

# CS 655 Computer Networks

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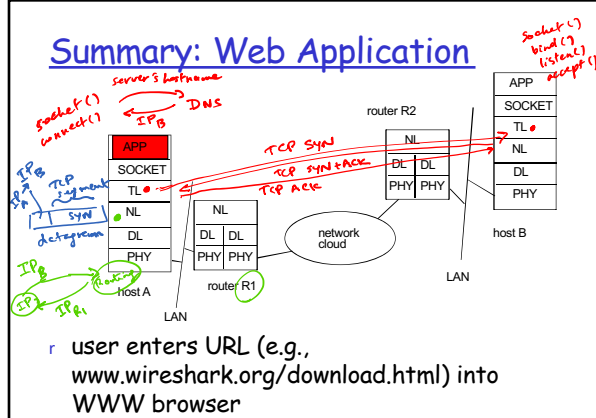
## Putting it Together & Closing Remarks



Closing Remarks 1

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## Summary: Web Application

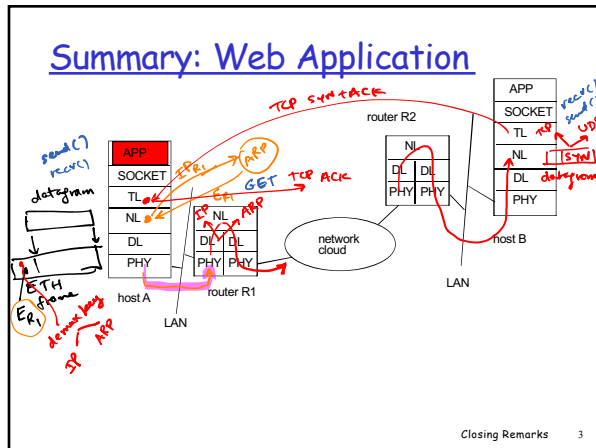


user enters URL (e.g.,  
[www.wireshark.org/download.html](http://www.wireshark.org/download.html)) into  
WWW browser

Closing Remarks 2

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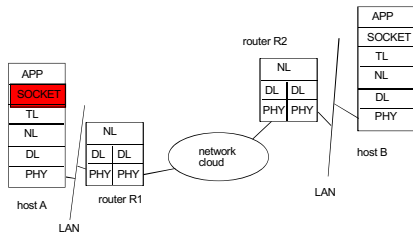
## Summary: Web Application



Closing Remarks 3

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## API



- browser (client) determines host name, uses DNS to get server's IP address, `gethostbyname()`
- client creates stream socket, `socket()`
- client calls `connect()`, server port 80

Closing Remarks 4

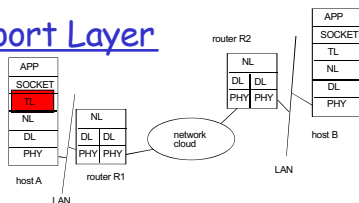
4

A DNS packet walks into a liquor store - where do I find beer "ABC"? Clerk: aisle 4, top row on the right.  
@fsmontenegro

Closing Remarks 5

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## Transport Layer

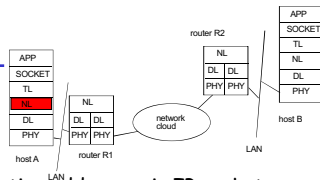


- `connect()` call causes TCP connection establishment
- choose initial sequence number
- generate SYN segment, server IP address, port 80
- TCP forms segment, computes checksum
- TCP calls IP, passing SYN segment and IP address information

Closing Remarks 6

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## Network Layer



- r adds IP source, destination addresses in IP packet
- r IP forwarding consults routing table
  - m routing table gives IP address of, and local interface to get to next router (i.e., on its LAN), R, on route to destination
- r runs ARP to get 802.3 physical address corresponding to R's IP address
- r ARP will generate Ethernet broadcast frame on LAN, requesting R to reply with its physical address
- r R replies with physical address

Closing Remarks 7

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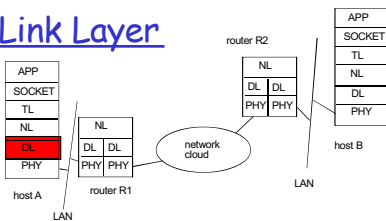
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## Data Link Layer



- r TCP SYN segment (inside IP packet), as payload in Ethernet frame sent onto LAN using Ethernet protocol
- r transparent bridge may be involved (not shown)

