G.fast Ultrafast Access Technology Standardization in ITU-T

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Abstract

The International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group 15 (SG15) is the largest Study Group in ITU-T and has been working on the standardization of various issues in transport networks and telecommunication infrastructures, which cover transport technologies in home networks, access networks, packet transport networks, and optical transport networks as well as optical fiber cables. This article explains the latest metallic access technology called G.fast, one of the newest and most active technologies being examined for standardization in SG15. G.fast technology is classified as DSL (digital subscriber line) technology, with which an ultrafast transmission rate of 1 Gbit/s would be available for various services in access networks over metallic cables.

Keywords: G.fast, DSL, ITU-T

1. Introduction

This article introduces the ultrafast digital subscriber line (DSL) technology called G.fast, which is the newest standardization topic to be studied in Question 4 of the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group 15 (SG15). Question 4 concerns the development of standards for broadband access technologies over metallic conductors. SG15 started its work on DSL technologies in 1998, with its first ITU-T DSL-related Recommendation for high-bit-rate DSL (HDSL) technology being finalized in October 1998. That Recommendation covered private-line HDSL 2-Mbit/s and 1.5-Mbit/s services. Following this initial work, several Recommendations were developed under Question 4 up until 2010 based on such technologies as asymmetric DSL (ADSL), very high speed DSL (VDSL), and VDSL with vectoring functionality in order to provide improved Internet access services for public use; these are listed in **Table 1**. These standardization activities together with the development of relevant faster transmission technologies have been a strong driving force in the introduction of broadband Internet services in Japan.

It is worth mentioning that more than 10 million ADSL subscriber lines have been deployed in Japan, and more than 4 million VDSL subscriber lines have been installed in apartment buildings. It should be noted that a great demand for optical broadband access has been driven by this VDSL technology in FTTB (fiber-to-the-building) applications.

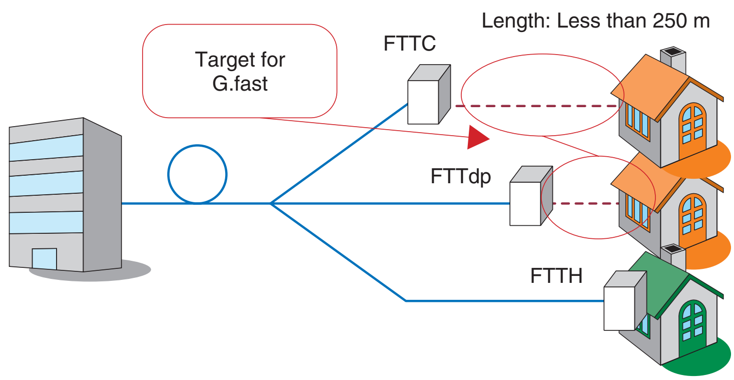
The G.fast standardization project started in December 2010 when ITU-T received a liaison letter from the Broadband Forum (BBF). The liaison letter drew attention to two things; the first was that the BBF planned to produce a white paper describing a set of broadband requirements based on requests from carriers deploying FTTC (fiber to the curb) and fiber to the distribution point (FTTdp), and the second was to ask ITU-T to develop relevant Recommendations that would satisfy the carriers' requests. After receiving this request from the BBF, ITU-T decided to start detailed studies under Question 4 in February 2011.

These G.fast studies cover those requirements issued by multiple carriers within the BBF targeting the areas shown in **Fig. 1**. G.fast technology will involve transmission technology over a distance of up

Table 1. Standards of metallic access technologies.

Technology	Standard	Yr. approved	Data rate	Applications
HDSL	G.991.1	1998	2048 kbit/s	1.5–2 Mbit/s symmetrical service
SHDSL	G.991.2	2001	768 kbit/s	HDSL on a single pair
ADSL	G.992.1	1999	6 Mbit/s / 640 kbit/s	Internet access, multimedia database access, and video distribution
ADSL2	G.992.3	2002	8 Mbit/s / 800 kbit/s	
ADSL2+	G.992.5	2003	16 Mbit/s / 800 kbit/s	
VDSL	G.993.1	2004	52 Mbit/s / 2.3 Mbit/s	Internet access, HDTV service
VDSL2	G.993.2	2006	100 Mbit/s	Internet access, HDTV service over longer loops with more users than VDSL
VDSL2 vectoring	G.993.5	2010	200 Mbit/s	
G.fast	G.9701	2014	1000 Mbit/s	Internet access, 4K TV service

HDTV: high-definition television
SHDSL: single-pair high-speed DSL



FTTH: fiber to the home

Fig. 1. Configurations of access networks: FTTH, FTTdp, and FTTC.

to around 250 m from distribution points where optical transmission is terminated so that subscribers can enjoy ultrafast broadband Internet access services of 1 Gbit/s aggregated (upstream and downstream) transmission rates using existing metallic cables.

