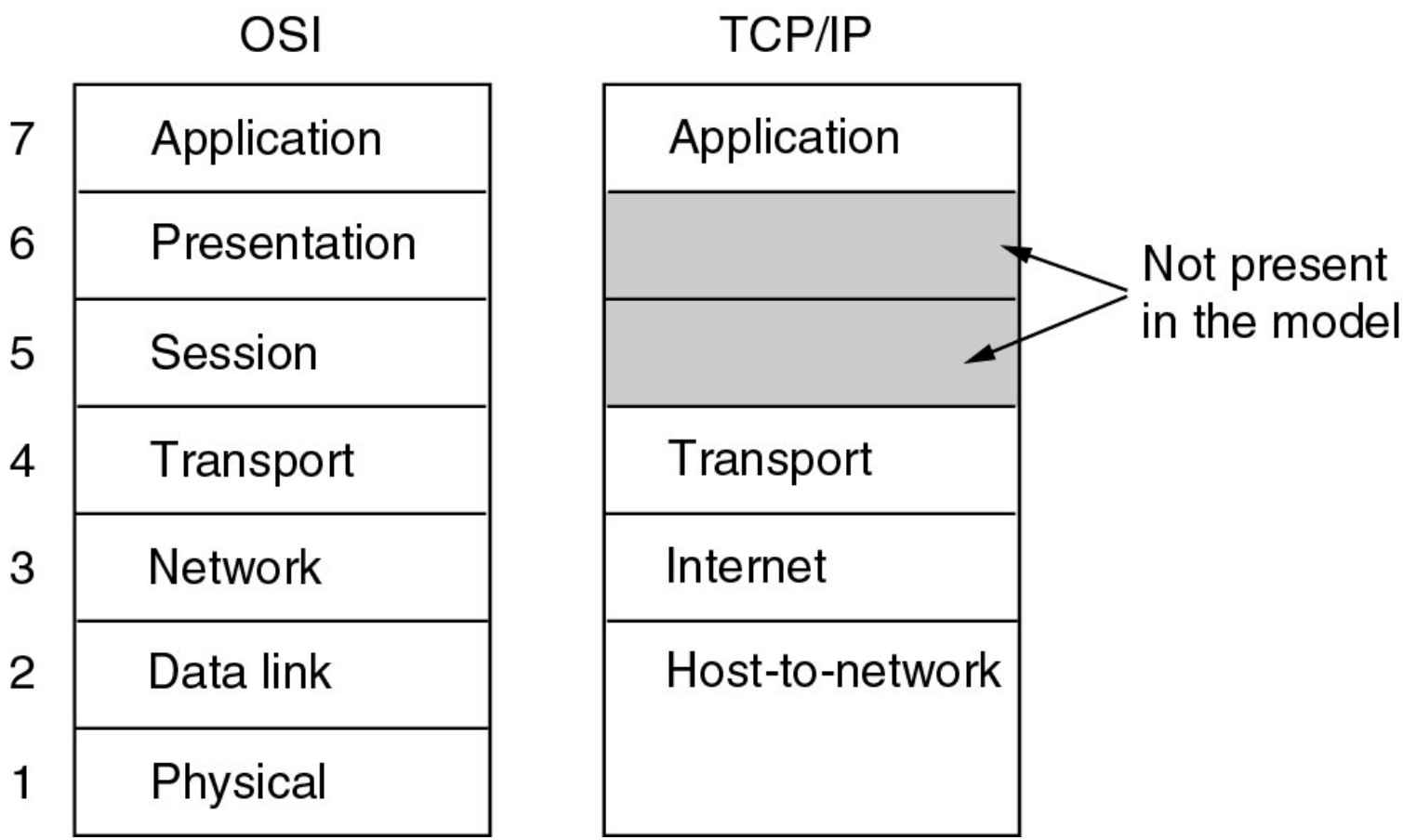
Sieťová vrstva

Sieťová vrstva

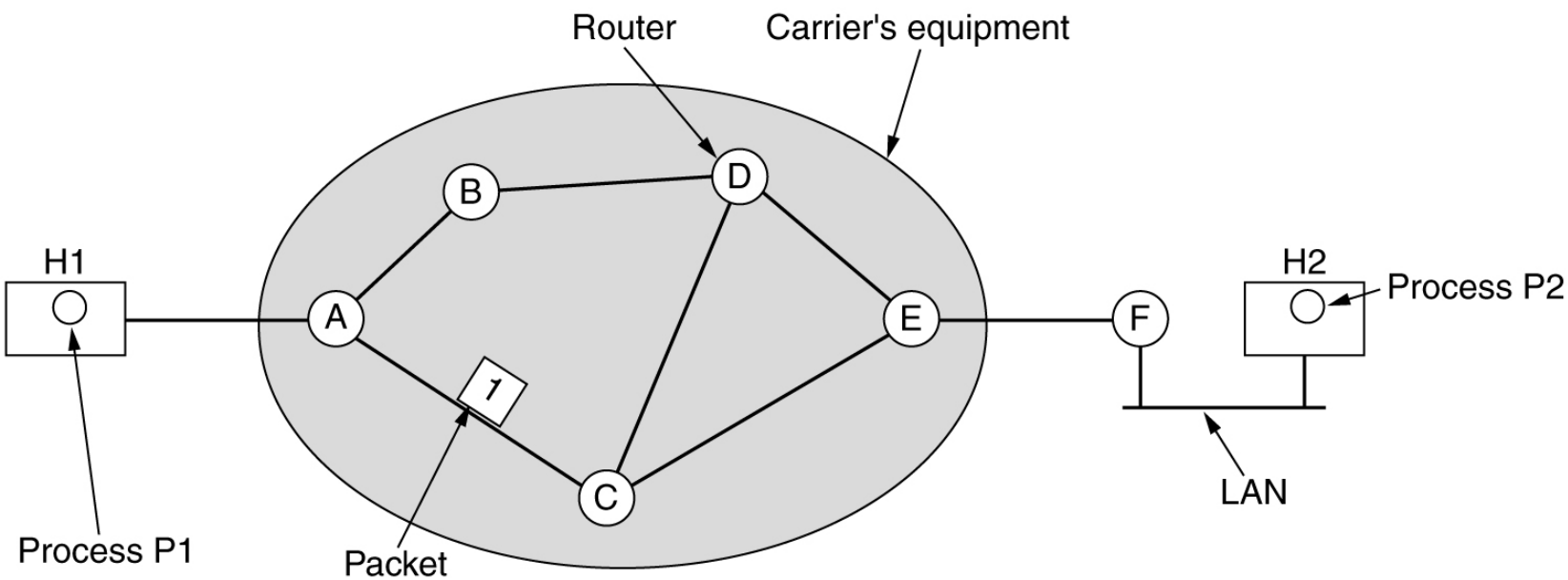
- end-to-end prenos (celá cesta od zdroja do cieľa)
- včítane všetkých smerovačov
  - linková vrstva - prenos rámcov medzi 2 bodmi (z jedného konca média na druhý)

Smerujeme k IP ... (ako časti TCP/IP)



