METHODOLOGY OF THROUGHPUT TESTS IN TELECOMMUNICATION NETWORKS FOR MV/LV SUBSTATIONS

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ABSTRACT

This paper describes the methodology of throughput tests and its deployment in the telecommunication network, connecting MV/LV substations with the control centre of Elektro Primorska. While the behaviour of such networks in respect of parameters like availability, capacity, delays and variation of delays (jitter) are mostly unknown, the methodology provides the procedures to quantify these parameters for better network operation understanding, optimisation and planning of the telecommunication infrastructure, for future SmartGrid application development and deployment.

INTRODUCTION

Growth of different subsystems required at MV/LV substations level (AMI, SCADA, power quality measurements and analysis, etc) and introduction of new technologies in SmartGrids rapidly expands quantity of data exchange. Telecommunication infrastructure providing connectivity of MV/LV substations became important segment of the SmartGrids infrastructure.

When considering the telecommunication networks the designers are aware that each subsystem (AMI, SCADA, power quality, protection...) has different requirements regarding telecommunication network parameters (bandwidth, latency, jitter, availability, packet loss).

There are several methods available to perform measurements of telecommunication network parameters, but most of them lack simplicity, can use expensive equipment, and are consuming a great deal of time if there is a large number of endpoints to be connected, measured and analysed over number of parameters.

TELECOMMUNICATION NETWORK FOR MV/LV SUBSTATIONS

Elektro Primorska, d.d., one of the five distribution operator companies (DSO) in Slovenia has deployed unified telecommunication concept, providing connectivity of several MV/LV substations with control center (DCV), using different telecommunication technologies (WiMAX, ADSL, GPRS and optical fibre). The evaluation of this concept is out of the scope for this article.

METHODOLOGY OF THROUGHPUT TESTS

The principle of throughput tests for telecommunication network

The principle of throughput test is based on the communication between two end point devices. The flow of packet datagrams in the data path in both directions is influenced by the telecommunication devices and the links between them. Observing the data flows and characteristics of selected network parameters will return the information about parameters over selected time period. For the simplicity only two endpoints will be used in further explanation of throughput tests shown on the Figure 1.

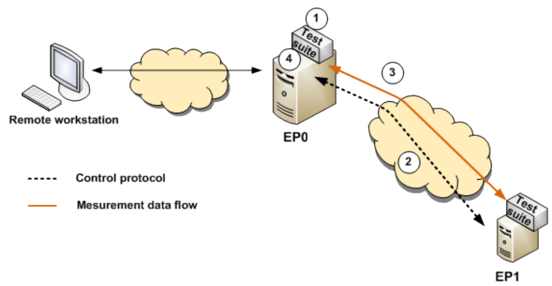

Figure 1: The principle of the throughput tests

The Endpoint 0 (EP0) is a computer used for the design of throughput tests (with endpoint matrix), capture, storage and graphical representation of measured network parameters. EP0 resides at the central location - in the case of described throughput tests at the control centre (DCV) of Elektro Primorska. The Endpoint 1 (EP1) is located on a far end of the network and communicates with the EP0 with designed traffic flow and protocols. The steps to establish and perform the measurements of the data channel between EP0 and EP1 are following:

1. The EP0 contains the module of the throughput tests parameters and variables.
2. EP0 communicates the test procedure with EP1. When ready, EP1 returns acknowledgement. EP0

starts the test procedure, when receives the acknowledgement from EP1.

3. The testing procedure is executed; EP0 collects the results of the tests.
4. When finished, control module at EP0 captures results, analyses and presents them.

It is important, that the described testing methodology can perform multiple simultaneous tests between EP0 and remote EP's to provide fast and efficient testing of larger number of remote endpoints.

The implementation

The following tests were implemented in the test suite integrated at end points (EP):

- Availability test
- Capacity test
- Performance test

Availability test

When using mobile networks the service provided by service provider is an APN. To ensure required level of security the VPN tunnel is established over APN between MV/LV substation and central device, using IPSec protocol. The tests performed over the specified time period should return the availability of the APN and VPN, so the correlation can be evaluated. The protocol integrated into the test suite is the ICMP PING. The target will return echo ICMP packet back to transmitter (e.g. echo from EP2 to EP1, when EP1 transmits the PING) if the communication channel is available. In case of network failure or packet loss there will be no echo reply received. The PING using UDP packets provides additional information about the availability and delay inside VPN tunnel.

