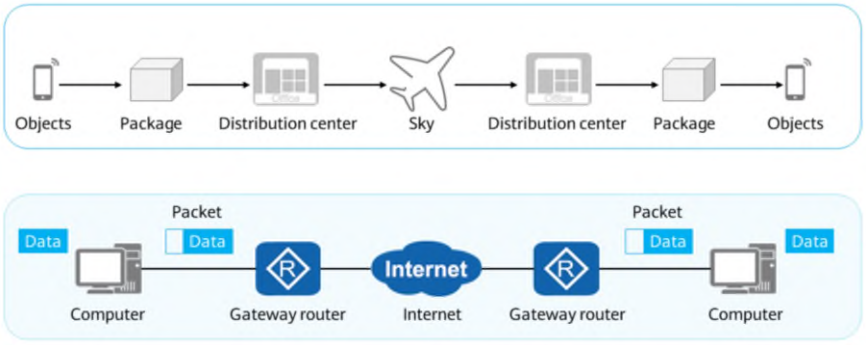
Routing Fundamentals

Data Encapsulation

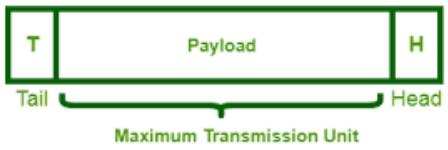
Encapsulation is a process wherein a new string of information is added to an existing unit to form a new unit of information. A new datagram is formed by adding headers and trailers to a data payload

Decapsulation is the reverse process of encapsulation wherein the header and tail of a packet are removed to obtain the data payload.



Concept of Network Communication
Virtual information transfer is similar to real object transfer.

Data payload can be considered as the information to be transmitted. In a hierarchical communication process, the data unit (packet) transmitted from the upper layer to the lower layer can be called the data payload of the lower layer.

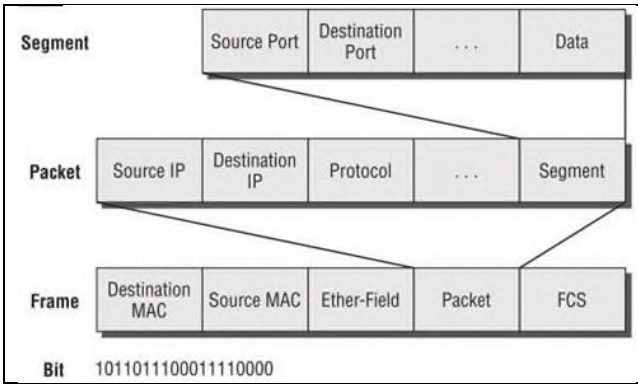


- **Packet** is a data unit that is exchanged and transmitted on a network. It is in the format of header+data payload+tail. During transmission, the format and content of packets may change.
- **Header** is the information segment added before the data payload during packet assembly to facilitate information transmission.
- **Tail** is the information segment added after the payload to facilitate information transmission.

TCP Protocol Data Units

A **Protocol Data Unit (PDU)** is a specific block of information transferred over a network. It is often used in reference to the OSI model, since it describes the different types of data that are transferred from each layer.

- **Physical layer** – **raw bits** (1s or 0s) transmitted physically via the hardware
- **Data Link layer** – a **frame** (or series of bits)
- **Network layer** – a **packet** that contains the source and destination address
- **Transport layer** – a **segment** that includes a TCP header and data
- **Session layer** – the **data** passed to the network connection
- **Presentation layer** – the **data** formatted for presentation
- **Application layer** – the **data** received or transmitted by a software application



OSI Model	PDU	TCP/IP Stack
Application	Data	Application
Presentation		
Session		
Transport	Segment	Transport
Network	Packet	Internet
Data Link	Frame	Network Access/Link
Physical	Bits	

