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THE COMMUNICATION STANDARD IEC61850 SUPPORTS FLEXIBLE AND OPTIMISED SUBSTATION AUTOMATION ARCHITECTURES

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ABSTRACT
Today a lot of different physical architectures for Substation Automation systems are in use, depending on the functionality as well as on the used protocol and needed reliability. Due to the manufacturer chosen communication protocol for certain functionality classes or reliability classes compromises have to be made or higher costs result. The new Substation Automation Communication standard IEC61850 allows by its flexible approach to separate functionality from physical architecture, and so allows to choose an architecture optimised according to needed reliability and functionality. This is illustrated by some examples.

1 INTRODUCTION

Today, substation automation systems including protection are using proprietary communication systems. No international standard is available with the exception of the very dedicated informative protection interface according to IEC61850-5-103. This dependency from single suppliers restricts both the acceptance of this beneficial systems and innovative competition. It forces the utilities to follow the pre-defined system configurations of these suppliers independent if these are optimised for the user. In addition, cost pressure forces the suppliers to offer a limited number of so-called standard configurations. The standard has to overcome all these limits and to have a long lifetime safeguarding the investments of the utilities. The conclusion is that a communication standard is needed which provides interoperability with a lot of additional very demanding service requirements.

2 SCOPE OF THE STANDARD

The standard IEC61850 “Communication Networks and Systems in Substations” supports all communication for substation tasks like control, protection and monitoring. It covers communication between all IEDs (intelligent electronic devices) from the process level (data acquisition, sensors and actuators) over the bay level (protection, monitoring and control tasks) up to the station level. Typical devices on process level are intelligent switchgear interfaces or unconventional (non-magnetic) instrument transformers. The goal of IEC61850 is the interoperability between IEDs of different suppliers. In addition, the standard should be future-proof, i.e. having a long lifetime in line with the long lifetime of switchgear. Nevertheless, the standard should not stop technological innovations and advanced operation philosophies of the utilities.

3 AUTOMATION ARCHITECTURES IN SUBSTATIONS (DEVICE VIEW)

There exist currently a lot of different system structures for automation within a substation, depending on functionality, needed reliability, and cost. From the functionality point of view we can distinguish the following bases:
Remote control: this starts with a simple central Remote Terminal Unit (RTU) as addition to a conventional control panel (Figure 1 left). On extensions or to change wirings this continues with the distributed RTU with sub – RTUs (called also remote I/O units or RIOs), communication links to protection devices and HMI for station level control (Figure 1 middle). To overcome the availability bottle neck at which network control centre (NCC) and station HMI are connected, it ends with a fully distributed, remotely controlled substation automation system (Figure 1 right). It includes interlocking, synchrocheck, protection connection, and a station HMI for local control, which is independent from the gateway to the network control centre.
Local control: this is a classical substation automation system with interlocking, synchrocheck, and local control from station level as well as bay level. The local control is so important, that high system availability is needed, leading to redundancy of critical components. It can naturally be expended with a gateway to network control centres, i.e. the final system looks like the fully extended one from the previous class (Figure 1 right). SA systems are typically distributed systems at least for bay level functionality. Depending on the manufacturers

solutions master-slave star configurations similar to the distributed RTU as well as bus configurations with Peer to Peer communication facilities exist.

