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**G.991.2**

**Amendment 1**  
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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,  
DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Access networks

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Single-pair high-speed digital subscriber line  
(SHDSL) transceivers

**Amendment 1**

ITU-T Recommendation G.991.2 (2003) – Amendment 1

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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 TESTING EQUIPMENTS	G.450–G.499
TRANSMISSION MEDIA CHARACTERISTICS	G.500–G.599
DIGITAL TERMINAL EQUIPMENTS	G.600–G.699
DIGITAL NETWORKS	G.700–G.799
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.800–G.899
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
<b>Access networks</b>	<b>G.990–G.999</b>
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.991.2**

## **Single-pair high-speed digital subscriber line (SHDSL) transceivers**

### **Amendment 1**

#### **Summary**

This amendment resolves the passing of a target margin in an SHDSL access link with repeaters and introduces the addition of the TU-12/VC-12 framing. The revisions relative to G.991.2 (2003) are indicated with revision marks.

#### **Source**

Amendment 1 to ITU-T Recommendation G.991.2 (2003) was approved on 22 July 2004 by ITU-T Study Group 15 (2001-2004) under the ITU-T Recommendation A.8 procedure.

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## CONTENTS

	<b>Page</b>
1) Resolution to passing of a target margin in an SHDSL access link with repeaters.....	1
2) Addition of TU-12/VC-12 framing .....	12



Single-pair high-speed digital subscriber line (SHDSL) transceivers

Amendment 1

1) Resolution to passing of a target margin in an SHDSL access link with repeaters

Modify Annex D and Appendix III as follows:

Annex D

Signal regenerator operation

In order to achieve data transmission over greater distances than are achievable over a single SHDSL segment, one or more signal regenerators (SRUs) may be employed. In the optional  $M$ -pair mode,  $M$ -pair regenerators may be used when this reach extension is required. This annex specifies operational characteristics of signal regenerators and the start-up sequence for SHDSL spans containing signal regenerators. Additional explanatory text is included in Appendix III.

D.1 Reference diagram

Figure D.1 is a reference diagram of a SHDSL span containing two regenerators. Up to eight (8) regenerators per span are supported within the EOC addressing scheme (9.5.5.5), and no further limitation is intended herein. Each SRU shall consist of two parts: an SRU-R for interfacing with the STU-C (or a separate SRU-C), and an SRU-C for interfacing with the STU-R (or a separate SRU-R). An internal connection between the SRU-R and SRU-C shall provide the communication between the two parts during start-up and normal operation. An SHDSL span containing  $X$  regenerators shall contain  $X + 1$  separated SHDSL segments, designated TR1 (STU-C to SRU<sub>1</sub>), TR<sub>2</sub> (SRU<sub>X</sub>-C to STU-R), and RR <sub>$n$</sub>  (SRU <sub>$n$</sub> -C to SRU <sub>$n+1$</sub>  - R, where  $1 \leq n \leq X - 1$ ). Each segment shall follow the general principles described in 6.2, 6.3 and 7.2 for the preactivation and activation procedures. Additional requirements specific to spans containing regenerators are described in this annex.

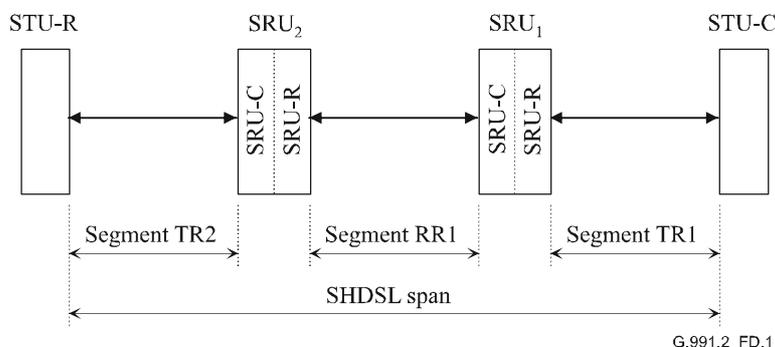


Figure D.1/G.991.2 – Block diagram of a SHDSL span with two signal regenerators

## D.2 Startup procedures

### D.2.1 SRU-C

Figure D.2 shows the state transition diagram for SRU-C start-up and operation. The SRU-C begins in the "Idle0" state and, in the case of an STU-R initiated start-up, transitions first to the "~~Wait for STU-C~~Idle0a" state. If line probe is disabled, the STU-C shall transition from the "Idle0a" state to the "Wait for STU-C" state; otherwise the STU-C will return to "Idle0" and wait for target margins to be passed across the internal regenerator interface with the indication that they originated at the STU-C. In this annex, the term "target margin" refers to both the current condition target margin and the worst-case target margin as described in 6.3.6 and 6.4.1. For an STU-C initiated start-up, the SRU-C moves from "Idle0" to the "~~G.994.1 Session 1~~Idle0b" state. If target margins have been received across the internal regenerator interface with the indication that they originated at the STU-C, the SRU-C will transition from "Idle0b" to Check "G.994.1" and the SRU-C will use these target margins in subsequent capabilities exchanges with its "CO target margin" capability bit set to a one. An SRU initiated start-up shall function identically to an STU-C initiated start-up from the perspective of the SRU-C.

The SRU-C shall communicate "Capabilities Available" status and transfer a list of its capabilities to the SRU-R across the regenerator's internal interface upon entering the "Wait for STU-C" or "Idle0a" state. The SRU-C's capabilities list, as transferred to the SRU-R, shall be the intersection of its own capabilities, the capabilities list it received from the STU-R (or SRU-R) in its G.994.1 session, and the segment capabilities determined by the line probe, if used.

The SRU-C shall receive mode selection information from the SRU-R in association with the "SRU-R Active" indication. In the subsequent G.994.1 session, the SRU-C shall select the same mode and parameter settings for the SHDSL session.

The timer  $T_{SRUC}$  shall be set to 4 minutes. If  $T_{SRUC}$  expires before the SRU-C reaches the "Active" state, the SRU-C shall return to the "Idle" state and shall indicate link failure to the SRU-R across the internal interface. The SRU-C shall also indicate failure and return to the "Idle" state if a G.994.1 initiation is unsuccessful after 30 s.

The "Diagnostic Mode" bit, if set in the G.994.1 Capabilities Exchange, shall cause an SRU-C to function as an STU-C if the subsequent segment fails. This implies that an internal failure indication received while in the "Wait for STU-C" state shall cause the SRU-C to select an operational mode, initiate a G.994.1 session, and transition to state "G.994.1 Session 2".



## D.2.2 SRU-R

Figure D.3 shows the state transition diagram for SRU-R start-up and operation. The SRU-R begins in the "Idle0" state and, in the case of an STU-R initiated train, transitions first to the "~~G.994.1 Session 1~~Idle0a" state. For an STU-C initiated train, the SRU-C moves from "Idle0" to the "~~G.994.1 Session 2~~Idle0b" state. If line probe is enabled, the SRU-R will transition to the "G.994.1 Session 1" state once the target margins are received from the STU-C, or once the target margins are received from the SRU-C with the "CO target margin" capability bit set to a one. In this annex, the term "target margin" refers to both the current condition target margin and the worst-case target margin as described in 6.3.6 and 6.4.1.

The SRU-R shall communicate "Link initiation" status to the SRU-C across the regenerator's internal interface upon entering the "Wait for STU-R" or "Idle0b" state. If the SRU-R exchanges capabilities with a STU-C, it shall communicate the target margins from the STU-C across the regenerator's internal interface. If the SRU-R exchanges capabilities with a SRU-C, and the SRU-C has the "CO target margin" capability bit set to a one, then it shall communicate the target margins from the SRU-C across the regenerator's internal interface. Upon entering the "Active" state, it shall communicate "SRU-R Active" status to the SRU-C. If plesiochronous operation (Clock Mode 1; see clause 10) is selected, the SRU-R may optionally indicate its entry into the "Active" state to the SRU-C prior to the completion of the SHDSL activation sequence. If synchronous or network referenced plesiochronous clocking is selected (Clock Modes 2, 3a or 3b; see clause 10), the SRU-R shall not indicate entry into the "Active" state until the SHDSL activation sequence has been completed.

The SRU-R shall receive a list of capabilities from the SRU-C across the regenerator's internal interface in association with the "Capabilities available" indication. The SRU-R's capabilities list, as indicated in the subsequent G.994.1 session, shall be the intersection of its own capabilities with the capabilities list it received from the SRU-C.

