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Perspective in Next-Generation Home Networks: Toward Optical Solutions?

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ABSTRACT

The meaning of broadband connection is in continuous evolution. FTTH and ever-improving ADSL technologies are capable of offering to the final residential user a very-high-performance access network connection to the main door of our homes. At the same time, high-definition and interactive video will require higher and higher bit rates inside the home. Both drivers lead to the requirement for high-quality networking also inside homes, to avoid a somehow ironic, but indeed possible situation in which the home area network becomes the actual bottleneck of the full system. In this article we review the requirements for next-generation HANs and show that this environment may end up taking advantage of optical cabling solutions as an alternative to more traditional copper or pure wireless approaches.

INTRODUCTION

Today, high-speed Internet connection at home is becoming a commodity in most countries. In May 2008 Strategy Analytics forecasted that there would be more than 621 million broadband lines subscriptions worldwide in 2012, based on a figure of 355 million at the end of 2007 showing a cumulative annual growth rate of around 12 percent [1]. In this last decade the connections to the final user have shown a constant increase in performance, so the term *broadband connection* is continuously changing its meaning. In fact, beyond the original asynchronous digital subscriber line (ADSL) technology, the newer versions of the different xDSL technologies today offer several tens of mebabits per second (very-high-rate DSL [VDSL2] is potentially able to deliver more than 100 Mb/s over some hundreds of meters), and fiber to the home (FTTH, or some intermediate version such as FTT-curb) is seen as an enabler of increasingly higher-speed services. Hundreds of megabits per second per user are reasonably reachable in the coming future, backed up by emerging standards such as gigabit passive optical network (GPON, International Telecommunication Union — Telecommunication Standaradization Sector [ITU-T] Recommendation G.984.2). FTTH is indeed today widely deployed in countries like Japan and Korea, while in Europe and the United States several companies are developing detailed commercial plans for mass deployment of FTTH [2]. It is thus possible to envision in the near future a scenario in which a large amount of users will be offered a very-high-performance connection up to the *main door* of their homes.

As of today, new high-data-rate services such as TV programs or video on demand over xDSL are made available to end users and are already a commercial success. New mass storage devices are on the market, such as media renderers and servers, and promise to make the digital experience even more exciting. For instance, as of 2009, HDTV transmission is becoming commercially available in many countries in the 1080p format (1080 horizontal pixels). But much more is to be expected, with new ultra-HDTV format such as 4K (4000 horizontal pixels, with an expected increase in the required bandwidth of a factor of approximately 16). Also, digital mass storage devices gain more success in the home every day. These devices, whose prestandardization is ongoing, for instance, within the Wireless World Research Forum, Digital Living Network Alliance, and Home Gateway Initiative, offer not only demodulation of digital broadcast programs and access to remote services by operators' networks, but also high connectivity to end devices such as TVs, home cinema, or PCs. To enable the use of these devices, the trend is that it shall be possible to use them everywhere at home with high-data-rate connectivity to transfer content either from remote servers or between end devices sparsely distributed everywhere at home. Moreover, end-user devices are fitted with high-speed interfaces to easily transfer all types of multimedia supports. These trends will certainly in the near future make the home area network (HAN) a ultra-high-bandwidth convergence arena where these devices and services will have to interwork at home and in continuity to the operator's network. Regarding its performance, the HAN should have at least the same

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A key role to meet all these specifications will be played by the Home Gateway, i.e., the box that will interface the HAN to the Access Network. This is a key element of the home network, and its architecture is currently being investigated by many groups and by large European projects.

quality as the access network to which it is connected, but likely more, for reasons explained in the following. Regarding its possible architectures, which are currently being studied by several groups and projects, some specific requirements are identified that make it quite different from the rest of the access network [3]:

- It should be easily reconfigurable at the physical level: while the access network, once deployed, is not expected to be reconfigured for tens of years, the HAN cabling should be easily changed and adapted to suit the changing needs of the end user. As a result, the HAN should be very easy to install, possibly by unskilled technicians or even by the final user him/herself (do-it-yourself approach).
- It should have very high data rates. Some HAN scenarios requires the capability of handling bit rates even higher than the feeding access connection, in order to be able to distribute inside the apartment very high quality video services or to connect at very high speed a PC and, say, a home mass storage server.
- Newer applications may also require very low latency. Not only sustained transfer services that demand stable bandwidth are possible, but also highly interactive services that may benefit from ultra-short latency times (e.g., online gaming, online remote storage, applications using thin client terminals, telepresence). As a reference, the latency for VDSL is greater than 16 ms, while for FTTH GPON it is below 200 μs, which should be considered a target value inside the HAN as well.

