Internetworking Seminar

Modem, DSL and Powerline technologies

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Overview

- Modem technology
- DSL technologies
- Powerline networks

Modem technology

Modem technology

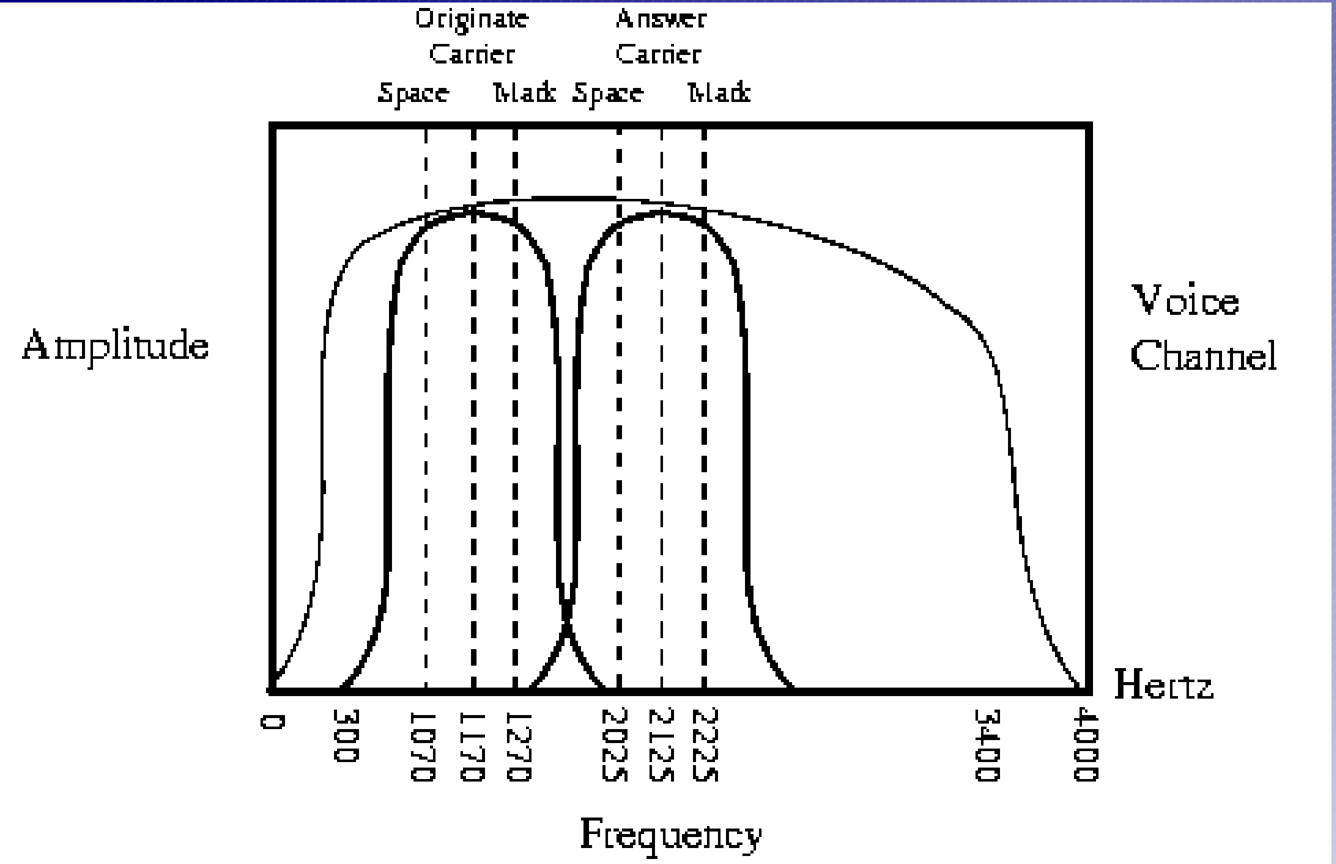
- modem stands for modulate/demodulate
- used to communicate data over the PSTN
- the first modem was invented in the 1950's
- the first commercial modem was manufactured by AT&T in 1962
- the “Bell 103”: full-duplex operation, frequency shift keying, 300 baud
- baud means “bits per second”

Modulation/Demodulation techniques

- Frequency Shift Keying (FSK)
- FSK is the frequency modulation of a carrier to represent digital data
- Simplex of Half Duplex Operation
  - carrier signal frequency: 1170 Hz
  - 1 is represented by 1270 Hz
  - 0 is represented by 1070 Hz
- for Full Duplex a second carrier has to be used

Modulation/Demodulation techniques (cont.)

- Full Duplex example

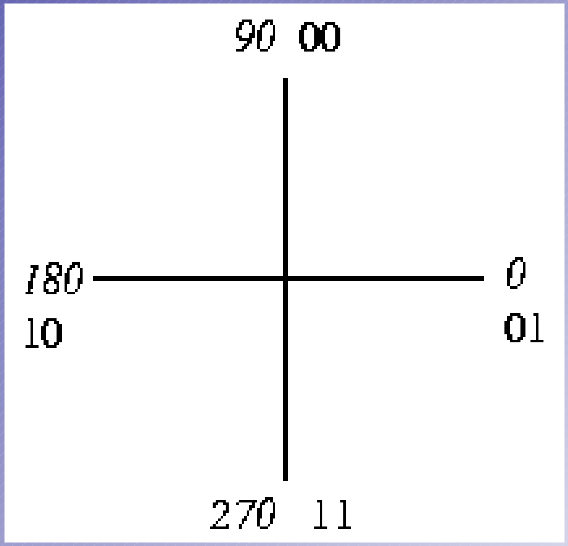


Modulation/Demodulation techniques (cont.)

- what is the maximum baudrate for FSK?
- bauds = bits per second
- 2400 bauds: at least 2400 Hz
- the usable bandwidth for telephone lines is 0–3400 Hz
- full-duplex operation needs two carriers
- the physical limit is reached
- what is the way out?

Modulation/Demodulation techniques (cont.)

