Tandem Connection Monitoring: Fundamentals, Operation, Test Solutions

Application Note 73

ANT-20 application
Qualification of
a TCM link section

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Communications Test Solutions

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The ANT-20 Advanced Network Tester is designed for mobile testing of digital communications systems. With its modular design, the latest test requirements for SDH, SONET and ATM transport networks and network elements are easily covered.

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1 Introduction

Global liberalization in the telecom sector has lead to a virtual mushrooming of new network operators. The first step involves construction of high-speed ring structures covering multiple cities to provide interregional data transport. The “final mile” to end users is often provided by a regional urban network operator or another larger network operator. Smaller network operators sometimes find it more economical to lease network resources from larger operators than to build their own networks. As a result, complete SDH paths are routed via networks of different operators.

Smooth operation is the rule. But what happens when impairments do occur? If the availability of the path is contractually stipulated, then errors must be corrected within a specific time span.

However, this entails knowledge of the section or subnetwork in which the error is occurring. In the end run, it comes down to who is responsible in case the end user decides to make a legal claim.

SDH and SONET technologies have a way of dealing with such issues. It is known as tandem connection monitoring (TCM).

Before examining the basic operation of TDM, we will first consider the basis for TCM, i.e. hierarchical error checking using the parity bytes.

2 Error checking in SDH networks

2.1 Hierarchical error checking using parity bytes B1, B2, B3 and V5

Compared to PDH systems, SDH systems provide an easier way to monitor errors during system operation. Using parity bytes B1 to B3 or V5, any bit errors that occur can be clearly assigned to a link section, making it easy to isolate the error source. SDH uses a technique known as bit interleaved parity (BIP) (see section 2.2).

Fig. 1 shows the sections used in parity monitoring. The link sections for which the parity bytes are generated and checked should be clear from the diagram. The length of the parity bytes is determined by the respective position in the SDH frame.

Table 1 shows how the bytes are arranged in the overhead and how long they are. The number following the hyphen is the number of bits, e.g.: BIP-2 (2 bits), BIP-8 (8 bits).

Fig. 2 on the next page uses another format to show what part of the SDH frame is evaluated by each parity byte.

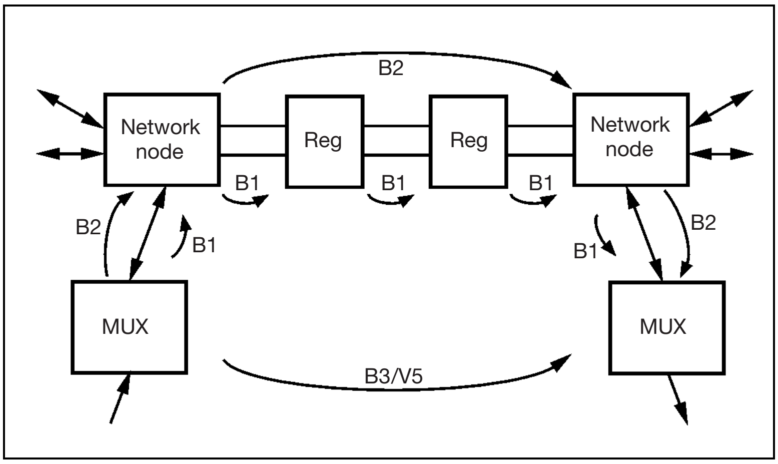


Fig. 1: Hierarchical error check

Byte	At position	Monitors	Using	The
B1	RSOH	Reg section	BIP-8	STM-n
B2	MSOH	MUX section	BIP-24	STM-1
B3	POH	Entire path	BIP-8	VC-3/VC-4
V5	POH	Entire path	BIP-2	VC-11/VC-12/VC-2

Table 1: Assignment of the parity bytes

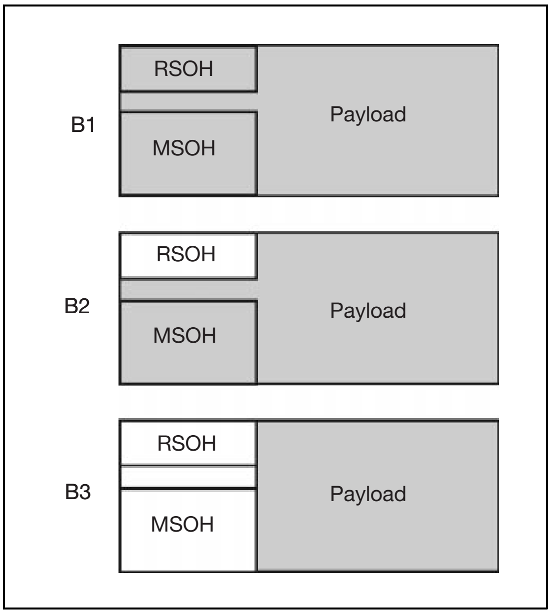


Fig. 2: Quality monitoring using parity bytes B1, B2, B3

- B1 (8 bits) is used for parity evaluation over the entire STM-1 frame (regenerator section).
- B2 (N × 24 bits) is used for parity evaluation without the regenerator SOH (multiplex section).
- B3 (8 bits) – based on the example of a VC-4 here – is used for parity evaluation over the entire transmission path.

2.2 Generation of the parity bytes

As was already mentioned, SDH uses a technique known as bit interleaved parity (BIP) to generate parity bytes. The payload, illustrated here using the example of a VC-4 container, is arranged in rows with a column width of 8 bits (BIP-8). The parity byte is then used to give each column an even number of ones **(Fig. 3).**

If bit errors occur in a transmission section, then the parity byte no longer matches its block and the bit errors are detected at the path termination. The limitation of this technique is reached if multiple errors occur in a column during a high error rate. Even numbers of errors cancel one another out.

Fig. 3: Generation of the parity byte

BIP-8

The parity byte gives each column an even number of ones.

1	0	0	1	1	0	1	1
0	1	1	1	0	0	0	0
1	1	0	1	0	0	1	0

0	0	1	1	1	0	0	1

B1 parity

1	0	0	1	1	0	1	1	1	1	0	1	1	0	1	1	1	0	0	1	1	0	1	1
0	1	1	1	0	0	0	0	0	1	1	1	0	1	0	0	1	1	1	1	0	0	0	0
1	1	0	1	0	0	1	0	1	1	0	1	0	0	1	0	1	1	0	1	0	0	1	1

BIP-24

0	0	1	1	1	0	0	1	0	1	1	1	1	1	0	1	1	0	1	1	1	0	0	0

B2 parity

2.3 Parity check

After parity generation is completed on the transmitting end for the VC in frame n, the related parity byte is computed. It is then inserted into the frame n+1 and transmitted to the receiving end. There, parity generation takes place likewise for the VC received in frame n, followed by comparison with the parity byte in frame n+1. If the BIP-8 value computed by the network element agrees with the received BIP-8 value in the B3 byte, this means that no signal degradation took place in the link section being monitored. Any bit errors that occurred are evaluated based on the number of different bits in the BIP-8. **Fig. 4** illustrates this procedure.

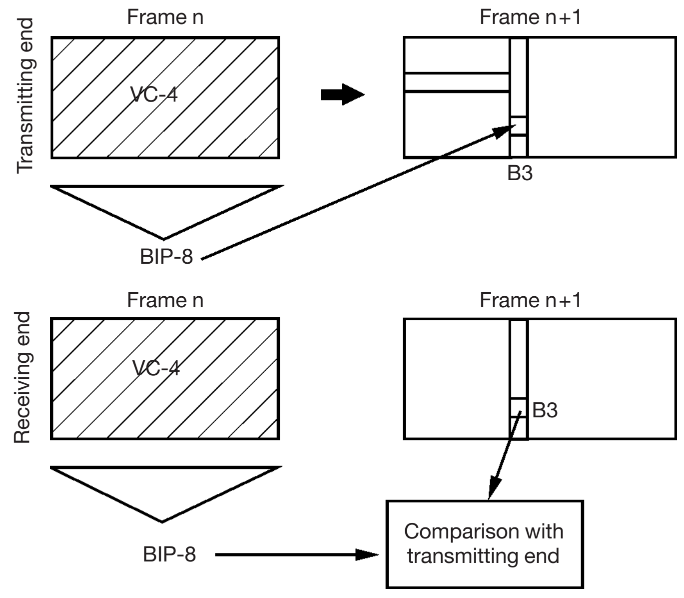


Fig. 4: Parity check using the example of a VC-4 container

3 TCM – How does it work?

3.1 VC-n path without a TCM section

In a VC-n connection, an error check is performed for the entire communications path using the B3 byte (HP) or the V5 byte (LP) **(Fig. 5).** If errors occur, they are detected by the receiver and evaluated. However, if part of this path passes via the network of a second operator, it is not possible to determine who is responsible for the bit errors that occurred. This makes it harder to resolve any problems.