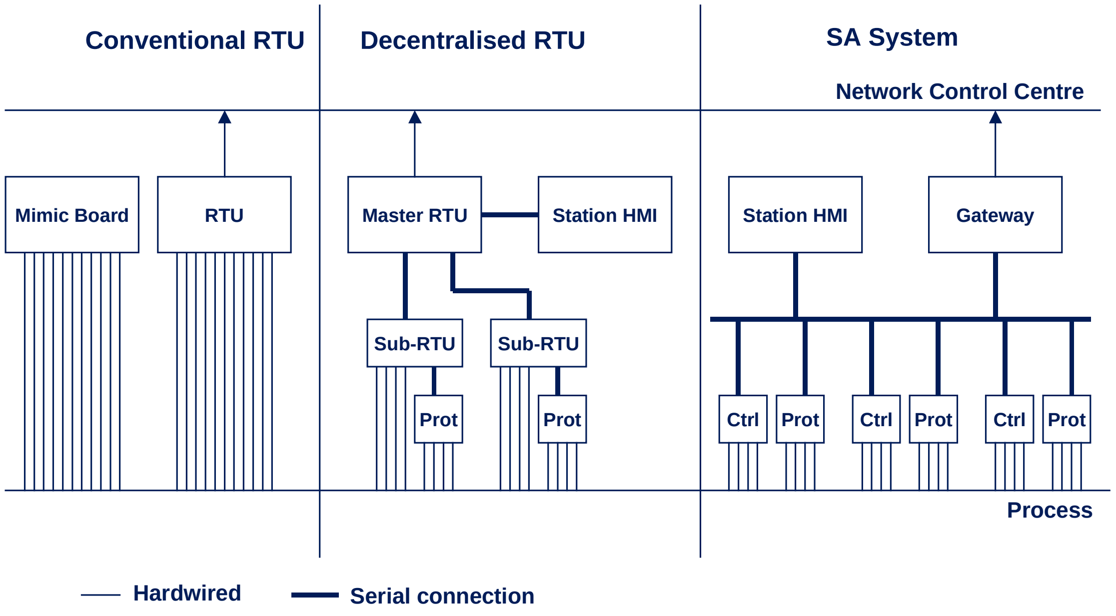

Figure 1 From RTU to SA system architecture

Protection monitoring: this starts with protection devices, whose communication facilities allow (remote) communication and time synchronisation for event logging, disturbance recorder evaluation, device supervision and (possibly remote) parameter set switching or even parameter setting (Figure 2). It ends as a substation monitoring system with remote communication to a central protection evaluation and maintenance centre. The monitoring data flow is mostly star like, from the process via the bay level to a central HMI or a connection to a remote monitoring centre, and availability as well as performance are not critical.

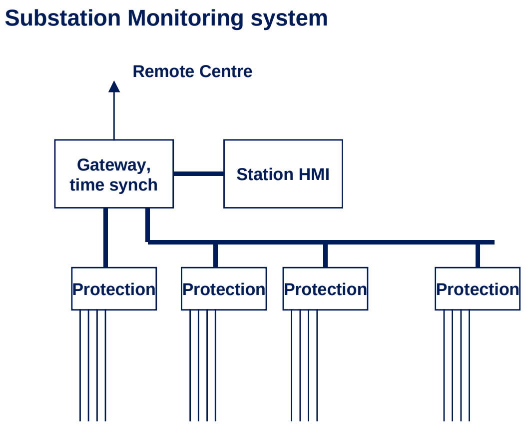

Figure 2 Substation Monitoring system architecture

Mixed structures: Because of substation history and partial retrofit, there exist also systems with a mixture of all these structures mentioned.

Assessment

All resulting physical structures have their disadvantages and advantages: the star structures are cost effective, but have a single point of failure, while bus (peer to peer and multicast) structures have an inherent higher reliability and better performance, but are more costly. Dependent on the needs on functionality and reliability each one can be cost optimal. Unfortunately the (mostly manufacturer specific) protocols force certain solutions, although they are not always optimal from the requirements side. Therefore a communication infrastructure, beneath allowing to mix devices of different manufacturers, should also allow to separate the system functionality from the physical and communication structure, i.e. to support any structure.

Trends

The newest developments at the switch gear side lead to new sensors with integrated electronics and process bus connection to bay level, the so called PISAs (Process Interface for Sensors and Actuators). These save a lot of costs at the sensor side as well as on the cabling side in HV substations. Manufacturer specific process busses however prevent a 'plug and play' facility for connection of PISAs to bay level equipment of different manufacturers. This is only assured if also a process bus standard is available.

4 APPROACH OF IEC61850

The approach is based on the description of the substation automation system from the application point of view. The requirements have been transformed into an application data model (data objects) with standardised semantics, and a communication model (data sets of data object attributes, reports, logs, and services). Both features support a long lifetime of the standard. For implementation, this model is mapped on a clearly separated communication infrastructure (ISO/OSI seven layer stack). This allows following the trends in communication technology on all stack levels. Today, the commonly accepted stack for IEC61850 consists of MMS, TCP/IP and Ethernet.

Standardising functions is outside the scope of the standard, but to identify the communication needs, the functions have been split in smallest possibly communicating pieces called *Logical Nodes*. Allocating the Logical Nodes allows free allocation of functions to devices and levels. The standardised logical node and data object naming provides the semantics for substation automation, and assures interoperability also on application level. Extension rules for the naming support new application functionality also.

