MANAGEMENT OF SLA PARAMETERS IN ICT NETWORKS FOR SMART GRIDS

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ABSTRACT

This paper describes an innovative approach in management of SLA parameters inside the ICT networks, which should support different Smart Grids applications, for communication data flows between broad range of end devices in DSO's ICT networks and furthermore also other subsystems needed by DSO to provide business and operational services to the users inside the organisation. DSO's ICT networks tend towards converged networks, based on Ethernet/IP protocols, where the management of SLA parameters became important task.
Elektro Primorska, as one of five distribution companies working for the DSO in Slovenia has a long tradition in building the Ethernet/IP networks for the operational and business processes as well as deploying many Smart Grids applications in past years and with the vision for further development in the field of Smart Grids applications, thus requiring even more strict demands to the ICT network. Some of the subsystems provide mission critical services and the requirement to monitor and manage ICT network parameters became one of crucial functions.

INTRODUCTION

ICT networks became mission critical segment inside smart grids infrastructure. Apart from using public mobile or service providers' networks infrastructure many of DSO's build their own ICT network, in majority based on optical fibre infrastructure or packet radio systems. As this approach provides high level of security in conjunction with the applied network and application security mechanisms, it brings also the need to manage the ICT network by the DSO itself. The ICT services for different smart grid applications (e.g. SCADA, AMI, teleprotection,…) as well as other services inside DSO (business IT, data centres, telephony, video surveillance, digital mobile radio networks, etc.), carried by the common ICT network require compliance of the network service parameters to certain levels. The set of telecommunication parameters required can be summarized under the term of SLA (Service Level Agreement) parameters**.** As the ICT network is managed by the DSO, the management of SLA parameters also needs to be addressed in order to ensure the required SLA levels.
While the mechanisms for the SLA management in the legacy networks (based on PDH, SDH, FR or ATM technologies) are well developed and standardized, this was initially not the case with the Ethernet based networks. The legacy technologies are becoming more and more obsolete, on the other side packet based technologies (Ethernet, IP/MPLS, MPLS-TP, etc.) already became the technologies of choice for most new generation ICT networks at DSO's on a global level. These technologies, are often used in converged networks for operational and business services inside the DSO organization, due to robustness, simplicity and lower cost comparing to other technologies. However, due to lack of SLA management mechanism in the past, Ethernet needed additional mechanisms to ensure possibilities for this technology to become optimized for utility deployment. With standards dealing with OAM (Operation, Administration and Maintenance) mechanisms, Ethernet gained important tools for usage in mission critical networks as SLA parameters can be managed, thus ensuring required characteristics to the applications.

THE PRINCIPLE AND THE BUILDING BLOCKS OF THE INTRODUCED SOLUTION

The ICT networks in DSO organizations provide the communication services to its users, which are of operational nature i.e. SCADA, AMI, teleprotection, etc., of business nature i.e. corporate IT, telephony, data centres, etc., as well as to many new Smart Grid applications. All of them require information flows between two or more endpoints. Each service should comply with the user requirements with a set of parameters, which shall retain certain levels, providing performance and operation of services as expected.

The experience and the best practices from the ICT networks management and operation show that most important KPIs (Key Performance Indicators) are: availability, bandwidth, latency (delay), variation of latency (jitter) and packet loss. Availability of the service is one of the most important parameters, especially in the mission critical infrastructure of DSO, as certain user systems e.g. SCADA require high level of service availability. The bandwidth is important from the point of throughput ability of the network to ensure the information flow between endpoints. Often, there is no strict requirement for the bandwidth, however it is important to manage the bandwidth utilization on the link and network level, as overbooking leads to bottlenecks and thus service degradation. Latency (delay), affected by the network behaviour is a parameter important for certain applications e.g. voice, where additional jitter can degrade the performance of voice communications, in worst case even to unavailability of voice services. Packet loss is critical for services like SCADA or teleprotection as network behaviour can cause service interruption. In case of retransmission of the packets due to packet loss this may increase packet traffic and cause overutilization of the network resources.

