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Did you know that GOOSE accelerates your communication aided protection scheme?

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Abstract

In the past, the application of communication aided protection schemes (teleprotection) was limited because of the limited availability, high cost and decent performance of communication channels. Even if protection for important lines was communication aided, extensions added to the system and their related protection were often not included in such schemes. But exactly the complexity added by such extensions and new challenges to protect these modified systems made the application of protection communication even more desirable.

Conventional protection communication

Before the introduction of fast peer-to-peer messaging in protection relays, dedicated communication equipment was wired to the binary I/Os of the relays. The communication equipment had to make optimal use of communication channel which often provided only small bandwidth, so only a few bits could be transmitted between the relays. The configuration of the communication equipment was tightly related to the information to be transmitted.

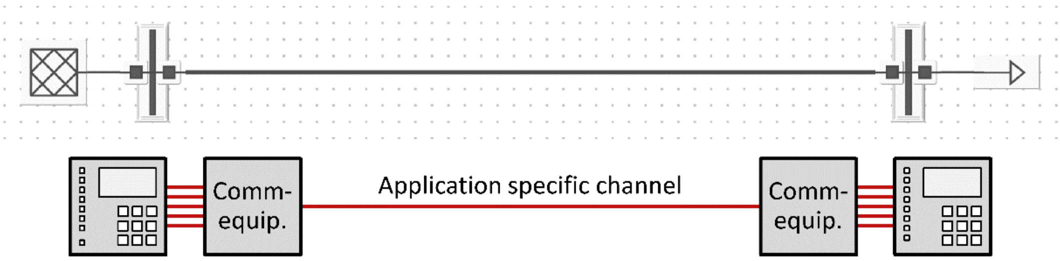

Figure 1: Conventional communication aided line protection scheme

The communication could be established over a power line carrier or a pilot wire and the communication equipment were essentially special modulators / demodulators that were installed in matched pairs.

But even when the underlying communication infrastructure was more sophisticated and standardized (e.g. SONET/SDH), the equipment for protection communication from different manufacturers was not interoperable in most cases. IEEE C37.94 intends to resolve this, but equipment based on this standard is mostly used in the power utility field only and thus rather exotic.

Modern protection communication via WANs

Nowadays, GOOSE messaging is the state-of-the-art for peer-to-peer communication between IEDs. Although this mechanism was initially designed for use within local networks, it is ideally suited for teleprotection purposes as well.

But even with the upcoming availability of IP networks, GOOSE messaging could not be directly used for teleprotection because it is OSI network layer 2 traffic and as such not routed via an IP WAN between different local networks. Therefore, some network routers designed for the use in the power utility field with IEC 61850 provide features to wrap GOOSE messages into IP packets and transmit them over a WAN.

Recently, MPLS (multi protocol label switching) networks became evaluated and deployed in power utilities. Such networks provide connectivity for all kinds of services within a utility, not just teleprotection. This technology provides also the option to engineer paths between substations that can transport layer 2 traffic through the WAN, thus effectively extending the LAN into the remote substation. IEDs communicating via GOOSE can exchange information with remote device just as if they were connected to the same local network.

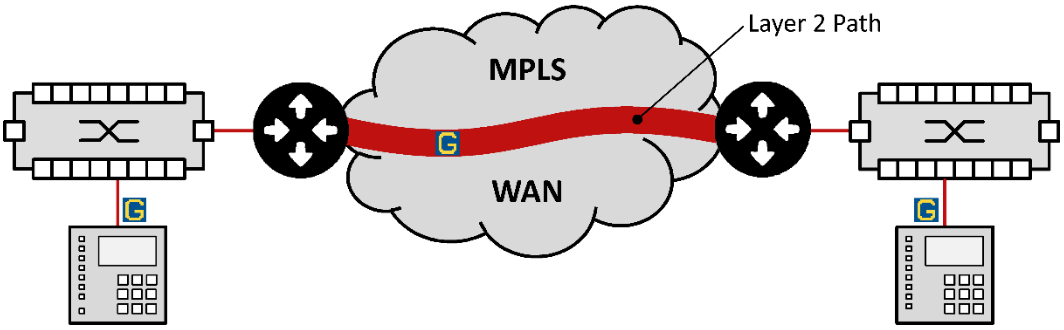

Figure 2: GOOSE communication between substations via a layer 2 path

Such layer 2 paths in MPLS networks provide good performance and quality of service. They need to be specifically engineered and typically no dynamic routing is involved to find the paths for the packets. Thus, such paths are more deterministic than routes via IP networks.

