Next-generation Metallic Access Technologies and Their Standardization Activities

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Abstract

This article introduces certain next-generation metallic access technologies and the standardization activities relating to them under study in the International Telecommunication Union's Telecommunication Standardization Sector (ITU-T) Study Group 15 with a strong focus on G.fast ("G" stands for ITU-T G series of recommendations and "fast" stands for fast access to subscriber terminals) and MGfast (multi-gigabit fast access to subscriber terminals) that can provide optical-fiber-grade ultrahigh-speed transmission services using pre-installed metallic cables in the existing infrastructure. MGfast, which is expected to be a next-generation metallic access technology, targets a transmission rate of 5 to 10 Gbit/s (uplink and downlink combined) over twisted-pair cables and coaxial cables.

Keywords: MGfast, G.fast, access

1. Development of metallic access networks

Question 4, which is responsible for the standardization of metallic access technologies, in the International Telecommunication Union's Telecommunication Standardization Sector (ITU-T) Study Group 15 (SG15) started to develop digital subscriber line (DSL)-related standards in 1998. Asymmetric DSL (ADSL) and very high-speed DSL (VDSL) technologies and standards have been developed by 2010 and provide capabilities supporting Internet access for home users. These technologies have supported the demand for high-speed Internet not only in Japan but also worldwide. Since then, network configurations that bring optical network termination closer to customer premises equipment (CPE), such as fiber to the cabinet (FTTC), fiber to the distribution point (FTTdp), fiber to the building (FTTB), and fiber to the home (FTTH), have been adopted due to the lower cost of optical fibers. One of these configurations connects optical fibers from the central office to the distribution point (DP) then to the CPE using G.fast ("G" stands for ITU-T G series of recommendations and "fast" stands for fast access to subscriber terminals). DPs are located in manholes, utility poles, and basements of apartment buildings, depending on the service provider. G.fast, included in **Fig. 1**, provides a transmission rate of 2 Gbit/s (uplink and downlink combined) over a 50-m twisted-pair cable. MGfast (multi-gigabit fast access to subscriber terminals), the next-generation metallic access technology described in detail in this article, targets a transmission rate of 5 Gbit/s (uplink and downlink combined) over a 30-m twisted-pair cable.

1.1 Ultrahigh-speed access technology G.fast

G.fast was originally standardized in 2014 (G.9700/G.9701) then revised in 2019 to achieve Gbit/s-level transmission rates with substantial expansion of frequency bands (adoption of 106- and 212-MHz profiles) and has the additional functionality of changing the transmission rates of uplink and downlink directions using the time division duplex (TDD) method. Unlike conventional ADSL and VDSL, which use the frequency division duplex (FDD) method, the TDD method allows easy control of the transmission rates in uplink and downlink directions, as shown in the frame structure in **Fig. 2**.

