Testing SIP Using XML Protocol Templates

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http://www-x.antd.nist.gov/index.html

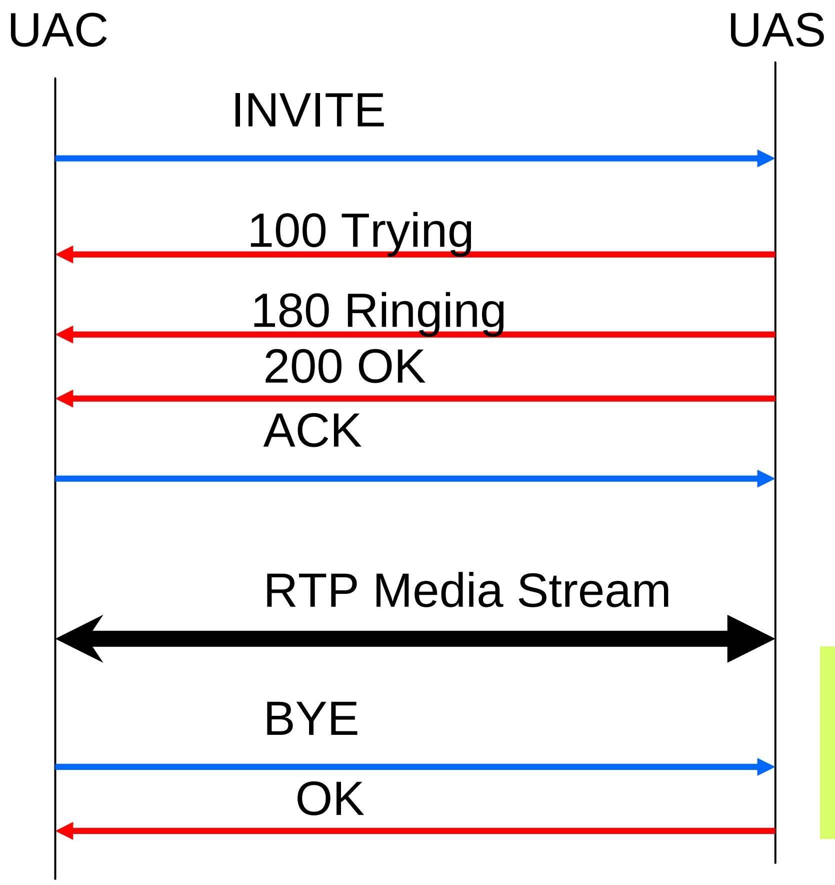
Introducing SIP

- Peer-to-peer Signaling Protocol used for IP Telephony, Conferencing and Instant Messaging
- Introduced in 1999
  - 9 revisions and 2 RFCs since then!
- Widely deployed - Microsoft RTC Server, IM Client, Cisco gateways etc.

Introducing SIP

- Text based
  - unlike H.323
- “Stateless”
  - Protocol state encoded in message
- Extensible
  - Many extensions exist.
- Can run over unreliable or reliable transports
  - Out of order / dropped signaling messages.

Simple SIP Call Flow



UAS – User Agent Server

UAC – User Agent Client

There can be intermediate Signaling nodes (Proxy Servers that keep call state).

Protocol Complications

- Protocol is robust and extensible:
  - SIP keeps enough state in the Messages to deal with all these complications.
  - Correct implementation is tricky.
- Signaling may have to go through multiple hops.
- Proxy servers may go down without warning.
- Peers may go down without warning.
- Sessions can move without prior planning.
- Network can fail without warning.

