Playing with the GSM RF Interface

26C3

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Agenda

- Motivation for playing with GSM

- Introducing GSM related projects

- What about an „open“ phone ?

- Sniffing the air traffic using the hardware of a phone (work in progress)

- DoS attack to the GSM network using a phone with modified firmware

- Demonstration of the DoS attack

Motivation

- GSM system and protocols not that well researched compared to TCP/IP (although GSM in use since 1992 in Germany)

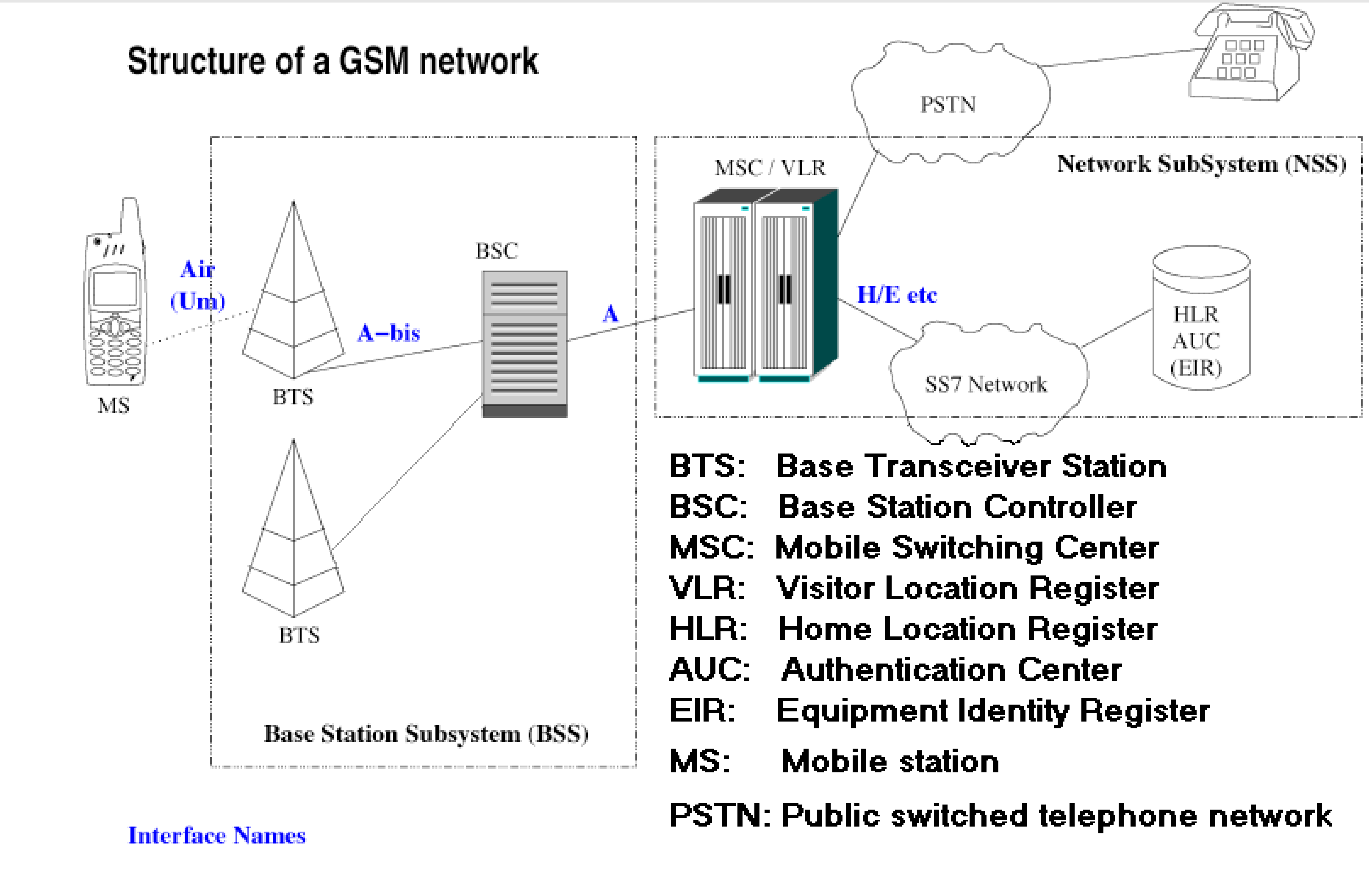
- Nearly impossible to "play" with GSM without major effort

- Situation has changed:

  * used equipment can be found
  * OpenBTS
  * OpenBSC
  * Airprobe

- Specification is available from 3GPP or ETSI (huge, about 2000 documents)

Simplified GSM Network Structure diagram to better understand the abbreviations and acronyms



BTS: Base Transceiver Station

BSC: Base Station Controller

MSC: Mobile Switching Center

VLR: Visitor Location Register

HLR: Home Location Register

AUC: Authentication Center

EIR: Equipment Identity Register

MS: Mobile station

PSTN: Public switched telephone network

Diagram derived from Wikipedia (http://en.wikipedia.org/wiki/File:Gsm_network.png), GNU Free Documentation License applies to this diagram

