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

Data over Transport – Generic aspects – General

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Internet protocol aspects – Transport

Hitless adjustment of ODUflex(GFP)

Recommendation ITU-T G.7044/Y.1347

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Recommendation ITU-T G.7044/Y.1347

Hitless adjustment of ODUflex(GFP)

Summary

Recommendation ITU-T G.7044/Y.1347 defines hitless adjustment of ODUflex(GFP) (HAO), which provides a control mechanism to hitlessly increase or decrease the bandwidth of an ODUflex(GFP) connection in an optical transport network (OTN).

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.7044/Y.1347	2011-10-29	15

FOREWORD

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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1 Scope

This Recommendation specifies hitless adjustment of ODUflex(GFP) (HAO) that should be used to hitlessly increase or decrease the bandwidth of an ODUflex(GFP) that is transported in an optical transport network (OTN). The Recommendation is based on the OTN signals specified in [ITU-T G.709].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.709] Recommendation ITU-T G.709 (2009), *Interfaces for the Optical Transport Network (OTN).*

[ITU-T G.798] Recommendation ITU-T G.798 (2010), *Characteristics of optical transport network hierarchy equipment functional blocks*.

[ITU-T G.870] ITU-T Recommendation G.870 (2012), *Terms and definitions for optical transport networks (OTN).*

[ITU-T Z.100] Recommendation ITU-T Z.100 (2007), *Specification and Description Language (SDL)*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 Terms defined in [ITU-T G.870]:

– GMP normal mode

– GMP special mode

– OPUk multiframe

– Resize Multiframe (RMF)

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ACK	Acknowledge
BG	BWR Generator
BR	BWR Receiver
BRG	BWR Relay Generator
BRR	BWR Relay Receiver
BWR	Bandwidth Resize
CC	Consistent Configuration
C_m	number of m-bit client data entities
C_n	number of n-bit client data entities
C_{nD}	difference between C_n and ($m/n \times C_m$)
CRC	Cyclic Redundancy Check
CTRL	Control
CV	Consistent Verification
EMF	Equipment Management Function
FRR	Flex RCOH Receiver
GMP	Generic Mapping Procedure
HAO	Hitless Adjustment of ODUflex
HO	High Order
LC	Link Connection
LCAS	Link Capacity Adjustment Scheme
LCR	Link Connection Resize
LG	LCR Generator
LO	Low Order
LR	LCR Receiver
MC	Matrix Connection
MSI	Multiplex Structure Identifier
NACK	Negative Acknowledgement
NCS	Network Connectivity Status
NE	Network Element
ODU	Optical channel Data Unit
ODUk	Optical channel Data Unit-k
OH	Overhead
OPU	Optical channel Payload Unit
OPUk	Optical channel Payload Unit-k
OTN	Optical Transport Network

PSI	Payload Structure Identifier
RCOH	Resize Control Overhead
RES	Reserved for future international standardization
RG	RCOH Generator
RMF	Resize Multiframe
RP	Resizing Protocol
RR	RCOH Receiver
SDL	Specification and Description Language
TPID	Tributary Port ID
TS	Tributary Slot
TSCC	Tributary Slot Connectivity Check
TSGS	Tributary Slot Group Status
TSOH	Tributary Slot Overhead
VCAT	Virtual Concatenation
xI	CI or MI or AI

5 Conventions

Transmission order: The order of transmission of information in all the diagrams in this Recommendation is first from left to right and then from top to bottom. Within each byte the most significant bit is transmitted first. The most significant bit (bit 1) is illustrated at the left in all the diagrams.

Value of reserved bit(s): The value of an overhead bit, which is reserved or reserved for future international standardization, shall be set to "0".

6 Introduction

Hitless adjustment of ODUflex(GFP) (HAO) is a resizing mechanism within the optical transport network (OTN) that allows it to support an increase or decrease of ODUflex(GFP) client data rate across its entire end-to-end path. In many ways, it is similar to the virtual concatenation/link capacity adjustment scheme (VCAT/LCAS). It should be noted that unlike the VCAT, where each component of the end-to-end container is an optical channel data unit-k (ODUk) which can be connected through the OTN independently from all other ODUk components of the same container, an ODUflex signal is carried over a single end-to-end path over a group of tributary slots on each high order-optical channel payload unit-k (HO OPUk) of the path. ODUflex(GFP) resizing has the advantage over VCAT and LCAS that since all the TSs that carry the ODUflex(GFP) client signal follow the same path from the source of the OTN to the sink, it is not necessary to compensate for the individual TSs having different timing delays. In addition, the ODUflex is a single managed entity rather than containing separate managed entities for each member of a VCAT group. It should also be noted that unlike VCAT/LCAS resizing, which requires participation by only the border NEs, HAO requires the participation of each and every NE along the ODUflex(GFP) path.

6.1 Methodology

HAO functionality in the ODUflex(GFP) to packet source and sink adaptation functions and in HO ODUk to LO ODUflex adaptation source and sink functions provides a control mechanism to hitlessly increase or decrease the capacity of an ODUflex(GFP) connection to meet the bandwidth needs of the application. To accomplish hitless bandwidth adjustment of an ODUflex(GFP) connection, all nodes in the connection must support the HAO protocol, otherwise, the connection requires tear down and rebuilding. The bit rate adjustment of the ODUflex(GFP) occurs simultaneously among all the nodes in the ODUflex(GFP) connection to prevent buffer overflow or underflow.

A resizable ODUflex(GFP) occupies the same number of tributary slots on every link of the server. In cases of bandwidth adjustment (i.e., increase or decrease), the same number of tributary slots (at least one TS) on each link traversed by the resized ODUflex(GFP) must be involved. Resizable ODUflex(GFP) bit rates are specified in Table 7-8 of [ITU-T G.709], illustrated in Figure 6-1, where n is the number of tributary slots that are assigned to the resizable ODUflex(GFP). The HAO application supports ODUflex(GFP) bandwidth increase or decrease from current n range to a different n range if the link of the server permits.

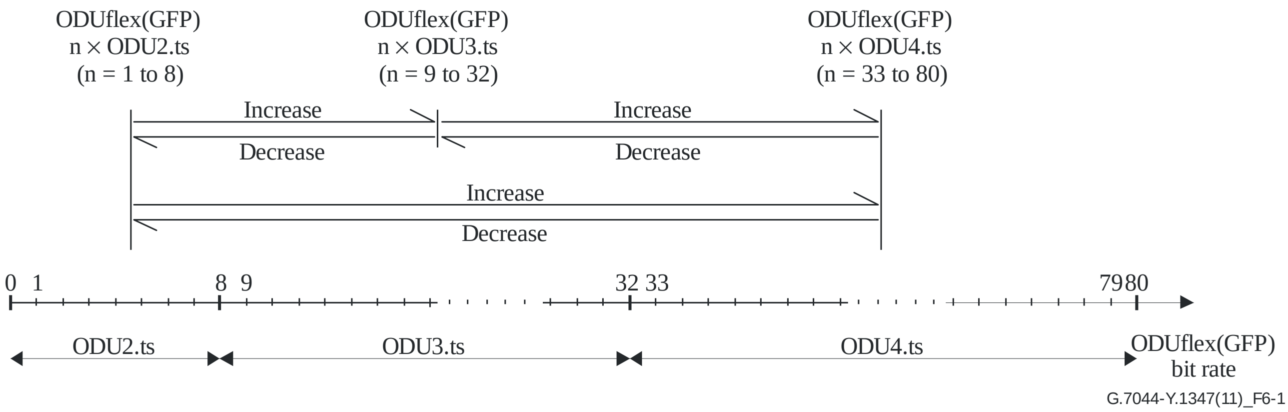

Figure 6-1 – Recommended ODUflex(GFP) bit rate in HAO capability

The modification of the ODUflex(GFP) link and matrix connection configurations are the responsibility of the network management or control plane.

6.2 Control overhead

Synchronization of changes in the capacity of an ODUflex(GFP) connection shall be achieved by resize control overhead (RCOH). The RCOH consists of fields dedicated to a specific function. Changes are sent in advance so that the receiver can switch to the new configuration as soon as it arrives.

The RCOH is carried in the HO OPUk tributary slot overhead (TSOH) and the OPUflex overhead as shown in Figure 6-2. These RCOH (RCOH1, RCOH2 and RCOH3) bytes are located in column 15, row 1, 2 and 3. The HO OPUk RCOH is carried in the tributary slot which is to be added or to be removed. If multiple tributary slots are involved in one resize operation, the protocol is carried in all of these TS RCOHs to be added or to be removed. The RCOHs of these TSs involved in the same resize operation are always the same and transmitted identically.

NOTE – This Recommendation only specifies the RCOH for HAO protocol. For use of these bytes for other applications, refer to [ITU-T G.709].

The RCOH is divided into two parts: link connection resize (LCR) protocol overhead and bandwidth resize (BWR) protocol overhead.

The LCR protocol overhead includes the control (CTRL) field, tributary port ID (TPID) field and tributary slot group status (TSGS) bit.

The BWR protocol overhead includes the network connectivity status (NCS) bit, tributary slot connectivity check (TSCC) bit, resizing protocol indicator (RP) bit and bandwidth resize indicator (BWR_IND) bit.

The LCR protocol bits, the RP bit and the TSCC bit in the BWR protocol are carried in HO OPUk (k = 2, 3, 4) tributary slot overhead, and the NCS bit and BWR_IND bit in the BWR protocol are carried in the OPUflex overhead.

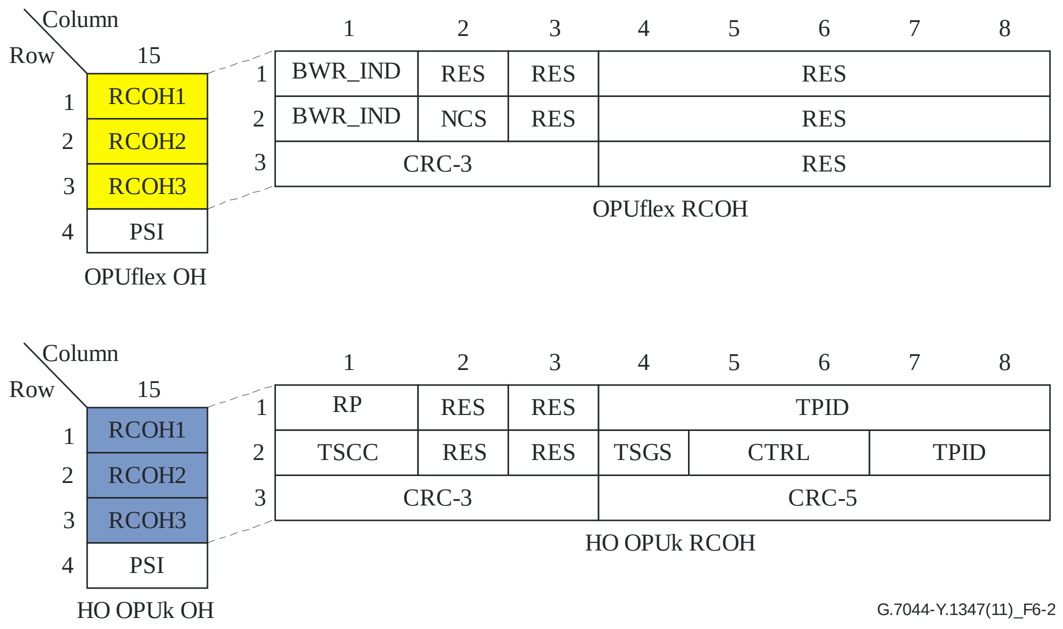

Figure 6-2 – RCOH format

This RCOH supports ODUflex(GFP) LCR control fields and ODUflex(GFP) BWR control fields. The default value of this RCOH is all-0's.

6.2.1 Control (CTRL) field

The control field is used to transfer LCR protocol status information from source to sink. It shall be used to provide the operation indication of the individual tributary slot that belongs to a specified ODUflex(GFP) connection. The CTRL field is carried in the LCR protocol overhead in HO OPUk (k = 2, 3, 4) overhead row 2, column 15, bits 5 and 6.

Table 6-1 – HAO CTRL words

Value	Command	Remarks
00	IDLE	Indication that the node has completed LCR and there is no new LCR operation. IDLE may also be transmitted for a short time at operation start before transmission of the ADD/REMOVE command.
01	ADD	Indication that the tributary slot is to be added to the ODUflex(GFP) connection
10	REMOVE	Indication that the tributary slot is to be removed to the ODUflex(GFP) connection
11	NORM	Indication that LCR will be started at the next resize multiframe boundary when sending out NORM command after ADD or REMOVE command at the resize multiframe boundary

6.2.2 Tributary port ID (TPID) field

The TPID field is used to identify the tributary port ID. The TPID field carries the tributary port number to which the tributary slot is to be added or to be removed. The TPID field is carried in the LCR protocol overhead in HO OPUk (k=2, 3, 4) overhead row 1, column 15, bits 4 to 8, and row 2, column 15, bits 7 and 8.

Row 1					Row 2	
4	5	6	7	8	7	8

000 0000: Tributary Port 1
000 0001: Tributary Port 2
000 0010: Tributary Port 3
000 0011: Tributary Port 4
:
10 01111: Tributary Port 80

Figure 6-3 – TPID field coding

6.2.3 Tributary slot group status (TSGS) bit

The TSGS bit is used for link connection acknowledgement indication.

