A TTCN-3 Test Automation Framework for HL7/IHE based Applications

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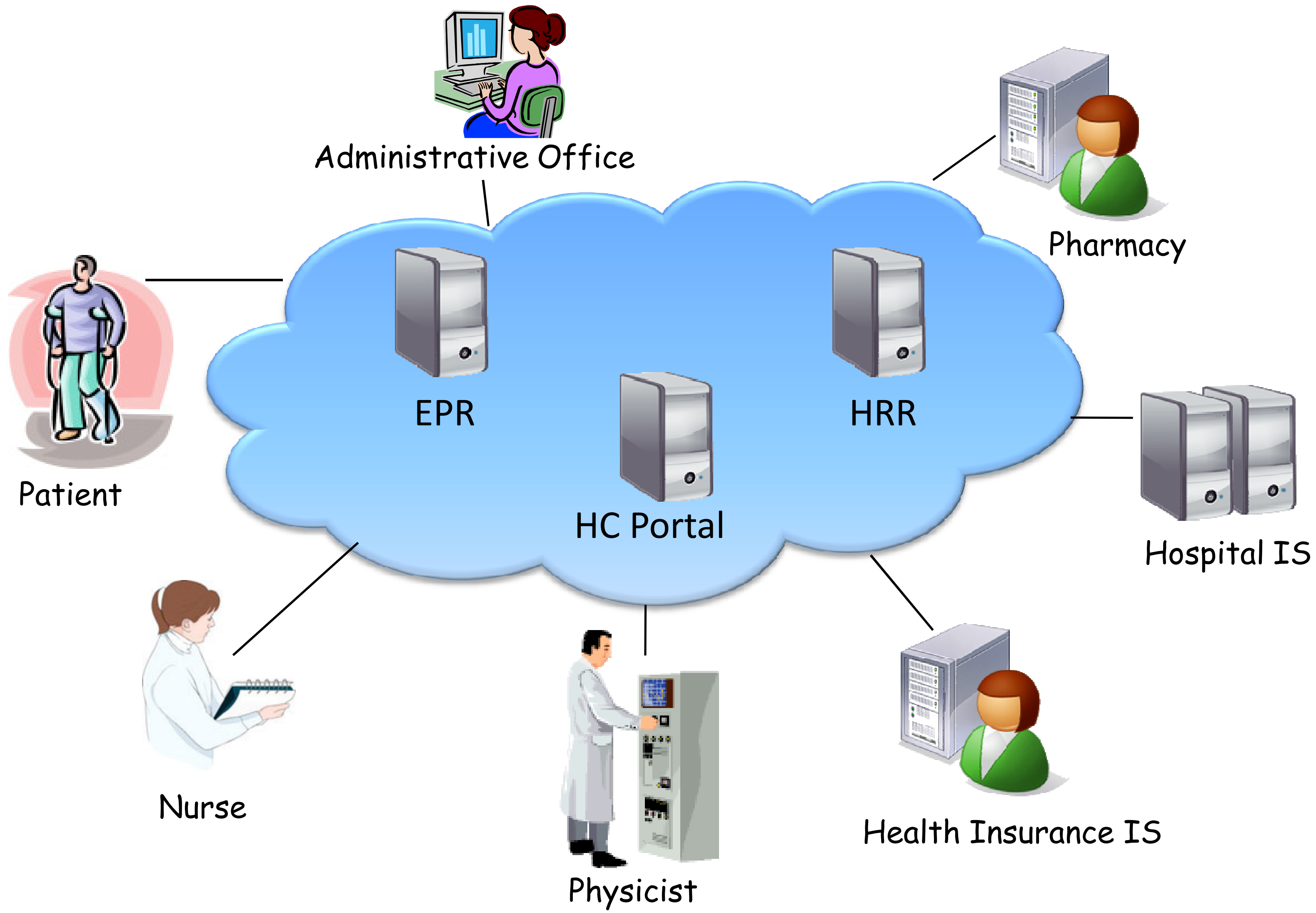
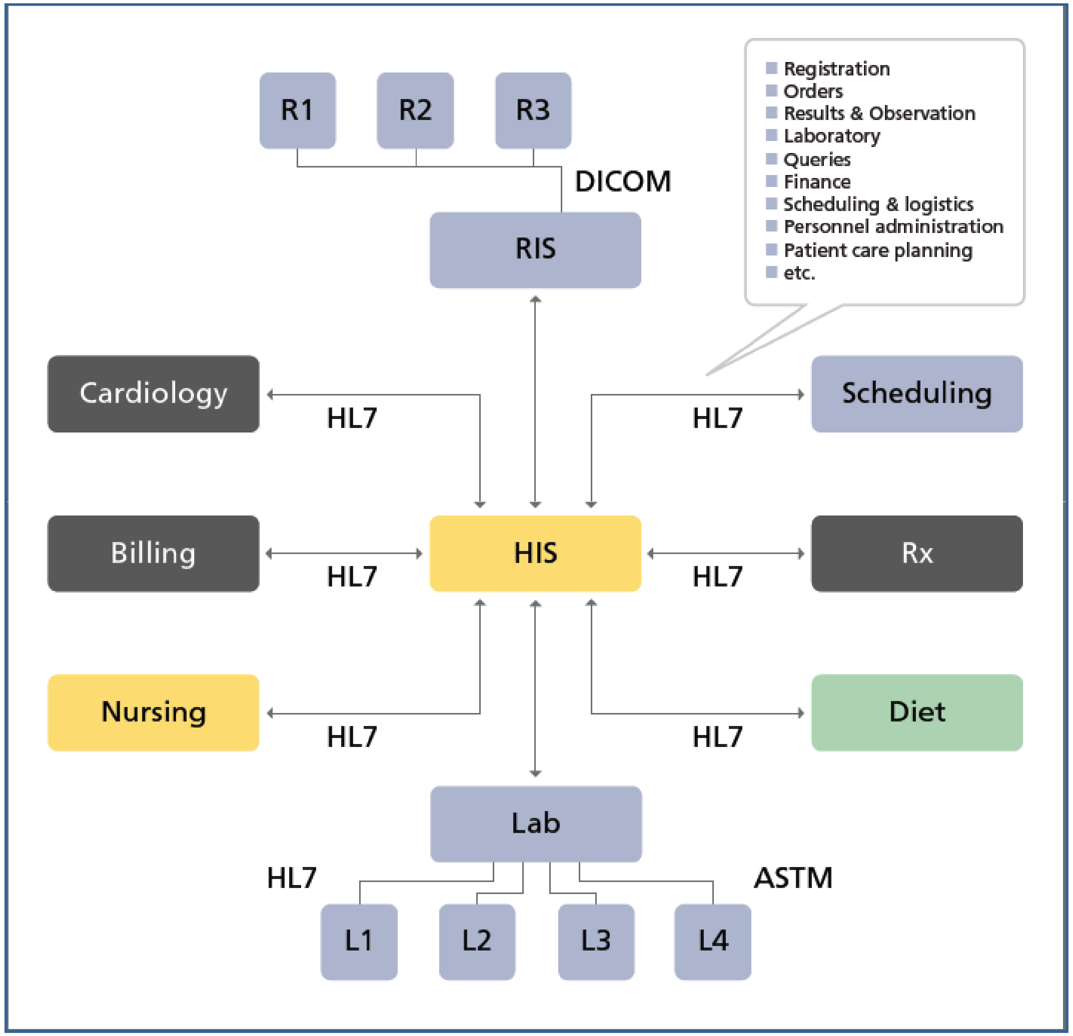
- ❑ Healthcare Information Systems (HIS)
- ❑ Health Level 7 (HL7) Applications
- ❑ TTCN-3 Test Bed for HL7 Applications
  - ❑ Architecture
  - ❑ Design
- ❑ Conclusions

Healthcare Information Systems (HIS)



