High-Performance TDM Solutions using PTP 650/700

The Cambium Networks TDM solution enables network operators to deliver up to eight T1/E1 TDM circuits over unlicensed or lightly-licensed wireless links using PTP 650 and PTP 700 units. This application is typically used for lease line replacement, resilient backup links or 2G/3G backhaul applications.

The TDM solution delivers highly reliable T1/E1 transmission, with easier configuration, higher efficiency and more accurate timing than competing pseudo-wire approaches.

Some of our customers have asked for a more detailed description of how the TDM service has been implemented in PTP 650 and PTP 700, and challenged us to explain its superior efficiency and excellent wander performance. We've collected our most useful answers together here:

What hardware do I need to purchase to deploy TDM circuits over PTP 650 and PTP 700 wireless links?

In addition to the equipment needed for the PTP 650 or PTP 700 link, you will need one Network Indoor Unit (NIDU), Cambium Part Number C000065L043, for each end of the link. We also have an optional rack-mount kit and AC-DC supply that might be useful.

FIGURE 1 – NETWORK INDOOR UNIT

What licenses do I need to use the NIDU with PTP 650 or PTP 700?

You will need to purchase an upgrade for the 8-Port T1/E1 Software License (Cambium part number C000065K049) for each end of the link.

How do I connect the NIDU to the PTP 650/700 ODUs?

See the schematic diagram in FIGURE 2.

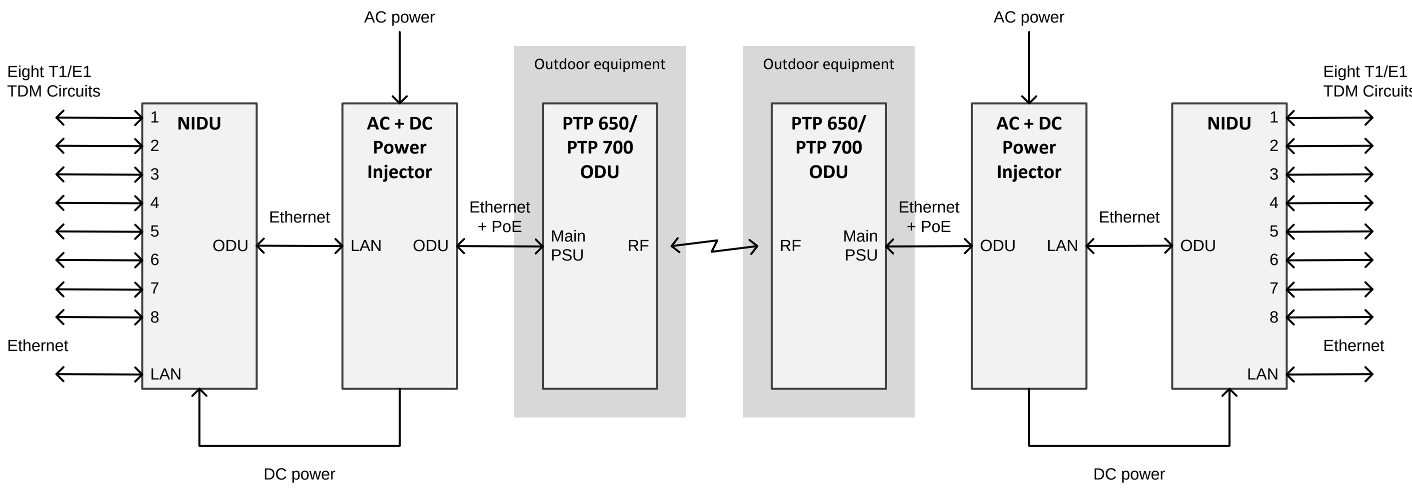

FIGURE 2 – TYPICAL NIDU DEPLOYMENT

What are the advantages of the PTP 650/700 NIDU solution compared with standards-based pseudo-wire devices?

The PTP 650/700 NIDU solution has several significant advantages over standards-based TDM pseudo-wire devices in a deployment over a single wireless link. These advantages are:

- Excellent wander performance
- Low latency
- Quick settling time
- Efficient use of link capacity
- Easy deployment
- Accurate timing maintained when the link capacity falls below the minimum needed to support data transfer

Each of these advantages is a consequence and benefit of the tight integration between the NIDU and the PTP 650/700 ODU, and the optimization of the NIDU for this particular application.

