

Standards-Based IoT Testing with Open-Source Test Equipment

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aufgrund eines Beschlusses
des Deutschen Bundestages



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IoT-T
Project

Testlab and Testware for the Internet of Things



<http://www.iot-t.de/en/>



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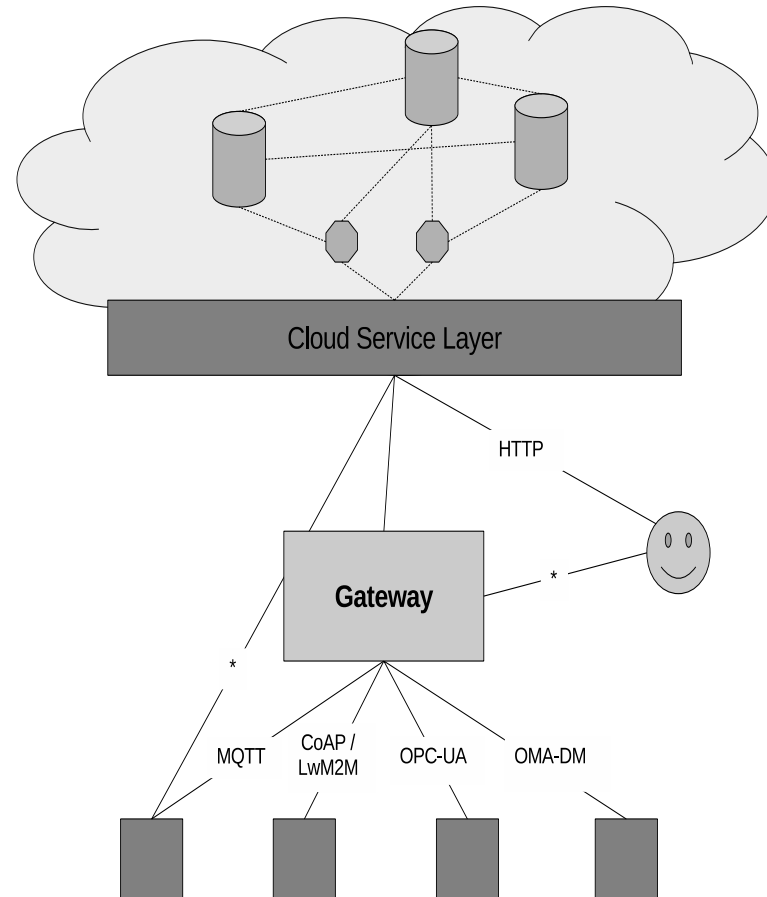
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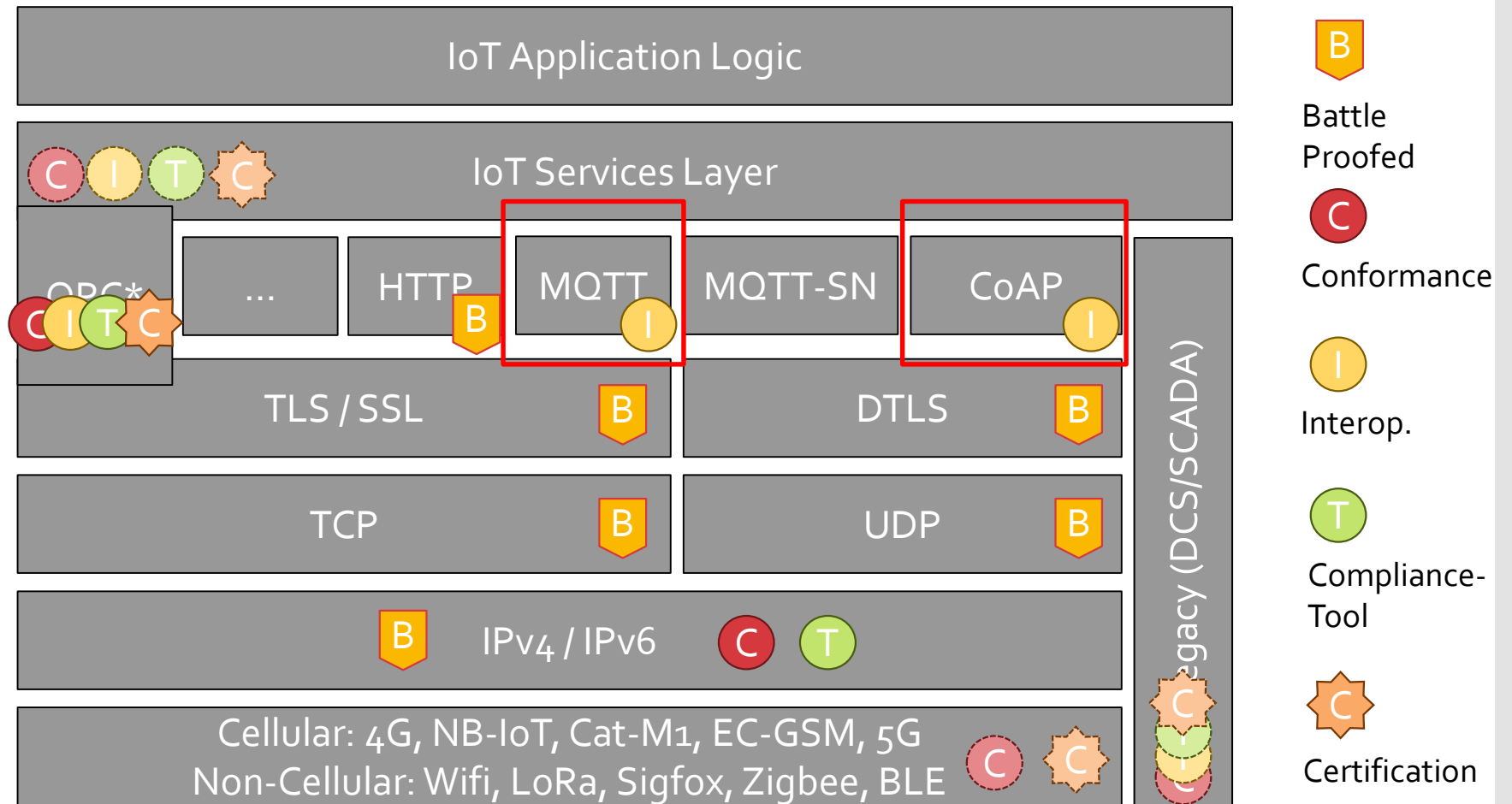
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Motivation



