RTDS Technologies

twenty years as the world standard for

REAL TIME DIGITAL SIMULATION

OPEN PROTOCOL COMMUNICATION WITH THE RTDS SIMULATOR

Outline

Hardware Features

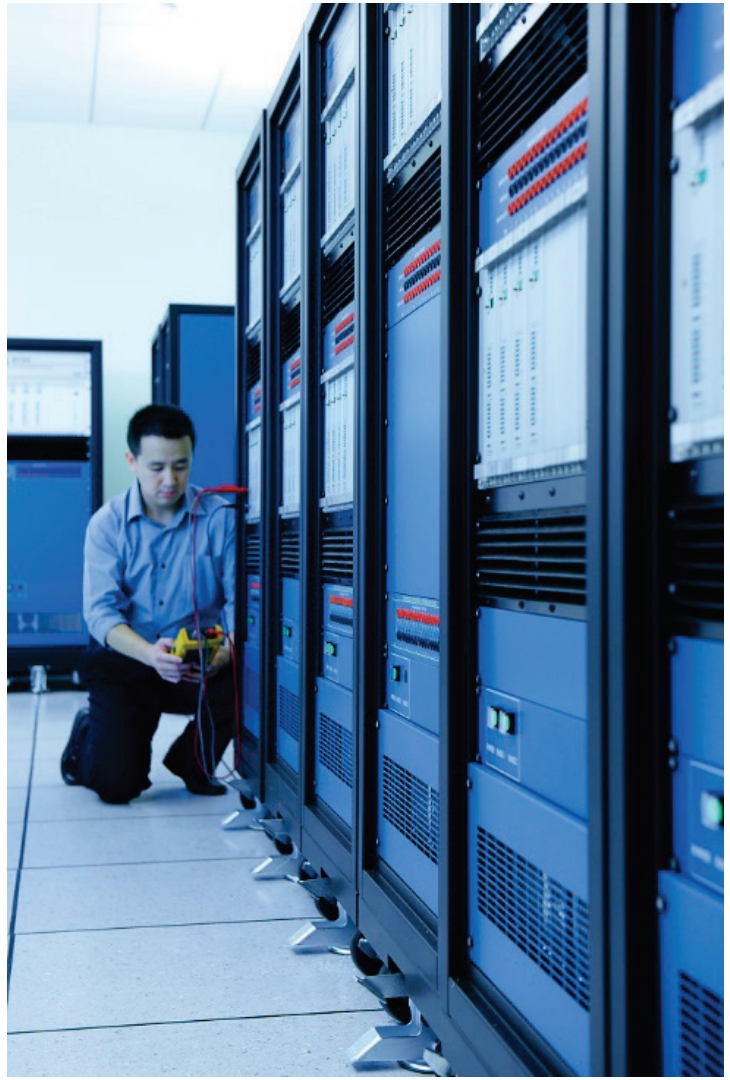
Software Support

GTFPGA-SV

Aurora Communication

Protection & Automation Suite

Questions and Answers



GTNETx2

What is the purpose of the GTNETx2 card?

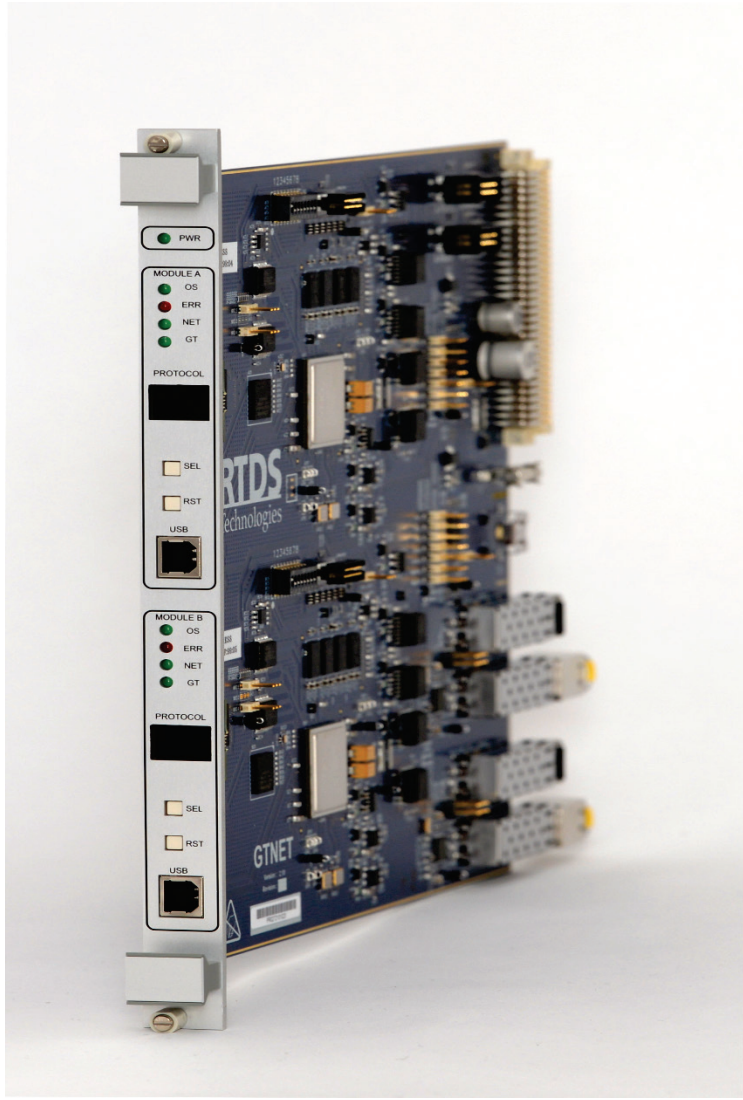
- Provides an interface between the simulation and the real world using known substation automation protocols

1 – GTNET-SV
2 – GTNET-GSE
3 – GTNET-PMU
4 – GTNET-DNP
5 – GTNET-104
6 – GTNET-PB
7 – GTNET-SKT
8 – GTNET-MODBUS

GTNETx2

Main Hardware Features

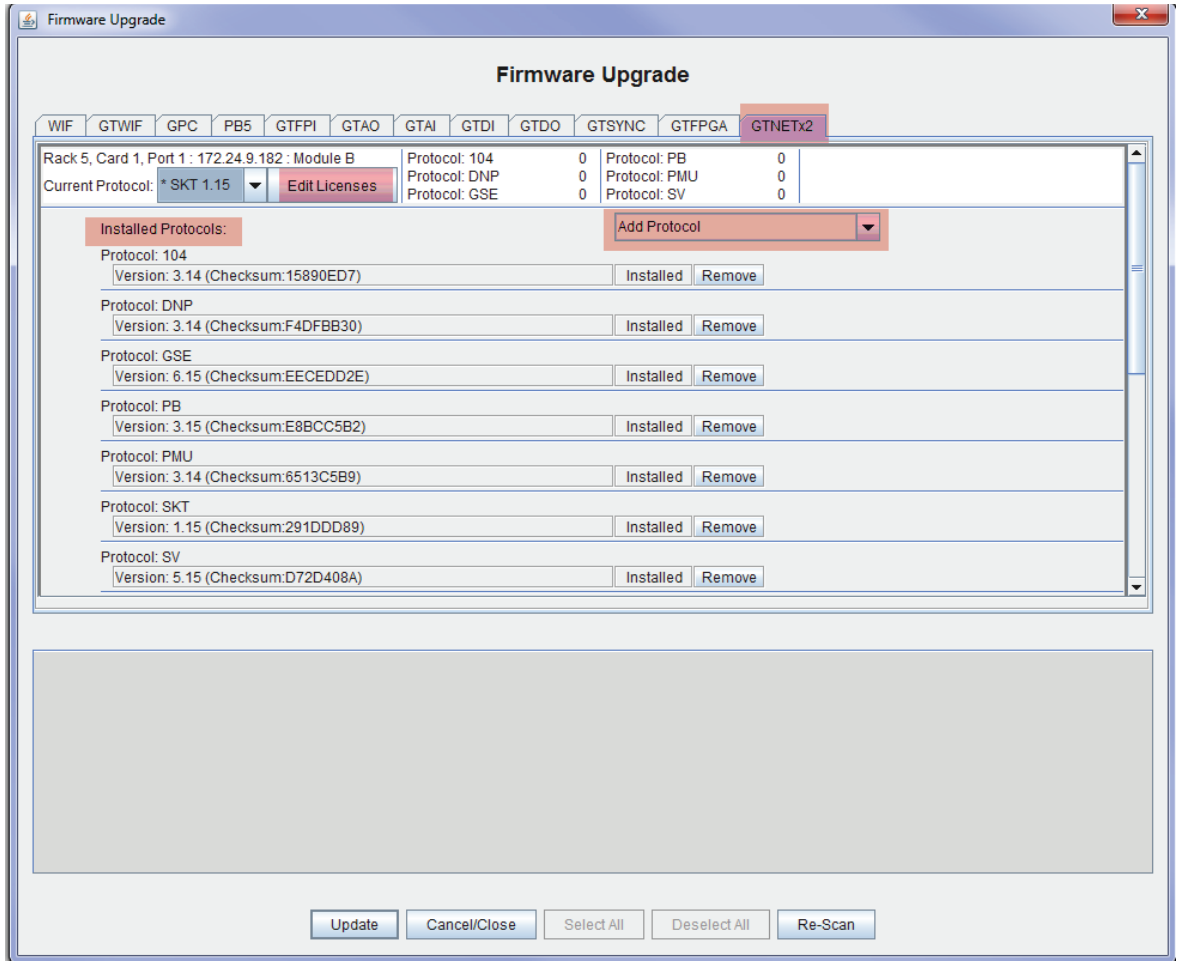
- Combined two existing GTNETs into one card
- Each ‘module’ is completely independent with no shared resources
- Support SFP modules for Ethernet
- Run 5-10 times faster than the previous GTNET card
- Separate front panel display
- Require GTWIF firmware OS 104 build 7



GTNETx2

Software Support

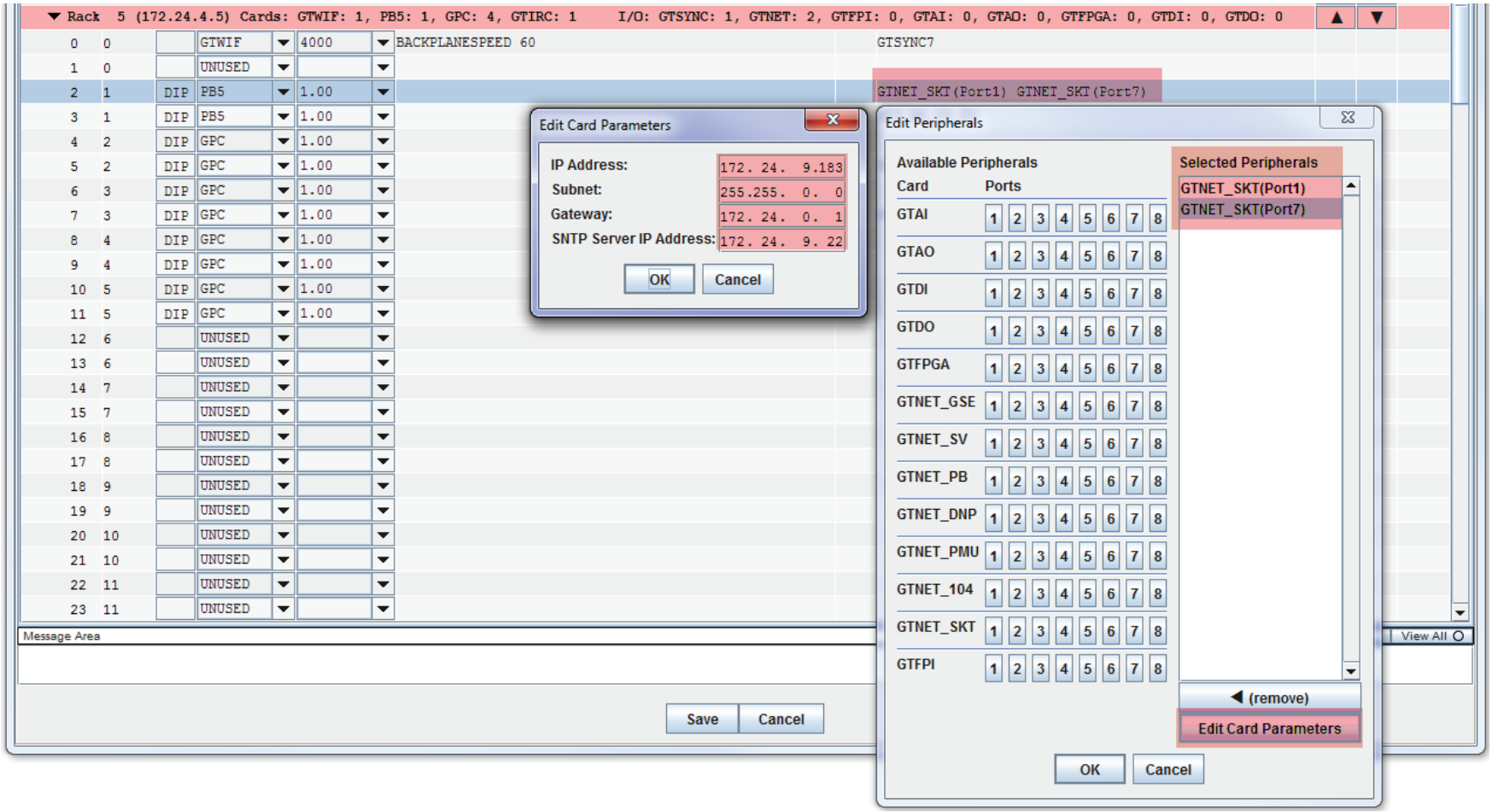
- Firmware upgrades are handled using software GUI
  - Switch protocols
  - Add new protocols & License management
  - Delete old version protocols



