White Paper

MPLS-TP: A Superior Packet-based Technology for Industrial Applications

Simplified, lower cost MPLS variant built specifically for the needs of many non-carrier applications

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Executive Summary

Traditional circuit-switched TDM backbone networks such as SONET and SDH are being sunsetted in the face of increasing demands for bandwidth, driving network operators to investigate packet-based networks, most often Carrier Ethernet or IP/MPLS. While these networks serve some types of operations adequately, a large number of operators—most notably those at industrial organizations such as power utilities and transportation systems—find the feature mix offered by these systems less than optimum for their needs. Fortunately, a newer version of MPLS—MPLS-TP—has been developed that is more specifically suited to the needs of these operators. This white paper explains how the MPLS-TP standard adds functionality that makes the protocol significantly more effective, familiar and "SONET-like" in its operation. Plus, it removes many unneeded IP/MPLS features that create complexity and expense.

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Bandwidth demands overwhelm circuit-switched system

For decades, large high-speed backbone networks have been circuit-switched systems, based on the Time Division Multiplexing (TDM) standard and most commonly running Synchronous Optical NETwork (SONET) or Synchronous Digital Hierarchy (SDH) protocols. Over the years, operators have developed a high degree of expertise and familiarity with SONET/SDH networks, and they have served industry very well.

However, with the escalation in demand for video, data and other bandwidth-hungry applications, the limitations of circuit-based systems such as SONET/SDH have become readily apparent, hindering the growth of many operations until they can evolve to a packet-switched system. Indeed, TDM-related equipment vendors have clearly seen the writing on the wall, and most that I am aware of have announced the sunsetting of these products. In addition, the availability of replacement parts—and service and support resources—for TDM networks have been substantially diminishing over time. This increases the urgency of the need for operators to migrate, with their SONET/SDH networks not only becoming increasingly inadequate but also increasingly costly and challenging to maintain as they hasten toward obsolescence.

Today's networks must carry heavy traffic loads, including data and video. Some packets are mission-critical and need to fly past standard operational packets. MPLS-TP enables this segregation.

Evolving to packet-switched networks

With circuit-switched systems like SONET, of course, single dedicated circuits are reserved for transfers whether the capacity is fully needed or not, resulting in underutilized or "wasted" bandwidth. Packet-switched systems innovatively reimagine this function by breaking communications into small, separate data packets that can seek out available routes to get to their destinations most efficiently, where they are reassembled at the receiving end based upon header addresses.

The respective operating characteristics of a dedicated medium – such as a circuit-switched system – as compared to a shared medium – such as a packet-based system – was likely of less concern for many operations before the explosion in demand for bandwidth. For example, trends such as increased wireless CCTV transfer of security streams in railway stations and continuous monitoring of operations in utilities and facilities of all kinds point clearly to packet-based switching as a highly desirable evolutionary strategy for many organizations.

Initially, the two most common packet-based options to choose from were Carrier Ethernet and Internet Protocol/MultiProtocol Label Switching (IP/MPLS), with the latter most frequently selected for its superior mix of capabilities for the application. This capability mix, however, proved to be best suited for carrier networks, organizations in the business of selling bandwidth to third parties.

It has been less desirable for operators including power utilities; transportation operations such as mass transit systems, railway and metro stations; pipeline distribution operations; and other industrial users building a backbone for their own use. For this large subset of operators, the choice is frequently seen as a "lesser of two evils" since neither option came close to "checking all the boxes" needed to operate most efficiently. Indeed, many desirable features familiar to SONET/SDH users were no longer in evidence.

In addition, the relative complexity of these systems not only caused added expense and resource drain, but also presented features that could be detrimental to these types of operations. For example, in power utility protection applications, false fault messages could be generated, often necessitating that the feature mix of purchased systems be individually modified by the operator. At least one utility operation we're aware of, after installation, has even elected to remove their IP/MPLS network due to its complexity, cost and demonstrated lack of suitability for their needs.

