Course 13 SDH/SONET multiplexing strategy

Elements of the SDH/SONET multiplex

- Container C – represents a bloc structure with imposed dimensions which contains data belonging to a tributary and doesn't contain any control or management information.
- There are containers with different dimensions adapted to the data generated by different PDH tributaries. The containers transport capacity is chosen larger than the rate of the corresponding PDH tributaries → an appropriate positive justification is used to manage the rate deviation of the PDH signals from the nominal value.
- Containers characteristics to the SDH system:

- C4 – 149,76Mbps binary rate;
- C3 – 48,384Mbps binary rate;
- C2 – 6,784Mbps binary rate;
- C12 – 2,176Mbps binary rate;
- C11 – 1,6Mbps binary rate;

- Virtual container VC – represents the container extended with a „Path Overhead” (POH)
  - POH is used to control and monitor the transmission of information of the container on the entire path between the source and the destination; it is used also to identify the content of the container; POH is not modified during the transmission.
  - Superior order containers (C3 and C4) have the POH composed of a column of 9 bytes.
  - Inferior order containers (C11, C12 and C2) have the POH composed of 4 bytes distributed over 4 successive containers, one container including just a single POH byte.

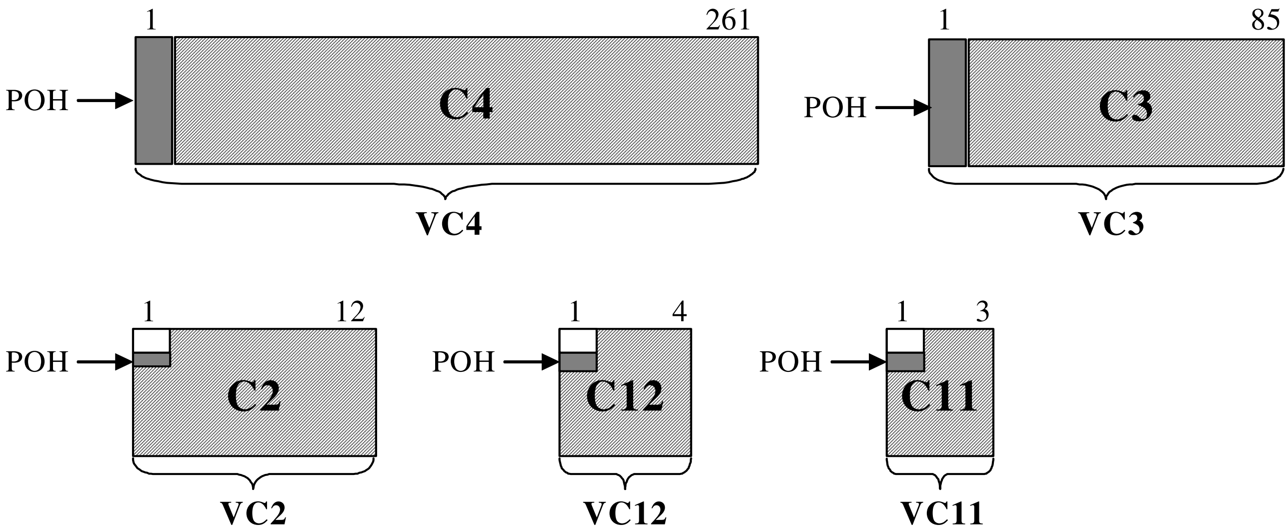

Fig. 1 Structure of the containers and virtual containers used in the SDH transmission – multiplexing system

o Administrative units AU – these units are obtained from the VC-3 and VC-4 virtual containers by adding to these structures of pointers which establish the relation between the STM-1 reference point and the beginning of the VC-3 and VC-4 virtual containers.

- The AU3 pointer is composed of 3 bytes, and the AU4 pointer is composed of 9 bytes, from which are used only 5 bytes (2 pointer bytes + 3 negative justification bytes).
- The payload of the STM-1 frame consists of one AU4 unit or three AU3 units.

o Tributary units TU (Tributary Unit) – these units are composed of VC11, VC12, VC2 and VC3 virtual containers plus a pointer.

- In the TU11, TU12 and TU2 units is place only for one pointer byte, but there are necessary 4 bytes for pointer operations → the solution is the distribution of the pointer bytes on 4 TU units.
- In the TU3 unit obtained from a VC3 container is used a 3 bytes pointer.

TU type	Structure	Global rate
TU11	9 lines, 3 columns	1,728Mbps
TU12	9 lines, 4 columns	2,304Mbps
TU2	9 lines, 12 columns	6,912Mbps
TU3	9 lines, 86 columns	49,535Mbps

Tab. 1 Parameters of the tributary units of the SDH transmission – multiplexing system

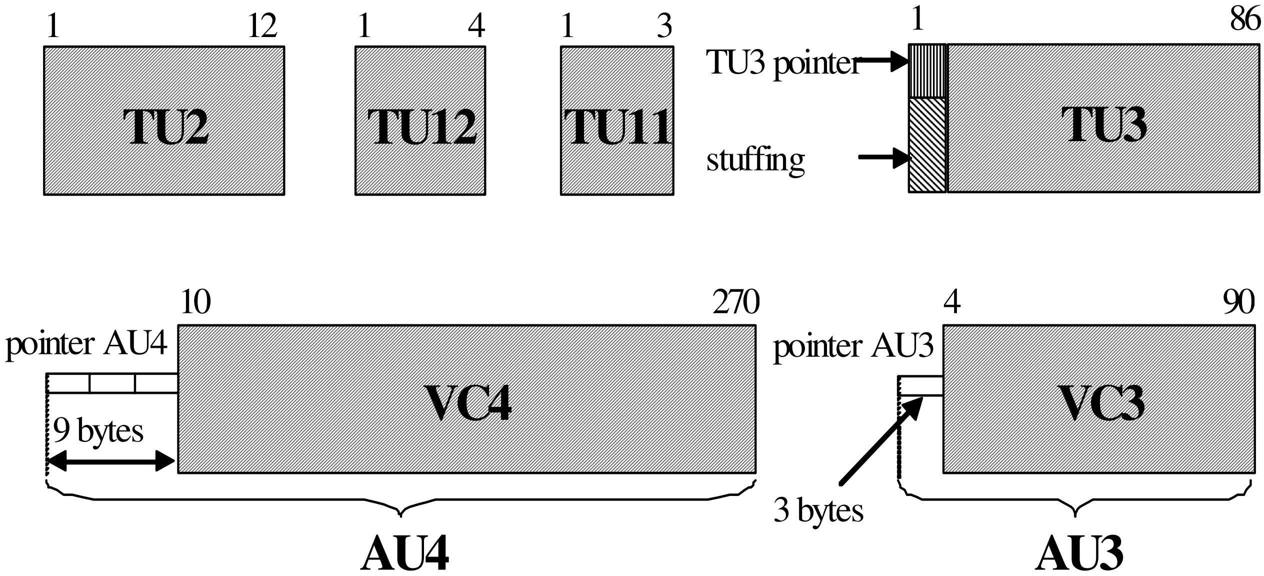

Fig. 2 Structure of the administrative units and of the tributary units used in the SDH transmission – multiplexing system

- Tributary Unit Group TUG – tributary units are multiplexed in tributary unit groups.
  - These units represent a grouping of signals structured in frames with 125µs period and having identical phase (position).
  - The generation of the TUG units is done by a simple column by column multiplexing of the TU units, without and phase (position) adjustment.
  - There are two types of TUG units:
    - TUG2 – includes a TU2 unit or 3 TU12 units or 4 TU11 units.
    - TUG3 – includes one TU3 units.
- Administrative Unit Group AUG – is composed of one AU4 unit or three multiplexed AU3 units. Represents a structure composed of 261 columns, 9 rows plus 9 pointer bytes in the fourth row.

Note: the described matrix structures are generated only in multiplexers, the transmission on the line being a serial one.

Bloc structures used in the case of the SONET system

- SPE - SONET Payload Envelope – composed of "payload", a matrix structure with the following dimensions: 9 lines × 86 columns and a POH composed of one column with 9 lines – it is a structure equivalent with the VC3 virtual container of the SDH system.
  - The "payload" capacity is 49,536 Mbps, and the capacity of the entire SPE container is 50,112 Mbps.
- Virtual Tributary VT – these units are similar with the TU units of the SDH system. There are 4 such units:

VT type	Structure	Rate
VT1.5	9 lines, 3 columns	1,728Mbps
VT2	9 lines, 4 columns	2,304Mbps
VT3	9 lines, 6 columns	3,456Mbps
VT6	9 lines, 12 columns	6,912Mbps

Tab. 2 Parameters of the tributary units of the SONET transmission - multiplexing system

- VT units have (like the TU units of the SDH system) a POH on 4 bytes and a pointer also on 4 bytes.
- POH and the pointer are distributed on 4 consecutive VT units.
- Virtual Tributary Group VTG – matrix structure composed of 9 lines and 12 columns which can include 4 VT1.5 units, 3 VT2 units, 2 VT3 units and 1 VT6 unit.

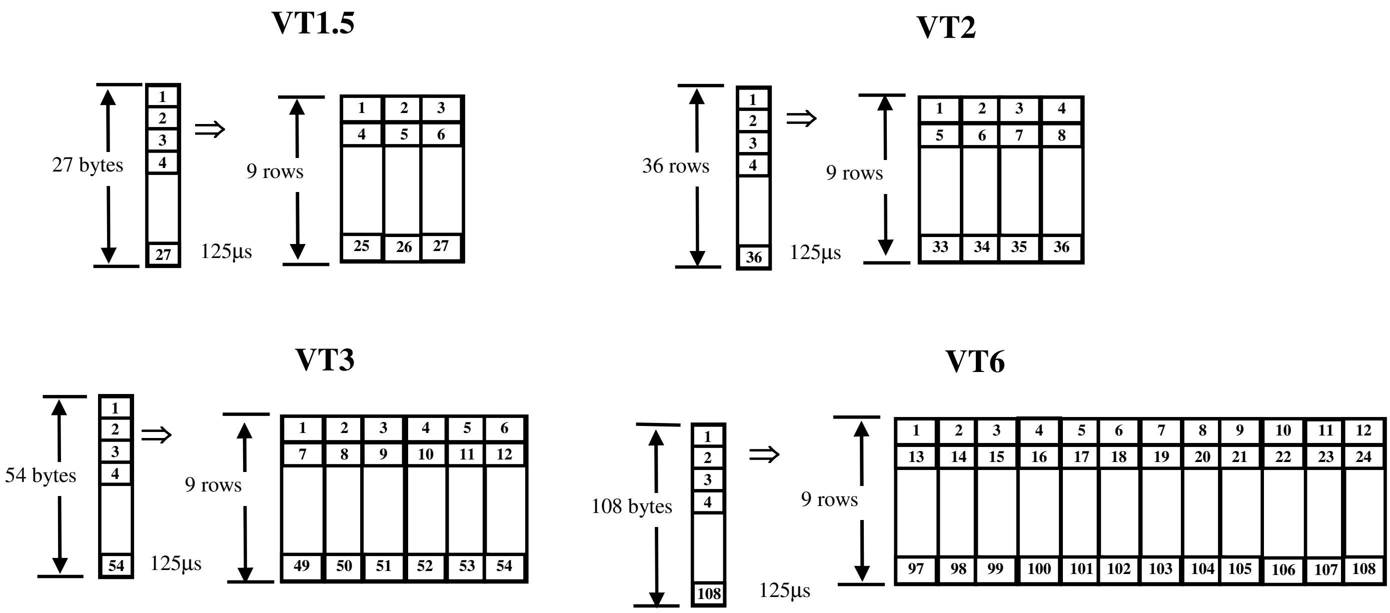

Fig. 3 Structure of the tributary units used in the SONET system

SDH/SONET synchronous multiplexing scheme

- Synchronous multiplexing implies in general the following operations:

• assembling of the PDH data flows or flows generated by other sources in the appropriate containers;

• generation of the virtual containers by attaching the POH („ Path Overhead");

• assembling of the tributary units by attaching the pointers and inserting the containers at the appropriate positions in these units;

• generation of the administrative units similarly to the tributary units;

• generation of the transport frames and finally multiplexing several basic transport frames in a superior order transport frame;

