Unified Synchronization Solution for LTE Backhaul

Symmetricom-PMC

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Agenda

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- Overview of Backhaul and Timing Synchronization
  - LTE Backhaul Needs
  - Current Sync Technologies
  - Challenges with LTE backhaul
- Unified Solution from Symmetricom & PMC
  - Symmetricom SoftClock overview
  - PMC WinPath overview
  - Implementation details
  - Decision points and benefits
- Getting Started with the Unified solution
- Key Takeaways

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Overview of Backhaul and Timing Synchronization

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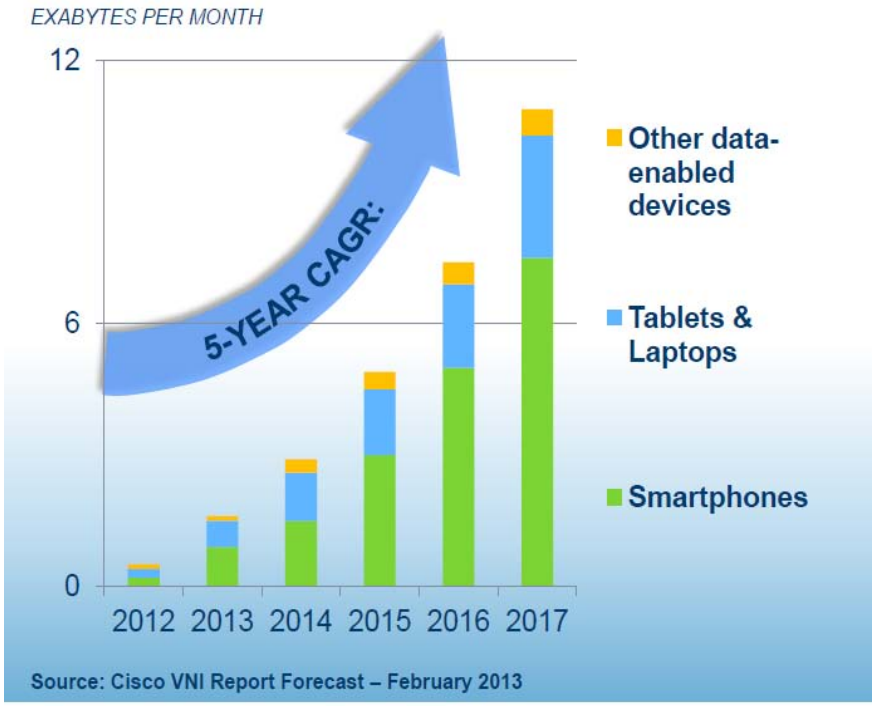
Next Gen Networks and Timing Synchronization

- New technologies: LTE , 4G are packet based designed to meet this demand
  - In 2012, an LTE network connection generated 19x the traffic of a non-LTE*
  - LTE is expected to grow from 1% to 10% of connections in 2017*
- Smart phone driving explosive growth in demand for data bandwidth
  - 4x growth in from 2012 to 2017*
- End-to-end IP/Packet based Mobile backhaul require
  - Improved Scalability and cost
  - Leading edge, stable and consistent performance
  - Multi-Sync Inputs



*Data Source: Cisco VNI Report Forecast – Feb 2013

Timing Synchronization for packet based network is complex
– **Efforts underway by IEEE, ITU-T (1588, SyncE, G8261.1 etc) to standardize timing synchronization methods**

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Wireless Base Station Frequency and Phase Specifications

Application	Frequency: Transport / Air Interface	Phase
GSM / UMTS / W-CDMA	16 ppb / 50 ppb	N/A
UMTS/ W-CDMA Femtocells	n/a / 200 - 250 ppb	
GSM, UMTS, LTE Network Interface	16 ppb / 50 ppb	
CDMA2000	16 ppb / 50 ppb	+/-3 – 10 µs
TD-SCDMA	16 ppb / 50 ppb	+/- 1.5 µs
LTE (FDD)	16 ppb / 50 ppb	N/A
LTE (TDD)	16 ppb / 50 ppb	+/- 1.5 µs
LTE MBSFN	16 ppb / 50 ppb	+/- 1-32 µs
LTE-A CoMP (Network MIMO)	16 ppb / 50 ppb	+/- 500 ns (0.5 µs)
WiMAX (TDD)	16 ppb / 50 ppb	+/-1 - 8 µs

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Synchronization & Timing Technology Options

PTP 1588v2	SyncE	NTP	GNSS (Global Navigation Satellite System)
Frequency & Phase	Frequency Only	Frequency & Phase	Frequency & Phase
Layer 2 and 3	Physical Layer	Layer 3	Physical Layer
Legacy & Greenfield LTE / Carrier Ethernet	Greenfield Deployments LTE / Carrier Ethernet	LAN / WAN IMS, Billing / Logging / SLA / IPTV / Femtocell	Legacy & Greenfield
IEEE 1588, ITU-T G.8261 G.8271 and G.8271.1 G.8265.1, G.8275.1 (pre)	ITU-T G.8261 / 2 / 4	IETF RFC 1305, RFC 5905-8	ITU-T G.811

Synchronization can be achieved by a variety of technologies that are driven by different standards

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Timing Robustness Options: 2 out of 3 Technologies

GPS with PTP “Holdover”

GPS with Rubidium Holdover*

PTP with Rubidium Holdover*

** Rubidium Holdover < 1.5 µs per 24 hrs*

** Holdover definition – continuous operation when primary sync source is lost*

- GPS, PTP or Rubidium: A network needs 2 out of 3 synchronization sources to ensure robustness
- Network performance can be severely compromised with only one timing option

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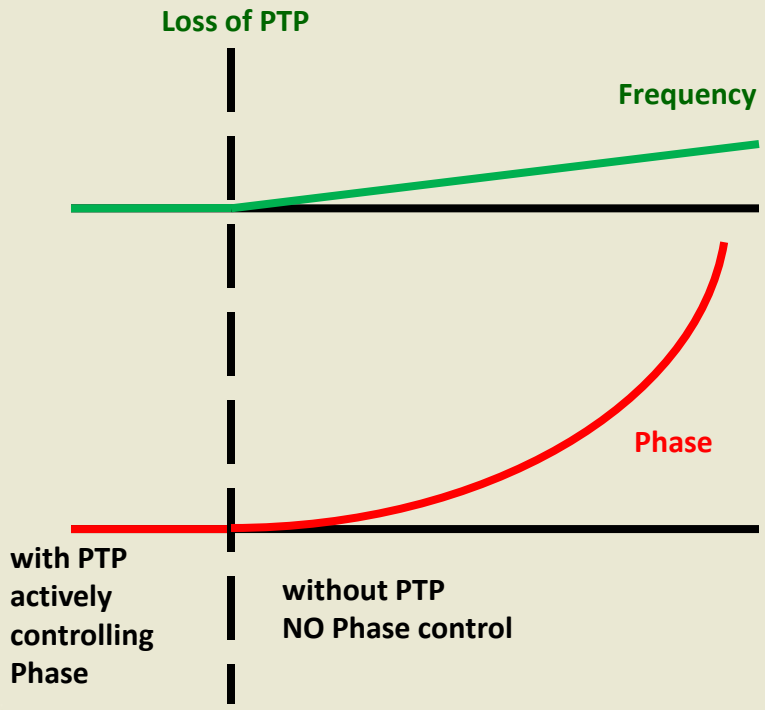
2 out of 3 Timing Synchronization Technologies: Benefit of using PTP + SyncE

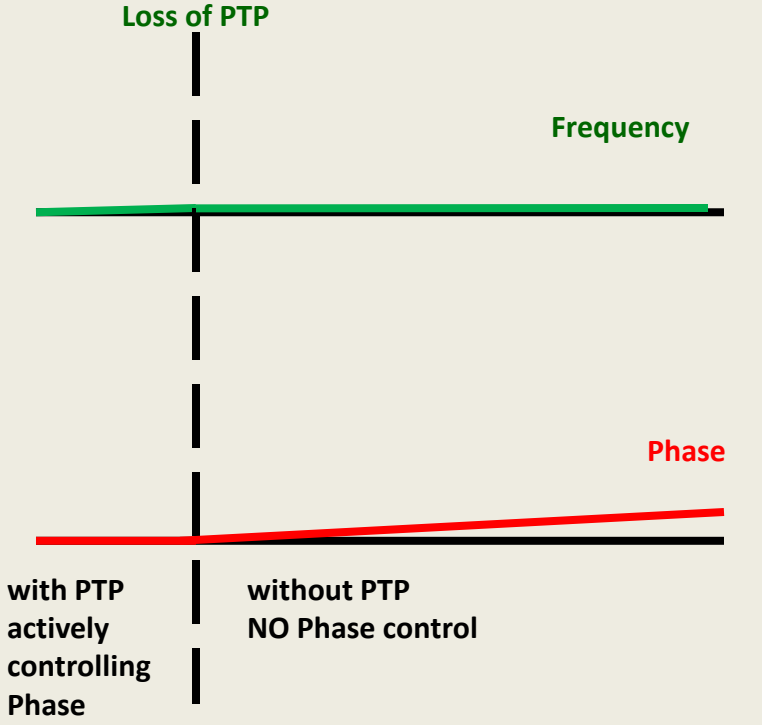
Running PTP Only

Phase and Frequency drift off during holdover when PTP is lost



Running PTP + SyncE

ONLY Phase drift off during holdover when PTP is lost



Using PTP in addition to SyncE will improve the overall performance of Synchronization