HL7 and HIS Integration

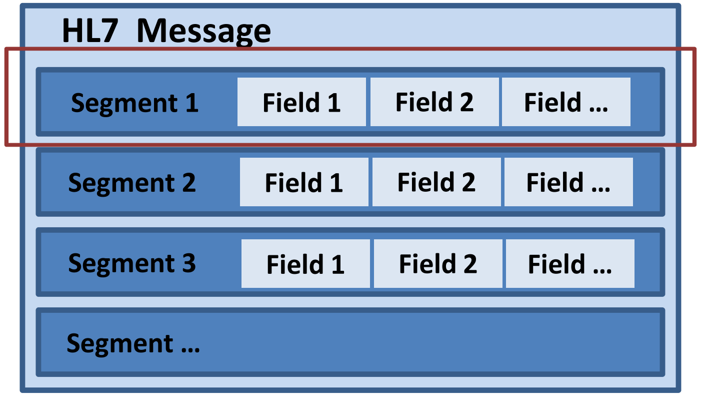


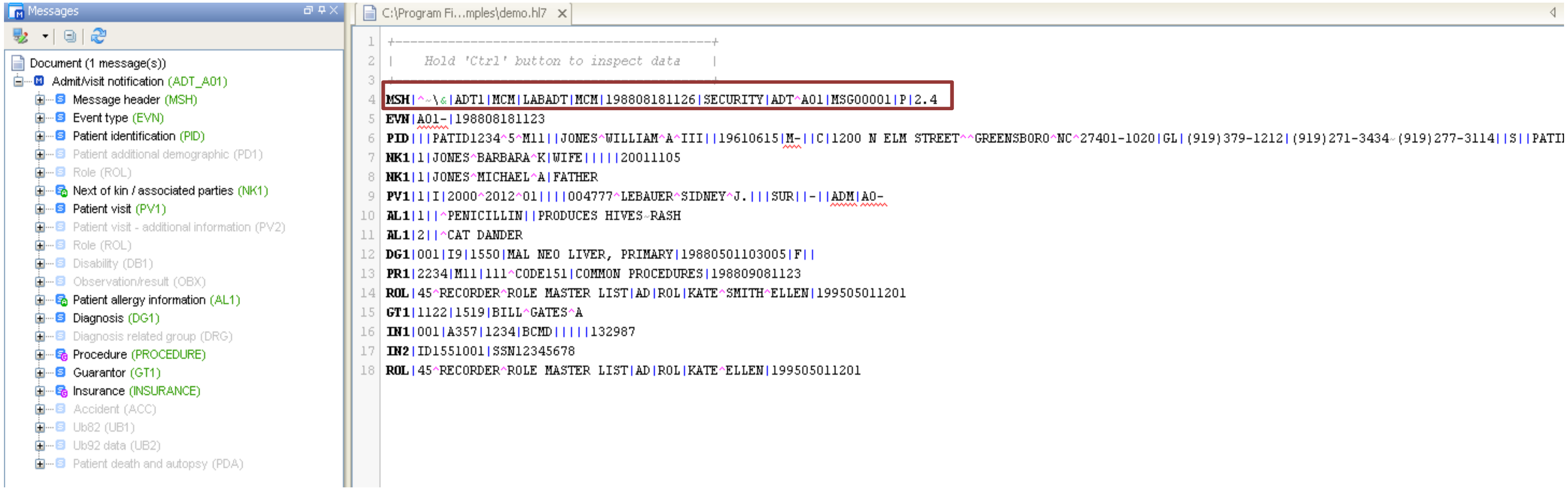
- Registration
- Orders
- Results & Observation
- Laboratory
- Queries
- Finance
- Scheduling & logistics
- Personnel administration
- Patient care planning
- etc.

- HL7 (Health Level Seven) Messaging Standard (Application level)
- Standards for the exchange, management and integration of data for medical devices
  - Messages model real world events
    - e.g., Messages for registering a patient (ADT) or requesting a lab order
- HL7 provides a flexible framework to build messages

HL7 Standard

- ANSI (American National Standards Institute) , ISO (partial)
- Organization: www.hl7.org
- HL7 Versions: v2.5.x, currently v3
- Exchange data mechanism for health systems
- HL7-Message Structure



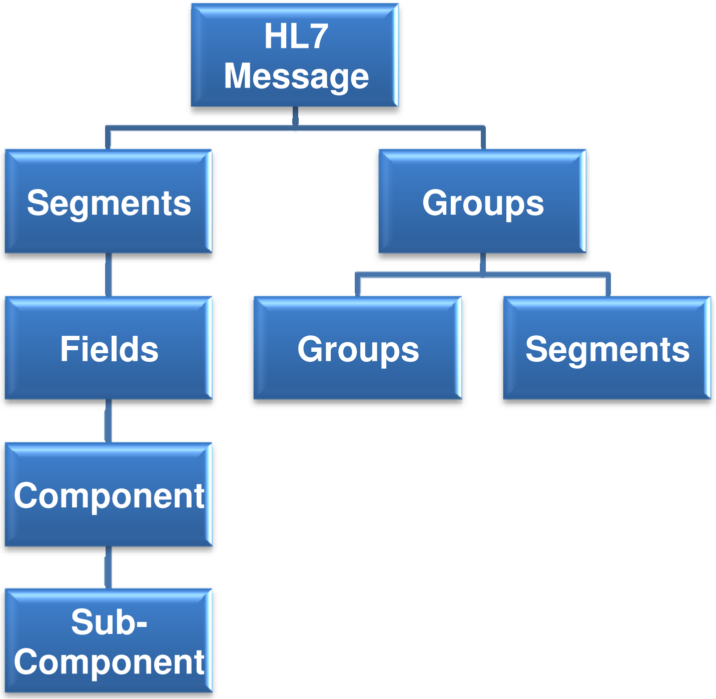


Document (1 message(s))
- Admit/visit notification (ADT_A01)
  - Message header (MSH)
  - Event type (EVN)
  - Patient identification (PID)
  - Patient additional demographic (PD1)
  - Role (ROL)
  - Next of kin / associated parties (NK1)
  - Patient visit (PV1)
  - Patient visit - additional information (PV2)
  - Role (ROL)
  - Disability (DB1)
  - Observation/result (OBX)
  - Patient allergy information (AL1)
  - Diagnosis (DG1)
  - Diagnosis related group (DRG)
  - Procedure (PROCEDURE)
  - Guarantor (GT1)
  - Insurance (INSURANCE)
  - Accident (ACC)
  - Ub82 (UB1)
  - Ub92 data (UB2)
  - Patient death and autopsy (PDA)

```
+-----------------------------------------+
|    Hold 'Ctrl' button to inspect data    |
+-----------------------------------------+
MSH|^~\&|ADT1|MCM|LABADT|MCM|198808181126|SECURITY|ADT^A01|MSG00001|P|2.4
EVN|A01-|198808181123
PID|||PATID1234^5^M11||JONES^WILLIAM^A^III||19610615|M-||C|1200 N ELM STREET^^GREENSBORO^NC^27401-1020|GL|(919)379-1212|(919)271-3434~(919)277-3114||S||PATI
NK1|1|JONES^BARBARA^K|WIFE||||20011105
NK1|1|JONES^MICHAEL^A|FATHER
PV1|1|I|2000^2012^01||||004777^LEBAUER^SIDNEY^J.|||SUR||-||ADM|A0-
AL1|1||^PENICILLIN||PRODUCES HIVES~RASH
AL1|2||^CAT DANDER
DG1|001|I9|1550|MAL NEO LIVER, PRIMARY|19880501103005|F||
PR1|2234|M11|111^CODE151|COMMON PROCEDURES|198809081123
ROL|45^RECORDER^ROLE MASTER LIST|AD|ROL|KATE^SMITH^ELLEN|199505011201
GT1|1122|1519|BILL^GATES^A
IN1|001|A357|1234|BCMD|||||132987
IN2|ID1551001|SSN12345678
ROL|45^RECORDER^ROLE MASTER LIST|AD|ROL|KATE^ELLEN|199505011201
```

HL7 Message Elements

- Groups, Segments, Fields, Components, and Sub-Components
- Groups and Segments can contain additional elements
- Fields and Components can contain additional elements or are primitive elements
- Sub-components are primitive elements (i.e. data values)



Many Message Events model real world events, such as:

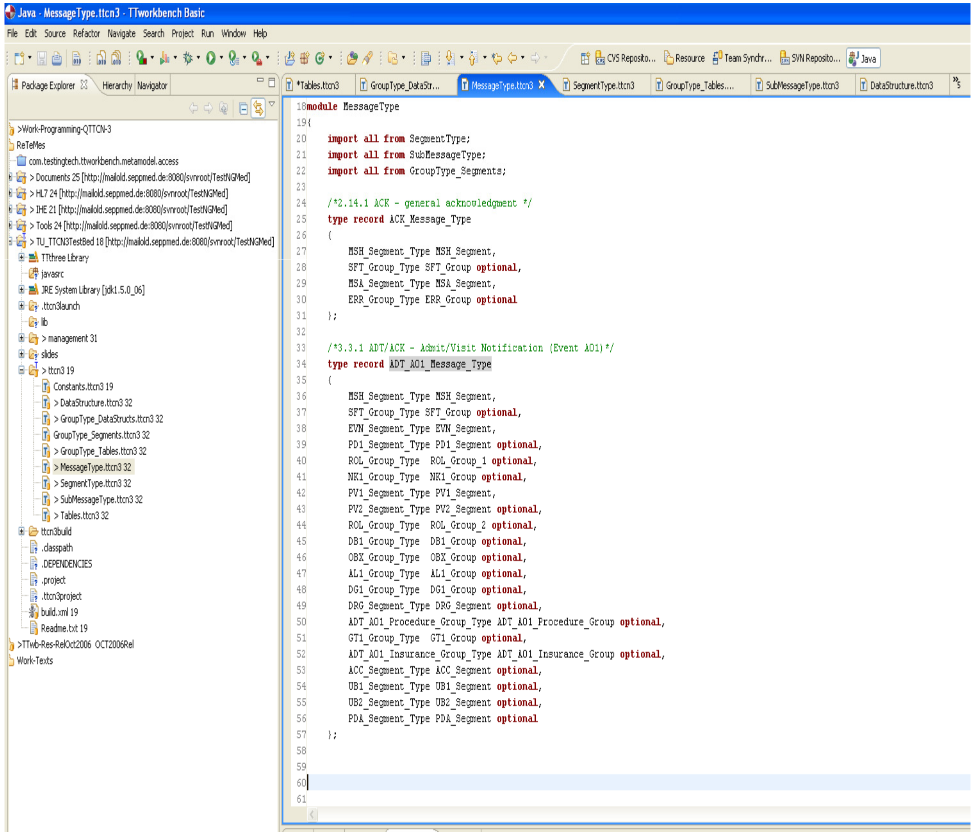
- Admit/Discharge/Transfer (ADT)
  - ADT A04 (Register Patient)
  - ADT A08 (Update Patient Data)
  - etc.
- Lab Orders (ORM)
  - ORM O01 (Order Message)
- Lab Results (ORR)
  - ORR O02 (Order Response)
- etc.

Testing of HL7 Applications

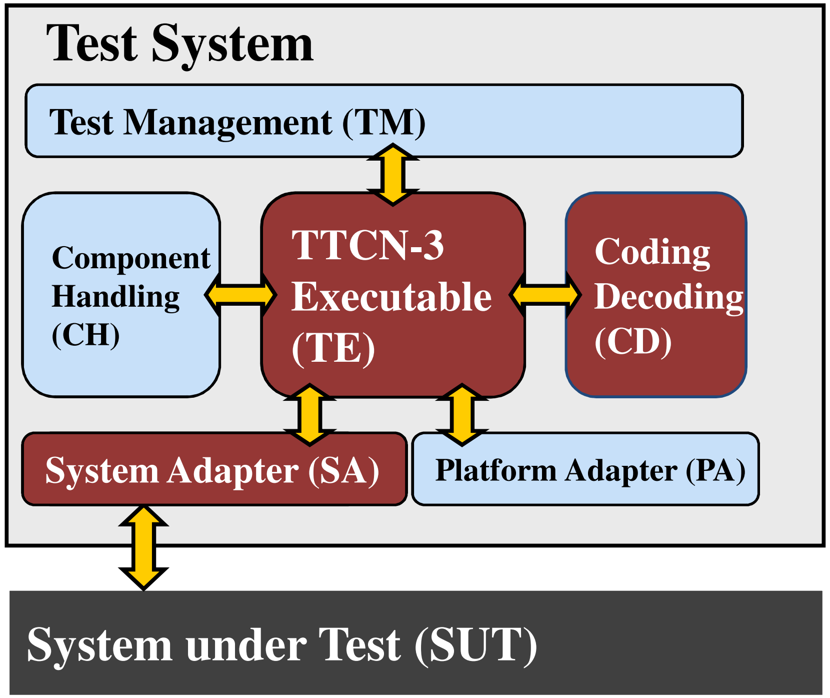
- ❑ Testing related to interoperability aspects
    - ❑ HL7 interface unit testing – testing that HL7 messages sent and/or received from a medical application conform to the HL7 interface specification
    - ❑ HL7 interface integration testing – testing of business scenarios to ensure that information is able to flow correctly between medical applications
    - ❑ HL7 system testing – end-to-end scenario testing focused on ensuring all relevant components of all relevant medical applications are able to interoperate correctly
- ❑ Further testing needs
    - ❑ system level test design for the overall system reliability
    - ❑ automated test generation from message and system interactions
    - ❑ risk-oriented test strategies and test selection
    - ❑ test coverage metrics for a quantifiable reliability analysis

TTCN-3 - The Testing and Test Control Notation

- ❑ Official web page: www.ttcn-3.org
- ❑ Standard: www.ttcn-3.org/StandardSuite.htm
- ❑ Tool: TTworkbench: www.testingtech.com/


Java - MessageType.ttcn3 - TTworkbench Basic
File Edit Source Refactor Navigate Search Project Run Window Help
Package Explorer Hierarchy Navigator
*Tables.ttcn3
GroupType_DataStr...
MessageType.ttcn3
SegmentType.ttcn3
GroupType_Tables....
SubMessageType.ttcn3
DataStructure.ttcn3

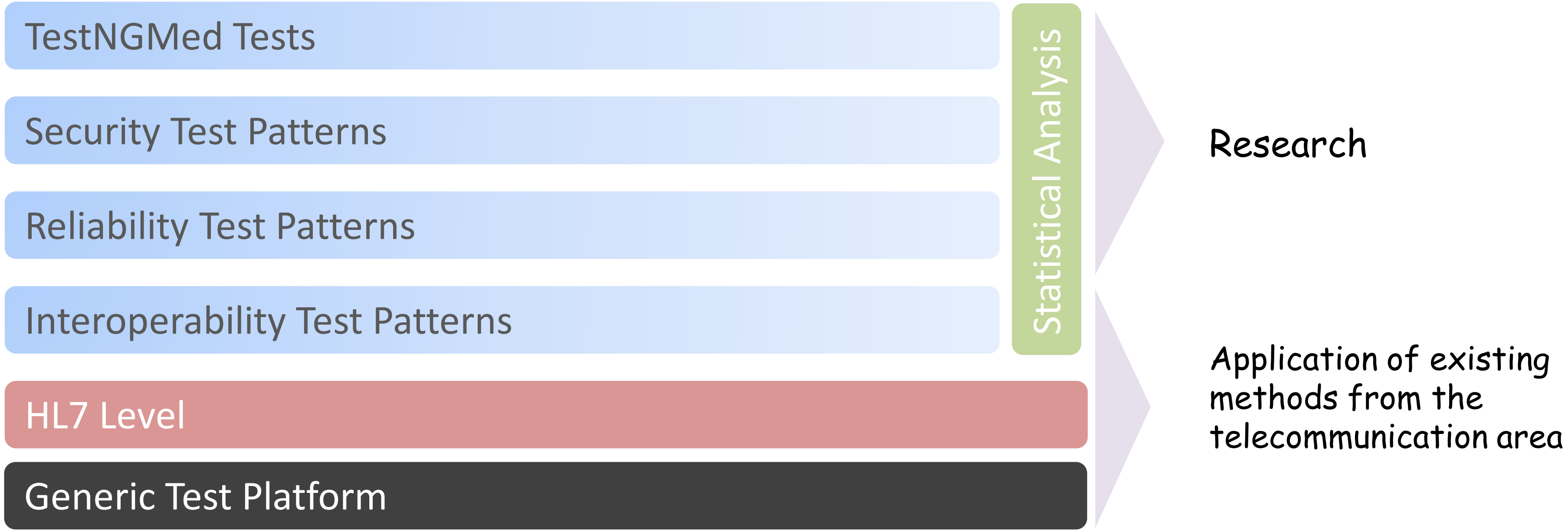
```
module MessageType
{
    import all from SegmentType;
    import all from SubMessageType;
    import all from GroupType_Segments;

    /*2.14.1 ACK - general acknowledgment */
    type record ACK_Message_Type
    {
        MSH_Segment_Type MSH_Segment,
        SFT_Group_Type SFT_Group optional,
        MSA_Segment_Type MSA_Segment,
        ERR_Group_Type ERR_Group optional
    };

    /*3.3.1 ADT/ACK - Admit/Visit Notification (Event A01)*/
    type record ADT_A01_Message_Type
    {
        MSH_Segment_Type MSH_Segment,
        SFT_Group_Type SFT_Group optional,
        EVN_Segment_Type EVN_Segment,
        PD1_Segment_Type PD1_Segment optional,
        ROL_Group_Type  ROL_Group_1 optional,
        NK1_Group_Type  NK1_Group optional,
        PV1_Segment_Type PV1_Segment,
        PV2_Segment_Type PV2_Segment optional,
        ROL_Group_Type  ROL_Group_2 optional,
        DB1_Group_Type  DB1_Group optional,
        OBX_Group_Type  OBX_Group optional,
        AL1_Group_Type  AL1_Group optional,
        DG1_Group_Type  DG1_Group optional,
        DRG_Segment_Type DRG_Segment optional,
        ADT_A01_Procedure_Group_Type ADT_A01_Procedure_Group optional,
        GT1_Group_Type  GT1_Group optional,
        ADT_A01_Insurance_Group_Type ADT_A01_Insurance_Group optional,
        ACC_Segment_Type ACC_Segment optional,
        UB1_Segment_Type UB1_Segment optional,
        UB2_Segment_Type UB2_Segment optional,
        PDA_Segment_Type PDA_Segment optional
    };
```



