



IEC 61850 Sampled Values Communication using RTDS Simulator and GTFPGA

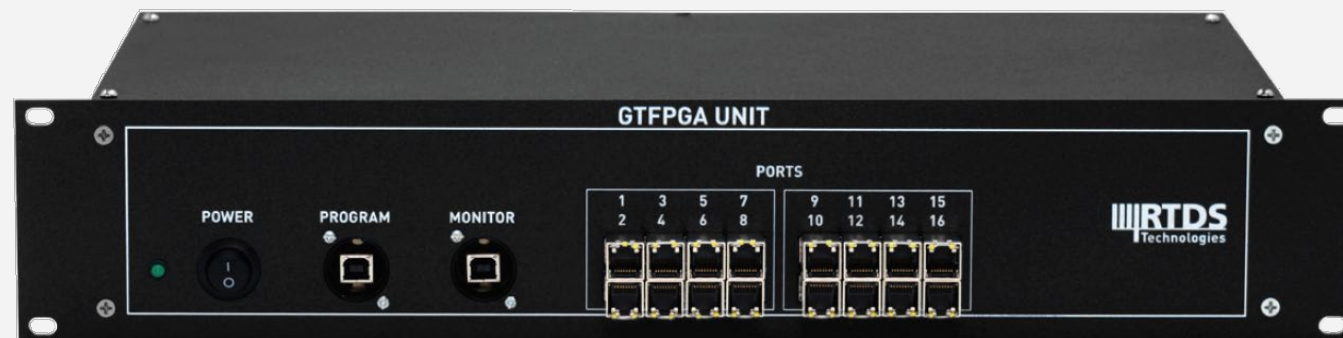


IEC 61850 SV

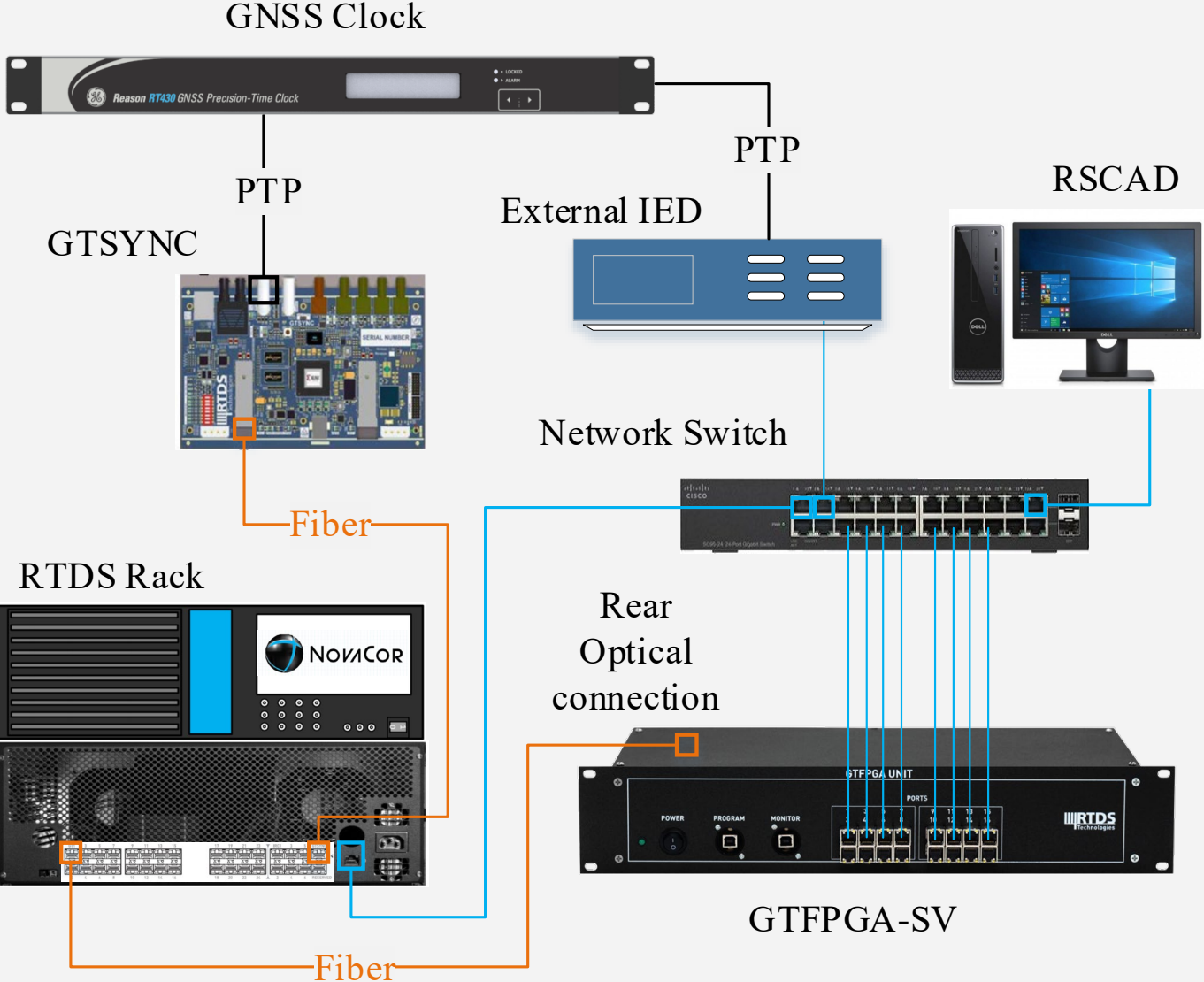
- Protection & control systems increasingly rely on critical measurements delivered through IEC 61850/IEC 61869 Sampled Value (SV)
- SV is one of the most commonly used protection & automation protocol to interface the simulator with external IEDs
- Non-genuine and non-ideal SV streams → misoperation, serious damage, cascading failures
- Need to identify the weakness and vulnerability of SV-based protection systems