To describe and control the overall system behaviour, and allow interoperable exchange of system engineering data between engineering tools of different manufacturers, a Substation Configuration Description Language is part of this standard. Due to its unique features to describe in separate sections the substation switchgear, the functionality attached to it in terms of logical nodes, the grouping of logical nodes on physical devices (IEDs), and the communication connections between the IEDs, this language is also an excellent tool to handle the flexibility in a very efficient way.

The standardisation of conformance testing completes the standard to really assure interoperability.

5 SOLUTION EXAMPLES

5.1 Modelling and allocation

IEC 61850 allows modelling the functionality of a substation automation system or a substation monitoring system completely with logical nodes and data flow connections between them. This web of logical nodes (see Figure 3 as example) can be flexibly mapped to any IED and communication system structure, as long as

- the needed communication paths between logical nodes can be mapped to physical communication paths,
- the resulting communication capacity requirements and the needed performance can really be provided by the physical communication bus,
- and the IED computing capacity is high enough.

The resulting allocation of logical nodes to physical devices is then the base for the system design, and can be exchanged between the engineering tools of different manufacturers in a standardised form. If the cost / performance relation of equipment and communication busses changes, then the communication structure can be changed accordingly, and the unchanged logical node web allocated in a different way.

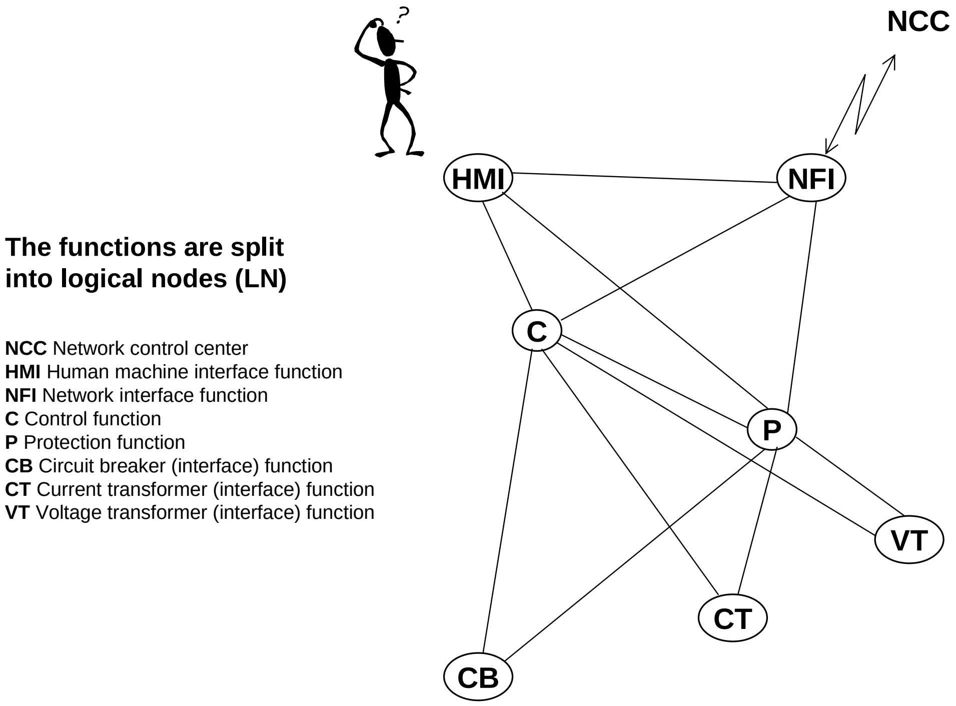

Figure 3 Logical Node Web example

Note: the Logical node names in the figures are not according to the standard, but chosen to easier recognize their meaning.

Some few examples for free allocation of function parts (logical nodes) to devices are shown in the following figures. There is always only one bay shown. Much more combinations are possible. The point-to-point connections between the logical nodes are merged either into the process bus (LAN) or into the station bus (LAN). There is no difference in the common data and service model, but depending on the allocation and architecture different performance requirements may apply to these LANs.