MPLS-TP—A new "flavor" of MPLS

Fortunately, there is a newer, lesser known, alternative packet-switched data protocol that is especially suitable for the needs of this previously "neglected" subset of industrial backbone operators. MultiProtocol Label Switching-Transport Profile (MPLS-TP) is a variant of IP/MPLS that, while operating with similar architecture, presents a very different feature mix. In many ways it is a specialized version of IP/MPLS, removing those features not likely to be needed by its target industrial users and maintaining or adding familiar features that make it more suited to their specific needs. I look at MPLS-TP as a packet-based protocol option giving well-suited users such as utilities and transportation operators all the functionality that they need with none of the complexity that they don't.

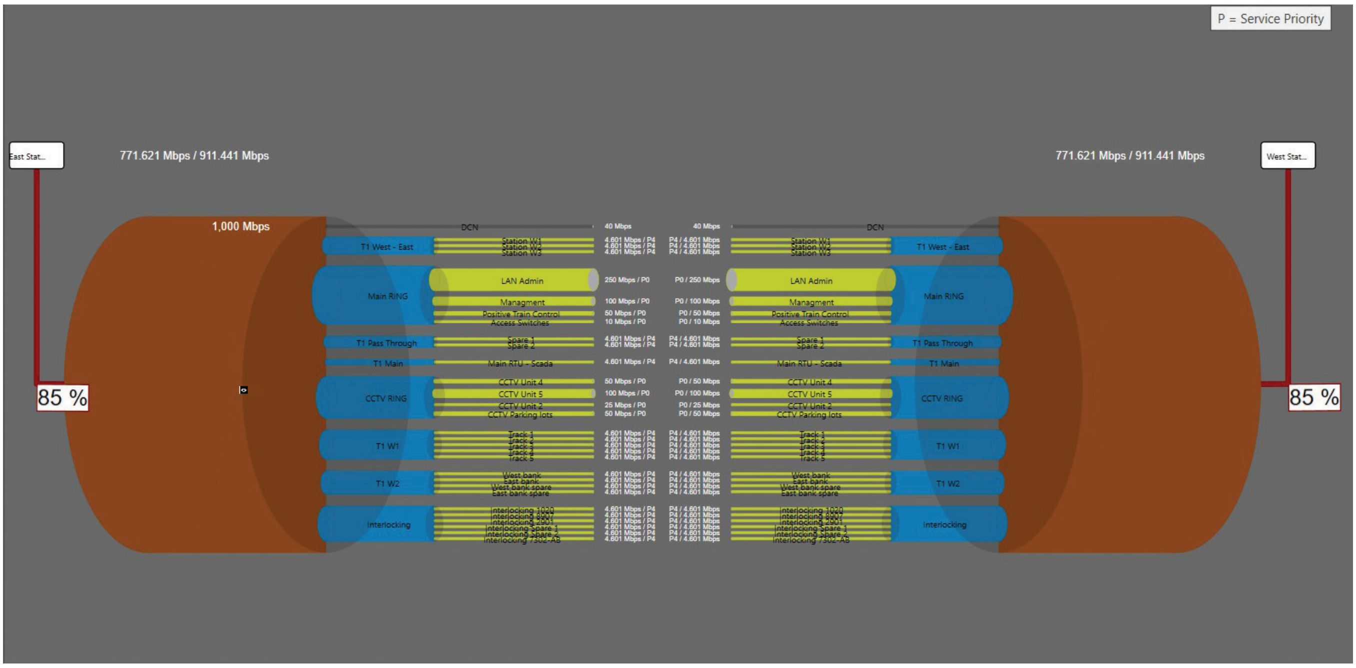
In addition, like those other protocols, MPLS-TP is also a fully open standard, developed and administered jointly by the Internet Engineering Task Force (IETF) and the International Telecommunication Union Telecommunication Standardization Sector (ITU-T). Indeed, during the development of MPLS-TP, IETF noted that its two objectives for the new standard were "to enable MPLS to be deployed in a transport network and operated in a similar manner to existing transport technologies (like SONET/SDH, and)...to enable MPLS to support packet transport services with a similar degree of predictability to that found (in them)."[1]

With this pedigree, although often overshadowed by the more mature and widely known IP/MPLS, MPLS-TP is generating significant interest among early adopting utilities, transportation systems and similar industrial users. In fact, the Paris-based electric grid trade association International Council on Large Electric Systems (with the French acronym CIGRÉ) told its members that the "transition to packet for power utility networks having extensive SDH infrastructure, management tools and skills is almost smooth for MPLS-TP because of its SDH-like behavior...(while) IP/MPLS is a jump into another type of network operation."[2]

As its name might suggest, MPLS-TP, while operating differently, looks similar under the hood as the older MPLS version, albeit in a smaller, more streamlined way.