Vsuvka - IP adresy

Prepájanie paketov Store-and-Forward

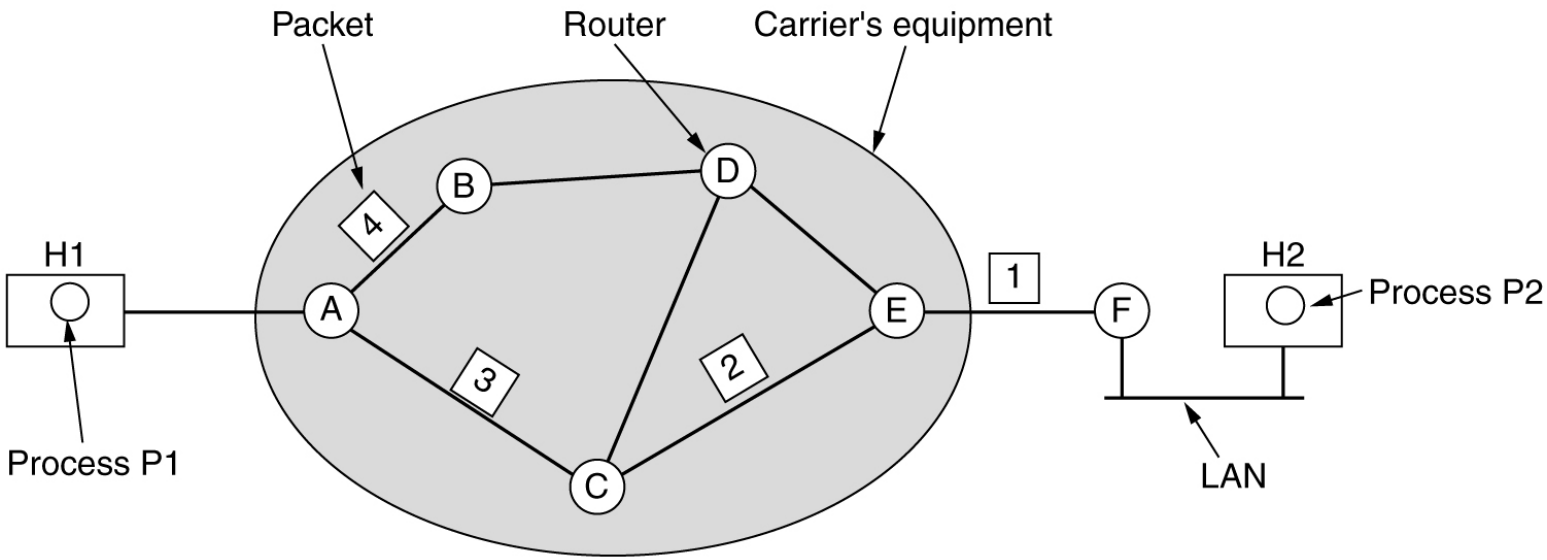


Internetovská komunita vs. telefónny svet

Siete bez a so spojovou orientáciou

- Siete bez spojovej orientácie (connectionless)
  - pakety vstupujú do siete nezávisle a sú aj nezávisle smerované
  - bez výstavby spojenia
  - paket sa nazýva DATAGRAM
- Siete so spojovou orientáciou (connection-oriented)
  - výstavba spojenia - SIGNALIZÁCIA
  - spojenia sa nazýva VIRTUÁLNY OKRUH (virtual circuit)

Služba bez spojovej orientácie (Connectionless Service)



A's table

initially		later	
A	–	A	–
B	B	B	B
C	C	C	C
D	B	D	B
E	C	E	B
F	C	F	B

Dest. Line

C's table

A	A
B	A
C	–
D	D
E	E
F	E

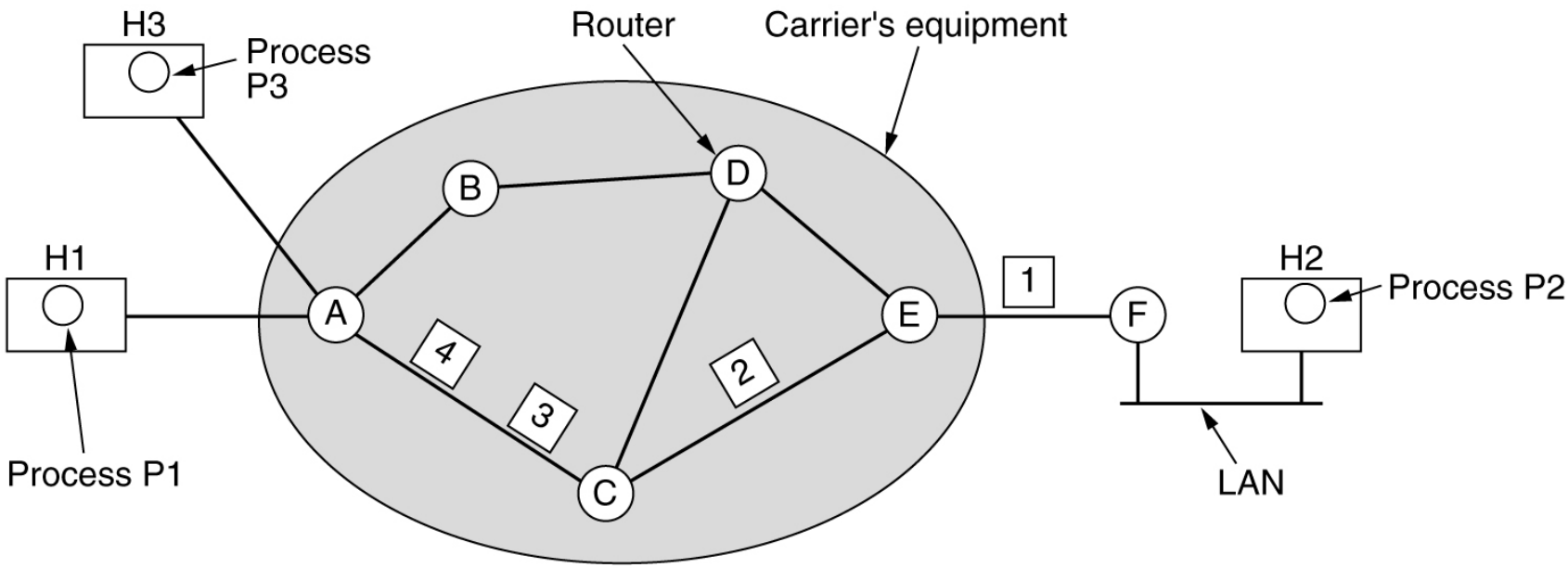
E's table

A	C
B	D
C	C
D	D
E	–
F	F

Smerovacia tabuľka a smerovací algoritmus

- smerovacia tabuľka (routing table)
  - návod, kam poslať paket pre každý možný cieľ
- smerovací algoritmus (routing algorithm)
  - algoritmus, ktorý spravuje smerovacie tabuľky a robí rozhodnutia o smerovaní

Služba so spojovou orientáciou (Connection-Oriented Service)



A's table

In		Out	
H1	1	C	1
H3	1	C	2

C's table

A	1	E	1
A	2	E	2

E's table

C	1	F	1
C	2	F	2

Porovnanie sietí s datagramami a s virtuálnymi okruhmi

Issue	Datagram subnet	Virtual-circuit subnet
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

Smerovacie algoritmy

(Routing algorithms)

Pojmy

- Smerovací algoritmus - časť softvéru sieťovej vrstvy zodpovedná za rozhodnutie, ktorou výstupnou linkou sa pošle prichádzajúci paket
  - pre datagramové podsiete rozhodnutie pre každý paket
  - pre virt. okruhy - rozhodnutie iba pri zostavení virt. okruhu (tzv. session routing)

- posielanie (forwarding) na výst. linku <-> smerovanie (routing) - vyplňovanie a aktualizácia smerovacích tabuliek

- smerovacie algoritmy:
  - neadaptívne - statické (cesty určené vopred)
  - adaptívne - dynamické (zmeny na základe topológie, prevádzky, ...)

