How to implement TTCN-3 codecs and adapters efficiently

Anthony Baire, César Viho

UMR IRISA

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Scope of the Tutorial

- TTCN-3 is an abstract language, it focuses on test logics, e.g:
  - describe of the messages sent and received
  - define the timing constraints
- other implementation details *(communications, encoding, logging, ...)* are not addressed in the language

Scope of the Tutorial

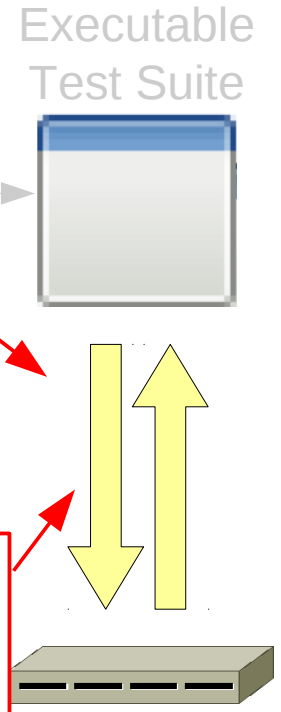
TTCN-3 Abstract Test Suite

```
testcase TC_Example()
runs on DNSClient
{
  dns_port.send (
    a_DNSQuery ("www.irisa.fr")
  );


  dns_port.receive(
    a_DNSAnswer ("131.254.254.46")
  );
}
```

how to transmit
the message to the SUT
and receive the reply?

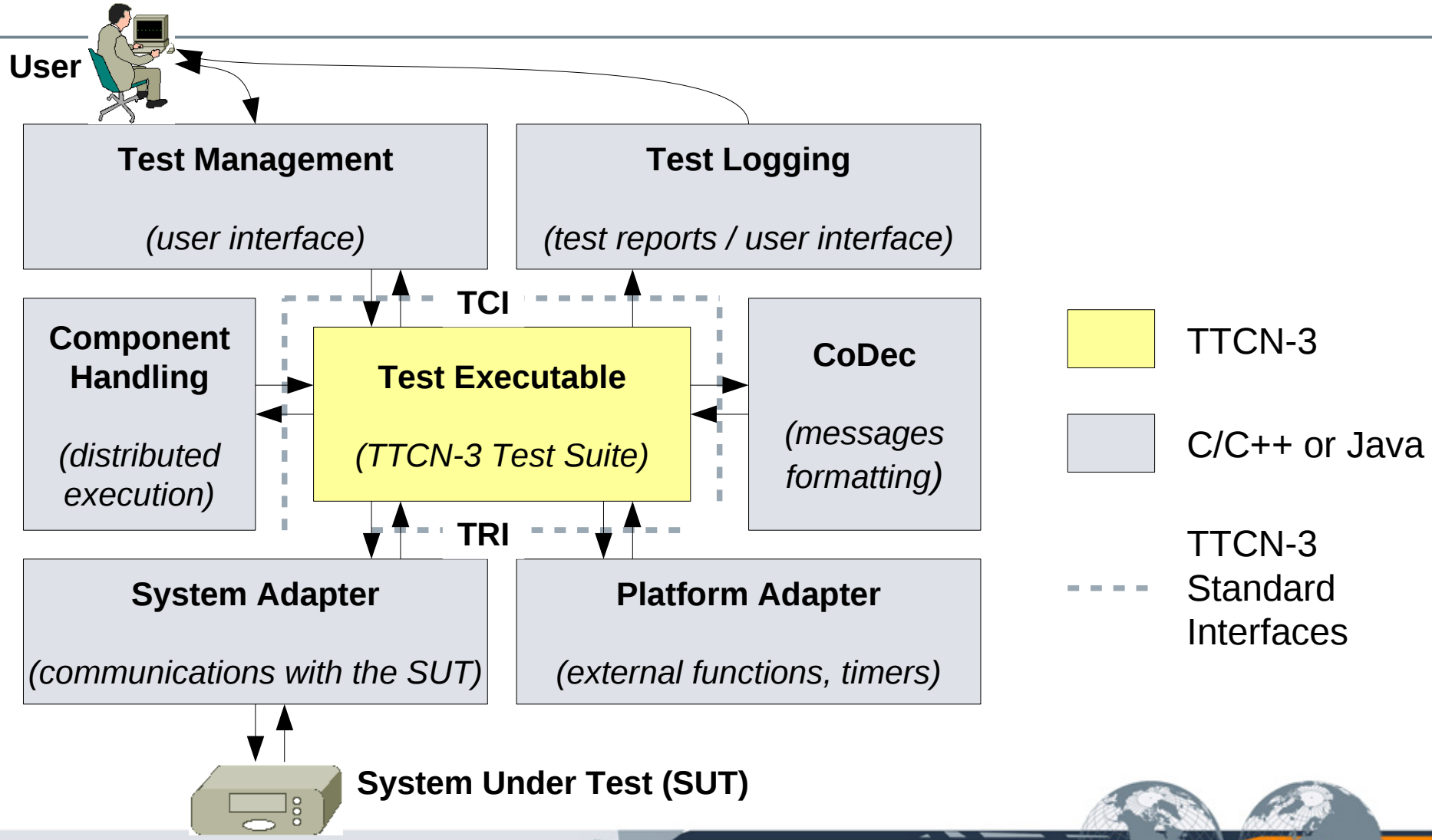
how the messages shall
be formatted?



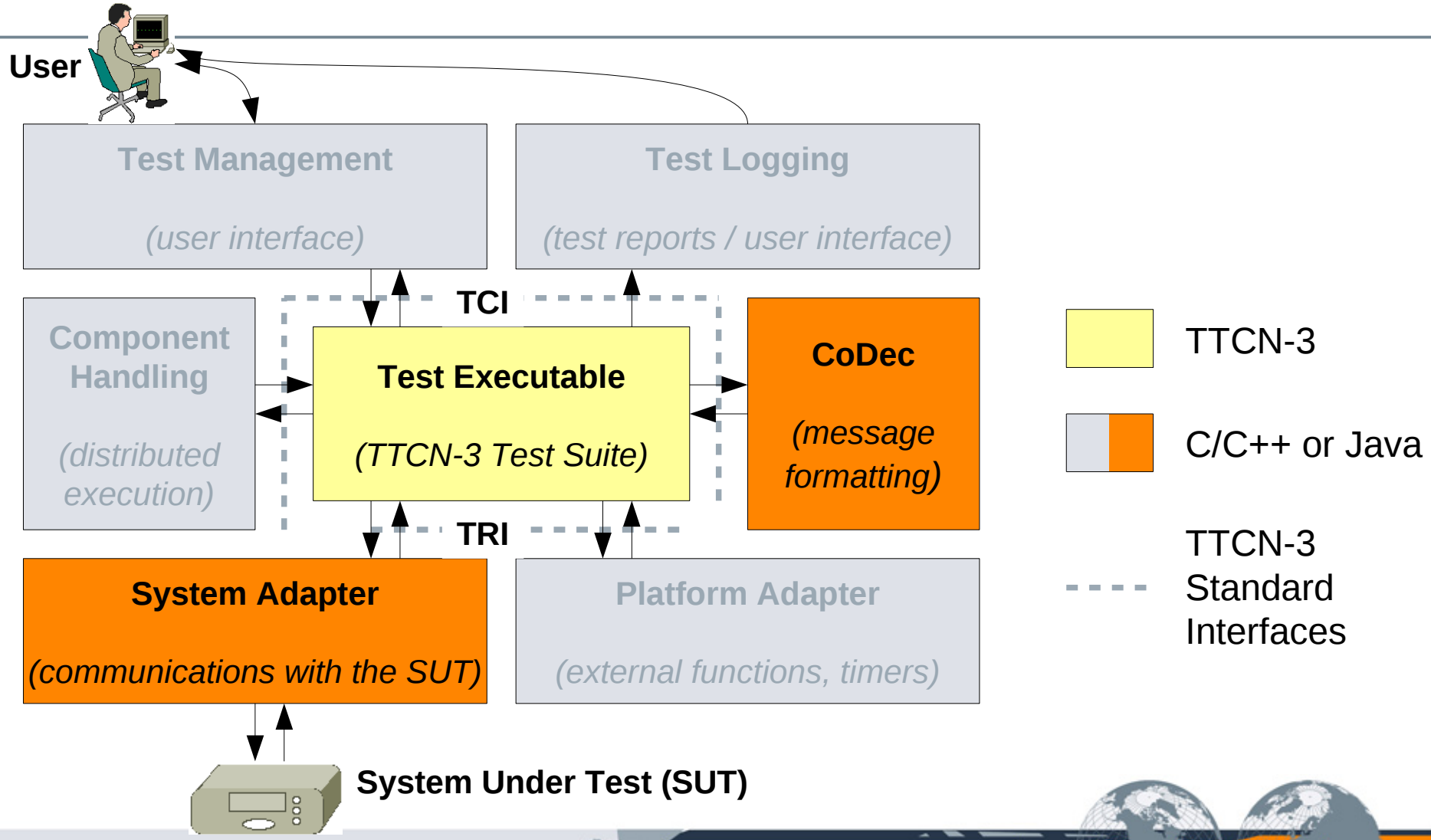
Scope of the Tutorial

- Implementation details *(communications, encoding, logging, ...)* are handled in separate modules :
  - either provided by the TTCN-3 tool suite
  - or implemented in the platform language (C, C++ or Java) by the test developer

