Fieldbus Technology in Industrial Automation

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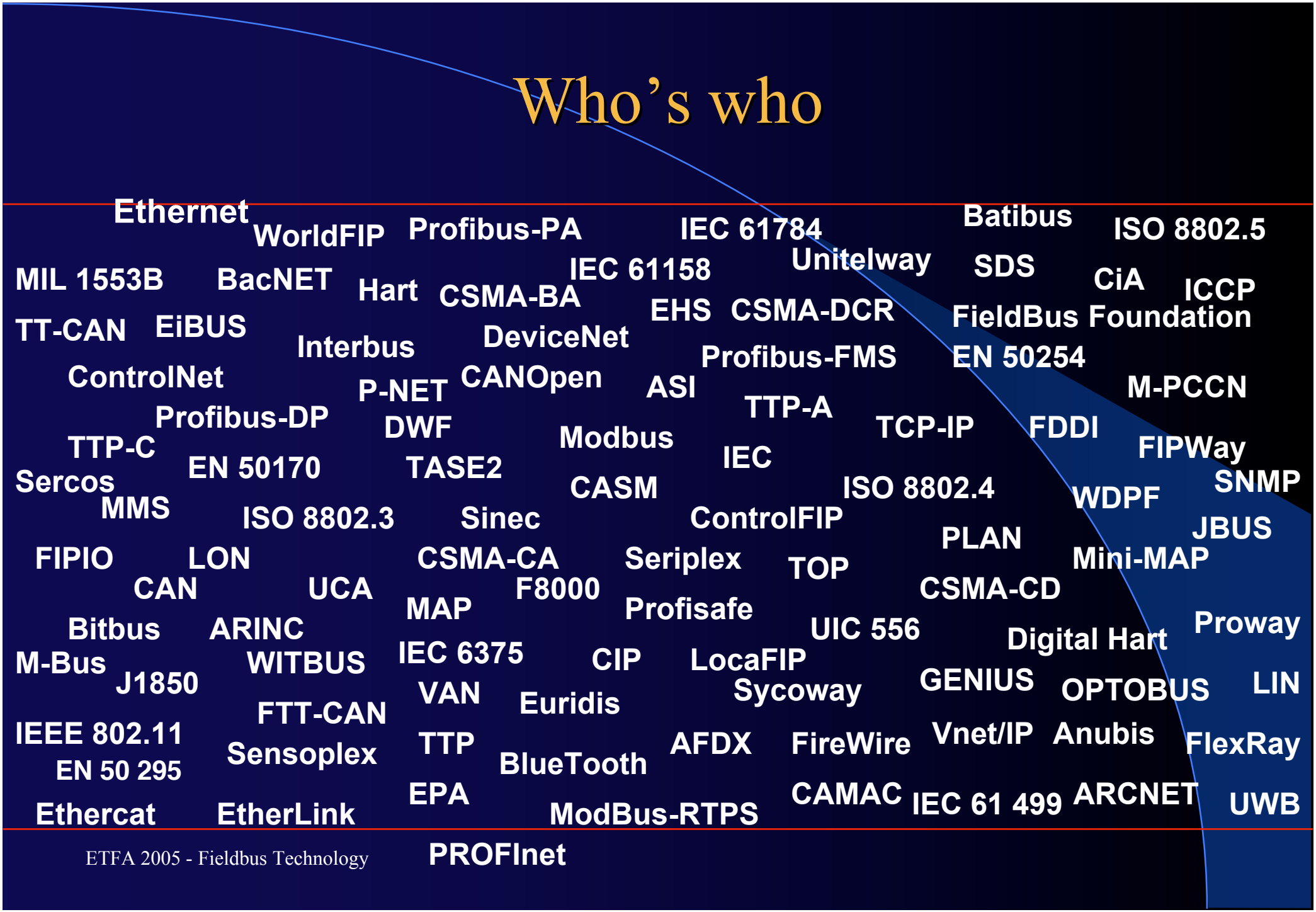
Who's who


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

content

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

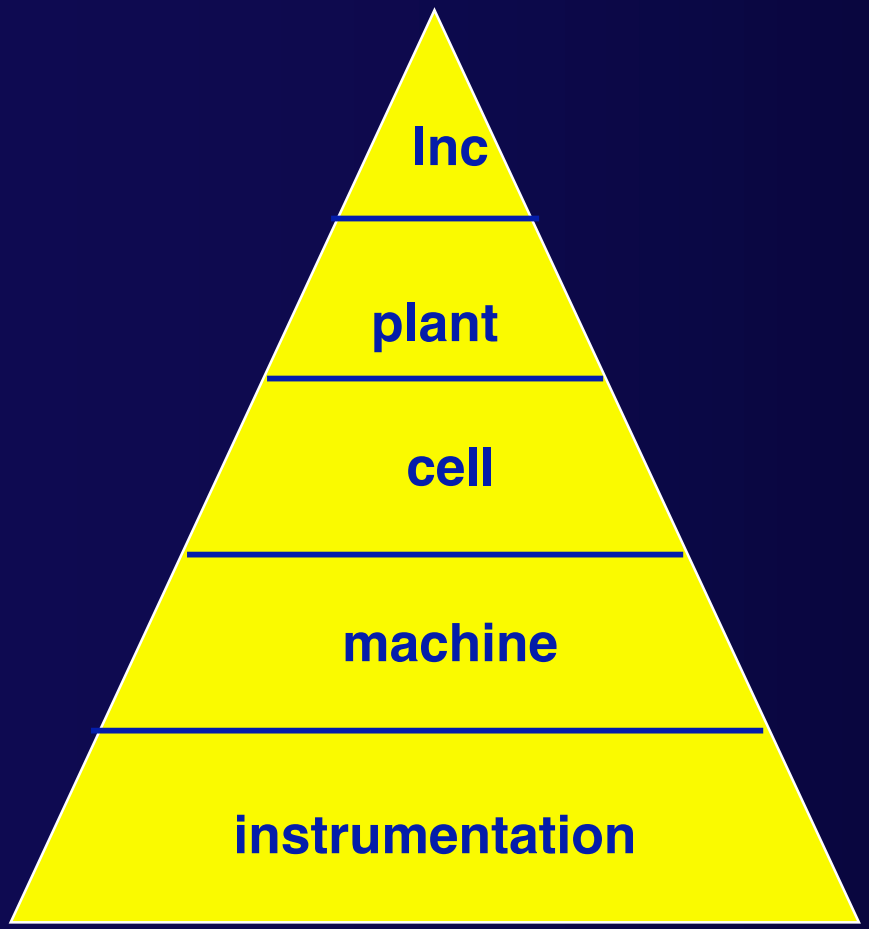
prehistory

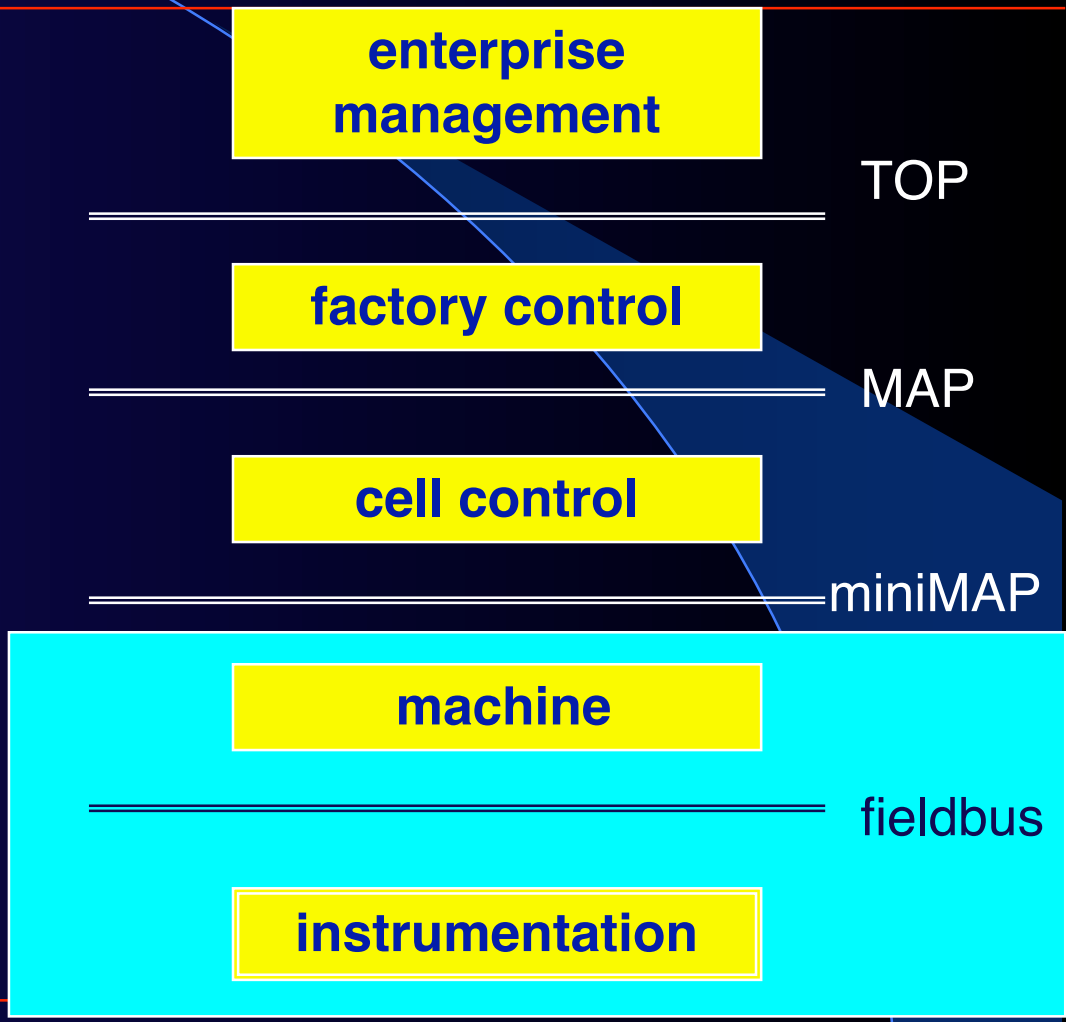
- need for networking
- 60s : CAMAC in nuclear experiments
- 70s :
  - MODBUS (PLC network)
  - WDPF (continuous process)
  - ARCNET (office communication and data acquisition)
  - Mil Std 1553B
- Data HighWay (Allen Bradley), TiWay (Texas Instr)…
- needs for reducing costs, then for standards

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



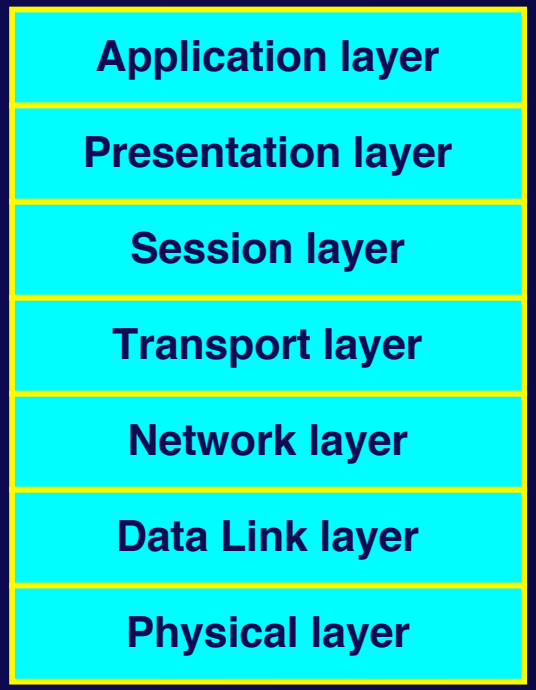


enabling technologies

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

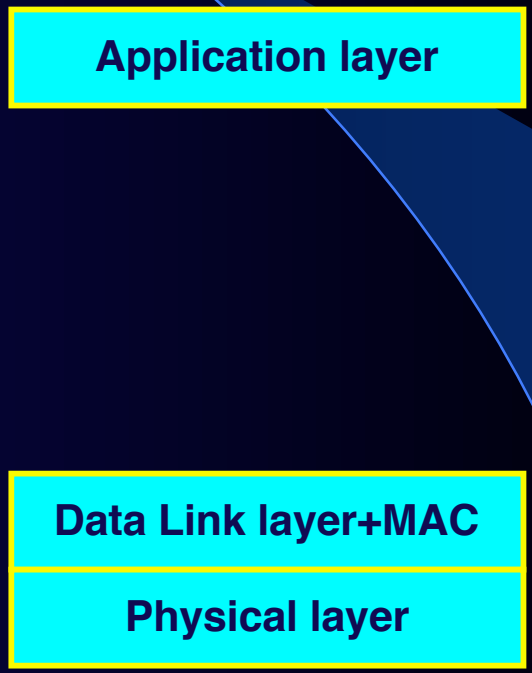
enabling technologies

OSI reference model



conceptual model

“reduced models”



implementation model

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

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  - architectures

first development

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

“Digital Data Communication for Measurement and Control - Fieldbus for Use in Industrial Control Systems“
part 2 PL, part 3,4 DLL, part 5,6 AL

- call for proposals------> answers

IEC std contenders

- 1st group
- existing systems
  - Mil Std 1553B
  - IEEE P1118 (Bitbus)
  - Foxboro
  - Rosemount
  - …
- 2nd group
- paper proposals
  - FIP
  - PROFIBUS

survey 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

no intelligence in devices is explicitly identified

requirements - application

- definition of traffic
  - process (real time traffic)
    - measurement
    - alarm setting
    - status
  - installation (non real time traffic)
    - tag number
    - manufacturer's data
    - additional information for maintenance

identified data or messages

identified data or messages

requirements - application

- definition of other services
  - control the access - security
- types of data
- polled and unsolicited messages
- full logical connectivity
- application 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

