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Synchronisation Architectures: Engineering a Network for Time/Phase

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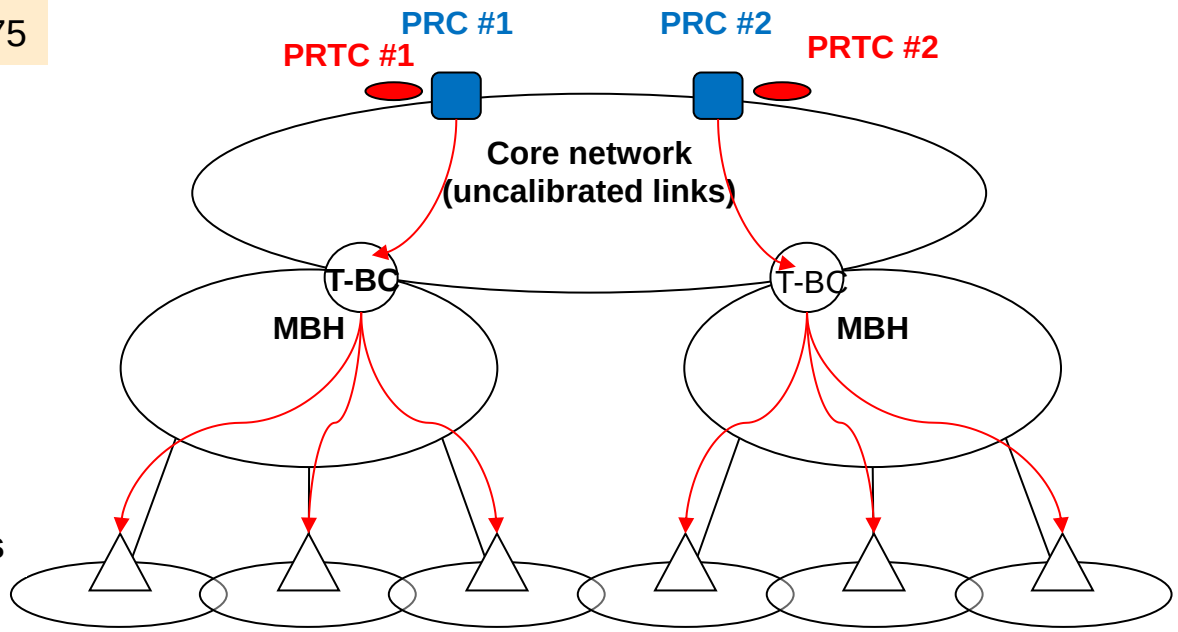
Current Model Predicated on Centralized Frequency Distribution

