Running Your own GSM Network

by

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Why?

Why would you run your own GSM network?

- For the same reason you might run other networks
  - To learn and experiment with technology
  - To boldly go where no [free] man has gone before ;)
- Practical demonstration of known GSM security problems
- Raise public awareness abut GSM [in]security
  - thus increase the incentive for the market to improve

Legal Disclaimer

Legal Disclaimer

- Don't try this at home!
- GSM operates on LICENSED spectrum
  - Thus, you need approval from the regulatory authority
  - Only use BTS with dummy load!
  - Don't interfere with the operators!
- Our software is strictly for research purpose only

GSM Network Architecture

The Hitchhikers Guide to the GSM Network

- unfortunately does not exist

The GSM related literature

- is typically too high-level

The GSM protocol specifications

- are publicly available but _very_ comprehensive (1,108 PDFs, 414MByte)

GSM Network Architecture

GSM is a bit-synchronous network

- it draws many analogies from ISDN and SDN
- layer 2 modelled after Q.921 / LAPD
- call signalling modelled Q.931
- but: many more protocols for mobility management, radio resources, ...
- like all traditional Telco protocols: Intelligence in the network, not in the end nodes.

GSM is a TDMA "nightmare"

- e.g. you never know from/for whom data is without the timing context

GSM Network Architecture

MS
- Mobile Station (your Phone)

BTS
- Base Transceiver Station

BSC
- Base Station Controller

MSC
- Mobile Switching Center

HLR/VLR
- Home/Visitor Location Register

GSM Base Transceiver Station

BTS

- As the name indicates "transceiver"
- Handles
  - Layer 1 and some parts of RF layer2
  - Modulation/Demodulation
  - Time Multiplex, scheduling of frames
- Is not a "Base Station", i.e. not self-contained
  - True 'slave' to the BSC

GSM Base Station Controller

BSC

- Base Station Controller
- Handles
  - most of the actual decision making
  - really controls most aspects of BTSs
  - handles intra-BSC cell handover

GSM Mobile Switching Center

MSC

- Mobile Switching Center
- Handles
  - Actual switching of the calls
  - Interworking with ISDN or POTS
  - Inter-BSC cell handover

HLR/VLR

- Home/Visitor Location Register
- Handles
  - database of local / roaming subscribers

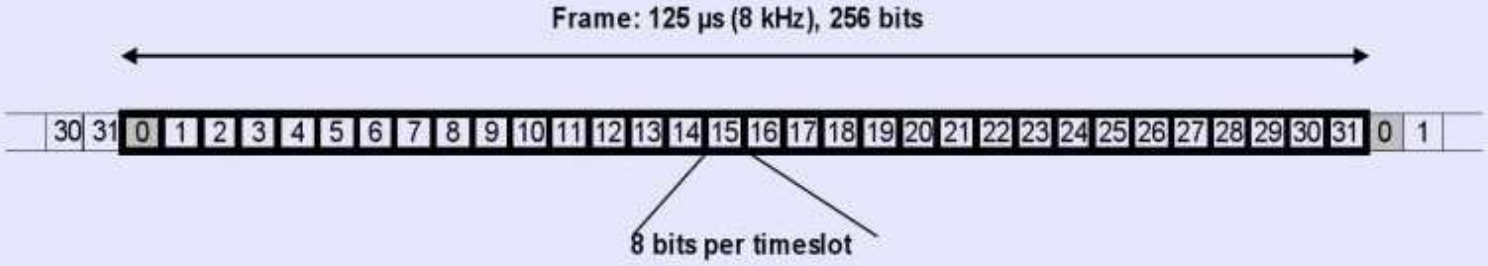
GSM A-bis interface

BSC <-> BTS Interface

- is called A-bis
- has the following control layers on E1 TS1
  - L2ML (Layer 2 Management)
    - TEI management similar to ISDN
  - OML (Organization & Maintenance)
    - System parameters, events
  - RSL (Radio Subsystem Layer)
- has encoded voice data (TRAU frames) on other E1 TS

GSM A-bis interface

ISDN PRI (Primary Rate Interface), European variant (E1)



32 bidirectional channels transfered using TDM (time-division multiplexing)

two wire pairs, one for each direction

ternary signal (three levels) on the wire, HDB3 (high density bipolar of order 3) coding

64 kbit/s on each channel (32 * 64 kbit/s = 2048 kbit/s total)

timeslot 0 is used for synchronization and error handling (CRC)

timeslot 16 usually used for signalling (D-Channel), the others for traffic (B-Channels)

GSM A-bis interface

Speech/Data traffic

a timeslot is subdivided into four sub-channels with 16 kbit/s each

division is done by using 2 bits of a byte for each of the four sub-channels

"transparent" mode, no HDLC

in GSM speech is compressed, several options (e.g. Full Rate or Half Rate)

Full Rate (GSM 06.10) compresses speech into blocks of 260 bits every 20 ms (13 kbit/s)

Source code for a Full-Rate codec at http://kbs.cs.tu-berlin.de/~jutta/toast.html

each block of 260 bits is packed into a TRAU (Transcoder and Rate Adaptation Unit) frame of 320 bits by the BTS (Base Transceiver Station), total 50 * 320 bits/s = 16 kbit/s

