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Recommendation

ITU-T G.9940 (12/2023)

SERIES G: Transmission systems and media, digital systems and networks

Access networks – In premises networks

High speed fibre-based in-premises transceivers – system architecture

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Recommendation ITU-T G.9940

High speed fibre-based in-premises transceivers – system architecture

Summary

Recommendation ITU-T G.9940 belongs to the family of ITU-T G.fin Recommendations. Recommendation G.9940 specifies the system architecture and requirements for high-speed fibre-based in-premises transceivers.

History[*]

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T G.9940	2023-12-02	15	11.1002/1000/15549

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Fibre in-premises, G.fin, home network, requirement, small and medium enterprise, system architecture.

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High speed fibre-based in-premises transceivers – system architecture

1 Scope

This Recommendation specifies the system architecture (SA) and general requirements of high speed fibre-based in-premises networking systems. This Recommendation acts as the foundation for the technical specification of the physical layer (PHY), data link layer (DLL) and management.

Specifically, this Recommendation defines:

- system architecture and reference models;
- deployment environments and application scenarios;
- requirements for service support, optical transmission, system functionalities, and management.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.652] Recommendation ITU-T G.652 (2016), *Characteristics of a single-mode optical fibre*.

[ITU-T G.657] Recommendation ITU-T G.657 (2016), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable*.

[ITU-T G.671] Recommendation ITU-T G.671 (2019), *Transmission characteristics of optical components and subsystems*.

[ITU-T L.109.1] Recommendation ITU-T L.109.1 (2022), *Type II optical/electrical hybrid cables for access points and other terminal equipment*.

[IEC 60794-2] Standard IEC 60794-2:2017, *Optical fibre cables – Part 2: Indoor cables - Sectional specification*.

[IEC 60825-2] Standard IEC 60825-2:2021, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCSs)*.

[IEC 61753-031-2] Standard IEC 61753-031-2:2014, *Fibre optic interconnecting devices and passive components – Performance standard – Part 031-2: Non-connectorized single-mode 1 × N and 2 × N non-wavelength-selective branching devices for Category C – Controlled environment*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 controller: A module comprising one or more coordinators within the main fibre unit (MFU) that dynamically collects network information from different network interfaces within the MFU and makes control plane decisions for those network interfaces.

3.2.2 fibre in-premises (FIP) network: An in-premises communication network that uses an indoor fibre distribution network to connect the residential gateway with remote communication devices, providing extended connectivity.

3.2.3 G.fin network: The part of a FIP network that provides a connection between a main fibre unit (MFU) and one or more sub fibre units (SFU) using G.fin. A G.fin network enables network functionalities, including Wi-Fi data backhauling, Wi-Fi coordination, and network management. A G.fin network is defined between the A-interface in the G.fin transceiver located in the MFU and the A-interface in the G.fin transceiver in each of the FIP network SFUs.

3.2.4 G.fin transceiver: A high speed optical communication module, consisting of a transmitter and a receiver. The G.fin transceiver is specified in the physical layer and data link layer Recommendations.

3.2.5 IFDN splitting ratio: The number of lines into which the optical signal in the downstream direction is distributed in the indoor fibre distribution network (IFDN).

NOTE – For the case when a single optical splitter is used, splitting ratio and IFDN splitting ratio will be the same.

3.2.6 indoor fibre distribution network (IFDN): An in-premises optical fibre infrastructure. An IFDN can be entirely passive, constructed with one or multiple interconnected optical splitters, and contains other passive optical components such as combiners and filters. The IFDN can also support remote power feed functionality to SFUs by using optical and electrical hybrid cables (OEHC).

3.2.7 local coordinator: A peer module within the SFU that communicates with the controller in the MFU, providing it with the necessary information and implementing the actions decided by the controller.

3.2.8 main fibre unit (MFU): A network element that terminates the access network at its northbound interface, includes gateway functionality, and includes a G.fin transceiver that provides a medium dependent interface (MDI) to communicate with one or more connected sub fibre units over the IFDN.

3.2.9 maximum differential fibre length: The maximum difference in length between the shortest and longest MFU-to-SFU link distance in the IFDN.

3.2.10 maximum fibre length: The maximum length of fibre between the G.fin transceiver in the MFU (M-FTR) and any G.fin transceiver in an SFU (S-FTR) in the IFDN.

3.2.11 optical and electrical hybrid cable (OEHC): A hybrid cable comprising an optical fibre and metallic conductors.

3.2.12 optical and electrical hybrid splitter (OEHS): A hybrid splitter that supports simultaneous transmission of an optical signal and electrical power when used with OEHCs.

3.2.13 optical splitter: A passive optical component that distributes the optical signal into multiple lines in the downstream direction and combines the optical signals from multiple lines into a single signal in the upstream direction.

3.2.14 optical splitter with remote power feed: An optical splitter with OEHC connections to support remote power feed.

3.2.15 splitting ratio: The number of lines into which an optical splitter distributes the optical signal in the downstream direction.

3.2.16 sub fibre unit (SFU): A network element with a G.fin transceiver that provides a medium dependent interface (MDI) to communicate with the MFU over the IFDN. An SFU normally has a built-in Wi-Fi access point (AP).

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AES	Advanced Encryption Standard
ALG	Application Level Gateway
AP	Access Point
APP	Application
AR	Augmented Reality
BH	Backhaul
CPE	Customer Premises Equipment
DLL	Data Link Layer
DLNA	Digital Living Network Alliance
DTA	Dynamic Time Assignment
EMS	Element Management System
ESMC	Ethernet Synchronization Messaging Channel
ETH	Ethernet
FH	Fronthaul
FIP	Fibre In-premises
HD	High-Definition
HDTV	High-Definition Television
HPNA	Home Phoneline Networking Alliance
IFDN	Indoor Fibre Distribution Network
IoT	Internet of Things
IP	Internet Protocol
IPTV	Internet Protocol TV
L2	Layer 2
LAN	Local Area Network
MAC	Media Access Control
MCE	MFU Controller Entity
MDI	Medium Dependent Interface
M-FTR	G.fin transceiver in the MFU
MFU	Main Fibre Unit
MME	MFU Management Entity

MoCA	Multimedia over Coax Alliance
NAS	Network Attached Storage
NT	Network Terminal
ODN	Optical Distribution Network
OEHC	Optical and Electrical Hybrid Cable
OEHS	Optical and Electrical Hybrid Splitter
OLT	Optical Line Termination
ONU	Optical Network Unit
OPL	Optical Path Loss
P2MP	Point to Multi Point
PC	Personal Computer
PHY	Physical Layer
PLC	Power Line Communication
PMD	Physical Media Dependent
PON	Passive Optical Network
QoS	Quality of Service
RMS	Remote Management System
SA	System Architecture
SAP	Service Access Point
SME	SFU Management Entity
SCE	SFU Coordinator Entity
SFU	Sub Fibre Unit
S-FTR	G.fin transceiver in an SFU
STA	Station
TC	Transmission Convergence
TV	Television
UPnP	Universal Plug and Play
VR	Virtual Reality
VLC	Visible Light Communication
VoIP	Voice Over IP
WLAN	Wireless Local Area Network
xPON	x Passive Optical Network
XR	Extended Reality

5 Conventions

None.

6 Architecture of the G.fin network

6.1 Network architecture

Figure 6-1 shows a G.fin based fibre in-premises (FIP) network. Such a network includes a main fibre unit (MFU), an indoor fibre distribution network (IFDN), and one or more sub fibre units (SFUs). The MFU is directly connected to an access network, such as an x passive optical network (PON) on its northbound interface. The MFU and SFUs are connected to the IFDN using G.fin transceivers. The MFU and SFUs provide wireless (e.g., wireless local area network (WLAN)) and wireline network (e.g., Ethernet) interfaces for end user devices (e.g., laptops, smartphones). Adaptation devices such as set top boxes can also be connected to the MFU or SFUs to provide network services (e.g., Internet protocol TV) to end user devices (e.g., television). The MFU is the converging point for data, management, and control, providing point to multi point (P2MP) optical connections to SFUs. It is the network terminal (NT) of the access network and the starting point of the in-premises network.