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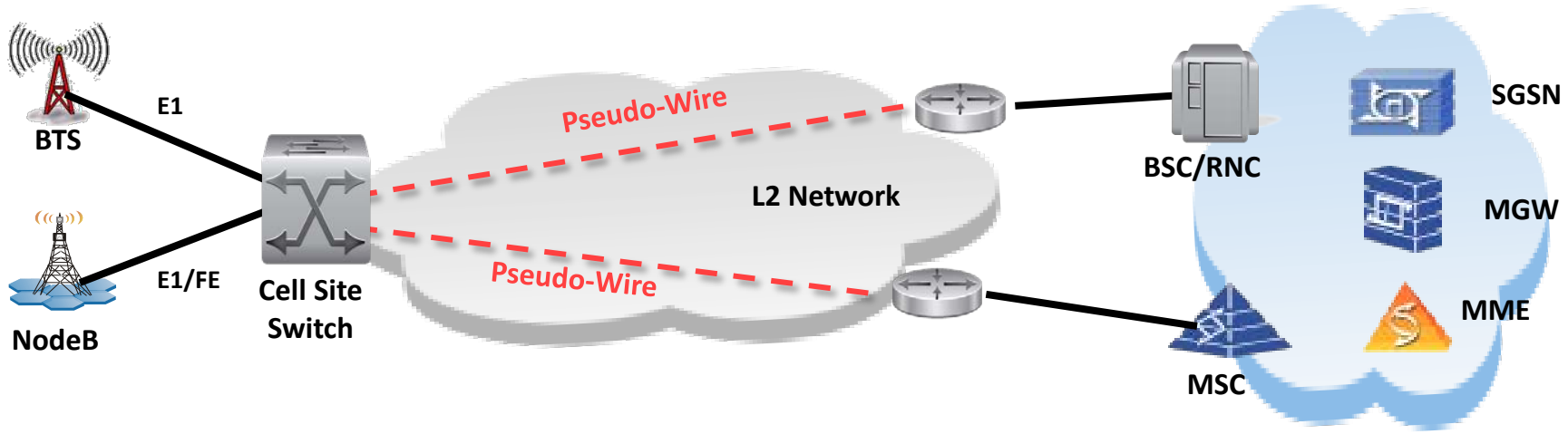
Today's 2G/3G Backhaul Status



- Circuit based backhaul is slowly vanishing
- Packet based backhaul is dominating
  - Mostly L2 networks such as PBB*, MPLS or PTN**
  - Pseudo-wire technology is widely deployed to tunnel the cell site traffic back to RNC/BSC
- Timing Synchronization for packet based network is complex
  - Efforts underway by IEEE, ITU-T to standardize timing synchronization methods
  - Standards include
    - IEEE 1588, Synchronous Ethernet, G 8261.1, G8265.1, G8275.1 etc.

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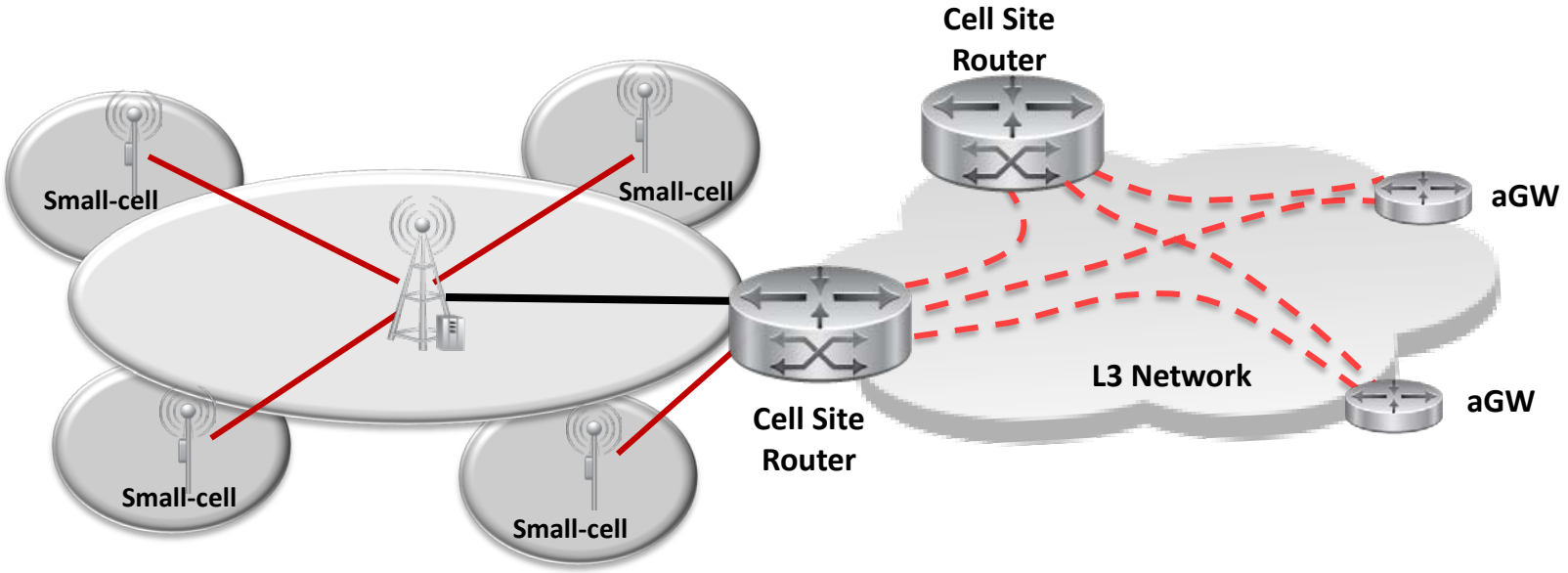
*PB=Packet Backbone **PTN=Packet Transport Network

4G/LTE Backhaul – What's Different from 3G



- IP Mesh topology for LTE backhaul
- Flat IP structure pushes more intelligence and L3 functions towards cell site
- Mixture of macro-cell and small cells for higher throughput and better coverage
- Macro-cell backhaul through cell site routers and radio access network, similar to 3G
- Small-cell traffic is aggregated at Macro-cell or cell site router for backhaul

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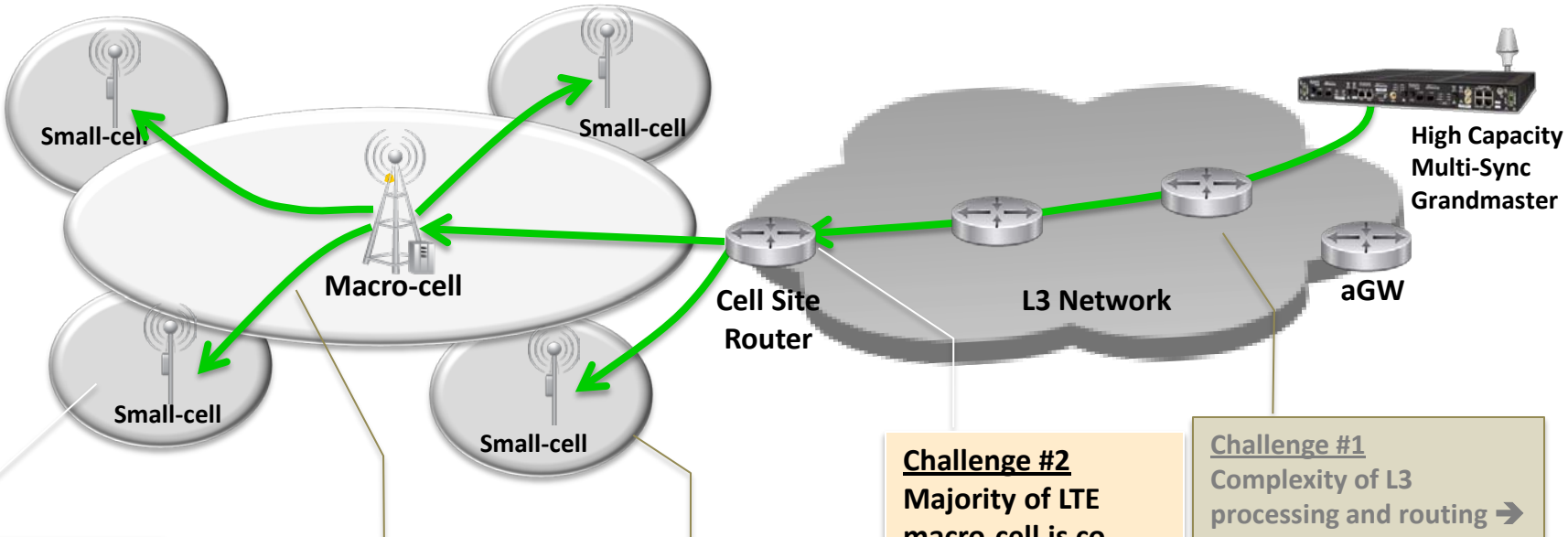
New Challenges in Timing and Sync for LTE



Challenge #5
Small cell is very cost sensitive

Solution
Find a cost effective timing solution for small cell

Challenge #4
Diversity of small cell backhaul ➔ microwave, millimeter wave, DSL or PON can all be used ➔ Can 1588 still work?

Solution
Find a way to get 1588 work over microwave, DSL or PON

Challenge #3
Large amount of small cells ➔ Big burden on 1588 Grandmaster

Solution
Enable BC on macro-cell or cell site router

Challenge #2
Majority of LTE macro-cell is co-located with 2G/3G ➔ Multiple sync sources available ➔ Which one to choose?

