Copper vs. Fibre: The Dilemma of the Access Network

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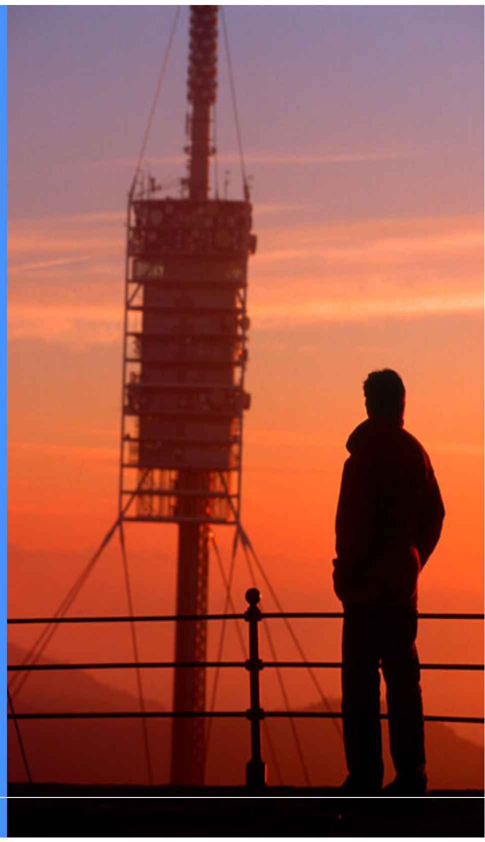
by Francisco J. Hens



Testing the World's Networks

TrendCommunications

Copper pairs are still the main transmission media in the local loop. One of the main advantages of copper is that today, more than one hundred years after it was first used, it is still available for almost any potential customer in any developed country. And copper cables are still being rolled out today.

Digital Subscriber Loop (DSL) technologies were designed for digital transmission over the existing telephone copper pairs. This combined cost-effectiveness and acceptable performance. However, copper is now reaching its limits, and new access technologies based on optical fibre are arising.

While nobody doubts that fibre will be an important part of the local loop, or the 'first mile', the optimum combination of fibre and copper has not yet been found. This paper gives an overview of the technologies that are currently available for the first mile, discussing their advantages and disadvantages.

THE LIMITS OF COPPER

Telecommunications companies worldwide are still transmitting data over copper wires, using different variations of DSL, and there are still more than 160 million subscribers around the world today.

The problem with DSL is that due to *attenuation* and *crosstalk*, this technology cannot achieve long range and high speed at the same time. While it is possible to deliver a few megabits per second to customers who are miles away from the local exchange, delivering 100 Mbit/s is limited to a couple of hundred metres.

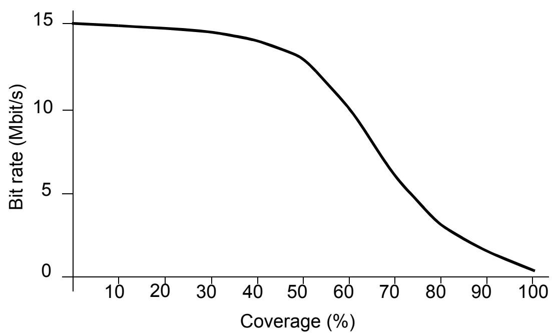


Figure 1 The limits of copper in a European country

DSL was developed when an important change occurred in the telecommunications business: many governments deregulated their markets to make them more competitive. State-owned telecom companies (*Incumbent Local Exchange Carriers* or ILECs) were privatised, and new network operators (*Competitive Local Exchange Carriers* or CLECs) entered the market and started to compete with them.

The unbundling of the local loop made it possible for the new operators to use the Incumbent Local Exchange Carriers' access facilities. National authorities forced ILECs to open their networks to competition and lease their copper pairs. For example in Europe, this is guaranteed by both European and local legislation in each of the member states of the European Union.

Some of the players in the telecommunications market see these regulations as a barrier for real technological innovations. This is why some countries have changed their unbundling regulations. For example in the United States, the Federal Communications Commission (FCC) has limited the number and types of elements that must be unbundled on a mandatory basis. It is expected that more countries will make similar changes to their unbundling regulations in the near future.

Another problem with DSL is how to maintain *spectrum compatibility*. A signal that is being transmitted over a copper pair may potentially damage the signals travelling in the neighbouring pairs. The probability of damage depends on the shape of the frequency spectrum of both the disturbing signal and the victim signal.

After unbundling, the number of signals in the local loop has increased. Due to *crosstalk*, spectrum compatibility is an important issue, because two signals that are spectrally incompatible cannot co-exist without damaging each other. So, operators may end up damaging each other's service.

