SWITCHING OVERVIEW

F. MICHAUX

2020

GENERAL AGENDA 1/2

- Introduction : Justification, quick history, main components ..
- Input ouput
- Transport, TDM technologie
- Switching matrix
- Signaling
- CPU
- Intelligent peripherals
- Traffic calculation

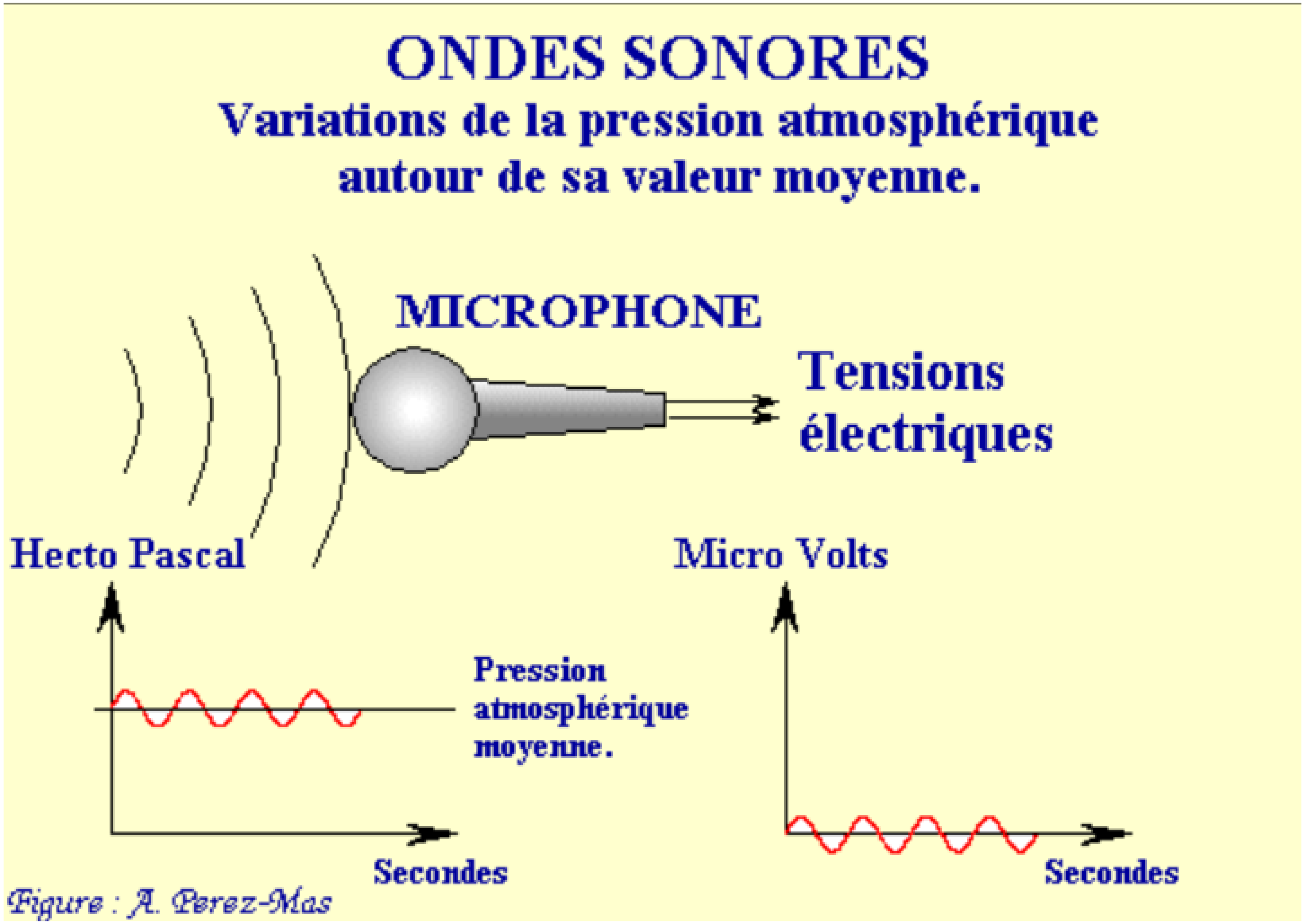
GENERAL AGENDA 2/2

- Conclusion
- Questions

INTRODUCTION

Quick history,justification, main components ..

Quick history



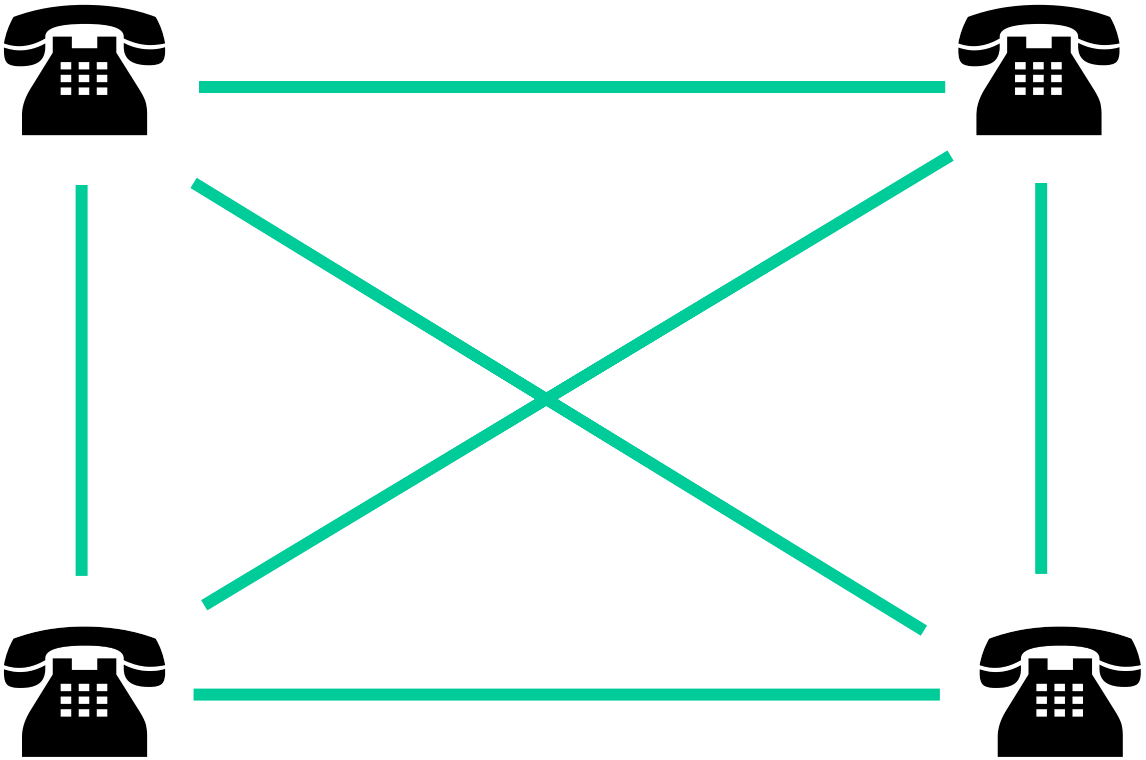
Quick history Analogic/Digital

Un microphone traduit les signaux sonores - variations de la pression atmosphérique - en variations proportionnelles de tension élecrique, - qui seront appliqués à des amplificateurs puis, finalement, à des haut-parleurs - à moins qu'ils ne soient envoyés sur une ligne de transmission. etc.
D'abord, pourquoi "Analogique" ? Dans les courbes ci-dessus les courbes du signal réel et de sa représentation par une tension électrique présentent une certaine analogie de forme (homothétie). Le signal numérique est, lui, une suite de nombres. Aucune analogie visuelle. Une toute autre technique.

Quick history

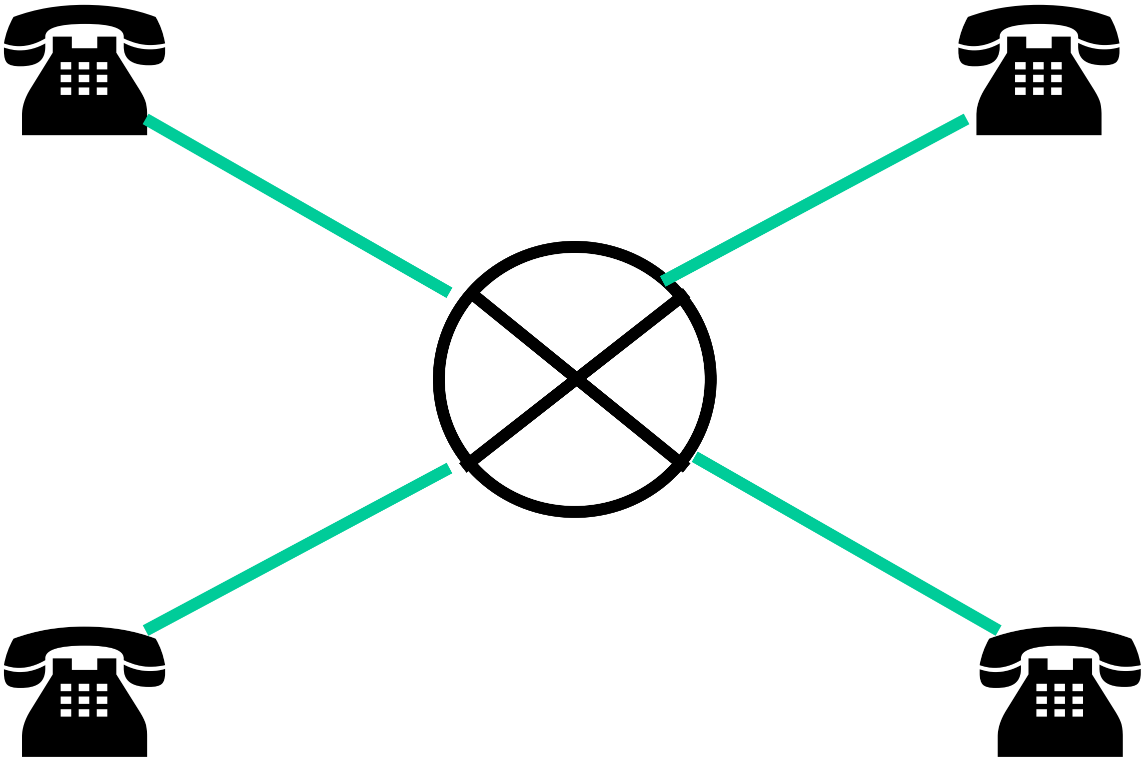
- The transmission was digital at the first step and analog
  - • Morse transmission (Digital)
  - •Voice transmission (Analog)
- Patent regarding the telephone has been registered by A.G Bell in 1876 :
  - •Analog line and modulation,
  - •Reversible Microphone/ Receiver
- The switch introduction came quickly 1878 two years after the A.G Bell patent registration.

VOICE NETWORK WITHOUT SWITCH



6 links for a full meshed network

VOICE NETWORK WITH A SWITCH



4 links with a switch

BENEFIT WITH AN EXAMPLE

- N phones : NX(N-1)/2 Links for a meshed network
- N phones: N Links and one switch
- Example 100 phones : 100 links instead 4950 links without a switch

QUICK HISTORY

The first switches were :

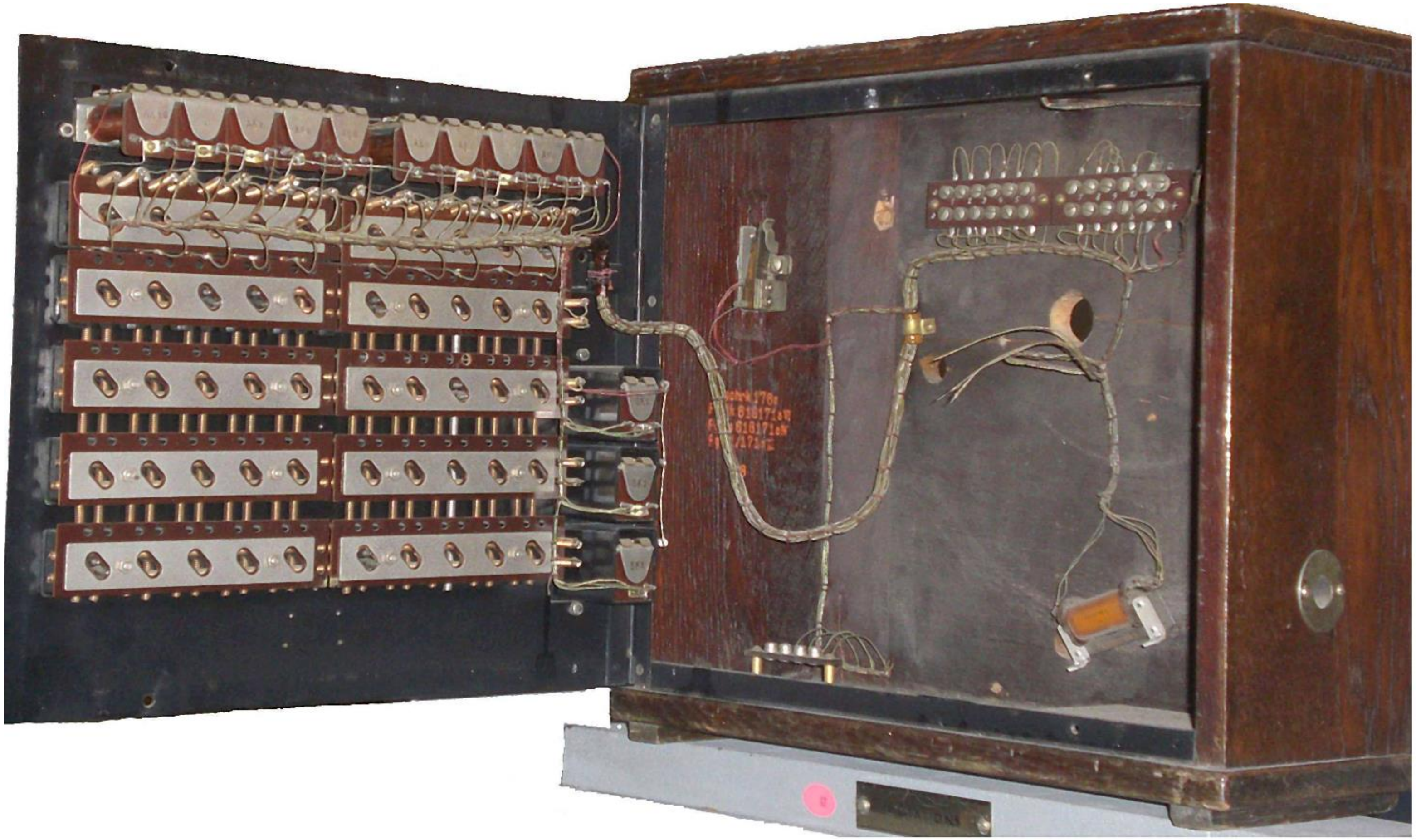
- Manual done by a human operator then,
- Mechanic then,
- Electromechanical and now
- Electronic.

First type of phone

«Au début du téléphone, l'utilisateur, dit « abonné » car il possède un contrat avec le fournisseur du réseau téléphonique, actionne la manivelle de son poste téléphonique pour « sonner » ou appeler l'opératrice; l'opératrice rentre en contact phonique avec le demandeur pour lui demander qui il veut contacter puis connecte physiquement sa ligne à la ligne de destination pour atteindre le demandé. »

Subscriber side

Switch Manual done by a human operator

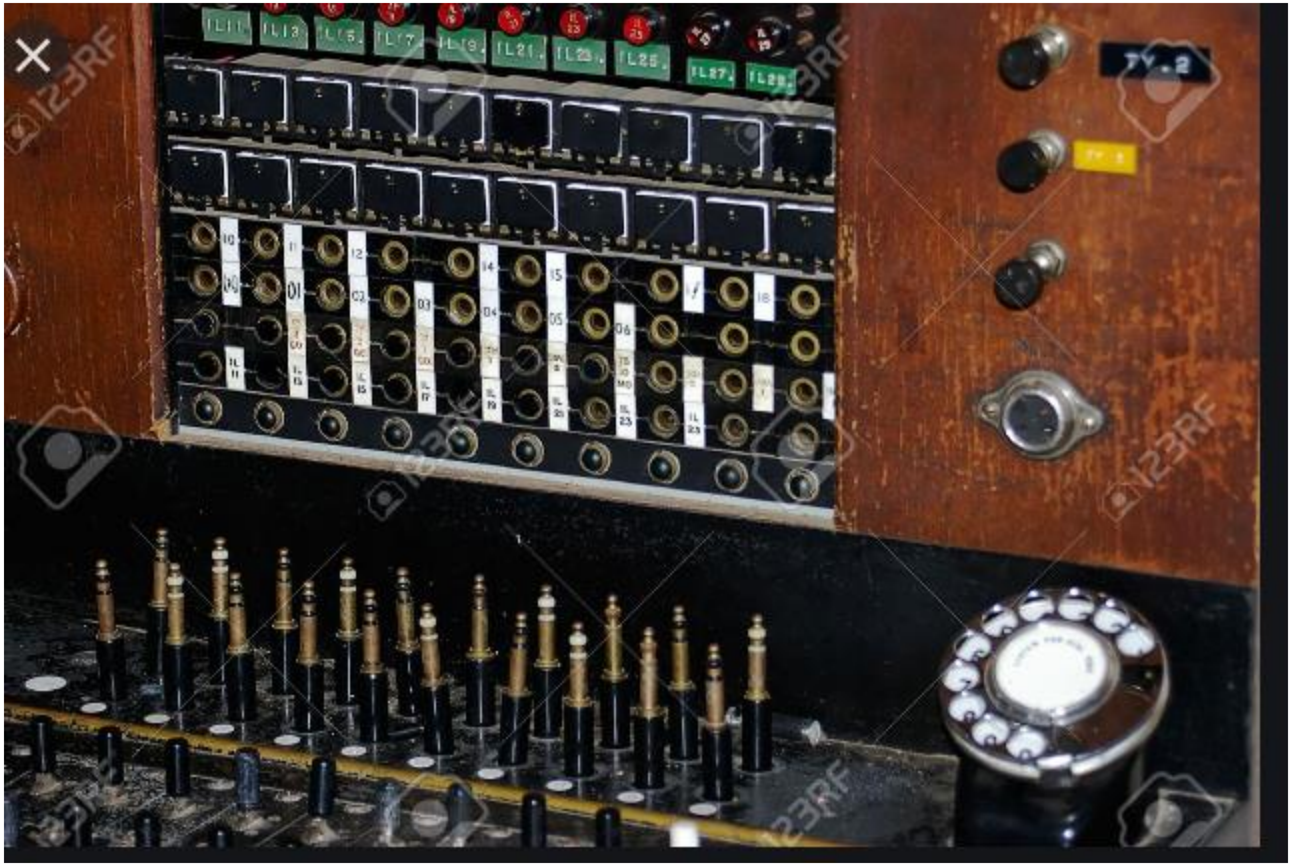


Switch board Inside View

Manual done by a human operator

Switch board Inside View

Manual done by a human operator



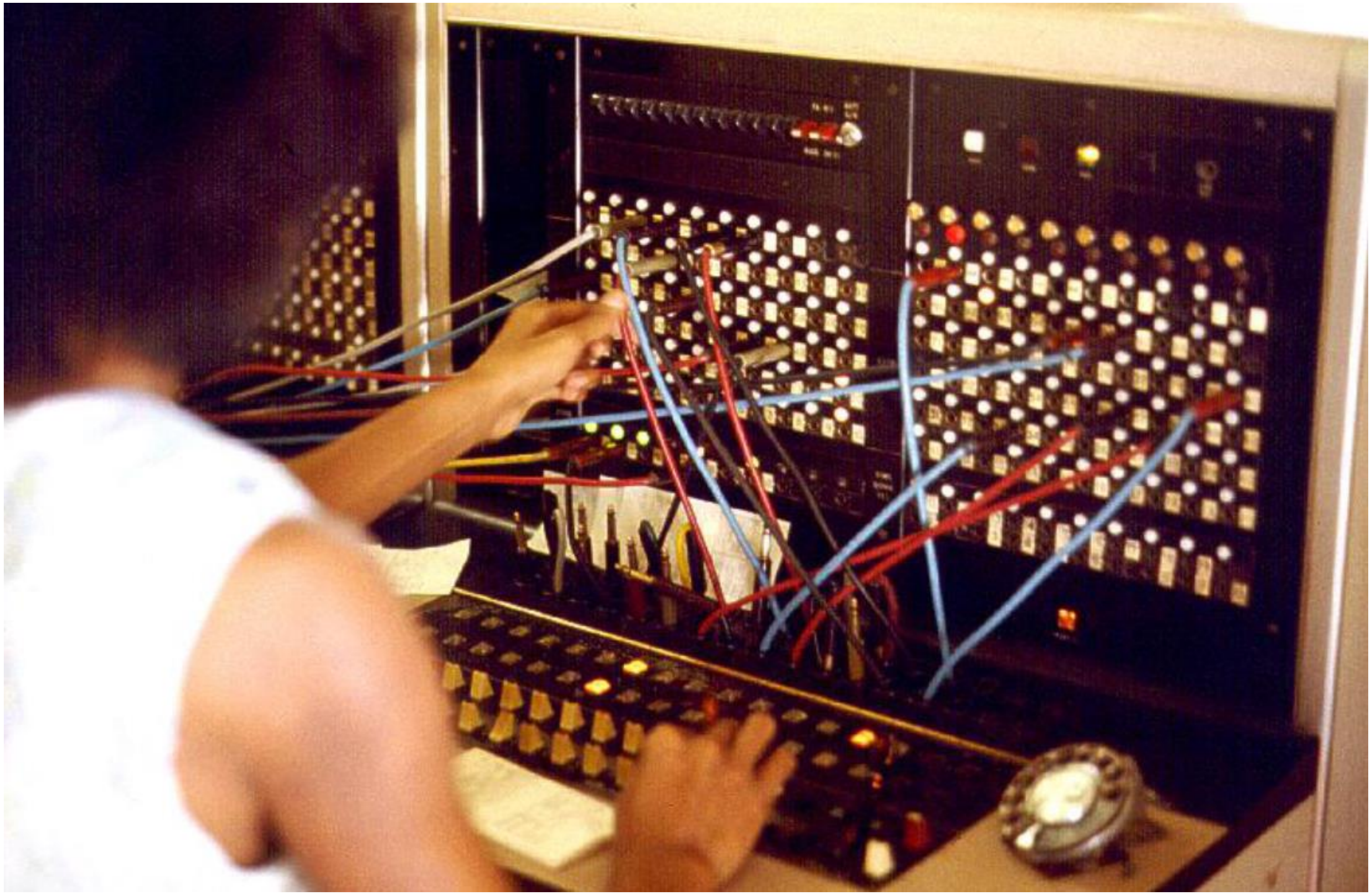
Switch board front View with the jack plug

Manual done by a human operator

Switch Board operator

Manual done by a human operator

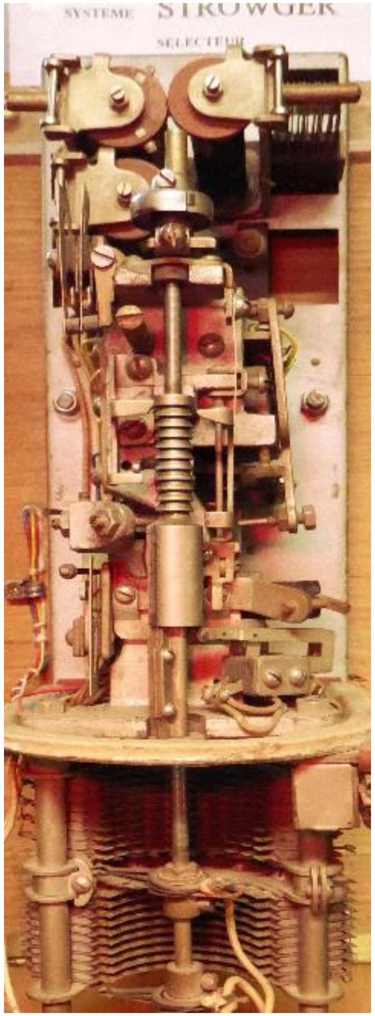
Manual done by a human operator



PBX 1975

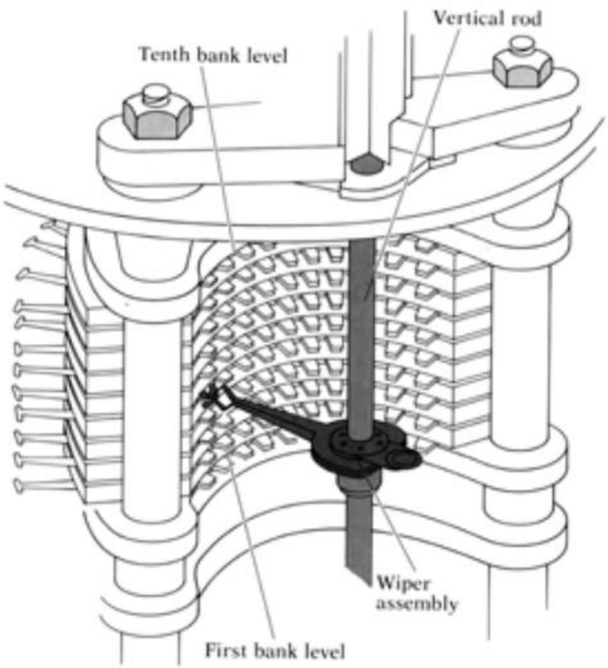
Mechanic switch

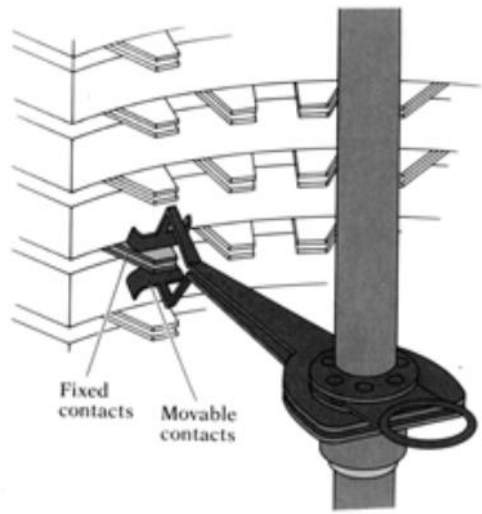
Almon Brown Strowger (1839-1902), was at the begining an undertaker, was motivated to invent an automatic telephone exchange after having difficulties with the local telephone operators, one of whom was the wife of a competitor. He was said to be convinced that she, as one of the manual telephone exchange operators, was sending calls "to the undertaker" to her husband.



F. MICHAUX

Mechanic Strowger step by step switch





The movable contacts in a step-by-step switch can connect to any of a 100 different pairs of fixed contacts, each leading to a different line.

https://www.youtube.com/watch?v=xZePwin92cI&feature=emb_title

https://www.youtube.com/watch?v=cNNKLuM8yY8

Electromecanical switch Pentaconta switch 1950-1970

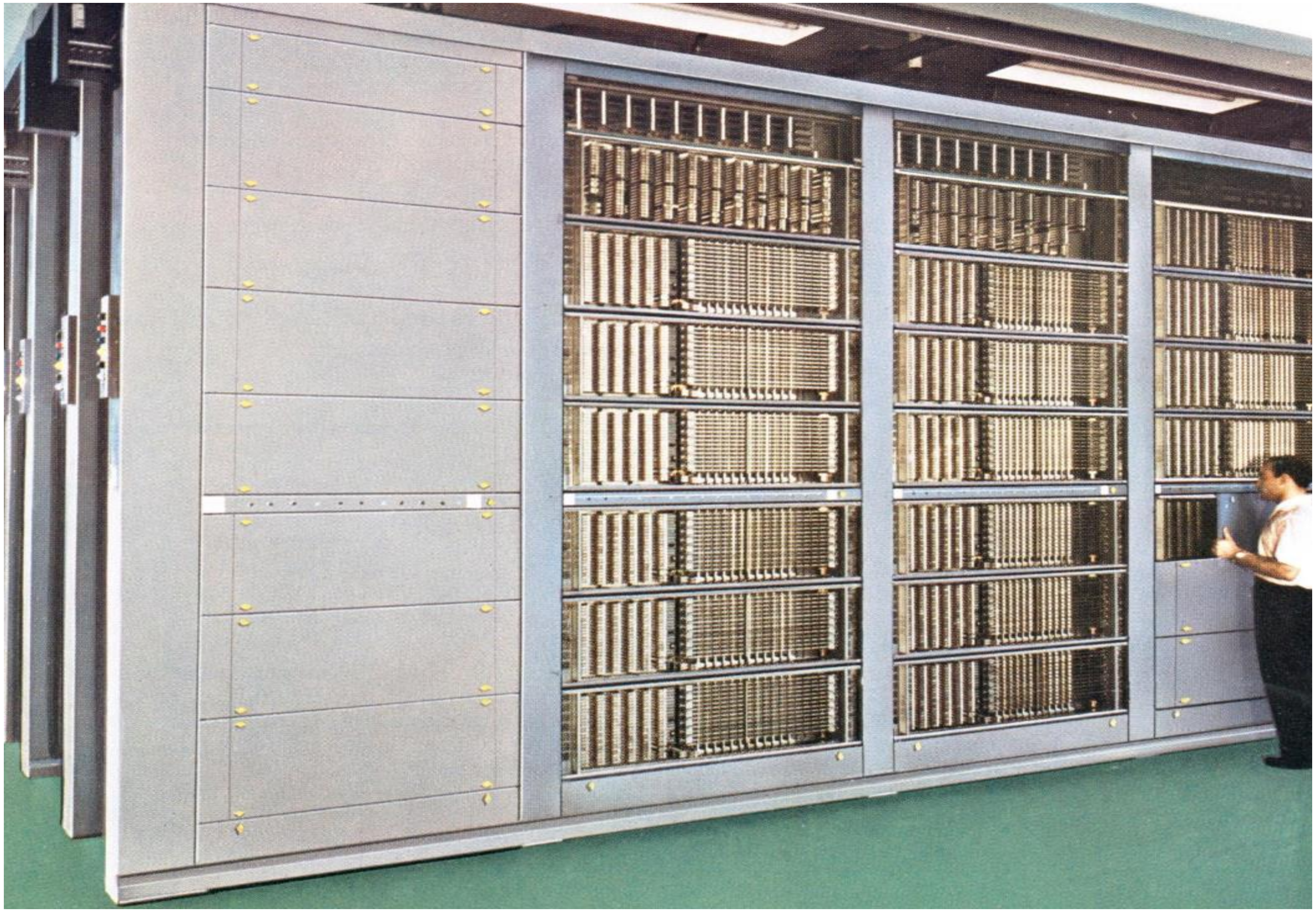
https://www.youtube.com/watch?v=Ahdd-r3Oq_o

https://www.youtube.com/watch?v=oM6OLeGOE6M

PENTA : Subscribers grouped by primary module of 50

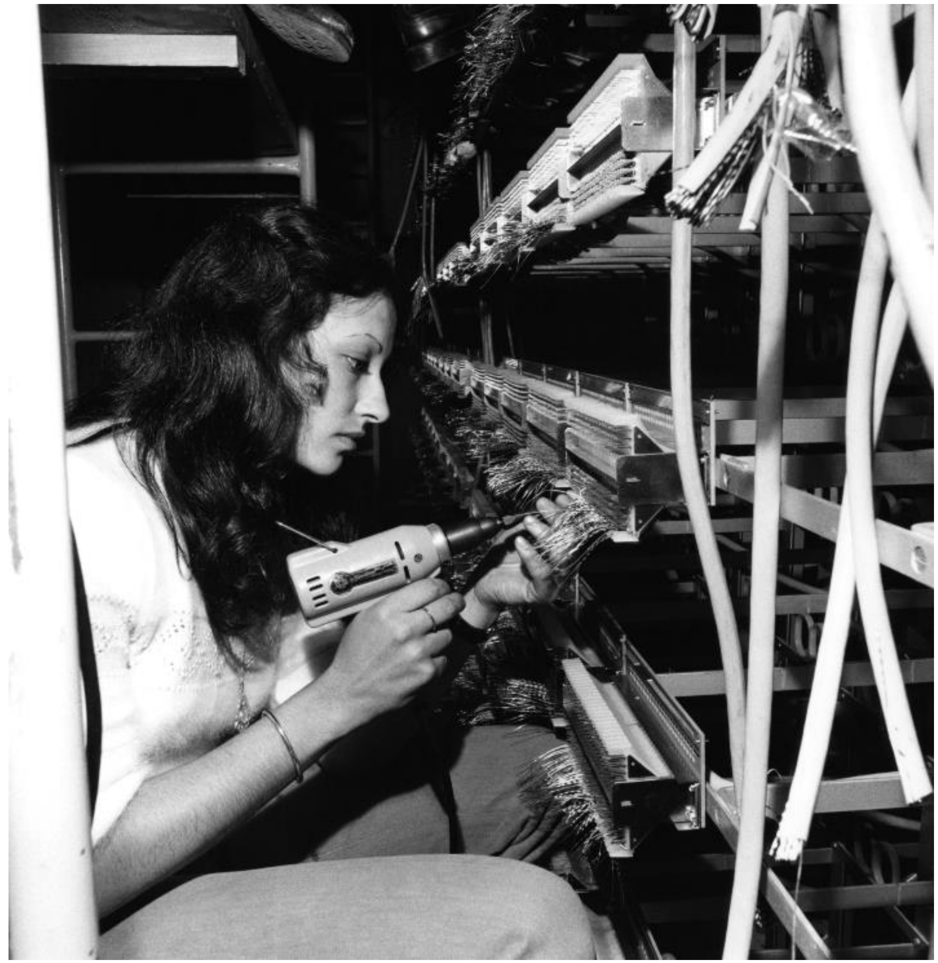
Vendor : LMT & CGCT subsidiaries of ITT (an American company)

