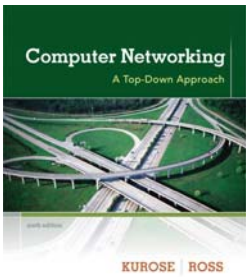
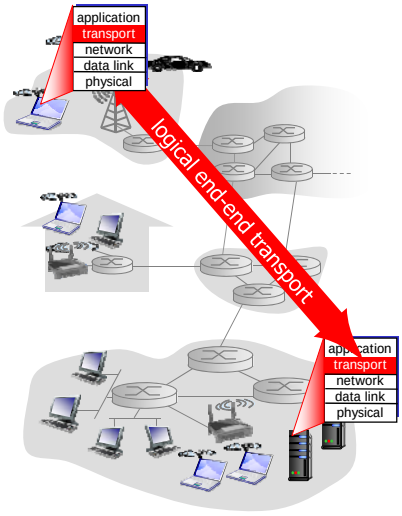
Permbledhje



Computer Networking: A Top Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012

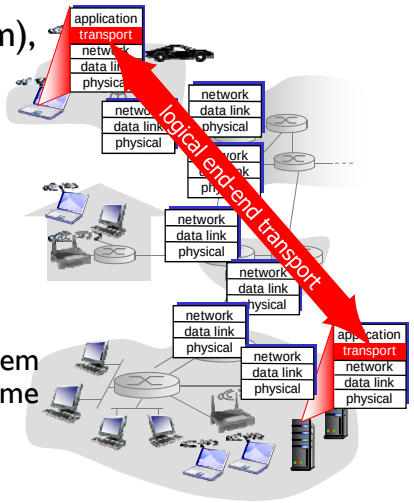
Sherbimet dhe protokollet e Transportit

- Krijon komunikim llogjik ndermjet proceseve te aplikimeve qe hoste te ndryshem
- Protokollet e transportit funksionojne ne sistemet fundore
  - Ana derguese: ndan mesazhet e aplikimeve ne *segmente*, dhe i kalon tek shtresa e rrjetit (network)
  - Ana marrese: rinderton segmentet ne mesazhe, dhe i kalon tek shtresa e zbatimit
- Me shume se sa nje protokol transporti qe mund te perdoret nga zbatimet
  - Internet: TCP and UDP



Protokollet e shtreses se transportit te Internetit

- Dergim Reliable (i besueshem), dhe sipas rradhes (TCP)
  - Kontrolli i kongestion
  - Kontrolli i rrjedhes
  - Vendosja (setup) I lidhjes
- Dergim i pabesueshem (Unreliable), jo sipas rradhes (unordered): UDP
  - Pa ndonje zgjerim te rendesishem ndaj "best-effort" (perpjekses me te mire) te IP
- Sherbime jo te pranishem:
  - Garantim vonese
  - Garantim bandwidth



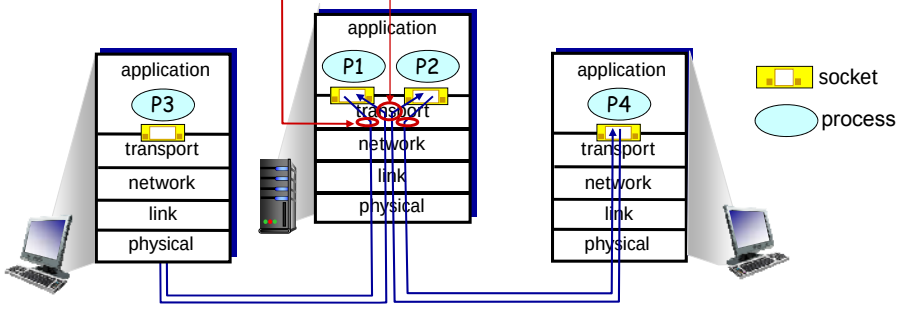
Multiplexing/demultiplexing

multiplexing ne dergues:

Trajton te dhena te dhana nga disa sockets, shton header te transportit (i perdorur me vone per demultiplexing)

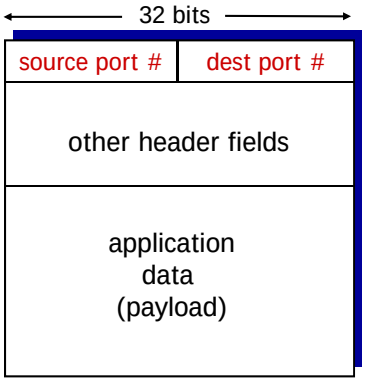
demultiplexing ne marres:

Perdor informacionin e headerin per te derguar segmentet e Marre tek socket e duhura



Si funksionon demultipleximi

- Hosti merr diagramat IP
  - Cdo datagram ka adresen IP te burimit, adresen IP te destinacionit
  - Cdo datagram mban nje segment te shtreses se transport
  - Cdo segment ka nje nje numer porte te burimit dhe destinacionit
- Hosti perdor adresat IP dhe numerat e portave per te drejtuar segmentet ne portat e duhuara

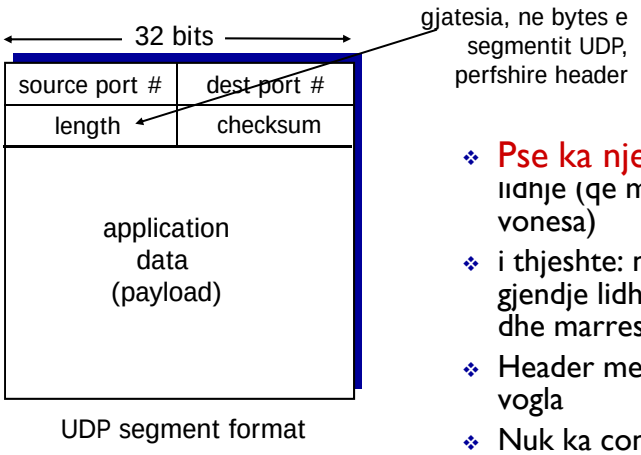


TCP/UDP segment format

UDP: User Datagram Protocol [RFC 768]

- Pa sherbime shtese, minimumi i protokollit te transportit ne Internet
- Sherbim "best effort" (perpjeken me te mire), segmentet UDP mund te:
  - humbin
  - Te dergohen jashte rradhes tek aplikimet
- *Connectionless (pa lidhje):*
  - Pa dhenie dore ndermjet derguesit dhe marresit UDP
  - Cdo segment UDP trajtohen pavaresisht nga te tjeret
- Perdorime te UDP:
  - streaming multimedia apps (tolerant ndaj humbjeve, sesitive ndaj shpejtesia)
  - DNS
  - SNMP
- Transferim i besueshem mbi UDP:
  - Shto besueshmeri (reliability) ne shtresen e aplikimit
  - Korrigjimi i gabimeve specifike te aplikimit!

UDP: segment header



UDP segment format

- Pse ka nje UDP? dosje lidhje (qe mund te shtoje vonesa)
- i thjeshte: nuk mbahet gjendje lidhje ne dergues dhe marres
- Header me permasa te vogla
- Nuk ka congestion control: UDP mund te dergosa sa shpejte te munde

UDP checksum

Qellimi: te detektoje "gabime" (psh. bitet e ndryshuar) ne segmentin e transmetuar

dergues:

- Trajton permbajtjen e segmenteve, si sequence numerash te plote 6-bite
- checksum: shton addition (one's complement sum) ne permbajtjen e segmentit
- Derguesi vendos vleren e checksum ne fushen e checksum ne UDP

marres:

- Llogarit checksum e segmentit te marre
- Kontrollon nese checksum I llogaritur eshte I barabarte me vleren e fushes se checksum:
  - JO – eshte detektuar nje gabim
  - PO – nuk eshte detektuar gabim. *Por megjithate mund te kete gabime?* ….

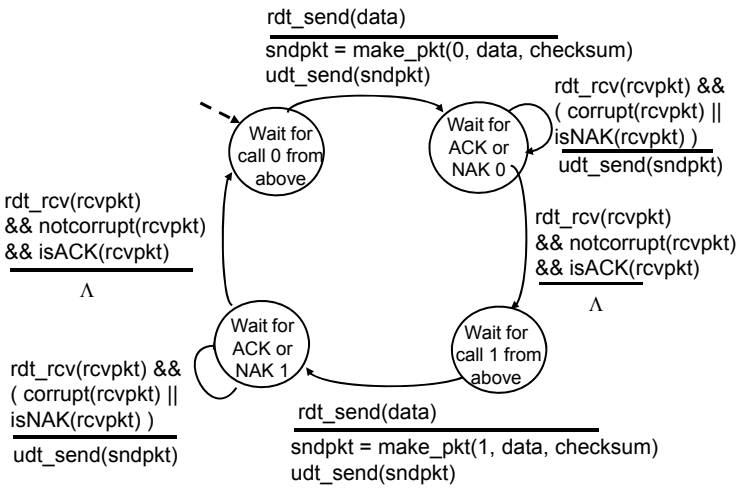
Internet checksum: shembull

example: mblidh dy numerate plote 16-bitesh

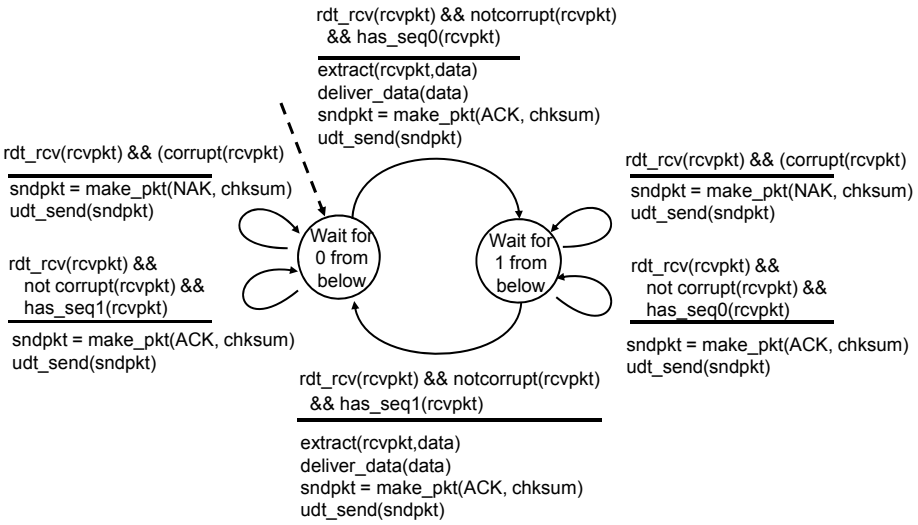
		1	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
		1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
mbartje	(1)	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1
shuma		1	0	1	1	1	0	1	1	1	0	1	1	1	1	0	0
checksum		0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	1

