GPS and GLONASS Constellations for Better Time Synchronizing Reliability

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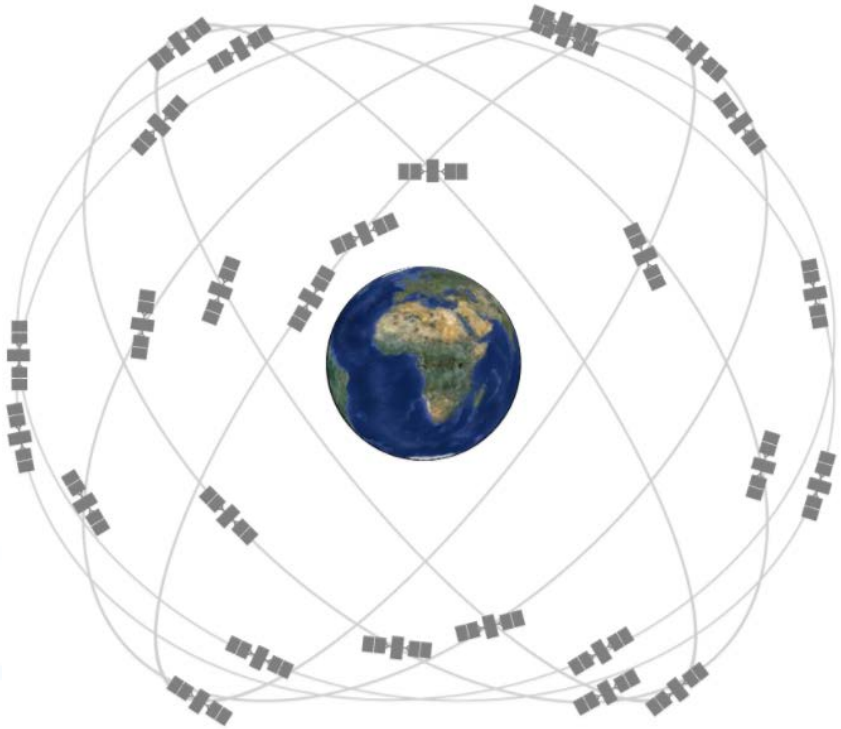
Timing Requirements for Power Systems

Application	Acceptable Overall Time Error	Time Accuracy Required
Fault disturbance recording	Within a few ms	1 ms
SER/SOE	< 1 to few ms	< 1 to 1 ms
Synchronized end-to-end testing	< 1 to few ms	< 1 to 1 ms
EMS/SCADA	Within a few ms	1 ms
Metering: Time-of-use metering Calibration standard	 Within a few ms ≤1 µs	 1 ms 1 µs
Synchrophasor measurements	< 26 µs	1 µs
Protection networks (IEC 61850) - General reporting - Synchrophasor and process bus	 < 1 to few ms 1 to few µs	 < 1 to 1 ms 1 µs
Travelling Wave Fault Location	< 1 to 1 µs	1 µs

GPS (Global Positioning System)



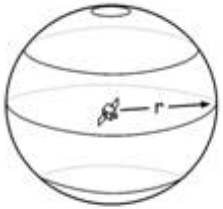
Developed by USA, has a network of 31 satellites covering this planet (24 available simultaneously)

GPS satellites use atomic clocks for accuracy

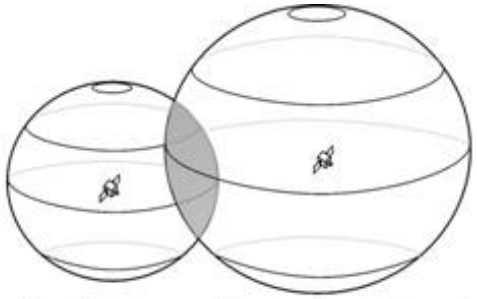
GPS uses precise time algorithms to measure the distance between a receiver and satellites

- ±100 nanosecond accuracy
- GPS time is not UTC time:
  - GPS does not add leap seconds
  - GPS time is 17 sec ahead of UTC

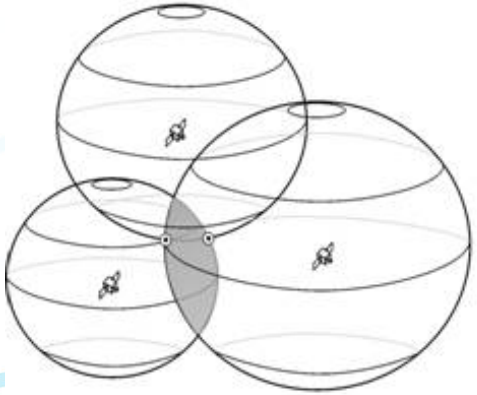
Why Four Satellites?