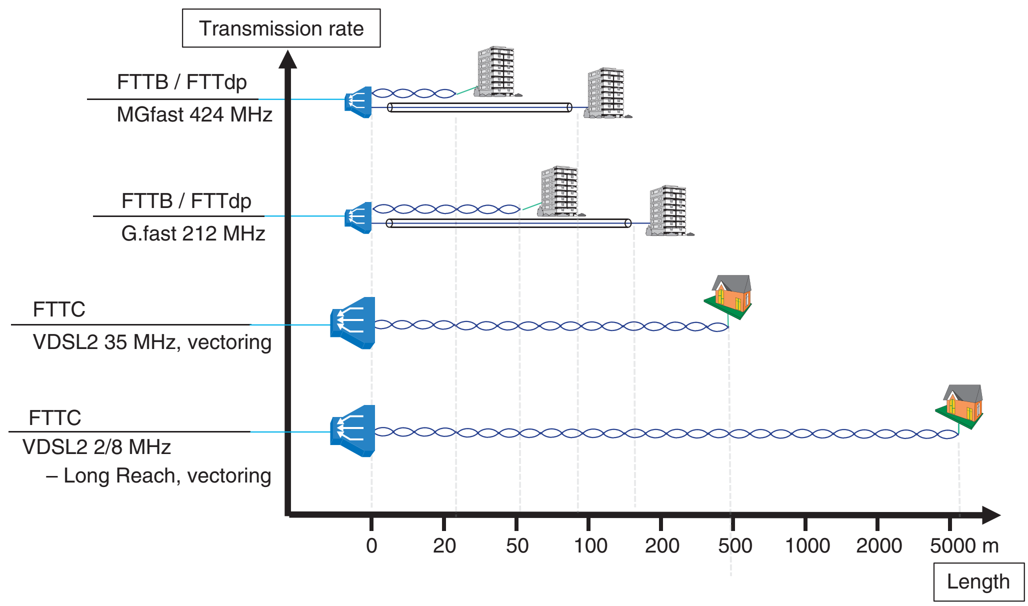

Fig. 1. Metallic access network solutions.

There are also the following features of specific profiling, which are also listed in **Table 1**:

- Transmission over coaxial cables in addition to twisted-pair cables
- Expansion of the transmission distance by increasing the transmission signal power
- Reverse power feeding (power-feeding capability from CPE to distribution point unit (DPU))

It should be mentioned that G.fast (106-MHz profile) is provided in Japan for commercial services for multi-dwelling units.

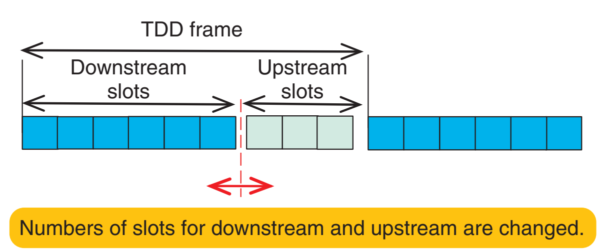

Fig. 2. Frame structure in G.fast.

1.2 Multi-gigabit ultrahigh-speed access technology MGfast

While G.fast was being deployed commercially, it was agreed at the ITU-T SG15 meeting in June 2017 to start developing standards for next-generation ultrafast access technology to achieve further enhancements in functionality and performance. Requirements proposed by service providers in Europe and the U.S. brought about the study of MGfast targeting transmission rates of 5 to 10 Gbit/s. As was the case with G.fast, reliable ultrahigh-speed transmission services of optical-fiber grade are required for next-generation access networks. In transmission systems using metallic cables, signals from neighboring lines result in interference, and how to eliminate such noise (far-end crosstalk noise and near-end crosstalk noise) is a major issue. In DSL technology, which uses a multi-carrier modulation scheme to achieve higher speeds, the subcarrier spacing and number of subcarriers are important system parameters as well as the frequency band used to complete subcarrier-by-subcarrier processing. Although it is effective to increase the number of subcarriers to achieve higher speed, the computational complexity increases accordingly; thus, the subcarrier spacing is generally determined to limit the number of subcarriers. As shown in **Table 2**, the subcarrier spacing is 51.375 kHz and the number of subcarriers is 2048 for G.fast (106-MHz profile). MGfast (424-MHz profile), which is described later, has the same subcarrier spacing, but the number of subcarriers is significantly increased to 8192. In MGfast (848-MHz profile), which is expected to be standardized, the subcarrier spacing is anticipated to

Table 1. Profile specifications in G.fast.

G.fast profiles	106a	106b	212a	106c	212c
Type of cables	Twisted-pair cables			Coaxial cables	
Maximum transmit power	+4 dBm	+8 dBm	+4 dBm	+2 dBm	+2 dBm
Precoding for vectoring	Linear coding			N/A	
Transmission rate with uplink and downlink combined	1 Gbit/s	1 Gbit/s	2 Gbit/s	1 Gbit/s	2 Gbit/s
Minimum frequency	2.2 MHz				
Maximum frequency	106 MHz	106 MHz	212 MHz	106 MHz	212 MHz
Limit PSD mask (LPM)	LPM_106	LPM_106 LPM_106high (downlink)	LPM_212	LPM_106	LPM_212

PSD: power spectral density

Table 2. System parameters for high speed copper access technologies.

