# Fuzzing the Phone in your Phone

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December 28th 2009

# About me

- PhD Student at TU-Berlin
- Specialized in mobile and smart phone security
- Previous work:
  - MMS remote exploit for WinMobile in 2006
  - Hacked: WinMobile, Symbian, iPhone, NFC, Bluetooth, to name a few.

# My Co-Author

- Charlie Miller
  - Security Researcher at Independent Security Evaluators
- Claim to fame:
  - First one to hack the iPhone and G1 Phone
  - Pwn2Own winner 2008 and 2009

# Agenda

- SMS
- Fuzzing SMS
- iPhone injection
- Android injection
- WinMobile injection
- Some fuzzing results

# SMS – Short Message Service

# SMS

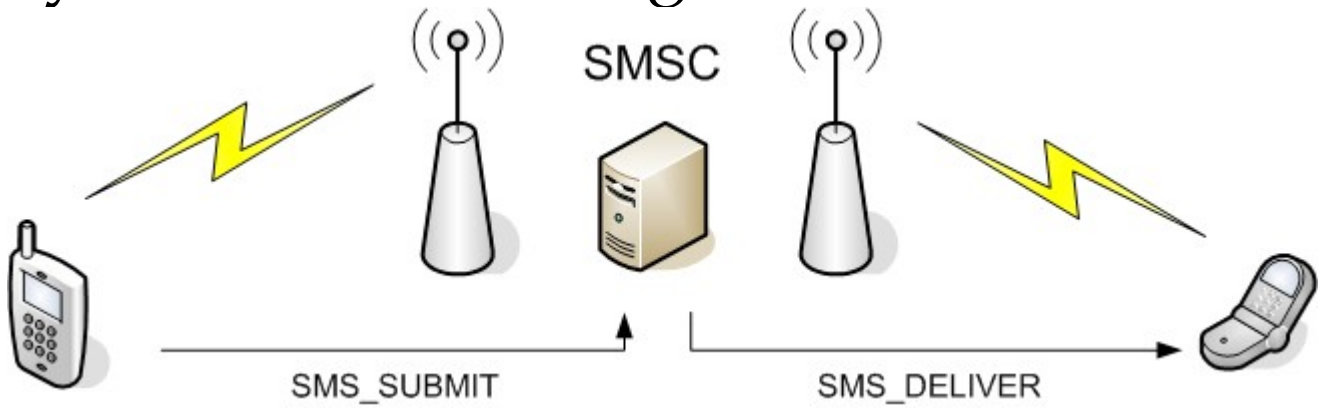
- Uses extra bandwidth in control channel (used for establishing calls, status, etc.)
- Message data limited to 140 bytes (160 7-bit chars.)
- Commonly used for “text messages”
- Can also deliver binary data:
  - OTA configuration
  - Ringtones
- Building block for the essential mobile phone service

# Why pick on SMS?

- SMS is received by and processed by almost all phones
- No way to firewall it (and still receive calls/texts)
- SMS is processed with no user interaction
  - Server side attack surface with no firewall, a 1990's flashback!
- Can be targeted with only a phone number!
- SMS firewalls/filters exist on the network but those on the phones are too high in the stack to protect against these attacks

# The life of an SMS message

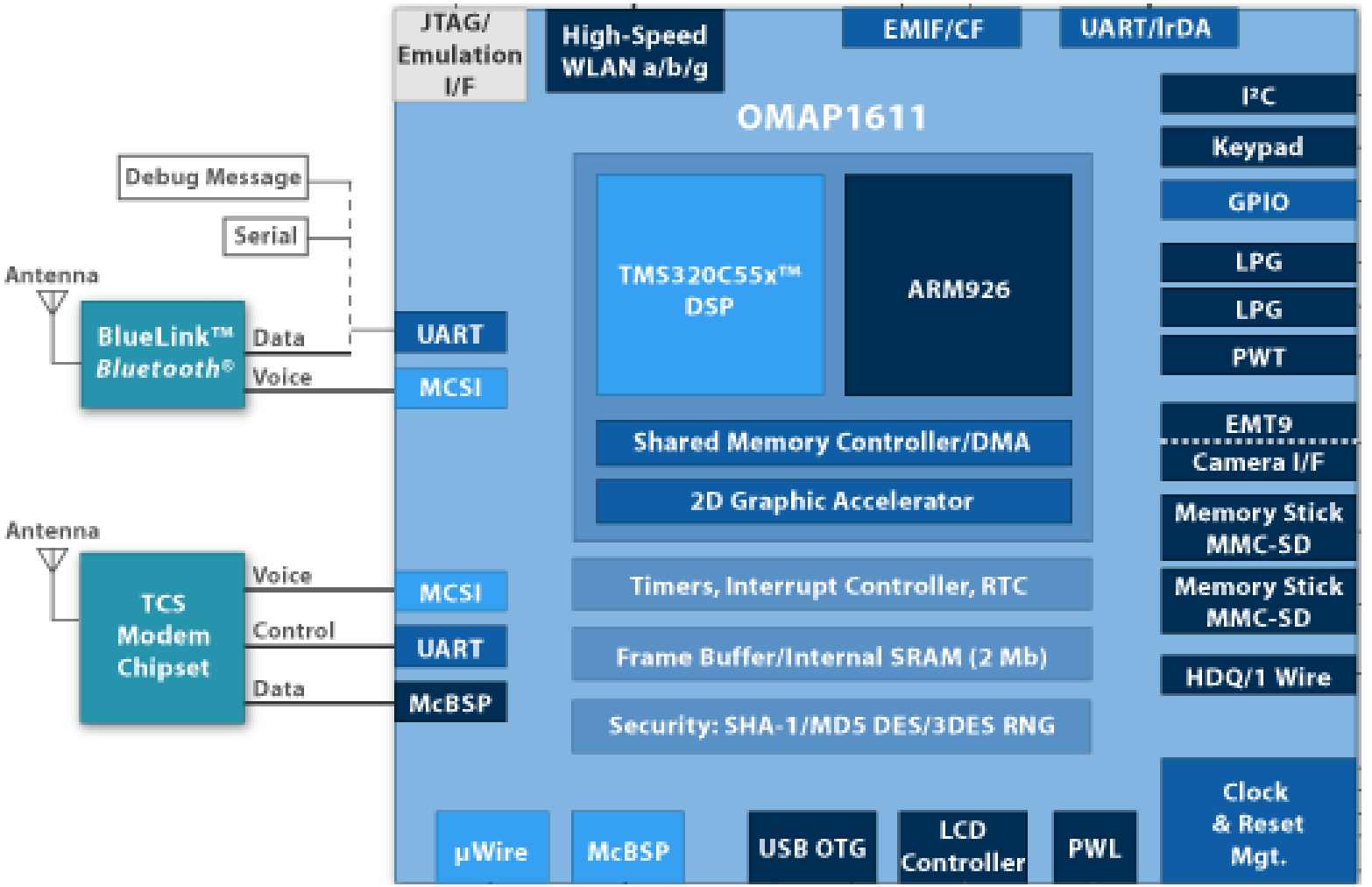
- Message is sent from the device to the Short Message Service Center (SMSC)
- The SMSC forwards to the recipient, either directly or through another SMSC
- SMSC will queue messages if recipient is not available
- Delivery is best effort, no guarantee it will arrive



