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E-Newsletter

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IP Routing with Cisco

Introduction :

The data networks that we use in our everyday lives to learn, play, and work range from small, local networks to large, global internetworks. At home, a user may have a router and two or more computers. At work, an organization may have multiple routers and switches servicing the data communication needs of hundreds or even thousands of PCs.

Routers forward packets by using information in the routing table. Routes to remote networks can be learned by the router in two ways: static routes and dynamic routes. In a large network with numerous networks and subnets, configuring and maintaining static routes between these networks requires a great deal of administrative and operational overhead. This operational overhead is especially cumbersome when changes to the network occur, such as a down link or implementing a new subnet. Implementing dynamic routing protocols can ease the burden of configuration and maintenance tasks and give the network scalability.

This article introduces static and dynamic routing protocols. It explores the benefits of using dynamic routing protocols, how different routing protocols are classified, and the metrics routing protocols use to determine the best path for network traffic. Other topics covered in this article include the characteristics of dynamic routing protocols and how the various routing protocols differ. Network professionals must understand the different routing protocols available in order to make informed decisions about when to use static or dynamic routing. They also need to know which dynamic routing protocol is most appropriate in a particular network environment.

Mrs. A. N. Chauhan,
Lecturer,
Department of
Computer Engineering

Static Routing :

Before identifying the benefits of dynamic routing protocols, consider the reasons why network professionals use static routing. Dynamic routing certainly has several advantages over static routing; however, static routing is still used in networks today. In fact, networks typically use a combination of both static and dynamic routing. Static routing has several primary uses, including:

- Providing ease of routing table maintenance in smaller networks that are not expected to grow significantly.
- Routing to and from a stub network, which is a network with only one default route out and no knowledge of any remote networks.
- Accessing a single default route (which is used to represent a path to any network that does not have a more specific match with another route in the routing table).

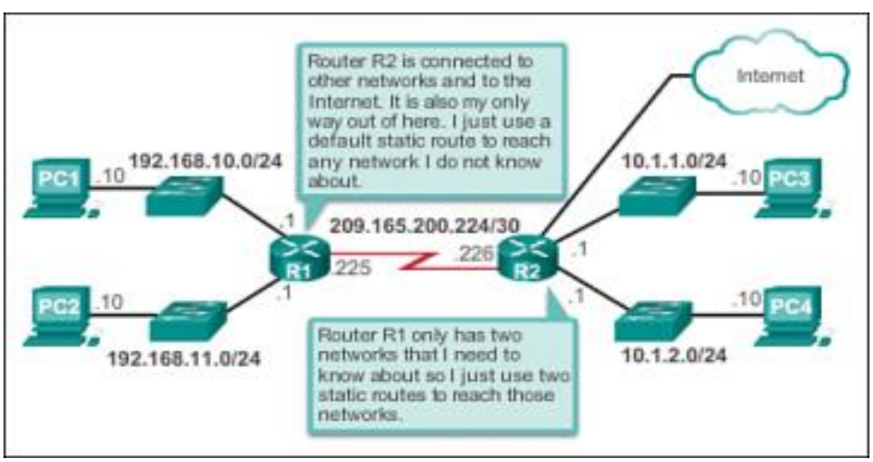

Fig1: Static routing scenario

Classification of Dynamic routing Protocol :

Routing protocols can be classified into different groups according to their characteristics. Specifically, routing protocols can be classified by their:

- **Purpose**: Interior Gateway Protocol (IGP) or Exterior Gateway Protocol (EGP)
- **Operation**: Distance vector protocol, link-state protocol, or path-vector protocol
- **Behaviour**: Classful (legacy) or classless protocol

For example, IPv4 routing protocols are classified as follows:

- **RIPv1 (legacy)**: IGP, distance vector, classful protocol
- **IGRP (legacy)**: IGP, distance vector, classful protocol developed by Cisco (deprecated from 12.2 IOS and later)
- **RIPv2**: IGP, distance vector, classless protocol
- **EIGRP**: IGP, distance vector, classless protocol developed by Cisco
- **OSPF**: IGP, link-state, classless protocol
- **IS-IS**: IGP, link-state, classless protocol
- **BGP**: EGP, path-vector, classless protocol

The ***classful routing protocols***, RIPv1 and IGRP, are legacy protocols and are only used in older networks. These routing protocols have evolved into the ***classless routing protocols***, RIPv2 and EIGRP, respectively. Link-state routing protocols are classless by nature.