Shenim: kur blidhen numerat, nje mbartje nga bitet me me vlere duhet t'i shtohen rezultatit

rdt2.1: sender, handles garbled ACK/NAKs



rdt2.1: receiver, handles garbled ACK/NAKs



rdt2.1: discussion

sender:

- seq # shtuar tek pkt
- A mjaftojne dy seq. #' s (0,1)? Pse?
- Duhet te kontrolloje nese ACK/NAK e marrura jane te korruptuara (me gabime)
- Dyfish gjendjesh
  - Gjendja duhet te "kujtoje" nese pkt e "pritur" duhet te kete seq # 0 ose 1

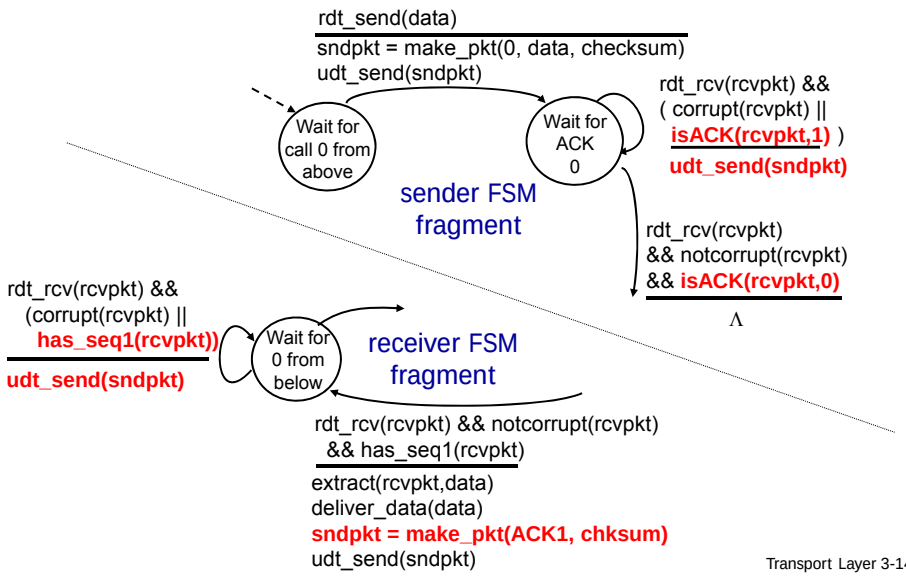
receiver:

- Duhet te kontrolloje nese paketa e marre eshte duplicate (e perseritur)
  - Gjendja tregon nese 0 apo 1 pritet si pkt seq #
- shenim: marresi nuk mund te dije nese ACK/NAK I tij i fundit eshte marre OK ne dergues

rdt2.2: nje protokoll pa NAK

- Te njejtat funksions si rdt2.1, por duke perdour vetem ACKs
- Ne vend te NAK, marresi dergon ACK per pkt e fundit te marre OK
  - Marresi duhet te fuse ne menyre eksplicitese q # e pkt qe po ACKed
- ACK e perseritur ne dergues con ne te njejtin veprim si NAK: ritranmetim i paketes ne fjale

rdt2.2: derguesi dhe marresi



rdt3.0: kanale me gabime dhe humbje

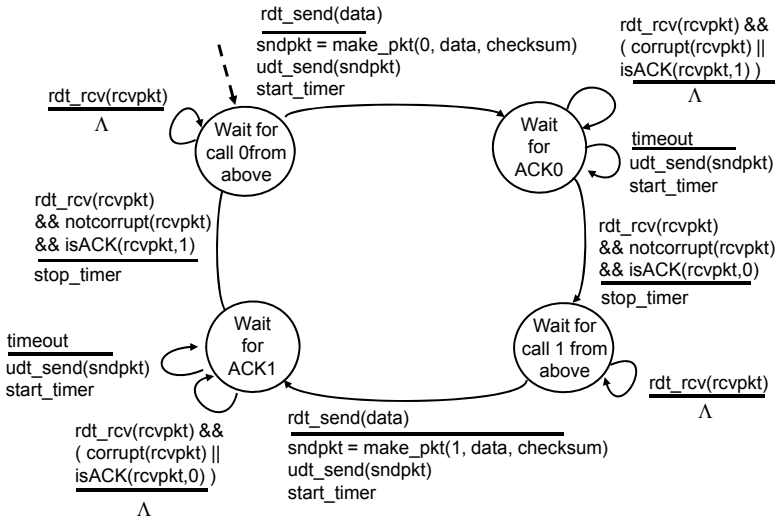
Kushte te reja: kanali mund gjithashtu te humbi paketa (data, ACKs)

- checksum, seq. #, ACKs, ritransmetimet do te ndihmojne … por nuk mjaftojne

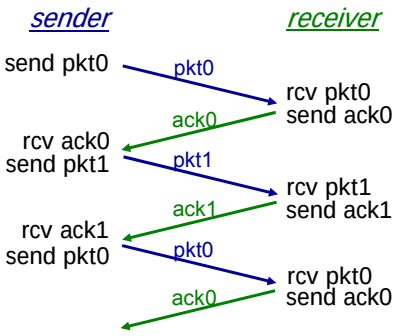
qasja: derguesi pret per nje sasi kohe te "arsyeshme" per ACK

- Ritransmeton nese nuk merr ndonje ACK gjate kesaj kohe
- Nese pkt (apo ACK) nuk jana humbur por vec vonuar:
  - Ritransmetimi do te rezultoje ne nje perseritje te paketes, por seq. #' s e zjgidhin kete problem
  - Marresi duhet te specifikoje seq # e paketes qe po ACKed
- Kerkon ore countdown

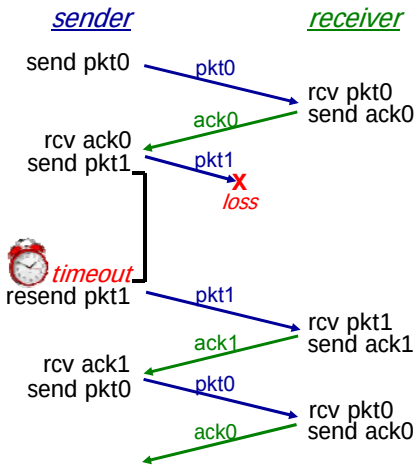
rdt3.0 dergues



rdt3.0 ne veprim

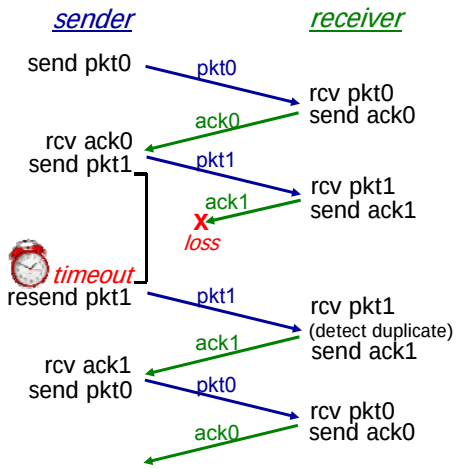


(a) no loss

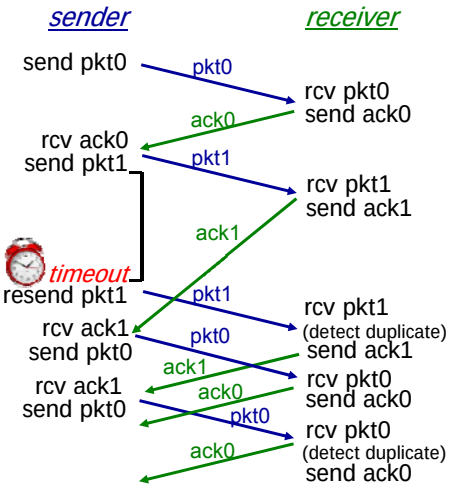


(b) packet loss

rdt3.0 ne veprim



(c) ACK loss



(d) premature timeout/ delayed ACK

Performanca e rdt3.0

- rdt3.0 eshte korrekte, por me performance te ulet
- e.g.: 1 Gbps link, 15 ms prop. delay, 8000 bit packet:

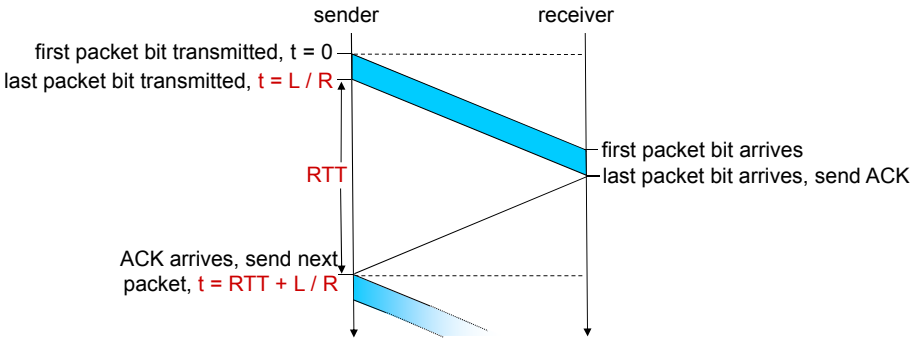
$$D_{trans} = \frac{L}{R} = \frac{8000\ bits}{10^9\ bits/sec} = 8\ microsecs$$

  - U $_{sender}$: *utilization* – fraction of time sender busy sending

$$U_{sender} = \frac{L/R}{RTT + L/R} = \frac{.008}{30.008} = 0.00027$$

    - if RTT=30 msec, 1KB pkt every 30 msec: 33kB/sec thruput over 1 Gbps link
- Protokolli kufizon perdorimin e risurseve fizike!

