

Fieldbus :
Industrial Network
Real Time Network

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Who's who

IEC 61784 PROFInet
TT-CAN Hart TTP Profibus-PA Unitelway ISO 8802.5
Ethernet Batibus SNMP
MIL 1553B WorldFIP IEC 61158 P-NET CiA ICCP
Sercos BacNET CSMA-BA EHS CSMA-DCR SDS
EiBUS Interbus DeviceNet Profibus-FMS FieldBus Foundation
ControlNet CANOpen ASI TTP-A EN 50254 M-PCCN
Profibus-DP DWF Modbus IEC TCP-IP FDDI FIPWay
TTP-C EN 50170 TASE2 CASM ISO 8802.4 WDPF
MMS ISO 8802.3 Sinec ControlFIP PLAN JBUS
FIPIO LON UCA CSMA-CA Seriplex TOP CSMA-CD Mini-MAP
CAN UCA MAP F8000 Profisafe UIC 556 CSMA-CD Digital Hart Proway
Bitbus ARINC WITBUS IEC 6375 CIP LocaFIP UIC 556 Digital Hart Proway
M-Bus J1850 VAN Euridis Sycoway GENIUS OPTOBUS LIN
IEEE 802.11 FTT-CAN BlueTooth AFDX FireWire Vnet/IP Anubis FlexRay
EN 50 295 Sensoplex EPA BlueTooth AFDX FireWire Vnet/IP Anubis FlexRay
Ethercat EtherLink ModBus-RTPS CAMAC IEC 61 499 ARCNET UWB

content

- 1st part : history and state of the art
 - **fieldbus origins**
 - development of fieldbus and standards
- 2nd part : technical aspects
 - application relationships
 - Medium Access Control
 - Data Link Layer
 - architectures

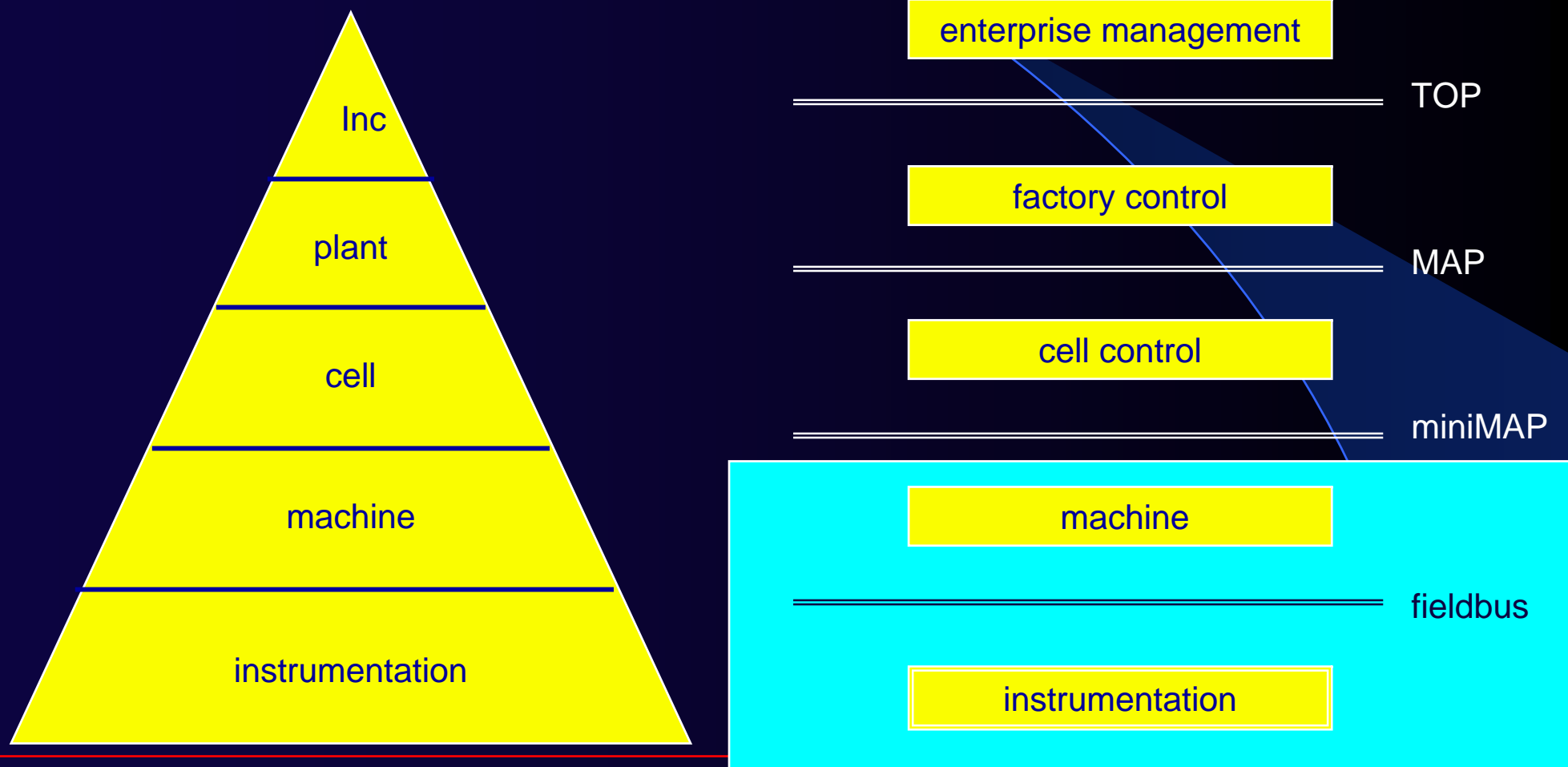
prehistory

- 60s : CAMAC in nuclear experiments
- 70s :
 - MODBUS (PLC network)
 - WDPF (continuous process)
 - ARCNET (office communication and data acquisition)
 - Mil Std 1553B
- Data Highway (Allen Bradley), TiWay (Texas Instr)...
- needs for standards

MAP and TOP (1980)

- Manufacturing Automation Protocol
 - General Motors
 - communication between design offices and factories
 - communication between machine tools and robots
- Technical and Office Protocol
 - Boeing
 - communication between business and technical offices

CIM architecture

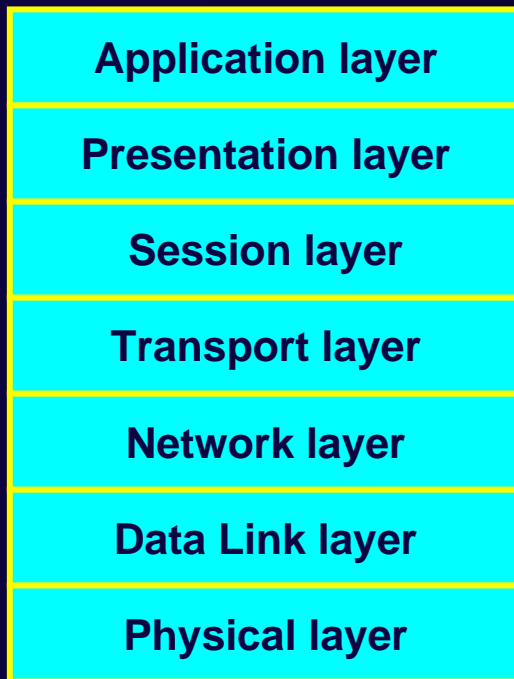


enabling technologies

- OSI reference model (1980)
 - communication model and concepts
- LANs (Ethernet, Token...)
 - deterministic protocols
 - nondeterministic protocols
- microelectronics and integrated circuits

enabling technologies

OSI reference model



“reduced models”



enabling technologies

- LANs (Ethernet, Token, TDMA...) development
 - deterministic protocols
 - nondeterministic protocols
 - centralized access or not
- DCS
 - Digital Control System vs. Distributed Control System

enabling technologies

- microelectronics and integrated circuits
 - full and semi-custom
 - micro processors
 - micro controllers
 - DSP
 - communication dedicated ICs (I2C- Inter IC network)
 - “intelligence” embedded in ICs

roles of a fieldbus

- **connection of field devices and field controllers**
 - sensors, actuators, drives controllers, PLCs...
- **system considerations**
 - simplification of wiring
 - standardization of communication between devices
 - development of smart devices
- **real time communication system**
 - with different services and various qualities of service
 - multiple domains of application

fieldbus

- backbone of distributed and real time systems

fieldbus

- backbone of distributed and real time systems

but also

- bone of contention between automation companies
beginning of the fieldbus saga

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first development

- 1982 - FIP - WorldFIP
- 1983 - PROFIBUS and CAN
- 1984 - P-Net
- 1985 - IEC NWI TC65C/WG6
- 1985 - ISA SP50

IEC std contenders

- 1st group
 - existing systems
 - Mil Std 1553B
 - IEEE P1118 (Bitbus)
 - Foxboro
 - Rosemount
 - ...
 - 2nd group
 - paper proposals
 - FIP
 - PROFIBUS
- discussion draft and questionnaire
for functional requirements (ISA)

questionnaire

- benefits of fieldbus
 - lowering cost, ease of adding devices, accuracy of information, enhancing the maintainability, remote access to data, advanced control strategies
- describing field devices
 - max response time and message frequency
- information flows
 - grouping of devices, topology, number of stations, redundancy
- application environment
 - power, wires type, insulation, flammable atmosphere

two fieldbuses H1 and H2

- H1
 - low data rate
 - a few sensors
 - small distances
 - continuous process
- H2
 - high data rate
 - manufacturing process
 - connection of several H1

requirements - application

- definition of Application Protocol Data Units
 - process (real time traffic)
 - measurement
 - alarm setting
 - status
 - installation (non real time traffic)
 - tag number
 - manufacturer's data
 - additional maintenance

name	value	status
------	-------	--------

requirements - application

- definition of other services
 - control access
 - configuration services
- types of data
- polled and unsolicited messages
- full logical connectivity
- architectures (distributed or centralized)
- time coherences (of data, of actions)
- space consistency

requirements

- environment

- medium
- insulation
- power
- flammable atmosphere
- topologies

- performances

- number of stations
- length
- data rate
- response time
- integrity of data
- addressing

IEC 61158

- 8 types for data link layer
 - Type 1 : compromise (Technical Report)
 - Type 2 : ControlNet
 - Type 3 : Profibus
 - Type 4 : P-Net
 - Type 5 : Foundation fieldbus
 - Type 6 : Swiftnet
 - Type 7 : WorldFIP
 - Type 8 : Interbus

IEC 61158

- 10 types for application layer
 - Type 1 : compromise (Technical Report)
 - Type 2 : ControlNet
 - Type 3 : Profibus
 - Type 4 : P-Net
 - Type 5 : Foundation fieldbus
 - Type 6 : Swiftnet
 - Type 7 : WorldFIP
 - Type 8 : Interbus
 - Type 9 : Foundation fieldbus H1
 - Type 10 : Profinet

IEC 61 784

- Communication Profile Family - CPF
- IEC 61 784-1
 - 18 profiles
- IEC 61 784 -2 under specification (based on Ethernet)
 - VNET/IP,
 - TCNet,
 - EtherCAT,
 - EtherNet PowerLink,
 - EPA : Ethernet for Plant Automation
 - ModBus RTPS : Real Time Publish - Subscribe

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- status

- installation (non real time traffic)

