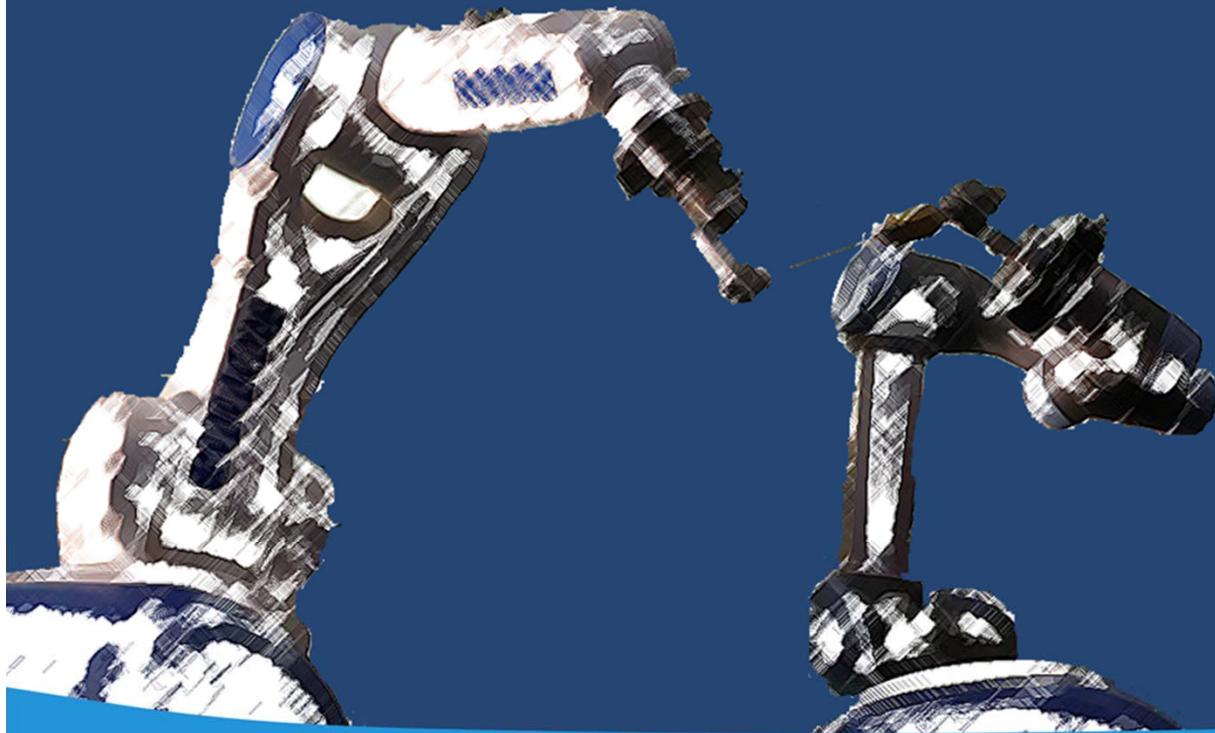
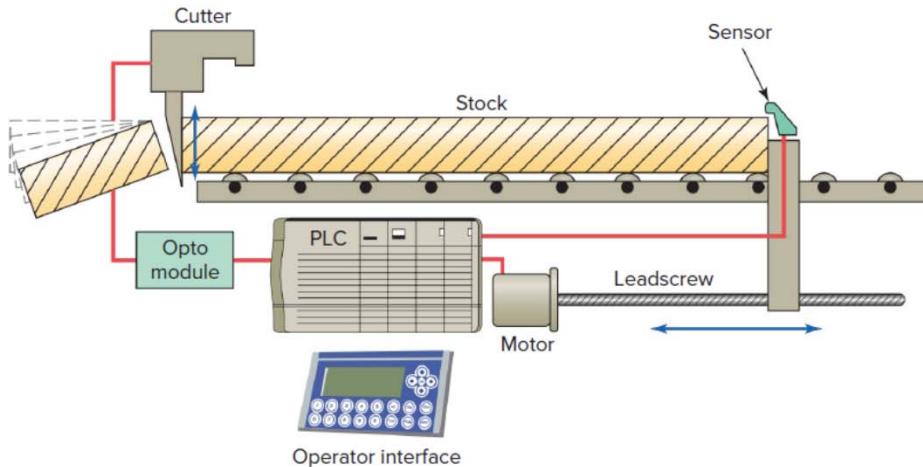


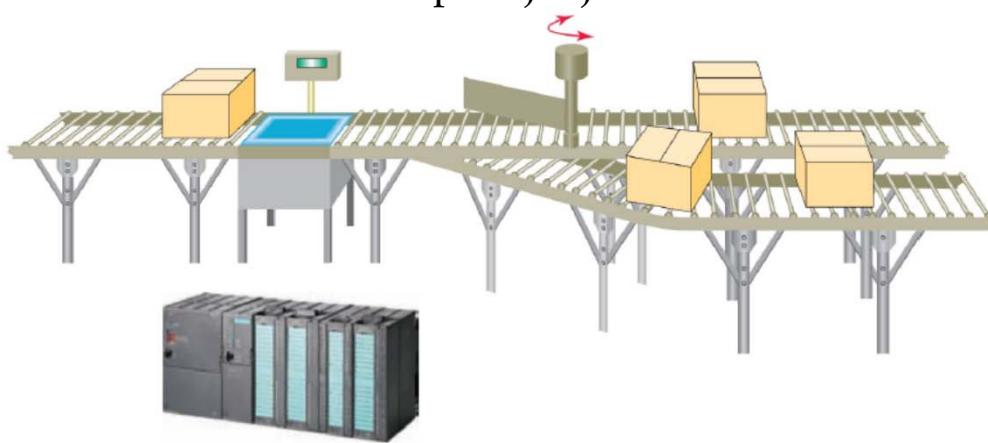
# INDUSTRIJSKE RAČUNALNE MREŽE



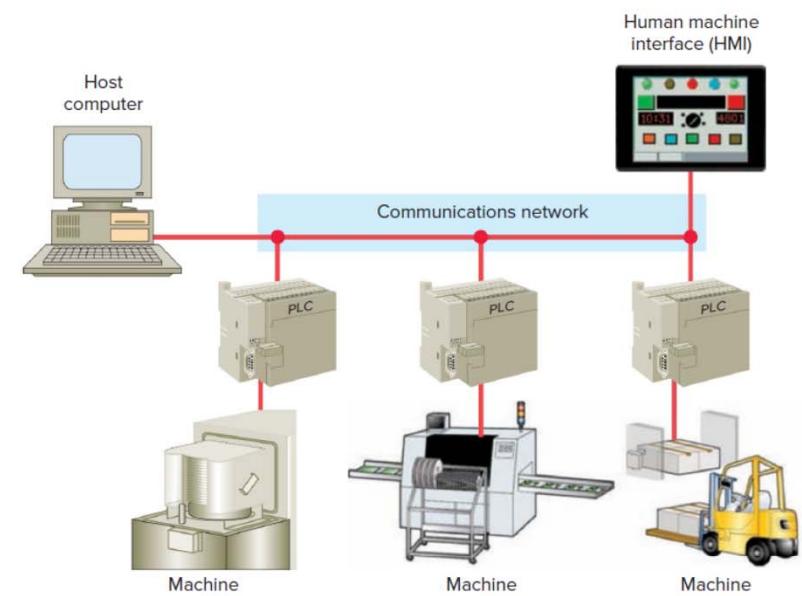
# Upravljačke konfiguracije



Samostalno upravljanje

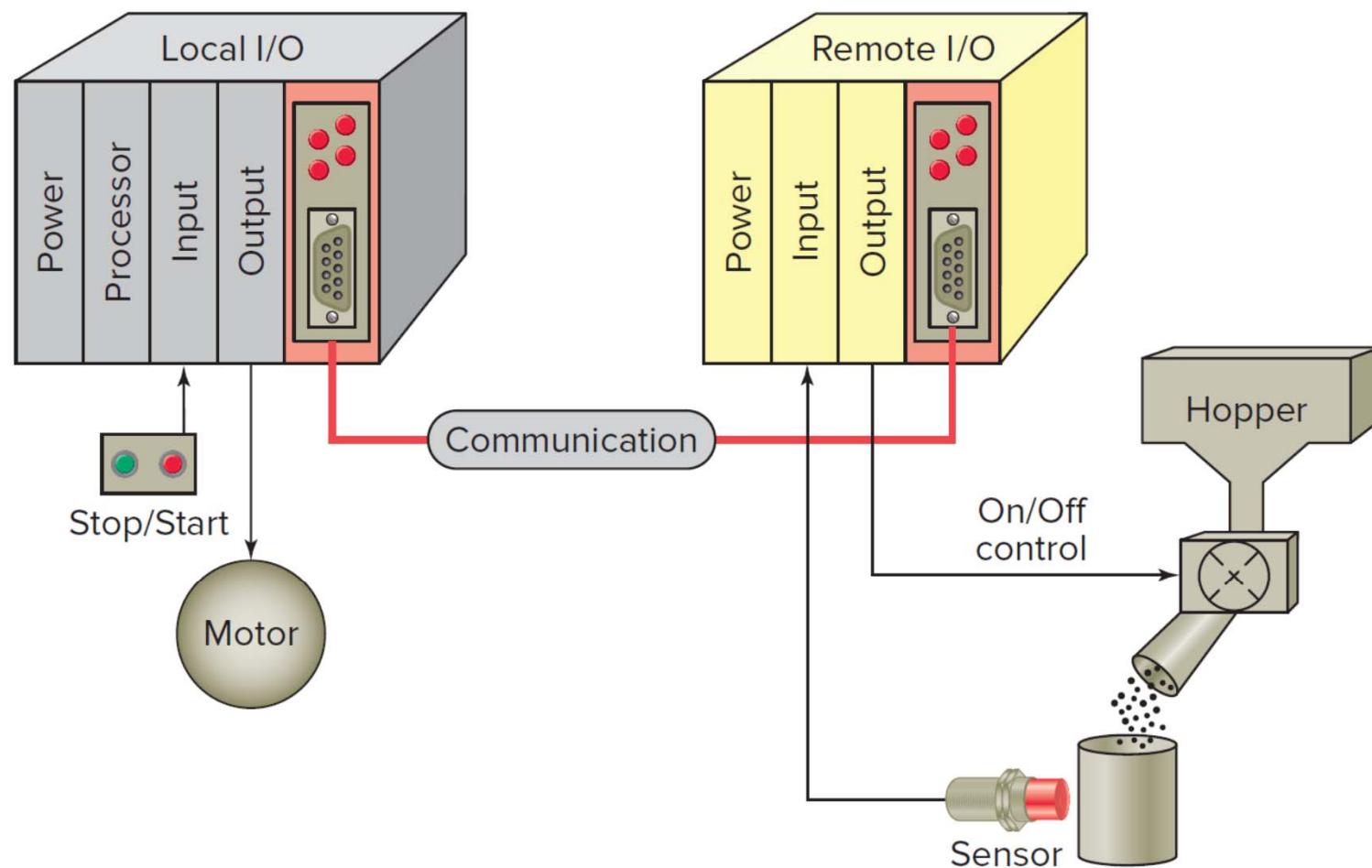


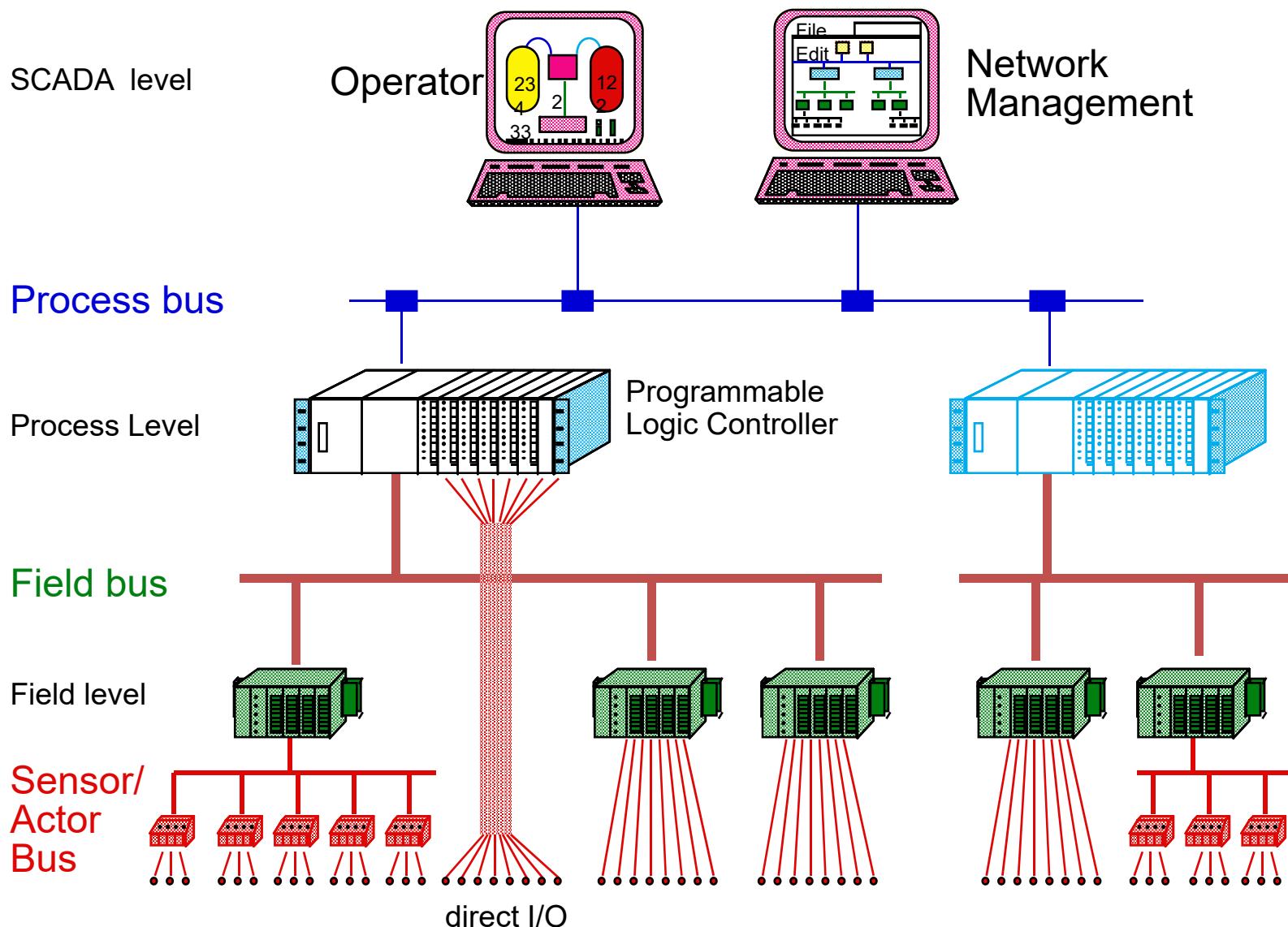
Centralno upravljanje



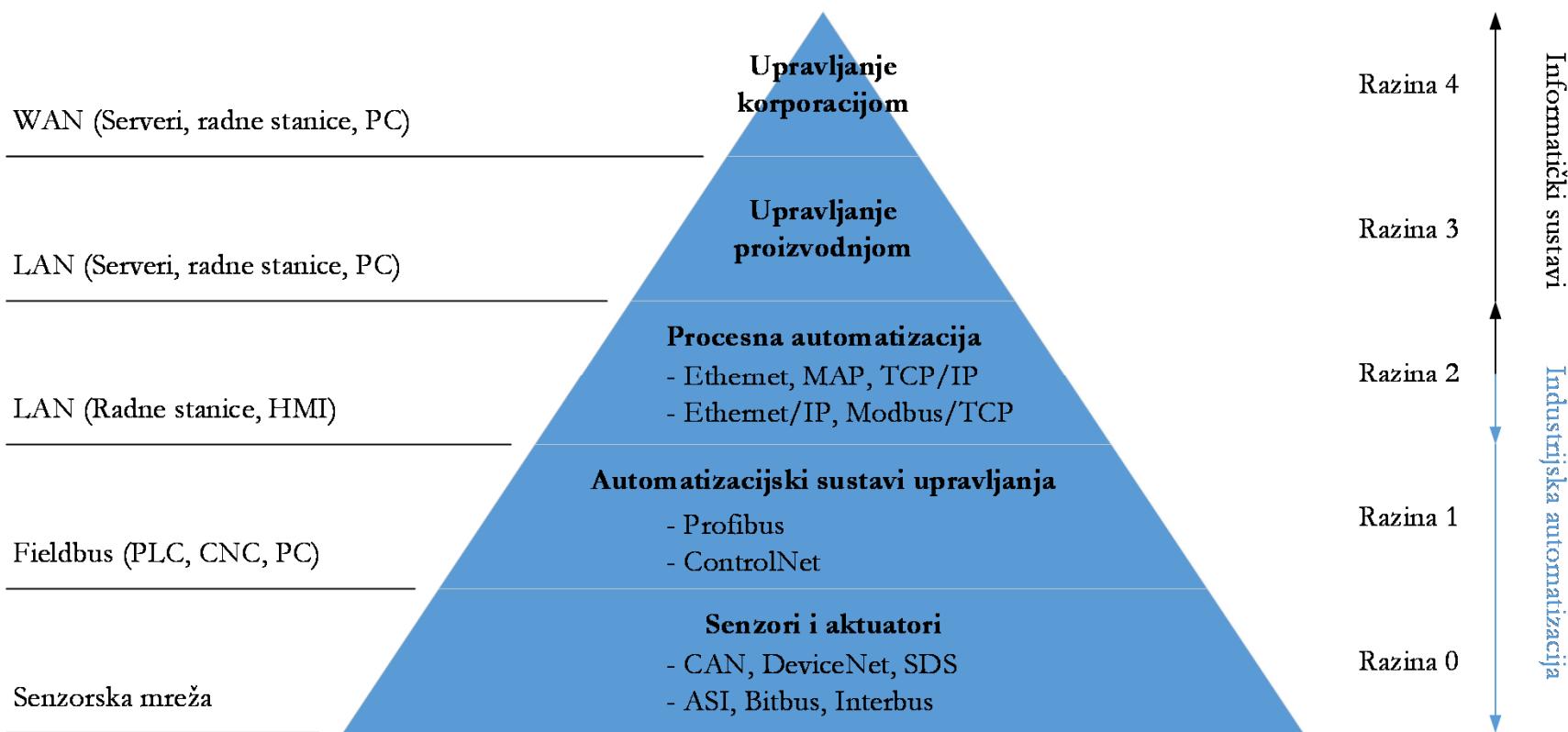
Distribuirano upravljanje

# Dislocirano upravljanje

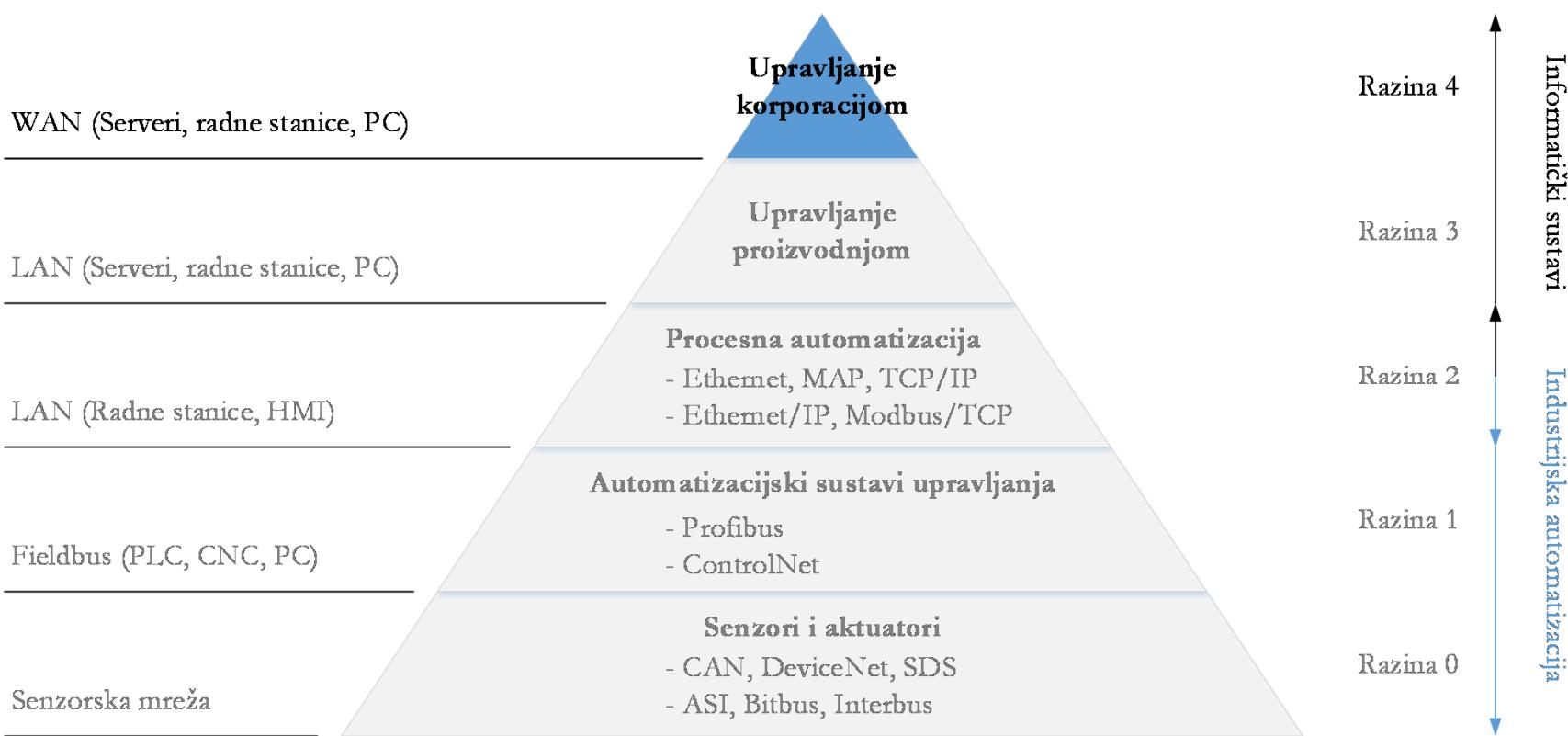




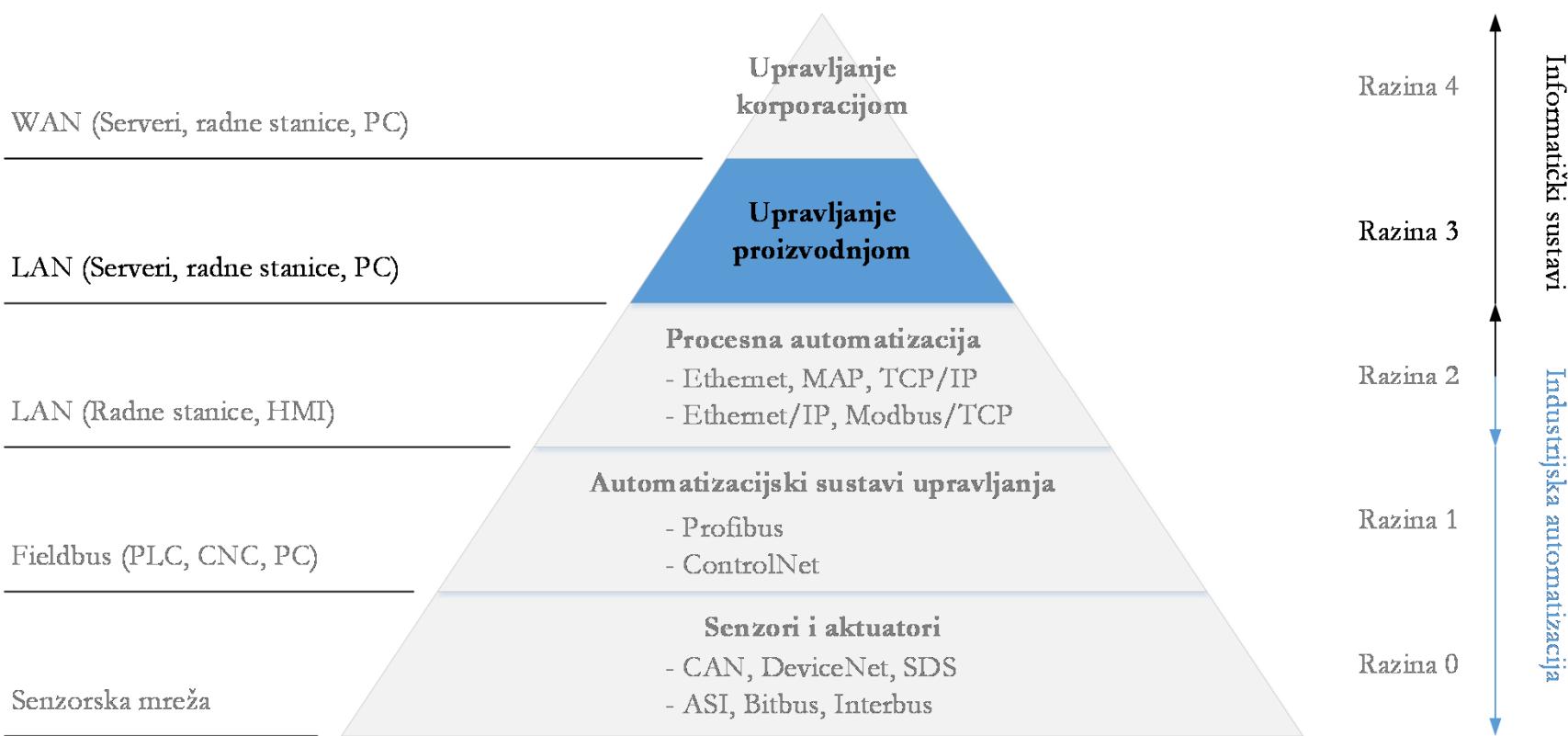
# Hijerarhija industrijske automatizacije



