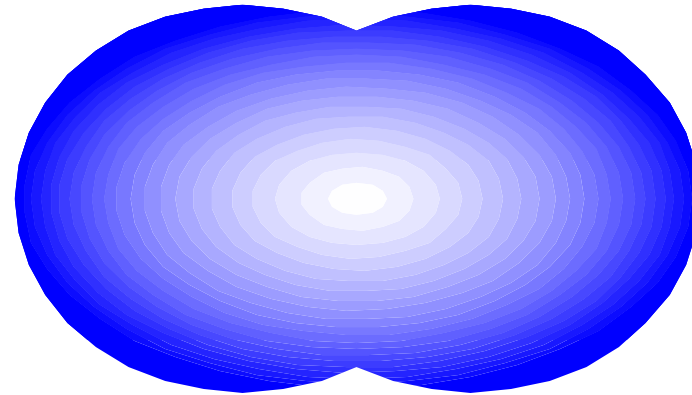
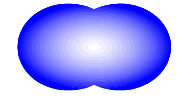


شاهین ارتباط تهران



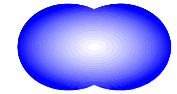
شرکت مهندسين مشاور
شاهين ارتباط تهران



شاهین ارتباط تهران

Multiplexing

Contents



شاهین ارتباط تهران

● **Multiplexing**

● **PDH**

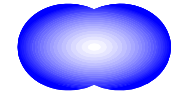
● **SDH**

● **Frame Structure & Multiplexing Methods**

● **Overhead & Pointers**

● **Logical Functional Blocks**

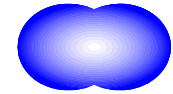
Definition of Multiplexing



شاهین ارتباط تهران

- In electronics, telecommunications and computer networks, **multiplexing** is a term used to refer to a process where multiple analog message signals or digital data streams are combined into one signal.
- In digital signal processing (DSP), the multiplexer takes several separate digital data streams and combines them together into one data stream of a higher data rate.
- This allows multiple data streams to be carried from one place to another over one physical link, which saves cost.

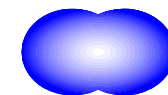
Multiplex



شاهین ارتباط تهران

- To combine multiple signals ([analog](#) or [digital](#)) for transmission over a single line or media. A common type of multiplexing combines several low-speed signals for transmission over a single high-speed connection. The following are several examples of different multiplexing methods:
 - [Frequency Division Multiplexing \(FDM\)](#) : each signal is assigned a different frequency
 - [Time Division Multiplexing \(TDM\)](#) : each signal is assigned a fixed time slot in a fixed rotation
 - [Statistical Time Division Multiplexing \(STDM\)](#): time slots are assigned to signals dynamically to make better use of bandwidth
 - [Wavelength Division Multiplexing \(WDM\)](#) : each signal is assigned a particular wavelength; used on optical fiber.

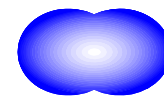
MUX & DEMUX



شاهین ارتباط تهران

- A device that performs the multiplexing is called a multiplexer (**MUX**), and a device that performs the reverse process is called a demultiplexer (**DEMUX**).

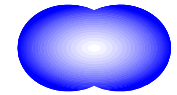
TDM



شاهین ارتباط تهران

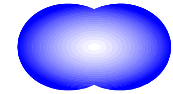
- **Time-division multiplexing (TDM)** is a method of putting multiple data streams in a single signal by separating the signal into many segments, each having a very short duration. Each individual data stream is reassembled at the receiving end based on the timing.

TDM



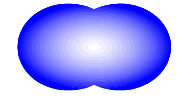
شاهین ارتباط تهران

- *Time Division Multiplexing*, a type of [multiplexing](#) that combines data streams by assigning each stream a different time slot in a set. TDM repeatedly transmits a fixed sequence of time slots over a single transmission channel.



Transmission of Signal

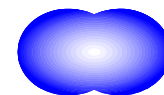




شاهین ارتباط تهران

Pulse Code Modulation

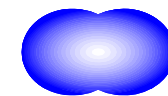
PCM Procedure



شاهین ارتباط تهران

• Sampling & Holding

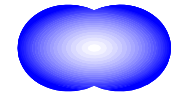
Pulse Code Modulation (PCM)



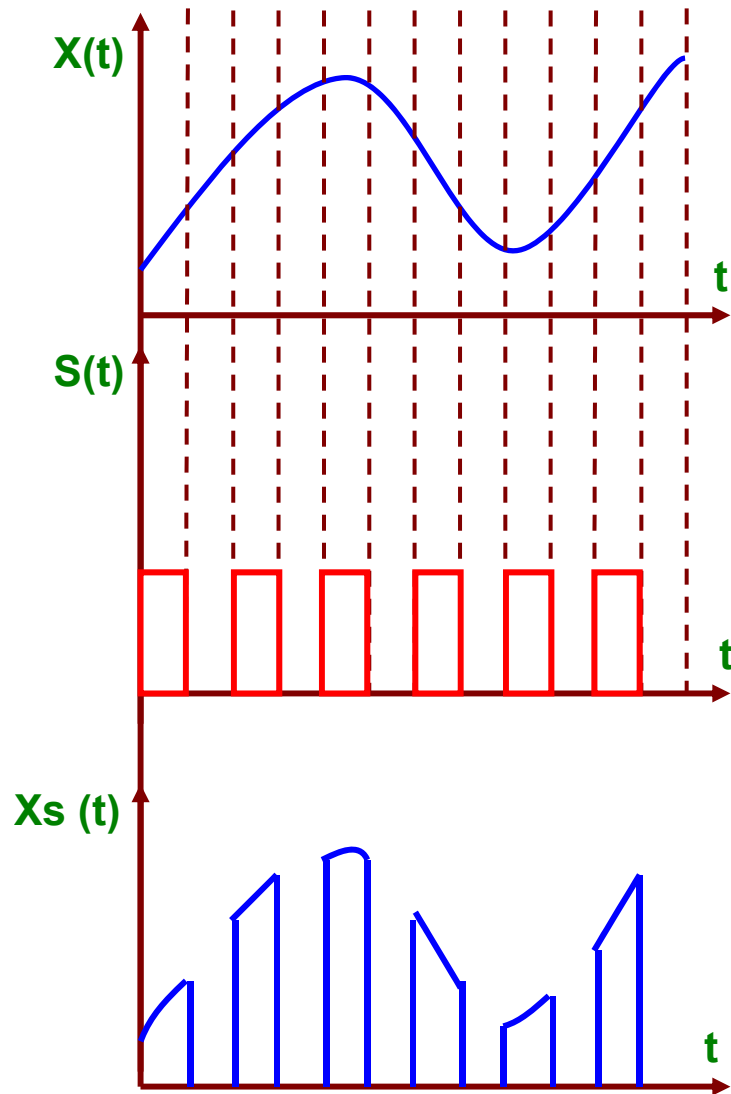
شاهین ارتباط تهران

- Pulse Code Modulation (PCM), first proposed by STC in 1937. PCM allowed analog waveforms, such as the human voice, to be represented in binary form, and using this method it was possible to represent a standard 4 kHz analog telephone signal as a 64 kbit/s digital bit stream.

Sampling



شاهین ارتباط تهران

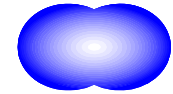


$$X_s(t) = X(t) \cdot S(t)$$

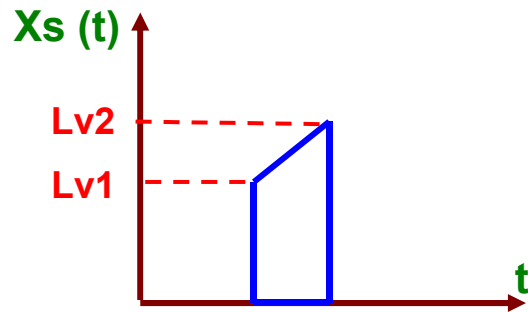
PAM

$$f_s \geq 2f_m$$

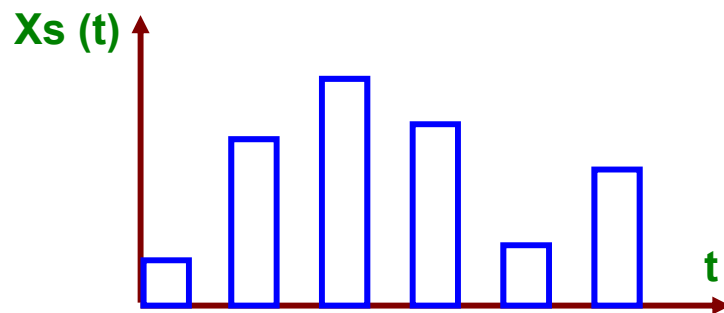
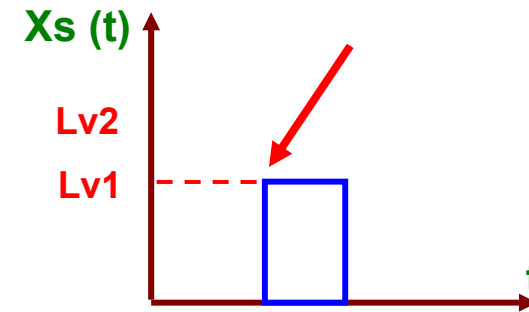
Holding



شاهین ارتباط تهران

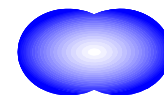


Hold



Holded PAM

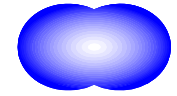
PCM Procedure



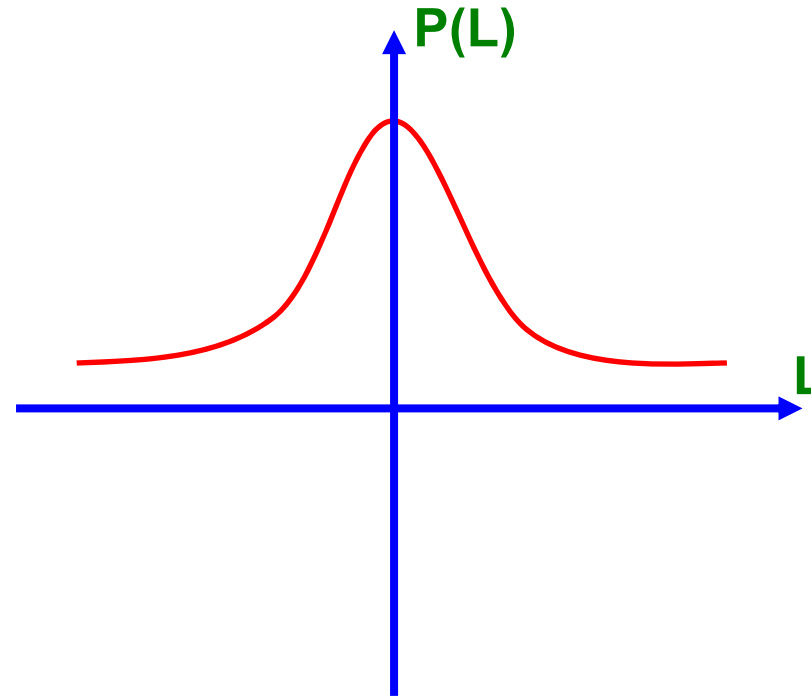
شاهین ارتباط تهران

- **Quantizing**

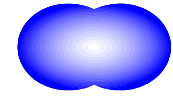
Quantizing



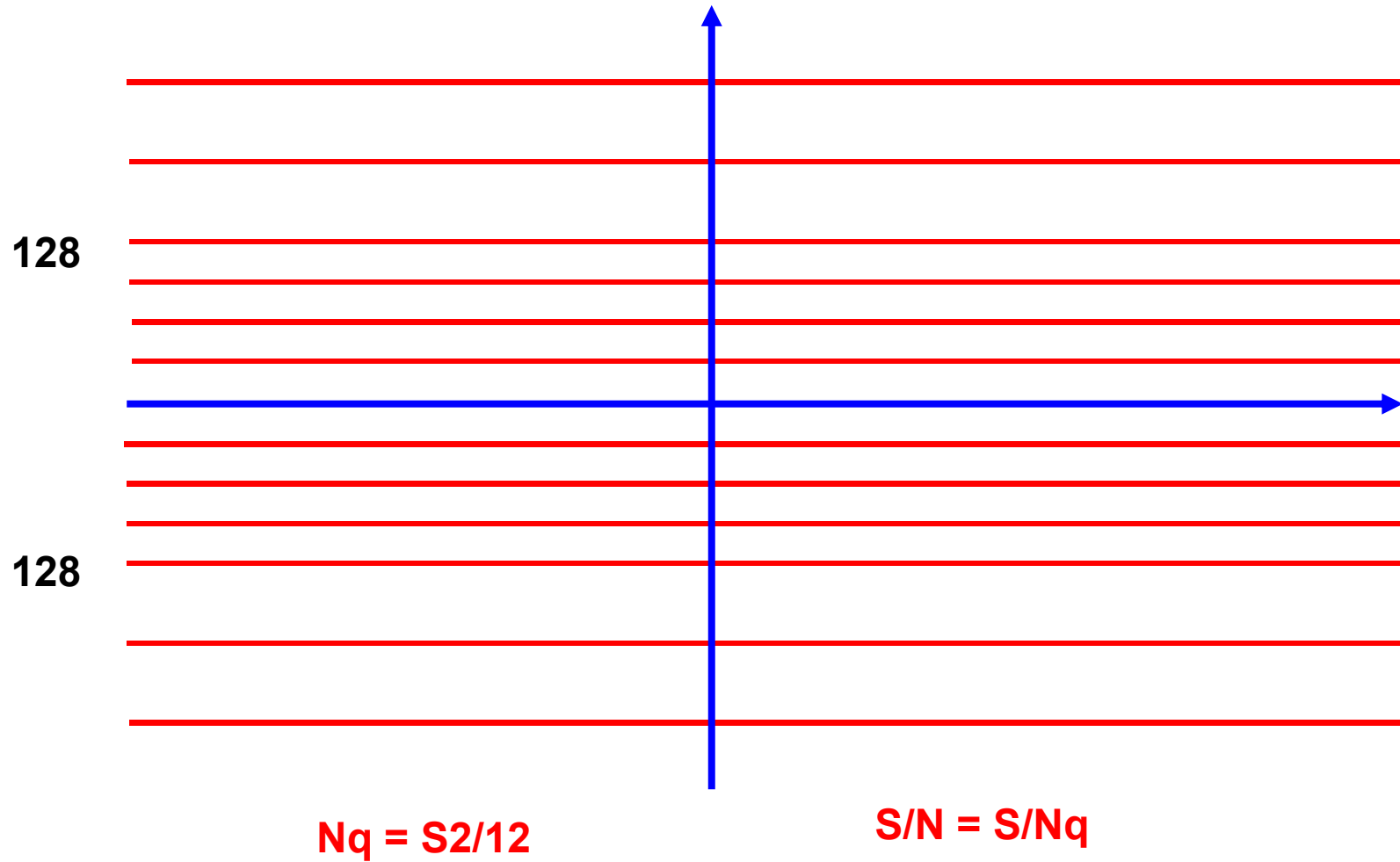
شاهین ارتباط تهران



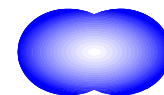
Quantizing



شاهین ارتباط تهران



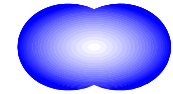
PCM Procedure



شاهین ارتباط تهران

- **Coding**

Coding

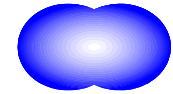


شاهین ارتباط تهران

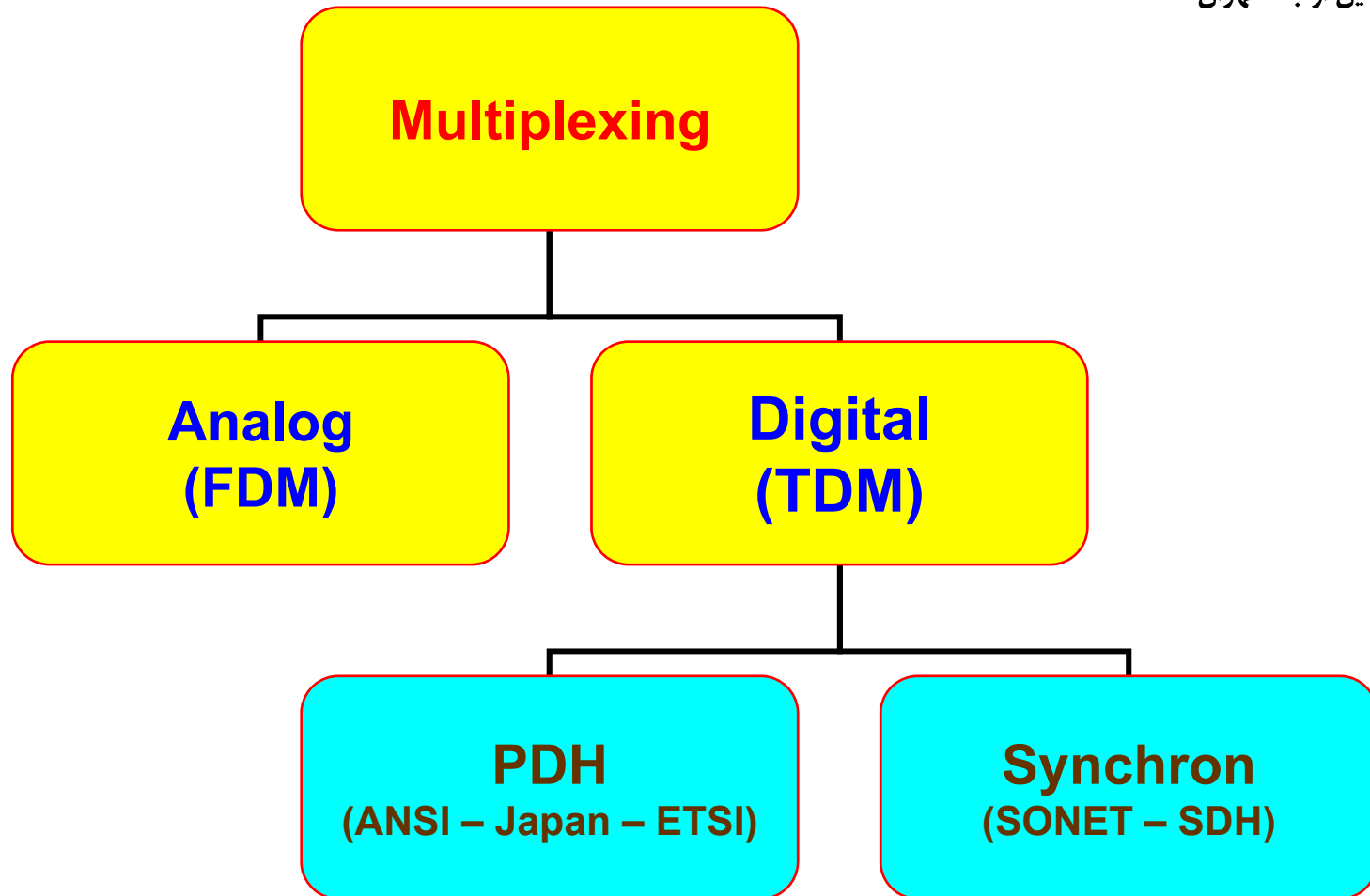
1	0	0	1	1	0	1	1
---	---	---	---	---	---	---	---

