



Study Committee: B5

# Experiences and Learning on Monitoring Digital Substation Communication Networks

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# Introduction

- Concept of **network monitoring: systematic verification** in search of **anomalies** that could compromise its **proper functioning**;
- **IEC 61850 network monitoring** throughout the **life cycle** of the **digital substation: commissioning, continuous monitoring** and **maintenance tests**;
- **Importance of monitoring:**
  - **Early error detection**;
  - **Network operating** conditions;
  - Reducing **network unavailability**;
  - **Logging** all network events;
  - **Security and stability** of the power system.

# Monitoring for PACS / Brazilian TSO

- **Monitoring system** as an essential **tool for troubleshooting** the digital substation network;
- **Brazilian TSO – ONS:**
  - **IEC 61850 network monitoring** included in the **power system best practices**;
  - **PACS network** must incorporate **monitoring functions** able to:
    - Detect **anomalies** or **lacking of messages**;
    - Detect **lacking of synchronism** signal;
    - Verify **abnormal propagation time**;
    - **Independent system**;
    - Storing **event records**.
- **Specialized device:** for monitoring - “**communication network DFR (Digital Fault Recorder)**”
  - Implemented both in **hardware and software** to cover all the **time-critical** requirements – **GOOSE and SV**.

# Network monitoring system: general aspects



- **Network aspects covered by the monitoring system:**
  - **Integrity** of the messages;
  - **Configuration and security** of the data;
  - **Frame's structure**;
  - System's time **synchronism**;
  - Message timing **statistics**;
  - **Test / Simulation** configuration;
- Alert potential **communication failures** or **invasions**;
- **PCAP files** can be **recorded** for more detail;
- Monitoring through a **Trunk Port** or **Mirror Port**.

# Network monitoring system: device and modes



- **Monitoring system features:**
  - **SCL validation mode:**
    - SCL imported x frame on network.
  - **Sniffer mode:**
    - Scan the network in search of **traffic not foreseen** by the SCL files.
  - **Supervision mode:**
    - Network errors;
    - Supervision events: GOOSE, SV and PTP;
    - PCAP recording.
  - **Statistics mode:**
    - Statistical analysis of GOOSE and SV traffic.

