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Meeting the 100ns Challenge

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ITSF ’11, Edinburgh, November 2011

Applications for Sub-Microsecond Accuracy

Methods of distributing accurate time

Conclusions

Location Services

Reminder: 100ns = 30m, or 100m = 330ns

- "E911" emergency location requirements
  - Network-based location (via triangulation from base station)
    - Within 100 meters for 67 percent of calls
    - Within 300 meters for 95 percent of calls
    - Requires < 150ns time accuracy at the base stations
  - Location of handsets with integrated GPS
    - Within 50 meters for 67 percent of calls
    - Within 100 meters for 95 percent of calls
  - Network-based location requirement to be "sunset" in 2019 in favour of GPS-based location
    - Most (all?) phones sold in USA contain GPS receivers
    - What if phone is out of GPS reception, or there is local jamming?

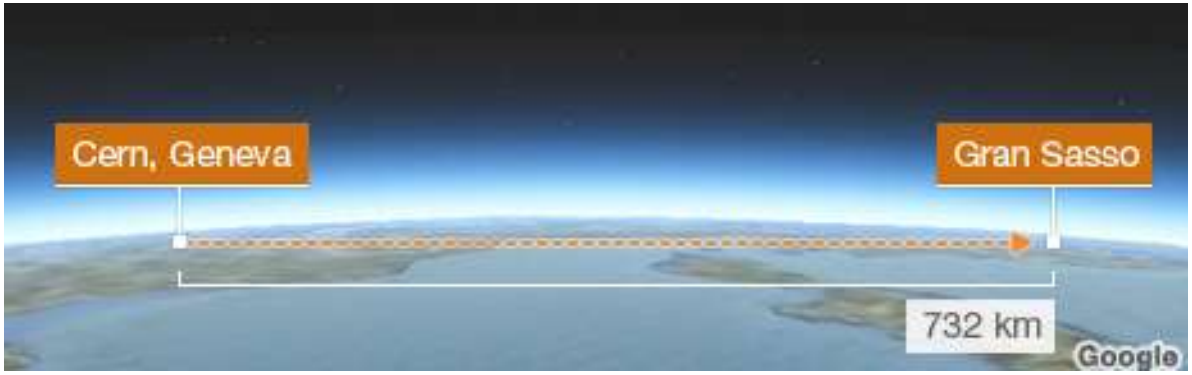
LTE Advanced

- LTE-Advanced does not require time synchronization for initial deployment
- Some features proposed for LTE-Advanced do require accurate time synchronization
- Examples:
  - Enhanced network MIMO (Multiple Input, Multiple Output)
  - CoMP (Co-ordinated Multi-Point Transmission)
  - Single Frequency Networks
  - Carrier Aggregation
- Time accuracy required still to be confirmed
  - Expected to be in the range 500ns to 1µs

Scientific Applications

- Remote calibration and metrology
- Particle physics
- Very long baseline interferometry

- Example in the news: Flight time of neutrinos
  - Neutrinos arrived 60ns “early” after a 732km journey
  - 60ns ≈ 20m at the speed of light