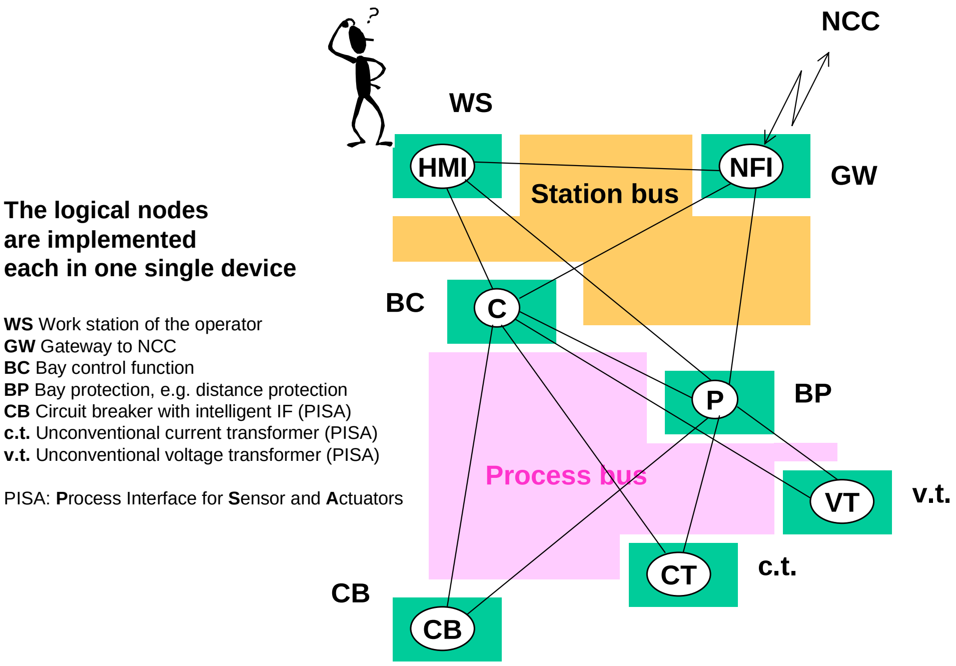

Figure 4 Dedicated distributed devices with station bus and process bus

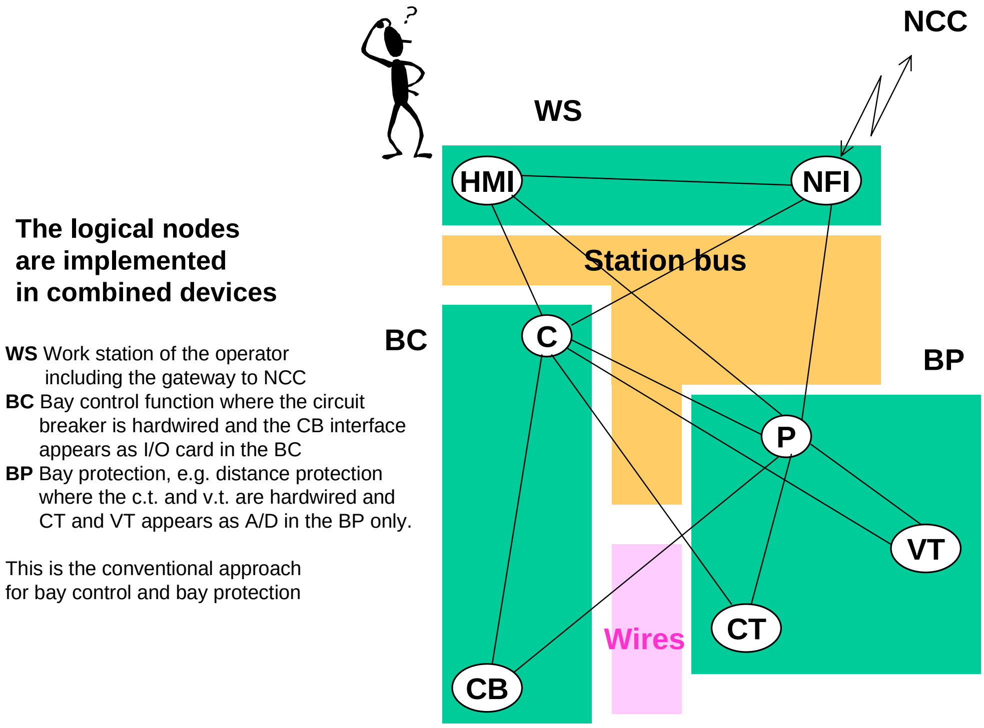

Figure 5 Typical distributed SA system with station bus only

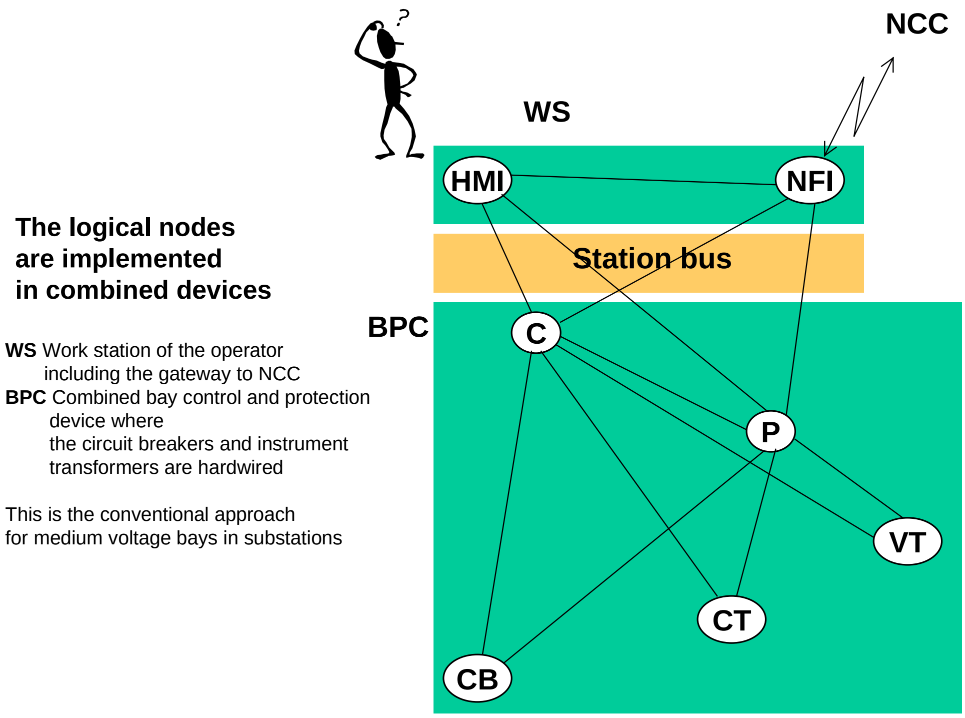

Figure 6 Combined control and protection unit without process bus

It has to be noted that this highest degree of flexibility illustrated above exists only for system modelling during the planning phase. Not all commercially available IEDs will support the completely free allocation of logical nodes. Especially the simpler and cheaper ones will have a fixed set of logical nodes, which then might be enabled in a system or not. Others might allow choosing an arbitrary, but restricted number of logical nodes from a given set of types. Based on the results of the planning phase the physical devices that are best suited to the planning result have to be selected.

5.2 Benefits using Ethernet

The first mapping of the abstract model of IEC61850 is done to Ethernet communication equipment. This choice provides a broad range in cost and performance from simple twisted pair 10 MBit/sec busses up to 100 MBit/sec switched networks with optical connections and bus traffic separation by filtering bridges or routers. This allows a cost effective communication system tailored to the needed communication performance and reliability requirements.

5.3 Examples of optimization

A high performance SA system for high availability can be mapped to a fully distributed IED system with a separation of the communication system into a process bus per bay and one or two station level busses. This allows full availability of a bay in case there is some fault in another bay (bus), and in case of a redundant station bus also the station level communication is guarantied on any single failure. An example configuration with an optical Ethernet loop instead of a second bus at station level, and an optical switched Ethernet for the process bus is shown in the following figure.

