

Компютърни Мрежи и GNU/Linux

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Боян Кроснов

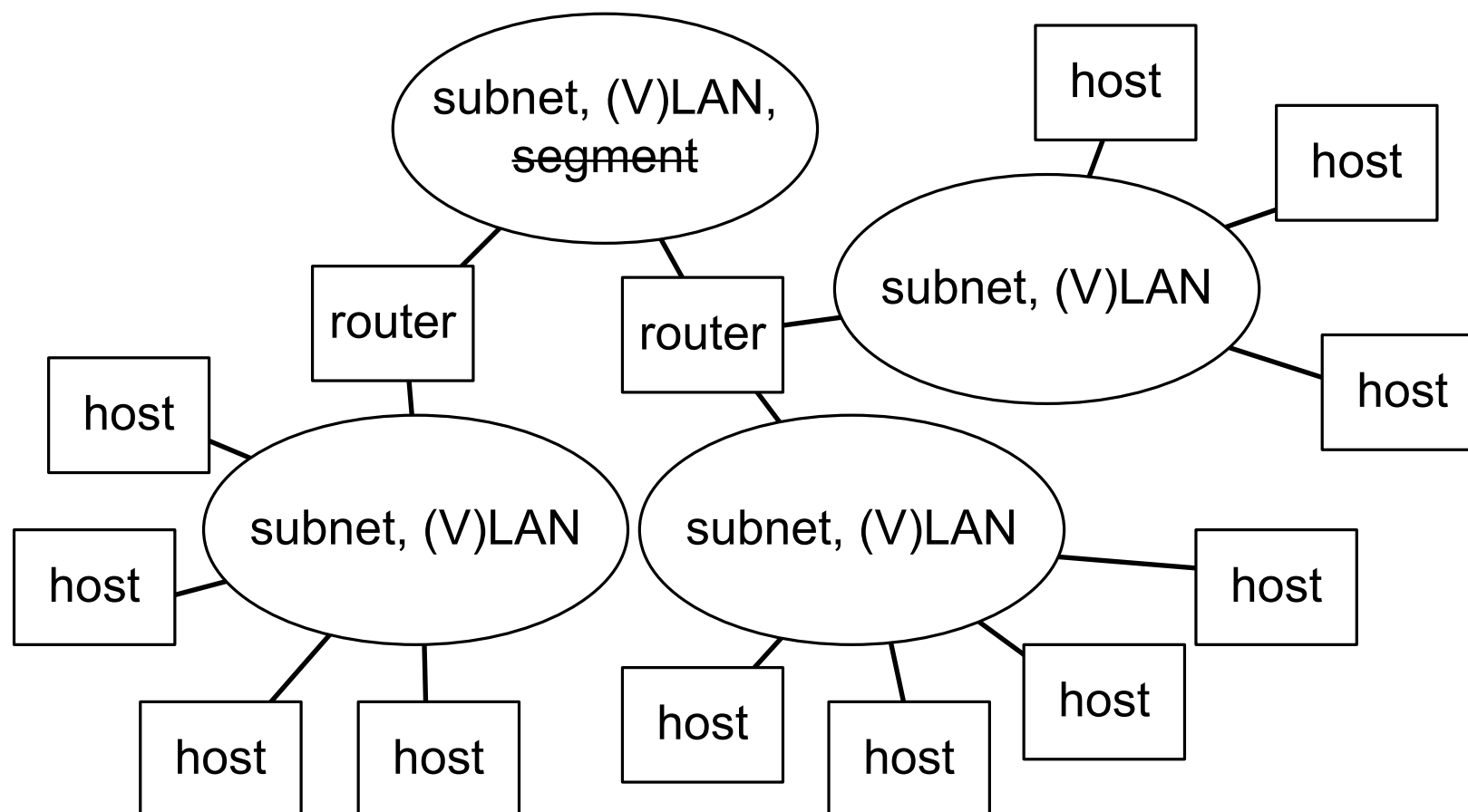
boyan@krosov.org
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Кой съм аз

- Независим консултант
- За свободен софтуер, свобода на словото, достъпа до информация и т.н, както и Хуманизъм, Neurodiversity, Freedom of thought, etc.
- CCIE #8701 (Януари 2002)

Увод

- Какво са компютърните мрежи?



Лекцията

- Мрежови модели
- Често срещани протоколи
- Стандартни организации
- Инструменти и примери
- Хардуер
 - Дънни платки
 - Мрежови карти
- Ethernet, VLANs
- IP, UDP, TCP

Слоести ...



Слоести мрежови модели

OSI

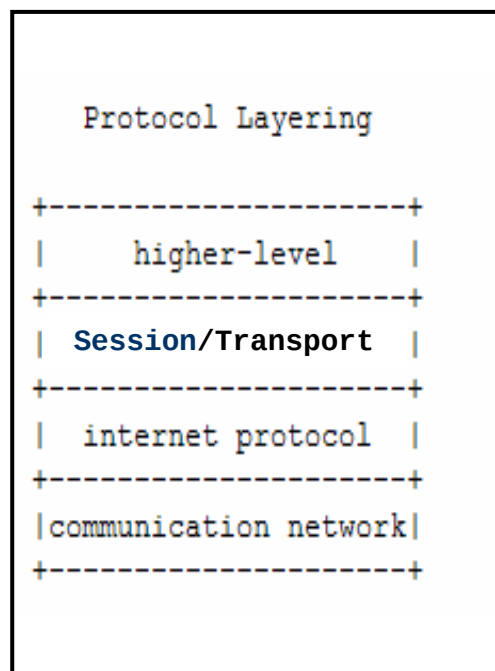
7. Application
6. Presentation
5. Session
4. Transport
3. Network
2. Datalink
1. Physical

Моделите

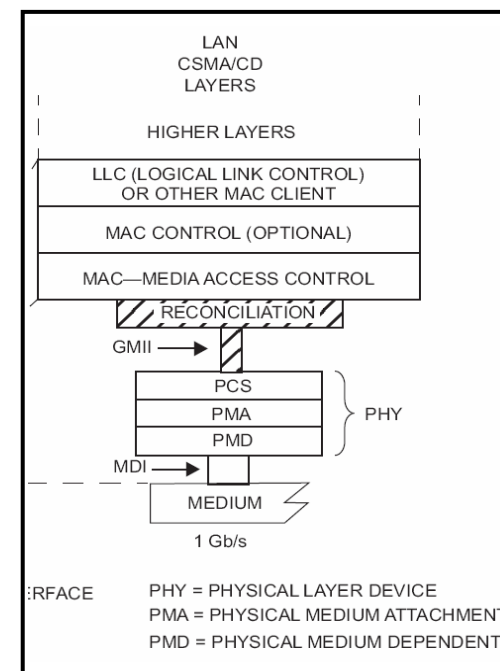
OSI

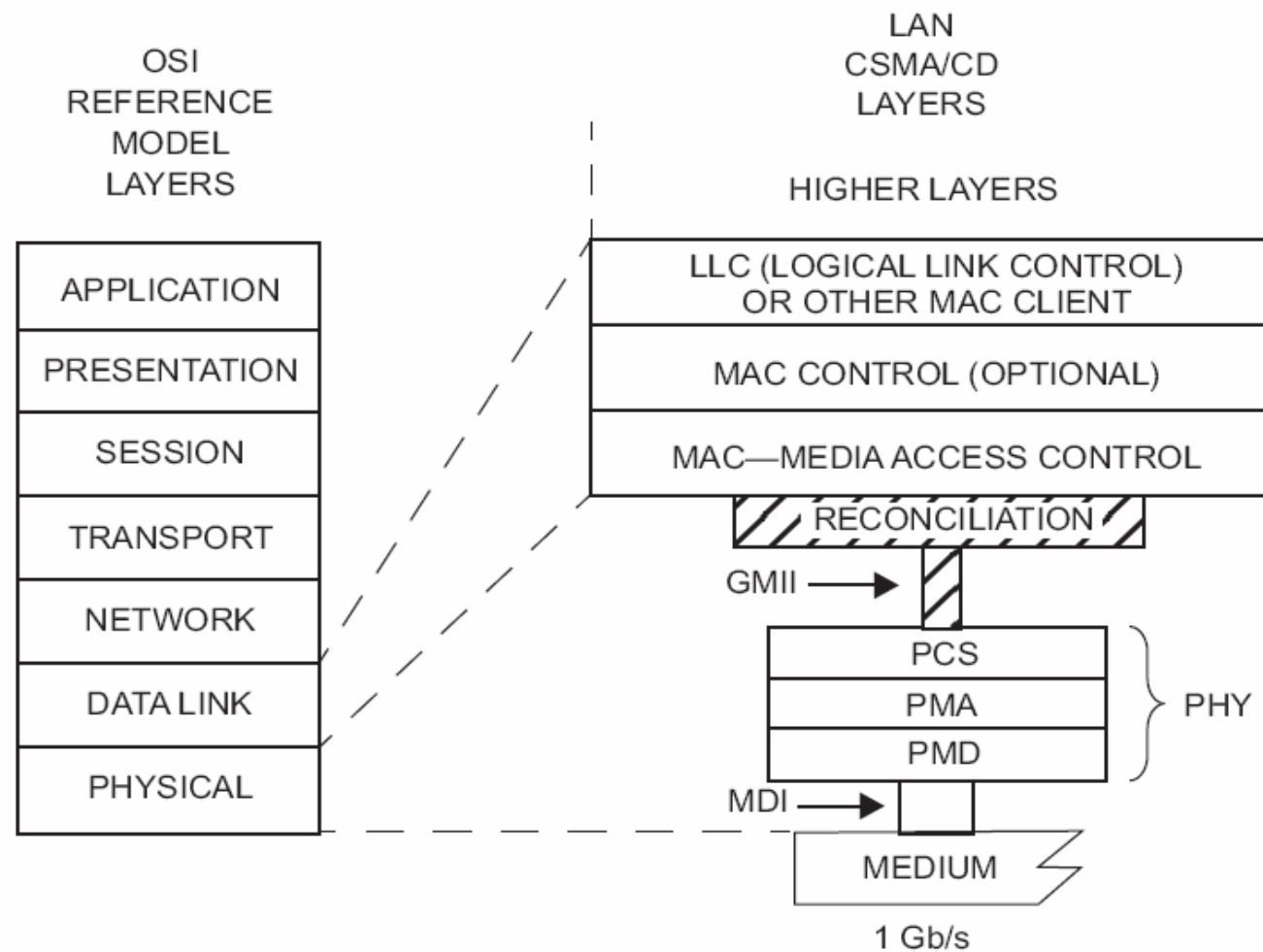
7. Application
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IETF



