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Digital sections and digital line system – Metallic access
networks

Ethernet-based multi-pair bonding

Recommendation ITU-T G.998.2

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Recommendation ITU-T G.998.2

Ethernet-based multi-pair bonding

Summary

Recommendation ITU-T G.998.2 describes a method for bonding of multiple digital subscriber lines (DSLs) for Ethernet transport. This Recommendation can support single-pair high-bit-rate digital subscriber line (SHDSL), very high-speed digital subscriber line (VDSL) and asymmetric digital subscriber line (ADSL) transport as well as future xDSL technologies as they emerge.

This Recommendation builds on the IEEE 802.3ah-2004 methods and extends Ethernet transport over other xDSL technologies, including ADSL. The Recommendation does not describe the details of the specific xDSL transport technology, but rather, it focuses on the aspects of the physical coding sublayer (PCS) layer modifications required for bonding.

This version of the Recommendation integrates all previous amendments and corrigenda with the 2005 version of ITU-T G.998.2.

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Aggregation, bonding, DSL, encapsulation, Ethernet, IEEE 802.3ah.

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FOREWORD

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Recommendation ITU-T G.998.2

Ethernet-based multi-pair bonding

1 Scope

This Recommendation specifies portions of clause 61 of [IEEE 802.3ah]-2004 amendment to carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specification as a normative reference and identifies the requirements for multi-pair bonding in [IEEE 802.3ah]-2004 that are different in the United States. Further, this Recommendation specifies the requirements for extending the bonding methods in [IEEE 802.3ah]-2004 to xDSL technologies other than very high-speed digital subscriber line (VDSL) and single-pair high-bit-rate digital subscriber line (SHDSL).

This Recommendation has the following four objectives:

- 1) provide support for operation of xDSL technologies on multiple pairs of voice-grade twisted pair cable;
- 2) provide 100 Mbit/s burst data rate at the Ethernet media independent interface using rate matching;
- 3) provide full duplex operation;
- 4) provide a communication channel with a mean bit error rate (BER) at the α/β service interface of less than 10^{-7} .

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.991.2] | Recommendation ITU-T G.991.2 (2003), <i>Single-pair high-speed digital subscriber line (SHDSL) transceivers</i> . |
| [ITU-T G.992.1] | Recommendation ITU-T G.992.1 (1999), <i>Asymmetric digital subscriber line (ADSL) transceivers</i> . |
| [ITU-T G.992.3] | Recommendation ITU-T G.992.3 (2009), <i>Asymmetric digital subscriber line transceivers 2 (ADSL2)</i> . |
| [ITU-T G.992.5] | Recommendation ITU-T G.992.5 (2009), <i>Asymmetric digital subscriber line transceivers 2 (ADSL2) – Extended bandwidth ADSL2 (ADSL2plus)</i> . |
| [ITU-T G.993.1] | Recommendation ITU-T G.993.1 (2004), <i>Very high speed digital subscriber line transceivers (VDSL)</i> . |
| [ITU-T G.993.2] | Recommendation ITU-T G.993.2 (2015), <i>Very high speed digital subscriber line transceivers 2 (VDSL2)</i> . |
| [ITU-T G.994.1] | Recommendation ITU-T G.994.1 (2017), <i>Handshake procedures for digital subscriber line transceivers</i> . |

- [ATIS T1.424] T1.424* (2004), *Interface between Networks and Customer Installation – Very-high-bit-rate Digital Subscriber Lines (VDSL) Metallic Interface (DMT-Based)*.
- [IEEE 802.3-2002] IEEE 802.3-2002, *IEEE Standard for IT – Telecommunications and Information Exchange Between Systems – LAN/MAN – Specific Requirements – Part 3: CSMA/CD Access Method and Physical Layer Specifications*.
- [IEEE 802.3-2005] IEEE 802.3-2005, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*.
- [IEEE 802.3ah] IEEE 802.3ah-2004, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specification – Amendment: Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 10PASS-TS: The IEEE 802.3 standard for delivering single and multi-pair Ethernet transport over ITU-T G.993.1 (MCM) transceivers.