- ❑ Abstract test specification (ATS)
  - ❑ **data templates** allow unlimited structuring and reusability of test data
  - ❑ **matching mechanism** to compare an oracle to response data
  - ❑ communication paradigms: message and procedure oriented **ports**
  - ❑ **parallel test components**
- ❑ Concrete test implementation
  - ❑ **Adapter** and **CoDec** (Coder/Decoder of data types)

TestNGMed Project

- ❑ **Partners**
  - ❑ Sepp.med
  - ❑ TU Berlin
  - ❑ Applied Biosignals
- ❑ **Target**
  - ❑ test methods adapted to Next Generation Medical Systems
  - ❑ extend TTCN-3 tools and methods to support the needs in the medical applications
  - ❑ high level of automation in specifying and executing next generation medical systems tests



TestNGMed Tests
Security Test Patterns
Reliability Test Patterns
Interoperability Test Patterns
Statistical Analysis
HL7 Level
Generic Test Platform
Research
Application of existing methods from the telecommunication area

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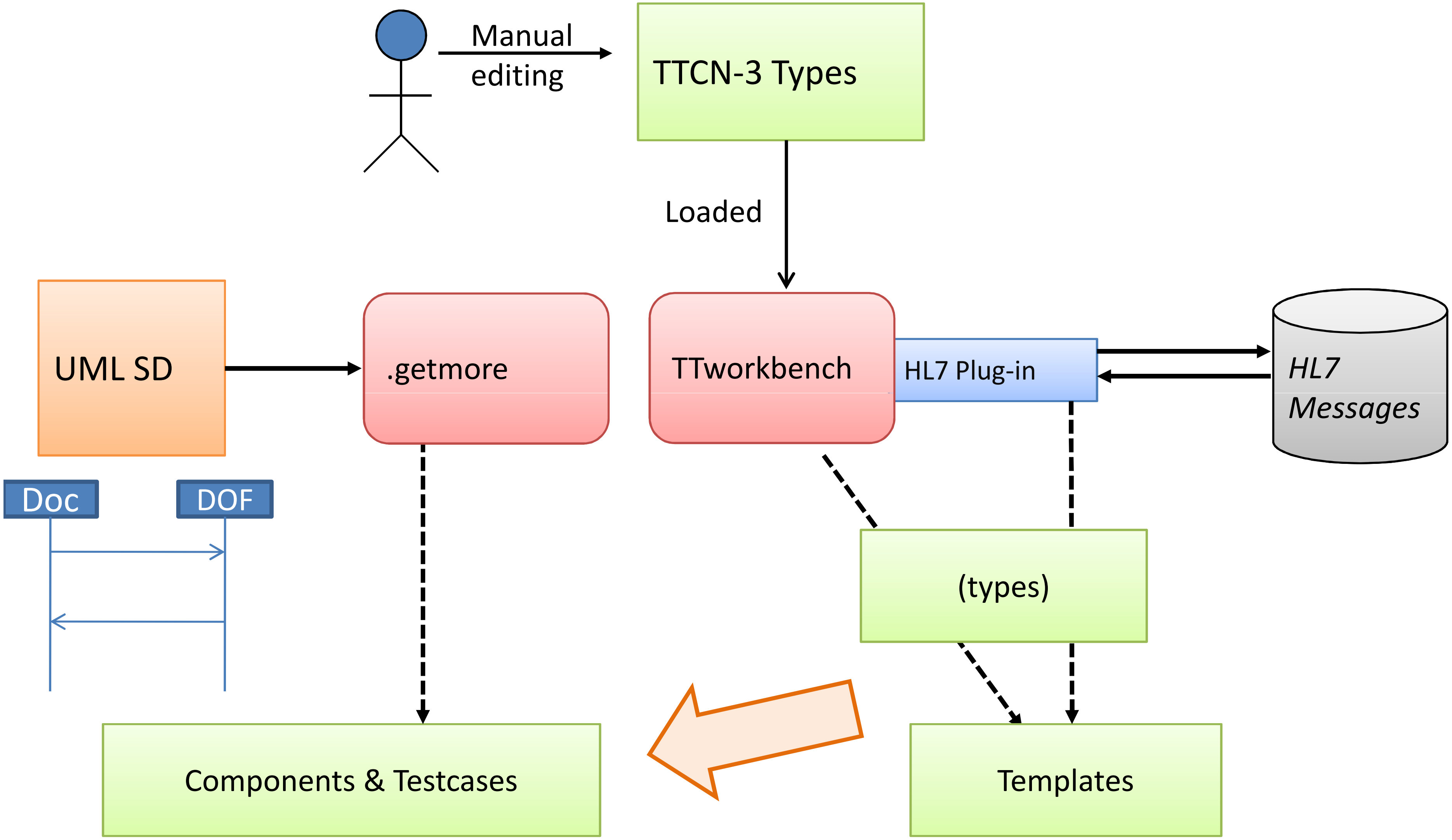
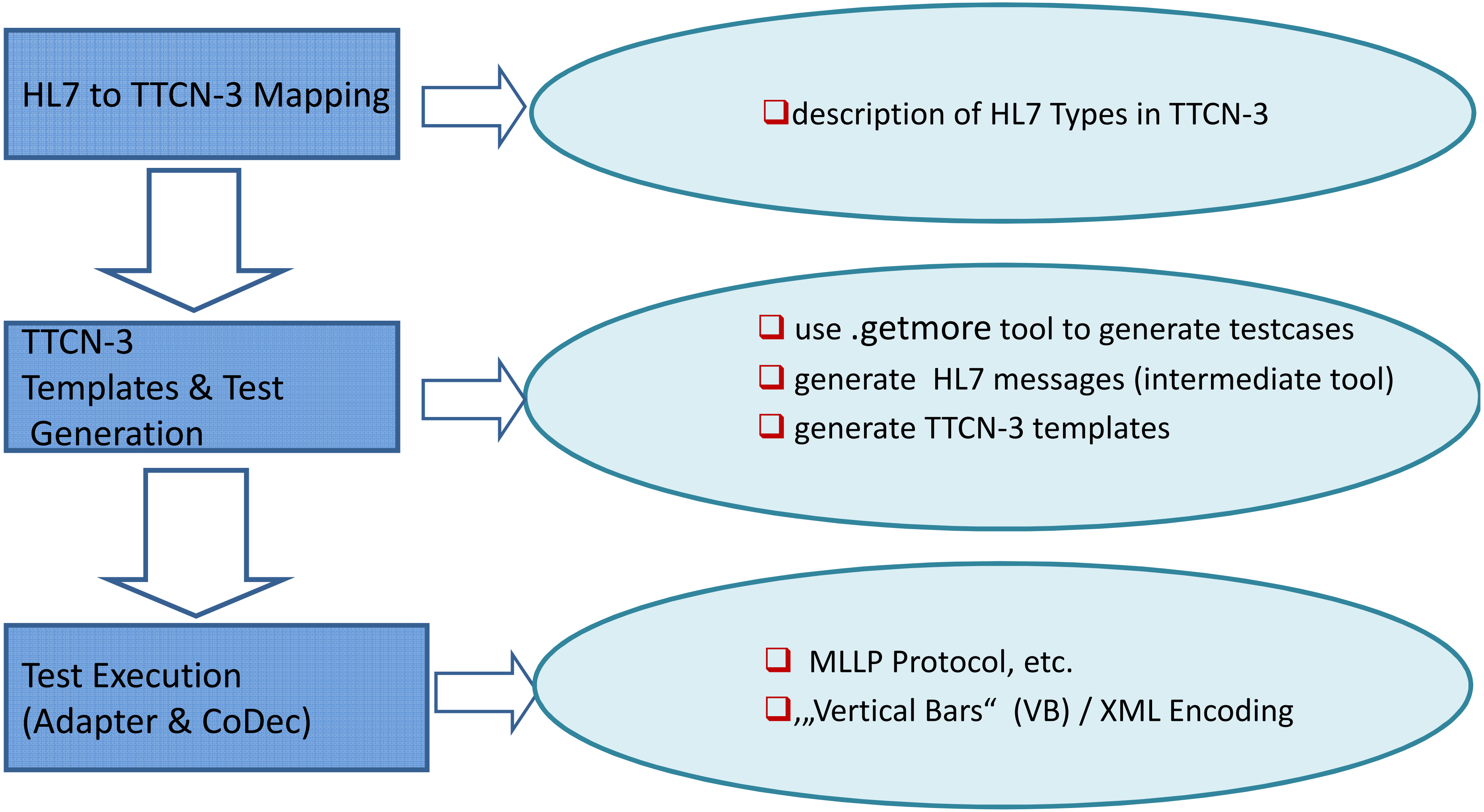
TTCN-3 Testbed Architecture