This article proposes a study of how the network inside the apartment or HAN may be implemented and deployed in the medium to long term, with a specific focus on optical fiber technologies. After defining the HAN-specific requirements, we analyze how they can be met by means of the deployment of an optical backbone at home. Even though it is quite obvious that the last connectivity to the terminal will tend to be wireless, optical technology is a very promising backbone alternative candidate to the *no new wires* approach such as pure power line communication (PLC), HomePNA, or wireless.

Lastly, we discuss the different types of fiber that are available for deployment of a high-speed optical backbone:

- Plastic optical fibers (POF), typically with very large core diameter (up to 1 mm)
- Glass optical fibers (GOF) in their different types:
  –Multimode fiber (MMF), typically graded index with core diameter from 50 to 62.5 μm
  –Single Mode Fiber (SMF) with core diameter from 9 μm to 10 μm

The article is organized as follows. The next section presents the technical requirements for the HAN in terms of bit rates and latencies. Then we address the physical and topological architectures that best suit HAN requirements, while we proceed to present several types of optical cabling and solutions that may meet the HAN requirements. Finally, we draw some conclusions and compare the proposed solutions with other more traditional approaches.

HAN Technical Requirements

In this section we introduce the technical requirements the HAN should meet in terms of data rates and latency, considering both applications available today and a longer-term view which includes high-speed services that will likely find a market in the next decade. First of all, high data rate needs definition. In the near future peak access speed per user on the order of several hundred megabits per second can be envisaged for next-generation GPON FTTH access. Over this access network, ultra-small latency time (less than 1 ms round-trip time) can be offered thanks to simple framing and coding of short packets. This performance has to be equaled by the HAN for low-latency services.

The detailed studies carried out in the framework of the Architectures for Flexible Photonic Home and Access Networks (ALPHA) [3] and Home Gigabit Access (OMEGA) [4] Information and Communications Technology Framework Programme 7 (ICT-FP7) projects have defined six kinds of profiles for the traffic flows that have to be transmitted on the HAN, and the required characteristics are summarized in Table 1. The resulting required bit rates are way above hundreds of megabits per second, and this is particularly true for *intra-home communication*; that is, for all connections internal to the apartment between two end devices using the HAN as a cable connecting them, such as the connection between a video server and an HDTV screen, or for video surveillance. To be future-proof, a very-high-bit-rate link (up to 2 Gb/s) should be deployed, for instance, to feed a display with uncompressed video. Here a jitter constraint less than 100 s is requested.

In designing the next-generation HAN, attention also has to be paid to express coverage issues, not only in terms of geography, but also in terms of (semi-) static or dynamic scenarios:

- Moving from one room to the other, an end device can be seen as either nomadic or mobile, transposing a set of issues with cellular network coverage everywhere at home.
- Intrusive access or eavesdropping is clearly to be considered.
- End devices such as HDTV shall be connected by some means to the HAN.
- End devices from different manufacturers have to interwork either directly or via the HAN.
- When several services run simultaneously, some of them may tolerate transfer disruption or delay whereas others cannot. Quality of service (QoS) is another dimension for consideration to guarantee quality of simultaneous services. The network performances can be individually adapted to the needs of different services by creating virtual LANs and setting different priorities for each network device.

Profile type	Throughput	Delay end-to-end (one way)	Jitter	Packet loss	TCP	Mobility
Web navigation	Variable from a few kilobits per second to 1.5 Mb/s				Variable return flow less than 4% of data	Nomad within home = work in all the rooms of the house but no mobility
VoIP	2 constant flows of a few tens of kilobits per second; 27 kb/s IP	High constraints around 10–100 ms < 150 ms	< 20 ms	$< 10^{-3}$	UDP	Mobility throughout the house
Videophony	2 flows from 128 kb/s up to 10 Mb/s	10–100 ms	< 10 ms	$< 10^{-5}$	None	Mobile or nomad within home (depending on the terminal used)
File downloading (8–20 Gbytes), such as video	Variable high data rate 1 Gb/s to prevent TCP from congestion				Variable return flow for TCP ACK; less than 4% of data	Nomad within home
Video and audio broadcasting	CBR flow with peak data rate used for addition control: 2–50 Mb/s for video and a few kilobits per second for audio	Real-time constraints < 400 ms to sync video and audio	Packet shift < 1 ms	$< 10^{-5}$	CBR or VBR with a low data rate	Nomad within home
Intra-home communication DVI/HDMI	Several hundreds of megabits per second up to 2 Gb/s	< 400 ms	< 1 ms		None	One single room