# On the device

- Phones have 2 processors, application processor and modem
- Modem runs a specialized real-time operating system that handles all communication with the cellular network
- Communication between CPUs via logical serial lines
- Text based GSM AT command set is used

# Looking inside



# Continued life of an SMS

- When an SMS arrives at the modem, the modem uses an unsolicited AT command result code
- This consists of 2 lines of text
  - The result code and the number of byes of the next line
  - The actual SMS message (in PDU mode)

```
+CMT: ,30
07919471060040340 40D91947196466656F800009010821142
15400AE8329BFD4697D97D9EC377D
```

# A PDU

**07**91947106004034**04**0D**91**947196466656F8**0000**901082114215400A**E8329BFD4697D9EC377D**

| Field | Size | Bytes |
|---|---|---|
| Length of SMSC address | 1 byte | 07 |
| Type of address | 1 byte | 91 |
| SMSC address | variable | 947106004034 |
| DELIVER | 1 byte | 04 |
| Length of sender address | 1 byte | 0d |
| Type of sender address | 1 byte | 91 |
| sender address | variable | 947196466656F8 |
| TP-PID | 1 byte | 00 |
| TP-DCS | 1 byte | 00 |
| TP-SCTS | 7 bytes | 90108211421540 |
| TP-UDL | 1 byte | 0a |
| TP-UD | variable | AE8329BFD4697D9EC377D |

# But there is more

- The previous PDU was the most simple message possible, 7-bit immediate alert (i.e. a text message)
- Can also send binary data in the UD field
- This is prefaced with the User Data Header (UDH)

# UDH example

**0500003000301**

| Field | Size | Bytes |
|---|---|---|
| UDHL | 1 byte | 05 |
| IEI | 1 byte | 00 |
| IEDL | 1 byte | 03 |
| IED | Variable | 000301 |

# UDH example

**050003000301**

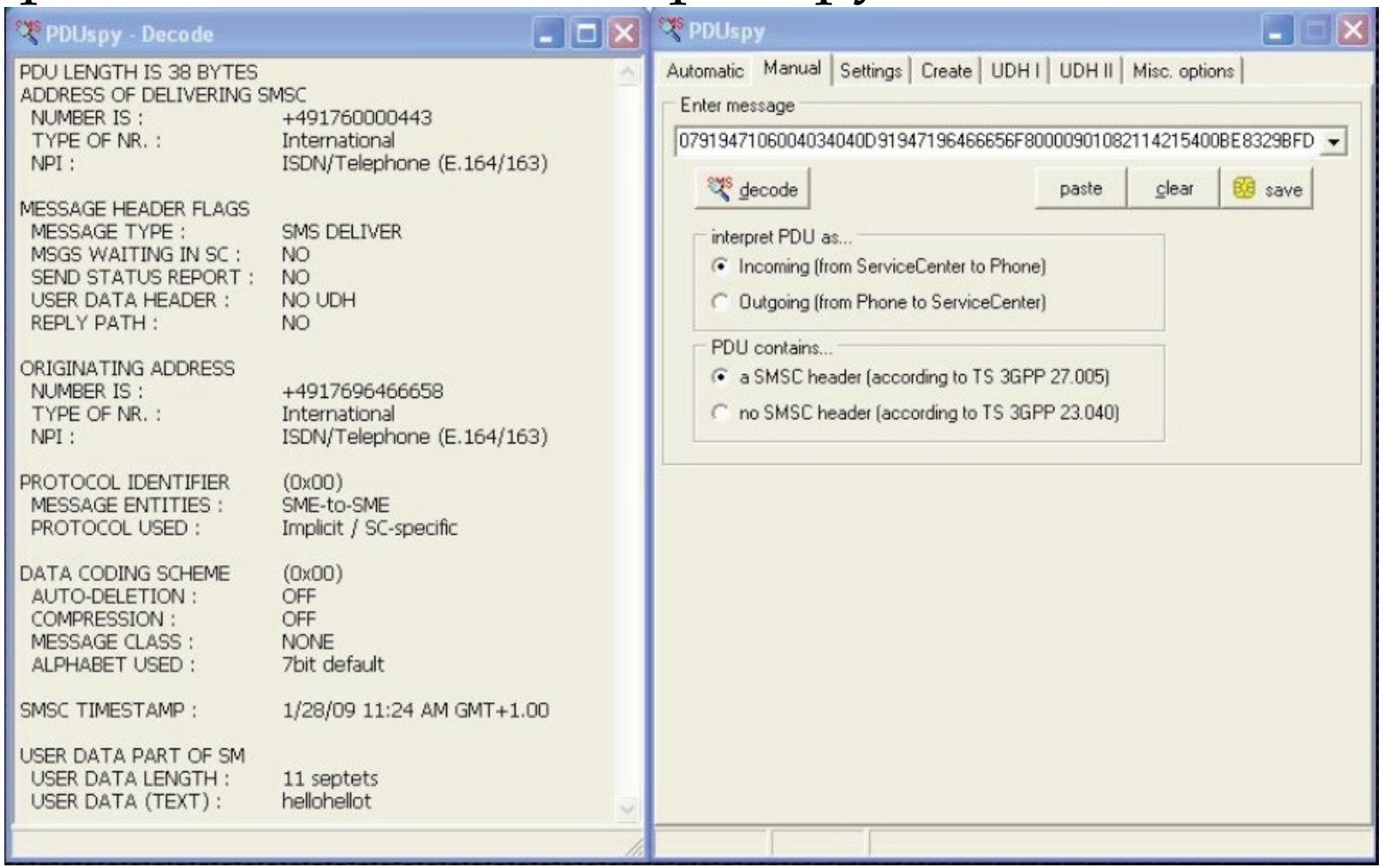
- Concatenated messages
  - Can send more then 140/160 bytes
  - IEI = 0 → concatenated with 8 bit reference number
  - IEDL = 03 → 3 bytes of data
  - Reference number = 00
  - Total number of message parts = 03
  - This message number = 01