GTFPGA-SV Hardware

- 16 fiber/copper Ethernet ports
- 100 Mbit/s or 1Gbit/s
- Publish (output) and subscribe (input) up to 16 independent SV streams **simultaneously**
- GTFPGA unit connects to the simulator by an optical fibre



Typical Connection



Sampling Rates

Table 902 – Standard sample rates

Digital output sample rates Hz	Number of ASDUs per frame	Digital output publishing rate frames/s	Remarks
4 000	1	4 000	For use on 50 Hz systems backward compatible with 9-2LE guideline.
4 800	1	4 800	For use on 60 Hz systems backward compatible with 9-2LE guideline, or 50 Hz systems backward compatible with 96 samples per nominal system frequency cycle.
4 800	2	2 400	Preferred rate for general measuring and protective applications, regardless of the power system frequency.
5 760	1	5 760	For applications on 60 Hz systems backward compatible with 96 samples per nominal system frequency cycle.
12 800	8	1 600	Deprecated, only for use on 50 Hz systems.
14 400	6	2 400	Preferred rate for quality metering applications, regardless of the power system frequency including instrument transformers for time critical low bandwidth d.c. control applications.
15 360	8	1 920	Deprecated, only for use on 60 Hz systems.
96 000	1	96 000	Preferred rate for instrument transformers for high bandwidth d.c. control applications.