rdt3.0: stop-and-wait operation

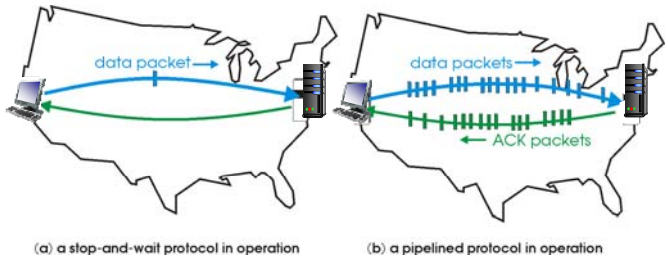


$$U_{sender} = \frac{L/R}{RTT + L/R} = \frac{.008}{30.008} = 0.00027$$

Pipelined protocols

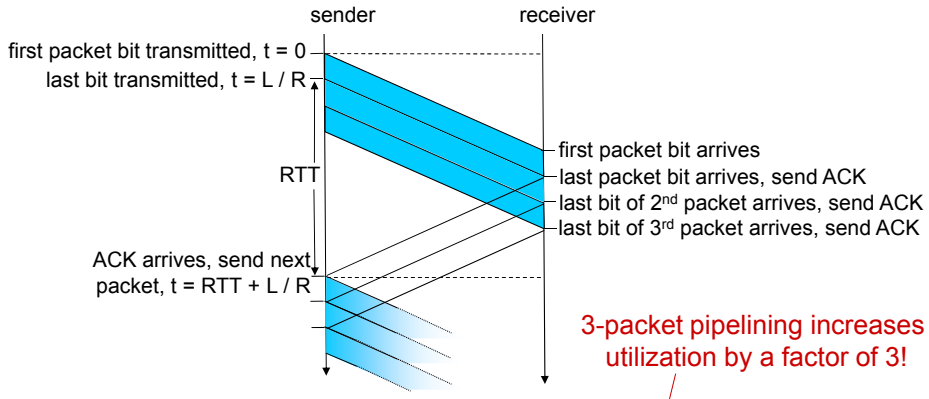
pipelining: derguesi lejon disa, "in-flight", yet-to-be-acknowledged pkts

- Hapesira e numerave te sequencave duhet rritur
- buffering at sender and/or receiver



- Dy forma te pergjithshme te pipelined protocols: *go-Back-N, selective repeat*

Pipelining: increased utilization



3-packet pipelining increases utilization by a factor of 3!

$$U_{sender} = \frac{3L / R}{RTT + L / R} = \frac{.0024}{30.008} = 0.00081$$

Pipelined protocols: overview

Go-back-N:

- Derguesi mund te kete deri ne N paketa unacked (te pa konfirmuara) ne pipeline
- Marresi dergon vetem *cumulative (grumbullues) ack*
  - Nuk e ack paketen nese ka nje gap
- Derguesi ka timer per paketen me te vjeter te pa konfirkuar
  - kur timer mbaron, ritransmston te gjitha kapetat e pakonfirmuara

Selective Repeat:

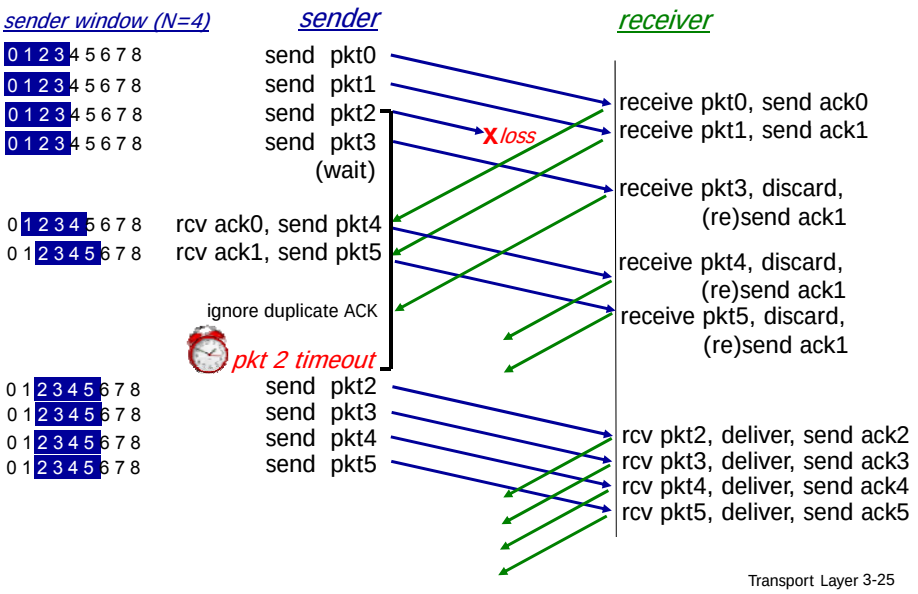
- Derguesi mund te kete deri ne N paketa te pa konfirmuara ne pipeline
- marresi con *individual ack* per cdo pakete
- Derguesi mban nje timer per cdo pakete te pakonfirmuar
  - kur timer mbaron, ritransmeton vetem ate pakete te pa konfirmuar

Go-Back-N: derguesi

- k-bit seq # in pkt header
- "dritarja" gjer ne N, lejohen paketa te pakonfirmuara njera pas tjetres

- ACK(n): konfirmon te gjitha paketa deri, perfshire seq # n - *"cumulative ACK" (ACK grumbullues)*
  - Muns te marre ACKs te perseritura (shiko marresin)
- timer per paketen me vjeter qe eshte ne udhetim
- *timeout(n):* ritrnasmeton paketen n dhe te gjitha paketat e tjera me seq # me te madh ne dritare

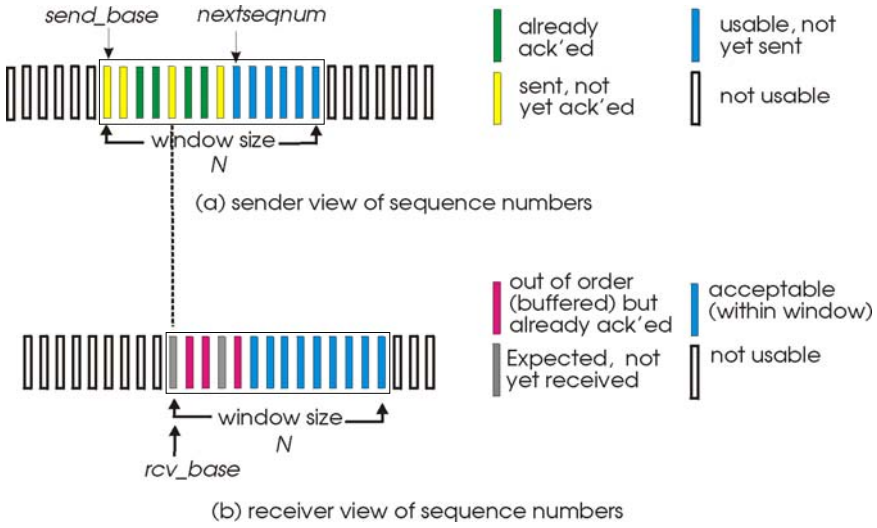
GBN ne veprim



Selective repeat

- Marresi ne menyre individuale konfirmon te gjitha paketat e marra ne rregull
  - Ruan pkts ne bufera, sipas nevojes, per tu derguar simbas rradhes tek shtresa e lartme
- Derguesi ridwergon vetem paketat per te cilat nuk eshte marre konfirmim (ACK)
  - Derguesi ka timer per cdo pakete te pakonfirmuar
- Dritarja e derguesit
  - *N* seq # te njepasnjeshme
  - Kufizon seq #s e paketave te derguara dhe te te atyre te pakonfirmuara

Selective repeat: sender, receiver windows



Selective repeat

dergues

Te dhena nga lart:

- Nqs ka seq # in window, dergo pkt

timeout(n):

- ridergo pkt n, rifillo timer

ACK(n) in [sendbase,sendbase+N]:

- shenjo pkt n si te marre
- Nqs n eshte paketa me sec # me te vogel e pakonfirmuar, perparo window base tel seq # I paketes tjeter te pakonfirmuar

marres

pkt n in [rcvbase, rcvbase+N-1]

- dergo ACK(n)
- out-of-order (jashte rradhes) : buffer
- in-order: dergo tek aplikimi (gjithashtu dergo paketat e ruajtura simbas rradhes), perparo dritaren paketa pasardhese qe nuk eshte marre akoma

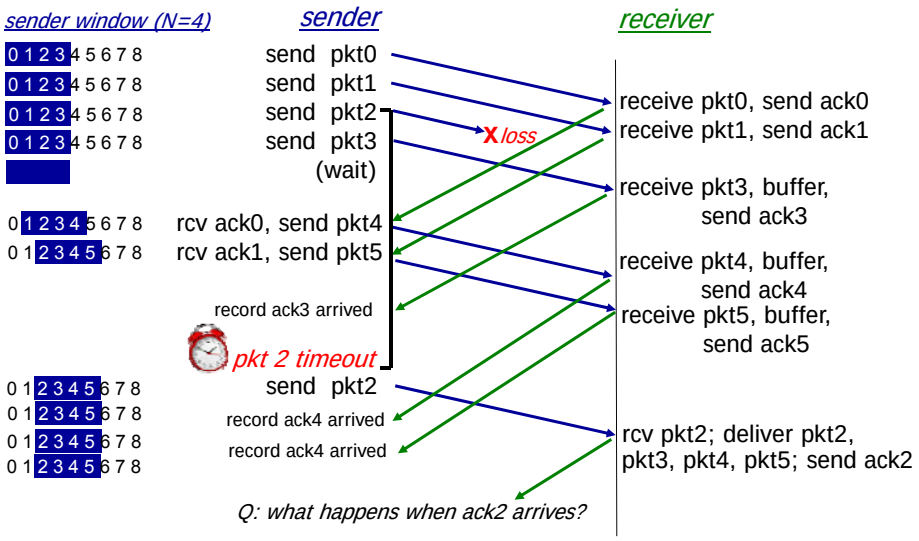
pkt n in [rcvbase-N,rcvbase-1]

- ACK(n)

perdryshe:

- Mos bej gje

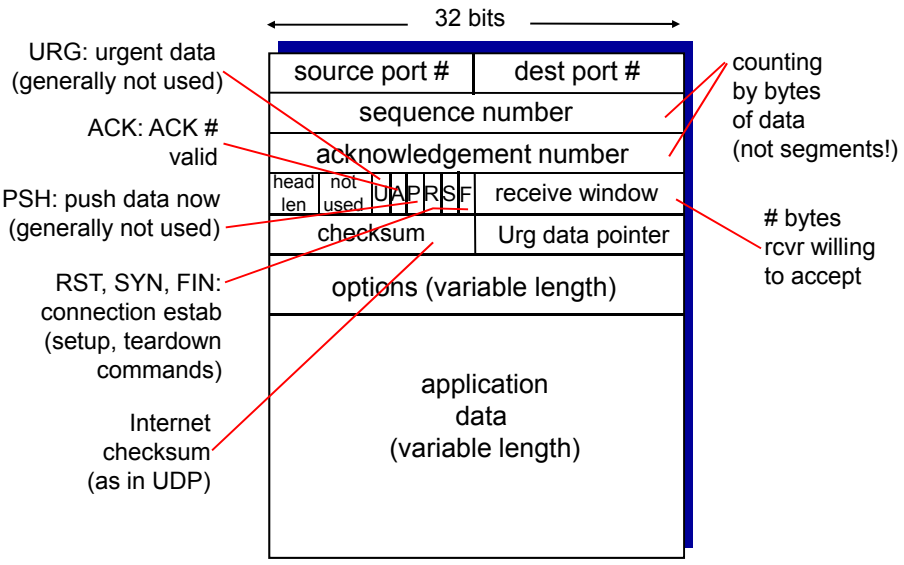
Selective repeat in action



TCP: Overview RFCs: 793,1122,1323, 2018, 2581

- point-to-point:
  - Nje dergues, nje marres
- reliable, in-order varg *byte:*
  - no "message boundaries"
- pipelined:
  - TCP congestion and flow control vendosin per madhesine e dritares
- full duplex data:
  - Rrjedhje dy drejtimeshe e te dhenave ne te njejten lidhje (connection)
  - MSS: gjatesia me e madhe e segmentit
- connection-oriented (me lidhje):
  - handshaking (pershendetje) (shkembim mesazhesh) inits sender, receiver state before data exchange
- flow controlled (kontroll I rrjedhjes):
  - Derguesi nuk do te dergoje me shume se sa marresi mund te pranoje

TCP segment structure



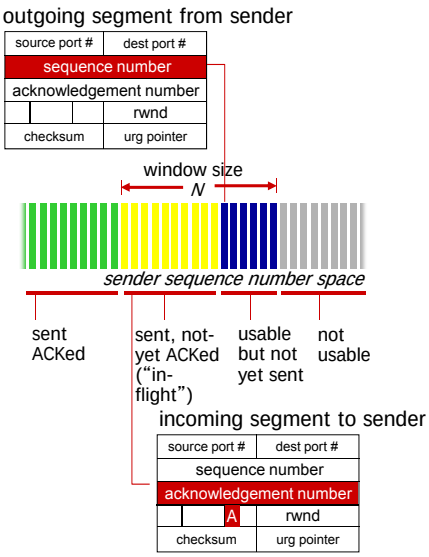
TCP seq. numbers, ACKs

sequence numbers:

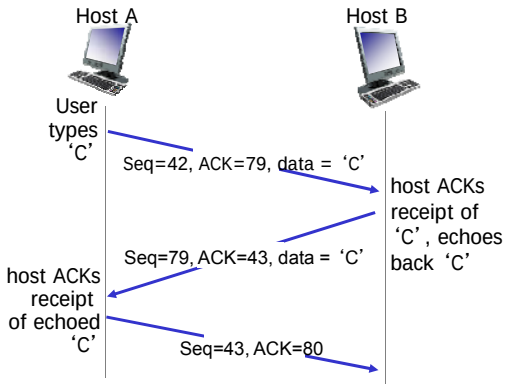
- Numeri i bytit te pare ne te dhenat e segmentit

acknowledgements:

- seq # e bytit pasardhes qe pritet nga ana tjeter
- cumulative ACK (grumbullues)



TCP seq. numbers, ACKs



simple telnet scenario

TCP round trip time, timeout

Q: Si te vendoset vlera e timeout e TCP?

- Me e gjate se RTT
  - por RTT ndryshon
- *Shume e shkurter:* timeout te parakohshem, ritransmetim te panevojshesm
- *Shume te gjate:* reagim te ngadalte ndaj humbjes se segmentit

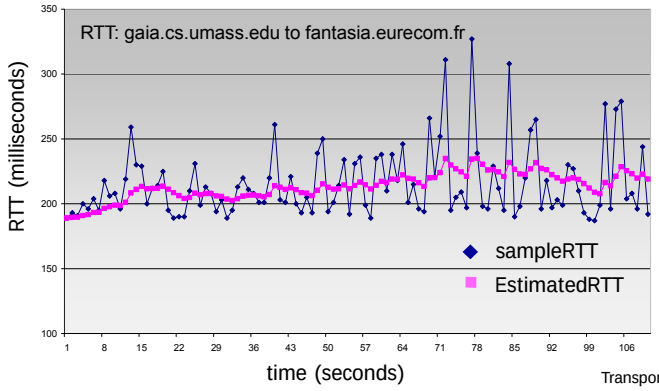
Q: si ta vleresojme RTT?

- **`SampleRTT`**: matet qe nga transmetimi I segmentit gjer ne marrjen e ACK
  - Nuk konsiderohen retransmissions
- **`SampleRTT`** ndryshon
  - Behet nje mesatare midis matjeve

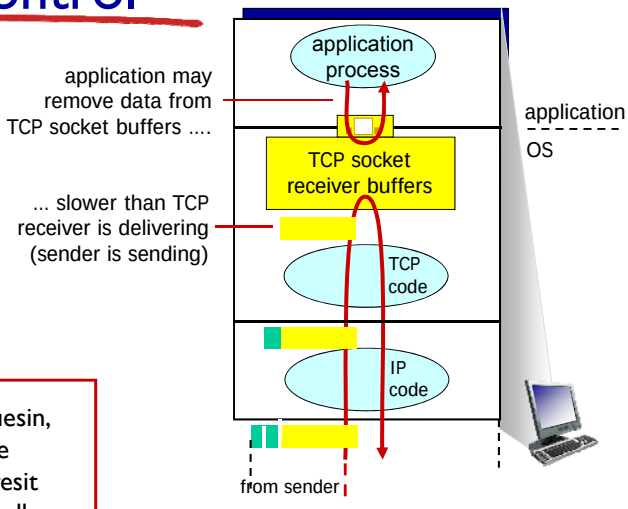
TCP round trip time, timeout

EstimatedRTT = (1- α)*EstimatedRTT + α*SampleRTT

- exponential weighted moving average
- influence of past sample decreases exponentially fast
- typical value: α = 0.125



TCP flow control

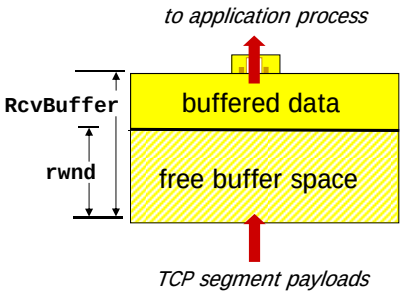


flow control

Marresi kontrollon derguesin, pra derguesi nuk mund te permbyse buferin e marresit duke transmetuar shume dhe shume shpejt

TCP flow control

- Marresi "reklamon" hapesiren e lire te buferit duke perfshire vleren e **rwnd** ne TCP header te segmenteve receiver-tek-sender
- Derguesi kufizon sasine e paketave te pakonfirmuara (ne udhetim) sac eshte **rwnd** e marresit
- Garanton qe buferi i marresit nuk permbytet

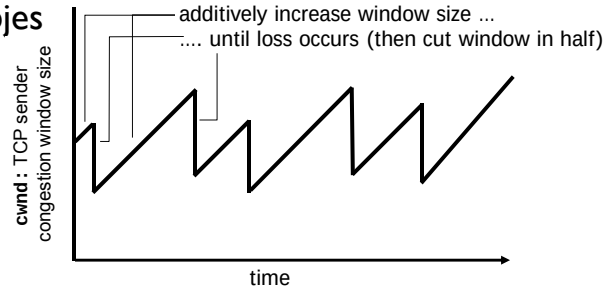


receiver-side buffering

TCP congestion control: additive increase multiplicative decrease

- *qasje:* *derguesi* rrit transmission rate (window size), duke testuar per bandwidth qe mund te perdore, gjerisa ndodh ndonje humbje
  - *additive increase:* rritje e **cwnd** me 1 MSS per cdo RTT gjersa dedektohen humbje
  - *multiplicative decrease:* ngushton **cwnd** ne gjysem mbas humbjes

AIMD saw tooth behavior: probing for bandwidth



Chapter 3: summary

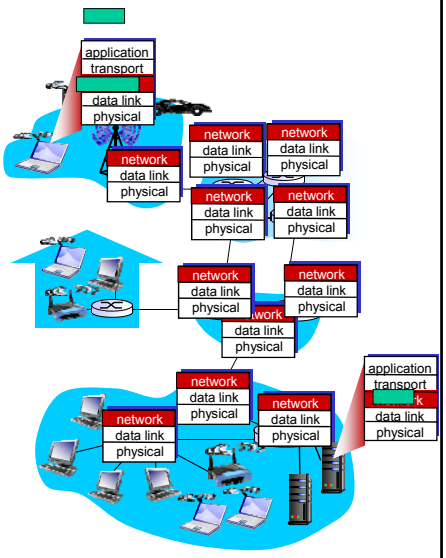
- principles behind transport layer services:
  - multiplexing, demultiplexing
  - reliable data transfer
  - flow control
  - congestion control
- instantiation, implementation in the Internet
  - UDP
  - TCP

next:

- leaving the network "edge" (application, transport layers)
- into the network "core"

Shtresa e Rrjetit

- Transporton segmentet nga derguesi tek marresi
- ne anen derguese i mbeshtjellin segmentet ne datagrama
- Ne anen marrese, con segmentet tek shtresa e transportit
- Protokollet e shtreses rrjetit ne cdo *every* host, routera
- routerat examinojne fushen e header ne te gjithat datagramat IP e kalojne nder ta



Dy funksionet kryesore te shtreses se rrjetit

- *Forwarding (shtyrja):* leviz paketat nga hyrja e router ne daljet e duhur te router
- *Routing (rrugezimi):* percakton rrugen e paketer nga burimi ne destinacion
  - *Algoritmat e routing*

analogji:

- *routing:* procesi I planifikimit te udhetimit nga burimi ne destinacion
- *forwarding:* procesi i kalimit ne nje nyje lidhese