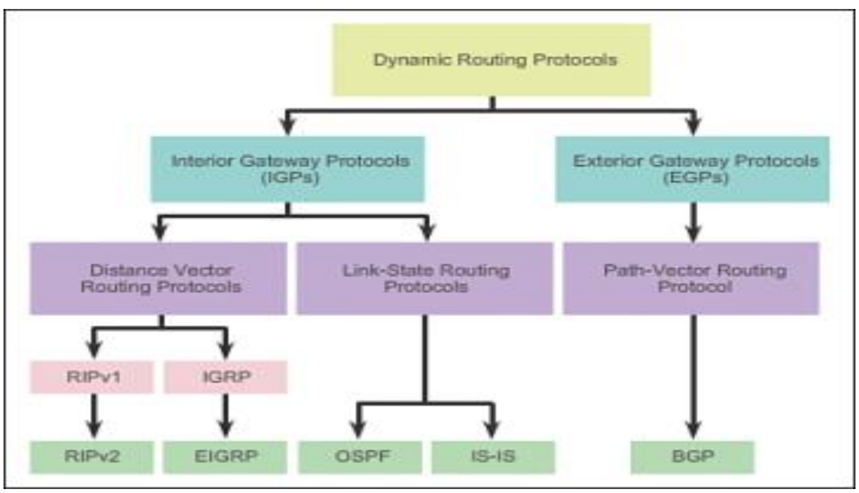

Fig2: Classification of Dynamic routing protocols

IGP and EGP Routing Protocols :

An ***autonomous system (AS)*** is a collection of routers under a common administration such as a company or an organization. An AS is also known as a routing domain. Typical examples of an AS are a company's internal network and an ISP's network.

The Internet is based on the AS concept; therefore, two types of routing protocols are required:

- ***Interior Gateway Protocols (IGP)***: Used for routing within an AS. It is also referred to as intra-AS routing. Companies, organizations, and even service providers use an IGP on their internal networks. IGPs include RIP, EIGRP, OSPF, and IS-IS.
- ***Exterior Gateway Protocols (EGP)***: Used for routing between autonomous systems. It is also referred to as inter-AS routing. Service providers and large companies may interconnect using an EGP. The Border Gateway Protocol (BGP) is the only currently viable EGP and is the official routing protocol used by the Internet.
- Following fig. provides simple scenarios highlighting the deployment of IGPs, BGP, and static routing.

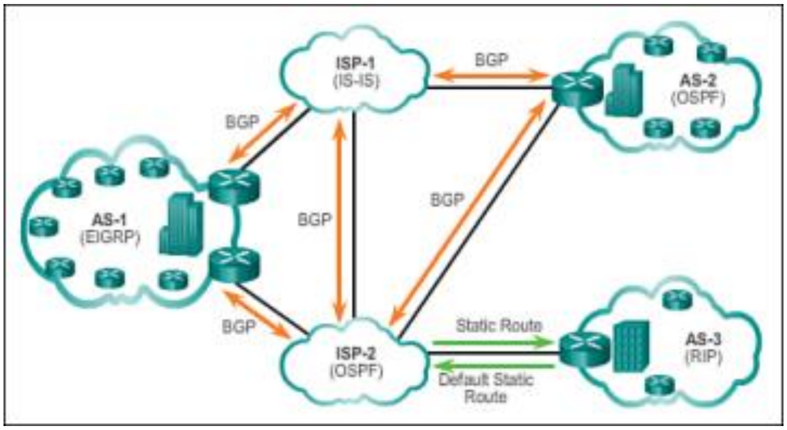

Fig3: deployment of IGPs, BGP, and static routing.

There are five individual autonomous systems in the scenario:

- **ISP-1**: This is an AS and it uses IS-IS as the IGP. It interconnects with other autonomous systems and service providers using BGP to explicitly control how traffic is routed.
- **ISP-2**: This is an AS and it uses OSPF as the IGP. It interconnects with other autonomous systems and service providers using BGP to explicitly control how traffic is routed.
- **AS-1**: This is a large organization and it uses EIGRP as the IGP. Because it is multihomed (i.e., connects to two different service providers), it uses BGP to explicitly control how traffic enters and leaves the AS.
- **AS-2**: This is a medium-sized organization and it uses OSPF as the IGP. It is also multihomed; therefore, it uses BGP to explicitly control how traffic enters and leaves the AS.
- **AS-3**: This is a small organization with older routers within the AS; it uses RIP as the IGP. BGP is not required because it is single-homed (i.e., connects to one service provider). Instead, static routing is implemented between the AS and the service provider.