Table 1. *Expected HAN specifications for different types of digital traffic. Empty cells denote relaxed constraints [4].*

A key role in meeting all these specifications will be played by the *home gateway*, the box that will interface the HAN to the access network. This is a key element of the home network, and its architecture is currently being investigated by many groups and large European projects (e.g., ALPHA and OMEGA).

On top of the digital services above, the deployment of high-speed wireless services is seen as key to the ease of use of the multiservice HAN, indeed wireless terminal connectivity is expected. Wireless services include femtocells (indoor mobile telephone coverage) and high speed wireless technologies [5]. All these services use signals at the radio frequency (RF) level that are analogue in nature, at least in the sense that they cannot be carried directly by digital baseband modulation. Optical cabling solutions offer the possibility for semi-transparent transport of these signals by using radio over fiber (RoF). These analog services will induce a special set of requirements on the HAN, leading to the following additional types of flow:

- Wireless home coverage using RoF (LAN): Some next-generation HAN architectures envision the use of next-generation high-speed wireless technologies. For instance, ultra-wideband (UWB) can be used to cover each individual room with an extremely high-performance link. Clearly, such a scenario imposes on the HAN the same requirements as the radio protocol.
- Femtocells (wireless access): Same requirements as for mobile (Universal Mobile Telecommunications System [UMTS], high-speed downlink packet access [HSDPA], Long Term Evolution [LTE]) distribution [6]. This analog service may be digitized in the gateway and aggregated to the digital flow.
- CATV: Complete analog community antenna TV spectrum distribution (downlink only, no uplink needed). This service is a HAN-only service.

In addition to the applications described so far, sensing and control applications will gain more and more interest in the home scenario. While these applications do not depend on high data rates and low latency times, the reliability of the network will be of utmost importance. Hence, optical fibers, well known for their immunity against electromagnetic interference (EMI), can meet the requirements of these networks, whereas wireless technologies like ZigBee (IEEE 802.15.4) may offer mobility, but eventually will have higher failure rates. Interoperability and convergence of all services and devices is obviously essential, thus requiring universally convergent protocols for the HAN [7]. As FTTH is heading toward Ethernet-based GPON, Ethernet seems to be the most promising standard in the upcoming HAN architectures [8].

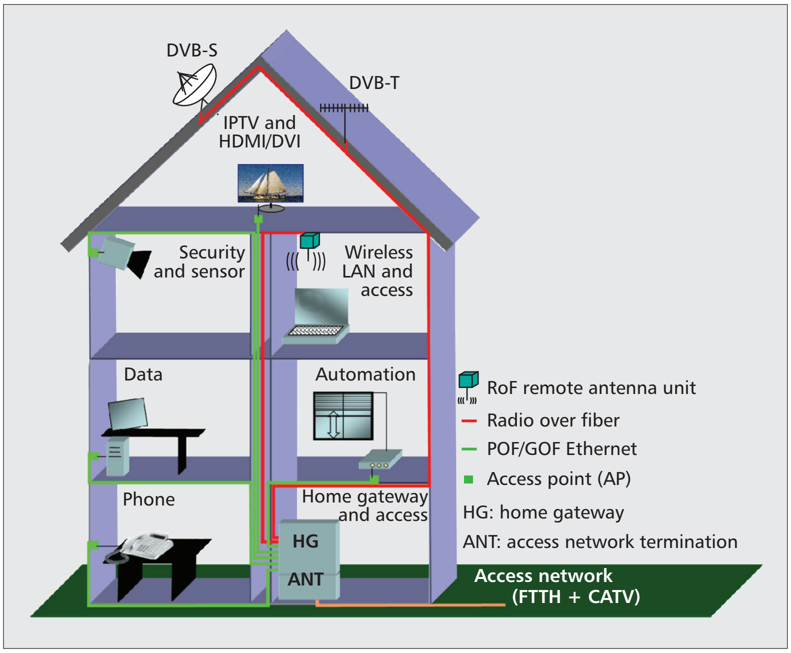

Figure 1. *General point-to-point HAN architecture and services.*

HAN ARCHITECTURE

The specifications discussed in the previous section are, at least for the most advanced scenarios, very challenging to meet, and show the rationale for optical cabling inside the house. In this section we analyze the possible architectures of the HAN. While the previous section was quite general in scope, in this section we focus specifically on HAN architectures based on optical fibers.