- Quadrature Phase Shifted Keying (QPSK)
- carrier frequency at 600 baud
  + encoding technique
Bits to send	Phase Shift
01	0°
00	90°
10	180°
11	270°

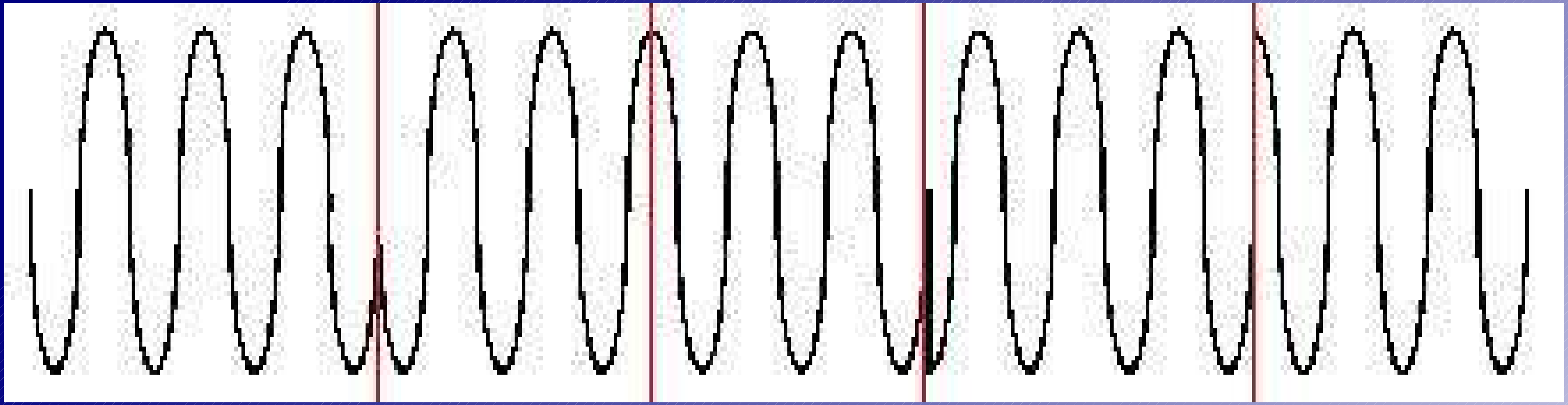


Modulation/Demodulation techniques (cont.)

- every change in the baud rate (phase shift) decodes 2 bits
- 2 bits * 600 baud = 1200 bps

Modulation/Demodulation techniques (cont.)

- example of Carrier Phase Modulation



180°	0°	270°	90°
10	01	11	00

- data transmitted: 10011100

Modulation/Demodulation techniques (cont.)

- the datarate can be increased by:
  - using more phase angles
  - modulating the amplitude
- example: 16-QAM
- 12 phase angles, 4 of them with 2 amplitude values, gives 16 values (4 bit)
- calculation for 16-QAM:
  - 4 bits * 2400 baud = 9600 bps Modems

Modulation/Demodulation techniques (cont.)

- now we understand the basic modulation/demodulation techniques
- these are used in all common types of modems (DSL-, Powerline-, Cable-, ...-Modems)
- only differs in frequencies and channel count

Modulation/Demodulation techniques (cont.)

- how can we seperate the frequencies?
- 2 frequencies can be seperated with a low/high-pass filter
- we will see a high-pass filter in our demonstration
- 3 or more frequencies can be seperated by using bandwidth filters

DSL technologies

DSL technologies

- What is DSL?
- Different types of xDSL
- How does DSL work?
- Specifications of different xDSL-types
- Prices
- Experiments

What is DSL?

Means: Digital Subscriber Line

- Uses ordinary copper telephone-lines to provide a high-speed internet-connection
- DSL is a cheap alternative to other high-speed connections, where new cables are needed
- Is available with up to 52 Mbps
- Offers parallel use of data and telephone services over the same line

What is DSL (cont.)

- Connections are only possible on the 'last mile' from the telco central office to the private telephone jack.
- Some houses may be too far away, so only a slow connection or no connection at all may be possible
- There are many types of DSL to meet everybodies needs

Different types of xDSL

- ADSL: Asymmetric DSL, with a larger portion of the capacity downstream, less upstream
- HDSL: High-bit-rate DSL, a technology for the business market. In commercial operation several years. Using two wire pairs
- SDSL: Symmetric DSL is a variation of HDSL using only one wire-pair
- VDSL: Very-high-bit-rate DSL which provides speeds up to 52 Mbps, but only for short distances, highest datarate of all

How does DSL work?

- Basic Principle
- Splitters
- Modulation techniques

Basic Principle

- POTS (and therefore regular modems) can only use frequencies up to 4 kHz
- This is due to the fact that the signals have to survive the switching centers and sometimes very long distances
- DSL uses much higher frequencies to achieve much higher data rates
- This works only on the 'last mile' from the telco to the user

Splitters

- ADSL and VDSL allow simultaneous use of telephone and data services
- In order to do this, the signal has to be split up at 4 kHz
- This is done by the splitter
- A splitter is a passive device (low pass filter)
- It splits the signal in the parts above and below 4 kHz and feeds it to the POTS and to the DSL-hardware

Modulation techniques

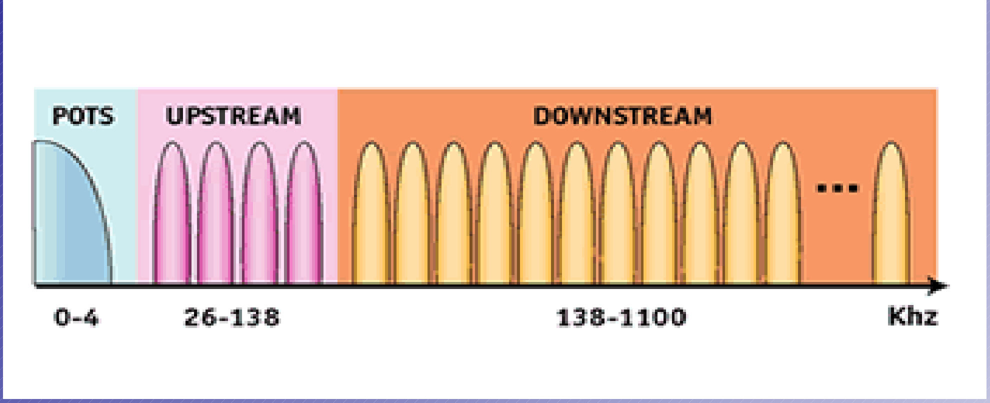
Carrierless Amplitude/Phase (CAP)

- A version of QAM. A single carrier is modulated and transmitted over the line.
- The carrier itself is supressed and reconstructed from the signal
- Easy to implement

Modulation techniques (Cont.)