IEEE





GMII = GIGABIT MEDIA INDEPENDENT INTERFACE
 MDI = MEDIUM DEPENDENT INTERFACE
 PCS = PHYSICAL CODING SUBLAYER

PHY = PHYSICAL LAYER DEVICE
 PMA = PHYSICAL MEDIUM ATTACHMENT
 PMD = PHYSICAL MEDIUM DEPENDENT

Протоколи

7. HTTP, FTP, SMTP, POP3, IMAP4, SIP, XMPP, IRC, SNMP, SSH, TELNET, DNS, NTP, DHCP

4 and 5. TCP, UDP, RTP

3. IP/IPv6

2. Ethernet (802.3) , 802.11, 802.15, 802.16, PPP

1. baseband, *PSK, QAM-*, OFDM, CDMA, etc. over Cat5, Fiber, HFC, phone line, RF etc.

Протоколи

7. HTTP, FTP, SMTP, POP3, IMAP4, SIP, XMPP, IRC, SNMP, SSH, TELNET, DNS, NTP, DHCP			
4 and 5. TCP, UDP, RTP		6? SSL / TLS	
3. IP/IPv6		3.5? – IGMP, MLD	
	3? – ICMP		2.5? – ARP
2. Ethernet (802.3) , 802.11, 802.15, 802.16, 802.17, 802.18, 802.22			
1. baseband, *PSK, QAM-*, OFDM, CDMA, etc. over Cat5, Fiber, HFC, phone line, RF etc.			

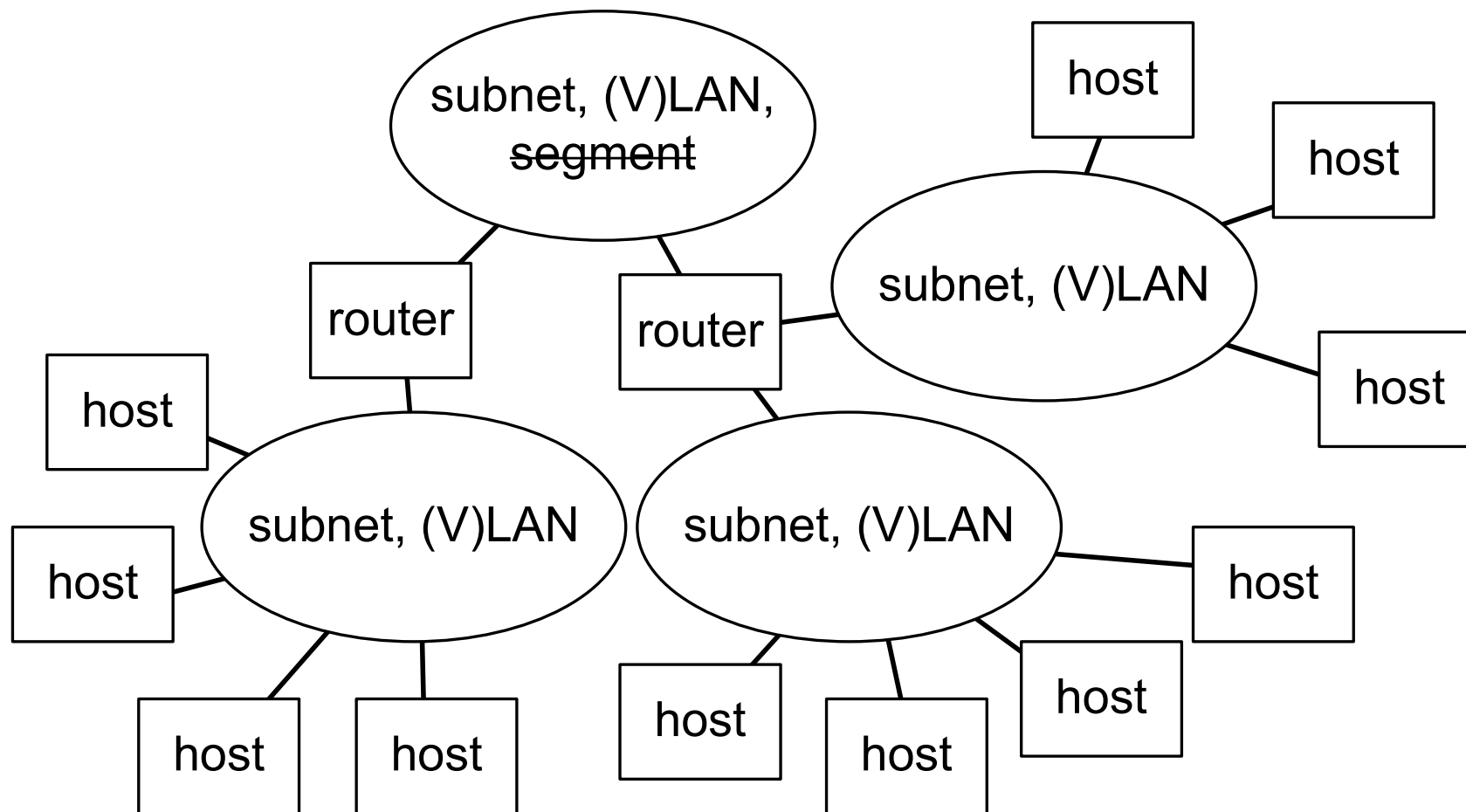
Стандартни организации

7.	IETF	W3C	3GPP	...	IRC, SMTP, SSH, TELNET, DNS, NTLM, LDAP
4	IETF	...	IETF	...	
3.	IETF	3?	IETF	3.5?	IETF MLD
2.	IEEE	ITU	IETF	...	2.5? IETF
1.	IEEE	ITU	...		FDMA, CDMA, etc. over Cat5, Fiber, HFC, phone line, RF etc.

Стандартни организации

- IETF (www.ietf.org)
- IEEE (www.ieee.org)
- ITU (www.itu.int)
- 3GPP (www.3gpp.org)
- x Forum, y Alliance, z Foundation (WiMax Forum, WiMedia Alliance, XMPP Standards Foundation, и т.н.)
- Повечето широко-използвани протоколи в мрежите са свободни