Pentaconta switch 1000A Model Crossbar

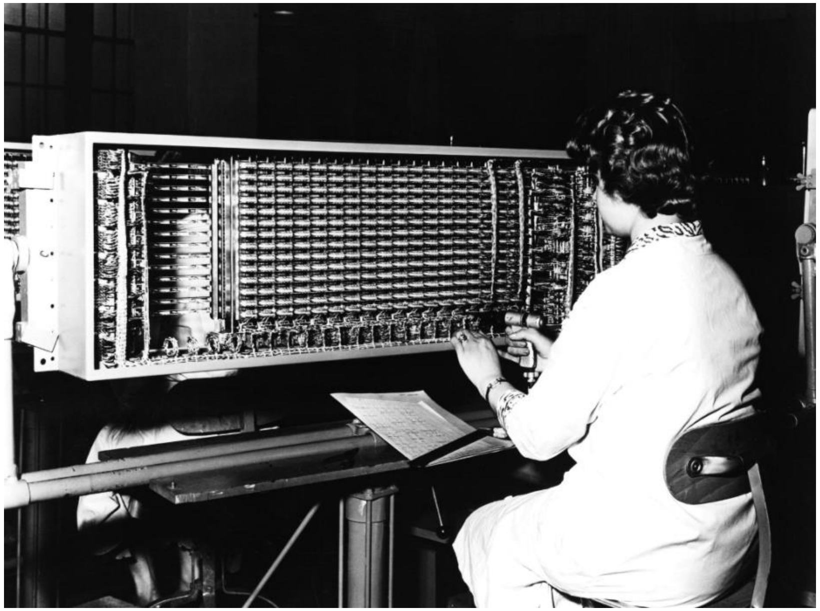


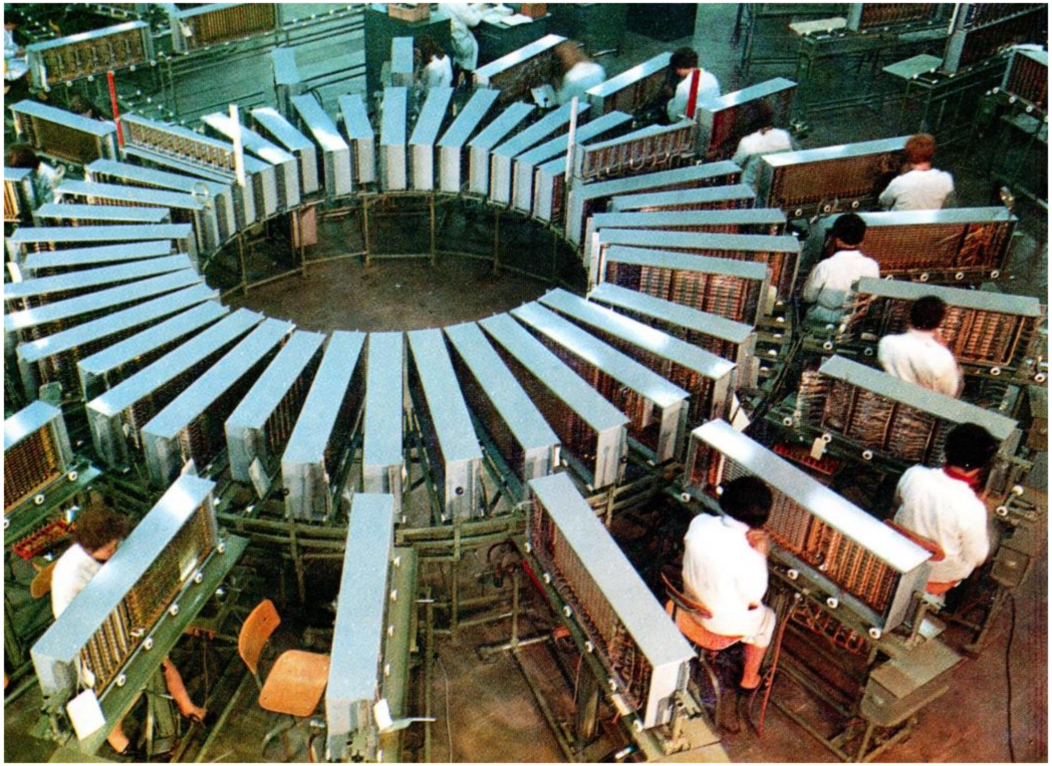
PENTACONTA GCID Montsouris Transit Switch Crossbar commissioned 1977 - Decommissioned 1993
Vendor : LMT

PENTACONTA crossbar wiring phase

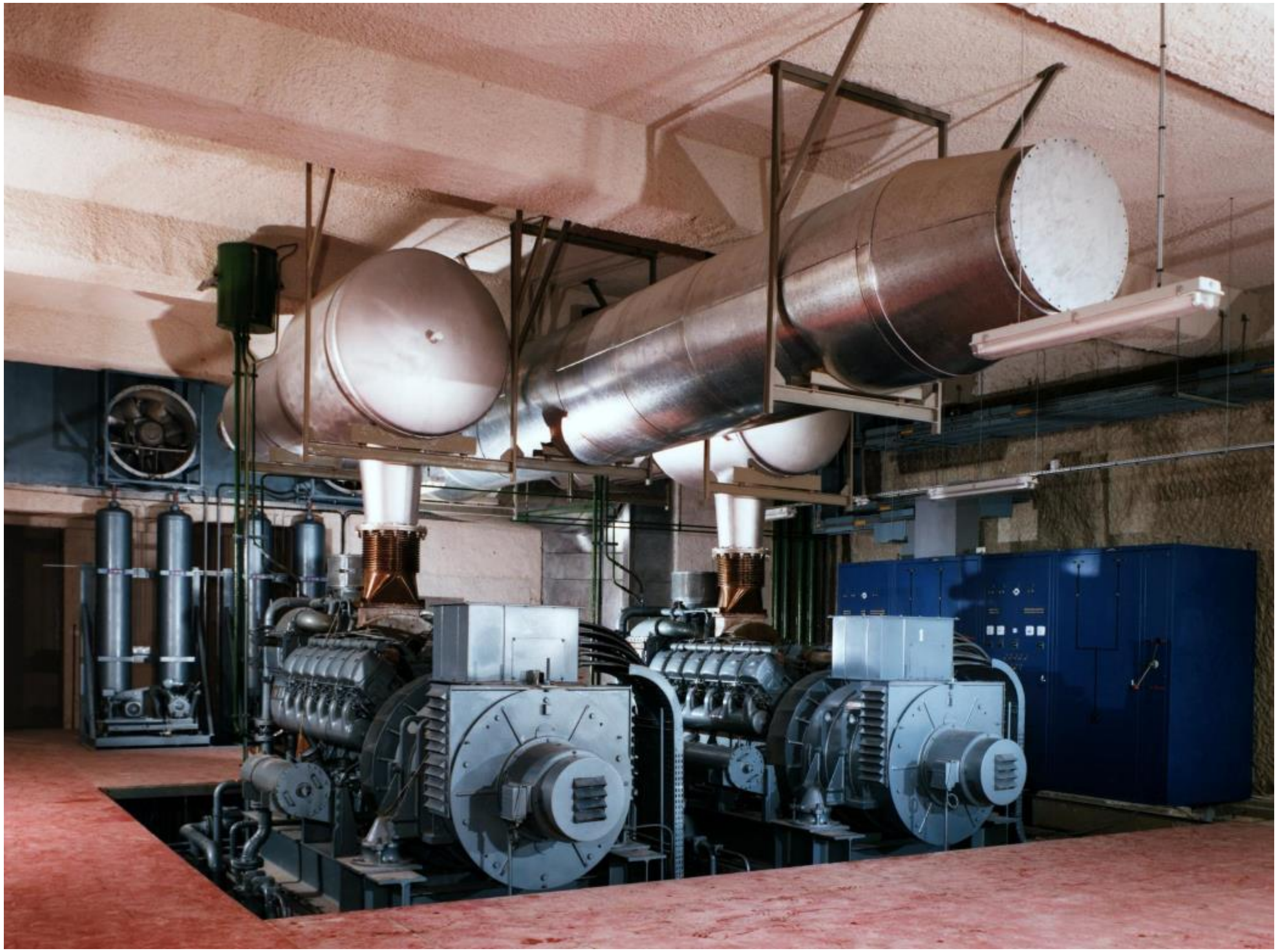


PENTACONTA wraping phase





PENTACONTA Stand by Electric Generator



First Electronic TDM switch in France « The platon » in 1970 for 800 subscribers (Electronic Switch)

Nortel « DSM 100 » Local Switch (Electronic Switch) 2000 years

TYPE OF SWITCHES

We could consider that we have two type of switches :

- Private corporate switches (eg. PABX).

- Public Switches used by operators

MAIN Digital Switching System VENDOR

Today the market is shared by 5 vendors which propose 6 different public switches :

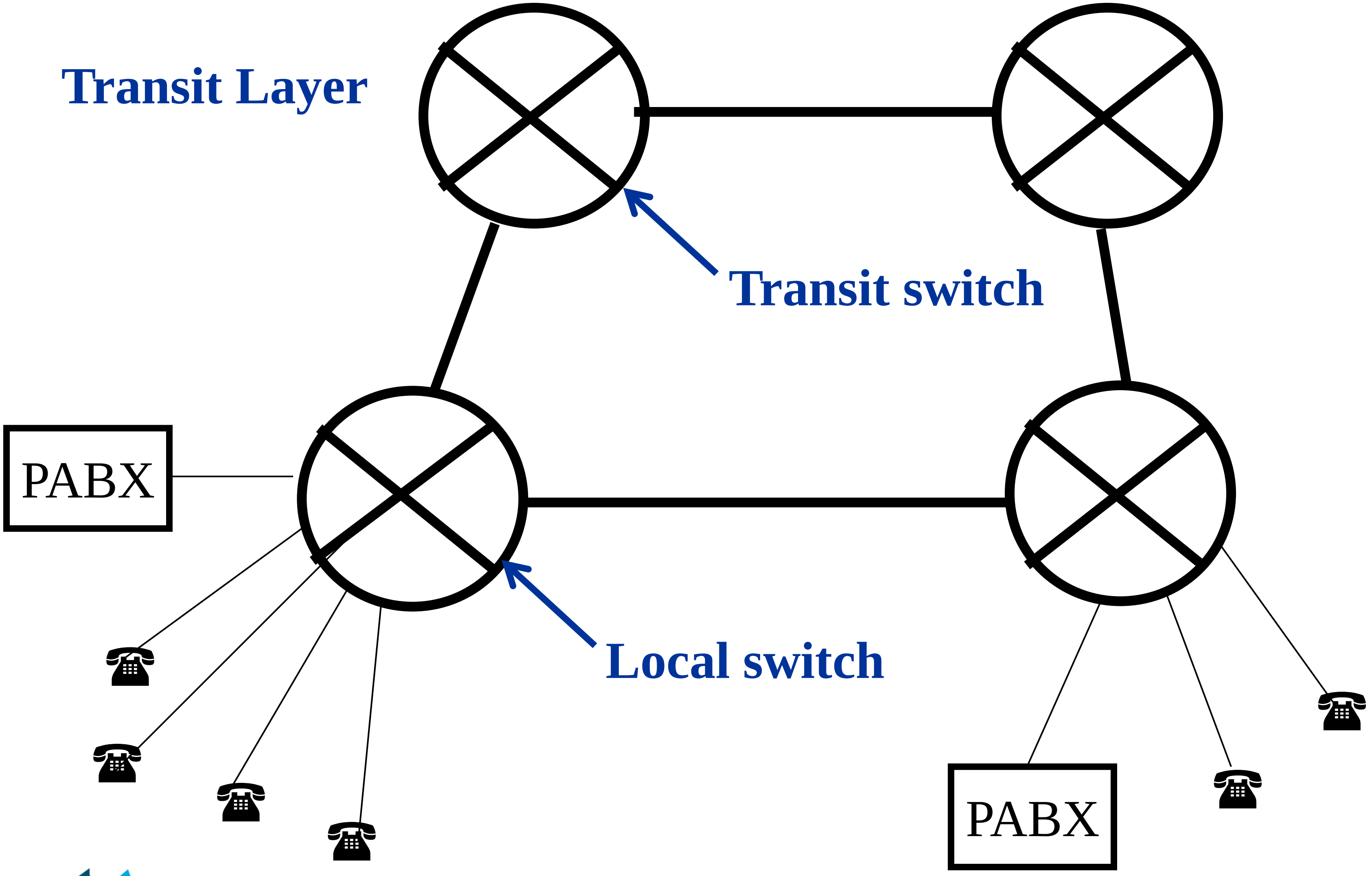
- SIEMENS : EWSD (1975-2017)
- ALCATEL : E10 (1976) (&CGE product) S12 (ITT product) merge of CGE and ITT.
- LUCENT TECHNOLOGIES : 5ESS Eletronic Switching System 1982-
- ERICSSON : AXE 10 Automatic eXchange Electric (1975 - .
- NORTEL : DMS (1979 – 2010)

TYPE OF PUBLIC SWITCHES

There is 3 family of public switches

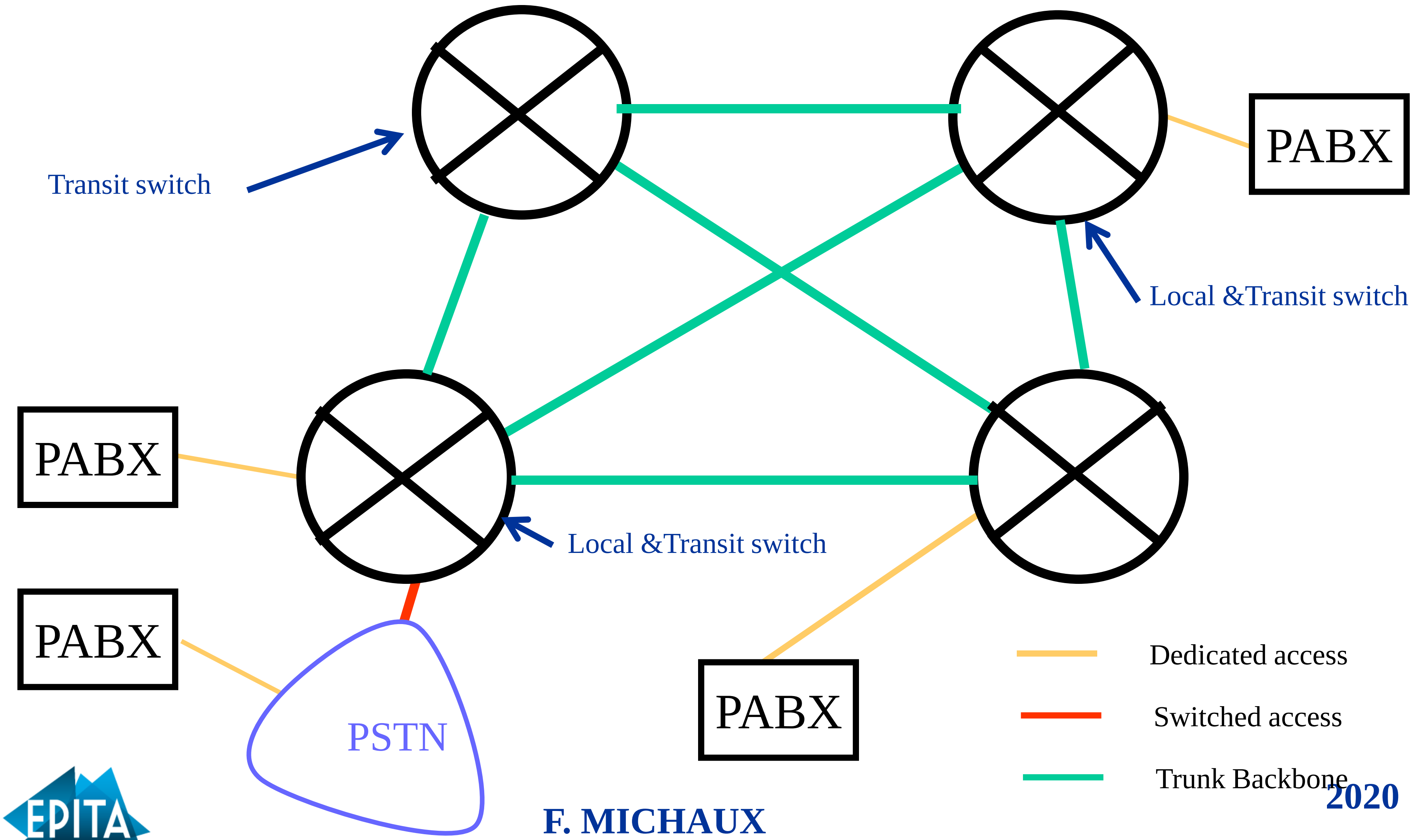
- LOCAL: used to connect customers and others switches
- TRANSIT : Used to interconnect switches
- "TRANS-LOCAL" : Which as the both functions generally used alternate operators which have not enough traffic for having a transit network.

PUBLIC VOICE NETWORK ARCHITECTURE

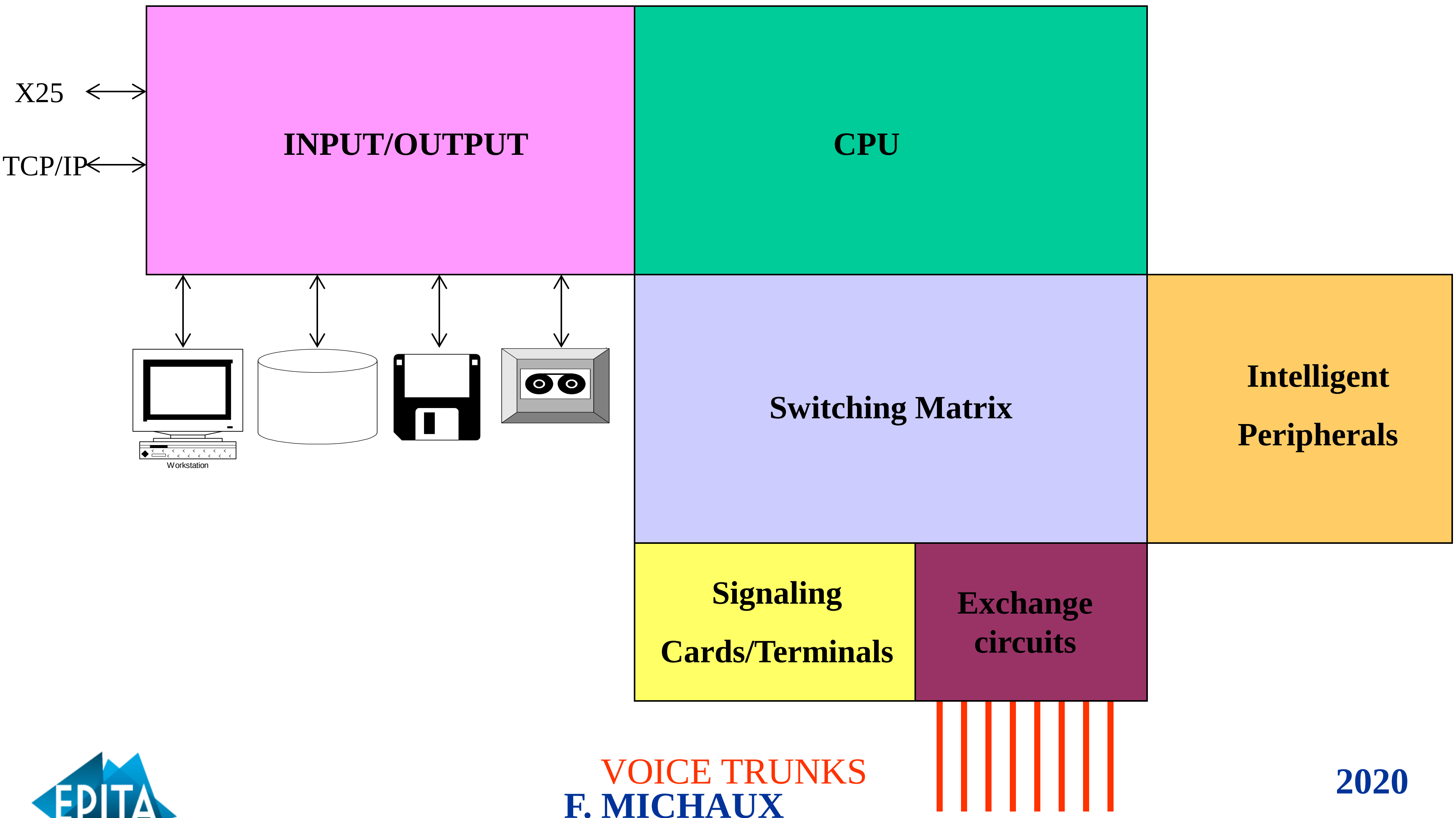


VOICE NETWORK ARCHITECTURE

The voice network architecture is flat no transit layer

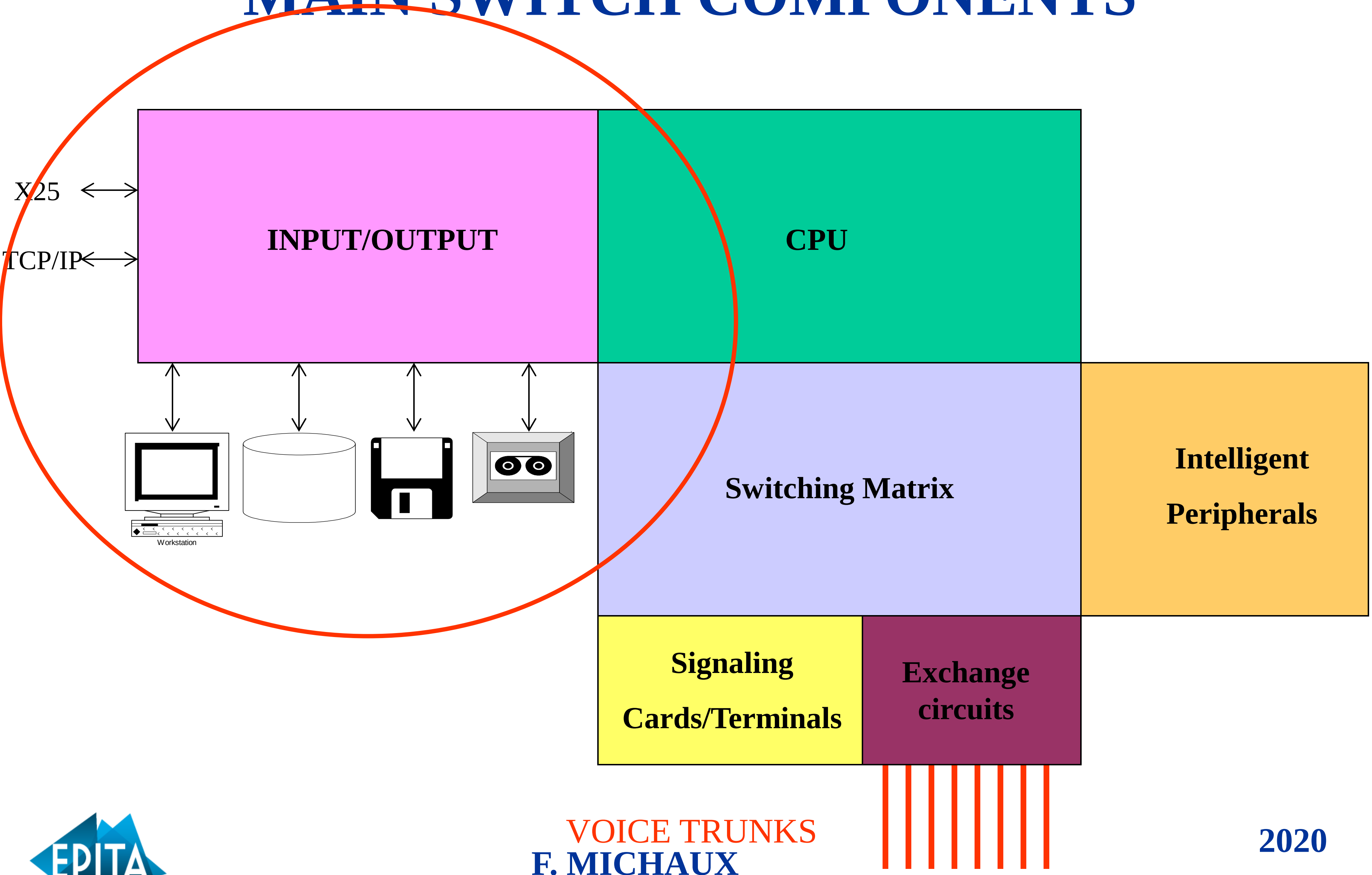


MAIN SWITCH COMPONENTS



INPUT/OUPUT

MAIN SWITCH COMPONENTS



INPUT/OUTPUT

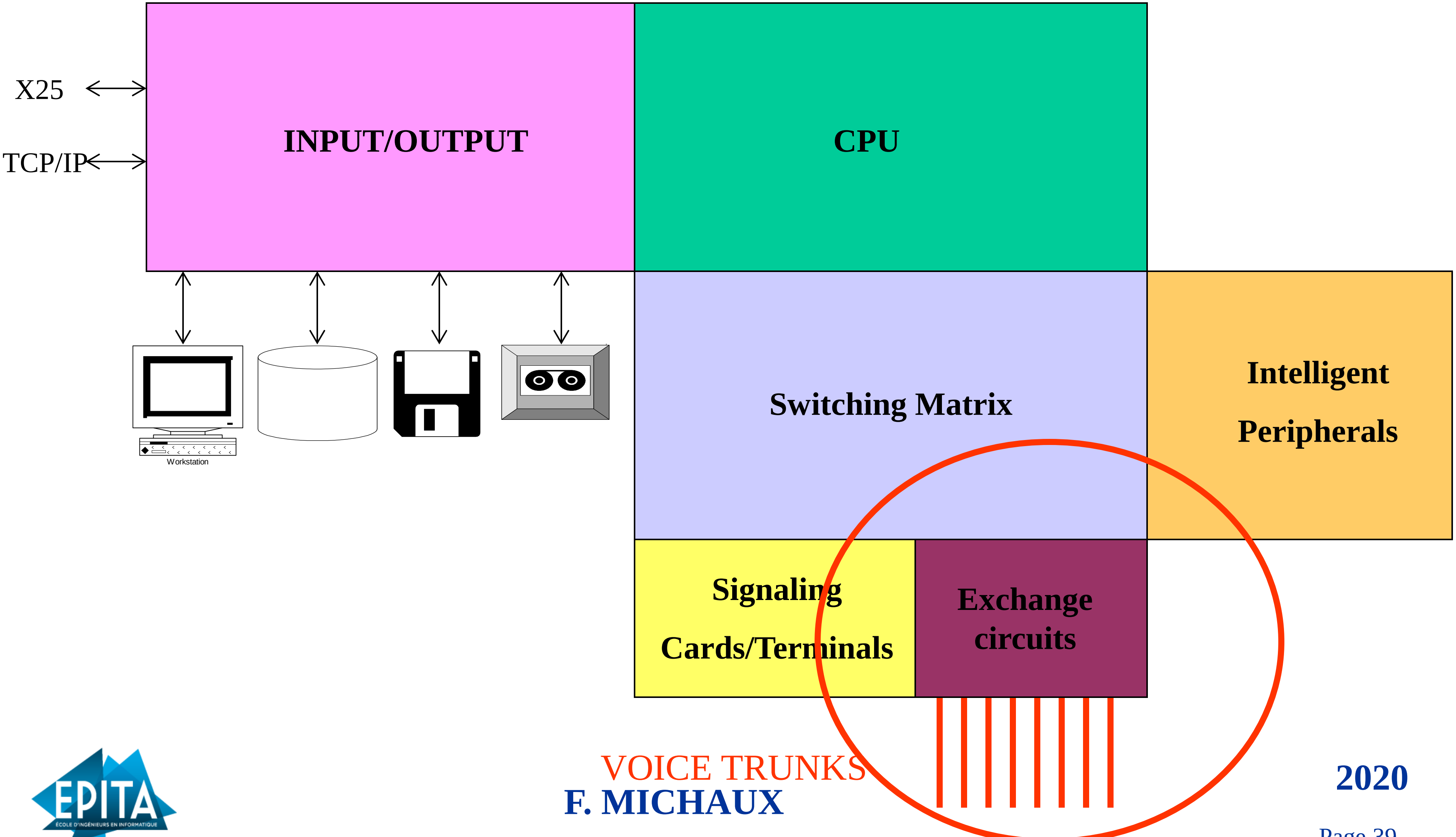
This device is the interface equipment between the switch and

- The billing system X25 or/and TCP/IP.
- Monitoring system remotely and locally.
- Saving system (Call detail records, translations ….
- The disks

TDM TECHNOLOGIE

Transport, PCM...

MAIN SWITCH COMPONENTS



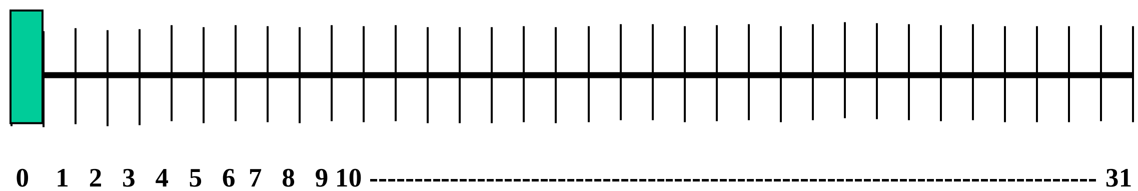
TDM TECHNOLOGIE

TDM means Time Division Multiplexing

This technologie :

- is known for more than 60 years, but deployed for 30 years. Patent dated before the second world war.
- Consists of divided the time in order to carry in the same link different trafic stream

TDM TECHNOLOGIE



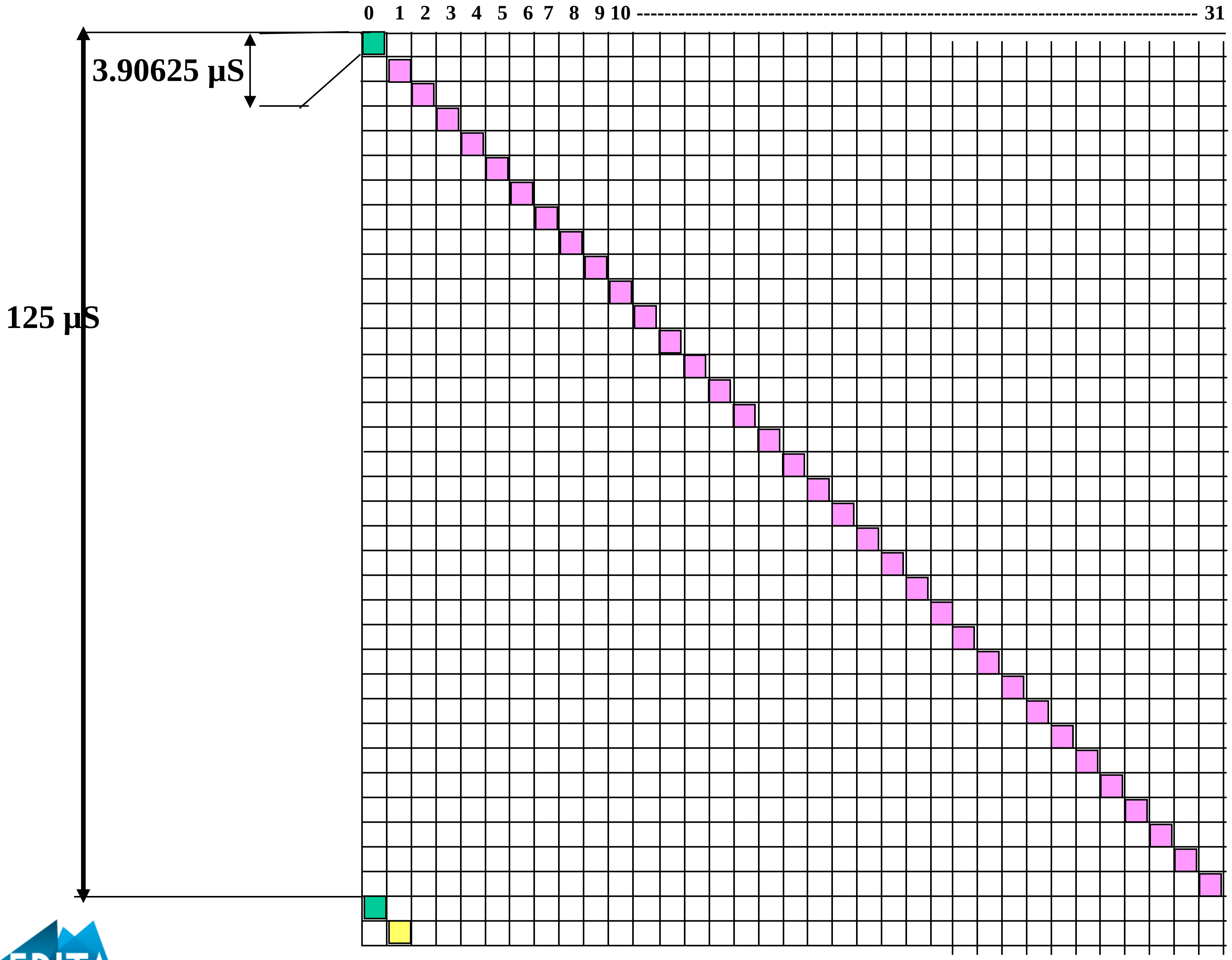
The time is divided in 32 time slots (E1) for the international standart and 24 (T1) for the american standart.

