Optične komunikacije

Predavanje 15:

Ethernet

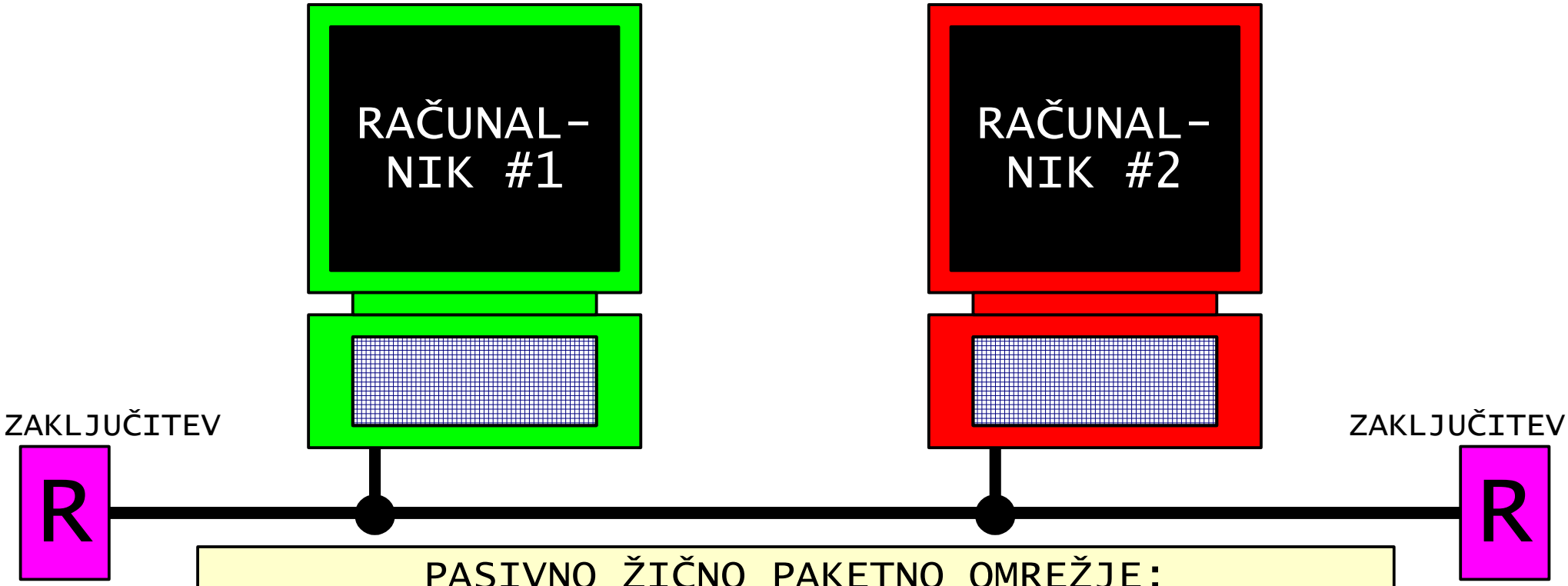
1. Mejniki v zgodovini telekomunikacij
2. Kaj je bil Ethernet pred pol stoletja (1973)?
3. Kratka zgodovina Etherneta
4. Thick Ethernet 10BASE-5
5. Oznake Ethernet inačic
6. Zasnova Ethernet okvirja
7. Thin Ethernet 10BASE-2
8. Računalniški duh uide iz steklenice
9. TCP/IP Ethernet okvirji
10. Program Wireshark
11. TCP/IP Ethernet omrežja
12. Address Resolution Protocol (ARP)
13. Neoklopljena sukana parica (UTP)
14. Zvrsti UTP/STP vodnikov
15. Vtikač in trafo vtičnica RJ45
16. Manchester, 4B5B in MLT3
17. Delovanje 10BASE-T in 100BASE-TX
18. TCP/IP/Ethernet/UTP sklad protokolov
19. Nadzor pretoka (Flow control)
20. Različice Media-Independent Interface (MII)
21. Reduced Media-Independent Interface (RMII)
22. 100BASE-TX 3R regenerator (Extender)
23. 100BASE-TX/100BASE-FX Media Converter
24. Hub v središču zvezde UTP kablov
25. Aktivno Ethernet stikalo
26. Uporaba stikala v domačem usmerjevalniku
27. Virtual Local Area Network (VLAN)
28. Zgodovina optičnega Etherneta
29. Linijsko kodiranje v optičnem Ethernetu
30. Različice 1Gbps Media Converterjev
31. Ethernet standardi 100Gbps (40,200,400Gbps)
32. Neuspehi Etherneta
33. Kaj je to Ethernet danes?

pr.n.š. - svetlobni signali (naprava in protokol)
~1830 - električni telegraf (naprava) več izumiteljev
~1865 - mednarodna telegrafska abeceda (standard)
~1880 - analogna komunikacija (naprava) Bell-ov telefon
~1900 - radijska zveza (naprava) Marconi
~1912 - elektronsko ojačanje/obdelava (naprava) Meissner
~1930 - frekvenčni prostor (naprava) Armstrong
~1948 - teorija informacije (protokol) Shannon
~1957 - umetni satelit (naprava) hladna vojna
~1965 - svetlobno vlakno (naprava) čisti silicij / SiO2
~1970 - paketni prenos (protokol) mikroračunalnik
~1980 - sklad protokolov (protokol) OSI ravni
~1990 - svetovni splet (standard) HTTP
~2000 - združljivost in odpornost na napake (naprava)
~2000 - Peer-to-Peer omrežja (protokol) Skype
~2000 - WLAN-WiFi (standard) nelicenciran in globalni
~2010 - opuščanje tokokrogovnih omrežij (protokol)

Mejniki v zgodovini telekomunikacij

1971: radijsko paketno omrežje ALOHAnet (Univerza Hawaii)

1973: Robert Metcalfe in sodelavci (Xerox)



PASIVNO ŽIČNO PAKETNO OMREŽJE:

Skupna prenosna pot = "ETHER" = koaks 2.94Mbps

Sodostop CSMA/CD = Carrier-Sense Multiple Access / Collision Detect

1972: univerza Harvard zavrne Metcalfejev doktorat

1979: Metcalfe ustanovi podjetje 3Com za Ethernet opremo

1990: managerji odstranijo Metcalfeja na vrhuncu uspeha 3Com

Kaj je bil Ethernet pred pol stoletja (1973)?

1973 - prvo omrežje (2.94Mbps) na skupnem vodilu "Ether", 8-bitni naslovi, CSMA/CD sodostop (Xerox, ZDA)

1980 - 10Mbps, Manchester, 48-bitni MAC naslovi, 16-bitni opis vsebine, DIX EthernetII (Digital-Intel-Xerox)

1982 - 10Mbps 10BASE-5 Thick Ethernet, MAU priklop na vodilo RG8X (debel koaks) z dometom 500m

1985 - 10Mbps 10BASE-2 Thin Ethernet, BNC priklop na vodilo RG58 (tanek koaks) z dometom 185m

1990 - 10Mbps 10BASE-T, dve parici (UTP), domet 100m točka-točka, omrežje zvezda do Ethernet hub

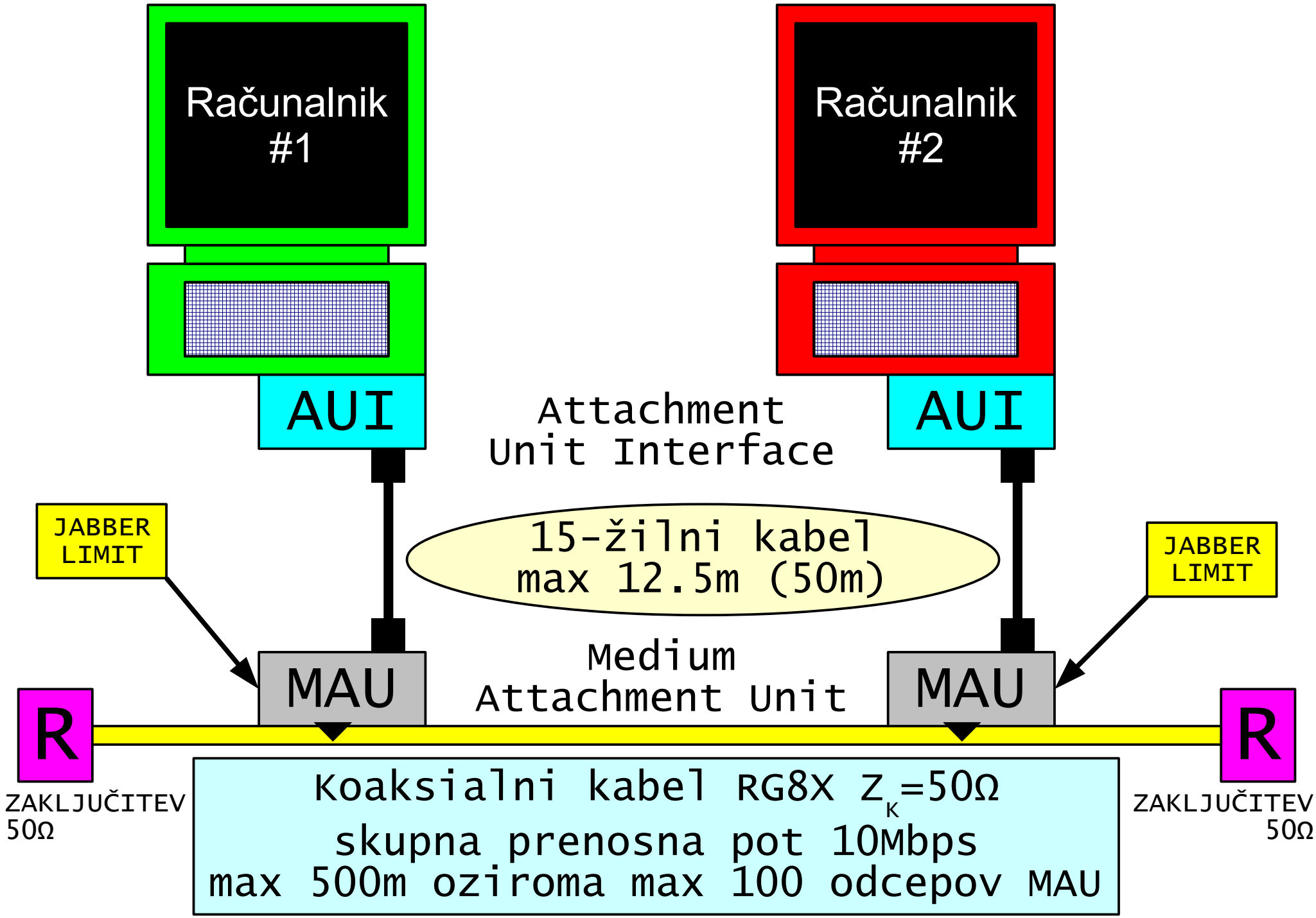
1995 - 100Mbps 100BASE-TX, MLT3, dve parici (UTP), domet 100m točka-točka, omrežje zvezda do Ethernet stikala (switch), full-duplex, auto-negotiation

