Tutorial on Access Technologies

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TelCon srl http://www.tel-con.com
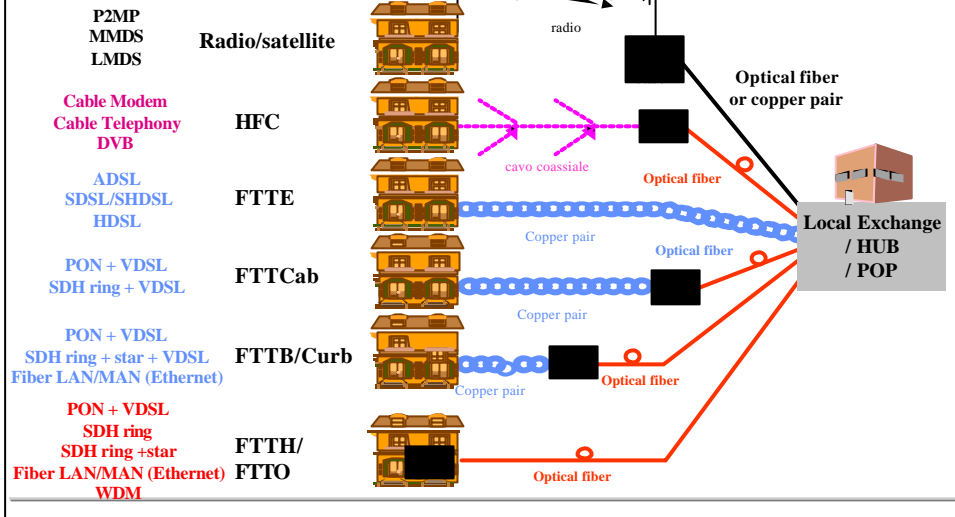**gdemarchis@tel-con.com**

Tutorial on Access Technologies

Outline
- ‣ **Introduction**
- ‣ **xDSL**
- ‣ **HFC**
- ‣ **FTTx**
- ‣ **PON**
- ‣ **Radio Access**
- ‣ **PLC**

First Mile Network Technologies

Technologies   **Architecture**

P2MP / MMDS / LMDS — Radio/satellite

Cable Modem / Cable Telephony / DVB — HFC

ADSL / SDSL/SHDSL / HDSL — FTTE

PON + VDSL / SDH ring + VDSL — FTTCab

PON + VDSL / SDH ring + star + VDSL / Fiber LAN/MAN (Ethernet) — FTTB/Curb

PON + VDSL / SDH ring / SDH ring +star / Fiber LAN/MAN (Ethernet) / WDM — FTTH/ FTTO

radio — Optical fiber or copper pair — cavo coassiale — Optical fiber — Copper pair — Local Exchange / HUB / POP

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xDSL Systems

xDSL system birth

Historically DSL (Digital Subscriber Loop) was the line system for basic rate access ISDN (ISDN BRA)

ANSI & ETSI (end of 80's beginning of 90's) encourage activities on copper-based HDSL systems (High bit rate DSL) standardization

- **Need: fast provisioning of leased lines**
  - **DS1 1,544 kbit/s in USA**
  - **E1 2,048 kbit/s in Europe**
- **Requirement: cost-effective systems**
  - **no repeater up to 3- 4 km from LEX**
  - **no line upgrade required**
- **Enabling factor: high performance DSPs available**

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xDSL system today

- **High performance video compression/coding (MPEG-1, MPEG-2, MPEG-4) make possible Video On Demand (VOD) service distribution**
- **Internet access with fast increasing band requirements**
- **Highly asymmetrical bandwidth requirements in the two directions (upstream « downstream)**
- **Copper pair is already deployed and can be used to provide residential customers with interactive multimedia services**
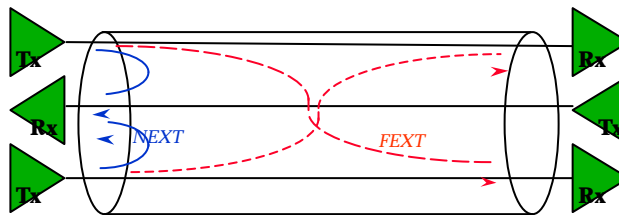
xDSL System Impairments

xDSL transmission uses the frequency band between a few tens kHz up to a few tens MHz

Performance depends on:

- **Copper pair attenuation and transfer function (amplitude and phase)**
- **Stubs on copper pair (distortion increases)**
- **Cable crosstalk**
- **Burst noise (non-steady state effect)**
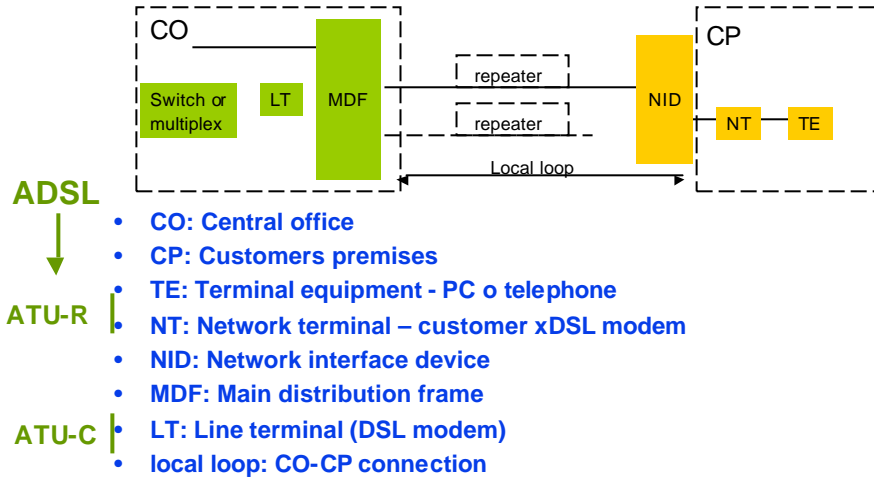

Crosstalk

Tx Rx

Rx *NEXT* *FEXT* Tx

Tx Rx

- **Near-end crosstalk (NEXT) is present when the uplink and downlink share the same frequency bands**