The SRU-R shall provide mode selection information to the SRU-C in association with the "SRU-R active" indication, based on the selections it has received in the G.994.1 session.

The timer  $T_{SRUR}$  shall be set to 4 minutes. If  $T_{SRUR}$  expires before the SRU-R reaches the "Active" state, the SRU-R shall return to the "Idle" state and shall indicate link failure to the SRU-C across the internal interface. The SRU-R shall also indicate failure and return to the "Idle" state if a G.994.1 initiation is unsuccessful after 30 s.

The "Diagnostic mode" bit, if set in the G.994.1 capabilities exchange, shall cause an SRU-R to function as an STU-R if the subsequent segment fails. This implies that an internal failure indication received while in the "Wait for STU-R" state shall cause the SRU-R to initiate a G.994.1 session and transition to state "G.994.1 Session 2".

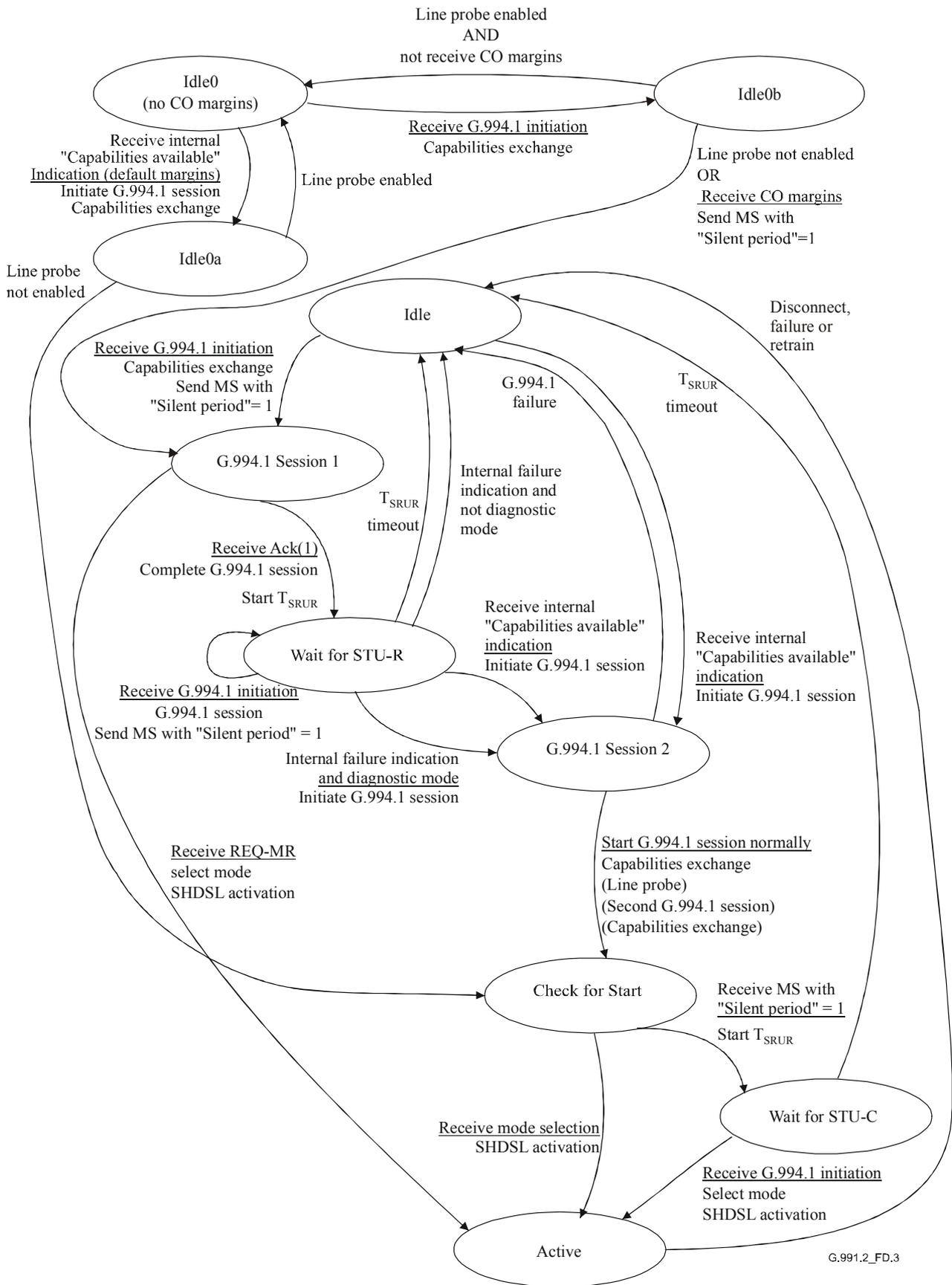


Figure D.3/G.991.2 – SRU-R state transition diagram

### **D.2.3 STU-C**

In order to support operation with regenerators, each STU-C shall support the Regenerator Silent Period (RSP) bit, as specified in ITU-T Rec. G.994.1. Second, the STU-C shall not indicate a training failure or error until it has been forced into "silent" mode for at least 5 consecutive minutes.

### **D.2.4 STU-R**

In order to support operation with regenerators, each STU-R shall support the Regenerator Silent Period (RSP) bit, as specified in ITU-T Rec. G.994.1. The STU-R shall not indicate a training failure or error until it has been forced into "silent" mode for at least 5 consecutive minutes.

### **D.2.5 Segment failures and retrains**

In the case of a segment failure or a retrain, each segment of the span shall be deactivated, with each SRU-C and each SRU-R returning to its "Idle" state. The restart may then be initiated by the SRU, the STU-R, or the STU-C.

## **D.3 Symbol rates**

For Annex A operational modes, signal regenerators may transmit at symbol rates up to and including 280 ksymbol/s in either two-wire or the optional  $M$ -pair mode. This corresponds, for 16-TCPAM, to maximum user data rates (not including framing overhead) of 832 kbit/s and  $M \times 832$  kbit/s for two-wire and  $M$ -pair operation, respectively. Operation at higher symbol rates is for further study.

For Annex B operational modes, signal regenerators may transmit at symbol rates up to and including 685.33 ksymbol/s in either two-wire or the optional  $M$ -pair mode. This corresponds, for 16-TCPAM, to maximum user data rates (not including framing overhead) of 2.048 Mbit/s and  $M \times 2.048$  Mbit/s for two-wire and  $M$ -pair operation, respectively. Operation at higher symbol rates is for further study.

In either case, each STU and SRU on a span shall select the same operational data rate.

## **D.4 PSD masks**

Any of the PSDs from Annex A or Annex B may be used for the TR1 segment (STU-C to SRU<sub>1</sub>-R), as appropriate to the given region. All other segments shall employ one of the appropriate symmetric PSDs, as described in either A.4.1 or B.4.1. The selection of PSD shall be limited by the symbol rate considerations of D.3.

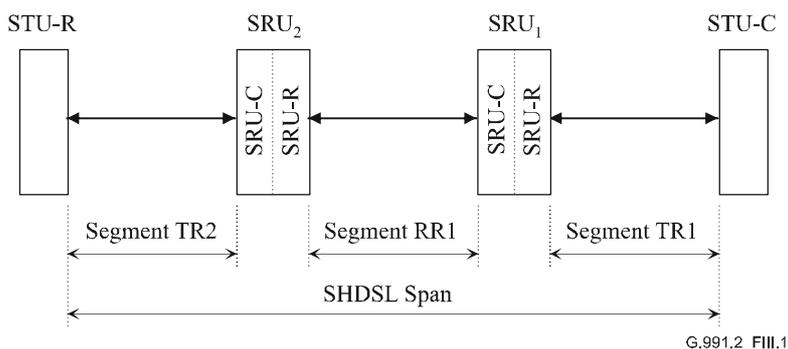
## **Appendix III**

### **Signal regenerator startup description**

This appendix describes the startup sequence used on spans employing regenerators. The sequence applies to spans with an arbitrary number of regenerators (up to 8), but for simplicity, the description here assumes a two-regenerator link. The use of line probing is optional, but its use is assumed for the purpose of this description.