- IoT (protocols) quite young and implementations often immature
- Complexity through interconnectivity and diversity
- (Mostly) standardized protocols

Challenges in testing IoT



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Newcomer vs. Fieldbuses



Level 4 Business

- › Enterprise Cloud
- › ERP
- › Office

Level 3 Operations Support

- › MES
- › Control DMZ

Level 2 Supervisory

- › DCS / SCADA
- › HMI

Level 1 Control

- › PLCs
- › Edge Devices

Level 0 Field

- › Sensors
- › Machinery

Protocol	Open Specification	Stand. Testcases	Testware available	Conformance Certification
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CoAP



- IT ensures Quality with Ref. Implementations and Plugfests
- OT is driven by standards and independent certifications

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Eclipse
IoT-Testware



Open-Source Test Suites for
standardized IoT protocols



<https://projects.eclipse.org/projects/technology.iottestware>



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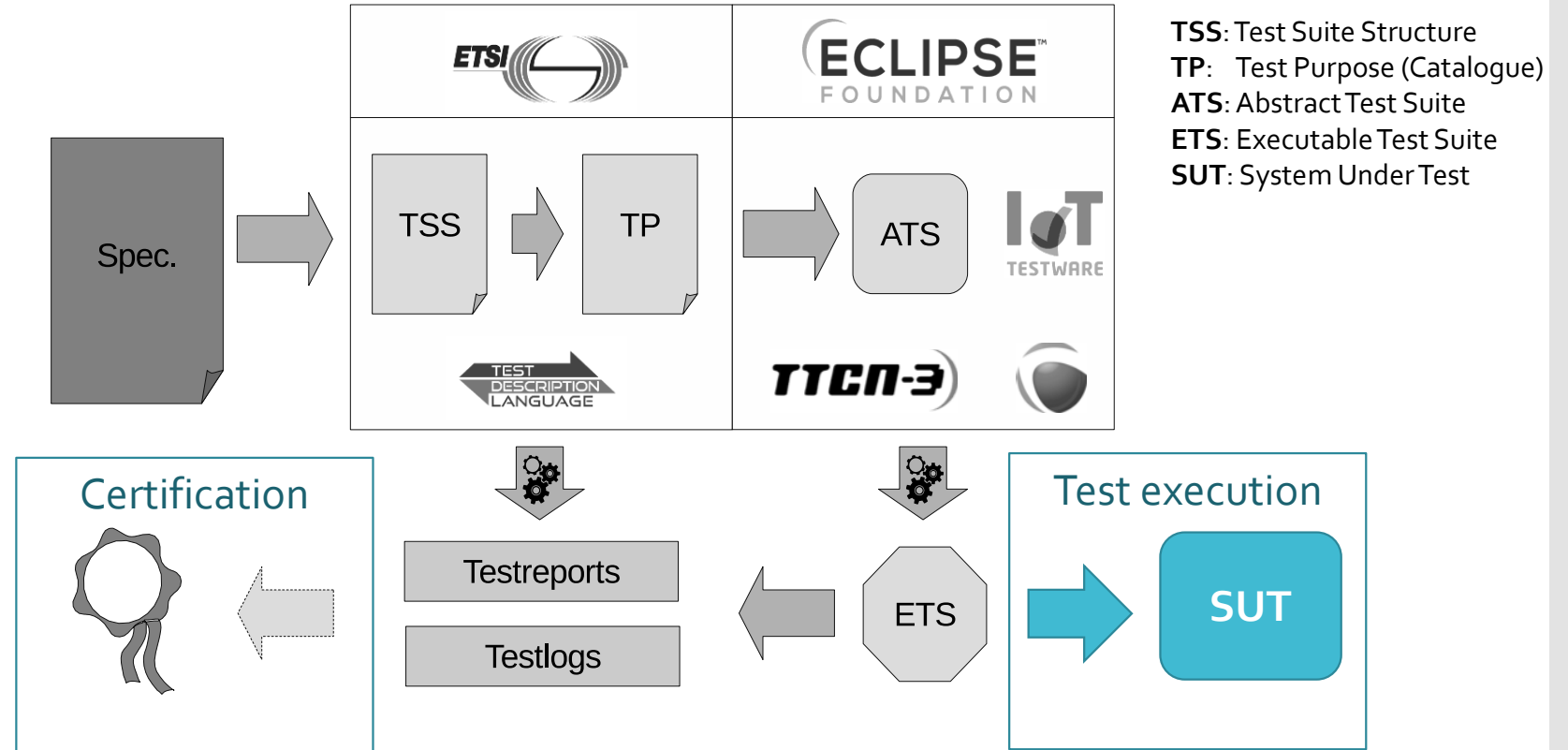
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Approach



