APPLICATION NOTE

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CORIANT® 8600 SMART ROUTER SYNCHRONIZATION SOLUTIONS FOR NEXT-GENERATION MOBILE NETWORKS

Delivering Integrated, Flexible Synchronization Migration

Mobile technologies have rapidly evolved from a network infrastructure primarily designed for the support of voice services toward a data service centric network. The rollout of new technologies from WCDMA toward LTE, LTE-Advanced (LTE-A), and 5G in the future provides high data rates up to 10 Gbps. This evolution delivers shorter latency values in the user plane and control plane and enables the use of highly sophisticated applications. These next-generation mobile networks bring new challenges for underlying infrastructure. One challenge driven mostly by the need for more economic and scalable transport capacity has been the transition from TDM-based transport infrastructure toward a fully packet backhaul network. Another important challenge is the necessity of a new synchronization solution for packet network infrastructures. This application note describes various synchronization migration scenarios for mobile transport network infrastructures and describes options for the synchronization of next-generation mobile networks.

UNDERSTANDING SYNCHRONIZATION CHALLENGES IN EVOLVING NETWORKS

Mobile technologies such as GSM and WCDMA rely on frequency synchronization. Within a legacy mobile backhaul transport infrastructure, the network can be easily synchronized via SDH/PDH and SONET. With the migration of mobile backhaul toward packet-based infrastructure, the industry faces the challenge of incorporating frequency synchronization within a packet transport environment. Reliable methods for the synchronization of mobile networks via a packet-based network are IEEE 1588v2 and Synchronous Ethernet (SyncE). In addition, Global Navigation Satellite System (GNSS) is a solution for the timing of the mobile infrastructure. New challenges will arise for synchronization with the continuing introduction of LTE-FDD, LTE-TDD, LTE-A, and 5G in the future. Whereas LTE-FDD still relies on frequency accuracy, LTE-TDD, LTE-A, and 5G require phase synchronization based on IEEE 1588v2 or GNSS, including for example, Global Positioning System (GPS). SyncE is only able to provide frequency synchronization within a packet-based transport environment.

Advanced Coriant® 8600 Smart Router Synchronization Solutions

- **Provide highly accurate** time-of-day, frequency, and phase synchronization
- **Ensure flexible and simple evolution** toward phase synchronization for LTE-TDD, LTE-A, and 5G
- **Offer a cost-efficient pluggable GPS (GNSS) SFP receiver** for flexible implementation and rollout of phase synchronization
- **Include integrated Boundary Clock (BC), Grandmaster (GM), Slave Clock (SC), and Synchronous Ethernet** to complete a full feature set for packet-based synchronization of next-generation mobile networks
- **Deliver highest robustness** with the combined usage of Synchronous Ethernet and IEEE 1588v2
- **Leverage high performance data processing** to guarantee reliable and precise synchronization

IEEE 1588v2 STANDARDS COMPLIANT SYNCHRONIZATION

The IEEE 1588-2008 standard, also known as IEEE 1588v2, defines the Precision Time Protocol (PTP) and includes the Telecom Grandmaster (T-GM), Telecom Boundary Clock (T-BC), and Telecom Time Slave Clock (T-TSC). PTP provides frequency and phase/time synchronization to network elements connected to a packet-based transport network. This standard offers distinct advantages for operators who deploy IEEE 1588v2 compliant equipment, and Coriant delivers these fully integrated functionalities on the Coriant® 8600 Smart Router Series. IEEE 1588v2 synchronization can be easily activated and configured locally or remotely through the complete management and monitoring of the Coriant Transcend™ Chorus for Packet network management system.

The T-GM connected to a Primary Reference Time Clock (PRTC) generates time-stamped packets for a large number of network elements with integrated T-TSC. The IEEE 1588v2 protocol uses OSI Layer 2 (Ethernet) or Layer 3 (UDP/IP) for the transmission of PTP packets. IEEE 1588v2 can be used for frequency or phase synchronization. In case of frequency synchronization, PTP packets are transparently transmitted from the T-GM toward the T-TSC, as shown in Figure 1.