Solution
Cell site router to provide unified multi-sync solution

Challenge #1
Complexity of L3 processing and routing ➔ larger PDV and less predictability of network latency ➔ harder for 1588 to work

Solution
Enable BC or TC for network elements

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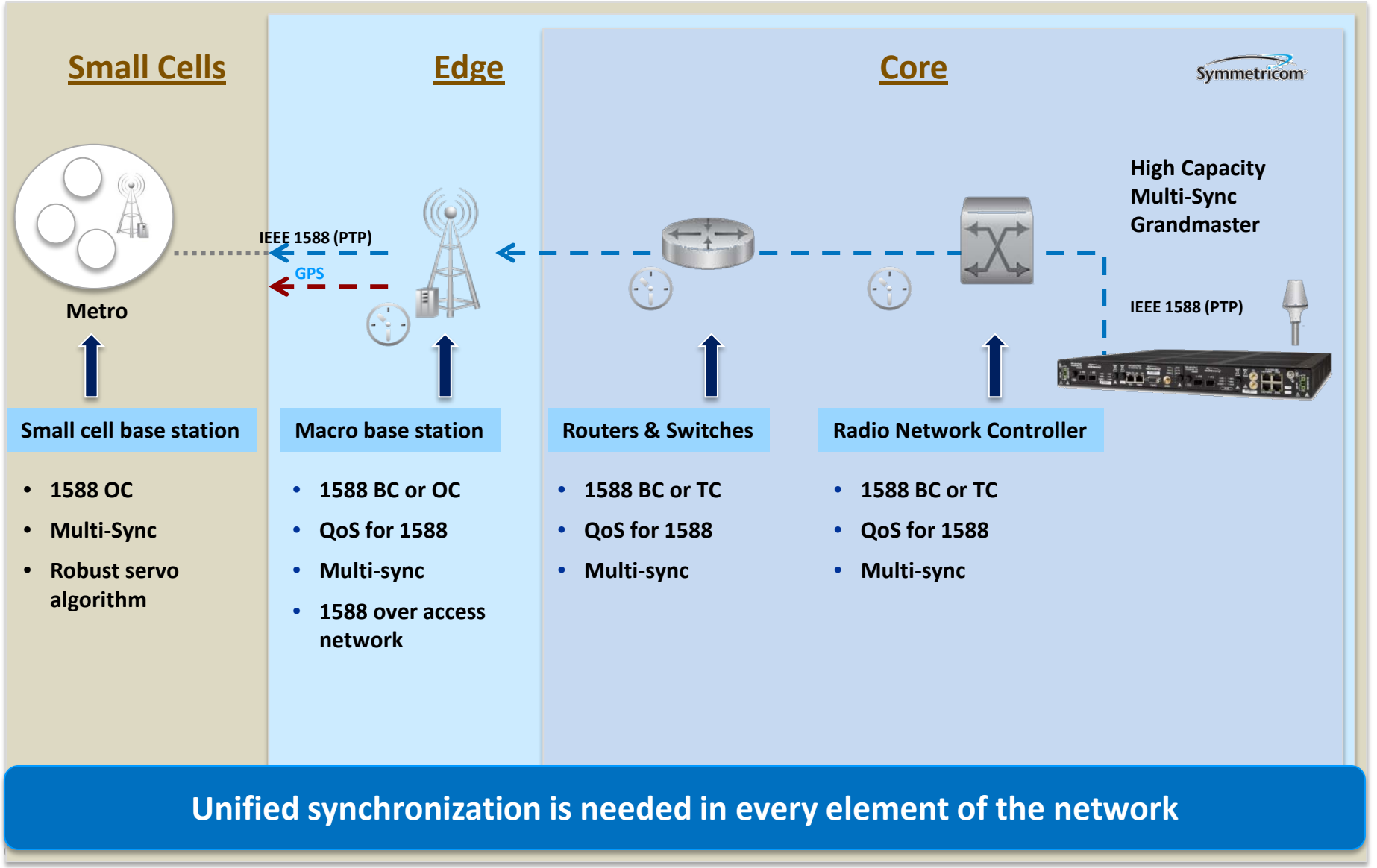
Unified Solution will support the requirements of Packet based timing



Symmetricom SCi 2000 SoftClock - Overview

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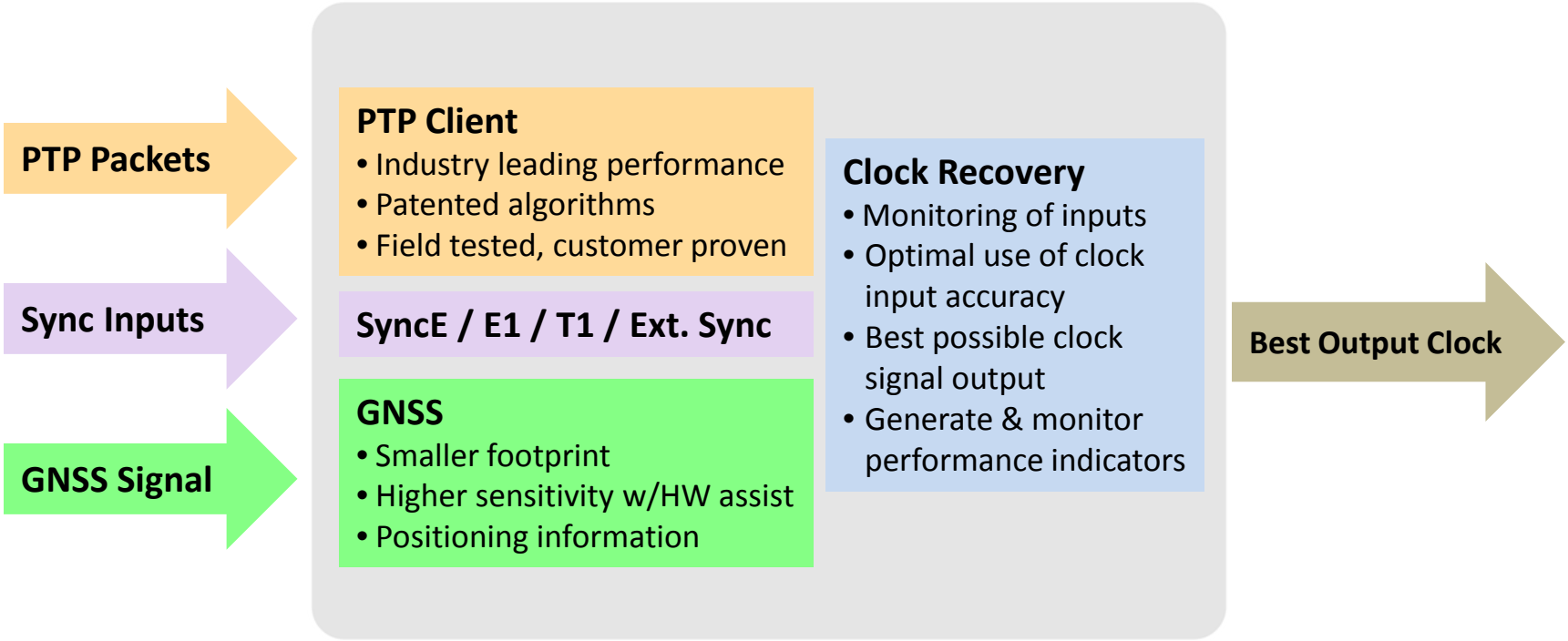
Introducing the SCi 2000 SoftClock from Symmetricom



- Single solution for multiple sync standards
- Carrier class performance
- Software based solution leverages customer's existing hardware
- Target-architecture and hardware-platform agnostic

Multiple Sync Inputs for Reliability and Flexibility

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SCi 2000 SoftClock Feature: Multiple Sync Service Tiers

- Sync Service Tiers define performance expectation for PTP services
- Each service tier identifies a performance target for a given set of network conditions
- User configuration at the appropriate Sync Service Tier will assure performance under given network condition

Sync Service Tier	Performance Mask Assured	Network Conditions	Performance Target
1	**Sync Mask**	G.8261 compliant Ethernet traffic	Meet G.823, G.824 ***Sync*** MTIE and TDEV masks
2	**Traffic Mask**	Non-G.8261, non-native Ethernet traffic	Meet G.823, G.824 ***Traffic*** MTIE mask *
3	**Modified Traffic Mask**	High jitter traffic	Meet G.8261.1-Case 3 MTIE mask *