Smerovacie algoritmy - kratučký prehľad

Statické algoritmy

- smerovanie najkratšou cestou (Shortest Path Routing) - podsieť ako neorientovaný graf
  - NAJKRATŠIA cesta: vetvám prislúcha METRIKA (hop, geografická vzdialenosť, šírka pásma, pravádzka, náklady, priemerná dĺžka radu, oneskorenie, ...)
  - Dijkstrov algoritmus výpočtu najkratšej cesty (statický algoritmus)
- záplavové smerovanie (Flooding)

Dynamické algoritmy

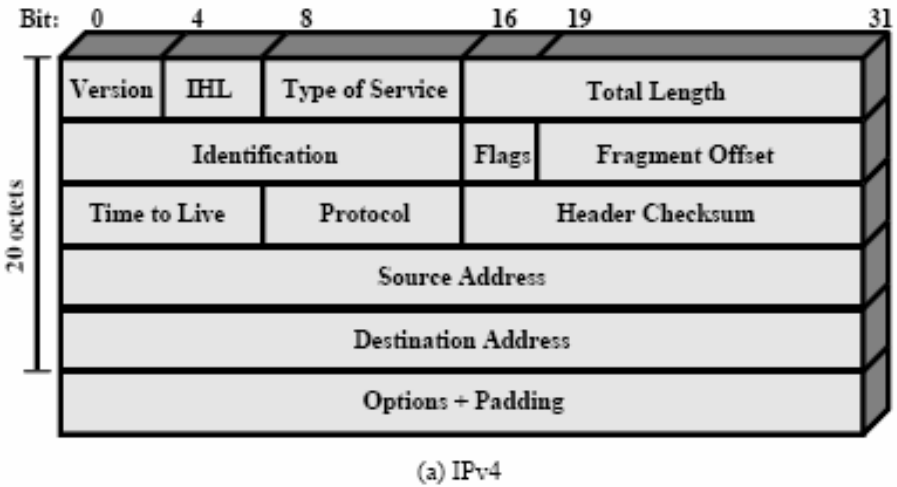
- Distance Vector Routing (Bellman-Ford, Ford-Fulkerson, RIP)
- Link State Routing

- Hierarchické smerovanie
- Broadcastové smerovanie
- Multicastové smerovanie
- Smerovanie pre mobilné uzly
- Smerovanie v ad-hoc sieťach (mobilné sú uzly aj smerovače)

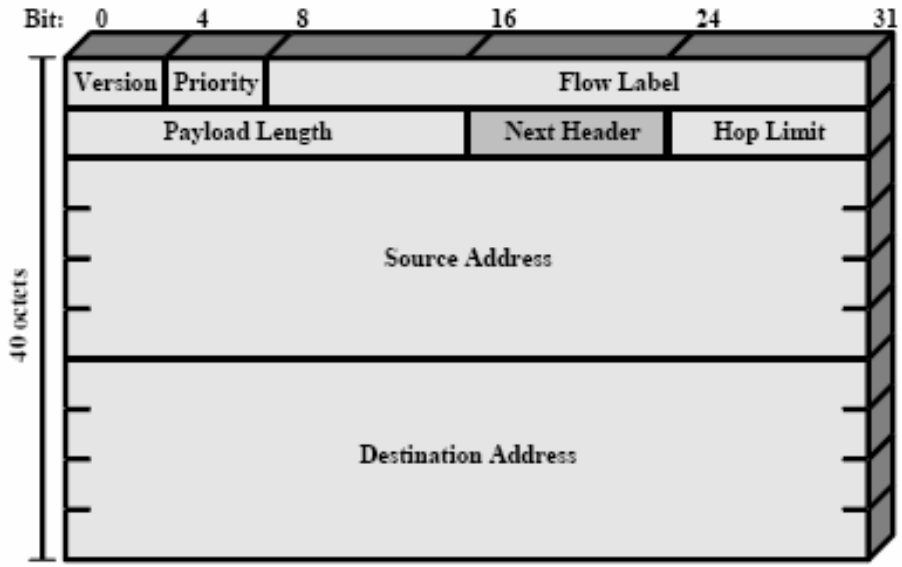
Protokol IP

(Internet Protocol)

