Considerations for building accurate PTP networks for now and the future

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Making next-generation networks a reality.

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Why Timing Is So Important

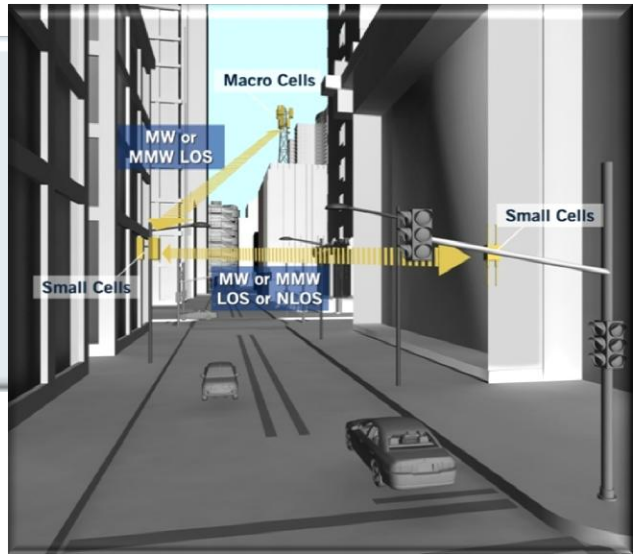
Application	Frequency / Air Interface	Time / Phase	Why You Need to Comply	Impact of Non-compliance
LTE (FDD)	16 ppb / 50 ppb	N/A	Call initiation	Call interference Dropped calls
LTE (TDD)	16 ppb / 50 ppb	± 1.5 µs	Time slot alignment	Packet loss/collisions Spectral efficiency
LTE MBSFN	16 ppb / 50 ppb	± 32 µs	Proper time alignment of video signal decoding from multiple BTSs	Video broadcast interruption
LTE-A MIMO/COMP	16 ppb / 50 ppb	± 500ns	Coordination of signals to/from multiple base stations	Poor signal quality at edge of cells, LBS accuracy, lower data speeds

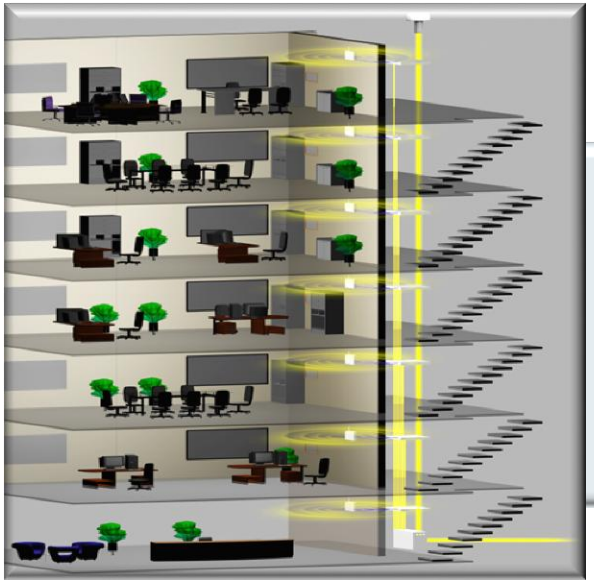
Poor Phase Synchronization has severe impact on TD-LTE and LTE-A

IEEE1588 Network Timing Is Required For LTE

Outdoor Small Cells

- Small Cells to deliver LTE capacity
- Often no line of sight to GPS satellites
- More vulnerable to attacks at street level





Indoor Picocells

- Picocells or Enterprise Femtocells for LTE indoor coverage & capacity
- Can't get timing to Femtocells using GPS

The Biggest Misconceptions and Problems

Timing Error Budget is ±1µs

- "So it's ok if my equipment is only 100ns accurate…"
- Base Stations, Routers, Gateways, Microwave Equipment – all say that