- **Far-end crosstalk (FEXT) is always present**

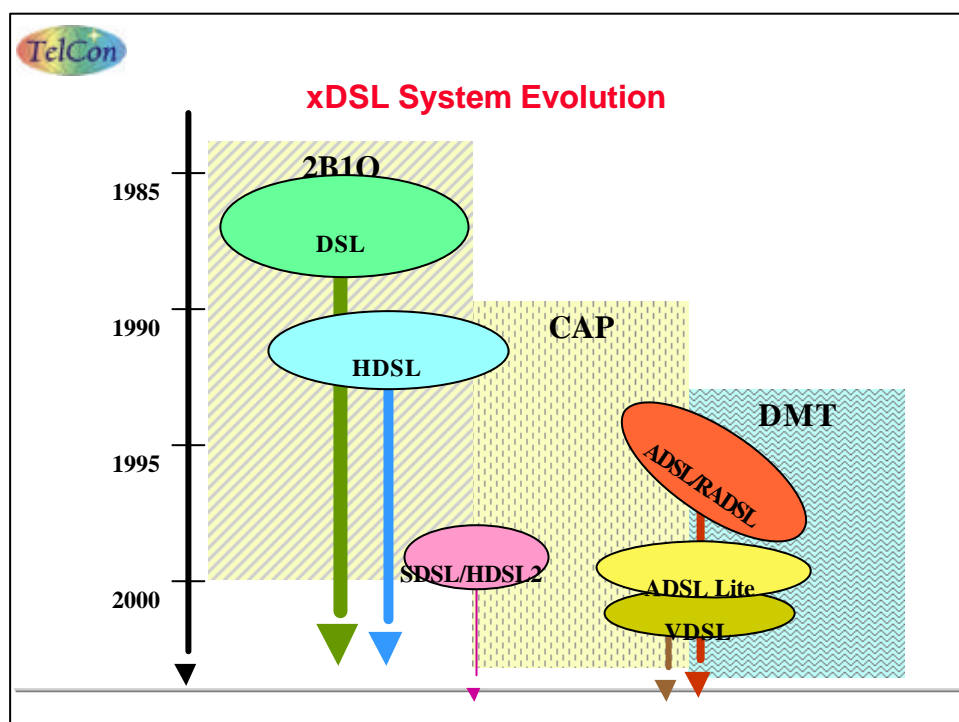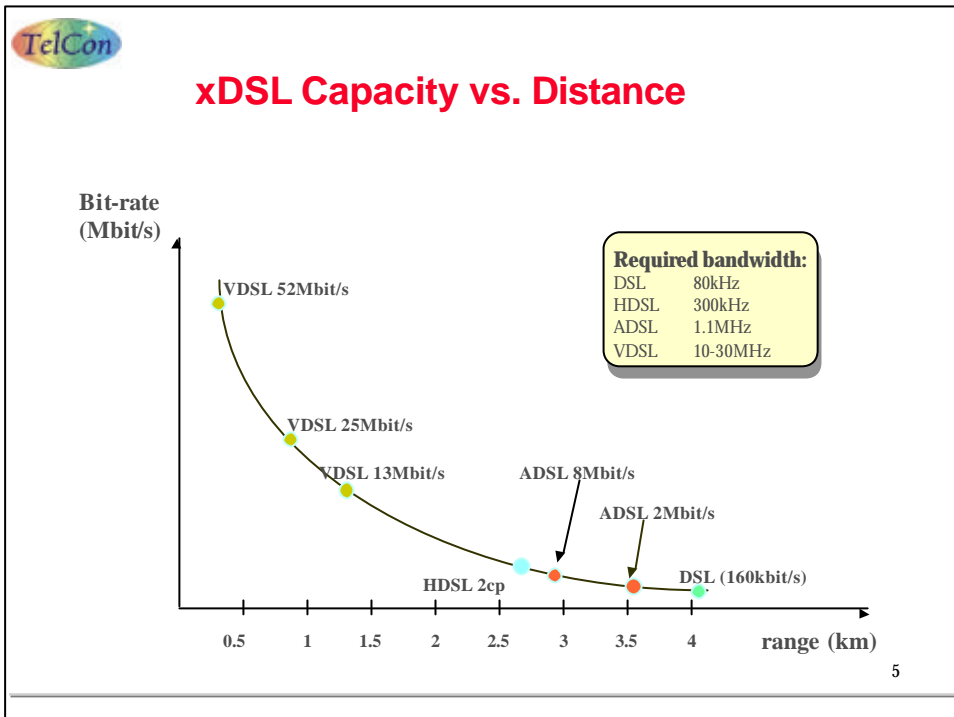- **Environment conditions modify Xtalk and line impedance**

xDSL Reference Model

ADSL

↓

ATU-R

ATU-C

- **CO: Central office**
- **CP: Customers premises**
- **TE: Terminal equipment - PC o telephone**
- **NT: Network terminal – customer xDSL modem**
- **NID: Network interface device**
- **MDF: Main distribution frame**
- **LT: Line terminal (DSL modem)**
- **local loop: CO-CP connection**

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xDSL Flavours

HDSL High bit-rate DSL
     2Mbit/s over 2 cp, 2B1Q code

SDSL Symmetric DSL
     up to 2Mbit/s, 1 cp + POTS, CAP & 2B1Q code

ADSL Asymmetric DSL
     up to 8Mbit/s down, 1Mbit/s up + POTS , 1 cp,
     CAP & DMT code

VDSL Very high bit-rate DSL
     52, 26 or 13Mbit/s down, 2Mbit/s up + POTS
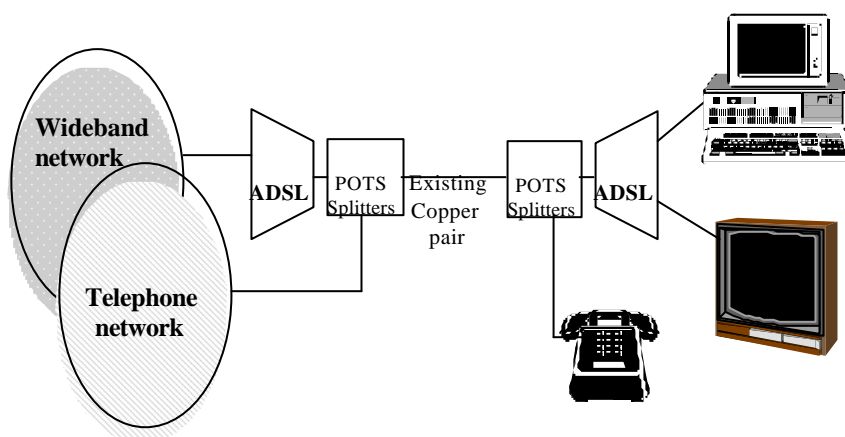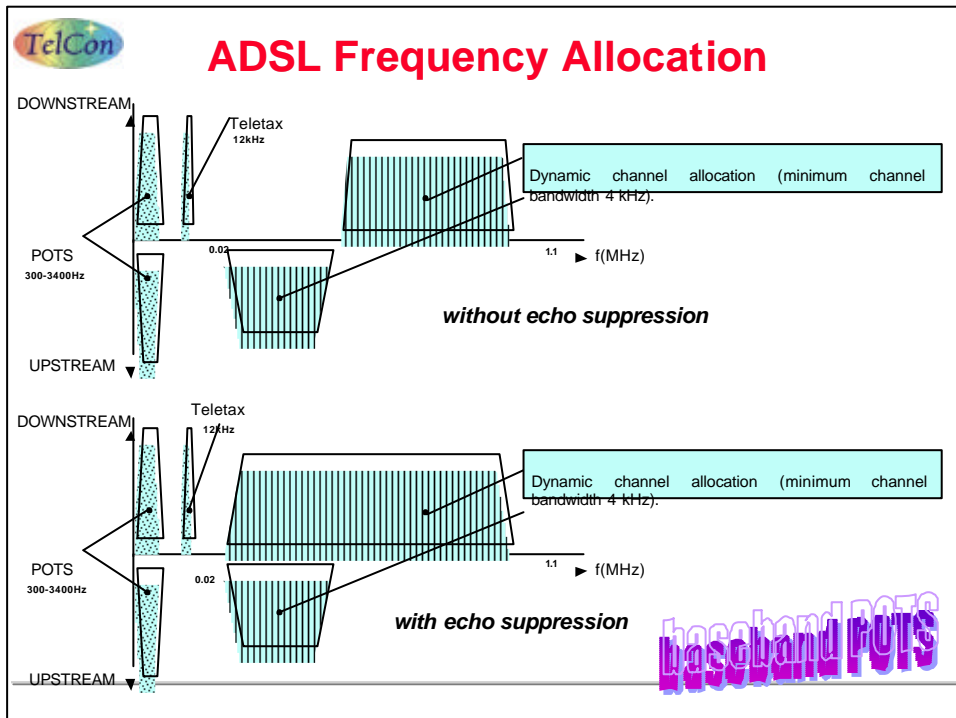   (or ISDN), 1 cp, CAP & DMT code

xDSL Capacity vs. Distance

Bit-rate
(Mbit/s)

Required bandwidth:
DSL   80kHz
HDSL   300kHz
ADSL   1.1MHz
VDSL   10-30MHz

VDSL 52Mbit/s

VDSL 25Mbit/s

VDSL 13Mbit/s

ADSL 8Mbit/s

ADSL 2Mbit/s

DSL (160kbit/s)

