BLACKHAT BRIEFINGS 2005

The Art of SIP fuzzing and Vulnerabilities Found in VoIP

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About the authors

Ejovi Nuwere

Ejovi Nuwere is the founder of SecurityLab Technologies. Nuwere gained media attention and international recognition for his highly publicized security audit of Japan's National ID system--JukiNet. Nuwere is the Chief Technology Officer of SecurityLab Technologies where he heads the companies VoIP security auditing group. He currently lives in Boston and is working on his second book, Practical Penetration Testing (O'Reilly).

Mikko Varpiola

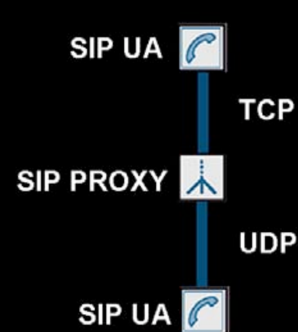
Mikko Varpiola is the head of test tool development at Codenomicon Ltd. His specific area of expertise is in anomaly design - e.g. what to feed into software to make it fail. Before Codenomicon he worked as a researcher in the acclaimed PROTOS project at Oulu University Secure Programming Group (OUSPG). He is the author of the ASN.1 encoding anomalies first deployed in the widely-publicized PROTOS LDAP and SNMP test suites.

Agenda

1. Proof of concept
2. Current state of the VoIP security
3. The art of SIP fuzzing

Proof of concept test setup

- Two user agents
- One infrastructure component
- Demonstrate the loss of availability
- Potential security implications of found bugs still under investigation
- Vendors have been notified



Current state...

- Open-source vs. proprietary
  - Large product companies are doing fairly well
  - Some telcos and hardware vendors lacking?
  - How to measure the differences between products?
- Military and private usage
  - Multilevel Precedence and Preemption (MLPP)
  - Small businesses at risk
  - Off shoring by large corporations

Current state continued...

- Progress since 2000?
  - Lack of basic coding flaws (sorry no easy overflows)
  - PROTOS (2001), discovered most basic bugs
  - Some companies begin to have very mature threat modeling
- Back to 1999…
  - Some VoIP vendors have no concept of vulnerabilities (usual call the lawyers, downplay,…)
  - Make it work mentality
  - Closed network assumptions

Testing Approach

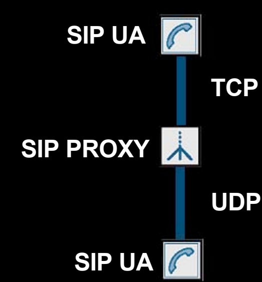
- Defining fuzzing terminology
- Products evaluated
  - sipXphone (sip foundry stack)
  - PartySIP (GNU SIPo stack)
  - SIPset (vovida/vocal stack)
  - linPhone (GNU SIPo stack)
  - Commercial Brand X (unknown stack, proprietary?)
- Doesn't look too promising!
  - At least two critical bugs per product

The problems with SIP

- Share and share alike
  - Many are using the same flawed code base
  - No one admits they are using the same code base
- No update mechanisms for most products
  - Hardware devices
  - Consumer products
- Writing parsers are inherently complex
  - Ethereal (150+ vulnerabilities since 1999)

Don't forget the environment

- It is essential to understand the enviroment
- Some errors trigger in only certain environments and certain configurations
- In context of SIP – just think of UDP vs. TCP as a transport
  - Stream vs. Datagram
  - alternate physical limitations for maximum message size
- Beyond the parser lies the application



The Art of SIP fuzzing

- What's all the fuzz about?
- Deciding what to fuzz
- Isolated bug fault model
- A systematic approach
- What ASCII (as in SIP) brings to the table
- Types of anomalies

What's all the fuzz about

To guarantee:
- Safety
- Security
- Dependability

Positive tests to prove coverage/conformance

Negative tests

Infinity of possible tests

Bug symptoms usually located:
- Crashes
- Performance degradation
- Other unexpected behaviour