OpenBTS

- Hardware based on the USRP (Universal Software Radio Peripheral)

- Air Interface (Um) is a Software Defined Radio

- Does not model classic GSM architecture (BSC, MSC, ...) but uses a direct Um-to-SIP approach

- Uses Asterisk via SIP (Session Initiation Protocol) and Voice-over-IP

OpenBSC

- Implements the Abis protocol plus BSC/MSC/HLR

- Supports the Siemens BS11 microBTS

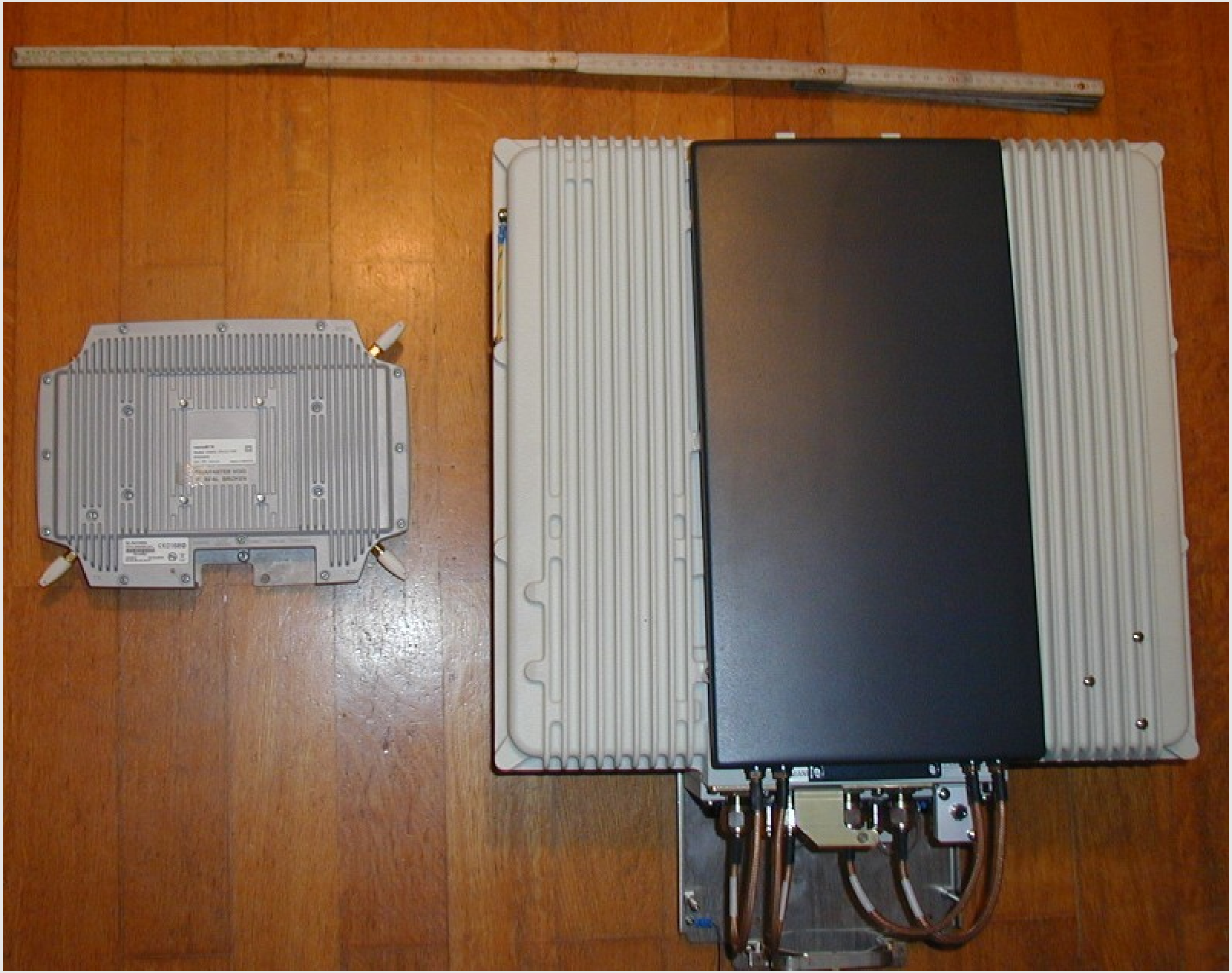
    * GSM 900, 2 W (can be reduced to 30 mW)
    * about 10 years old
    * cheap
    * heavy (30 to 40 Kg, depending on the configuration)
    * E1 interface for Abis

- Supports the ip.access nanoBTS

    * various bands, 200 mW for DCS 1800
    * small
    * GPRS/EDGE
    * Abis over IP

- Runs the 26C3 GSM network with four nanoBTS units

nanoBTS versus BS11



Airprobe

- Passively sniff the GSM Air Interface
- Based on the USRP and GNU Radio
- Analyze the protocols with Wireshark
- Can be used to capture the traffic for A5/1 GSM encryption cracking

What about an „open“ phone ?

