INTERSTATE: A Stateful Protocol Fuzzer for SIP

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Fuzzing Basics

- Transmit a sequence of messages to a server, attempting to “break” it
- Apply “fuzzing functions” to message fields to reveal vulnerabilities

Typical Fuzzing Functions

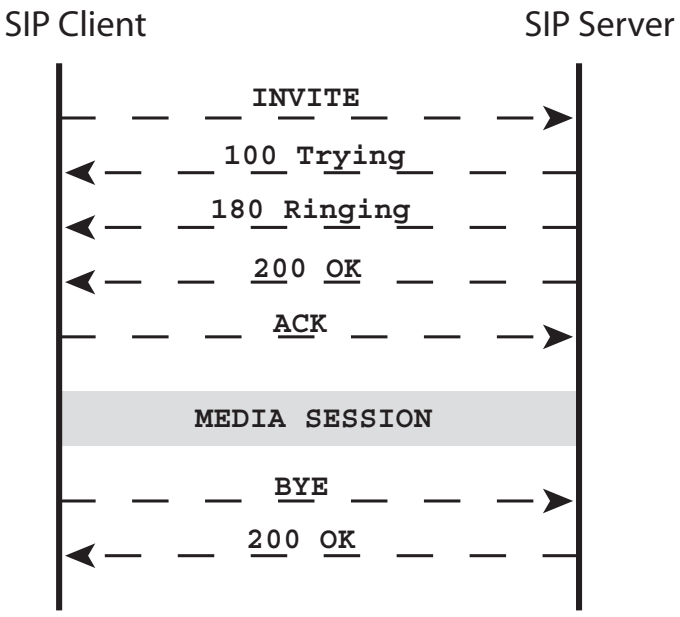
- **Buffer Overflow** - Make a field very long to force buffer overflow
- **Command Injection** - Insert shell metacharacters to see if string is passed to a shell
- **SQL Injection** - Insert SQL reserved word to see if string is used to build an SQL query

```
INVITE sip:marXXXXXXXXXXXXXXXXXXXXXXXXXXXconi@radio.org SIP/2.0
Via: SIP/2.0/UDP lab.test.org:5060;branch=ziuh2w
Max-Forwards: 70
To: G. Marconi <sip:Marconi@radio.org>
From: Nikola Tesla <sip:n.tesla@test.org>;tag=98767
Call-ID: 123456789@lab.test.org
Cseq: 1 INVITE
```

Session Initiation Protocol (SIP)

•Used to start, end, and modify communication sessions between VOIP phones

•SIP does not transfer media (audio/video)



User Agent Client (UAC)

- Initiates call
- Sends Request Messages

User Agent Server (UAS)

- Receives call requests
- Send Response Messages

•We do not consider other SIP entities, proxies, registrar servers, etc.

•We are fuzzing the UAS, fuzzer is a client

Previous Work, SIP Fuzzers

- **SNOOZE Fuzzer**
- "SNOOZE: toward a Stateful NetwOrk prOtocol fuzZEr", G. Banks, M. Cova, V. Felmetsger, K. Almeroth, R. Kemmerer, G. Vigna, Information Security Conference, 2006
- Protocol state machine is used, XML-based description
- Fuzzing scenario defines message sequence, what to fields to fuzz, what fuzzing primitives to use
- Fuzzing scenarios must be developed manually

Previous Work, SIP Fuzzers

- **PROTOS Suite**
- Free version: http://www.ee.oulu.fi/research/ouspg/protos/testing/c07/sip
- Industrial version: http://www.codenomicon.com
- Predefined test suite, 4527 test cases
- Fuzz the INVITE message, teardown with CANCEL/ACK messages
- Detected vulnerabilities in several SIP implementations (8 of 9)

INTERSTATE Fuzzer, Contributions

1. Automatic exploration of server state machine

- Input sequences are generated (messages, etc.) to perform a random walk of the state machine