- tag number
- manufacturer's data
- additional maintenance

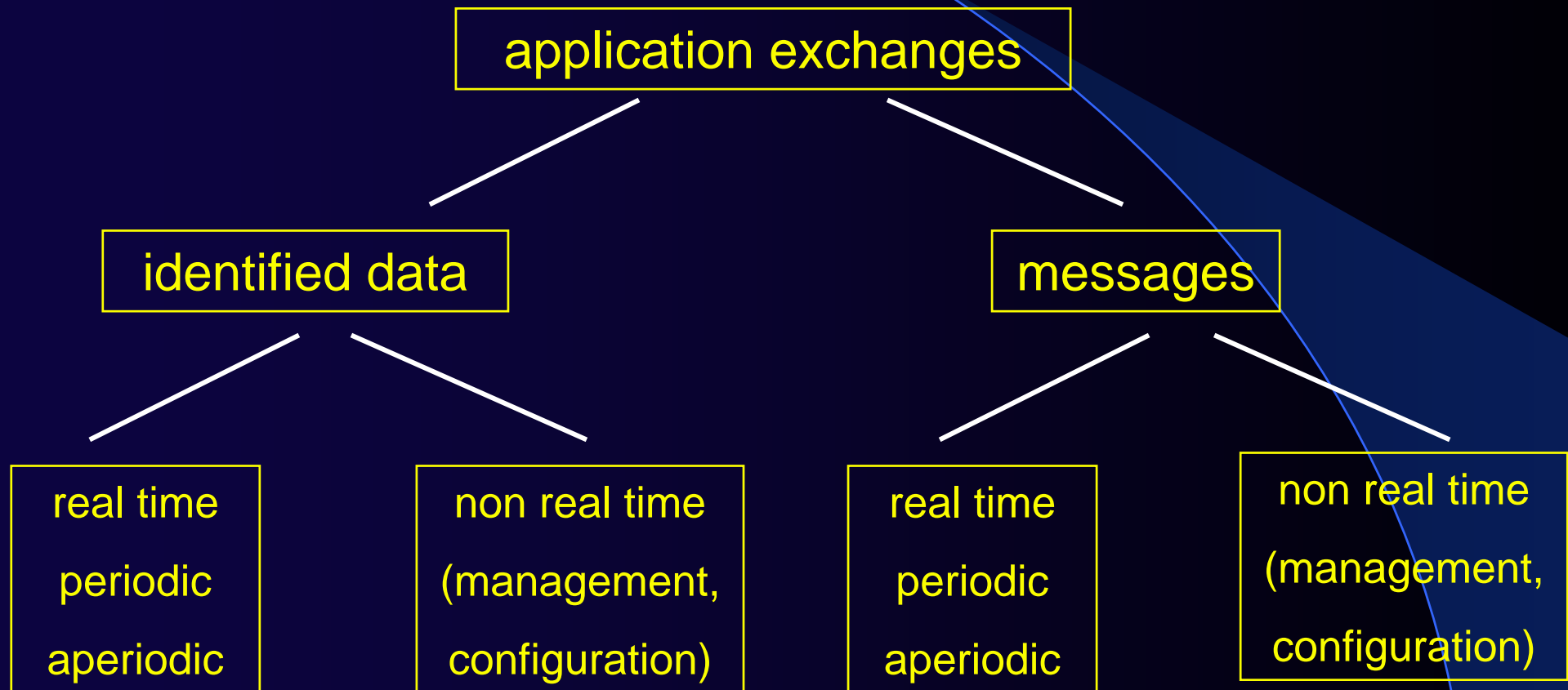
identified data



messages



fieldbus traffic



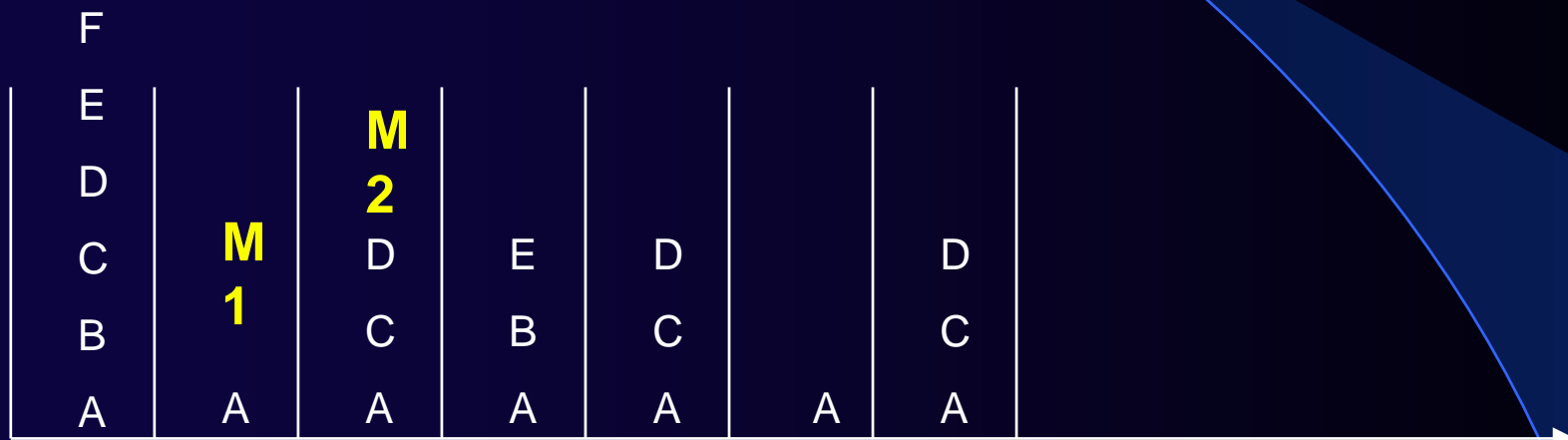
periodic traffic

periodic traffic of identified data

F						
E						
D						
C		D	E	D		D
B		C	B	C		C
A	A	A	A	A	A	A

aperiodic traffic

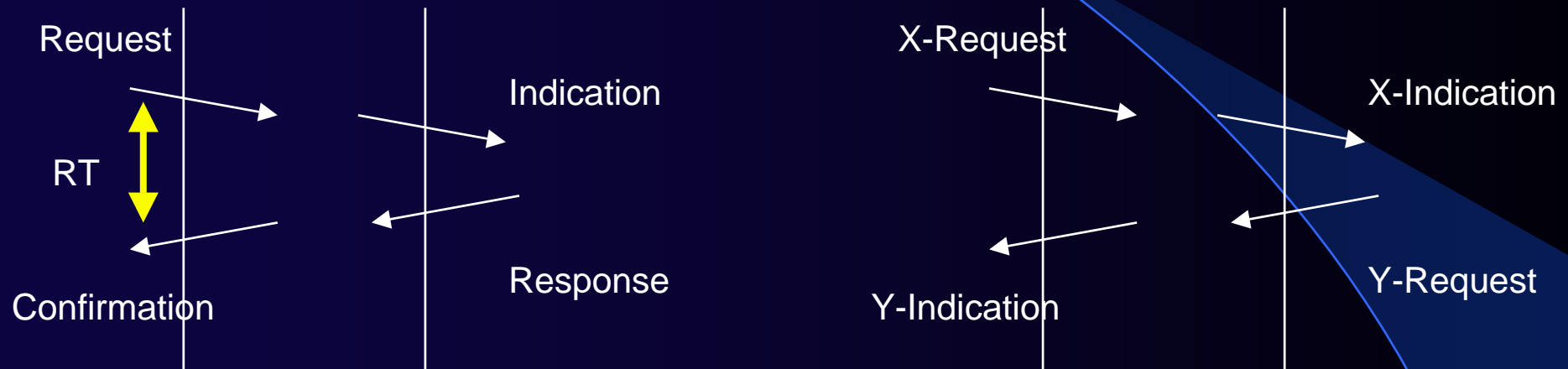
Aperiodic traffic



application layer

- two main classes of relationships
- client - server
 - and variants
- publisher - subscriber
 - and variants

client-server

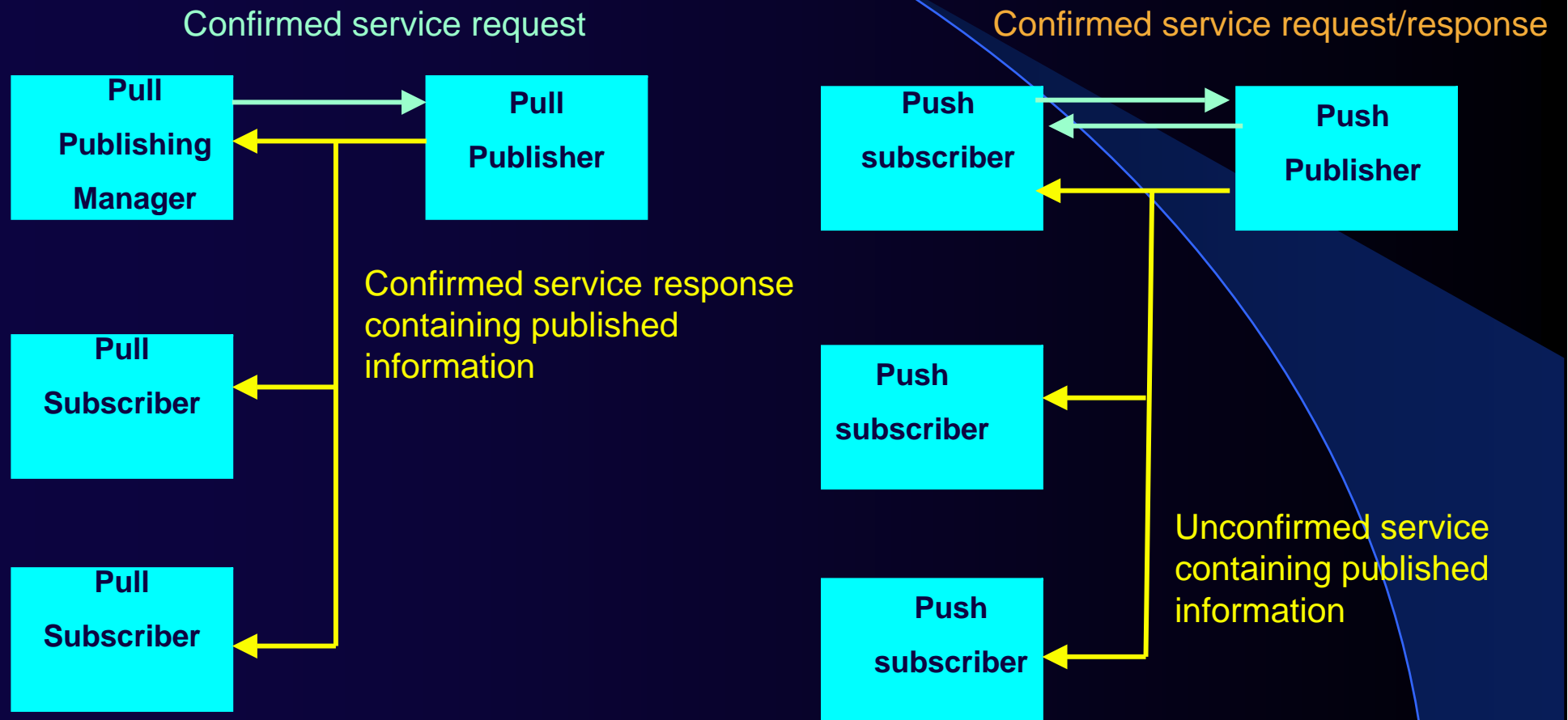


quality of service:

safety : confirmed service

response time : transport delay + local server response time

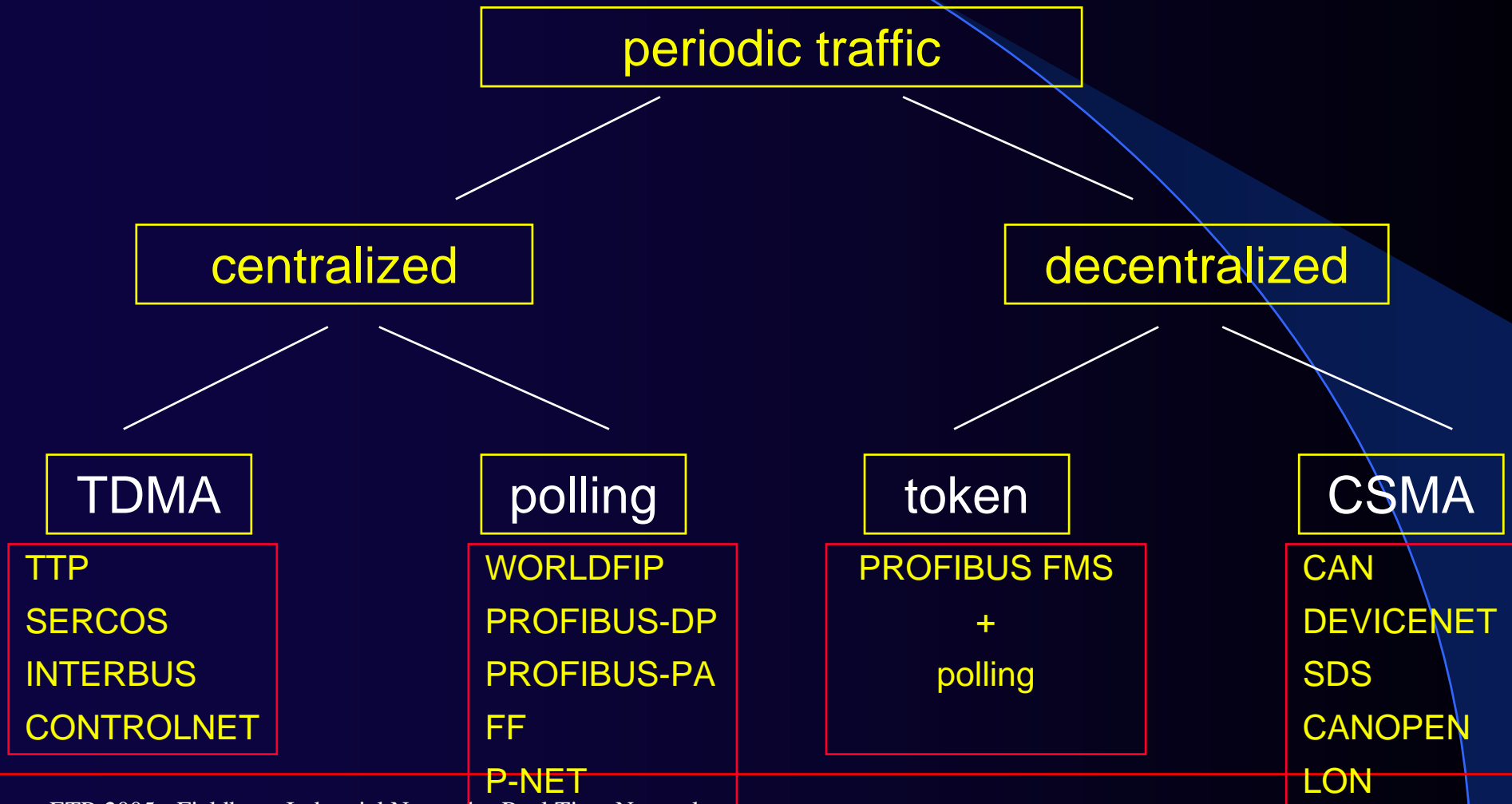
publisher - subscriber models



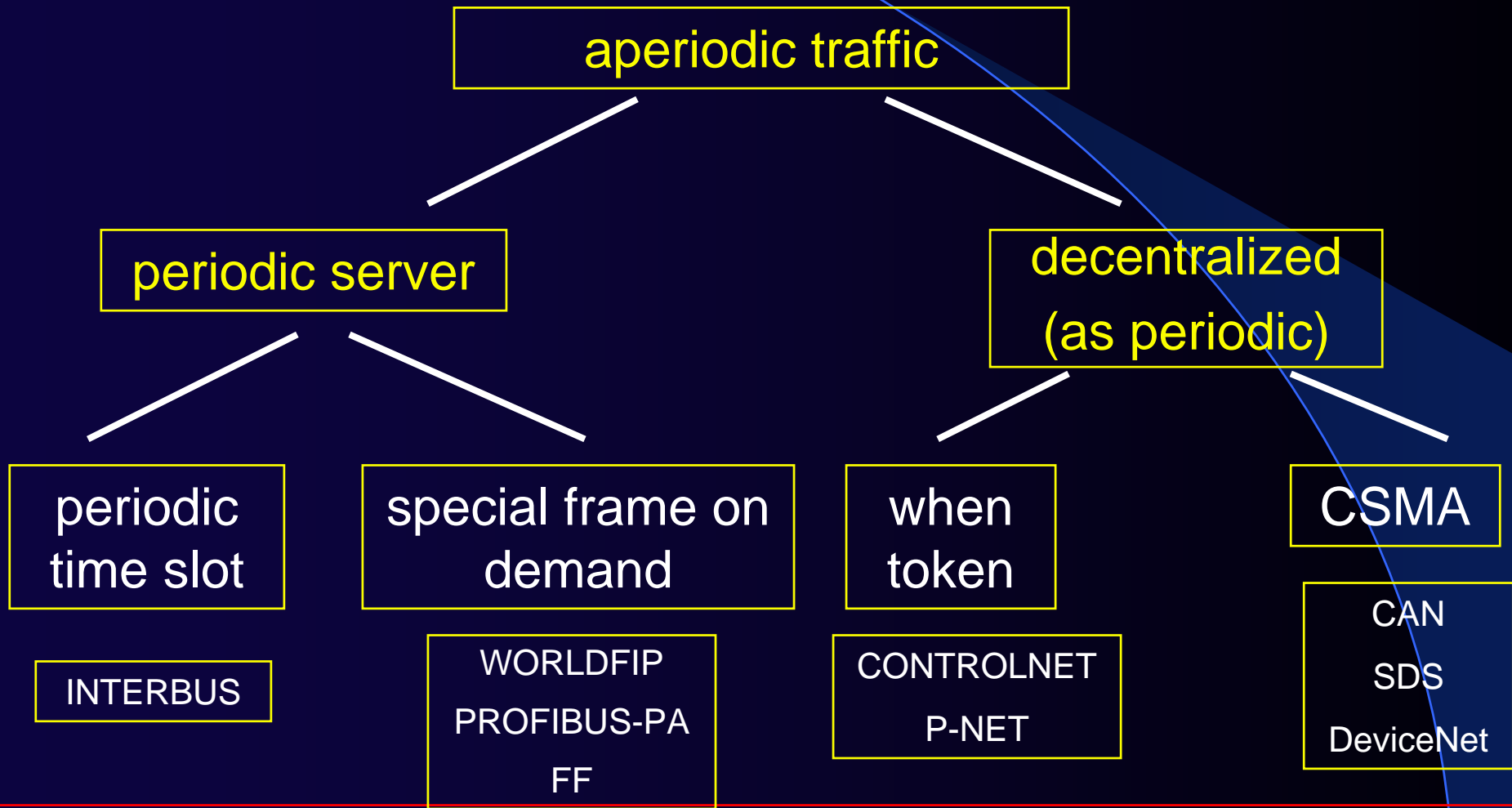
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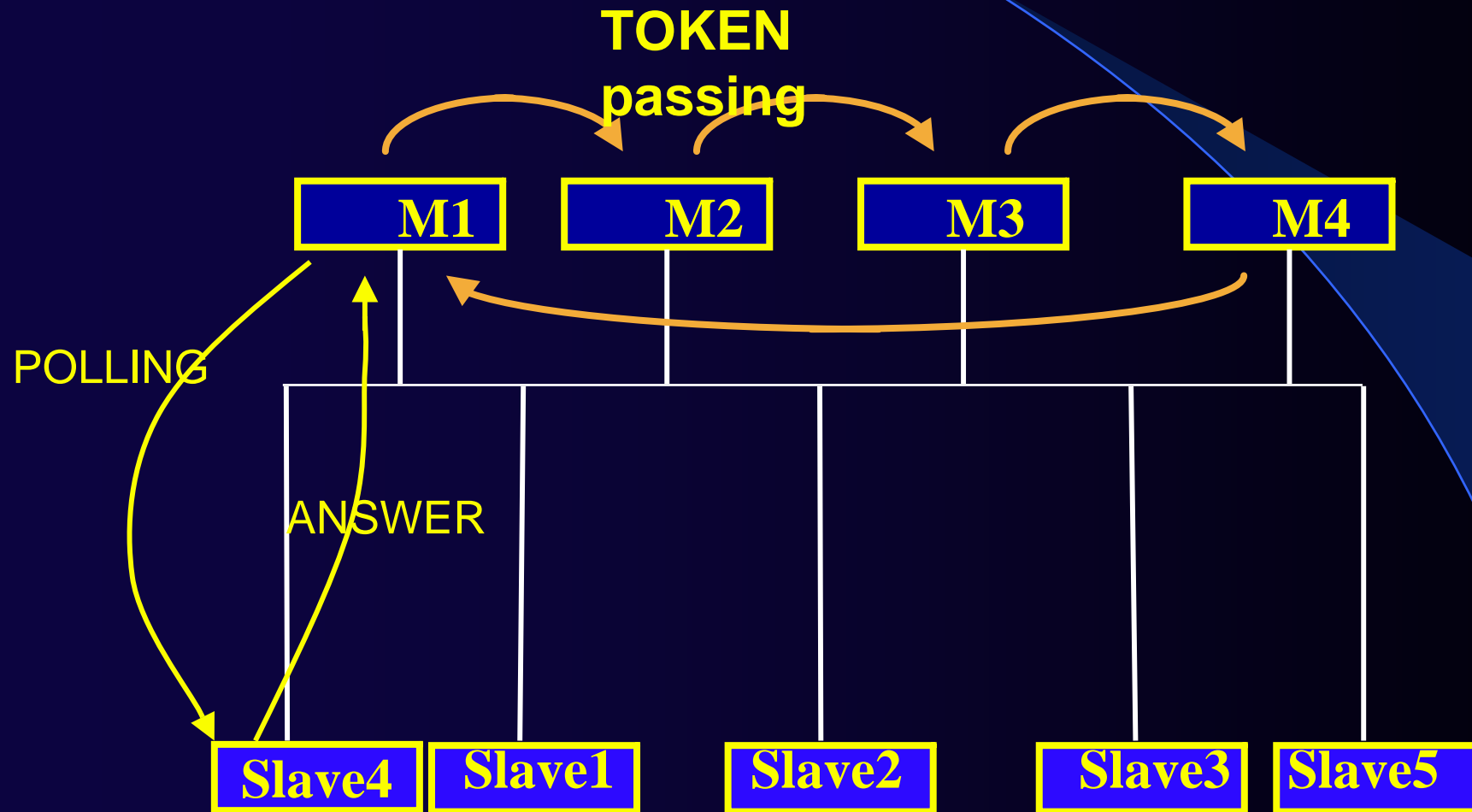
fieldbus traffic



fieldbus traffic



Profibus - 1

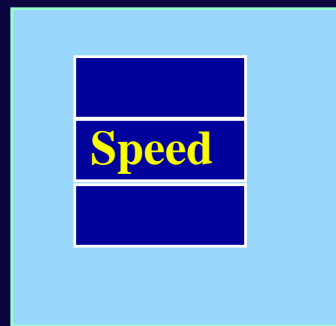


Profibus -2

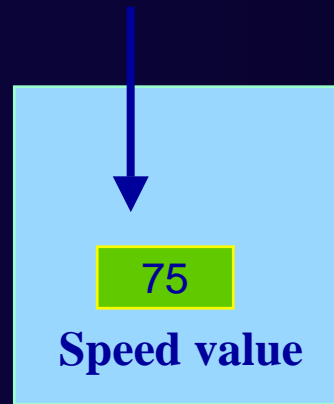
- role of a Profibus master
 - receive the token
 - perform high priority messages first
 - perform the exchanges specified in the Poll List
 - perform low priority messages
 - perform station registration (live list)
 - send the token