Multiplexing in the SDH system

- SDH multiplexing scheme for plesiochronous data flows

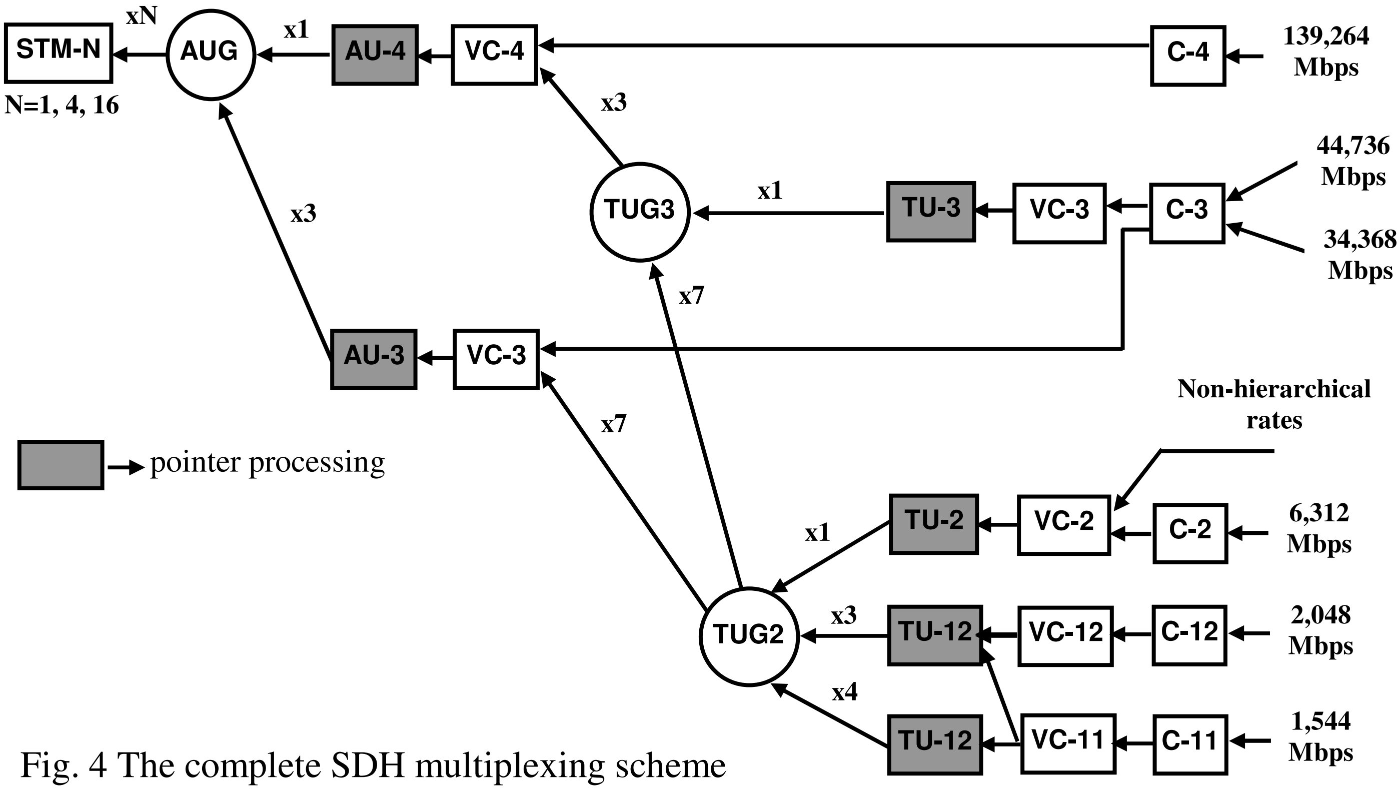

Fig. 4 The complete SDH multiplexing scheme

- Multiplexing of the C4 container in the STM-N frame.

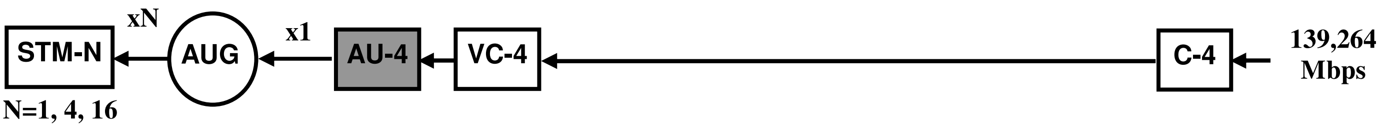

Fig. 5 Multiplexing of the C4 container in the STM-N frame

- The operations done in these case are the following: the plesiochronous tributary with 139,264Mbps rate is assembled into a C4 container → VC4 is generated by adding the POH → the AU pointer is added to the VC4 and it is obtained the AU4 unit → the AU4 administrative unit is converted in an AUG structure → AUG is inserted in a STM-1 frame.

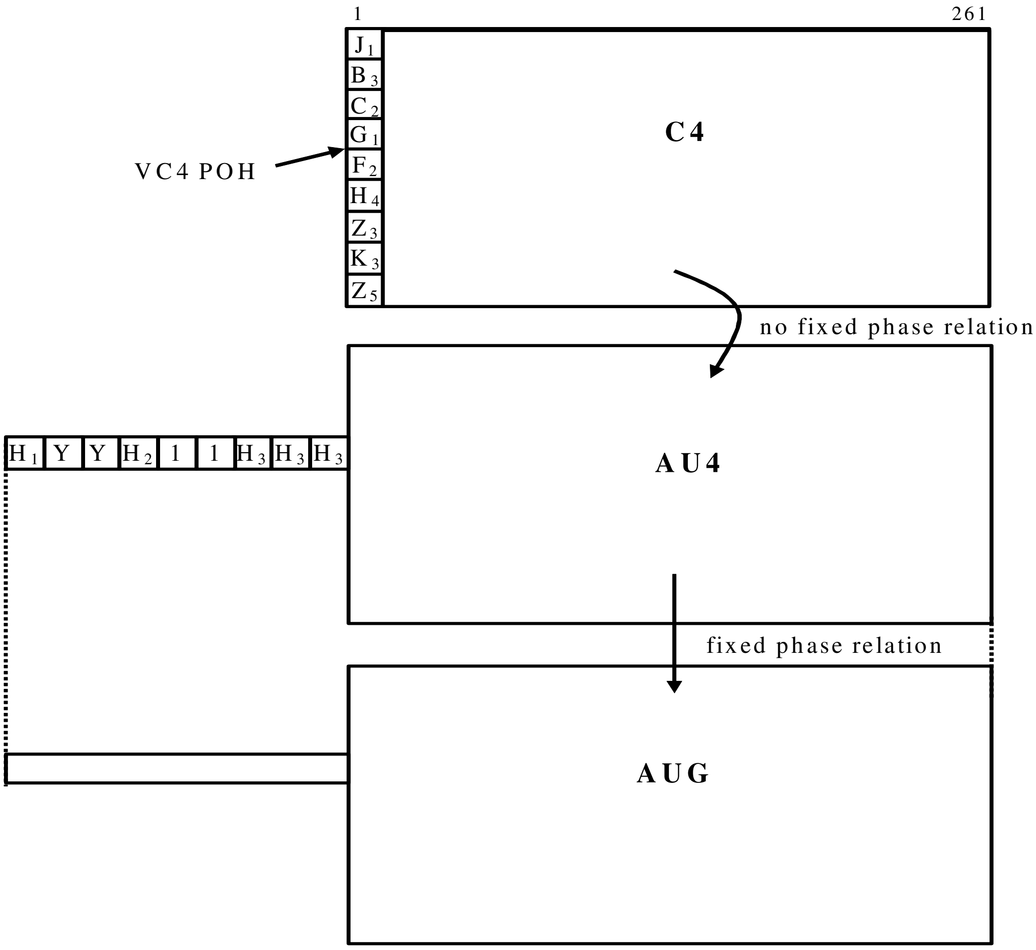

Fig. 6 Multiplexing of a C4 container in an AUG unit. Phase adjustment related to the use of the AUG pointer

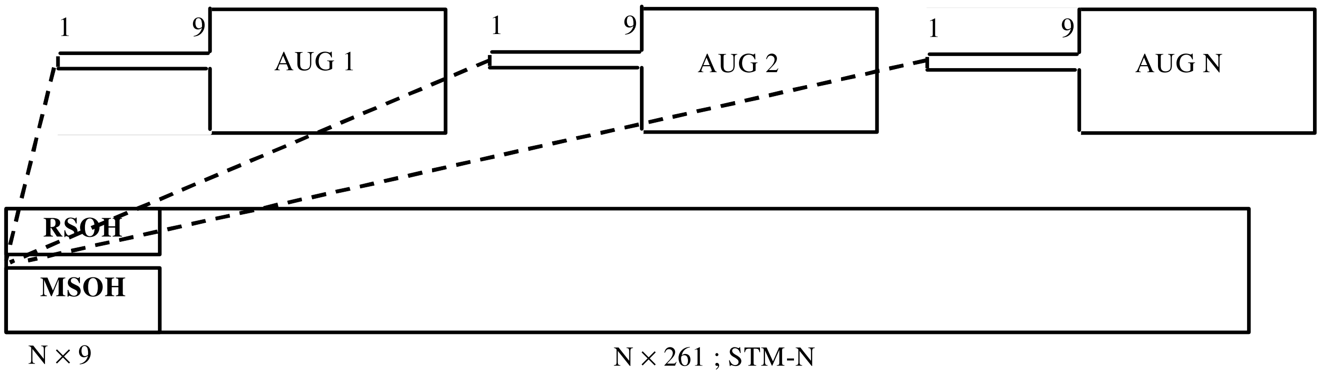

Fig. 7 Multiplexing of AUG unit in a STM-N transport frame

o Direct multiplexing of the C3 container in a STM-N frame

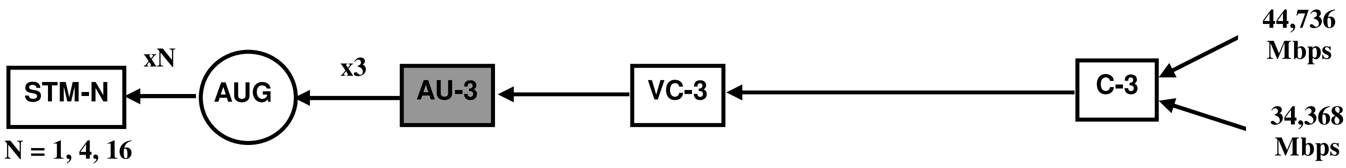

Fig. 8 Multiplexing of the C3 container in the STM-N frame

- The VC3 container is transformed in the AU3 units by adding the AU3 pointer composed of 3 bytes, pointer which establishes the position (the phase) of each VC3 container in the STM-1 frame.
- AU3 units have the same fixed phase relatively to the beginning of the STM-1 frame.
- The AUG structure is obtained by multiplexing three AU3 unit byte by byte.
- The generated AUG can be mapped directly in a STM-1 frame, or can be multiplexed N AUG units byte by byte in a STM-N frame, being non-important if the AUG includes AU3 or AU4 units.