Hlavičky IPv4 a IPv6

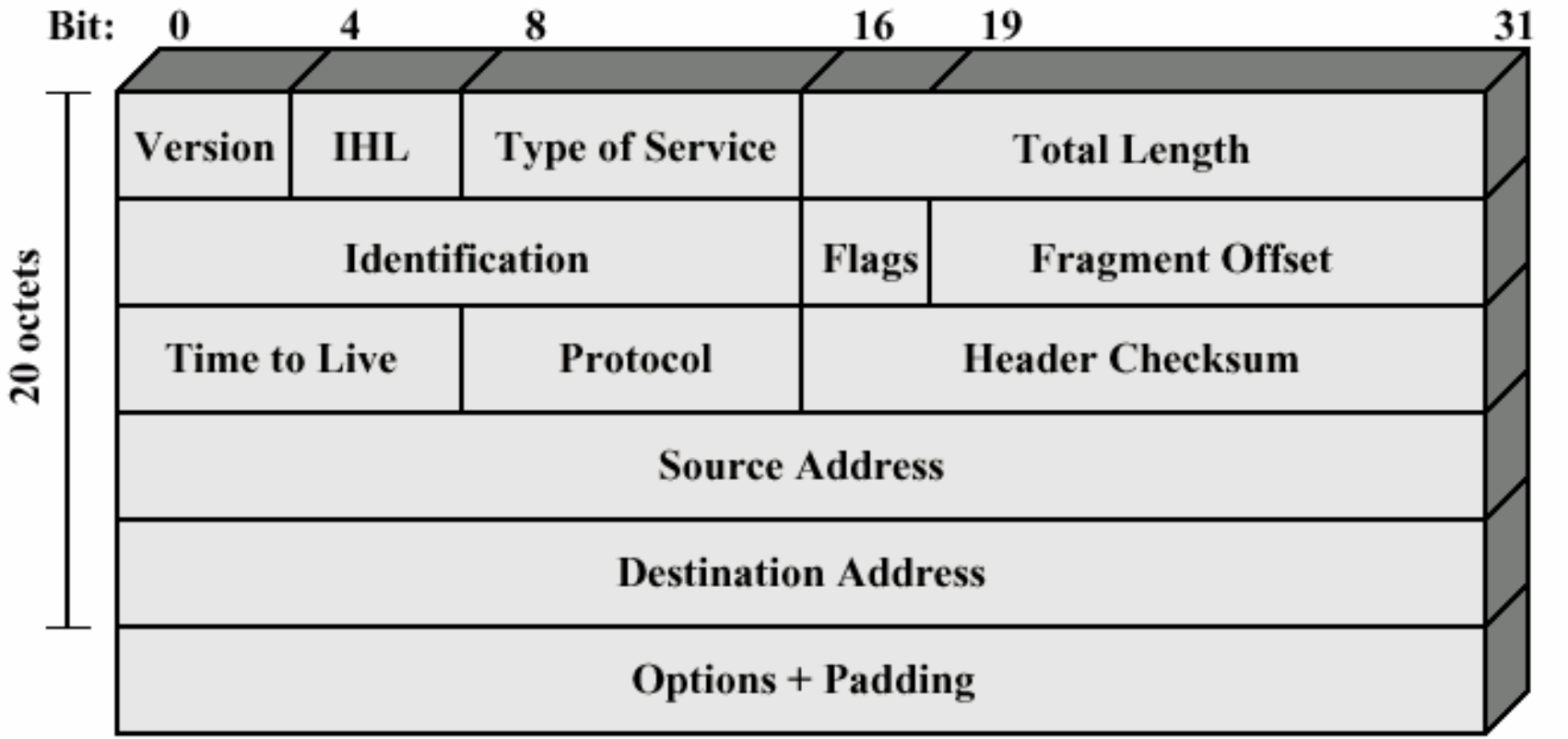


(a) IPv4

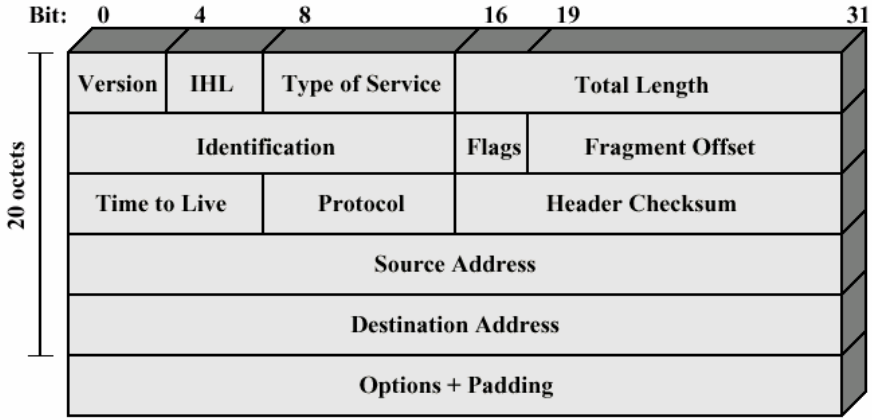


(b) IPv6

Hlavička IPv4

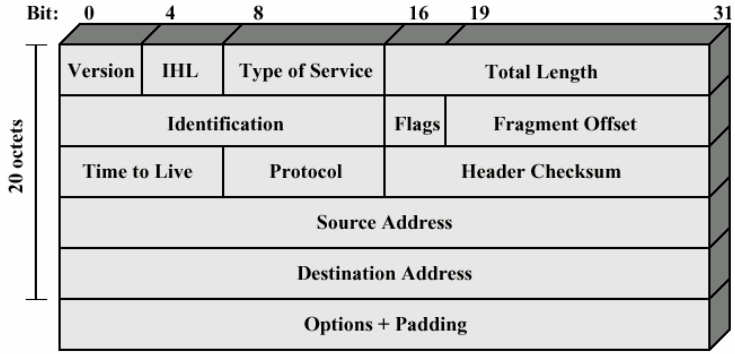


Hlavička IPv4



- **Version (4 bits):** Indicates version number, the value is 4
- **IHL – Internet Header Length (4) bits:** length of header in 32-bit words; the minimum value is 5, for a minimum header length of 20 bytes (max is 15 -> 60 bytes)
- **Type of Service (8 bits):** provides guidance to end-system IP modules and to routers along the datagram's path *(examples of TOS: minimize delay, maximize throughput, maximize reliability, minimize monetary cost, normal service – various combinations of speed and reliability are possible)*
- **Total Length (16 bits):** total datagram length, in bytes (max 65536, for gigabit networks longer datagrams will be needed)
- **Identifier (16 bits):** a sequence number, that, together with the source address, destination address, and user protocol, is intended to identify a datagram uniquely

Hlavička IPv4

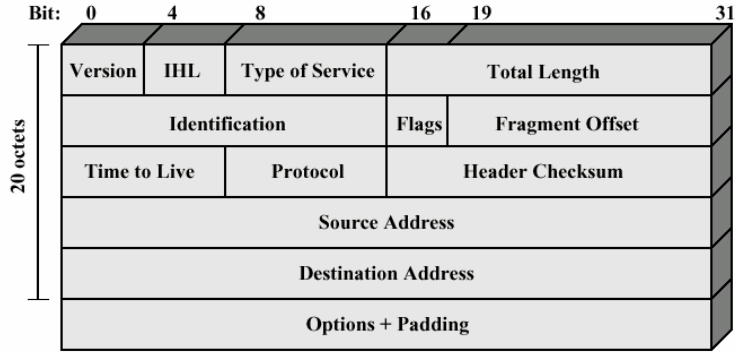


- **Flags (3 bits)**:only 2 bits are defined
  - the More Fragments (MF) bit – indicates whether this is the last fragment in the original datagram (all fragments except the last one have this bit set)
  - the Don't Fragment (DF) bit – when it is set, it prohibits fragmentation

- **Fragment Offset (13 bits):** indicates where in the original datagram this fragment belongs, measured in 64-bit units (this implies that fragments other than the last fragment must contain a data field that is multiple of 64 bits in length)