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
  - and later development of smart devices
- real time communication system
  - common services
  - various protocols and then various qualities of service
  - depending on architectural approaches
  - depending on different domains of application

fieldbus

- backbone of distributed and real time systems

fieldbus

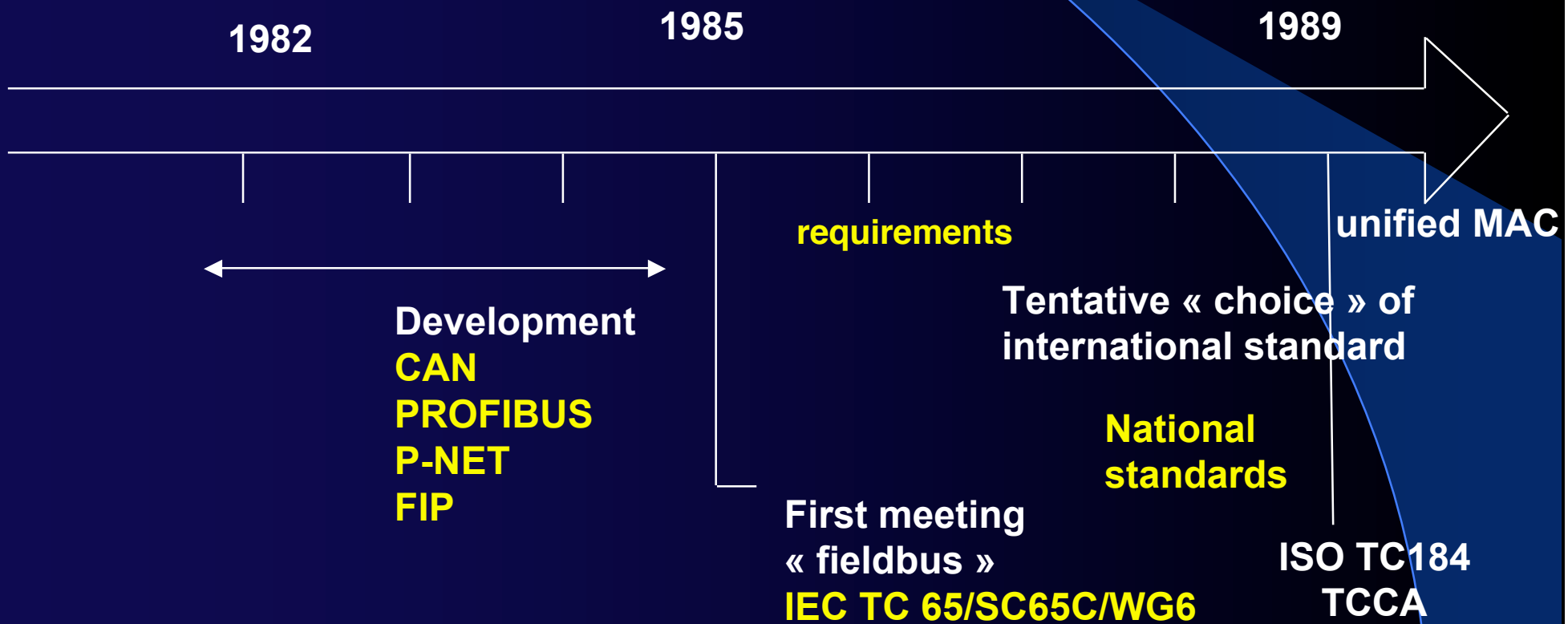
- backbone of distributed and real time systems

but also

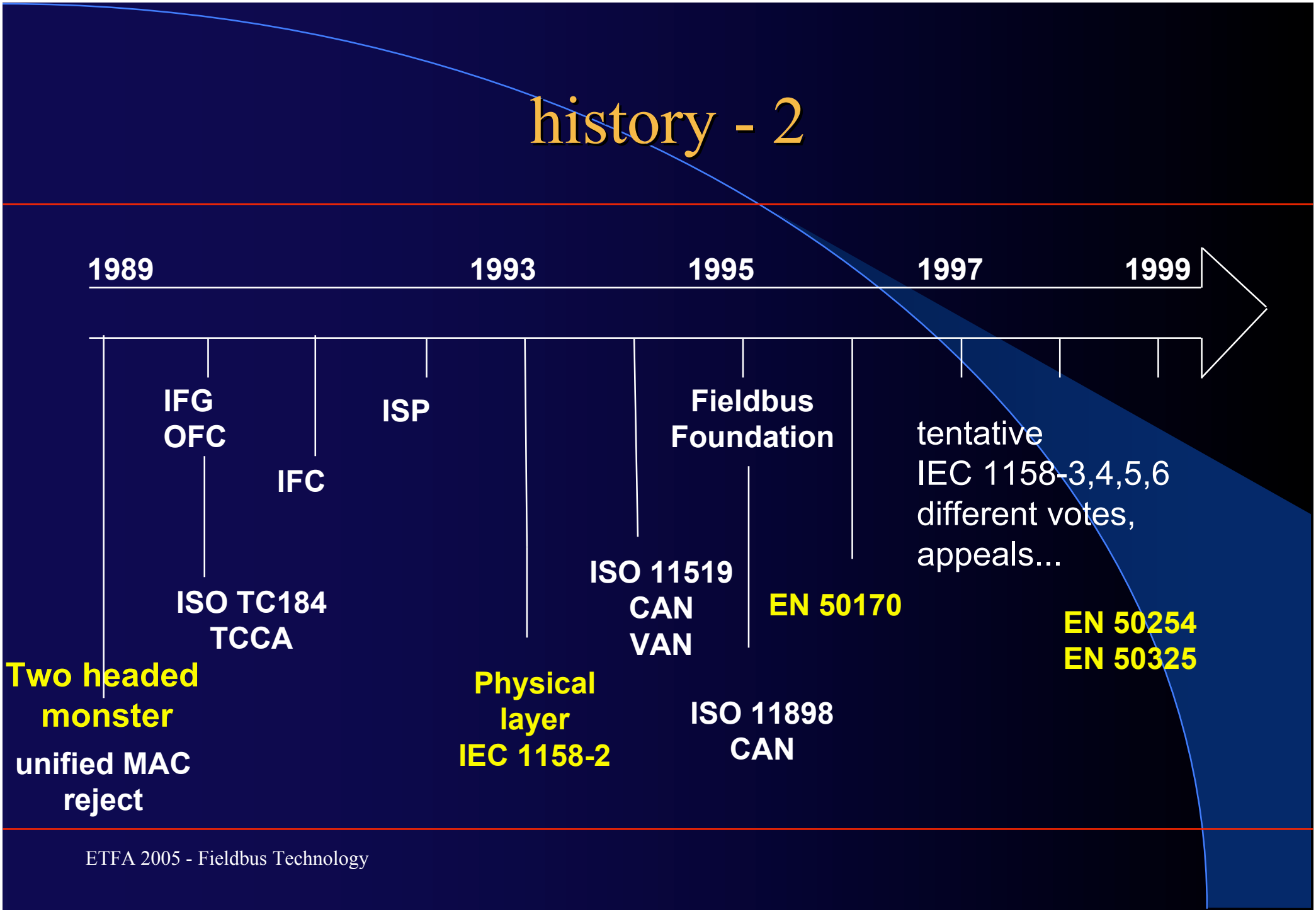
- bone of contention between automation companies

beginning of the fieldbus saga

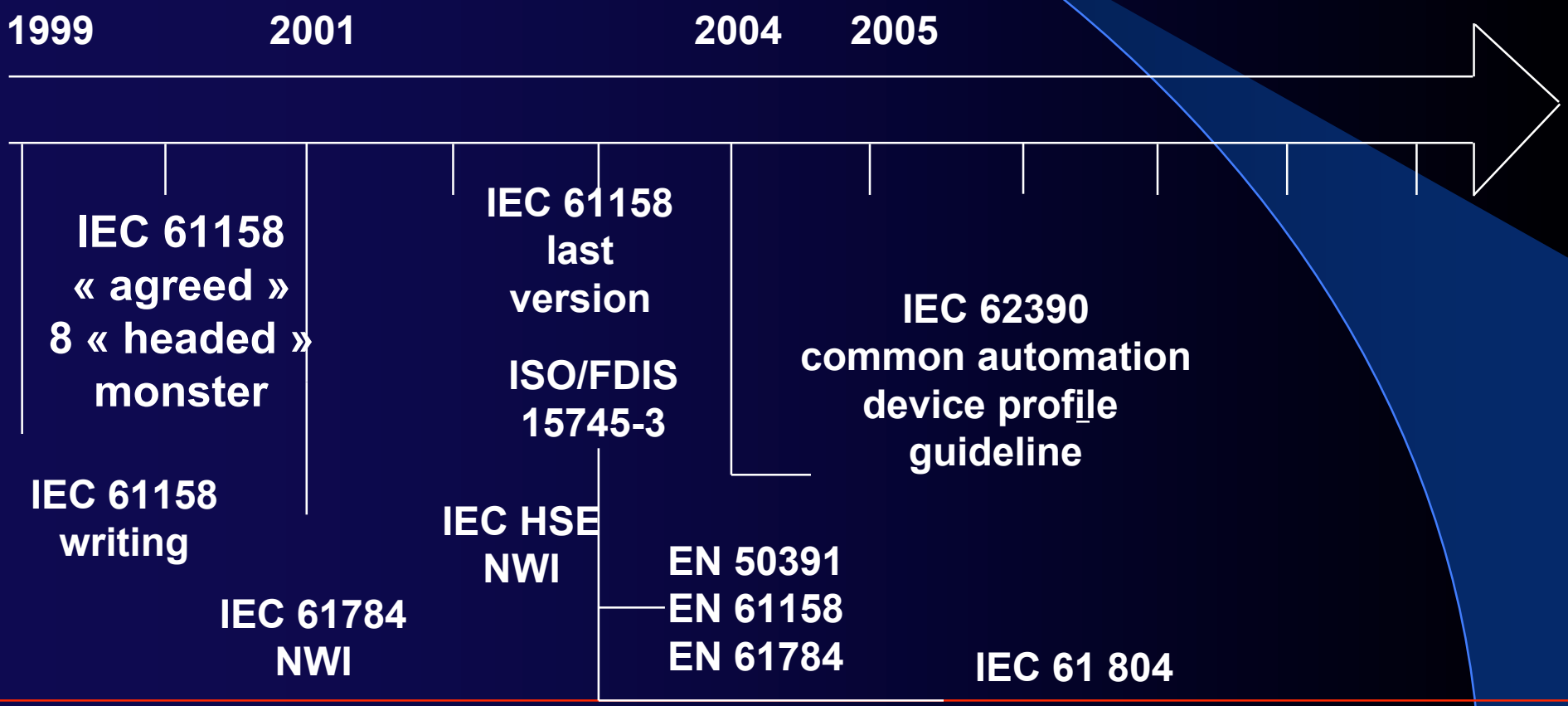
history - 1


1982
1985
1989
requirements
unified MAC
Development
CAN
PROFIBUS
P-NET
FIP
Tentative « choice » of
international standard
National
standards
First meeting
« fieldbus »
IEC TC 65/SC65C/WG6
ISO TC184
TCCA

history - 2


1989
1993
1995
1997
1999
IFG
OFC
IFC
ISP
Fieldbus
Foundation
tentative
IEC 1158-3,4,5,6
different votes,
appeals...
ISO TC184
TCCA
ISO 11519
CAN
VAN
EN 50170
EN 50254
EN 50325
Two headed
monster
unified MAC
reject
Physical
layer
IEC 1158-2
ISO 11898
CAN

history - 3


1999
2001
2004
2005
IEC 61158
« agreed »
8 « headed »
monster
IEC 61158
writing
IEC 61784
NWI
IEC 61158
last
version
ISO/FDIS
15745-3
IEC HSE
NWI
EN 50391
EN 61158
EN 61784
IEC 62390
common automation
device profile
guideline
IEC 61 804

IEC 61158

- 8 types for data link layer
  - Type 1 :proposed 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

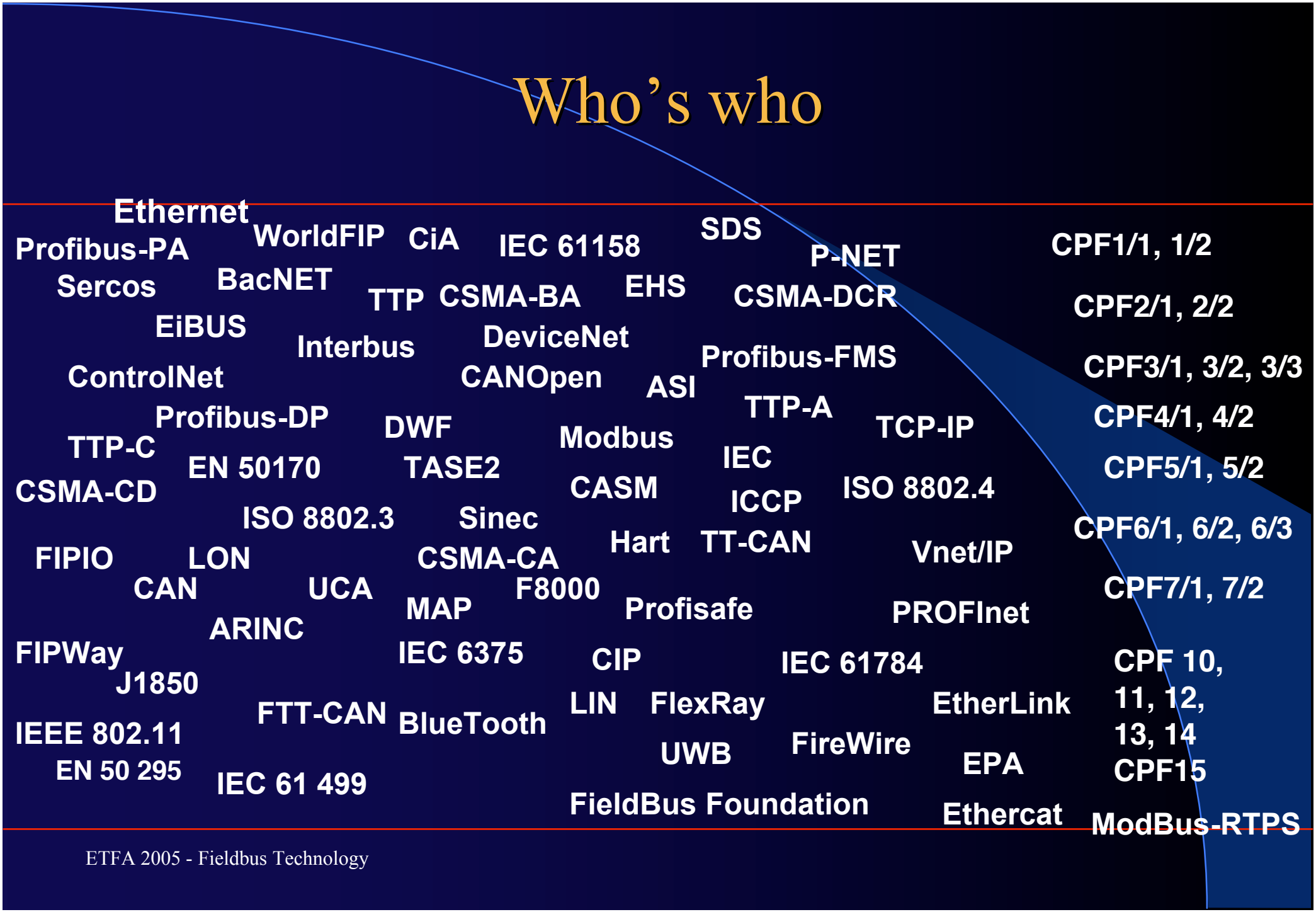
IEC 61158

- 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
  - 16 profiles
- IEC 61 784 -2 under specification (based on Ethernet)
  - CPF 10: VNET/IP,
  - CPF 11: TCNet,
  - CPF 12: EtherCAT,
  - CPF 13: EtherNet PowerLink,
  - CPF 14: EPA : Ethernet for Plant Automation
  - CPF 15: ModBus RTPS : Real Time Publish - Subscribe

Who's who


Ethernet
Profibus-PA
WorldFIP
CiA
IEC 61158
SDS
P-NET
CPF1/1, 1/2
Sercos
BacNET
TTP
CSMA-BA
EHS
CSMA-DCR
CPF2/1, 2/2
EiBUS
Interbus
DeviceNet
Profibus-FMS
CPF3/1, 3/2, 3/3
ControlNet
CANOpen
ASI
TTP-A
Profibus-DP
DWF
TCP-IP
CPF4/1, 4/2
TTP-C
Modbus
IEC
EN 50170
TASE2
CPF5/1, 5/2
CSMA-CD
CASM
ICCP
ISO 8802.4
ISO 8802.3
Sinec
CPF6/1, 6/2, 6/3
FIPIO
LON
Hart
TT-CAN
Vnet/IP
CSMA-CA
CAN
UCA
F8000
CPF7/1, 7/2
MAP
Profisafe
PROFInet
ARINC
FIPWay
IEC 6375
CIP
IEC 61784
CPF 10,
11, 12,
13, 14
J1850
LIN
FlexRay
EtherLink
FTT-CAN
IEEE 802.11
BlueTooth
UWB
FireWire
EPA
CPF15
EN 50 295
IEC 61 499
FieldBus Foundation
Ethercat
ModBus-RTPS