Advantages of industrial-focused feature mix

As noted, industrial network operators have been faced with a challenge—their well-proven and familiar circuit-based TDM networks such as SONET/SDH are becoming obsolete and they must evolve to packet-switched networks. Before now, their choices were limited to carrier Ethernet and IP/MPLS, neither of which has the optimum feature set for their specific needs. In comparison, the emerging protocol MPLS-TP seems to be almost "custom-built" for the requirements of utilities, transportation and other industrial users. Here are several of the features that make this so.



[1] M. Bocci, Ed., et al. "A Framework for MPLS in Transport Networks." Internet Engineering Task Force (IETF) RFC 5921, July 2010.

[2] Samitier, Carlos, Ed. Utility Communication Networks and Services: Specification, Deployment and Operation. CIGRÉ Green Books, 2017.

Traffic Engineering with static provisioning

In packet-switched networks, Traffic Engineering is the process of directing communications traffic to available paths to find optimal bandwidth from point to point. In the evolution from a single channel circuit-based network, many believe that the jump to IP/MPLS raised the complexity stakes considerably and unnecessarily due to the protocol's dynamic routing capabilities. For every packet, IP/MPLS uses complex discovery algorithms to analyze dozens or hundreds of alternate paths to determine how to most quickly route the message, as well as, when needed, identifying multiple redundant back-up paths. These algorithms are constantly running in the background, hunting for more efficient routes. This process may have advantages for more complex carrier networks, but for streamlined, single-user industrial networks, it can usually be considered "overkill," adding significant complexity for little performance benefit. In fact, the algorithms can detrimentally add unpredictability to the operation.

MPLS-TP, on the other hand, provides static routing capabilities. The user defines a path for the traffic for each service, and the system follows that path. This not only reduces the demand on system resources, but also allows the user, presumably well familiar with the individual reliability and operating aspects of each part of their network, to strategically define preferred or underutilized links for each communication. In addition to the pre-determined primary path, the user can also designate an alternate redundant path. If there is an issue, the system will immediately route the traffic along this pre-defined secondary path.

High predictability, with bi-directional transmit and receive communications

In the dynamic routing process of IP/MPLS, with the system continually looking for optimal transmission speeds, the transmit and receive message paths do not typically follow the same route.. While perhaps immaterial to carrier networks, this feature can cause significant issues for networks operated by other types of facilities. For example, it is extremely common for modern power utilities to protect their multi-million dollar transformer network against electrical faults using sophisticated differential protection or differential relaying schemes, allowing the faults to be detected and isolated rapidly.

This strategy, certainly one of the most critical applications of communications within power utility operations, is based upon the notion that transmit and receive paths are predictable and have the same latency. By this method, voltages between lines are automatically monitored using a difference in demonstrated latency between the transmit and receive paths. Maximum tolerances are set and if the difference is deemed too wide—usually a few microseconds—an imbalance is inferred, circuit breakers will trip and the power system is automatically shut down to avoid the presumed threat of damage to the assets. Since this differential will occur more frequently with IP/MPLS for reasons unrelated to transformer operation, false trips—leading to unnecessary power delivery interruptions and subsequent fines to the utility for non-compliance to service requirements—could be a significant problem. Utilities using differential protection methods with IP/MPLS and its unidirectional paths would be unable to use the protocol as provided and would need to find a workaround. With MPLS-TP, of course, transmit and receive go through the same bidirectional path and demonstrate similar latencies, so no such issue would exist, and the highly effective differential protection method would be fully compatible.