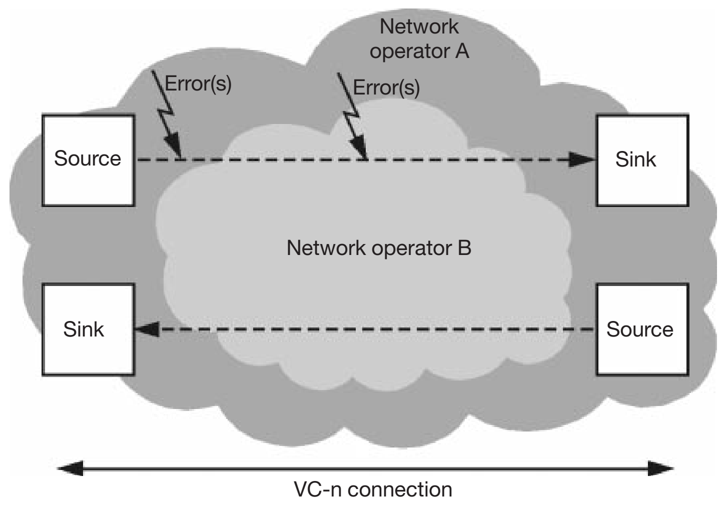


Fig. 5: VC-n path without a TCM section

3.2 VC-n path with a TCM section

Although we were previously unable to determine in what subnetwork the error occurred, we can now use the TCM section to determine exactly which operator caused any errors **(Fig. 6).**

Error detection is not limited to bit errors. An incoming AIS or an invalid VC-n can also be detected and reported. The data gathered from the TCM section are forwarded to network management (TMN) for quality analysis purposes.

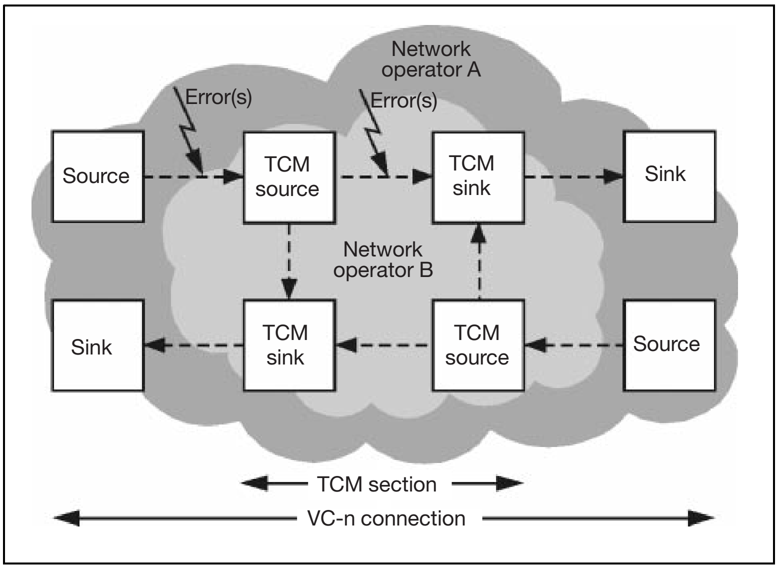


Fig. 6: VC-n path with a TCM section

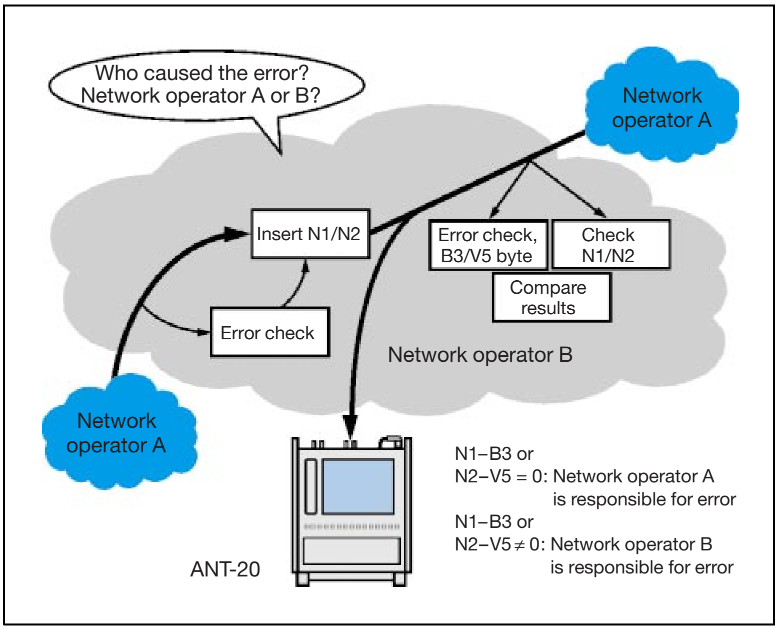


Fig. 7: Who caused the errors that occurred?

3.3 Basic operation of TCM

To enable an error check in the TCM section, the state of the VC-n path at the network interconnection from operator A to operator B must first be determined **(Fig. 7).** This involves a comparison of the incoming parity byte with the value of the parity byte computed in the network element. The comparison result is then transferred using a special byte to the end of the TCM section at the network interconnection from operator B to operator A. The byte used depends on the container size: The results are transported in the N1 byte for VC-4 and VC-3 containers and in the N2 byte for VC-2, VC-11 and VC-12 containers. At the end of the TCM section, there is another check of the parity byte with a subsequent comparison of the content of N1 or N2. If the difference is equal to zero, then network operator A is responsible for any errors that occurred. If the difference is not equal to zero, then additional errors might have occurred in the network of operator B. Besides error monitoring, the N1 and N2 bytes are also used for TCM alarm and event handling and for identifying the correct connection using the trace identifier.

3.4 Case studies for the N1 byte

The usage of the N1 byte for alarm, error and event handling in the VC-3 and VC-4 will now be illustrated using the following three case studies. Using the ANT-20, it is possible to simultaneously measure bit errors that occur within and outside of the TCM section and to separately evaluate and log them.

3.4.1 Bit errors that occur outside of the TCM section

(see also **Fig. 8).** The incoming signal on network element 2 (NE2) is checked for bit errors by comparing the value of the incoming B3 byte (from NE1) with the BIP-8 value computed in NE2. The two values differ since bit errors occurred on the sublink. The difference is transmitted as the incoming error count (IEC) in the N1 byte to NE n. The change in the content of N1 necessitates compensation of the incoming B3 byte in NE2. At the end of the TCM section (NE n), the BIP-8 value is recomputed again. BIP-8 and the incoming B3 are compared in turn. Since the values differ due to the bit errors that occurred between NE1 and NE2, the outgoing error indication (OEI) is set in the backwards direction in the N1 byte to indicate the anomaly, which is evaluated by NE2. Then, the computed BIP-8 and the value from the IEC are compared. These two values are equal since no additional bit errors occurred within the TCM section. The N1 byte is reset to the default “0” outside of the TCM section and B3 is recompensated. The incoming B3 byte on NE n+1 is compared again with the computed BIP-8. Due to the bit errors that occurred in the link section between NE1 and NE2, the two values are different. The B3 error count is reported back to NE1 for evaluation in the G1 byte of the POH (HP-REI).

3.4.2 Bit errors that occur within the TCM section

(see also **Fig. 9).** The incoming B3 byte from NE1 is compared with the BIP-8 value computed in NE2. Since no bit errors occurred in the subsection between NE1 and NE2, these two values are equal. In the N1 byte transmitted to NE n, the IEC value is set to zero and the B3 byte is then compensated. At the end of the TCM section (NE n), the incoming B3 is compared with the BIP-8 value computed in NE n. However, since bit errors occurred within the TCM section, the two values are different and in the