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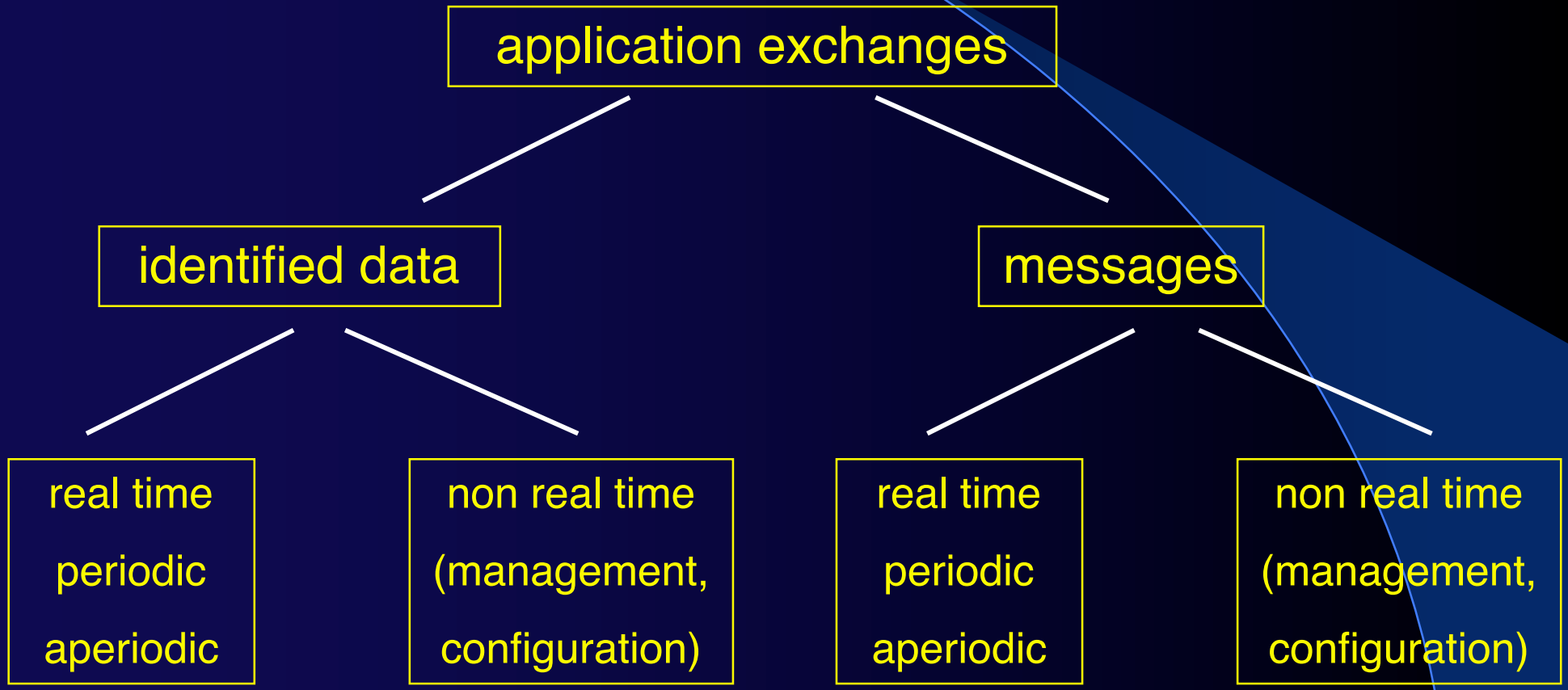
fieldbus traffic



from requirements to solutions

- applications exchanges
  - identified data vs. messages
  - full logical connectivity
  - polled vs. unsolicited
  - periodic vs. aperiodic
  - real time vs. non real time
  - performances
    - transport reliability
    - timeliness
    - coherences and consistencies

- protocol solutions
  - application relationships
  - Medium Access Control
  - quality of service
    - data link layer
    - Medium Access Control
    - time attributes
    - time stamping

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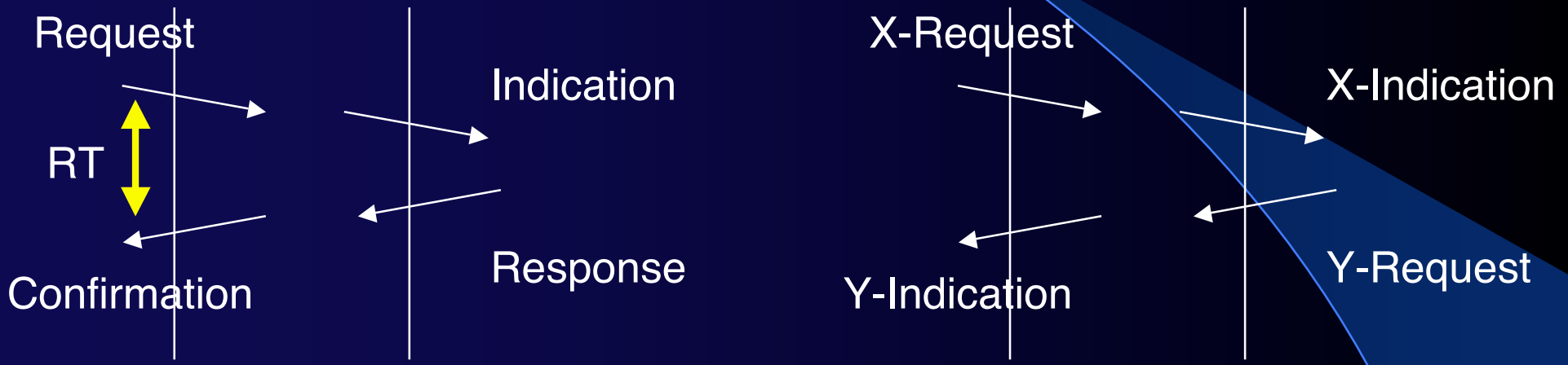
application layer

- two main classes of relationships
- client - server
  - for messages and identified data
  - and variants
- publisher - subscriber
  - for identified data
  - and variants

client-server

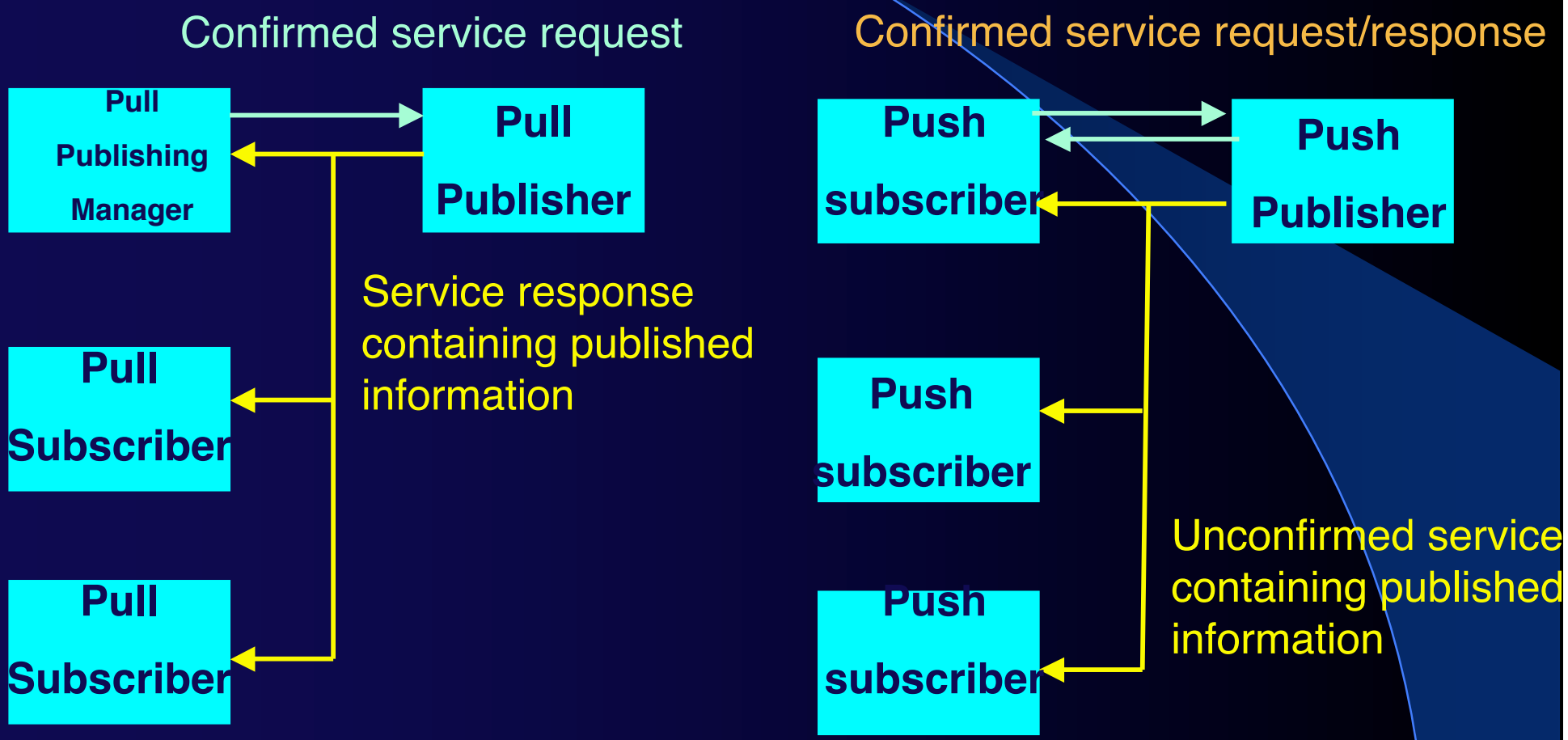


quality of service:

reliability : confirmed service

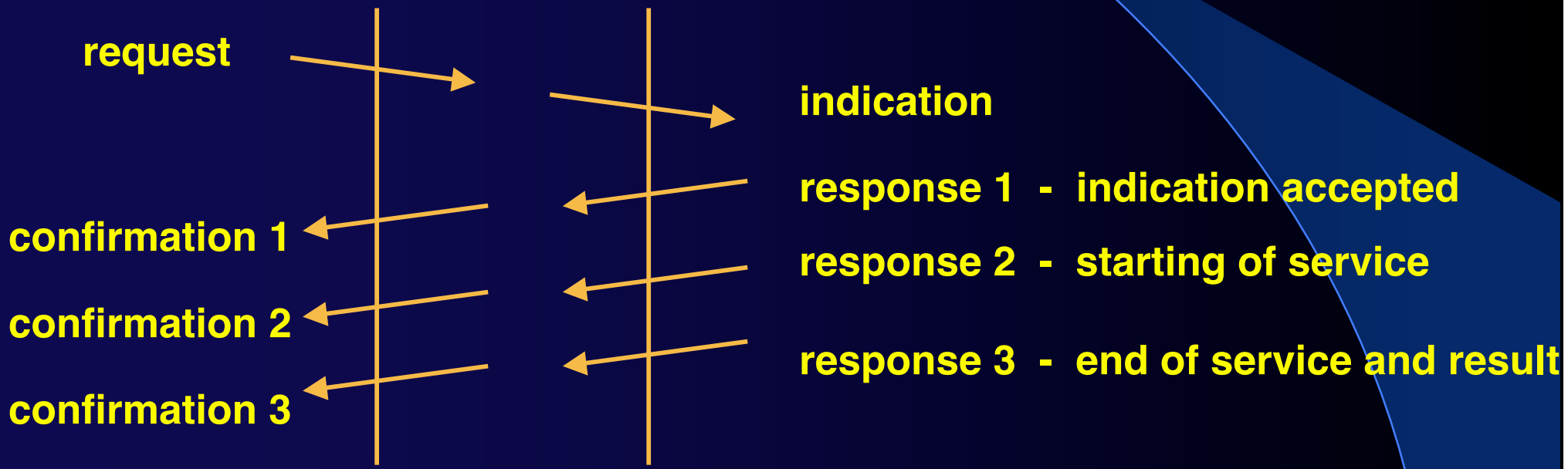
response time : transport delay + local server response time

