We adapt. You succeed.

SMB debugging tools

the art of hair pulling

Aurélien Aptel <aaptel@suse.com>
SUSE

Who am I?

- Aurélien Aptel
- Work in SUSE, Samba Team
- Focus on SMB kernel client aka “cifs.ko”
  - Cifs-utils, Wireshark, Pike, ...

What is this about?

- Different debugging approaches I use
- Some new features I worked on

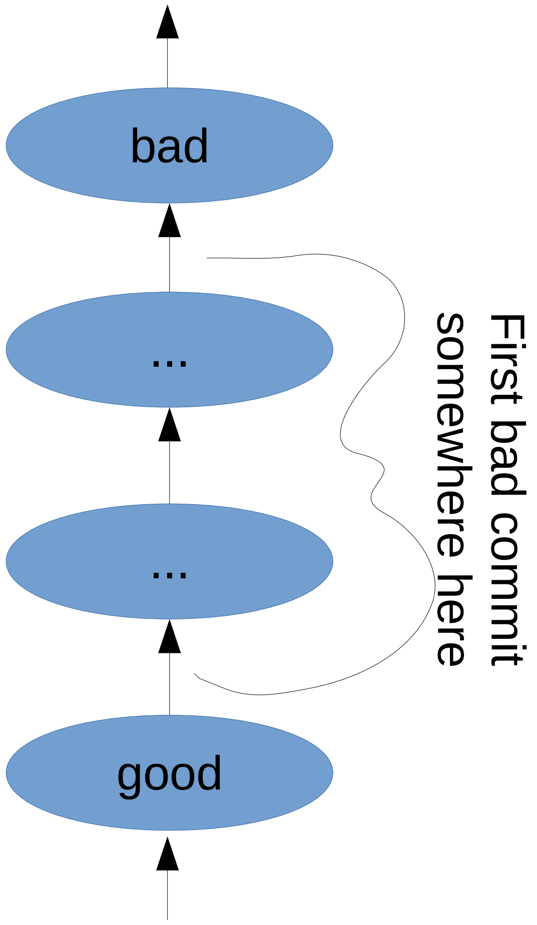
- Mostly useful to developers
- But also for administrators, to diagnose network issues

Debugging is hard

- No silver bullet
- Some approaches work better than others for certain bugs
- SMB bugs
  - In client?
  - In server?
  - Both?
  - Specifications wrong?
  - Unspecified?
- Lot of possible failures
  - Goal: isolate as much as possible before digging in

Different versions: git bisect

- Setup
  - Find “good” commit
  - Find “bad” commit
- Dichotomy
  - Tries to find first bad commit
  - Checkouts intermediaries commits you can test
  - Search space divided by 2 at each step
  - N commits → O(log N) steps to determine first bad commit
  - Really powerful: 130k commits in 17 steps
- Can be automated
  - Reproduce script
    - Indicate if “good” or “bad” via the exit code
  - git bisect run myscript.sh



Code reading

- The inevitable code/doc-reading part
  - Reading the spec one time to get an idea of how it’s supposed to work at the protocol layer
  - Finding the corresponding codepath
  - Reading source code of the relevant functions
  - Look for bug, typos, and wrong logic wrt the specs
  - Repeat
- Amount of code to grok can be very big
  - Long process, easy to miss the bug

Different implementations

- Sometime there are no good commits or its very impractical to find
- Try different combination of servers/clients
  - Windows, samba, smbclient, cifs.ko
- Try writing a test client that only does the buggy steps
  - – Samba torture test framework
  - – Pike (https://github.com/emc-isilon/pike)
    - Clean, pure-python, SMB2/3 lib, with easily tweakable fields
    - Used to test SMB3 POSIX extensions (https://github.com/aaptel/pike/commits/smb3unix)
  - – Microsoft has open-sourced a massive testing framework
    - https://github.com/Microsoft/WindowsProtocolTestSuites

