Introduction to the C/C++ to TTCN-3 mapping

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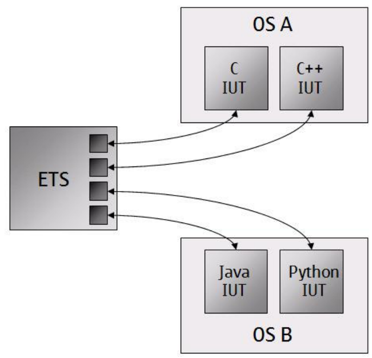
Background

- New test domains for TTCN-3 testing; based on procedural and object-oriented programming languages requires a mapping of the language under test in to TTCN-3
  - Procedure-based communication can be used for direct interfacing to software modules
  - Testing can be applied in an earlier phase (unit testing)
  - One test language for testing of SUTs in different programming languages, same test suite, same test case
  - Combining traditional TTCN-3 testers with additional direct software interaction, stimulus, mock objects
  - Controlling/configuring SUTs, preamble/postamble

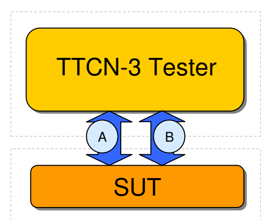


The need for a mapping

- Test architecture possibilities, many combinations
  - Internal interfaces
  - Many programming languages
- Callable interface needs to be represented in TTCN-3
  - Functions
  - Types
- Mapping must provide same operational semantics as mapped language

A) Control/ configuration/ interaction

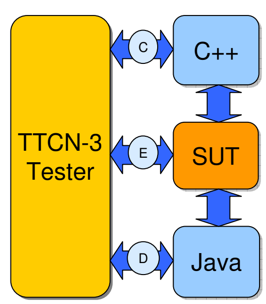
B) Traditional protocol testing



C) C++ interface, mock object/ stimulus

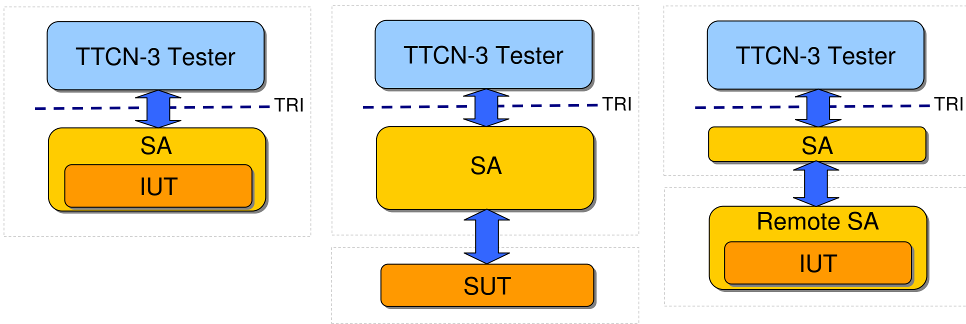
D) Java interface, mock object/ stimulus

E) Test case interaction



Historical background

- Two independent projects at Nokia/Helsinki and VTT/Oulu. Outcome was a combined mapping proposal, C/C++ to TTCN-3.
- Test system architectures to verify mappings with where based on remote SUT, remote SA and a ‘tight’ IUT, all had different ways of handling memory access.
- Procedure-based communication had not been frequently used. Immature TTCN-3 tools and non-existing or unsatisfying test system components.



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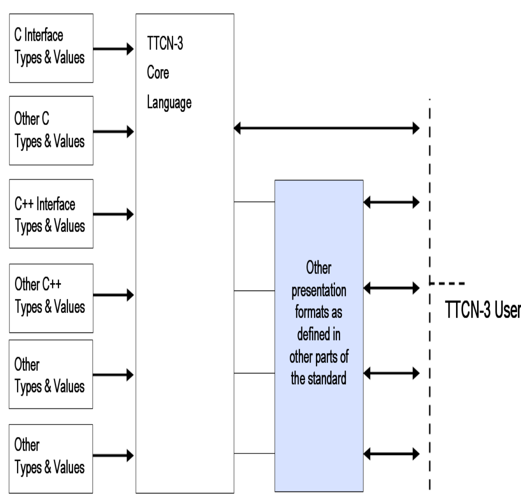
Choice of mapping languages

- C and C++ is together the largest preferred programming language in the world, ~28% (www.tiobe.com/tpci.htm)
- C / C++ suitable for software module testing/mapping exploration; strong typing, OO-language, pointers
- C++ does not impose a single rooted inheritance hierarchy
- Neither C or C++ can be mapped in full in an un-ambiguous way



