Test Automation with TTCN-3

Introduction

Motivation

How much does testing cost?

„ ... the national annual cost estimates of an inadequate infrastructure for software testing are estimated to be $59.5 billion.

The potential cost reduction from feasible infrastructure improvements is $22.2 billion.“

The Economic Impacts of Inadequate Infrastructure for Software Testing

Study by NIST, May 2002

Planning Report 02-3

The Economic Impacts of Inadequate Infrastructure for Software Testing

Prepared by:
RTI
for

National Institute of Standards & Technology

Program Office
Strategic Planning and
Economic Analysis Group

May 2002

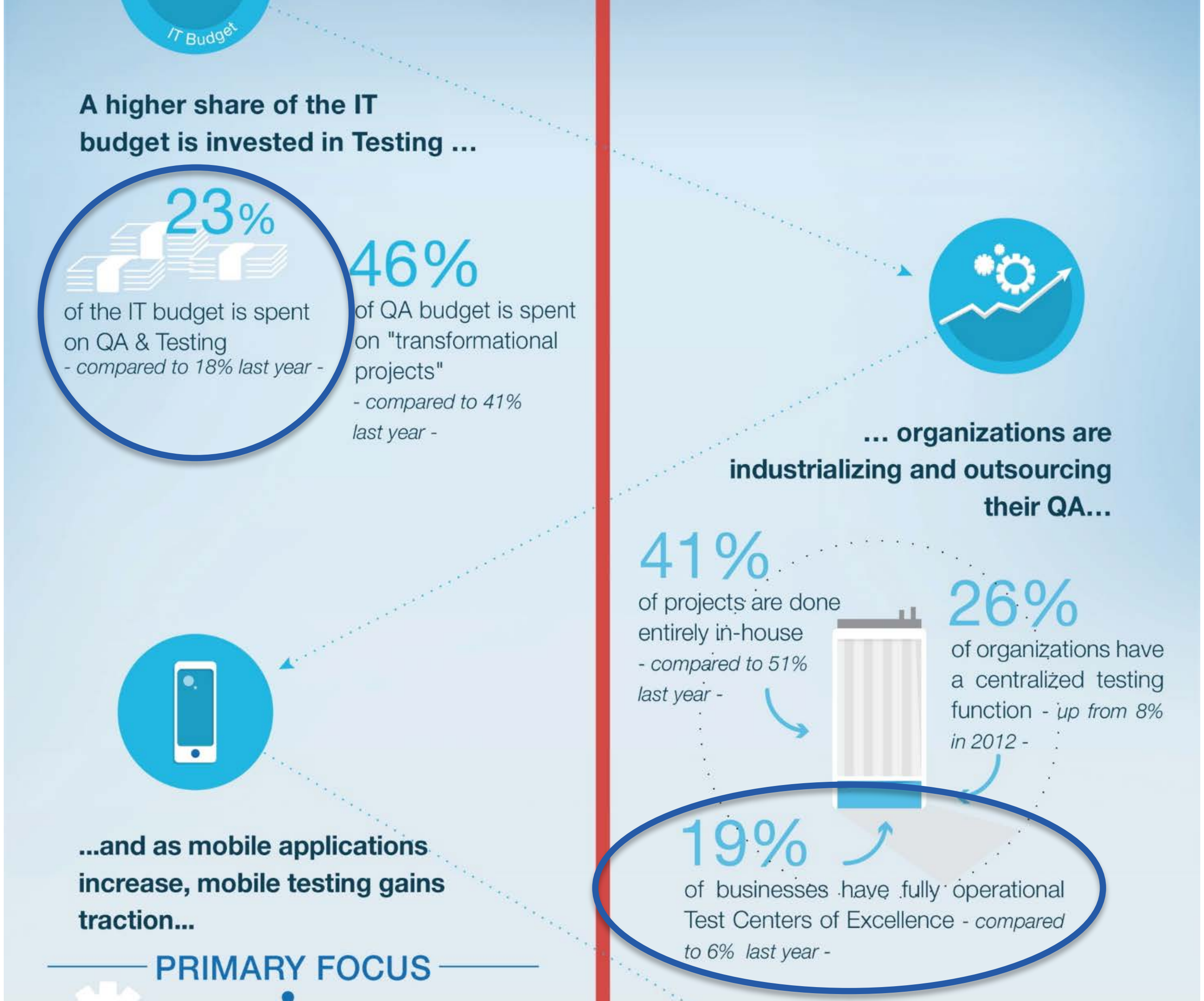
NIST
U.S Department of Commerce
Technology Administration

And today?

World Quality Report 2013-14

As consumers demand high performance, error-free applications, organizations are increasing their QA budgets and more testing functions are centralized

Focus on Testing is growing everywhere...



A higher share of the IT budget is invested in Testing ...

23%

of the IT budget is spent on QA & Testing

- compared to 18% last year -

46%

of QA budget is spent on "transformational projects"

- compared to 41% last year -

... organizations are industrializing and outsourcing their QA...

41%

of projects are done entirely in-house

- compared to 51% last year -

26%

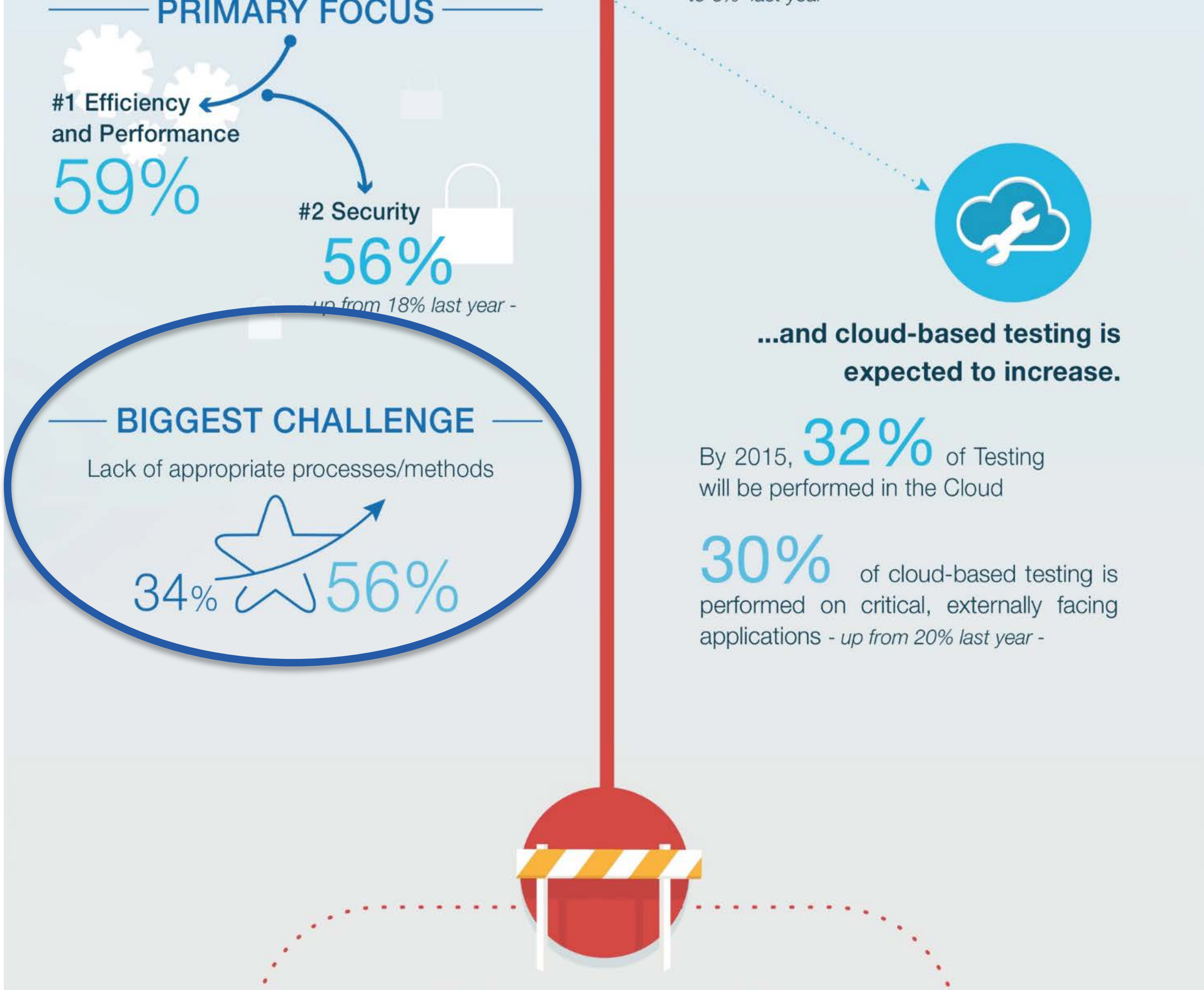
of organizations have a centralized testing function *- up from 8% in 2012 -*

19%

of businesses have fully operational Test Centers of Excellence *- compared to 6% last year -*

...and as mobile applications increase, mobile testing gains traction...

PRIMARY FOCUS



to 6% last year

PRIMARY FOCUS

#1 Efficiency and Performance

59%

#2 Security

56%

- up from 18% last year -

BIGGEST CHALLENGE

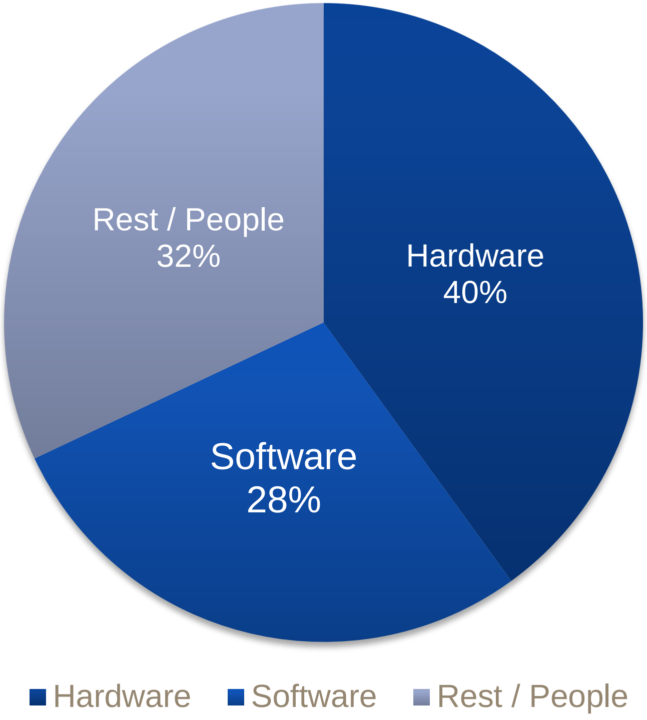
Lack of appropriate processes/methods

...and cloud-based testing is expected to increase.