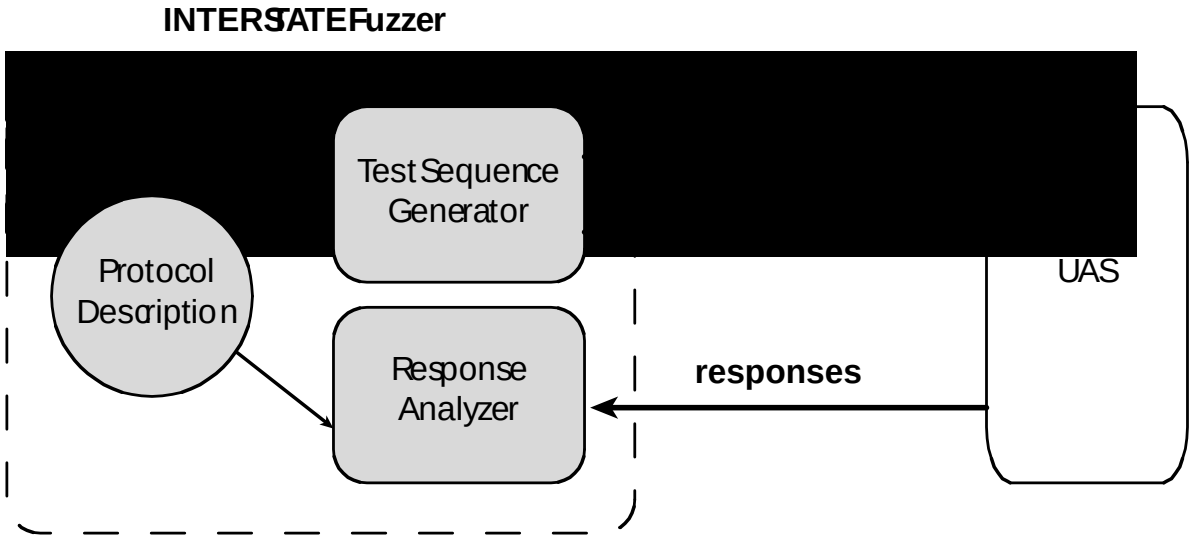
2. Evaluation of response messages

- Responses received from server are checked for correctness
- Allows the detection of more subtle failures
- Needed to accurately maintain current state of UAS

3. Control server GUI during fuzzing

- GUI control needed to fully explore state space (ie. accepting a phone call)

