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ABSTRACT

This contribution is some implementation and "newbie" information regarding G.994.1 (G.hs). It is the basis for a living document that will be publicly available to aid in the understanding of the published Recommendation G.994.1. It was presented to ETSI TM6 last week to introduce G.hs to them.
Perhaps some parts of the contribution may be used as a basis for the informative Appendix I in G.994.1

1. Introduction

The ITU-T has recently standardized a handshake and activation method for xDSL modems. This method is contained in the ITU-T Recommendation G.944.1 (formerly known as G.hs). Several of the features of G.994.1 came from the voiceband handshake Recommendations V.8 and V.8bis, but there are several differences and extensions that may appear confusing at first glance. This document attempts to introduce G.994.1 from the basics and then addresses some of the subtleties.

The basic function of G.994.1 is to provide a consistent way of initiating the various types of xDSL modems available now and in the future. Before G.994.1, each of the various xDSL standards used different tones or signals at different frequencies in order to indicate to the opposite end that modem startup (activation) was desired. Additionally, various modem options were negotiated by using different combinations of tones. With the rapidly expanding number of options and the expanding number of different types of xDSL modems, it was quickly becoming difficult to find unused spectrum/signals or to uniquely identify what type of xDSL modem was at each end of the connection.

This was very similar to the situation of voiceband modems in the early 1990's when a "box modem" often contained several different voiceband modulation Recommendations (e.g., V.22, V.22bis, V.32, V.32bis, etc). The voiceband solution was to create the V.8 procedure. Instead of using different tones and timings to indicate different options, a simple digital communication path (modulation) is initially established and messages are digitally transferred between the two ends to 1) identify the types of modulations contained in the units, 2) the various available options, and 3) select the single modulation to be used.

G.994.1 basically accomplishes the same functionality for xDSL modems, however, the initial digital communication path and the contents of the messages are a bit more complicated in order to support the extensive needs of the broadband xDSL modems.

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2. Spectrum

V.8 used two different frequency bands for the digital communication path. Data was transferred in one direction in a spectrum band centered around 1080 Hz and in the other direction in a spectrum band centered around 1750 Hz. It was rather easy to select those frequencies since all voiceband communications occurred in the spectrum from 300 to 3700 Hz.

In the xDSL world, essentially the entire spectrum can be used. As could be suspected given the opportunity, the different xDSL modulations and different regions (countries) have chosen to use different and often non-overlapping spectrum for their xDSL specification. Another complication in local xDSL installations is that certain parts of the spectrum may be unusable due to interference or problems in a given copper loop. In order to establish the initial digital communication, several simultaneous upstream and several simultaneous downstream frequencies were needed. These are described in Tables 1 and 3 in G.994.1. (Also see Figure 1 on the next page) Each carrier set is designed for the different regions in the world and each carrier set typically contains three frequencies. With the redundancy in each carrier set, the possibility of communication even in a difficult environment is greatly increased.

The spacing of the 4.3125 kHz family carrier was selected to be convenient for the existing G.992.x modems although DMT and FFTs are <u>not</u> necessary to implement them. The three different 4.3125 kHz Carrier sets (A43, B43, and C43) are for the three different regions in the world using ADSL. A43 is primarily for North America and the regions that provide ADSL and standard telephone services (POTS) on the same loop. B43 is primarily for regions (eg: Germany, France) which provide ADSL and ISDN basic rate services on the same loop. C43 is primarily for Japan where a different method must be utilized due to the TCM-ISDN environment.

Similarly the 4kHz family uses tone spacing that was convenient for HDSL type modems. The 4kHz family (A4) only uses a single upstream and single downstream carrier since that portion of the spectrum tends to be very robust and noise free.

Although a given carrier set is mandatory for it corresponding Recommendation or Annex, a modem box is encouraged to monitor the spectrum and transmit in as many tones as possible without interfering into the surrounding services. Thus a G.994.1 handshake may start off with as many nine simultaneous upstream tones and ten simultaneous downstream tones. This allows for the greatest possibility of detection at the opposite end of the cooper loop.

