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G.991.2

Amendment 1
(07/2004)

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

Digital sections and digital line system – Access networks

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

Amendment 1:

CAUTION !

PREPUBLISHED RECOMMENDATION

This prepublication is an unedited version of a recently approved Recommendation. It will be replaced by the published version after editing. Therefore, there will be differences between this prepublication and the published version.

ITU-T Recommendation G.991.2

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

Amendment 1

Summary

The following text reflects the agreed modification per the comment resolution given above. The text modifications are shown with revision control. The revisions are relative the consented text for G.991.2 as given in TD 47 (PLEN) of the April 19-30, 2004 SG 15 Meeting.

1. Resolution to Passing of Target Margin in an SHDSL Access Link with Repeaters

Provide the edits to Annex D and Appendix III as shown in the following:

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_1), TR2 (SRU_X-C to STU-R), and RRn (SRU_n-C to SRU_{n+1} – R, where $1 \le n \le X$-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.

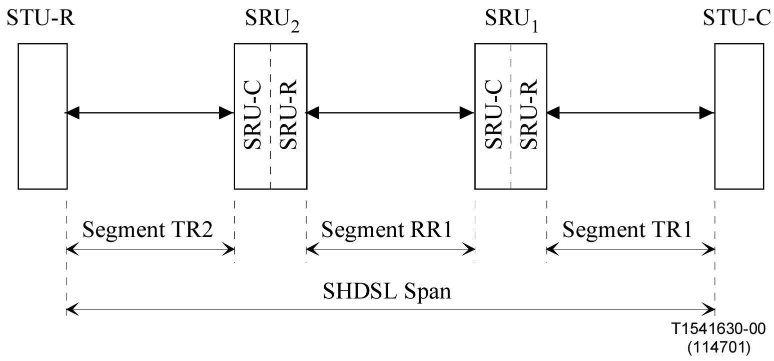


FIGURE D-1

Block Diagram of a SHDSL Span with Two Signal Regenerators

D.2 Startup Procedures

D.2.1 SRU-C

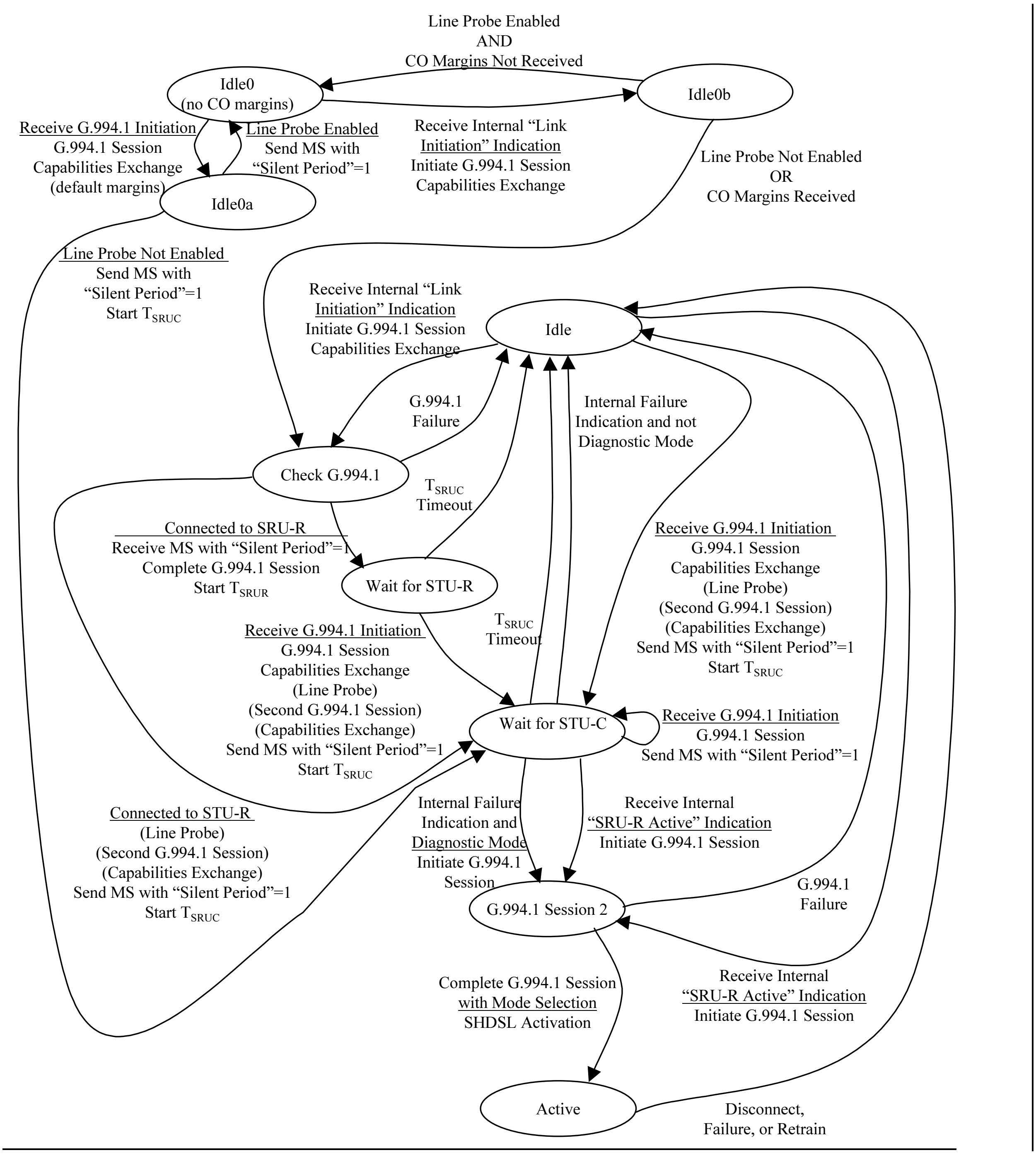
Figure D-2 shows the State Transition Diagram for SRU-C start-up and operation. The SRU-C begins in the "Idle0" state and, in the case of an STU-R initiated start-up, transitions first to the "~~Wait for STU-C~~Idle0a" state. If line probe is disabled, the STU-C shall transition from the "Idle0a" state 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 margin 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".