publisher - subscriber models



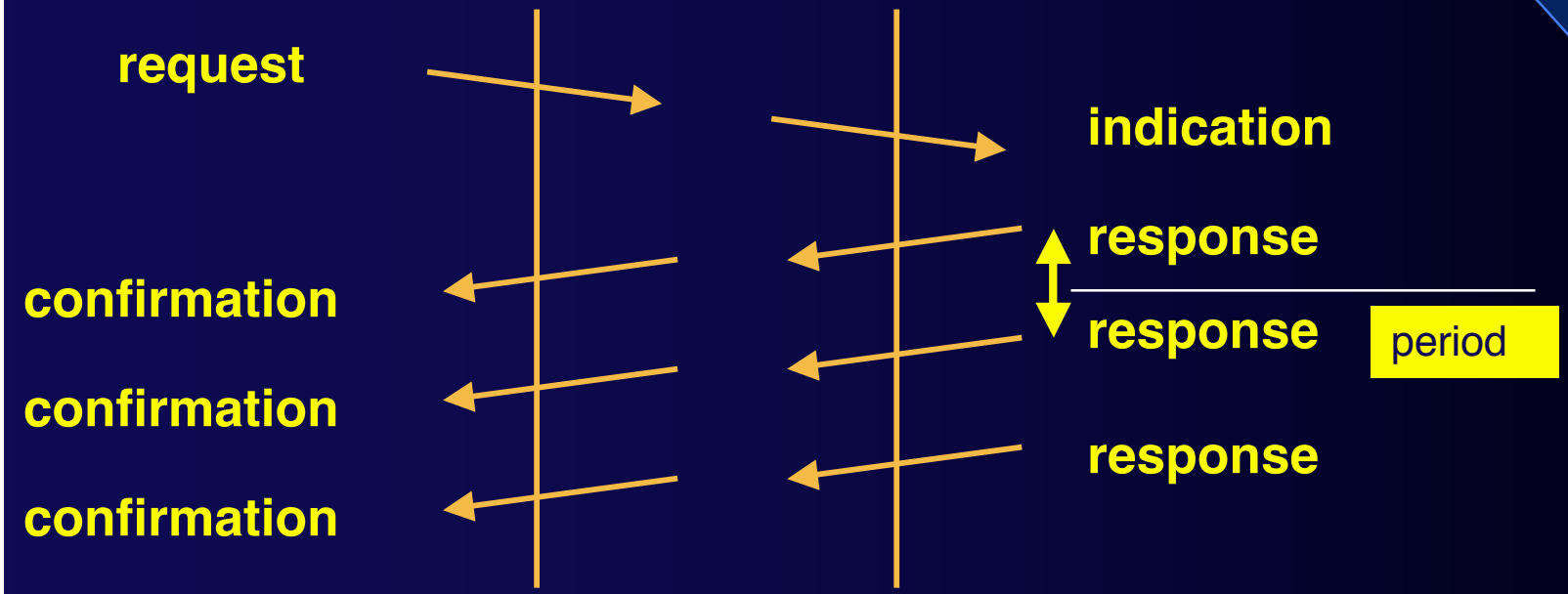
other models

multi confirmation client server



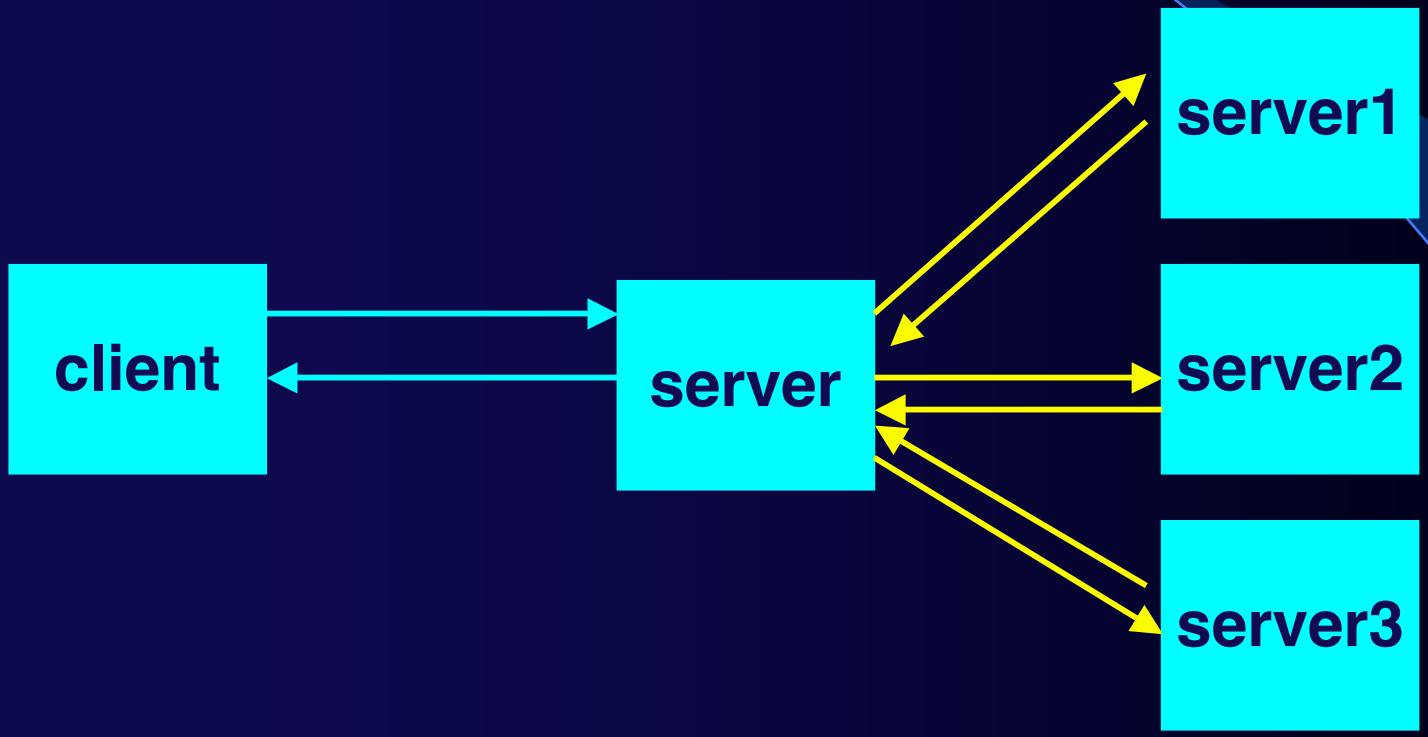
other models

multi responses client server - cf. Push Publisher



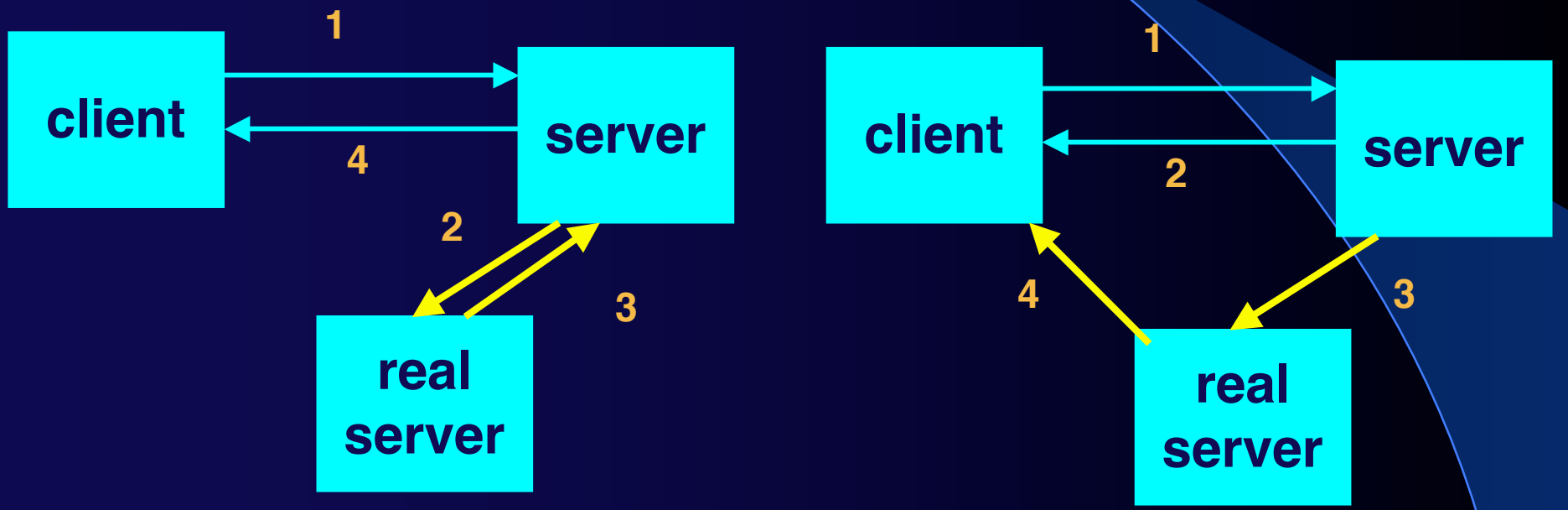
other models

client multi-server



other models

third part model



content

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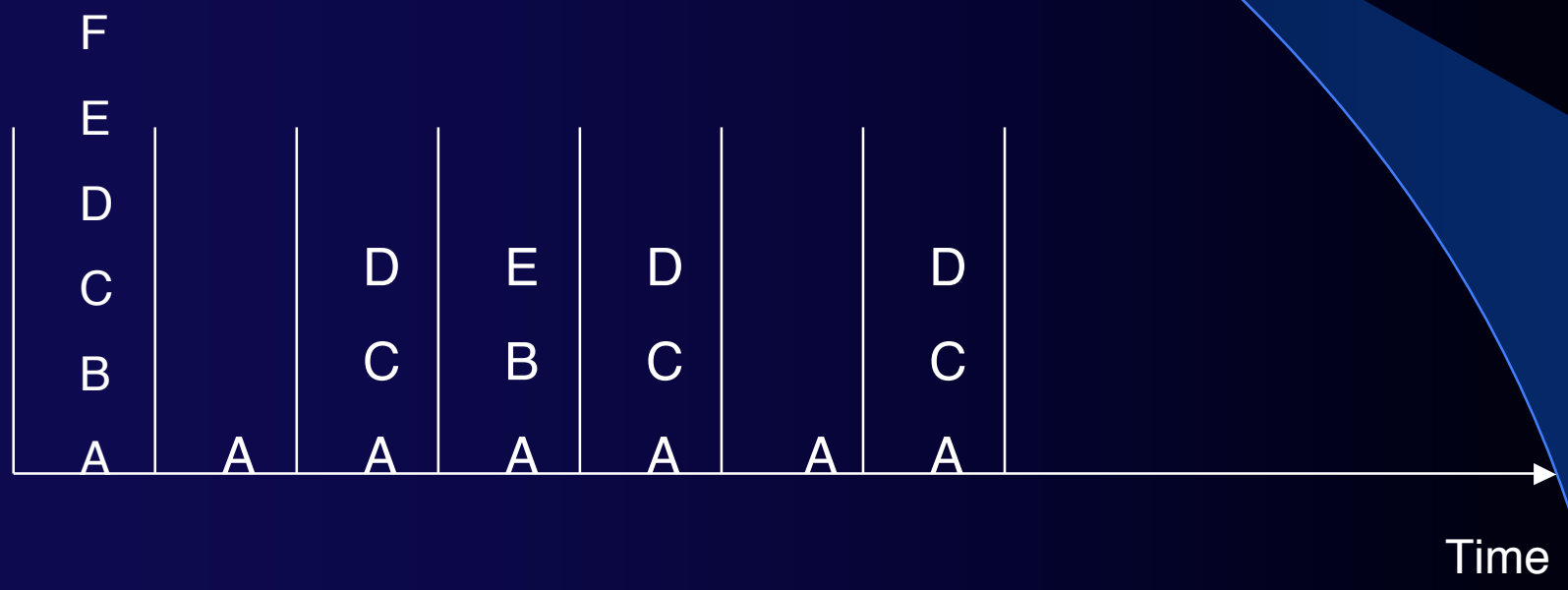
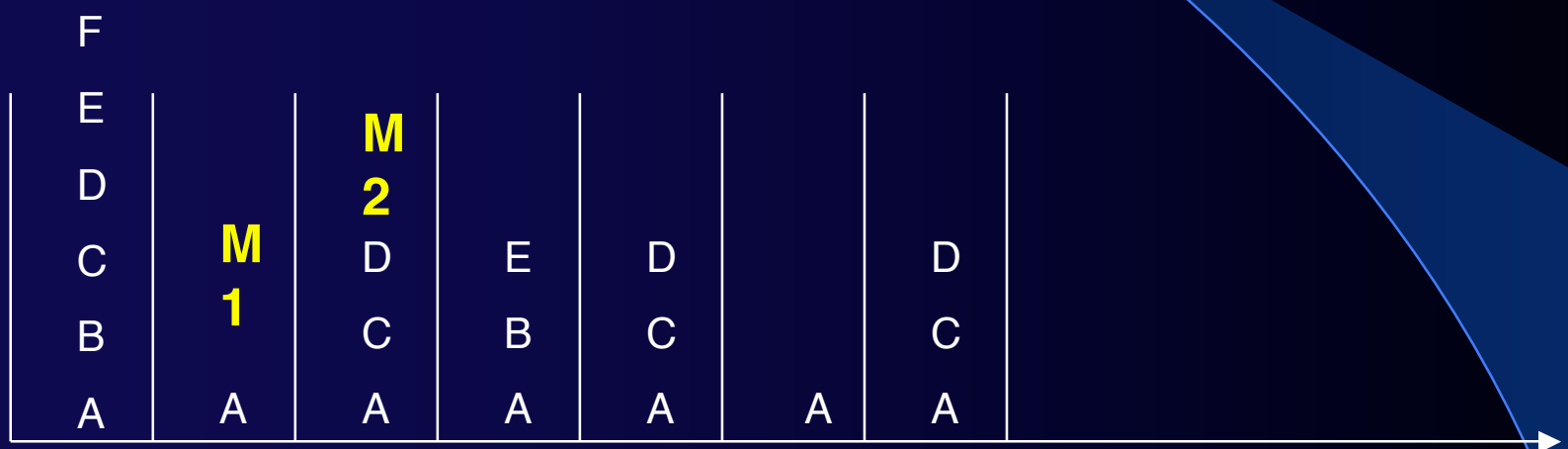
periodic traffic