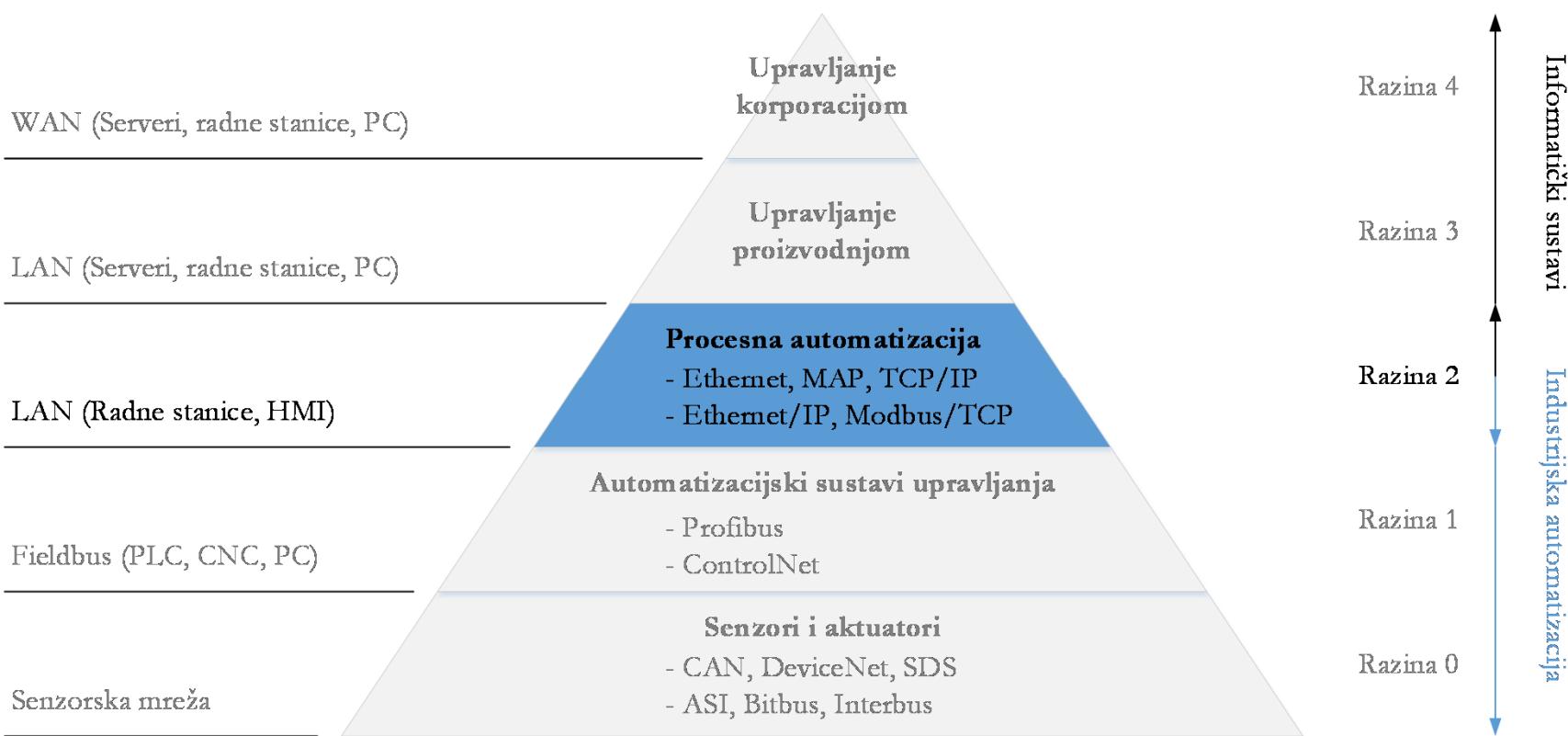
# Razina korporacijskog upravljanja



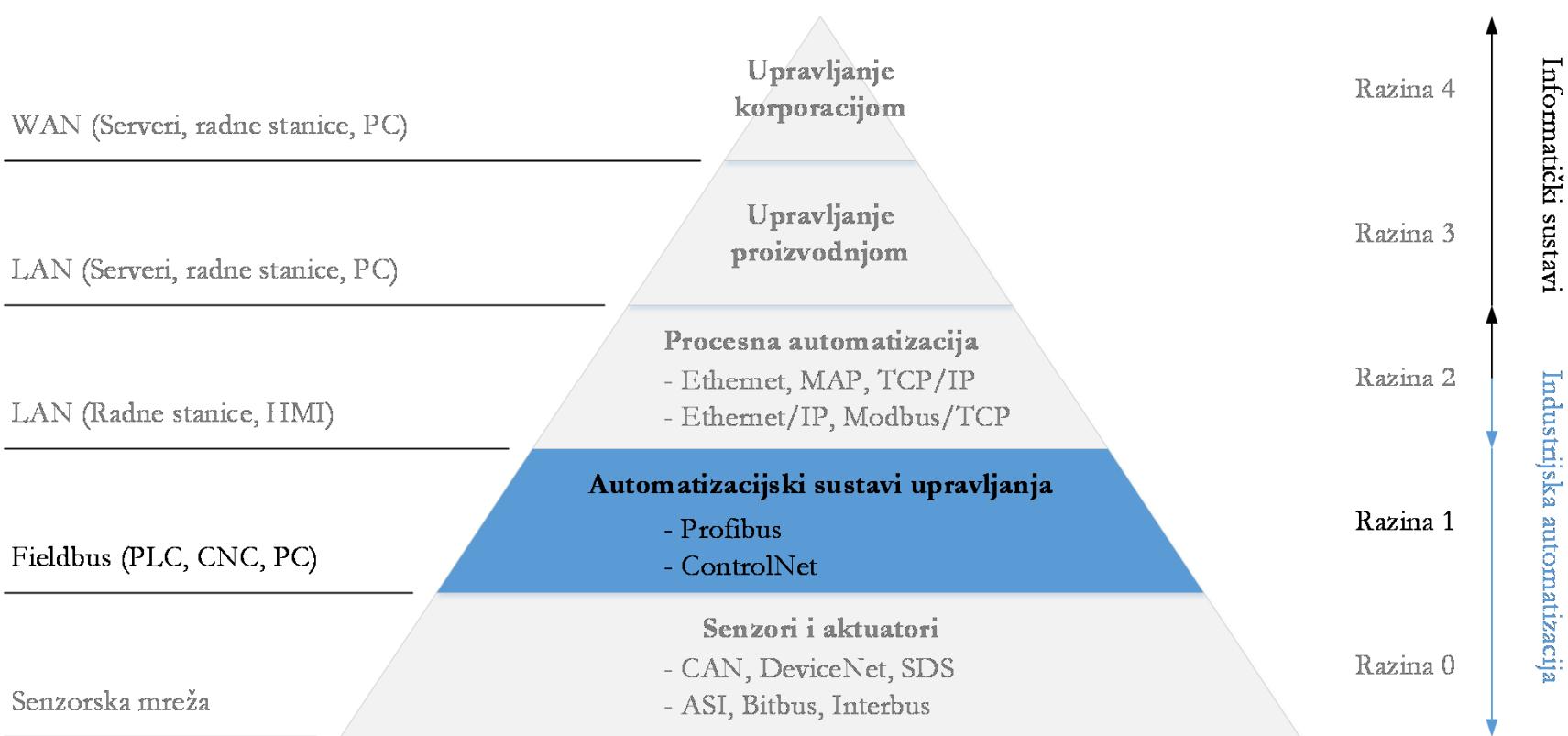
# Razina upravljanja proizvodnjom



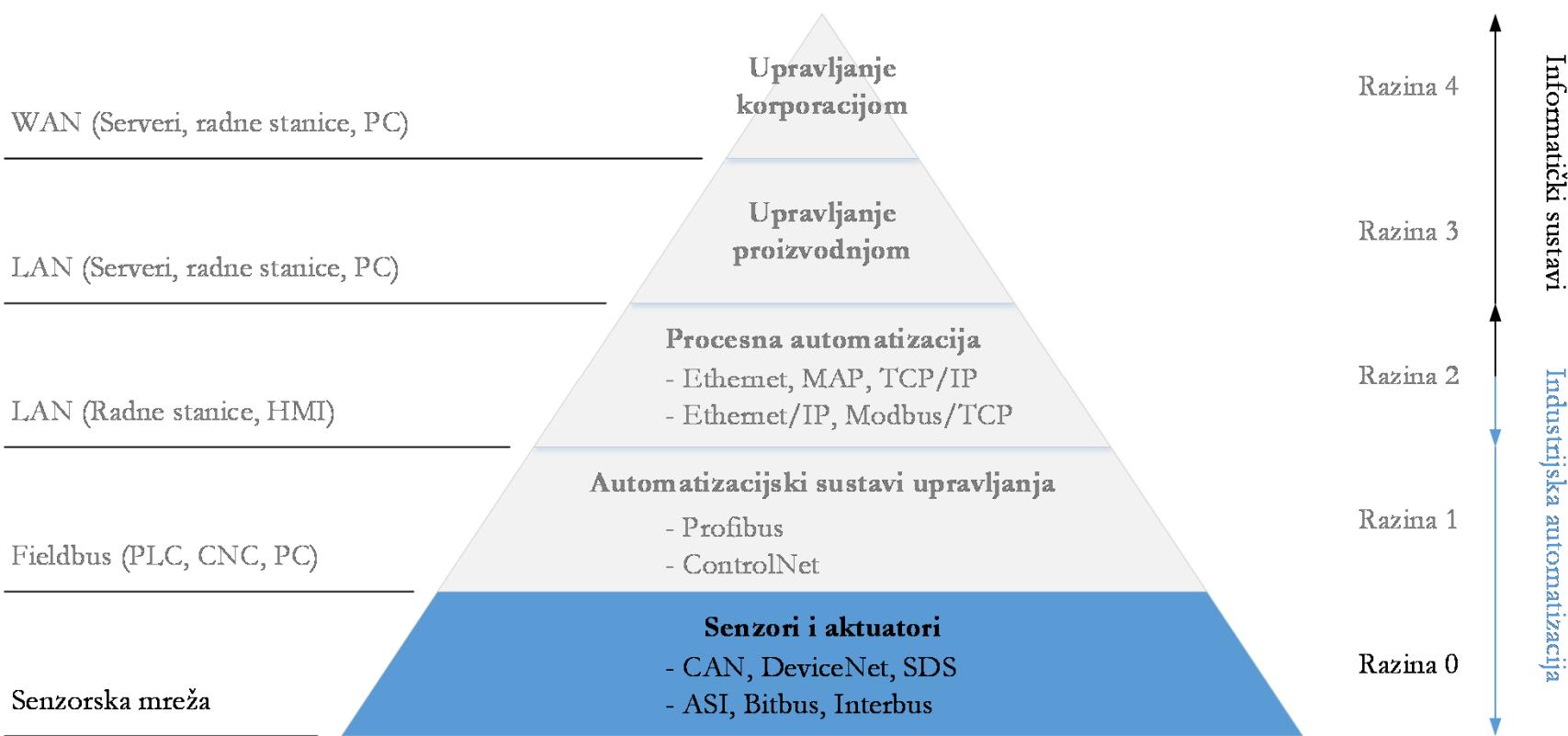
# Razina procesne automatizacije



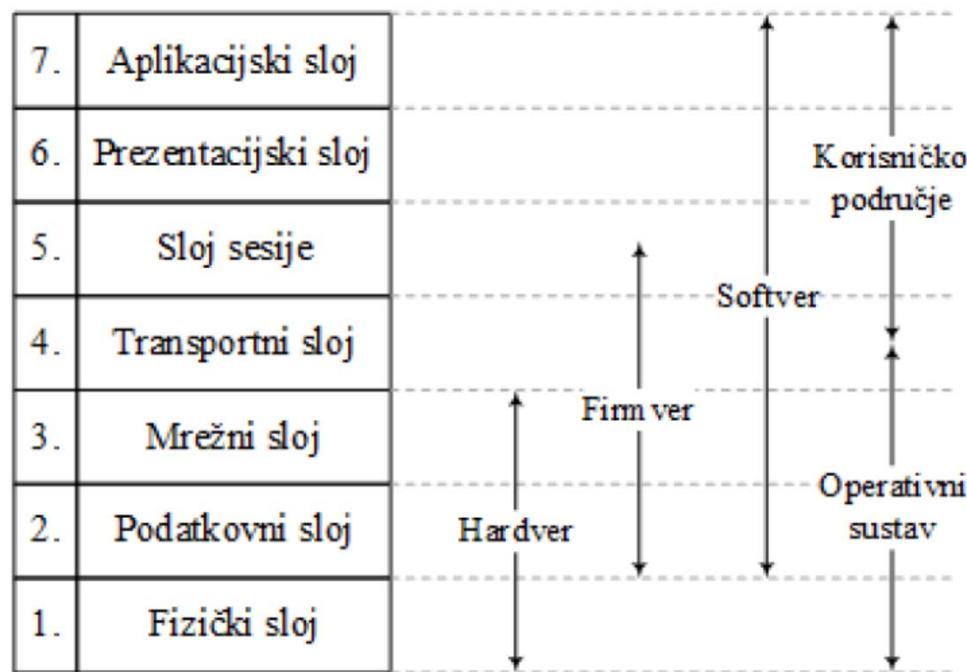
# Razina automatizacijskih sustava upravljanja



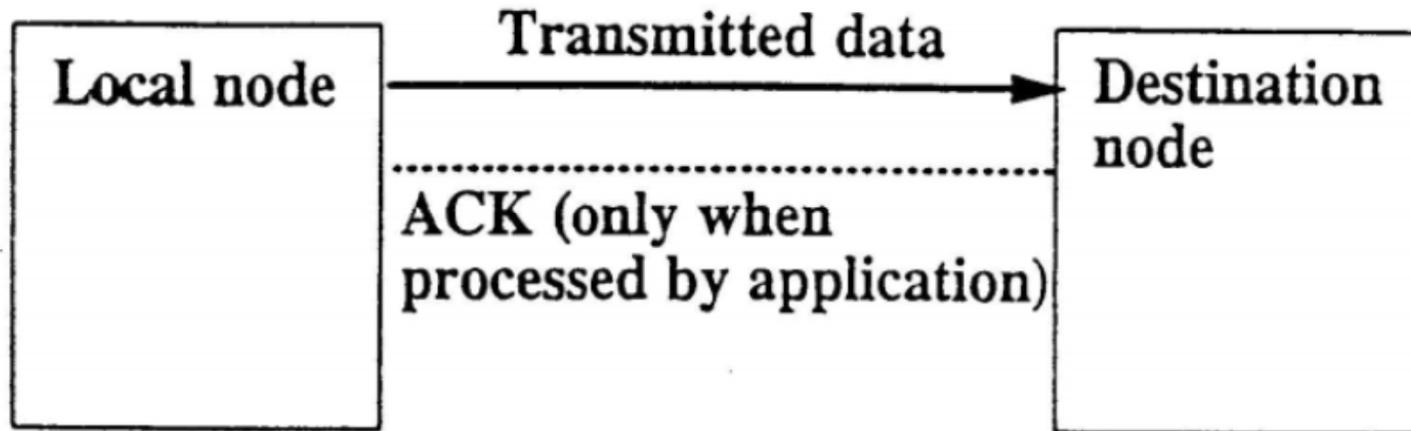
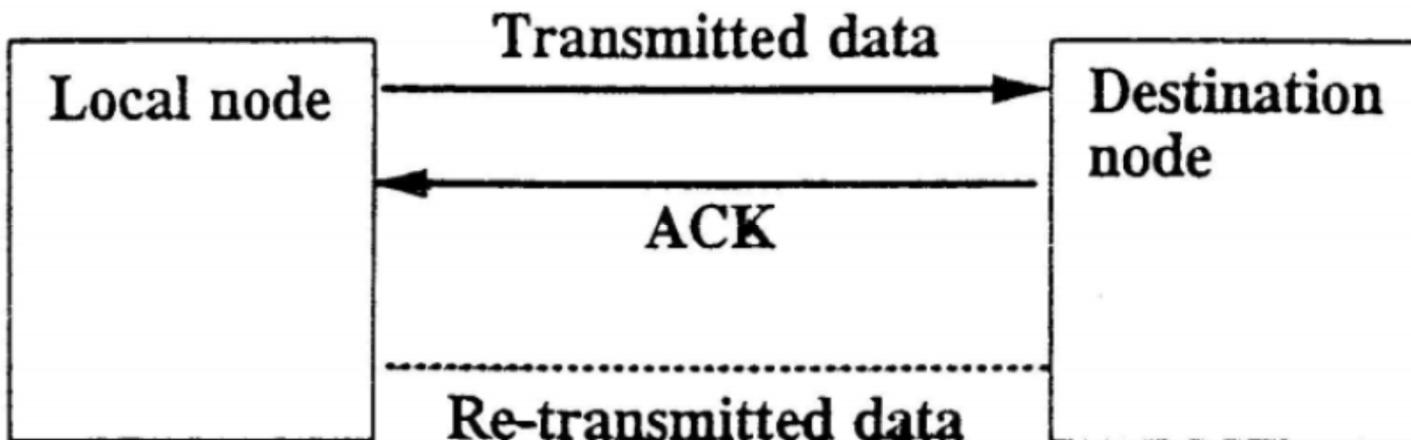
# Razina senzora i aktuatora

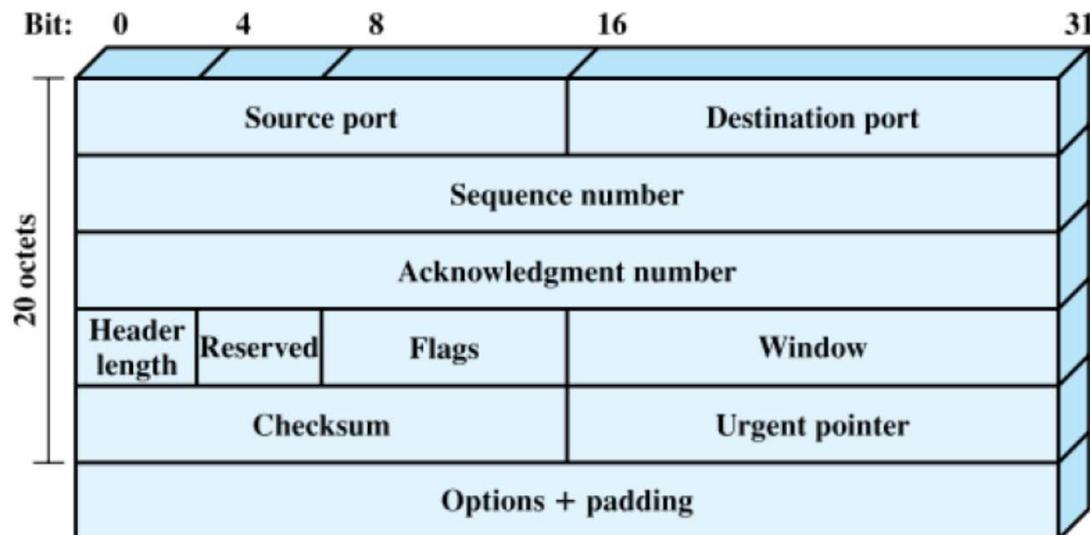


# Slojevi OSI referentnog modela

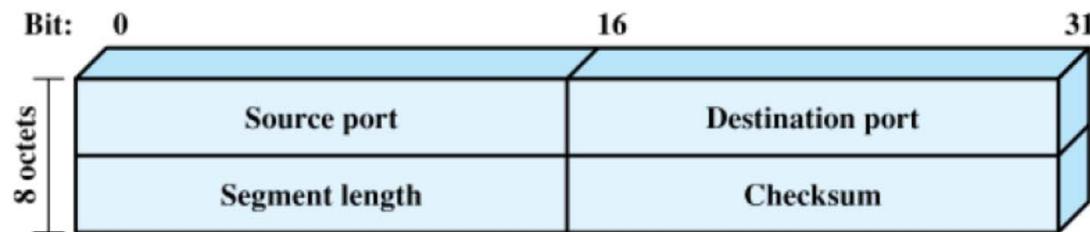


## TCP i UDP

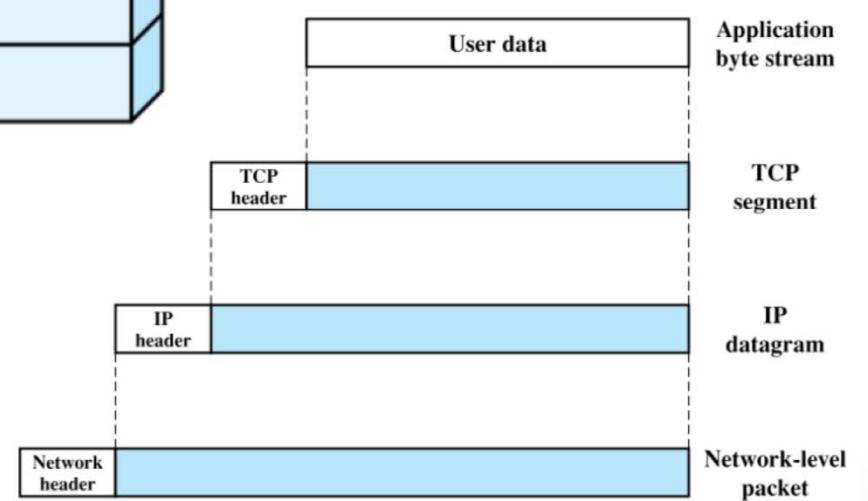




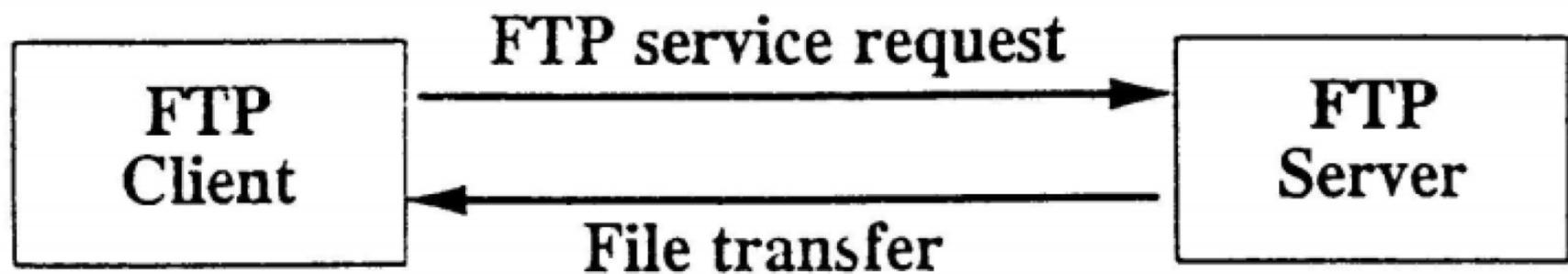
(a) TCP header



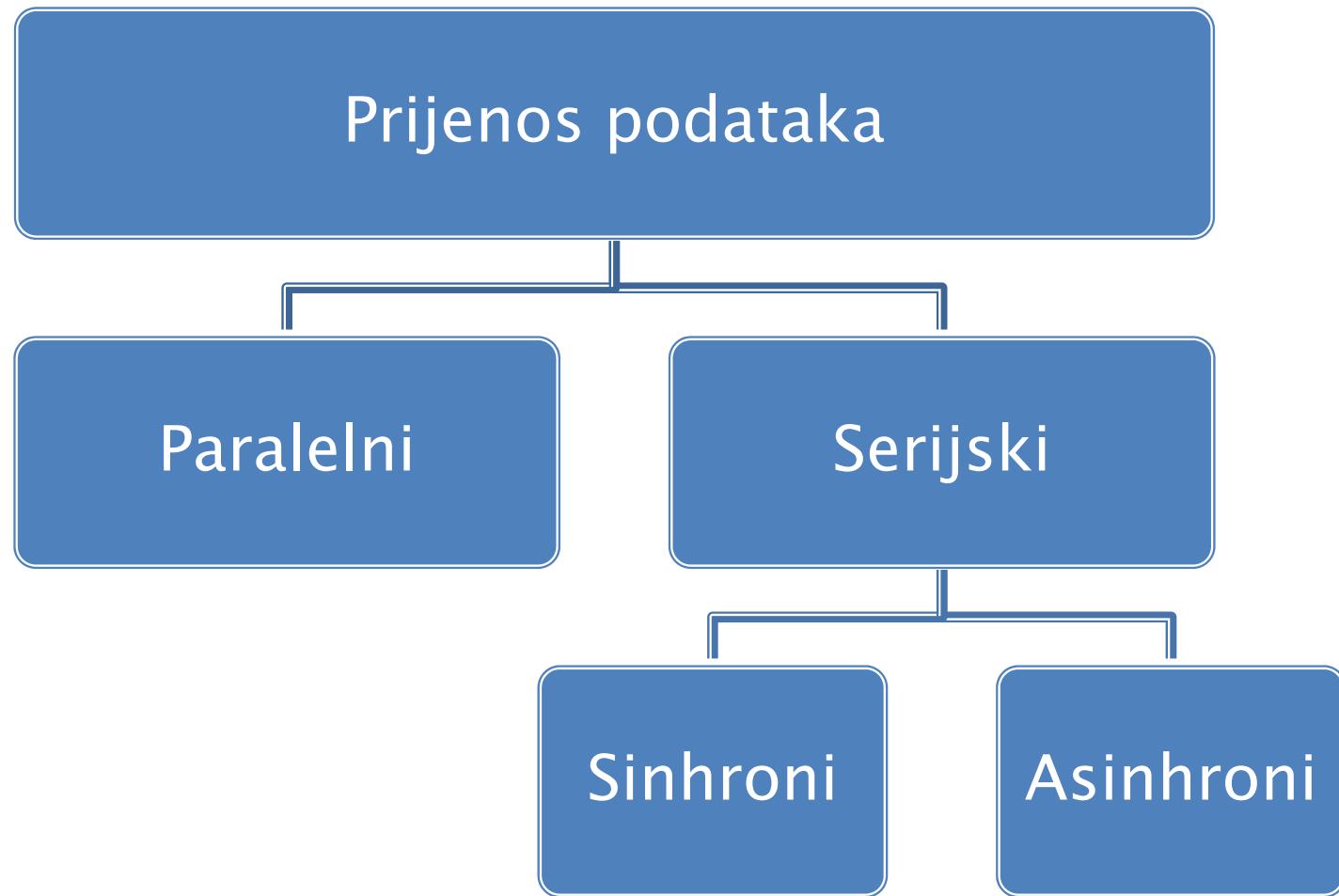
(b) UDP header



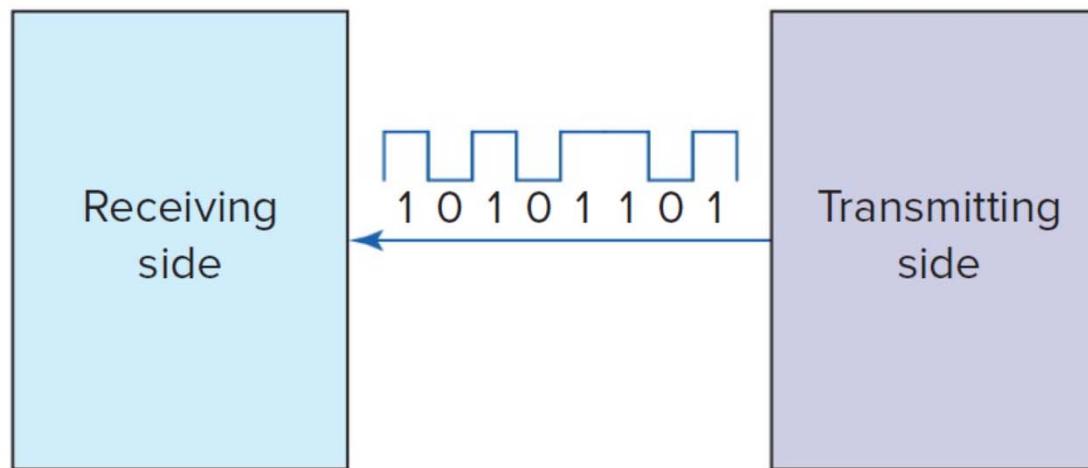
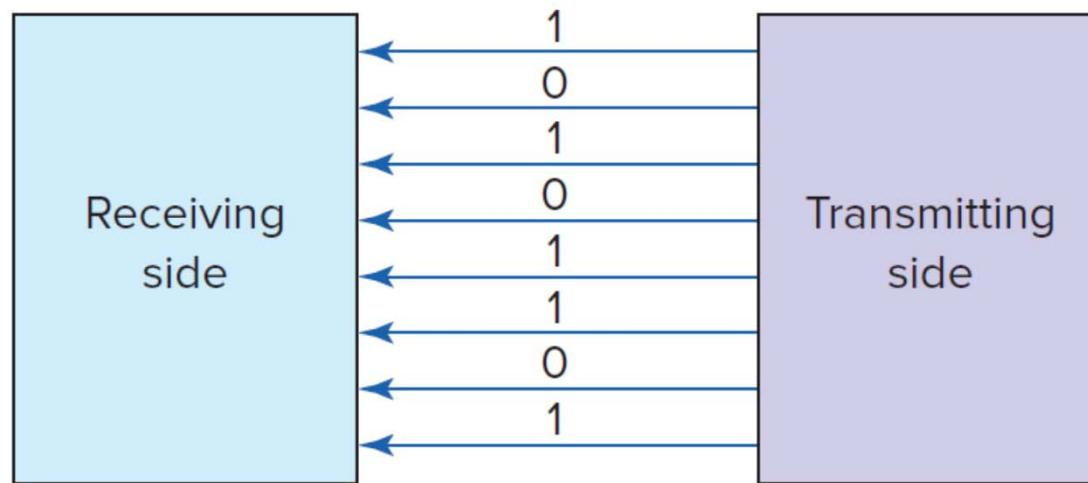
# FTP



## Prijenos podataka



# Paralelan i serijski prijenos podataka

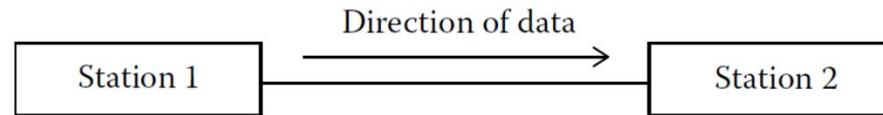


# Paralelan i serijski prijenos podataka

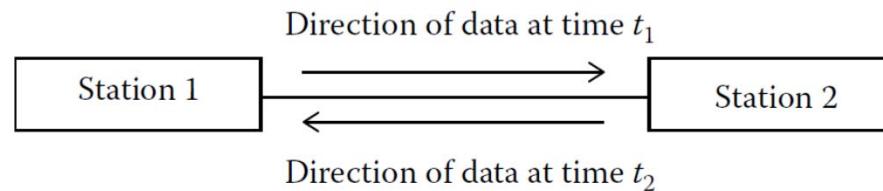
Faktor	Serijski	Paralelni
1. Broj prenesenih bitova u jednom pulsu	1 bit	n bitova
2. Broj potrebnih linija za prijenos n bitova	1 linija	n linija
3. Brzina prijenosa	Sporo	Brzo
4. Cijena prijenosa	Niska – potrebna jedna linija	Visoki – potrebno n linija
5. Primjena	Udaljena komunikacija između dva uređaja	Na malu udaljenost npr. računalo – printer

