NOKIA

Harness the superior power of IP/MPLS for power grid communications

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Modernizing the grid

The way that we generate and consume energy is changing.

Clean energy sources such as wind and solar generate more and more of our power. These generators may be widely distributed, unlike coal-fired and nuclear power stations. As a result, the shape of the grid is changing. Power utilities are preparing to deliver carbon-neutral or even zero-carbon grids.

At the same time, the demand on the grid is changing. Electric vehicles are often charged in locations and at times not normally associated with high energy demand. The signs are that this challenge for power utilities is only going to intensify. Global sales of electric cars grew by 43 percent in 2020, even though car sales overall fell by 20 percent in the same period.[1]

To deliver power we can rely on, utilities are increasingly using digital technologies such as grid automation, distributed grid intelligence, and machine learning.

As the energy grid transitions, it imposes immense strain on the communications network. Grid intelligence and Intelligent Electronic Devices (IEDs) require resilient connectivity. The communications network must be more dynamic, so it can accommodate new connections easily.

New applications based on Internet Protocol (IP) and multicast capabilities are on the rise. Synchrophasors are enabling precise measurements to be taken of the grid, 120 times more frequently than was possible using SCADA. CCTV for grid monitoring and security and the emerging R-GOOSE for communicating substation events both require multicast capabilities. Applications connect to the cloud for Distributed Energy Resource Management Systems (DERMS) and augmented reality.

As the energy grid transforms, so too must the communications grid it relies on.

[1] Source: https://www.theguardian.com/environment/2021/jan/19/global-sales-of-electric-cars-accelerate-fast-in-2020-despite-covid-pandemic

MPLS enables network modernization

Time Division Multiplexing (TDM) technology has given utilities a reliable communications backbone in the past. It's a narrowband technology, though, and cannot meet the new needs of the power grid.

To replace it, utilities usually choose Multiprotocol Label Switching (MPLS). MPLS creates virtual label switched paths (LSPs) in the network to deliver data from source to destination. There are several realizations of MPLS, including MPLS-TP (Transport Profile), G-MPLS (Generalized MPLS), and IP/MPLS. They share the following core capabilities, which meet the power grid's basic communication needs. The core capabilities of MPLS are:

Multiservice

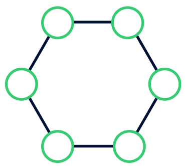
MPLS can support the wide portfolio of applications that utilities use, including:

- Teleprotection
- Synchrophasors
- SCADA
- Video surveillance

MPLS supports multiple Virtual Private Networks (VPNs), each dedicated to an application.

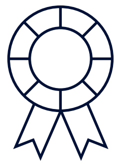
Operations, Administration, Management (OAM)

MPLS includes OAM features to detect faults, measure network performance, and manage the communications network effectively.



Ring Topologies

MPLS networks can support ring network architectures, much like SDH/SONET networks.



Quality of Service

MPLS enables you to prioritize critical traffic through the network. Teleprotection can be shielded from jitter or latency even if other applications send large amounts of data over the network.

Single-fault Resiliency

A smart grid with self-healing capabilities needs a reliable and resilient network as its foundation. MPLS provides the necessary resiliency to restore communications at SONET/SDH speed when one fault occurs. This can be considered to be "good enough".

However, in the era of energy transition, the communications network needs to not only satisfy the basic needs listed above. It must be able to do more as utilities embrace more digital capabilities. Only IP/MPLS can do that.

The superior capabilities of IP/MPLS

IP/MPLS combines the strengths of IP and MPLS. The IP layer gives you total flexibility in network topology design and deployment, utmost resiliency, and integrated IP services. The multicast support enables efficient distribution of data so it can be consumed wherever it is needed, without significantly increasing the bandwidth used.

In this section, we'll talk you through the benefits of IP/MPLS.

Total flexibility in network topology

In the past, substations mainly communicated with a central control center. With distributed grid intelligence, substations increasingly need to communicate with each other. Utilities need to be able to connect substations flexibly, using whatever transport medium is available.

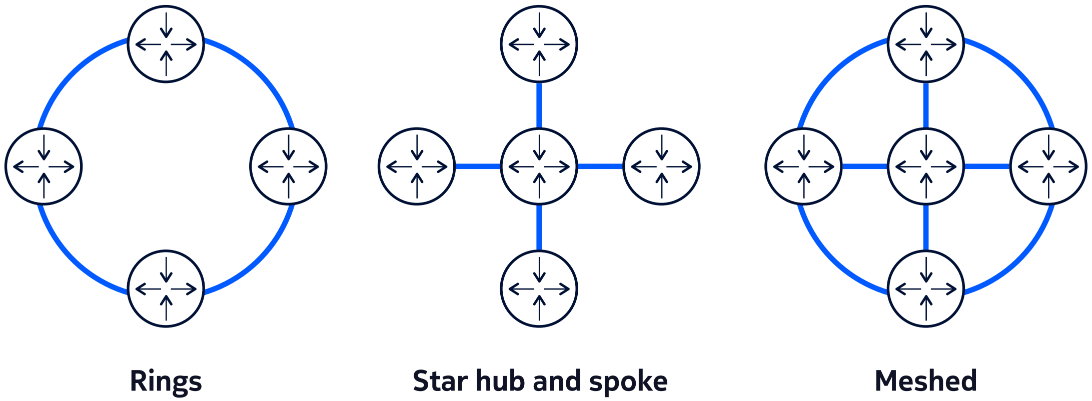
Because IP/MPLS includes a control plane, nodes on the network can discover each other, simplifying connection provisioning. Links can be created dynamically, without the requirement for manual point-to-point configuration. The network can automatically adapt to any future network expansion and topology optimization.

IP/MPLS is agnostic about the medium it uses. Utilities can choose between fiber, microwave, and even a telco's Ethernet services for each substation, depending on availability and economic viability.