By 2015, 32% of Testing will be performed in the Cloud

30% of cloud-based testing is performed on critical, externally facing applications *- up from 20% last year -*

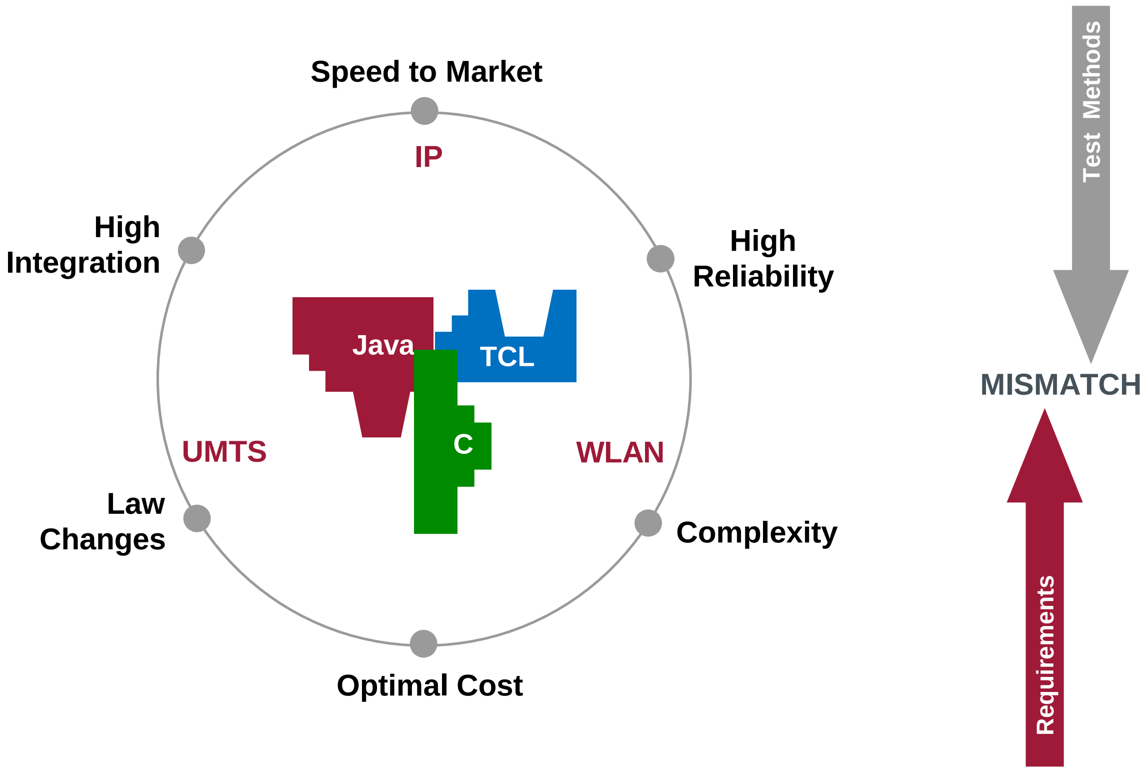
Spendings in testing (WQR 2013)



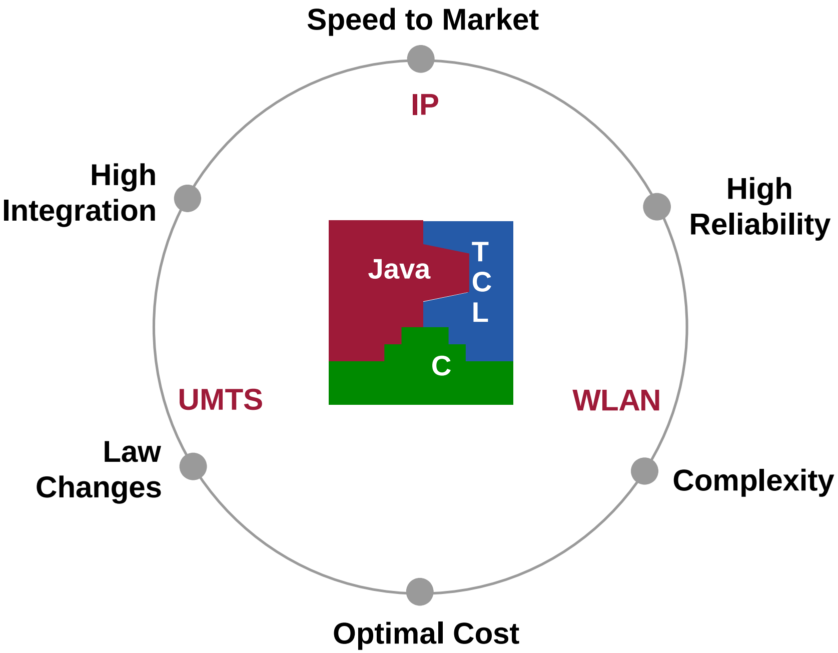
Testing today

- Is
  - Important
  - Expensive
  - Time critical
- But
  - Only rarely practiced
  - Unsystematic
  - Performed by hand
  - Error-prone
  - Uncool („If you are a bad programmer you might be a tester.“)
  - Unconstructive

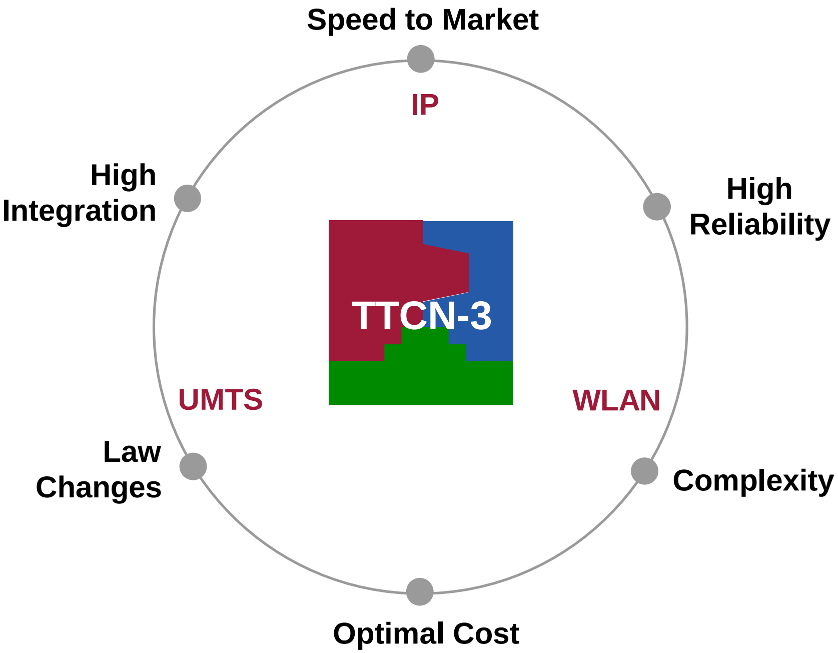
Why using TTCN-3

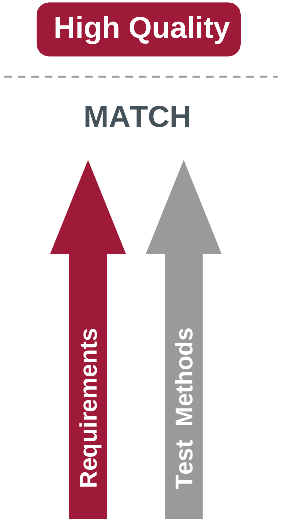


Why using TTCN-3



Why using TTCN-3





Testing is…

- a technical process
- performed by experimenting with a software product
- in a controlled environment
- following a specified procedure
- with the intent of observing one or more characteristics of the product
- by demonstrating the deviation of the product’s actual status from the required status/specification.

Testing today‘s systems

- Component-based
  - Test-components contribute to SUT functionality and performance
- Distributed
  - Not only local, but also distributed test setups
- Dynamic in terms of behavior and configuration
  - Testing of static and dynamic aspects; dynamic creation of test components
- Use various type systems to exchange data
  - Open to all type systems
- Service is essential
  - Concentration on service-oriented black-box testing

Design principles of TTCN-3

- One test technology for different kind of testing
  - Distributed, platform-independent testing
  - Integrated graphical test development, -documentation and -analysis
  - Adaptable, open test environment
- One test technology for distributed IT and telco systems and beyond

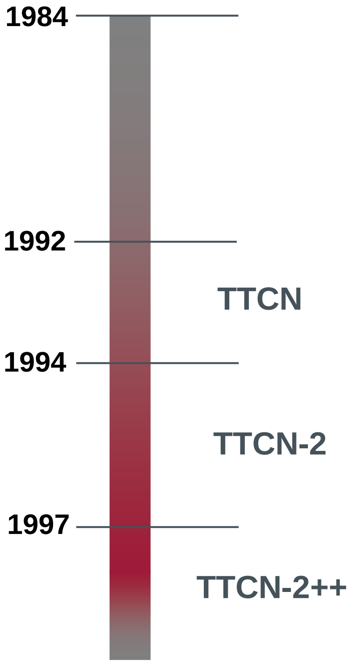
Standardization process

- ETSI (European Telecommunications Standards Institute) works on European telecom standards
- Divided in TCs (Technical Committees)
- TC MTS (Methods for Testing and Specification) works on the evaluation and development of methods and tools for testing and specification, helps other committees to introduce and use the new methods
- Standard creation
  - ETSI member submits a standard proposal to TC
  - Adopting a work item for it
  - Drafting of the standard