periodic traffic of identified data, or of messages

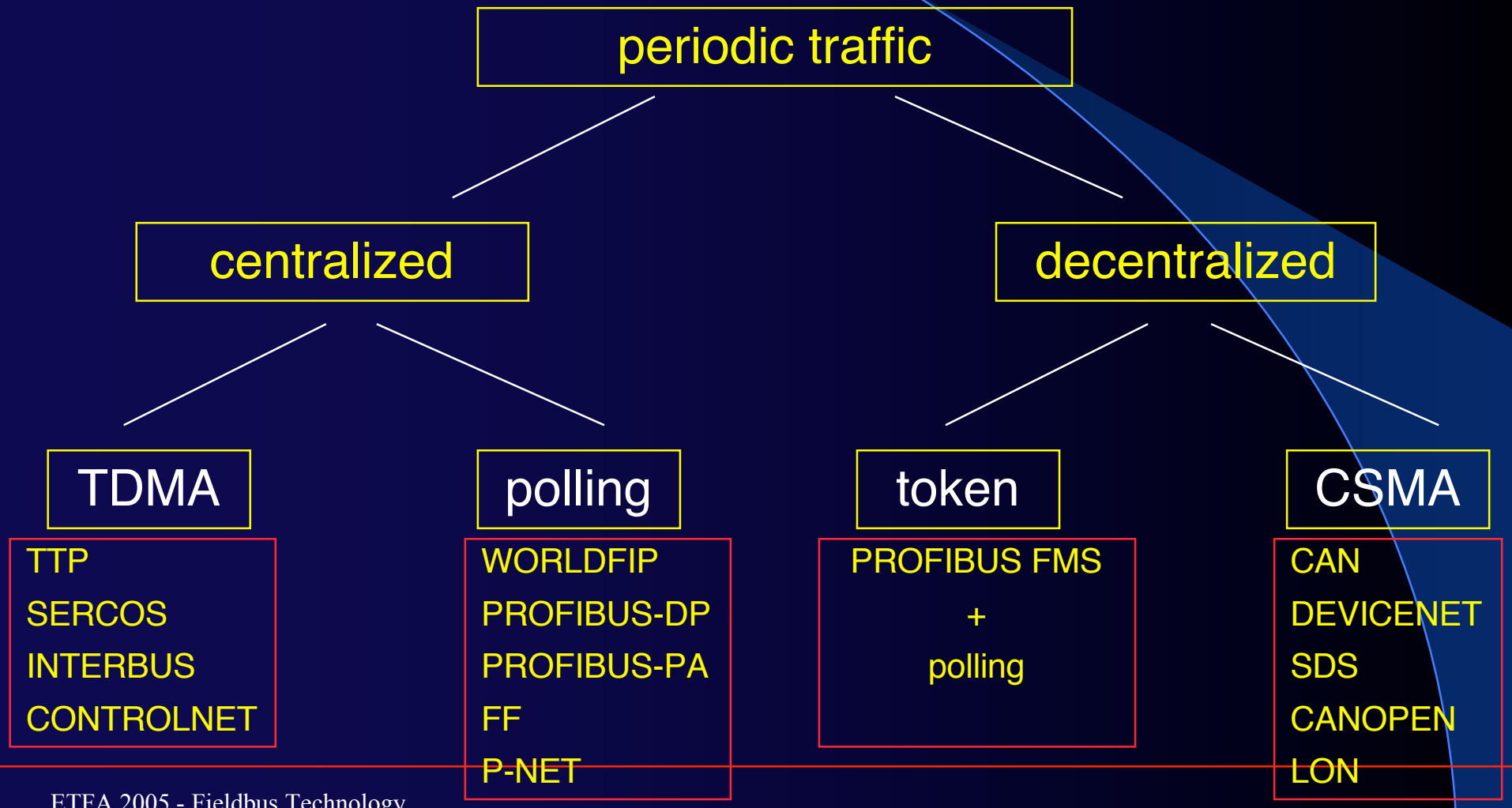


aperiodic traffic

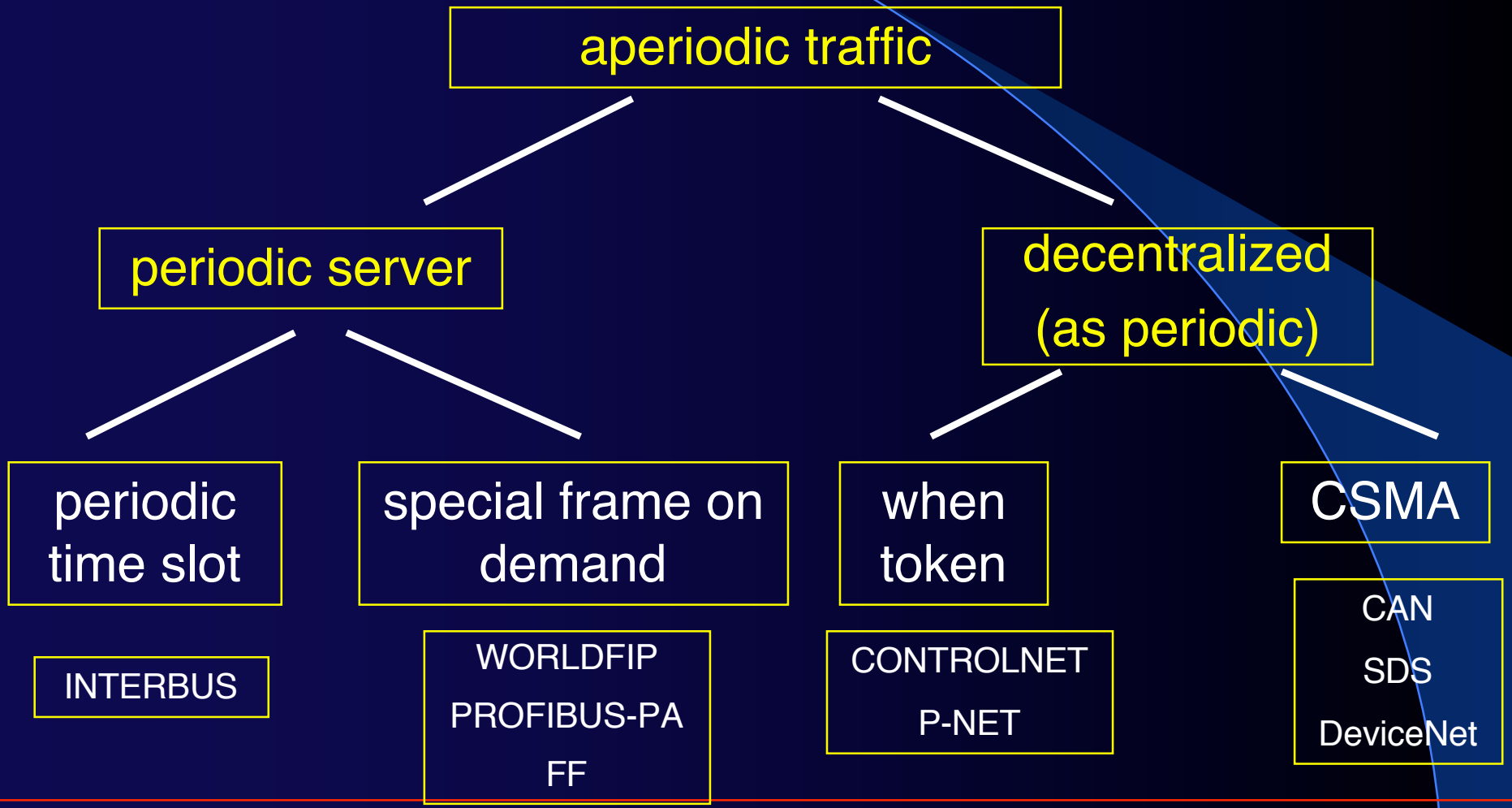
Aperiodic traffic



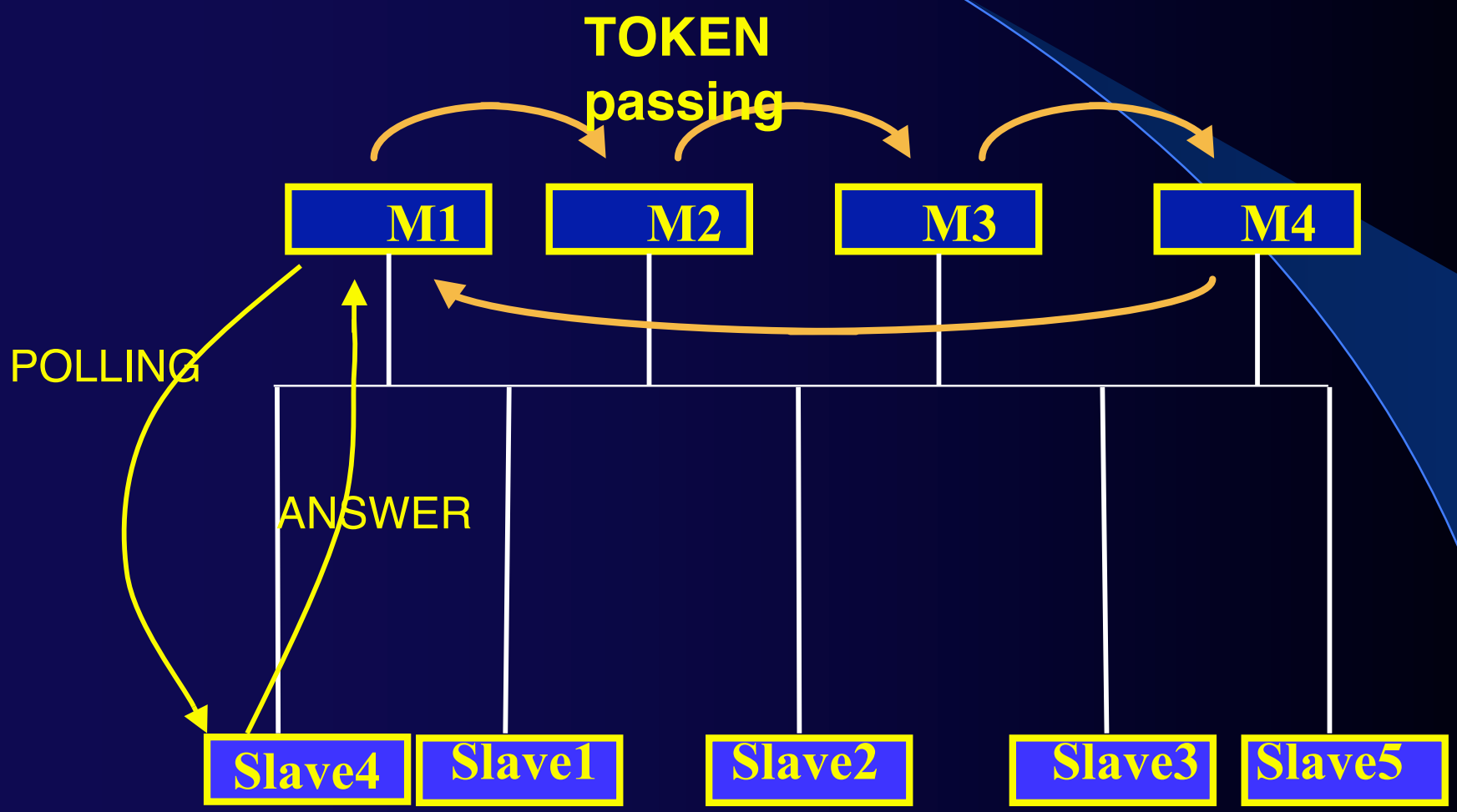
fieldbus traffic



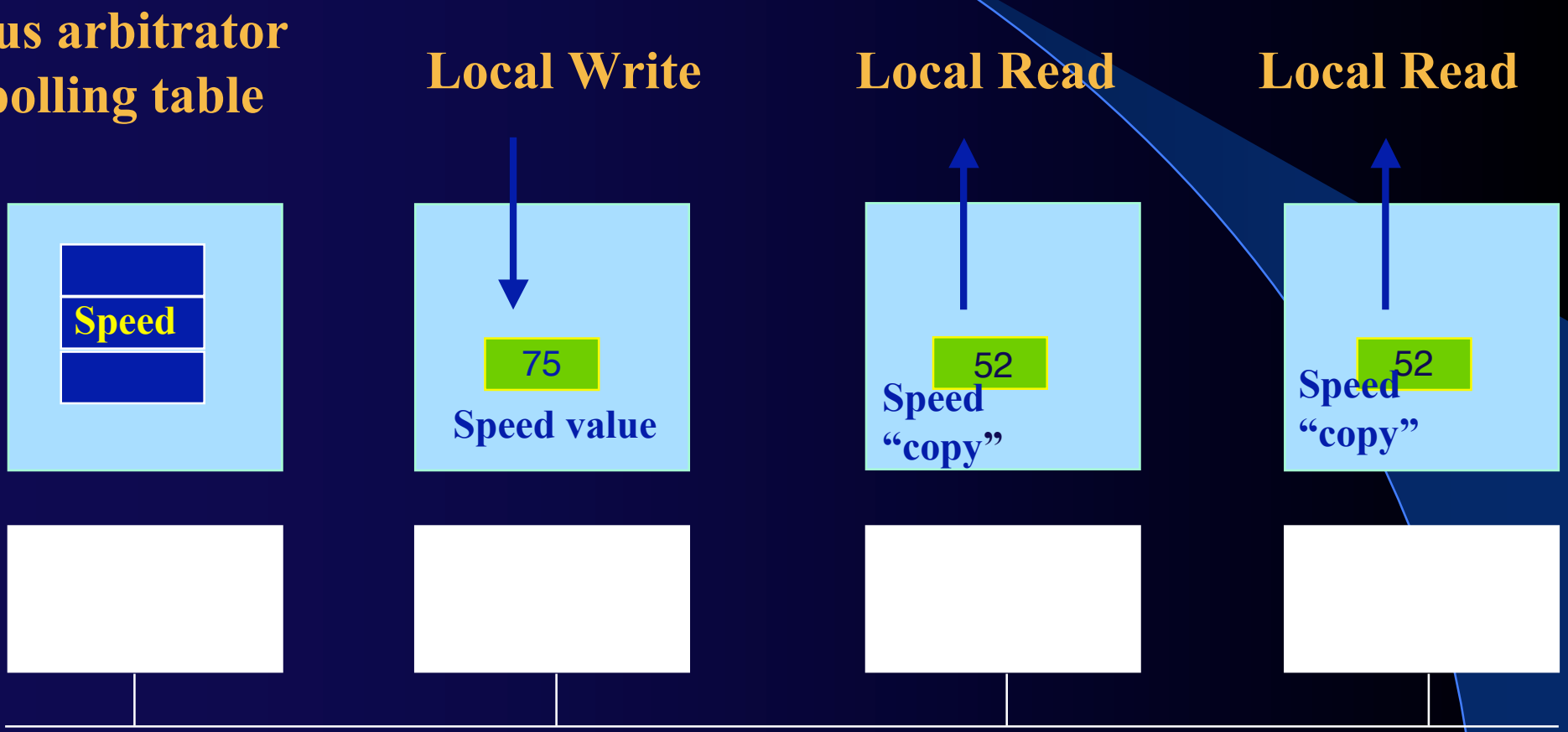
fieldbus traffic



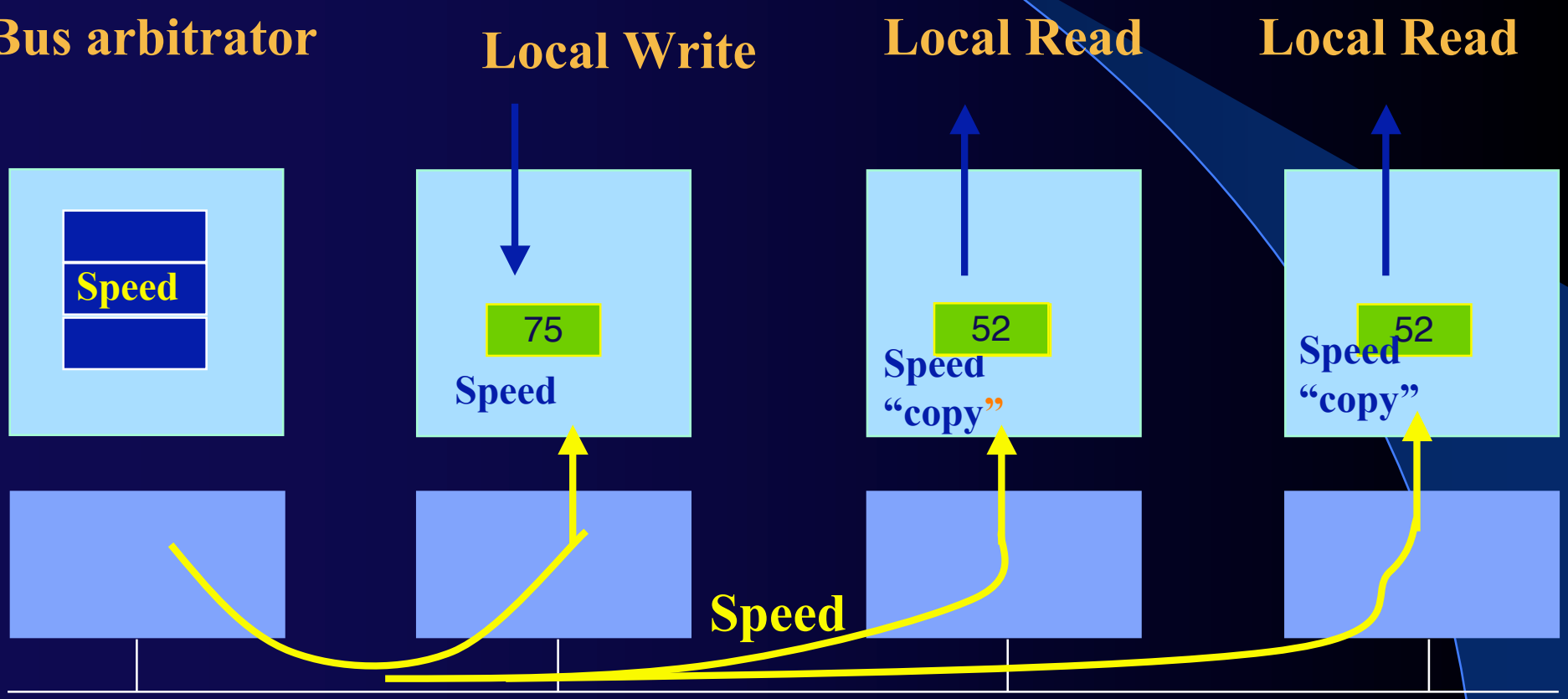
token and polling



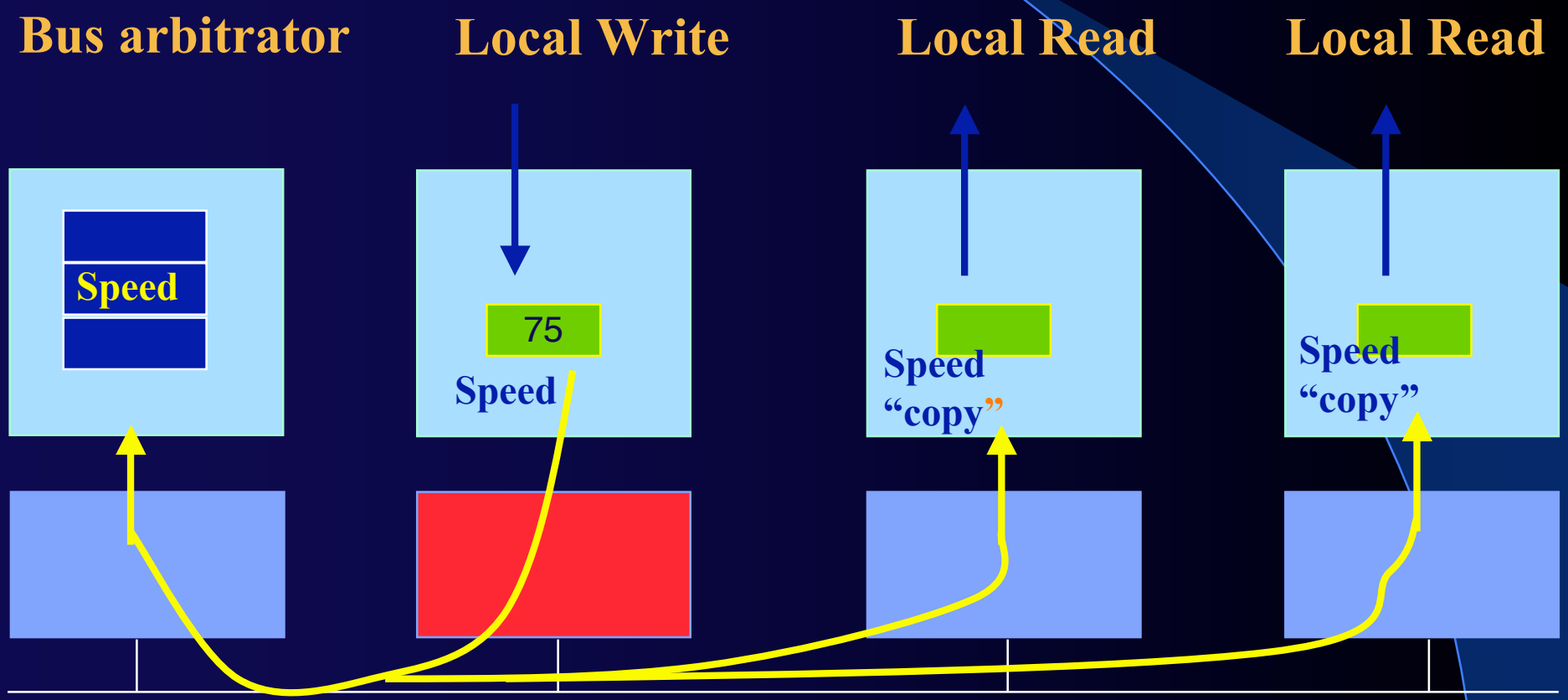
polling of identified data - pull PS



polling of identified data

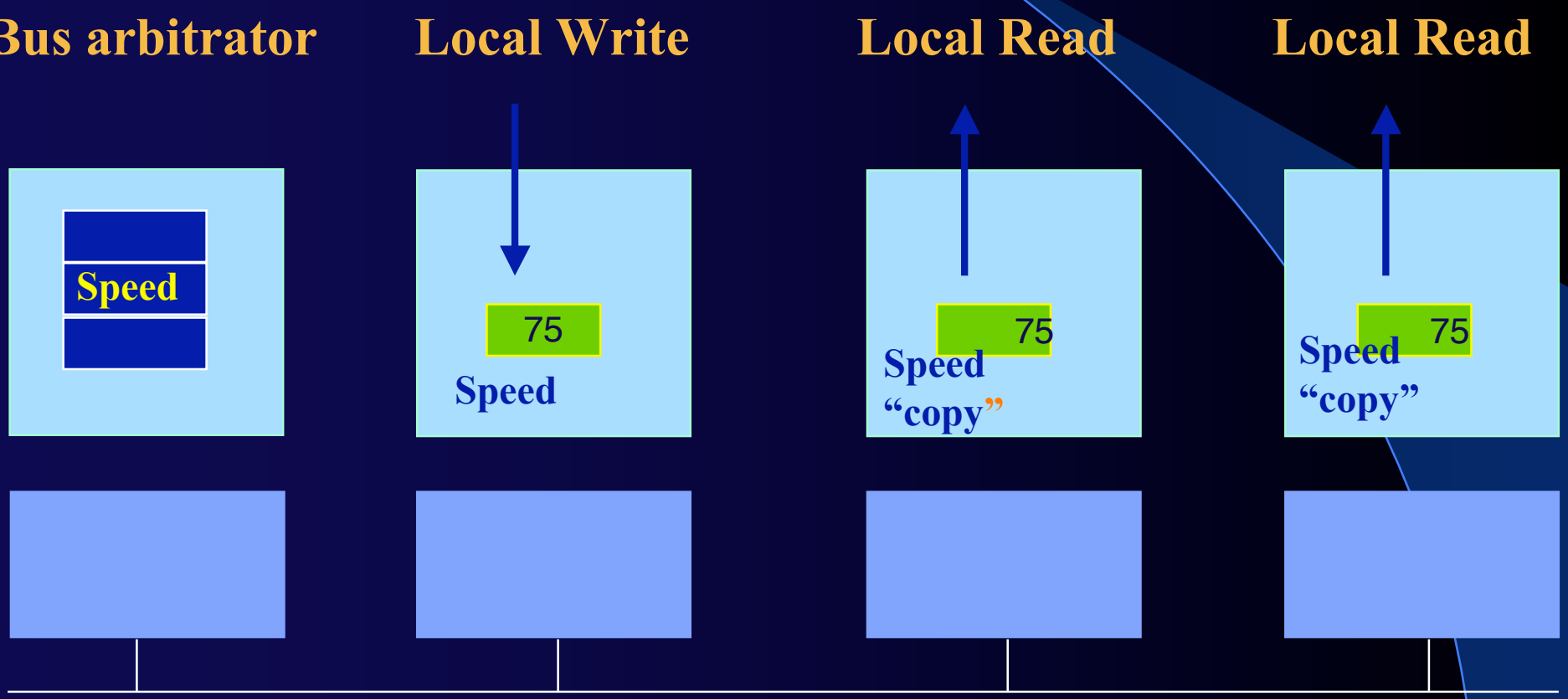