The total rate for the link is 2.048 Mb/s

The rate for the a time slot is 64 Kb/s = 2048/32

The time slot 0 is used for the synchronisation, the paylaod is not 32*64 Kb/s but 31*64 Kb/s

TDM TECHNOLOGIE



F. MICHAUX

TDM TECHNLOLOGIE

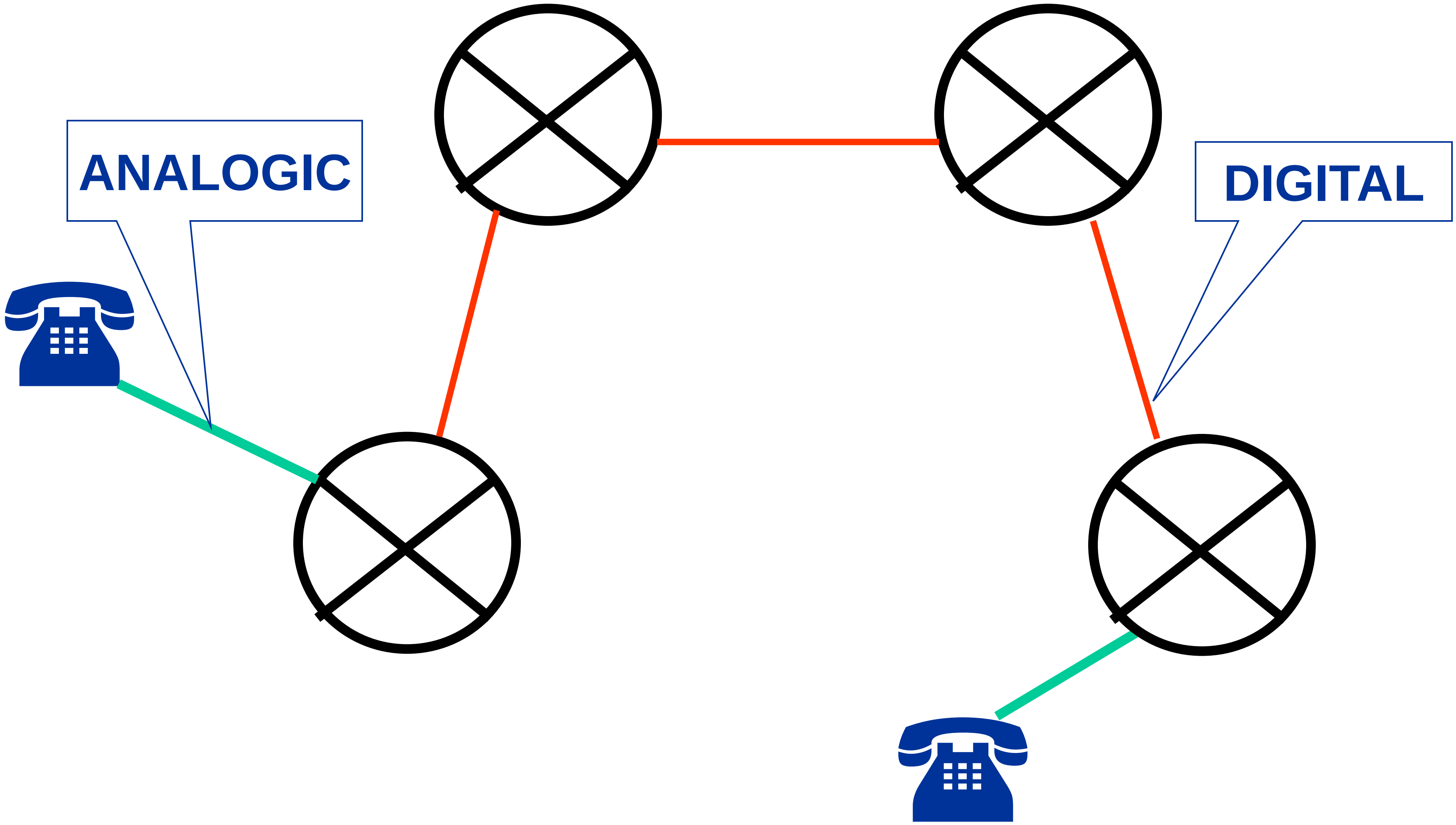
- Every 125 µS each time slot has a window of 125 µS / 32 = 3.90625 µS

- As the total rate of the link is 2.048 Mb/s therefore a time slot sends every 125 µS.

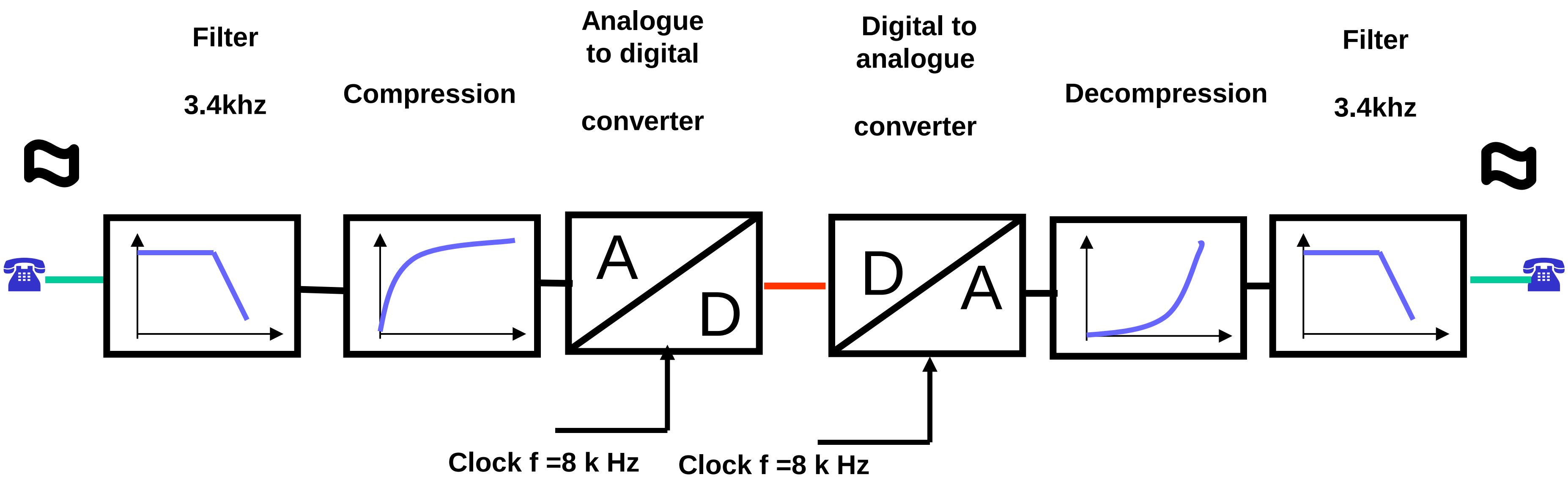
2 048 000 b/s X 3.90625 µS = **8 bits**

Conlusion: 1 Byte is sent every 125 µS per time slot. It corresponds of 8000 Bytes/s or 64Kb/s.

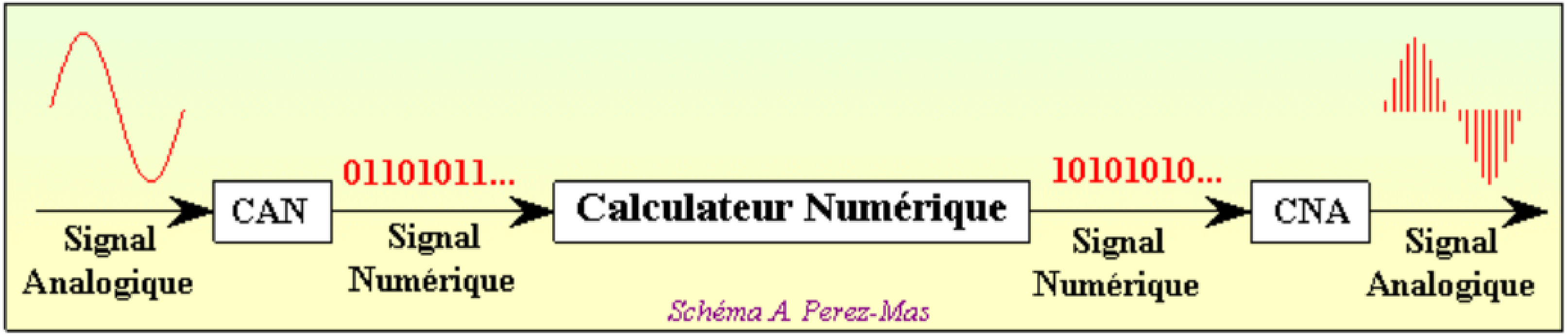
ANALOGIC & DIGITAL LINES



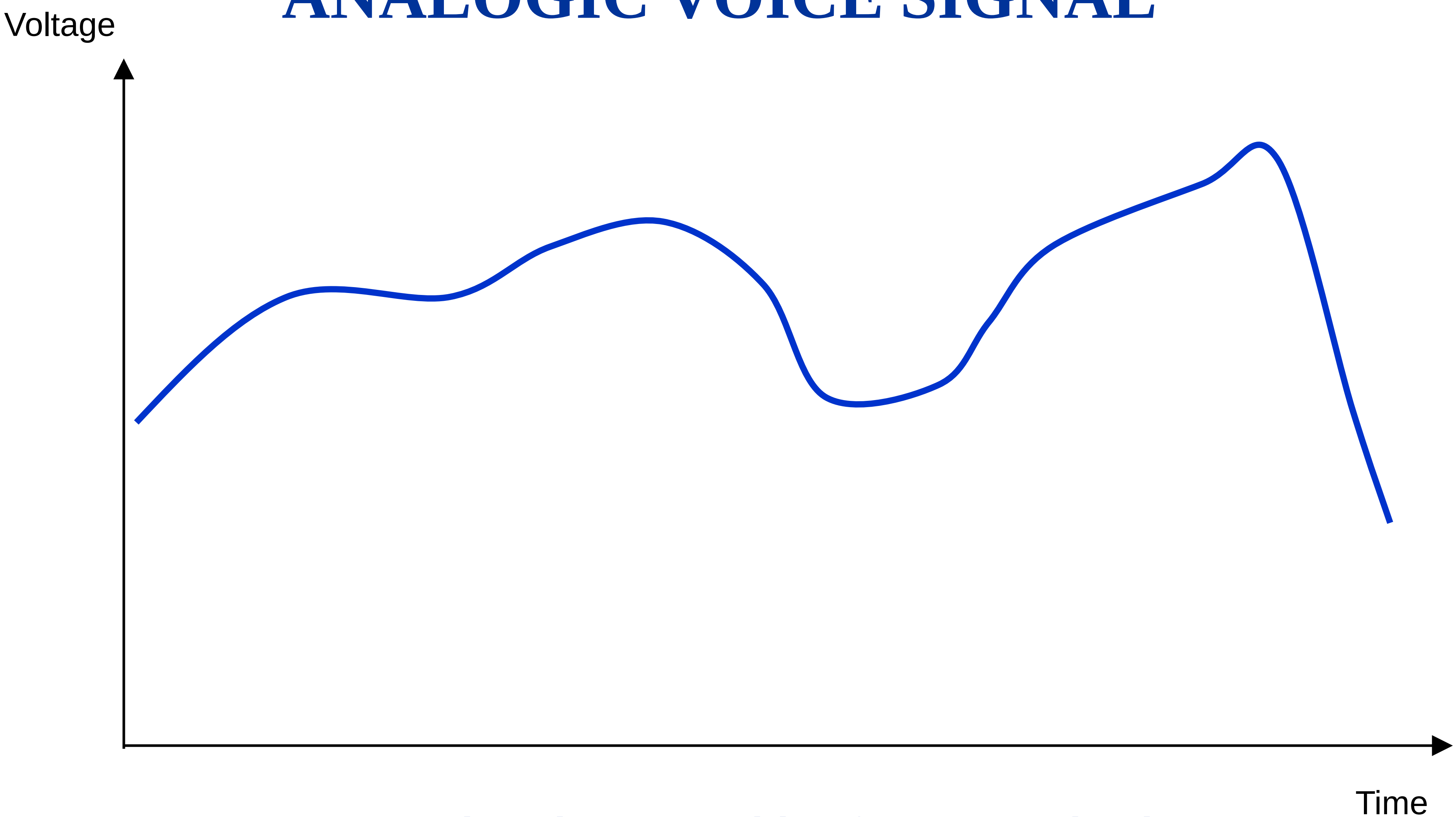
DIGITALIZATION PRINCIPLE



DIGITALIZATION PRINCIPLE

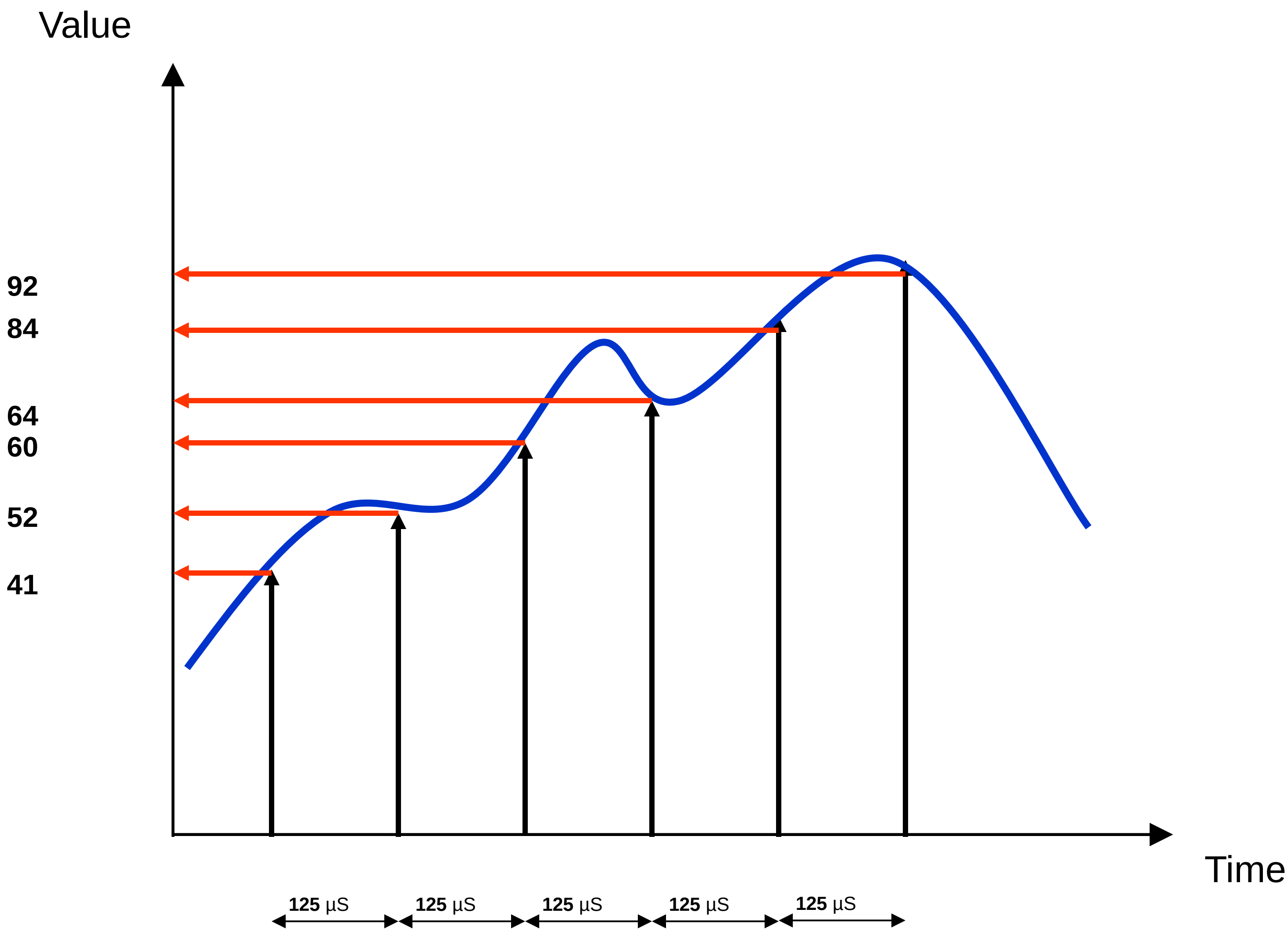


ANALOGIC VOICE SIGNAL

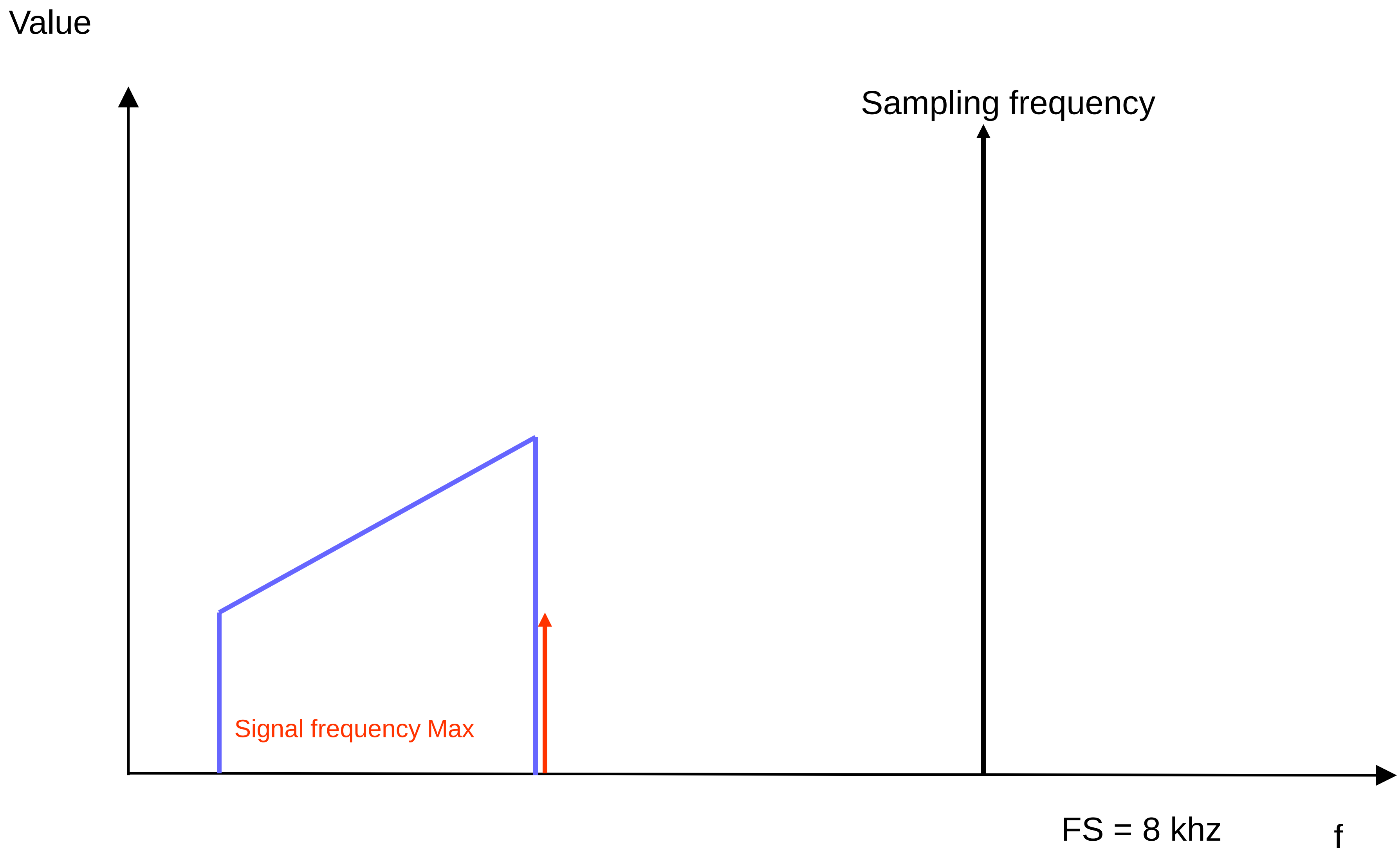


Voice signal outside of an analogic phone

PULSE CODING MODULATION

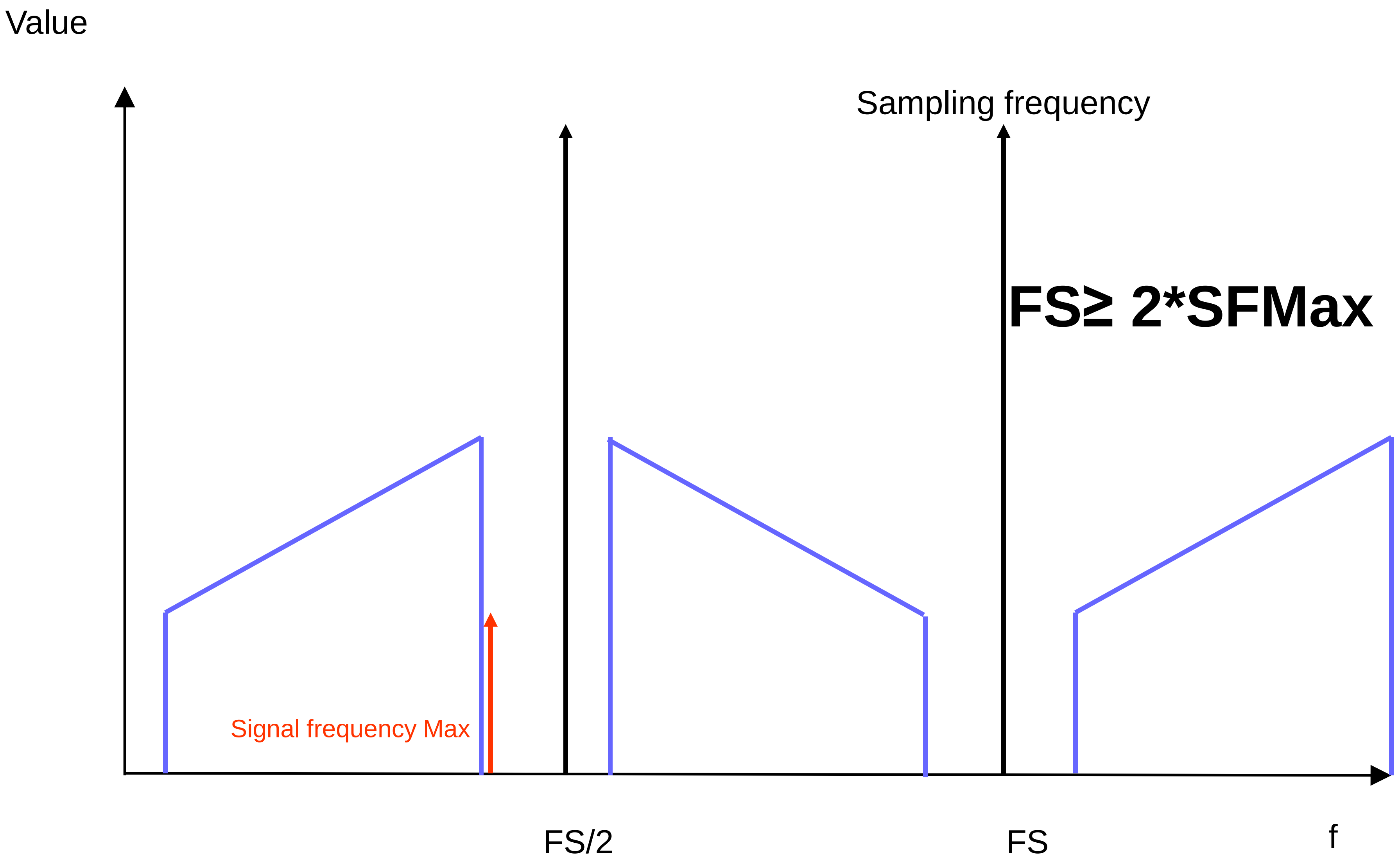


SIGNAL THEORY



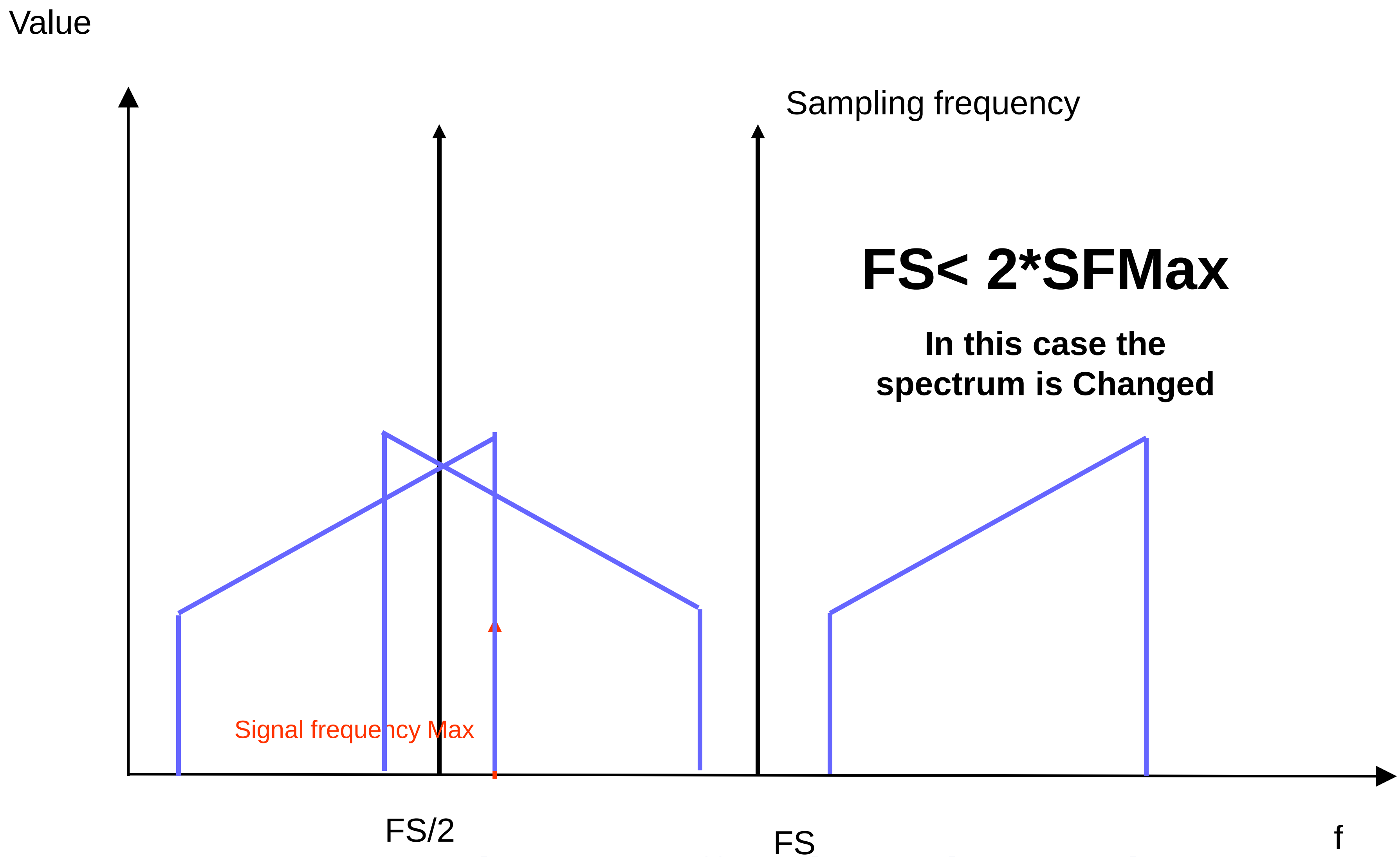
Voice spectrum

SIGNAL THEORY



Spectrum about turn effect due to the sampling

SIGNAL THEORY

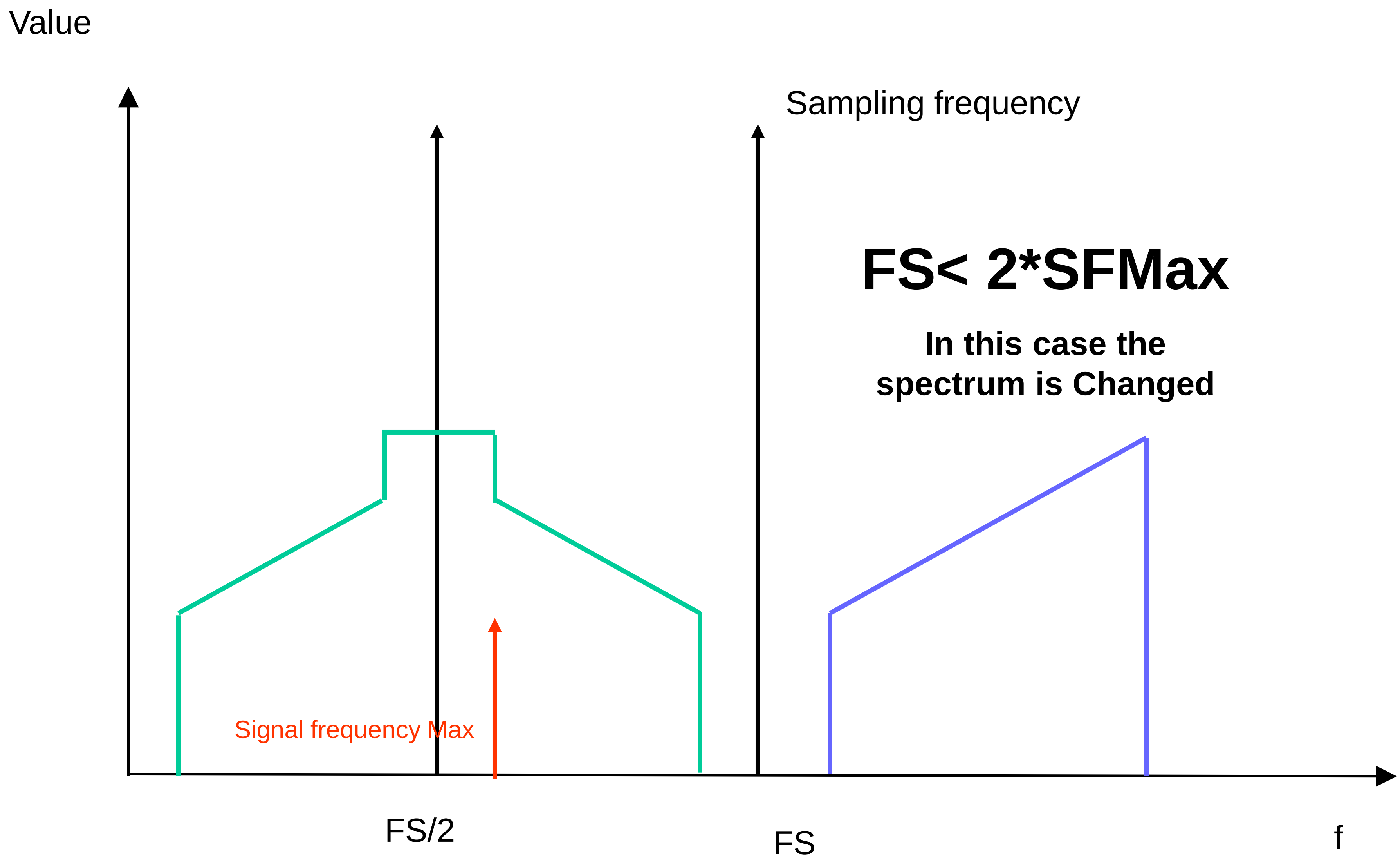


FS< 2*SFMax

In this case the spectrum is Changed

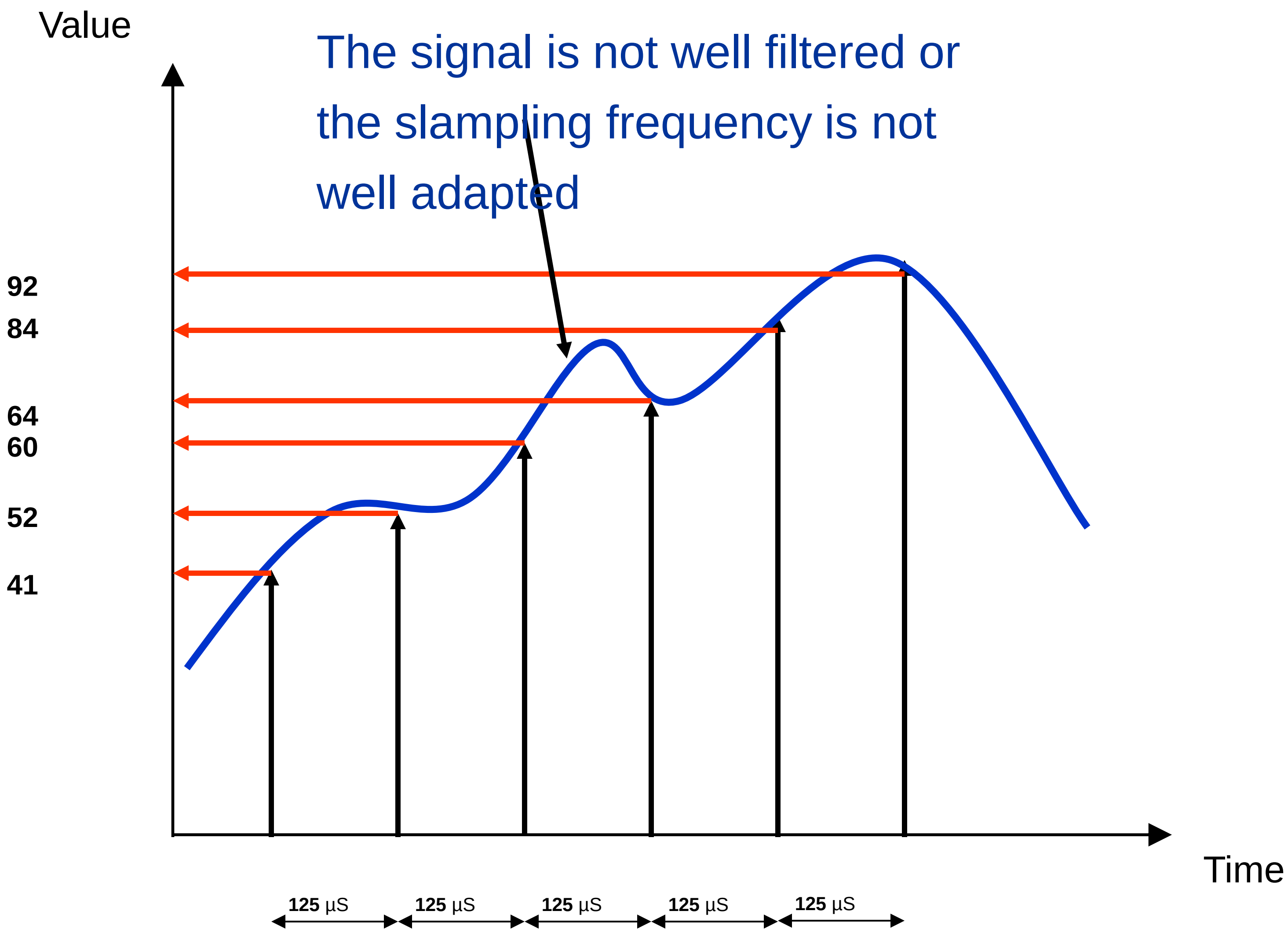
Spectrum about turn effect due to the sampling