Using IP/MPLS, you can create a network of any size and of any topology. Where budgets allow, IP/MPLS enables a meshed network to be used. This provides the highest level of resilience by enabling multiple router or link failures to be circumvented. With IP/MPLS, networks can be designed to enable any two locations to communicate with the fewest hops.

Without the IP network layer (Layer 3), which only IP/MPLS offers, meshed networks are hard to implement. Utilities would need to individually configure and plan for each path, causing a significant overhead in network operations.

IP/MPLS enables any network topology



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The superior capabilities of IP/MPLS

Multi-fault resiliency

As we said on the previous page, all variants of MPLS offer "good enough" resiliency for many applications. But that's not sufficient for power utilities, which require extremely high levels of resilience.

The power grid must be robust in the face of wildly fluctuating demand, technical faults, and adverse weather events. The communications network the grid relies upon must be similarly resilient. Even a minor communications outage could block real-time grid data, disrupting grid applications and making utilities blind to what's going on in their grids.

While other flavors of MPLS enable you to have a primary link and a backup link, only IP/MPLS provides multi-fault resiliency to restore traffic. Because IP/MPLS is aware of every other router and all routes, it can always find a path where one exists so that a substation is not islanded, even with a multi-fault scenario.

For example:

- In a substation with two fiber paths and two microwave paths, an IP/MPLS router will direct traffic to the last surviving microwave link when all other routes are down.
- If an intermediate router is down, IP/MPLS can automatically route traffic around it if alternate paths exist.

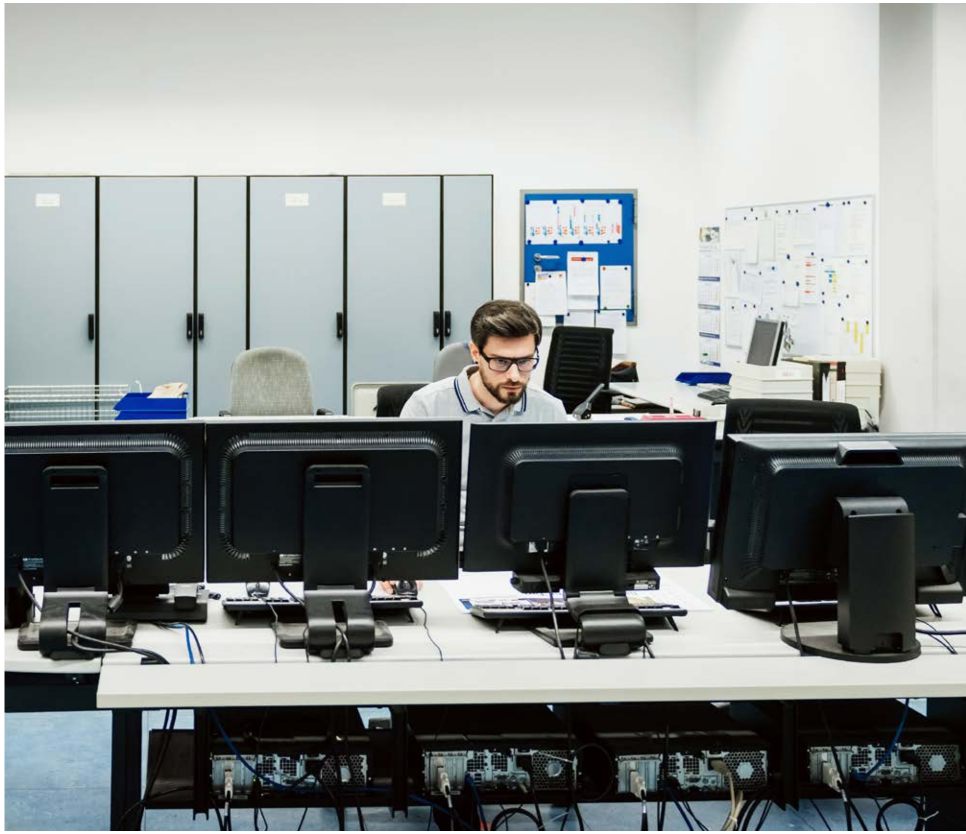
The IP layer in IP/MPLS adds several resiliency features to MPLS:

- IP Equal Cost Multipath (ECMP) enables multiple links to be established between routers, and for packets to be distributed across those links. This significantly improves bandwidth utilization across the network and helps to avoid congestion.
- Non-stop routing enables hot failover to a standby routing control card if there is a failure in the active card, without any service impact.
- Virtual router redundancy protocol (VRRP) means substation applications do not need to be aware of which router in the gateway router pair is active. If the active one fails, VRRP directs traffic seamlessly to the alternative router.

The superior capabilities of IP/MPLS

Multi-fault resiliency

IP/MPLS uses redundancy protection at all layers to restore traffic	
Service layer	• Pseudowire redundancy • Multi-chassis Link Aggregation Group (MC-LAG) / Multi-chassis Automatic Protection (MC-APS)
MPLS layer	• MPLS Fast Reroute/standby Label Switched Path (LSP) • Label distribution protocol (LDP) Equal Cost Multipath (ECMP) • Non-stop signaling
IP layer	• IP Equal Cost Multipath (ECMP) • Non-stop routing • Virtual Router Redundancy Protocol (VRRP)
Link layer	• 802.3ad Ethernet LAG • Microwave 1+1/2+0 • SONET/SDH 1+1
Equipment layer	• Dual DC power • Control redundancy • Fan redundancy • Hot swappable



