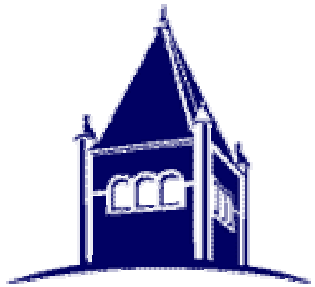

ITU-T G.994.1 (G.hs)

Handshake Procedures for Digital Subscriber Line (DSL) Transceivers

A detailed look at G.hs and how it works

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2003

Presentation Overview

- Physical Layer Signaling
  - Modulation
- “Handshaking for G.hs”
  - Session Startup
  - Session Cleardown
- Messages
  - Format
  - Error Checking
  - Types
  - Frames
  - Fields
  - Octet Transparency
  - Segmentation
- Field Structure
  - Parameter Fields
  - Delimiting Bits

Some Definitions

- HSTU – Hand Shaking Transceiver Unit
- xTU-C – xDSL Transceiver Unit (Central Office)
  - xTU-R – See above (Remote Unit)
  - HSTU-C – See above.
- Transaction – A sequence of G.hs messages.
- Session – Contains startup procedure, one or more transactions, and a clear-down procedure.

Physical Layer Signaling

- 4 Carrier sets currently defined.
  - A43, B43, C43, A4
- Carriers are FDM, at frequencies defined in the following tables.
- The carriers are DPSK modulated (more on this later).

Physical Layer Signaling (cont)

- A43, B43, C43 Carrier Sets
  - Use three carriers transmitted in each direction on three different frequencies.
  - All three carriers transmit the same information, and the median average of the three is the data the receiver actually parses.
  - Carriers are full duplex only.
- A4 Carrier Sets
  - Use single carrier in each direction.
  - Carriers are half duplex only.

Description of 4.3 kHz Family

Table 1/G.994.1 – Carrier sets for the 4.3125 kHz signalling family

Carrier set designation	Upstream carrier sets		Downstream carrier sets		Transmission mode
	Frequency indices (N)	Maximum power level/carrier (dBm)	Frequency indices (N)	Maximum power level/carrier (dBm)	
A43	9 17 25	–1.65	40 56 64	–3.65	duplex only
B43	37 45 53	–1.65	72 88 96	–3.65	duplex only
C43	7 9	–1.65	12 14 64	–3.65	duplex only

Description of 4 kHz Family

Table 3/G.994.1 – Carrier sets for the 4 kHz signalling family

Carrier set designation	Upstream carrier sets		Downstream carrier sets		Transmission mode
	Frequency indices (N)	Maximum power level/carrier (dBm)	Frequency indices (N)	Maximum power level/carrier (dBm)	
A4	3	+5	5	+5	half-duplex only

Current Use of the Carrier Sets

Table 2/G.994.1 – Mandatory carrier sets

xDSL Recommendation(s)	Carrier set designation
G.992.1 – Annex A, G.992.2 – Annex A/B	A43
G.992.1 – Annex B	B43
G.992.1 – Annex C, G.992.2 – Annex C, G.992.1 – Annex H	C43

Table 4/G.994.1 – Mandatory carrier sets

xDSL Recommendation(s)	Carrier set designation
G.991.2	A4

DPSK Modulation

- Differential Encoded Binary Phase Shift Keying
- Modulation of a serial bit stream, ideal for something such as G.hs.
- Requires no phase reference to demodulate.
- Symbol rate depends on Carrier Set.
  - A43, B43, or C43 use 4312.5/8 = 539.0625 symbols/sec.
  - A4 uses 4000/5 = 800 symbols/sec.

