S-38.3192 Verkkopalvelujen tuotanto
S-38.3192 Network Service Provisioning

Lecture 1: Subscriber line technologies

Subscriber line technology

- Subscriber line is the last mile to the customer
  - Customer can be
    - **Residential user**
      - Typically economically constrained technologies
    - **Corporation**
      - SME:s operate with tight budget – technologies are similar to residential users
      - Large corporations business in tightly bound to networks
        - » Readiness to invest and use money for better (more reliable) services

Subscriber line technology

- Subscriber line is the last mile to the customer
  - Conventionally only PSTN subscriber lines
    - Twisted pair copper
      - One or several pairs to each house
  - In urban areas CATV subscriber lines provide same service
    - Hybrid fiber coax network
  - Power lines are the last to arrive to the scene
    - Power lines are used to transmit also data traffic
      - Conventionally only control messages to fusebox
- Subscriber lines are the most expensive part of the network
  - A lot of physical construction work for each customer

Subscriber line technology

- Technology options for broadband data connections are
  - PDH/SDH/ATM
  - Long Range Ethernet (LRE)
  - XDSL over PSTN subscriber lines
  - DOCSIS over CATV lines
  - Power line communication (PLC)
  - Wireless local loops
    - 802.11 WLAN / HiperLAN
    - 802.16 WiMax

xDSL

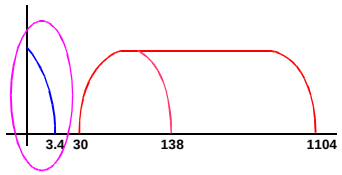
- **XDSL is a digitalizion of subscriber line**
  - IDSL (ISDN Digital Subscriber Line) was the initial invention
    - Local loop was digitized with high reliability and low bit error rate
  - Both ends of the subscriber line is equipped with modems
    - Information is modulated to frequency range that best serves the communication
      - PSTN copper pairs are in general old and contain a lot non-linearities
        - » Joints made with variable mechanisms
        - » Irregular twisting of pairs
        - » Highly variable di-electric properties of insulations
        - » Optimized for frequency range below 4kHz

xDSL

- Non-linearities cause a lot of problems in high data rate communications
  - Attenuation
  - Crosstalk
  - Distortion
- Magnitude depends on frequency and other usage of copper infrastructure
  - Copper pairs do not run individually on the ground ;-)

Remote Modem

- Transceiver Unit Remote (xTU-R)
  - Subscriber network termination
    - Either
      - Separate active device (bridge, router)
      - NIC in PC
    - With certain technologies can be equipped with low pass filter to extract voice signal (analog)from data.



Central Office Modem

- Transceiver Unit Central Office
  - Core network termination
    - Counterpart for user side mode
  - Usually build into larger unit (DSLAM)
    - Several modems
    - Multiplexing unit which concentrates the traffic into high speed backbone link
      - ATM 155 – ATM 622
      - Gigabit ethernet

HDSL

- **HDSL** (High Bit-Rate Digital Subscriber Line)
  - First real xDSL-technique
  - Baseband operation (2B1Q)
    - Subscriber line cannot be used same time for POTS services
  - Symmetric operation
    - Suitable for corporate LAN interconnection
    - PBX subscriber lines
      - Part of the time-slots can be left out of usage
  - Uses multiple copper pairs
    - Two pairs – 1.5Mbps (T1)
    - Three pairs – 2Mbps (E1)
  - Maximum distance 3-4 km

SDSL

- **SDSL** (Single-Line Digital Subscriber Line)
  - Single copper pair version of HDSL
    - Uses same modulation (2B1Q)
    - Transmission rates are same as in HDSL
  - More popular than HDSL
    - Copper pairs are expensive to rent in urban area
  - Maximum distance 3 km

G.SHDSL

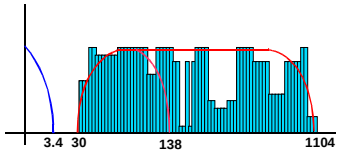
- **G.SHDSL** (Symmetric High Bit-Rate Digital Subscriber Line)
  - ITU-T Recommendation G.991.2
    - T1E1 - HDSL2
    - ETSI - SDSL
  - Transmission rates 192 kbps - 2.312 Mbps
  - Coding 16-Level TC-PAM (Trellis Coded Pulse Amplitude Modulation)
  - Single copper pair technology
  - Information is framed based on various technologies:
    - ATM
    - TDM
    - IP
    - Ethernet