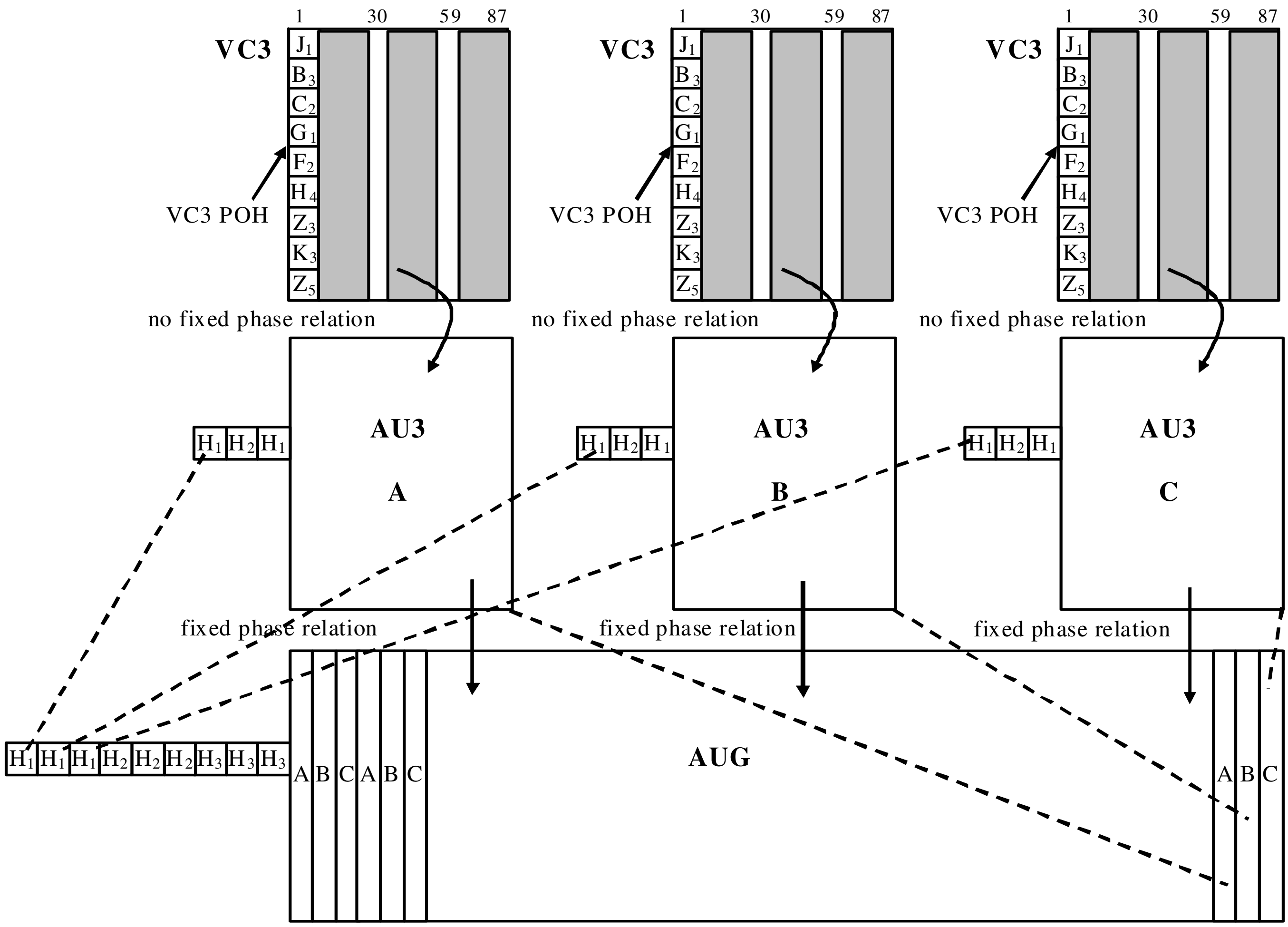

Fig. 9 Details related to the multiplexing of the C3 containers in AUG units

o Indirect multiplexing of the C3 container in the STM-N frame

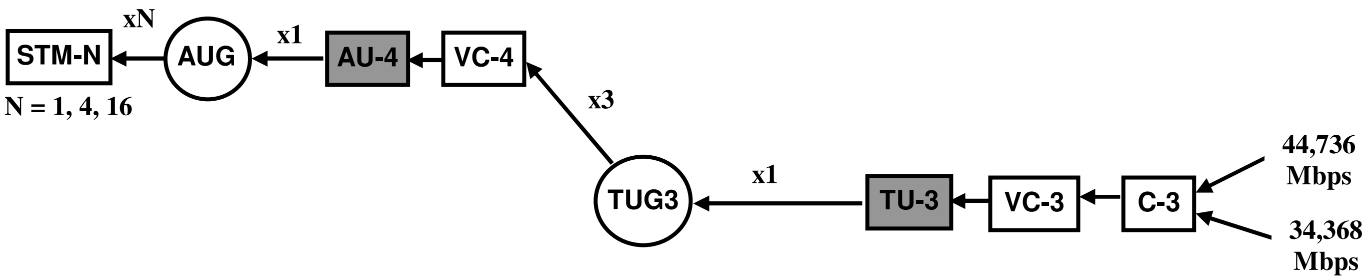

Fig. 10 Indirect multiplexing of the C3 container in the STM-N frame

- The 34,368Mbps signal (or 44.736Mbps) is assembled into the C3 container → the VC3 virtual container (composed of 9 lines and 85 columns) is generated by adding the POH → adding a pointer to the VC3 the TU3 tributary unit is generated (86 de columns and 9 lines) → the TU3 tributary unit generates TUG3 units (TUG3 is practically identical with TU3) and 3 TUG3 units can be multiplexed in a C4 container → the VC4 virtual container is generated by adding the POH → VC-4 is inserted in a STM-1 frame or STM-N frame.

- three TUG3 units are multiplexed in a C4 container byte by byte, TUG3 having a fixed position relatively to the VC4 container.

- the position of the VC3 container in the TUG3 unit is established by the TU3 pointer composed of 3 bytes.

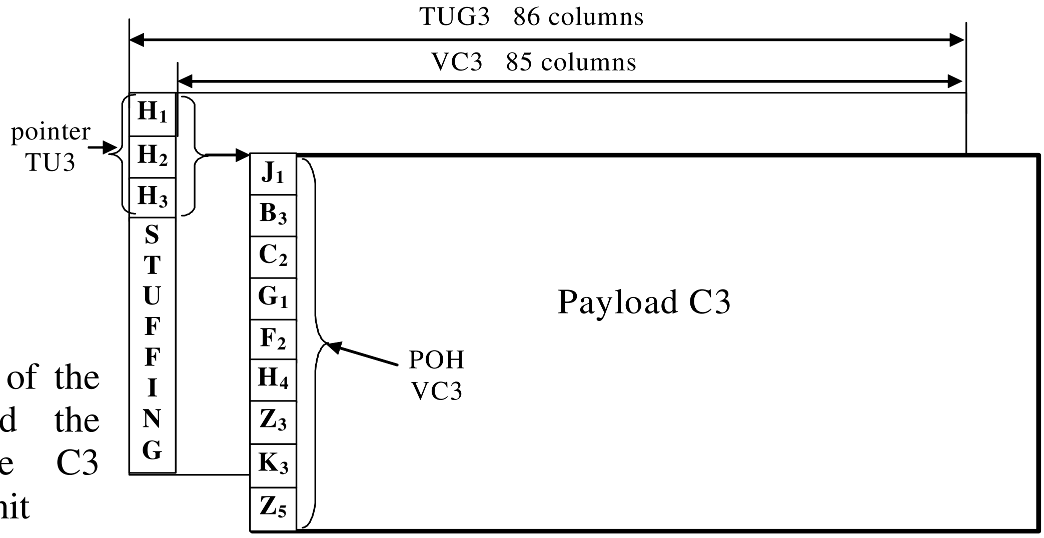

Fig. 11 Structure of the TUG3 units and the insertion of the C3 container in this unit

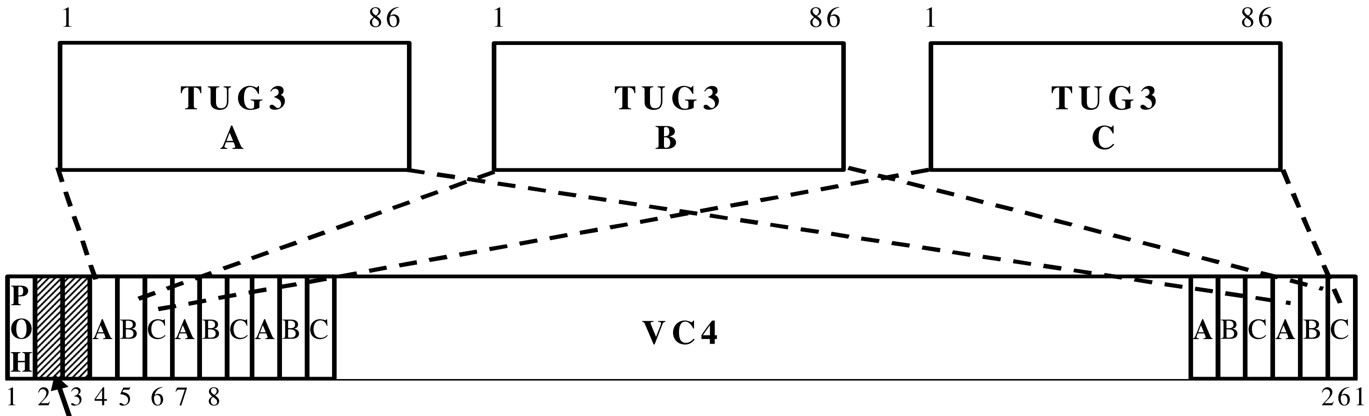

Fig. 12 Multiplexing of the TUG3 units in a VC4 container

o Multiplexing of the C11, C12 and C2 containers into the TUG2 units.

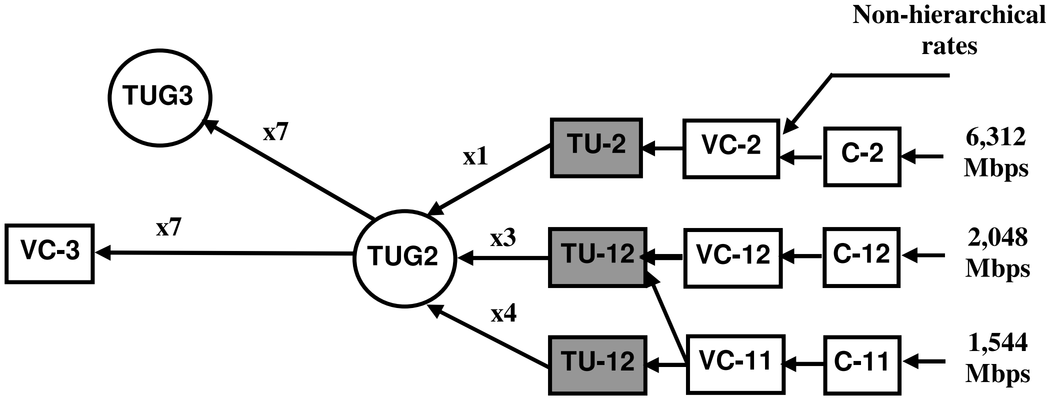

Fig. 13 Multiplexing of the C11, C12 and C2 containers into the TUG2 unit

- According of the bit rate, the signals are assembled in containers with different dimensions → virtual containers are generated by adding the POH → TU11, TU12 and TU2 units are generated by adding the POH and the pointer (POH and the pointer are distributed on 4 TU units, each having only one POH and pointer byte) → TU11, TU12 and TU2 units are multiplexed in a TUG2 unit columns by columns – there is a fixed relation between the TUG2 unit and the TU units multiplexed into TUG2.

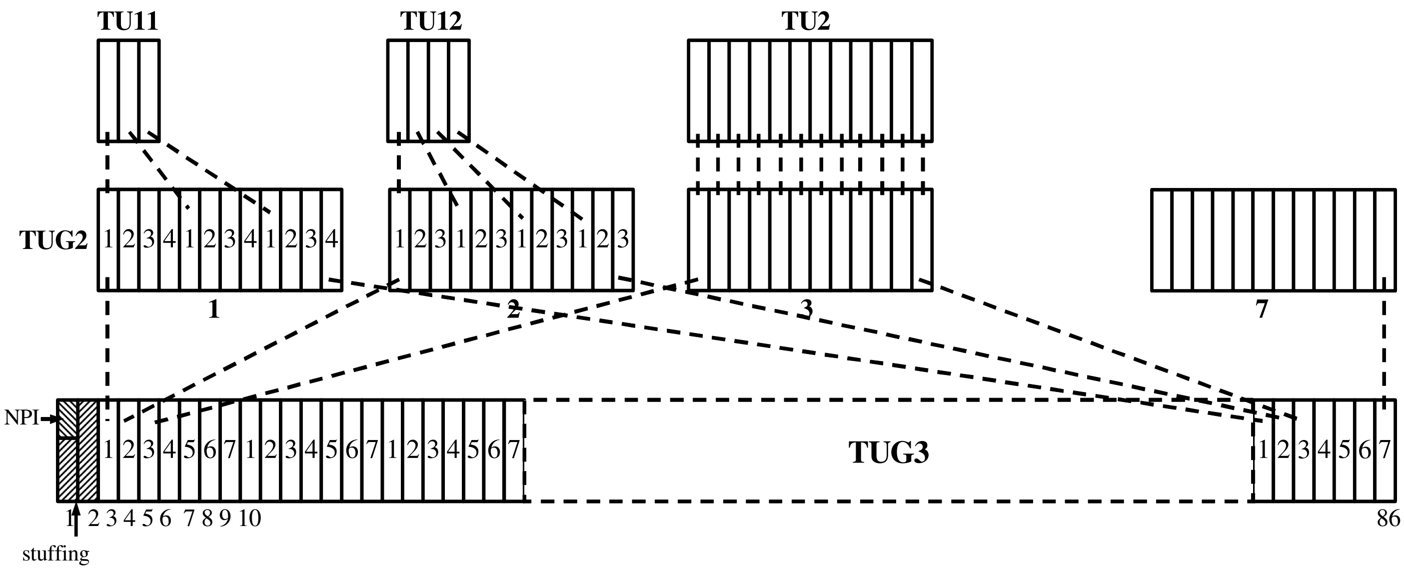

Fig. 14 Multiplexing of the TU tributary units into the tributary group unit TUG2 and after that into the TUG3 unit

o Multiplexing of the TUG2 tributary units into TUG3 tributary unit groups (fig. 14).

- A TUG3 unit can be generated by multiplexing 7 TUG2 units byte by byte.

- In the first column of the TUG3 unit there are reserved positions for the VC3 pointer – due to the fact that it is a fixed phase relation between the TUG2 and the TUG3 unit it is not necessary a pointer; the positions for the pointer are occupied by a null pointer indicator (NPI – Null Pointer Indicator).

o Multiplexing of the TUG2 tributary unit groups into VC3 containers (fig. 15).

- A VC3 virtual container is generated by multiplexing 7 TUG2 units byte by byte; the multiplexing of the TUG2 units is made in the columns 2 – 85, column 1 being occupied by the VC3 POH.