From G.8275

PTP path

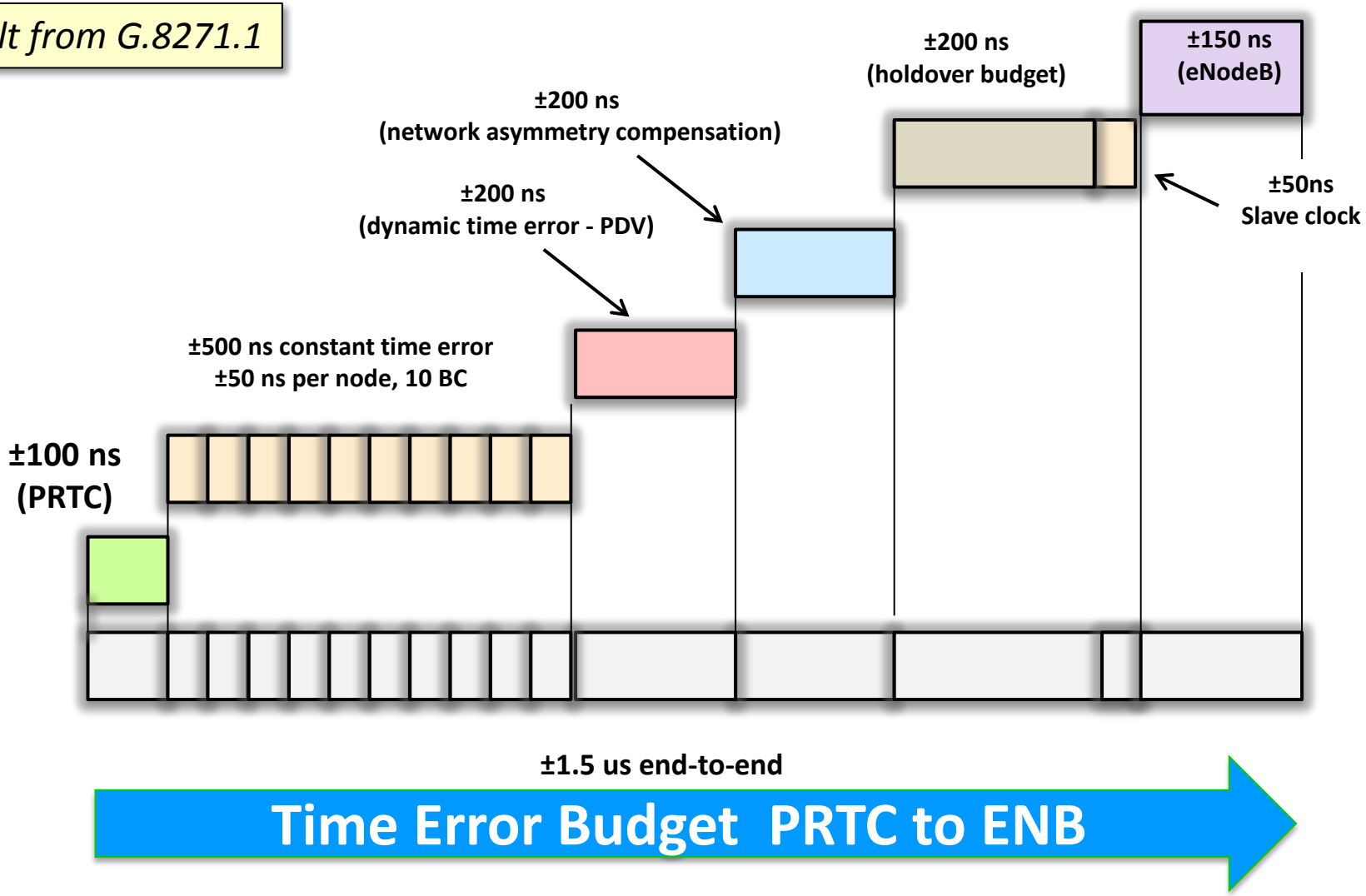


Core
To Edge
sync &
time
budget

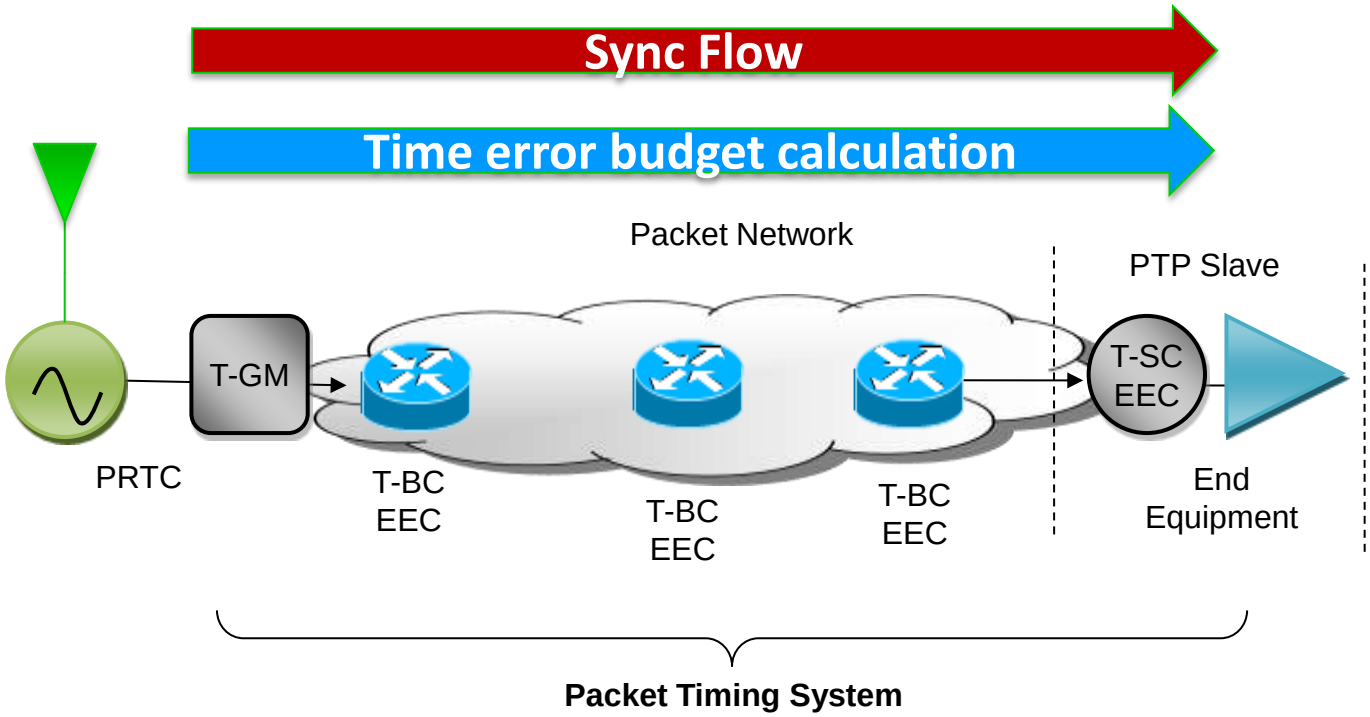
- Core > Edge time distribution.
- Uses model developed in 1980's for frequency distribution
- "Distributed PRTC" same Core > Edge philosophy –recognizes proximity issues but does not simplify planning challenges

