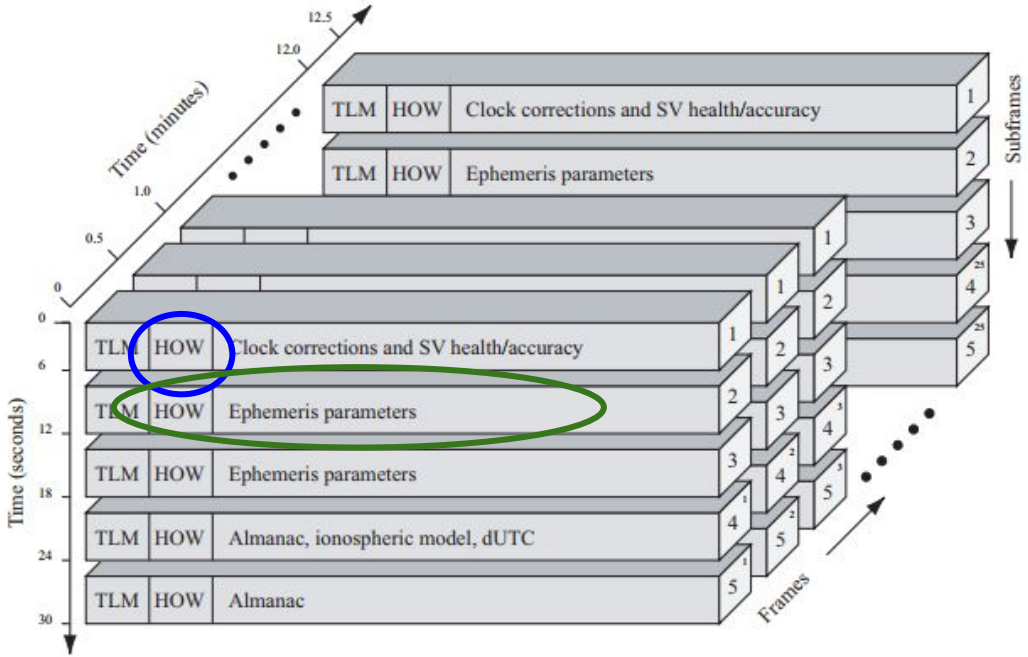


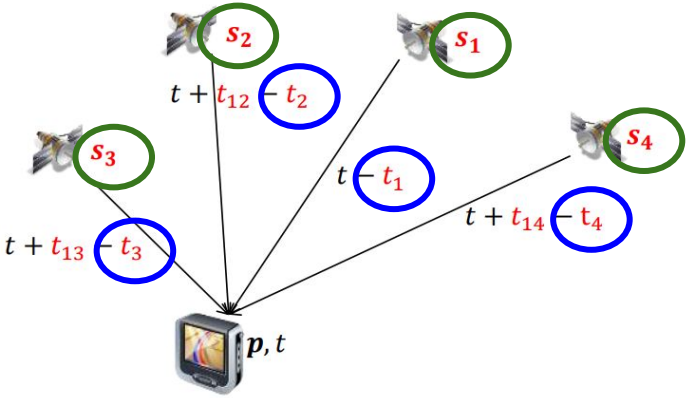
$$\left\|\frac{s_1 - p}{c}\right\| = t - t_1$$
$$\left\|\frac{s_2 - p}{c}\right\| = t + t_{12} - t_2$$
$$\left\|\frac{s_3 - p}{c}\right\| = t + t_{13} - t_3$$
$$\vdots$$
$$\left\|\frac{s_n - p}{c}\right\| = t + t_{1n} - t_n$$

