Symmetricom

Complementary Operation of Satellite and Network Time Distribution

Tim Frost

ITSF ’12, Nice, November 2012

Confidential © Copyright 2012

Agenda

- Time Synchronization Requirements
- Satellite time distribution
- Network time distribution
- Complementary operation

Confidential © Copyright 2012

Mobile Synchronization Requirements

Symmetricom

Application	Frequency: Network / Air Interface	Phase
UMTS / LTE FDD Small Cell	NA / 100 – 250 ppb	NA
GSM / UMTS / W-CDMA	16 ppb / 50 ppb	NA
CDMA2000		± 3 to 10 µs
TD-SCDMA		± 1.5 µs
LTE – FDD		NA
LTE – TDD		± 1.5 µs (≤3 km cell radius) ±5 µs (>3km cell radius)
LTE-A MBSFN		± 1 µs inter-cell time difference*
LTE-A Hetnet Coordination (eICIC)		± 5 µs inter-cell time difference*
LTE-A CoMP (Network MIMO)		± 0.5 µs inter-cell time difference*
WiMAX (TDD)		± 1 to 8 µs
Handset Location to 100m (E911)		± 100 ns

** Figures still under discussion in 3GPP*

Confidential © Copyright 2012

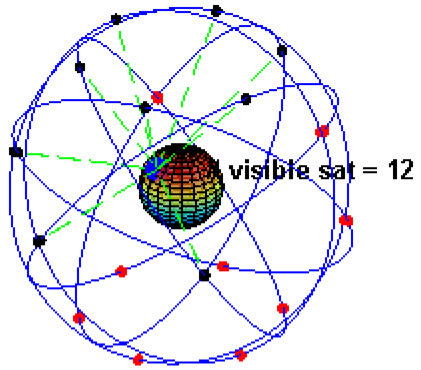
Symmetricom

Satellite Time Distribution

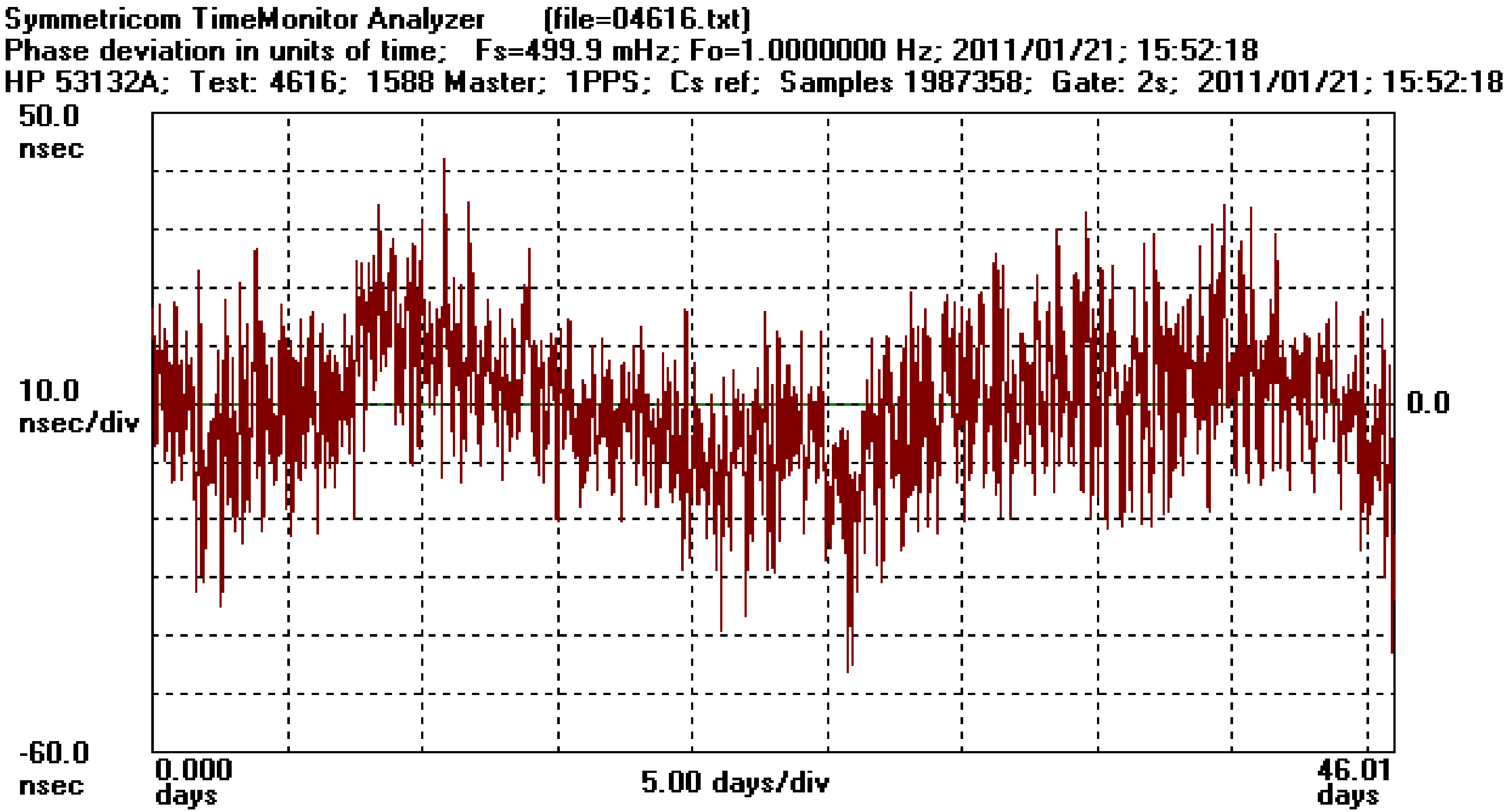
Confidential © Copyright 2012

Satellite Time Distribution (GNSS)

- Time distributed by radio from satellite
- Typical accuracy: < 100ns
- Advantages:
  - Global availability
    (provided there is a clear view of the sky)
  - Accuracy
  - System reliability
- Disadvantages:
  - Clear view of sky may not be available
  - Vulnerability to interference from ground based transmissions
  - Antenna issues – wind, rain, snow, ice, corrosion, bullets!
  - Political issues