DPSK Example

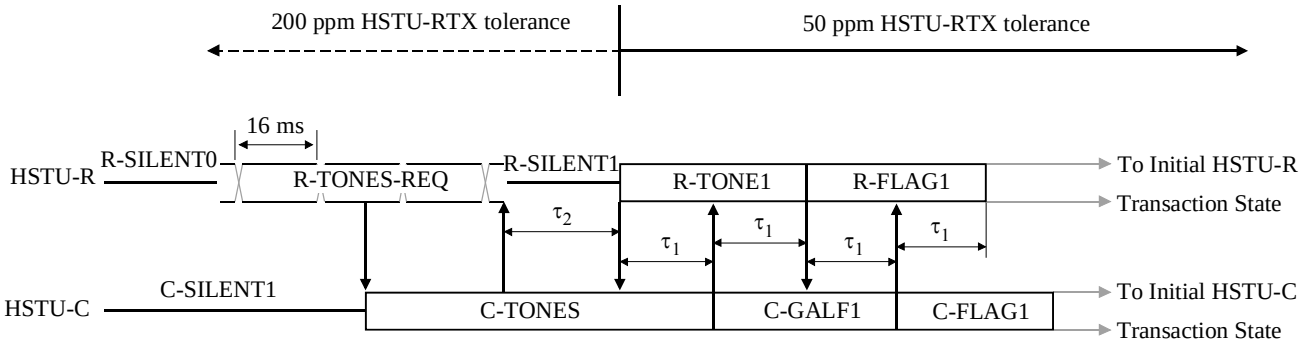
Data to Encode	0	1	1	1	1	1	1	0	
Differential Data	1	1	0	1	0	1	0	1	1
Phase	180	180	0	180	0	180	0	180	180
Decoded Phase		-	+	+	+	+	+	+	-
Decoded Data		0	1	1	1	1	1	1	0

- The above table shows the process to encode/decode a BPSK signal.
- Serial Binary data is first differentially encoded.
- Each set bit in the differential data represents a transmitted phase of 180 degrees for the symbol period.
- To decode the received signal, the phase changes have to be detected.
- The detected phase changes are then converted back to the original binary message.

Handshaking for G.hs

- Known as Start-up and Clear-down procedures.
- Actually allows the xTU-C to detect the initial presence of the xTU-R on the line.
- Allows for a clean start of a G.hs session, prior to sending any G.hs messages.
- 4 Different Start-ups and 2 different Clear-downs defined
  - Full / Half Duplex
  - xTU-C / xTU-R