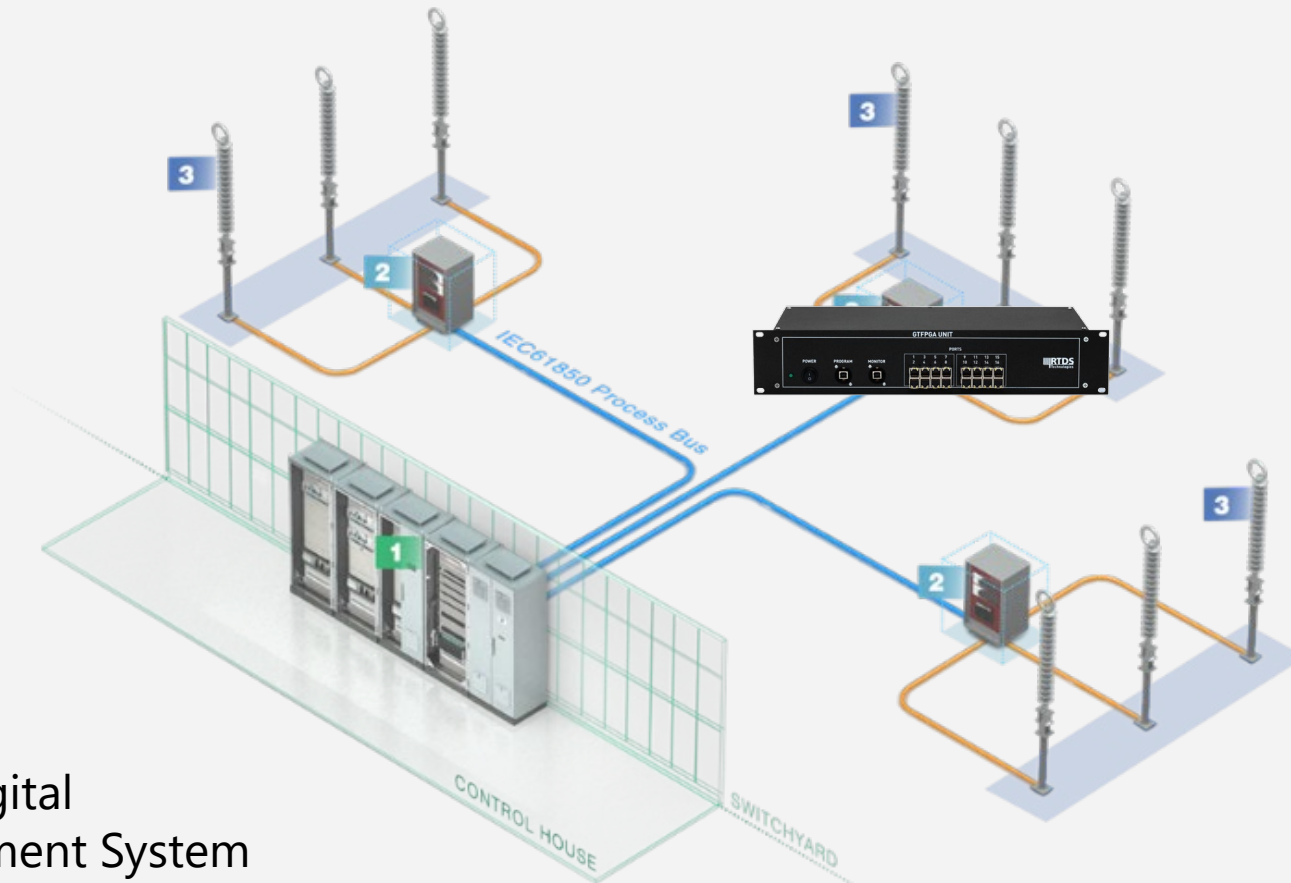
Capabilities

Sampling Rates and Number of Channels

Mode	Max. Number of SV Streams	Sampling Rate	Max. Number of Channels per Stream
Mainstep	16 Outputs and 16 Inputs	80 s/c, 96 s/c, 4800 Hz	24
		256 s/c, 14400 Hz	9
Substep	2 (Output only)	96 kHz	24
	1 (Output only)	250 kHz	48

250 kHz Sampling Rate

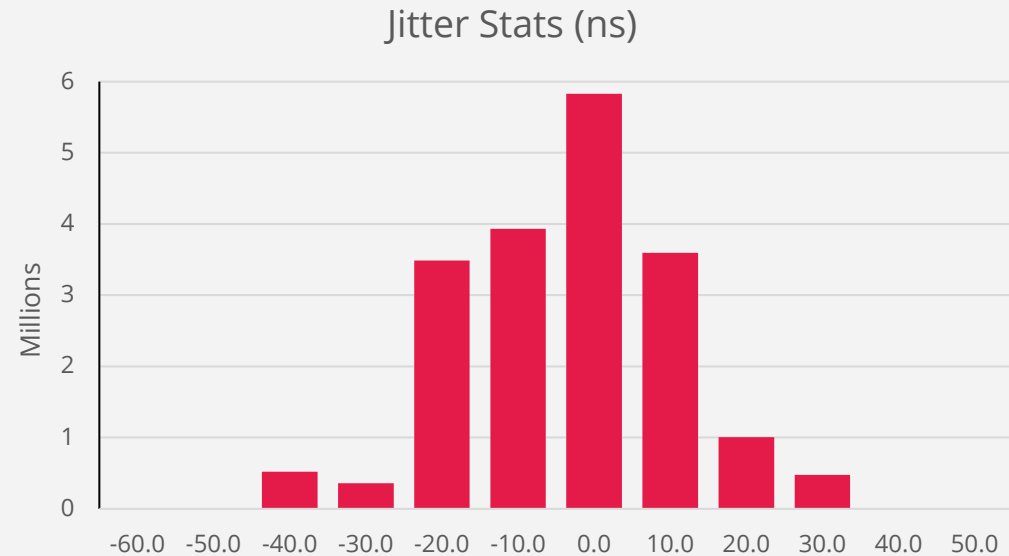
High bandwidth HVDC protection and control applications