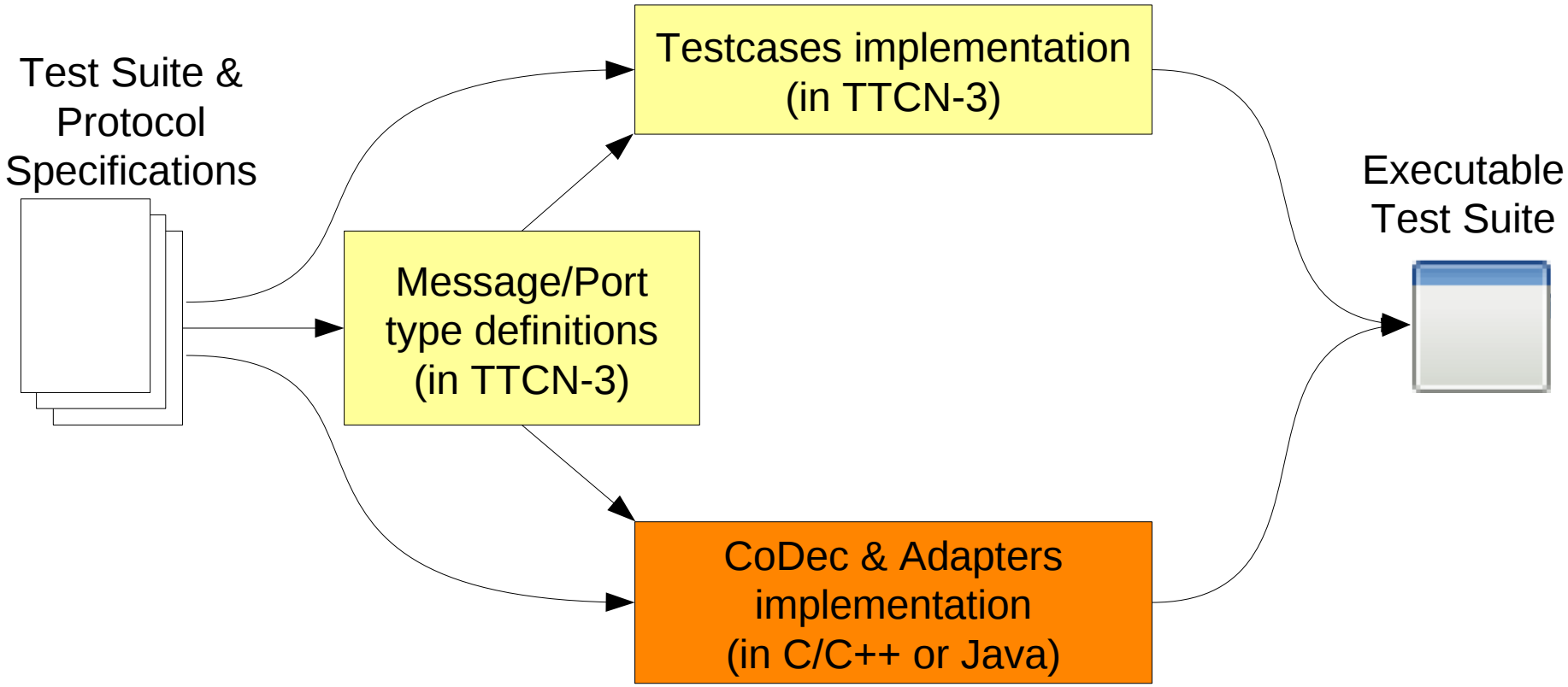
Layout of a TTCN-3 ExecutableTest Suite



Layout of a TTCN-3 ExecutableTest Suite



Test Suite Development Process



Tutorial motivation

- The internal design of codecs and adapters is not addressed by the TTCN-3 Standard
  - ➔ this is left free to the developer

- It is not the focus of the test but still a critical task
  - errors in the adapters/codecs give a biased view of what's happening in the test and they are more difficult to detect
  - developing the CoDec is error-prone because there is a lot of redundant code to be written
  - merging several codecs/adapters

Tutorial Purpose

- Provide good practises for developing the codec & adapter ensuring :
  - quick development
  - reliability
  - reusability

- These objectives will be facilitated thanks to T3DevKit, a free software toolkit for TTCN-3

Summary

1. The TTCN-3 standard interfaces TRI & TCI
2. Overview of T3DevKit Features
3. Examples
   a) HelloWorld
   b) Quiz
   c) DNS

Summary

1. The TTCN-3 standard interfaces TRI & TCI

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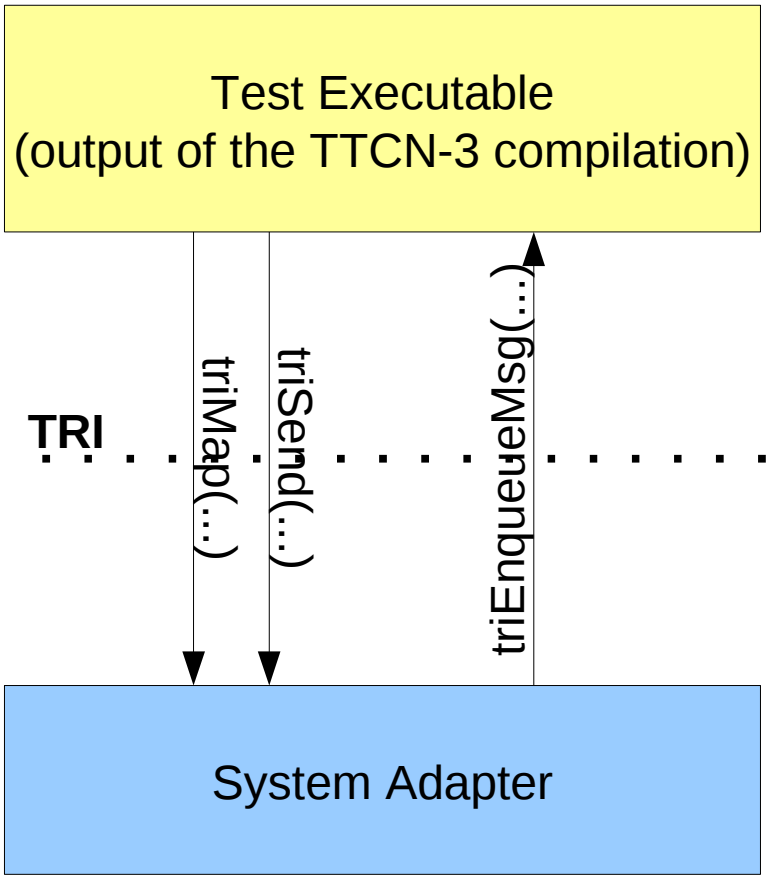
Accessing the System Under Test (SUT)

- In a TTCN-3 test suite, the *System Under Test* is viewed as a black-box *component* with one or several *ports*

- The actual communications are implemented in C/C++ or Java in a separate module : the *System Adapter*

Implementing a System Adapter



- The SA interacts with the compiled test suite using a standardised interface: the ***TRI (TTCN-3 Runtime Interface)***
- the *TRI* can be used in C/C++ or Java

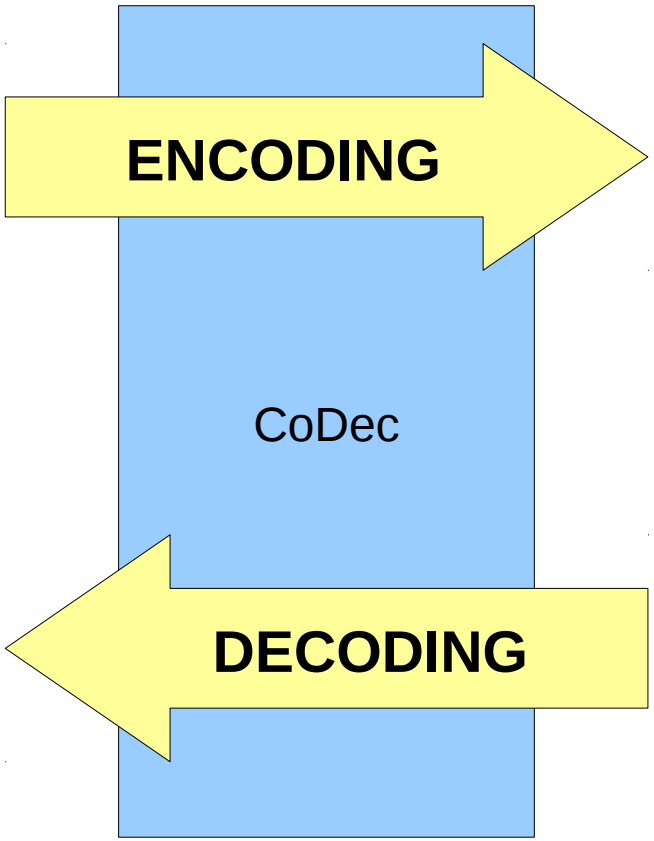
CoDec Development

- TTCN-3 uses an abstract representation for the messages (similar to ASN.1)
- Messages exchanged with the SUT need to be encoded in a binary format
  - protocol messages that are based on ASN.1 can be encoded/decoded automatically using the adequate rules (BER, PER, ...)
  - for the other protocols it is necessary to develop an external CoDec (Coding/Decoding module)

CoDec Module Features

Message to be sent to the SUT
(generated by the TTCN-3 test)

4	**20**	**154**	**44**
132.154.14.21			
80		**1025**	



Actual binary message
transmitted to the SUT

0100110001011101...