- Project Blacksphere for Nokia DCT3 phones, no longer active ?

- TSM30, based on the TI Calypso GSM chipset, source code can be found. Approach:

  * don't use the source code, control the hardware on our own (Example: sniffing the air traffic)

  * modify the exisiting source code and see what can be done (Example: DoS attack to the GSM network)

- Openmoko GTA01/GTA02: GSM modem based on the TI Calypso however different version and different RF-Transceiver chip. Note: Even for „Open Source“ phones, no source code for GSM.

- Future plans: Take a GSM RF-Transceiver and Baseband chip, connect it to a DSP/FPGA board, develop true open software

TSM30

- Spanish phone (also distributed in Mexico and Chile), about 6 years old
- GSM, GRPS, WAP
- TI Calypso chipset: RF-Transceiver, Digital baseband, MCU (ARM+DSP core), leaked documents can be found
- Firmware C Source Code:

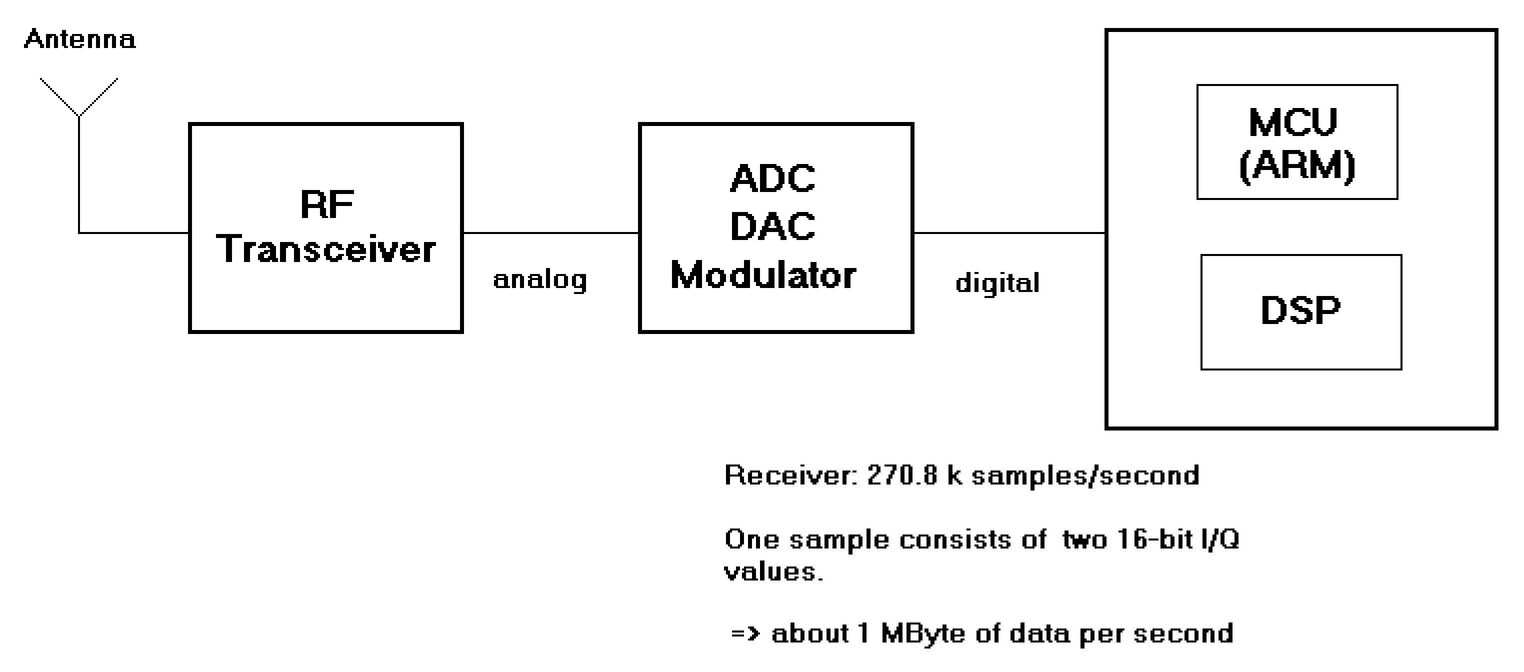
  * Calypso ARM: ca. 6500 files, 2.5 Mio lines of code

    - GSM protocol stack: ca. 700 files, 400 000 lines of code
    - Layer 1 (without DSP): ca. 130 files, 130 000 lines of code

  * Second microcontroller: ca. 1500 files, 350 000 lines of code

Sniffing the air traffic

- (Very) simplified diagram of the Calypso chipset:



Receiver: 270.8 k samples/second

One sample consists of two 16-bit I/Q values.

=> about 1 MByte of data per second

- Sample data can be processed with „gsm-receiver“ from Airprobe

- Problem: how to get the data in „real-time“ out of the Calypso

- Future plans: make use of the DSP ? (56 kByte RAM, ROM based GSM signal processing code, no source code)

DoS Attack

- Theory known for quite some time

- However no practical demonstration or implementation ?

