# Organization of the Network layer

We'll study the two internal organizations of the network layer in this lesson!

WE'LL COVER THE FOLLOWING


- Datagram Organization
  - Forwarding Tables
- Virtual Circuit Organization
- Virtual Circuit Organization vs. Datagram Organization
  - Advantages of Datagram Organization
  - Advantages of The Virtual Circuit Organization
- Quick Quiz!


There are two possible internal organizations of the network layer: **datagram** and **virtual circuits**.

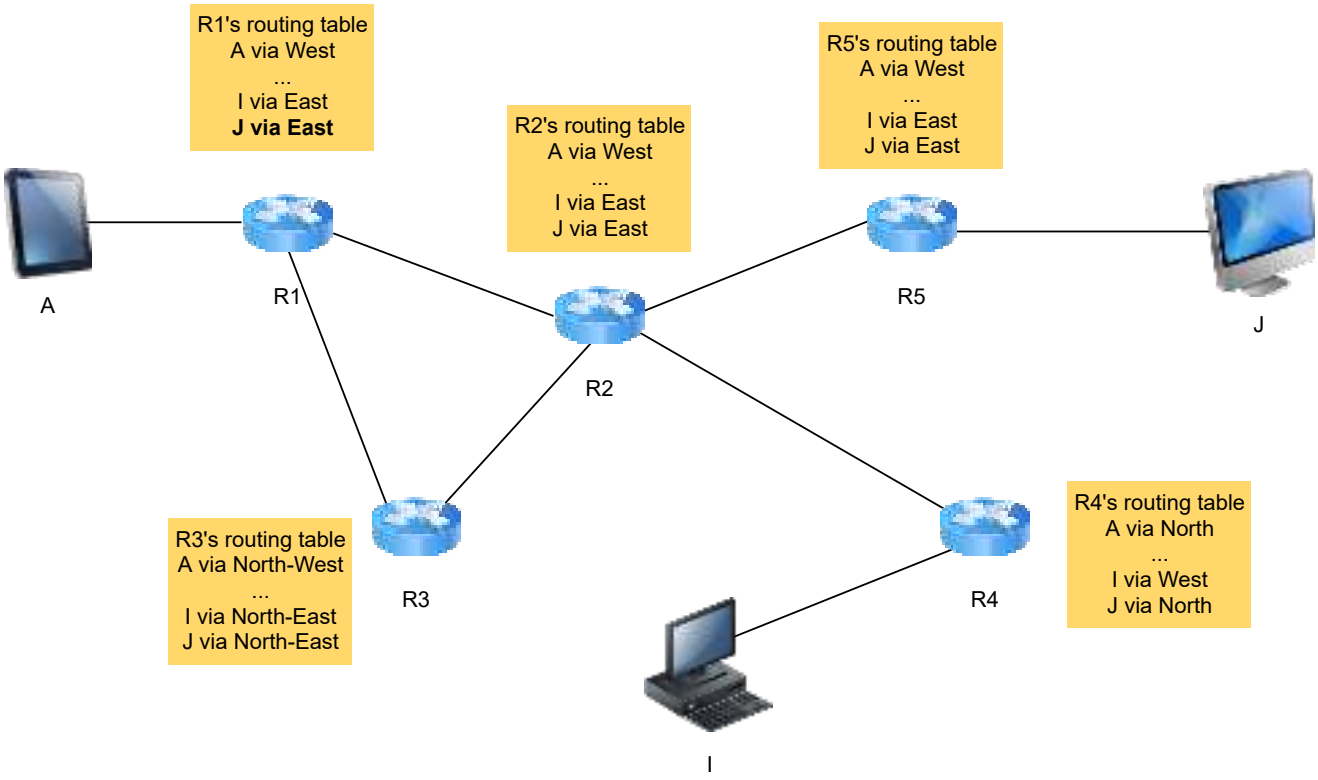
## Datagram Organization #

The datagram organization has been very popular in computer networks. Datagram-based network layers include **IPv4 and IPv6** in the **global Internet**, CLNP defined by the ISO, IPX defined by Novell or XNS defined by Xerox.