The basic premise is that capability lists and line probe results propagate from the STU-R toward the STU-C and that the SHDSL training begins at the STU-C and propagates in the direction toward the STU-R. The Regenerator Silent Period (RSP) bit in ITU-T Rec. G.994.1 is used to hold off segments while the startup process propagates across the span.

The block diagram in Figure III.1 shows a typical SHDSL span with two regenerators as a reference for the startup sequences described below.



**Figure III.1/G.991.2 – Block diagram of a SHDSL span with two signal regenerators**

### III.1 STU-R initiated startup

In most typical SHDSL installations, the STU-R can be expected to initiate the startup process.

The proposed SHDSL startup process for STU-R initiation when the line probe is enabled, is described in the text below and shown graphically in Table III.1a.

In this mode, the STU-R triggers the startup process by initiating a G.994.1 session with the regenerator closest to it (over segment TR2). The STU-R and the SRU<sub>2</sub>-C then exchange capabilities. Because the target margins have not been passed from the STU-C to the STU-R and, therefore, line probe has not yet been performed, the SRU<sub>2</sub>-C issues an MS with the RSP bit set to hold off the STU-R while the startup process propagates across the span. In this appendix, the term "target margin" refers to both the current condition target margin and the worst-case target margin as described in 6.3.6 and 6.4.1. The G.994.1 session terminates normally, and the STU-R begins its waiting period.

Next, the SRU<sub>2</sub>-C conveys the capabilities from segment TR2 to the SRU<sub>2</sub>-R across the regenerator's internal interface. The SRU<sub>2</sub>-R then initiates a G.994.1 session with the SRU<sub>1</sub>-C and performs the same capabilities exchange described above for the first segment. The capabilities expressed by the SRU<sub>2</sub>-R are the intersection of its own capabilities with the capabilities it has received for segment TR2. The units still do not have sufficient information to begin SHDSL activation, so, again, the SRU<sub>1</sub>-C issues an MS with the RSP bit set. The G.994.1 session terminates normally, and the SRU<sub>2</sub>-R begins its waiting period.

As before, the SRU<sub>1</sub>-C then conveys the capabilities from segment RR1 (intersected with capabilities from segment TR2) to the SRU<sub>1</sub>-R across the regenerator's internal interface. The SRU<sub>1</sub>-R initiates a G.994.1 session with the STU-C and performs a capabilities exchange. The units still do not have sufficient information to begin SHDSL activation, but the SRU<sub>1</sub>-R now has the target margins from the STU-C, so the SRU<sub>1</sub>-R issues an MS with the RSP bit set. The G.994.1 session terminates normally, and the STU-C begins its waiting period.

At this point, the STU-C knows the STU-R has initiated a startup, but the target margins have not been passed all the way from the STU-C to the STU-R and therefore the line probe has not yet been performed on any segment. The SRU<sub>1</sub>-R communicates the STU-C target margins and other parameters to the SRU<sub>1</sub>-C across the regenerator's internal interface. At this point, the SRU<sub>1</sub>-C initiates a G.994.1 session with the SRU<sub>2</sub>-R over segment RR1 and then exchanges capabilities, using the target margins passed from the STU-C and setting the "CO target margin" capability bit set to a one. The SRU<sub>2</sub>-R issues an MS with the RSP bit set. The G.994.1 session terminates normally, and the SRU<sub>1</sub>-C begins its waiting period. The SRU<sub>2</sub>-R communicates the STU-C target margins and other parameters to the SRU<sub>2</sub>-C across the regenerator's internal interface. At this

point, the SRU<sub>2</sub>-C initiates a G.994.1 session with the STU-R over segment TR2. The STU-R and the SRU<sub>2</sub>-C then exchange capabilities, using the target margins passed from the STU-C and setting the "CO target margin" capability bit set to a one, and optionally perform a line probe and a second capabilities exchange. The units do not have enough information to begin SHDSL activation at this point, so the SRU<sub>2</sub>-C issues an MS with the RSP bit set to hold off the STU-R while the startup process propagates across the span. The G.994.1 session terminates normally, and the STU-R begins its waiting period.

Next, the SRU<sub>2</sub>-C conveys the capabilities from Segment TR2 to the SRU<sub>2</sub>-R across the regenerator's internal interface. The SRU<sub>2</sub>-R then initiates a G.994.1 session with the SRU<sub>1</sub>-C and performs the same capabilities exchange and line probing sequence described above for the first segment. The capabilities expressed by the SRU<sub>2</sub>-R are the intersection of its own capabilities with the capabilities it has received for Segment TR2. The units still do not have sufficient information to begin SHDSL activation, so, again, the SRU<sub>1</sub>-R issues an MS with the RSP bit set. The G.994.1 session terminates normally, and the SRU<sub>2</sub>-R begins its waiting period.

As before, the SRU<sub>1</sub>-C then conveys the capabilities from Segment RR1 (including the information from Segment TR2) to the SRU<sub>1</sub>-R across the regenerator's internal interface. The SRU<sub>1</sub>-R initiates a G.994.1 session with the STU-C and performs a capabilities exchange. Optionally, a line probe and a second capabilities exchange may be used. As before, the capabilities expressed by the SRU<sub>1</sub>-R are the intersection of its own capabilities with the capabilities it has received for Segments RR1 and TR2. At this point, the STU-C possesses all of the required information to select the span's operational parameters. The data rate and other parameters are selected, just as in a normal (non-regenerator) preactivation sequence and then the SHDSL activation begins for Segment TR1.

When the STU-C/SRU<sub>1</sub>-R link (over Segment TR1) has completed the SHDSL activation sequence (or the G.994.1 session, if clock mode 1 is selected), the SRU<sub>1</sub>-R communicates the selected operational parameters to the SRU<sub>1</sub>-C across the regenerator's internal interface. At this point, the SRU<sub>1</sub>-C initiates a G.994.1 session with the SRU<sub>2</sub>-R over Segment RR1. Parameters are selected – there should be no need for another CLR-CL exchange at this point – and the units perform the normal SHDSL activation. If clock mode 1 is selected (classic plesiochronous) there is no need to lock symbol timing to a network clock reference. In this case, the SRU<sub>1</sub>-C/SRU<sub>2</sub>-R G.994.1 session and activation should begin as soon as the STU-C/SRU<sub>1</sub>-R G.994.1 sessions complete. In clock modes 2, 3a, and 3b, such a network or data clock reference is necessary for establishing symbol timing. In these modes, the SRU<sub>1</sub>-C will delay the initiation of its G.994.1 session until the STU-C/SRU<sub>1</sub>-R activation is complete. In this way, the required reference clock will be available for symbol timing on the SRU<sub>1</sub>-C/SRU<sub>2</sub>-R segment.

When the SRU<sub>1</sub>-C/SRU<sub>2</sub>-R link (over Segment RR1) has completed the SHDSL activation sequence (or the G.994.1 session, if clock mode 1 is selected), the SRU<sub>2</sub>-R communicates the selected operational parameters to the SRU<sub>2</sub>-C across the regenerator's internal interface. The SRU<sub>2</sub>-C initiates a G.994.1 session with the STU-R over Segment TR2. Parameters are selected and the units perform the normal SHDSL activation. When this activation sequence is complete, the span can become fully operational.

If the line probe is disabled, then there is no reason to pass the target margins from the STU-C to the STU-R, and only the second wave of G.994.1 transactions need to occur. Table III.1b shows the typical transactions for the case where the line probe is disabled and the STU-R initiates the startup.