Bahkveprimi ndermjet routing dhe forwarding

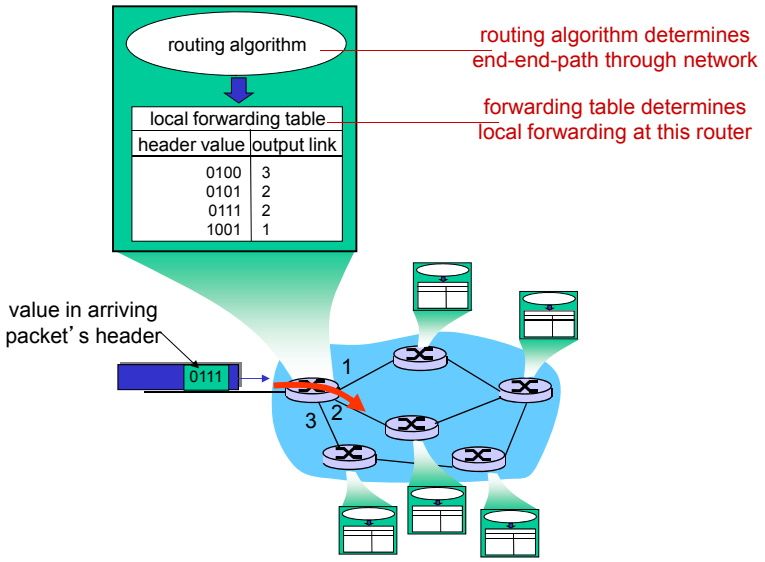
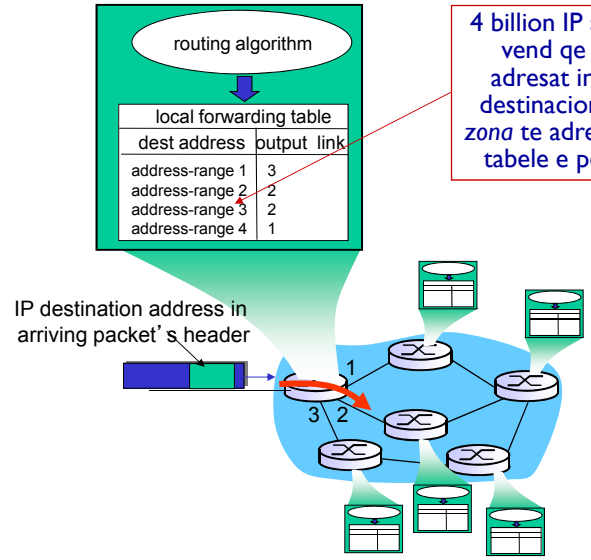


Tabela e forwarding se datagramit



4 billion IP adresa, pra ne vend qe te listohen adresat individuale te destinacioneve listohen *zona* te adresave (hyrje ne tabele e permbledhur)

Datagram forwarding table

Destination Address Range	Link Interface
11001000 00010111 00010000 00000000 through **11001000 00010111 00010111 11111111**	0
11001000 00010111 00011000 00000000 through **11001000 00010111 00011000 11111111**	1
11001000 00010111 00011001 00000000 through **11001000 00010111 00011111 11111111**	2
otherwise	3

Q: but what happens if ranges don't divide up so nicely?

Perputhja me e gjate e prefiksit

Perputhja me e gjate e prefiksit

Kur shikon per hyrjen ne tabelen e forwarding per nje adrese destinacioni te dhene, perdor prefiksin me te gjate te adreses qe perputhet me adresean e destinacionit

Destination Address Range	Link interface
11001000 00010111 00010*** *********	0
11001000 00010111 00011000 *********	1
11001000 00010111 00011*** *********	2
otherwise	3

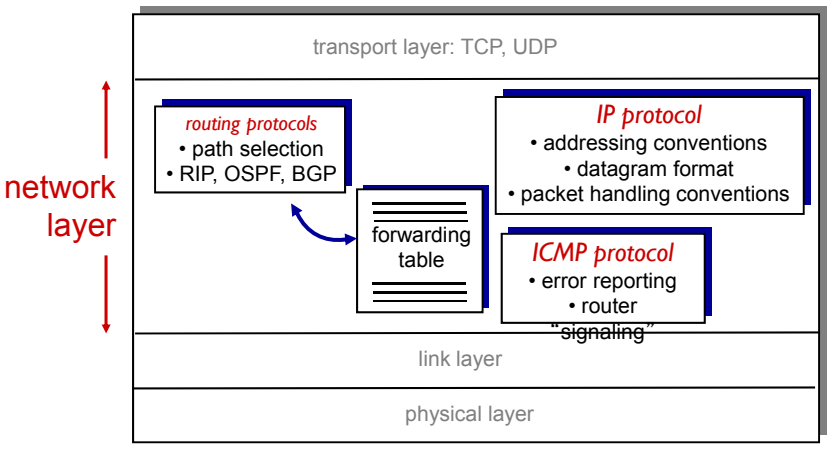
examples:

DA: 11001000 00010111 00010110 10100001 — which interface?

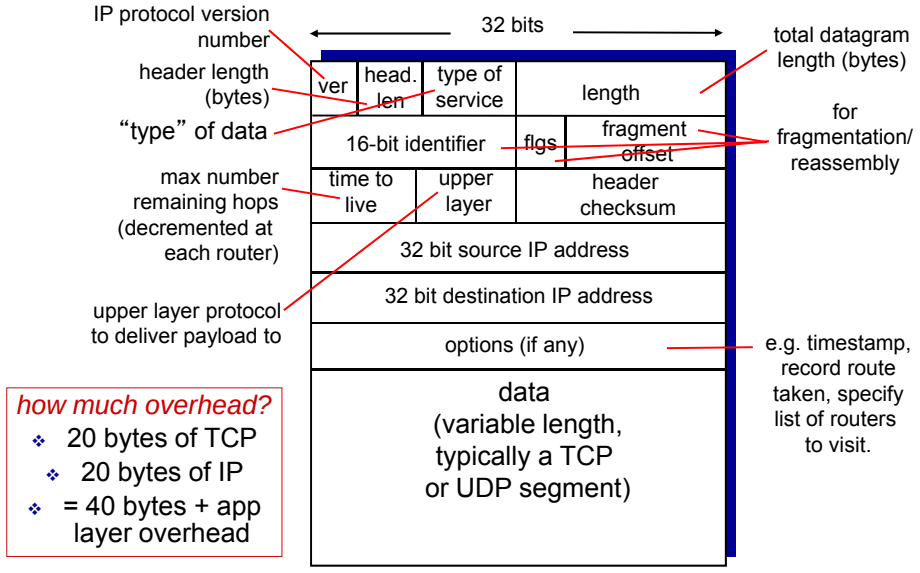
DA: 11001000 00010111 00011000 10101010 — which interface?

Shtresa e rrjetit te Internetit

Funksione te shtreses se rrjetit ne host, router:



IP datagram format

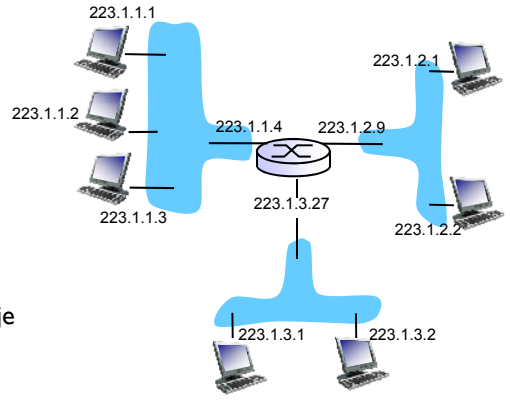


how much overhead?

- 20 bytes of TCP
- 20 bytes of IP
- = 40 bytes + app layer overhead

Hyrje ne adresimin IP

- *IP address:* 32-bit identifikues per host, nderfaqen e routerit
- *nderfaqe:* lidhje ndermjet host/router dhe linkut fizik
  - Routerat zakonisht kane shume nderfaqe
  - Hostet kane zakonisht nje apo dy nderfaqe (psh, wired Ethernet, wireless 802.11)
- *Adresat IP te asociuara me cdo nderfaqe*



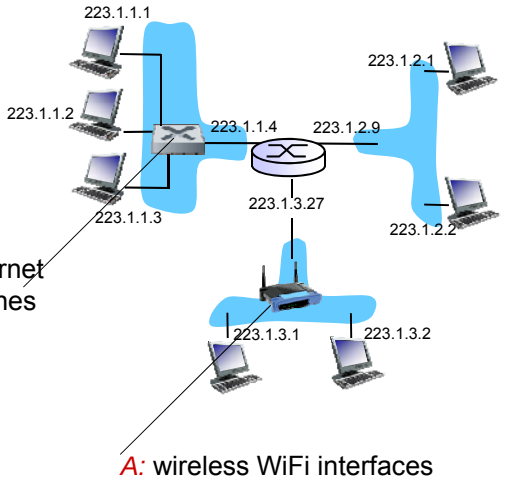
223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

IP addressing: introduction

Q: si jane lidhur nderfaqet?

A: chapter 5, 6.

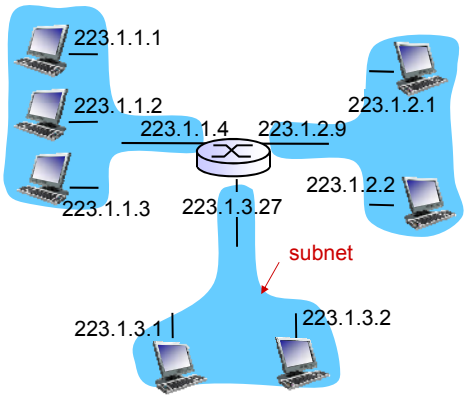


A: nderfaqer kabllore Ethernet lidhen me Ethernet switches

A: wireless WiFi interfaces connected by WiFi base station

Subnets

- IP address:
  - subnet part – bitet e pare
  - host part – bitet e fundit
- *Cfare eshte nje subnet ?*
  - Nderfaqe paisjesh me pjese subnet te njejte te adreses IP
  - Mund t elidhen fizikisht me njera tjetren pa nderhyrjen e routerave

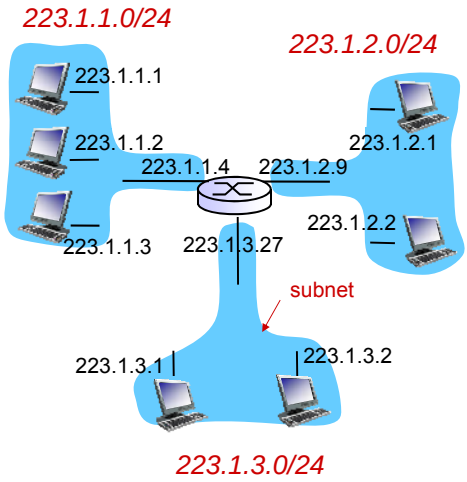


Rrjet qe perbehet nga 3 subnete

Subnets

recipe

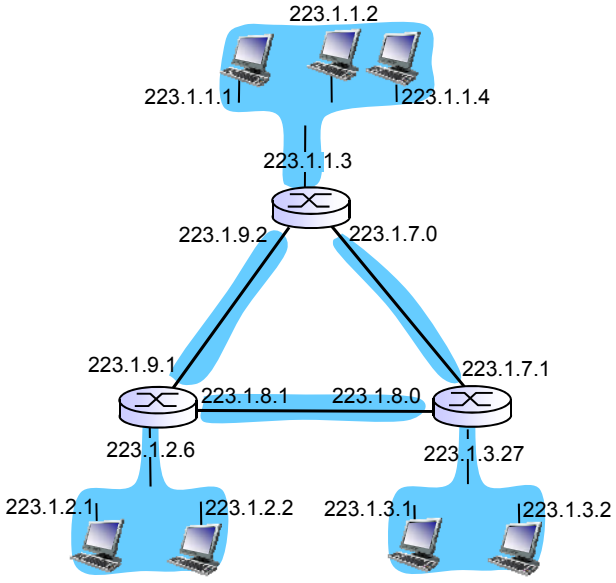
- Per te percaktuar subnetet, zgjidh cdo nderfaqe nga hosti apo routeri i saj, duke krijuar ishuj rrjetash te izoluara
- Cdo rrjet i izoluar quhet nje *subnet*



subnet mask: /24

Subnets

how many?