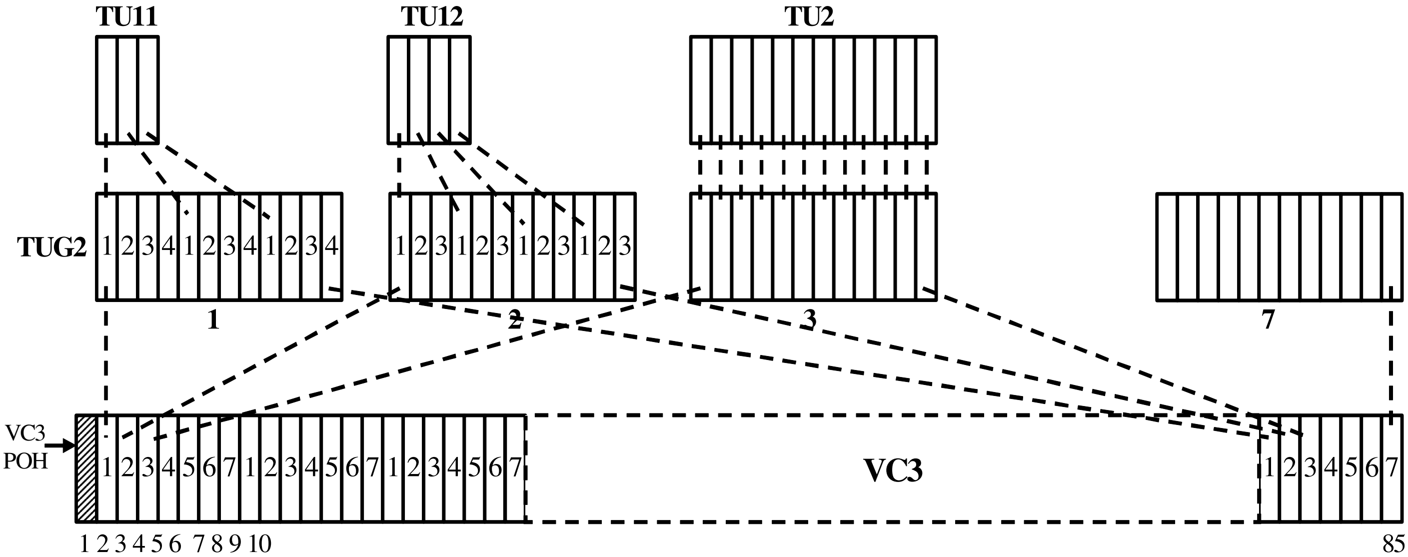

Fig. 15 Multiplexing of the TU tributary units into TUG2 tributary unit group and after that into a C3 container

EXEMPLES

1. multiplexing of a 140Mbps flow into a STM-1 frame.

2. multiplexing of several 2,048Mbps flows into a STM-1 frame.

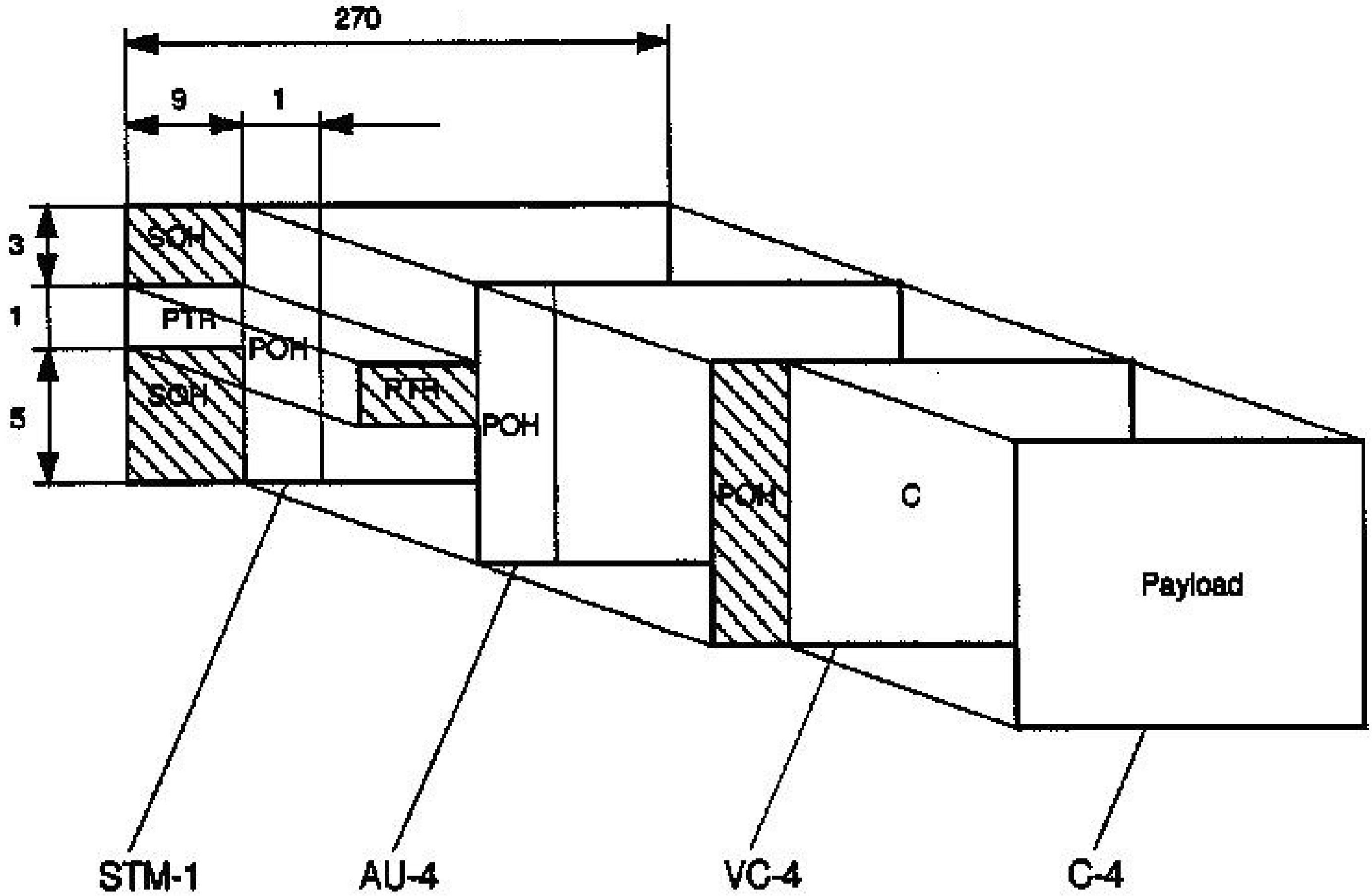

Fig. 16 Multiplexing of a 140Mbps PDH signal into a STM-1 transport frame

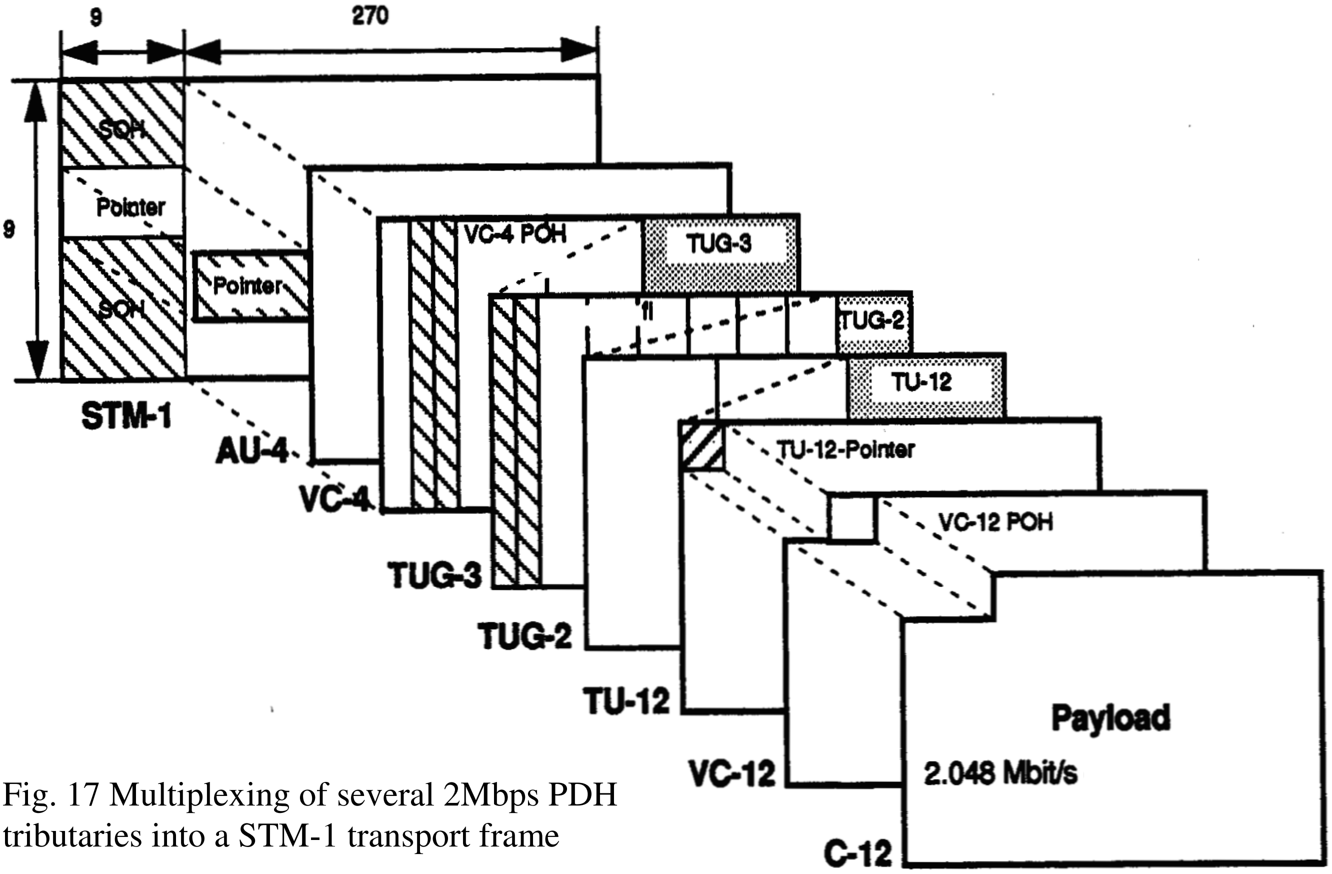

Fig. 17 Multiplexing of several 2Mbps PDH tributaries into a STM-1 transport frame

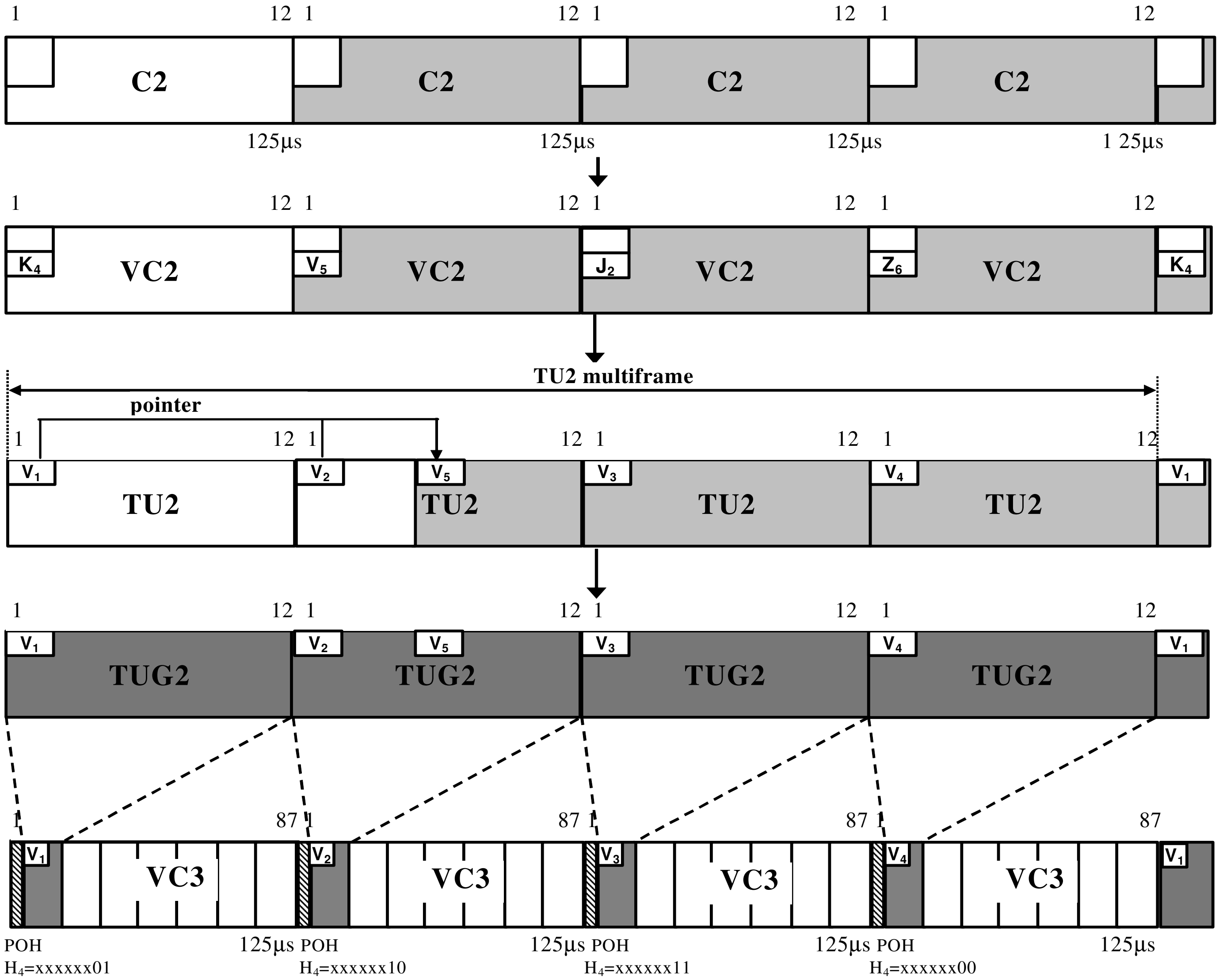

Fig. 18 Generation of the TU2 multiframe, generation of the TUG2 units and multiplexing of the TUG2 units into VC3 containers.