# Prijenos podataka

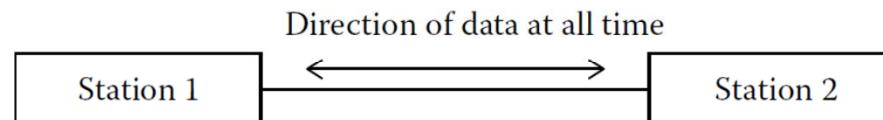
Simplex



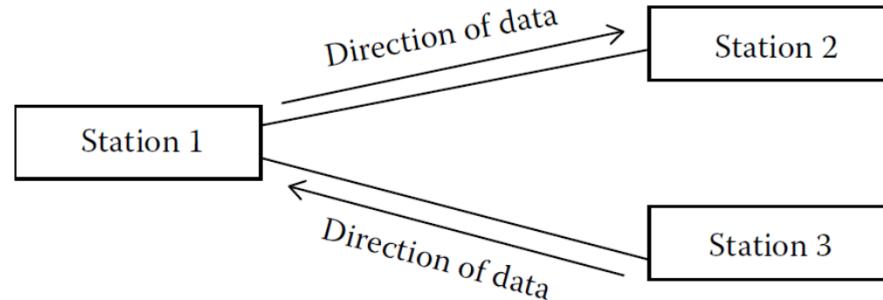
Half-duplex



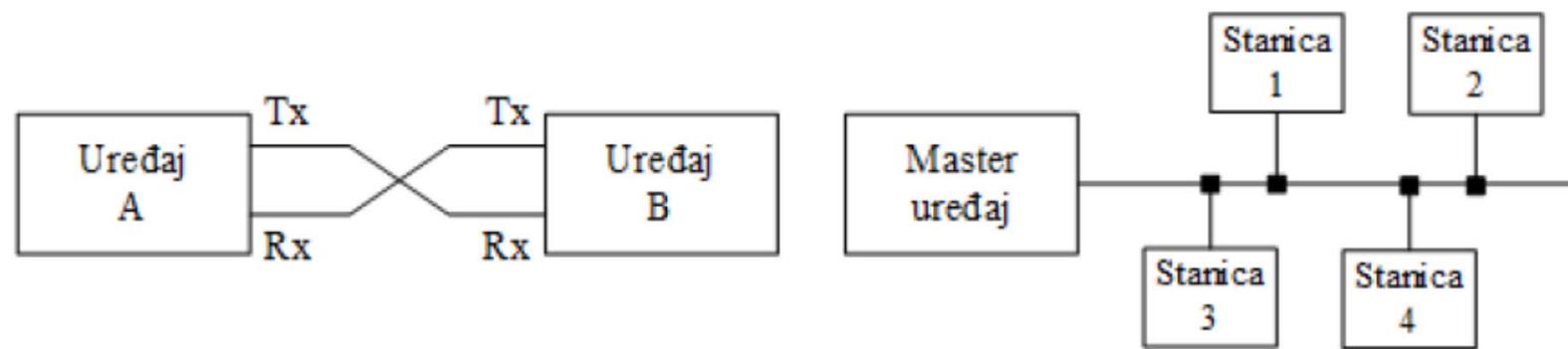
Full duplex



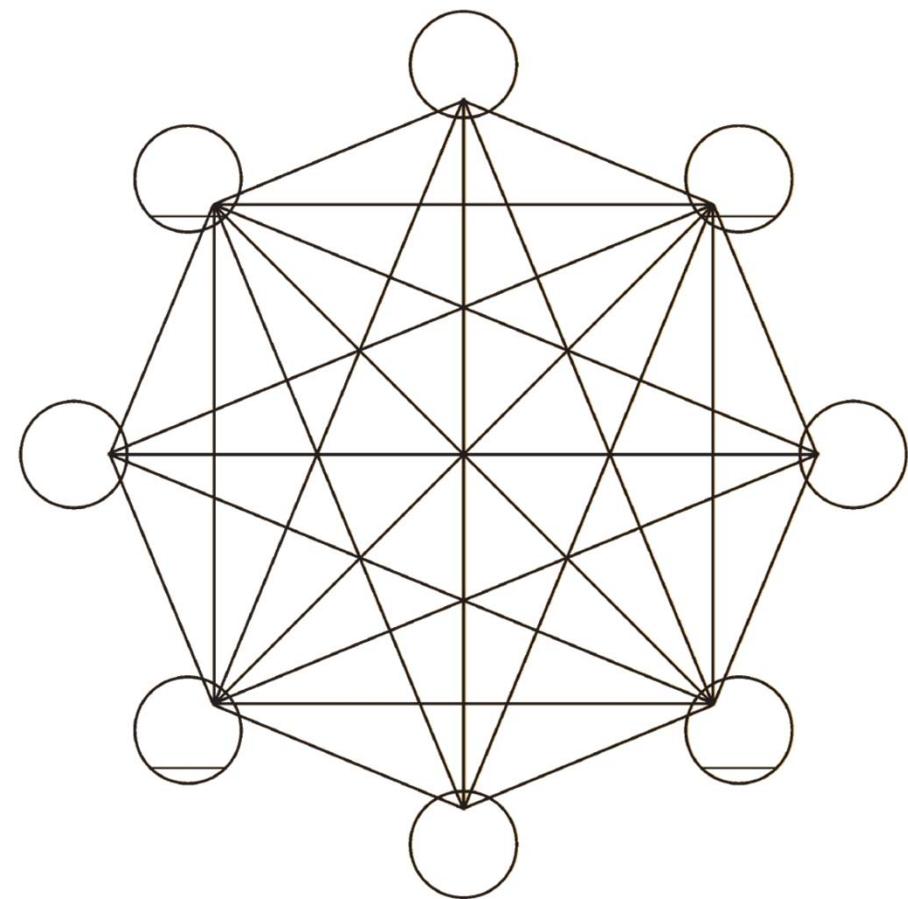
Full/full duplex



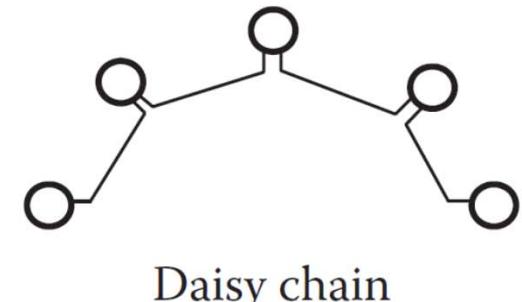
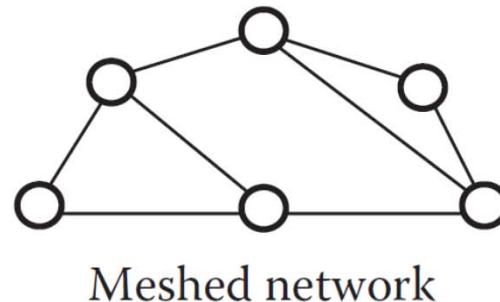
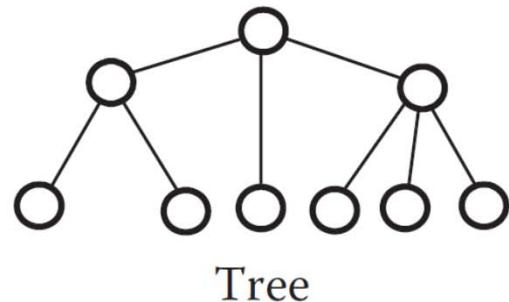
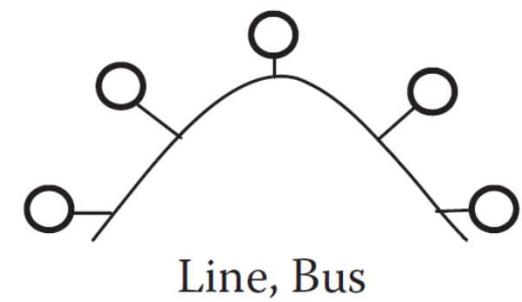
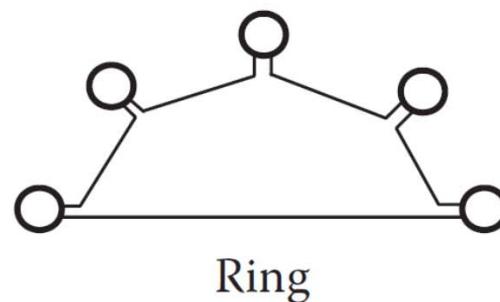
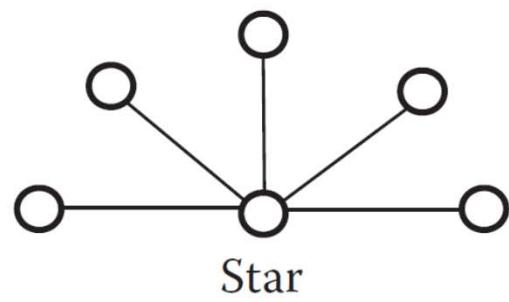
# Prijenos podataka



# Topologija



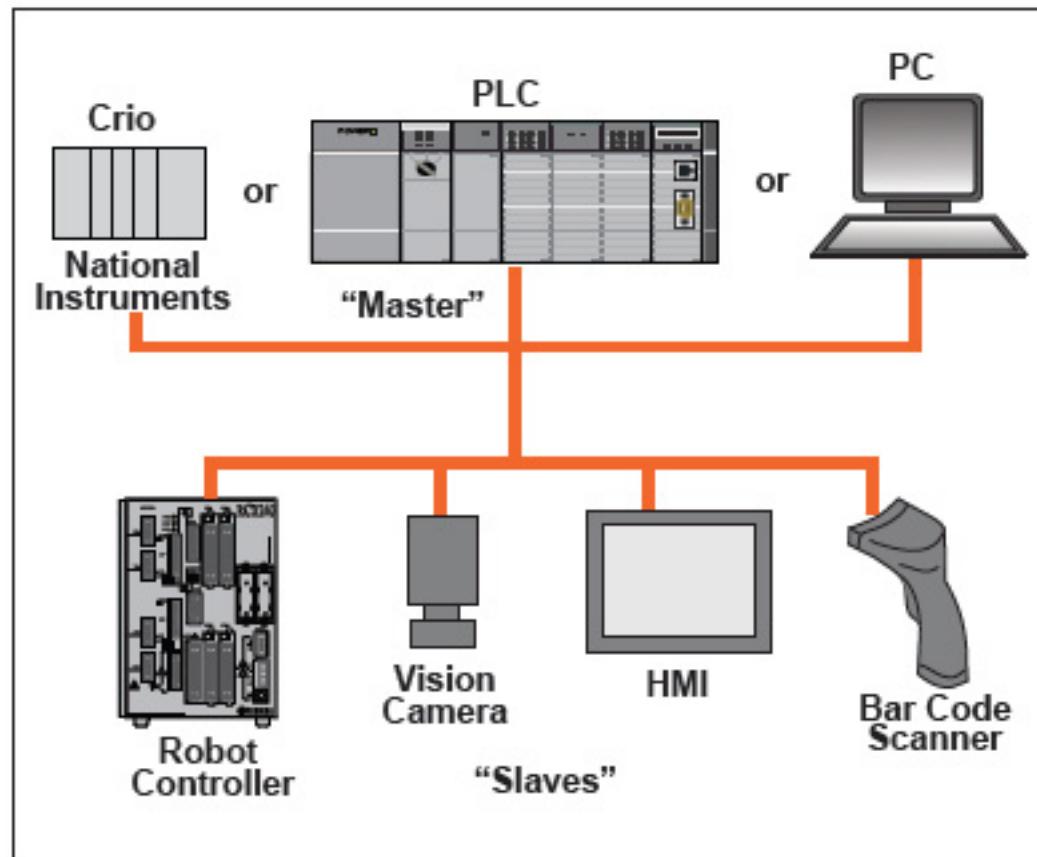
# Topologija



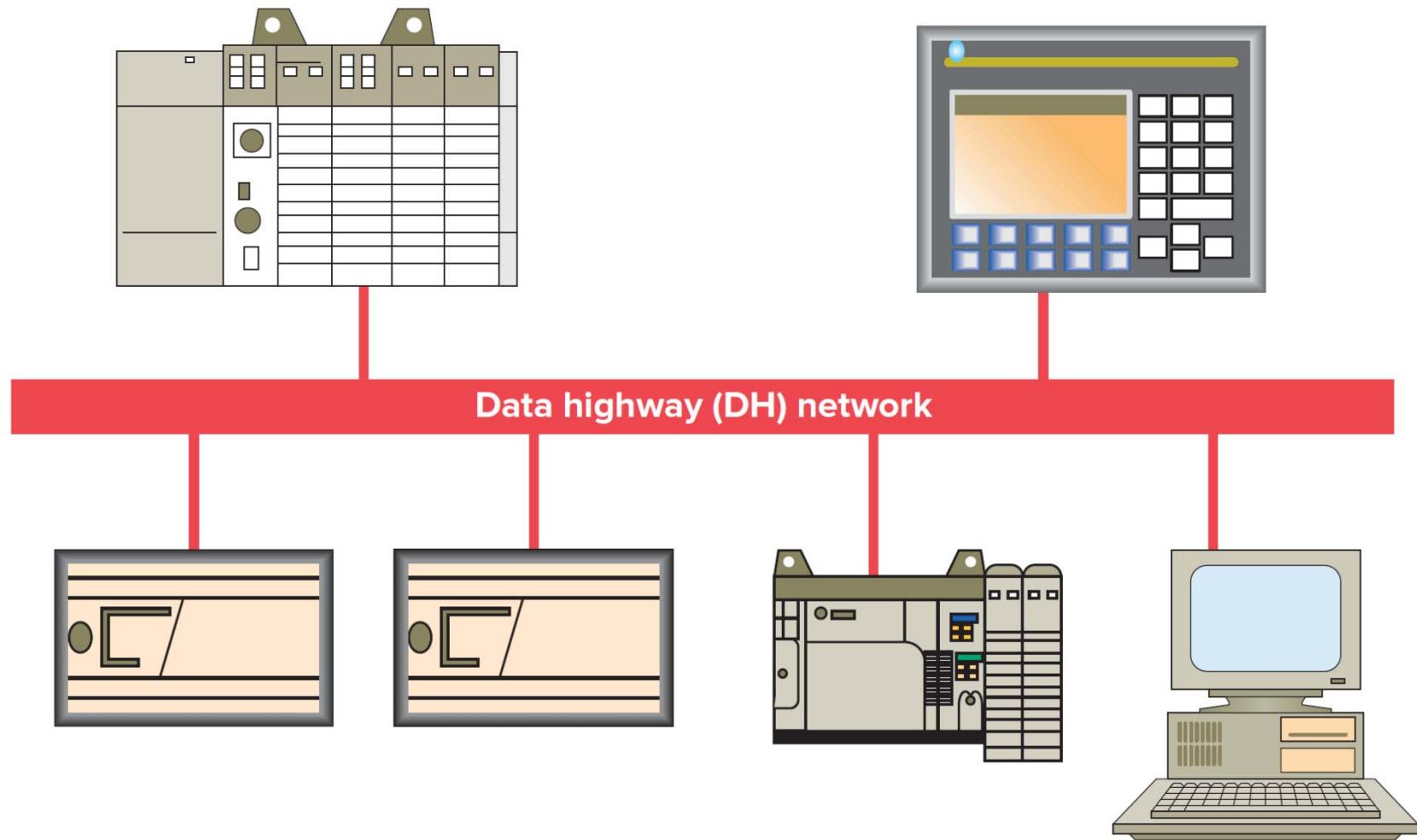
# Metode pristupa

- ▶ Prozivanje (engl. pooling)
- ▶ Token-passing
- ▶ CSMA/CD.

# Master/slave

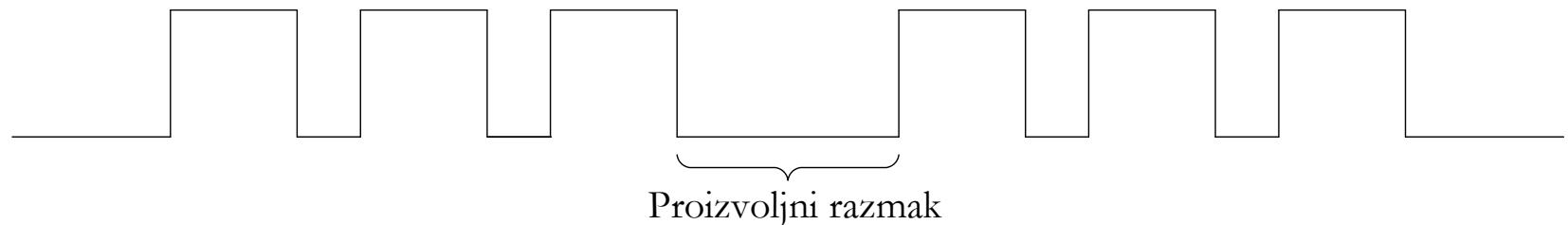


# Peer-to-peer

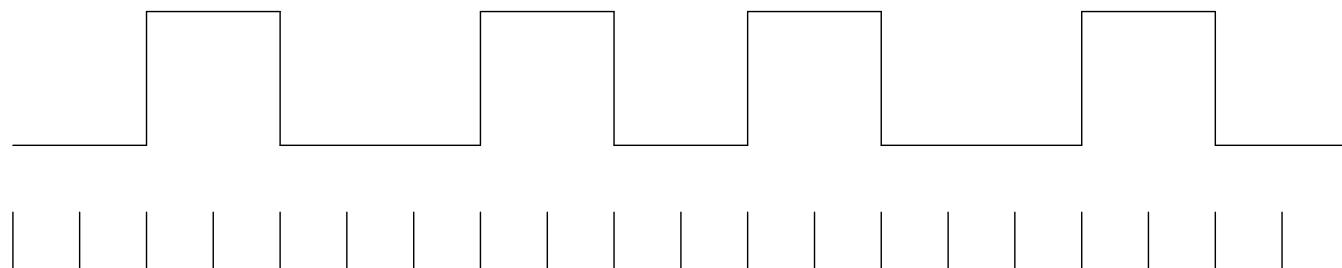


# Prijenosne metode

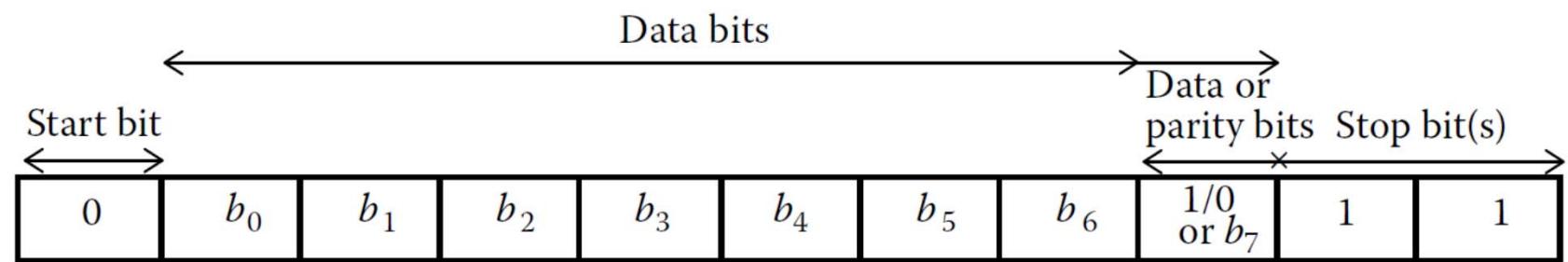
A sinhroni signal



Sinhroni signal

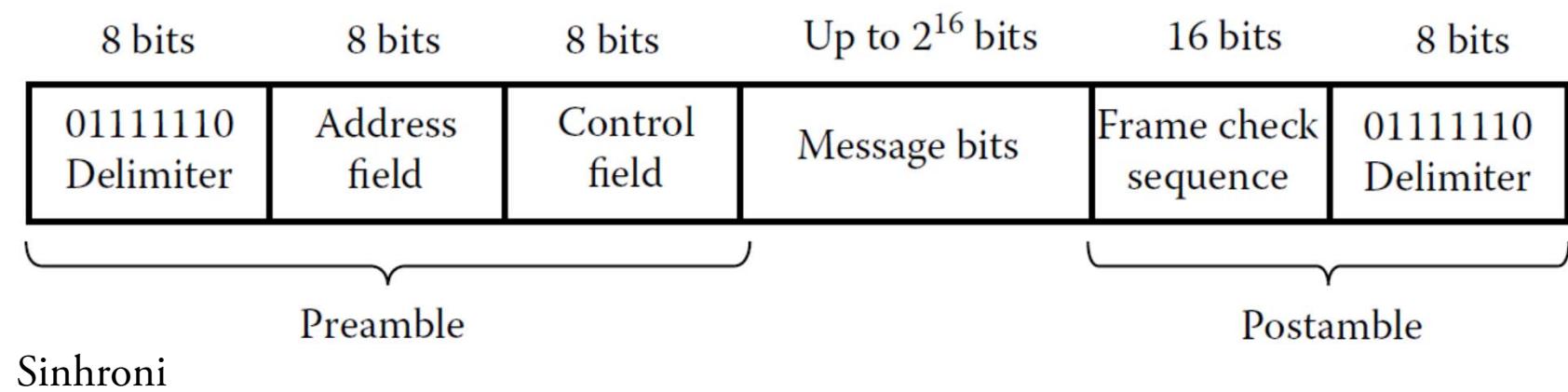


# Prijenosne metode



Asinhroni

# Prijenosne metode



# Prijenosne metode

Primjer: Usporediti prijenos podataka od 10 kB pomoću asinkronog prijenosa i sinkronog prijenosa. Odrediti učinkovitost ( $10 \text{ kB} = 80 \text{ kbit}$ ).

Asinhroni: Dodaje 3 bit-a (1 Start i 2 Stop bit) za svaki preneseni bajt.  
 $80 \text{ kbit} + 30 \text{ kbit} = 110 \text{ kbit}$

$$\text{efikasnost} = \frac{\text{preneseno podataka}}{\text{ukupan broj bitova}} = \frac{80 \text{ kbit}}{110 \text{ kbit}} = 0,7273 \rightarrow 72,73\%$$

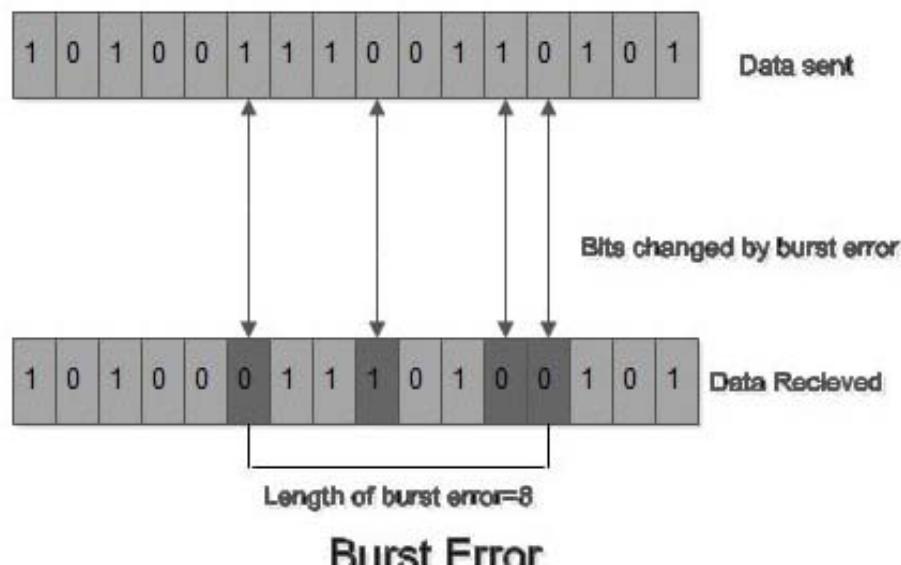
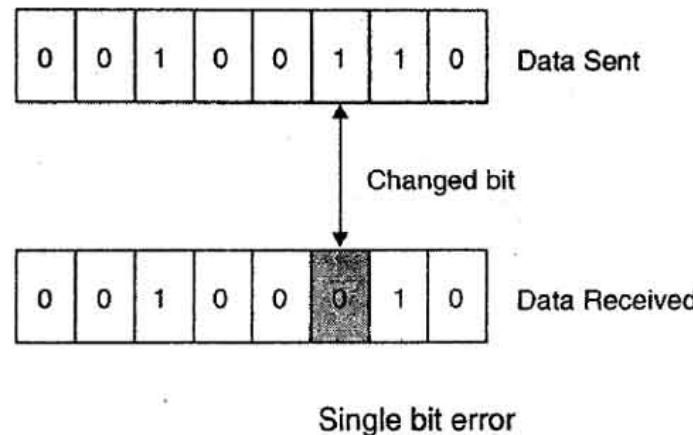
Sinhroni: Dodaje 4 bajta (32 bit) za cijeli 10KB paket podataka.  
 $80 \text{ kbit} + 32 \text{ bits} = 80,032 \text{ kbit}$

$$\text{efikasnost} = \frac{\text{preneseno podataka}}{\text{ukupan broj bitova}} = \frac{80 \text{ kbit}}{80,032 \text{ kbit}} = 0,9996 \rightarrow 99,96\%$$

# Prijenosne metode

	Prednosti	Nedostatci
Asinhroni prijenos	Jednostavno, ne zahtijeva sinkronizaciju obje komunikacijske strane Jeftini, jer asinkroni prijenos zahtijeva manje hardvera Postava je brža od ostalih prijenosa	Visoki udio bitova jedinstveno za kontrolne svrhe i stoga ne donose korisne informacije
Sinhroni prijenos	Veća propusnost	Nešto složenije Hardver je skuplji

# Detekcija greške



# Detekcija greške - provjera pariteta

Parni paritet	$\Sigma '1' = \text{pama}$		Neparni paritet	$\Sigma '1' = \text{neparna}$	
Bitovi podataka	Paritetni bit	$\Sigma '1'$	Bitovi podataka	Paritetni bit	$\Sigma '1'$
01011011	1	6	01011011	0	5
01010011	0	4	01010011	1	5

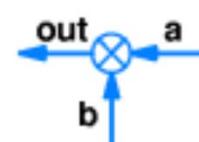
# Detekcija greške - provjera sume

H	e	I	I	o	w	o	r	I	d	.
48	65	6C	6C	6F	20	77	6F	72	6C	64 2E

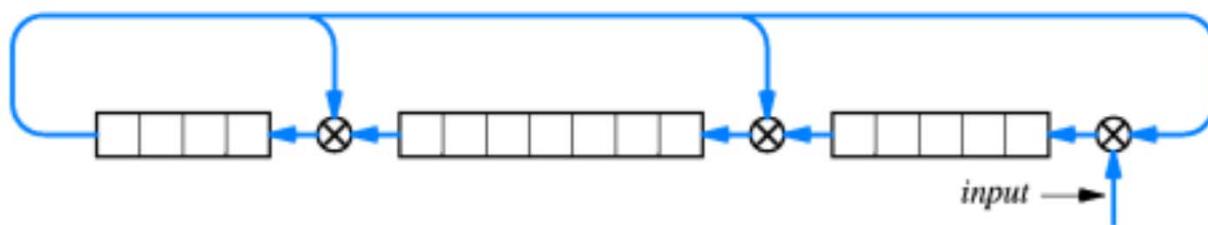
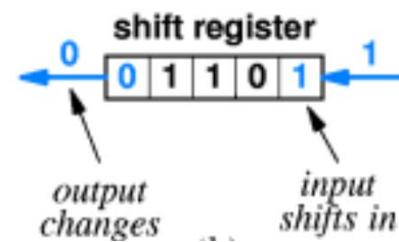
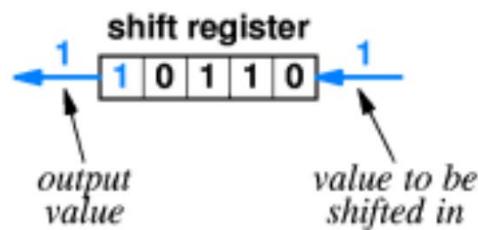
$$4865 + 6C6C + 6F20 + 776F + 726C + 642E + \text{carry} = 71FC$$

Data Item In Binary	Checksum Value	Data Item In Binary	Checksum Value
0001	1	0011	3
0010	2	0000	0
0011	3	0001	1
0001	1	0011	3
totals	7		7

# Detekcija greške - ciklička kontrola pogrešaka



a	b	out
0	0	0
0	1	1
1	0	1
1	1	0



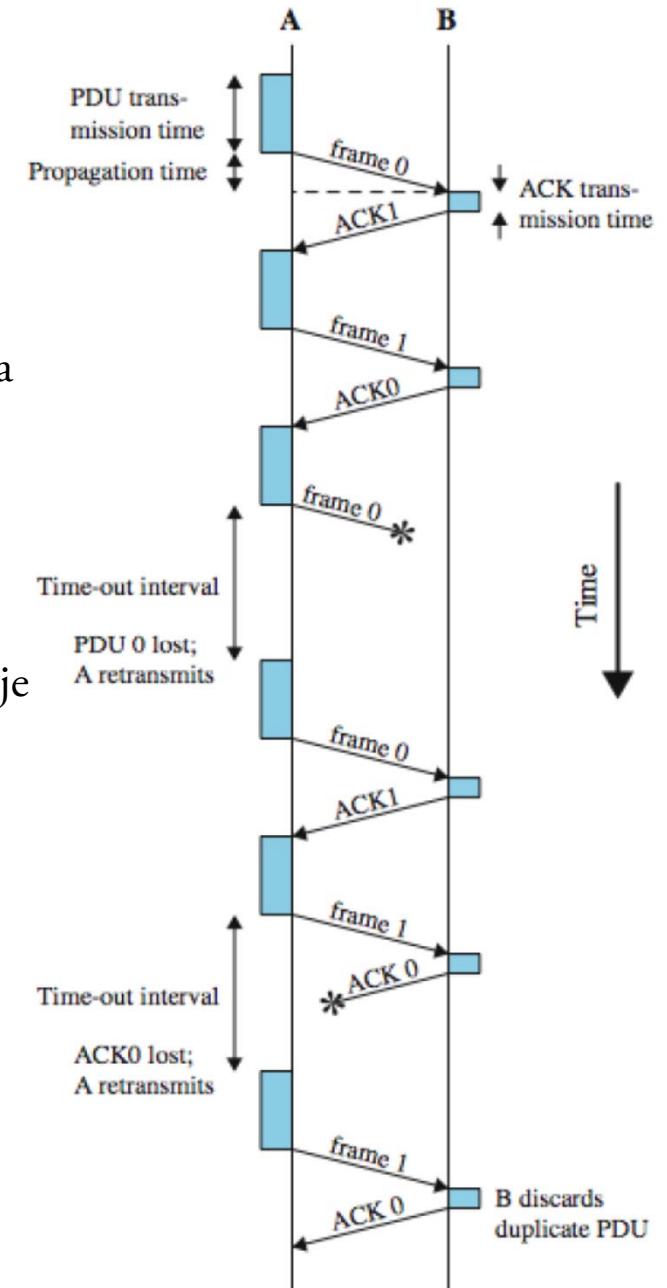
# Upravljanje pogreškom

- ▶ Dvije vrste pogrešaka

- Izgubljeni okvir - nikada ne stigne ili je previše pogrešaka
- Oštećeni okvir - pogreška u bitovima, ali prepoznatljiva

- ▶ Tehnike uključuju

- Otkrivanje pogrešaka (npr. CRC)
- Pozitivna potvrda - ako nema pogrešaka
- Ponovno slanje nakon vremenskog ograničenja - nije primljen ACK
- Negativna potvrda i ponovni prijenos



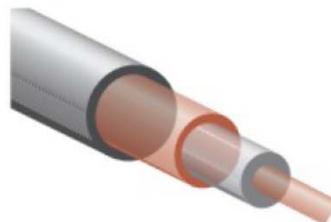
# Mrežna oprema

- ▶ Obnavljač (engl. Repeater)
- ▶ Usmjerivač (engl. Router)
- ▶ Premosnik (engl. Bridge)
- ▶ Poveznik (engl. Gateway)
- ▶ Koncentrator (engl. Hub)
- ▶ Preklopnik (engl. Switch)
- ▶ Pretvornik za medij (engl. Media Converter)

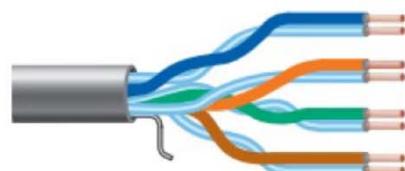
# Mediji za prijenos podataka - mjere za performanse

- ▶ Kašnjenje (delay, latency ) – mjeri se u vremenskim jedinicama.
- ▶ Propusnost (throughput) – mjeri se u bitovima po vremenskoj jedinici.
  - Propusnost mjeri stvarnu količinu podataka koji se mogu slati u jedinici vremena.
  - Širina pojasa daje teorijsku gornju granicu za propusnost koju postavlja sam fizički medij.