**Table III.1a/G.991.2 – STU-R initiated startup sequence (line probe enabled)**

<u>Segment TR2</u> <u>(STU-R/SRU<sub>2</sub>-C)</u>	<u>Segment RR1</u> <u>(SRU<sub>2</sub>-R/SRU<sub>1</sub>-C)</u>	<u>Segment TR1</u> <u>(SRU<sub>1</sub>-R/STU-C)</u>
<u>G.994.1 Start →</u> <u>Capabilities exchange</u> <u>(default target margins)</u> <u>← MS (RSP)</u>	<u>G.994.1 Start →</u> <u>Capabilities exchange</u> <u>(default target margins)</u> <u>← MS (RSP)</u>	<u>G.994.1 Start →</u> <u>Capabilities exchange</u> <u>(CO target margins)</u> <u>MS (RSP) →</u>
<u>← G.994.1 Start</u> <u>Capabilities exchange</u> <u>(CO target margins)</u> <u>Line probe</u> <u>Capabilities exchange</u> <u>← MS (RSP)</u>	<u>← G.994.1 Start</u> <u>Capabilities exchange</u> <u>(CO target margins)</u> <u>MS (RSP) →</u>	
	<u>G.994.1 Start →</u> <u>Capabilities exchange</u> <u>Line probe</u> <u>Capabilities exchange</u> <u>← MS (RSP)</u>	<u>G.994.1 Start →</u> <u>Capabilities exchange</u> <u>Line probe</u> <u>Capabilities exchange</u> <u>Mode selection</u> <u>SHDSL activation</u>
<u>← G.994.1 Start</u> <u>Mode selection</u> <u>SHDSL activation</u>	<u>← G.994.1 Start</u> <u>Mode selection</u> <u>SHDSL activation</u>	

**Table III.1b/G.991.2 – STU-R initiated startup sequence (line probe disabled)**

Segment TR2 (STU-R/SRU <sub>2</sub> -C)	Segment RR1 (SRU <sub>2</sub> -R/SRU <sub>1</sub> -C)	Segment TR1 (SRU <sub>1</sub> -R/STU-C)
G.994.1 Start → Capabilities exchange <i>Line probe</i> <del>Capabilities exchange</del> ← MS (RSP)	G.994.1 Start → Capabilities exchange <i>Line probe</i> <del>Capabilities exchange</del> ← MS (RSP)	G.994.1 Start → Capabilities exchange <i>Line probe</i> <del>Capabilities exchange</del> Mode selection SHDSL activation
← G.994.1 Start Mode selection SHDSL activation	← G.994.1 Start Mode selection SHDSL activation	

### III.2 STU-C Initiated Startup

In some cases, it may be desirable for the STU-C to initiate the startup process. The proposed SHDSL startup process for STU-C initiation is described in the text below and shown graphically in Table III.2.

In this mode, the STU-C triggers the startup process by initiating a G.994.1 session with the regenerator closest to it (over segment TR1) and exchanges capabilities (including the target margins from the STU-C). In this appendix, the term "target margin" refers to both the current condition target margin and the worst-case target margin as described in 6.3.6 and 6.4.1. The SRU<sub>2</sub>-C issues an MS with the RSP bit set to hold off the STU-C while the startup process propagates across the span. The G.994.1 session terminates normally, and the STU-C begins its waiting period. Next, the SRU<sub>1</sub>-C initiates a G.994.1 session with the SRU<sub>2</sub>-R, exchanges capabilities (including the target margins from the STU-C), ~~which~~ and again is terminated following an MS from the SRU<sub>2</sub>-R with the RSP bit set.

The SRU<sub>2</sub>-C next initiates a G.994.1 session with the STU-R. From this point on, the start sequence is as described in clause III.1 for the STU-R initiated startup.

**Table III.2/G.991.2 – STU-C initiated startup sequence**

Segment TR2 (STU-R/SRU <sub>2</sub> -C)	Segment RR1 (SRU <sub>2</sub> -R/SRU <sub>1</sub> -C)	Segment TR1 (SRU <sub>1</sub> -R/STU-C)
		← G.994.1 Start <u>Capabilities exchange</u> (CO target margins) MS (RSP) →
	← G.994.1 Start <u>Capabilities exchange</u> (CO target margins) MS (RSP) →	
← G.994.1 Start Capabilities exchange (CO target margins) <i>Line probe</i> <i>Capabilities exchange</i> ← MS (RSP)		
	G.994.1 Start → Capabilities exchange <i>Line probe</i> <i>Capabilities exchange</i> ← MS (RSP)	
		G.994.1 Start → Capabilities exchange <i>Line probe</i> <i>Capabilities exchange</i> Mode selection SHDSL activation
	← G.994.1 Start Mode selection SHDSL activation	
← G.994.1 Start Mode selection SHDSL activation		

### **III.3 SRU initiated startup**

In some limited applications (including some maintenance and retrain scenarios), it may be desirable for a regenerator to initiate the start sequence. In this mode, the SRU will initiate the train in the downstream direction – i.e., toward the STU-R in the same manner that it would have for the corresponding segment of the STU-C Startup Procedure (as described in III.2). The STU-R will then initiate the capabilities exchange and line probing procedure toward the STU-C, as in a normal STU-C initiated startup. The startup sequence begins with the initiating SRU-C and propagating toward the STU-R.

### III.4 Collisions and retrains

Collisions (equivalent to "glare" conditions in voice applications) can occur in cases where both the STU-C and the STU-R attempt to initiate connections simultaneously. Using the process described above, these collisions are resolved by specifying that R-to-C capabilities exchanges and probes will always take precedence over C-to-R train requests. G.994.1 sessions inherently resolve collisions on individual segments.

In ITU-T Rec. G.994.1, the RSP timeout is specified as approximately 1 minute. For spans with no more than one regenerator, this is ideal. For multi-regenerator spans, however, an STU may time out and initiate a new G.994.1 session before the SRU is prepared to begin the next phase of the train. In such cases, the SRU should respond to the G.994.1 initiation and issue an MS message with the RSP bit set to hold off the STU once again. For its part, the SRU should implement an internal timer and should not consider a startup to have failed until that timer has expired. The timer should be started when the SRU receives a RSP bit in an MS message and should not expire for at least 4 minutes.

If any segment must retrain due to line conditions or other causes, each segment of the span shall be deactivated and the full startup procedure shall be reinitiated.

### III.5 Diagnostic mode activation

If a segment fails, the startup procedure will also fail for the entire span. This would normally be characterized at the STU by being told to enter a silent interval via the RSP bit and never receiving another G.994.1 request. Without some diagnostic information, the service provider would have no easy way to test the integrity of the various segments.

This concern is resolved by the use of the "Diagnostic Mode" in ITU-T Rec. G.994.1 to trigger a diagnostic training mode. This bit, when set, causes an SRU connected to a failed segment to act as an STU and allow the startup procedure to finish. In this way, all of the segments before the failed segment may be tested using loopbacks and EOC-initiated tests, allowing network operators to quickly isolate the segment where the failure has occurred.

## 2) Addition of TU-12/VC-12 framing

*Add the following items to the References in clause 2:*

### 2 References

- [12] ITU-T Recommendation G.707/Y.1322 (2003), *Network node interface for the Synchronous Digital Hierarchy (SDH)*.
- [13] ITU-T Recommendation G.781 (1999), *Synchronization layer functions*.
- [14] ITU-T Recommendation G.813 (2003), *Timing characteristics of SDH equipment slave clocks (SEC)*.

*Add the following items alphabetically to the Abbreviations list in 3.2:*

### 3.2 Abbreviations

DCC	Data Communication Channel
SDH	Synchronous Digital Hierarchy
SEC	SDH Equipment Clock
TU-12	Tributary Unit-12
TUG	Tributary Unit Group

## VC-12 Virtual Container-12

Add the following text to Annex E defining TU-12/VC-12 framing:

### E.14 TPS-TC for synchronous digital hierarchy tributary unit 12 (TU-12) with a Data Communication Channel (DCC)

This TPS-TC defines a transport format for:

- a single SDH TU-12 frame with an optional  $8 \times i$  kbit/s Data Communication Channel (DCC) over a single wire pair; and
- an optional  $N \times$  SDH TU-12 frames with an optional  $(M \times i \times 8)$ -kbit/s DCC over  $M$  wire pairs.

The number  $N$  of TU-12 links can be 1 to 9 while the number  $M$  of wire pairs can be 1 to 4.

Table E.42 gives an overview of the transmission of  $N \times$  TU-12/VC-12 connections with a combination of  $M$ -pair SHDSL and Enhanced SHDSL data rates.