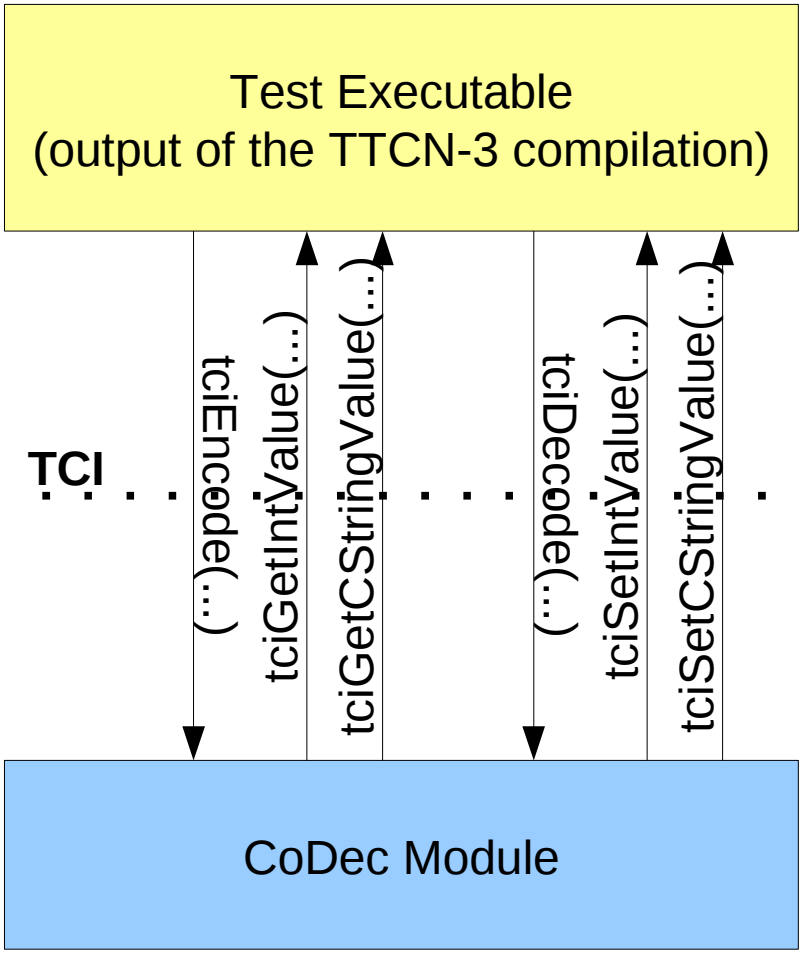
Message reported to the
TTCN-3 test

4	**20**	**154**	**44**
10.1.2.20			
1025		**80**	

Binary message
received from the SUT

0100110001011101...

Implementing an external CoDec



- The CD interacts with the compiled test suite using a standardised interface: the ***TCI (TTCN-3 Control Interface)***
- the *TCI* can be used in C/C++ or Java

Summary

1. The TTCN-3 standard interfaces TRI & TCI

2. Overview of T3DevKit Features

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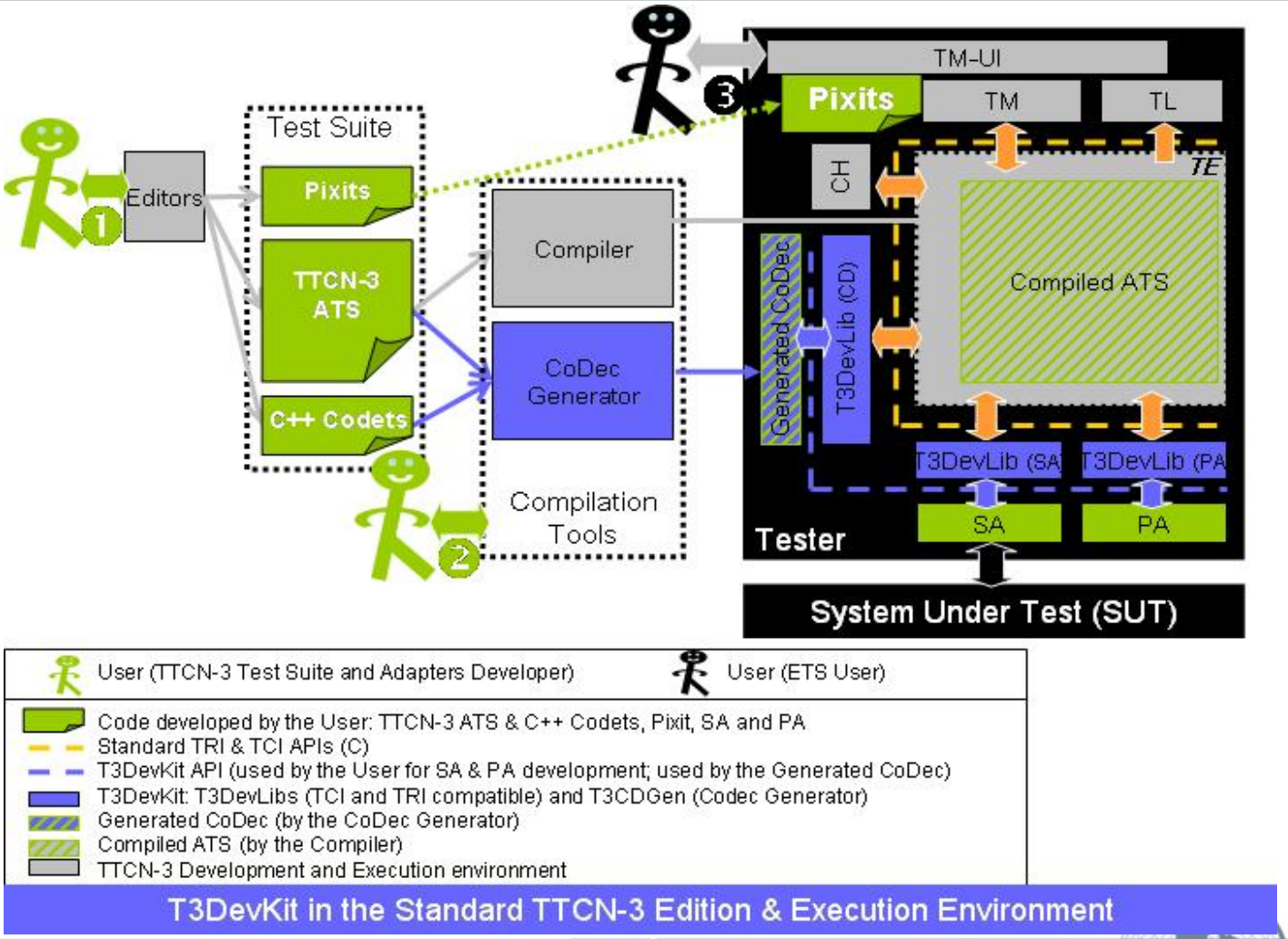
   b) Quiz

   c) DNS

T3DevKit Features

- T3DevKit: a toolkit for developing TTCN-3 tests:
  - a C++ library (t3devlib) which provides:
    - an object-oriented framework to manipulate TTCN-3 entities (values, ports, timers, ...)
    - an implementation of the TRI & TCI interfaces
    - default codecs
    - some debugging features
  - a CoDec generator (t3cdgen)
  - a set of portable build scripts based on *waf*

T3DevKit Layout



T3DevKit in the Standard TTCN-3 Edition & Execution Environment

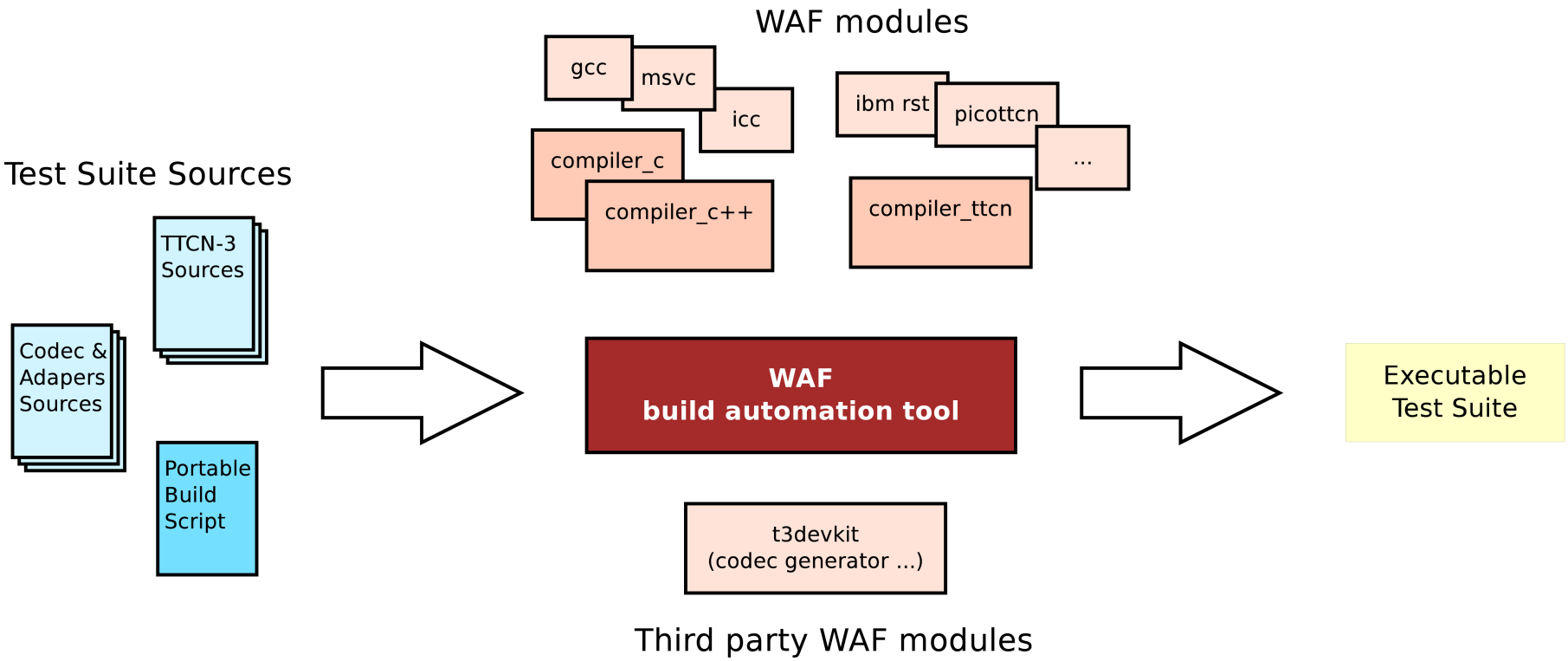
T3DevKit Motivations

- Why use a toolkit ?
  - TRI & TCI are low-level interfaces, they do not provide:
    - functions to manipulate data
    - a generic framework for the internal design of the modules
  - we want to avoid “reinventing the wheel”
    - ➔ lots of features are not specific to one test suite
      - an object-oriented generic framework
      - memory management
      - defaults implementations (codecs, timers, ...)
      - synchronisation between C++ & TTCN-3 type definitions
      - interactions with the TE

