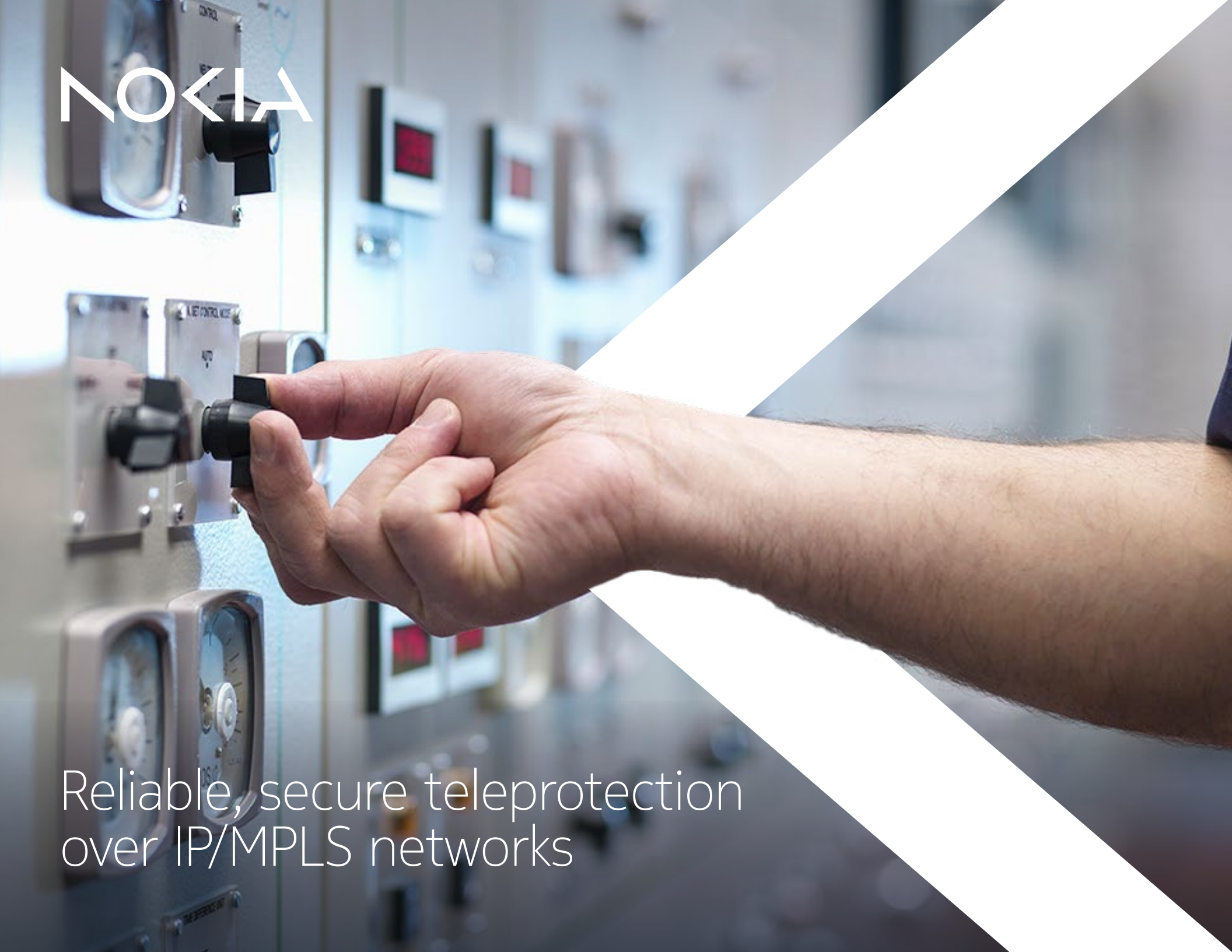


Reliable, secure teleprotection over IP/MPLS networks

Migrating teleprotection* to a converged packet-based network

Operating a reliable, efficient and stable electric grid requires safeguards. In particular, fault detection and subsequent rapid corrective action are extremely important. Teleprotection, the most stringent grid application transported over utility communications networks, addresses this issue. Protective relays, upon detection of abnormal conditions such as short circuits, trip circuit breakers to disconnect the faulted section. This prevents problems from rippling through the grid, protecting crucial, expensive assets such as generators and high voltage transformers from potentially catastrophic damages.