Starting from a quite general description, the boundary between the access network and the HAN lies between the access network termination (ANT) and the home gateway (HG). The ANT and HG are generally separate devices, but they could be packaged in a unique box [9]. The HAN should connect the Home Gateway to several access points (APs) scattered around the house (Fig. 1) carrying different services and applications, as described in the previous section. The AP is defined here as a *plug* through which the HAN services can be accessed in order to provide suitable connectivity throughout the house. The usual figure is at least one AP per used room (lounge, kitchen, home office, bedrooms), leading to a minimum of approximately five APs per house. As a maximum, a significantly higher number of AP, up to some tens, can be necessary, covering each room and giving extra ease of use in the most connected rooms (e.g., home office). The maximum cabling distance is typically considered to be 50 m. Starting from these general considerations, the next subsection proposes and studies different possible architectures.

POINT-TO-POINT SOLUTIONS

Today, most home networks are based on a home gateway typically placed at the apartment entrance, where the external access network is terminated. Terminal premises are connected to this gateway through either cabled point-to-point links or wireless links. For the cabled solutions — today usually unshielded twisted pair (UTP) — the physical configuration is nearly always a point-to-point star topology, as is also done for structured cabling in the last part of a LAN. In this case the gateway acts as a central switch, and the resulting star architecture is indicated as point-to-point (P2P) (Fig. 1). The simplest configuration is when all data are digital and encapsulated into the same protocol. For instance, the gateway can consist of an Ethernet switch or an IP router.

Today, in residential areas, the most used cabling system is the standard UTP copper cable with RJ45 outlets extensively used in LANs. The progressive introduction of optical cables in the HAN backbone can be made by proposing a hybrid wiring solution containing either a hybrid cable (a copper cable and an optical cable placed inside the same sheath) or a copper cable juxtaposed with an empty tube into which a small optical cable can be pushed or blown on demand in the future. The last solution is more economical today, because the overcharge due to the optical fiber is pushed into the future. Moreover, the choice of fiber type is also delaye,d and potentially the optical cable can be upgraded in the future. At the physical layer, since all connections are simple P2P, the link budget is comfortable, and the choice for fiber technology is quite open (SMF, MMF, or POF).

In this simplest configuration, the key advantages given by optical cabling are:
- Very high available bandwidth.
- Complete immunity to electromagnetic interference.
- Fiber, being completely dielectric cables, can be laid down in the same pipes that contain power cables, while (in most countries) this is not legal for UTP copper cables.
- Total protection against eavesdropping.

The P2P star-like architecture we are discussing here is a relatively simple one, where fibers are used simply as a *cable replacement* for copper. Despite its simplicity, but thanks to the aforementioned advantages, several companies (e.g., Netopia and HomeFibre) working in the field of home gateway are today proposing these solutions, offering on the market home gateways equipped with optical ports for POF (further details later). Many other companies (Firecomms, Luceat, Avago/Infineon) are offering simple media converters, for instance from UTP to POF, to be attached to traditional home gateways.

This solution is straightforward if only baseband digital traffic is requested, such as for Ethernet transmission. If RF-like applications are also required, such as analog or digital cable or terrestrial TV, satellite TV, transportation of radio signals toward remote antennas, or any other, it is then necessary to add specialized ports to the gateway (adapted to the relevant format, e.g., analog, quasi-analog, digital) and multiplex them on a single fiber. An implementation of such a multiformat home gateway including RoF solutions is clearly more complex and inflexible. To solve this issue, we propose in the following sections more advanced and longer-term solutions.