Waf Motivations

- Why build the test suites with *waf* ?
  - Portability (TTCN-3 tool, OS, c++ toolchain)
  - Simplicity
    - A unique build procedure for every environment
    - Automatic detection of the tools
  - Extensibility
    - Write new python modules to integrate new tools (eg. the CoDec generator)

Waf workflow



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The HelloWorld Example

- Purpose:
  - display the string "Hello World!" to the console
- Objective:
  - demonstrate how to develop a basic System Adapter

HelloWorld TTCN-3 source

```
module HelloWorld
{
    type port ConsolePort message          { inout charstring; }

    type component HelloTester             { port ConsolePort console; }

    testcase ExampleHelloWorld()
      runs on HelloTester
    {
        console.send("Hello World!");
    }

    control {
        execute (ExampleHelloWorld());
    }
}
```

one basic port that can send character strings

Implementing the System Adapter (1/3)

C++ Header

```
class ConsolePort : public t3devlib::Port
{
public:
    ConsolePort (t3devlib::PortId& id);


protected:
    bool Send (const t3devlib::ComponentId& from,
               const t3devlib::Bitstring& msg);
};
```

define a class that inherits from `t3devlib::Port`

reimplement the function Send()

Implementing the System Adapter (2/3)

C++ implementation of Console Port

```
bool ConsolePort::Send (const ComponentId& from,
                        const Bitstring& msg)
{
        cout.clear();

        cout << endl;
        cout.write ((char*) msg.GetValueBin(),
                            msg.GetLength()/8);
        cout << endl << endl;

        return cout.good();
}
```

write the message to the standard output

return true in case of success

Implementing the System Adapter (3/3)

C++ Initialisation function for the SA

```
namespace t3devlib
{
    void SAInit()
    {
        Port::RegisterType ("HelloWorld", "ConsolePort",
                            &createPort<ConsolePort>);
    }
}
```

function called by T3DevKit when initialising the System Adapter

register this port type so that T3DevKit knows how to handle it

Building the Test Suite

HelloWorld *waf* script

```
def configure(conf):
  conf.check_tool ('compiler_ttcn3 t3devkit')


def build(bld):

  bld.ttcn3_ets(

    features =  't3devkit',

    target =    'HelloWorld',

    te_source = 'HelloWorld.ttcn',

    sa_source = 'ConsolePort.cpp sa-init.cpp'
  )
```

Load the *waf* modules supporting
- TTCN-3 compilers
- T3DevKit

Build a TTCN-3 Executable Test Suite using T3DevKit's features (generator...)

Source files:
- Test Executable (TTCN-3)
- System Adapter (C++)

Execution

```
abaire@kakrafoon:~/git/t3devkit/examples/HelloWorld$ twaf configure
Checking for program gcc,cc              : ok /usr/local/bin/gcc
Checking for program cpp                 : ok /usr/bin/cpp
Checking for program ar                  : ok /usr/bin/ar
Checking for program ranlib              : ok /usr/bin/ranlib
Checking for gcc                         : ok
Checking for Rational Systems Tester     : ok /opt/telelogic/tau/bin/t3cg
Checking for program g++,c++             : ok /usr/local/bin/g++
Checking for program ar                  : ok /usr/bin/ar
Checking for program ranlib              : ok /usr/bin/ranlib
Checking for g++                         : ok
Checking for t3devkit                    : ok /usr/local/stow/t3devkit/share/t3devkit/config.py
Checking for t3devkit supports 64-bit integer : not found
Checking for t3devkit supports debugging      : not found
'configure' finished successfully (0.189s)
abaire@kakrafoon:~/git/t3devkit/examples/HelloWorld$ twaf
  :
[18/18] cxx_link: __build__/default/__t3devkit__/pa_init_8.o __build__/default/c++/ConsolePort_8.o __build__/default/c++/sa-init_8.o
     __build__/default/__t3devkit__/cd_init_8.o __build__/default/__t3devkit__/gen_classes_8.o __build__/default/__t3devkit__/root_module_8.o
     __build__/default/t3rts_conditional_8.o __build__/default/codec_plugin_8.o __build__/default/__tau__/ts_modules_8.o
     __build__/default/__tau__/HelloWorld_8.o -> __build__/default/HelloWorld
'build' finished successfully (8.991s)
16:35:37 abaire@kakrafoon:~/git/t3devkit/examples/HelloWorld$ twaf --run
13:09:18 (null):0 [(null)::(null) ''B] Info 0 Module HelloWorld registered
13:09:18 ../ttcn/HelloWorld.ttcn:41 [(null)::(null) ''B] Info 0 Module HelloWorld initialized
13:09:18 ../ttcn/HelloWorld.ttcn:41 [(null)::(null) ''B] Info 0 Module HelloWorld - module parameters initialized
13:09:18 ../ttcn/HelloWorld.ttcn:53 [(null)::(null) '00000000'O] CtrlStart
13:09:19 ../ttcn/HelloWorld.ttcn:54 [(null)::(null) '00000000'O] TcExecute HelloWorld::ExampleHelloWorld {} 0
13:09:19 ../ttcn/HelloWorld.ttcn:54 [(null)::(null) '00000000'O] CCreate [HelloWorld::HelloTester '00010000'O] MTC 0
13:09:19 ../ttcn/HelloWorld.ttcn:54 [(null)::(null) '00000000'O] TcStart HelloWorld::ExampleHelloWorld {} 0
13:09:19 ../ttcn/HelloWorld.ttcn:47 [HelloWorld::HelloTester '00010000'O] PMap [HelloWorld::HelloTester '00010000'O]::console[-1]
     [HelloWorld::HelloTester '00020000'O]::console[-1]
13:09:20 ../ttcn/HelloWorld.ttcn:50 [HelloWorld::HelloTester '00010000'O] Encode "Hello World !" 0 '48656C6C6F20576F726C642021'O user encoder

Hello World !

13:09:20 ../ttcn/HelloWorld.ttcn:50 [HelloWorld::HelloTester '00010000'O] MSend_m [HelloWorld::HelloTester '00010000'O]::console[-1]
     [HelloWorld::HelloTester '00020000'O]::console[-1] "Hello World !" ''B 0 '48656C6C6F20576F726C642021'O 0
13:09:20 (null):0 [HelloWorld::HelloTester '00010000'O] CStop [HelloWorld::HelloTester '00010000'O]
13:09:20 (null):0 [HelloWorld::HelloTester '00010000'O] TcStop
13:09:20 ../ttcn/HelloWorld.ttcn:54 [(null)::(null) '00000000'O] TcStarted HelloWorld::ExampleHelloWorld {} 0
13:09:20 (null):0 [HelloWorld::HelloTester '00010000'O] CTerminated none
13:09:20 ../ttcn/HelloWorld.ttcn:54 [(null)::(null) '00000000'O] TcTerminated HelloWorld::ExampleHelloWorld {} none
13:09:21 (null):0 [(null)::(null) '00000000'O] CtrlTerminated
```

Stages:

1. configure
2. build
3. run

HelloWorld Summary

- System Adapter
  - write a C++ class with a specialised Send() function
  - register the port type at SA initialisation (in SAInit)
- Makefile
  - store the list of TTCN-3 & C++ files and the root module name in the adequate T3DK_XXXXX variables
  - include T3DevKit's generic makefile
- CoDec
  - nothing to do (using the default codec for charstring)