Мрежова топология



Инструменти

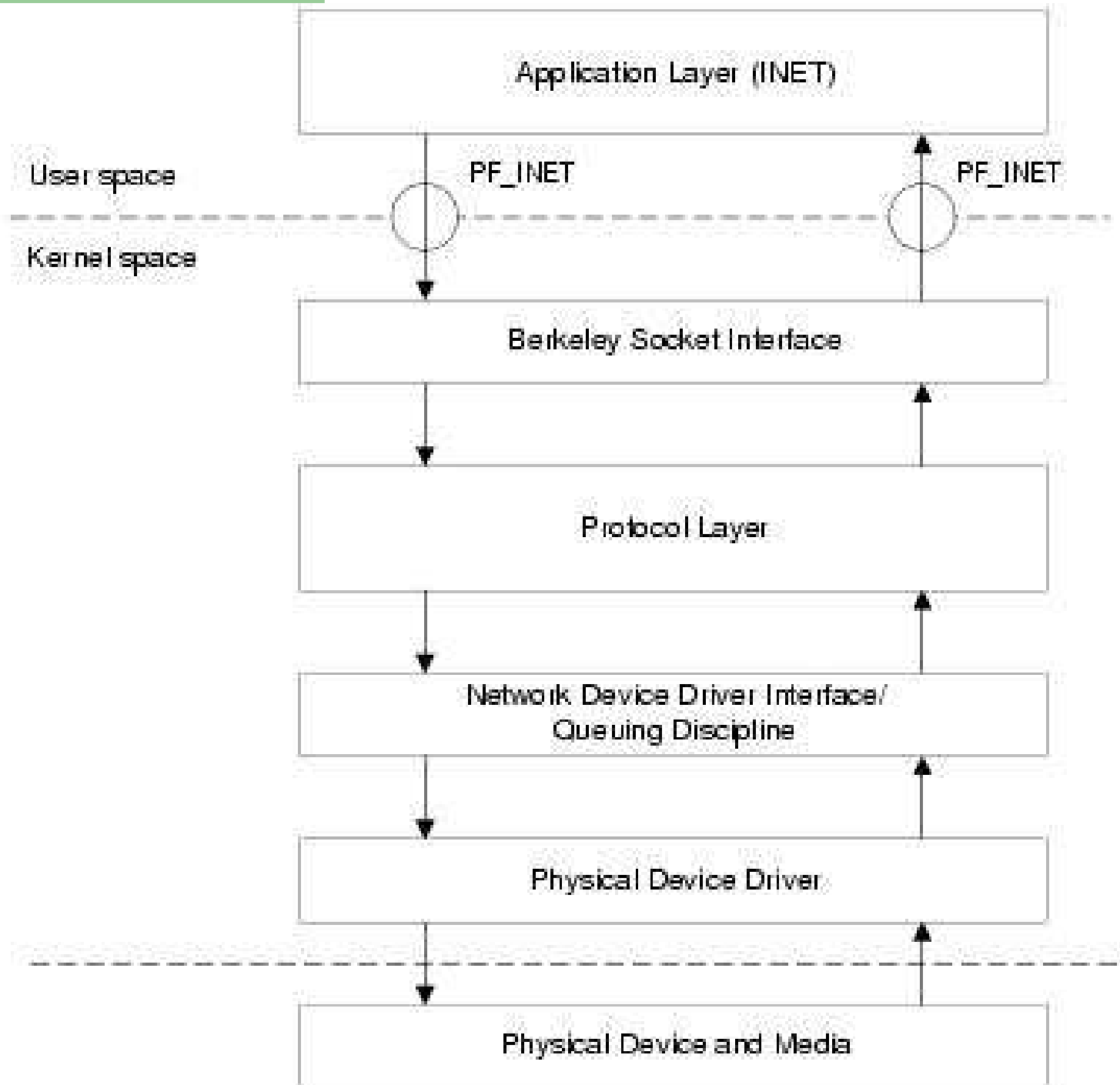


Инструменти

- Wireshark, демонстрация

```
+ Frame 1 (508 bytes on wire, 508 bytes captured)
+ Ethernet II, Src: 00:12:3f:ed:ff:0d (00:12:3f:ed:ff:0d), Dst: 00:30:48:83:93:e9 (00:30:48:83:93:e9)
+ Internet Protocol, Src: 172.19.55.203 (172.19.55.203), Dst: 145.97.39.155 (145.97.39.155)
+ Transmission Control Protocol, Src Port: 1856 (1856), Dst Port: http (80), Seq: 0, Ack: 0, Len: 454
+ Hypertext Transfer Protocol
```