TCP/IP Internet Layer Common Protocols

- ***Internet Protocol (IP):*** It performs the following operations:
  - Defines a packet and an addressing scheme
  - Transfers data between the Internet layer and network access layers
  - Routes packets to remote hosts
- ***Internet Control Message Protocol (ICMP):*** It refers to a TCP/IP protocol that handles errors and controls the process of sending data between computers. Specifically, routers and hosts use ICMP to send reports of problems about packets that return to the original source that sent the packet. ICMP also includes an echo request/reply that is used to test whether a destination is reachable and responding.
- ***Internet Group Management Protocol (IGMP):*** It refers to a TCP/IP protocol that handles multicasting. Hosts use IGMP to keep local routers apprised of their membership in multicast groups. When all hosts leave a group, routers no longer forward packets that arrive for the group.
- ***Address Resolution Protocol (ARP):*** It refers to a TCP/IP protocol that obtains the physical address of a node from a specific IP number. It is used to dynamically bind a high-level IP address to a low-level physical hardware address and is used across a single physical network. It is limited to networks that support hardware broadcast.
- ***Reverse Address Resolution Protocol (RARP):*** It refers to a TCP/IP protocol that allows a host with no local permanent data storage media to find its Internet address given its physical address.

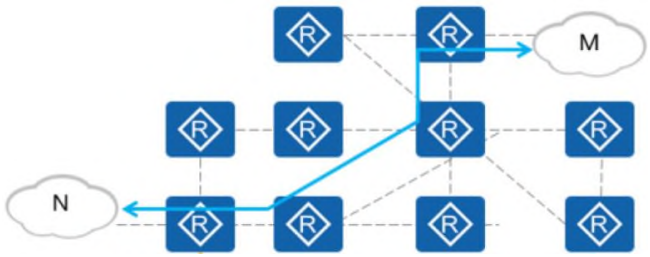
Common Network Access Layer Protocols

- ***Ethernet:*** It refers to a family of LANs, covered by a group of IEEE 802.3 standards. Ethernet is a best-effort delivery system that uses a CSMA/CD access method.
- ***Point-to-Point Protocol (PPP):*** This refers to the protocol used for data transfer across a serial line.
- ***Fiber distributed data interface (FDDI):*** This is a set of ANSI protocols for sending digital data over fiber optic cable.
- ***Asynchronous Transfer Mode (ATM):*** This refers to a wide area protocol that features high data rates and equal-sized packets/cells suitable for text, audio, and video data transfer.
- ***Frame Relay:*** This is a WAN protocol for LAN internetworking that provides a fast and efficient method of transmitting information from one user device to another across multiple switches and routers.
- ***Proxy ARP:*** This protocol is used when a network terminal needs to pass data from one segment to another without changing its current IP address information.

Routing Fundamentals

Routing is the basic element of data communication networks, which is the process of selecting paths on a network along which packets are sent from a source to a destination.

- ***Path determination*** enables a router to compare the destination address to the available routes in its routing table and to select the best path.



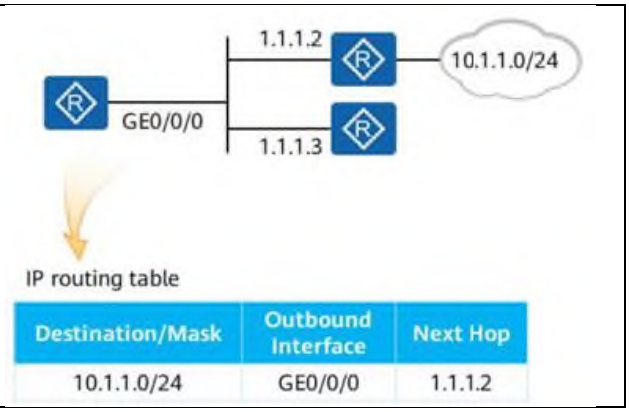
A gateway and an intermediate node (a router) select a proper path according to the destination address of a received IP packet and forward the packet to the next router.

- **Routes** are the path information used to guide packet forwarding.
- A **routing device (Router)** is a network device that forwards packets to a destination subnet based on routes. It maintains an **IP routing table** that stores routing information.
- ***Packet routing*** is the overall network-wide process of finding the most efficient path for forwarding the IP packet from source to destination through the use of network routing tables, protocols, and algorithms.
- Network devices need to forward IP packets from different subnets to their destination IP subnets.

A **route** contains the following information:

- **Destination** identifies a destination subnet.
- **Mask** identifies a subnet together with a destination IP address.
- **Outbound interface** indicates the interface through which a data packet is sent out of the local router.
- **Next hop** indicates the next-hop address used by the router to forward the data packet to the destination subnet.