DSL technology	Transmission scheme	Frequency band	Subcarrier spacing	Symbol rate	# of subcarriers	Transmission rate	ITU-T standard
VDSL2	FDD	17 MHz	4.3125 kHz	4 kHz	4096	100 Mbit/s	G.993.2
G.fast (106)	TDD	106 MHz	51.375 kHz	48 kHz	2048	1 Gbit/s	G.9700 G.9701
G.fast (212)	TDD	212 MHz	51.375 kHz	48 kHz	4096	2 Gbit/s	
MGfast (424)	FDX	424 MHz	51.375 kHz	48 kHz	8192	5 Gbit/s	G.9710/G.9711

be double.

A full duplex (FDX) method is also effective to increase the transmission rate. However, to avoid interference from near-end crosstalk noise and echo signals, VDSL uses the FDD method, while G.fast uses the TDD method. In this context, MGfast, a newly developed next-generation technology, is aimed at doubling the transmission rate by enabling full-duplexing in the single-pair while eliminating the effects of near-end crosstalk noise and echo signals.

2. Next-generation metallic access technology: MGfast standardization activities

This section describes the technical specifications and standardization status of MGfast, which has been studied in ITU-T SG15. MGfast is a technology to achieve even higher transmission rates while maintaining compatibility with G.fast for easy migration from G.fast systems. MGfast is mainly applicable to apartment buildings.

2.1 Objective of MGfast standardization

Standardization have been undertaken since 2017 with the following objectives:

- Provision of multi-gigabit access technology using twisted-pair cables for plain old telephone services (POTS) and coaxial cables for television services as transmission media, both of which are existing infrastructure
- Provision of symmetric and asymmetric communications with a combined transmission rate of up to 8 Gbit/s uplink and downlink using a frequency bandwidth of up to 424 MHz to achieve optical fiber grade high performance (extension of optical fiber)
- Removal of far-end and near-end crosstalk noise over multiple lines

2.2 Features of MGfast

The following features have been specified to enable easy migration from G.fast systems:

- Uplink and downlink transmission rates changeable by the operational mode of the TDD method
- Impulse noise removal by retransmission processing
- Frequency notch capability (use of the frequency bands in consideration of other services)
- Vectoring capability to eliminate far-end crosstalk noise

- Reverse power-feeding capability

The following new features are specified for the next-generation MGfast technology:

- The 424-MHz profile using frequency bandwidth up to 424 MHz is specified to achieve transmission rates of up to 5 Gbit/s in one direction. Although the specifications are optimized for operation over twisted-pair cables of 30 to 100 m, the specifications allow operation over twisted-pair cables and coaxial cables up to 400 m.
- The FDX method is specified to achieve almost twice the transmission rate over coaxial cables, while reducing the transmission delay at the same time. However, the simultaneous transmission of uplink and downlink signals requires removal of near-end crosstalk noise and echo signals.
- In addition to the forward error correction (FEC) combined trellis coded modulation and Reed-Solomon (RS), which is specified in G.fast, an advanced FEC combining low-density parity check/probabilistic constellation shaping and RS is newly specified. The adoption of this scheme also contributes to the improvement in the transmission rate.
- Quality-of-service classes based on the delay are specified separately for the uplink and downlink directions. This makes it possible to provide low-latency services.
- The point-to-multipoint configuration, in which multiple CPEs are connected to the same line, enables MGfast to meet the diversified needs of home users, unlike conventional VDSL and G.fast. It can change the set of subcarriers serving any particular CPE, which addresses a dynamic redistribution of bandwidth among multiple CPEs depending on traffic demands. Since multiple CPEs are connected to the same line, the Institute of Electrical and Electronics Engineers (IEEE) 802.1X authentication is included to ensure security.