Distance vector means that routes are advertised by providing two characteristics:

- **Distance**: Identifies how far it is to the destination network and is based on a metric such as the hop count, cost, bandwidth, delay, and more
- **Vector**: Specifies the direction of the next-hop router or exit interface to reach the destination

For example, in fig 4, R1 knows that the distance to reach network 172.16.3.0/24 is one hop and that the direction is out of the interface Serial 0/0/0 toward R2.

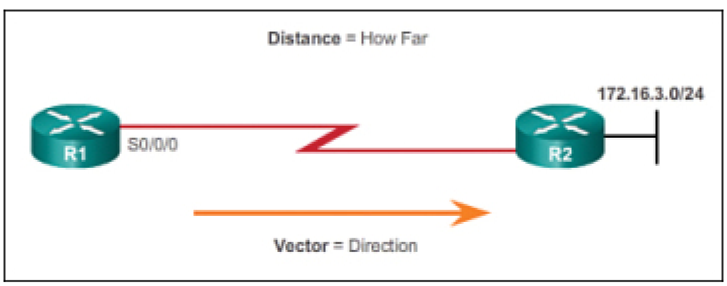

Fig4:The Meaning of Distance Vector

A router using a ***distance vector routing protocol*** does not have the knowledge of the entire path to a destination network. Distance vector protocols use routers as sign posts along the path to the final destination. The only information a router knows about a remote network is the distance or metric to reach that network and which path or interface to use to get there. Distance vector routing protocols do not have an actual map of the network topology.

There are four distance vector IPv4 IGPs:

- **RIPv1**: First generation legacy protocol
- **RIPv2**: Simple distance vector routing protocol

- **IGRP**: First generation Cisco proprietary protocol (obsolete and replaced by EIGRP)
- **EIGRP**: Advanced version of distance vector routing

Link state routing Protocol :

In contrast to distance vector routing protocol operation, a router configured with a ***link-state routing protocol*** can create a complete view or topology of the network by gathering information from all of the other routers.

To continue our analogy of sign posts, using a link-state routing protocol is like having a complete map of the network topology. The sign posts along the way from source to destination are not necessary, because all link-state routers are using an identical map of the network. A link-state router uses the link-state information to create a topology map and to select the best path to all destination networks in the topology.

RIP-enabled routers send periodic updates of their routing information to their neighbours. Link-state routing protocols do not use periodic updates. After the network has converged, a link-state update is only sent when there is a change in the topology. For example, in Fig 5 the link-state update is sent when the 172.16.3.0 network goes down.

Link-state protocols work best in situations where:

- The network design is hierarchical, usually occurring in large networks
- Fast convergence of the network is crucial
- The administrators have good knowledge of the implemented link-state routing protocol

There are two link-state IPv4 IGPs:

- **OSPF**: Popular standards-based routing protocol
- **IS-IS**: Popular in provider networks

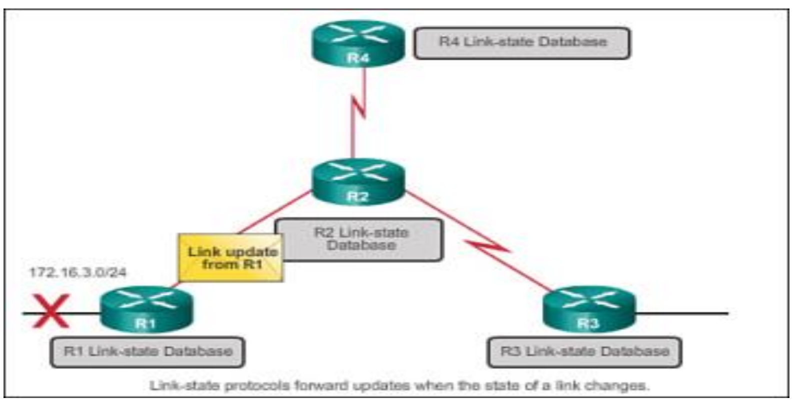

Fig5: Link state operation

Classful Routing Protocols :

The biggest distinction between classful and classless routing protocols is that classful routing protocols do not send subnet mask information in their routing updates. Classless routing protocols include subnet mask information in the routing updates.