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GNSS Time Distribution

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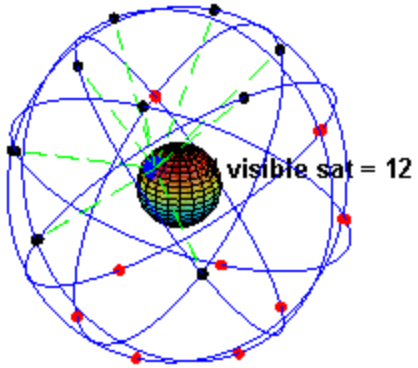
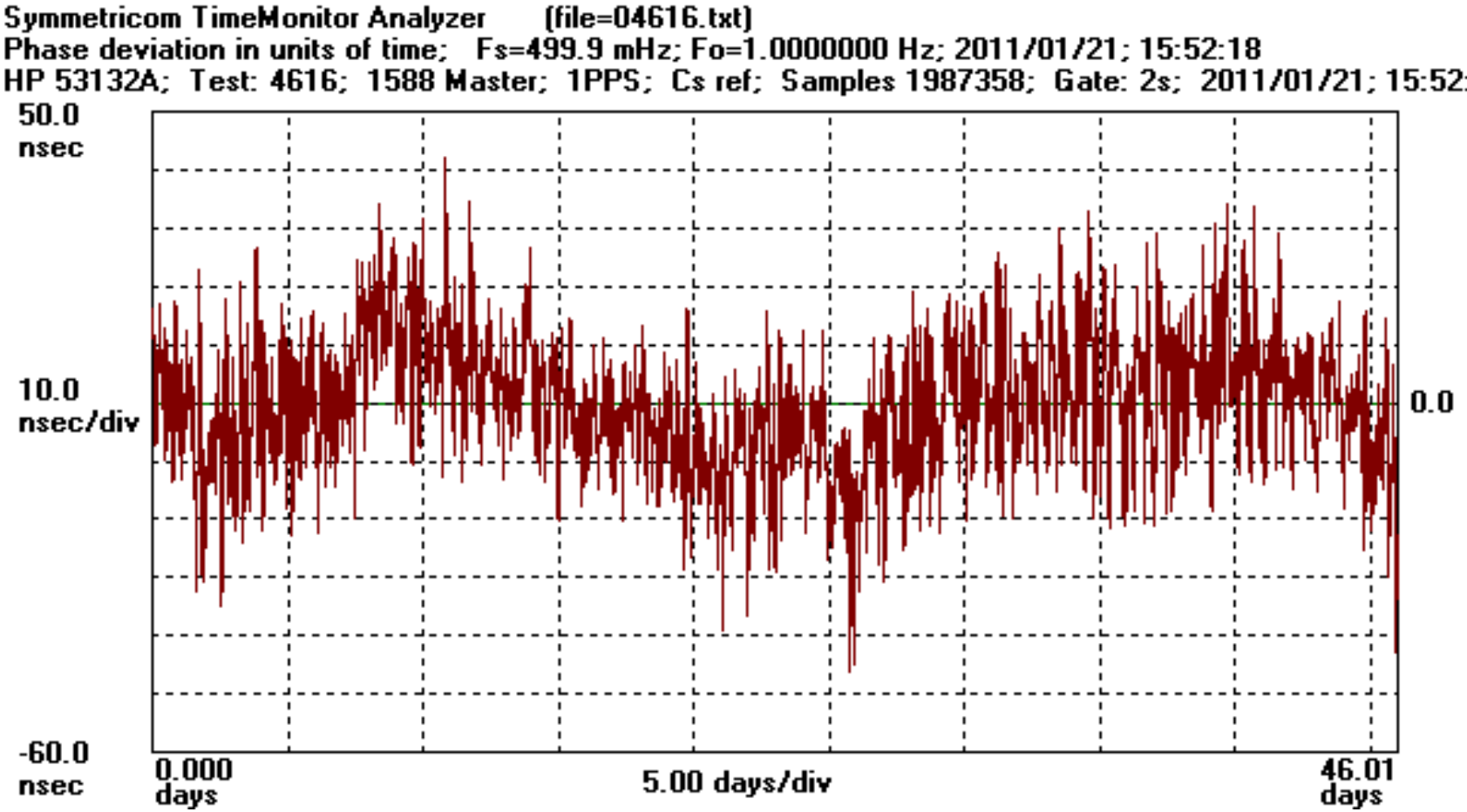
- Time distributed by radio from satellite
- Typical accuracy: < 100ns
- Advantages:
  - Global availability
    (provided there is a clear view of the sky)
  - Accuracy
  - System reliability
- Disadvantages:
  - Clear view of sky may not be available
  - Vulnerability to interference from ground based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