The information identifies the destination subnet and specifies the path for forwarding data packets.



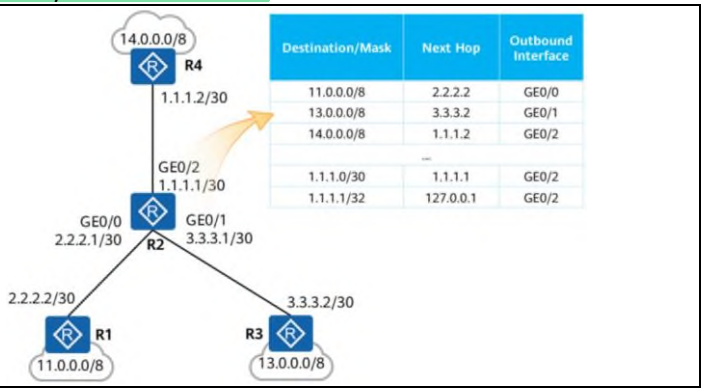
Packet Forwarding

It is simply a passing or moving of information between interfaces (which can be from a host/router to the final destination/intermediate connecting device) according to the "directions".

- **Packet Delivery** refers to the way a packet is handled by the underlying physical networks under the control of the network layer.
  - ***Direct* Delivery** – occurs when the IP node forwards a packet to its final destination in the network.
  - ***Indirect* Delivery** – occurs when the IP node (host) forwards a packet to an intermediate node (IP router) because the final destination is not on a directly attached network.

To implement route-based packet forwarding, the router needs to obtain routes:

- A router discovers routes using multiple methods in which it selects the optimal route and installs it in its IP routing table.
- A router forwards IP packets based on routes in the IP routing table and manages path information by managing its IP routing table.



Routing Table (Huawei)

It is a database that contains information about which router network interface or port to place information to send it to a particular network segment.

- **Destination/Mask** indicates the destination network address and mask of a specific route.
  - For example, if the destination address is 1.1.1.1 and the mask is 255.255.255.0, the IP address of the subnet to which the host or router belongs is 1.1.1.0.
- **Protocol (Proto)** indicates the protocol type of the route, that is, the protocol through which a router learns the route.
- **Preference (Pre)** indicates the routing protocol preference of the route. It is used to compare routes from different routing protocols.
- **Cost** indicates the cost of the route. It is also known as the metric.
  - When multiple routes to the same destination have the same preference, the route with the lowest cost is selected as the optimal route.
- **Next Hop** indicates the local router's next-hop address of the route to the destination network.
  - This field specifies the next-hop device to which packets are forwarded.
- **Interface** indicates the outbound interface of the route.
  - This field specifies the local interface through which the local router forwards packets.

Run the **display ip routing-table** command to check the IP routing table.

Example:

```
<Quidway> display ip routing-table
Route Flags: R - relay, D - download to fib
------------------------------------------------------------------------------
Routing Tables: Public
         Destinations : 6        Routes : 6

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

        1.1.1.1/32  Static  60   0           D   0.0.0.0         NULL0
        2.2.2.2/32  Static  60   0           D   100.0.0.2       Vlanif100
      100.0.0.0/24  Direct  0    0           D   100.0.0.1       Vlanif100
      100.0.0.1/32  Direct  0    0           D   127.0.0.1       Vlanif100
      127.0.0.0/8   Direct  0    0           D   127.0.0.1       InLoopBack0
      127.0.0.1/32  Direct  0    0           D   127.0.0.1       InLoopBack0
```

Destination/Mask — Protocol — Route preference — Cost (Metric) — Flag — Next-hop address — Outbound interface

Protocol	Route Type	Default Preference
Direct	Direct route	0
Static	Static route	60
Dynamic	OSPF internal route	10
	OSPF external route	150

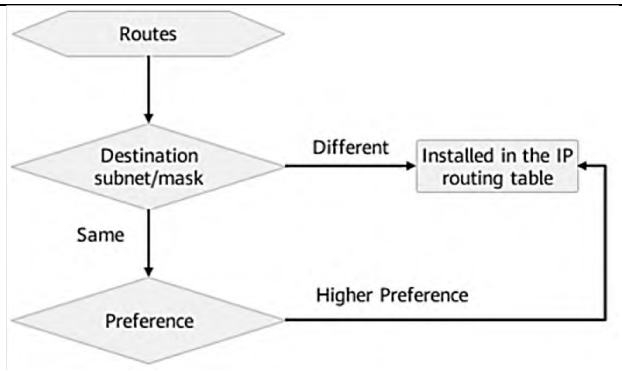
The table lists the preferences of some common routing protocols.