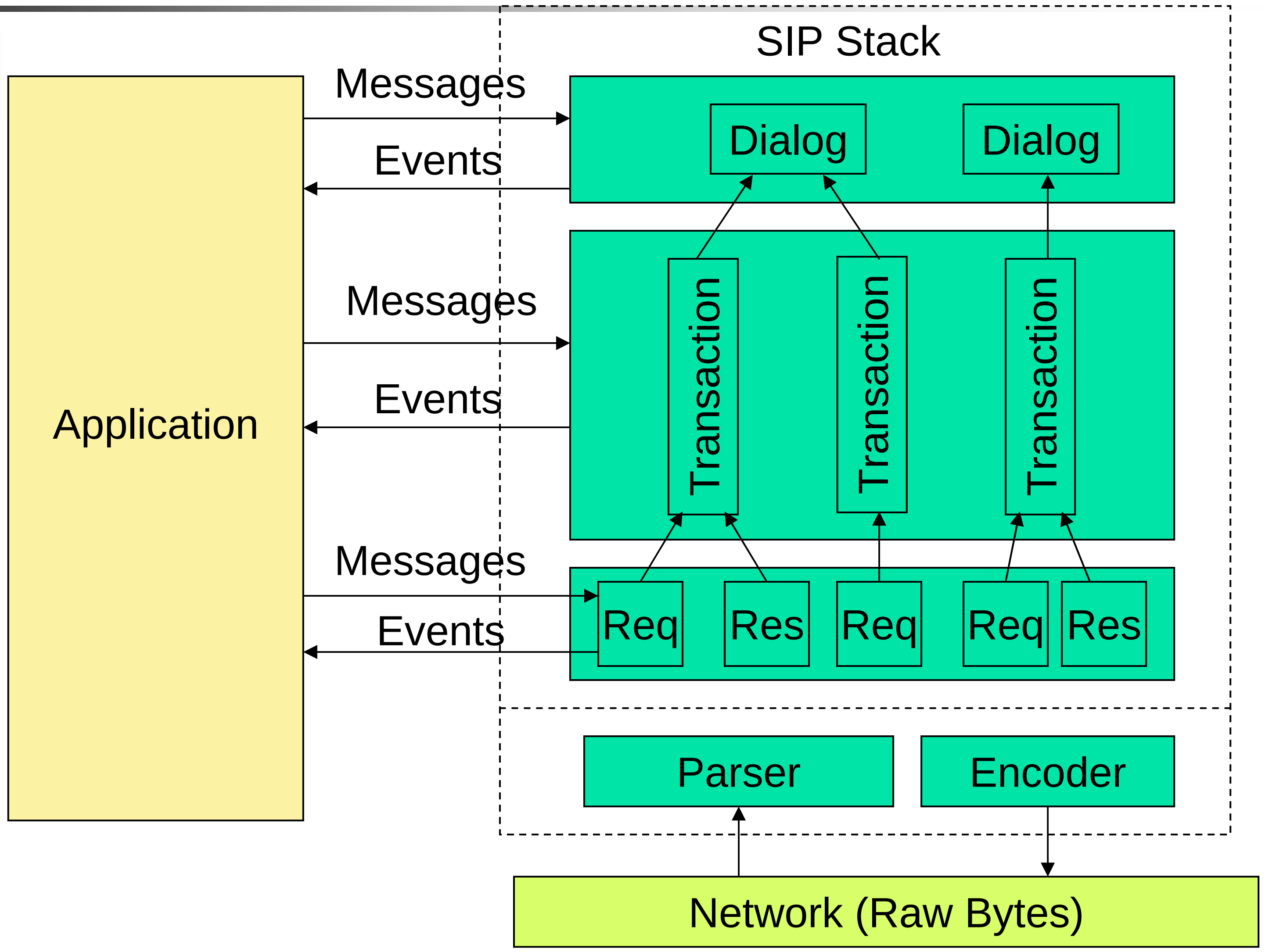
SIP Testing

- Load Testing
  - Generate 100's of simultaneous sessions.
- Call Flow Testing
  - Unit testing the SIP Protocol Implementation by generation of scenarios.
  - Primary mode of testing during SIP interoperability test events.

Generating SIP Test Cases

- Exhaustive testing generates too many test cases.
- End-to-end testing is feasible
    - protocol state and causality is encoded in the Messages/Call Flows.
- Understanding implementation complexities results in good test cases.

SIP Application Structure



Constructing Test Cases For SIP

- Layer the Test Cases like Applications/Stacks are layered
  - Message Layer, Transaction Layer and Dialog Layer tests
  - This prunes the number of tests and makes the tests more meaningful.

SIP Messages

- Protocol encodes all the state it needs in the message.
  - HTTP/Mail – like headers and a Request Line or a Status Line.
  - SIP Components use Messages to Identify protocol abstractions.
- Protocol State is encoded in
  - Request URI, From, To, Via, CSeq, CallId, Max-Forwards
- *Stateless* components built directly on Message Layer.