HDSL 2cp

| 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | range (km) |

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xDSL System Evolution

1985

2B1Q

DSL

1990

CAP

HDSL

DMT

1995

ADSL/RADSL

SDSL/HDSL2

ADSL Lite

2000

VDSL

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ADSL

Asymmetric Digital Subscriber Line

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Asymmetrical Digital Subscriber Line

Wideband network

Telephone network

ADSL

POTS Splitters
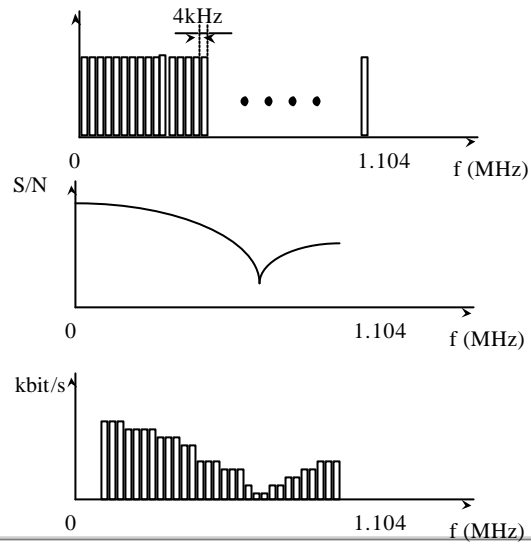
Existing Copper pair

POTS Splitters

ADSL

ADSL DMT CODING/MODULATION

- ITU-T G.992.1 **defines an ADSL modem based on DMT (Discrete Multi Tone) modulation**
- **Downstream:**
  - **Sampling frequency 2,208 MHz, 256 carriers between 0 and 1,104 MHz**
  - **4000 simbols/s. Each channel 4,3 kHz wide**
  - **Maximum rate 32 kbit/s per channel**
- **Upstream:**
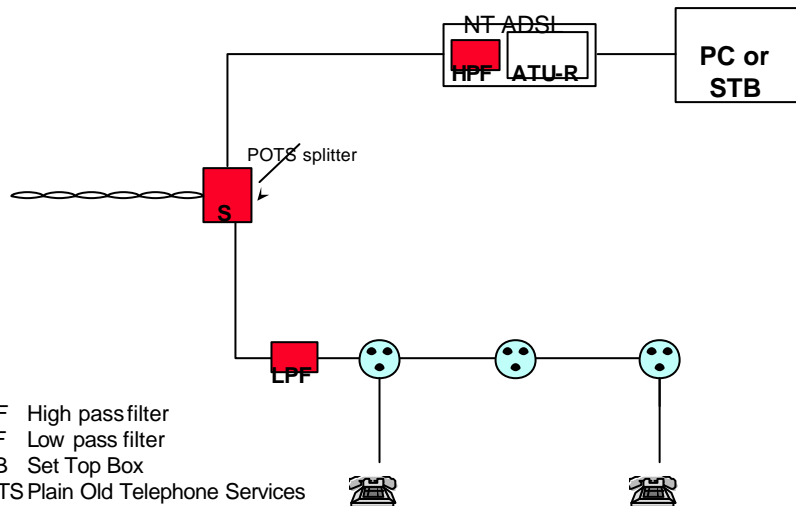 - **Sampling frequency 275 kHz, 32 carriers between 0 and 138 kHz**

ADSL Frequency Allocation

Channel response DMT modulation matching

4kHz

0   1.104   f (MHz)

S/N

0   1.104   f (MHz)

kbit/s

0   1.104   f (MHz)

Splittered installation

NT ADSL

HPF   ATU-R   PC or STB

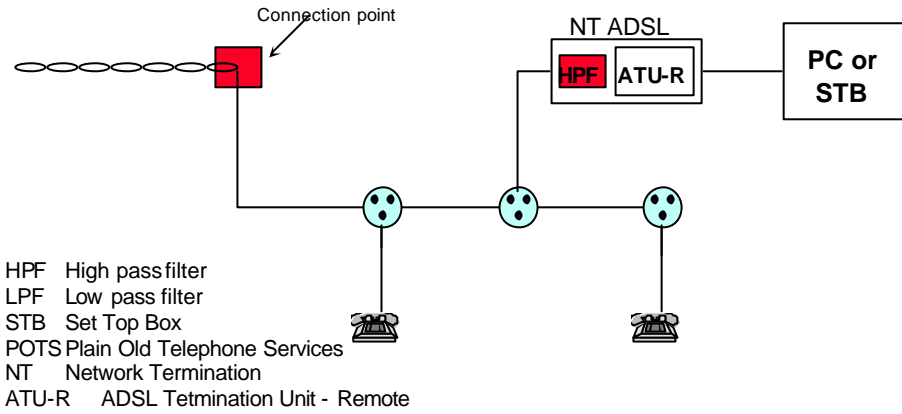POTS splitter

S

LPF

HPF   High pass filter
LPF   Low pass filter
STB   Set Top Box
POTS   Plain Old Telephone Services
NT   Network Termination
ATU-R ADSL Tetmination Unit - Remote

Splitterless installation

Connection point

NT ADSL

HPF ATU-R

PC or STB
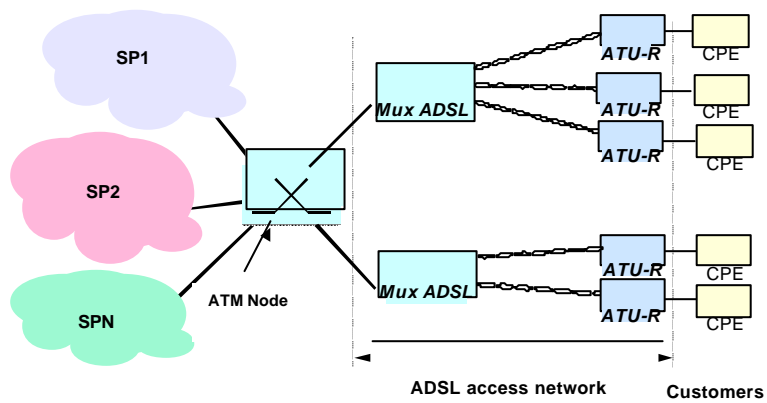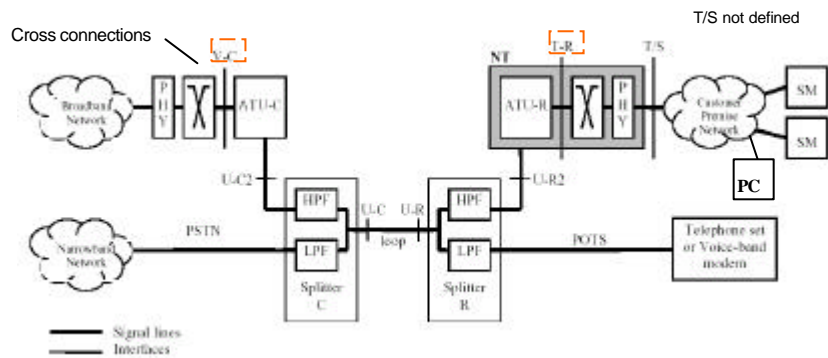
HPF High pass filter
LPF Low pass filter
STB Set Top Box
POTS Plain Old Telephone Services
NT Network Termination
ATU-R ADSL Tetmination Unit - Remote

ADSL Network Architecture

SP1

SP2

SPN

ATM Node

Mux ADSL

Mux ADSL

ATU-R CPE
ATU-R CPE
ATU-R CPE

ATU-R CPE
ATU-R CPE

ADSL access network

Customers

ATU-R: ADSL Terminal Unit - Remote
SP: Service Provider
CPE: Customer Premises Equipment