The superior capabilities of IP/MPLS

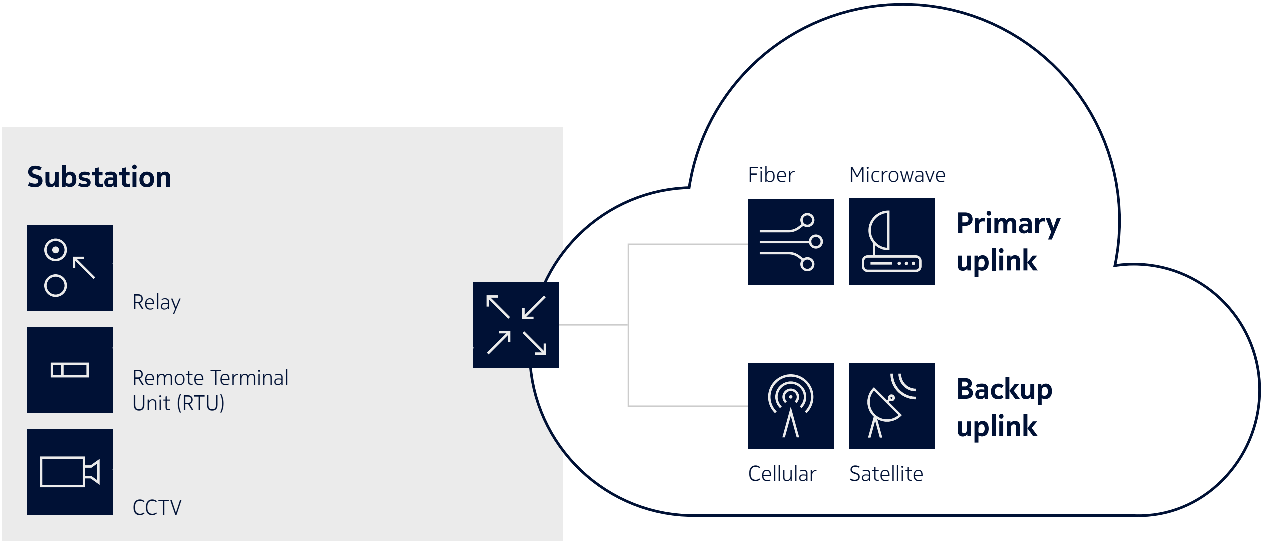
Cellular uplink support

It's not always possible to provision fiber or deploy a microwave link to reach a substation, especially for low voltage substations outside of urban areas.

Satellite or cellular connections can be used to connect these substations, but these technologies require IP transport. IP/MPLS can run natively over them.

For substations that are already connected, satellite or cellular communications can be used as a backup communications medium. This is particularly useful for applications that are not strictly time sensitive or that have low impact. As noted earlier, IP/MPLS can automatically failover to use the cellular or satellite link in the case of a major transmission system failure.

Cellular and satellite links can be used for backup on IP/MPLS



The superior capabilities of IP/MPLS

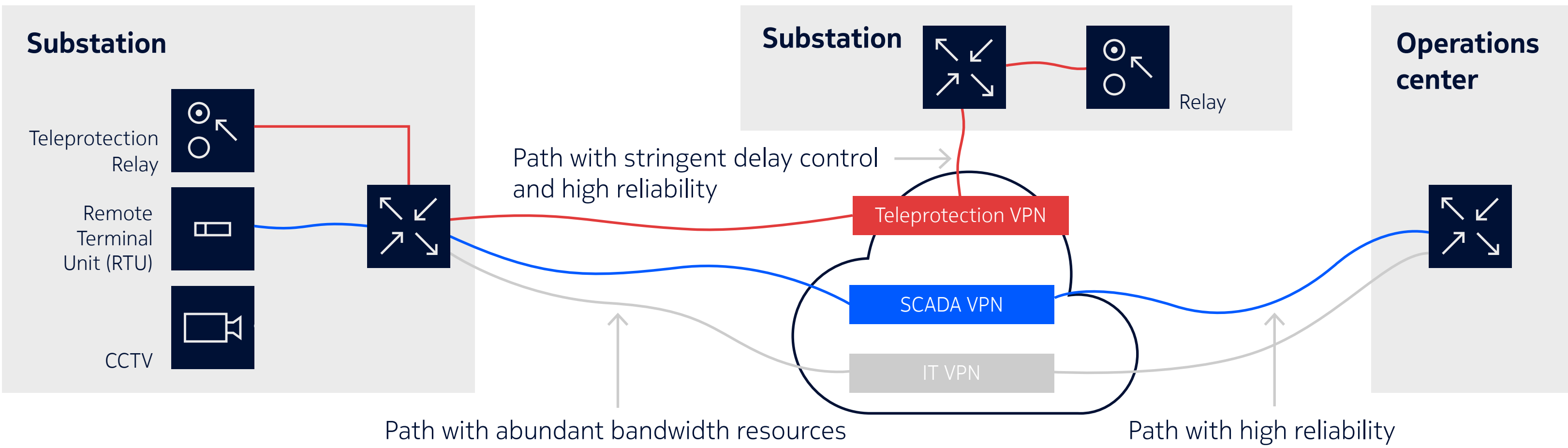
Traffic engineering

Not all grid applications have the same communications requirements. Teleprotection (which includes distance protection and differential protection) is safety critical and needs extremely high priority. SCADA traffic is critical for operations, but can tolerate more latency and jitter than teleprotection. CCTV might be considered essential, rather than critical, for operations, but it has a much higher bandwidth requirement than SCADA and teleprotection.

With IP/MPLS VPNs, utilities have complete control over the network path and resources used for each application. IP/MPLS can steer traffic along the same route with different priorities, or it can enable different routes to be used depending on the application. The teleprotection VPN, for example, should use the fiber route with the least number of hops, while the SCADA VPN could use a longer route as long as it is reliable. For teleprotection, strict paths will be configured, so the teleprotection data always follows the same path along specified nodes. Other data may be configured on loose paths where the network has more freedom to choose the optimal path.

With traffic engineering capability, IP/MPLS gives utilities greater control over their network resources, while ensuring that applications get the network resources they require.

IP/MPLS enables utilities to control the network path for each application



The superior capabilities of IP/MPLS

Scaling

Typically, in each power utility substation there are multiple application services to be provisioned. These include voice, administrative data, CCTV, fault recorders, SCADA systems, and protection systems. Often there are more than ten application services to be provisioned in each substation. Each one needs an MPLS label switched path (LSP), which is a virtual tunnel between two MPLS routers, one inside the substation and the other in another substation or the operations center. Because power utility networks often use ring topologies (some even use ring of rings), the LSPs need to traverse a large number of nodes before reaching the destination. This can easily result in several hundred LSPs being provisioned in the access rings of the power utility network, which is cumbersome process. It can even be beyond what MPLS platforms can support.