Testing HL7 Based Systems using TTCN-3



HL7 to TTCN-3 Mapping

- ❑description of HL7 Types in TTCN-3

TTCN-3 Templates & Test Generation

- ❑ use .getmore tool to generate testcases
- ❑ generate HL7 messages (intermediate tool)
- ❑ generate TTCN-3 templates

Test Execution (Adapter & CoDec)

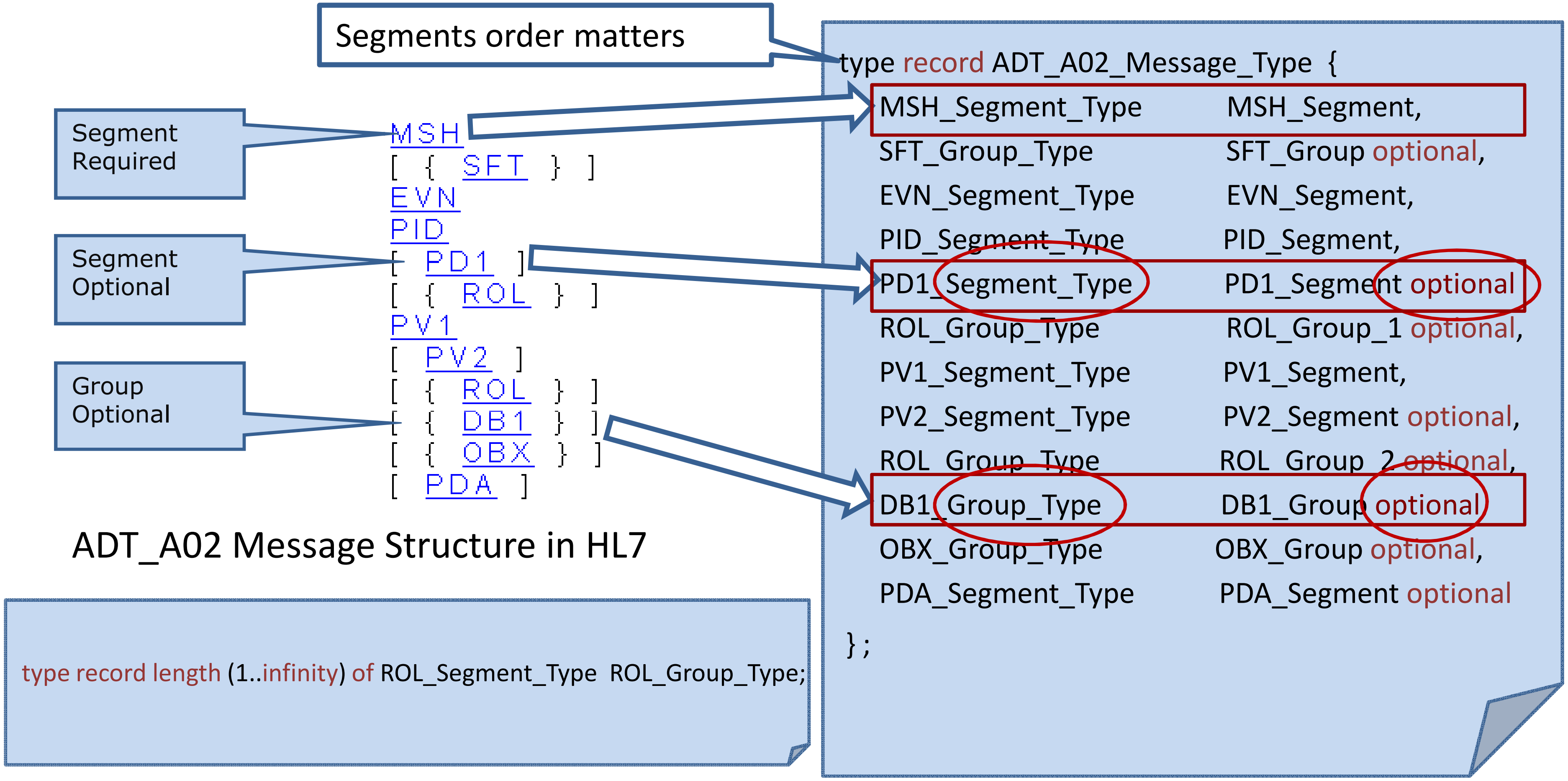
- ❑ MLLP Protocol, etc.
- ❑„Vertical Bars“ (VB) / XML Encoding

Mapping of HL7 Types to TTCN-3

HL7 Entities	Mapping in TTCN-3
Functional Group e.g. ADT, Order Entry, Finance, etc.	**many record types** whose name start with the name of the HL7 functional group, e.g. - type record **ADT_**A01_Message_Type {… - type record **ADT_**A02_Message_Type {…
Message Type e.g. ADT distinguishes among more than thirty separate message definitions based on **"trigger events"** such as A01, A02, etc.	**record types** containing fields of other TTCN-3 types corresponding to HL7 segments as the order of fields matters. e.g. - type record **ADT_A01_Message_Type** {…
Segment Type -can be ***required*** or ***optional***, can be ***nested***, and ***can repeat***. e.g. MSH (Message Header)	**record types** having as fields other simple, e.g., **charstring**, or structured types, i.e., **record**, e.g. - type record **MSH_Segment_Type** { …

Field Type
e.g.
ST (String Data)
VID (Version Identifier)
	charstring based types, e.g.
	- type charstring **ST** length (0..199);
	record types - contain fields of either *basic types* or of *record types,* e.g.
	- type record **VID** {
	Version_ID_Table Version_ID **optional,**
	Country_Code_Table Internationalization_Code **optional,**
	CE International_Version_ID **optional**
	};

Cardinality Mapping



Segments order matters

Segment Required

Segment Optional

Group Optional

```
MSH
[ { SFT } ]
EVN
PID
[ PD1 ]
[ { ROL } ]
PV1
[ PV2 ]
[ { ROL } ]
[ { DB1 } ]
[ { OBX } ]
[ PDA ]
```

ADT_A02 Message Structure in HL7

```
type record length (1..infinity) of ROL_Segment_Type  ROL_Group_Type;
```

```
type record ADT_A02_Message_Type {
  MSH_Segment_Type        MSH_Segment,
  SFT_Group_Type          SFT_Group optional,
  EVN_Segment_Type        EVN_Segment,
  PID_Segment_Type        PID_Segment,
  PD1_Segment_Type        PD1_Segment optional
  ROL_Group_Type          ROL_Group_1 optional,
  PV1_Segment_Type        PV1_Segment,
  PV2_Segment_Type        PV2_Segment optional,
  ROL_Group_Type          ROL_Group_2 optional,
  DB1_Group_Type          DB1_Group optional
  OBX_Group_Type          OBX_Group optional,
  PDA_Segment_Type        PDA_Segment optional
};
```