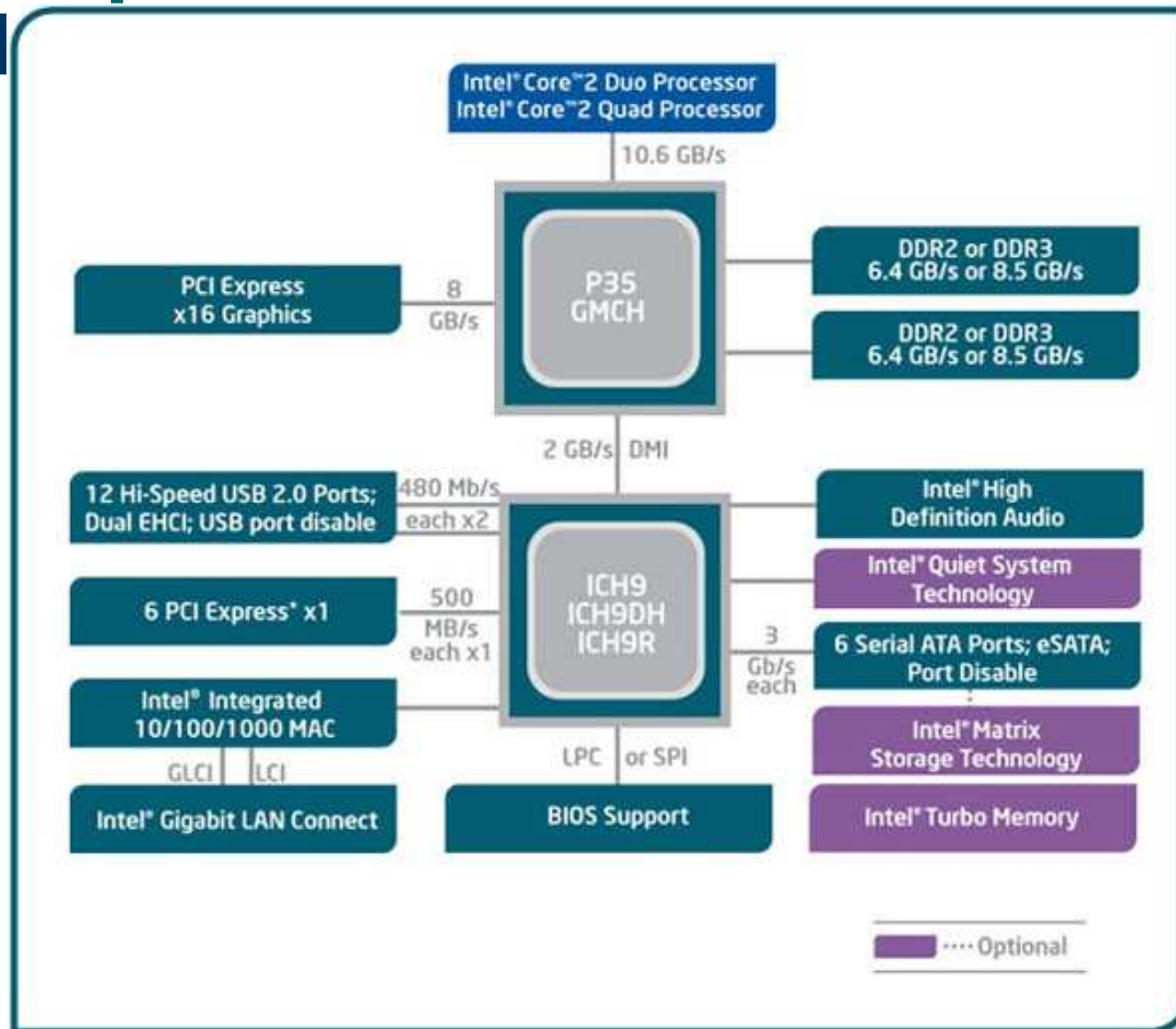
- tcpdump





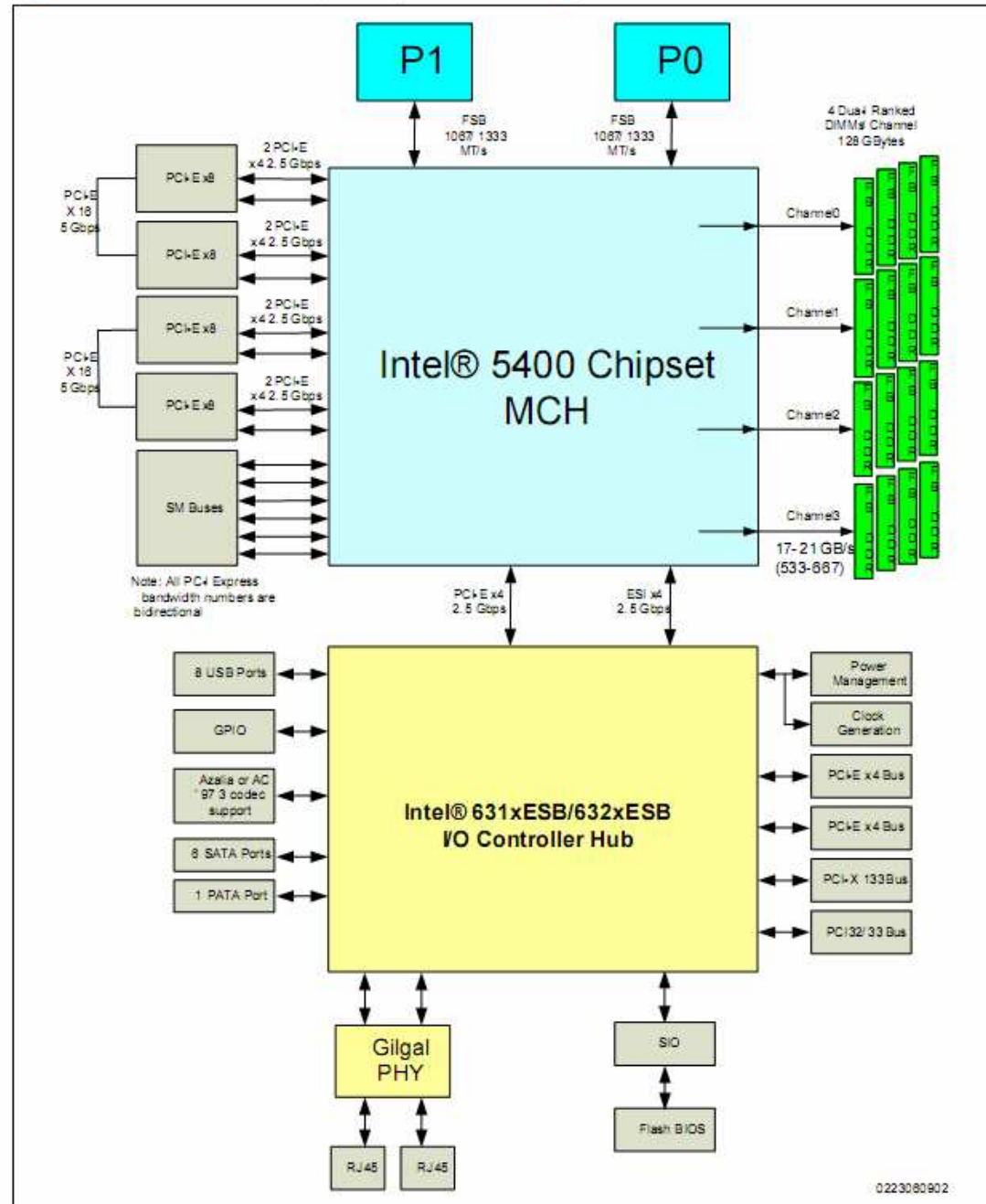
Q&A

Desktop Hardware



Server

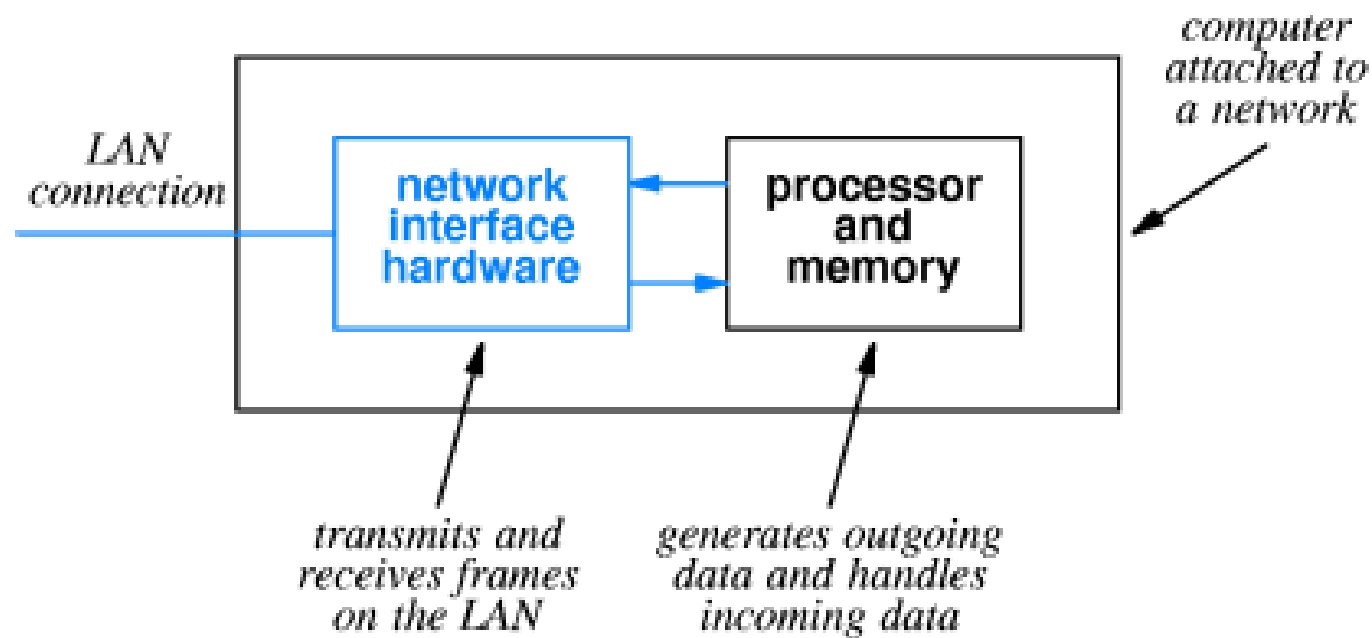
Figure 1-1. Intel® 5400 Chipset System Block Diagram



lspci

```
gaia:~# lspci
00:00.0 Host bridge: Intel Corporation E7320 Memory Controller Hub (rev 0c)
00:00.1 Class ff00: Intel Corporation E7320 Error Reporting Registers (rev 0c)
00:02.0 PCI bridge: Intel Corporation E7525/E7520/E7320 PCI Express Port A (rev 0c)
00:03.0 PCI bridge: Intel Corporation E7525/E7520/E7320 PCI Express Port A1 (rev
0c)
00:1c.0 PCI bridge: Intel Corporation 6300ESB 64-bit PCI-X Bridge (rev 02)
00:1d.0 USB Controller: Intel Corporation 6300ESB USB Universal Host Controller
(rev 02)
00:1d.1 USB Controller: Intel Corporation 6300ESB USB Universal Host Controller
(rev 02)
00:1d.4 System peripheral: Intel Corporation 6300ESB Watchdog Timer (rev 02)
00:1d.5 PIC: Intel Corporation 6300ESB I/O Advanced Programmable Interrupt
Controller (rev 02)
00:1d.7 USB Controller: Intel Corporation 6300ESB USB2 Enhanced Host Controller
(rev 02)
00:1e.0 PCI bridge: Intel Corporation 82801 PCI Bridge (rev 0a)
00:1f.0 ISA bridge: Intel Corporation 6300ESB LPC Interface Controller (rev 02)
00:1f.1 IDE interface: Intel Corporation 6300ESB PATA Storage Controller (rev 02)
00:1f.3 SMBus: Intel Corporation 6300ESB SMBus Controller (rev 02)
03:01.0 RAID bus controller: 3ware Inc 9550SX SATA-RAID
04:03.0 VGA compatible controller: ATI Technologies Inc Rage XL (rev 27)
04:04.0 Ethernet controller: Broadcom Corporation NetXtreme BCM5705 Gigabit
Ethernet (rev 03)
```

NIC

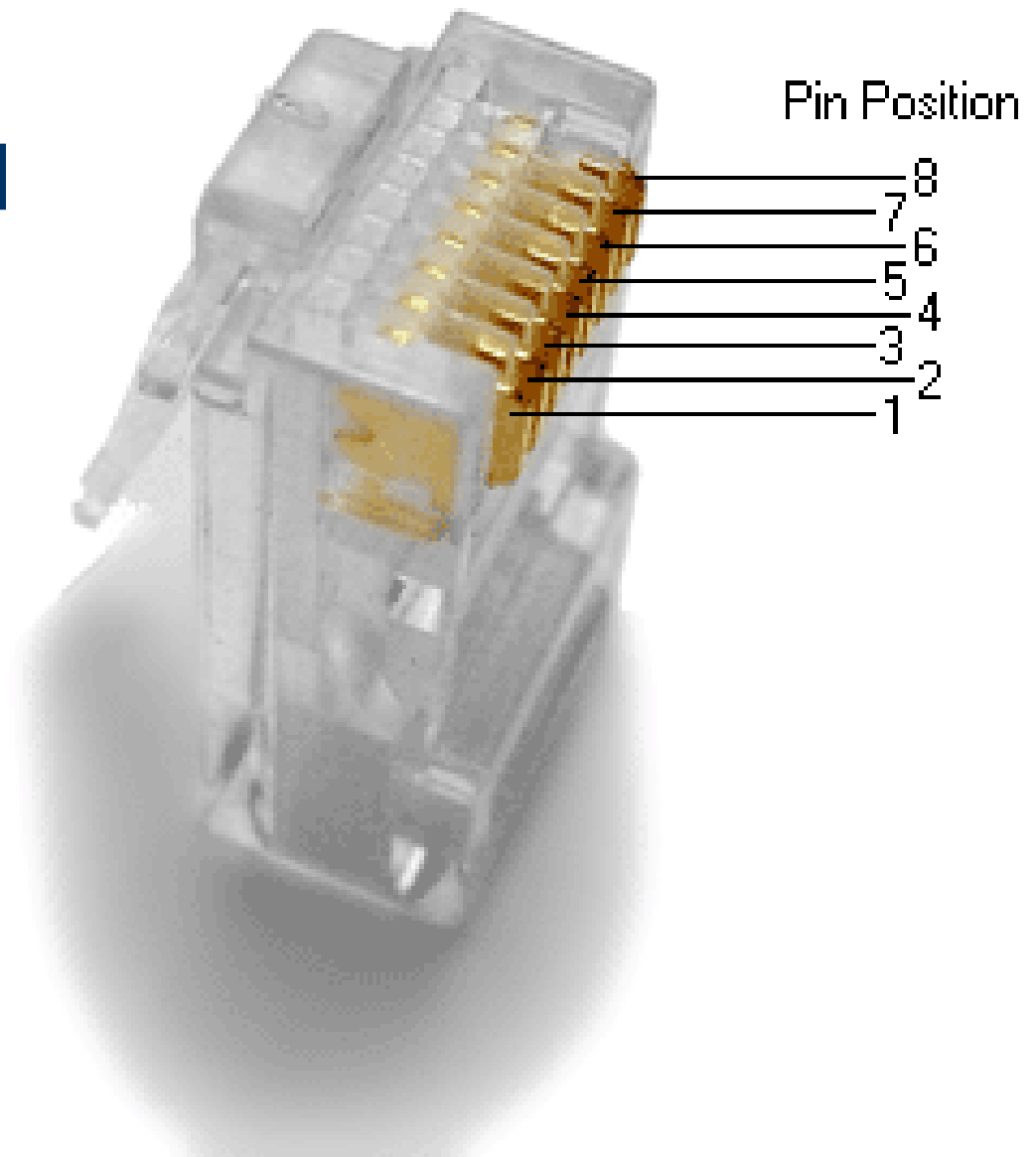


Ethernet PHY

- Диференциални сигнали
- Усукани двойки
- Категории кабели
 - 5/5e (100MHz)
 - 6/6a (250/500 MHz)

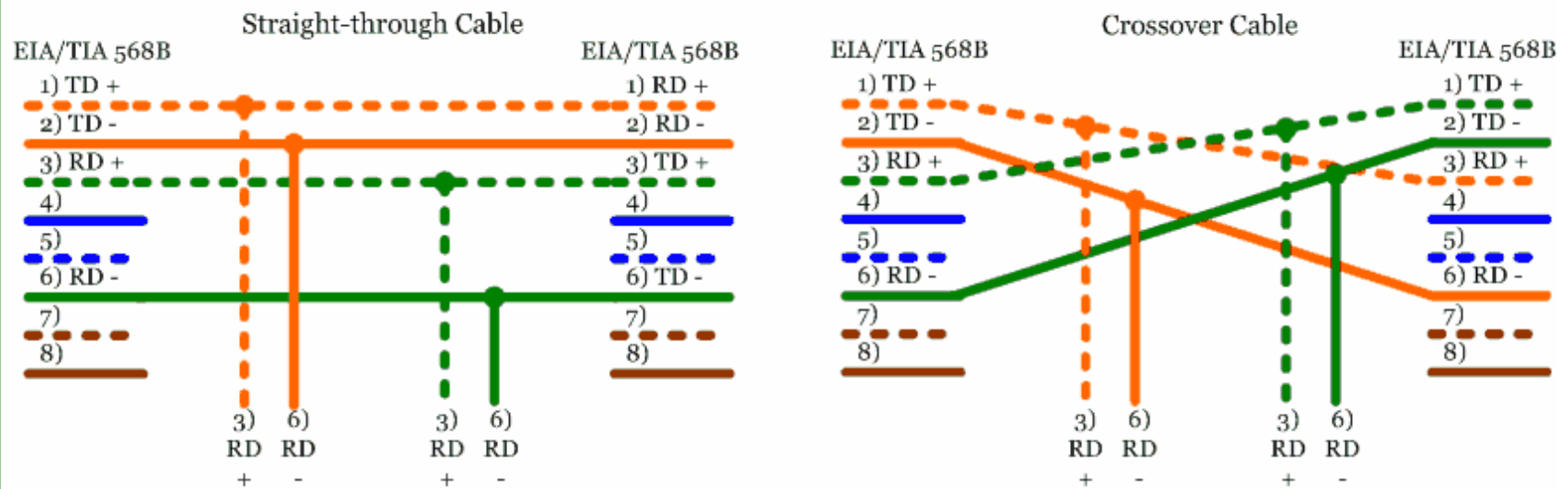


8P8C (RJ-45)