**Table E.42/G.991.2 – Transmission of  $N \times$  TU-12/VC-12 connections over  $M$ -Pair SHDSL**

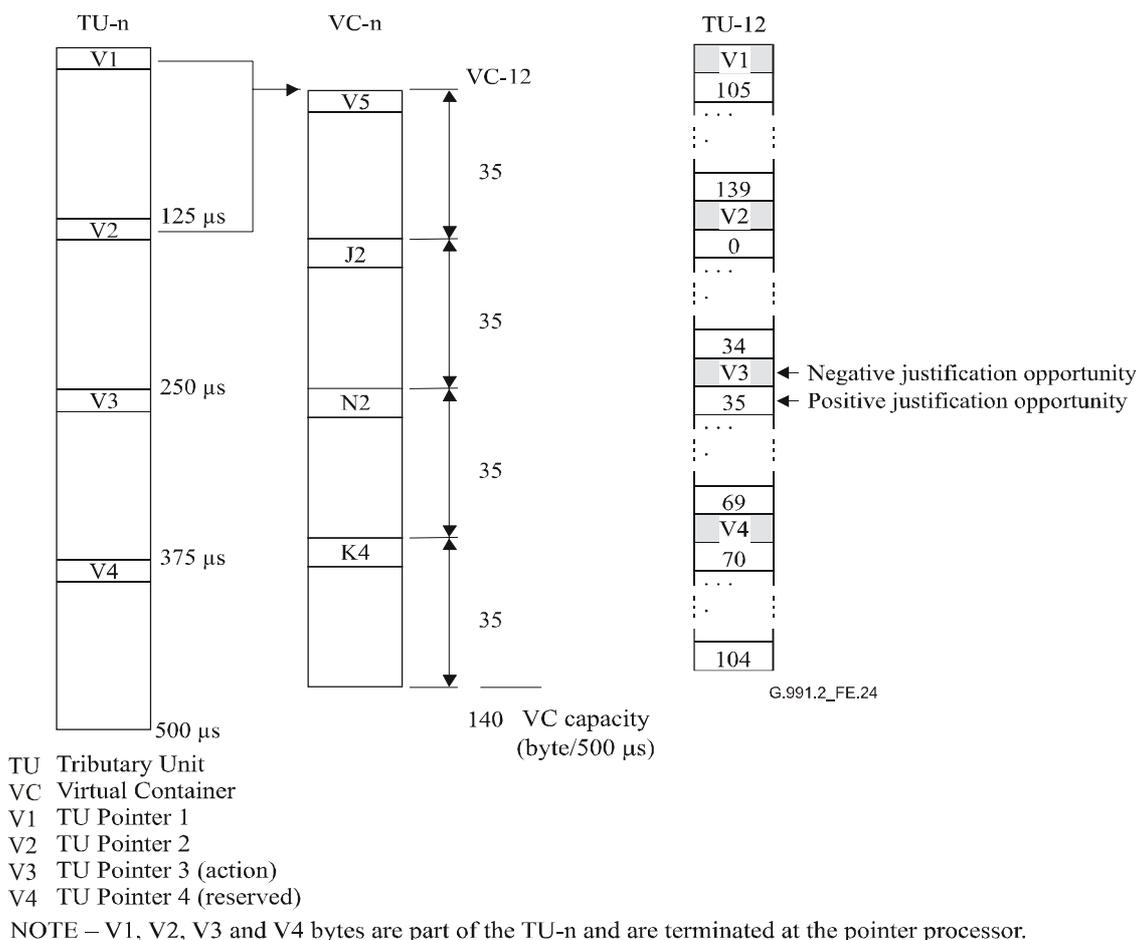
Number $N$ of TU-12/ VC-12 connections	Aggregate payload bit rate [kbit/s]	1-Pair SHDSL	2-Pair SHDSL	3-Pair SHDSL	4-Pair SHDSL
		Size $1 \times k_s$ bits of each payload sub-block with $k_s = i + n \times 8$ [bits] $M = 1$	Size $2 \times k_s$ bits of each payload sub-block with $k_s = i + n \times 8$ [bits] $M = 2$	Size $3 \times k_s$ bits of each payload sub-block with $k_s = i + n \times 8$ [bits] $M = 3$	Size $4 \times k_s$ bits of each payload sub-block with $k_s = i + n \times 8$ [bits] $M = 4$
1	$2304 + M \times i \times 8$	$n = 36; i = 0, \dots, 7$	$n = 18; i = 0, \dots, 4$	$n = 12; i = 0, \dots, 3$	$n = 9; i = 0, \dots, 2$
2	$4608 + M \times i \times 8$	$n = 72; i = 0, \dots, 7$	$n = 36; i = 0, \dots, 4$	$n = 24; i = 0, \dots, 3$	$n = 18; i = 0, \dots, 2$
3	$6912 + M \times i \times 8$	–	$n = 54; i = 0, \dots, 4$	$n = 36; i = 0, \dots, 3$	$n = 27; i = 0, \dots, 2$
4	$9216 + M \times i \times 8$	–	$n = 72; i = 0, \dots, 4$	$n = 48; i = 0, \dots, 3$	$n = 36; i = 0, \dots, 2$
5	$11\ 520 + M \times i \times 8$	–	–	$n = 60; i = 0, \dots, 3$	$n = 45; i = 0, \dots, 2$
6	$13\ 824 + M \times i \times 8$	–	–	$n = 72; i = 0, \dots, 3$	$n = 54; i = 0, \dots, 2$
7	$16\ 128 + M \times i \times 8$	–	–	$n = 84; i = 0, \dots, 3$	$n = 63; i = 0, \dots, 2$
8	$18\ 432 + M \times i \times 8$	–	–	–	$n = 72; i = 0, \dots, 2$
9	$20\ 736 + M \times i \times 8$	–	–	–	$n = 81; i = 0, \dots, 2$
		If no data communication channel is used $i = 0$ . If management, signalling, control and maintenance functions are to be transmitted over the Z-bits, $i \times 8$ kbit/s per wire-pair are additionally required with $i = 1, \dots, 7$ (1-pair), $i = 1, \dots, 4$ (2-pair), $i = 1, 2, 3$ (3-pair) and $i = 1, 2$ (4-pair).			

#### E.14.1 SDH tributary unit

A SDH Tributary Unit (TU) is an information structure, which provides adaptation between the SDH lower order path layer and a server layer (e.g., SDH higher order path layer, SHDSL). It consists of an information payload, in which the lower order Virtual Container (VC) is transported, and a Tributary Unit pointer. The TU pointer indicates the offset of the VC frame start relative to the TU frame start. The TU frame always appears in the defined position within each server layer signal (e.g., SHDSL).

The TU-12 consists of a VC-12 together with a TU-12 pointer. The TU-12 frame is specified in 8.3/G.707/Y.1322 and consists of 144 bytes organized in four groups of 36 bytes. The first byte in each of the four groups is a TU-12 pointer byte (V1, V2, V3, V4). V1 to V3 identify the location

in the information payload, which contains the first byte (V5) of the VC-12. The 140 information payload bytes in the TU-12 are numbered from 0 to 139.



**Figure E.24/G.991.2 – Virtual container mapping in tributary unit and TU-12 pointer offsets (combination of Figures 8-9/G.707/Y.1322 and 8-11/G.707/Y.1322)**

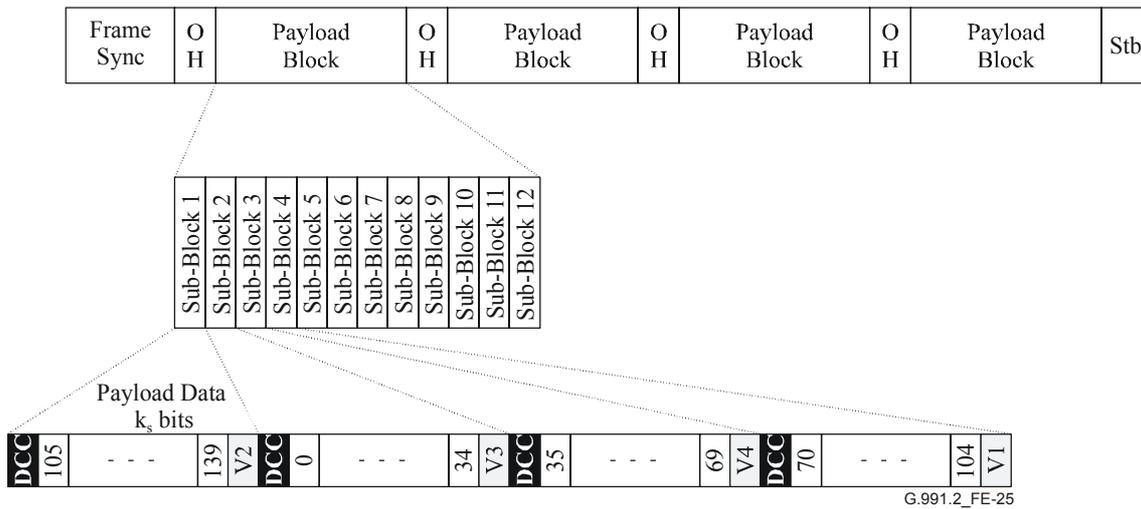
### E.14.2 TU-12 into SHDSL mapping

Figure E.25 shows the alignment of a single TU-12 frame and the optional DCC within the SHDSL frame. Each payload sub-block contains an *i*-bit DCC ( $i = 0, \dots, 7$ ), followed by *thirty-six* bytes of the TU-12. Bytes are transmitted MSB first, in accordance with ITU-T Rec. G.707/Y.1322.