Standardization process

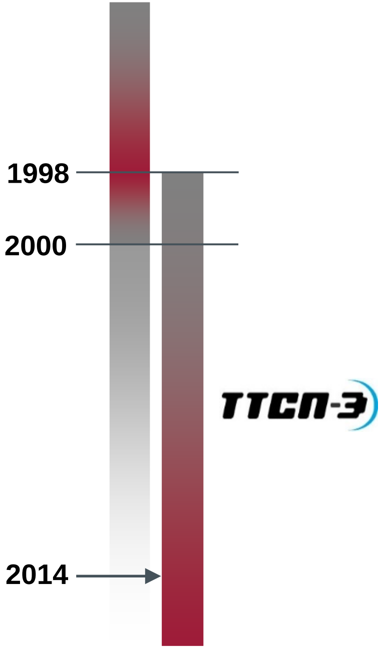
- Standards making process
  - Objective is to convert market needs into ETSI standards
  - Several approval procedures depending upon the deliverable type to be used
  - The process itself consists of
    - Identifying needs for standardization
    - Defining the most suitable technical committee for such standardization
    - Identification, definition, approval and adoption of work items
    - Drafting, editing and publication

History



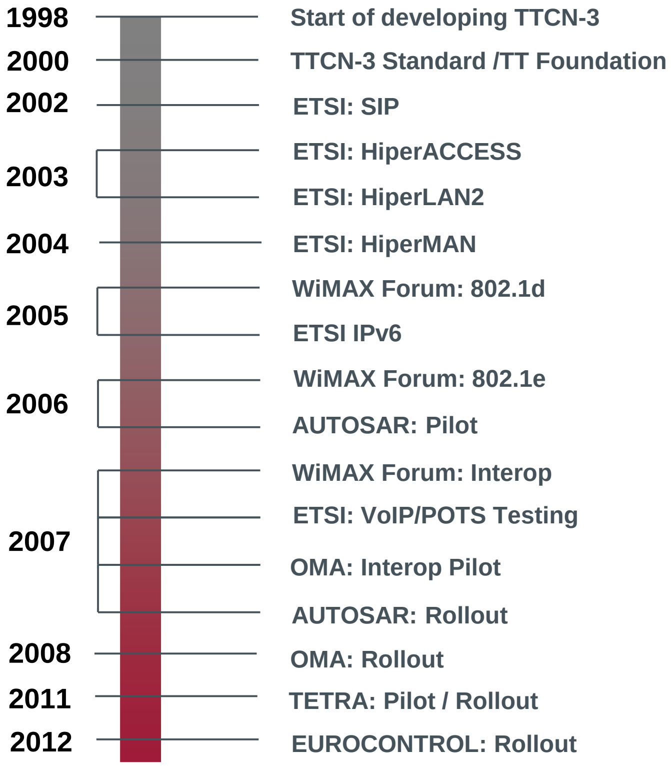
- TTCN (1992)
  - Published as an ISO standard
  - Tree and Tabular Combined Notation
  - Used for protocol testing only
    - GSM, N-ISDN, B-ISDN
- TTCN-2/2++ (1997)
  - Concurrent tests
  - Modularization
  - Manipulate external data
  - Rather for conformance testing
  - Developed by ETSI MTS

History



- TTCN-3 (2000)
  - Testing and Test Control Notation
  - Developed by ETSI MTS
  - Standard language
    - Well defined syntax and semantics
  - Enhanced communication, configuration and control
  - Standard test specifications
    - SIP, SCTP, M3UA, IPv6
    - HiperLan, HiperAccess, WiMAX
    - 3GPP LTE, OMA
    - TETRA
    - MOST, AUTOSAR
    - EUROCONTROL

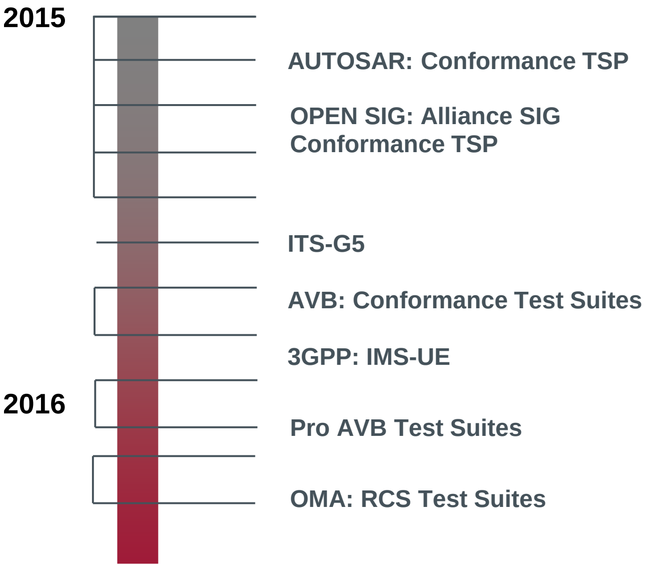
History



1998	Start of developing TTCN-3
2000	TTCN-3 Standard /TT Foundation
2002	ETSI: SIP
2003	ETSI: HiperACCESS
	ETSI: HiperLAN2
2004	ETSI: HiperMAN
2005	WiMAX Forum: 802.1d
	ETSI IPv6
2006	WiMAX Forum: 802.1e
	AUTOSAR: Pilot
2007	WiMAX Forum: Interop
	ETSI: VoIP/POTS Testing
	OMA: Interop Pilot
	AUTOSAR: Rollout
2008	OMA: Rollout
2011	TETRA: Pilot / Rollout
2012	EUROCONTROL: Rollout

- Since 2002 standard bodies are using TTCN-3 to define test specifications
  - ETSI 3GPP
  - WiMAX Forum
  - OMA
  - TETRA
  - AUTOSAR
  - MOST
  - EUROCONTROL

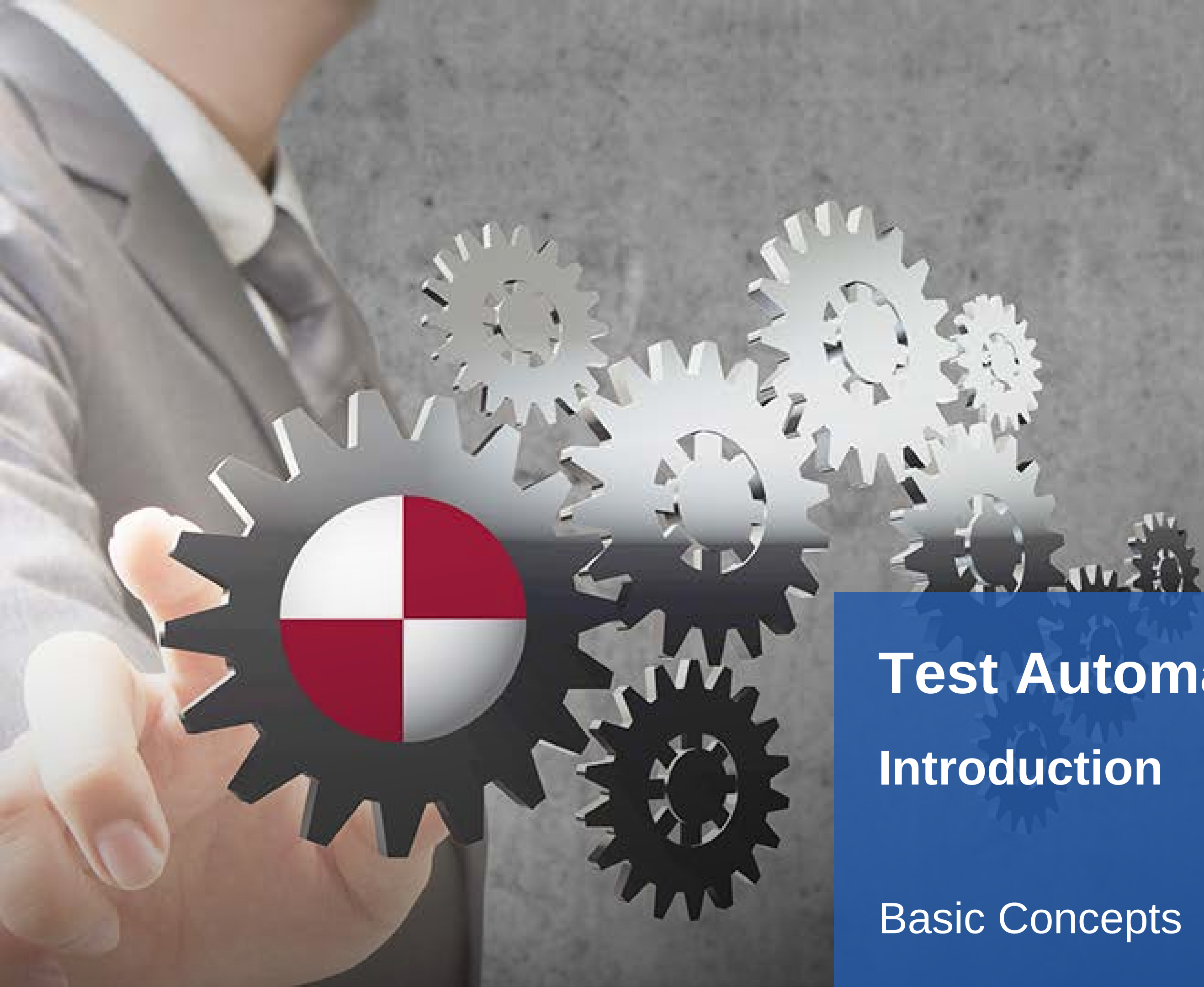
History



- Automotive solutions
  - AUTOSAR
  - OPEN Alliance
  - AVB
  - Automotive Ethernet
  - ITS

Maintenance of TTCN-3

- Standard is constantly maintained
  - Through Change Requests (CRs)
  - Extension proposals
  - Active contributions in the TTCN-3 community: TTCN-3 mailing list, TTCN-3 users conference
  - ETSI STFs (Specialist Task Force)
- Change requests result in new editions of the standard
  - 2000: Edition 1
  - 2003: Edition 2
  - 2005: Edition 3
  - 2010: Edition 4.2.1
  - 2011: Edition 4.3.1
  - 2012: Edition 4.4.1
  - 2013: Edition 4.5.1
  - 2014: Edition 4.6.1
  - 2015: Edition 4.7.1
- Resources: http://portal.etsi.org & http://www.ttcn-3.org



Test Automation with TTCN-3

Introduction

Basic Concepts

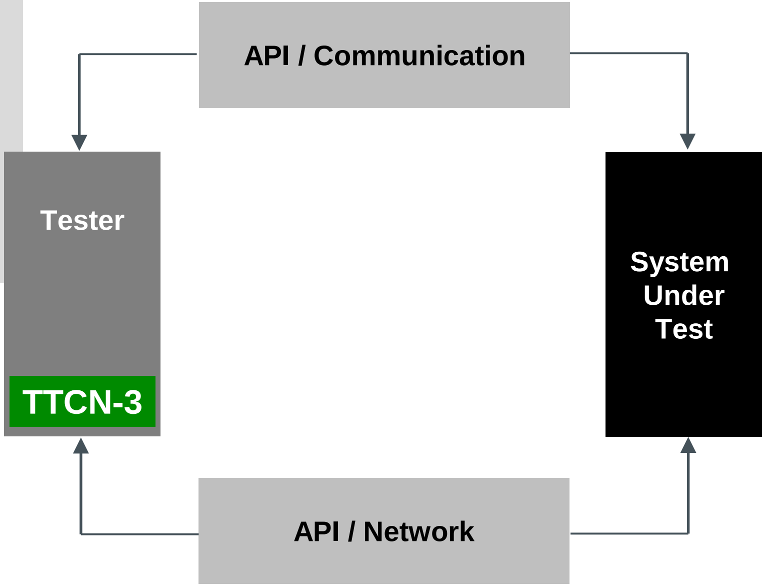
What is TTCN-3?