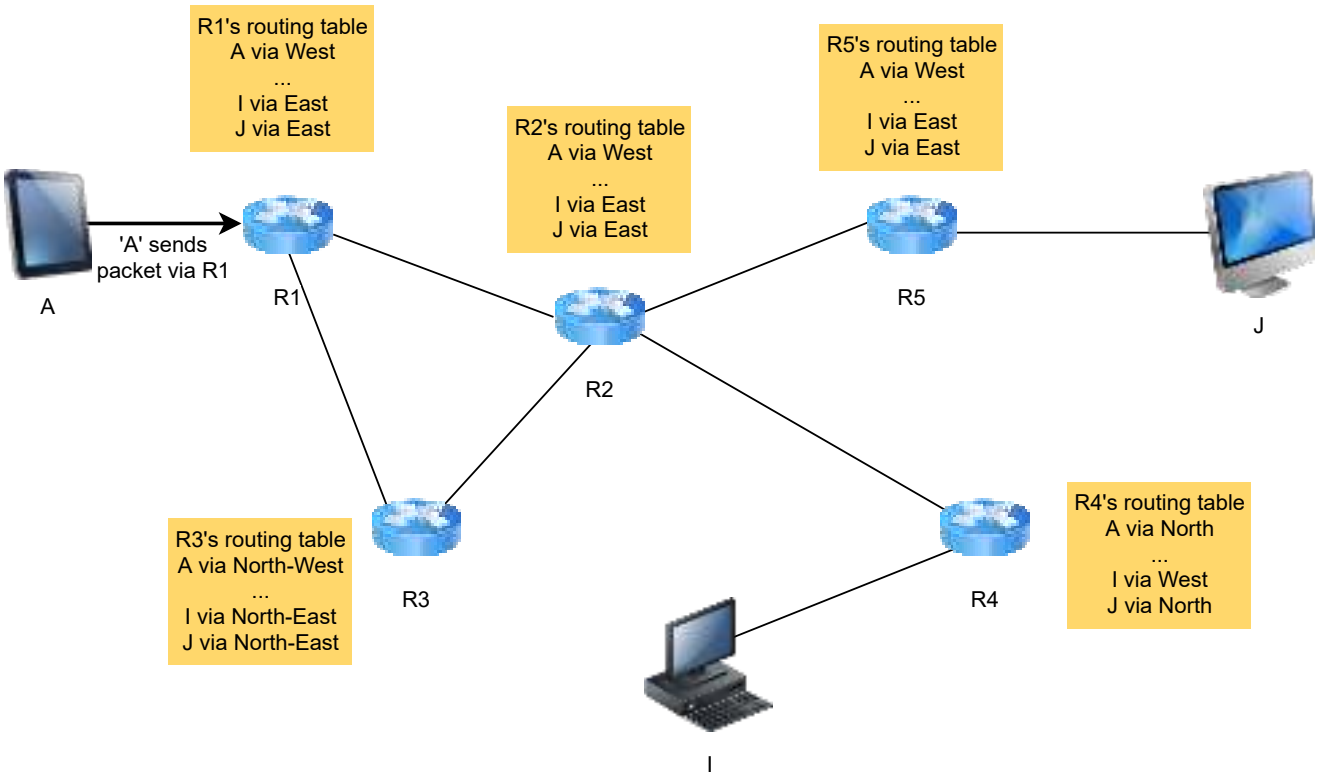
This organization is **connectionless** and hence each packet contains:

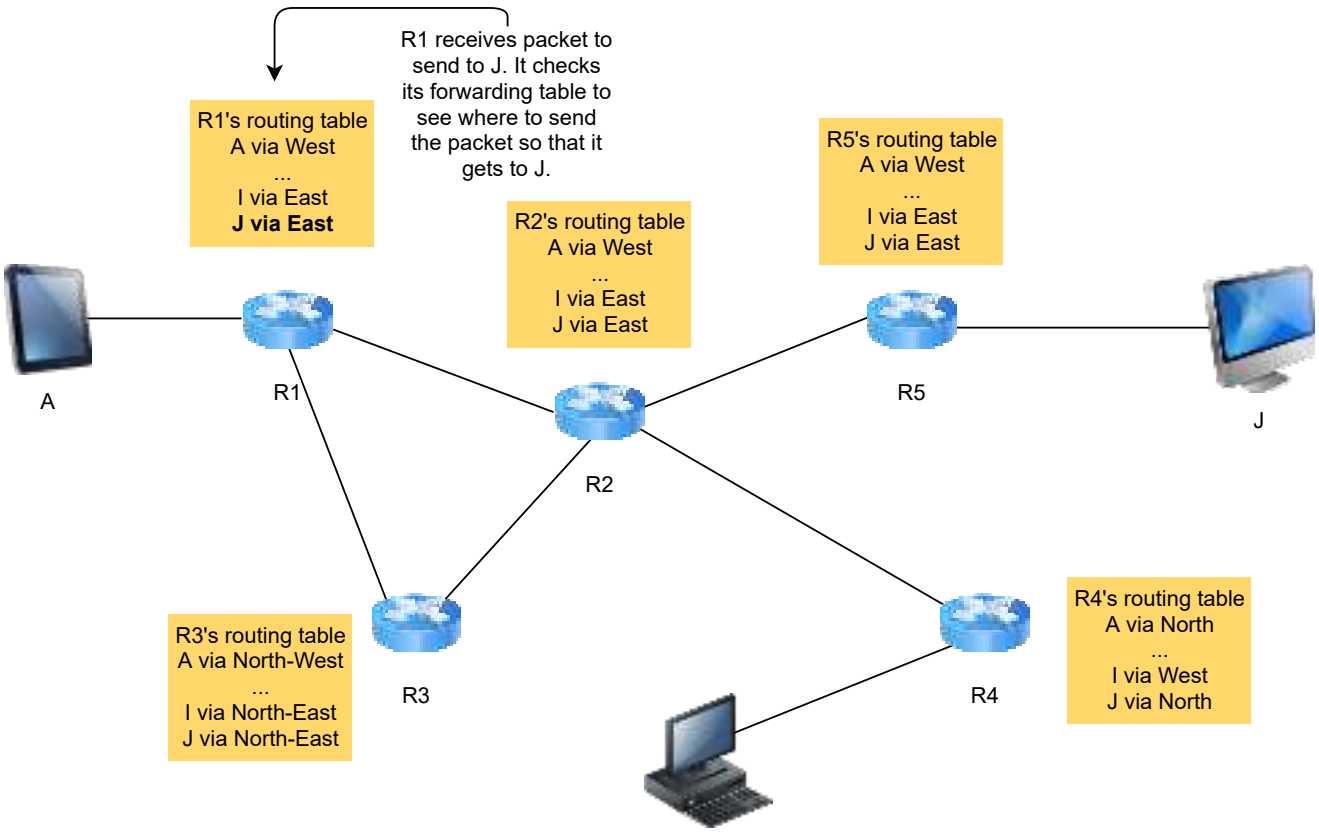
- The network layer address of the destination host.
- The network layer address of the sender.
- The information to be sent.

To understand the datagram organization, let's consider the slides below. A network layer address represented by a letter, has been assigned to each host and router. **Host A** wishes to send some information to **host J**.