A total of  $k_s$  bits of contiguous data shall be contained within each sub-block, as specified in 8.1, where  $k_s = i + n \times 8$ . If a DCC is used,  $i = 1, \dots, 7$ ; if no DCC is used,  $i = 0$ ; and  $n = 36$ .

The TU-12 framing clock shall be synchronized to the SHDSL clock such that the TU-12 frame always appears in the defined position within each group of four consecutive SHDSL payload sub-blocks. See Figure E.25 for additional details.

The  $4 \times 36$  octet TU-12 frames shall be aligned within the group of four consecutive SHDSL payload sub-blocks  $4j + 1$  to  $4j + 4$  ( $j = 0, 1, 2$ ) such that the TU-12 byte with TU-12 pointer offset 105 begins at the first bit position after the optional DCC within the payload sub-block  $4j + 1$ , followed by TU-12 byte with TU-12 pointer offset 106, ..., and TU-12 pointer byte V1 ends at the last bit position within the payload sub-block  $4j + 4$ .



NOTE – V1, V2 and V3 are TU-12 pointers 1, 2 and 3; V4 is set to ONE. These bytes are part of the TU-12 and terminated at a pointer processor.

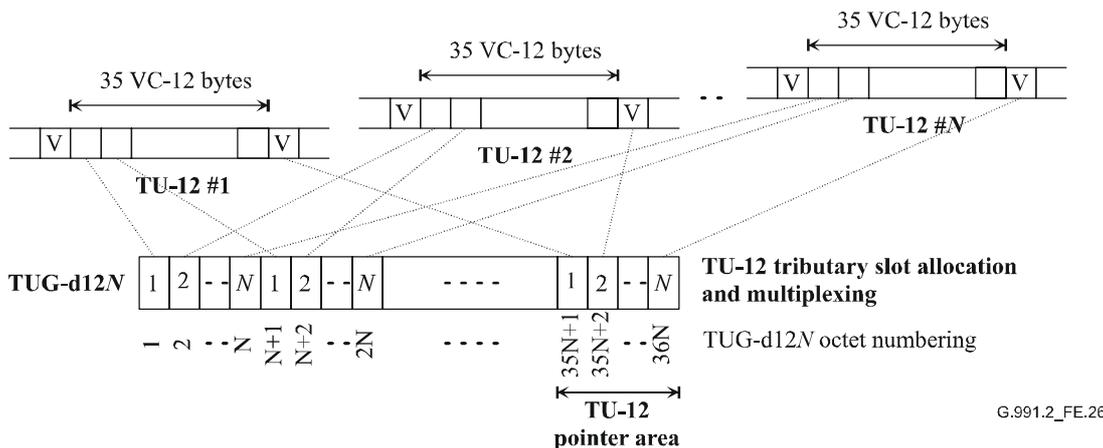
**Figure E.25/G.991.2 – TU-12 mapping into a single pair SHDSL signal with optional data communication channel**

### E.14.3 SDH tributary unit group

One or more tributary units, occupying fixed, defined positions in a server signal's (e.g., SHDSL) payload is termed a Tributary Unit Group (TUG). A TUG-d12N is a DSL optimized TUG containing a homogeneous assembly of N TU-12s. The TU-12s are byte interleaved in the TUG-d12N.

The multiplexing of  $N \times$  TU-12 ( $N = 1..9$ ) into a TUG-d12N is shown in Figure E.26. A TU-12 is byte interleaved with  $N - 1$  other TU-12s into the TUG-d12N.

NOTE – The TU-12 pointer bytes of the N TU-12s are mapped in the last N octets of the TUG-d12N as shown in Figure E.26.



**Figure E.26/G.991.2 – Arrangement of  $N \times$  TU-12s multiplexed into a TUG-d12N ( $N = 1, 2, \dots, 9$ )**

#### E.14.4 $N \times$ TU-12 into $M$ -pair SHDSL mapping

In the optional  $M$ -pair mode ( $M = 1,2,3,4$ ), both the TUG-d12 $N$  with the  $N$  TU-12s and the optional DCC are carried over all  $M$  pairs using interleaving, as described in 8.2. In the  $M$ -pair mode of operation, the DCC bit rate is  $M \times i \times 8$  kbit/s.

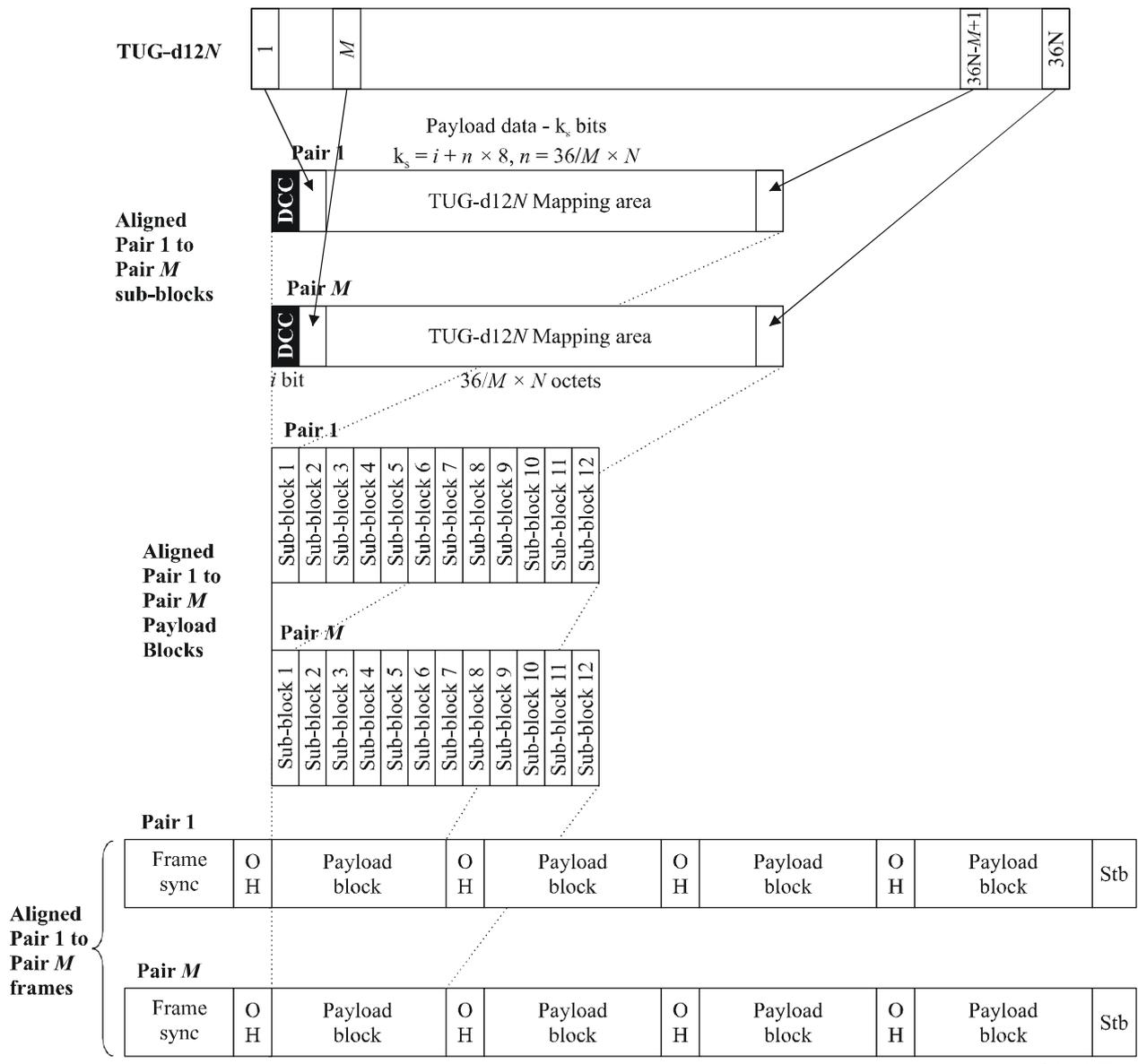
Each pair carries a SHDSL frame of which each payload sub-block contains an  $i$ -bit DCC with  $i = 0, \dots, 7$  (single-pair mode),  $i = 0, \dots, 4$  (2-pair mode),  $i = 0, \dots, 3$  (3-pair mode) and  $i = 0, 1, 2$  (4-pair mode), followed by a TUG-d12 $N$  mapping area of  $36/M \times N$  octets. Octets are transmitted MSB first, in accordance with ITU-T Rec. G.707/Y.1322.