- Testing and Test Control Notation
- Internationally standardized testing language for formally defining test scenarios
  - Designed purely for testing
- In its essence it can be considered as a kind of scripting language that includes tons of testing specific features!

```
testcase tc_Hello_Bob () {
   p.send("How do you do?");
      alt {
         [] p.receive("Fine!"){
             setverdict( pass );}
         [else]{
             setverdict( inconc );}  //Bob asleep!
      }
}
```

TTCN-3 execution

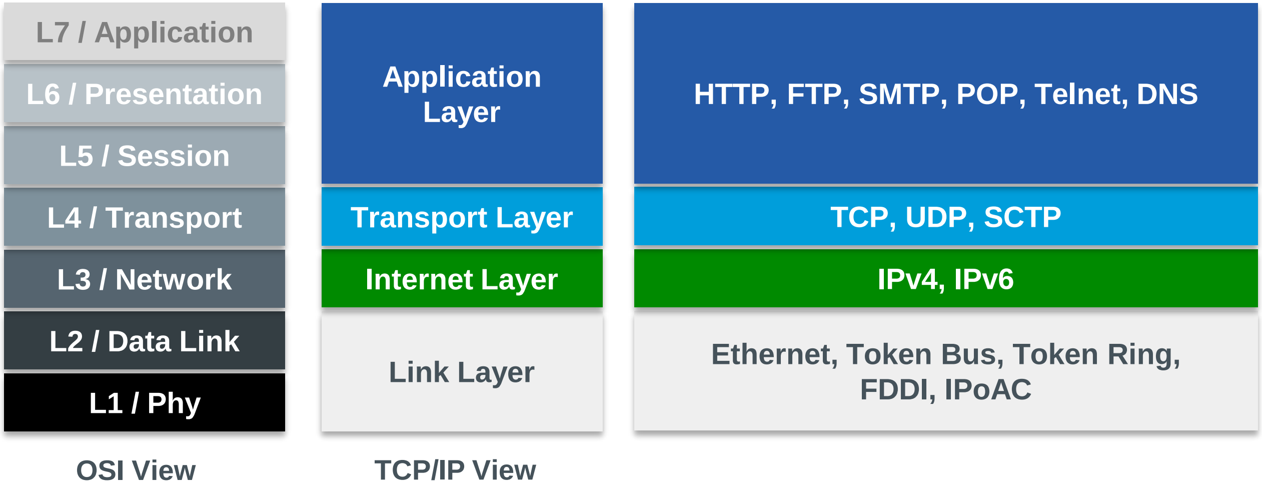
```
testcase tc_Hello_Bob () {
   p.send("How do you do?");
   alt {
     [] p.receive("Fine!"){
        setverdict( pass ); }
     [else]{
        setverdict( inconc ); }
   }
}
```



Application areas

- Multiple application areas
  - Reactive systems with technical interfaces
  - Communication protocols
  - Software testing
- Two communication paradigms
  - Message-based communication
  - Procedure-based communication
- Different kinds of testing
  - Functional testing
  - Conformance testing
  - Scalability testing …
- Addresses the complete development cycle
  - From unit via integration testing up to system level tests

Generic protocol architecture(s)



L7 / Application

L6 / Presentation

L5 / Session

L4 / Transport

L3 / Network

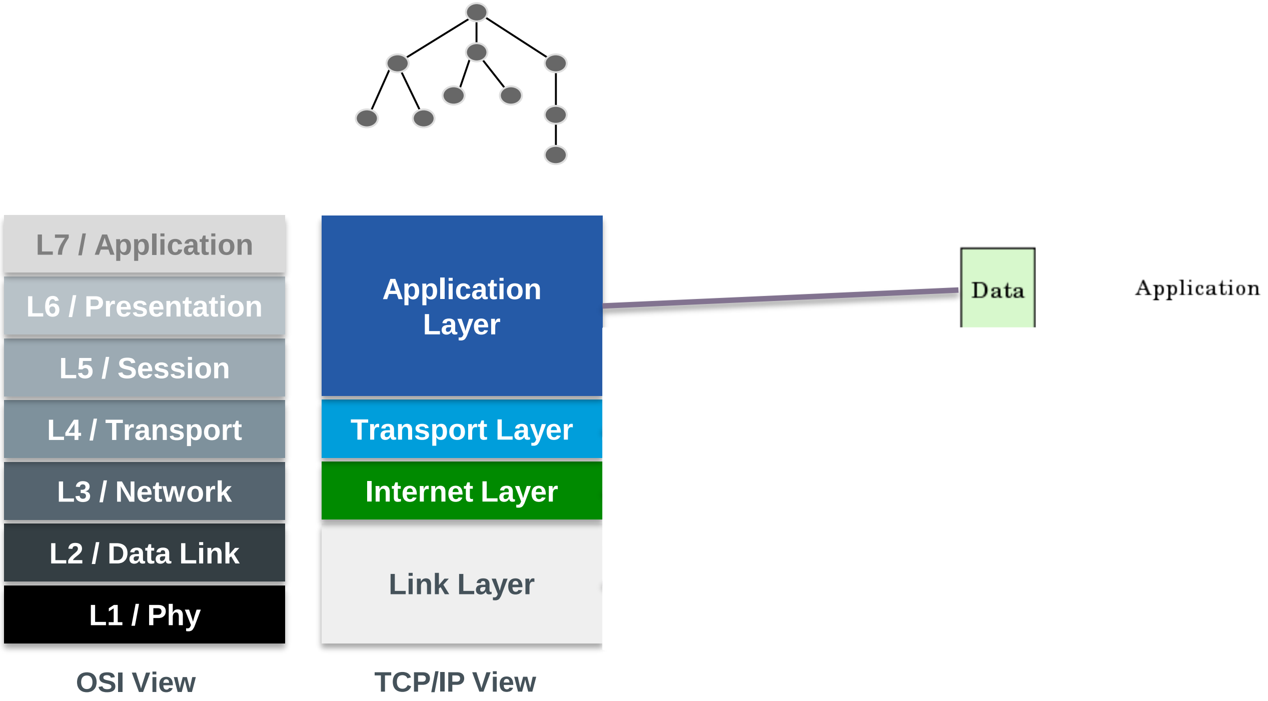
L2 / Data Link

L1 / Phy

OSI View

TCP/IP View	
Application Layer	HTTP, FTP, SMTP, POP, Telnet, DNS
Transport Layer	TCP, UDP, SCTP
Internet Layer	IPv4, IPv6
Link Layer	Ethernet, Token Bus, Token Ring, FDDI, IPoAC

Generic protocol architecture(s)



L7 / Application

L6 / Presentation

L5 / Session

L4 / Transport

L3 / Network

L2 / Data Link

L1 / Phy

OSI View

Application Layer

Transport Layer

Internet Layer

Link Layer

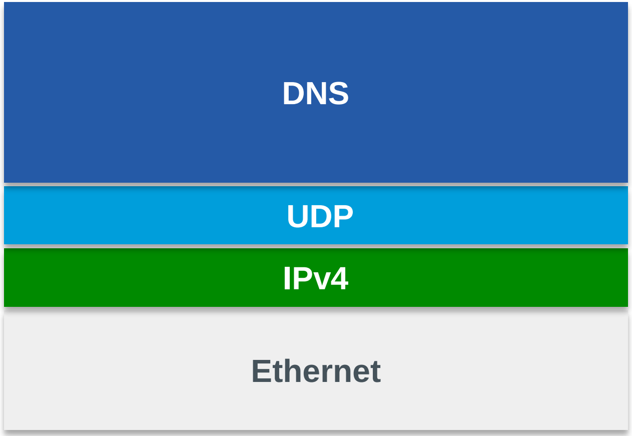
TCP/IP View

Data

Application

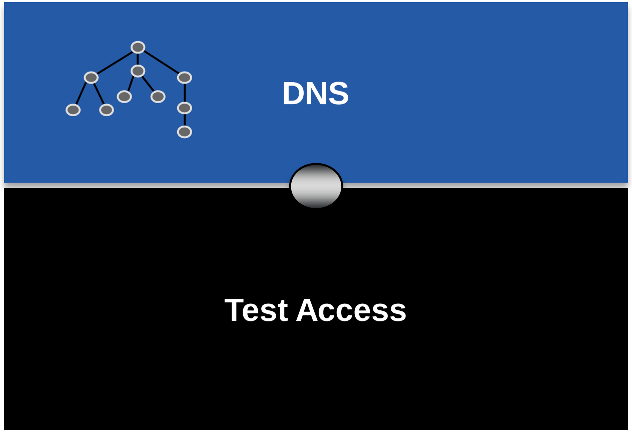
When we test we...

- Select the protocol or application to test
  - DNS
- Select the test access
  - UDP, IPv4, Ethernet



When we test we would like to ...