polling of identified data

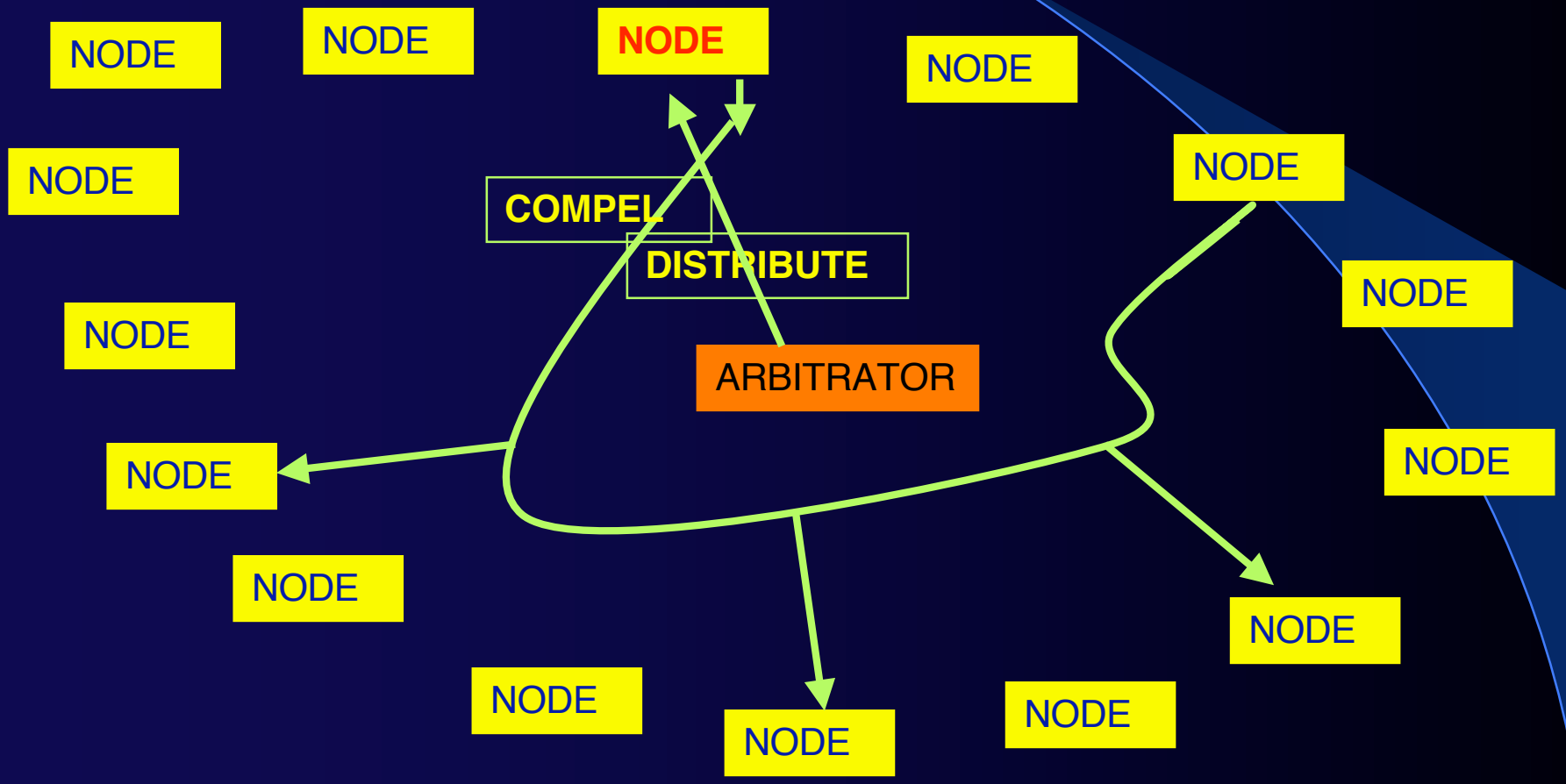


v(Speed)=75

polling of identified data



arbitrator


NODE
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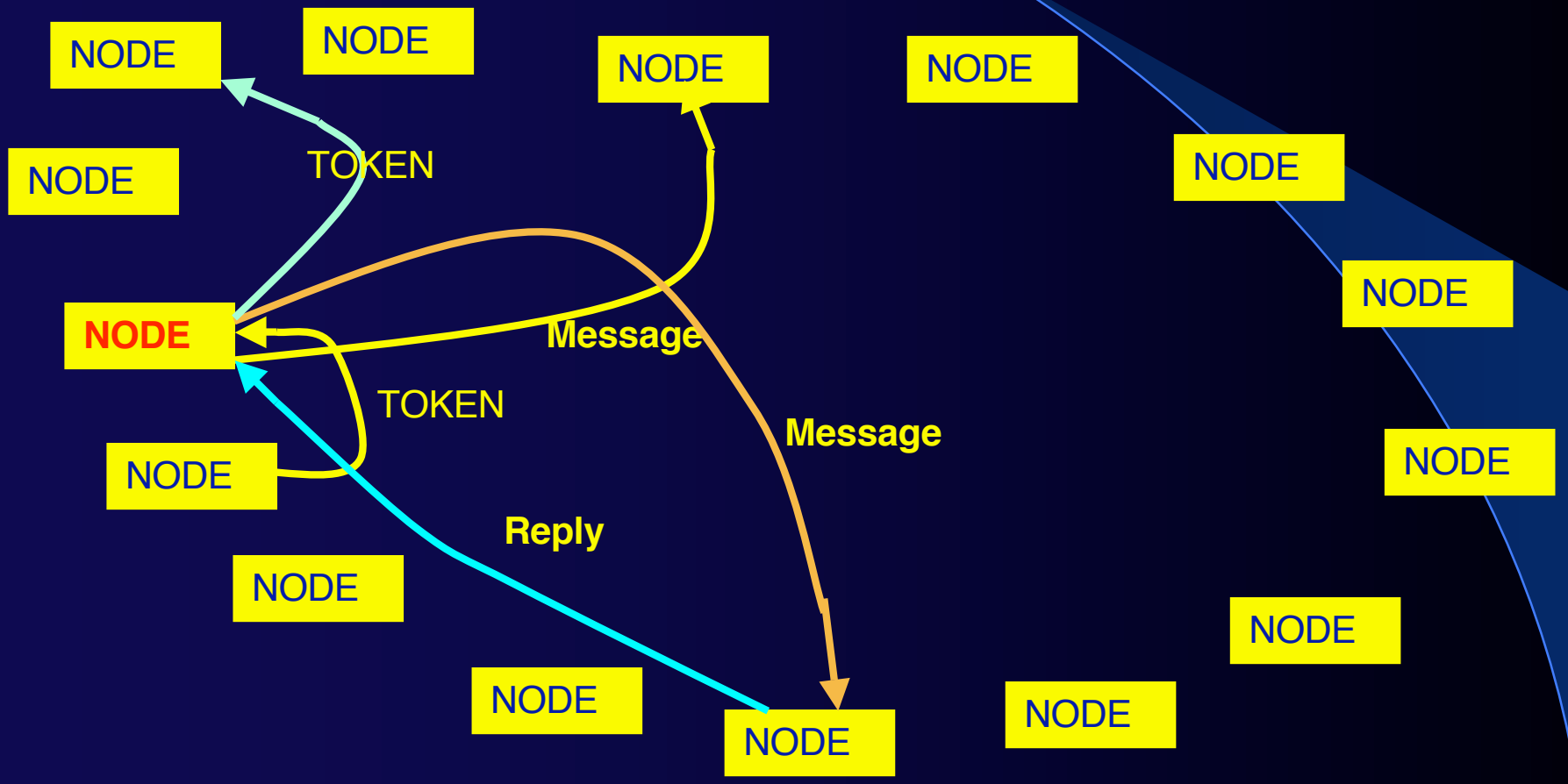
NODE
NODE
NODE
COMPEL
DISTRIBUTE
ARBITRATOR

token


NODE
NODE
NODE
NODE
NODE
NODE
TOKEN
NODE
NODE
Message
TOKEN
Message
NODE
NODE
Reply
NODE
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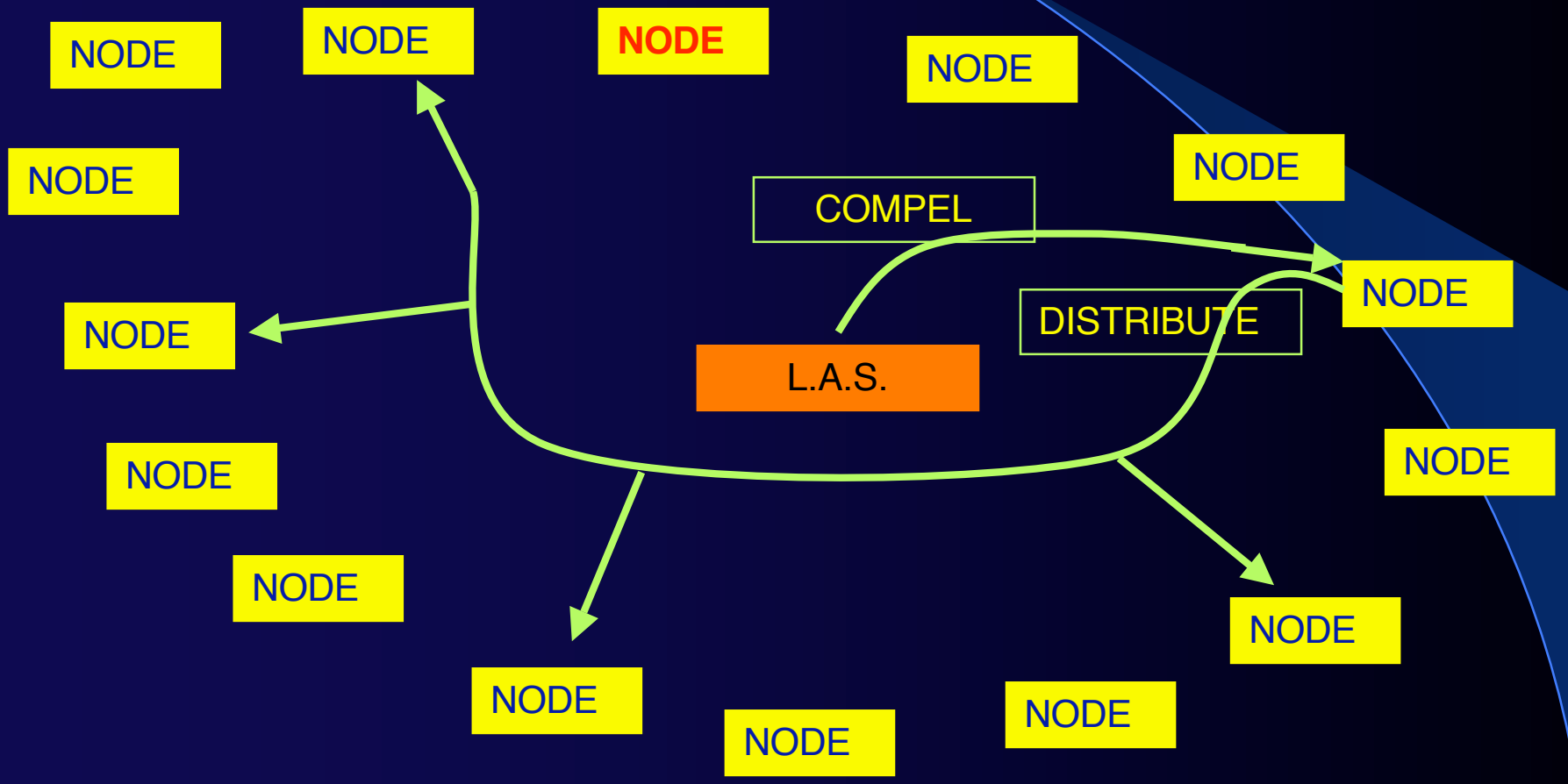
NODE
NODE

L.A.S.