ITU Time Error Budget: Core to Edge model

Built from G.8271.1

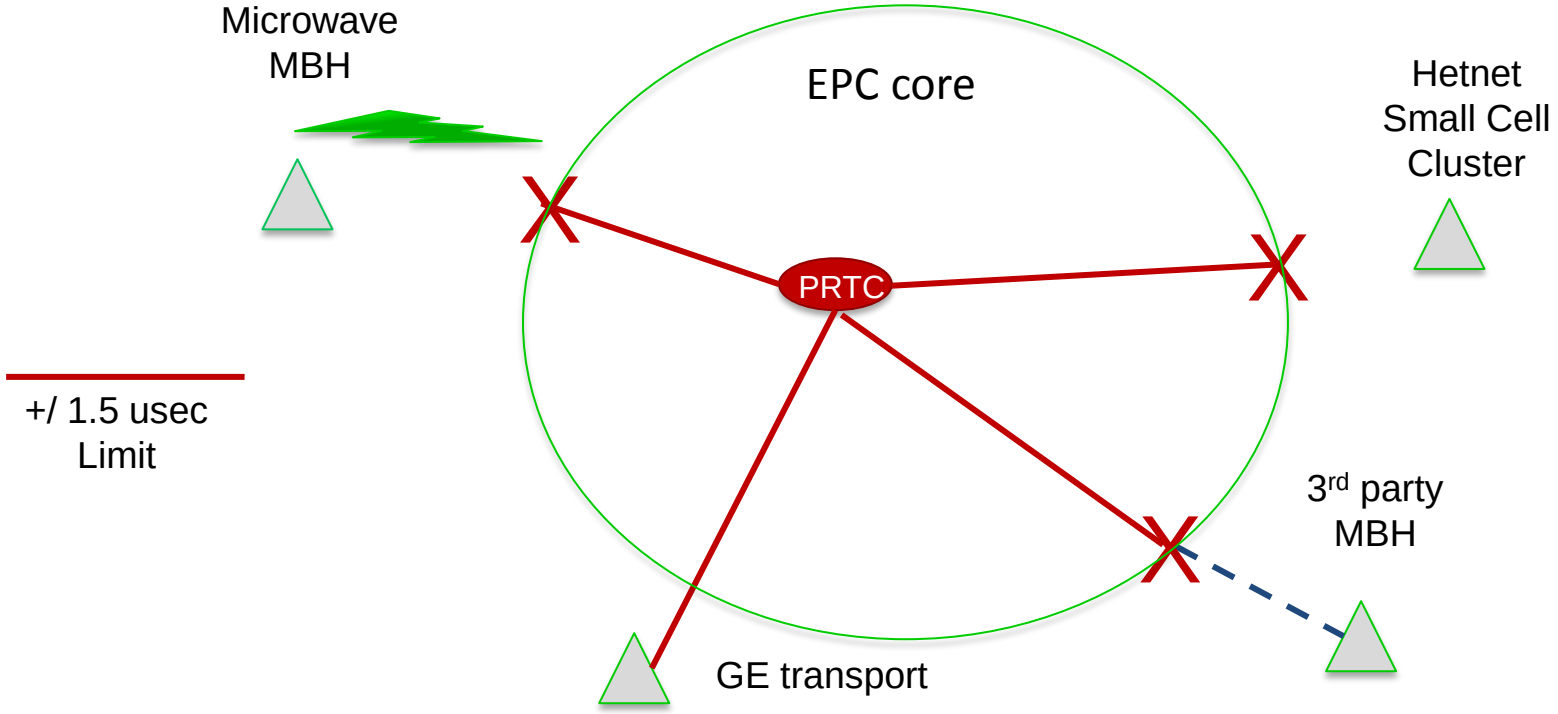


Sync Flow & Network Limits



- Possible on geographically small network with few hops and good transport
- More problematic on geographically large networks with potentially noisy transport, many hops, and complex asymmetry models

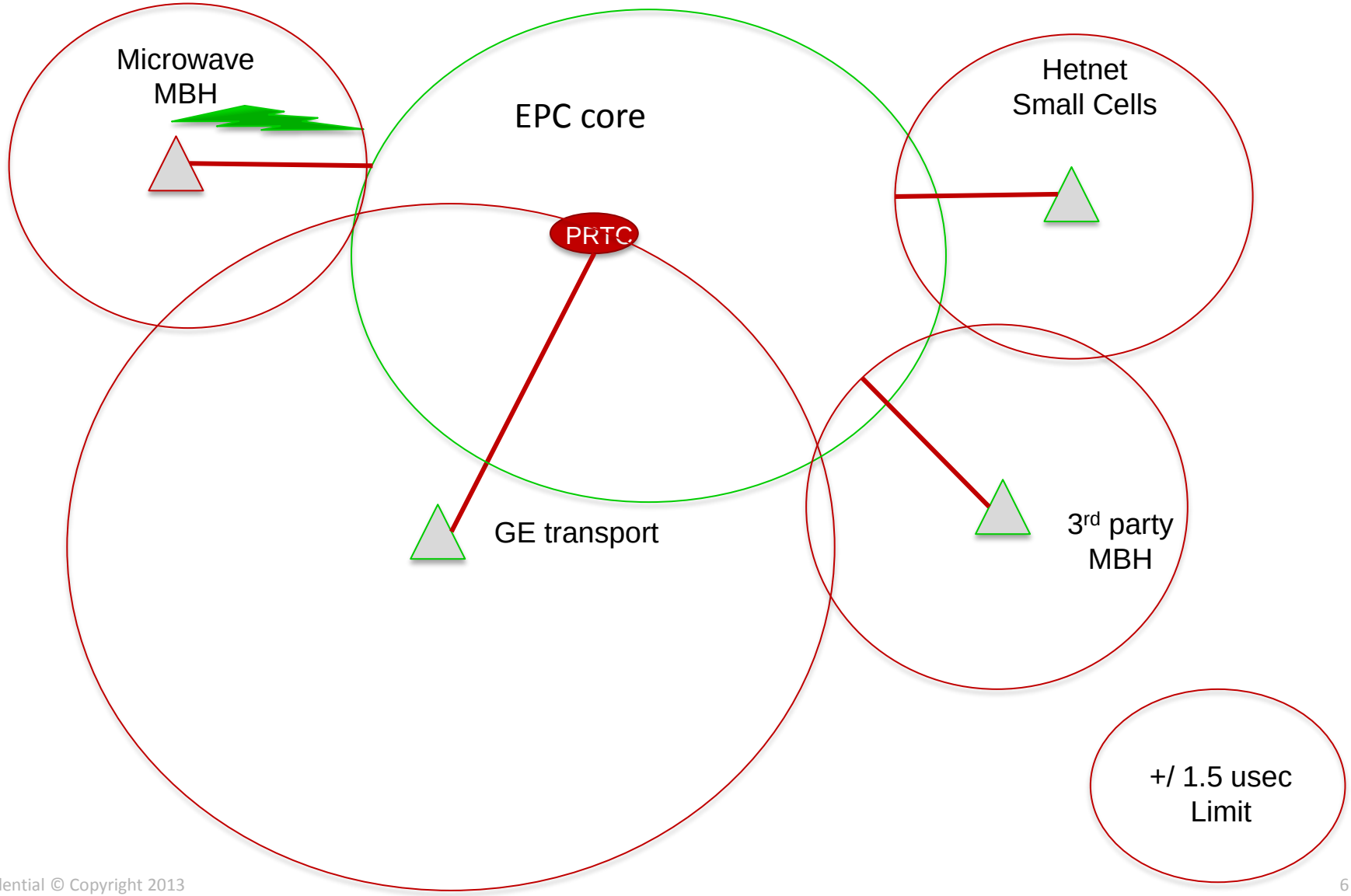
Problem: 1.5usec "reach" depends on MBH & real world network constraints