SIGNAL THEORY



Spectrum about turn effect due to the sampling

SIGNAL THEORY



SIGNAL THEORIE

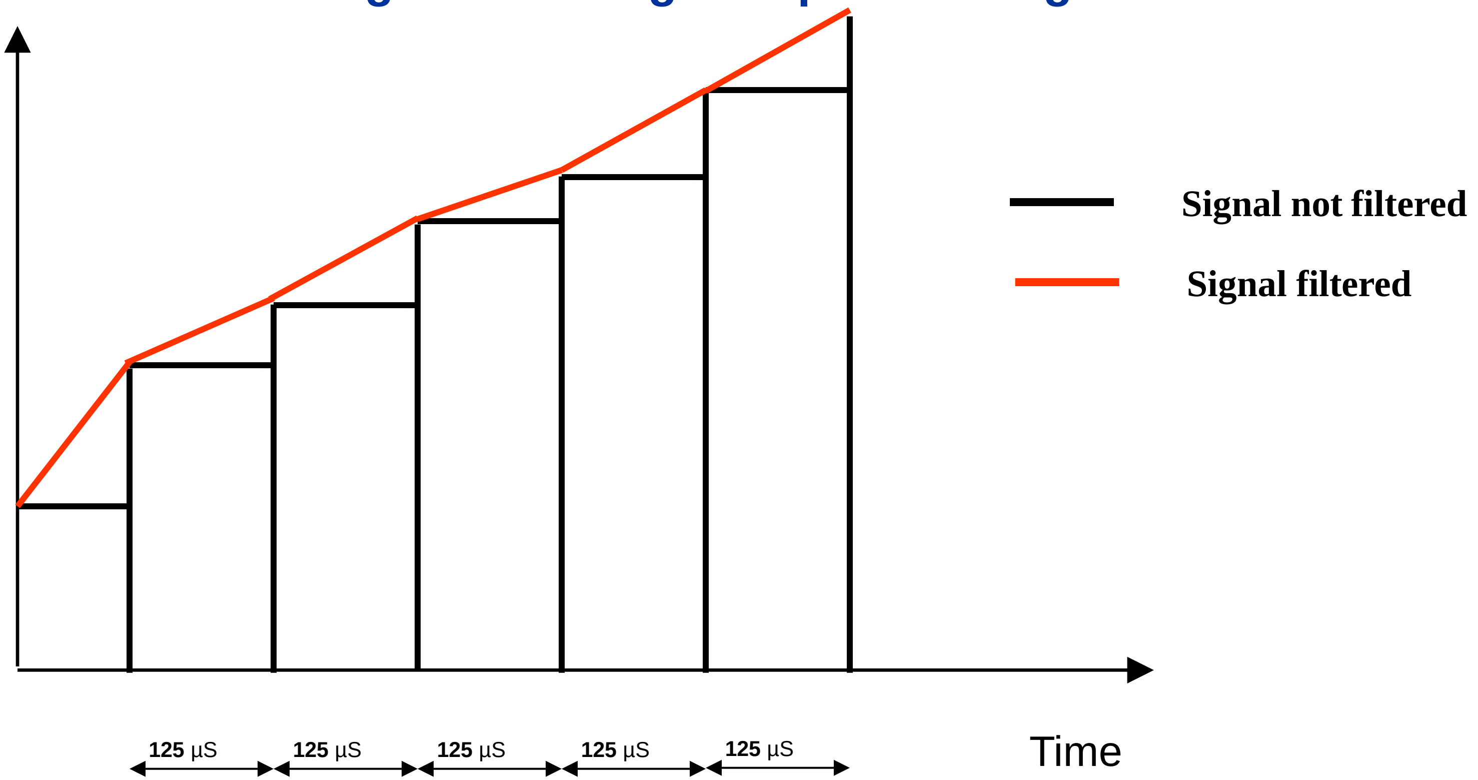
The Shannon theorem : the spectrum will be reproduced identically if the sampling frequency is superior or equal to 2*Fmax (of the voice signal) in telephony :

- The Sampling frequency is 8 KHz
- The voice spectrum is between 300-3400 hz
- Checking : 8000 ≥ 2 * 3400 = 6800
- This the reason why the voice signal is filtered

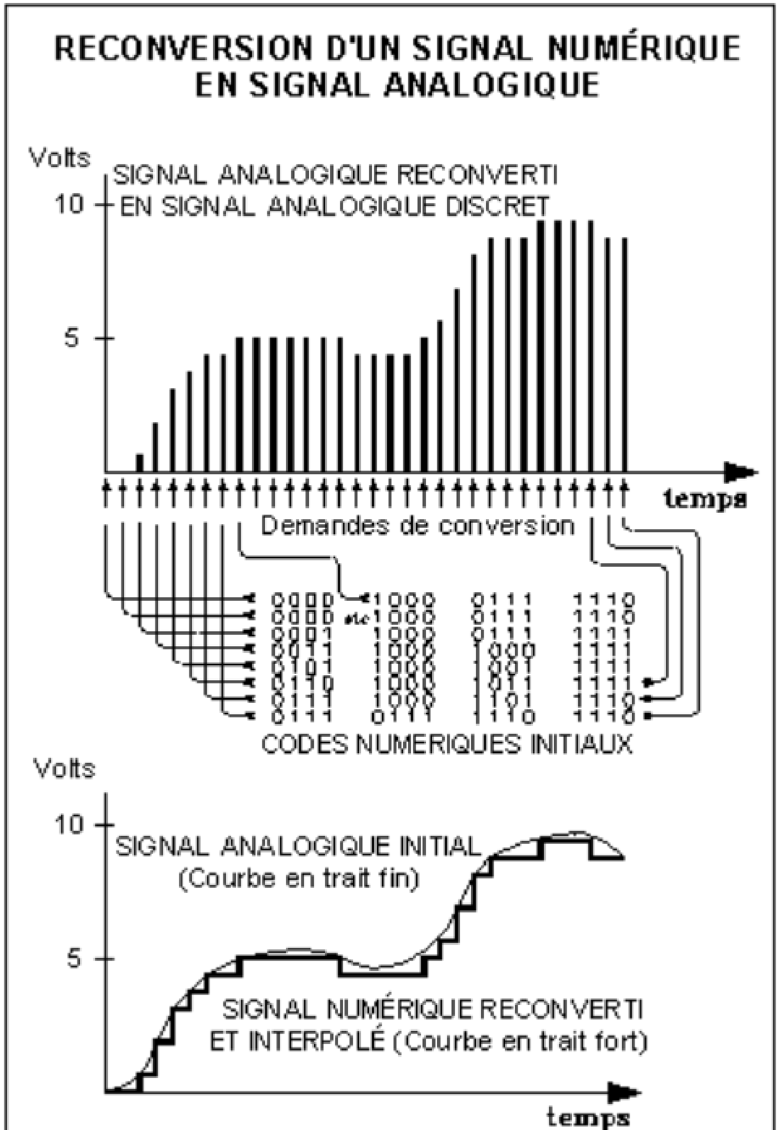
SIGNAL THEORIE

- The signal has to be filtered after the conversion digital to analog :

The conversion D to A generates high frequencies signal.

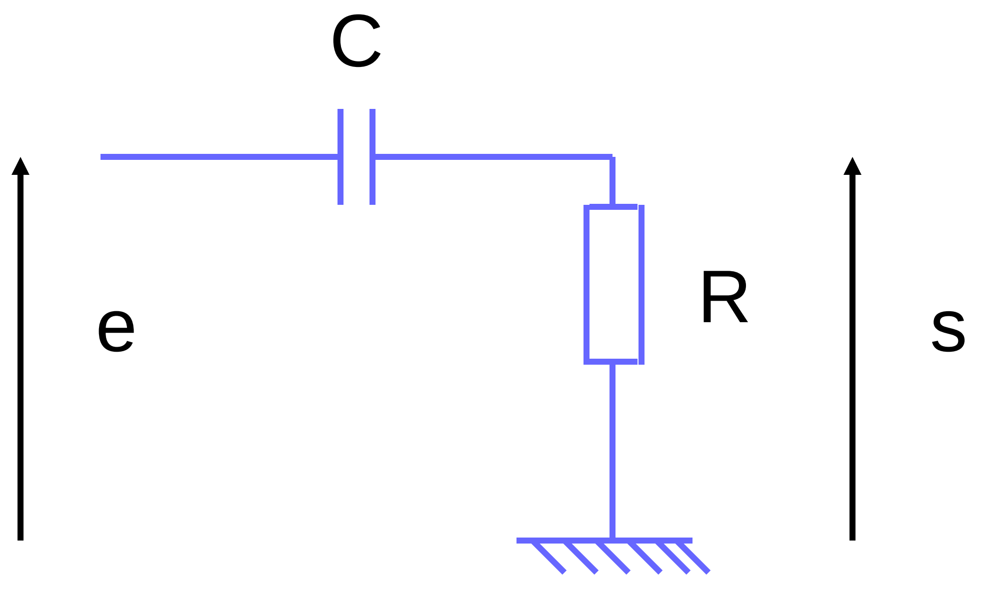


SIGNAL THEORIE



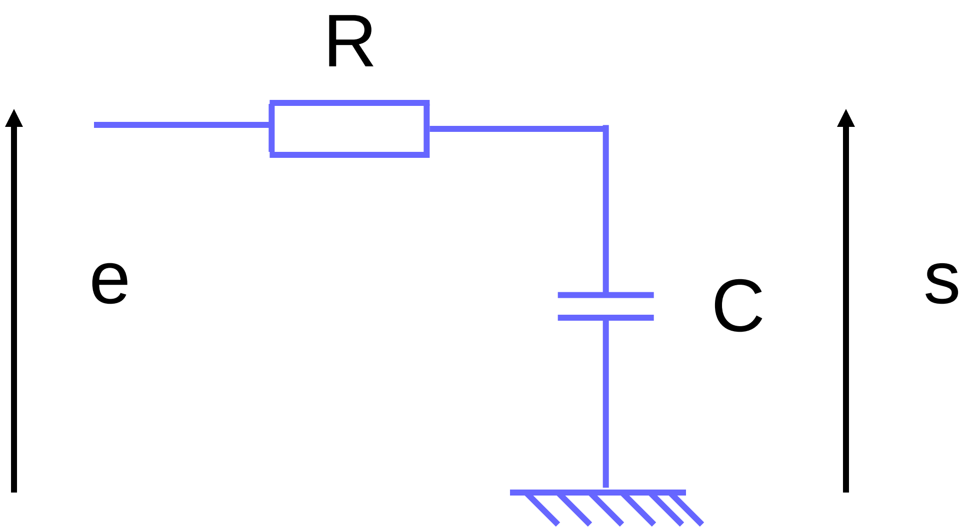
SIGNAL THEORIE

Low frequencies suppressor



SIGNAL THEORIE

- High frequencies suppressor



COMPRESSION 1/5

Résolution d'un convertisseur CAN (ou CNA)

Nous observons qu'à chaque niveau, un même nombre binaire correspond à toute une plage de valeurs analogiques d'entrée.
La "largeur" commune de ces plages est nommée parfois "**quantum**".

$$\boxed{q = \frac{(V_{max} - V_{min})}{2^n - 1}}$$

Dans le cas de la fig. précédente, n = 4 ; 2^4=16 ; 2^4-1=15 ; Mmin=0 V ; Vmax = 10 V
q = 10/15 = 666,6... mV

Il est évident que plus un convertisseur différentie de valeurs pour une même étendue de tensions d'entrée, plus l'information sur la tension mesurée sera précise.
Le mot "**résolution**" est souvent utilisé pour qualifier cette précision.

D'autres appellent "résolution" le quantum lui-même.
Dans ce cas, plus le quantum est petit, plus la résolution serait grande, ce qui est paradoxal !

Pour être plus logique, nous pouvons qualifier de **résolution** le **nombre de bits** du convertisseur.

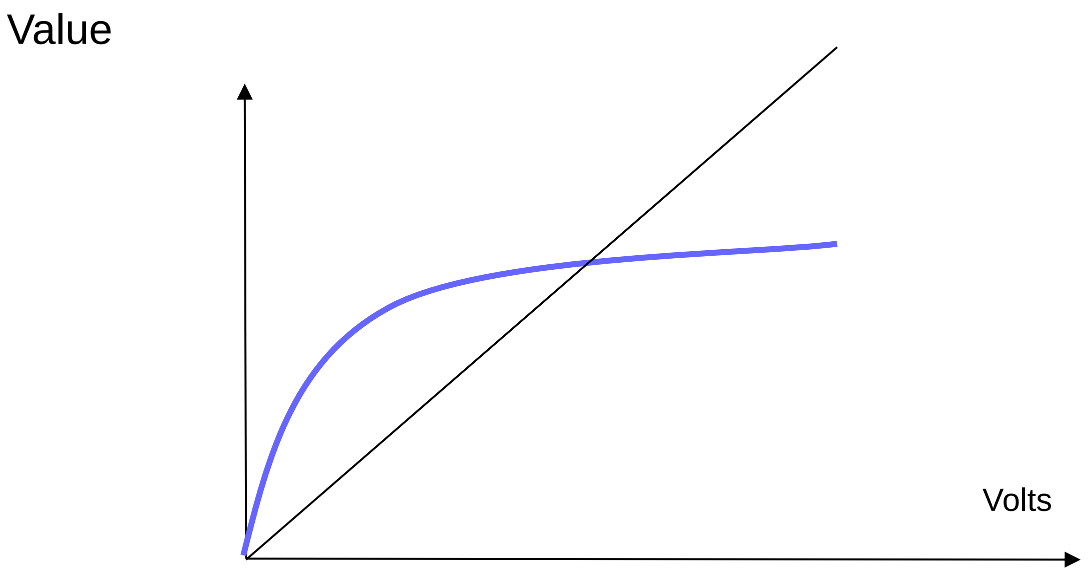
Avec **8** bits, on peut écrire 256 valeurs. D'où la valeur du quantum :
q = (Vmax - Vmin) / 2^n-1 = 10/255 = 39,215... mV

On peut encore évaluer l'incertitude relative de la mesure. q / (Vmax - Vmin)
C'est **1 / 2^{n-1}**

Nb de bits	Nb d'échelons	Incert. Rel.
8	255	0,39215 %
12	4095	0,02442 %
16	?	?

COMPRESSION 2/5

The conversion analogic to digital and the conversion digital to analogic is not linear. The reason is to extract the law signal from the noise and also to reduce the quantization noise.



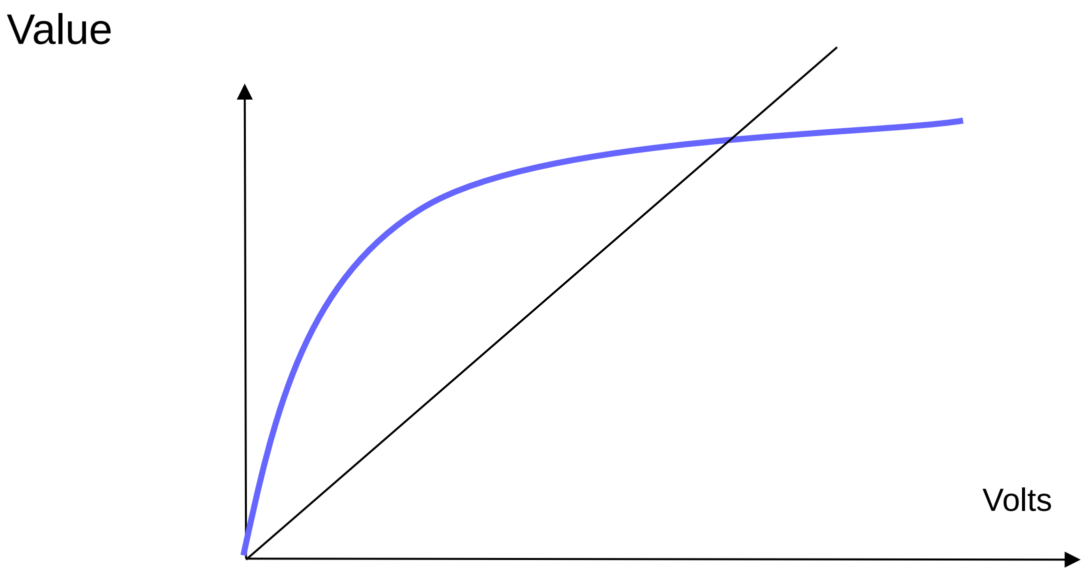
COMPRESSION 3/5

There is two kind of compression law :

- The law µ used in North America and Japan.
- The law A used for the rest of the world.
- The law A has priority

COMPRESSION 4/5

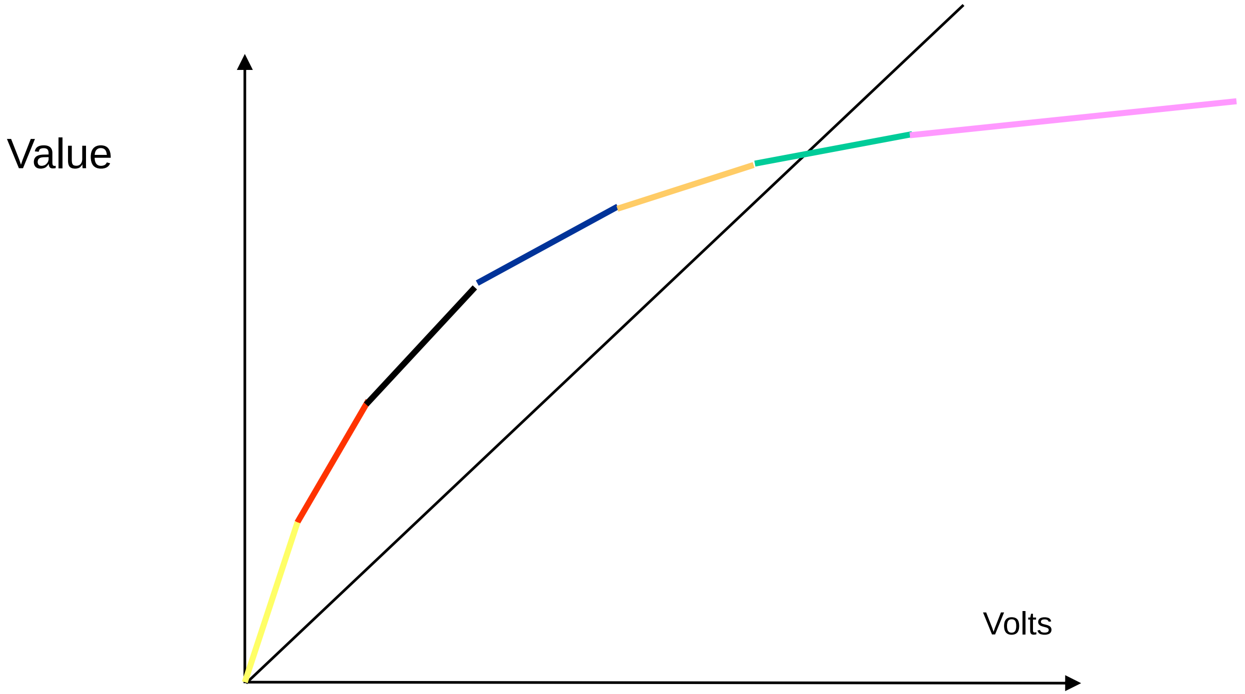
The law µ is a pure logarithmic curve.



The law µ

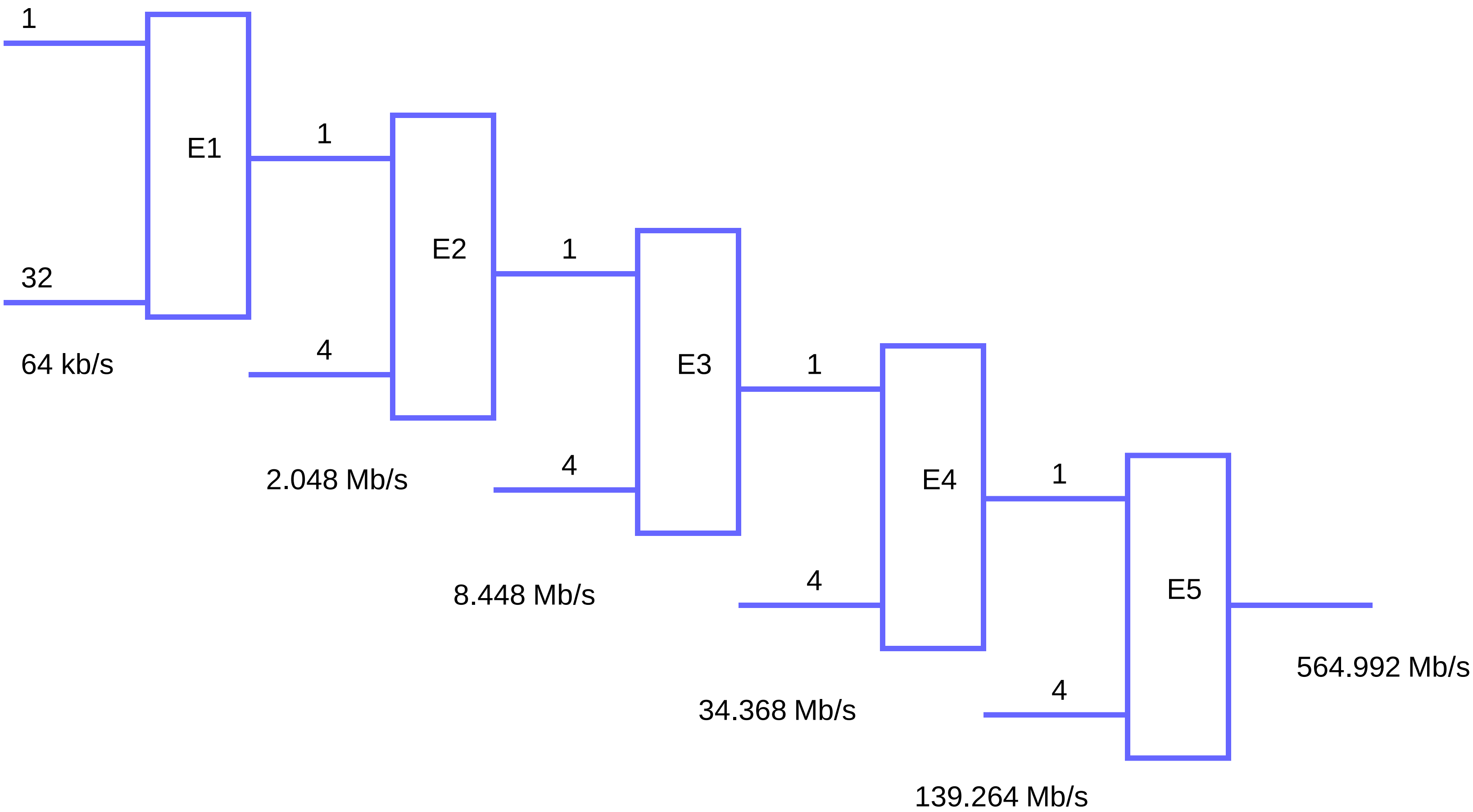
COMPRESSION 5/5

The law A is a sum of 7 linear segments



The law A

PLESIOCHRONE DATA HIERARCHY 1/2



PLESIOCHRONE DATA HIERARCHY 2/2

This technology has some constraints :

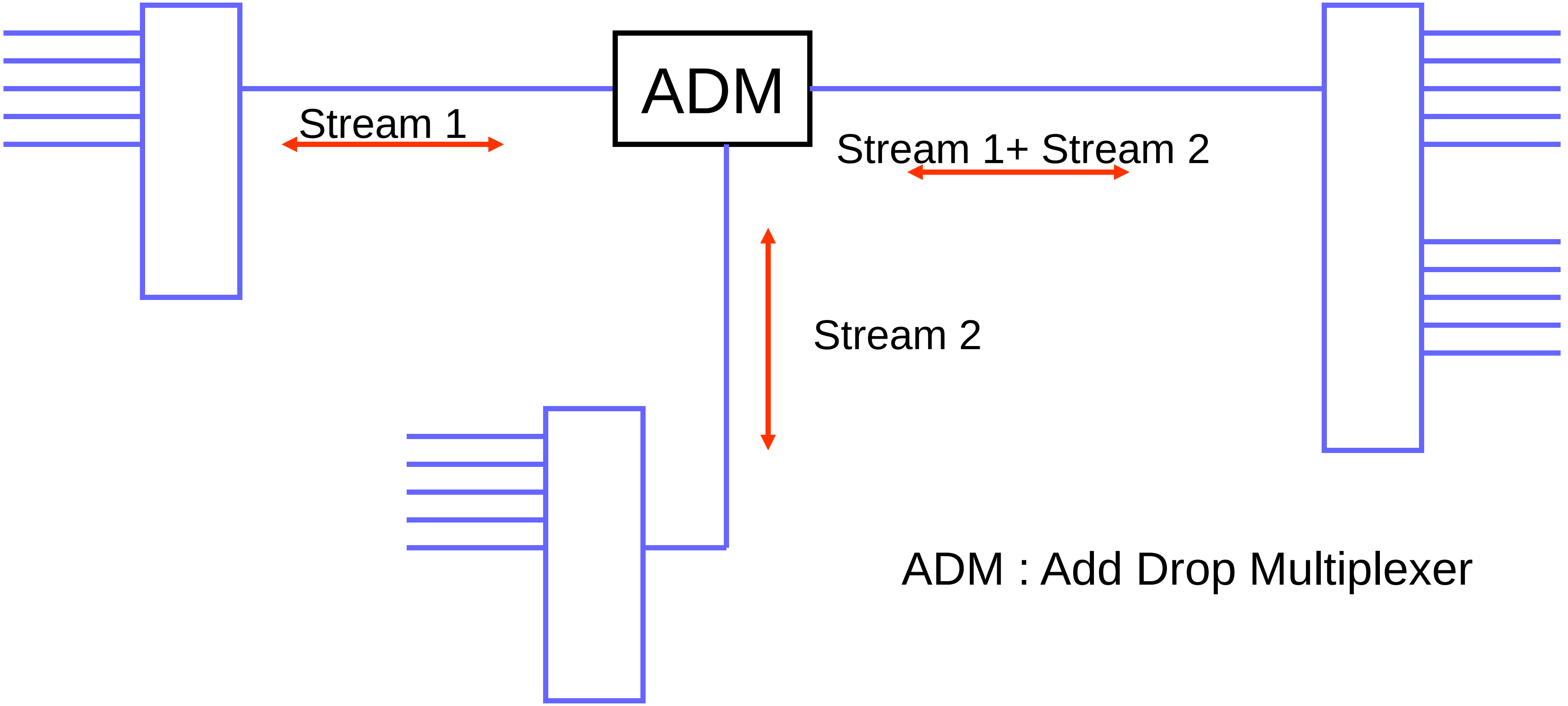
- The links have to be synchronized
- Impossible to drop one time slot or all of the traffic has to be de multiplexed.

Conclusion:

- Interesting for a point to point traffic

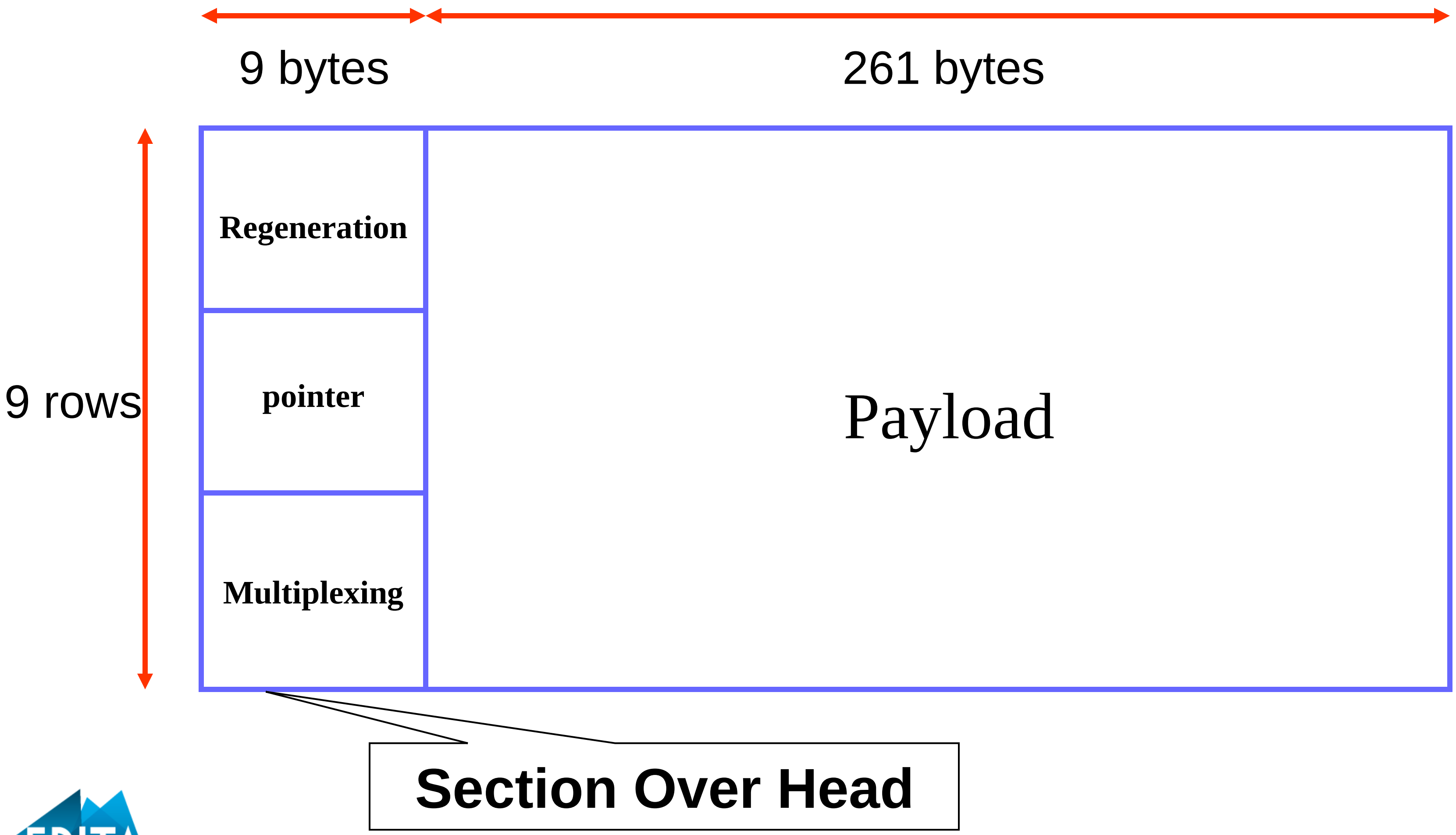
SYNCHRONOUS DATA HIERARCHY 1/6

This technology is used in case of ring transport architecture



SYNCHRONOUS DATA HIERARCHY 2/6

STM1 Container description



SYNCHRONOUS DATA HIERARCHY 3/6

SOH DESCRIPTION

- Overhead of regeneration : used for error correction
- Overhead of position : used to synchronized the upstream traffic
- Overhead of multiplexing : used to add and drop the traffic at the ADM level.