HVDC Digital
Measurement System

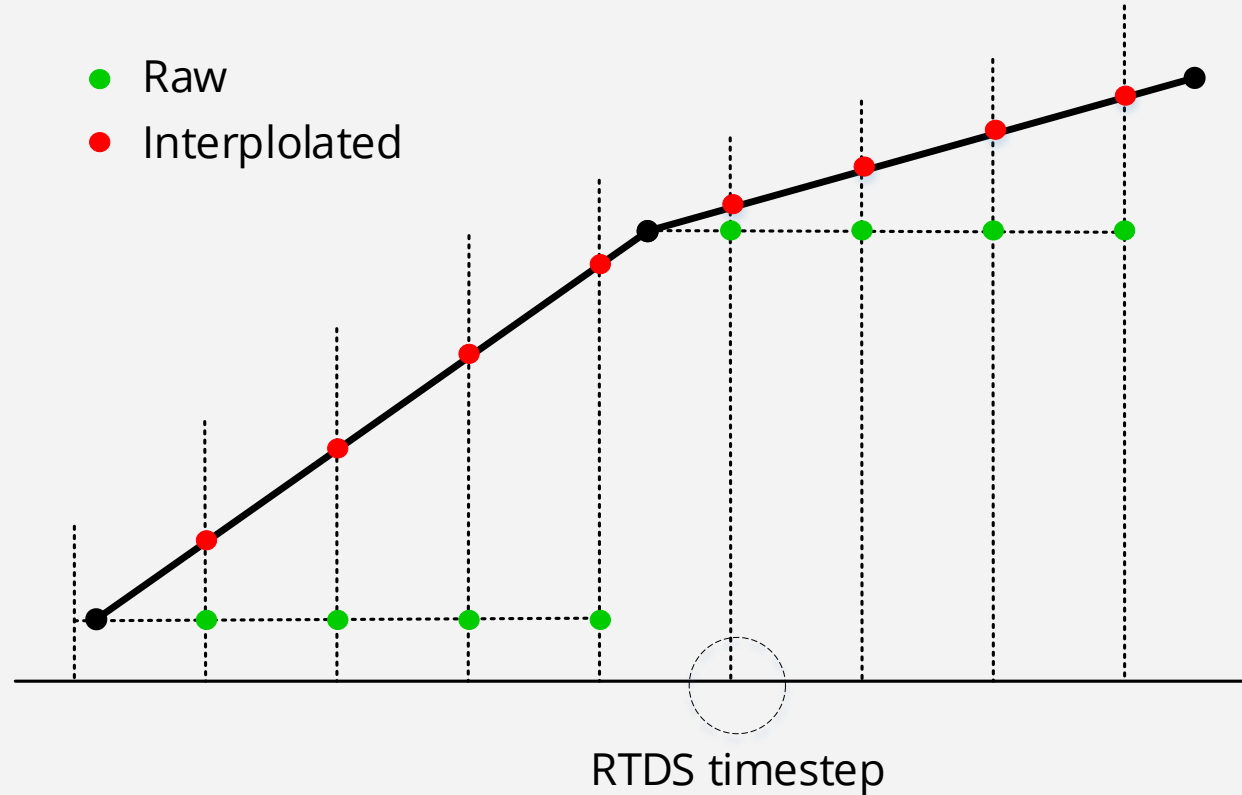
Subscriber

- SCL file parsing
- Filtering
 - APPID
 - Simulation Flag
- Monitoring
 - Packet interval (jitter stats)
 - Detailed subscription status (SV stream lost, CRC error, etc.)