ISO/IEC 9646 – Conformance testing methodology and framework

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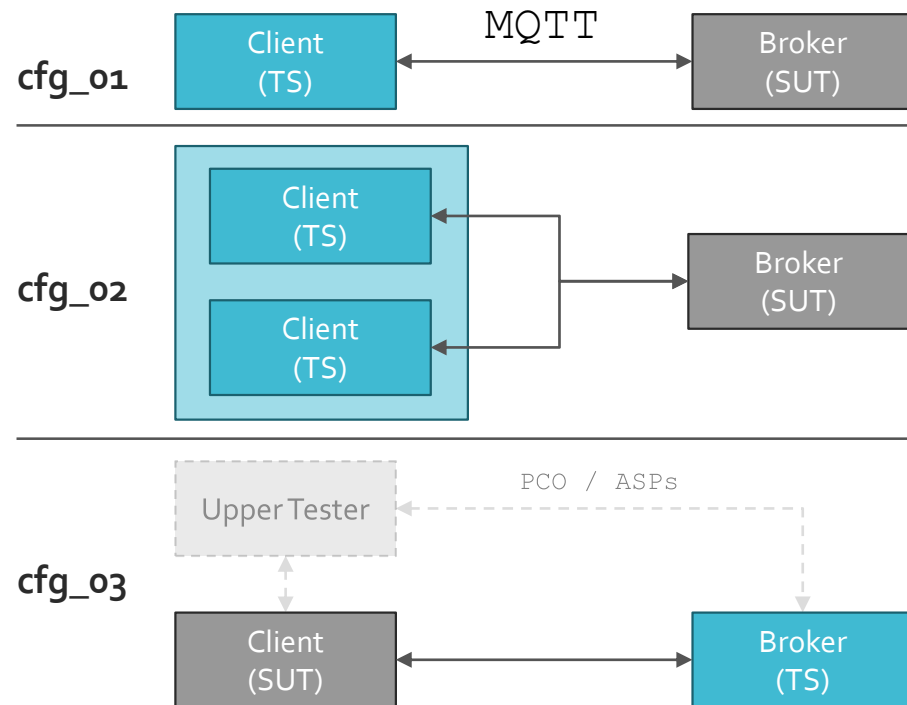
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Test Suite Structure (MQTT)



– Broker as SUT

- All mandatory **message data** fields
 - Regular and illegal data (Fixed/variable header, payload)

– Protocol features

- Connect/disconnect (session)
- Subscribe/unsubscribe
- Immediate publish
- Last will and Testament (LWT)
- Heartbeats keepAlive values
- Topic
- Error handling

– Client as SUT

– ...

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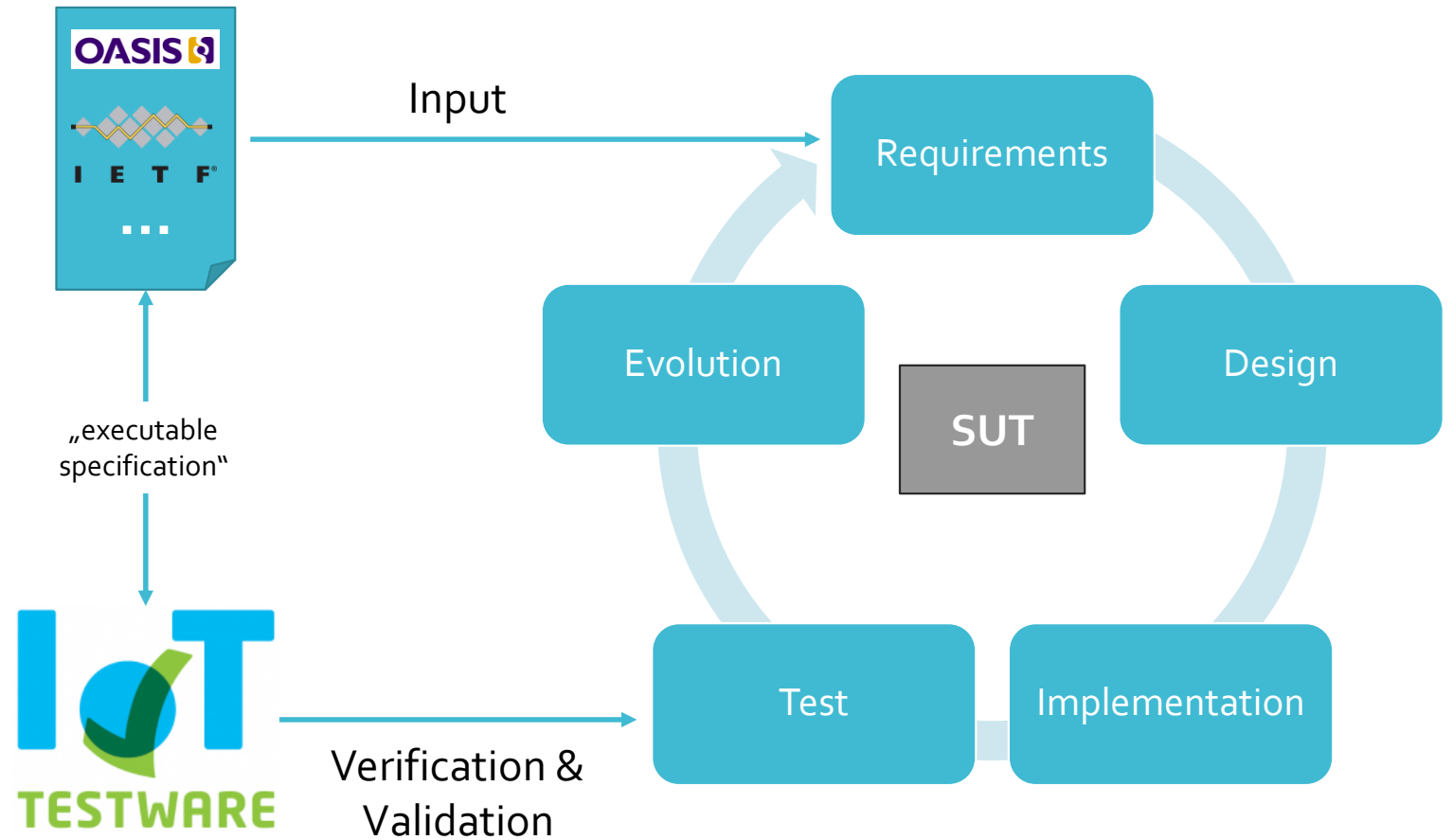
Test Purposes