SYNCHRONOUS DATA HIERARCHY 4/6

There is 8000 containers per second :

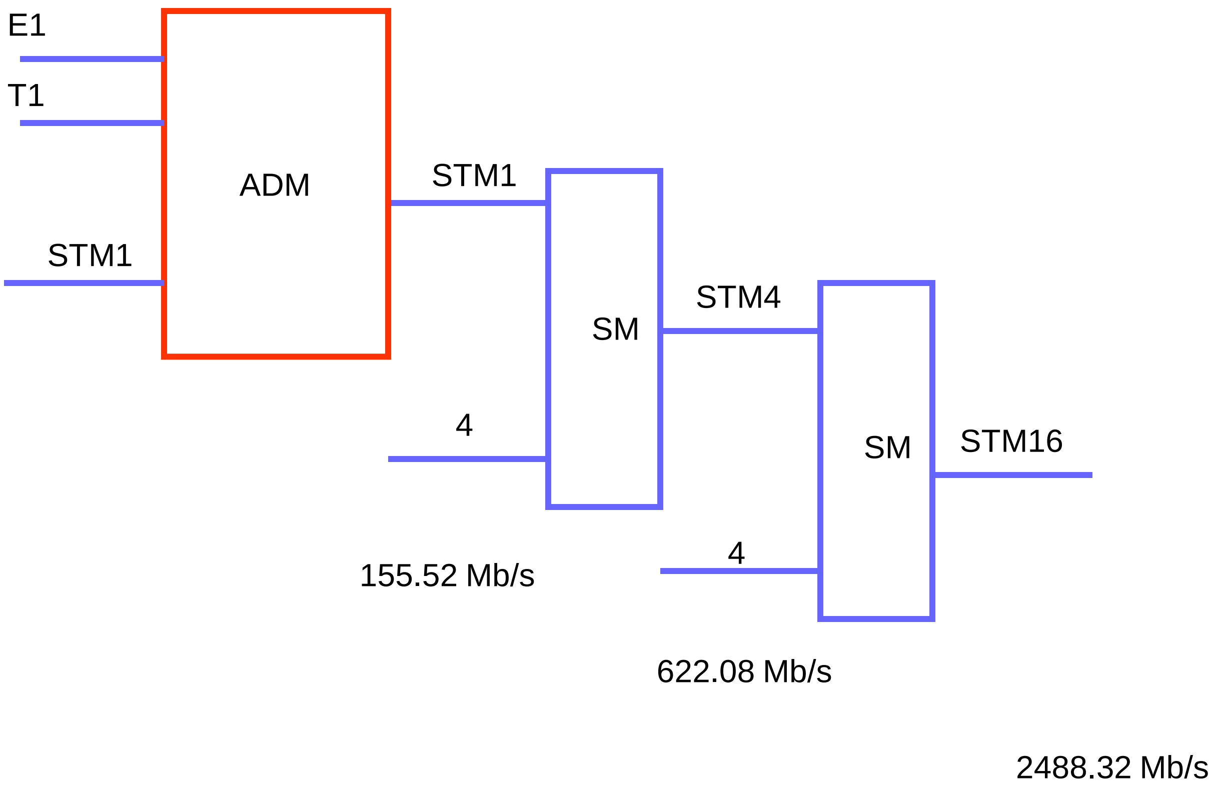
- The total rate is : 270x9X8000X8 = 155.52 Mbit/s
- The payload is 261X9X8000X8 = 150.336 Mbit/s
- STM4 rate is: 622.08 Mbit/s
- STM16 rate is: 2488.32 Mbit/s

SYNCHRONOUS DATA HIERARCHY 5/6

The benefit is :

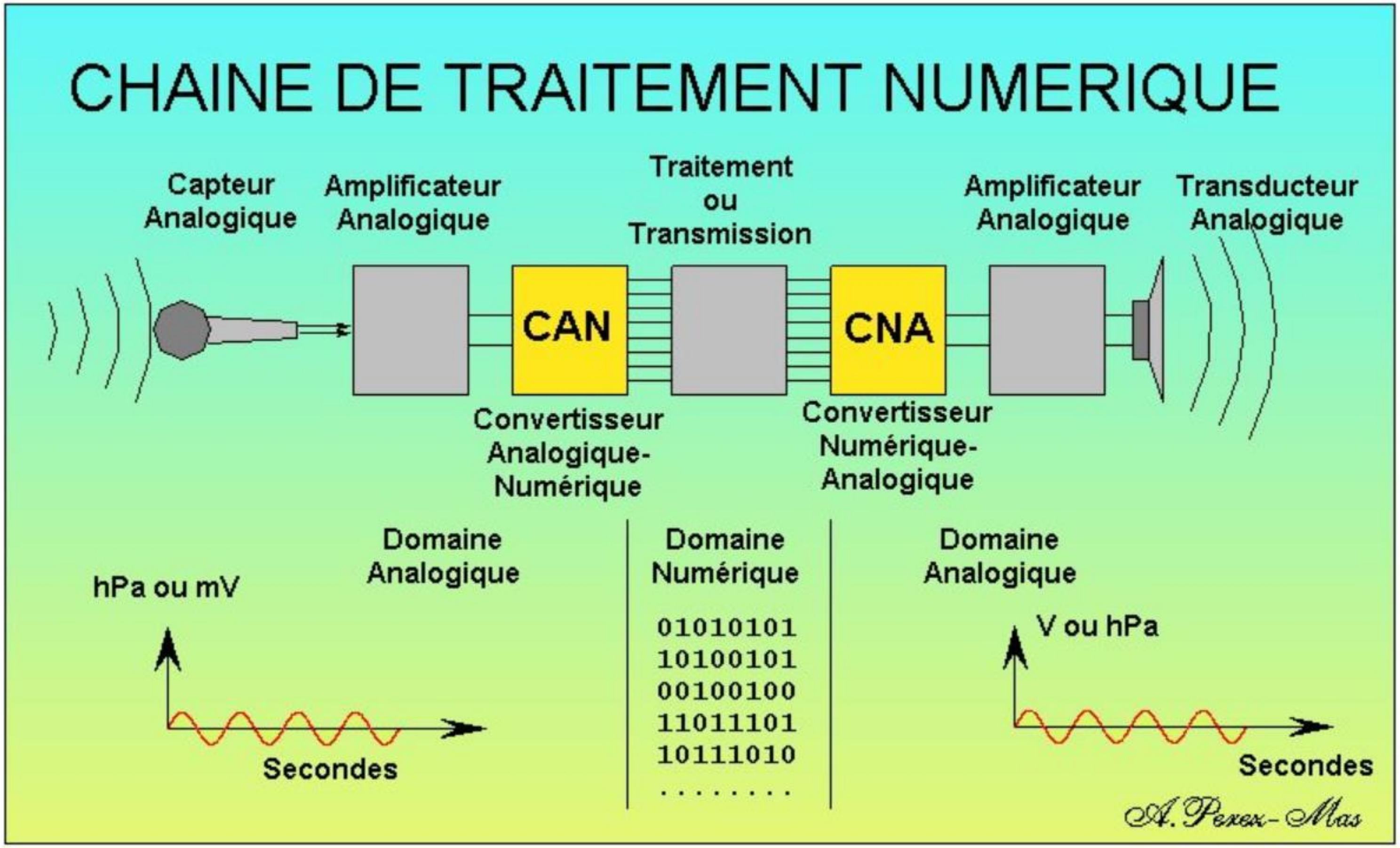
- to multiplex a plesiochronous and synchronous traffic
- to multiplex E1 and T1
- to extract an E1 in a STM16
- Very flexible

SYNCHRONOUS DATA HIERARCHY



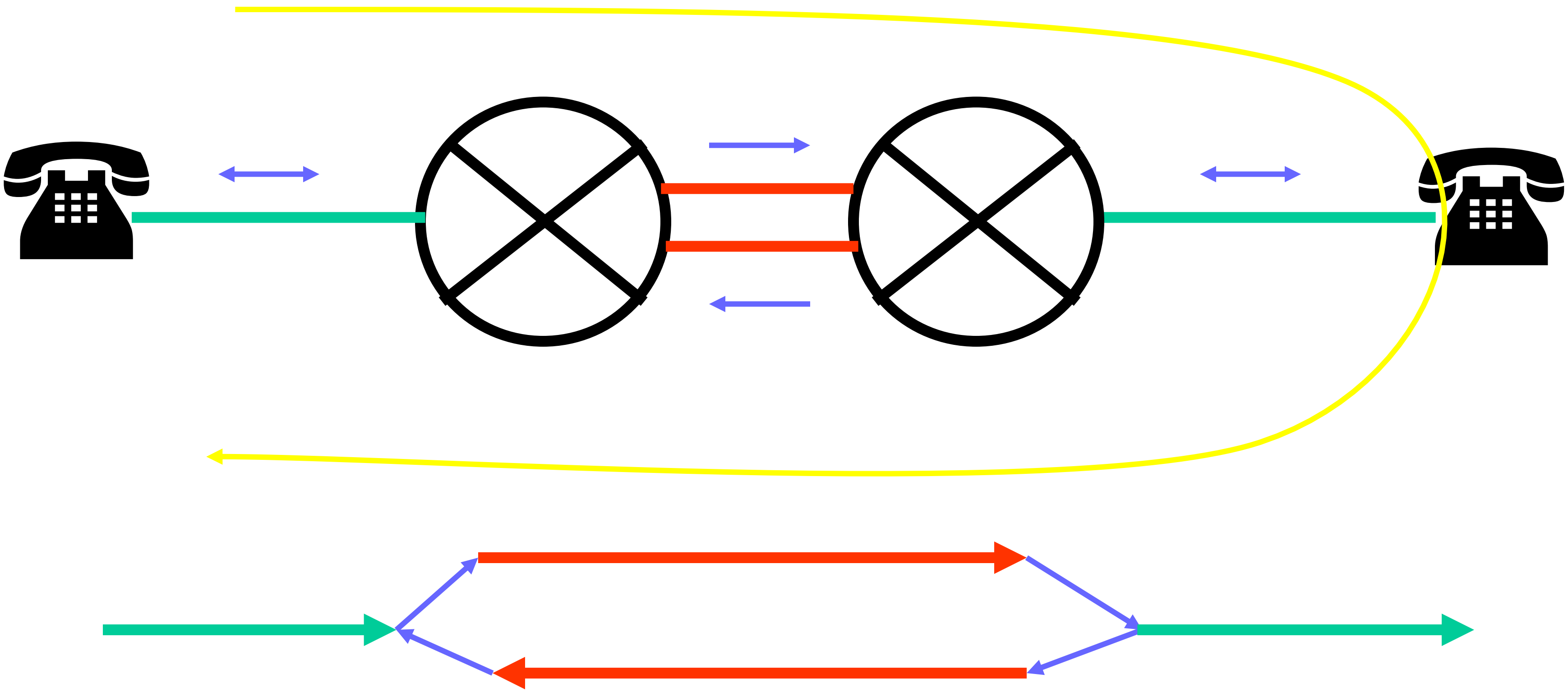
ECHO EFFECT 1/4

In a long distance network a echo effect appears



ECHO EFFECT 2/4

In a long distance network a echo effect appears



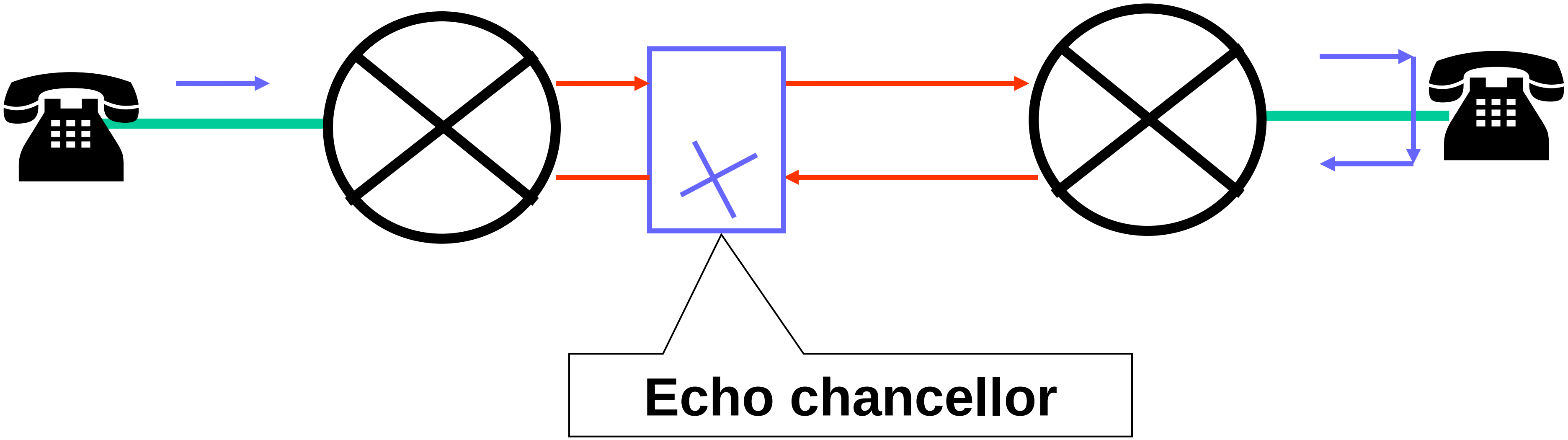
ECHO EFFECT 3/4

- **The voice signal is on one wire at the phone level**

- **When the voice signal arrives at the destination. It is returned to the origin and overlaid with the "normal" voice signal**

ECHO EFFECT 4/4

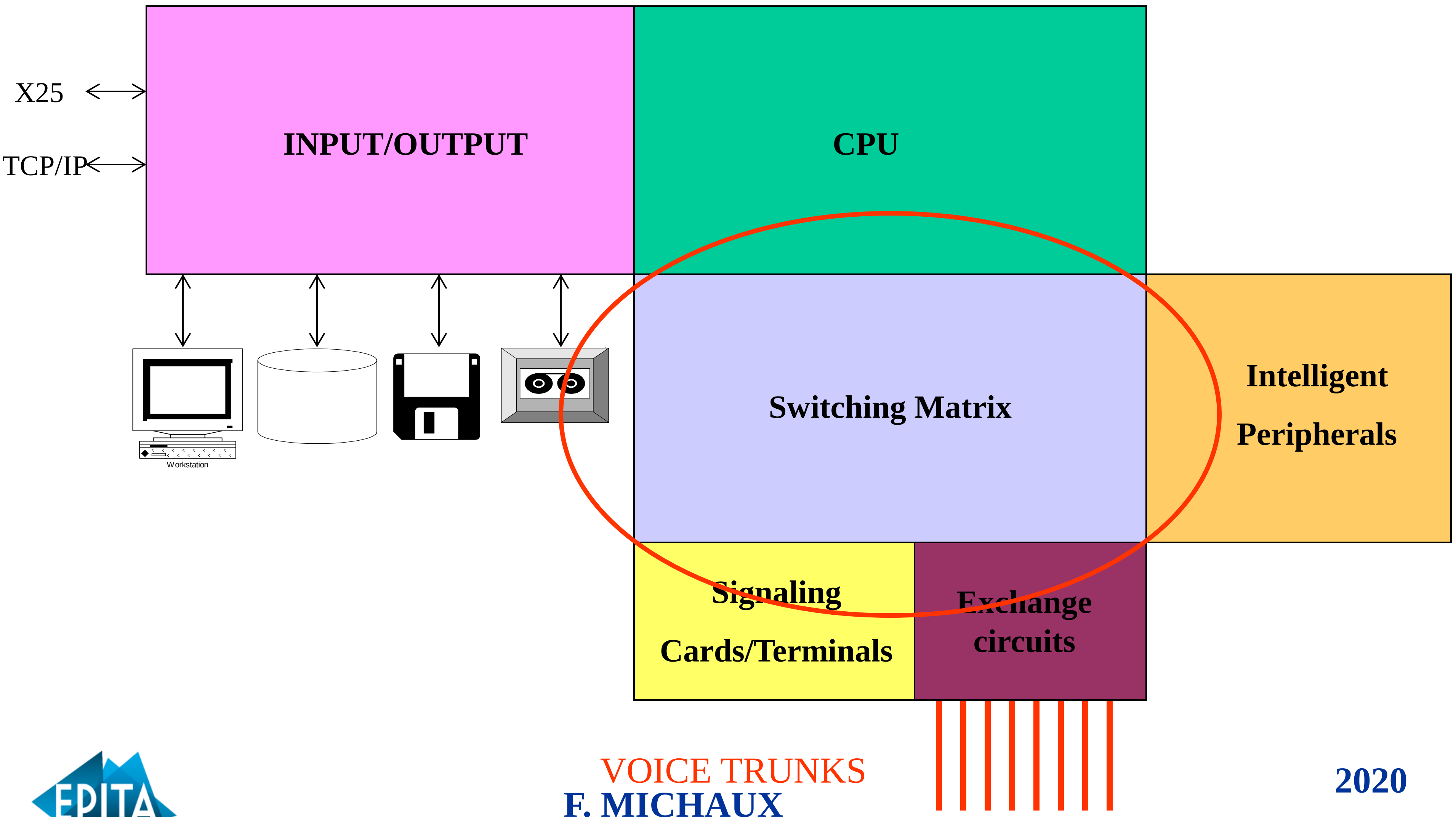
The solution consist of introducing an Echo chancellor



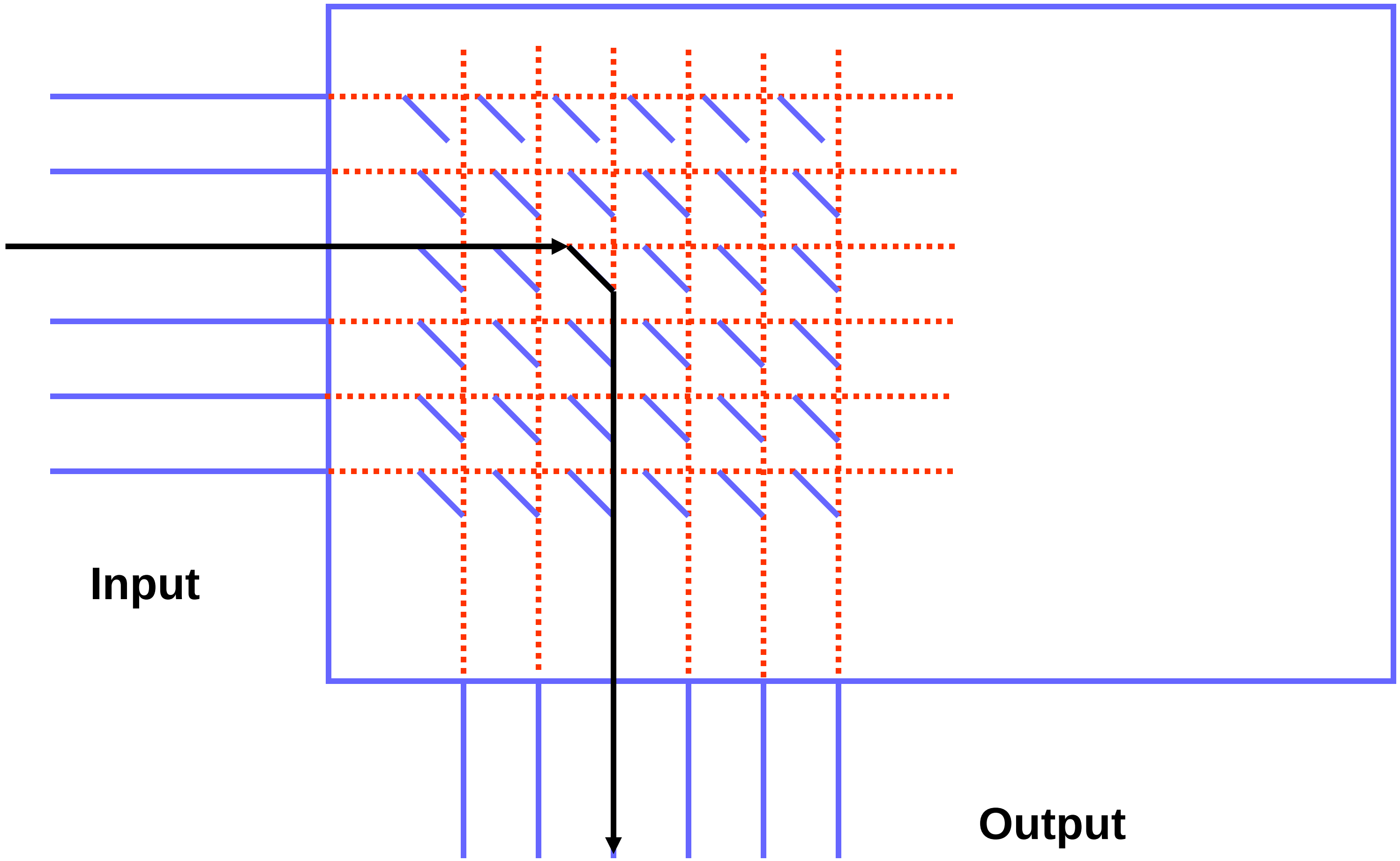
The echo chancellor memories the signal and cancels it at the return

Switching Matrix

MAIN SWITCH COMPONENTS



SWITCHING MATRIX



Switching Matrix Principle

SWITCHING MATRIX

- The switching matrix is controlled by the CPU

- The switching matrix is named for the DMS “ENET” and “Group Switch or GSS” for the AXE 10.

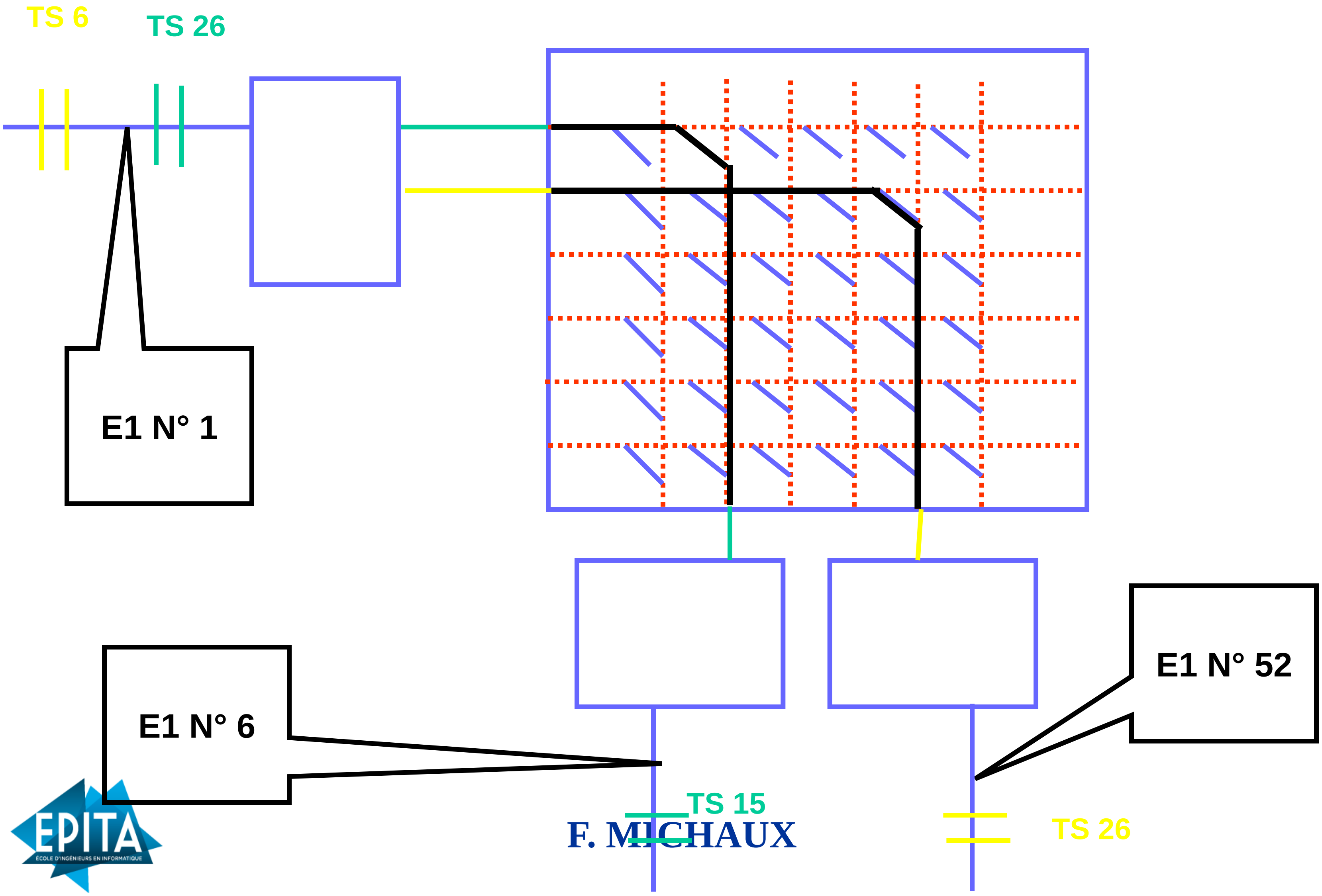
SWITCHING MATRIX

The size of a switching is calculated as the following:

- 1 E1 = 32 Time slot
- With 32 E1 you have 32*32= 1024 cross connections
- 32 E1 per 1K of Switching Matrix
- Example a switch with 16 k will have a maximum of 16 * 32 = 512 E1.

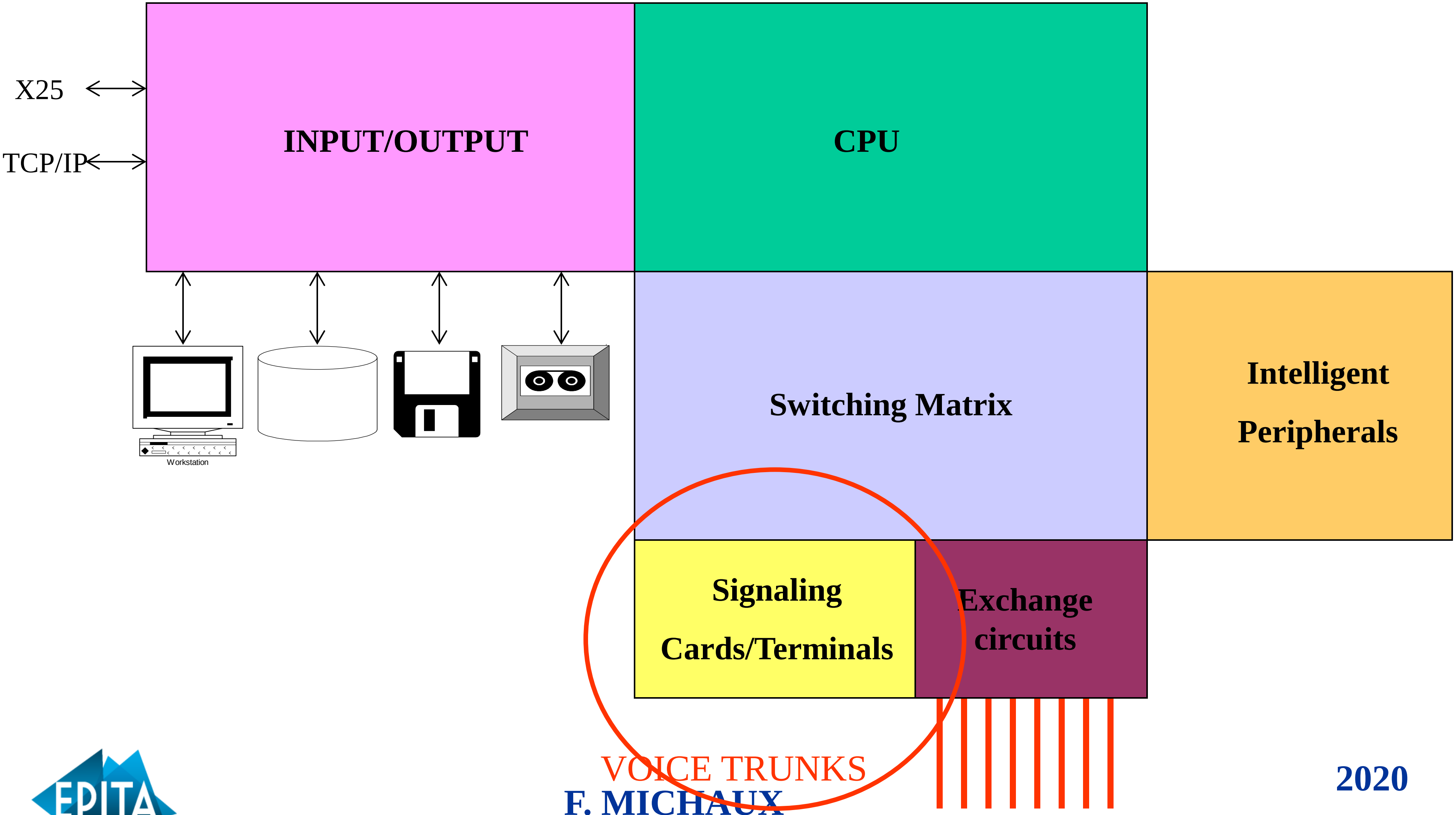
SWITCHING MATRIX PROBLEMATIC

The E1 links have to be synchronised between them.



Signaling

MAIN SWITCH COMPONENTS



SIGNALING

The signaling allow to exchange information between nodes.

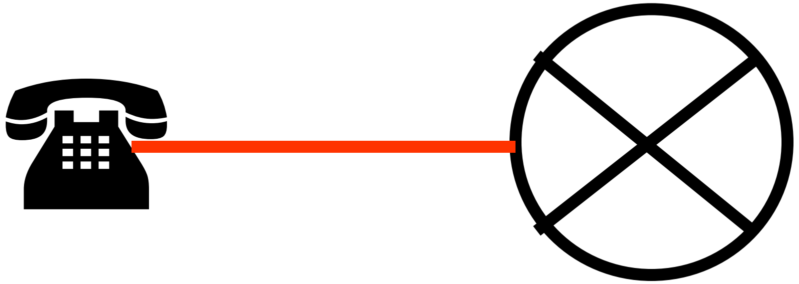
There is several kind of signaling

- Signaling circuit associated : eg : ISUP, ISDN, R2...
- Signaling non circuit associated : eg : INAP (for added value services IN), MAP (for mobility GSM or PCS network).

CIRCUIT SIGNALING ASSOCIATED

User to Network Interface

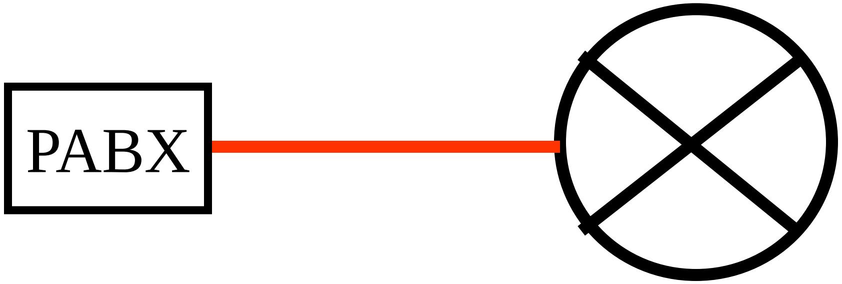
- USER signaling UNI (User to Network Interface) : (eg DTMF) between a analogic phone and a public switch



CIRCUIT SIGNALING ASSOCIATED

User to Network Interface

- USER Signaling UNI (User to Network Interface) : between public and private switch PABX e.g. ISDN, R2.



CIRCUIT SIGNALING ASSOCIATED

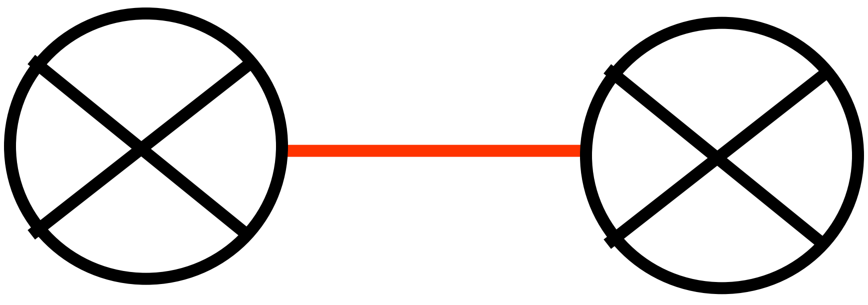
User to User Interface

- User to User Interface: (eg QSIG, DPNSS,..) between two PABX.

CIRCUIT SIGNALING ASSOCIATED

Network to Network Interface

- Network Signaling : NNI (Network to Network Interface) between public switch e.g. R2, TUP, ISUP..

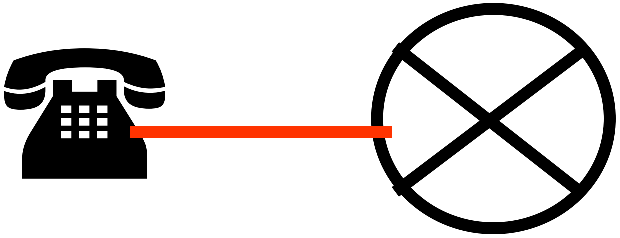


CIRCUIT SIGNALING ASSOCIATED

Signaling between an analogic phone and a public switch

Two Signaling exists

- **by pulse**
- **by dual tone multi frequency DTMF**



CIRCUIT SIGNALING ASSOCIATED

Signaling by pulse

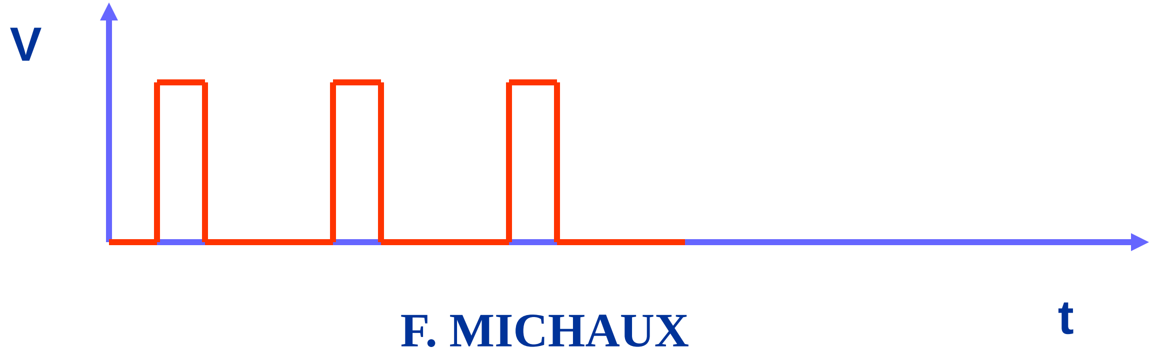
Used in the past when the phone was mechanic

Dial 10 => 10 pulse on the line

Dial 9 => 9 pulse on the line

Dial 1 => 1 pulse on the line.