ADSL

- **ADSL** (Asymmetric Digital Subscriber Line)
  - Most popular xDSL technique (residential user oriented)
  - Asymmetric uplink and downlink
  - Three bands
    - 0-3400Hz POTS
    - 20-160kHz Bidirectional data band
    - 240-1100kHz downlink data band
  - Bands are divided into 256 carriers
    - Carriers can be activated and passivated
      - Downlink maximum rate 1.5-8Mbps
      - Uplink maximum rate 1.5 Mbps
  - Maximum distance 3-4 km

ADSL

- ADSL systems measure the quality of copper pair and adapt symbol rate in each carrier to compensate possible defects
  - Crosstalk
  - Bit error rate
  - Attenuation

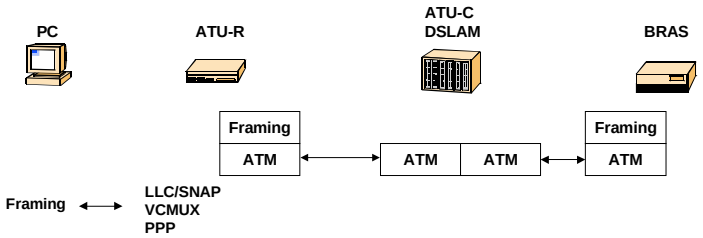


XDSL Framing

- XDSL systems are typically build for data transmission
- Data is transmitted between
  - Residential subscriber and ISP (Internet)
  - Residential subscriber and corporate network (Intranet)
  - Corporate offices (LAN interconnection)
- In all cases subscriber can be operated as
  - Routed
    - Subscriber has its own subnet
  - Bridged
    - Several subscribers share one subnet

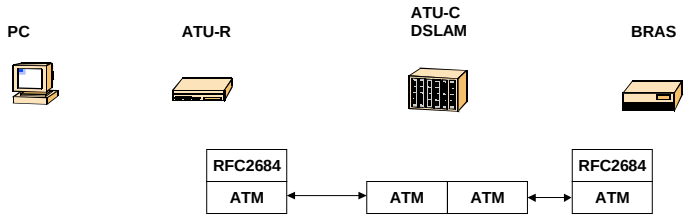
XDSL Framing (ATM)

- RFC2684: Multiprotocol Encapsulation over ATM Adaptation Layer 5
- RFC2364: Point to Point Protocol over ATM
- RFC 2516: A Method for Transmitting PPP Over Ethernet (PPPoE)
- Point to Point Protocol over Ethernet over ATM



RFC 2684

- **RFC 2684**: Multiprotocol Encapsulation over ATM Adaptation Layer 5
  - Previous version RFC 1483 (Classical IP)



RFC2684

- Two modes
  - **VC-multiplexing**
    - No framing -> individual ATM PVC can be used only for transmitting one type information
    - Both ends of the connection must share common view of the structure of information
    - Efficient
  - **LLC-encapsulation**
    - IEEE 802.2 encapsulation is added to information -> contains pointer to data type

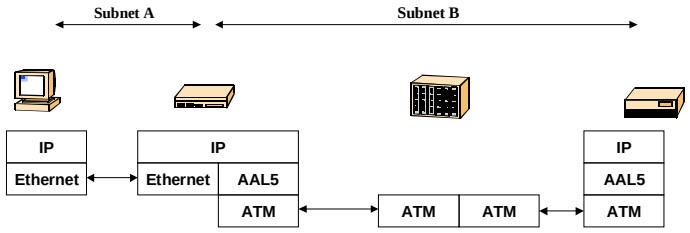
RFC 2684

- **VC-multiplexing** is based on raw ATM AAL5:n CPCS-interface
  - **Routed protocols** are interleaved directly in to CPCS-PDU
  - **Bridged protocols** require destination MAC-address for delivery

CPCS-PDU
PAD (0-47 octet)
~~CPCS-UU (1 octet)~~
CPI (1 octet) = 0x00
Length (2 octet)
CRC (4 octet)

PAD =00-00
MAC Destination
MAC frame
LAN FCS (depends VC:)
PAD (0-47 octet)
~~CPCS-UU (1 octet)~~
CPI (1 octet) =0x00
Length (2 octet)
CRC (4 octet)

Routed protocols

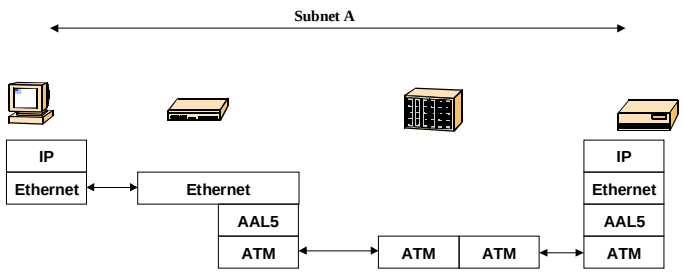


RFC 2684

- **LLC-encapsulation**
  - LLC header expresses frame type (protocol)
  - **IP** uses LLC/SNAP encapsulation