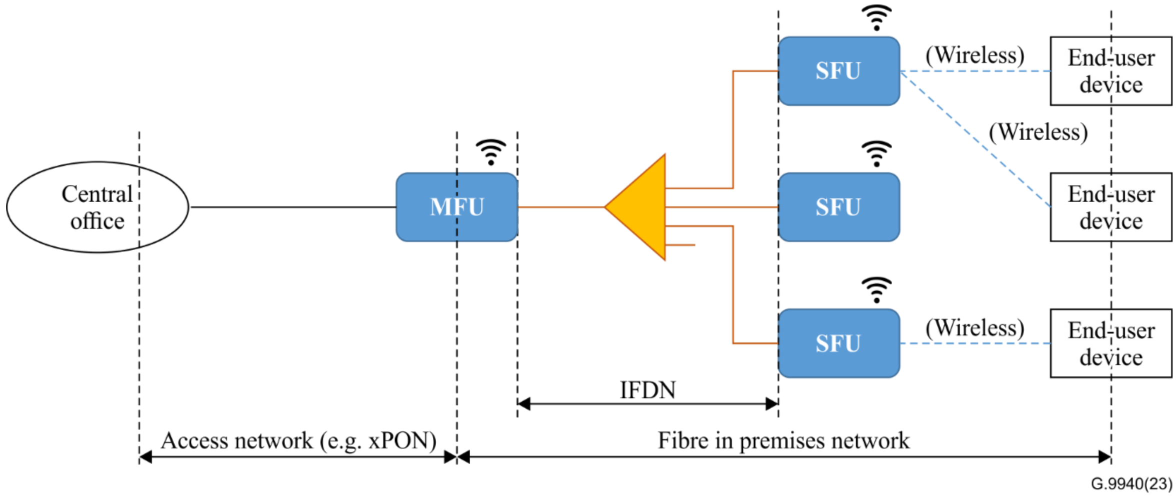

Figure 6-1 – Illustration of a G.fin-based FIP network

A G.fin-based FIP network can be used in one of two main environments, a home network or a small and medium enterprise, supporting different services and requiring dedicated network capabilities.

6.1.1 Home environment

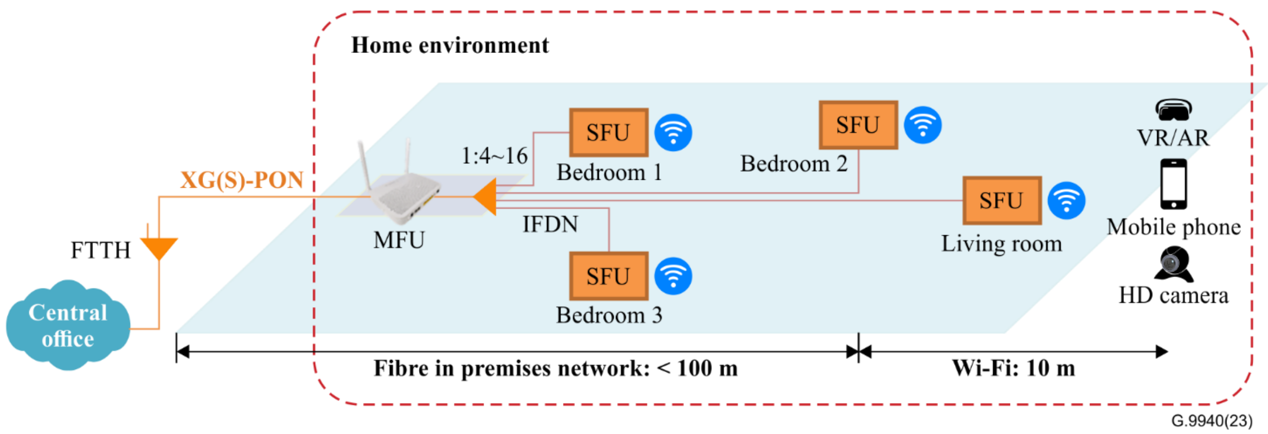

Figure 6-2 – Application of G.fin in a home environment

NOTE – Figure 6-2 is modified from Figure 13 of [b-ETSI GR F5G 008] with a change of terminology.

Figure 6-2 shows the application (APP) of G.fin in a home environment. From the central office to the MFU, there is an access network system, such as an XG(S)-PON system (FTTH) that can deliver gigabit access throughputs from the service provider. From the MFU, a G.fin-based FIP network and Wi-Fi are used for the connectivity of end user devices within the home network.

Within the home, devices such as mobile phones, high-definition televisions (HDTV), HD surveillance cameras and virtual reality (VR) / augmented reality (AR) head mounted displays need end to end stable connections to offer a good quality experience. The MFU establishes connections with the Wi-Fi access points (included in the SFUs) located in several rooms of the home through the G.fin network. In order to optimize the performance of the Wi-Fi network, coordination of the Wi-Fi access points (APs) is supported by the G.fin network.

[b-ITU-T GSTP-FTTR] defines the detailed use cases and requirements for using G.fin for home applications, including in-home Wi-Fi backhauling, broadband deployment for the dense apartment building, Internet of things (IoT) support of smart homes, low latency services, network slicing, and east-west data transmission.

6.1.2 Business environment

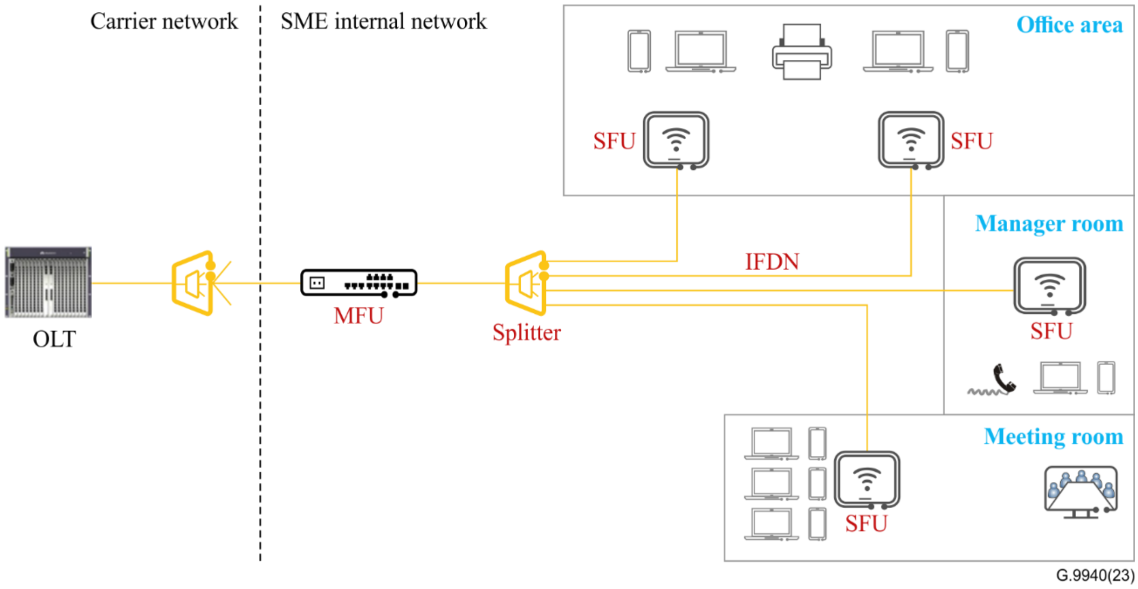

Figure 6-3 – Application of G.fin in a small and medium enterprise environment

NOTE – Figure 6-3 is modified from Figure 15 of [b-ETSI GR F5G 008] with the change of terminology.