Line Probe Enabled
AND
CO Margins Not Received
Idle0
(no CO margins)
Idle0b
Receive G.994.1 Initiation
G.994.1 Session
Capabilities Exchange
(default margins)
Line Probe Enabled
Send MS with
"Silent Period"=1
Receive Internal "Link
Initiation" Indication
Initiate G.994.1 Session
Capabilities Exchange
Line Probe Not Enabled
OR
CO Margins Received
Idle0a
Line Probe Not Enabled
Send MS with
"Silent Period"=1
Start T_{SRUC}
Receive Internal "Link
Initiation" Indication
Initiate G.994.1 Session
Capabilities Exchange
Idle
G.994.1
Failure
Internal Failure
Indication and not
Diagnostic Mode
Check G.994.1
T_{SRUC}
Timeout
Connected to SRU-R
Receive MS with "Silent Period"=1
Complete G.994.1 Session
Start T_{SRUR}
Wait for STU-R
Receive G.994.1 Initiation
G.994.1 Session
Capabilities Exchange
(Line Probe)
(Second G.994.1 Session)
(Capabilities Exchange)
Send MS with "Silent Period"=1
Start T_{SRUC}
T_{SRUC}
Timeout
Receive G.994.1 Initiation
G.994.1 Session
Capabilities Exchange
(Line Probe)
(Second G.994.1 Session)
(Capabilities Exchange)
Send MS with "Silent Period"=1
Start T_{SRUC}
Wait for STU-C
Receive G.994.1 Initiation
G.994.1 Session
Send MS with "Silent Period"=1
Connected to STU-R
(Line Probe)
(Second G.994.1 Session)
(Capabilities Exchange)
Send MS with "Silent Period"=1
Start T_{SRUC}
Internal Failure
Indication and
Diagnostic Mode
Initiate G.994.1
Session
Receive Internal
"SRU-R Active" Indication
Initiate G.994.1 Session
G.994.1
Failure
G.994.1 Session 2
Complete G.994.1 Session
with Mode Selection
SHDSL Activation
Receive Internal
"SRU-R Active" Indication
Initiate G.994.1 Session
Active
Disconnect,
Failure, or Retrain

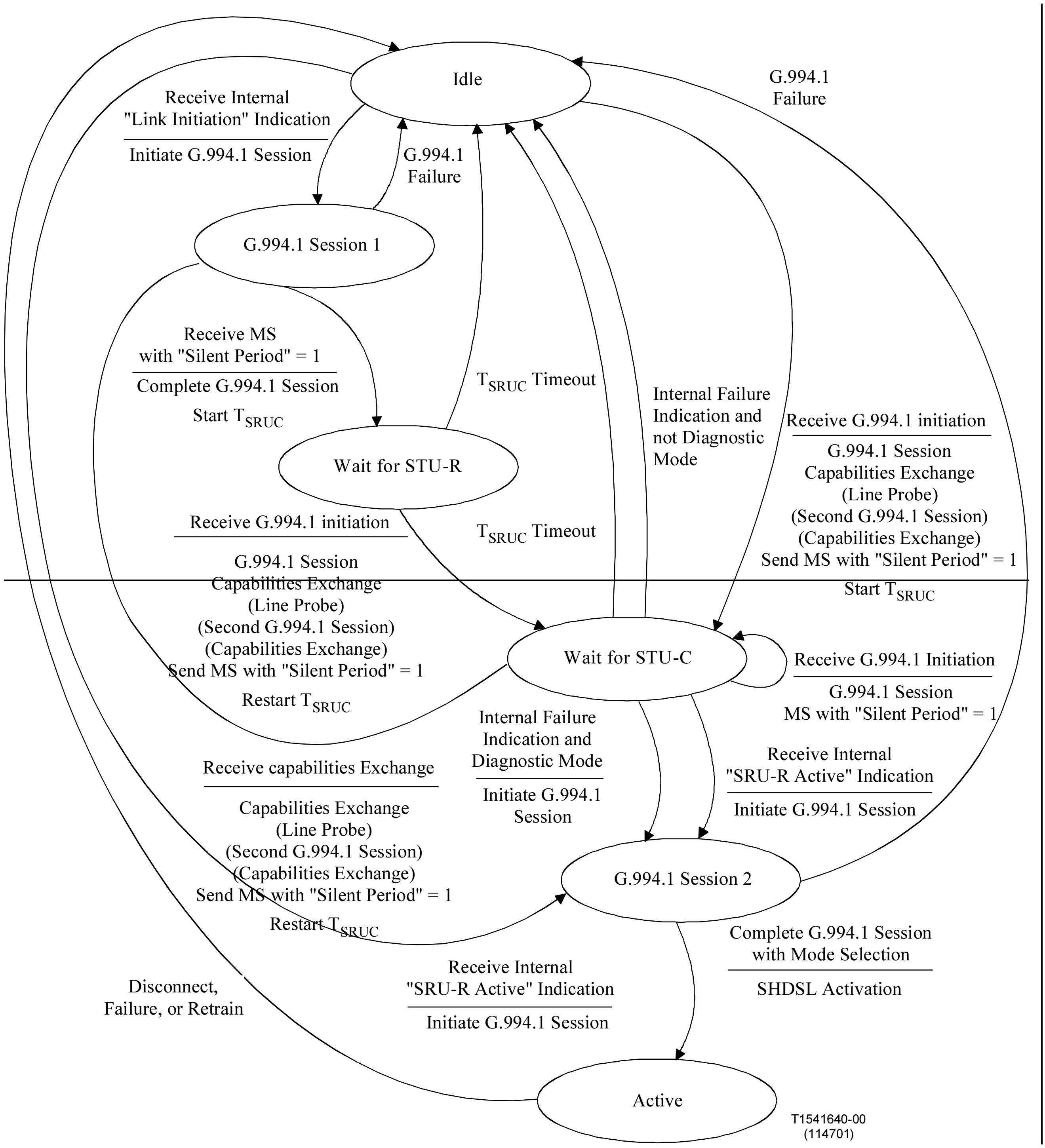


FIGURE D-2

SRU-C State Transition Diagram

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.