Find least squares solution in **p and t**

Source: http://dcg.ethz.ch/lectures/distsys/lnotes/chapter11_clocksync.pdf

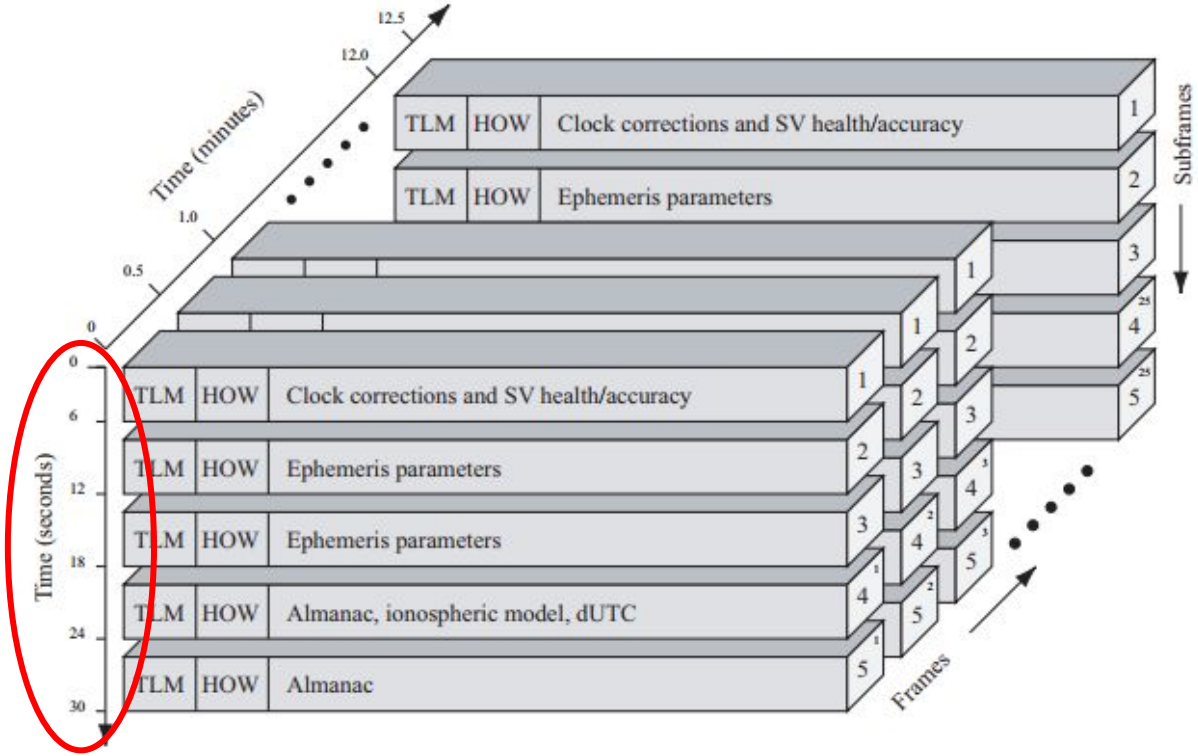
GPS - Frames





Source: http://www.gps.gov/technical/ps/1995-SPS-signal-specification.pdf

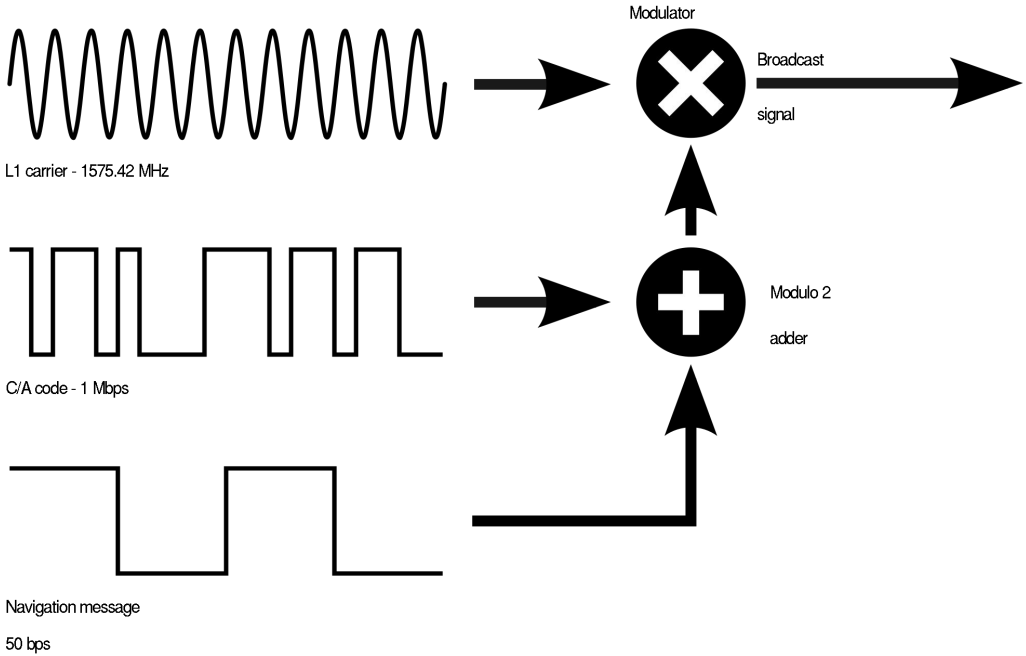
Problems - Signal Length



Source: http://www.gps.gov/technical/ps/1995-SPS-signal-specification.pdf

Problems - Satellite Acquisition

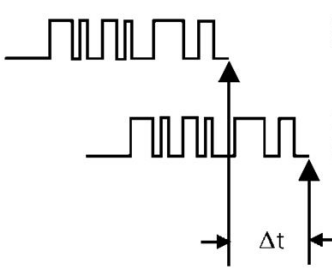
Which satellites are visible ?