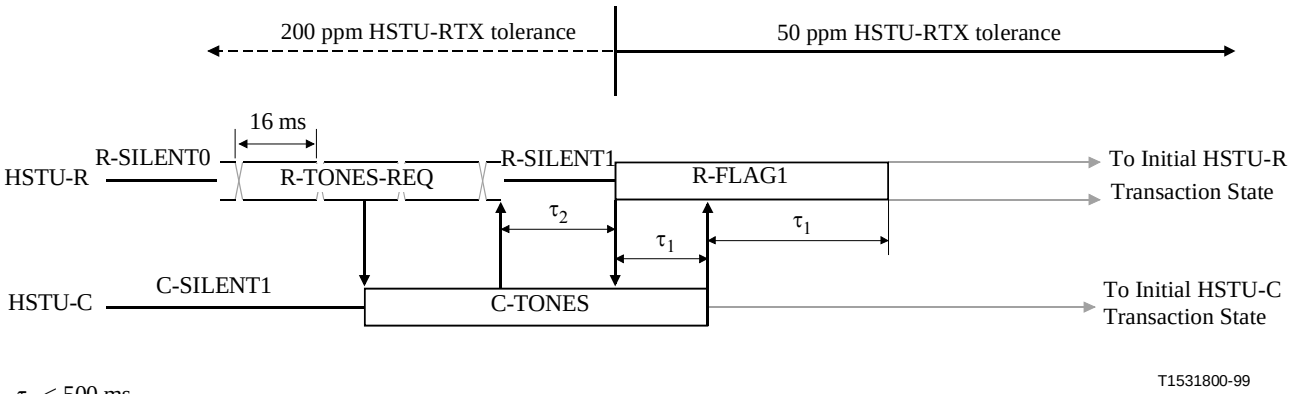
Start-up Figures



τ_1 < 500 ms

50 ms < τ_2 < 500 ms

Figure 14/G.994.1 – HSTU-R initiated duplex start-up procedure



τ_1 < 500 ms

50 ms < τ_2 < 500 ms

Figure 16/G.994.1 – HSTU-R initiated half-duplex start-up procedure

Clear-down Figures

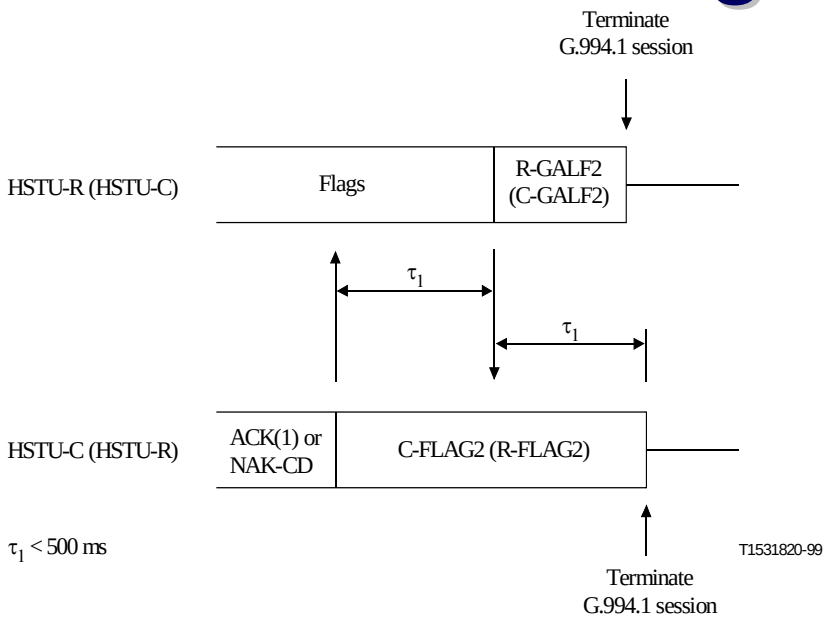


Figure 18/G.994.1 – Duplex cleardown procedure

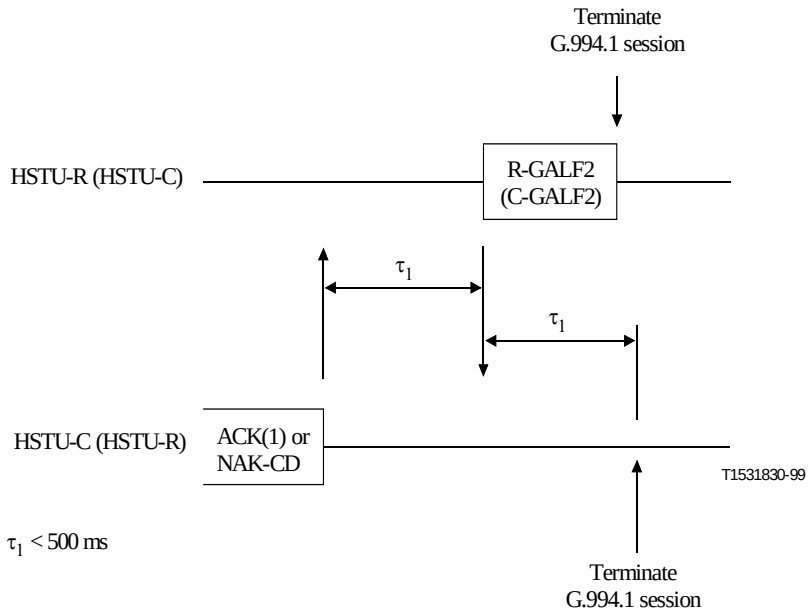


Figure 19/G.994.1 – Half-duplex cleardown procedure

G.hs Messages

- Messages are the “top level data type.”
- A message may be segmented in to more than one frame (more on this in a bit).
- Each message may contain up to, but it’s not mandatory, 3 fields (more on that later).
  - I-Field – Information field (not xDSL specific)
  - S-Field – Standard Information field (xDSL specific)
  - NS-Field – Non-standard Information field (vendor specific)

Identification (I) field	Standard information (S) field	Non-standard information (NS) field

I-Field Structure

Message type field	Revision number field	Vendor ID field	Bit-encoded parameter field

- Message Type – 1 octet specifying the message type.
- Revision Number – 1 octet, Revision 1 or 2.
  - For backwards compatibility.
- Vendor ID Field – 8 octet field (just wait a bit and I'll show you what this looks like), not mandatory.
- Parameter Field – Arbitrary length, (2 – n) octets.
  - Is a bit-encoded set of parameters.
    - More on this structure later.
  - Contains information such as:
    - If NS-Field is present.
    - Splitter information
    - Relative power levels of each carrier.