This situation has made it necessary to study the compatibility between copper access technologies, and develop new regulations on how to manage the copper spectrum. The result is that local loop operators cannot freely choose the signals they want to use to deliver their services to subscribers.

OPTICAL FIBRE SOLUTIONS

Unlike copper, optical fibre has an almost unlimited transmission bandwidth. In fact, the bandwidth limitations of the existing optical transmission systems do not depend on the transmission medium itself, but more on the transmitter or the receiver. Furthermore, optical fibre has low attenuation and distortion, and it is not sensitive to radio interferences, nor does it cause interference in remote systems.

The problem with fibre is that it is not widely available. Here, cable operators have an advantage over telcos, because they started the deployment of their *Hybrid Fibre Coaxial* (HFC) networks earlier. As these networks can offer TV together with voice and data services, telcos have seen their business drop, and this is pushing them to invest more money to make fibre available to their customers.

The technologies available for the local loop are active Ethernet and *Passive Optical Networks*:

- *Active Ethernet* is made up of point-to-point fibre links between the local exchange and the customer premises. This involves deploying large quantities of optical fibre in the local loop, but it also ensures maximum bandwidth, thanks to the use of dedicated fibre links. Installing an Ethernet switch close to the subscriber will reduce the amount of fibre to deploy, because the switch will act as a concentrator. It is enough to install a single optical link, or maybe two, between the switch and the local exchange.
- *Passive Optical Networks* (PONs) could be used to avoid installing active elements such as Ethernet concentrators in the local loop. Active elements are replaced by simple passive optical splitters, resulting in a point-to-multipoint topology. A PON can be used to offer gigabit-level bandwidth to subscribers. This technology is considered more cost-effective than active Ethernet, and at the same time it is well suited for broadcast applications such as TV and data. The main drawback of this technology is the need for complex shared-media access mechanisms to avoid collisions between the traffic of different subscribers.

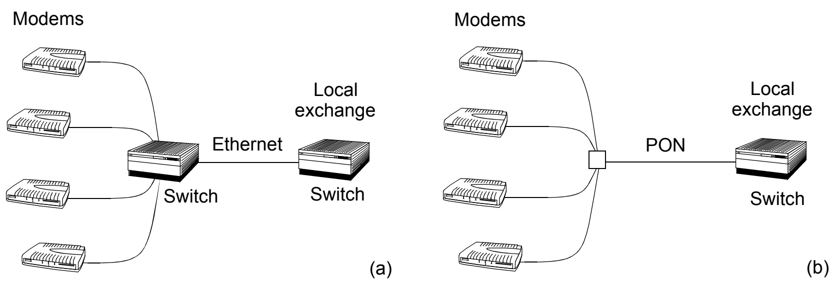


Figure 2 Optical solutions for the access network: (a) Active Ethernet (b) PON

COPPER SOLUTIONS

Copper transmission is evolving to support higher rates. Basically, there are two different techniques to achieve this:

- *Deep fibre roll-outs.* As copper transmission cannot achieve high bit rates and long reach simultaneously, some of the new DSL interfaces are specialised in higher bit rates, even if these interfaces have a reduced range. For these roll-outs, all network equipment must be installed close to the subscriber. Any external equipment is linked to the local exchange by means of optical fibre with active Ethernet or PON.
- *Copper pair bonding.* Bonding makes it possible to provide a single high-speed channel by combining the capacity of two or more pairs by using inverse multiplexing techniques. Of course, this technique can only be successful if spare pairs are available.

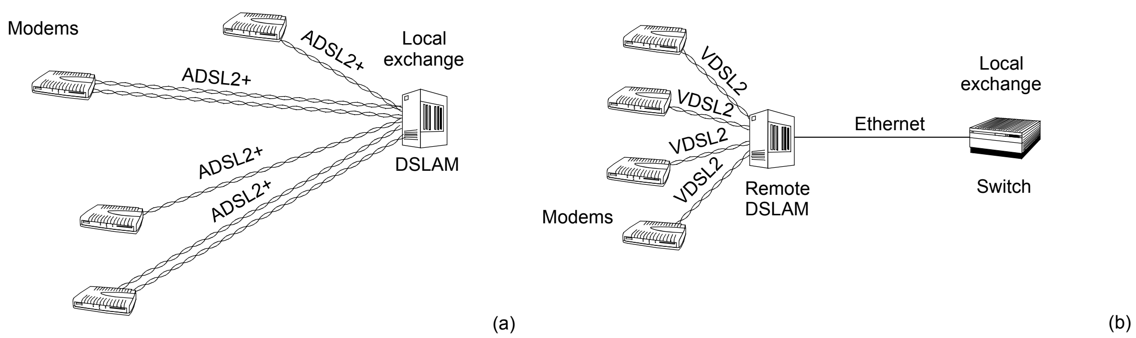


Figure 3 Copper solutions for the access network: (a) ADSL2+ bonding (b) Short-range VDSL2