**** TDEV is not defined for this network condition***

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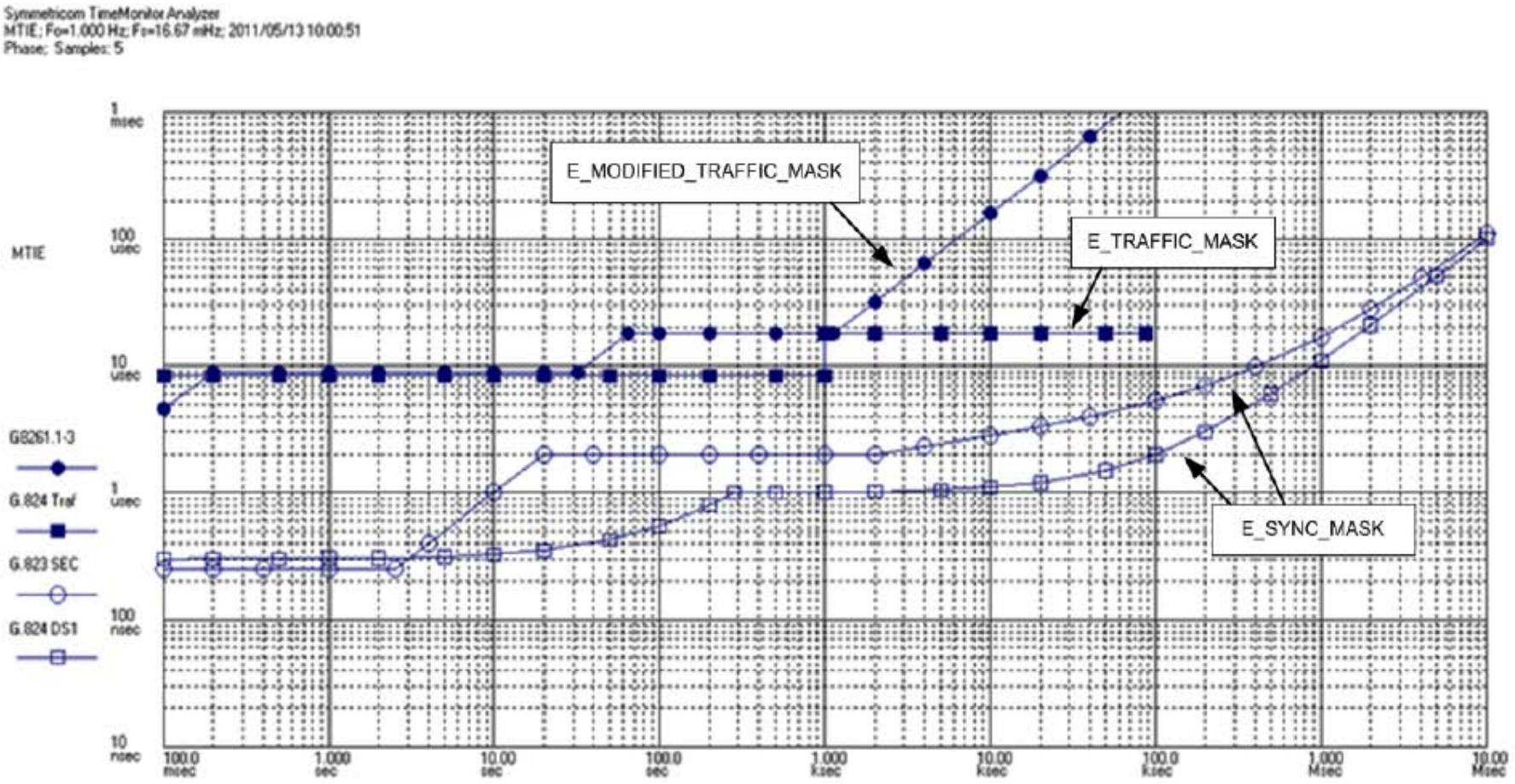
SCi 2000 SoftClock Feature:
MTIE Mask Targets for Each Sync Service Tier



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SCi 2000 SoftClock
PTP Client Performance Metrics

Metrics	
Output TDEV Estimate (ns)	Frequency and Phase Output Performance Estimates
Output MDEV Estimate (ppb)	
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)

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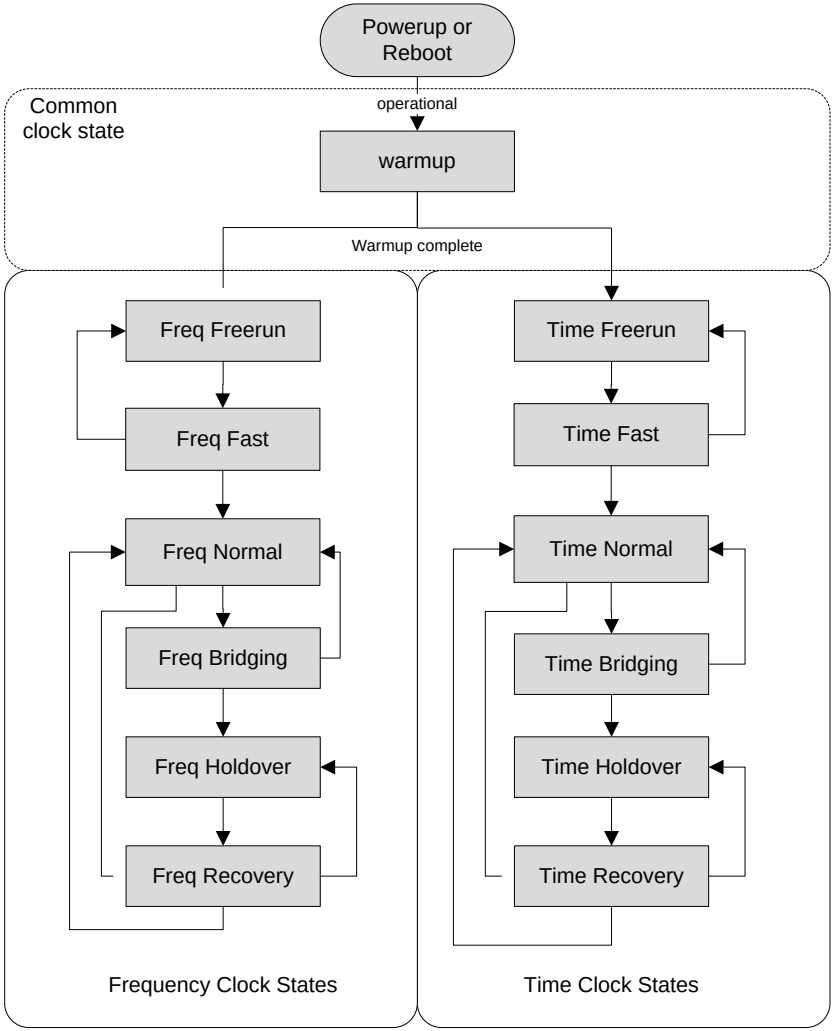
SoftClock SCi 2000 Feature: Independent Clock State for Frequency & Time

- Supports different references for frequency and time (e.g. SyncE for freq, PTP for time)
- Example: start with SyncE input only
  - Freq clock state attains Freq **Normal**
  - Time clock state can't move past Time **freerun**
  - now add PTP: time state gets to **Normal**
  - Also PTP backs up SyncE for freq



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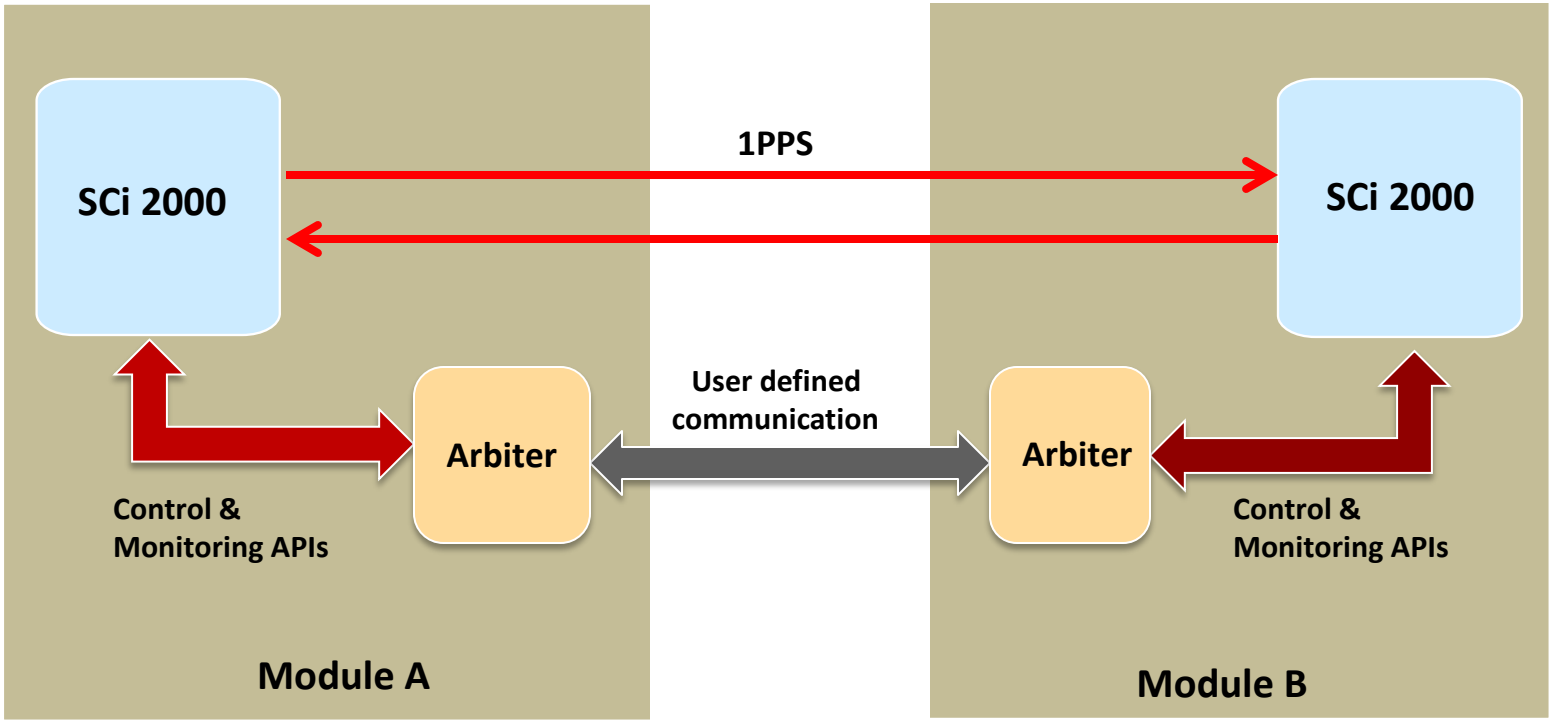
SCi 2000 SoftClock Feature: Redundancy for Reliability