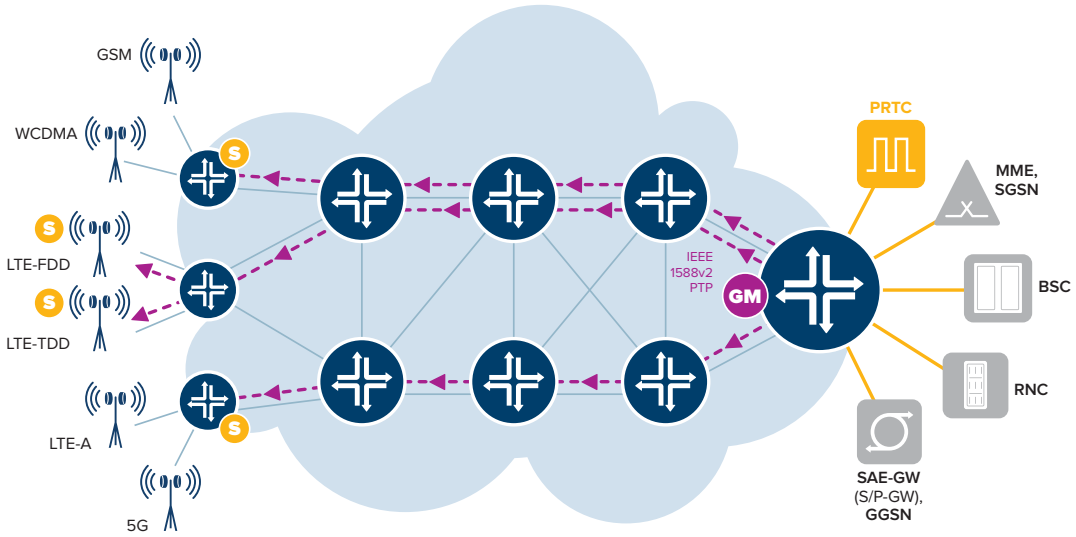

FIGURE 1: *IEEE 1588v2 Frequency Synchronization*

When it comes to full-on path phase synchronization, all of the intermediate nodes on the transmission path from the grandmaster to the slave must provide and support Boundary Clock (BC) functionality, as illustrated in Figure 2. By using T-BC or Transparent Clock (T-TC) functions in the nodes between the master and slave clocks, IEEE 1588v2 significantly reduces the effects of latency and other network delays.

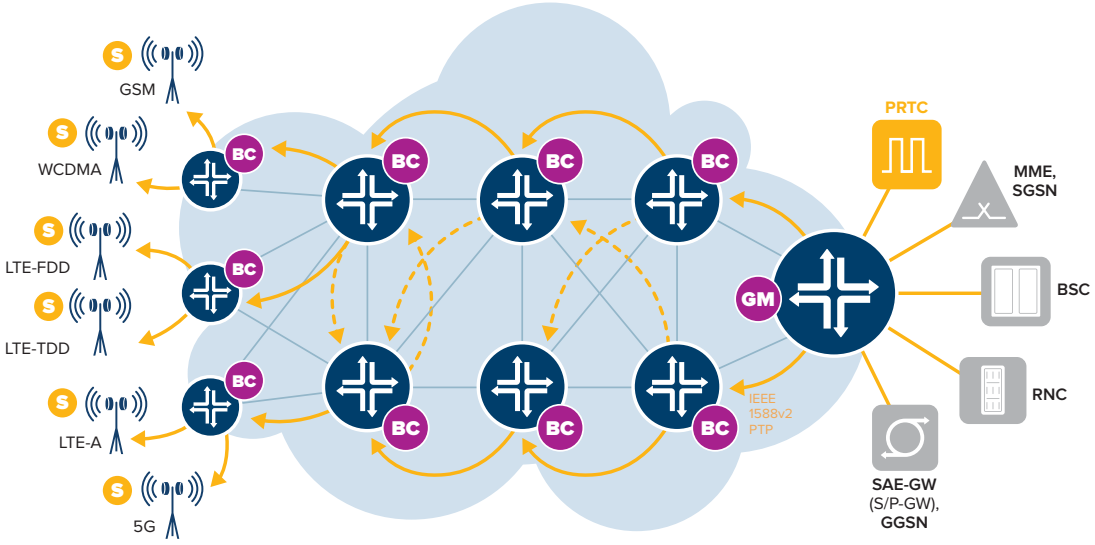

FIGURE 2: *IEEE 1588v2 Boundary Clock Enabled Network*

To further advance the flexibility of the solution and cost efficiency of deployment, IEEE 1588v2 T-BC Partial On-Path Support (POPS) as indicated in G.8275.2 (refer to Figure 3 for more details) is a planned feature for the 8600 Series. In POPS synchronization, intermediate router/switch hops that are not able to regenerate the synchronization messages (T-BC unaware) can exist. This will significantly reduce the requirement for network forklift upgrades as equipment replacement costs are minimized.