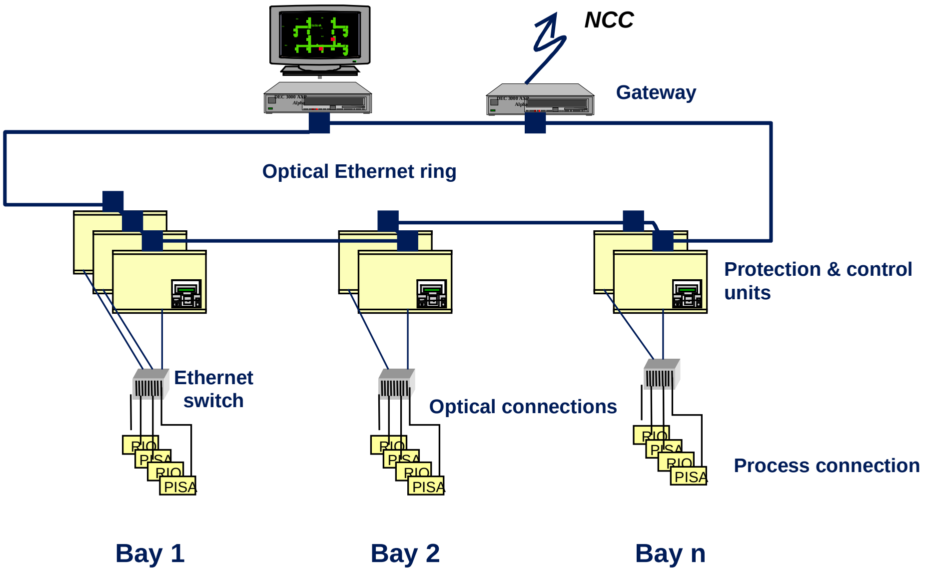

Figure 7 SA system with station bus and Switched Ethernet process bus

For a simple substation (or even only protection) monitoring system the redundant optical station bus of the above system is overkill. For such a simple substation monitoring system, possibly even without PISAs, the station bus can be mapped to a single twisted pair bus connecting all protection IEDs to the HMI and gateway IED, thus providing a cost-effective solution (see Figure 8 below). In case that the Network Monitoring Centre (NMC) also talks IEC61850, even commercial wide area connection equipment on bridge level can be used instead of a gateway

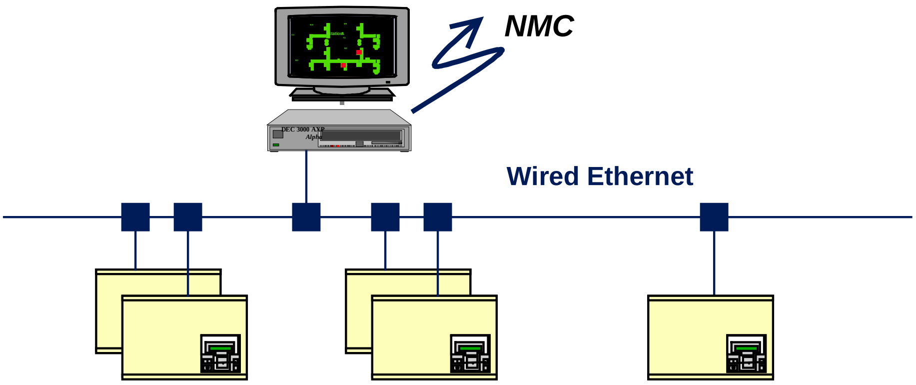

Figure 8 Substation Monitoring system with twisted pair Ethernet

In case of simple RTU solutions there might be no need for the IEC61850 protocol. But as soon as only protection devices shall be connected to the RTU, it might already pay off. The architecture of the IEC61850 model allows considering the Logical Node / Data object definitions just as a wrapper to the data coming from protection devices or the switchyard. So if this wrapper is already implemented in the data acquisition units of a distributed, switchyard object oriented RTU, then there exists only one standardised application level model which must be mapped to (different?) NCC protocols (or, as stated already above, no protocol conversion at all is necessary, if the NCC talks IEC61850). So even a RTU can be implemented in a more cost-effective way, saving a lot of engineering effort. And in case that PISAs with IEC61850 protocol exist, which perform among others the data acquisition task, the RTU can be completely replaced by an Ethernet bus connection and a bridge to the Network Control Centre.

Despite of these different structures in the physical communication system, all these systems use the same communication protocol above the Ethernet physical level and can use the same communication and application engineering tools. Therefore the way of application and communication engineering is identical in all above cases, and protection devices from one system can also be connected to the other one, if needed.

6 CONCLUSION

IEC61850 introduces a strict separation between application and communication by modelling the functional (application level) structure in form of logical nodes and logical connections, and then map this to a full seven layer communication stack, which allows different physical media and configurations. This, together with a set of communication services which fulfil all needs from high speed real time data transmission up to event logging and monitoring, allows to implement the same protocol on low cost communication equipment as well as on more costly high performance communication equipment. It further allows choosing a function distribution leading to minimal cost regarding cabling and reliability. You can even mix different configuration approaches in different system parts, to tailor different system parts to different reliability and performance requirements. And on later system extension, an approved cost/performance ratio of communication equipment and IEDs during the system life time might again lead to other structures in the added part, which can nevertheless easily be directly connected to the existing system.