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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Access networks

ATM-based multi-pair bonding

ITU-T Recommendation G.998.1

ITU-T G-SERIES RECOMMENDATIONS
TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
General	G.900–G.909
Parameters for optical fibre cable systems	G.910–G.919
Digital sections at hierarchical bit rates based on a bit rate of 2048 kbit/s	G.920–G.929
Digital line transmission systems on cable at non-hierarchical bit rates	G.930–G.939
Digital line systems provided by FDM transmission bearers	G.940–G.949
Digital line systems	G.950–G.959
Digital section and digital transmission systems for customer access to ISDN	G.960–G.969
Optical fibre submarine cable systems	G.970–G.979
Optical line systems for local and access networks	G.980–G.989
Access networks	G.990–G.999
QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DIGITAL TERMINAL EQUIPMENTS	G.7000–G.7999
DIGITAL NETWORKS	G.8000–G.8999

For further details, please refer to the list of ITU-T Recommendations.

ITU-T Recommendation G.998.1

ATM-based multi-pair bonding

Summary

This Recommendation describes a method for bonding of multiple digital subscriber lines (DSL) to transport ATM streams. The specifications of this Recommendation provide a complete description of startup, operational, and contingency modes of operation which allows for interoperability between vendors.

This Recommendation includes the following types of requirements, recommendations, and information for defined DSL systems, including:

- higher-layer transport-independent requirements;
- higher-layer transport-dependent, e.g., ATM, requirements.

Source

ITU-T Recommendation G.998.1 was approved on 13 January 2005 by ITU-T Study Group 15 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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CONTENTS

Page

1	Scope	1
2	References.....	1
3	Definitions	2
4	Abbreviations and acronyms	2
5	Overview	4
6	Mode of operation.....	5
6.1	Sequencing payload traffic	5
6.2	Bonding Group ID (GID) and Management Entity (ME).....	5
6.3	Autonomous Status Messages (ASMs)	6
6.4	Link eligibility and link activation	6
6.5	Measurement of bonding group differential delay	8
6.6	Compensation of differential delay by the CPE transmitting entity.....	8
7	Reference models.....	9
7.1	User plane protocol reference model.....	9
7.2	Bonding sublayer in layer reference model.....	10
7.3	Functional reference model	10
8	Cell header formats.....	11
8.1	Autonomous Status Messages (ASM).....	11
8.2	Idle and unassigned cells	11
8.3	OAM and ATM payload cells	11
8.4	HEC errors.....	11
9	Bonding group internal control protocol	11
9.1	Types of control message	11
10	Initialization.....	18
11	External management	20
11.1	OAM interface primitives.....	20
11.2	OAM channel between NMS and bonding entity	21
11.3	Cell rate adjustment.....	21
11.4	MIB elements	22
	Appendix I – Optional initialization procedure facilitating spectral optimization	23
	Appendix II – Sample initialization for the ATM bonding protocol	24
	Appendix III – Link status state machine	26
	Appendix IV – Example of algorithm to derive the end-to-end delay.....	27
	BIBLIOGRAPHY	28

ITU-T Recommendation G.998.1

ATM-based multi-pair bonding

1 Scope

The purpose of this Recommendation is to assist manufacturers, providers, and users of products on how to use multiple DSL lines to carry a single ATM payload stream. In order to satisfy this purpose, requirements and guidelines are provided. This Recommendation is written to satisfy the following bonding objectives:

- 1) bonding shall support dynamic removal and restoration of pairs without human intervention;
- 2) bonding shall support disparate data rates, up to a ratio of 4-to-1 (fastest to slowest), amongst its pairs;
- 3) the protocol shall allow bonding of 2-32 pairs;
- 4) the protocol shall permit bonding of randomly assigned ports on an access node;
- 5) the protocol shall be PHY independent;
- 6) the protocol shall incur a maximum overall one-way bonding delay of 2 ms.