Source: wikipedia

Problems - Acquisition

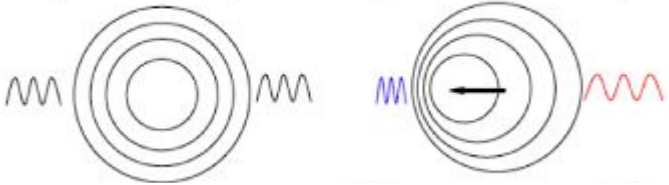
Code Phase Delay

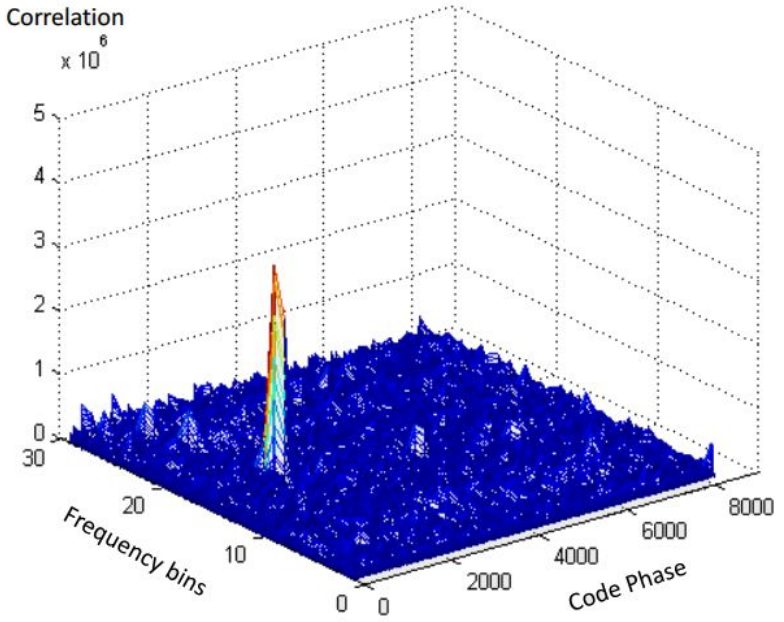


Code from signal

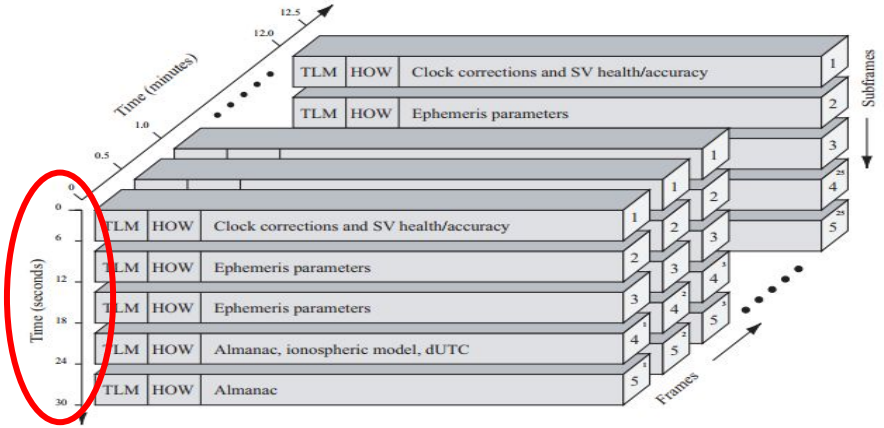
Identical Code generated in receiver

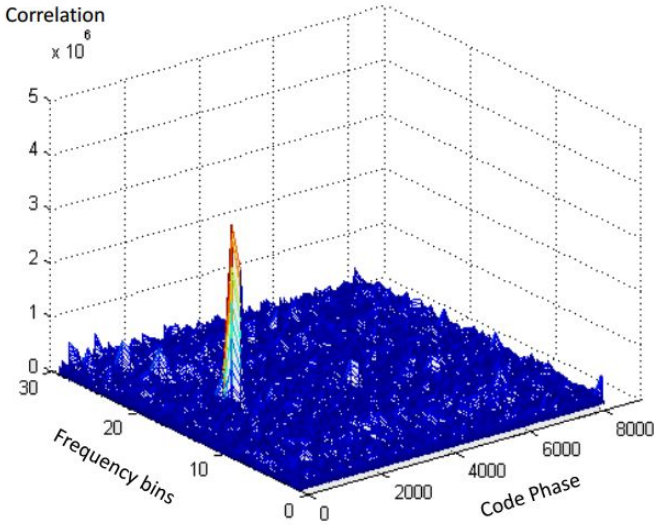
Doppler Shift





Problems - Summed Up

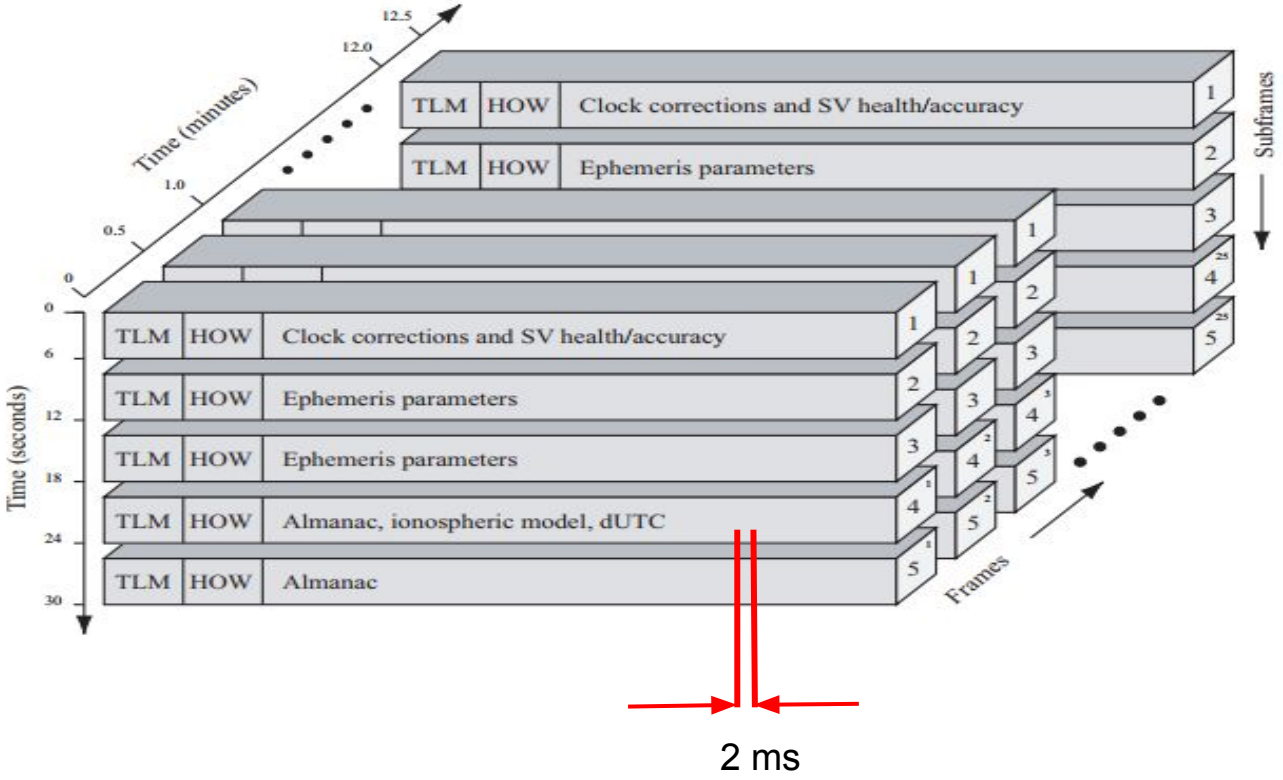




1. Low data rate -> 6 sec up to 30 sec

2. Big search space

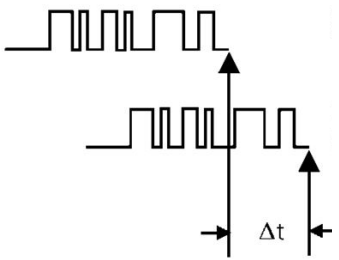
What if ?


Time (minutes)
12.5
12.0
1.0
0.5
0
Time (seconds)
0
6
12
18
24
30
TLM HOW Clock corrections and SV health/accuracy
TLM HOW Ephemeris parameters
TLM HOW Ephemeris parameters
TLM HOW Almanac, ionospheric model, dUTC
TLM HOW Almanac
Subframes
Frames
2 ms

Coarse Time Navigation (CTN)

Basic idea

- Approximate Time
- Approximate Position
- Sub-ms Propagation Time



Δt = 0,24 msec

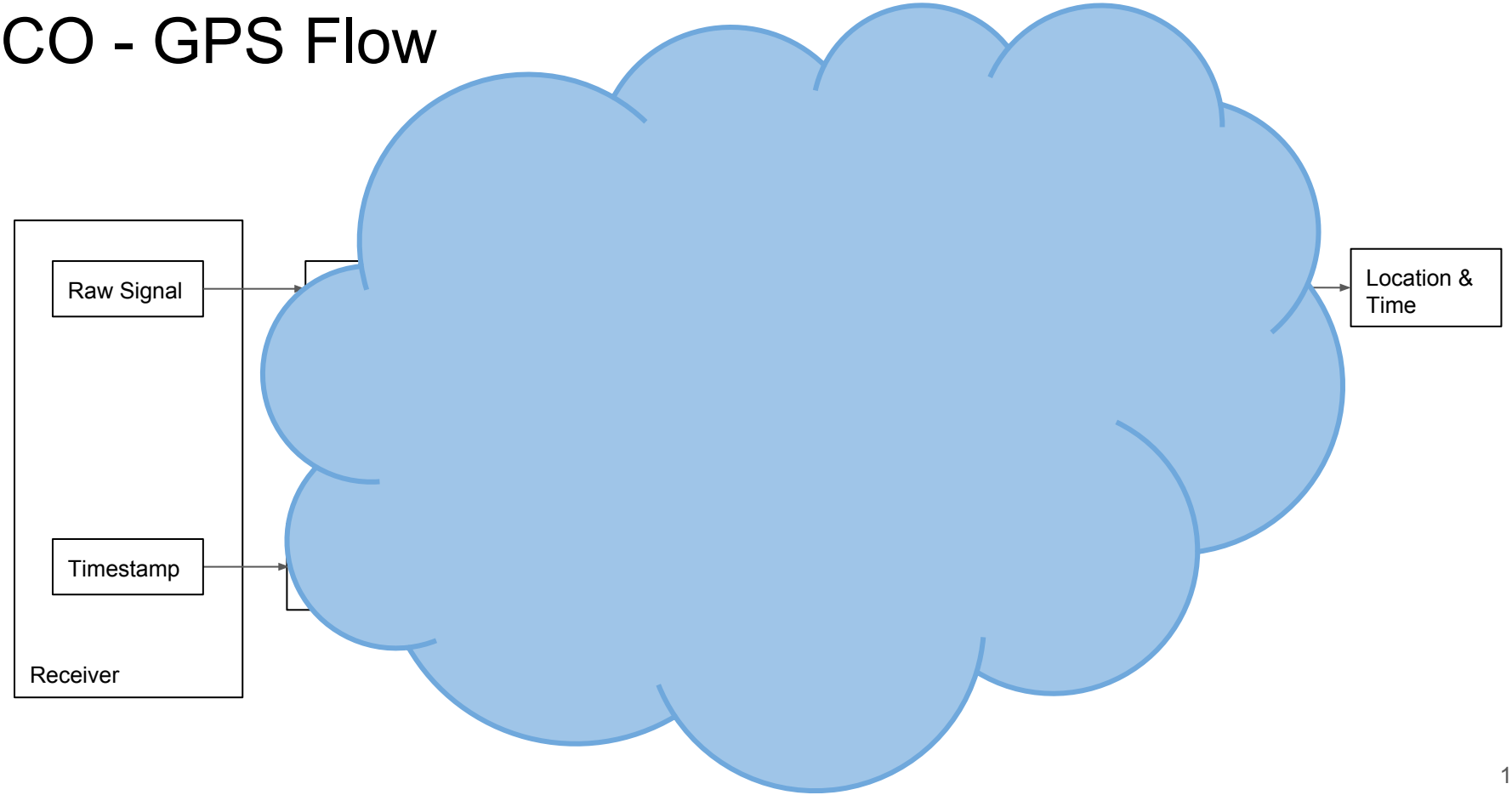
Source: Frank van Diggelen, A-GPS: Assisted GPS, GNSS, and SBAS

Cloud Offloaded (CO) - GPS

Energy Efficient GPS Sensing with Cloud Offloading
Jie Liu, Bodhi Priyantha, Ted Hart, Heitor S. Ramos and Antonio A.F. Loureiro. SenSys 2012.