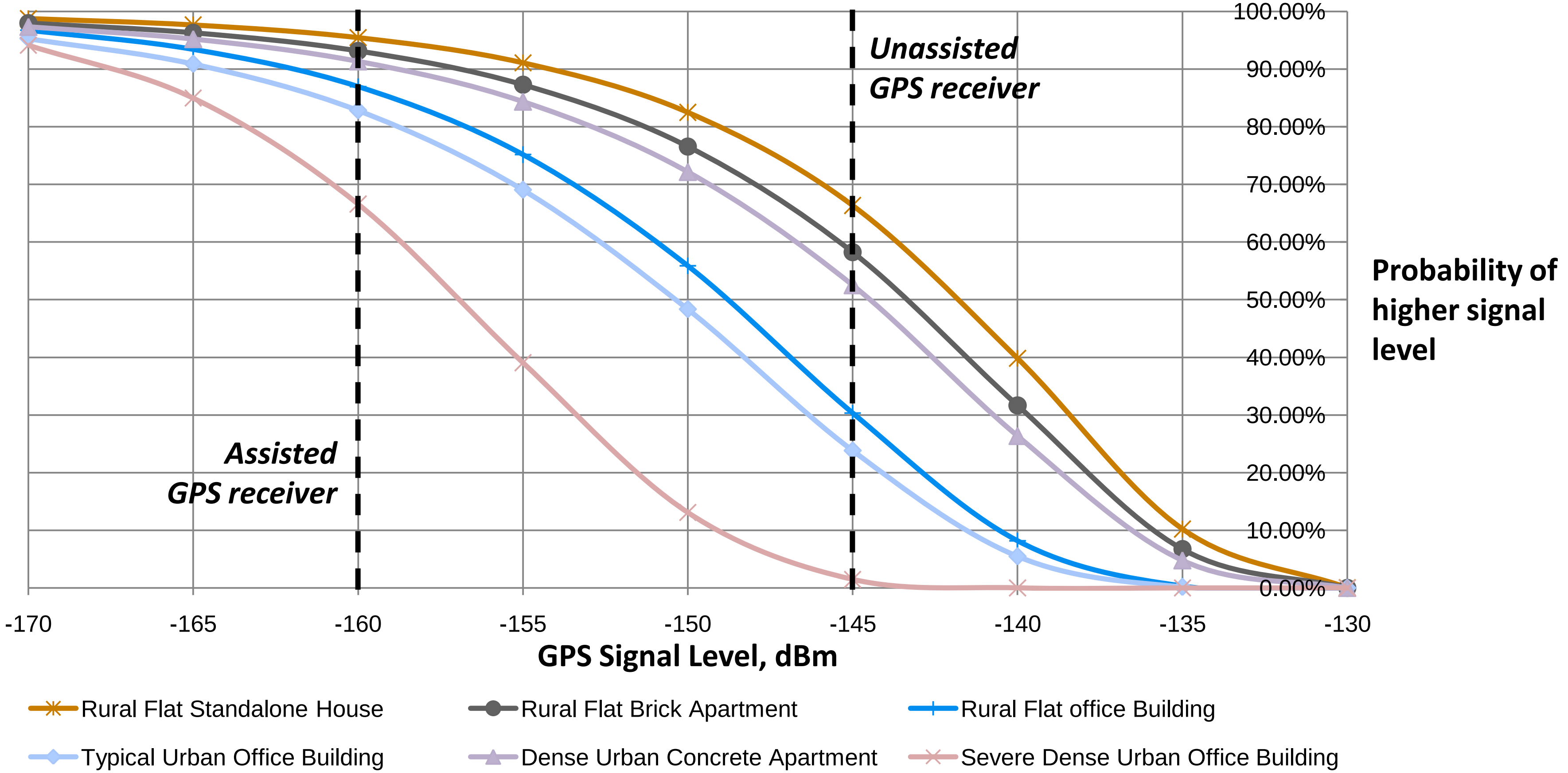


Long Term GPS Performance



In-Building Reception

- Signal strength at earth surface around -130dBm
- Buildings may attenuate this by over 40dB