- Concentrate on the protocol (application) on an abstract level
- Do not care for the concrete technical details like test access



Main aspects of TTCN-3

- Triple C
  - Configuration
    - Dynamic concurrent test configurations with test components
  - Communication
    - Various communication mechanisms (message-based, procedure-based)
  - Control
    - Test case execution and selection mechanisms
- Features
  - Well-defined syntax, static and operational semantics
  - Different presentation formats
  - Module concept
  - Extendibility via attributes, external function, external data
  - Integration of different languages like ASN.1, XML, IDL, …

Differences TTCN-2 / **TTCN-3**

- Configuration
  - Static configuration with configuration tables
  - **Dynamic configuration with arbitrary amount of components**
  - Differentiation between PCOs and CPs
  - **One port concept**
- Communication
  - Asynchronous communication only
    - Abstract Service Primitives
    - Protocol Data Unit
  - **Procedure and message-based communication**
    - **Procedures**
    - **Messages**
- Control
  - Static selection of test cases via selection expression
  - **Complete high level control flow mechanisms**

Differences TTCN-2 / **TTCN-3**

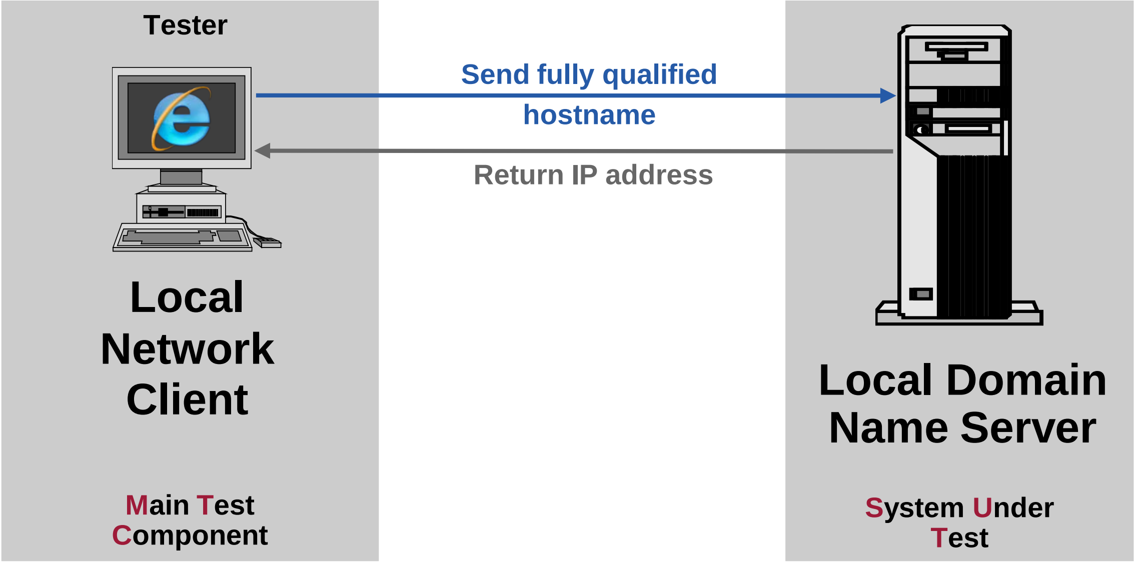
- Externalisation
  - Test suite operations
  - **External function**
  - PICS / PIXIT
  - **Module parameters**
- Data types, values
  - TTCN-2 / ASN.1
  - **TTCN-3, ASN.1, IDL, XML, ...**
- Modularisation
  - Possible but seldom used
  - **Central concept**
- Extensibility
  - Not possible
  - **Attributes, languages**
- Methodology
  - Conformance Testing Methodology and Framework (CTMF), (ISO 9646/ ITU X.290)
  - **No specific**
- Presentation
  - Tabular, machine processable
  - **Textual, graphical, tabular, ...**
- Implementation
  - No runtime interfaces
  - **TTCN-3 Runtime Interfaces, TTCN-3 Control Interfaces**
- Acronym
  - Tree and Tabular Combined Notation
  - **Testing and Test Control Notation**

TTCN-3 standards

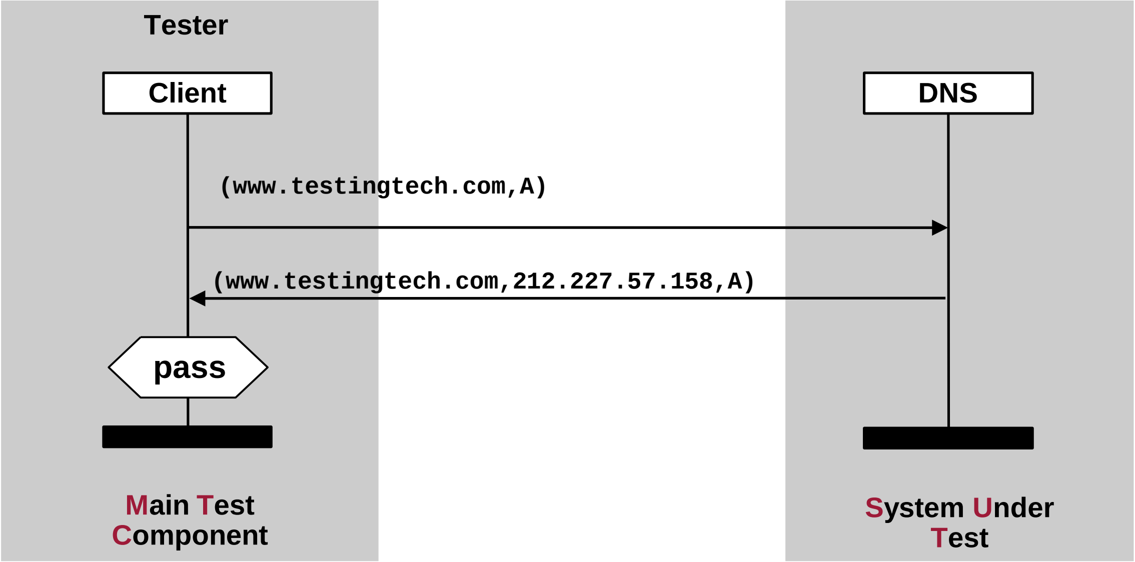
ETSI ES 201 873-1	TTCN-3 Core Language (CL)
ETSI ES 201 873-2	TTCN-3 Tabular Presentation Format (TFT)
ETSI ES 201 873-3	TTCN-3 Graphical Presentation Format (GFT)
ETSI ES 201 873-4	TTCN-3 Operational Semantics
ETSI ES 201 873-5	TTCN-3 Runtime Interface (TRI)
ETSI ES 201 873-6	TTCN-3 Control Interfaces (TCI)
ETSI ES 201 873-7	Integration of ASN.1
ETSI ES 201 873-8	Integration of IDL
ETSI ES 201 873-9	Integration of XML
ETSI ES 201 873-10	T3Doc
ETSI ES 202 781	TTCN-3 Extension: Configuration And Deployment Support
ETSI ES 202 782	TTCN-3 Extension: Performance & Real-Time Testing
ETSI ES 202 784	TTCN-3 Extension: Advanced Parametrization
ETSI ES 202 785	TTCN-3 Extension: Behaviour Types
ETSI ES 202 786	TTCN-3 Extension: Continuous Signals
ETSI ES 202 789	TTCN-3 Extension: Extended TRI

- Maintenance on the basis of change requests by ETSI
- Standard available for download at http://www.etsi.org
- Testing Tech / Spirent tools support latest edition
- Also standardized by the ITU-T as ITU-T Z.16x series

TTCN-3 by example



TTCN-3 by example



TTCN-3 modules

- Main building block of TTCN-3 is a module
  - Unit of compilation
  - Contains definitions
  - Optional control part

```
module DNS {

// module definitions

// module control (optional)

}
```

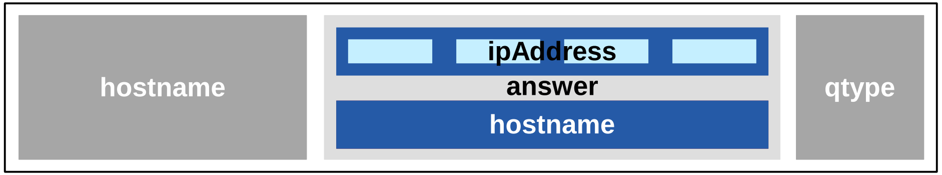
Module definitions

- Contains descriptions for
  - What type of data the System Under Test understands
  - How the System Under Tests can be accessed and what environment a test component needs
  - When to communicate what with the SUT and why
  - Dependencies between test cases, if any

Module definitions

- Module definitions
  - **Type definitions**
  - Port definitions
  - Component definitions
  - Templates
  - Test case
- Control part
  - Controls the execution of test cases

```
type record DNSQuery {
   charstring hostname,
   AnswerType answer optional,
   QueryType qtype
}
type union AnswerType {
   Byte ipAddress[4],
   charstring hostname
}
type integer Byte (0 .. 255);
type enumerated QueryType {
   A, NS, CNAME, MX
}
```



Module definitions

- Module definitions
  - Type definitions
  - **Port definitions**
  - **Component definitions**
  - Templates
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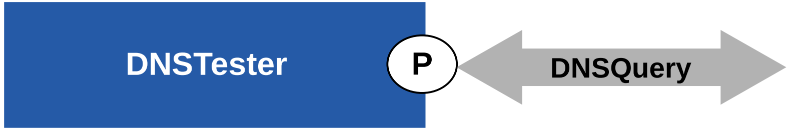
- Control part
  - Controls the execution of test cases

Port definitions

```
type port DNSPort message {
   inout DNSQuery;
   // a port may send/receive messages
   // of more than one type
}
```

Component definitions

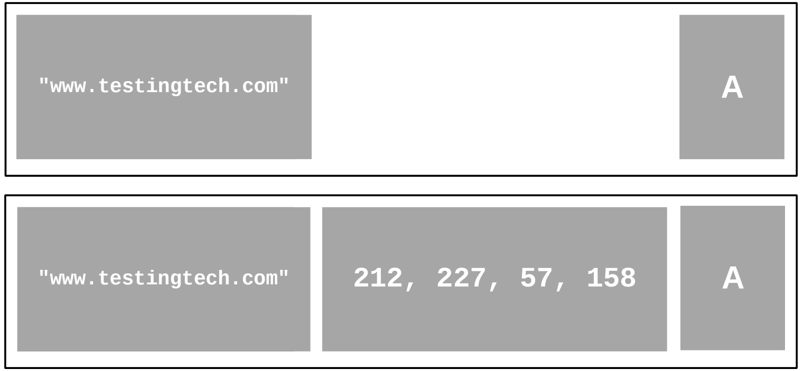
```
type component DNSTester {
   port DNSPort P;
   timer t := 3.0;
   // a component may have more than one port
}
```