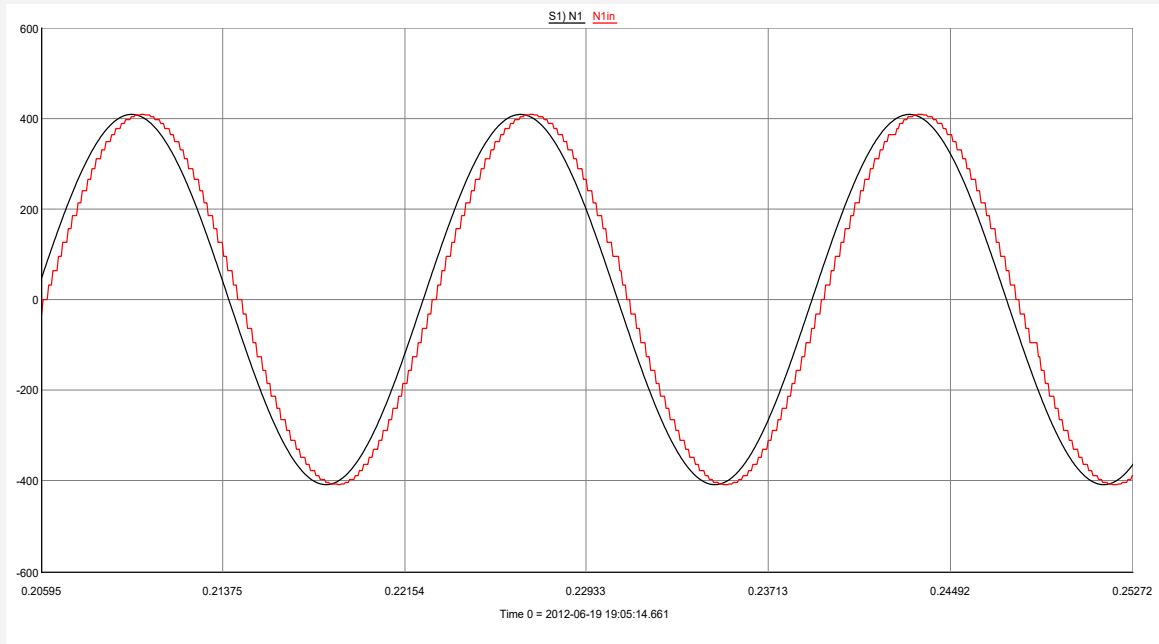
Subscriber

Raw vs Interpolated

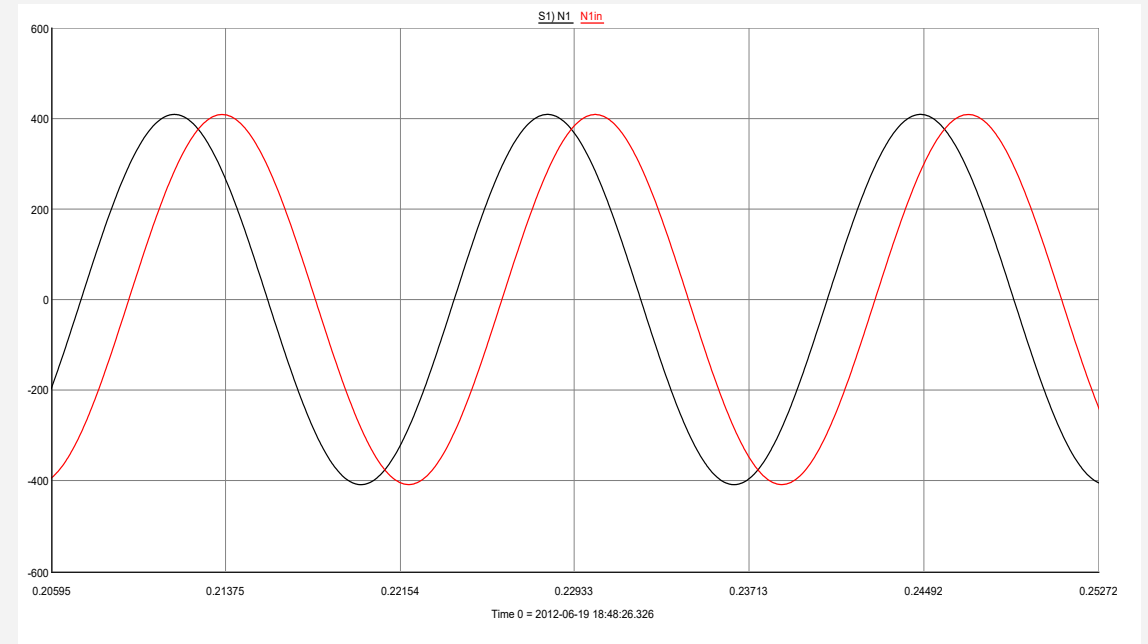


Subscriber

Raw

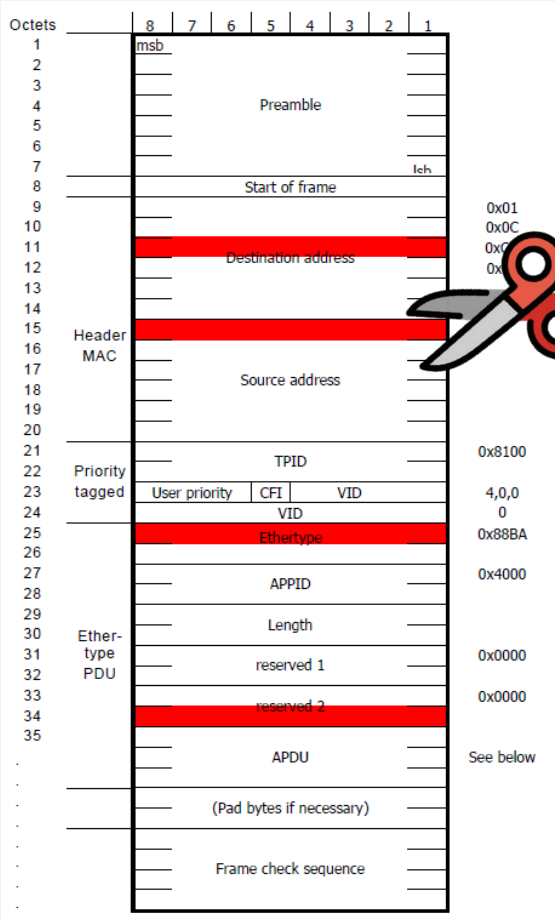


Interpolated

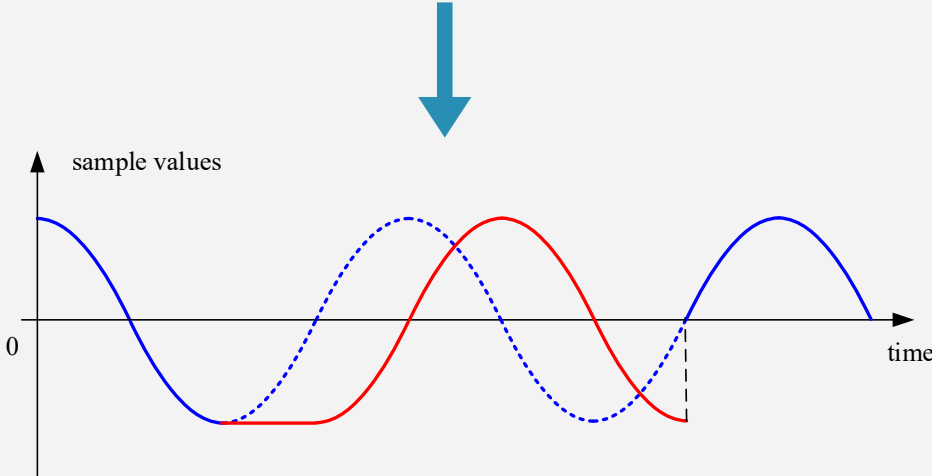


SV Publisher Manipulation

Data Manipulation

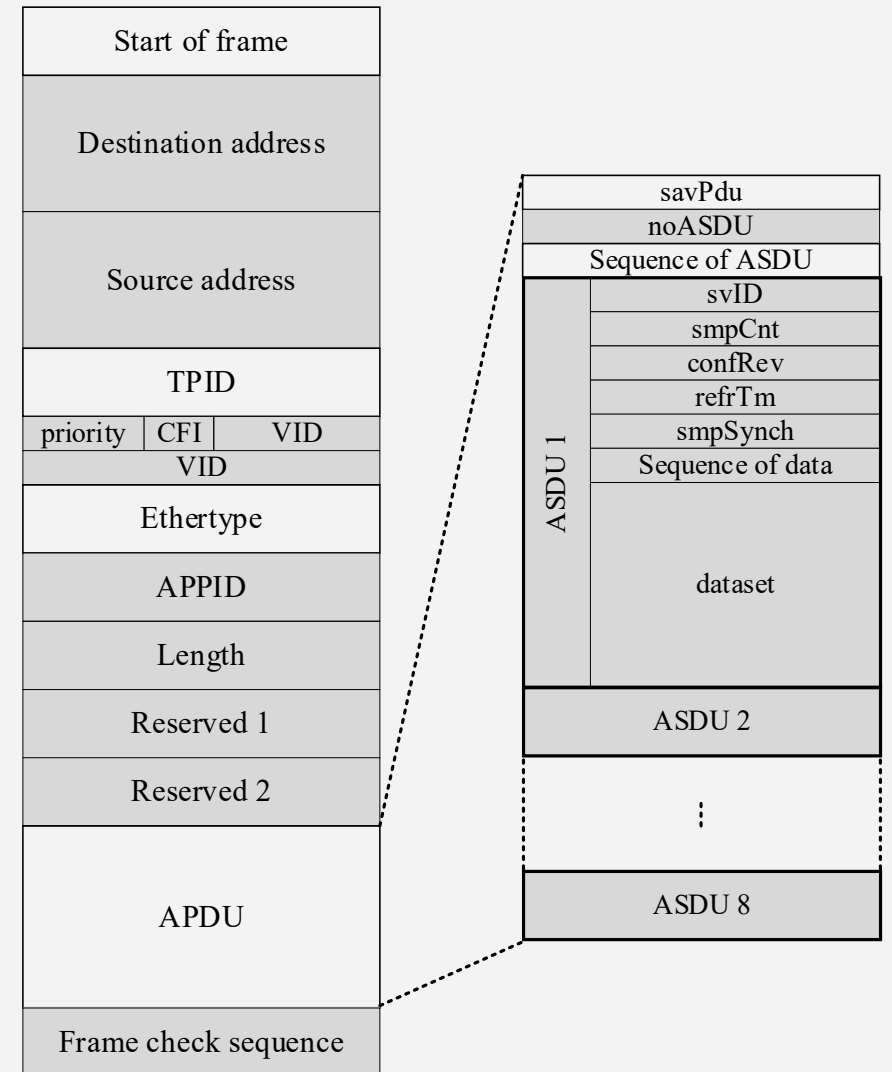


Stream Manipulation



Data Manipulation

- | | |
|------------------------|-----------------------------|
| 1) VLAN Priority | 7) Number of ASDU |
| 2) VLAN ID | 8) Configuration revision |
| 3) Application ID | 9) Sample count |
| 4) Length of SV packet | 10) Destination MAC address |
| 5) Reserved 1 | 11) Source MAC address |
| 6) Reserved 2 | 12) Stream identification |