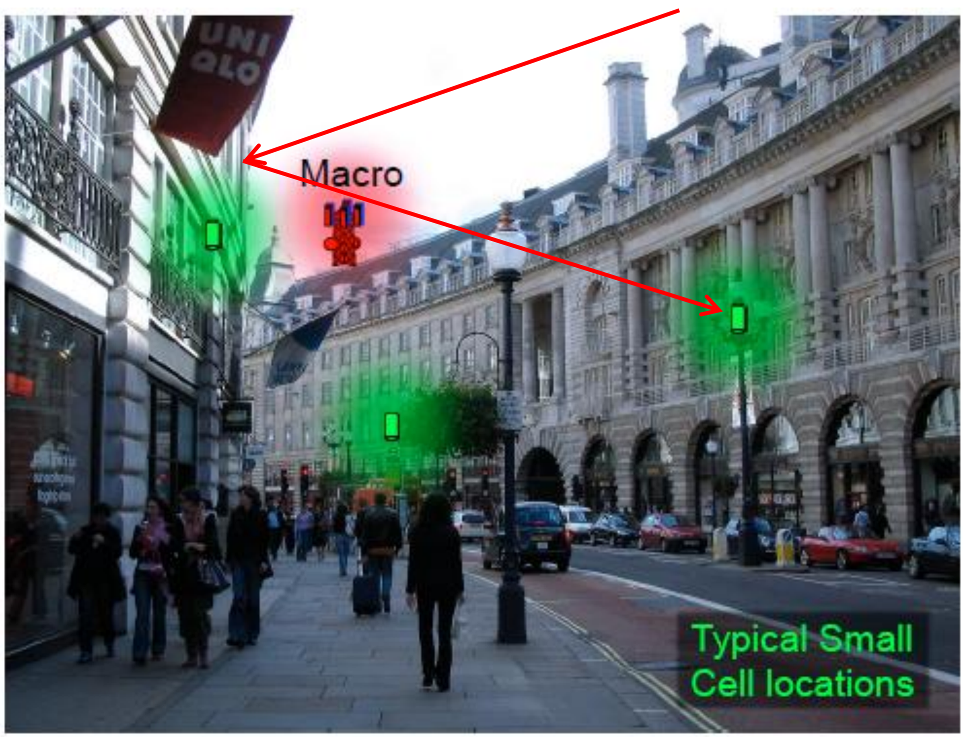


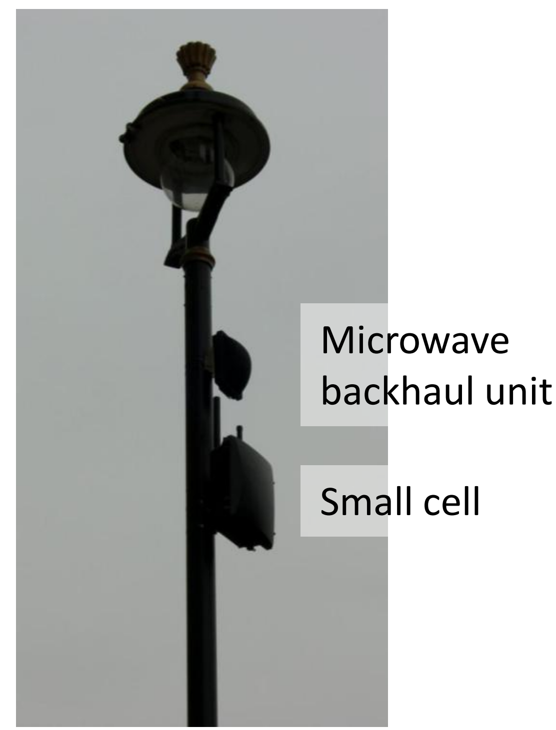
Graph adapted from Small Cell Forum white paper "Femtocell Synchronization and Location", May 2012

Confidential © Copyright 2012

Urban Canyons

- May not be able to view sufficient satellites all of the time
  - Intermittent fixes
- Multi-path reflections distort range measurements
  - Path length change of 30m = time change of 100ns