IP/MPLS routers do not have this problem because they allow multiple services to be carried over a single LSP, which greatly reduces complexity and scaling issues.

No need for standalone IP routers

New applications such as synchrophasors, Voice over IP (VoIP), and CCTV require IP.

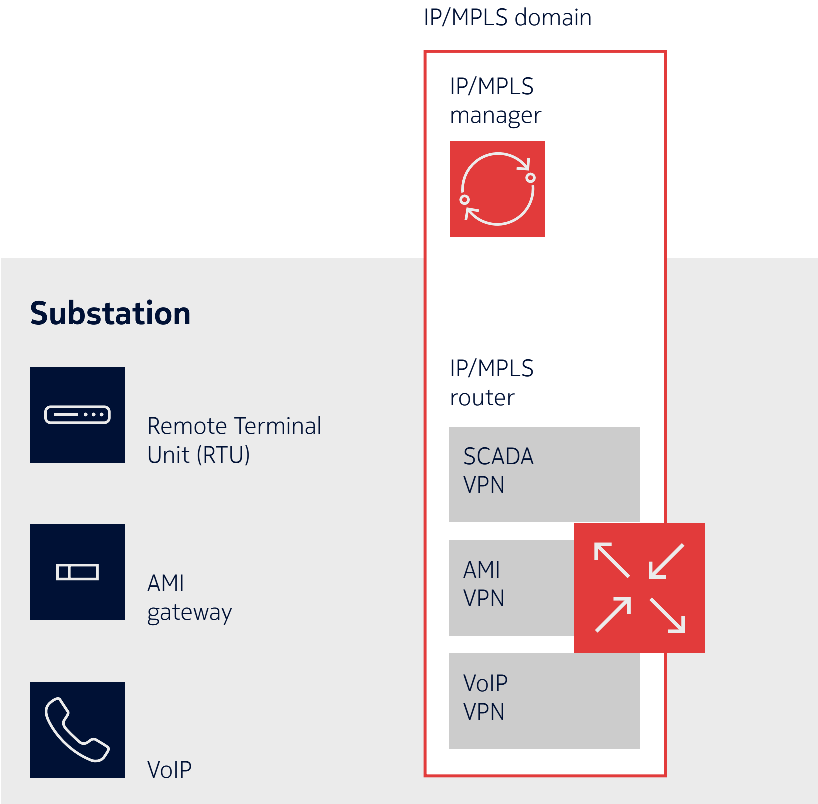
If you use a variant of MPLS that does not have IP integrated in it, you need to deploy additional routers to provide the IP connections for these applications separately. This increases network management and equipment costs, uses more power, and takes up more space. It also increases the risk of IP applications being disrupted because the IP layer is not aware of the transport layer underneath, so it can't discover the multi-layer topology and react quickly in the event of transport link failure or changes.

Alternatively, a single IP/MPLS router can offer segregated VPNs for multiple services, with a single unified manager overseeing all the VPNs. This avoids the risks of disjointed IP and transport layer behavior.