The FTTdp project has been coordinated by the standards bodies indicated in **Fig. 2**. As explained above, the BBF initiated the project to consider use cases, corresponding requirements, and the necessary architectures, while ITU-T SG15 has been studying the detailed mechanisms and protocols of G.fast. At the same time, ETSI (European Telecommunication Standards Institute) has begun studying the remote power feeding functionality that would be supplied by remote subscribers. At present, the main concerns of the BBF are various specifications concerning interoperability and conformance tests so that FTTdp systems under development can be deployed commercially in the field.

2. Detailed technical specifications and G.fast standardization activities in ITU-T

The standardization work has been led by major carriers such as AT&T Inc., BT Group plc, Orange S.A., and Swisscom AG, all of which are the original promoters of this technology. The carriers made their requirements clear, enabling system vendors and chip vendors to develop detailed specifications satisfying carriers' requirements and implementing them into

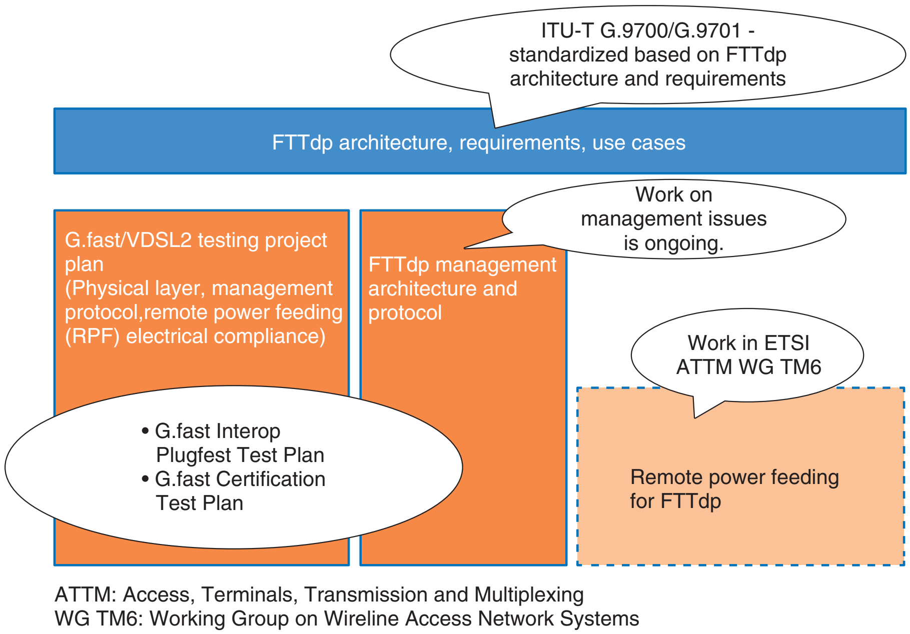


Fig. 2. Overview of FTTdp project in the BBF.

the Recommendations.

2.1 Main characteristics of G.fast

(1) Ultrafast broadband access system over existing metallic cables
(2) Transmission rate of 1 Gbit/s between ONU (optical network unit) that terminates optical fiber and customer premises equipment (CPE)
(3) Specifications relevant to regulations such as frequency and power spectral density (PSD) described in ITU-T Recommendation G.9700
(4) Physical specifications described in ITU-T Recommendation G.9701
(5) Targeted downstream and upstream aggregated transmission rates:
  - 500–1000 Mbit/s for cable length less than 100 m
  - 200 Mbit/s for cable length of 200 m
  - 50 Mbit/s for cable length of 250 m

To achieve the above features, the following core technologies have been implemented:

1) Time division duplex (TDD) multiplexing of downstream and upstream signal transmissions with frequencies as high as 212 MHz. Initially, however, 106 MHz is being utilized. This is different from VDSL, which uses FDD (frequency division duplex) multiplexing of downstream and upstream signal transmissions with frequencies up to 30 MHz.
2) Orthogonal frequency division multiplexing (OFDM) modulation, which is also used in VDSL

2.2 Vectoring functionality

G.fast is considered to be a next generation DSL technology and includes all the functionalities that VDSL provides, including vectoring, which facilitates mitigation of interference caused by far-end crosstalk (FEXT) noise from neighboring cables. The vectoring functionality requires some explanation. Although there are no systems in operation with this vectoring functionality in Japan, there are many carriers in North America and Europe that are deploying systems commercially with the vectoring functionality. Compared with ADSL systems, which are typically used to transmit signals from a telephone central office to CPE installed in subscribers' homes that are located up to a few kilometers away, VDSL systems tend to suffer from strong interference from neighboring lines. VDSL systems were developed to cover areas in which the cable length is less than or equal to about 1 km and to provide services with higher transmission rates than ADSL systems. VDSL is typically considered to be applicable to apartment buildings. Because of these requirements, VDSL systems suffer a lot of interference in the form of FEXT noise from

Table 2. Comparison between G.fast and VDSL2.