- **Time to Live (8 bits):** specifies how long (in seconds – max 255 s) a datagram is allowed to remain in the internet; every router, that processes a datagram must decrease the TTL by at least one – in practice TTL is similar to a hop count (hop = the passage of a packet through one router), when it hits zero, the packet is discarded and a warning packet is sent to the source (this prevents datagrams for wandering around forever)

Hlavička IPv4



- **Protocol (8 bits):** indicates the next higher-level protocol, which is to receive the data field at the destination (e.g. TCP, UDP)
- **Header checksum (16 bits):** an error-detecting code applied to the header only (because some header fields may change during transmit (e.g. TTL or segmentation-related fields), this is reverified and recomputed at each router
- **Source Address (32 bits):** coded to allow a variable allocation of bits to specify the network and the end system attached to the specified network
- **Destination Address (32 bits):** same characteristics as source address
- **Options (variable):** encodes the options requested by the sending user
- **Padding (variable):** used to ensure that the datagram header is a multiple of 32 bits in length
- **Data (variable):** the data field must be an integer multiple of 8 bits in length; the maximum length of the datagram (data field + header) is 65 535 bytes

Classless Routing

- Classless IPv4 addressing
- jedno z riešení nedostatku IP adries
- RFC 1519
- prideľovanie zostávajúcich adries v blokoch premenlivej dĺžky
- bez ohľadu na triedy (A ,B, C)

- napr. ak organizácia potrebuje 2000 adries, dostane blok 2048 adries
- každej položke smerovacej tabuľky sa priradí 32-bitová maska
- jednotná smerovacia tabuľka pre všetky siete:
  - pole trojíc (IP adresa, sieťová maska, výstupná linka)