ADT_A02 Message Structure in TTCN-3

Example Mapping: TTCN-3 Message

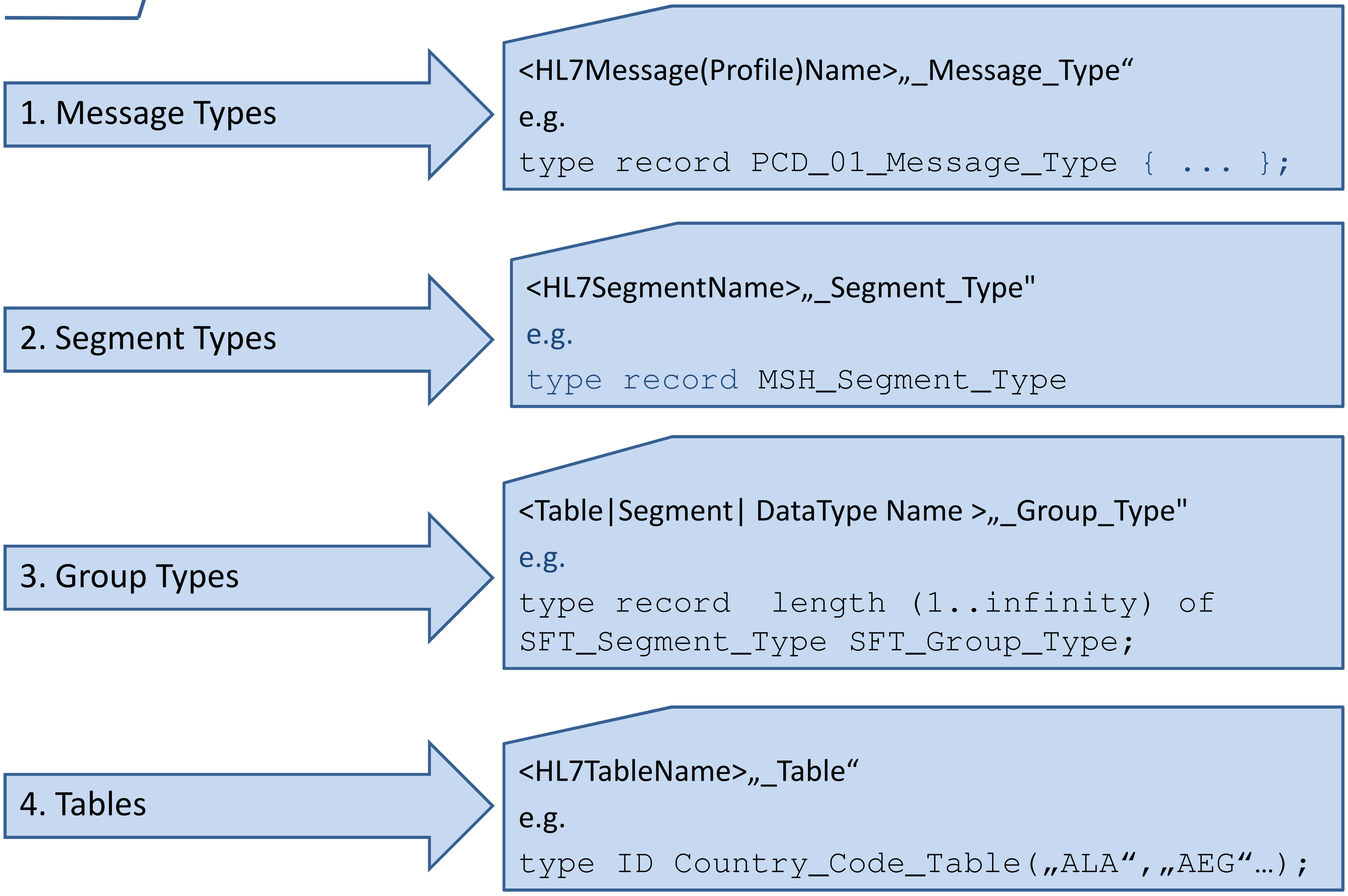
```
type record ADT_A01_Message_Type
{
        MSH_Segment_Type MSH_Segment,
        SFT_Group_Type SFT_Group optional,
        EVN_Segment_Type EVN_Segment,
        PD1_Segment_Type PD1_Segment optional,
        ROL_Group_Type  ROL_Group_1 optional,
        NK1_Group_Type  NK1_Group optional,
        PV1_Segment_Type PV1_Segment,
        PV2_Segment_Type PV2_Segment optional,
        ROL_Group_Type  ROL_Group_2 optional,
        DB1_Group_Type  DB1_Group optional,
        OBX_Group_Type  OBX_Group optional,
        AL1_Group_Type  AL1_Group optional,
        DG1_Group_Type  DG1_Group optional,
        DRG_Segment_Type DRG_Segment optional,
        ADT_A01_Procedure_Group_Type ADT_A01_
        GT1_Group_Type  GT1_Group optional,
        ADT_A01_Insurance_Group_Type ADT_A01_
        ACC_Segment_Type ACC_Segment optional,
        UB1_Segment_Type UB1_Segment optional,
        UB2_Segment_Type UB2_Segment optional,
        PDA_Segment_Type PDA_Segment optional
};
```

```
type record MSH_Segment_Type
{
  MSH_Segment_ID_Type MSH_Segment_ID,
  ST1 Field_Separator,
  ST4 Encoding_Characters,
  HD Sending_Application o
  HD Sending_Facility optio
  HD Receiving_Application
  HD Receiving_Facility opti
  TS TimeOfMessage,
  ST40 Security optional,
  MSG Message_Type,
  ST20 Message_Control_ID
  PT  Processing_ID,
  VID Version_ID,
  NM Sequence_Number op
  ST180 Continuation_Point
  Acc_App_Acknowledgeme
  Acc_App_Acknowledgeme
  Country_Code_Table Coun
  Character_Set_Group_Typ
  CE Principal_Language_Of
  Character_Set_Handling_S
  EI_Group_Type Message_
};
```

```
/*2.A.1.74 ST - string data -- LEN 40*/
type charstring ST40 length (0..40);
```

```
/*Table 0399: Country code*/
type ID Country_Code_Table(
"ALA", //AALAND ISLANDS   AX    248
"AFG", //AFGHANISTAN  AF    004
"ALB", //ALBANIA     AL    008
"DZA", //ALGERIA     DZ    012
"ASM", //AMERICAN SAMOA AS    016
"AND", //ANDORRA    AD    020
"AGO", //ANGOLA     AO    024
"AIA", //ANGUILLA   AI    660
...
);
```

Mapping Guidelines – Naming Conventions



1. Message Types

<HL7Message(Profile)Name>„_Message_Type“

e.g.

```
type record PCD_01_Message_Type { ... };
```

2. Segment Types

<HL7SegmentName>„_Segment_Type"

e.g.

```
type record MSH_Segment_Type
```

3. Group Types

<Table|Segment| DataType Name >„_Group_Type"

e.g.

```
type record  length (1..infinity) of
SFT_Segment_Type SFT_Group_Type;
```

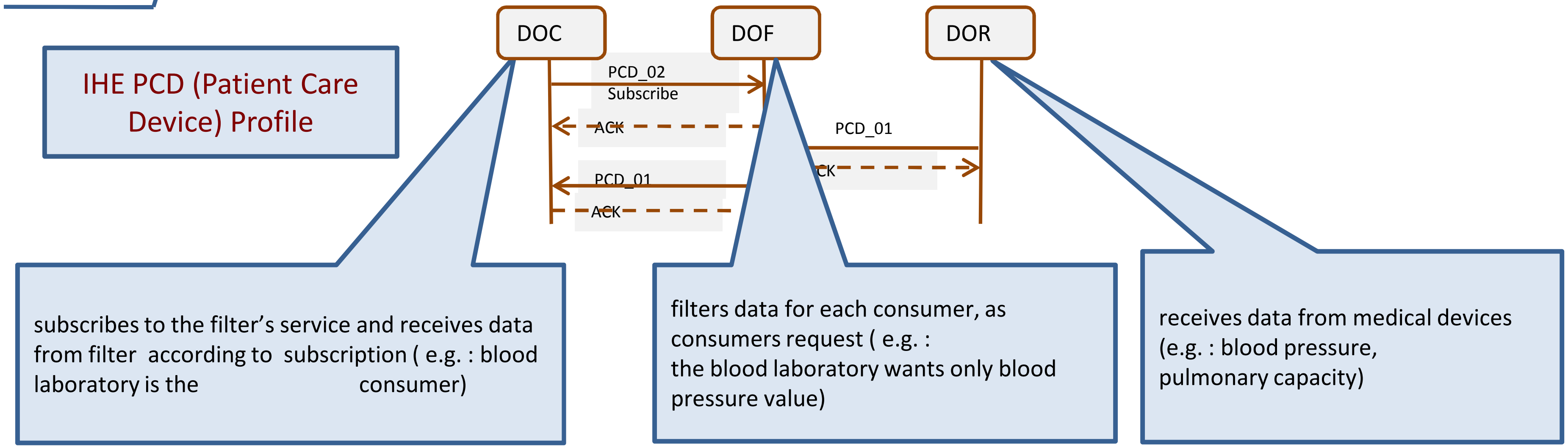
4. Tables

<HL7TableName>„_Table“

e.g.

```
type ID Country_Code_Table(„ALA“,„AEG“…);
```

An Example – Description



IHE PCD (Patient Care Device) Profile

subscribes to the filter's service and receives data from filter according to subscription (e.g. : blood laboratory is the consumer)

filters data for each consumer, as consumers request (e.g. : the blood laboratory wants only blood pressure value)

receives data from medical devices (e.g. : blood pressure, pulmonary capacity)