Is the NIDU based on pseudo-wire or native transmission of TDM data?

That's not a straightforward question. The NIDU encapsulates TDM data in Ethernet frames for transmission to the NIDU at the remote end of a wireless link, and the PTP 650/700 wireless link forwards Ethernet frames between the NIDUs. A pseudo-wire is defined as emulation of a circuit by transmission over a packet data network. From this perspective, the NIDUs must be classified as pseudo-wire devices.

However, the TDM service in PTP 650/700 provides very precise synchronization between NIDUs, building on the synchronization of the two ODUs and the tight integration between the NIDUs and ODUs. The excellent wander and low latency provided by the PTP 650/700 NIDU solution are competitive with native TDM solutions, and are significantly better than the performance achieved with generic standards-based pseudo-wire solutions.

Can the NIDU interwork with standards-based pseudo-wire devices?

No. The encapsulation of TDM data at the Ethernet port of the NIDU is optimized for the PTP 650/700 application and is not based on industry standards.

Of course, it's always possible to connect the TDM ports of the NIDU to the TDM ports of a pseudo-wire device, or any other E1 or T1 transmission system for that matter. TDM is a flexible way to interconnect different systems.

Tell me more about the TDM circuits supported by the PTP 650/700 NIDU

The PTP 650/700 NIDU supports up to eight E1 circuits, or up to eight T1 circuits. Each circuit is between one port on the NIDU at the local end of the link and the corresponding port on the NIDU at the remote end of the link.

Does the NIDU support structured or structure-agnostic operation?

The TDM circuits provided by PTP 650/700 and the NIDU are structure agnostic. This means that the NIDUs relay every bit received at a TDM input with no expectation that framing or any other structure will be present in the data. It also means that the TDM circuits cannot connect or multiplex individual time slots, and the NIDU cannot provide concentration for fractional E1 or T1 circuits.

What timing modes does the NIDU support?

The NIDUs provide "through" timing. Through timing means that the frequency of the clock used to transmit data at a TDM port is locked to the E1 or T1 signal received at the corresponding port at remote NIDU. The timing is independent between transmit and receive directions of the same port, and between ports on the same NIDU. Through timing is the closest we can get to the model of a conventional copper connection. The NIDU does not support (and does not need to support) internal, external or loopback timing modes.

Does the NIDU solution use adaptive clock recovery?

The most critical question in the design of a pseudo-wire service is how to set the TDM transmit clock frequency. Most standards-based pseudo-wire devices use adaptive clock recovery (ACR). ACR matches the TDM transmit clock to the arrival rate of data from the packet data network. The packet delay in a packet data network is unpredictable, so ACR averages the arrival rate in an attempt to provide a stable TDM transmit clock. The gold-standard of TDM clock stability is set by ITU-T G.823 and G.824. In our experience, systems based on ACR cannot comply with these standards in a network where the packet data is forwarded by time division duplex (TDD) wireless links. The uncorrected packet delay variation from a TDD link is many orders of magnitude greater than the desired wander performance at the TDM clock output, and it is unrealistic to expect the averaging process to operate to this level of accuracy.

A much better approach to setting the TDM transmit clock frequency is to use differential clock recovery (DCR). DCR relies on having a common frequency reference at both ends of the pseudo-wire circuit. The TDM receiver at the near end of the pseudo-wire circuit measures the offset of the recovered TDM clock from the reference, and passes this across the packet data network along with the encapsulated TDM data. At the remote end, the pseudo-wire device clocks the TDM transmitter at the required offset from the common reference. DCR is capable of providing excellent wander performance, but distribution of the common reference is often inconvenient. Practical means to distribute the common reference in a generic pseudo-wire network are essentially only Synchronous Ethernet, IEEE 1588 or GPS.

The PTP 650/700 NIDU uses DCR with a common reference derived from the synchronized wireless link. The reference is passed from each of the ODUs to the associated NIDU using Synchronous Ethernet. It is the availability of this accurate common reference in the NIDU at each end of the link that allows the PTP 650/700 NIDU to provide very low levels of wander in the TDM service.

What is the typical wander performance of the TDM service in PTP 650/700?