Destination SAP =AA	AA-AA-03 -> SNAP
Source SAP =AA	
Frame Type =03	
OUI =00-00-00	00-00-00 -> Ethertype
Ethertype =08-00	08-00 -> IPv4
IPv4 packet	
PAD (0-47 octet)	
~~CPCS-UU (1 octet)~~	
CPI (1 octet) =0x00	
Length (2 octet)	
CRC (4 octet)	

Bridged protocols



RFC 2684

- Ethernet bridging uses same LLC/SNAP encapsulation as IP does

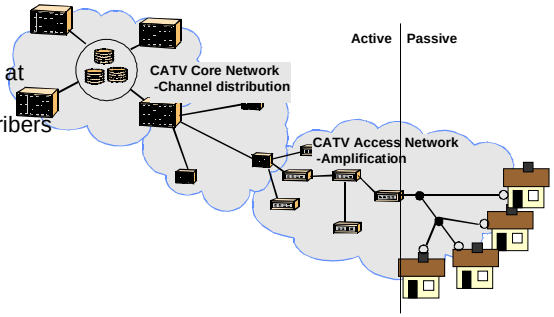
Destination SAP =AA
Source SAP =AA
Frame Type =03
OUI =00-80-C2
PID =00-01 / 00-07
MAC Destination
MAC frame
LAN FCS (PID=00-01)
PAD (0-47 octet)
~~CPCS-UU (1 octet)~~
CPI (1 octet) =0x00
Length (2 octet)
CRC (4 octet)

AA-AA-03 -> SNAP

00-80-C2 -> Bridging
00-01 -> FCS preserved
00-07 -> FCS not preserved

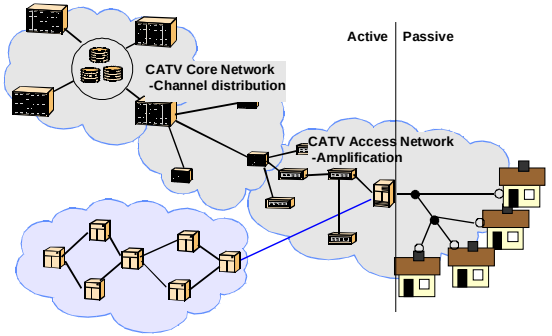
Classical CATV Network

- Designed for transmission of TV/Radio signals
  - 6 - 446 Mhz
- Access network
  - Amplifier lines
  - Passive tap network at last mile
    - Up to 500 subscribers



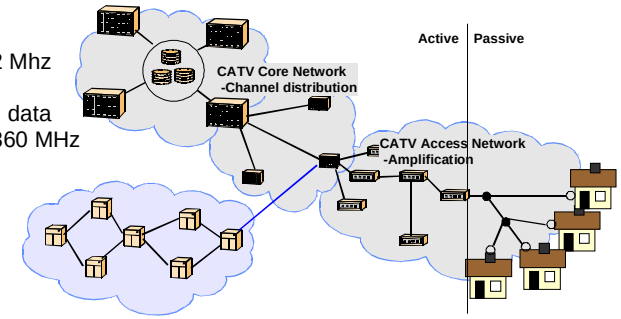
CATV Network with data connections

- Root amplifier of tap network is changed
  - Connection to data network (Internet)
  - Modulates the data to high frequency area
    - 470 – 860 MHz



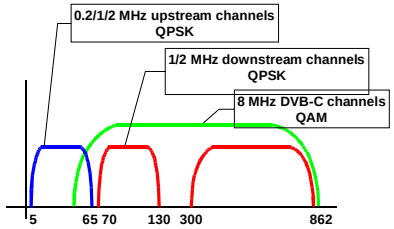
(Euro) DOCSIS CATV Network

- Amplifiers in coax segment are changed to bidirectional
  - Uplink
    - Data
      - 5 – 42 Mhz
  - Downlink
    - Video and data
      - 50 – 860 MHz



(Euro) DOCSIS

- US
  - Frequency ranges
    - Uplink 5 – 42 MHz
    - Dowlink 50 – 750 MHz
  - 6 MHz video channels
- Europe
  - Frequency ranges
    - Uplink 5 – 65 MHz
    - Downlink 50 – 860 MHz
  - 8 Mhz video channels