Figure E.27 shows the octet interleaving of the TUG-d12 $N$  and the bit interleaving of the DCC within the  $M$ -pair mode SHDSL frame. The octets in the TUG-d12 $N$  shall be interleaved among all  $M$  wire-pairs, such that pair  $m$  carries the  $m$ th octet out of every block of  $M$  octets and a total of  $36/M \times N$  octets per payload sub-block.

The optional DCC is interleaved among the  $M$  pairs such that it occupies the first  $i$  bit positions within each payload sub-block on each of the  $M$  wire pairs. The values for  $i$  may be in the range  $i = 0, \dots, 7$  (single-pair mode),  $i = 0, \dots, 4$  (2-pair mode),  $i = 0, \dots, 3$  (3-pair mode) and  $i = 0, 1, 2$  (4-pair mode). So a total of  $M \times i$  bits make up the DCC. The first bit of DCC data shall be contained within a sub-block on Pair 1, and the following bits of DCC data shall be interleaved bit-by-bit among all  $M$  wire pairs. The DCC bits shall be interleaved among all  $M$  wire pairs such that they occupy the first  $i$  bit positions within each payload sub-block on each of the  $M$  pairs. The first  $M$  bits of DCC data go into bit 1 on pairs 1, ...,  $M$ ; and bits  $(i - 1) \times M + 1, \dots, (i - 1) \times 2 \times M$  go into bit  $i$  of pair 1, ...,  $M$ .

A total of  $k_s$  bits of contiguous data shall be contained within each sub-block, as specified in 8.2, where  $k_s = i + n \times 8$ . If a DCC is used,  $i = 1, \dots, 7$  (single-pair mode),  $i = 1, \dots, 4$  (2-pair mode),  $i = 1, 2, 3$  (3-pair mode) and  $i = 1, 2$  (4-pair mode); if no DCC is used,  $i = 0$ ; and  $n = 36/M \times N$ .

NOTE – The terms *interleaving* and *de-interleaving* are differently applied in G.991.2 and in SDH standards like ITU-T Recs G.701, G.707/Y.1322 or G.806.

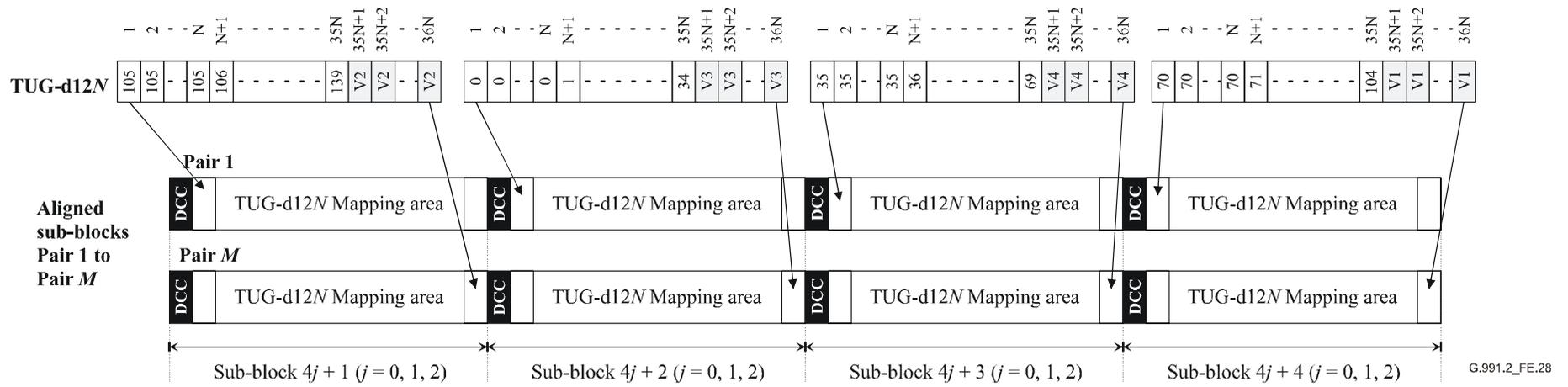


G.991.2\_FE.27

**Figure E.27/G.991.2 – TUG-d12N mapping into a M-pair SHDSL signal with data communication channel**

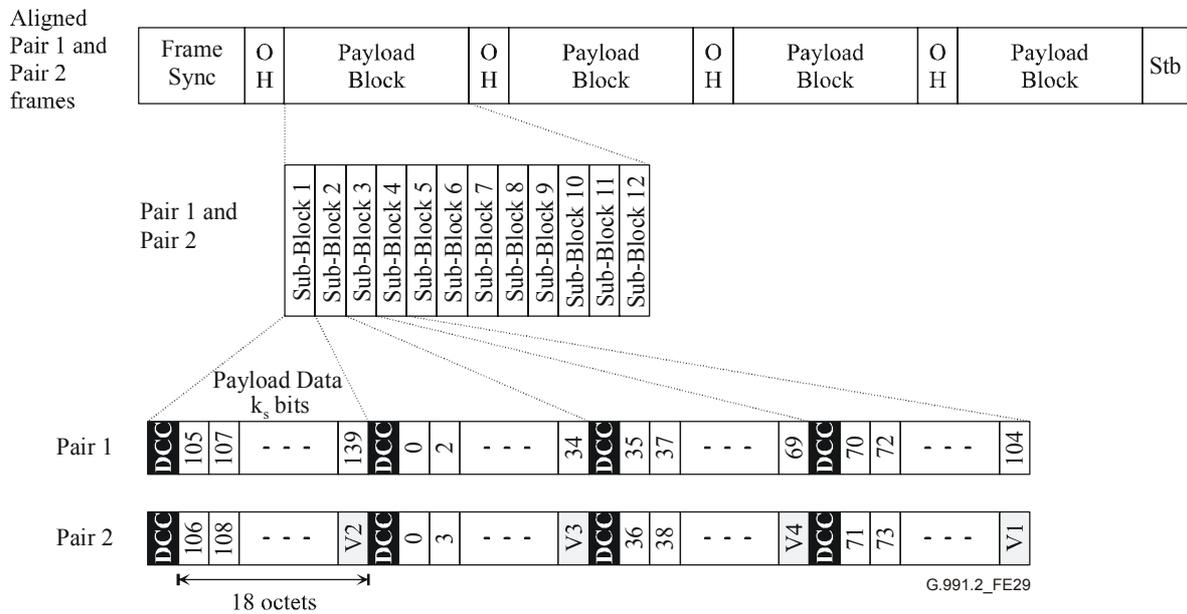
The TU-12 framing clocks shall be synchronized to the SHDSL clocks such that the TU-12 frames always appear in a defined position within each group of four SHDSL payload sub-blocks  $4j + 1$  to  $4j + 4$  ( $j = 0, 1, 2$ ) as shown in Figure E.28.

Sub-blocks  $4j + 1$  contain the TU-12 bytes numbered 105 to 139 and pointer byte V2, sub-blocks  $4j + 2$  contain the TU-12 bytes numbered 0 to 34 and pointer byte V3, sub-blocks  $4j + 3$  contain the TU-12 bytes numbered 35 to 69 and pointer byte V4, and sub-blocks  $4j + 4$  contain the TU-12 bytes numbered 70 to 104 and pointer byte V1.



