Fixed Network Access

Core is the trunk of the network, the main part that is least likely to change

Metro is the main branches from the core, here customers might start being served for example an ISP

Access is the part of the network which changes that most, this is the individual customers coming onto and going off the network

Infrastructural changes to the network happen from the core outwards.

Aggregation

At the access layer it could be ~ 1 fibre connection per user

The users get aggregated in the metro connection

Finally at the cire level you could have 1M - 100M+ connections per fibre

But the Aggregation times access capacity is greater than the actual capacity because only a few users are using the link at any one time.

Statistical multiplexing is used to figure out how much capacity should be available on a given link to make sure that users have access most of the time.

Issues in the access layer

- Cost per connection is quite high when compared to the metro and core layers

Must try to reduce the distance of copper cabling to reduce attenuation

FTTC

Replacing the copper from the central office to a cabinet closer to the end users

The distance of copper is now on average ~ 500m

Attenuation is dealt with but there is a high SNR ration reducing the effectiveness.

FTTC uses a twiested copper pair in some part of the

The copper is a twisted pair and VDSL/VDSL2 are used

VDSL/VDSL2

Down 52Mbps Up 16Mpds for VDSL

VDSL2 uses higher frequencies (up to 100 30MHz) in order to achieve a symmetric 100Mbps

Vectoring

Significant portion of noise in line is due to radiation from adjacent twisted copper pairs

vectoring is a way of removing cross-talk at the cabinet to counteract the noise the line is expected to receive on its journey

G.fast

G.fast uses a much larger bandwidth, 106MHz. Overlaps with Radio, VDSL etc.

Duplex in the time domain

distances of up to 500m

Fibre to the Distribution point (FTTDp)

One step further than FTTC, replacing the copper all the way to the distribution point

Average distance ~50-100m

Also referred to as FTTB (think the fibre reaching the office and copper doing to rest)

FTTDp uses G.fast

XG.fast

Still being researched

Speeds up to 10Gbps

- It uses bandwidth up to 500MHz
- Bonding: use of two copper pairs per users (where available)
- Phantom mode: create a third virtual pair of two physical copper pairs
- Advanced cross-talk cancellation
- Full-Duplex transmission (FDX): use same bandwidth both DS and US with echo cancellation

Uses two twisted copper pairs and a third virtual pair. The virtual pair is just treating the original two pairs as another twisted copper pair

FTTH

Fibre all the way to the house

Technology

- Point-to-Point
- Passive Optical Networks (PON)

Point to point

- Independent fibres
- User with potential whole fibre bandwidth

But

- Very expensive in both deployment and local exchange
- User won't benefit from the whole bandwidth

PONs

The idea is to share the optical fibre into a tree structure using passive optical splitters

TDM-PON

Stands for Time Division Multiplexing PON

Downstream the OLT broadcasts data to every ONU, and each ONU filters out the data destined to it

In the upstream direction a MAC is implemented to avoid collision of signals from different ONUs

The access to the upstream channel is TDMA

The OLT receiver operates in "burst-mode", i.e. it receives short burst of data. A burst-mode receiver is much more complex and expensive than a continuous-mode one

The Downstream and upstream frames is scrambled to as to avoid any synchronization issues (a sequence of too many ones or zeros causing de-synchronization)

de scrambling occurs at the receiver

Downstream is a continuous stream of data

Upstream is a burst structure. The OLT receives bursts of data. More expensive and complicated

DBA

DBA is the process by which the OLT decides how to assign upstream transmission opportunities (e.g., bandwidth) to the ONUs

Works by either status reporting or traffic monitoring

Status reporting: The ONU tells the OLT how much bandwidth it requires

Traffic reporting: The OLt decides based off observed traffic patterns

Ranging

The ONUs are not equidistant from the OLT and this needs to be accounted for. Packets could overlap otherwise

ONU Registration

1. The OLT sends a halt msg to all ONUs to stop upstream transmission
2. OLT request serial number to unregistered ONU(s)
3. After receiving the request, an unregistered ONU transmits the serial number after waiting for a random time (up to 48 μs)
4. The OLT registers the ONU assigning it an ONU-ID value

A ranging window sets the limit on the distance from an OLT to an ONU

Round Trip Delay

1. OLT sends a halt msg to all ONUs to stop upstream transmission
2. OLT sends a Ranging request to a specific ONU (using ONU-ID)
3. The ONU with that ONU-ID sends back a Ranging message to OLT
4. OLT calculates the RTD for that ONU and notifies the ONU of its Equalization Delay(=Teqd-RTD), where Teqd is max RTD (e.g., 200μs)
5. The ONU stores the Equalization delay and uses it for all upstream transmissions

A Split ratio is the number of ONUs that can be served by an OLT

The Higher the split ratio the

- Better the cost benefit
- Less capacity per user
- More optical loss

Security Issues

ONUs physically broadcast and filter messages meaning that a malicious ONU could eavesdrop on messages not meant for it.