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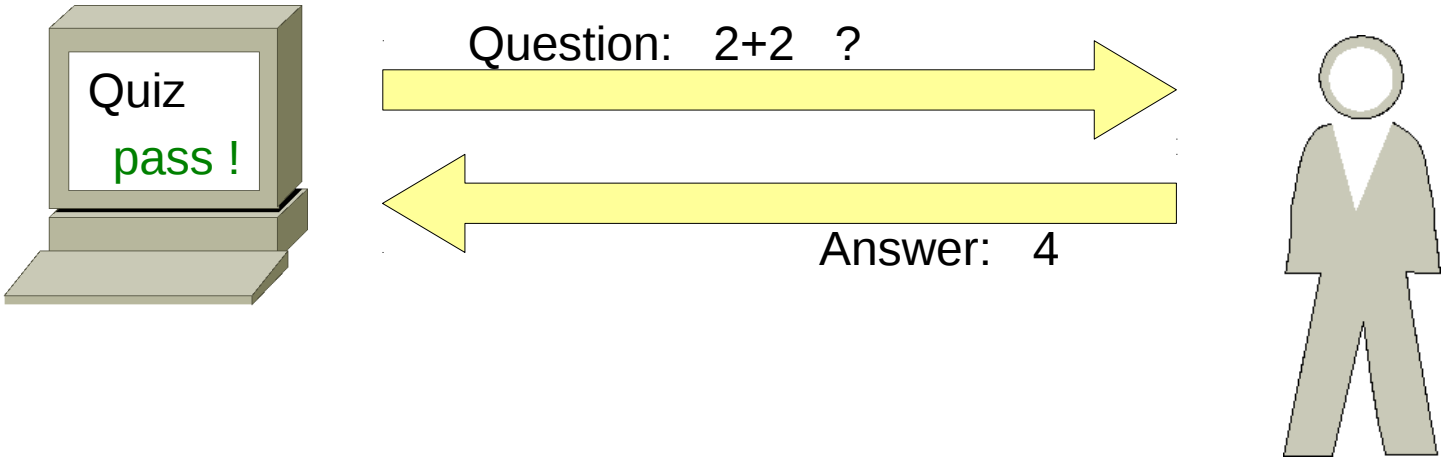
The Quiz Example

- Purpose:
  - implement a simple Question/Answer game in TTCN-3
- Objectives:
  - develop a fully functional System Adapter
  - demonstrate how to generate a basic CoDec

The Quiz Example

A Question/Answer game in TTCN-3



Quiz TTCN-3 source (testcase)

```
module Quiz
{
    testcase    Quizz_2_plus_2()
    runs on     QuizComponentTester
    {
        timer t;
        qportTester.send (Addition (2, 2));

        t.start (20.0);
        alt {
            [] qportTester.receive (Result: 4)  { setverdict (pass); }

            [] qportTester.receive              { setverdict (fail); }
            [] t.timeout                        { setverdict (fail); }
        }
    }
```

send a question

expect an answer

Quiz TTCN-3 source (types)

```
module Quiz
{
        type port QuizPort message {
            out   Operation;
            in    Result;
        };
        type record Operation {
            Operand     a,
            Operator    operator,
            Operand     b
        };
        type integer    Operand;
        type charstring Operator  length (1);

        type integer    Result;
```

message to be sent, eg:
Operation: { 2, "+", 2 }

message to be received, eg:
Result: 4

Quiz TTCN-3 source (template)

```
module Quiz
{

    template Operation Addition (integer val_a, integer val_b) :=
    {
        a               :=  val_a,
        operator        :=  "+",
        b               :=  val_b
    }
```

Implementing the System Adapter

- Implement a C++ class deriving from `t3devlib::Port`
  - Sending messages
    → implement a Send() function *(see HelloWorld)*
  - Receiving messages
    → implement a listening thread that reads the input from the console and reports it to the TTCN-3 runtime system

Implementing Message Reception (1/2)

Initialisation of the Port

reimplement the Map() function (called at the beginning of the testcase)

```
bool QuizPort::Map (const PortId& port_id)
{
    if (mMappedPort != NULL) {
        cerr << "QuizPort: cannot map to more than one port";
        return false;
    }
    mThread.reset (new boost::thread (boost::bind
        (&QuizPort::QuizThread, this)));
    mMappedPort = &port_id;
    return true;
}
```

allow only one mapped port (for simplicity)

start a listening thread on this port

remember the id of the mapped port

Implementing Message Reception (2/2)

Listening thread for QuizPort

```
void QuizPort::QuizThread ()
{
    cin.clear();
    string buff;
    while (getline (cin, buff).good()) {

        buff = buff.substr (0, buff.find_first_of("\r\n"));

        EnqueueMsg (*mMappedPort, buff.c_str(), buff.size()*8);
    }
}
```

read a line from the console

remove the trailing newline characters

forward the message to the TTCN-3 runtime system

Implementing the CoDec for Quiz

- Two parts:
  - implement the codecs for the subtypes :
    - `Operand`, `Result` (integers)
    - `Operator` (charstring)
  - implement the codec for the structured type:
    - `Operation` (record)

Reminder: TTCN-3 user-defined types used in Quiz

```
module Quiz
{

        type integer    Operand;
        type integer    Result;

        type charstring Operator  length (1);


        type record Operation {
            Operand     a,
            Operator    operator,
            Operand     b
        };
```

Encoding/Decoding the subtypes

Codec header file `quiz_codec.h`

```
#include <t3devlib/t3devlib.h>
#include <t3devlib/generator.h>

namespace t3devlib
 namespace gen {
  T3DEVLIB_ASCII_INTEGER_DEFINITION(Quiz, Operand, Signed);
  T3DEVLIB_ASCII_INTEGER_DEFINITION(Quiz, Result,  Signed);

  T3DEVLIB_FIXED_STRING_DEFINITION (Quiz, Operator, Charstring, 8);
}}
```

encode and decode the integer subtypes Quiz.Operand and Quiz.Result in textual format

encode and decode the charstring subtype Quiz.Operator as a fixed-length string (8-bit long)

Encoding/Decoding the record type

nothing to do !

(the CoDec generator will generate a default CoDec automatically for the 'Operation' record type)

Building the Test Suite

Quiz *waf* script

```
def configure(conf):
  conf.check_tool ('compiler_ttcn3 t3devkit')


def build(bld):

  bld.ttcn3_ets(

    features =  't3devkit',

    target =    'Quiz',

    te_source = 'Quiz.ttcn',
    sa_source = 'QuizPort.cpp sa-init.cpp',

    t3cdgen_header = 'quiz_codec.h'
  )
```

tell T3DevKit to include our header when generating the CoDec

Execution

```
abaire@kakrafoon:~/git/t3devkit/examples/Quiz$ twaf
Waf: Entering directory `/home/abaire/git/t3devkit/examples/Quiz/__build__'
  :
[18/18] cxx_link: __build__/default/__t3devkit__/pa_init_8.o __build__/default/c++/QuizPort_8.o __build__/default/c++/sa-
     init_8.o __build__/default/__t3devkit__/cd_init_8.o __build__/default/__t3devkit__/gen_classes_8.o
     __build__/default/__t3devkit__/root_module_8.o __build__/default/t3rts_conditional_8.o __build__/default/codec_plugin_8.o
     __build__/default/__tau__/ts_modules_8.o __build__/default/__tau__/Quiz_8.o -> __build__/default/Quiz_ETS
Waf: Leaving directory `/home/abaire/git/t3devkit/examples/Quiz/__build__'
'build' finished successfully (10.321s)



abaire@kakrafoon:~/git/t3devkit/examples/Quiz$ twaf --run
Waf: Entering directory `/home/abaire/git/t3devkit/examples/Quiz/__build__'
Test case started: Quiz.Quizz_2_plus_2

--------------------------------
--  Quizz Question            --

    Enter the result of 2+2
-> 4

Test case terminated --> pass

Waf: Leaving directory `/home/abaire/git/t3devkit/examples/Quiz/__build__'
'build' finished successfully (6.328s)
```

Quiz Summary

- System Adapter
  - reimplement Port::Map() and launch a listening thread
  - forward the received messages using Port::Enqueue()
- CoDec
  - record type: nothing to do (automatically generated)
  - subtypes: write a header to define each type and associate it with a codec
- Makefile
  - include our new header in the CoDec generation

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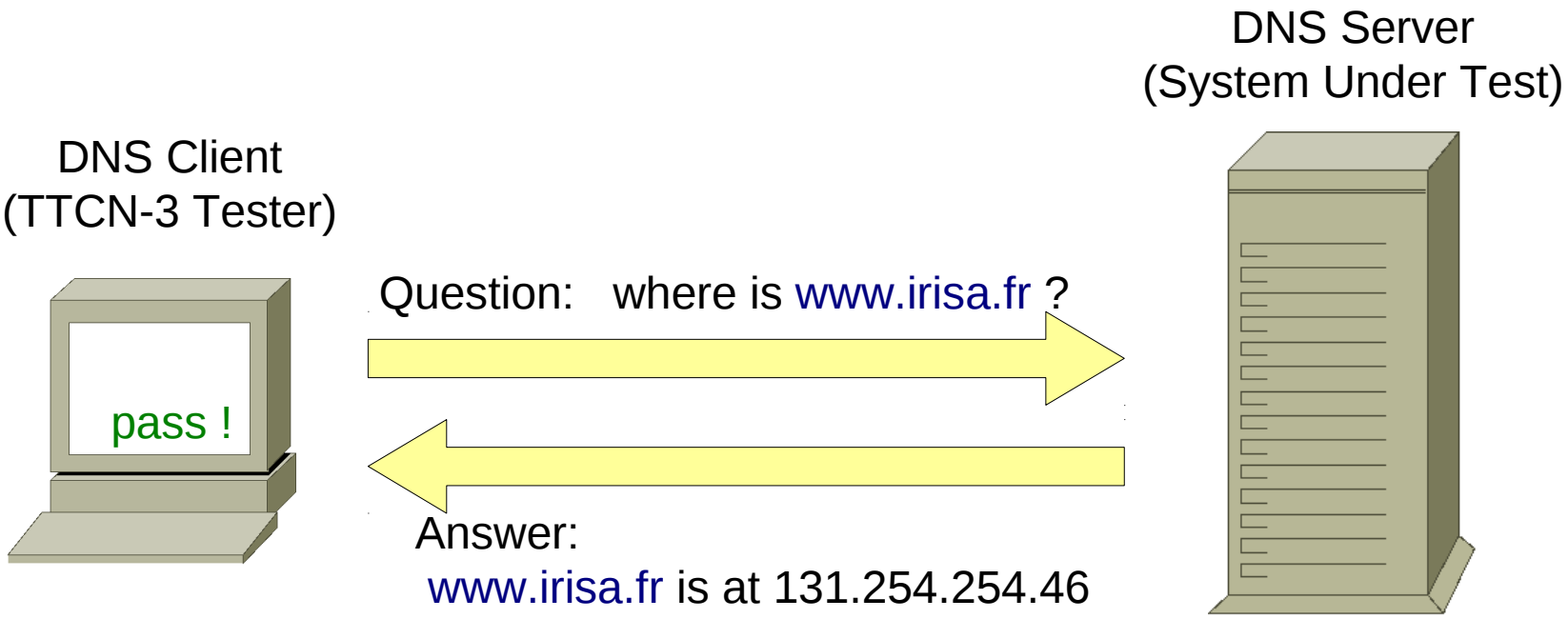
The DNS Example