Message Layer

- Handle Incoming Requests/Responses
  - Read Raw messages from Network.
  - Output Parsed Messages to Transaction layer.
- Dispatch outgoing messages
  - Input Parsed Messages from Transaction Layer.
  - Encode Parsed Messages and send out on Network.

Message Layer

- Grammar is context sensitive and defined using ABNF
  - Grammar has changed between RFCs
- Grammar is compositional (mail, URL, HTTP)
- Parser generators have trouble with RFC grammar
  - usually hand coded parsers are used
  - Some tools are available – antlr
- Headers are Text (Body can be Binary)

Transaction Layer

- SIP Applications are transaction oriented and usually interact directly with a transaction layer.
- Primary duties of the Transaction Layer
  - Request Response matching
  - Retransmission handling for unreliable media.
  - Timeout handling

Transaction Layer: Common Bugs

- Implementations do not implement the Transaction State Machine correctly
- Implementations have difficulty keeping backward compatibility
  - In RFC 3261 the branch ID of the topmost “Via” header identifies the Transaction
  - RFC 2543 used a hash over From, To, Request URI and Via headers

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Transaction Layer Testing

Testing the State Machine

- Simulate lost messages
  - Drop Requests/Responses
- Simulate timing variations
  - Delay Responses
  - Generate out of order responses Simulate stray messages
- CANCEL messages for Server Transactions that do not exist.
  - Late CANCELS
  - Late ACKs
  - Duplicate ACKs
  - Out of Sequence messages.

Transaction Layer Testing

Transaction matching / identification

- Via Header branch parameter variations
  - RFC 3261 relies on this for matching
- Variations in From / To, Request URI and CSeq Sequence Number and CSeq Method
  - RFC 2543 relies on this for matching.

Dialog Layer

- Dialog is a peer-to-peer association between communicating SIP endpoints
  - Dialogs established by Dialog creating Transactions.
  - Not all transactions create Dialogs.
  - A Transaction may belong to exactly one Dialog.
- SIP messages carry enough state to identify the Dialog directly from the message

Dialog Layer

- Manages Dialog Creation/Teardown
  - Dialogs created by transaction completion
- Manages Route Sets
  - Test agent must test for expected Route / Record-Route headers in requests
- Manages Sequence Numbers
  - Test agent must test for sequence number assignment
- Manages the Request URI

Dialog Layer: Common Bugs

- Dialogs are identified by portions of a message:
  - CallID, From, To tags in RFC 3261
  - CallID, From, To addresses RFC2543
  - Stacks try to keep backward compatibility
  - Bugs are frequently caused by tag management problems.

Testing the Dialog Layer

- Requests/Responses within and outside Dialog
- Requests/Response for Spurious Dialogs
  - Variation in From/To Headers and Tags
  - Generate Requests for Dialogs that do not exist.
- CSeq Header Sequence number variations
  - Out of sequence message arrivals

Call Flow Testing Approach

- Test the causal sequence of messages required to establish and release SIP Calls
- SIP Protocol Template – an XML pattern for a SIP Call Flow.
- XML Pattern input to a customizable user agent which can run the Call Flow (Responder)