Capacity test

The capacity of the communication channel represents maximum possible volume of data that can be transferred by the network between a source and a destination over a defined time period. If the source and destination are connected, then the capacity between the devices is the smallest capacity of links between them. The measurement shouldn't be intrusive and shouldn't have significant influence to the data traffic between control centre and MV/LV substations. The technique of packet pairs which is accurate, quick, robust and non-intrusive, shown on the Figure 2 is used. A source sends two packets of the same size back to back to the destination. Short packets of 64 bytes were selected, having in mind that GPRS packet network can have higher delays, causing the measurement not to be quick as required if the packet length is higher. When entering the communication channel each packet has serialisation delay, the length of which is determined by the packet length. The capacity of the link is inferred by the dispersion time of two packets as they exit the link.

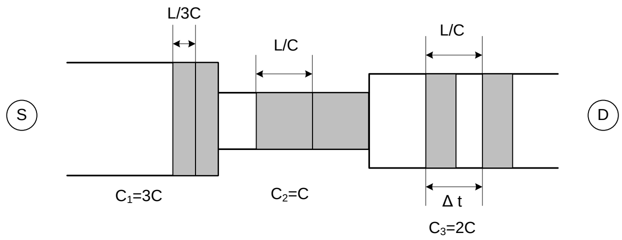

Figure 2: Technique of packet pairs for capacity test

The time elapsed between the last bit of first packet from the last bit of the second packet is used to calculate the capacity of the link by dividing the packet size by the spacing (time interval) of the two packets as they arrive at the destination.

Performance test

The communication path between control centre and the remote MV/LV substation uses one communication channel to carry data streams for several applications (AMI, SCADA, power quality measurements, etc). While these applications have different requirements regarding the telecommunication network parameters the behaviour under the realistic traffic conditions needs to be observed. The performance test basically consists of generating the data stream sent to the communication channel. While starting with the lower capacity of the data sent over single TCP session into the channel, the additional TCP sessions are added, simulating the applications entering the communication channel. At the receiver side the mutual influence of the TCP sessions are observed to the full capacity of the channel.

METHODOLOGY OF THROUGHPUT TESTS IMPLEMENTED IN REALISTIC NETWORK

The test environment

The throughput tests were performed over the network topology connecting the control centre and 6 MV/LV substations at Elektro Primorska. The control centre communicates with remote MV/LV substations, using 4 types of communication technologies: GPRS/UMTS mobile network (3 substations), Broadband Wireless Access (BWA), ADSL access public network and optical fibre network. The substations are connected to the network infrastructure using IPSec encryption protocol and aggregated at the central VPN concentrator at the location of control centre (Elektro Primorska DCV). The embedded Linux based small microcontroller devices (PIC's) with Ethernet interface and complete Ethernet/IP/TCP_UDP protocol stack were used as the platform for the software modules, containing the software code and scripts dedicated for the throughput tests. Figure 3 shows the topology of the throughput tests at Elektro Primorska.

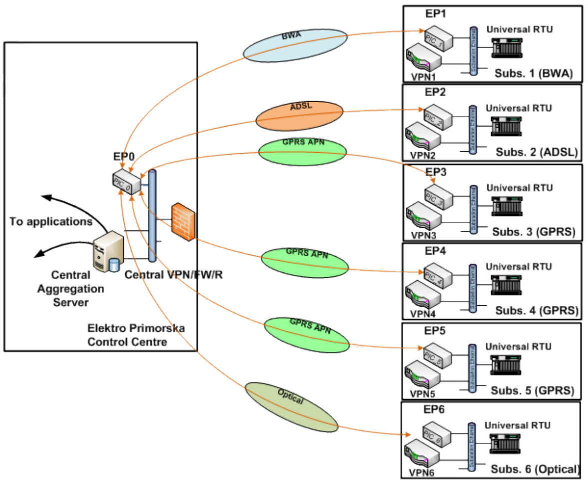

Figure 3: The topology of throughput tests at Elektro Primorska

The measurements

Availability of the communication paths

The measured values for the availability and the response times of the communication channels between Control centre and MV/LV substations were captured and visualised as shown on Figure 4. The blue line depicts the availability of VPN (IPSec connectivity) for each location; the red line depicts the availability for APN at GPRS/UMTS connected substations.