Problems of existing networks

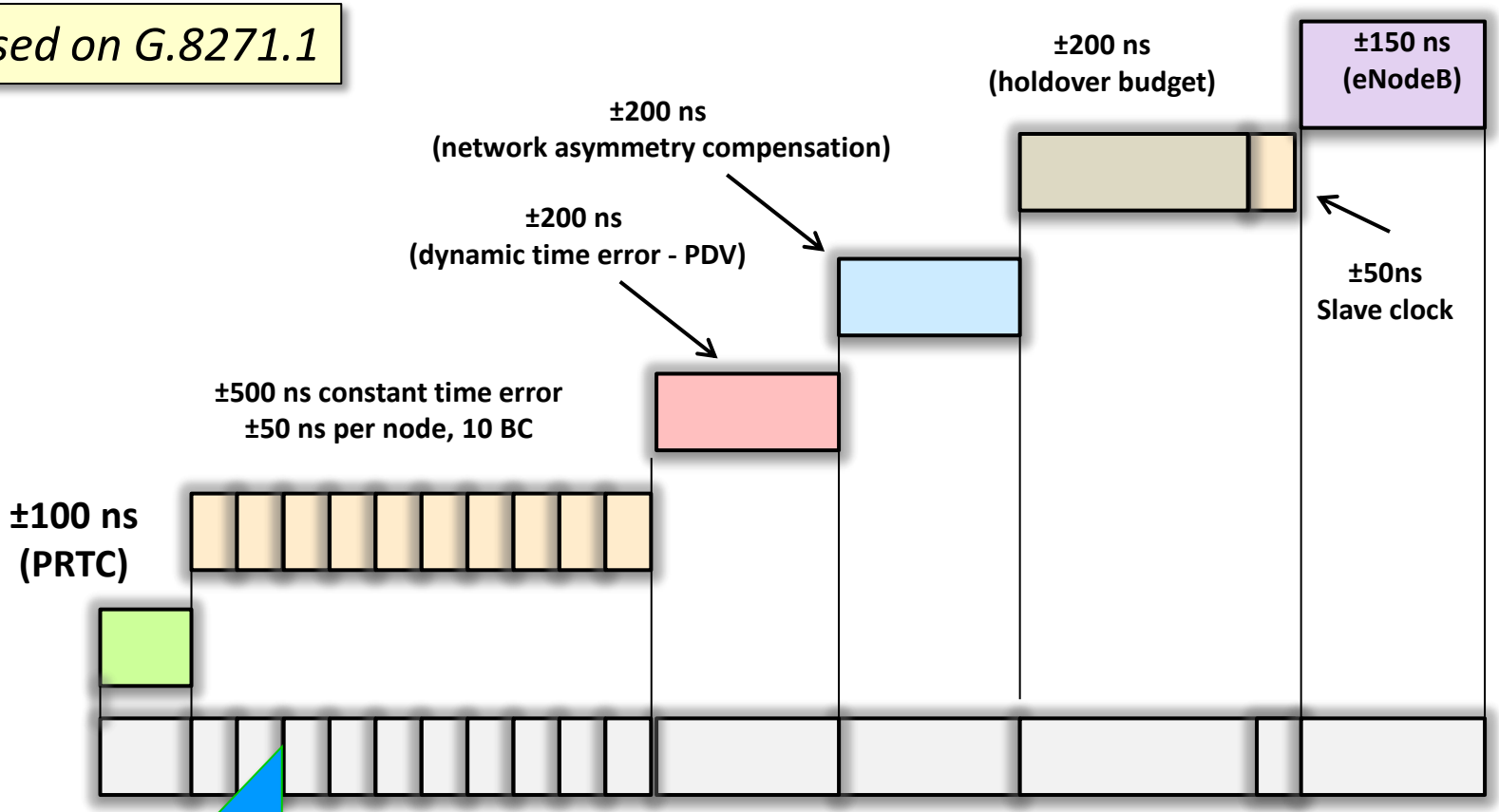
- Legacy transport networks were not designed to distribute phase
- Many asymmetry sources, static and dynamic