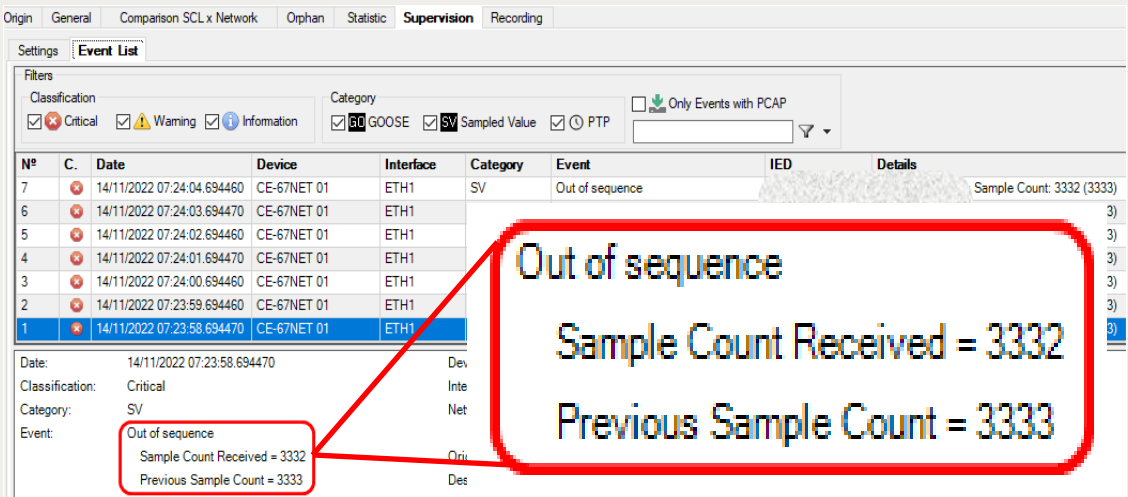


# Study Cases: Experiences and Learning (1<sup>st</sup>)



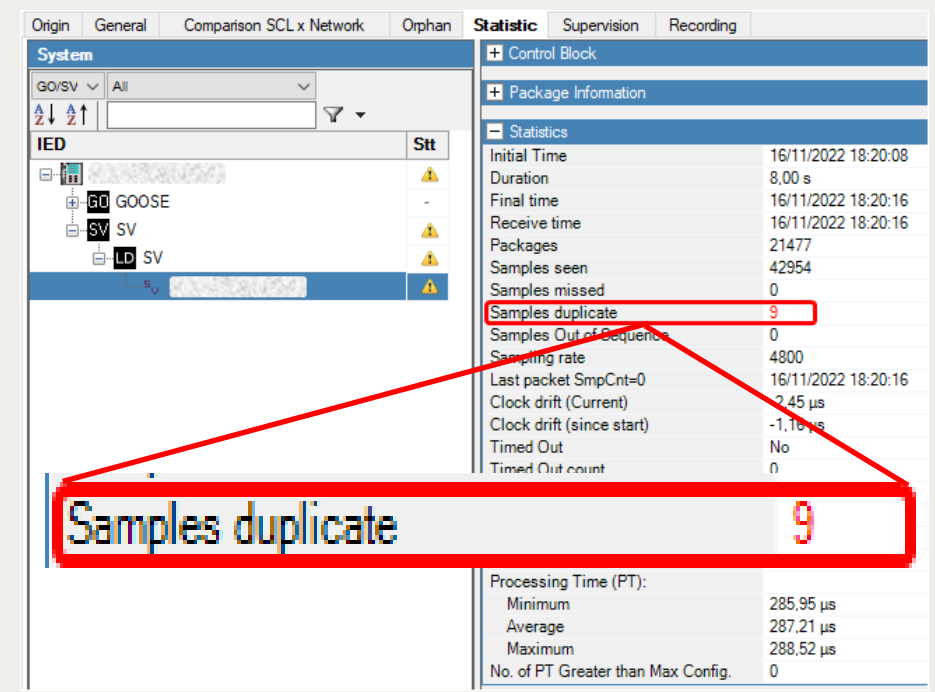
- **Network issues in Brazilian digital substations:**
  - **Monitoring system: detect and identify** these problems to help find a solution.
- **First study case: duplicated SV frames errors** due to a **RedBox** problem:
  - **Digital substation** with **13 Merging Units** and about **168 GOOSE messages** inserted into the network architecture;
  - **SV frames** published at **IEC 61869-9 preferred sampling rate** – 4800 samples/second and 2 ASDUs;
  - The **duplication issue: every second** on the **same sample count**, in **RedBox output**;
  - Detection by the monitoring system: **out of sequence event** in **supervision mode**, as also in **statistical mode**.