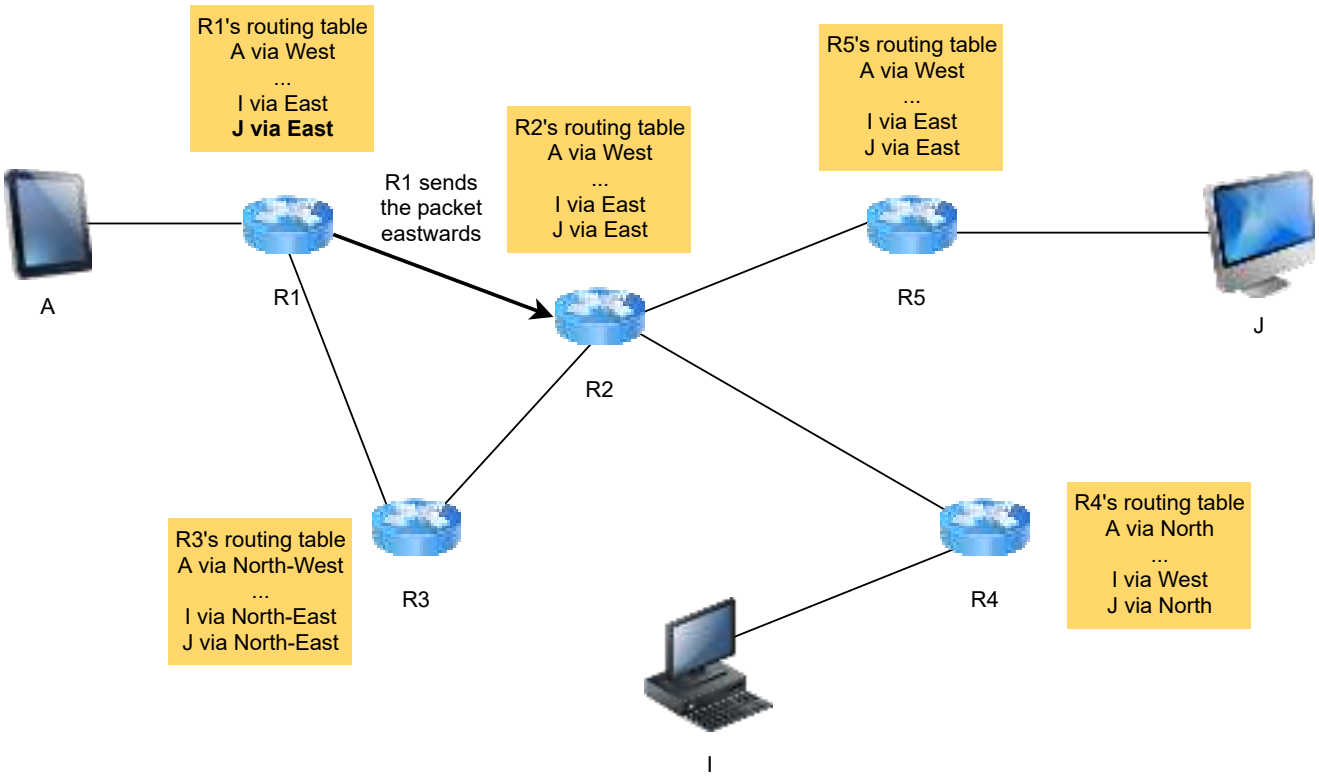

R1's routing table
A via West
...
I via East
J via East
R2's routing table
A via West
...
I via East
J via East
R5's routing table
A via West
...
I via East
J via East
A
R1
R2
R5
J
R3's routing table
A via North-West
...
I via North-East
J via North-East
R3
R4
R4's routing table
A via North
...
I via West
J via North
I