WorldFIP - 1

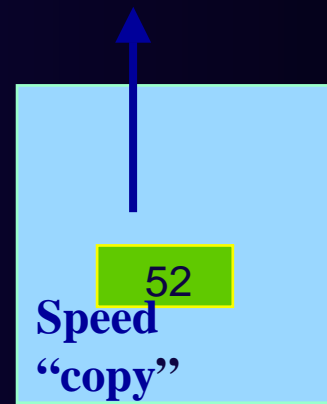
**Bus arbitrator
polling table**



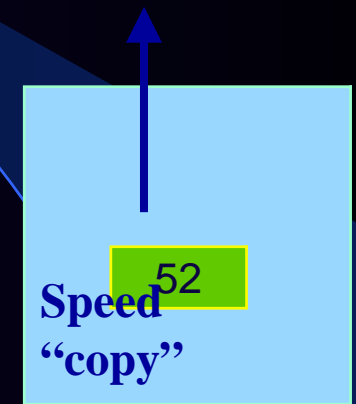
Local Write



Local Read



Local Read



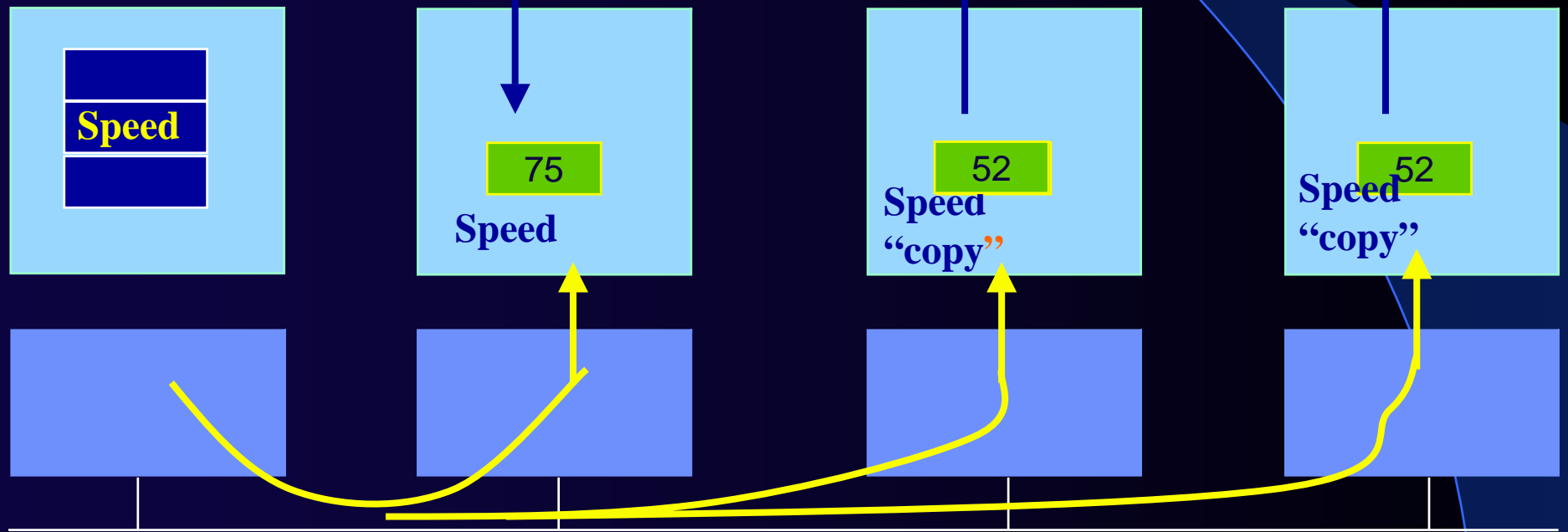
WorldFIP - 2

Bus arbitrator

Local Write

Local Read

Local Read



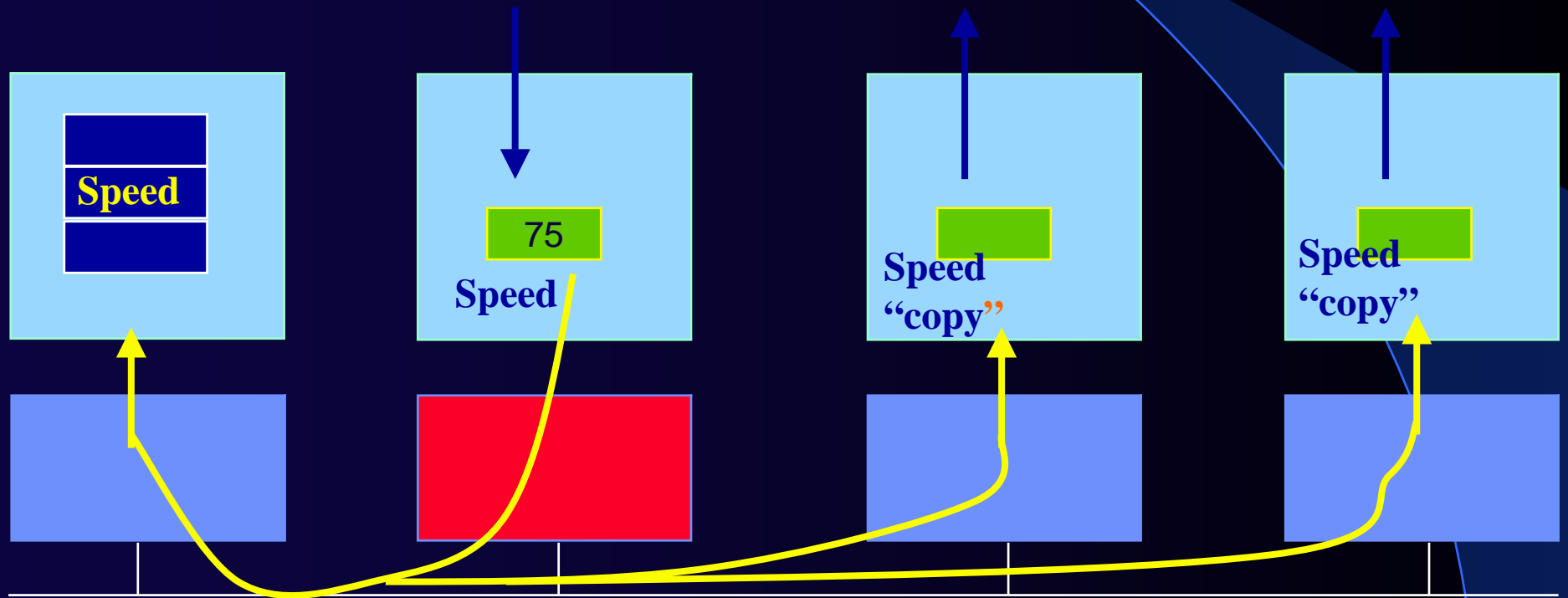
WorldFIP - 3

Bus arbitrator

Local Write

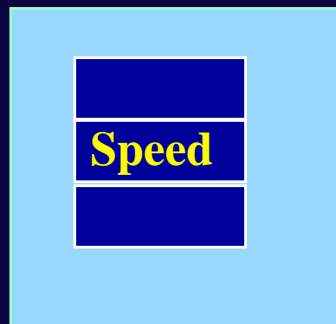
Local Read

Local Read

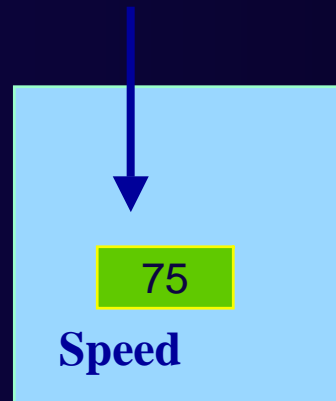


WorldFIP - 4

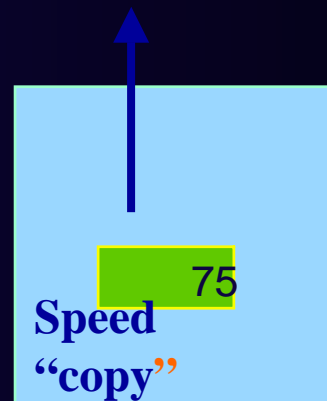
Bus arbitrator



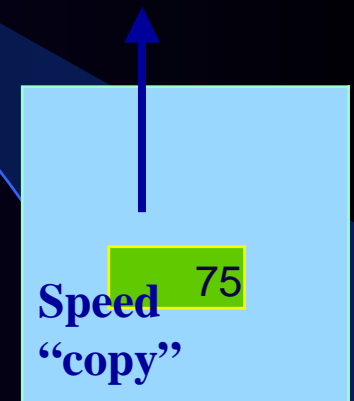
Local Write



Local Read



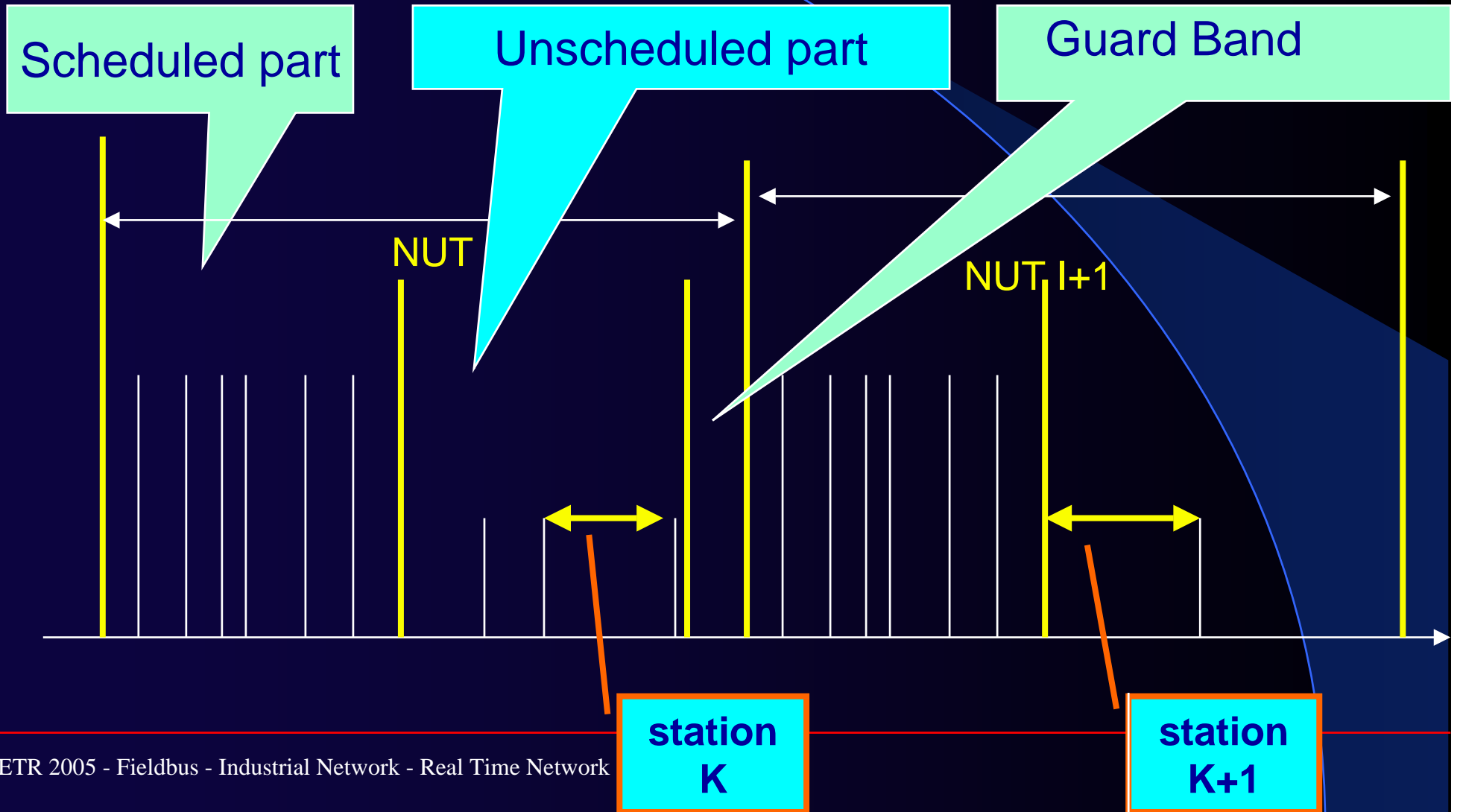
Local Read



ControlNet - 1

- based on a fixed repetitive time cycle
 - Network Update Time (NUT)
 - close synchronism
 - each node - a clock synchronised to the NUT
 - access to the medium in sequential order based on the MAC ID of the node
 - implicit token passing
 - at the end of a frame, comparison of the received MAC ID +1 with the own address