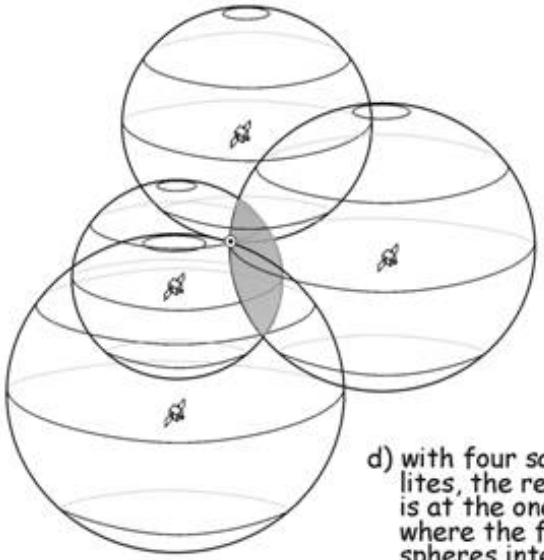
a) with a range measurement from one satellite, the receiver is positioned somewhere on the sphere defined by the satellite position and the range distance, r



b) with two satellites, the receiver is somewhere on a circle where the two spheres intersect



c) with three satellites the receiver is at one of two points where the three spheres intersect



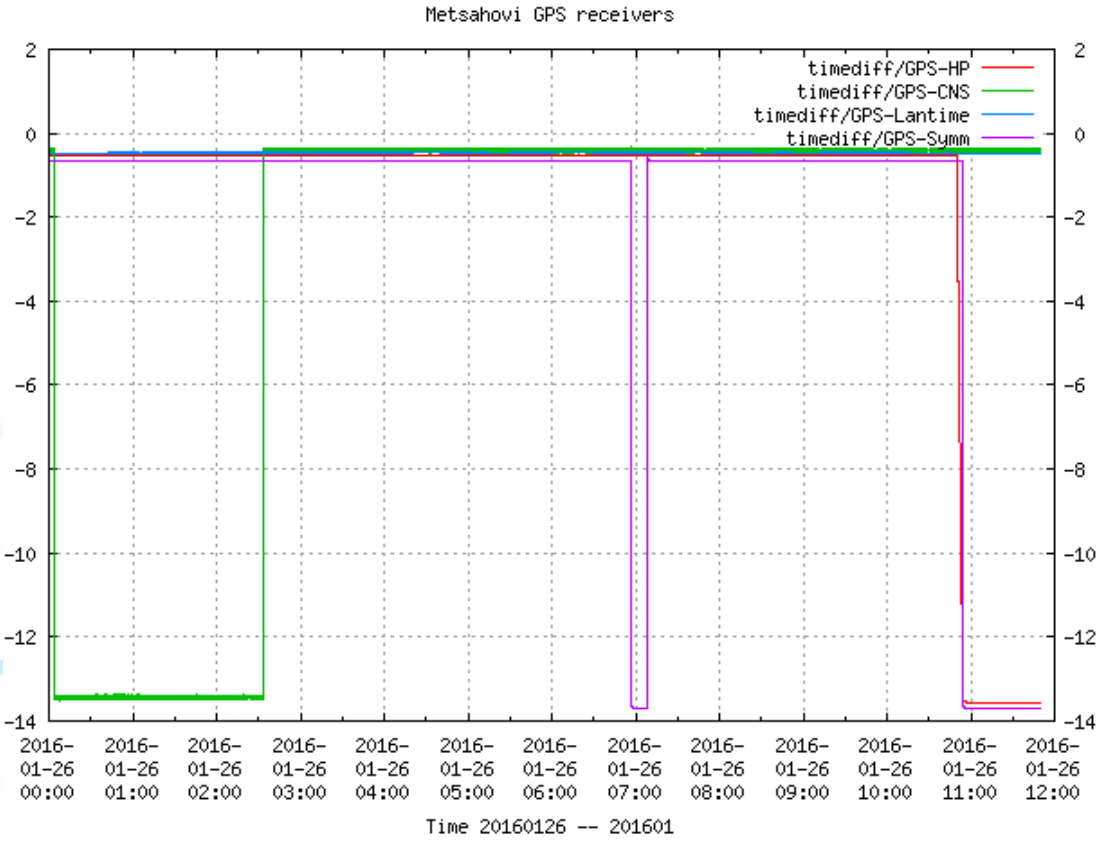
d) with four satellites, the receiver is at the one point where the four spheres intersect.