Discrete Multi-tone (DMT)

- Divides the frequencies in bands (channels) of 4.3125 kHz each
- Provides more bands for downstream, than for upsteam. This is the reason for the assymmetry of the resulting technologies

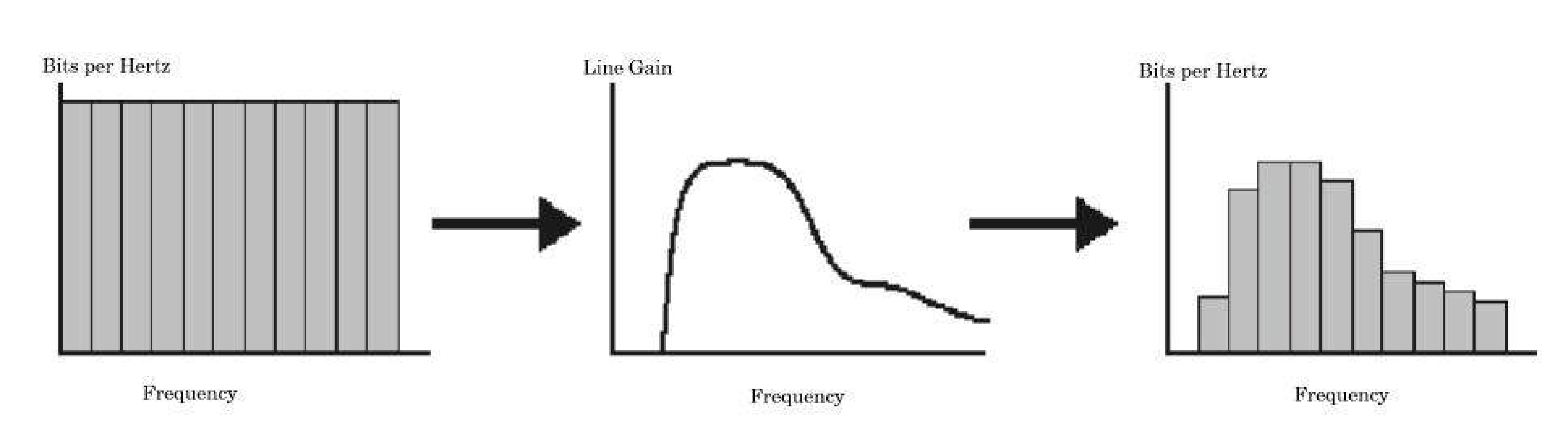


Modulation techniques (Cont.)

- Uses QAM as described in the beginning for each channel, resulting in 60 kbps per channel
- Uses the Fast Fourier Transform (FFT) Algorithm for modulation/demodulation
- At the beginning of the communication the two modems test each channel and calculate its signal to noise (S/N) ratio
- More bits are assigned to channels with a high S/N ratio

Modulation techniques (Cont.)

- The line does not carry all frequencies equally well



Modulation techniques (Cont.)

Two Binary, One Quaternary (2B1Q)

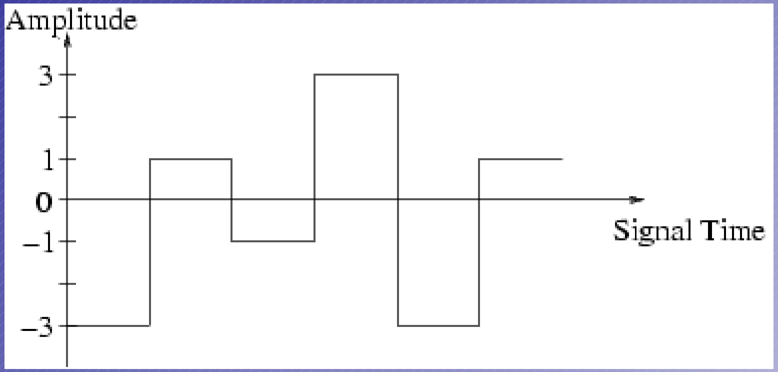
- Straightforward signal type
- 4 amplitude levels (voltages) are used to transfer 2 bits per signal time step
- To increase the data rate, more levels are needed, thus its getting harder to discriminate between them at the receiver side
- or the signal time has to be increased

Modulation techniques (Cont.)

- Bits Voltage

Bits	Voltage
00	+3
01	+1
10	-1
11	-3

- Example: 110110001101



Specifications

- Here is a list of the most important facts about some types of xDSL

	ADSL	HDSL	SDSL	VDSL
Bits/second	768kbps-9Mbps down 16-640kbps up	1.5 or 2Mbps	144kbps-1.5Mbps	13-52Mbps down 1.5-2.3Mbps up
Mode	asymmetric	symmetric	symmetric	asymmetric
Copper pairs	1	2	1	1
Range (˜)	3.7 to 5.5km	3.7km	3km	1.2km
Signalling	analog	digital	digital	analog
Line Code	CAP/DMT	2B1Q	2B1Q	DMT
Frequency	up to 1-5MHz	196kHz	196kHz	up to 12MHz
Bits/cycle	varies	4	4	varies

Prices

- ADSL
  768/128 kbps 42,- € (incl. port)
  1536/192 kbps 129,- € (incl. port)
- SDSL/HDSL
  256 kbps 239,- €
  2048 kbps 889,- €
- ATM E1
  2048 kbps 1190,- €, but:
  new cabling is needed!

All prices are flatrate-prices + tax, 06/2003

Powerline Networks

What is Powerline?