Measuring and monitoring mentioned parameters provide the ICT network administrators and designers important information how applied network mechanisms and protocols operate and how to react in case of deviations. An example of this would be applying new QoS policy on the basis of measured higher delays than allowed, to provide prioritization of critical applications e.g. teleprotection, SCADA or voice over other services (e.g. corporate IT).

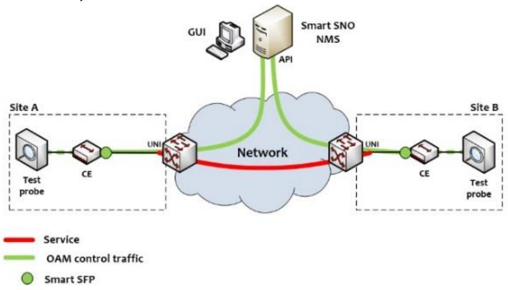

Figure 1: Typical integration of OAM functionalities into ICT network

Figure 1 shows functional scheme of typical integration of OAM functionalities into ICT network. Such integration requires devices on measurement endpoints, whether it be Smart SFP or dedicated test probe and NMS (Network Management System) with OAM functionalities capable of collecting and presenting measured data.

Standards

The goal of presented solution for management of SLA parameters was to use available industrial standards to the highest possible extent, as this gives the DSO like Elektro Primorska possibilities to use broad range of the equipment available on the market to ensure management of SLA parameters.

The most adequate reference using OAM functions can be found within the IEEE, ITU-T and MEF standards. The presented solution is based on three most relevant standards within Ethernet OAM field: IEEE 802.3ah, IEEE 802.1ag and ITU-T Y.1731. The MEF has no separate standards, however it defines requirements and framework of OAM operation within ICT network.

IEEE 802.3ah

The IEEE 802.3ah represents the link based OAM standard and was first introduced on access links – Ethernet in the First Mile (EFM). In the ICT network for DSO it can be used on any link level between two Ethernet interconnecting interfaces e.g. between two substations Ethernet nodes.

IEEE 802.1ag

The IEEE 802.1ag provides the service based OAM mechanisms – CFM (Connectivity Fault Management) functions, which can be deployed between any two Ethernet endpoints in the network, where services terminate. Therefore this standard provides end to end OAM capabilities giving network administrators the ability of fault management between any endpoints, regardless of the carrier technology for Ethernet packets (optical, wireline, wireless or mobile network). The example would be monitoring Ethernet based SCADA services between DSO control centre and remote substations.

ITU-T Y.1731

Y.1731 provides all the IEEE 802.1ag functions and supports additional functions, which enable end to end performance monitoring capabilities of Ethernet services. The implementation of the Y.1731 mechanisms into the DSO ICT network would provide delay measurement, delay variation and loss measurement for the Ethernet services. Typical implementation would be monitoring of voice based operational services inside DSO. Example is operational DMR (Digital Mobile Radio) for critical infrastructure, integrated with Ethernet based DSO ICT network.

Optical modules SFP with OAM functions – Smart SFPs

Most interfaces on new generation communication network equipment are SFP based. The regular SFPs provide only optical to electrical conversion and vice versa. Using the latest generation technology enabled the integration of network functions within SFP, so called Smart SFP. Smart SFP represents a System-on-SFP, adding network functions to existing network equipment. Having a protocol processor available inside an SFP allows a broad range of functions such as OAM.

In order to upgrade an Ethernet network from best effort to carrier class, adding support for OAM (Operation, Administration and Maintenance) is essential. The OAM protocols inside Smart SFPs provide the tools to get actual insight into KPI’s of services carried across the Ethernet ICT network of DSO. The OAM protocols defined in afore mentioned standards have been integrated in a Smart SFP providing the tools to proactively assure the SLA management. Figure 2 presents the protocol integration into the Smart SFP. Additionally DDM (Digital Diagnostic Measurement) of physical parameters is integrated into

Smart SFP.