Message Types

- CLR – Capabilities List Request
- CL - Capabilities List
- MR – Mode Request
- MS – Mode Select
- MP – Mode Propose
- ACK(1) – Acknowledge, Type 1
- ACK(2) - Acknowledge, Type 2
- NAK-EF – Negative Acknowledge, Errored Frame
- NAK-NR - Negative Acknowledge, Not Ready
- NAK-NS – Negative Acknowledge, Not Supported
- NAL-CD – Negative Acknowledge, Clear Down
- REQ-MS – Request MS Message
- REQ-MR – Request MR Message
- REQ-CLR – Request CLR Message

Vendor ID Field Structure

Table 7/G.994.1 – Vendor ID information block

T.35 country code (2 octets – see Note 1)
provider code (vendor identification) (4 octets – see Note 2)
vendor-specific information (2 octets)

NOTE 1 – If the bits in the first octet are not all set to binary ONE, the bits in the second octet shall be set to binary ZERO by the transmitter and ignored by the receiver. The only purpose of the country code is to identify the country of registry of the provider code.

NOTE 2 – Specification of the coding and order of transmission of this field is the responsibility of the regional standards body allocating the provider code. See Appendix II for provider code contact information.

S-Field Structure

- Contains all the information used for specific DSL implementations.
- Uses the bit encoded parameter structure (to be defined later).
  - This was the same format used by the I-Field parameter field.
- Can be an arbitrary length, (2-n) octets long.

NS-Field Structure

Number of non-standard information blocks = N (1 octet)
Non-standard information block 1
Non-standard information block 2
. . .
Non-standard information block N

Figure 10/G.994.1 – Non-standard information field (NS) format

8	7	6	5	4	3	2	1
Non-standard information length = M + 6 (1 octet)							
T.35 country code (2 octets – see Note 1)							
Provider code (vendor identification) (4 octets – see Note 2)							
Vendor-specific information (M octets)							

Figure 11/G.994.1 – Non-standard information block format

G.hs Frames

- Each G.hs message makes up 1 or more frames.
- Frames follow the structure shown below.
- Each frame contains a 2 byte FCS (defined later).
- Maximum length of 64 octets, not including FCS.
- Start and end with HDLC flags for receiver sync.

8	7	6	5	4	3	2	1	Octet
Flag								1
Flag								2
Flag								
Flag (optional)								
Flag (optional)								
Message segment								
FCS (first octet)								
FCS (second octet)								
Flag								N – 2
Flag								N – 1
Flag (optional)								N

FCS Field

- 16 bit CRC, generated as listed below.
- Protects data from the first bit after the last "starting flag" to the last bit of the FCS.

The FCS field is 16 bits (2 octets) in length. As defined in ISO/IEC 3309, it shall be the ones complement of the sum (modulo 2) of:

a) the remainder of x^k ($x^{15} + x^{14} + x^{13} + x^{12} + x^{11} + x^{10} + x^9 + x^8 + x^7 + x^6 + x^5 + x^4 + x^3 + x^2 + x + 1$) divided (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$, where k is the number of bits in the frame existing between, but not including, the last bit of the final opening flag and the first bit of the FCS, excluding octets inserted for transparency; and

b) the remainder of the division (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$, of the product of x^{16} by the content of the frame existing between, but not including, the last bit of the final opening flag and the first bit of the FCS, excluding octets inserted for transparency.

Octet Transparency

- Protect from frames containing two “special” octets:
  - FLAG (0x7E)
  - CTRL-ESC (0x7D)
- Performed after the FCS has been appended to the frame.
- If a frame contains one of these octets:
  - The octet is removed and replaced with a two octet sequence defined as:
    - CTRL-ESC followed by the original octet XOR’ed with 0x20.
  - In other words:
    - A data octet of 7E is encoded as 7D, 5E.
    - A data octet of 7D is encoded as 7D, 5D.
- The receiving HSTU must first check for escaped octets before checking the CRC, “undoing” the encoding.
- Note, this can make the frame on the “wire” longer then 66 octets.

Message Segmentation

- Frames longer than 64 octets must be segmented.
- How exactly does it work...Good question!
- Three implementations:
  - Simply cut the message data into 64 octet pieces, the receiver has to do the rest.
  - Don’t send messages longer than 64 octets.
  - “Round” off the message by sending a complete Npar(2 or 3) then continue sending in the next frame.
  - In all cases, it is up to the receiver to correctly determine if a message has been segmented and if so, correctly parse the message.
- The next frame in a segmented message will only be sent upon the receipt of a ACK(2) message.