# Other common UDH IEIs

- IEI 01 = voice mail indicator
- IEI 05 = port numbers (applications can register them)
  - Port 5499 = iPhone visual voicemail
    - `allntxacds12.attwireless.net:5400?f=0&v=400&m=XXXXX&p=&s=5433&t=4:XXXXXX:A:IndyAP36ms:ms01:client:46173`
  - Port 2948 = WAP push

# PDU Spy

- http://www.nobbi.com/pduspy.html



# Fuzzing SMS

# Fuzzing 101

- Create malformed input
  - Take existing input and “mutate” it
  - Create inputs from scratch (from RFC, for example)
- Send to target
- Monitor for faults
- Goto step 1

# Unmanned fuzzing exploration

- The ultimate goal of a fuzzing harness is complete automation
  - Record interesting events for human analysis
  - Detect and restart if service hangs/crashes
  - Handle dialogue boxes and other UI
  - Reboot if necessary

# Creating test cases

- Can take some sample PDUs and mutate
  - These aren't exactly easy to find!
- Might as well use our knowledge of protocol to generate intelligent test cases
- We can use Sulley fuzzing framework
  - This is how Charlie did it
- Build a SMS crafting library to generate messages
  - This is how I did it

# SMS crafting library

- Support SMS_DELIVER and SMS_SUBMIT
  - DELIVER is used for fuzzing!
  - Can generate and parse PDUs
- UDH support, IEIs:
  - Port Addressing 8 + 16 bit
  - Multipart messages
  - Indication (voice mail, etc...)
- All PDU fields can be auto-filled or set by hand!

# Some SMS test cases

- Multipart messages
- Port addressing
  - “Portscanning” → send random data to every port
  - WAP Push → send “less” random data to port 2948
- UDH bomb
  - Build a number of UDHs with valid length fields and random data, put all UDHs in same SMS message
- Voicemail indication

# SMS library

- Add-on utilities to store, load, and send test cases to/from a file
- Written in Python
- Was released in September
- http://www.mulliner.org/security/sms/

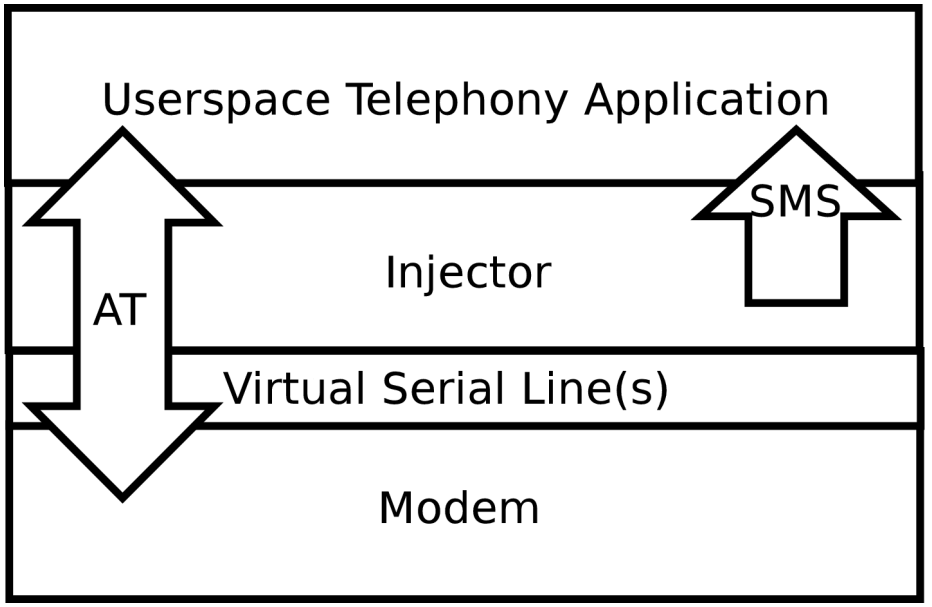
# Sending the test cases

- Could send over the air
  - Costs $$$$/€€€€
  - Telcos get to watch you fuzz
  - You might (make that WILL) crash Telco's equipment
- Could build your own transmitter
  - That is hard!
- Could inject into the process which parses
  - Would be very device/firmware dependent