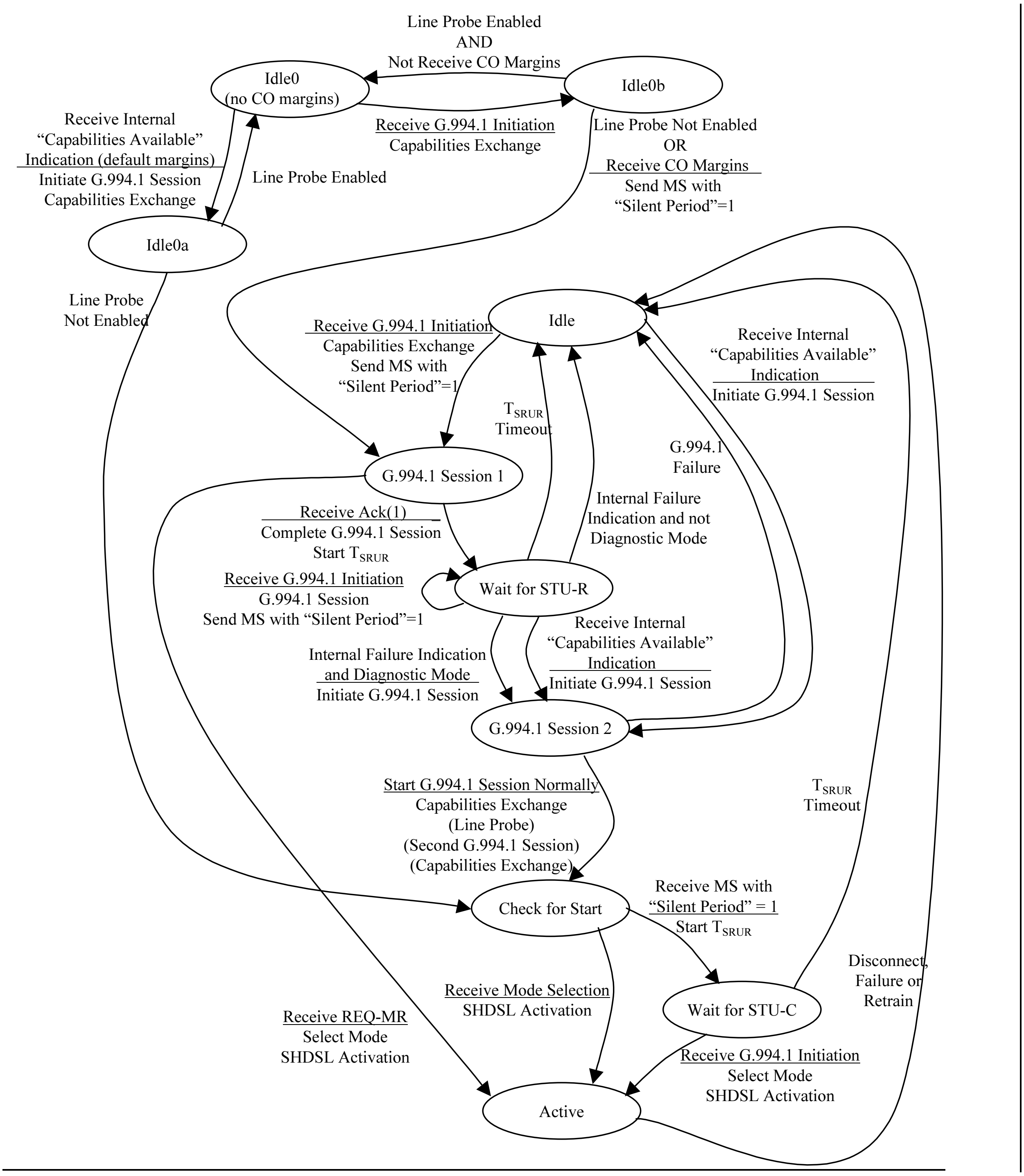
The SRU-R shall communicate "Link Initiation" status to the SRU-C across the regenerator's internal interface upon entering the "Wait for STU-R" or "Idle0b" state. If the SRU-R exchanges capabilities with a STU-C, it shall communicate the target margins from the STU-C across the regenerator's internal 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 §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 §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".


Line Probe Enabled
AND
Not Receive CO Margins
Idle0
(no CO margins)
Idle0b
Receive G.994.1 Initiation
Capabilities Exchange
Line Probe Not Enabled
OR
Receive CO Margins
Send MS with
"Silent Period"=1
Receive Internal
"Capabilities Available"
Indication (default margins)
Initiate G.994.1 Session
Capabilities Exchange
Line Probe Enabled
Idle0a
Line Probe
Not Enabled
Idle
Receive G.994.1 Initiation
Capabilities Exchange
Send MS with
"Silent Period"=1
T SRUR
Timeout
Receive Internal
"Capabilities Available"
Indication
Initiate G.994.1 Session
G.994.1
Failure
G.994.1 Session 1
Internal Failure
Indication and not
Diagnostic Mode
Receive Ack(1)
Complete G.994.1 Session
Start T SRUR
Receive G.994.1 Initiation
G.994.1 Session
Send MS with "Silent Period"=1
Wait for STU-R
Receive Internal
"Capabilities Available"
Indication
Initiate G.994.1 Session
Internal Failure Indication
and Diagnostic Mode
Initiate G.994.1 Session
G.994.1 Session 2
Start G.994.1 Session Normally
Capabilities Exchange
(Line Probe)
(Second G.994.1 Session)
(Capabilities Exchange)
T SRUR
Timeout
Check for Start
Receive MS with
"Silent Period" = 1
Start T SRUR
Disconnect,
Failure or
Retrain
Receive Mode Selection
SHDSL Activation
Wait for STU-C
Receive REQ-MR
Select Mode
SHDSL Activation
Receive G.994.1 Initiation
Select Mode
SHDSL Activation
Active