# Mediji za prijenos podataka



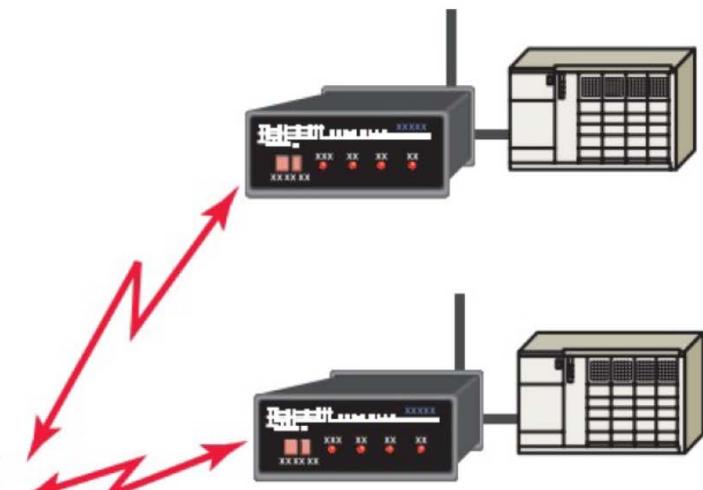
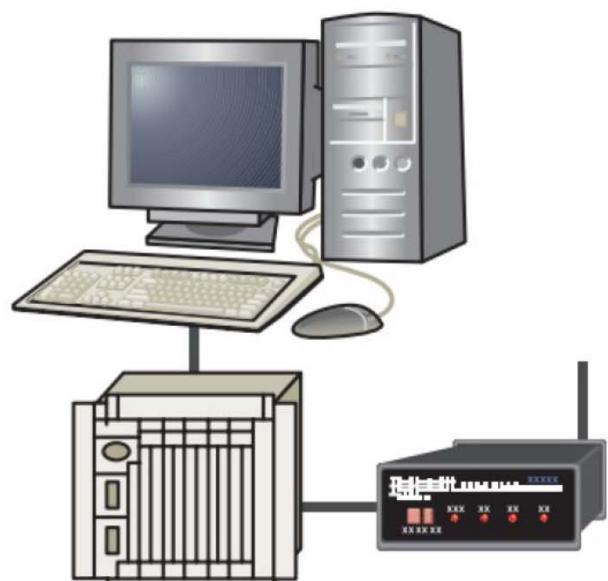
Coaxial



Twisted pair

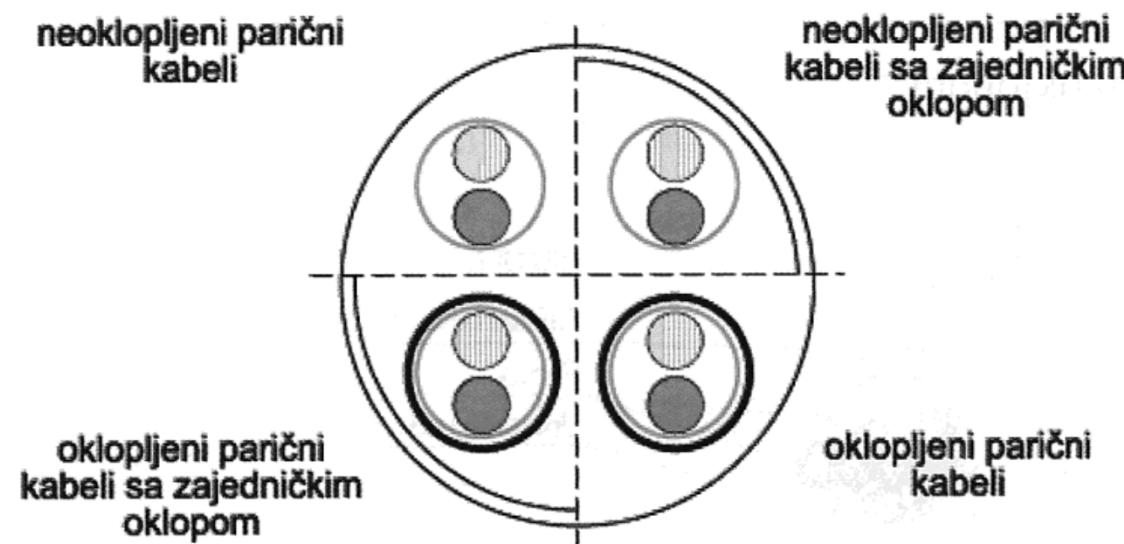


Fiber optic



Wireless system

# Parica



XX/XXX

Oklapanje snopa:

U = neoklopljeno  
F = oklopljeno folijom  
S = oklopljeno pletenicom  
SF = oklopljeno pletenicom i folijom

Kabelski element:

TP = upletena parica  
Q = upletena četvorka

Oklapanje elementa:

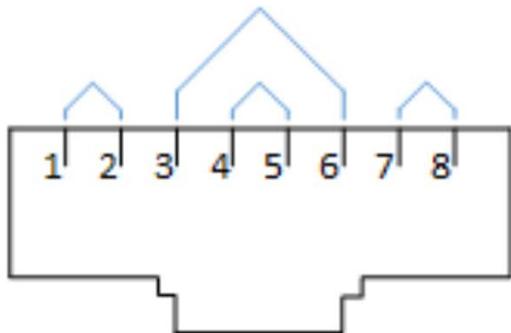
U = neoklopljeno  
F = oklopljeno folijom

# Parica

KATEGORIJA	FREKV. OPSEG	PRIMJENA
1*	1 MHz	Analogni prijenos
2*	4 MHz	Analogni i digitalni prijenos
3	16 MHz	Token Ring 4 Mbit/s, 10Base-T, 100Base-T4
4	20 MHz	LAN
5	100 MHz	Token Ring 16 Mbit/s, Token Ring 100 Mbit/s, ATM 25 Mbit/s, ATM 155 Mbit/s, 100Base-TX, 1000Base-T
5e	100 MHz	LAN (poboljšana kategorija 5, stroži zahtjevi u pogledu preslušavanja i slabljenja )
6	250 MHz	1000Base-TX, ATM LAN 1200 Mbit/s
6A	500 MHz	10Gbase-T
7	650 MHz	1000Base-TX2
7A	1000 MHz	10Gbase-T, Broadband CATV

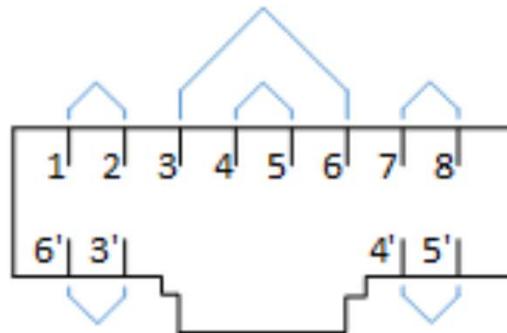
\*A – Augmented (proširen), Kategorija 1 i 2 se više ne koristi

# Parica



RJ-45

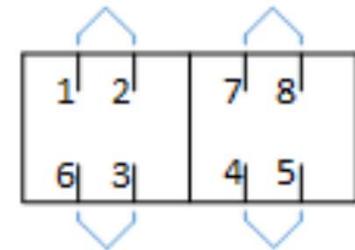
EN 60603-7



RJ-45

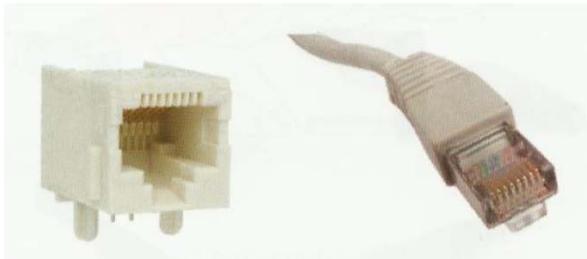
EN 60603-7-7

za kat.7 izvodi 3',4',5' i 6'  
za kat5 i 6 izvodi 3,4,5 i 6



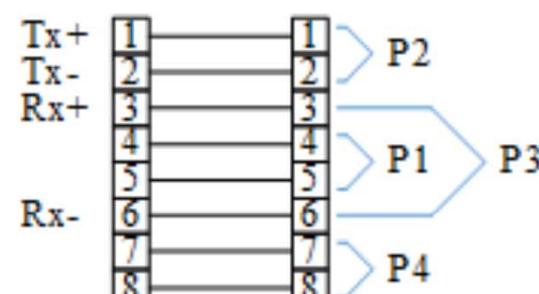
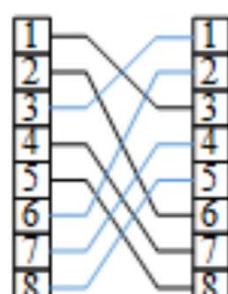
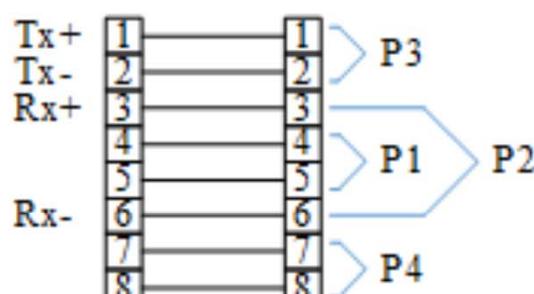
TERA

EN 61076-3-104



# Parica

IZVOD NA RJ-45	VODIČ U 4-PARIČNOM KABELU	
	T568A	T568B
1	Bijelo / zelena	Bijelo / narančasta
2	Zelena	Narančasta
3	Bijelo / narančasta	Bijelo / zelena
4	Plava	Plava
5	Bijelo / plava	Bijelo / plava
6	Narančasta	Zelena
7	Bijelo / smeđa	Bijelo / smeđa
8	Smeđa	Smeđa



# Parica

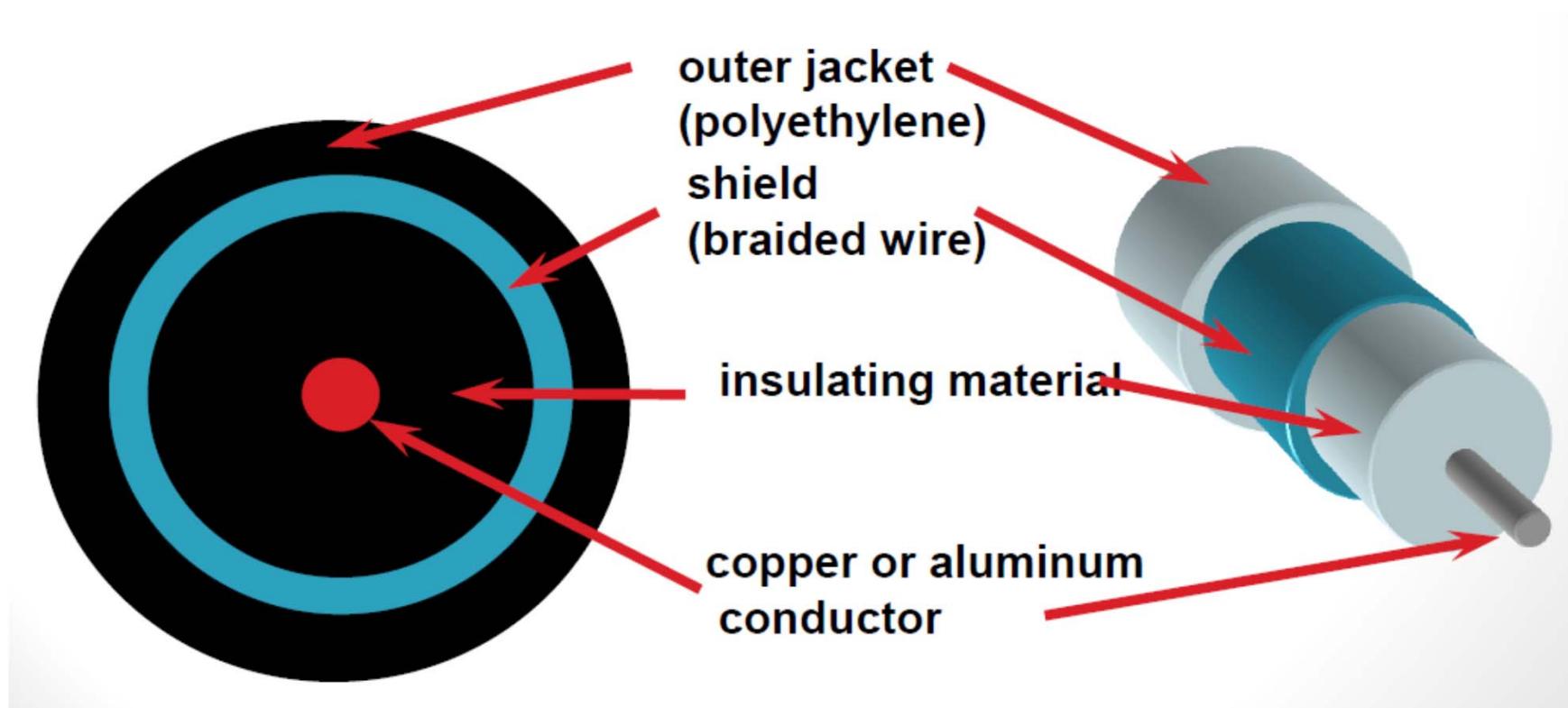


- jeftino i lako dostupno
- fleksibilnost, male težine
- jednostavan za instalaciju



- osjetljivost na smetnje i buke
- problem slabljenja
  - analogni, ponavljači potrebni svakih 5-6 km
  - digitalni, ponavljači potrebni svaka 2-3 km
- relativno niske propusnosti (100 MHz)

# Koaksijalni kabel



# Koaksijalni kabel

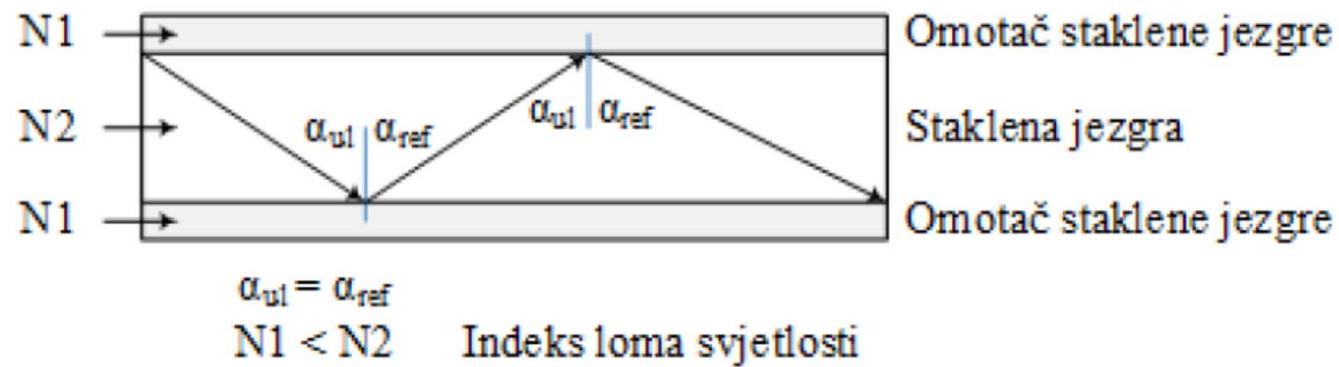


- veća propusnost
- 400 do 600 MHz
- jednostavno spajanje (prednosti i mane)
- mnogo manje osjetljiv na smetnje od parica



- visoka stopa prigušenja, skupo na velike udaljenosti - više ponavljača - posebno za digitalno na većim brzinama prijenosa
- ponavljači potrebni svaka 2-3 km
- glomazan

# Optičko vlakno



# Optičko vlakno



FC konektor



ST konektor



SC konektor



LC konektor



FDDI konektor

# Optičko vlakno



- veći kapacitet (stotine Gbps)
- manja veličina i manja težina
- malo slabljenje
- otpornost na smetnje okoliša
- veći razmak repetitora - desetci KM
- vrlo sigurno zbog poteškoće pri spajanju i nedostatka zračenja signala



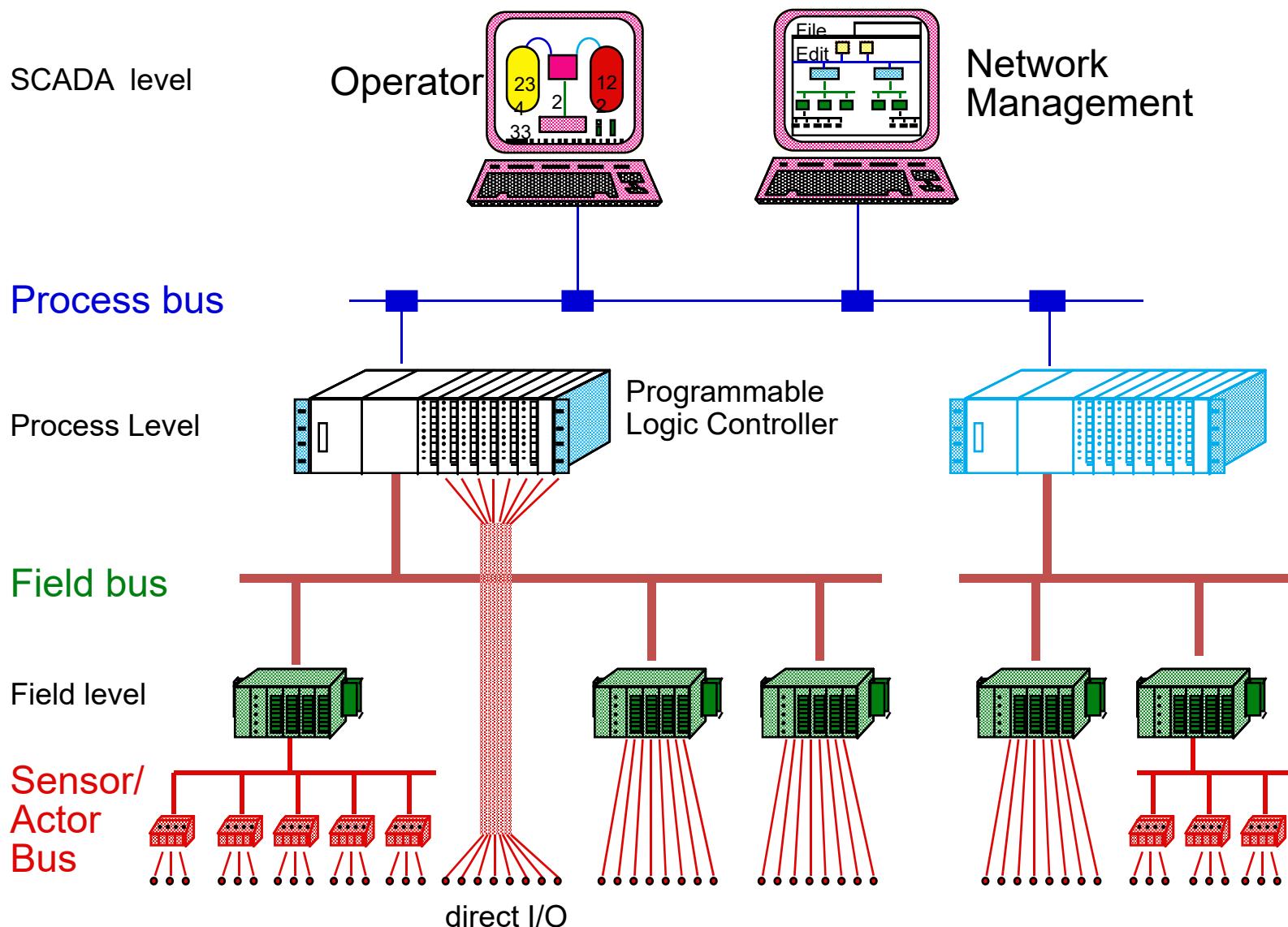
- skupi preko kratke udaljenosti
- zahtijeva kvalificirane instalatere
- dodavanje dodatnih čvorova je teško

# Usporedba

Medij	Brzina - Mbps	Propusnost - MHz	Ponavljači - km
Parica	100	3,5	2-6
Koaksijalni kabel	500	500	1-10
Optičko vlakno	200000	200000	10-50