Multiplexing in the SONET system

- SONET multiplexing scheme for PDH data flows.

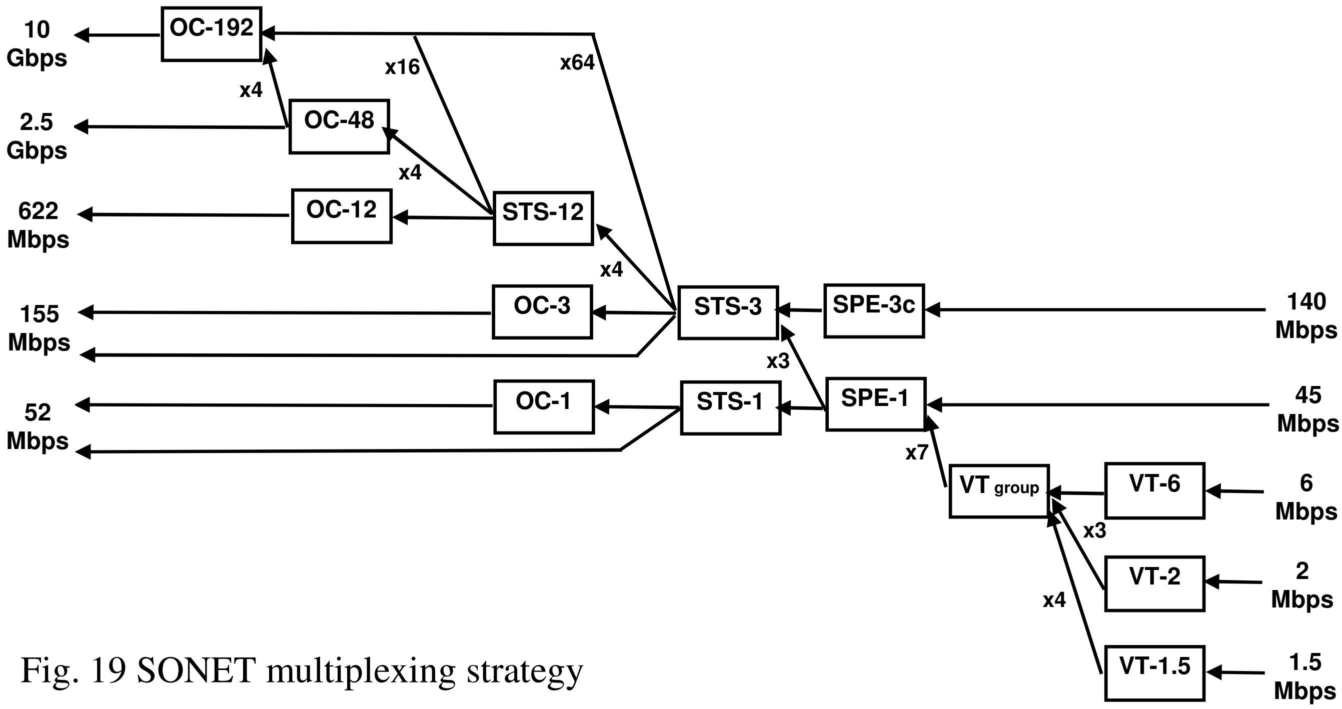

Fig. 19 SONET multiplexing strategy

- Plesiochronous signals with 1,5Mbps rate (DS1 primary PCM frame), 2Mpbs (E1 primary PCM frame) and 6Mbps (DS2 PDH frame) are inserted into VT1.5, VT2 and VT6 units → VT units form a VTG group → VTG units are multiplexed column by column into SPE ("Payload Envelope") → STS-1 transport frame is composed of the SPE unit by adding a pointer and a „Section Overhead" – SOH.

- Insertion of a 45Mbps flow, which includes the third PDH level (European + American), can be done directly into the SPE, and the 140Mbps PDH flow which includes the fourth PDH level (European + American), can be inserted into three concatenated SPE unit.

- The difference between the OC-x and STS-x units consists only in the type of the carrier; the OC units are transmitted on optical carrier and the STS units on electrical carrier.

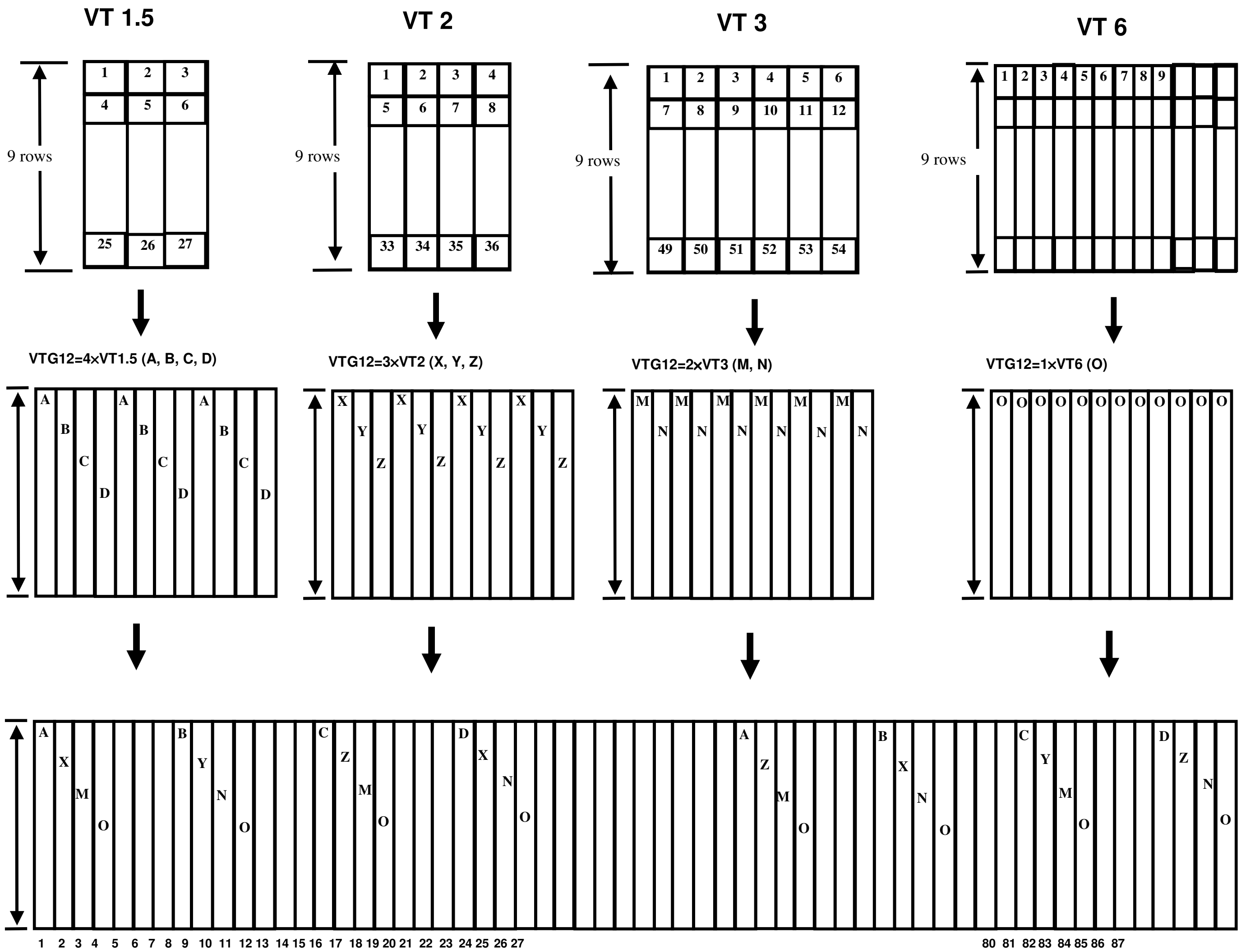

Fig. 20 Generation of the VTG units in the case of SONET system

Course 14 The „Overhead" information used for the control of the transmission in the synchronous SDH/SONET networks

SDH/SONET sections. Error monitoring

- There are two sections which characterize the transmission of the SDH/SONET transport frames, namely: regenerator section – located between two regenerators – and multiplexer section – located between two multiplexers.
- The management and information control necessary for the transmission on these sections is included in the „section overhead", SOH, associated to transport frames.
    - SOH is divided in two groups, namely: RSOH – „Regenerator Section Overhead" – and MSOH – „Multiplex Section Overhead".
- Differently to the PDH systems, the regenerators of the synchronous systems achieve the quality control of the transmission and the control of the faults on the line, the information necessary for these operations being included in the RSOH – it is processed in each regenerator.
    - The information included in MSOH is processed only in multiplexers, this information being transmitted unaltered through regenerators.

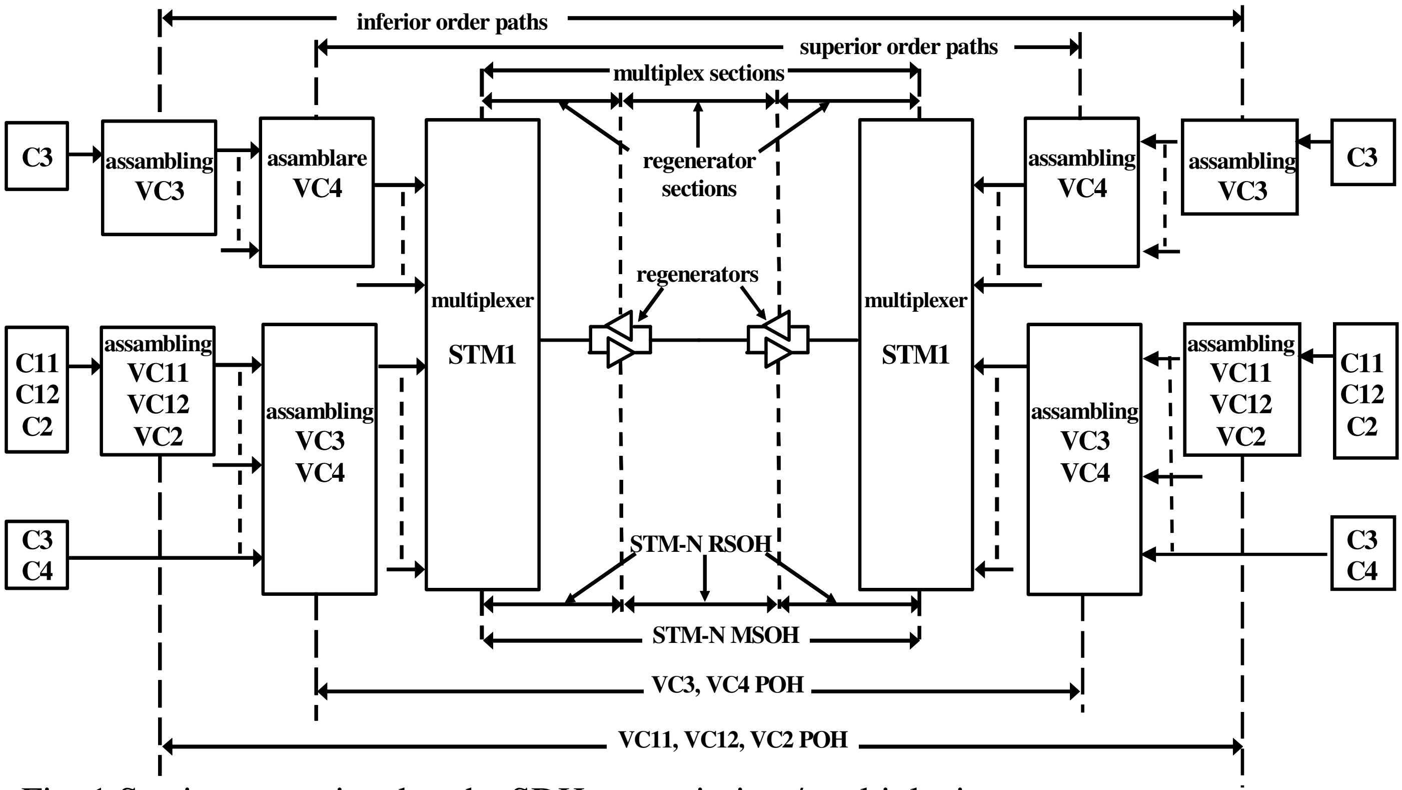

Fig. 1 Sections associated to the SDH transmission / multiplexing system

- The presented sections are components of the transmission paths of the containers (paths identified by the generation and destination points of the containers).
- The information necessary for the management and the control of the transmission on these paths is included in the „path overhead" POH.
    - There are inferior and superior order paths, the difference between these types of paths being the bit rates associated to the units transmitted on these paths and the insertion modality of these units into the transport frames – see fig. 1

- In the case of the SONET system the inferior order paths are associated to the VT1.5, VT2, VT3 and VT6 units, and the superior order path is associated to the SPE unit.

o The quality control of the transmission on the SDH/SONET sections is achieved by the bit error monitoring based on the BIP-X method („Bit Interleaved Parity-X”).