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ADSL Reference Model

Cross connections

T/S not defined

- **Standard defines both interfaces and modems:**
  - **ATU-R: ADSL transceiver unit - remote terminal**
  - **ATU-C: ADSL transceiver unit - central office terminal** ← modem
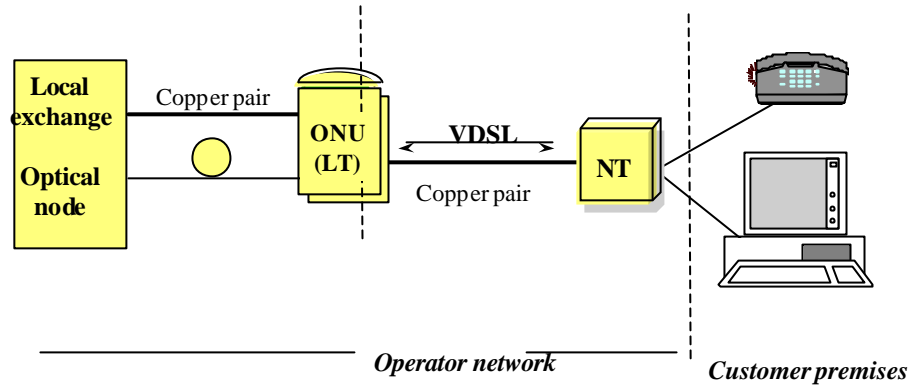 - **U-C (2), U-R (2)** ← interfaces
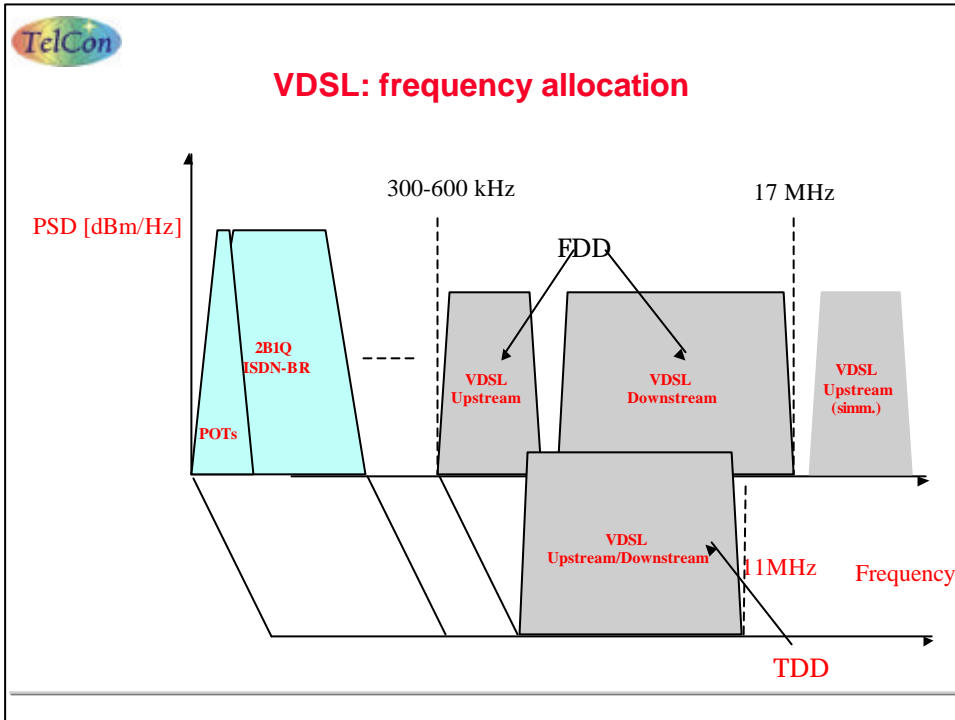

