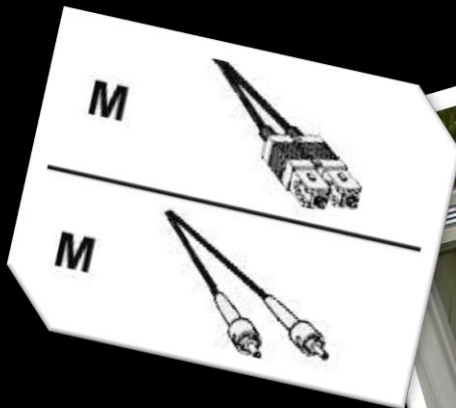




Marc Seeger,
Computerscience and Media, HdM Stuttgart
Next Generation Internet WS 08/09

XDSL, DSLAM UND CO...





What I will talk about

- The high level things
 - The low level things
- 

The tubes!



The internet: A series of tubes



Senator Ted Stevens of Alaska

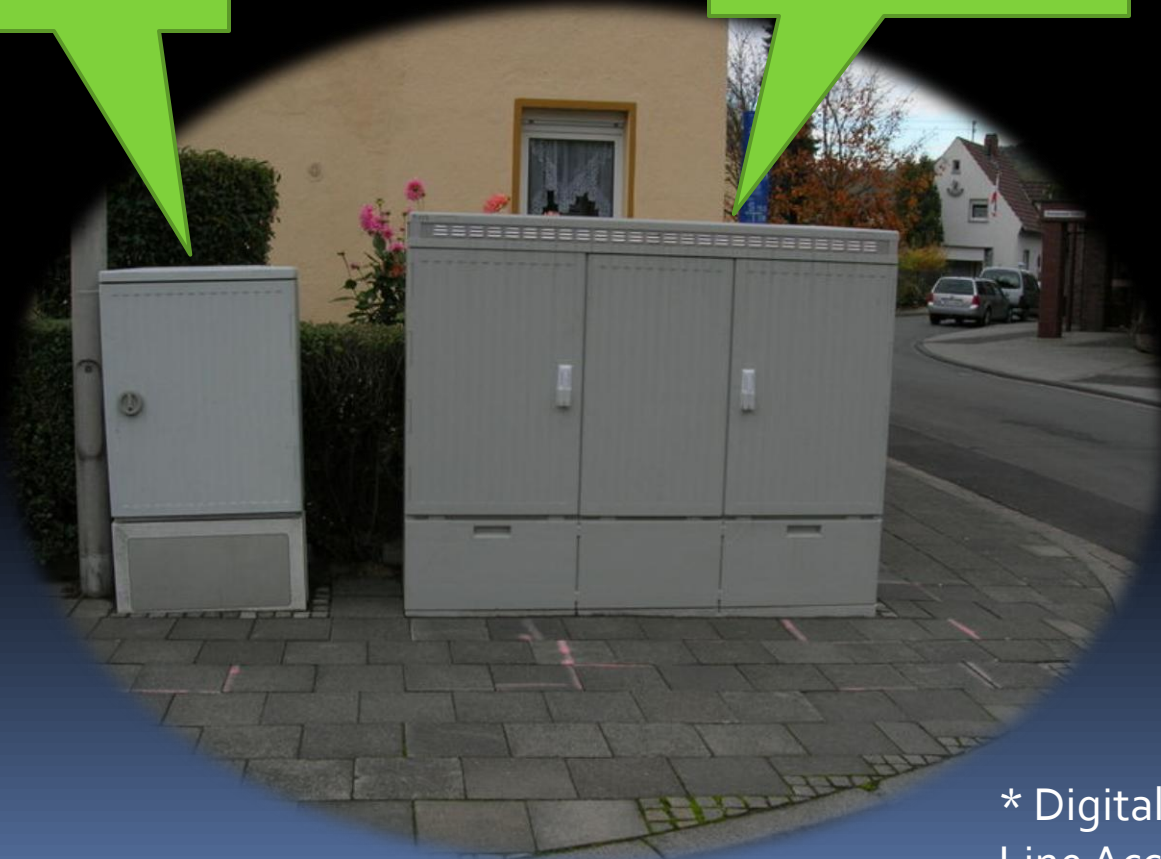


They want to deliver vast amounts of information over the internet. And again, the internet is not something that you just dump something on. It's not a big truck. It's a series of tubes. And if you don't understand those tubes can be filled and if they are filled, when you put your message in, it gets in line and its going to be delayed by anyone that puts into that tube enormous amounts of material, enormous amounts of material.

The grey boxes

Kabelverzweiger

(„outdoor“)
DSLAM*



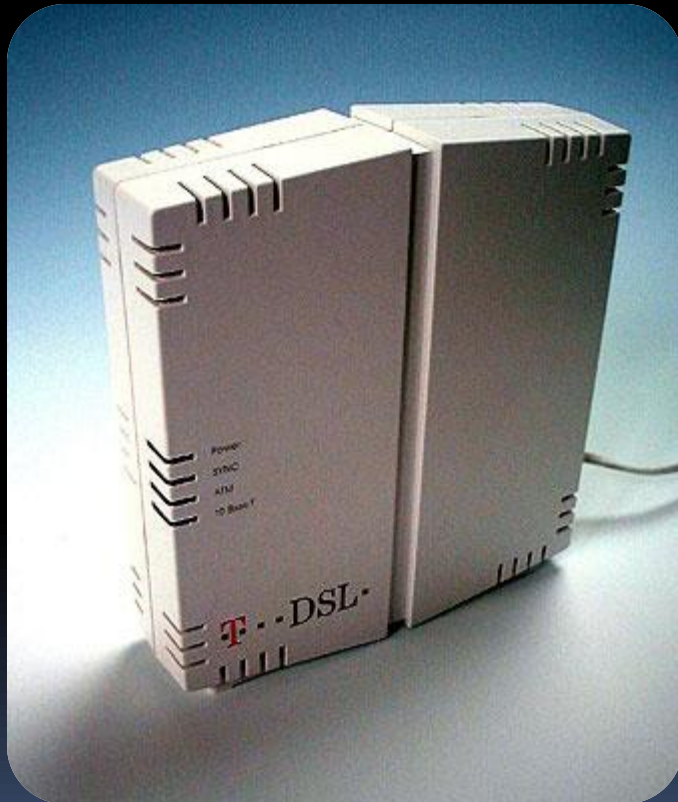
* Digital Subscriber
Line Access Multiplexer

The good old days

Kabelverzweiger



The beginning: ADSL/ADSL2



The evolution: ADSL2+



The present: VDSL 2



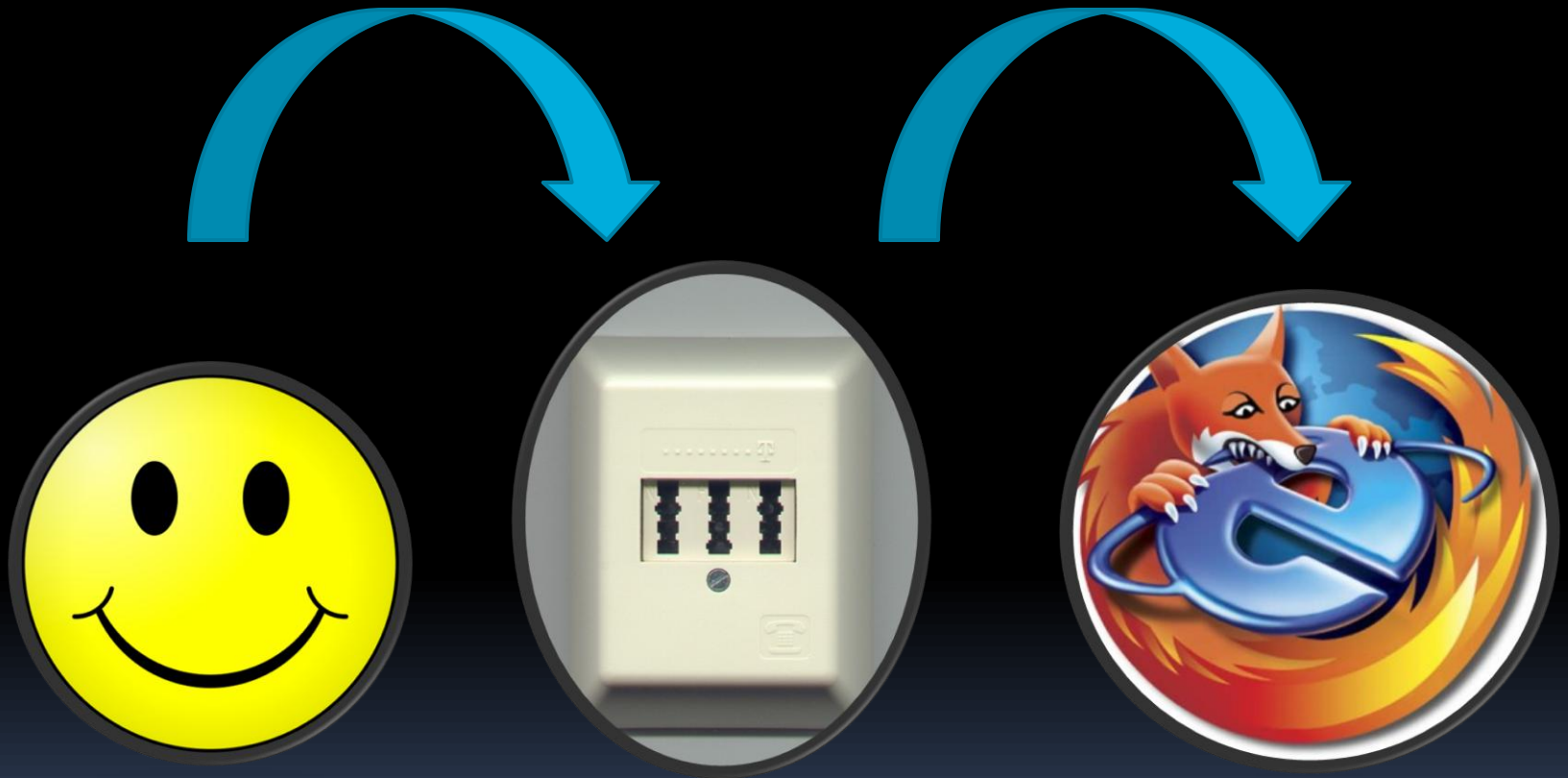
What is in it for me?



This!

ADSL/VDSL Standards			
Standard	Title	Max Downstream	Max Upstream
ANSI T1.413 Issue 2	ADSL	6 Mbit/s	0.6 Mbit/s
ITU-T G.992.1 Annex B	G.dmt	6 Mbit/s	0.6 Mbit/s
ITU-T G.992.3/4	ADSL2	12 Mbit/s	1.0 Mbit/s
ITU-T G.992.3/4 Annex J	ADSL2	12 Mbit/s	3.5 Mbit/s
ITU-T G.992.5	ADSL2+	24 Mbit/s	1.2 Mbit/s
ITU-T G.992.5 Annex L	ADSL2+	25 Mbit/s	3.5 Mbit/s
ITU-T G.993.1	VDSL 1	52 Mbit/s	11 Mbit/s
ITU-T G.993.2	VDSL 2	200 Mbit/s	200 Mbit/s

Where does it go?