$$8 * 8000 = 64\text{Kbps}$$

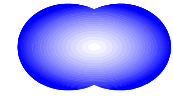
Multiplexing



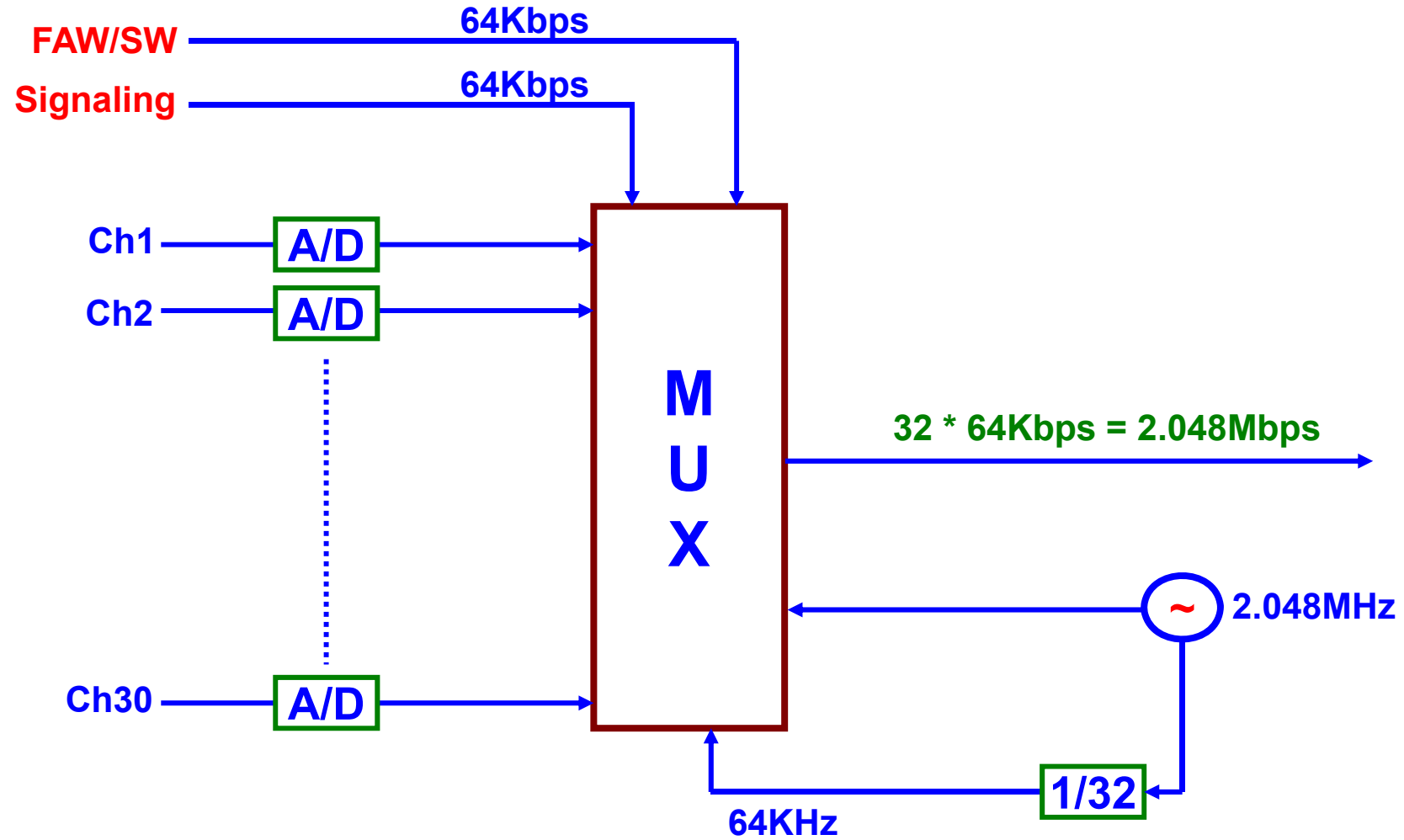
شاهین ارتباط تهران



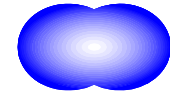
2M Multiplexer



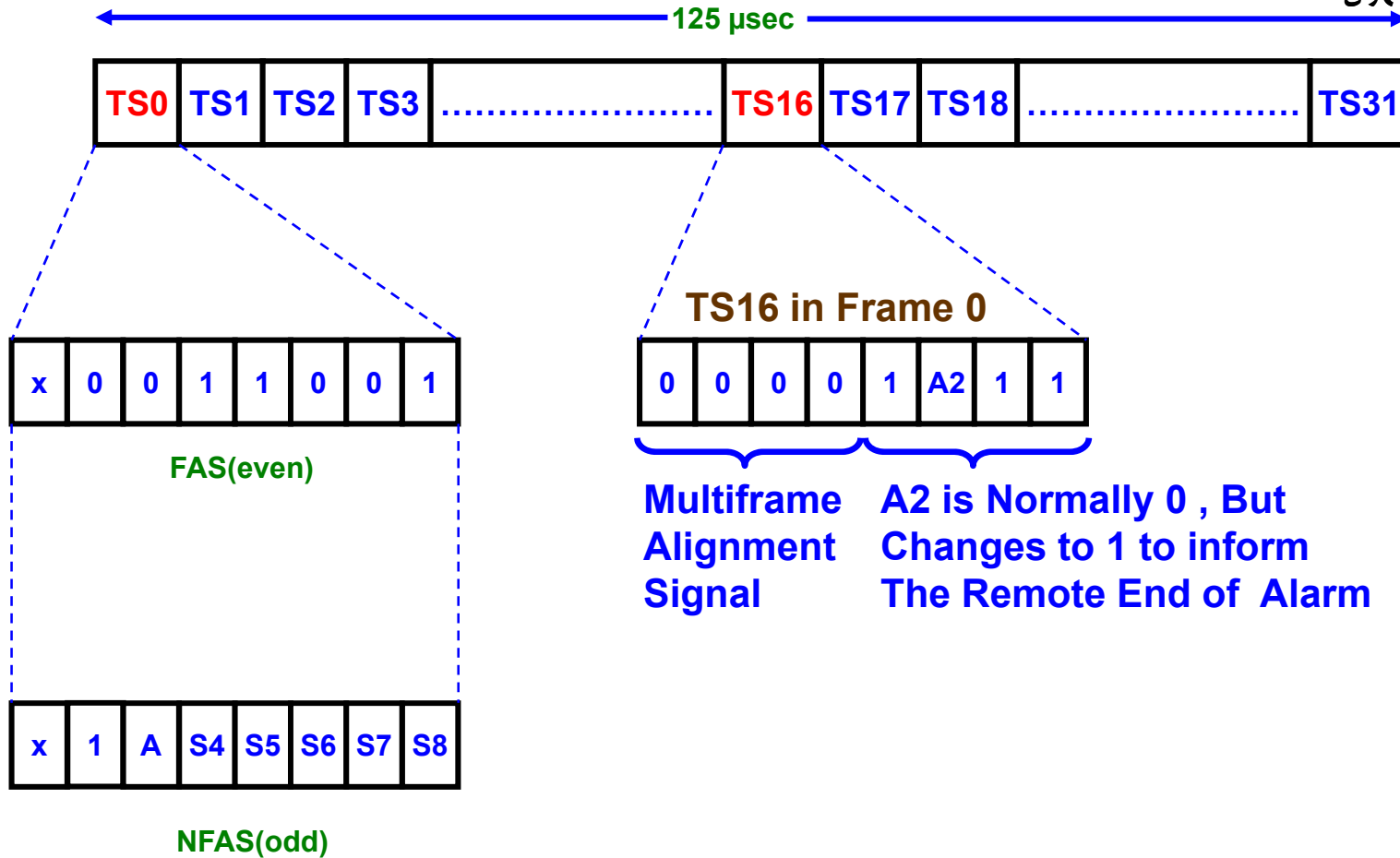
شاهین ارتباط تهران



2Mbps Frame

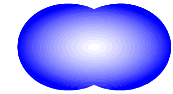


شاهین ارتباط تهران

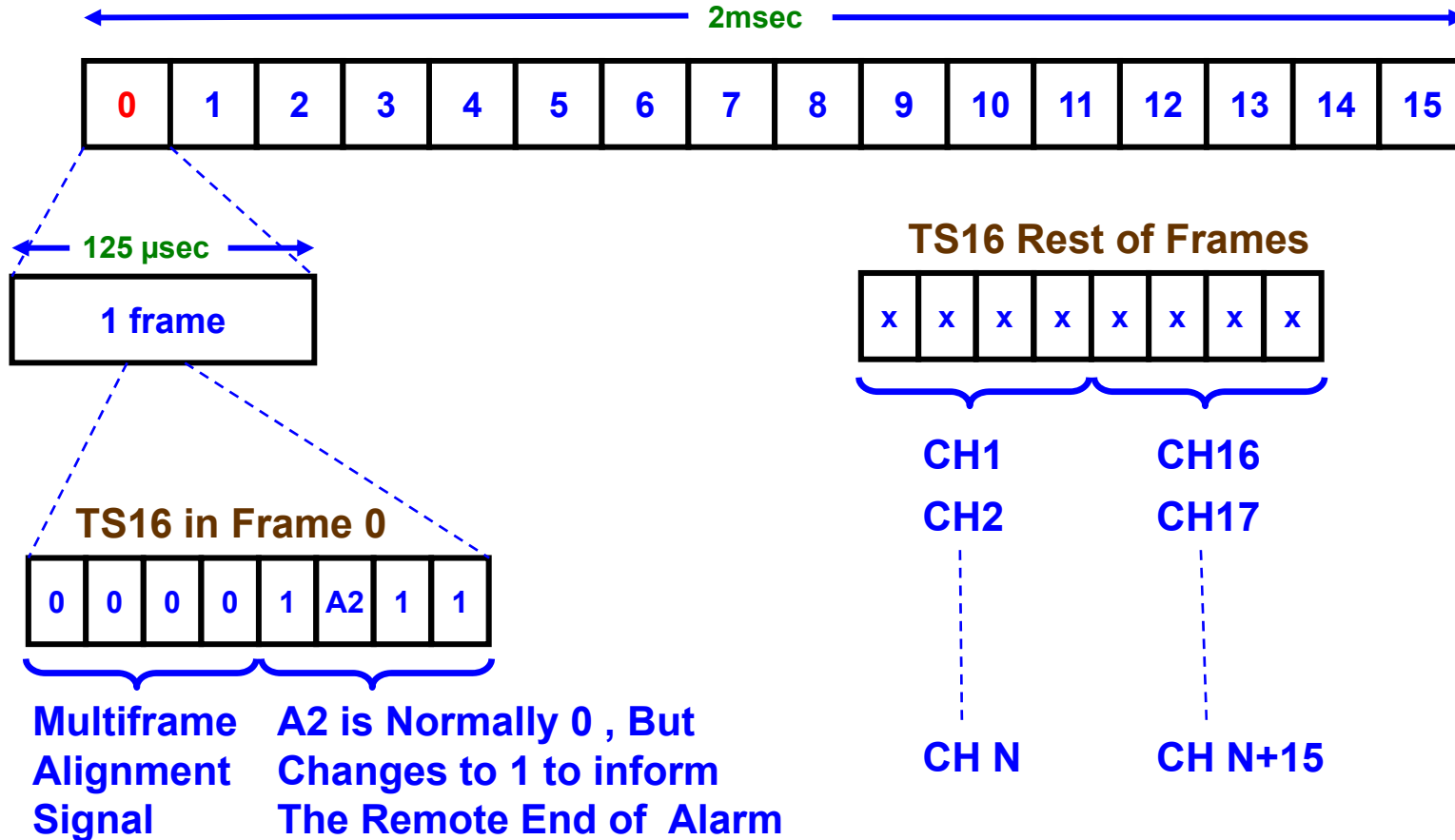


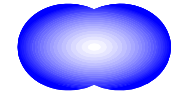
A = Remote Alarm Indicator

Multiframe



شاهین ارتباط تهران



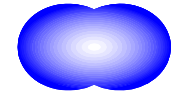


شاهین ارتباط تهران

PDH

(Plesiochronous Digital Hierarchy)

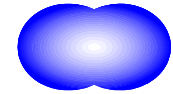
PDH hierarchy



شاهین ارتباط تهران

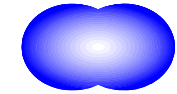
- **Plesiochronous** means **nearly synchronous**.
- This process is known as **plesiochronous operation**, from **Greek**, meaning "almost synchronous".
- The use of plesiochronous operation throughout the hierarchy has led to adoption of the term "**plesiochronous digital hierarchy**", or PDH.
- Thus, before these 2 Mbit/s channels can be bit interleaved they must all be brought up to the same bit rate adding 'dummy' information bits, or 'justification bits'. The justification bits are recognized as such when demultiplexing occurs, and discarded, leaving the original signal.

PDH hierarchy



شاهین ارتباط تهران

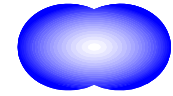
- 2 Mbit/s service signals are multiplexed to 140 Mbit/s for transmission over optical fiber or radio.
- Multiplexing of 2 Mbit/s to 140 Mbit/s requires two intermediate multiplexing stages of 8 Mbit/s and 34 Mbit/s.
- Before SDH transmission networks were based on the PDH hierarchy.
- Multiplexing of 2 Mbit/s to 140 Mbit/s requires multiplex equipment known as 2, 3 and 4 DME.
- 2 Mbit/s service signals are multiplexed to 140 Mbit/s for transmission over optical fiber or radio.
- Alarm and performance management requires separate equipment in PDH.



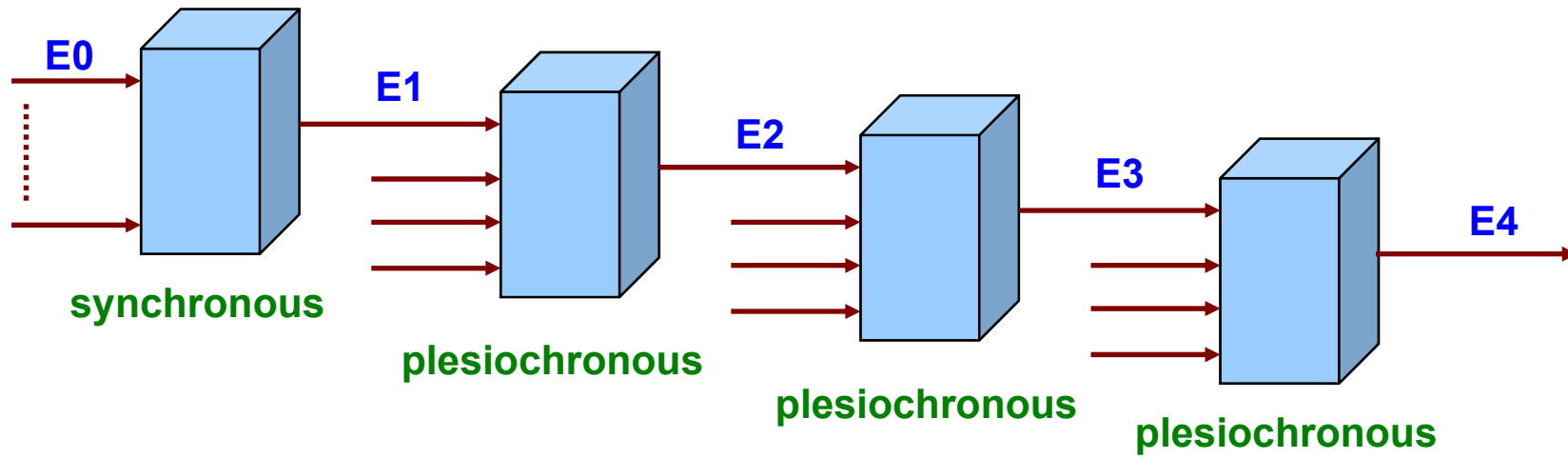
PDH Hierarchy

Hierarchy Level	(Eu)		(USA)	
	۰	64 Kbit/s	E0	64 Kbit/s
۱	2.048 Mbit/s	E1(32x)	1.544 Mbit/s	T1(24x)
۲	8.448 Mbit/s	E2(4x)	6.312 Mbit/s	DS-2(4x)
۳	34.368 Mbit/s	E3(4x)	44.736 Mbit/s	DS-3(7x)
۴	139.264 Mbit/s	E4(4X)		

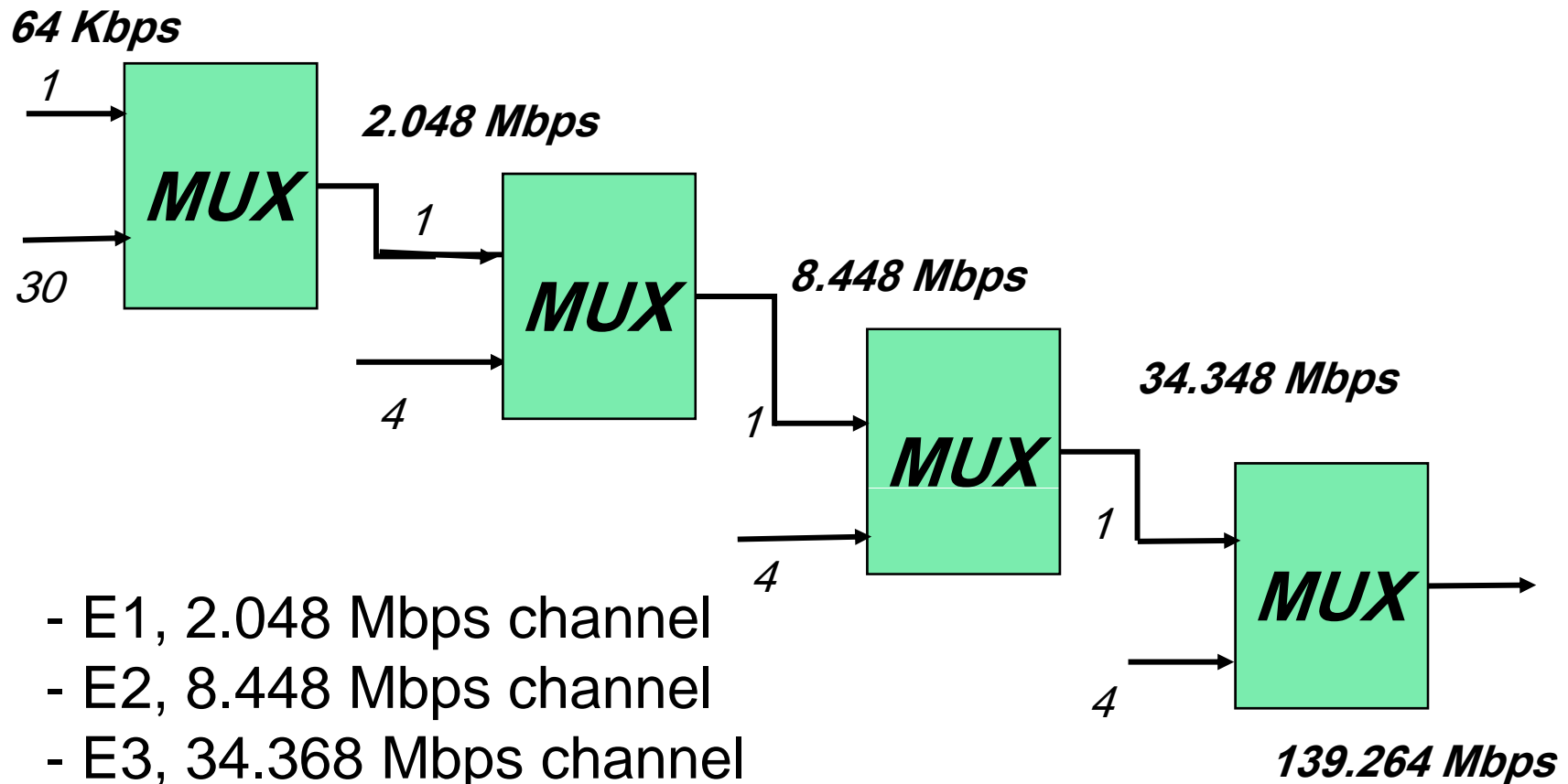
PDH Multiplexing



شاهین ارتباط تهران

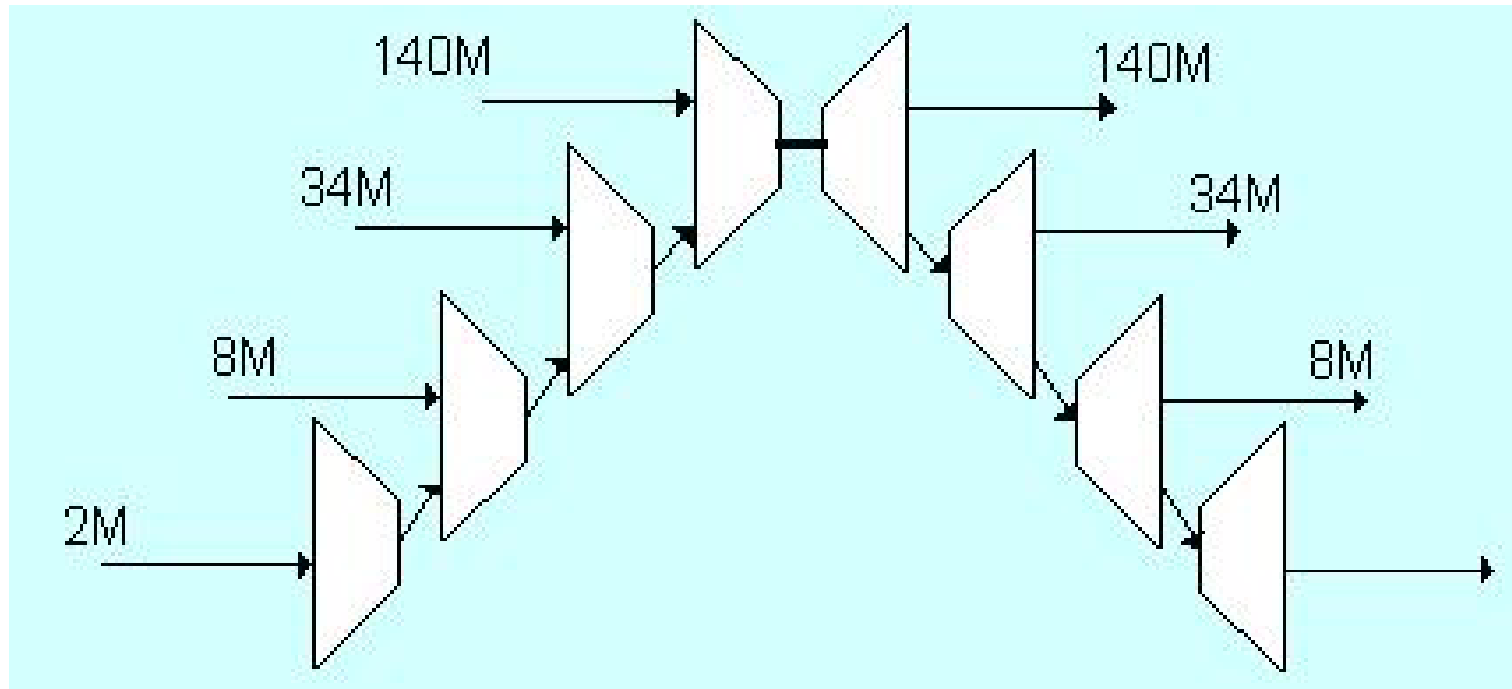


ITU-T Digital Hierarchy

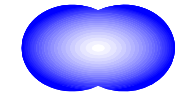


- E1, 2.048 Mbps channel
- E2, 8.448 Mbps channel
- E3, 34.368 Mbps channel
- E4, 139.264 Mbps channel

PDH network elements



PDH vs. SDH Hierarchy



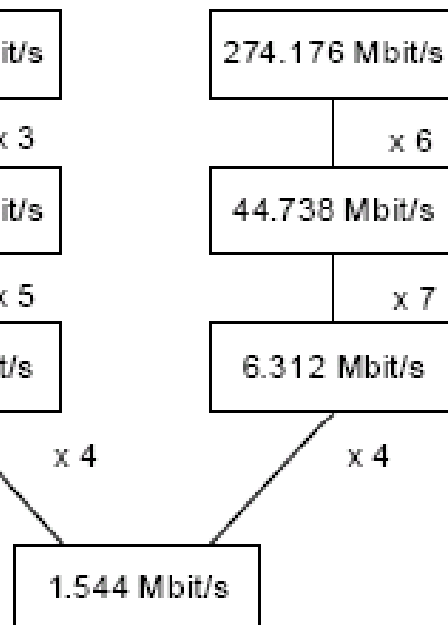
شاهین ارتباط تهران

- PDH transmission rates:

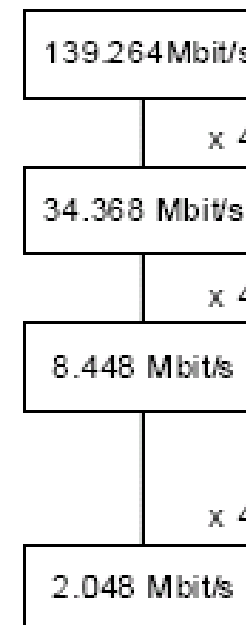
Japan



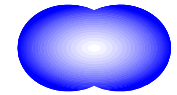
North America



Europe



Disadvantages of PDH



شاهین ارتباط تهران

1. Interfaces

Electrical interfaces

- Only regional standards, 3 PDH rate hierarchies for PDH: European (2.048Mb/s), Japanese, North American (1.544 Mb/s).

Optical interfaces

- No standards for optical line equipment, manufacturers develop at their will.

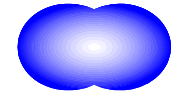
2. Multiplexing methods

Asynchronous Multiplexing for PDH

The location of low-rate signals in high-rate signals is not regular nor predictable.

Plesiochronous
Digital Hierarchy

Disadvantages of PDH



شاهین ارتباط تهران

3. OAM function

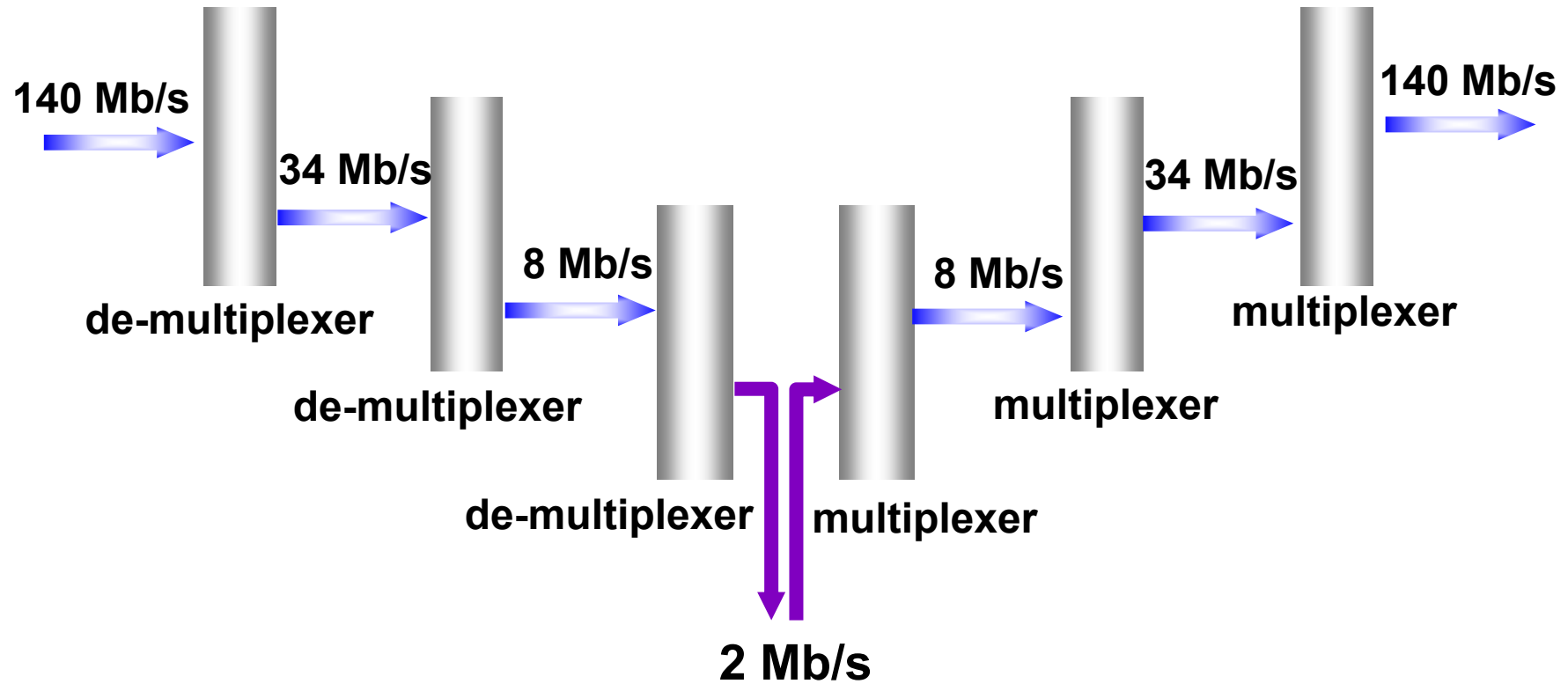
- Weak Operation, Administration & Maintenance function.
- Provisioning circuits is time consuming & labor-intensive.

4. No universal network management interface

- Capabilities to setup a TMN is limited.