- Enables two independent SCi 2000s to interact in an Active or Standby mode
  - standby clock locks to the active clock
- SCi 2000s interact to maintain a reliable timing source in the event that either module becomes incapable of providing good synchronization



Redundancy Architecture Representation

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SCi 2000 SoftClock Feature: Leading Edge PTP Convergence Time

- Convergence time is the time required from start up to reach the expected performance
  - Base stations typically require reaching 5 ppb in 15 minutes
- 10 min convergence time achieved using OCXO under warm start
- After running for 30 minutes, SCi 2000 can reach performance level at 1 ppb

Startup Type	Oscillator Type	Performance Level	Convergence Time
Warm Start	OCXO or mini-OCXO	+/-5 ppb; +/-2µs	10 min
Cold Start	OCXO or mini-OCXO	+/-5 ppb; +/2µs	15 min
Warm Start or Cold Start	OCXO	+/-1ppb; +/-1µs	30 min
	mini-OCXO	+/-2ppb; +/-1µs	30 min

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PMC WinPath
Network Processor - Overview

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WinPath – Mobile Backhaul SoC

- ***Purpose-build*** SoC for Mobile Backhaul
  - Four generations of innovation powering mobile backhaul world wide
  - Unique "Router on a Chip" architecture optimized for PTN/IP RAN
  - "LTE-Ready" by design
    - Scalable performance for LTE and LTE-Advanced
    - Enables L3 PTN and IPv6 for LTE era
    - Seamless integration of small cells in an advanced All-IP mobile backhaul
    - Built-in Packet Timing Support

- Support 2G, 3G and 4G co-located cells
- Production ready and field proven protocol suite
    - PTN, IPv4/IPv6, MPLS-TP, PBB, L2 VPN, L3 VPN, MEF, PWE3, IPSec, ……

Architecture flexibility enables OEMs to drive differentiation of their solutions

PTN=Packet Transport Network
MEF=Metro Ethernet Forum
PB=Packet Backbone
PWE3=Pseudowire Edge to Edge Emulation
VPN=Virtual Private Network
IPSec=IP Security

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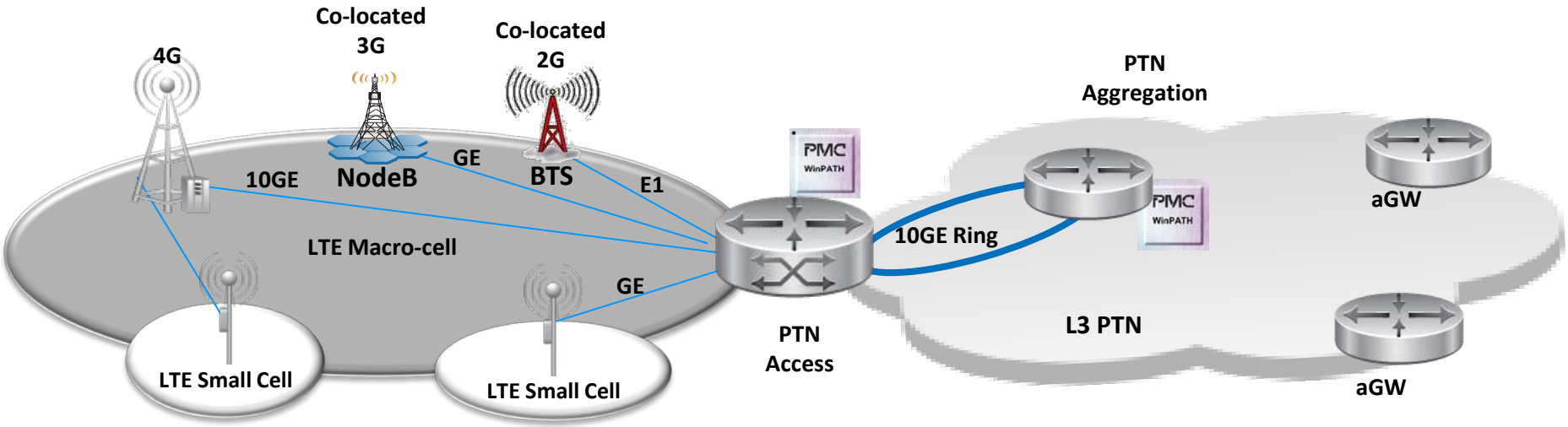
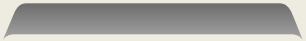
WinPath in LTE Backhaul



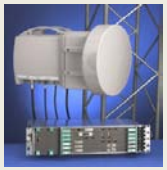
Optimized LTE Backhaul Processor

WinPATH use

PTN Access and Aggregation Platforms



Carrier Ethernet Switch Router Platforms



µWave Platforms

BTS Transport

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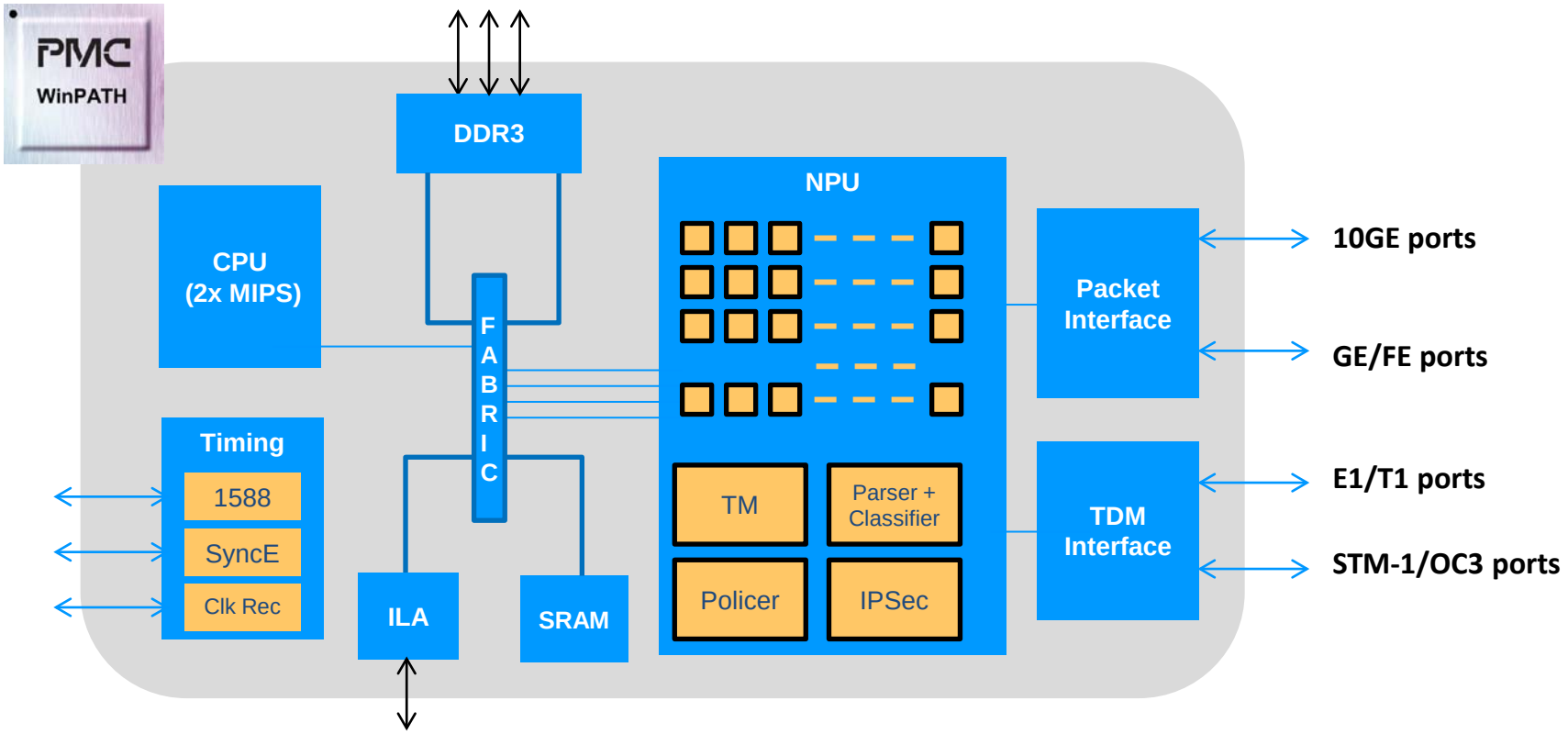
WinPath Block Diagram Overview



- WinPath → Family of devices for differing performance & interfaces requirements
- Symmetric multi-thread multi-processor NPU coupled with general purpose CPU
- Hardware accelerators optimized for data path processing