# Bežični prijenos

- ▶ Radio valovi
- ▶ Infracrvene zrake
- ▶ Laserske zrake



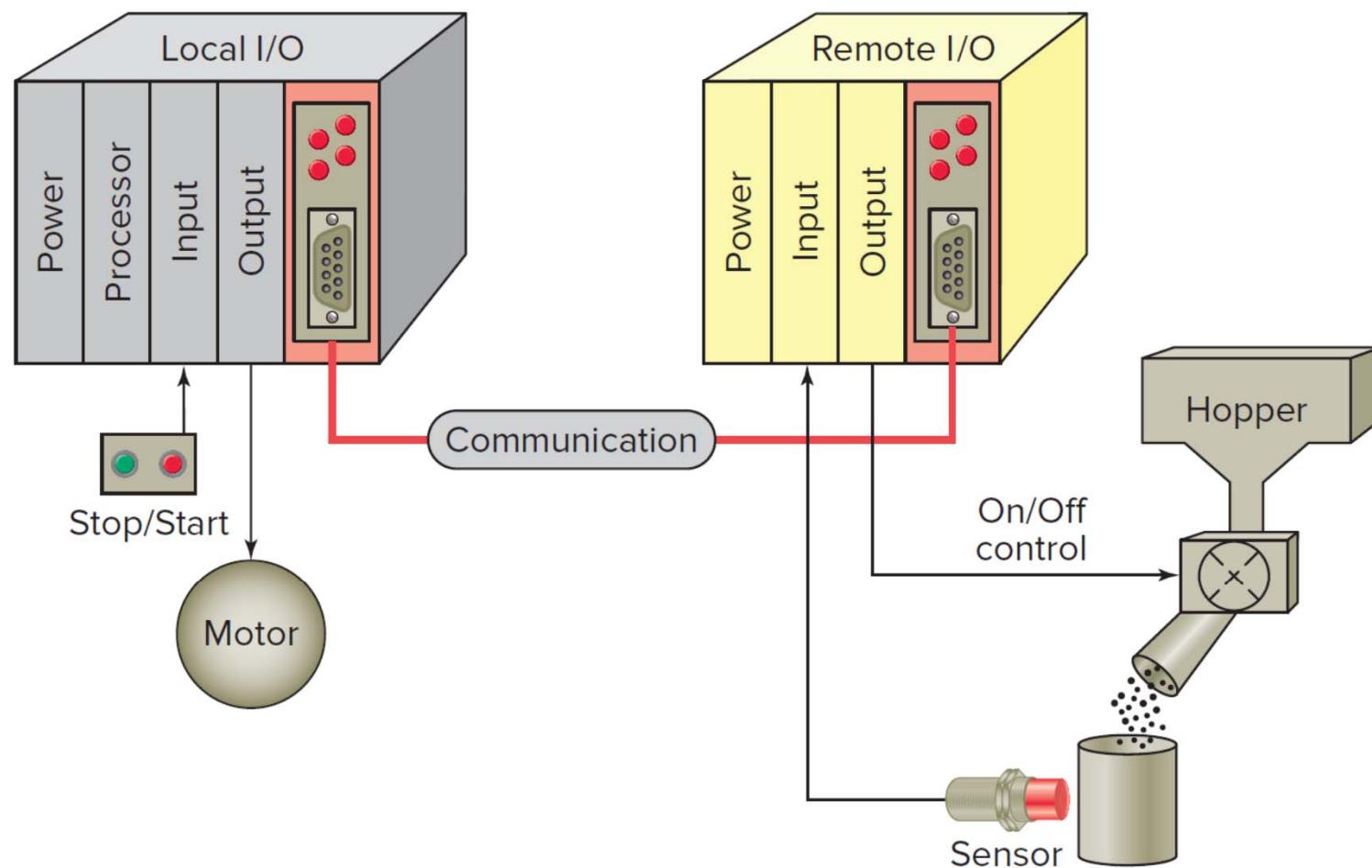


# INDUSTRIJSKE RAČUNALNE MREŽE



dr. sc. Bojan Šekoranja  
Fakultet strojarstva i brodogradnje

# Dislocirano upravljanje



# Komunikacija

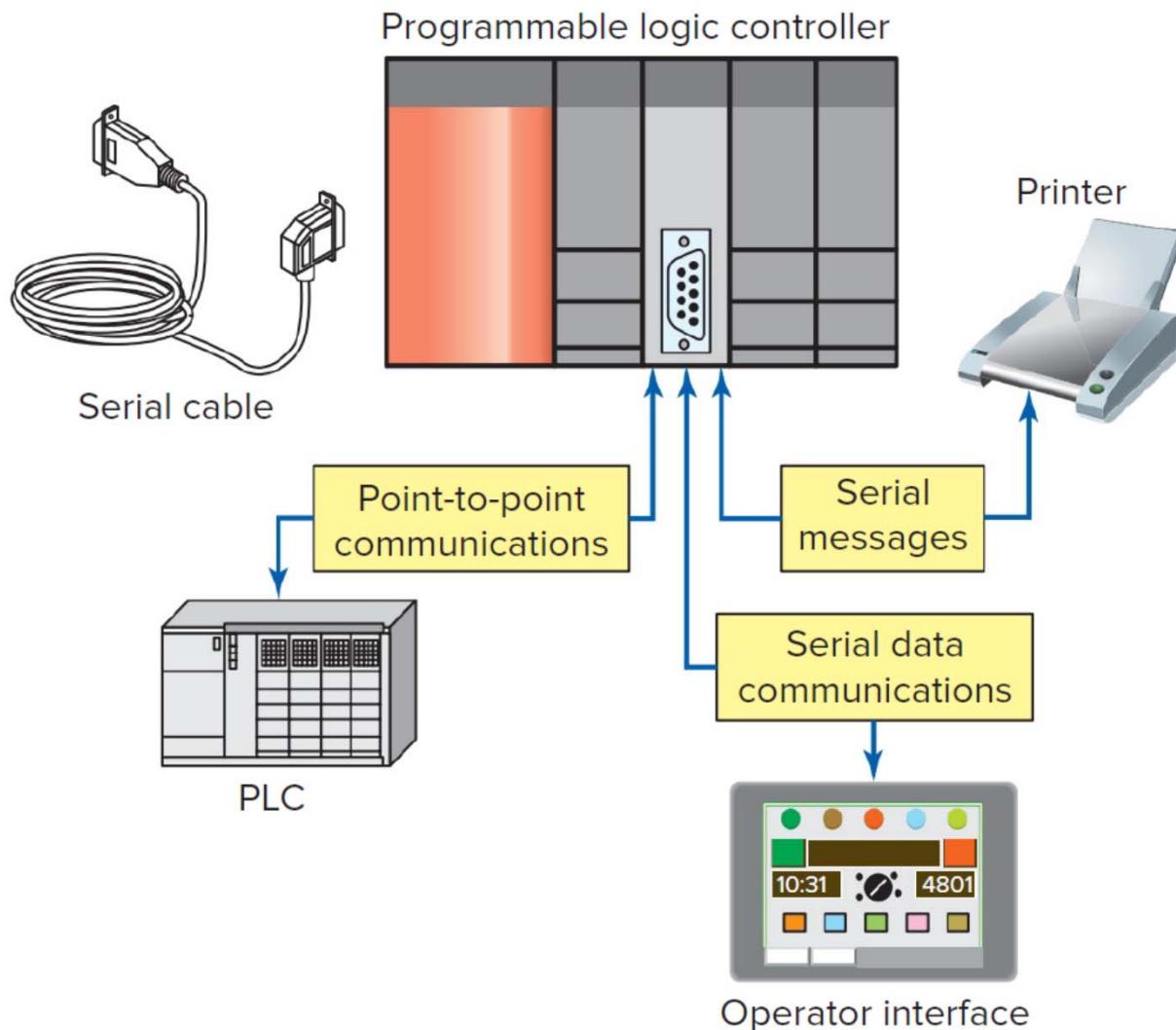


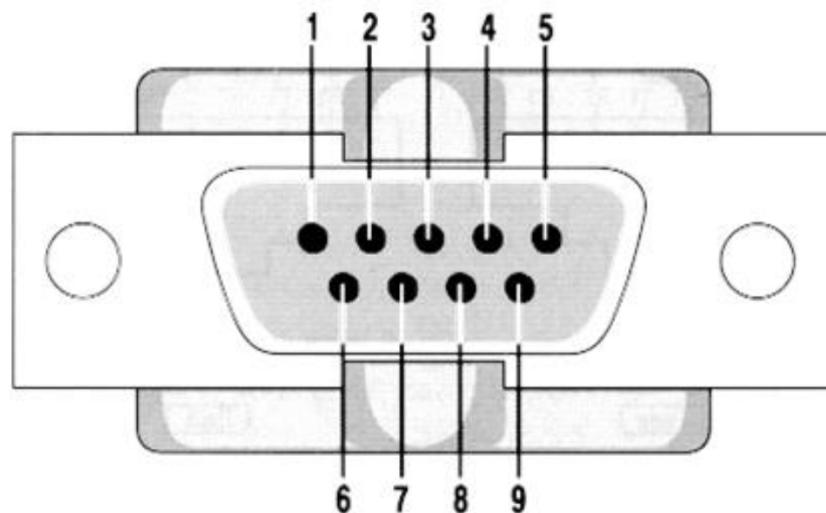
Serial Port Module



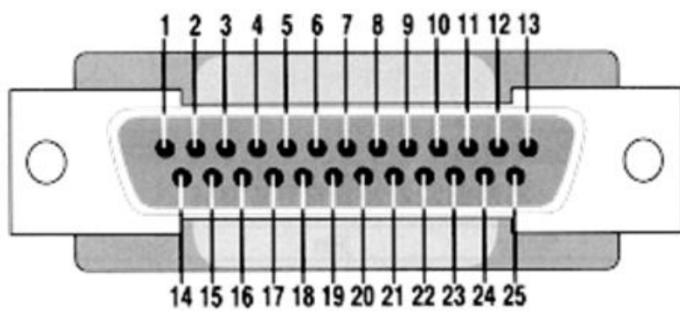
Ethernet Module

# Serijska





PIN BR.	DB-9 SIGNAL	OPIS - NAMJENA
1	DCD	Signalizacija uspostave veze
2	RxD	Prijem podataka
3	TxD	Slanje podataka
4	DTR	DTE uređaj spreman za rad
5	GND	Masa signala
6	DSR	DCE uređaj spreman za rad
7	RTS	Zahtjev za slanje podataka
8	CTS	Uredaj spreman za prijem podataka
9	RI	Signalizacija zvonjenja



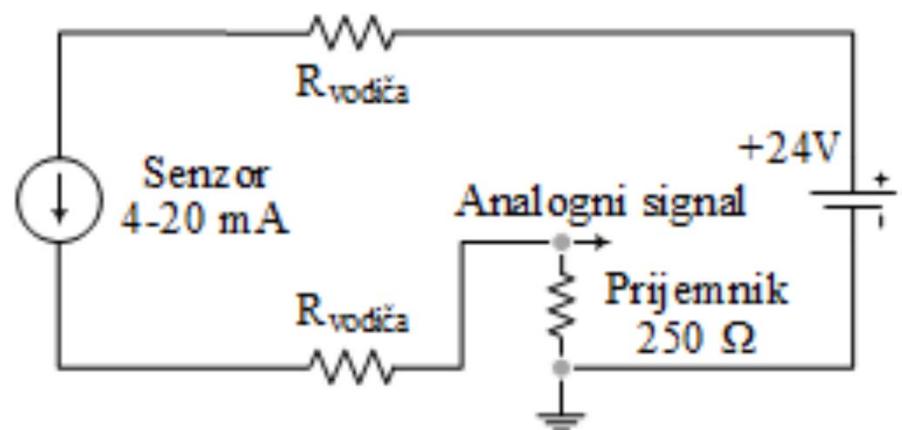
PIN BR.	DB-25 SIGNAL	OPIS - NAMJENA
1	PG	Zaštitno uzemljenje
2	TxD	Slanje podataka
3	RxD	Prijem podataka
4	RTS	Zahtjev za slanje podataka
5	CTS	Uređaj spreman za prijem podataka
6	DSR	DCE uređaj spreman za rad
7	GND	Masa signala
8	DCD	Signalizacija uspostave veze
9*		Priklučak za potrebe testiranja
10*		Priklučak za potrebe testiranja
11		
12*	DCD	Signalizacija uspostave veze
13*	CTS	Uređaj spreman za prijem podataka
14*	TxD	Slanje podataka
15*		Signal takta predajnika (DCE)
16*	RxD	Prijem podataka
17*		Signal takta prijemnika
18		
19*	RTS	Zahtjev za slanje podataka
20	DTR	DTE uređaj spreman za rad
21*		Detekcija kvalitete signala
22	RI	Signalizacija zvonjenja
23*		Detekcija brzine prijenosa podataka
24*		Signal takta predajnika (DTE)
25		

\*Sekundarne linije

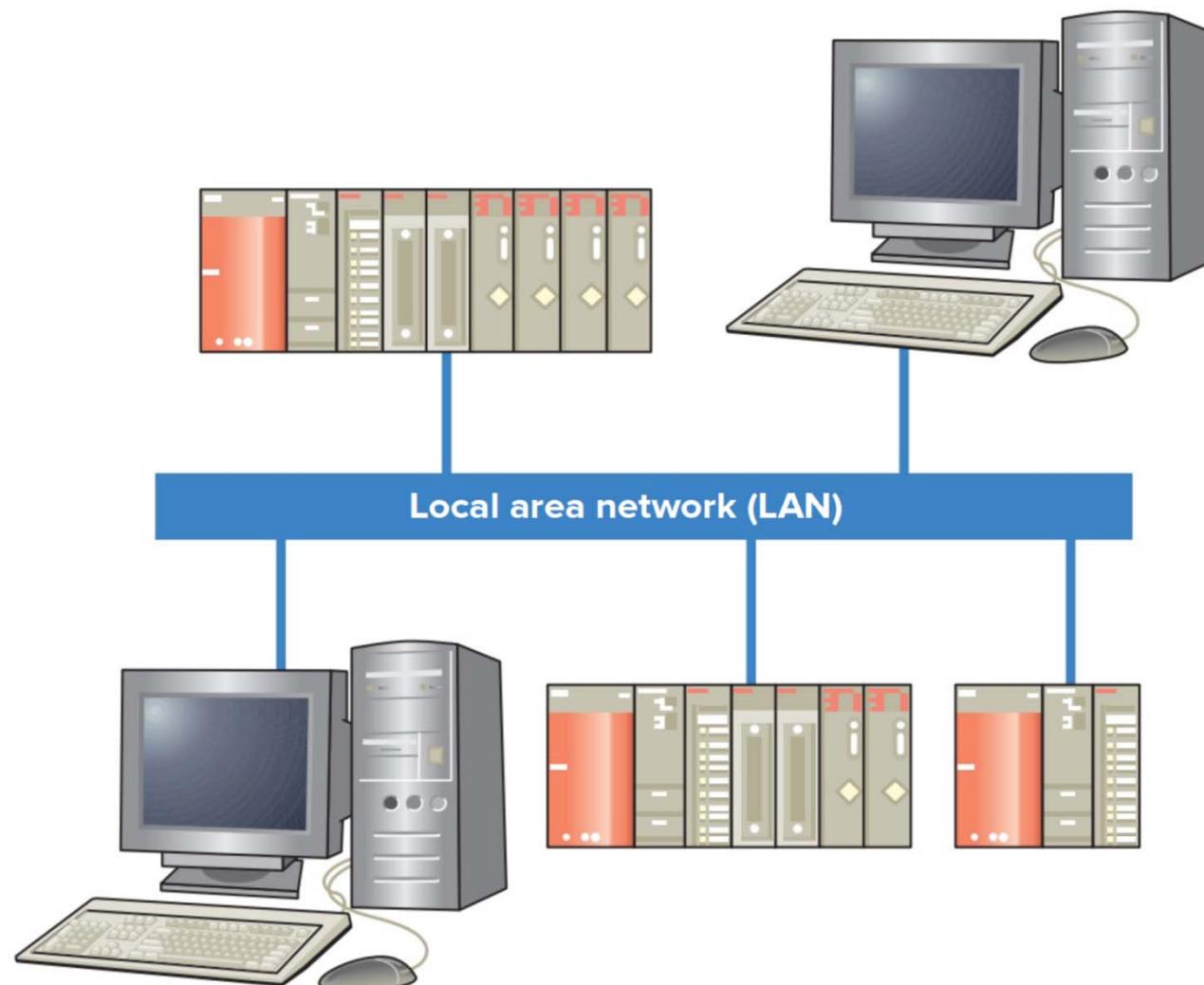
## RS-232 i RS-485

	<b>RS-232</b>	<b>RS-485</b>
Mode of Operation	SINGLE-ENDED	DIFFERENTIAL
Total Number of Drivers and Receivers on One Line	1 DRIVER 1 RECEIVER	32 DRIVER 32 RECEIVER
Maximum Cable Length	50 FEET	4000 FEET
Maximum Data Rate @Max length	20kb/s	100kb/s
Driver Output Signal Level (Loaded Min.)	Loaded	+/-5V to +/15V
Driver Output Signal Level (Unloaded Max)	Unloaded	+/-25V
Driver Load Impedance		3kΩ to 7kΩ
Max. Driver Current in High Z State	Power On	N/A
Max. Driver Current in High Z State	Power Off	+/-6mA @ +/-2v
Slew Rate (Max.)		30V/µS
Receiver Input Voltage Range	+/-15V	-7V to +12V
Receiver Input Sensitivity	+/-3V	+/-200mV
Receiver Input Resistance	3kΩ to 7kΩ	≥ 12kΩ

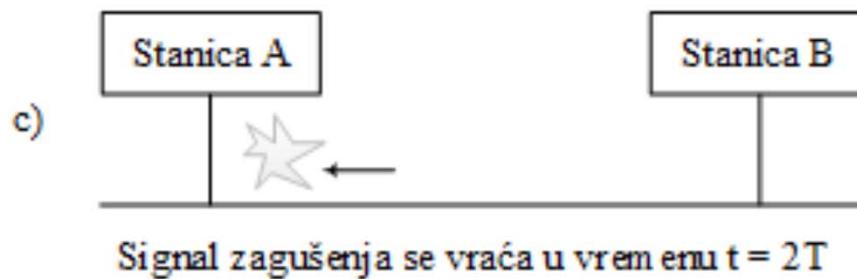
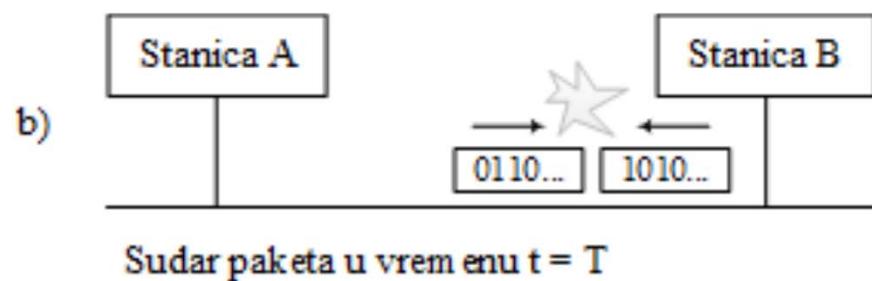
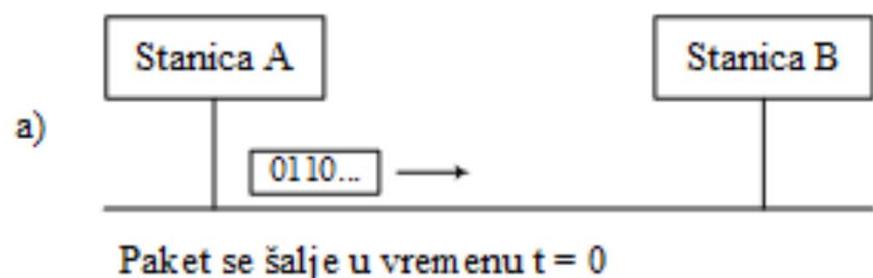
## Analogna strujna petlja 4-20 mA



# Ethernet



# CSMA/CD protokol



## Ethernet - struktura

Preambula	SFD	Odredišna adresa	Izvorišna adresa	Duljina/tip podataka	LLC/Podaci	Provjera greške (CRC)
7 bajta	1 bajt	6 bajta	6 bajta	2 bajta	1500 bajtova	4 bajta

## Adresiranje

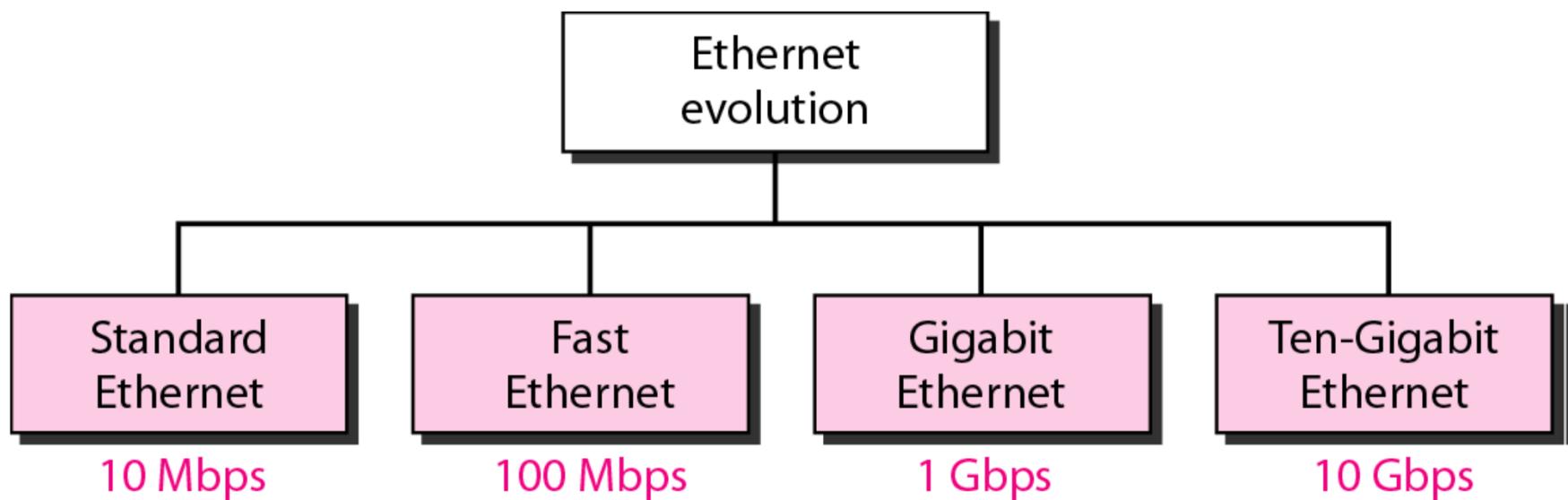
B0-48-7A-93-F2-1E

B0:48:7A:93:F2:1E

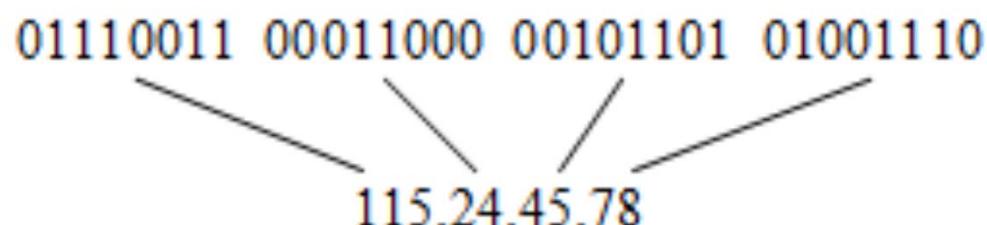
B048.7A93 F21E

6 bajta = 12 hex znamenki = 48 bita

# Ethernet standardi



# IP Adresiranje



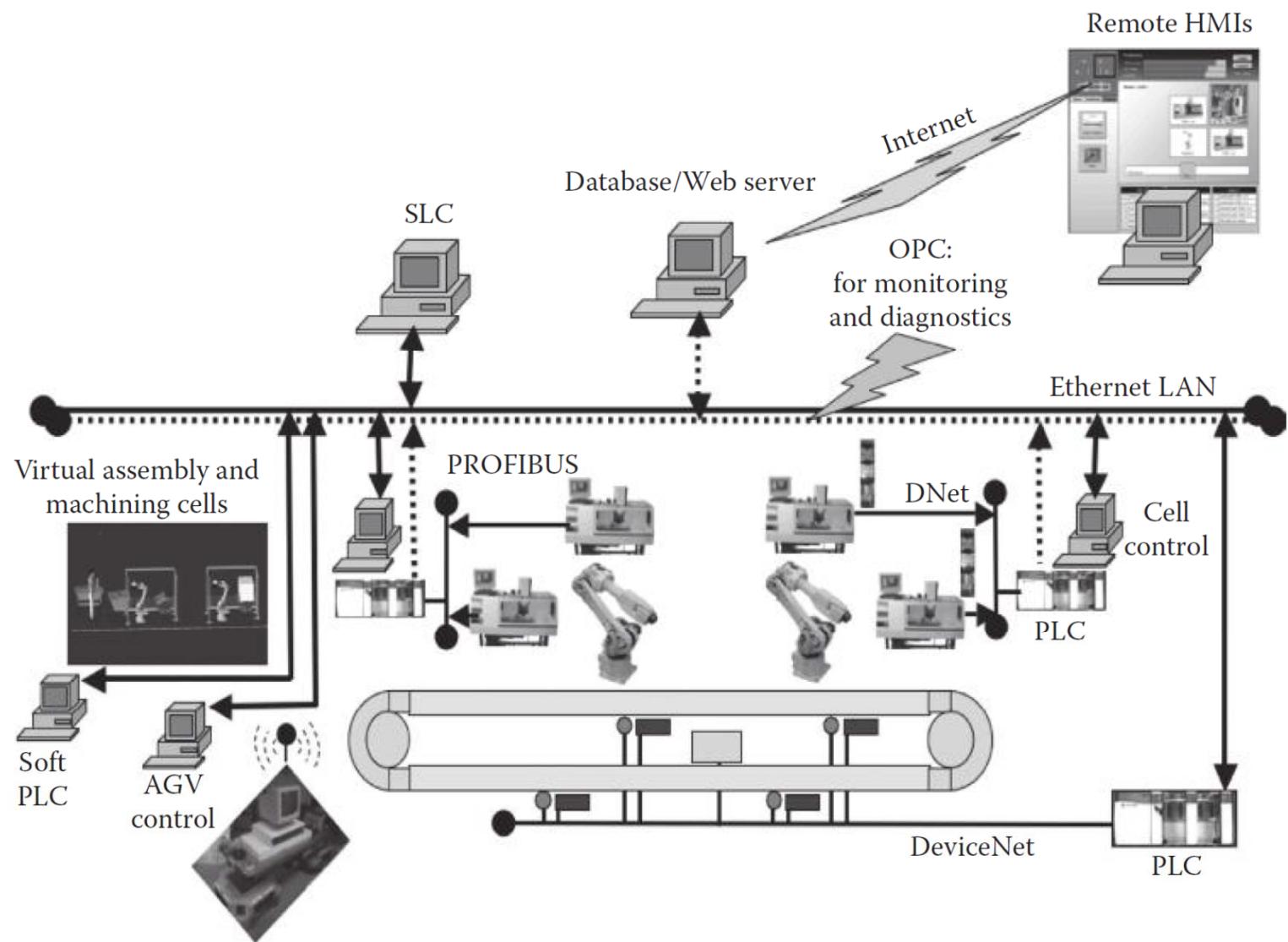
	1. bajt	2. bajt	3. bajt	4. bajt
Klasa A	0			
Klasa B	10			
Klasa C	110			
Klasa D	1110			
Klasa E	1111			

	1. bajt	2. bajt	3. bajt	4. bajt
Klasa A	0-127			
Klasa B	128-191			
Klasa C	192-223			
Klasa D	224-239			
Klasa E	240-255			

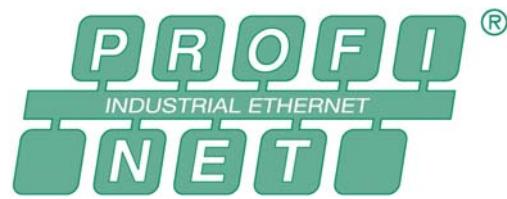
# IP Adresiranje

KLASA	IP ADRESE	PREFIKS
A	10.0.0.0. – 10.255.255.255.	/8
B	172.16.0.0. – 172.31.255.255.	/12
C	192.168.0.0. – 192.168.255.255.	/16

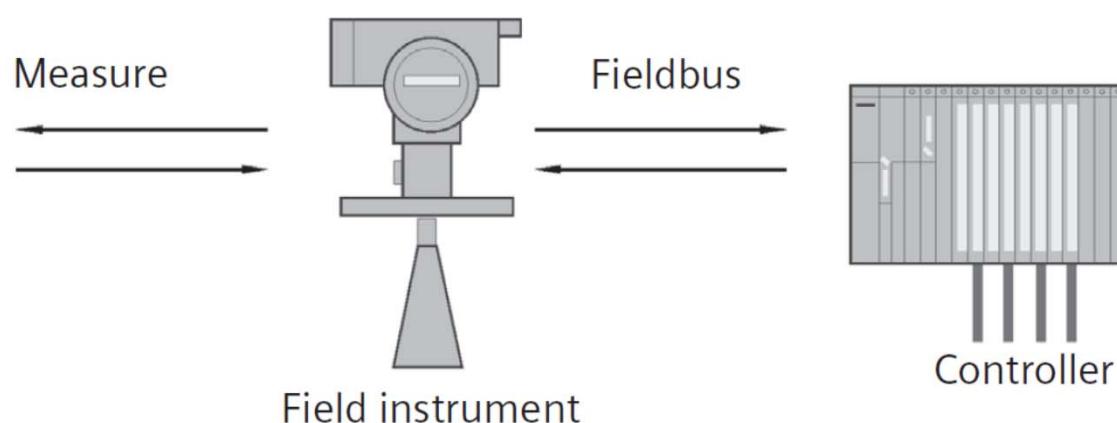
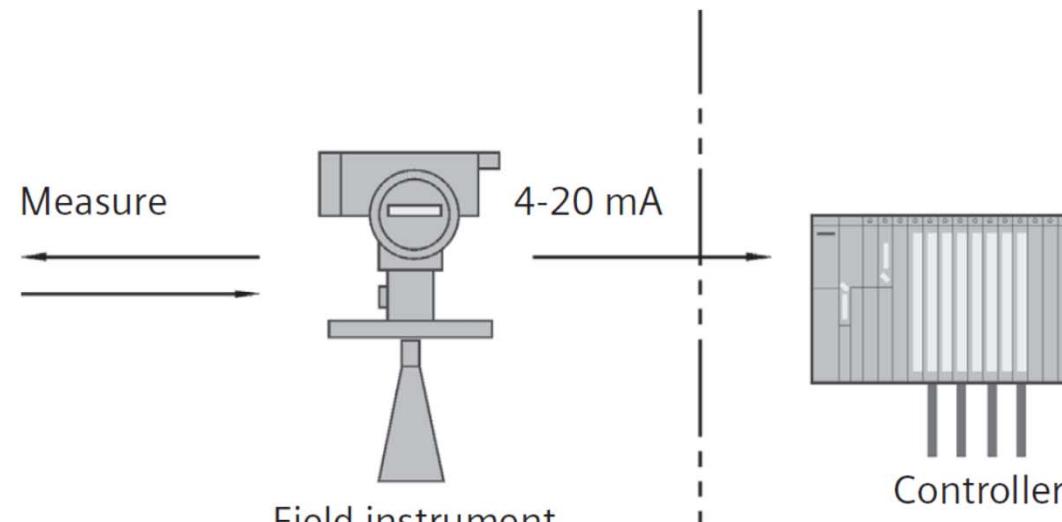
# Komunikacija