Nevertheless, the availability of IP networks is higher than the availability of MPLS networks and the desire to send GOOSE messages over IP network still persists. IEC 61850-90-5 defines such a “routable GOOSE”, abbreviated as the “R-GOOSE”.

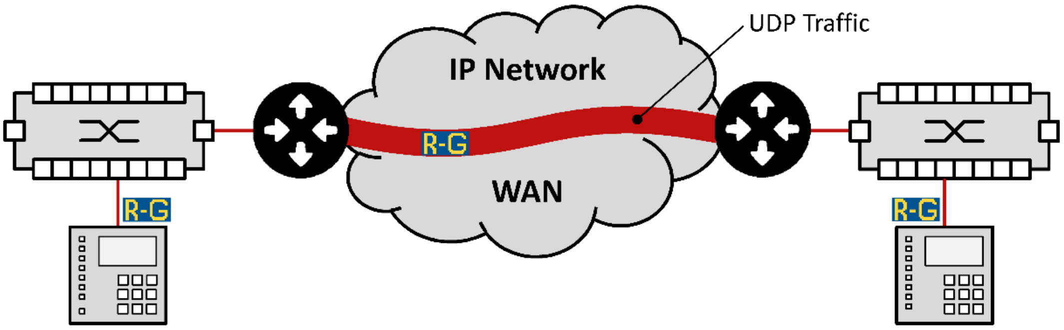

Figure 3: Routable GOOSE communication between substations via an IP route

The functionality of the special routers mentioned above is now performed by the network stack in the IEDs that can send and receive such R-GOOSE messages. This allows teleprotection by utilizing just standard IP networking infrastructure and equipment.

By utilizing the utility WANs, which become always more widely deployed and increasingly performant, the possibilities to apply communication aided protection and automation functions are greatly extended.

A new scale of performance

To assess the performance of a communication channel over a WAN, e.g. for teleprotection between different substations, a distributed test setup is used. Multiple, precisely time synchronized acquisition devices are used.

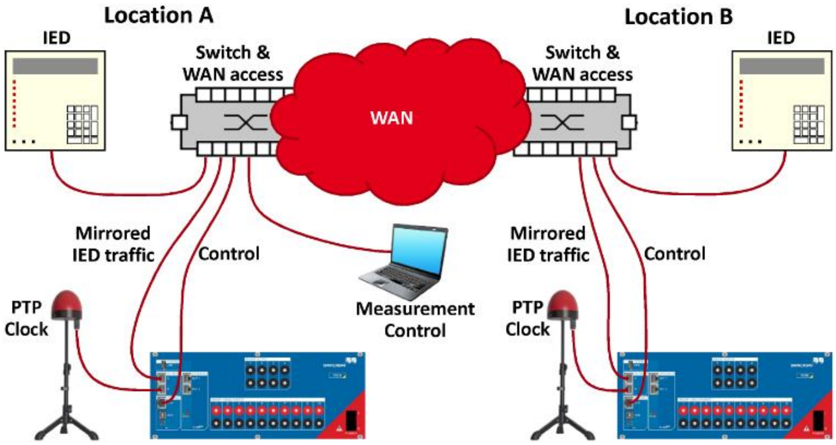

Figure 4: Propagation time measurement over a WAN

The whole measurement system is controlled from one single computer, making the operation as easy as possible. Of course, such a distributed measurement setup as required with a WAN may be also used in a LAN (e.g. in a large substation) when the capture locations are too far from each other.

To explore the extremes, a delay time measurement between two locations in two different continents was performed. It is unlikely that time critical data for protection, automation and control will be exchanged over such a distance, but it serves to show the orders of magnitudes that can be expected for the traveling time of information. The following figure illustrates the locations of the two involved sites in Austria and in Texas.