MULTIPOINT ARCHITECTURES

To increase flexibility in the HAN, multiplexing and transparency to different transmission and modulation formats would be beneficial. Optical technologies give solutions for such architectures, with multipoint transparent architectures that can eventually use the wavelength domain to achieve multiplexing. For the long-term evolution of home networks, we propose three different optical solutions, based on $1 \times N$ and $N \times N$ configurations that can be seen as a long-term evolution for home networking. They will be briefly presented in the following subsection. The interested reader can find more details on the testbeds implemented by France Télécom in [10]. The proposed solutions basically transfer to the home networking arena architectures that are today used in the access and transport networks.

1 × N PON-Like Architecture — Passive optical network (PON) [1] concepts can be deduced from access to the home networking architecture, as shown in Fig. 2. The gateway is then a home gateway optical line termination (HG-OLT). Premises are connected using access optical network termination (ONT). All PON mechanisms can be reused. Real-time traffic and best effort traffic coexist with good QoS, as PON allows resource reservation. Increasing the number of APs is very easy: PONs are presently sized with up to 128 ONTs. A major advantage is the optical transparency as services can be transmitted in various formats (RoF, CATV, etc.) using one or more wavelengths in overlay (course wavelength-division multiplex [CWDM] technologies, see below). The main issue today is to reduce the cost of PON equipment, taking into account the relaxed specifications compared to the access context (reduced transmission distance, tolerable increased failure rate, etc.).

N × N LAN-Like Architecture — Another solution that was addressed in our studies [10] uses an optical version of the old 10Base-T Ethernet shared media approach, in which many networks cards were physically attached to the same bus. In our idea, all premises equipment can be connected using optical transceivers to a logical bus that is actually based on an optical $N \times N$ splitter, as shown in Fig. 3. We are thus proposing an all-optical packet approach on a shared medium. The gateway is on the same hierarchical level as other premises equipment and the network manages itself. The architecture requires a medium access control algorithm, which can be the well-known carrier sense multiple access with collision detection (CSMA-CD) of Ethernet. The drawback is that, in its simplest implementation, CSMA-CD does not support QoS differentiation. But with short transmission distances, the limited number of APs — compared to the LAN context and taking into account the increasing speed of transceivers — simultaneous transport of real-time and best effort traffic is possible. All

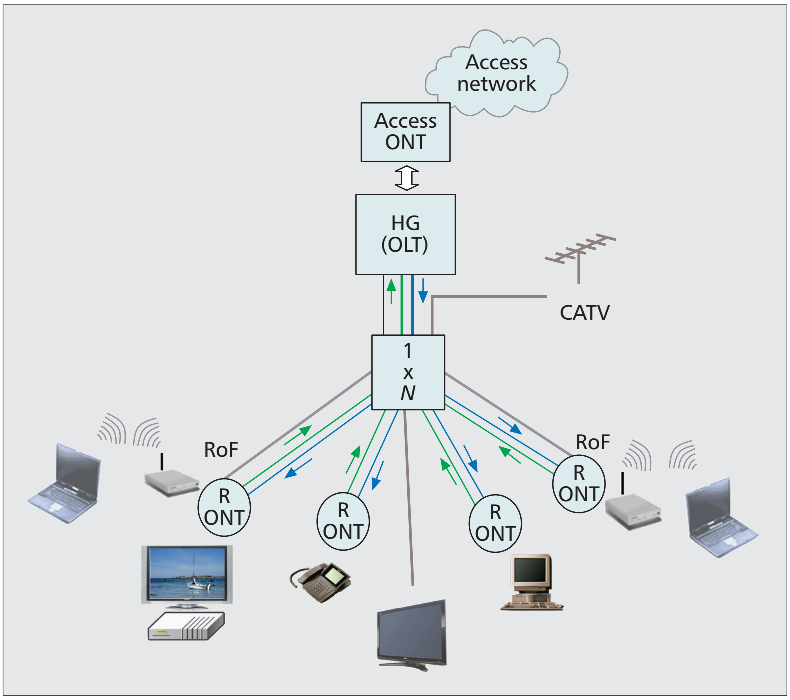

Figure 2. *1 × N PON-like architecture.*

previous remarks on transparency, in order to implement services in various formats on different wavelengths in overlay, are also relevant in this configuration.