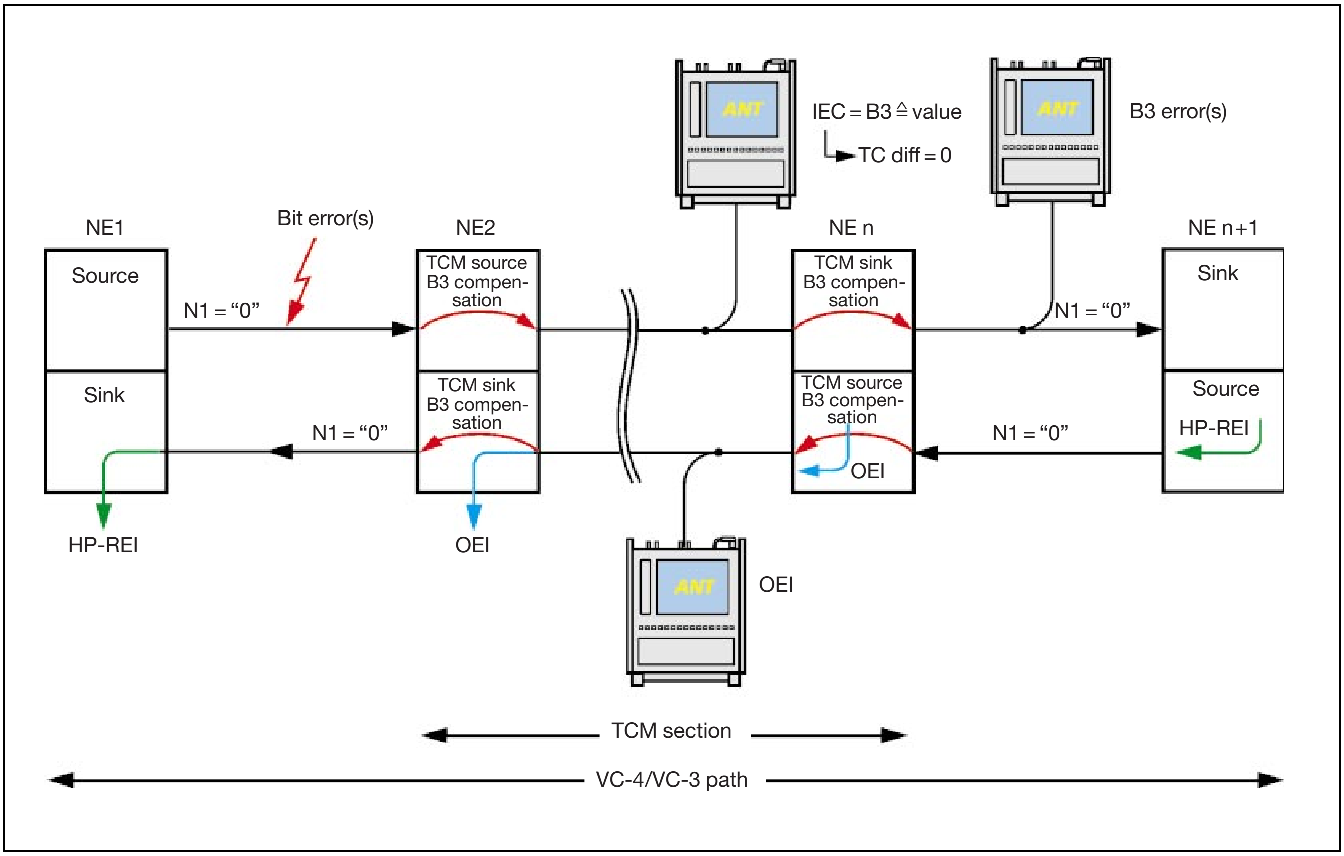


Fig. 8: VC-4/VC-3 path with bit errors outside of the TCM section

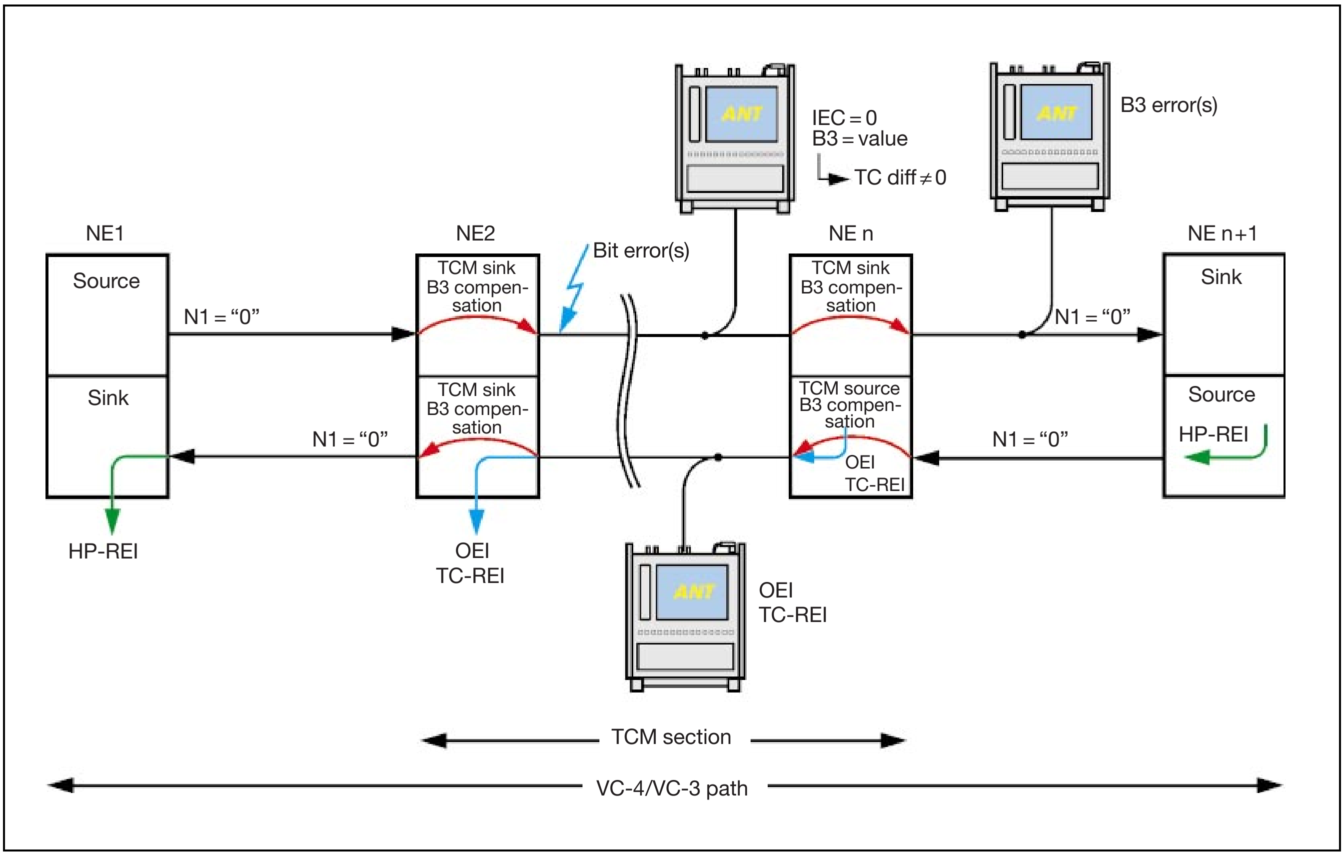


Fig. 9: VC-4/VC-3 path with bit errors within the TCM section

N1 byte the anomaly bit (OEI) is set in the backwards direction to NE2. Now, the computed value for BIP-8 is compared with the value of the IEC. Since these values also differ due to the bit errors within the TCM section, the bit for the anomaly TC-REI is set in the N1 byte additionally in the backwards direction. Both anomalies (OEI and TC-REI) are evaluated in turn by NE2. Using the TC-REI in the backwards direction, it is easy to detect the fact that bit errors occurred in the TCM section. Outside of the TCM section, the N1 byte is reset to the default “0” and B3 is recompensated. The incoming B3 byte on NE n+1 is again compared with the computed BIP-8. The two values differ due to the bit errors that occurred in the link section between NE2 and NE n. The B3 error count is reported back to NE1 for evaluation in the G1 byte of the POH (HP-REI).

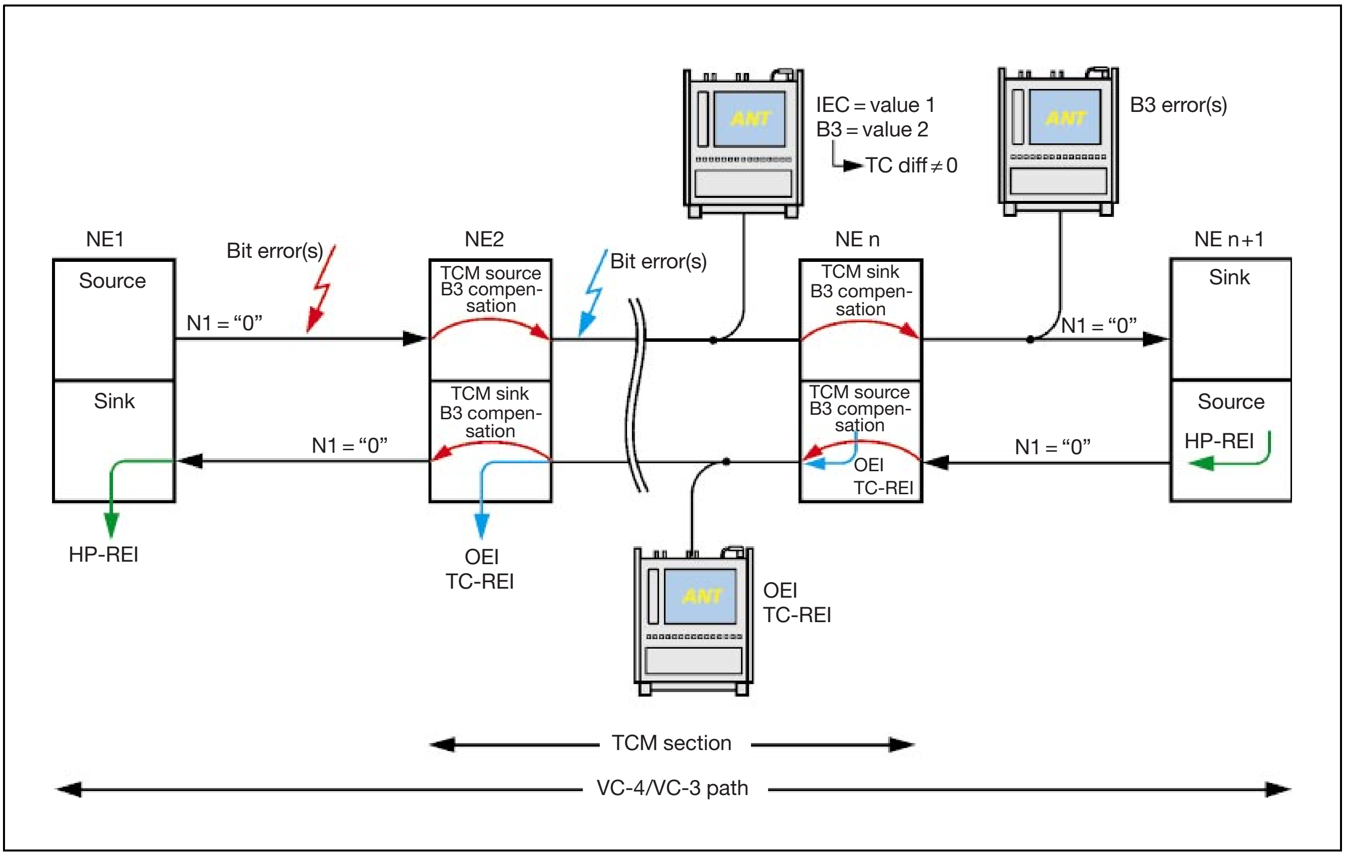
3.4.3 Bit errors occurring within and outside of the TCM section

(See also **Fig. 10**). The incoming B3 byte from NE1 is compared with the BIP-8 value computed in NE2. The two values differ since bit errors occurred in the subsection between NE1 and NE2 (e.g. three BIP-8 errors). In the N1 byte of NE n, the IEC value is set to three and B3 is then compensated. At the end of the TCM section (NE n), the incoming B3 is compared with the BIP-8 computed in NE n (3 BIP-8 errors between NE1 and NE2 + 4 more BIP-8 errors between NE2 and NE n = 7 BIP-8 errors).