# SMS injection

- We Man-in-the-Middle the channel between the application processor and the modem
- Can send messages quickly
- Its free
- Requires no special equipment
- The receiving process doesn't know the messages weren't legit
- Telco (mostly) doesn't know its happening
- Warning: results have to be verified over the carrier network

# SMS injection



# Get SMS sniffing for free

- Log AT commands as you forward them
- Useful for RE'ing apps that register SMS ports, vendor, specific SMS data, etc...

```
ssfd3 connected
/dev/dlci.spi-baseband.3 opened
ssfd4 connected
/dev/dlci.spi-baseband.4 opened
csfd3 to fd3 write 5 bytes
---
ate0^M
+++
csfd4 to fd4 write 5 bytes
…
csdf3 to fd3 write 35 bytes
---
00100b8.....
```

# Speaking of free...

- Free to test with the injector
- We sent thousands of fuzzed SMS's during fuzzing
- We sent thousands of fuzzed SMS's during exploit dev
- Injector makes this whole thing possible

# iPhone injection

# iPhone SMS fun fact

- The CommCenter process is responsible for handling SMS and Telephone calls. **It runs as root with no application sandbox.**

# iPhone SMS

- CommCenter communicates with the modem using 16 virtual serial lines
- `/dev/dlci.h5-baseband.[0-15]` (2G)
- `/dev/dlci.spi-baseband.[0-15]` (3G)

# Man-in-the-Middle

- Use Library Pre-loading to hook basic API
- com.apple.CommCenter.plist:

```
...
<key>EnvioronmentVariables</key>
  <dict>
    <key>DYLD_FORCE_FLAT_NAMESPACE</key>
      <string>1</string>
    <key>DYLD_INSERT_LIBRARIES</key>
      <string>/System/Library/Test/libopen.0.dylib</string>
  </dict>
...
```

# Open (highlights)

```
#define FD3 “/tmp/fuzz3.sock”

Int open(const char *path, int flags, …)
{
    real_open = dlsym(RTLD_NEXT, “open”);
    if ((strncmp(“/dev/dlci.h5-baseband.3”, path, 23) == 0 ||
            (strncmp(“/dev/dlci.spi-baseband.3”, path, 24) == 0)) {

        struct sockaddr_un saun;
        fd = socket(AF_UNIX, SOCK_STREAM, 0);
        saun.sun_family = AF_UNIX;
        strcpy(saun.sun_path, FD3);
        int len = offsetof(struct sockaddr_un, sun_path) + strlen(FD3);
        connect(fd, &saun, len);
        fd3 = fd;
    } else {
        fd = real_open(path, flags);
    }
    return fd;
}
```

# The injection

- CommCenter thinks it opened the serial line, but actually it opened up a UNIX-domain socket
- A daemon runs which opens up the real serial line and copies all data to and from the UNIX-domain socket
- Daemon also listens on TCP port 4223 and writes all data read from the port on the socket
- Therefore, can inject AT command over TCP

# Sending PDUs

```
def send_pdu(ip_address, line):
    leng = (len(line) / 2) – 8
    buffer = “\n+CMT: ,%d\n%s\n”, % (leng, line)
    s = connect((ip_address, 4223))
    s.send(buffer)
    s.close()
```

# Detecting crashes with CrashReporter

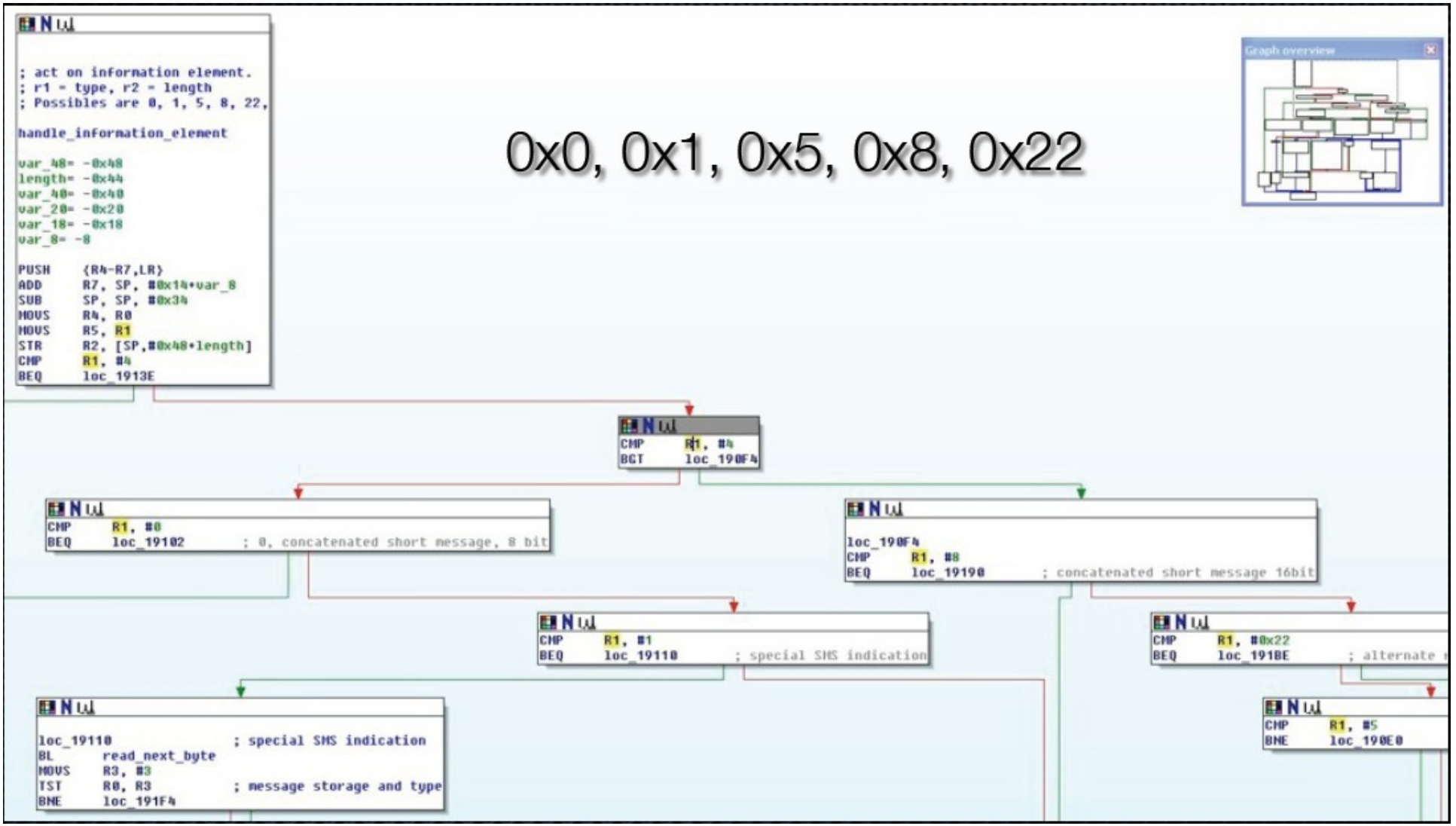
```
def check_for_crash(test_number, ip):
  Commcenter = '/private/var/logs/CrashReporter/
   LatestCrash.plist'
  Springboard = '/private/var/mobile/Library/Logs/
   CrashReporter/LatestCrash.plist'
  command = 'ssh root@'+ip+' “cat %s 2>/dev/null; cat %s
   2>/dev/null”' % (commcenter, springboard)
  c = os.popen(command)
  crash = c.read()
  if crash:
    clean_clogs()
    print “CRASH with %d” % test_number
    print crash
    time.sleep(60)
  else:
    print ' . ',
  c.close()
```