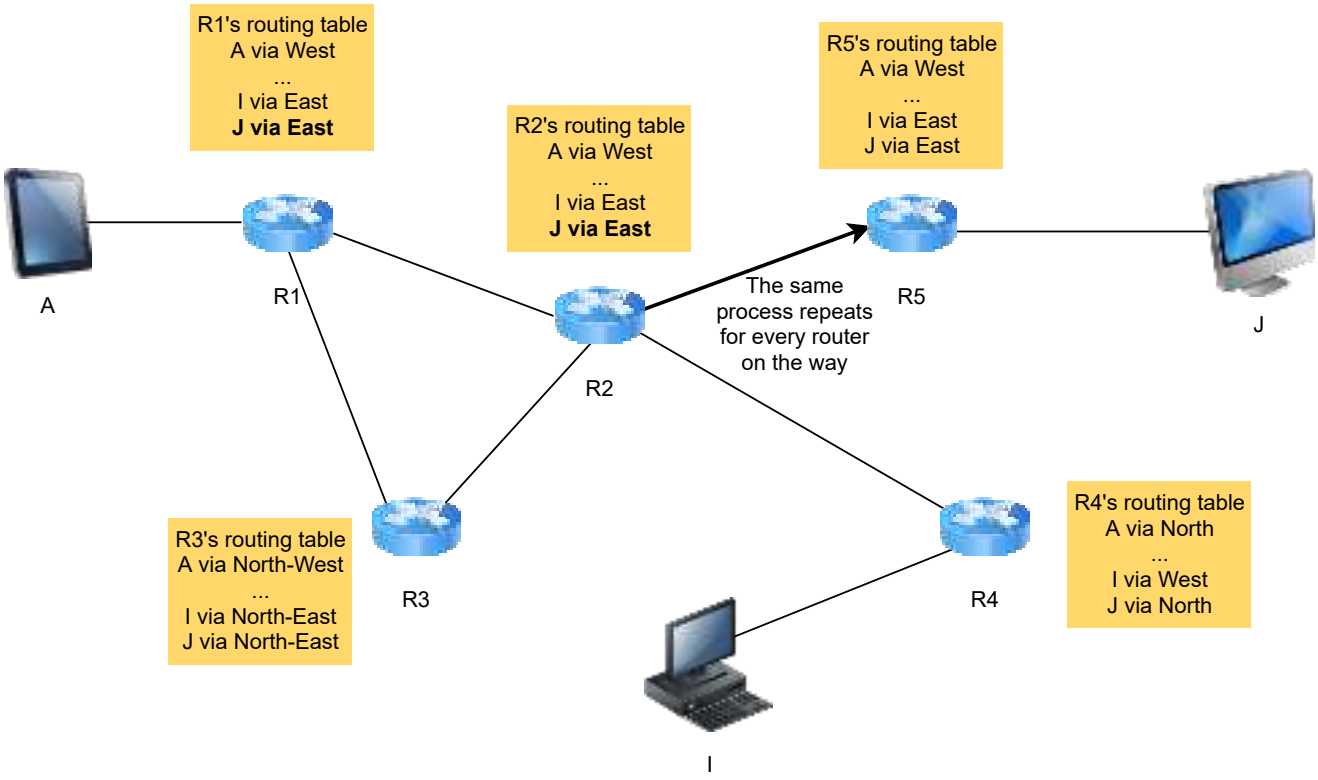



R1's routing table
A via West
...
I via East
J via East
R2's routing table
A via West
...
I via East
J via East
R5's routing table
A via West
...
I via East
J via East
'A' sends
packet via R1
A
R1
R2
R5
J
R3's routing table
A via North-West
...
I via North-East
J via North-East
R3
R4
R4's routing table
A via North
...
I via West
J via North
I