- AND každej položky smerovacej tabuľky s 32-bitovou maskou, až potom porovnanie s adresami v smerovacej tabuľke
- ak je zhoda s 2 položkami, akceptuje sa prípad s viacerými 1

Classless Routing

- napr. voľné adresy počnúc 192.24.0.0
- potreby univerzít:
  - Cambridge: 2048 adries

University	First address	Last address	How many	Written as
Cambridge	194.24.0.0	194.24.7.255	2048	194.24.0.0/21
Edinburgh	194.24.8.0	194.24.11.255	1024	194.24.8.0/22
(Available)	194.24.12.0	194.24.15.255	1024	194.24.12/22
Oxford	194.24.16.0	194.24.31.255	4096	194.24.16.0/20

Privátne IP adresy

- tri intervaly IP adries:
  - 10.0.0.0 - 10.255.255.255/8 (16 777 216 adries)
  - 172.16.0.0 - 172.31.255.255/12 (1 048 576 adries)
  - 192.168.0.0 - 192.168.255.255/16 (65 536 adries)
- interné využitie je ľubovoľné
- nesmú sa objaviť na internete

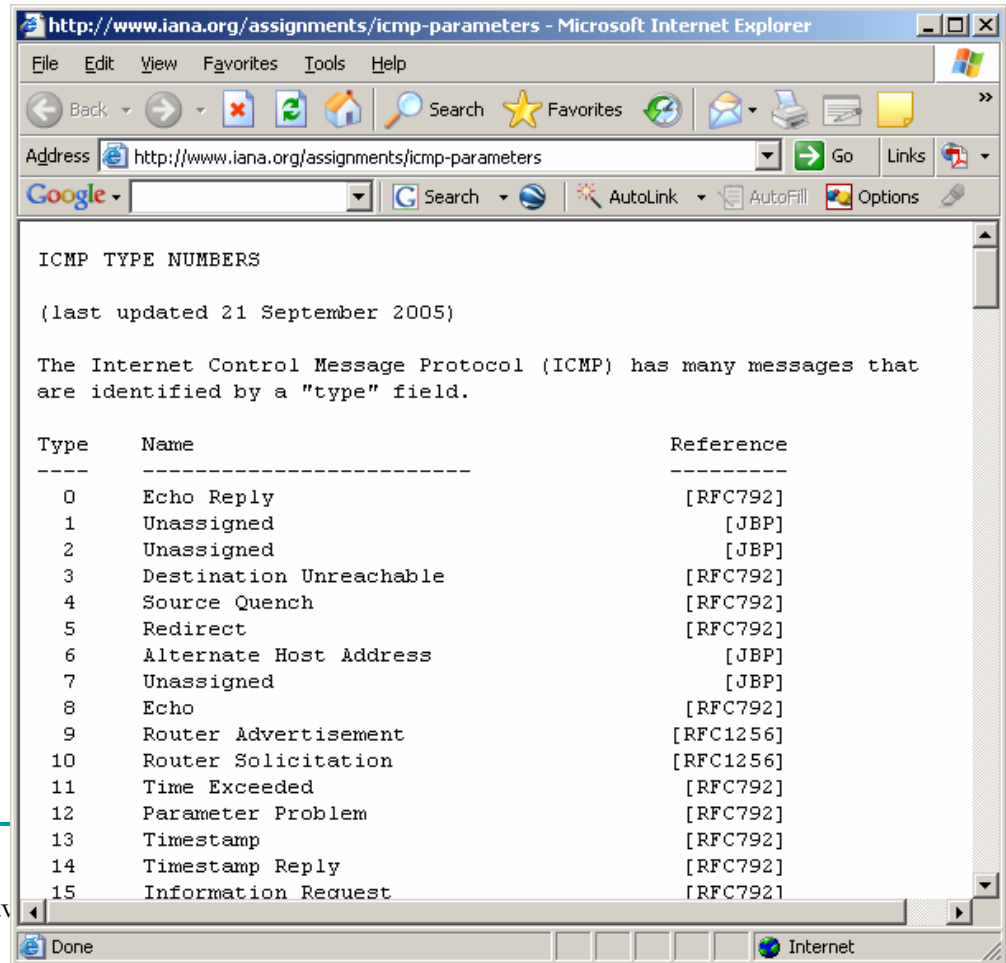
- NAT (Network Address Translation): RFC 3022

Riadiace protokoly siet'ovej vrstvy

(Internet Control Protocols)

ICMP - Internet Control Message Protocol

- ICMP - hlásenie nečakaných udalostí
- definované správy ICMP
- zoznam správ ---------->