GTNETx2

Software Support

- Card parameters can be configured within the Config File Editor



GTNET

GTNET-SV

- Simulates IEC 61850 9-2LE or IEC 61869-9 compliant Merging Unit
  - 50Hz or 60Hz system frequency
  - Publish and Subscribe to SV

9.2LE Output Mode

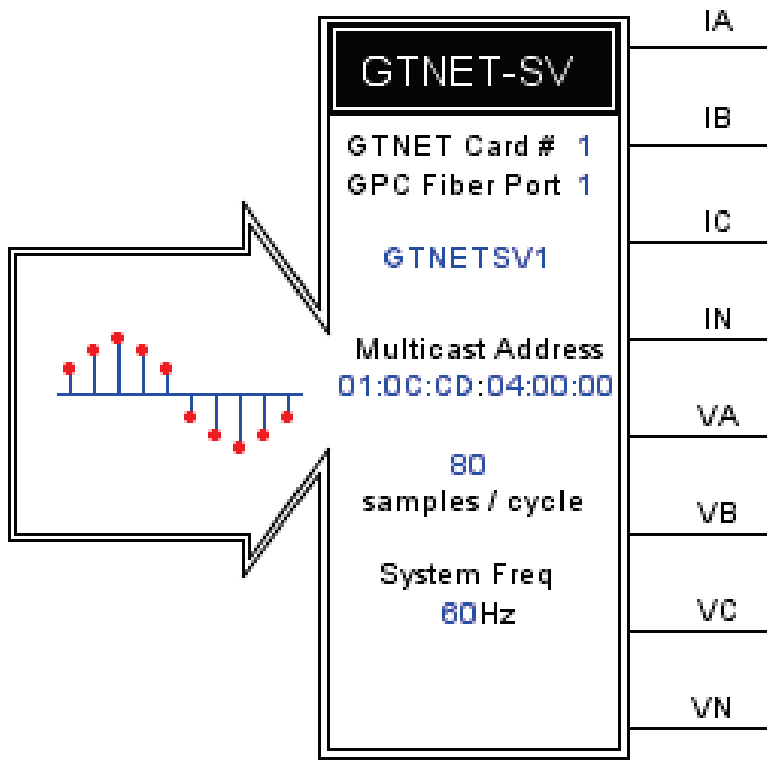
- Can be configured to publish up to 2 output data streams
- Sample rate at either 80 or 256 samples per cycle

IEC 61869-9 Output Mode

- Able to publish one data stream with up to 24 channels of voltages or currents
- Sample rate at 80 samples per cycle
- Jitter between samples is less than 10 usec
- Supports the Chinese National Standard for SV merging units

GTNET_SV9-2_v5 Input Mode

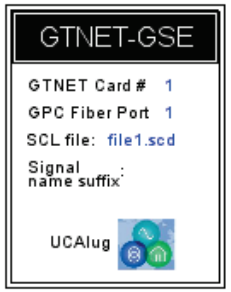
- Can be configured to subscribe 1 data stream from 1 MU at 80 or 256 samples per cycle
- GTSYNC is needed for use of the GTNET_SV9-2_v5 component



GTNET

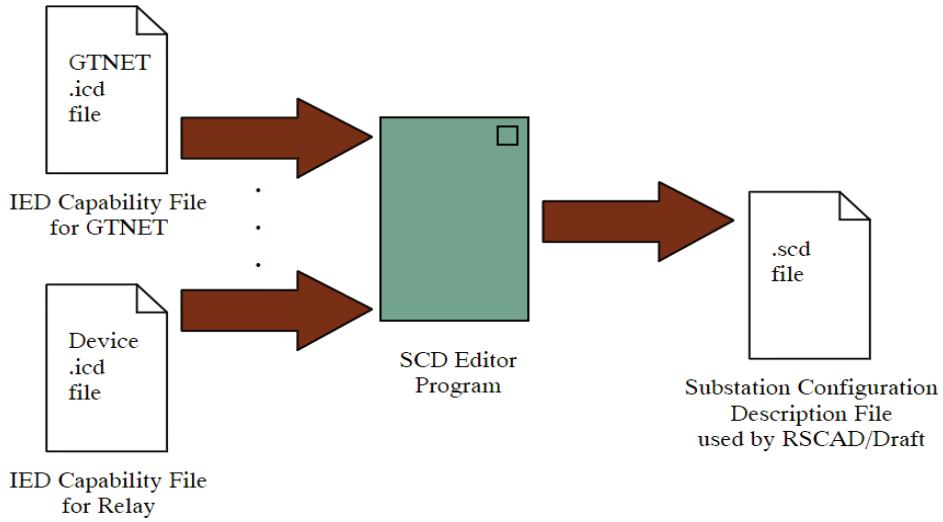
GTNET-GSE
GTNET_GSE_v5.def

- Provides IEC 61850 GOOSE communications
- Supports up to 4 TX/RX modules, which can be arranged to simulate 1-4 IEDs (i.e. 1 IED with 4 modules, 4 IEDs each with 1 module…)
- Each module can send up to 64 points (stVal) (Boolean, or INT32, or FLOAT32, or Dbpos), or 32 points with Quality
- Each module can receive up to 32 points (16 Booleans) with Quality
- Can receive GOOSE message from up to 16 unique external IEDs
- Required firmware GTNET-GSE v5.16 or higher (not compatible with GTNET_GSE_v2)



GTNET-GSE
SCD Editor (IED Configuration Tool)

- A engineering tool to generate required configuration files (IEC 61850 SCL format)
  - Exports GTNET-GSE ICD file - the configuration file defines the capabilities of the configured GTNET IED
  - Creates and edits a Substation Configuration Description (SCD) file
    - Firstly imports SCL files (SCD, ICD, CID, SSD…) of the external devices
    - Then maps the external references to the GTNET inputs



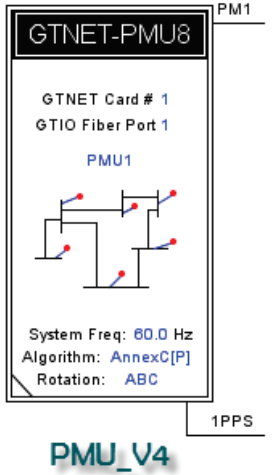
GTNET-PMU
PMUv4 & PMU_v5

- Designed to provide symmetrical component information related to three phrase sets of instantaneous values of voltage and current samples
- Large number of PMUs may be included in the simulated power system network
- Designed according to IEEE C37.118.1a™-2014 and IEEE C37.118.2 - 2011

GTNET

GTNET-PMU
PMUv4

- Simulates up to 8 PMUs
- Provides phasor information for voltage and current, including phase values, positive, negative, and zero sequence values
- Up to 12 phasors can be enabled for each PMU
- Provides measured frequency and rate of change of frequency information
- PMU algorithm includes P class, and M class
- Two modes
  - Metering mode
    - GTNET card and GTSYNC are not needed
    - Enabled phasor data only available as named output variables
  - C37.118 data output mode
    - Need GTNET-PMU and GTSYNC
    - Send phasor data out to the network through GTNET



_rtds_GTNET_PMU_v4.def

PMU1-8 AC SOURCE | PMU1-8 ANALOG/DIGITAL SOURCE

CONFIGURATION | PMU1 CONFIG | PMU1-8 CALIBRATION

Name	Description	Value	Unit	Min	Max
eC37data	Enable output of C37.118 data using GTNET	Yes		0	1
Name	GTNET Component Name	PMU1			
pmutype	PMU Model Type	Annex...		0	2
cfgtype	Configuration frame format	Config 2		0	1
freq	Base Frequency (Hz)	60.0		0	1
nPMU	Number of PMUs (maximum 8)	1		0	8
adv	Delay Input Signal to align V & I	V by 1dt		0	1
eAngM	Enable Angle Difference Meter	NO		0	1
nAngDiff	Angle Difference Meter Name (PMUx-PMUy)	angdiff		0	0
sfx	Plot Signal Suffix				
calib_const	Common offset applied to all PMU inputs	0	degrees	-360.0	360.0
dt_adj	Time-step adjustment to all input signals	-3	dt	-500	500

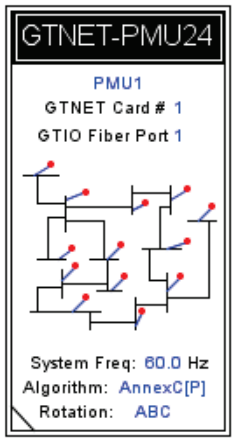
Update | Cancel | Cancel All

GTNET

GTNET-PMU

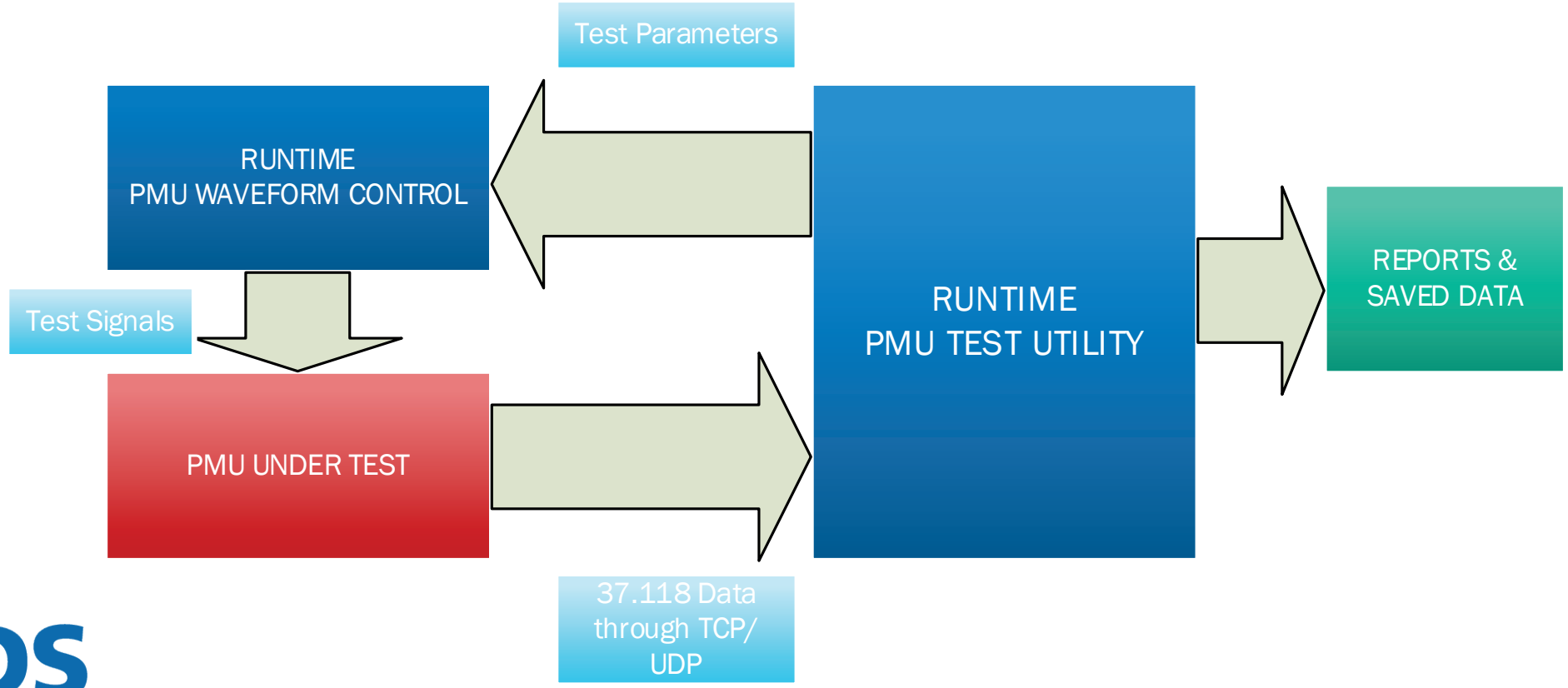
PMUv5

- Simulates more PMUs with few GTNETs for large networks
- Simulates up to 24 PMUs
- Up to 2 phasors can be enabled for each PMU, which are the positive sequence phasor information for voltage and current
- Provides measured frequency and rate of change of frequency
- PMU algorithm includes P class
- Two modes
  - Metering mode
    - GTNET card and GTSYNC are not needed
    - Enabled phasor data only available as named output variables
  - C37.118 data output mode
    - Need GTNET-PMU and GTSYNC
    - Send phasor data out to the network through GTNET