In the bandwidth increase case, the TSGS bit is generated by the HO OPU sink to acknowledge to the HO OPU source there is a match between the tributary slots indicated by the received CTRL and TPID as being added, and the provisioning for those tributary slots (by the management plane or control plane) at the sink end. It furthermore acknowledges that the HO OPU sink end is ready to receive the increase of the ODTUk.M into the ODTUk.M+N.

In the bandwidth decrease case, the TSGS bit is generated by the HO OPU sink to acknowledge to the HO OPU source that the ODUflex(GFP) bandwidth has been decreased and that it has exited GMP special mode after receiving TSCC=0 in So to Sk direction. It furthermore acknowledges that the HO OPU sink end is ready to receive the decrease of the ODTUk.M into the ODTUk.M-N.

The TSGS bit reports link connection acknowledgement with two values: ACK(1) and NACK (0). The TSGS bit is carried in the LCR protocol overhead in HO OPUk (k=2, 3, 4) overhead row 2, column 15, bit 4.

6.2.4 Tributary slot connectivity check (TSCC) bit

The TSCC bit is used to check the connectivity of the link connection and ODUflex(GFP) connection. It carries signalling information associated with a TS being added or removed and is propagated hop by hop from the So to the Sk. Initially, the value of TSCC is set to 0.

During the resize period, TSCC =1 confirms GMP special mode at intermediate nodes and signals to the sink that all NEs in the source to sink direction are ready to support the bandwidth resizing operation.

After the ODUflex(GFP) resize operation is complete, TSCC=0 is used by the source to indicate the bandwidth resize completion and its exit from GMP special mode in the source to sink direction. It triggers exit from GMP special mode at the intermediate nodes and sink, and is only forwarded by intermediate nodes when they have exited GMP special mode.

The TSCC bit is defined as a BWR protocol overhead in HO OPUk (k=2, 3, 4) overhead row 2, column 15, bit 1.

6.2.5 Network connectivity status (NCS) bit

The NCS bit is used for a network connection acknowledgement indication. It is defined as an end-to-end acknowledgment indication in the OPUflex overhead. It is used by the ODUflex(GFP) sink to acknowledge to the ODUflex(GFP) source directly when the sink receives the correct TSCC value. The intermediate nodes do not need to process this signal since it is transparent to them.

When the sink receives TSCC=1, the NCS=1 is used by sink as an ACK for the source to the sink path resize preparation completion. When the sink receives TSCC=0, the NCS=0 is used by the sink to acknowledge the BWR completion. The NCS transparently passes through each intermediate node going back to source.

The NCS bit is defined as a BWR protocol overhead carried in the OPUflex overhead row 2, column 15, bit 2.

6.2.6 Resizing protocol indicator (RP) bit

The RP bit is used to indicate whether the resizing protocol is carried in the RCOH. RP=1 indicates that the RCOH is carrying resizing protocol. When RP=0, these bytes carry overhead associated with the mapping specific information, such as GMP overhead (C_nD), as defined in Recommendation G.709. At the beginning of the resize operation, the RP bit should be set to 1 by the management plane or control plane. The RP bit is reset to 0 by the source as indicated below in order to indicate that it has exited all resizing protocol processing. The RP = 0 terminates the TSCC information relay and all other resizing processing operations in that direction at intermediate nodes. When an intermediate node receives RP = 0, it forwards it after confirming that it has exited GMP special mode and terminated LCR protocol processing in that direction. When the sink receives RP = 0, it confirms the exit from resizing processing by the source and all intermediate nodes. The sink can then report the resizing completion to network management or control plane.

The RP bit is defined as a BWR protocol overhead carried in the HO OPUk (k=2, 3, 4) overhead row 1, column 15, bit 1.

6.2.7 Bandwidth resize indicator (BWR_IND) bit

The BWR_IND bit is used to indicate that the ODUflex(GFP) source is adjusting the ODUflex(GFP) signal's bit rate. It is set to "0" before ODUflex(GFP) signal's bit rate adjustment starts. Once it transitions from "0" to "1", the ODUflex(GFP) source shall start ramping x μs later. When the BWR_IND will transition from "1" to "0", the ODUflex(GFP) source shall stop ramping y μs later. x is almost equal to y and shall be in the range of 125 to 250 μs.

The BWR_IND is used to trigger the start of the ramp at the downstream nodes, and to signal the end of the ramp. Refer to 7.1.1 and 7.2.1.

The BWR_IND signal is encoded into bit 1 of both the ODUflex(GFP) RCOH1 and RCOH2 bytes, as illustrated in Figure 6-2. When BWR_IND is set, both bits are '1', and when it is reset both bits are '0'. The receiver determines a transition in the BWR_IND state after examining RCOH3. The CRC-3 values allow detection of an error affecting the BWR_IND bit in RCOH1 or RCOH2, and can be used to determine the correct value. The receiver rules are as follows:

The receiver determines that BWR_IND is set after examining RCOH1-RCOH3 when the BWR_IND bits in both RCOH1 and RCOH2 are set to '1' and the received CRC-3 has a value corresponding to the source sending BWR_IND set to '1' (and NCS set to '1').

The receiver determines that BWR_IND is reset after examining RCOH1-RCOH3 when the BWR_IND bits in both RCOH1 and RCOH2 are set to '0' and the received CRC-3 has a value corresponding to the source sending BWR_IND set to '0' (and NCS set to '1').

Otherwise, the receiver maintains its current value for the received BWR_IND.

NOTE – If the second and third bits of RCOH1 and the third bit of RCOH2 are '0' and the NCS bit is '1', the corresponding CRC-3 values are 110 when BWR_IND = 1 and 111 when BWR_IND = 0.

6.2.8 CRC field

To simplify the validation of the changes in the RCOH, a CRC field is used to protect the resizing protocol overhead. The RCOH is divided into two parts as shown in Figure 6-2. The CRC3 monitors the RP bit together with BWR protocol in HO OPU Overhead area and ODUflex(GFP)

Overhead area. The CRC5 monitors the LCR protocol. Since the unused bits are 0 and the CRC remainder for an all-0 word is all 0s, the CRC-3 will always be valid even when it is not being used for resizing. Similarly, the CRC-5 is valid if these fields carry no information (all 0s) or CnD. The CRC check is performed after it has been received, and the contents rejected if the test fails. If the RCOH passed CRC test, then its contents are used immediately.

The CRC-3 is calculated over bits 1-3 in RCOH1 and RCOH2. The CRC-3 uses the $g(x) = x^3 + x^2 + 1$ generator polynomial, and is calculated as follows:

1) The RCOH1 bits 1-3 and RCOH2 bits 1-3 are taken in network transmission order, most significant bit first, to form a 6-bit pattern representing the coefficients of a polynomial *M(x)* of degree 5.
2) *M(x)* is multiplied by x^3 and divided (modulo 2) by *G(x)*, producing a remainder *R(x)* of degree 2 or less.
3) The coefficients of *R*(*x*) are considered to be a 3-bit sequence, where x^2 is the most significant bit.
4) This 3-bit sequence is the CRC-3 where the first bit of the CRC-3 to be transmitted is the coefficient of x^2 and the last bit transmitted is the coefficient of x^0.

The demapper process performs steps 1-3 in the same manner as the mapper process. In the absence of bit errors, the remainder shall be 000.

A parallel logic implementation of the source CRC-3 is illustrated in Table 6-2.

Table 6-2 – Parallel logic equations for the CRC-3 implementation

Mapping overhead bits	**CRC checksum bits**		
	crc1	**crc2**	**crc3**
RCOH1 bit 1		X	
RCOH1 bit 2			X
RCOH1 bit 3	X	X	
RCOH2 bit 1		X	X
RCOH2 bit 2	X	X	X
RCOH2 bit 3	X		X

The CRC5 and its calculation are defined in Annex D of [ITU-T G.709].

6.3 Resize protocol

6.3.1 Link connection resize (LCR) protocol

The LCR protocol has an LCR_Source process in the ODUkP/ODUj-21_A_So function and an LCR_Sink process in the ODUkP/ODUj-21_A_Sk function. The LCR_Source process communicates with the LCR_Sink process to adjust the tributary slot assignment to the ODUflex(GFP). Each link connection in the ODUflex(GFP) trail has its own LCR protocol. The LCR overhead is carried in HO OPU RCOH1-RCOH3 bytes referred to in Figure 6-2.

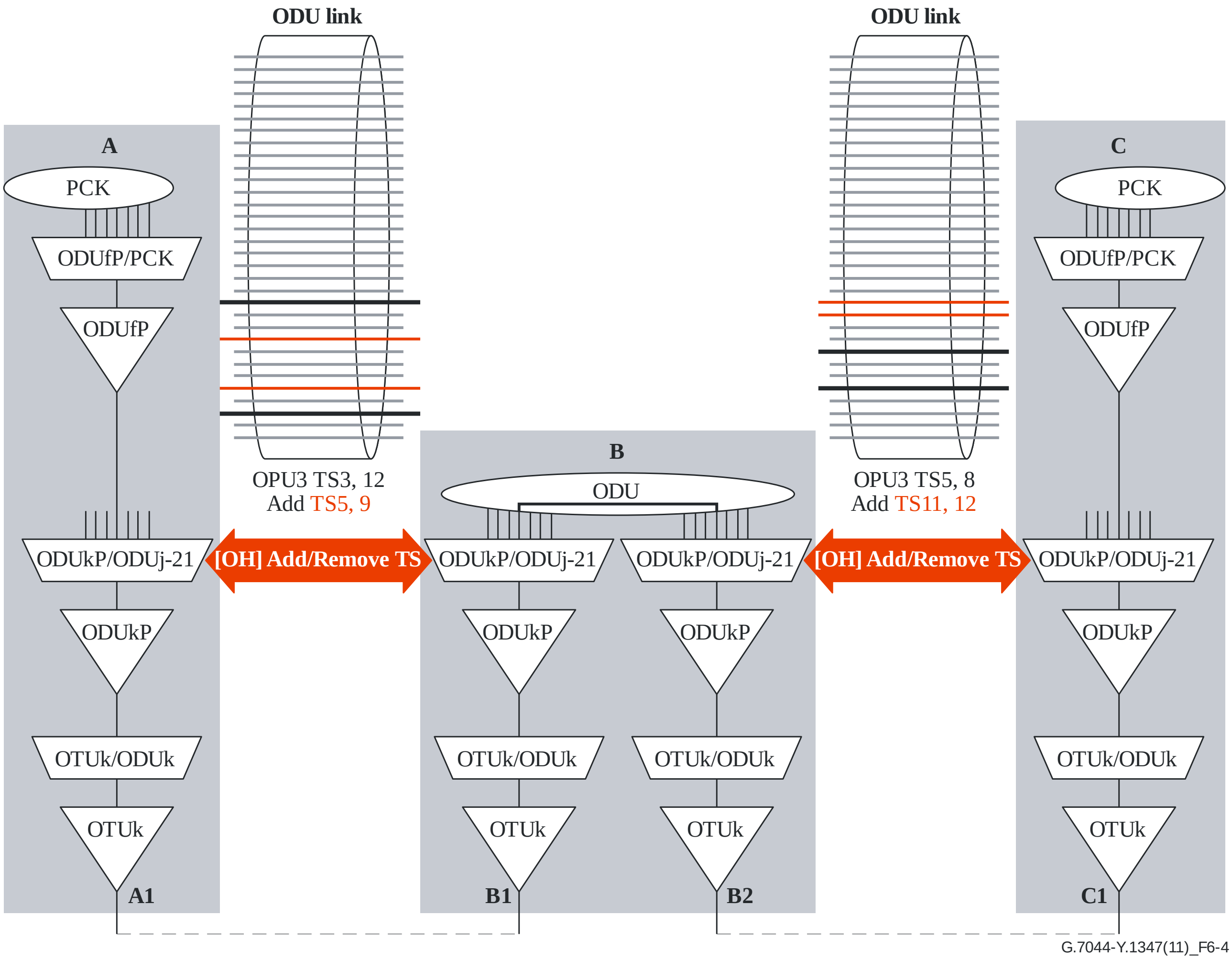

Figure 6-4 – LCR protocol

The LCR protocol uses the CTRL, TSGS, and TPID fields defined in clause 6.2.

6.3.2 Bandwidth Resize (BWR) protocol

The BWR protocol has a BWR_Source process in the ODUfP/PCK_A_So function and a BWR Sink process in the ODUfP/PCK_A_Sk function. The BWR_Source process communicates with the BWR_Sink process via two ways, indirectly the BWR_Relay processes in the ODUkP/ODUj-21_A functions and directly via OPUflex OH to check for consistent configuration of the tributary slot(s) to be added to or removed from the ODUflex(GFP) link connections along the trail and verify the network connectivity of the trail.

Each ODUkP/ODUj-21_A_So in the trail has a BWR_Relay_So process and each ODUkP/ODUj-21_A_Sk in the trail has a BWR_Relay_Sk process. Adjacent BWR_Relay_So and BWR_Relay_Sk functions communicate with each other via the ODU_C function using additional, equipment specific ODUflex_CI signals or via the EMF using additional, equipment specific ODUflex_MI signals.

The BWR_Source process communicates with the BWR_Relay_So function via the equipment specific ODUflex_CI signals or via the EMF using additional, equipment specific ODUflex_MI signals.

