Case Study: SIIT Internetworking

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ICT, SIIT

An Internetworking Example

SIIT Bangkadi

Source Host

Router

Switch

**Thammasat Rangsit**

ISP

NECTEC (NSTDA)

Wireless Router

Destination Host
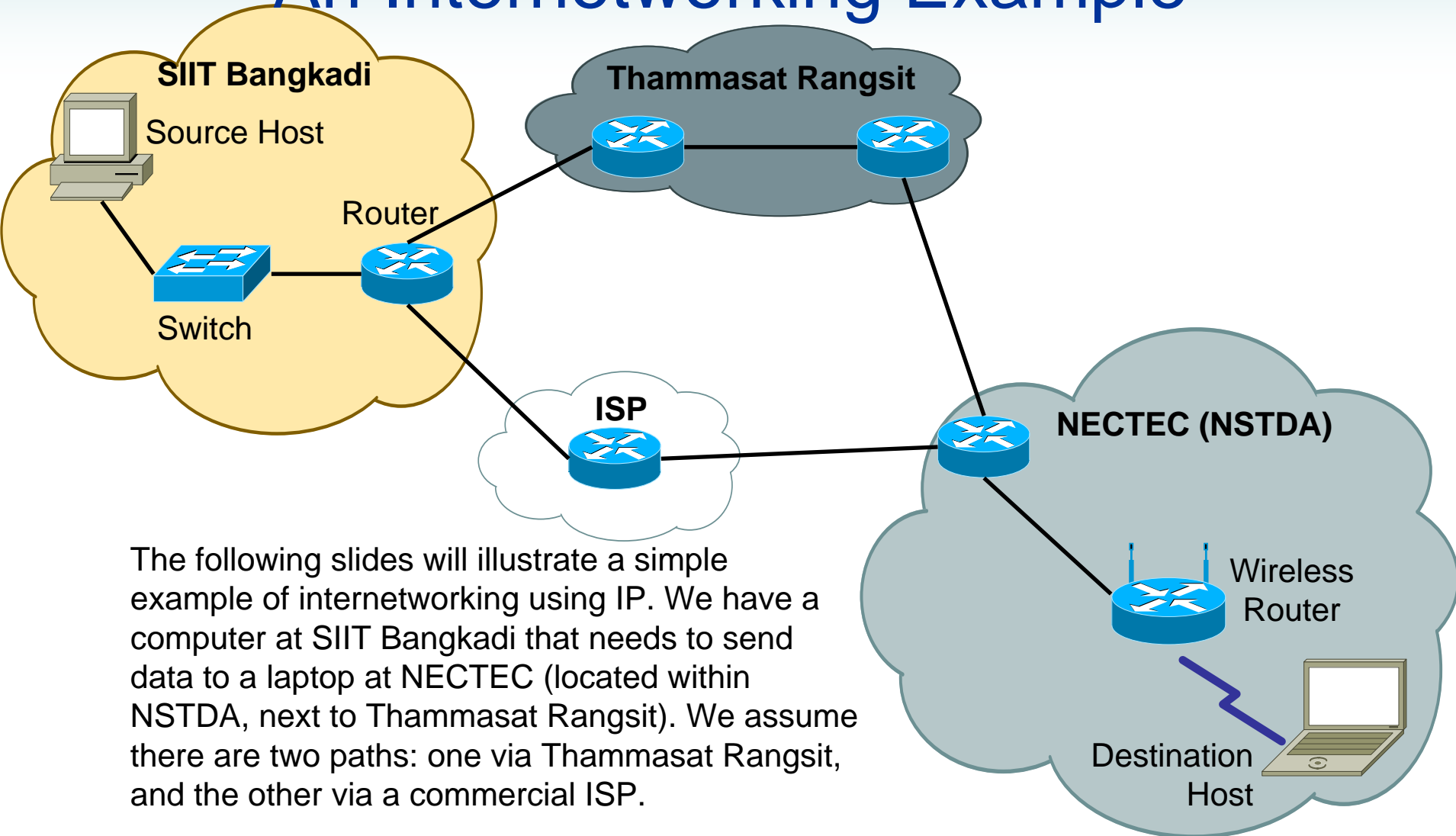
The following slides will illustrate a simple example of internetworking using IP. We have a computer at SIIT Bangkadi that needs to send data to a