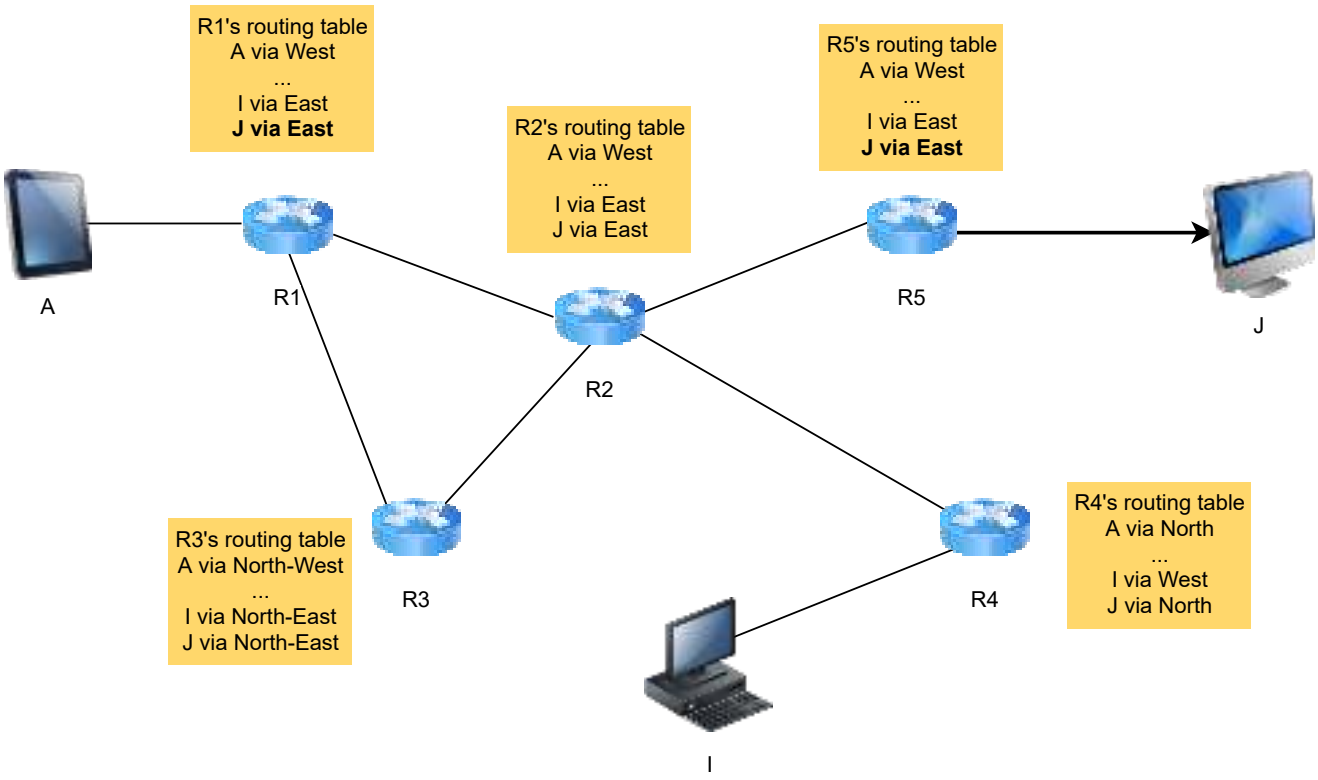

R1 receives packet to send to J. It checks its forwarding table to see where to send the packet so that it gets to J.
R1's routing table
A via West
...
I via East
J via East
R2's routing table
A via West
...
I via East
J via East
R5's routing table
A via West
...
I via East
J via East
A
R1
R2
R5
J
R3's routing table
A via North-West
...
I via North-East
J via North-East
R3
R4
R4's routing table
A via North
...
I via West
J via North