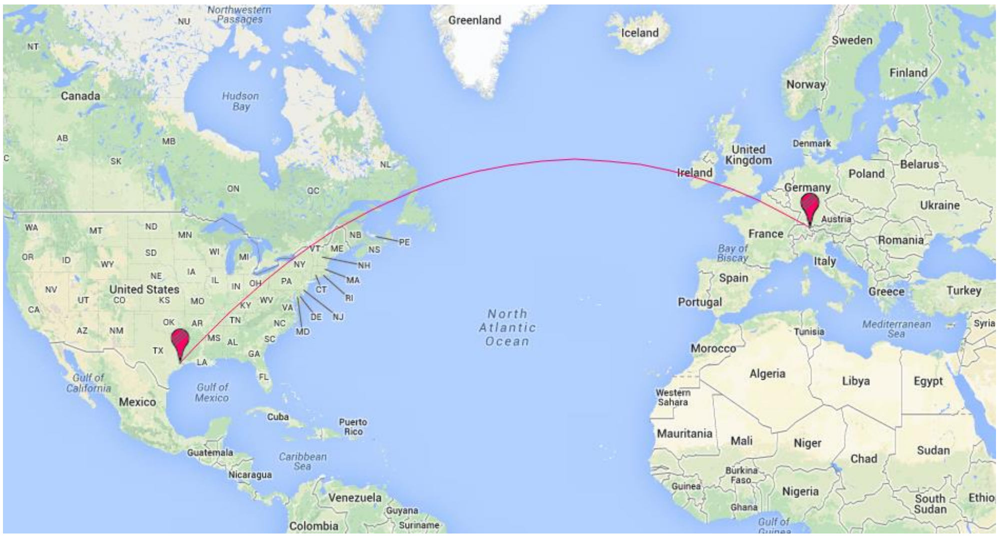

Figure 5: Locations and shortest path (beeline) in between

Map data © 2014 Google. Draft Logic distance calculator © 2014 draftlogic.com

The connection between the sites is established by “the internet”. Thus, it is an IP network, optimized for office use and in no way tuned for teleprotection applications. The measured propagation delays are in the range of 80 ms to 100 ms, which is actually quite impressive.

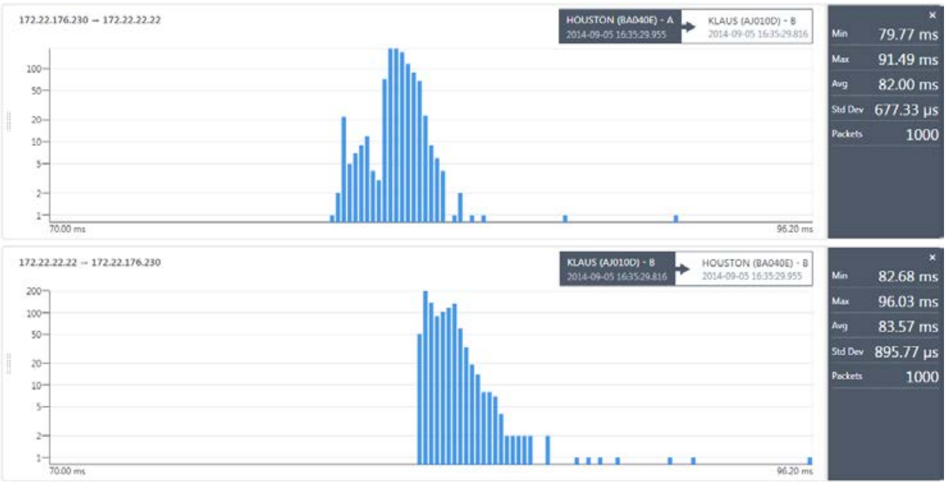

Figure 6: One-way propagation delays between Texas and Austria

It has to be noted that the measured transfer times of less than 100ms are well below typical zone 2 operation times of distance relays. And the delay across the Atlantic ocean is not so much off typical times that occurred in the past on communication channels used e.g. for line protection schemes.

For comparison follows a look on the measurements taken from a line protection scheme in the city area of Vienna that was commissioned in the year 2000 [14]. It is a protection for a 110kV cable with a length of just 4 km. The distance relays were upgraded, the existing pilot wire communication was reused. An end-to-end test was performed to test the scheme.