laptop at NECTEC (located within NSTDA, next to Thammasat Rangsit). We assume there are two paths: one via Thammasat Rangsit, and the other via a commercial ISP.
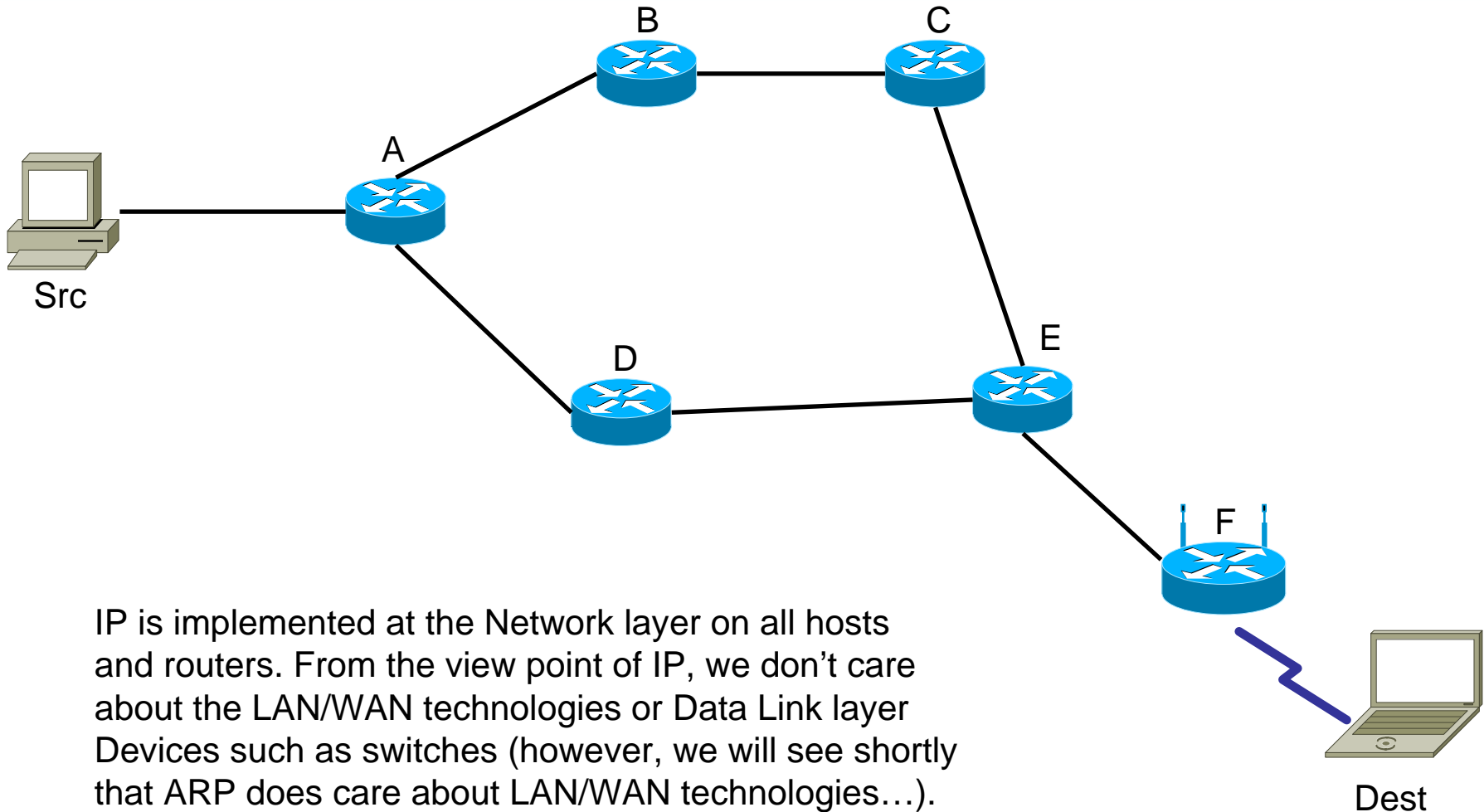
LAN/WAN Technologies
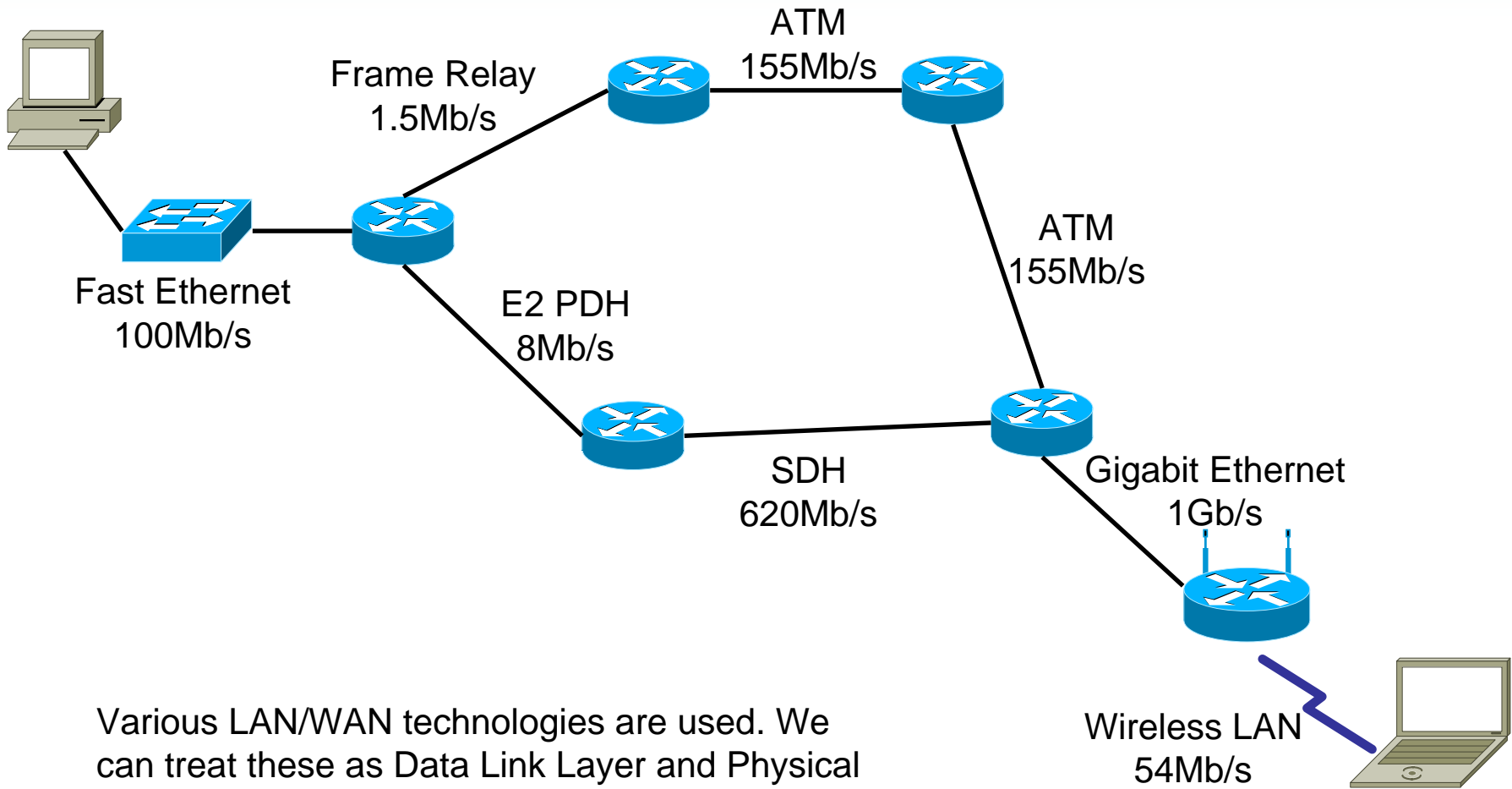
Various LAN/WAN technologies are used. We can treat these as Data Link Layer and Physical Layer technologies.
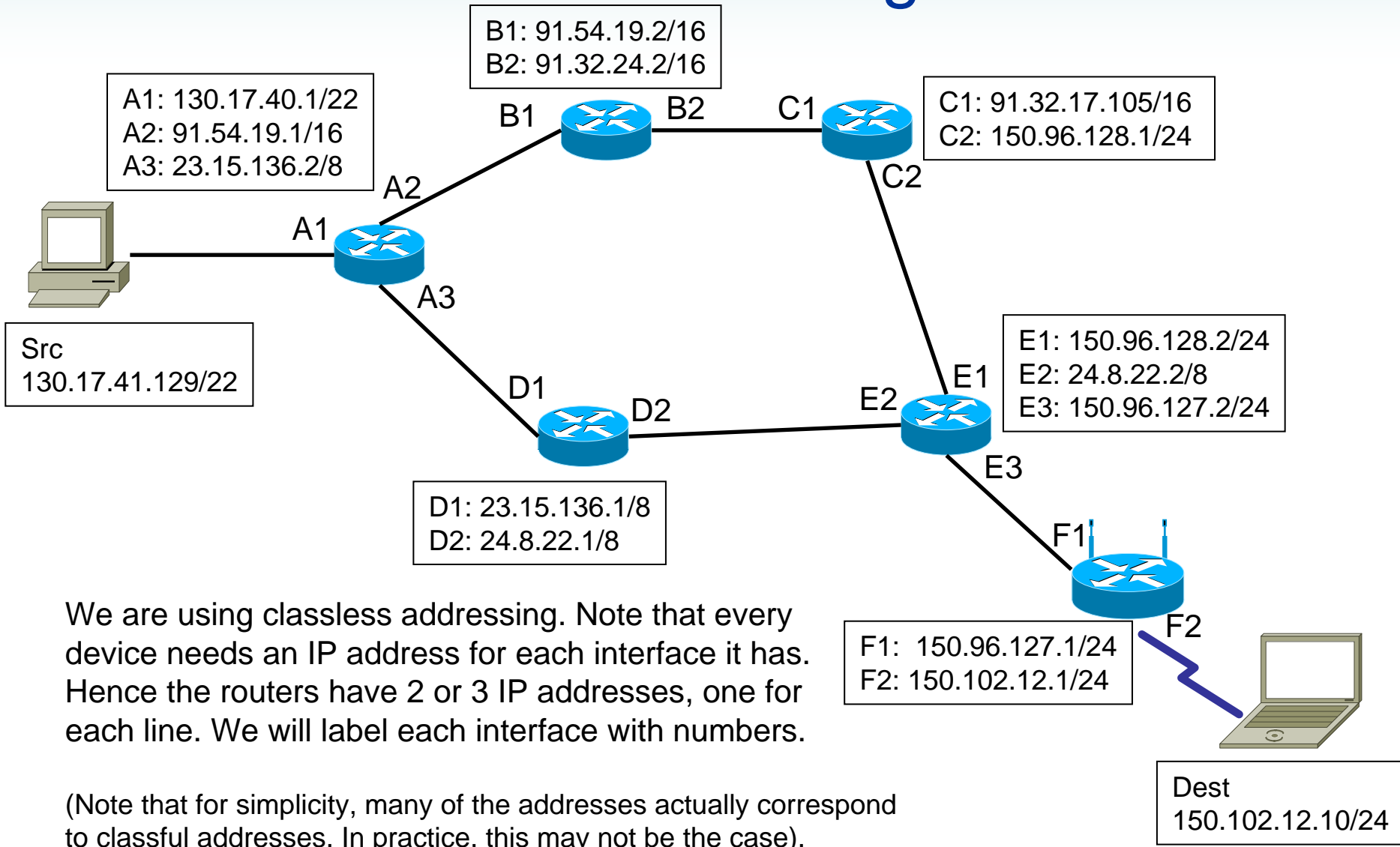
Internetworking with IP