3.2.2 2BASE-TL: The IEEE 802.3 standard for delivering single and multi-pair Ethernet transport over ITU-T G.991.2 transceivers.

3.2.3 aggregation group: A collection of lines that may be aggregated into a single Ethernet interface.

3.2.4 carrier sense: In a local area network, an ongoing activity of a data station to detect whether another station is transmitting.

NOTE – The carrier sense signal indicates that one or more DTEs are currently transmitting.

3.2.5 collision: A condition that results from concurrent transmissions from multiple data terminal equipment (DTE) sources within a single collision domain.

3.2.6 downstream: Direction from central office to remote terminal.

3.2.7 media independent interface: In IEEE 802.3, a transparent signal interface at the bottom of the Reconciliation sublayer.

3.2.8 physical medium attachment: That portion of the physical layer that contains the functions for transmission, reception collision detection, clock recovery and skew alignment.

* T1 standards are maintained since November 2003 by ATIS.

3.2.9 physical medium dependent: That portion of the physical layer responsible for interfacing to the transmission medium. The physical medium dependent (PMD) is located just above the medium dependent interface (MDI).

3.2.10 physical media entity: In IEEE 802.3-2005, a reference to an individual transceiver contained within an aggregate group where a transceiver carries only one packet stream. This Recommendation also supports operation over transceivers carrying multiple (at gamma interface logically separated) packet streams. In this Recommendation, a physical media entity (PME) is a reference to one logical channel out of a set of one or more channels on the same individual transceiver. Each such PME carries a single packet stream and is contained within one aggregate group.

NOTE 1 – In case preemption is used on a bearer channel, two PMEs each reference one of the two logical channels on the same bearer channel. In case pre-emption is not used on a bearer channel, a PME defaults to a reference to the one bearer channel.

NOTE 2 – Although such a PME cannot be physically isolated within a transceiver carrying multiple packet streams, the naming PME is maintained for consistency with IEEE 802.3-2005 and for consistency in case the transceiver carries only one packet stream.

3.2.11 remote terminal: A terminal located downstream from a central office switching system.

3.2.12 upstream: Direction from remote terminal to central office.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations:

α	the interface between the PMS-TC and TPS-TC layers at a CO
β	the interface between the PMS-TC and TPS-TC layers in CPE
γ	the interface between the TPS-TC layer and the PCS layer
ADSL	Asymmetric Digital Subscriber Line
ANSI	American National Standards Institute
ATIS	Alliance for Telecommunications Industry Solutions
BACP	Bonding Allocation Control Protocol
BACPDU	BACP Data Unit
BCE	Bonding Control Engine
BER	Bit Error Rate
CL	Capabilities List
CLR	Capabilities List Request
CO	Central Office
CPE	Customer Premises Equipment
CRC	Cyclic Redundancy Check
CS	Carrier Sense
CSMA/CD	Carrier Sense Multiple Access/Collision Detection
DSL	Digital Subscriber Line
DSLAM	DSL Access Multiplexer
DTE	Data Terminal Equipment

DTU	Data Transfer Unit
EFM	Ethernet in the First Mile
EMS	Element Management System
FEC	Forward Error Correction
FIFO	First In, First Out
GID	Group ID
HDLC	High-level Data Link Control
MAC	Media Access Control
MCM	Multi-Carrier Modulation
MII	Medium Independent Interface
MP	Mode Proposal
MS	Mode Select
MSB	Most Significant Bit
OAM	Operations, Administration, and Maintenance
PAF	PMA Aggregation Function
PCS	Physical Coding Sublayer
PHY	Physical Layer Entity Sublayer
PMA	Physical Medium Attachment
PMD	Physical Medium Dependent
PME	Physical Media Entity
PMS-TC	Physical Media-Specific TC Layer
PTM	Packet Transfer Mode
SFD	Start Frame Delimiter
SHDSL	Single-Pair High-bit-rate DSL
TC	Transmission Convergence layer
TC-CRC	Transmission Convergence – Cyclic Redundancy Check
TLV	Type Length Value
TPS-TC	Transmission Protocol-Specific TC Layer
VDSL	Very High-speed Digital Subscriber Line
xDSL	a collective term referring to any of the various types of DSL technologies

5 Technologies addressed and architecture

This clause addresses technology specific parameters for some bonded physical layer entity sublayers (PHYs). The values presented here were derived from the rules set forth in clause 61 of [IEEE 802.3ah]-2004. Other PHYs may be addressed by following these rules.