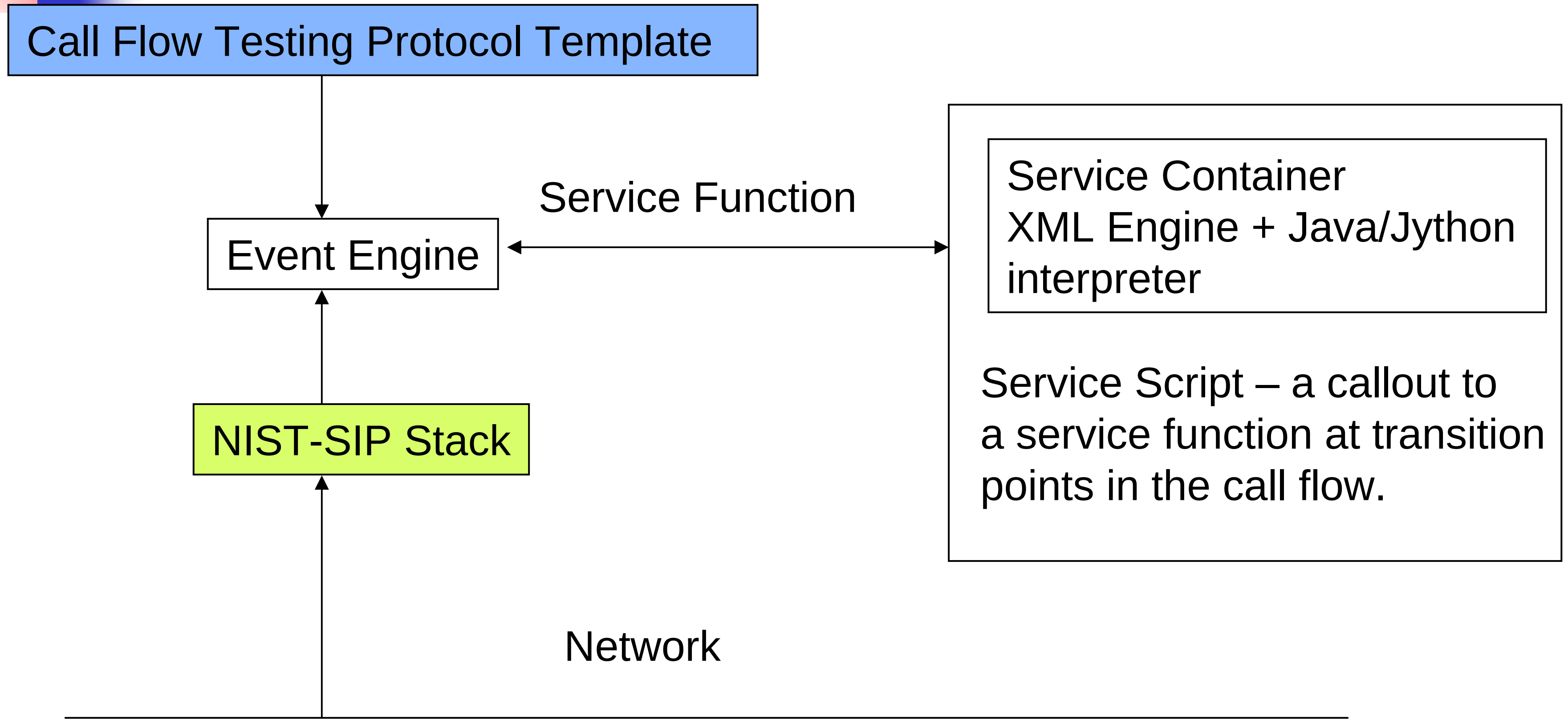
Motivation

- XML is hierarchical
  – good way to represent SIP protocol abstractions
- Interoperability testing with control
  - Typically components are tested in call flow scenarios
  - Typically operating in an un-controlled environment
  - Reproducing complex scenarios is difficult

XML representation of SIP

- Define a set of XML tags to represent the required headers in a SIP message
- Define XML tags to express call flow state machine
- Input to Event Engine that can run the call flow
- Generate variations of the call flow by modifying the XML script