In order for implementations compliant to this Recommendation to be interoperable between vendors, an initialization procedure, a payload tagging method, and OAM capability are provided.

The applications supported within this Recommendation relate to bonding of multiple DSL loops to deliver ATM payload beyond the rate/reach capability of a single DSL loop. Each ATM TPS-TC (assuming multiple bearer channels) shall operate in an independent bonded group. As described within this Recommendation, the customer premises equipment (CPE) represents the User-Network Interface (UNI) to the ATM network.

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

- [1] ITU-T Recommendation G.992.3 (2005), *Asymmetric digital subscriber line transceivers2 (ADSL2)*.
- [2] ITU-T Recommendation G.994.1 (2003), *Handshake procedures for digital subscriber line (DSL) transceivers*.
- [3] ITU-T Recommendation G.997.1 (2003), *Physical layer management for digital subscriber line (DSL) transceivers*.
- [4] ITU-T Recommendation I.363.5 (1996), *B-ISDN ATM Adaptation Layer specification: Type 5 AAL*.

3 Definitions

This Recommendation defines the following terms:

3.1 carrier: An organization that provides telecommunications services to customer installations.

3.2 central office: In this Recommendation, the telephone building that is the origin of the outside loop plant.

3.3 customer installation: All cabling and equipment on the customer side of the network interface.

3.4 customer premises equipment: Telecommunications equipment located at the customer installation on the customer side of the network interface. For the purposes of this Recommendation, it is defined as multiple receivers that aggregate traffic from multiple lines into one ATM stream.

3.5 downstream: The direction of transmission from the carrier central office to the customer installation.

3.6 Inverse Multiplexing over ATM (IMA): IMA is used in this Recommendation to refer to ATM Forum specifications, not the bonding method of this Recommendation.

3.7 loop: A communication path between the distributing frame in a carrier central office and the network interface at a customer location.

3.8 network: All equipment and facilities, including loop plant, located on the carrier side of the network interface.

3.9 network interface: The physical demarcation point between carrier network loop facilities and the CI.

3.10 pair: Two insulated conductors.

3.11 showtime: A mode of operation of DSL modems that corresponds to transmission of live user data. It follows as a last step after all initialization and retraining procedures.

3.12 upstream: The direction of transmission from the customer installation to the carrier Central Office.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations:

AAL 5	ATM Adaptation Layer 5
ADSL	Asymmetric Digital Subscriber Line
ANSI	American National Standards Institute
ASM	Autonomous Status Message
ATM	Asynchronous Transfer Mode
ATM-TC	ATM Transmission Convergence (sublayer)
CAC	Connection Admission Control
CI	Customer Installation (see definition)
CLP	Cell Loss Priority
CO	Central Office (see definition)
CPE	Customer Premises Equipment (see definition)

CRC	Cyclic Redundancy Check
DS	Downstream
DSL	Digital Subscriber Line
FE	Far End
GID	Group Identifier
GFC	Generic Flow Control
HEC	Header Error Control
ICP	IMA Control Protocol (cell)
IMA	Inverse Multiplexing over ATM (see definition)
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
ME	Management Entity
MIB	Management Information Base
ms	Millisecond
NE	Near End
NI	Network Interface (see definition)
NMS	Network Management System
OAM	Operations, Administration and Maintenance
PHY	Physical layer
PMD	Physical Media Dependent (sublayer)
PMS-TC	Physical Media-Specific Transmission Convergence (sublayer)
PTI	Payload Type Identifier
Rx	Receive
SAR	Segmentation And Reassembly
SID	Sequence Index
SNMP	Simple Network Management Protocol
TPS-TC	Transport Protocol Specific – Transmission Convergence (sublayer)
TU-C	Transceiver Unit – Central office end. Sometimes combined with another letter; e.g., ATU-C for a central office ADSL transceiver
TU-R	Transceiver Unit – Remote terminal end. Sometimes combined with another letter; e.g., ATU-R for a remote ADSL transceiver
Tx	Transmit
UNI	User-Network Interface
US	Upstream
UTOPIA	Universal Test and Operations PHY Interface for ATM
VC	Virtual Channel
VCI	VC Identifier
VP	Virtual Path