PMU TEST UTILITY

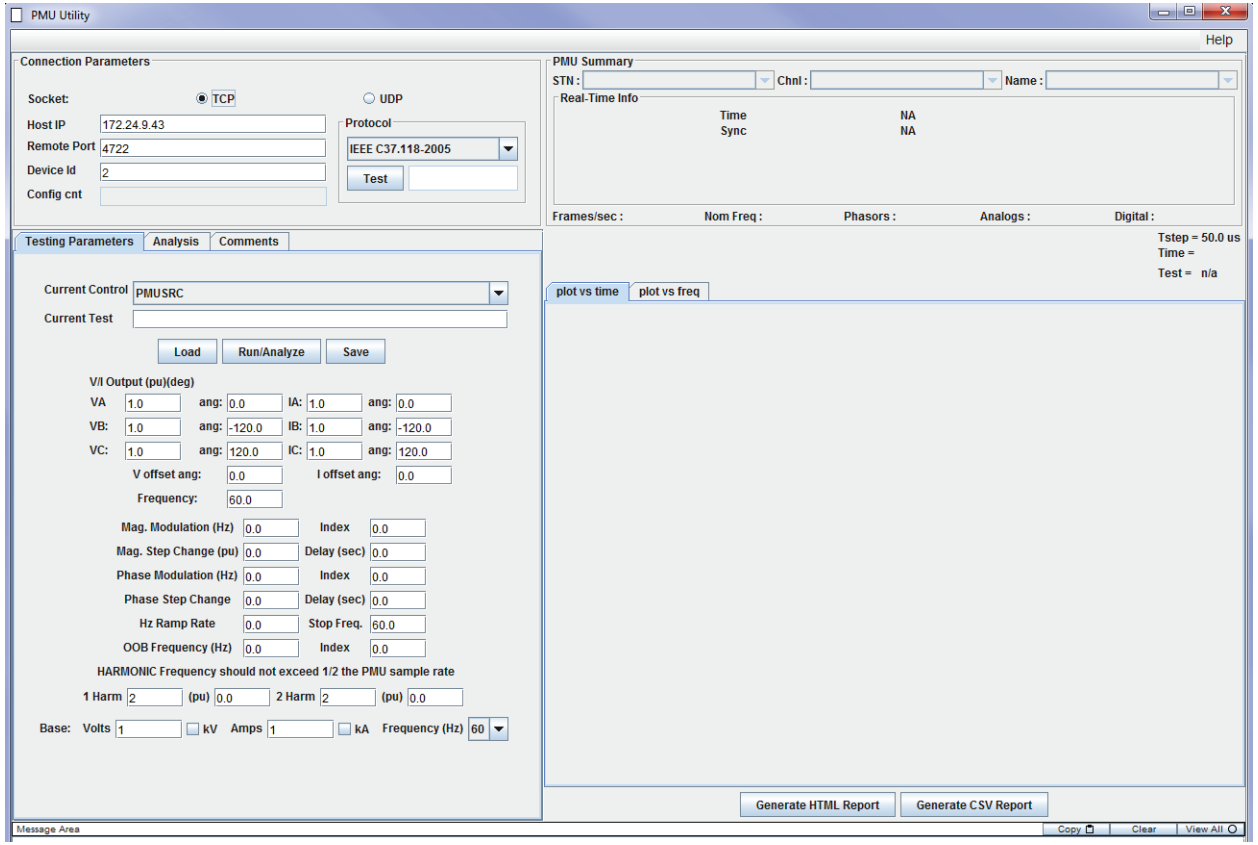
Testing External Physical PMUs
A RunTime Feature - PMU Test Utility



PMU TEST UTILITY

Testing External Physical PMUs
A RunTime Feature - PMU Test Utility

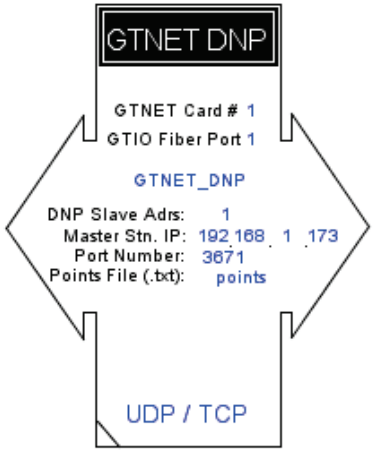
- ❑ Test PMU total vector error (TVE)
- ❑ Gather PMU data
- ❑ Control test parameters
- ❑ Analysis tools
- ❑ Export results

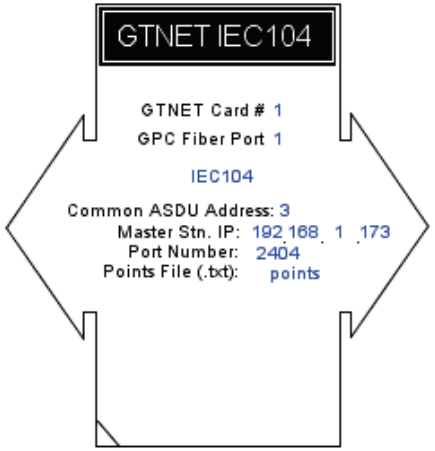


GTNET

GTNET-DNP & -104 (60870-5-104)

- Binary simulation status/input (i.e. breaker position)
  - 1024 (scan rate 1000 Hz)
- Binary simulation control/output (i.e. breaker commands)
  - 512 (scan rate 1000 Hz)
- Analogue status
  - 500 (scan rate 10 Hz)
- Analogue control
  - 100 (scan rate 10 Hz)
- The GTNET – DNP and -104 supports one master with a maximum polling rate of less than 5 Hz

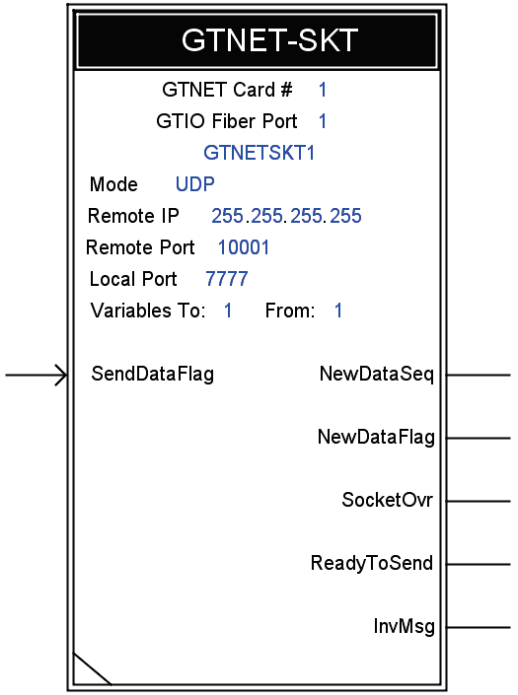




GTNET

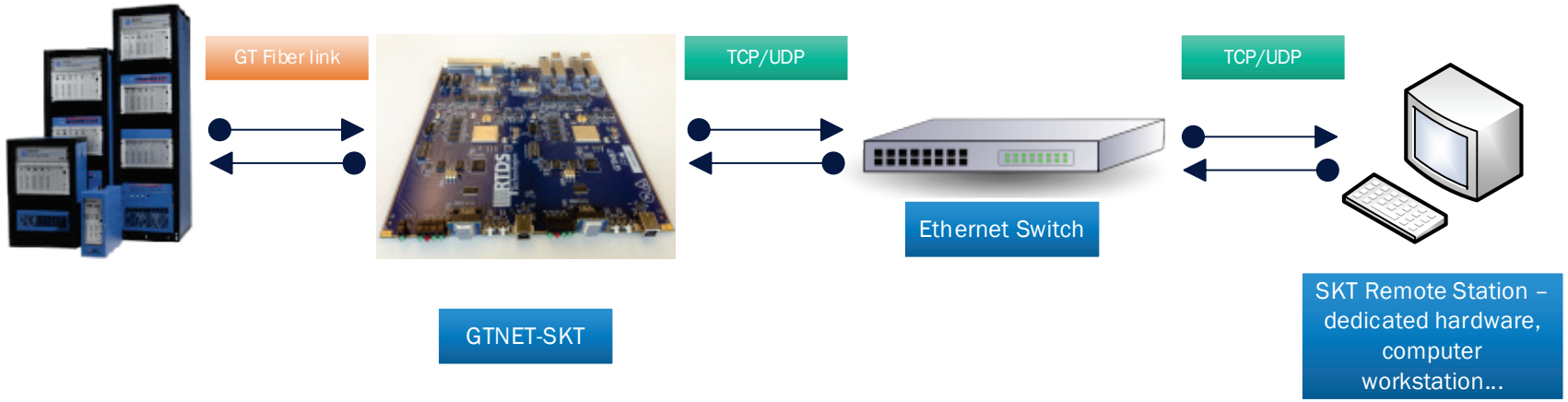
GTNET-SKT

- Interface with external software/hardware over a LAN/WAN using TCP or UDP sockets
- The communication is
  - Bidirectional
  - Asynchronous
  - Unsolicited
  - Initiated by each side of the Ethernet based communication link
- Able to send data size up to 300 points (4 bytes/point) per packet
- Data type is defined either be Integer or Float (IEEE 754)
- Maximum recommended update rates
  - GTNETx2 - 1K Hz for 300 points or 5K Hz for less than 60 points
  - GTNET – 100 Hz for any number of points



GTNET

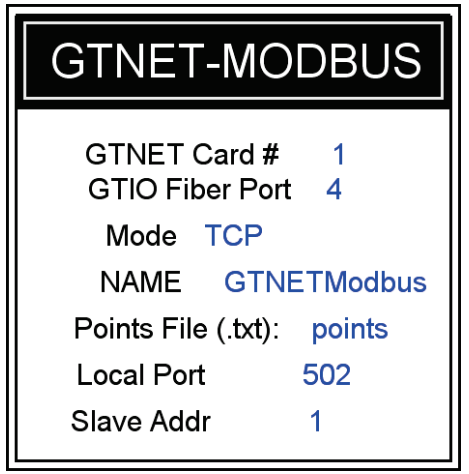
GTNET-SKT



GTNETx2

GTNETx2-Modbus

- The protocol is commonly used in SCADA system automation to facilitate communication between a Mater Station and a RTU (Remote Terminal Unit)
- The GTNETx2 Modbus component provides Modbus communication over TCP/IP networks using the GTNETx2 hardware. Three variants are supported –
  - Modbus TCP
  - Modbus RTU over TCP
  - Modbus ASCII over TCP
- Operates as a Modbus Server/Slave to communicate with a Modbus Client/Master



GTNETx2-Modbus

Capability

Primary Table	Maximum Quantity	Data Reference Range
Discrete Inputs	2000	0 - 1999 (0x0000 - 0x07CF)
Coils	2000	0 - 1999 (0x0000 - 0x07CF)
Input Registers	125	0 – 124 (0x0000 – 0x007C)
Holding Registers	125	0 – 124 (0x0000 – 0x007C)
Exception Status	8	0 - 7

GTNETx2-Modbus

Update frequency

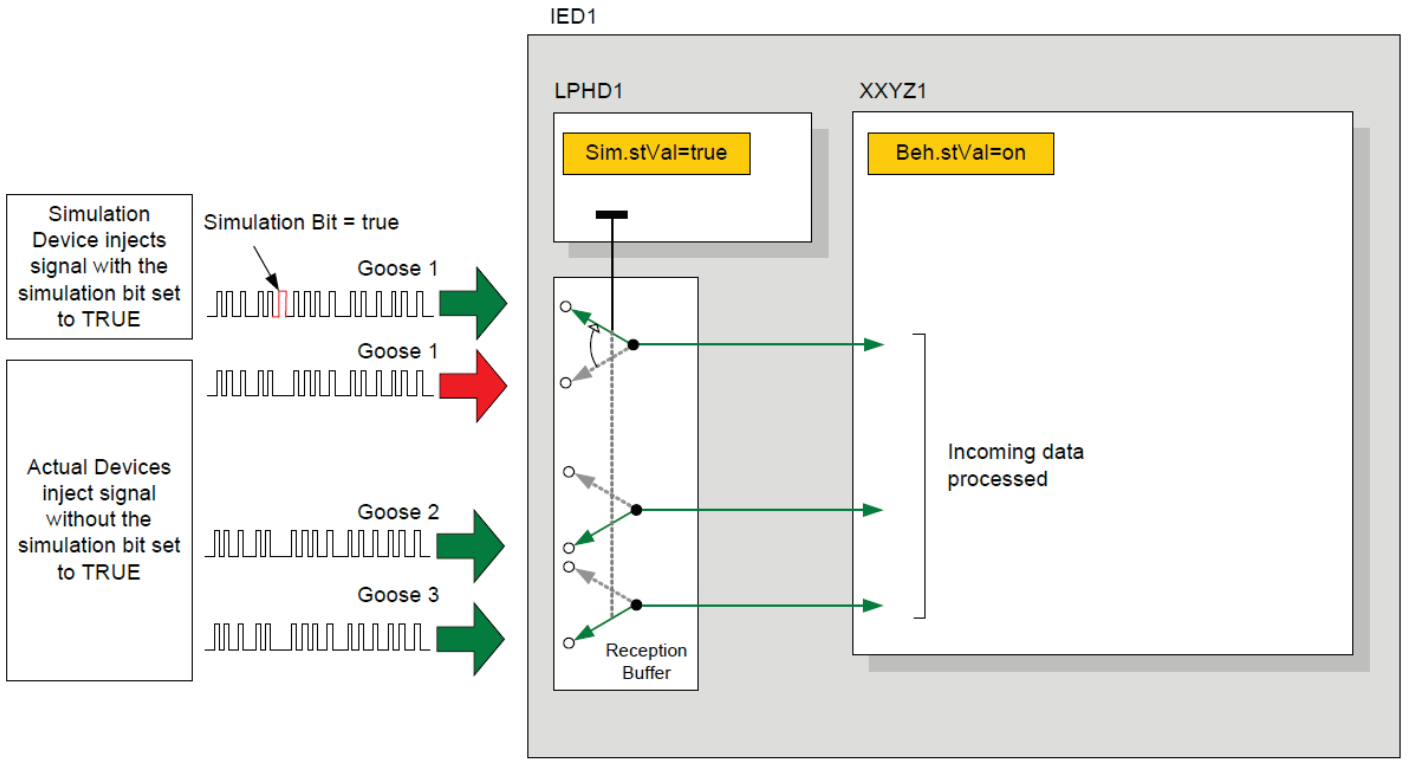
- The update frequency for the Discrete Inputs and Coils is 100 Hz; for Input Registers and Holding Registers is 10 Hz