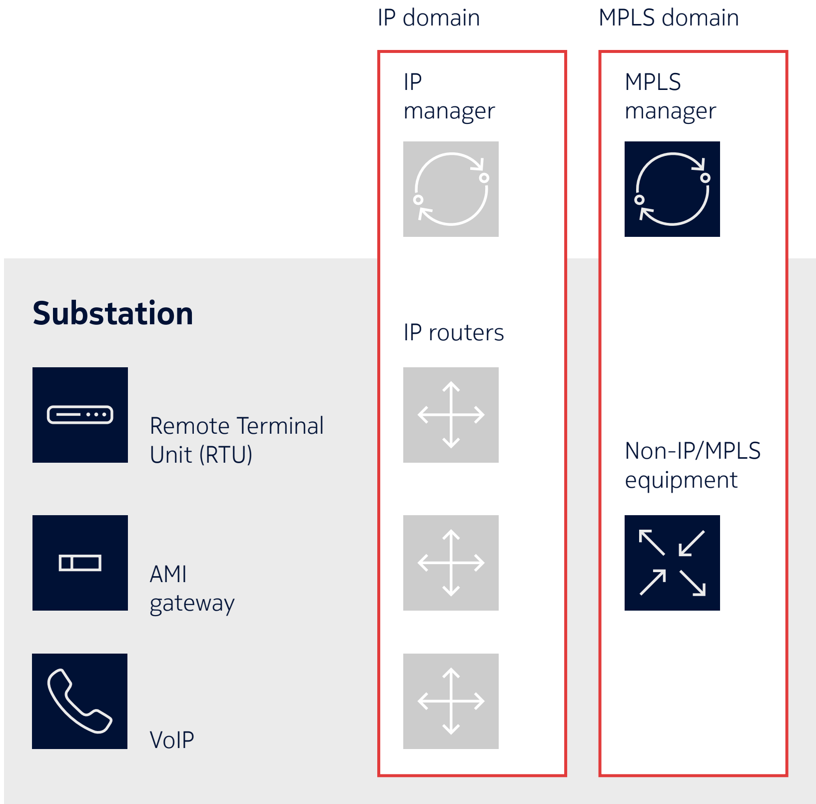
The superior capabilities of IP/MPLS

No need for standalone IP routers

Using IP/MPLS, a single integrated router serves multiple applications



Using other MPLS variants, separate IP routers are required for each application



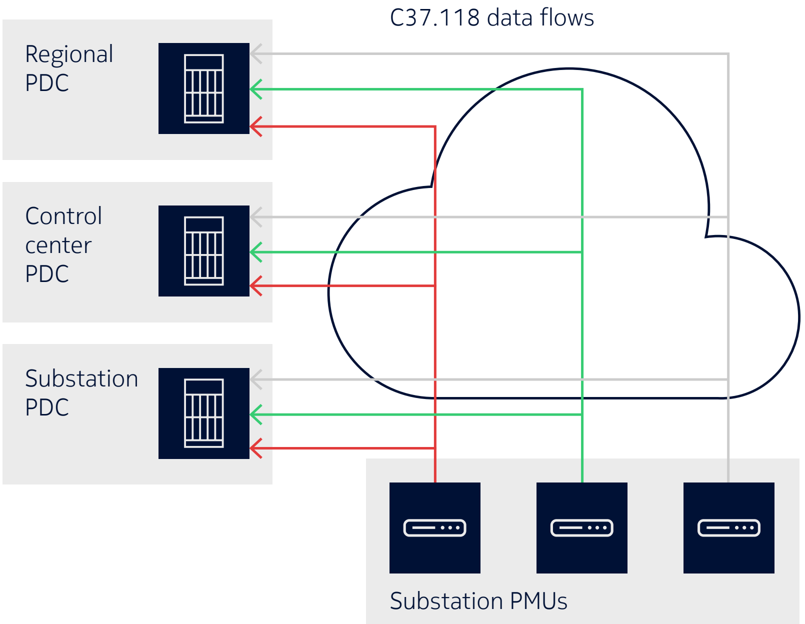
The superior capabilities of IP/MPLS

Support for multicast

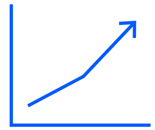
Data coming from the substation may be needed in multiple locations. Applications such as synchrophasors send data from phase measurement units (PMUs) in substations to the substation Phasor Data Concentrator (PDC), control center PDC, and regional PDC, for example. CCTV footage could be used for real-time analytics in one location, monitored in a separate control center, and backed up in a datacenter in a third location.

IP/MPLS supports IP multicast at scale, which means data is replicated only where necessary, as shown below.

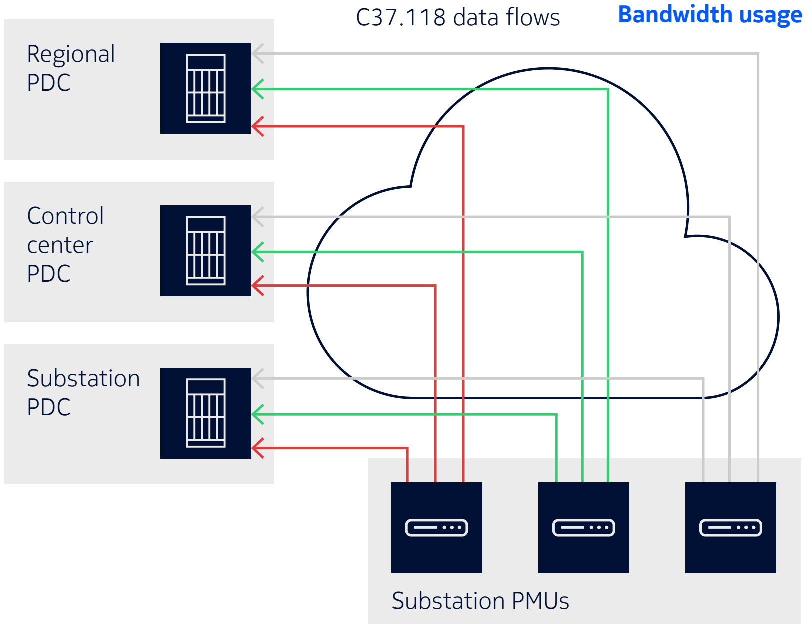
Using IP/MPLS with P2MP multicast trees



Non-multicast alternative with multitudes of replicated flows



Bandwidth usage



The superior capabilities of IP/MPLS

Support for multicast

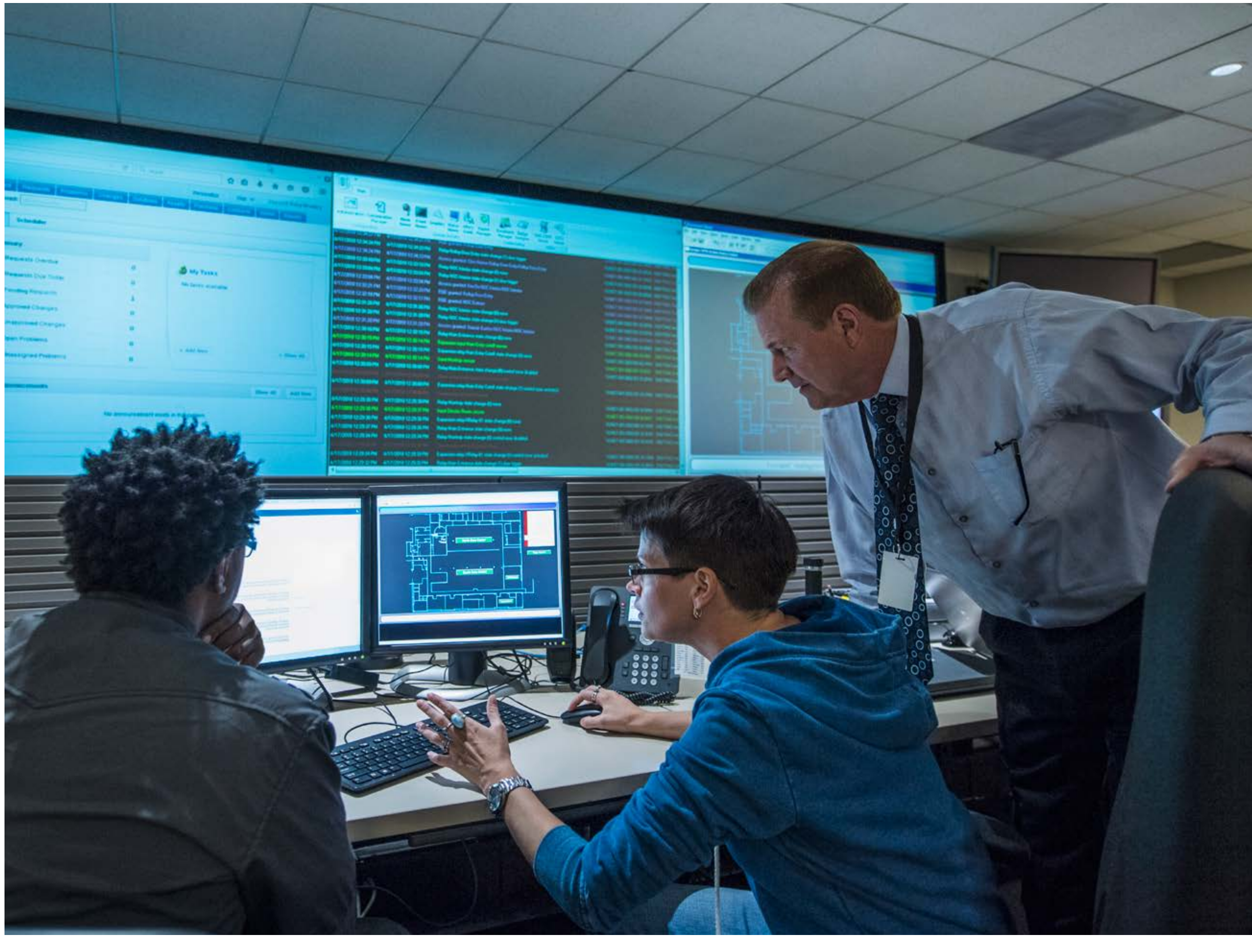
A networking solution that does not support IP multicast would have to duplicate the data for each destination, for the entire journey through the network.