- Attack possible because of the way an idle phone has to access the GSM network (details later)

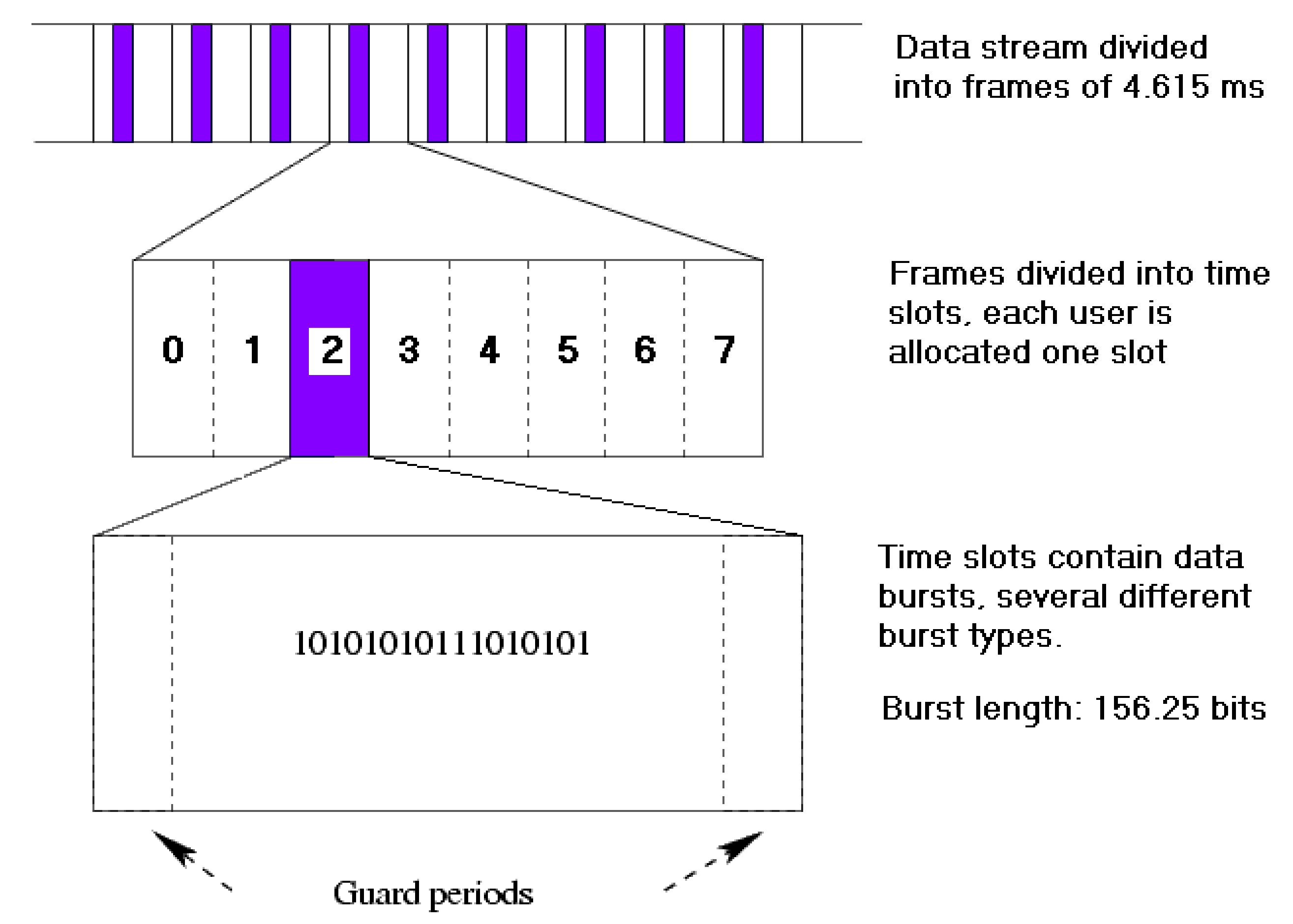
- Affects one cell

- Very early stage, no authentication of the phone yet

- No information of the phone has been transferred yet (anonymous attack)

- Not much can be done against it, try to locate the attacking mobile

GSM TDMA (Time division multiple access)