VDSL

Very High bit rate Digital Subscriber Line

VDSL: reference configuration

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```
Local
exchange          Copper pair        ONU        VDSL         NT
                                     (LT)
Optical                                      Copper pair
node
```

Operator network   *Customer premises*
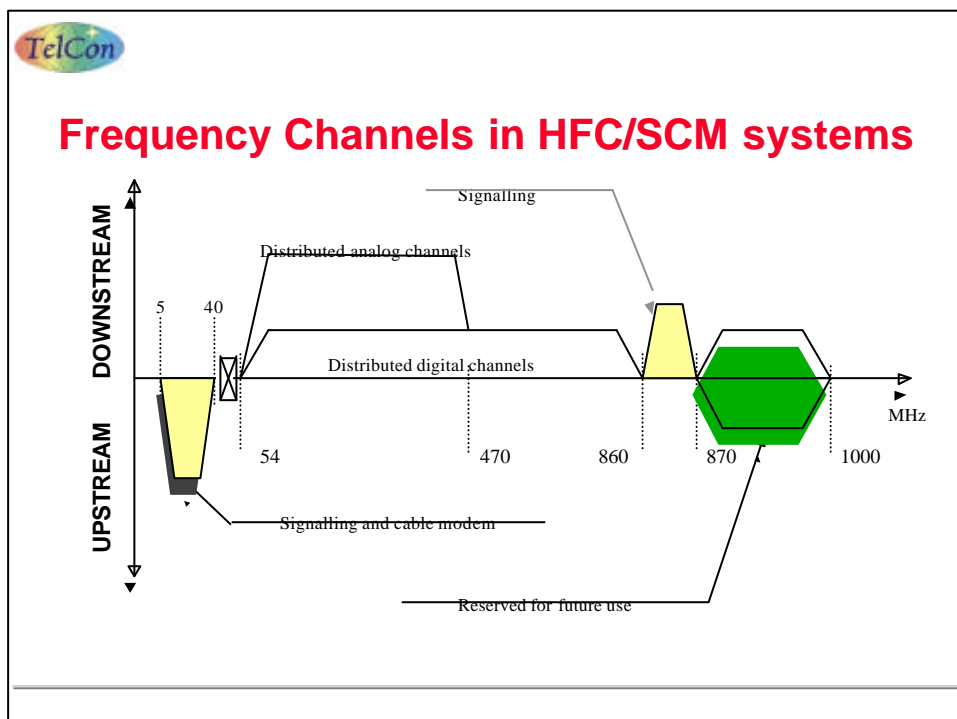

Performance

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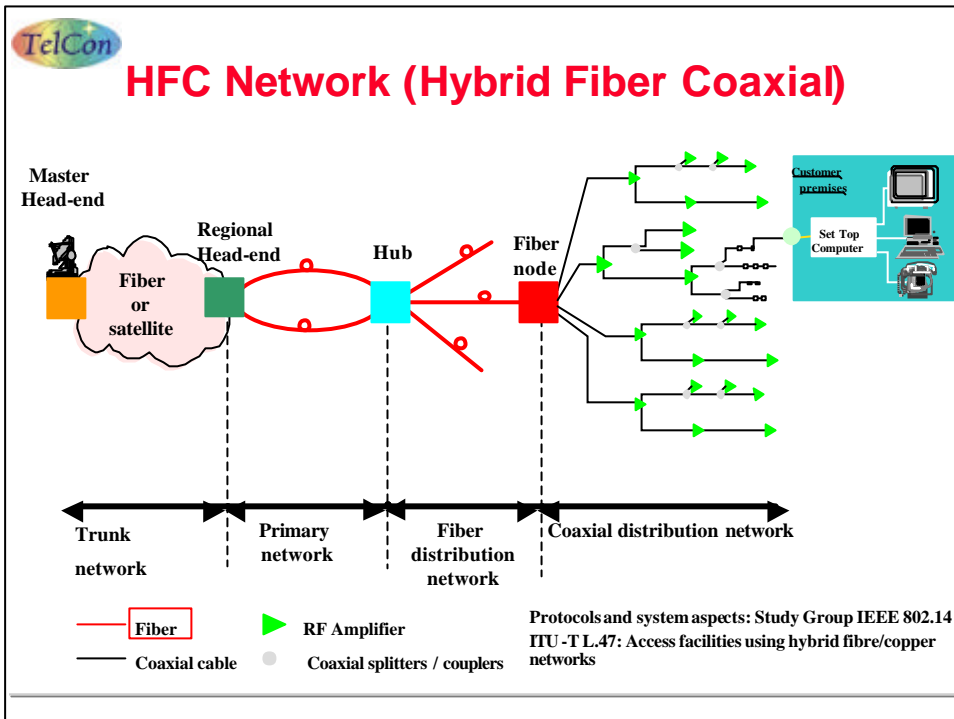- **ETSI standard defines various rates, both for symmetrical and asymmetrical data streams :**

SYMMETRICAL TRAFFIC		ASYMMETRICAL TRAFFIC		
Bitrate (Mbit/s)	Distance (m)	Bitrate (Mbit/s)		Distance (m)
28	< 500	Down	Up	
23	< 600	23	4	< 700
14	< 800	14	3	< 1100
8	< 1000	8	2	< 1300
6	< 1200	6	2	< 1400

VDSL: frequency allocation

HFC Networks

Hybrid Fiber Coaxial Networks

HFC Network (Hybrid Fiber Coaxial)

Master Head-end

Regional Head-end

Hub

Fiber node

Customer premises

Set Top Computer

Fiber or satellite

Trunk network

Primary network

Fiber distribution network

Coaxial distribution network

Fiber

Coaxial cable

RF Amplifier

Coaxial splitters / couplers

Protocols and system aspects: Study Group IEEE 802.14
ITU - T L.47: Access facilities using hybrid fibre/copper networks

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Frequency Channels in HFC/SCM systems

DOWNSTREAM

UPSTREAM

Signalling

Distributed analog channels

Distributed digital channels

Signalling and cable modem

Reserved for future use

5   40

54   470   860   870   1000

MHz

Network Coverage

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Distribution Node
20 km II window
28 km III window
50 km with amplifier

Local Node
10 km

100-400 customers

Fiber Node
500 m
coax
NT

1
48
1
192

Total number of customers = 48 x 192 x 400 = 3,686,400

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PON Networks

Passive Optical Networks

Passive Optical Network

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Primary network   Cabinet   Secondary network

OLT   ONU

Lmax=10 km

Exchange

**16-32 ONU/OLT
20-30 customers/ONU**

Customer
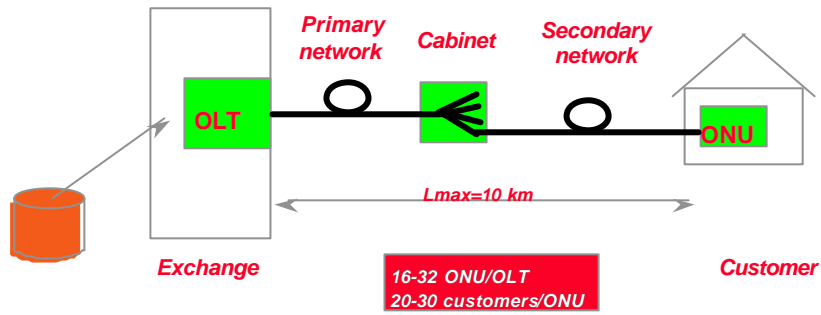
- **Full Service Access Network**
- **Various topologies: FTTCab, FTTC, FTTB, FTTH**
- **Possible overlay of FTTB and HFC**

PON Topologies

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Exchange | Primary network | Secondary network | Building | Customer premises

PON FTTCab/B/H

PON LT

ONU

ADSL

NT

F.o.
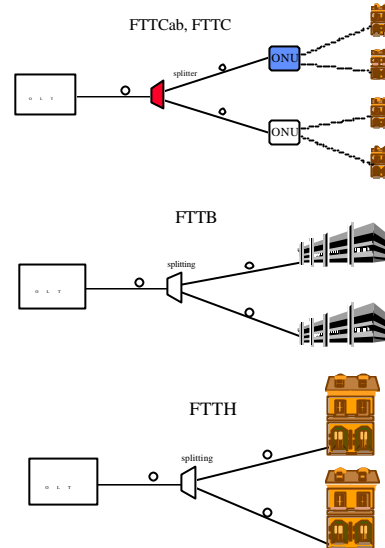
Copper pair

ONU

VDSL

NT