1999 - 1Gbps 1000BASE-T, štiri parice (UTP), 100m

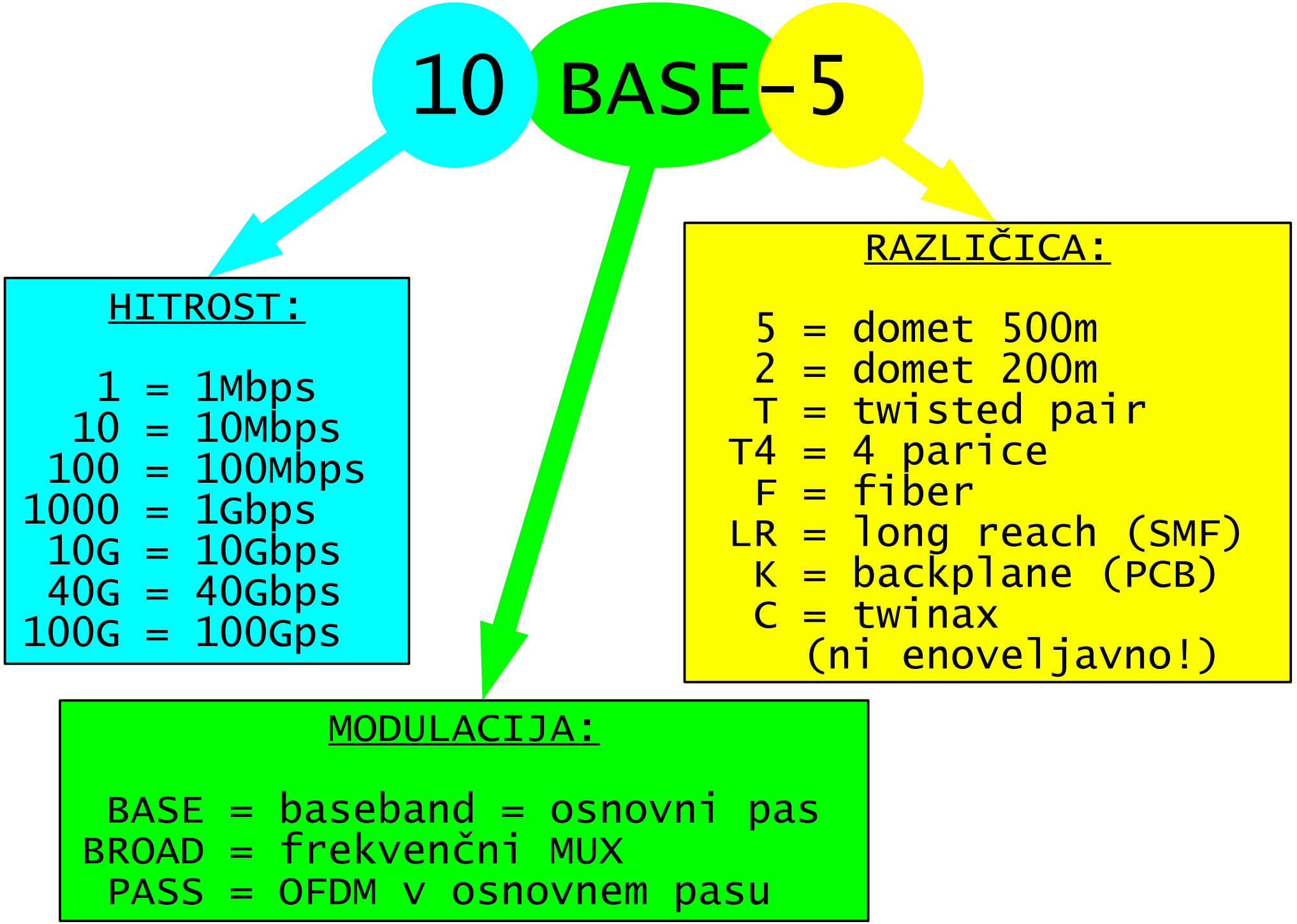
2003 - PoE (UTP) in 10Gbps ETH po svetlobnem vlaknu

2010 - prvi standardi za 40Gbps in 100Gbps Ethernet

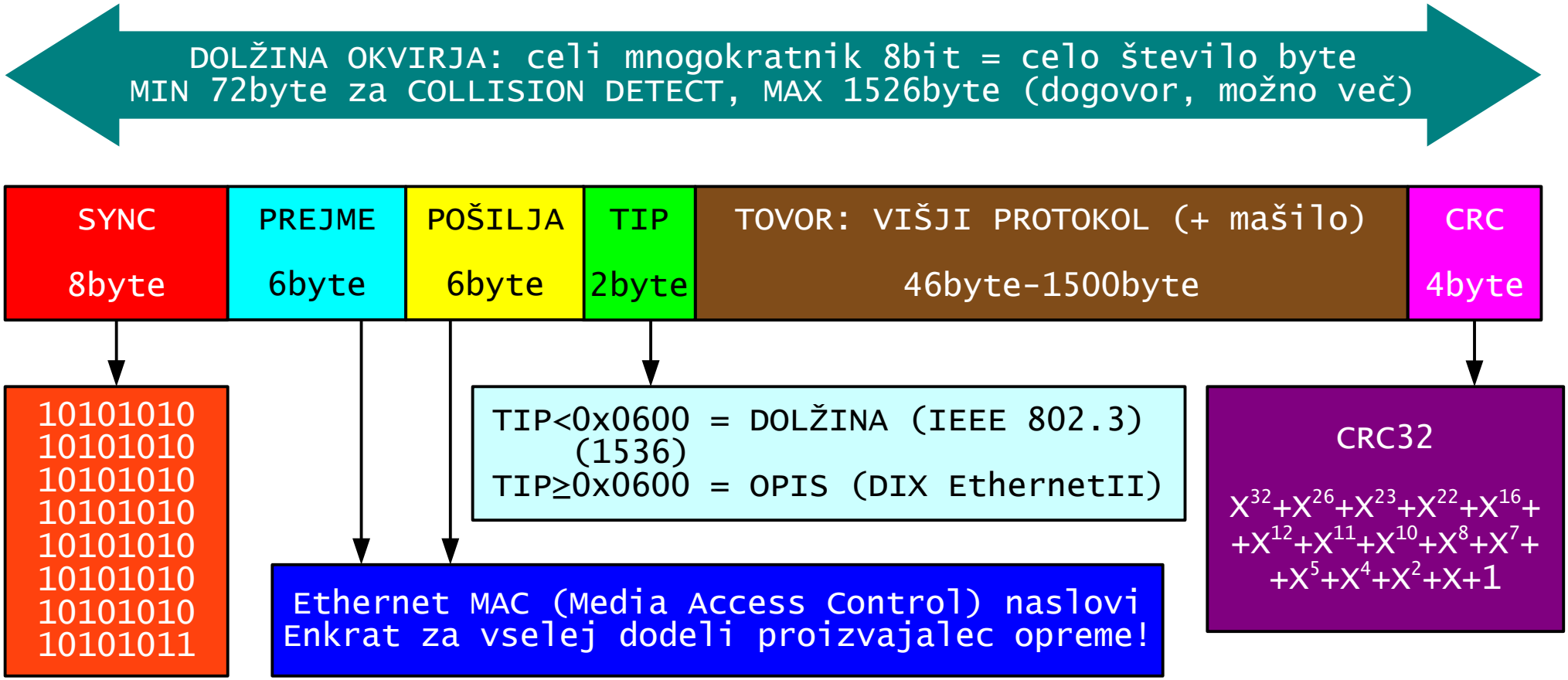
<u>Kratka zgodovina Etherneta</u>



Thick Ethernet 10BASE-5



Oznake Ethernet inačic



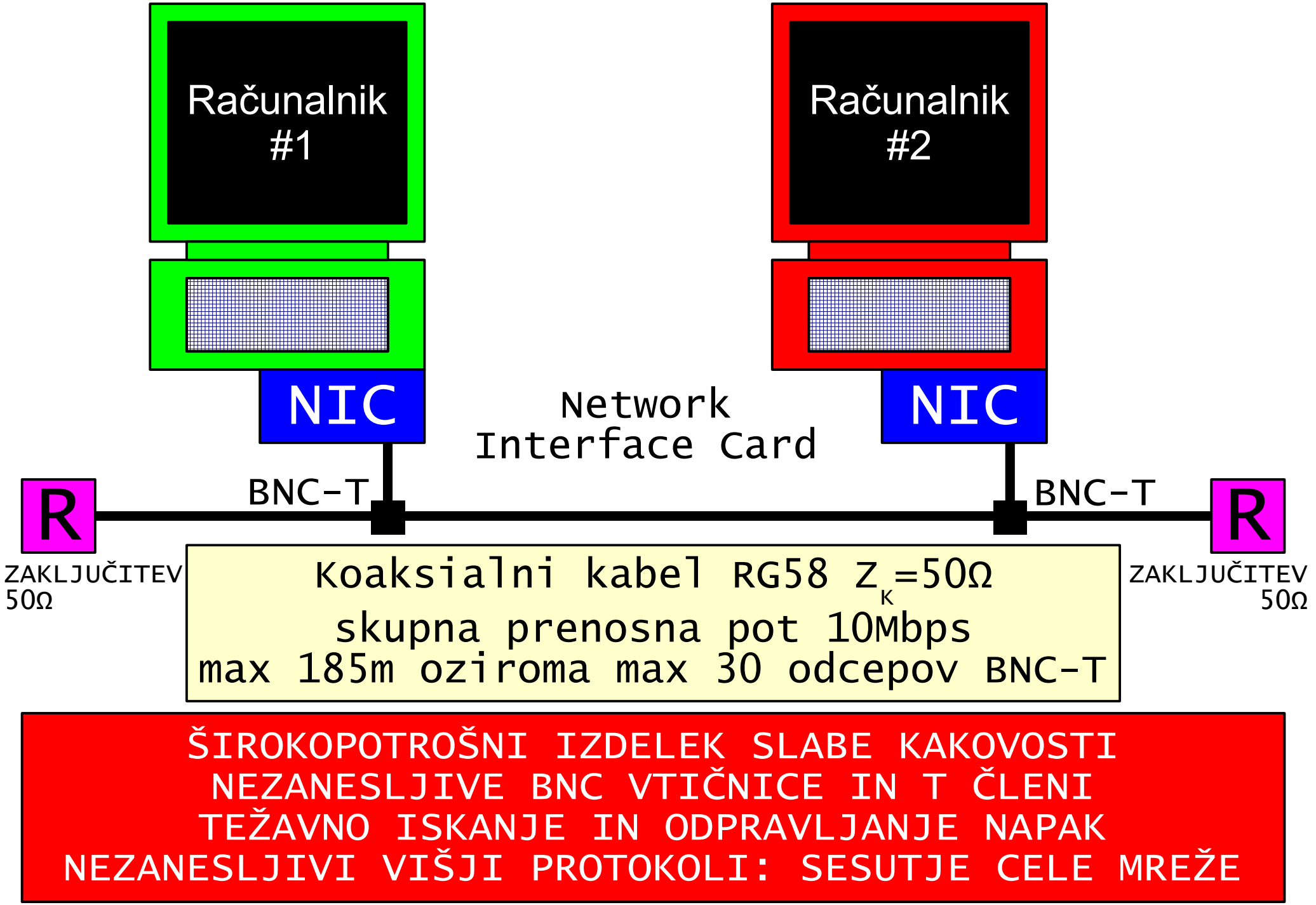
Začetek in konec okvirja nista natančno določena, to je prepuščeno nižji (PHY) ravni! Lahko se pojavi "dribble nibble".

Ponavljajo se samo okvirji v primeru zaznave trčenja (COLLISION DETECT)!

Sprejem katerihkoli okvirjev se ne potrjuje na Ethernet MAC ravni!

Sprejeti okvirji z neveljavnim CRCjem se zavržejo, brez javljanja napake!