The most important copper technology for deep fibre roll-outs is *Very-high bit-rate DSL* (VDSL2). The second generation of VDSL2, specified in ITU-T Recommendation G.993.2, is designed for increased bit rate over short and medium length loops. VDSL2 aims to achieve the following basic goals:

- Offer a 100 Mbit/s symmetric service over loops shorter than 300 m.
- Deliver at least 25 Mbit/s streams in loops shorter than 1000 m.

Other options to consider include the *Ethernet in the First Mile* (EFM) copper interface defined in IEEE 802.3ah. Actually, copper EFM interfaces are also based on DSL, for spectrum compatibility reasons. There are two EFM interfaces available:

- The *2BASE-TL interface*, based on SHDSL, is best suited for long-haul applications. It provides a symmetric, full-duplex 2-Mbit/s Ethernet transmission channel with a nominal reach of 2.7 km.

- The *10PASS-TS interface* is intended for short-haul applications. It offers a symmetric, full-duplex 10-Mbit/s transmission channel with a nominal reach of 750 m. This interface is based on VDSL (ANSI T1.424) and optimised for deep fibre roll-outs.

  EFM and DSL can be bonded to offer increased bandwidth for customers without installing optical fibre.

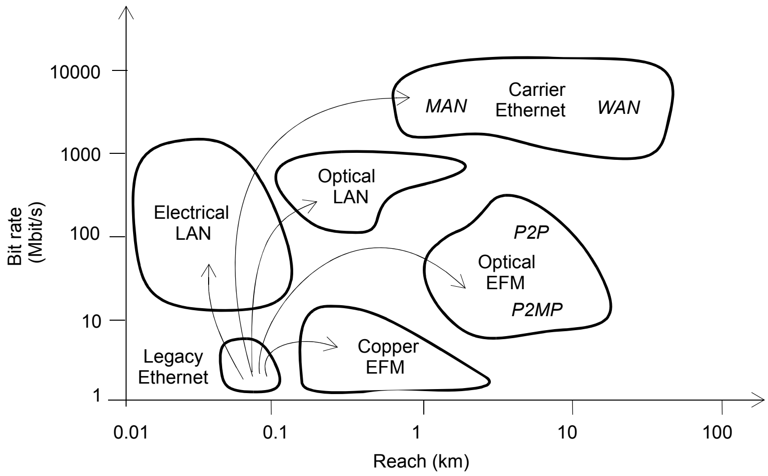


Figure 4 Ethernet applications and EFM

FTTx Architectures

Many operators have already started to deploy new access networks based on optical fibre, and many others are planning to do the same in the near future. Only a few of these deployments deliver *Fibre To The Home* (FTTH)[1].

Some companies, like Verizon (US), Free (France) or NTT (Japan), prefer FTTH with a dedicated wavelength for video. Others prefer fibre-to-the-neighbourhood. AT&T (US), Qwest (US) Deutsche Telekom (Germany) and FT (France) are deploying VDSL2, and FTTH in some cases. Bell South (US), BT(UK), KPN (the Netherlands), Telefónica (Spain and Latin America) are using ADSL2+ and migrating to VDSL2.

In some countries, like Japan, the FTTH market is growing rapidly, even though there is no 'killer application'. The reason for this is

1. *Depending on where the optical link is terminated, we can talk about Fibre To The Building (FTTB), Fibre To The Cabinet (FTTCab), Fibre To The Node (FTTN), and so on.*

competition between providers. However, a basic requirement for sustained and massive FTTH deployment *is* to develop applications that can only be delivered using FTTH. Currently, the best candidate is *High-Definition TV* (HDTV). FTTH is the only technology that can deliver several MPEG-4-encoded HDTV channels to a large number of residential subscribers.