What can be included in the message:

Messages	Identification			Standard information	Non-standard information
	Message type and revision (2 octets)	Vendor ID (8 octets)	Service and channel parameters (Note 1)	Modulations and Protocols available (Note 2)	(Note 3) octets
MR	X	–	–	–	–
CLR	X	X	X	X	as necessary
CL	X	X	X	X	as necessary
MS	X	–	X	X	as necessary
MP	X	–	X	X	as necessary
ACK	X	–	–	–	–
NAK	X	–	–	–	–
REQ	X	–	–	–	–

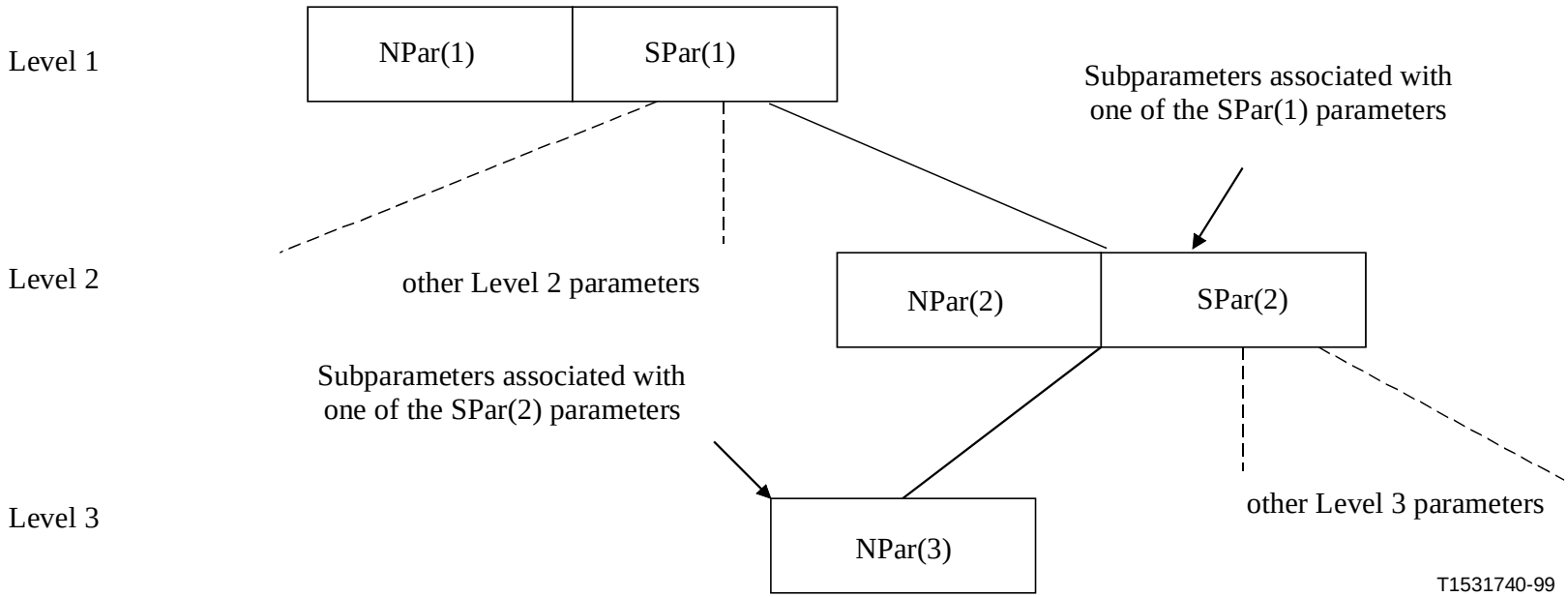
NOTE 1 – As defined in the tables in § 9.3.4/G.994.1.
NOTE 2 – As defined in the tables in § 9.4/G.994.1.
NOTE 3 – As defined in Figures 10 and 11 in § 9.5/G.994.1.

Bit Encoded Parameter Fields

- This is the method used for both the I-Field parameters and the S-Field.
- Uses a three level parameter tree structure.
  - Npar(x)'s have no sub parameters.
  - Spar(x)'s have sub parameters.
  - X denotes the level.
- Each parameter may span multiple octets.
- Delimiting bits denote the end of each parameter.
- A parameter does to be transmitted as it's full length.
  - If after octet 3 of a 10 octet parameter, no data is contained, octets 4-10 do not need to be sent.