DHCP: Dynamic Host Configuration Protocol

Qellim: lejon hostin qe ne menyre dinamike marre IP address nga serveri I rrjetit kur i bashkohet rrjetit

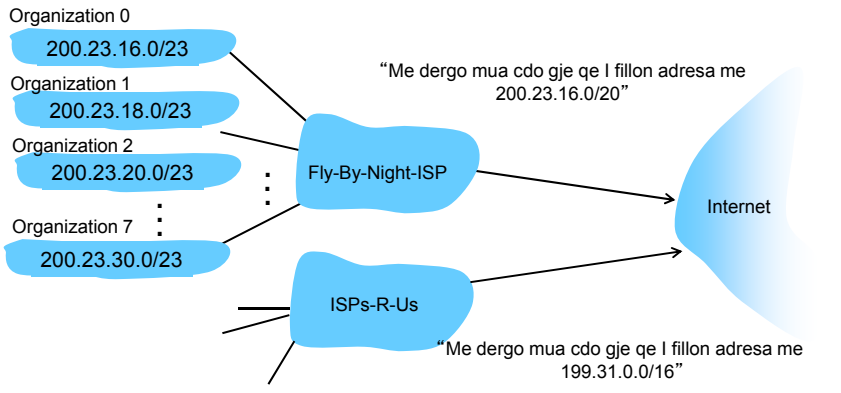
- Mund ta rinovoje mbajtjen e adreses ne perdorim
- Lejon ripordorimin e adresave (i mban adresat vetem kur jane te lidhur)
- Suporton perdoruesit mobile qe duan t'I bashkohen rrjetit

DHCP overview:

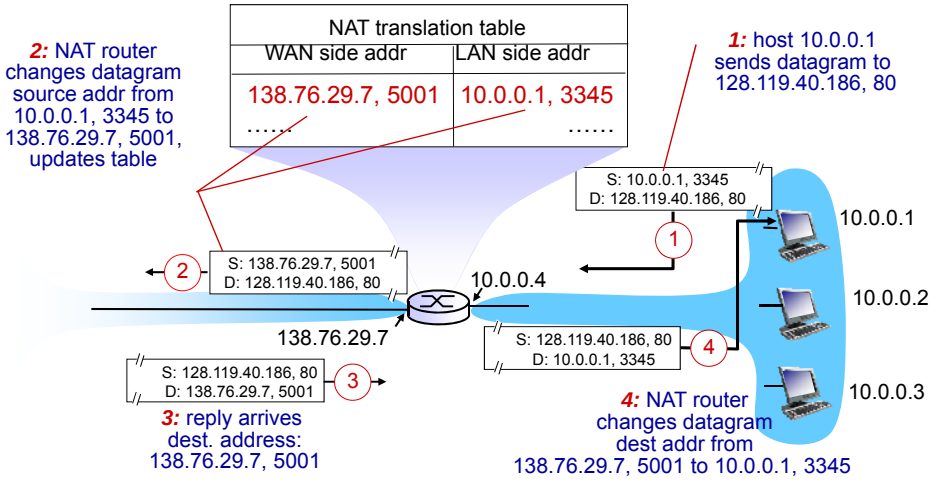
- host broadcasts "DHCP discover" msg [optional]
- DHCP server pergjigjet me "DHCP offer" msg [optional]
- host kerkon IP adres: "DHCP request" msg
- DHCP server dergon adresen: "DHCP ack" msg

Adresimi hierarkik: permbledhja e rrugeve

Adresimi hierarkik lejon reklamim eficient te informacionit te rrugeve:



NAT: network address translation



Dijsktra's Algorithm

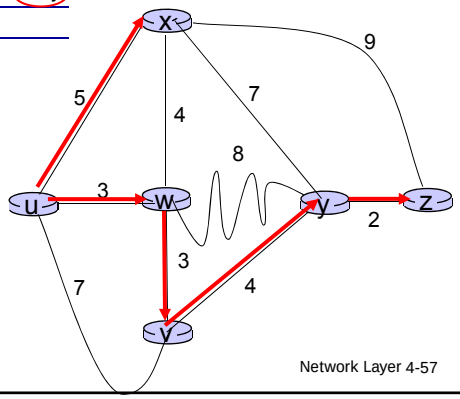
```
1  Initialization:
2    N' = {u}
3    for all nodes v
4      if v adjacent to u
5        then D(v) = c(u,v)
6      else D(v) = ∞
7
8  Loop
9    find w not in N' such that D(w) is a minimum
10   add w to N'
11   update D(v) for all v adjacent to w and not in N' :
12     D(v) = min( D(v), D(w) + c(w,v) )
13   /* new cost to v is either old cost to v or known
14    shortest path cost to w plus cost from w to v */
15 until all nodes in N'
```

Dijkstra's algorithm: example

Step	N'	D(v) p(v)	D(w) p(w)	D(x) p(x)	D(y) p(y)	D(z) p(z)
0	u	7,u	3,u	5,u	∞	∞
1	uw	6,w		5,u	11,w	∞
2	uwx	6,w			11,w	14,x
3	uwxv				10,v	14,x
4	uwxvy					12,y
5	uwxvyz					

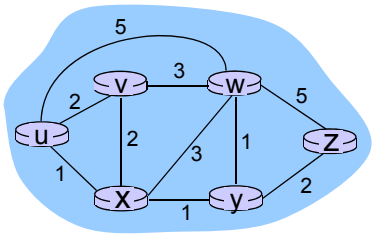
notes:

- construct shortest path tree by tracing predecessor nodes
- ties can exist (can be broken arbitrarily)



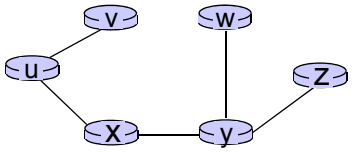
Dijkstra's algorithm: another example

Step	N'	D(v),p(v)	D(w),p(w)	D(x),p(x)	D(y),p(y)	D(z),p(z)
0	u	2,u	5,u	1,u	∞	∞
1	ux	2,u	4,x		2,x	∞
2	uxy	2,u	3,y			4,y
3	uxyv		3,y			4,y
4	uxyvw					4,y
5	uxyvwz					



Dijkstra's algorithm: example (2)

resulting shortest-path tree from u:



resulting forwarding table in u:

destination	link
v	(u,v)
x	(u,x)
y	(u,x)
w	(u,x)
z	(u,x)

Distance vector algorithm

Bellman-Ford equation (dynamic programming)

let

$d_x(y)$:= cost of least-cost path from x to y

then

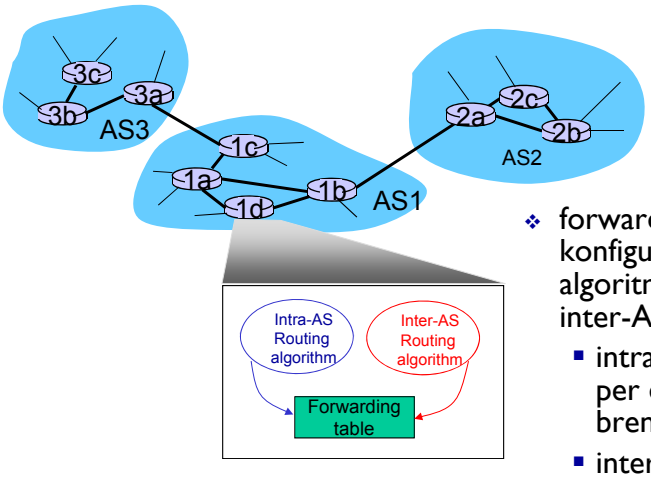
$$d_x(y) = \min_v \{c(x,v) + d_v(y)\}$$

$d_v(y)$: cost from neighbor v to destination y

$c(x,v)$: cost to neighbor v

$\min_v$: *min* taken over all neighbors v of x

Autonomous Systems (Ases) e nderlidhur



- forwarding table te konfiguruara nga te dy algoritmet intra- and inter-AS routing
  - intra-AS vendos hyrje per destinacione te brendeshme
  - inter-AS & intra-AS vendos hyrje per destinacione te jashteme

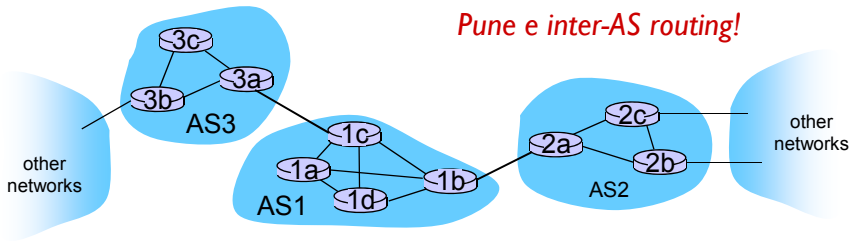
Inter-AS tasks

- Supozo routeri AS1 merr datagram te destinuar jashte AS1:
  - router duhet te dergoje paketen drejt gateway router, por te cili?

AS1 duhet:

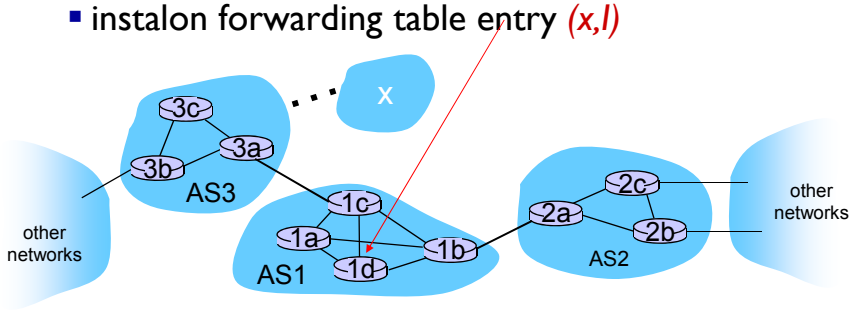
1. Mesoje cilet destinacione jane te arritshme nepermjet AS2, e cilet nepermjet AS3
2. Shperndaje kete informacion arritshmerie tek te gjithe routerat ne AS1

Pune e inter-AS routing!