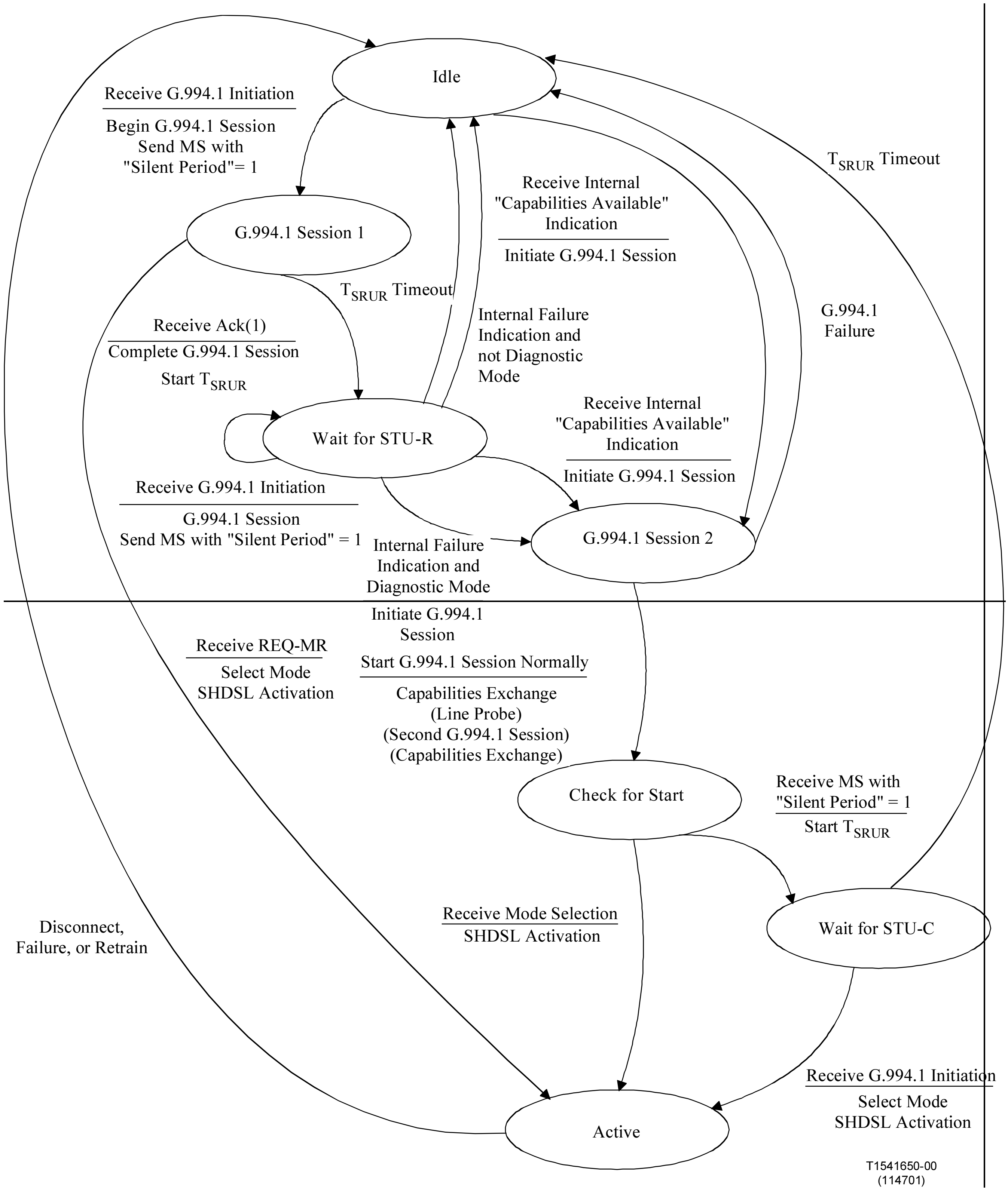


FIGURE D-3
SRU-R State Transition Diagram

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 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 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_1-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 (Informative)

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 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.

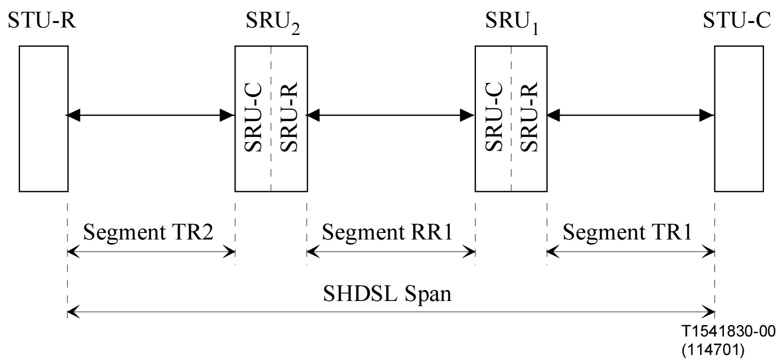


FIGURE III-1

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 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$_2$-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$_2$-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$_2$-C conveys the capabilities from Segment TR2 to the SRU$_2$-R across the regenerator's internal interface. The SRU$_2$-R then initiates a G.994.1 session with the SRU$_1$-C and performs the same capabilities exchange described above for the first segment. The capabilities expressed by the SRU_2-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_1-C issues an MS with the RSP bit set. The G.994.1 session terminates normally, and the SRU_2-R begins its waiting period.

As before, the SRU_1-C then conveys the capabilities from Segment RR1 (intersected with capabilities from Segment TR2) to the SRU_1-R across the regenerator's internal interface. The SRU_1-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_1-R now has the target margins from the STU-C, so the SRU_1-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_1-R communicates the STU-C target margins and other parameters to the SRU_1-C across the regenerator's internal interface. At this point, the SRU_1-C initiates a G.994.1 session with the SRU_2-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_2-R issues an MS with the RSP bit set. The G.994.1 session terminates normally, and the SRU_1-C begins its waiting period. The SRU_2-R communicates the STU-C target margins and other parameters to the SRU_2-C across the regenerator's internal interface. At this point, the SRU_2-C initiates a G.994.1 session with the STU-R over Segment TR2. The STU-R and the SRU_2-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_2-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_2-C conveys the capabilities from Segment TR2 to the SRU_2-R across the regenerator's internal interface. The SRU_2-R then initiates a G.994.1 session with the SRU_1-C and performs the same capabilities exchange and line probing sequence described above for the first segment. The capabilities expressed by the SRU_2-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_1-R issues an MS with the RSP bit set. The G.994.1 session terminates normally, and the SRU_2-R begins its waiting period.

As before, the SRU_1-C then conveys the capabilities from Segment RR1 (including the information from Segment TR2) to the SRU_1-R across the regenerator's internal interface. The SRU_1-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_1-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_1-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_1-R communicates the selected operational parameters to the SRU_1-C across the regenerator's internal interface. At this point, the SRU_1-C initiates a G.994.1 session with the SRU_2-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_1-C / SRU_2-R G.994.1 session and activation should begin as soon as the STU-C / SRU_1-R G.994.1 sessions completes. 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_1-C will delay the initiation of its G.994.1 session until the STU-C / SRU_1-R activation is complete. In this way, the required reference clock will be available for symbol timing on the SRU_1-C / SRU_2-R segment.

When the SRU_1-C / SRU_2-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_2-R communicates the selected operational parameters to the SRU_2-C across the regenerator's internal interface. The SRU_2-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 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-1 shows the typical transactions for the case where the line probe is disabled and the STU-R initiates the startup.

TABLE III-1A

STU-R Initiated Startup Sequence (Line Probe Enabled)

Segment TR2 (STU-R / SRU_2-C)	Segment RR1 (SRU_2-R / SRU_1-C)	Segment TR1 (SRU_1-R / STU-C)
G.994.1 Start →		
Capabilities exchange		
(default target margins)		
← MS (RSP)		
	G.994.1 Start →	
	Capabilities exchange	
	(default target margins)	
	← MS (RSP)	
		G.994.1 Start →
		Capabilities exchange
		(CO target margins)
		MS (RSP) →
	← G.994.1 Start	
	Capabilities Exchange	
	(CO target margins)	
	MS (RSP) →	
← G.994.1 Start		
Capabilities Exchange		
(CO target margins)		
Line Probe		
Capabilities Exchange		
← MS (RSP)		
	G.994.1 Start →	
	Capabilities Exchange	
	Line Probe	
	Capabilities Exchange	
	← MS (RSP)	
		G.994.1 Start →
		Capabilities exchange

		Line Probe Capabilities Exchange Mode Selection SHDSL activation
	← G.994.1 Start Mode Selection SHDSL activation	
← G.994.1 Start Mode Selection SHDSL activation		

TABLE III-1

STU-R Initiated Startup Sequence (Line Probe Disabled)

Segment TR2 (STU-R / SRU$_2$-C)	Segment RR1 (SRU$_2$-R / SRU$_1$-C)	Segment TR1 (SRU$_1$-R / STU-C)
G.994.1 Start →		
Capabilities exchange		
~~*Line probe*~~		
~~*Capabilities exchange*~~		
← MS (RSP)		
	G.994.1 Start →	
	Capabilities exchange	
	~~*Line probe*~~	
	~~*Capabilities exchange*~~	
	← MS (RSP)	
		G.994.1 Start →
		Capabilities exchange
		~~*Line probe*~~
		~~*Capabilities exchange*~~
		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$_2$-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 wait period. Next, the SRU$_1$-C initiates a G.994.1 session with the SRU$_2$-R, exchanges capabilities (including the target margins from the STU-C), ~~which,~~and again is terminated following an MS from the SRU$_2$-R with the RSP bit set.

