Test Case 21

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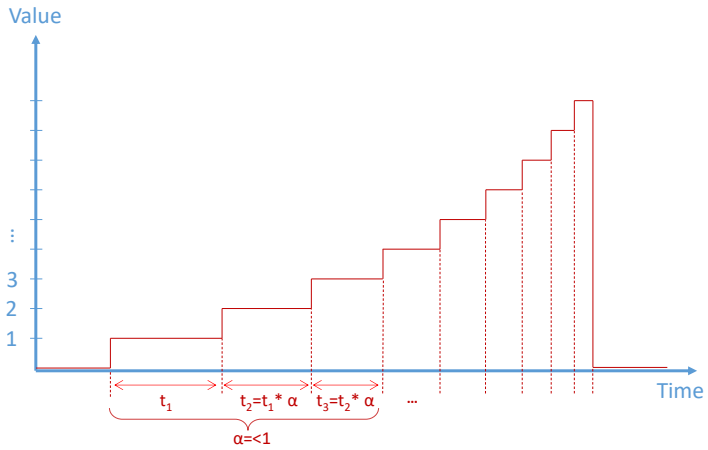
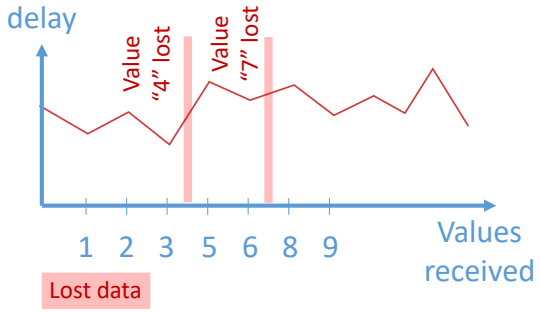
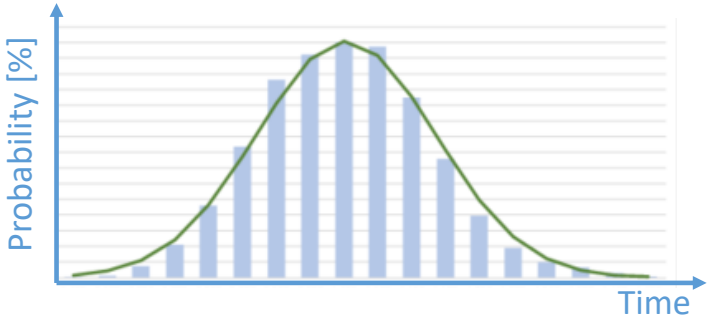
Name of the Test Case	Performance characterization of new equipment and communication technologies
Narrative	The aim of this test case is to assess the performance of equipment used for communication in smart grids and power systems, such as Remote Terminal Units (RTU). The characterization of this performance is one of the major goals of this test case, taking into account the different communication technologies that could be supported in such devices (e.g. communication protocols) and the stochastic nature of communication effects. In particular, the experiments in the test case allow characterizing the performance of communication equipment by means of communication delay calculation and the rate of dropped packets between two RTUs. Through this experiment, it is possible to determine the mean value and the standard deviation of the communication delay between two devices, together with the packet loss rate for different polling times.
Function(s) under Investigation (*FuI*) "the referenced specification of a function realized (operationalized) by the object under investigation"	The characteristics of two communication devices exchanging information. The delay of the information transmission and the loss packet rate, for different communication protocols.
Object under Investigation (*OuI*) "the component(s) (1..n) that are to be qualified by the test"	At least two communication components connected together.
Domain under Investigation (*DuI*): "the relevant domains or sub-domains of test parameters and connectivity."	Information and Communication Technology (ICT)
Purpose of Investigation *(PoI)* The test purpose in terms of Characterization, Verification, or Validation	Verify whether the performance of the devices is adequate for the applications for which their use is intended. Specifically, verify that the mean delay and packet loss rate of the communication complies with the minimum expected requirements for the application for which they will be used.
System under Test (*SuT*): Systems, subsystems, components included in the test case or test setup.	In order to execute this test, the following components are needed: • Real time simulator, such as OPAL-RT • At least two communication devices, such as remote terminal units (RTU) • One communication emulator, such as ATTERO • Ethernet connection cables (RJ45) The test consists in the connection of the Real Time simulator to both communication devices, and the connection of these devices to the communication emulator.