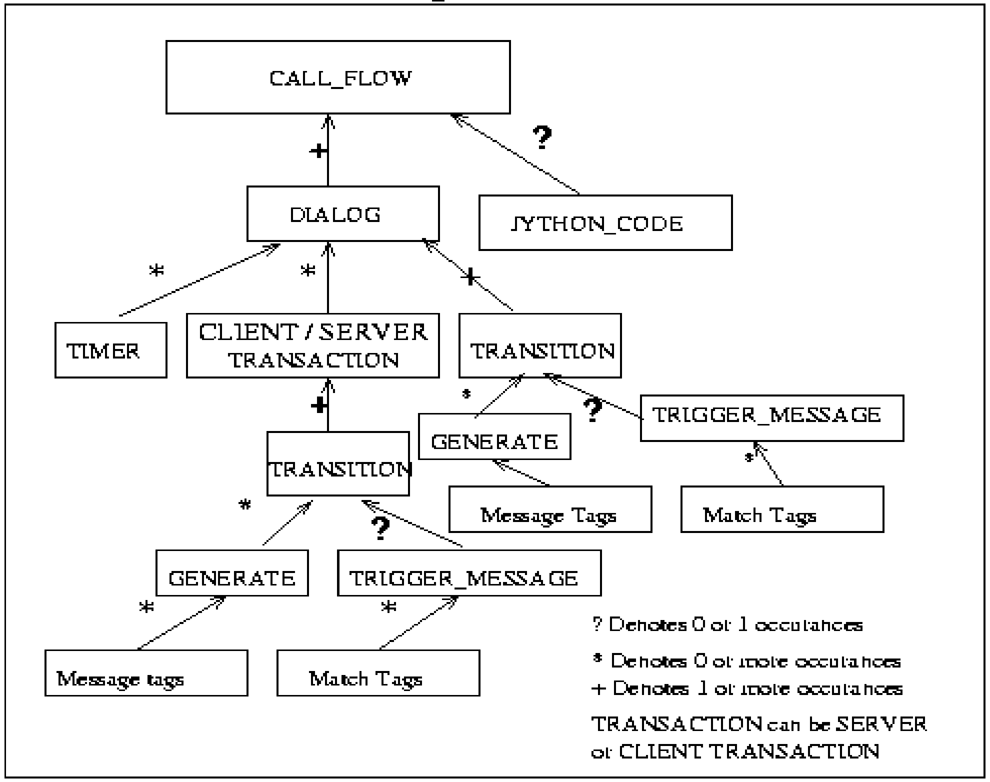
Test Scripting Architecture



Service Script – a callout to a service function at transition points in the call flow.

XML Tags Mirror Protocol Structure

XML Tags



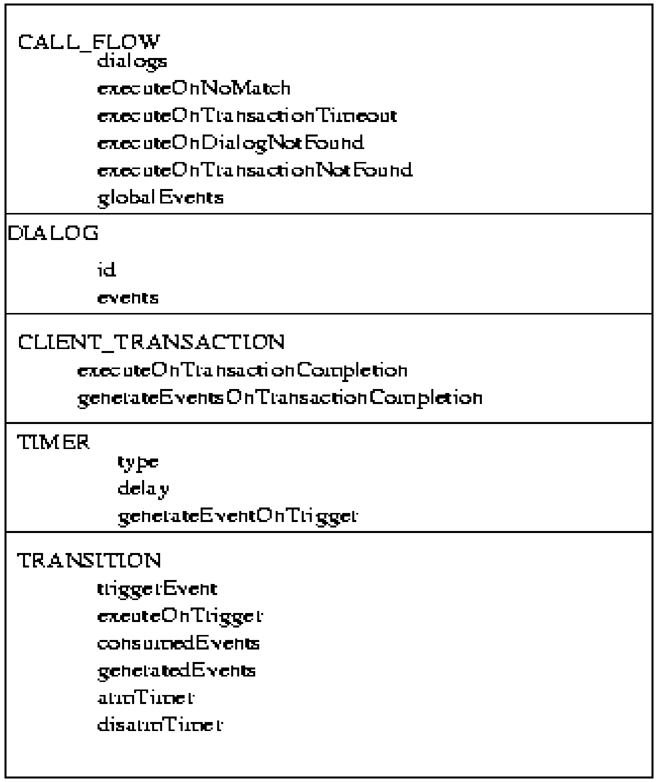
? Denotes 0 or 1 occurances

* Denotes 0 or more occurances

+ Denotes 1 or more occurances

TRANSACTION can be SERVER or CLIENT TRANSACTION

Partial List of Attributes



CALL_FLOW
- dialogs
- executeOnNoMatch
- executeOnTransactionTimeout
- executeOnDialogNotFound
- executeOnTransactionNotFound
- globalEvents

DIALOG
- id
- events

CLIENT_TRANSACTION
- executeOnTransactionCompletion
- generateEventsOnTransactionCompletion

TIMER
- type
- delay
- generateEventOnTrigger

TRANSITION
- triggerEvent
- exeuteOnTrigger
- consumedEvents
- generatedEvents
- armTimer
- disarmTimer