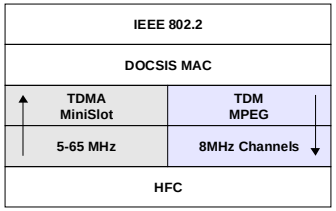


(Euro) DOCSIS

- Architecture requires two different components
  - Cable modem (CM)
    - User device which modulates and demodulates the information to/from coax network
      - Ethernet interface for end-user
  - Cable modem termination system (CMTS)
    - Modem unit on CATV head-end or distribution hub
      - Controls the uplink channel usage
        - » Separate CMTS for each frequency that is used for DOCSIS
      - Modulates and demodulates the data to proper frequency

(Euro) DOCSIS

- Framing is based on Ethernet framing but within the HFC network separate framing is used for data communication
  - Downlink: TDM based MPEG-2 frames
  - Uplink: TDMA based minislots



(Euro) DOCSIS

- Downlink framing based on MPEG-2
  - 204 bytes
  - Similar with video
    - Mix and match in single channel
  - Header contains info what frame content is
    - PID field 0x1FFE equals to MCNS Data over Cable
  - FEC is used to correct possible (probable) errors on transmission
    - Coax networks with multiple amplifiers are prone to bit errors
      - Reed Solomon coding

Sync (1 byte)	Header (3 bytes)	Data (184 bytes)	FEC (16 bytes)

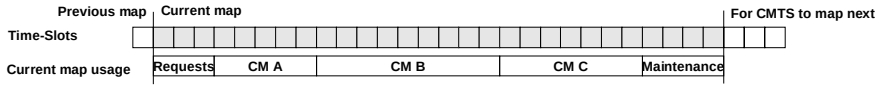
(Euro) DOCSIS

- Uplink framing is based on timely division of link capacity for different subscribers
  - Similar than PDH
  - Individual time-slot 6.25 us
  - Amount of bytes depends on modulation and coding
  - Required amount of time-slots is requested from CMTS to send data
  - Length of sync field depends on physical transmission rate
  - Data is normal Ethernet frame

Sync (x bytes)	Header (6 bytes)	Data (18-1518 bytes)	FEC (x bytes)

(Euro) DOCSIS

- CMTS controls the resource usage on uplink by allocating certain time-slots for certain CM:s
  - Done in granularities of MAP PDU
    - Several time-slots



(Euro) DOCSIS

- Downlink (per CMTS channel)
  - 64-QAM: 38 Mbps
  - 256-QAM: 52 Mbps
- Uplink
  - Capacity depends on
    - Version of specification
    - Modulation method
    - Symbol rate (channel size)

DOCSIS 1.0 and 1.1

Symbol Rate	Bandwidth Used (KHz)	QPSK Data Rate (Kb/s)	16-QAM Data Rate (Kb/s)
160	200	320	640
320	400	640	1280
640	800	1280	2560
1280	1600	2560	5120
2560	3200	5120	10240

DOCSIS 2.0

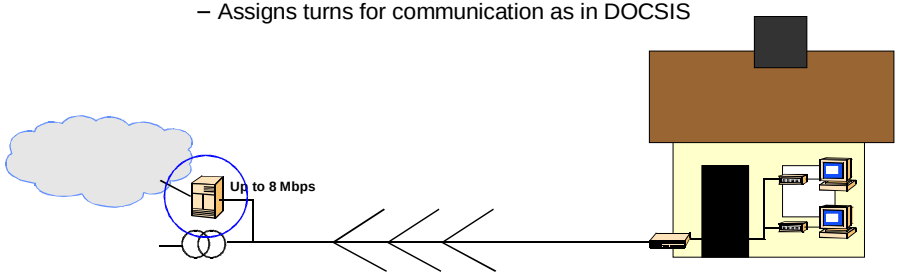
Symbol Rate	QPSK (Kb/s)	8-QAM (Kb/s)	16-QAM (Kb/s)	32-QAM (Mb/s)	64-QAM (Mb/s)	128-QAM (Mb/s)
160	320	480	640	0.96	1.28	1.92
320	640	960	1280	1.92	2.56	3.84
640	1280	1920	2560	3.84	5.12	7.68
1280	2560	3840	5120	7.68	10.24	15.36
2560	5120	7680	10240	15.36	20.48	30.72
5120	10240	15360	20480	30.72	40.96	61.44

Power Line Communications

- Based on fact that majority of houses are connected power grid
  - Same cabling system can be used to transmit information other than 50Hz electricity
  - Modulation of data information to frequency range that operates in power network
    - Power line twisting
      - outdoors is optimized for low frequencies
      - Indoors is basically none
    - High frequencies
      - Power line operates as antenna
        - » Regulations to control the emissions