Function / Operation	Modbus Function Code	Maximum Quantity
Read Coils	01 (0x01)	2000
Read Discrete inputs	02 (0x02)	2000
Read Holding Registers	03 (0x03)	125
Read Input Registers	04 (0x04)	125
Write Single Coil	05 (0x05)	1
Write Single Register	06 (0x06)	1
Read Exception Status	07 (0x07)	1
Write Multiple Coils	15 (0x0F)	1920
Write Multiple Registers	16 (0x10)	120
Mask Write Register	22 (0x16)	1
Read/Write Multiple Registers	23 (0x17)	120

IEC 61850 Edition 2

IEC 61850 ED2 – Testing and Simulated Signals

- In order to carry out functional, commissioning or maintenance tests, a communications network-based SAS that supports testing functions should offer some of the following facilities:
  - at the IED level, the option of receiving multicast simulation signals instead of actual signals
  - at the LN (function) level, the option of receiving test input signals instead of actual signals
  - at the LN (function) level, the option of setting a function or a group of functions of the system in test mode



Example of an IED (IED1) receiving simultaneously simulation and actual signals -
To allow the IED1 to process the simulated Goose1 message instead of the actual Goose 1 message, the Data Attribute Sim.stVal in the LN LPHD1 shall be set to TRUE

IEC 61850 Edition 2

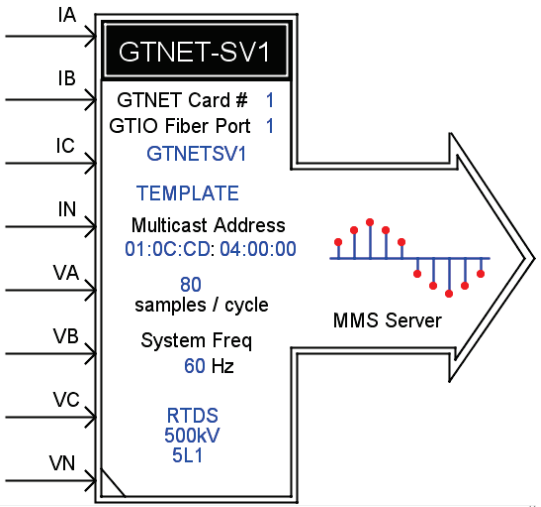
IEC 61850 ED2 – Subscription Monitoring (LGOS and LSVS)

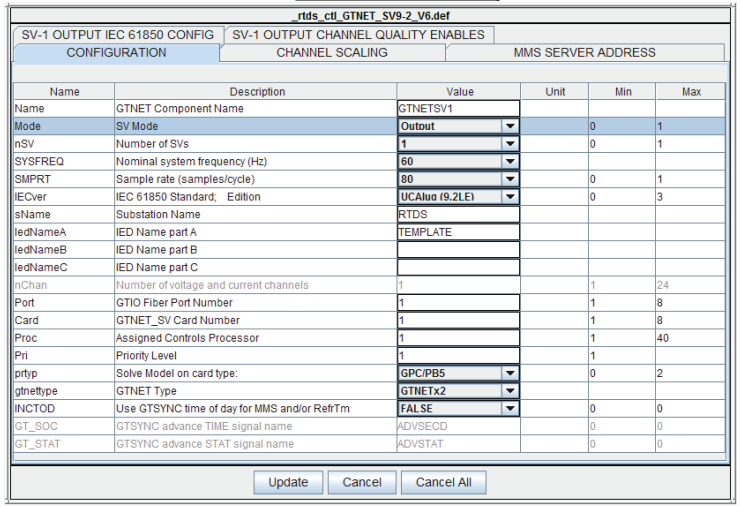
- The LGOS and LSVS logical nodes may be used to monitor subscription states to GOOSE or SV signals
- They contain mandatory information like status of the subscription (active, not active) and other optional information e.g. the source GOOSE or SV control block identification
- The root LD LPHD.Sim.StVal is used to switch the ability of the DUT to accept real or simulated test signals, then LGOS or LSVS will indicate the state of the incoming signals
  - For example if LPHD.Sim.StVal=true and there is a SV telegram with the simulation flag set=true then LSVS1.St.stVal=true and LSVS1.SimSt.StVal=true

GTNETx2-SV-v6

GTNETx2-SV-v6

- Only supported on GTNETx2 cards
- Supports IEC 61850 Edition 2
- Simulates a MMS server using a GTNETx2 module
  - Connects up to 4 simultaneous IEC 61850 MMS client sessions*, which are able to -
    - Browse GTNETx2 data models
    - Read values from logical nodes
    - Enable/disable SV Control Block
    - Control the Sim.stVal under the logical node LPHD1 to process simulated SV messages
    - Support logical node LSVS which contains
      - Optional Data Attribute – St (status of the subscription -> True=active, False=not active)
      - Optional Data Attribute – SimSt (status showing that real Sim messages are received and accepted)
- Allows to use GTSYNC time of day for MMS and/or the "RefrTm" field in the SV telegram



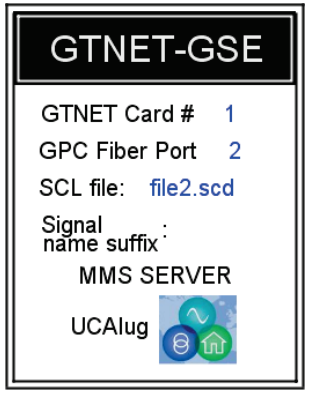


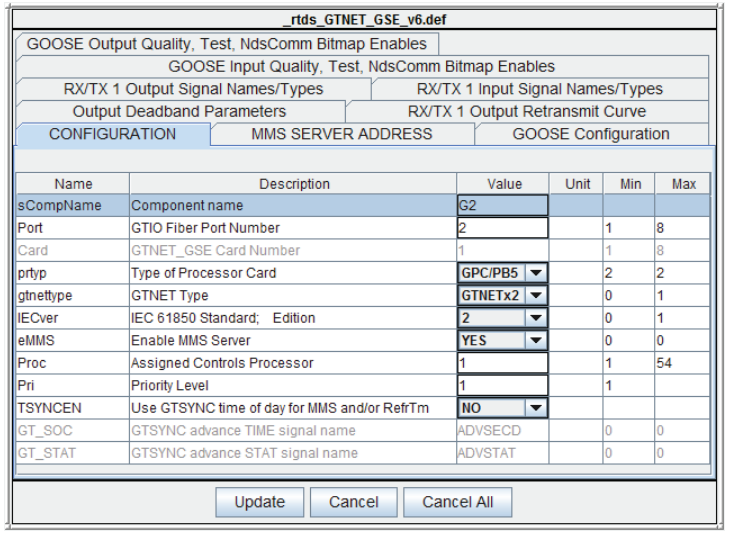
*More connections may be supported if required

GTNETx2-GSE-v6

GTNETx2-GSE-v6

- Only supported on GTNETx2 cards
- Supports IEC 61850 Edition 2
- Can be configured to simulates a MMS server using a GTNETx2 module
  - Only one IED is simulated since there is only one IP address associated to each GTNETx2 module
  - Provides XCBR/XSWI status information and supports CSWI Control Service through MMS messages
- Allows to use GTSYNC time of day for MMS and/or the “RefrTm” field in the GOOSE telegram



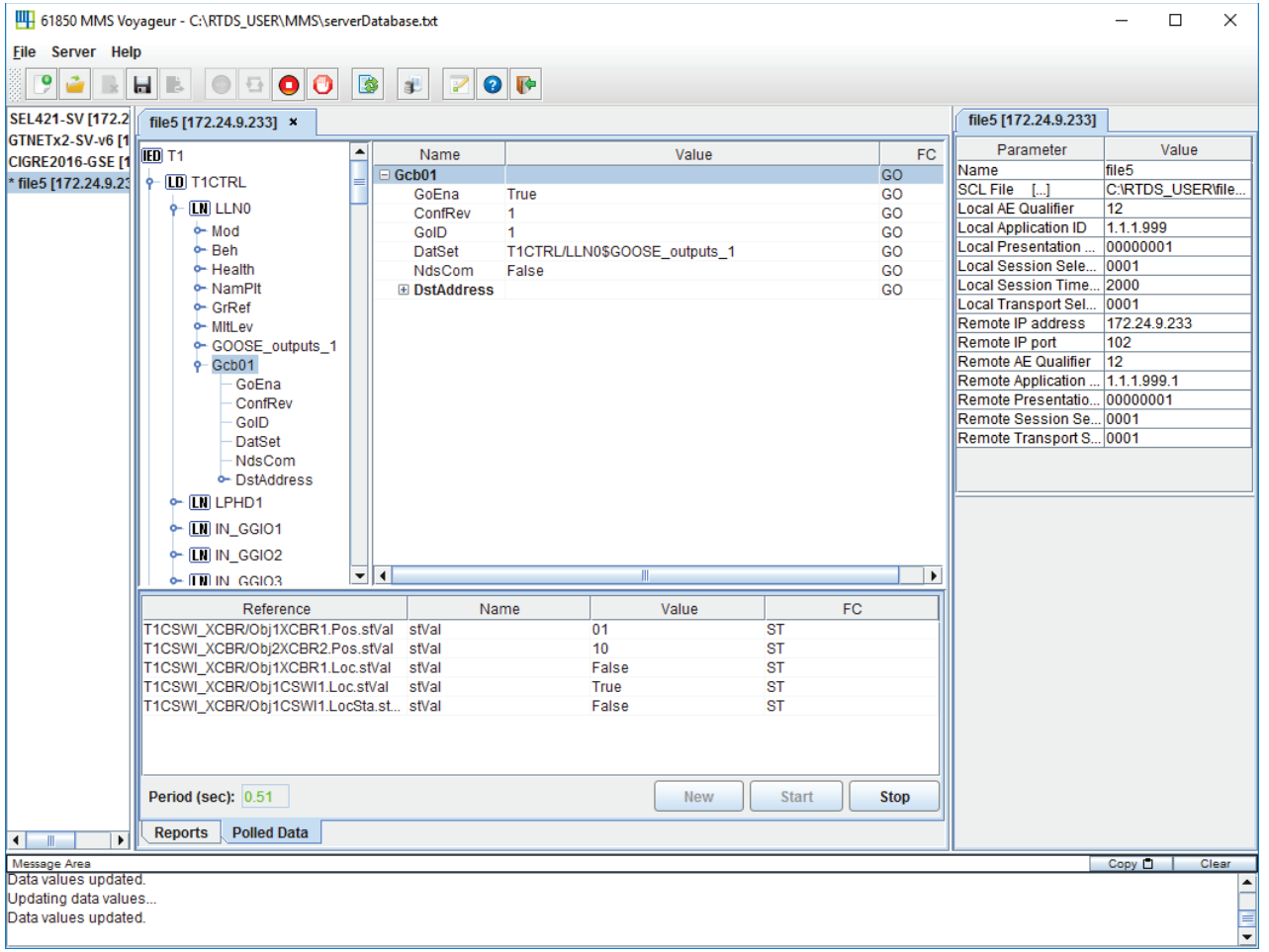


Name	Description	Value	Unit	Min	Max
sCompName	Component name	G2			
Port	GTIO Fiber Port Number	2		1	8
Card	GTNET_GSE Card Number	1		1	8
prtyp	Type of Processor Card	GPC/PB5		2	2
gtnettype	GTNET Type	GTNETx2		0	1
IECver	IEC 61850 Standard; Edition	2		0	1
eMMS	Enable MMS Server	YES		0	0
Proc	Assigned Controls Processor	1		1	54
Pri	Priority Level	1		1	
TSYNCEN	Use GTSYNC time of day for MMS and/or RefrTm	NO			
GT_SOC	GTSYNC advance TIME signal name	ADVSECD		0	0
GT_STAT	GTSYNC advance STAT signal name	ADVSTAT		0	0