Every Hop has the same TE Budget

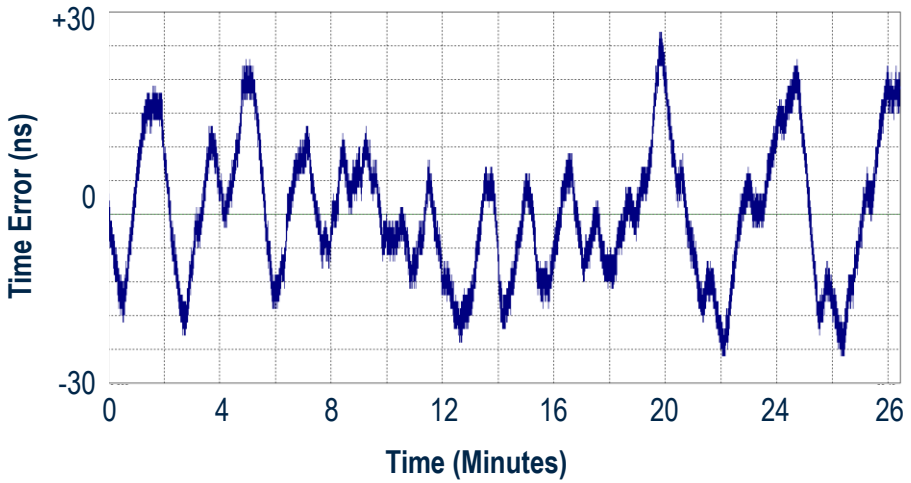
- This won't be true in real networks
- Base Stations, Routers, Gateways can be much higher accuracy
- MW and MMW Backhaul will need more slack

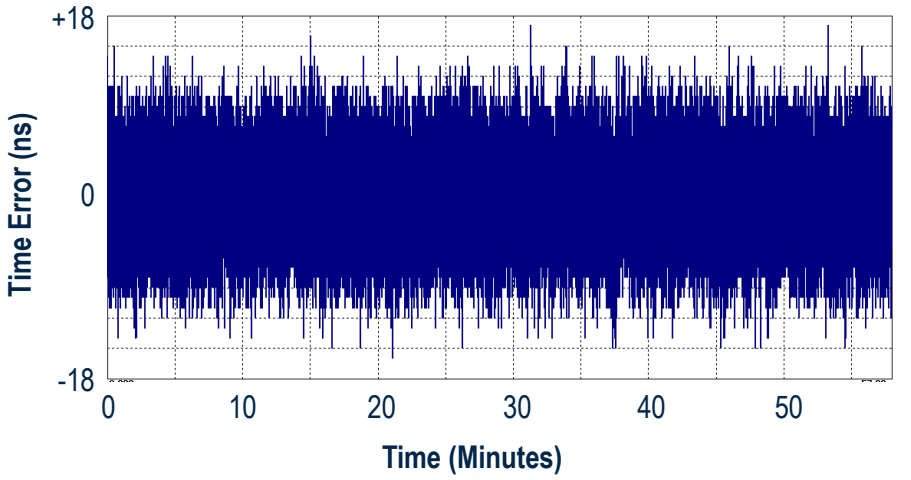
And the Biggest Problem?

- Right now, no operator can figure out if they will meet the timing budget before the network is installed and can be tested!

PTP Equipment Performance

- **The PTP performance of equipment can be divided into 2 parts**
  - Constant Time Error (cTE)
    - Caused by inaccuracy in the timestamp points
  - Dynamic Time Error (dTE)
    - Caused by Timestamp resolution, Local oscillator noise, Other sources
    - Can to some degree be filtered off by the next node





ITU-T G.8273.2 T-BC Performance Classification

- **ITU-T G.8273.2 will specify two T-BC equipment classes**
  - Class A: Maximum Constant Time Error of 50 ns
  - Class B: Maximum Constant Time Error of 20 ns
  - More accurate classes can be added in the future if needed