- Purpose:
  - implement a real-life protocol (DNS)
- Objective:
  - demonstrate how to customise the CoDec for a complex protocol

The DNS Example

- Implement a DNS Client in TTCN-3 so as to test a DNS Server

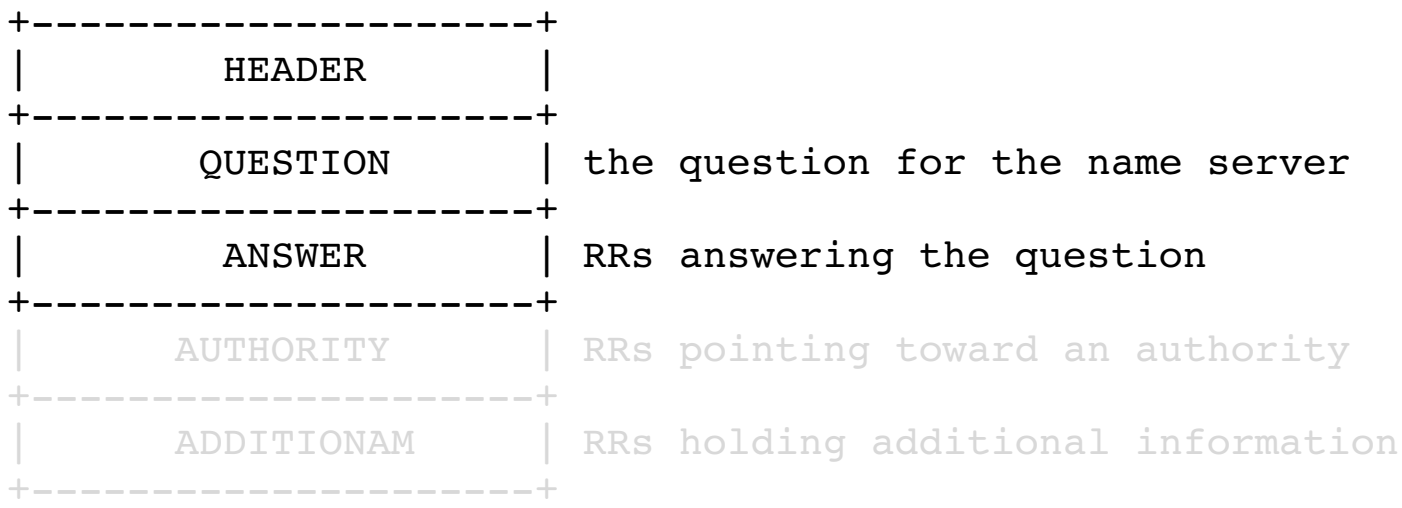


DNS messages in TTCN-3

[RFC 1035] Domain Implementation and Specification

4. MESSAGES

4.1. Format



DNS messages in TTCN-3

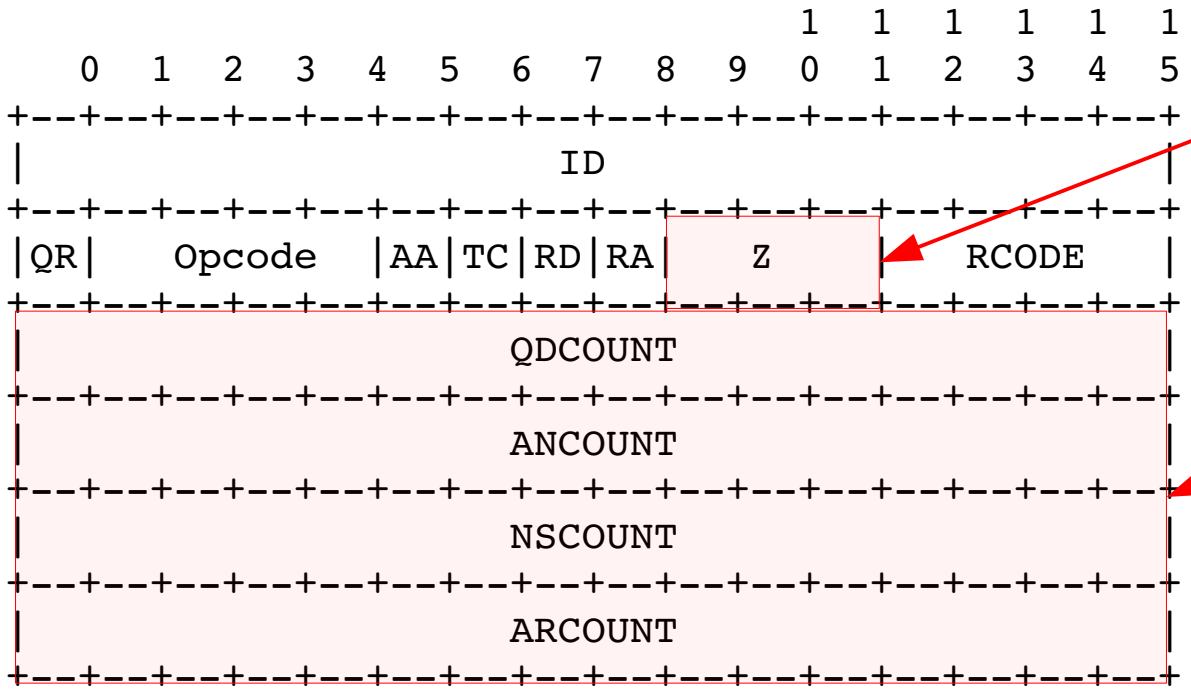
```
module DNS
{
        type record DNSMessage {
                DNSHeader               header,
                DNSQuestions            questions,
                DNSResourceRecords      answers

                // authorities & additional info omitted
                // to keep the example simple
        };

        type set of DNSQuestion         DNSQuestions;
        type set of DNSResourceRecord   DNSResourceRecords
```

the actual number of fields is variable

DNS header in TTCN-3

[RFC 1035] Domain Implementation and Specification

4.1.1. Header section format



padding field (filled with zeros)

number of entries in each section of the message

DNS header in TTCN-3

```
module DNS
{
        type record DNSHeader {
                UInt16                  Id,
                boolean                 QRflag,
                UInt4                   Opcode,
                boolean                 AAflag,
                boolean                 TCflag,
                boolean                 RDflag,
                boolean                 RAflag,
                // 3 padding bits omitted
                UInt4                   Rcode
                // QDCount, ANCount, NSCount & ARCount omitted
        };
```

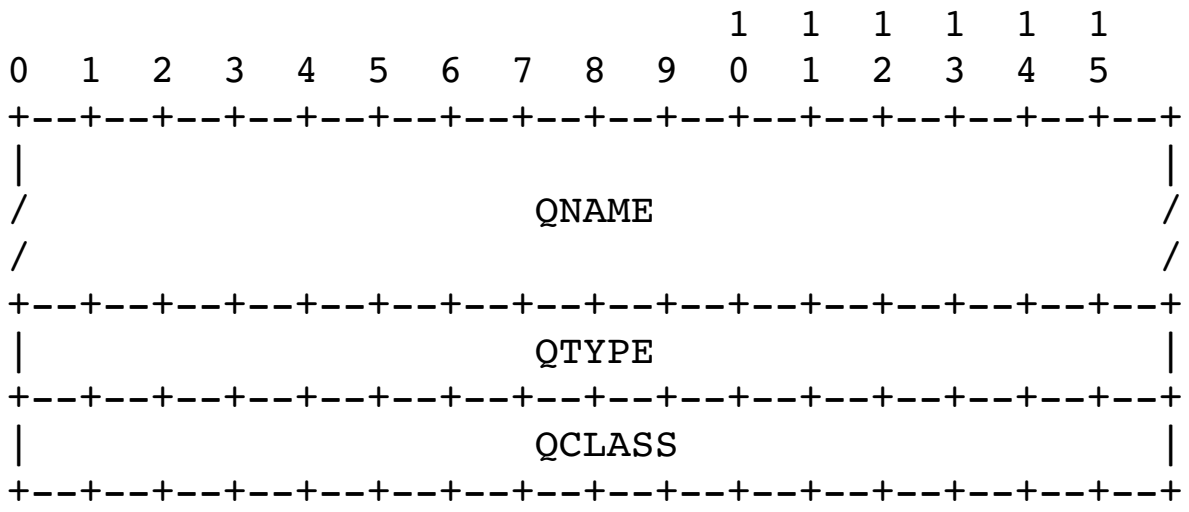
These fields will be handled inside the CoDec only (not necessary in the test suite)

NOTE: this is just a design choice

DNS question in TTCN-3

[RFC 1035] Domain Implementation and Specification

4.1.2. Question section format



DNS question in TTCN-3

```
module DNS
{
        type record DNSQuestion {
                DNSName         Name,
                UInt16          Type,
                UInt16          Class
        }
```