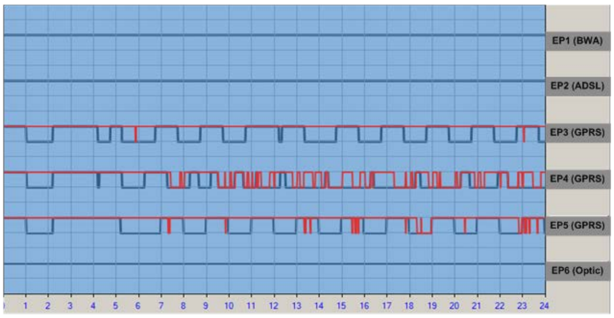

Figure 4: Availability of MV/LV substations connectivity

There is high availability of VPN tunnels achieved for the EP1, EP2 and EP6 remote locations, which are connected over BWA, ADSL and optical access networks, while we can see instability in GPRS APN connections towards end locations. Furthermore VPN tunnel over the APN is influenced by the APN best effort nature; therefore we can see also the VPN downtime in spite of APN availability.

Figure 5 depicts detailed caption of the GPRS end locations regarding the round trip delay (RTD). The level of round trip delay is in some cases higher than 10s, which needs to be considered in the applications design.

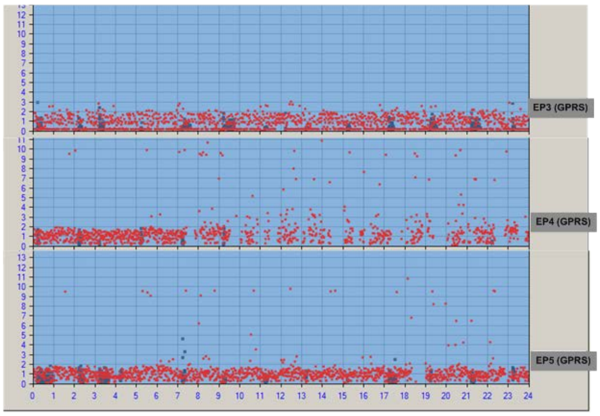

Figure 5: Round trip delay for GPRS locations

The PING using UDP packets is used to measure the RTD inside the VPN tunnels. The graph representing the round trip delay inside the VPN tunnels is shown on the Figure 6.

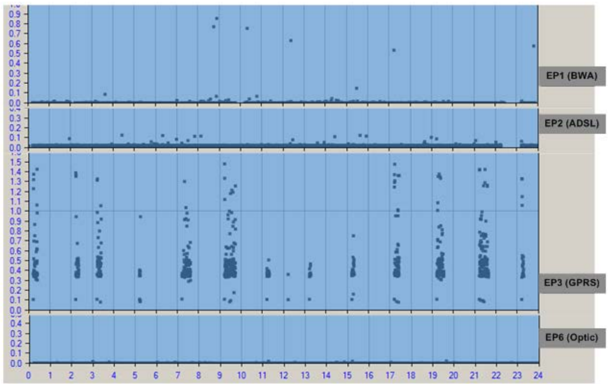

Figure 6: Round trip delay over VPN's

While RTD pattern for EP1, EP2 and EP6 displays very stable and low level of delay, the GPRS end points (shown only EP3) are subject to higher level of delay – higher than 1 s. There is also higher level of jitter present at this type of connectivity.

Capacity of the communication channels

The graphs of the capacity measurements are shown on the Figure 7. The capacity measurements for communication channels give clear picture of behaviour for different technologies used to connect the substations. While high capacities for EP1 (BWA), EP2 (ADSL) and EP6 (Optical) end locations are available, the GPRS locations (shown only EP3) have low capacity available for the communication. This fact needs to be considered when designing the applications, since the capacity of the communication channel is shared among several applications. The graph for EP3 on Figure 7 shows also dynamic changes of the capacity at GPRS infrastructure, caused by the best effort nature of APN service, while the capacities of other network types remain constant over the selected period of time.