  - The method consists in the addition of the every X-th bit transmitted in a transport frame at a given hierarchy level or in a container (see figure 2).
  - It is practically a parity type method, and the value of X can be 2, 8 or 24; the obtained result is transmitted in the „overhead” of the next frame or container to the receiver where the BIP-X is recomputed.
  - It is possible to identify a maximum number of X errors; X is 2 for inferior order containers, is 8 for superior order containers and RSOH and it is 24 for MSOH; before the transmission the bits are randomized using a scrambler; BIP-X is computed in front of the scrambler and it is inserted in the next frame also in the front of the scrambler.

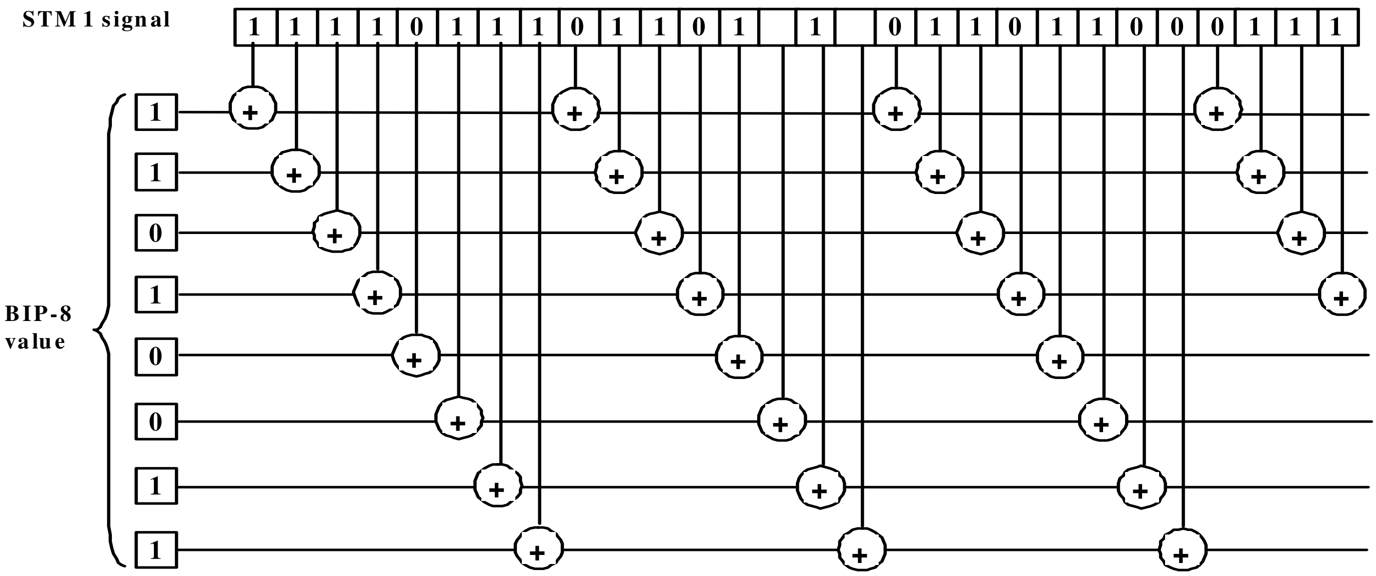

Fig. 2 BIP-8 computation algorithm

„Overhead” information associated to SDH/SONET transport frames

o „Section Overhead” (SOH) together with the useful data („payload”) compose the STM-N frame of the SDH system; the structures includes information necessary for frame synchronization, maintenance, performance monitoring and for different other functions.

  - It is composed of a block consisting of 9 rows and N*9 columns (N=1,4,16); SOH is composed of „Regenerator Section Overhead” (RSOH) – composed of rows 1 to 3 and it is processed in regenerators - and „Multiplex Section Overhead” (MSOH) – composed of rows 5 to 9 and processed in multiplexers; between them, in row 4 is placed the AU pointer.

- Structure of the „Regenerator Section Overhead” (RSOH) bytes:
  - A_1, A_2 – frame alignment signal A_1=1 1 1 1 0 1 1 0 ; A_2=0 0 1 0 1 0 0 0.
  - C_1 – STM-N identification – can be used to identify a STM-N connection between two multiplexers.
  - B_1 - BIP-8 monitoring– defined only in STM-1. It is used for error monitoring in regenerators, it is computed on al the bits of the STM-N signal using an even parity and it is inserted into the next frame.
  - E_1 – regenerator service channel – defined only in STM-1. It is used to create a service voice channel having a bit rate of 64kbps; the channel accessible in all the regenerators and multiplexers.
  - F_1 – user channel – defined only in STM-1. It is reserved for network operations and it is accessible in all the regenerators and multiplexers.
  - D_1 , D_2 , D_3 – data communication channel - defined only in STM-1. Generate a common data communication channel DCC_R with a 192kbps bit rate, dedicated for management information exchange between regenerators.

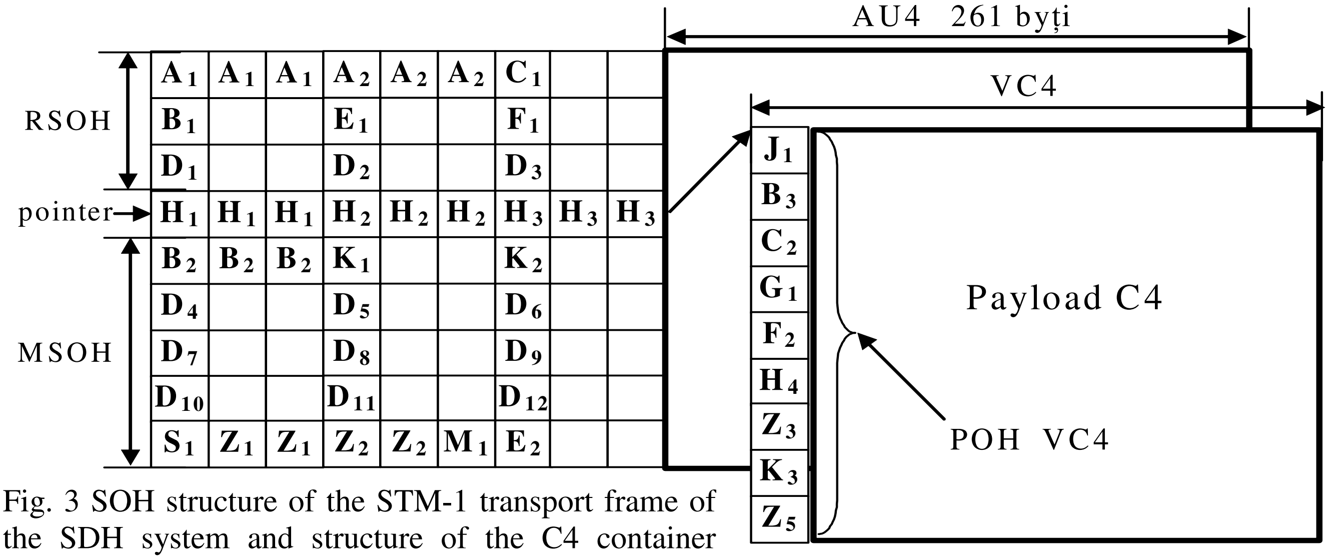

Fig. 3 SOH structure of the STM-1 transport frame of the SDH system and structure of the C4 container POH.

- Structure of the „Multiplex Section Overhead” (MSOH) bytes:
  - B_2 – BIP-N*24 monitoring – N*3 bytes are used for error monitoring in the multiplexer section. It is computed in such a way to obtain an even parity on all bits of the STM-N frame, excepting the RSOH and it is inserted in the next frame.
  - K_1 , K_2 – automatic protection switching – defined only in STM-1. It is used for the control of the automatic protection switching, the structure of these bytes being defined for several protection configurations (1+1 , 1:n). Bits 3, 7 and 8 of byte K_2 are reserved for subsequent applications.
  - D_4...D_{12} – data communication channel DCC. These 8 bytes compose a common data channel DCC_M with a 576kbps bit rate for the multiplex section.
  - S_1 – synchronization status – defined only in STM-1. Inform the operator about the performances of the clock used in the unit which generates the frame.
  - Z_1 , Z_2 – N*4 bytes reserved for subsequent applications.
  - M_1 – distant error indication for the multiplex section.
  - E_2 – multiplexer service channel – defined only in STM-1. Composes a service voice channel accessible only in the multiplexers.

- „Section Overhead” (SOH) together with the useful data (SPE) compose a STS-1 frame in the SONET system.
  - The structure of the „overhead” is three times smaller than the SOH of the SDH system.
  - Essential differences consist in the fact that the pointer has only 3 bytes, the error monitoring in MSOH is done using a single byte and the frame alignment signal has only 2 bytes and there are missing some reserved bytes of the STM-1 SOH.

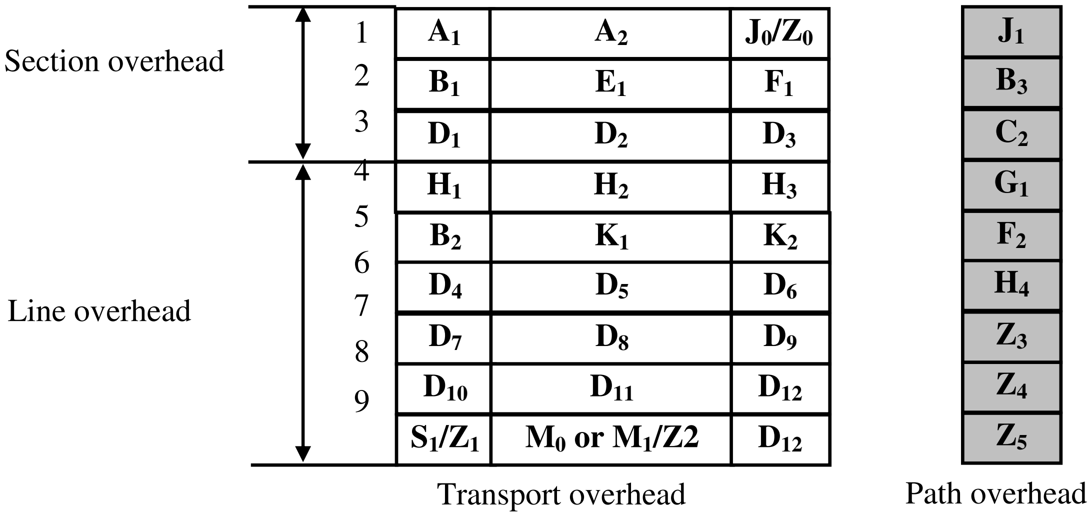

Fig. 4 Structure of the SONET system STS-1 transport frame SOH and of the POH associated to SPE container.