IP is implemented at the Network layer on all hosts and routers. From the view point of IP, we don't care about the LAN/WAN technologies or Data Link layer Devices such as switches (however, we will see shortly that ARP does care about LAN/WAN technologies…).
A, B, C, D, E, F = routers

IP Addressing

B1: 91.54.19.2/16
B2: 91.32.24.2/16

A1: 130.17.40.1/22
A2: 91.54.19.1/16
A3: 23.15.136.2/8

C1: 91.32.17.105/16
C2: 150.96.128.1/24

B1   B2   C1

A2

A1

A3

Src
130.17.41.129/22

E1: 150.96.128.2/24
E2: 24.8.22.2/8
E3: 150.96.127.2/24

E1

D1   D2   E2

E3

D1: 23.15.136.1/8
D2: 24.8.22.1/8

F1

F2

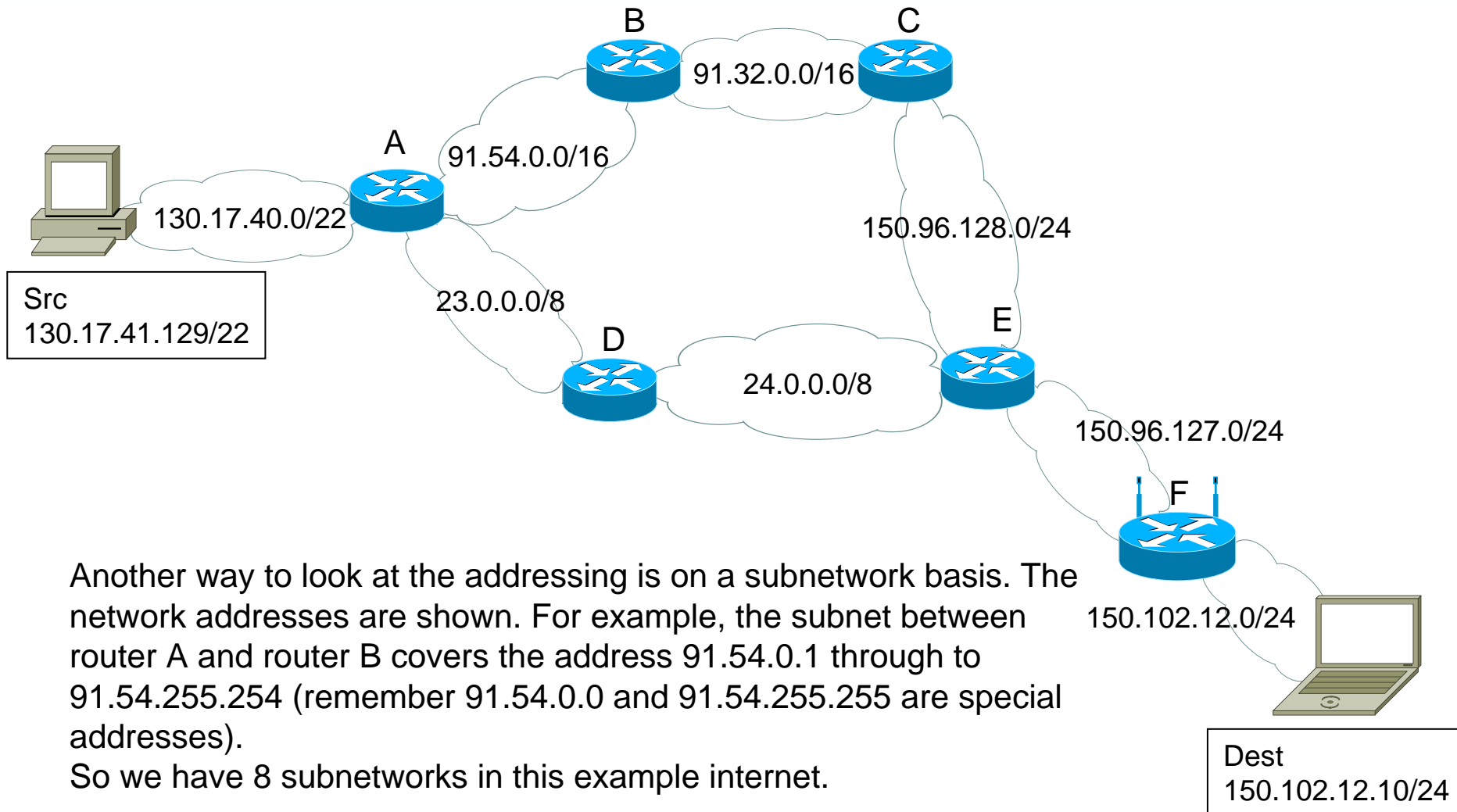We are using classless addressing. Note that every
device needs an IP address for each interface it has.
Hence the routers have 2 or 3 IP addresses, one for
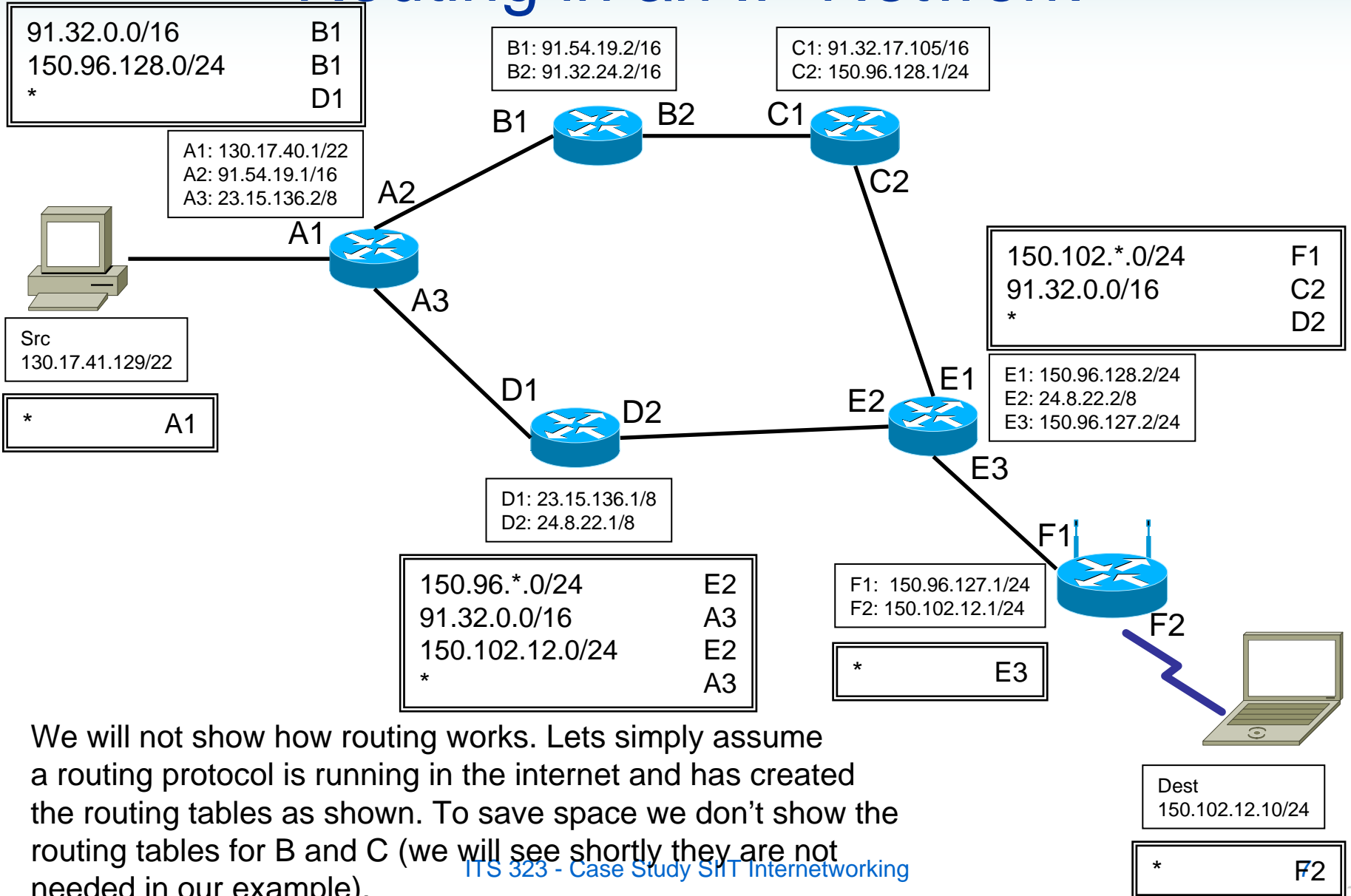each line. We will label each interface with numbers.

F1: 150.96.127.1/24
F2: 150.102.12.1/24

(Note that for simplicity, many of the addresses actually correspond
to classful addresses. In practice, this may not be the case).

Dest
150.102.12.10/24

Another View of the Network

B

C

91.32.0.0/16

A

91.54.0.0/16

130.17.40.0/22

150.96.128.0/24

Src
130.17.41.129/22

23.0.0.0/8

E

D

24.0.0.0/8

150.96.127.0/24

F

Another way to look at the addressing is on a subnetwork basis. The network addresses are shown. For example, the subnet between router A and router B covers the address 91.54.0.1 through to 91.54.255.254 (remember 91.54.0.0 and 91.54.255.255 are special addresses).
So we have 8 subnetworks in this example internet.

150.102.12.0/24

Dest
150.102.12.10/24

Routing in an IP Network

91.32.0.0/16	B1
150.96.128.0/24	B1
*	D1

B1: 91.54.19.2/16
B2: 91.32.24.2/16

C1: 91.32.17.105/16
C2: 150.96.128.1/24

A1: 130.17.40.1/22
A2: 91.54.19.1/16
A3: 23.15.136.2/8

B1   B2   C1

A2

C2

A1

150.102.*.0/24	F1
91.32.0.0/16	C2
*	D2

Src
130.17.41.129/22

A3

*	A1

D1
D2

E2

E1

E1: 150.96.128.2/24
E2: 24.8.22.2/8
E3: 150.96.127.2/24

E3

D1: 23.15.136.1/8
D2: 24.8.22.1/8

F1

150.96.*.0/24	E2
91.32.0.0/16	A3
150.102.12.0/24	E2
*	A3

F1: 150.96.127.1/24
F2: 150.102.12.1/24

F2

*	E3

We will not show how routing works. Lets simply assume
a routing protocol is running in the internet and has created
the routing tables as shown. To save space we don't show the
routing tables for B and C (we will see shortly they are not
needed in our example).