Since the computed BIP-8 and the received B3 byte (from NE2) are different, the anomaly OEI is indicated in N1 in the backwards direction to NE2. Then, the computed value of the BIP-8 (7 errors) is compared with the IEC value (3 errors). The difference (4 errors) must have occurred on the TCM section and is evaluated by network management. Since the BIP-8 and IEC also differ, the TC-REI anomaly is indicated additionally in the backwards direction to NE2. Both anomalies (OEI and TC-REI) are evaluated by NE2.

Outside of the TCM section, the N1 byte is reset to the default “0” and B3 is recompensated. The incoming B3 byte on NE n+1 is compared again with the computed BIP-8. The two values differ due to the bit errors that occurred in the link sections NE1/NE2 and NE2/NE n. The B3 error count is reported back to NE1 for evaluation in the G1 byte of the POH (HP-REI).

Fig. 10: VC-4/VC-3 path with bit errors within and outside of the TCM section



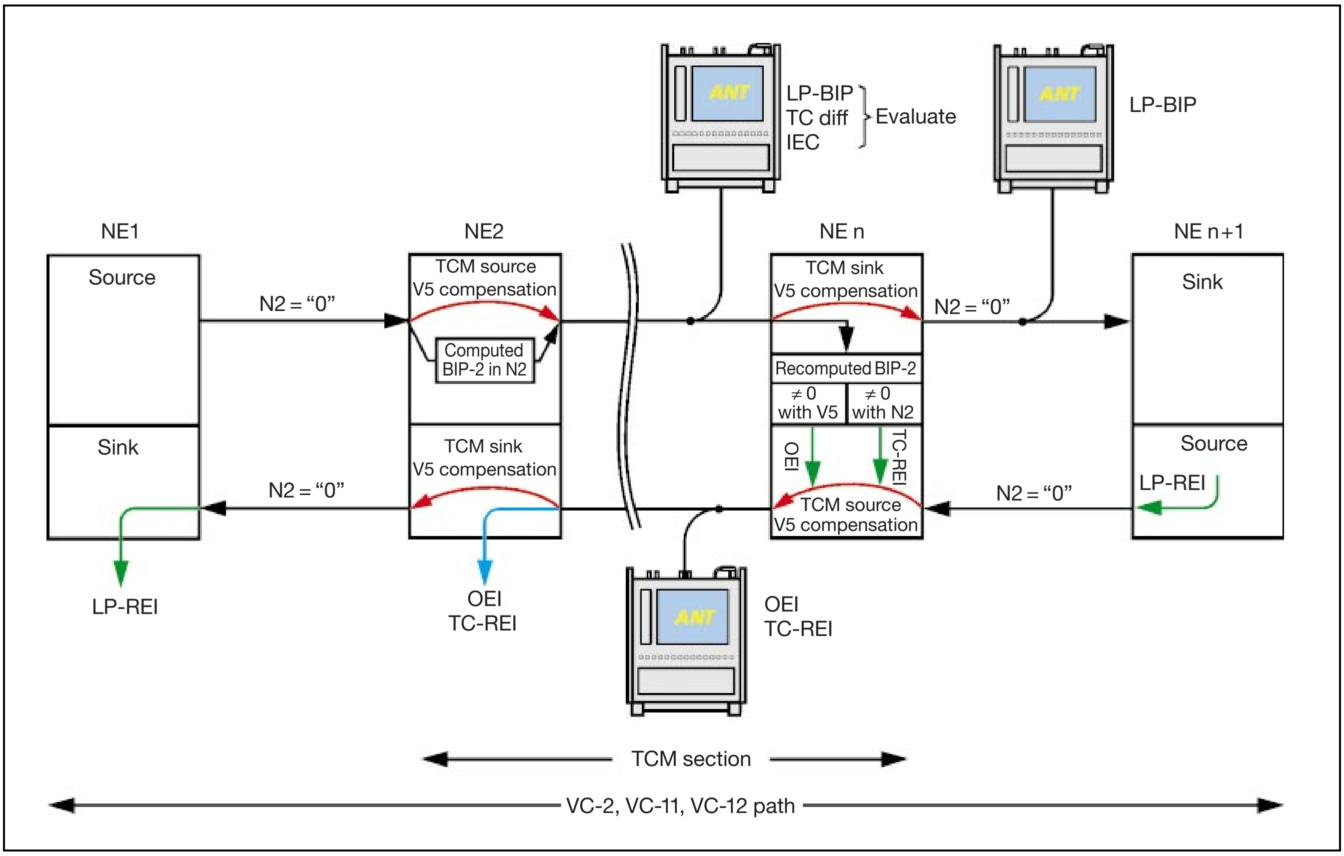
3.5 N2 byte: What changes?

The N2 byte is used for the C-2, C-11 and C-12 containers like the N1 byte is used for TCM operation in the VC-3 and VC-4. Alarm, event handling and the trace identifier are identical with these two bytes. However, transmission of errors that occur in the TCM section is handled differently **(Fig. 11).**

The value of BIP-2 is computed for the incoming signal on NE2 from NE1, and this value is inserted into the N2 byte. The incoming V5 byte from NE1 is compensated in NE2 since the value of the N2 byte has changed due to the inserted BIP-2 and the trace identifier. At the end of the TCM section, the value of the incoming V5 byte and the BIP-2 value of the N2 byte is compared in NE n with the computed value of BIP-2. If V5 and the computed BIP-2 differ, then bit errors occurred on the link section from NE1 to NE n, and the anomaly OEI is inserted in the backwards direction to NE2. It is still not possible to say whether the bit errors occurred within or outside of the TCM section.

If the values of the BIP-2 in the N2 byte and the computed BIP-2 in NE n agree, then the bit errors occurred outside of the TCM section. However, if the values differ, then additional bit errors occurred in the TCM section and the anomaly TC-REI is indicated additionally in the backward direction to NE2. OEI and TC-REI are evaluated by NE2. In NE n, the N2 byte is set to “0” in the direction NE n+1 and V5 is recompensated. The incoming V5 byte in NE n+1 is compared with the BIP-2 value computed in NE n+1. If they differ, the anomaly LP-REI is inserted into the POH in the backwards direction, which is evaluated by NE1.