Can We Rely on GPS?

- Errors
- It's a radio signal, so:
  - Line of sight
  - Power (typical -130 dBm at receiver)
- GPS jamming and spoofing
- Signal reception

GPS Error

2016 January 26th, 13.7 microsecond error introduced due to retirement of one GPS satellite



GPS Spoofing and Jamming

- Jamming is the malicious use of typically stationary RF frequency signals to deliberate interfere or block lawful communications
- Aspoofing attack is the malicious use of a simulated signal from an unknown source disguised as a known source with the intention of tampering the synchronization of the GNSS receiver

- BUT first you need to find the antenna!

1st step, find the antenna

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GPS Jamming

- Many simple devices available on the web, can disrupt signals from over 600 m (i.e. Newark in 2013[2])
- Source can be easily traced
- Modern receivers have front-end SAW (Surface Acoustic Wave) filters to increase jamming immunity
- Jamming can be detected and alarmed

[2] Truck driver has GPS jammer, accidentally jams Newark airport, CNET, https://goo.gl/s3t4BD

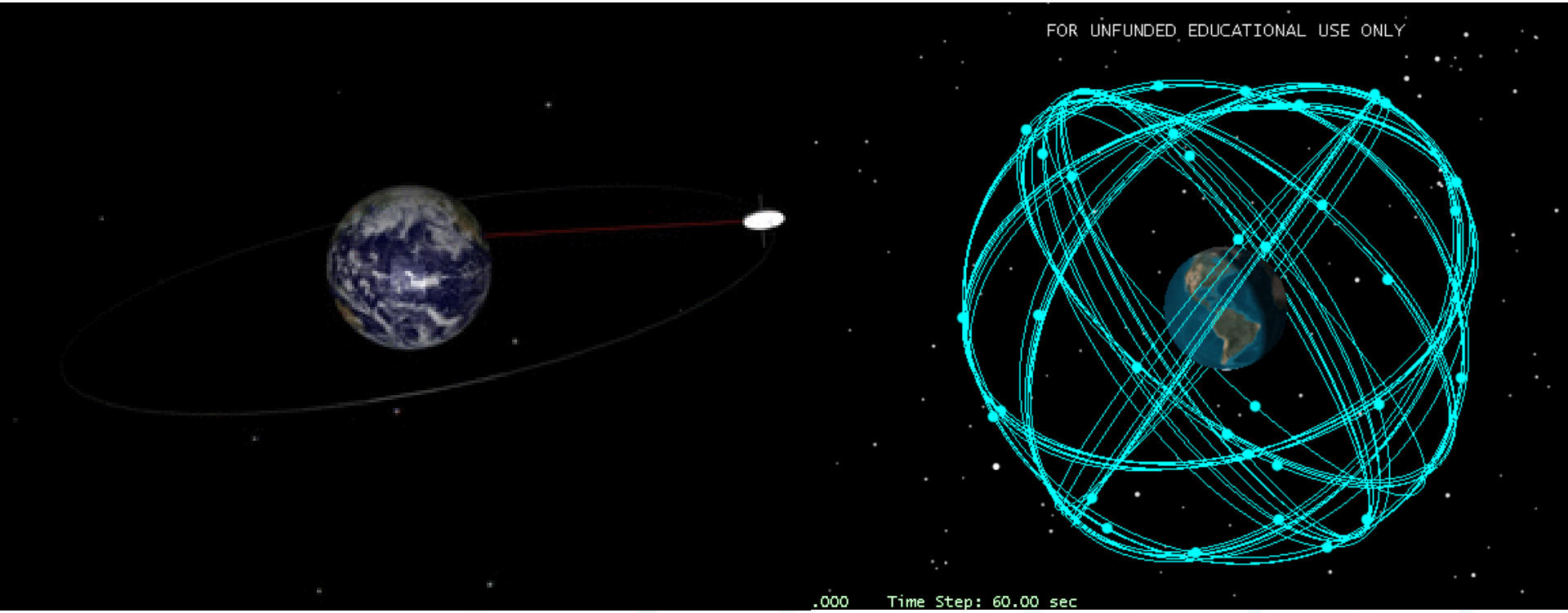
GPS Spoofing

- Three kinds of spoofing attacks[1]:
  1. *Simplistic*: commercial devices, step change in signal, easy to detect;
  2. *Intermediate*: retransmits signals, slightly increases or decreases the second pulse reference from satellites
  3. *Sophisticated*: retransmits signals, coordinated and geographically sparse intermediate attacks

- Most likely attack is an intermediate level

[1] Detection of Time Spoofing Attacks on GPS Synchronized Phasor Measurement Units, Texas A&M CPRE, A.K. Mattei et. al.

GPS Coverage: Bad Satellite Days



- GPS also needs maintenance: Satellite Outage Calendar
- In some cases, the antenna does not track the minimum required number of satellites visible during all day long to ensure time quality for critical applications, which may disable a current differential protection for instance.

Other GNSS Systems

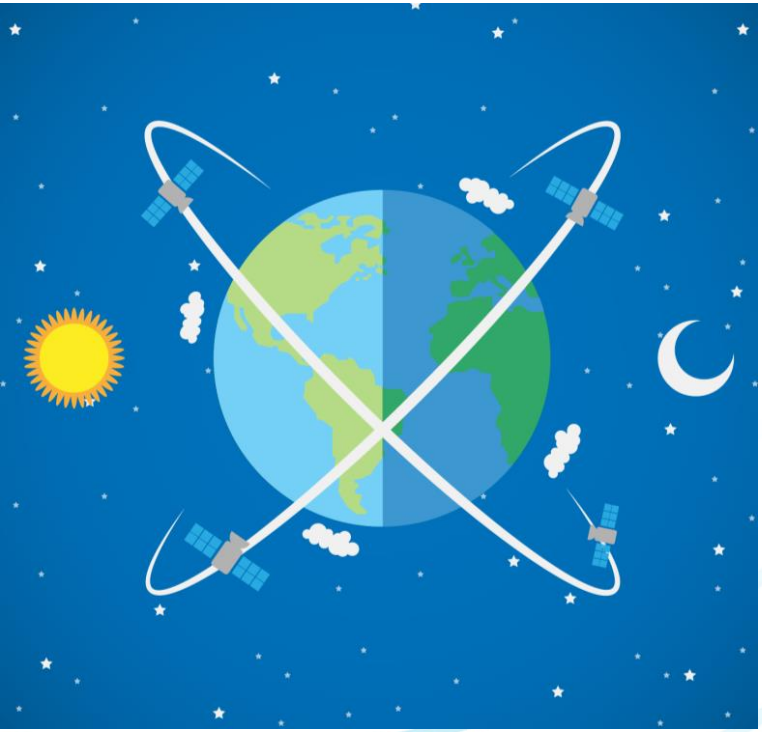
GNSS: Global Navigation Satellite System

- GLONASS (RU) – fully operational, since Oct 2011

- Galileo (EU) - started offering Early Operational Capability on Dec 2016 and is expected to reach Full Operational Capability in 2019

- BeiDou (CH) – Although it is offering navigation services in China region, it is planned to operate globally upon its completion in 2020.