# Final checks

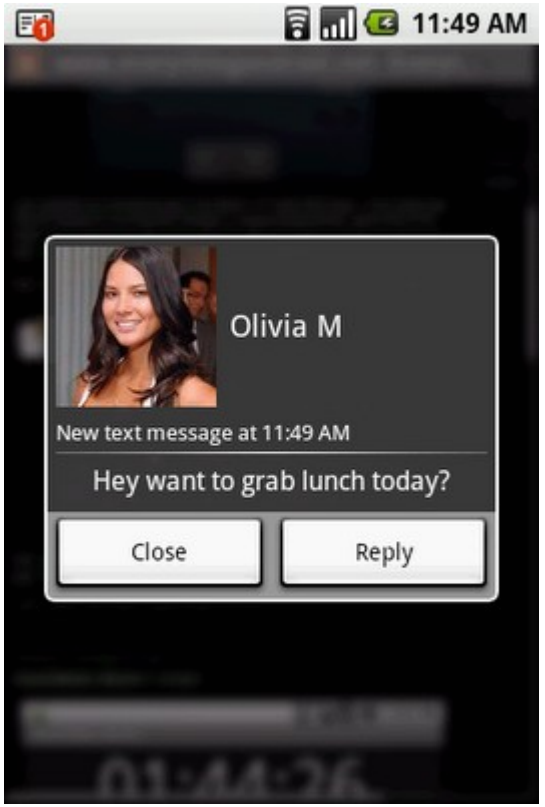
- To make sure the device is still handling SMS messages send a legit message between each test case and make sure it is processed
- SMS message show up in the sqlite database /private/var/mobile/Library/SMS/sms.db
- Display contents of last message received:

```
# sqlite3 -line /private/var/mobile/Library/SMS/sms.db
'select text from message where ROWID = (select MAX(ROWID)
from message);'
```

# iPhone IEI support



# Android injection



# Android fuzzing fun-fact

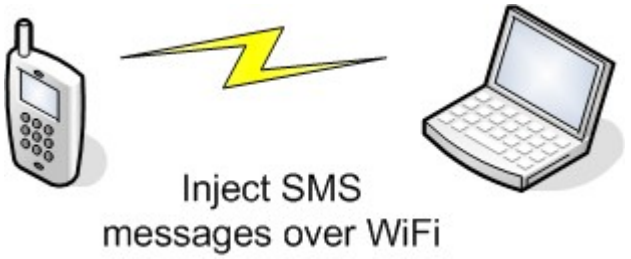
- Process which handles SMS is a Java app :(

# Android MITM

- Rename serial device from: `/dev/smd0` to `/dev/smd0real`
- Start injector daemon, daemon will create fake `/dev/smd0`
- Kill -9 33 (kills /system/bin/rild)
- When rild restarts it talks to the injector daemon via `/dev/smd0`

# Sending test cases

- Identical to iPhone case, use TCP 4223



# Crash monitoring

- Monitor output of ADB (Android Debug Bridge)
  - `logcat -d` gives you the logdump
- "*** *** ***" indicates a CRASH
- "uncaught exception" indicates a Java crash
- Automized with a small Python script...

# Valid test case injection

- Same as iPhone except the sqlite command is:

```
/system/xbin/sqlite3 -line /data/data/com.android.
providers.telephony/databases/mmssms.db 'select body from
sms where id = (select MAX(_id) from sms);'
```

# Android is not sturdy

- It is easy to make the SMS app unresponsive (in fact it is hard not to)
- When things hang:
  - `/data/busybox/killall -9 com.android.phone`
  - `/data/busybox/killall -9 com.android.mms`
- When things are really broken (this is almost a reboot):
  - `/data/busybox/killall -9 system_server`

# Windows Mobile injection

# Not surprisingly

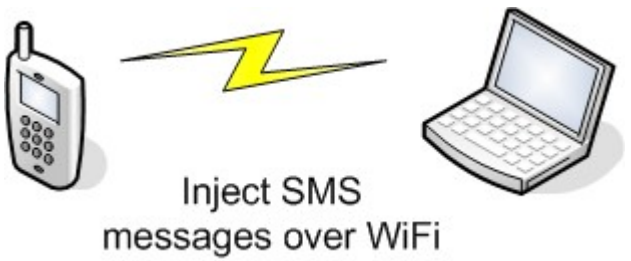
- Things are a little different in Windows Mobile
- Need all kinds of hacks
- “app unlock” device (registry hacks)

# MITM Kernel Style

- Add new serial driver
- Driver provides same interface as original driver
- Uses original driver to talk to modem
- Open TCP port 4223
- Built on top of Willem Hengeveld's log-driver
  - Thanks for your help!