The gold-standard for wander performance with E1 and T1 is defined in Section 6.2.4 of ITU-Y G.823 and Section 6.2.2 of ITU-T G.824 respectively. However, it's important to understand that these are limits for any node in a network. Wander accumulates, so the G.823 and G.824 limits represent the maximum permissible total wander of all the devices and links between a node and a primary reference clock. The wander contributed by one device or link must of course be only a small part of the total. Some manufacturers claim compliance with G.823 and G.824 for individual products that consume almost the whole of the network allowance; these products would be almost impossible to deploy in a network.

The excellent wander performance of the PTP 650/700/NIDU combination uses only a small fraction of the network wander limit. FIGURE 3 shows measured wander performance of E1 circuits on a non-line-of-sight PTP 650/700 link with NIDUs. Note that the measured wander is always at least one order of magnitude below the limit and at most points two orders of magnitude below the limit.

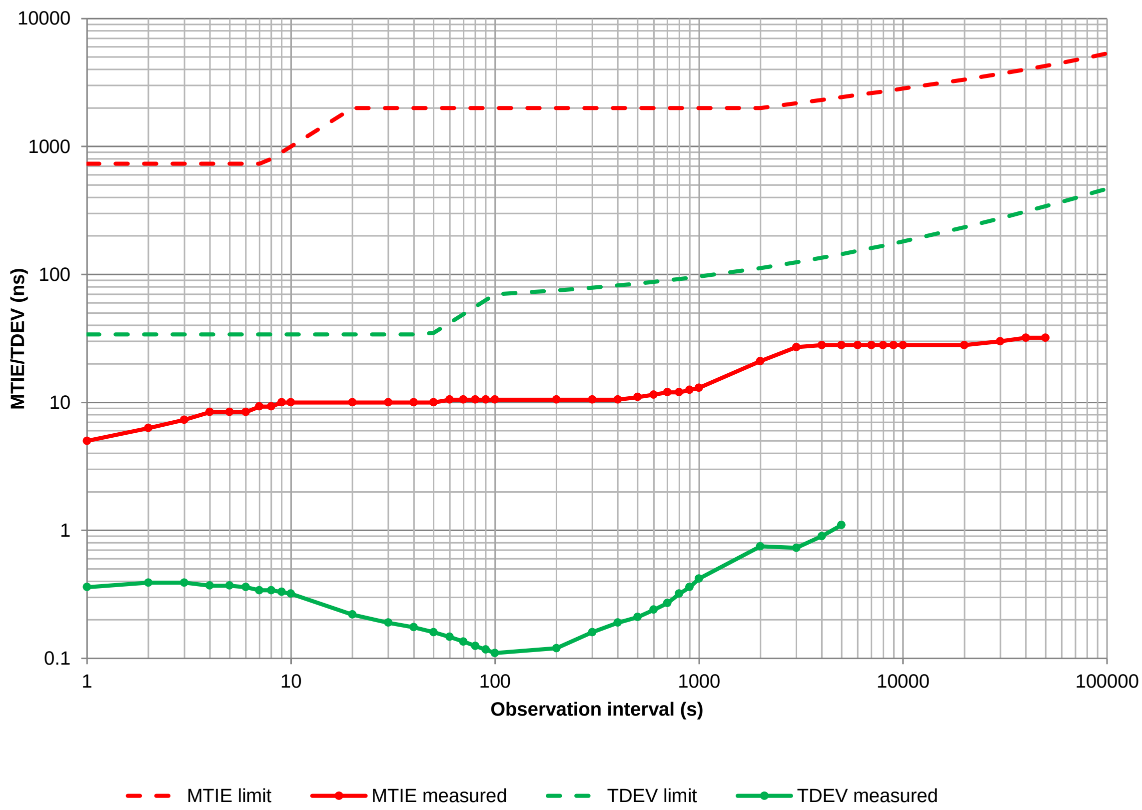

FIGURE 3 – TYPICAL WANDER PERFORMANCE OF A SINGLE PTP 650 LINK

[1] ITU-T Recommendation G.823, The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy

How does the NIDU achieve low latency?

The second most critical question in the design of a pseudo-wire service is how to set the pointer offset in the jitter buffer. The jitter buffer absorbs the variable packet delay from the packet data network. The offset between read and write pointers determines how much data is stored in the buffer. If the buffer stores too much data, the latency in the TDM service is excessive, which is bad. If the buffer stores too little data, there is a danger that the TDM transmitter will have no data to send, which is worse.