From the eNB perspective



Solution: Engineer from the Edge

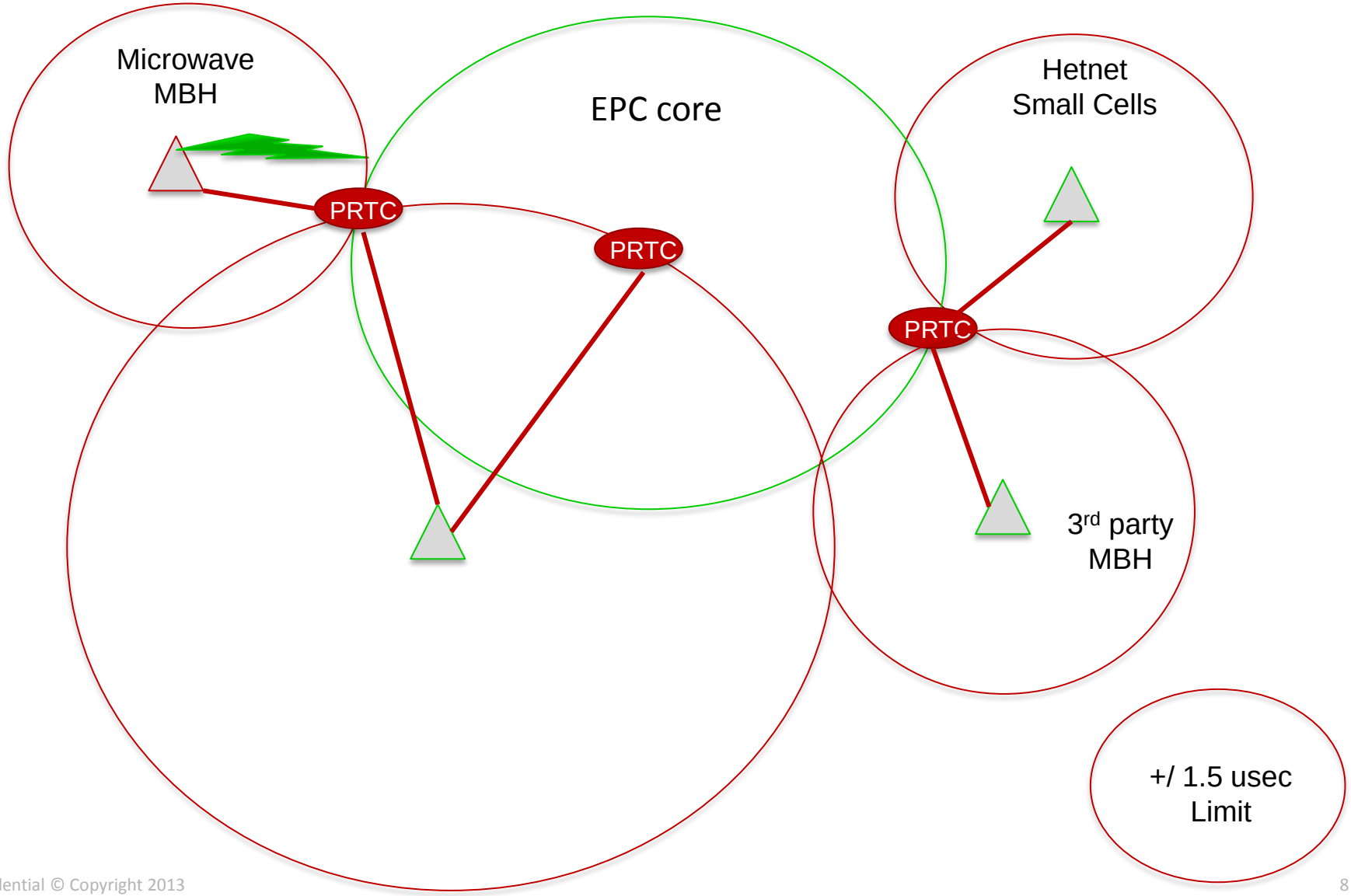
Based on G.8271.1



Time Error Budget eNB to PRTC

PRTC sites are determined based on eNB locations

Best Fit PRTC/GM placement



Distributed Edge PRTC Model

- **Engineering back from eNodeB to determine best fit PRTC locations**
  - Link asymmetry is minimized
  - Within a few miles, not hundreds of miles
  - Closest aggregation point where GNSS is physically accessible

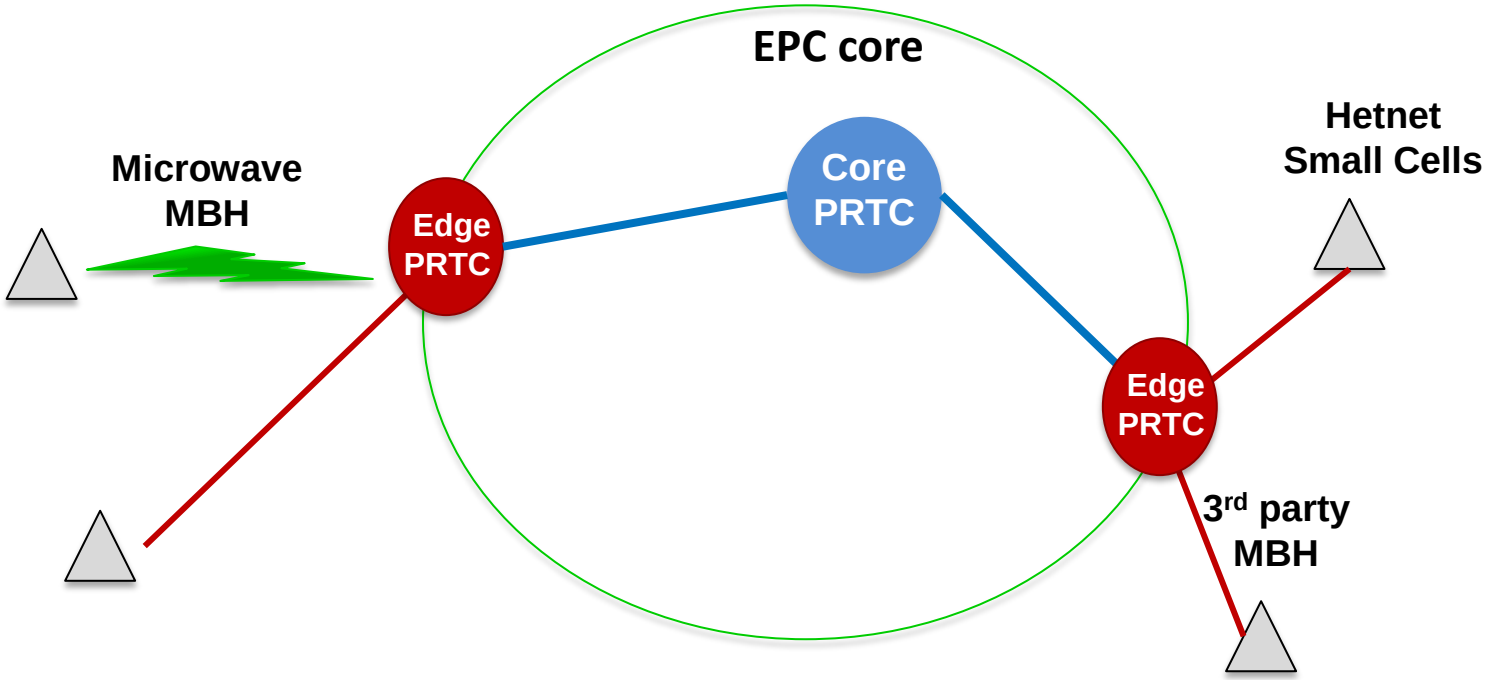
✓**Reduces potential time error and gives more control over the time budget**