As utilities modernize their communications and move all operations traffic onto a converged packet-based Internet Protocol (IP) network, it is imperative that teleprotection applications continue to protect the grid with no performance compromise.

This eBook examines how utilities can use the Nokia 7705 Service Aggregation Router (SAR) and the Nokia Wavence microwave in a converged network based on Internet Protocol/Multiprotocol Label Switching (IP/MPLS) to reliably transport teleprotection traffic with assured protection performance.

*Teleprotection includes differential protection

Traditional teleprotection communications

TDM networks, based on PDH, SONET and SDH, have reliably provided the essential communications channel between relays. However, they are passing beyond end of support and are not capable of efficiently supporting new smart grid applications.

IP/MPLS-based teleprotection communications

Networks utilizing IP/MPLS provide the full benefits of TDM communications, while significantly expanding capability and bandwidth efficiency for new packet-based protection communications and smart grid applications.

IP/MPLS network fundamentals to support teleprotection

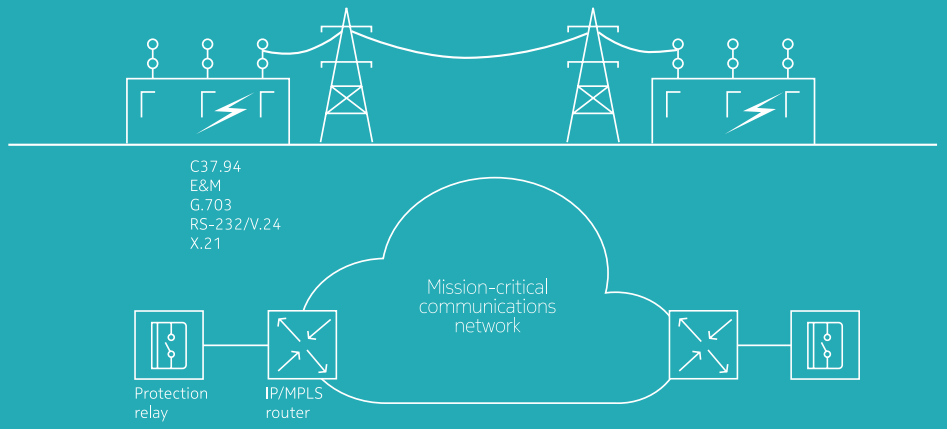
Native connection to prevalent relay interfaces

Teleprotection equipment traditionally connects to the communications network using a range of interfaces such as IEEE C37.94, G.703, E&M, RS-232/V.24 and X.21. While newer protective relays are configured with Ethernet interfaces, the network must also support a multitude of already-deployed relays.

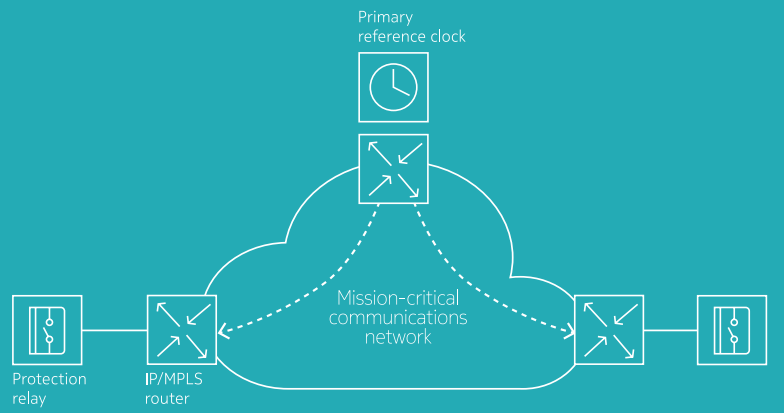
Precise end-to-end network synchronization

Since relay interfaces are TDM-based, it is crucial that they operate with the same clock rate. This requires a precise network-wide synchronization distribution. You can achieve this using synchronization technologies, including GPS, IEEE 1588v2, line timing (with synchronous Ethernet and PDH/SDH/SONET), and timing over packet (ACR and DCR) to attain frequency synchronization. IEEE1588v2 can also support time synchronization.