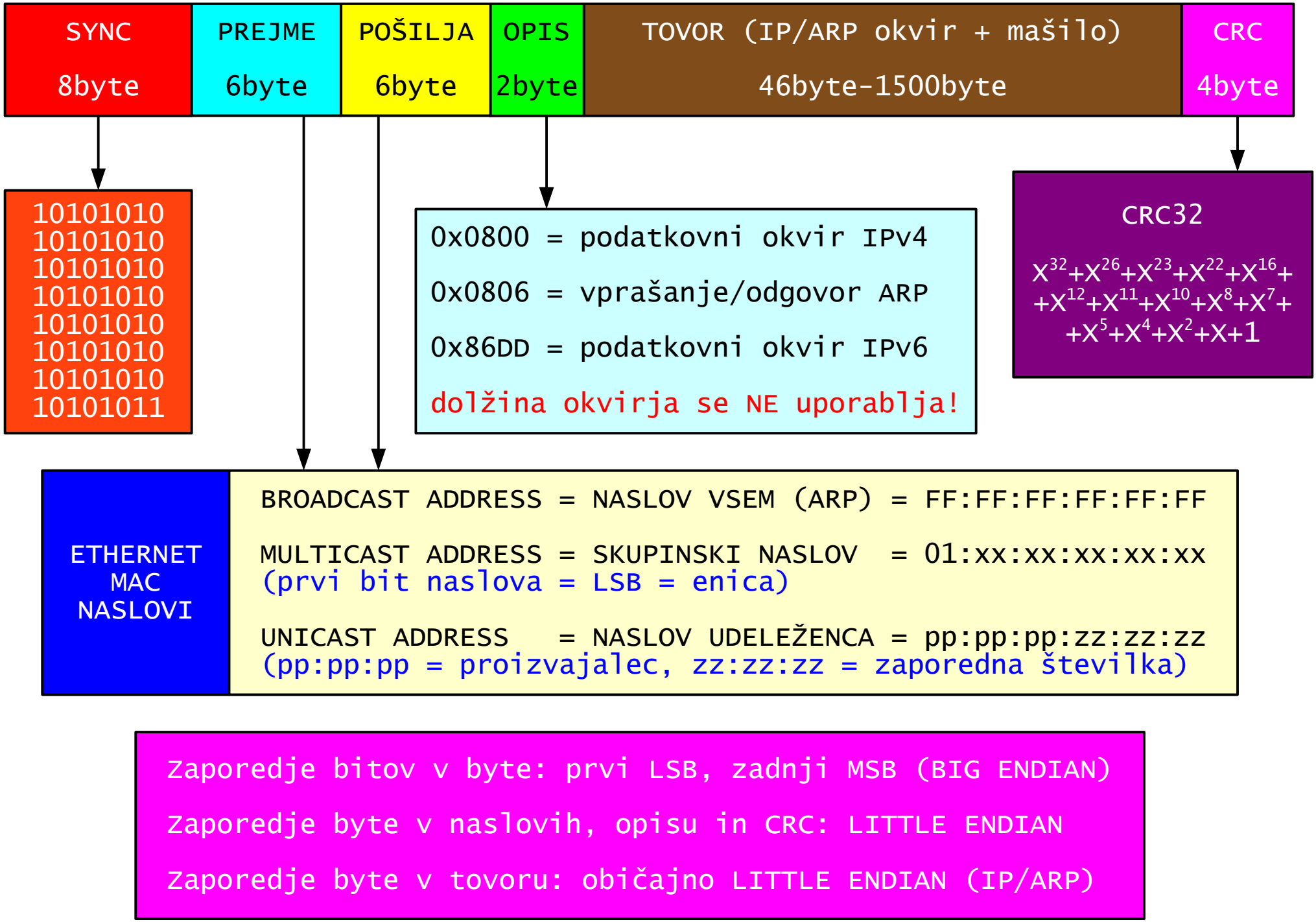
Zasnova Ethernet okvirja



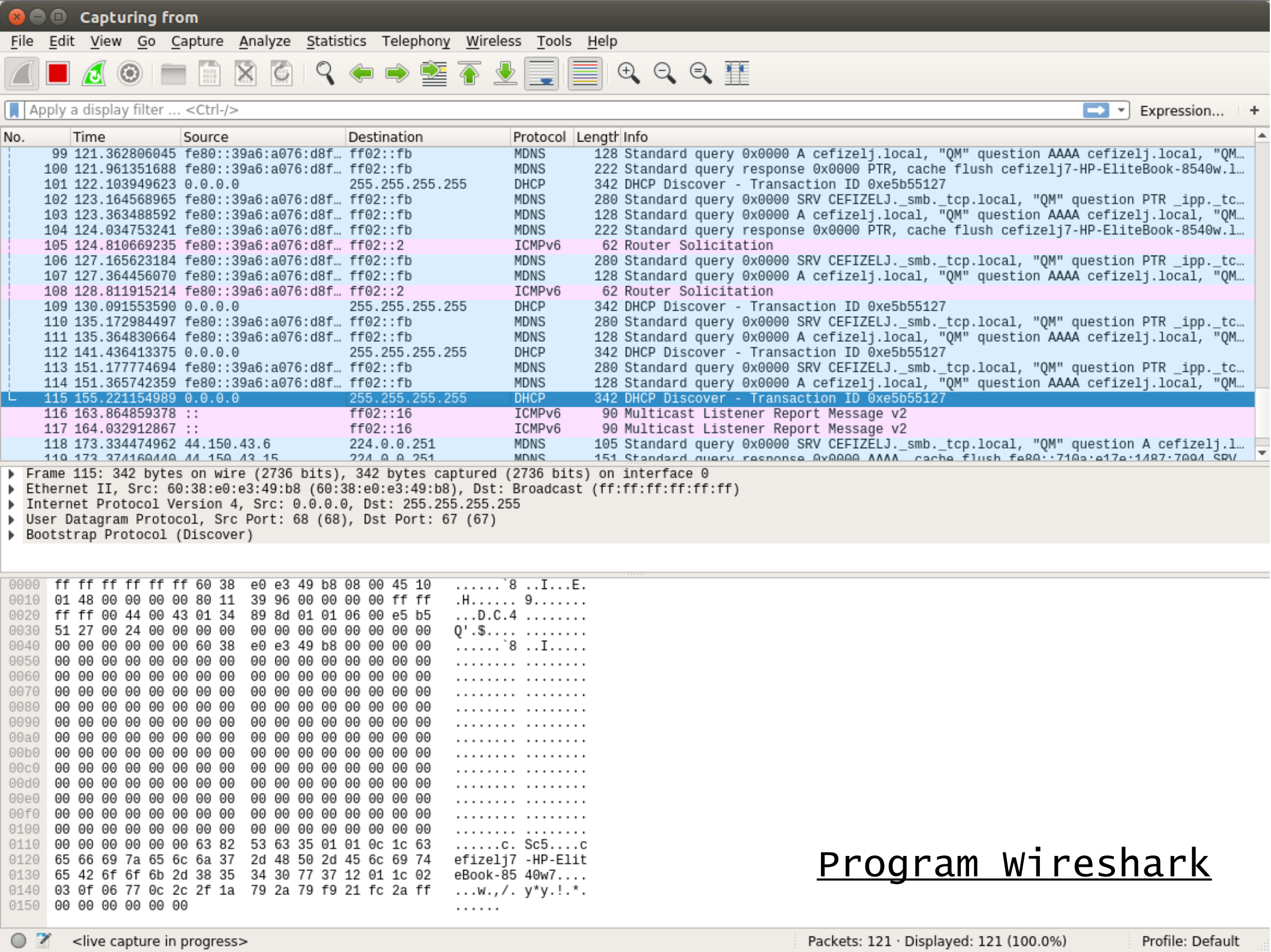
Thin Ethernet 10BASE-2

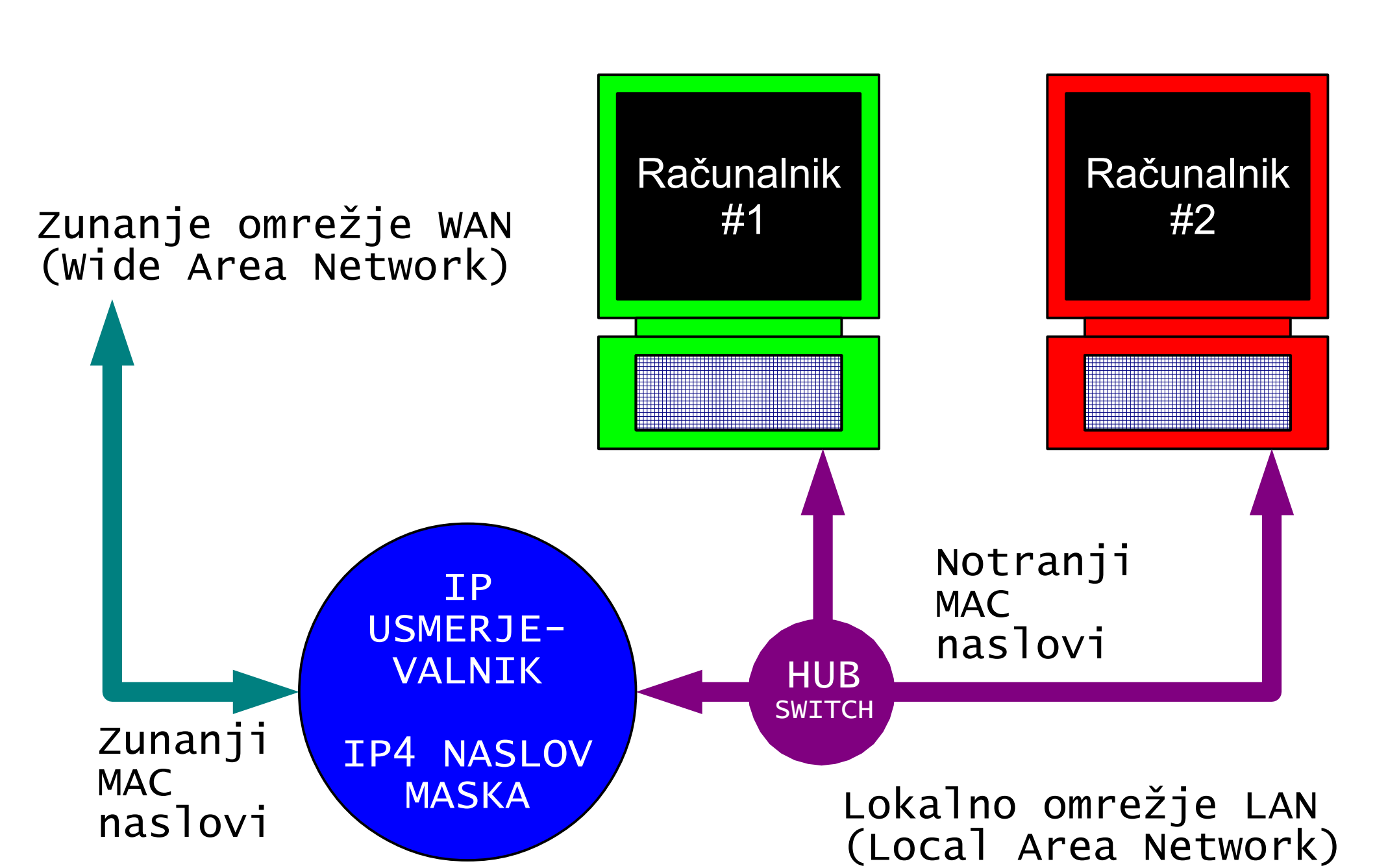
LETO	1990	10 let	2000
OSEBNI RAČUNALNIK	širokopotrošni izdelek najslabše kakovosti	>>>>>>	vrhunska računalniška tehnologija
PCB	LEPENKA (EMC?)	>>>>>>	VEČSLOJNI FR4 (Z_K)
CPU	8bit/16bit	X4	32bit/64bit
TAKT	25MHz	X100	2.5GHz
DISK	40Mbyte	X1000	40Gbyte
ZASLON	ČRKE ENEGA FONTA GROBA GRAFIKA	>>>>>>	BARVNE FOTOGRAFIJE ŽIV VIDEO
PROTOKOL	PISANA MNOŽICA PROTOKOLOV	>>>>>>	TCP/IP
MREŽA	PISANA MNOŽICA MREŽ	X1000	ETHERNET 100Mbps 100BASE-TX
ZVEZA	TELEFONSKI MODEM 20kbps	X100	ADSL 2Mbps