It's possible to re-align buffer pointers after the TDM circuit is established, but the kind of devices that generate or consume TDM data are generally intolerant of this sort of brute force action. This means that the initial setting of buffer pointers is critical. This critical task is made all the more difficult when TDD wireless links are in the network, because the packet delay has a wide, rectangular distribution and sudden changes in packet delay tend to occur when adaptive modulation (AMOD) changes the modulation mode.

Most pseudo-wire devices take a precautionary approach and set the jitter buffer to hold plenty of data, and suffer the additional latency that arises as a consequence. Because the NIDU is tightly integrated with the PTP 650 ODU, we can take an altogether more intelligent approach.

Each NIDU contains an accurate clock. The two clocks are precisely aligned using a timestamped Ethernet frame from the associated ODUs when the TDM service is initialized. The clocks are then incremented at precisely the same rate using the Sync E clock generated in the ODUs, so that the real-time clocks remain precisely synchronized. The ODUs calculate the required offset between read and write pointers based on the channel bandwidth, link range, and lowest permitted modulation mode. This means that the latency of the TDM service is exactly predictable and no greater than absolutely necessary to accommodate the packet delay in the wireless link.

It's also worth pointing out that the exact TDM latency can be checked for any planned link using the Cambium Networks too called LINKPlanner. LINKPlanner is available from www.cambiumnetworks.com in the PTP support area of the site.

What is the efficiency of the TDM service in PTP 650/700?

All pseudo-wire systems incur some sort of overhead in the encapsulation of the TDM data in IP and Ethernet frames. In some industry standards the overhead can be quite significant. The NIDU uses the bare minimum of overhead, avoiding most of the protocol headers needed in a standards-based solution. The resulting design is relatively efficient. TABLE 1 shows the efficiency as a function of the number of TDM channels configured. We define efficiency as the ratio of the number of TDM bits forwarded and the number of bits in the encapsulated Ethernet frame.

Number of TDM circuits	Efficiency	Overhead (Mbit/s)
1	71%	0.832
2	82%	0.928
3	86%	1.024
4	88%	1.120
5	89%	1.216
6	90%	1.312
7	91%	1.408
8	92%	1.504

TABLE 1 – NIDU ENCAPSULATION EFFICIENCY

How is the NIDU managed?

The NIDU is managed through the associated PTP 650/700 ODU. The ODU acts as a proxy for managing the NIDU. The NIDU has no IP address, no web server and no SNMP client of its own. This dramatically simplifies the configuration relative to traditional pseudo-wire approaches. With the PTP 650/700 solution there is no need to have separate logins/passwords/configuration files, etc. All configuration, monitoring and troubleshooting can be done in a single GUI.

Is it difficult to configure TDM on the PTP 650/700?

It is extremely easy to configure the TDM service on the PTP 650/700. Simply select the number of circuits required from one to eight. The PTP 650/700 takes care of quality of service (QoS) and jitter buffer settings automatically. There are no IP addresses or Ethernet addresses to worry about.

Are there any limitations or restrictions I should *be aware of?*

Yes. The TDM service is built on top of the IEEE 1588 and Sync E synchronisation features in PTP 650/700, and these features are not separately available when the TDM service is enabled. In practice this is not a severe limitation as opportunities to deploy TDM, IEEE 1588 and Sync E together are rare.

Can I connect two (or more) NIDUs to the same ODU?

No. The system supports only one NIDU connected to each ODU. The NIDU solution does not support more than eight TDM circuits over a single wireless link.

Can I connect two ODUs to the same NIDU?

No. It's always a one-to-one connection between the NIDU and the ODU.

There are two spare Ethernet ports on the NIDU. What are these used for?

These ports have no function at present.

Can the NIDU be used with other wireless products or in other network applications?

No. The NIDU is entirely dependent on its connection to a PTP 650/700 ODU. It has no applications as a standalone device.

Can I bridge TDM data between NIDUs separated by two (or more) PTP 650/700 links?

No. The TDM service is always between a pair of NIDUs connected to the ODUs in a single link. To bridge TDM data over a chain of two or more PTP 650 or PTP 700 links, use multiple NIDUs and interconnect the TDM ports of the NIDUs at the intermediate sites.

We hope you've found these frequently asked questions helpful. If you have questions of your own then we're here to help. Additional information can be found at:

Community Forum: http://community.cambiumnetworks.com/t5/PTP/ct-p/forums_ptp

Web Site: http://www.cambiumnetworks.com/products/backhaul/ptp-650/

User Guide: https://support.cambiumnetworks.com/files/ptp650/