Example:
Npar(1)
Spar(1)
  $Npar(2)_1$
  $Spar(2)_1$
    $Npar(3)_1$
    $Npar(3)_2$
  $Npar(2)_2$
  $Spar(2)_2$
    $Npar(3)_1$
    $Npar(3)_2$

Tree According to the ITU-T

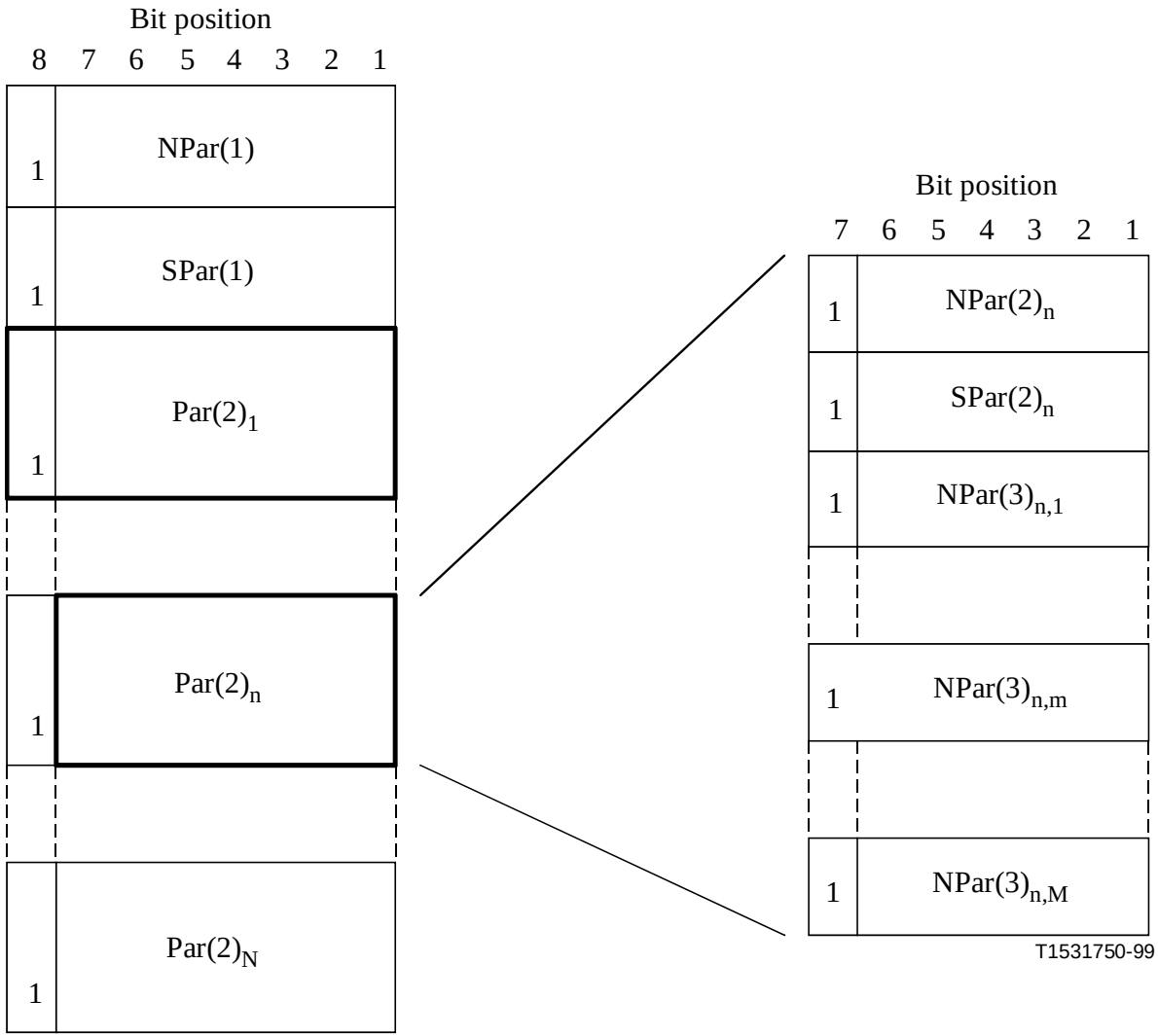


NPar(n) indicates a set of NPar parameters at level n in the tree.

Delimiting Bits

- Each octet contains one or two delimiting bits.
- The two MSB's are used (bit 8 and bit 7).
- Bit 8 is used to delimitate level 1 parameters.
- Bit 7 is used to delimitate level 2 and 3 parameters.
- (This will be confusing until you see how it works.)