TRAU frames are specified by GSM 08.20

GSM A-bis interface

Abis RSL

- contains messages for
  - Radio Link Layer (RLL)
  - Dedicated Channel (DCHAN)
  - Common Channel (CCHAN)
  - Transceiver (TRX)

GSM Mobile Switching Center

Abis RSL Radio Link Layer

- contains messages for
  - Call Control (CC)
  - Mobility Management (MM)
  - Radio Resource (RR)
  - Short Message Service (SMS)
- mostly specified in GSM TS 04.08

The Siemens BS-11 microBTS

Siemens BS-11 microBTS

- plain old 2G (GSM voice calls, CSD)
- one or two TRX, 30mW to 2W each, GSM900
- two E1 interfaces (for daisy-chaining)
- documentation under NDA, but
  - 99.9% of the A-bis protocol available from GSM specs
    - See TS 04.08 (RLL), 12.21 (OML), 08.58 (RSL)
- RS232 serial port for Local Maintenance Terminal
  - LMT software proprietary under NDA
    - not needed for operation of the BTS

The Siemens BS-11 microBTS

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The Siemens BS-11 microBTS

First steps with the Siemens BS-11

- Harald bought a BS-11 on e-Bay in 2006
  - Started to read some specs (08.5x) about A-bis
  - Started to build cables for E1 and power
  - Bought HFC-E1 PCI card
  - Bought Elmi EGM35 Abis analyzer (e-Bay once again)
  - Contacted with other people who also bought BS-11
  - Found somebody who could provide Abis traces
  - Never really had time due to Openmoko and other projects

The Siemens BS-11 microBTS

Further steps with the Siemens BS-11

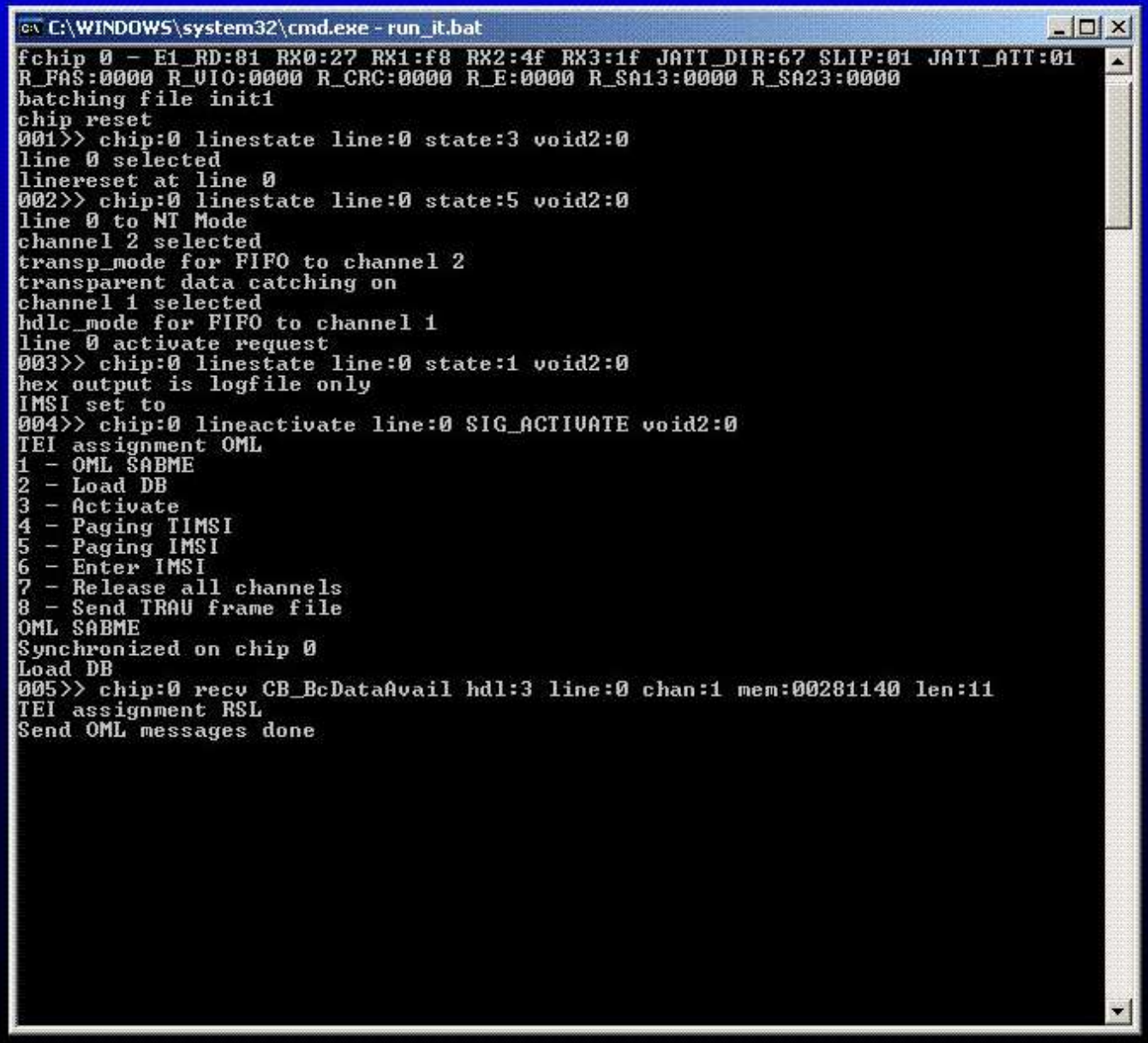
- Dieter bought a BS-11 09/2008
  - Bought HFC-E1 PCI card
  - Started development based on HFC-E1 reference driver code
  - Found somebody who could provide Abis traces
  - Made very quick progress