Računalniški duh uide iz steklenice

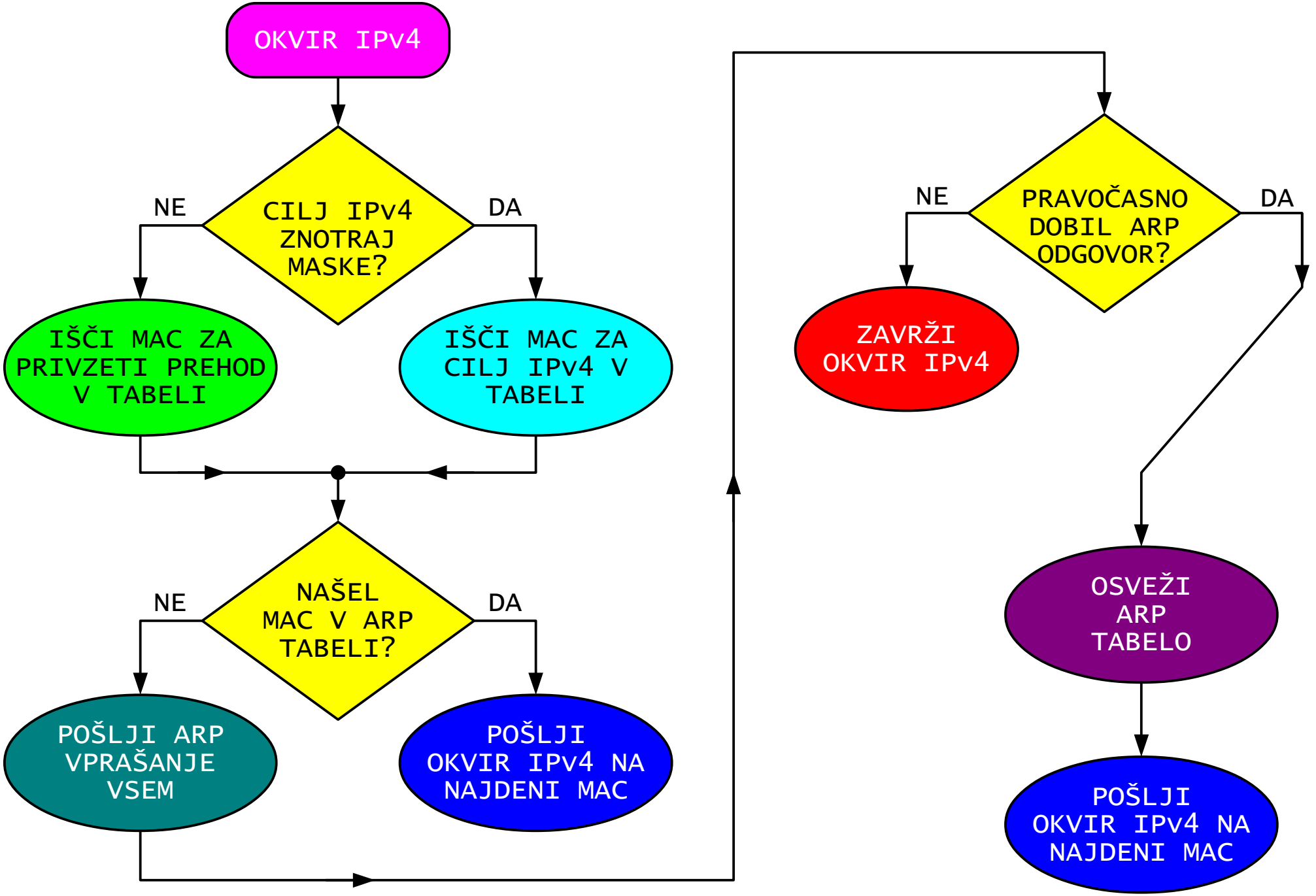


TCP/IP Ethernet okvirji


Capturing from
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Expression...
No. Time Source Destination Protocol Length Info
99 121.362806045 fe80::39a6:a076:d8f… ff02::fb MDNS 128 Standard query 0x0000 A cefizelj.local, "QM" question AAAA cefizelj.local, "QM…
100 121.961351688 fe80::39a6:a076:d8f… ff02::fb MDNS 222 Standard query response 0x0000 PTR, cache flush cefizelj7-HP-EliteBook-8540w.l…
101 122.103949623 0.0.0.0 255.255.255.255 DHCP 342 DHCP Discover - Transaction ID 0xe5b55127
102 123.164568965 fe80::39a6:a076:d8f… ff02::fb MDNS 280 Standard query 0x0000 SRV CEFIZELJ._smb._tcp.local, "QM" question PTR _ipp._tc…
103 123.363488592 fe80::39a6:a076:d8f… ff02::fb MDNS 128 Standard query 0x0000 A cefizelj.local, "QM" question AAAA cefizelj.local, "QM…
104 124.034753241 fe80::39a6:a076:d8f… ff02::fb MDNS 222 Standard query response 0x0000 PTR, cache flush cefizelj7-HP-EliteBook-8540w.l…
105 124.810669235 fe80::39a6:a076:d8f… ff02::2 ICMPv6 62 Router Solicitation
106 127.165623184 fe80::39a6:a076:d8f… ff02::fb MDNS 280 Standard query 0x0000 SRV CEFIZELJ._smb._tcp.local, "QM" question PTR _ipp._tc…
107 127.364456070 fe80::39a6:a076:d8f… ff02::fb MDNS 128 Standard query 0x0000 A cefizelj.local, "QM" question AAAA cefizelj.local, "QM…
108 128.811915214 fe80::39a6:a076:d8f… ff02::2 ICMPv6 62 Router Solicitation
109 130.091553590 0.0.0.0 255.255.255.255 DHCP 342 DHCP Discover - Transaction ID 0xe5b55127
110 135.172984497 fe80::39a6:a076:d8f… ff02::fb MDNS 280 Standard query 0x0000 SRV CEFIZELJ._smb._tcp.local, "QM" question PTR _ipp._tc…
111 135.364830664 fe80::39a6:a076:d8f… ff02::fb MDNS 128 Standard query 0x0000 A cefizelj.local, "QM" question AAAA cefizelj.local, "QM…
112 141.436413375 0.0.0.0 255.255.255.255 DHCP 342 DHCP Discover - Transaction ID 0xe5b55127
113 151.177774694 fe80::39a6:a076:d8f… ff02::fb MDNS 280 Standard query 0x0000 SRV CEFIZELJ._smb._tcp.local, "QM" question PTR _ipp._tc…
114 151.365742359 fe80::39a6:a076:d8f… ff02::fb MDNS 128 Standard query 0x0000 A cefizelj.local, "QM" question AAAA cefizelj.local, "QM…
115 155.221154989 0.0.0.0 255.255.255.255 DHCP 342 DHCP Discover - Transaction ID 0xe5b55127
116 163.864859378 :: ff02::16 ICMPv6 90 Multicast Listener Report Message v2
117 164.032912867 :: ff02::16 ICMPv6 90 Multicast Listener Report Message v2
118 173.334474962 44.150.43.6 224.0.0.251 MDNS 105 Standard query 0x0000 SRV CEFIZELJ._smb._tcp.local, "QM" question A cefizelj.l…
Frame 115: 342 bytes on wire (2736 bits), 342 bytes captured (2736 bits) on interface 0
Ethernet II, Src: 60:38:e0:e3:49:b8 (60:38:e0:e3:49:b8), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
Internet Protocol Version 4, Src: 0.0.0.0, Dst: 255.255.255.255
User Datagram Protocol, Src Port: 68 (68), Dst Port: 67 (67)
Bootstrap Protocol (Discover)
0000 ff ff ff ff ff ff 60 38 e0 e3 49 b8 08 00 45 10 ......`8 ..I...E.
0010 01 48 00 00 00 00 80 11 39 96 00 00 00 00 ff ff .H...... 9.......
0020 ff ff 00 44 00 43 01 34 89 8d 01 01 06 00 e5 b5 ...D.C.4 ....
0030 51 27 00 24 00 00 00 00 00 00 00 00 00 00 00 00 Q'.$.... ....
0040 00 00 00 00 00 00 60 38 e0 e3 49 b8 00 00 00 00 ......`8 ..I.....
0050 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
0060 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
0070 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
0080 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
0090 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
00a0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
00b0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
00c0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
00d0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
00e0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
00f0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
0100 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ....
0110 00 00 00 00 00 00 63 82 53 63 35 01 01 0c 1c 63 ......c. Sc5....c
0120 65 66 69 7a 65 6c 6a 37 2d 48 50 2d 45 6c 69 74 efizelj7 -HP-Elit
0130 65 42 6f 6f 6b 2d 38 35 34 30 77 37 12 01 1c 02 eBook-85 40w7....
0140 03 0f 06 77 0c 2c 2f 1a 79 2a 79 f9 21 fc 2a ff ...w.,/. y*y.!.*.
0150 00 00 00 00 00 00 ......
<live capture in progress>
Packets: 121 · Displayed: 121 (100.0%)
Profile: Default
Program Wireshark



TCP/IP Ethernet omrežja



Address Resolution Protocol (ARP)

RJ-45 Wiring (TIA/EIA-568-B T568A)

Pin	Pair	Color	telephone	10BASE-T	100BASE-TX	1000BASE-T	PoE mode A	PoE mode B
1	3	white/green	-	TX+	z	bidi	48V out	-
2	3	green	-	TX-	z	bidi	48V out	-
3	2	white/orange	-	RX+	z	bidi	48V return	-
4	1	blue	ring	-	-	bidi	-	48V out
5	1	white/blue	tip	-	-	bidi	-	48V out
6	2	orange	-	RX-	z	bidi	48V return	-
7	4	white/brown	-	-	-	bidi	-	48V return
8	4	brown	-	-	-	bidi	-	48V return

(WIKIPEDIA)

ZVEZA TOČKA-TOČKA

ZAKLJUČITEV Z_K=100Ω

DOMET ~100m (10/100Mbps)

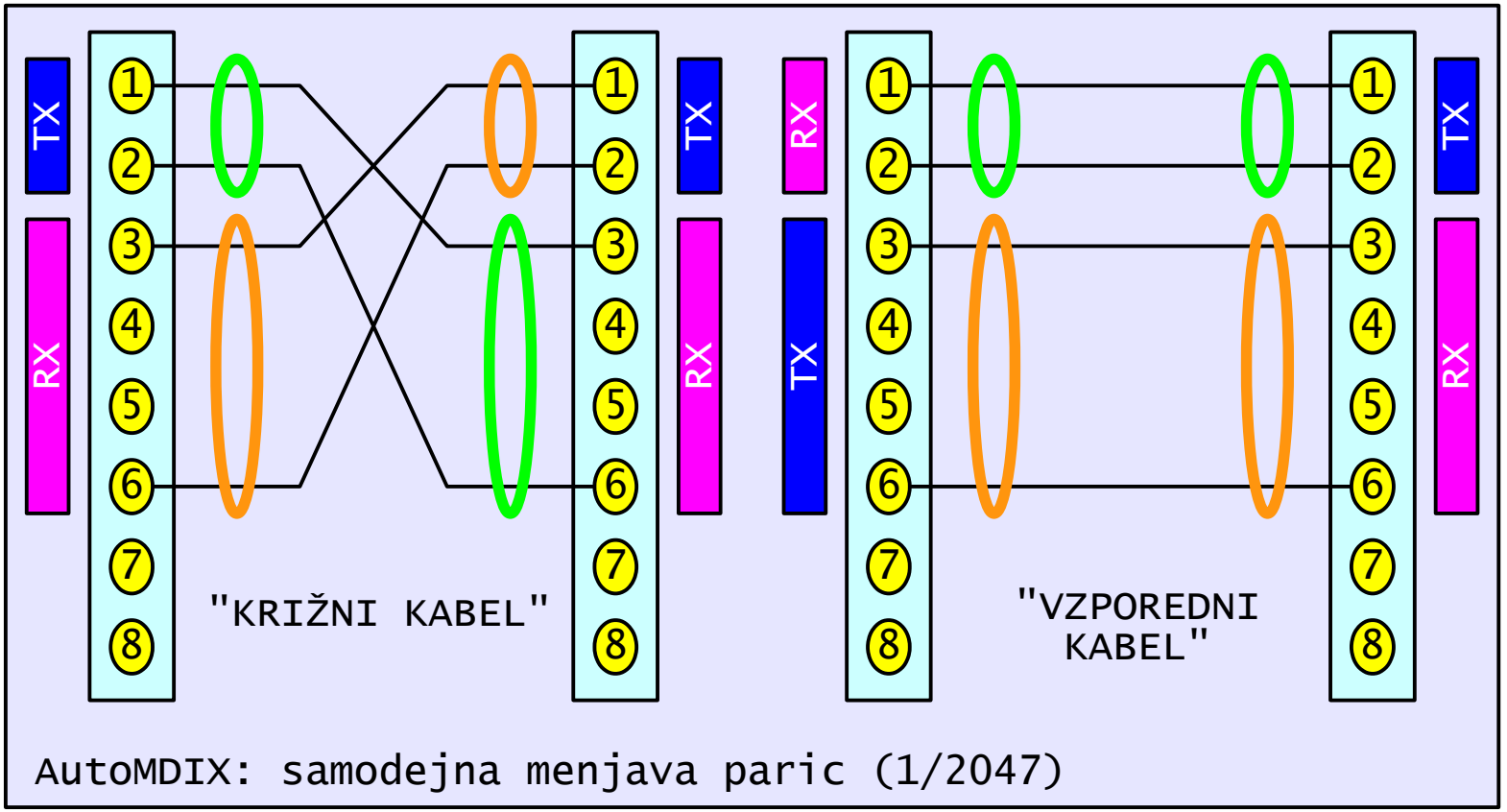
TIA/EIA-568 T568A termination

Pin	Pair	Wire	Color
1	3	tip	white/green
2	3	ring	green
3	2	tip	white/orange
4	1	ring	blue
5	1	tip	white/blue
6	2	ring	orange
7	4	tip	white/brown
8	4	ring	brown

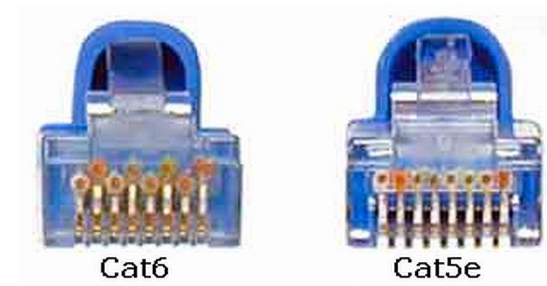
TIA/EIA-568 T568B termination

Pin	Pair	Wire	Color
1	2	tip	white/orange
2	2	ring	orange
3	3	tip	white/green
4	1	ring	blue
5	1	tip	white/blue
6	3	ring	green
7	4	tip	white/brown
8	4	ring	brown

(WIKIPEDIA)



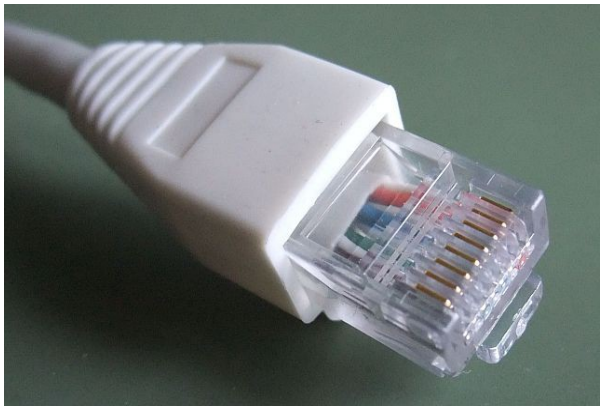
Neoklopljena sukana parica (UTP)