Broadcast and Select CWDM Architecture — An even more advanced architecture, shown in Fig. 4, is based again on an $N \times N$ coupler, but extensively uses the wavelength multiplexing degree of freedom. A pair of fibers (TX and RX) connects one coupler to each AP. Each TX fiber is connected to all RX fibers through this coupler. This fully transparent architecture uses CWDM technology to pile different network layers in parallel without interference between each other. Different topologies (P2P, $1 \times N$, $N \times N$), different protocols, and different formats can coexist. At any AP, an optical filter (e.g., CWDM thin film filter) is used to separate or aggregate traffic to the WDM spectrum on the wavelength specific to the desired service. Note that all services (i.e., all wavelengths) are accessible at each AP using the correct filter. Banks of parallel optical filters can be used to access several services at the same AP. An experimental demonstration of this architecture can be found in [11].

OPTICAL TECHNOLOGIES FOR THE HAN BACKBONE

Several optical media could be used to deploy the architectures described above and enable high-performance HANs, and thus provide many broadband services. These media are classified into three main categories: standard SMFs, MMFs (silica and polymer), and microstructured fibers. Each category of fiber has specific properties, and a comparison is necessary to assess the choice of the best trade-off between fibers, architecture, and, above all, overall cost. For this, several characteristics must be addressed such as attenuation loss, wavelengths to use, bandwidth, macro bending loss, connectivity issue, and maturity of the technology. We discuss in this section the available options for optical cabling inside the house. Just as in the previous sections, we present the solutions in order of increasing performance. Table 2 summarizes the most relevant physical parameters for each of the proposed fibers.

Polymer Optical Fiber

The generic term polymer optical fiber (POF) does not specify a single type of fiber, but a variety of fibers that have in common the use of plastic materials for core and cladding, and usually a large diameter. Among the many available options, only two are interesting for home networking [13]: polymethylmethacrylate (PMMA) step index fibers (SI-POF, 980 μm core diameter and 1 mm fiber diameter, PMMA is the material used) and perfluorinated graded index fibers (PF GI-POF, 120 μm core diameter and 500 μm fiber diameter). These two kinds of fiber do not have the same optical and physical characteristics. PMMA step index fibers show the advantage of having great ease of installation and connection; as previously mentioned, a home gateway equipped with optical ports for POF were already on the market as of 2008. Recent developments in two EC funded projects, POF-ALL and POF-PLUS, showed that using these fibers on a target distance of 50 m, bit rates up to 1 Gb/s are feasible [12], while even higher bit rates have been demonstrated on shorter distances [13]. This should easily fulfill all reasonable HAN requests in the medium term.

Perfluorinated graded-index fibers are more difficult to connect because of a smaller core diameter, but show improved optical characteristics (lower attenuation loss and higher bandwidth, especially in the infrared region), similar to silica multimode fibers. A transmission of 40 Gb/s over 50 m of PF GI-POF has already been shown [14].