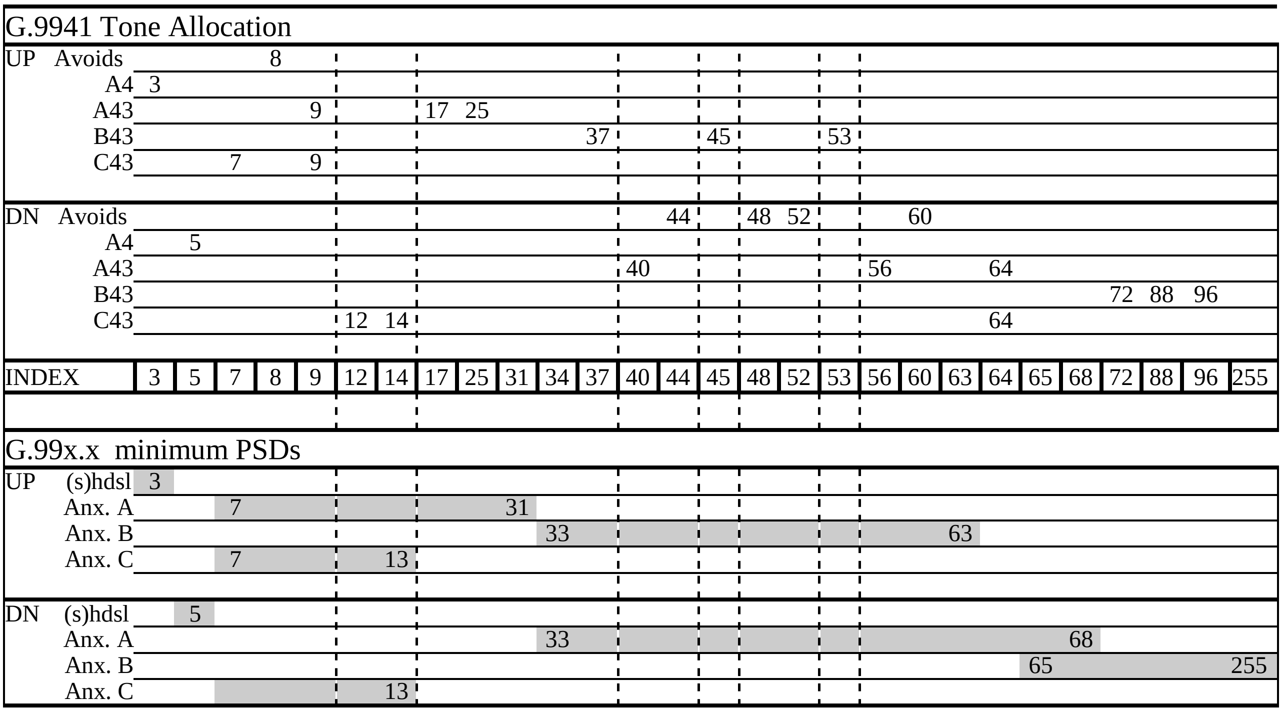

FIGURE 1. CARRIER ALLOCATION

3. Duplexing and Initial Signals

In the previous section, we examined where the G.994.1 transmission occurs, now we examine what types of signals are sent.

Either end of the copper loop may send the first signal of initialization. Additionally there are two transmission methods, duplex and half duplex, depending on the xDSL Recommendation. The four different combinations of which end starts and which duplexing method is illustrated in Figures 14 through 17 of G.994.1. Although it appears that there may be four different startup methods in G.994.1, the first signals in all fourth methods are identical allowing complete interoperability between all four cases.

If the xTU-R wishes to initiate G.994.1, it transmits the R-TONES-REQ signal upstream to the HSTU-C. If the HSTU-C wishes to initiate G.994.1, it transmits the C-TONES signal downstream to the HSTU-R. Whether or not the HSTU-R send R-TONES-REQ, the startup methods thereafter are identical.

Both R-TONES-REQ and C-TONES may be composed of both 4kHz and 4.3125kHz family tones to allow communication with either family. The HSTU-R decides which family to use after observing the C-TONES signal. The HSTU-R indicates which duplexing method it will use by sending one of two signals in response to C-TONES:

- For Duplex modulation negotiations, the HSTU-R sends R-TONE1 and proceeds as shown in Figure 14/G.994.1.
- For Half Duplex modulations negotiations, the HSTU-R sends R-FLAGS1 and proceeds as shown in Figure 16/G.994.1

Independent of the modulation duplexing method, the messages and protocol are identical.

4. Messages Structure

G.994.1 uses the same frame and message structure as V.8bis.