- **Constant time error accumulates linearly (worst-case)**
- **Unknown fiber asymmetries also cause constant time errors**
  - Happens if two fibers in an RX/TX pair has different lengths (~2.5 ns cTE per meter skew)
  - Can be manually measured and compensated for at installation

Other part of the Time Error Budget…

- **The GPS/GNSS/Grandmaster has been allocated 100 ns**
- **Dynamic time error (caused by timestamp resolution, noise from the local oscillators/SyncE) will also exist but *most* of it can be filtered out by the end application.**
  - ITU-T is working on equipment specification limits for the dynamic time error as well
- **Some part of the timing budget might be allocated for short-term holdover, depending on the application**
- **The end application (base station) also needs a piece of the budget**
  - <150 ns for LTE-TDD
  - <50 ns for LTE-A

LTE-A MIMO/CoMP Budget Example

Budget Component	Budget allocation
PRTC (incl. T-GM)	100 ns
Equipment cTE	250 ns
Link asymmetry	50 ns
Holdover	0 ns
Error caused by dynamic time errors	50 ns
End Application	50 ns
Total	**500 ns**

BC/TC performance only has 60% of the 500 ns budget

So what about these Equipment Timing Classes

- Most legacy PTP Switches and Routers today only achieve max cTE of 100ns
- MW/MMW links with 1588 support can achieve cTE well below 100ns
- 10-20ns accuracy can easily be achieved with PHY-based timestamping for both Boundary and Transparent Clocks

- Equipment vendors can continue selling older equipment but must specify cTE and dTE performance
- Operators can mix and match older and new equipment, and can foresee what time accuracy they will achieve