Deciding what to fuzz

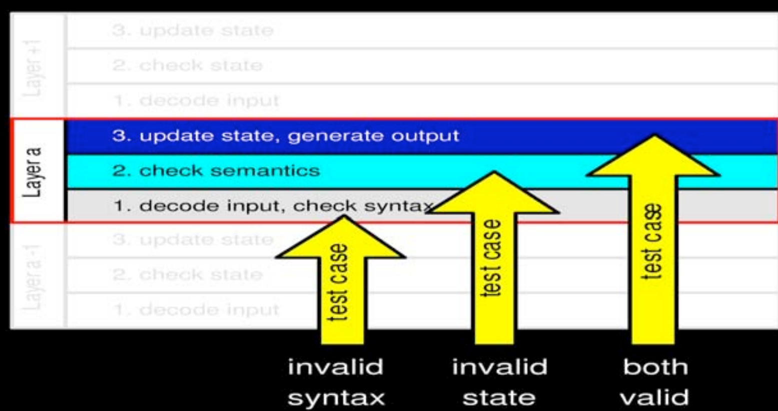
- Decision need to relate to available protocols and surrounding environment
- Ideally test all open interfaces
- Environment
  - What are the open interfaces
  - History of identified protocols
  - Risk analysis
- Protocol
  - Only test the actual behaviour
  - Check common sources for known vulnerabilities -> Improvise

WITH SIP TRY THESE:

- SIP REQUEST LINE
- SIP URIs in headers below
- Authorization headers
- Contact header
- CSeq
- From header
- Route header
- Record-Route header
- To header
- Via Header

Isolated bug fault model

YOU CAN'T TEST EVERYTHING AT SAME TIME – NEITHER YOU CAN DO EVERYTHING IN SAME MESSAGE/ELEMENT!



A systematic approach

1. Identify sub structures (required and optional)
2. Identify data types of identified fields
3. Anomalise fields one at the time with proper anomalies for data type
4. Or apply structural mutations

Fuzzing SIP

- ASCII (as in SIP) allows various levels of freedom
  - Human readable protocols tend to be harder to parse
  - Binary vs. ASCII protocols
  - It is easier to create huge amount of (redundant?) test cases with ASCII based protocols
  - SDP and other content payloads a task of their own (may requre special injection arrangements)

Anomalies for ASCII based protocols

- For each anomaly we present
  - Examples up close and personal
  - Them applied to SIP message
- We cover:
  - standard overflows (ascii, c-format strings, control/non-ascii,utf8)
  - standard integers (negative, 'float', big)
  - addresses (IPv4, IPv6, ISDN (tel uris))
  - structural (repetitions (header, header element), underflows)
  - protocol specifics (by closely observing the SIP & related specs)
- Why different lengths / values for each data type?
  - All rules of boundary value testing apply to fuzzing as well
  - Different software, different limits
  - Different routines likely get excercised with different strings

Standard overflows

- ASCII (alpha vs. Alphanumeric)
- C-format string
- Control character
- UTF8

16x 0x61 ; ('aaaaaaaaaaaaaaaa')

1024x 0x62

2048x 0x34

'%s%s%s%s' , '%n%a', '%99d', %.9999f'

128x 0x00, 512x 0x07, 1024x 0x7f, ...

```
INVITE sip:user@to.example.com SIP/2.0
To: <sip:user@to.example.com>
From: "user" <sip:user@from.example.com:5060>;tag=00017756
Via: SIP/2.0/aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa 192.168.2.8;branch=eez9hG4bK17756
Call-ID: s0c00017756i0t1110906390910@from.example.com
Contact: "user" <sip:user@from.example.com;transport=udp>
Content-Length: 177
```

Standard integer anomalies

- Cover the data range with presentative values
- Examine specification for enumerations

STANDARD:
-1, 0, 1, 2, 4, 5, 6, 7, 15, 16, 32, 63, 64, 127, 128, 255,256 ,1023, 1024, 4095, 4096, ...