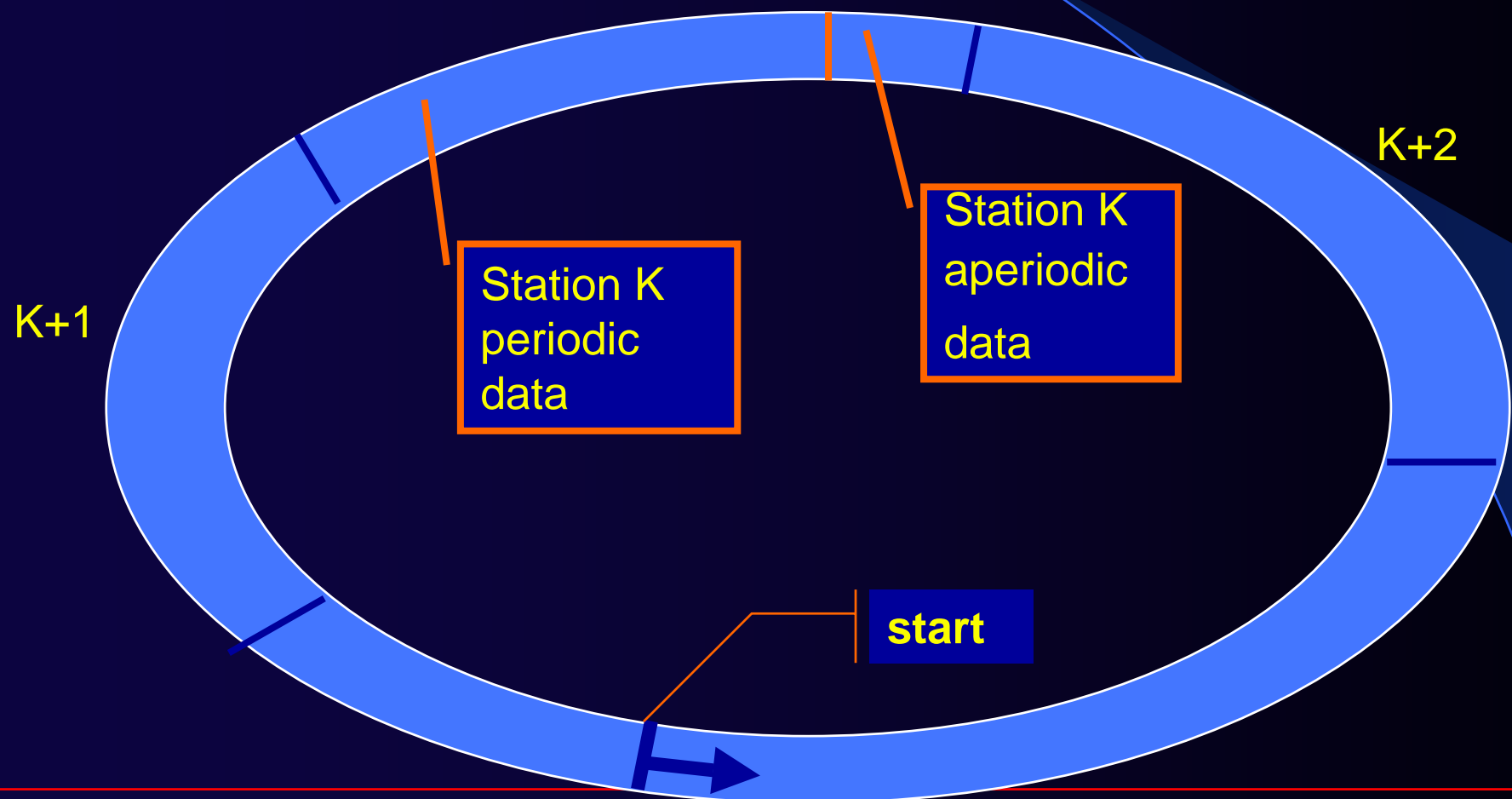
ControlNet - 2



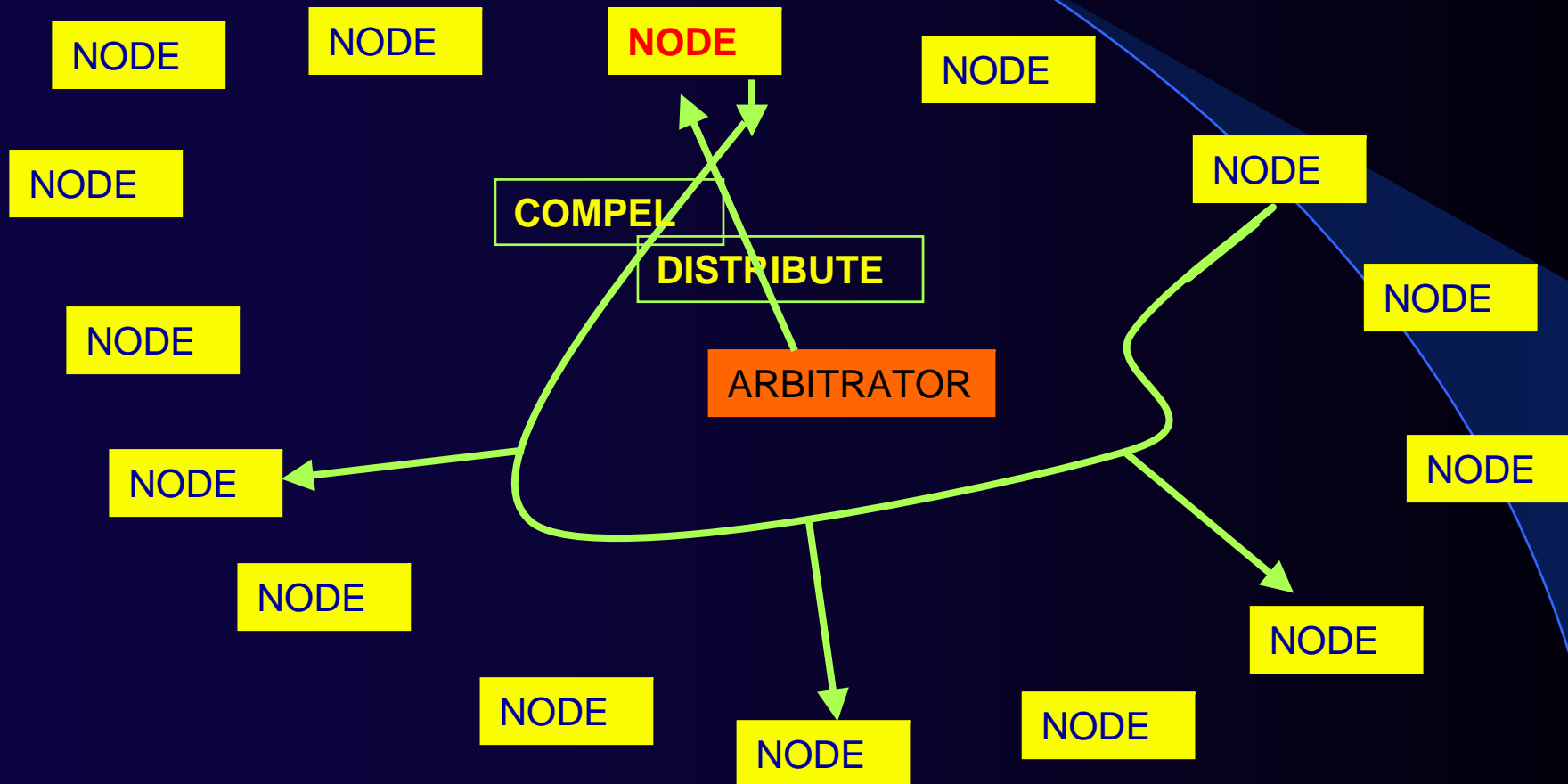
ControlNet - 3

- in a NUT, three time windows
 - scheduled
 - unscheduled
 - Guard Band
- one MAC Frame by node in scheduled part
- predictable and deterministic manner
- Round Robin in the unscheduled part