Closing Remarks 8

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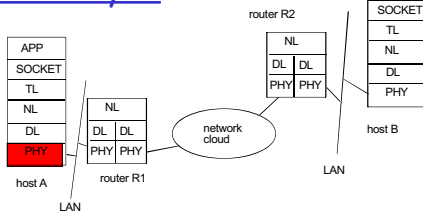
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## Physical Layer



- r Ethernet frame transmitted at 100Mbps

Closing Remarks 9

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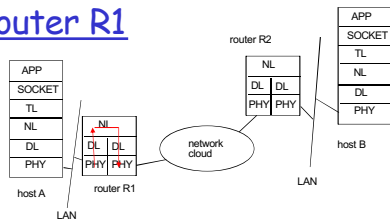
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## At Router R1



- r physical layer receives Ethernet frame bits, passes up
- r data link layer recognizes frame, computes OK checksum, removes IP packet, passes up
- r network layer consults routing table
  - m passes IP packet down to data link layer

Closing Remarks 10

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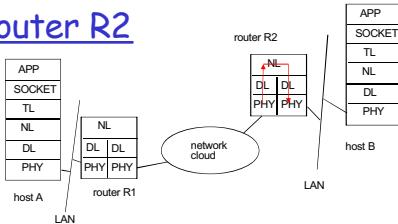
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## At Router R2



- r frame arrives, passed up to network layer
- r network layer determines outgoing interface to get to host B
- r Ethernet frame sent (R2 knew/learned B's physical address)

Closing Remarks 11

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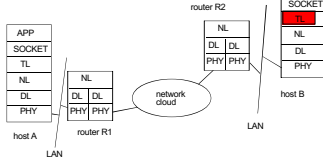
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## At Host B



- r Ethernet frame arrives, checksum OK, pass up to IP
- r IP layer extracts TCP segment, demultiplexes up to TCP (note: not UDP message)
- r TCP sees SYN segment
  - m server must have previously opened socket and made accept(), else SYN dropped
  - m TCP determines flow control window, chooses initial sequence no
  - m sends SYN+ACK back

Closing Remarks 12

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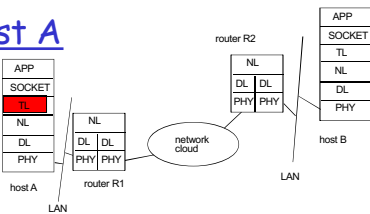
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## At Host A



- r SYN+ACK eventually received
- r send transport-level ACK to B
- r move to established state
- r return from connect() system call

Closing Remarks 13

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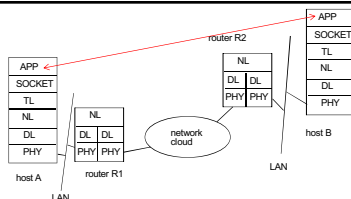
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## Finally!



- r Host A can now request .html file, write()
- r Host B reads request, read()
- r Host B sends requested file, write()
- r Host A reads requested file, read()
- r Data is transferred using TCP
  - m Error, flow and congestion control
  - m R1, R2 and A,B (network layer and below) act exactly the same with data as with SYN/ACK segments

Closing Remarks 14

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A TCP packet walks in to a bar and says "I want a beer", barman says "you want a beer?" and TCP packet says "yes, a beer" @stevie chambers

Closing Remarks 15

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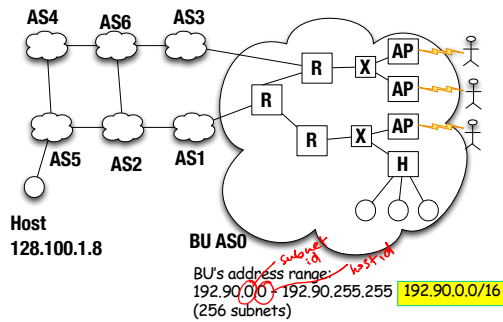
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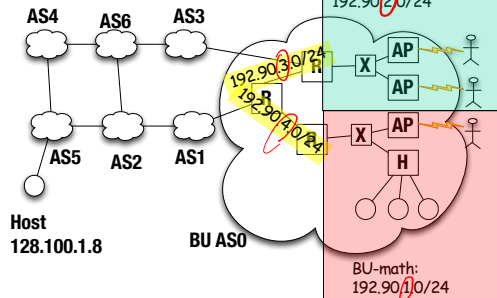
## Summary: Addressing & Routing



Closing Remarks 16

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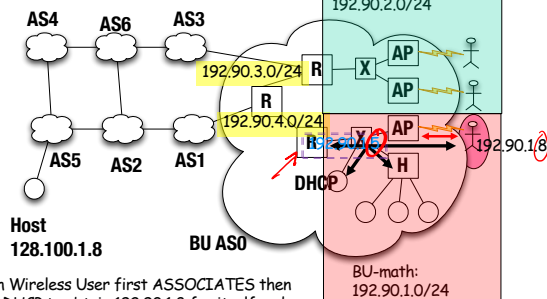
## Subnet Addressing