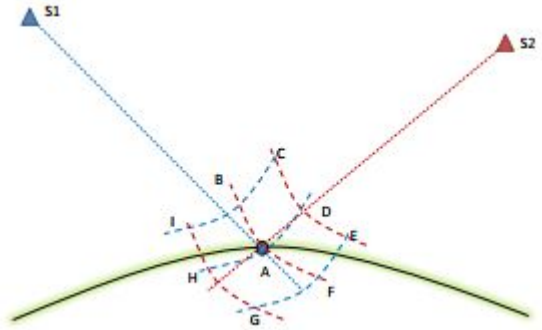
Goal : “Achieve the best possible energy efficiency in GPS sensing”

CO - GPS Flow



CO - GPS

- Coarse Time Navigation with unknown location

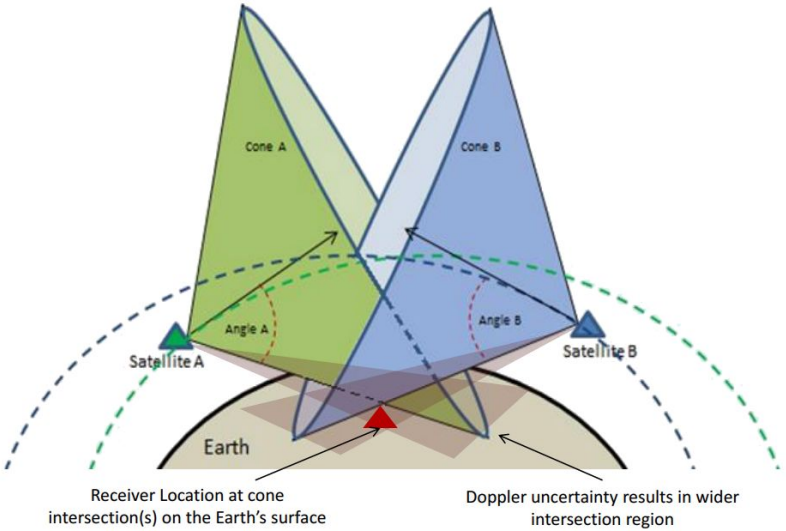


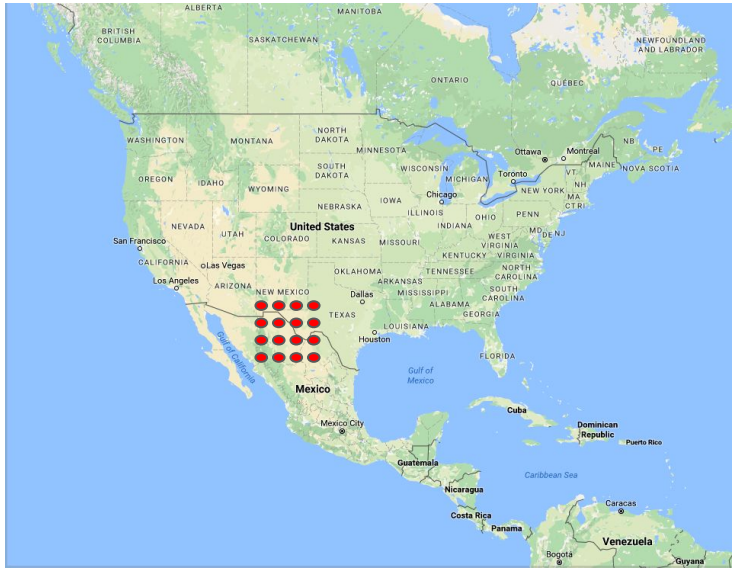
Multiple feasible solutions under 1ms ambiguity due to missing reference

Source: https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/SenSys147-co-gps.pdf

Solution for Shadow Locations

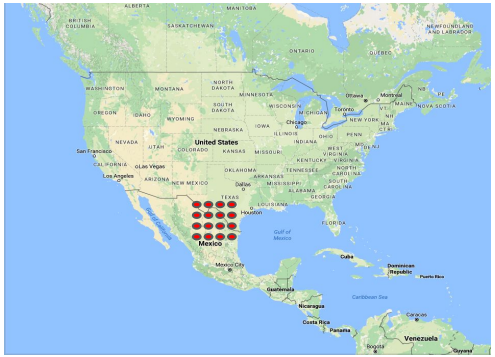
- Guess Landmark using Doppler Shift and Satellite's velocity





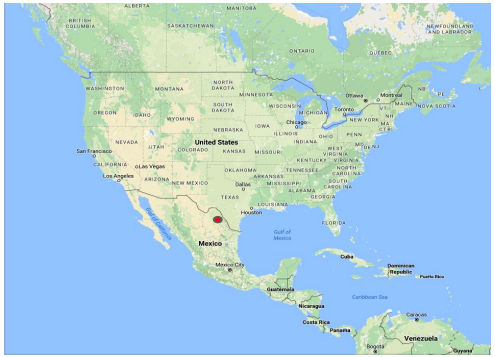
Source: https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/SenSys147-co-gps.pdf