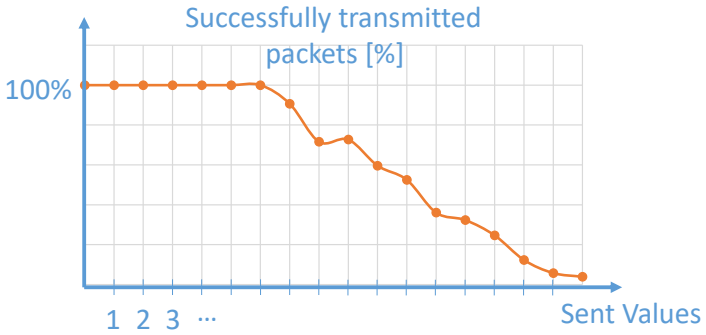
Functions under Test (*FuT*) Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT.	• Capability of the real time simulator to transmit data under different communication protocols (e.g. MODBUS, IEC 60870-5-104, IEC 61850) • Capability to generate and transmit data by the real time simulator with different characteristics (data profiles) • Data transmission from real time simulator to the OuI. • Capability of Communication protocol translation by OuI. • One communication emulator, such as ATTERO • Ethernet connection cables (RJ45)
Test criteria *(TCR)* Formulation of criteria for each PoI based on properties of SuT; encompasses properties of test signals and output measures.	• The real time simulator needs to send a data profile periodically using a certain pre-defined communication protocol. • Due to the stochastic nature of communication phenomena, the data profile needs to be sent periodically enough times to be able to obtain statistically valid results. • The real time simulator needs to register the time for which data is sent and for which data is received, in order to calculate the communication delay of each data value.
Target Metrics *(TM)* Measures required to quantify each identified test criteria	Data profile: • The data profile needs to be arranged in a way that it is possible to determine the communication roundtrip time (delay) of each data value. A series of increasing integer values is proposed with an increasing value change periodicity. For example:  In the previous figure, the constant α represents the reduction of the time during a particular value is sent. It is noted that the polling time of the devices must be less than the time duration of a sent value. • The delay and the lost packages have to be registered:



- The delay for each successfully transmitted data value can be used to create a normal distribution of the delay probability (obtaining the mean delay value and its standard deviation):



- The successful transmission rate can be calculated for each value sent from the profile, allowing to determine the minimum periodicity that can be 100% successfully transmitted



Variability Attributes *(VA)* controllable or uncontrollable factors and the required variability; ref. to PoI.	• Periodicity for which a data value changes. • The delay between the OuI devices set in the communication emulator. • The amount of repetitions of the experiment to obtain statistically valid results. • The communication protocols involved between the real time simulator and the OuI devices, and between each of the OuI devices.
Quality Attributes *(QA)* threshold levels for test result quality	For delay calculation, at least have a packet loss rate less than 1%

	as well as pass/fail criteria.	

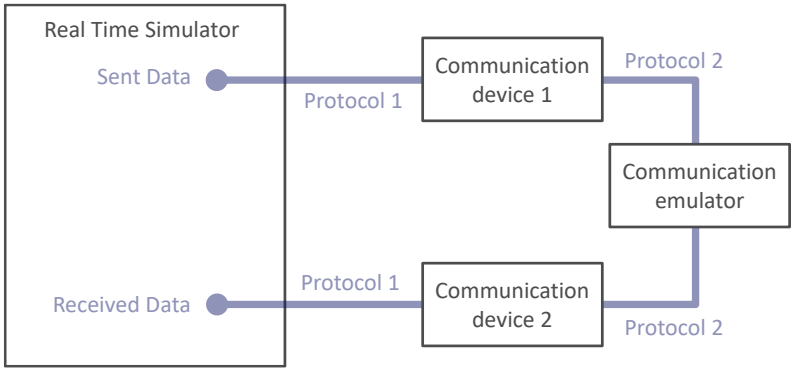
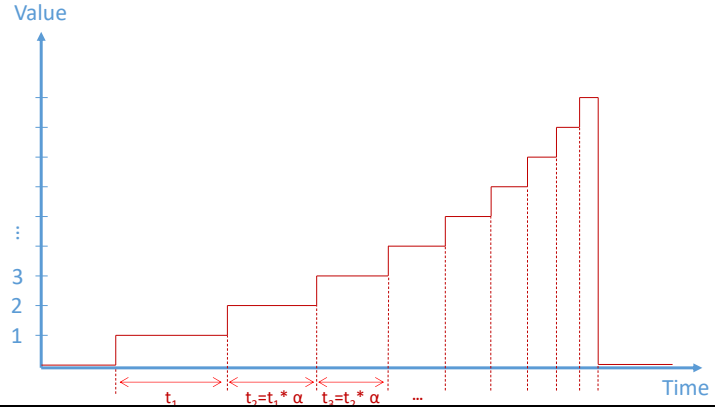
Qualification Strategy