Fig. 11: VC-2, VC-11, VC-12 section



4 Qualifying a TCM section

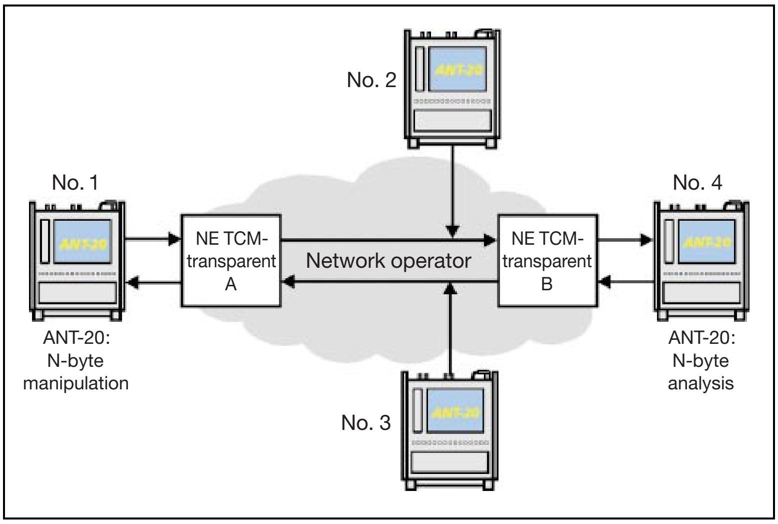


Fig. 12: N-byte transparency test

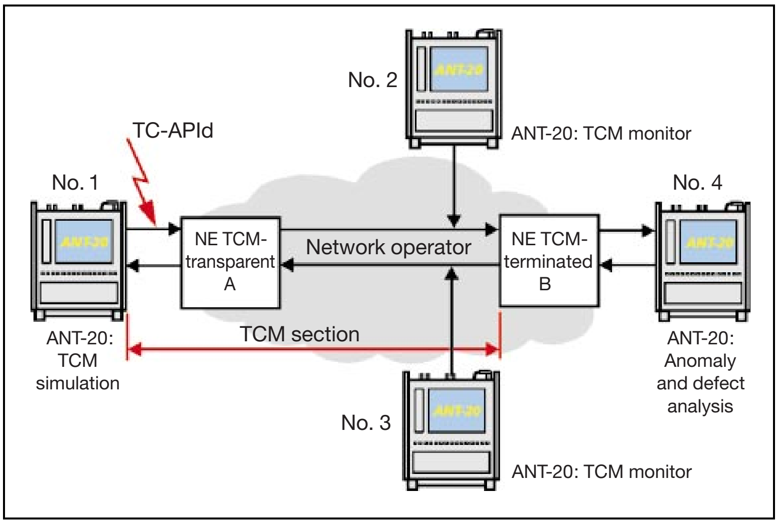


Fig. 13: TC-APId functional test

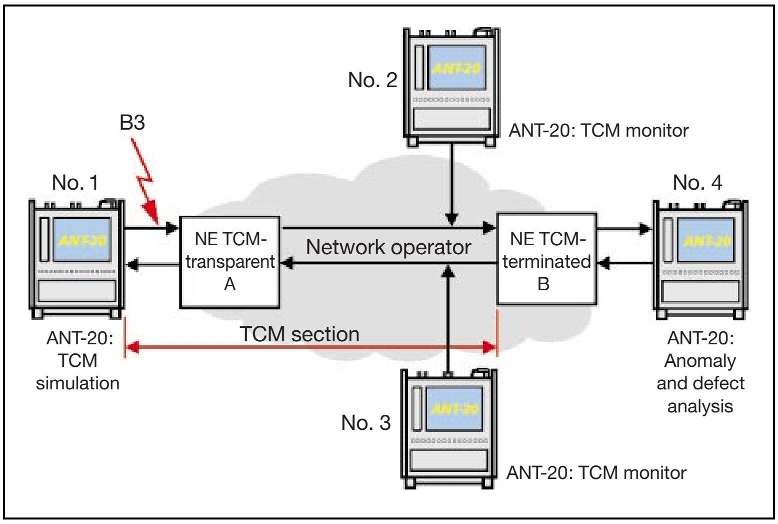


Fig. 14: Insertion of B3 errors for checking for proper network management operation

The following measurements are "half-channel" measurements, and are described using the example of the NE A to NE B direction. For a complete test, these measurements should also be performed in the direction NE B to NE A.

4.1 N-byte transparency test

Synchronization of the TCM frame and exchange of information between the TCM source and TCM sink take place via the N1 or N2 byte in the POH. It must be ensured that no network elements terminate the N1 or N2 byte within a TCM section. The required transparency can be easily checked using the ANT-20 by loading the N byte in the overhead generator of ANT-20 No. 1 with different values and checking them at the end of the section with the overhead analyzer in ANT-20 No. 4 **(Fig. 12).** ANT-20 No. 2 and No. 3 can be used to measure along the path. For this test, the two network elements (NE A and NE B), which later provide the functions of TCM source and TCM sink, must also be set to "transparent".

4.2 TC-APId transparency test

In addition to the path trace for the complete VC-n path, a special path trace known as TC-APId is also defined within the TCM section. This is intended to prevent transmission of user information to the wrong receiver in case of misconnection of the VC-n path within the TCM section. To test this function, NE B is now defined as a TCM sink in order to terminate and evaluate the N1 or N2 byte **(Fig. 13).** Using ANT-20 No. 1, which here assumes the role of the TCM source, a TC-APId is now transmitted which does not correspond to the value expected by the TCM sink. As a result, AU-AIS is inserted into the outgoing signal, which is evaluated by ANT-20 No. 4. It is also possible to check whether the N byte is terminated with the default "00h" using ANT-20 No. 4. In the backwards direction, the anomaly TC-RDI is inserted, which is evaluated by ANT-20 No. 3 and ANT-20 No. 1. ANT-20 No. 2 documents the transmitted TC-APId of ANT-20 No. 1.

4.3 B3 errors within the TCM section

Bit errors that occur within the TCM section are evaluated and documented by the network management system (TMN). If a spare path is configured for the TCM section, network management automatically switches to this path if the bit error rate exceeds a defined value. By inserting B3 errors with ANT-20 No. 1, the operation of the NE can be checked **(Fig. 14).** ANT-20 No. 2 documents the incoming B3 errors, while the two analyzers ANT-20 No. 3 and No. 1 evaluate the anomalies RC-RDI and OEI that are inserted in the backwards direction by NE B. The number of B3 errors transmitted by ANT-20 No. 1 must also be measured by ANT-20 No. 4.

4.4 IEC error simulation

When ANT-20 No. 1 inserts IEC errors, bit errors are simulated as if they had occurred prior to the TCM source and thus outside of the TCM section **(Fig. 15).** NE B detects the incoming IEC errors, terminates the N byte in the outgoing signal and transmits the OEI anomaly in the backwards direction, which can be verified with ANT-20 No. 3 and ANT-20 No. 1. In the outgoing signal from NE B, the same number of B3 errors should be measured as was determined with the IEC on NE B. This is easy to check with ANT-20 No. 4. The evaluation of the bit error rate on NE B by the TMN system must likewise agree with measured value.

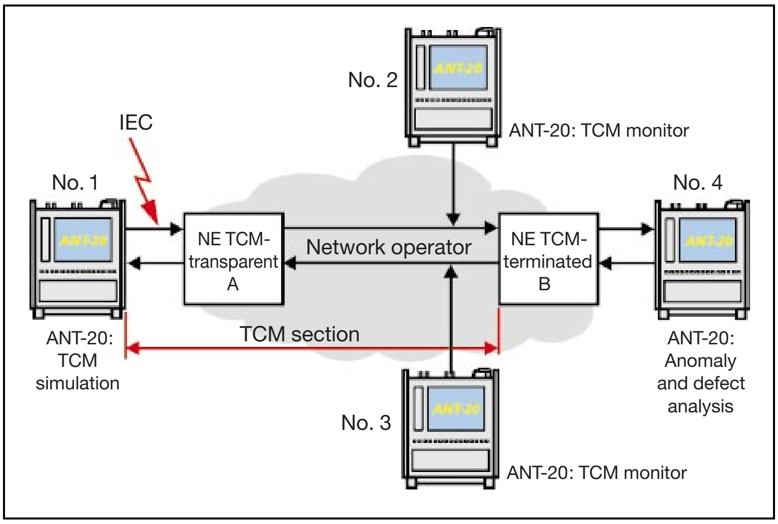


Fig. 15: IEC error simulation

4.5 TC-AIS functional test

If there is an AIS outside of the TCM section on the TCM source, then this information is passed to the TCM sink with the aid of the “incoming AIS” in the IEC. Using ANT-20 No. 1, which is configured as a TCM source here, the incoming AIS is simulated **(Fig. 16).** Within the TCM section, this can be logged using ANT-20 No. 2. At NE B, the N byte is terminated and AU-AIS is inserted into the outgoing signal, which can be measured by ANT-20 No. 4. In the backwards direction, the anomaly ODI is inserted by NE B, which can be detected using ANT-20 No. 3 and ANT-20 No. 4.

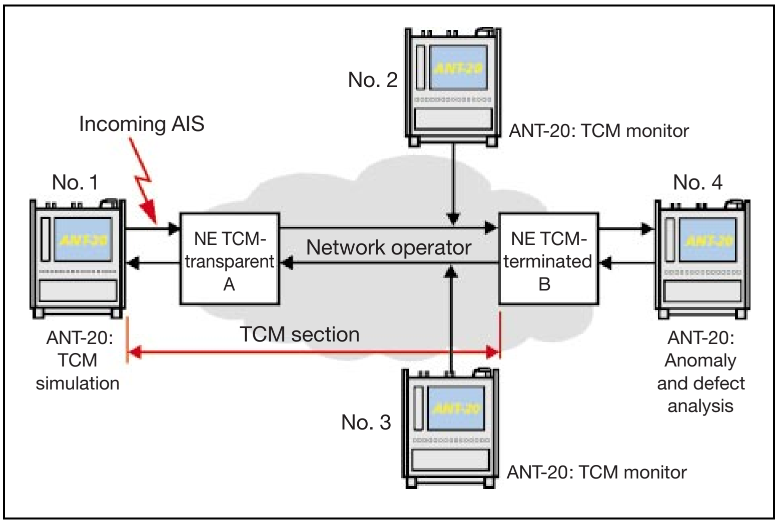


Fig. 16: TC-AIS functional test

4.6 Link test

Once proper operation of the TCM sink has been verified, NE A is now defined as a TCM source **(Fig. 17).** ANT-20 No. 1 now simulates the incoming signal of network operator A. In this test, we check the TCM source for error-free behavior by using ANT-20 No. 1 to insert B3 errors. The inserted TC-APId, the number of B3 errors and the IEC of the TCM source can be verified with ANT-20 No. 2. In the outgoing signal from NE B, the N byte is terminated. The B3 errors measured by ANT-20 No. 4 must agree with the B3 errors transmitted by ANT-20 No. 1 and with the B3 and IEC errors measured by ANT-20 No. 2. In the backwards direction, NE B inserts the anomaly OEI, which can be evaluated using ANT-20 No. 3 in addition to the TC-APId.