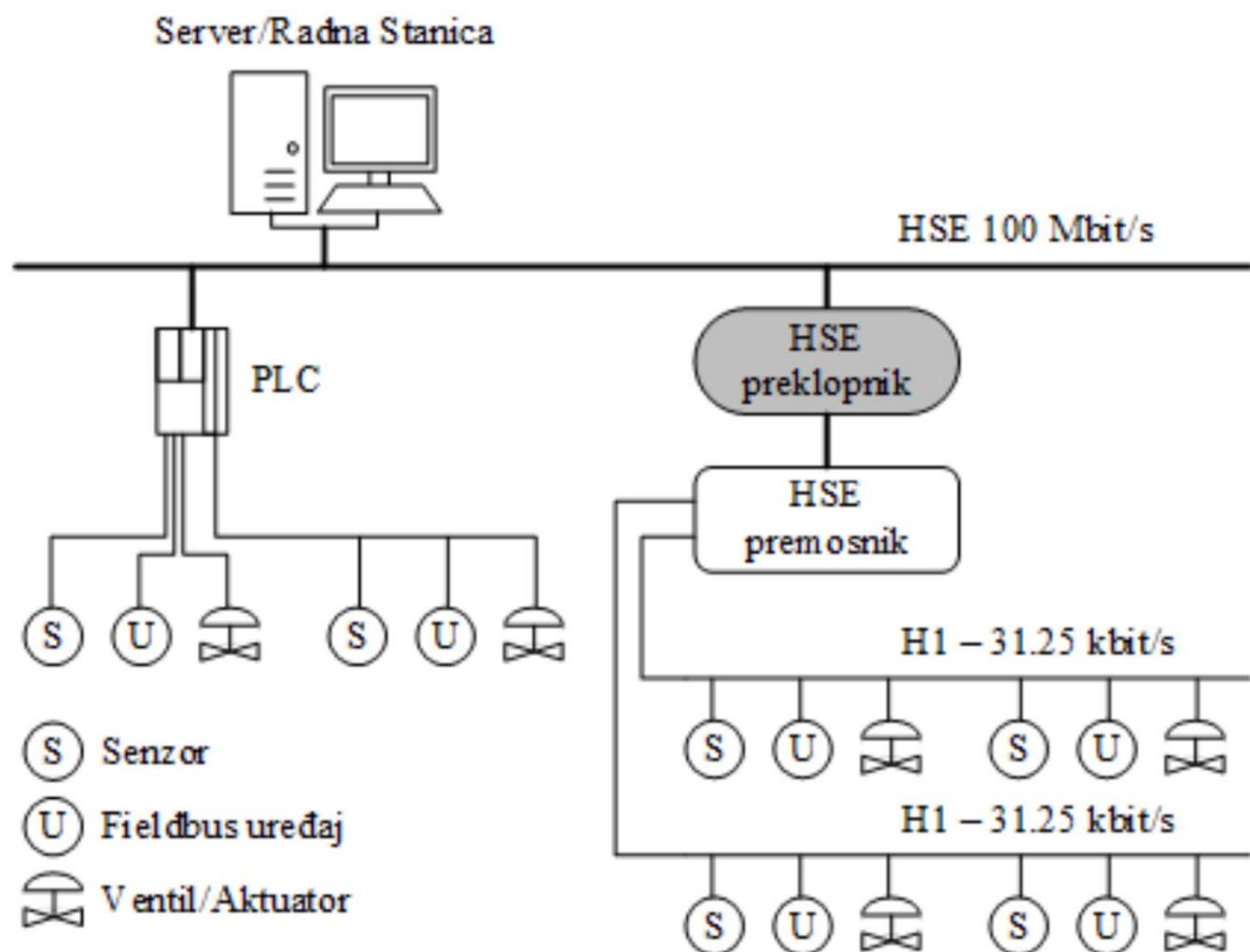
# Sabirnički protokoli



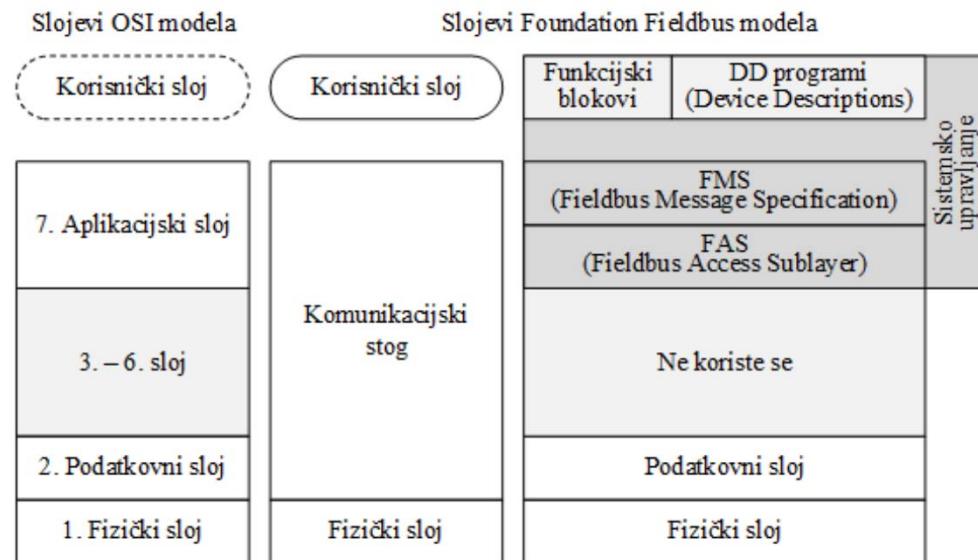
# Sabirnički protokoli



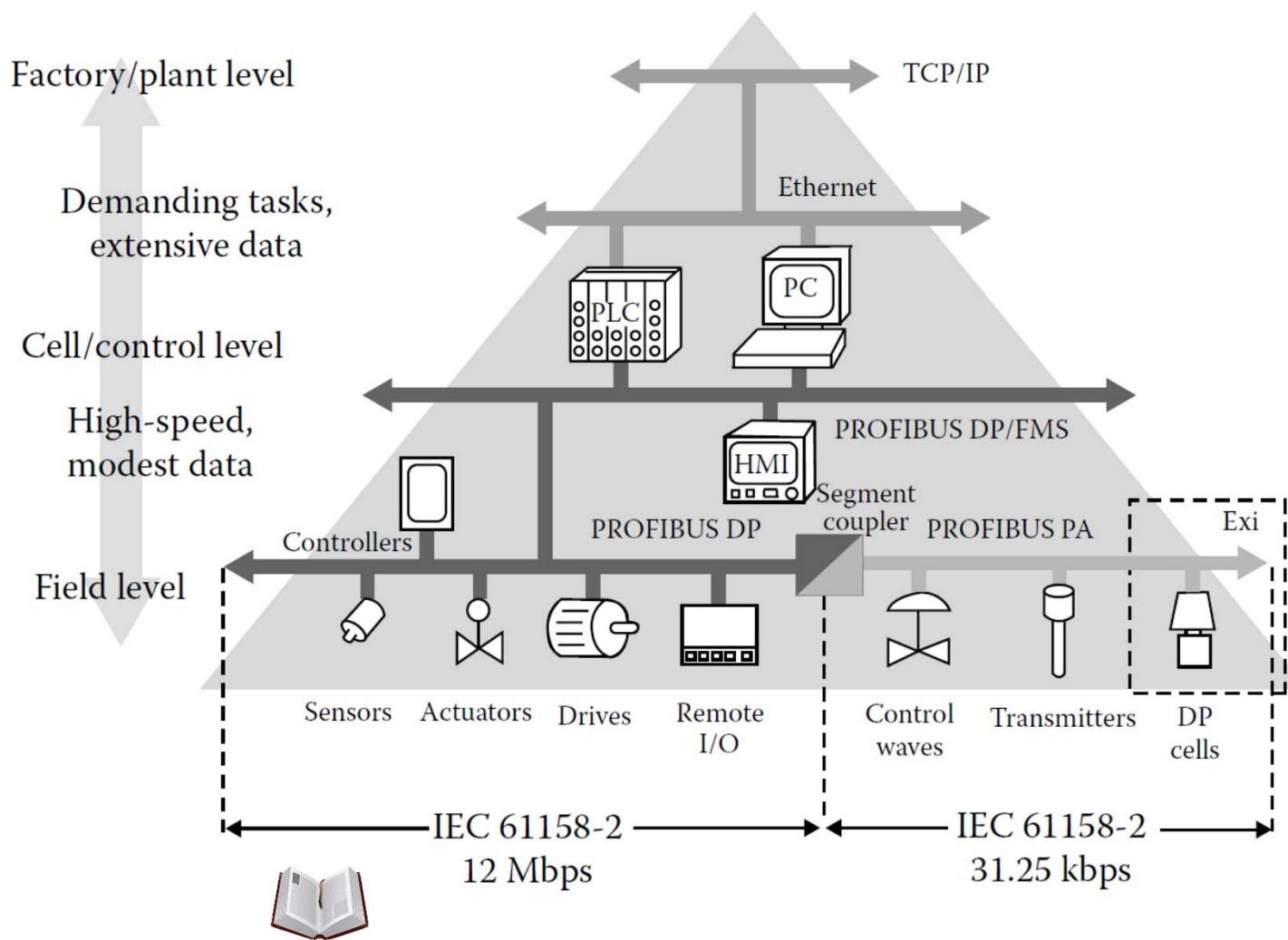
# Foundation Fieldbus



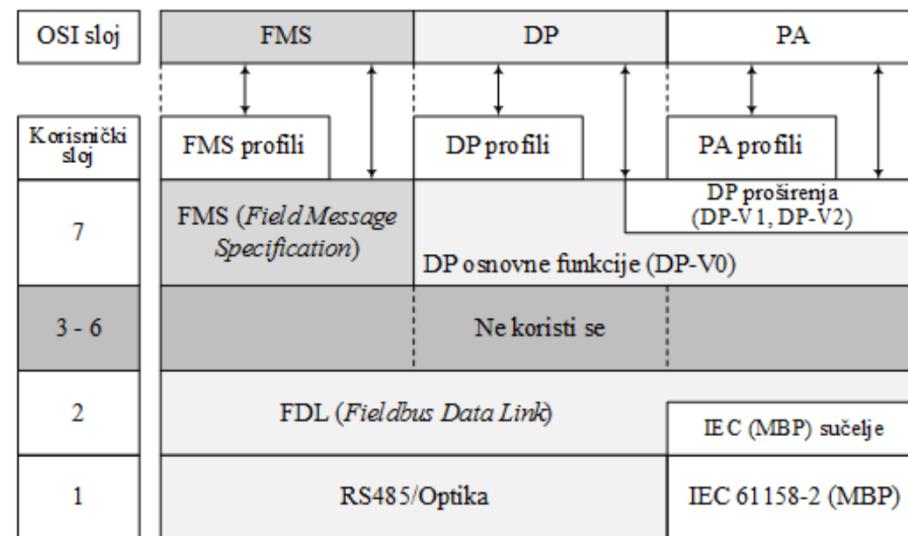
# Foundation Fieldbus



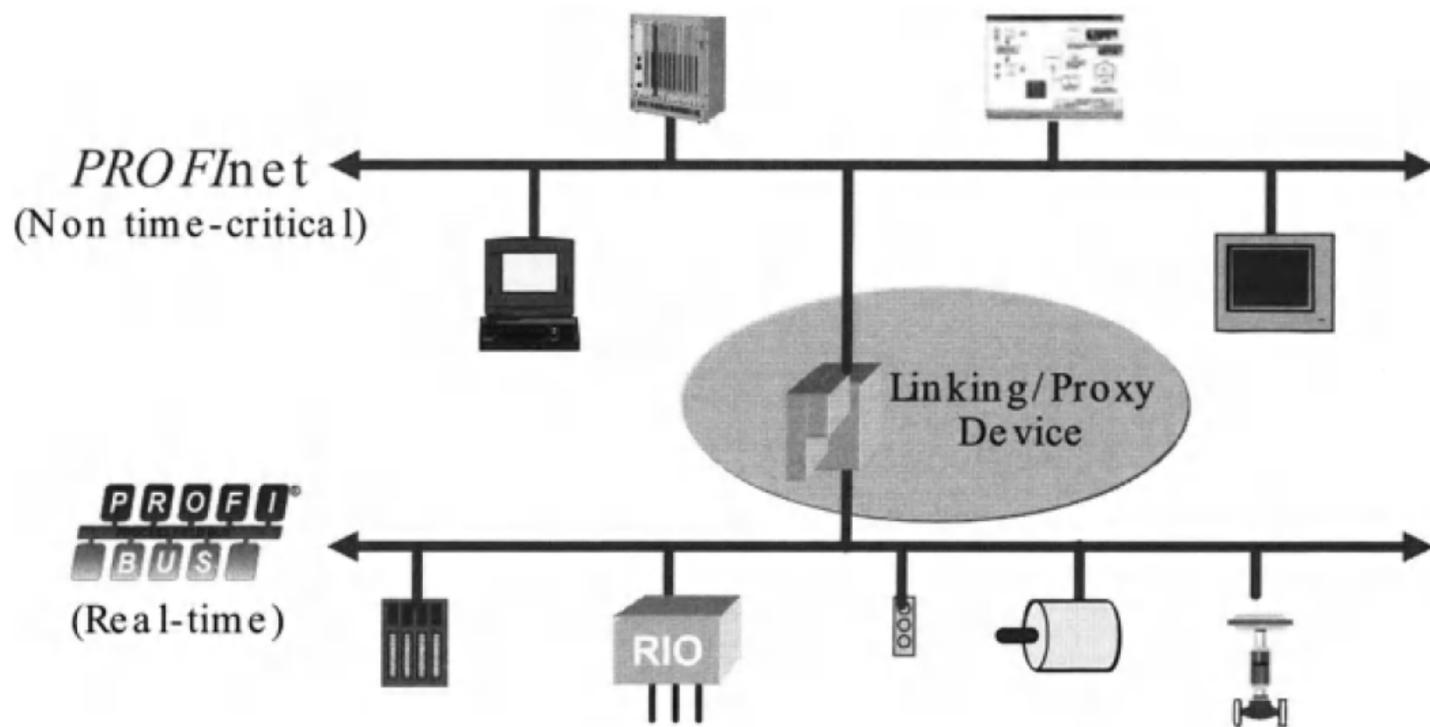
# Profibus



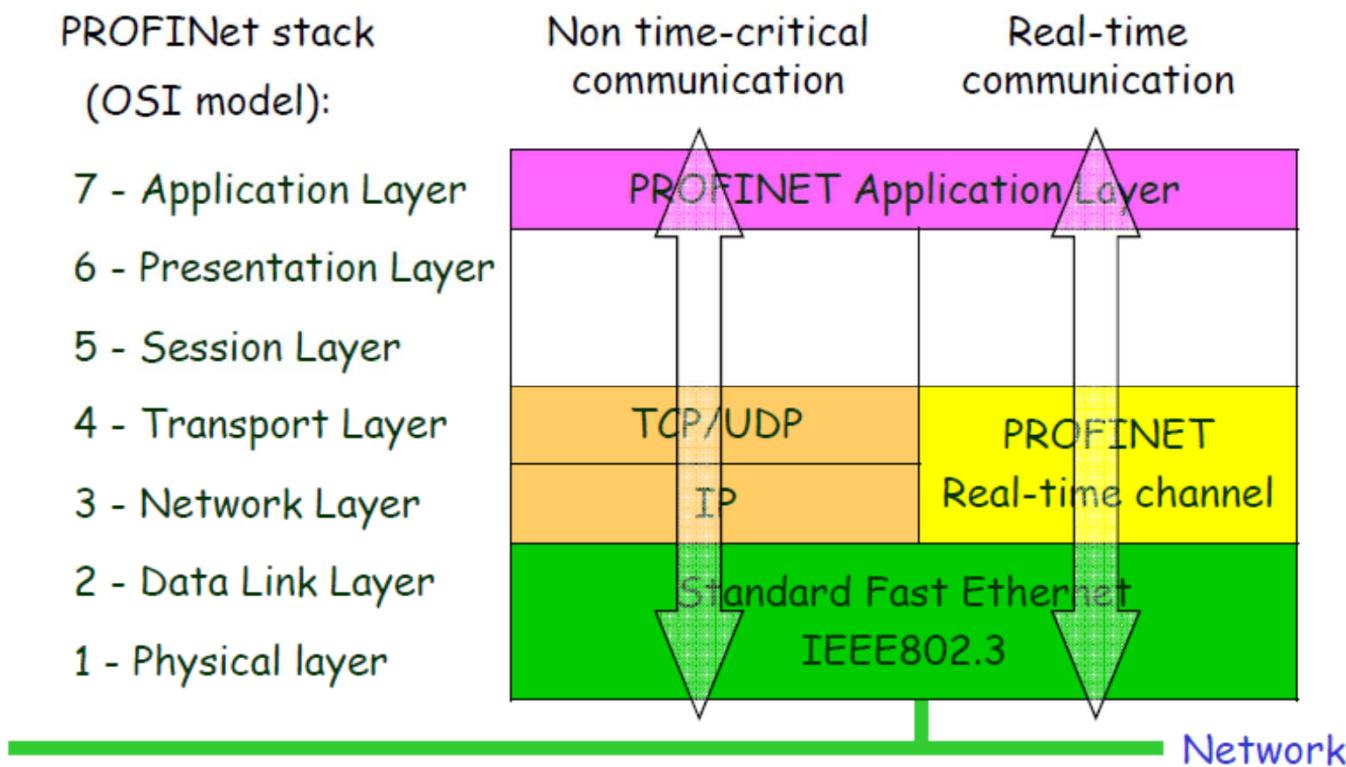
# Profibus



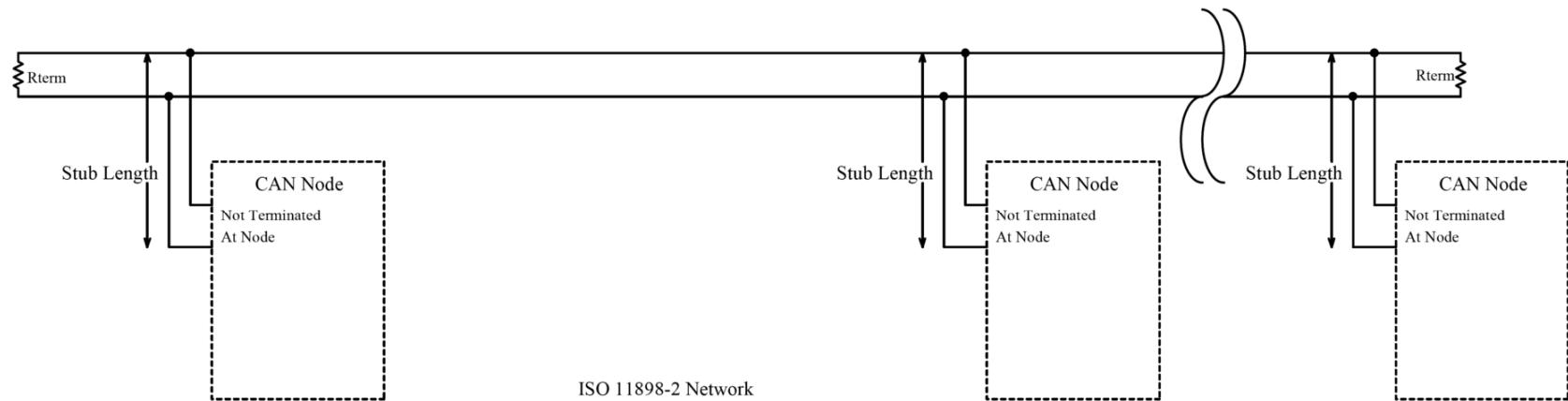
# Profinet



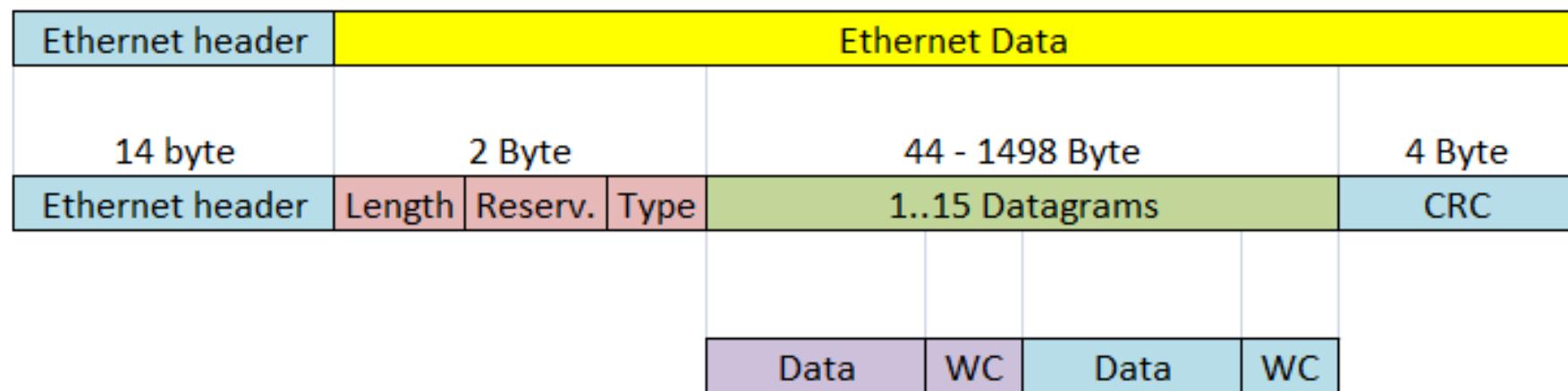
# Profinet



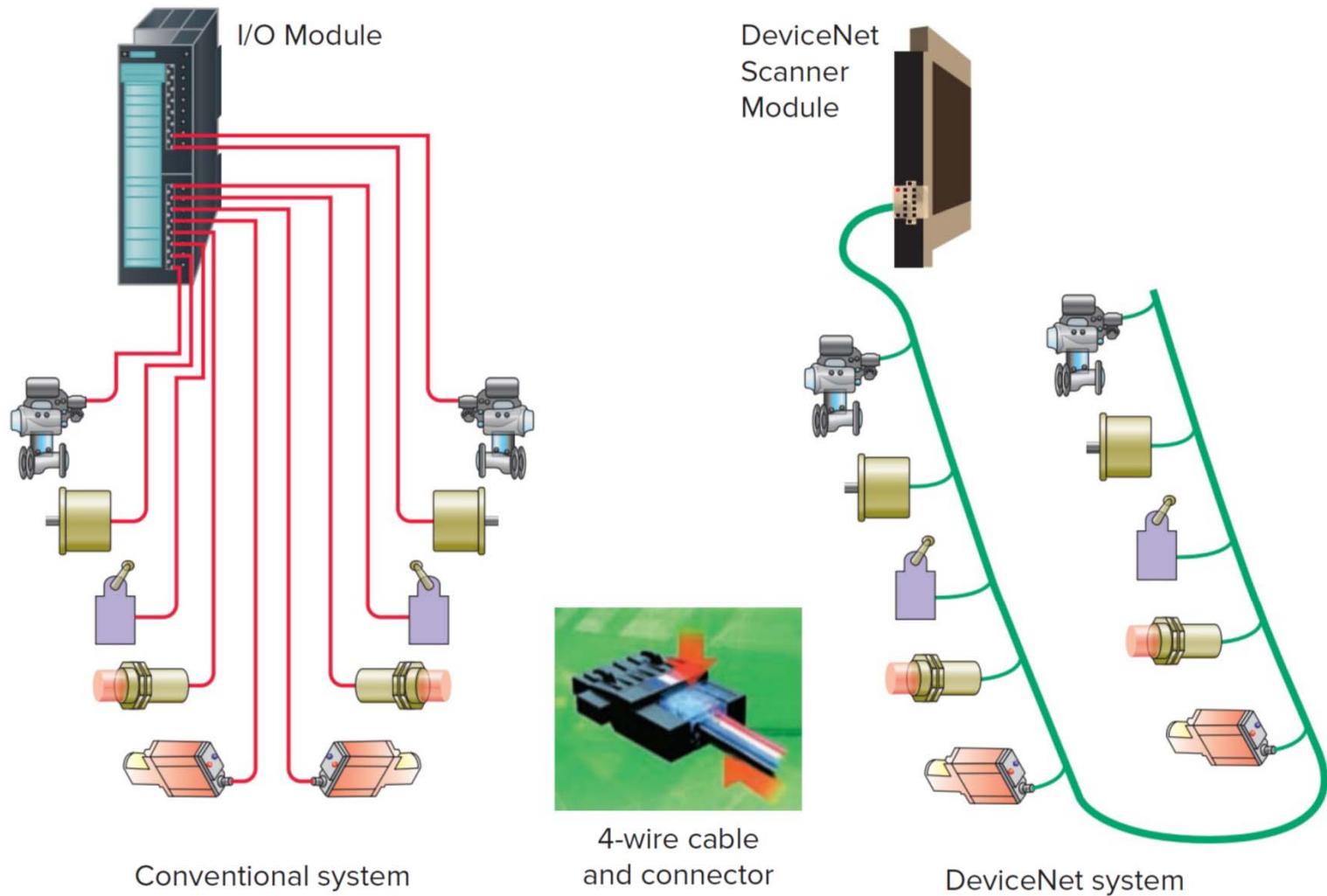
# CAN



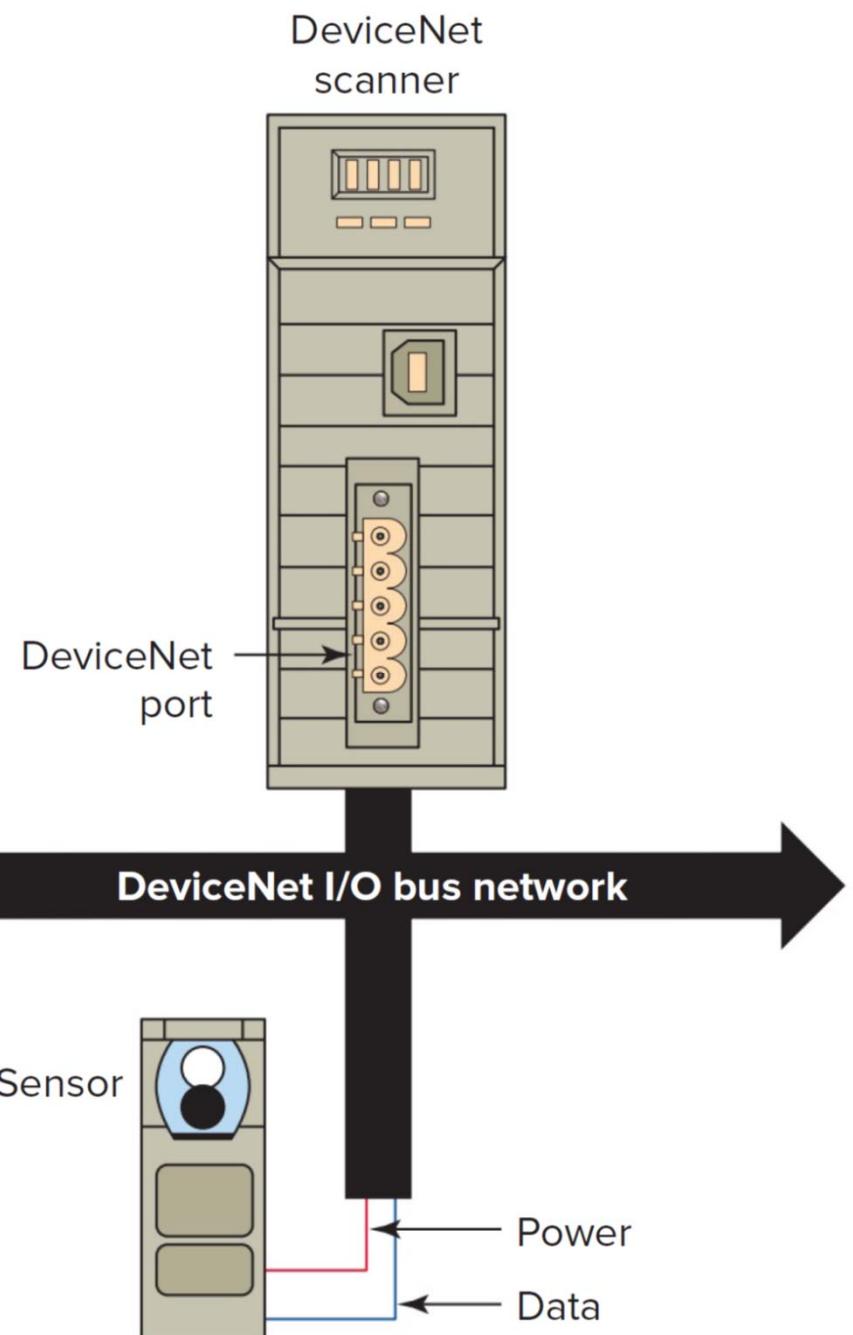
# EtherCAT



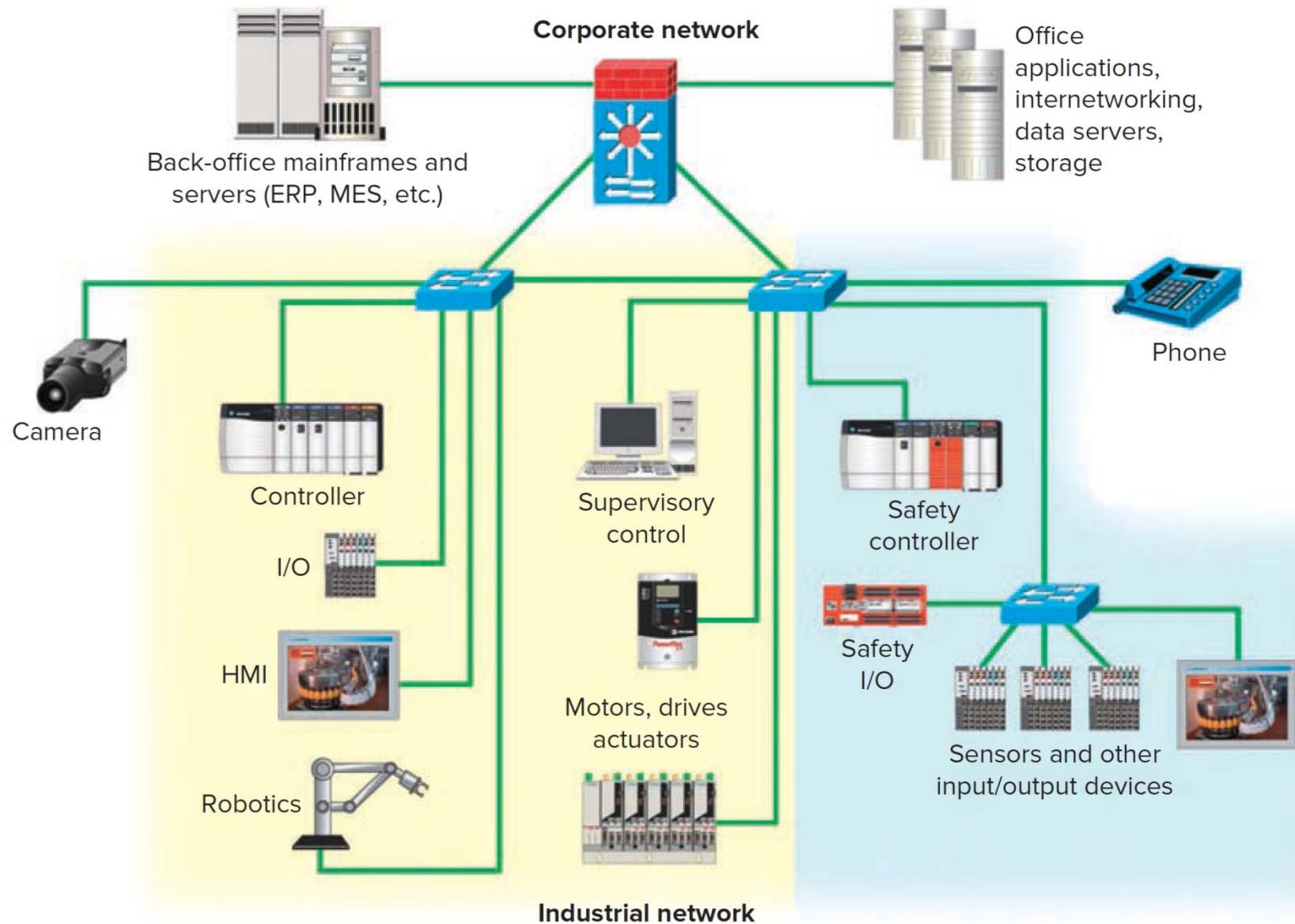
# DeviceNet



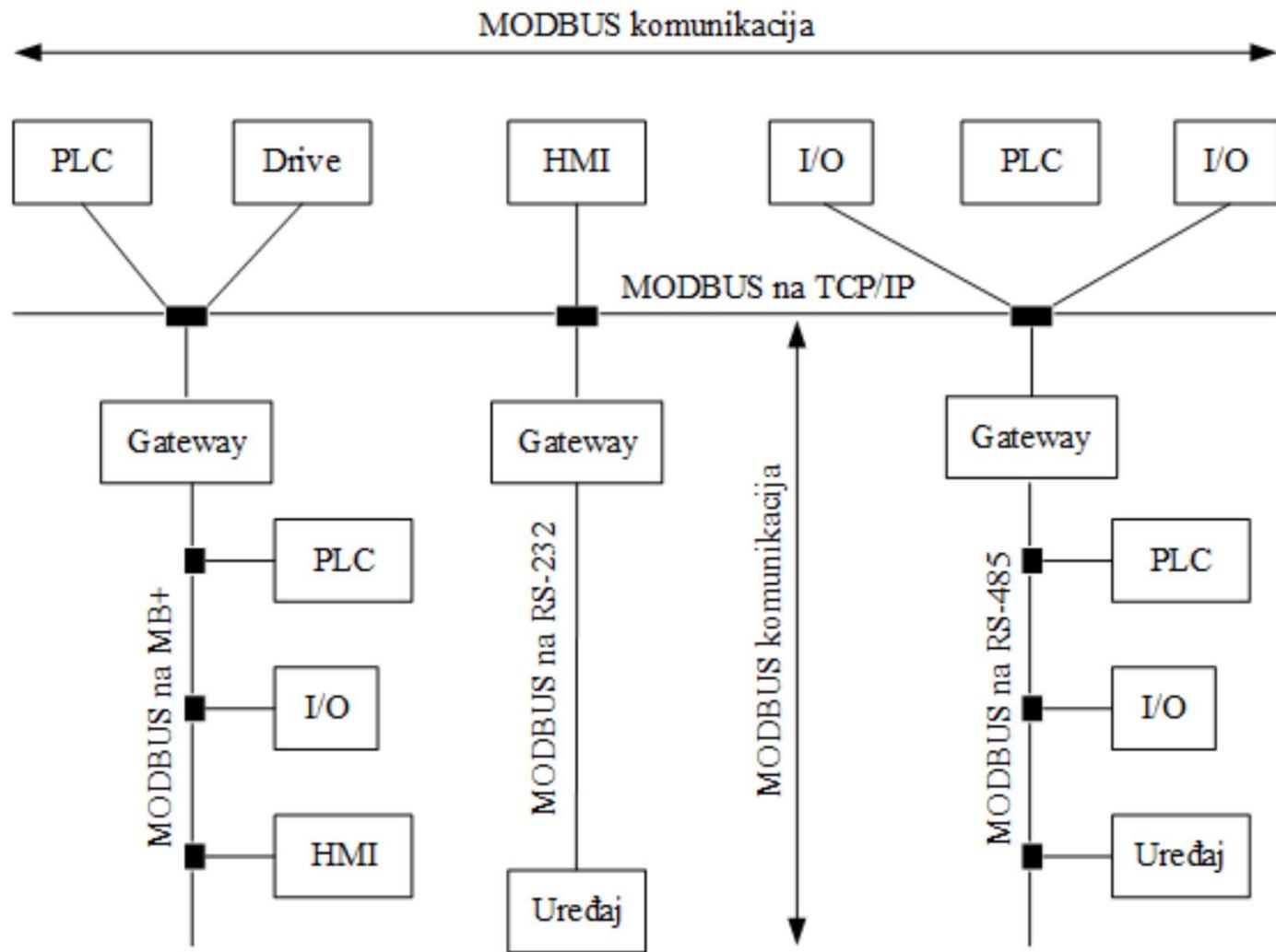
# DeviceNet



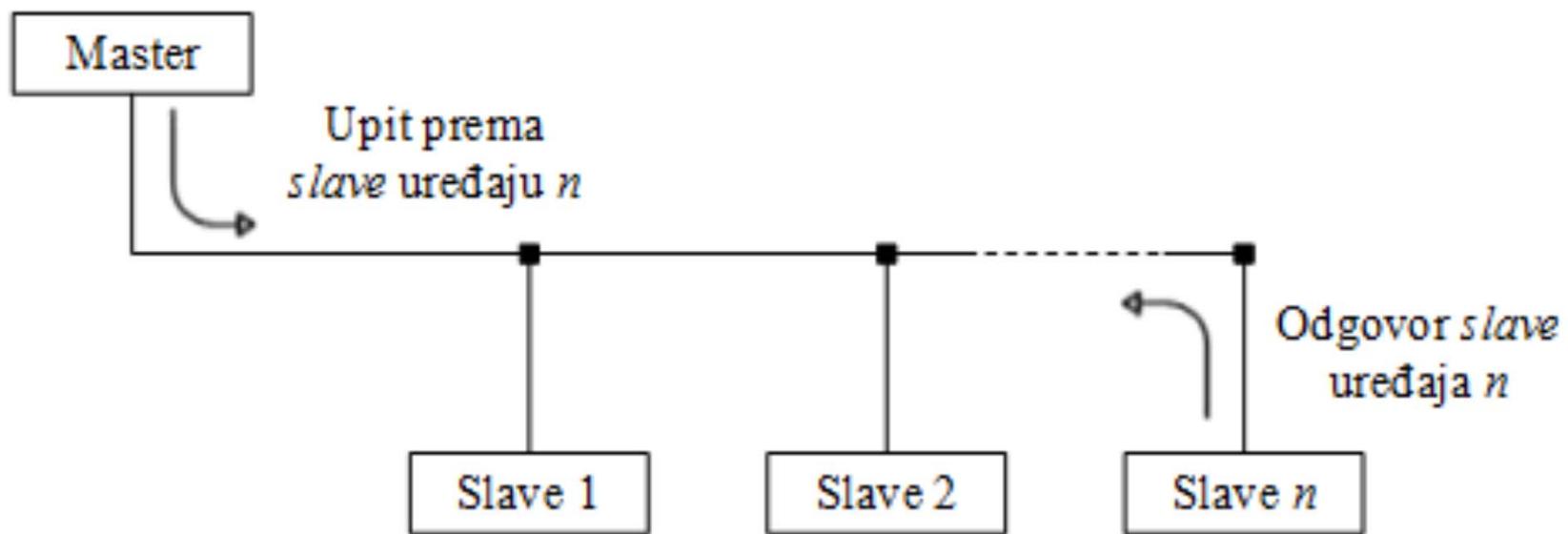
# EtherNet/IP

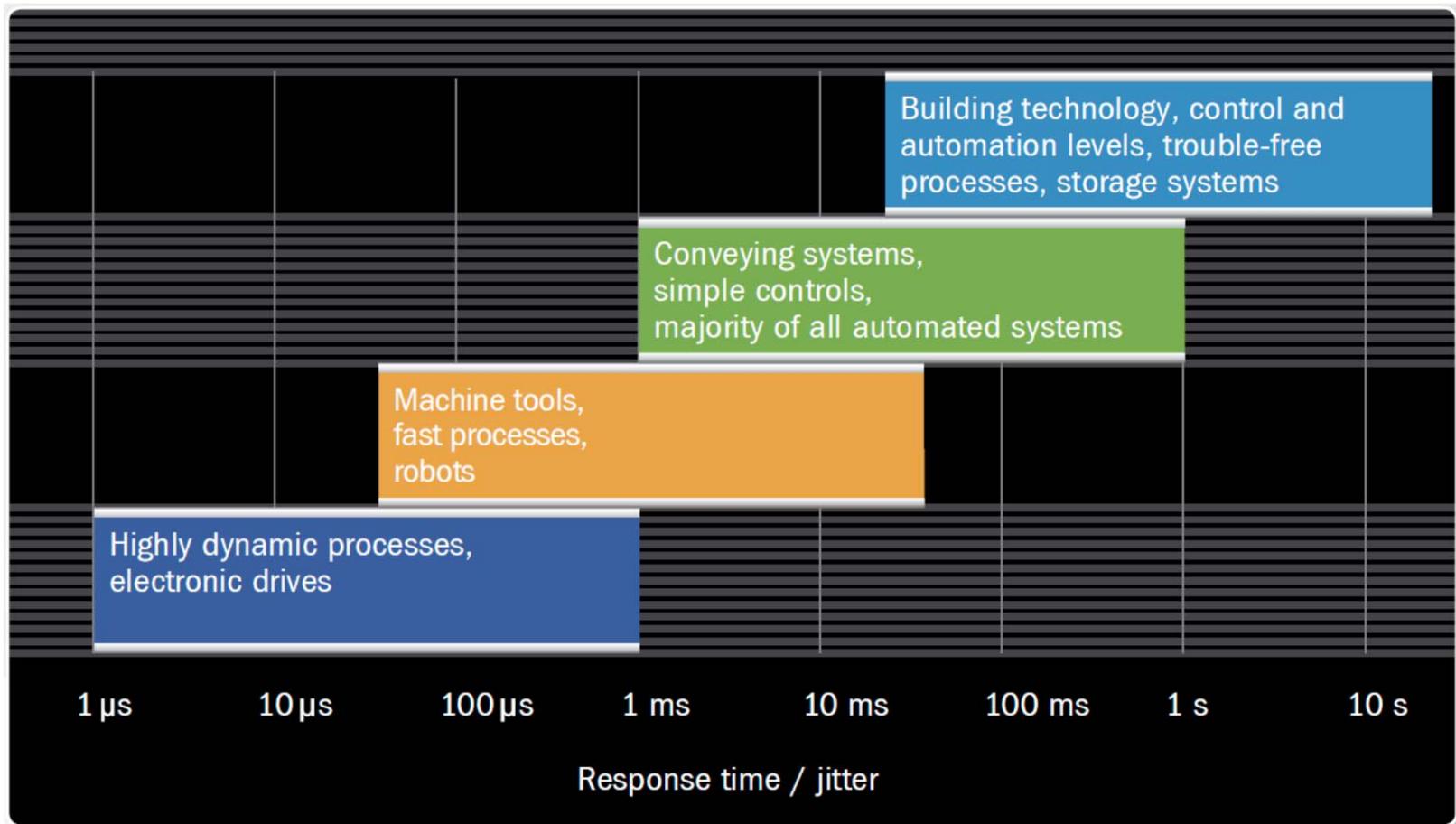


# ModBus



# ModBus





Industrial Ethernet Facts – system comparison

# Kompatibilnost

Criteria	PROFINET RT   IRT	POWER- LINK	EtherNet/ IP	EtherCAT	SERCOS III
	PROFIBUS	CANopen	DeviceNet	CANopen	SERCOS II
Downward compatibility	+	+	+	+	+



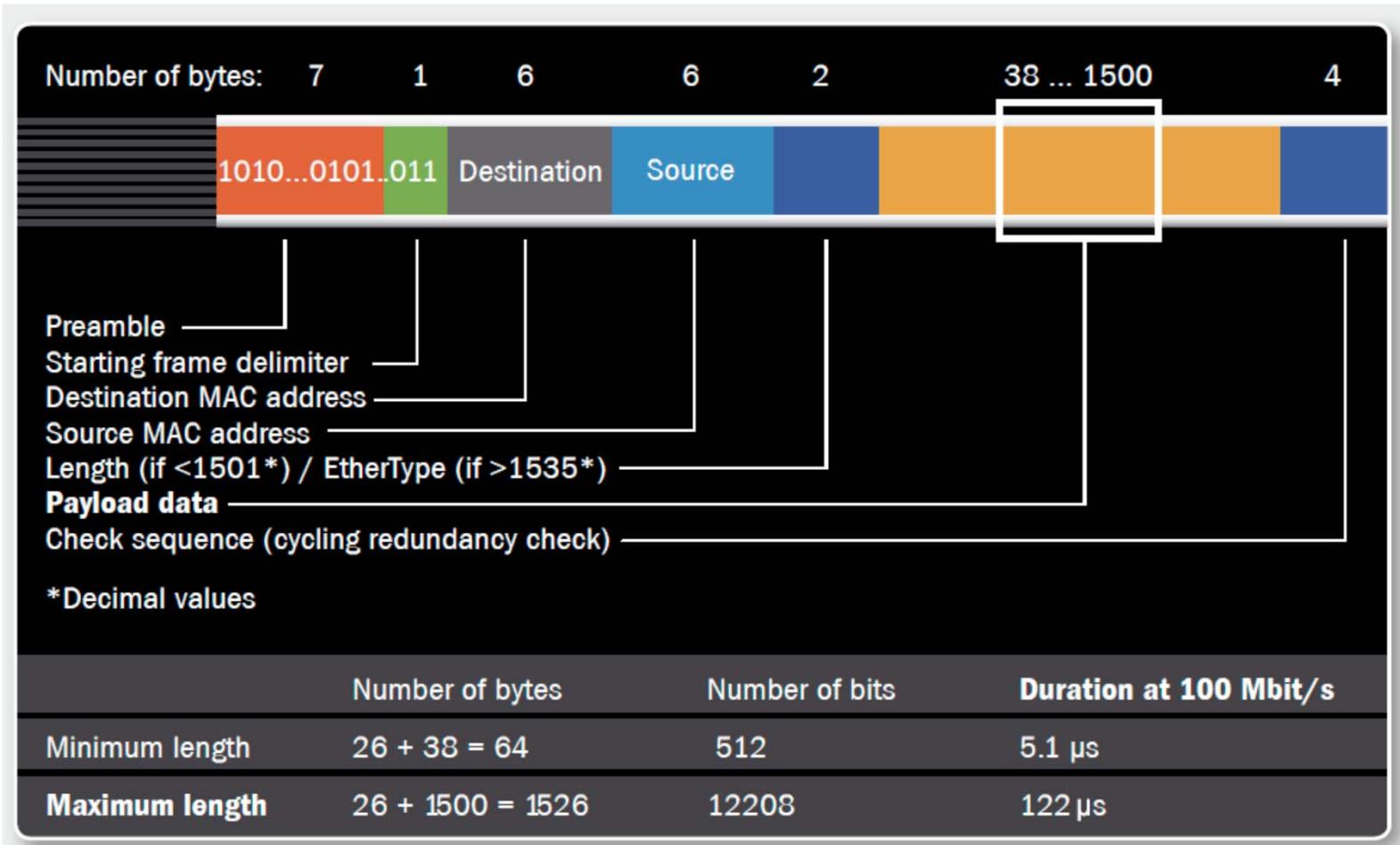
Industrial Ethernet Facts – system comparison

# Podržane topologije

Criteria	PROFINET RT   IRT	POWER- LINK	EtherNet/ IP	EtherCAT	SERCOS III
Tree topology	+	+	+	o	o
Star topology	+	+	+	o	o
Ring topology	+	+	+	+	+
Daisy-chain topology	+	+	+	+	+



Industrial Ethernet Facts – system comparison



Industrial Ethernet Facts – system comparison

