FTTH-THEORY
FTTH Theory

To put it simply, FTTH (Fiber To The Home) is about getting fiber out to each individual household. Two basic variants exist, PON (Passive Optical Network) and AON (Active Optical Network).

**PON**

A Passive Optical Network begins with one single fiber, that is distributed to 16, 32 or 64 customers. It is called a passive network, as the actual splitting up is done by a device called a passive splitter (one which needs no power).

**Figure 1**

![Passive Optical Network Diagram]

**AON/P2P**

With regard to an Active Optical Network, there is a fiber connection to every customer. For example, if you have 32 customers, you will have to lay out 32 fiber connections. An AON is also called a P2P network (Point-to-Point network).

**Figure 2**

![Active Optical Network Diagram]
Regarding the PON access house, the biggest advantage is the somewhat smaller amount of fiber and electronics – compared to an AON access house. Fiber and electronics take up less space, and the power consumption is lower. An additional advantage is, that the installations are easier to manage.

On the other hand, customers will have to share the bandwidth. Special media converters must be placed close to the houses, separating the customers from one another. The biggest problems, however, concern measuring and trouble-shooting. Measuring and trouble-shooting is troublesome, and you will need an Optical Time-Domain Reflectometer (OTDR), an instrument that requires skill as well as experience to use.

Quite many PON standards exist, and new ones turn up all the time to compensate for the ongoing bandwidth development.

**APON** (ATM PON)
This was the original PON standard, based on ATM cells, small packets which were usable for everything from telephony to video. There was not much bandwidth available for the customers.

**Figure 3**

A splitter – PON installations are build with splitters. This is an example of a splitter with two ports.

**BPON** (Broadband PON)
This standard was designated as Broadband PON, a solution with more available bandwidth. But the customers were still in the slow lane of the internet highway. The standard was not widespread.
**EPON** (Ethernet PON)
The first two PON standards had the disadvantage that, close to the customer, the data had to be converted from ATM cells to Ethernet, which is commonly used. As a consequence of this, much data power was needed and furthermore it was time consuming. That is why EPON was developed. But still, the amount of bandwidth was not sufficient.

**GPON** (Gigabit PON)
The latest addition is Gigabit PON, which is now used as the standard PON solution. As for security, the problems have now been solved. All users of PON systems get all packages, and that is why safety was a problem. GPON uses ATM cells too, and therefore a conversion to Ethernet is necessary.

**GEPON** (Gigabit Ethernet PON)
Solutions, using ethernet frames have now turned up, making the electronics cheaper, as the technology is well known and widespread. Even though not that many choose this solution, it absolutely has its benefits.

**Figure 4**

**GE-PON for FTTH**

1550nm: CATV Downstream
1490nm: Data Downstream
1310nm: Data Upstream

**Splitter requirements**
- High Uniformity
- Low insertions loss
- Long term reliability
- Low Cost
**10GPN** (10 Gigabit PON)
This solution will bring more bandwidth to everybody, but still not unlimited. Then again, you will have to consider both the needs of tomorrow and the original investment. 10GPN solutions in practice is yet to be seen.

**WDM-PON** (Wavelength Division Multiplexing PON)
All the previous solutions are based on the use of one fiber only and the splitting of the signal to a number of users. If it is a 1:32 system, every user will get only one-thirty-second part of the bandwidth and one-thirty-second part of the power. The power is only of importance with regard to the transmitting distance and most systems have a range of 20 km. When using WDM-PON, the splitter is replaced for an AWG (Arrayed-Waveguide-Grating), a wavelength demultiplexer.

A wavelength is now allocated to every customer. The result is practically full bandwidth for all. You may say, that you make a point-to-multipoint solution, but use it as a point-to-point solution, which is a great idea. The component that makes this possible is the AWG, which is manufactured by Ignis Photoniks, one of the biggest manufacturers in the world.

Ignis Photoniks, a Danish company, is predicted to have a promising future.

**Figure 5**

![A WDM-PON System](image)

It is a disadvantage, however, that all transmitters must be carefully tuned to a specific wavelength. Consequently, the costs are going up, but despite the rising costs, this may very well be the only way to solve the problems concerning the need for more bandwidth in PON systems.
Let us try to compare the two technologies, but bear in mind, that a lot of religion is involved.