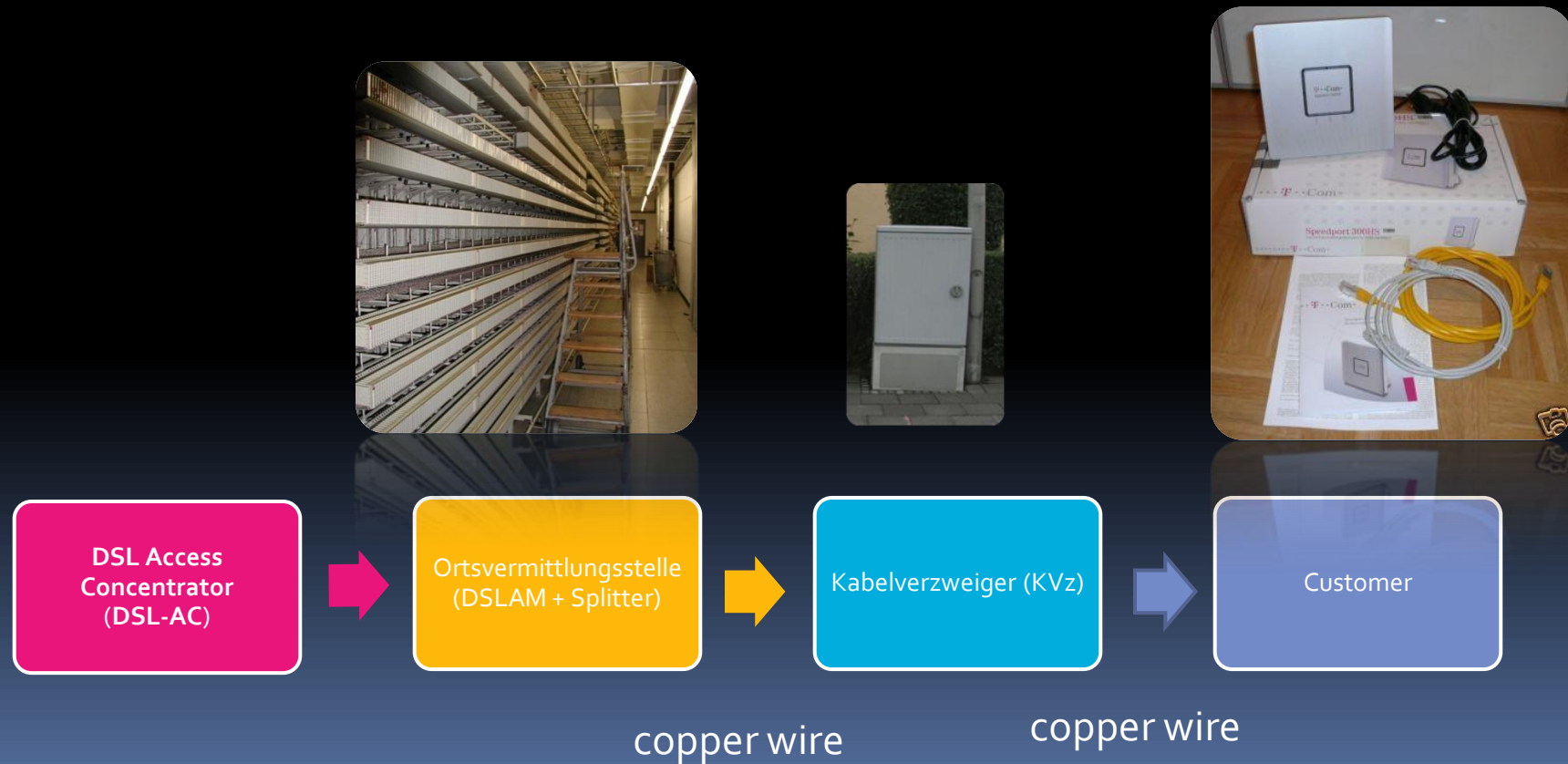


me

hole in the wall

internet

ADSL / ADSL 2+



ADSL / ADSL 2+

ATM

DSL Access
Concentrator
(DSL-AC)

Ortsvermittlungsstelle
(DSLAM + Splitter)

Kabelverzweiger (KVz)

Customer

copper wire

copper wire

PPPOE

VDSL/VDSL₂



DSL Access
Concentrator
(DSL-AC)



Ortsvermittlungsstelle



Kabelverzweiger
DSLAM Splitter

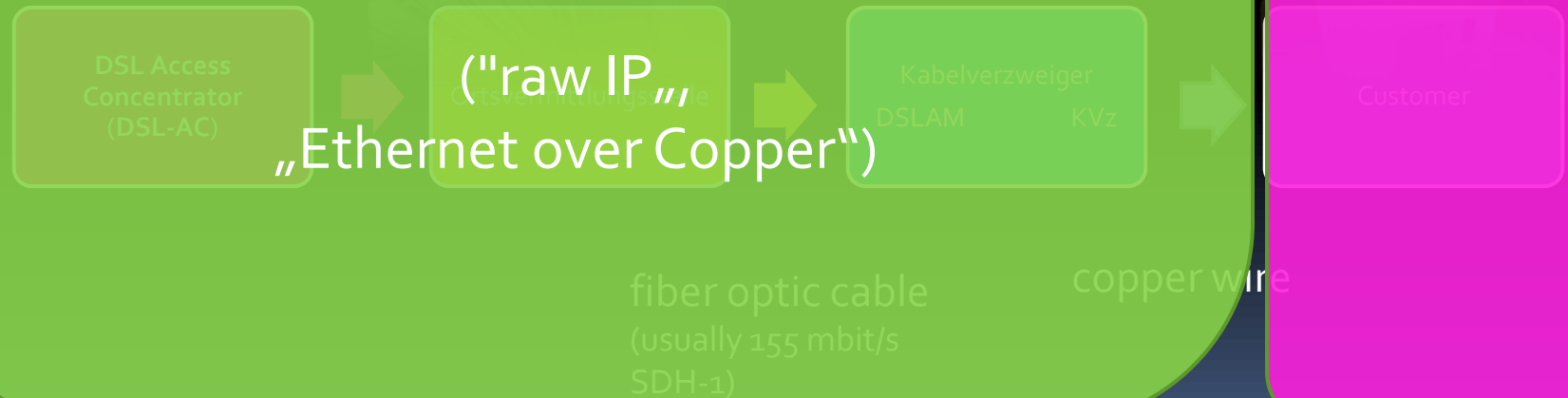


Customer

fiber optic cable
(usually 155 mbit/s SDH-1)

copper wire

IP over VDSL



DSL Modem



What does it do?

- Modulate
- Demodulate

bits

modulator

audio

phone
network

audio

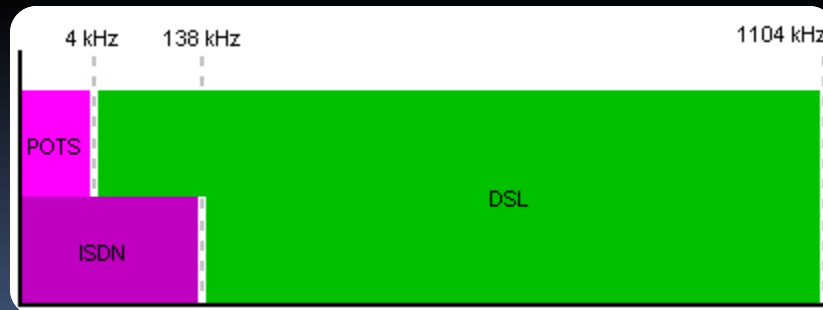
demodulator

bits

DSL splitter



- Breitbandanschlusseinheit (BBAE)
- Simple frequency division filter („Frequenzweiche“)



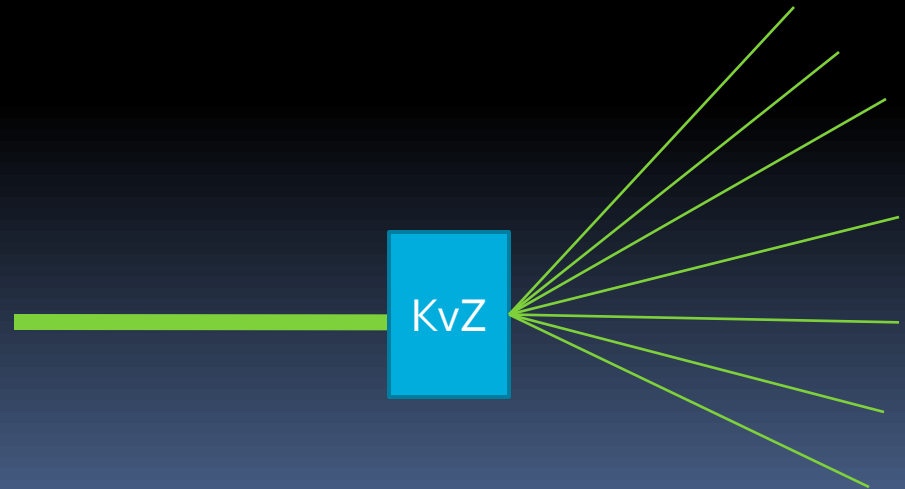
Kabelverzweiger



active

passive

- passive ...
- ... or active (amplification)
- Approximately 300.000 in Germany



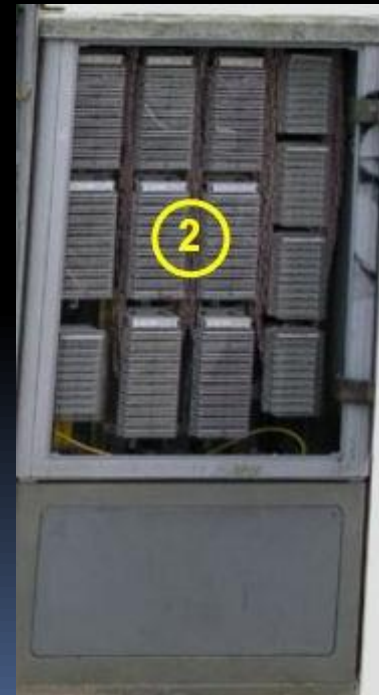
Kabelverzweiger



active (OPAL)



Kabelverzweiger





DSLAM

- Digital Subscriber Line Access Multiplexer
 - Indoor / Outdoor
 - Distribute Bandwidth to the seperate customers
 - Assign customers DSL Modem an IP via DHCP
 - Possible TCP/UDP filtering
- 