Closing Remarks 17

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## Dynamic Host Config



Math Wireless User first ASSOCIATES then runs DHCP to obtain 192.90.1.8 for itself and learns of 192.90.1.5 (gateway router)

Closing Remarks 18

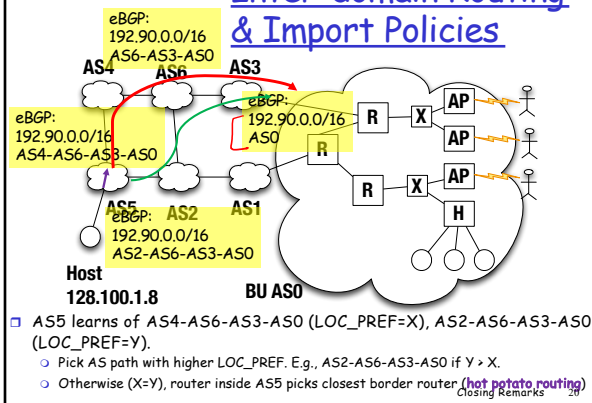
18

A DHCP packet walks into a bar  
and asks for a beer. Bartender  
says, "here, but I'll need that  
back in an hour!"  
@brandoncarroll

Closing Remarks 19

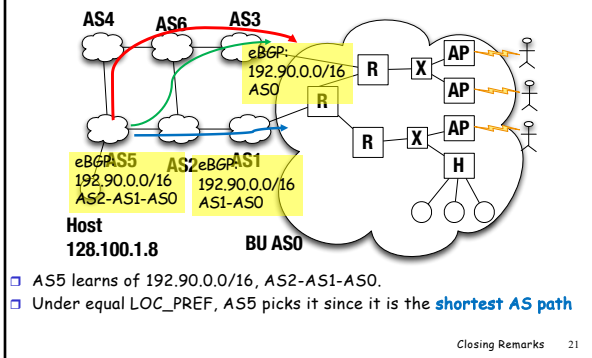
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## Inter-domain Routing & Import Policies



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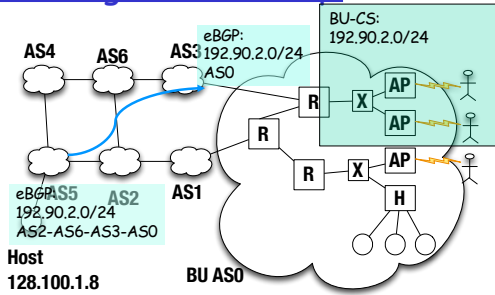
## AS Path Selection



Closing Remarks 21

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## IP Routing Table Lookup



- AS5 learns of 192.90.2.0/24, AS2-AS6-AS3-AS0.
- AS5 uses this path to route to BU-CS (**longest prefix matching**)

Closing Remarks 22

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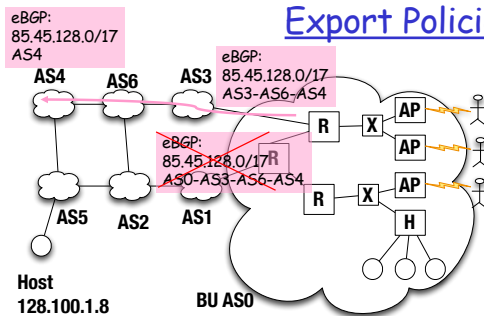
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## Export Policies



- AS0 does NOT advertise 85.45.128.0/17 to AS1 since BU is a **multi-homed stub** AS and not a "transit" AS. This is set by BU's "export policies"

Closing Remarks 23

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An IPv6 packet walks into a bar. Nobody talks to him.  
@fsmontenegro

Closing Remarks 24

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### So what's more / next?

- Further study: multimedia, mobility, high-speed, traffic engineering, virtual networks, ... (CS 556)
- Security (CS 558, CS 511 & 512, ...)
  - CS 511 & 512 teaches formal methods to verify protocol correctness
- Data center networks (CS 528, ...)
- Application management (CS 451/651, ...)
- Internet of Things (CS 552, CS 654, ...)
- 
- Certification programs!
  - Network Programmability (e.g. Cisco), Network Virtualization (e.g. VMware), Risk & Information Systems Control, Cloud Networking (e.g. Amazon), Wireless Networking, Storage Networking, ...

Closing Remarks 25

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