5.1 Technologies nomenclature

Large portions of this Recommendation reference the IEEE 802.3ah-2004 specification. A cross-reference to the technology nomenclature, and a reference to the relevant standards, are given in Table 1.

Table 1 – Technology nomenclature

Reference in this Recommendation	IEEE 802.3ah-2004 reference	Relevant standard
VDSL	10PASS-TS	[ATIS T1.424]
SHDSL	2BASE-TL	[ITU-T G.991.2]
ADSL	N/A	[ITU-T G.992.1]

As shown in Table 1, the IEEE reference to 10PASS-TS is the IEEE 802.3 standard for transporting Ethernet using a multi-carrier modulation (MCM)-VDSL-based PHY. Likewise, 2BASE-TL is the IEEE 802.3 standard for transporting Ethernet using an SHDSL-based PHY. There is no IEEE standard for transporting Ethernet over asymmetric digital subscriber line (ADSL), though that operation is clarified in this Recommendation.

5.2 System considerations

The copper PHYs addressed by this Recommendation are only defined for full duplex operation as defined in the IEEE 802.3 specification.

5.3 Relationship between IEEE 802.3ah-2004 terminology and layering (informative)

The physical coding sublayer (PCS) contains two functions: media access control (MAC)-PHY rate matching and physical media entity (PME) aggregation. The functional position of the PCS is shown in Figure 1.

The γ -interface and the $\alpha(\beta)$ -interface are generic interfaces used in various digital subscriber line (xDSL) specifications such as the ones referenced in clause 2. The $\alpha(\beta)$ -interface is a simple octet-synchronous data interface; the γ -interface add protocol-awareness.

For physical medium dependent (PMD), the bit rates in the shaded area labelled "PMD rate domain" are derived from the DSL bit rates. Data is transferred across the γ -interface at the rate imposed by the lower layers. The bit rates in the shaded area labelled "100 Mbit/s rate domain" are synchronous to the medium independent interface (MII) rate. Data is transferred across the MII at the rate of one nibble per MII clock cycle. The MAC-PHY rate matching function adjusts the inter-packet gap so that the net data rate across this interface matches the sum of rates across the γ -interface.¹