The SRU$_2$-C next initiates a G.994.1 session with the STU-R. From this point on, the start sequence is as described in §III.1 for the STU-R initiated startup.

TABLE III-2

STU-C Initiated Startup Sequence

Segment TR2 (STU-R / SRU$_2$-C)	Segment RR1 (SRU$_2$-R / SRU$_1$-C)	Segment TR1 (SRU$_1$-R / STU-C)
		← G.994.1 Start
		Capabilities Exchange
		(CO target margins)
		MS (RSP) →
	← G.994.1 Start	
	Capabilities Exchange	
	(CO target margins)	
	MS (RSP) →	
← G.994.1 Start		
Capabilities exchange		
(CO target margins)		
Line probe		
Capabilities exchange		
← MS (RSP)		
	G.994.1 Start →	
	Capabilities exchange	
	Line probe	
	Capabilities exchange	
	← MS (RSP)	
		G.994.1 Start →

		Capabilities exchange *Line probe* *Capabilities exchange* 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 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 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 Section 2 of G.991.2.

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), Synchronisation layer functions

[14] ITU-T Recommendation G.813 (2003), Timing characteristics of SDH equipment slave clocks

Add the following items to the Abbreviations list in Section 3.2 of G.991.2

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 of G.991.2 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 × *i* kbit/s Data Communication Channel (DCC) over a single wire pair, and
- an optional *N* × SDH TU-12 frames with an optional (*M* × *i* × 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-41 gives an overview of the transmission of *N* × TU-12/VC-12 connections with a combination of *M*-pair SHDSL and Enhanced SHDSL data rates.

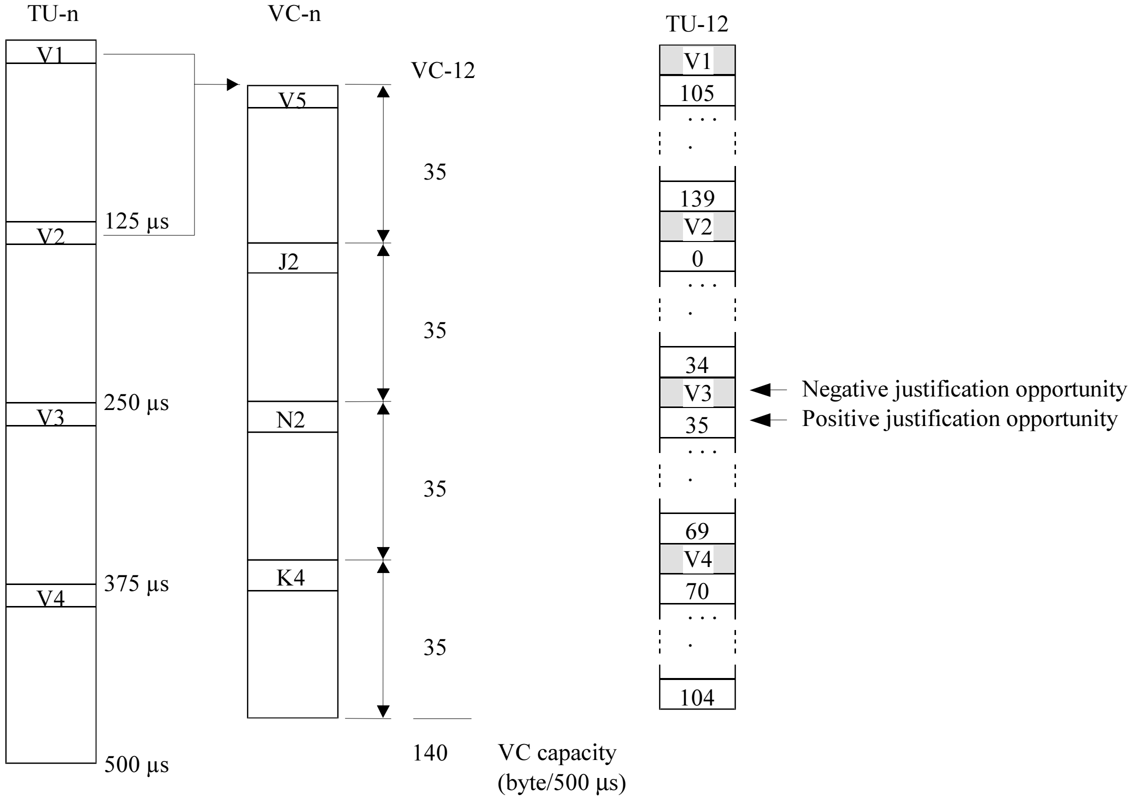
Table E-41 - Transmission of *N* × TU-12/VC-12 Connections over *M*-Pair SHDSL

Number *N* of TU-12 / VC-12 Connections	Aggregate Payload Bit Rate [kbits/s]	1-Pair SHDSL Size 1 × k_s bits of each payload sub-block with k_s = i + n×8 [bits] *M* = 1	2-Pair SHDSL Size 2 × k_s bits of each payload sub-block with k_s = i + n×8 [bits] *M* = 2	3-Pair SHDSL Size 3 × k_s bits of each payload sub-block with k_s = i + n×8 [bits] *M* = 3	4-Pair SHDSL Size 4 × k_s bits of each payload sub-block with k_s = i + n×8 [bits] *M* = 4
1	2304 + M × i × 8	n = 36; i=0,..,7	n = 18; i=0,..,4	n = 12; i=0,..,3	n = 9; i=0,..,2
2	4608 + M × i × 8	n = 72; i=0,..,7	n = 36; i=0,..,4	n = 24; i=0,..,3	n = 18; i=0,..,2
3	6912 + M × i × 8	-	n = 54; i=0,..,4	n = 36; i=0,..,3	n = 27; i=0,..,2
4	9216 + M × i × 8	-	n = 72; i=0,..,4	n = 48; i=0,..,3	n = 36; i=0,..,2
5	11 520 + M × i × 8	-	-	n = 60; i=0,..,3	n = 45; i=0,..,2
6	13 824 + M × i × 8	-	-	n = 72; i=0,..,3	n = 54; i=0,..,2
7	16 128 + M × i × 8	-	-	n = 84; i=0,..,3	n = 63; i=0,..,2
8	18 432 + M × i × 8	-	-	-	n = 72; i=0,..,2
9	20 736 + M × i × 8	-	-	-	n = 81; i=0,..,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* × 8 kbits/s per wire-pair are additionally required with *i* = 1,..,7 (1-pair), i = 1,..,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 subclause 8.3 of Recommendation G.707 and consists of 144 bytes organised 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.