Data stream divided into frames of 4.615 ms

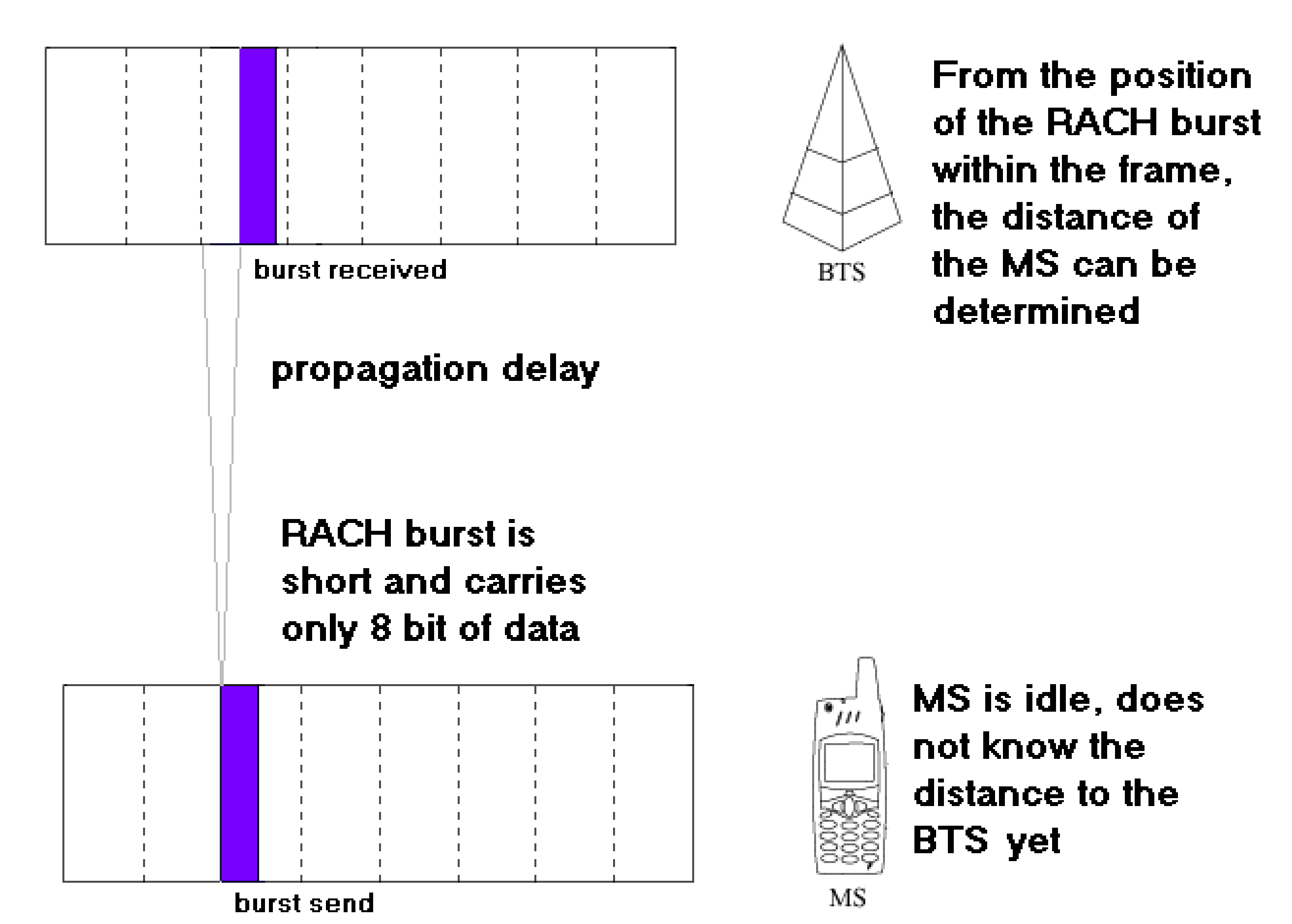
Frames divided into time slots, each user is allocated one slot

Time slots contain data bursts, several different burst types.