<table>
<thead>
<tr>
<th></th>
<th>P2P</th>
<th>PON</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bandwidth</strong></td>
<td>No limitations</td>
<td>Many limitations</td>
</tr>
<tr>
<td><strong>Prospective possibilities</strong></td>
<td>No limitations</td>
<td>Still limitations concerning WDM-PON</td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td>High consumption – unnoticed by many</td>
<td>Less consumption than P2P</td>
</tr>
<tr>
<td><strong>Fiber consumption</strong></td>
<td>One fiber to everybody</td>
<td>The first length of the fiber is common – no cost savings, though, as fiber is so cheap</td>
</tr>
<tr>
<td><strong>Duct consumption</strong></td>
<td>Ducts to everybody</td>
<td>Ducts to everybody. No cost savings, even though the first ducts are somewhat smaller</td>
</tr>
<tr>
<td><strong>Testing</strong></td>
<td>Testing is simple</td>
<td>Testing is very complicated. You will have to place connectors in street cabinets, which may not be the best solution</td>
</tr>
<tr>
<td><strong>Connector consumption</strong></td>
<td>One in the beginning – and one at the end of a fiber system</td>
<td>One shared connector in the beginning, one set on the way (in a street cabinet), and one at the customer. Thus the number of connectors is appr. the same</td>
</tr>
<tr>
<td><strong>Patch cables</strong></td>
<td>One patch cable each</td>
<td>Patch cables to 16 or 32 customers. Cost saving, considering error possibilities, cleaning etc.</td>
</tr>
<tr>
<td><strong>Trouble-shooting</strong></td>
<td>Very easy</td>
<td>Very difficult</td>
</tr>
<tr>
<td><strong>In case of errors in the access network</strong></td>
<td>Affects one customer</td>
<td>Affects 16 or 32 customers</td>
</tr>
<tr>
<td><strong>Demands on cleanliness</strong></td>
<td>The same in both systems</td>
<td>The same in both systems</td>
</tr>
<tr>
<td><strong>Space in access houses</strong></td>
<td>A big need for space</td>
<td>The need for space is somewhat less</td>
</tr>
<tr>
<td><strong>Lay out of access houses</strong></td>
<td>Becomes easily chaotic. Requires tidiness from the beginning</td>
<td>Does not contain so much equipment, therefore a much simpler lay out. Yet, errors disturb more customers at the same time</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>Working with low powers</td>
<td>Working with high powers. Be aware of potential safety problems</td>
</tr>
<tr>
<td><strong>Spreading</strong></td>
<td>Widely spread in Scandinavia</td>
<td>Widely spread around the world</td>
</tr>
<tr>
<td><strong>Geographical Coverage</strong></td>
<td>Suitable for small areas (like in Denmark)</td>
<td>Suitable for longer distances</td>
</tr>
<tr>
<td><strong>The price</strong></td>
<td>Has not yet been agreed upon</td>
<td>Has not yet been agreed upon</td>
</tr>
</tbody>
</table>
The figure shows P2P systems in comparison with PON systems, with regard to differences in bandwidth. These days, EU (European Union) is working on new legislation, intending to ban PON in FTTH installations in EU. The reason for this initiative is, that it is difficult to make an open system, with various service suppliers.

Building a complete FTTH installation

On the next pages I will show examples of how a complete FTTH installation can be made. The pictures are from around Europe and do not show a specific system, but show lots of the components which are being used. But is a typical setup for Denmark.