Telecommunications Management
Network

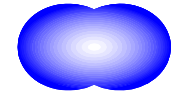
Disadvantages of PDH



level by level

Not suitable for huge-volume transmission

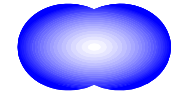
PDH problems



شاهین ارتباط تهران

- The use of justification bits at each level in the PDH means that identifying **the exact location of the frames in a single 2 Mbit/s** line within say a 140 Mbit/s channel is **impossible**.
- In order to access a single 2 Mbit/s line the 140 Mbit/s channel must be completely demultiplexed to its 64 constituent 2 Mbit/s lines via 34 and 8 Mbit/s. Once the required 2 Mbit/s line has been identified and extracted, the channels must then be multiplexed back up to 140 Mbit/s.

PDH problems

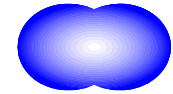


شاهین ارتباط تهران

- PDH has reached a point where it is no longer sufficiently flexible or efficient to meet the demands being placed on it. As a result, synchronous transmissions has been developed to overcome the problems associated with plesiochronous transmission, in particular the inability of PDH to extract individual circuits from high capacity systems without having to demultiplex the whole system.

Conclusion

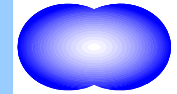
Problems of PDH



شاهین ارتباط تهران

- The Plesiochronous Digital Hierarchy had a number of problems:
- Each multiplexing section has to add overhead bits for justification (higher rate -> more overhead)
 - Each part of the world has its own transmission hierarchy (expensive interconnection equipment)
 - **Justification** (bit stuffing) spreads data over the frame
 - add-drop-multiplexers are hard to build
 - extract a single voice call -> demultiplex all steps down
 - switching of bundles of calls ($n * 64$ kbit/s) is difficult
 - (every switch has to demultiplex down to DS0 level)
 - The **management and monitoring** functions were not sufficient in PDH
 - PDH did **not define a standard format** on the transmission link
 - Every vendor used its own line coding, optical interfaces etc.
 - Very hard to interoperate

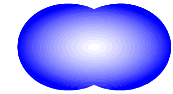
The History of Digital Transmission



شاهین ارتباط تهران

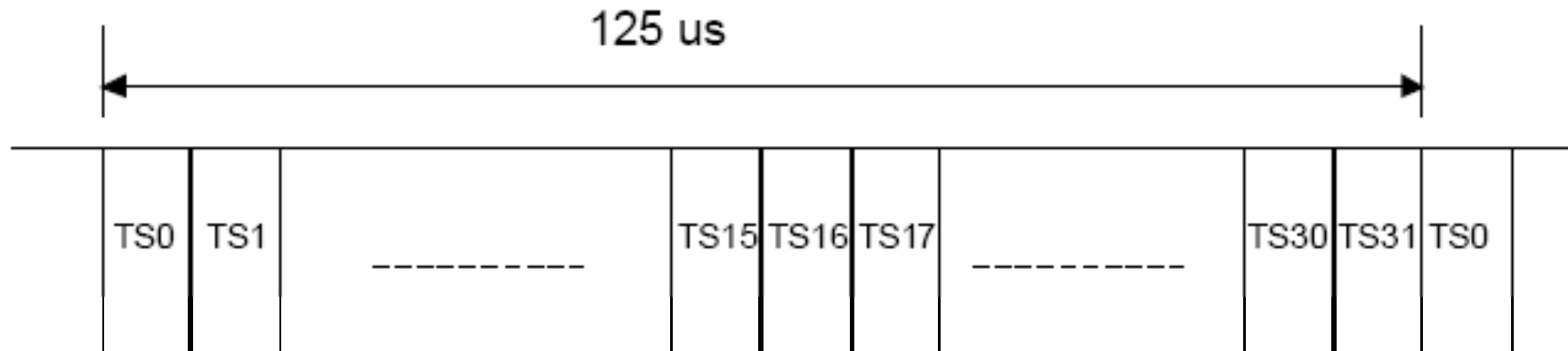
- 1970 - introduction of PCM into Telecom networks, 32 PCM streams are Synchronously Multiplexed to 2.048 Mbit/s (E1), Multiplexing to higher rates via PDH
- 1985 Bellcore proposes SONET
- 1988 **SDH** standard introduced.

Heritage of PCM

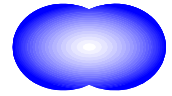


شاهین ارتباط تهران

- The SDH frame rate is inherited from PCM.
- As with PCM, the SDH has 8 bits per time slot.
- As with PCM, the SDH frame rate is 125 us per frame.
- The following diagram shows the PCM30 frame:



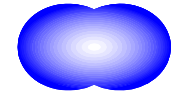
SDH



شاهین ارتباط تهران

Synchronous Digital Hierarchy

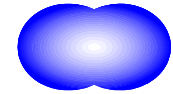
SDH – Introduction



شاهین ارتباط تهران

- SONET Started by Bellcore in 1985 as standardisation effort for the US telephone carriers (after AT&T was broken up in 1984),
- Later joined by CCITT (later: ITU), which formed SDH in 1987
- Three major goals:
 - Avoid the problems of PDH
 - Achieve higher bit rates (Gbit/s)
 - Better means for Operation, Administration, and Maintenance (OAM)
- SDH is THE standard in telecommunication networks now
- It is designed to transport voice rather than data
- **It covers the lower 2-3 OSI layers**
- SONET/SDH defines only a point-to-point connection in the network

Emergence of SDH



شاهین ارتباط تهران

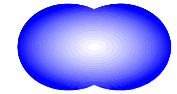
**What is
SDH?**

- Synchronous Digital Hierarchy
- It defines frame structure, multiplexing method, digital rates hierarchy and interface code pattern.

**Why did SDH
emerge?**

- Need for a system to process increasing amounts of information.
- New standard that allows mixing equipment from different suppliers.

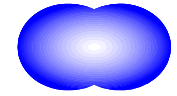
Why did SDH emerge ?



شاهین ارتباط تهران

- Existence of disadvantages in PDH transmission system
- Existence of advantages in SDH transmission system

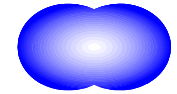
The goal of SDH



شاهین ارتباط تهران

- The SDH defines a structure which enables **plesiochronous** signals to be combined together and encapsulated within a standard SDH signal. This protects network operators' investment in plesiochronous equipment, and enables them to deploy synchronous equipment in a manner suited to the particular needs of their network.

What is SDH?



شاهین ارتباط تهران

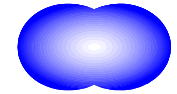
- The basis of Synchronous Digital Hierarchy (SDH) is **synchronous multiplexing** - data from multiple tributary sources is byte interleaved.
- In SDH the multiplexed channels are in fixed locations relative to the framing byte.
- Demultiplexing is achieved by gating out the required bytes from the digital stream.
- This allows a single channel to be 'dropped' from the data stream without demultiplexing intermediate rates as is required in PDH.

SDH multiplexing includes two types:



Multiplexing of lower-order SDH signals into higher –order signals **and** multiplexing of low –rate signals (e.g. 2 Mbps, 34 Mbps and 140 Mbps) into signals... STM-N

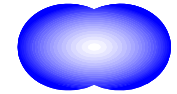
A glance to SDH



شاهین ارتباط تهران

- Electrical Interface
- Optical interface
- Multiplexing method
- Operation, administration and maintenance
- Compatibility

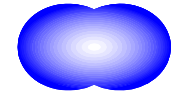
Advantages of SDH 1



شاهین ارتباط تهران

- Worldwide standard
- First standard for bit rates higher than 45/140 Mbps
- Standardized optical interfaces simple coding of the electrical signal into the line signal (scrambling) Integration of multiplexer and line equipment
- Huge overhead capacity for error monitoring and for management purposes (TMN)
- Direct access to tributary channels
- Only small buffers required --> small group delay figures

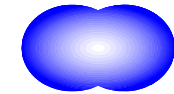
Advantages of SDH 2



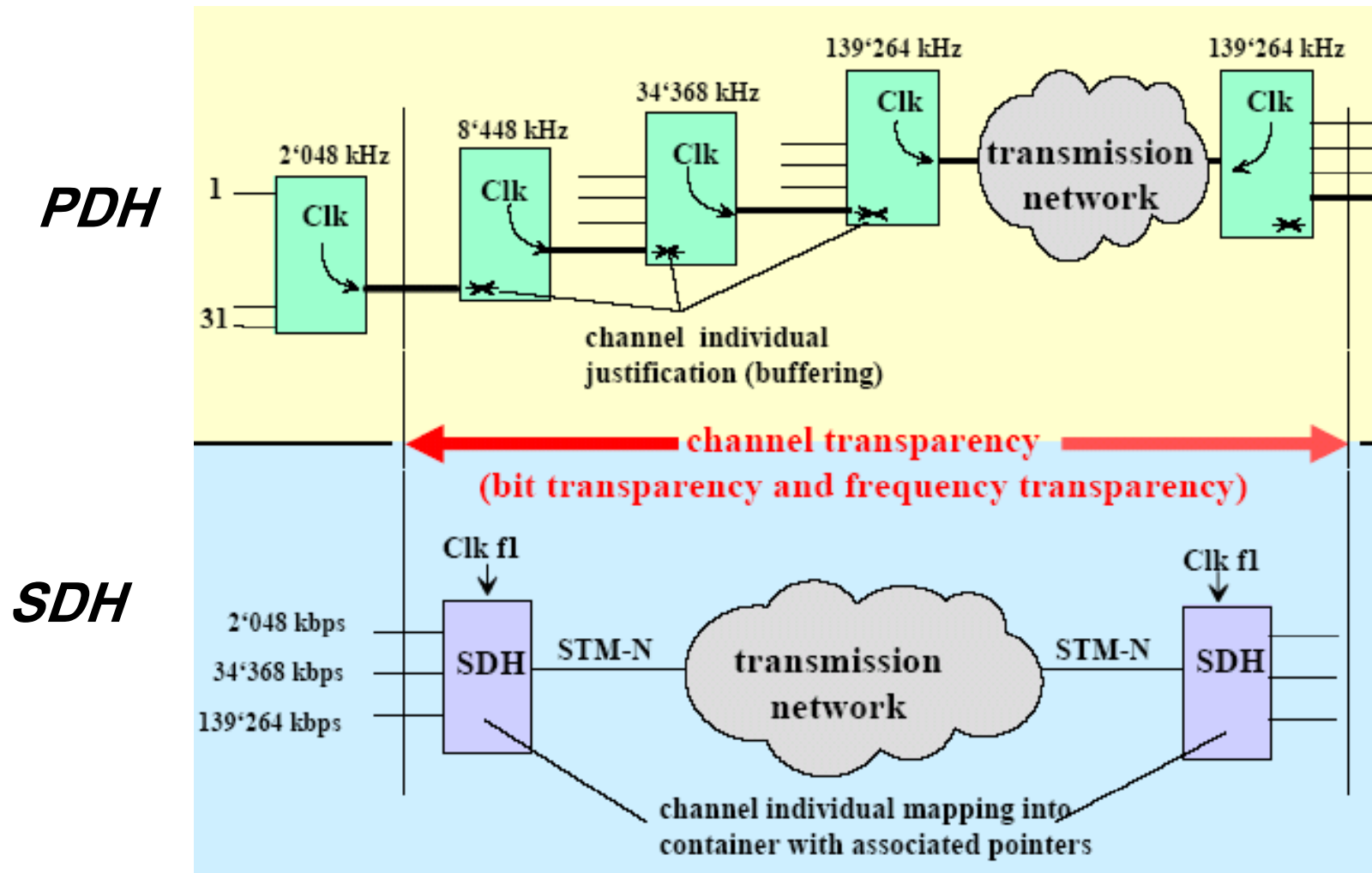
شاهین ارتباط تهران

- Provides concept for clock/synchronization, protection switching etc.
- Suitable as the physical layer of ATM networks
- Optical Interface only scrambles the electrical signal
- The optical code pattern SDH uses is Scrambled NRZ
- Synchronous multiplexing method and flexible mapping structure
- Use multistage pointer to align PDH loads in SDH frame, thus, dynamic drop-and-insert capabilities

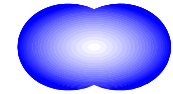
Comparison of PDH and SDH Clocking Scheme



شاهین ارتباط تهران



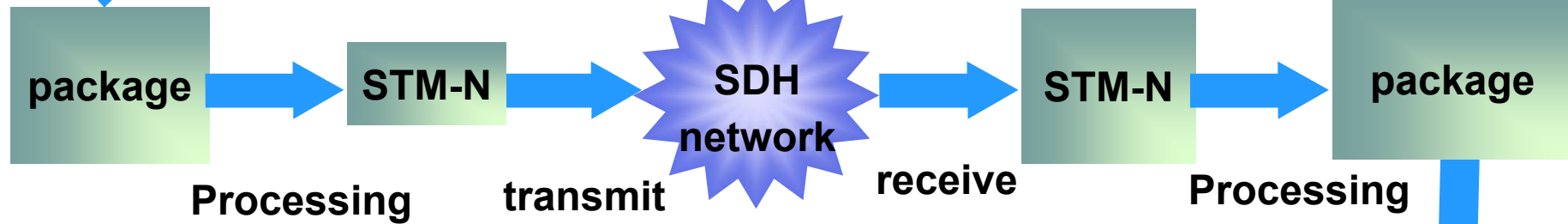
SDH Compatibility



شاهین ارتباط تهران

PDH, SDH, ATM,
FDDI Signals

packing

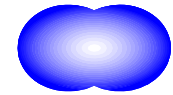


unpacking

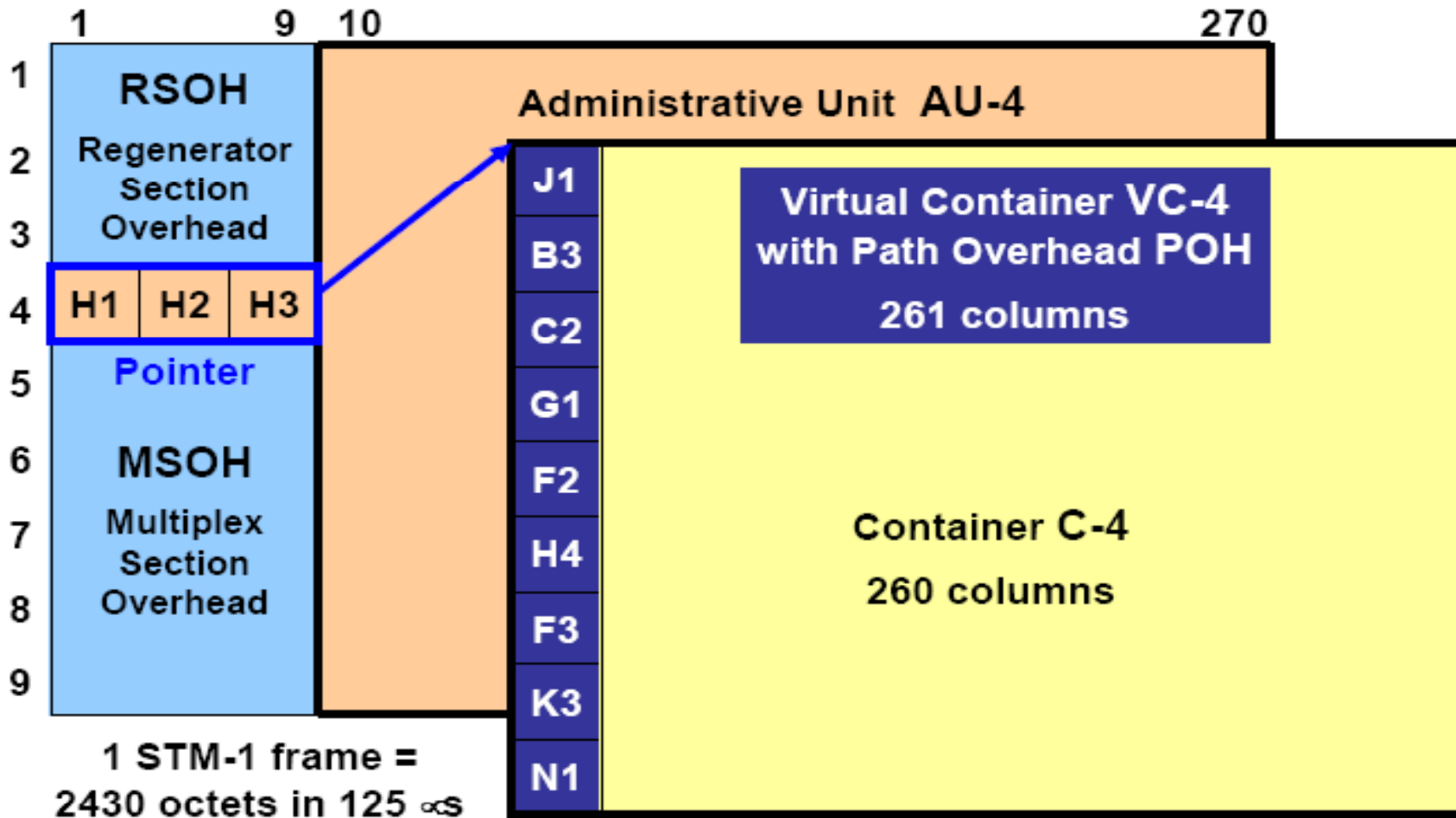
PDH, SDH,
ATM, FDDI
Signals

SDH Frame Structure

Synchronous Transmission Module STM-1

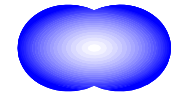


شاهین ارتباط تهران



SDH Overhead

STM-1 Section Overhead (SOH)

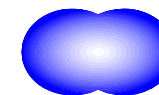


شاهین ارتباط تهران

- Nine rows of nine bytes at the front of the SDH frame form the section overhead.
- The first three rows are the regenerator section overhead.
- The last six rows are the multiplex section overhead.

	1	2	3	4	5	6	7	8	9	
1	A1	A1	A1	A2	A2	A2	J0			RSOH
2	B1			E1			F1			
3	D1			D2			D3			
4	AU-4 Pointer									
5	B2	B2	B2	K1			K2			MSOH
6	D4			D5			D6			
7	D7			D8			D9			
8	D10			D11			D12			
9	S1					M1	E2			

SDH Frame Structure

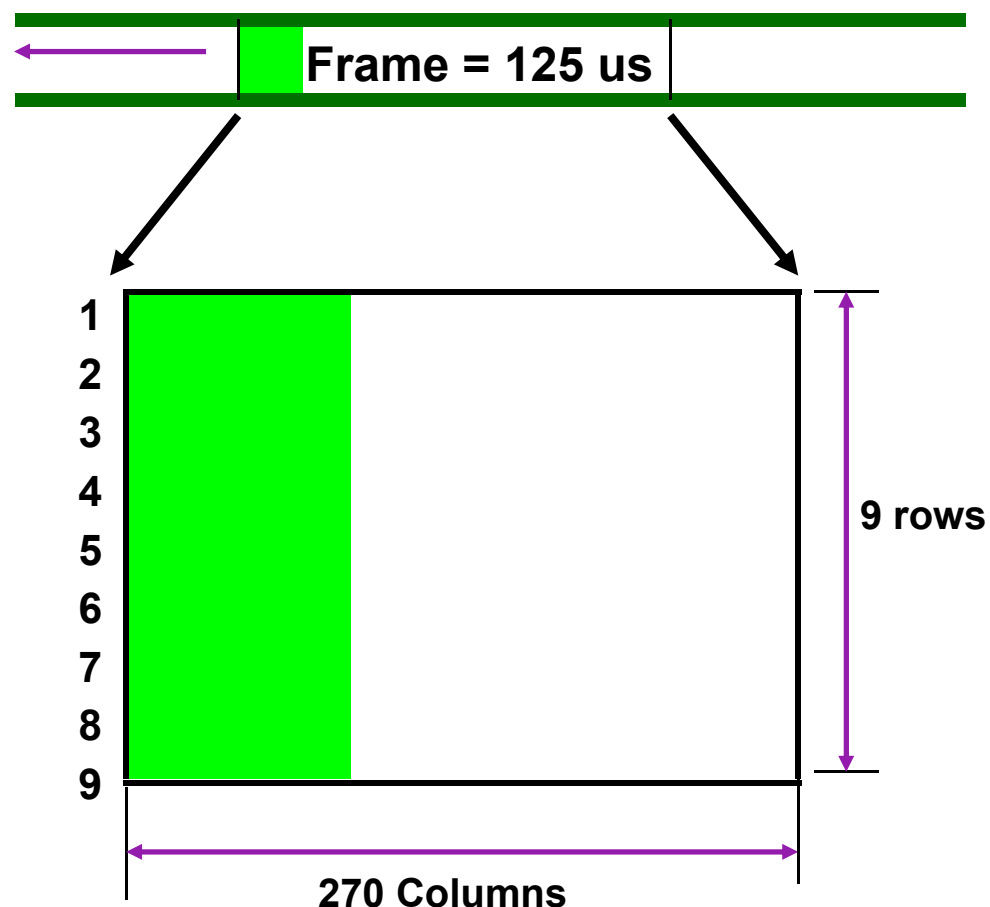


شاهین ارتباط تهران

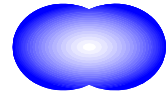
From ITU-T G.707:

1. STM-1 is the basic transmission format
2. One frame lasts for 125 microseconds (8000 frames/s)
3. Rectangular block structure 9 rows and 270 columns
4. Each unit is one byte (8 bits)
5. Transmission mode: Byte by byte, row by row, from left to right, from top to bottom

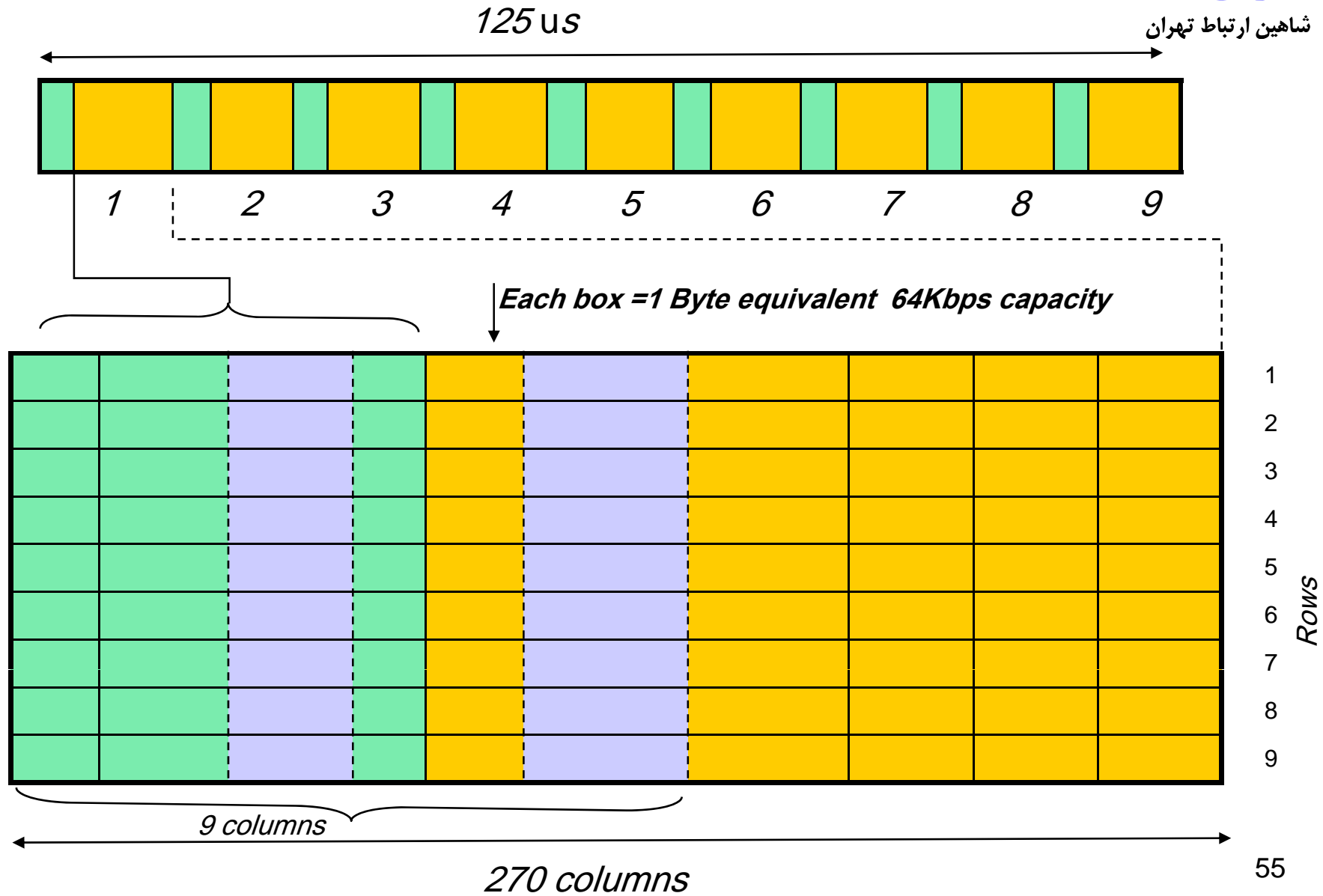
1 byte = One 64 kbit/s channel
STM-N = 9 X 270 X N (N = 4, 16, 64)