Shembull: vendosja e forwarding table ne routerin 1d

- supozo AS1 meson (nepermjet inter-AS protocol) qe subnet *x* arrihet nepermjet AS3 (gateway 1c), por jo nepermjet AS2
  - inter-AS protocol shperndan info e arritshmerise tek te gjithe routerat e brendeshem
- router 1d percakton nga intra-AS routing info qe nderfaqia e tij *I* eshte ne rrugen me te lire tek 1c
  - instalon forwarding table entry *(x,I)*



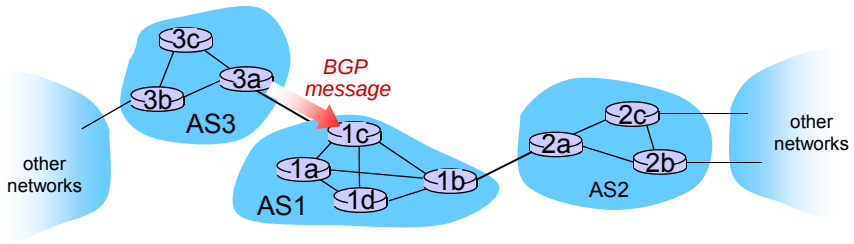
Internet inter-AS routing: BGP

- BGP (Border Gateway Protocol): *the* de facto inter-domain routing protocol
  - "ngjitesi qe mban Internetin bashke"
- BGP i jep cdo AS nje menyre per:
  - eBGP: perftoje informacionin e arrtshmerise se subneteve nga Ass fqinje.
  - iBGP: perhap informacionin e arrtshmerise tek te gjithe ruterat brenda AS.
  - Percakton rruget e "mira" tek rrjetat e tjera bazuar tek informacioni I arrtshmerise dhe and rregullat.
- Lejon subnet te reklamoje eksistencen e vet tek Interneti: *"Jam ketu"*

BGP basics

- BGP session: dy routera BGP ("peers") shkembejne BGP messages:
  - Duke reklamuar *paths (rruge)* tek prefikset e rrjetave te ndryshme destinacion ("path vector" protocol)

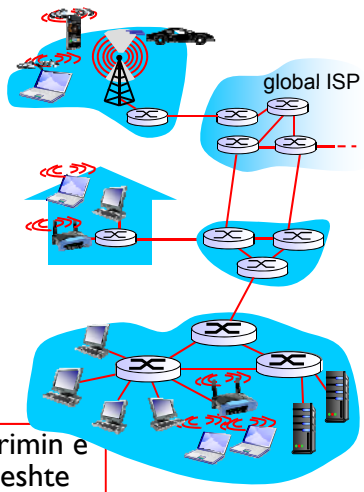
- kur AS3 reklamon nje prefiks tek AS1:
  - AS3 *premton* qe do te drejtoje datagramet drejt atij prefiksi
  - AS3 mund te permbledhe prefixet ne reklamimet e veta



Shtresa e Linkut: hyrje

terminology:

- Hoste dhe routera: nyje
- Kanale komunikimi qe lidhin nyje fqinje gjate rrugeve te komunikimit: links
  - Links te kablluar
  - wireless links
  - LANs
- layer-2 packet: frame, mbeshtjell datagram



data-link layer ka pergjegjesi per transferimin e datagram nga nje nyje tek nje nyje qe eshte fizikisht fqinje ne nje link

Link layer: context

- datagram te transferuara nga protokolle te ndryshem ne linke te ndryshem:
  - psh, Ethernet ne linkun e pare, frame relay ne linket e ndermjetem, 802.11 linkun e fundit
- Cdo protokoll linkusiguron sherbime te ndryshme
  - psh, mundet ose jo te siguroje transmerim te besueshem mbi link

Link layer - sherbime

- *framing, link access:*
  - Mbeshtjell datagram ne frame, shton header, trailer
  - channel access nqs eshte mjedis i perbashket
  - "MAC" addresses perdoren ne headerat e frame per te identifikuar burimin, dest
    - Te ndryshem nga IP address!
- *Transmetim i besueshem ndermjet nyjeve fqinje*
  - Kete e kemi diskutuar tek shtresa e transmetimit

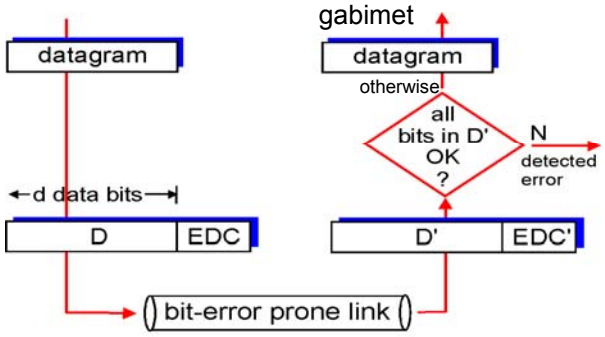
Link layer services (more)

- *flow control:*
  - Nyja me e ngadalte percakton ritmin e rrjedhes
- *error detection:*
  - Gabimet e shkaktuara nga signal attenuation, zhurma.
  - Marresi detekton pranine e gabimeve:
    - I sinjalizon derguesit per ritransmetim apo framet e humbur
- *error correction:*
  - Marresi identifikon dhe rregullon bit error(s) pa bere ritransmetim
- *half-duplex and full-duplex*
  - me half duplex, nyjet ne fund te linkut mund te transmetojne, por jo ne te njejten kohe

Error detection

EDC= Error Detection and Correction bits (redundancy)
D = Data protected by error checking, may include header fields

• Error detection jo 100% I besueshem!
• protocollit mund t'i shpetojne disa gabime, por rradhe
• sa me e madhe fusha EDC aq me mire detektohen dhe korrigjohen gabimet



Multiple access links, protocols

Dy tipe "links":

- point-to-point
  - PPP for dial-up access
  - point-to-point link ndermjet Ethernet switch, host
- *broadcast (shared wire or medium)*
  - Ethernet tip i vjeter
  - upstream HFC
  - 802.11 wireless LAN

shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 WiFi)

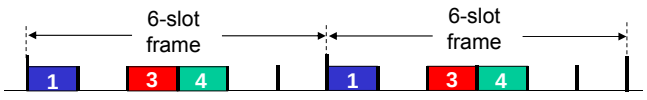
shared RF (satellite)

humans at a cocktail party (shared air, acoustical)

Protokolle te ndarjes se kanaleve: TDMA

TDMA: time division multiple access

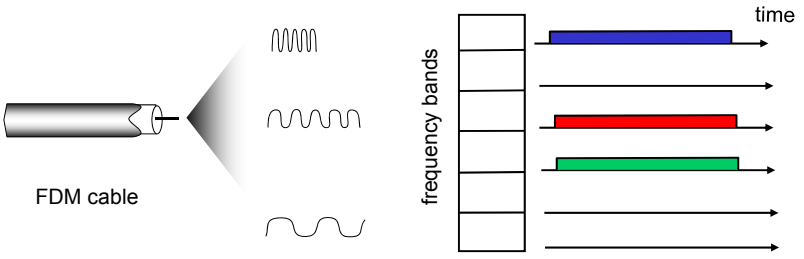
- Kapja e kanalit "me rradhe"
- Cdo stacion merr intervale fikse kohe (length = pkt trans time) ne cdo rradhe
- Intervalet e paperdorur shkojne bosh
- shembull: 6-station LAN, 1,3,4 kane pkt, intervalet 2,5,6 bosh



Channel partitioning MAC protocols: FDMA

FDMA: frequency division multiple access

- Spektri i kanalit ndahet ne zona frekuencash
- Cdo stacioni i jepet nje zone frekencash
- Kur nuk ka transmetim banda e frekencave eshte bosh
- example: 6-station LAN, 1,3,4 have pkt, frequency bands 2,5,6 idle

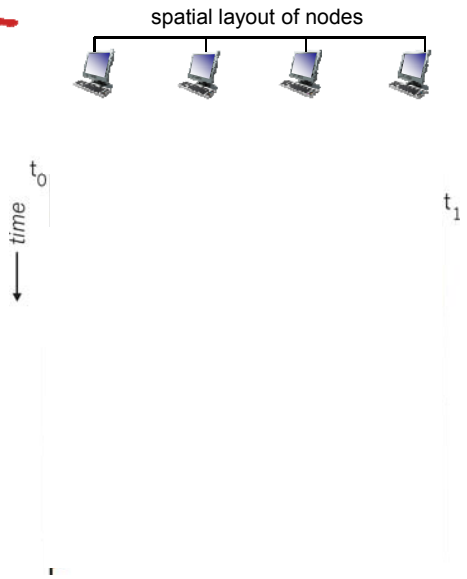


Random access protocols

- Kur nyja ka pakete per te derguar
  - Transmeton me te gjithe shpejtesine e transmetimit te kanalit R.
  - Pa koordinim paraprak midis nyjeve
- Dy ose me shume nyje transmetimi ➜ "collision (perplasje)",
- random access MAC protocol percakton:
  - Si te detektohen collisions
  - Si te kalohetcollisions (e.g., duke vonuar ritransmetimet)
- Shembuj te random access MAC protocols:
  - slotted ALOHA
  - ALOHA
  - CSMA, CSMA/CD, CSMA/CA

CSMA collisions

- collisions *mund te ndodhin*: vonesa e perhapjes ben qe dy nyje te mos mund te degjojne transmetimet e anasjellta
- collision: e gjithe paketa e shkuar dem
  - distanca & vonesa e perhapjes luajne rol ne percaktimin e probabilitetit te collision

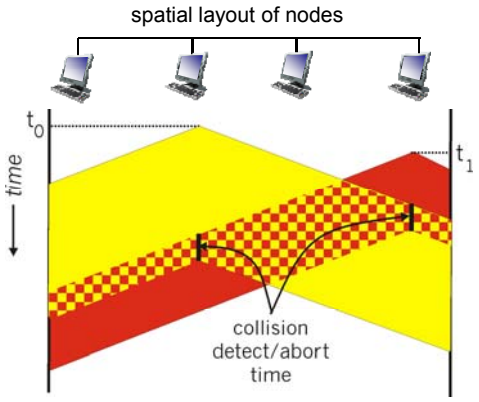


CSMA/CD (detektim i collision)