Ethernet PHY

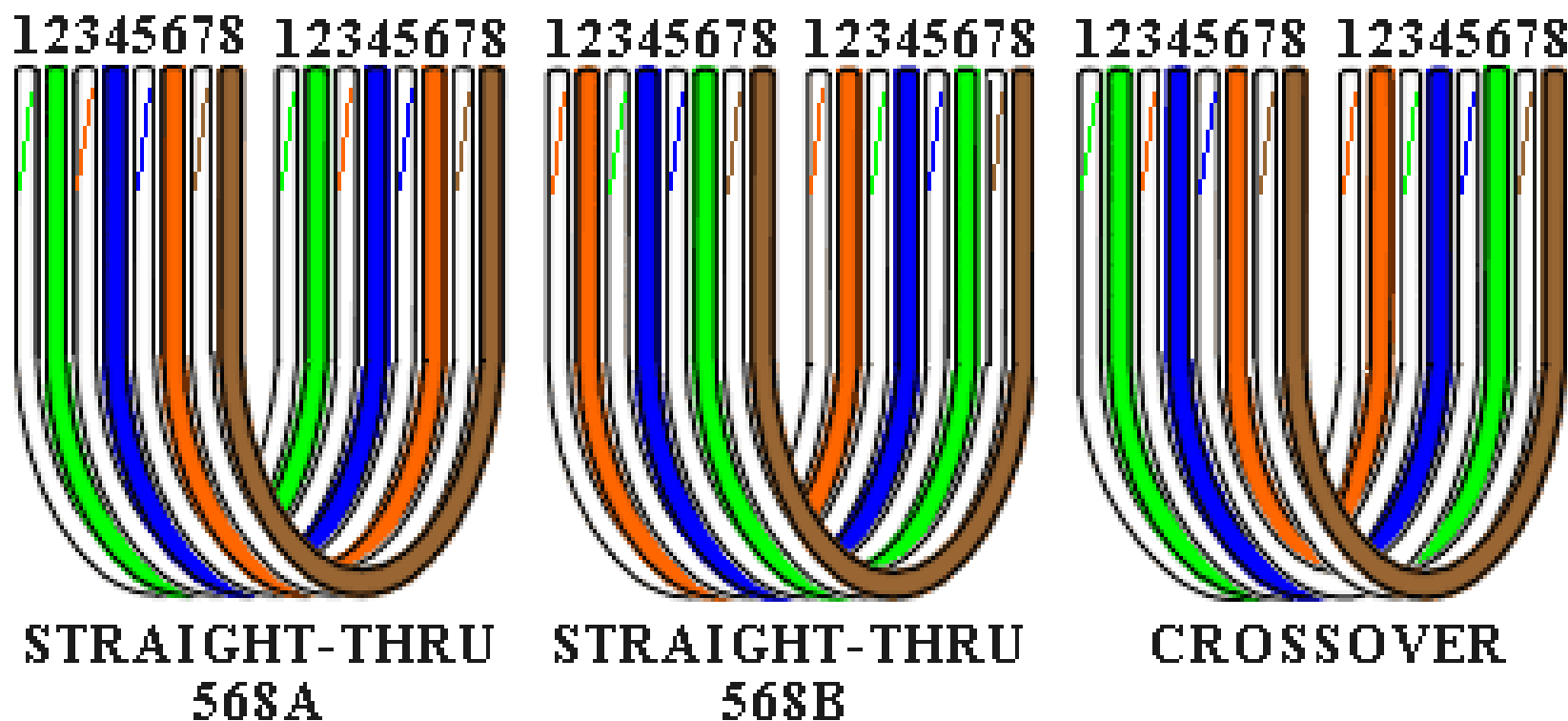
Ethernet Tap



100BASE-TX

Crossed cable

- бо,о,бз,с,бс,з,бк,к – тип В
- 1,2 <-> 3,6 и обратно



ethtool, mii-tool

```
gaia:~# ethtool eth0
Settings for eth0:
    Supported ports: [ MII ]
    Supported link modes:   10baseT/Half 10baseT/Full
                           100baseT/Half 100baseT/Full
                           1000baseT/Half 1000baseT/Full

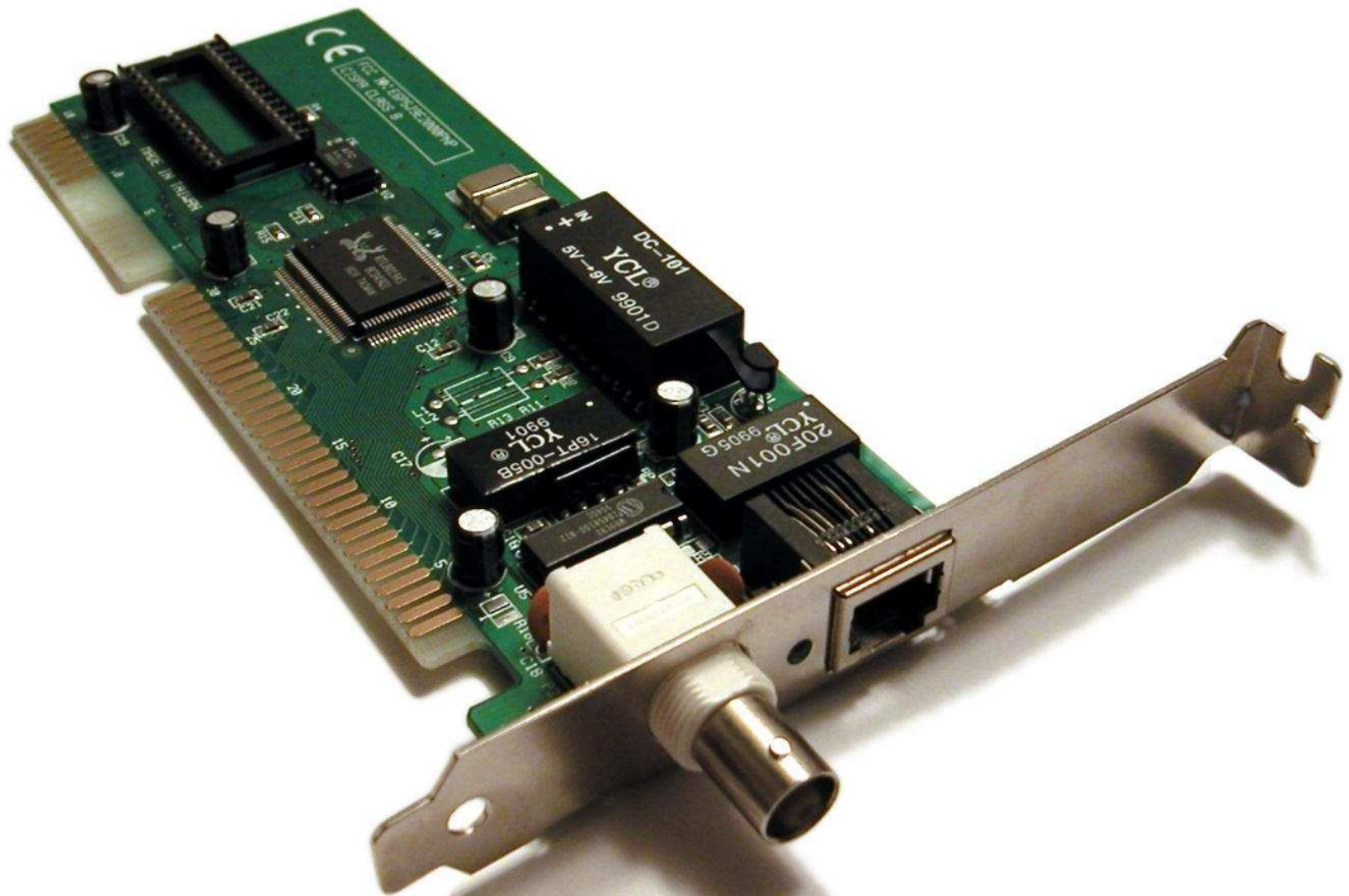
    Supports auto-negotiation: Yes
    Advertised link modes:  10baseT/Half 10baseT/Full
                           100baseT/Half 100baseT/Full
                           1000baseT/Half 1000baseT/Full

    Advertised auto-negotiation: Yes
    Speed: 1000Mb/s
    Duplex: Full
    Port: Twisted Pair
    PHYAD: 1
    Transceiver: internal
    Auto-negotiation: on
    Supports Wake-on: g
    Wake-on: d
    Current message level: 0x000000ff (255)
    Link detected: yes
```

MII-TOOL(8)

...

NOTE This program is obsolete. Valid media are only **100baseT4**, **100baseTx-FD**, **100baseTx-HD**, **10baseT-FD** and **10baseT-HD** ethernet cards. For replacement check **eth-tool**.