BS11-Init

BS11-Init (09/2008)

- Chip cologne HFC-E1 reference code for DOS
  - polling, no interrupts
- ported to Windows and Linux (mmap of HFC registers to userspace)
- proof-of-concept code based on challenge-response
- handles TEI assignment, brings OML and RSL up
- allows for location update and paging of single phone

BS11-Init


C:\WINDOWS\system32\cmd.exe - run_it.bat
fchip 0 - E1_RD:81 RX0:27 RX1:f8 RX2:4f RX3:1f JATT_DIR:67 SLIP:01 JATT_ATT:01
R_FAS:0000 R_VIO:0000 R_CRC:0000 R_E:0000 R_SA13:0000 R_SA23:0000
batching file init1
chip reset
001>> chip:0 linestate line:0 state:3 void2:0
line 0 selected
linereset at line 0
002>> chip:0 linestate line:0 state:5 void2:0
line 0 to NT Mode
channel 2 selected
transp_mode for FIFO to channel 2
transparent data catching on
channel 1 selected
hdlc_mode for FIFO to channel 1
line 0 activate request
003>> chip:0 linestate line:0 state:1 void2:0
hex output is logfile only
IMSI set to
004>> chip:0 lineactivate line:0 SIG_ACTIVATE void2:0
TEI assignment OML
1 - OML SABME
2 - Load DB
3 - Activate
4 - Paging TIMSI
5 - Paging IMSI
6 - Enter IMSI
7 - Release all channels
8 - Send TRAU frame file
OML SABME
Synchronized on chip 0
Load DB
005>> chip:0 recv CB_BcDataAvail hdl:3 line:0 chan:1 mem:00281140 len:11
TEI assignment RSL
Send OML messages done

From BS11-Init to OpenBSC

From BS11-Init to OpenBSC (12/2008)

- get L2ML to work with mISDN
  - mainline mISDN doesn't deal with multiple SAPIs and fixed TEI
- learn how new sockets-based mISDN API works
- come up with event-driven architecture, single sleect loop, no threads, ...
- At 25C3:
  - add libdbi/sqlite database for "HLR"
  - get paging to work, support for configurable network ID
  - debugging + stabilization with > 1000 test users ;)
  - IMSI + IMEI skimming

Work at 25C3

IMSI+IMEI skimming

- very simple:
  - phones with automatic network selection pick strongest network
  - they send LOCATION UPDATE REQUEST
  - we send IDENTITY REQUEST IMSI + IMEISV
  - they send IMSI + IMEISV
  - we store this in the databasa
  - and then send LOCATION UPDATE REJECT

Work at 25C3

Mobile Originated Call

- once a MS is registered, we can
  - dial a number from the MS
  - allocate and establish a TCH/F
  - deal with the Signalling and get into Connect
- unfortunately, code for handling voice streams not finished

Work at 25C3

Mobile Originated SMS

- once a MS is registered, we can
  - send a SMS
  - parse + acknowledge SMS PDU data

Work at 25C3

The Egypt simulation

- apparently GPS is illegal in mobile phones in Egypt
  - "Egypt detection" implemented by checking if any surrounding cells are with Egypt country code
  - phones don't even have to register to our BTS!
  - so if we claim to be e.g. MobiNil, phones will shut off their GPS

Other GSM related FOSS

Other GSM related FOSS

- OpenBTS
  - 100% Software Defined Radio bsed on USRP + gnuradio
  - implements entire RF+layer1/2/3 and interfacing to SIP/Asterisk
  - much more than just a BTS!!
  - some code overlap with OpenBSC

Links

- OpenBSC
  - http://openbsc.gnumonks.org/
- 3GPP / ETSI GSM Specs
  - http://www.3gpp.org/
- Priv-Doz. Dr.-Ing Joachim Goeller
  - http://www2.informatik.hu-berlin.de/~goeller
- THC GSM Wiki
  - http://wiki.thc.org/gsm
- OpenBTS
  - http://gnuradio.org/trac/wiki/OpenBTS
- Harald's branch of gsm-tvoid, etc
  - git://git.gnumonks.org/gsm.git

Thanks

Thanks to

- zecke, alphaone, Stefan for their work on OpenBSC
- W. for his extensive A-bis protocol traces and MA-10
- all the voluntary testers at 25C3
- Karsten Keil for mISDN

Thanks

LIVE DEMO