DNS resource record in TTCN-3

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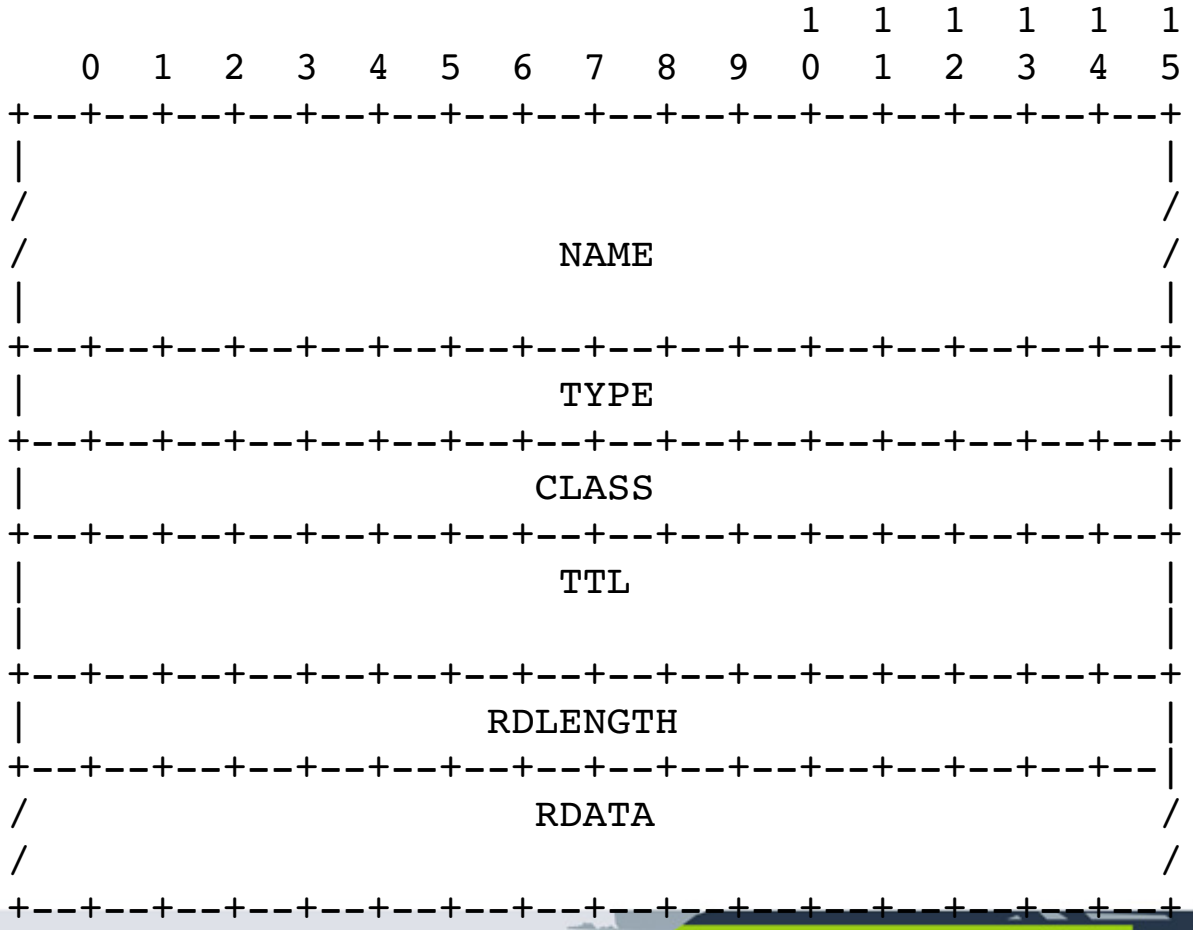
4.1.3. Resource record format



DNS resource record in TTCN-3

```
module DNS
{
        type record DNSResourceRecord {
                DNSName          Name,
                UInt16           Type,
                UInt16           Class,
                UInt32           TTL,
                // the RdLength field is omitted
                DNSResourceData Rdata
        };

        type union DNSResourceData {
                DNSName          name,
                IPAddress        ip,
                octetstring      str
        };
```

the resource data has several possible formats

DNS basic types in TTCN-3

```
module DNS
{
    type integer UInt4  (0..15);
    type integer UInt16 (0..65535);
    type integer UInt32 (0..4294967295);

    type charstring IPAddress;

    type charstring DNSName;
```

must be binary encoded (32-bit field)

eg: "131.254.254.46" => 0x83fefe2e

must be encoded in a DNS-special format (possibly with compression)

eg: "www.irisa.fr" => "\x03www\x05irisa\x02fr\0"

Implementing the DNS CoDec

- Automatically generated by T3DevKit...
- ...but additional informations are necessary:
  - how many entries in DNSQuestions & DNSAnswers ?
  - omitted fields in DNSHeader
  - which union variant in DNSResourceData?
  - what is the length of a DNSResourceData?
  - special formats for IPAddress & DNSName

Implementing the DNS CoDec

- Solution: customise the generated CoDec by inserting additional code at specific points
  - this customised code is written in special functions named *codets*
  - *codets* may be hooked in lots of places in the encoding/decoding processes, eg:
    - PreDecode(), PostDecode()
    - PreEncodeField()
    - ...

How does the generated CoDec looks like?

TTCN-3 Definitions

```
type union DNSResourceData
{
    DNSName      name,
    IPAddress    ip,
    octetstring  str
};
```

Generated CoDec (C++)

```
class DNSResourceData
    : public t3devlib::Union
{
public:
    void Encode (Buffer&);
    void Decode (Buffer&);

    DNSName&      Get_name();
    IPAddress&    Get_ip();
    Octetstring&  Get_str();

    enum {
        id_name  = 0,
        id_ip    = 1,
        id_str   = 2
    }
};
```

one c++ class generated for each type

T3DevKit's base class

specialised encode/decode functions

field accessors

field index IDs

Customising the CoDec
Example: length of DNSResourceData

```
module DNS
{
        type record DNSResourceRecord {
                DNSName          Name,
                UInt16           Type,
                UInt16           Class,
                UInt32           TTL,
                // the RdLength field is omitted
                DNSResourceData Rdata
        };

        type union DNSResourceData {
                DNSName          name,
                IPAddress        ip,
                octetstring      str
        };
```

the binary length size
of the resource data is
is given by the RdLength field

Decoding DNSResourceData

Decoding *codet* for DNSResourceData

function called automatically
before decoding a DNSResourceData

```
void DNSResourceData::PreDecode (Buffer& buffer)
                                 throw (DecodeError)
{
  UInt16 Rdlength;
  Rdlength.Decode (buffer);

  SetHypLength (Rdlength.GetValue() * 8);
}
```

Read a 16-bit integer from the buffer
(field RdLength)

tell T3DevKit how big is this value (we set an hypothesis)

=> in case of mismatch, T3DevKit will throw an exception later

Decoding DNSResourceData

```
module DNS
{
        type record DNSResourceRecord {
                DNSName          Name,
                UInt16           Type,
                UInt16           Class,
                UInt32           TTL,
                // the RdLength field is omitted
                DNSResourceData Rdata
        };

        type union DNSResourceData {
                DNSName          name,
                IPAddress        ip,
                octetstring      str
        };
```

the variant of the union depends on the class & type of the entry

Decoding DNSResourceData

function called automatically
after decoding each field in DNSResourceRecord

once the Class field is decoded, we decide which variant to decode in the next DNSResourceData

Decoding *codet* for

```
void DNSResourceRecord::PostDecodeField (int id, Buffer& buffer)

 if (id == id_Class) {


   DNSResourceData::SetHypChosenId (DNSResourceData::id_str);

   if (Get_Class().GetValue() == 1) { // class IN
     if (Get_Type().GetValue() == 1) { // Type A
         DNSResourceData::SetHypChosenId (DNSResourceData::id_ip);
     } else if (Get_Type().GetValue() == 5) { // Type CNAME
         DNSResourceData::SetHypChosenId (DNSResourceData::id_name)
}}}}
```

Decoding the DNS Header

```
module DNS
{
        type record DNSHeader {
                UInt16                  Id,
                boolean                 QRflag,
                UInt4                   Opcode,
                boolean                 AAflag,
                boolean                 TCflag,
                boolean                 RDflag,
                boolean                 RAflag,
                // 3 padding bits omitted
                UInt4                   Rcode
                // QDCount, ANCount, NSCount & ARCount omitted
        };
```

We must decode these additional fields and make the correct hypothesis when decoding the Questions & Answers sections

Decoding the DNSHeader

Decoding *codet* for DNSHeader

function called automatically
after decoding each field in DNSHeader

```
void DNSHeader::PostDecodeField (int id, Buffer& buffer)
                                 throw (DecodeError)
{
    switch (id) {
    case id_RAflag: {
        // padding : need to skip three bits
        Unsigned(3).Decode (buffer);
        break;
    }
```

after decoding the RAflag field,
we skip the next 3 padding bits

Decoding the DNSHeader

Decoding *codet* for DNSHe

```
case id_Rcode: {
        UInt16 count;
        count.Decode (buffer); // QD count
        DNSQuestions::SetHypSize (count.GetValue());

        count.Decode (buffer); // AN count
        DNSResourceRecords::SetHypSize (count.GetValue());

        count.Decode (buffer); // NS count (ignored)
        count.Decode (buffer); // AR count (ignored)
        break;
}}
```

read the QD count field (16-bit integer) and use its value as an hypothesis when decoding the DNSQuestions set of

idem for the answer count

read the NS count and AR count fields (so as to be aligned with the end of the header when leaving)