INTERSTATE Fuzzer System

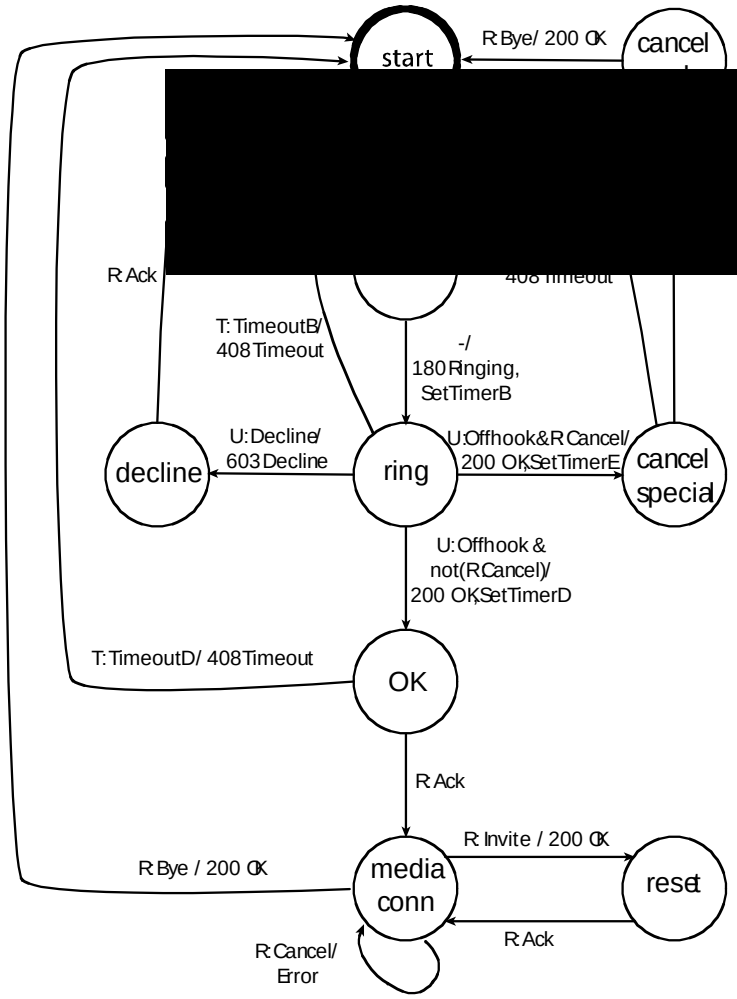


Protocol Description - State machine describing the protocol

Test Sequence Generator - Selects paths in the state machine and generates inputs (messages, timeouts, GUI) to explore the paths

Response Analyzer - Verifies correctness of response messages. Supports synchronization between fuzzer and UAS

Protocol Description

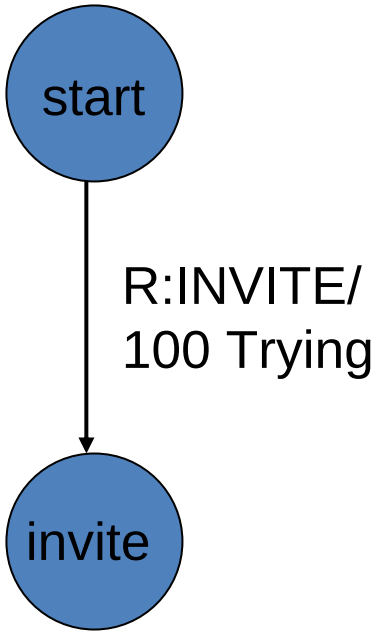


- State machine describes [redacted] e UAS

[redacted] er the following requests: INVITE, CANCEL, BYE, ACK

- Edges are not included in this picture for clarity
- Edges are labeled with Inputs and Outputs
- Inputs are Messages (R:), Timeouts (T:), or GUI (U:)

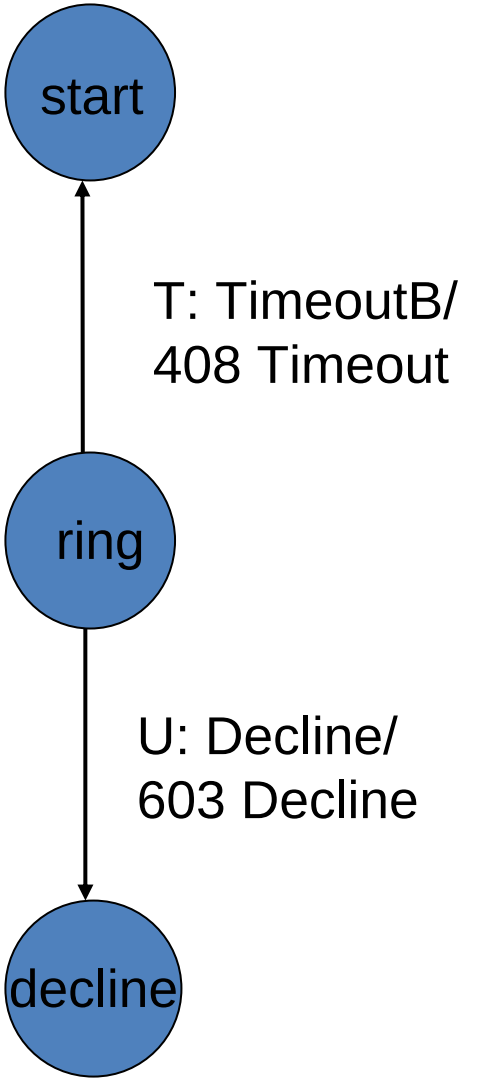
Message Inputs



- Fuzzer generates the message required to traverse selected edge
- Dialog state is generated for INVITE and used for all other messages in dialog

- Messages are fuzzed with a given probability
- The following fuzzing functions are used:
  - **Repeat String** - Increase string length by repeating it to force buffer overflow
  - **Command Injection** - Insert shell metacharacters to see if string is passed to a shell

Timer and GUI Inputs



- Some UAS state transitions depend on timeouts
- Some UAS state transitions depend on local user inputs
  - Accepting and declining a call
- Control of UAS GUI is needed to fully explore state machine
- X11::GUITest Toolkit
  http://soureforge.net/projects/x11guitest