5 Overview

An illustration of the bonding system for transport of an ATM payload across several DSL lines with disparate data rates is provided in Figure 1 below. In traditional inverse multiplexing over ATM (IMA) as specified in the ATM Forum document, Inverse Multiplexing for ATM (IMA) Specification, Version 1.1 [B1], it is assumed that all bonded links operate at the same nominal rate. The original cells are not modified, and control (ICP) cells are inserted for OAM communication between the two ends. In this Recommendation, each cell is tagged with a Sequence ID (SID). The transmitter may place any cell on any link, and the receiver can reassemble the original sequence.

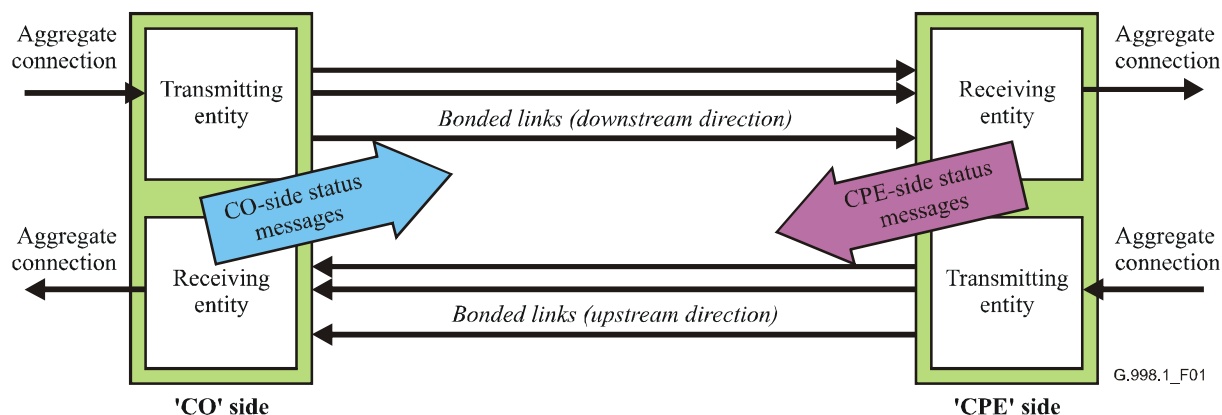


Figure 1/G.998.1 – Status message flow. Each transmission direction is treated independently

A bonding group is defined as a bidirectional ATM stream transported by multiple bidirectional bearers across multiple physical media in both upstream and downstream directions.¹ A single bonding group cannot span multiple CPE entities or CO-side access nodes. As a consequence, the control channel is also a bidirectional ATM stream, consisting of ATM messages called Autonomous Status Messages (ASMs). The content and sequence of these messages defines a control protocol between the two bonding entities in both directions. Some implementations may support multiple bearers on each physical link. Different bearers on the same line shall never be bonded together into the same group.

The control protocol communicates the status of each link in the bonding group. The way a bonding group is defined at startup, maintained during operation, and put out of service is discussed below.

The underlying bit rate of the individual links within a bonded group may be freely and independently changed by their respective PHY layers.² It is the responsibility of the transmitter not to overrun PHY transmit buffers, nor add delay created by excess buffering (by either carefully controlling the PHY bit rate itself, by allowing the PHY bit rate to "float" and then honoring back pressure, or by monitoring instantaneous bit rate and rate shaping its transmissions, matching multiplex ordering to rates, etc.).

¹ It should be noted that the upstream and downstream rates may be different.

² Resultant changes in bit rate are subject to constraints of buffer size, number of lines, and differential delay. The 4-to-1 ratio is not a hard limit, and may be violated provided these other constraints are satisfied.