The BWR_Sink process communicates with the BWR_Relay_Sk function via the equipment specific ODUflex_CI signals or via the EMF using additional, equipment specific ODUflex_MI signals.

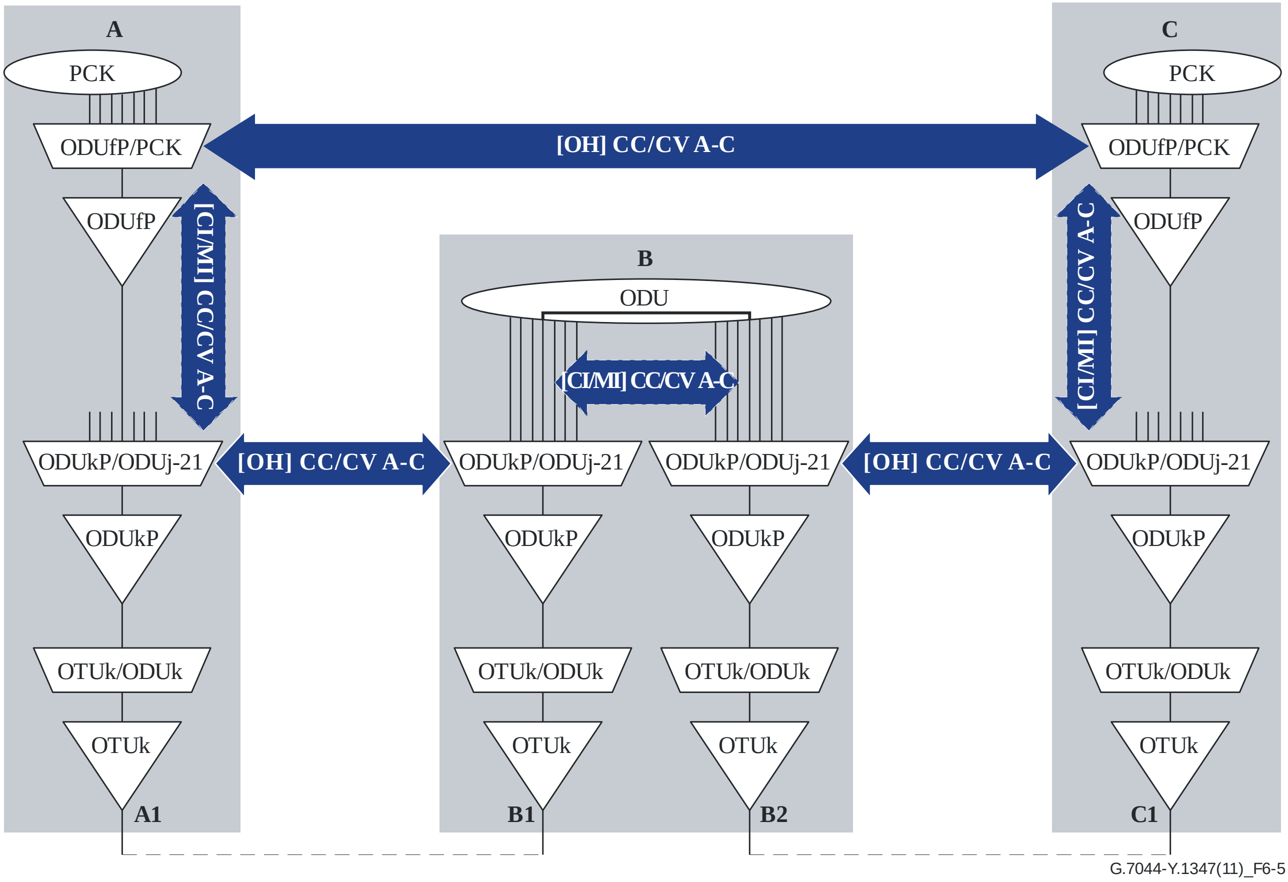

Figure 6-5 – BWR protocol

The BWR protocol uses the TSCC, NCS and BWR_IND fields defined in clause 6.2.

6.4 Management and/or control plane interaction

The management and control plane is intimately tied with HAO in assigning which TSs across which link and matrix connection are to be added or deleted and in verifying that the resizing operation has completed successfully. The TPIDs that are used for identifying the tributary port to which the tributary slots are to be added or removed across a link are also assigned by the management or control plane. From a control plane perspective it is important to note that a link connection does not involve each individual TS of the ODUflex, but the whole set of HO OPUk TSs that carry the ODUflex client. It is also important that from a control plane perspective no assumption should be made regarding the ordering of link connection resizing across the end-to-end path. It should also be noted that multiple ODUflex(GFP) signals, with different starting and/or ending points could be carried across intermediate NEs. The coordination of ODUflex(GFP) resizing in such scenarios is beyond the scope of this Recommendation.

7 Resize procedure

Resizing an ODUflex(GFP) involves both the LCR and BWR protocols. During the LCR protocol, matrix connections in all nodes in the ODUflex(GFP) connection must support a correspondent increase or decrease in capacity. Details of this capability is equipment specific and beyond the scope of this Recommendation.

7.1 Bandwidth Increase

Figure 7-1 shows the sequence of interactions between the LCR and BWR protocol during increase.

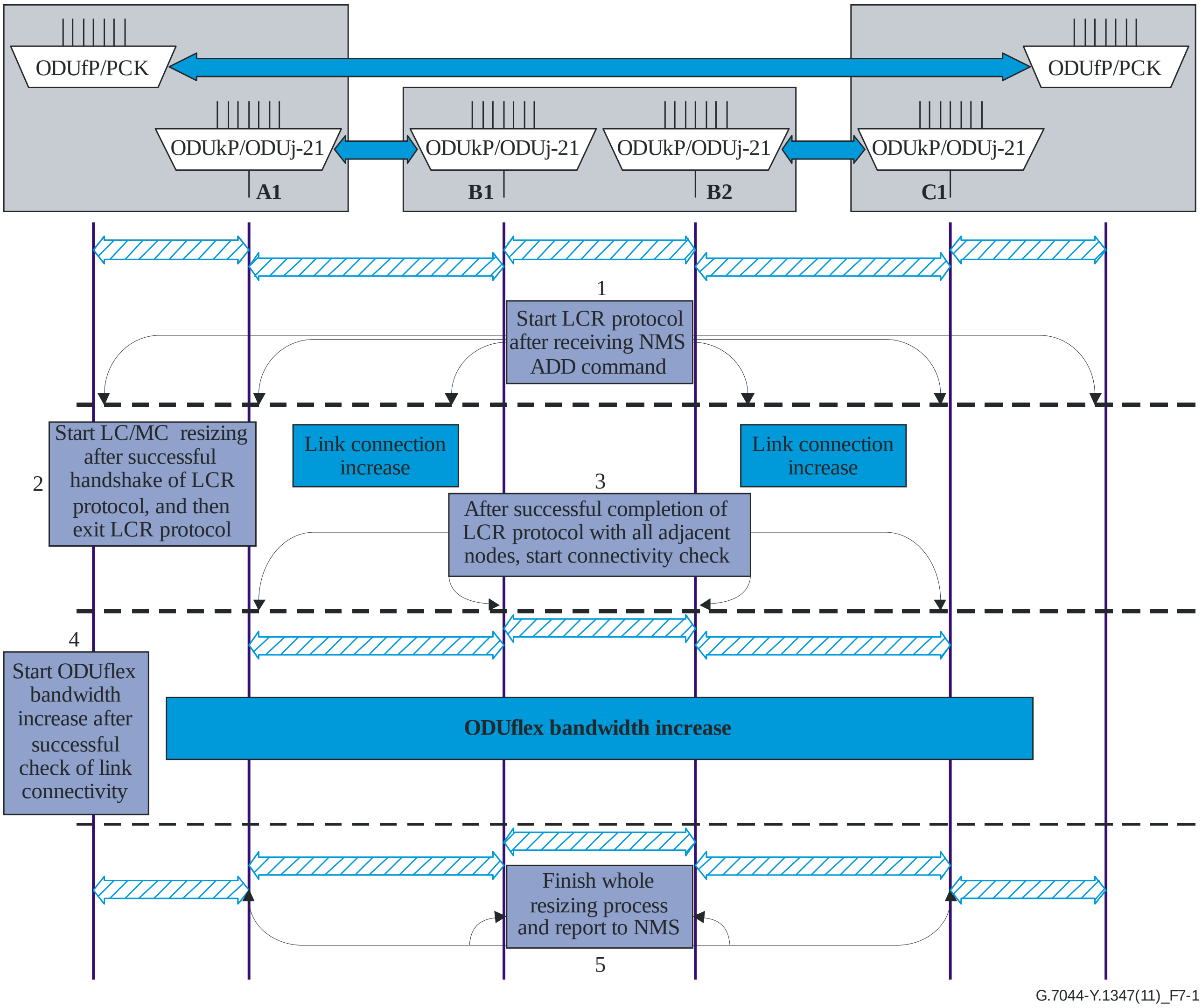

Figure 7-1 – Interworking scheme of increasing case

The increase sequence consists of the following steps:

Step 1 Every node will start the LCR protocol after receiving the ADD command from network management or control plane. Each ODUkP/ODUj-21_A source and sink pair will signal the [ADD] in the LCR CTRL field and wait for the acknowledgement [ACK] in the LCR TSGS bit.

Step 2 Every node will check the configuration of the set of TSs to be added. The node will acknowledge [ACK in the LCR TSGS bit] the addition only if it has a TS configuration that is identical to what the node at the other end of the span is signalling. After this handshake, the node will start link connection increase. And after link connection increase, the node will exit LCR protocol.

Step 3 After completion of a LCR protocol, an ODUflex(GFP) Source node sends the tributary slot connectivity check [TSCC = 1] in each TS being added. An intermediate node will relay the BWR protocol information over the resized ODUflex(GFP) link connection to progress the tributary slot connectivity check. After completion of the LCR protocol on both ports, an intermediate node will relay the [TSCC =1] BWR protocol information received at its input port to its output port.

Step 4 The two end nodes will start ODUflex(GFP) bandwidth increase after the completion of tributary slot connectivity check. The resizing will be gradual to avoid overflow of the GMP buffer.

Step 5 The BWR protocol terminates after the bandwidth increase is over. Two end nodes will report to network management or control plane the completion of the increase resizing process.

The detailed procedure of bandwidth increase is divided into two parts: the LCR protocol and the BWR protocol, which are shown separately in Figures 7-2 and 7-3. The LCR signalling in this description uses the format [<CTRL value>, <TPID#>, <TSGS value>].

Figure 7-2 shows LCR protocol of bandwidth increase. Detailed description is as follows.

1 Every node starts the LCR protocol and BWR protocol after receiving the network management or control plane INCREASE command. After receiving the INCREASE command from the network management or control plane, every node checks the availability of the TS to be added (in EMF). Ports in intermediate nodes send [ADD, #a, NACK] (LCR Generator) as well as RP=1 and TSCC=0 (BWR Relay Generator) after the availability check. The ports in the two end nodes send [ADD, #a, NACK] (LCR Generator) and RP=1 and TSCC=0 (BWR Relay Generator).

2 After checking that the CTRL=ADD is received from the port at the other end of the span (LCR Generator) and the TS configuration of the local port is identical to what the port at the other end of the span is signalling (RCOH Receiver), each port sends TSGS=ACK signal (LCR Generator) as a reply to the adjacent port.

3 Every port starts link connection increase process after LCR handshaking successfully in both directions, meaning that the configuration check is passed and TSGS=ACK has been both sent (LCR Generator) and received (LCR Receiver) on all TS involved in the same link connection resize. After receiving the ACK for all the added TS, a port first sends [NORM, #a, ACK] instead of [ADD, #a, ACK] for every added TS at a resize multiframe boundary after LCR handshaking. Note that the time between when a node receives ACKs for all TS and the resize multiframe boundary at which it starts sending [NORM, #a, ACK] is implementation dependent. Then, at the first resize multiframe boundary after sending [NORM, #a, ACK], the node starts link connection increase using all the added TS. The change from [ADD, #a, ACK] to [NORM, #a, ACK] signals the downstream port that the link connection increase will start at the next resize multiframe boundary.

4 After completing the LCR resize and receiving CTRL=NORM, a node exits LCR protocol by sending [IDLE, 0, NACK] (LCR Generator) for every added TS at the resize multiframe boundary P. In other words, all affected TS make each of their signalling transitions simultaneously (in the same resize multiframe).

5 After checking that the CTRL=IDLE is received from the port at the other end of the span (LCR Generator) the LCR protocol is finished in one direction. It then begins the BWR protocol.