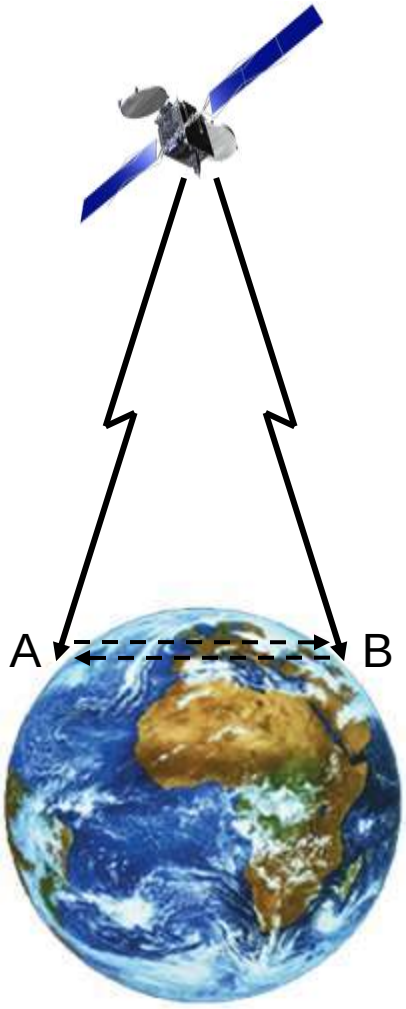


Long Term GPS Performance



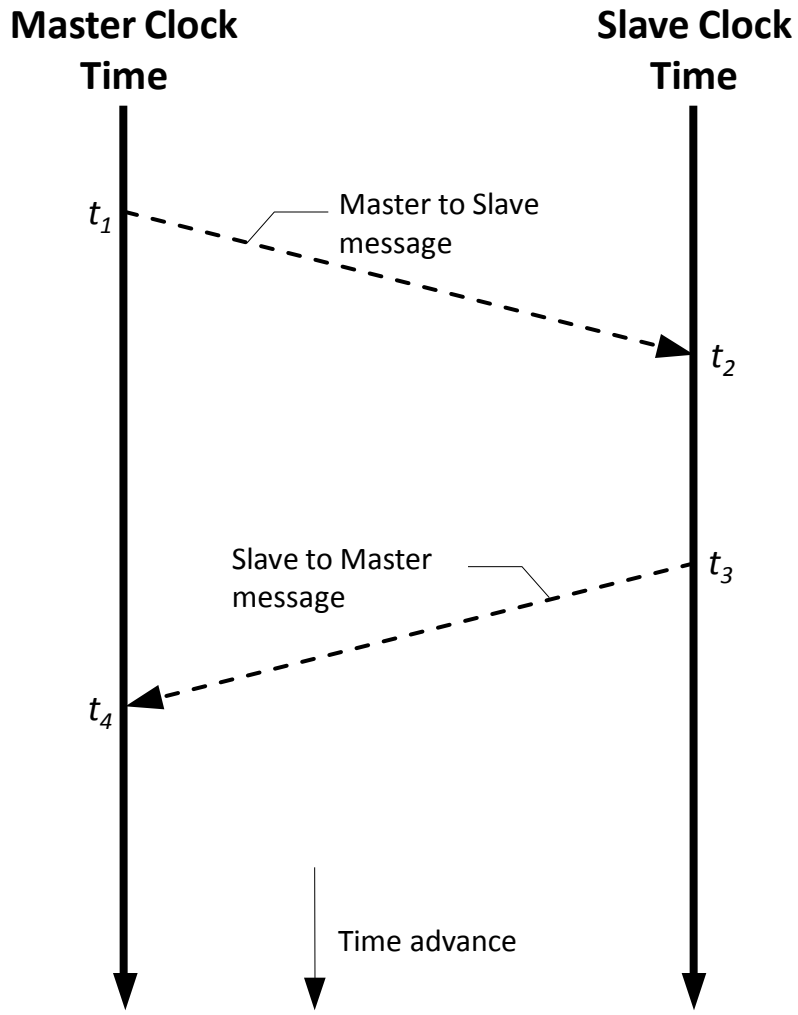
GNSS Common View Time Distribution

- Satellite time signal simultaneously observed at two locations
- Allows time difference between two locations to be estimated by exchange of local observations
- Typical accuracy: < 10ns
- Advantages:
  - Very high accuracy achievable
- Disadvantages:
  - Installation and calibration expensive
  - For best accuracy, requires calibration of the satellite to earth transmission delay
- Used by the CERN-LNGS neutrino experiment
  - Calibration report estimated a 2.3ns time difference with 0.9ns uncertainty
- Provided as a service by some national physics labs