Dest
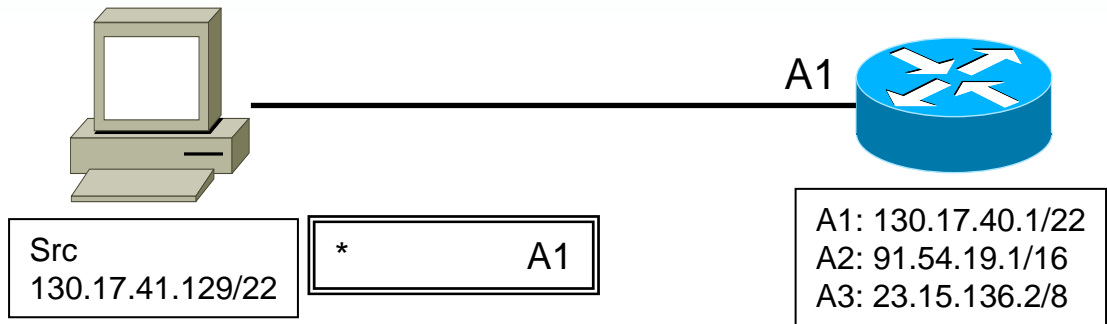150.102.12.10/24

*	F2

Routing in an IP Network

- How to read the routing tables?
  - When a node receives a datagram it looks at the destination IP address and performs these checks (in order):
    1. Is the datagram destined to this host?
       - Yes: send the datagram to the Transport layer
       - No: continue
    2. Is the datagram destined to a host on a network I am directly connected to?
       - Yes: send to that host using the LAN technology (e.g. Ethernet)
       - No: continue
    3. Look at the routing table, line by line (starting from the top, going down in order):
       - Does the destination address match the network address on the left of the table?
         » Yes: send the datagram to the interface given on the right of the table
         » No: repeat for next line in routing table
       - If none of the lines match, then send an error message to the source
       - Note that pattern matching is used
         » * means any value: so 130.17.42.7 matches 130.17.*.0/24 since 130.17.42.7/24 has a network address of 130.17.42.0 (in this case, * = 42)

(Note: in the Internet the method for looking up routing tables is slightly different!)
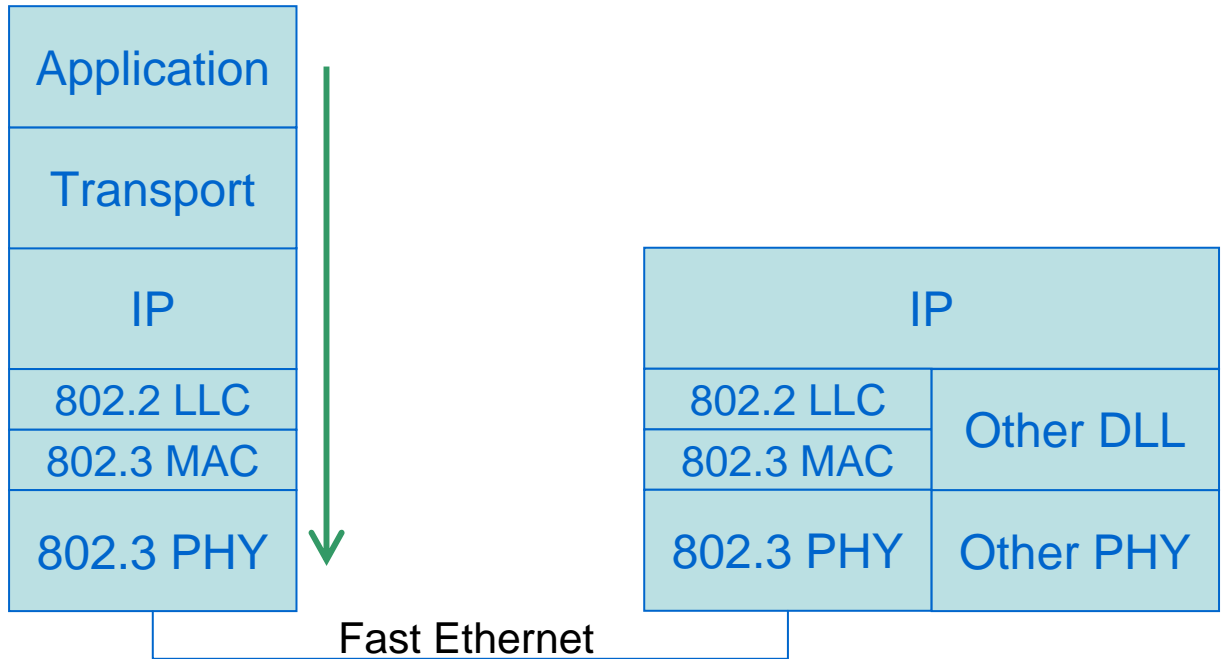
Sending the Datagram from Source

A1

A1: 130.17.40.1/22
A2: 91.54.19.1/16
A3: 23.15.136.2/8

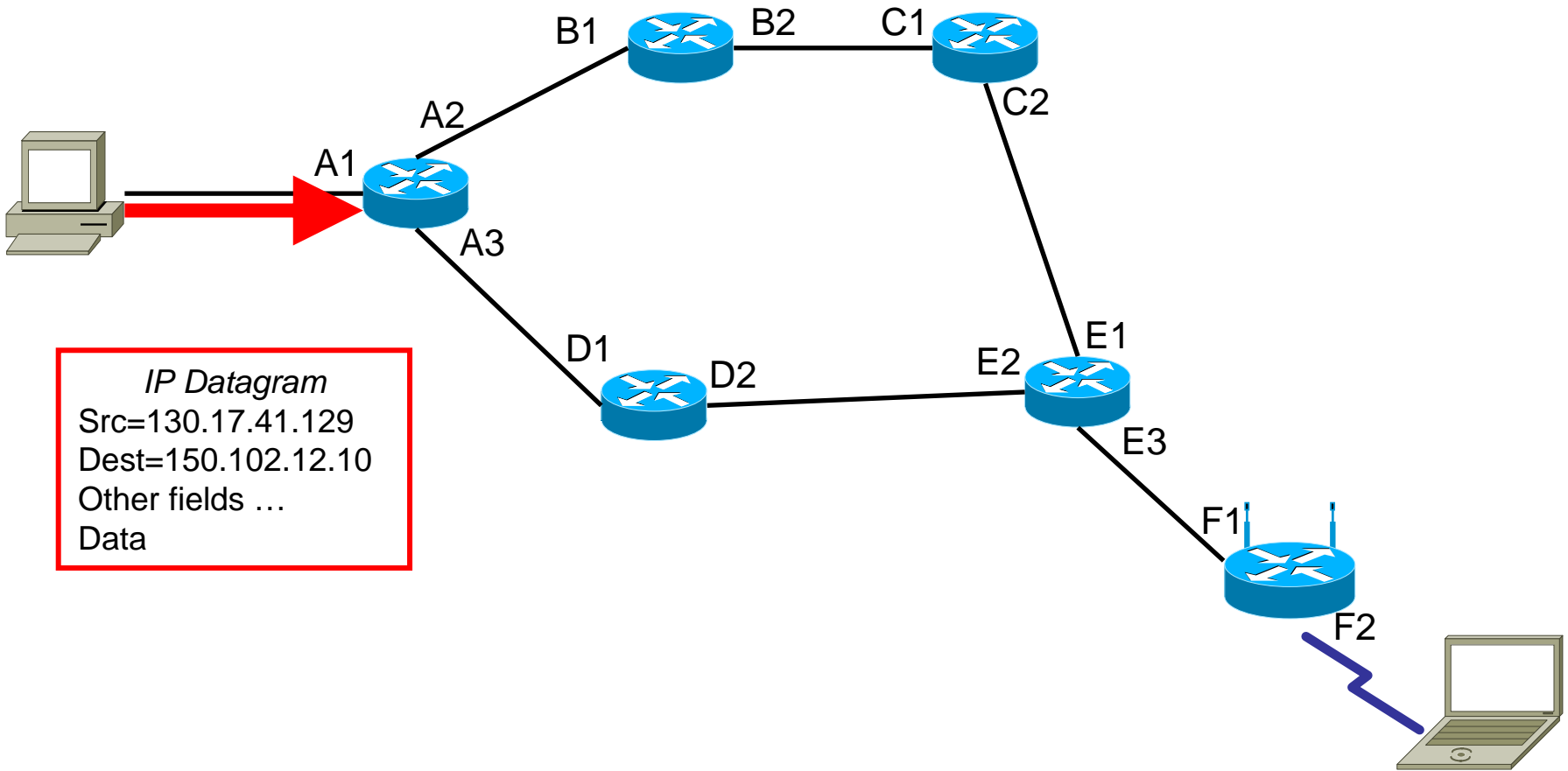| Src 130.17.41.129/22 |
| --- |

*	A1

IP at the source creates a datagram, by adding the IP header to the transport layer data. The IP header includes:
Source address: 130.17.41.129
Dest. address: 150.102.12.10

IP performs the checks (previous slide) and determines it must send the datagram to A1, that is, the router it is connected to. The datagram is sent using Fast Ethernet (IEEE 802.3).