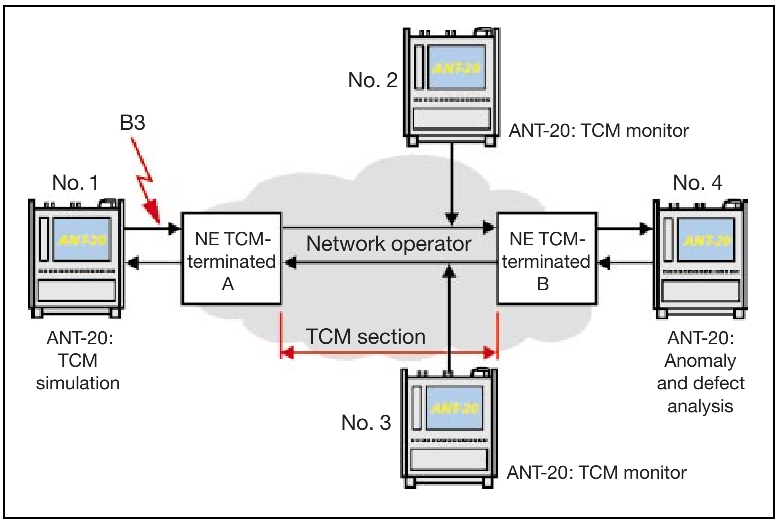


Fig. 17: Link test for checking the TCM source for error-free behavior

5 Technical appendix

5.1 Structure and frame layout of the N1 byte

5.1.1 Structure of the N1 byte

The N1 byte is located in the POH of the VC-3 or VC-4 container in the first column in the last position **(Fig. A1).**

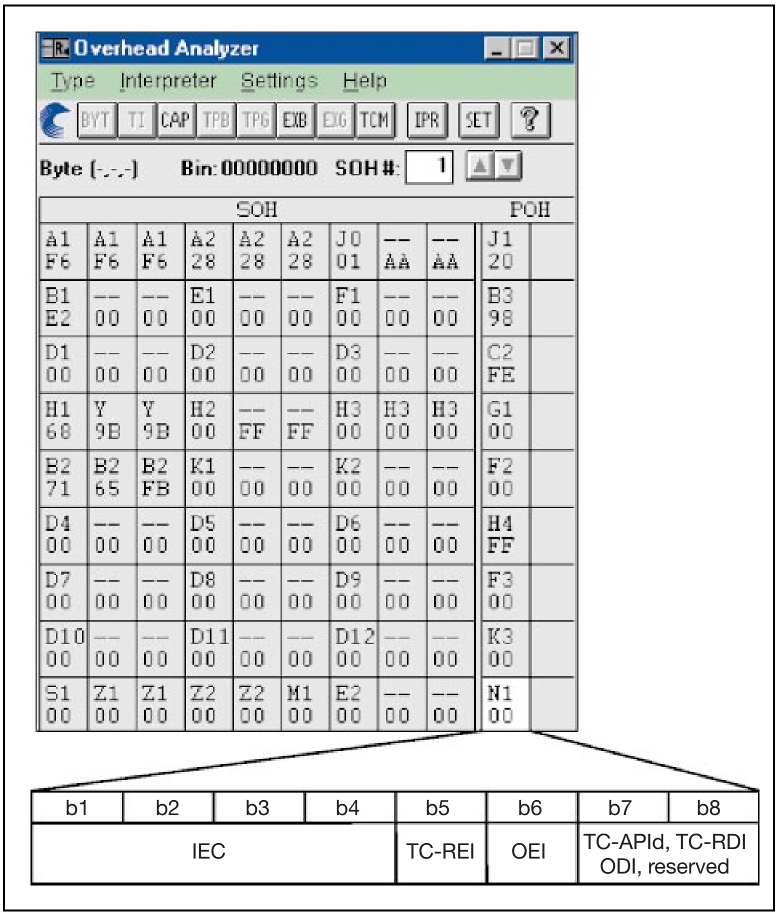


Fig. A1: Structure and position of the N1 byte in the POH

5.1.2 TCM frame layout of the N1 byte

A TCM frame comprises 76 N1 bytes in sequence. Based on the 125 µs frame length of an STM-n signal, we obtain a length of

$$76 \cdot 125\ \mu s = 9.5\ ms$$

for a complete TCM frame **(Fig. A2).**

During the 76-byte frame duration, the 8 bits of the N1 byte perform different functions such as synchronization, CRC7 checking of the frame, alarm handling and transmission of the TCM access point identifier and the B3 errors determined at the start of the TCM section.

Bits 1 to **8** are used in N1 as follows:

- **Bits 1 to 4** are used for the incoming error count (IEC). The difference between the incoming B3 and the computed BIP-8 on the TCM source is transmitted using these four bits to the TCM sink. **Table B1** shows the allocation of BIP-8 errors.
- **Bit 5** is used to transmit the TC-REI in the backwards direction to the TCM source in order to indicate errors that occurred within the TCM section.
- **Bit 6** is used to transmit the OEI from the TCM sink in the backwards direction in order to indicate errors that occurred within and outside of the TCM section to the TCM source.
- **Bits 7** to **8** are used in the 76-byte frame for miscellaneous purposes:
  - Frames 1- 8 are for frame synchronization (frame ID).
  - Frames 9-12 are for transmission of the CRC7 checksum of the tandem connection access point identifier (TC-APId).
  - Frames 13-72 (60 frames) are for transmission of the 15 ASCII characters of the TC-APId. Note that in each case four frames (8 bits) are required per ASCII character.
  - Frame 73 is used to transmit the TC-RDI in the backwards direction from the TCM sink to the TCM source in order to indicate defects that occurred within the TCM link to the TCM source.
  - In frame 74 in the backwards direction, the anomaly ODI is indicated to the TCM source if AU/TU-AIS is transmitted as an outgoing signal due to a defect within or outside of the TCM section.
  - Frames 75 and 76 are reserved for future uses.

Number of BIP violations	Bit 1	Bit 2	Bit 3	Bit 4
0	1	0	0	1
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
Incoming AIS	1	1	1	0

Table B1: IEC coding

Frame No.	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Function Bit 7/8
1	IEC	IEC	IEC	IEC	TC-REI	OEI	1	1	FAS
2	IEC	IEC	IEC	IEC	TC-REI	OEI	1	1	
3	IEC	IEC	IEC	IEC	TC-REI	OEI	1	1	
4	IEC	IEC	IEC	IEC	TC-REI	OEI	1	1	
5	IEC	IEC	IEC	IEC	TC-REI	OEI	1	1	
6	IEC	IEC	IEC	IEC	TC-REI	OEI	1	1	
7	IEC	IEC	IEC	IEC	TC-REI	OEI	1	1	
8	IEC	IEC	IEC	IEC	TC-REI	OEI	1	0	
9	IEC	IEC	IEC	IEC	TC-REI	OEI	1	C1	CRC7
10	IEC	IEC	IEC	IEC	TC-REI	OEI	C2	C3	
11	IEC	IEC	IEC	IEC	TC-REI	OEI	C4	C5	
12	IEC	IEC	IEC	IEC	TC-REI	OEI	C6	C7	
13	IEC	IEC	IEC	IEC	TC-REI	OEI	0	X	TC-APId-Byte 1
14	IEC	IEC	IEC	IEC	TC-REI	OEI	X	X	
15	IEC	IEC	IEC	IEC	TC-REI	OEI	X	X	
16	IEC	IEC	IEC	IEC	TC-REI	OEI	X	X	
17	IEC	IEC	IEC	IEC	TC-REI	OEI	0	X	TC-APId-Byte 2
18	IEC	IEC	IEC	IEC	TC-REI	OEI	X	X	
19	IEC	IEC	IEC	IEC	TC-REI	OEI	X	X	
20	IEC	IEC	IEC	IEC	TC-REI	OEI	X	X	
21–68	IEC	IEC	IEC	IEC	TC-REI	OEI			TC-APId-Byte 3–14
69	IEC	IEC	IEC	IEC	TC-REI	OEI	0	X	TC-APId-Byte 15
70	IEC	IEC	IEC	IEC	TC-REI	OEI	X	X	
71	IEC	IEC	IEC	IEC	TC-REI	OEI	X	X	
72	IEC	IEC	IEC	IEC	TC-REI	OEI	X	X	
73	IEC	IEC	IEC	IEC	TC-REI	OEI	Reserved	TX-RDI	
74	IEC	IEC	IEC	IEC	TC-REI	OEI	ODI	Reserved	
75	IEC	IEC	IEC	IEC	TC-REI	OEI	Reserved	Reserved	
76	IEC	IEC	IEC	IEC	TC-REI	OEI	Reserved	Reserved	

Fig. 2A: Frame layout of the N1 byte

5.1.3 Condition for TCM-unequipped

To allow easy identification of a TCM path, the value of the N1 byte must never equal “00h”. Outside of the TCM section, the default value of the N1 byte is “00h”. To prevent the N1 byte from assuming a value of “00h” within the TCM section, it is necessary to have at least one “1” in the IEC field (bits 1 to 4). This is ensured by representing the value for no BIP-8 violations in the IEC using two “1”s.
However, if the N1 byte does assume a value of “00h” within the TCM section, this indicates an interruption or misconnection of the VC-n container within the TCM section. In this case, an AU/TU-AIS is inserted by the TCM sink in the outgoing AU-n/TU-n and the anomalies TCM-RDI and ODI are inserted in the backwards direction to the TCM source.