Localization

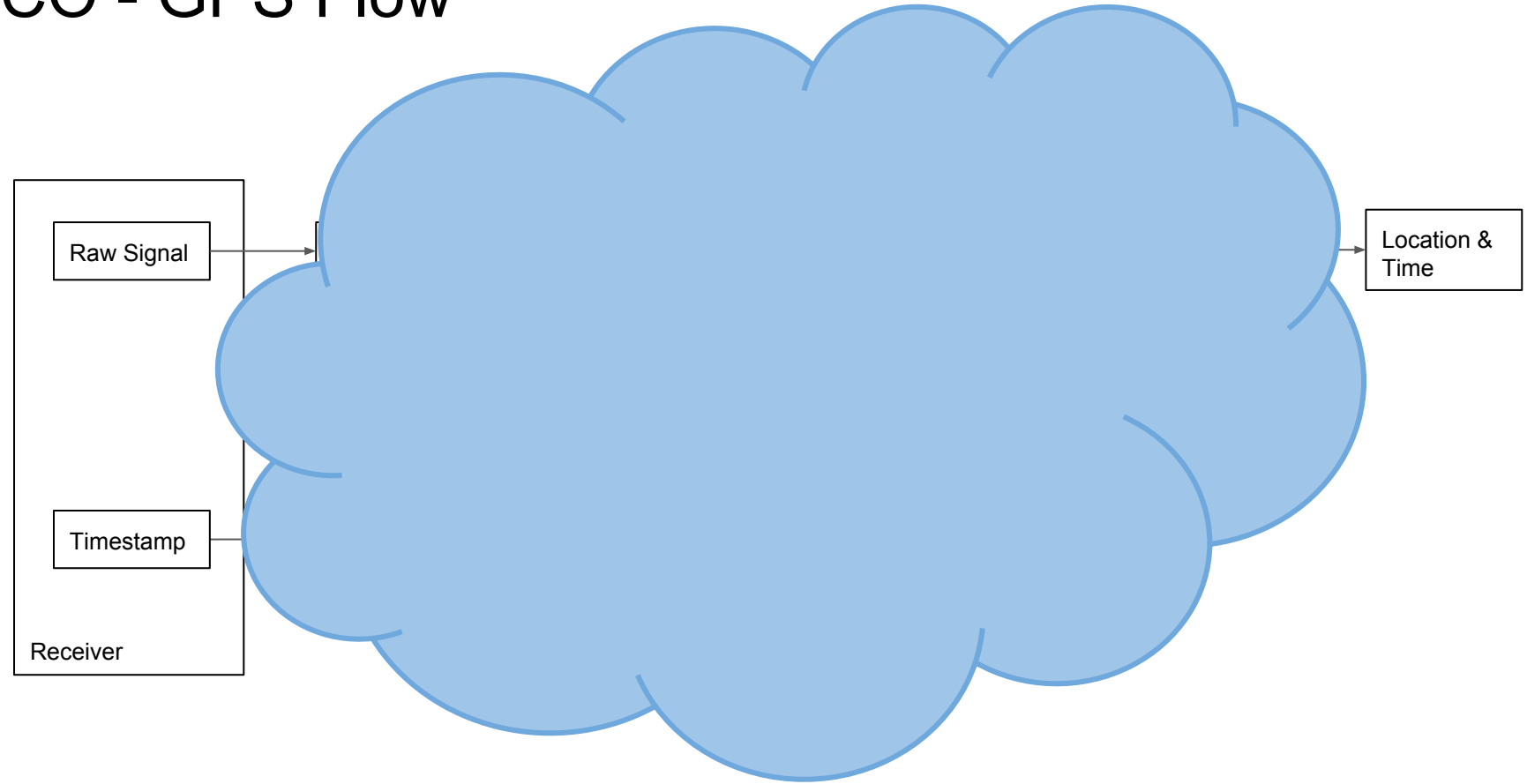


CTN

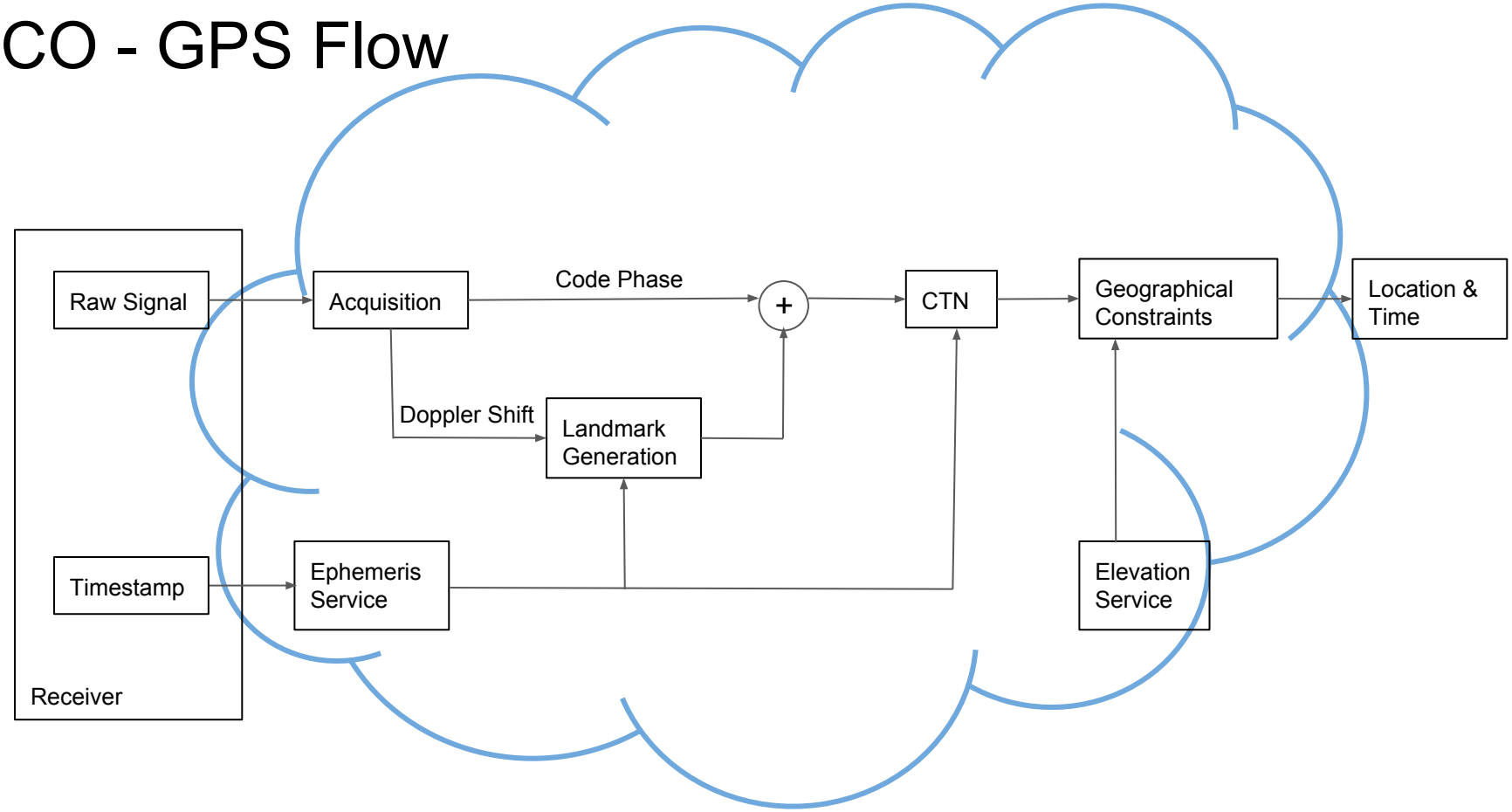
Elevation



CO - GPS Flow

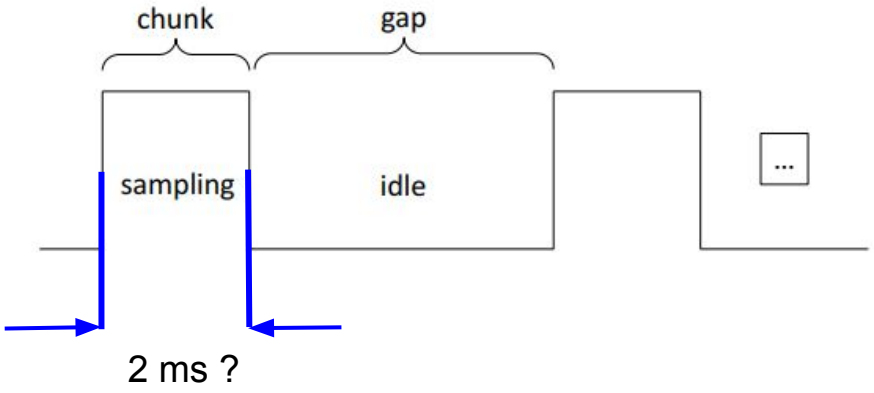


CO - GPS Flow

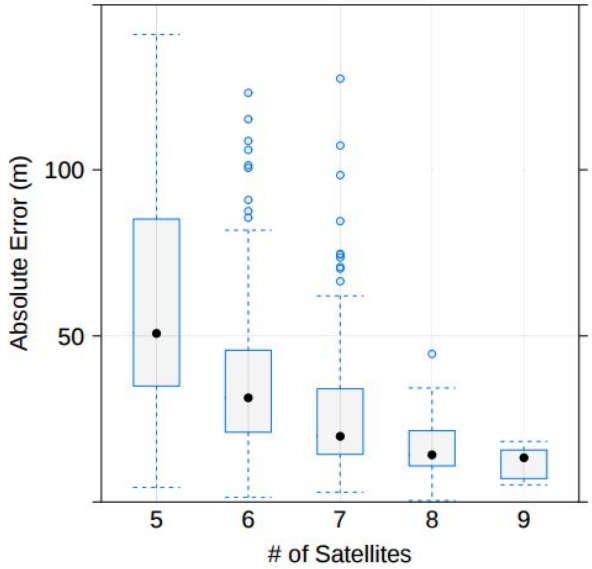

Raw Signal
Acquisition
Code Phase
+
CTN
Geographical Constraints
Location & Time
Doppler Shift
Landmark Generation
Timestamp
Ephemeris Service