Item	ComVDSL2	G.fast
Frequency range	Up to 30 MHz	• 2–106 MHz • 2–212 MHz (planned)
Max rate	• 250 Mbit/s (30a), 150 Mbit/s (17a) • 30–80 Mbit/s in the field	• 1 Gbit/s (Less than 100 m) • 500 Mbit/s or more (100 m)
Modulation	OFDM	OFDM
Number of carriers	4K	2K (106-MHz profile)
Multiplexing scheme	FDD	TDD, synchronized among different copper pairs
Vectoring	G.993.5	G.9701 (mandatory)
Tx power	14.5 dBm (varies by profile)	4 dBm / 8 dBm
Downstream/Upstream ratio	Fixed	Configurable (90:10–30:70)
Retrain time	Very long (30–90 s)	Very short (a few seconds)
Rate adaptation	Very slow (128 carriers at a time)	Very fast (quick and robust adaptation -- within a few ms)
Low power mechanisms	Under development	• Specified discontinuous operation

multiple neighboring VDSL lines when the system is deployed in apartment buildings. To counteract this FEXT interference, ITU-T standardized vectoring functionality. The vectoring works as follows:

1) FEXT interference levels among multiple lines are estimated within a single vectoring group.
2) The degree to which the interference level would be cancelled is calculated based on information on interference levels between relevant lines with respect to FEXT.
3) VDSL transmission power is controlled based on the above calculation.

It is possible to mitigate FEXT interference with this vectoring function and to provide much faster transmission services. It should be noted that vectoring functionality is a key feature of G.fast. Since G.fast is a transmission mechanism used for cable lengths of only a few hundred meters, it would seem logical that G.fast lines experience much more severe FEXT interference than VDSL lines. Therefore, although vectoring is specified as optional in the VDSL Recommendations, Recommendation G.9701 for G.fast specifies this vectoring functionality as mandatory. Although there are some VDSL systems that utilize vectoring with several hundred lines as a vectoring group, the current vectoring function for G.fast systems only works with 16 to 24 lines as a vectoring group. This would indicate that intensive calculations to estimate FEXT interference levels among multiple lines are necessary for vectoring. However, in view of the fact that the vectoring functionality is one of the most essential features of G.fast systems, it is expected that further development of vectoring functionality implementation will accelerate the number of lines that G.fast can handle.

Table 2 lists detailed functionalities and features other than vectoring that are implemented in both VDSL and G.fast systems. Although both technologies use some common mechanisms such as OFDM modulation and FEC (forward error correction), G.fast specifications include much more sophisticated improvements in order to realize an ultrahigh transmission scheme. Some of the details are as follows:

- Extension of frequency bands that would result in a 106-MHz profile and a 212-MHz profile, in order to realize transmission rates of 1 Gbit/s
- Use of TDD mechanism making it possible to change the ratio of upstream and downstream transmission rates
- Realization of low power consumption by both low transmission power mechanisms and the introduction of a new low power mode

G.fast has been standardized with the following ITU-T Recommendations:

- G.9700, approved in April 2014, which specifies items relevant to regulations such as frequency and PSD
- G.9701, approved in December 2014, which specifies physical layer related items
- G.994.1 Amendment 4, approved in December 2014, which specifies code points of G.fast for the initial handshake procedure
- G.997.2, approved in May 2015, which specifies physical layer OAM (operations, administration, and management) functionality
- G.998.2 Amendment 4, approved in August

2015, which specifies Ethernet-based multi-pair bonding for G.fast

3. Next steps for G.fast

Currently, carriers in Europe and North America are examining the performance and capabilities that G.fast technology has shown in their labs and/or field trials, and are considering how this technology could be applied to their access network infrastructures. There seem to be various ways the technology could be deployed in access networks. BT in the UK is considering deploying G.fast distribution point unit (DPU) systems inside cabinets, where the distance from the DPU to the CPE is about 500 m, and also on telephone poles. Swisscom in Switzerland is thinking of deploying DPU systems in manholes where the distance to the CPE is about 150 m, while in Canada, Bell Canada is evaluating whether to deploy DPU systems in the basements of apartment buildings. Almost all of the major carriers in Europe and North America are expected to make the necessary preparations for commercial deployment of G.fast systems based on the results of their tests in labs and/or field trials.

Now that the basic standardization work in ITU-T has been completed, work is moving towards the next phase, taking into account the above-mentioned plans. Specifically, proposals have been made and discussions held on improving the functionality and performance such as raising the transmission signal power, which would result in longer transmission distances, and adding additional frequency bands. Furthermore, G.fast implementation over coaxial cables has recently been proposed. Indeed, it is not only the standardization activities in this field that need to be followed carefully. What the pioneering carriers and vendors are doing is equally important.

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He received an M.S. and Ph.D. in electrical engineering from Northwestern University in Evanston, Illinois, USA, in 1990 and 1994, with a specialization in signal processing. He worked for OKI Electric Industry Co., Ltd., where he developed optical access network systems. He joined NTT Advanced Technology in 2006. Since then, he has been working on standardization of access networking systems, home networking systems, and other areas. He is a member of the Institute of Electronics, Information and Communication Engineers and the Institute of Electrical and Electronics Engineers.