✓**Enables eNB to have guaranteed access to PRTC within budget**

✓**Fully compliant to the ITU-T model**

Needs Measuring/Characterizing the backhaul network (worst case, typical case sites)

Resilient Time/Phase deployments – Core and Edge PRTC



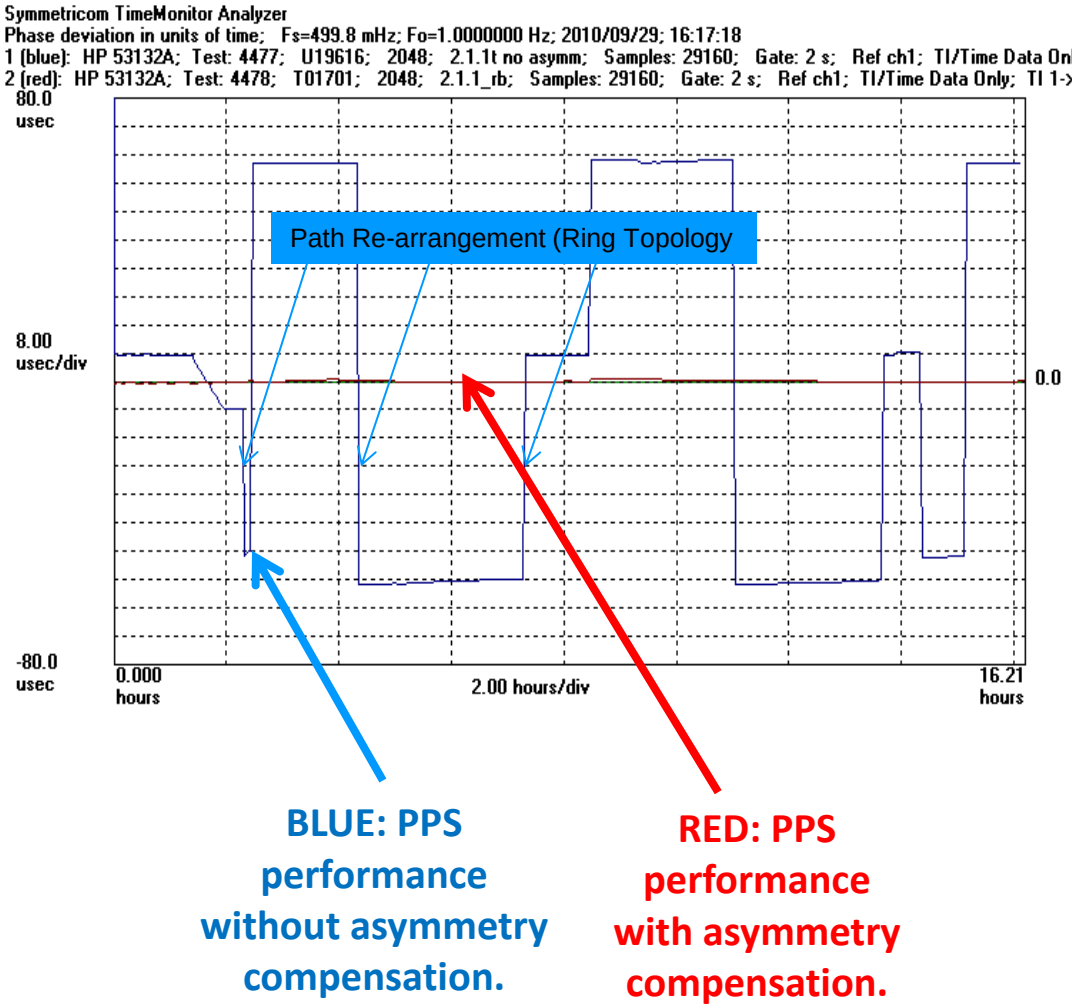
- In case of GPS outage/jamming, Edge PRTC runs Boundary clock mode from the Core PRTC

- Asymmetries in Core network can be measured and compensated for to maintain accurate Time/Phase