Burst length: 156.25 bits

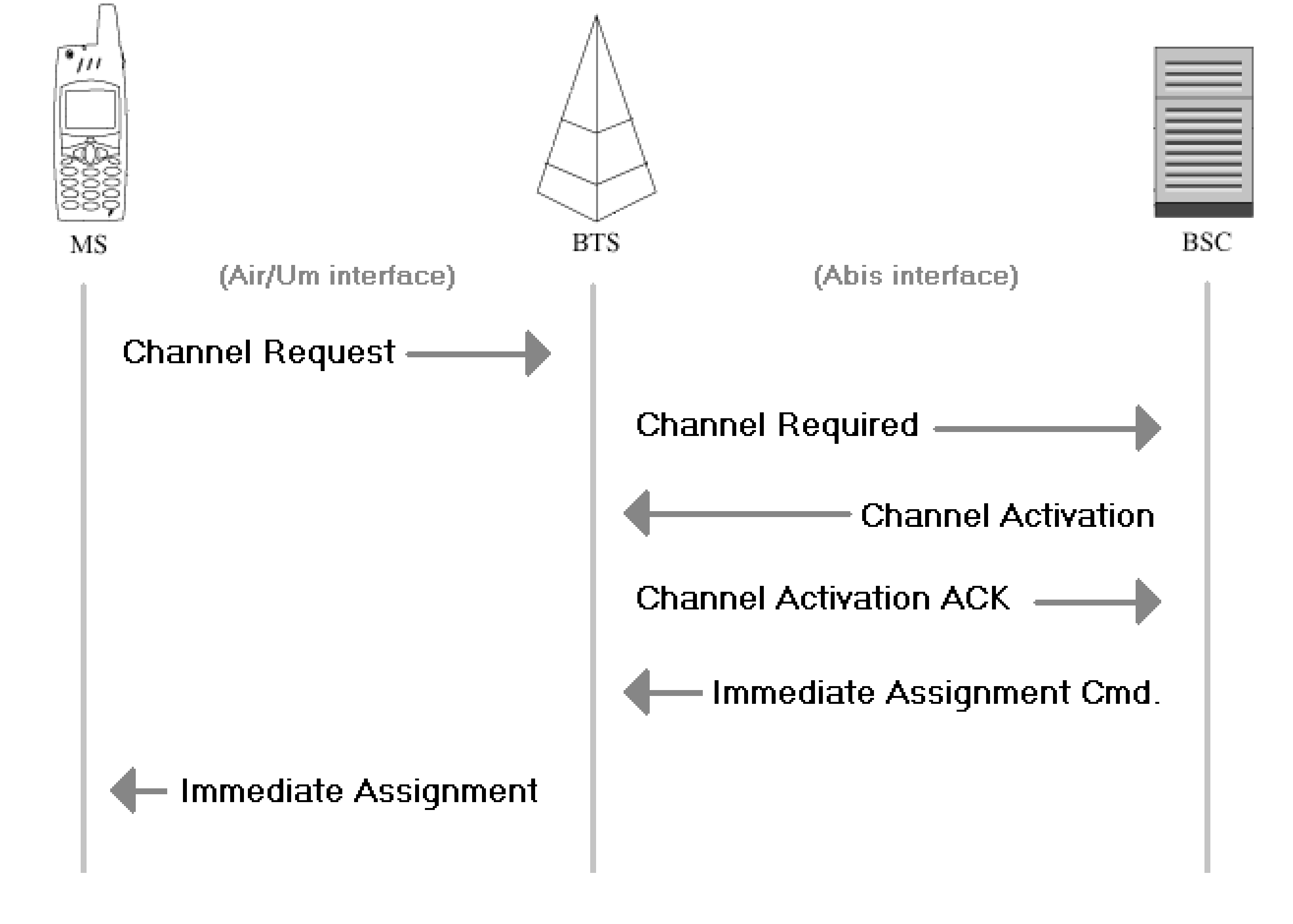
Diagram derived from Wikipedia (http://en.wikipedia.org/wiki/File:Tdma-frame-structure.png), GNU Free Documentation License applies to this diagram

RACH (Random Access Channel) burst


burst received
BTS
From the position of the RACH burst within the frame, the distance of the MS can be determined
propagation delay
RACH burst is short and carries only 8 bit of data
MS is idle, does not know the distance to the BTS yet
burst send
MS

MS sends a RACH burst to access the GSM network (Channel Request)

Message flow Channel Request



If the channel is not established within a certain time, it is released by the BSC

Effects of continuously sending RACH burst

- Jamming (disturbing the signal of other phones)

- Resource allocation (BTS channels)

- No influence on already existing connections

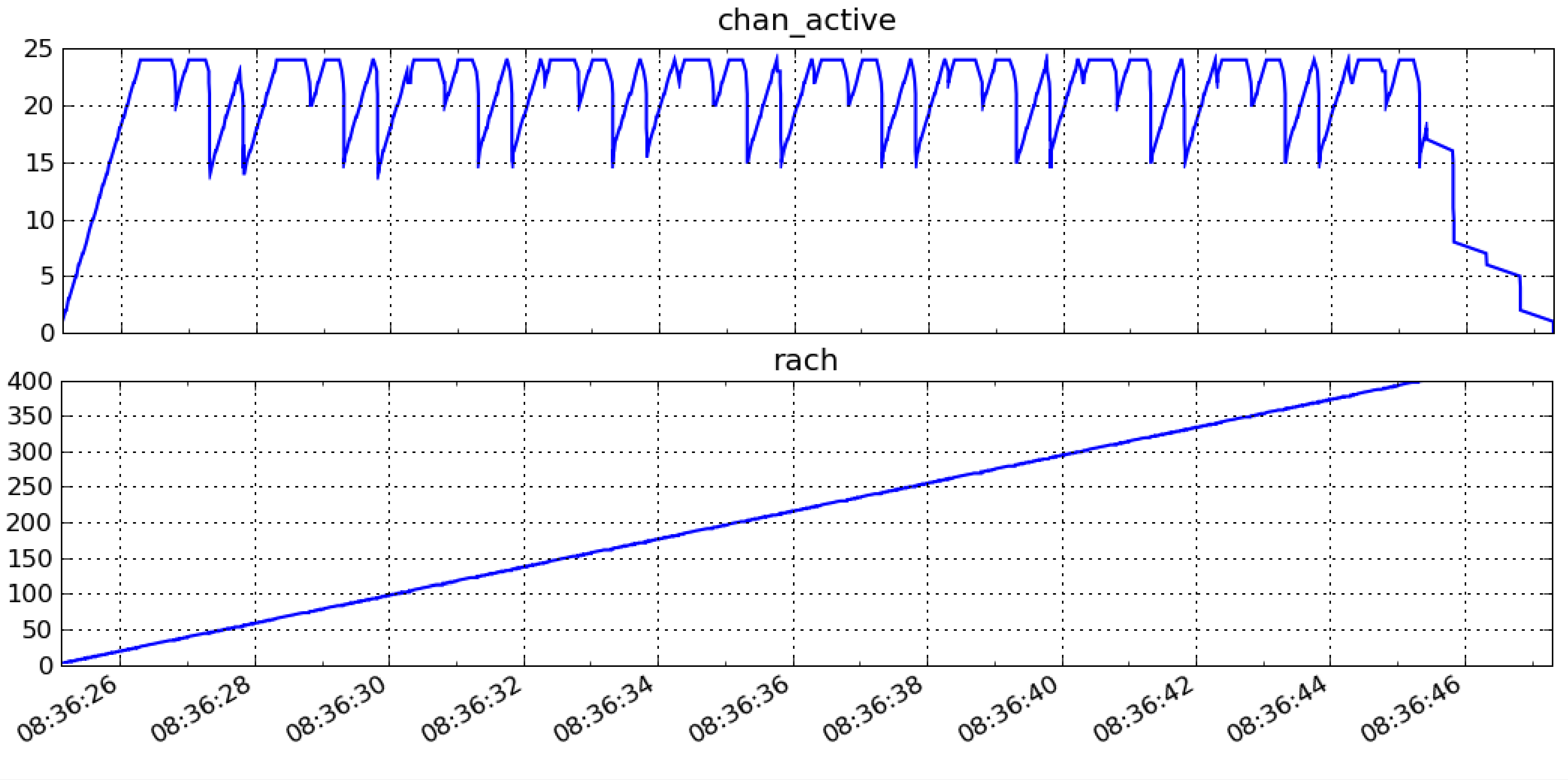
- Difficult or impossible for other phones to access the network through the attacked cell