- using the existing power cabling (~220V in Germany) for data-transmission
- two types:
  “access” (seems to be obsolete)
  “in-home”
- focus on “in-home”
- different types of bridges available (usb, ethernet etc.)
- we used Ethernet-over-Powerline

ALLNET 1682 Ethernet Bridge

- based on Intellon's PowerPacket chipset
- provides Ethernet-over-Powerline
- connects via Twisted-Pair to PC(NIC) or Switch
- Operating system independent (easy to handle)
- up to 12 nodes per network
- 56-bit encryption (password)
- works within 110V and 220V power circuits

ALLNET 1682 Ethernet Bridge

- throughput: ~5MBit/s
- frequency band: 4.3 – 20.9 MHz
- range: up to 200m

- ~99€ per bridge

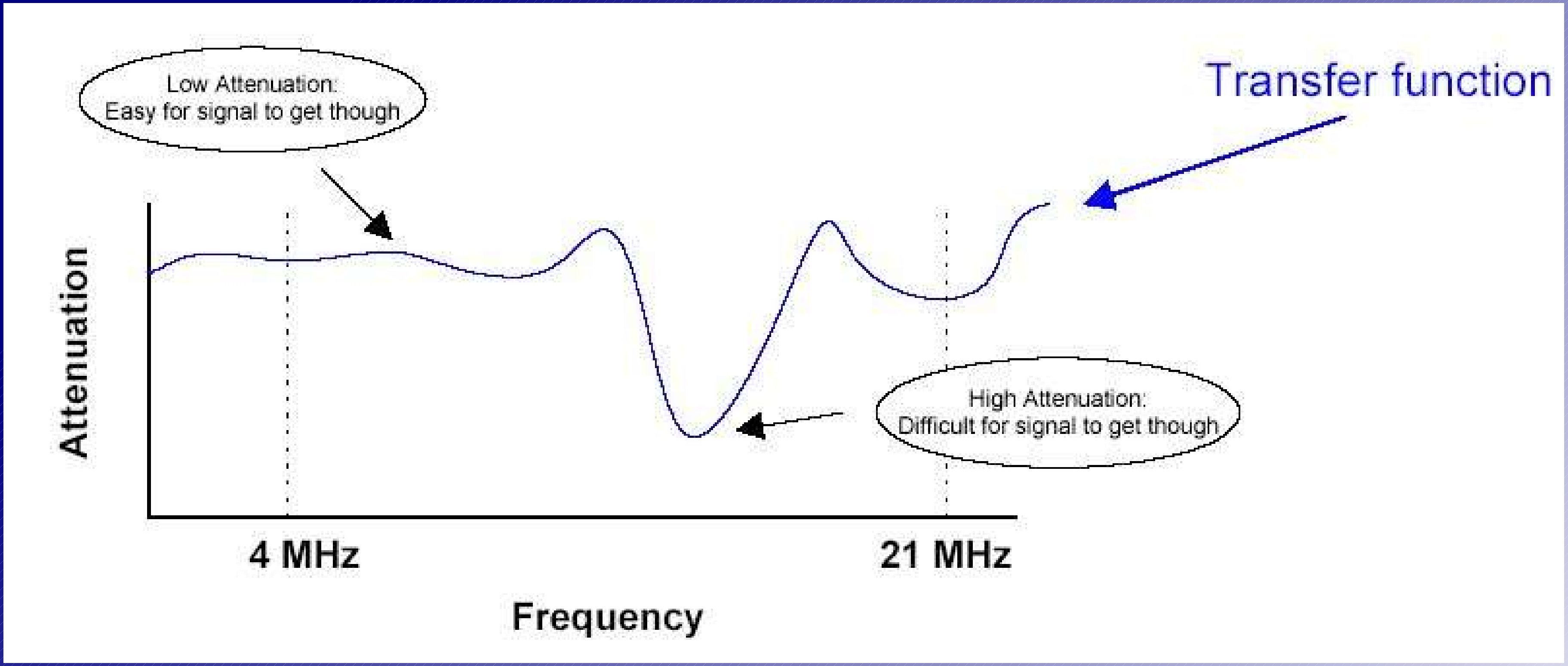
Obstacles

- no predictable medium
- changing conditions, caused by:
  other appliances (fan, vaccum cleaner etc.)
  and wire quality
- changing conditions are:
  attenuation
  and noise

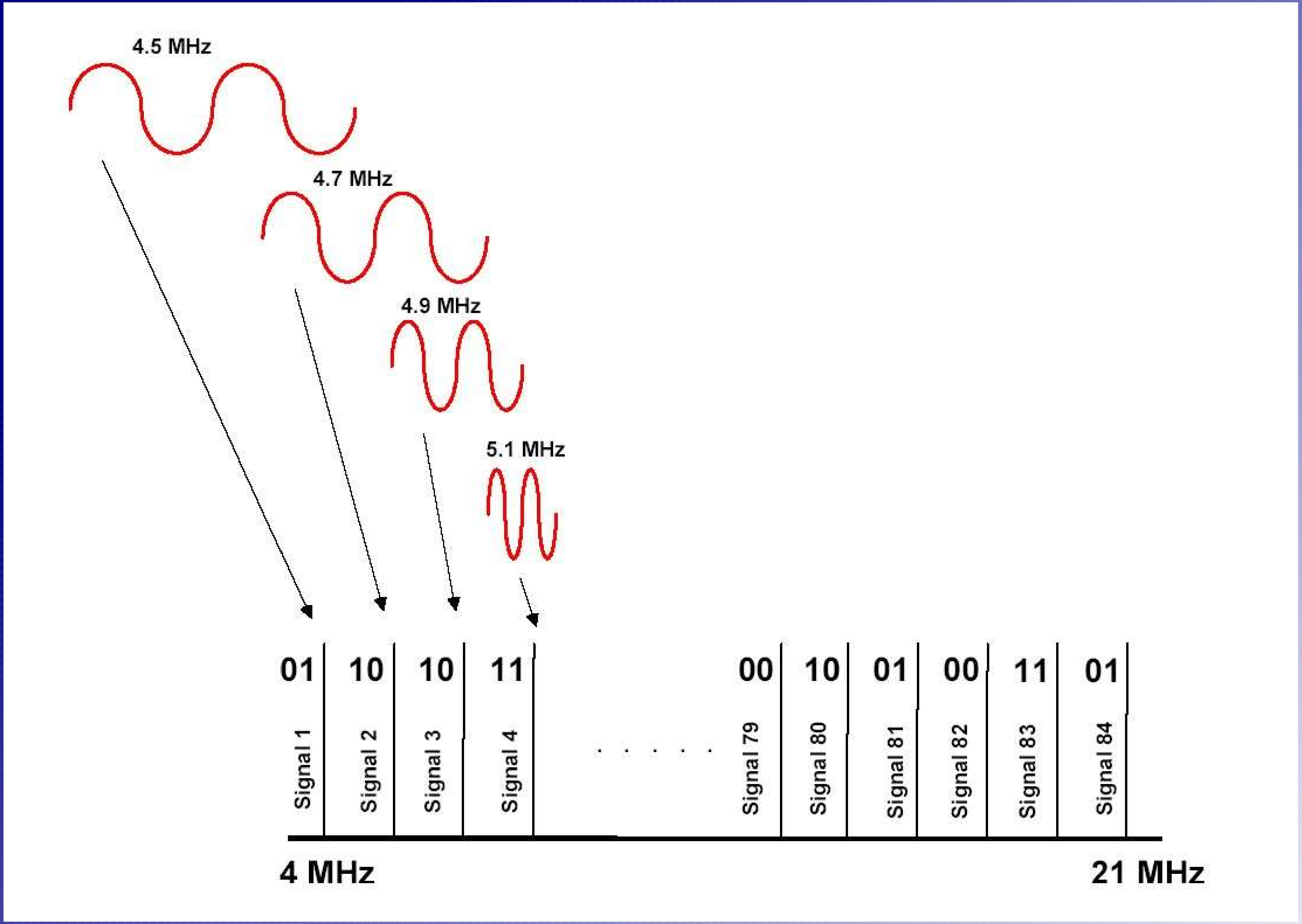
How to solve these problems ?