The bandwidth consumed adds up fast: if you have three destinations for the traffic, you'll need three times the bandwidth if your networking solution is not multicast aware, compared to using IP/MPLS. Here's a worked example:

Bandwidth requirement comparison	
Number of sources	100
Bandwidth per source (CCTV)	3 Mbps
Number of receivers	3

	Point-to-point VPN	**Multicast VPN**
Total bandwidth	900 Mbps	300 Mbps

Multicast VPN bandwidth saving	**66%**



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The superior capabilities of IP/MPLS

First line of cyber defense

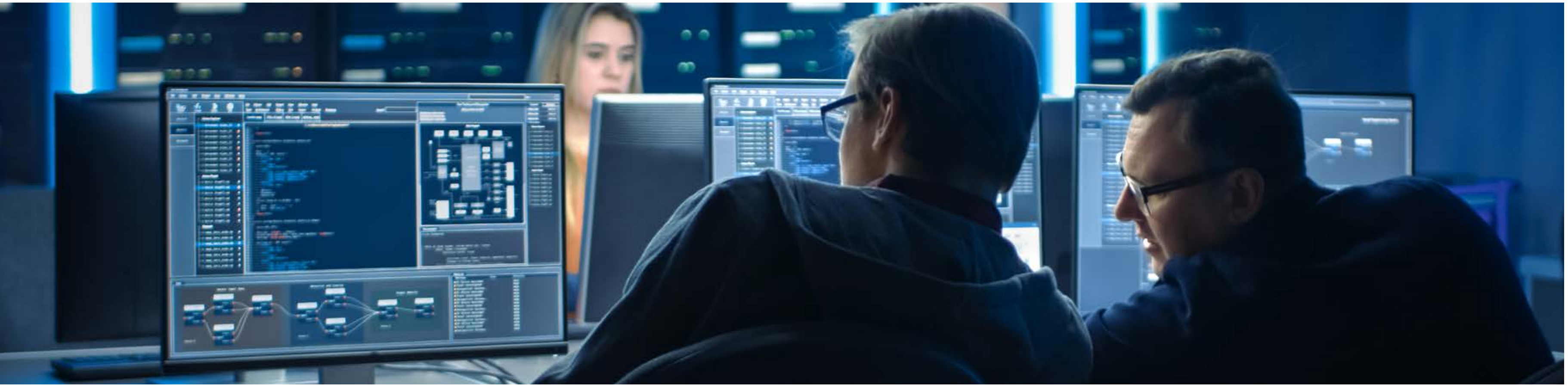
Because IP/MPLS is an active participant in the IP layer, the network can be the first line of defense against cyberattacks.

By using IP/MPLS VPNs, you can segregate traffic for different services. This prevents any attackers who get in from traversing from one service to another.

A firewall can be integrated in the IP/MPLS node that is able to block illicit flows at layer 2 (data link layer), layer 3 (network layer), or layer 4 (transport layer). Together with IP filtering, a robust cyber defense perimeter comprising IP/MPLS routers can be deployed. Additionally, with traffic rate-limiting capability, IP/MPLS routers provide distributed denial of service (DDoS) mitigation.

Nokia IP/MPLS also harnesses Network Group Encryption (NGE) for universal encryption, safeguarding MPLS services (layer 2 and 3) and control traffic. NGE enables encryption tunnels to be centrally managed in groups, greatly simplifying the process compared to a point-to-point security technology such as IPSec. It also has less overhead and therefore reduces latency and bandwidth utilization.

By way of contrast, MPLS solutions that are not IP aware are not able to be part of the cyber defense, and are not able to intelligently intervene if there is an attack. An additional cyber defense layer would be needed in the network, which increases both costs and management complexity.



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Towards the future

As well as meeting the needs of today's electric grid, IP/MPLS provides a solid foundation for the future. Because of the integrated IP layer, IP/MPLS extends easily to cover different data sources and new applications.

Field Area Networks (FANs) for the distribution grid are today based on narrowband, proprietary wireless technology. They can no longer serve the growing need of distribution automation and the proliferation of DERs. Using IP/MPLS, utilities can use broadband cellular communications to connect to distribution automation devices and Distributed Energy Resources (DERs). Only IP/MPLS provides a seamless service for connecting machines and applications across the FAN and the Wide Area Network (WAN).