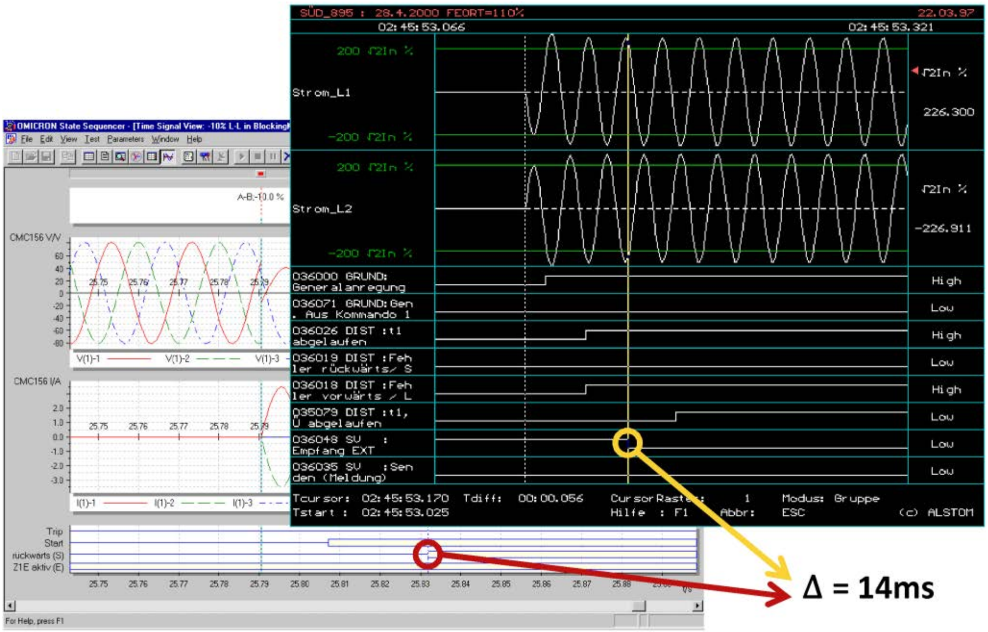

Figure 7: Transfer time of blocking signal evaluated from fault records

From the fault records, it was possible to derive the propagation time of the blocking signal from one substation to the other, the value was about 14 ms.

During testing a protection scheme for a 380 kV overhead line in Germany in 1999, propagation delays of about 60 ms were measured for the teleprotection channel [15].

Another benchmark comes from a measurement taken between two locations in Central Europe, about 275 km apart, a distance that may well apply for distributed PAC applications. The measured delay times were safely below 20 ms. Again, IP packets were transmitted over the internet, the transmission within a utility communication network would be most likely more performant and with a higher quality of service.

The different measurements from communication technologies of different generations are summarized in the following table.

Technology Era	
1990s	**2010s**
60 ms 120 km 380 kV overhead line protection scheme	< 100 ms 9000 km IP traffic over WAN
14 ms 4 km 110 kV cable protection scheme	< 20 ms 300 km IP traffic over WAN

Figure 8: Typical transfer times and distances in different eras

Technologies that can be optimized for Power Utility Communication, e.g. MPLS, can deliver even lower delays. Values in the range of just 5 ms over several 100 km have been achieved.

The evolution of the communication networks now allows the application of proven protection schemes for even larger distances. And the existing schemes can be even accelerated by using the now available faster communication channels. In comparison to the case from Vienna described above, we can now easily achieve the same transfer times over several 100 km that we obtained for 4 km 20 years ago.

By exploiting these advances in communication network performance, protection and automation experts can now design and implement improved protection schemes. Concepts that were formerly usable only locally or over short distances because of the requirements on the communication performance are now feasible over large distances utilizing the improved wide area communication. This will ultimately result in more reliable and more stable electrical power systems.

A case study

A 110 kV system in Austria serves as an example for the successful application of new communication technology. The system grew from a two terminal line to a three terminal configuration and was later again extended by two additional feeders. The protection on the two main buses was from the solid state generation, while the protection for the third (newer) leg was already numerical. None of these relays had built-in communication features, the protection communication for the transfer tripping scheme of the initial system was established by external communication devices that could just transfer a few bits point-to-point.

On the other hand, a migration strategy was in place that shall lead a way from the existing SDH/PDH network, that could be utilized anyway only by the most important applications, to an MPLS network that serves a wide range of applications. Now available layer 2 paths through the MPLS infrastructure allow even to exchange IEC 61850 GOOSE messages directly between devices in different substations. The following figure indicates how the three main locations involved in the scheme are connected via the MPLS network.