- OFDM as transmission protocol (Orthogonal Frequency Devision Protocol)
- nearly the same as DMT modulation (ADSL)
- not scaling the amount of bits carried by a channel
- monitoring the medium for changes in transfer function
- determine treshold for adapting to transfer function

transfer function - “snapshot”

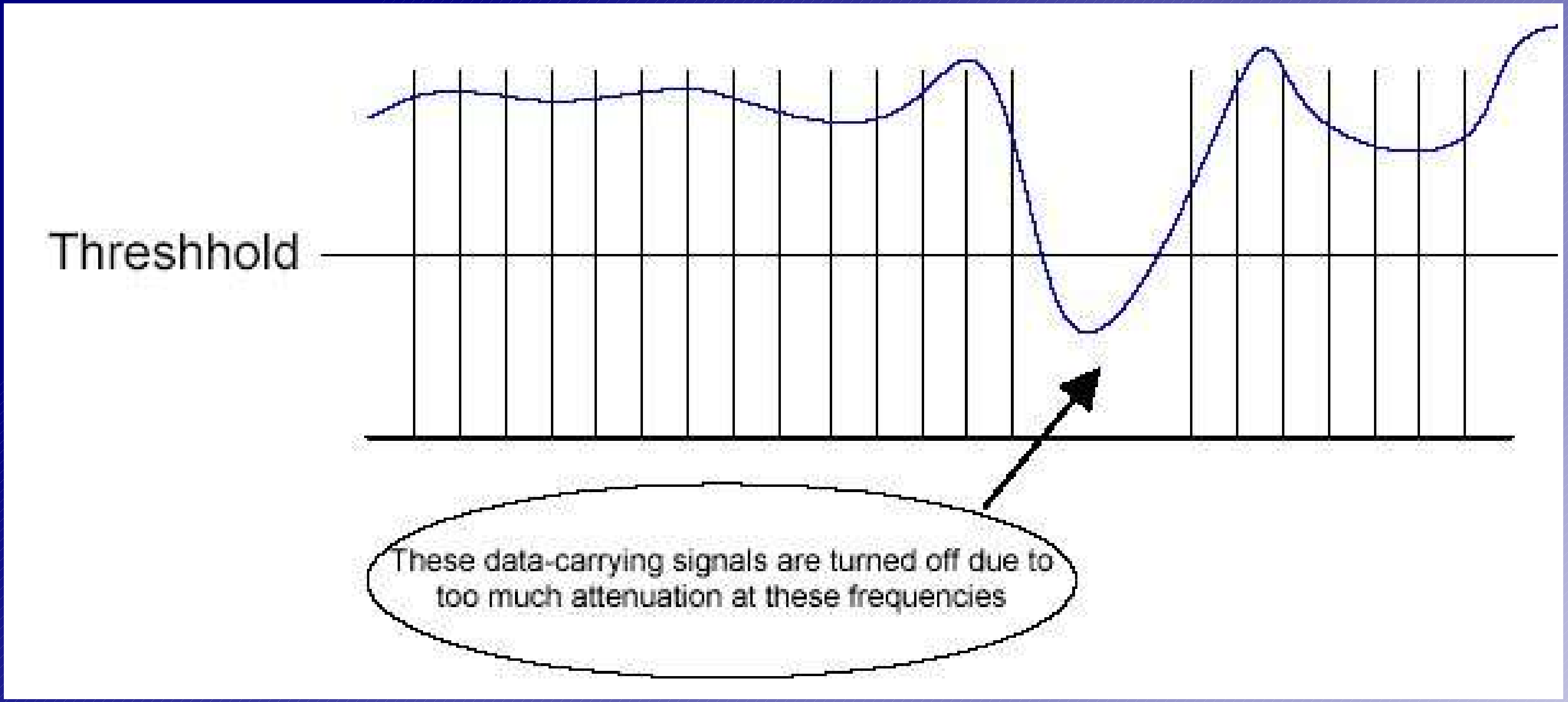


84 channels



4.5 MHz
4.7 MHz
4.9 MHz
5.1 MHz
01
10
10
11
00
10
01
00
11
01
Signal 1
Signal 2
Signal 3
Signal 4
Signal 79
Signal 80
Signal 81
Signal 82
Signal 83
Signal 84
4 MHz
21 MHz