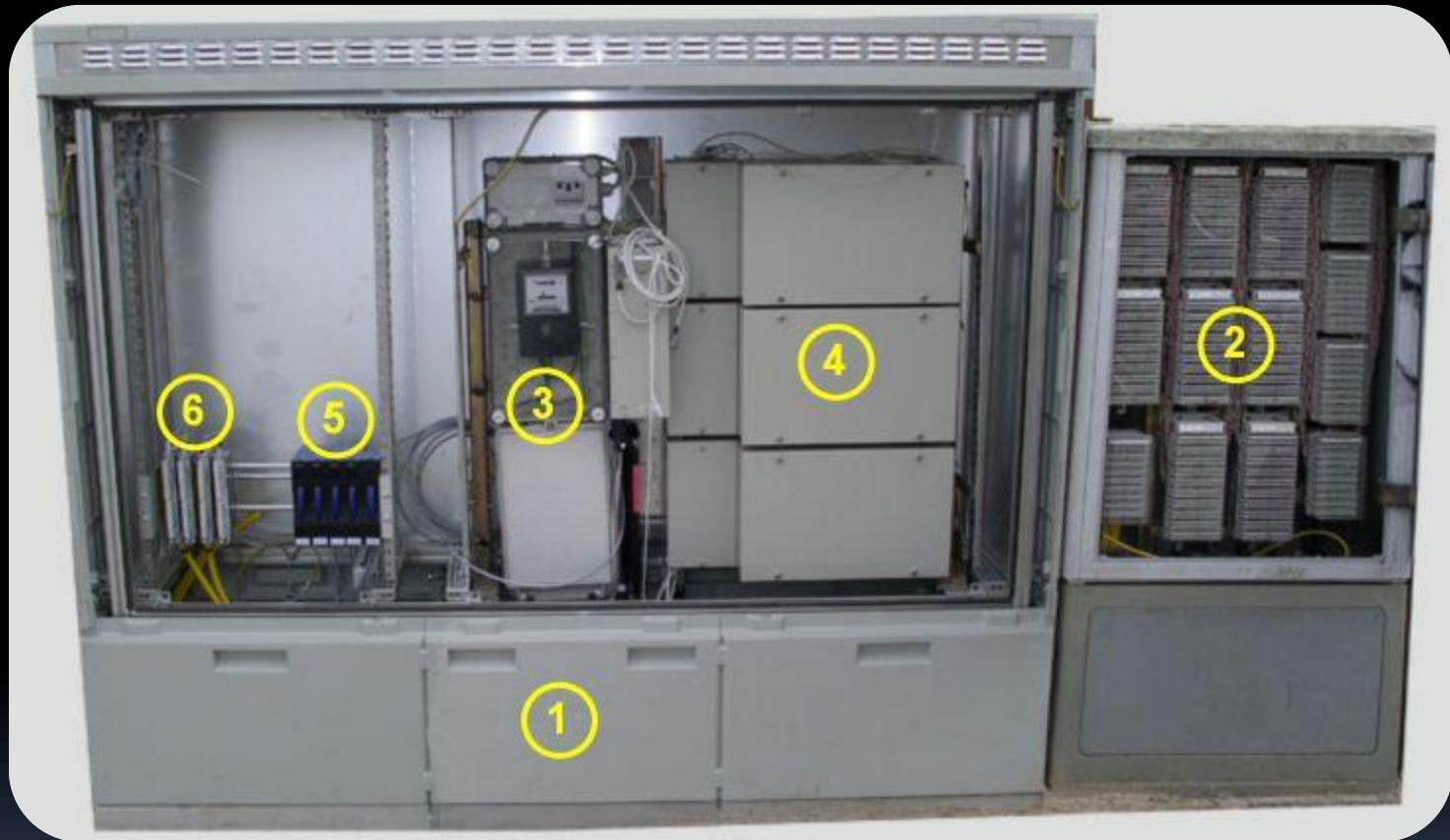
Indoor DSLAM



Outdoor DSLAM

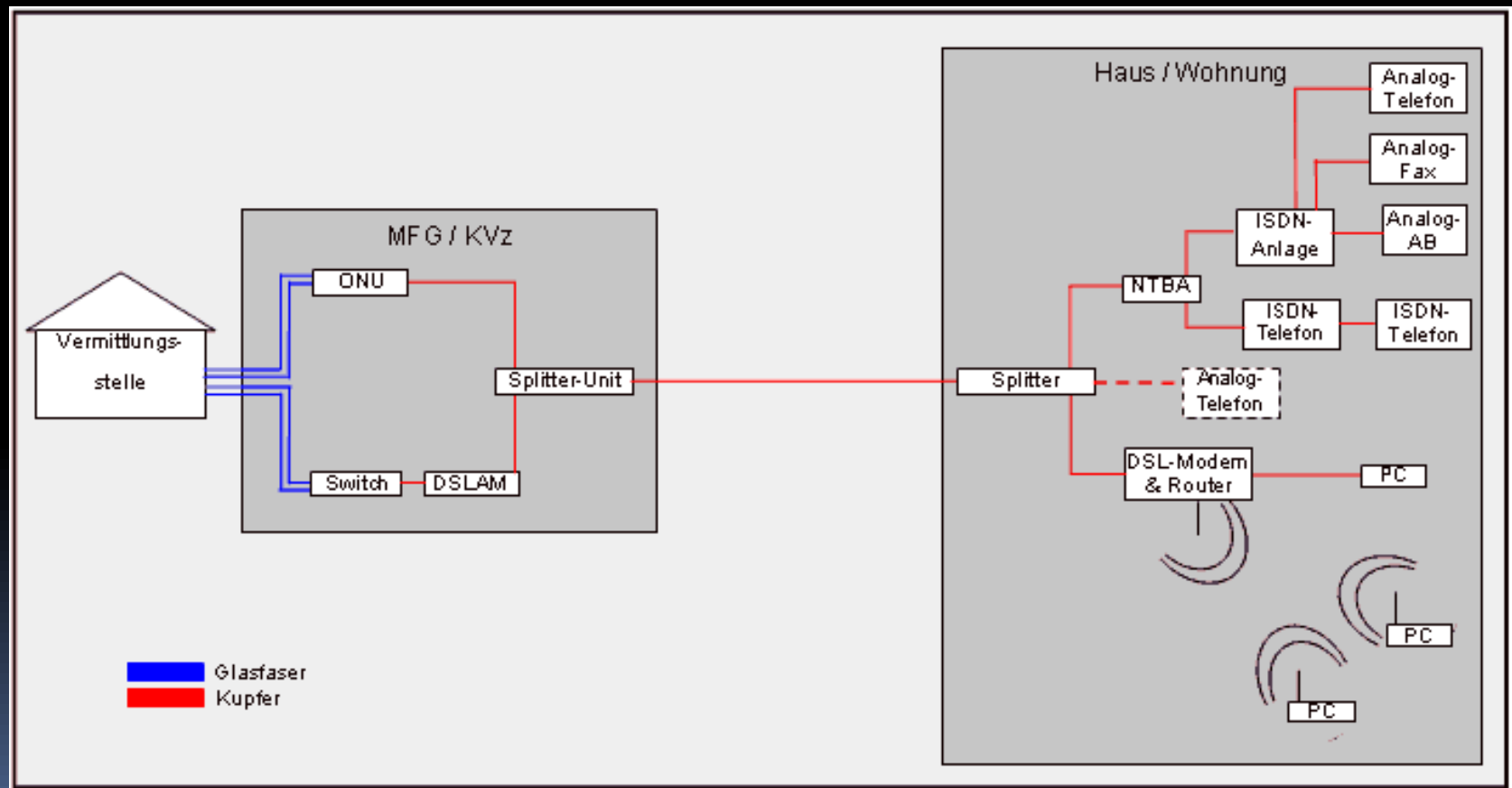


Outdoor DSLAM + Kabelverzweiger



- 1 - Multifunktionsgehäuse (MFG)
- 2 - Kabelverzweiger (KVz)
- 3 - Power Supply
- 4 - ONU (Optical Network Unit): Transforms optical signals to electrical signals
- 5 - Group of 4 DSLAMs and a Switch
- 6 - Splitter-Unit

In the mix...



Digital Subscriber Line Access Concentrator (DSLAC)

```
Cmd
File Edit View Help
Microsoft Windows [Version 6.0.6001]
Copyright (c) 2006 Microsoft Corporation. All rights reserved.

C:\>tracert www.hdm-stuttgart.de

Tracing route to www.hdm-stuttgart.de [141.62.1.52]
over a maximum of 30 hops:

 1      1 ms      <1 ms      <1 ms      10.0.1.1
 2      26 ms     29 ms     27 ms      lo1.br01.str.de.hansenet.net [213.191.89.16]
 3      27 ms     52 ms     27 ms      ae0-101.cr02.str.de.hansenet.net [213.191.88.194]
 4      31 ms     31 ms     39 ms      so-2-1-0-0.cr02.fra.de.hansenet.net [213.191.87.205]
 5      31 ms     29 ms     29 ms      gi4-0-0.pr02.decix.de.hansenet.net [62.109.109.178]
 6      39 ms     29 ms     29 ms      decix.Frankfurt1.belwue.de [80.81.192.175]
 7      55 ms     36 ms     37 ms      Stuttgart2.belwue.de [129.143.1.129]
 8      38 ms     37 ms     59 ms      Stuttgart1.belwue.de [129.143.1.29]
 9      36 ms     42 ms     37 ms      HDM-Stuttgart1.belwue.de [129.143.101.202]
10     37 ms     37 ms     35 ms      firewall.hdm-stuttgart.de [141.62.60.1]
11     57 ms     36 ms     37 ms      www.hdm-stuttgart.de [141.62.1.52]

Trace complete.

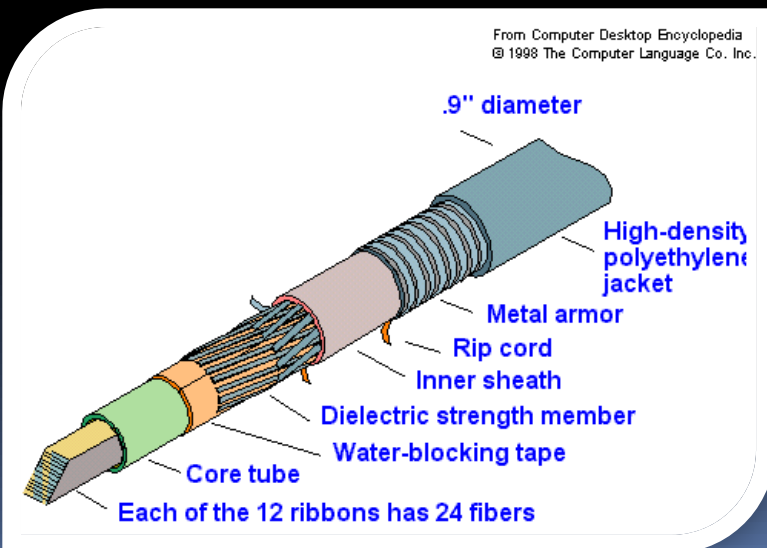
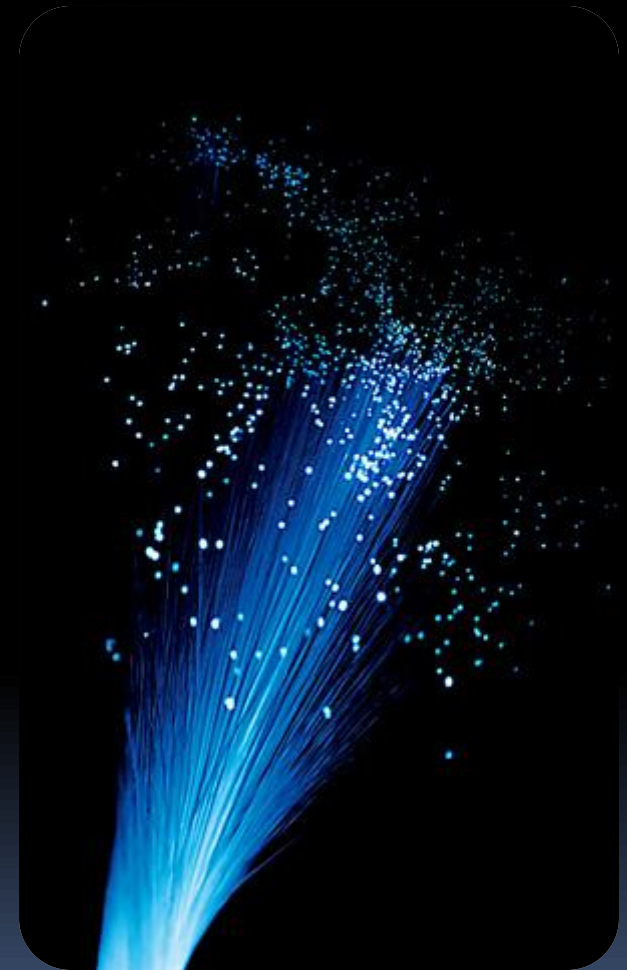
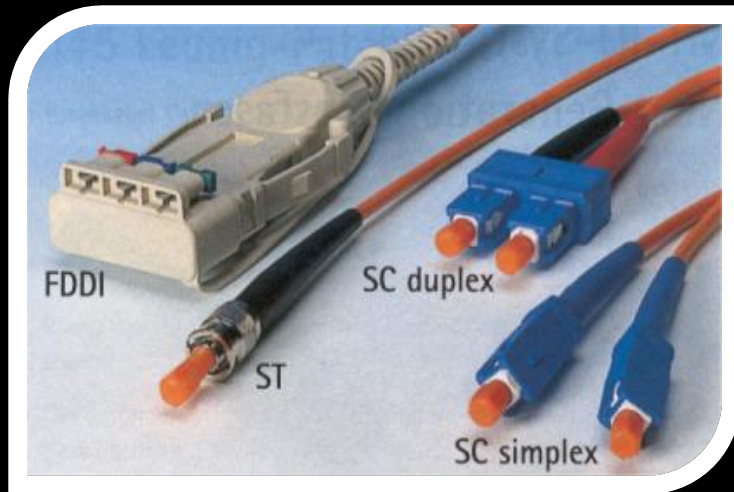
C:\>
```



You don't like copper? Buzzwordtime!