Encoding & Decoding the IP Address

Manual CoDec implementation codec for IPAddress

```
class IPAddress : public t3devlib::Charstring
{
public:
  const char* GetModuleName() const { return "DNS"; }
  const char* GetTypeName()   const { return "IPAddress"; }

  void Encode (Buffer& buffer) throw (EncodeError);
  void Decode (Buffer& buffer) throw (DecodeError);
};
```

Decoder for the IP Address

Manual CoDec implementation codec for IPAddress

```
void IPAddress::Decode (Buffer& buffer) throw (DecodeError)
{
    Unsigned ip(32);
    ip.Decode (buffer);

    SetValue (
        inet_ntoa ((const struct in_addr*) ip.GetValueBin())
    );
}
```

read a 32-bit integer from the buffer

convert it into the textual format
with the system function inet_ntoa()

Decoder for the DNS Name

- similar to the decoder of IPAddress's
  (there is nothing new)

  => the complete example is available on the CD

Decoder for NameServers and Additional Info

- this example does not address the last two sections in the DNSMessage
  - need to skip the sections when decoding the message

Codet for DNS Message

```
void DNSMessage::PostDecode (Buffer& buffer)
                              throw (DecodeError)
{
    buffer.SetPosition (buffer.GetEndMarker());
}
```

move the buffer cursor to the end of the message
(T3DevKit would report an error if the buffer was not fully decoded)

Implementing the DNS Encoder

- specific actions to be implemented in the encoder:
  - adding missing fields (eg. QD/AN/NS/AI count)
  - computing the length of ResourceRecords
  - custom encoder for IPAddress and DNSName
    - `Encode()` member function

(see the complete example on the CD)

Encoding the length of DNSResourceData

```
module DNS
{
        type record DNSResourceRecord {
                DNSName          Name,
                UInt16           Type,
                UInt16           Class,
                UInt32           TTL,
                // the RdLength field is omitted
                DNSResourceData Rdata
        };

        type union DNSResourceData {
                DNSName          name,
                IPAddress        ip,
                octetstring      str
        };
```

the RdLength field must be filled with the length of the DNSResourceData in the encoded message

Encoding the length of DNSResourceData

dns_codec.h

```
#define DEFINITIONS_DNSResourceData()    \
        int mPosition;
```

Define a new attribute in the class `DNSResourceData`
(the generator will include this macro)

dns_codets.cpp

```
void DNSResourceData::PreEncode (Buffer& buffer)
                              throw (EncodeError)
{
    Unsigned(16).Encode(buffer);

    mPosition = buffer.GetPosition();
}
```

Insert a blank 16-bit field
(to store RdLength later)

remember our current location in the buffer
(for later use)

Encoding the length of DNSResourceData

dns_codets.cpp

```
void DNSResourceData::PostEncode (Buffer& buffer)
                                  throw (EncodeError)
{
    int current_position = buffer.GetPosition();

    Unsigned Rdlength (16, (current_position - mPosition) / 8);

    buffer.SetPosition (mPosition - 16);
    Rdlength.Encode (buffer);

    buffer.SetPosition (current_position);
}
```

remember the current position in the buffer

compute RdLength and write it into the buffer at the correct location

move the buffer cursor back to the end of the resource record

Building the Test Suite

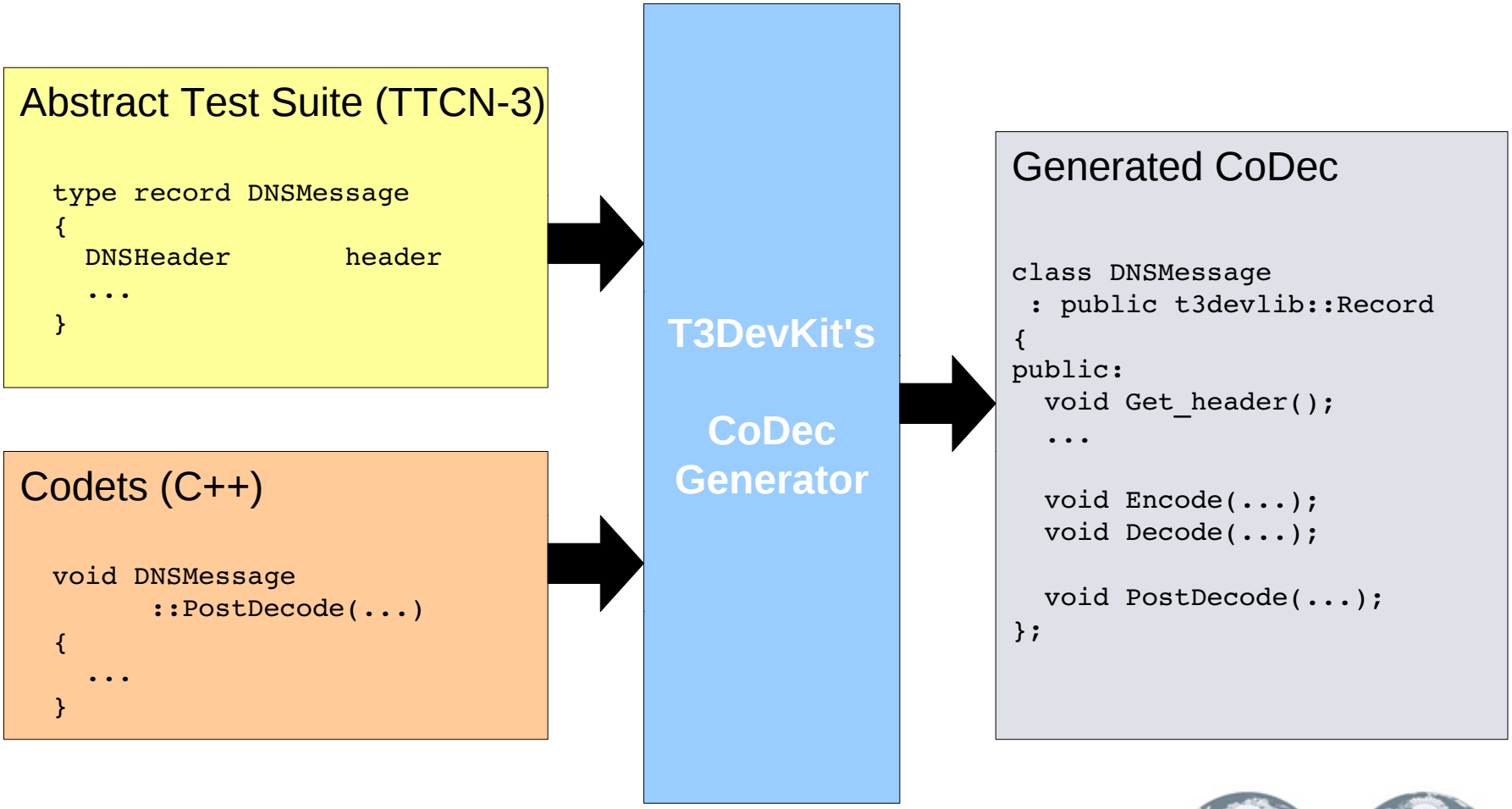
DNS Makefile

```
def configure(conf):
  conf.check_tool ('compiler_ttcn3 t3devkit')

def build(bld):

  bld.ttcn3_ets(

    features =  't3devkit',

    target =    'DNS',

    te_source = 'DNS.ttcn',
    sa_source = 'DNSPort.cpp sa-init.cpp',
    cd_source = 'dns_codets.cpp',

    t3cdgen_header = 'dns_codec.h'
  )
```

Source files for the CoDec

T3DevKit will scan them
to detect which codets are implemented

CoDec Generation Process



Execution

```
abaire@kakrafoon:~/git/t3devkit/examples/DNS$ DEBUG_CODEC=1 ./waf --run
Waf: Entering directory `/home/abaire/git/t3devkit/examples/DNS/__build__'
Test case started: DNS.ExampleResolveIrisa
******************** Encode: DNSMessage ********************
DNSMessage (record)
 header
  DNSHeader (record)
   Id                                    12345 - 0x3039 (16 bit unsigned i
   QRflag                                false (boolean)
   Opcode                                0 - 0x0 (4 bit unsigned integer)
   AAflag                                false (boolean)
   TCflag                                false (boolean)
   RDflag                                true (boolean)
   RAflag                                false (boolean)
   Rcode                                 0 - 0x0 (4 bit unsigned integer)
 questions
  DNSQuestions (set of)
    DNSQuestion (record)
     Name                                "www.irisa.fr" (charstring)
     Type                                1 - 0x1 (16 bit unsigned integer)
     Class                               1 - 0x1 (16 bit unsigned integer)
 answers
  DNSResourceRecords (set of)

Encoded to: '303901000001000000000000037777770569726973610266720000010001'O
************************************************************
*************** Decode: DNSMessage, 1520bits ***************
   :                                                        :
************************************************************
Test case terminated --> pass
Waf: Leaving directory `/home/abaire/git/t3devkit/examples/DNS/__build__'
'build' finished successfully (0.096s)
abaire@kakrafoon:~/git/t3devkit/examples/DNS$
```

enable CoDec debugging (T3DevKit feature)

DNS Example Summary

- CoDec
  - implement special actions in codets => eg: `PreDecode()`
  - make predictions when decoding
    - binary length of a field => `SetHypLength()`
    - variant of a union => `SetHypChosenId()`
    - size of a set of => `SetHypSize()`
  - new class attributes can be defined using a C macro
  - custom formats (IPAddress, DNSName): implement `Encode()` and `Decode()` directly
- Makefile
  - give the list of files containing codets

Questions ?

Contacts: abaire@irisa.fr / viho@irisa.fr

Complete source code (T3DevKit & examples) available at:

http://t3devkit.gforge.inria.fr/