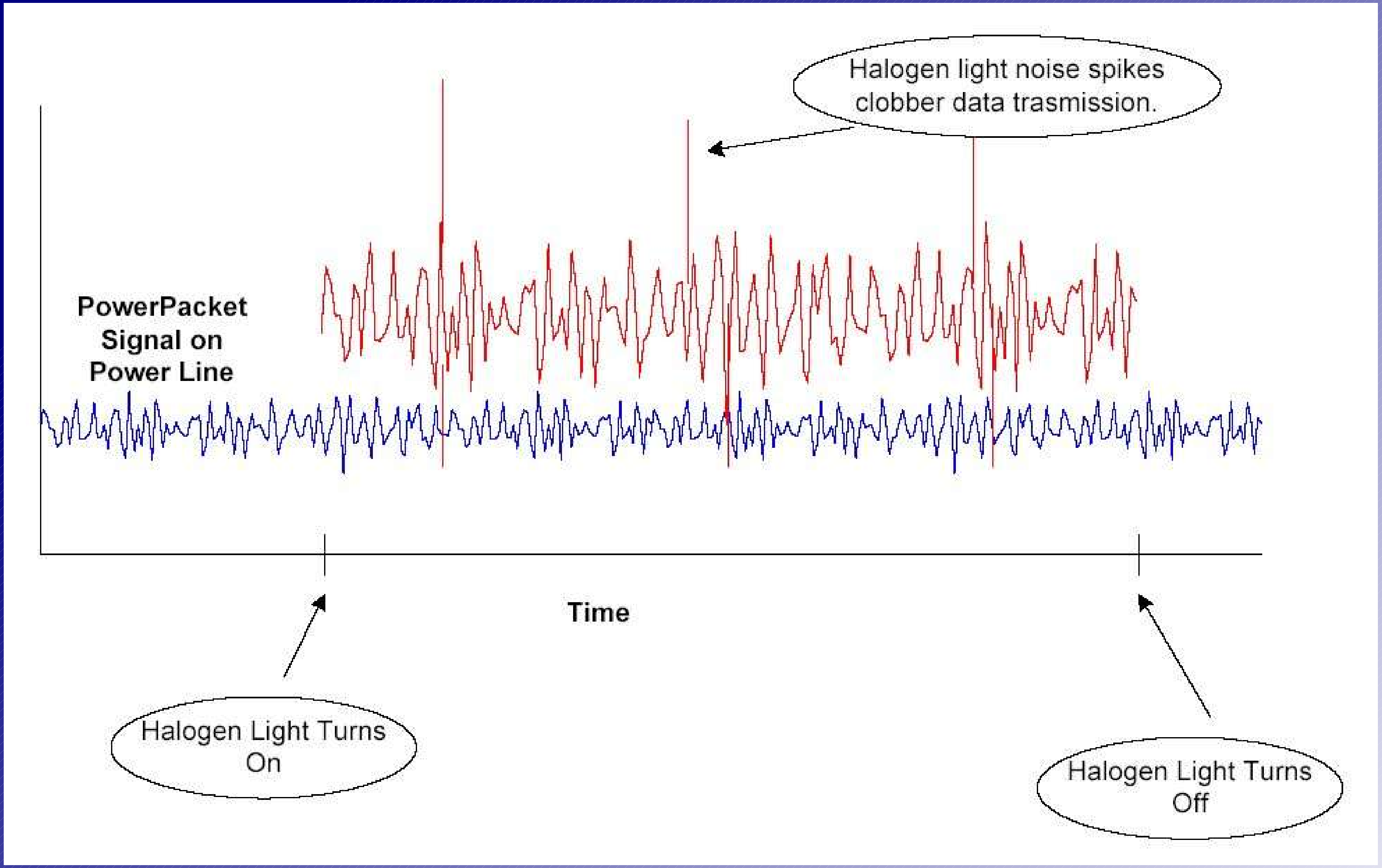
threshold


Threshhold
These data-carrying signals are turned off due to
too much attenuation at these frequencies

noise spikes

- now we know how to deal with the steadily changing attenuation conditions
- but attached appliances could cause spikes on the line...
- ...which can do harm to our data stream
- forward error correction is used
- surrounding data bits with correction bits for reconstruction (like hamming-code)