• **Out of Sequence Event – Supervision Mode:**



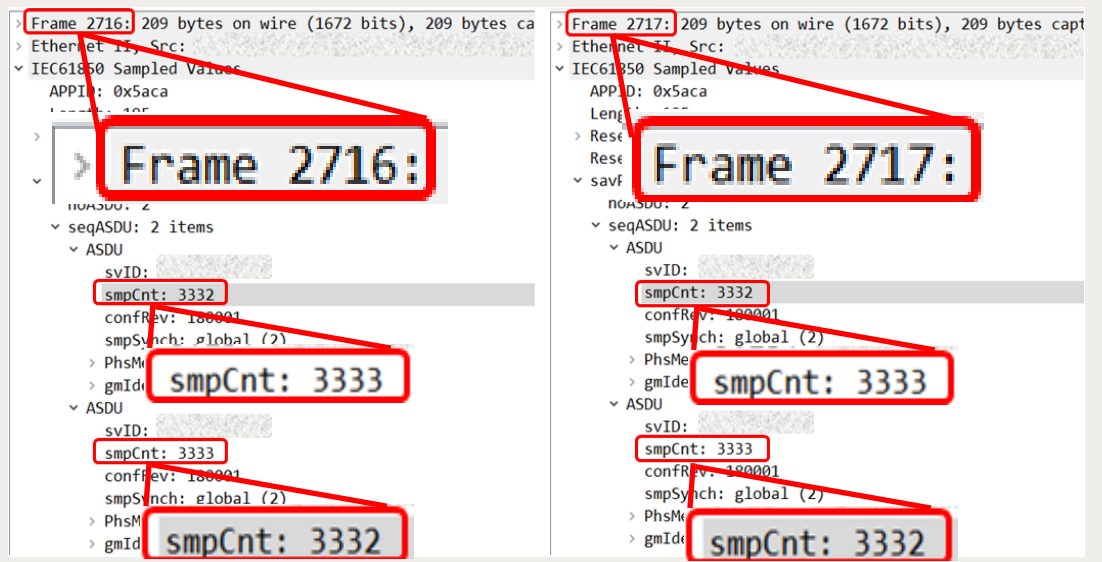
Nº	C.	Date	Device	Interface	Category	Event	IED	Details
7	⊗	14/11/2022 07:24:04.694460	CE-67NET 01	ETH1	SV	Out of sequence		Sample Count: 3332 (3333)
6	⊗	14/11/2022 07:24:03.694470	CE-67NET 01	ETH1				3)
5	⊗	14/11/2022 07:24:02.694460	CE-67NET 01	ETH1				3)
4	⊗	14/11/2022 07:24:01.694470	CE-67NET 01	ETH1				3)
3	⊗	14/11/2022 07:24:00.694460	CE-67NET 01	ETH1				3)
2	⊗	14/11/2022 07:23:59.694460	CE-67NET 01	ETH1				3)
1	⊗	14/11/2022 07:23:58.694470	CE-67NET 01	ETH1				3)

• **Statistical mode:**



Statistic	Value
Initial Time	16/11/2022 18:20:08
Duration	8,00 s
Final time	16/11/2022 18:20:16
Receive time	16/11/2022 18:20:16
Packages	21477
Samples seen	42954
Samples missed	0
Samples duplicate	9
Samples Out of Sequence	0
Sampling rate	4800
Last packet SmpCnt=0	16/11/2022 18:20:16
Clock drift (Current)	2,45 µs
Clock drift (since start)	-1,16 µs
Timed Out	No
Timed Out count	0

• **PCAP file register:**



# Study Cases: Experiences and Learning (1<sup>st</sup>)

- **First study case - SCL file non-compliance with the recommendation of IEC 61850-9-2 Ed. 2, Annex B. Detected through SCL validation mode:**

Service	Recommended address range assignments	
	Starting address (hexadecimal)	Ending address (hexadecimal)
GOOSE	01-0C-CD-01-00-00	01-0C-CD-01-01-FF
GSSE	01-0C-CD-02-00-00	01-0C-CD-02-01-FF
Multicast sampled values	01-0C-CD-04-00-00	01-0C-CD-04-01-FF

```
<SMV IdInst="SV" cbName= >
  <Address>
    <P type="VLAN-ID" xsi:type="tP_VLAN-ID">8C6</P>
    <P type="VLAN-PRIORITY" xsi:type="tP_VLAN-PRIORITY">6</P>
    <P type="MAC-Address" xsi:type="tP_MAC-Address">01-0C-CD-04-24-23</P>
    <P type="APPID" xsi:type="tP_APPID">5ACA</P>
  </Address>
</SMV>
```

01-0C-CD-04-24-23

> Frame 2717: 209 bytes on wire (1672 bits), 209 bytes captured (1672 bits) on interface  
> Ethernet II, Src: , Dst: Iec-Tc57\_04:24:23 (01:0c:cd:04:24:23)