# SMS injection

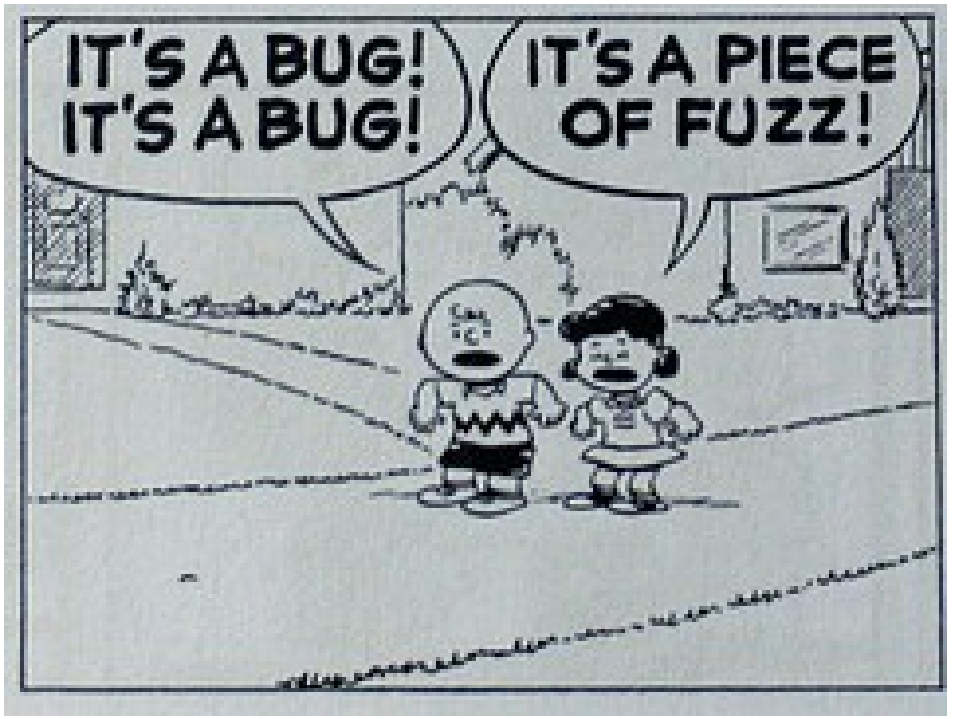
- Same as iPhone and Android :-)



# Monitoring

- Done with IDA Windows Mobile remote debugger
- Multiple processes to monitor
  - tmail.exe → SMS/MMs app from Microsoft
  - Manila2D.exe → TouchFLO GUI from HTC

# Some fuzzing results

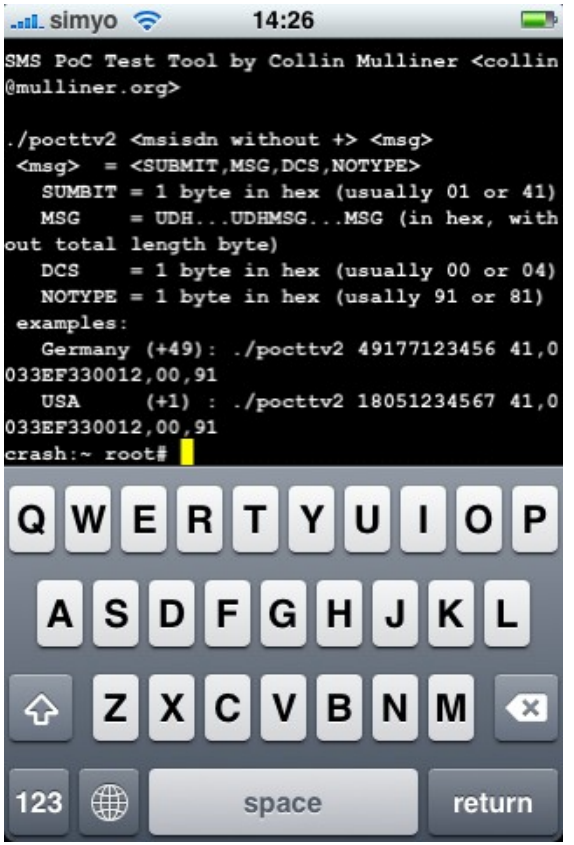


# From potential bug to attack

- Not all bugs found through injection can be sent over the phone network
  - Test-send fuzzing results over the network
  - Messages that go through are real attacks
- We built a small application that runs on the iPhone
  - Easy testing while logged in via SSH
  - Awesome demo tool via mobile terminal
- Test different operators
  - Not all operators allow all kinds of messages
  - May not be able to attack people on all networks

# Send over the network

- Open `/dev/tty.debug`
- Read/write AT commands to send message

# iPhone SMS DoS

- iPhone
  - Crashing CommCenter kicks phone off the network
  - Kills all other network connections (WiFi + Bluetooth)
  - Phone call in progress is interrupted!
  - Repeat as necessary
- SpringBoard crash
  - Locks iPhone (user has to: slide to unlock)
  - Blocks iPhone for about 15 seconds

# Digging the DoS

# Android SMS DoS

- Denial-of-Service against com.android.phone **kicks Android phone off the mobile phone network**
- Restart of com.andoid.phone locks SIM card **if SIM has a PIN set, phone can no longer register with network**
- Attack is silent, user does not see or hear it
- User is unreachable until he checks his phone!