- ❑ Components
  - ❑ emulate the Roles

type component DOF_System_Component_Type
type component DOC_Component_Type

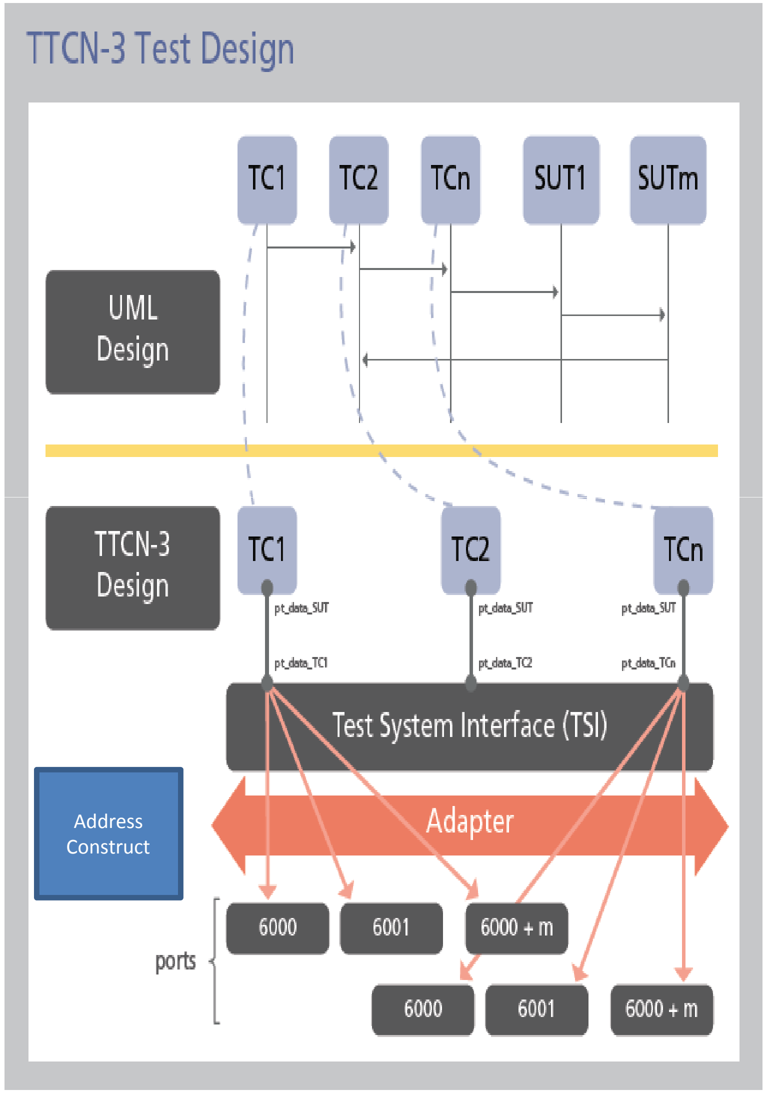
- ❑ Ports
  - ❑ emulate the interaction points between actors
  - ❑ Design rule: different protocols (e.g. MLLP, DICOM) different port types

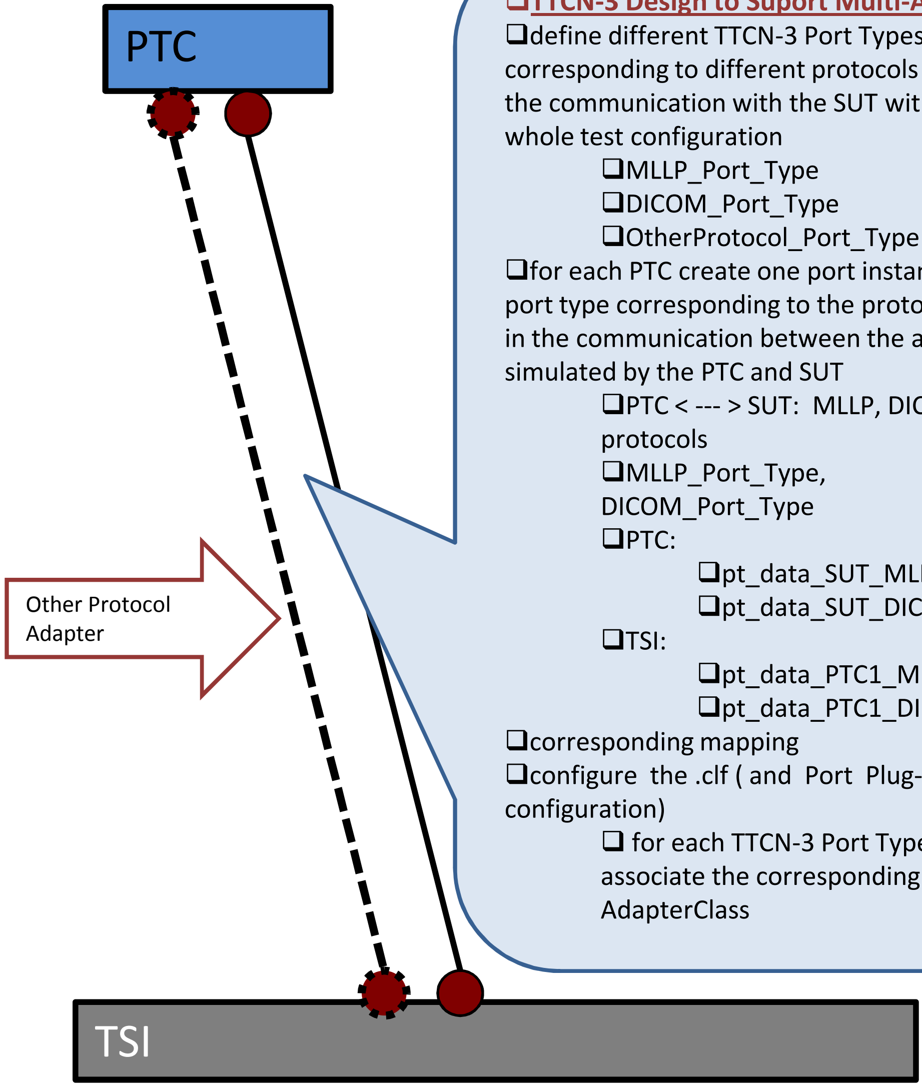
type port HL7_Port_Type p_data;

- ❑ Templates

template PCD_01_Message_Type
    PCD_01_Send_DORActor2DOFActor_Template

Test Design and Multi-Adapter Realization





❑**TTCN-3 Design to Suport Multi-Adapter:**

❑define different TTCN-3 Port Types corresponding to different protocols used in the communication with the SUT within the whole test configuration

- ❑MLLP_Port_Type
- ❑DICOM_Port_Type
- ❑OtherProtocol_Port_Type

❑for each PTC create one port instance of port type corresponding to the protocol used in the communication between the actor simulated by the PTC and SUT