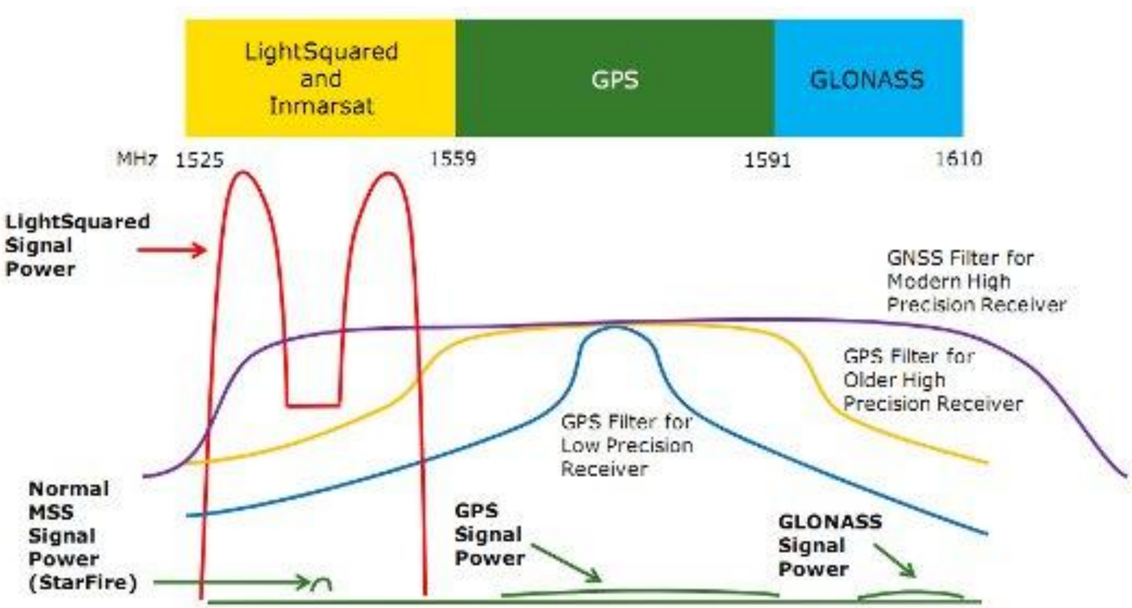




Pictures from Telefonica wi-fi small cell trial, London, summer 2012

Interference and Jamming

- Doesn't take much to jam a -130dBm signal!
  - Personal jammers
  - Legal terrestrial transmissions,
    e.g. Light Squared (now closed down)
  - Political jamming, e.g. North Korea

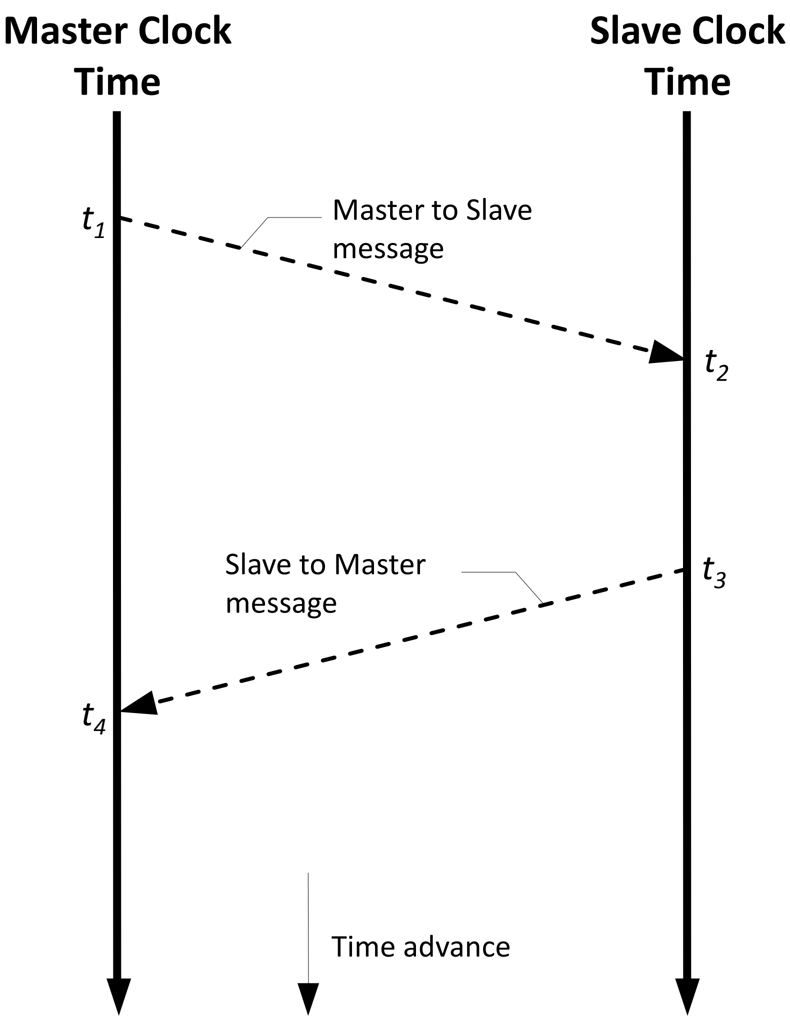


Network Time Distribution

Confidential © Copyright 2012

Two-Way Time Transfer Techniques

- Basis of most network time distribution mechanisms
  - NTP, PTP, DTI, custom
- Based on a two-way timed message exchange between the master and slave
- Time offset calculation requires all four timestamps:
  - Slave time offset = $\frac{(t_2 - t_1) - (t_4 - t_3)}{2}$
- **Assumes symmetrical delays**
  - i.e. the forward path delay is equal to the reverse path delay



Confidential © Copyright 2012

Precision Time Protocol (PTP, IEEE1588)