Figure 6-3 shows an example of the application of G.fin in a small and medium enterprise environment. Optical and electric hybrid cable (OEHC) may be used for remote powering of SFUs, facilitating flexible deployment in various business sites, such as office areas, manager rooms, and meeting rooms. Compared with the home environment, more diversified device types and a larger number of end user devices are connected to the MFU and SFUs.

[b-ITU-T G Suppl. 78] defines the detailed use cases and requirements for using G.fin for small and medium enterprise applications, including live applications, small offices, smart service halls, classrooms in schools, business buildings, indoor leisure and entertainment, advertising design and virtual effect processing, workshops and smart community.

6.2 Reference models

6.2.1 G.fin network

A G.fin network is composed of an MFU, an IFDN and SFU(s) as illustrated in Figure 6-4. By making use of splitters for different fibre deployment solutions, an IFDN can cope with a variety of topologies, such as 1-tier symmetrical splitting, 2-tier symmetrical splitting and cascaded asymmetrical splitting.

As shown in Figure 6-5, if there is only one SFU to be connected, the IFDN might not include any splitters, creating a direct link between the MFU and SFU.

Traffic (including data and management information) transmission over the IFDN includes:

- downstream transmissions from the MFU to the SFU(s);
- upstream transmissions from the SFU(s) to the MFU.

Transmission between SFU(s) is first switched in the MFU at the layer 2 (L2)+ layer and is beyond the scope of this Recommendation. Direct exchange between SFU(s) at lower layers (PHY or DLL) is left for further study.

Downstream and upstream transmission takes place over the same fibre and optical components operating in duplex.

An IFDN may support remote powering of the SFUs, simultaneously distributing optical signals and electrical power to the SFU(s) using OEHCs and OEHSs. The power source connected to the OEHCs can be located in the MFU, in an OEHS, or in an external component.

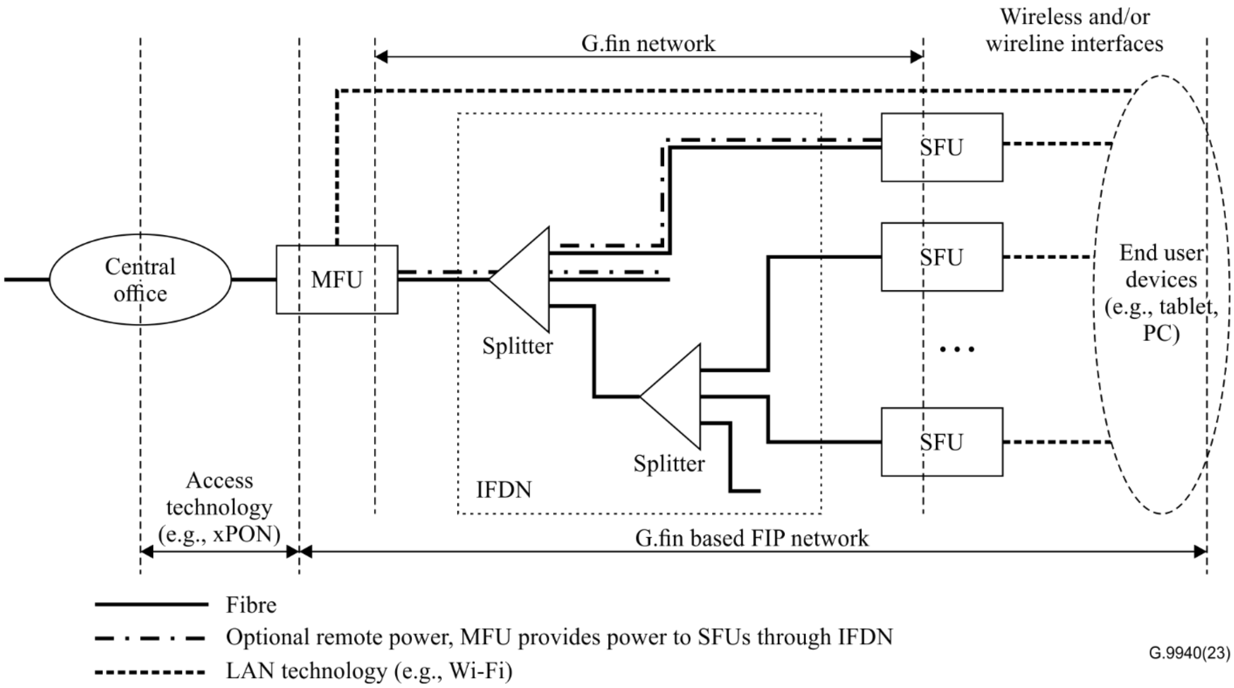

Figure 6-4 – G.fin network with multiple SFU(s)

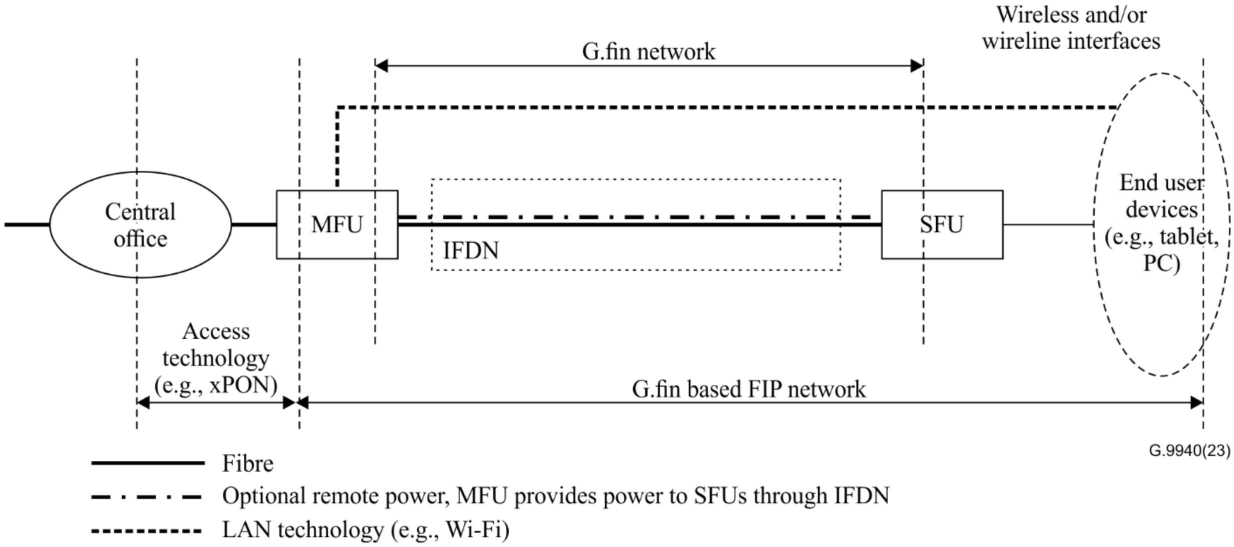

Figure 6-5 – G.fin network with single SFU

6.2.2 Functional architecture of a G.fin-based FIP network

A communication link is established over the IFDN between the MFU and SFU(s) using G.fin transceivers. As shown in Figure 6-6, the functional architecture of a G.fin-based FIP network consists of a management plane, a control plane, and a data plane. The MFU conducts centralized management (via MFU management entity) and control (via MFU controller entity) on the entire G.fin network, managing and configuring the G.fin transceiver in the SFU via the SFU management entity (SME) and the SFU coordinator entity (SCE), respectively.

a) Management plane

The MFU should be able to manage the SFU(s) and maintain the G.fin transceiver through its southbound management interface. The MFU should report information for the entire G.fin network to the management system through its northbound interface. The management system monitors carriers' assets and device status and optimizes the G.fin network.