STB

Home network

Copper pair

ONU
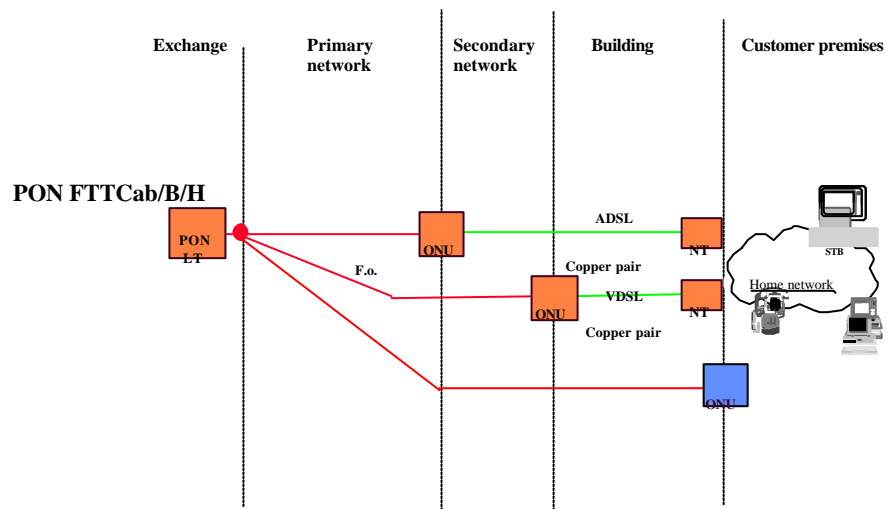
FTTx Architecture

- **Splitting ratio: up to 1:32**
- **Range: up to 20 km**
- **Capacity**
  - 50 Mbit/s symmetrical
  - 155 Mbit/s symmetrical
  - 155 Mbit/s- 622 Mbit/s
- **Ranging**
- **Bandwidth and resource allocation flexibility**

FTTCab, FTTC

FTTB

FTTH

Characteristics of PON networks

- **PON reduce the amount of fibers, transceivers and line terminals**

- **Longer reach than ADSL (15/20 km)**

- **First wideband PON were known as APON (ATM-PON with ATM as layer 2 protocol)**

- **APON technology based on results from FSAN consortium (Full Services Access Network), agreed in 1995 among main world operators.**
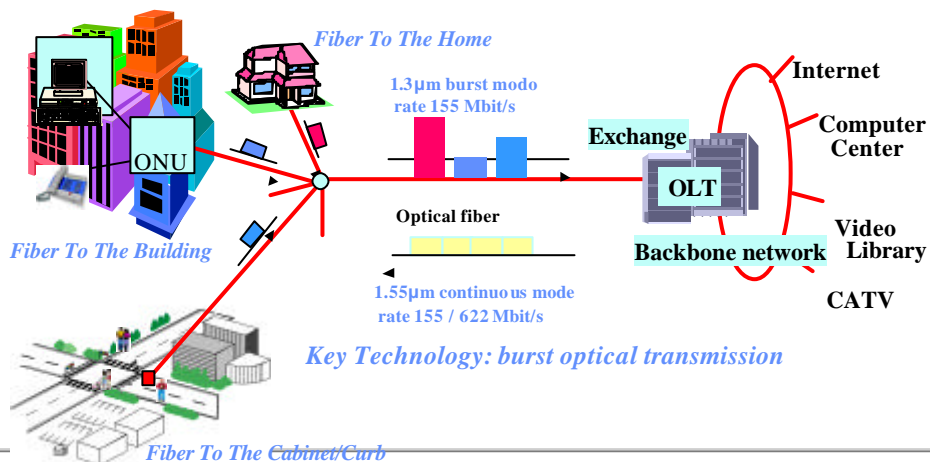
PON Standardization

- **Specification of APON in FSAN group and endorsed in ITU-T SG.15 G.984 –series: Broadband optical access systems based on Passive Optical Networks (PON)**
    - **G.983.1 – APON physical layer and transmission convergence**
    - **G.983.2 – ONT Management and Control Interface (OMCI)**
    - **G.983.3 – WDM upgrades**
- **Ongoing standardization work**
    - **G.983.dba – Dynamic bandwidth allocation**
    - **G.983.sur – Survivability schemes**
- **G.984-series Gigabit-capable PON**

G.671 - Transmission characteristics of passive optical components
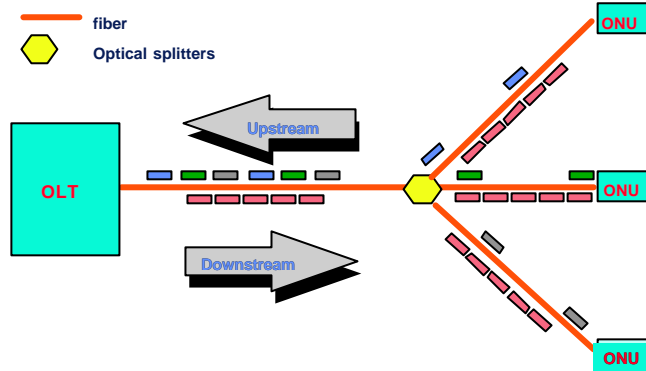
ATM-PON high speed access

ATM: Asynchronous Transfer Mode
>service(CATV, VOD, POTS etc) multiplexing
PON: Passive Optical Network
>high speed, low cost subscriber loop

Fiber To The Home

1.3μm burst modo
rate 155 Mbit/s

ONU

Fiber To The Building

Optical fiber

1.55μm continuous mode
rate 155 / 622 Mbit/s

Key Technology: burst optical transmission

Fiber To The Cabinet/Curb

Exchange

OLT

Backbone network

Internet

Computer Center

Video Library

CATV

TDM/TDMA Protocol

— fiber

⬡ Optical splitters

Upstream
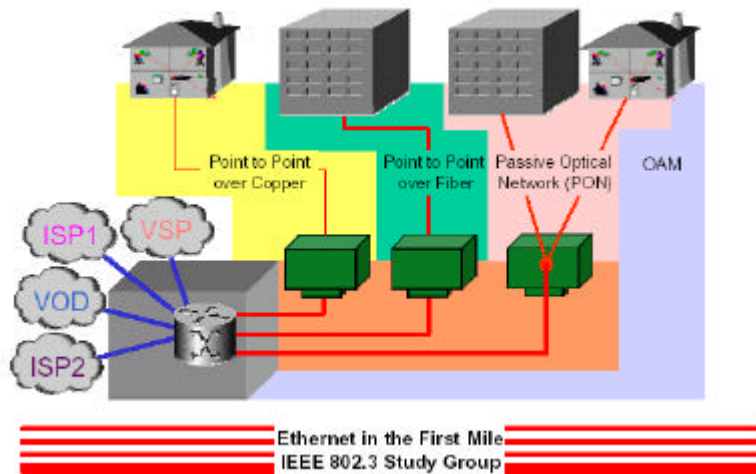
Downstream

OLT

ONU

ONU

ONU

Problems:
- *ranging*
- laser power control

EFM: Ethernet in the First Mile

- **Study Group IEEE 802.3ah EFM (Ethernet in the First Mile)**
- **EFM started in September 2001**
- **Specification issued in September 2003**
- **Key aspects for further study:**
  - security and privacy though cryptographic encoding
  - QoS aspects

EFM: Technologies

Point to Point over Copper
Point to Point over Fiber
Passive Optical Network (PON)
OAM

ISP1 VSP VOD ISP2

Ethernet in the First Mile
IEEE 802.3 Study Group
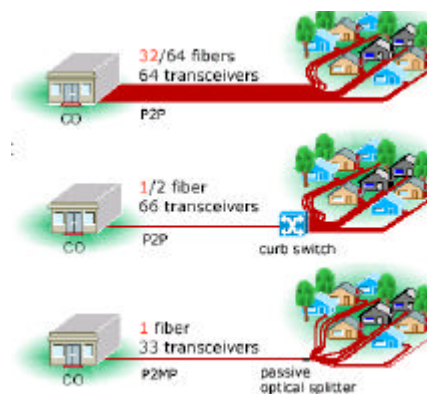

Optical First Mile

- **P2P Ethernet**