The IP integration in IP/MPLS also enables end-to-end connections from sensor to cloud, which is important for applications such as asset management, predictive maintenance, and video analytics. The dynamic control plane in IP/MPLS with Border Gateway Protocol 4 (BGP-4) enables graceful internetworking with the datacenter switch fabric. An IoT VPN, for example, could connect IoT on poles and extend the connection beyond the IP/MPLS network with the analytics application residing in the cloud domain.

As the grid expands with more distributed generation, new IEDs, and smart grid applications, the communications network too must adapt and become dynamic. IP/MPLS can support network automation, to help utilities provision and optimize network resources quickly and easily.

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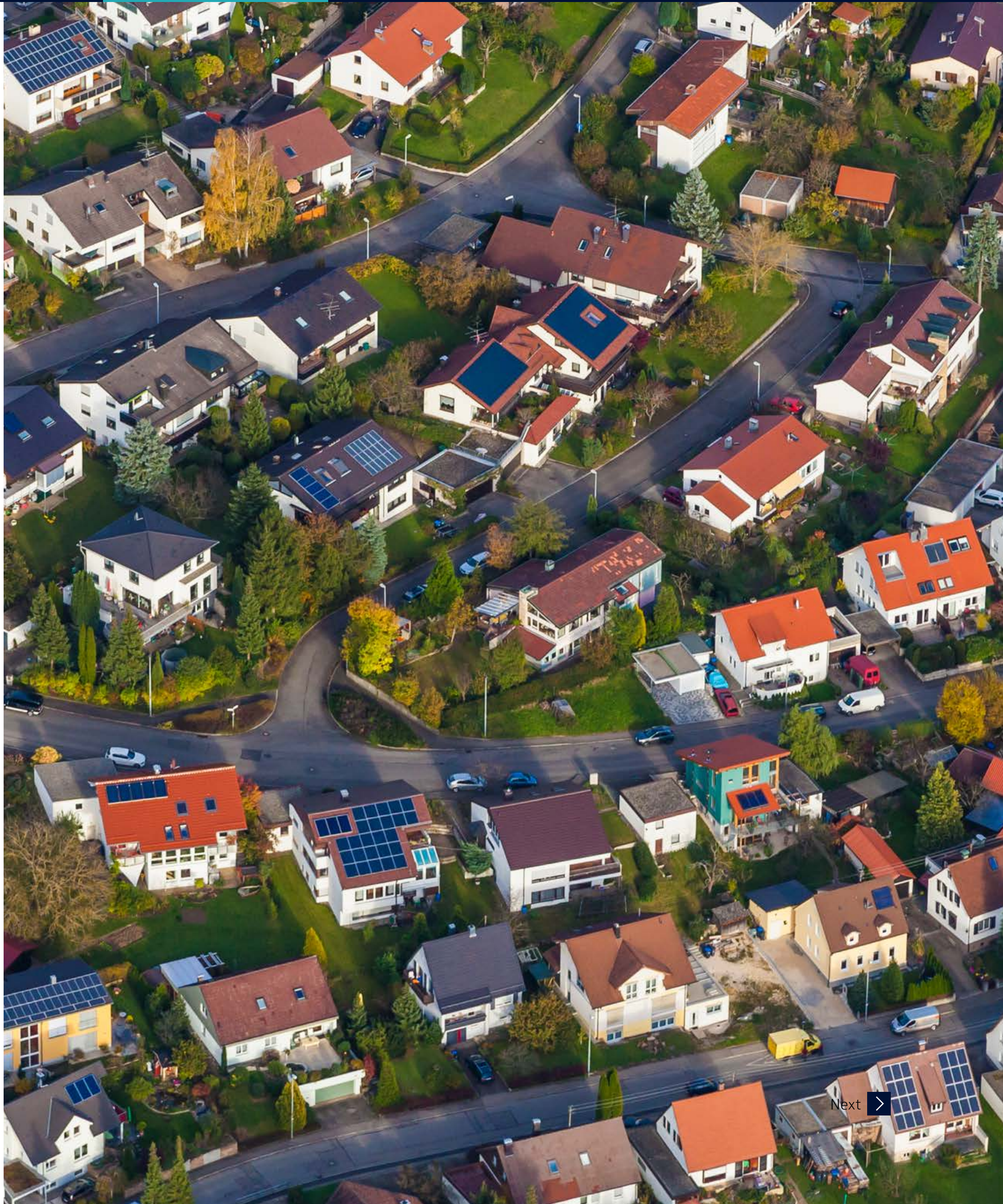
Conclusion

While all flavors of MPLS have a useful core feature set for basic grid communications needs, only IP/MPLS can satisfy the demanding full requirements of today's power grid. The IP layer integrated in IP/MPLS gives you flexibility over your network topology, self-healing capabilities with multi-fault resiliency, and freedom to hop on cellular and satellite links. IP/MPLS enables the latest applications, with support for multicast for synchrophasors and CCTV, and the ability to incorporate cyber defense solutions. With IP/MPLS, you have full control to traffic engineer network paths, and no need for standalone IP routers inside substations.