ITU-T Delimiting Bits - Picture



An Actual Example of D-Bits

Octet #	Bit #	Binary Data	Decode		Octet #	Bit #	Binary Data	Decode
1	1	0	Npar(1)		4	1	1	Npar(2)
	2	0				2	0	Training Mode
	3	1	Silent Period			3	0	
	4	0				4	0	
	5	0				5	0	
	6	0				6	0	
	7	0				7	1	
	8	1				8	0	
2	1	0	Spar(1)		5	1	1	Spar(2)
	2	0				2	1	Up/Down Training Info
	3	0				3	0	
	4	0				4	0	
	5	0				5	1	TPS-TC Info
	6	0				6	0	
	7	0				7	0	
	8	0				8	0	
3	1	1	SHDSL, Annex A		6	1	0	No Parameters
	2	0				2	0	
	3	0				3	0	
	4	0				4	0	
	5	0				5	0	
	6	0				6	0	
	7	0				7	1	
	8	1				8	0	

A closer look at the S-Field

Table 10/G.994.1 – Standard information field – NPar(1) coding

Bits								
8	7	6	5	4	3	2	1	**NPar(1)s**
x	x	x	x	x	x	x	1	Voiceband: V.8 (Note 1)
x	x	x	x	x	x	1	x	Voiceband: V.8 *bis* (Note 1)
x	x	x	x	x	1	x	x	Silent period (Note 2)
x	x	x	x	1	x	x	x	G.997.1 (Note 3)
x	x	x	1	x	x	x	x	Reserved for allocation by the ITU-T
x	x	1	x	x	x	x	x	Reserved for allocation by the ITU-T
x	1	x	x	x	x	x	x	Reserved for allocation by the ITU-T
x	0	0	0	0	0	0	0	No parameters in this octet

NOTE 1 – Setting this bit to binary ONE in an MS message initiates the G.994.1 session cleardown procedure specified in 11.3, and requests a V.8 or V.8 *bis* handshake in the voiceband, with the xTU-R taking on the role of a calling station and the xTU-C taking on the role of an answering station.

NOTE 2 – This bit shall be set to binary ONE in a CLR or CL message. Setting this bit to binary ONE in an MS message initiates the G.994.1 session cleardown procedure specified in 11.3, and requests a silence period at the other transmitter of approximately 1 minute. The station that invoked the silent period by transmitting MS may terminate the silent period prior to the 1 minute by restarting a G.994.1 session.

NOTE 3 – The use of this bit is for further study and shall be set to binary ZERO in CLR, CL and MS.

A closer look at the S-Field (cont)

Table 11/G.994.1 – Standard information field – SPar(1) coding – Octet 1

Bits								
8	7	6	5	4	3	2	1	**SPar(1)s – Octet 1**
x	x	x	x	x	x	x	1	G.992.1 – Annex A (Note 1)
x	x	x	x	x	x	1	x	G.992.1 – Annex B (Note 1)
x	x	x	x	x	1	x	x	G.992.1 – Annex C (Note 1)
x	x	x	x	1	x	x	x	G.992.2 – Annex A/B (Note 1)
x	x	x	1	x	x	x	x	G.992.2 – Annex C (Note 1)
x	x	1	x	x	x	x	x	G.992.1 – Annex H (Note 1)
x	1	x	x	x	x	x	x	Reserved for allocation by the ITU-T
x	0	0	0	0	0	0	0	No parameters in this octet

NOTE 1 – The spectrum information indicated in the NPar(3) fields associated with these Recommendations is of informative nature and does not imply any requirements on the transmit spectrum used during initialization and data mode. Regardless of the spectrum information, the transmit spectrum shall comply with their respective Recommendations. Spectrum information may only be included in a CLR or CL message, not in an MP or MS message. The spectrum information is coded in 8 bits (across 2 octets) as a binary representation of the subcarrier index.

Maximum frequencies: up to and including the subcarrier index
Minimum frequencies: above and including the subcarrier index.

A closer look at the S-Field (cont)

Table 11.1/G.994.1 – Standard information field – G.992.1 Annex A NPar(2) coding

Bits								
8	7	6	5	4	3	2	1	**G.992.1 Annex A NPar(2)s**
x	x	x	x	x	x	x	1	R-ACK1
x	x	x	x	x	x	1	x	R-ACK2
x	x	x	x	x	1	x	x	Reserved for allocation by the ITU-T
x	x	x	x	1	x	x	x	STM
x	x	x	1	x	x	x	x	ATM
x	x	1	x	x	x	x	x	G.997.1 – Clear EOC OAM
x	x	0	0	0	0	0	0	No parameters in this octet