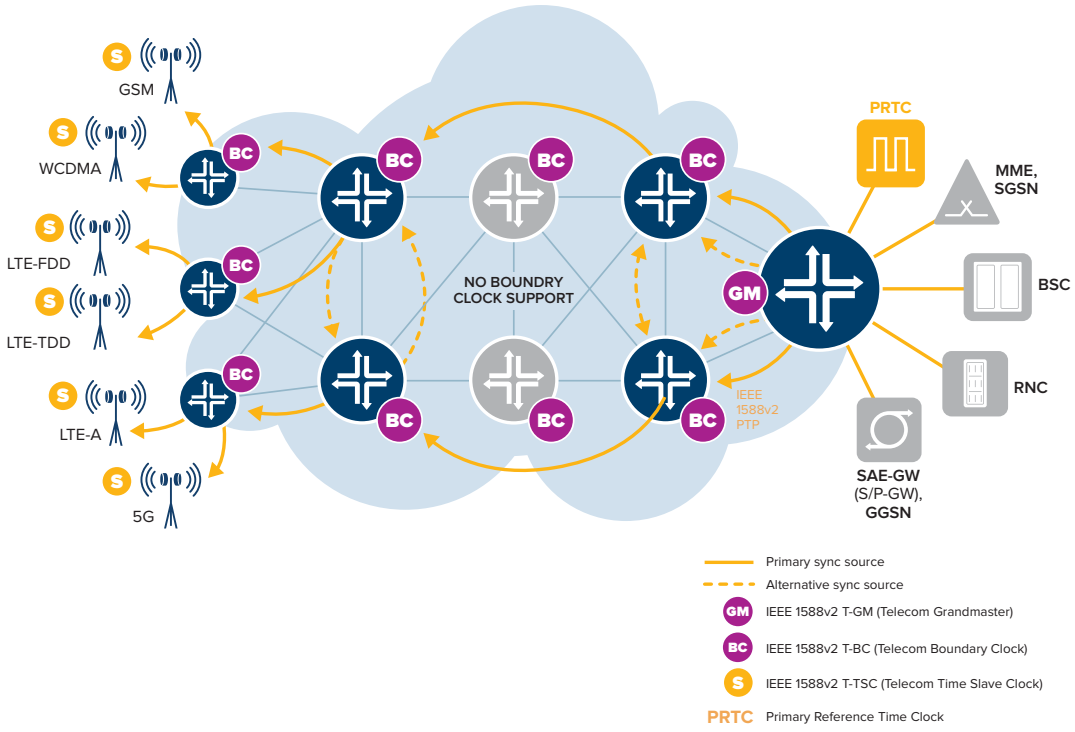

FIGURE 3: *IEEE 1588v2 Partial On-Path Support*

SYNCHRONOUS ETHERNET

SyncE is another option for synchronizing packet networks that is fully integrated into the 8600 Series. SyncE was standardized in February 2008 by ITU-T G.8261, G.8262, and G.8264 for frequency synchronization in a packet transport environment. Unlike IEEE 1588v2 PTP, SyncE operates only on the physical layer, Layer 1, independent of the network load on Layer 2 and Layer 3. SyncE offers greater robustness against network impairments on higher layers and effectively incorporates many of the SDH synchronization mechanisms into packet transport. This method provides a relatively simple mechanism for mobile network elements to recover the synchronization signal from the physical layer. As shown in Figure 4, SyncE must be supported at every hop along the chain of nodes between the switching office and the cell site.

The 8600 Series can be configured to either terminate the node for the SyncE timing signal and forward the clock input as a PPS signal to the base station or to act as a next hop SyncE node toward the base station.

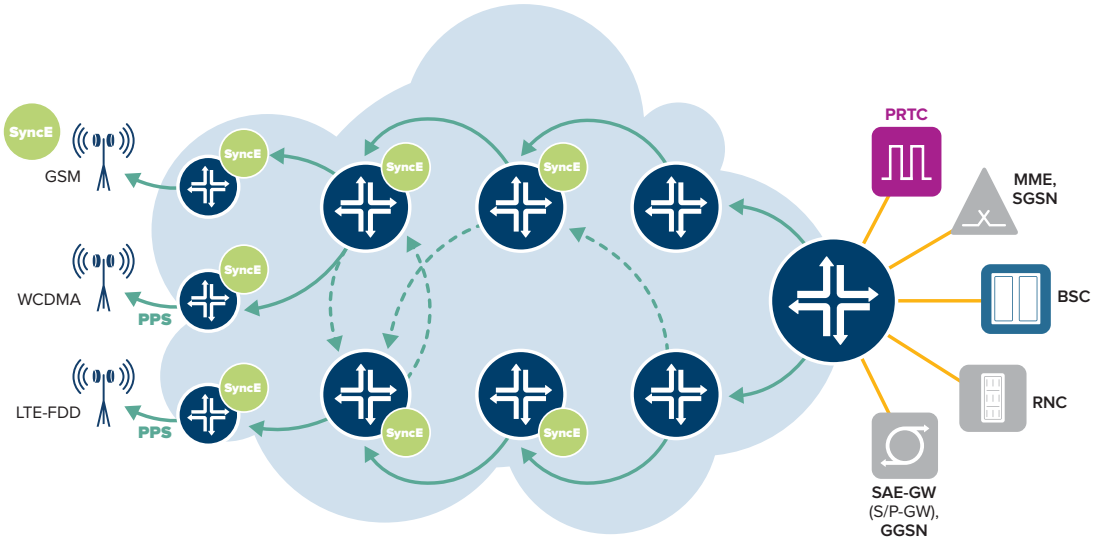

FIGURE 4: *Synchronous Ethernet Enabled Mobile Backhaul*

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

Satellite-based synchronization is an option for the synchronization of mobile networks. Using timing input received via a satellite system such as GPS, GNSS systems provide reliable input for frequency and phase synchronization. Featuring a high degree of flexibility, this solution can be installed at base station sites unlike other network-based options.

A typical drawback of this solution is high investments in equipment as traditional satellite solutions require GNSS infrastructure including satellite receivers at different sites within the mobile networks. Furthermore, effort is required to manage the integration and installation of external equipment into the relevant base station site and to maintain the GNSS infrastructure. The Coriant® Integrated GPS (GNSS) SFP Module in the 8600 Series addresses these challenges through its GPS receiver functionality. As the most cost-efficient, most compact, and most flexible GNSS synchronization solution in the market, the 8600 Series provides this Integrated GPS (GNSS) SFP Module, which can be installed at all sites where satellite-based timing is required.