Elevation Service
Receiver

CO - GPS Evaluation

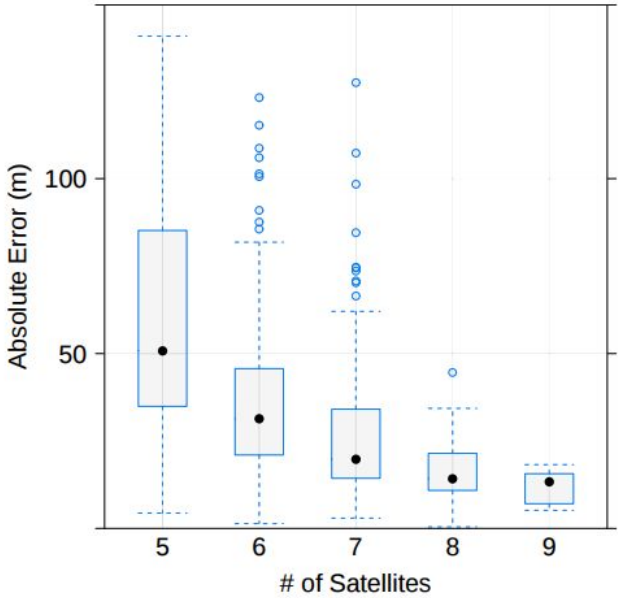
Goal : “Achieve the best possible energy efficiency in GPS sensing”

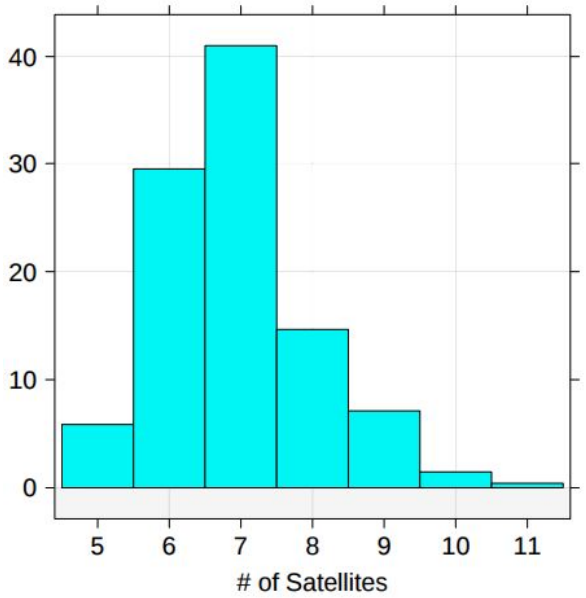


VS



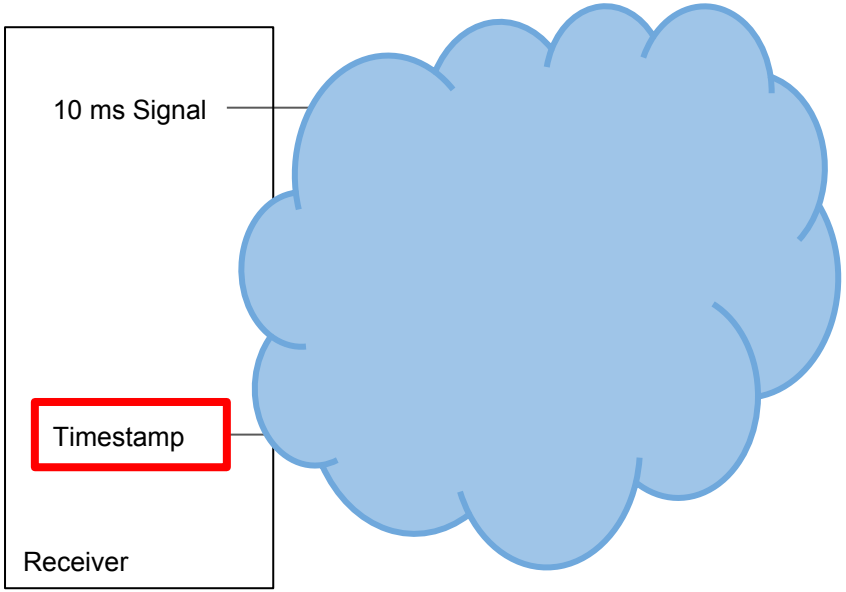
CO - GPS Evaluation

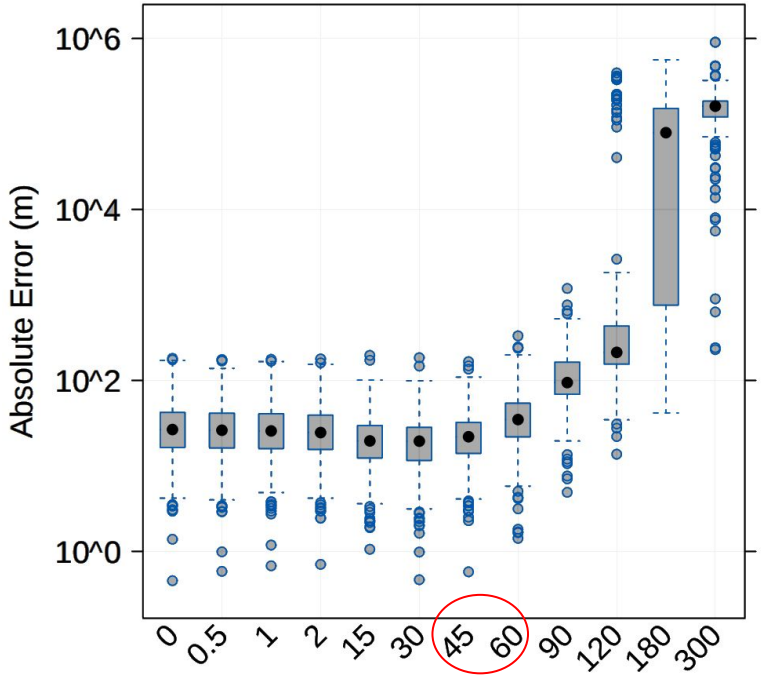




CO - GPS Evaluation

What about the time ?