Example 3 is dialled



CIRCUIT SIGNALING ASSOCIATED

Signaling by pulse

- **This solution was used when the phones were mechanic**

- **Very slow 1s per digit**

- **It was possible to dial only digits and not (*,#,..)**

CIRCUIT SIGNALING ASSOCIATED

Signaling by Dual Tone MultiFrequency

The phone has a kind of modem which is able to generate 8 different frequencies. 2 among 8 are chosen to dial a digit

	1 209 Hz	1 336 Hz	1 447 Hz	1 633 Hz
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

CIRCUIT SIGNALING ASSOCIATED

Signaling by Dual Tone MultiFrequency

- **The both frequencies are sent simultaneously**

Example 3 is dialled

CIRCUIT SIGNALING ASSOCIATED

Signaling by Dual Tone MultiFrequency

- **This solution is quicker than the previous one**

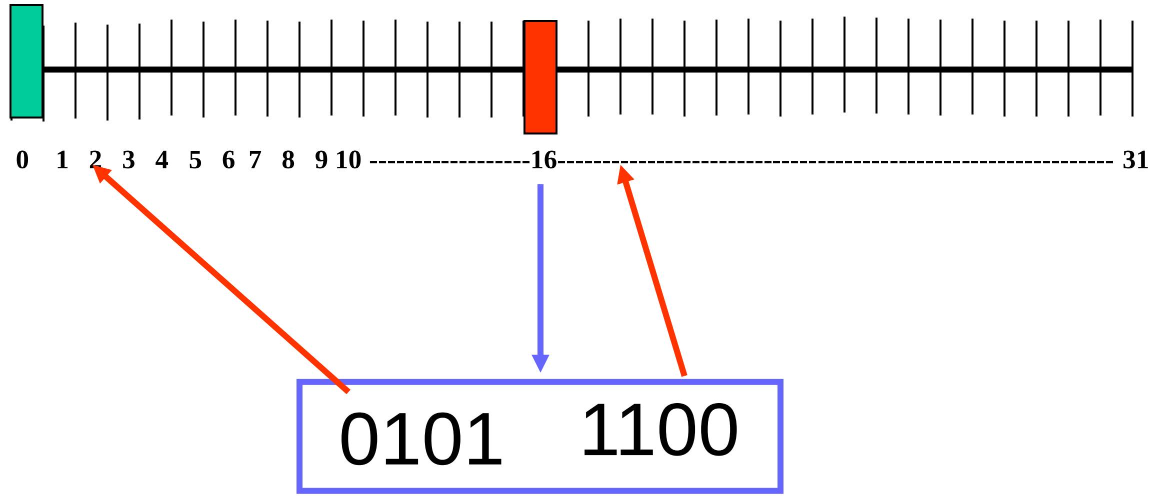
- **It's possible to dial other character (*,#,A,B..)**

- **This solution is better but is still very poor**

CIRCUIT SIGNALING ASSOCIATED

CAS Signaling

- **CAS Means Channel Associated Signaling**



CIRCUIT SIGNALING ASSOCIATED

CAS Signaling

- **The 4 highest bits of the time slot 16 are used for signaling the time slot 1 to 15**
- **The 4 lowest bits of the time slot 16 are used is used for signaling the time slot 17 to 31**
- **At the time the TS 16 give the signaling of the TS 1 and TS 17. 125 µs later the TS 16 give the signaling of the TS 2 and TS 18 ……………..**

CIRCUIT SIGNALING ASSOCIATED

CAS Signaling

- **The TS 16 give the sate of the circuit e.g. : sleep, hang up..**

- **The numbering is sent by frequencies inside the circuit as the DTMF but the frequencies are different**

CIRCUIT SIGNALING ASSOCIATED

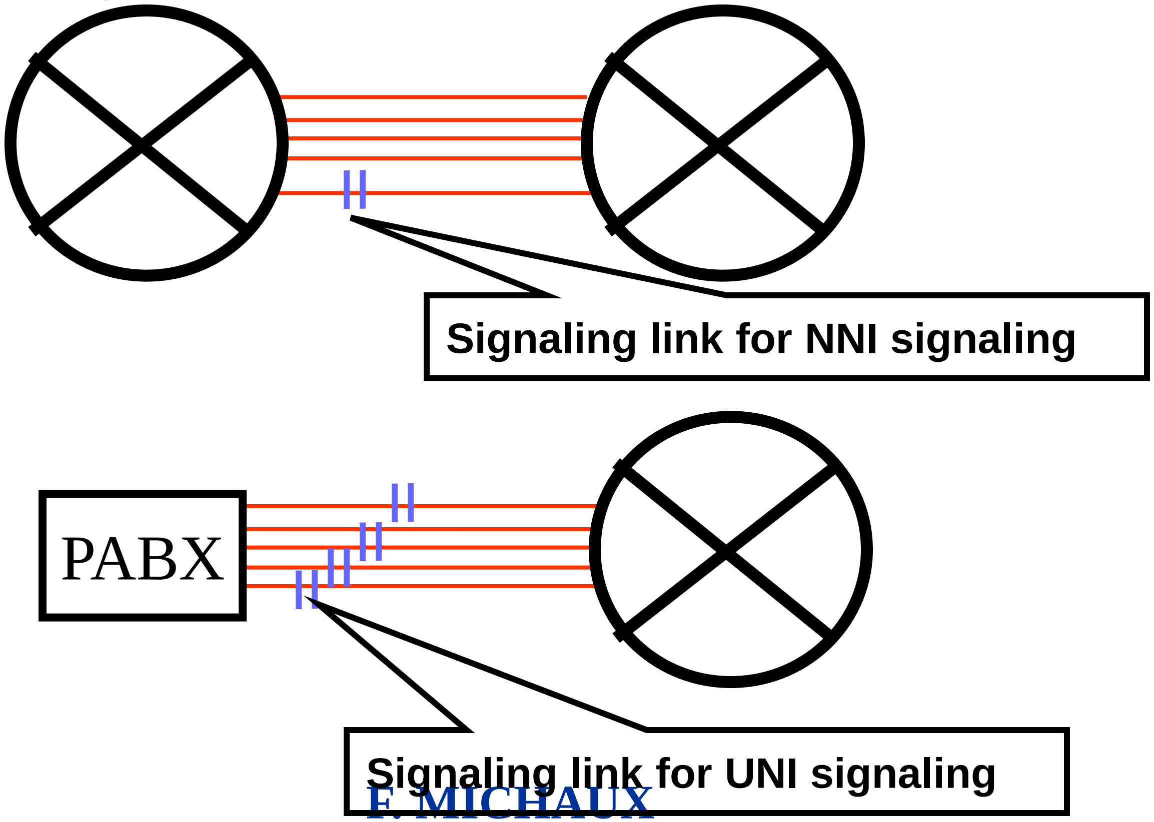
CAS Signaling

- This signaling is a UNI and NNI signaling
- This signaling is very rich
- R1, R2 are an example of CAS signaling
- Only one default very slow

CIRCUIT SIGNALING ASSOCIATED

CCS Signaling

- CCS Means Common channel signaling
- A signaling link has a rate of 64 Kb/S



CIRCUIT SIGNALING ASSOCIATED

CCS Signaling

- The signaling channel is common for several circuit.

- The CCS signaling is in message mode: ISDN for UNI signaling, TUP, ISUP.. For the NNI signaling

- In the UNI signaling one signaling link per E1 in the timeslot 16 named D chanel.

CIRCUIT SIGNALING ASSOCIATED

CCS Signaling

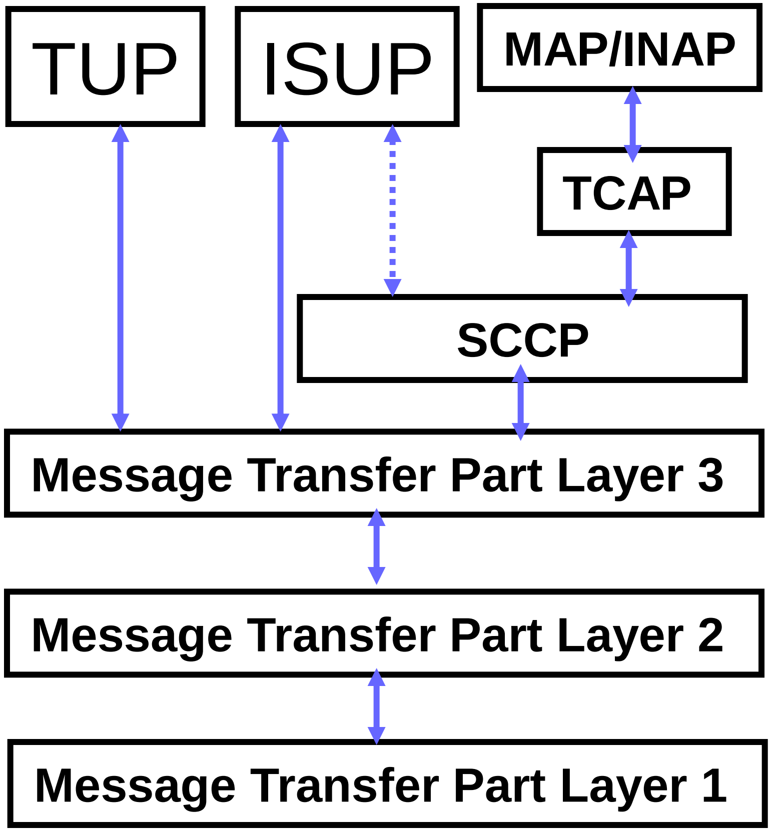
- **The CCS Signaling is named signaling N°7, it's a message mode signaling.**

- **The protocols are different at UNI and NNI level**
  UNI : ISDN
  NNI : ISUP

- **The benefits of the SS7 signaling are :**
  •A better efficiency, the Post Dial Delay (PDD) decreases from 10/20 s in CAS signaling to 2/4 s consequence économy of ressources.
  •Mandatory for added value services and supplementary services.

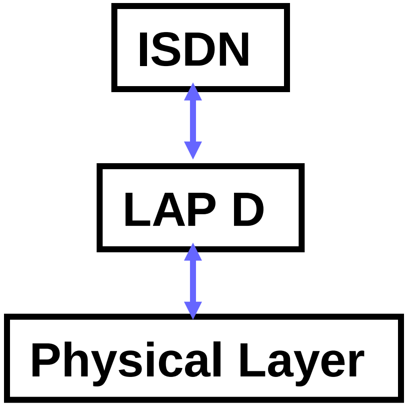
SIGNALING SS7

NNI Signaling N°7 layers description



SIGNALING SS7

UNI Signaling N°7 layers description



SIGNALING SS7

EXAMPLE OF ISUP MESSAGE

CIC 12 bits

F	CRC	INF	H1H0		SLS	OPC	DPC	SIO	L	FSN	BSN	F

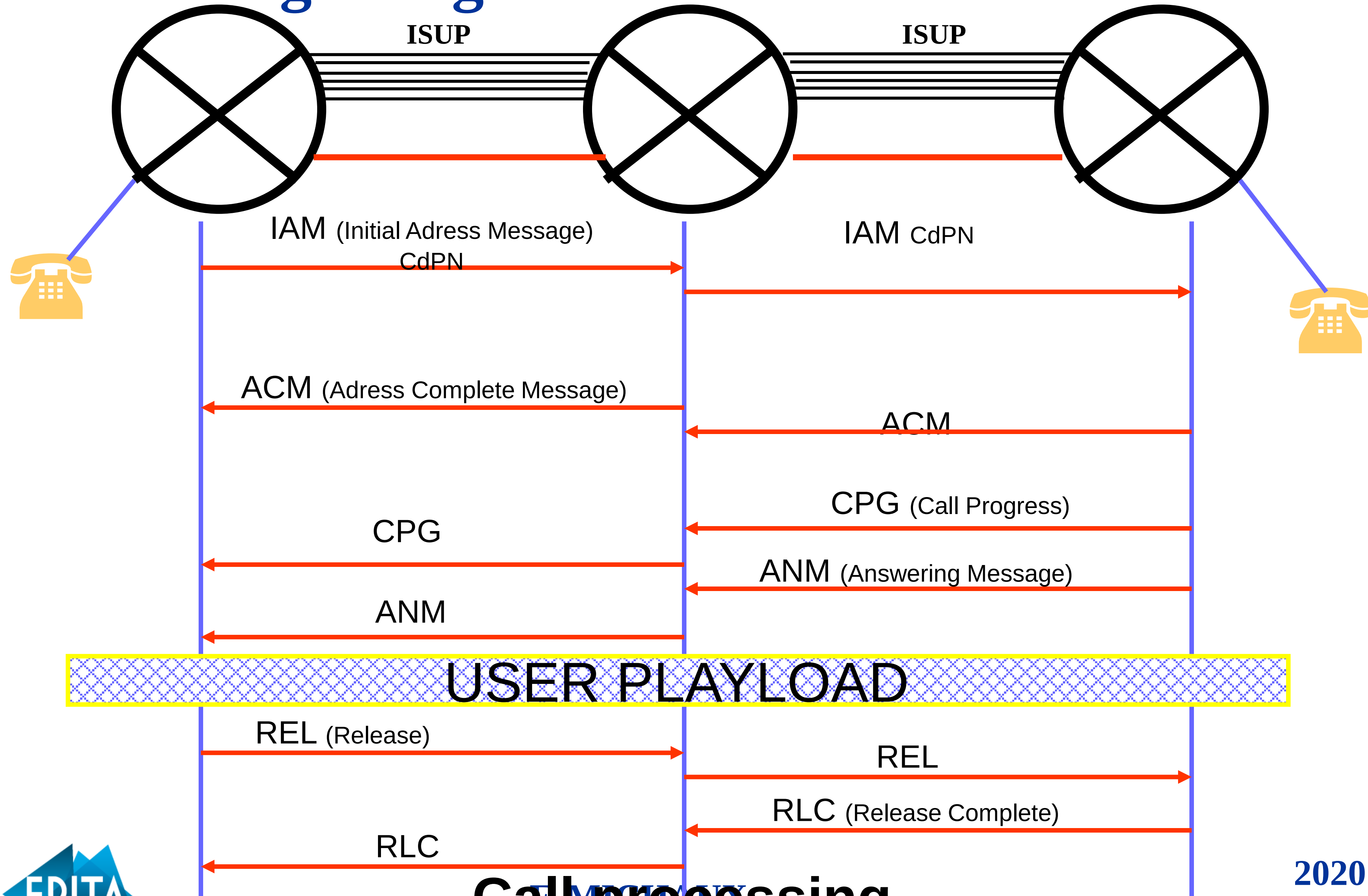
MTP1

MTP2

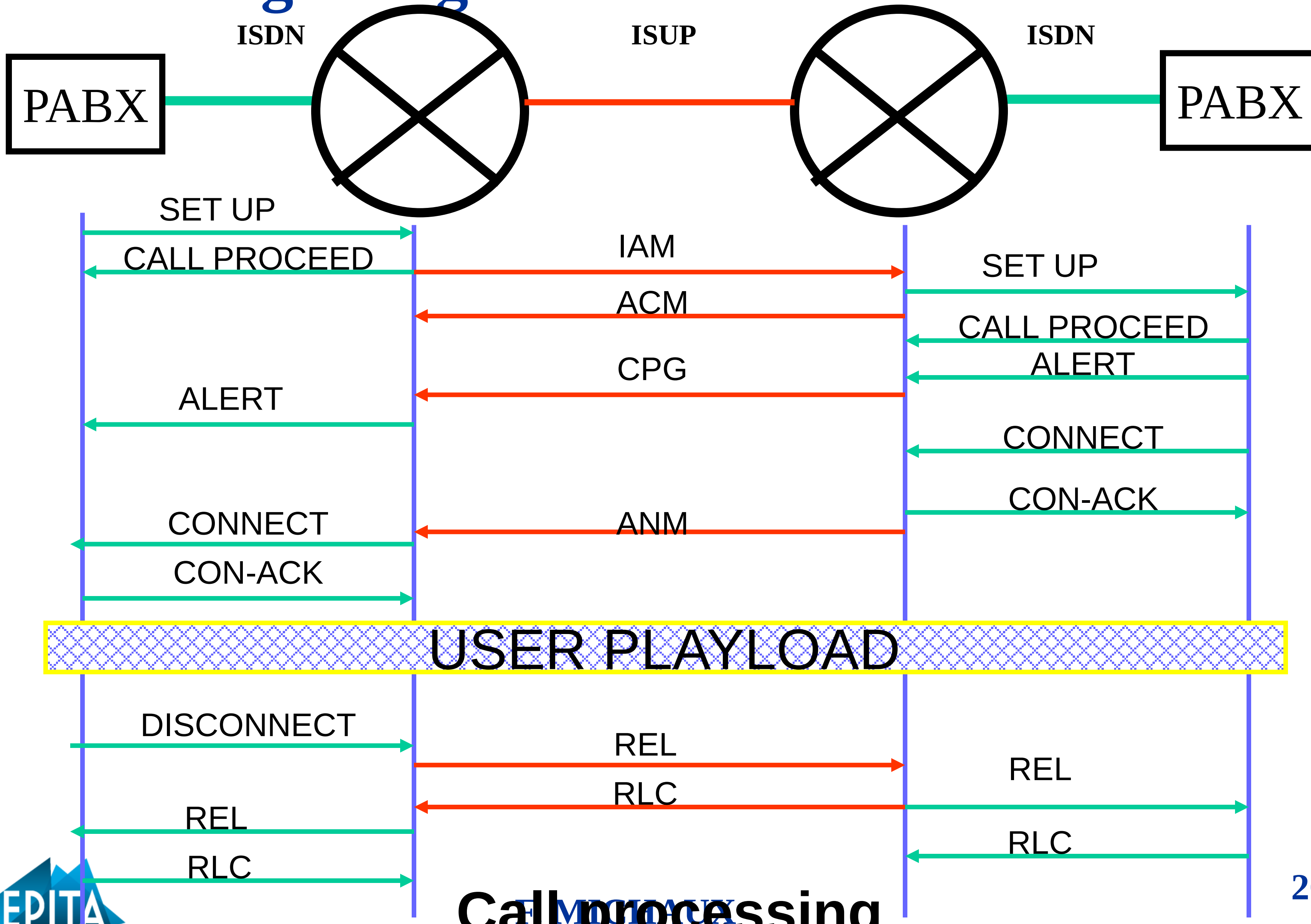
MTP3

ISUP

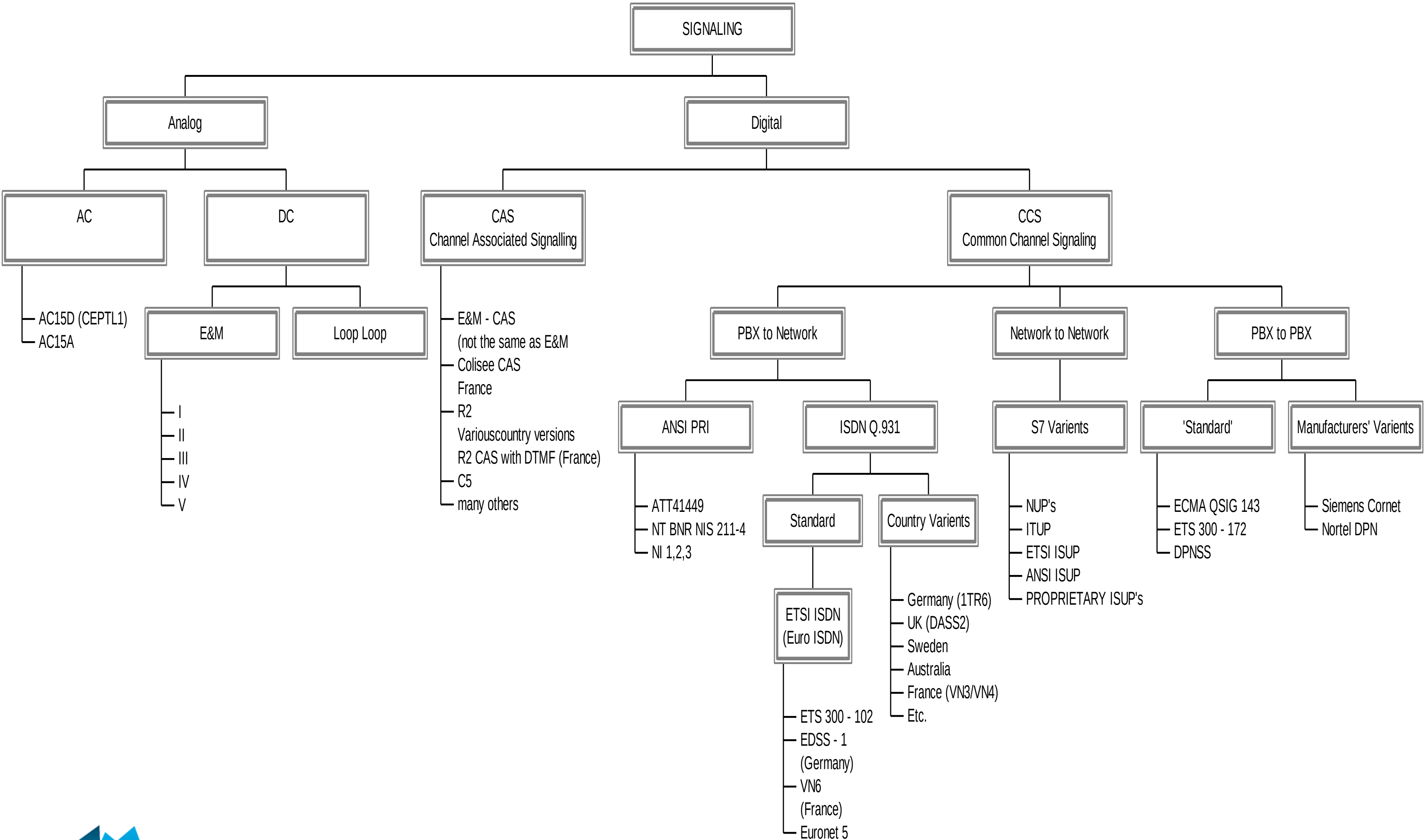
Signaling CIRCUIT ASSOCIATED



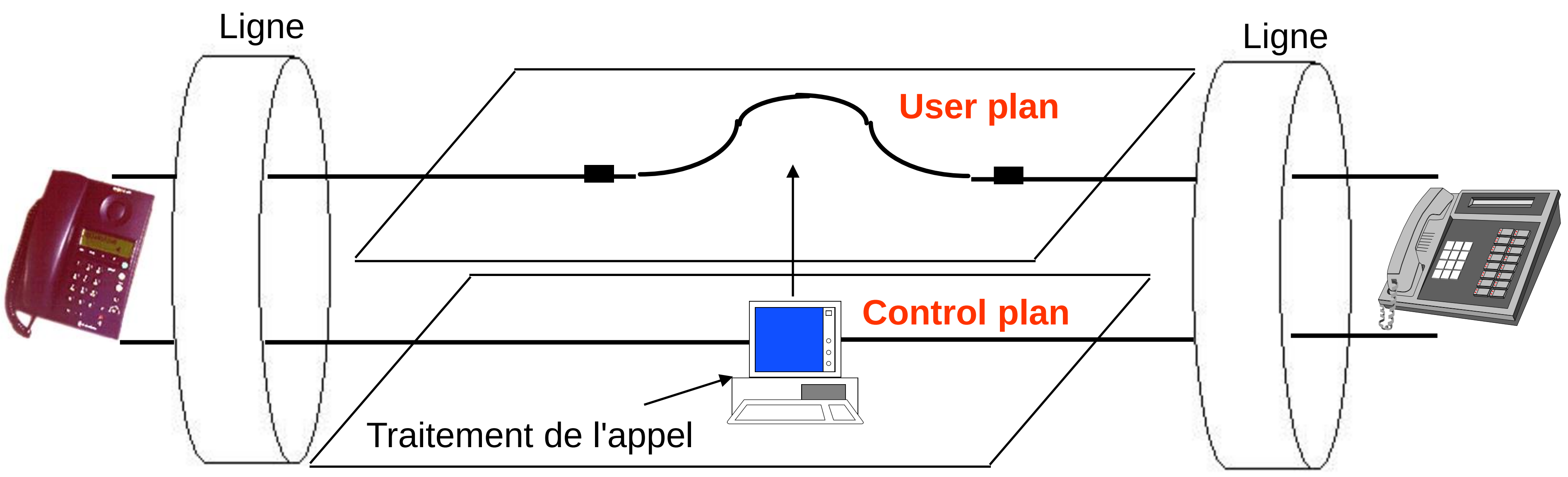
Signaling CIRCUIT ASSOCIATED



Signaling CIRCUIT ASSOCIATED



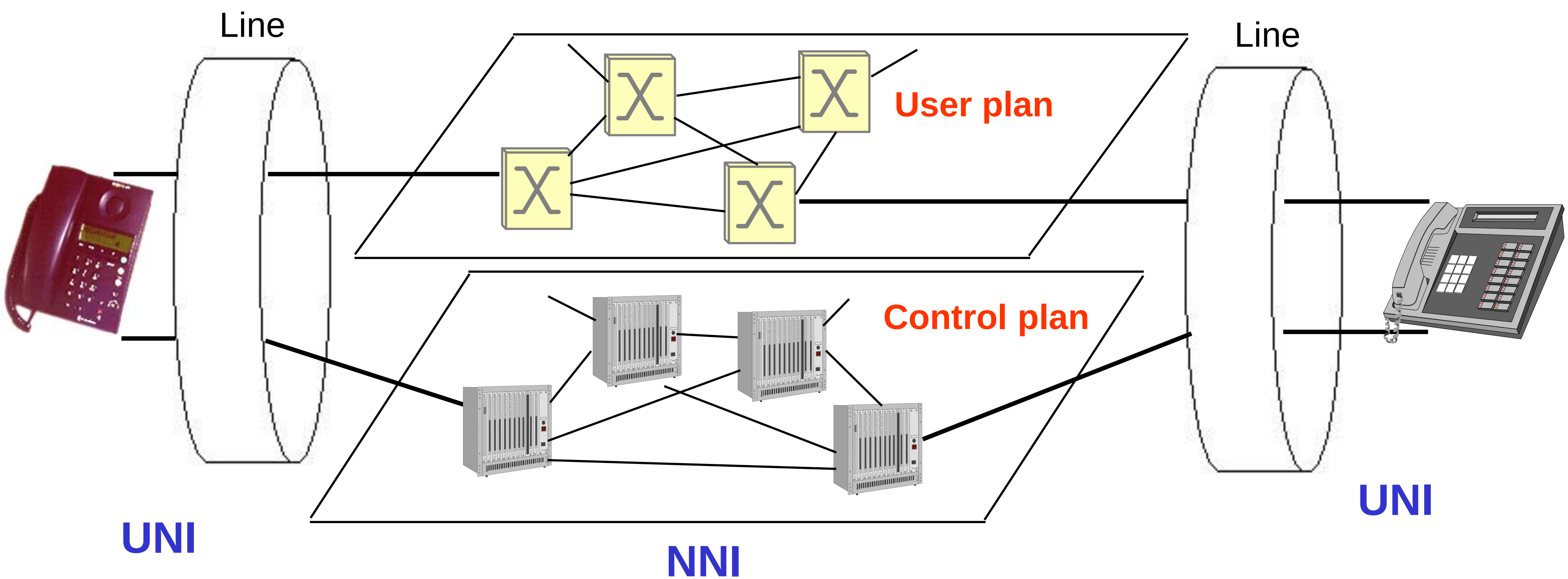
Control plan / User plan 1/7



Control Plan : In charge to establish the connexion
User Plan : In charge to connect the voice ressources

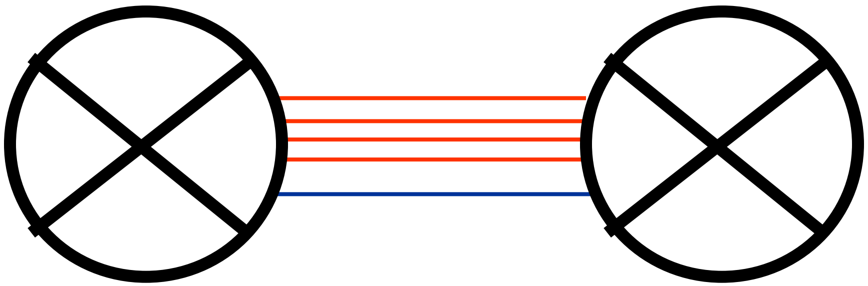
⇨ **the both networks are parrallele**

Control plan / User plan 2/7



It's a logical separation which can be also physical with an overlay network

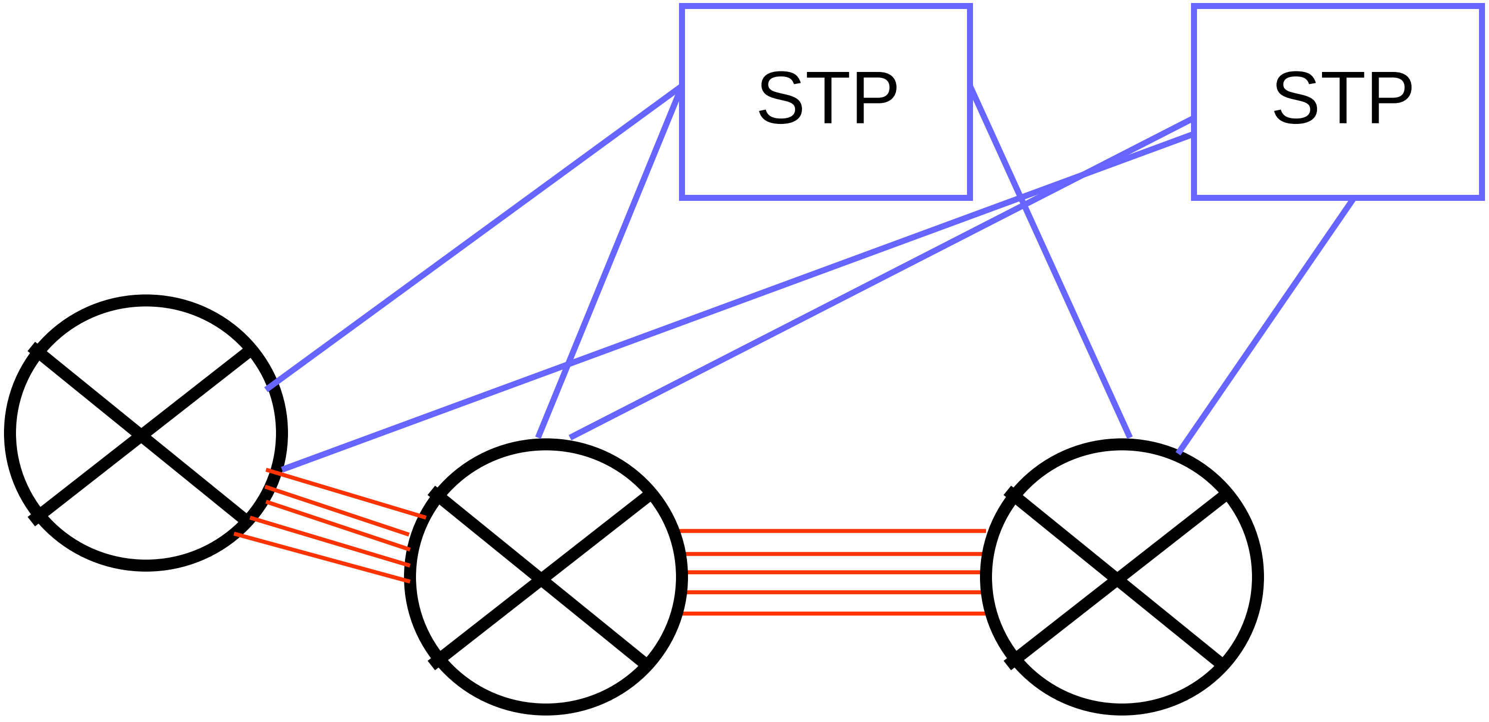
Control plan / User plan 3/7



Associated mode

The Signaling link is dedicated to one voice trunk

Control plan / User plan 4/7



Quasi Associated mode

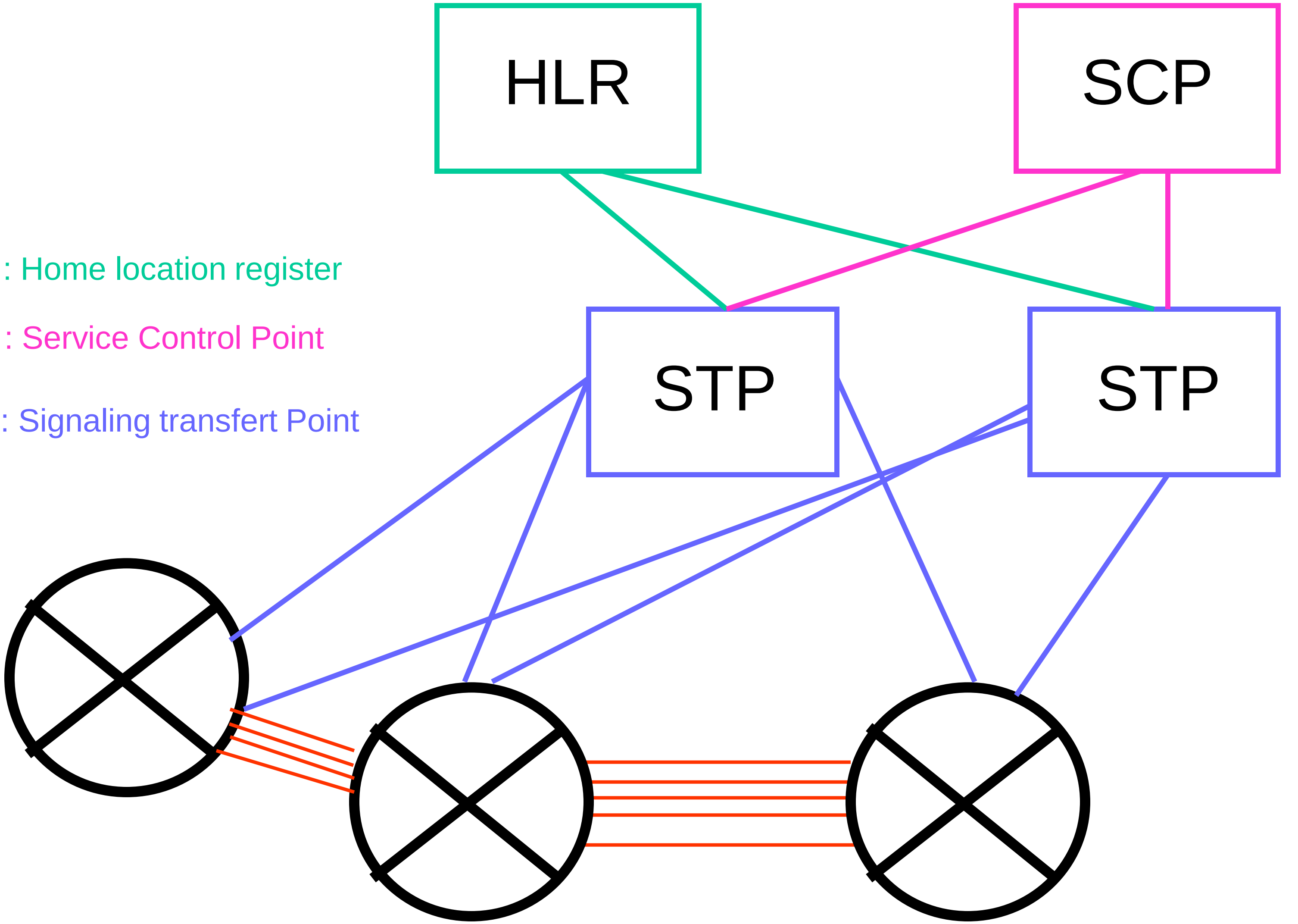
The Signaling link is not dedicated to one voice trunk