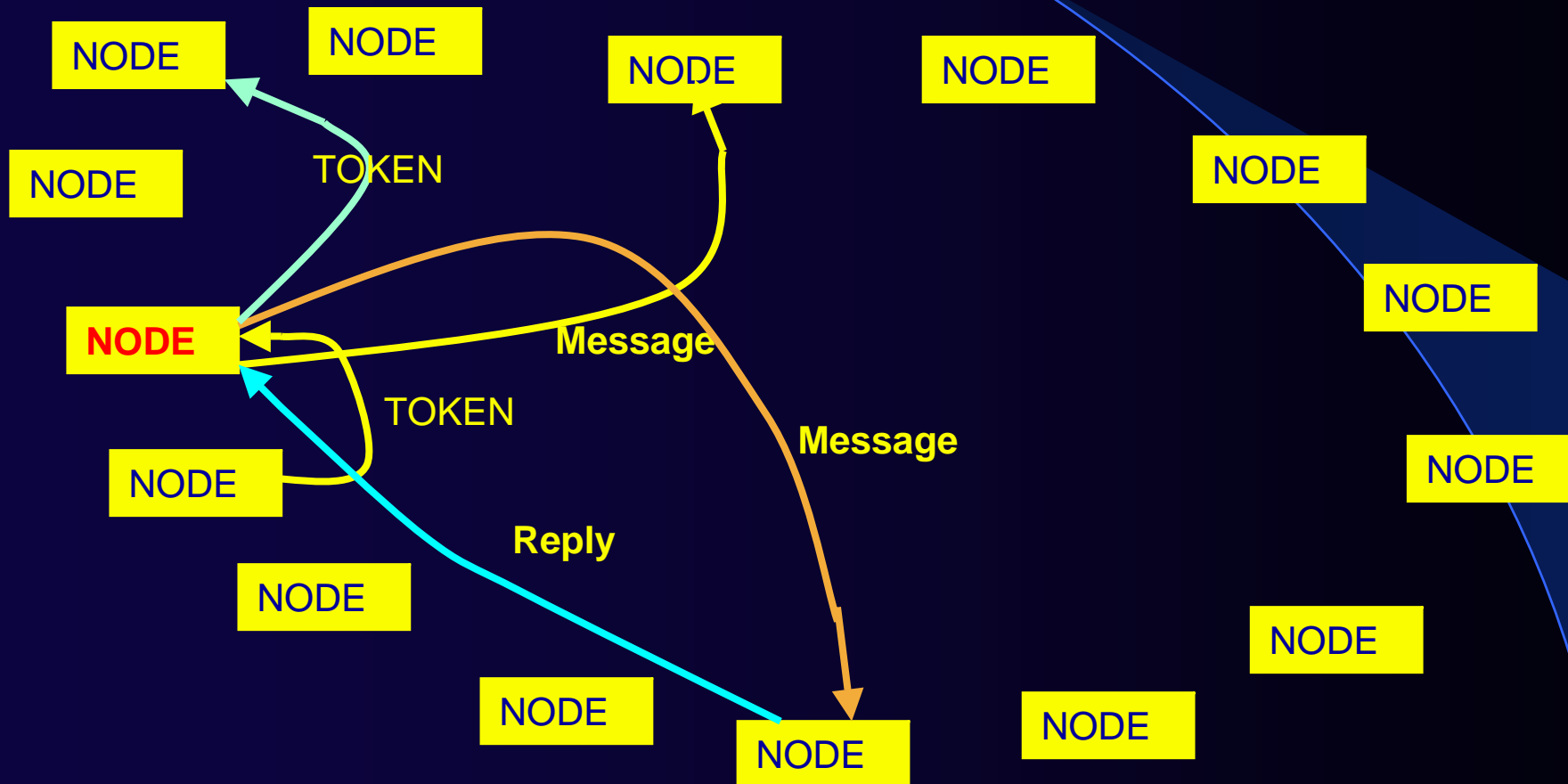
Interbus - 1



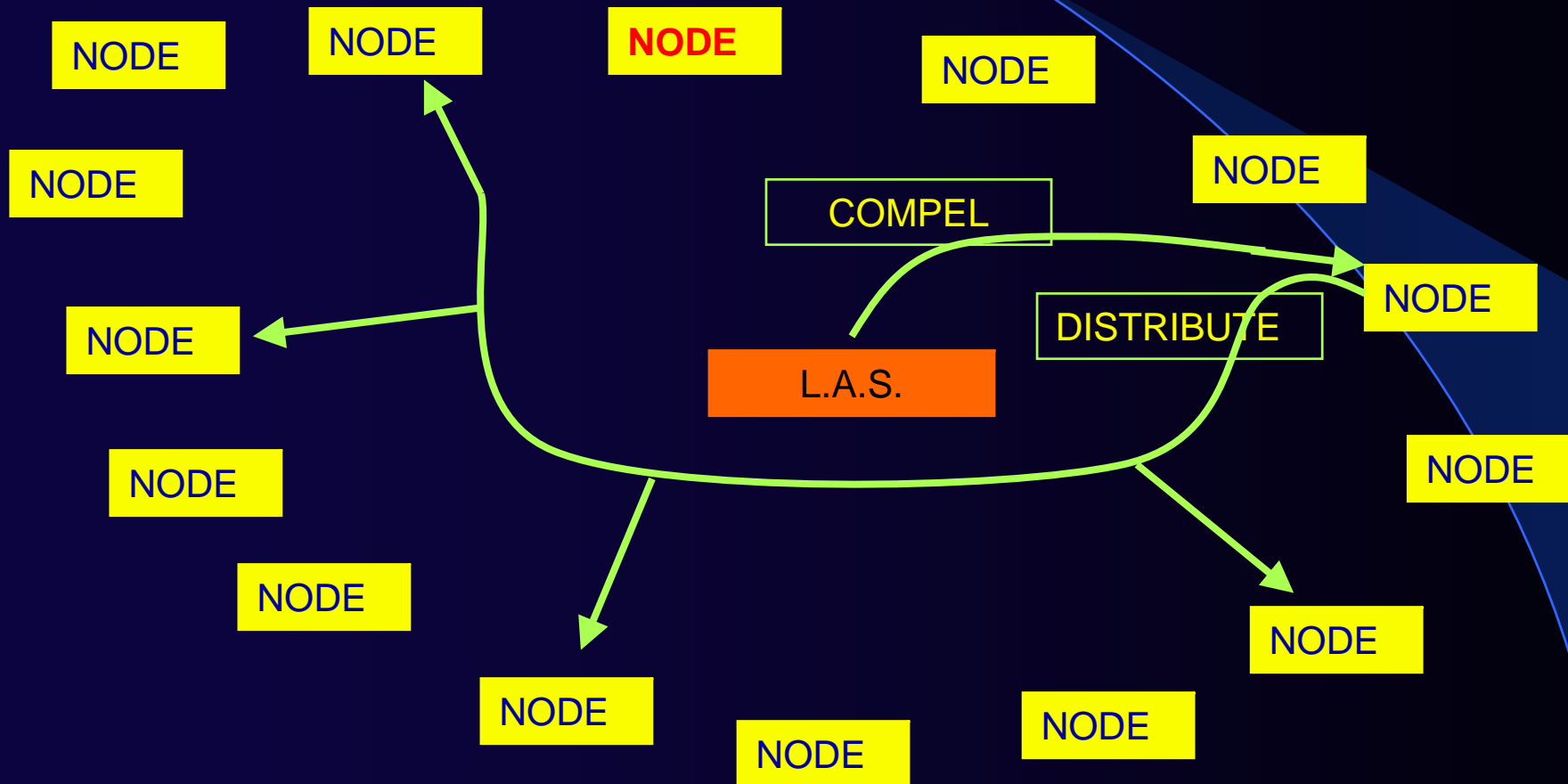
arbitrator



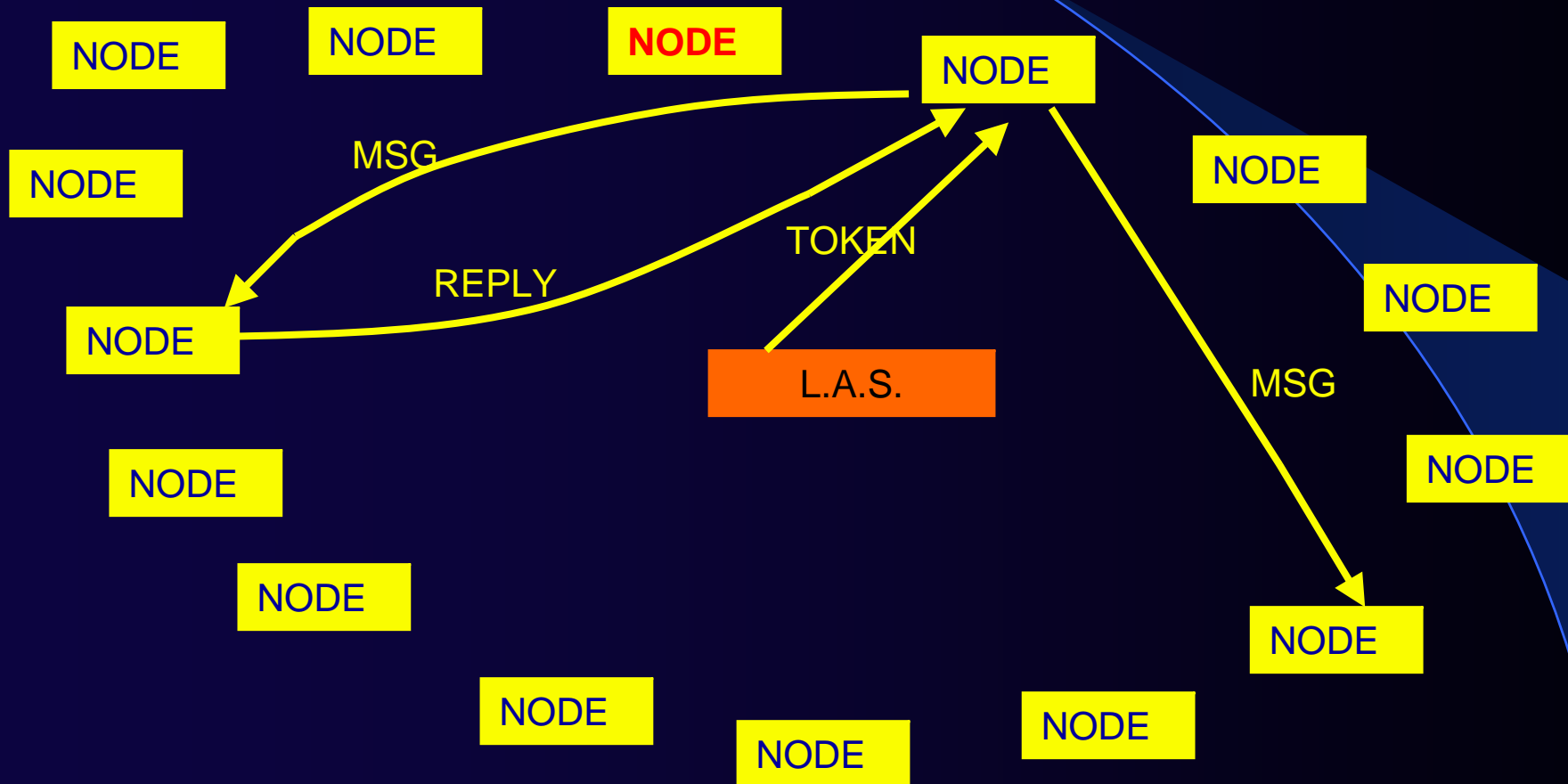
token



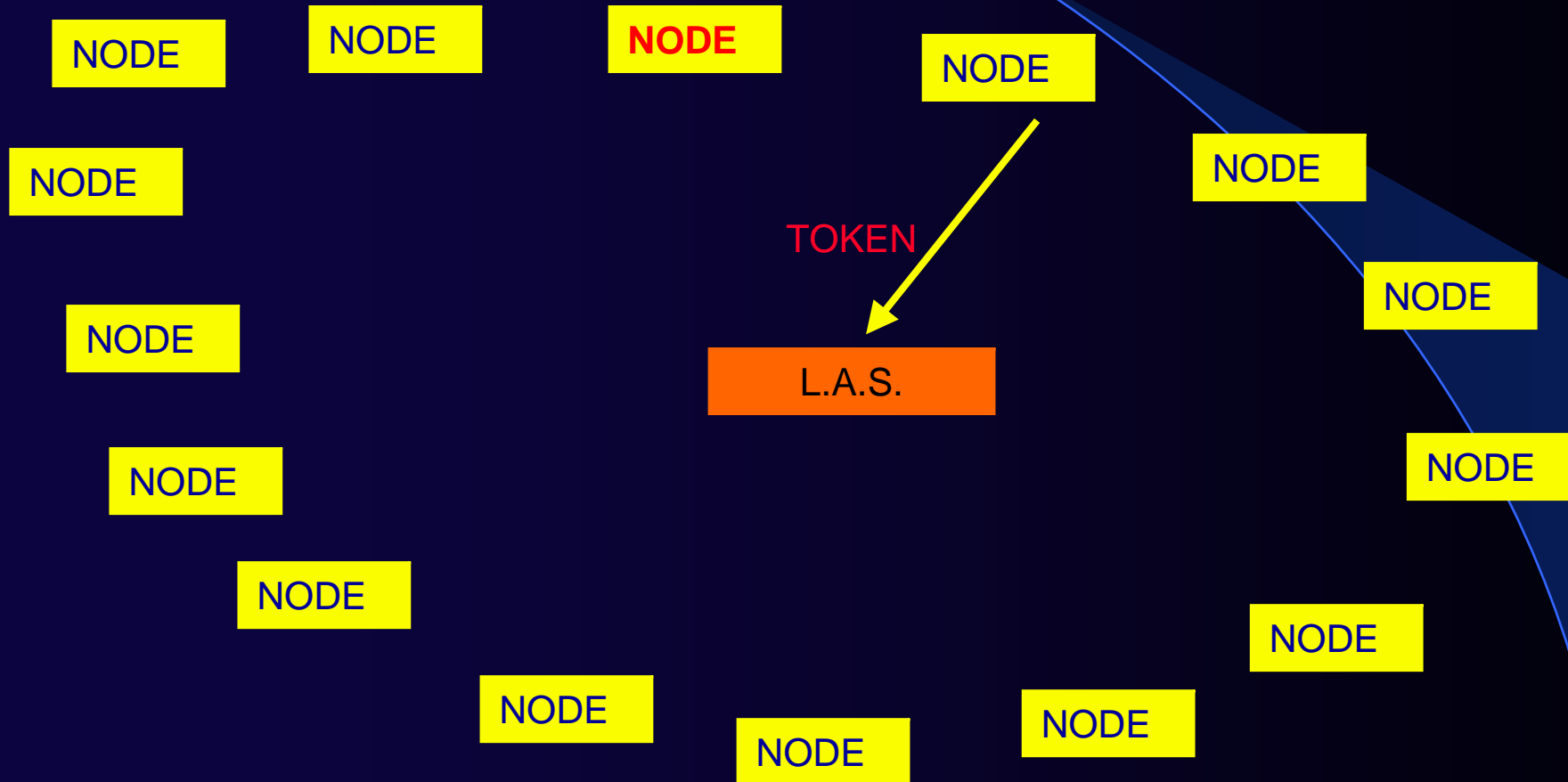
L.A.S.



L.A.S.



L.A.S.



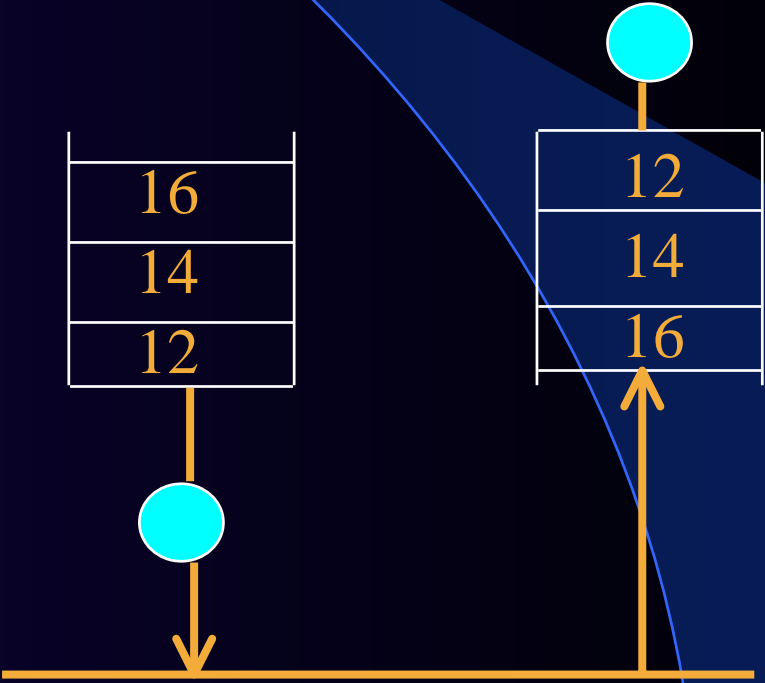
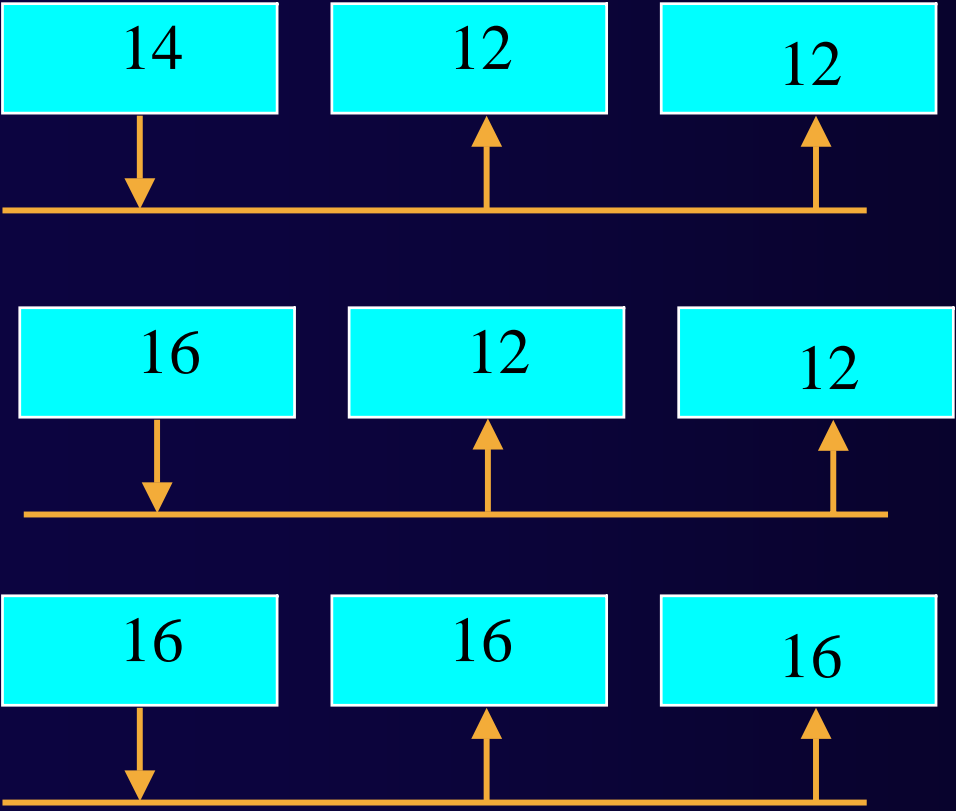
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quality of service

- QoS transport
 - reliability of transmission
 - storing methods
 - queues
 - buffers (retentive or not)
 - connections
 - with or without
 - peer to peer, multipeer
- QoS timeliness
 - time stamping
 - timeliness attributes
 - residence time
 - update time
 - synchronous