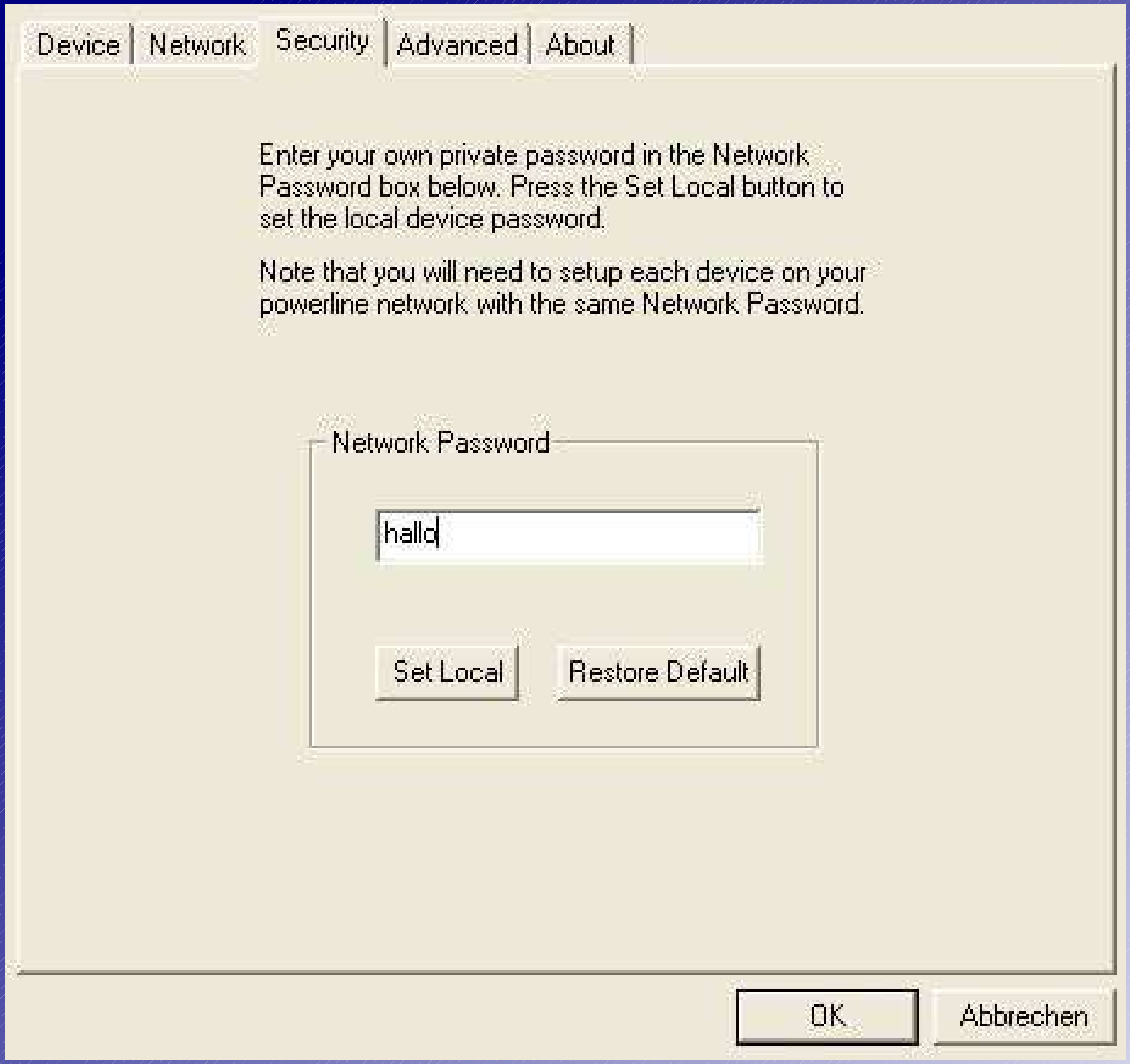
noise spikes



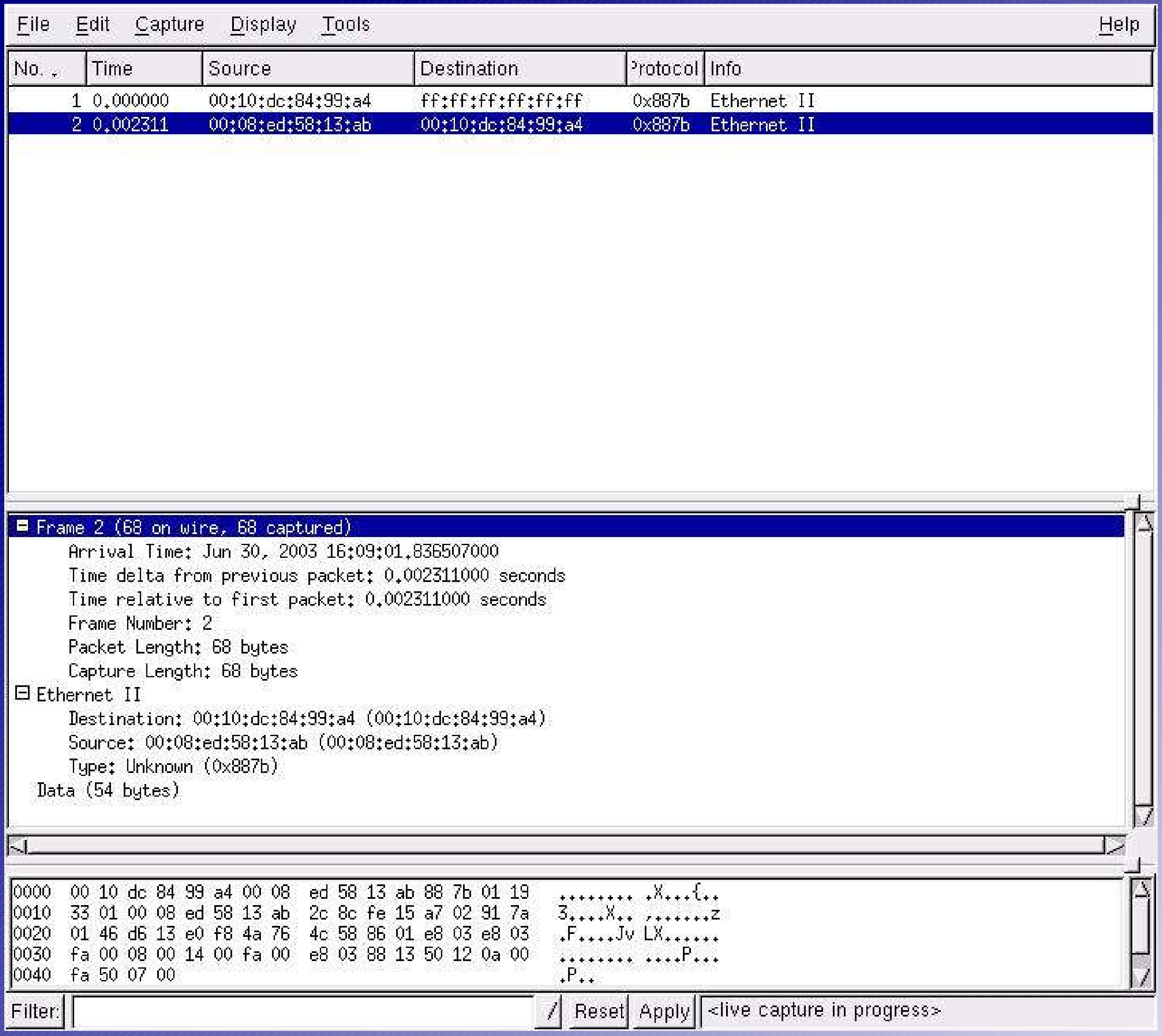
security issues

- 56-bit data encoding
- communication is only established if every participating bridge has the same password
- sniffing is nearly impossible, without special hardware
- arp-spoofing, ip-spoofing etc. won't work