Core + Edge PRTC Combined Automatic Path Asymmetry Compensation

- Automatic Path Asymmetry Compensation algorithm supplies external compensation factor as permitted in IEEE 1588 standard
- Algorithm learns path asymmetries to the north-bound master … even while system may be using GNSS as the primary clock source
- In the event of a GNSS failure, the system will operate using asymmetry corrected PTP
- Included with the TimeProvider 2700 PTP Input SW License

Customer network test environment



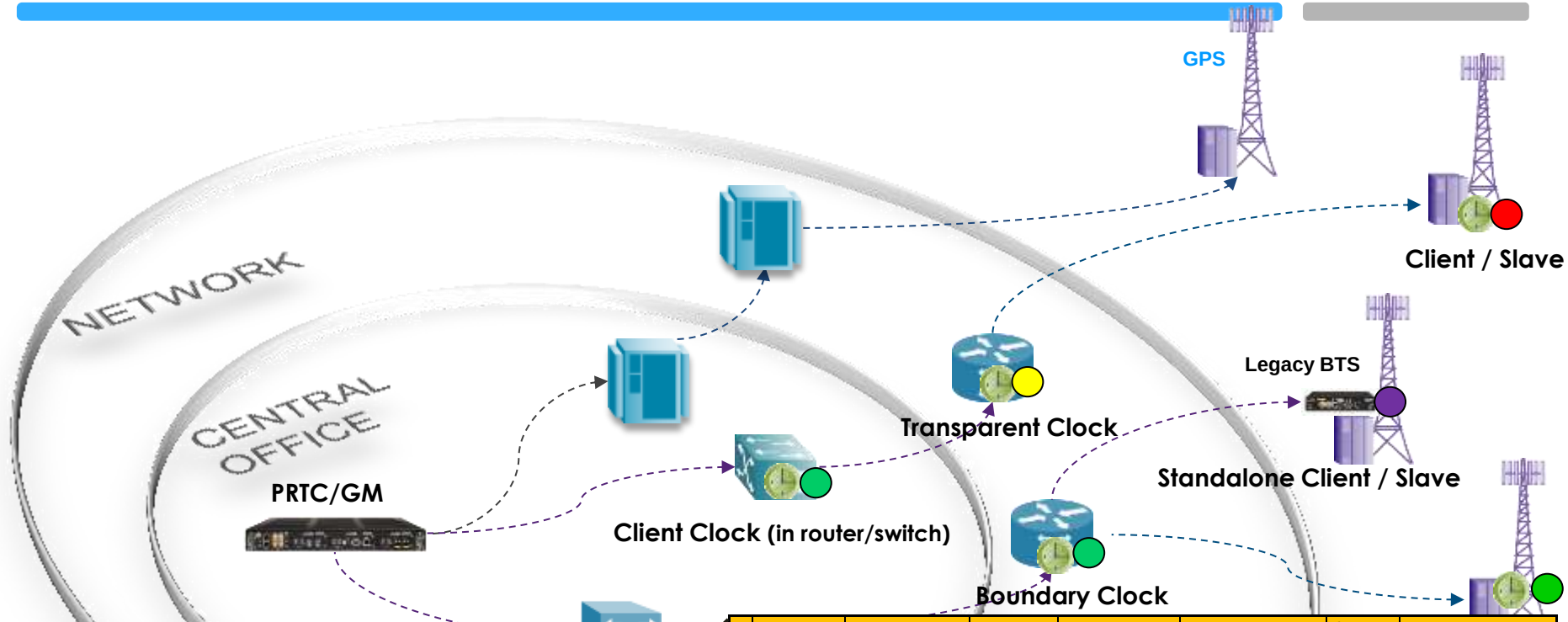
Buiding Resiliency: Enhanced Holdover

- **Implementing high end holdover enhances resiliency at the network edge**
  - In case of GPS and/or network outage
  - Allows for practical repair times
  - Avoids switching off eNodeB to prevent interference with other sites or operators

Holdover examples: Rubidium vs OCXO

Oscillator	Phase ± 1.5 µsec	Phase 5 µsec	Phase 10 µsec	Freq. 16 ppb
OCXO	1 hour	4 Hours	12 Hours	1 month
Rubidium	24 hours	3 days	5 days	5 years

Monitoring Sync End to End



	Server Name	Server IP Address	Client Name	Client IP Address	Client Clock ID	Client VLAN ID	Estimate Performance
	RNC03	192.168.45.3	CellSite 200	192.168.1.10	00:b0:ae:ff:fe:01:31:f9	1	2
	RNC03	192.168.45.3	CellSite 201	192.168.1.11	00:b0:ae:ff:fe:01:31:f1	1	2
	RNC03	192.168.45.3	CellSite 202	192.168.1.20	00:b0:ae:ff:fe:01:31:f14	1	2
	RNC03	192.168.45.3	CellSite 203	192.168.1.23	00:b0:ae:ff:fe:01:31:f5	3	2
	RNC03	192.168.45.3	CellSite 204	192.168.1.15	00:b0:ae:ff:fe:01:31:f2	3	2
	RNC03	192.168.45.3	CellSite 205	192.168.2.13	00:b0:ae:ff:fe:01:31:f20	2	1
	RNC03	192.168.45.3	CellSite 206	192.168.2.12	00:b0:ae:ff:fe:01:31:f3	2	1
	RNC03	192.168.45.3	CellSite 207	192.168.2.33	00:b0:ae:ff:fe:01:31:f5	2	1
	RNC03	192.168.45.3	CellSite 208	192.168.2.19	00:b0:ae:ff:fe:01:31:f10	2	1
	RNC03	192.168.45.3	CellSite 209	192.168.2.31	00:b0:ae:ff:fe:01:31:f12	2	1
	RNC03	192.168.45.3	CellSite 210	192.168.2.14	00:b0:ae:ff:fe:01:31:f11	2	1
	RNC03	192.168.45.3	CellSite 211	192.168.5.15	00:b0:ae:ff:fe:01:31:f22	5	4
	RNC03	192.168.45.3	CellSite 212	192.168.5.21	00:b0:ae:ff:fe:01:31:f6	5	4
	RNC03	192.168.45.3	CellSite 213	192.168.5.31	00:b0:ae:ff:fe:01:31:f8	5	4
	RNC03	192.168.45.3	CellSite 214	192.168.5.34	00:b0:ae:ff:fe:01:31:f15	5	4
	RNC02	192.168.45.3	CellSite 215	192.168.5.25	00:b0:ae:ff:fe:01:31:f16	5	4