NODE
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COMPEL
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L.A.S.
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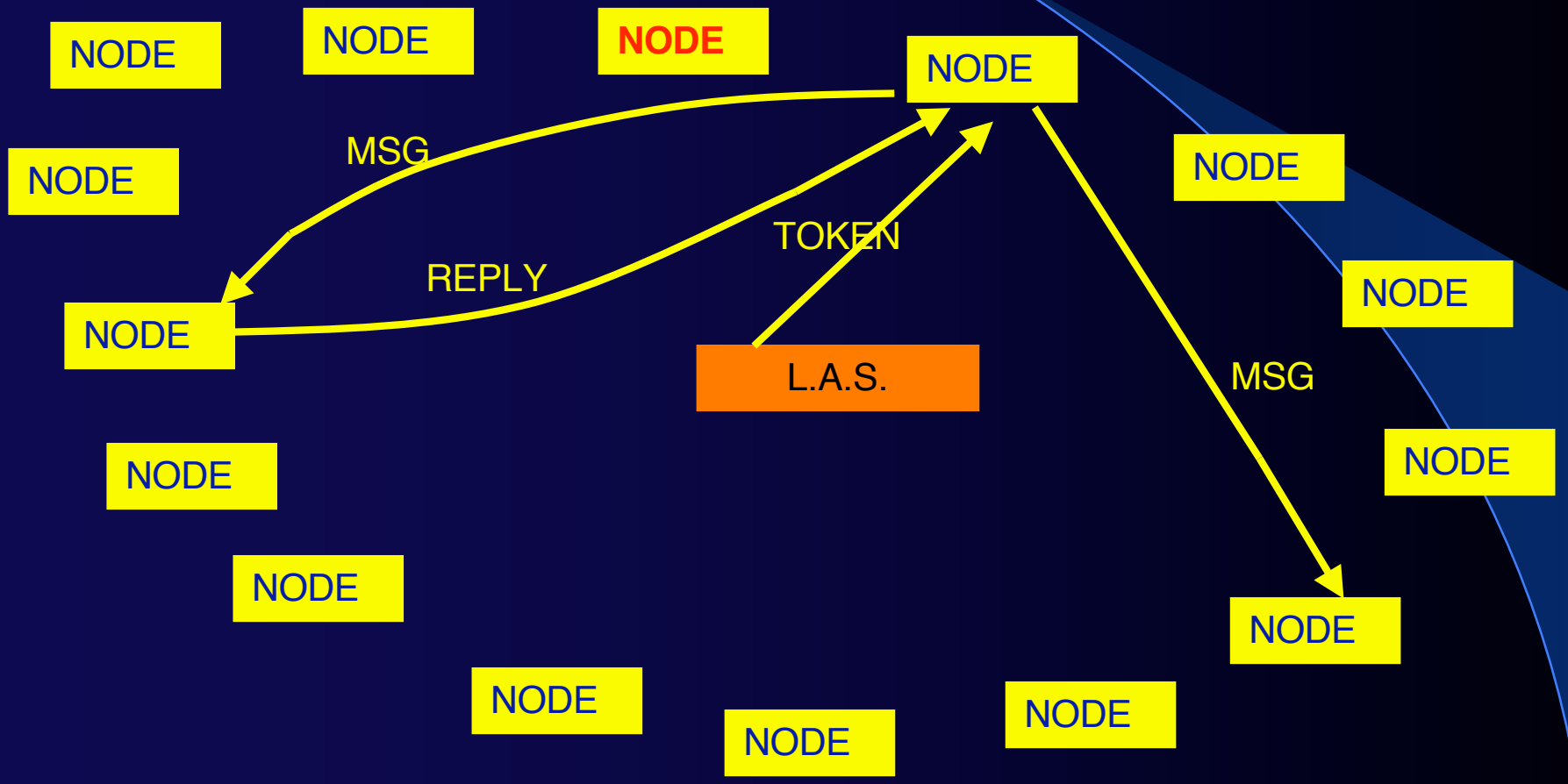
NODE

L.A.S.


NODE
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NODE
NODE
NODE
NODE
NODE
NODE
NODE
NODE
MSG
REPLY
TOKEN
L.A.S.
MSG

content

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quality of service

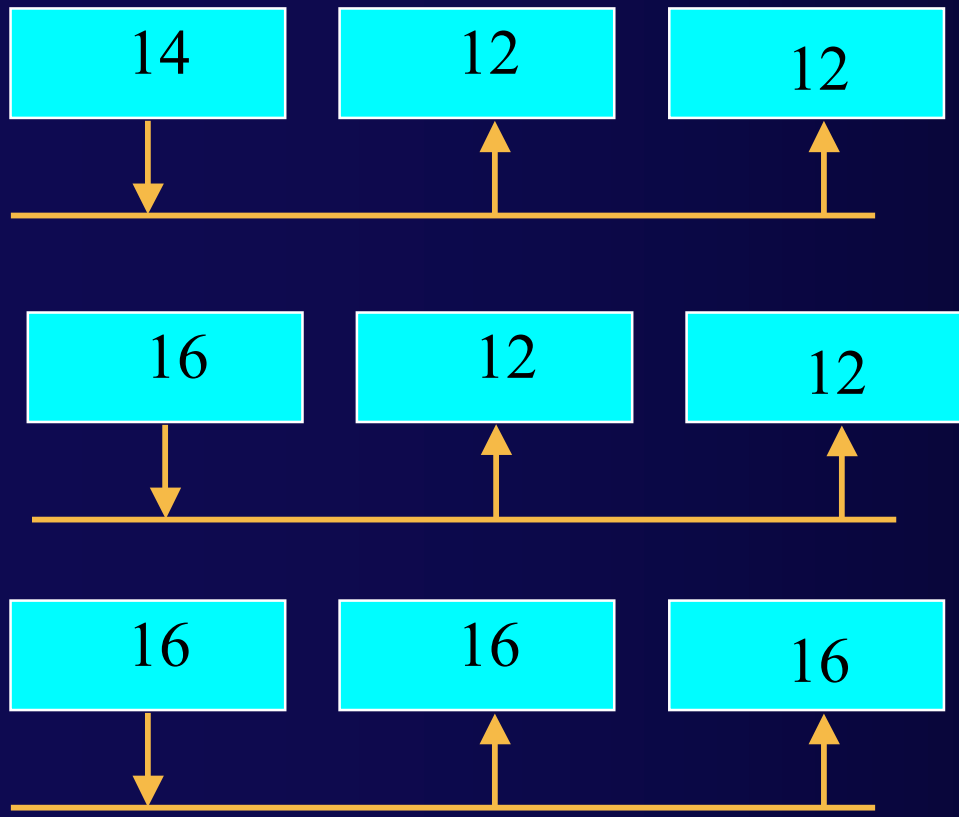
- QoS transport
  - reliability of transmission
  - storing methods
    - queues
    - buffers (retentive or not)
  - connections
    - with or without
    - peer to peer, multipeer
- QoS timeliness
  - time stamping
  - timeliness attributes
    - residence time
    - update time
    - synchronous

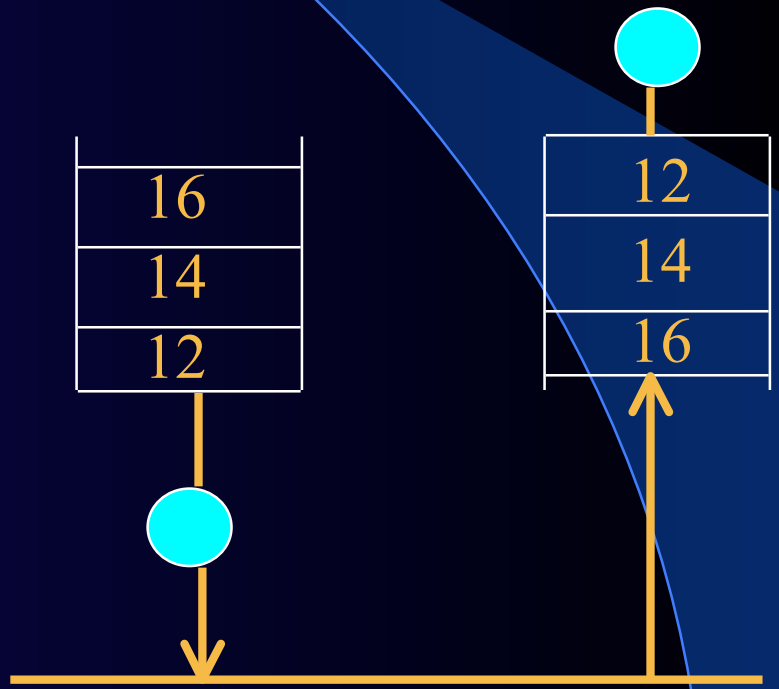
w/wo acknowledgement

- transmission of state information (no acknowledgement)
  - transmission or server failure detected by client
  - lack of confirmation (CS)
  - lack of periodic message (PS)
- transmission of event information (with acknowledgement)
  - transmission failure undetectable by receiver

  (no news - good news !)
  - necessary detection by sender thanks to protocol with acknowledgement

buffers and queues

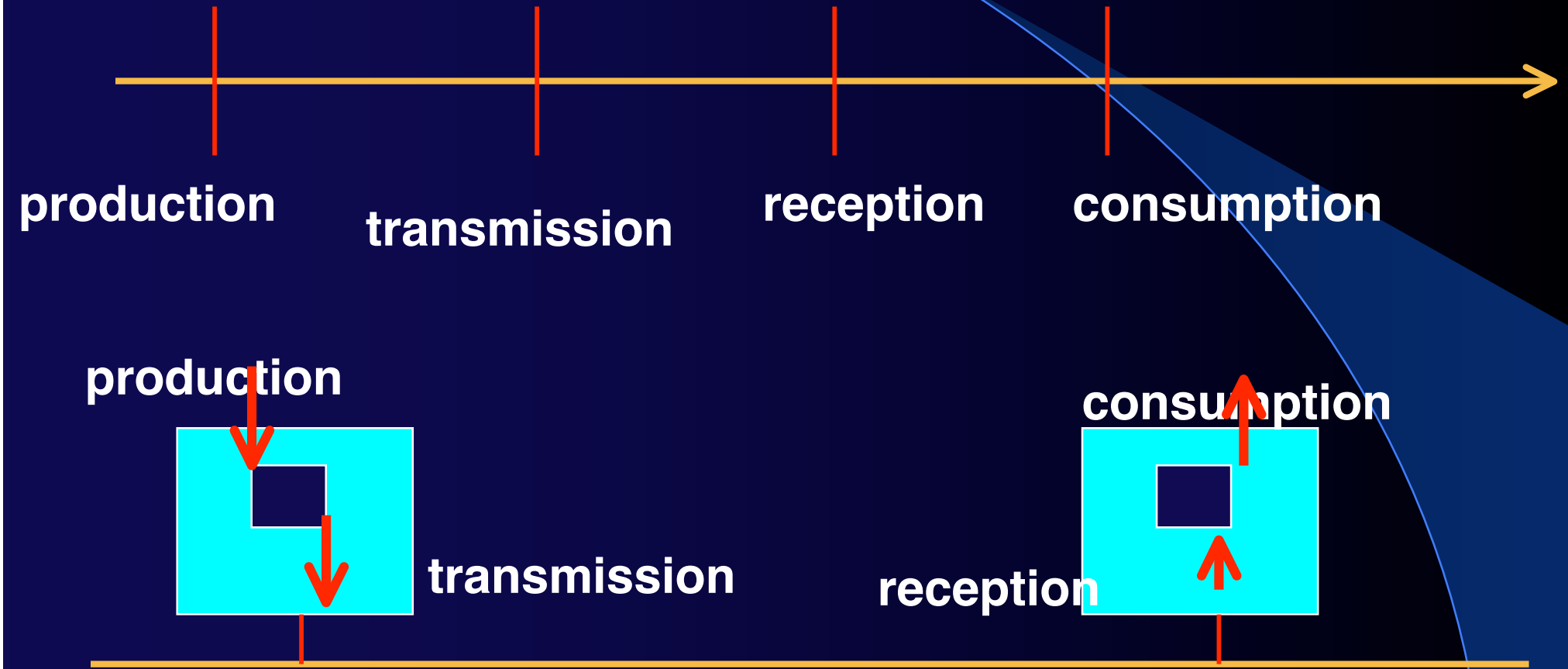




QoS in fieldbus - transport

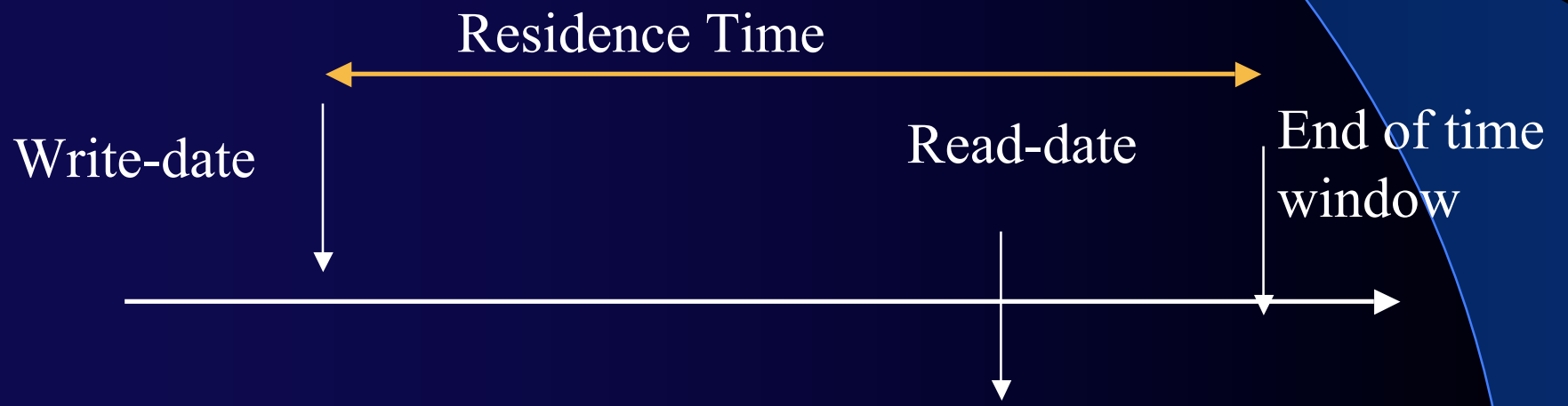
- connections
  - four qualities related to frames ordering
    - classical (queues…)
    - disordered without loss
    - ordered (but with possible loss)
    - unordered (as received)