TP Id	TP_MQTT_Broker_CONNECT_001
Test Objective	The IUT MUST close the network connection if fixed header flags in CONNECT Control Packet are invalid
Reference	[MQTT-2.2.2-1], [MQTT-2.2.2-2], [MQTT-3.1.4-1], [MQTT-3.2.2-6]
PICS Selection	PIC_BROKER_BASIC
Initial Conditions	
Expected Behaviour	
<pre>ensure that { when { the IUT receives a CONNECT message containing header_flags indicating value '1111'B; } then { the IUT closes the TCP_CONNECTION } }</pre>	
Final Conditions	



Test description

Executable IoT-Testware



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MQTT Evaluation

Broker		PASS		FAIL		INCONC	
Name	Version	#	%	#	%	#	%
Mosquitto	1.5.5	90	85,71%	11	10,48%	4	3,81%
HiveMQ CE	2019.1	86	81,90%	15	14,29%	4	3,81%
	v0.9.8	68	64,76%	33	31,43%	4	3,81%
	5.15.9	58	55,24%	43	40,95%	4	3,81%
	0.38.0	58	55,24%	43	40,95%	4	3,81%
	1.3.0.2	50	47,62%	51	48,57%	4	3,81%
	2.8.3	43	40,95%	58	55,24%	4	3,81%
	1.7.1	34	32,38%	70	66,67%	1	0,95%

April 2019 – 105 Test Cases

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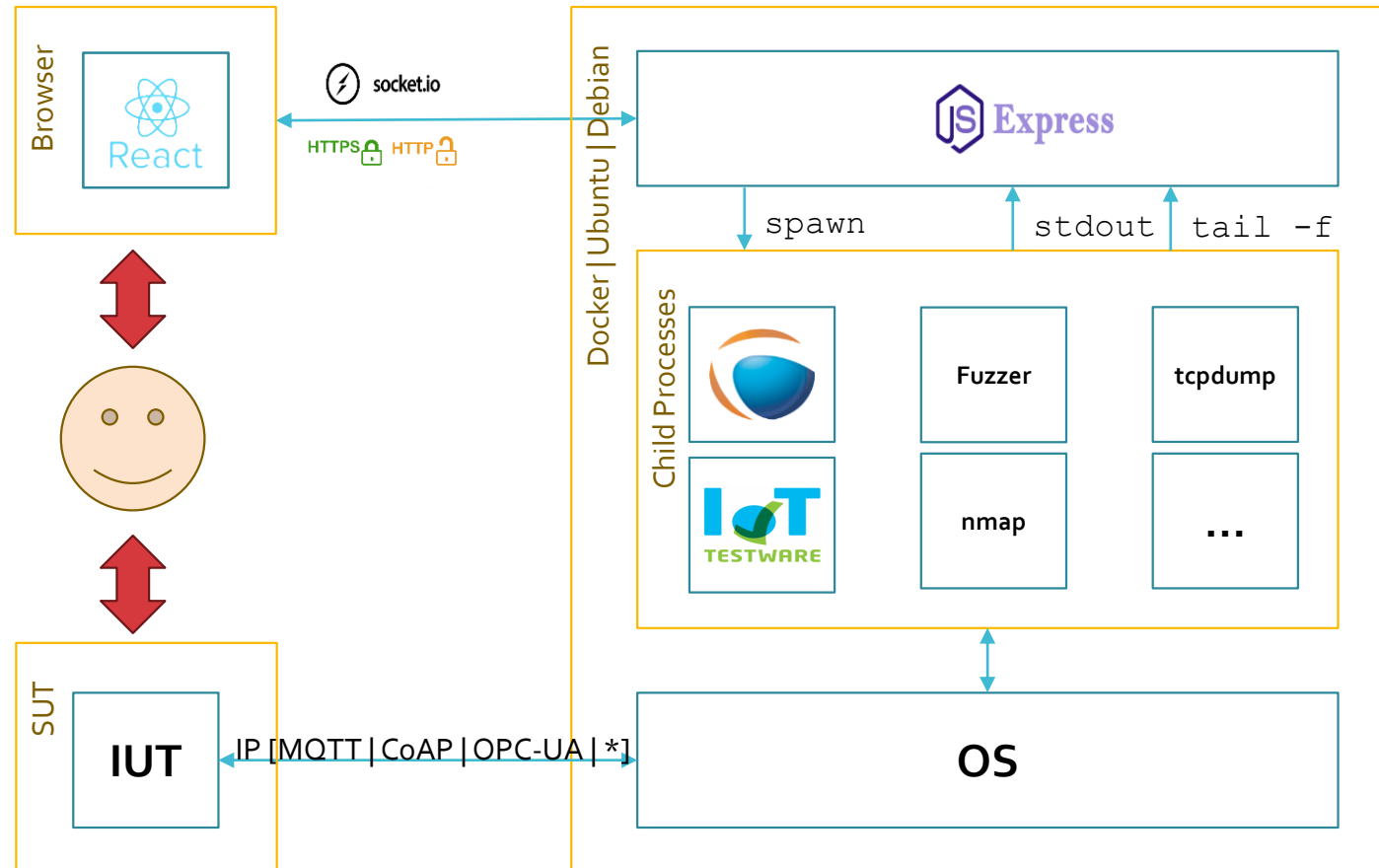
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Usability