Test Script

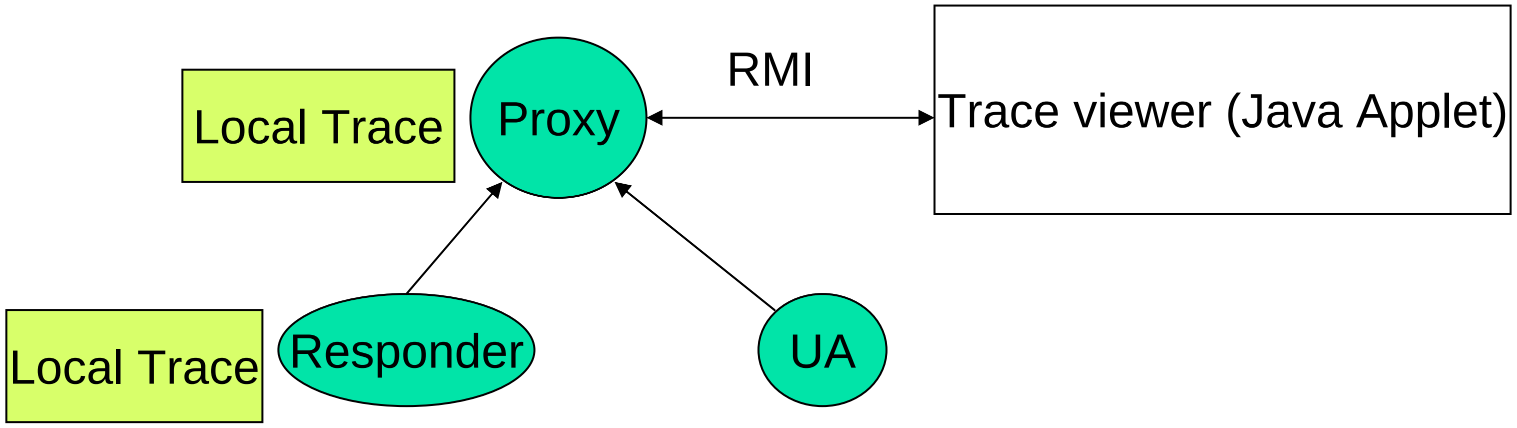
- Pattern matching, timer events and transitions used for triggering transitions in test script.
- Test script is represented by a set of Transactions that may be nested within a dialog.
- The entire transaction state machine is exposed and defined using XML.
  - Timing can be varied and controlled errors can be created.
- Service code can be called when messages arrive, transactions are started, transactions complete, dialogs are created or dialogs complete.

Why Do It?

- Simple, clear expression of test scenarios
  - Protocol maps to XML script one to one
- Can generate multiple scenarios based on small variations for the same call flow.
- Can simulate common end-point (User Agent) behavior.
- Can generate controlled error conditions/timing variations.