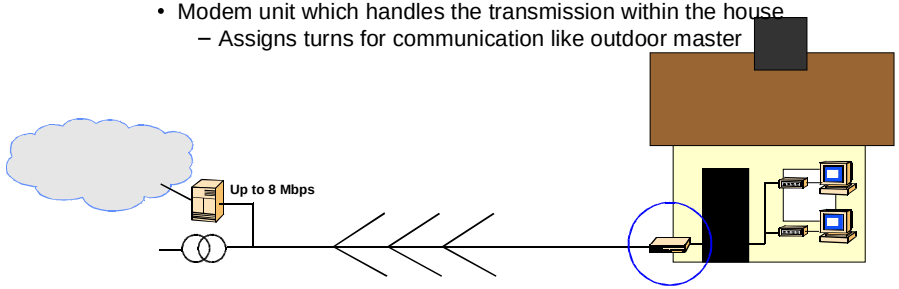
PLC

- Based on three components
  - Power line master unit
    - Connects into power line after last transformer
    - Modem unit which handles the transmission on power line
      - Assigns turns for communication as in DOCSIS



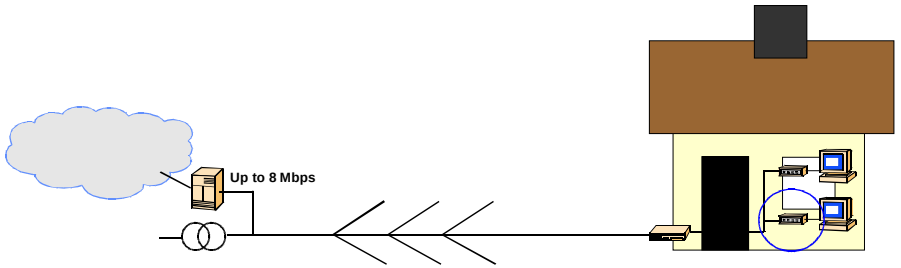
PLC

- Based on three components
  - Indoor/Outdoor converter
    - Changes the frequency range which used within the house to one which is used outside the house
    - Modem unit which handles the transmission within the house
      - Assigns turns for communication like outdoor master



PLC

- Based on three components
  - Indoor modem unit
    - Provides Ethernet connection to PC and modem services to indoor PLC network



PLC

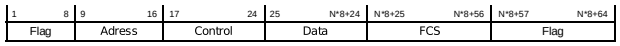
- Frequency range 1.6MHz to 30 Mhz
  - Several independent carriers (4-8 normally)
  - Overall datarate 8Mbps
    - Next generation will bring 16-40 Mbps (depending on source of estimation)
- Locally several power companies have tested technology but only few are really offering services based on it

Corporate connection models

- Subscriber line technologies for corporate usage are the same as for residential usage with the exception that conventional core network technologies are extended to customers:
  - Ethernet
    - Normal
    - LRE (Ethernet over VDSL/HDLC)
  - PDH
    - HDLC
    - Cisco HDLC
    - PPP
  - FrameRelay

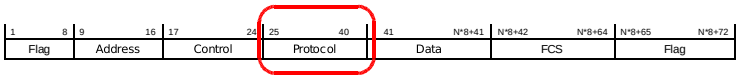
HDLC

- HDLC-protocol is a ISO standard protocol based on IBM SDLC-protocol
  - HDLC frame contains
    - Markers for the frame (0x7E - 01111110)
    - Address field to indicate receiving station of the frame (128)
    - Control field for indication of frame type
      - I: Information frame
      - S: Supervisory frame
      - U: Unnumbered frame



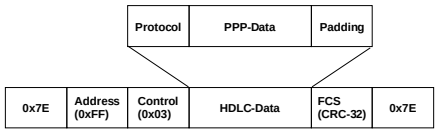
Cisco HDLC

- Cisco HDLC is a HDLC variant intended for multiprotocol encapsulation over transmission link
  - Cisco HDLC adds
    - Protocol field for indicating the post processing option for the frame
      - Protocol field contains either
        - » Ethernet type codes
        - » Cisco add-ons indicating that content is Ethernet or its sub protocol



PPP

- Point-to-point protocol is standard variant of Cisco HDLC
  - Only two devices on the communication path
    - Address 0xFF (broadcast)
    - Control (0x03) for U-frames without flow control
    - PPP-frame itself contains protocol indication
      - Like cisco HDLC



Frame Relay

- Popular variant of HDLC
- Omits the control field
  - Error and flow control are left for application protocols
- Restructured address field
  - Address and control integrated
- DLCI: Connection ID (10/16/23bits)
- xECN: congestion indication forward / backward
- DE: Discard eligible
- EA: Extended address
- C/R: Command Response