Figure 6
Driving across the Danish island of Funen, you may notice fiber wound around the overhead ground wire and if you are driving on the motorway, heading for Esbjerg, a Danish seaport by the North Sea, you may see fiber cables wound around the three overhead phase wires. Not far from Esbjerg, in the North Sea, is the small Island of Romo located. A dam connects Romo with the Danish mainland. The difference between the high and low tide is quite big here, so you have to be very careful, when planning to visit Romo, stay on the top of the dam, and you have no problems. Driving the car over the dam on your way to Romo you may see an OPFW along the road. The OPFW looks like any other overhead high tension wire, but on the way, you will notice a splice enclosure. It is not an exaggeration to say, that the connection to Romo is the most vandal resistant connection in Denmark. The voltage around the fiber is 60Kv. The following photos show how to make a full FTTH installation. This is only an example of how it can be made, as there are many solutions. The photos have been taken in Denmark, Sweden, Norway, Iceland and in Belgium. They reflect a way to build up an installation.

First of all we must have transmitted the tv, internet and telephony signals to the town. For that purpose we will use the high tension distribution network.
When we have come to town, the fiber must be distributed. For that purpose a number of access houses will be set up. From the access houses, data signals will be spread to every resident in the town. The photos below show examples of different kinds of access houses.

The purpose of the access house is to distribute the optical signal, and thus deliver the content to the many users.
The purpose of the access house (also known as a POP) is to get the content to the area, the fiber optic signal is converted into an electrical signal, and put into the router, the router is good for transmitting over long distances. From the router the signal is transmitted (typically in fiber) to the switch. This component distributes the signals out to many customers. Lots of access houses in Denmark distribute signals to thousands of customers.

**Figure 12**

A large installation with Tyco components

**Figure 13**

A patch cassette. The fiber is patched to the active equipment.
Figure 14
An example of how to strain relieve fiber from tyco

Figure 15
A splice cassette from tyco
Normally, cables leave the access houses through 10 mm ducts enclosed by 40 or 110 mm ducts.

Figure 16

![Cables leaving the access house](image)

Figure 17 shows some micro cables (containing 72 fibers) on their way into a 10 mm ducts. Enclosed in a 40 mm duct, the ducts then continue to a manhole.
Figure 18
The first division is made in a manhole.

Figure 19
The fiber is divided again, in a half-buried street cabinet. From here, fiber is spliced to every individual customer. The spliced fibers leave the cabinet enclosed in a 40 mm pipe.

Figure 20
The picture shows the 40 mm duct and a fixed enclosure. Two 10 mm ducts have been separated and from here they will be taken to the customer.
Another way of connecting customers (see figure 20). Here the connection is made by means of a taped enclosure (Erikson). The enclosure consists of self vulcanizing tape. If made correctly, the enclosure is 100 percent waterproof.

Now the duct must be taken into the house. Some companies chose to mount a terminal box, which makes it possible to measure the installation from the outside, so you do not have to trouble the customer inside the house. Others chose to take the fiber below ground level, to hide the installations.

An example of how to end an installation close to the customer. The media converter may be placed in different places – in a cabinet, a technical room or in a utility room. Some problems concerning the location may occur, as you have to consider a duct from the street outside. You also have remember that from here you need cables for tv, telephone and computers.

This is a set up box, being able to convert an IPTV signal into a usable tv signal.
The Technical Part
There are several possibilities, when making the system.

Three fiber solution
In the old days 3 fibers were used. Typically, multimode for the Internet connection. From the Internet to the customer 850nm (one fiber, download), and from the customer to the internet 850nm (one fiber, upload). For the analog TV, single mode fiber at 1550nm. After the drop in price of single mode components, the signals for Internet are transmitted at 1310nm. The telephone signal is transmitted as IP telephony on the Internet fibers, and thus needs no extra fiber.

Figure 25

Two fiber solution
The next generation uses only two fibers. Only one for Internet connection. 1550nm transmitting towards the customer, and 1310nm transmitted back from the customer. There is no problem having the two signals at different wavelengths in the same fiber. It’s a bit like the different colours coming from the TV, and not getting mixed with each other. The TV is still transmitted at 1550nm.
One fiber solution
The latest development is a single fiber solution. Analog TV is transmitted towards the customer at 1550nm, Internet to the customer at 1490nm, and the return Internet from the customer at 1310nm.

The best solution
IP to the customer at 1550nm, and 1310nm return from the customer. Internet IP telephony, and IPTV are all transmitted as IP signals.

By 2011 og 2012 it is expected, that the whole of Denmark will be connected to the Internet by fiber.