How That Would Look Visually…

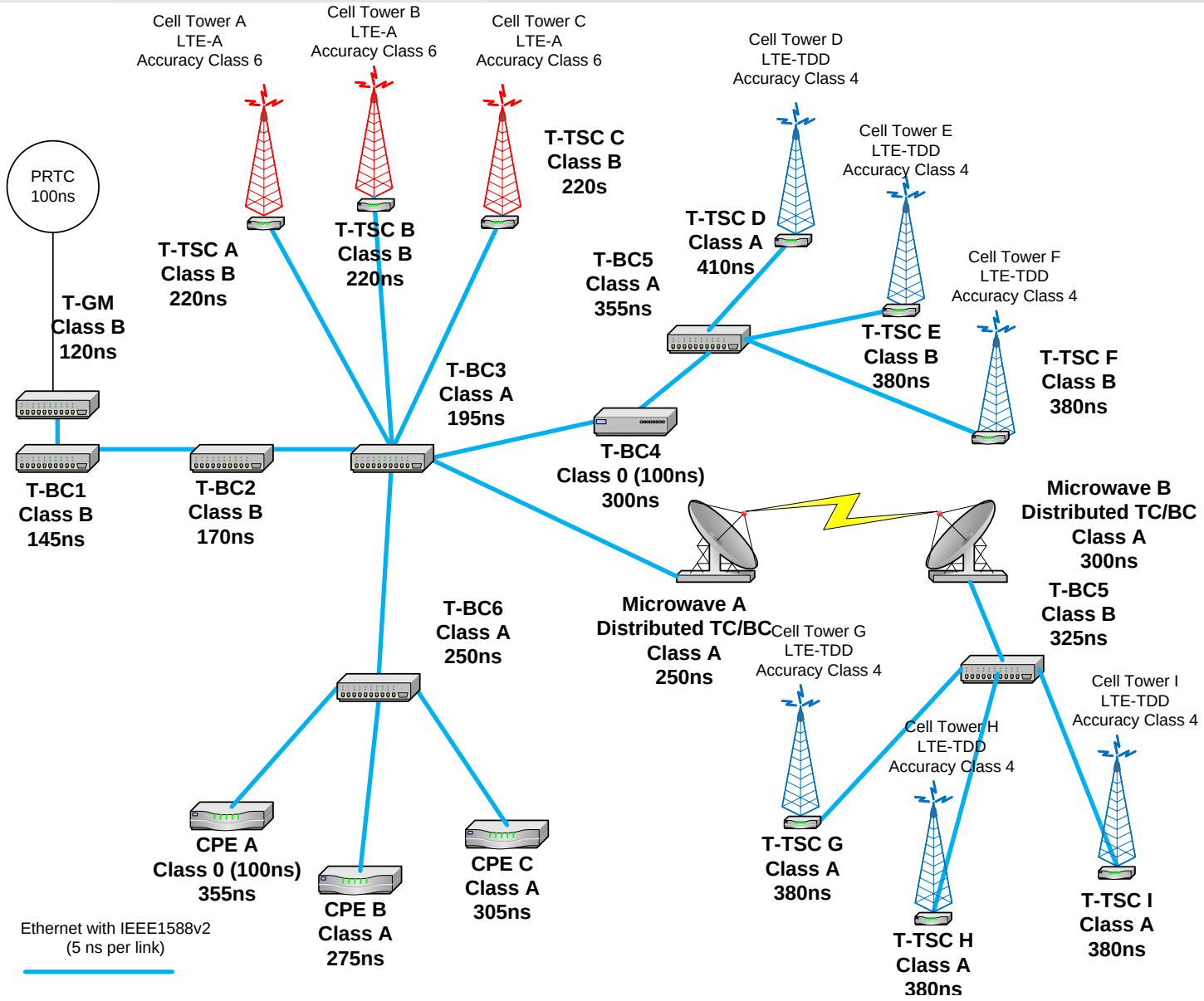
500ns LTE-A MIMO Time Error Budget

A) 6 hops Class A (50ns) – Link budget of 10 ns (350 ns cTE)

B) 14 hops Class B (20ns) – Link budget 5 ns (345 ns cTE)

C) 3 hops Class A & 7 hops Class B – Link budget 5/10 ns (345 ns cTE)