Figure 5 shows typical examples of flexible and simple GNSS deployment scenarios for macrocells, femtocells, and microcells.

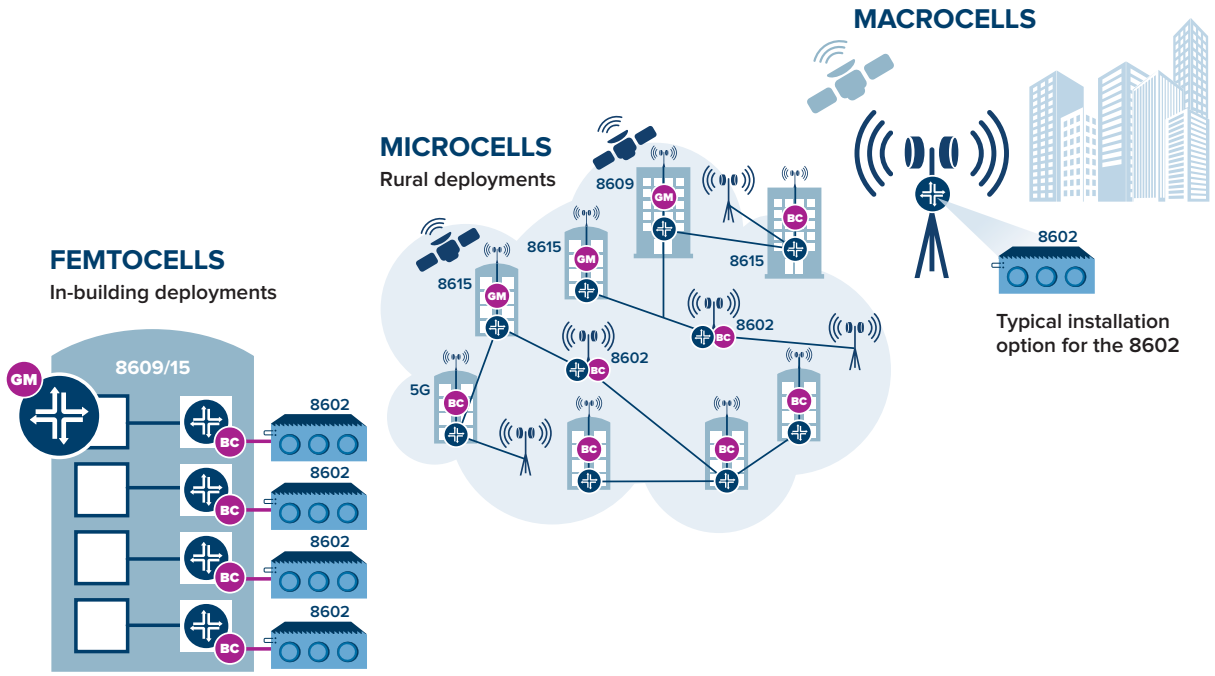

FIGURE 5: *8600 Smart Router GNSS Deployment Scenarios*

PHASE SYNCHRONIZATION IN MOBILE BACKHAUL NETWORKS

For the realization of phase synchronization in mobile networks, transport infrastructure must be upgraded to achieve higher accuracy. The 8600 Series provides a highly sophisticated integrated synchronization concept that includes:

- IEEE 1588v2 Grandmaster (T-GM) (G.8275.1)
- IEEE 1588v2 Frequency Slave (G.8265.1)
- IEEE 1588v2 Slave Clock (TSC) (G.8275.1)
- IEEE 1588v2 Boundary Clock (T-BC) (G.8275.1 profile)
- Synchronous Ethernet (ITU-T G.8261/G8262/G.8264)
- GPS (GNSS) SFP receiver

All 8600 Series synchronization functionalities are fully integrated into Transcend Chorus, which supports the remote configuration and monitoring of synchronization performance on each network element. This concept enables flexible and cost-efficient implementation of various synchronization solutions based on existing network conditions in the different domains of the mobile backbone.

With the ongoing rollout of mobile technologies, such as LTE, LTE-A, and 5G in the future, network deployments require maximum economic efficiency and technical reliability. Networks must be architected to include functionalities for the latest mobile standards and to enable a smooth evolution for technology innovation in diverse network domains. The mobile backhaul must provide relevant functionalities and flexibility for the installation of next-generation mobile networks. The 8600 Series offers all necessary features and synchronization processing performance to ensure network flexibility, as depicted in Figure 6.