Table 1 Standard and high-definition bandwidth after compression

	Lines	*Pixels*	*Broadcast*	*MPEG-2*	*MPEG-4*	*WM9*
SDTV	480	704 x 480	6 Mbit/s	3.5 Mbit/s	2-3.2 Mbit/s	2-3.2 Mbit/s
HDTV	1080	1920 x 1080	19.2 Mbit/s	15 Mbit/s	7.5-13 Mbit/s	7.5-13 Mbit/s

HDTV is still at an early stage, and wide subscriber acceptance will probably take some years. For almost all the potential customers of the current applications, fibre-to-the-neighbourhood is enough. This is the reason why many important operators prefer this type of access architectures. These operators will probably need a smaller initial investment, but there are some important issues they will have to take into account; for example:

- All external equipment must be placed correctly, far from electromagnetic interference or access by unauthorized staff.
- DSLAMs must be prepared for difficult weather conditions. For example, if the typical temperature in the local exchange ranges from -5 ºC to +40 ºC, the remote DSLAM must be prepared for temperatures that range from -40 ºC to +65 ºC.
- Suitable electrical power sources must be found. Sometimes, remote feeding can be used. In FTTB roll-outs, access to local power sources is an alternative. However, extra power sources should be available to minimise service shortcuts.

The main problem with FTTH is that it calls for a big initial investment, but there are some other issues as well that cannot be ignored, for example:

- Optical fibre is more difficult to handle than copper, and specialised staff is needed. Experience shows that the first 100 metres are the most challenging.
- Deploying optical fibre usually involves long administrative procedures that can be a source of significant delays.

TREND MULTIPRO

The Trend Multipro test platform was developed to make installation and troubleshooting tasks in the local loop more productive. One of the main applications of Trend Multipro is fibre-to-the-neighbourhood with triple-play services to residential subscribers. Trend Multipro weighs less than a laptop computer, so technicians can easily carry the tester with them.

Trend Multipro evaluates the technology used in the local loop and makes sure that the service is working as expected. The tester also detects configuration errors or poor performance in the service-provider network by using QoS, authentication and signalling tests.

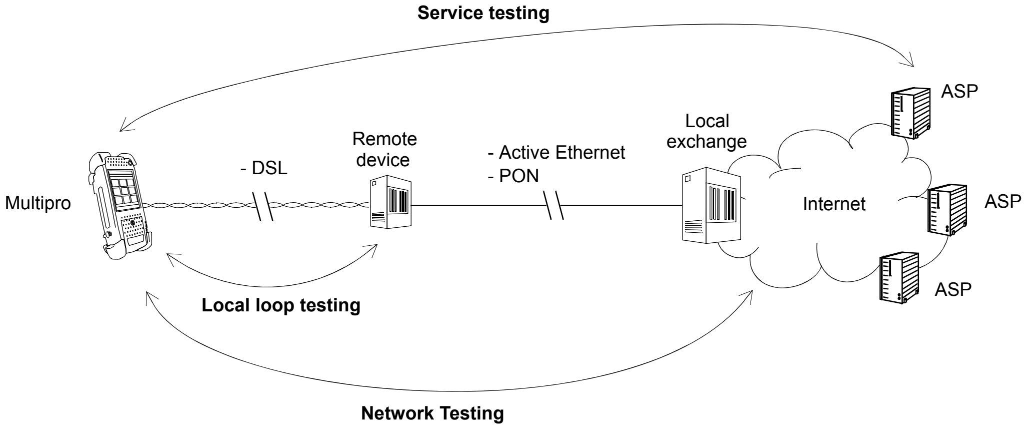


Figure 5 Trend Multipro is a test platform for installing and troubleshooting the local loop in fibre-to-the-neighbourhood roll-outs. The tester can also be used to ensure error-free end-to-end service provisioning.

One of the main features of this tester is its ability to test end-to-end services and display the results the same way as they are experienced by the subscriber. For example, live IPTV video streams can be previewed on the tester's touch screen. The tester can also be used for Internet service testing and VoIP SIP call testing. These tests significantly speed up installation and make installation tasks easier.

SUMMARY

Fibre will play a fundamental role in the future of the access network, but copper cannot be ignored either, as it is more widely available.

Only some of the existing fibre roll-outs for access networks are based on fibre-to-the-home. Many operators prefer to use fibre-to-the-neighbourhood instead, because a 'killer application' for fibre-to-the-home has not yet been found.

Trend Multipro significantly speeds up fibre installation and makes installation tasks easier, ensuring that triple play services for residential customers work as expected.

Trend Communications Ltd.
Whitebrook Park
Lower Cookham Rd.
Maidenhead, Berkshire
SL6 8XY - UK

TrendCommunications

Americas: +1 256 461 0790
China: +86 10 8518 3141
Deutschland: +49 (0)89 32 30 09 30
España: +34 93 300 3313
France: +33 01 69 35 54 70
India: +91 11 25554161
UK: +44 (0) 1628 503529

web: www.trendcomms.com
mail: infoline@trendcomms.com

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