The two original IPv4 routing protocols developed were RIPv1 and IGRP. They were created when network addresses were allocated based on classes (i.e., class A, B, or C). At that time, a routing protocol did not need to include the subnet mask in the routing update, because the network mask could be determined based on the first octet of the network address.

Only RIPv1 and IGRP are classful. All other IPv4 and IPv6 routing protocols are classless. Classful addressing has never been a part of IPv6.

The fact that RIPv1 and IGRP do not include subnet mask information in their updates means that they cannot provide variable-length subnet masks (VLSMs) and Classless Inter-Domain Routing (CIDR).

Classful routing protocols also create problems in discontinuous networks. A discontinuous network is when subnets from the same classful major network address are separated by a different classful network address.

To illustrate the shortcoming of classful routing, refer to the topology in Fig 6.

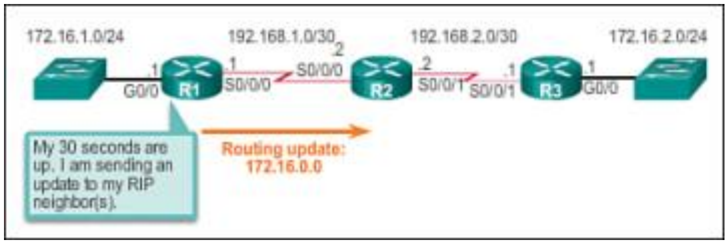

Fig6: R1 Forwards a Classful Update to R2

Notice that the LANs of R1 (172.16.1.0/24) and R3 (172.16.2.0/24) are both subnets of the same class B network (172.16.0.0/16). They are separated by different classful network addresses (192.168.1.0/30 and 192.168.2.0/30).

When R1 forwards an update to R2, RIPv1 does not include the subnet mask information with the update; it only forwards the class B network address 172.16.0.0.

R2 receives and processes the update. It then creates and adds an entry for the class B 172.16.0.0/16 network in the routing table, as shown in Fig 7.

```
R2# show ip route | begin Gateway
Gateway of last resort is not set

R        172.16.0.0/16 [120/1] via 192.168.1.1, 00:00:11,
         Serial0/0/0
         192.168.1.0/24 is variably subnetted, 2 subnets,
         2 masks
C           192.168.1.0/30 is directly connected, Serial0/0/0
L           192.168.1.2/32 is directly connected, Serial0/0/0
         192.168.2.0/24 is variably subnetted, 2 subnets, .
         2 masks
C           192.168.2.0/30 is directly connected, Serial0/0/1
L           192.168.2.2/32 is directly connected, Serial0/0/1
R2#
```

Fig7: R2 Adds the Entry for 172.16.0.0 via R1

When R3 forwards an update to R2, it also does not include the subnet mask information and therefore only forwards the classful network address 172.16.0.0.

R2 receives and processes the update and adds another entry for the classful network address 172.16.0.0/16 to its routing table, as shown in fig 8. When there are two entries with identical metrics in the routing table, the router shares the load of the traffic equally among the two links. This is known as load balancing.

```
R2# show ip route | begin Gateway
Gateway of last resort is not set

R        172.16.0.0/16 [120/1] via 192.168.2.1, 00:00:14,
                       Serial0/0/1
                       [120/1] via 192.168.1.1, 00:00:16,
                       Serial0/0/0
         192.168.1.0/24 is variably subnetted, 2 subnets,
         2 masks
C           192.168.1.0/30 is directly connected, Serial0/0/0
L           192.168.1.2/32 is directly connected, Serial0/0/0
         192.168.2.0/24 is variably subnetted, 2 subnets,
         2 masks
C           192.168.2.0/30 is directly connected, Serial0/0/1
L           192.168.2.2/32 is directly connected, Serial0/0/1
R2#
```

Fig8: R2 Adds the Entry for 172.16.0.0 via R3 R2 Adds the Entry for 172.16.0.0 via R3

Discontinuous networks have a negative impact on a network. For example, a ping to 172.16.1.1 would return "U.U.U" because R2 would forward the first ping out its Serial 0/0/1 interface toward R3, and R3 would return a Destination Unreachable (U) error code to R2. The second ping would exit out of R2's Serial 0/0/0 interface toward R1, and R1 would return a successful code (.). This pattern would continue until the **ping** command is done.