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Usability

```
(MODULE_PARAMETERS)
PX_SUT_HOSTNAME := "192.168.56.1"
PX_SUT_PORT := 1883
PX_CLIENTS :=
(
  {
    clientId := "CLIENT1",
    username := "2067a272-4355-4ba-9586-de5443745de1",
    password := "01xq1550fayjKv0Fukia6",
  },
  {
    clientId := "SECONDARYCLIENT",
    username := "6296f3d5-e105-4b22-b68b-381bfab128a9",
    password := "0e7NND0Av5WRH55VQeBPC",
  }
)
PX_TOPIC_NAME := "eclipse/jst/testware/48d415c8-2c5b-48af-bab6-46c3477672f7/"
PX_REUSE_ADDRESS := true
PX_MAX_RESPONSE_TIME := 3.0
[LOGGING]
Logfile := "../logs/client_logs/v1_no_hu_no"
FileMask := LOG_ALL | TESTCASE | STATISTICS | MATCHING | PORTEVENT | ERROR | WARNING | DEBUG | USER
ConsoleMask := TESTCASE_START | TESTCASE_FINISH | VERDICTOP_FINAL | VERDICTOP_SERVEREXIT | STATISTICS
LogSourceInfo := Yes
AppendFile := No
TimestampFormat := DateTime
LogEventTypes := Yes
+EmergencyLogging:=15
+EmergencyLoggingBehaviour := BufferFlushed
+EmergencyLoggingMask := LOG_ALL | DEBUG
SourceInfoFormat := Single
LogEntityName := Yes
[TESTPORT_PARAMETERS]
+,.noDelay:=No"
[EXECUTE]
MQTT_TestCases.TC_MQTT_BROKER_CONNECT_001
MQTT_TestCases.TC_MQTT_BROKER_CONNECT_002
MQTT_TestCases.TC_MQTT_BROKER_CONNECT_003
MQTT_TestCases.TC_MQTT_BROKER_CONNECT_004
root@38ef83caa5fa:/home/titan/playground/mqtts# ttcn3_start iottestware.mqtt broker_testing_01.cfg
ttcn3_start: Starting the test suite
spawn /home/titan/core/Install/bin/mctr_cli broker_testing_01.cfg

=====
* TTCN-3 Test Executor - Main Controller 2
* Version: CRL 113 200/6 RMA
* Copyright (c) 2000-2018 Ericsson Telecom AB
* All rights reserved. This program and the accompanying materials
* are made available under the terms of the Eclipse public license v1.0
* which accompanies this distribution, and is available at
* http://www.eclipse.org/legal/epl-v10.html
=====

Using configuration file: broker_testing_01.cfg
MC@38ef83caa5fa: Unix server socket created successfully.
MC@38ef83caa5fa: Listening on TCP port 38615.
MC@> 38ef83caa5fa is the default
spawn ./iottestware.mqtt 38ef83caa5fa 38615
TTCN-3 Host Controller (parallel mode), version CRL 113 200/6 RMA
MC@38ef83caa5fa: New HC connected from 38ef83caa5fa [172.17.0.2]. 38ef83caa5fa: Linux 4.15.0-52-generic on x86_64.
CRLC
MC@38ef83caa5fa: Downloading configuration file to all HCs.
MC@38ef83caa5fa: Configuration file was processed on all HCs.
MC@38ef83caa5fa: Creating MTC on host 38ef83caa5fa.
MC@38ef83caa5fa: MTC is created.
MC@> exit
Executing all items of [EXECUTE] section.
MC@38ef83caa5fa: Test case TC_MQTT_BROKER_CONNECT_001 started.
MC@38ef83caa5fa: Port IPL4_PCO was started.
MC@38ef83caa5fa: Initialize Client 0
MC@38ef83caa5fa: [MQTT_v4] [checked]: {MQTT-1.5.3-1}, {MQTT-1.5.3-2}, {MQTT-3.1.3-41}
MC@38ef83caa5fa: [MQTT_v4] [checked]: {MQTT-3.1.3-51}
MC@38ef83caa5fa: [MQTT_v4] [checked]: {MQTT-3.1.1-113}
MC@38ef83caa5fa: [MQTT_v4] [checked]: {MQTT-3.1.1-140}
MC@38ef83caa5fa: [MQTT_v4] [checked]: {MQTT-4.7.1-11}
MC@38ef83caa5fa: Port IPL4_PCO was mapped to system: IPL4_PCO.
MC@38ef83caa5fa: Connect to SUT: "127.0.0.1":1883 from local Port: 58039
MC@38ef83caa5fa: entering f IPL4_PCOV4_connect: 0.0.0.0:58039 -> 127.0.0.1:1883 / TCP
MC@38ef83caa5fa: Connection failed: retry 1 of 1 in 1.000000s
MC@38ef83caa5fa: Connect to SUT: "127.0.0.1":1883 from local Port: 58039
MC@38ef83caa5fa: entering f IPL4_PCOV4_connect: 0.0.0.0:58039 -> 127.0.0.1:1883 / TCP
MC@38ef83caa5fa: "closing connection -1"
MC@38ef83caa5fa: Cleanup started.
MC@38ef83caa5fa: Port IPL4_PCO was unmapped from system: IPL4_PCO.
MC@38ef83caa5fa: Port IPL4_PCO was stopped.
MC@38ef83caa5fa: Test case TC_MQTT_BROKER_CONNECT_001 finished. Verdict: Inconcl reason: Connection to SUT ("127.0.0.1":1883) not possible
MC@38ef83caa5fa: Test execution finished.
MC@38ef83caa5fa: Test case TC_MQTT_BROKER_CONNECT_002 started.
MC@38ef83caa5fa: Port IPL4_PCO was started.
MC@38ef83caa5fa: Initialize Client 0
```