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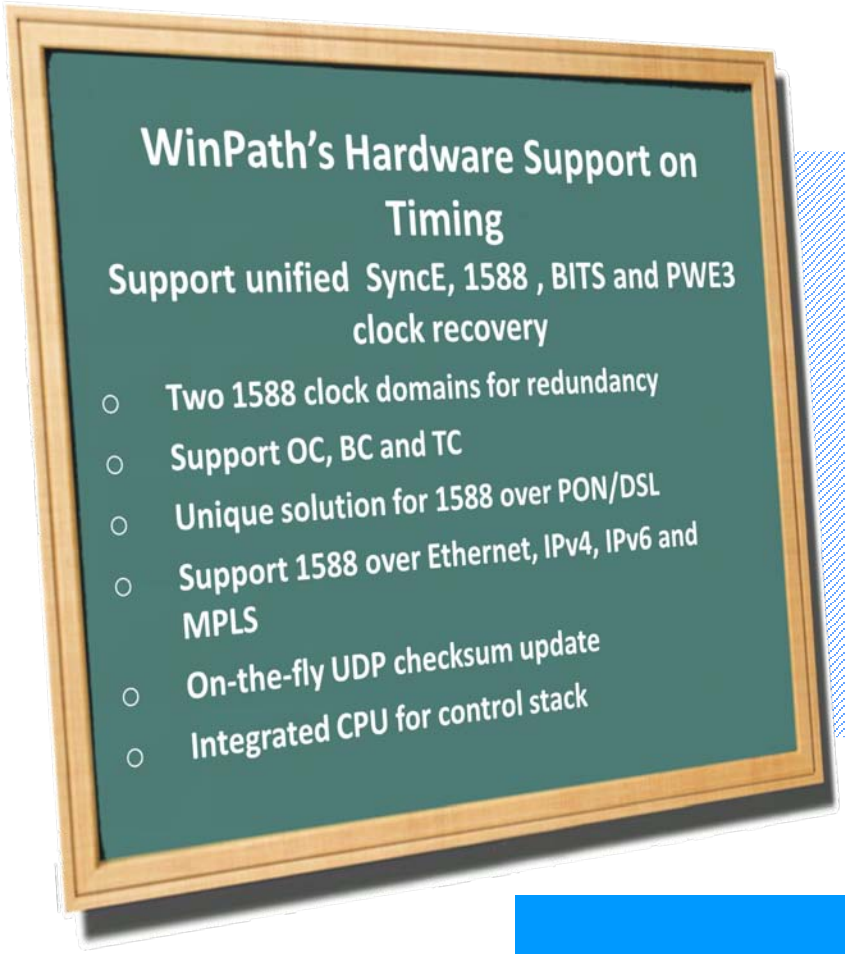
Benefits of Packet Timing in WinPath



Customer Benefits

- Seamless integration of packet timing and packet processing
- Highest integration for multi-sync
- Standardize timing across pizza box, line card and chassis
- Easy for control stack integration
- Future IPv6 proof

WinPath is architected for unified synchronization

OC=Ordinary Clock
BC=Boundary Clock
TC=Transparent Clock

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Unified Synchronization Solution From Symmetricom & PMC

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Symmetricom + PMC: Leading Edge 1588 Solution

- Sync and Timing Experts
- Market Leader
  - 60%+ worldwide market share in sync for commercial communications
  - Key influencer in IEEE and ITU standards
- Over 150 PTP deployments
- Timing experts with 19 man years of investment to deliver disruptive SW solution
- Continue to invest in SW expertise to maintain leadership position

Best-in-Class 1588 Solution

- Gain competitive advantage
- Allows design teams to focus on core competencies
- BOM reduction
- Get to Market Faster by using a proven solution
- Stay in Market Longer by using a platform that allows migrating seamlessly to next gen products

- Mobile backhaul SoC
- Four generations powering mobile backhaul world wide
- LTE Optimized Processor – Silicon + Software
- Carrier Ethernet Router–on-Chip
- Programmable Forwarding Engine for SDN
- Highest integration of packet timing features

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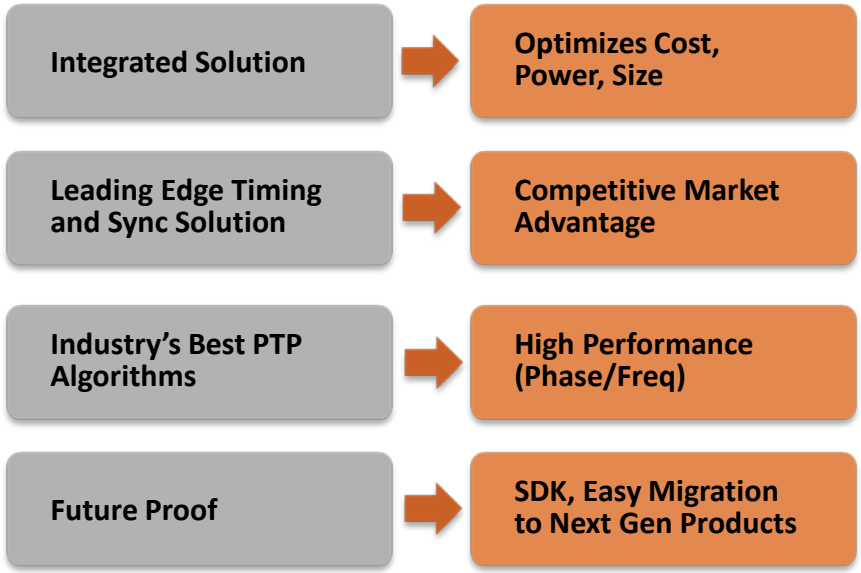
What is the Integrated 1588v2 Solution

- Integrated 1588 solution
  - Frequency Synthesis and Timing Stamping Unit
  - Servo algorithm for clock recovery
  - IEEE 1588v2 PTP Stack
  - Built-in processor
- Benefits of Integrated Solution
  - Faster time to market and revenue
  - Fully tested for interoperability
    - Backed by extensive test efforts utilizing state-of-art lab equipment
  - Minimum external components
    - High Level of Integration lowers BOM
  - Lower Maintenance and upgrades costs



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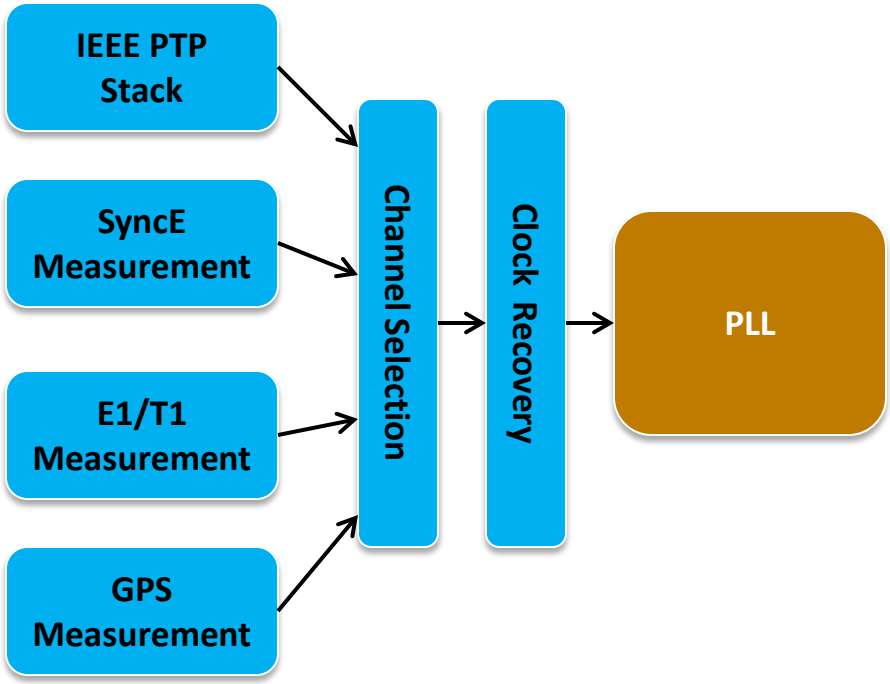
What is the Unified Solution from Symmetricom-PMC

- Supports multiple sync sources (SyncE, 1588, TDM or GPS) all at the same time
- Select the best source or combination of sources for frequency and ToD sync
- Fallback support to another source
- Support master mode, slave mode, Boundary Clock or Transparent Clock
- Integrated control stack support for PTP and ESMC



Unified Synchronization Platform

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Implement a Unified Sync
Step 1: HW and SW Partitioning

Functions that require special hardware implementation	Functions that can be implemented in software
Timestamp counters	Phase lock loop or Servo algorithm
Timestamping packets at the closest point toward the Ethernet port	Impairment detection
On-the-fly timestamp insertion and UDP checksum update	Best source selection
On-the-fly CorrectionField update for 1-step TC	Control stack
Frequency synthesizer and 1PPS input/output	
Jitter attenuation	

Partition as many functions into software to reduce BOM cost, to be HW agnostic and for easy upgrades

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Implement a Unified Sync
Step 2: Share with data path functions

Functions that can be implemented on the data path processor for decreased BOM cost

- SyncE feature is part of the Serdes design
- Timestamp counter, timestamping and timestamp insertion also needed for Ethernet OAM function (Y.1731 Delay Measurement)
- Reuse the data path packet classifier to identify 1588 messages
- Share clock synthesizer with CES functions such as E1/T1 clock recovery in SAToP/CESoPSN
- Offload some of the PTP master functions into data path processor for high performance

• Many hardware blocks required by unified sync are also needed for other data path functions
• A data path processor that can support these features will significantly reduce the BOM cost

CES=Circuit Emulation Service
SAToP=Structure Agnostic TDM over Packet or RFC4553
CESoPSN=Structure-Aware TDM Circuit Emulation Service over Packet Switched Network or RFC5086