The northbound management between the G.fin network and management system is beyond the scope of this Recommendation. It can be done using existing protocols such as [b-BBF TR-069] or [b-BBF TR-369], or by a proprietary solution provided by the service operator. The management between G.fin transceivers (such as quality of service configuration, device upgrade, device restart, and default setting restoration) shall follow the G.fin management Recommendation. G.fin shall provide a low latency channel to convey management information for other technologies, such as Wi-Fi.

b) Control plane

The G.fin transceiver in the MFU (M-FTR) collects G.fin-based FIP network information in real time through a centralized control mechanism. The MFU should use this information to define transmission strategies for the entire network. The MFU should use this mechanism to convey coordination information to the wireless interfaces in the SFU(s) and to define transmission policies in the FIP network to implement coordination between the optical and wireless networks.

c) Data plane

The data plane provides communication channels for exchanging service data, management data, and control data to ensure normal operation of G.fin connection and exchange control information between the M-FTR and the S-FTR(s).

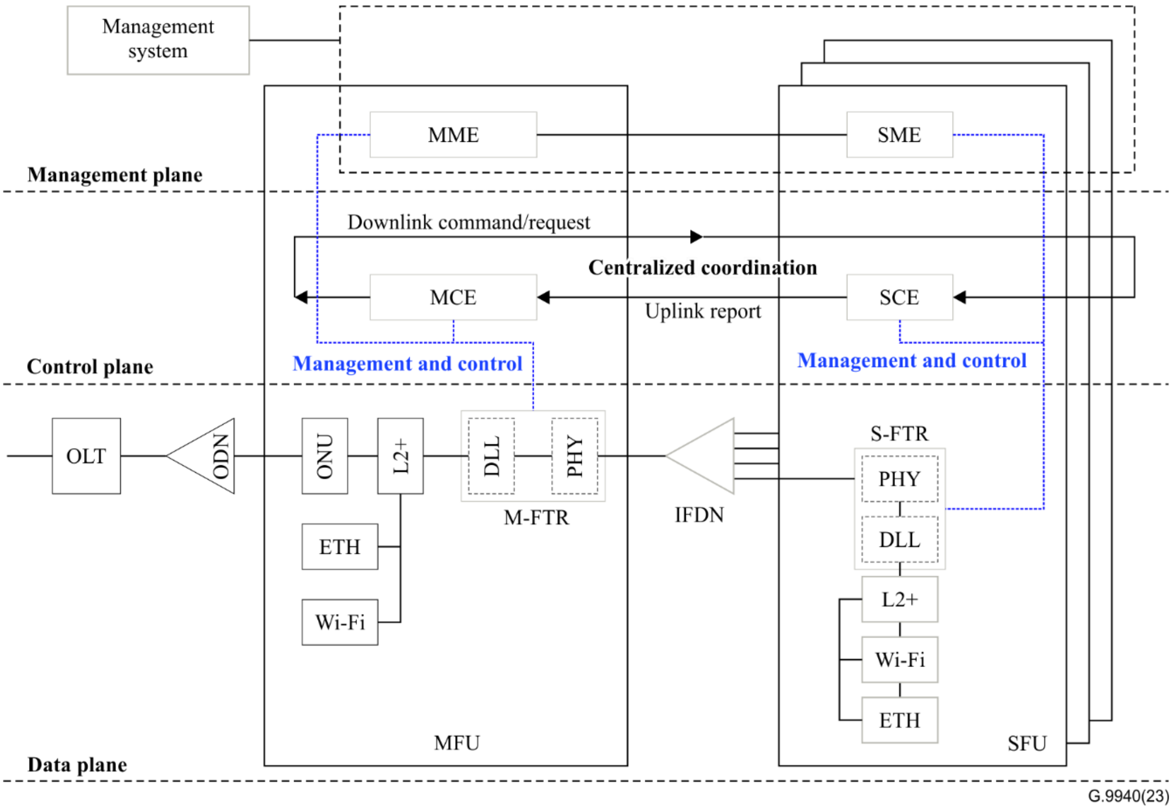

Figure 6-6 – Functional architecture of a G.fin-based FIP network

NOTE – G.fin network transmits service data based on a point-to-multipoint (P2MP) fibre topology. East-west data communication between G.fin transceivers is done by the MFU.

6.3 Protocol reference model

The protocol stack diagram of the data service is shown in Figure 6-7. In the MFU, Ethernet frames are bridged/routed through L2+ between the xPON transmission convergence (TC) layer and the G.fin DLL. Other access technologies may also be used to support the uplink of the G.fin-based FIP network. In the SFU, Ethernet (ETH) frames are bridged between the G.fin DLL and the Ethernet/Wi-Fi media access control (MAC) layer.

It should be noted that there are several different interfaces that can take the place of an Ethernet/Wi-Fi MAC and PHY. These include the power line communication (PLC), visible light communication (VLC), multimedia over coax alliance (MoCA), home phoneline networking alliance (HPNA), and perhaps others yet to be devised. However, due to the Ethernet's pervasive nature, these alternative protocols are defined so that they operate in a way nearly the same as the Ethernet.

G.fin transceivers are composed of a G.fin PHY and a G.fin DLL including their respective functionalities. G.fin transceivers in the MFU and SFUs are connected by IFDN. The G.fin PHY and G.fin DLL and corresponding management functions are specified in other Recommendations.

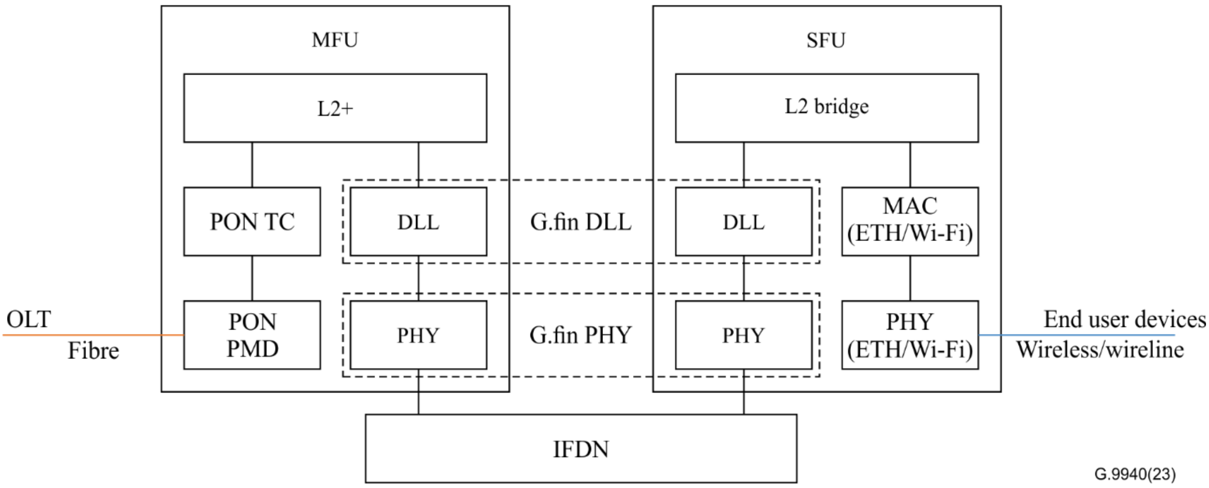

Figure 6-7 – Protocol reference model of G.fin-based FIP network

NOTE – The G.fin PHY sets requirements for the IFDN but specification of the IFDN is beyond the scope of the G.fin PHY Recommendation.