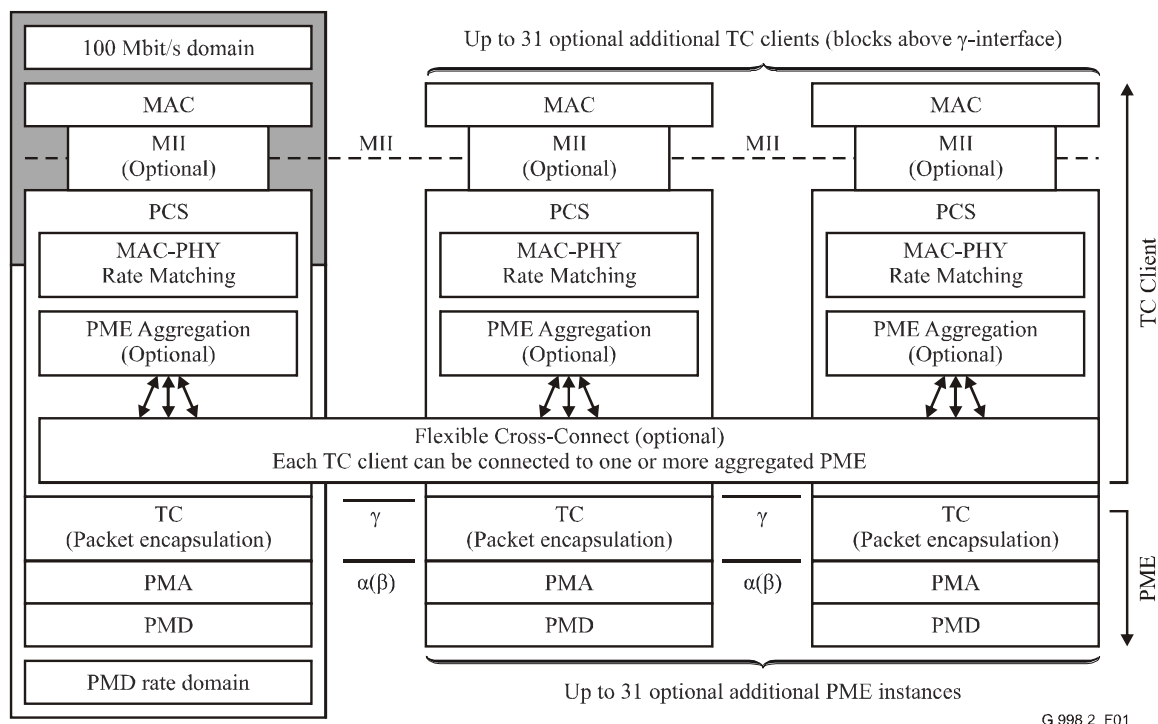
In the transmit direction, frames are transferred from the MAC to the PCS across the MII when the MAC-PHY rate matching function allows this. In the PCS, preamble and start frame delimiter (SFD) octets are removed. The data frame is fragmented by the physical medium attachment (PMA) aggregation function (PAF), and fragments are forwarded, optionally through a flexible cross-connect, towards each of the aggregated PME instances via the γ -interface. The transmission convergence layer (TC) accepts data from the MAC-PHY rate matching function or the PAF, at the rate at which it can be processed by the TC sublayer, by asserting Tx-Enbl on the γ -interface.

The optional flexible cross-connect function may be present to provide access from a centralized bonding function (PAF) to TCs on lines distributed throughout a system. The method by which frames

¹ Bit domains and physical clock domains do not necessarily coincide. The TC sublayer receives as clock signal from the PMA via the $\alpha(\beta)$ -interface, and a clock signal from the optional PAF or the MAC-PHY Rate Matching function via the γ -interface. The TC provides matching between the two clock domains.

are transferred between the bonding function and the various TCs in the bonded group is outside the scope of this Recommendation.

In the receiver direction the TC sublayer pushed data to the PAF (if present) or the MAC-PHY rate matching function by asserting Rx_Enbl on the γ -interface. The PAF reassembles the received fragments into data frames. Preamble and SFD octets are generated and prepended to the data frame prior to passing it up to the MAC across the MII. The MAC-PHY rate matching function may delay the transfer of the frame to avoid simultaneous transfer of transmit and receive frames if required.



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Figure 1 – Overview of PCS functions

Figure 2 compares the ITU layering with the IEEE layering by showing the relative positions of the γ and $\alpha(\beta)$ interfaces and the relevant architectural blocks. Some things to note include:

- 1) In [IEEE 802.3ah]-2004, the entire function of a bonded group (taking in/out frames, fragmenting/reassembly across multiple lines, encapsulating fragments on a line, etc.) is referred to as the PCS function. In Figure 2, two lines are shown being aggregated into the leftmost PAF function in both protocol stacks.
- 2) Since [IEEE 802.3ah]-2004 has only a single TPS-TC (it defines only 64/65-octet encapsulation as the TPS-TC), the TPS-TC function is abbreviated TC.
- 3) [IEEE 802.3ah]-2004 requires a rate matching function to provide an interface between the well-defined 100 Mbit/s Ethernet MAC and the variable rate aggregation function. The ITU protocol stack does not require the use of the standard Ethernet MAC, and thus, no rate matching function is required.

As shown in the diagram, the protocol stacks are very similar, but have terminology and architectural differences related to the historical terminology and architecture of the individual standards organization.