Symmetricom

- Two-Way Time Transfer over packet networks, using accurate timestamps at the physical interface
- Designed to operate over standard communications networks such as Ethernet and IP in both LAN and WAN environments
- Introduces "on-path timing support" to mitigate variable delay in the network elements
  - Boundary clocks terminate and re-generate timing at each node
  - Transparent clocks add a correction for the delay through each node
- Typical accuracy: depends on size of network
  - Error may not accumulate linearly
  - Doesn't include asymmetry of link delays

There are no automatic network-based techniques that can compensate for link delay asymmetry

PTP Advantages and Disadvantages

- Advantages
  - Operates over standard communications networks
  - Spans multiple network nodes
- Disadvantages
  - Requires asymmetry correction
    - Forward/reverse signals may not take same route through network
    - Forward/reverse fibres may be different length, even in same bundle
    - Delays through PHY component may be different in each direction (especially at 10Gbit/s and above)
  - Requires adapted network elements for best performance
    - Boundary, transparent clocks at each node
    - **BUT** intelligent slave algorithms can filter PDV in absence of BCs or TCs

Confidential © Copyright 2012

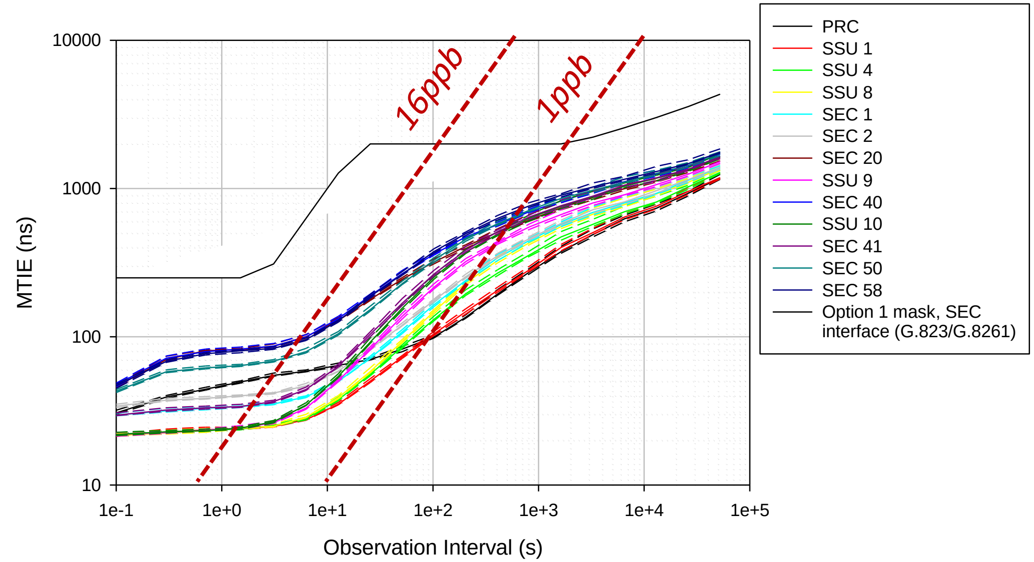
Synchronous Ethernet

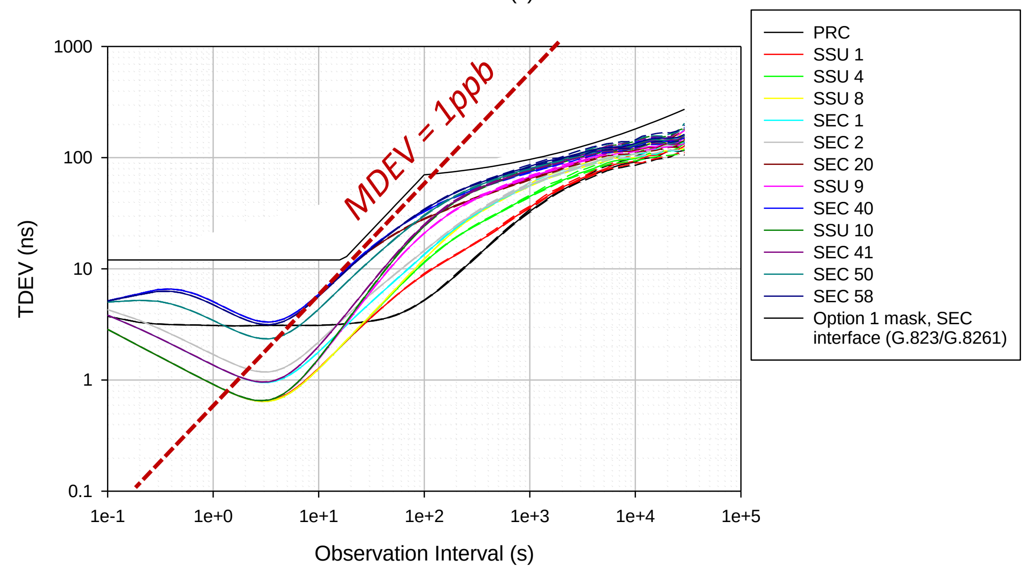
- Uses Ethernet bit clock to carry synchronization signal
- Equivalent performance to conventional physical layer synchronization