Debugger

- Good tool but often impractical
- Breakpoints = timeouts
- Samba
  - Forks for user sessions

  -
    ```
    set follow-fork-mode child
    set detach-on-fork off
    ```
- Kernel
  - Qemu gdb server
  - `qemu … -s`

  -
    ```
    gdb -ex ‘add-auto-load-safe-path /’ \
        -ex ‘target remote :1234’ vmlinux
    ```

Debugger

- Python helper funcs in kernel.git
- Kernel cannot be compiled without optimization
  - Out of order execution
  - dreaded `<optimized out>`
  - Inline code
  - Since GCC v4.8 '-Og'
    “kernel hacking: GCC optimization for better debug experience (-Og)”
    - https://www.mail-archive.com/linux-kernel@vger.kernel.org/msg1707708.html

Logs

- Samba
  - smb.conf
    - Log level = 10
  - Smblog-mode for emacs :)
    - DEMO

Logs

- Samba
  - smb.conf
    - Log level = 10
    - Smblog-mode for emacs :)
- Kernel

    -
      ```
      echo 1 > /proc/fs/cifs/cifsFYI
      echo 8 > /proc/sys/kernel/printk
      echo 1 > /sys/module/dns_resolver/parameters/debug
      echo "module cifs +p" > /sys/kernel/debug/dynamic_debug/control
      echo 'file fs/cifs/* +p' > /sys/kernel/debug/dynamic_debug/control
      ```
  - ftrace / trace-cmd
    - Record call graph
      - https://jvns.ca/blog/2017/03/19/getting-started-with-ftrace/

Kernel logs: ftrace

- Deeper strace
- Records call graph
  - `trace-cmd record -e all -p function_graph -F \`
    `         mount.cifs //localhost/myshare /mnt -o …`
  - `trace-cmd report`

```
...
mount.cifs-29190 ....            |            cifs_do_mount() {
mount.cifs-29190 ....            |              cifs_get_volume_info() {
mount.cifs-29190 ....            |                kmem_cache_alloc_trace() {
mount.cifs-29190 ....  0.394 us  |                }
mount.cifs-29190 ....            |                cifs_setup_volume_info() {
mount.cifs-29190 ....            |                  cifs_parse_mount_options() {
mount.cifs-29190 ....            |                    kstrndup() {
mount.cifs-29190 ....            |                      __kmalloc_track_caller() {
mount.cifs-29190 ....  0.050 us  |                        kmalloc_slab();
mount.cifs-29190 ....  0.673 us  |                      }
mount.cifs-29190 ....  1.189 us  |                    }
...
```

Kernel logs: ftrace

- System wide recording
- Filter for specific syscalls (mount 165, umount 166)
  - https://filippo.io/linux-syscall-table/

```
# trace-cmd record -e sys_enter -f id==165
Hit Ctrl^C to stop recording
^C
# trace-cmd report
mount.cifs-21482 [001] …: sys_enter:  NR 165 (...)
```

```
# mount.cifs //localhost/myshare /mnt
```

Kernel logs: ftrace

- Usable without trace-cmd
- Fs-like API via /sys/kernel/debug/tracing

```
#!/bin/bash
set -v
d=/sys/kernel/debug/tracing

# set event and filter
echo sys_enter > $d/set_event
echo id==166 > $d/events/raw_syscalls/sys_enter/filter


# start/wait/stop tracing
echo 1 > $d/tracing_on
read -p "recording... press enter to stop"
echo 0 > $d/tracing_on


# print & clear
cat $d/trace
echo 0 > $d/trace
```

```
# tracer: nop
#
#           TASK-PID    CPU#    TIMESTAMP  FUNCTION
#              | |       |         |         |
         umount-13991 [000] ...: sys_enter: NR 166 (.
```

Network capture

- Wire log
- When applicable, network trace analysis is very effective
- Wireshark!
  - smb||smb2||dns||krb4

Network capture

- Wireshark decryption (3.0 and 3.11)
  - https://wiki.samba.org/index.php/Wireshark_Decryption
  - Requires wireshark 3.0.0 (28 feb 2019)