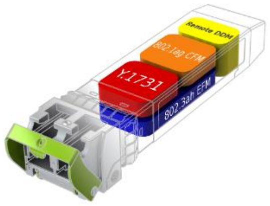

Figure 2: Smart SFP with embedded OAM protocols

Such SFPs therefore represent highly cost effective means for transforming existing ICT network into OAM aware network. This can be simply done by exchanging regular SFPs with Smart SFPs and adding corresponding management system. Being vendor independent Smart SFPs can be plugged in any type of equipment – Ethernet switches, routers – of any vendor. Enabling DSO's ICT network with OAM possibilities and SLA management there is no need for swapping entire set of network equipment that doesn't support OAM functionalities. This is of crucial importance, since network equipment lifecycles in any DSO's ICT network are comparatively longer than lifecycles of similar equipment in service providers' or enterprise environments.

Integration of Smart SFPs with NMS

By inserting Smart SFPs into network equipment such network becomes capable of supporting OAM standards. To exploit mentioned functionalities appropriate Network Management System with OAM functionalities is needed. There are few Network Management Systems with OAM functionalities available on the market, some of them linked with dedicated devices and using proprietary protocols. Network Management Systems that are equipment vendor independent, where integration of any equipment is done through so called APIs (Application Programming Interface) don't require any proprietary protocol or modification, but use common SNMP protocol instead. This way NMS remains compatible with any SNMP capable device, whether it be switch, router, firewall, printer or server. Such NMS was used for the presented solution.

Smart SFPs integrated in mentioned NMS represent major part of its OAM functional module, the other part being Linux based Smart SLA probes covering advanced IP SLA parameters. During the development of the solution the need for measurements on IP layer was recognized, due to specific topology of DSO's ICT network.

Beside device provisioning, in our case Smart SFPs and Smart SLA probes, the main advantage of NMS with OAM functionalities represent collection of measurement results and capability of corrective actions. Typically this is realized through configurable GUI with real time topology view. Through very same GUI OAM related measurement results should be accessible via dashboard charts. These charts can be of extreme importance as they graphically present development of measured parameters within larger and selectable time period. Commonly fault on particular service can be anticipated through gradually degraded performance of a given measured parameter. OAM part of NMS covers surveillance over parameters that are not surveyed by regular NMS, but are of crucial importance for mission critical services. Parameters such as optical levels, attenuation, packet loss or packet delay might well stay within required thresholds for fairly long time, until being slowly degraded to the point of service interruption. Anticipating such development of a given parameter, corrective action can be applied prior to service outage. This principles bring the measures for maintaining high availability in ICT network of DSO.

THE IMPLEMENTATION

There are three different typical situations in DSO's ICT network, like Elektro Primorska, where introduction of OAM functionalities would bring operational benefits for quality assurance.

Figure 3 shows a part of DSO's Ethernet optical network, where monitoring on a link level (green line) and on a service level (blue line) is provided. The link between Ethernet nodes spans over longer distance and was found more susceptible to failures in the past. The service between Control centre and substation is VLAN based Ethernet service, carrying SCADA datagrams.

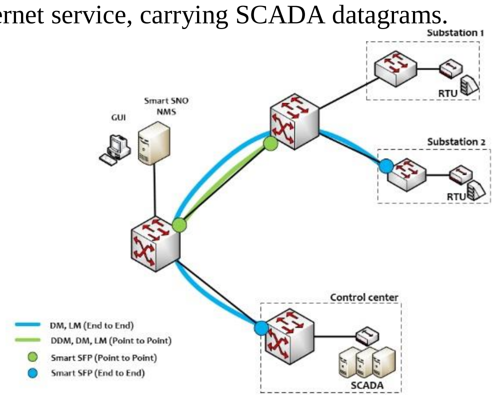

Figure 3: Ethernet optical segment in DSO's ICT network

Figure 4 shows integration of DMR radio system of DSO with Ethernet optical network, where monitoring on a link level (green line) and on a service level (blue line) is provided. The link between Ethernet nodes remains the same as in Figure 3. The service between DMR radio server on a central site and the DMR repeater (similar to base stations in mobile networks) is VLAN based Ethernet service, carrying voice traffic for DSO field operation staff.