Module definitions

- Module definitions
  - Type definitions
  - Port definitions
  - Component definitions
  - **Templates**
  - Test case
- Control part
  - Controls the execution of test cases

```
template DNSQuery query := {
   hostname := "www.testingtech.com",
   answer   := omit,
   qtype    := A
}
template DNSQuery reply modifies query := {
   answer := { ipAddress :=
               {212,227,57,158} }
}
```



"www.testingtech.com"

A

"www.testingtech.com"

212, 227, 57, 158

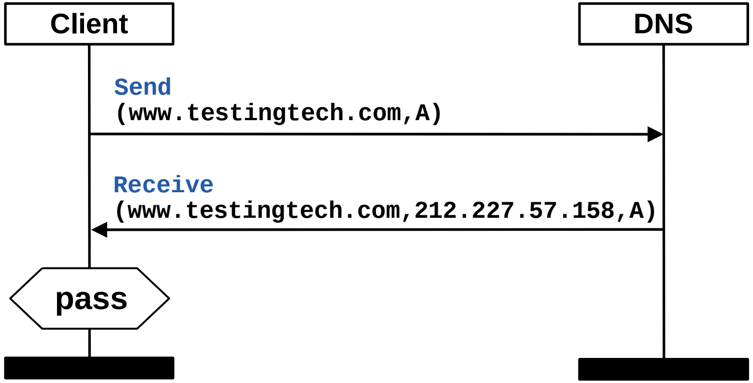
A

Module definitions

- Module definitions
  - Type definitions
  - Port definitions
  - Component definitions
  - Templates
  - **Test case**
- Control part
  - Controls the execution of test cases

```
testcase tc_testcase1() runs on DNSTester {
  P.send(query);
  P.receive(reply);
  setverdict(pass);
}

// there may be more than one in a module
```



Module definitions

- Module definitions
  - Type definitions
  - Port definitions
  - Component definitions
  - Templates
  - Test case
- Control part
  - **Controls the execution of test cases**

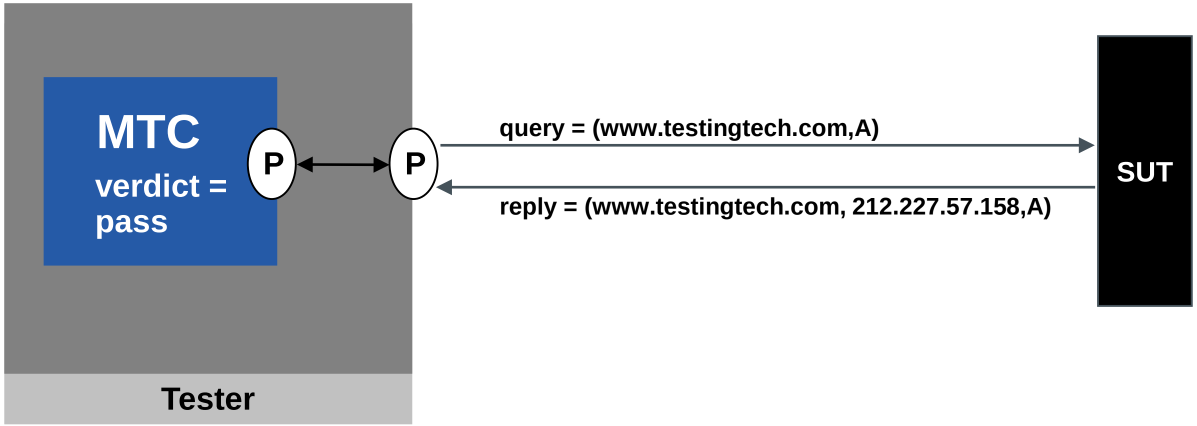
```
control {

   execute(tc_testcase1(), 5.0);
   while( /* condition */ ) { };

   // more testcases might follow
   // C-like control structures available

}
```

Execution of a test case


MTC
verdict = pass
P
P
Tester
query = (www.testingtech.com,A)
reply = (www.testingtech.com, 212.227.57.158,A)
SUT

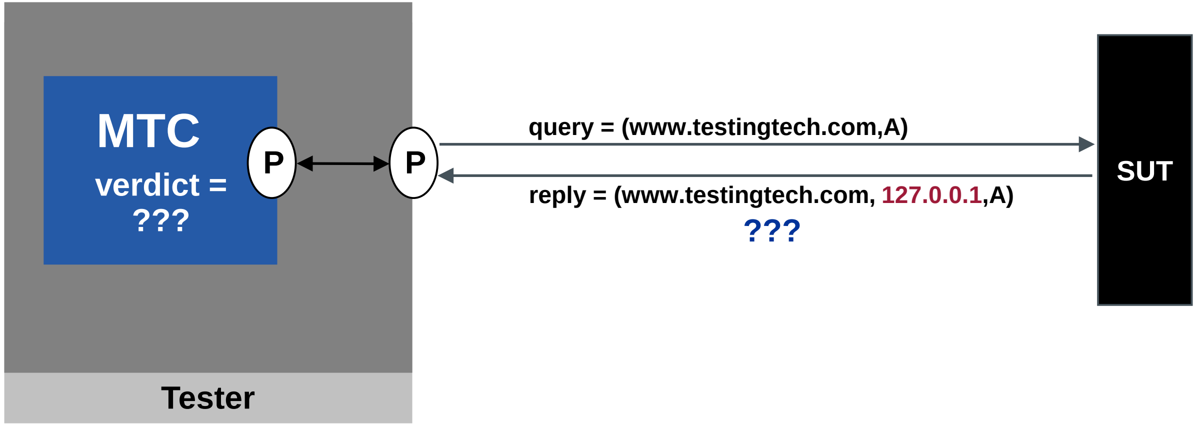
```
testcase tc_testcase1() runs on DNSTester {
   P.send(query);
   P.receive(reply);
   setverdict(pass);

}
```

Is this test case definition adequate?

Is this an effective test case definition?

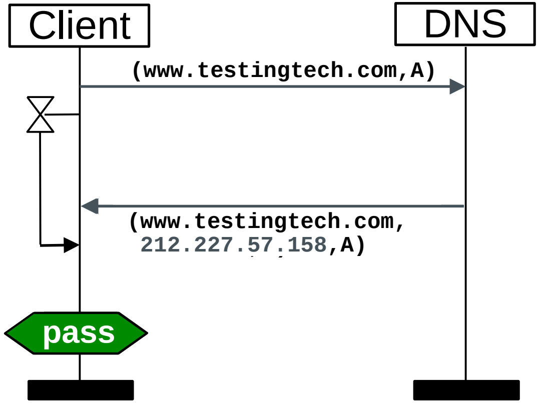
Dealing with erroneous behavior


MTC
verdict = ???
P
P
query = (www.testingtech.com,A)
reply = (www.testingtech.com, 127.0.0.1,A)
???
SUT
Tester

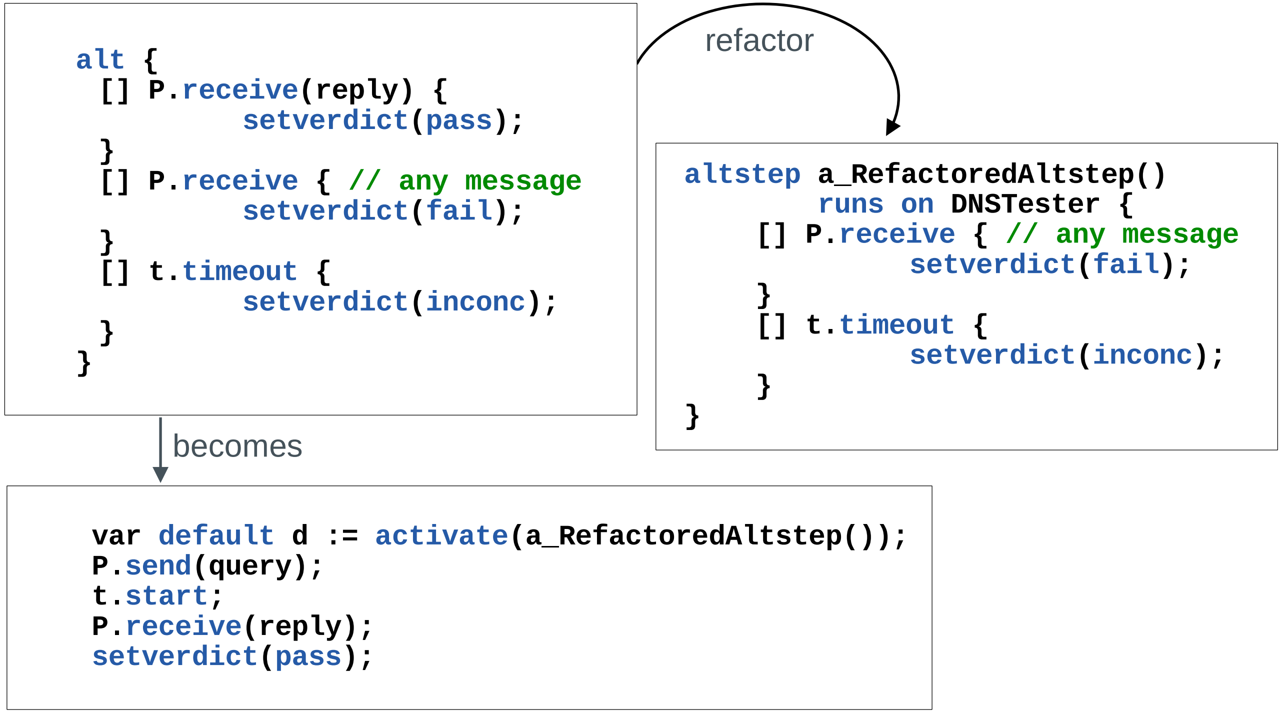
- `P.receive (reply)` blocks until it receives a message that matches the reply
- If unexpected message is received, any other correct message does not unblock the tester, which then blocks forever
- If no message is received, the tester will also block forever