Control plan / User plan 5/7

HLR : Home location register

SCP : Service Control Point

STP : Signaling transfert Point



Control plan / User plan 6/7

link set dimensioning

- A link set dimensioning is a set of signaling links connected to the same signaling adress.
- The link set dimensioning depends of the trunk group size. One signaling per 2000 circuits, they are duplicated for security reason.
- Example : 2000 circuits 2 signaling links
  1000 circuits 2 signaling links
  4000 circuits 4 signaling links

Control plan / User plan 7/7

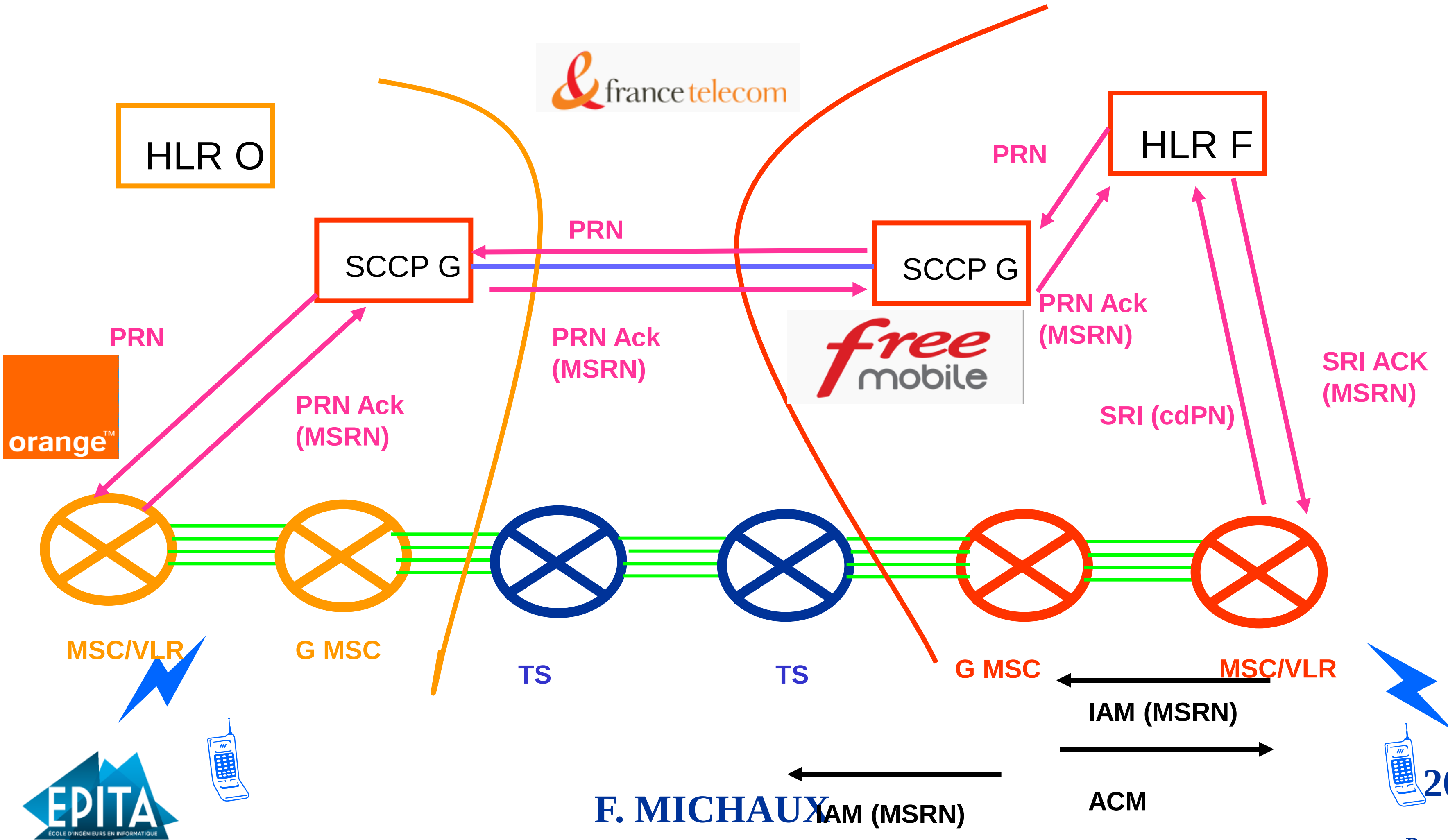
Signaling link dimensioning

- Signaling link economy.
- The traffic is centralized in the STP interesting for the monitoring.
- Mandatory to plug service added value platforms

Free customer call in Roaming

HLR : Home location register
MSC : Mobile Switch Centre
G MSC : Gateway MSC
SCCP G : Signalling Connection Control Part Gateway:
SS7 : Signaling N° 7

SRI : Send Routing Information
PRN : Provide Roaming Number



Free customer call in Roaming

HLR : Home location register

MSC : Mobile Switch Centre

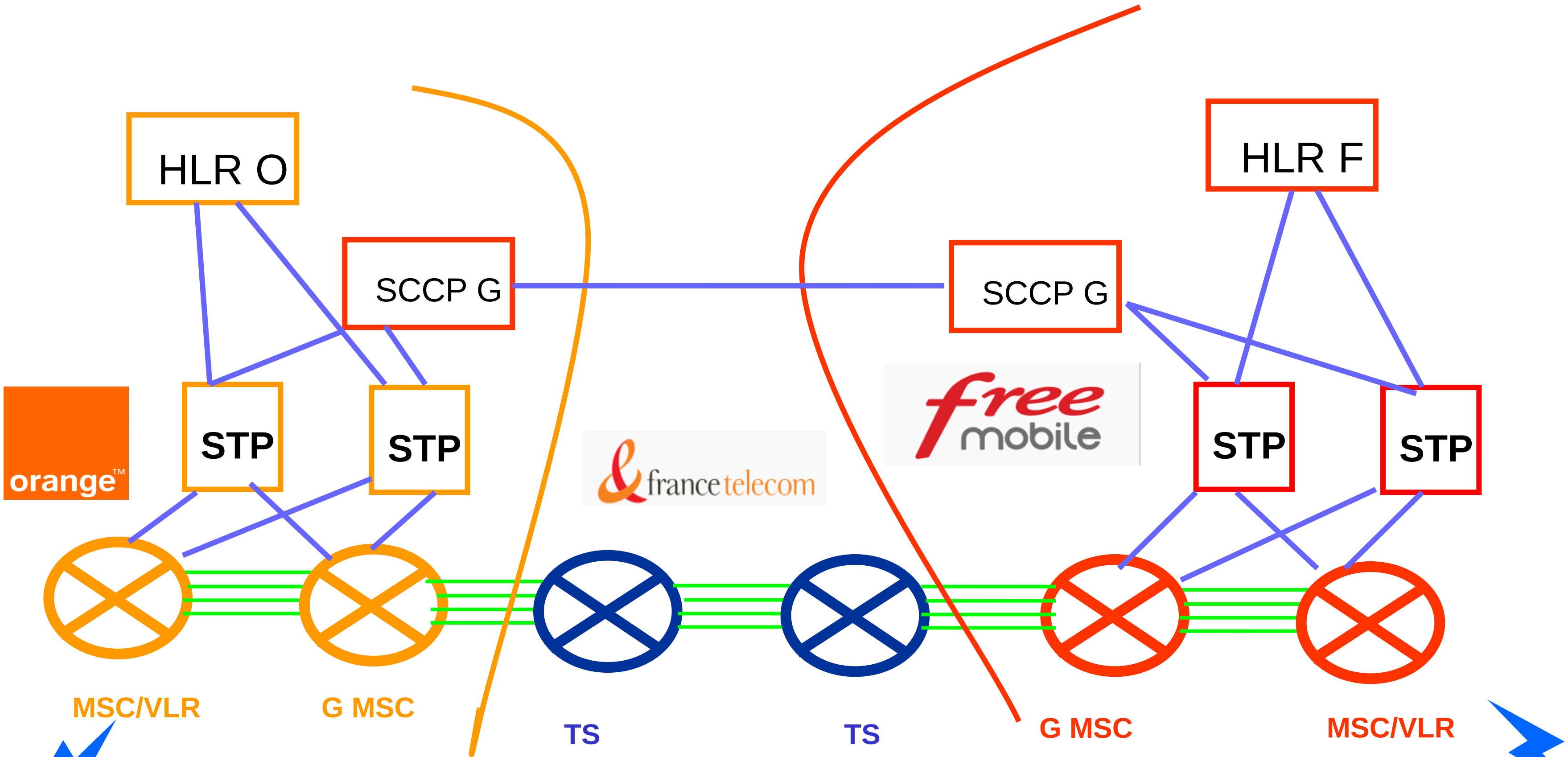
G MSC : Gateway MSC

SCCP G : Signalling Connection Control Part Gateway:

SS7 : Signaling N° 7

SRI : Send Routing Information

PRN : Provide Roaming Number



Free customer call in Roaming

HLR : Home location register

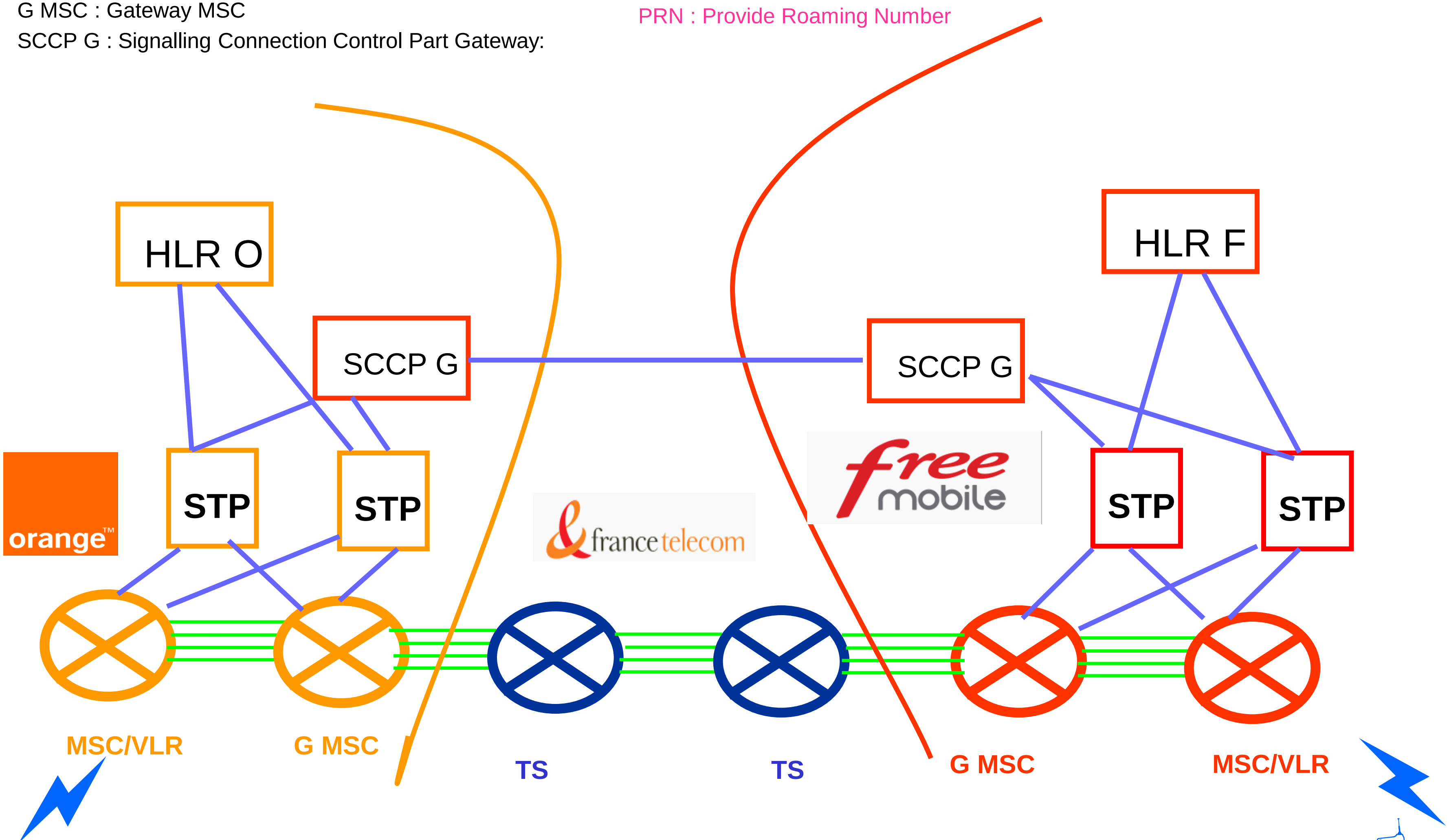
MSC : Mobile Switch Centre

G MSC : Gateway MSC

SCCP G : Signalling Connection Control Part Gateway:

SRI : Send Routing Information

PRN : Provide Roaming Number



“Les villes de Lyon, Grenoble, Angers et bien sûr Paris ont ont été touchées, entre autres. Hier soir, Orange a tenu à réagir en affirmant ne pas être à l’origine du problème : « Vu de notre fenêtre, tout est au vert. On pense savoir que Free a un problème sur un de ses équipements. Il y a eu un incident il y a déjà trois semaines. Un équipement de signalisation de Free Mobile était en cause. On constate les mêmes symptômes aujourd'hui », a expliqué un représentant de l’opérateur historique à 20 Minutes.”

Free customer call in Roaming

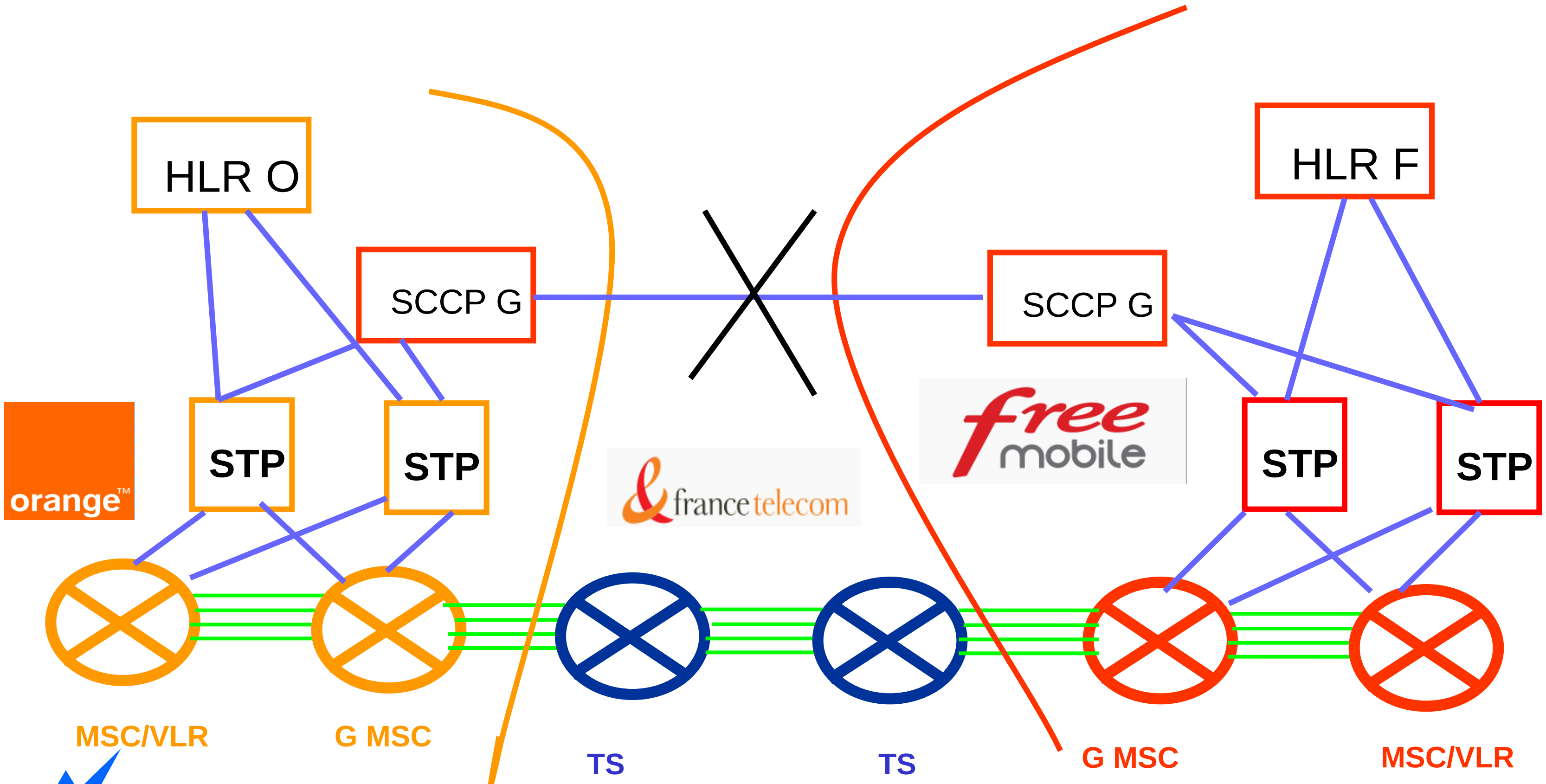
HLR : Home location register

MSC : Mobile Switch Centre

G MSC : Gateway MSC

SCCP G : Signalling Connection Control Part Gateway:

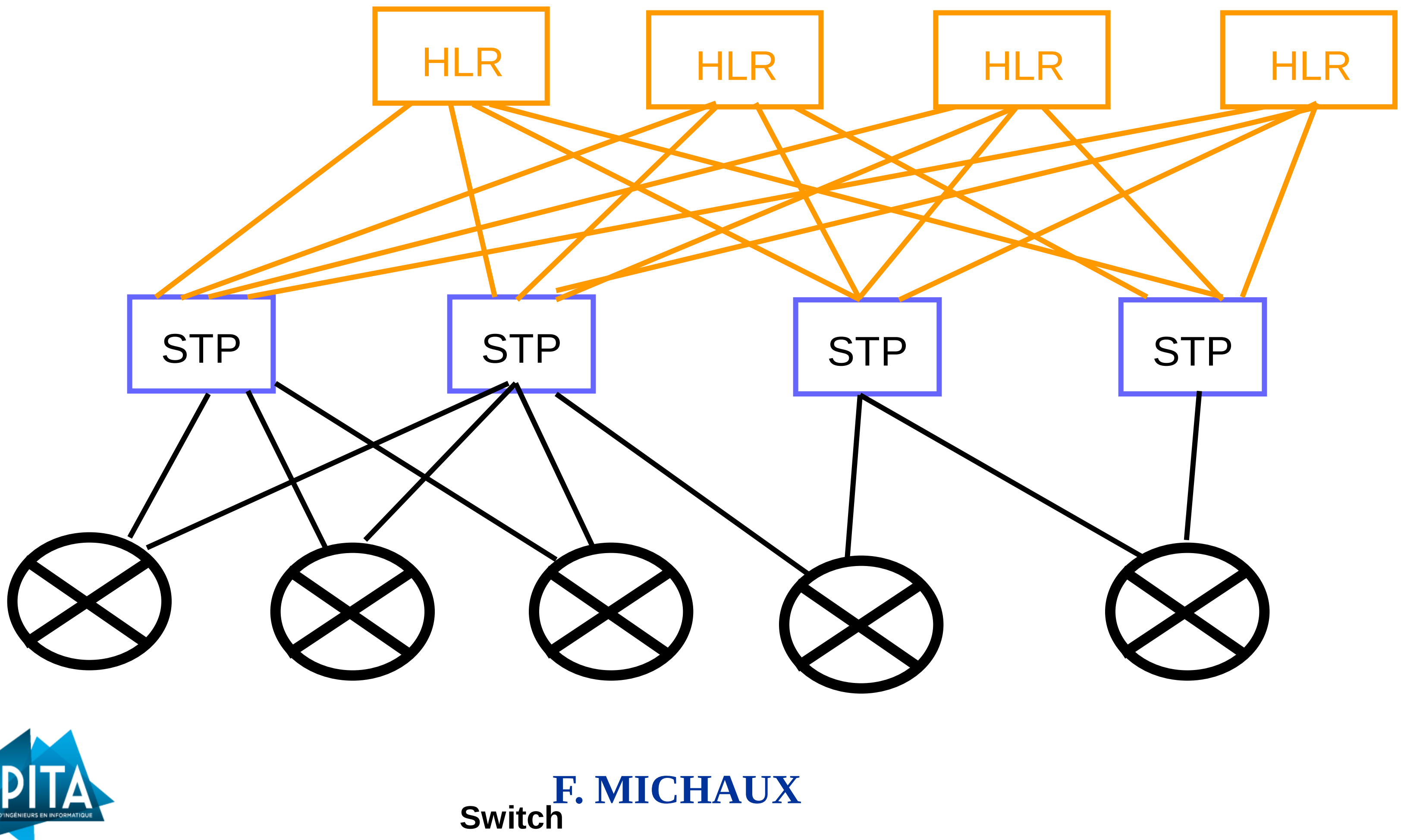
SS7 : Signaling N° 7



HLR classi connection to the STP ’s

HLR : Home location register

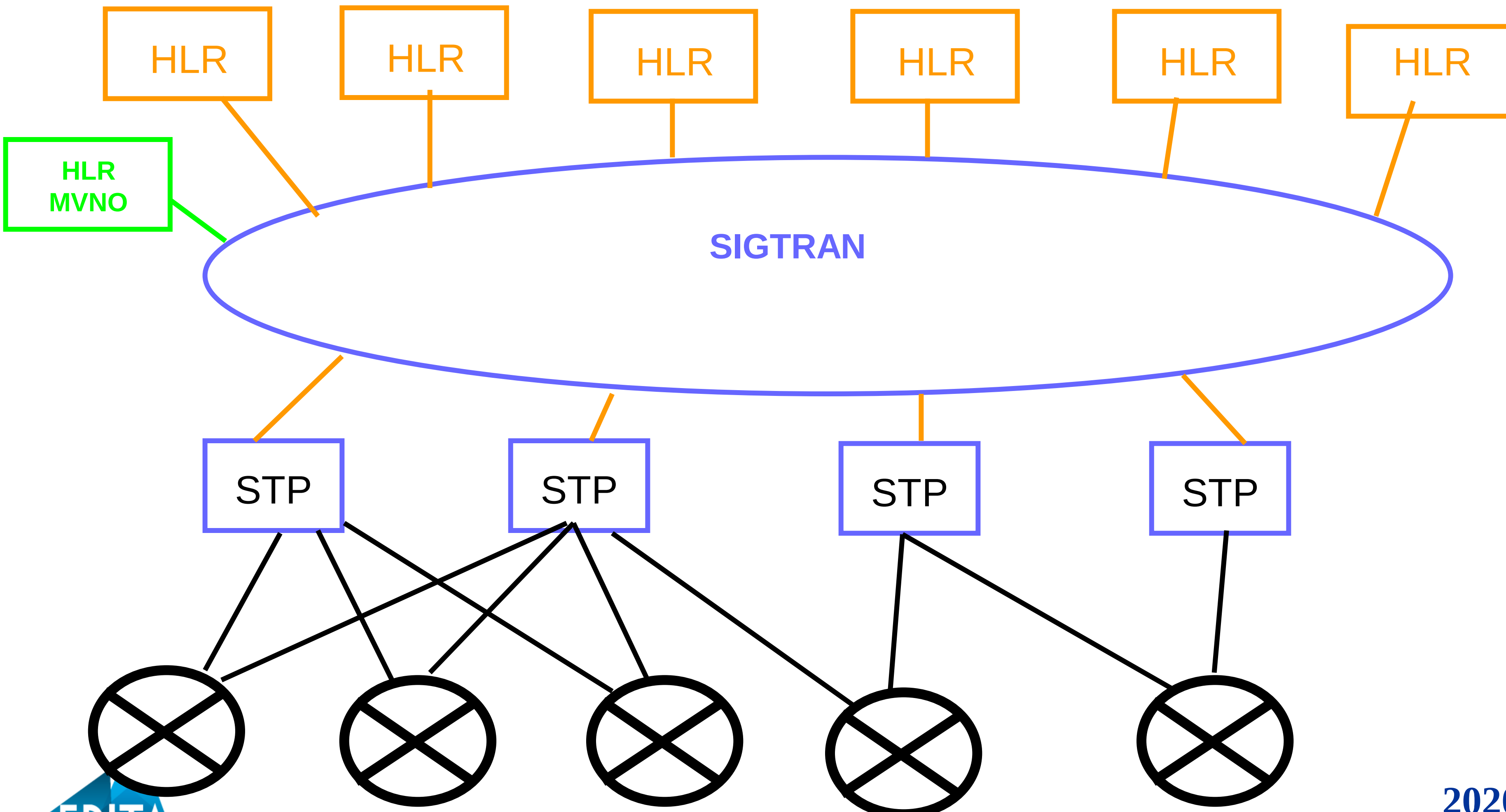
STP : Signalling Transfer Point



HLR connection to the STP 's via Sigtran

HLR : Home location register
STP : Signalling Transfer Point

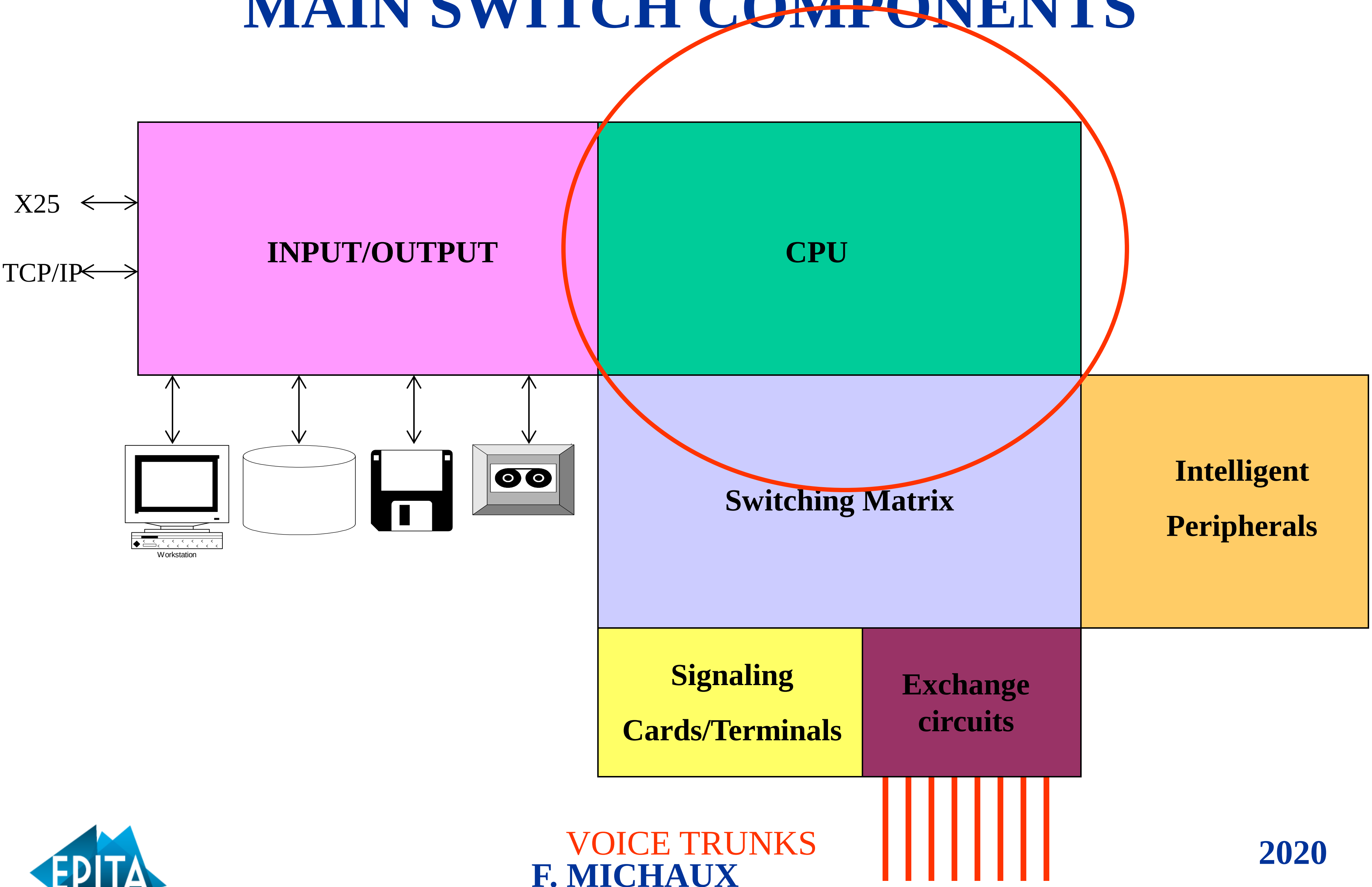
Sigtran : **Sig**naling **tran**sport (infrastrucure to carry SS7 singnaling on an IP network)



Switch

CPU

MAIN SWITCH COMPONENTS



CPU

The CPU is the Central Processor Unit. It is the main switch component

The CPU :

- handles the call processing
- Controls the switching matrix
- Controls the intelligent peripherals
- Handles the translations
- Handles the signaling protocol from the network layer to the application layer.

CPU

- There is 2 CPU's in a switch in order to Increase the reliability.
- One active and one standby in case of failure
- There is no loss of call in case of channel change over from the active to the stand by
- The size of the software is huge
- It's a real time software each call lauches a task.

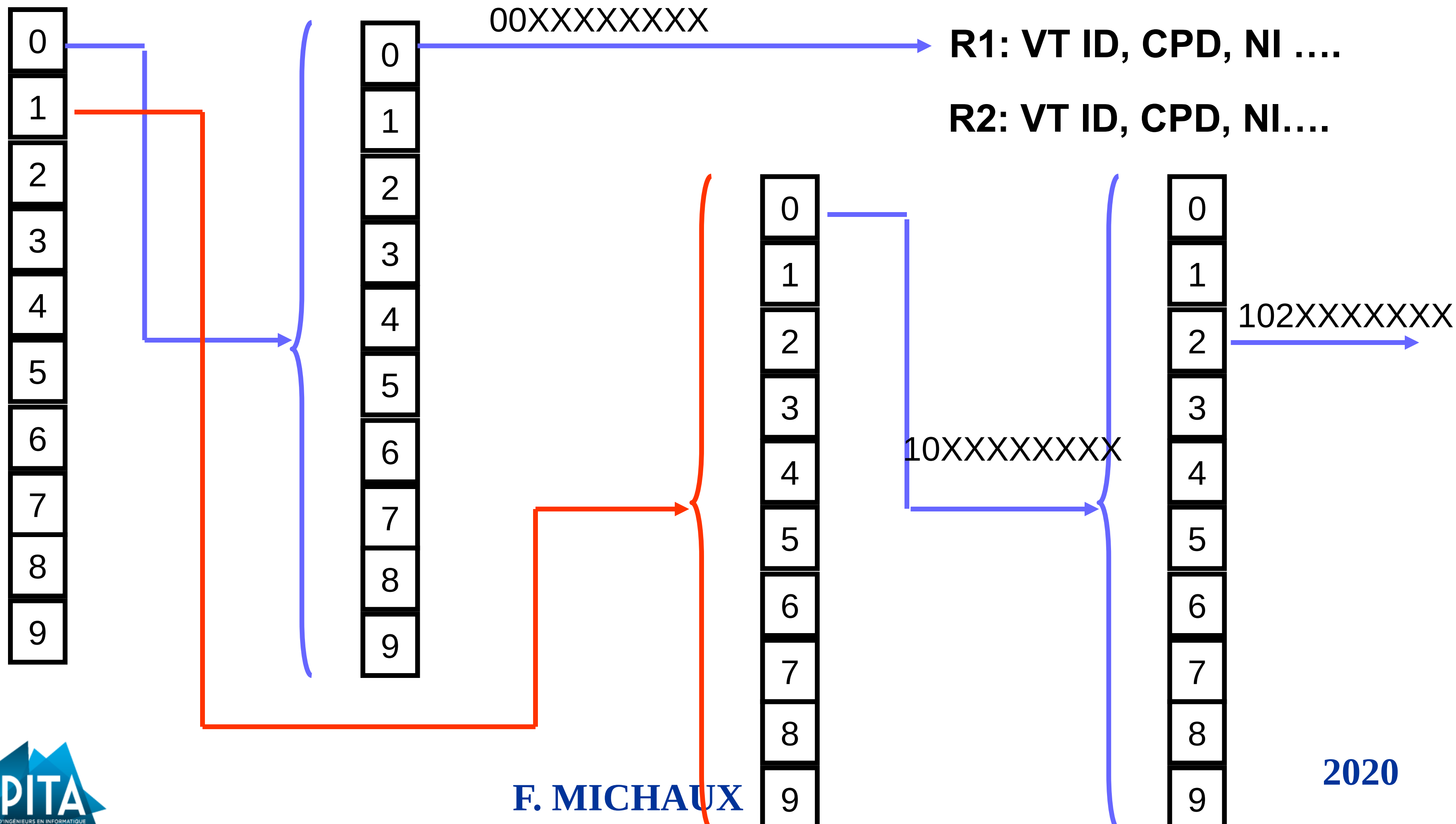
CPU

The CPU is dimensioned by the traffic handles by the switch at the peak hour

- The BHCA is the unity
- BHCA : Busy Hour Call Attempt
- The CPU size is linked to the switching matrix size and the type of traffic. IN traffic ….