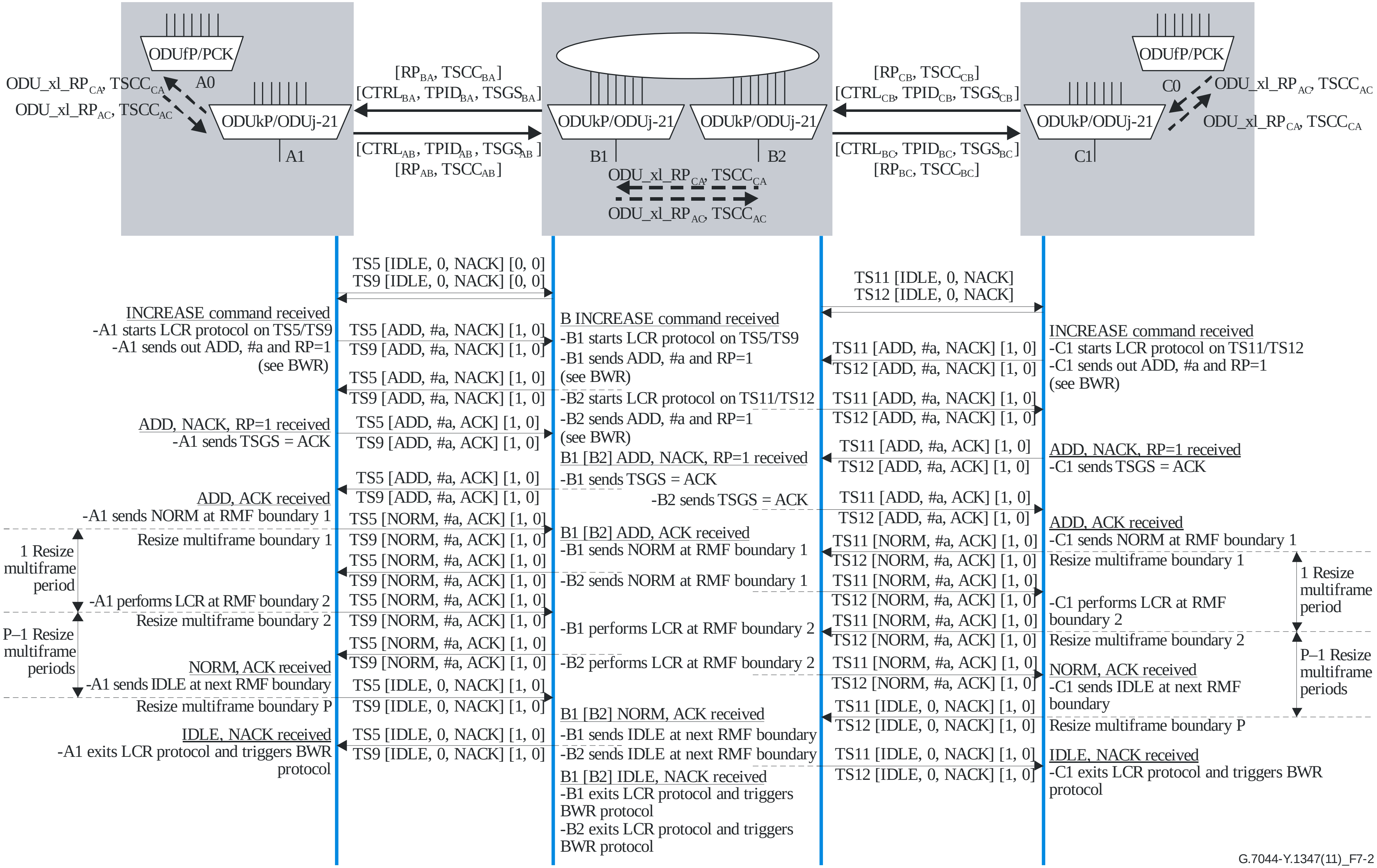

Figure 7-2 – LCR protocol of bandwidth increase

The steps of the BWR protocol of the bandwidth increase (Figure 7-3) are:

1. When LCR protocol is finished and SCC = 1 is received in the sink direction, the input port begins to set its GMP Sink processor into special mode (BWR Relay Receiver). When LCR protocol is finished in the source direction, the output port sets its GMP Source processor into special mode (BWR Relay Generator). The node is expected to perform any required internal buffer adjustments associated with the change in word size prior to entering GMP special mode in a given direction. After setting these GMP Sink and Source processors into special mode successfully, and confirming that there are no dTIM defects associated with the new matrix connections at the upstream nodes, the node relays the TSCC = 1 in that direction and disables TCM dTIM-related consequential actions for the duration of BWR protocol (using the TIMActDis). When all intermediate nodes relay the TSCC =1, it propagates from source to sink.
2. When TSCC = 1 and RP = 1 for all the added TS reaches the ODUflex(GFP) sink node, the input port responds by setting NCS = ACK(1) (BWR Generator) to indicate that in this direction the whole path is OK and that its provisioning matches the TS configuration that it sees in the received TSCC values (RCOH Receiver). Since the NCS is located in the ODUflex(GFP) overhead area, NCS = ACK(1) passes transparently through each intermediate port back to the far end ODUflex(GFP) node.
3. When an end node receives TSCC = 1, RP = 1 and NCS = ACK and has sent NCS=ACK in response to TSCC=1, the bi-directional signalling is complete. It then begins the bandwidth increase. Bandwidth increase starts with setting BWR_IND to 1. Refer to 7.1.1 for details on increase rate. Bandwidth increase ends after setting BWR_IND to 0.
4. The ODUflex(GFP) source node begins to send out TSCC=0 instead of TSCC=1 (BWR Generator) to signal the completion of the bandwidth increase and its return to GMP normal mode in its transmit direction.
5. When an intermediate input port receives TSCC=0 and RP=1, it sets its GMP Sink processor into normal mode (BWR Relay Receiver) and forwards the TSCC=0 to the output port. When bandwidth increase ends and TSCC = 0 is received, the output port sets its GMP Source processor now into normal mode (BWR Relay Generator). After setting these GMP processors into normal mode, TSCC=0 is immediately relayed through that node in that direction.
6. When TSCC = 0 reaches the ODUflex(GFP) sink (BWR Receiver), the associated ODUflex(GFP) source sends a reply by setting NCS = NACK (BWR Generator).
7. When the end node receives and sends NCS=NACK, it begins to send out frames with RP=0 (BWR Generator). When an intermediate node receives RP = 0 (BWR Relay Receiver), it transparently forwards it to downstream node (BWR Relay Generator). The increase operation is complete when RP = 0 has propagated to the other end node, indicating that the intermediate nodes have ended their relay of TSCC information and all other resizing protocol operations. When the ODUflex(GFP) sink node receives RP=0 and has sent RP=0 in the opposite direction, it reports to network management or control plane the completion of the increase resizing process in that direction (BWR Generator).
8. The total process is complete when the network management or control plane has received, indication of completion of both directions.

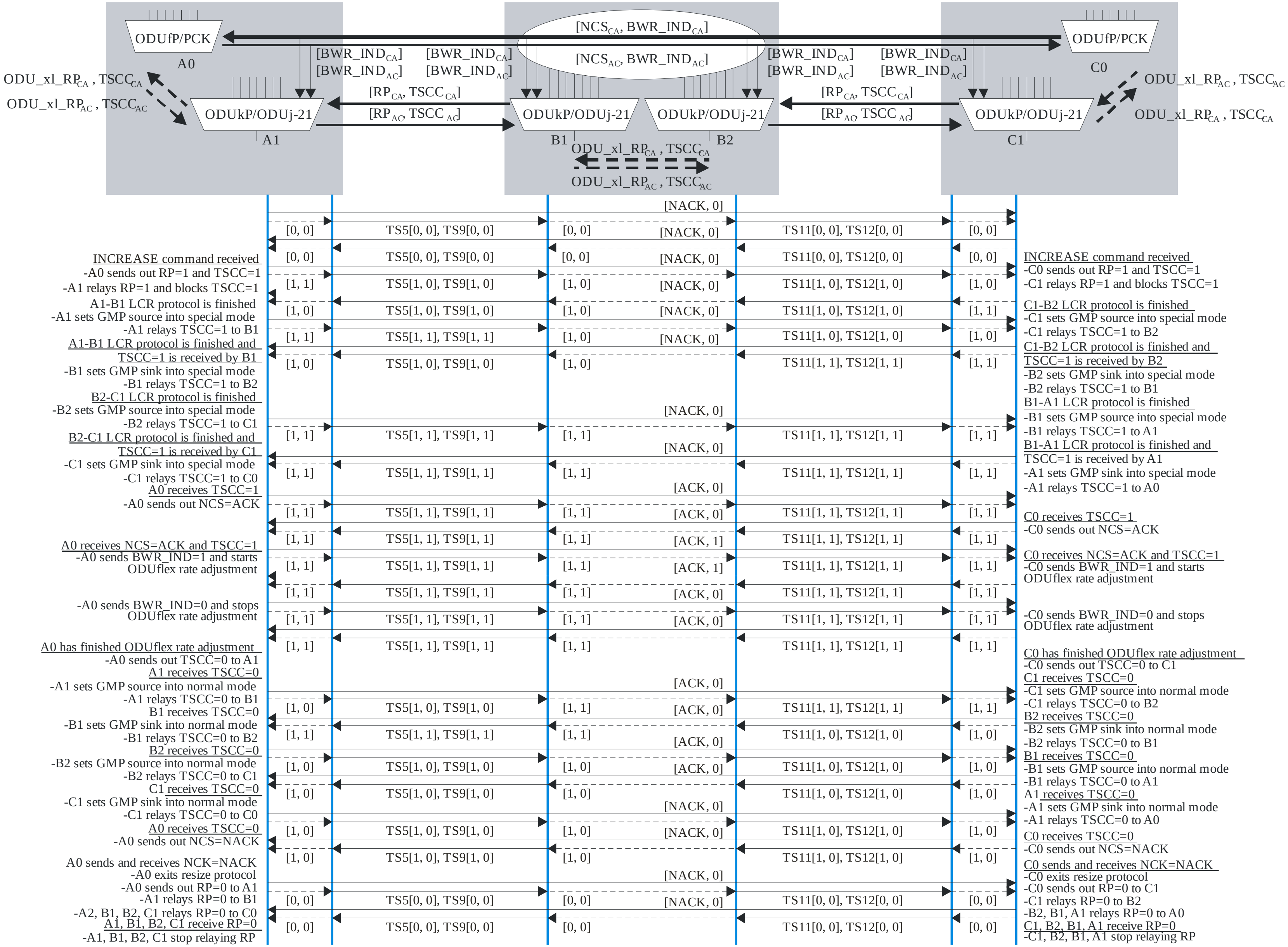

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Figure 7-3 – BWR protocol of bandwidth increase

7.1.1 ODUflex(GFP) bandwidth increase rate

During BWR (controlled by the source node, signalled to downstream nodes using the BWR_IND overhead), the rate of the ODUflex(GFP) clock shall be increased at a rate of 512 000 kbit/s^2 with a slope tolerance of ±100 ppm [511 897 .. 512 102 kbit/s^2]. This rate increase can be achieved by an increase of 8 bits every 125 µs. The BWR_IND is used to trigger the start and stop of the ramp at the downstream nodes.

Methods to measure the timing transfer performance across an intermediate node are described in Appendix I.

The ODUflex(GFP) data shall be extracted from the groups of M successive bytes of the ODTUk.M payload area under control of the GMP data/stuff control mechanism as defined in clause 19.6 of [ITU-T G.709] and be written into the buffer. The Cn information associated with the ODUj is computed from the GMP Cm parameter carried within the JC1/2/3 overhead of the ODTUk.M as specified in clause 19.6 of [ITU-T G.709]. For the GMP data/stuff control mechanism refer to Annex D of [ITU-T G.709].

The ODUflex(GFP) data (CI_D) shall be read out of the buffer under control of the ODUflex(GFP) clock (CI_CK).

Smoothing and jitter limiting process: The function shall provide for a clock smoothing and elastic store (buffer) process. The ODUflex(GFP) data signal shall be written into the buffer under control of the associated (gapped) ODUk input clock (with a frequency accuracy within ±20 ppm). The behaviour shall be as if the data signal is read out of the buffer under control of a smoothed ODUflex(GFP) clock (the rate is determined by the ODUflex(GFP) signal at the input of the remote ODUkP/ODUflex-21_A_So).

The clock parameters, including jitter and wander requirements, as defined in Annex A of [ITU-T G.8251] (ODCp clock), apply.

Buffer size: In the presence of jitter as specified by [ITU-T G.8251] and a frequency within the tolerance range specified for the ODUj signal in Table 14-2, this justification process shall not introduce any errors. The buffer hysteresis shall not exceed 4×M bytes for an ODUflex(GFP) which occupies M tributary slots.

7.1.2 GMP OH location update during increase

The GMP OH is allocated in the last TSOH occupied by an ODUflex in a HO OPUk. When we add a higher numbered TS to the ODUflex(GFP) during an increase of HAO, the GMP OH location will be changed.

Before LCR, the source carries the GMP OH in the original last TSOH occupied by the ODUflex(GFP). In the same way, the sink extracts the GMP OH from the original last TSOH occupied by the ODUflex(GFP).

During LCR increase, the source begins to send out [NORM, #a, ACK] instead of [ADD, #a, ACK] at a resize multi-frame boundary after LCR handshaking. Then, at the following resize multiframe boundary, the source starts the resizing of the link connection and carries the GMP OH in the new last TSOH occupied by the ODUflex(GFP). Before that, the source carries the GMP OH in the original last TSOH occupied by the ODUflex(GFP). The sink expects to extract GMP OH from the new last TSOH occupied by the ODUflex(GFP) during the next resize multiframe after the reception of [NORM, #a, ACK] from the source. After that, the GMP OH is allocated in the new last TSOH occupied by the ODUflex(GFP) in the HO ODUk.

E.g., TP1 is initially allocated with TS3, 4 and 8 of an OPU3, and is increased by two TSs (e.g., TS1 and TS13) to itself now. Before LCR, the GMP OH is present in the original last TSOH, i.e., TSOH of TS8. After LCR, the GMP OH is allocated in the new last TSOH, i.e., TSOH of TS13.