- Path Overhead” (POH) together with the container C compose the virtual container VC; for the superior order containers there are available 9 byres (a column) per container, and for inferior order containers it is available only 1 byte per container.
- POH is composed at the generation of the container and remains unchanged until the container is disassembled; POH is the same for the SDH and SONET containers for both inferior and superior containers.
- The bytes of the high order SDH containers are defined as follows::
  - J_1 – path trace – it is the access point in the virtual container – can be used to transmit either a repetitive telegram with length 64bytes or a 16 byte telegram; this channel permits to check the link over the complete path.
  - B_3 – BIP-8 monitoring – error monitoring over the entire path; it is computed over all bits of the current VC-3 or VC-4 to obtain an even parity and it is inserted in the next frame.
  - C_2 – content identifier of the VC – see tab.1

MSB 1 2 3 4	LSB 1 2 3 4	Hex code	Explication
0 0 0 0	0 0 0 0	0 0	Unequipped
0 0 0 0	0 0 0 1	0 1	Equipped – non specific
0 0 0 0	0 0 1 0	0 2	TUG structure
0 0 0 0	0 0 1 1	0 3	Locked TUG
0 0 0 0	0 1 0 0	0 4	Asynchronous mapping of 34,368kbps or 44,736kbps into C3 container
0 0 0 1	0 0 1 0	1 2	Asynchronous mapping of 136,264kbps into C4 container
0 0 0 1	0 0 1 1	1 3	ATM mapping
0 0 0 1	0 1 0 0	1 4	MAN (DQDB) mapping
0 0 0 1	0 1 0 1	1 5	FDDI mapping

Man – Metropolitan Area Network
DQDB – Dual Queue Dual Bus
FDDI – Fiber Distributed Data Interface

Tab. 1 Structure of the C_2 byte of POH of SDH container corresponding to superior paths

- G_1 – path status – using this byte, data related to the performances are sent by the receiver to the transmitter; it is possible the monitoring of the path between the two ends of the link; the structure is given in fig.5.
  - ❖ Bits 1-4 (REI) – remote error indication – the binary value transmitted corresponds to the number of parity violations detected on comparison of the received B_3 with recomputed BIP-8; numbers higher than 8 are evaluated as 0.
  - ❖ Bit 5 – remote defect indication – this signal is returned if at the receiver we do not have a valid signal.
  - ❖ Bits 6-8 – not defined

REI				RDI	Neutilizat		
1	2	3	4		1	2	3

Fig. 5 Structure of the G_1 byte of the SDH POH corresponding to superior paths (containers)

- F_2 – user channel – 64kbps channel available for communication between the path ends for user purposes.
- H_4 – multi-frame indicator – used for lower order multi-frame synchronization (see fig.5.4)
- Z_3 – user channel - 64kbps channel available for communication between path ends.
- K_3 – automatic protection switching – bits 1-4 ensure the control of the protection switching process on higher order paths; bits 5-8 are reserved.
- Z_5 – network operator byte – it is provided for management purposes.

o Lower-order POH (VC-1/VC-2) – is composed of bytes V_5, J_2, Z_6, K_4.

- V_5 is the first byte in VC-1/VC-2 and is the reference point for the lower order VC; V_5 is used to transmit the following information:

BIP-2		REI	RFI	Etichetă			RDI
1	2	3	4	5	6	7	8

Fig. 6 Structure of the V_5 byte of the SDH POH corresponding to inferior paths (containers)

bit 5	bit 6	bit 7	Explications
0	0	0	Unequipped
0	0	1	Equipped – non specific
0	1	0	Asynchronous
0	1	1	Bit level synchronous
1	0	0	Byte level synchronoust
1	0	1	Equipped - unused
1	1	0	
1	1	1	

Tab. 2 Structure of the V_5 byte of POH of the SDH containers corresponding to inferior paths

  - Bit 1, 2 – BIP-2 monitoring – it is used for error monitoring over the entire lower-order path; an even parity is used; POH bytes are included without bytes V_1 – V_4 of TU-1/TU-2; if information is transmitted in byte V_3 in the negative justification process, then this byte is included in the BIP computation.
  - Bit 3 – remote error indication (REI –Remote Error Indication) – indicates the apparition of parity violations in the BIP-2 re-computation.
  - Bit 4 – remote failure indication (RFI).
  - Bit 5, 6, 7 – contents identifier – correspond to the C2 byte of the higher order POH; the significance of these bits is shown in tab. 2.
  - Bit 8 – VC-path remote defect indication (RDI).

- J_2 – path trace – identical with byte J_1 of the higher-order POH; a 16 byte telegram is transmitted to check the link over the entire communication path.
- K_4 – automatic protection switching - bits 1-4 ensure the control of the protection switching on lower order paths; bits 5-8 are unused.
- Z_6 – unused – spare byte.

Pointers and operations with pointers in SDH/SONET transmission-multiplexing systems

- The pointers used in the administrative and tributary units of the synchronous SDH/SONET systems have two main roles, namely:
  - Establishment of the phase relation between the containers with useful data and the administrative and tributary units, being established in such a way the phase relation (meaning the relative position) between the containers with useful data and the transport frame;
  - Bit rate adaptation between the data streams received by a multiplexer and the transmitted (and multiplexed) stream by the multiplexer in the situation of interruption of the synchronization link.
    - Dynamic establishment of the position of containers carrying useful data in different units and implicitly in the transport frame ensures an easy insertion / extraction of different elementary streams into / from the transport frame, without being necessary the demultiplexing and remultiplexing of the entire multiplex stream, situation encountered in the case of PDH systems;
    - It is ensured a flexible and efficient use of the transmission capacity for a wide range of services with various characteristics;
    - The container loaded in the transport frame can start anywhere (practically can be some restrictions), the starting position being given by the pointer value and the container can extend over two units (administrative or tributary units according to the considered case);

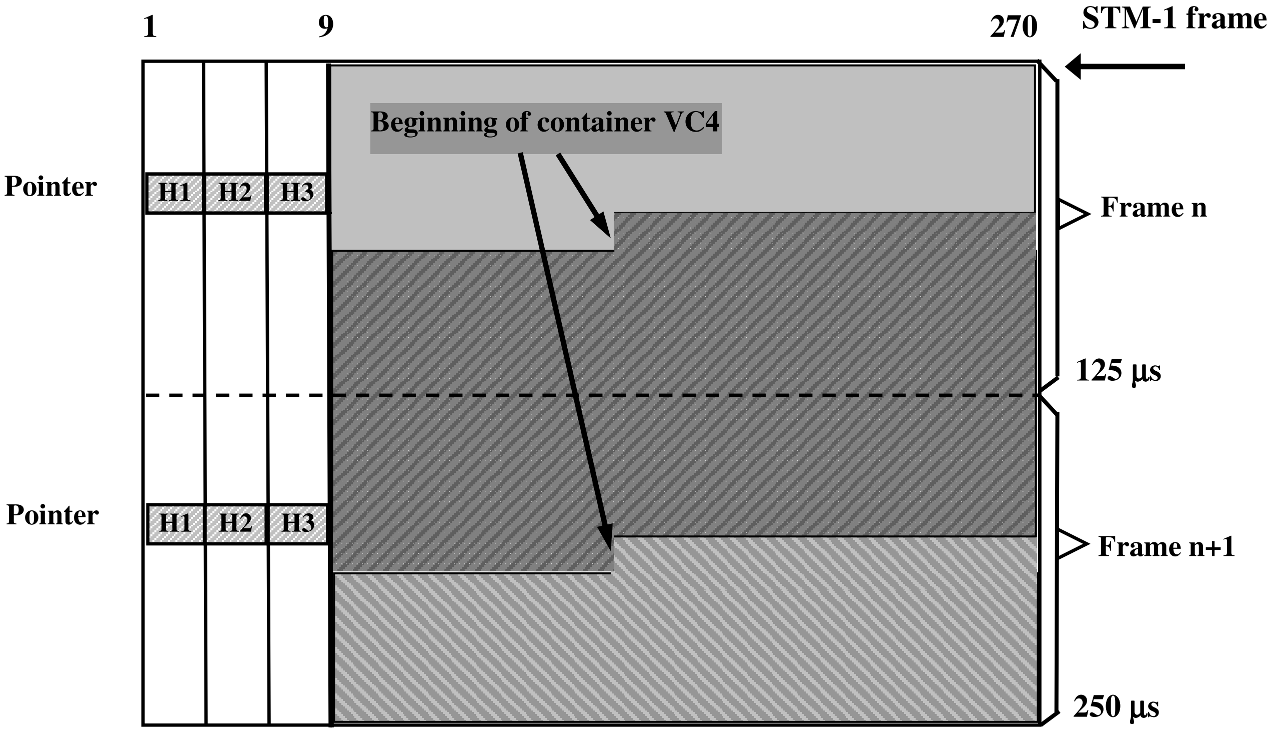

Fig.7 Establishment of the position of a VC4 container relatively to the beginning of the STM-1 transport frame by using the AU4 pointer

- The pointer includes three or four bytes, three bytes in the case of the SDH administrative units and four bytes in the case of the SDH tributary units; only the first two bytes (H1 and H2) give the beginning position of the container (in the considered case), the third byte being reserved for negative justification operations (byte H3 in the considered case), and the fourth byte, if exists, has no defined role.

- In SOH STM-1 there are reserved 9 bytes for pointer; if in STM-1 is loaded a VC4 container we have a single pointer on two bytes plus three positions for negative justification (the other bytes are not used) – each position in AU4 is composed of three bytes – if three VC3 containers are loaded in STM-1, three pointers are used – each position in AU3 is composed of a single byte.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		265	266	267	268	269	270
1										522	522	522	523	523	523	524	524	524	.....	607	607	607	608	608	608
2										609	609	609	610	610	610	611	611	611	.....	694	694	694	695	695	695
3										696	696	696	697	697	697	698	698	698	.....	781	781	781	782	782	782
4	H1	H1	H1	H2	H2	H2	H3	H3	H3	0	0	0	1	1	1	2	2	2	.....	85	85	85	86	86	86
5										87	87	87	88	88	88	89	89	89	.....	172	172	172	173	173	173
6										174	174	174	175	175	175	176	176	176	.....	259	259	259	260	260	260
7										261	261	261	262	262	262	263	263	263	.....	346	346	346	347	347	347
8										348	348	348	349	349	349	350	350	350	.....	433	433	433	434	434	434
9										435	435	435	436	436	436	437	437	437	.....	520	520	520	521	521	521
1										522	522	522	523	523	523	524	524	524	.....	607	607	607	608	608	608
2										609	609	609	610	610	610	611	611	611	.....	694	694	694	695	695	695
3										696	696	696	697	697	697	698	698	698	.....	781	781	781	782	782	782
4	H1	H1	H1	H2	H2	H2	H3	H3	H3	0	0	0	1	1	1	2	2	2	.....	85	85	85	86	86	86
5										87	87	87	88	88	88	89	89	89	.....	172	172	172	173	173	173

Fig. 8 Structure of the AU3 pointers and the position of these pointers inside the STM-1 transport frame. Numbering of positions inside the STM-1 frame in the case of insertion of three AU3 units

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		265	266	267	268	269	270
1										522	-	-	523	-	-	524	-	-	.....	607	-	-	608	-	-
2										609	-	-	610	-	-	611	-	-	.....	694	-	-	695	-	-
3										696	-	-	697	-	-	698	-	-	.....	781	-	-	782	-	-
4	H1	H1	H1	H2	H2	H2	H3	H3	H3	0	-	-	1	-	-	2	-	-	.....	85	-	-	86	-	-
5										87	-	-	88	-	-	89	-	-	.....	172	-	-	173	-	-
6										174	-	-	175	-	-	176	-	-	.....	259	-	-	260	-	-
7										261	-	-	262	-	-	263	-	-	.....	346	-	-	347	-	-
8										348	-	-	349	-	-	350	-	-	.....	433	-	-	434	-	-
9										435	-	-	436	-	-	437	-	-	.....	520	-	-	521	-	-
1										522	-	-	523	-	-	524	-	-	.....	607	-	-	608	-	-
2										609	-	-	610	-	-	611	-	-	.....	694	-	-	695	-	-
3										696	-	-	697	-	-	698	-	-	.....	781	-	-	782	-	-
4	H1	H1	H1	H2	H2	H2	H3	H3	H3	0	-	-	1	-	-	2	-	-	.....	85	-	-	86	-	-
5										87	-	-	88	-	-	89	-	-	.....	172	-	-	173	-	-

Fig. 9 Structure of the AU4 pointers and the position of these pointers inside the STM-1 transport frame. Numbering of positions inside the STM-1 frame in the case of insertion of one AU4 units

- The use of the pointers in the SDH/SONET systems creates the possibility to maintain the synchronous character of the connection in the situation when the clock connection is interrupted;
  - It is used the positive or negative justification according to the difference between the value of the local clock frequency and the frequency of the input stream (byte H3 of the pointers facilitates the negative justification) and the change of the container's starting position in the transport frame (or other SDH/SONET units, meaning administrative or tributary units);

- The realization of the positive and negative justification is explained in figures 10 and 11, considering the case of insertion of a VC4 container in the STM-1 frame;
  - figure 10 presents the situation in which the frequency of the multiplexer local clock is larger than the frequency of the received signal; the frequency correction is realized by positive justification and increases with one unit the pointer value; the justification is realized at byte level, the justification position is the first position after byte H3, and the beginning position of the container is increased with one unit.
  - Figure 11 presents the case in which the frequency of the multiplexer local clock is smaller than the frequency of the received signal; the frequency correction is realized by negative justification and decreases with one unit the pointer value; the justification is realized at byte level, the justification position being the position occupied by the byte H3, and the starting position of the container is decreased with one unit.