FLOATS:
0.1, 0.9, -0.1, 0.0, -0.0, ...

UNEXPECTED NUMERIC SYSTEMS:
000b, 0x01, 042364

```
Contact: "user" <sip:us
Content-Length: -1
Content-Type: applicati
```

```
INVITE sip:user@to.example.com SIP/2.0
To: <sip:user@to.example.com>
From: "user" <sip:user@from.example.com:5060>;tag=00006944
Via: SIP/2.0/UDP from.example.com:5060;branch=z9hG4bK6944t1110905098730
Call-ID: s0c00006944i0t1110905098730@from.example.com
Contact: "user" <sip:user@from.example.com;transport=udp>
Content-Length: 177
Content-Type: application/sdp
CSeq: 444444444444444444444444444444444444444444444444444444444444444 INVITE
Max-Forwards: 70
```

Addresses

```
0.0.0.0/8          "This" Network                        [RFC1700, page 4]
10.0.0.0/8         Private-Use Networks                          [RFC1918]
14.0.0.0/8         Public-Data Networks                [RFC1700, page 181]
24.0.0.0/8         Cable Television Networks                          --
39.0.0.0/8         Reserved but subject to allocation            [RFC1797]
127.0.0.0/8        Loopback                              [RFC1700, page 5]
128.0.0.0/16       Reserved but subject to allocation
169.254.0.0/16     Link Local                                         --
172.16.0.0/12      Private-Use Networks                          [RFC1918]
191.255.0.0/16     Reserved but subject to allocation
192.0.0.0/24       Reserved but subject to allocation
192.0.2.0/24       Test-Net
192.88.99.0/24     6to4 Relay Anycast                            [RFC3068]
192.168.0.0/16     Private-Use Networks                          [RFC1918]
198.18.0.0/15      Network Interconnect Device Benchmark Testing
223.255.255.0/24   Reserved but subject to allocation
224.0.0.0/8        Various multicast
240.0.0.0/4        Reserved for Future Use               [RFC1700, page 4]
255.255.255.255    Broadcast
```

```
INVITE sip:user@[?::1] SIP/2.0
To: <sip:user@to.example.com>
From: "user" <sip:user@from.example
Via: SIP/2.0/UDP from.example.com:5
Call-ID: s0c00000545i0t111090429066
Contact: "user" <sip:user@from.exam
Content-Length: 177
Content-Type: application/sdp
```

"[ffff:ffff:ffff:ffff:ffff:ffff:ffff:ffff]"
"[0::0]"
"[?::1]"

”-1.-1.-1.-1”
”10.10.10.-1"”
”%s.%x.%n.%d”

```
"FF01:0:0:0:0:0:0:1" | #    All Nodes Address                  [RFC2373]
"FF01:0:0:0:0:0:0:2" | #    All Routers Address                [RFC2373]
"FF02:0:0:0:0:0:0:1" | #    All Nodes Address                  [RFC2373]
"FF02:0:0:0:0:0:0:2" | #    All Routers Address                [RFC2373]
"FF02:0:0:0:0:0:0:3" | #    Unassigned                         [JBP]
"FF02:0:0:0:0:0:0:4" | #    DVMRP Routers                      [RFC1075,JBP]
"FF02:0:0:0:0:0:0:5" | #    OSPFIGP                            [RFC2328,Moy]
"FF02:0:0:0:0:0:0:6" | #    OSPFIGP Designated Routers         [RFC2328,Moy]
. . . . .
```