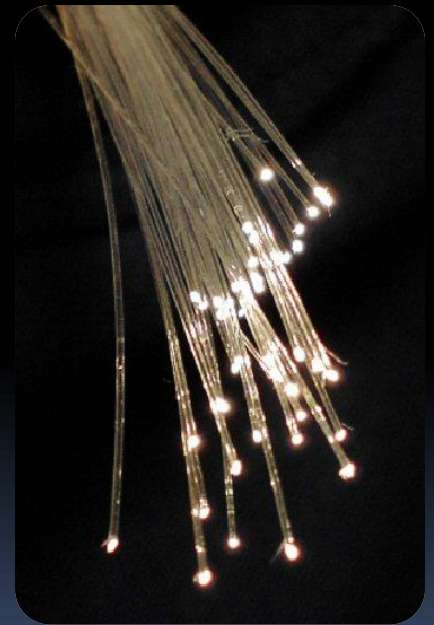
PASSIVE OPTICAL NETWORKS (PON)

Fiber



Advantage over copper?

- Greatly increased bandwidth and capacity
- Lower signal loss
- Immunity to electrical noise
- cheaper



Active $\leftrightarrow$ Passive

- Active optical networks :
 - electrically powered equipment to distribute the signal (switch, router)
 - Incoming signals $\rightarrow$ Buffered in equipment
- Passive optical networks:
 - beam splitters.
 - 1 fiber $\rightarrow$ up to 64 fibers
 - No switching/buffering
 - wavelength-division multiplexing
 - time-division multiplexing.

What can be done I

- Fiber To The node
 - aka *Fiber to the neighborhood*
 - aka *Fiber to the cabinet*
- Fiber to the Curb
- Fiber To The building
 - aka Fiber to the basement

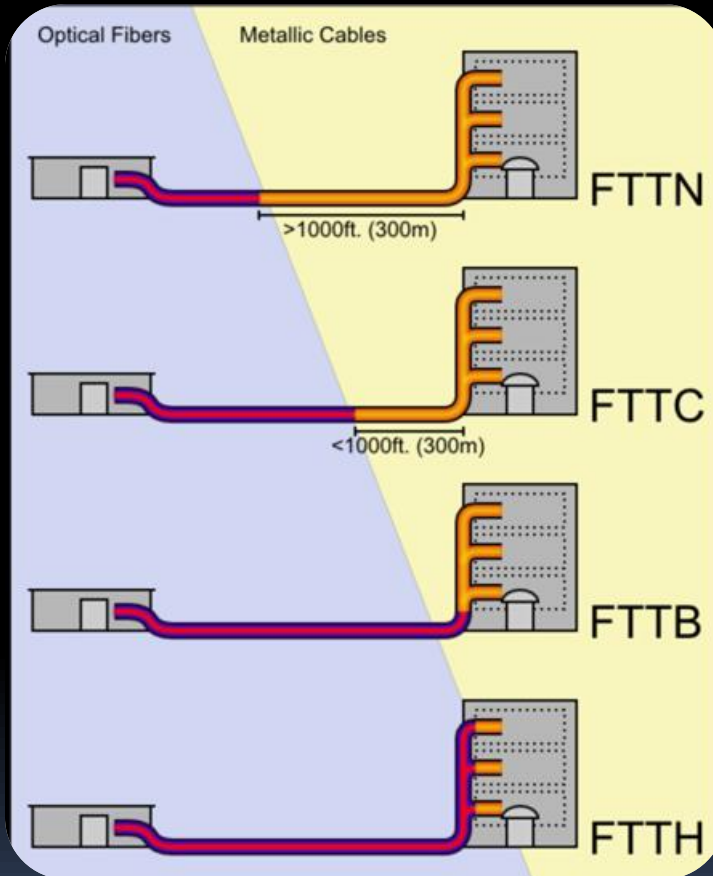


What can be done II

- Fibre To The Home

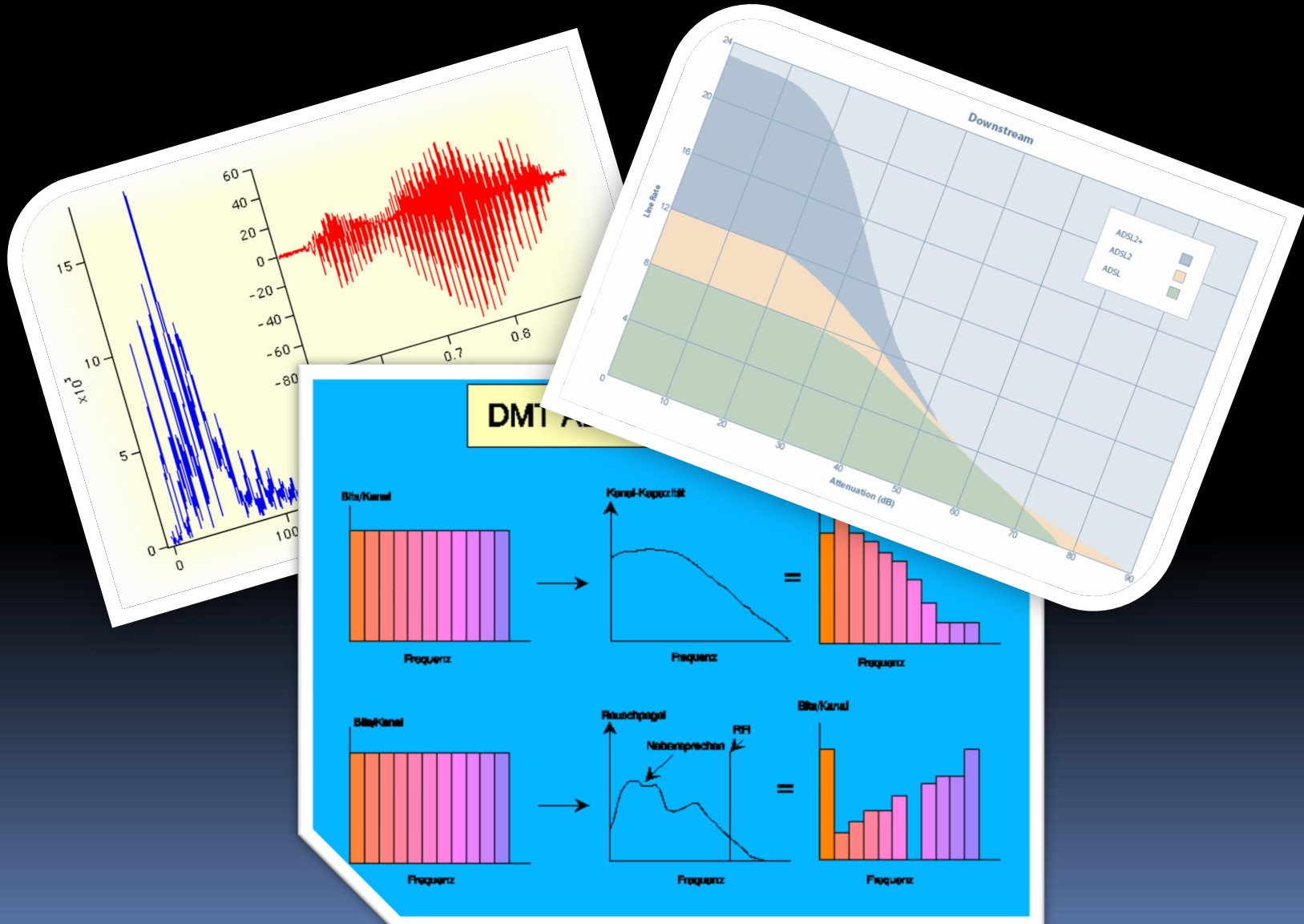


PON summary



- Fiber to the node / neighborhood (FTTN) / cabinet (FTTCab)
- Fiber to the curb (FTTC)
- Fiber to the building (FTTB)
- Fiber to the home (FTTH)

The gory details





Coding

- Digital $\rightarrow$ Digital (101010 $\rightarrow$ 11001100)
 - Source Coding: Data Compression
 - Channel Coding: Error Correction/Detection
- 

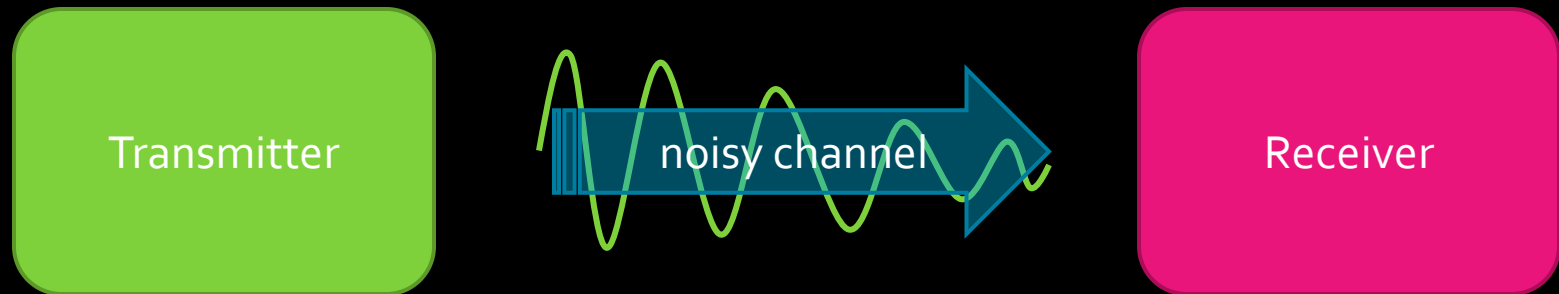
Channel Coding: FEC

- $001 = 0$
- $010 = 0$
- $110 = 1$
- $000 = 0$
- $011 = 1$



Error correction by "democratic voting"