GTNETx2-GSE-v6

GTNETx2-GSE-v6

- When the MMS Server is enabled, it can be Connected up to 4 simultaneous IEC 61850 MMS Client sessions* which are able to –
  - Browse GTNETx2 data models
  - Read values from logical nodes
  - Enable/disable GOOSE Control Block
  - Control the Sim.stVal under the logical node LPHD1 to process simulated GOOSE messages
  - Support logical node LGOS which contains
    - Mandatory Data Attribute – St (status of the subscription -> True=active, False=not active)
    - Optional Data Attribute – SimSt (status showing that real Sim messages are received and accepted)



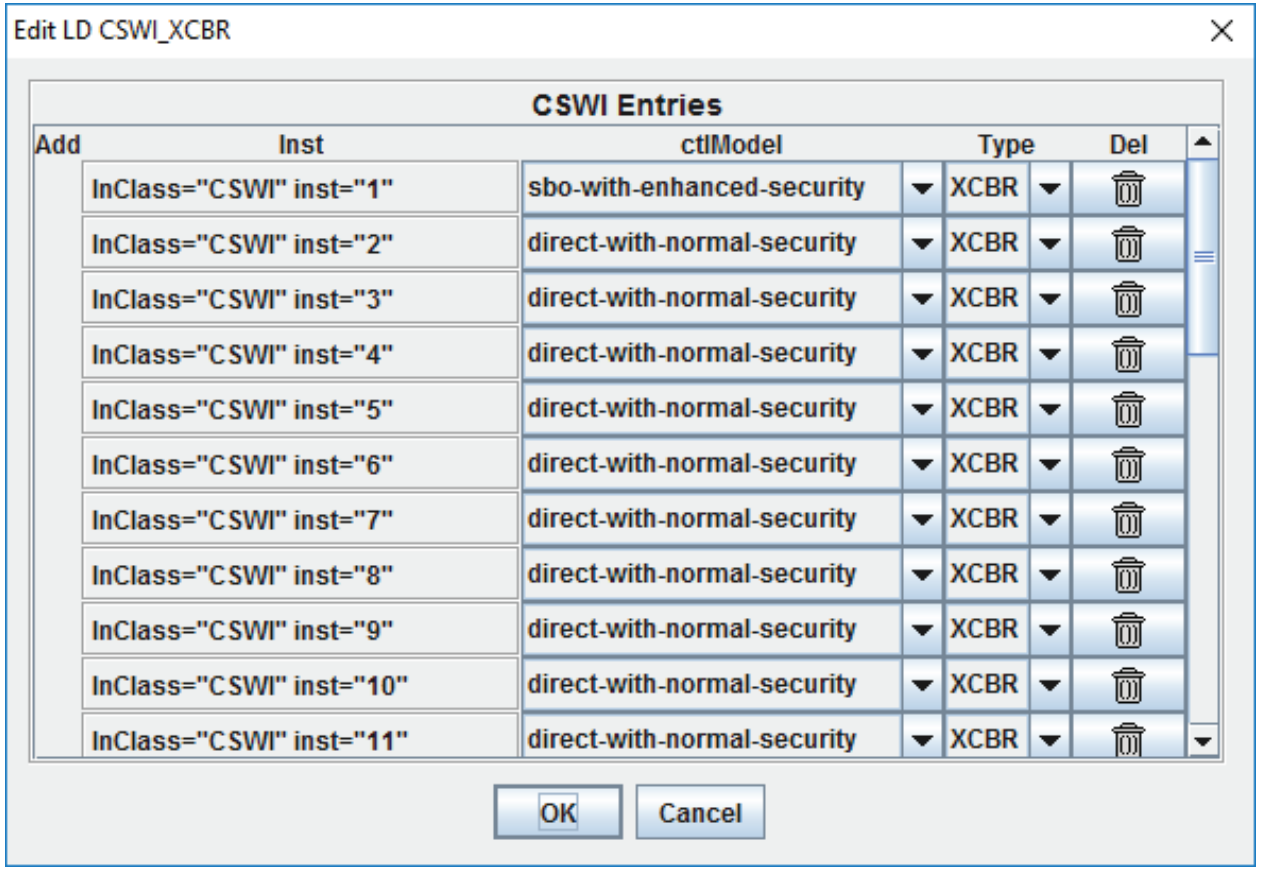
*More connections may be supported if required

GTNETx2-GSE-v6

GTNETx2-GSE-v6

MMS XCBR/XSWI/CSWI support

- ❑ Enabled from SCD editor
- ❑ Supports up to 32 Logical Node Instances
- ❑ Supported Control Mode
  - ❑ Direct with normal security
  - ❑ SBO (Select Before Operate) with normal security
  - ❑ Direct with enhanced security
  - ❑ SBO with enhanced security

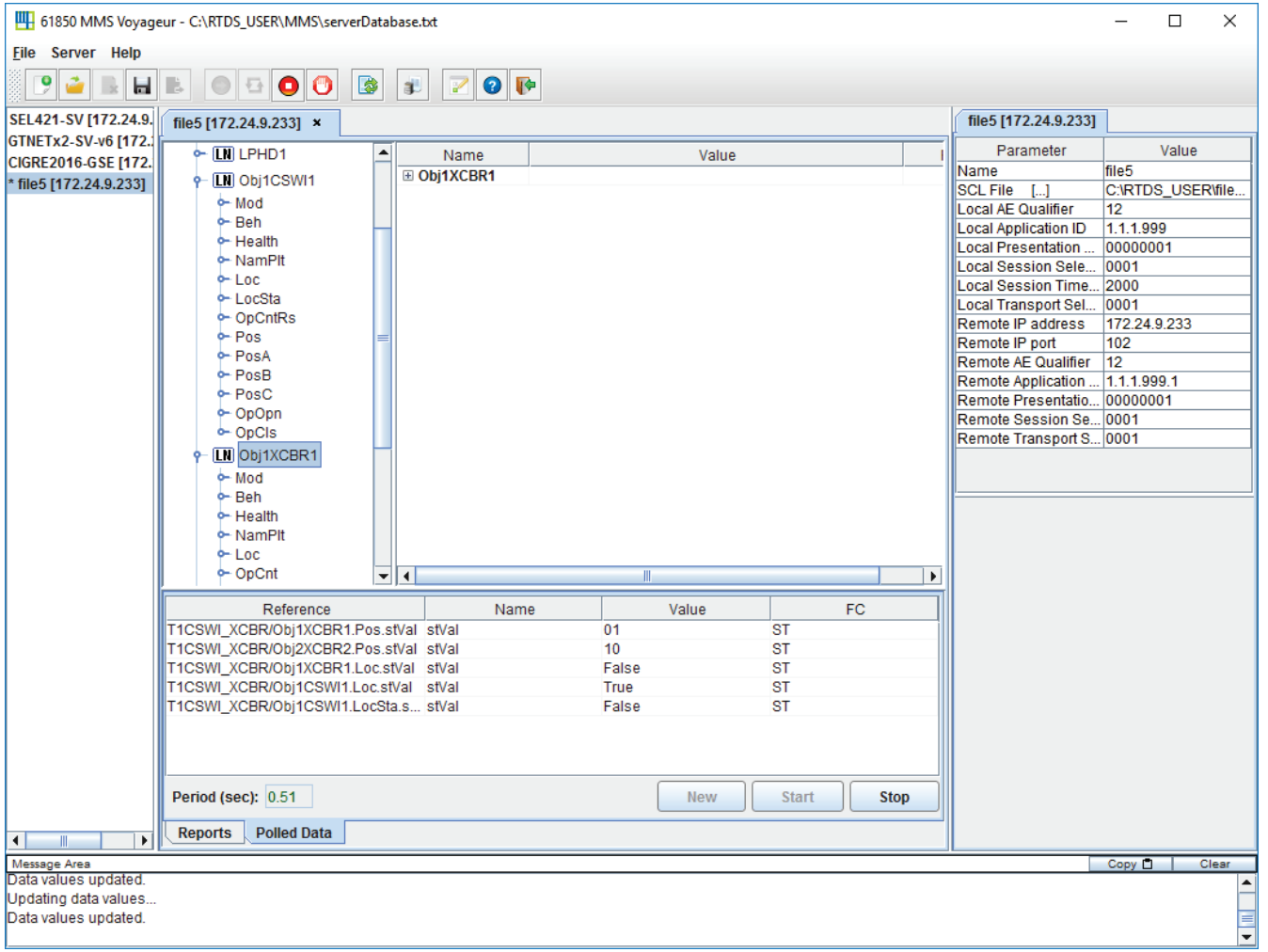


GTNETx2-GSE-v6

GTNETx2-GSE-v6

MMS XCBR/XSWI/CSWI support

- The position status of the enabled XCBR/XSWI can be monitored in a MMS Client

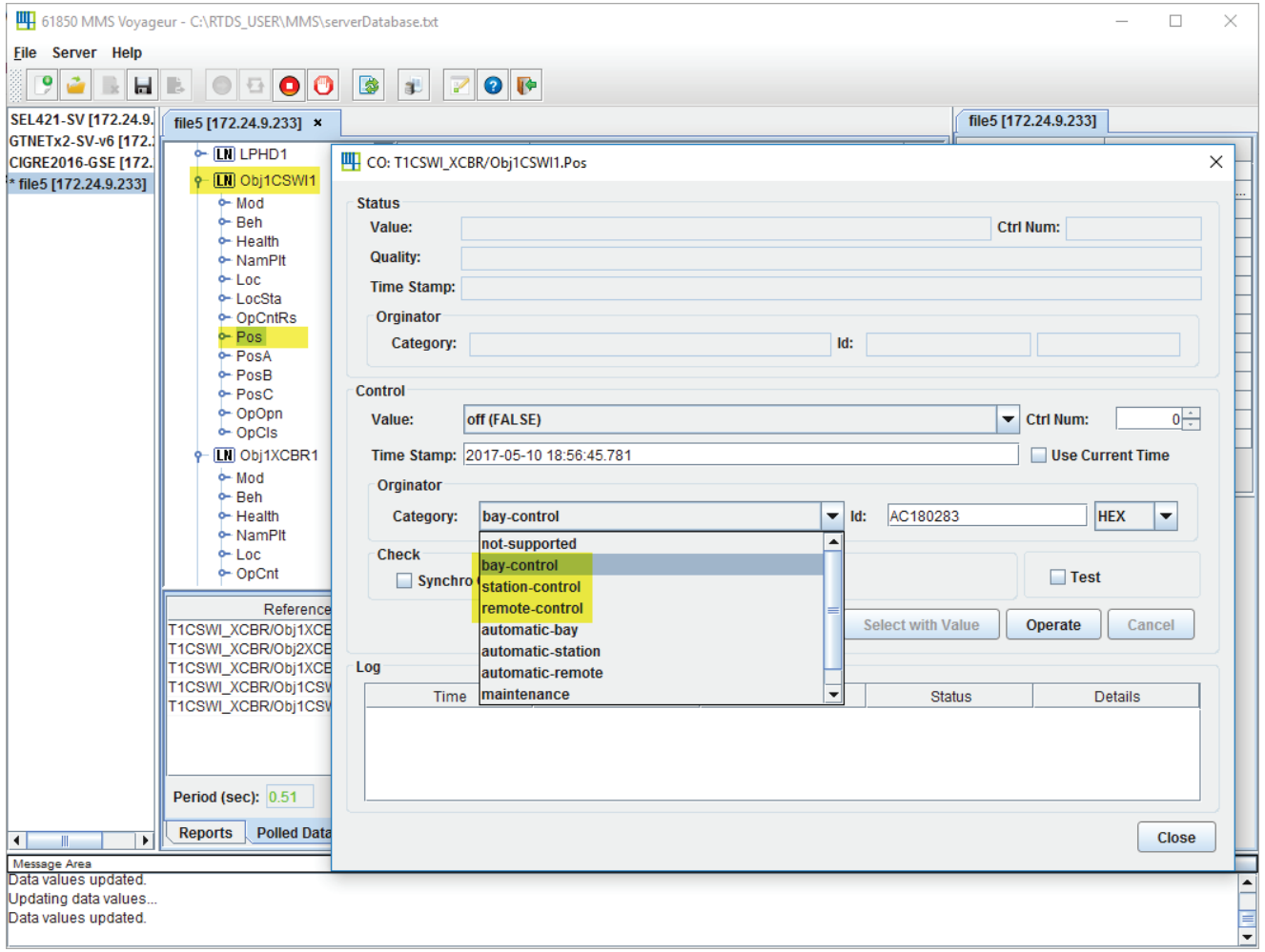


GTNETx2-GSE-v6

GTNETx2-GSE-v6

MMS XCBR/XSWI/CSWI support

- The CSWI Control Service commands can be sent to the GTNET MMS Server though MMS messages
- The control authority is compliant with the concept specified in Annex B of IEC 61850-7-4 Edition 2