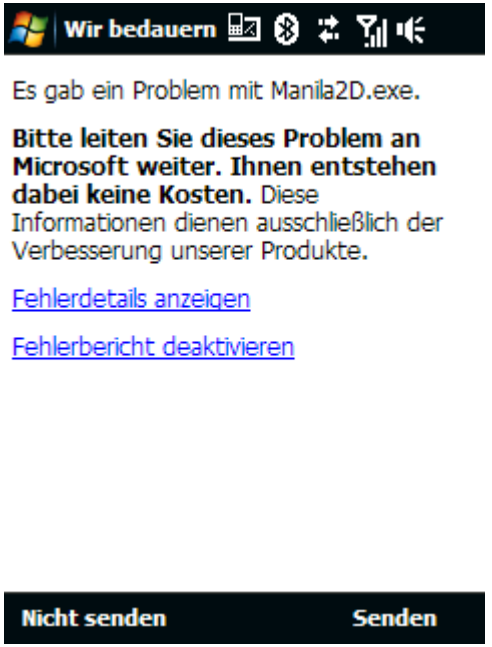
# DoS

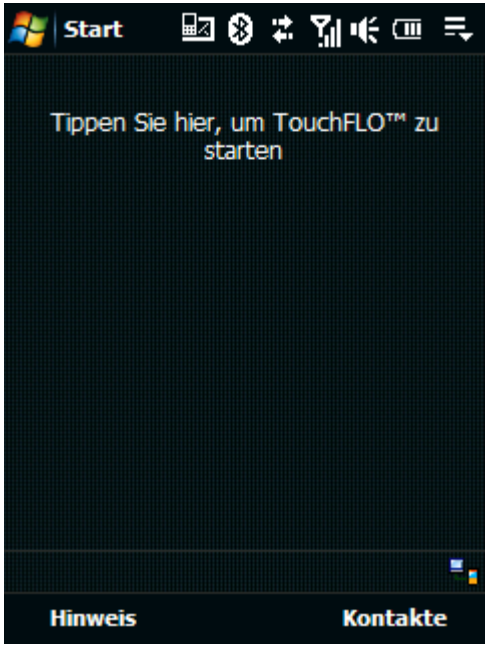

18:01
Berlin, Berlin
18°
Mostly Cloudy
Google Tall
Berlin City
Twidroid
Calendar
No upcoming calendar events
K-9
Messaging
Dialer
Contacts
Browser
18:07
Sorry!
The process com.android.phone has stopped unexpectedly. Please try again.
Force close
Maps
16:59
SIM card is locked.
16:59
22-06-2009
Charging (69%)
Tue 7:00
Screen locked.
Press Menu to unlock or place emergency call.

# Windows Mobile DoS

- HTC Touch 3G (Windows Mobile 6.1)
  - Manil2D.exe (TouchFLO by HTC) crashes
    - App doesn't restart as long as the bad SMS is in the inbox
    - TouchFLO interface will not restart
  - In this case the fix is easy (if you know what to do)
  - Just delete the bad SMS using the Windows Mobile SMS app instead of TouchFLO

# Windows Mobile DoS

# The Demo we did at Black Hat

- Send iPhone CommCenter DoS SMS for 1 hour
  - One message every 10 seconds
- Victim was not able to use his iPhone during the talk and for about 2,5 hours after the talk
  - SMS messages queued up at the SMSC
  - Everytime the phone came back online it got the next message that was waiting for him → bang offline again

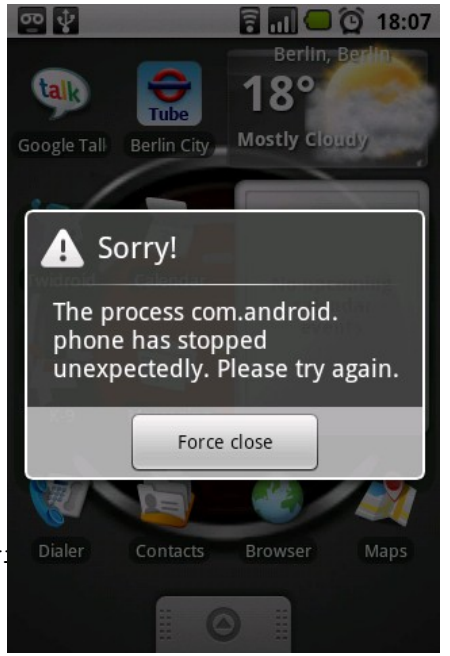
# iPhone SMS code exec summary

- I'm not Charlie, I can write exploits but haven't done it for the iPhone.
- The story:
  - 519 SMS's (@ 1/sec), only one shows up to the user
  - Can control program counter (PC)
  - Could only be found with “smart” fuzzing

# Android DoS

- Send any SMS to port 2948 (WAP push)
- Get java.lang.ArrayIndexOutOfBoundsException
- Knocks phone off network for a few seconds
- Works on European carriers, not on AT&T
  - Bug would not have been found if we had tested only in the US and on AT&T!