The PoI can be addressed by firstly determining which are the requirements in terms of Quality of Service (QoS) of the application for which the communication is being assessed. These requirements are to be determined by the user depending on individual criteria.

Secondly, the minimum periodicity for which a value is sent and for which there is a packet loss less than 1% can be assessed by following the Test Specification NA4-TC21.TS1.

Finally, considering the results from NA4-TC21.TS1, the QoS performance indicators can be obtained for different emulated delays by following the Test Specification NA4-TC21.TS2.

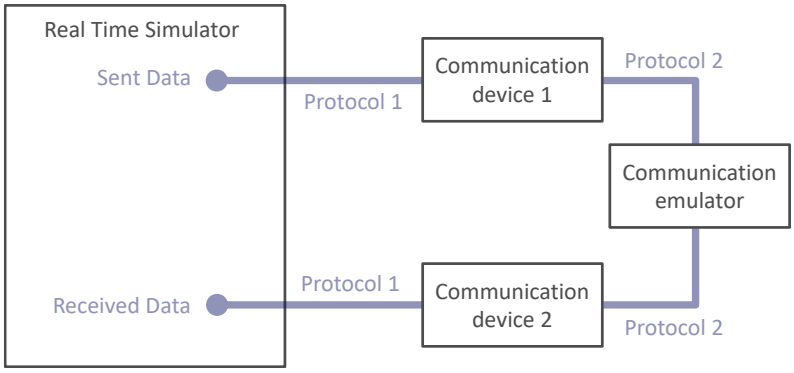
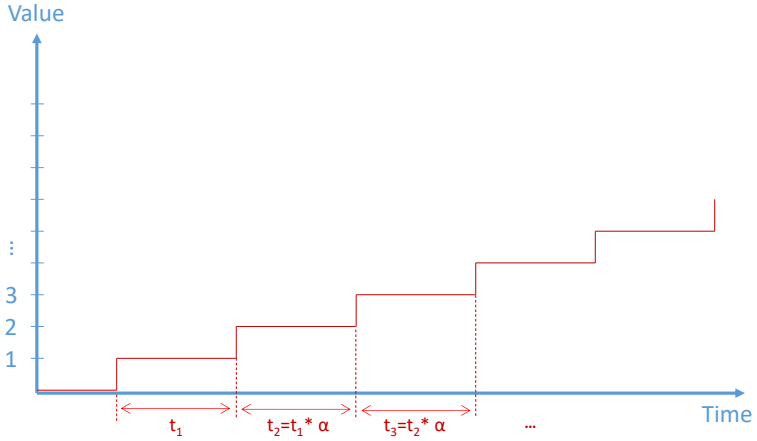
Test Specification TC21.TS1

Reference to Test Case	TC21
Title of Test	Determining minimum periodicity of data transmission for a successful transmission rate over 99%
Test Rationale	This test allows determining, as a first step, which is the minimum periodicity for which data sent from the real time simulator will result in a packet loss rate less than 1%. This information is needed for the design of the experiment needed to run TS02.
Specific Test System (graphical)	 The test system is comprised by the components and their interconnection according to the figure shown above. The real time simulator must send a data profile composed of integer values using “protocol 1” and a value α less than 1. 