Channel Coding: Interleaving



Sender



Channel

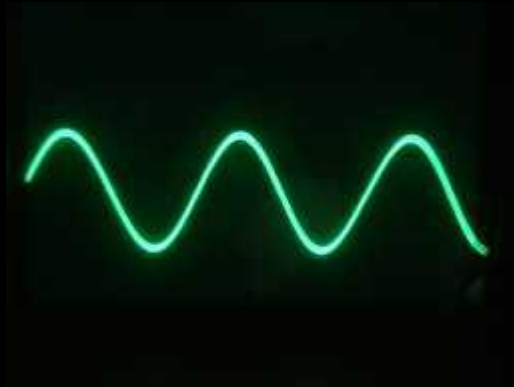


Receiver

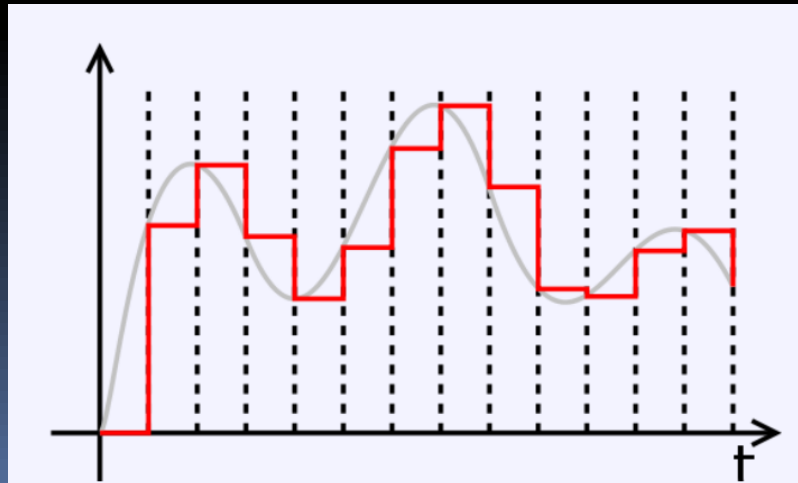


„Interleaving“

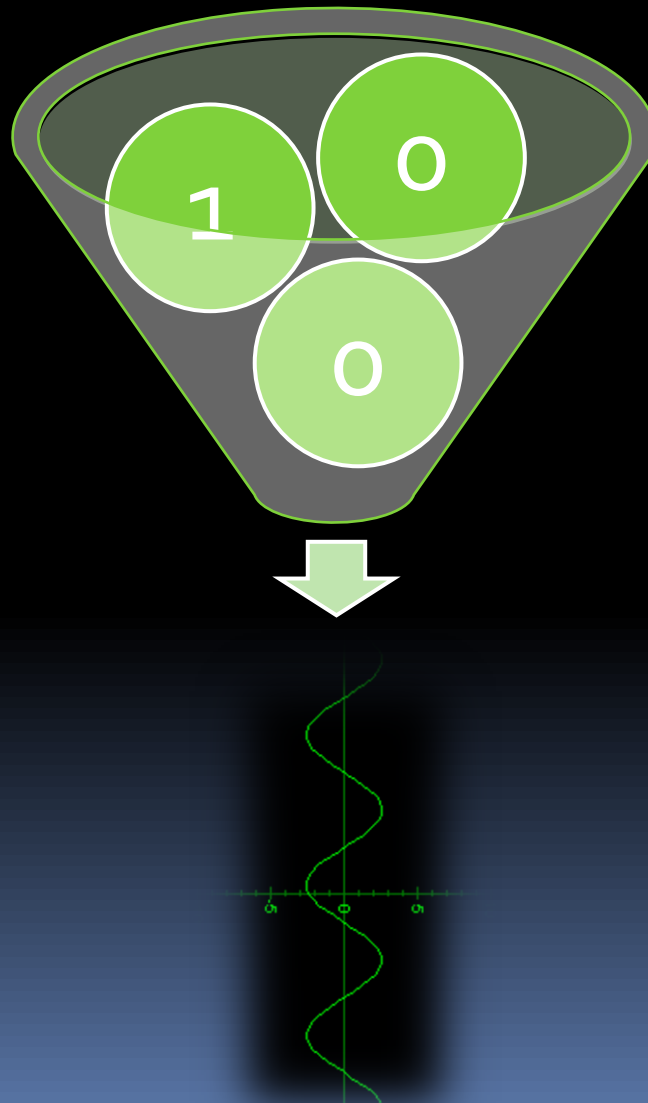
Sampling: Analog $\rightarrow$ Digital



101101

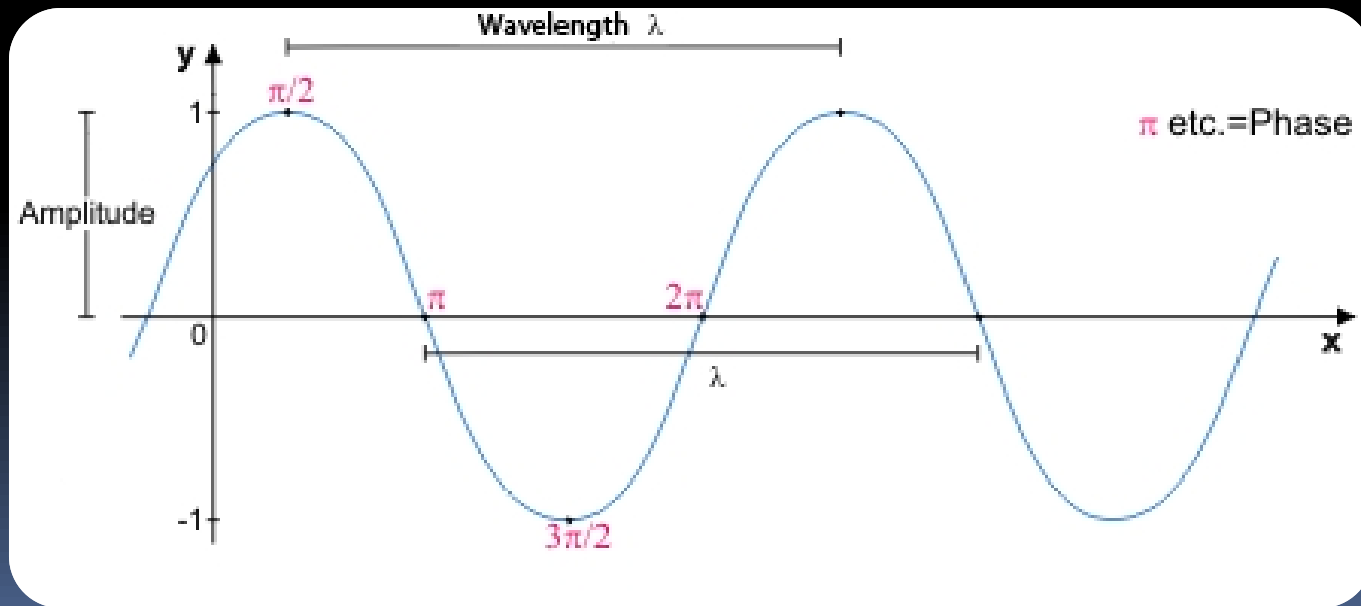


Modulation

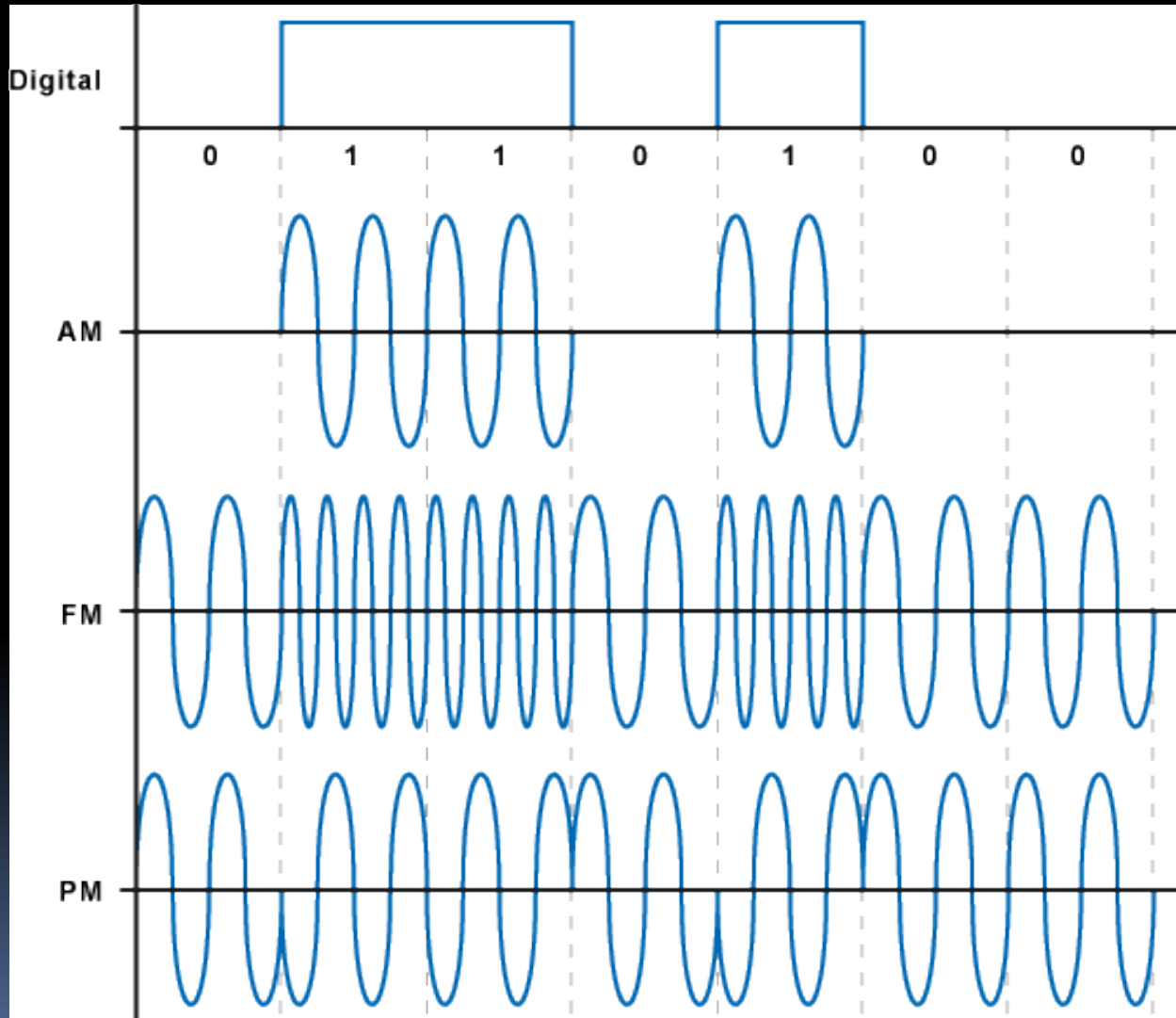


Modulation

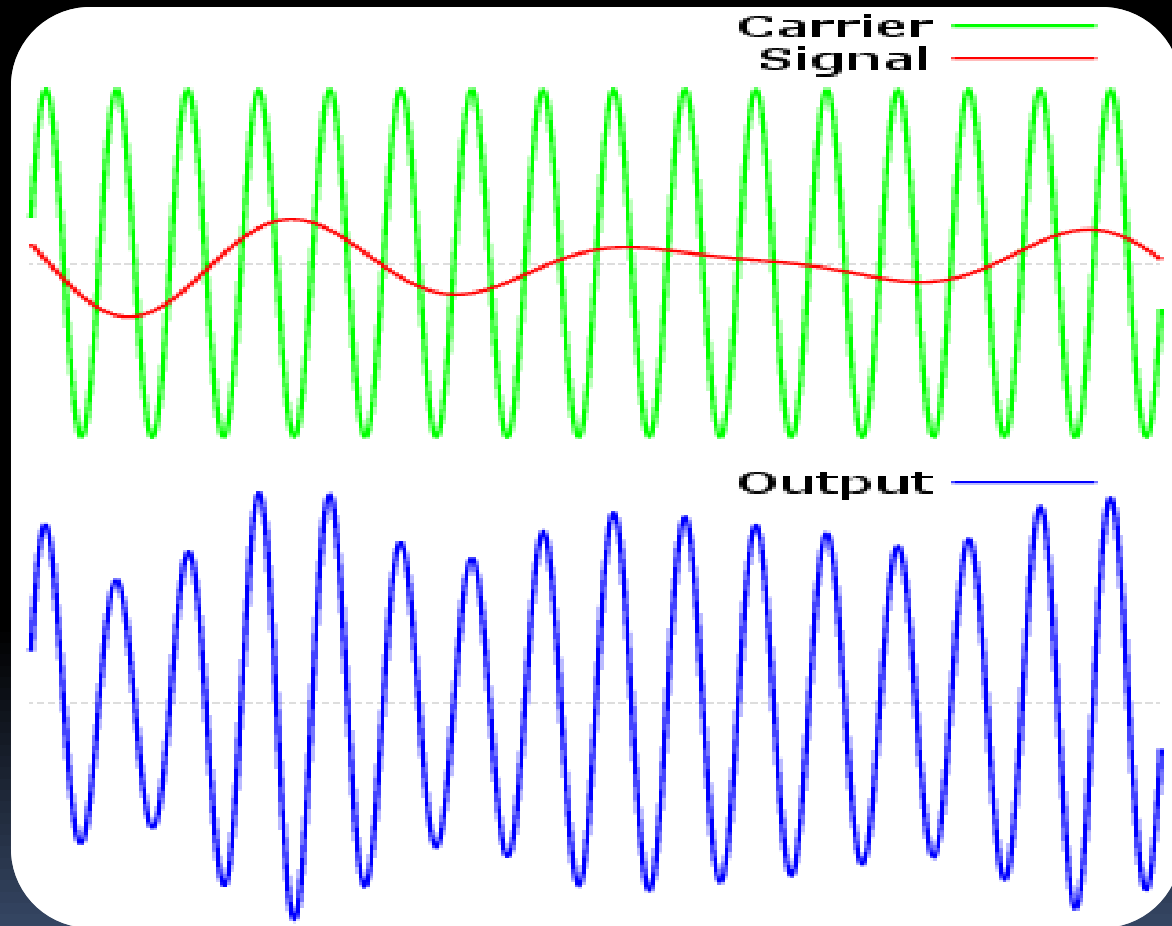
- Amplitude
- Frequency (= speed of light / wavelength)
- Phase



Analog Modulation: AM/FM/PM