Dealing with erroneous behavior

```
testcase tc_testcase2() runs on DNSTester {
P.send(query);
t.start;
alt {
     [] P.receive(reply) {
          setverdict(pass);
     }
     [] P.receive { // any message
          setverdict(fail);
     }
     [] t.timeout {
          setverdict(inconc);
     }
}
stop;
}
```



Code reusability – Altsteps and defaults



```
alt {
 [] P.receive(reply) {
        setverdict(pass);
 }
 [] P.receive { // any message
        setverdict(fail);
 }
 [] t.timeout {
        setverdict(inconc);
 }
}
```

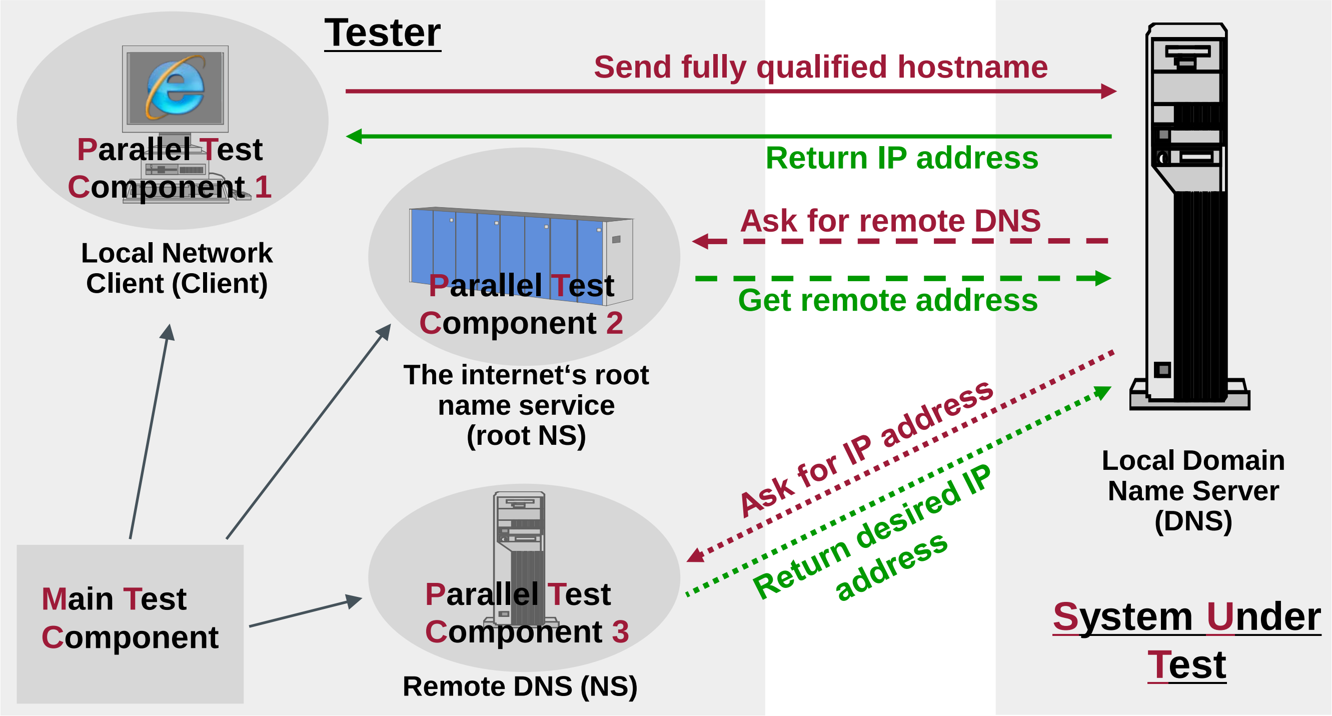
refactor

```
altstep a_RefactoredAltstep()
        runs on DNSTester {
    [] P.receive { // any message
            setverdict(fail);
    }
    [] t.timeout {
            setverdict(inconc);
    }
}
```

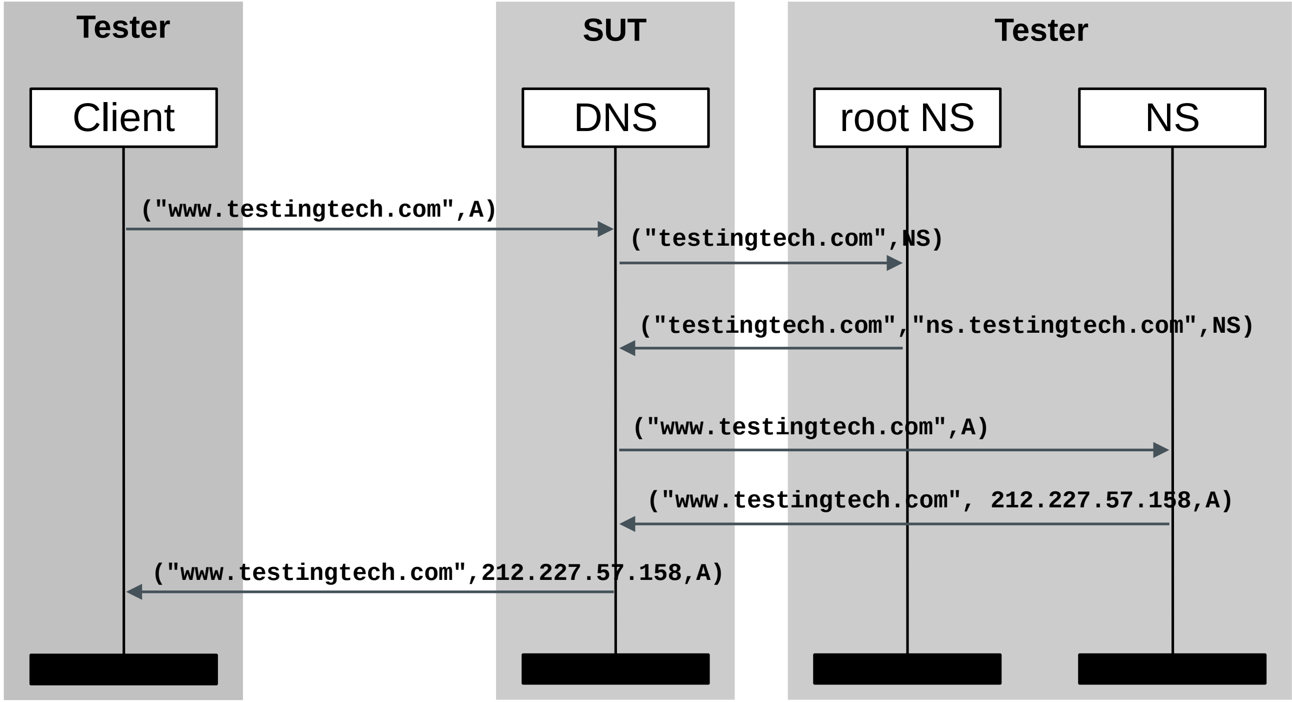
becomes

```
var default d := activate(a_RefactoredAltstep());
P.send(query);
t.start;
P.receive(reply);
setverdict(pass);
```

Non-local DNS query


Tester
Send fully qualified hostname
Return IP address
Ask for remote DNS
Get remote address
Parallel Test Component 1
Local Network Client (Client)
Parallel Test Component 2
The internet's root name service (root NS)
Parallel Test Component 3
Remote DNS (NS)
Main Test Component
Ask for IP address
Return desired IP address
Local Domain Name Server (DNS)
System Under Test

Non-local DNS query


Tester
SUT
Tester
Client
DNS
root NS
NS
("www.testingtech.com",A)
("testingtech.com",NS)
("testingtech.com","ns.testingtech.com",NS)
("www.testingtech.com",A)
("www.testingtech.com", 212.227.57.158,A)
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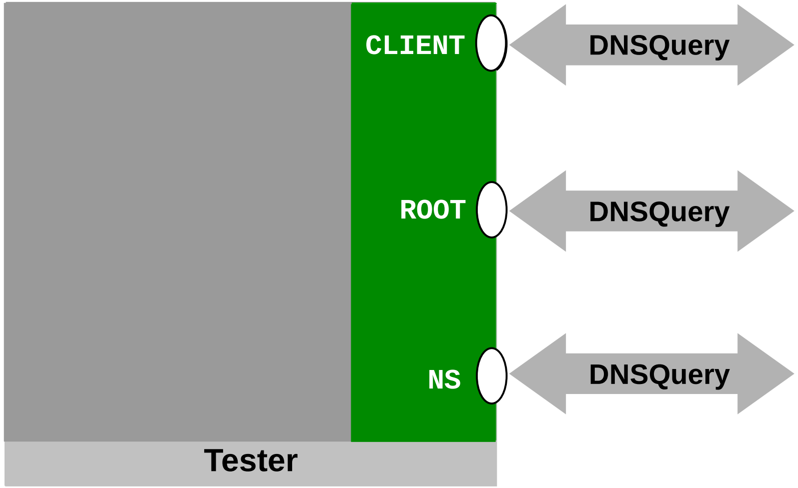
Parallel test components

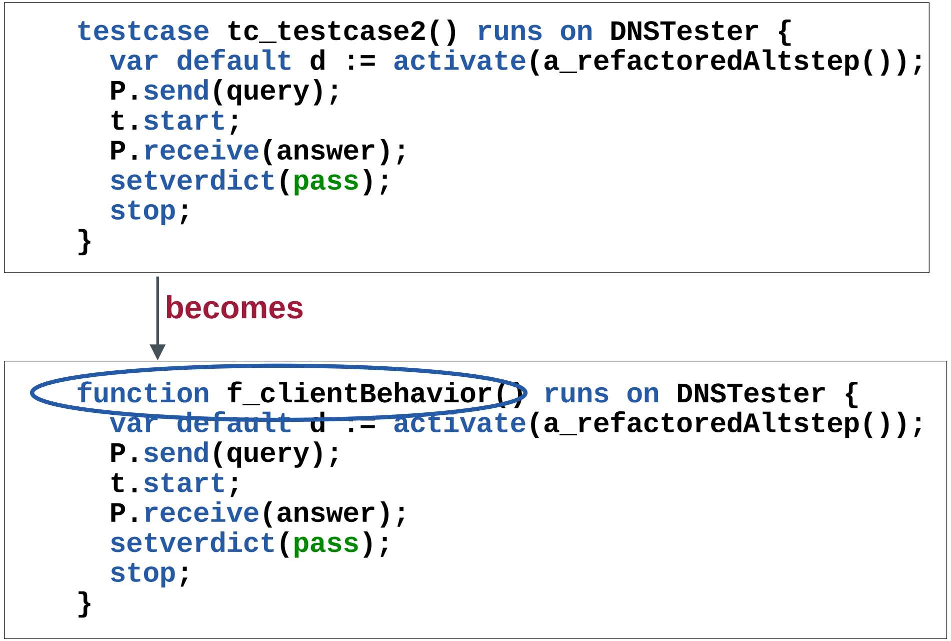
- Test system interface

```
type component TestSystemInterface {
   port DNSPort CLIENT;
   port DNSPort ROOT;
   port DNSPort NS;
}
```