5. Information Classes

After the G.994.1 modulation has initialized and the digital communication channel is available, various information is exchanged between the HSTU-R and HSTU-C. The classes of information in G.994.1 are contrasted to V.8 (in Table 1) and described in an overview manner (in Table 2).

TABLE 1. INFORMATION CLASSES

Information Class	Comment	V.8	G.994.1
Available Modulations (Recommendations)	Equipment at each end of the loop	√	√
Channel Information (splitters, Spectrum, etc)	Characteristics of the physical connection between the equipment		√
Application/Service Requirements (Desired Bandwidth and Latency)	What the user wants or is willing to pay for		√

TABLE 2. G.994.1 MESSAGE INFORMATION STRUCTURE

- Identification (Service Parameters/ Channel Capabilities) NPar(1) (No sub-parameters)
- Identification (Service Parameters/ Channel Capabilities) SPar(1) (sub-parameters)
  - Message Type and version (Tables 5/6)
  - Vendor Identification using T.35 codes (Table 7/G.994.1)
  - Amount/type of bandwidth (Tables 10 - 15, 16-19)
  - Known splitter information (Tables 20 and 21)
  - Spectrum usable frequencies - generalization of FDM and overlapped spectrum
  - Carrier families, groups, and tone numbers being transmitted

- Standard Information (Modulations/protocols) NPar(1) (Table 22)
  - Escape to voiceband (V.8/V.8 bis) capabilities.
- Standard Information (Modulations/protocols) SPar(1)
  - Which type of xDSL etc. (Table 23)
    - Number and Type of Data channel information (eg Table 25)
    - Spectrum usable frequencies (eg Table 25)
  - Regional considerations (i.e., use of a specific Annex in a Recommendation) (Table 23)
  - Protocol information error correction, data compression etc. (eg Table 24)
  -

- Non-standard Information

6. Transactions - G.994.1 Figures 12/13

The 3 basic transactions and 4 extended transactions composed on concatenations of the basic transactions. Each of the basic transactions is composed of 3 or 4 messages (of the structure in Table 2 and §8).

6.1 Three Basic Transactions

- Exchange Capabilities
- Mode Select - HSTU-R
- Mode Select - HSTU-C

6.2 Four "extended" transactions

- 2 composed of basic transactions to revert control to the other end
- 2 to request a capabilities exchange when a mode select (MS) was proposed

6.3 Sample Sessions (Transactions)

Below are some sample G.994.1 sessions. The associated explanations describe an example application usage but it should not be construed as a exclusive or limiting application for the given transactions.

6.3.1 Initial Power On (Activation)

The session is the typical G.994.1 session that would take place upon initially provisioning a line. First capabilities are exchanged and then a mode is selected.

HSTU-R	G.hs startup	CLR		ACK(1)	MS		G.hs cleardown	G.992.x startup
HSTU-C			CL			ACK(1)		
	Modulation Initialization	Capabilities list and request	Capabilities List	Acknow-ledgement	Mode Select	Acknow-ledgement	termination of modulation	xDSL training

6.3.2 Subsequent Power On (Activation)

Activations that occur after a capabilities exchange has occurred may simply do a mode select transaction. This takes advantage of the storage of the modem capabilities to allows a much shorter exchange.

HSTU-R	G.hs startup	MS		G.hs cleardown	G.992.x startup
HSTU-C			ACK(1)		
	Modulation Initialization	Mode Select	Acknow-ledgement	termination of modulation	xDSL training

6.3.3 ATU-C push application

In cases after a capabilities exchange, when the ATU-C initiates the G.hs modulation, the ATU-R probably does not know the desired mode. The ATU-R can defer to the ATU-C by using transaction B, where the ATU-R requests the ATU-C to select the mode by sending an MR.

HSTU-R	G.hs startup	MR		ACK(1)	G.hs cleardown	G.992.x startup
HSTU-C			MS			
	Modulation Initialization	Mode Request	Mode Select	Acknow-ledgement	termination of modulation	xDSL training

6.3.4 ATU-C requests control

In cases after a capabilities exchange, when the ATU-R proposes a particular mode, the ATU-C can reject the proposed mode and then explicitly propose it's own mode.