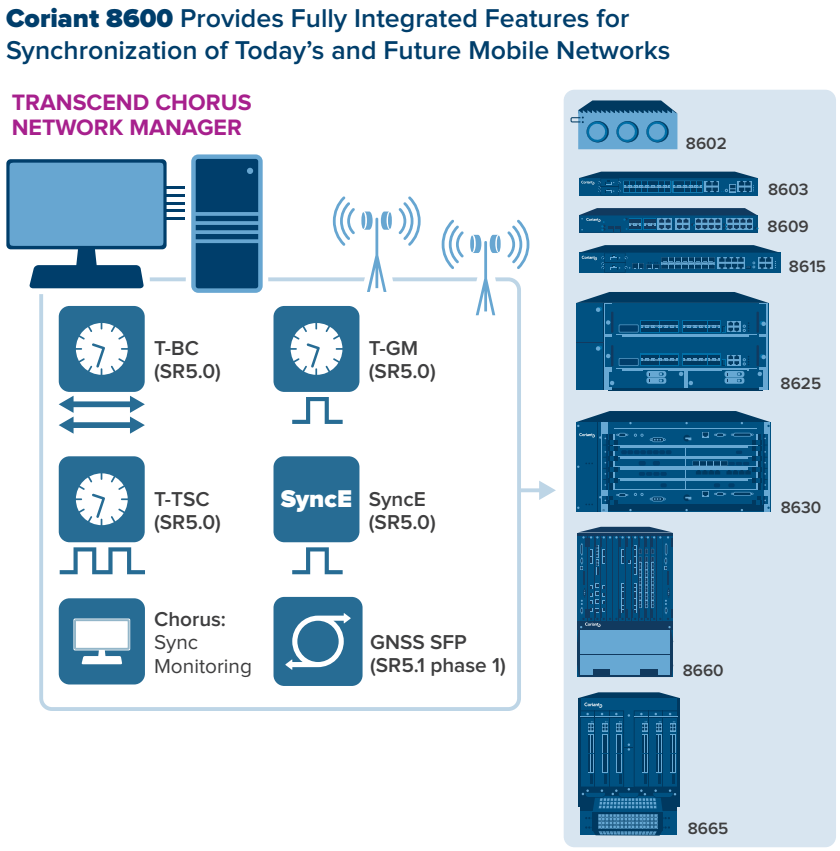

FIGURE 6: *8600 Smart Routers provide a fully integrated synchronization feature set*

The 8600 Series enables the implementation of various synchronization solutions in different domains of the network according to the rollout strategy of the Mobile Service Provider (MSP) and as required by mobile technology. The integrated synchronization features are software-configurable via a Local Craft Terminal (LCT) or remotely with Transcend Chorus.

Integrated synchronization provided by the 8600 Series simplifies network structure, eliminates the need for external equipment, and removes complexity from the transport network.

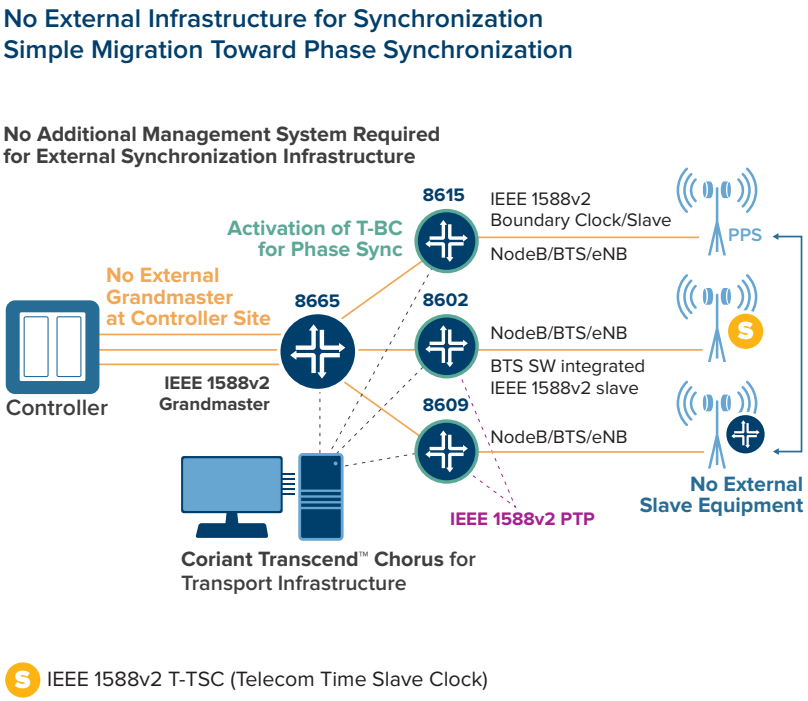

FIGURE 7: *8600 Smart Routers remove network complexity*

EXAMINING FLEXIBLE NETWORK PHASE SYNCHRONIZATION MIGRATION SCENARIOS

As mobile networks migrate toward new mobile standards, mobile transport networks that interconnect mobile network elements must evolve as well. Therefore, transport networks must be enabled to support new functionalities that are required by new mobile standards. Typically, the architecture of mobile transport networks is heterogeneous. Within a mobile transport network, various types of deployed platforms with different levels of functionalities provide a complex network structure with different levels of readiness for phase synchronization. Some nodes are enabled for the support of phase synchronization, other nodes require further investments to support phase synchronization, and some nodes simply cannot support phase synchronization.