7.2 Bandwidth Decrease

Figure 7-4 shows the sequence of interactions between the LCR and BWR protocol during decrease.

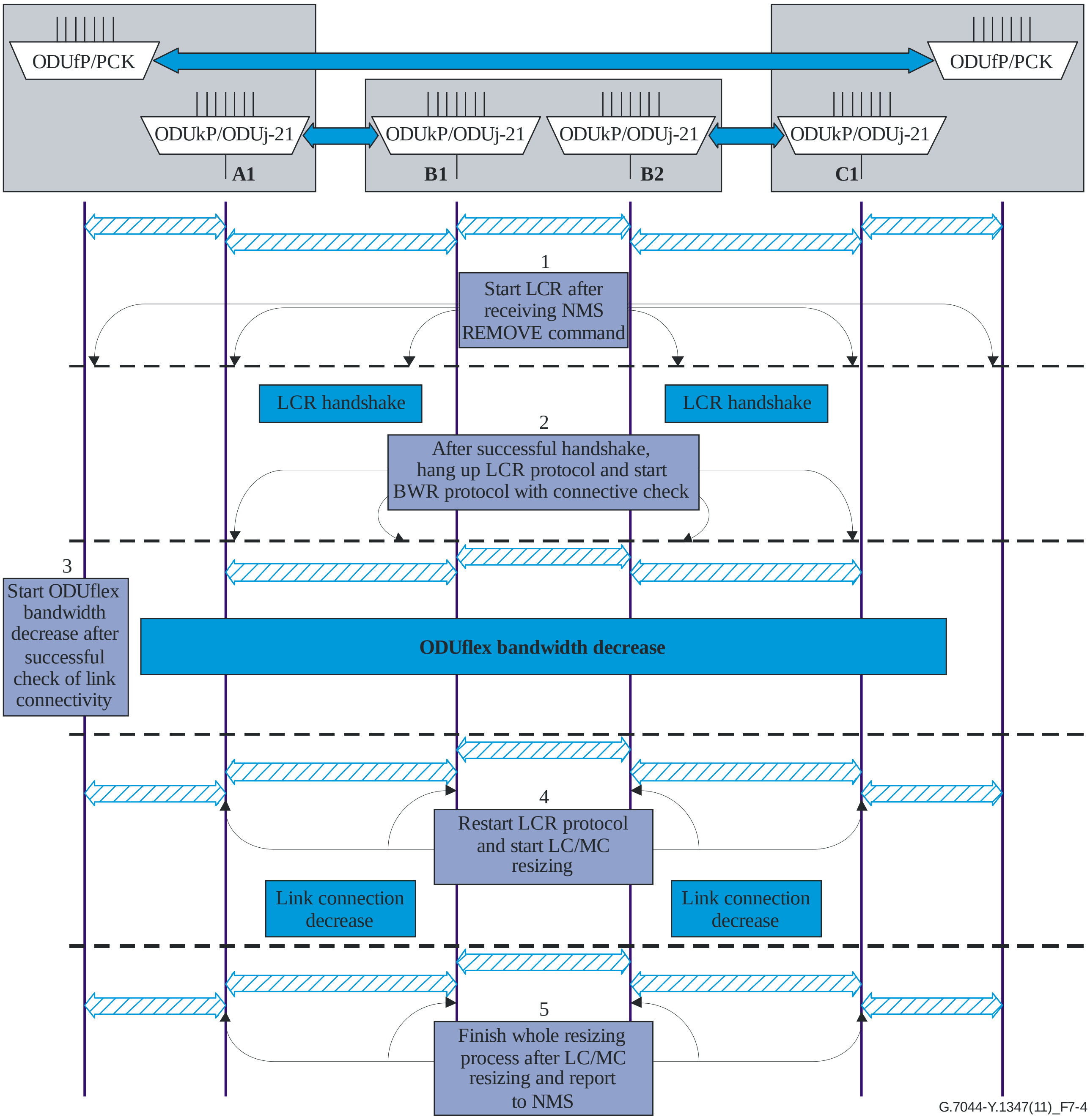

Figure 7-4 – Interworking scheme of decreasing case

The decrease sequence consists of the following steps:

Step 1 Every node will start the LCR protocol after receiving the REMOVE command from the network management or control plane. Each ODUkP/ODUj-21_A source and sink pair will signal the [REMOVE] in the LCR CTRL field.

Step 2 Every node will check for consistent configuration of the set of TSs to be removed. The node will pause the LCR protocol and enter the BWR protocol only if the set of TSs signalled to be removed is identical to the set that the node has been provisioned to remove. An ODUflex(GFP) Source node will send the tributary slot connectivity check information [TSCC = 1] in each TS being removed. Intermediate nodes relay this TSCC information toward the ODUflex(GFP) Sink.

Step 3 The two end nodes will start ODUflex(GFP) bandwidth decrease after the completion of tributary slot connectivity check. The resizing will be gradual to avoid overflow of the GMP buffer.

Step 4 LCR protocol will be restarted after finishing of ODUflex(GFP) bandwidth decrease.

Step 5 Every node will start the LC resizing process after the LCR protocol continues. After this, every node exits LCR protocol and BWR protocol. Two end nodes will report to network management or control plane the completion of the decrease resizing process.

The procedure of bandwidth decrease is divided into three parts: the LCR protocol at beginning of decrease, the BWR protocol, and the LCR protocol at end of decrease. These three parts are shown separately in Figures 7-5, 7-6, and 7-7.

Figure 7-5 shows LCR protocol at beginning of bandwidth decrease. The detailed description is as follows. The LCR signalling in this description uses the format [<CTRL value>, <TPID#>, <TSGS value>].

1. Every node starts the LCR protocol and BWR protocol after receiving the network management or control plane DECREASE command. After receiving the DECREASE command from the network management or control plane, every node checks the usage of the TS to be removed (in EMF). Ports in intermediate nodes send [REM, #a, NACK] (LCR Generator) as well as RP=1 and TSCC=0 (BWR Relay Generator) after the usage check. The ports in the two end nodes send [REM, #a, NACK] and RP=1 and TSCC=0 (BWR Relay Generator).

2. After checking that the CTRL=REM is received from the port at the other end of the span (LCR Generator) and the TS configuration of the local port is identical to what the port at the other end of the span is signalling (RCOH Receiver) each port sets its GMP Source or GMP Sink processor into special mode. Now, the LCR protocol is paused and a port continues with the BWR protocol. After receiving TSCC = 1, each input port sets its GMP Sink processor into special mode.

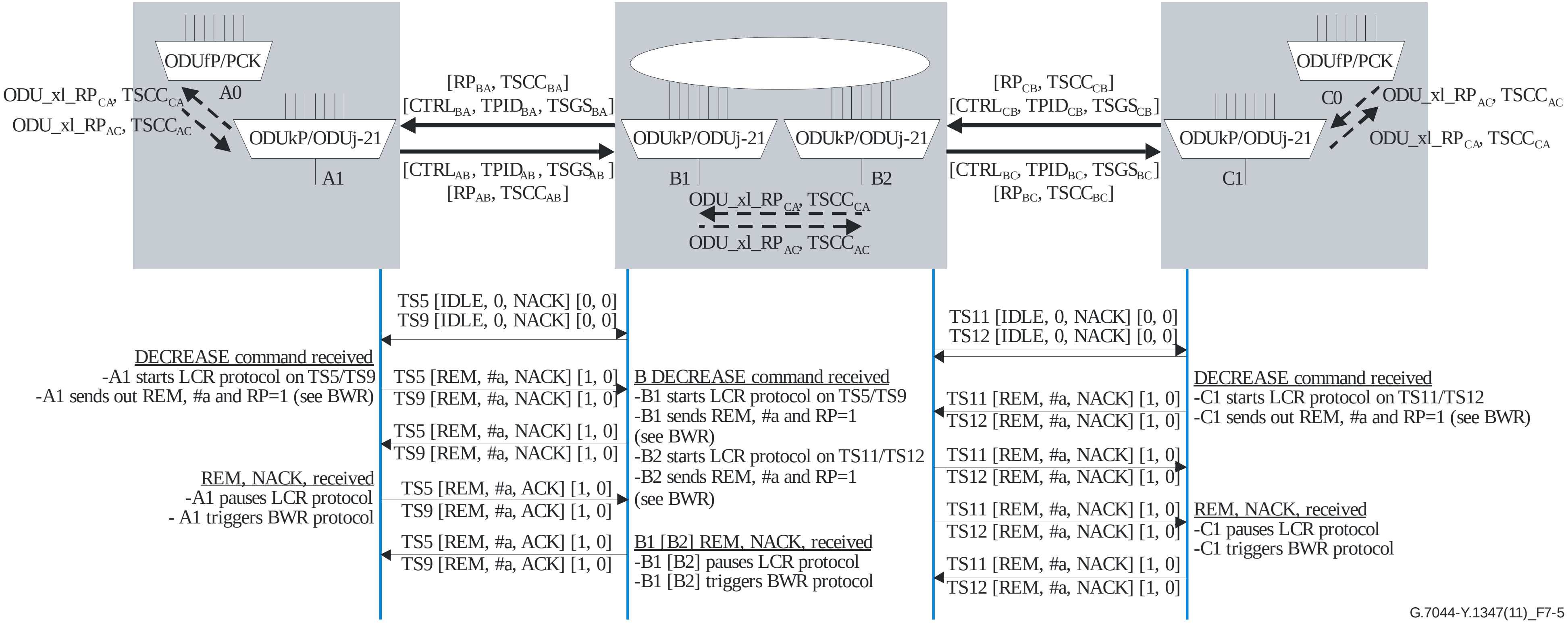

Figure 7-5 – LCR protocol of bandwidth decrease

The steps of the BWR protocol of the bandwidth decrease (Figure 7-6) are:

1. When LCR protocol in an output port (within an end node or an intermediate node) is paused, the output port sets its GMP Source processor into special mode (BWR Relay Generator). The node is expected to perform any required internal buffer adjustments associated with the change in word size prior to entering GMP special mode in a given direction. After setting the GMP Source processor into special mode successfully, and confirming that there are no dTIM defects associated with the new matrix connections at the upstream nodes, the output port relays a received TSCC=1 in that direction (BWR Relay Generator) and disables TCM dTIM-related consequential actions for the duration of BWR protocol (using the TIMActDis). TSCC is sent in the HO OPUk overhead associated with each to be removed TS.
2. When LCR protocol in an input port (within an end node or intermediate node) is paused, the input port begins to set its GMP Sink processor into special mode after receiving TSCC=1 (BWR Relay Receiver). The node is expected to perform any required internal buffer adjustments associated with the change in word size prior to entering GMP special mode in a given direction. After setting the GMP Sink processor into special mode successfully, and confirming that there are no dTIM defects associated with the new matrix connections at the upstream nodes, the input port relays the TSCC = 1 (BWR Relay Receiver) in that direction and disables further TCM dTIM consequential actions for the duration of BWR protocol (using the TIMActDis).
3. When all intermediate input and output ports relay the TSCC =1, it propagates from source to sink.
4. When TSCC = 1 for all the removed TS reaches the ODUflex(GFP) sink, it responds by setting NCS = ACK(1) (BWR Generator) to indicate that in this direction the whole path is OK. Since NCS is located in the ODUflex overhead area, NCS=ACK(1) passes transparently through each node and far end ODUflex(GFP) end node.
5. When an ODUflex(GFP) end node receives both TSCC = 1 and NCS = ACK(1) and has sent NCS=ACK(1) in response to TSCC=1, the bi-directional signalling is complete. It then begins the bandwidth decrease. Bandwidth decrease starts with setting BWR_IND to 1. Refer to 7.2.1 for details on decrease rate. Bandwidth decrease ends after setting BWR_IND to 0.
6. After setting its GMP Source processor into normal mode (BWR Relay Generator), the ODUflex(GFP) source node begins to send out TSCC=0 instead of TSCC=1 (BWR Generator, BWR Relay Generator) to signal the completion of the bandwidth decrease direction and its return to GMP normal mode in its transmit direction.
7. When an intermediate input port receives TSCC=0 and RP=1, it sets its GMP Sink processor into normal mode (BWR Relay Receiver) and forwards the TSCC=0 to the output port. The output port sets its GMP Source processor now into normal mode (BWR Relay Generator). After setting these GMP processors into normal mode, TSCC=0 is immediately relayed through that node in that direction.
8. When TSCC = 0 reaches the ODUflex(GFP) sink (BWR Receiver), the associated ODUflex(GFP) source sends a reply by setting NCS=NACK(0) (BWR Generator).
9. When the ODUflex(GFP) end node receives and sends NCS=NACK(0), the BWR protocol is almost complete and the LCR protocol can resume.
10. When the ODUflex(GFP) end node receives and sends NCS=NACK, it sets RP=0 (BWR Generator). The BWR Relay Generator blocks the forwarding of this RP=0 onto the output port until the LCR protocol is finished.

11. When the LCR protocol is finished at an ODUflex(GFP) end node it will unblock the forwarding of RP=0. When an intermediate input port receives RP = 0 (BWR Relay Receiver), it transparently forwards it to its associated output port (BWR Relay Generator). The increase operation is complete when RP = 0 has propagated to the ODUflex(GFP) far end node, indicating that the intermediate nodes have ended their relay of TSCC information and all other resizing protocol operations. When the ODUflex(GFP) sink node receives RP=0 and has sent RP=0 in the opposite direction, it reports to network management or control plane the completion of the increase resizing process in that direction (BWR Generator).