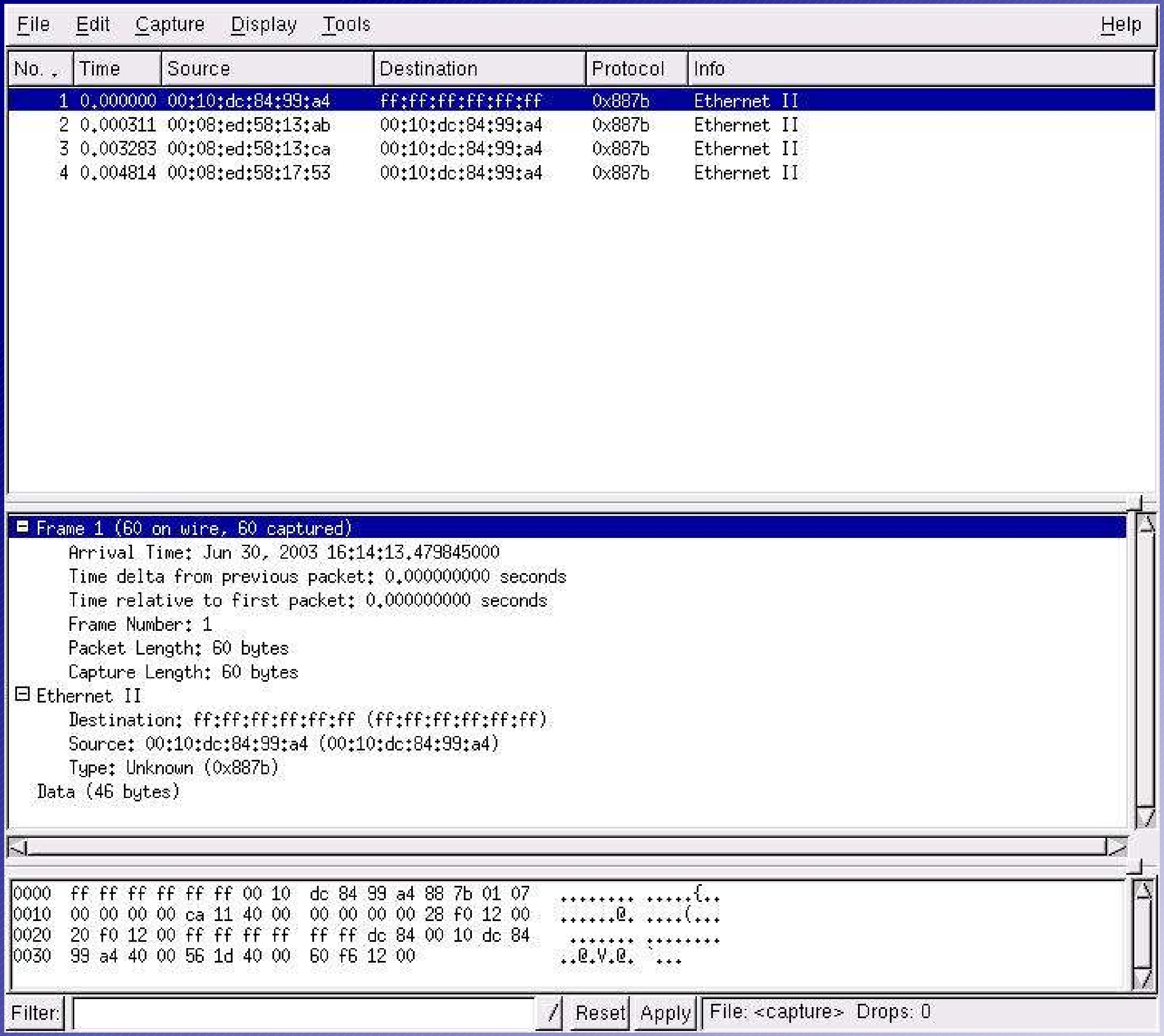
Sniffing the line (cont.)



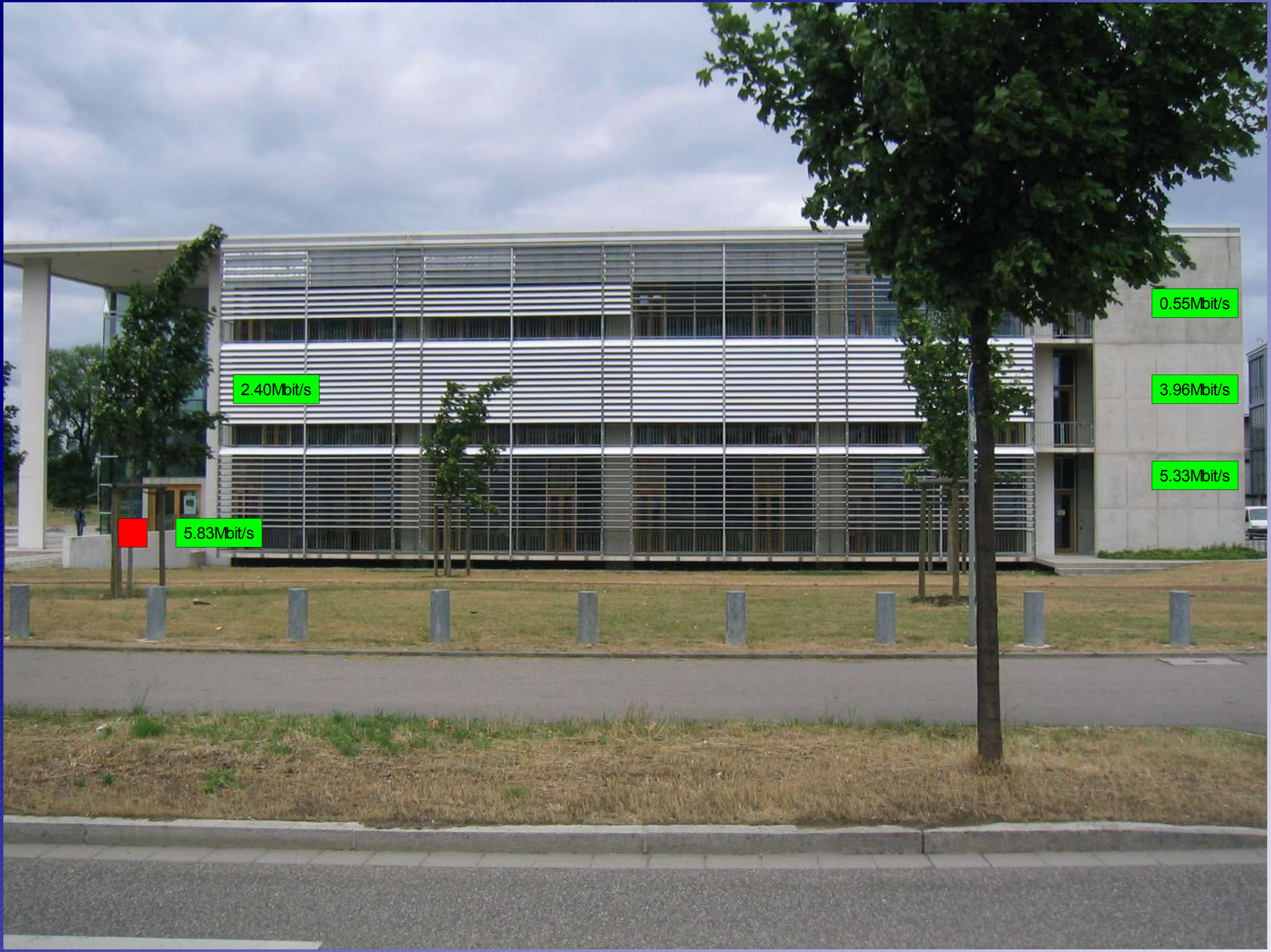
Detection of Powerline-Devices (attached to PC)



Detection of Powerline-Devices (all)



“throughput benchmark” - building 101 using netperf



outlook

- there are more efficient and cheaper ways for data tansmission
(like XDSL, WLAN etc.)
- but it is easy to handle
- more secure than WLAN (sniffing)
- nice toy ;)
- could be interesting for home automation purposes