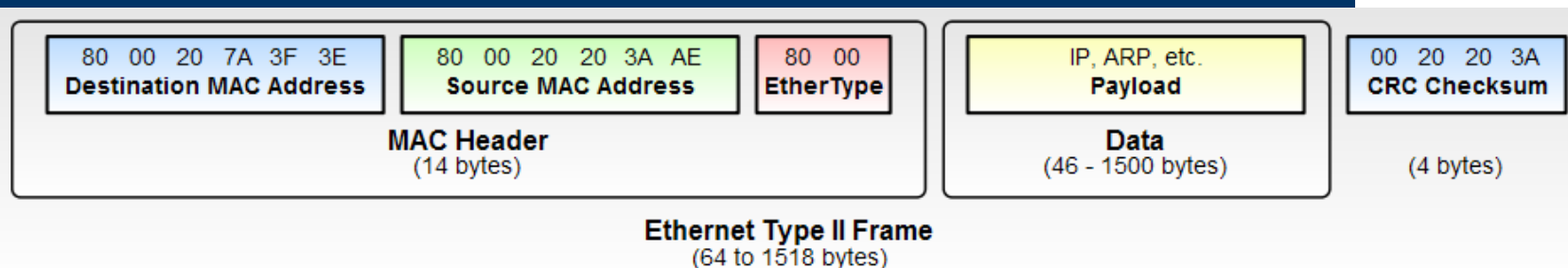
Рамки, пакети, сегменти



Рамки, пакети, сегменти

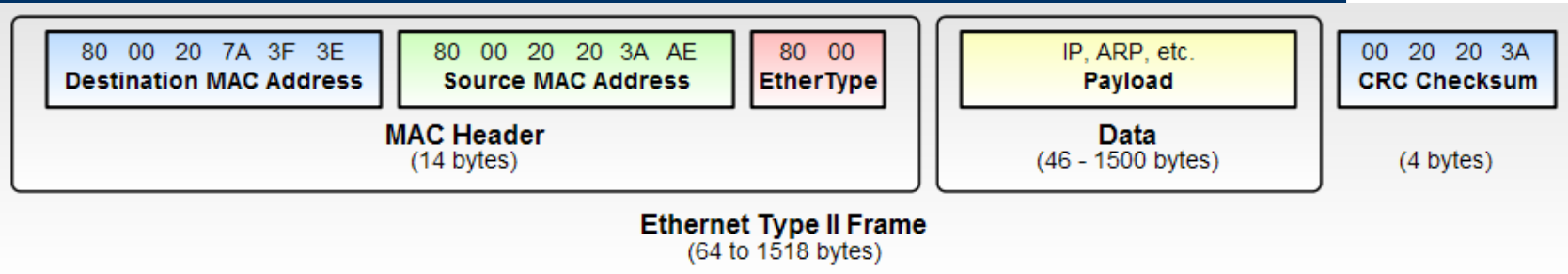
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Ethernet памка



- Network order / Machine order ...
- битове 6 и 7 от MAC адреса ...
- max 150 Kpps @ 100Mbps

ip link



```
gaia:~# ip link show
```

```
1: lo: <LOOPBACK,UP,10000> mtu 16436 qdisc noqueue
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
2: eth0: <BROADCAST,MULTICAST,UP,10000> mtu 1500 qdisc pfifo_fast qlen
    1000
    link/ether 00:11:d8:92:95:50 brd ff:ff:ff:ff:ff:ff
3: eth0.77@eth0: <BROADCAST,MULTICAST,UP,10000> mtu 1500 qdisc noqueue
    link/ether 00:11:d8:92:95:50 brd ff:ff:ff:ff:ff:ff
4: sit0: <NOARP> mtu 1480 qdisc noop
    link/sit 0.0.0.0 brd 0.0.0.0
```

ip link

```
gaia:~# ip link help
```

```
Usage: ip link set DEVICE { up | down |  
    arp { on | off } |  
    dynamic { on | off } |  
    multicast { on | off } |  
    allmulticast { on | off } |  
    promisc { on | off } |  
    trailers { on | off } |  
    txqueuelen PACKETS |  
    name NEWNAME |  
    address LLADDR | broadcast LLADDR |  
    mtu MTU }
```

Hub, Switch, Router

7. HTTP, FTP, SMTP, POP3, IMAP4, SIP, XMPP, IRC, SNMP, SSH, TELNET, DNS, NTP, DHCP

4 and 5. TCP, UDP, RTP

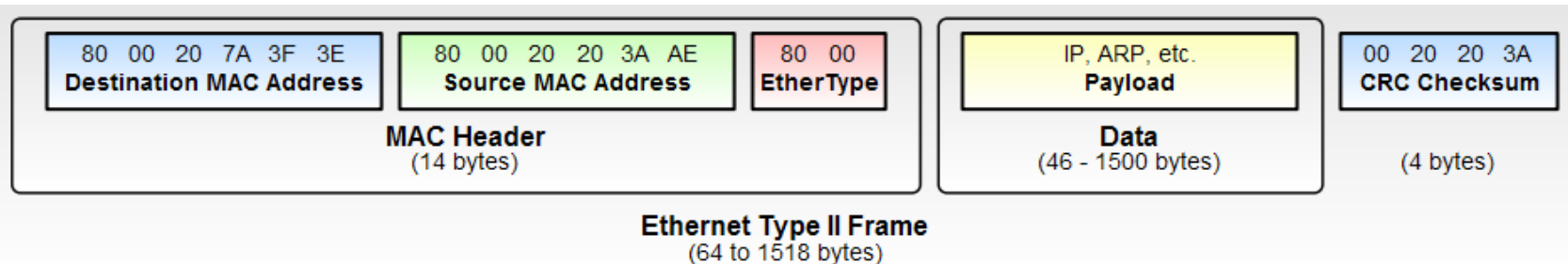
3. IP/IPv6

2. Ethernet (802.3) , 802.11, 802.15, 802.16, PPP

1. baseband, *PSK, QAM-*, OFDM, CDMA, etc. over Cat5, Fiber, HFC, phone line, RF etc.

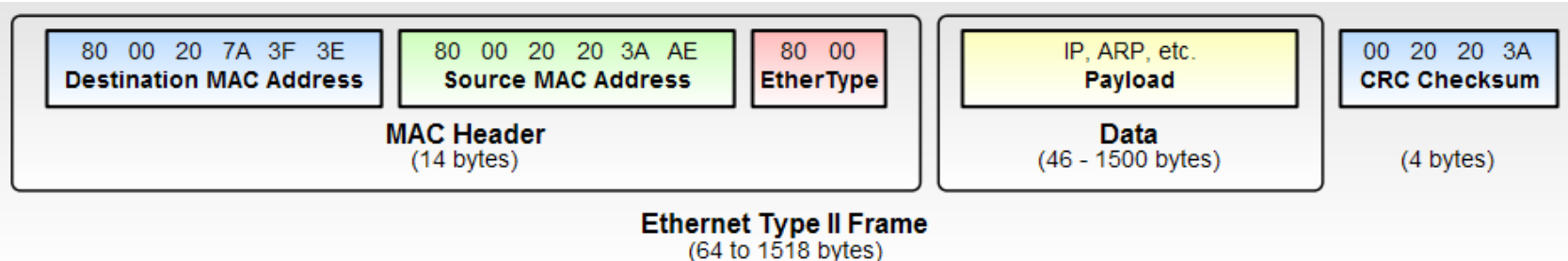
Switch

- Принцип на работа
- Broadcast/Multicast/Unicast
- Unknown Unicast



VLANs and Trunking

- IEEE 802.1q / 802.1p
- Принцип на работа
- Native(untagged) VLAN
- Tag Protocol ID (TPID) 0x8100
- 3-bit priority, 12-bit VLAN ID



/proc/net/

```
gaia:/proc/net# cat dev
Inter-|   Receive   | Transmit
face |bytes  packets errs drop fifo frame compressed multicast|bytes  packets errs drop fifo colls carrier compressed
lo:722835999 5214026 0 0 0 0 0 0 0 722835999 5214026 0 0 0 0 0 0 0
eth0:1722281520 72143612 0 0 0 0 0 0 2552497 3699585559 81525468 0 0 0 0 0 0 0
eth0.77:2712763872 13381195 0 0 0 0 0 0 1286414 1545956936 10611550 0 0 0 0 0 0 0
sit0: 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

gaia:/proc/net# ifconfig
eth0      Link encap:Ethernet  HWaddr 00:11:D8:92:95:50
          inet addr:85.130.111.169 Bcast:85.130.111.191 Mask:255.255.255.224
          inet6 addr: fe80::211:d8ff:fe92:9550/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:72155996 errors:0 dropped:0 overruns:0 frame:0
          TX packets:81537624 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1732889567 (1.6 GiB)  TX bytes:3710171482 (3.4 GiB)
          Interrupt:193

eth0.77   Link encap:Ethernet  HWaddr 00:11:D8:92:95:50
          inet addr:192.168.182.1 Bcast:192.168.182.255 Mask:255.255.255.0
          inet6 addr: fe80::211:d8ff:fe92:9550/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:13385392 errors:0 dropped:0 overruns:0 frame:0
          TX packets:10618872 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:2713063519 (2.5 GiB)  TX bytes:1556175542 (1.4 GiB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1 Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:16436  Metric:1
          RX packets:5214062 errors:0 dropped:0 overruns:0 frame:0
          TX packets:5214062 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:722841481 (689.3 MiB)  TX bytes:722841481 (689.3 MiB)
```