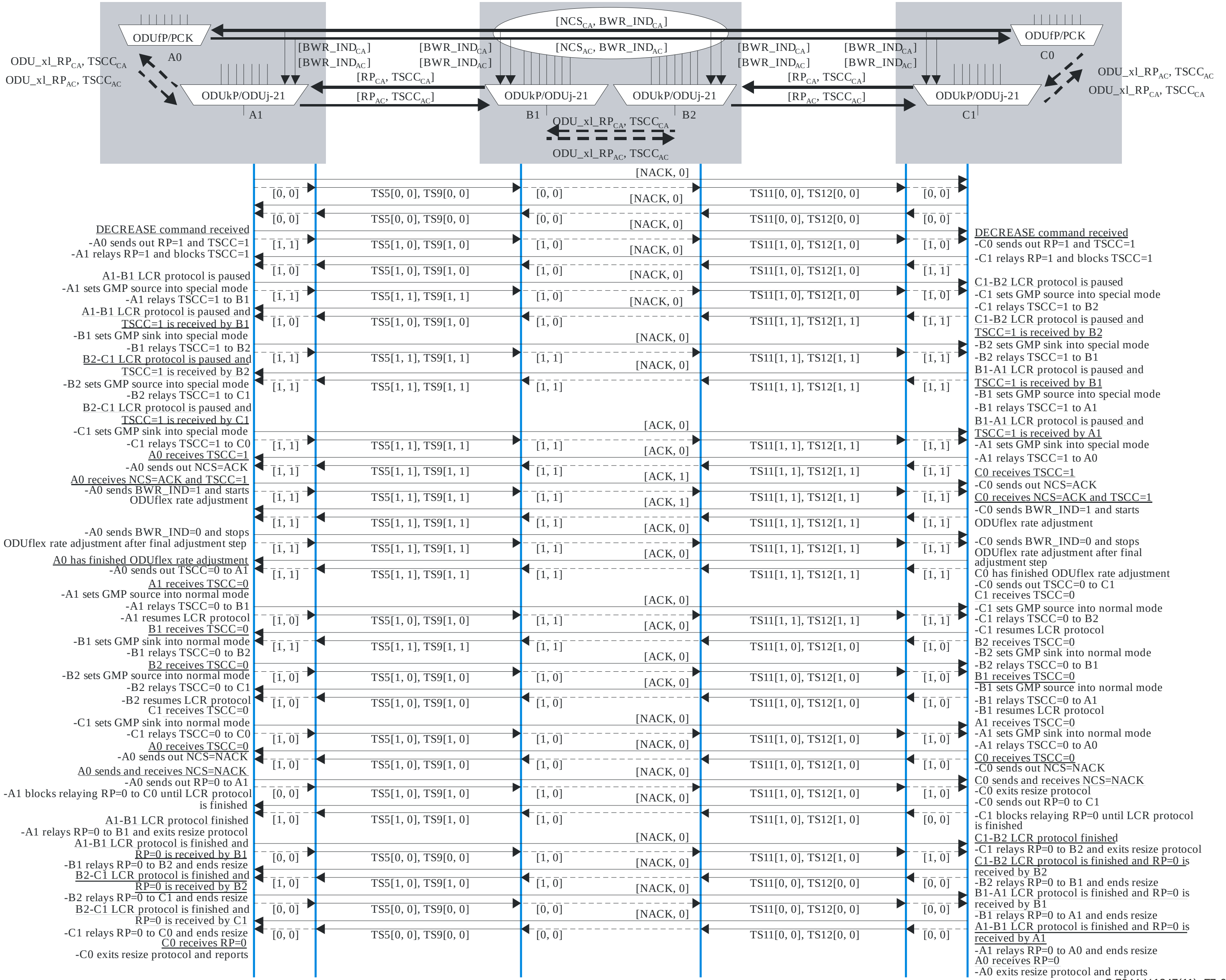

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Figure 7-6 – BWR protocol of bandwidth decrease

Figure 7-7 illustrates the LCR protocol operation at the end of the bandwidth decrease. The steps of the LCR protocol in this phase are:

1. When triggered by the BWR Relay Generator process, an output port sends TSGS=ACK(1).
2. When sending CTRL=REM and TSGS=ACK and receiving CTRL=REM and TSGS = ACK(1) on the same side, after an implementation dependent time, a port sends [NORM, #a, ACK] for every TS being removed at the same resize multiframe boundary (RMF boundary 1) (LCR Generator) . After sending [NORM, #a, ACK], a port performs ODUflex(GFP) link connection decrease. The change from [REM, #a, ACK] to [NORM, #a, ACK] signals the downstream port that the link connection decrease will start at the next resize multiframe boundary (RMF boundary 2).
3. After an implementation specific time after completing the LCR resize and receiving NORM for every TS being removed, a port exits the LCR protocol by sending out [IDLE, 0, NACK] for every TS being removed at the resize multiframe boundary P (LCR Generator).
4. When the output port on an ODUflex(GFP) end node has completed the LCR protocol, it forwards RP=0.
5. An output port on an intermediate node forwards RP=0 after it finishes the LCR protocol (BWR Relay Generator). An input port relays the incoming RP=0 (BWR Relay Receiver).
6. When an ODUflex(GFP) end node receives RP=0 and has sent RP=0 in the opposite direction, it reports to the network management or control plane the completion of the decrease resizing process in that direction.

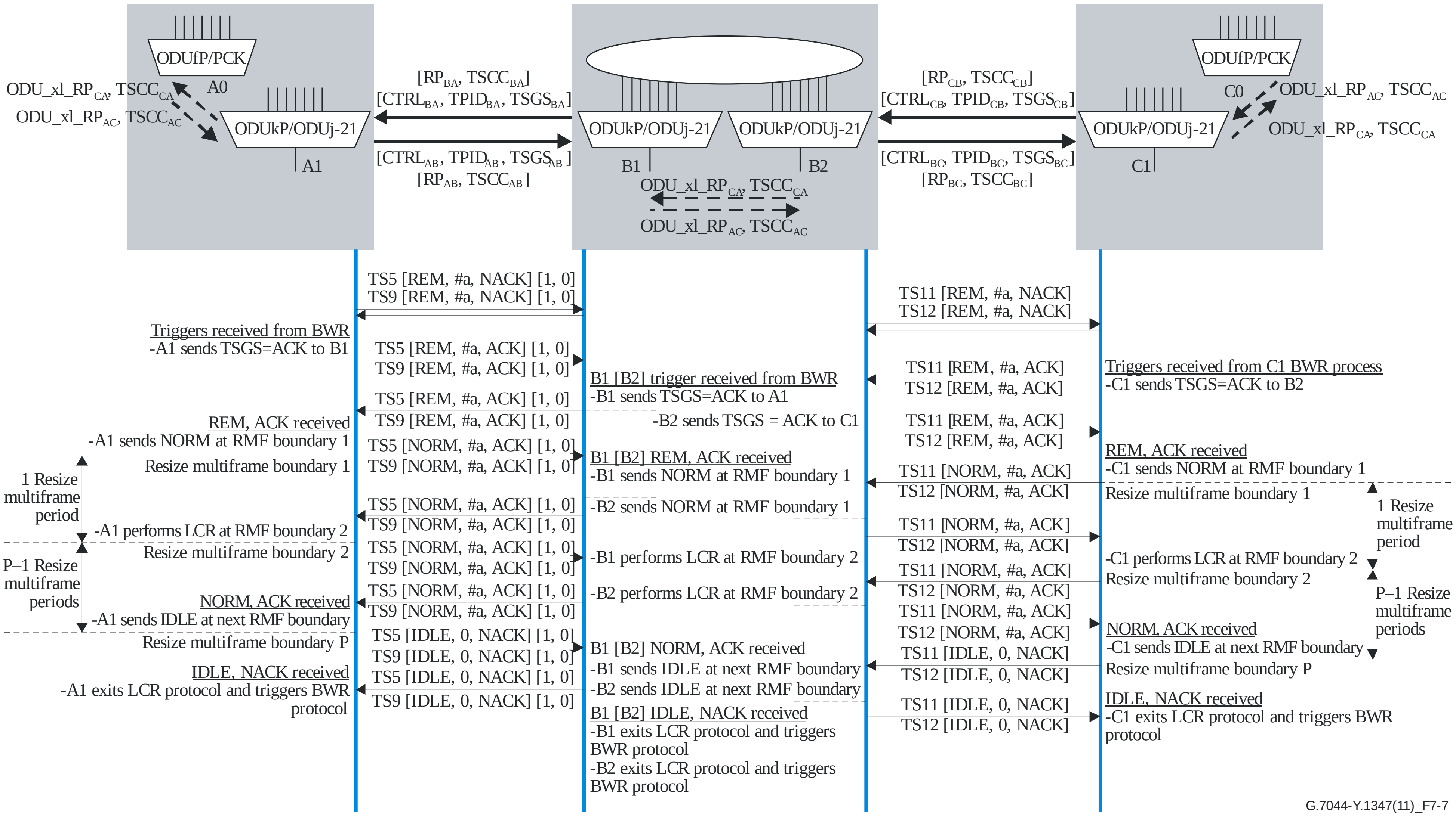

Figure 7-7 – LCR protocol at end of bandwidth decrease

7.2.1 ODUflex(GFP) bandwidth decrease rate

During BWR (controlled by the source node, signalled to downstream nodes using the BWR_IND overhead), the rate of the ODUflex(GFP) clock shall be decreased at a rate of 512 000 kbit/s^2 with a slope tolerance of ±100 ppm [511 897 .. 512 102 kbit/s^2]. This rate decrease can be achieved by a decrease of 8 bits every 125 µs. The BWR_IND is used to trigger the start and stop of the ramp at the downstream nodes.

Methods to measure the timing transfer performance across an intermediate node are described in Appendix I.

The ODUflex(GFP) data shall be extracted from the groups of M successive bytes of the ODTUk.M payload area under control of the GMP data/stuff control mechanism as defined in clause 19.6 of [ITU-T G.709] and be written into the buffer. The Cn information associated with the ODUj is computed from the GMP Cm parameter carried within the JC1/2/3 overhead of the ODTUk.M as specified in clause 19.6 of [ITU-T G.709]. For the GMP data/stuff control mechanism, refer to Annex D of [ITU-T G.709].

The ODUflex(GFP) data (CI_D) shall be read out of the buffer under control of the ODUflex(GFP) clock (CI_CK).

Smoothing and jitter limiting process: The function shall provide for a clock smoothing and elastic store (buffer) process. The ODUflex(GFP) data signal shall be written into the buffer under control of the associated (gapped) ODUk input clock (with a frequency accuracy within ±20 ppm). The behaviour shall be as if the data signal is read out of the buffer under control of a smoothed ODUflex(GFP) clock (the rate is determined by the ODUflex(GFP) signal at the input of the remote ODUkP/ODUflex-21_A_So).

The clock parameters, including jitter and wander requirements, as defined in Annex A of [ITU-T G.8251] (ODCp clock), apply.

Buffer size: In the presence of jitter as specified by [ITU-T G.8251] and a frequency within the tolerance range specified for the ODUj signal in Table 14-2, this justification process shall not introduce any errors. The buffer hysteresis shall not exceed 4×M bytes for an ODUflex(GFP) which occupies M tributary slots.

7.2.2 GMP OH location update during decrease

During a bandwidth decrease of an ODUflex(GFP), HAO restricts that the highest numbered TS occupied by ODUflex(GFP) should not be removed. So there is no need for an update of the GMP OH location.

E.g., TP1 is initially allocated with TS3, 4 and 8 of an OPU3, and is reduced by two TSs. As per HAO, the last TS, TS8, will not be removed, but rather TS3 and TS4 will be removed. Before LCR, the GMP OH is present in the TSOH of the last of the 3 Tributary Slots (TSOH ofTS8). After the LCR, the GMP OH remains in the same location.

8 Maintenance signals

The ODUflex(GFP) signal follows the maintenance signal specification of clause 16.5 of [ITU-T G.709], with the exceptions described here.

When a node in BWR has begun its output bandwidth ramp due to receiving BWR_IND, and subsequently detects a signal defect in that direction, it inserts AIS at the nominal ramping rate. In other words, the output AIS rate from that node follows that node's internal ramping rate so that the AIS signal will continue to have the rate expected by the downstream nodes. The node that sources the AIS will continue to ramp until it reaches the nominal final target rate for the ODUflex(GFP) signal.

In order to prevent potential over/underflow problems due to TCM layer dTIM defects, AIS insertion due to TCM layer dTIM defects shall be disabled during BWR.

Annex A

HAO SDL diagrams

(This annex forms an integral part of this Recommendation.)

A.1 Hitless adjustment of ODUflex(GFP) (HAO) process overview

Figure A.1 presents the use of the hitless adjustment of ODUflex(GFP) HAO processes for the case of an ODUflex(GFP) connection that has two link connections. The example illustrates the HAO functionality within two ODUflex(GFP) end nodes and one intermediate node. This example illustrates the possible connectivity between the HAO processes.