Cryptography could fix this issue

Not an issue on the upstream

WDM-PON

Each user is given a wavelength channel and a WDM splitter separates the wavelengths in their own fibre at the cabinet

Logically a point-to-point solution

The wavelength is fixed so there is little to no room for arbitrary wavelength allocation

TWDM-PON

Same as TDM-PON but now the one fibre has multiple wavelengths over it.

ONUs have tuneable lasers, meaning the ONU can tune their laser and filtering to select different OLTs

- If an OLT is congested the ONU can choose a different OLT
- A ONU could have a logical PtP connection to an OLT for the time taken to complete a service

Passive splitters and tunable end point is the most flexible solution as it can offer very different capacity, on demand, to different type of users

DOCSIS

The faster (on average) provider in Ireland right now is Virgin Media, who provide a copper service...

They achieve this by using coaxial copper cables, previously left around from the days of cabled TV (No infrastructure setup cost)

DOCSIS: Data Over Cable Service Interface Specification

Basically Fibre runs some of the route before it reaches an optical node where the old cable network kicks in. New protocols are being used over this network to achieve faster speeds DOCSIS 3.1 could theoretically reach 10Gb

Socio-Economic issues

EU goal (2020) of 30-100Mbps in every household and 100-1000Mbps in 50% of households

NBP

- Government subsidises the operator but network must be shared (foster competition)

Regulators can force the most significant player in the market to build the infrastructure and then also to share that infrastructure at a price determined by the regulator

Access Network Sharing

- Copper Access
  - LLU
  - SLU
  - Bitstream
  - VULA
  - NGA
- Fibre Access

– LLU

Local Loop Unbundling

Local loop is the transmission medium from the central office to the end users

LLU gives new OLOs access the previous national operators network (incumbent operator)

The OLO is physically connecting its end user to its own equipment in the central office

Thi equipment either terminates there at the office OR is multiplexed to the OLOs core network

Sub Loop Unbundling

Thinking along the lines of the shared copper running from the cabinet to the end user (sub-loop)

The OLO would terminate the twister copper pair of an end user at its cabinet

This creates issues in vectoring. Efficient vectoring can not be achieved anymore as the OLOs are terminating the cable elsewhere

Bitstream access

involves the creation of virtual circuits so that an OLO can offer broadband to an end user through a virtual circuit

OLO has no physical infrastructure

- Reduced capital cost
- Increased competition

BitStream doesn't allow operators to fully control their service

OLOs can not differentiate their service, all users receive the same bandwidth

VULA

With VULA OLOs can differentiate their service by

- Putting the interconnection at the first aggregation point
- Having uncontended access between user and interconnection point
- Being able to decide quality of service parameters
- Being in control of the Customer Premises Equipment (CPE)

Requires more investment from the OLO

Next Generation Access

It provides a way for OLOs to avoid the need to interconnect at every Local Exchange, while offering better service than legacy bitstream

Improvements

- Higher bit rates and FTTH technology
- IPTV
- Multicast
- Layer2 access
- Traffic QoS classification
- Ability for the user to subscribe to multiple OLOs

PON unbundling

All you need to know is that Power-split is the way to go for these reasons

- OLOs can operate at specific wavelengths were end users can subscribe by tuning
- Capacity assignment is quite arbitrary, as OLOs can decrease the number of users per PON dynamically to give more capacity
- OLOs can assign more than one wavelength to a user, if the user has ONUs with more transceivers
- Lowest cost

With the wavelength approach each user must have an individual port with which to terminate and there is very little flexibility

Acronyms

- OEO: Optical-Electronic-Optical
- FTTC: Fibre To The Cabinet
- FTTH: Fibre To The Home
- FTTDp: Fibre To The Distribution point
- FTTB: Fibre To The Building
- PON: Passive Optical Network
- CAPEX: Cost Per Capital Expenditure
- OPEX: Operational Expenditure
- OLT: Optical Line Termination
- ONU: Optical Network Unit
- TDMA: Time Division Multiple Access
- DBA: Dynamic Bandwidth assignment
- DOCSIS: Data Over Cable Service Interface Specification
- NBP: National Broadband Plan
- LLU: Local Loop Unbundling
- SLU: Sub Loop Unbundling
- VULA: Virtual unbundling Line Access

- NGA: Bitstream Next eneration Access
- OLO: Other Licensed Operators