Workshop on GPS Protection and Receiver Performance

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Key Points

- GPS for time requires calibration of the antenna/cable/receiver delays – unlike Navigation/Positioning
- There's a trade-off between time accuracy and susceptibility to interference
- ITU-T standard G.8273.1 defines a Grand Master clock with +/- 100 ns against UTC – essentially must be a GNSS receiver system

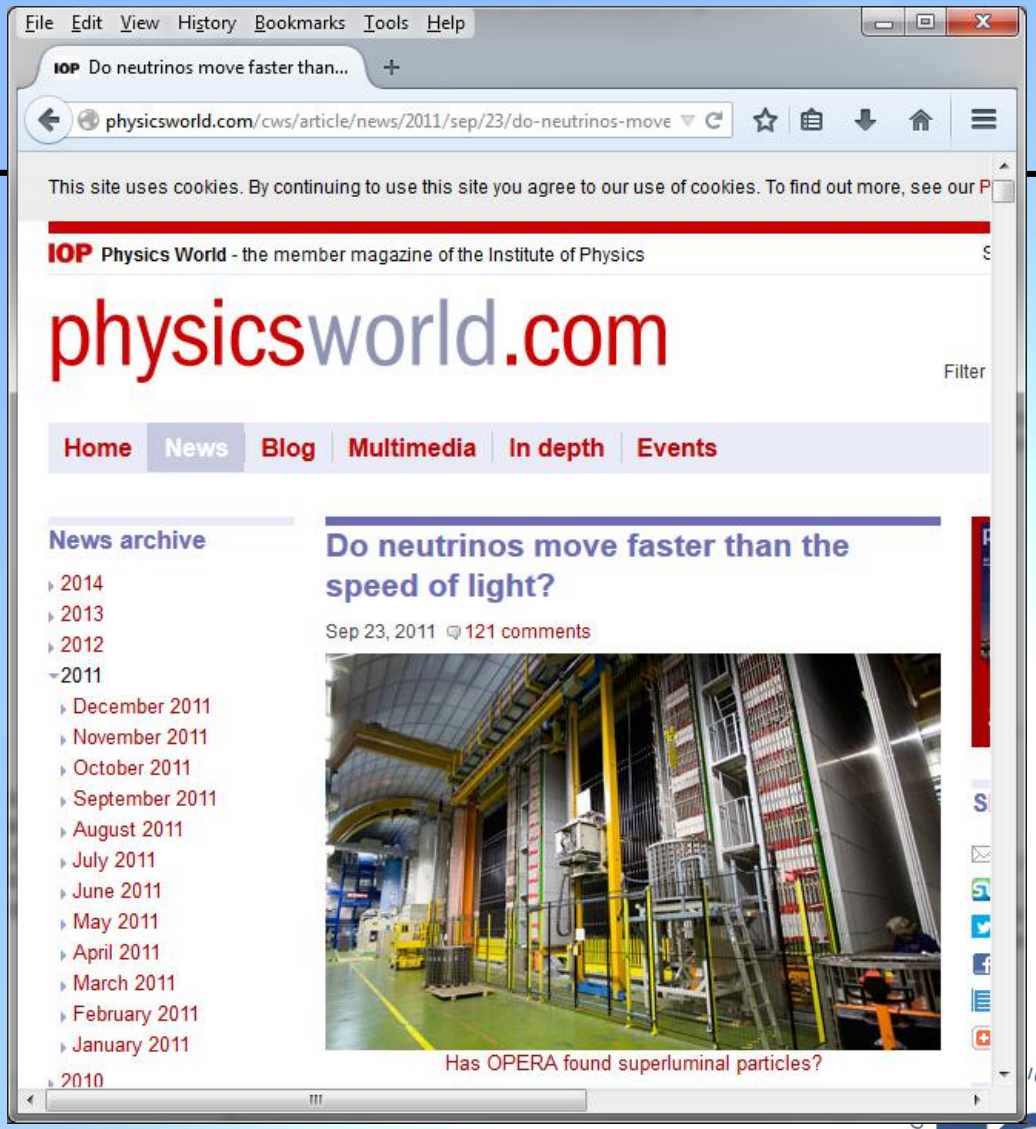
Time from GPS Requires Calibration

- Delay through the analog components
  - Antenna
  - Antenna cable
  - Receiver front end
- Processing delay in Digital Signal Processor
  - Delay can be quite large or even negative
- Calibration only as valid as the long-term stability of the delay
- Antenna cable must have good impedance matching or can cause large time errors