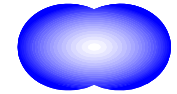
SDH Frame structure



شاهین ارتباط تهران

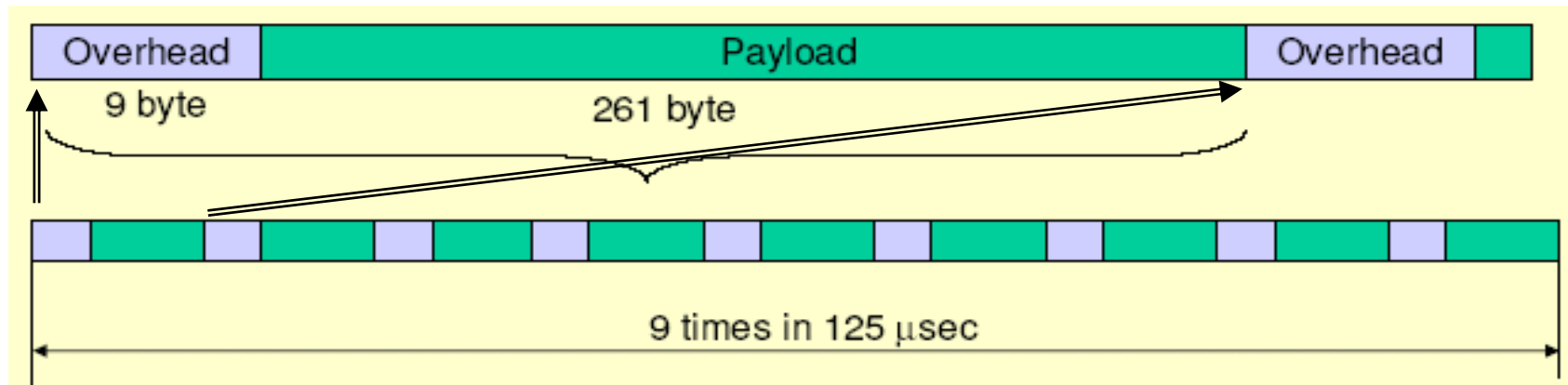


SDH - Framing



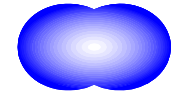
شاهین ارتباط تهران

Frame format in SDH:



- Sampling rate of a 3400 Hz voice channel -> 8000 Hz
- $8000 \text{ Hz} * 1 \text{ byte} = 64 \text{ kbit/s}$
- $9 * 270 * 8 \text{ bit} * 8000 \text{ Hz} = 155.52 \text{ Mbit/s}$
- Basic data rate in SDH
- STM-1 -> Synchronous Transport Module

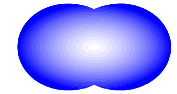
Transport of PDH payloads



شاهین ارتباط تهران

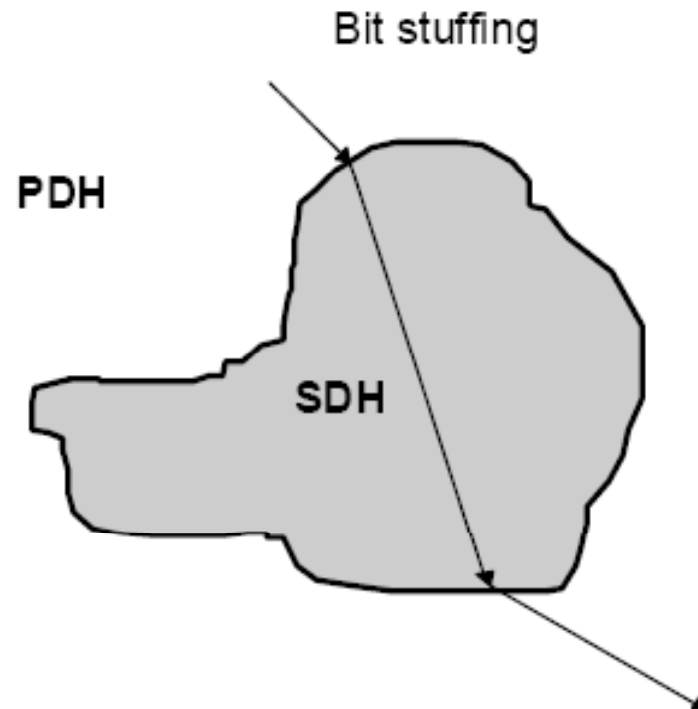
- SDH is essentially a transport mechanism for carrying a large number of PDH payloads.
- A mechanism is required to map PDH rates into the STM frame.
- This function is performed by the container (C).
- A PDH channel must be synchronised before it can be mapped into a container.
- The synchroniser adapts the rate of an incoming PDH signal to SDH rate.

SDH and non-synchronous signals

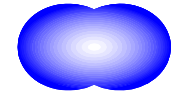


شاهین ارتباط تهران

- At the PDH/SDH boundary Bit stuffing is performed when the PDH signal is mapped into its container.



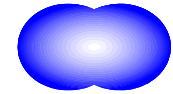
SDH virtual Containers



شاهین ارتباط تهران

- Once a container has been created, path overhead byte are added to create a virtual container.
- Path overheads contain alarm, performance and other management information.
- A path through an SDH network exists from the point where a PDH signal is put into a container to where the signal is recovered from the container.
- The path overheads travel with the container over the path.

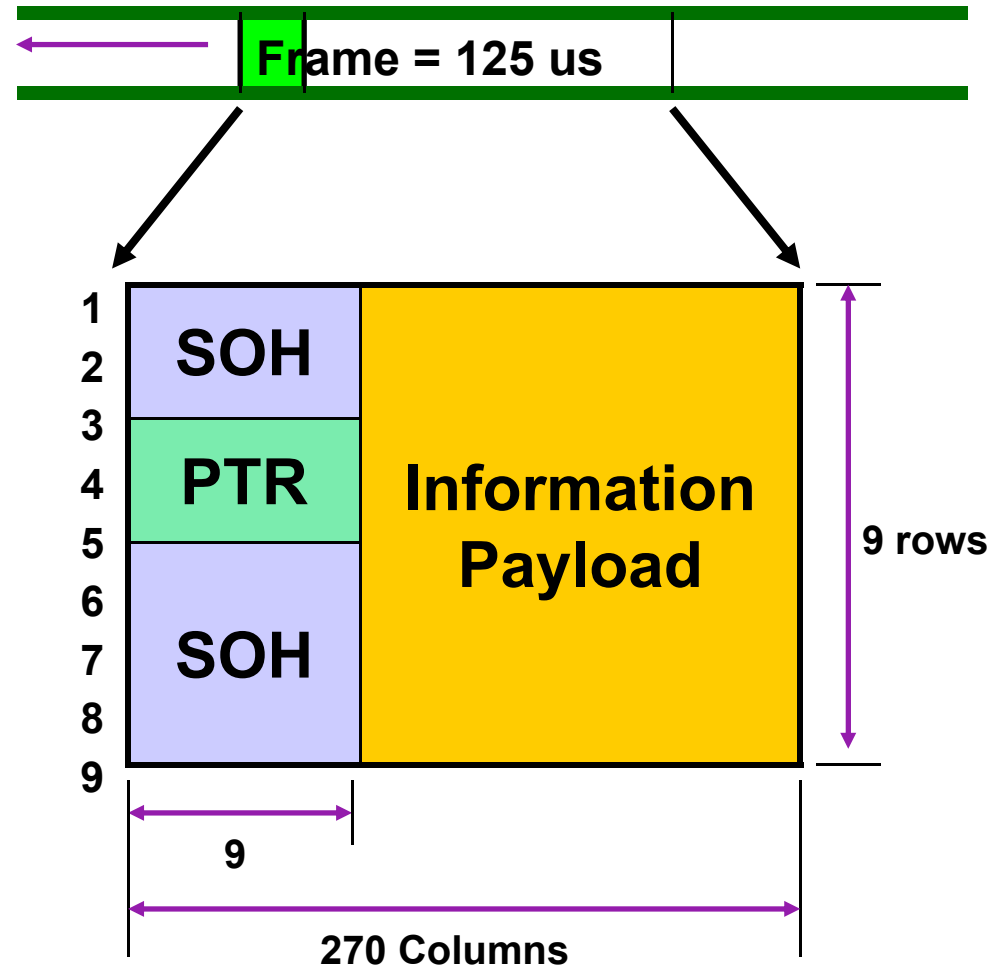
SDH Frame Structure



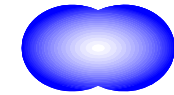
شاهین ارتباط تهران

Three parts:

1. Information Payload
2. Section Overhead
3. Pointer



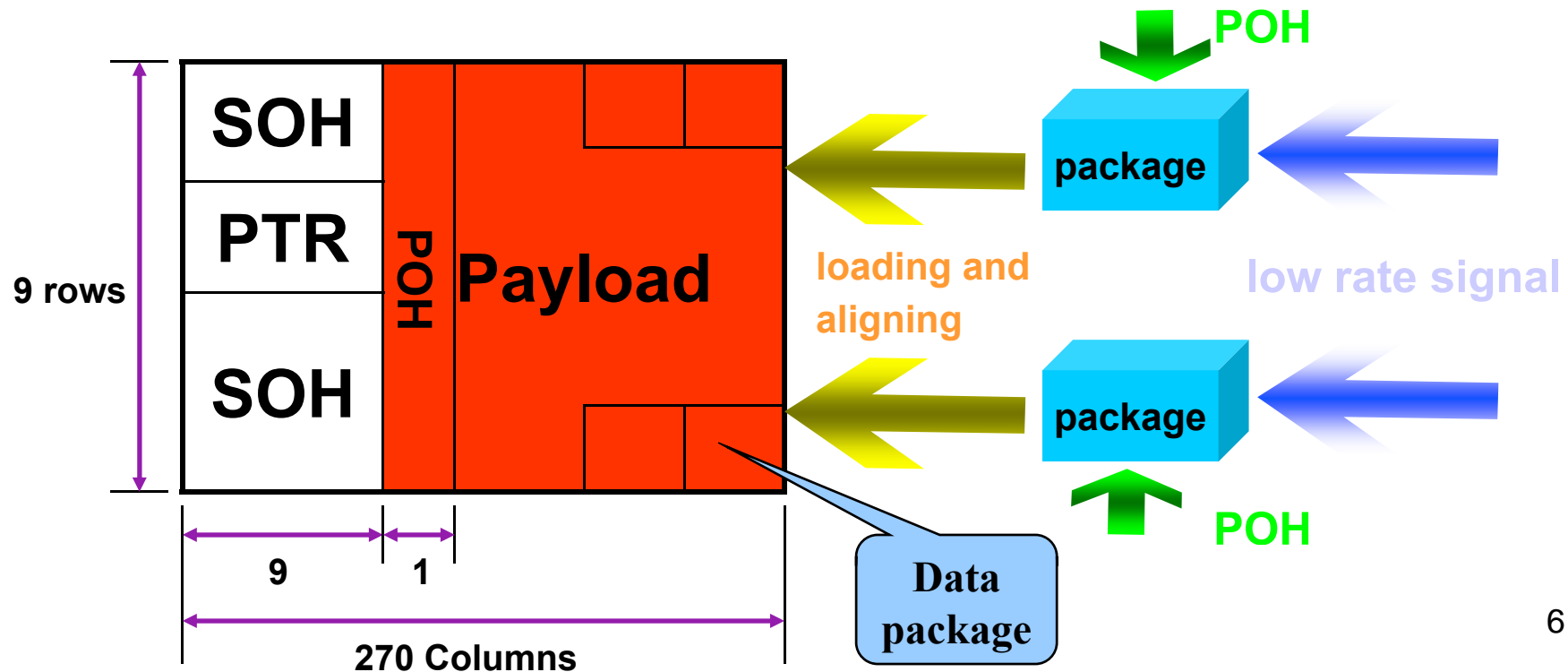
Information Payload



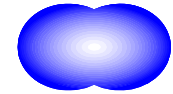
شاهین ارتباط تهران

Information Payload

- ✓ Also known as Virtual Container level 4 (VC-4)
- ✓ Used to transport low speed tributary signals
- ✓ Contains low rate signals and Path Overhead (POH)
- ✓ Location: rows #1 ~ #9, columns #10 ~ #270

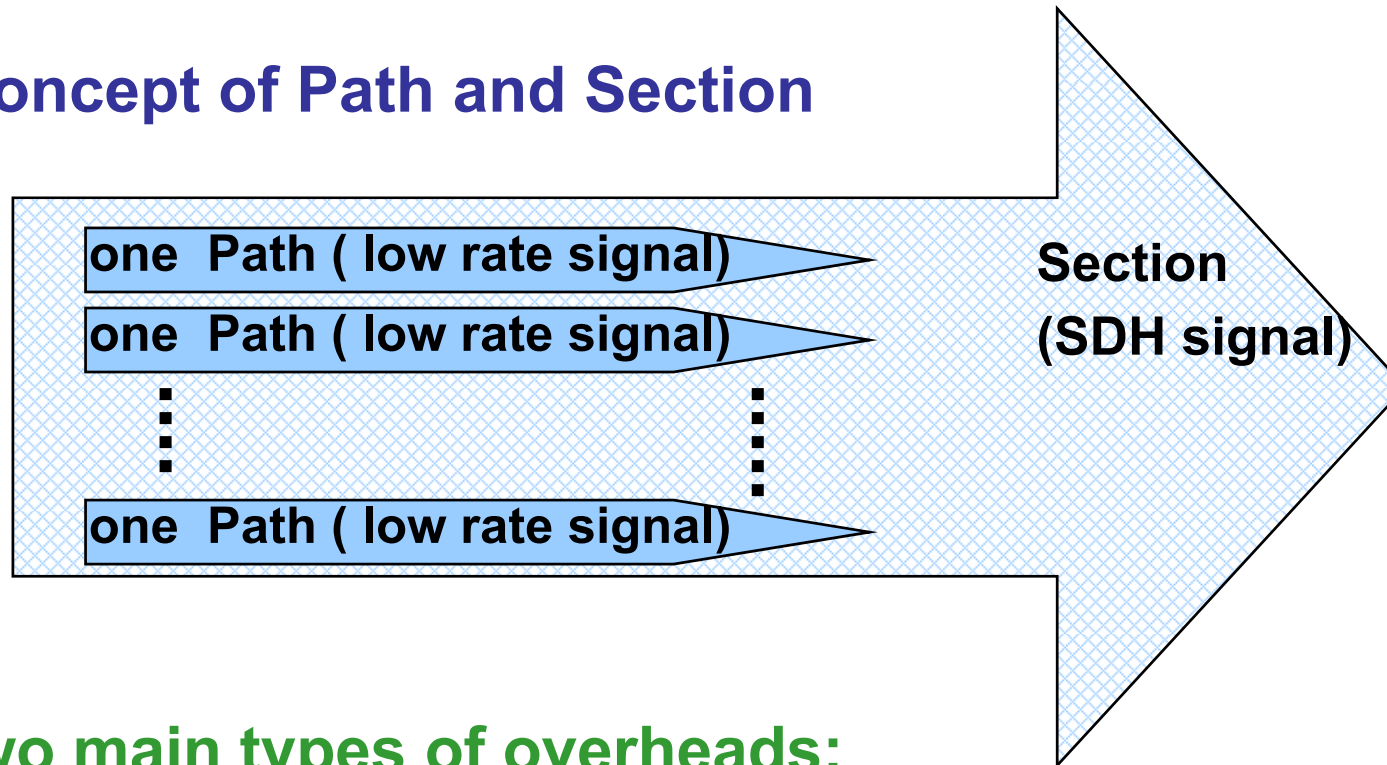


SDH Overhead



شاهین ارتباط تهران

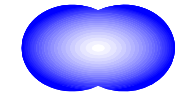
Concept of Path and Section



Two main types of overheads:

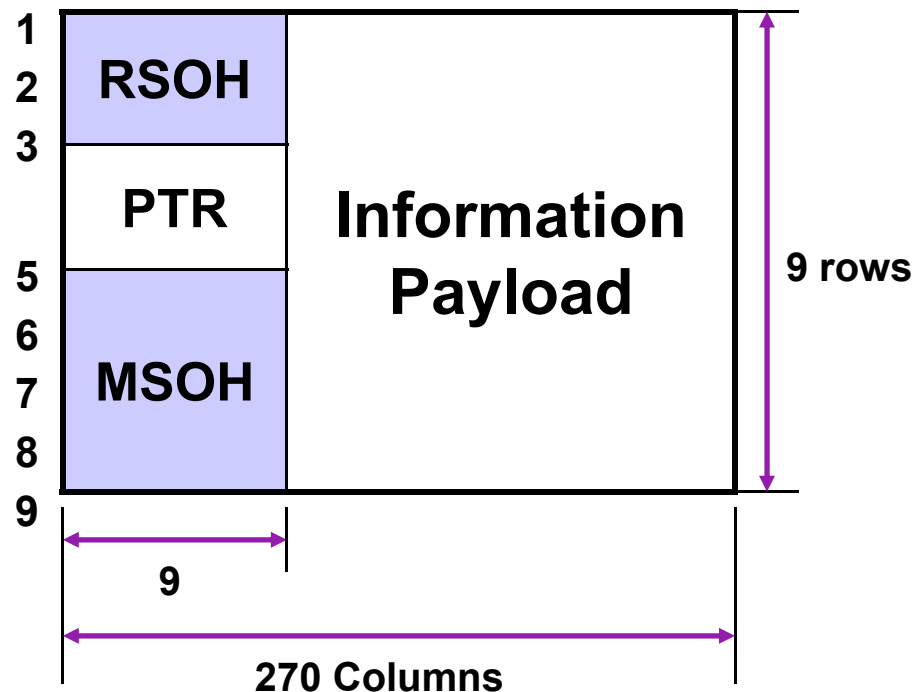
- 1. Section Overhead**
- 2. Path Overhead**

Section Overhead



شاهین ارتباط تهران

Fulfills the section layer OAM functions



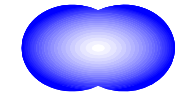
Types of Section Overhead

1. Regenerator Section Overhead (RSOH), monitors the whole STM-N
2. Multiplex Section Overhead (MSOH), monitors STM-1 in STM-N

✓ Location:

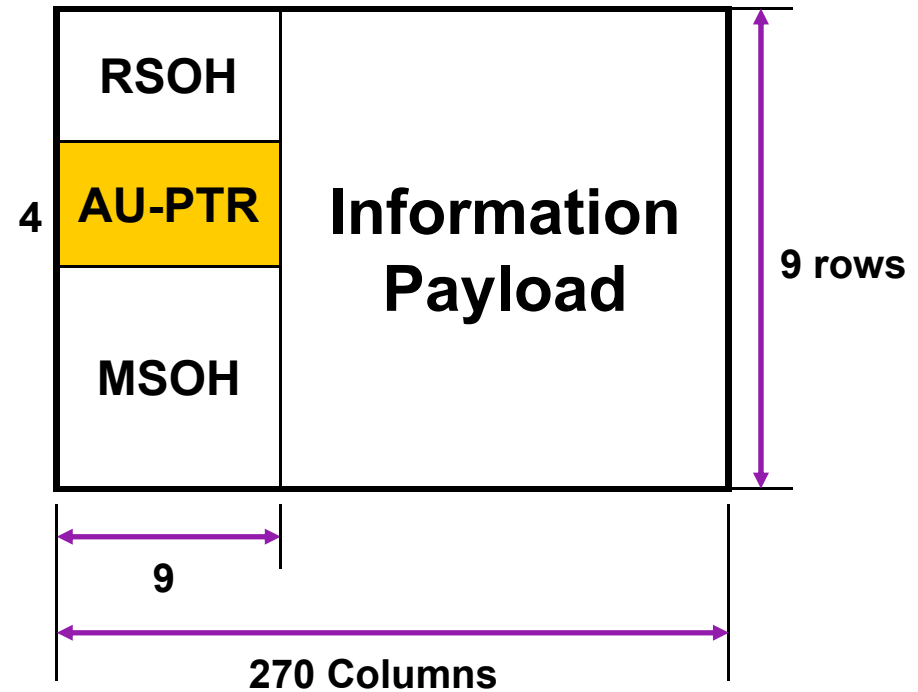
1. RSOH: rows #1 ~ #3, columns #1 ~ #9
2. MSOH: rows #5 ~ #9, columns #1 ~ #9

Pointer

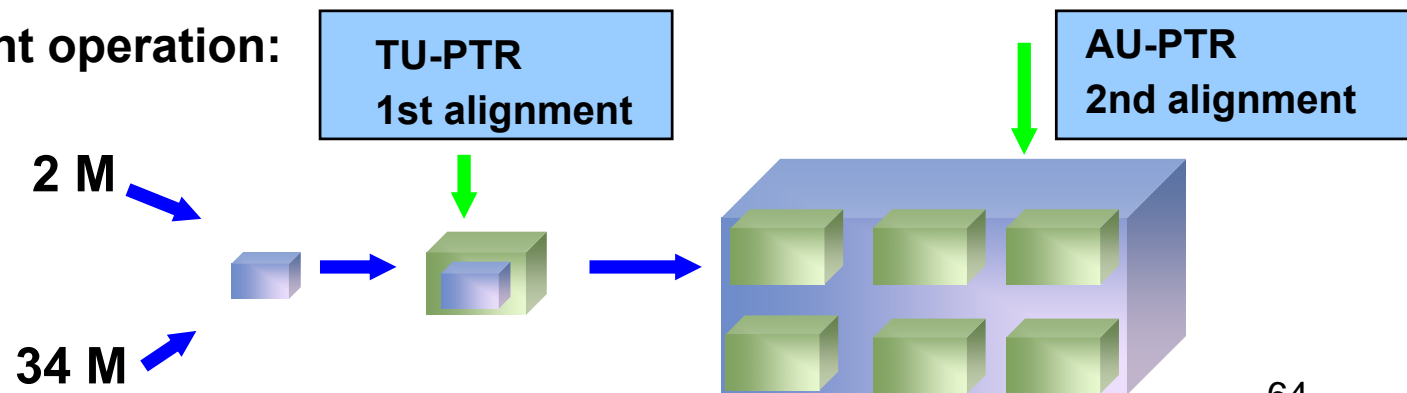


شاهین ارتباط تهران

- ✓ Indicates the first byte of the payload container
- ✓ Pointers permit phase and frequency differences of the VCs
- ▶ Location:
row #4, columns #1 ~ #9



Two stage alignment operation:



SDH Multiplexing



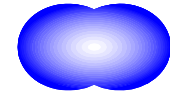
SDH Multiplexing includes:

- ✓ Low to high rate SDH signals (STM-1 → STM-N)
- ✓ PDH to SDH signals (2M, 34M & 140M → STM-N)
- ✓ Other hierarchy signals to SDH Signals (ATM → STM-N)