ICMP - Internet Control Message Protocol

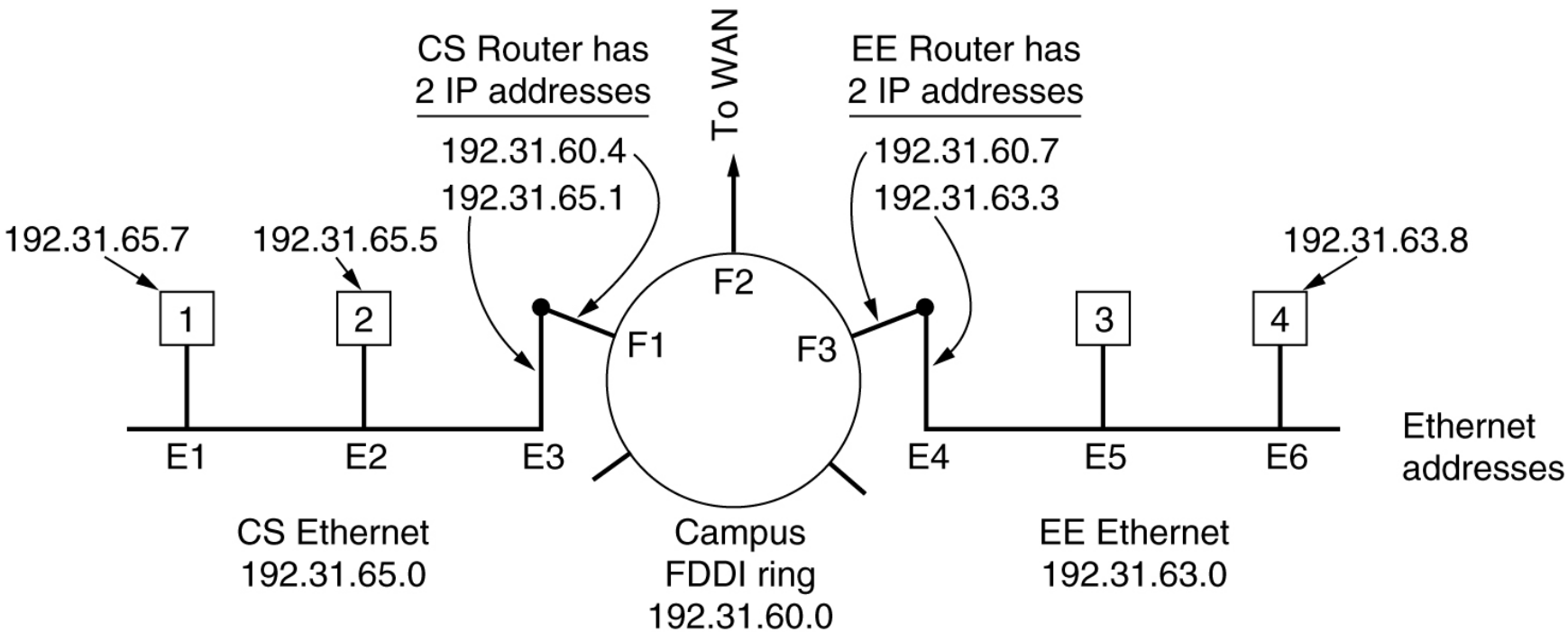
Message type	Description
Destination unreachable	Packet could not be delivered
Time exceeded	Time to live field hit 0
Parameter problem	Invalid header field
Source quench	Choke packet
Redirect	Teach a router about geography
Echo request	Ask a machine if it is alive
Echo reply	Yes, I am alive
Timestamp request	Same as Echo request, but with timestamp
Timestamp reply	Same as Echo reply, but with timestamp

Hlavné správy ICMP

ARP– Address Resolution Protocol

- mapovanie IP adries na linkové adresy (napr. Ethernet MAC adresy)
  - konfiguračné súbory ☹
  - ARP ☺ (RFC 826)
    - broadcast paket po Ethernete: Kto vlastní IP adresu x.y.z.q?
    - komunikácia v rámci jednej podsiete
    - komunikácia medzi podsieťami

ARP– Address Resolution Protocol



RARP, BOOTP

Riešenie opačnej otázky: Aká IP adresa zodpovedá danej Ethernetovej adrese?

- napr. bootovanie bezdiskovej pracovnej stanice

- **RARP**
  - RFC 903
  - RARP server odpovedá na lokálny broadcast (RARP požiadavka)
  - RARP používa adresu 11...1, nie j smerovaná smerovačmi – 1 RARP server pre každú podsieť

- **BOOTP**
  - RFC 951, 1048, 1084
  - využíva UDP správy smerované smerovačmi
  - aj prídavné infomácie pre bezdiskovú pracovnú stanicu (IP adresa servera s jej memory imagom, IP adresa default smerovača, router, subnet maska
  - nevýhoda – manuálna konfigurácia tabuliek mapovania IP adresa <-> Ethernet adresa

DHCP - Dynamic Host Configuration Protocol

- RFC 2131, 2132
- manuálne aj automatické priradenie adries
- DHCP server na požiadavku uzla priraďuje IP adresu
- DHCP relay agent pre každú LAN
- leasing adresy