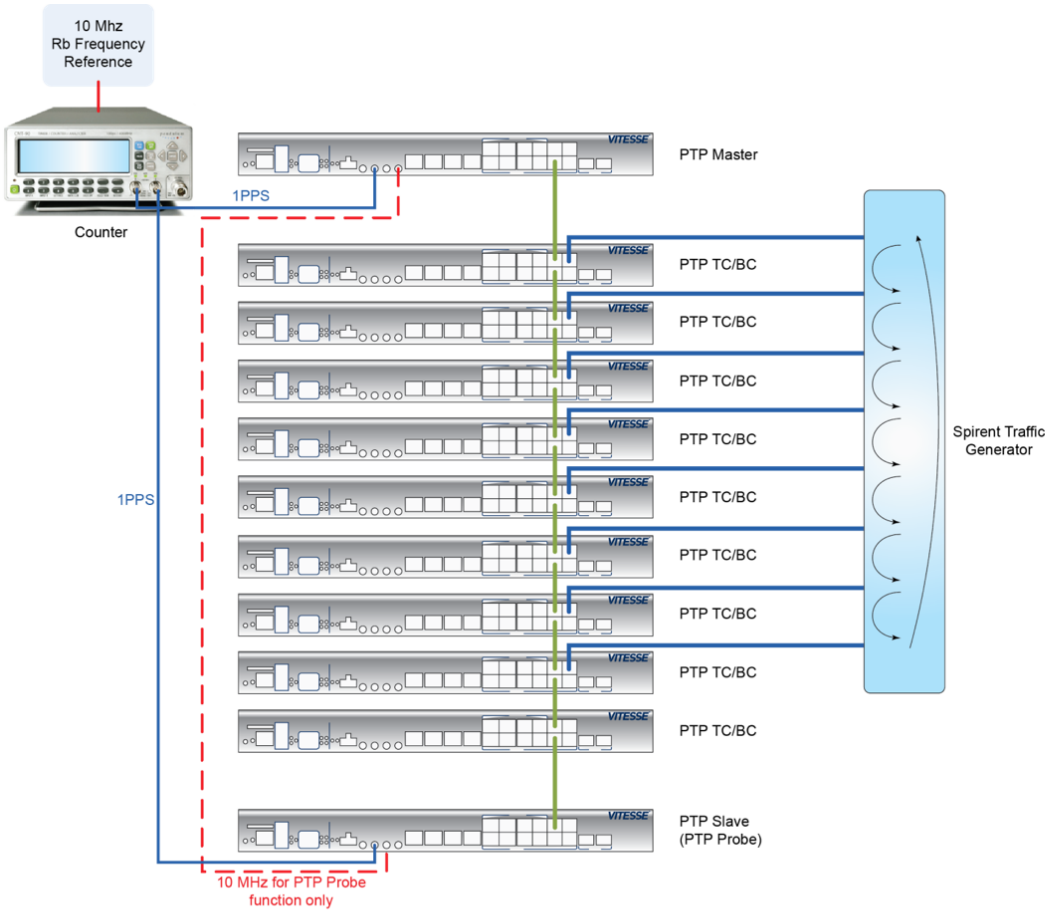
Network Diagram with cTE



< 20 ns – Is that really feasible? – YES IT IS!

- **Vitesse CE Switch reference system**
  - cTE for a single T-BC: < 5 ns
  - Unfiltered dTE: < 10 ns
  - Filtered dTE: < 3 ns (0.1Hz low pass filter)
- **System Level Test results**
  - All links are 10GE (No cable skew)
  - GM-> 9 x T-BC -> T-TSC (slave)
    - Maximum Time Error at slave: -21 ns
    - Average Time Error at slave: 2 ns
  - GM-> 9 x TC -> T-TSC (slave)
    - Maximum Time Error at slave: -20 ns
    - Average Time Error at slave: -1 ns

BC and TC Systems Testing
Using Vitesse VeriTime™ 1588 Technology



Configuration Details

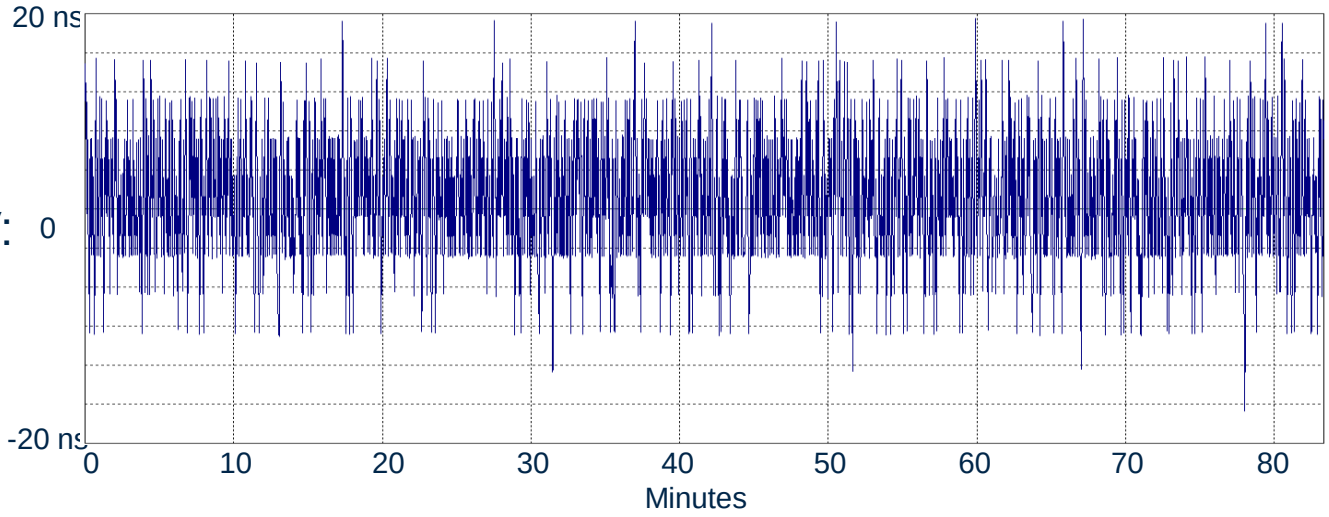
PTP Network Equipment:
VSC5621EV Carrier Ethernet Switch Reference Design