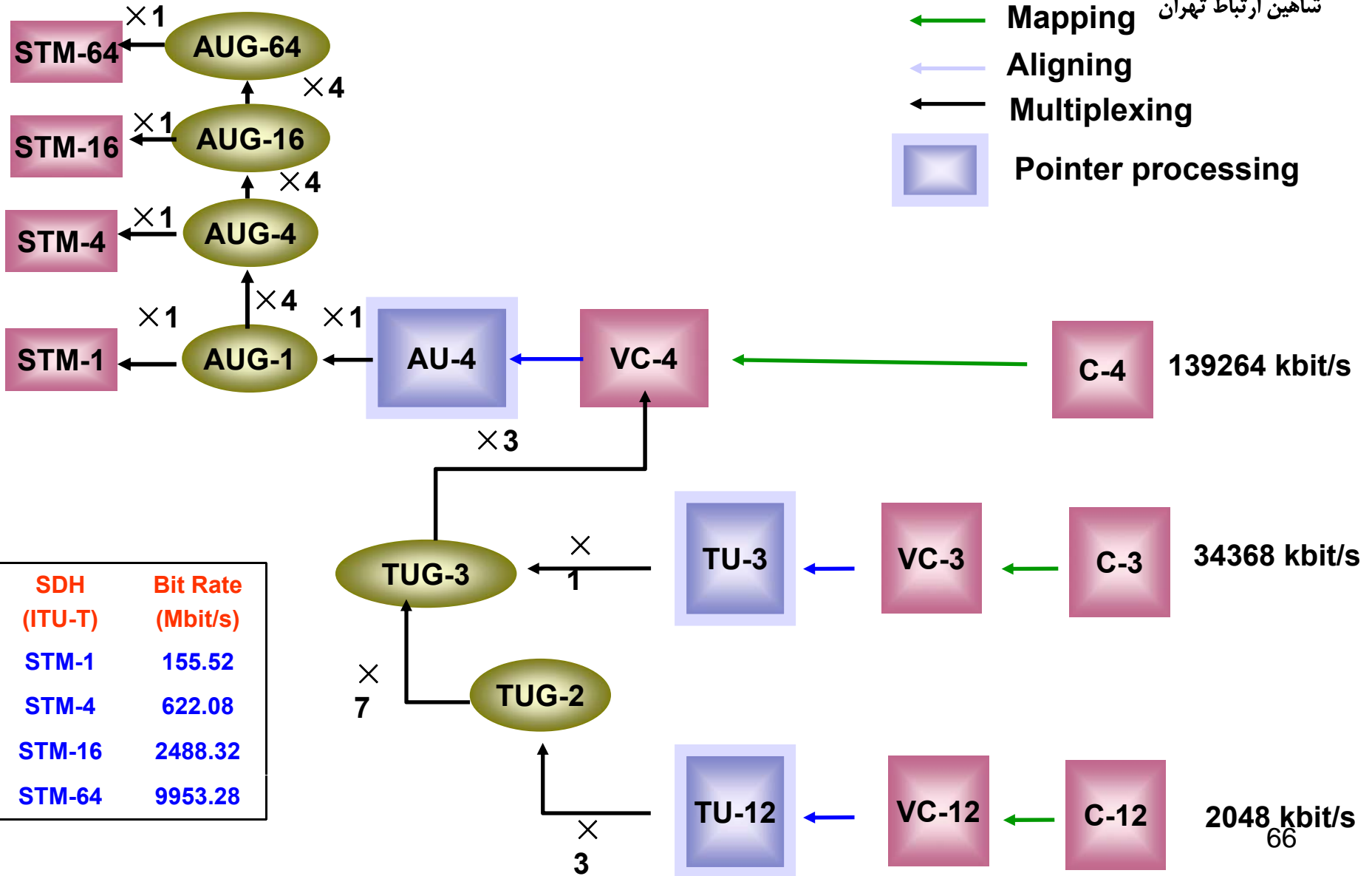
Some terms and definitions:

- ▶ Mapping
- ▶ Aligning
- ▶ Multiplexing
- ▶ Stuffing

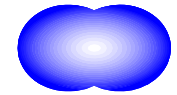
SDH Multiplexing Hierarchy ETSI Branch



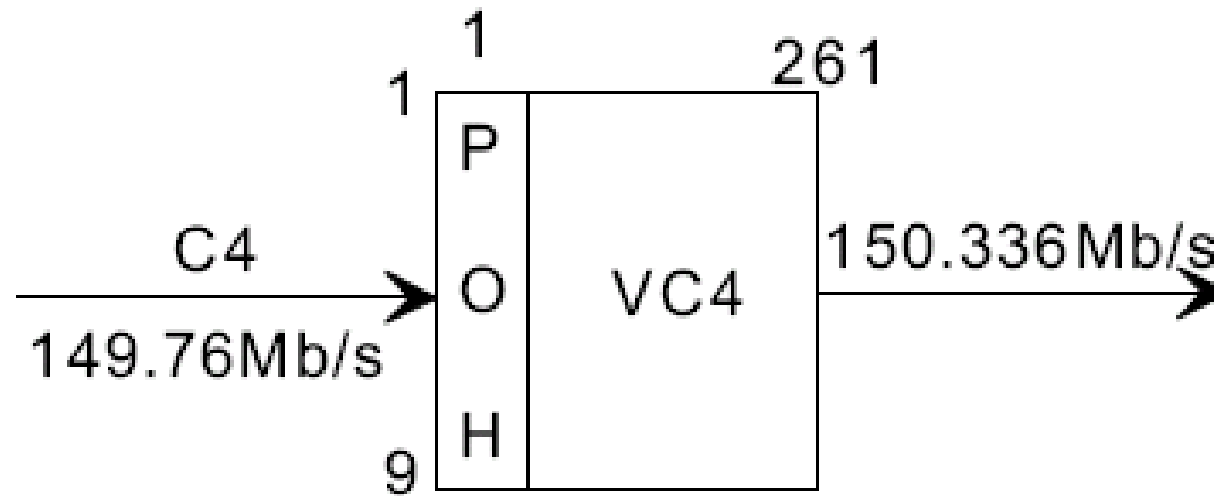
شاهین ارتباط تهران



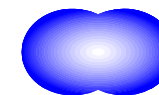
VC-4 Structure



شاهین ارتباط تهران

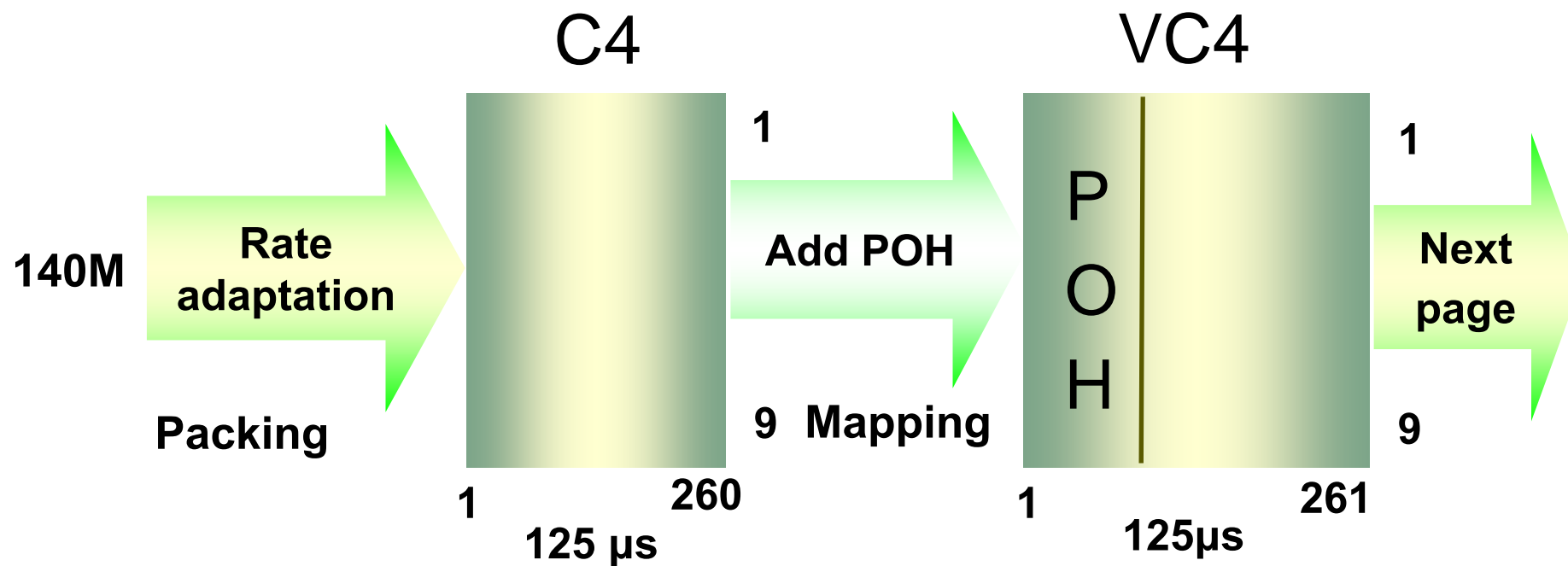


SDH Tributary Multiplexing (140M)

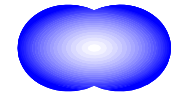


شاهین ارتباط تهران

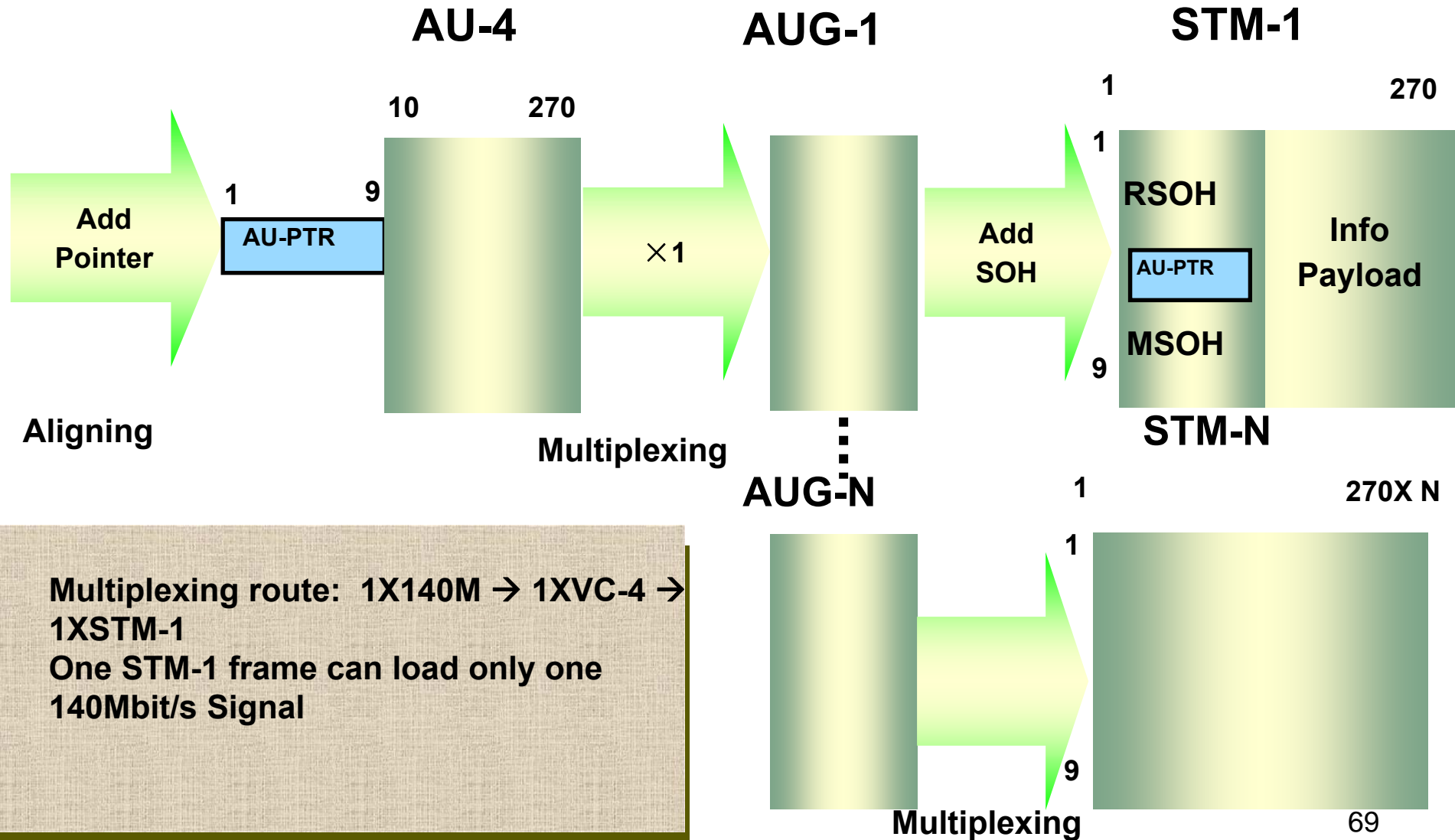
140 Mbit/s to STM-N



SDH Tributary Multiplexing (140M)



شاهین ارتباط تهران

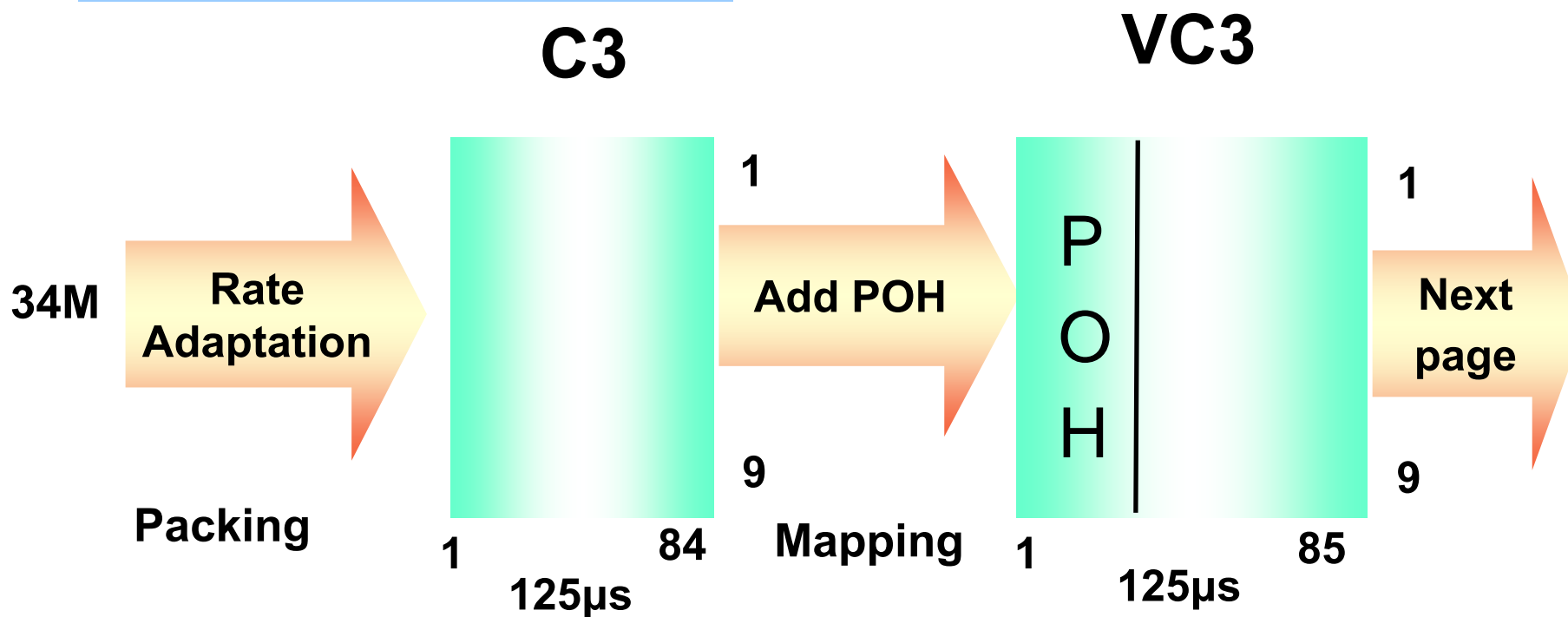


Multiplexing route: 1X140M → 1XVC-4 → 1XSTM-1
 One STM-1 frame can load only one 140Mbit/s Signal

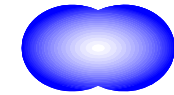
SDH Tributary Multiplexing (34M)



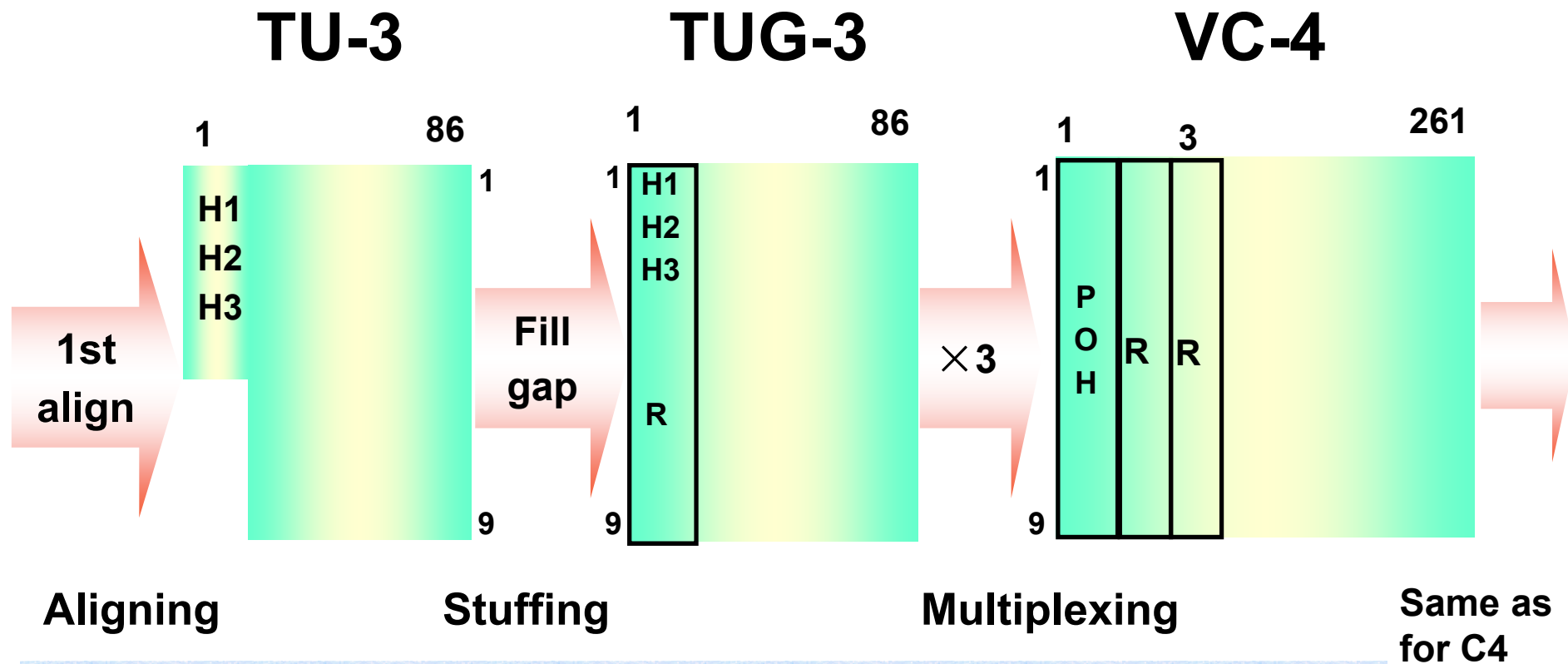
34 Mbit/s to STM-N



SDH Tributary Multiplexing (34M)

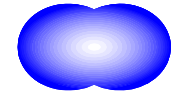


شاهین ارتباط تهران



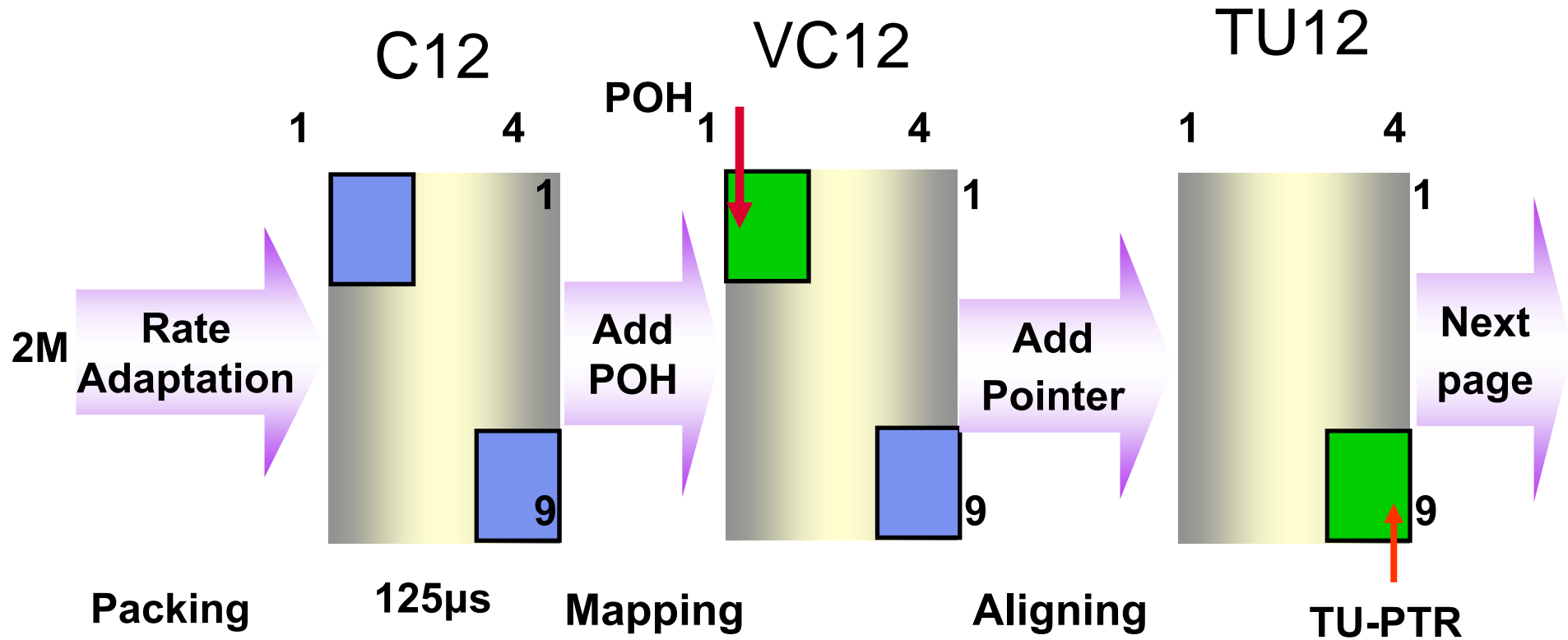
Multiplexing route: 1X34M → 1XTU-3 → 3XTUG-3 → 1XAU-4---One STM-1 can load three 34Mbit/s signals

SDH Tributary Multiplexing (2M)

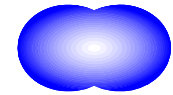


شاهین ارتباط تهران

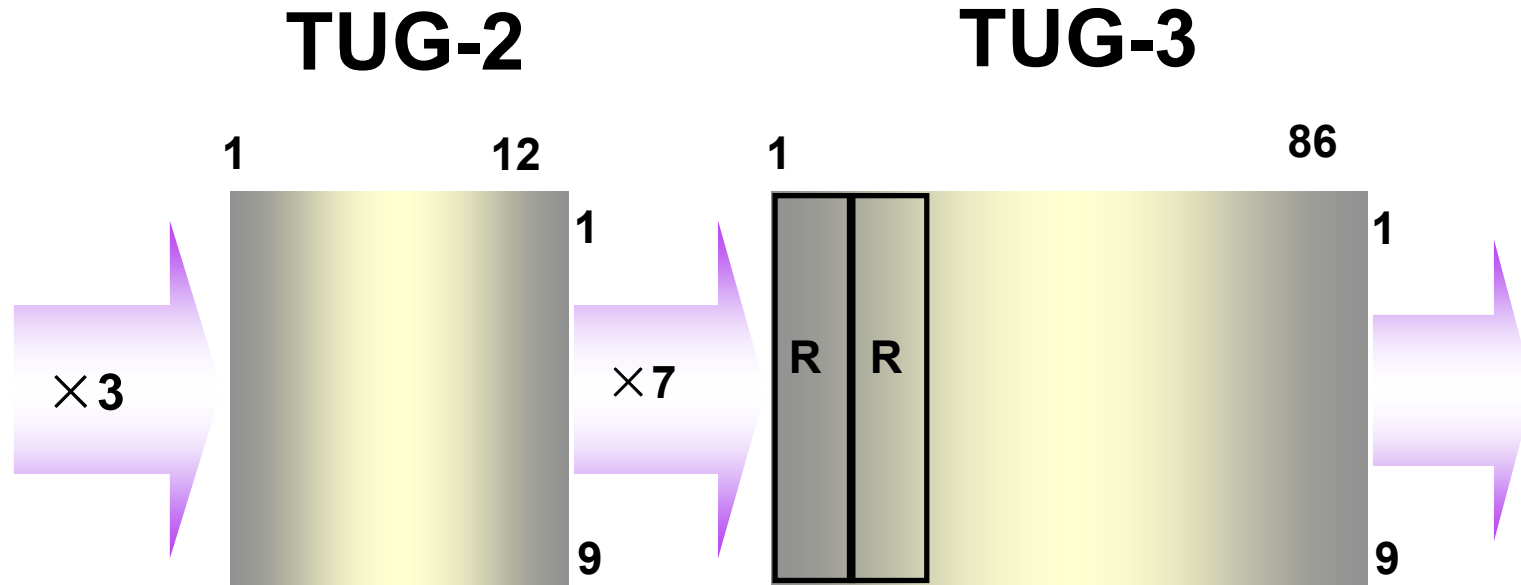
2 Mbit/s to STM-N



SDH Tributary Multiplexing (2M)