  - Samba (master)
    - Controls both client and server
    - smb.conf
      - `debug encryption = yes`
    - `smbclient … --option='debugencryption=yes' -e -mSMB3_11`

  - Kernel (4.13+)
    - `CONFIG_CIFS_DEBUG_DUMP_KEYS=y`
    - **Enable carefully!**

Network capture

- Wireshark decryption (3.0 and 3.11)

```
$ smbclient //localhost/scratch --option='debugencryption=yes' \
                                 -e -mSMB3 -U aaptel%aaptel -c quit
debug encryption: dumping generated session keys
Session Id     [0000] 26 48 BF FD 00 00 00 00                            &H......
Session Key    [0000] 63 D6 CA BC 08 C8 4A D2   45 F6 AE 35 AB 4A B3 3B   c.....J. E..5.J.;
Signing Key    [0000] 4E FE 35 92 AC 13 14 FC   C9 17 62 B1 82 20 A4 12   N.5..... ..b.. ..
App Key        [0000] A5 0F F4 8B 2F FB 0D FF   F2 BF EE 39 E6 6D F5 0A   ..../... ...9.m..
ServerIn Key   [0000] 2A 02 7E E1 D3 58 D8 12   4C 63 76 AE 59 17 5A E4   *.~..X.. Lcv.Y.Z.
ServerOut Key  [0000] 59 F2 5B 7F 66 8F 31 A0   A5 E4 A8 D8 2F BA 00 38   Y.[.f.1. ..../..8
```

```
$ wireshark -ouat:smb2_seskey_list:2648BFFD00000000,63D6CABC08C84AD245F6AE35AB4AB33B \
            -r capture.pcap
```