From test case to behavior function

- Functions can be used to define the behavior of the parallel test components



```
    testcase tc_testcase2() runs on DNSTester {
      var default d := activate(a_refactoredAltstep());
      P.send(query);
      t.start;
      P.receive(answer);
      setverdict(pass);
      stop;
    }
```

becomes

```
    function f_clientBehavior() runs on DNSTester {
      var default d := activate(a_refactoredAltstep());
      P.send(query);
      t.start;
      P.receive(answer);
      setverdict(pass);
      stop;
    }
```

Additional test behavior

- Simple „react-on-request“ behavior

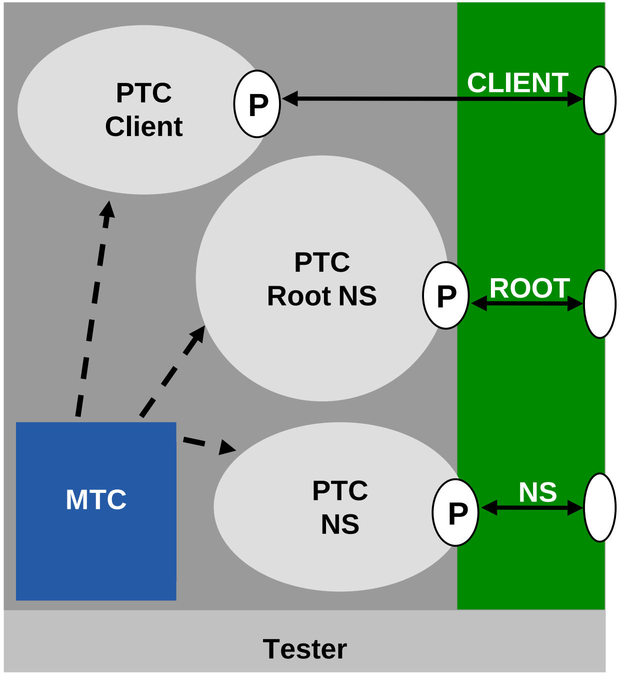
```
function f_rootBehavior() runs on DNSTester {
   alt {
      [] P.receive(rootquery) {
          P.send(rootanswer);
          setverdict(pass);}
      [] P.receive {
          setverdict(fail);}
   }
}
```

```
function f_nSBehavior() runs on DNSTester {
   alt {
      [] P.receive(nsquery) {
          P.send(nsanswer);
          setverdict(pass);}
      [] P.receive {
          setverdict(fail);}
   }
}
```

Dynamic configuration

- Re-configuration during runtime is possible

```
testcase testcase3() runs on DNSTester
 system TestSystemInterface {

 var DNSTester ClientComp, RootComp,
     NSComp;

 ClientComp := DNSTester.create;
 RootComp   := DNSTester.create;
 NSComp     := DNSTester.create;

 map(ClientComp:P, system:CLIENT);
 map(RootComp:P,   system:ROOT);
 map(NSComp:P,     system:NS);

 ClientComp.start(f_clientBehavior());
 RootComp.start  (f_rootBehavior());
 NSComp.start    (f_nSBehavior());

 ClientComp.done;
 // block until ClientComp is done
 stop;
 }
```



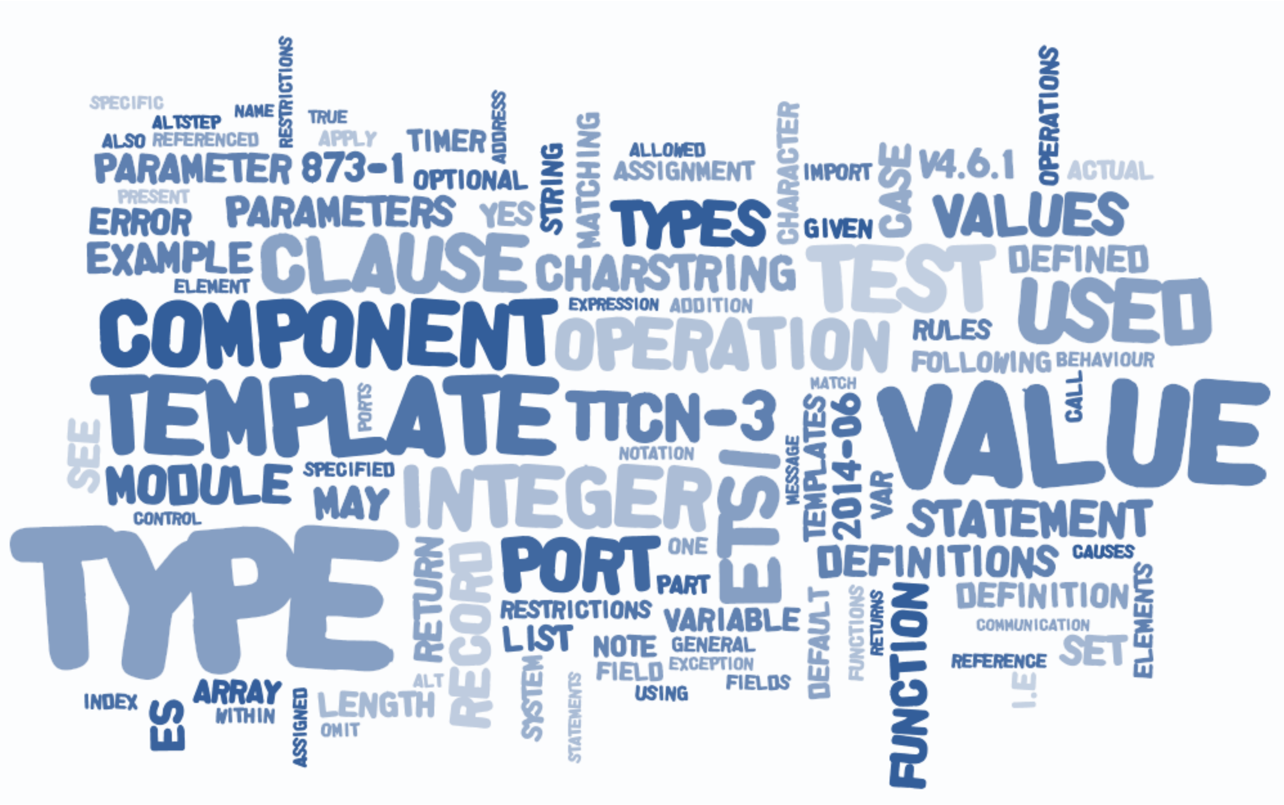
A little bit on syntax

- Case sensitive
  - More than 130 (edition 4) keywords, all lower case
  - Identifiers
- Comments
  - Multi line comments: `/* */`
  - Single line comments: `//`
- Statements are terminated with: `;`
- Statement blocks are enclosed in: `{ }`
- Operators
  - Assignment: `:=`
  - Comparison: `!=, ==, <=, >=`

Summary

- TTCN-3 as standardized language for testing
- Easy description of test scenarios
  - Different presentation formats
- Clear specification of test configurations
  - Parallel test components / concurrent behavior
- Wide range of applicability
  - Different communication paradigms - like message based and procedure based
  - Procedure based communication covered later

Summary


SPECIFIC
NAME
RESTRICTIONS
TRUE
ALTSTEP
ALSO
REFERENCED
APPLY
TIMER
ADDRESS
PARAMETER
873-1
OPTIONAL
STRING
MATCHING
ALLOWED
ASSIGNMENT
CHARACTER
IMPORT
CASE
V4.6.1
OPERATIONS
ACTUAL
PRESENT
ERROR
PARAMETERS
YES
TYPES
GIVEN
VALUES
EXAMPLE
CLAUSE
CHARSTRING
TEST
DEFINED
ELEMENT
EXPRESSION
ADDITION
USED
COMPONENT
OPERATION
RULES
FOLLOWING
BEHAVIOUR
MATCH
CALL
PORTS
TEMPLATE
TTCN-3
TEMPLATES
2014-06
VALUE
SEE
NOTATION
ETSI
MESSAGE
SPECIFIED
MODULE
MAY
INTEGER
VAR
STATEMENT
CONTROL
TYPE
RETURN
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PORT
ONE
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CAUSES
PART
DEFINITION
RESTRICTIONS
VARIABLE
DEFAULT
FUNCTIONS
RETURNS
FUNCTION
ELEMENTS
COMMUNICATION
LIST
NOTE
GENERAL
SET
SYSTEM
REFERENCE
FIELD
EXCEPTION
ALT
FIELDS
I.E
INDEX
ARRAY
USING
ES
WITHIN
ASSIGNED
LENGTH
STATEMENTS
OMIT

Why you should use TTCN-3

- To have
  - an industrial grade
  - multi-os and
  - multi-technology
- middleware testing platform
  - to build your methods
  - to create supporting tools and tool chains
  - to be able to educate people
- in order to
  - cover the whole software development process.

Some references

- The language
  - www.ttcn-3.org
  - www.spirent.com/go/TTCN-3
  - de.wikipedia.org/wiki/TTCN-3
  - en.wikipedia.org/wiki/TTCN-3
- The TTCN-3 Certificate
  - www.german-testing-board.info/english/exam-candidates/ttcn-3-certificateR/ttcn-3R-in-a-nutshell.html
- The Quick Reference Card
  - www.blukaktus.com/card.html
- Some tools
  - www.ttcn-3.org/index.php/tools/tools-com