With its integrated synchronization functionalities, the 8600 Series provides synchronization solutions that minimize required investments for phase synchronization and maximize flexibility. Figure 8 shows a typical example of an efficient evolution of the transport network for phase synchronization. A flexible combination of various synchronization features in the appropriate routers in the affected network domain offer the opportunity to rollout phase synchronization as required and eliminate the need to upgrade the entire mobile backhaul.

By making use of an SFP-based GPS receiver and integrated T-GM functionality in a suitable router (e.g., Coriant® 8665 Smart Router) and the simple activation of T-BC functionality in intermediate nodes (e.g., Coriant® 8609 Smart Router, Coriant® 8615 Smart Router, Coriant® 8630 Smart Router, Coriant® 8660 Smart Router), the mobile backhaul can be upgraded incrementally and cost efficiently for phase synchronization.

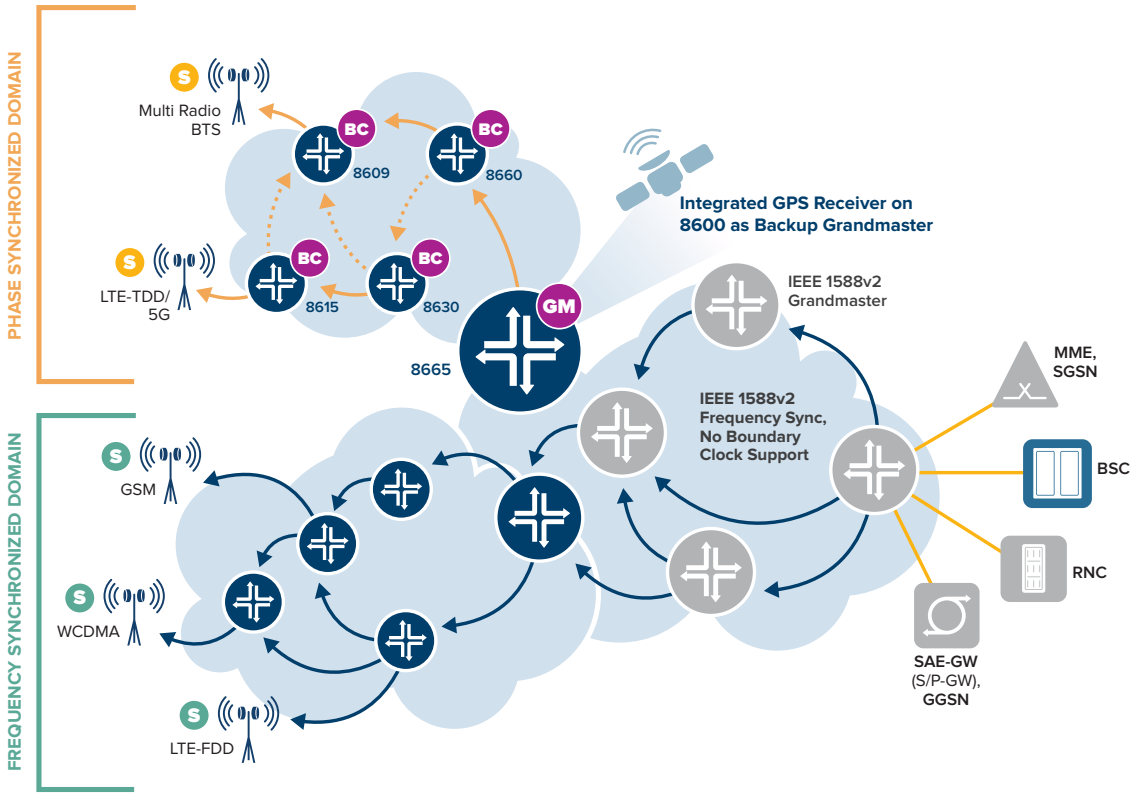

FIGURE 8: *Flexible rollout of phase synchronization with the integrated GPS (GNSS) SFP solution*

Furthermore, the 8600 Series synchronization solution supports subdomain synchronization and offers the possibility to rollout phase synchronization within a heterogeneous network structure in the same transport domain. Figure 9 shows an example of a simple installation of 8600 Series platforms, including the 8609 Smart Router and 8602 Smart Router, for the implementation of phase synchronization only in the access layer of a transport domain. The intelligent mix of required synchronization features brings phase synchronization close to the base stations. This avoids unnecessary upgrades and additional investments in the network domain for phase synchronization.