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)*

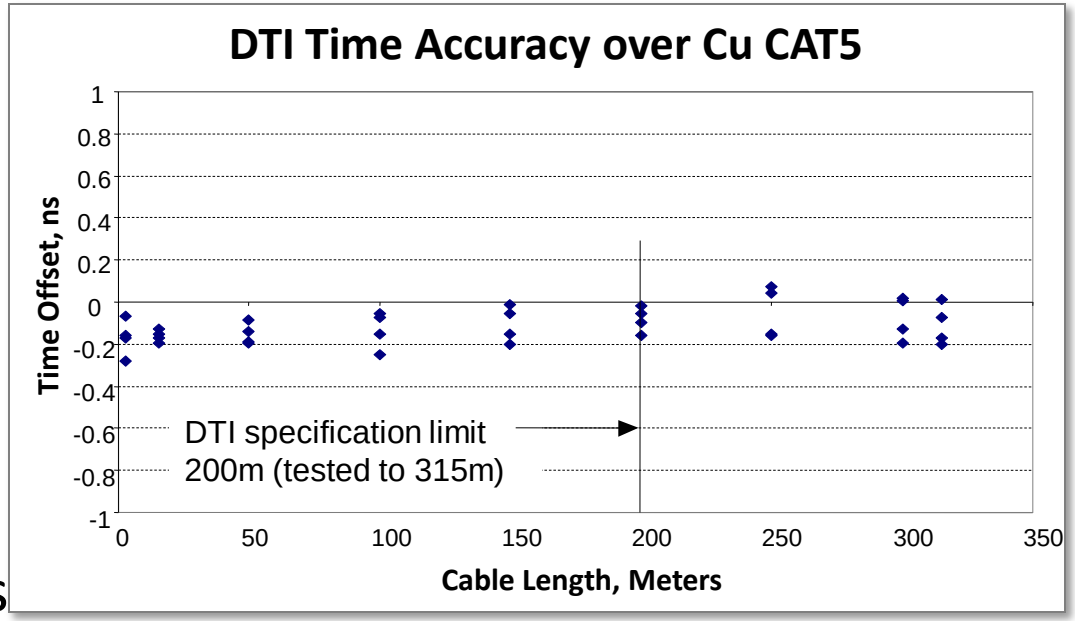


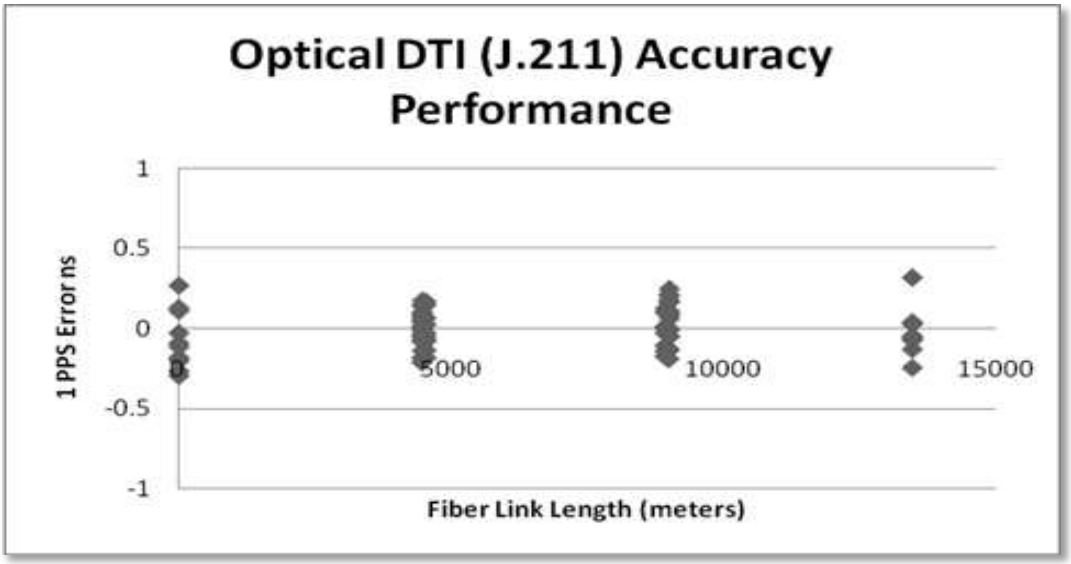
DOCSIS Timing Interface (ITU-T Rec. J.211)

- Two-Way Time Transfer over a dedicated cable or fibre, with a synchronized physical layer
- Originally designed to synchronize modular cable TV plant
- Typical accuracy: <1 ns from master time (5ns standard)
- Advantages:
  - Very high accuracy
  - Highly symmetrical (both directions over same cable)
- Disadvantages
  - Requires dedicated cabling (e.g. CAT5, dark fibre)
  - Point-to-point (doesn't pass through switches/routers)
- Future work
  - Investigate performance over a DWDM wavelength

DTI Performance

- Potential time accuracy:
  - Cu: 1ns over 200m UTP
  - Fibre: 1ns over 10km
- Cu uses single twisted pair in half duplex mode
- Optical uses single fibre with different wavelengths in each direction
  - Uses “Ethernet in First Mile” at 1550/1310nm
- Identical layer 2 structure as copper DTI





Precision Time Protocol (PTP, IEEE1588)

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- 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 support” to mitigate variable delay in the network
  - 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
  - Current simulations presented in ITU suggest 50ns error per node
  - Error may not accumulate linearly
  - Doesn’t include asymmetry of link delays