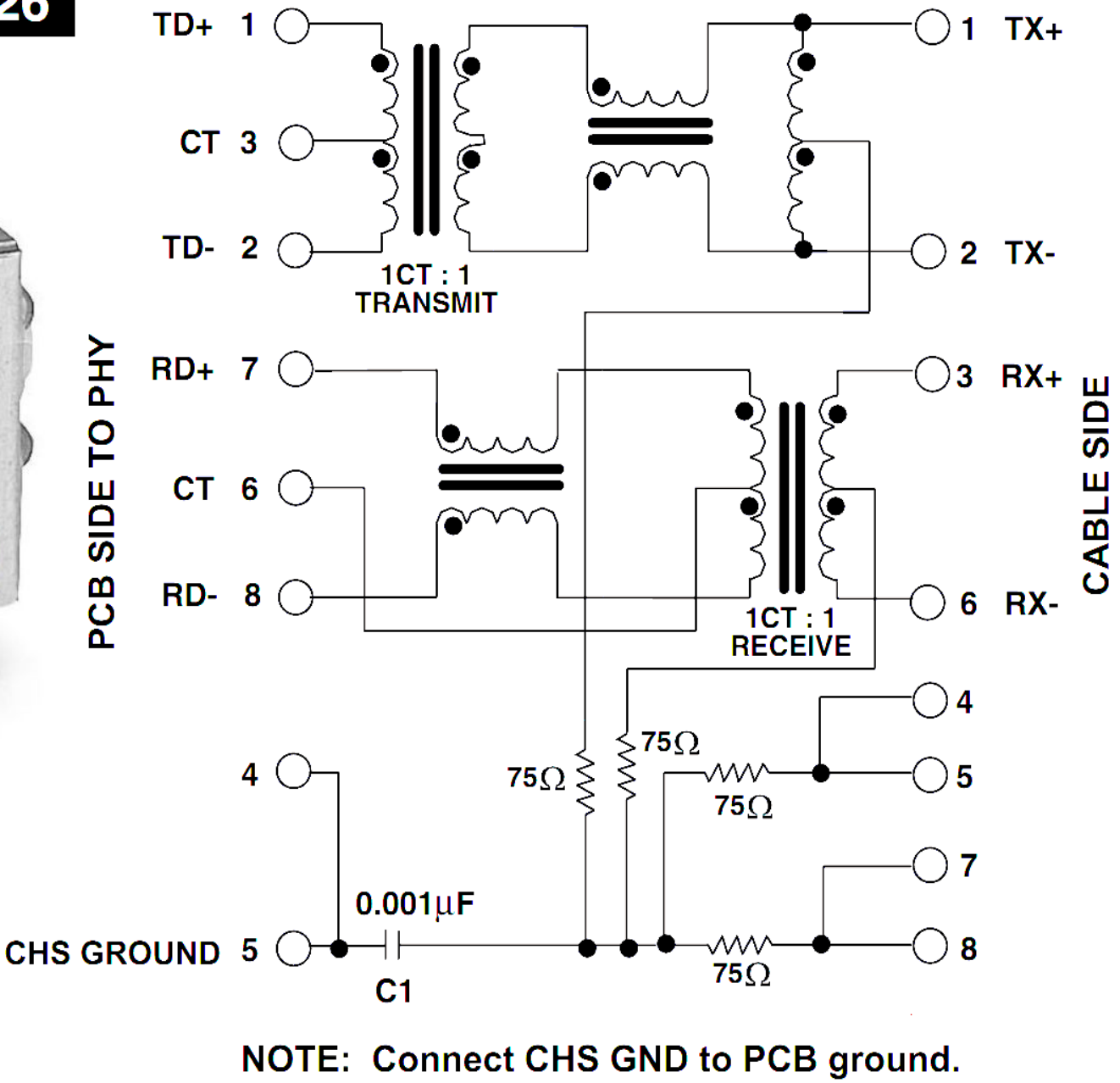


Zvrst	Cat1	Cat2	Cat3	Cat4	Cat5	Cat5e	Cat6	Cat6a	Cat7	Cat7a
Izvedba	UTP	UTP	UTP	UTP	UTP (+PE)		UTP (+Cu)		S/FTP (+oklop)	
B [MHz]	0.4	4	16	20	100	100	250	500	600	1000
10BASE-T 2xManchester	-		100m	<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<						
100BASE-TX 2x4B5B+MLT3	-				100m	<<<<<<<<<<<<<<<<<<<<<<<<<<<<				
1000BASE-T 4x8B10B+PAM5	-				100m	<<<<<<<<<<<<<<<<<<<<<<<<<<<<				
10GBASE-T 4x64B66B+ THP-PAM16	-					45m	55m	100m	<<<<<<<<<	

Zvrsti UTP/STP vodnikov

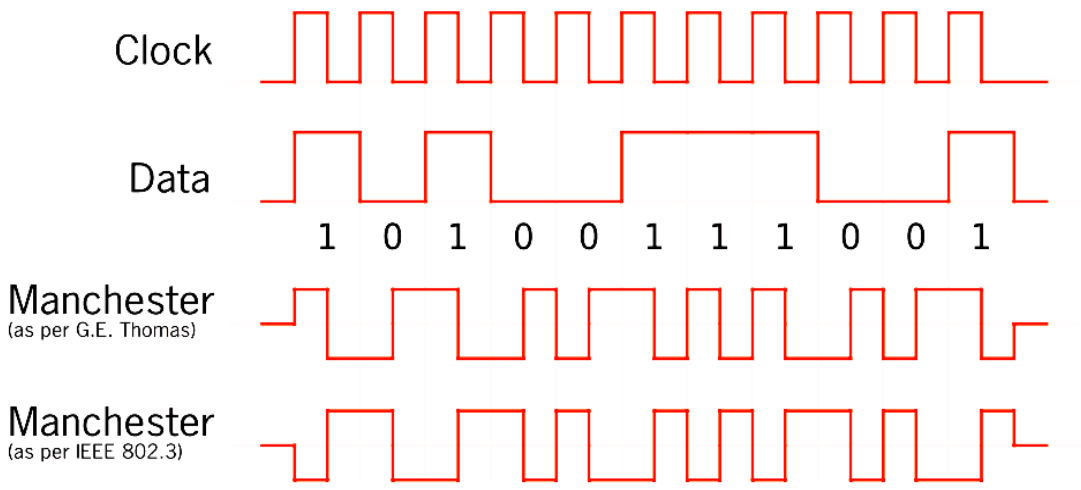
J0026



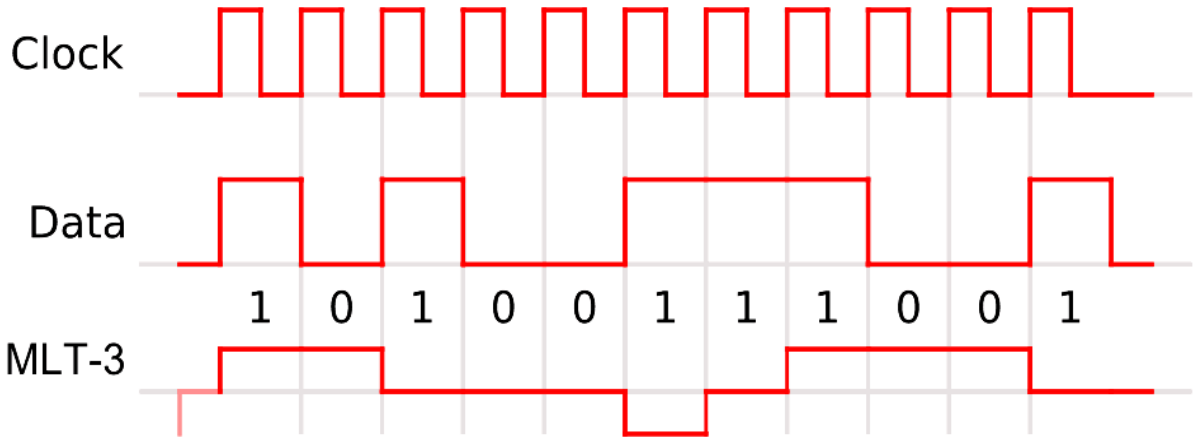


NOTE: Connect CHS GND to PCB ground.

Vtikač in trafo vtičnica RJ45



KODIRANJE MANCHESTER (WIKIPEDIA)



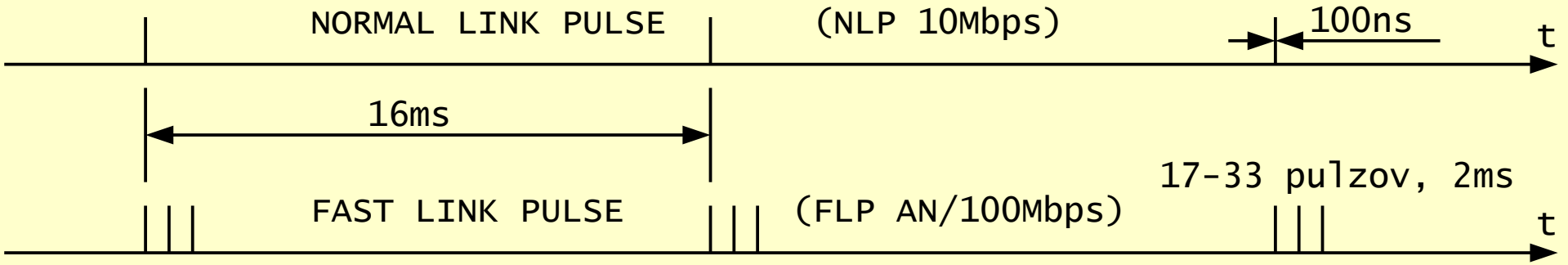
TRINIVOJSKO KODIRANJE MLT3 (WIKIPEDIA)

Name	4b	5b	Description
0	0000	11110	hex data 0
1	0001	01001	hex data 1
2	0010	10100	hex data 2
3	0011	10101	hex data 3
4	0100	01010	hex data 4
5	0101	01011	hex data 5
6	0110	01110	hex data 6
7	0111	01111	hex data 7
8	1000	10010	hex data 8
9	1001	10011	hex data 9
A	1010	10110	hex data A
B	1011	10111	hex data B
C	1100	11010	hex data C
D	1101	11011	hex data D
E	1110	11100	hex data E
F	1111	11101	hex data F
Q	-NONE-	00000	Quiet (signal lost)
I	-NONE-	11111	Idle
J	-NONE-	11000	Start #1
K	-NONE-	10001	Start #2
T	-NONE-	01101	End
R	-NONE-	00111	Reset
S	-NONE-	11001	Set
H	-NONE-	00100	Halt

4B5B (WIKIPEDIA)

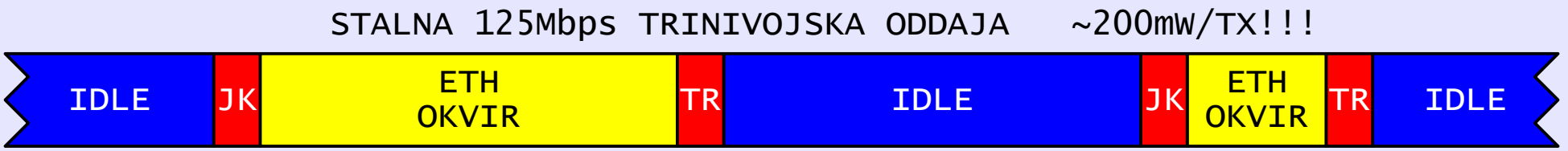
Manchester, 4B5B in MLT3

NEPOVEZAN



10Mbps: Manchester (občutljiv na polariteto)