Carrier signal



Digital Modulation: Basics

envelope-and-phase form

$$A(t) \cdot \sin[2\pi ft + \phi(t)],$$

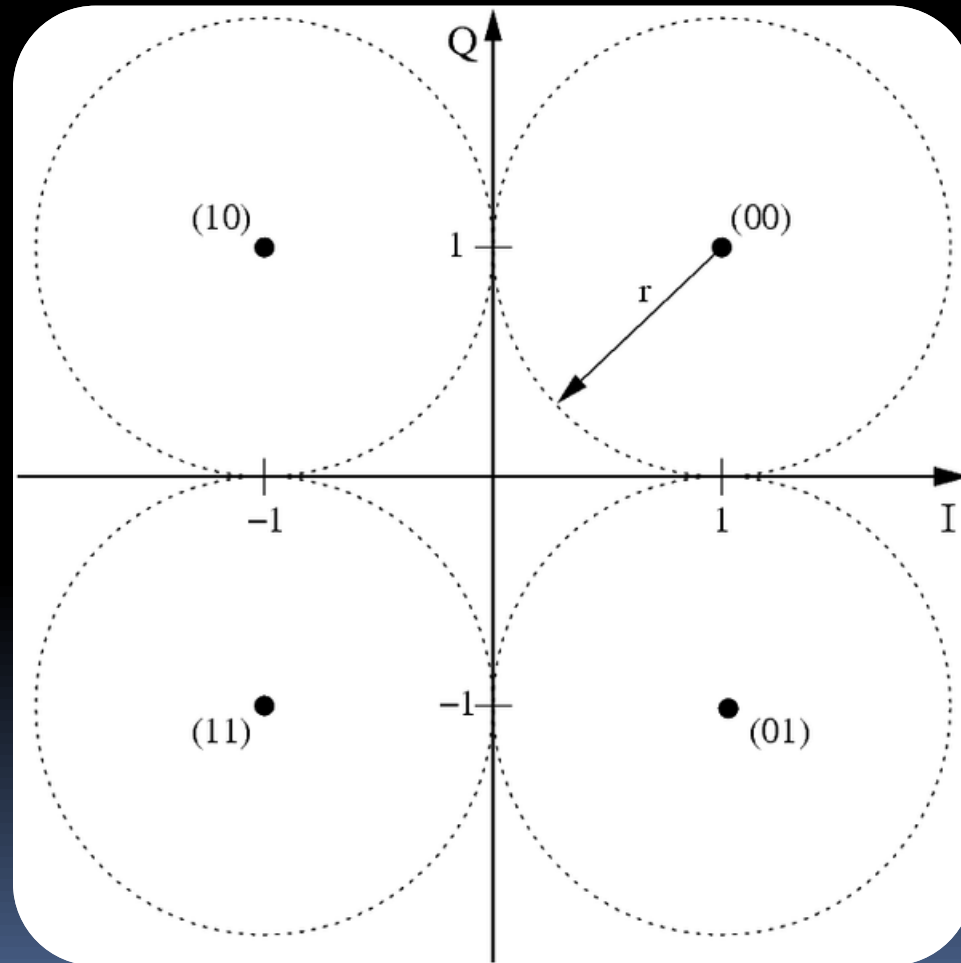
quadrature-carrier form



$$I(t) \cdot \sin(2\pi ft) + Q(t) \cdot \underbrace{\cos(2\pi ft)}_{\sin\left(2\pi ft + \frac{\pi}{2}\right)},$$

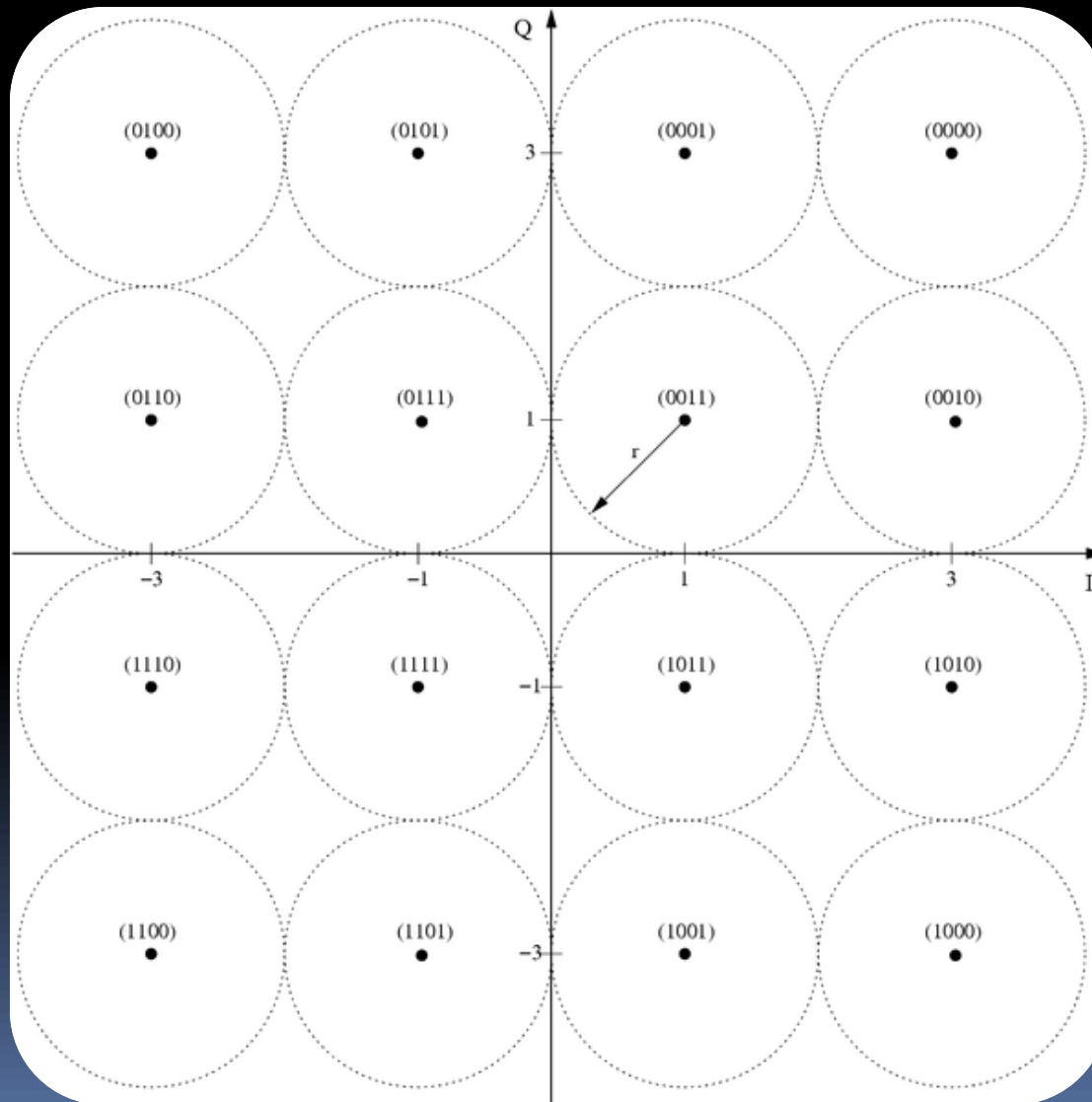


Digital Modulation: QAM



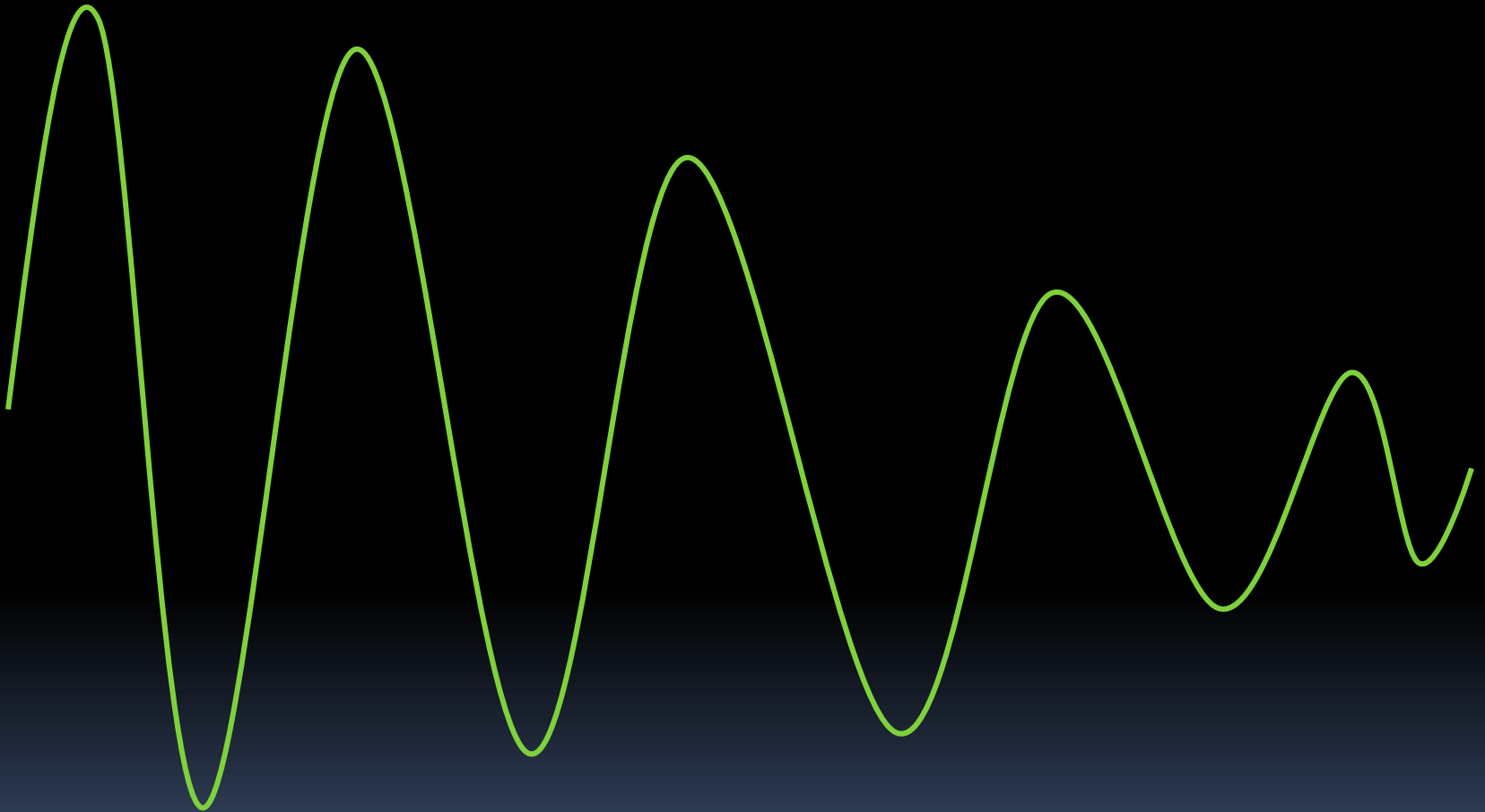
4-QAM

Digital Modulation: QAM



16-QAM

Problem: attenuation



Problems:

- Frequency
- Time/Space

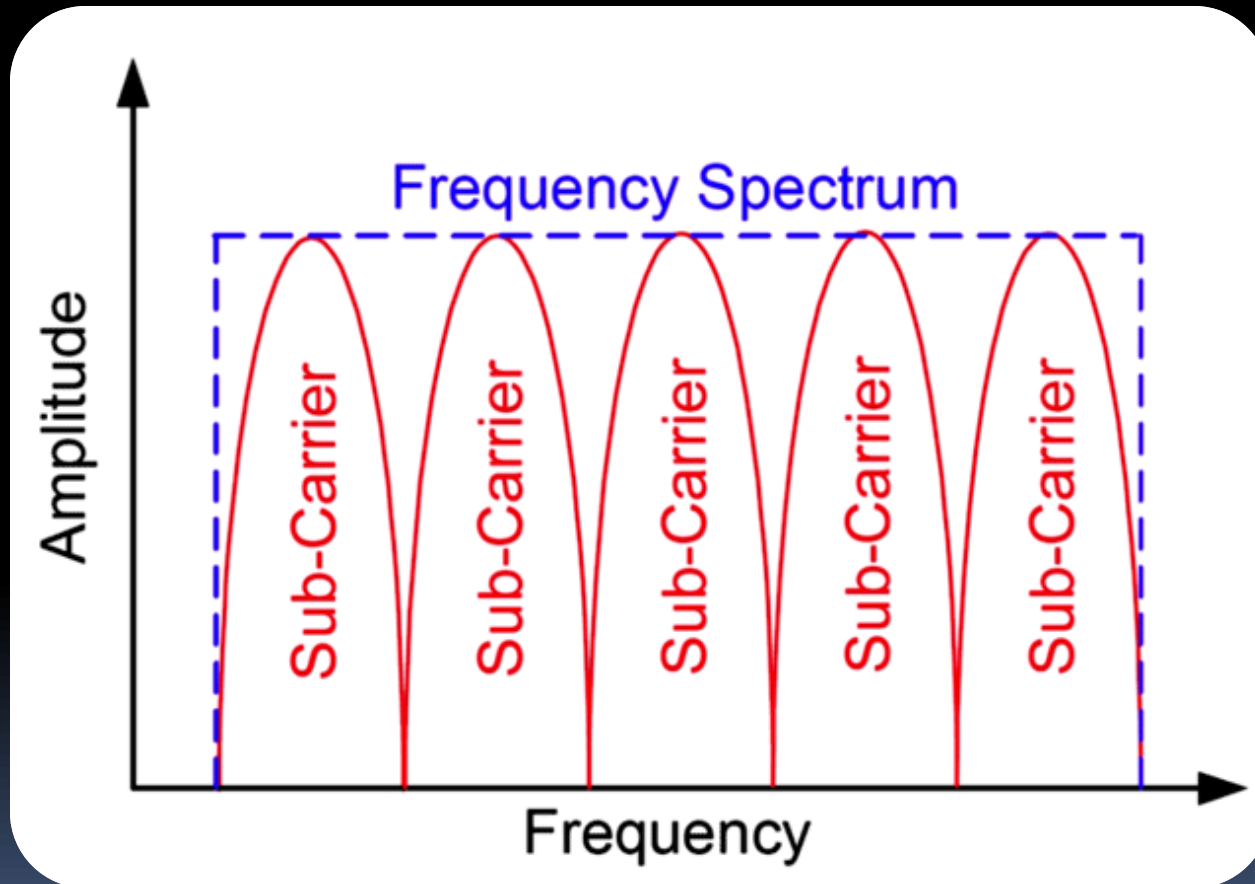


Ok... but seriously...



**HOW DOES DSL USE ALL OF
THIS?**

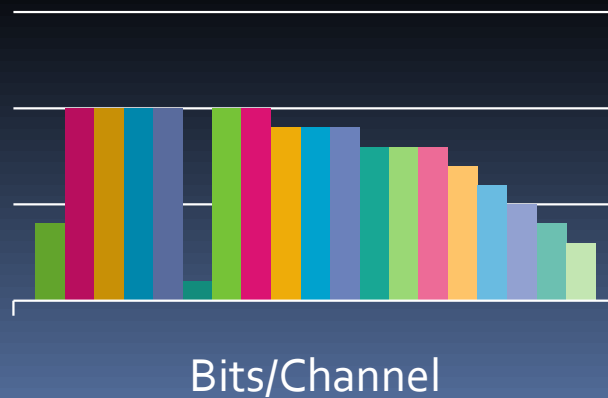
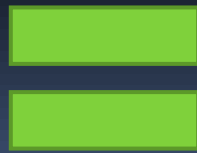
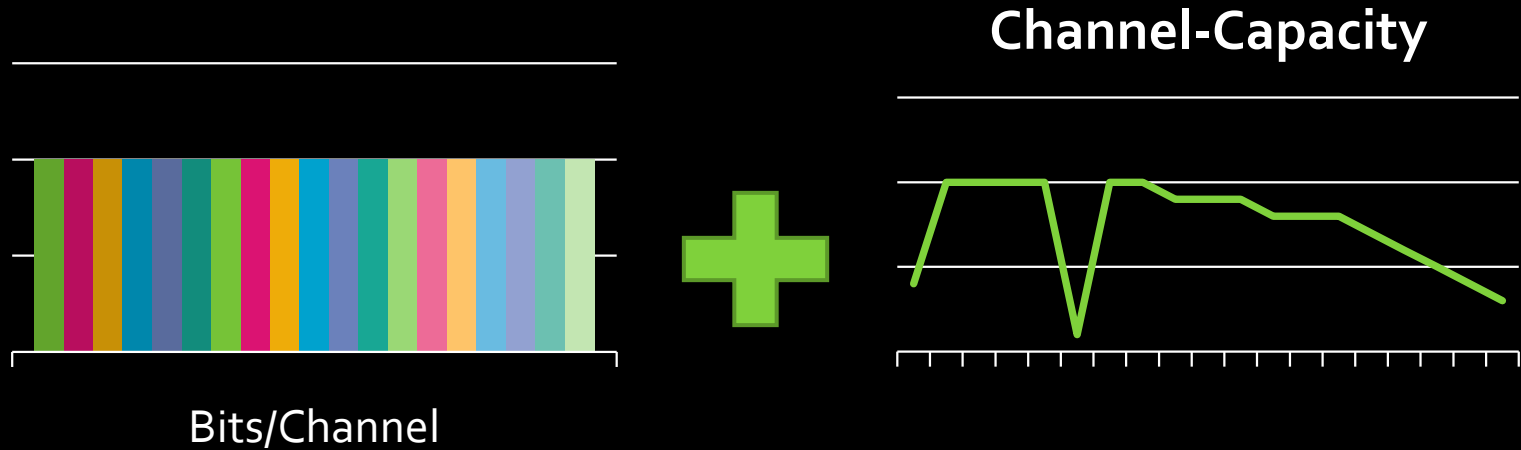
xDSL: DMT*