PTP Advantages and Disadvantages

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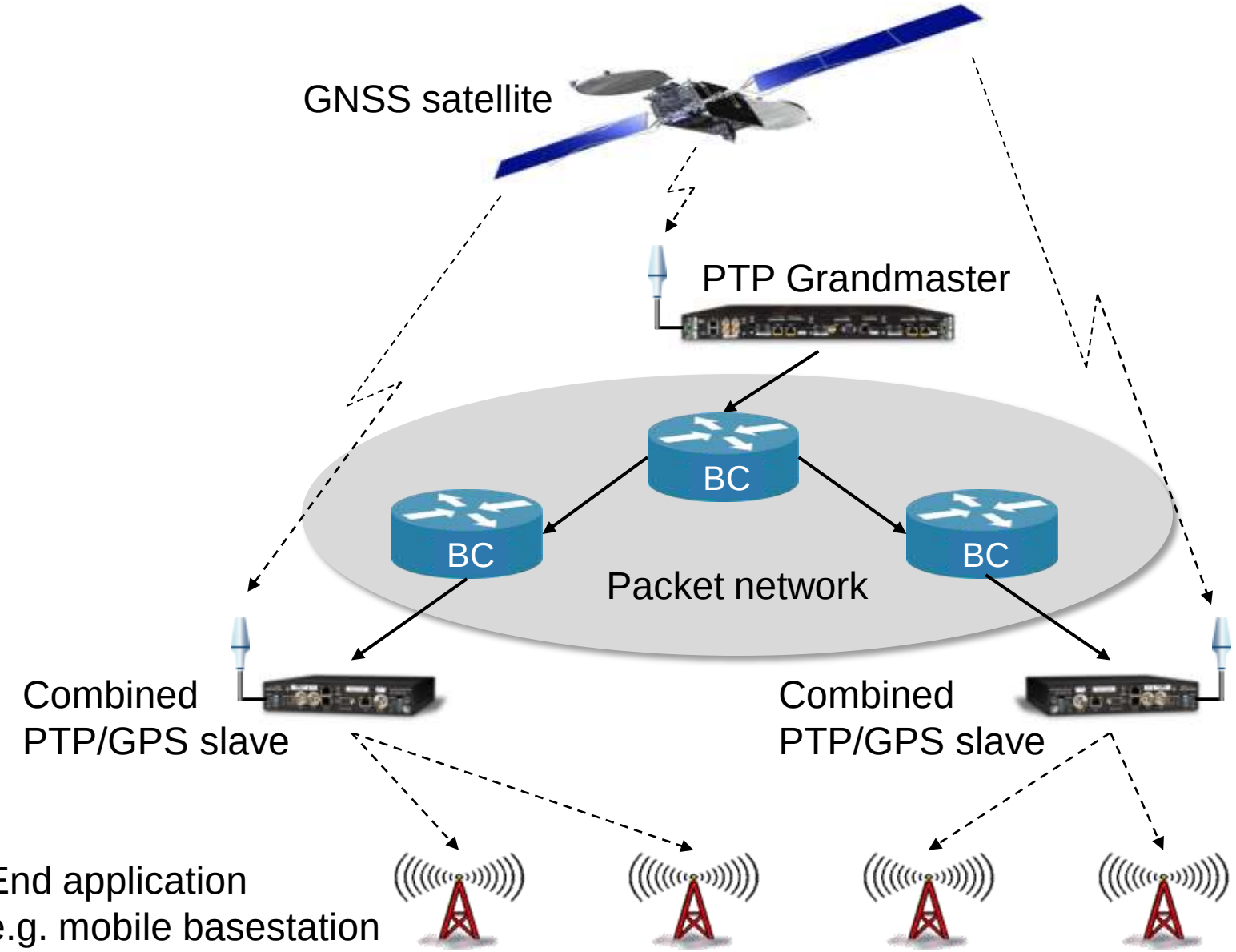
- Advantages
  - Operates over standard communications networks
  - Spans multiple network nodes
- Disadvantages
  - Requires asymmetry correction
    - Forward/reverse signals may not take same route through network
    - Forward/reverse fibres may be different length, even in same bundle
    - Delays 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

Hybrid PTP/GPS solution



Hybrid PTP/GPS Solution

- Advantages
  - Initial PTP time allows fix on GNSS time in low signal conditions
  - Accurate GPS time allows calibration of overall PTP asymmetry
  - PTP provides backup in event of GNSS failure
- Disadvantages
  - Requires installation of two infrastructures

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- Several commercial applications require time accuracy well below 1µs
- Multiple techniques are available to realise this
  - GNSS, and GNSS common view
  - DTI
  - PTP
- Hybrid PTP and GNSS addresses the deficiencies of both
  - Creates an accurate, robust solution for precise time distribution

Thank You

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