Computers also send packets through the optimal route. After a computer constructs IP packets to be sent out at the network layer, it searches its routing table for entries that match the packets' destination address. The process is the same for both routers and computers, and once the computer identifies the optimal route, it sends the packets out through this route.

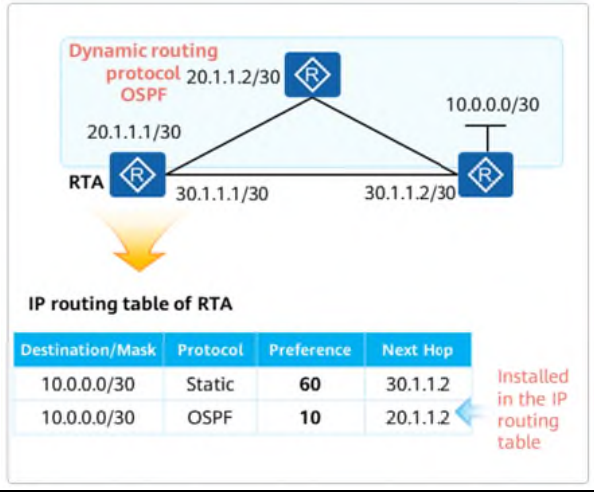
Route Preference

When a router obtains routes to the same destination subnet from different routing protocols, the router compares the preferences of these routes and prefers the route with the lowest preference value.

- Routes generated from different information sources are assigned different preferences.
- The smaller the preference value, the higher the preference.
- The router selects the optimal route for the assigned IP with the highest preference among all routes.
- The assigned IP has the same destination/mask generated from different information sources in which the route is injected into the IP routing table.
- The other routes remain in the deactivated state and do not appear in the IP routing table.
- Routes generated from different information sources have different default preference values. These values may differ between devices of different vendors.

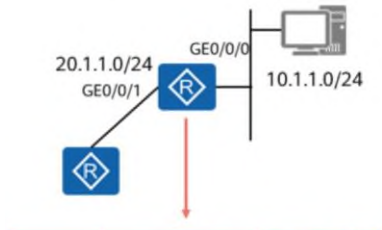


RTA discovers two routes to 10.0.0.0/30, one is an OSPF route and the other is a static route. In this case, RTA compares the preferences of the two routes and selects the route with the lowest preference value.



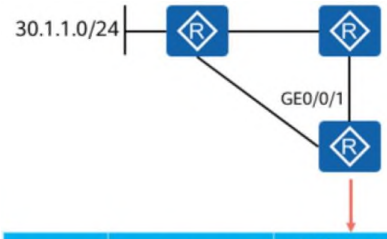
Types of Routing

- **Direct routes** are automatically generated by devices and point to local directly connected networks. These are the routes destined for the subnets to which directly connected interfaces belong.
- **Static routes** are manually configured by network administrators. This can be an effective method for networks with small and simple structures and reduce the effect of bandwidth and CPU resource consumption that occurs when other protocols are implemented.
- **Dynamic routes** are learned by dynamic routing protocols running on routers. This route uses routing protocols to talk to other routers and find out what networks they are attached to.



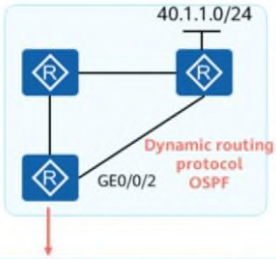
Protocol	Destination/Mask	Outbound Interface
Direct	10.1.1.0/24	GE0/0/0
Direct	20.1.1.0/24	GE0/0/1

Direct Route



Protocol	Destination/Mask	Outbound Interface
Static	30.1.1.0/24	GE0/0/1

Static Route



Protocol	Destination/Mask	Outbound Interface
OSPF	40.1.1.0/24	GE0/0/2

Dynamic Route