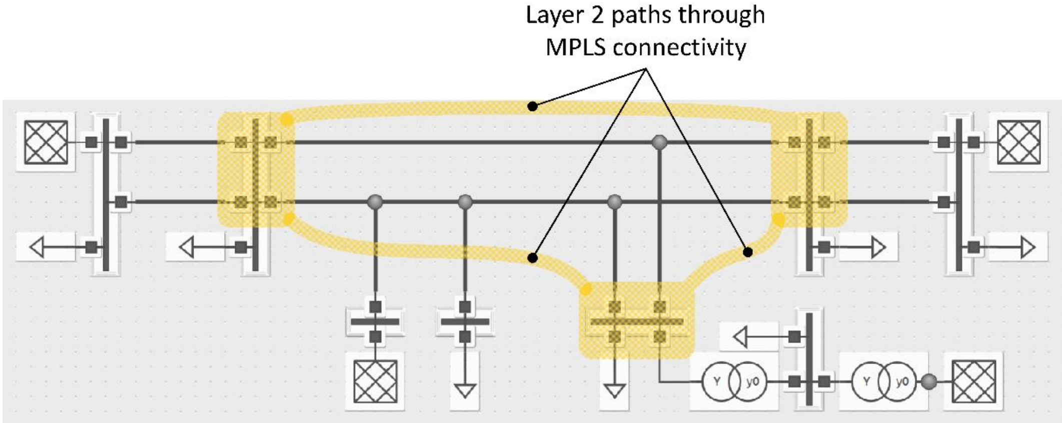

Figure 9: The IEDs in the three main locations in the scheme directly communicate via GOOSE

With simple GOOSE to binary I/O converters attached to the protection relays, a protection scheme including all important feeders could be set up with decent effort.

During the commissioning of the protection scheme, tests with a distributed test and measurement system have been performed. The same communication infrastructure that transports the protection information could as well used to connect and control test and measurement equipment. Besides the assessment of the protection's ability to detect faults in the electrical power system, the performance of the communication was measured as well.

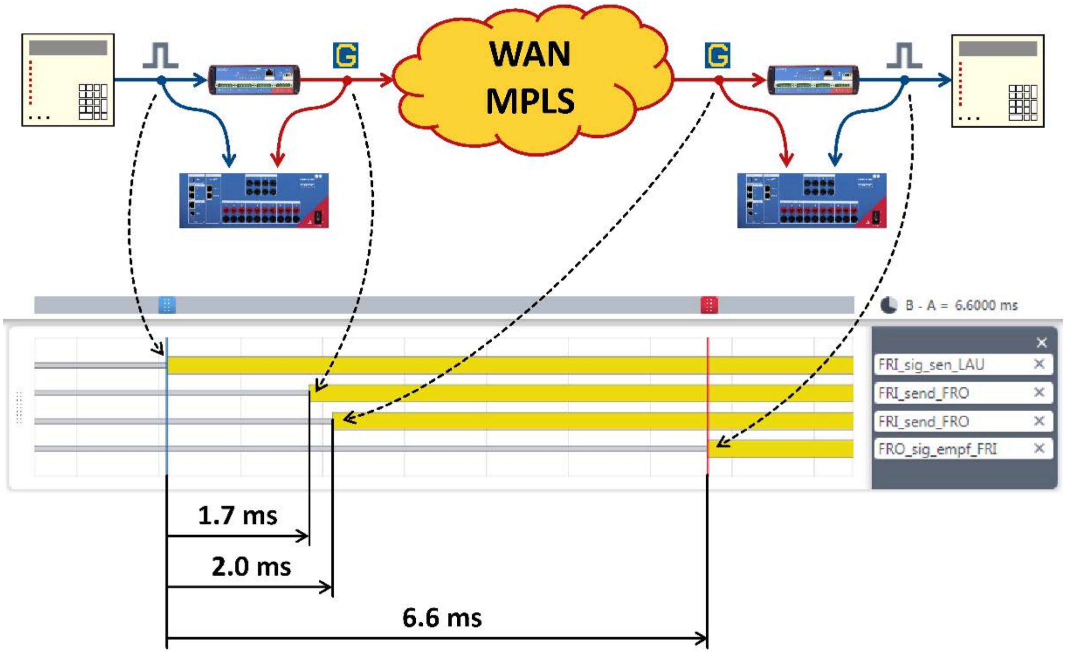

Figure 10: Signal propagation in the protection scheme

Figure 10 shows a typical propagation of a signal in this scheme. It reveals that the MPLS network is very fast, the transfer time of the GOOSE message itself is only about 300 µs for a distance of about 15 km. Hybrid measurement equipment also delivers the timing of the binary signals from relay to relay.

As the scheme utilizes the standardized GOOSE communication, it is highly interoperable and would be easily expandable with devices from other vendors. The engineering of the paths through the MPLS network was done by the process IT based on the requirement from the protection experts. The configuration of the GOOSE communication was done by the protection engineers.

The applied concept resulted in a simple, performant, and very cost effective solution. The concept is to be applied again for further extensions and modifications of this kind.

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