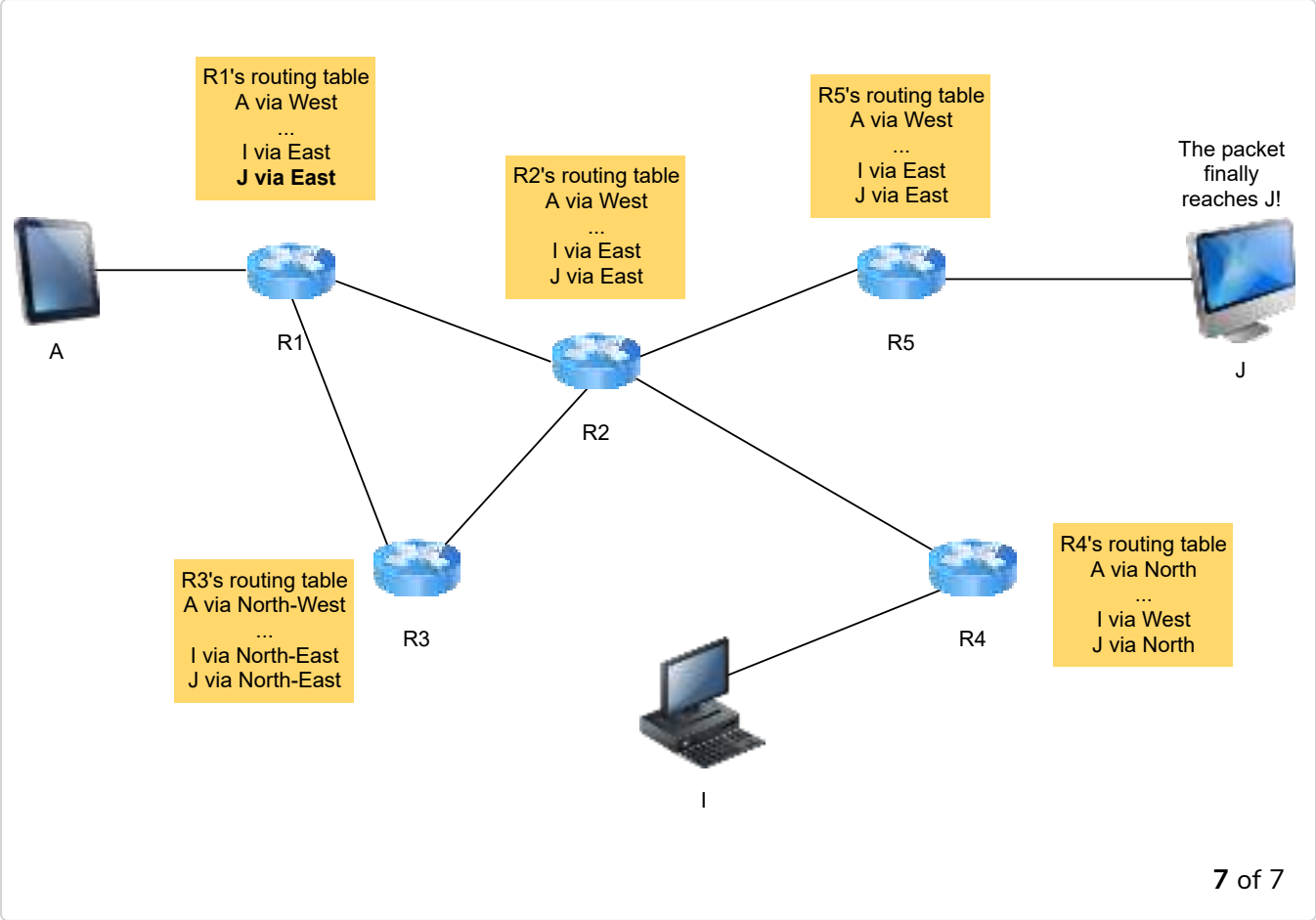



R1's routing table
A via West
...
I via East
J via East
R2's routing table
A via West
...
I via East
J via East
R5's routing table
A via West
...
I via East
J via East
R1 sends the packet eastwards
A
R1
R2
R5
J
R3's routing table
A via North-West
...
I via North-East
J via North-East
R3
R4
R4's routing table
A via North
...
I via West
J via North
I


R1's routing table
A via West
...
I via East
J via East
R2's routing table
A via West
...
I via East
J via East
R5's routing table
A via West
...
I via East
J via East
A
R1
R2
R5
J
The same process repeats for every router on the way
R3's routing table
A via North-West
...
I via North-East
J via North-East
R3
R4
R4's routing table
A via North
...
I via West
J via North
I




R1's routing table
A via West
...
I via East
J via East
R2's routing table
A via West
...
I via East
J via East
R5's routing table
A via West
...
I via East
J via East
A
R1
R2
R5
J
R3's routing table
A via North-West
...
I via North-East
J via North-East
R3
R4
R4's routing table
A via North
...
I via West
J via North
I




## Forwarding Tables #

Routers use *hop-by-hop* forwarding in the datagram organization. This means that when a router receives a packet that is not destined to itself, it looks up the destination address of the packet in its **forwarding table**.