MQTT Test Suite

...here some basic information about the Test Suite

Host

PIXIT

PICS

Conformance Test: MQTT

Finished
Test Run finished

Expand all: ☐ Off

#	Test Case	Verdict	Reason
0	TC_MQTT_BROKER_CONNECT_001	Success	IUT closed the Network Connection correctly
1	TC_MQTT_BROKER_CONNECT_002	Success	IUT does not accept incorrect Protocol Names
2	TC_MQTT_BROKER_CONNECT_003	Success	IUT answered correctly with ACK and return code 0x00
3	TC_MQTT_BROKER_CONNECT_004	Success	IUT closed the Network Connection correctly
4	TC_MQTT_BROKER_CONNECT_005	Success	IUT closed the Network Connection correctly
5	TC_MQTT_BROKER_CONNECT_006	Success	IUT closed the Network Connection correctly
6	TC_MQTT_BROKER_CONNECT_007	Success	IUT closed the Network Connection correctly
7	TC_MQTT_BROKER_CONNECT_008	Success	IUT closed the Network Connection correctly
8	TC_MQTT_BROKER_CONNECT_009	Success	IUT answered correctly with ACK and return code 0x00
9	TC_MQTT_BROKER_CONNECT_010	Success	IUT closed the Network Connection correctly
10	TC_MQTT_BROKER_CONNECT_011	Success	IUT answered correctly with ACK and return code 0x00
11	TC_MQTT_BROKER_CONNECT_012	Success	IUT closed the Network Connection correctly
12	TC_MQTT_BROKER_CONNECT_013	Failure	IUT MUST close the Network Connection
13	TC_MQTT_BROKER_CONNECT_015	Failure	IUT MUST close the Network Connection
14	TC_MQTT_BROKER_CONNECT_017	Success	IUT accepts clientids longer than 23 Bytes
15	TC_MQTT_BROKER_CONNECT_018	Success	IUT accepts clientids with special characters
16	TC_MQTT_BROKER_CONNECT_019	Success	IUT answered correctly with ACK and return code 0x00
17	TC_MQTT_BROKER_CONNECT_020	Failure	IUT MUST close the Network Connection
18	TC_MQTT_BROKER_CONNECT_021	Failure	IUT MUST close the Network Connection
19	TC_MQTT_BROKER_CONNECT_001	Success	IUT answered correctly with ACK and return code 0x00
20	TC_MQTT_BROKER_CONNECT_002	Success	IUT accepted connection with clean session set to 1