Application
Transport
IP
802.2 LLC
802.3 MAC
802.3 PHY

IP	
802.2 LLC	Other DLL
802.3 MAC	
802.3 PHY	Other PHY

Fast Ethernet

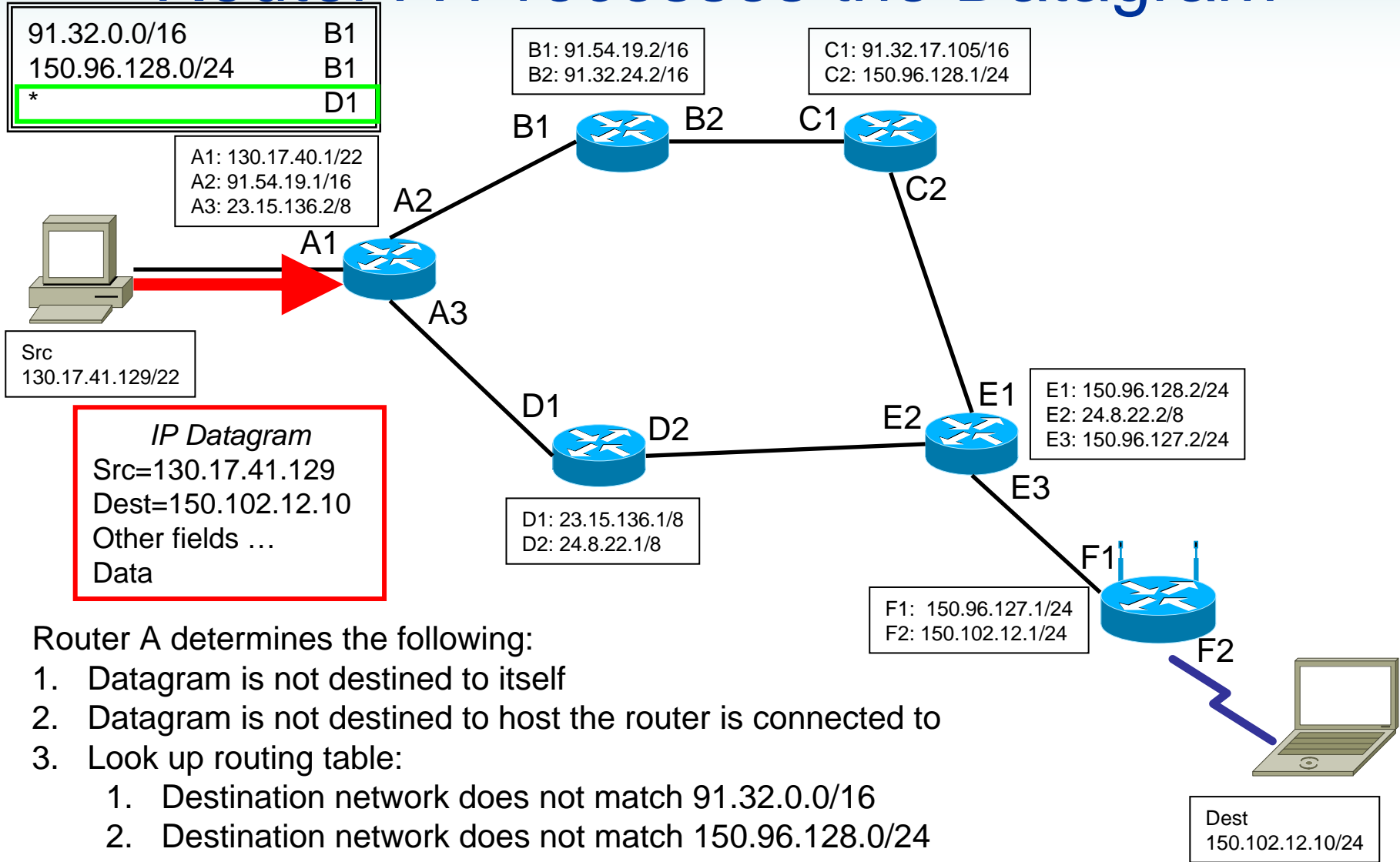# Source to Router A

IP Datagram
Src=130.17.41.129
Dest=150.102.12.10
Other fields …
Data

Router A Processes the Datagram

91.32.0.0/16	B1
150.96.128.0/24	B1
*	D1

A1: 130.17.40.1/22
A2: 91.54.19.1/16
A3: 23.15.136.2/8

B1: 91.54.19.2/16
B2: 91.32.24.2/16

C1: 91.32.17.105/16
C2: 150.96.128.1/24

E1: 150.96.128.2/24
E2: 24.8.22.2/8
E3: 150.96.127.2/24

D1: 23.15.136.1/8
D2: 24.8.22.1/8

F1: 150.96.127.1/24
F2: 150.102.12.1/24

Src
130.17.41.129/22

IP Datagram
Src=130.17.41.129
Dest=150.102.12.10
Other fields …
Data

Dest
150.102.12.10/24

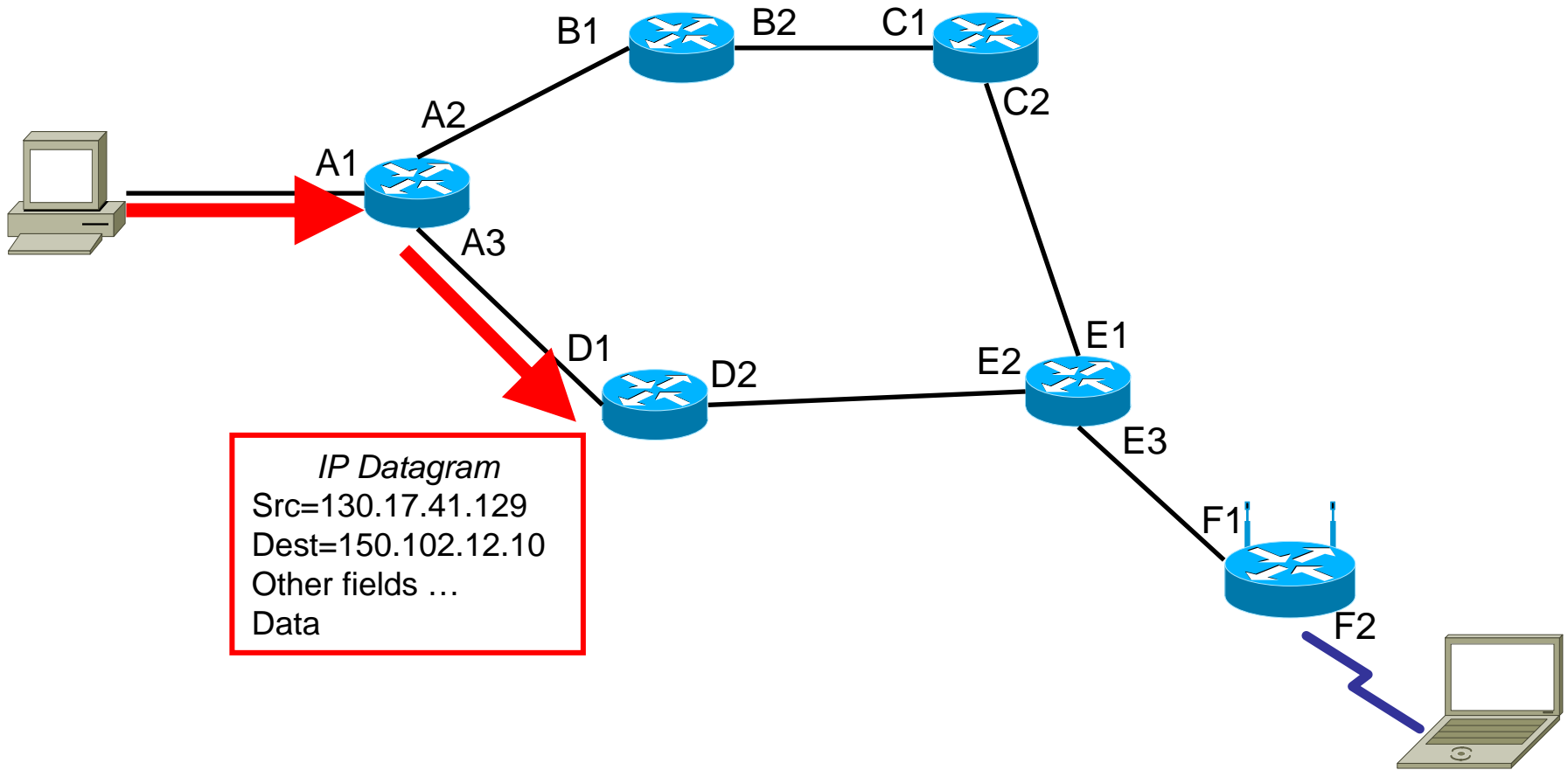B1 B2 C1 C2 A2 A1 A3 D1 D2 E1 E2 E3 F1 F2