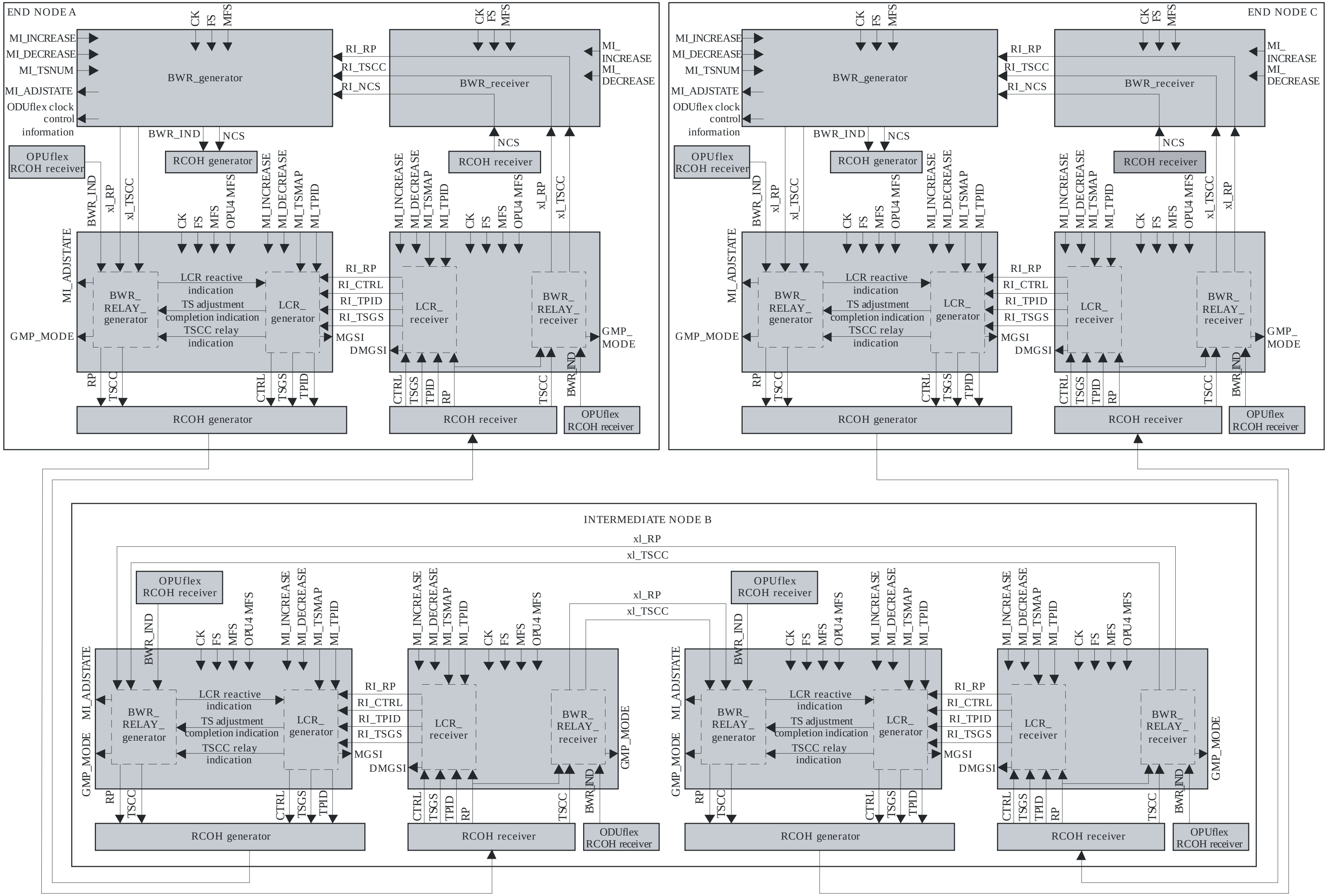

Figure A.1 – HAO process overview

A.2 HAO SDL diagrams

Although the HAO protocol specifies the link connection resize (LCR) protocol and the bandwidth resize (BWR) protocol, one session timer is used to report the error message to the equipment management function (EMF) to avoid infinite protocol hanging. This would allow implementing more flexible control policies (for instance performing sessions resume in case of errors).

After the LCR protocol starts, a session timer will be started at the same time. The session timer will expire in case of error conditions. After session timer expiration, the abort signal MI_ABORT is sent to all HAO processes, the value of the LCR protocol overhead shall be set to IDLE, while the value of the BWR protocol overhead shall be maintained as the latest value until the error message has been reported to the EMF, and then the value of the BWR protocol overhead shall be set to IDLE.

The RCOH receiver verifies if the tributary slot configuration of the local port is identical to what the port at the other end of the span is signalling. A mismatch is reported to the NMS.

The HAO SDL diagrams use the following conventions:

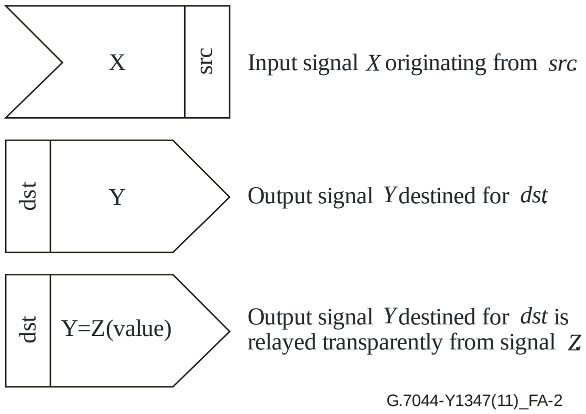

Figure A.2 – SDL legend

Figure A.3 presents SDL specification for the LCR generator.

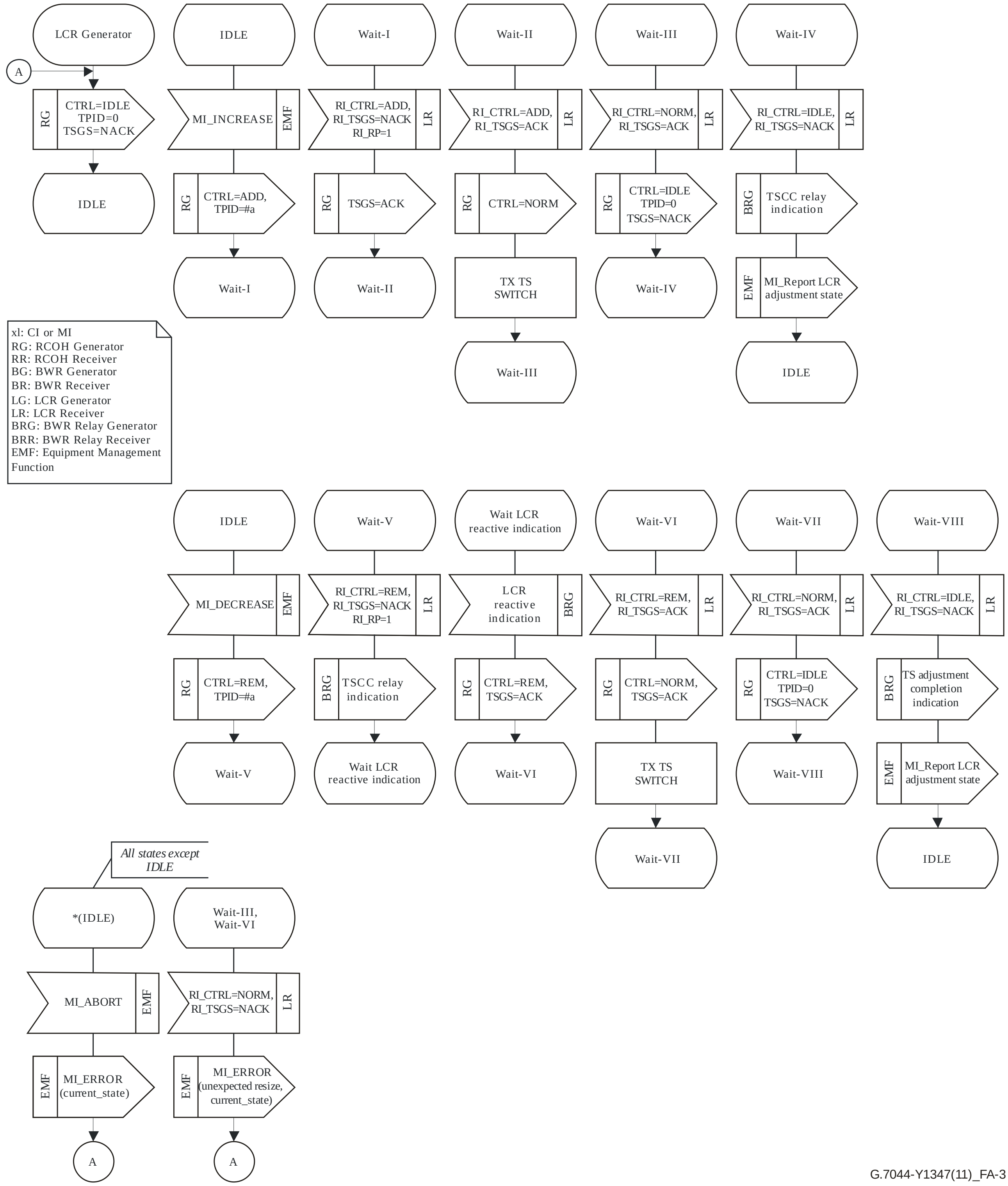

Figure A.3 – SDL diagram for the LCR generator

Figure A.4 presents SDL specification for the LCR receiver.

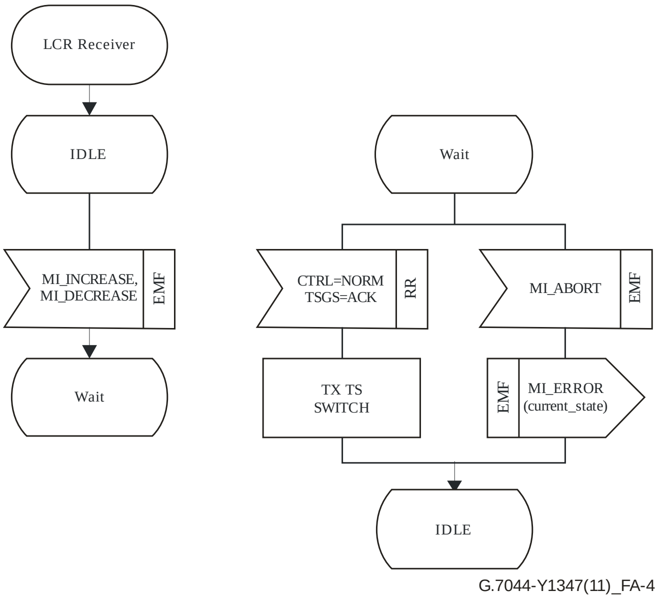

Figure A.4 – SDL diagram for the LCR receiver

Figure A.5 presents SDL specification for the BWR generator.

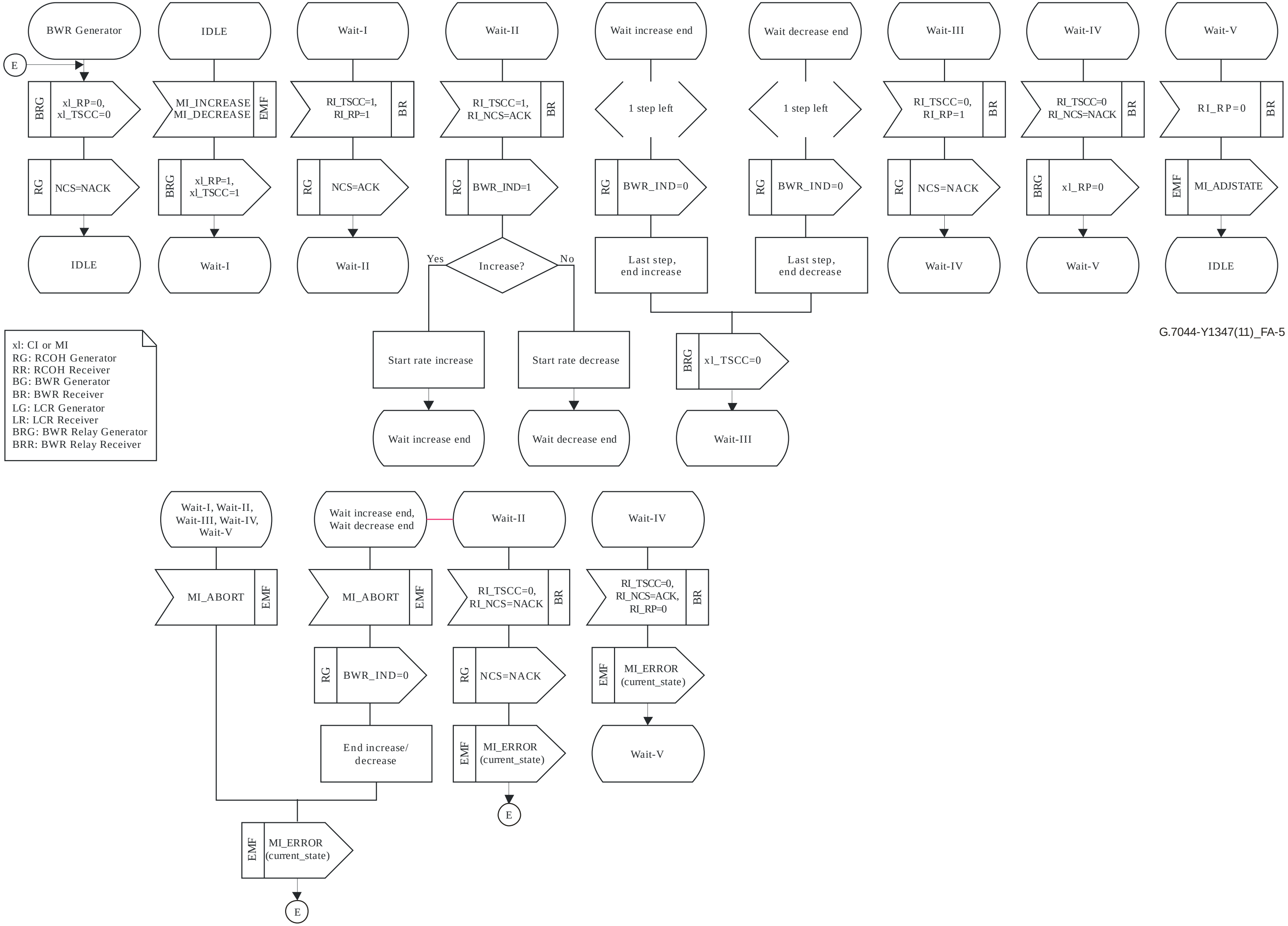

Figure A.5 – SDL diagram for the BWR generator

Figure A.6 presents SDL specification for the BWR receiver.