QoS in fieldbus - timeliness



residence attribute

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

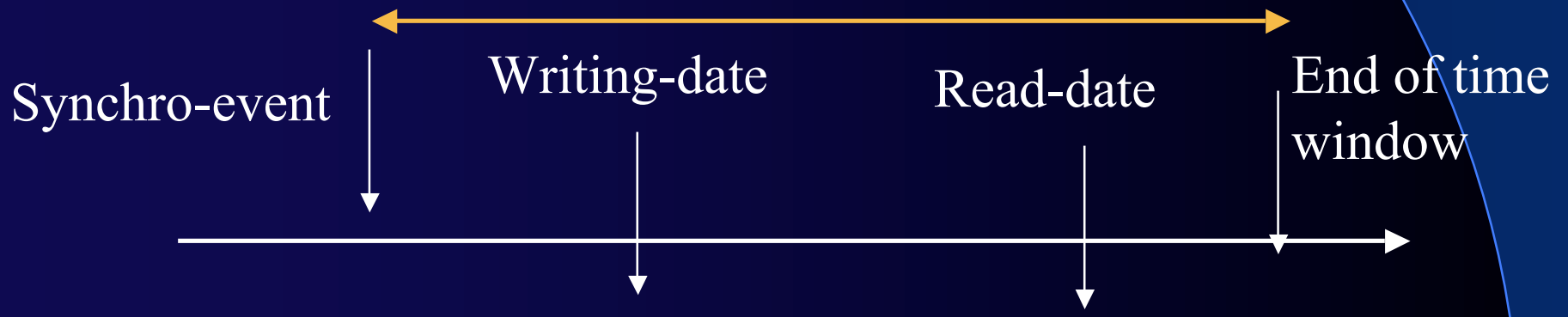


update attribute

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

synchronous attribute

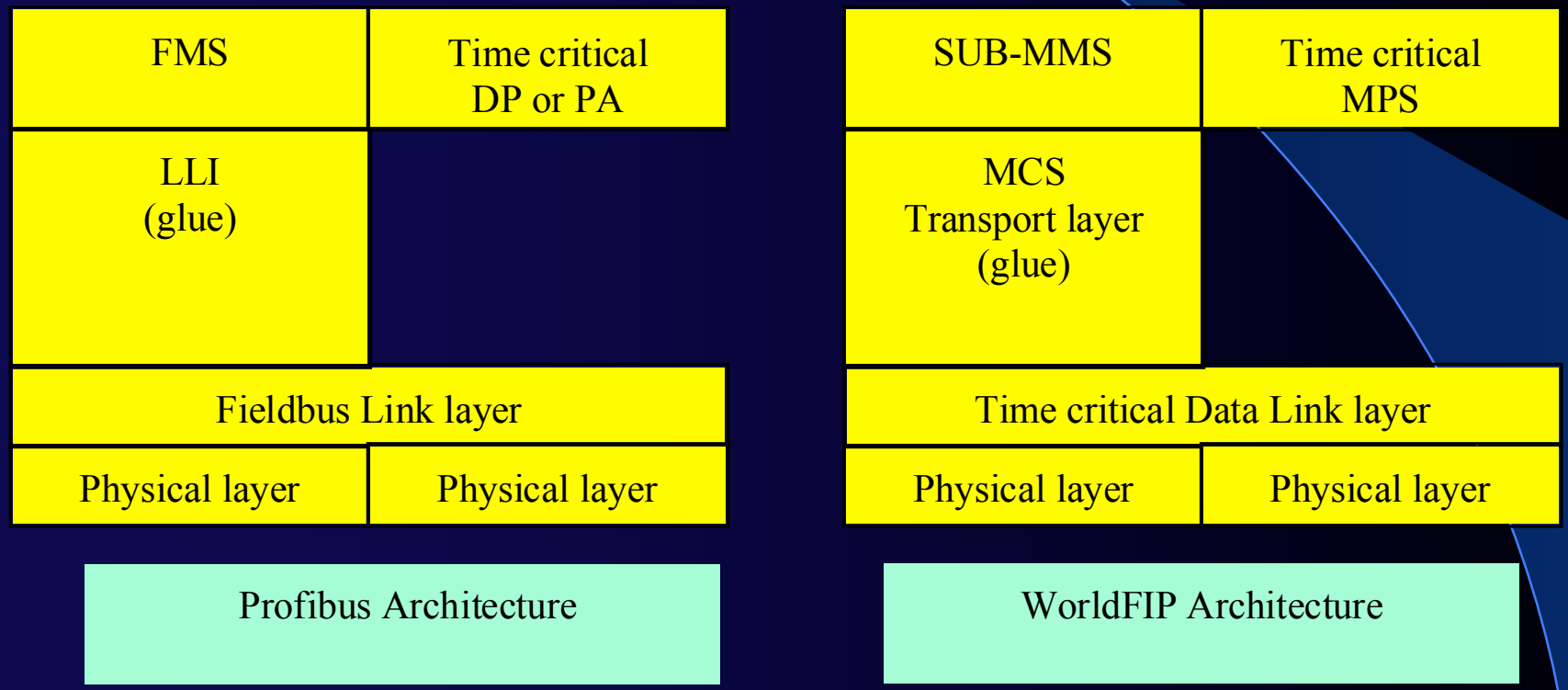
- assessment based upon the time intervals and timing relationships between
  - a synchronising event
  - the moment when the buffer is written
  - the moment the buffer is read



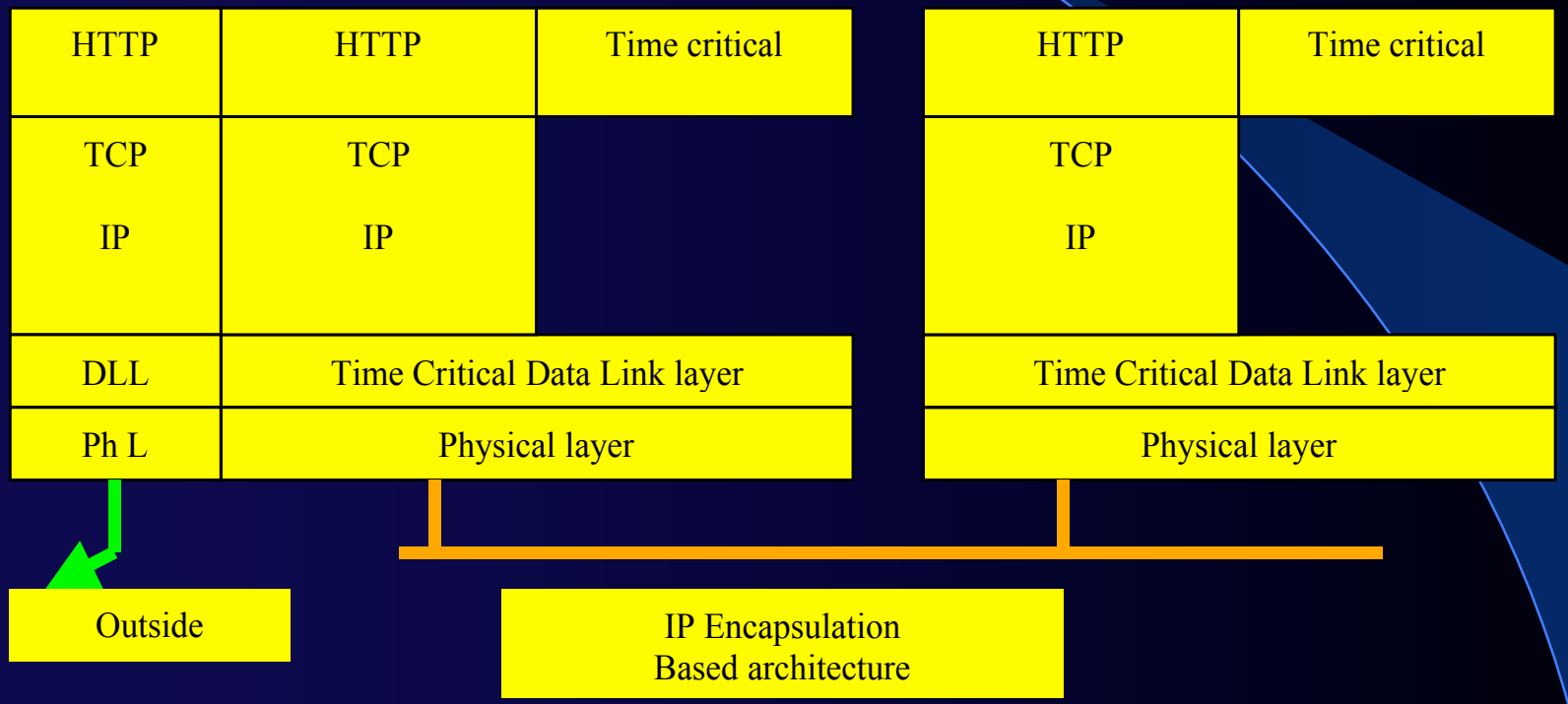
content

- 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

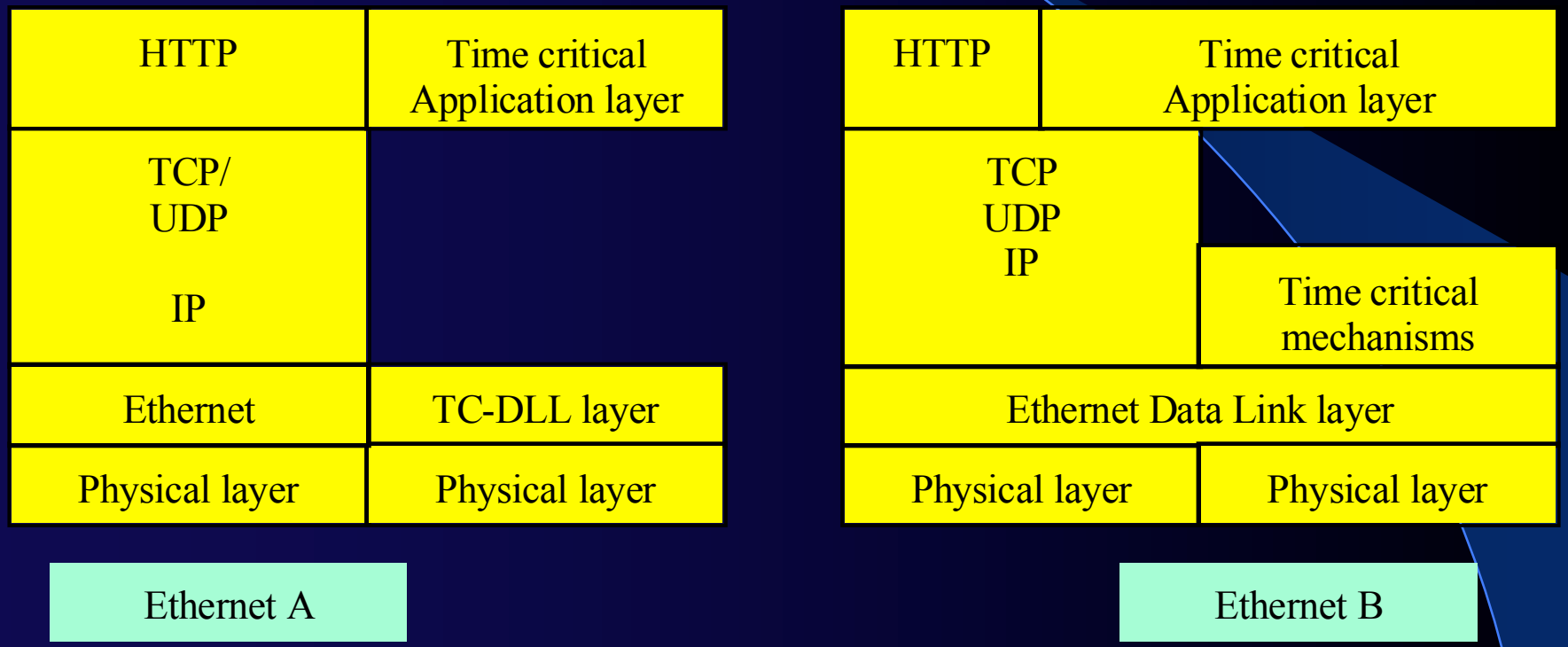
two stacks architectures



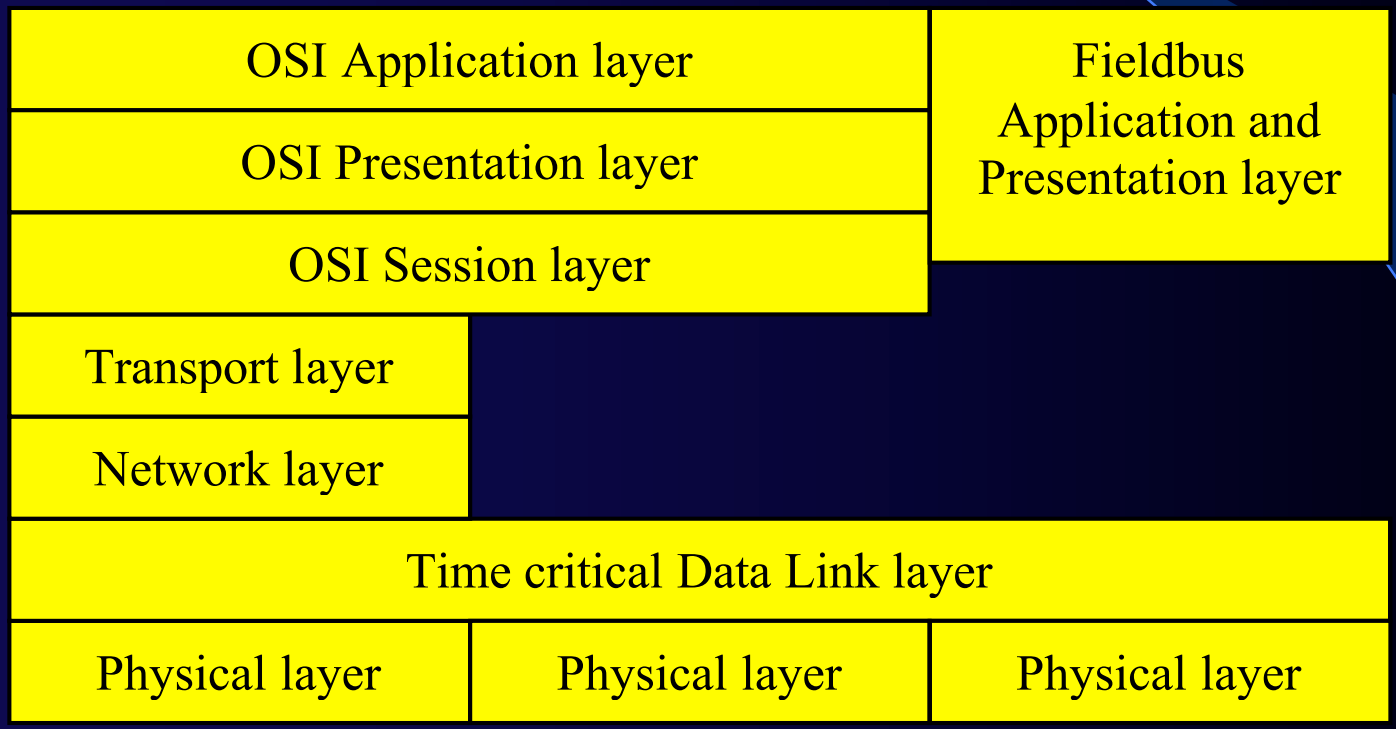
Internet and fieldbus



Ethernet based architectures



time critical architecture



conclusion - fieldbus technology?

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

fieldbus technology?

- future
  - which Ethernet ? and where?
  - Internet and Web technologies
  - interoperability (function blocks, EDDL…)
  - wireless, mobile and autonomous agents
- standard(s) as in general purpose computing ?
  - relations with OPC, MIMOSA and other initiatives…
  - a common communication architecture ?
  - a single fieldbus? (the Lernean Hydra immortal head) which one?

reference:

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Fieldbus Technology in Industrial Automation

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