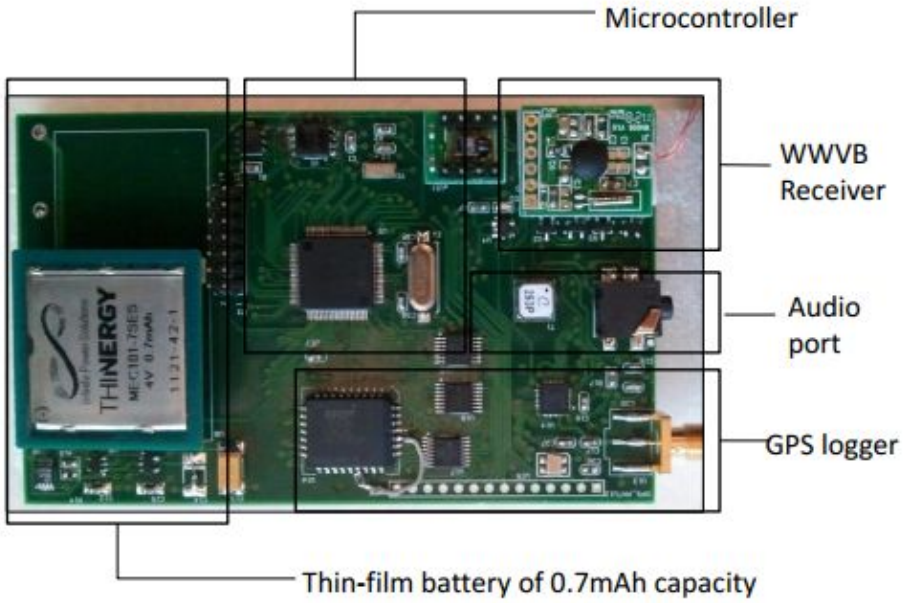
CO - GPS Implementation

Goal : “Achieve the best possible energy efficiency in GPS sensing”

-> Can we quantify energy efficiency ?

CO - GPS Implementation

Can we quantify energy efficiency ?



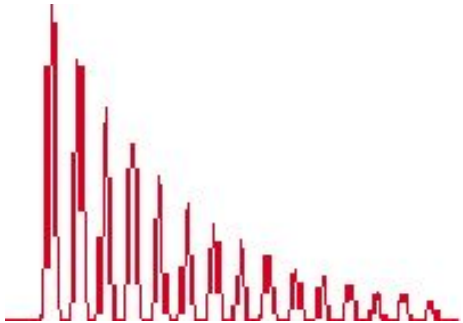
- ~ 0.5 mJ per location fix vs. 1 J
- Continuous tracking for 1 Year with 2 AA batteries

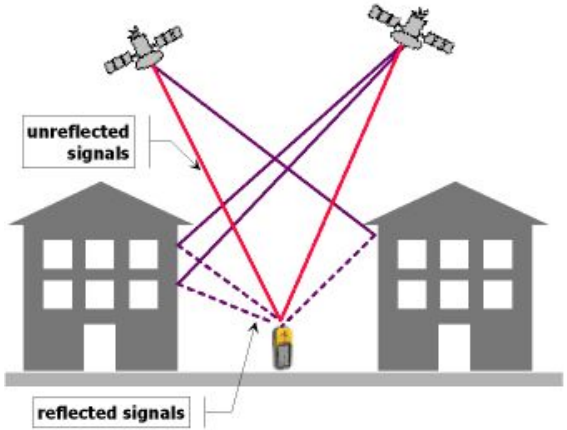
COIN - GPS

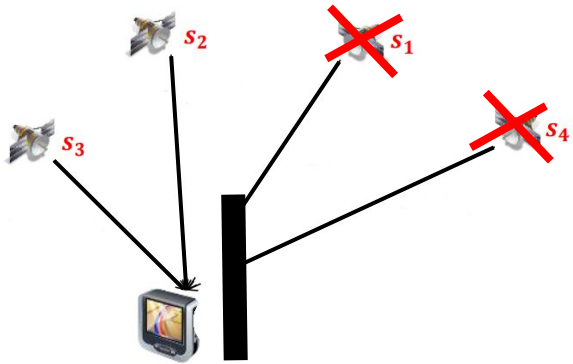
Indoor Localization from Direct GPS Receiving
Shahriar Nirjon, Jie Liu, Gerald DeJean, Bodhi Priyantha, Yuzhe Jin and Ted Hart. MobiSys 2014.

Goal : “Extend GPS receiving to indoor environments [...]”

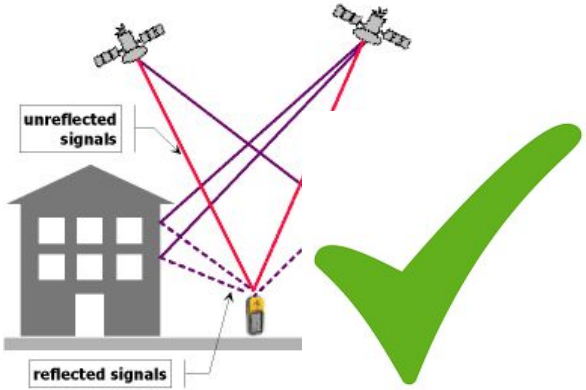
Indoor Problems

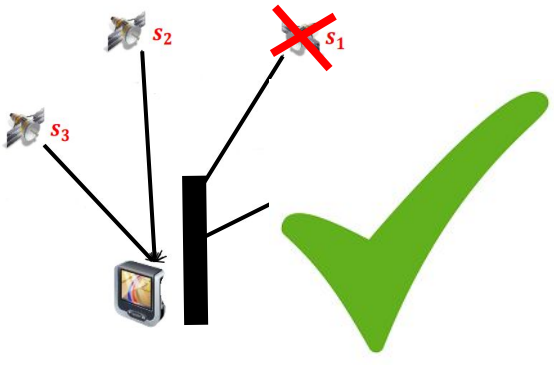






Motivations & Solutions





- Slowly moving objects
- Single floor buildings
- Cloud Offloading (CO) - GPS
- Directed antenna

Results

System	Locations	Fixes
Garmin	2	None
COIN-GPS	2	2

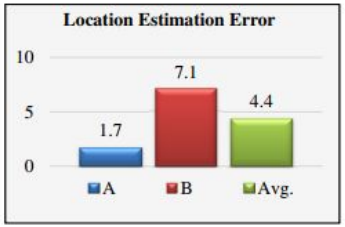
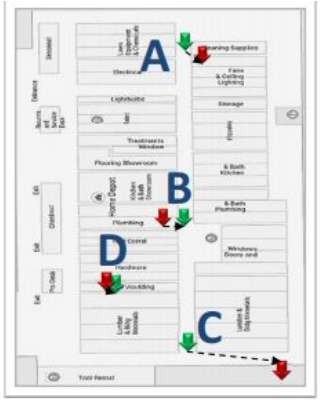


Figure 18: Starbucks.