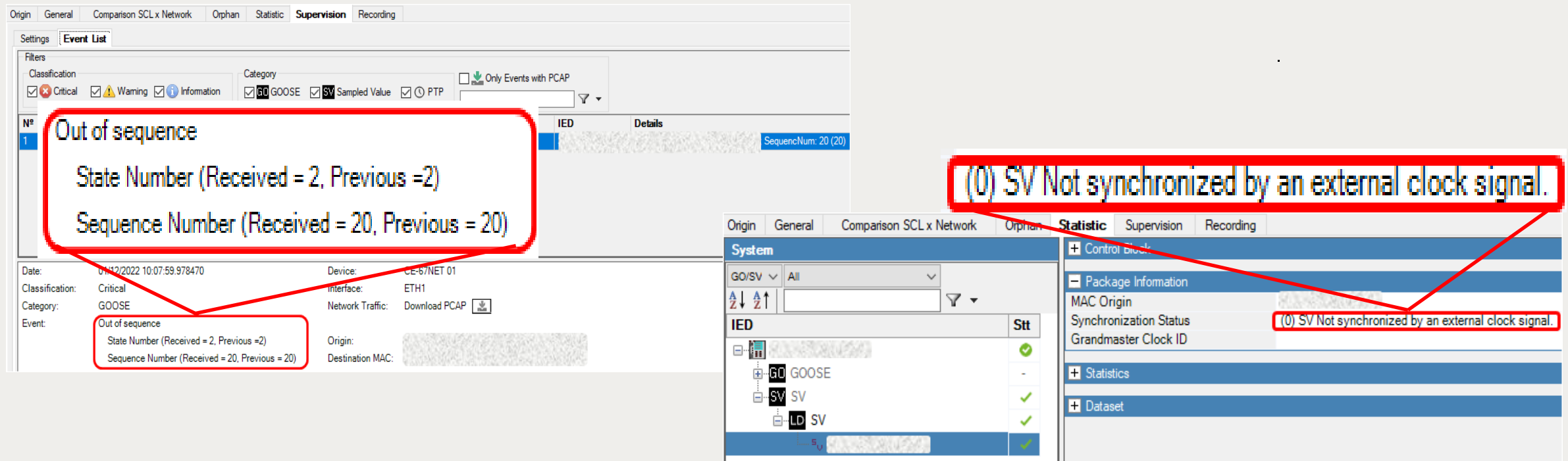
IEC61850 Sampled Values  
APPID: 0x5aca  
Length: 195  
> Reserved 1: 0x0000 (0)  
> Reserved 2: 0x0000 (0)

savPdu  
noASDU: 2  
seqASDU: 2 items  
ASDU  
svID:



# Study Cases: Experiences and Learning (2<sup>nd</sup>)

- **Second study case** – digital substation with four different IEDs vendors; GOOSE and SV streams being published:
  - **Network issues: duplicated GOOSE frames and loss of MUs' synchronism;**
  - **Detection by the monitoring system: supervision mode and statistical mode.**



The screenshot displays a monitoring system interface with several key components:

- Event List:** Shows a single event with the following details:
  - Classification:** Critical
  - Category:** GOOSE
  - Event:** Out of sequence
  - State Number (Received = 2, Previous = 2)**
  - Sequence Number (Received = 20, Previous = 20)**
- System Configuration:** Shows a tree view of IEDs (GOOSE, SV, LD) with their status (Sst) indicated by green checkmarks.
- Package Information:** Shows synchronization status as **(0) SV Not synchronized by an external clock signal.**

# Study Cases: Experiences and Learning (3<sup>rd</sup>)



- **Third study case** – digital substation with **26 MUs** and about **148 GOOSE messages**:
  - **SCL files incompatibility;**
  - Detection by the monitoring system: **SCL validation mode.**

AppID	10242	AppID	9984
Control Block		Control Block	✓
MAC Destination		MAC Destination	✓
AppID	10242	AppID	9984 ⚠
GOOSE ID		GOOSE ID	✓
Dataset		Dataset	✓
VLAN ID	2242	VLAN ID	2242 ✓
VLAN Priority	6	VLAN Priority	6 ✓
Needs Commissioning	False	Needs Commissioning	False ✓
Config Rev	40001	Config Rev	40010 ⚠
Simulation	False	Simulation	False ✓
Time to Live	2000 ms	Time to Live	2000 ms ✓
Number of DataSets	4	Number of DataSets	4 ✓

Config Rev	40001	Config Rev	40010
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# Conclusions



- Detailed **network monitoring** study in a **digital substation context**:
  - Discussion of the **requirements** for **implementation** of a **complete monitoring system**.
- **Experiences and learning** with **network problems** occurred in **Brazilian digital substations**, and **the role of monitoring system**;
- The **importance** of **network monitoring system**:
  - **Specialized device** for **network troubleshooting**.
- It is expected that this work contributes to enable **proper operation of communication networks**, as this is the only way to ensure **safe and reliable power system**.

THANK YOU!



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