شاهین ارتباط تهران



Multiplexing

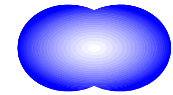
Multiplexing

**Same
as for
C3**

Multiplexing route: 1X2M → 3XTU12 → 7XTUG-2 → 3XTUG-3 → 1XSTM-1--- One STM-1 can load 3X7X3 = 63X2M Signals

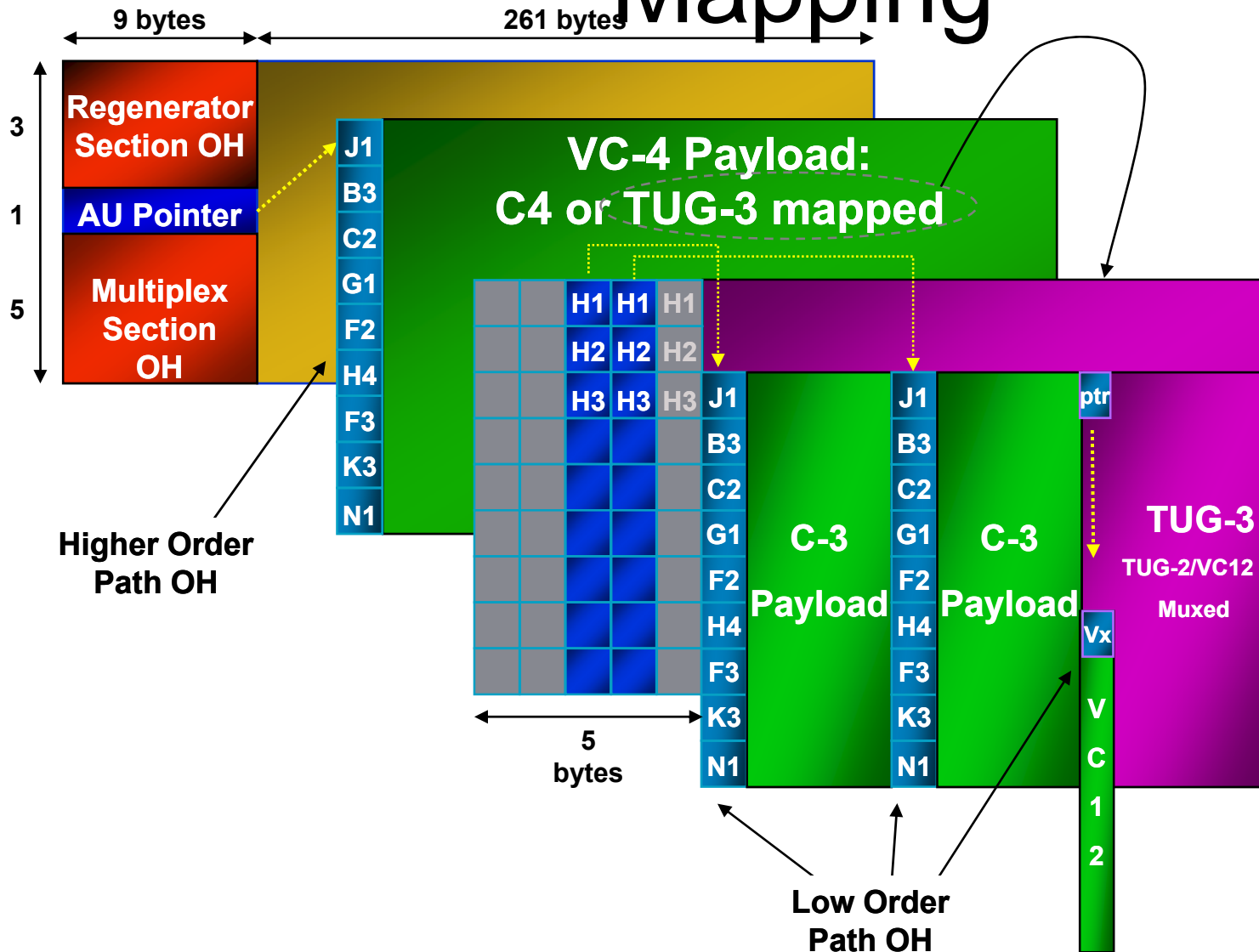
Multiplexing structure: 3-7-3 structure

STM-1 Frame with AU-4



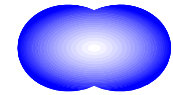
شاهین ارتباط تهران

Mapping



SDH Overhead

STM-1 Section Overhead (SOH)



شاهین ارتباط تهران

	1	2	3	4	5	6	7	8	9	
1	A1	A1	A1	A2	A2	A2	J0			RSOH
2	B1			E1			F1			
3	D1			D2			D3			
4	AU-4 Pointer									
5	B2	B2	B2	K1			K2			MSOH
6	D4			D5			D6			
7	D7			D8			D9			
8	D10			D11			D12			
9	S1					M1	E2			

SDH Overhead

RSOH - Regenerator Section Overhead



A1..A2

- Framing bytes - designate start of STM-1 frame

B1

- RS bit interleaved parity (BIP-8) - parity computed over previous frame

J0

- RS trace - connection verification (E.164 number)

E1

- RS orderwire – 64 kbit/s voice connection for operators

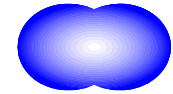
F1

- RS user channel – 64 kbit/s user channel for operators

D1..D3

- RS data communications channel (DCC) – 192 kbit/s OAM channel (Operations, Administration and Maintenance)

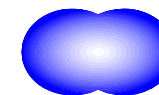
SDH Overhead



MSOH - Multiplex Section Overhead

B2..B2	MS bit interleaved parity (BIP-24) - parity computed over previous frame
E2	MS orderwire – 64 kbit/s voice connection for operators
D4..D12	MS data communications channel (DCC) – 576 kbit/s OAM channel (Operations, Administration and Maintenance)
M1	MS remote error indication (REI) – number of errored BIP-24 blocks received at the remote end
K1/K2	Automatic protection switching (APS) – MS protection / alarm indication signal (AIS) / remote defect indication (RDI)
S1	Synchronisation status – Quality of STM-1 signal when used as synchronisation and timing source

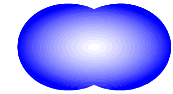
SDH Overhead



POH - Higher Order Path Overhead (VC-4/3) شاهین ارتباطی

J1	Path trace - connection verification (E.164 number)
B3	Path bit interleaved parity (BIP-8) - parity computed over previous container
C2	Path signal label – mapping type in VC-n
G1	Path status – monitoring of bidirectional path status
F2	Path user channel – 64 kbit/s user channel for operators
H4	Tributary unit multiframe indicator - start of multiframe
F3	Path user channel – 64 kbit/s user channel for operators
K3	Automatic Protection Switching (APS) – path protection
N1	Network operator byte – higher order tandem connection overhead (TCOH)

SDH Overhead



POH - Lower Order Path Overhead (VC-2/1)

V5

BIP-2 / Remote error indication (REI) / Remote failure indication (RFI) / signal label / remote defect indication (RDI)

J3

Path trace – connection verification (E.164 number)

N2

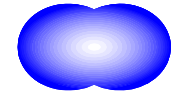
Network operator byte – lower order tandem connection overhead (TCOH)

K4

Automatic Protection Switching (APS) – path protection

- **The lower order POH is a single overhead octet per VC-2/1 organized as a multiframe of 4 frames.**

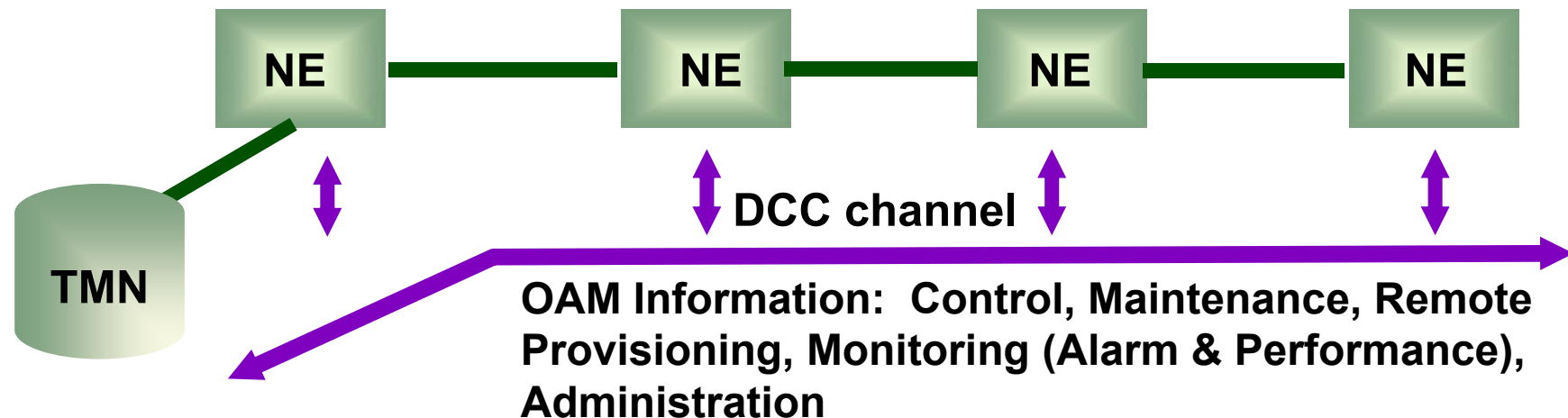
D1 ~ D12 Bytes



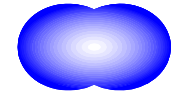
شاهین ارتباط تهران

Data Communications Channels (DCC) Bytes –

- ◆ Message-based Channel for OAM between NEs and NMS
- ◆ RS-DCC – D1 ~ D3 – 192 kbit/s (3X64 kbit/s)
- ◆ MS-DCC – D4 ~ D12 – 576 kbit/s (9X64kbit/s)

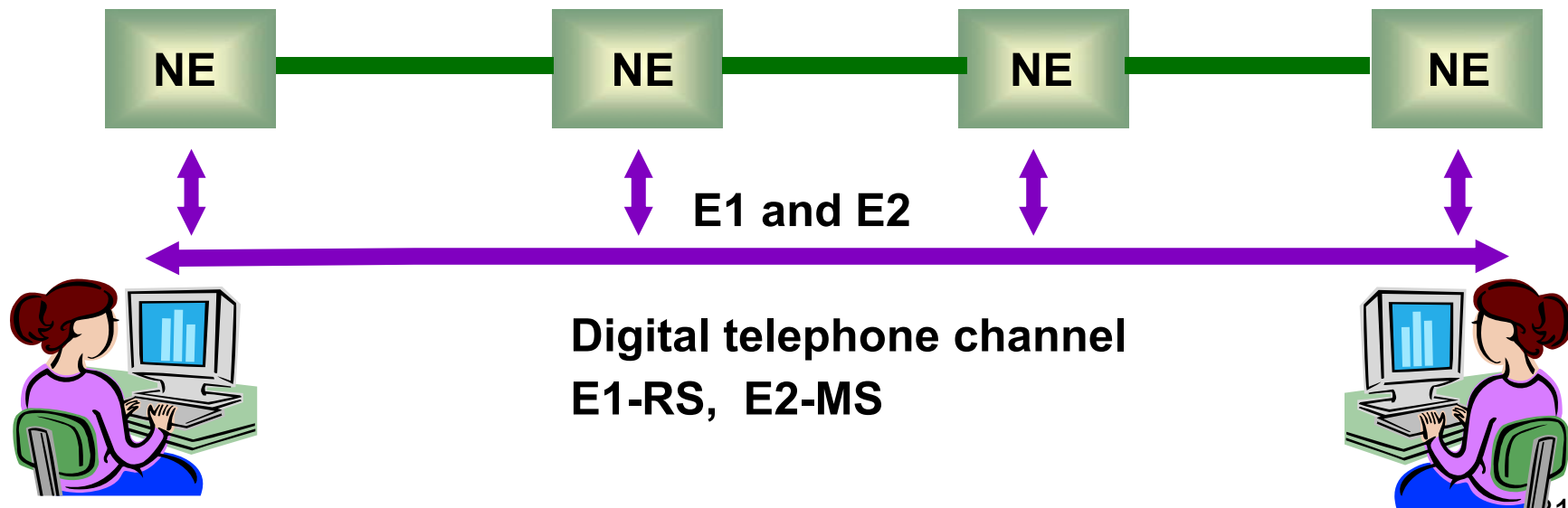


E1 and E2 Bytes



شاهین ارتباط تهران

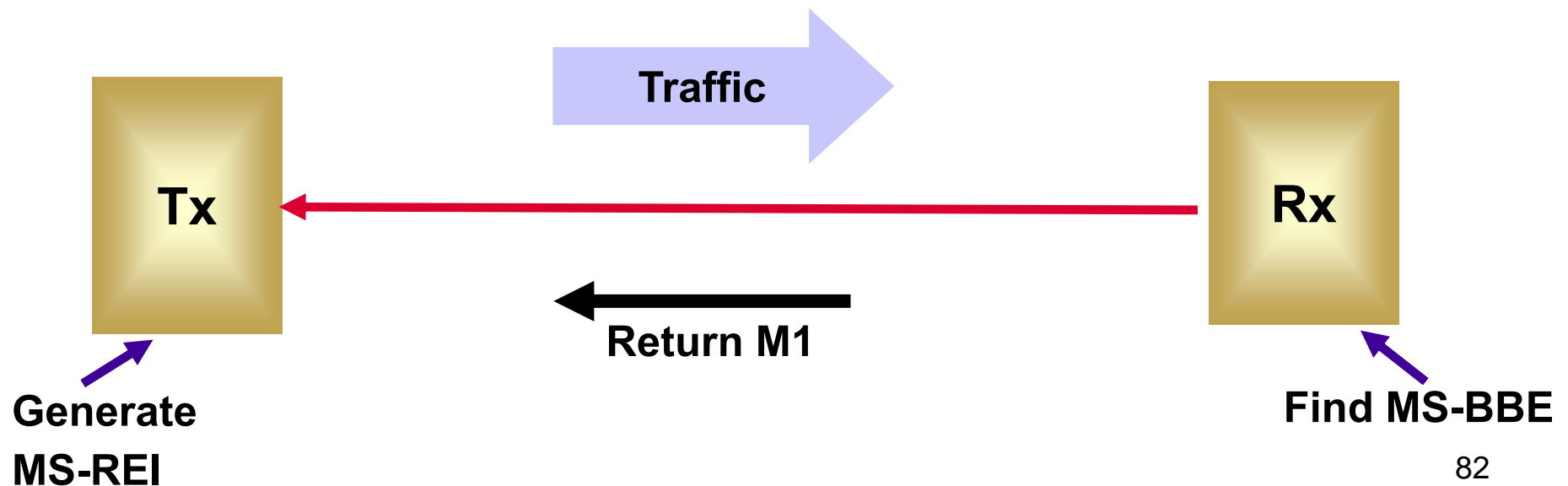
- ◆ **Orderwire Bytes** – Provides one 64 kbit/s each for voice communication
- ◆ **E1 – RS Orderwire Byte** – RSOH orderwire message
- ◆ **E2 – MS Orderwire Byte** – MSOH orderwire message



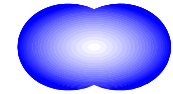
M1 Byte

Multiplex Section Remote Error Indication (MS-REI) Byte

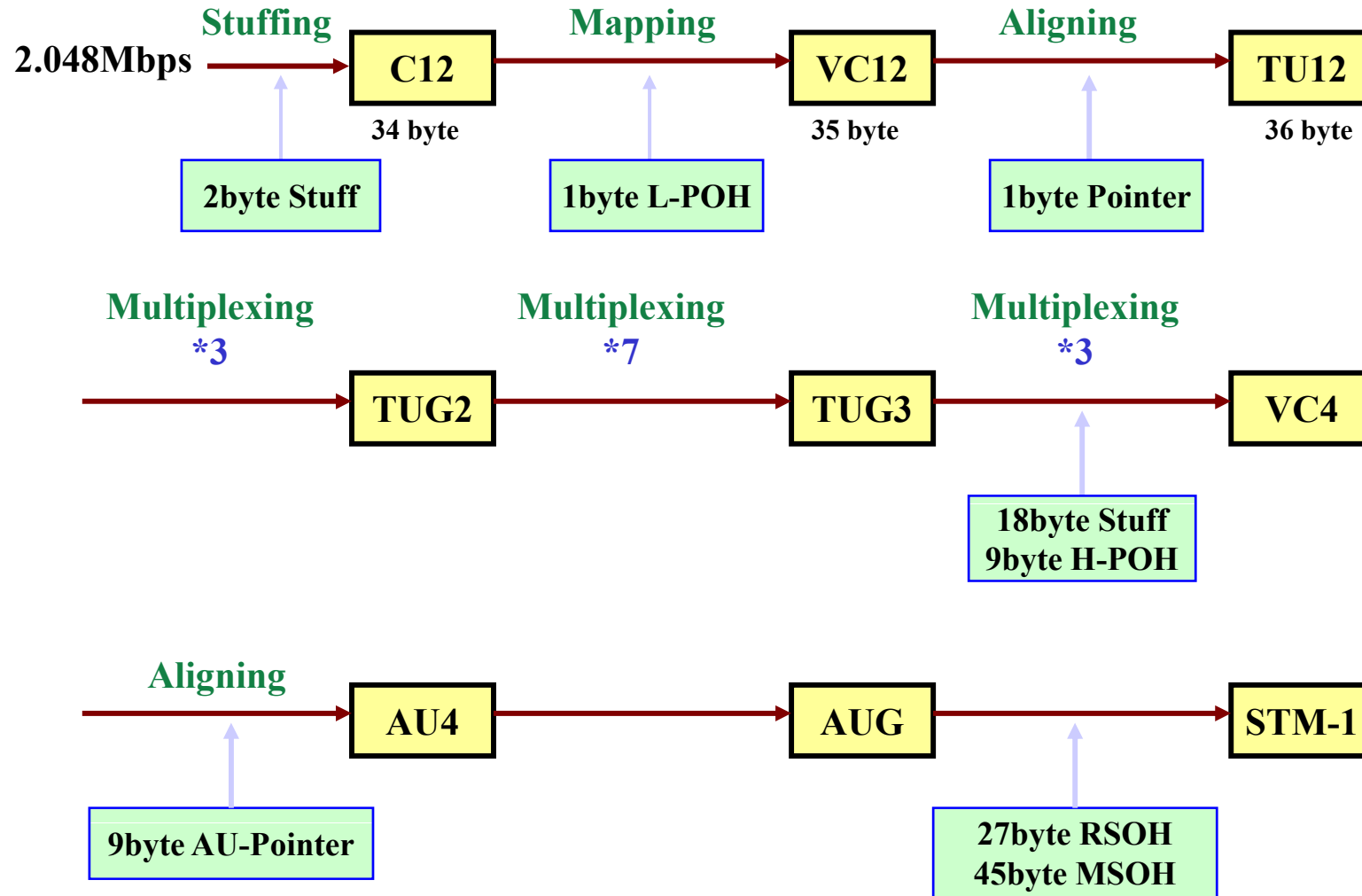
- ◆ A return message from Rx to Tx ,when Rx find MS-BBE
- ◆ A count of the number of BIP-24xN (B2) errors
- ◆ Tx generate corresponding performance event MS-REI



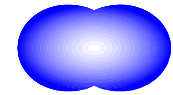
STM-1 Frame



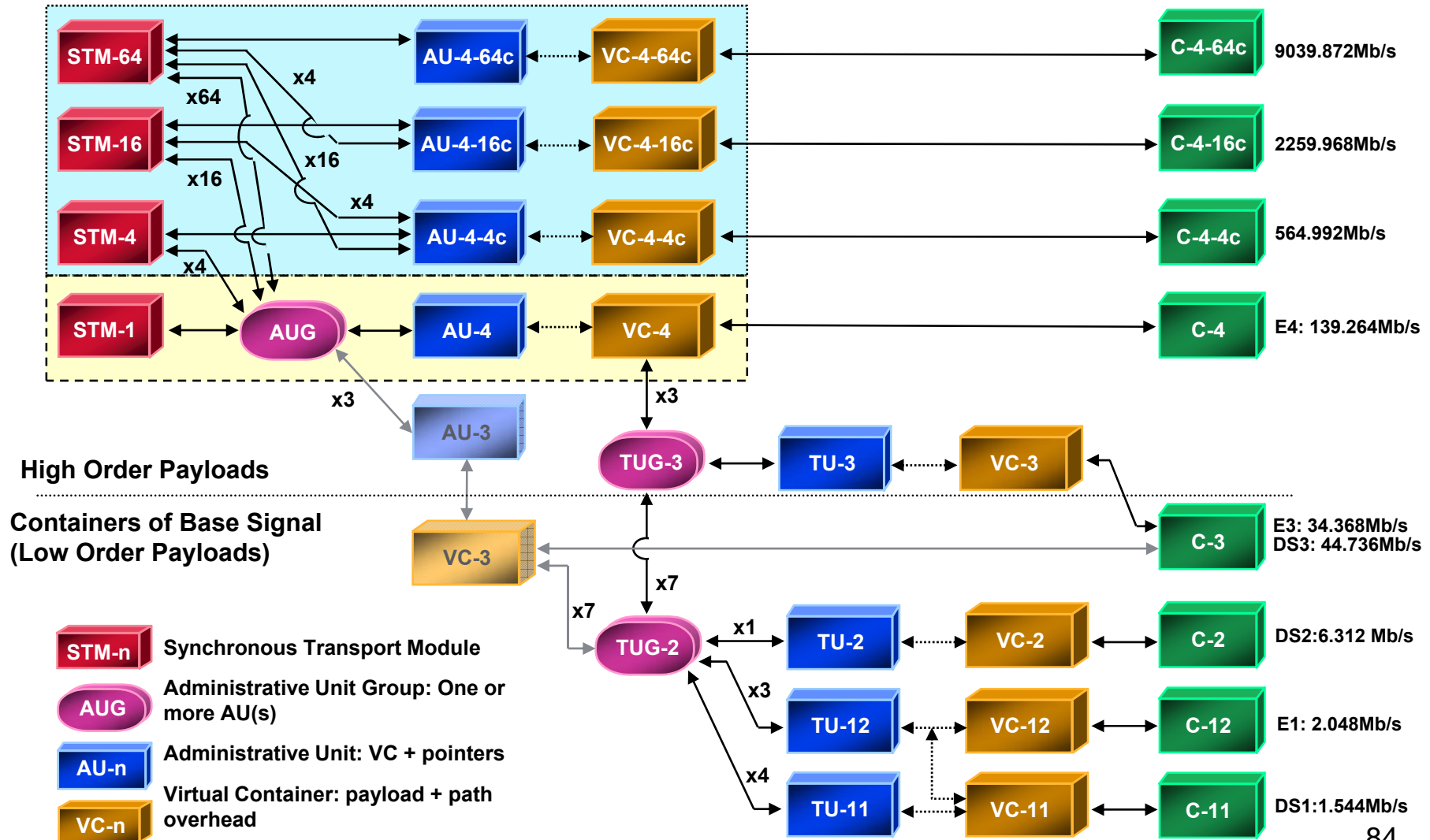
شاهین ارتباط تهران



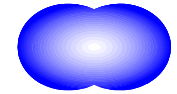
SDH Hierarchy



شاهین ارتباط تهران



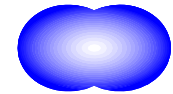
SDH - Clocking



شاهین ارتباط تهران

- All network elements are totally synchronous
- Expensive clocks needed
- Still, there are delays in the network
- Delay variance of $5 \cdot 10^{-10}$ means that two tributaries differ in one frame length every 3 days
- Justification still needed
 - Put the tributaries into containers
 - Let the container start anywhere in the payload frame
 - Keep and manage the movement of pointers to these containers