5.1.4 Graphical illustration of the relationships within the N1 byte

Fig. A3 gives a quick and easy overview of the relationships within the N1 byte on the TCM source or the TCM sink.

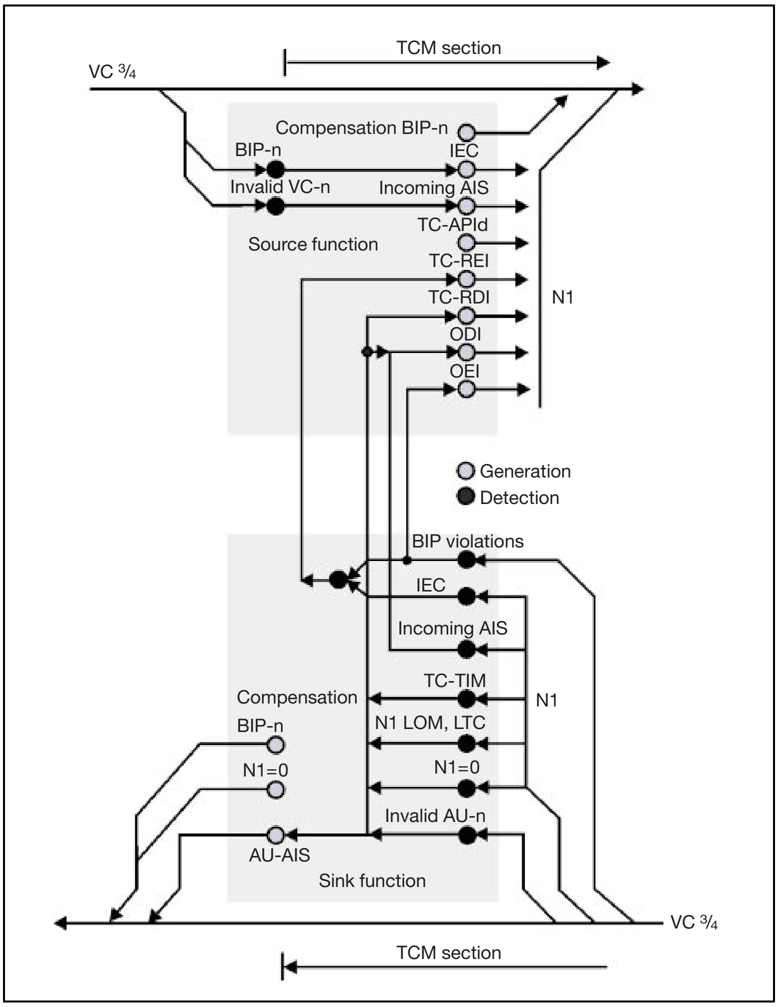


Fig. A3: Graphical illustration of events in the N1 byte

5.2 N2 byte: Structure and frame layout

5.2.1 Structure of the N2 byte

In the POH of the VC-2, VC-11 or VC-12, the N2 byte is located after the V5 and J2 byte at the 3rd position **(Fig. A4).**

Whereas with the N1 byte the number of B3 errors that occurred at the start of the TCM link section is encoded using the IEC and transmitted to the TCM sink, another technique is used for transmission in the N2 byte.

Since with the C-11, C-12 and C-2 containers, the parity check is performed in the V5 byte using a BIP-2 value and there is room in the N2 byte for a BIP-2 value, the computed BIP-2 value is used instead of the encoded number of parity errors at the start of the TCM section and is transmitted to the TCM sink.

5.2.2 Multiframe of the VC-11, VC-12 and VC-2

Given 8000 frames per second for an STM-1 signal and an 8-bit byte, we obtain a rate of 64 kbit/s for each byte in the STM-1 signal. Due to the multiframe structure **(Fig. A5)** for VC-2, VC-11 and VC-12 in which the bytes V5, J2, N2 and K4 are transmitted only in every 4th STM-1 frame, the speed is reduced by a factor of 4, i.e. to 16 kbit/s. The frame length is quadrupled, yielding a frame duration of $4 \cdot 125\ \mu s = 500\ \mu s$. As with the N1 byte, the TCM frame for the N2 byte also comprises 76 successive N2 bytes. The resulting TCM frame duration of the N2 byte is thus computed as follows:
$76 \cdot 500\ \mu s = 38\ ms$.

Unlike the TCM frame for the N1 byte, the duration of the TCM frame for the N2 byte is four times as long.

Fig. A4: Structure and position of the N2 byte in the POH Pointer

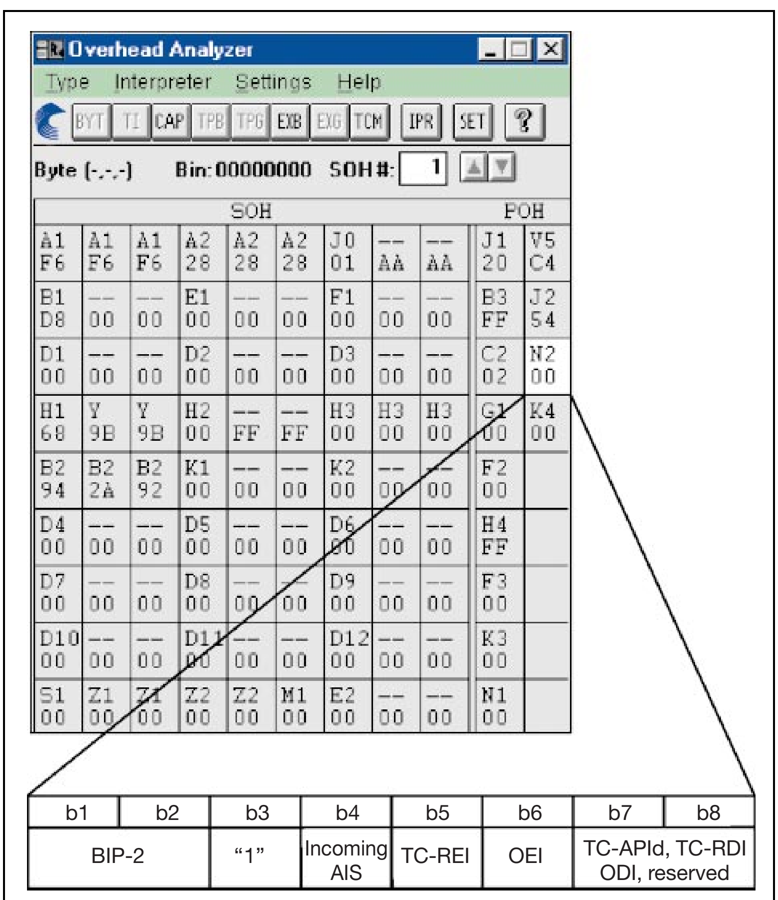
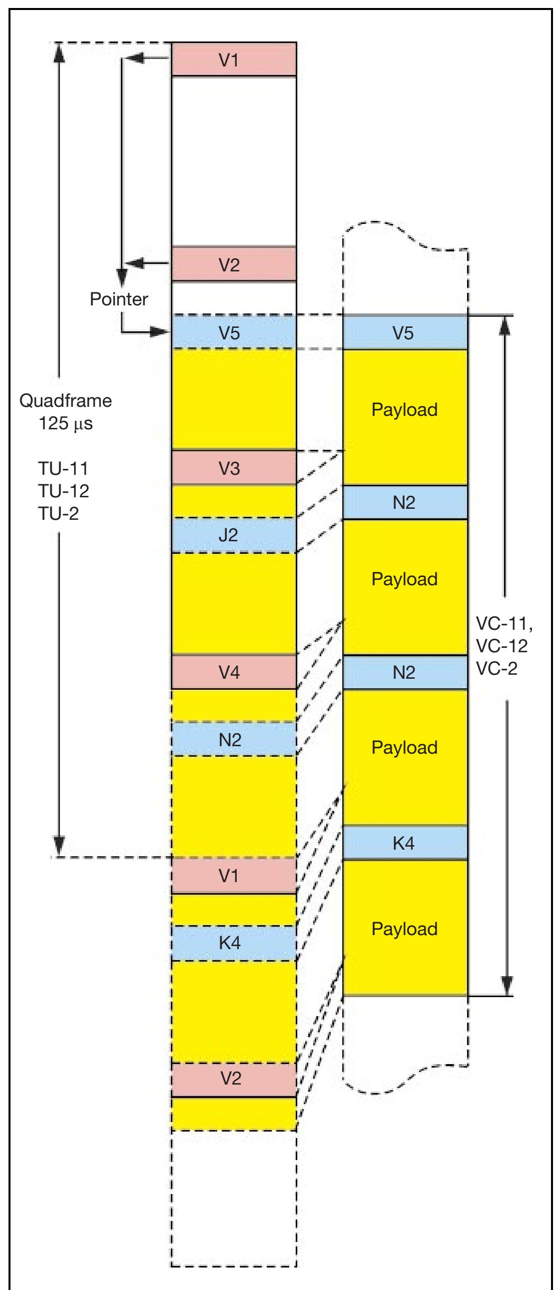


Fig. A5: VC-11, VC-12, VC-2 multiframe



5.2.3 TCM frame layout of the N2 byte

The usage of bits 1 to 8 in the N2 byte can be easily illustrated in the TCM frame of the N2 byte **(Fig. A6).**