TU Tributary Unit
VC Virtual Container
V1 TU Pointer 1
V2 TU Pointer 2
V3 TU Pointer 3 (action)
V4 TU Pointer 4 (reserved)

NOTE – V1, V2, V3 and V4 bytes are part of the TU-n and are terminated at the pointer processor.

Figure E-24/G.991.2 – Virtual Container mapping in Tributary Unit and TU-12 pointer offsets (combination of Figures 8-9/G.707 and 8-11/G.707)

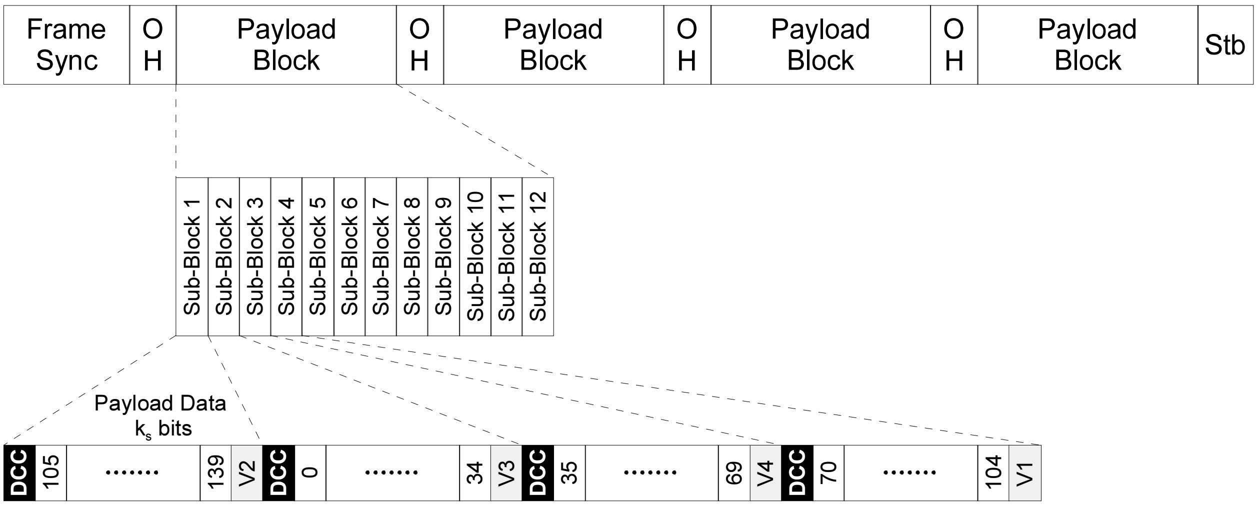
E.14.2 TU-12 into SHDSL mapping

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,..,7), followed by *thirty-six* bytes of the TU-12. Bytes are transmitted MSB first, in accordance with ITU-T recommendation G.707.

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,..,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 Figures E-25 for additional details.

The 4 x 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-d12*N* is a DSL optimised TUG containing a homogeneous assembly of *N* TU-12s. The TU-12s are byte interleaved in the TUG-d12*N*.

The multiplexing of *N*x TU-12 (*N* = 1..9) into a TUG-d12*N* is shown in Figure E-26. A TU-12 is byte interleaved with *N-1*other TU-12s into the TUG-d12*N*.

NOTE - The TU-12 pointer bytes of the *N* TU-12s are mapped in the last *N* octets of the TUG-d12*N* as shown in Figure E-26.

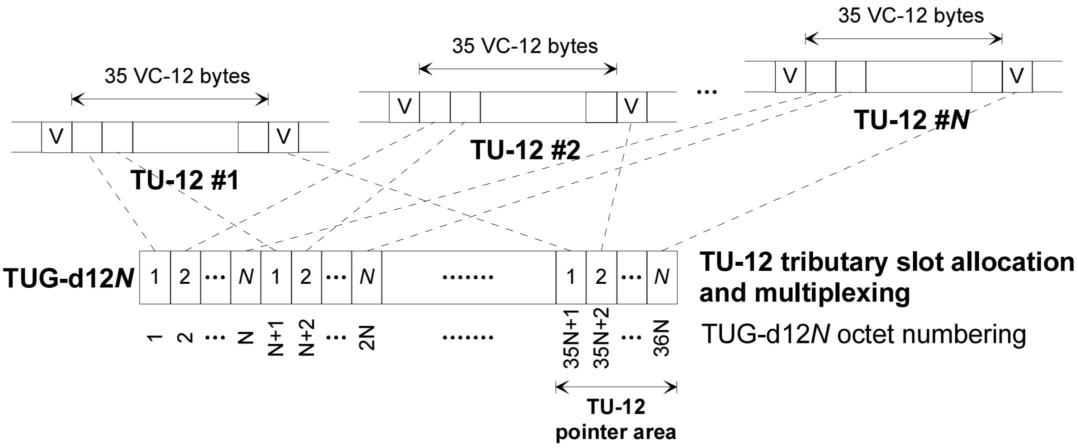


Figure E-26/G.991.2 – Arrangement of $N \times$ TU-12s multiplexed into a TUG-d12*N* (N = 1, 2, .., 9)

E.14.4 *N*x 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 × i × 8 kbit/s.

Each pair carries a SHDSL frame of which each Payload Sub-Block contains an *i-bit* DCC with i = 0,~~1~~..,7 (single-pair mode), $i = 0,..,4$ (2-pair mode), $i = 0,..,3$ (3-pair mode) and $i = 0,1,2$ (4-pair mode), followed by a TUG-d12*N* Mapping area of *36/M* x *N* octets. Octets are transmitted MSB first, in accordance with ITU-T recommendation G.707.

Figure E-28 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-d1*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 $i = 0,..,7$ (single-pair mode), $i = 0,..,4$ (2-pair mode), $i = 0,..,3$ (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 postions 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 $(i\text{-}1)\times M+1,..,(i\text{-}1)\times 2\times M$ 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,..,7 (single-pair mode), $i = 1,..,4$ (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 G.701, G.707 or G.806.