Criteria	<b>PROFINET RT   IRT</b>	<b>POWER- LINK</b>	<b>EtherNet/ IP</b>	<b>EtherCAT</b>	<b>SERCOS III</b>
Supports central control	+	+	+	+	+
Supports decentral control	+	+	+	-	o

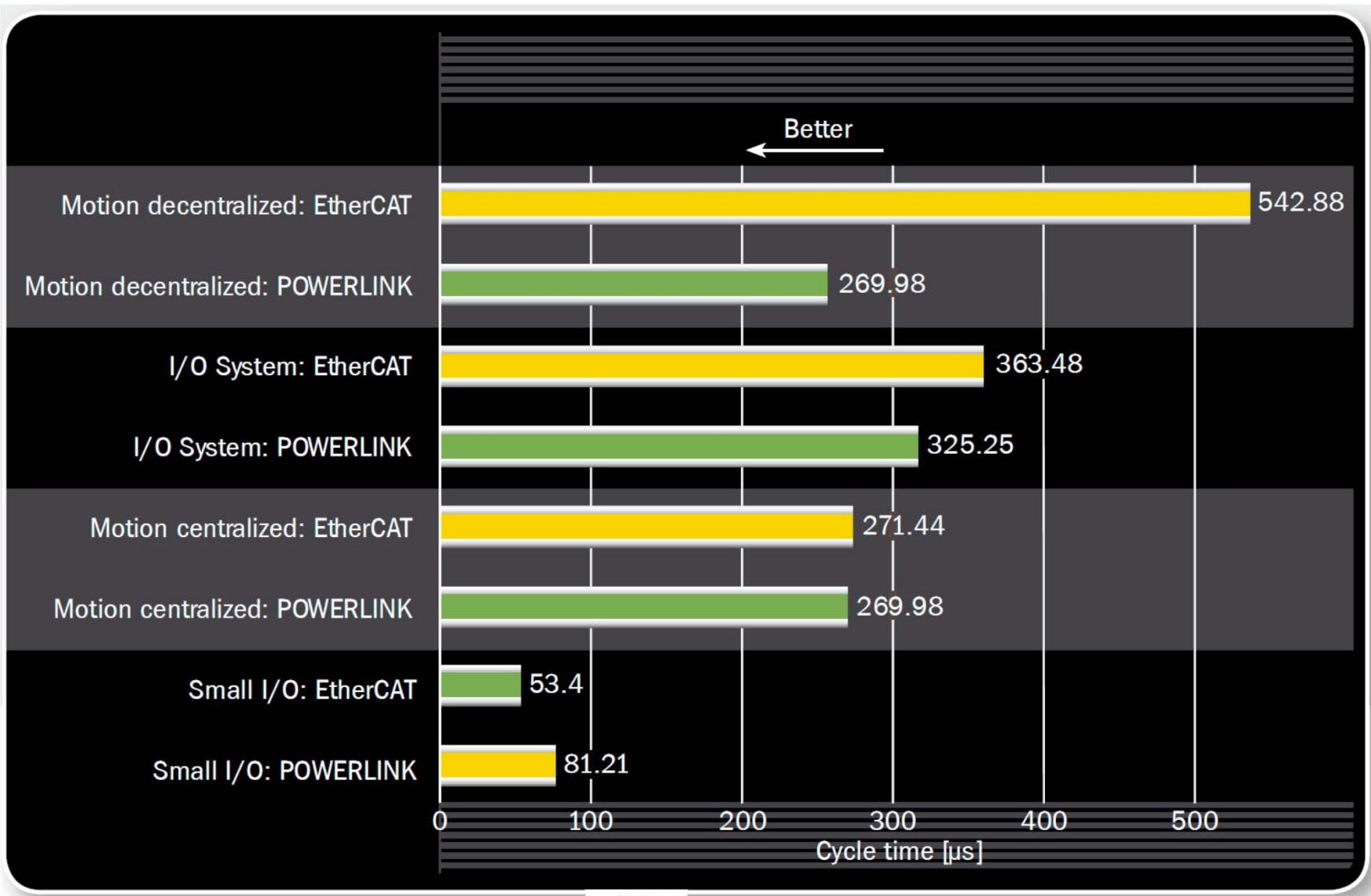


Industrial Ethernet Facts – system comparison

Criteria	<b>PROFINET RT   IRT</b>	<b>POWER- LINK</b>	<b>EtherNet/ IP</b>	<b>EtherCAT</b>	<b>SERCOS III</b>
Performance	o	+	+	o	+



Industrial Ethernet Facts – system comparison



Industrial Ethernet Facts – system comparison

Network components costs	PROFINET RT   IRT		POWERLINK	EtherNet/IP	EtherCAT	SERCOS III
External devices	+	o	+	o	o	o
	standard switch	special switch, IRT support required	standard hubs or switches	managed switch with complex functionality required (IGMP snooping, port mirroring, etc.)	special network components required <sup>1</sup>	designated for future use of external infrastructure devices, but no such use at the time of writing
Internal multiports	o	o	+	o	+	+
	integrated switch	Siemens ASIC required	standard hub	integrated switch, very complex	Beckhoff ASIC required <sup>2</sup> or Beckhoff FPGA IP-Core	FPGA-based technology



Industrial Ethernet Facts – system comparison

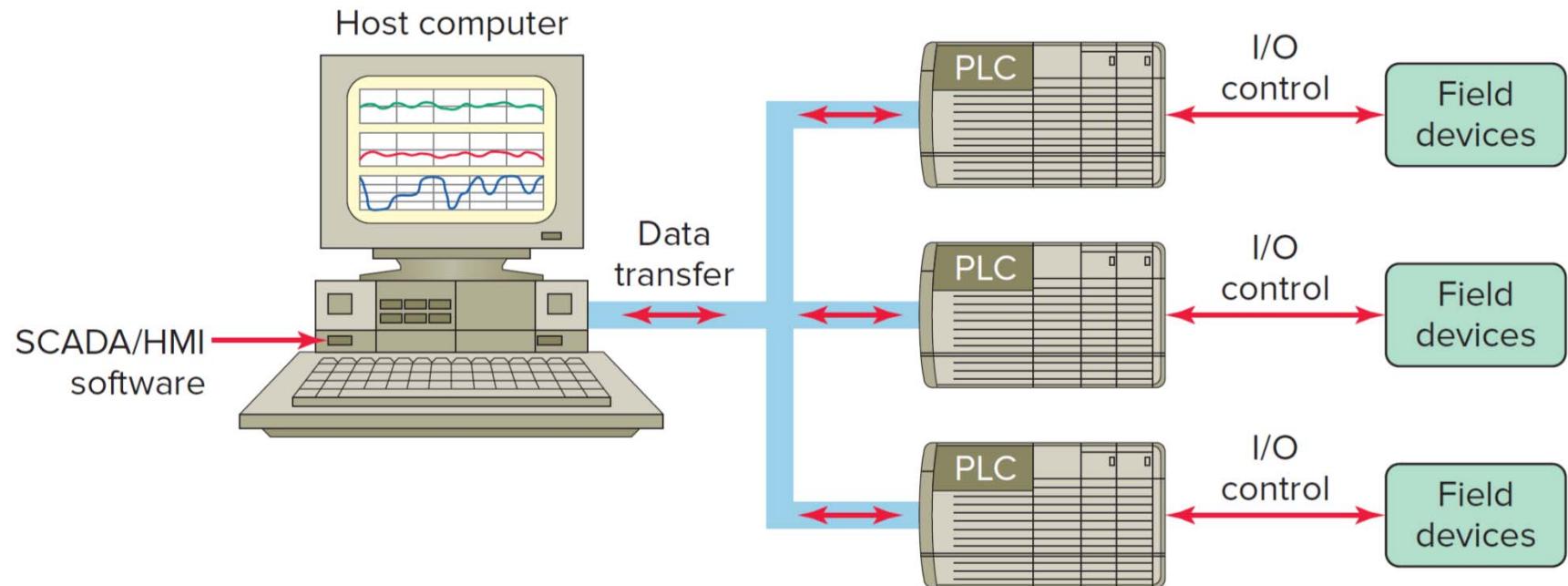
# Sigurnost

Criteria	CIP Safety	PROFIsafe	openSAFETY	FSoE
Supported Industrial Ethernet protocols	EtherNet/IP SERCOSIII	PROFINET	PROFINET EtherCAT EtherNet/IP Modbus POWERLINK PROFINET SERCOSIII	EtherCAT
Open-Source Implementation available	-	-	+	-