Network capture

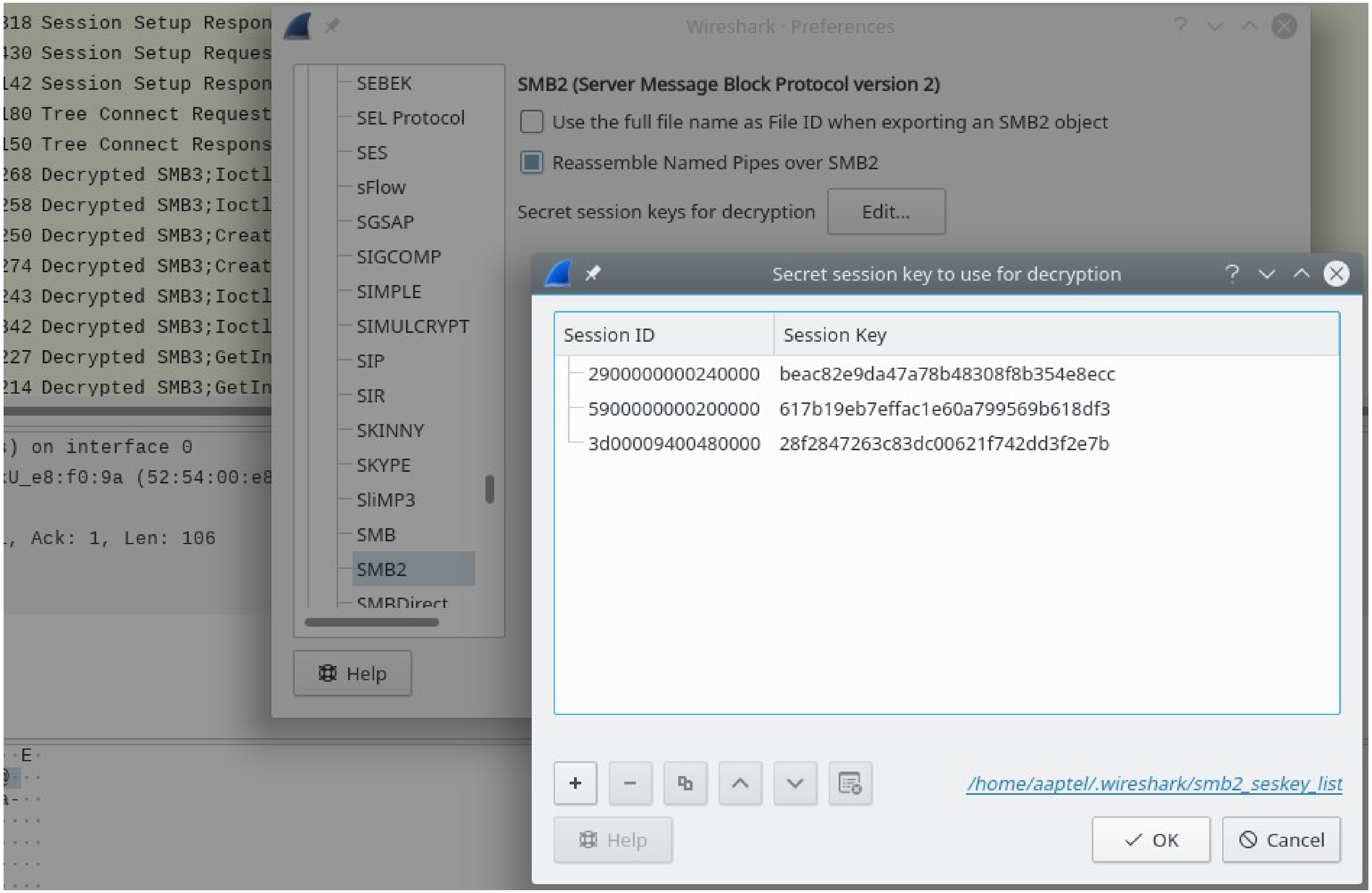
- Wireshark decryption (3.0 and 3.11)

```
# mount.cifs //localhost/myshare -o vers=3.0,seal
# dmesg | grep CIFS
CIFS VFS: generate_smb3signingkey: dumping generated AES session keys
CIFS VFS: Session Id    31 00 00 54 64 1c 00 00
CIFS VFS: Session Key   5a 92 df 3f a4 a5 c2 52 46 06 05 e5 52 75 ca 0c
CIFS VFS: Signing Key   cb 7b 5d 7f d3 e5 21 68 74 3e 36 8f 12 da 2f 50
CIFS VFS: ServerIn Key  0a 47 11 de a8 7a 96 c2 c3 7f c5 82 3c ff ac 3f
CIFS VFS: ServerOut Key 48 81 e5 42 69 15 d1 a0 d0 70 ca 74 af f5 b3 ce
```

```
$ wireshark -ouat:smb2_seskey_list:31000054641C0000,5a92df3fa4a5c252460605e55275ca0c \
            -r capture.pcap
```

Network capture

- Wireshark decryption (3.0 and 3.11)



```
318 Session Setup Respon
430 Session Setup Reques
142 Session Setup Respon
180 Tree Connect Request
150 Tree Connect Respons
268 Decrypted SMB3;Ioctl
258 Decrypted SMB3;Ioctl
250 Decrypted SMB3;Creat
274 Decrypted SMB3;Creat
243 Decrypted SMB3;Ioctl
342 Decrypted SMB3;Ioctl
227 Decrypted SMB3;GetIn
214 Decrypted SMB3;GetIn

) on interface 0
U_e8:f0:9a (52:54:00:e8

, Ack: 1, Len: 106
```

Wireshark · Preferences

SEBEK, SEL Protocol, SES, sFlow, SGSAP, SIGCOMP, SIMPLE, SIMULCRYPT, SIP, SIR, SKINNY, SKYPE, SliMP3, SMB, SMB2, SMBDirect

SMB2 (Server Message Block Protocol version 2)

- ☐ Use the full file name as File ID when exporting an SMB2 object
- ☑ Reassemble Named Pipes over SMB2

Secret session keys for decryption [Edit...]