GTFPGA-SV

GTNETx2-SV

Challenges

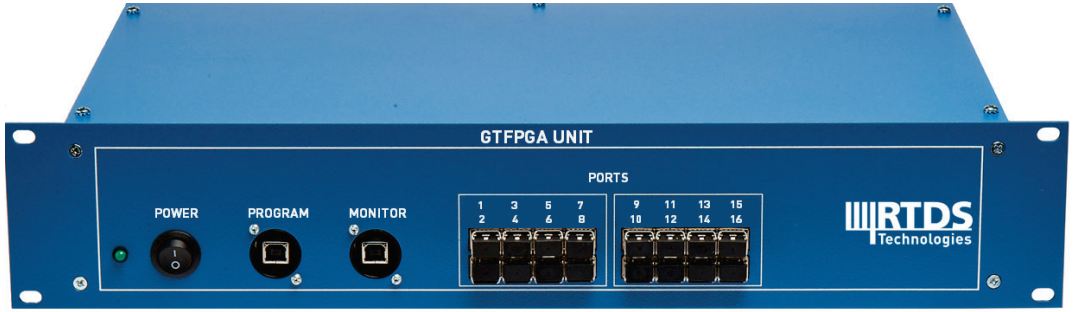
- ❑ Publishes only maximum of two 61869-9 compatible SV streams per GTNETx2 card
- ❑ The non-configurable, sequential based architecture makes it challenging to meet the stricter jitter requirements defined by the Chinese National Standard (less than 10 us)

GTFPGA-SV

GTFPGA-SV

Hardware – GTFPGA Unit

- Based on a Xilinx Virtex®-7 Field Programmable Gate Array (FPGA) evaluation kit
- Connects up to 16 SFP Ethernet Physical Layer adapters (copper or fiber optic based)
- LAN port SFP options
  - 100/1000 Base T Copper SFP Module Finisar FCLF-8521-3
  - 100/1000 Base T Copper SFP Module Avago ABCU-5730RZ
  - 100 Base-FX fiber SFP Module Finisar FTLF-1217P2xTL
  - 1000 Base-SX fiber SFP Module Finisar FTLF-8519P3BNL (the same insert used for the GT portscom)

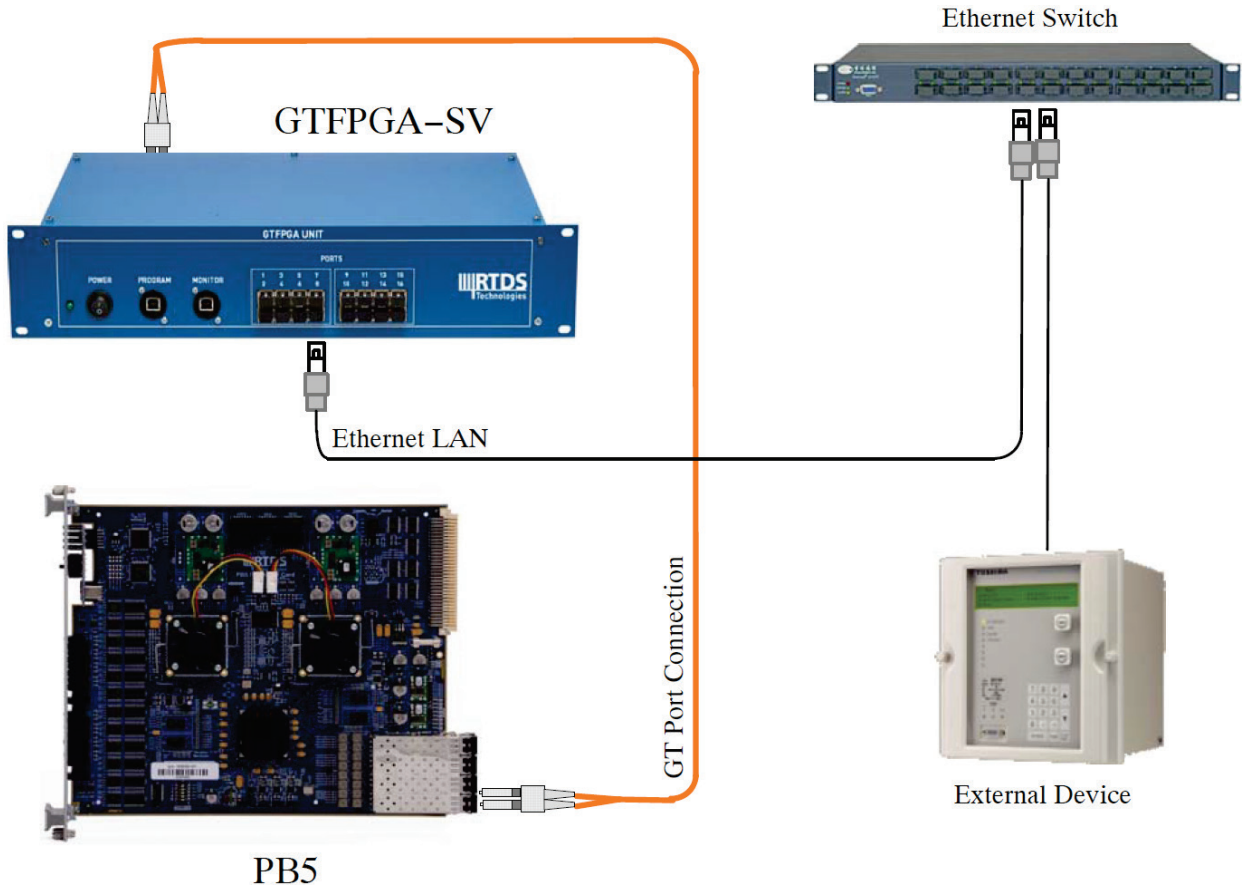


GTFPGA-SV

GTFPGA-SV

Hardware – GTFPGA Unit

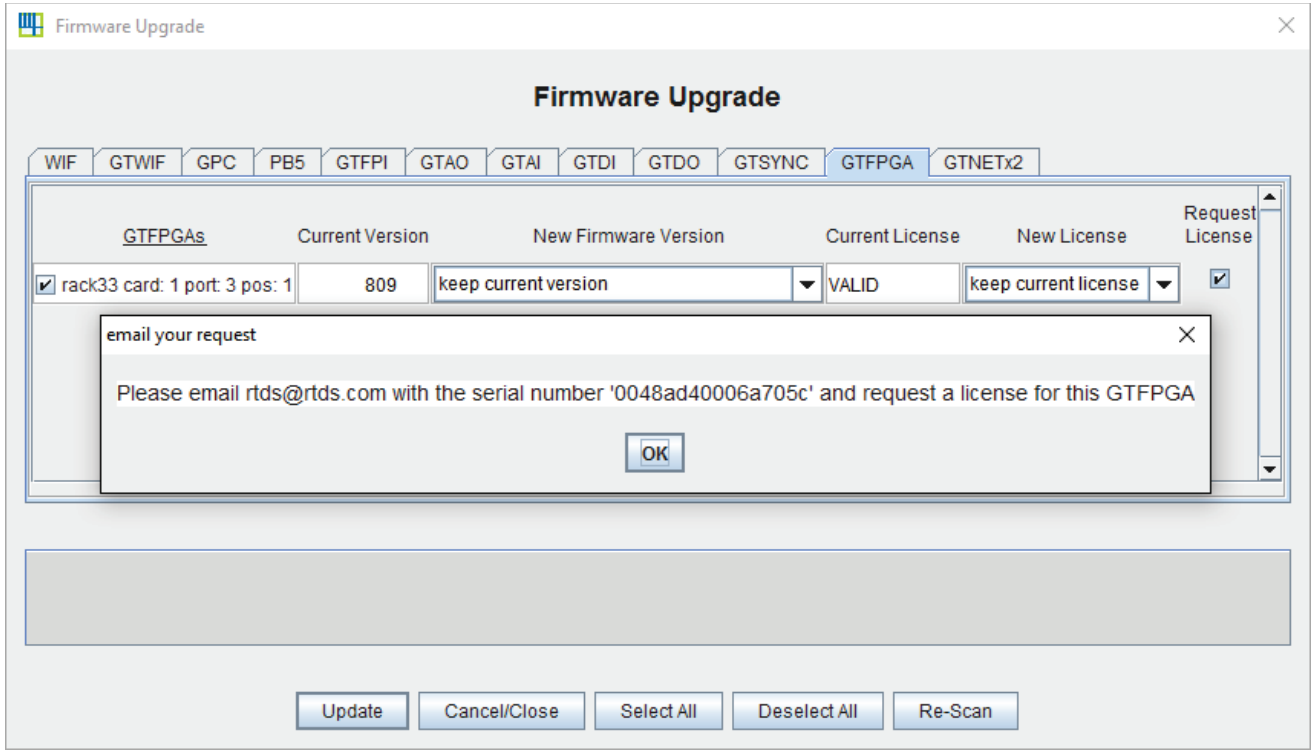
- Typical connection



GTFPGA-SV

Hardware – GTFPGA Unit

- Firmware installation/upgrade can be done through Firmware Upgrade Utility

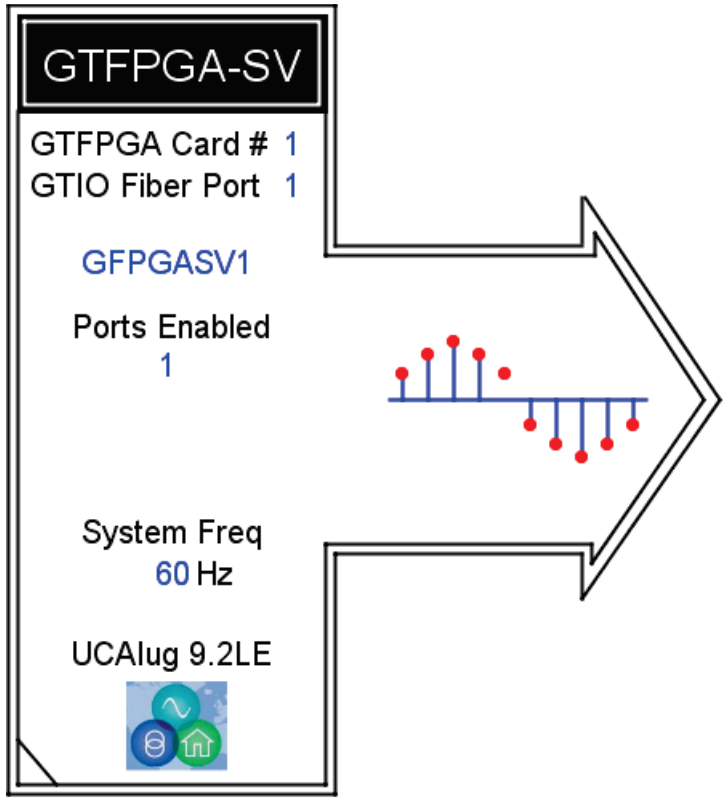


GTFPGA-SV

GTFPGA-SV

RSCAD Component

- Handles the sampling, processing and packaging of analog values to the FPGA hardware
  - Due to the difference between the simulation time-step and the SV sampling rate, the input analog signals are reconstructed using linear interpolation to prevent signal distortion
- Currently supports the following pre-configured sampling rates –
  - 4,000Hz: for use on 50Hz systems backward compatible with 9-2LE guideline
  - 4,800Hz: preferred rate for general measuring and protective applications, regardless of the power system frequency
  - 5,760Hz: for applications on 60Hz systems backward compatible with 96 samples per nominal system frequency cycle
  - 14,400Hz: preferred rate for quality metering applications, regardless of the power system frequency including instrument transformers for time critical low bandwidth DC control applications