Structural anomalies

- Repetitions
  - Header
  - Sub elements
- Underflows
- Unexpected data

```
Content-Type: application/sdp
CSeq: 7038 INVITE a1 a2 a3 a4 a5 a6 a7 a8 a9 a10 a11 a12 a13 a14 a15 a16 a
Max-Forwards: 70
```

```
INVITE sip:user@to.example.com SIP/2.0\r
To: <sip:user@to.example.com>\r
From: "user" <sip:user@from.example.com:5060>;tag=00031912\r
Via: SIP/2.0/UDP from.example.com:5060;branch=z9hG4bK31912t1110908159733\r
Call-ID: s0c00031912i0t1110908159733@from.example.com\r
Contact: "user" <sip:user@from.example.com;transport=udp>\r
Cont
```

```
INVITE sip:user@to.example.com SIP/2.0
To: <sip:user@to.example.com>
From: "user" <sip:user@from.example.com:5060>;tag=00001889
Via: SIP/2.0/UDP from.example.com:5060;branch=z9hG4bK1889t1110904451140
Accept: application/sdp, text/html
Accept: application/sdp, text/html
Accept: application/sdp, text/html
Accept: application/sdp, text/html
Accept: application/sdp, text/html
Accept: application/sdp, text/html
Accept: application/sdp, text/html
Accept: application/sdp, text/html
Accept: application/sdp, text/html
Accept: application/sdp, text/html
Accept: application/sdp, text/html
```

Protocol specific anomalies

- SIP Tokens as in RFC3261
- SIP line continuations as in RFC3261
- URI escapes as in RFC2616/RFC1945
- Embedded BASE64 encoding of RFC2617 headers
- UTF8 (see ttp://www.cl.cam.ac.uk/~mgk25/unicode.html)
- Other SIP specific escapings
- MIME multipart bodies
- You name it!

Protocol specifics continued

```
INVITE http:user@to.example.com SIP/2.0
To: <sip:user@to.example.com>
From: "user" <sip:user@from.example.com:5060>;tag=00000154
Via: SIP/2.0/UDP from.example.com:5060;branch=z9hG4bK154t1110904245845
Call-ID: s0c00000154i0t1110904245845@from.example.com
Contact: "user" <sip:user@from.example.com;transport=udp>
Content-Length: 177
Content-Type: application/sdp
CSeq: 155 INVITE
Max-Forwards: 70
```

```
To: <sip:user@to.example.com>
From: "Displayname" <sip:%25%32%35%25%33%36%25%33%31@to.e
Via: SIP/2.0/UDP from.example.com:5060;branch=z9hG4bK8708
Call-ID: s0c00008708i0t1110905304013@from.example.com
Contact: "user" <sip:user@from.example.com;transport=udp>
Content-Length: 177
```

```
INVITE ;sip:user@to.example.com SIP/2.0
To: <sip:user@to.example.com>
From: "user" <sip:user@from.example.com
Via: SIP/2.0/UDP from.example.com:5060;
Call-ID: s0c00000065i0t1110904235150@fr
Contact: "user" <sip:user@from.example.
Content-Length: 177
Content-Type: application/sdp
```

```
Authorization:Basic YWFhYWFhYWFhYWFhYWFhYWFhYWFhYWFhYWFhYWE6cGFzc3dvcmQ=
Call-ID: s0c00003568i0t1110904666562@from.example.com
```

Is that all about anomalies?

“Thrill to the excitement of the chase!
Stalk bugs with care, methodology, and reason.
Build traps for them..... [Beizer]”

“Testers! Break that software (as you must) and
drive it to the ultimate - but don’t enjoy the
programmer’s pain. [Beizer]”

“The tester in you must be suspicious,
uncompromising,
hostile, and compulsively obsessed with
destroying, utterly destroying, the programmer’s
software.
The tester in you is your Mister Hyde ...
[Beizer]”

Conclusions

- VoIP is going prime time – lets fix it before its too late!!!
- Find out what stacks your vendors are using and how they are testign them!
- Its not only the signaling - there is voice and management among others to be worried about as well
- Beyond presented fundamental problems there are other cans of worms to be opened:
    - Tapping, session hijacking, etc....

Questions?

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