Secret session key to use for decryption

Session ID	Session Key
2900000000240000	beac82e9da47a78b48308f8b354e8ecc
5900000000200000	617b19eb7effac1e60a799569b618df3
3d00009400480000	28f2847263c83dc00621f742dd3f2e7b

/home/aaptel/.wireshark/smb2_seskey_list

Network capture

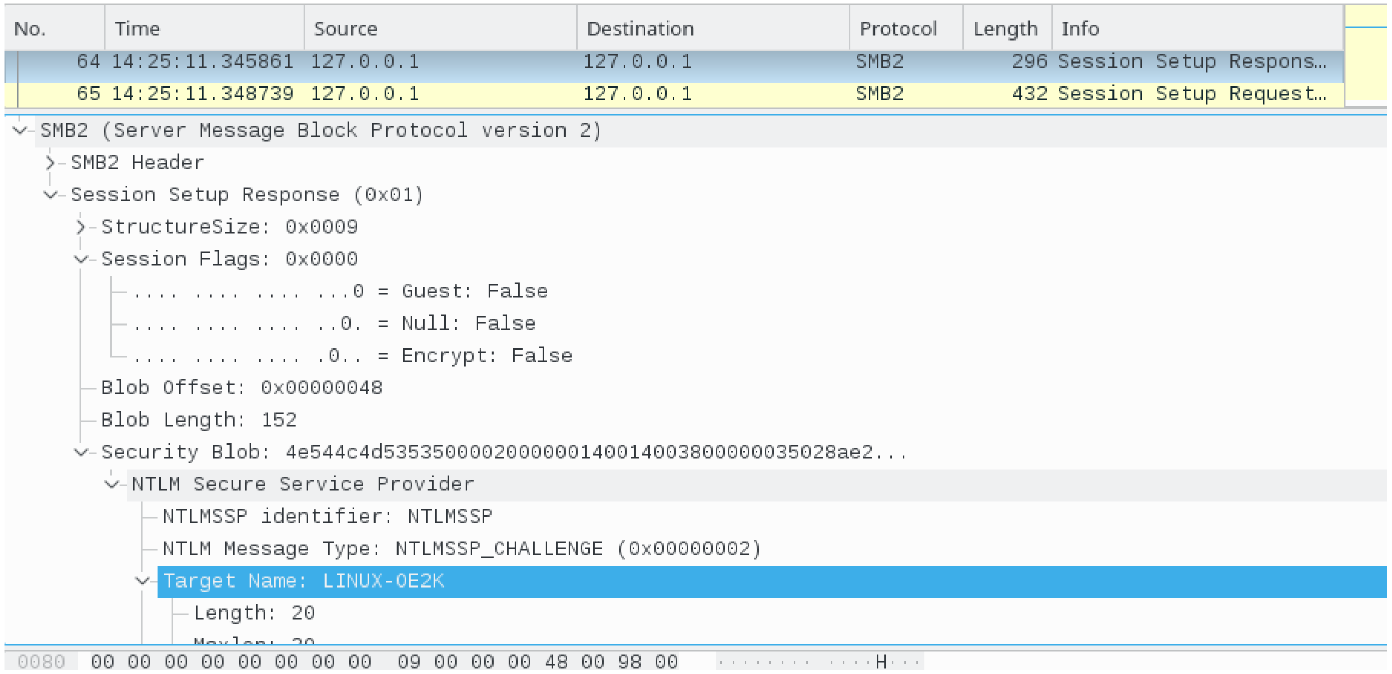
- Some other new changes in Wireshark SMB2 dissector:
  - Better parsing of compounded responses
  - Proper parsing of error contexts
  - Support for parsing reparse point data
    - NFS reparse tags (symlinks, block/char device, pipes, ...)