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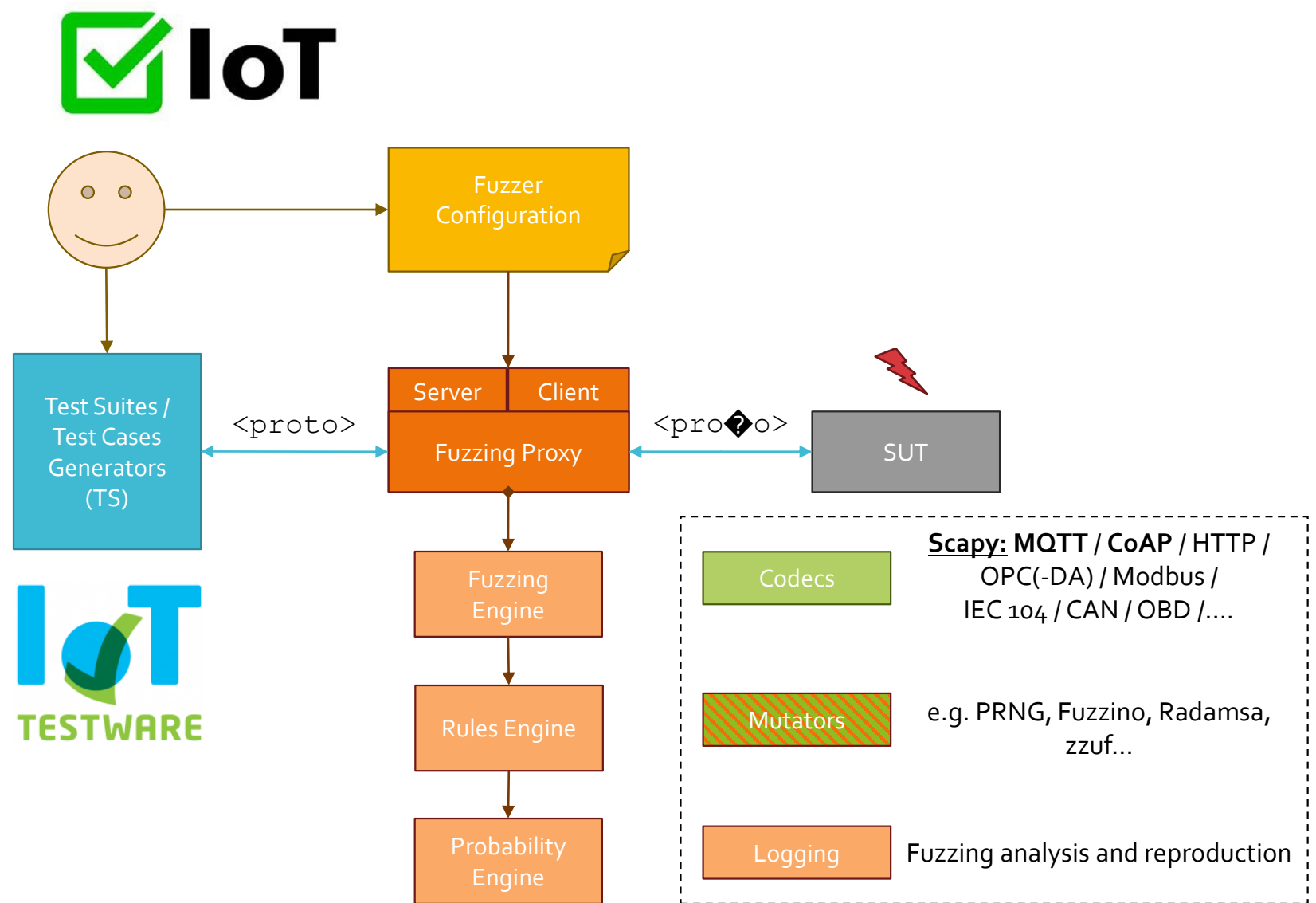
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Protocol Fuzzing



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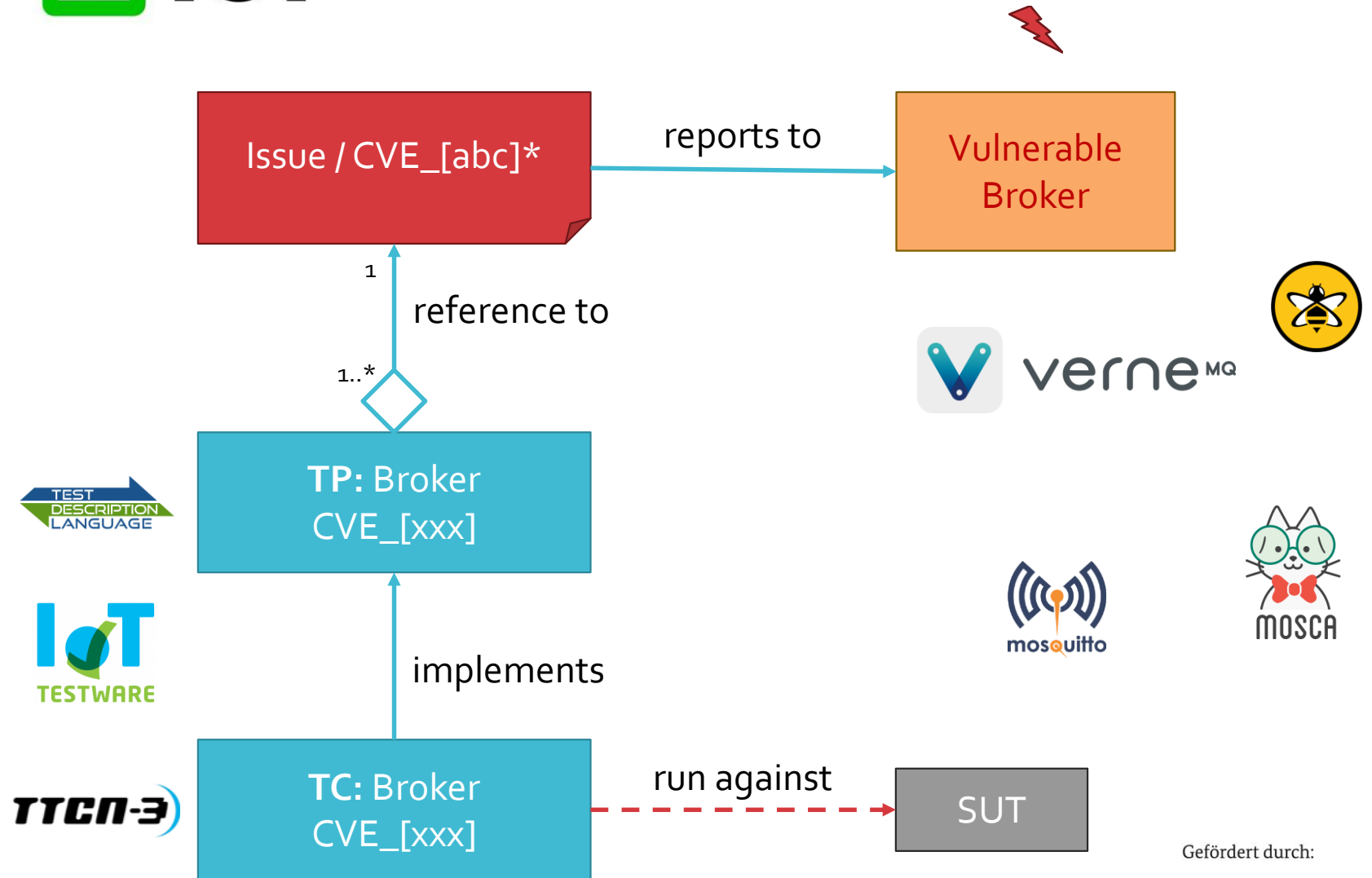
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Security Regression Testing