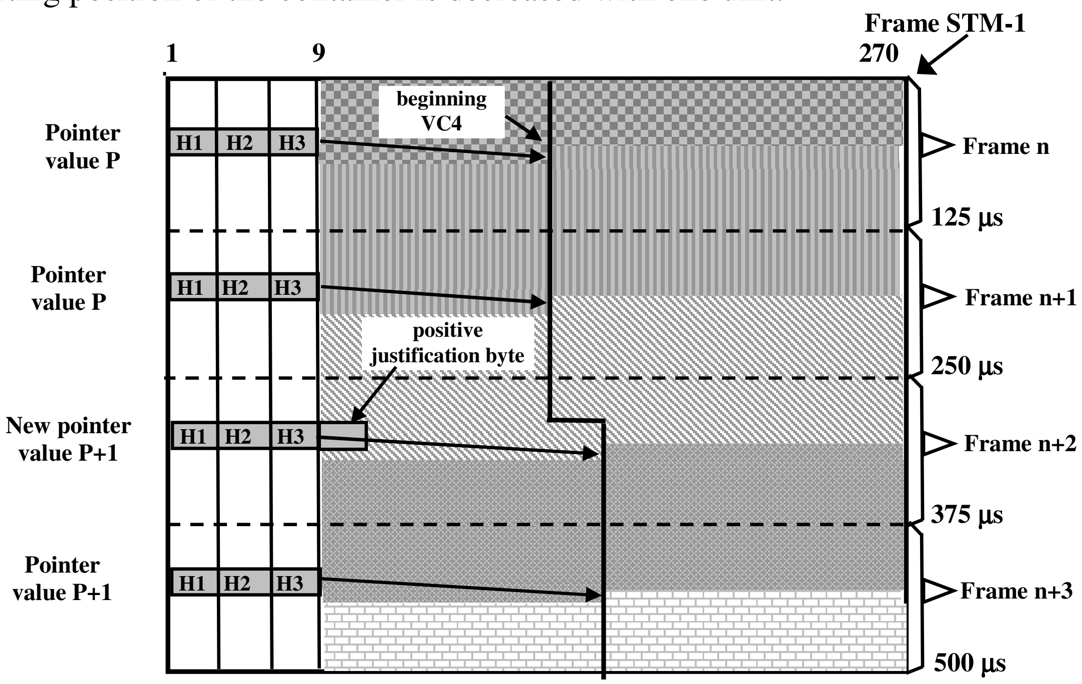

Fig. 10 Bit rate adjustment between the STM-1 transport frame of a multiplexer and a VC4 container received with a frequency lower than the local frequency

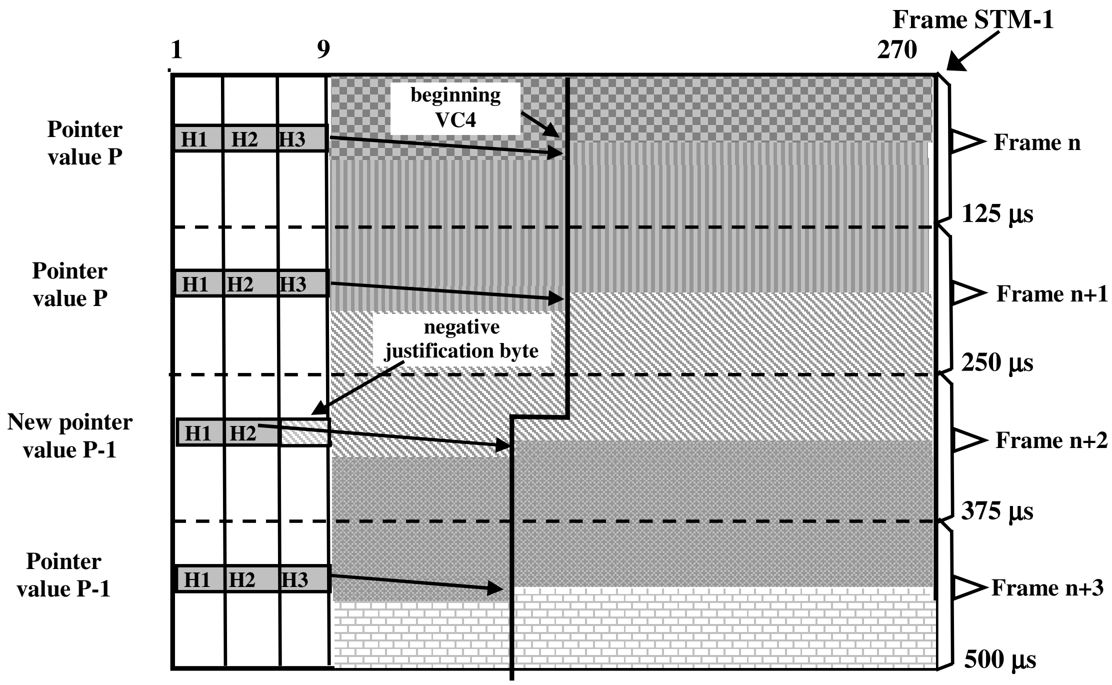

Fig. 11 Bit rate adjustment between the STM-1 transport frame of a multiplexer and a VC4 container received with a frequency larger than the local frequency

Structure of the SDH pointer

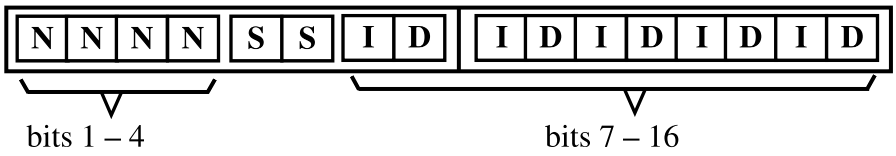

Fig. 12 Structure of the H_1 and H_2 bytes of the SDH administrative units

- The significance of bits of the word composed of bytes H1 and H2 is the following:
  - Bits 1 – 4 compose the so called NDF (New Data Flag) which indicates the change of the pointer value. There are defined two values, namely NDF=0110 (non active) – it is maintained the value of the pointer - and NDF=1001 (active) – it is specified a new value for the pointer;
  - Bits 5 and 6 called S S have the value 1 0 – identify the pointer type;
  - Bits 7 – 16 represents the value of the pointer;
    - If a new value is attributed to the pointer then bits 7 – 16 contain effectively the value of the pointer;
    - If it is about frequency matching and the pointer value must be incremented or decremented, then bits 7 – 16 are divided in two groups, of increment bits (I) and respectively of decrement bits (D). There are 5 bits in each group and if the pointer must be incremented the I bits are inverted, and if the pointer must be decremented the D bits are inverted. Identification of the pointer incrementing and decrementing operations is done based on a majority logic which takes in consideration the changes of I and D bits. This signaling method of the pointer modification ensures some error protection in the case of a low bit error probability channel, protection necessary due to the frequent changes in the pointer value if bit rate adaptation is realized. There is also some error protection of the NDF bits, the Hamming distance between the codes associated to active and inactive states being 4.
    - The modification of the pointer value by setting a new value or by incrementing / decrementing the old value can be realized at most once in 4 units. If we have a pointer adjustment in one unit or transport frame then in the following three units or transport frames there are not allowed pointer adjustments (regular adjustments or incrementing / decrementing operations);
- In the case of concatenation of AU4 units, the first AU has a normal pointer and the following units include a concatenation indication CI – these units must be processed like the first unit; bits H_1 and H_2 are defined as: H_1 : 1 0 0 1 S S 1 1 (S – undefined), H_2 : 1.
- The TU3 pointer allows a dynamic adaptation of the VC3 container phase to the TU3 frame. The TU3 pointer is located in the first column of the unit and is composed also of bytes H_1, H_2 and H_3.The structure of this pointer and the operations with this are identical with the structure and operations presented earlier for the AU pointers.
- The TU3 unit is identical as dimensions with the TUG3 unit; if in the TUG3 unit are multiplexed TUG2 units, which have a fix phase relation with the TUG3 frame, the positions corresponding to bytes H_1 and H_2 of the pointer are replaced with NPI („Null Pointer Indicator”) having the structure: 1 0 0 1 S S 1 1   1 1 1 0 0 0 0 0 (S – undefined).

	1	2	3	4	5	6	7	8	9	10		81	82	83	84	85	86
1	H1	595	596	597	598	599	600	601	602	603	.....	674	675	676	677	678	679
2	H2	680	681	682	683	684	685	686	687	688	.....	759	760	761	762	763	764
3	H3	0	1	2	3	4	5	6	7	8	.....	79	80	81	82	83	84
4	S T U F F I N G	85	86	87	88	89	90	91	92	93	.....	164	165	166	167	168	169
5		170	171	172	173	174	175	176	177	178	.....	249	250	251	252	253	254
6		255	256	257	258	259	260	261	262	263	.....	334	335	336	337	338	339
7		340	341	342	343	344	345	346	347	348	.....	419	420	421	422	423	424
8		425	426	427	428	429	430	431	432	433	.....	504	505	506	507	508	509
9		510	511	512	513	514	515	516	517	518	.....	589	590	591	592	593	594
1	H1	595	596	597	598	599	600	601	602	603	.....	674	675	676	677	678	679
2	H2	680	681	682	683	684	685	686	687	688	.....	759	760	761	762	763	764
3	H3	0	1	2	3	4	5	6	7	8	.....	79	80	81	82	83	84
4	S T	85	86	87	88	89	90	91	92	93	.....	164	165	166	167	168	169
5		170	171	172	173	174	175	176	177	178	.....	249	250	251	252	253	254

Fig. 13 Structure of the TU3 pointer and his position in this unit. The numbering of TU3 positions

- The TU2 pointer allows a dynamic adaptation of the VC2 container phase to the phase of TU2 frame. This pointer is composed of 4 bytes: V_1, V_2, V_3 and V_4; these 4 bytes are located in 4 consecutive TU2 frames, frames which compose a multiframe (see figure 14).
  - Bytes V1 and V2 are equivalent with bytes H1 and H2 and give effectively the value of the pointer - see figure 12; the difference to the AU pointers is given by the S S bits (see fig. 12), which have in this case the value 0 0.
  - Byte V3 is used for negative justification operations, similar to byte H3 of the AU pointers, and the structure of byte V4 is undefined.
  - The definition of the pointer byte available in a TU2 frame is given by byte H_4 – multiframe indicator – of POH VC3 and POH VC4.

V1	321	322	····	426	427	V2	0	1	····	105	106	V3	107	108	····	212	213	V4	214	215	····	319	320			

Fig. 14 Structure of the TU2 pointer and his position in this unit. Numbering of the TU2 unit positions

- The TU11 pointer allows a dynamic adaptation of the VC11 container phase to the phase of TU11 frame. The structure of this pointer is identical with that of pointer TU2. The insertion and extraction of data in / from TU11 multiframe and the multiplexing in superior units is realized like in the case of TU2 units. The bits S S of byte V1 are 1 1;

- The TU12 pointer allows a dynamic adaptation of the VC12 container phase to the phase of frame TU12. The structure of this pointer is identical with that of pointer TU2. The insertion and extraction of data in / from TU12 multiframe and the multiplexing in superior units is realized like in the case of TU2 units. The bits S S of byte V1 are 1 0;

V1	78	79	····	102	103	V2	0	1	····	24	25	V3	26	27	····	50	51	V4	52	53	····	76	77

Fig. 15 Structure of the TU11 pointer and his position in this unit. Numbering of the TU11 unit positions

V1	105	106	····	138	139	V2	0	1	····	33	34	V3	35	36	····	68	69	V4	70	71	····	103	104

Fig. 16 Structure of the TU12 pointer and his position in this unit. Numbering of the TU12 unit positions

- In the case of the low order tributary units the insertion and extraction of data is realized using a multiframe composed of 4 units and this multiframe has a vector type structure, as it is presented in figure 14. The zero position in this multiframe is the first position after byte V2 and the pointer value specifies the effective position where is inserted the group of 4 consecutive C2 containers.
    - After the insertion of the useful information, the vector type structure is transformed into a structure composed of 4 matrices having dimensions 9×12=108; each matrix has in the position located in the upper left corner a pointer byte (see the figure with the structure of the containers);
    - The multiplexing of the TU2 units in the superior units is realized byte by byte and column by column.
    - At the reception side the TU2 matrices are extracted from the superior units by column by column demultiplexing and the group of 4 consecutive matrices is transformed into the vector structure presented in figure 14 and the information is extracted starting with the position specified by the pointer.
    - For the transport of the nonhierarchical PDH bit rates, several TU2 multiframes can be concatenated, being possible in this way the transport of information with bit rates multiples of VC2 bit rate in concatenated VC2-mc containers;
- In the case of the SONET system the STS-1 transport frame has a pointer composed of three bytes, similar with the pointer of AU3 SDH units. The structure of this pointer is also H1, H2 and H3, with H1 and H2 containing the value of the pointer, and H3 used for negative justification. The operations which can be done with this pointer are identical with the SDH AU pointer operations.
    - In the case of the VT tributary units the pointer is similar with the pointer of the SDH TU units. The operations with VT pointers are identical with the SDH TU pointer operations and the structure of the VT multiframes used for insertion and extraction of the data (vector type structure) is also similar with the structure of the TU multiframes.