The MGfast related standards consist of the following:

- ITU-T G.9710 published in February 2020: regulatory specifications, including frequency-related and power-spectrum-density-related issues
- ITU-T G.9711 approved in April 2021: system and physical layer specifications for MGfast
- ITU-T G.997.3 approved in April 2021: physical layer OAM (operations, administration and maintenance) specifications

3. Considerations for the future

System development based on the MGfast specifications approved at the ITU-T SG15 meeting held in April 2021 is expected to be accelerated. For service providers who do not have sufficient optical fiber assets, one of the options would be to provide high-performance services of optical-fiber grade using existing metallic cables. The standardization of the next-generation metallic access technologies described in this article is expected to continue to be studied to satisfy the demand for higher speed services by effectively using existing facilities. The following topics have been discussed in the standardization meetings as future themes for metallic access technology.

3.1 Specifications regarding MGfast (848-MHz profile)

The MGfast system for coaxial cables uses a frequency of up to 848 MHz. The doubling of the frequency band, combined with FDX technology, will make it possible to achieve transmission rates of up to 10 Gbit/s in one direction. It will be necessary to study the details of system parameters such as subcarrier spacing and the number of subcarriers, as explained earlier.

3.2 Bundling of multiple G.fast lines (G.fastback)

A project called G.fastback is under consideration as a technology to provide a transmission path between a cabinet and DPU as a single high-capacity line by combining multiple G.fast lines. It should be possible to use multiple metallic cables as an alternative to optical fiber cables with G.fastback technology. As application examples, this configuration would be connected in tandem in a number of stages to increase the distance, while in another example of G.fastback, multiple G.fast lines are bundled where G.fast signals are frequency multiplexed over the existing service lines such as ADSL and VDSL shown in **Fig. 3**. In both cases, the objective is to provide reliable and higher data-rate operations while effectively using metallic cables. Regarding G.fastback, there are several issues to be solved, which include how to eliminate near-end crosstalk noise in DPUs and signal synchronization between lines when multiple lines are connected.

In this article, the next-generation metallic access technologies and standardization activities being

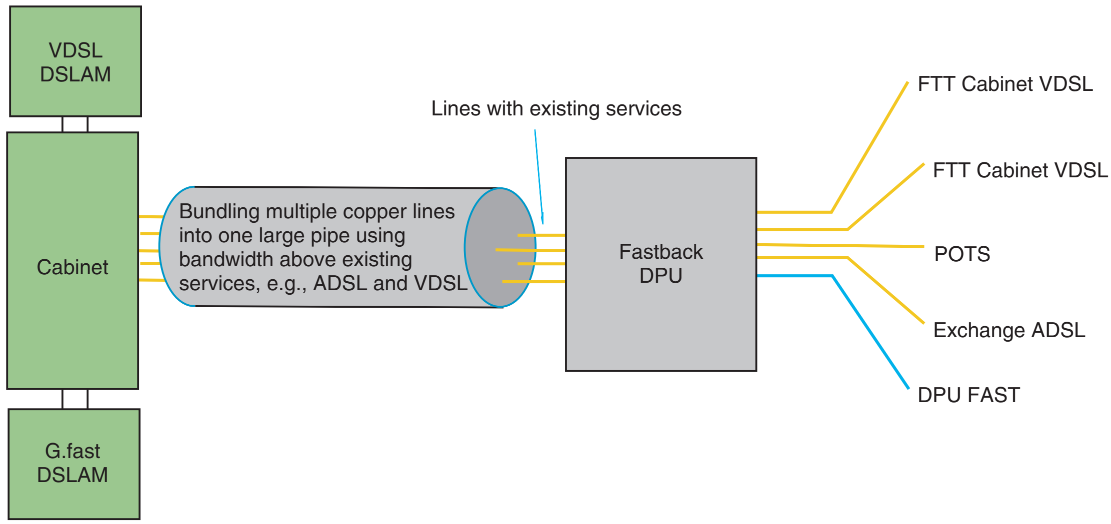

Fig. 3. Deployment scenario of G.fastback.

developed in ITU-T SG15 were described, which can provide ultrahigh-speed transmission operations of optical-fiber grade by using existing metallic cables specified in G.9700 series standards, as an extension of optical fiber in FTTdp and FTTB configurations. It will be necessary to contribute further to the standardization activities mentioned in this article and to cooperate with service providers in Europe and the U.S. to use existing network facilities effectively and economically.

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