> A **forwarding table** is a data structure that maps each destination address to the device. Then, a packet must be forwarded for it to reach its final destination.

forwarding tables must

- Allow any host in the network to reach any other host. This implies that **each router must know a route towards each destination**.
- The paths composed from the information stored in the forwarding tables **must not contain loops**. Otherwise, some destinations would be

unreachable.

The **data plane** contains all the protocols and algorithms that are used by hosts and routers to create and process the packets that contain user data.

The **control plane** contains all the protocols and mechanisms that are used to compute, install, and maintain forwarding tables on the routers.

> **Note: Routing Tables vs. Forwarding Tables** Routing tables are generally used to *generate* the information for a forwarding table, which is a subset of the routing table. So, a routing table may have 3 paths for one source, and destination pair generated from a few different algorithms that's perhaps also entered manually. The forwarding table, however, will only have one of those entries which is usually the preferred one based on another algorithm or criteria. The forwarding table is usually optimized for storage and lookup.

## Virtual Circuit Organization #

The second organization of the network layer, called **virtual circuits**, has been *inspired by the organization of telephone networks*.

- Telephone networks have been designed to carry phone calls that usually last a few minutes.
- Each phone is **identified by a telephone number** and is attached to a **telephone switch**.
- To initiate a phone call, a telephone first needs to send the destination's phone number to its local switch.
- The switch cooperates with the other switches in the network to create a bi-directional channel between the two telephones through the network.
- This channel will be used by the two telephones during the lifetime of the call and will be released at the end of the call.
- Until the 1960s, most of these channels were **created manually**, by telephone operators, upon request of the caller.

- Today's telephone networks use automated switches and allow several channels to be carried over **the same physical link**, but the principles remain roughly the same.

In a network using virtual circuits, all hosts are **identified with a network layer address**. However, a host must explicitly request the establishment of a virtual circuit before being able to send packets to a destination host. The request to establish a virtual circuit is processed by the control plane, which installs state to create the virtual circuit between the source and the destination through intermediate routers.

This organization is **connection-oriented** which means that resources like buffers, CPU, and bandwidth are reserved for every connection. The first packet sent reserves these resources for subsequent packets, which all follow a single path for the duration of the connection.

The virtual circuit organization has been mainly used in public networks, starting from X.25, and then Frame Relay and Asynchronous Transfer Mode (ATM) network.

## Virtual Circuit Organization vs. Datagram Organization #

Both the datagram and virtual circuit organizations have advantages and drawbacks.

### Advantages of Datagram Organization #

The main advantage of the datagram organization is that **hosts can easily send packets to any number of destinations**, while the virtual circuit organization requires the establishment of a virtual circuit before the transmission of a data packet. This can cause high overhead for hosts that exchange small amounts of data.

Another advantage of the datagram-based network layer is that **it's resilient**. If a virtual or physical circuit breaks, it has to go through the connection establishment phase, again. In case of datagram-based network layer, **each packet can be routed independently** of each other, hop-by-hop, so

intermediate routers can divert around failures.

### Advantages of The Virtual Circuit Organization #

On the other hand, the main advantage of the virtual circuit organization is that the **forwarding algorithm used by routers is simpler** than when using the datagram organization. Furthermore, the utilization of virtual circuits may allow the **load to be better spread through the network**.

Also, since the packets follow a particular dedicated path, they **reach the destination in the order they were sent**. Virtual circuits can be configured to provide a variety of services including best effort, in which case *some* packets may be dropped. However, in case of bursty traffic, there is a possibility of packet drops.

Note that the Internet uses a **datagram organization**. We'll be focusing on that for the rest of the chapter.

## Quick Quiz! #

1 Which of the following is not a network layer principle?

In the next lesson, we'll look at how the control plane's routing algorithms work!