6.4 Centralized coordination network architecture

G.fin-based FIP networks intend to provide quality-assured in-premises network service to end users. To leverage the new capabilities of wireless links (e.g., Wi-Fi new deterministic MAC functions), a G.fin network shall support the coordination of resources and access to the channel between fibre links (i.e., using G.fin transceiver) and wireless links. Figure 6-8 shows a centralized coordination network architecture.

The MFU contains a controller that dynamically collects the network transmission necessities and characteristics (data buffer status, traffic priority, latency requirements, etc.), identifies the network environment (such as channel status between the MFU and the SFU(s), interferences, etc.) and creates a strategy to coordinate the behaviour of the different networks connected to it. Due to this controller, fast network operation and control, including ordered medium access, global handover, and real-time link visibility can be achieved.

The MFU is a system level device (shown in Figure 6-8), that includes a G.fin transceiver, a local area network (LAN) switch, a controller, and other related functionalities.

NOTE – An MFU is equivalent to a residential gateway (RGW).

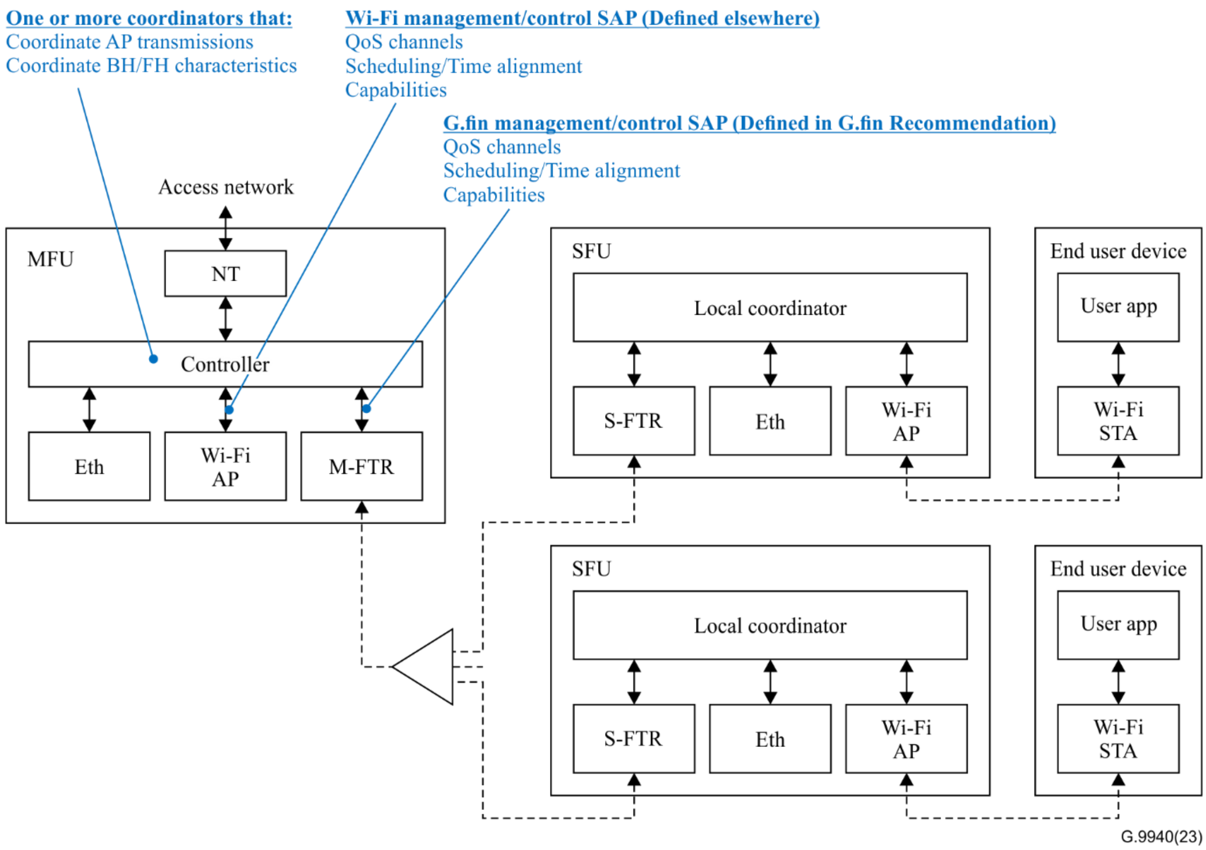

Figure 6-8 – Centralized coordination network architecture

6.4.1 Centralized status collection

Based on the quality of service (QoS) requirements of the services over the network, the controller in the MFU initiates requests to the functional modules in the SFU(s) (Wi-Fi, LAN switch, data buffer, etc.). The SFU(s) receiving the requests can collect the network status information and provide feedback to the MFU. The controller behaviour is vendor discretionary and is beyond the scope of the G.fin Recommendations. The controller in the MFU may also dynamically forward control commands over the G.fin network to the local coordinator in each SFU. The real-time configuration of the network interfaces by the controller within the MFU is vendor discretionary. The requests and collection of feedback over the G.fin network shall be carried over a latency controlled channel (see clause 6.4.3).

6.4.2 Centralized network control

The controller may have controlling functionalities over the fibre link, wireless link, etc. For example, the controller may calculate the optimal air time/frequency/space resources to optimize the use of the air interface. The controller may suggest transmission opportunities to be used over the fibre link to support QoS requirements of selected services over the network. The controller may coordinate global handover and data path switching. The control information exchanged between the coordinators in the MFU and the local coordinator in each SFU is addressed in a separate G.fin Recommendation.

6.4.3 Latency controlled transmission mechanism

The G.fin PHY and data link layer (DLL) shall support a priority specific information channel to support latency controlled transmissions, and to enable the upper layers to control the whole network access to the medium. Due to different control requirements of the technologies that can be connected to a G.fin-based FIP network, the round-trip latency on the channel should be less than 64 µs for extremely high demand coordination such as air interface signalling coordination.

7 Service requirements

7.1 Service types

A G.fin network is required to support various services for residential subscribers, business customers, Wi-Fi backhauling, and other applications leveraging its high bit-rate capabilities. Furthermore, a G.fin network intends to provide better latency and jitter performance.

The services supported by a G.fin network should include:

– High-speed indoor networking: support high-speed networking of wired or wireless terminals (personal computer (PC), network attached storage (NAS), pad, mobile phone, etc.) within the in-premises.

– High-speed Internet: provide users with broadband Internet access services.

– High quality video: (IPTV, extended reality (XR), etc.): support high-definition (HD) IPTV and high-quality AR/VR or hologram transmissions in the future.

– Voice over IP (VoIP): provide users with IP telephony services.

– Others: support multiple interconnection protocols or interfaces such as a universal plug and play (UPnP), digital living network alliance (DLNA), and application level gateway (ALG) for cloud storage, multi-screen interaction, and IoT services.

7.2 Mean signal transfer delay

A G.fin network should accommodate services that require a mean signal transfer delay $\leq$ 1.5 ms, between the A-interface of the M-FTR and the A-interface of the S-FTR(s).

7.3 Maximum Ethernet packet size

A G.fin network shall support Ethernet jumbo frames with lengths beyond 2 000 bytes and up to 9 000 bytes. If jumbo frames beyond 2 000 bytes are used for non-delay-sensitive services on the same IFDN, the delay-sensitive services shall not be degraded by jumbo frame transport.

7.4 Synchronization features and quality

A G.fin network shall provide mechanisms to allow the coordination of optical and wireless links, since accurate synchronization and low latency may be required. For this, the MFU may receive a high-quality timing clock to serve as a master timing source for the SFUs. The SFUs can use accurate timing/synchronization to feed the wireless interface and application requirements.

Aspects of clock propagation, frequency and time of day synchronization scenarios, and Ethernet synchronization messaging channel (ESMC) messages transport over a G.fin network with [b-IEEE 1588], are left for further study.