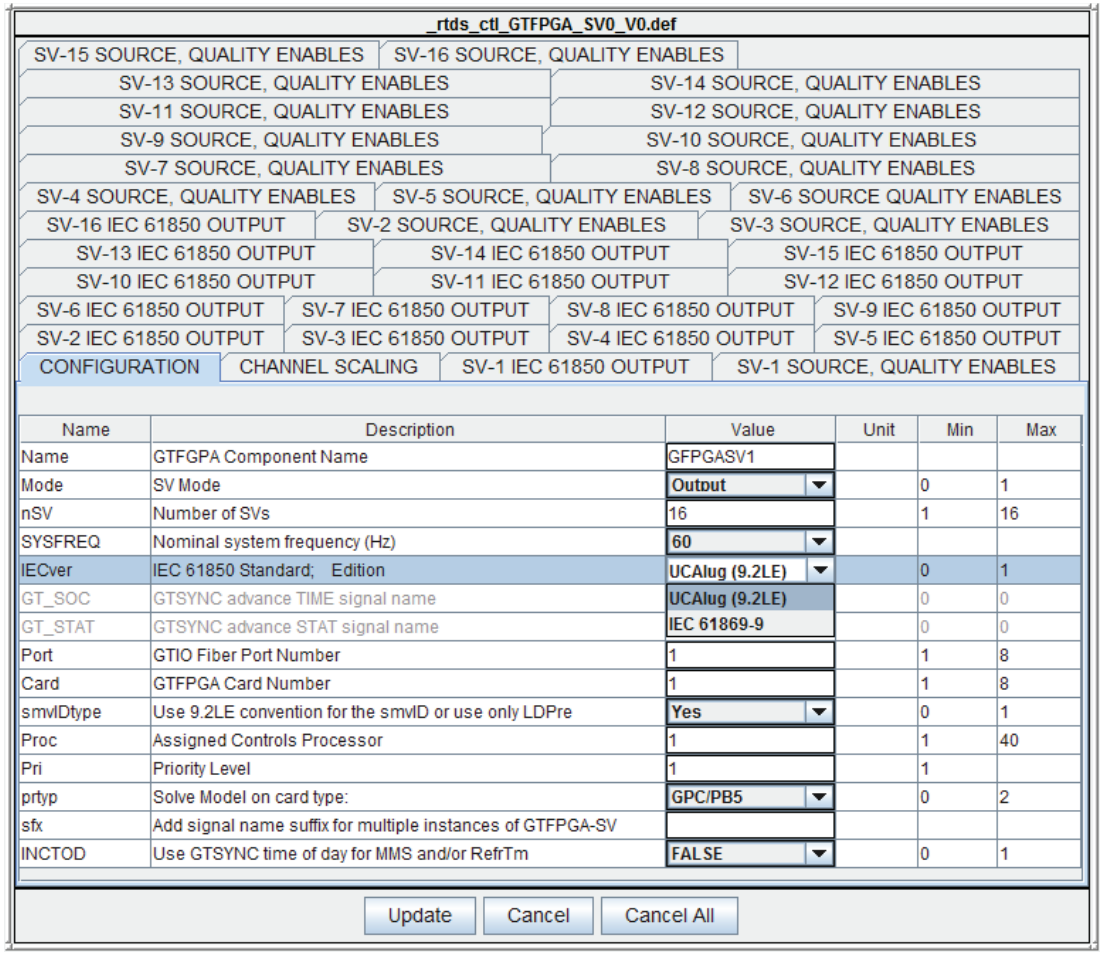


GTFPGA-SV

GTFPGA-SV

RSCAD Component

- Currently supports output mode only
- Can be configured to have maximum of 16 outputs, 1 SV stream per output port*
- Supports nominal frequency of 50Hz and 60Hz
- Runs either in 9-2LE mode or 61869-9 mode
  - UCAIug 9-2LE
    - 4 voltages and 4 currents per SV stream, fixed configuration
  - 61869-9 & Chinese National Standard
    - Up to 24 free-configured data channels per SV stream
      - 61869-9 limits to maximum of 24 channels for general measuring and protection and maximum of 8 channels for quality metering
      - Chinese National Standard typically uses 24 channels with the Time Delay assigned to the first channel

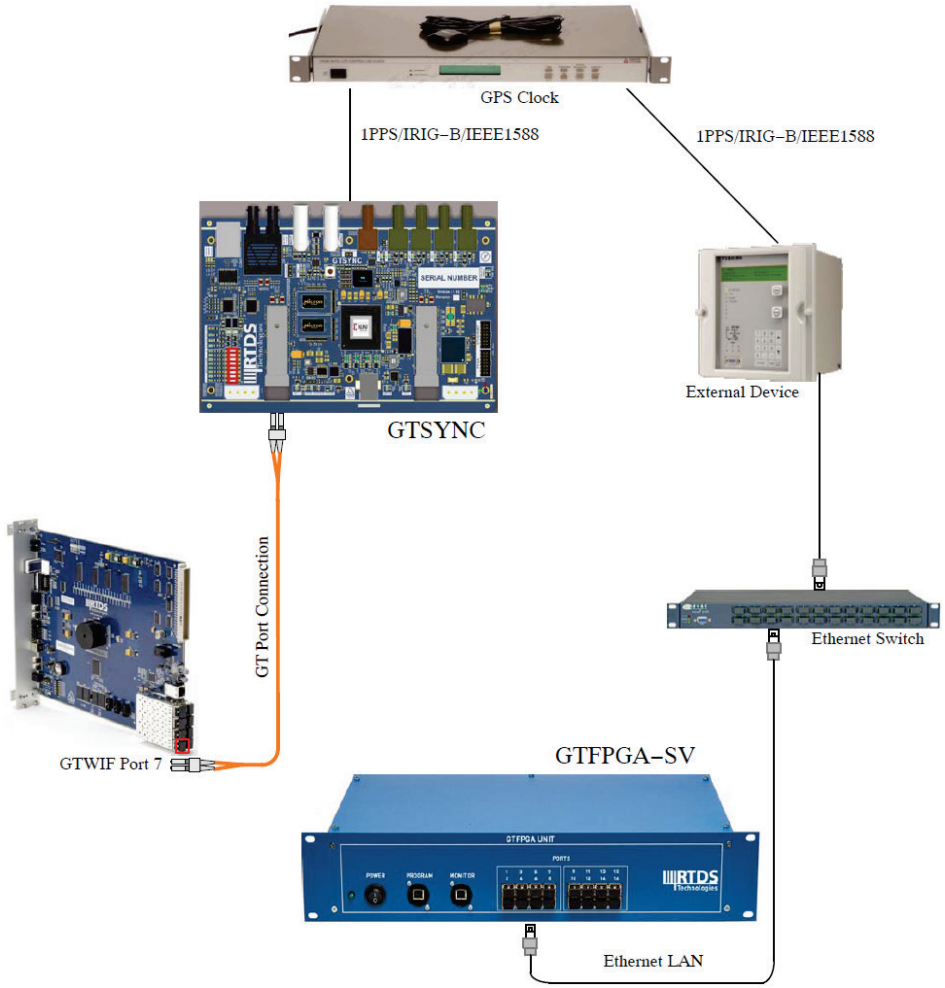


*refer slide 21 for limitations

GTFPGA-SV

Time Synchronization

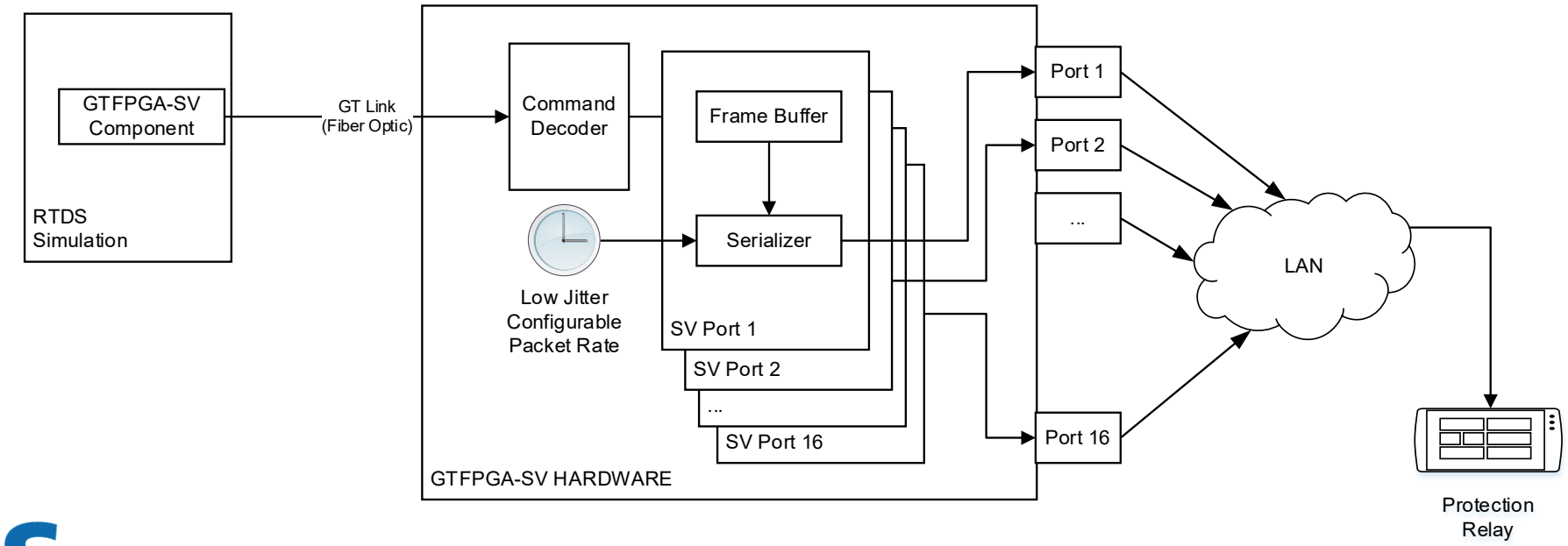
- The GTSYNC card is used to synchronize the RTDS simulation time step to an external time reference and to synchronize devices under test



GTFPGA-SV

GTFPGA-SV Data Flow

- RSCAD Component transmits SV samples to the FPGA using a dedicated fiber optic based GT link
- The FPGA triages the incoming simulated data and stores it to a specific Ethernet port frame buffer
- SV frame packets are assembled in the buffer then serialized to make eligible to be sent over the Ethernet link



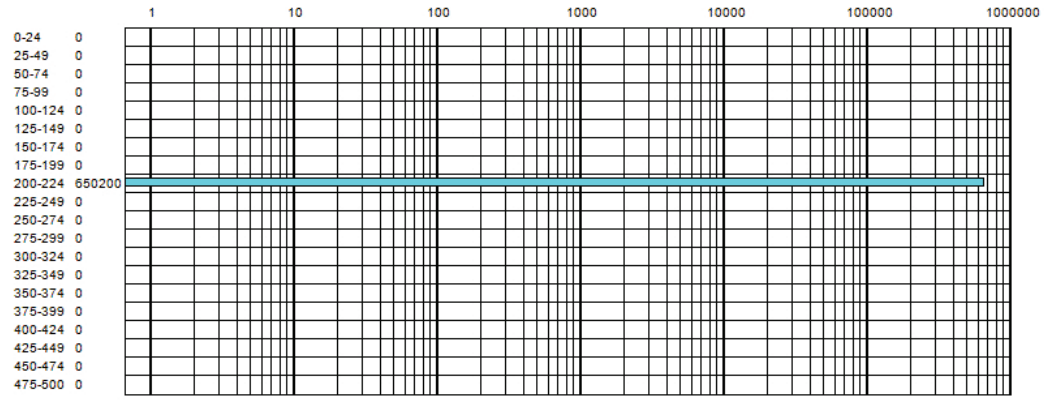
GTFPGA-SV

Testing and Validation

- Omicron SVScout
  - SVScout V1.50 was used in conjunction with a dedicated PCI network card, to validate the SV packet rate and jitter
  - Test setup
    - The GTFPGA-SV was configured to run a single output stream of 60Hz at 80 samples per cycle
    - The corresponding output port on the GTFPGA-SV Unit was directly connected via Ethernet to the computer running SVScout to eliminate any delay due to packet routing on the network
  - Test result
    - The packet delay graph shows that packets are sent on average at a 208us frequency, with a measured standard deviation of 0us

Packet delays

Minimum delay:	208 µs
Maximum delay:	209 µs
Mean:	208 µs
Median:	208 µs
Standard deviation:	0 µs
Lower - upper quantile:	208 - 209 µs



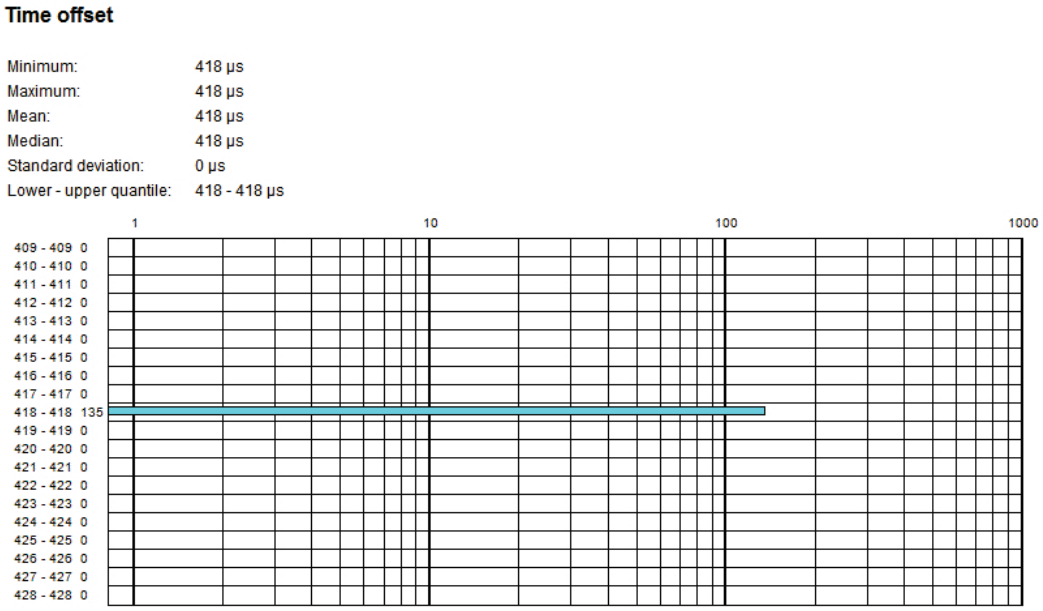
The frequency of occurrence of the measured packet delays within the time intervals is displayed*