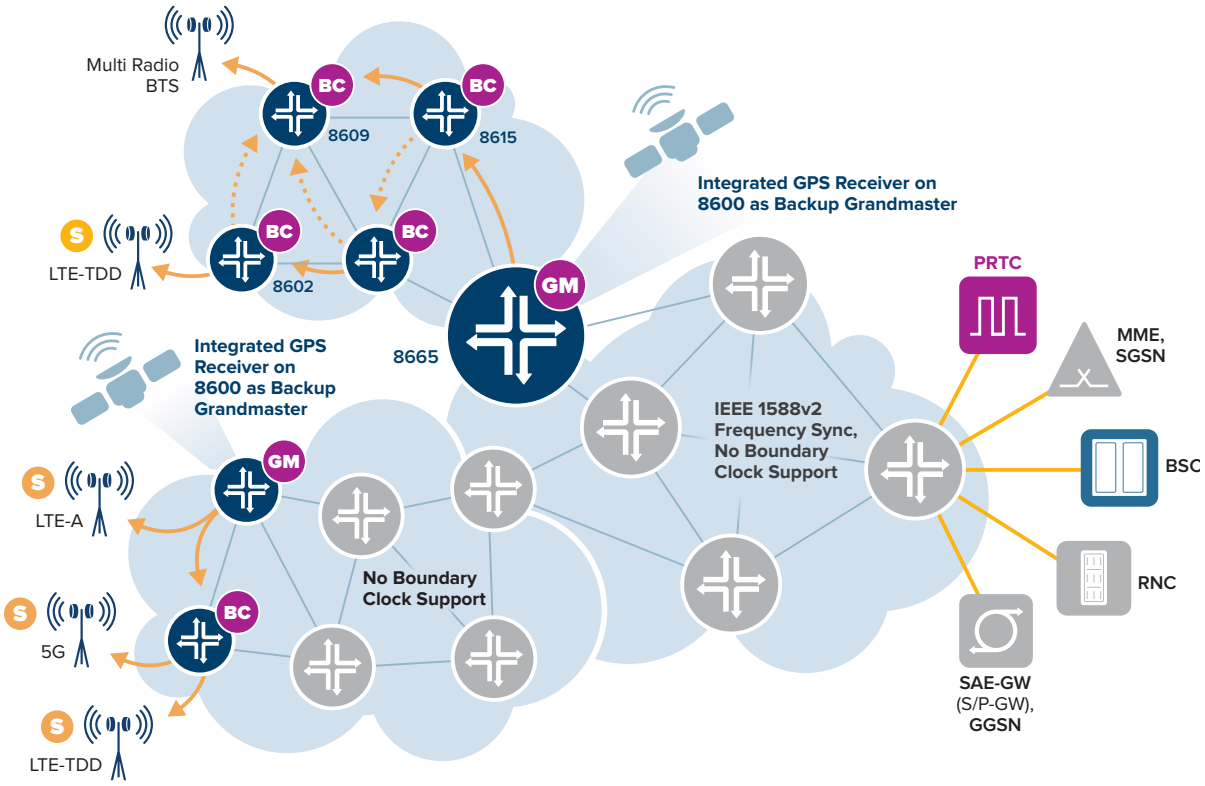

FIGURE 9: *Subdomain rollout of phase synchronization*

PROVIDING RELIABLE, HIGH PERFORMANCE SYNCHRONIZATION WITH THE 8600 SERIES

The rollout of synchronization within a packet-based transport environment necessitates careful network analysis and planning. Mobile networks require reliable synchronization via mobile backhaul. Therefore, the synchronization of the various nodes is essential even in difficult network scenarios. IEEE 1588v2 uses Layer 2 or Layer 3 for the transport of PTP packets. This implies a potential risk for synchronization data transmission due to overload, recovery, or reroute situations.

The 8600 Series provides a set of functionalities to overcome the potential risks of synchronization failure within the network. One such functionality is the simultaneous support of SyncE and IEEE 1588v2 in each router offering significant advantages, including:

1. Fast synchronization of the network (e.g., after network outages or enforced reroutes)
2. Improved phase accuracy during holdover after the loss of the PTP synchronization connection

If a router loses the reception of IEEE 1588v2 PTP synchronization packages, the node will change into holdover mode. The physical layer frequency reference provided by SyncE extends the period for which the router's integrated oscillator stays within the required limits for phase synchronization. With this SyncE assist feature activated, the 8600 Series guarantees the necessary accuracy of phase synchronization for a minimum period of 24 hours. In addition, various reference sources in each router can be configured for the retrieval of synchronization signals. The integrated Best Master Clock Algorithm (BMCA) selects the best source, and in case of the loss of the primary source, the algorithm selects an alternative source.

DELIVERING HIGH PERFORMANCE SYNCHRONIZATION DATA PROCESSING

The ITU Telecommunication Standardization Sector (ITU-T) has defined synchronization requirements for different mobile technologies (refer to Figure 10).

SYSTEM	MAXIMUM FREQUENCY ERROR AT THE AIR INTERFACE	MAXIMUM PHASE / TIME ERROR AT THE AIR INTERFACE
GSM	± 50 ppb	
WCDMA	± 50 ppb	
LTE-FDD	± 50 ppb	
LTE-TDD	± 50 ppb	± 1.5 µs (< 3 km cell radius)
LTE MBMS	± 50 ppb	± 10 µs
LTE-A	± 50 ppb	± 1.5 µs
5G*	± 50 ppb	± 0.51 µs

FIGURE 10: *Synchronization Requirements*

** Amin, Parth. Self-Organizing Radio Resource Management and Backhaul Dimensioning for Cellular Networks. Department of Computer Science and Engineering, 2014, Aalto University, Finland.*

For example, more recent mobile standards require phase synchronization with a maximum time error of + 1.5 µs for LTE-TDD and LTE-A. This timing relates to the end-to-end error budget for the complete transmission path of the PTP packets from the T-GM through the transport network to the base station. The different network instances or network elements have a certain time error budget available that is allowed to be consumed by each network instance.