Guaranteed bandwidth allocation

With the evolution from circuit-based to packet-based systems, concerns were reignited over the potential risk of co-transmitting traffic of differing priorities over a single network. For example, if critical train control information and Wi-Fi access for passengers rode on the same network, what could happen if there was a surge in bandwidth demand for the latter function, such as during a post-event peak ridership situation or a streaming demand during a major broadcast such as the Super Bowl or World Cup final? Could transmission of control information be impacted and potentially lead to safety issues? IP/MPLS, like SONET/SDH before it, readily allowed guaranteed bandwidth allocation; Carrier Ethernet did not. A major reason that IP/MPLS was often more strongly considered in the early transition to packet-based networks. MPLS-TP maintains this feature so vital to many industrial users. Users can assign bandwidth allocations to services and, regardless of how congested a particular service may become, demand impact is exclusive and will never affect the performance of other services. With MPLS-TP, users can ensure that mission-critical applications can always maintain optimum signal transmission and network availability.

"Replacing" OAM, resilience and other familiar SONET/SDH features lost in IP/MPLS

Although it's a given that circuit-switched systems are fast becoming obsolete in favor of packet-based systems, many types of facilities have found that IP/MPLS, the initial offering of MPLS, removed significant capability that was familiar and extremely useful to many circuit-switched SONET/SDH users.

Looming large is the capability to switch over to a secondary data transmission path in less than 50 microseconds if the primary path fails. This fast switch-over capability was offered in SONET/SDH and has become an expected "checkbox" demanded by many operators due to the prevalence of time sensitive protocols in their networks. MPLS-TP maintains the 50ms resilience switching time, and in my experience, the recovery time in practice for some MPLS-TP boxes is actually even faster than it was for SONET/SDH networks.

Another huge advantage in additional—and familiar—capability are the outstanding Operation, Administration and Maintenance (OAM) functions to be found in MPLS-TP. The protocol brings extensive OAM functions similar to those available in traditional circuit-based networks to packet-based networks for the first time. These include enhanced fault management, performance monitoring and alarm management. In addition, with MPLS-TP, the OAM packets are in-band with the data, following the same path and allowing verification of services during operation.

While SONET/SDH systems allowed isolation of the data plane from the control plane, IP/MPLS shared a management channel with data traffic. MPLS-TP again provides a dedicated management channel separate from the data flow so users can more flexibly manage the system if problems arise. Further, MPLS-TP also provides the end-to-end Quality of Service (QoS) features familiar to SONET/SDH users.

Lower complexity means lower cost

The upfront investment (CapEx) necessary for equipment and installation is often lower for an MPLS-TP network than for an IP/MPLS network. Of note, MPLS-TP is for the most part a "one and done" investment, with the initial purchase expense being the only cost. On the other hand, some IP/MPLS equipment is "discounted" upfront with vendors later generating additional revenues from operators by way of ongoing fees. Indeed, when one looks at the relative life-cycle costs and operating expenses (OpEx) and compares the two, the gap between IP/MPLS and MPLS-TP widens significantly. As noted, IP/MPLS requires frequent updates and often significant ongoing subscription/licensing fees—no such ongoing costs are usually required with MPLS-TP.

Even more impactful, however, is the fact that the complexity of an IP/MPLS network usually necessitates employing a large team of specialized staff members to operate and maintain it. Troubleshooting is significantly more challenging, time-consuming and demanding of expert-level network engineering skills. The cost of recruiting, training and retaining this staff can be substantial, even prohibitive in some geographic areas.

In contrast, with MPLS-TP, the staff demand can often be reduced to a single individual. In addition, training costs are minimal because of the familiar and intuitive nature of MPLS-TP. This can be illustrated simply by comparing the heft of the training manuals—MPLS-TP's manual is a fraction of the size of the tomes needed for IP/MPLS. Indeed, the complexity of the network demands constant attention and will keep the large IP/MPLS staff in constant motion. With MPLS-TP, once things are set up, little ongoing maintenance is required. And, the smaller footprint of MPLS-TP equipment means less square footage claimed in tight industrial facilities.