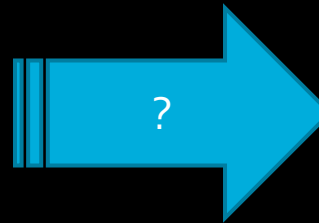
*Discrete Multitone Transmission

Source: „Mit Volldampf über die letzte Meile“

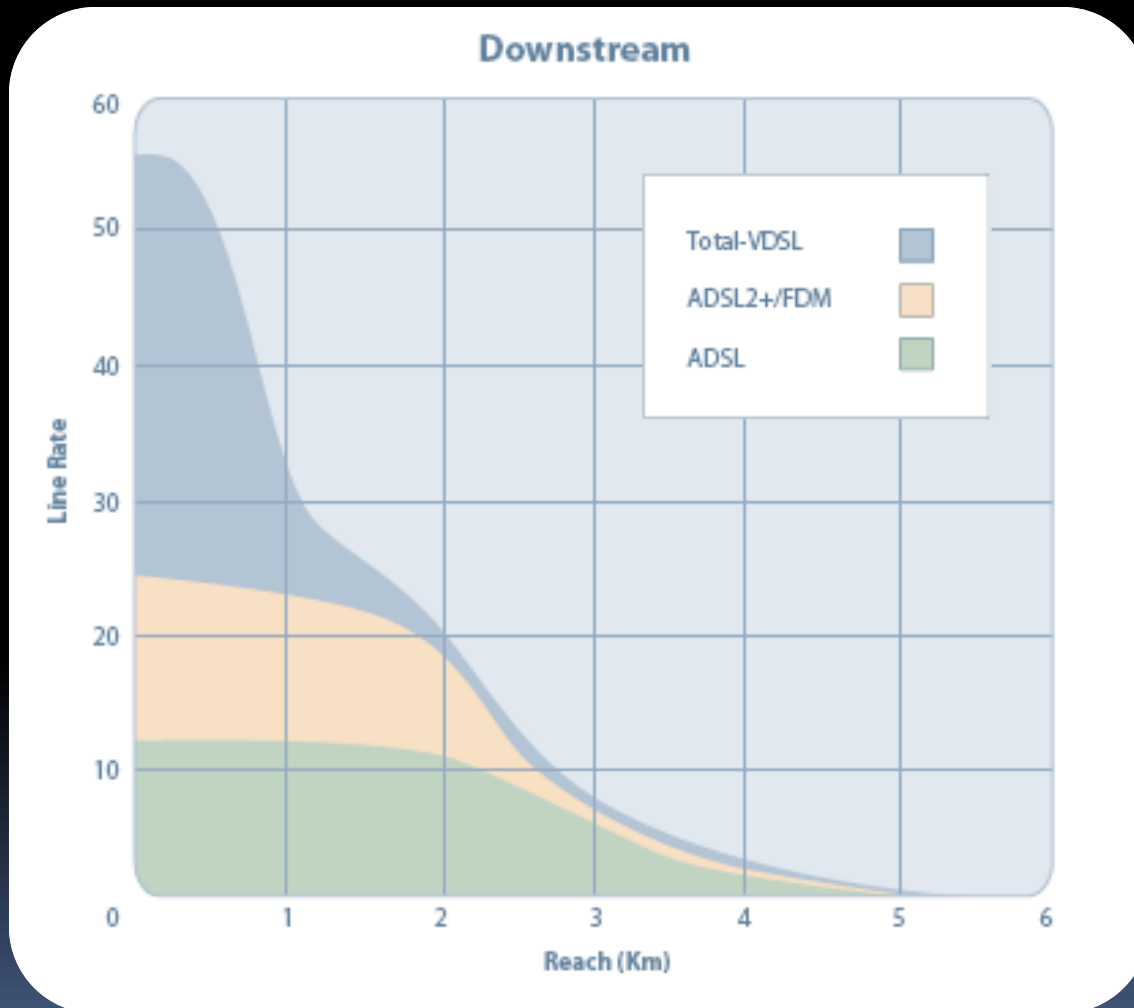
Adaptive Bitrate



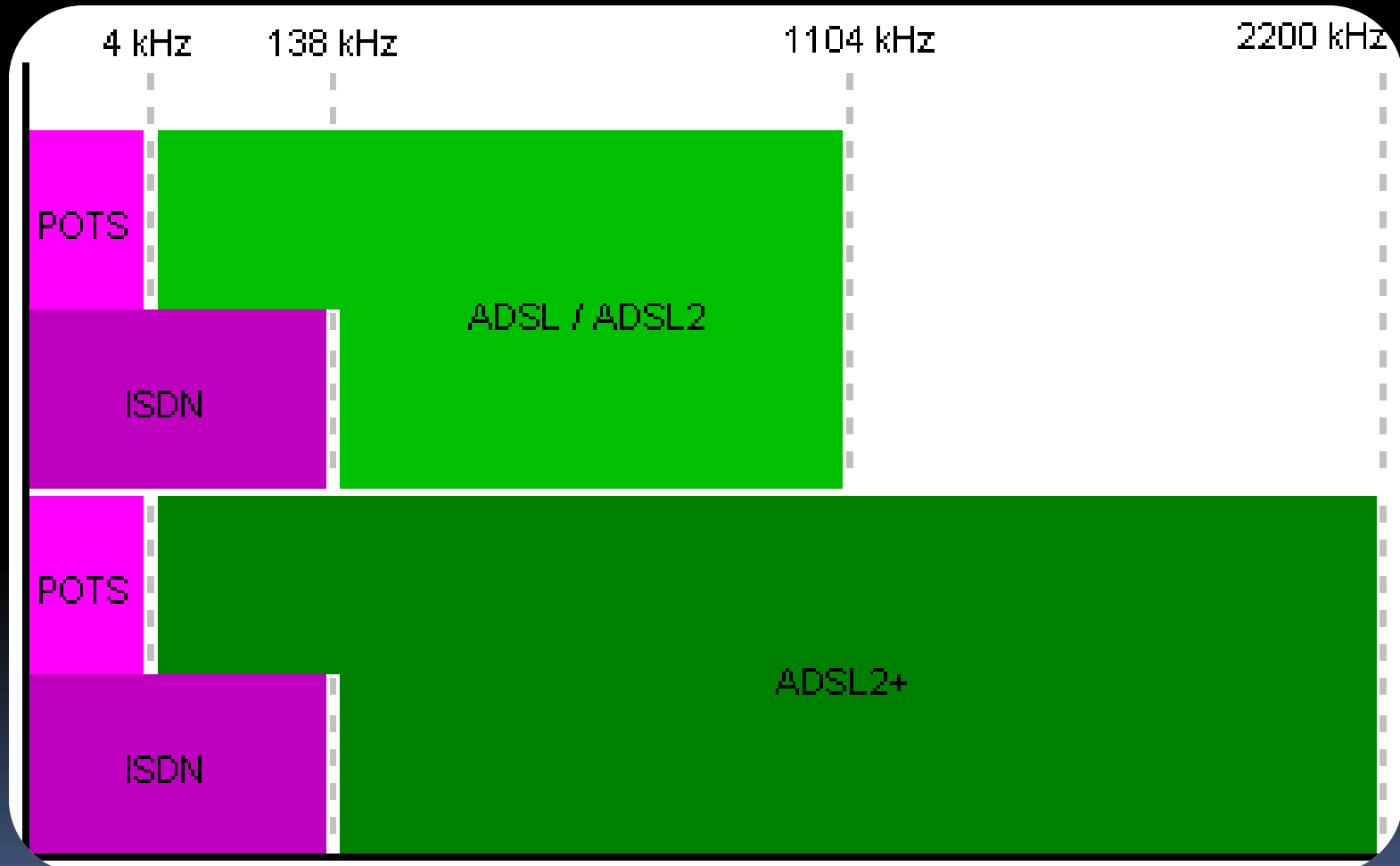
How did they get faster?



Hint:



frequency range



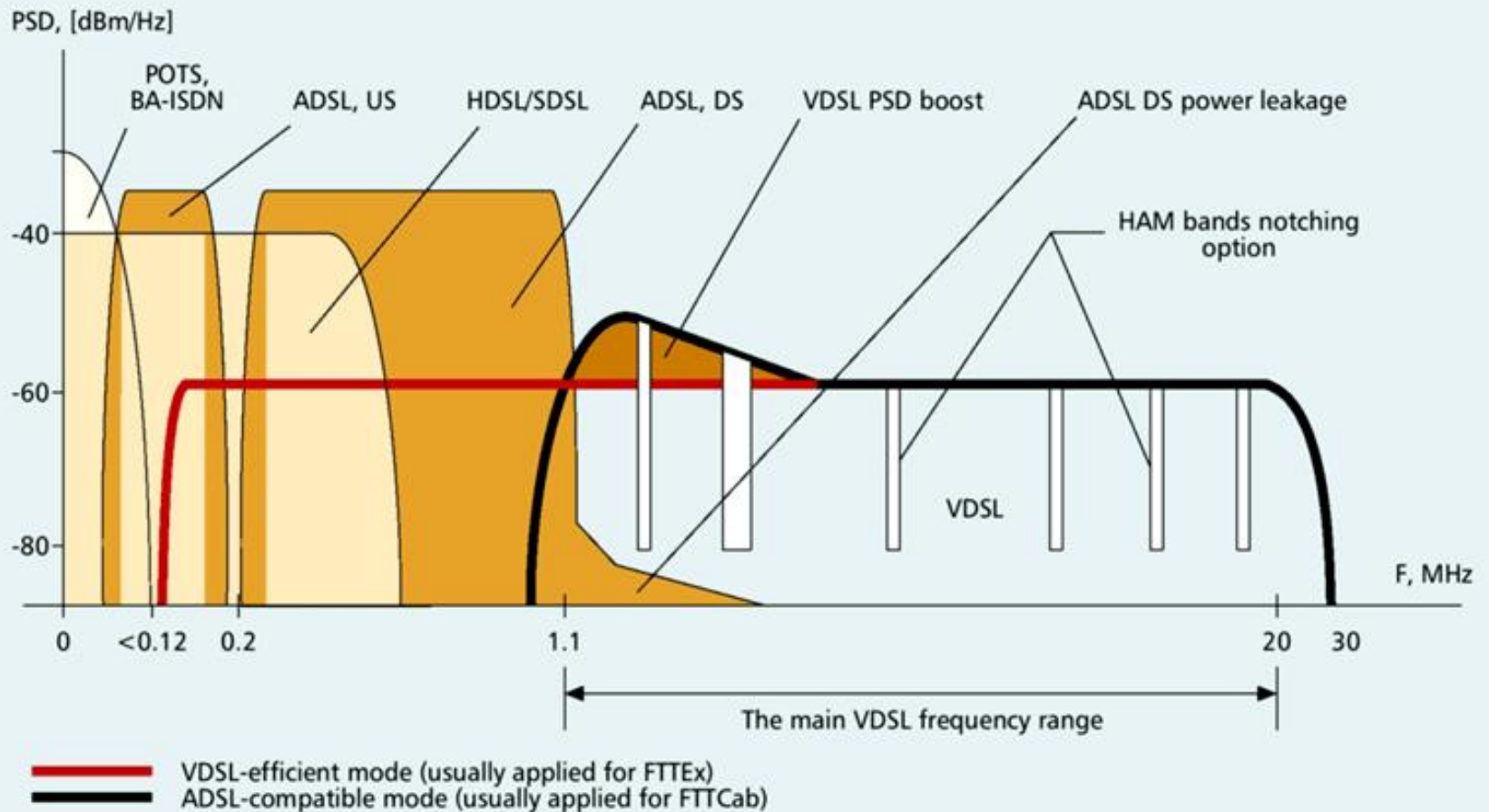
VDSL 2 and frequency

Profile	Bandwidth (MHz)	Tones	Tone-Distance (kHz)	Max. Transferspeed (Mbit/s, symmetrical)
8a	8,832	2047	4,3125	50
8b	8,832	2047	4,3125	50
8c	8,5	1971	4,3125	50
8d	8,832	2047	4,3125	50
12a	12	2782	4,3125	68
12b	12	2782	4,3125	68
17a	17,6604	4095	4,3125	100
30a	30	3478	8,625	200

Source:

http://de.wikipedia.org/wiki/Very_High_Speed_Digital_Subscriber_Line

frequency ranges



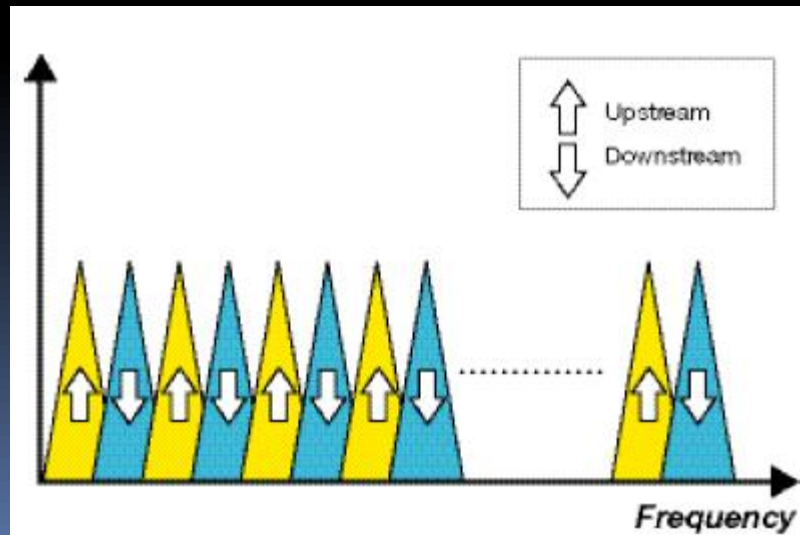
ADSL-compatible mode (usually applied for FTTC_{ab})

ADSL-efficient mode (usually applied for FTTE_x)

The main ADSL frequency range

Other things that changed:

- In ADSL2: less power consumption when idle
- In ADSL2: Seamless rate adaption
- In ADSL2: Reach-Extended-ADSL2 (ITU G.992.3 Annex L)
- IN VDSL2: Ethernet over the first mile (→ replaces ATM + start of VLAN usage)
- IN VDSL2: Frequency Division Duplex replaced by „Zipper“



Questions?



Questions
are
guaranteed in
life;
Answers
aren't.

Sources

- <http://condor.depaul.edu/~jkristof/xdsl-faq.txt>
- Mit Volldampf über die letzte Meile
http://www.s-t-e.de/content/Articles/Articles_12.php
- VDSL2 The Ideal Access Technology for Delivering Video Services Revision 2
(http://www.aware.com/dsl/whitepapers/wp_vdsl2.pdf)
- Ericson: VDSL2 The next important Broadband technology
(http://www.ericsson.com/ericsson/corpinfo/publications/review/2006_01/files/vdsl2.pdf)