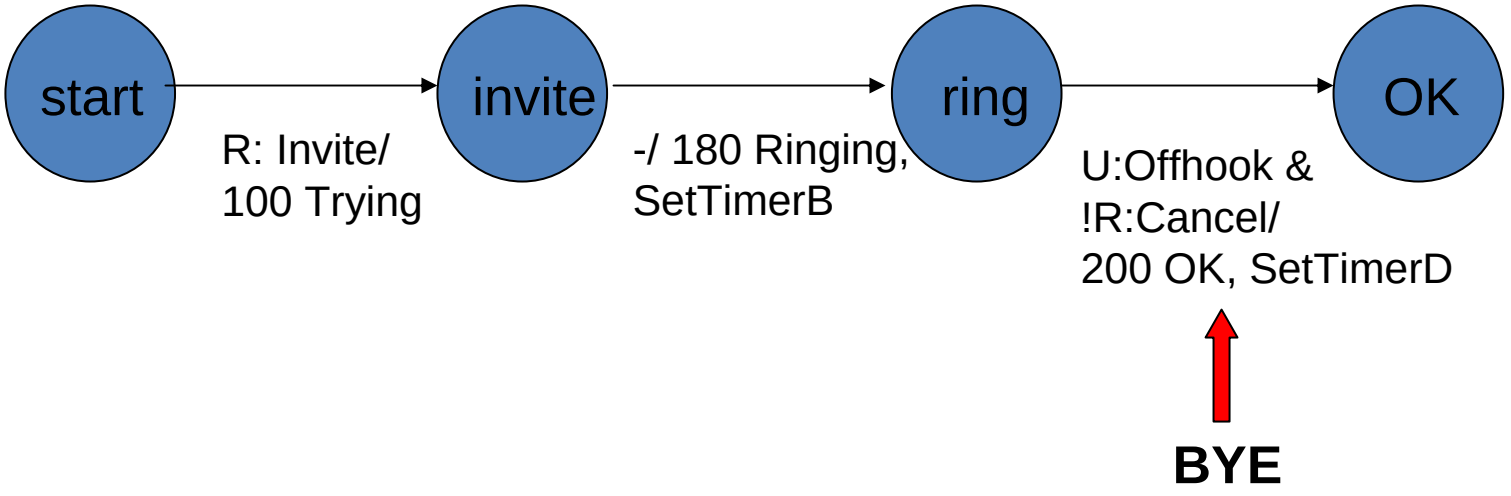
Fuzz Generation Algorithm

```
curr_state = 'start';
while () {
   e = select_outgoing_edge(curr_state);
   generate_trigger(e);
   r = get_response_message();
   if (!correct_response(r)) then
      exit(error detected);
   else
      curr_state = e.successor_state;
   }
```

1. **Select outgoing edge of UAS state machine**
2. **Generate input to trigger edge**
3. **Repeat until error is detected**

Result Summary

- Used INTERSTATE to fuzz KPHONE, an open source SIP phone
- Revealed a timing vulnerability which causes a crash
- After a phone call is accepted, KPHONE loads necessary codecs
- Crash occurs if a BYE message is received during that time (<1sec)



Fuzzer Result Information

- Vulnerability detected in 6 seconds wall clock time
- 1.3 GHz AMD Athalon, 512 MB RAM, Debian Linux
- 8 state machine edges traversed before vulnerability detected

Iteration 1:

Edge 1: start -> invite
Edge 2: invite -> ring
Edge 3: ring -> start

Iteration 2:

Edge 4: start -> invite
Edge 5: invite -> start

Iteration 3:

Edge 6: start -> invite
Edge 7: invite -> ring
Edge 8: ring -> OK (crash)

Conclusions

- Fuzzer automatically explores UAS state machine
- Verifies response messages for correctness
- Controls UAS GUI to enable full state space exploration

Future Work

- Test more open source soft phones
- Debug the phones to identify the source of the vulnerabilities
- Examine hard phones, circumvent keypad interface

http://testlab.ics.uci.edu/interstate

Get the source code!