- Phones might switch to another cell

- No 100% guarantee that another phone won't access the attacked cell

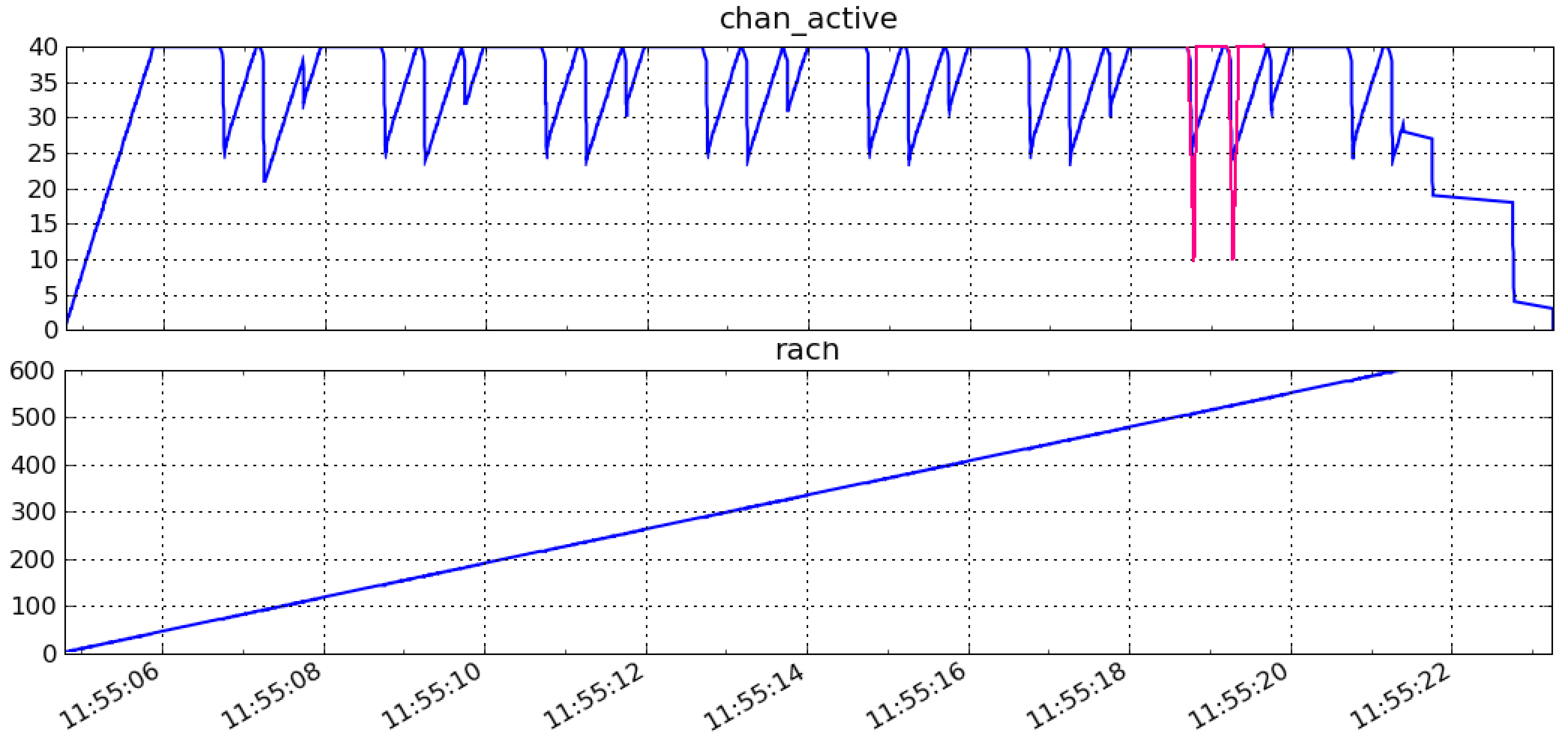
- Useful application: attack IMSI catchers