Router A determines the following:
1. Datagram is not destined to itself
2. Datagram is not destined to host the router is connected to
3. Look up routing table:
    1. Destination network does not match 91.32.0.0/16
    2. Destination network does not match 150.96.128.0/24
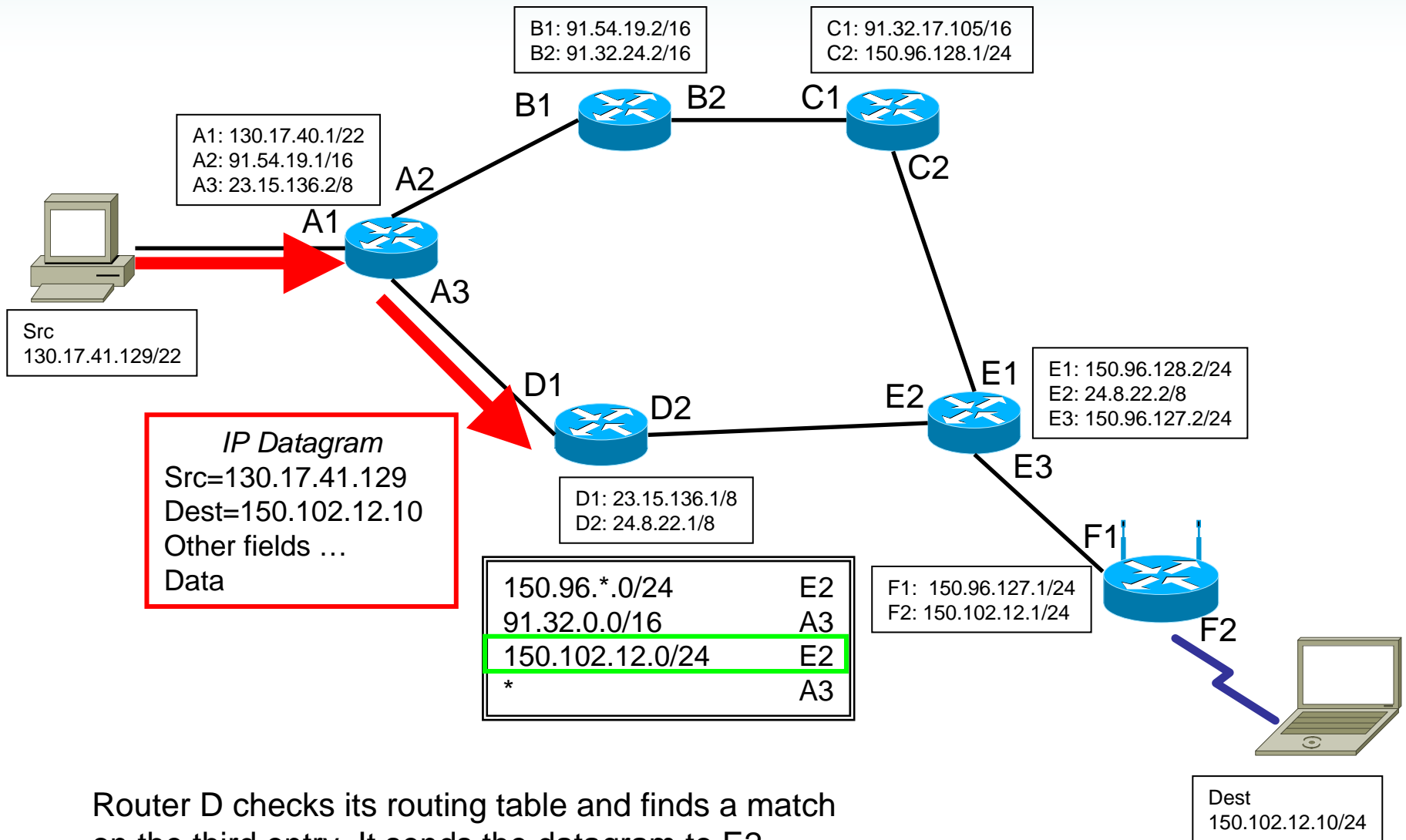   3. Destination network *does* match *

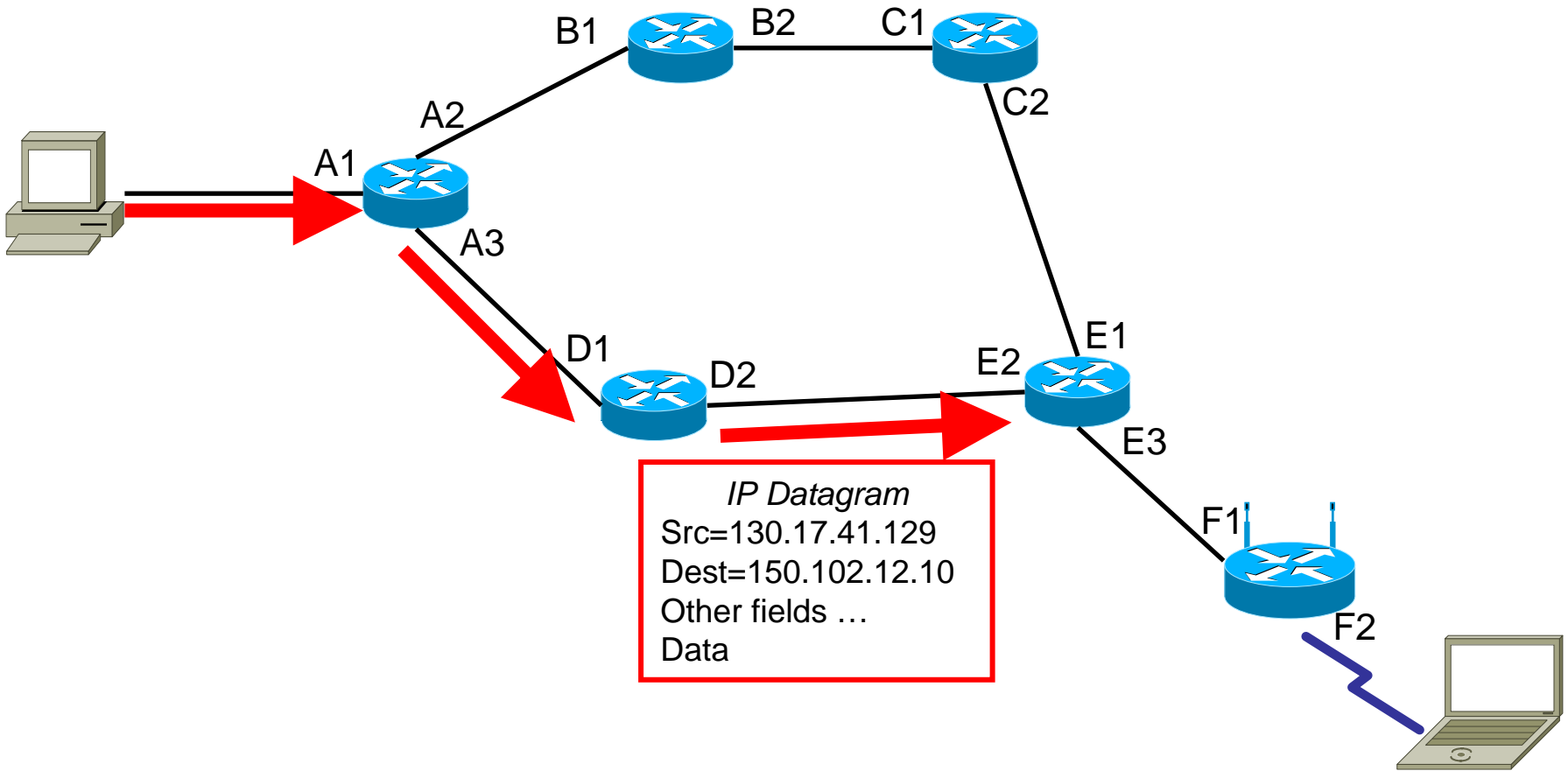Hence, router A sends the datagram to D1
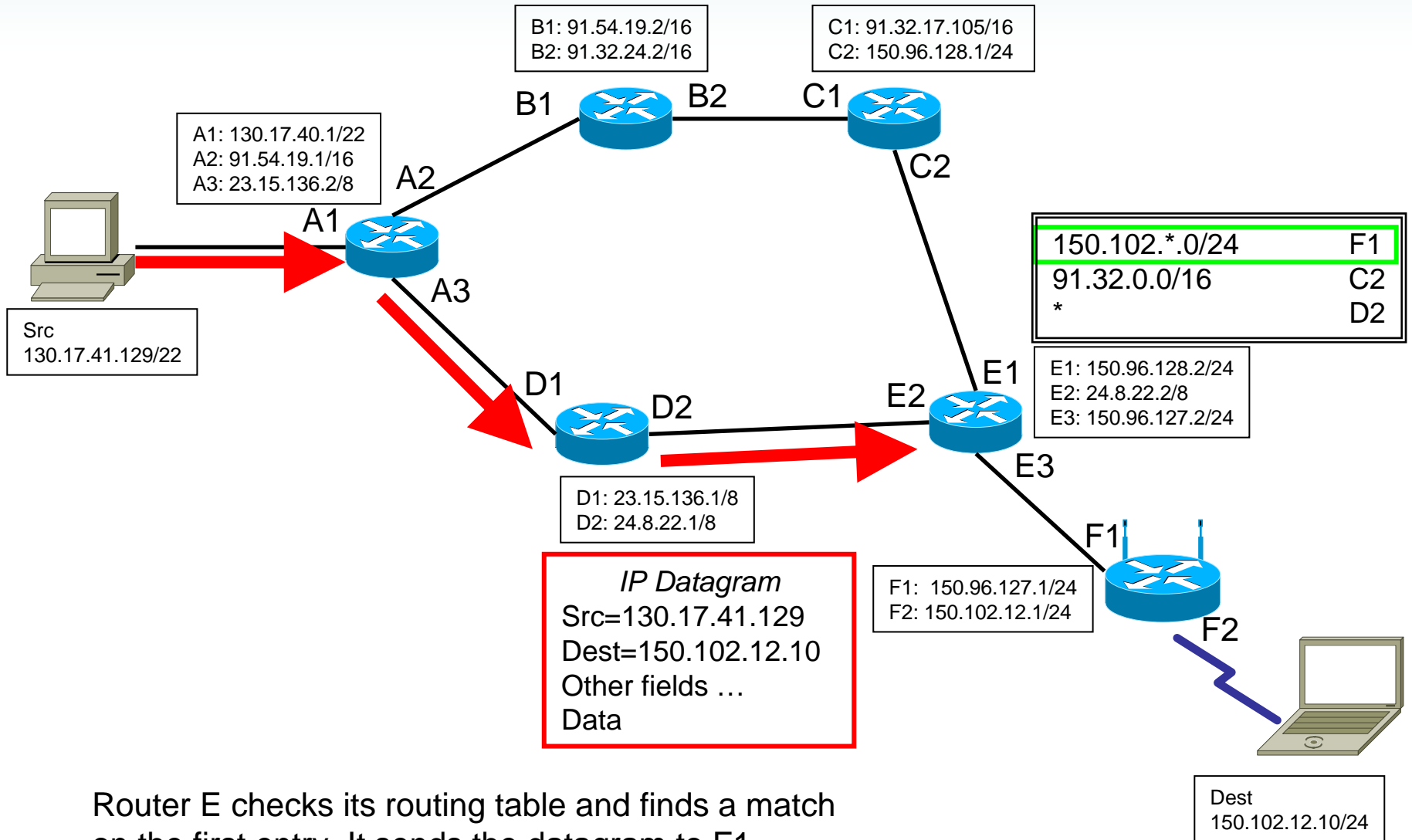
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Router A to Router D