Translation principle

The called party number is analysed by the translation

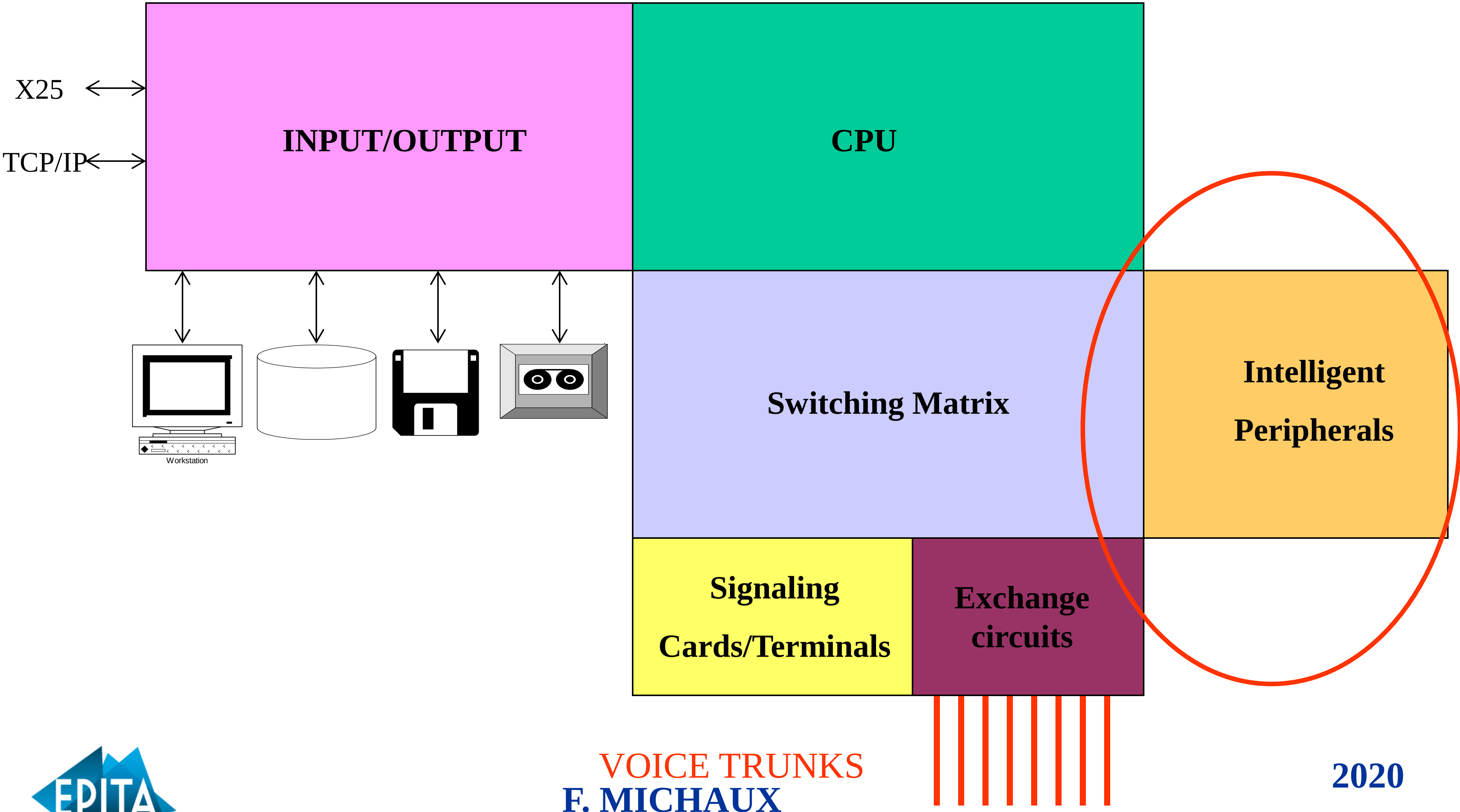


INTELIGENT PERIPHERALS

F. MICHAUX

2020

MAIN SWITCH COMPONENTS



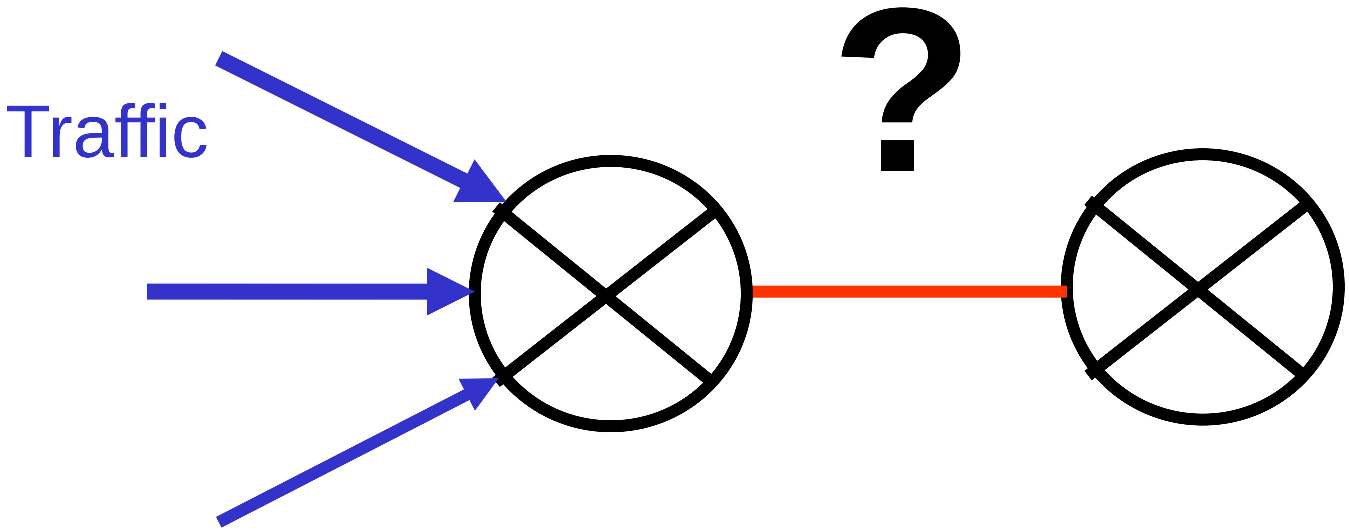
INTELLIGENT PERIPHERALS

The intelligent peripherals provide additional services for the basic calls :

- DTMF receivers
- Announcement machines

Traffic calculation

Traffic calculation



- **Problematic :**

if the trunk group is too small the consequence is an important lost of traffic => lost of Money

if the trunk group is too big the capacity is paid but not used => lost of Money

Traffic calculation

The size of the link between 2 switches depends of the traffic between the both switches

- **it’s based on : A stochastic process which means that It’s partially due to the luck, that’s why it’s possible to define a model.**
- **A formula which is named the Erlang law.**
- **The calculation is generally done at the busy hour**

Traffic calculation

An erlang (*) is :

the utilization of the resources in percentage

The resources are the circuits

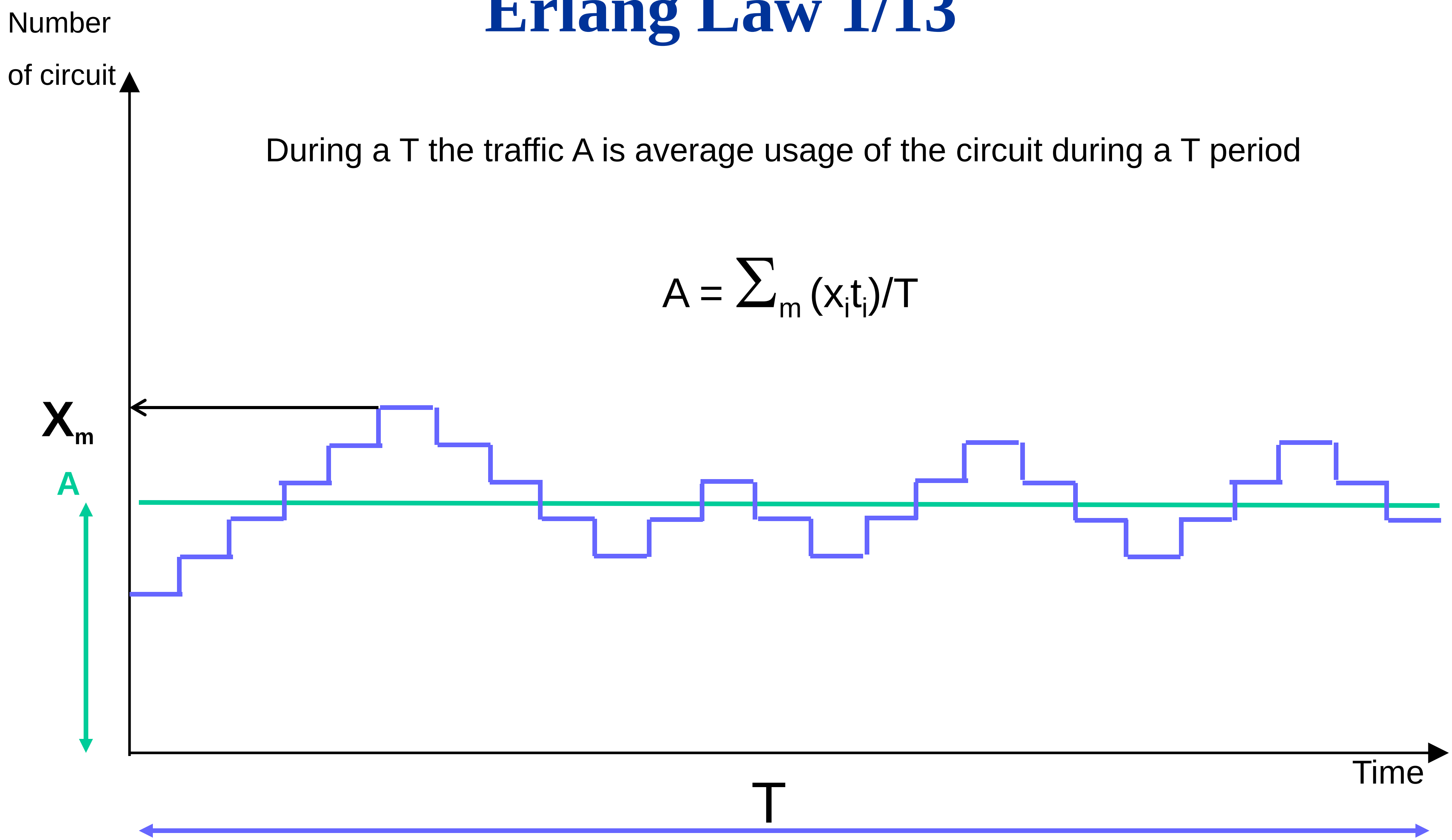
Example : if the average circuit traffics at 12%. The traffic is 0.12 E / circuit

(*) Mister Agner Krarup Erlang (1878-1929) was Danish

Erlang Law 1/13

During a T the traffic A is average usage of the circuit during a T period

$$A = \sum_m (x_i t_i)/T$$



Circuit occupation

Erlang Law 2/13

Generally the traffic is given per minutes

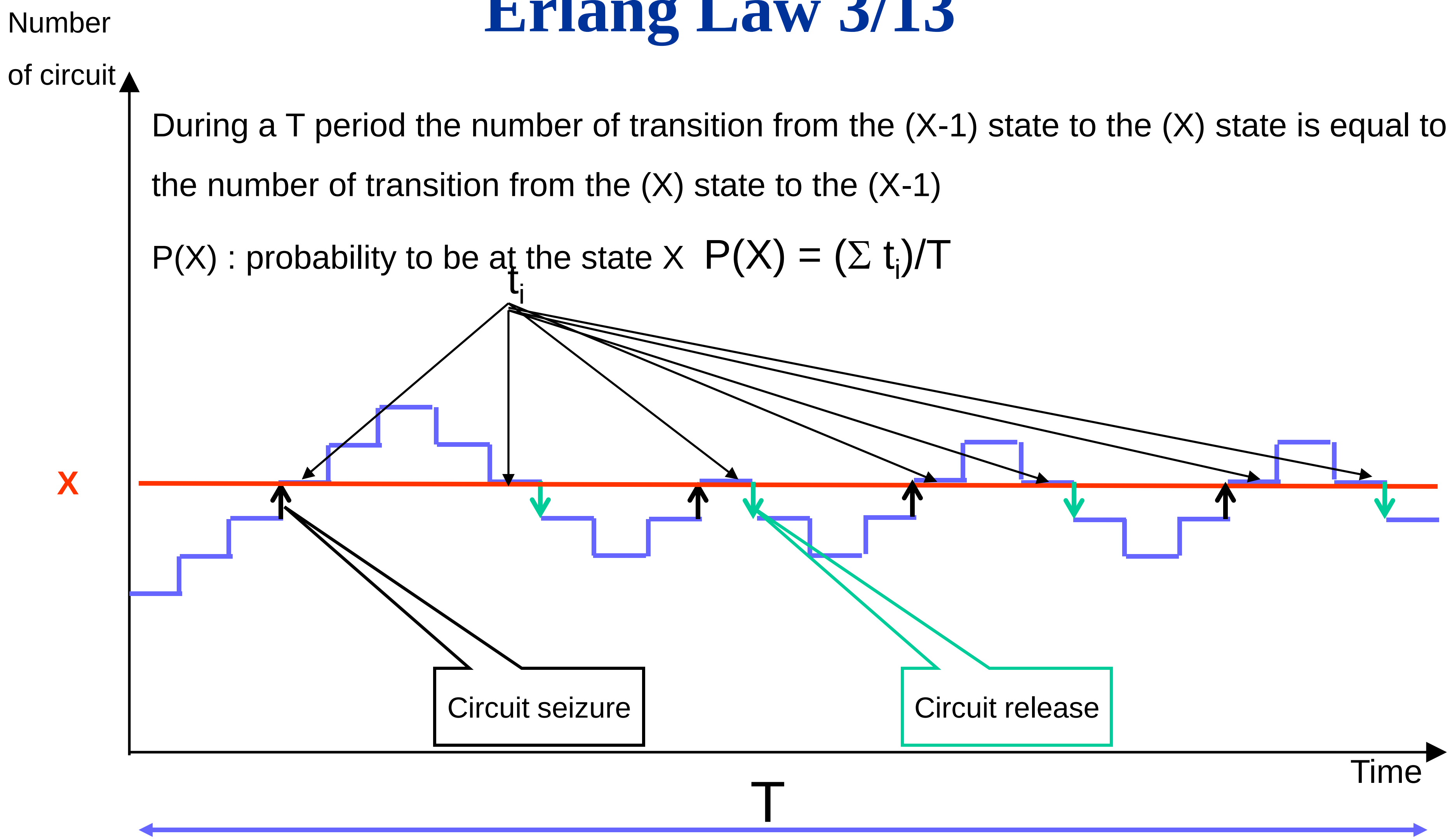
Example : 20 000 calls / hour and the average time per call is 3 minutes

Result : 3/60* 20 000 = 1000 Erlangs

Erlang Law 3/13

During a T period the number of transition from the (X-1) state to the (X) state is equal to the number of transition from the (X) state to the (X-1)

P(X) : probability to be at the state X $P(X) = (\Sigma\, t_i)/T$

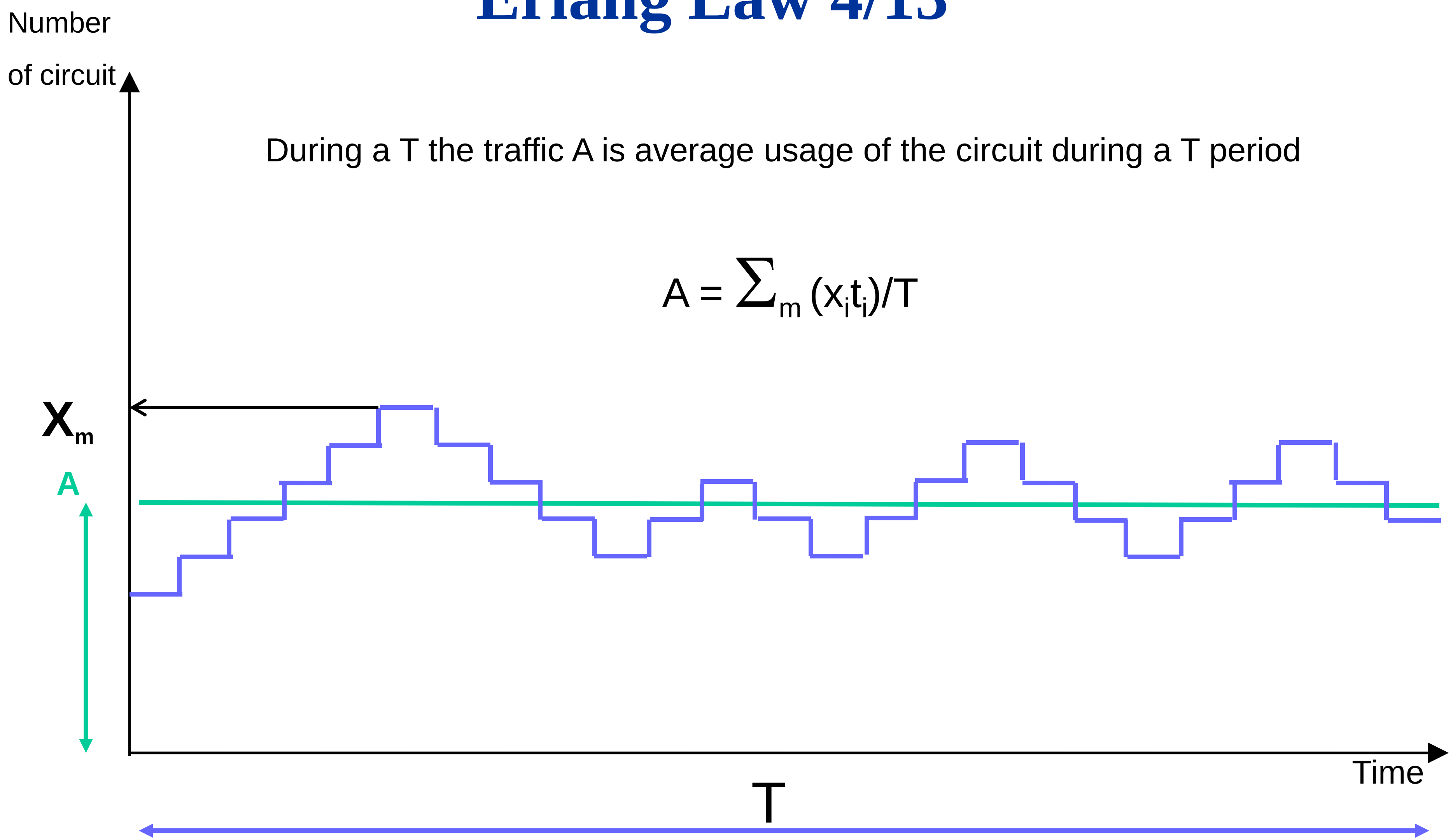


Circuit occupation

Erlang Law 4/13

During a T the traffic A is average usage of the circuit during a T period

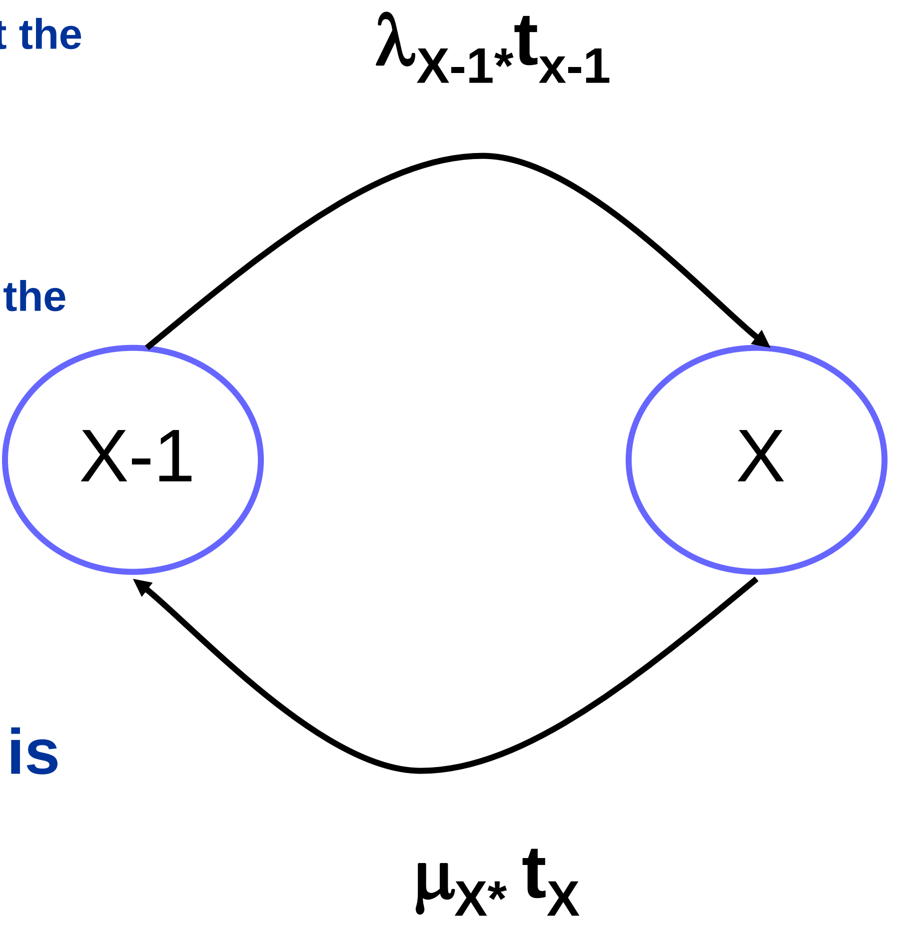
$$A = \sum_m (x_i t_i)/T$$



Circuit occupation

Erlang Law 5/13

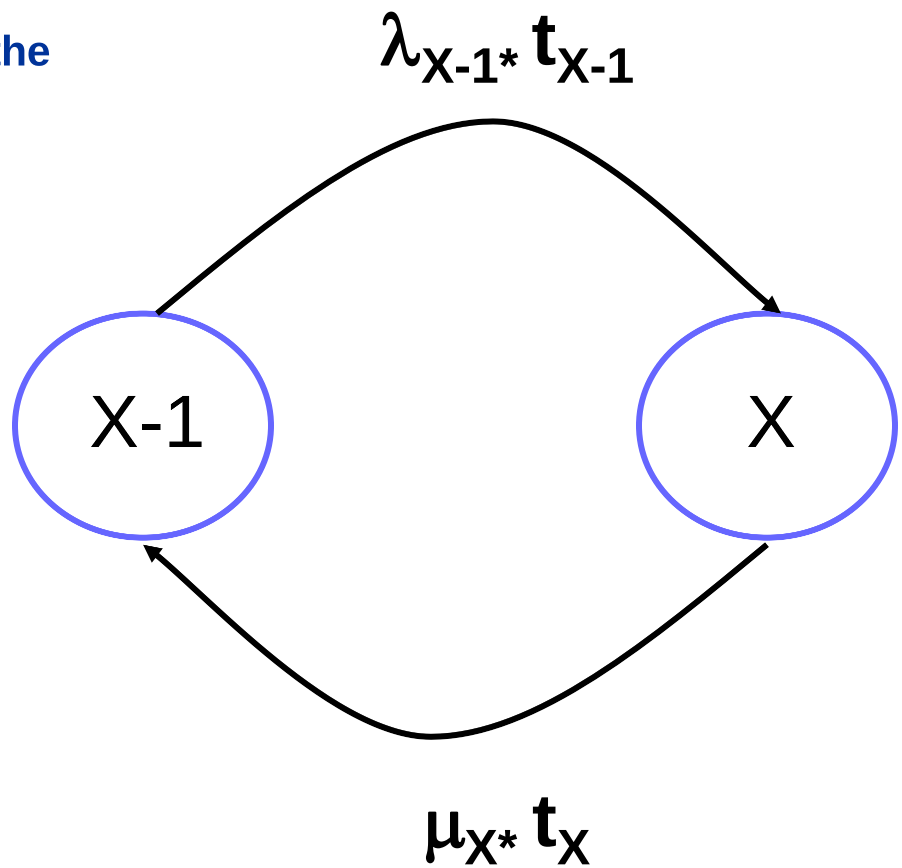
- λ_{X-1} is the rate of circuit seizure at the (X-1) state
- μ_X is the rate of circuit release at the (X) state
- **The balance equation is $\lambda_{X-1} P(X-1) = \mu_X P(X)$**



Transition between the states (X) and (X-1)

Erlang Law 6/13

- λ_{X-1} does not depend of the circuit already seized but depends only of the traffic A
- μ_X is proportional to the circuit seized. More the circuit are seized more the circuit could be released
- $\lambda_{X-1} = \lambda = n/T = \mathbf{A/\tau}$
- $\mu_X = \mathbf{X/\tau}$
- The balance equation is $A^* \mathbf{P(X-1)/\tau = (X)^* P\,(X)/\tau}$



Transition between the states (X) and (X-1)

Erlang Law 7/13

$P(X) = A/X\ P(X-1) = A/X*A/(X-1)*A/(X-2)*.......*P(0)$

$P(X) = (A^X/X!)*P(0)$

$\Sigma_0^N P(X) = 1$ N is the number of circuit of the trunk

$P(0)*\Sigma_0^N (A^i/i!) = 1 \rightarrow P(0) = 1/\Sigma_0^N (A^i/i!)$

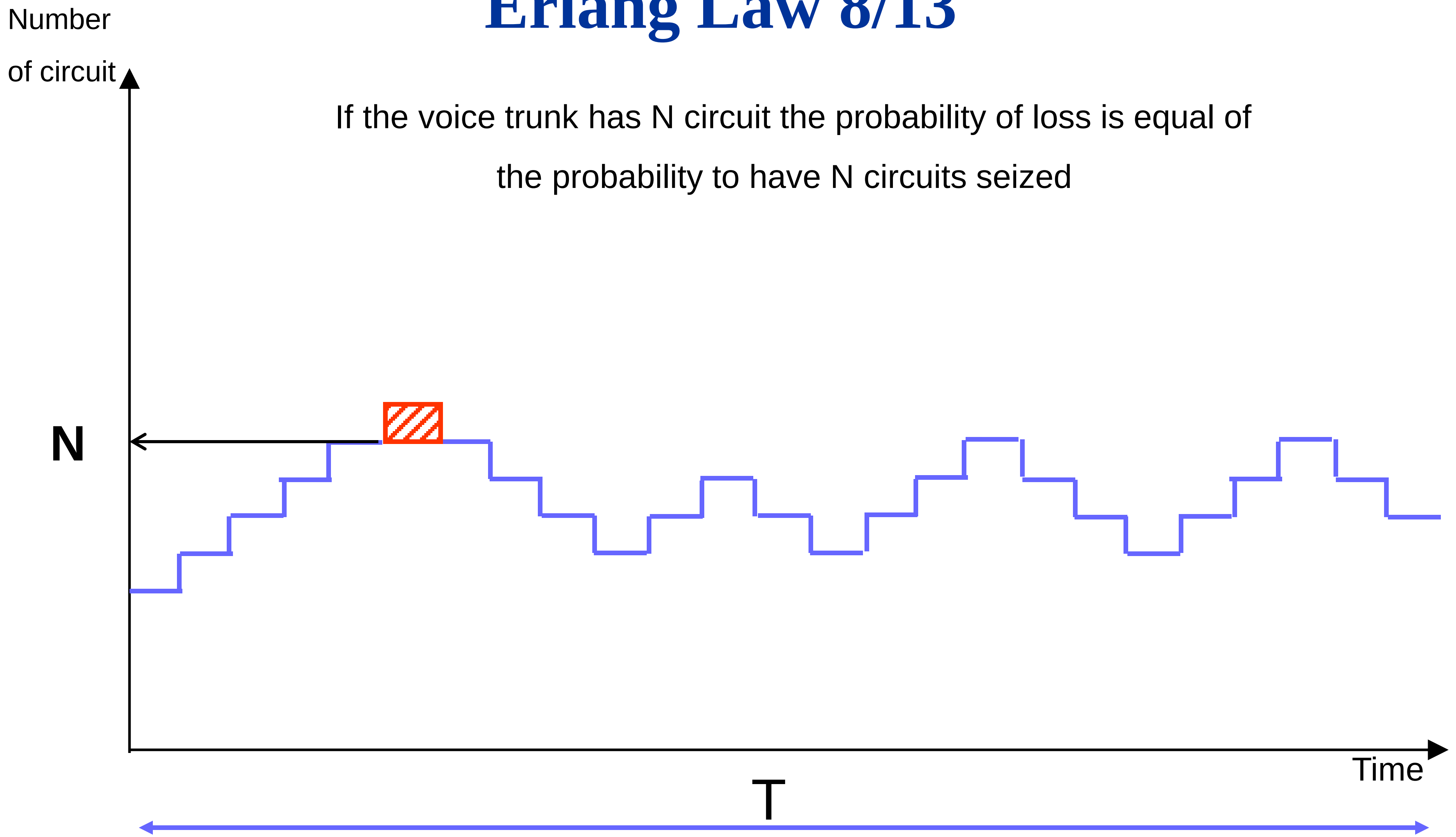
$P(X) = (A^X/X!)/\Sigma_0^N (A^i/i!)$ This is the Erlang distribution probability to have X circuit engaged when the traffic is A and the voice trunk has N circuits.

NOTA : The Erlang Law is very close to the Poisson Law

$\Sigma^\infty P(X) = 1 \rightarrow P(0) = 1/\Sigma^\infty (A^i/i!) = e^{-A} \rightarrow P(X) = A^X/X! * e^{-A}$

Erlang Law 8/13

If the voice trunk has N circuit the probability of loss is equal of the probability to have N circuits seized



Circuit occupation

Erlang Law 9/13

- $P(X) = (A^X/X!) \,/\, \Sigma^N (A^i/i!)$
  Probability to have X circuit engaged when the traffic is A and the voice trunk has N circuits.
- $1/P(N) = \Sigma^N (A^i/i!) \,/\, (A^N/N!)$
- $1/P(N) = (N!/A^N) * (1 + A + A^2/2+ \ldots.+ A^N/N!)$
- $1/P(N) = N/A *((N-1!)/A^{N-1})* (1 + A + A^2/2+ ..+ A^{N-1}/(N-1)! + A^N/N!))$
- $1/P(N) = N/A*1/P(N-1) + N!/ A^N * A^N/N!$
- $1/P(N) = N/A*1/P(N-1) + 1$ with $P(0)=1$

Erlang Law 10/13

The fist Erlang law is the following :

$$1/E_{(1,N)}A) = 1 + N/A^{*}\ 1/E_{(1,N-1)}(A) \qquad \text{with } E_{(1,0)}(A) = 1$$

N : is the Number of circuits

A : is the traffic in Erlang

$E_{(1,N)}(A)$: is the probability of loss with A Erlangs and N circuits

$E_{(1,0)}(A) = 1$ because with 0 circuit the probability of loss is 1

Erlang Law 11/13

$1/E_{(1,N)}(A) = 1 + N/A * 1/E_{(1,N-1)}(A)$ with $E_{(1,0)}(A) = 1$

$E_{(1,0)}(A) = 1.000000$ A = 100

$E_{(1,1)}(A) = 0.990099$

$E_{(1,2)}(A) = 0.980200$

$E_{(1,3)}(A) = 0.970303$

$E_{(1,4)}(A) = 0.960408$

$E_{(1,5)}(A) = 0.950515$

$E_{(1,100)}(A) = 0.075700$ $1/E_{(1,100)}(A) = 13.209960$

$E_{(1,140)}(A) = 0.000028$ $1/E_{(1,140)}(A) = 36185.150291$

Conclusion : as much as the circuit are important the probability of loss is small

Erlang Law 12/13

Conclusion :

As much as the circuit are important as the probability of loss is small.

Problematic :

Generally the inputs are the probability of loss and the traffic. N has to be found !

The probability of loss for n circuits depends the probability of loss for (n-1) circuits.
Very long to calculate before the computer the people used Palm table.

Erlang Law 13/13

It's not easy to calculate the number of circuit
A formula which gives a good approximation is

$E_{(1,N)}(A) = 10^{-k}$

$k = -\mathrm{LOG}_{10}[E_{(1,N)}(A)]$

$$\underline{\mathbf{N \# A + k * A^{1/2}}}$$

CONCLUSION

Conclusion

This switching overview shows the experience required is very large as :

- **Electronic : Modulation, filtering, digitalization**
- **Signal theory, compression,**
- **Protocol (Signaling),**
- **Real time software knowledge,**
- **Probability (traffic calculation).**
- **…………**

QUESTIONS

?

QUESTIONS

- **Questions regarding the presentation ?**

- **Questions regarding the Telecommunication World ?**

  How is the business ?
  What is the future ?

Thank you for your attention