6 Mode of operation

6.1 Sequencing payload traffic

The method for bonding ATM paths defined in this Recommendation is to tag each ATM cell with an 8-bit or 12-bit Sequence Index (SID)^{3,4}, which is done by replacing bits in the ATM header with SID bits between bonding entities and, depending on implementation, may recalculate the HEC. Although cells may be transmitted along paths with different delays, changing bit rates, and non-stationary delays, receivers can temporarily store incoming cells and use the SID to determine their original order.

Within the group, the SID increments consecutively from '0' through '255' (8-bit SID) or '0' through '4095' (12-bit SID), and wraps around to '0' again. After assembling the aggregate cell stream, these SID bits are replaced with zeros at the receiver. A transmitter shall never skip any of the sequence indices in this sequence.

The ATM cell header mappings are shown in Figure 2. CPE shall support all configurations. The CO may support either (or both) formats, but only one format shall be used in any given bonded group.

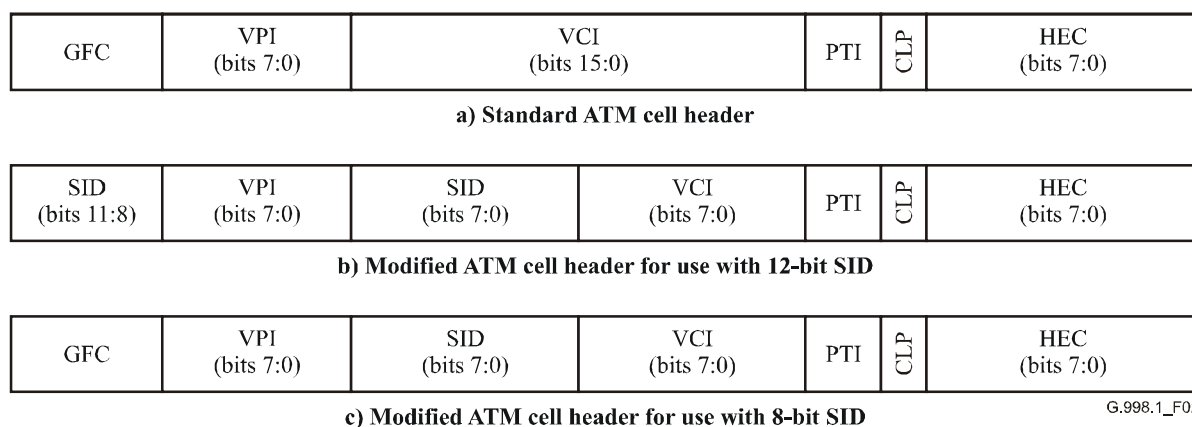


Figure 2/G.998.1 – Standard and modified ATM cell headers

6.2 Bonding Group ID (GID) and Management Entity (ME)

As shown in Figure 1, each side of a bonding group has a transmitting and a receiving entity. The bonding group operating from the Central Office (CO) side towards the Customer Premises Equipment (CPE) side has a unique Group ID (GID) assigned by the CO bonding management entity (bonding ME). The corresponding bonding group operating from the CPE side towards the CO side shall use the same GID (by definition), which it dynamically learns during initialization. All links within a bonding group shall use the same group ID in both the upstream and downstream directions. The ME also assigns the Tx link number to each of the links in the bonding group. The

³ In this Recommendation, 8 and 12 bits of sequence index space have been defined. Note that the use of a particular SID is bounded by the aggregate rate, differential delay, and number of links. Implementations are not compelled to provide buffer space to accommodate the full range of sequence indices and are free to provide a sufficient but smaller number of buffers to suit their target application.

⁴ Implementations should equalize latency on each link. However, when bonding DSL types that may have different latencies due to different values in PHY layer parameters, implementations should be able to tolerate at least 4 ms of differential delay. Differences in electrical length will not contribute significantly to the differential delay. No additional buffer is required for this variation.