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Known problematic issues

TTCN-3	C/C++	C++
Does NOT have • Object-oriented concepts • Overloading • Generic constructs eq. C++ templates, Java generics	• Mapping input • Pointers `int*` • Pointer arithmetic `ptr++` • Variadic functions `printf( const char *FORMAT, ... )` • Type casting `(int*)shortPtr` • Address of value (`&`)	• Inheritance • Polymorphism • Templates • Standard library items `string, vector<int>`

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What is covered by the mappings

Covered C/C++
- Built-in types, structured types
- Enumerated types
- Functions (inline, extern, volatile)
- Global variables
- Pointer types
- Dereferencing/address of variable
- Typedef

Covered C++
- Encapsulation
- Inheritance
- Polymorphism
- Operators
- References

- Proposed mappings/Normative (C/C++)
  - Variadic parameter lists
  - Templates
  - Preprocessor directives
- Not covered
  - Address of variable of built-in types
  - Type casting, built in types
  - Access specifiers

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Mapping input

- Preferred mapping input complete translation unit i.e. preprocessed source file
- Does not necessarily only have to be a preprocessed source file
  - Macro definitions (`#define MAX_SZ 1024`, `#define KEY "myKey"`)

- Items looked for in the source code are items of the interface under test and additional items useful for test suite implementations
  - Functions
  - Type definitions
  - Enumerated types
  - Global variables

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Mapping examples

- Pointers

```
int* intPtr;
```

- Address of variable

```
void* ptr = &myObject;
```

- Encapsulation

```
class A {/* attributes & methods */};
```

- Inheritance

```
class B: public A {/*...*/};
```


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Mapping C/C++ to TTCN-3

- Majority of the types can be mapped in a rather straight forward manner
  - `int->integer`
  - `float->float`
  - `struct->record`
  - `class->module`
  - function->`signature`

```
//int add( int x, int y );
type integer CInt ( c_CIntMin .. c_CIntMax );
signature add( in CInt x, in CInt y ) return CInt;
// . . .
pt_pb.call( add:{ 2,3 }, C_TIMEOUT ) {
  [] pt_pb.getreply( add:? value 5 ) { setverdict( pass ); }
  [] pt_pb.catch( timeout )          { setverdict( fail ); }
}
```


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Mapping C to TTCN-3 (pointers)

- Usefulness of an address to a memory location (!NULL)?
- Minimally needed functionality, allocate, initialize, write, read, release
- Pointer arithmetic
- Dereferencing, `*ptr`
- Address of variable, `&inst`

```
// int*
type integer CPtr;
type CPtr    CIntPtr;
type record of CInt CIntArr;
```


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Mapping C to TTCN-3 contd. (pointer handling)

- External functions or signatures, depends on the test architecture
  - SUT and tester share the same memory space
  - Multiple SUTs
  - Both approaches are proposed in the mapping

```
// malloc, set, get, free
external function ef_MallocCInt(in CUnsignedInt p_Length)
  return CIntPtr;
external function ef_SetCInt(in CIntPtr p_Self,
                             in CIntArr p_CInts);
// . . .
signature s_MallocCInt (in CUnsignedInt p_Length)
  return CIntPtr;
signature s_SetCInt (in CIntPtr p_Self,
                     in CIntArr p_CInts);
// . .  .
```


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Mapping C to TTCN-3 contd. (pointer handling, by example)

```
// int* ptr = (int*)malloc( sizeof(int)*4 );
// ptr[0]=5;ptr[1]=4;ptr[2]=3;ptr[1]=2;
// useIntArr(ptr);
// if ( ptr[2]==c_oracle ) { … }

var CIntPtr ptr; var CIntArr intArr;
ptr := f_MallocCInt(4);         // allocate
f_SetCInt( ptr, {5,4,3,2} );    // initialize/dereferencing

pt.call( s_useIntArr:{ptr}, c_TIMEOUT ) { // use/write
  [] pt.getreply( s_useIntArr:? ) {}
  [] pt.catch( timeout ) {}
}
pt.call( s_GetCInt:{ptr,4}, c_TIMEOUT ) { // read
  [] pt.getreply( s_GetCInt:? ) -> value intArr { /* if(ptr[2]…*/ }
  // …
}
```


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Mapping C to TTCN-3 contd. (address of variable/object)

- Getting address of variable/object using operator & (not for built-in types)

```
// struct MyStruct obj = retObject();
// useObject( &obj );

type record MyStruct {
      CPtr m_this optional, // instead of operator &
      // attributes ...
}
type CPtr CMyStructPtr;
signature retObject() return MyStruct;
signature useObject( in CMyStructPtr ptr );

var MyStruct obj;
pt.call( retObject:{}, c_TIMEOUT ) {
  [] pt.getreply( retObject:? ) -> value obj {…} // ...
}
if ( obj.m_this != omit ) {
  pt.call( useObject:{ obj.m_this }, 2.0 ) {…}  // operator &
}
```