8 Physical layer requirements

The G.fin PHY shall be specified to work over a single-fibre supporting bidirectional transmission.

8.1 Bit rates

G.fin should specify the following nominal line rate combinations per wavelength channel:

– approximately 10 Gbit/s in the downstream and 10 Gbit/s in the upstream;

– approximately 2.5 Gbit/s in the downstream and 2.5 Gbit/s in the upstream.

Other nominal line rate combination options are for further study.

8.2 Maximum number of connected S-FTRs

G.fin may be used in different environments. These environments usually need to support the following maximum number of connected S-FTRs:

– 8 for the home environment, using an optical link type Ra;

– 32 for the small and medium enterprise environment, using an optical link type Rb.

To cover these environments, G.fin M-FTRs shall support the connection of:

– 8 S-FTRs at the physical layer when using an optical link type Ra;

– 32 S-FTRs at the physical layer when using an optical link type Rb;

– 64 S-FTRs at the data link layer.

8.3 Fibre length

The G.fin PHY shall support:

– a maximum fibre length of at least 1 km;

– a maximum differential fibre length of up to 1 km.

The G.fin DLL shall support:

– a maximum fibre length of at least 2 km;

– a maximum differential fibre length of up to 2 km.

8.4 Optical link budget

The optical link budget mainly depends on the splitting ratio and splitting architecture. A G.fin transceiver shall support at least one of the two optical link types defined in Table 8-1.

The detailed specifications of these two types will be addressed in the G.fin-PHY Recommendation.

8.5 Operating wavelength

G.fin transceivers shall use the wavelengths defined in Table 8-1, depending on the optical link type they are operating on.

A G.fin transceiver operating with an optical link type Rb at the 10/10 Gbit/s line rate shall operate at one of the two specified wavelengths (Option 1 or 2) as specified in Table 8-1.

Table 8-1 – Overall relationship between optical link budget and wavelength set

Optical link type	Optical link budget	Typical IFDN splitting ratio	Upstream / downstream wavelength set	
			2.5/2.5 Gbit/s	10/10 Gbit/s
Ra	0-18 dB (home)	1:8	Up: 1 310 ± 10 nm Down: 1 490 ± 10 nm	For further study
Rb	13-28 dB (small and medium enterprise)	1:32	Up: 1 310 ± 10 nm Down: 1 490 ± 10 nm	Option 1: Up: 1 310 ± 10 nm Down: 1 490 ± 10 nm

Table 8-1 – Overall relationship between optical link budget and wavelength set

Optical link type	Optical link budget	Typical IFDN splitting ratio	Upstream / downstream wavelength set	
			2.5/2.5 Gbit/s	10/10 Gbit/s
				Option 2: Up: 1 270 ± 10 nm Down: 1 577 ± 10 nm
NOTE – Optical link type Ra is typically used in the home environment while type Rb is typically used in small and medium enterprise environments.				

Other wavelength combination options are for further study.

8.6 Indoor fibre distribution network (IFDN)

8.6.1 Fibre

The G.fin PHY shall support communication over IFDNs built using optical fibre of G.657A or G.657B types (see [ITU-T G.657]).

NOTE – These optical fibres have been chosen to overcome the bending loss due to complex cabling topologies during in-premises fibre deployments.

8.6.2 Optical cable

The G.fin PHY shall support communication over IFDNs built using passive optical cable (see [IEC 60794-2]) and OEHCs (see [ITU-T L.109.1]).

NOTE – Transparent / invisible optical cables should be used in open field deployment, such as sticking to a wall.

8.6.3 Optical splitter

The G.fin network shall support the use of symmetric or asymmetric optical splitters in the IFDN (see Appendix I).

NOTE – The splitting ratio of optical splitters depends on the deployment. The utilization of optical splitters is solution based and depends on the deployment scenario, splitting ratio, etc.

8.6.4 Optical and electrical hybrid splitter (OEHS)

Figure 8-1 shows an OEHS. G.fin shall support the use of OEHSs in an optical/electrical hybrid IFDN.

NOTE – Such a splitter integrates the passive optical splitter (see [IEC 61753-031-2]) and the electrical power distribution function, enabling the capability to convey optical signals and power energy from the MFU to SFUs. The splitter provides a single physical connector for optical and electrical transmission and adapts to the connector of the optical and electrical hybrid cable (OEHC).

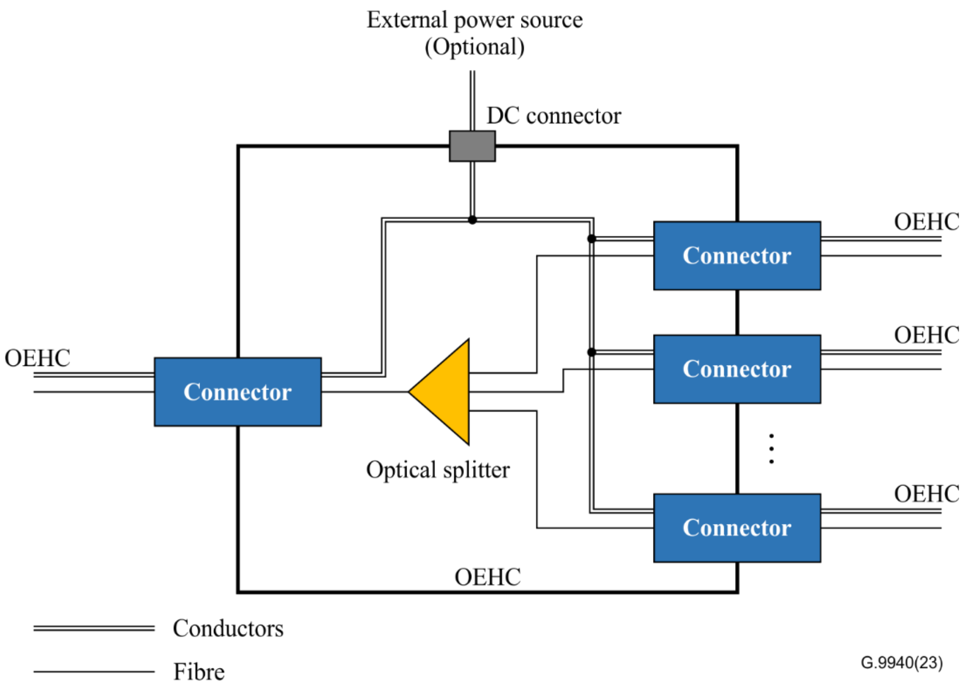

Figure 8-1 – OEHS

9 System level requirements

9.1 Power saving and energy efficiency

The G.fin PHY and DLL shall support power saving modes during specified time periods. Service quality and user experience should not be affected when using these power saving modes.

NOTE – Power saving modes may be used to reduce power consumption during periods where service requirements are limited (e.g., during the daytime when home networks are less used).

9.2 Security functions

Since a point to multi-point architecture is used in G.fin networks, the medium (fibre) is shared by all SFUs. Each SFU receives the downstream data for all SFUs through this shared fibre, so it is important to protect the shared fibre against impersonation, spoofing and snooping of data.

The G.fin DLL should support at least the following mechanisms to protect against impersonation:

– identification of the serial number / password / MAC address of the SFU;
– authentication of the customer premises equipment (CPE);
– a strong authentication mechanism such as the digital certificate authentication.

To protect against snooping at the SFUs, all unicast data transmitted by the M-FTR should be encrypted with a strong and well characterized algorithm (e.g., advanced encryption standard (AES)). Therefore, the G.fin DLL shall specify a reliable key exchange mechanism to start an encrypted communication.

Authentication, identification, and encryption shall be optional functions that may be disabled by the users. The G.fin DLL should provide user-friendly procedures for setting up a secure network.