The ITU-T G.8273.2 and ITU-T G.8271.1 recommendations describe the maximum time error budget of 100 ns per T-BC, T-TSC, and T-GM. Within the overall budget of 1.5 µs, each synchronization instance is allowed a maximum absolute time error of 100 ns. Therefore, the maximum time error of an end-to-end synchronization path is an important indicator of the quality and the robustness of a mobile transport network.

With the upcoming 5G mobile network technology, synchronization requirements are expected to be three times stricter than in LTE-TDD and LTE-A networks. The maximum time error will be reduced to 0.51 µs, which will lead to a further reduction in the allowed maximum time error budget per network element based on the ITU-T recommendation. In order to meet these future synchronization challenges, the 8600 Series provides extremely high performance synchronization data processing and extremely low time error. As depicted in Figure 11, the 8600 Series network elements consume only between 15% and 26% of the maximum allowed time error as recommended by the ITU-T standard. This low percentage range is a strongly differentiating factor that ensures reliable phase synchronization in current and future mobile networks.

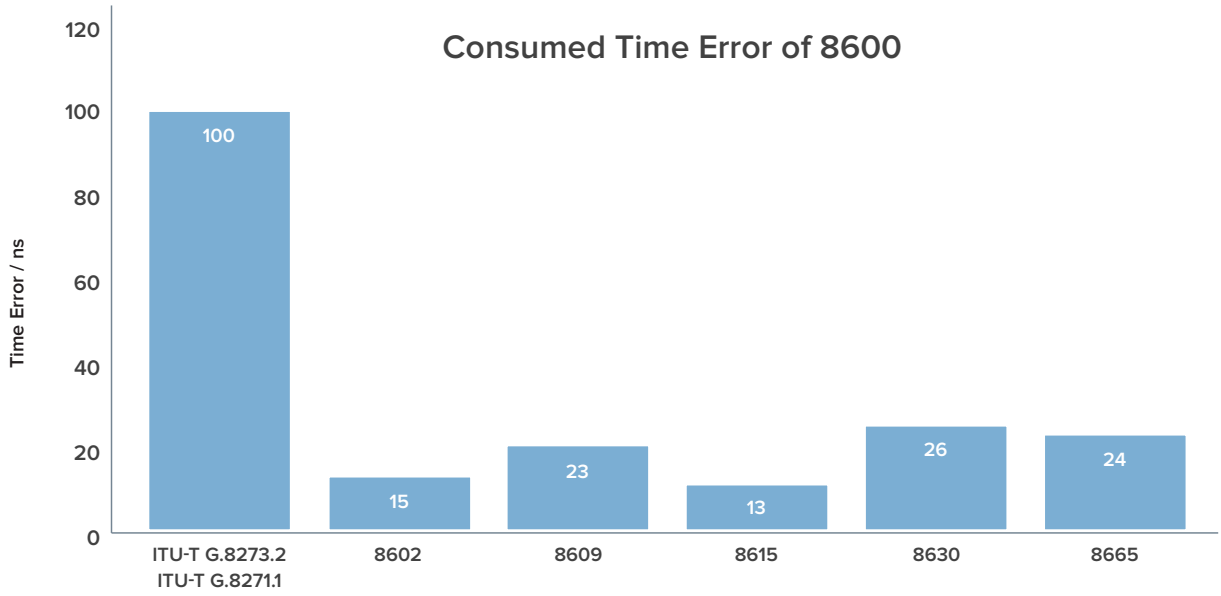

FIGURE 11: *8600 Smart Router High Performance Synchronization Data Processing*

8600 SERIES - FEATURING THE MOST ADVANCED AND FLEXIBLE SYNCHRONIZATION SOLUTION

The highly sophisticated and integrated synchronization solution of the 8600 Series offers significant advantages for the mobile transport infrastructure, including:

- Provides all functionalities for current and future packet synchronization of mobile networks
- Enables reliable and robust synchronization of the mobile network infrastructure
- Tolerates extremely difficult network conditions
- Ensures an easy upgrade for phase synchronization for installed base and new network rollouts through integrated software-configurable synchronization functionalities
- Delivers a low cost synchronization solution fully supported by Transcend Chorus through the Integrated GPS (GNSS) SFP Module
- Incorporates end-to-end configuration and monitoring via Transcend Chorus

CONCLUSION

The network evolution from TDM to packet transport in mobile backhaul networks creates technology migration challenges and leads to new synchronization support requirements. To address multiple types of synchronization throughout the network, Coriant offers an all-around synchronization solution, the 8600 Series. With full support for IEEE 1588v2 frequency and phase/time synchronization, SyncE, and GNSS through the Integrated GPS (GNSS) SFP Module, the 8600 Series supports all legacy and evolving synchronization scenarios to ensure a smooth migration to next-generation mobile networks. Designed to meet infrastructure challenges with cost-efficient and reliable integrated capabilities, the 8600 Series ensures optimal synchronization for diverse mobile networks.