In addition, while both flavors of MPLS are future-proof and scalable, the complexity of an IP/MPLS network grows exponentially as the network grows, resulting in a need to increase the hiring of trained staff members to run and maintain it. The simplicity of MPLS-TP, on the other hand, usually allows existing staff—usually one or two operators to readily absorb the extra capacity.

Things to consider when "shopping" for MPLS-TP

As of this writing, there are a handful of pioneering vendors offering MPLS-TP products and support, including my company, Belden. As more and more utilities, transportation organizations and other industrial customers come to understand that there is an "alternative" MPLS that so effectively meets their needs, demand will continue to grow and additional brands will likely enter the market to help fulfill it.

Although MPLS-TP is a standards-based protocol, there are a number of brand distinctions one can already see in the several systems already on the market. These differentiations will likely continue, with proprietary methods developed to meet certain technological challenges. For example, to help meet the power industry's need to avoid asymmetry, different manufacturers have developed different techniques that may differ in effectiveness, so users needing this feature should shop around to see their options. Hirschmann's DRAGON PTN backbone network device, for example, uses a novel buffer management technique that I believe is worthy of note.

Another aspect to consider is how provisioning—the method by which the primary and redundant paths are created for each service and the bandwidth strategically assigned—needs to be performed. Following in the footsteps of IP/MPLS, many MPLS-TP vendors chose to provide only a command line interface for performing this vital task. This necessitates logging into and working on one node at a time and inputting long command strings. I have heard users describe the task of provisioning MPLS-TP using a command line interface using words such as "onerous," "tedious," "redundant" and "time-consuming." Indeed, provisioning even an 8-10 node network using a command line interface can take several days, and, because of the learning curve, requires extensive training. This is especially inefficient since it's mostly a "one time" upfront need. Some utilities and similar industrial organizations instead hire consultants at several hundred dollars per hour or need to tap into the existing specialized skills provided by the manufacturer, forcing adherence to their timetable and their work preferences.

In contrast, a number of MPLS-TP manufacturers offer a GUI-based, wizard-driven procedure, with visual building blocks and a drag-and-drop interface. In these systems, the software does the heavy lifting of taking the basic information and pushing out the configuration requirements to each node automatically "behind the scenes." This allows the provisioning process to be done in-house by just about any operator, and allows it to be performed effectively in just a few hours. Any needed "tweaks" can be done just as easily on an ongoing basis as well, with little need for subsequent calls for manufacturer assistance.

Finally, I think it is of value for manufacturers to realize that since the operation of MPLS-TP is geared toward industrial customers, it makes sense to provide industrial-grade equipment that is appropriately "ruggedized" in design to meet this group's more extreme environmental needs. For example, components used by transportation customers may likely be placed outdoors subject to severe heat and cold, as well as undergo significant vibration caused by moving rail cars. In power stations or refineries, boxes may be placed in extremely dirty or dusty environments. Therefore, features such as fan-less operation, use of vibration-resistant and robust housings and components, and/or severe temperature resilience might be of substantial benefit to users.

The Hirschmann DRAGON PTN backbone network family, provisioned using Operation Administration Maintenance (OAM) software HiProvision, offers resilient packet-based MPLS-TP technology to guarantee bandwidth availability across large networks.

Conclusion

IP/MPLS is no longer the only flavor of MPLS available. Utilities, transportation systems and other industrial users who may have been disappointed when investigating their packet-system migration alternatives are well-advised to consider MPLS-TP. The feature set of this newer, standardized protocol is extremely well-suited for replacing the aging, quickly sunsetting SONET/SDH infrastructure for these types of users. Indeed, MPLS-TP, for the first time, delivers the efficiency of packet-based networks in a system that eschews unneeded and costly complexity while retaining predictability, deterministic performance and powerful ease of use features familiar to users of circuit-switched networks. In fact, while the "TP" in MPLS-TP stands for "Transport Profile," it may just as readily stand for "Transportation/Power," since its appropriateness for these two key industries, so poorly served by the prior IP/MPLS protocol, is so clear and deliberate.

Belden Competence Center

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