/proc/net/

```
gaia:/proc/net/vlan# cat config
```

```
VLAN Dev name      | VLAN ID
```

```
Name-Type: VLAN_NAME_TYPE_RAW_PLUS_VID_NO_PAD
```

```
eth0.77            | 77      | eth0
```

```
gaia:/proc/net/vlan# cat eth0.77
```

```
eth0.77  VID: 77          REORDER_HDR: 1  dev->priv_flags: 1
```

```
    total frames received      13378090
```

```
    total bytes received      2712421717
```

```
    Broadcast/Multicast Rcvd    1286265
```

```
    total frames transmitted    10608215
```

```
    total bytes transmitted    1543330271
```

```
    total headroom inc          0
```

```
    total encap on xmit          0
```

```
Device: eth0
```

```
INGRESS priority mappings: 0:0  1:0  2:0  3:0  4:0  5:0  6:0  7:0
```

```
EGRESSS priority Mappings:
```

vconfig

```
gaia:/proc/net# vconfig
Expecting argc to be 3-5, inclusive.  Was: 2
```

```
Usage: add          [interface-name] [vlan_id]
       rem          [vlan-name]
       set_flag      [interface-name] [flag-num]      [0 | 1]
       set_egress_map [vlan-name]      [skb_priority]  [vlan_qos]
       set_ingress_map [vlan-name]      [skb_priority]  [vlan_qos]
       set_name_type  [name-type]
```

- * The [interface-name] is the name of the ethernet card that hosts the VLAN you are talking about.
- * The vlan_id is the identifier (0-4095) of the VLAN you are operating on.
- * skb_priority is the priority in the socket buffer (sk_buff).
- * vlan_qos is the 3 bit priority in the VLAN header
- * name-type: VLAN_PLUS_VID (vlan0005), VLAN_PLUS_VID_NO_PAD (vlan5),
DEV_PLUS_VID (eth0.0005), DEV_PLUS_VID_NO_PAD (eth0.5)
- * bind-type: PER_DEVICE # Allows vlan 5 on eth0 and eth1 to be unique.
PER_KERNEL # Forces vlan 5 to be unique across all devices.
- * FLAGS: 1 REORDER_HDR When this is set, the VLAN device will move the ethernet header around to make it look exactly like a real ethernet device. This may help programs such as DHCPd which read the raw ethernet packet and make assumptions about the location of bytes. If you don't need it, don't turn it on, because there will be at least a small performance degradation. Default is OFF.

Ethernet

Q&A

IP (RFC 791)

7. HTTP, FTP, SMTP, POP3, IMAP4, SIP, XMPP, IRC, SNMP, SSH, TELNET, DNS, NTP, DHCP

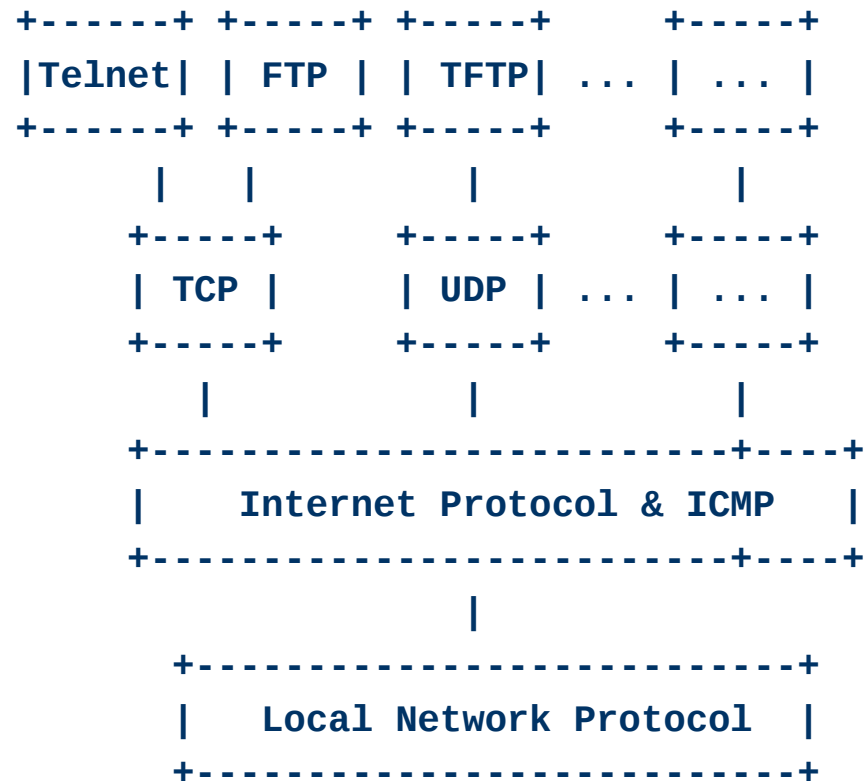
4 and 5. TCP, UDP, RTP

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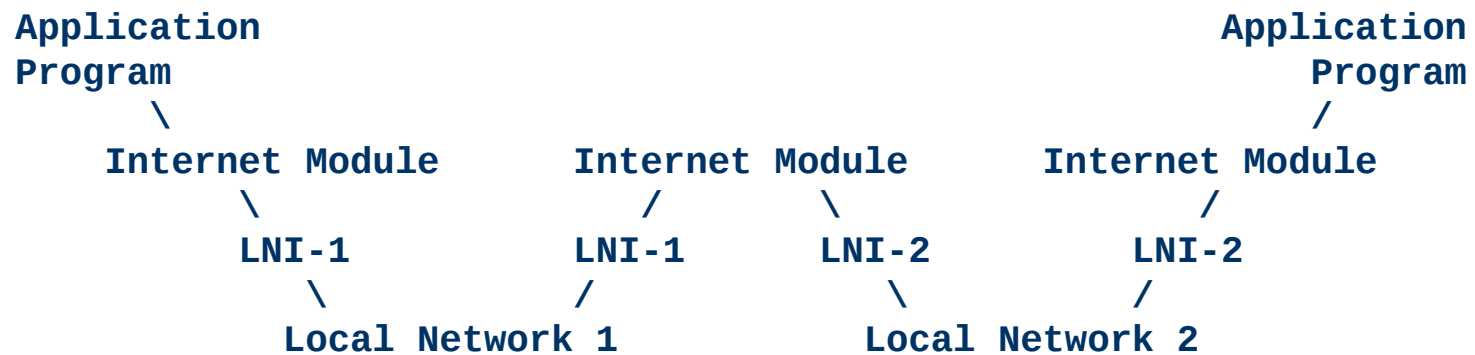
Relation to other protocols



Protocol Relationships

Figure 1.