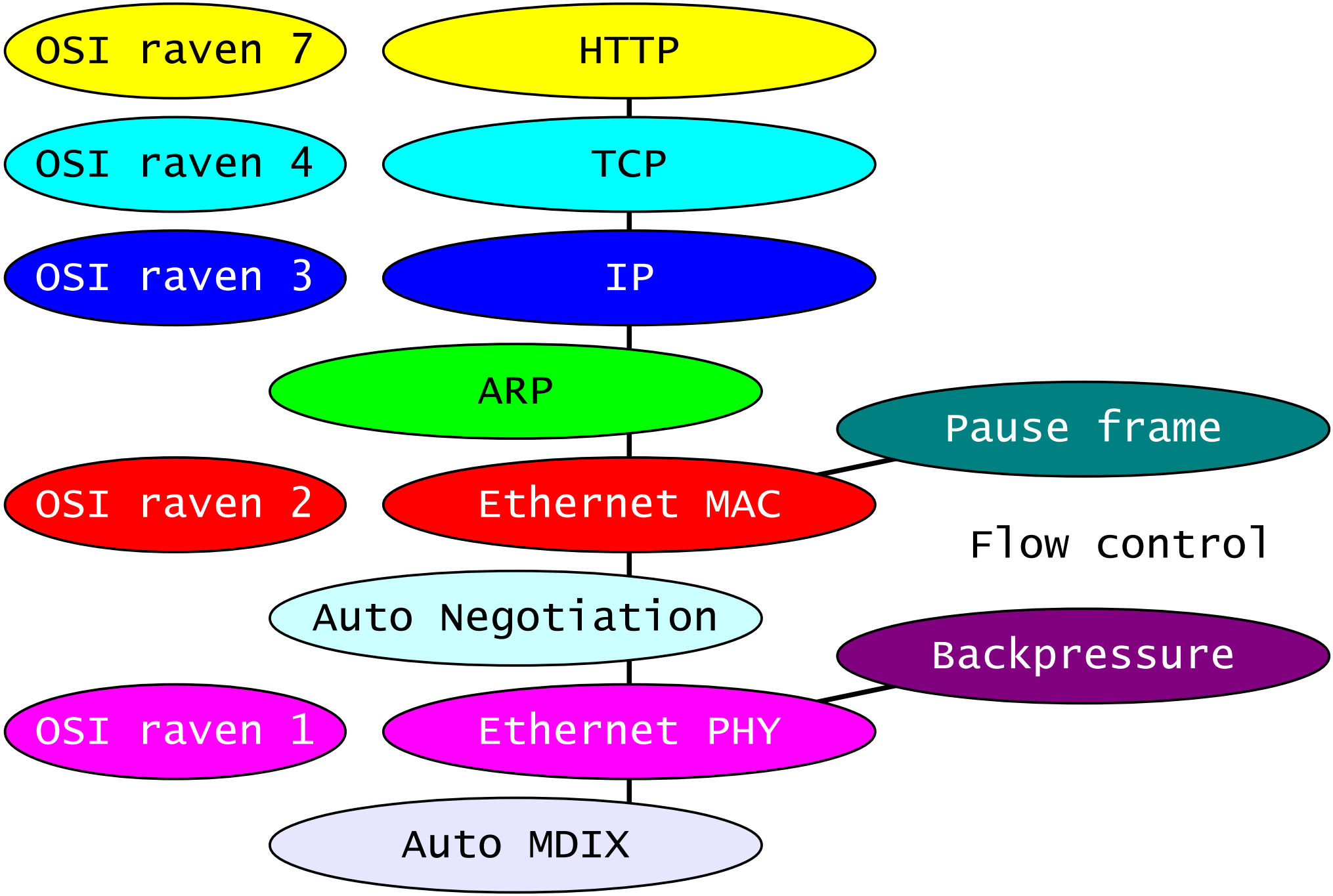
100Mbps: 4B5B+NRZI(1)+skrambler+MLT3



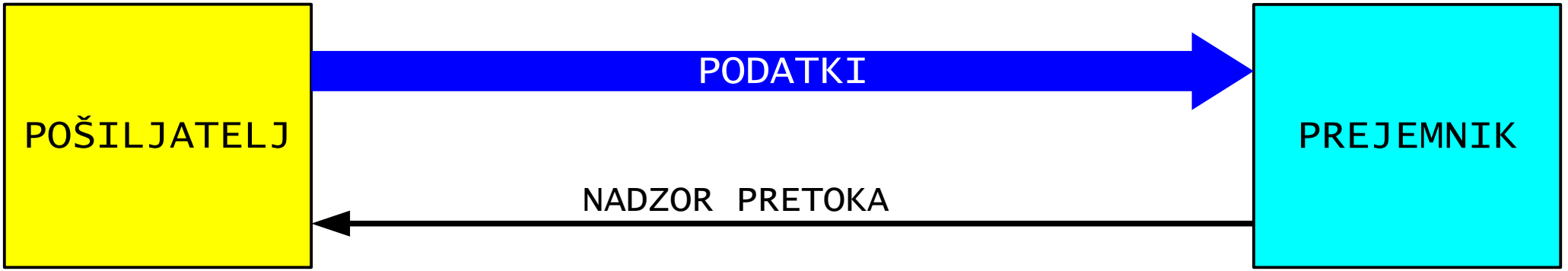
AN ≡ Auto Negotiation (10/100Mbps, half/fullduplex)

AutoMDIX ≡ Auto Media-Dependent-Interface eXchange

<u>Delovanje 10BASE-T in 100BASE-TX</u>



TCP/IP/Ethernet/UTP sklad protokolov



HALF-DUPLEX: zaustavlja pretok z oddajo BACKPRESSURE (stalni SYNC)
POZOR! Ustavi vse udeležence v omrežju. Ne sme preseči JABBER LIMIT!

FULL-DUPLEX: oddaja PAUSE okvirja (IEEE 802.3x) na skupinski naslov 01-80-C2-00-00-01, OPIS=0x8808, OPCODE=0x0001, čakanje PAUSE=0-65535 časovnih enot, časovna enota čakanja je 512 bitnih period:

SYNC	PREJME	POŠILJA	OPIS	OPCODE	PAUSE	NIČLE (mašilo)	CRC
8byte	01-80-C2--00-00-01	6byte	0x8808	0x0001	0--65535	42byte	4byte

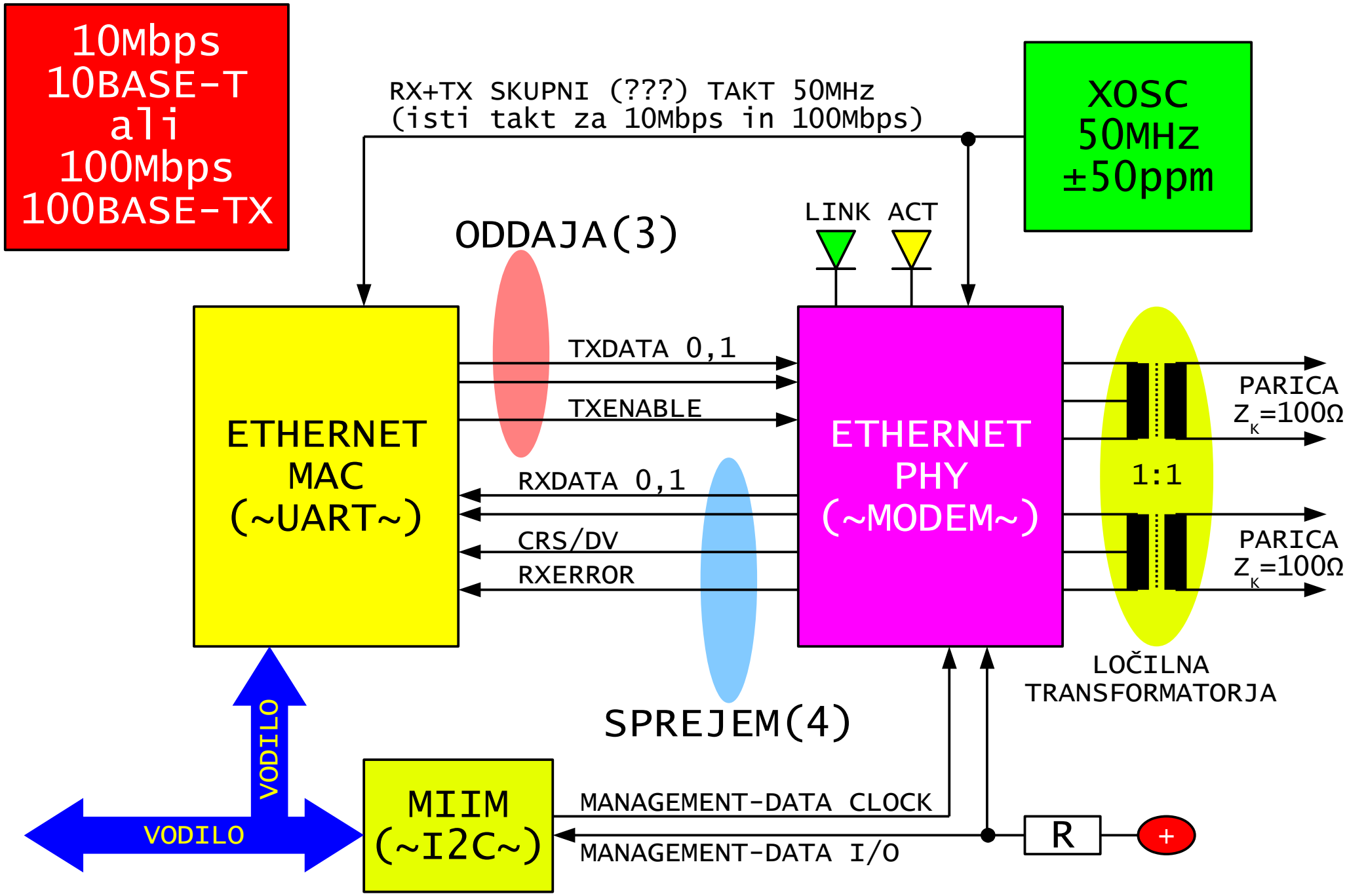
Cisco FULL-DUPLEX: razširitev PAUSE okvirja vsebuje 8 neodvisnih PAUSE za 8 različnih prioritet podatkov (VLAN), OPCODE=0x0101:

SYNC	PREJME	POŠILJA	OPIS	OPCODE	8X PAUSE	(mašilo)	CRC
8byte	01-80-C2--00-00-01	6byte	0x8808	0x0101	16byte	28byte	4byte

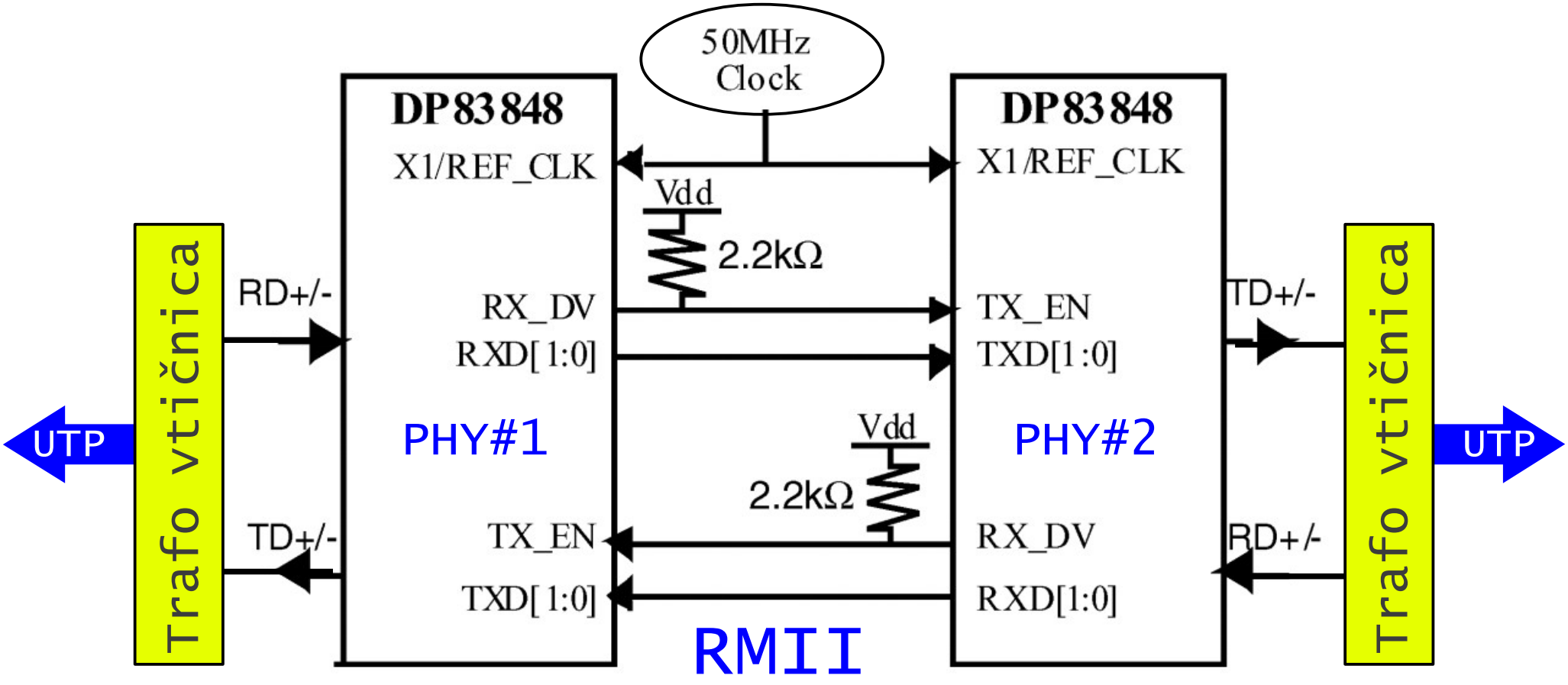
Nadzor pretoka (Flow control)

Ime	Vmesnik	Hitrost	Vodilo	Priklop
AUI	Attachment Unit Interface	10Mbps	2X 1bit	3parice
MII	Media-Independent Interface	10/100Mbps	2X 4bit	17pin
RMII	Reduced Media--Independent Interface	10/100Mbps	2X 2bit	10pin
SNI	Serial Network Interface	10Mbps	2X 1bit	9(7)pin
GMII	Gigabit Media--Independent Interface	10/100/ 1000Mbps	2X 8bit	27pin
RGMII	Reduced Gigabit Media--Independent Interface	10/100/ 1000Mbps	2X 4bit	14pin
SGMII	Serial Gigabit Media--Independent Interface	10/100/ 1000Mbps	2X 1bit	4parice 8B10B+takt
XGMII	10 Gigabit Media--Independent Interface	10Gbps	2X 32bit	74pin
XAUI	10 (Gbps) Attachment Unit Interface	10Gbps	2X 4bit	8paric 8B10B

Različice Media-Independent Interface (MII)



Reduced Media-Independent Interface (RMII)



100BASE-TX 3R regenerator (Extender)