Mapping C++ to TTCN-3 (encapsulation)

- `struct`, `union` and `class` provides encapsulation in C++

```
class MyClass {
  // Attributes
  . . .
  // Member functions
  void MyFunction();
  . . .
};
```

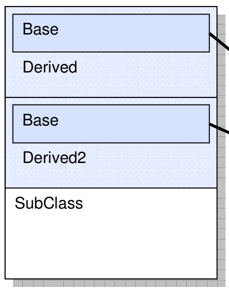
- A `module` provides encapsulation of mapped attributes and member functions in TTCN-3

```
module MyClass {
  type record MyClass_t {
    // Attributes
    . . .
  }
  // Member functions
  signature MyFunction(
    in CppPtr m_this );
  . . .
}
```

Mapping C++ to TTCN-3 contd. (inheritance)

- Inheritance the C++ way

```
class Base {};
class Derived  : public Base {};
class Derived2 : public Base {};
class SubClass :
  public Derived, Derived2 {};
```



- Using TTCN-3 `import`

```
module CppBase { type record CppBase_t
{} }
module CppDerived {
  import from CppBase all;
  type record CppDerived_t {
    CppPtr    m_this optional,
    CppBase_t m_base
  }
}
module CppDerived2 { /* as above */ }

module SubClass {
  import from CppDerived  all;
  import from CppDerived2 all;
  type record CppDerived2_t {
    CppPtr         m_this optional,
    CppDerived_t   m_derived,
    CppDerived2_t  m_derived2,
  }
}
```


Conclusions

- Approaching new test domains, using the defined mappings we can:
  - directly interact with software interfaces in their native language, enabling a multitude of test system configurations
  - combine traditional TTCN-3 testers with direct internal interaction using procedure-based communication
- C and C++ are very ambiguous languages and there can be alternative mappings to almost everything
- Usage of mappings requires knowledge of mapping background
- Usage will require additional tools, code generator C/C++ -> TTCN-3
- Other OO mappings, different approaches might be needed due to the single inheritance tree model of C++

- YES, some testing might be easier using native language of SUT, TTCN-3 adds additional capabilities

QUESTIONS?

Mapping C++ to TTCN-3 contd. (inheritance, methods)

- Polymorphism, usage of virtual functions

```
class Root {
  void Function();
};

class MySuperClass : Root {
  virtual void VirtualFunction();
  void MemberFunction();
};

class MySuperClass2 : Root {
  void MemberFunction();
};

class MySubClass :
  MySuperClass, MySuperClass2 {
  virtual void VirtualFunction();
  void MyFunction();
};
```

- All inherited member functions are overridden

```
module CppMySubClass {
  //. . .
  signature s_VirtualFunction(
    in MySubClassPtr p_this );
  signature s_MyFunction (
    in MySubClassPtr p_this );

  // to resolve ambiguity
  signature s_MySuperClass_MemberFunction
    (in MySubClassPtr p_this);
  signature s_MySuperClass2_MemberFunction
    (in MySubClassPtr p_this);
  signature s_Root_MySuperClass_Function
    (in MySubClassPtr p_this);
  signature s_Root_MySuperClass2_Function
    (in MySubClassPtr p_this);
  // . . .
}

// obj.Root::MySuperClass::Function();
pt_pb.call(
  s_Root_MySuperClass_Function:
    {CppMySubClass.m_this} ) { /* . . . */ }
```

Mapping C++ to TTCN-3 contd. (polymorphism, overloading)

```
void print(int value);               signature s_print_int(
                                       in CppInt p_value);

void print(const char* string);      signature s_print_constcharptr(
                                       in CppCharPtr p_string);

void print(int value,                signature s_print_int_def(
           int def=10);                in CppInt p_value);
                                     signature s_print_int_defint(
                                       in CppInt p_value,
                                       in CppInt p_def);
```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Mapping C++ to TTCN-3 contd. (polymorphism, virtual)

```
// Base* base = getObj();
// base->print();

module Base {
  import from CppBuiltInTypes all;
  signature print( in CppPtr m_this ); // virtual function
}
module Derived {
  import from Base all;
  signature Base_print( in CppPtr m_this ); // Base::print();
  signature print( in CppPtr m_this );      // virtual function
}

var CppPtr objPtr := f_getObj();
// polymorphism resolved in SUT
pt.call( Derived.print:{objPtr}, 2.0 ) {
  [] pt.getreply( Derived.print:? ){/*…*/}
  [] pt.catch( timeout ) {}
}
```


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