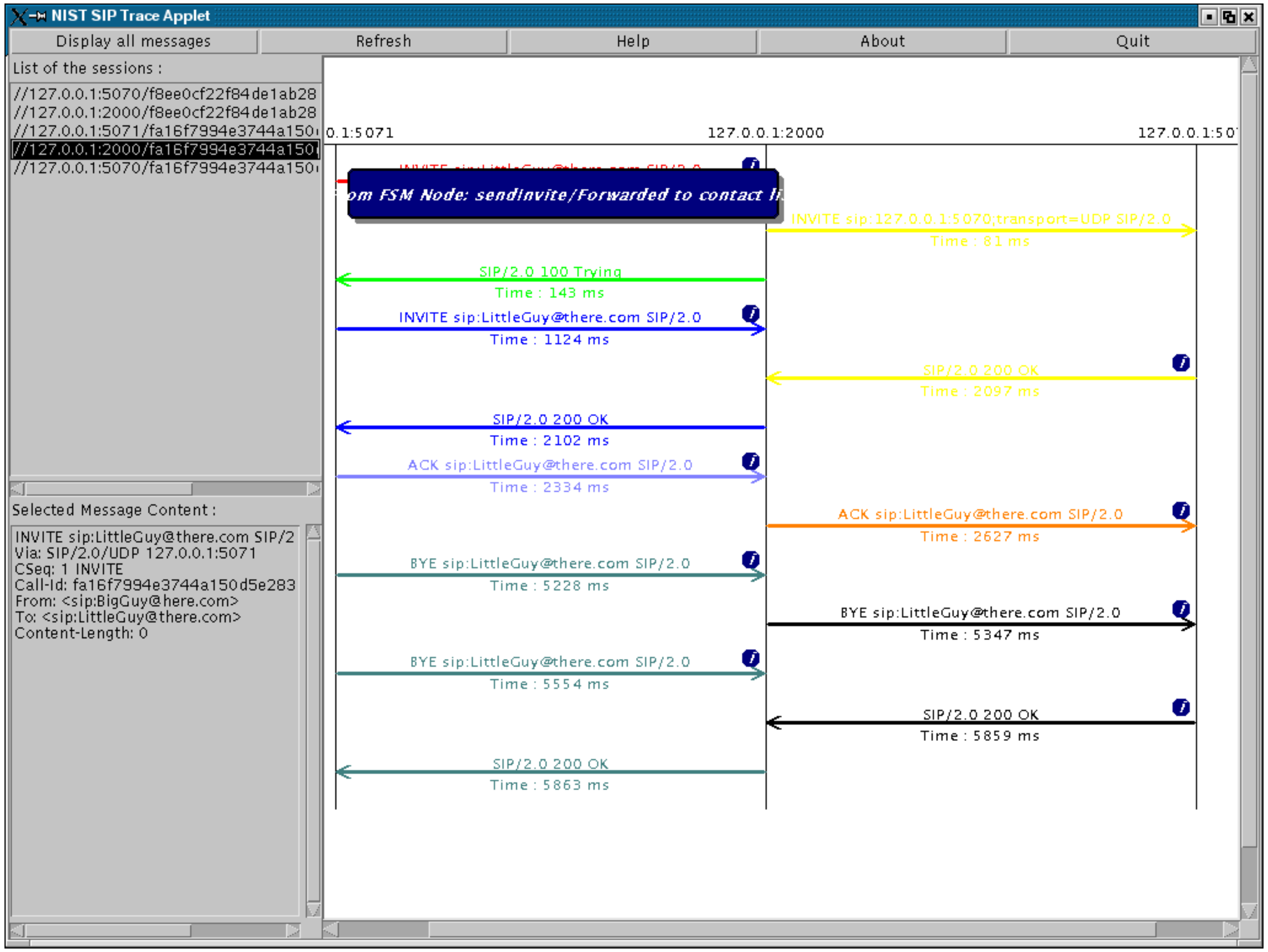
Test Log File Collection

- Log file is a diagnostic tool to help debug protocol problems.
- Stack generates log files using XML format.
  - Distributed traces are collated at test proxy
- Trace viewer pairs arcs by Transactions



Visualizing the Trace

- Java Applet collects and visualizes distributed call flow trace files.
- Augmented with XML script state information.
- Enables debugging call flows & test scripts.



```
//127.0.0.1:5070/f8ee0cf22f84de1ab28
//127.0.0.1:2000/f8ee0cf22f84de1ab28
//127.0.0.1:5071/fa16f7994e3744a150
//127.0.0.1:2000/fa16f7994e3744a150
//127.0.0.1:5070/fa16f7994e3744a150
```

```
INVITE sip:LittleGuy@there.com SIP/2
Via: SIP/2.0/UDP 127.0.0.1:5071
CSeq: 1 INVITE
Call-Id: fa16f7994e3744a150d5e283
From: <sip:BigGuy@here.com>
To: <sip:LittleGuy@there.com>
Content-Length: 0
```

```
om FSM Node: sendInvite/Forwarded to contact li
INVITE sip:127.0.0.1:5070;transport=UDP SIP/2.0
Time : 81 ms
SIP/2.0 100 Trying
Time : 143 ms
INVITE sip:LittleGuy@there.com SIP/2.0
Time : 1124 ms
SIP/2.0 200 OK
Time : 2097 ms
SIP/2.0 200 OK
Time : 2102 ms
ACK sip:LittleGuy@there.com SIP/2.0
Time : 2334 ms
ACK sip:LittleGuy@there.com SIP/2.0
Time : 2627 ms
BYE sip:LittleGuy@there.com SIP/2.0
Time : 5228 ms
BYE sip:LittleGuy@there.com SIP/2.0
Time : 5347 ms
BYE sip:LittleGuy@there.com SIP/2.0
Time : 5554 ms
SIP/2.0 200 OK
Time : 5859 ms
SIP/2.0 200 OK
Time : 5863 ms
```

Related work

- TTCN testing of SIP
  - Procedural test cases
  - Not explicitly tailored to SIP
- Using our approach
  - Simplifies logical design
  - XML tools can be used for test case design.

http://www-x.antd.nist.gov/proj/iptel

Extensions and Future Work

- Standardize XML representation of the SIP protocol
- Off line protocol verification
  - Generation of Call flows based on message logs
  - Verification of traces based on message logs
- Customizable test scripts
- Extensions to service creation.
  - Integration with other distributed scripting technologies
  - JXTA, SOAP