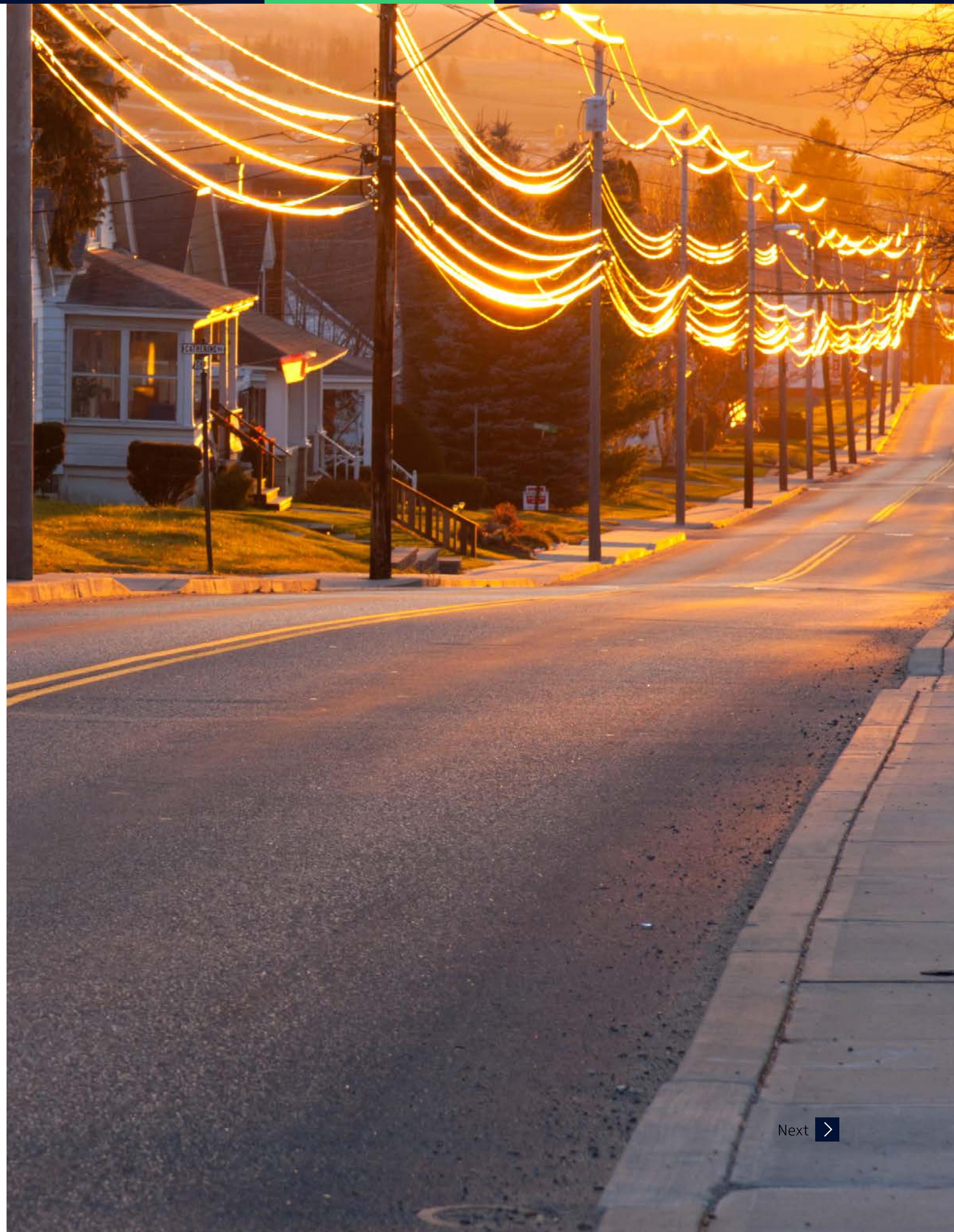
IP/MPLS is ready to meet the future needs of the grid, with the ability to extend from FANs to the cloud.



Nokia helps utilities to modernize the grid

Nokia Critical WAN for Power Utilities enables proven teleprotection, SCADA, and legacy application migration. With it, you can build an IP/MPLS communications network that helps increase the efficiency, safety, reliability, and sustainability of the grid. Critical WAN for Power Utilities supports protection, control, and telemetry for critical real-time grid applications. It provides a foundation for smart grid, Internet of Things (IoT), and other new business applications. More than 200 power utilities globally have trusted Nokia to build their critical WAN based on IP/MPLS.

Find out more



What do utilities say?

“ At SAPN, we recognized that we needed to be proactive in migrating away from the PDH/SDH networks that were nearing the end of their technology lifecycle. Waiting till the last moment could have introduced risk to our mission critical services. We chose IP/MPLS because it allowed convergence of all our existing and future communications services, including current differential protection and distance teleprotection. This technology is backed by mainstream telecommunications vendors, unlike other technologies. We found that the key to our success was thorough testing across all of our protection relay types in conjunction with our protection teams and ensuring that the IP/MPLS network was designed upfront for the stringent requirements of teleprotection. In fact, we found that the IP/MPLS network operated more reliably with fewer bit error rate alarms compared with the previous PDH/SDH network in some instances. ”

Geof Axon
Telecommunications Planning & Engineering Manager
SA Power Networks
Australia

“ At RTE, as part of our INUIT project, we have chosen IP/MPLS to migrate all of our existing services including teleprotection and SCADA from TDM technology to packet technology. This ensures the highest availability of our critical services while providing great flexibility to adopt new IP-based applications on over 600 substations on our network. ”

Sebastien Henry
Chief Information Officer, RTE
France

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Glossary

BGP	Border Gateway Protocol
CCTV	Closed Circuit Television
DER	Distributed Energy Resource
DERMS	Distributed Energy Resource Management Systems
FAN	Field Area Network
G-MPLS	Generalized Multi-Protocol Label Switching
IEDs	Intelligent Electronic Devices
IoT	Internet of Things
IP	Internet Protocol
IP/MPLS	Internet Protocol / Multi-Protocol Label Switching
LSP	Label Switched Path
MPLS	Multi-Protocol Label Switching
MPLS-TP	Multi-Protocol Label Switching - Transport Profile
OAM	Operations, Administration, Management
PDC	Phasor data concentrator
R-GOOSE	Routed Generic Object Oriented Substation Events
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical NETwork
VPN	Virtual Private Network
WAN	Wide Area Network

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At Nokia, we create technology that helps the world act together.

As a B2B technology innovation leader, we are pioneering the future where networks meet cloud to realize the full potential of digital in every industry.

Through networks that sense, think and act, we work with our customers and partners to create the digital services and applications of the future.

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