Figure 5 shows integration of MV/LV substation connectivity with DSO's Ethernet optical network, where monitoring on a link level (green line) and on a service level (blue line) is performed. The link between Ethernet nodes remains the same as in Figures 3 and 4. The service between Smart SLA test probe at Control centre and test probe at the substation router is L3 based TCP/IP service, carrying SCADA datagrams from/to MV/LV substation.

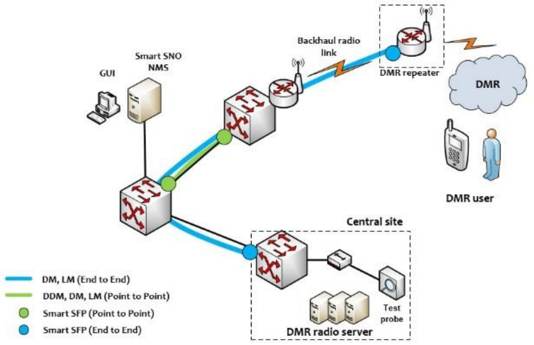

Figure 4: DMR radio system integrated with Ethernet optical segment in DSO's ICT network

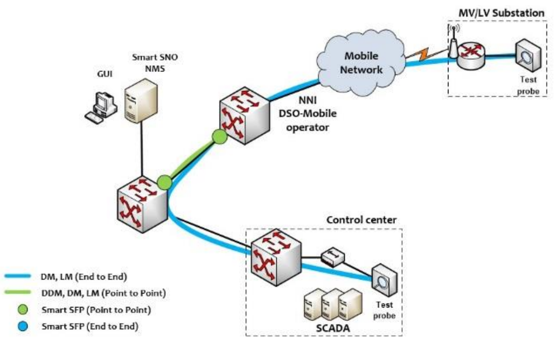

Figure 5: Mobile network used as alternative for MV/LV substation integration with Ethernet optical segment in DSO's ICT network

THE MEASUREMENTS

The following cases reflect realistic a relevant situations in DSO's ICT network being for the safety reasons simulated in laboratory environment.

Case 1: DDM (Digital Diagnostic Measurement)

This case relates to the DSO's ICT network segment as shown on Figure 3 and deals with layer 1 connectivity, covered by standard 802.3ah.

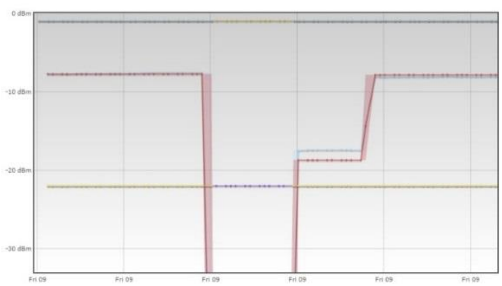

Figure 6: Case 1 – Receive (Rx) optical power levels

This type of measurement deals mainly with optical levels of the signal on transmitting and receiving side. By combining them, attenuation on a given connection segment can be observed. Knowing the characteristics of the SFP on receiving side (minimal and maximal receiving optical power) operational thresholds of the connection segment in question can be defined. Figure 6 denotes them with the two continuous horizontal lines. The discontinued two lines in-between (coloured red and pale blue) represent the actual measured receiving optical powers for both directions respectively.

Vertical decline of the red and pale blue lines was caused by fibre cut on observed segment. All services transported through it were interrupted. This would trigger a quick action of the field staff to resolve the situation, bringing this part of network back into service. This can be seen as vertical ascend of the lines in question. However, the initial level was not achieved since the work wasn't performed properly. Either not exact fibre splicing or some mistake on optical distribution frame were responsible. Such case could not be observed by regular management system, although it represents frequent case.

Case 2: CFM with L2 OAM

This case relates to setup as presented on Figure 4 and reflects the situation of mutual influence of different types of traffic running through the same physical infrastructure. For this scenario certain CFM measurements were used, specifically receiving packets, packet loss ratio and packet delay, as presented on Figures 7a, 7b and 7c, respectively.