Network visibility through OSS / mgmt system

OC/BC KPI Examples

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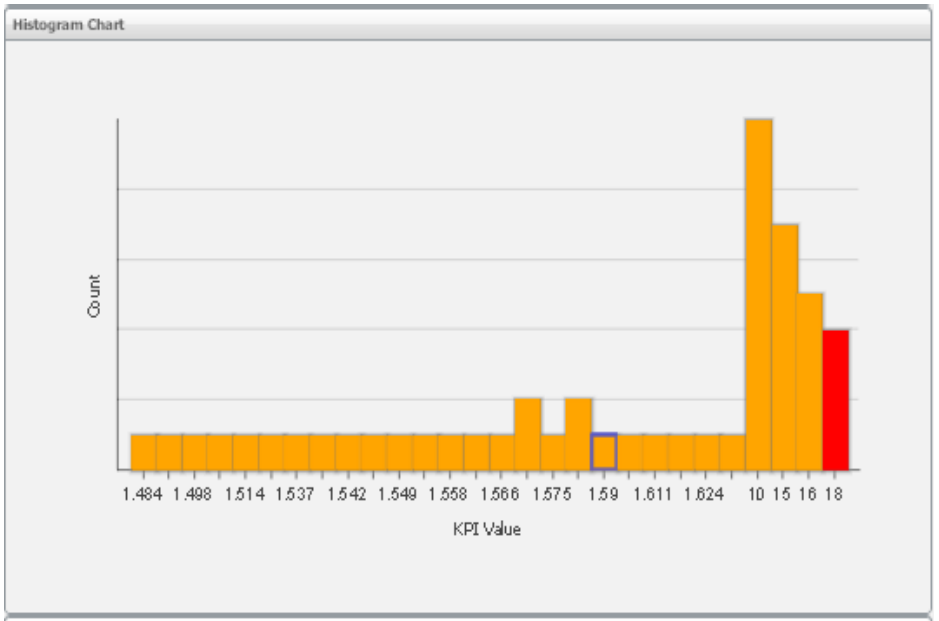
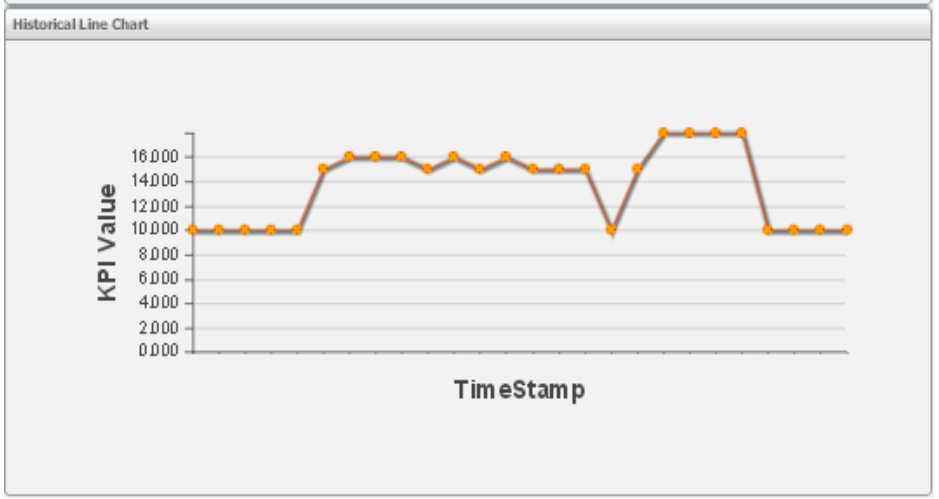
Summary Metrics	
Output TDEV Estimate (ns)	Frequency and Phase Output Performance Estimates
Output MDEV Estimate (ppb)	
Basic Metrics	
Forward Flow Transient-free (out of 900s)	Packet Availability and Usability
Forward Flow Transient-free (out of 3600s)	
Reverse Flow Transient-free (out of 900s)	
Reverse Flow Transient-free (out of 3600s)	
Forward Packet Rate (pkts/s)	
Reverse Packet Rate (pkts/s)	
Forward Flow Operational MinTDEV (ns)	Packet Stability
Forward Flow Operational MAFE (ppb)	
Reverse Flow Operational MinTDEV (ns)	
Reverse Flow Operational MAFE (ppb)	
Minimal Round Trip Delay (µsec)	Network Jitter (Path Delay Estimate)

Ennd to End Network Monitoring

- **Monitor all clocks, PRTC, Boundary clocks, Slaves in a single system**
  - **Best if clocks are smart and can report health condition**
- **Store historical performance data and run trending analysis**
- **Adjust to evolving network**





Summary:
To deploy Time/Phase

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Measure

- Apply ITU model backwards
- Minimize asymmetries

Implement resiliency

- Combine solutions
- Edge + Core with asymmetry compensation

Monitor

- End to End, all clocks
- Store and trend
- Adapt

Thank You

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