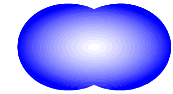
SDH - Justification



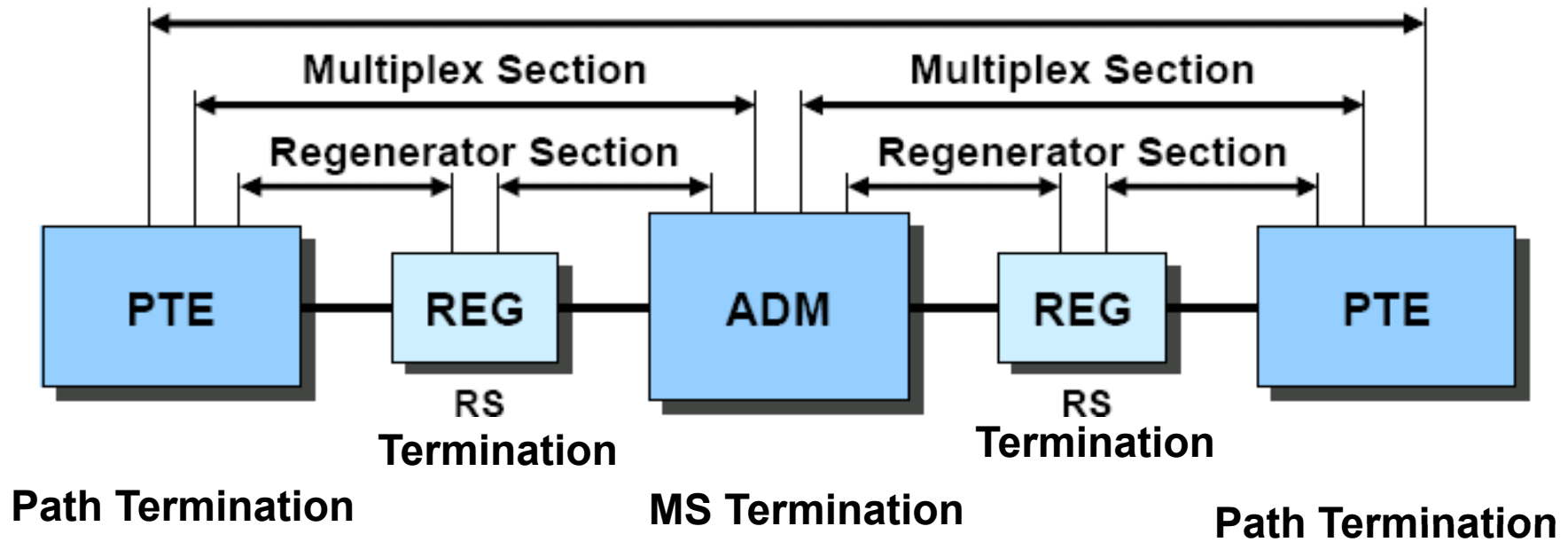
شاهین ارتباط تهران

- Problem: Streams of slightly different speed arrive at the multiplexer
 - Arriving data of stream A slower than output rate:
 - Positive stuffing
 - Increment AU pointer H1A and H2A by 1
 - Leave AU pointer H3A empty
 - Leave 1 byte (for STS-1) or 3 byte (for STM-1) after H3C empty
 - Arriving data of stream A faster than output rate:
 - Negative stuffing
 - Decrement AU pointer H1A and H2A by 1
 - 1 byte (for STS-1) or 3 byte (for STM-1) of user data is put into AU pointer H3A
- Differences in the data rates can be adjusted this way without the use of overhead bits

SDH Overhead Hierarchical Layers

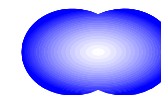


شاهین ارتباط تهران



- PTE** Path Terminating Element (Terminal Multiplexer)
- REG** Regenerator
- ADM** Add/Drop Multiplexer
- RS** Regenerator Section
- MS** Multiplex Section

BANDWIDTH ON DEMAND



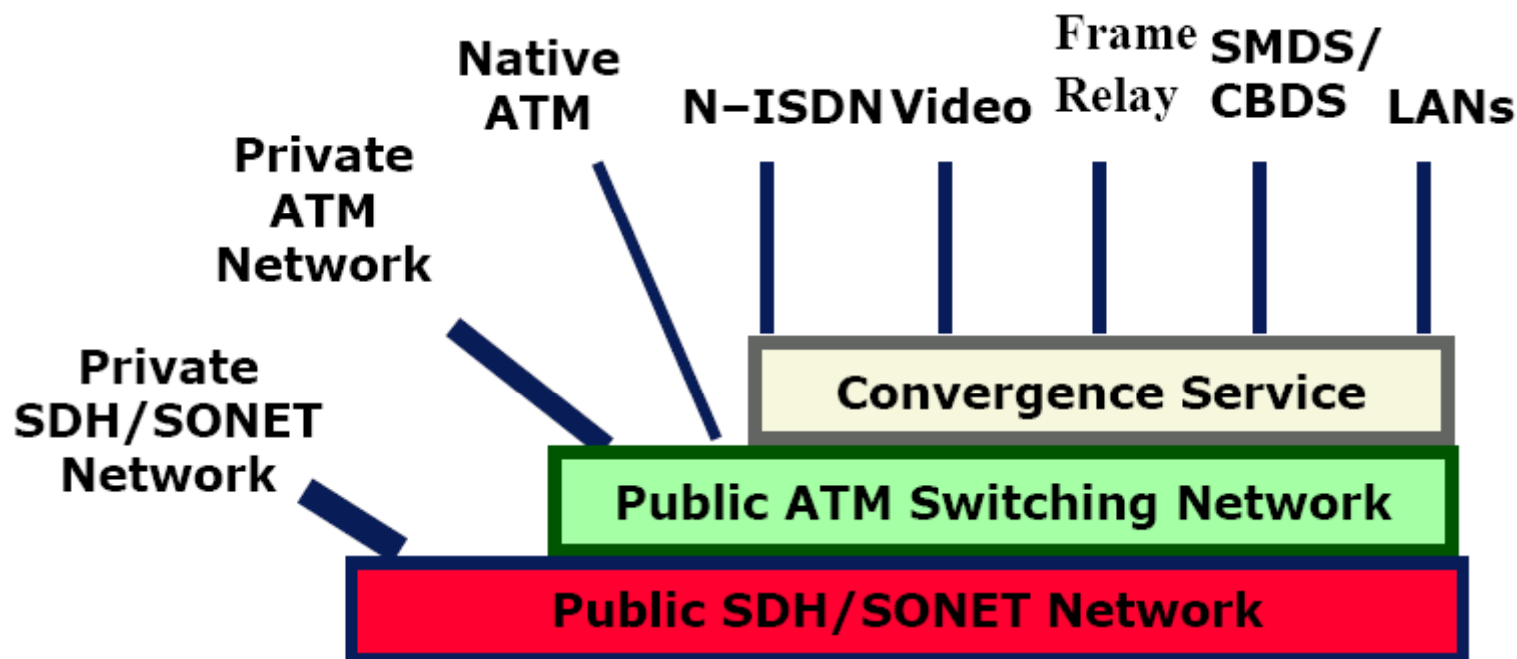
شاهین ارتباط تهران

- In a synchronous network it will be possible to dynamically allocate network capacity, or bandwidth, on demand.
 - An example of this is dial-up video-conferencing. Users will be able to obtain the required bandwidth for a video-conferencing link just by dialing the appropriate number, as opposed to the current situation where video-conferencing links must reserved days in advance.
 - Some examples of such services are high speed packet switched services, LAN interconnection, and High Definition TV (HDTV).

Broadband ISDN (B-ISDN) Service Architecture

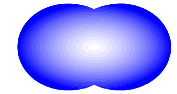


شاهین ارتباط تهران



- **N-ISDN:** Narrowband Integrated Services Digital Network
- **CPE:** Customer Premises Equipment
- **SDH:** Synchronous Digital Hierarchy (International)
- **SONET:** Synchronous Optical Network (North America)

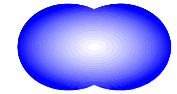
SOFTWARE CONTROL



شاهین ارتباط تهران

- Network management systems will **not only** perform traditional event management functions such as dealing with alarms in the network, but will also provide a host of other functions, like **performance monitoring, configuration management, resource management, network security, inventory management, and network planning and design.**

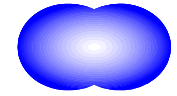
Synchronous standard



شاهین ارتباط تهران

- The opportunity of defining this new standard has been used to address a number of other problems. This standards work culminated in CCTTT Recommendations G.707, G.708, and G.709 covering the **Synchronous Digital Hierachy (SDH)**.
- These were published in the CCTTT Blue Book in 1989.
- **In a synchronous network, all equipment is synchronized to an overall network clock.**

Disadvantages of SDH

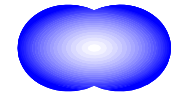


شاهین ارتباط تهران

2. Mechanism of pointer adjustment is complex.

3. Large-scale application of software makes SDH system vulnerable to viruses or malpractice.

SDH Optical and Electrical Line Rates

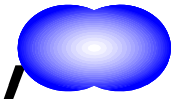


شاهین ارتباط تهران

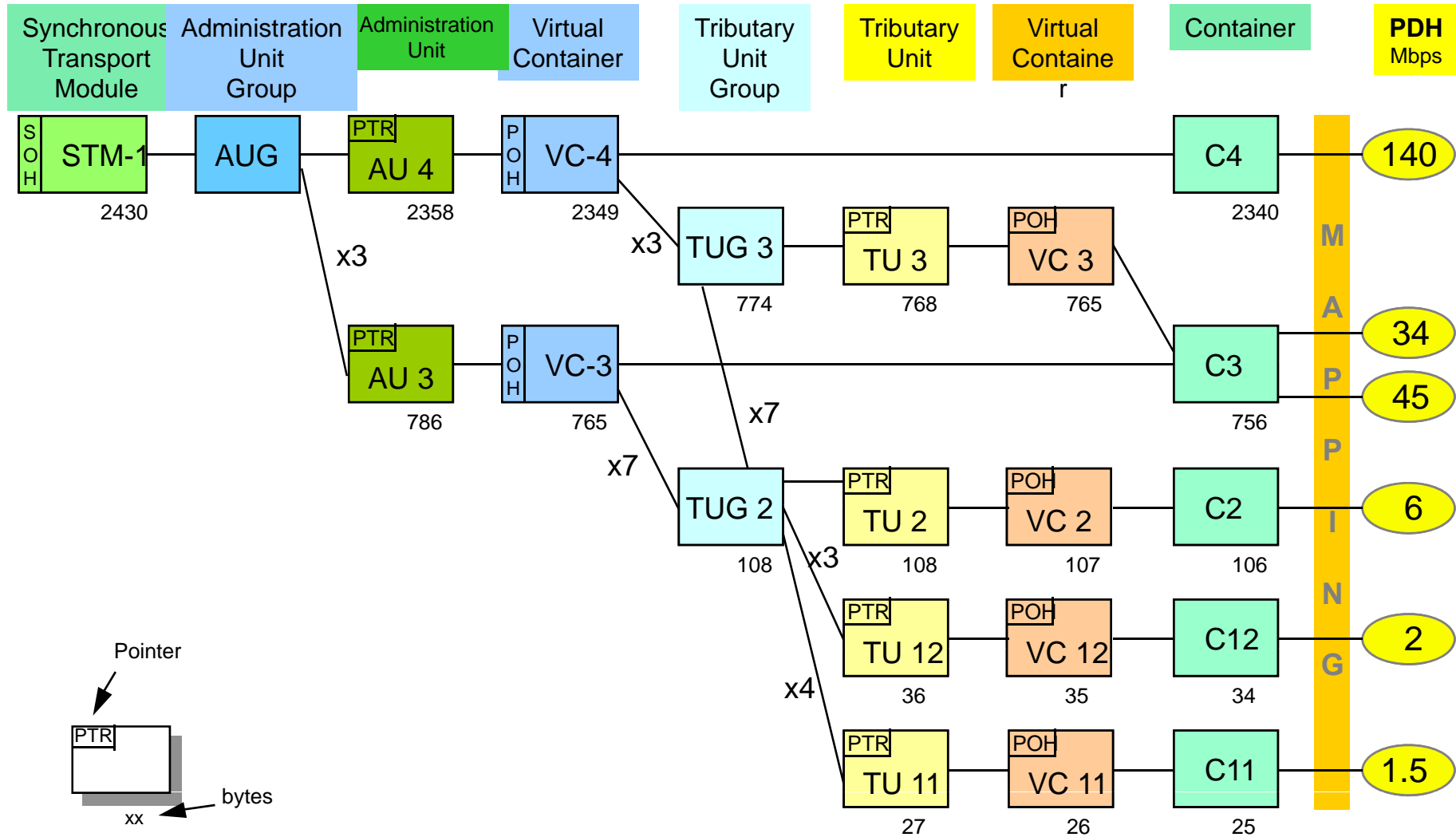
Electrical Level	Line Rate
STM-1	155.52 Mbps
STM-4	622.08 Mbps
STM-16	2488.32 Mbps
STM-64	10 Gbps

STM-n - Synchronous Transport Module level n

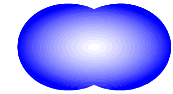
SDH Multiplexing Hierarchy



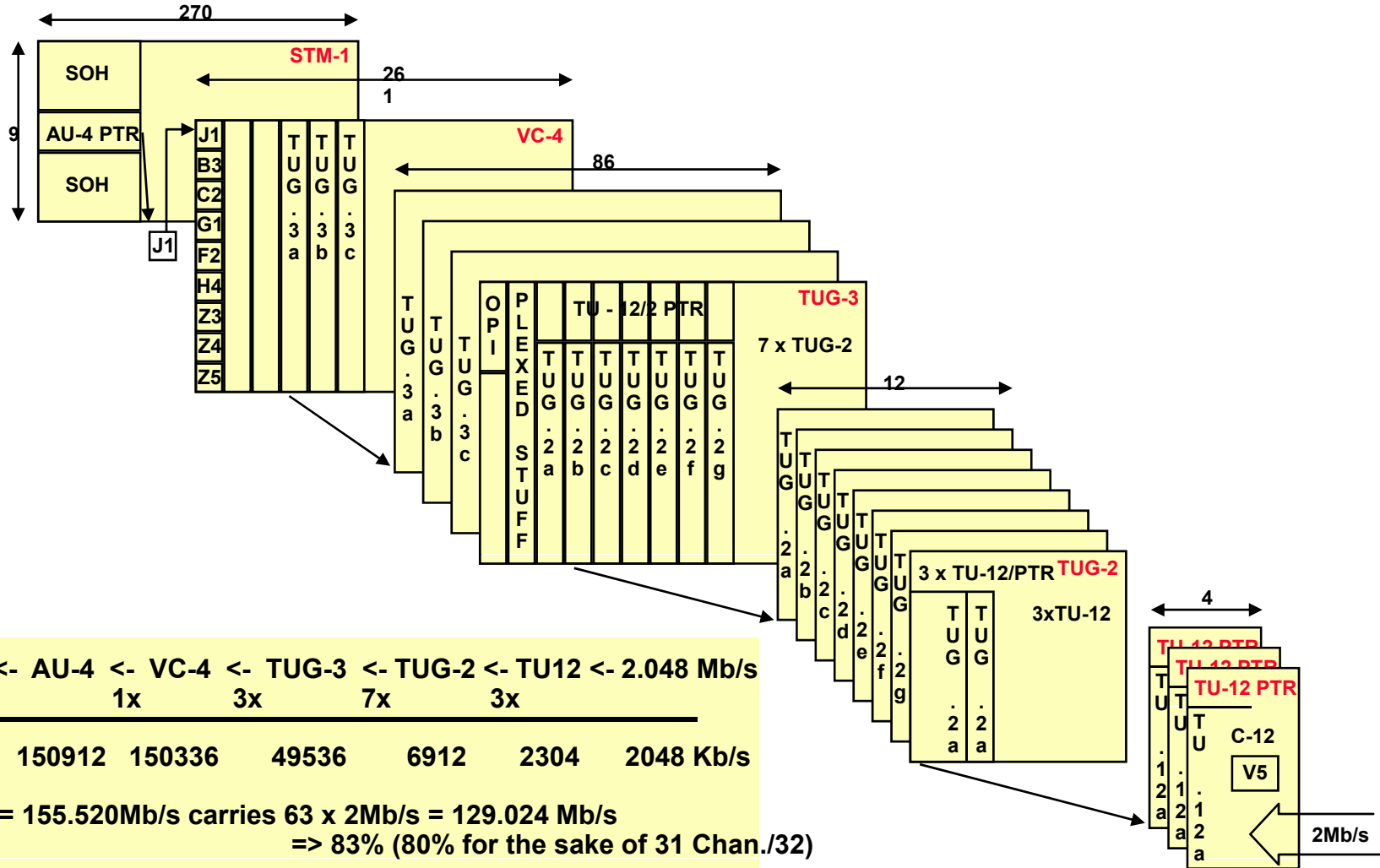
شاهین ارتباط تهران



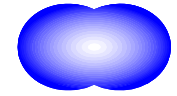
2 Mbps in SDH (STM-1)



شاهین ارتباط تهران



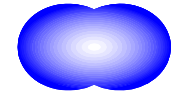
SDH terminology (1/2)



شاهین ارتباط تهران

- Container (C) =
 - Pure tributary information (PDH signal)
 - + Fixed stuffing (for approximate alignment)
 - + Justification bits and justification control bits
- Virtual Container (VC) =
 - Container
 - + Path Overhead (POH), i.e. end-to-end supervision & maintenance info
- Administrative Unit Group (AUG) =
 - Virtual container (VC-3, VC-4)
 - + AU - pointer (points to beginning of VC in the frame)

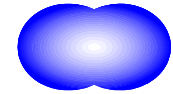
SDH terminology (2/2)



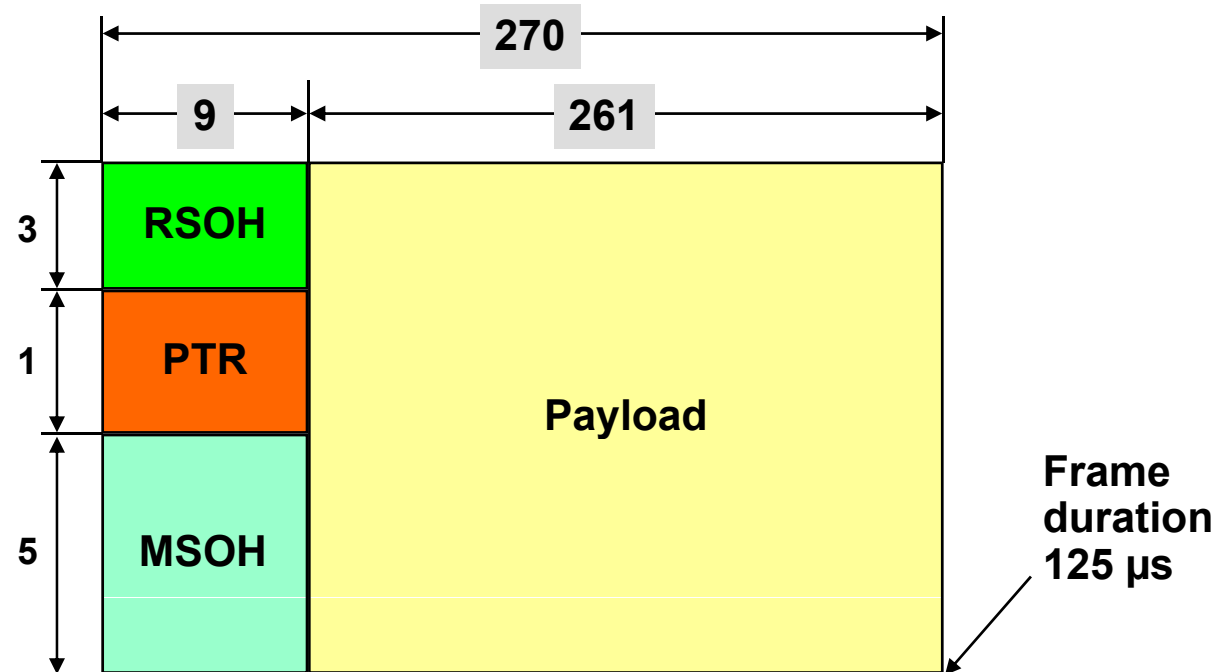
شاهین ارتباط تهران

- Administrative Unit Group (AUG) =
 - Byte - interleaved AU1
 - = STM-1 without SOH
- Tributary Unit (TU)
 - Virtual Container (VC-11, VC-12, VC-2, VC-3)
 - + TU - Pointer
 - (to include within larger VC)
- Tributary Unit Group (TUG) =
 - Byte - interleaved TUs

STM-1 Frame structure

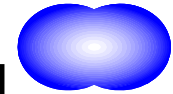


شاهین ارتباط تهران

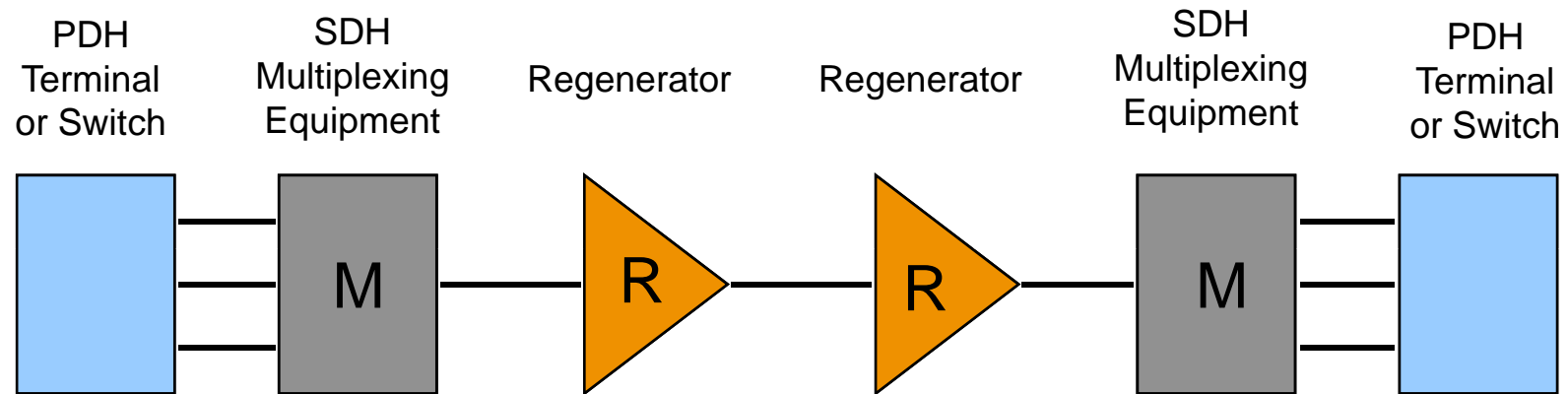


RSOH	R egenerator S ection O ver H ead
PTR	P oin T e R
MSOH	M ultiplexer S ection O ver H ead