Lab results, BTS with 2 TRX



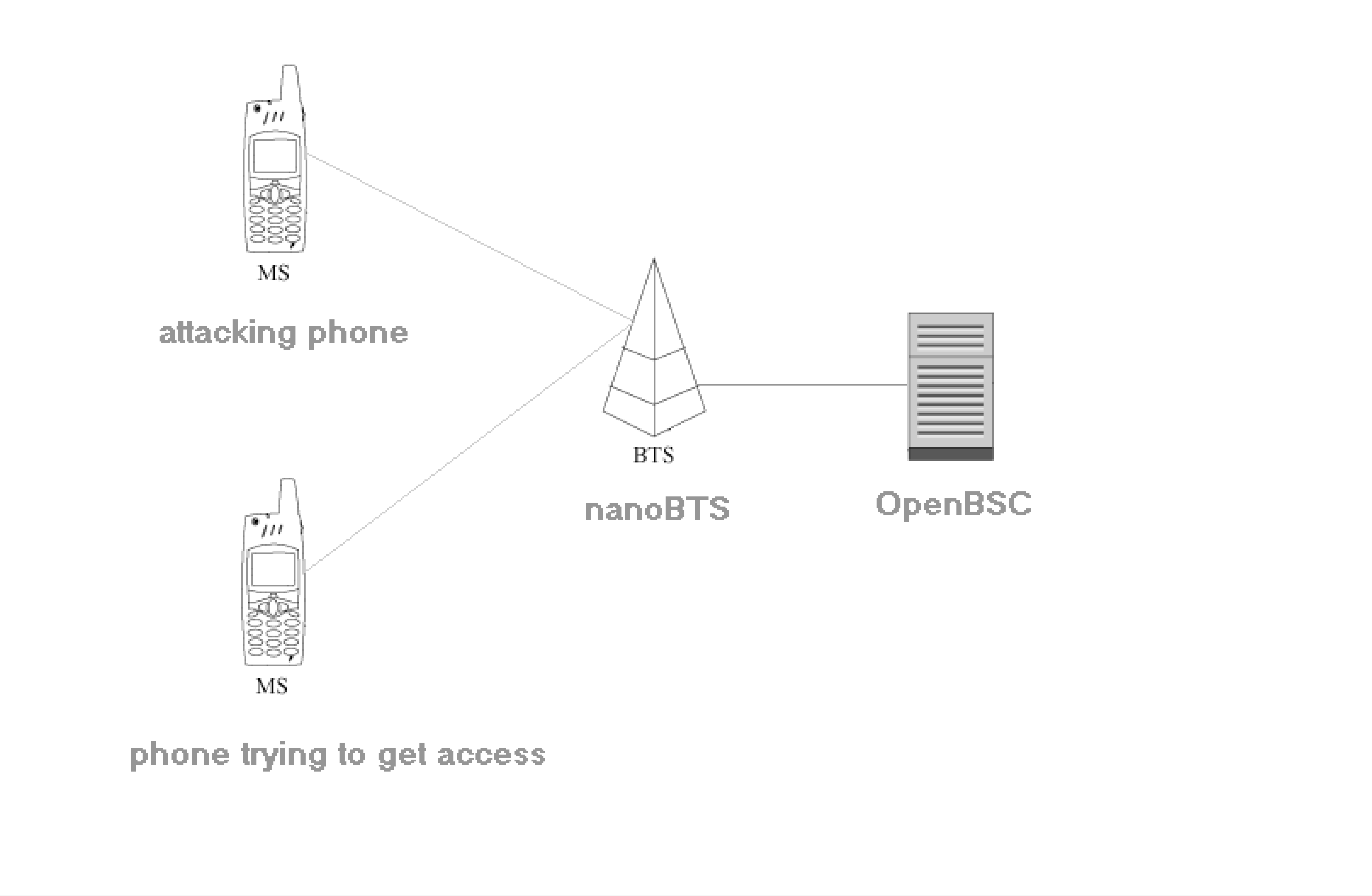
Note: At the time this measurement was made, the RACH density was not yet 100% as it is now

Lab results, BTS with 4 TRX



Note: At the time this measurement was made, the RACH density was not yet 100% as it is now
Red line: this is how it might look with 100% RACH density.

DoS Attack demonstration setup



Links

- OpenBTS: http://openbts.sourceforge.net/
- OpenBSC: http://bs11-abis.gnumonks.org/
- Airprobe: http://airprobe.org/
- 3GPP: http://www.3gpp.org/
- ETSI: http://www.etsi.org/

Thanks

Harald Welte, David Burgess

Feedback

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Questions

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