  - Sync signal traceable back to PRC
  - Long term frequency accuracy of 1 part in 10^{11}
- Advantages
  - Stable, accurate frequency reference
  - No need for expensive ovenized crystal at slave clock
- Disadvantages
  - Frequency only, doesn't provide time or phase
  - Requires end-to-end infrastructure to support it

Confidential © Copyright 2012

SyncE Phase Wander

- Graphs show simulations of MTIE and TDEV at different points along a SyncE reference chain
- MTIE approaches 1μs after around 2000s
  - Limits the amount of time SyncE can be used to hold accurate phase
- TDEV shows stability of SyncE signal
  - Over 10 – 100s comparable with good quality TCXO at constant temperature (1ppb)





Simulation results from ITU SG15 Q13 Contribution C965, Huawei, June 2010

Confidential © Copyright 2012

Complementary Operation

Confidential © Copyright 2012

Improving GNSS Detection and Acquisition

Symmetricom

- Assisted GPS (AGPS) uses information from the network to assist in demodulating the GPS signal
  - Ephemeris data describes where each satellite is at any given time
- Time fix from PTP (to within a ms)
  - Allows GPS signal to be acquired at lower signal to noise ratio
- Position fix (e.g. from local survey)
  - Base stations typically don't move!
  - Known position also allows the signal to be acquired at a lower SNR
- Coherent Integration
  - Stable frequency allows GPS signal to be integrated for longer, improving acquisition
  - SyncE allows integration times of ≈5s, similar to a good TCXO
  - OCXO or Rb oscillator will allow longer integration times