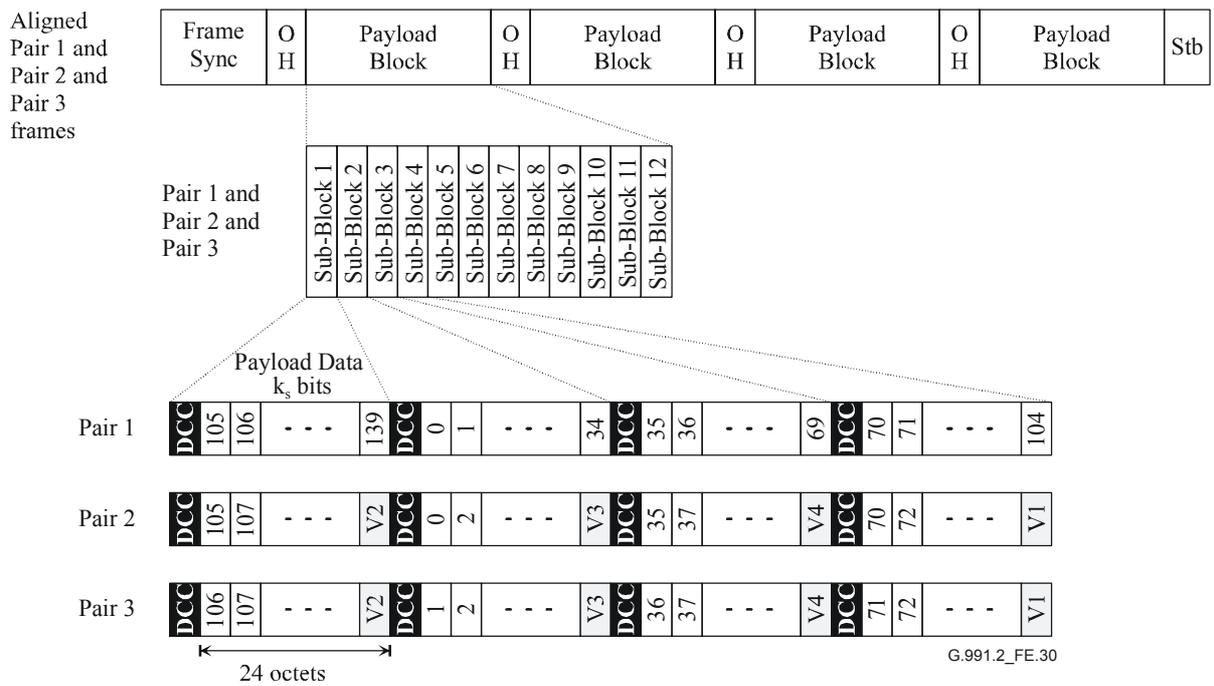
**Figure E.28/G.991.2 – TU-12 pointer offset numbering in  $M$ -pair SHDSL signal**

Figures E.29 to E.31 show three examples of  $N \times \text{TU-12}$  over SHDSL. Figure E.29 shows the alignment of a single TU-12 frame and the DCC within the 2-pair mode SHDSL frame. Each payload sub-block contains a 1-bit DCC, followed by *eighteen* bytes of the TU-12. The TU-12 bytes shall be interleaved among the *two* wire pairs, such that pair  $m$  carries the  $m$ th byte out of every block of *two* bytes and a total of  $36/2$  bytes per payload sub-block. The DCC is interleaved among the *two* pairs such that it occupies the first bit position within each payload sub-block on each of the *two* wire pairs.



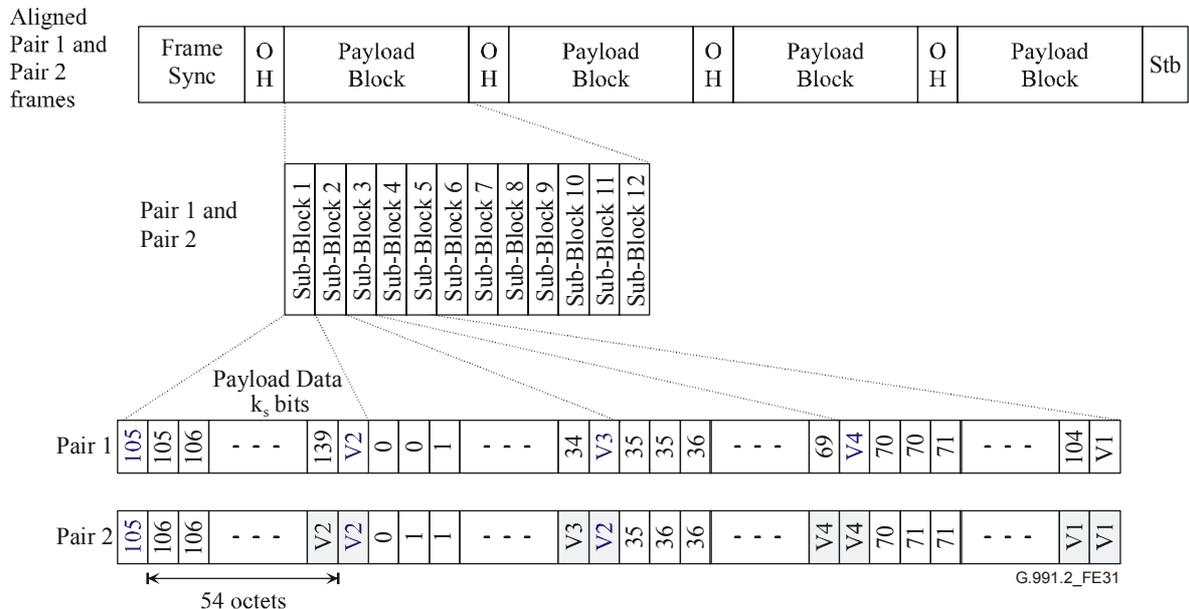
**Figure E.29/G.991.2 – M-Pair TU-12 framing with a data communication channel  
( $N = 1$  TU-12 links with  $i = 1$  over  $M = 2$  wire-pairs)**

Figure E.30 shows the alignment of a TUG-d12N and the optional DCC within the  $M$ -pair mode SHDSL frame for the case of  $N = 2$ ,  $M = 3$  and  $i = 1$ . Each payload sub-block contains a 1-bit DCC, followed by *twenty-four* octets of the TUG-d12N. The TUG-d12N octets shall be interleaved among the *three* wire pairs, such that pair  $m$  carries the  $m$ th octet out of every block of *three* octets and a total of  $36/3 \times 2$  octets per payload sub-block. The DCC is interleaved among the *three* pairs such that it occupies the first bit position within each payload sub-block on each of the *three* wire pairs. So a total of *three* bits make up the DCC. One bit of DCC data shall be contained within a sub-block on Pair 1, and the following two bits of DCC data shall be contained within the corresponding sub-blocks of the following two pairs.



**Figure E.30/G.991.2 –  $M$ -Pair TU-12 framing with a data communication channel**  
 ( $N = 2$  TU-12 links with  $i = 1$  over  $M = 3$  wire-pairs)

Figure E.31 shows the alignment of a TUG-d12N and the optional DCC within the  $M$ -pair mode SHDSL frame for the case of  $N = 3$ ,  $M = 2$  and  $i = 0$ . Each payload sub-block contains *fifty-four* octets of the TUG-d12N. The TUG-d12N octets shall be interleaved among the *two* wire pairs, such that pair  $m$  carries the  $m$ th octet out of every block of *two* octets and a total of  $36/2 \times 3$  octets per payload sub-block. There is no DCC present.



**Figure E.31/G.991.2 –  $M$ -Pair TU-12 Framing with a data communication channel**  
 ( $N = 3$  TU-12 links with  $i = 0$  over  $M = 2$  wire-pairs)

#### **E.14.5 SHDSL clock**

The SHDSL clock synchronization mode shall be the synchronous mode as specified in clause 10. The SHDSL line clock shall be the frequency lock to network clock, which is equivalent to the SDH Equipment Clock (SEC) as specified in ITU-T Recs G.813 and G.781.

#### **E.14.6 $N \times$ TU-12 over $M$ -pair SHDSL DCC**

The optional  $(M \times i \times 8)$ -kbit/s DCC in the  $N \times$  TU-12 over  $M$ -pair SHDSL may support one or more of the data communication network applications specified in ITU-T Rec. G.7712/Y.1703: distributed management communications related to the Telecommunication Management Network (TMN), distributed signalling communications related to the Automatic Switched Transport Network (ASTN), and other distributed communications (e.g., software download). Note that the details of the protocols used over this optional DCC are beyond the scope of this Recommendation.





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