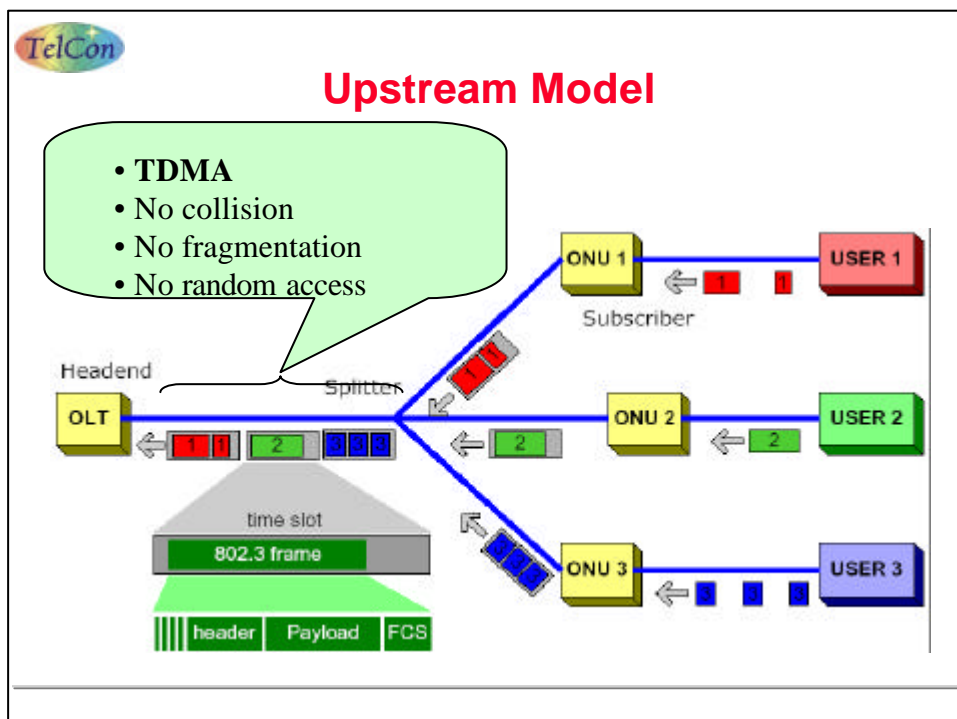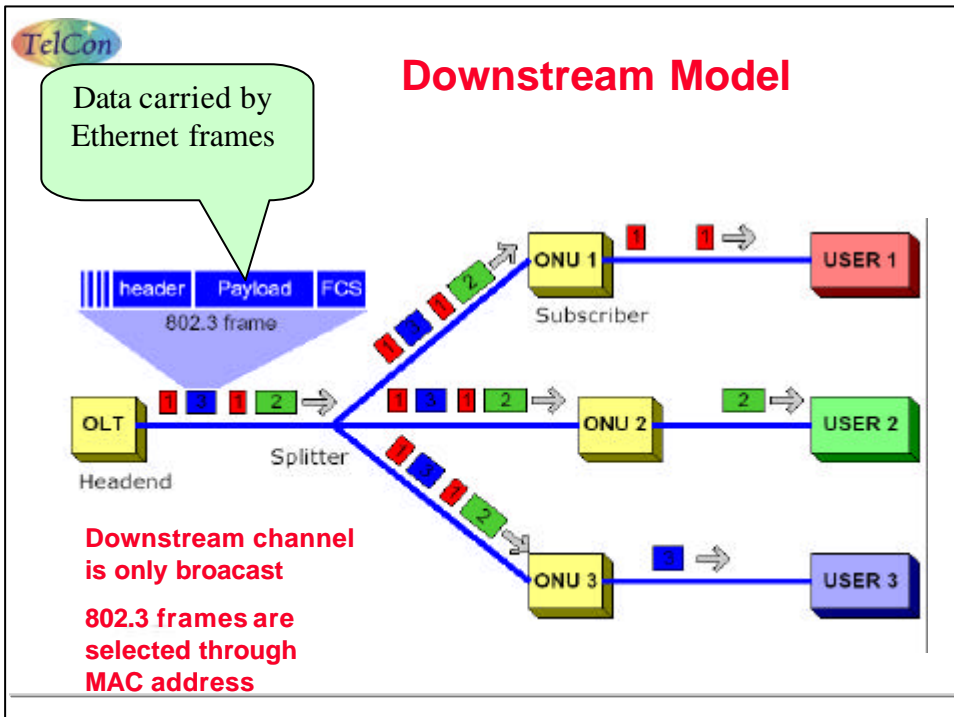 - N fibers
  - 2N optical transceivers

- **Curb Switched Ethernet**
  - 1 fiber
  - 2N+2 optical transceivers
  - Power supply needed

- **Ethernet PON (EPON)**
  - 1 fibra
  - N+1 optical transceivers
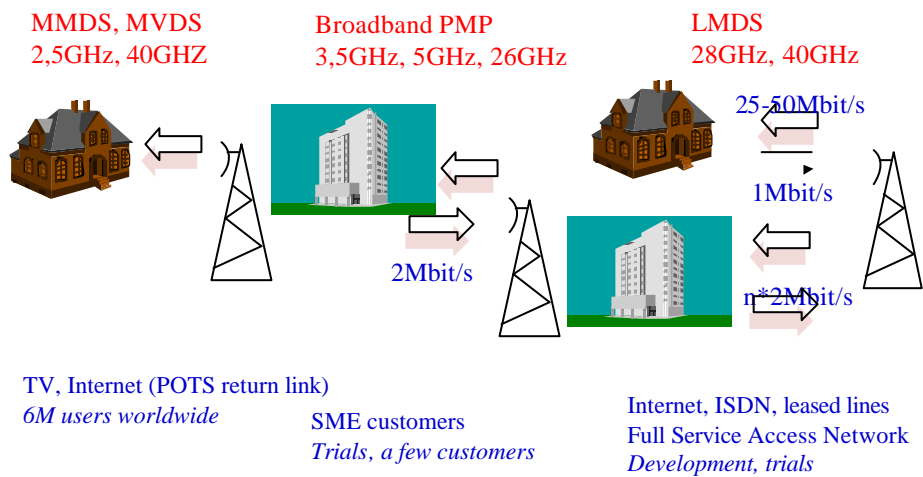 - Power supply not needed
  - Broadcast downstream (video)

32/64 fibers
64 transceivers
CO   P2P

1/2 fiber
66 transceivers
CO   P2P   curb switch

1 fiber
33 transceivers
CO   P2MP   passive optical splitter

Downstream Model

Data carried by Ethernet frames

header | Payload | FCS
802.3 frame

OLT
Headend

Splitter

ONU 1
Subscriber

ONU 2

ONU 3

USER 1

USER 2

USER 3

Downstream channel is only broacast

802.3 frames are selected through MAC address

Upstream Model

• **TDMA**
• No collision
• No fragmentation
• No random access

Headend
OLT

Splitter

time slot
802.3 frame

header | Payload | FCS

ONU 1
Subscriber

ONU 2

ONU 3

USER 1

USER 2

USER 3

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Radio Access Networks

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Wideband Radio Access Technologies

MMDS, MVDS
2,5GHz, 40GHZ

Broadband PMP
3,5GHz, 5GHz, 26GHz

LMDS
28GHz, 40GHz

25-50Mbit/s

1Mbit/s

2Mbit/s

n*2Mbit/s

TV, Internet (POTS return link)
6M users worldwide

SME customers
Trials, a few customers

Internet, ISDN, leased lines
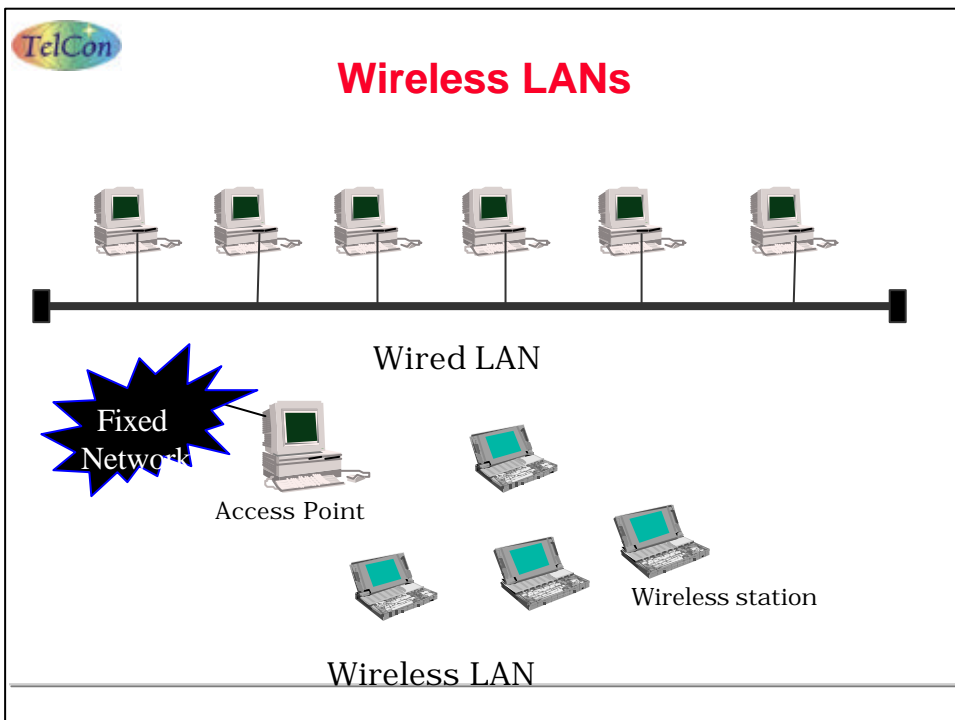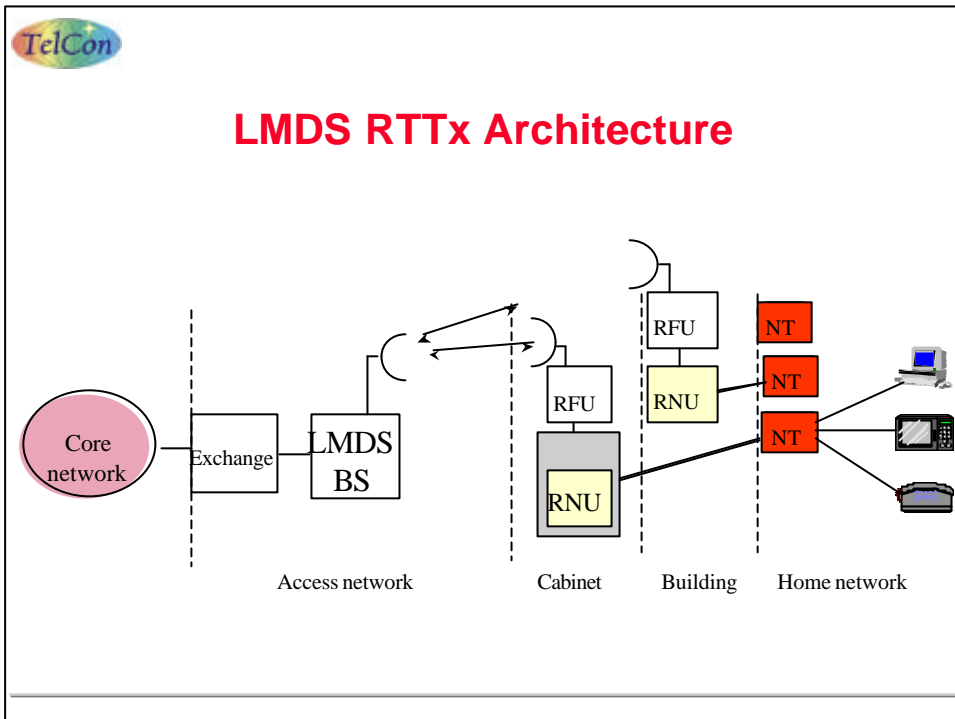Full Service Access Network
Development, trials

MMDS Systems

- **MMDS (Microwave Multipoint Distribution Services) systems were developed to deliver video services:**
  - ‣ **Pay-TV and/or pay-per-view services in rural areas**
  - ‣ **Pay-TV and/or pay-per-view services in cities where cable TV is not present or competitionis to be encouraged**

- **US MMDS operators deliver Internet access services with PSTN return channel**

LMDS Systems

- Local Multipoint Distribution System is a wideband radio technology used to deliver voice, data, Internet access and video services at carrier frequencies equal or higher than 25 GHz
- In USA LMDS Systems have been assigned a 1,3 MHz bandwidth

LMDS RTTx Architecture

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Core network — Exchange — LMDS BS

RFU, RNU, NT

Access network Cabinet Building Home network

Wireless LANs

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Wired LAN

Fixed Network

Access Point

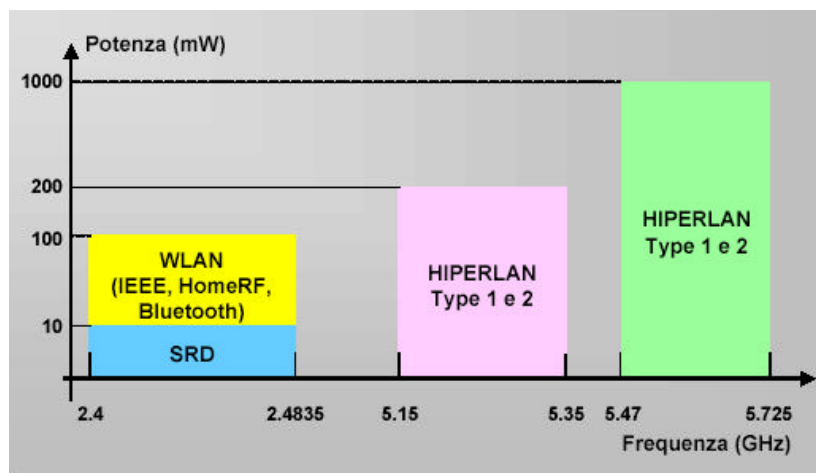Wireless station

Wireless LAN

WLAN components

- **Wireless station**
  - ‣ is usually a PC equipped with a wireless network interface card (NIC)