HSTU-R	G.hs startup	MS		MR		ACK(1)	G.hs cleardown	G.992.x startup
HSTU-C			REQ-MR		MS			
	Modulation Initialization	Mode Select	Request that HSTU-C do the MS.	Mode Request	Mode Select	Acknow-ledgement	termination of modulation	xDSL training

7. Interoperability and Interworking

There are 3 methods of G.994.1 interworking with legacy and new xDSL standards:

- Startup signals - G.994.1 Annex A
- Selection via Standard Information field
- Selection via Non standard Information field

Annex A of G.994.1 allows the G.994.1 startup signals to alternate with legacy startup signals on a 4 second cycle. The legacy startup signals can be rotated from different xDSL standards.

Since the message contents are extensible, new xDSL modulation

8. Sample Message Construction

The composition of a sample MS message in an type A transaction is illustrated in the following Table. The total time is approximately 700ms.

#	HSTU-R	HSTU-C	688 Time (ms)	Comment	
S1	R-SILENT0	C-SILENT1			
S2	R-TONES-REQ	C-SILENT1	33		
S3		C-TONES			
S4	R-SILENT1		100		
S5	R-TONE1		15		
S6		81 (C-GALF1)	15		
S7	7E R-FLAG1		15		
S8		7E C-FLAG1	15		
S9	FILL	FILL	0	Flags for duplex modulation	
1	7E	"	45	Flag	
2	7E	"		Flag	
3	7E	"		Flag	
4	0	"	30	MS Message Type	
5	1	"		Revision	
6	80	"	15	Ident. - Tbl. 8 - NPar(1)	last octet
7	8A	"	15	Ident. - Tbl. 9 - SPar(1)	last octet; downstream data; data flow downstream
8	10	"	45	Ident. - Tbl. 13 - NPar(2)	max 1 Mbit/s (16*64kbit/s)
9	6	"		Ident. - Tbl. 14 - NPar(2)	min 384 kbit/s (6*64kbit/s)
10	C8	"		Ident. - Tbl. 15 - NPar(2)	ave 512 kbit/s (8*64kbit/s); last octet
11	14	"	30	Ident. - Tbl. 18 - NPar(2)	max 20 msec
12	CA	"		Ident. - Tbl. 19 - NPar(2)	ave 10 msec; last octet; last octet
13	80	"	15	Std. - Tbl. 22 - NPar(1)	last octet
14	88	"	15	Std. - Tbl. 23 - SPar(1)	G.992.2 Annex A; last octet
15	E1	"	15	Std. - Tbl. 60 - NPar(2)	Clear EOC; RACK-1; last octet; See 9.3.2
16	XX	"	30	FCS	
17	XX	"		FCS	
18	7E	"	30	FLAG (HSTU-R)	
19	7E	"		FLAG (HSTU-R)	
20	FILL	7E	45	FLAG (HSTU-C)	
21	"	7E		FLAG (HSTU-C)	
22	"	7E		FLAG (HSTU-C)	
23	"	10	30	ACK(1)	
24	"	1		Revision	
25	"	XX	30	FCS	
26	"	XX		FCS	
27	"	7E	30	FLAG (HSTU-C)	
28	"	7E		FLAG (HSTU-C)	
29	"	7E C-FLAG2	15		
30	81 R-GALF2	7E C-FLAG2	60		
31	81 R-GALF2	7E C-FLAG2			
32	81 R-GALF2	7E C-FLAG2			
33	81 R-GALF2	7E C-FLAG2			
E1	R-SILENT2	C-SILENT2			

The minimum MS-ACK sequence takes a little over .5 seconds.
A CLR-CL-MS Exchange using all possible octets takes about 3.5 seconds as shown in the following Table.