GLONASS

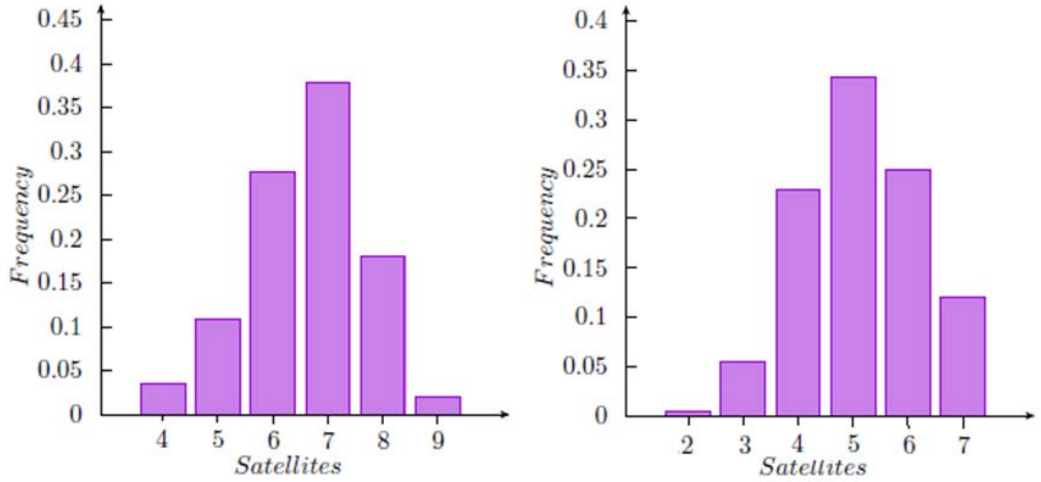


- GLONASS stands for GLObal NAvigation Satellite System – same as GNSS
- Achieved full global coverage in Oct 2011, with 24 active satellites
- On-board cesium atomic clocks provide the local clock source
- ±200 nanosecond accuracy
- GLONASS is synchronized with UTC time, adding leap seconds when necessary

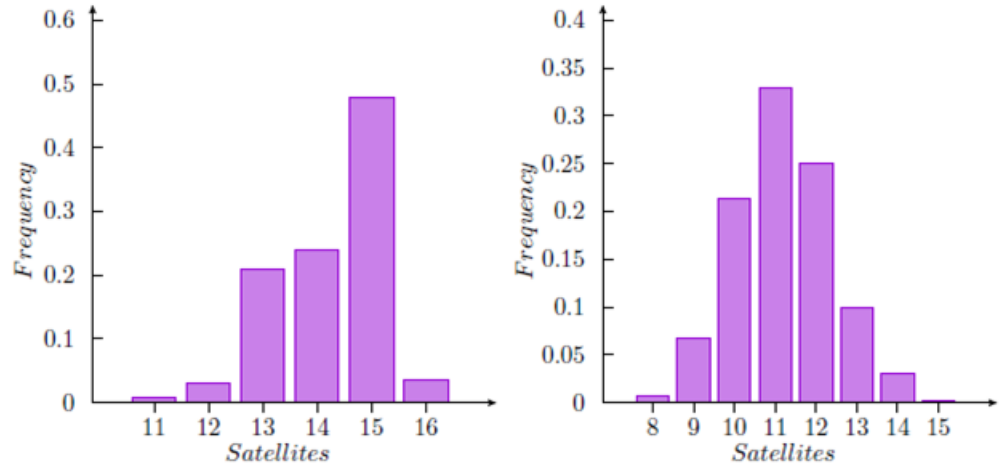
Multi-GNSS

- GNSS system using more than one satellite system source
- GPS / GLONASS most common
- Multi-GNSS system should use both GNSS systems to sync
- Provides:
  - Better reliability (48 satellites)
  - Improved accuracy
  - Increased refresh rate
- GNSS constellations combined increases immunity to jamming and spoofing attacks

Test Results



GPS only



Multi-GNSS

Summary

- Multi-GNSS systems offer a performance advantage over a single GNSS (increased coverage, anti spoofing)
- Whenever one constellation is lost, the clock will continue running in full synchronization based on the healthy source
- Multi-GNSS products are available:
  - Clocks
  - Antennas
  - Similar cost to single GNSS

Integration with other technologies

- For even greater reliability, Multi-GNSS clocks can be seamlessly integrated in IEEE 1588 networks for time distribution (increased reliability will reflect on the BMCA)

Thank You