9.3 Dynamic time assignment

The M-FTR shall support dynamic time assignment (DTA) for efficient sharing of upstream time among the connected SFUs. The DTA algorithms running on a G.fin transceiver are vendor discretionary and are beyond the scope of the G.fin Recommendations.

9.4 Quality of service (QoS)

Quality of service (QoS) is a measure of the quality of delivery of services in the network, placing requirements on the transmission and queuing of traffic. Detailed methods for achieving QoS (such as priority based, or parameter based) in a G.fin network are left for further study.

9.5 Eye safety

Necessary mechanisms shall be provided to ensure that no eye damage is caused to the end users that are unaware of the risks, especially if the fibre is terminated inside the home. G.fin optical elements need to conform to the Class 1 defined in [IEC 60825-2].

10 System management functions

10.1 Management schemes

It is highly desirable from the network operation perspective to manage a G.fin network, with a similar approach to existing management platforms of access and home networks. A G.fin network may be managed in parallel via two paths as shown in Figure 10-1:

NOTE – Avoiding management conflicts when using multiple management paths is left for further study.

1) Using OMCI

A G.fin network may be managed using OMCI (see [b-ITU-T G.988]) over the "I2" interface as shown in Figure 10-1. In this case, the MFU acts as an optical network unit (ONU) for registration and provisioning. The MFU uses the information received through OMCI to manage its own G.fin transceiver and the overall G.fin-based FIP network.

NOTE – The optical line termination (OLT) is configured by the element management system (EMS), which is out of the scope of this Recommendation.

The method to manage a G.fin transceiver from its SFUs via OMCI commands issued by the OLT is left for further study.

2) Internet protocol (IP) path

With the establishment of a link to the access network between the MFU and OLT, G.fin transceivers in the MFU and SFUs can be managed by existing IP based protocols like [b-BBF TR-069] or [b-BBF TR-369], or by a vendor-discretionary solution.

Several interfaces are defined in Figure 10-1:

– I1: The southbound management interface between the MFU and SFUs. The MFU manages the SFUs and maintains the G.fin link through I1. MFU management entity (MME) and SME are the management entities in the MFU and SFUs, respectively.
– I2: The northbound management interface between the OLT and the G.fin-based FIP network. The OMCI protocol is used at I2.
– I3: The northbound management interface between an operator's remote management system (RMS) and the G.fin-based FIP network. An IP based protocol is used at I3.

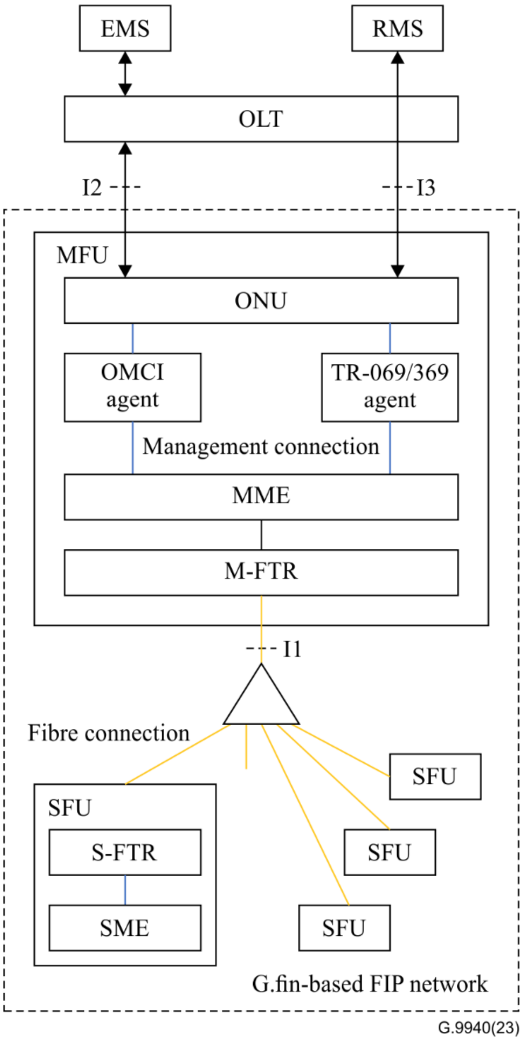

Figure 10-1 – An example of management schemes of G.fin-based FIP network

10.2 Management functions

The management of G.fin network is achieved by the collaboration of I1 and I2/I3. The management platform (such as EMS or RMS) triggers the management request through I2/I3 whilst I1 may assist in completing the various management functions.

The following management functions should be included:

a) System visualization: to support visualization of key information of the G.fin network (e.g., the topology of the G.fin network, status of G.fin transceivers), and to transport management data gathered by the MFU/SFUs (e.g., interference metrics of Wi-Fi).

b) System configuration: to support configuration of the G.fin transceivers and related network services, (e.g., authentication of G.fin transceivers at the MFU and SFU(s)), and to transport management information to the SFUs for the management of other interfaces (e.g., configuration of Wi-Fi, VLAN and QoS parameters).

c) Collection of system performance metrics: to support performance management of the G.fin network (e.g., collecting performance metrics) and to transport performance metrics of other interfaces connected to the SFUs (e.g., collecting performance metrics of wireless/LAN interfaces).

d) Fault management: to support fault management of the G.fin network (e.g., processing alarms from the G.fin network, diagnosing device and service faults).

e) Security management: to support security management of the G.fin network, e.g., authentication and authorization to management system users, and audit of management operations.

Appendix I

Optical link budget analysis for G.fin network

(This appendix does not form an integral part of this Recommendation.)

I.1 Optical path loss factors

The factors affecting the calculation of the optical path loss (OPL) for a G.fin network are optical fibre loss (including from splices), optical connector losses, and power splitter losses according to the following formulae.

$$OPL_{max} = FibreLoss_{max} + ConnLoss_{max} + Loss_{PS_{max}} \quad \text{(I.1)}$$

$$OPL_{min} = FibreLoss_{min} + ConnLoss_{min} + Loss_{PS_{min}} \quad \text{(I.2)}$$

Figure I.1 shows the case with a single power splitter. For this case, $Loss_{PS_{max}}$ is the maximum insertion loss of the splitter for a given splitting ratio according to Table I.1, and the indoor fibre distribution network (IFDN) splitting ratio is the same as the splitting ratio.

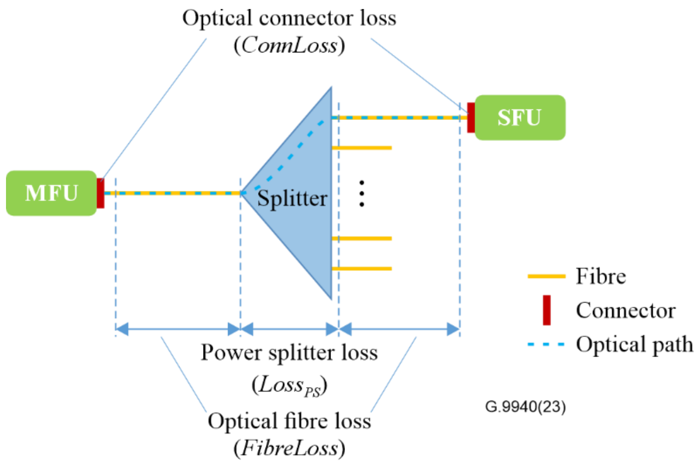

Figure I.1 – Optical path loss for a G.fin network with a single power splitter

The different attenuation coefficients for single mode fibre are:

– 0.35 dB/km (maximum at 1 550 nm) and 0.4 dB/km (maximum at 1 625 nm) of fibre type G.652.B as described in [ITU-T G.652].

– 0.4 dB/km (1 310 to 1 625 nm) and 0.3 dB/km (maximum at 1 530-1 565 nm) of fibre type G.652.D as described in [ITU-T G.652].