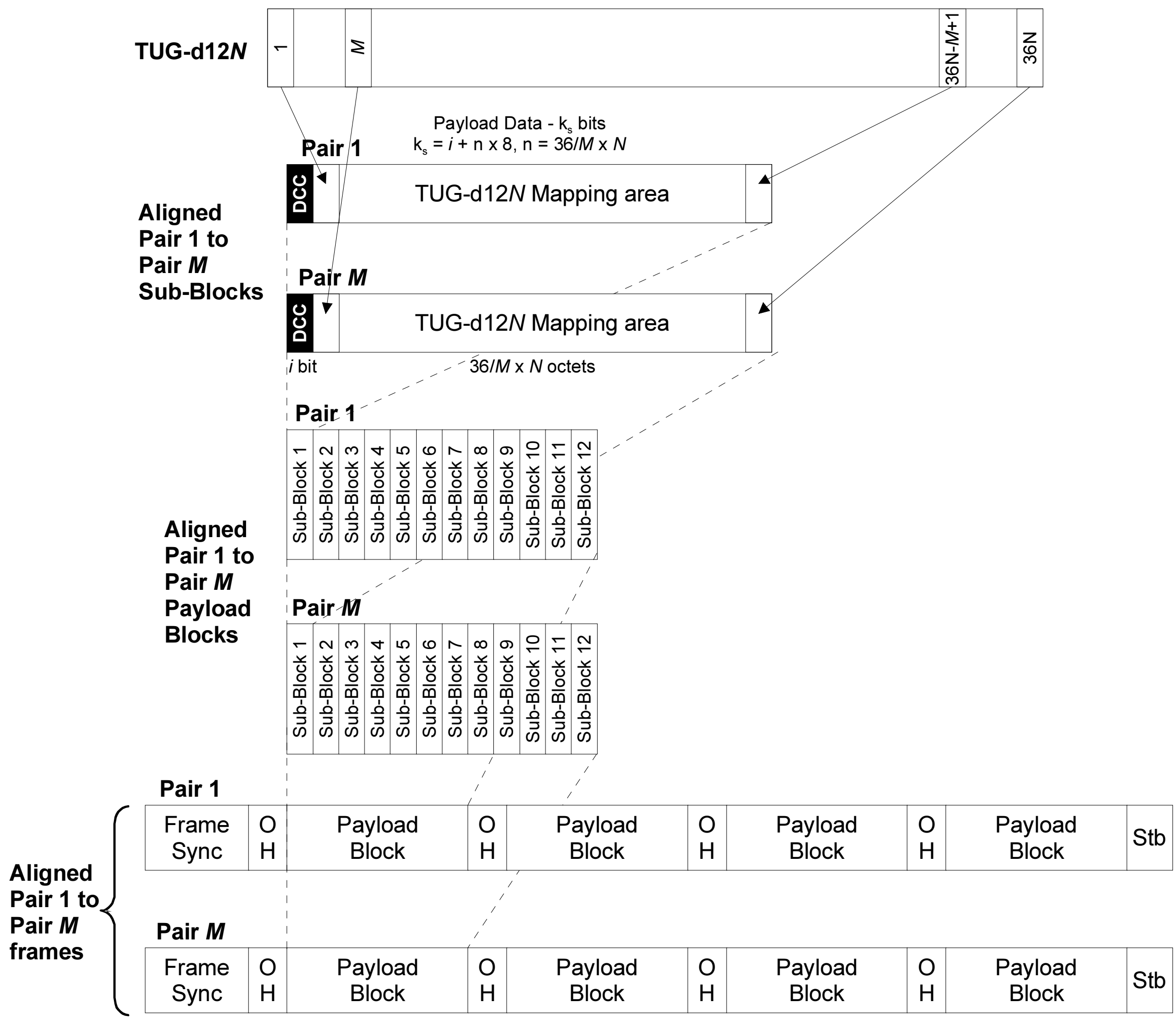


Figure E-28/G.991.2 – TUG-d12*N* mapping into a *M*-pair SHDSL signal with Data Communication Channel

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-29.

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.

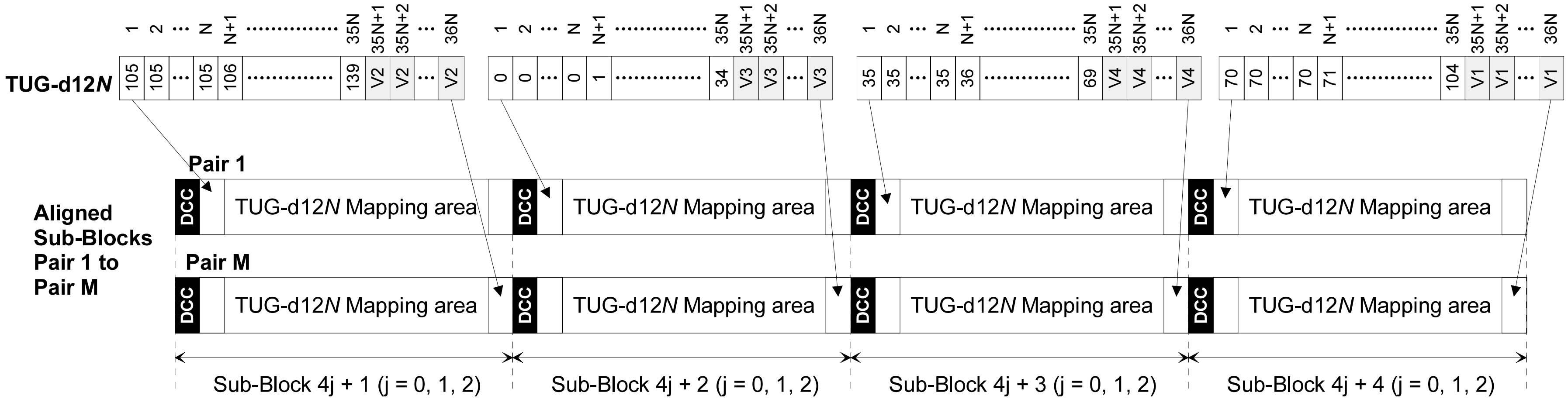


Figure E-29/G.991.2 – TU-12 pointer offset numbering in *M*-pair SHDSL signal

Figures E-30 to E-32 show three examples of *N*x TU-12 over SHDSL. Figure E-30 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.