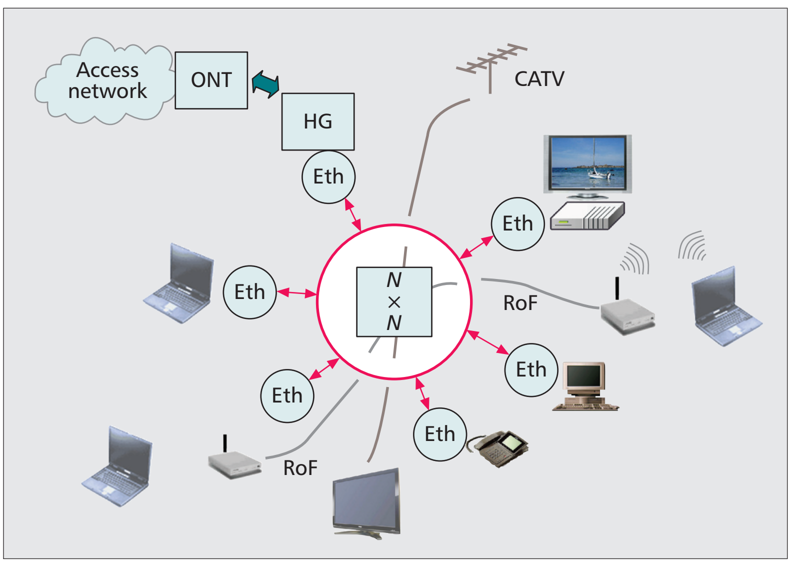

Figure 3. N × N *LAN-like architecture.*

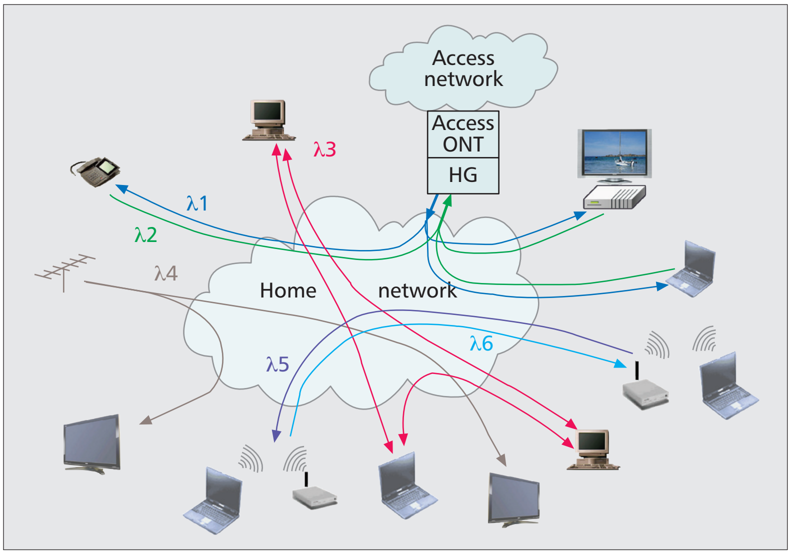

Figure 4. *Broadcast and select CWDM architecture.*

Multimode Fiber

Glass MMFs have a graded index profile and a 50 or 62.5 mm diameter. Over the last years, their bandwidth per distance product has been improved, so they are the most commonly used media for the LAN backbone requiring Gigabit Ethernet rate. Using recent 50 μm MMF, and considering the 50 m target distance in the HAN, these fibers can easily transmit 10 Gb/s data rates for fully digital on-off keying transmission, and can thus be considered future-proof at least in terms of data rates. This solution is interesting because it enables cheap sources like vertical cavity surface emitting lasers (VCSELs) to be used, and leads to easier and lower-cost connection compared to single-mode fibers. Not only pure digital data transmission, but also multistandard transparent RoF transmission can be supported by these fibers in small office and home office (SOHO) networks [6].

Single-Mode Fiber

Standard SMFs, compliant, for instance, with the recent ITU-T Recommendation G.652.D, are widely used in transport and access networks. They present very interesting properties in transmission (low attenuation loss, usable on a large wavelength window if the water peak is controlled, and no practical limitation in terms of bandwidth over distance). But for indoor cabling, fibers require additional characteristics, particularly low bending loss at small bending radius. This parameter has been an important issue in new optical fiber designs. For SMF used in FTTH, an optimization has been sought in order to achieve low bending and splice losses simultaneously. Recently, bend-optimized SMFs have attracted much attention. ITU-T Recommendation G.657 was defined at the beginning of 2006 to describe low bending loss SMFs for FTTH. The only drawback of SMF in the HAN is the high installation costs, due to the high precision required in the optical connectors.

	Silica SMF (glass single mode fiber)	Silica MMF (glass multi mode fiber)	POF (plastic optical fiber)	HAF (hole assisted fibers)
Wavelengths to use	850–1600 nm	850–1300 nm 1240–1550 nm	850–1300 nm for perfluorinated graded-index-POF 650 nm for PMMA POF	C-band
Attenuation loss (dB/km)	<0.4 from 1300 to 1600 nm <0.25 @1550 nm	<3 @850 nm <0.8 @1300 nm	<40 for GI-POF <160 for SI-POF	<0.5 @1550 nm
Bit-rate distance product	No reasonable limit available (for the home networking scenario)	1 Gb/s over 1 km 10 Gb/s over 300 m	40 Gb/s over 50 m for PF GI-POF 100 Mb/s over 200 m for SI-POF, 1 Gb/s over 100 m SI-POF [12]	No limit available
Macro bending loss	∅ = 30 mm < 0.25 dB/10 turns @1550 nm	∅ = 75 mm, < 0.5 dB/100 turns @850 and 1300 nm	∅ ≥ 40 mm for GI-POF ∅ ≥ 60 mm for SI-POF	∅ = 15 mm, < 0.1 dB/10 turns
Connection	< 0.1 dB for a splicing < 0.3 dB for a connector but these operations require specific setups and skilled technicians	Same values than S-SMF but the connection operations are simpler because the core diameter is higher	For GI-POF, a more simple connection (< 1 dB) For SI-POF, a do it yourself concept (< 2 dB)	A more difficult connection because of the holes presence but correct losses can be obtained (< 0.5 dB)