V_{CC}

RMII

21 22 Pin

Rx +/-

RxD

PHY#1
KS8721BL/SL

UTP

Trafo vtičnica

TxD

Tx +/-

TxC/ Ref_CLK

OSC

50MHz

LASER

FTx

TxC/ Ref_CLK

PHY#2
KS8721BL/SL
(Fiber Mode)

TxD

PINFET

FRx

RxD

2x SMF

Pin 34

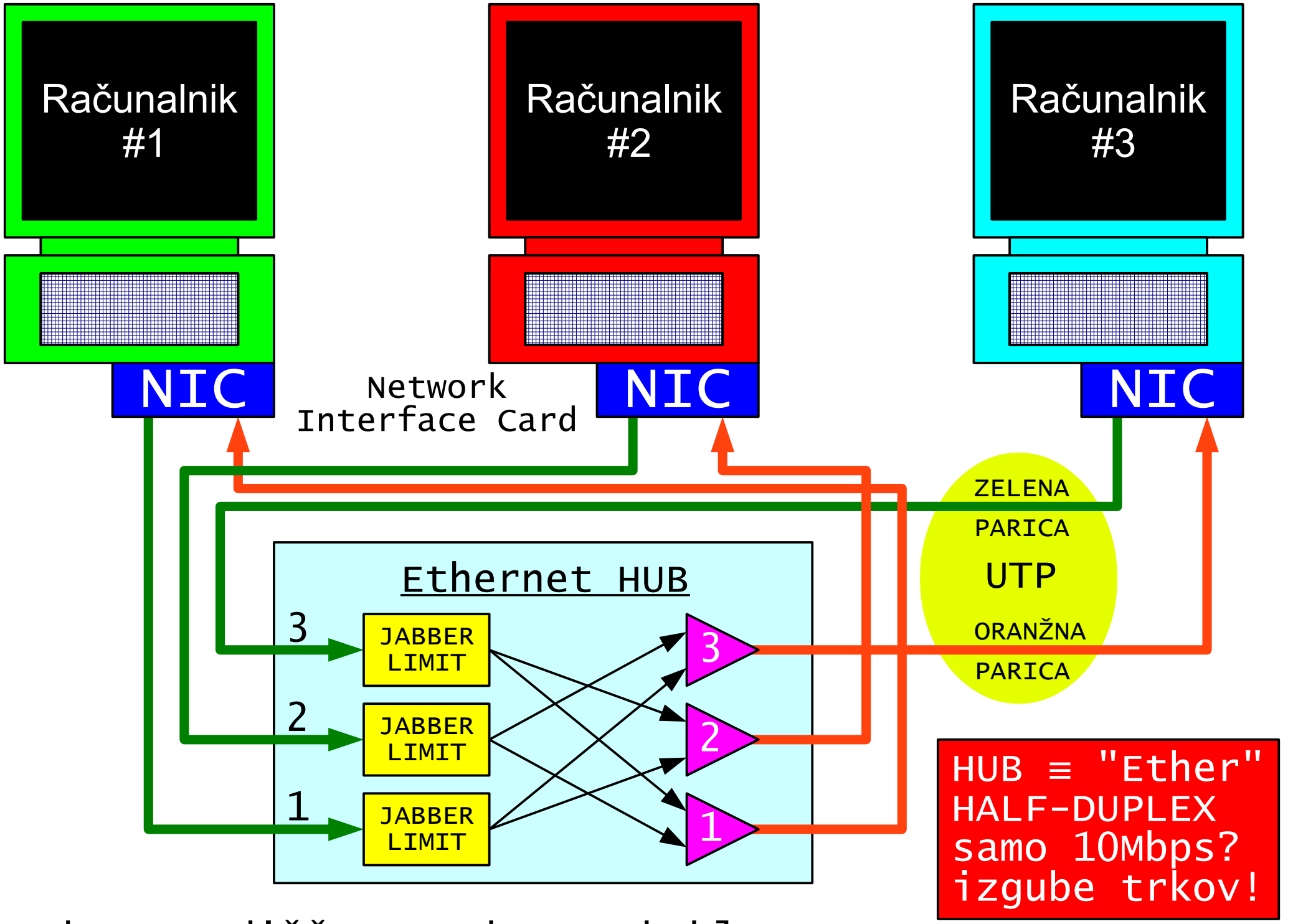
Pin 21 22

To the SD pin of the Fiber Module

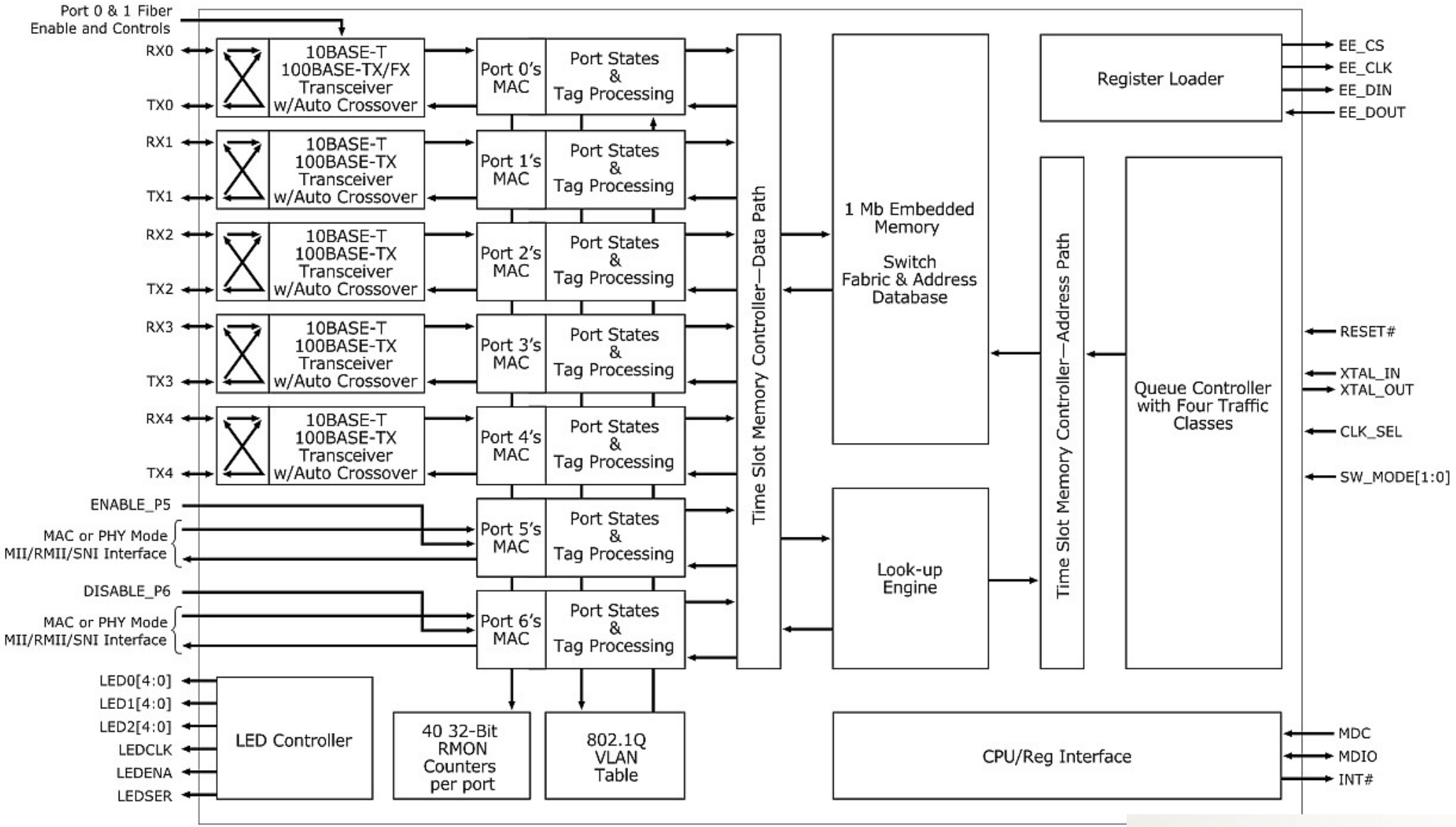
V_{CC}

Maloprodajna cena
(2013: SMF 10km)
100Mbps ~25 EUR
1Gbps ~50 EUR

100BASE-TX/100BASE-FX Media Converter



Hub v središču zvezde UTP kablov



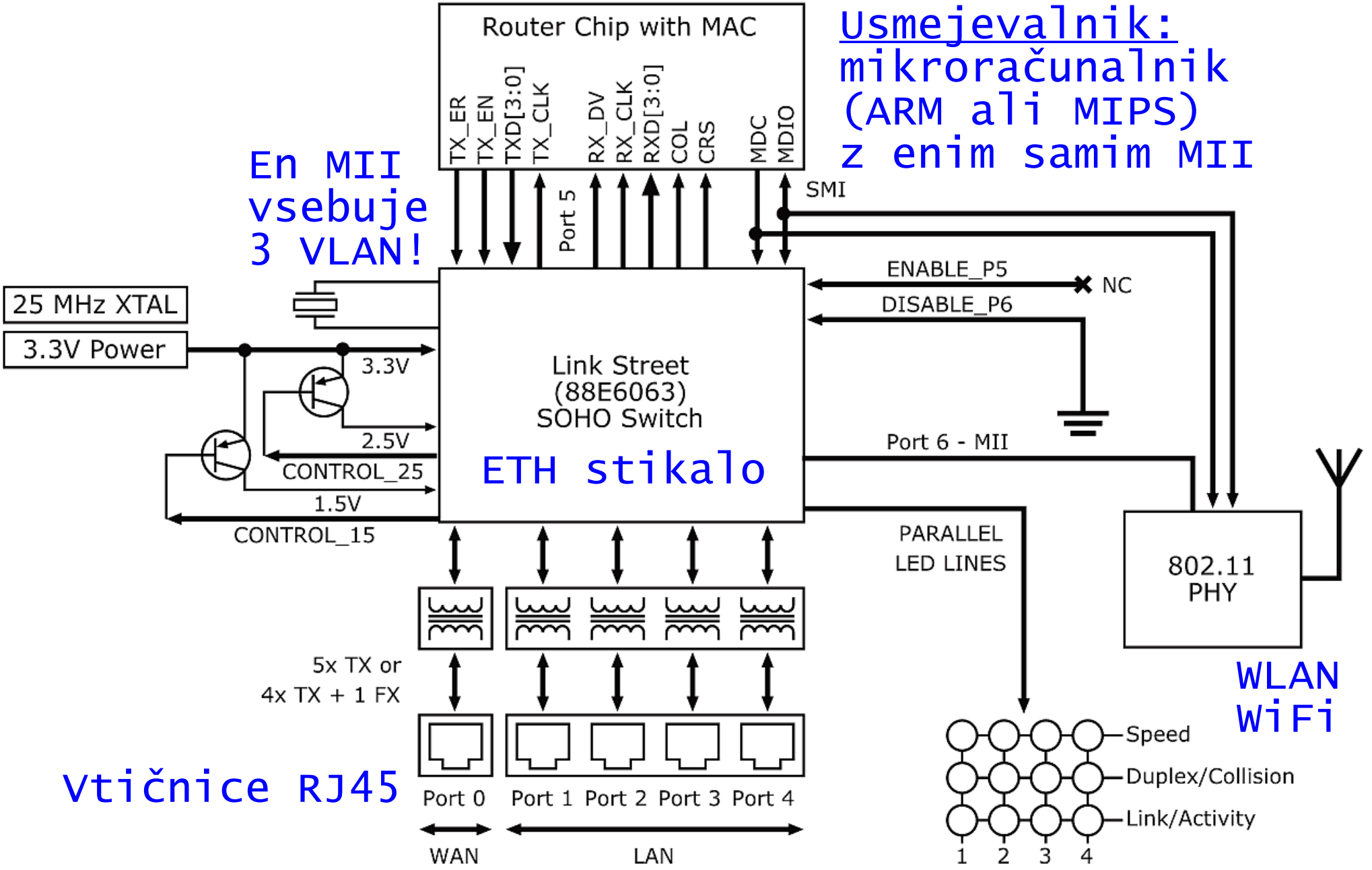
Link Street 88E6063 SOHO Switch Internal Block Diagram

Omogoča FULL-DUPLEX, hkrati in brez izgub 10Mbps in 100Mbps!