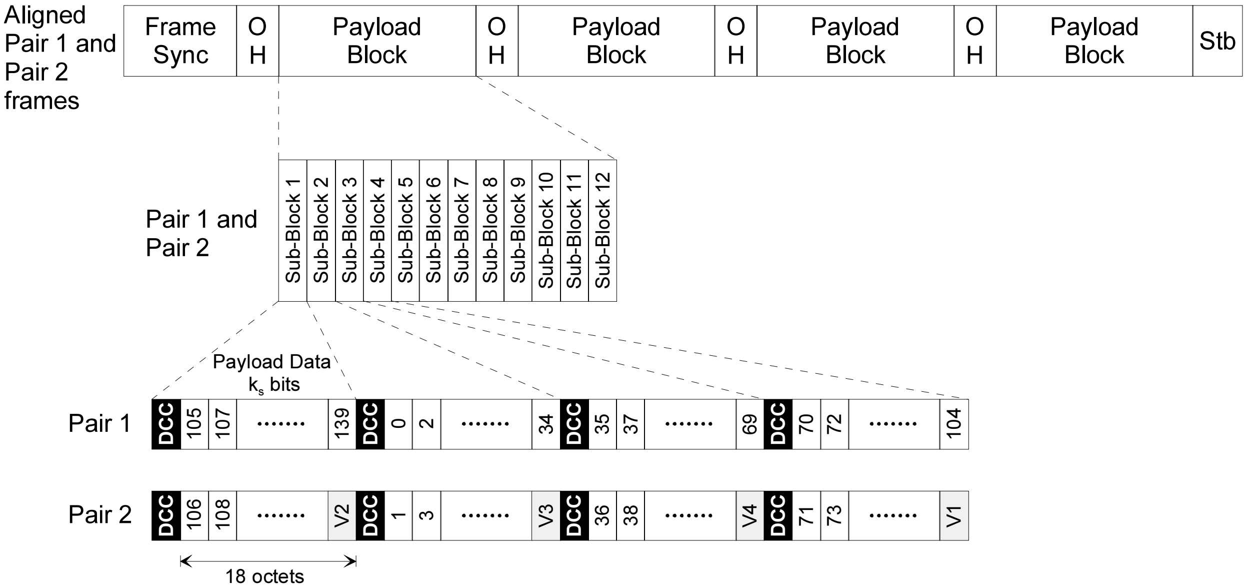


Figure E-30/G.991.2 – *M*-Pair TU-12 Framing with a Data Communication Channel (*N* = 1 TU-12 links with *i* = 1 over *M* = 2 wire-pairs)

Figure E-31 shows the alignment of a TUG-d12*N* 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-d12*N*. The TUG-d12*N* 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* x *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.

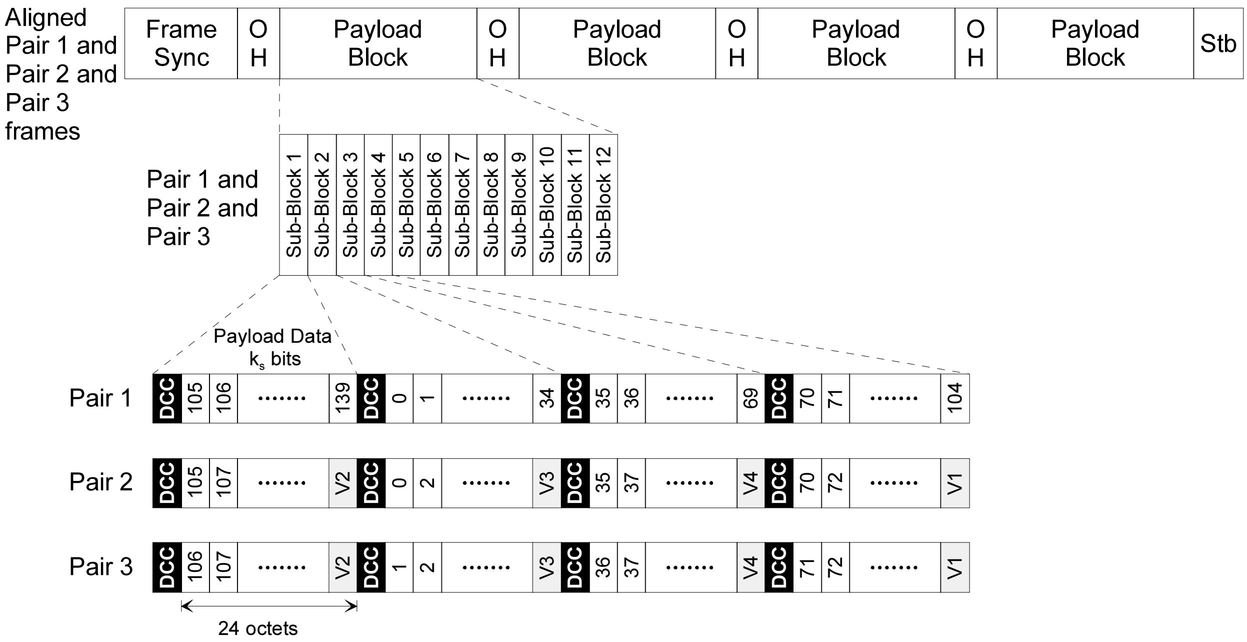


Figure E-31/G.991.2 – *M*-Pair TU-12 Framing with a Data Communication Channel (*N* = 2 TU-12 links with *i* = 1 over *M* = 3 wire-pairs)

Figure E-32 shows the alignment of a TUG-d12*N* 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-d12*N*. The TUG-d12*N* 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* x *3* octets per Payload Sub-Block. There is no DCC present.

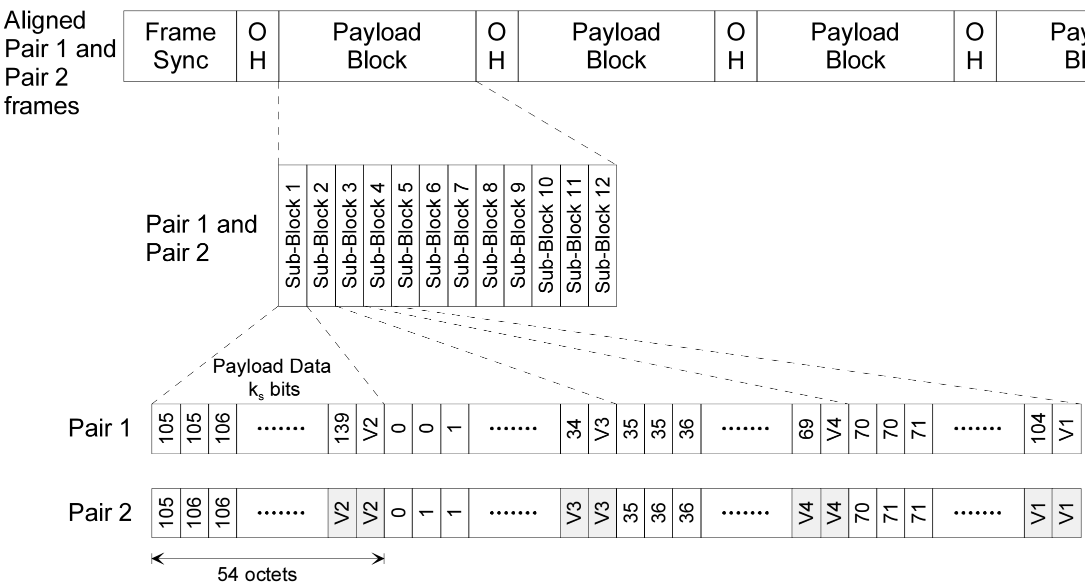


Figure E-32/G.991.2 – *M*-Pair TU-12 Framing with a Data Communication Channel (*N* = 3 TU-12 links with *i* = 0 over *M* = 2 wire-pairs)

E.14.5 SHDSL clock

The SHDSL clock synchronisation mode shall be the synchronous mode as specified in §10. The SHDSL line clock shall be frequency lock to network clock, which is equivalent to the SDH Equipment Clock (SEC) as specified in Recommendations G.813 and G.781.

E.14.6 *N*x TU-12 over *M*-pair SHDSL DCC

The optional ($M \times i \times 8$)-kbit/s DCC in the Nx TU-12 over *M*-pair SHDSL may support one or more of the data communication network applications specified in Recommendation G.7712: 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.