CSMA/CD: ndjen carrier (sinjalin), vonohet transmetimi si ne CSMA
- collisions *detektohen* ne kohe te shkurter
- Transmetimet qe po perplasen ndalohen, qe t ezvogelohet humbja e kanalit

- collision detection:
  - I lehte ne LANs kablore: mat nivelin e sinjalit, krahason sinjalet e tranmetuara e te marre
  - I veshtire ne wireless LANs: sinjali I marre eshte shume me I vogel se sa ai i transmetimit local
  -

CSMA/CD (collision detection)



Ethernet CSMA/CD algorithm

1. NIC merr datagram shtresa e rrjetit, krijon frame
2. Nqs NIC e ndjen kanaln e lire, fillon transmetimin e frame. Nqs NIC kanalin e zene, pret sa kanali te behet i lire, pastaj transmeton.
3. Nqs NIC transmeton te gjithe frame pa detektuar nje tjeter transmetim, NIC e ka mbaruar punen me kete frame !
4. Nqs NIC detekton nje transmetim tjeter gjate transmetimit, ndalon dhe dergon sinjalin jam
5. Mbas ndalimit, NIC fillon *binary (exponential) backoff:*
   - Zgjedh ne menyr te rastin kohen per te ritransmetuar

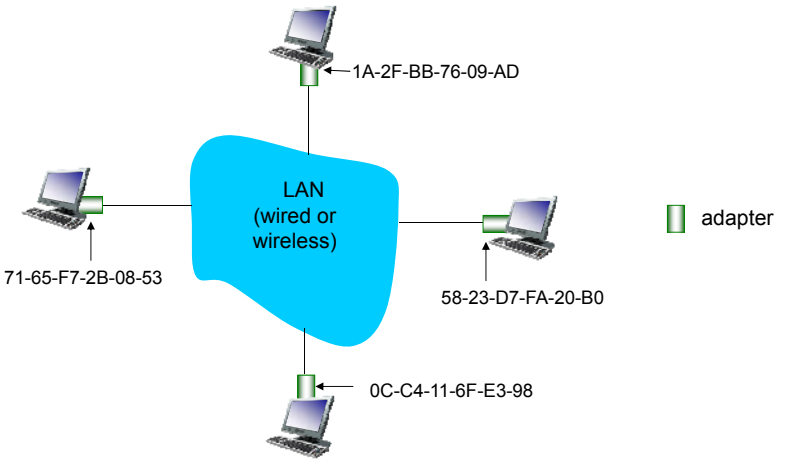
MAC addresses and ARP

- 32-bit IP address:
  - *network-layer* address for interface
  - used for layer 3 (network layer) forwarding
- MAC (or LAN or physical or Ethernet) address:
  - funksion: *perdoret 'lokalisht" per te cuar frame nga nje nderfaqe tek nje tjeter nderfaqe te lidhura fizikisht (i njejti rrjet, ne kuptimin e IP)*
  - 48 bit MAC address (for most LANs) te djegur ne NIC ROM, nganjehere ne software te ndryshueshme
  - e.g.: 1A-2F-BB-76-09-AD

hexadecimal (base 16) notation
(each "number" represents 4 bits)

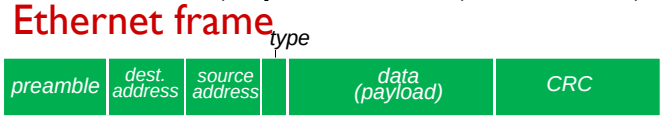
LAN addresses and ARP

Cdo adapter ne LAN ka nje adrese unike ne *LAN*



Ethernet frame structure

Adapteri dergues mbeshtjell IP datagram (ose pakete te ndonje protokolli tjeter te rrjetit) ne Ethernet frame



preamble:

- 7 bytes me pattern 10101010 ndjekur nga 10101011
- per te sinkonizuar

Ethernet frame structure (more)

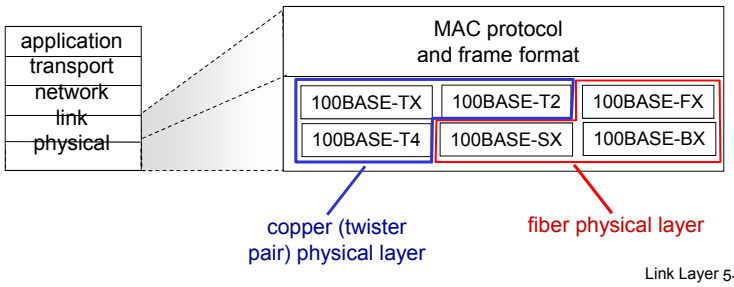
- *addresses:* 6 byte burimi, destinacioni MAC addresses
  - Nqs adapteri merr frame me adrese destinite te tij, ose me broadcast address (e.g. ARP packet), i kalon te dhenat e frame tek protokolli I shtreses se rrejtit
  - perndryshe, adapteri nuk merret me frame
- *type:* tregon tipin e protokollit me lart (mostly IP but others possible, e.g., Novell IPX, AppleTalk)
- *CRC:* cyclic redundancy check ne marres
  - error detektohet: frame hidhet

Ethernet: unreliable (pa besueshmeri), connectionless (pa lidhje)

- *connectionless:* nuk ka pershendetje ndermjet derguesit dhe marresit
- *unreliable:* NIC i marresit nuk dergon acks ose nacks tek NIC i derguesit
  - Nqs ka probleme merren protokollet e ma larte
- Ethernet's MAC protocol: unslotted *CSMA/CD wth binary backoff*

802.3 Ethernet standards: link & physical layers

- *shume* standarte te ndryshem Ethernet
  - Te njejtinMAC protocol dhe format frame
  - Shpejtesi te ndryshme: 2 Mbps, 10 Mbps, 100 Mbps, 1Gbps, 10G bps
  - Shtrese fizike te ndryshme: fiber, cable

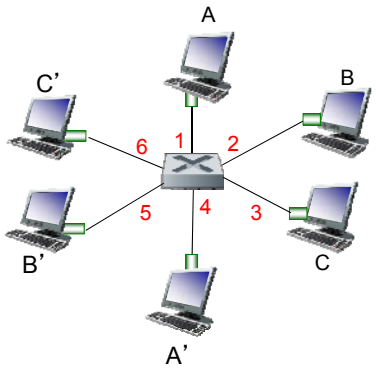


Ethernet switch

- Paisje e link-layer: ka rol aktiv
  - Ruan, forward Ethernet frames
  - Analizom adresen MAC ne framen ardhese, ne menyre selective dergon frame tek nje apo me shume linke dales kur frame duhet te dergohet ne nje segment, perdor CSMA/CD per te akses segmentin
- *transparent*
  - hosts nuk e dine pranine e switcheve
- *plug-and-play, self-learning*
  - Switchet nuk ka nevoje te configurohen

Switch: shume transmetime te njekohshem

- Hostet kane lidhje direkte, te dedikuara tek switch
- switchet buffer (ruajne) packets
- Ethernet protocol I perdorur ne cdo link hyres, per pa collisions; full duplex
  - Cdo link eshte collision domain me vehte
- *switching:* A-to-A' and B-to-B' mund t etransmetojne njekohesisht pa humbje



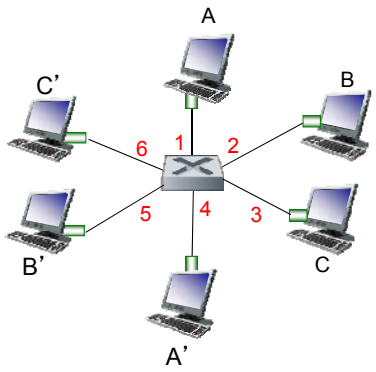
switch with six interfaces (1,2,3,4,5,6)

Switch forwarding table

Q: si e di switchi qe A' arrihet nepermjet nderfaqes 4, B' arrihet nepermjet nderfaqen 5?

- A: cdo switch ka nje switch table, ku cdo hyrje:
  - (MAC address e hostit, nderfaqeja per te arritur hostin, time stamp)
  - Ngjan si nje tabele routing

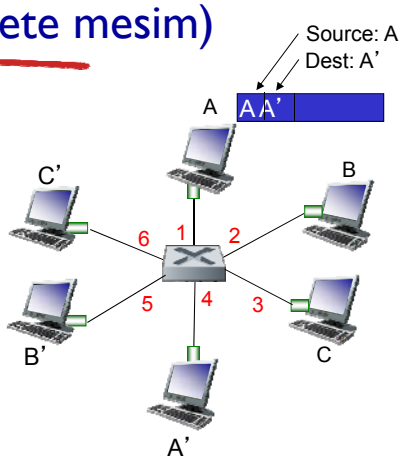
Q: si krojohen e mbahenhyrjet ne switch table?



switch with six interfaces (1,2,3,4,5,6)

Switch: self-learning (vete mesim)

- Switchi *meson* cilet hoste mund te arrihen nepermjet ciles nderfaqe
  - Kur merr nje frame, switchi "meson" vendosjen e derguesit: segmentin hyres LAN
  - Shenon ciftin dergues/vendosje ne switch table



MAC addr	interface	TTL
A	*1*	*60*

Switch table (initially empty)

Switch: frame filtering/forwarding

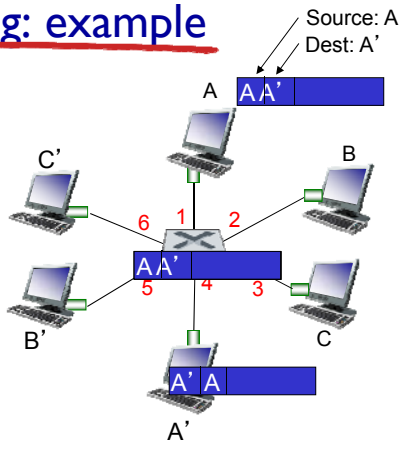
Kur nje frame merret ne switch:

1. Shenon linkun hyres, MAC address te hostit dergues
2. indekson switch table duke perdorur MAC destination address
3. if entry gjendet per destinacionin
   then {
   if destinacioni ne segmentin nga i cili erdhi frame
   then hedh frame
   else dergon frame ne nderfaqen e treguar nga entry
   }
   else flood /* forward on all interfaces except arriving interface */

Self-learning, forwarding: example

- frame destinacon, A', vendodhja e panjohur: *flood*
  - Vendodhja e A e njohur:

ne menyr selektive dergo ne nje link te vetem



MAC addr	interface	TTL
A	*1*	*60*
A'	*4*	*60*

switch table (initially empty)