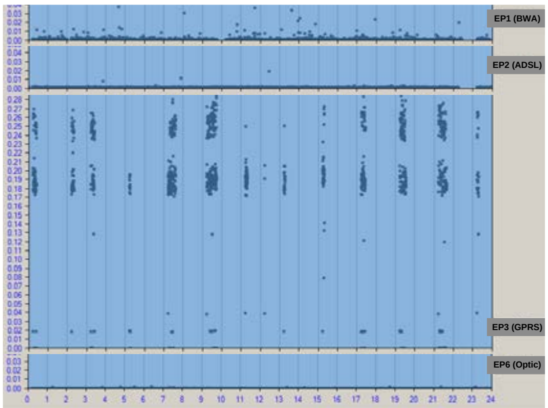

Figure 7: The capacity diagrams

Performance of the communication channels

The graphs of communication channel performance measurements are shown on the Figure 8. The selected interval of performance measurements is 5 minutes, starting with one way TCP session (from substation to control centre - blue line). After 1 minute period additional two way TCP session is added (red line). After next time intervals additional sessions are added (orange, yellow and green lines). This is simulation of multiple sessions per channel. The diagram depicts the performance of each session influenced by other sessions present in the communication channel.

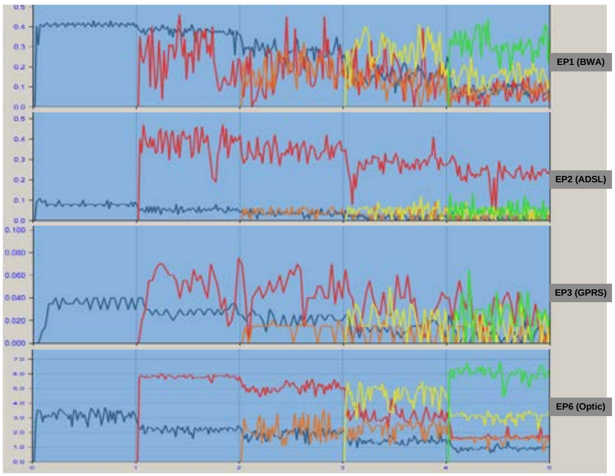

Figure 8: The performance diagrams

The summarisation of throughput tests

The data acquired during throughput tests are of important meaning for Elektro Primorska. Telecommunication networks behave very different regarding the parameters important for the DSO applications. The fixed access network technologies provide high capacity to the applications, low delays and jitter between end points. The same findings can be concluded for the BWA wireless technology. The parameters like availability, capacity, packet loss, QoS, delay and jitter are guaranteed inside required levels, and suitable for very demanding applications like SCADA. The GPRS/UMTS mobile networks provide only best effort services. The capacity of APN is significantly lower comparing to other technologies. Due to commercial nature of the mobile networks the data capacity left for other services is limited. Faced with higher delays and jitter current mobile services using GPRS are suitable for less demanding applications. Example is AMI, where the data required by MDM from AMI concentrators at the MV/LV substations are not required to be in real time. On the basis of throughput tests the DSO like Elektro Primorska has the possibility to discuss GPRS network parameters with mobile service provider, possibly apply certain mechanisms, which can improve the characteristics of the mobile network.

CONCLUSIONS

The conclusions for the methodology of throughput tests described in this article and verified during the realistic measurements can be summarised as follows:

- The test suite for throughput tests provides the method for exact quantisation of the communication network parameters and gives the possibility to DSO like Elektro Primorska to select the network technology, suitable for the applications required at the substation.
- The outcome of throughput tests gives answers to Elektro Primorska, what type of telecommunication networks are suitable for specific applications and thus giving clear directions for further development of the communication infrastructure
- Throughput tests can be periodic, since the conditions in the telecommunications networks (especially in mobile) vary in time. The results will be used to optimise or reconfigure relevant parameters and networking equipment or discuss steps with the service provider when needed.

However, the method of throughput tests gives possibilities for further improvements and development like integration with other testing products or NMS product suites. Due to open source platform it opens also the possibility to integrate into the networking devices.

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