Čip poštar:

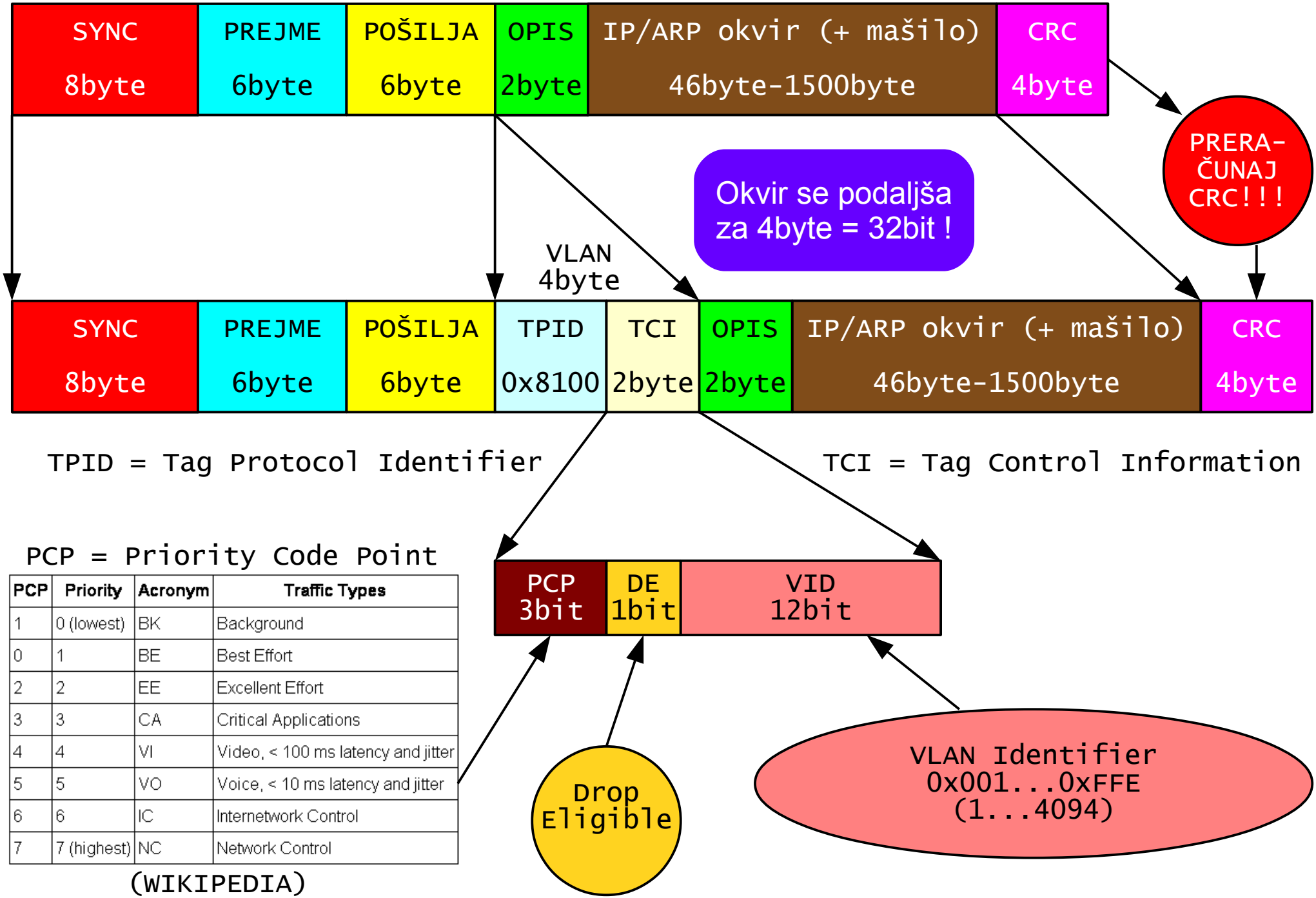
Izraz "Ether" izgubi pomen!

Aktivno Ethernet stikalo (switch)



Firewall Router Application

Uporaba stikala v domačem usmerjevalniku



PCP	Priority	Acronym	Traffic Types
1	0 (lowest)	BK	Background
0	1	BE	Best Effort
2	2	EE	Excellent Effort
3	3	CA	Critical Applications
4	4	VI	Video, < 100 ms latency and jitter
5	5	VO	Voice, < 10 ms latency and jitter
6	6	IC	Internetwork Control
7	7 (highest)	NC	Network Control

(WIKIPEDIA)

Virtual Local Area Network (VLAN)

1987 - FOIRL (Fiber-Optic Inter-Repeater Link) 10Mbps, 850nm, domet 1km, par vlaken 62.5/125 za povezavo med zgradbami in galvansko ločitev, izboljšan 1993 v združljiv 10BASE-FL, domet 2km (in več po SMF)

1995 - 100BASE-FX družina standardov za 100Mbps po MMF/SMF na 850/1310/1550nm z velikim dometom 500m do 40km, istočasno z žičnim 100BASE-TX dometa 100m

1998 - 1000BASE-X izvorna izvedba 1Gbps Etherneta po MMF/SMF na 850/1310/1550nm z velikim dometom 200m do 70km, UTP inačica pride šele leto kasneje (1999)

2003 - 10GBASE-SR/LR/ER/LX4/SW/LW/EW 10Gbps Ethernet po MMF/SMF na 850/1310/1550nm z velikim dometom 200m do 80km, WAN inačice SW/LW/EW delajo z 9.953Gbps za neposredno združljivost s STM-64 opremo brez ATM!

2004 - "Ethernet in the first mile" in 1Gbps EPON

2009 - 10Gbps EPON

2010 - prvi standardi za 40Gbps in 100Gbps Ethernet kot nadomestek za SDH STM-256, ki se umika iz uporabe

<u>Zgodovina optičnega Etherneta</u>

Izvedba	Hitrost prenosa	Linijsko kodiranje	Linijska hitrost	Polnilo med okvirji
FOIRL 10BASE-FL	10Mbps	Manchester	20Mbps	Pravokotnik 1MHz
Družina 100BASE-FX	100Mbps	4B5B NRZI(1)	125Mbps	62.5MHz (IDLE)
Družina 1000BASE-X	1Gbps	8B10B NRZI(1)	1.25Gbps	8B10B IDLE
Družina 10GBASE-SR/LR/ER	10Gbps	64B66B NRZI(1)	10.3125Gbps	64B66B IDLE

Linijsko kodiranje jamči enosmerno komponento signala (približno enako število enic in ničel), stalno regeneracijo takta in uokvirjanje (IDLE, začetek in konec okvirja).

Modulacija oddajnika (laserja) je do vključno 10Gbps dvonivojska ON/OFF (ASK). Sprejemnik je običajni PIN-FET.

Auto MDIX v optiki ni možen (samodejna menjava RX/TX vlaken).
Auto Negotiation običajno ni vgrajen v optični Ethernet.

Linijsko kodiranje v optičnem Ethernetu

Različice 1Gbps Media Converterjev

Skupna elektronika

~15 EUR (2013)

1000BASE-BX
1X SMF WDM
1310/1550nm
domet 10km

TX=1550nm
RX=1310nm

SFP optika +WDM

~40 EUR (2013)

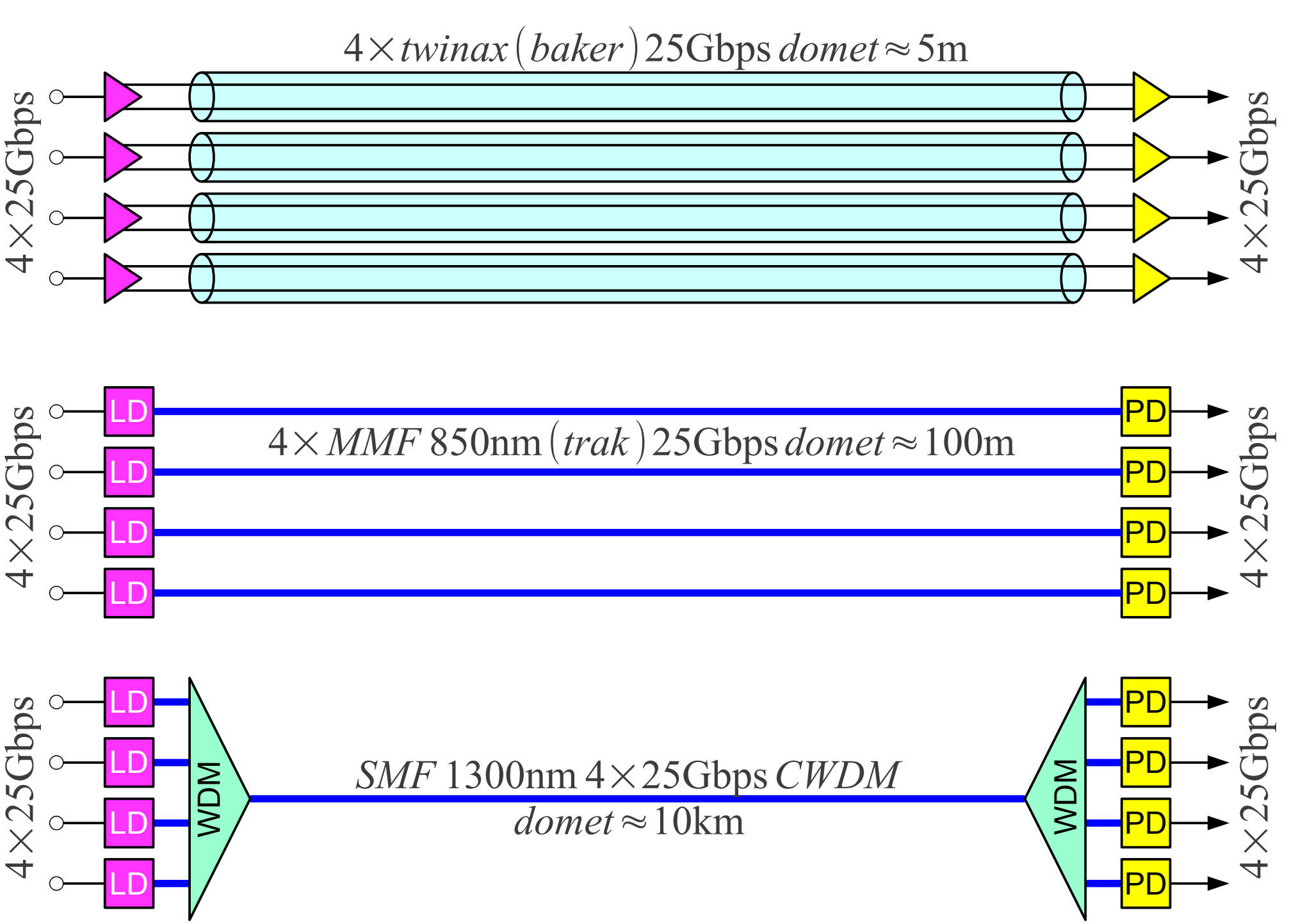
TX=1310nm
RX=1550nm

2013:

SMF cenejši od MMF!

1000BASE-LX
2x SMF 1310nm
domet 10km

1000BASE-SX
2x MMF 850nm
domet 550m



Ethernet standardi 100Gbps (40,200,400Gbps)

Pasivno žično omrežje, HALF-DUPLEX in CSMA/CD, torej začetna zasnova Etherneta, so se izkazali neučinkoviti. HALF-DUPLEX se uporablja samo na 10Mbps, čeprav ga standardi dopuščajo tudi na 100Mbps in 1Gbps. Beseda "Ether" je izgubila pomen.

Frekvenčni multipleks (FDM) po koaksialnem kablu kabelske TV (CATV) se ni uveljavil navkljub razmeroma velikemu dometu 3.6km standarda 10BROAD-36 (1985).

Valovno-dolžinski multipleks (WDM) je predrag. WDM standard 10GBASE-LX4 (2003) so nadomestile cenejše tehnologije brez WDM. WDM ostaja v standardih za 100Gbps, 200Gbps, 400Gbps.

OFDM, sicer uspešnica (x)DSL modemov, se v Ethernetu ni obnesel. Inačice 2PASS-TL, 2BASE-TL in 10PASS-TS so utonile v pozabo. Prezahtevna obdelava ali neželjene zakasnitve?

Opto-elektronski gradniki so še vedno nesorazmerno dragi? Pred tremi desetletji je optika izgledala potrebna že za 100Mbps. Danes ceneni UTP kljubuje optiki pri 10Gbps!

Pasivna optična omrežja (PON) na osnovi Etherneta se niso uveljavila. Standardi 10BASE-FP (1993) in 1000BASE-PX10/20 (EPON 2004) so že utonili v pozabo. Ponekod 10G-EPON (2009)?

Neuspehi Etherneta

90% Ethernet standardov ni nikoli zaživelo...
99% Ethernet standardov se ne uporablja več...
Nekatera določila Ethernet standardov so se kršila oziroma se še vedno zavestno in namerno kršijo...
Primer: uporaba "Jumbo" okvirjev >>1530byte?

Ethernet je bil vedno načrtovan od spodaj navzgor!

Ethernet pomeni štiri desetletja popolne združljivosti od 1980 do danes kljub razmerju prenosne zmogljivosti 1Mbps:100Gbps ali 1:100000!

Ethernet je združljiv in nadgradljiv v vse smeri!

Ethernet oprema ima vgrajen (built-in) self-test!

Radijski podaljšek Etherneta WLAN (WiFi) 802.11 je edini res svetovni dostopovni standard!

Zaprti, nezdružjivi in neučinkoviti protokoli se nezadržno ugrezajo v pozabo. Danes komaj opazimo take anahronistične otočke v oceanu Etherneta...

Kaj je to Ethernet danes?