IP Datagram
Src=130.17.41.129
Dest=150.102.12.10
Other fields …
Data

Router D Processes the Datagram

B1: 91.54.19.2/16
B2: 91.32.24.2/16

C1: 91.32.17.105/16
C2: 150.96.128.1/24

B1   B2   C1

C2

A1: 130.17.40.1/22
A2: 91.54.19.1/16
A3: 23.15.136.2/8

A2

A1

A3

Src
130.17.41.129/22

E1: 150.96.128.2/24
E2: 24.8.22.2/8
E3: 150.96.127.2/24

D1   D2   E2   E1

E3

IP Datagram
Src=130.17.41.129
Dest=150.102.12.10
Other fields …
Data

D1: 23.15.136.1/8
D2: 24.8.22.1/8

F1

150.96.*.0/24	E2
91.32.0.0/16	A3
150.102.12.0/24	E2
*	A3

F1: 150.96.127.1/24
F2: 150.102.12.1/24

F2

Router D checks its routing table and finds a match
on the third entry. It sends the datagram to E2.

Dest
150.102.12.10/24

Router D to Router E

IP Datagram
Src=130.17.41.129
Dest=150.102.12.10
Other fields …
Data

Router E Processes the Datagram

B1: 91.54.19.2/16
B2: 91.32.24.2/16

C1: 91.32.17.105/16
C2: 150.96.128.1/24

B1   B2   C1

A1: 130.17.40.1/22
A2: 91.54.19.1/16
A3: 23.15.136.2/8

A2   C2

A1

150.102.*.0/24	F1
91.32.0.0/16	C2
*	D2

Src
130.17.41.129/22

A3

E1: 150.96.128.2/24
E2: 24.8.22.2/8
E3: 150.96.127.2/24

D1   D2   E2   E1

E3

D1: 23.15.136.1/8
D2: 24.8.22.1/8

F1

IP Datagram
Src=130.17.41.129
Dest=150.102.12.10
Other fields …
Data

F1: 150.96.127.1/24
F2: 150.102.12.1/24

F2

Router E checks its routing table and finds a match
on the first entry. It sends the datagram to F1.

Dest
150.102.12.10/24

Router E to Router F

IP Datagram
Src=130.17.41.129
Dest=150.102.12.10
Other fields …
Data
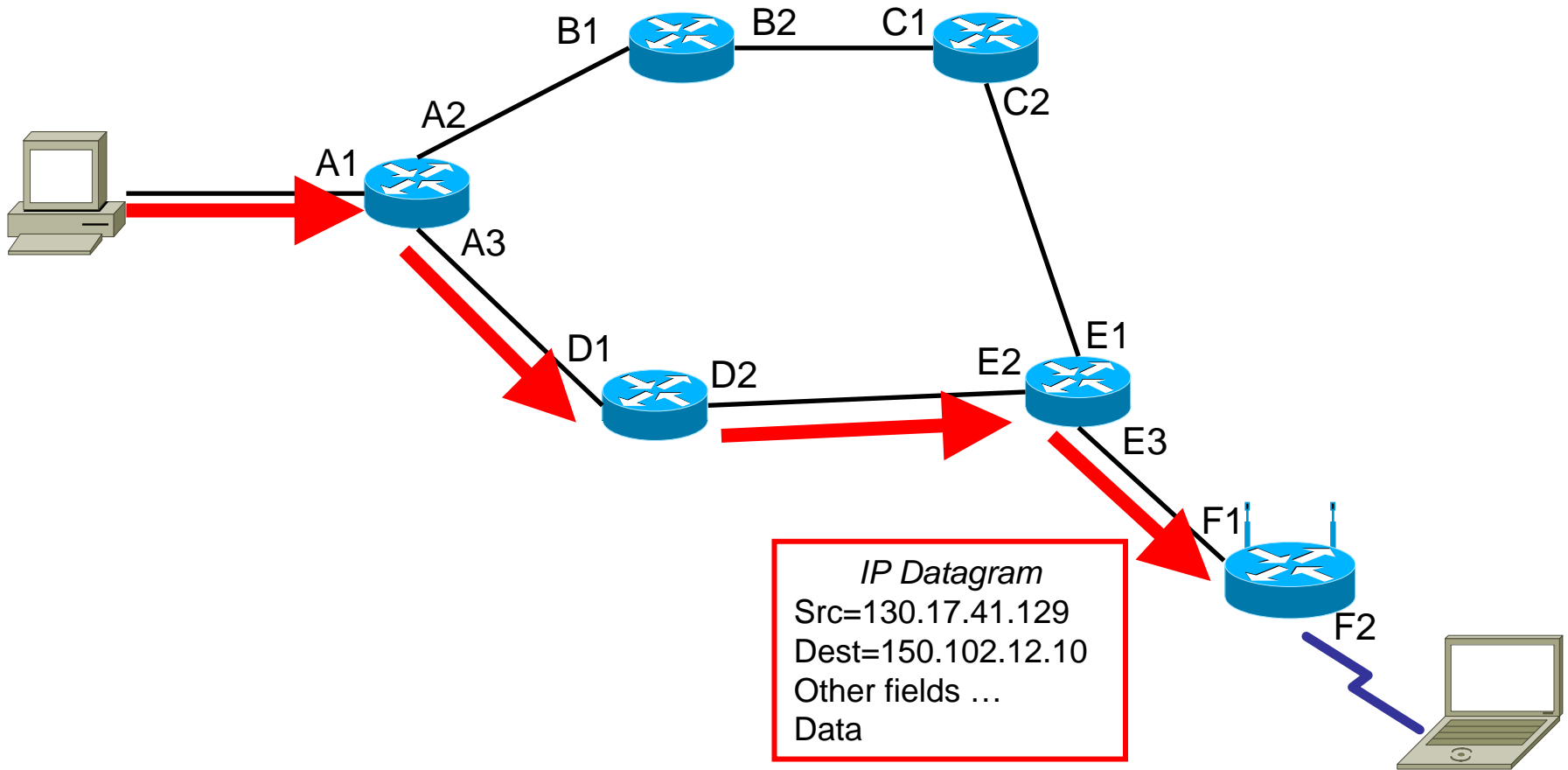
Router F Processes the Datagram