Carrying teleprotection over a communications network



Distributing synchronization to network edge for protective relays



Reliable, secure teleprotection over IP/MPLS

To attain reliable, secure teleprotection requires more than just the two fundamentals explained above. It is crucial for IP/MPLS to provide reliable and secure critical connectivity between relays with a consistent, high quality of service (QoS), characterized by deterministic delay, jitter and delay symmetry. Major considerations include:

- **Delay and jitter:** Packets associated with teleprotection communication are classified as high-priority traffic to ensure that the latency budgets are constantly met and network jitter is minimized. At the network egress, a playout buffer absorbs incurred jitter.
- **Delay symmetry:** Symmetric delay between the forward (go) and reverse (return) paths is pivotal for differential protection to prevent false trips, which can cause unnecessary power delivery disruption.
- **Hitless resiliency:** Teleprotection redundancy is key to grid disturbance prevention and safety. IP/MPLS supports hitless active/active redundancy switching, complementing "A"/"B" group relaying system protection.
- **Security:** While the tunnel- and virtual private network (VPN)-based MPLS services are inherently secure, increasing cyberattack sophistication necessitates additional safeguards on the confidentiality, integrity and authenticity of teleprotection traffic.

Attaining delay symmetry for differential protection

Attaining delay symmetry is more than assuring that the go and return paths take the same route. Network jitter also can cause delay asymmetry. Watch this video to find out how Nokia asymmetric delay control (ADC), an adaptive IP/MPLS QoS capability, can restore delay symmetry.

Achieving hitless resiliency for teleprotection

Nokia IP innovation brings not just hitless resiliency for safety-critical teleprotection traffic, it upkeeps consistent latency and symmetry after redundancy which are pivotal to differential protection.

Safeguarding the relay communications channel

Nokia network group encryption (NGE), with its native capability to protect IP and non-IP TDM/Ethernet traffic, is the ideal encryption technology to protect relay traffic today (TDM) and tomorrow (GOOSE and 87L over Ethernet). Watch this video to find out more.

Teleprotection support with microwave packet radio

Utilities have long used point-to-point microwave radios to provide transport for teleprotection traffic. As part of their migration to a packet network for all operations traffic, utilities have deployed the Nokia Wavence since its initial release in 2009. Its ability to support both TDM and Ethernet with proven low-latency transport enables a graceful migration, while built-in encryption capabilities protect confidentiality, authentication and data integrity.

Nokia's Wavence is approved for deployment by a large U.S. utility with a maximum transmission path of 345 miles (550 km), incorporating 11 links of Wavence, fiber, cross-connect panels, channel banks and protective relays. Testing demonstrated compliance to the utility's 8ms end-to-end latency budget, with a subsequent 24% latency improvement upon retrofitting protective relays with Ethernet-based interfaces.

Live deployment and performance evaluation

Nokia's 7705 SAR and 9500 MPR have been extensively validated through live deployment in many power grids and third-party industry labs utilizing numerous manufacturers' protective relays. The experiences of AltaLink (Canada) to Creos (Luxembourg) and Tata Power-DDL (India) illustrate the major benefits.

Case Study: Ameren achieves greater reliability and sustainability with a private IP/MPLS fiber network

Case Study: Creos Luxembourg saves time and money with IP/MPLS network

Case Study: ELFEC modernizes communications with fully redundant IP/MPLS for increased grid reliability

Case Study: Tata Power-DDL builds next gen smart grid communications network

Test report: Teleprotection over IP/MPLS validation by Schneider Electric

Test report: Teleprotection over IP/MPLS validation by University of Strathclyde

Test report: Teleprotection over packet microwave validation by Burns and McDonnell

Technical paper: Validating secure and reliable IP/MPLS communications for current differential protection

Ameren, a power utility across Illinois and Missouri, has been running IP/MPLS communications over fiber since 2017, connecting 420 substations and other locations in the transmission grid, supporting grid applications including current differential relays and supervisory control and data acquisition (SCADA).

Creos, the power utility of Luxembourg, has been using a Nokia IP/MPLS network since 2013, supporting current differential protection, along with SCADA, operational voice, private mobile radio, closed-circuit television (CCTV), advanced metering infrastructure (AMI) and other data traffic.