Table 2. *Characteristics of various kinds of optical media for home area networks.*

Other Types

To complete the overall picture, we briefly report on hole-assisted fibers (HAFs). Over recent years glass and polymer HAFs have attracted increasing attention because they offer unique optical properties and design flexibility that cannot be provided by the other conventional optical fibers. These fibers contain an arrangement of holes running along the fiber length and can present very interesting properties with regards to bending loss, which can be lower than 0.1 dB/turn for a 10 mm winding diameter compared to 40dB/turn of standard fiber. Although this technology is much less mature than standard SMFs, the performance of HAF in terms of attenuation loss can be very interesting (< 0.5dB/km @ 1550 nm). especially in the home context where transmission distances are short (< 50 m).

Comparison of Fiber-Based Technologies

Besides considering the physical transmission characteristics of each of the proposed fibers (as summarized in Table 2), it is equally important to consider that the optical components available to implement the advanced optical architectures proposed in a previous section, such as $1 \times N$ or $N \times N$ splitters, are available only for glass SMF and, partially, for MMF, while WDM multiplexers and demultiplexers support only SMF. For the two other fiber types (POF and HAF), these components are not (yet) available. Thus, the P2P architecture can support any fiber type, while the more advanced multipoint architectures support only SMF.

Following this initial consideration, two cases should be considered when designing home networks: new homes (usually called *green-field installation*) and existing homes (*brown-field installation*).

For an installation in new homes a pre-cabling solution using tubes or ducts at the time of construction (e.g., in the walls) is proposed. Thin optical cable can be pushed, pulled, or blown through these tubes on demand. All fiber types (POF, MMF, SMF, HAF) can be used, because the installation constraints are not strict (mostly regarding bending loss requirements).

For existing homes the situation is different. The trend is to develop do-it-yourself cabling solutions not requiring the intervention of an external technician. These solutions must provide all infrastructure components required to simply and safely install a residential home network. The POF technology is well adapted to fulfill these requirements. Regarding the use of silica fibers in this context, the connection issue remains the most difficult point, although some works are in progress to develop field mounting connectors, and installation technicians are being trained as well as field adapted termination tools developed for FTTH deployments.

We conclude this section by briefly mentioning that a new field of optical communication systems for HANs is free space or line of sight optical communication systems. White light that is used for illumination, if generated with LED, can also be modulated to transmit data wirelessly. Recent developments show that this technology may offer an alternative to radio transmission systems like IEEE 802.11a/b/g/n in mobile communication systems for in- house networking [15]. Data rates of 40 Mb/s with on-off keying and 100 Mb/s with subcarrier multiplexing were achieved over very short distances.

Conclusions

We show in this article the future requirements for home networking, advocating the need for optical fiber inside the apartment in the medium term, in order to have a high-bit-rate, low-delay, *Recent developments show that this technology may offer an alternative to radio transmission systems like IEEE 802.11a/b/g/n in mobile communication systems for in house networking. Data rates of 40Mb/s with OOK and 100Mb/s with subcarrier multiplexing were achieved over very short distances.*

and high-quality wired backbone inside the house. The deployment, architecture and fiber type used for such a backbone will be strongly influenced by economical factors, end-user requirements, and installation constraints. We envision two main possible scenarios:

- Medium-term brown-field installation: POF infrastructure to provide a point-to-point architecture suitable for already constructed houses. Home gateways equipped with POF port are today on the market, offering 100 Mb/s links. Recent EU projects show that 1 Gb/s is also possible for SI-POF, and even more for perfluorinated POF.
- Long-term green-field installation: Silica fiber infrastructure for new houses where the optical cables will be installed in ducts running in the walls at construction time. The architecture will have the possibility to evolve from a point-to-point to a fully transparent multipoint-to-multipoint network able to respond to any future bandwidth requirements. For this scenario, single-mode fiber is believed to be the best choice as it guarantees the long-term suitability of the network, and benefits from the economy of scale and experience gained from current FTTH deployments.

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