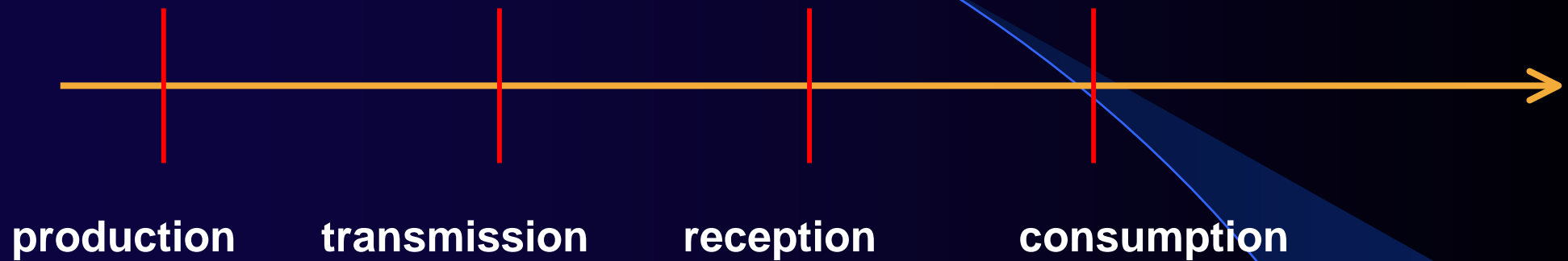
buffers and queues



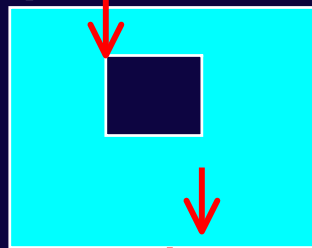
QoS in fieldbus - transport

- connections
 - four qualities related to frames ordering
 - classical (queues...)
 - disordered without loss
 - ordered (but with possible loss)
 - unordered (as received)

QoS in fieldbus - timeliness



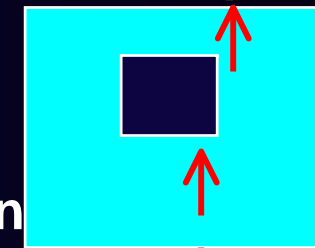
production



transmission

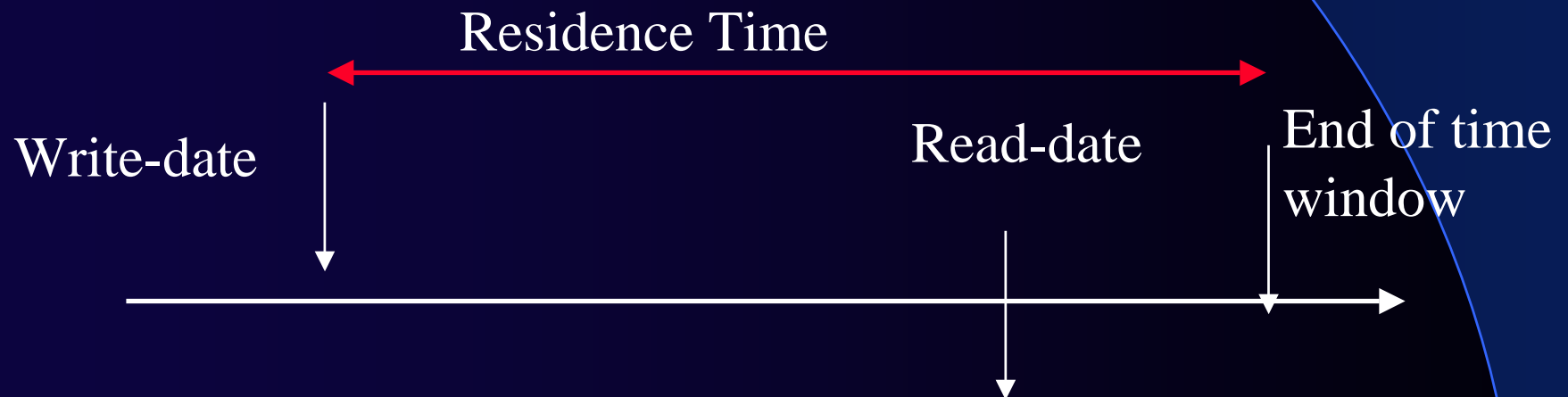
reception

consumption



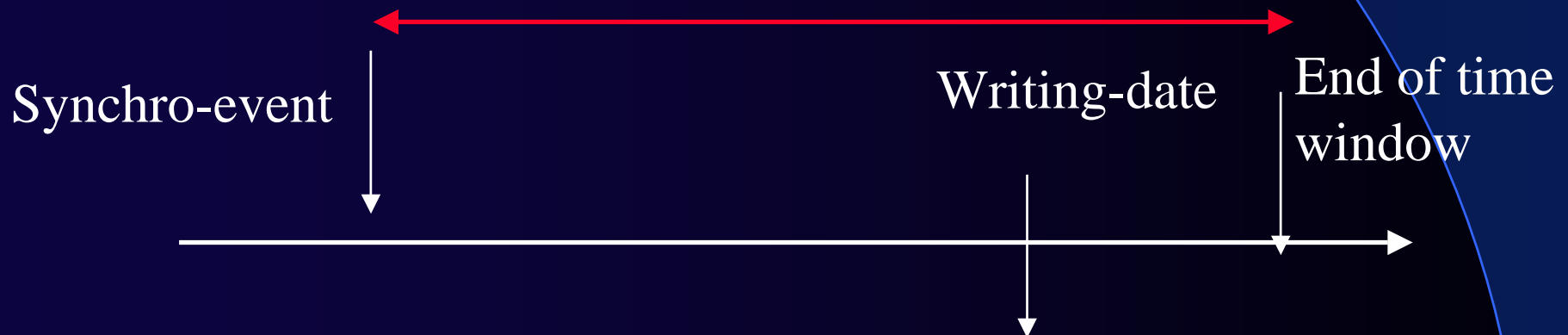
residence attribute

- assessment based upon the time that a data unit has been resident in a buffer.



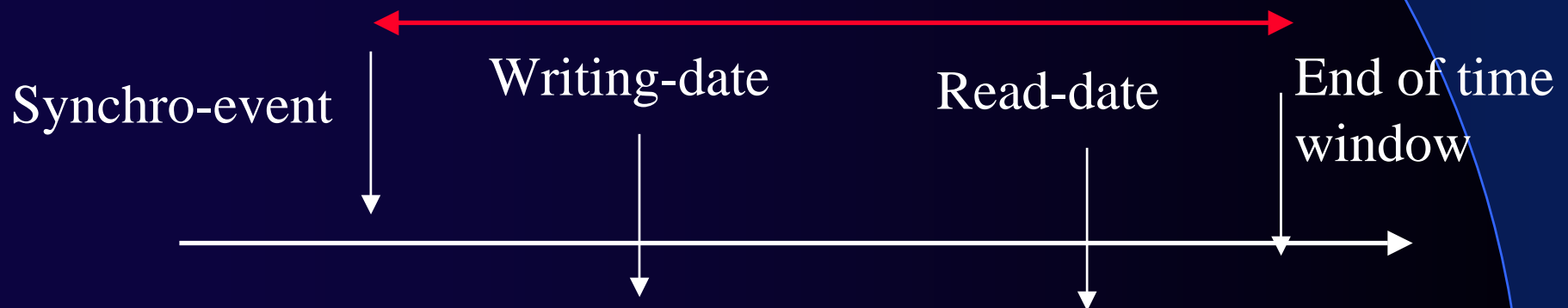
update attribute

- assessment based upon the time interval between a synchronising event and the moment the buffer is written
Update-Time



synchronous attribute

- assessment based upon the time intervals and timing relationships between
 - a synchronising event
 - the moment when the buffer is written
 - the moment the buffer is read



time coherence

- time coherence of actions, of events
- simultaneity of events
- occurrences in a given time window
- time coherence of
 - productions
 - consumptions
 - other actions

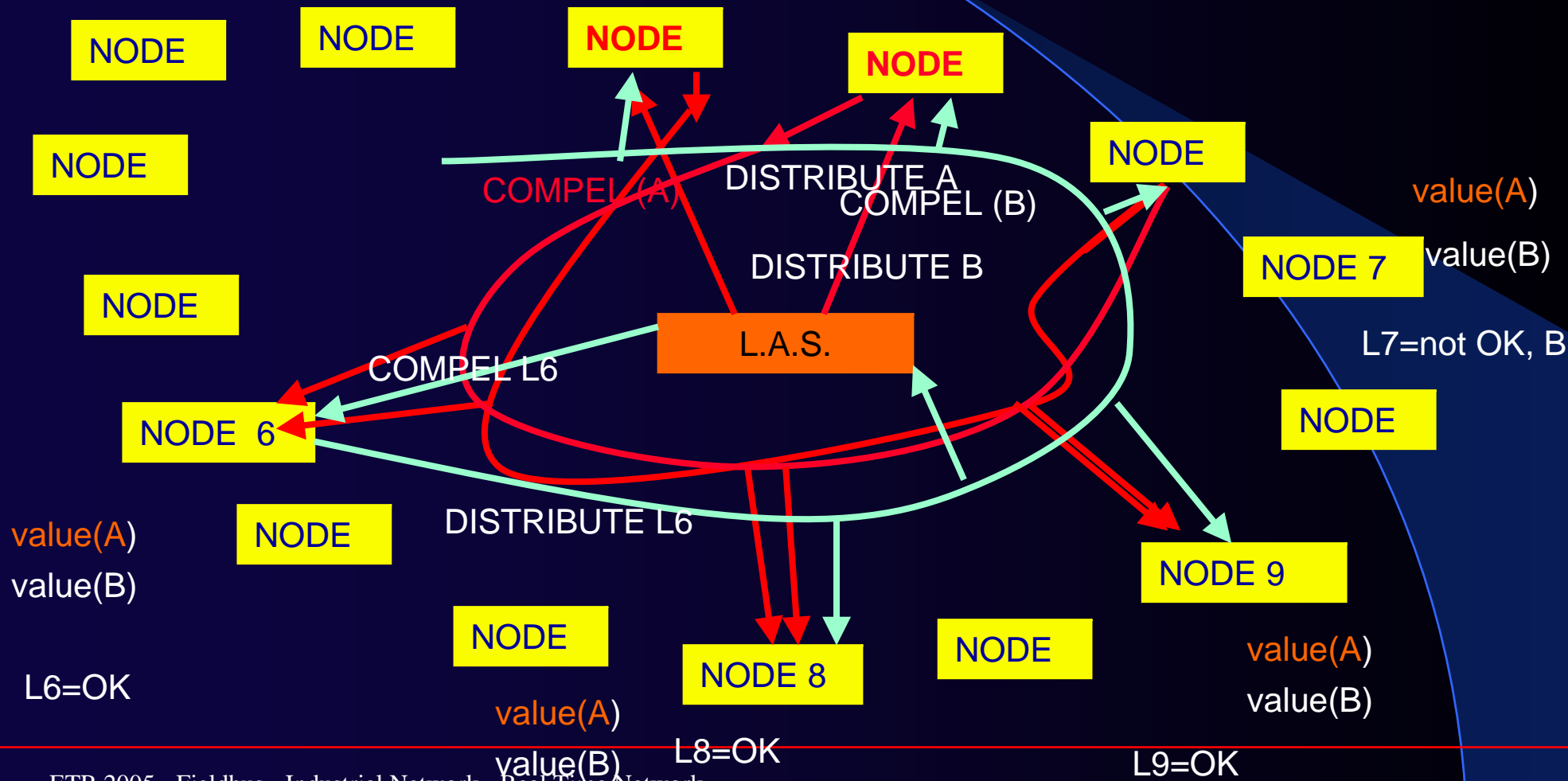
time coherence

- control of time coherence
 - data received indication
 - allows, in multi peer connections, the synchronization of subscribers
- usable to control any actions simultaneity
- verification of time coherence
 - by timeliness attributes

space - time consistency

- “reliable broadcasting”
- management of lists of variables (copies)
 - produced by different publishers
 - consumed by several subscribers
- verification and correction to obtain identical lists by the subscribers
- kind of global acknowledgement for different transmitters
- hypothesis:
 - two remote copies are considered identical if they are received without error and correct timeliness attributes