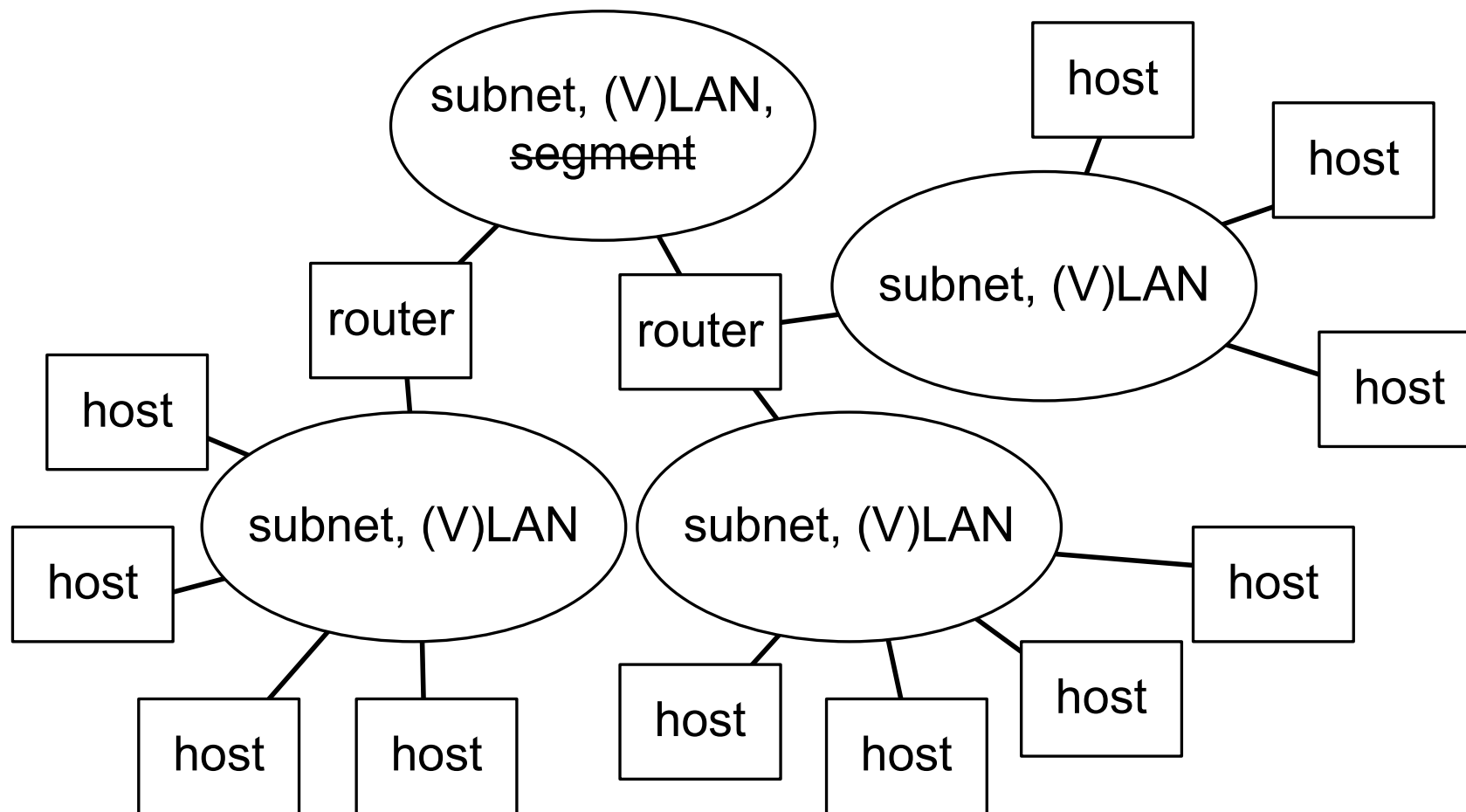
Model of operation



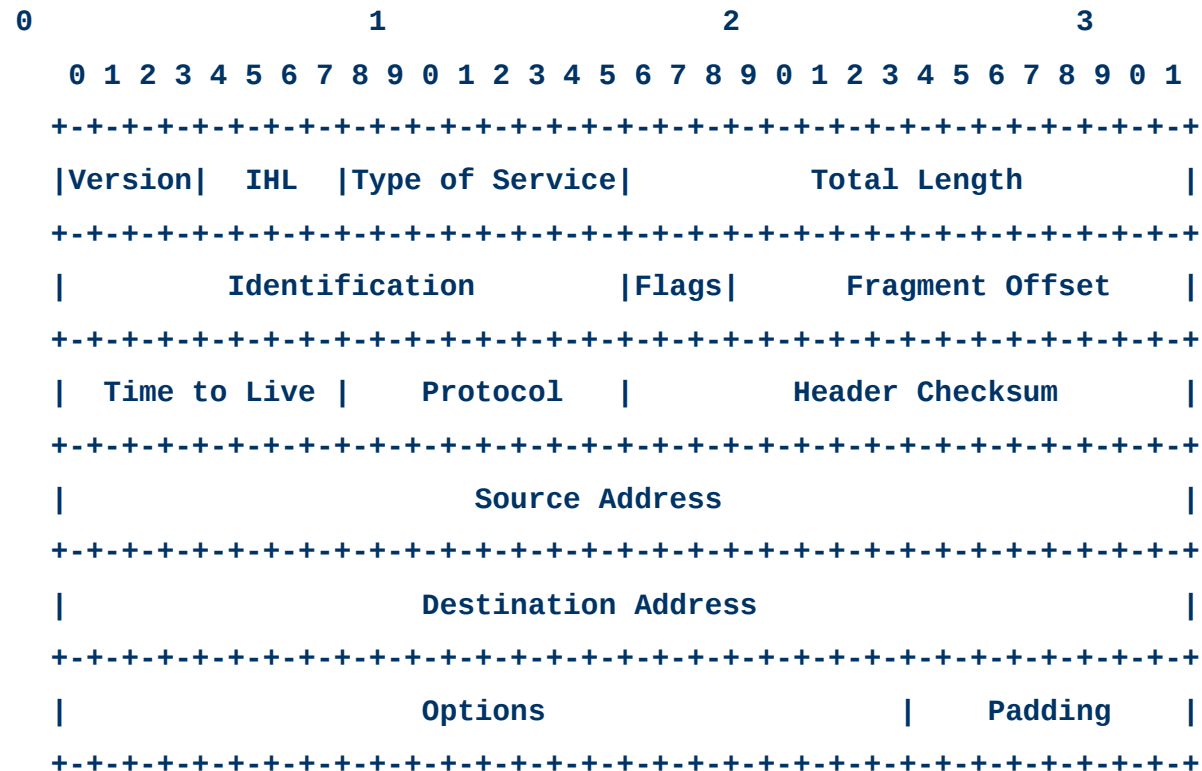
Transmission Path

Figure 2

Мрежова топология



IP Header



Example Internet Datagram Header

Figure 4.

IP Address

An IPv4 address (dotted-decimal notation)

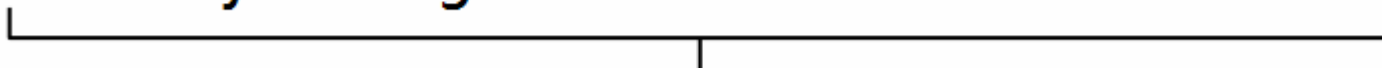
172 . 16 . 254 . 1



10101100 . 00010000 . 11111110 . 00000001



One byte = Eight bits



Thirty-two bits ($4 * 8$), or 4 bytes

IP Subnetting

- CIDR (RFC1519 '93 -> RFC4632)

notation	addrs/block	# blocks	
-----	-----	-----	
n.n.n.n/32	1	4294967296	"host route"
n.n.n.x/31	2	2147483648	"p2p link"
n.n.n.x/30	4	1073741824	
n.n.n.x/29	8	536870912	
n.n.n.x/28	16	268435456	
n.n.n.x/27	32	134217728	
n.n.n.x/26	64	67108864	
n.n.n.x/25	128	33554432	
n.n.n.0/24	256	16777216	legacy "Class C"
n.n.x.0/23	512	8388608	
n.n.x.0/22	1024	4194304	
n.n.x.0/21	2048	2097152	
n.n.x.0/20	4096	1048576	

IP Subnetting

n.n.x.0/19	8192	524288	
n.n.x.0/18	16384	262144	
n.n.x.0/17	32768	131072	
n.n.0.0/16	65536	65536	legacy "Class B"
n.x.0.0/15	131072	32768	
n.x.0.0/14	262144	16384	
n.x.0.0/13	524288	8192	
n.x.0.0/12	1048576	4096	
n.x.0.0/11	2097152	2048	
n.x.0.0/10	4194304	1024	
n.x.0.0/9	8388608	512	
n.0.0.0/8	16777216	256	legacy "Class A"
x.0.0.0/7	33554432	128	
x.0.0.0/6	67108864	64	
x.0.0.0/5	134217728	32	
x.0.0.0/4	268435456	16	
x.0.0.0/3	536870912	8	
x.0.0.0/2	1073741824	4	
x.0.0.0/1	2147483648	2	
0.0.0.0/0	4294967296	1	"default route"

ipcalc

```
boyan@luna:~$ ipcalc 192.168.1.3/24 20
Address: 192.168.1.3      11000000.10101000.00000001. 00000011
Netmask: 255.255.255.0 = 24 11111111.11111111.11111111. 00000000
Wildcard: 0.0.0.255      00000000.00000000.00000000. 11111111
=>
Network: 192.168.1.0/24   11000000.10101000.00000001. 00000000
HostMin: 192.168.1.1     11000000.10101000.00000001. 00000001
HostMax: 192.168.1.254   11000000.10101000.00000001. 11111110
Broadcast: 192.168.1.255 11000000.10101000.00000001. 11111111
Hosts/Net: 254           Class C, Private Internet

Supernet

Netmask: 255.255.240.0 = 20 11111111.11111111.1111 0000.00000000
Wildcard: 0.0.15.255      00000000.00000000.0000 1111.11111111

Network: 192.168.0.0/20    11000000.10101000.0000 0000.00000000
HostMin: 192.168.0.1      11000000.10101000.0000 0000.00000001
HostMax: 192.168.15.254   11000000.10101000.0000 1111.11111110
Broadcast: 192.168.15.255 11000000.10101000.0000 1111.11111111
Hosts/Net: 4094           Class C, Private Internet

boyan@luna:~$ █
```

```

boyan@luna:~$ ipcalc 192.168.1.3/24 26
Address: 192.168.1.3      11000000.10101000.00000001. 00000011
Netmask: 255.255.255.0 = 24 11111111.11111111.11111111. 00000000
Wildcard: 0.0.0.255      00000000.00000000.00000000. 11111111
=>
Network: 192.168.1.0/24   11000000.10101000.00000001. 00000000
HostMin: 192.168.1.1     11000000.10101000.00000001. 00000001
HostMax: 192.168.1.254   11000000.10101000.00000001. 11111110
Broadcast: 192.168.1.255 11000000.10101000.00000001. 11111111
Hosts/Net: 254           Class C, Private Internet

Subnets after transition from /24 to /26

Netmask: 255.255.255.192 = 26 11111111.11111111.11111111.11 000000
Wildcard: 0.0.0.63         00000000.00000000.00000000.00 111111

1.
Network: 192.168.1.0/26     11000000.10101000.00000001.00 000000
HostMin: 192.168.1.1       11000000.10101000.00000001.00 000001
HostMax: 192.168.1.62     11000000.10101000.00000001.00 111110
Broadcast: 192.168.1.63    11000000.10101000.00000001.00 111111
Hosts/Net: 62              Class C, Private Internet

2.
Network: 192.168.1.64/26    11000000.10101000.00000001.01 000000
HostMin: 192.168.1.65     11000000.10101000.00000001.01 000001
HostMax: 192.168.1.126    11000000.10101000.00000001.01 111110
Broadcast: 192.168.1.127   11000000.10101000.00000001.01 111111
Hosts/Net: 62              Class C, Private Internet

3.
Network: 192.168.1.128/26   11000000.10101000.00000001.10 000000
HostMin: 192.168.1.129    11000000.10101000.00000001.10 000001
HostMax: 192.168.1.190    11000000.10101000.00000001.10 111110
Broadcast: 192.168.1.191   11000000.10101000.00000001.10 111111
Hosts/Net: 62              Class C, Private Internet

4.
Network: 192.168.1.192/26   11000000.10101000.00000001.11 000000
HostMin: 192.168.1.193    11000000.10101000.00000001.11 000001
HostMax: 192.168.1.254    11000000.10101000.00000001.11 111110
Broadcast: 192.168.1.255   11000000.10101000.00000001.11 111111
Hosts/Net: 62              Class C, Private Internet

Subnets: 4
Hosts: 248
boyan@luna:~$ █

```

Special addresses

- 0.0.0.0 – uninitialized endpoint
- 0.0.0.0/8 – local network (not 0/0)
- 127.0.0.0/8 – loopback
- 169.254.0.0/16 – link-local addresses
- 224.0.0.0/4 – Multicast (Class D)
- 240.0.0.0/4 – Experimental (Class E)
- 255.255.255.255 – Local Broadcast

Special addresses

- RFC1918
- 10.0.0.0/8
- 172.16.0.0/12
- 192.168.0.0/16