Antenna Cable Impedance Matching Essential for Accurate GPS Time

Bad connector in neutrino experiment created a 60 ns time error

Mis-matches can cause errors of 10's to 100's of ns



Antenna Filter/LNA Issues

- In general, a narrower pass band filter with a sharper roll-off has a larger delay
  - Less vulnerable to interfering signals
  - Delay can vary many 10's of ns or more with aging and temperature
- ns-level accuracy needs the full 20 MHz band, leaves the receiver open to neighboring band interference

Drivers for UTC Time and Phase in LTE

- LTE Advanced features optimize use of the spectrum
  - eICIC (Enhanced Inter-cell Interference Coordination)
  - CoMP (Coordinated Multipoint) Network MIMO)(Multiple Input Multiple Output)

- LTE TDD (Time Division Duplex)

Trend: Mobile Bandwidth Growth

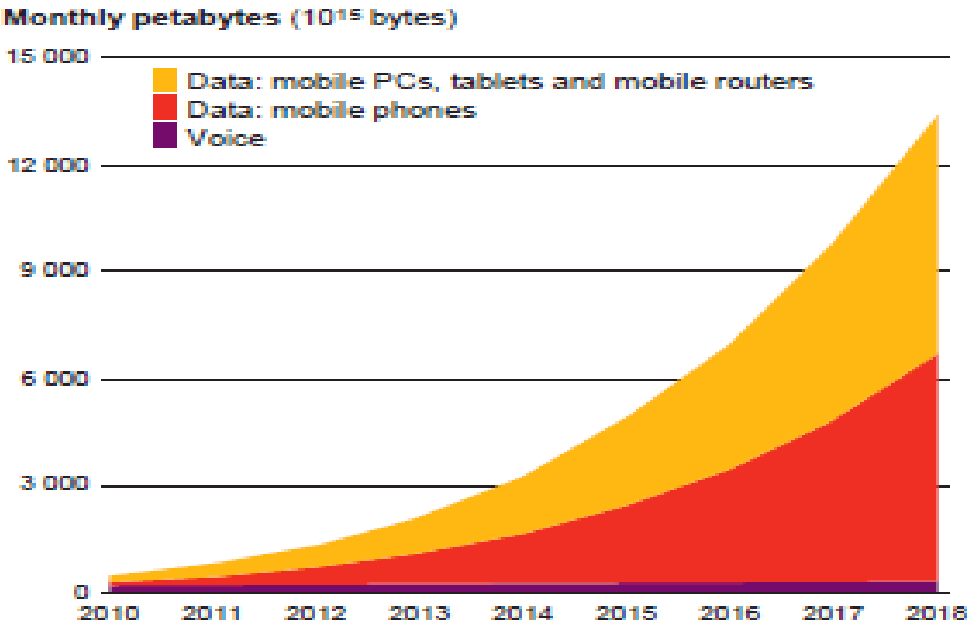


Figure1: Mobile data traffic to grow 12-fold by 2018 (source: Ericsson Mobility Report, November 2012)

- Demand for bandwidth is exponentially growing
- Available bandwidth is limited
- Tighter synchronization allows for better use of bandwidth

Note 1: Source is Infonetics “Using Ethernet to Backhaul LTE” white paper

LTE Synchronization Requirements

Application	Frequency	Time	Backhaul Spec
LTE (FDD)	**±50 ppb**	**N/A**	**±16 ppb** *(G.8261.1)*
LTE (TDD)	**±50 ppb**	**±1.5 µs** *(< 3km radius)* **±5 µs** *(> 3km radius)*	**±16 ppb** *(G.8261.1)* **±1.1µs** *(G.8271.1)*
LTE-A MBSFN	**±50 ppb**	**±1 to 5 µs** *implementation dependent*	**±16 ppb** *(G.8261.1)* **±1.1µs** *(G.8271.1)*
LTE-A CoMP *Network MIMO*	**±50 ppb**		
LTE-A eICIC *HetNet Coordination*	**±50 ppb**		
Small Cells	**±100 ppb**	**N/A** (FDD) **±1.5 µs** (TDD) **±1 to 5µs** (eICIC)	**±33 ppb** **±1.1µs** *(G.8271.1)*
Home Cells	**±250 ppb**	**N/A** (FDD) **±1.5 µs** (TDD)	**±100 ppb** **±1.1µs** *(G.8271.1)*

ITU-T Recommendations (Packet Sync – Phase/Time) – work in progress

- ITU T Recommendation G.8273.1 , Telecom Grand Master specification, includes 100 ns accuracy requirement
- ITU T Recommendation G.8273.3 , Telecom Transparent Clock specification
- ITU T Recommendation G.8273.4 , Assisted Partial Timing Support Slave Clocks (APTSC)
- ITU T Recommendation G.8275.2 , IEEE-1588 profile for time with partial support from the network
- ITU T G.Sup, Supplement to capture simulation model and results

GNSS Spectrum: For GNSS to backup GPS, they must use other bands besides primary