	Additionally, the real time simulator must internally register a timestamp for each value sent and a timestamp for when this value is received (if the value is not lost). The communication emulator delay setting must be “0”. This will allow determining the minimum duration a value has to be sent for a 100% successful transmission rate.
Target measures	• The roundtrip time for each value sent from the real time simulator to reach the real time simulator, going through the communication devices and the communication emulator.
Input and output parameters	Controllable input parameters: • Number of numbers that will be used for the data profile (e.g. 30). • The proportion for which the next sending duration of the next value will be decreased (factor α). • The specific communication protocol to send the information (Protocol 1 and 2). • The number of times the data profile will be sent around the system to obtain statistically valid results (e.g. 1000 times) Uncontrollable parameters: • Time that it takes the data to be received by the real time simulator Measured parameters: • Values received by the real time simulator • Roundtrip time of each value received by the real time simulator.
Test Design	• Choose data profile to be sent around the system. • Choose the number of times the data profile will be sent around the system. • Choose communication protocols “Protocol 1” and “Protocol 2” • Set the delay emulation from the communication emulator to “0” • Run the experiment and determine for each sent value whether the real time simulator received it. • If the value was received, determine the roundtrip time by calculating the difference of the timestamps registered by the real time simulator. • Assess test criteria for each of the values.
Initial system state	• Devices are on and running • The real time simulator has sent any value • The registrations (in the real time simulator) of successful received values and the timestamps of sending/receiving values are empty
Evolution of system state and test signals	• The successful received values and the timestamps of sending/receiving values are registered in the real time simulator.
Other parameters	*N/A*
Temporal resolution	• Polling frequency parameters of the protocols being used should be less than the value that has the minimum transmission duration. Polling frequency in the range 1ms-10ms is

	recommended.
Source of uncertainty	The delay that can occur within any of the devices used in the system has a stochastic nature. These are therefore sources of uncertainty.
Suspension criteria / Stopping criteria	Suspension criteria: Errors in devices Stopping criteria: the experiment concludes when the data profile has been sent a previously defined number of times.

Test Specification NA4-TC21.TS2

Reference to Test Case	TS02
Title of Test	This test allows determining and verifying the successful transmission rate of a data profile for different delay emulations enabled by the communication emulator. This would allow to verify the minimum periodicity of data value sent determined in TS1 (with 99% successful transmission rate), and determine if the successfully transmitted data is similar or decreases when including emulated delays.
Test Rationale	
Specific Test System (graphical)	 The test system is comprised of the components and their interconnection according to the figure shown above. The emulation delay must be set to different values depending on the delay to be assessed. One experiment must be carried out for each of these delays The real time simulator must send a data profile composed of integer values using “protocol 1” and a value α equal to 1. The values have to constantly increase throughout each experiment. 

	Additionally, the real time simulator must internally register a timestamp for each value sent and a timestamp for when this value is received (if the value is not lost).
Target measures	• The roundtrip time that takes each value sent from the real time simulator to reach the real time simulator, going through the communication devices and the communication emulator.
Input and output parameters	Controllable input parameters: • The time duration for which each value from the data profile is sent (Ideally, the minimum duration determined in TS1). • The specific communication protocol to send the information (Protocol 1 and 2). • The emulation delay of the communication emulator. Uncontrollable parameters: • Time that takes the data to be received by the real time simulator Measured parameters: • Values received by the real time simulator • Roundtrip time of each value received by the real time simulator.
Test Design	• Choose data profile to be sent around the system. • Choose the number of values that will be sent through the system (at least 1000 recommended for statistical purposes) • Choose communication protocols “Protocol 1” and “Protocol 2” • Select a set of delay emulation values to be assessed (e.g. {100ms, 150ms, 200ms}) • Set the delay emulation from the communication emulator to the first value from the set • Run the experiment and determine for each sent value whether the real time simulator received it. • If the value was received, determine the roundtrip time by calculating the difference of the timestamps registered by the real time simulator. • Assess test criteria for each of the values. • Repeat procedure selecting a different delay emulation value from the set, until all the experiments have been executed.
Initial system state	• Devices are on and running • The real time simulator has sent any value • The registrations (in the real time simulator) of successful received values and the timestamps of sending/receiving values are empty
Evolution of system state and test signals	• The successful received values and the timestamps of sending/receiving values are registered in the real time simulator.
Other parameters	*N/A*
Temporal resolution	• Polling frequency parameters of the protocols being used should be less than the value that has the minimum transmission duration. Polling frequency in the range 1ms-10ms is recommended.
Source of uncertainty	The delay that can occur within any of the devices used in the system has a stochastic nature. These are therefore sources of uncertainty.

Suspension criteria / Stopping criteria	Suspension criteria: Errors in devices Stopping criteria: the experiment concludes when the value from the data profile reaches the previously defined number.