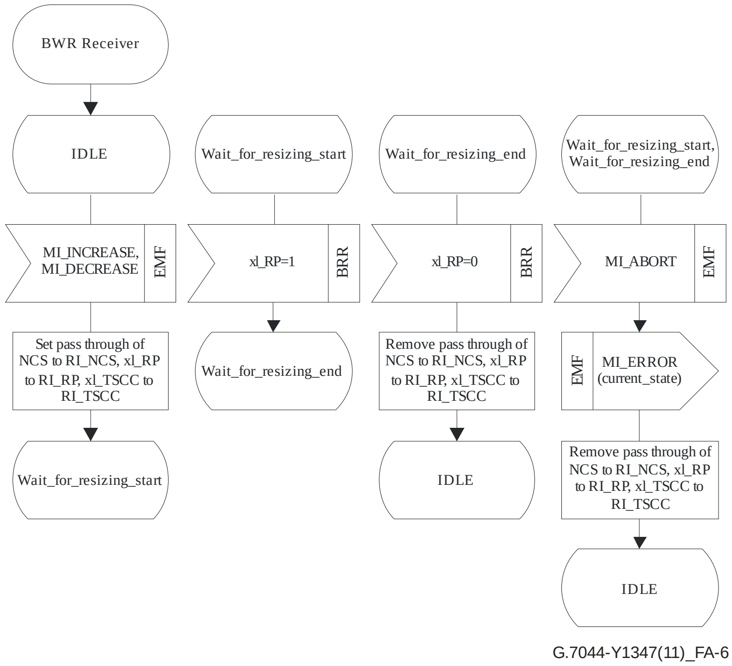

Figure A.6 – SDL diagram for the BWR receiver

Figure A.7 presents SDL specification for the BWR RELAY generator.

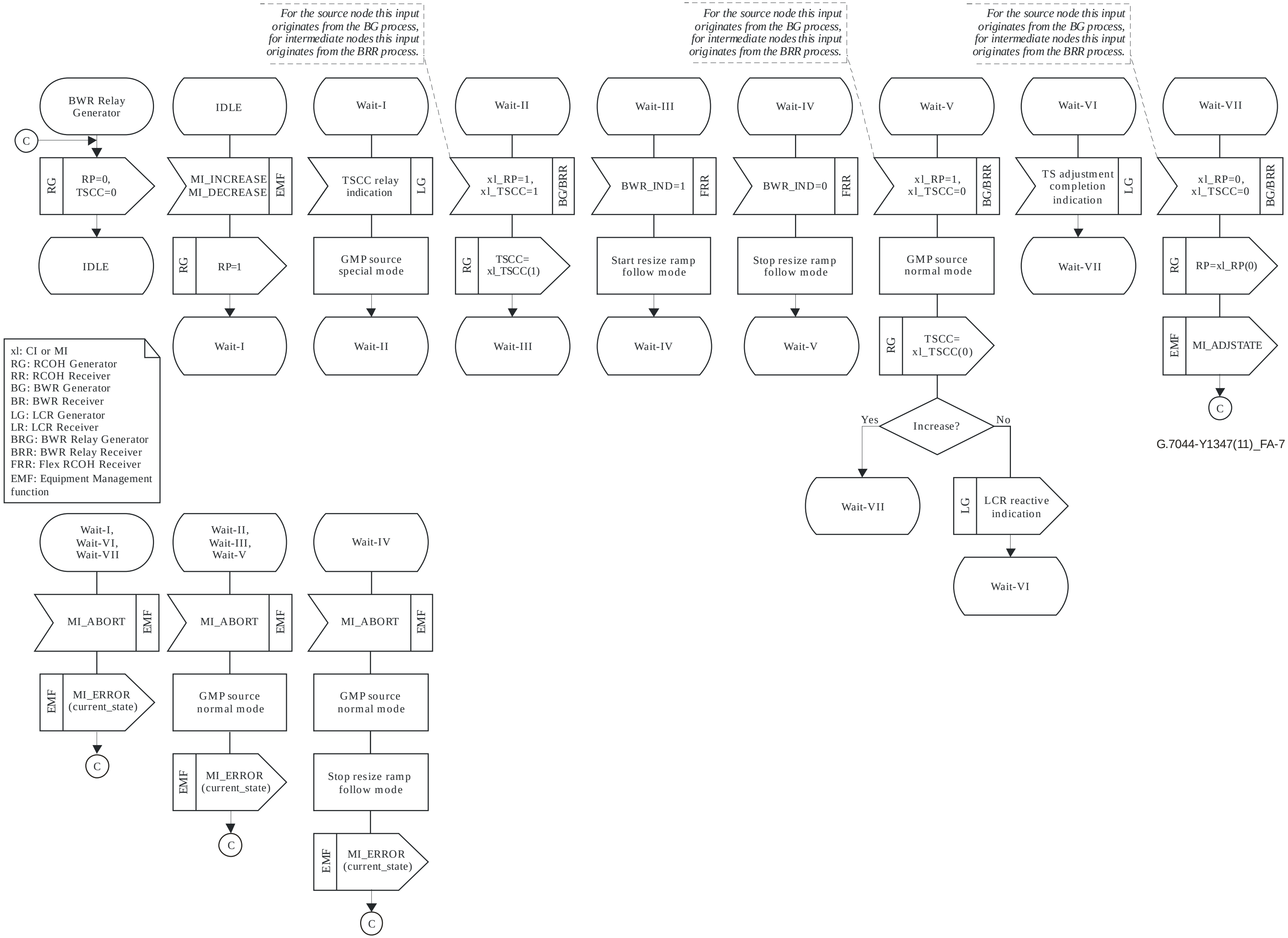

Figure A.7 – SDL diagram for the BWR RELAY generator

Figure A.8 presents SDL specification for the BWR RELAY receiver.

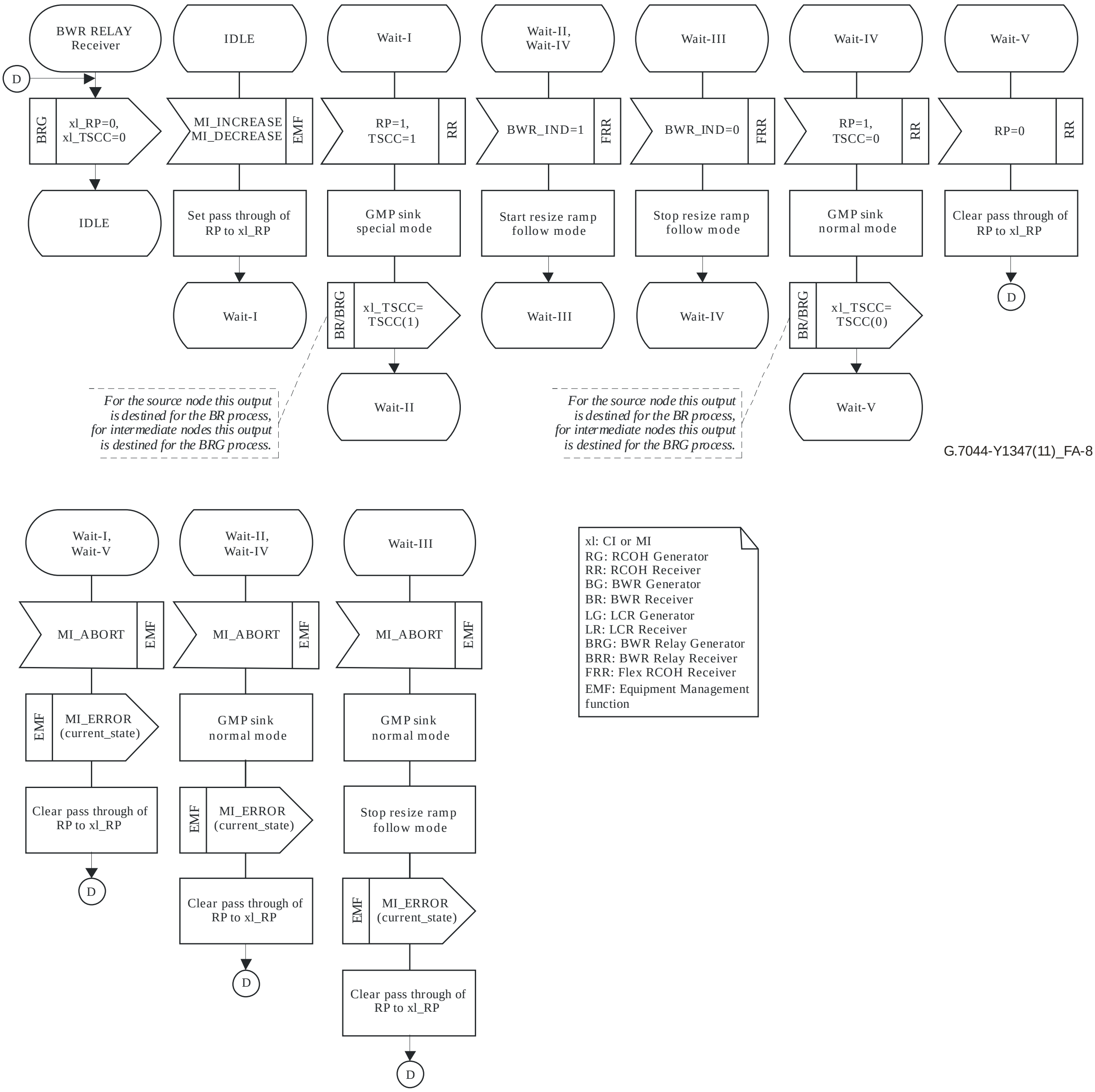

Figure A.8 – SDL diagram for the BWR RELAY receiver

Appendix I

BWR rate change stability measurement

(This appendix does not form an integral part of this Recommendation.)

One method to measure the BWR rate change performance across an intermediate node is based on maintaining a nominally constant transit latency for the ODUflex(GFP) signal. At an intermediate node, the transit latency is measured by sampling the delay or relative phases between the incoming and outgoing ODUflex(GFP) signals, as illustrated in the example test configuration of Figure I.1. Specifically, the latency (relative phase) measurements are performed by comparing the incoming and outgoing ODUflex(GFP) signals after they have been extracted from their respective HO ODUk signals and smoothed with a 300 Hz-filter in order to centre the latency. During the time interval in which the node is in GMP Special Mode, the variance of this latency (phase error) should be no more than ±1µs relative to the reference latency measured at the point when the node entered GMP Special Mode.

The latency measurement is intended for verification of a node's performance in a test configuration. It is not intended to be performed on an in-service node in a network.

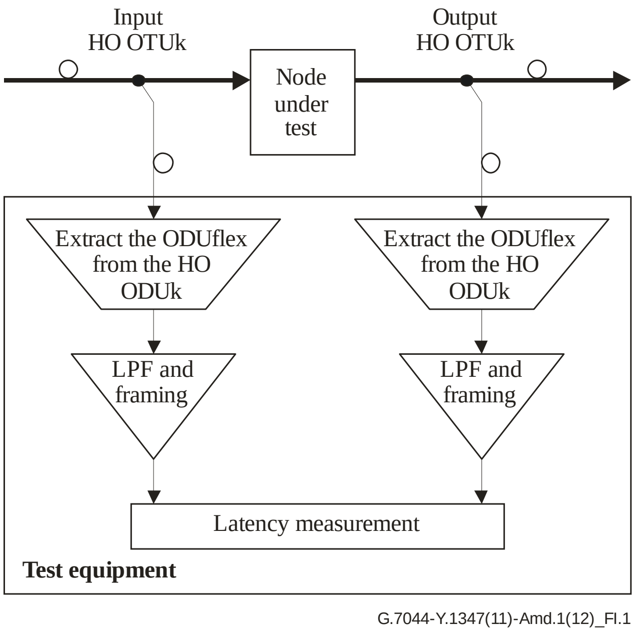

Figure I.1 – Example illustrating a BWR node latency measurement test configuration

ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
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