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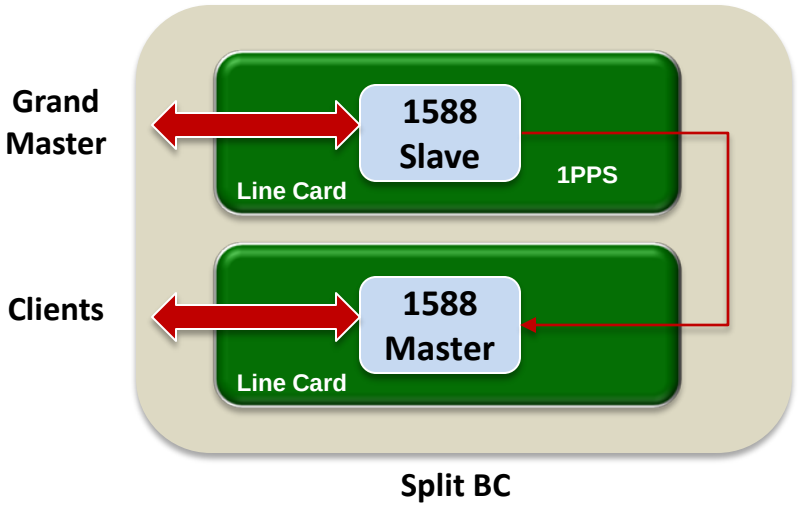
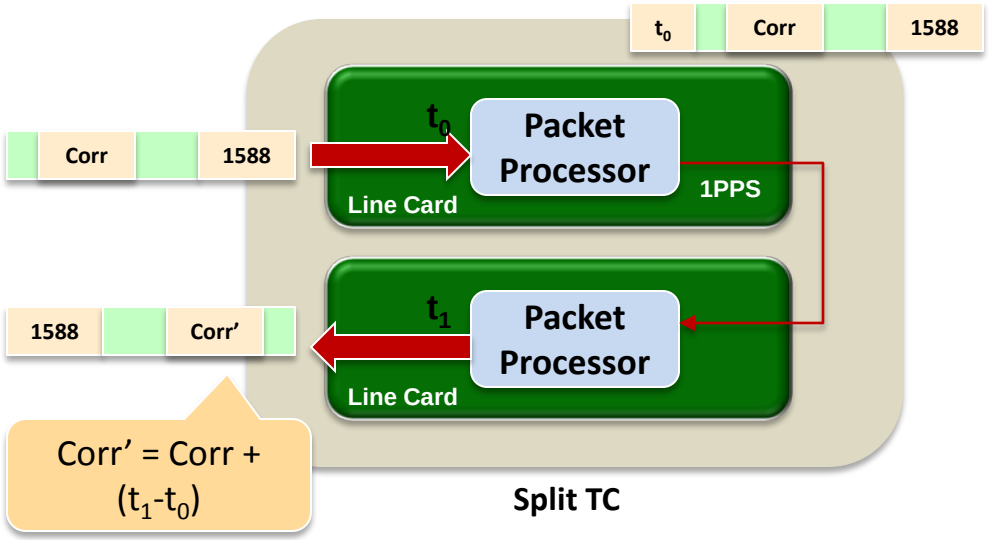
Implement a Unified Sync
Step 3: Special Considerations

- For BC mode, when the slave port and the master port are on different cards
  - Timestamp counters on both cards must be synchronized
  - This can be achieved by aligning 1PPS pulses on both cards
- For TC mode, when the ingress port and the egress port are on different cards
  - Synchronize the timestamp counters on both cards using 1PPS
  - Use in-band method to carry arrival timestamp (t_0) to the destination card
  - Destination card removes t_0 and updates the CorrectionField





BC=Boundary Clock
TC=Transparent Clock
1PPS=1 Part Per Second

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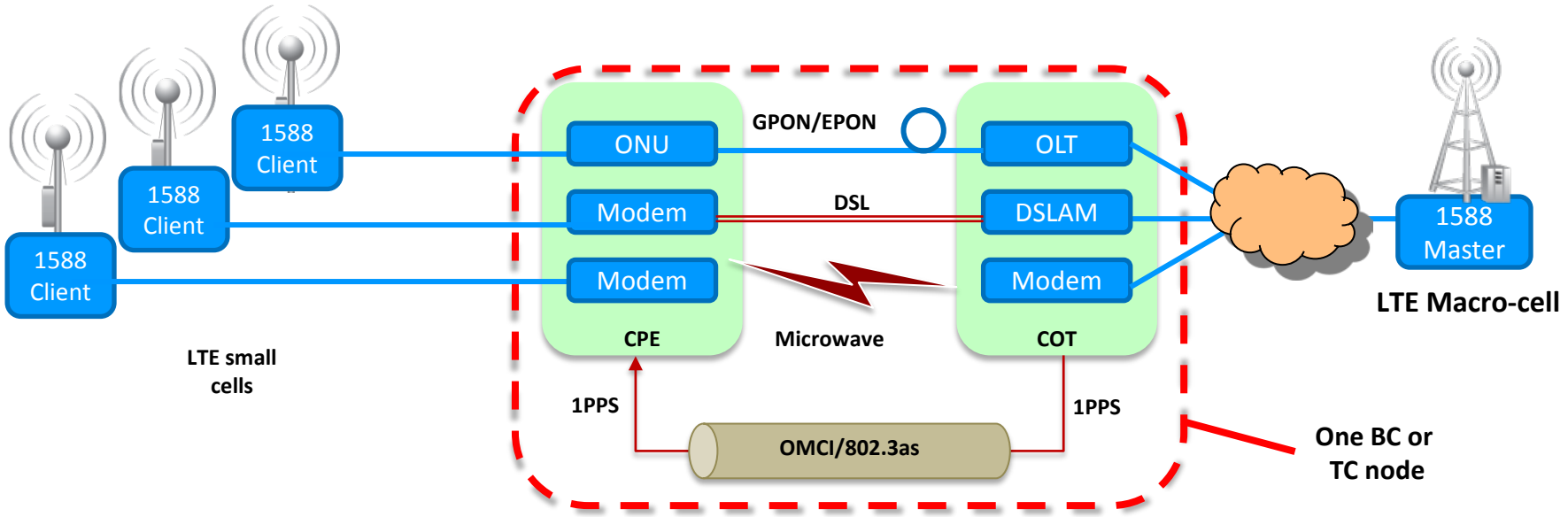
1588v2 Implications in Access Networks



- Small cell backhaul will use any available medium – Microwave, Millimeter, DSL, PON
- 1588 over such broadband access is troublesome
  - Excessive, non-deterministic and asymmetric latency make it impossible for 1588 to function
- Special care has to be taken to support such operation
  - One solution is to apply the split BC or split TC concept by synchronizing the 1PPS pulse between COT and CPE

Unified solution from Symmetricom & PMC will address this

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Unified Solution Implementation Details

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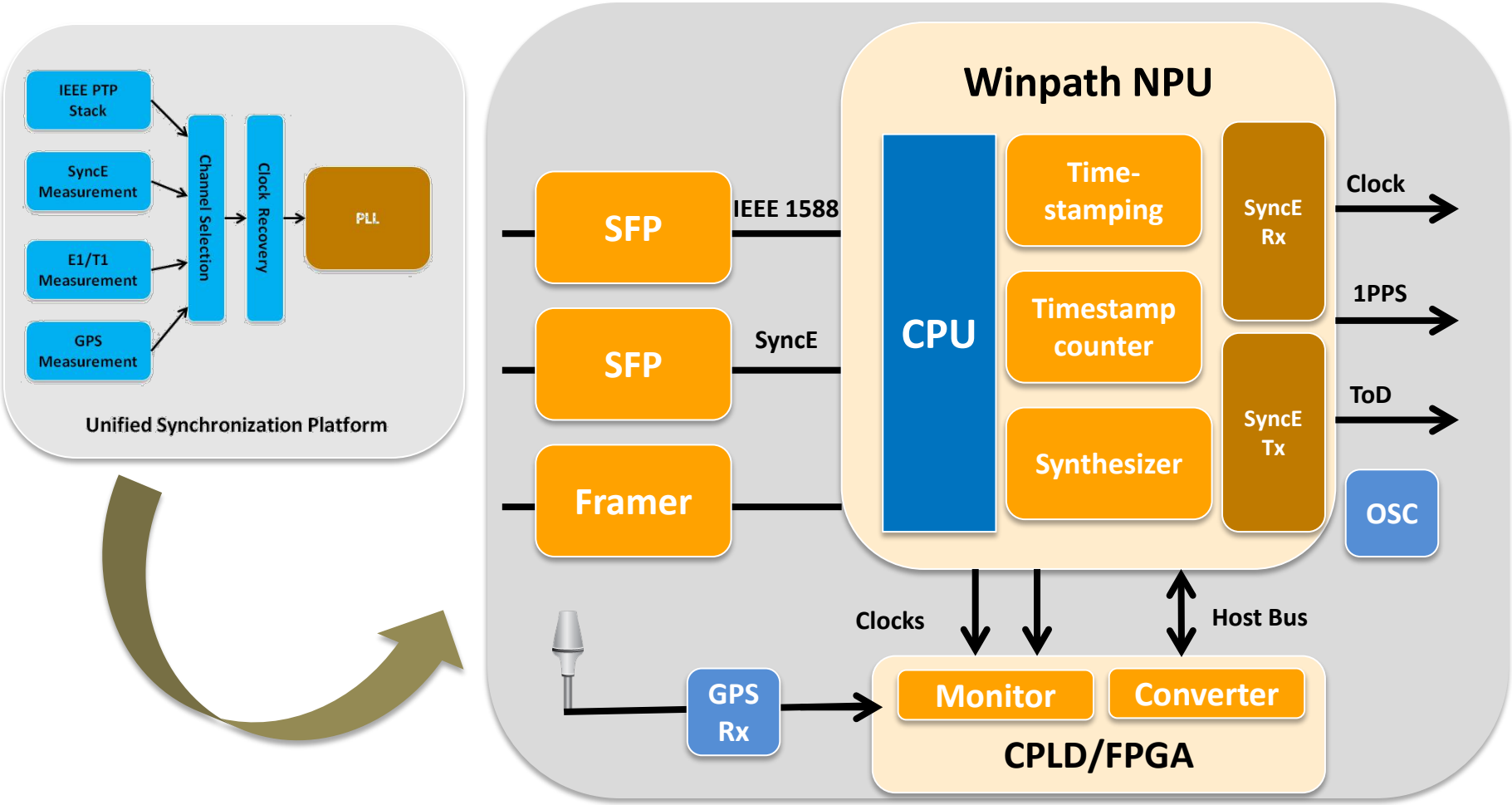
Overview of Hardware Blocks for Unified Solution