- All Interfaces are 10GE SFP+
- 1-step PTP using Ethernet Encapsulation
- TCs running E2E without Syntonization
- Sync/Delay_req frame rate: 16 FPS

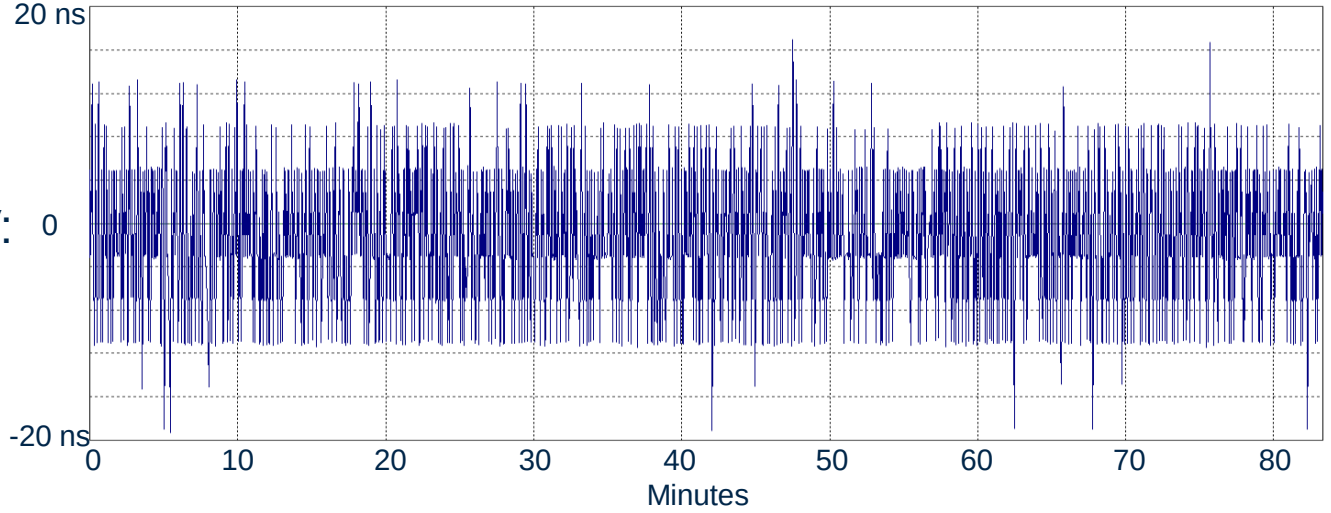
VeriTime™ Switch/PHY-based Carrier Ethernet Reference Design

Test Results – Time Error at slave

GM-> 9xBC->SLV:



GM-> 9xTC->SLV:



Summary and Conclusions

- TD-LTE & LTE-A require tight control of timing errors per link to meet timing requirements
- New base stations and fiber or copper connected switches and routers can easily meet 20ns time error per hop
- Older 1588-aware equipment and MW link time errors can meet 100ns time error per hop
- Operators need an easy way to know if their (heterogeneous) networks will meet timing (before finishing the build-out!)
- With 1588 equipment classes, network timing will be possible even with diverse equipment and transport technologies

Planning for tight timing requirements are future proofing the network for advanced mobile technologies

Thank You

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