- **Access Point (AC)**
  - ‣ aggregates access for multiple wireless stations onto the wired network

Reserved frequencies in Europe

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HyperLAN/1: Main Issues

- **5 GHz technology**
- **ETSI Standard for *ad hoc* networking of portable devices**
- **CSMA/CA**
- **No QoS control or guarantee over wireless link**
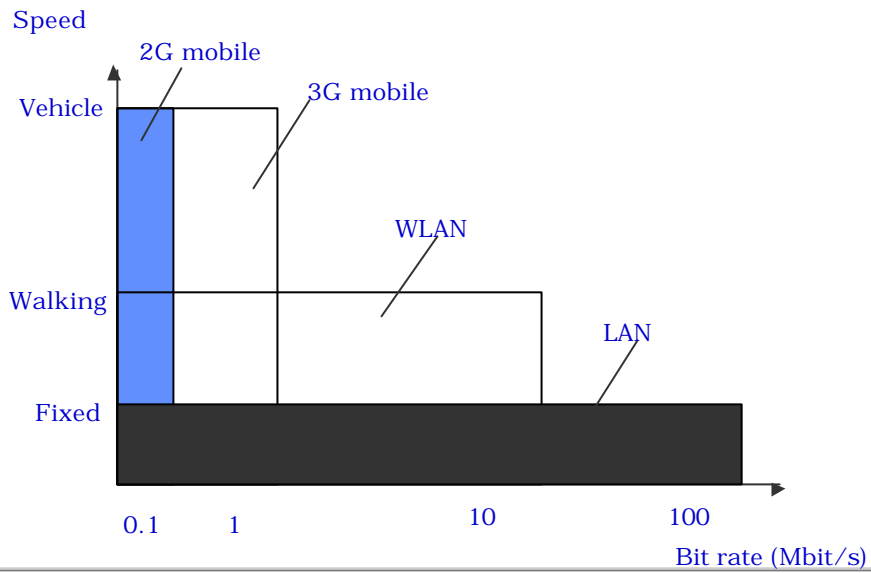- **Best effort data delivery**

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HIPERLAN/2

- **5 GHz technology**
- **High connection rates in hot spot areas**
- **Flexible platform to deliver business and multimedia residential applications with bit rate up to 54 Mbit/s**
- **Two basic operating modes**
  - **Centralized Mode (CM): used in cellular network topology with each radio transceiver controlled by a single access point (AP)**
  - **Direct Mode (DM): used in *ad hoc* network topology in private residential areas with a single radio cell covering the whole area**

LAN, WLAN and mobile systems

Speed axis with levels: Vehicle, Walking, Fixed

2G mobile, 3G mobile, WLAN, LAN

Bit rate (Mbit/s): 0.1, 1, 10, 100

PLC Networks

Power Line Communication

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Key regolatory issues

Vendors must comply with RF generation regulations

- ‣ PLC source of RF signals
- ‣ Normally rules limit non licensed RF emissions (PLC operate between 1,7 and 88 MHz)
- ‣ Devices are required to provide maximum reach using minimum power

PLC encourages competition

- ‣ PLC provide ISP with an alternative technology for service delivery
- ‣ PLC provide open access to any ISP; any ISP can use the network
- ‣ Technical limitation: only one ISP can use the Medium Voltage network

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Two Classes of Systems

Narrow band (up tp 500 kHz)

- Mainly used for building automations

- Subject to regulations
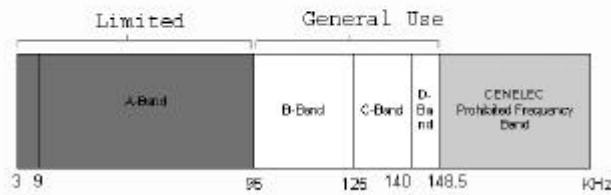
Wide band (1 MHz – 30 MHz)

- Mainly used in LANs

- Not subject to regulations, even if some frequencies are internationally used for radio broadcasting

Narrow band PLC Spectrum Allocation

(a) FCC Frequency Band Allocation for North America

(b) CENELEC Frequency Band Allocation for Europe

Main Standards

	Standard	Technology	Vendor
Narrow band 0-500 kHz	X-10	X-10	X-10
	CEBus	PL-I, CEWay	Domosys
		SSC P300	Intellon
	Lonworks	Neuron Chip	Echelon
Wide band 1-100 MHz	Powerbus	PowerBus	Domosys
	Powerstream	Powerstream	Adaptive Networks
	Homeplug Alliance	Piranha Chipset	Cogency
		Powerpacket	Intellon