Table 11.2/G.994.1 – Standard information field – G.992.1 Annex A SPar(2) coding

Bits								
8	7	6	5	4	3	2	1	**G.992.1 Annex A SPar(2)s**
x	x	x	x	x	x	x	1	Sub-channel information
x	x	x	x	x	x	1	x	Spectrum frequency upstream
x	x	x	x	x	1	x	x	Spectrum frequency downstream
x	x	x	x	1	x	x	x	Reserved for allocation by the ITU-T
x	x	x	1	x	x	x	x	Reserved for allocation by the ITU-T
x	x	1	x	x	x	x	x	Reserved for allocation by the ITU-T
x	x	0	0	0	0	0	0	No parameters in this octet

A closer look at the S-Field (cont)

Table 11.2.1/G.994.1 – Standard information field – G.992.1 Annex A Sub-channel information NPar(3) coding – Octet 1

Bits 8	7	6	5	4	3	2	1	G.992.1 Annex A Sub-channel information NPar(3)s – Octet 1
x	x	x	x	x	x	x	1	AS0 downstream
x	x	x	x	x	x	1	x	AS1 downstream
x	x	x	x	x	1	x	x	AS2 downstream
x	x	x	x	1	x	x	x	AS3 downstream
x	x	x	1	x	x	x	x	LS0 downstream
x	x	1	x	x	x	x	x	Reserved for allocation by the ITU-T
x	x	0	0	0	0	0	0	No parameters in this octet

Table 11.2.1.1/G.994.1 – Standard information field – G.992.1 Annex A Sub-channel information NPar(3) coding – Octet 2

Bits 8	7	6	5	4	3	2	1	G.992.1 Annex A Sub-channel information NPar(3)s – Octet 2
x	x	x	x	x	x	x	1	LS1 downstream
x	x	x	x	x	x	1	x	LS2 downstream
x	x	x	x	x	1	x	x	LS0 upstream
x	x	x	x	1	x	x	x	LS1 upstream
x	x	x	1	x	x	x	x	LS2 upstream
x	x	1	x	x	x	x	x	Reserved for allocation by the ITU-T
x	x	0	0	0	0	0	0	No parameters in this octet

G.hs Transactions

- These are the transactions that the G.hs session must follow.
- Defined in two sets:
  - Basic transactions
  - Extended transactions
    - Made up of basic transactions.
- Each transaction end in one of two ways:
  - A common mode of operation is selected. “ACK(1)”
  - No common mode of operation can be selected. “NAK-NS”

Basic Transactions

Table 13/G.994.1 – Basic G.994.1 transactions

Transaction identifier	HSTU-R	HSTU-C	HSTU-R	G.994.1 Revision 1 support	G.994.1 Revision 2 support
A	MS →	ACK(1)		X	X
B	MR →	MS →	ACK(1)	X	X
C	CLR →	CL →	ACK(1)	X	X
D	MP →	MS →	ACK(1)	–	X

Extended Transactions

Table 14/G.994.1 – Extended G.994.1 transactions

Transaction identifier	HSTU-R	HSTU-C	HSTU-R	HSTU-C	HSTU-R	G.994.1 Revision 1 support	G.994.1 Revision 2 support
A:B	MS →	REQ-MR →	MR →	MS →	ACK(1)	X	X
B:A	MR →	REQ-MS →	MS →	ACK(1)		X	X
A:C	MS →	REQ-CLR →	CLR →	CL →	ACK(1)	X	X
B:C	MR →	REQ-CLR →	CLR →	CL →	ACK(1)	X	X
D:C	MP →	REQ-CLR →	CLR →	CL →	ACK(1)	–	X

Sample Sessions

Session	msg 1	msg 2	msg 3	msg 4	msg 5	msg 6	msg 7	msg 8
1	CLR	cl	ACK(1)	MS	ack(1)			
2	MS	ack(1)						
3	MS	req-mr	MR	ms	ACK(1)			
4	MS	req-clr	CLR	cl	ACK(1)	MS	ack(1)	
5	CLR	cl	ACK(1)	MR	ms	ACK(1)		
6	MR	ms	ACK(1)					
7	MR	req-ms	MS	ack(1)				
8	MR	req-clr	CLR	cl	ACK(1)	MR	ms	ACK(1)

NOTE – HSTU-R transmitted messages are shown in uppercase, whilst HSTU-C transmitted messages are shown in lowercase.

The End

- Thank you for your attention.