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#	HSTU-R	HSTU-C	Time (ms)	Comment	
S1	R-SILENT0	C-SILENT1			
S2	R-TONES-REQ	C-SILENT1	33		
S3		C-TONES			
S4	R-SILENT1		100		
S5	R-TONE1		15		
S6		81 (C-GALF1)	15		
S7	7E R-FLAG1		15		
S8		7E C-FLAG1	15		
S9	FILL	FILL	0	Flags for duplex modulation	
1	7E	"	45	Flag	
2	7E	"		Flag	
3	7E	"		Flag	
4	3	"	30	CLR Message Type - Tbl. 5	
5	1	"		Revision - Tbl. 6	
6	XX		120	Vendor ID - Tbl. 7	
7	XX			Vendor ID - Tbl. 7	
8	XX			Vendor ID - Tbl. 7	
9	XX			Vendor ID - Tbl. 7	
10	XX			Vendor ID - Tbl. 7	
11	XX			Vendor ID - Tbl. 7	
12	XX			Vendor ID - Tbl. 7	
13	XX			Vendor ID - Tbl. 7	
14	80	"	15	Ident. - Tbl. 8 - NPar(1)	last octet
15	BF	"	15	Ident. - Tbl. 9 - SPar(1)	last octet; downstream data; data flow downstream
16	10	"	45	Ident. - Tbl. 10 - NPar(2)	max 1 Mbit/s (16*64kbit/s)
17	6	"		Ident. - Tbl. 11 - NPar(2)	min 384 kbit/s (6*64kbit/s)
18	C8	"		Ident. - Tbl. 12 - NPar(2)	ave 512 kbit/s (8*64kbit/s); last octet
19	10	"	45	Ident. - Tbl. 13 - NPar(2)	max 1 Mbit/s (16*64kbit/s)
20	6	"		Ident. - Tbl. 14 - NPar(2)	min 384 kbit/s (6*64kbit/s)
21	C8	"		Ident. - Tbl. 15 - NPar(2)	ave 512 kbit/s (8*64kbit/s); last octet
22	14	"	30	Ident. - Tbl. 16 - NPar(2)	max 20 msec
23	CA	"		Ident. - Tbl. 17 - NPar(2)	ave 10 msec; last octet; last octet
24	14	"	30	Ident. - Tbl. 18 - NPar(2)	max 20 msec
25	CA	"		Ident. - Tbl. 19 - NPar(2)	ave 10 msec; last octet; last octet
26	C0	"	15	Ident. - Tbl. 20 - NPar(2)	Splitter - xTU-R ; last octet
27	C0	"	15	Ident. - Tbl. 21 - NPar(2)	Splitter - xTU-C ; last octet
28	80	"	15	Std. - Tbl. 22 - NPar(1)	last octet
29	XX	"	15	Std. - Tbl. 23 - SPar(1)	
30	XX	"	15	Std. - Tbl. 24 - NPar(2)	G.992.1 Annex A
31	XX	"	15	Std. - Tbl. 25 - SPar(2)	G.992.1 Annex A
32	XX .. XX	"	150	Std. - Tbl. 26-35 - NPar(3)	G.992.1 Annex A
42	XX	"	15	Std. - Tbl. 36 - NPar(2)	G.992.1 Annex B
43	XX	"	15	Std. - Tbl. 37 - SPar(2)	G.992.1 Annex B
44	XX .. XX	"	150	Std. - Tbl. 38-47 - NPar(3)	G.992.1 Annex B
54	XX	"	15	Std. - Tbl. 48 - NPar(2)	G.992.1 Annex C
55	XX	"	15	Std. - Tbl. 49 - SPar(2)	G.992.1 Annex C
56	XX .. XX	"	150	Std. - Tbl. 50-59 - NPar(3)	G.992.1 Annex C
66	XX	"	15	Std. - Tbl. 60 - NPar(2)	G.992.2 Annex A/B
67	XX	"	15	Std. - Tbl. 61 - SPar(2)	G.992.2 Annex A/B
68	XX .. XX	"	150	Std. - Tbl. 62-69 - NPar(3)	G.992.2 Annex A/B
78	XX	"	15	Std. - Tbl. 70 - NPar(2)	G.992.2 Annex C
79	XX	"	15	Std. - Tbl. 71 - SPar(2)	G.992.2 Annex C
80	XX .. XX	"	150	Std. - Tbl. 72-79 - NPar(3)	G.992.2 Annex C
90	XX	"	30	FCS	
91	XX	"		FCS	
92	7E	"	30	FLAG (HSTU-R)	
93	7E	"		FLAG (HSTU-R)	

M2		CL	1395	CL
M3	ACK(1)		135	ACK
M4	MS		210	MS
M5		ACK(1)	135	ACK
	"	7E C-FLAG2	15	
	81 R-GALF2	7E C-FLAG2	60	
	81 R-GALF2	7E C-FLAG2		
	81 R-GALF2	7E C-FLAG2		
	81 R-GALF2	7E C-FLAG2		
E1	R-SILENT2	C-SILENT2		