# ADB logcat output




```
I/ActivityManager(   56): Stopping service: com.android.mms/.transaction.TransactionServi
D/dalvikvm( 7099): GC freed 2614 objects / 148896 bytes in 134ms
W/AudioFlinger(   35): write blocked for 97 msecs
D/WAP PUSH( 7085): Rx:
0606436b46673774261b69195d187d2b1610370c39456f5b3b58540e3c650b21542141630b6c214764240e707e5c533e0b1143090c4078de7770
5714193c1a2937066d75141c1835144753565d602f6a67152a7807106d35334a7214541774564925640a11335a3b30461145307d04df7b
D/AndroidRuntime( 7085): Shutting down VM
W/dalvikvm( 7085): threadid=3: thread exiting with uncaught exception (group=0x4000fe70)
E/AndroidRuntime( 7085): Uncaught handler: thread main exiting due to uncaught exception
E/AndroidRuntime( 7085): java.lang.ArrayIndexOutOfBoundsException
E/AndroidRuntime( 7085):     at
com.android.internal.telephony.WspTypeDecoder.decodeExtensionMedia(WspTypeDecoder.java:200)
E/AndroidRuntime( 7085):     at
com.android.internal.telephony.WspTypeDecoder.decodeConstrainedEncoding(WspTypeDecoder.java:222)
E/AndroidRuntime( 7085):     at
com.android.internal.telephony.WspTypeDecoder.decodeContentType(WspTypeDecoder.java:239)
```

# Windows Mobile results

- Format string bug in Manila2D.exe (TouchFLO)
- This is the user interface for HTC devices
- A simple text message containing "**%n**" crashes TouchFLO
- Format string should make it exploitable!

**07919471173254F6040C9194716720950800009930925161958002253 7**

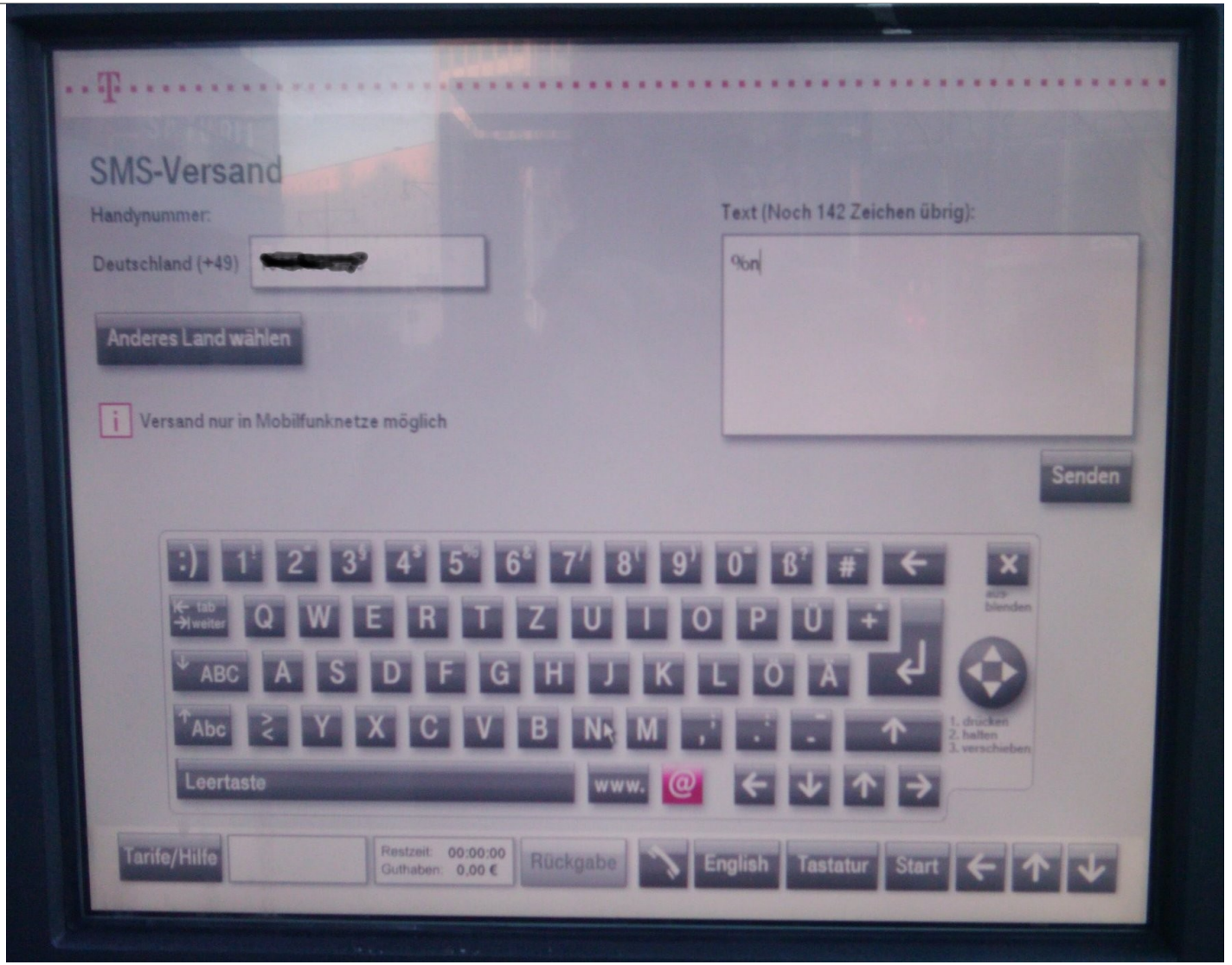
# Conclusions

- SMS is a great vector of attacks against smart phones
- SMS fuzzing doesn't have to be limited by equipment or cost of sending SMS
- Can inject SMS using software only by MITM the modem
- Can find some bugs, keep on fuzzing!

# Firmware Updates

- Android CRC1 also fixes our WAP push DoS bug
  - Released about 2 weeks after we reported the bug
- iPhone OS 3.0.1 was released on July 31th
  - ONLY fixes our CommCenter bug :-)
- HTC told us the bug in TouchFLO is fixed
  - ROM Build 1.00.19153530.00 (this is the HTC Touch 3G)
  - Haven't found a way to download/install it :-(

# Check out my new tool :-)



# The End

- Thanks to
  - Charlie Miller for being a über cool co-author :-)
  - Willem Hengeveld for his WinMobile log-driver
- Tools and slides
  - http://www.mulliner.org/security/sms/
- Contact
  - collin@sec.t-labs.tu-berlin.de