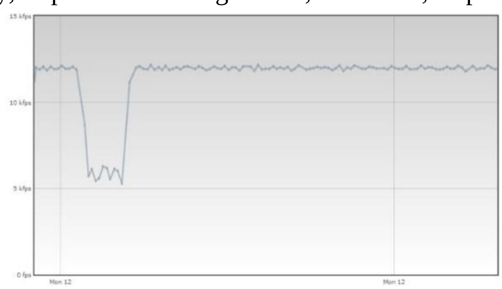

Figure 7a: Case 2 – Receive (Rx) packets

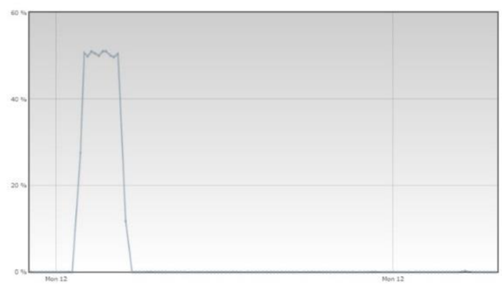

Figure 7b: Case 2 – Packet loss ratio

There was a voice traffic of constant bit rate running through connection segments denoted by blue line on the Figure 4. Furthermore there was a burst of traffic of different type coming through the segment denoted by green line on the Figure 4, exceeding the available bandwidth of that link. Since both types of traffic were of the same priority, although first one - voice being of higher importance for DSO, in consequence both faced packet dropping. Figure 7a shows substantially lower amount of traffic received, with significantly higher packet loss ratio as shown on Figure 7b. As a consequence delay of the mentioned traffic increased. This is presented on Figure 7c. Figures 7a, 7b and 7c all refer to voice traffic running through blue line segments as shown on Figure 4.

Figure 7c: Case 2 –Packet Delay

Considering the importance of the voice traffic for DSO corrective action was taken lowering the priority of the bursting traffic. Its outcome was that voice traffic consumed the bandwidth required, while bursting traffic got dropped to higher extent. This case shows successful application of QoS mechanisms.

Case 3: CFM with L3 OAM

The last case presented relates to setup as shown on Figure 5 and reflects the possibility of determining degraded service problem origin by combining OAM measurement results from different network segments. In given case even different measurement types involving different devices were used. In this case there was a traffic running between Control centre and MV/LV substation, connected through public mobile network. For this measurement Smart SLA probes were used performing end to end TCP/IP measurements between the endpoints denoted by blue line on Figure 5. Another measurement - point to point - took place on the segment denoted by green line, where Smart SFPs were used.

Figure 8a: Case 3 – Jitter (end to end)

At certain point in time end to end results show quality decline, which can be seen in increase of jitter and packet loss, as shown on Figures 8a and 8b, respectively. Analysis where the problem occurred can be time consuming operation, unless additional data available. For this purpose results from point to point measurement were checked. Packet loss and delay, as shown on Figures 8c and 8d, respectively show almost negligible increase, therefore it can be concluded that problem caused temporary lack of resources within mobile network.

Figure 8b: Case 3 – Packet loss (end to end)

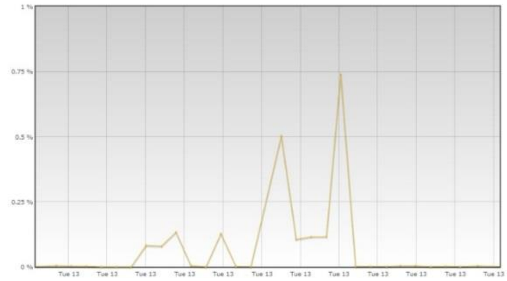

Figure 8c: Case 3 – Packet loss (point to point)

Figure 8d: Case 3 – Packet delay (point to point)

CONCLUSIONS

The measurements, integration, presentation and further redesign of ICT network mechanisms verified realistic cases in DSO's ICT network. Developed method and integration based on an industrial standards and proved on presented cases give further possibilities to add additional tools for management of SLA parameters in the ICT network of DSO like Elektro Primorska on a broader scale. Individual cases presented in this paper can be combined and applied for several tens or hundreds services in a single ICT network. Furthermore development and integration of additional OAM mechanisms on Smart SFP level gives possibilities for new enhanced functions in the future.

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