System	Locations	Fixes
Garmin	4	None
COIN-GPS	4	4

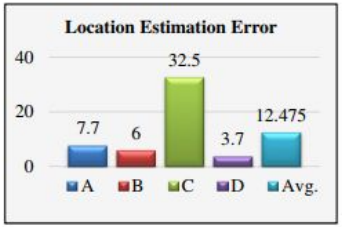
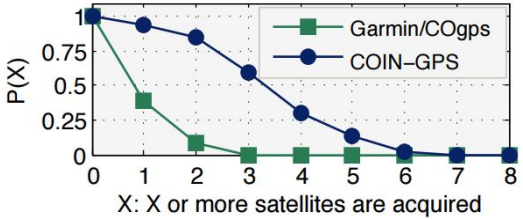
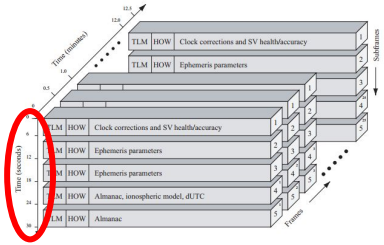
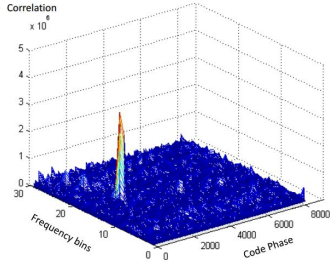


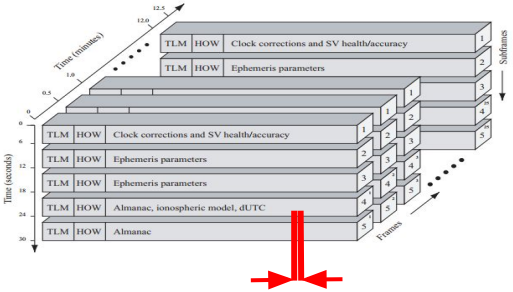
Figure 19: Home Depot.



Overview


Time (minutes)
Subframes
TLM HOW Clock corrections and SV health/accuracy
TLM HOW Ephemeris parameters
TLM HOW Clock corrections and SV health/accuracy
TLM HOW Ephemeris parameters
TLM HOW Ephemeris parameters
TLM HOW Almanac, ionospheric model, dUTC
TLM HOW Almanac
Time (seconds)
Frames


Correlation
x 10^6
Frequency bins
Code Phase


Time (minutes)
Subframes
TLM HOW Clock corrections and SV health/accuracy
TLM HOW Ephemeris parameters
TLM HOW Clock corrections and SV health/accuracy
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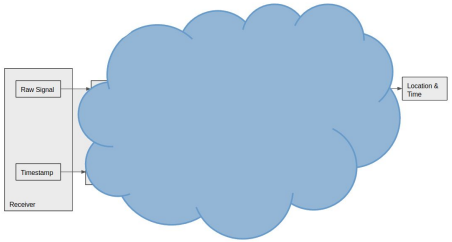
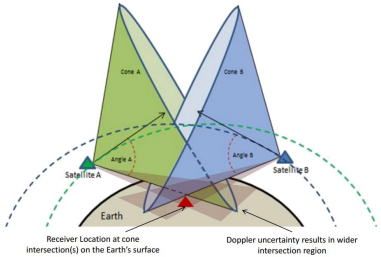
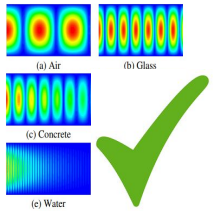
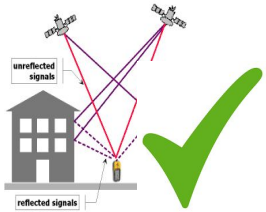
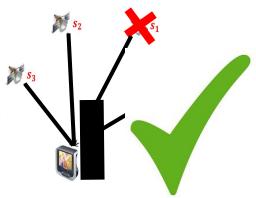
TLM HOW Almanac, ionospheric model, dUTC
TLM HOW Almanac
Time (seconds)
Frames


Raw Signal
Timestamp
Receiver
Location & Time


Cone A
Cone B
Angle A
Angle B
Satellite A
Satellite B
Earth
Receiver Location at cone intersection(s) on the Earth's surface
Doppler uncertainty results in wider intersection region


(a) Air
(b) Glass
(c) Concrete
(e) Water


unreflected signals
reflected signals


s_1
s_2
s_3

CO - GPS Discussion

+ 10 ms of data
  + Less energy for sensing
  + Less Storage (40 kB / Location)
+ Duty Cycling
+ Offline Calculation

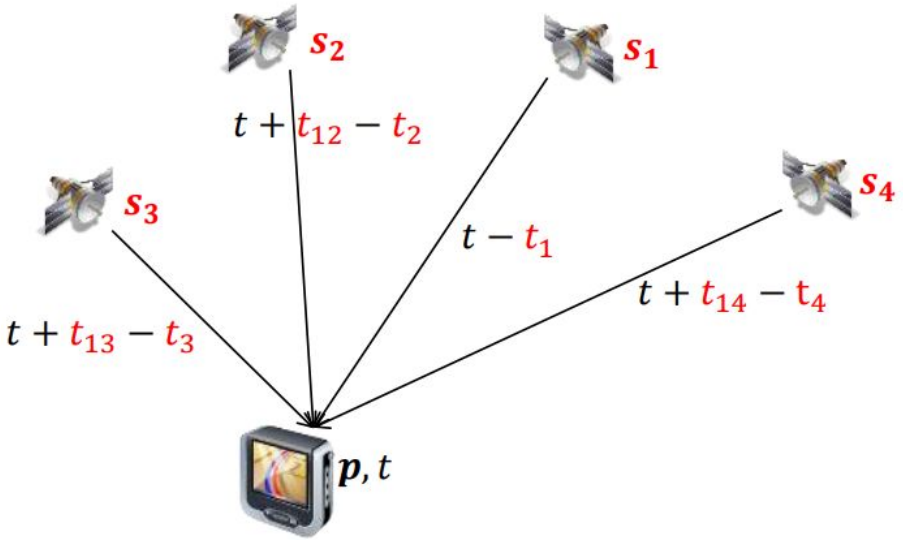
- Precision
- Offline Calculation
- Location on surface

Coin - GPS Discussion

+ Indoor GPS
+ No additional infrastructure

- Antenna
- High computational complexity
- Slow (60 - 90 sec)
- Single storied buildings

Thank you !



47°22'39.3"N 8° 33'10.6"E