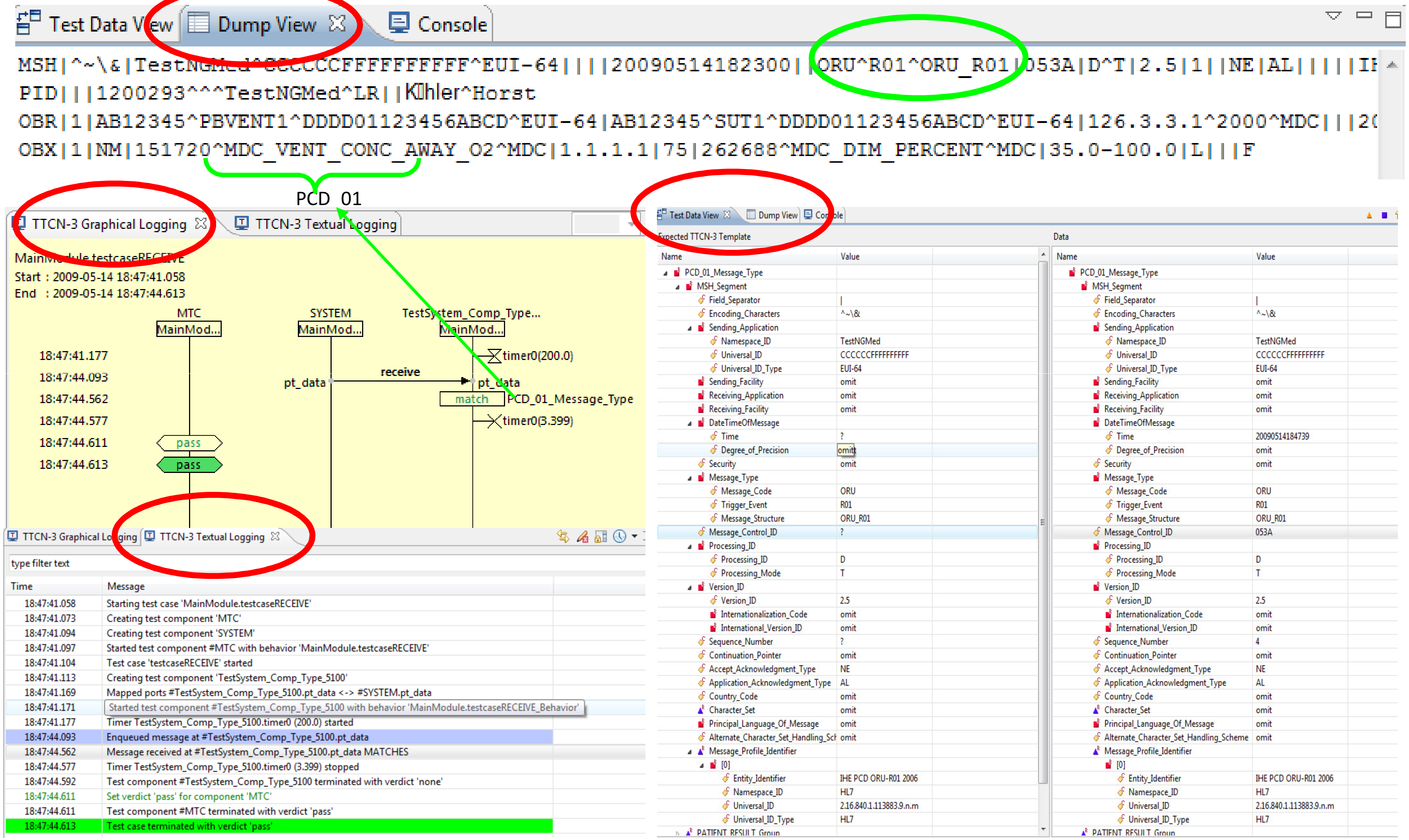
- ❑PTC < --- > SUT: MLLP, DICOM protocols
- ❑MLLP_Port_Type, DICOM_Port_Type
- ❑PTC:
  - ❑pt_data_SUT_MLLP
  - ❑pt_data_SUT_DICOM
- ❑TSI:
  - ❑pt_data_PTC1_MLLP
  - ❑pt_data_PTC1_DICOM

❑corresponding mapping

❑configure the .clf (and Port Plug-in configuration)

- ❑ for each TTCN-3 Port Type associate the corresponding AdapterClass

TTCN-3 Execution with TTworkbench



```
MSH|^~\&|TestNGMed^CCCCCCFFFFFFFFFF^EUI-64||||20090514182300||ORU^R01^ORU_R01|053A|D^T|2.5|1||NE|AL||||IH
PID|||1200293^^^TestNGMed^LR||K□hler^Horst
OBR|1|AB12345^PBVENT1^DDDD01123456ABCD^EUI-64|AB12345^SUT1^DDDD01123456ABCD^EUI-64|126.3.3.1^2000^MDC|||20
OBX|1|NM|151720^MDC_VENT_CONC_AWAY_O2^MDC|1.1.1.1|75|262688^MDC_DIM_PERCENT^MDC|35.0-100.0|L|||F
```

MainModule.testcaseRECEIVE
Start : 2009-05-14 18:47:41.058
End : 2009-05-14 18:47:44.613

type filter text

Time	Message
18:47:41.058	Starting test case 'MainModule.testcaseRECEIVE'
18:47:41.073	Creating test component 'MTC'
18:47:41.094	Creating test component 'SYSTEM'
18:47:41.097	Started test component #MTC with behavior 'MainModule.testcaseRECEIVE'
18:47:41.104	Test case 'testcaseRECEIVE' started
18:47:41.113	Creating test component 'TestSystem_Comp_Type_5100'
18:47:41.169	Mapped ports #TestSystem_Comp_Type_5100.pt_data <-> #SYSTEM.pt_data
18:47:41.171	Started test component #TestSystem_Comp_Type_5100 with behavior 'MainModule.testcaseRECEIVE_Behavior'
18:47:41.177	Timer TestSystem_Comp_Type_5100.timer0 (200.0) started
18:47:44.093	Enqueued message at #TestSystem_Comp_Type_5100.pt_data
18:47:44.562	Message received at #TestSystem_Comp_Type_5100.pt_data MATCHES
18:47:44.577	Timer TestSystem_Comp_Type_5100.timer0 (3.399) stopped
18:47:44.592	Test component #TestSystem_Comp_Type_5100 terminated with verdict 'none'
18:47:44.611	Set verdict 'pass' for component 'MTC'
18:47:44.611	Test component #MTC terminated with verdict 'pass'
18:47:44.613	Test case terminated with verdict 'pass'

Expected TTCN-3 Template

Name	Value
PCD_01_Message_Type	
MSH_Segment	
Field_Separator	|
Encoding_Characters	^~\&
Sending_Application	
Namespace_ID	TestNGMed
Universal_ID	CCCCCCFFFFFFFFFF
Universal_ID_Type	EUI-64
Sending_Facility	omit
Receiving_Application	omit
Receiving_Facility	omit
DateTimeOfMessage	
Time	?
Degree_of_Precision	omit
Security	omit
Message_Type	
Message_Code	ORU
Trigger_Event	R01
Message_Structure	ORU_R01
Message_Control_ID	?
Processing_ID	
Processing_ID	D
Processing_Mode	T
Version_ID	
Version_ID	2.5
Internationalization_Code	omit
International_Version_ID	omit
Sequence_Number	?
Continuation_Pointer	omit
Accept_Acknowledgment_Type	NE
Application_Acknowledgment_Type	AL
Country_Code	omit
Character_Set	omit
Principal_Language_Of_Message	omit
Alternate_Character_Set_Handling_Sch	omit
Message_Profile_Identifier	
[0]	
Entity_Identifier	IHE PCD ORU-R01 2006
Namespace_ID	HL7
Universal_ID	2.16.840.1.113883.9.n.m
Universal_ID_Type	HL7
PATIENT_RESULT_Group	

Data

Name	Value
PCD_01_Message_Type	
MSH_Segment	
Field_Separator	|
Encoding_Characters	^~\&
Sending_Application	
Namespace_ID	TestNGMed
Universal_ID	CCCCCCFFFFFFFFFF
Universal_ID_Type	EUI-64
Sending_Facility	omit
Receiving_Application	omit
Receiving_Facility	omit
DateTimeOfMessage	
Time	20090514184739
Degree_of_Precision	omit
Security	omit
Message_Type	
Message_Code	ORU
Trigger_Event	R01
Message_Structure	ORU_R01
Message_Control_ID	053A
Processing_ID	
Processing_ID	D
Processing_Mode	T
Version_ID	
Version_ID	2.5
Internationalization_Code	omit
International_Version_ID	omit
Sequence_Number	4
Continuation_Pointer	omit
Accept_Acknowledgment_Type	NE
Application_Acknowledgment_Type	AL
Country_Code	omit
Character_Set	omit
Principal_Language_Of_Message	omit
Alternate_Character_Set_Handling_Scheme	omit
Message_Profile_Identifier	
[0]	
Entity_Identifier	IHE PCD ORU-R01 2006
Namespace_ID	HL7
Universal_ID	2.16.840.1.113883.9.n.m
Universal_ID_Type	HL7
PATIENT_RESULT_Group	

Summary and Outlook

- ❑ Summary
  - ❑ TTCN-3 testbed architecture targeting a higher degreee of automation
  - ❑ mapping from HL7 types to TTCN-3 types
  - ❑ test derivation and design principles
  - ❑ multi-Adapter realization
  - ❑ mechanism for generating TTCN-3 templates out of specified types and existing pools of HL7 messages
- ❑ Outlook
  - ❑ use the framework for various test scenarios of HL7/IHE systems(support for multiple protocols, e.g. DICOM, MLLP)
  - ❑ identification of a taxonomy of security threats
  - ❑ risk-based model definition and test priotization in order to improve the fault-detection time