Common NPU and FPGA only - No dedicated timing device or component

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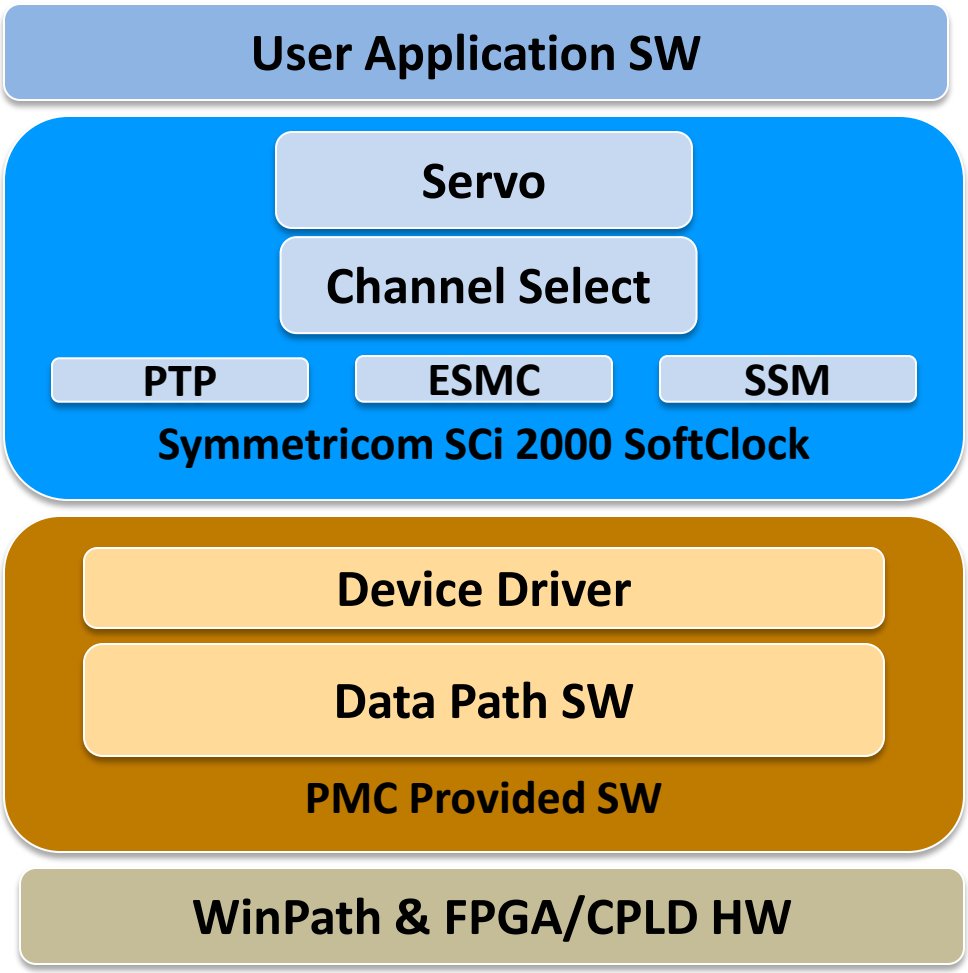
Overview of Software Structure For Unified Solution

- Seamless connection between Symmetricom SoftClock and device driver
- Ported to Linux
- Support
  - OC, TC, SyncE
- Fully integrated and verified



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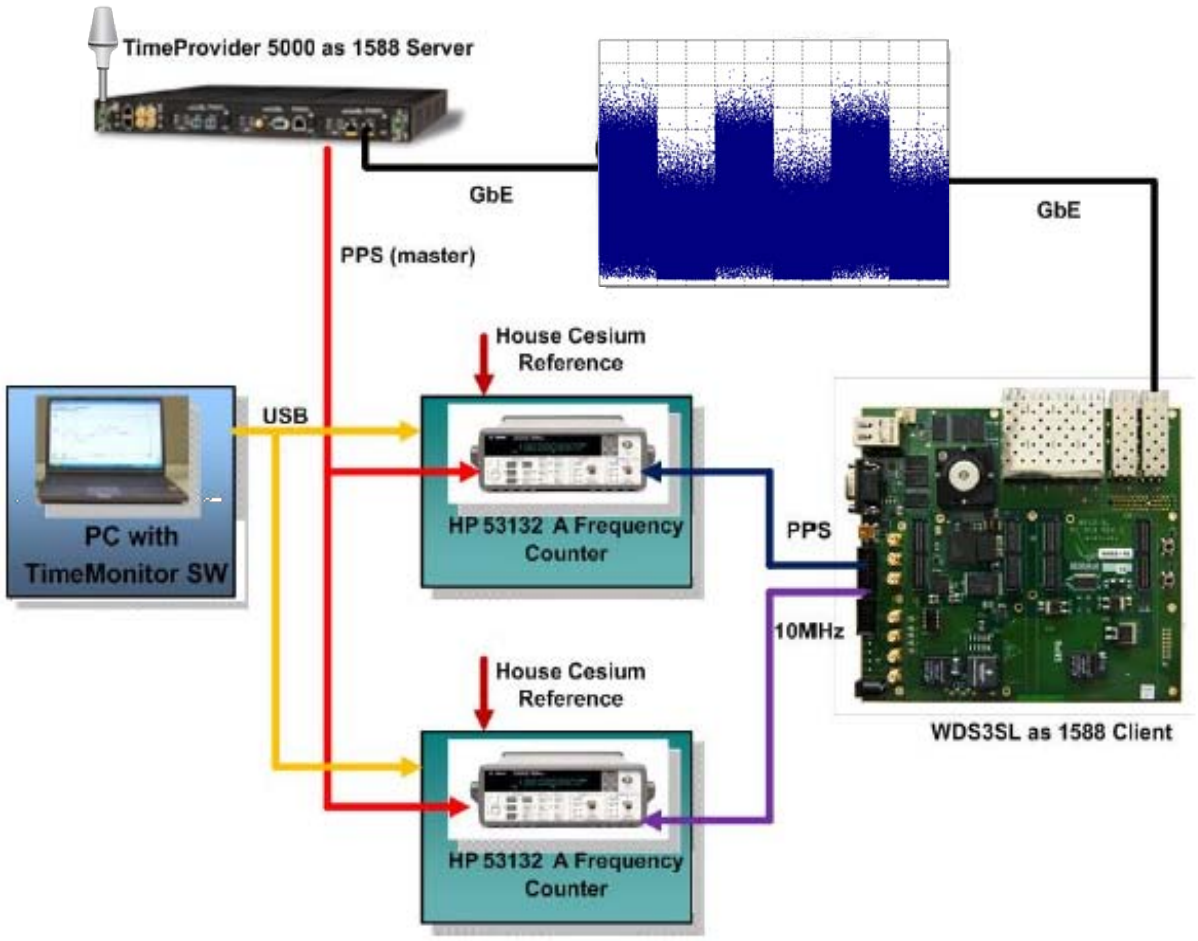
Unified Solution IEEE 1588 Performance

- Run G.8261 profile tests on PMC reference board
- Frequency performance
  - –Within 0.9 ppb
- PPS performance
  - –Within 1.04 µs



Note: Ref oscillator is Rakon Triton

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1588 v2 Solution Options and Decision Points

Solution Options	Timing BOM Cost/Unit*	Solution Design and Development Buy vs Build	Timing Performance
Discrete ICs/Block (CPU + Switch + TSU + Timing PLL)	Highest	Build can take up to 19 man years with timing expertise • Design, development and maintenance	Low level servo in timing PLL needs high performance double oven OCXO to meet MTIE, TDEV
Some Integration + Discrete (CPU w/TSU & + DPLL)	Medium	Timing is embedded Additional time to design-in DPLL	Symmetricom embeddable solution will easily meet MTIE , TDEV specs with good margins
Full Integration (CPU w/timing integrated)	Lowest	Buy – solution from NPU & timing experts. Fastest TTM** and longer TIM***	Symmetricom – PMC unified solution will easily meet MTIE , TDEV specs with good performance margins

** Based on 25K volume*

***TTM – Time To Market*

****TIM – Time In Market*

Choice is Clear:
Unified Solution from Symmetricom & PMC is the best option

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Gaining access to unified solution from Symmetricom & PMC

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Getting Started

- White Paper on Unified Synchronization
  - http://www.symmetricom.com/products/softclocks/SoftClock-for-Networking-Infrastructure/
  - http://pmcs.com/resources/whitepapers/unified_sync/
- G.8261 Test Report for SoftClock over WinPath
  - Contact Symmetricom or PMC Representative to obtain a copy
- Demo kit of SoftClock + Winpath
  - Kit includes Winpath evaluation board and demo software
  - User guide available on pmcs.com/mypmc
  - Demo software and evaluation board available upon request

Contact your local Symmetricom or PMC-Sierra sales representative for details

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Summary

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Key Takeaways

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- SyncE and 1588 becomes necessary as mobile backhaul trends towards packet based timing
- LTE synchronization faces new challenges due to the L3 networking and the small-cell/macro-cell mixture
- Unified synchronization makes the best use of SyncE and 1588 for mobile backhaul applications

WinPath processor embedded with the SCi 2000 SoftClock from Symmetricom delivers the best-in-class unified synchronization solution for 3G/4G/LTE mobile backhaul

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