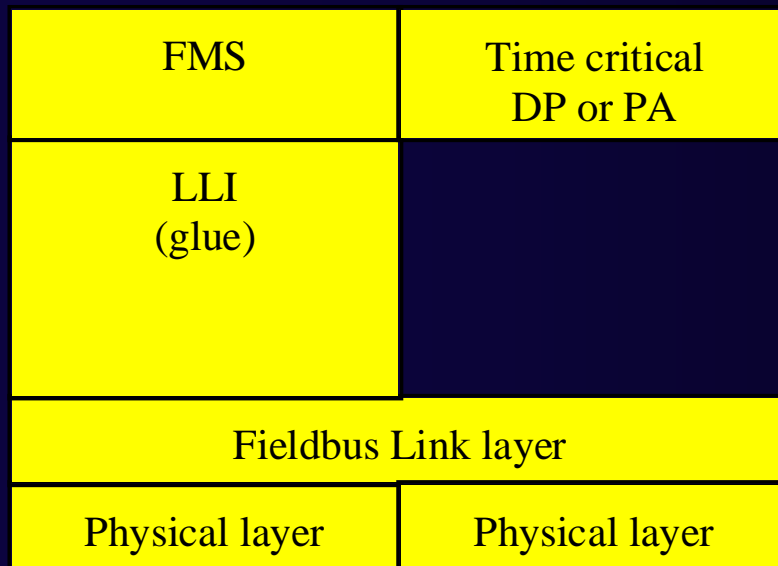
space - time consistency



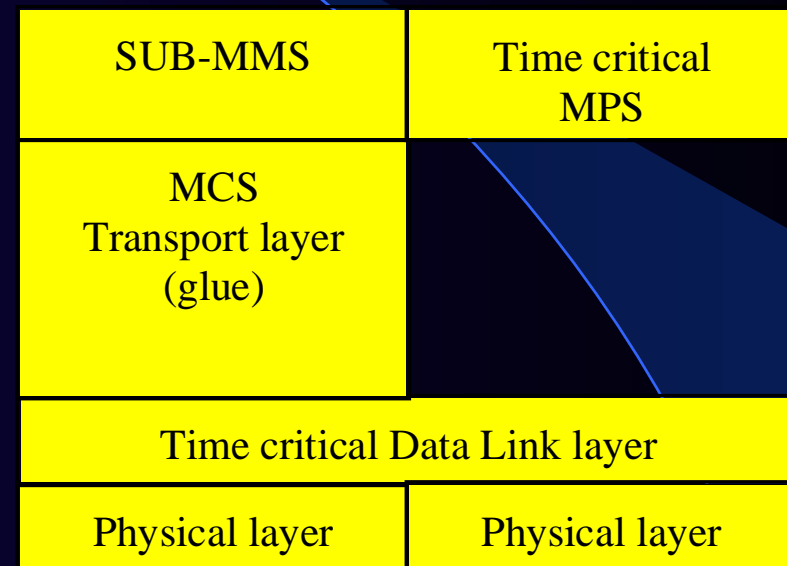
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two stacks architectures

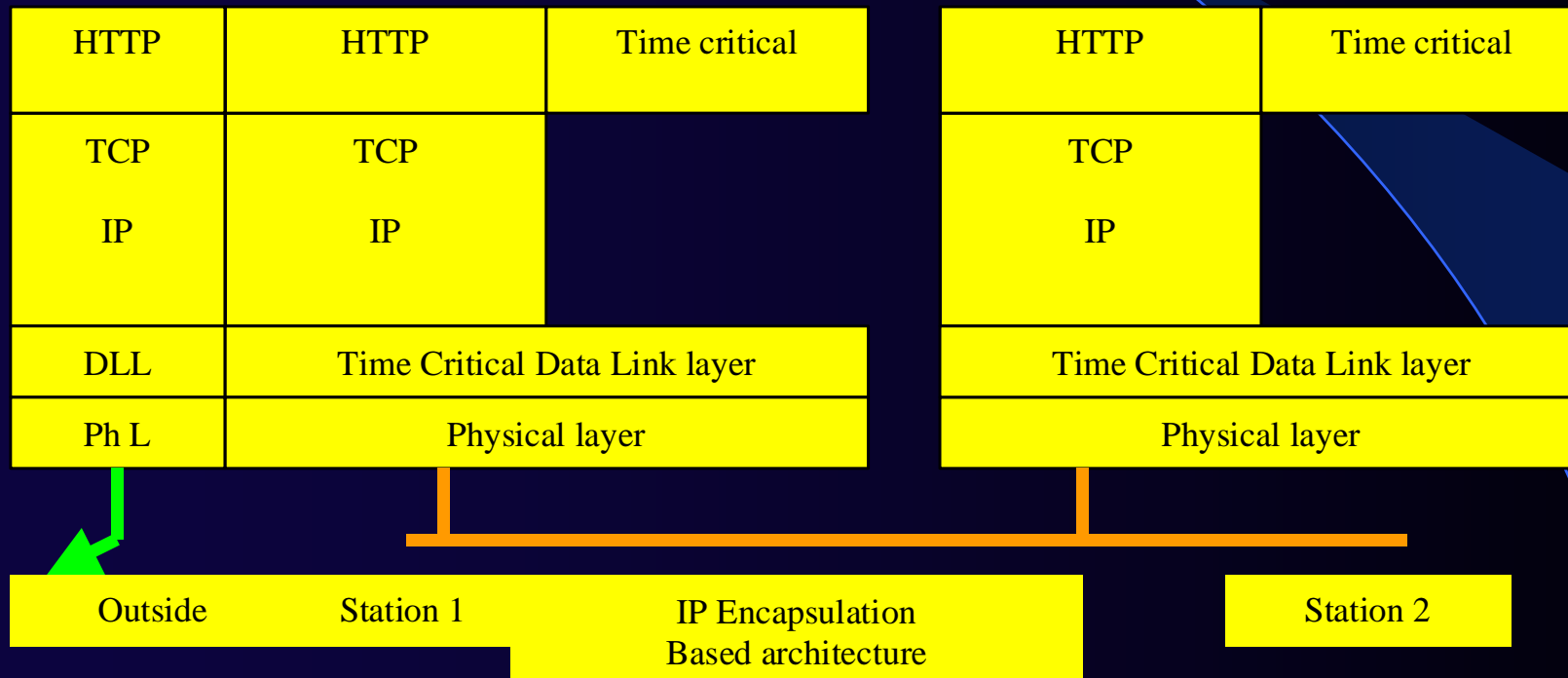


Profibus Architecture

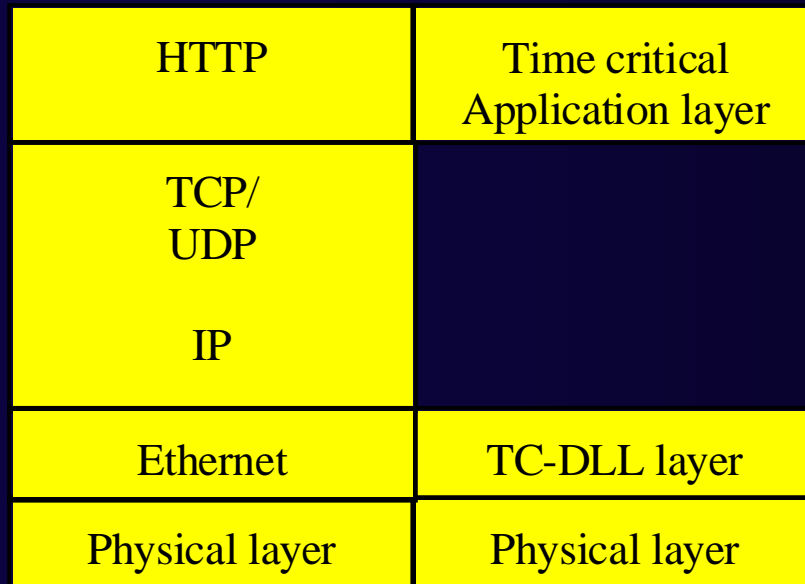


WorldFIP Architecture

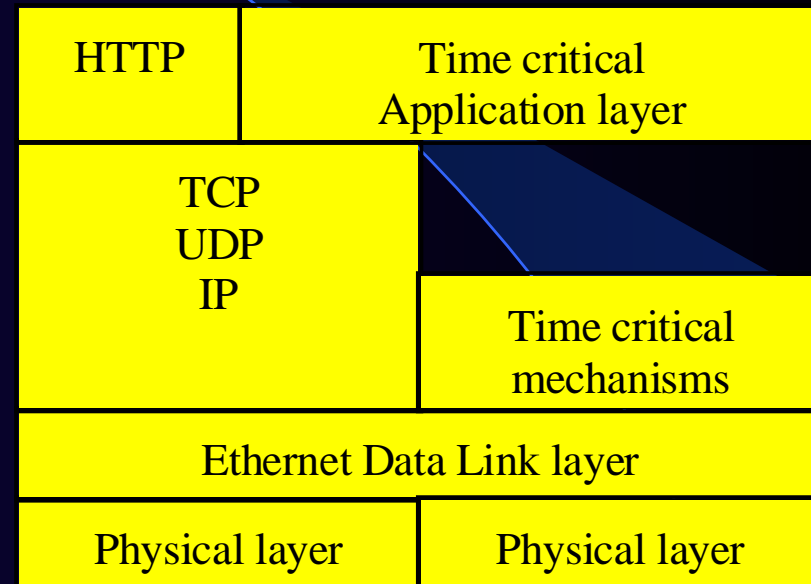
Internet and fieldbus



Ethernet based architectures

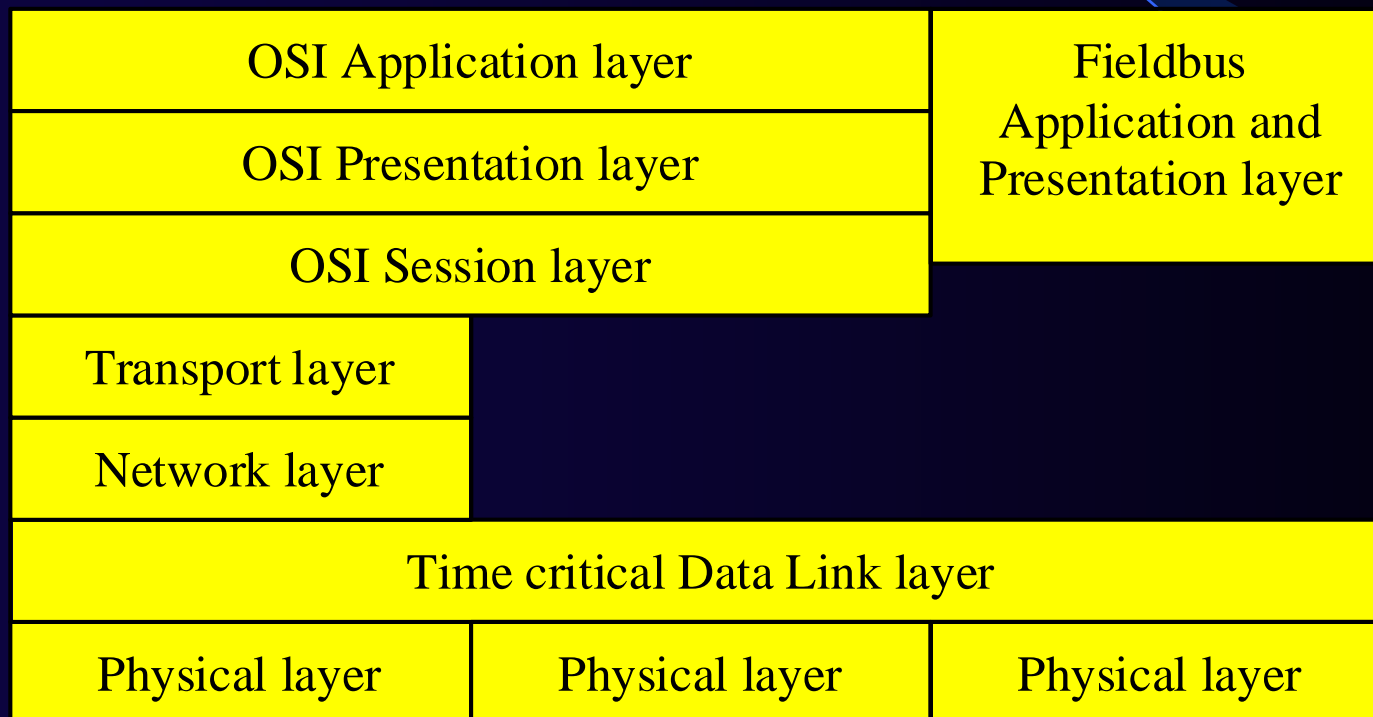


Ethernet A



Ethernet B

time critical architecture



conclusion - fieldbus technology?

- real time communication system and distributed data base
- new paradigms of cooperation between agents
- new views on quality of service
- impact on several computer science domains
 - protocol modeling and validation
 - performance evaluation
 - scheduling (joint scheduling of messages and tasks)
 - and now joint modeling of application and communication for proving distributed applications

fieldbus technology?

- future
 - which Ethernet ?
 - Internet and Web technologies
 - wireless
 - real intelligent devices and equipment
 - interoperability
- standards as in general purpose computing
 - one or two operating systems
 - a common communication architecture

reference:

Proceedings of IEEE, Vol 93, N°6, June 2005, pp 1073-1101

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