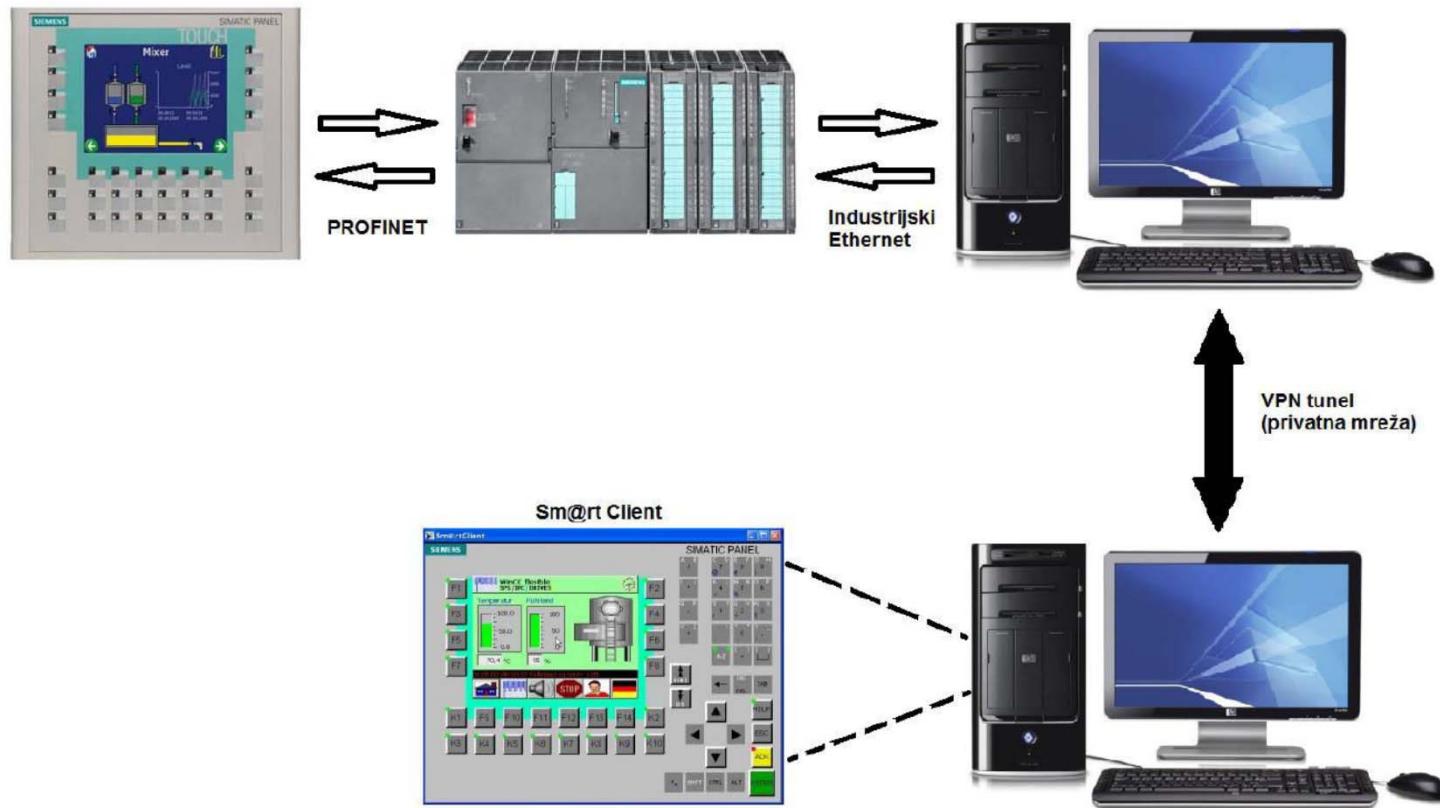


Industrial Ethernet Facts – system comparison

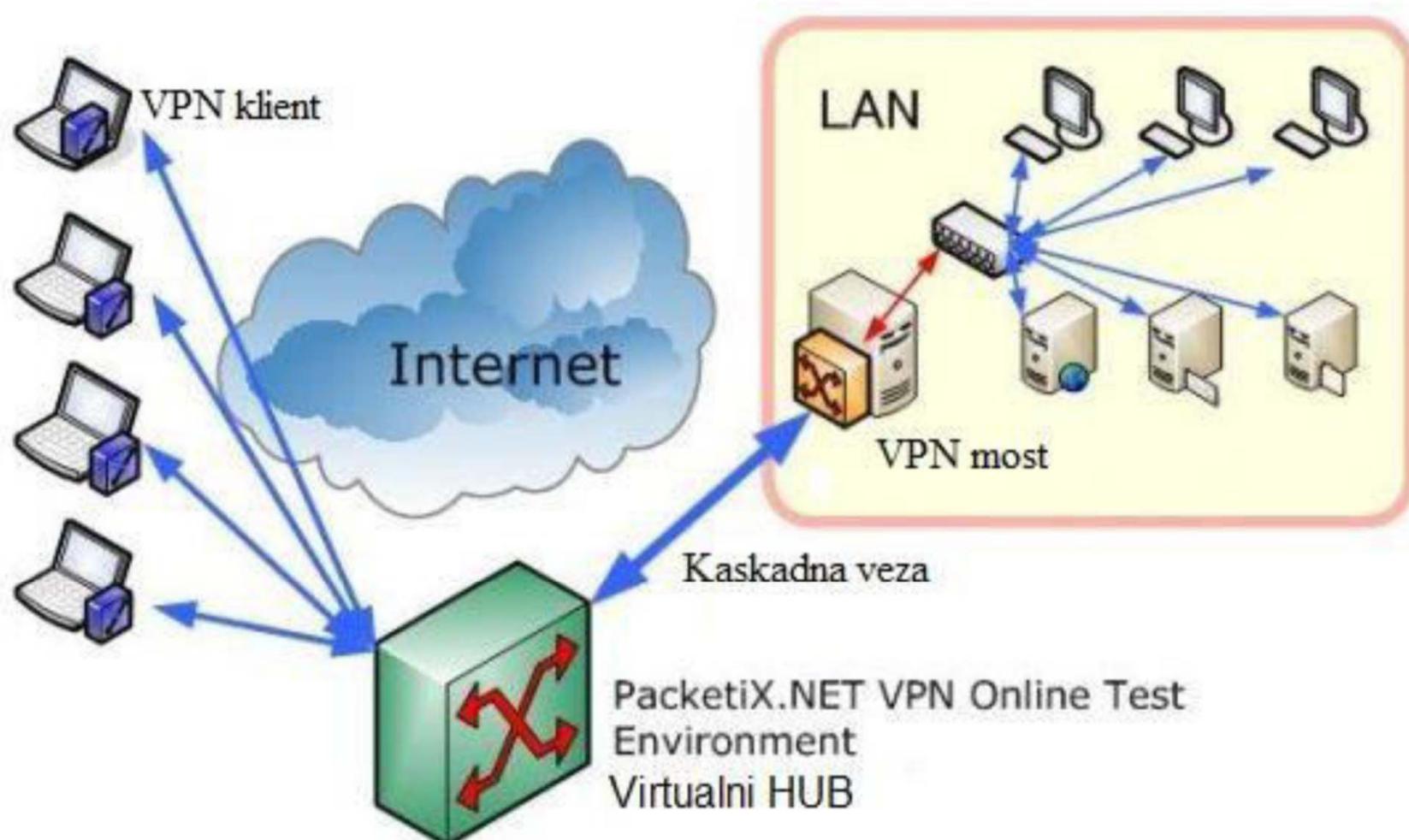
# SCADA - Supervisory Control And Data Acquisition



# Udaljeni pristup



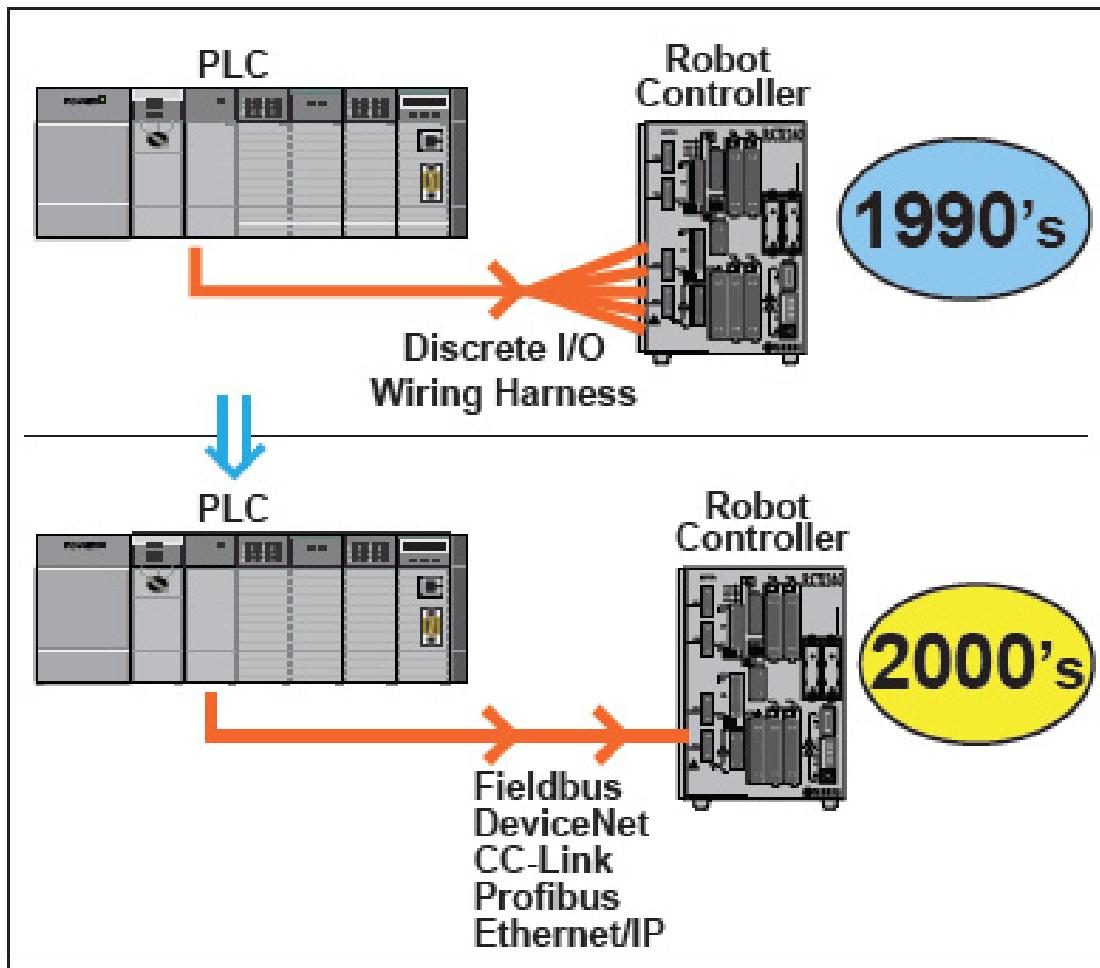
# Udaljeni pristup



# Robot



# Sabirnički protokoli



# Robot – zahtjevi

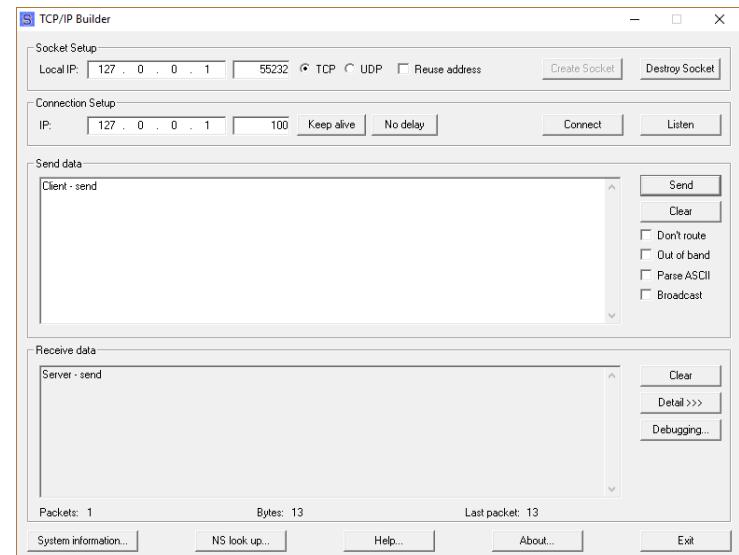
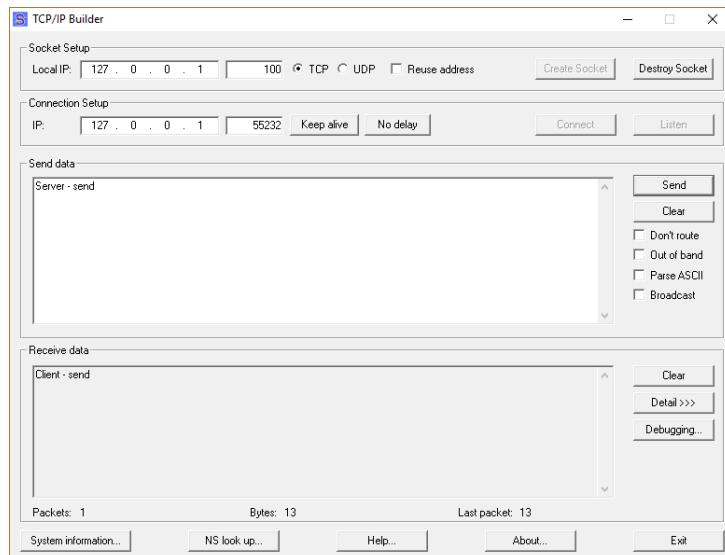
- ▶ Prikazati položaj i kretanje robota
- ▶ Mogućnost udaljenog nadzora i upravljanja
- ▶ Integracija inteligentnih senzora
- ▶ Napredni programski elementi
- ▶ Napredna korisnička sučelja (HMI)

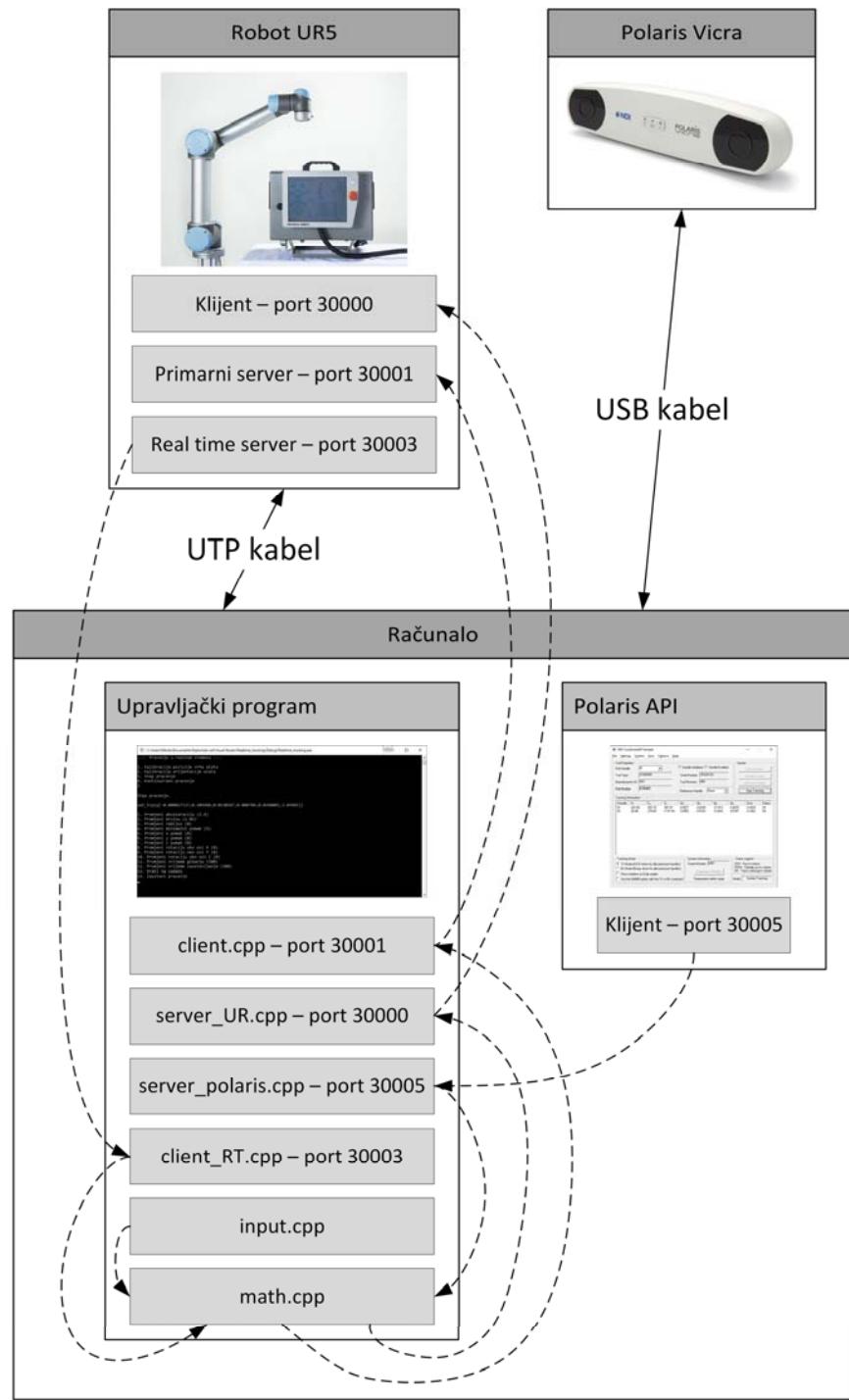
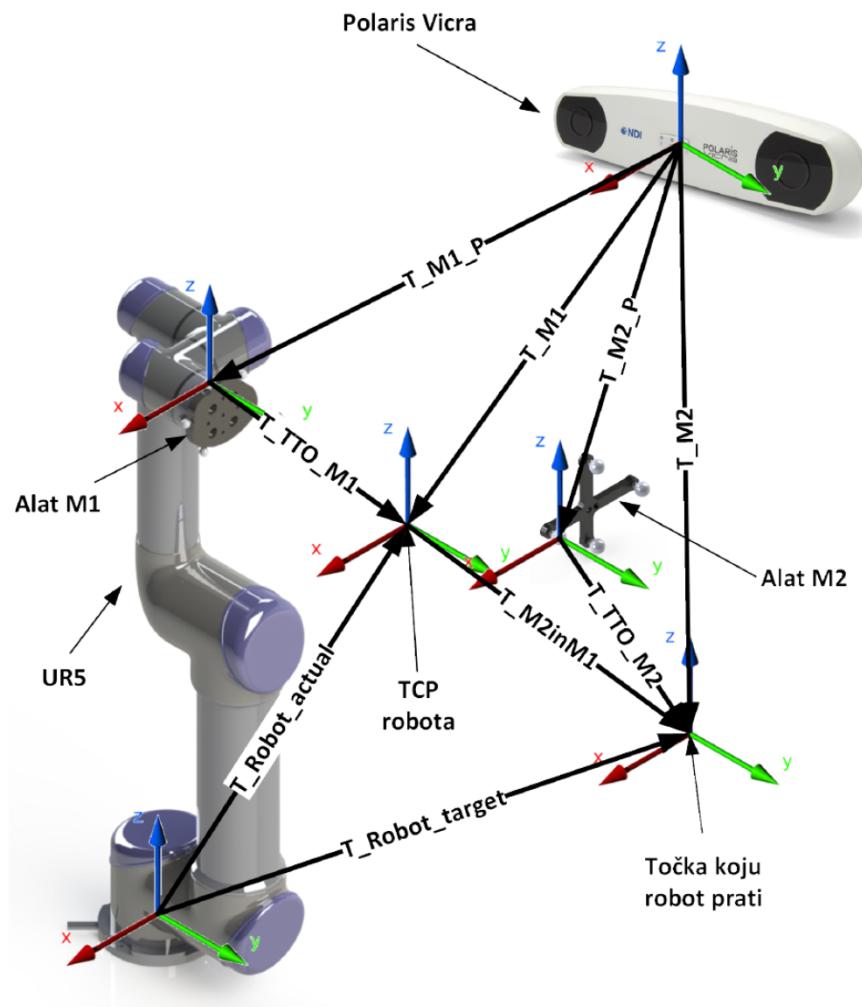
# Robot – protokoli i veze

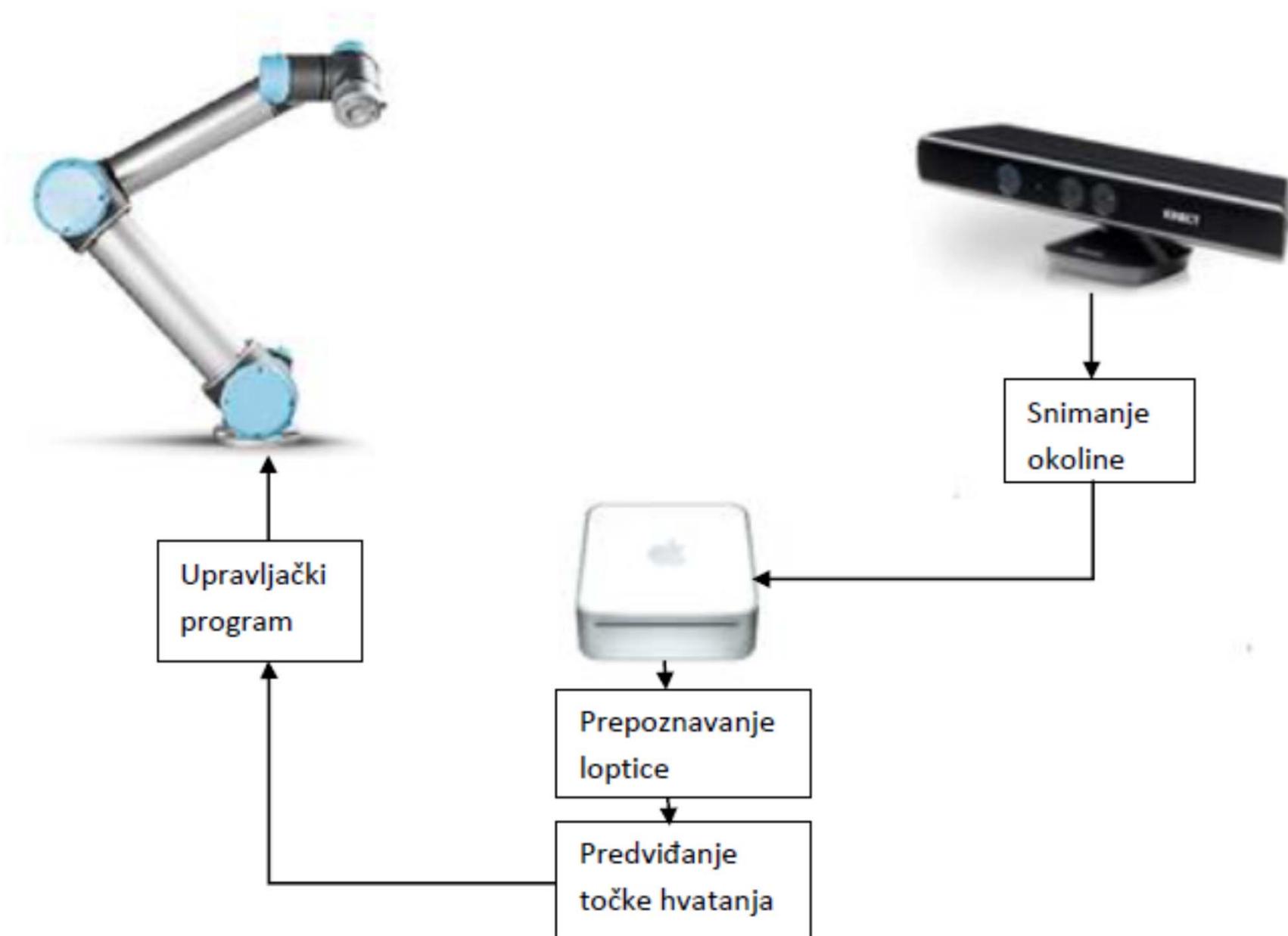
- ▶ Client-server
- ▶ Data sharing



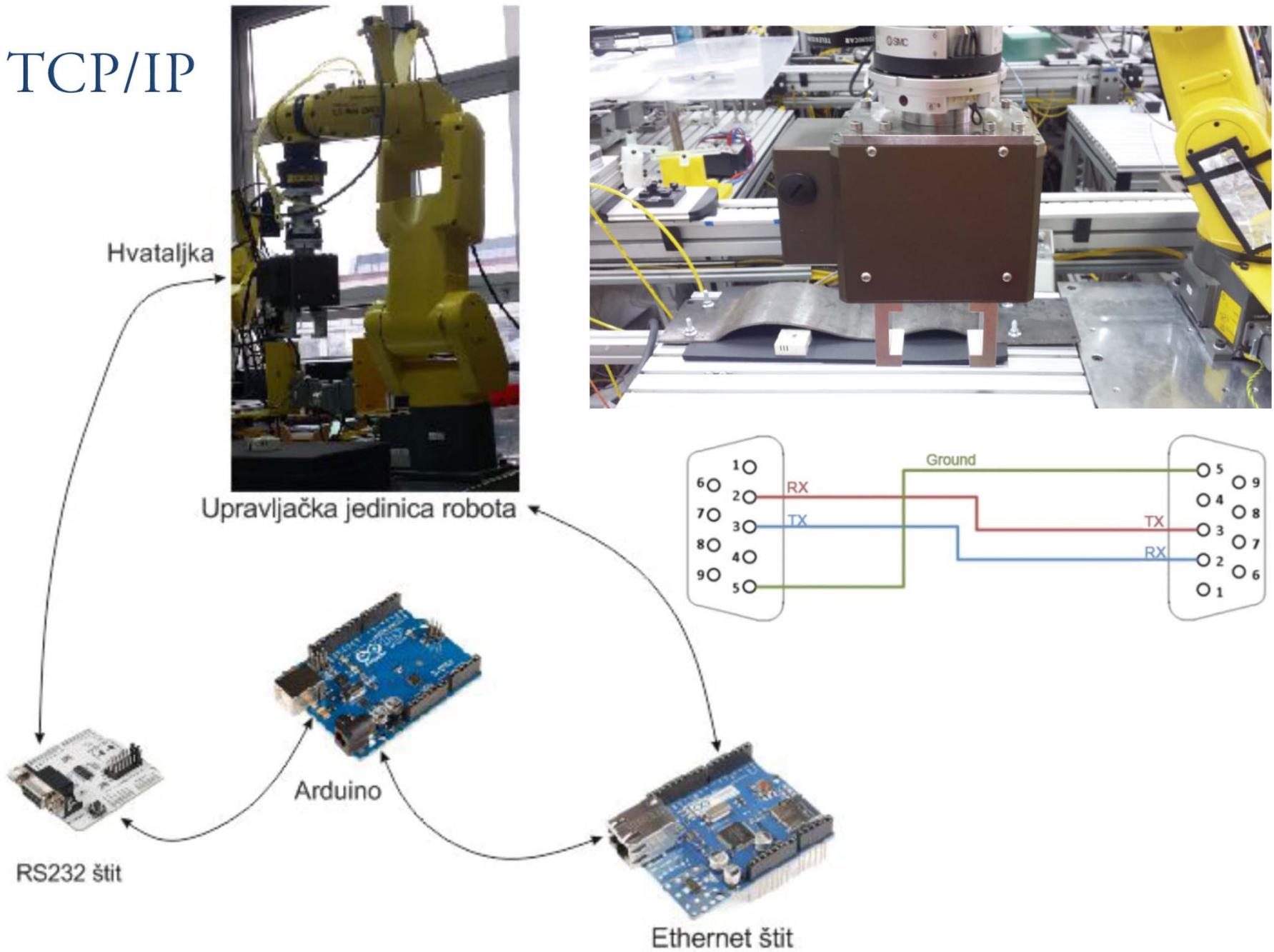
# Socket messaging





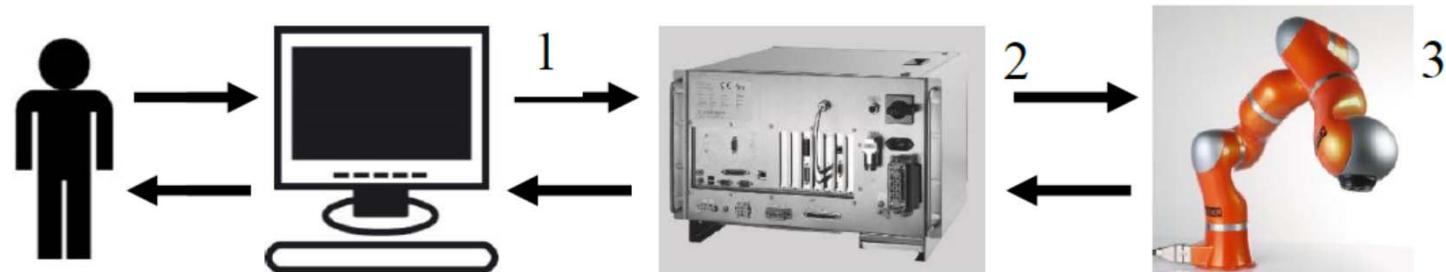


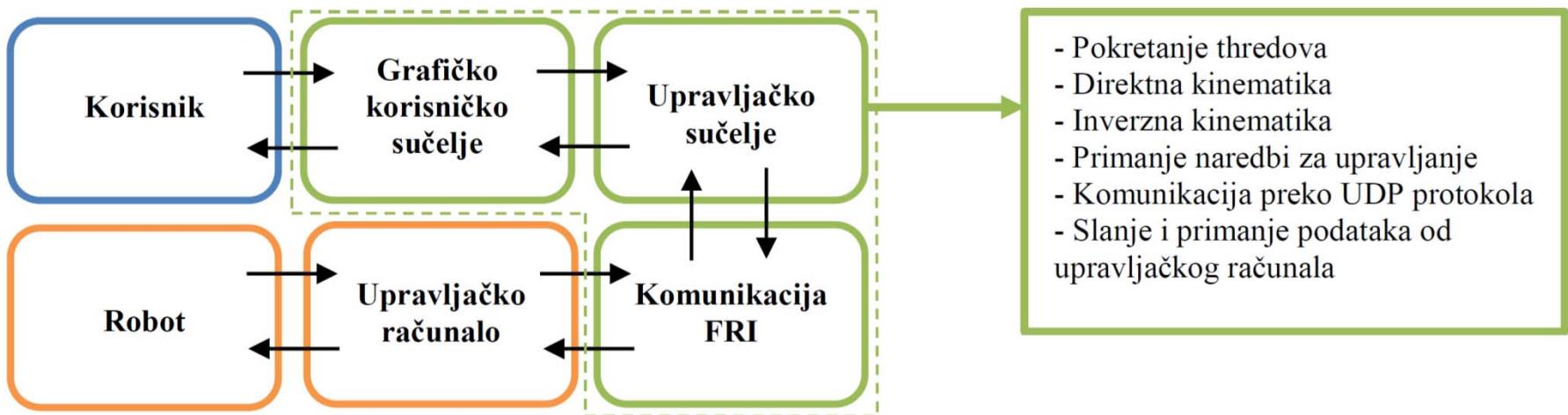
# TCP/IP



# UDP

- ▶ 1. Računalo koje korisniku prikazuje podatke o sustavu i koje od korisnika prima naredbe
- ▶ 2. Upravljačko računalo koje podatke prikupljene sa različitih senzora robotskog manipulatora obrađuje i šalje u korisničko računalo
- ▶ 3. Robotski manipulator KUKA LWR4+





KUKA + SIEMENS  
mxAutomation



# Socket messaging