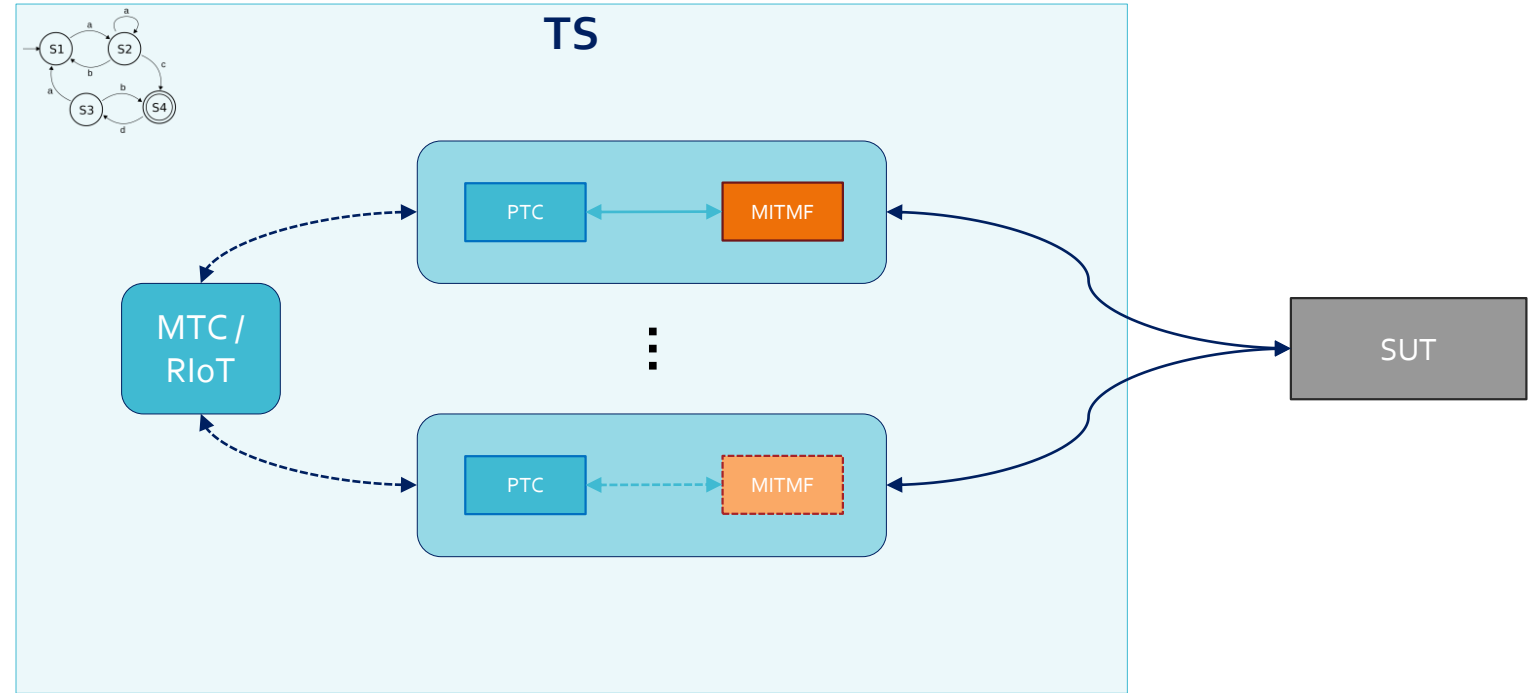


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Performance Testing



MTC: Main Test Component

PTC: Parallel Test Component

MITMF: Man-in-the-Middle Fuzzer / Fuzzing Proxy

SUT: System Under Test

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Takeaway

- Open standards require open-source test equipment
- Test equipment must be flexible though easy to use
- Reuse of standards-based test equipment frees resources for additional testing activities
- Cooperate on (Black-Box/conformance) testing, compete in implementation



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Questions?



<https://projects.eclipse.org/projects/technology.iottestware>

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