SONET / SDH Multiplexing



شاهین ارتباط تهران



Regenerator Section Regenerator Section Regenerator Section



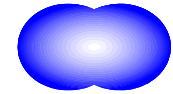
Multiplexer Section



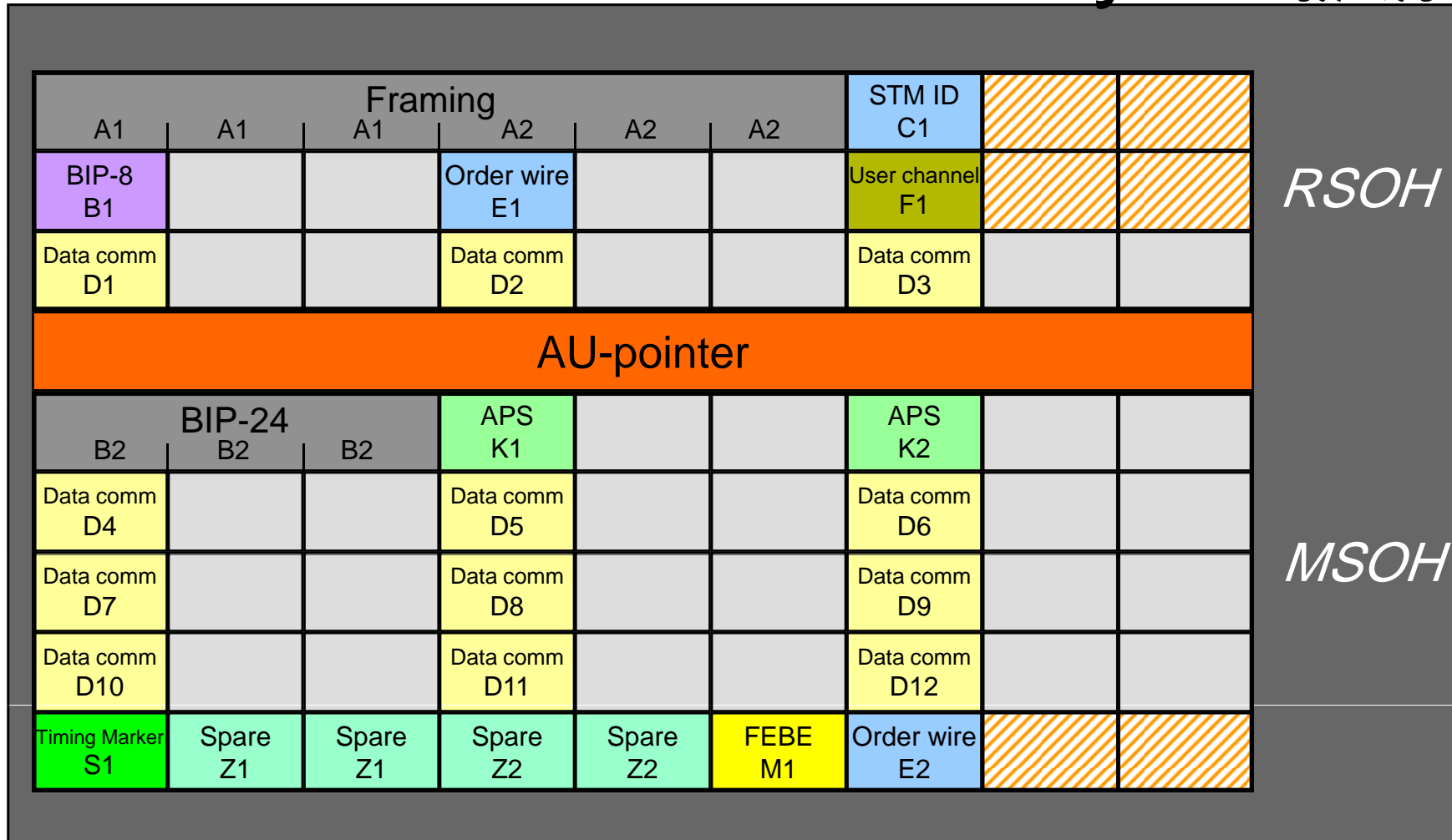
Path (end-to-end)



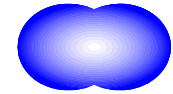
Section Overhead bytes



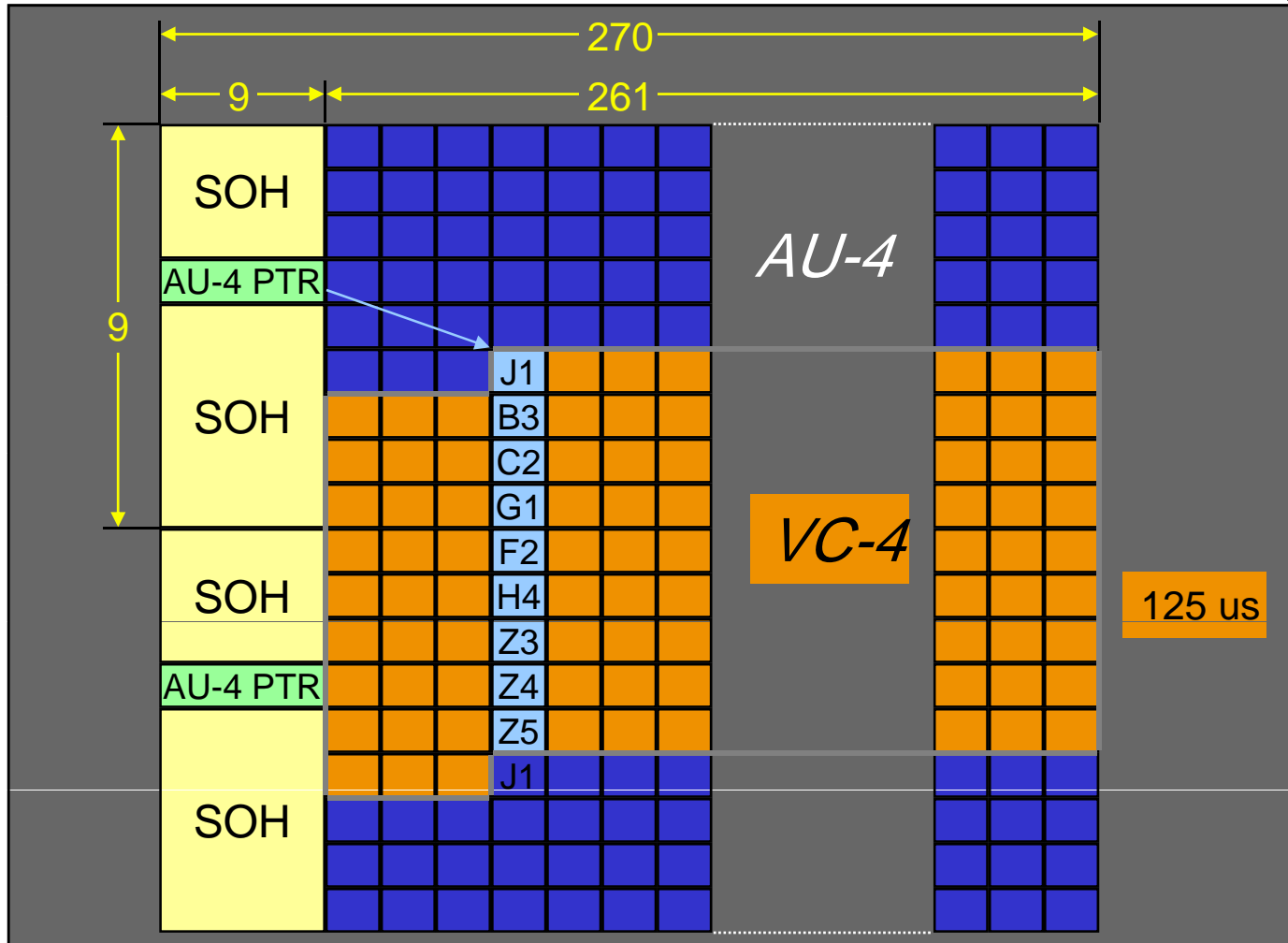
شاهین ارتباط تهران

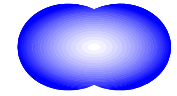


1 x VC-4 in STM-1



شاهین ارتباط تهران

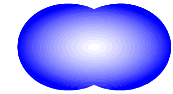




شاهین ارتباط تهران

STM-n *Multiplexing*

Path Overheads



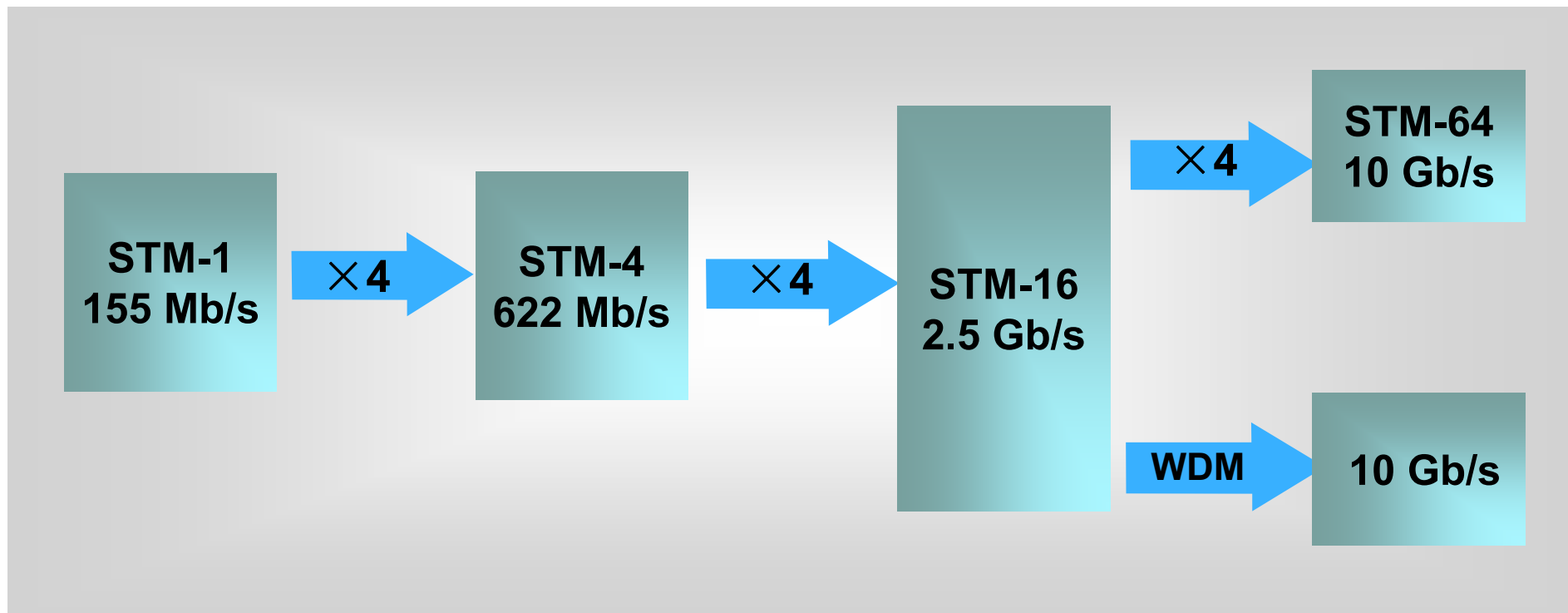
شاهین ارتباط تهران

	1	2	3	4	5	6	7	8	9	10		
1											J1	VC-n Path Trace Byte
2											B3	Path BIP-8
3											C2	Path Signal Label
4											G1	Path Status
5											F2	Path User Channel
6											H4	TU Multiframe Indi
7											F3	Path User Channel
8											K3	AP Switching
9											N1	Network Operator

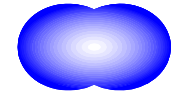
Higher Order Path Overhead

Advantages of SDH

Low rate SDH to higher rate SDH

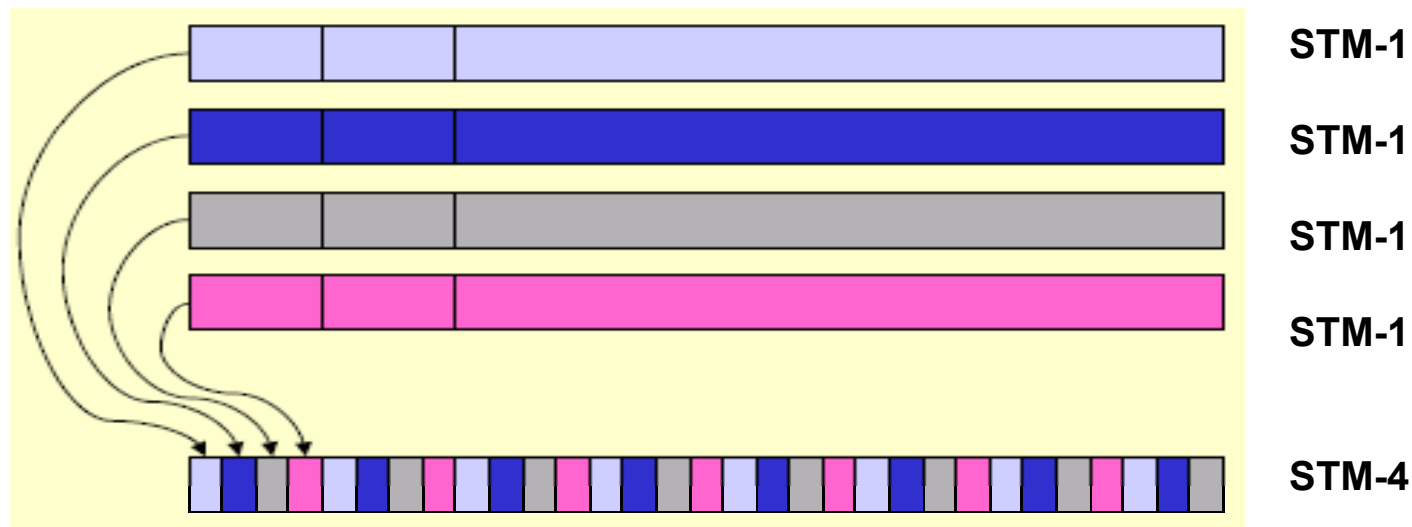


SDH – Multiplexing

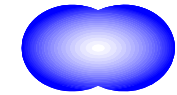


شاهین ارتباط تهران

- No overhead bits needed for justification
- higher speed link is formed by byte-interleaving data from lower speed links
- exact multiples of lower speed data rates (OC-12 contains 12 byte interleaved OC-1 frames)
- OC-12c or STM-4c means „concatenated“ payload, these containers are not multiplexed

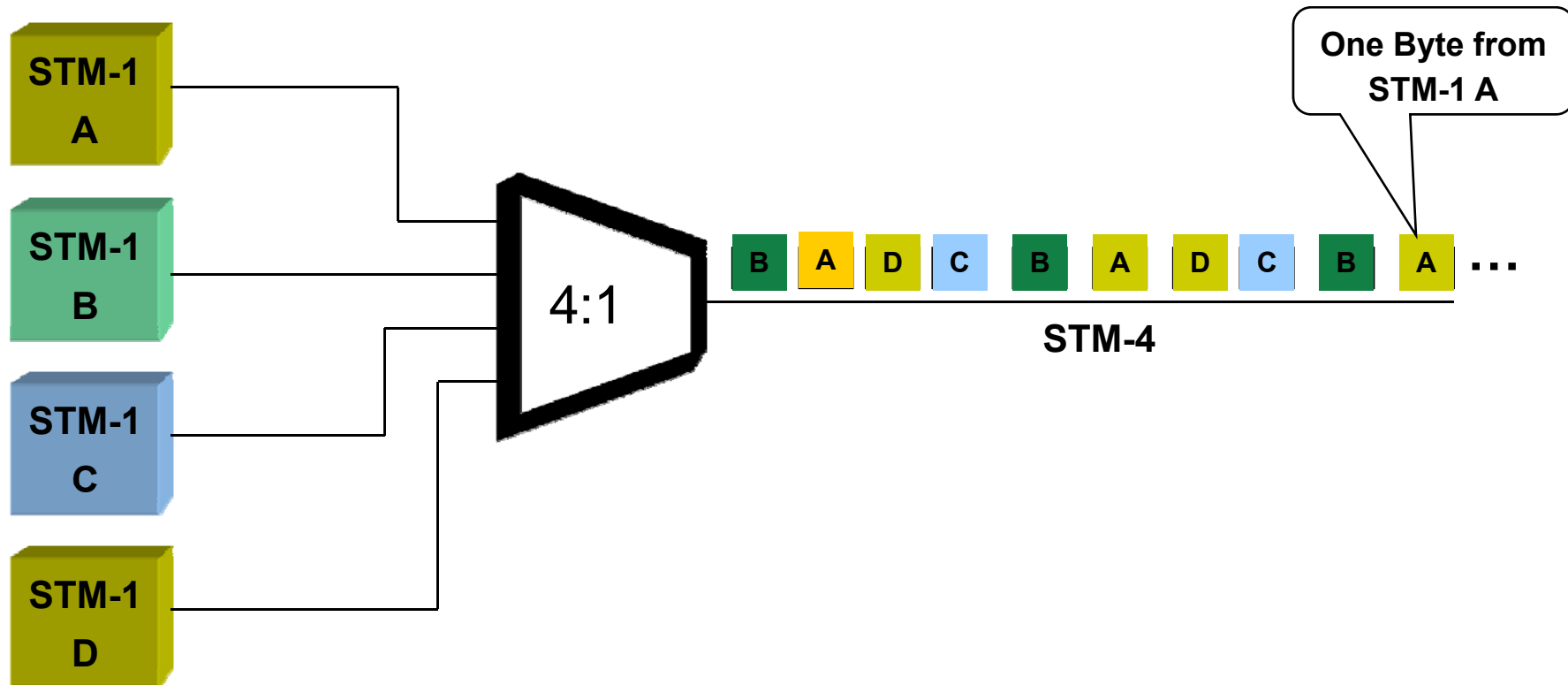


Advantages of SDH

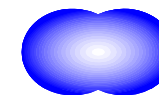


شاهین ارتباط تهران

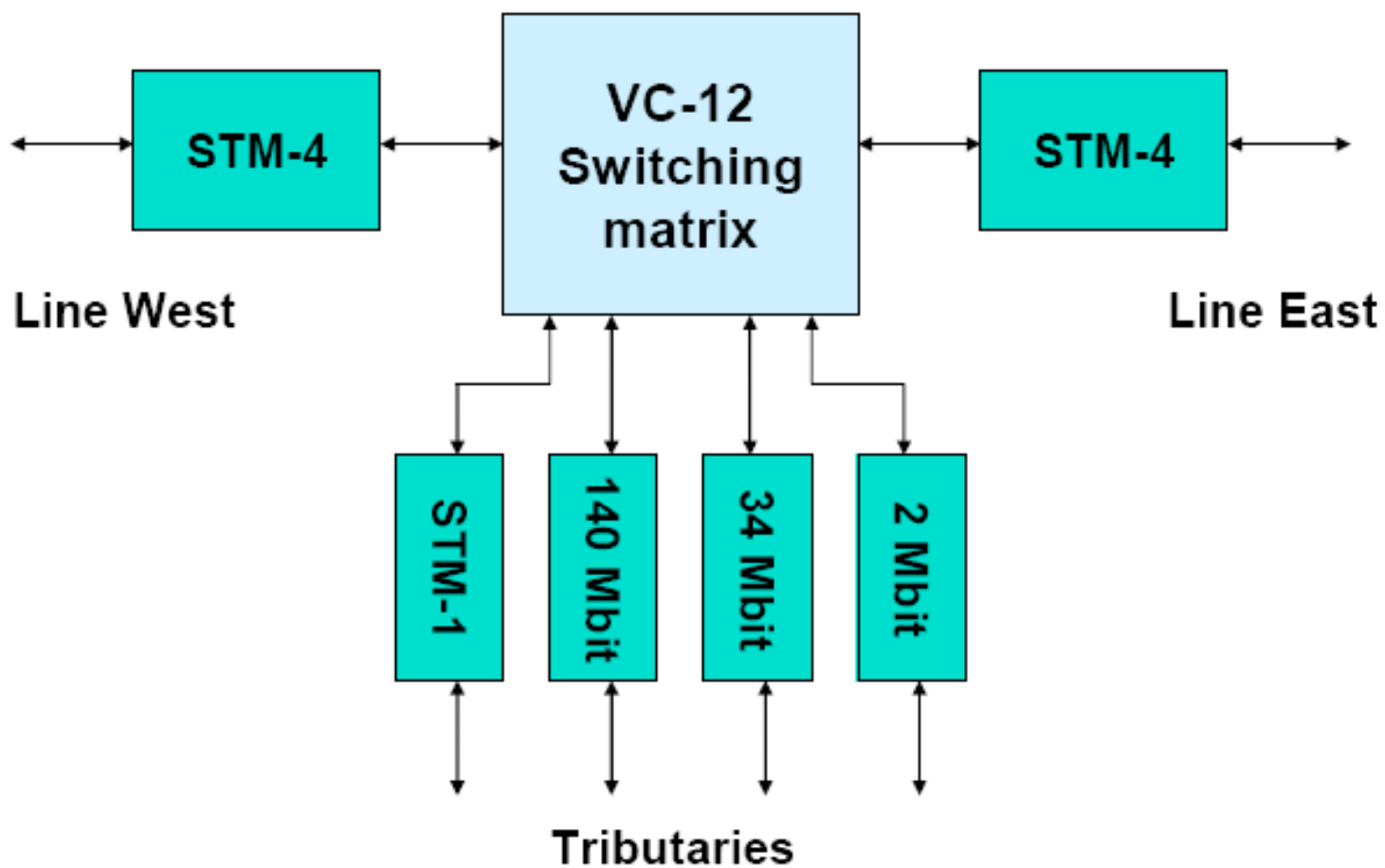
**byte interleaved
multiplexing method**



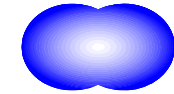
STM-4 Add/Drop Multiplexer Block Diagram



شاهین ارتباط تهران



SDH Hierarchy



شاهین ارتباط تهران

Low bandwidth utilization ratio

Signal	Digital Bit Rate	Channels
E0	64 kbit/s	One 64 kbit/s
E1	2.048 Mbit/s	32 E0
E2	8.448 Mbit/s	128 E0
E3	34.368 Mbit/s	16 E1
E4	139.264 Mbit/s	64 E1

**Non-Synchronous,
PDH Hierarchy**

Bit Rate	Abbreviated	SDH	SDH Capacity
155.52 Mbit/s	155 Mbit/s	STM-1	63 E1, 3 E3 or 1 E4
622.08 Mbit/s	622 Mbit/s	STM-4	252 E1, 12 E3 or 4 E4
2488.32Mbit/s	2.5 Gbit/s	STM-16	1008 E1, 48 E3 or 16 E4
9953.28Mbit/s	10 Gbit/s	STM-64	4032 E1, 192 E3, 64 E4

High bandwidth utilization ratio.

Relevant SDH Standards:



- ITU-T G.703 Physical/electrical Characteristics of Digital Interfaces

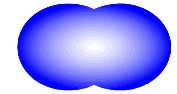
Plesiochronous Digital Hierarchy (PDH)

- ITU-T G.732/G.744/G.751

Synchronous Digital Hierarchy (SDH)

- ITU-T G.707 Network Node Interface for the Synchronous Digital Hierarchy
- ITU-T G.783 Characteristics of SDH Equipment Functional Blocks
- ITU-T G.784 SDH Management
- ITU-T G.957 Optical Interfaces for Equipment and Systems relating to SDH
- ETS 300 147 Synchronous Digital Hierarchy Multiplexing Structure
- ETS 300 417 Generic functional requirements for SDH equipment

Glossary



شاهین ارتباط تهران

C = Container

VC = Virtual Container

TU = Tributary Unit

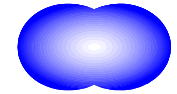
AU = Administrative Unit

TUG = Tributary Unit Group

AUG = Administrative Unit Group

STM = Synchronous Transfer Module

Glossary

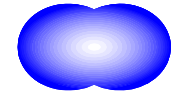


شاهین ارتباط تهران

- ▶ **Mapping** - A process used when tributaries are adapted into VCs by adding justification bits and POH information

- ▶ **Aligning** - This process takes place when a pointer is included in a Tributary Unit (TU) or an Administrative Unit (AU), to allow the 1st byte of the VC to be located

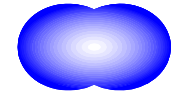
Glossary



شاهین ارتباط تهران

- ▶ **Multiplexing** - This process is used when multiple low-order path signals are adapted into a higher-order path signal, or when high-order path signals are adapted into a Multiplex Section
- ▶ **Stuffing** – As the tributary signals are multiplexed and aligned, some spare capacity has been designed into the SDH frame to provide enough space for all various tributary rates. Therefore, at certain points in the multiplexing hierarchy, this space capacity is filled with “fixed stuffing” bits that carry no information, but are required to fill up the particular frame

Glossary



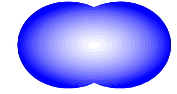
شاهین ارتباط تهران

- **TU Multiframe**

In the floating TU mode, four consecutive 125 microsecond frames of the VC-4 are combined into one 500 microsecond structure, called a TU Multiframe. The occurrence or the TU Multiframe and its phase is indicated in the VC-N Path Overhead.

- **Concatenation**

The linking together of various data structures. In SDH, a number (M) of TUs can be linked together to produce a concatenated container, M times the size of the TU.



شاهین ارتباط تهران

Question?
Thank You

خدا نگهدار

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