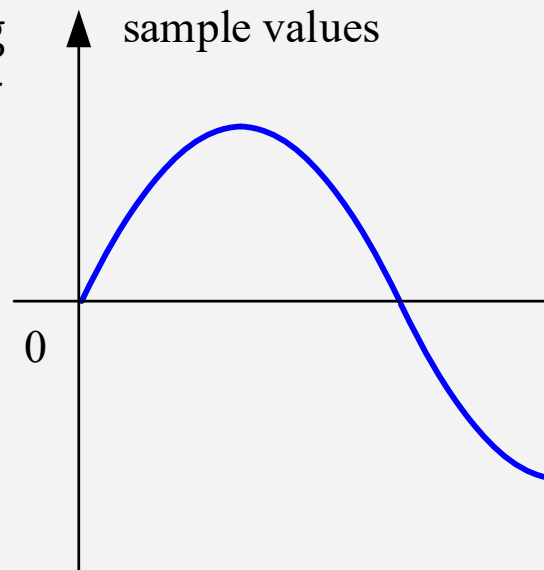


Stream Manipulation

- 1) Stop/resume
- 2) Duplicate
- 3) Swap
- 4) Delay
- 5) Jitter

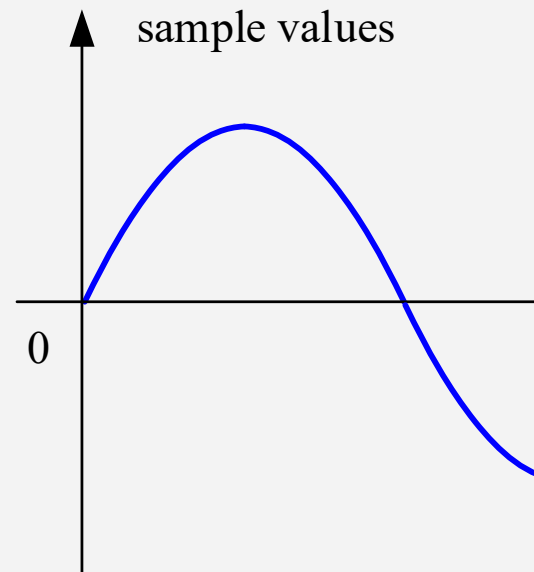
1) Stop/Resume

stop/resume publishing during runtime to simulate the loss of packets on the network



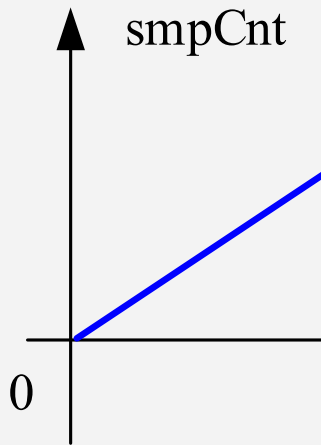
2) Duplicate

duplicate packets to simulate
a problematic network
topology



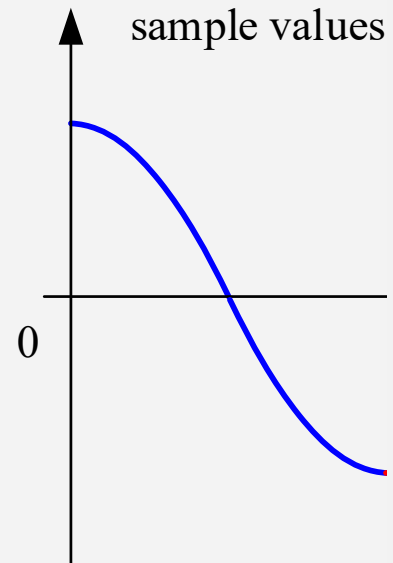
3) Swap

swap the order of two packets to simulate non-sequential arriving of packets, due to problematic network routing



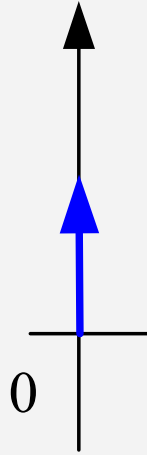
4) Delay

delay publishing to
simulate unwanted
latency on the network



5) Jitter

- add positive/negative jitter to simulate the variance of latency
- Resolution: 10 ns