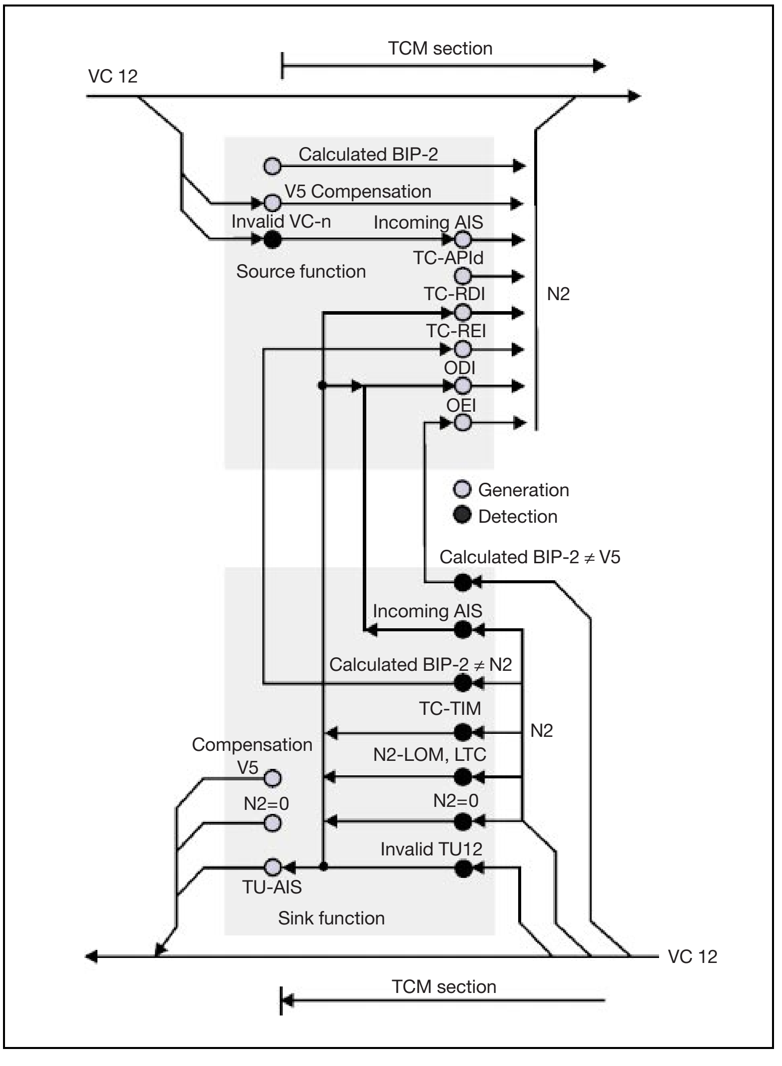
- Bits 1 and 2 are used to transmit the computed BIP-2 value to the TCM sink.
- Bit 3 is fixed to “1” so that the value of the N2 byte within the TCM section can never assume a value of “00h” (see section 5.1.3 “Condition for TCM-unequipped”).
- Bit 4 is used to inform the TCM sink of an AIS signal present on the TCM source.
- Bit 5 is used to transmit the TC-REI in the backwards direction to the TCM source to indicate errors that occurred within the TCM section.
- Bit 6 is used to transmit the OEI from the TCM sink in the backwards direction to indicate errors that occurred within and outside of the TCM section to the TCM source.
- Bits 7 to 8 are used in the 76-byte frame for miscellaneous purposes:
  - Frames 1–8 are for frame synchronization (frame ID).
  - Frames 9–12 are for transmission of the CRC7 checksum of the tandem connection access point identifier (TC-APId).
  - Frames 13–72 (60 frames) are for transmission of the 15 ASCII characters of the TC-APId. Note that in each case four frames (8 bits) are required per ASCII character.
  - Frame 73 is used to transmit the TC-RDI in the backwards direction from the TCM sink to the TCM source in order to indicate defects that occurred within the TCM link to the TCM source.
  - In frame 74 in the backwards direction, the anomaly ODI is indicated to the TCM source if AU/TU-AIS is transmitted as an outgoing signal due to a defect within or outside of the TCM section.
  - Frames 75 and 76 are reserved for future uses.

Frame No.	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Function Bit 7/8
1	BIP-2		1	inc. AIS	TC-REI	OEI	1	1	FAS
2	BIP-2		1	inc. AIS	TC-REI	OEI	1	1	
3	BIP-2		1	inc. AIS	TC-REI	OEI	1	1	
4	BIP-2		1	inc. AIS	TC-REI	OEI	1	1	
5	BIP-2		1	inc. AIS	TC-REI	OEI	1	1	
6	BIP-2		1	inc. AIS	TC-REI	OEI	1	1	
7	BIP-2		1	inc. AIS	TC-REI	OEI	1	1	
8	BIP-2		1	inc. AIS	TC-REI	OEI	1	0	
9	BIP-2		1	inc. AIS	TC-REI	OEI	1	C1	CRC7
10	BIP-2		1	inc. AIS	TC-REI	OEI	C2	C3	
11	BIP-2		1	inc. AIS	TC-REI	OEI	C4	C5	
12	BIP-2		1	inc. AIS	TC-REI	OEI	C6	C7	
13	BIP-2		1	inc. AIS	TC-REI	OEI	0	X	TC-APId-Byte 1
14	BIP-2		1	inc. AIS	TC-REI	OEI	X	X	
15	BIP-2		1	inc. AIS	TC-REI	OEI	X	X	
16	BIP-2		1	inc. AIS	TC-REI	OEI	X	X	
17	BIP-2		1	inc. AIS	TC-REI	OEI	0	X	TC-APId-Byte 2
18	BIP-2		1	inc. AIS	TC-REI	OEI	X	X	
19	BIP-2		1	inc. AIS	TC-REI	OEI	X	X	
20	BIP-2		1	inc. AIS	TC-REI	OEI	X	X	
21–68	BIP-2		1	inc. AIS	TC-REI	OEI			TC-APId-Byte 3–14
69	BIP-2		1	inc. AIS	TC-REI	OEI	0	X	TC-APId-Byte 15
70	BIP-2		1	inc. AIS	TC-REI	OEI	X	X	
71	BIP-2		1	inc. AIS	TC-REI	OEI	X	X	
72	BIP-2		1	inc. AIS	TC-REI	OEI	X	X	
73	BIP-2		1	inc. AIS	TC-REI	OEI	Reserved	TX-RDI	
74	BIP-2		1	inc. AIS	TC-REI	OEI	ODI	Reserved	
75	BIP-2		1	inc. AIS	TC-REI	OEI	Reserved	Reserved	
76	BIP-2		1	inc. AIS	TC-REI	OEI	Reserved	Reserved	

Fig. A6: Frame layout of the N2 byte

5.2.4 Graphical illustration of the relationships within the N2 byte

Fig. A7 provides a quick and easy overview of the relationships within the N2 byte on the TCM source or the TCM sink.



5.3 B3 or V5 compensation

Generation of the BIP-8 value is based on the entire content of the VC-3 or VC-4 container and thus also on the associated POH, which contains the N1 byte. Since the value of the N1 byte on the TCM source is changed from the default value of “00h” (or changed to the default value of “00h” on the TCM sink), it is necessary to subsequently compensate the BIP-8 value of the B3 byte in the outgoing signal. Here, the BIP-8 value is compensated for the altered value of the N1 byte. This is necessary to prevent imaginary errors from being detected during BIP-8 evaluation on the following network element due to an incorrect BIP-8 value. It is also ensured that quality assessment based on the B3 byte remains possible over the entire VC-3/VC-4 path. Since the value in the N2 byte of the VC-11, VC-12 and VC-2 containers was likewise changed on the TCM source and TCM sink, compensation of the BIP-2 value in the V5 byte of the outgoing signal is likewise necessary, as with the B3 byte.

Fig. A7: Graphical illustration of the relationships within the N2 byte

Standards

G.707: Basic Recommendation on SDH;
Annex D: Byte structure and frame layout for the VC-4 and VC-3 containers
Annex E: Byte structure and frame layout for the VC-2, VC-11 and VC-12 containers

G.783: Functional definition for the construction of
– Network elements
– TCM frame layout
– BIP generation and comparison
– BIP compensation

ETSI EN 300 417-4-1:
Basic operation of TCM

Abbreviations

AIS: Alarm Indication Signal
ANT: Advanced Network Testing
BIP-n : Bit Interleaved Parity
CRC: Cyclic Redundancy Check
HP: Higher Path
HP- REI: Higher Path Remote Error Indication
IEC: Incoming Error Counter
LOM: Loss of Multiframe
LP: Lower Path
LP-REI: Lower Path Remote Error Indication
LTC: Loss of Tandem Connection
MUX: Multiplexer
MSOH: Multiplex Section Overhead
NE: Network Element
ODI: Outgoing Defect Indication
OEI: Outgoing Error Indication
POH: Path Overhead
RSOH: Regenerator Section Overhead
SOH: Section Overhead
TC-APId: Tandem Connection Access Point Identifier
TC-RDI: Tandem Connection Remote Defect Indication
TC-REI: Tandem Connection Remote Error Indication
TC-TIM: Tandem Connection Trace Identifier Mismatch
TCM: Tandem Connection Monitoring
TMN: Network Management System
VC-n: Virtual Container

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