Network capture comparison

- Get a trace of a working case
- Get a network trace of the issue
- Look hard at both traces
  - try to see what the good client/server is doing that the bad one doesn’t (or vice versa)
  - Compare packets, fields, etc

Comparing network traces

- Open both traces side by side
- Expand the little handles
- Lots of them...
  - Nested
    - Into
      - Each
        - other



```
No.  Time             Source      Destination  Protocol  Length Info
  64 14:25:11.345861  127.0.0.1   127.0.0.1    SMB2         296 Session Setup Respons…
  65 14:25:11.348739  127.0.0.1   127.0.0.1    SMB2         432 Session Setup Request…
```

```
SMB2 (Server Message Block Protocol version 2)
  SMB2 Header
  Session Setup Response (0x01)
    StructureSize: 0x0009
    Session Flags: 0x0000
      .... .... .... ...0 = Guest: False
      .... .... .... ..0. = Null: False
      .... .... .... .0.. = Encrypt: False
    Blob Offset: 0x00000048
    Blob Length: 152
    Security Blob: 4e544c4d5353500002000000140014003800000035028ae2...
      NTLM Secure Service Provider
        NTLMSSP identifier: NTLMSSP
        NTLM Message Type: NTLMSSP_CHALLENGE (0x00000002)
        Target Name: LINUX-OE2K
          Length: 20
```

```
0080  00 00 00 00 00 00 00 00  09 00 00 00 48 00 98 00   ········ ····H···
```

Comparing network traces

- Eventually you switch to a different packet and the click-dance starts again
- Impractical for multiple reasons
  - Your index hurts
  - You skip expanding some fields because “it’s never going to be different here”
    - Until it does…
  - Your `l33t h4cker` eyes might just miss a difference
    - whitespace, caps, slash directions, flags..?
  - Some differences are false positives
    - Timestamps, random GUID, hashes, ...

Automating the comparison

- Wireshark is great…
- Would be nice to interact with it programatically
- API?
  - Not really :(
  - Tshark: text output
    - Also json and xml output
  - Also a daemon version sharkd
    - Undocumented?

tshark

```
tshark -r smb3-aes-128-ccm.pcap -Y smb2
    1 ... 10.160.64.139 → 10.160.65.202 SMB2 172 Negotiate Protocol Request
    2 ... 10.160.65.202 → 10.160.64.139 SMB2 318 Negotiate Protocol Response
    3 ... 10.160.64.139 → 10.160.65.202 SMB2 190 Session Setup Request, NTLMSSP_NEGOTIATE
    4 ... 10.160.65.202 → 10.160.64.139 SMB2 318 Session Setup Response, Error: STATUS_...
    5 ... 10.160.64.139 → 10.160.65.202 SMB2 430 Session Setup Request, NTLMSSP_AUTH, User:
SUSE\administrator
    6 ... 10.160.65.202 → 10.160.64.139 SMB2 142 Session Setup Response
...
```

tshark

```
tshark -r smb3-aes-128-ccm.pcap -Y smb2 -V
Frame 1: 172 bytes on wire (1376 bits), 172 bytes captured (1376 bits) on interface 0
    Interface id: 0 (unknown)
    Encapsulation type: Ethernet (1)
    Arrival Time: May 17, 2017 12:02:16.523633000 CEST
...
    [Protocols in frame: eth:ethertype:ip:tcp:nbss:smb2]
...
SMB2 (Server Message Block Protocol version 2)
    SMB2 Header
        Server Component: SMB2
        Header Length: 64
        Credit Charge: 0
        Channel Sequence: 0
        Reserved: 0000
        Command: Negotiate Protocol (0)
        Credits requested: 2
        Flags: 0x00000000
            .... .... .... .... .... .... .... ...0 = Response: This is a REQUEST
            .... .... .... .... .... .... .... ..0. = Async command: This is a SYNC command
```

smbcmp

- First prototype in emacs
  - https://github.com/aaptel/elshark
- Moved to Python script using curses
  - Calls tshark in the background
- 2 modes
  - Single trace
    - aka curses-wireshark (summaries + details)
  - Diff traces
    - Show 2 summaries
    - Diffs the detailed output
- Accepted GSoC project this year
  - Improving smbcmp by Paul Mairo

Future work

- Wireshark
  - New Negotiate Contexts
  - Compression
  - Support for all crypto modes
  - …
- Smbcmp
  - Deeper analysis
  - Ignore rules
  - Better UI
  - …
- Qemu record/replay