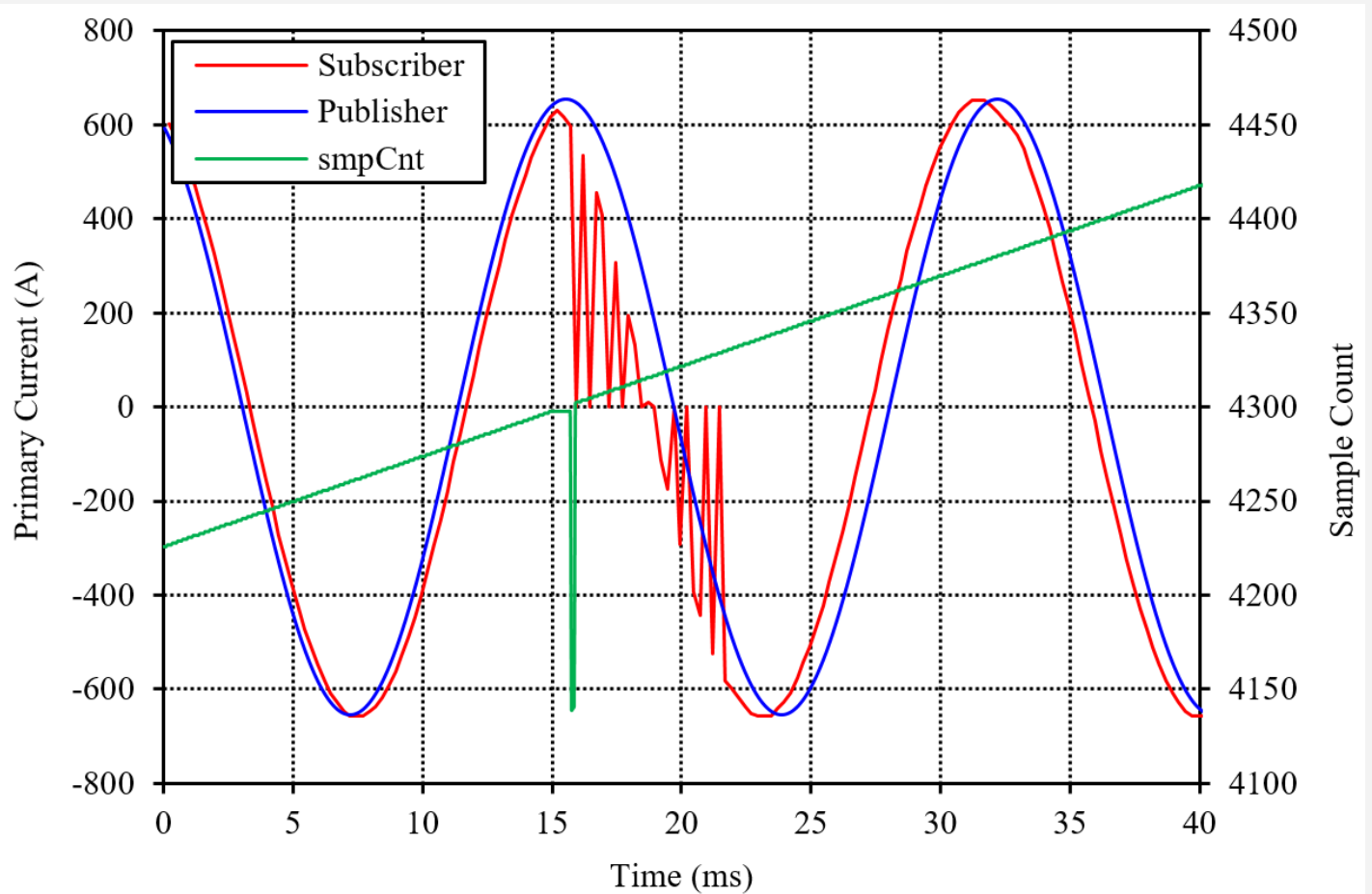


Data Manipulation

Field name	IED response
Destination MAC	Subscription stop
Source MAC	Does not affect
VLAN priority	Does not affect
VLANID	Subscription stop
APPID	Subscription stop
Length	Subscription stop
Reserved 1	Does not affect
Reserved 2	Does not affect
noASDU	Subscription stop
svID	Does not affect
smpCnt	Affected for operation
confRev	Subscription stop
smpSynch	Does not affect

Data Manipulation: smpCnt

- Manipulate 3 smpCnt
- Half-cycle abnormal measurements
- Corrupt IED buffer
- During resampling, generate incorrect values



Stream Manipulation: latency & jitter

- Latency
 - Delayed 2.5 ms
 - IED operated normally
 - IED's data buffer reduce the impact of delay
- Jitter
 - Gaussian distribution jitter
 - Standard deviation 2.5 ms
 - IED operated normally
 - IED's data buffer reduce the impact of jitter

Summary

- GTFPGA unit combined with RTDS simulator allows for efficient/accurate testing of many SV-compliant devices
- Up to 16 SV streams can be published/subscribed simultaneously and independently
- Suitable for ultra high bandwidth applications such as HVDC protection and control applications
- SV manipulation allow users to identify and address vulnerabilities in SV-based protection before the deployment on the grid



RSCAD Demonstration



RTDS.COM