**Packet Delays - Time intervals between the Sample Values packets*

GTFPGA-SV

Testing and Validation

- Omicron SVScout
  - Test result
    - The time offset graph shows that it takes 418us or about 2 sample periods from the time quantities are sampled until the time packets are sent
  - Testing showed that the GTFPGA-SV meets both:
    - The SV frame jitter requirement of 10us defined in Chinese National Standard, and other applications where require a low jitter
    - The maximum processing delay time limit for quality metering and protective and measuring applications (10 and 2ms respectively)



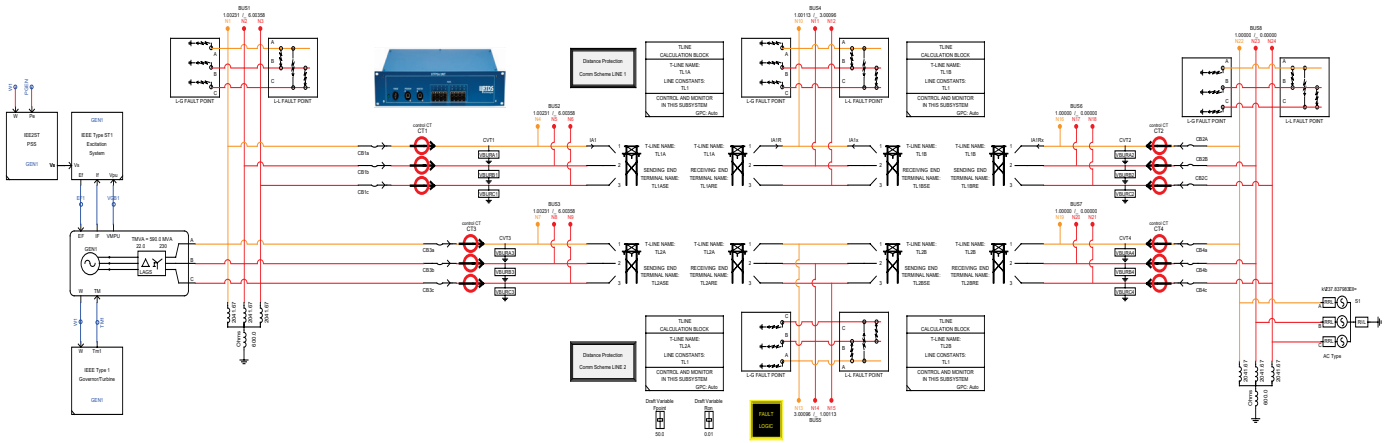
The frequency of occurrence of the measured time offsets within the time intervals is displayed*

**Time Offsets - Time intervals from the theoretical sampling time (leading edge of the PPS signal) to the reception of the corresponding packet with sample count zero*

GTFPGA-SV

Testing and Validation

- RTDS proprietary software suite
  - Developed to collect raw Ethernet packets and performs acceptance tests on any incoming SV packet
  - Accepts SV packets of any rate and quantities, and compares them against expected pattern
- GTNETx2-SV in Input Mode
  - Implements a closed loop test
    - Data is fed to the GTFPGA-SV which publishes it to a SV network, the GTNETx2-SV acquires the SV frames, and forwards them back into the case, where sent and received data are compared
- Testing of IEDs using GTFPA-SV



GTFPGA-SV

Performance and Limitations

- Currently capable of supporting –
  - 16 ports configured with maximum of 24 data channels, at 80 samples per cycle per SV stream
  - 16 ports configured with maximum of 9 data channels, at sample rates higher than 80 samples per cycle per SV stream
  - Several mixed sample rate configurations
- The present limitations of the system reside in the execution time of the component itself
  - The component is in charge of the interpolation, sampling, scaling and forwarding to the FPGA of each of the ports
  - The process is limited by the maximum length that the time step can take, which is driven by the following two factors –
    - The maximum time step the application requires
    - The maximum time step the SV sample rate allows

Potential Improvements

- Some of the processing operations could potentially be relocated to the FPGA

Aurora Communication

Aurora Communication

We are offering

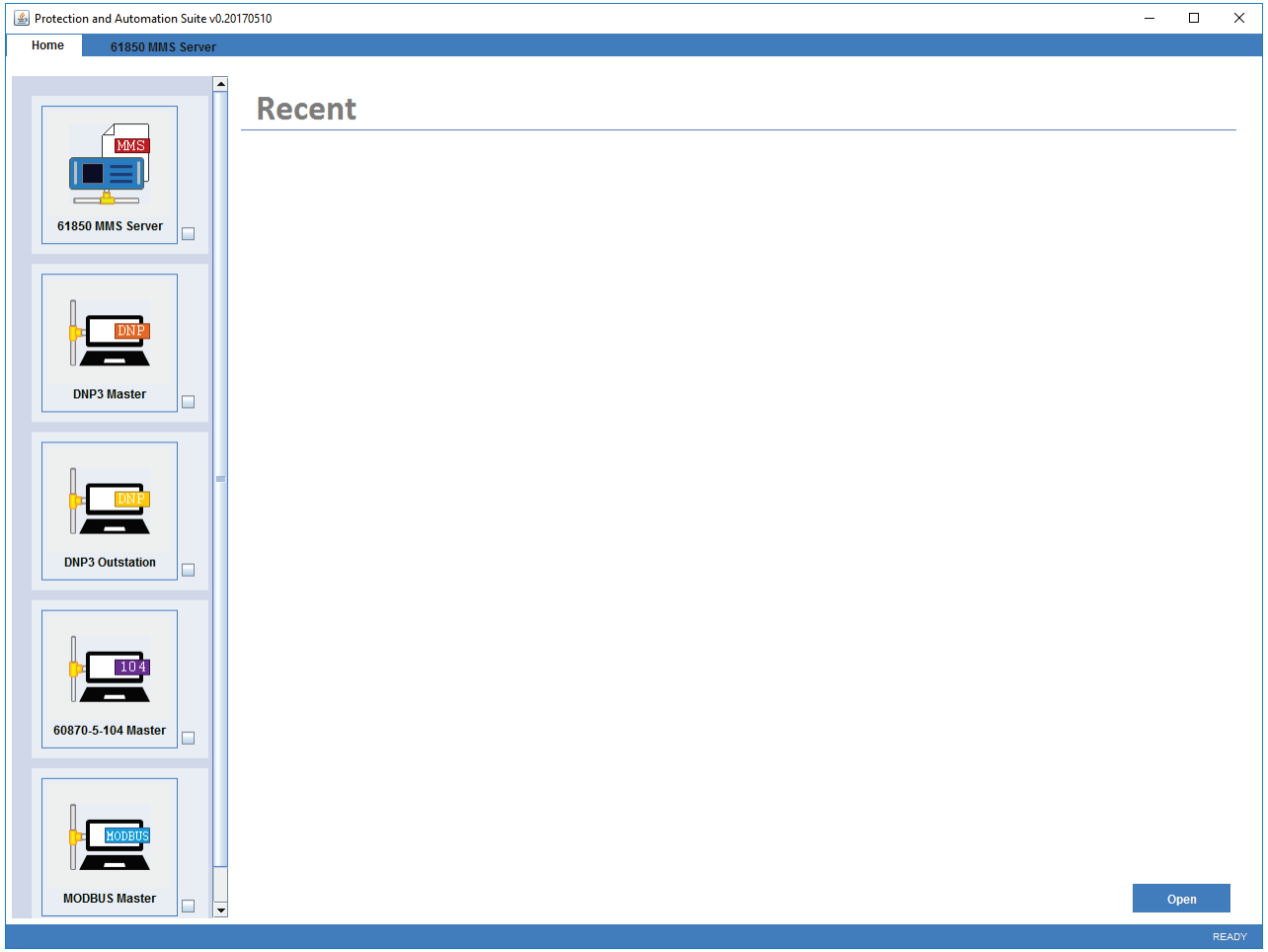
- Aurora protocol streaming from the GT fiber ports on a PB5 card
  - Will be licensed to a specific PB5 card(s) and port 4-8 on that PB5 card will be reserved for Aurora
  - Each PB5 Aurora license can have 4 Aurora streams from ports 4-8 on a PB5 card, each at a line rate of 2 Gbps
  - Each of the 4 streams can have 64 inputs and 64 outputs (each of them is a 32-bit word)
  - Each stream can come from either the large or small timestep

Protection & Automation Suite

Main Features

A stand alone program available in RSCAD that is capable of simulating:

- ❑ IEC 61850 MMS Servers
- ❑ DNP3 or IEC 60870-5-104 Masters
- ❑ DNP3 Outstations
- ❑ Modbus Masters

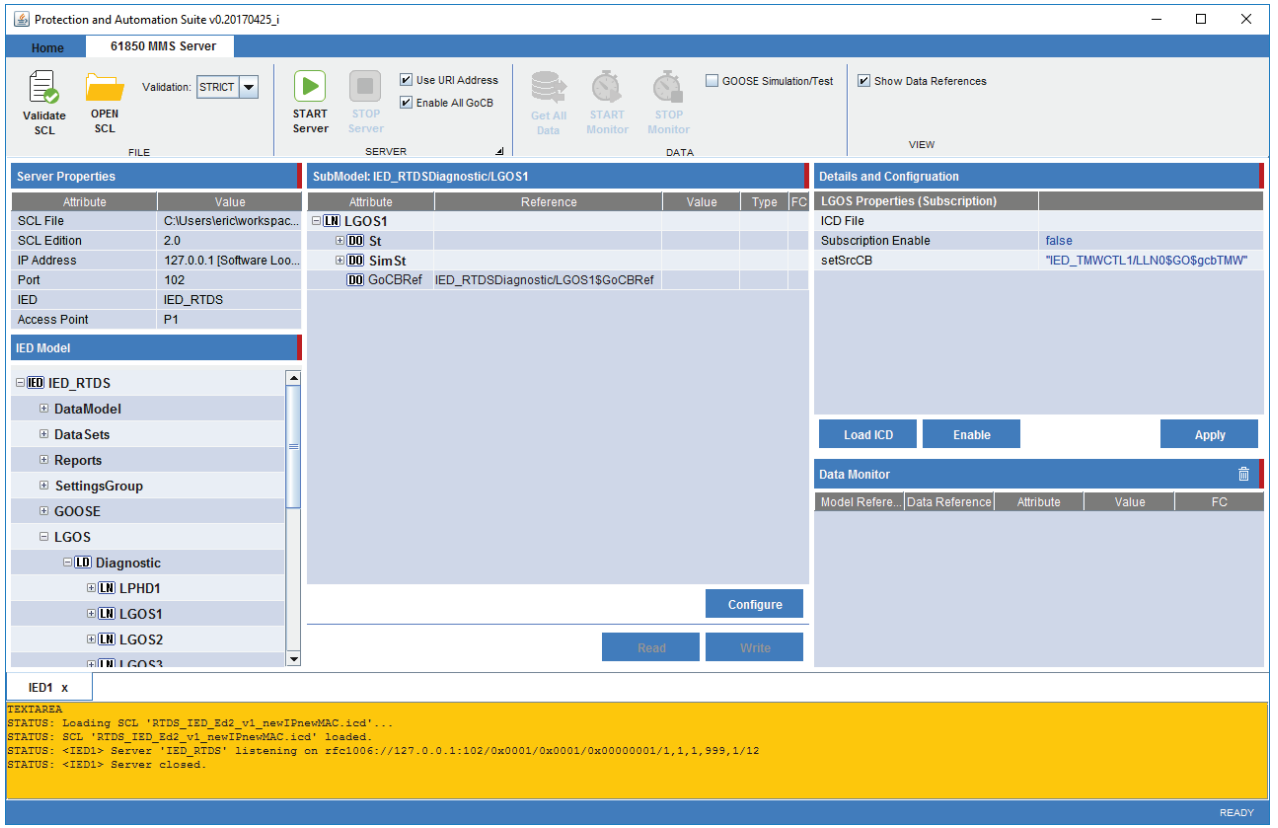


Protection & Automation Suite

IEC 61850 MMS Server

Capability

- ❑ Simulates one or multiple IEC 61850 Servers using the corresponding SCL (Substation Configuration Language) files that comply with IEC 61850-6
- ❑ Supports the Simulation of GOOSE telegram defined in IEC 61850-8-1 Edition2
- ❑ Supports GOOSE subscription if it is defined in the SCL file
- ❑ Supports Logical Node Class LGOS* (from IEC 61850 Editon2) if it is defined in the SCL file



*Logical Node LGOS allows a subscriber to either subscribe not simulated GOOSE telegrams or simulated GOOSE telegrams

RTDS Technologies

THANK YOU

QUESTIONS?