B1: 91.54.19.2/16
B2: 91.32.24.2/16

C1: 91.32.17.105/16
C2: 150.96.128.1/24

B1   B2   C1

A1: 130.17.40.1/22
A2: 91.54.19.1/16
A3: 23.15.136.2/8

A2

C2

A1

A3

Src
130.17.41.129/22

D1

D2

E2

E1   E1: 150.96.128.2/24
E2: 24.8.22.2/8
E3: 150.96.127.2/24

E3

D1: 23.15.136.1/8
D2: 24.8.22.1/8

F1

IP Datagram
Src=130.17.41.129
Dest=150.102.12.10
Other fields …
Data

F1: 150.96.127.1/24
F2: 150.102.12.1/24

F2

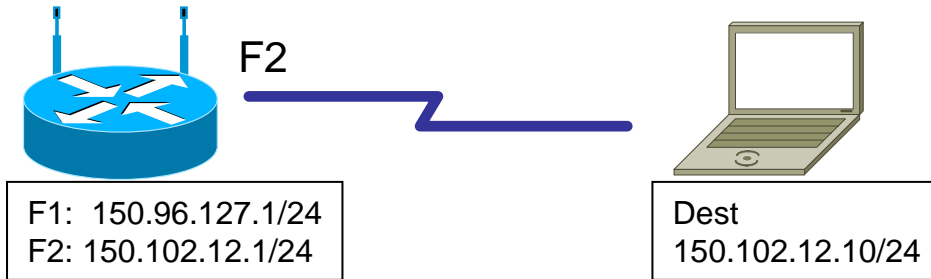| *	E3
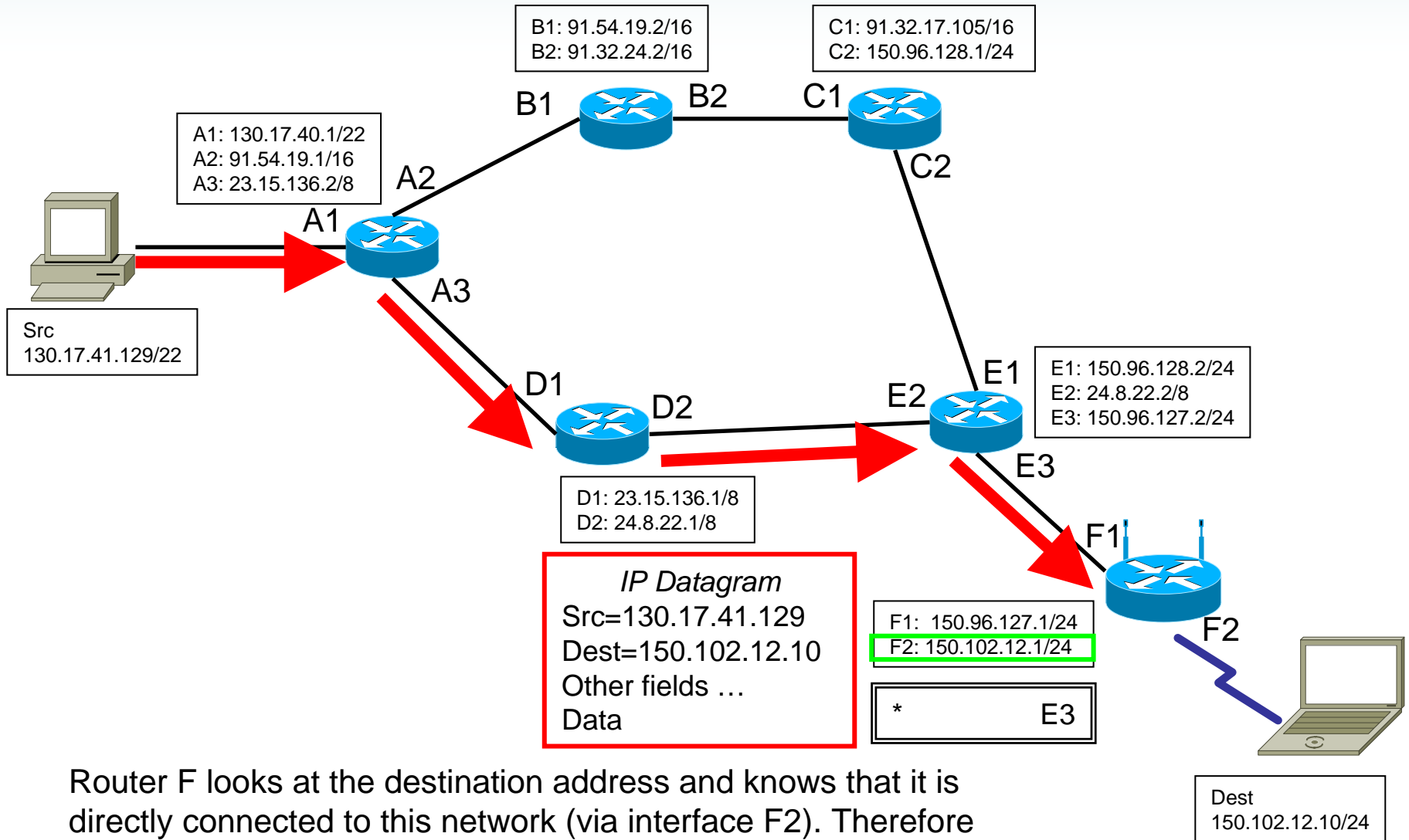
Dest
150.102.12.10/24

Router F looks at the destination address and knows that it is
directly connected to this network (via interface F2). Therefore
router F does not look in its routing table. Instead it sends the
datagram to the destination (via the wireless LAN).

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Router F to Destination

IP Datagram
Src=130.17.41.129
Dest=150.102.12.10
Other fields …
Data

Destination Receives the Datagram

F2

F1: 150.96.127.1/24
F2: 150.102.12.1/24
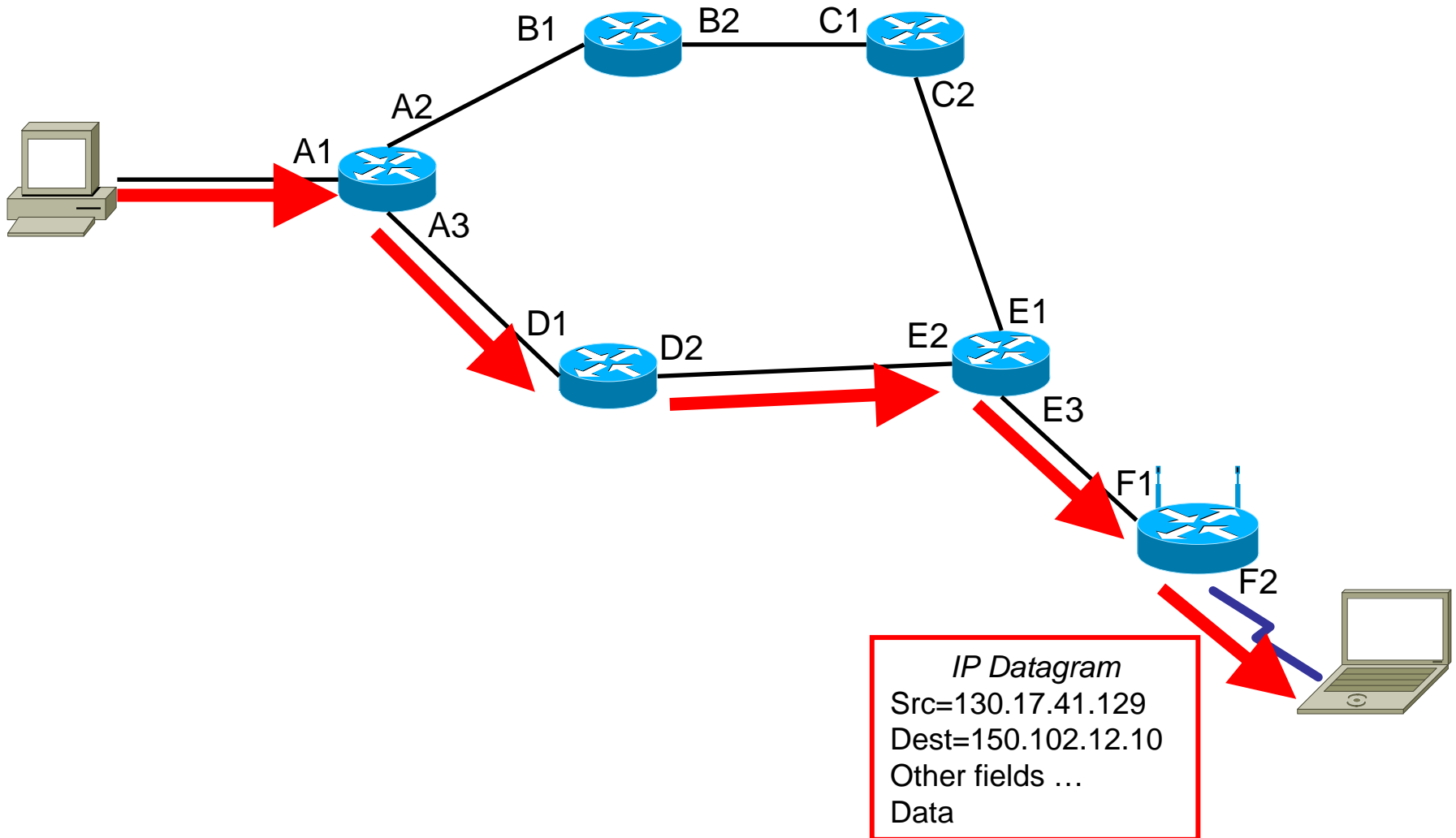
Dest
150.102.12.10/24

IP	
802.2 LLC	802.2 LLC
GbE MAC	802.11 MAC
GbE PHY	802.11 PHY

Application
Transport
IP
802.2 LLC
802.11 MAC
802.11 PHY

IP at the destination receives the datagram and recognises that it is the final destination. Hence IP removes the header and sends the data to the Transport layer.

Wireless LAN

Summary of IP Internetworking

- IP networking layer includes two main functions:
  - Routing: routing protocols are running on the routers/hosts to create the routing tables
    - As the network changes (new routers added, links fail, load increases) the routing protocols adjust the routing tables accordingly
    - In practice, routing tables can be quite complex
      - 1000's of entries; the main routers in today's Internet contain more than 100,000 entries
      - But still this is manageable because routers only record "how to get to a network", not to a particular host (if entries for every host were used, then routing tables would have 100's of millions of entries – far too large!)
  - Forwarding: when data is to be sent, the process is known as forwarding (our example showed the detailed steps of forwarding)
    - IP datagram contains the IP address of the source host and destination host
    - Each router looks at the destination and (using the routing tables) determines where to forward the datagram in order to reach the destination

- Although routing protocols can be quite complex, forwarding is relatively simple (and fast, cheap)

- Implementing IP in every host/router allows virtually any computer (using different LAN/WAN technologies) to communicate, that is, the Internet today