Conclusion

Power utilities rely on resilient, secure communications to support critical grid applications that monitor, protect, control and maintain the grid. The Nokia mission-critical IP/MPLS network solution enables power utilities to consolidate all of their OT and IT applications over a converged packet network without performance degradation.

This new converged network enables utilities to protect their existing investment in teleprotection equipment, while becoming ready to usher in a new generation of IEC61850/GOOSE-based grid applications. It allows them to enhance their grid efficiency and become climate-neutral in the face of an evolving energy landscape without jeopardizing safety, security or reliability.

Nokia leverages cutting-edge technologies, along with a broad and deep experience in the energy segment, to help utilities build better, new-generation IP/MPLS, packet optical and microwave networks. This enables utilities to build better, safer and sustainable power grids for the future. Nokia is here to help make reliable, secure teleprotection over packet networks a reality.

What Nokia delivers

A field-proven solutions path based on established teleprotection standards and interfaces

Nokia offers utilities a comprehensive packet communications solution for teleprotection that has been lab-validated and deployed globally for utility grid network support.

7705 Service Aggregation Router (SAR)

7705 SAR provides a comprehensive suite of teleprotection features that support both traditional and next-generation teleprotective relays. Routers natively support commonly used teleprotection interfaces, including IEEE C37.94, E&M, G.703, RS-232/V.24, and X.21, along with Ethernet for next-generation relays. Failover capabilities in real-world operations met or exceeded SONET/SDH standards for traffic re-routing (<50 ms) and total control of the bandwidth required per application.

Asymmetric delay control (ADC)

ADC is an innovative QoS mechanism that Nokia offers on our 7705 SAR IP/MPLS solution for differential protection to remedy asymmetric delay between the go and return paths caused by network jitter.

Hitless redundancy switching

Active/active path redundancy on 7705 SAR replicates differential protection traffic over two diverse paths. It recovers from primary path fault hitlessly with consistent latency and symmetry.

Network group encryption (NGE)

Nokia NGE on the 7705 SAR IP/MPLS solution protects all IP-based and non-IP-based (e.g. TDM and IEC61850 GOOSE/SV) grid applications traffic seamlessly. In addition, NGE also safeguards IP/MPLS network control traffic.

Reliable MPLS security

Nokia IP/MPLS products provide strong mechanisms which securely protect the management, control and data planes of mission-critical utility communications networks.

Wavence microwave packet radio (MPR)

Nokia's Wavence facilitates legacy-to-packet transformation that includes teleprotection support over a common, converged packet network. It also offers the highest functionality with the smallest footprint, addresses any network topology, and is highly scalable and resilient. Integrated IP/MPLS solutions with the 7705 SAR are available.

Nokia Bell Labs consulting

Nokia Bell Labs works as a trusted partner for connecting deep technology insights to critical financial decisions. Teleprotection support is a key dimension of our network and operations transformation consultative engagements globally.

Acronyms

ACR:	Adaptive clock recovery
ADC:	Asymmetric delay control
AMI:	Advanced metering infrastructure
CCTV:	Closed-circuit television
DCR:	Differentiated clock recovery
E&M:	“E” lead and “M” lead analog signaling
GOOSE:	Generic object-oriented substation events
GPS:	Global positioning system
ICT:	Information and communication technology
IP:	Internet protocol
IEEE:	Institute of Electrical and Electronics Engineers
ITU:	International Telecommunication Union
km:	Kilometers
MPLS:	Multiprotocol label switching
MPR:	Microwave packet radio
ms:	Milliseconds
NGE:	Network group encryption
NTP:	Network time protocol
OAM:	Operations, administration and maintenance
QoS:	Quality of service
PDH:	Plesiochronous digital hierarchy
SCADA:	Supervisory control and data acquisition
SDH:	Synchronous digital hierarchy
SONET:	Synchronous optical networking
TDM:	Time division multiplexing
VPN:	Virtual private network

Resources

Case studies:

- Ameren achieves greater reliability and sustainability with a private IP/MPLS fiber network
- Creos Luxembourg saves time and money with IP/MPLS network
- ELFEC modernizes communications with fully redundant IP/MPLS
- Tata Power-DDL builds next gen smart grid communications network

eBook:

- Ensuring cybersecurity for utility mission-critical communications

Technical paper:

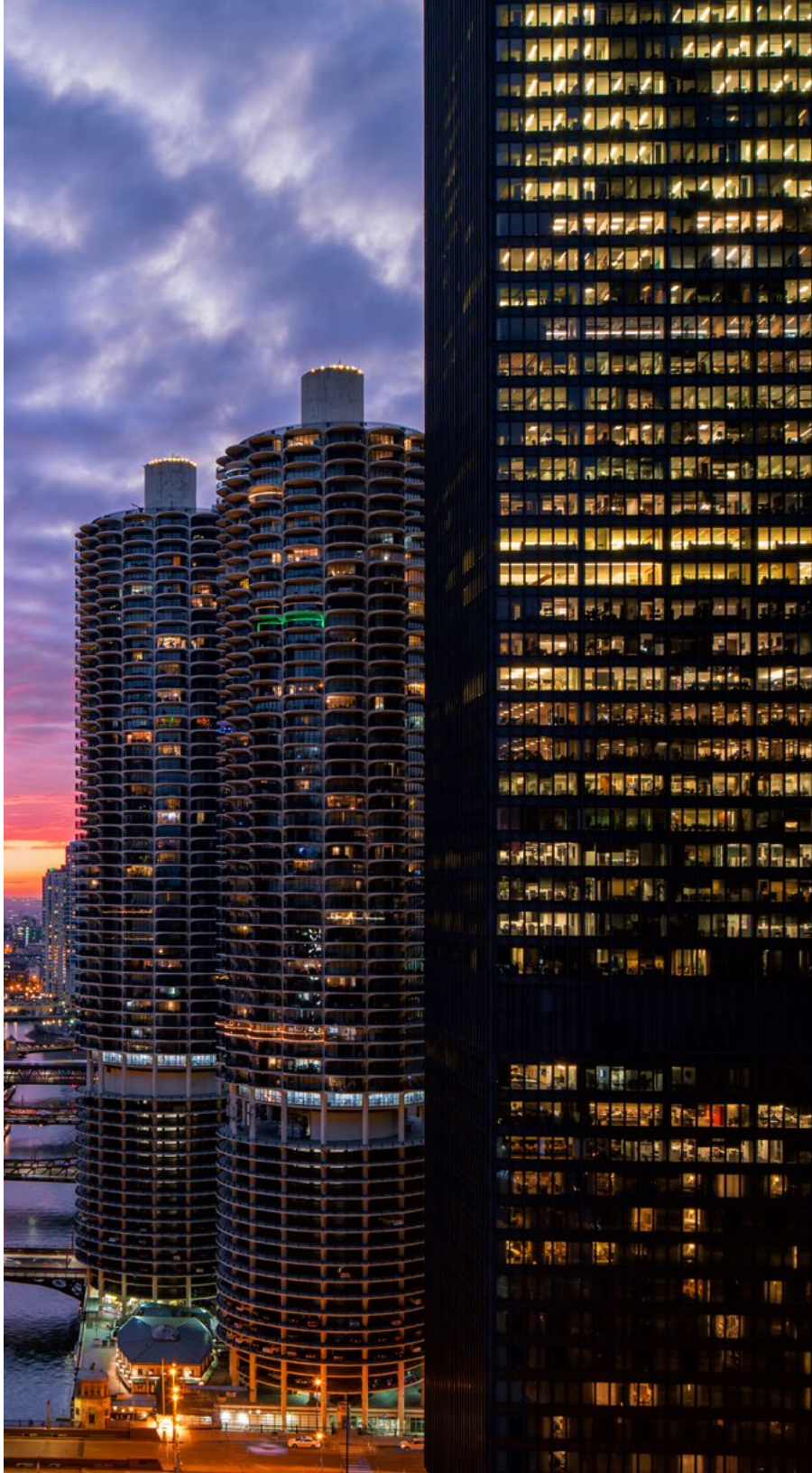
- Validating Secure and Reliable IP/MPLS Communications for Current Differential Protection

Test reports:

- Teleprotection over IP/MPLS validation by Schneider Electric
- Teleprotection over IP/MPLS validation by University of Strathclyde
- Teleprotection over packet microwave validation by Burns and McDonnell

Videos:

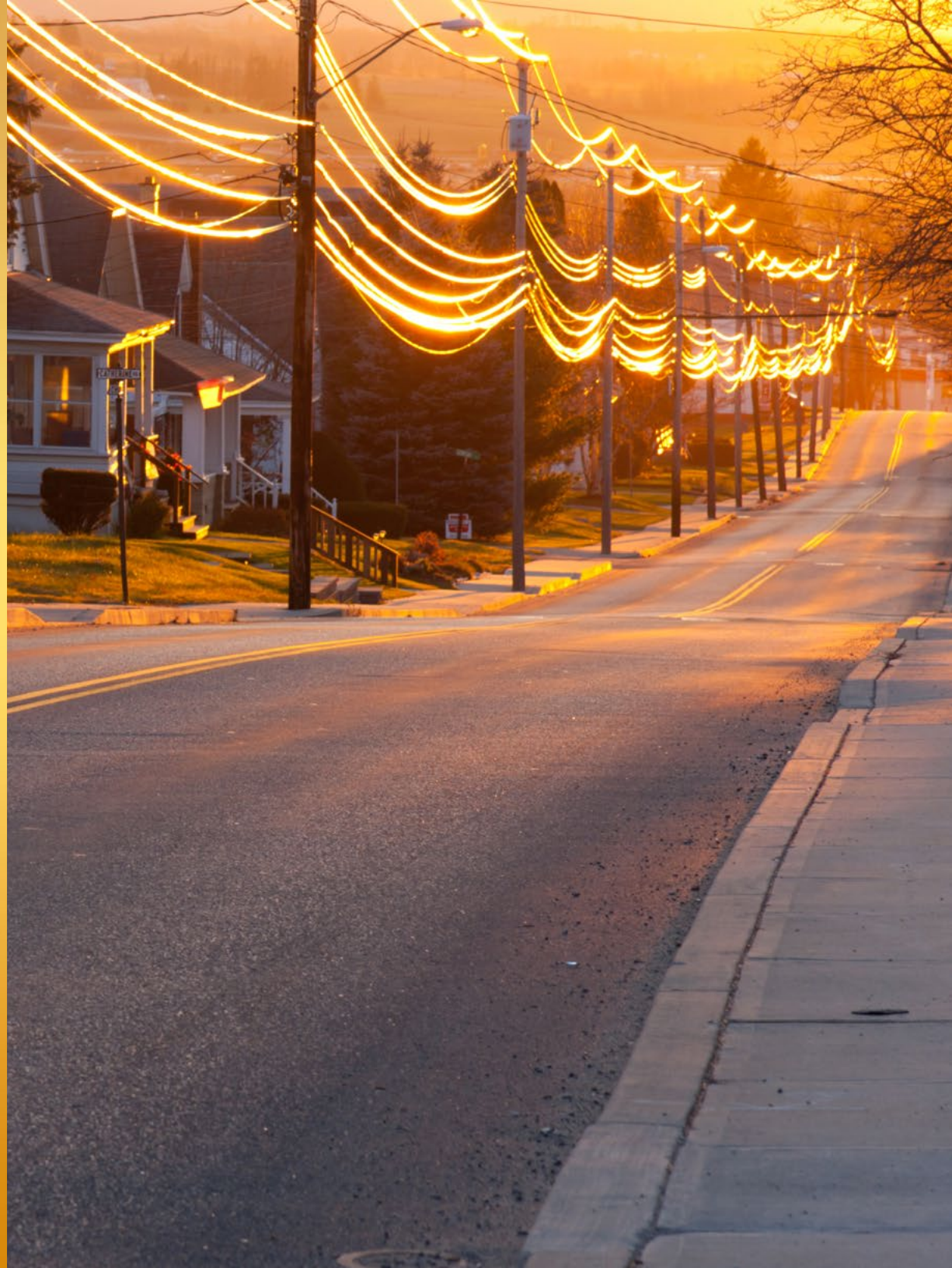
- Reliable teleprotection over IP/MPLS with Nokia
- Network group encryption secures IP/MPLS networks



Let us help with your teleprotection transformation.

As the world's mission-critical connections specialist, we bring our leadership and expertise in communications technology and network security to meet the most demanding requirements of power utilities. Our solutions help create an intelligent, responsive and adaptive communications network.

Talk to Nokia about how we can help build and secure your power utility communications network at all levels. For more information, visit networks.nokia.com/power-utilities.



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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.