– 0.4 dB/km (1 310 to 1 625 nm) and 0.3 dB/km (max at 1 530-1 565 nm) of fibre type G.657 (may be used for indoor cabling and/or drop section) as described in [ITU-T G.657].

Connector loss depends on the number of connectors. Insertion loss for each single fibre connector is a maximum of 0.5 dB as described in [ITU-T G.671].

Insertion loss of a power splitter depends on the splitting ratio (see [IEC 61753-031-2]). This may be the main contributor to the OPL.

The practical usage of the IFDN splitting ratio is environment dependent. The following table shows the insertion loss (including connection loss between the splitter and fibre) of splitters for different splitting ratios.

Table I.1 – Insertion loss of splitters with a different splitting ratio

Port configuration		1×2	1×4	1×8	1×16	1×32	1×64
Operating wavelength (nm)		1 260 ~ 1 650					
Insertion loss (dB)	Typical	3.5	6.8	10.2	13.1	16.2	20.2
	Maximum	4.0	7.4	10.5	13.5	16.9	21.0
Channel uniformity (dB)		0.5	0.7	1.0	1.4	1.8	2.0

I.2 Splitting architecture

For different environments, the requirements of the IFDN splitting ratio may be different. According to the analysis of the different use cases covered by G.fin, an IFDN splitting ratio of 1:8 is enough for most cases in a home networking environment, whilst the optical link budget Ra can support up to 1:16. This clause analyses optical path loss for different splitting architectures.

a) 1-tier symmetric splitting for an IFDN splitting ratio of 1:16

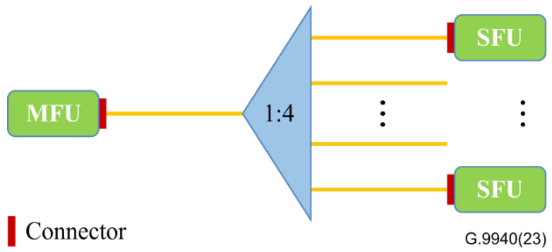

Figure I.2 – 1-tier symmetric splitting with 1:16

For this architecture, 1 km transmission distance and two connectors are considered. Therefore, the maximum optical path loss is 14.9 dB.

$$OPL_{max} = 0.4\text{ dB} + 13.5\text{ dB} + 0.5\text{ dB} * 2$$

b) 2-tier symmetric splitting for an IFDN splitting ratio of 1:16

For multi-tier symmetric splitting, $Loss_{PS_{max}}$ is the sum of the maximum insertion losses of the cascaded splitters for their given splitting ratios according to Table I.1.

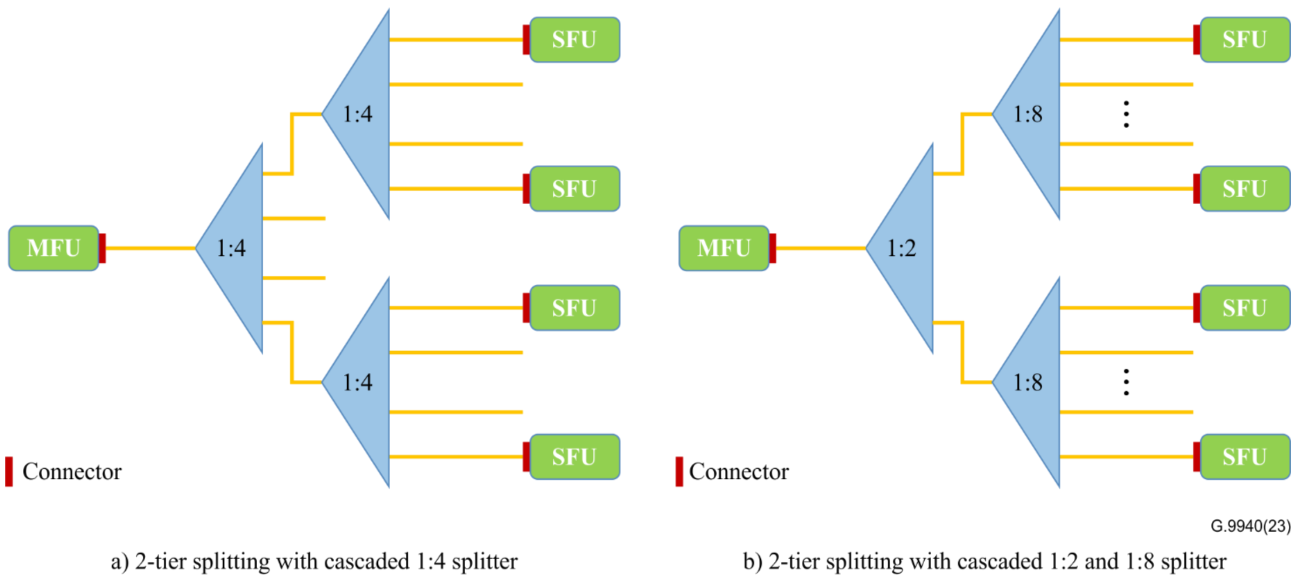

Figure I.3 – 2-tier symmetric splitting architecture

For architecture a) of 2-tier splitting, 1 km transmission distance and two connectors are considered. Then, the maximum optical path loss is 16.2 dB.

$$OPL_{max} = 0.4 \text{ dB } + 7.4 \text{ dB} + 7.4 \text{ dB } + 0.5 \text{ dB} * 2$$

For architecture b) of 2-tier splitting, 1 km transmission distance and two connectors are considered. Then, the maximum optical path loss is 15.9 dB.

$$OPL_{max} = 0.4 \text{ dB } + 4 \text{ dB} + 10.5 \text{ dB } + 0.5 \text{ dB} * 2$$

c) 2-tier asymmetric splitting for an IFDN splitting ratio of 1:9

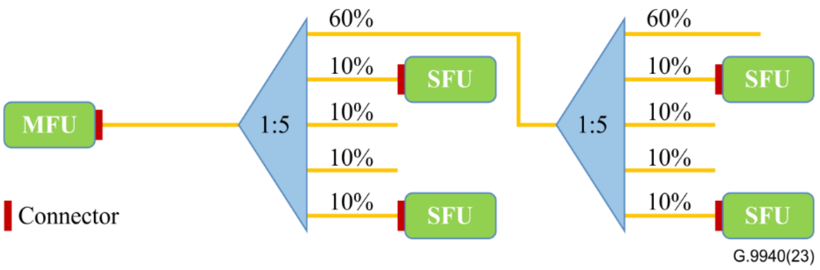

Figure I.4 – 2 tier asymmetric splitting architecture for 1:9

For an architecture of 2 tier asymmetric splitting for 1:9, 1 km transmission distance and two connectors are considered. Then, the maximum optical path loss is 16 dB.

$$OPL_{max} = 0.4 \text{ dB } + 3.2 \text{ dB} + 11.4 \text{ dB } + 0.5 \text{ dB} * 2$$

NOTE – The loss of 3.2 dB and 11.4 dB corresponds to 60% and 10% of the incoming optical signal for the respective ports of the splitter.

d) Direct connection

For the case where only one SFU is connected to the MFU in a home environment. The maximum optical path loss is 1.4 dB. The minimum link loss could be as low as 0 dB in an ideal case.

$$OPL_{max} = 0.4 \text{ dB} + 0.5 \text{ dB} * 2$$

Figure I.5 – Direct connection case

I.3 Optical link budget consideration

From the analysis of optical path loss with different splitting architecture, 16.5 dB is enough for an IFDN splitting ratio of 1:16 with a symmetric splitting architecture, and 1:9 with a 2-tier asymmetric splitting architecture. If a little extra margin for engineering is considered, 17 dB to 18 dB is sufficient for the home environment.

The analysis for the small and medium enterprise environment is left for further study.

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