Confidential © Copyright 2012

Maintaining time between GNSS fixes

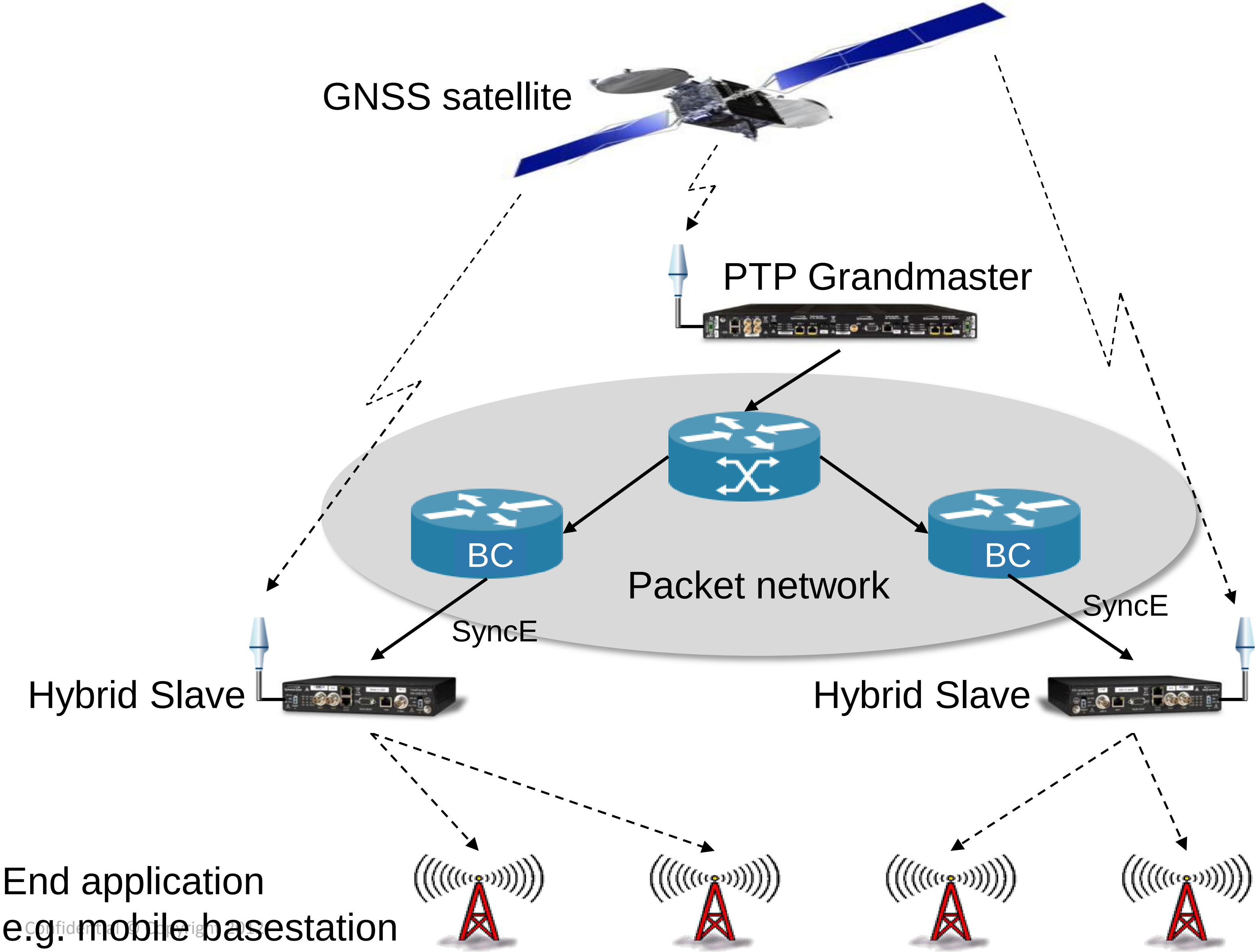
Symmetricom

- In urban canyons or in buildings, fixes may be several minutes apart
- Local interference or jamming may temporarily interrupt GNSS service
- Timebase maintained using stable frequency
  - OCXO will maintain 1µs for around 60s (variable temp)
  - SyncE will maintain 1µs phase for around 2000s
  - Rb oscillator will maintain 1µs for nearly 24 hours (variable temp)
- Timebase maintained using PTP
  - PTP will maintain phase indefinitely
  - GNSS time fix can be used to calibrate the asymmetry
  - Measures asymmetry on a "whole of network" basis

Confidential © Copyright 2012

Hybrid PTP/GPS/SyncE solution

Symmetricom



Hybrid PTP/SyncE/GNSS Solution

- Advantages
  - Initial PTP time fix allows acquisition of GNSS signal at lower power
  - SyncE or oscillator stability allows longer coherent integration
  - Accurate GPS time allows calibration of overall PTP asymmetry
  - PTP provides backup in event of GNSS failure

- Disadvantages
  - Requires installation of multiple infrastructures

Confidential © Copyright 2012

Conclusions

Confidential © Copyright 2012

Conclusions

- Several commercial applications require time accuracy well below 1µs
- No single technique is a complete solution to this:
  - GNSS
  - PTP
  - SyncE
  - Advanced oscillators
    - modern temperature compensation techniques
    - miniature atomics (Rb and Cs)
- Hybrid techniques addresses the deficiencies of each
  - Creates an accurate, robust solution for precise time distribution
  - At least two are required for a reliable solution (GNSS + 1 other)

Thank You

Tim Frost

CTO Office

tfrost@symmetricom.com

Phone : +44 7825 706952