Classless routing protocol :

Modern networks no longer use classful IP addressing and the subnet mask cannot be determined by the value of the first octet. The classless IPv4 routing protocols (RIPv2, EIGRP, OSPF, and IS-IS) all include the subnet mask information with the network address in routing updates. Classless routing protocols support VLSM and CIDR.

IPv6 routing protocols are classless. The distinction whether a routing protocol is classful or classless typically only applies to IPv4 routing protocols. All IPv6 routing protocols are considered classless because they include the prefix-length with the IPv6 address.

Fig 9 through 11 illustrate how classless routing solves the issues created with classful routing.

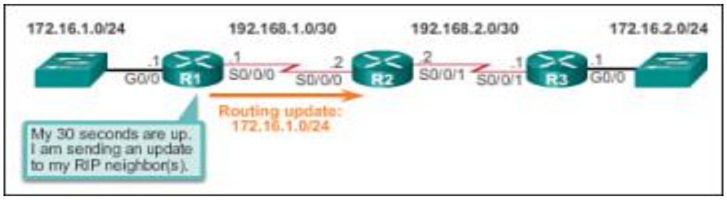

Fig9: R1 Forwards a Classless Update to R2

```
R2# show ip route | begin Gateway
Gateway of last resort is not set

      172.16.0.0/24 is subnetted, 1 subnets
R        172.16.1.0 [120/1] via 192.168.1.1, 00:00:06,
         Serial0/0/0
      192.168.1.0/24 is variably subnetted, 2 subnets,
      2 masks
C        192.168.1.0/30 is directly connected, Serial0/0/0
L        192.168.1.2/32 is directly connected, Serial0/0/0
R2#
```

Fig10: R2 Adds the Entry for the 172.16.1.0/24 Network via R1

```
R2# show ip route | begin Gateway
Gateway of last resort is not set

      172.16.0.0/24 is subnetted, 2 subnets
R        172.16.1.0 [120/1] via 192.168.1.1, 00:00:03,
         Serial0/0/0
R        172.16.2.0 [120/1] via 192.168.2.1, 00:00:03,
         Serial0/0/1
      192.168.1.0/24 is variably subnetted, 2 subnets,
      2 masks
C        192.168.1.0/30 is directly connected, Serial0/0/0
L        192.168.1.2/32 is directly connected, Serial0/0/0
      192.168.2.0/24 is variably subnetted, 2 subnets,
      2 masks
C        192.168.2.0/30 is directly connected, Serial0/0/1
L        192.168.2.2/32 is directly connected, Serial0/0/1
R2#
```

Fig 11:Entry for the 172.16.2.0/24 Network via R3

In the ***discontinuous network*** design of fig 8, the classless protocol RIPv2 has been implemented on all three routers. When R1 forwards an update to R2, RIPv2 includes the subnet mask information with the update 172.16.1.0/24.

In fig 9, R2 receives, processes, and adds two entries in the routing table. The first line displays the classful network address 172.16.0.0 with the /24 subnet mask of the update. This is known as the parent route. The second entry displays the VLSM network address 172.16.1.0 with the exit and next-hop address. This is referred to as the child route. Parent routes never include an exit interface or next-hop IP address.

When R3 forwards an update to R2, RIPv2 includes the subnet mask information with the update 172.16.2.0/24.

R2 receives, processes, and adds another child route entry 172.16.2.0/24 under the parent route entry 172.16.0.0, as shown in fig 10.

A ping from R2 to 172.16.1.1 would now be successful.

Routing protocol characteristics :

Routing protocols can be compared based on the following characteristics:

- **Speed of convergence**: Speed of convergence defines how quickly the routers in the network topology share routing information and reach a state of consistent knowledge. The faster the convergence, the more preferable the protocol. Routing loops can occur when inconsistent routing tables are not updated due to slow convergence in a changing network.
- **Scalability**: Scalability defines how large a network can become, based on the routing protocol that is deployed. The larger the network is, the more scalable the routing protocol needs to be.
- **Classful or classless (use of VLSM)**: Classful routing protocols do not include the subnet mask and cannot support ***variable-length subnet mask (VLSM)***. Classless routing protocols include the subnet mask in the updates. Classless routing protocols support VLSM and better route summarization.
- **Resource usage**: Resource usage includes the requirements of a routing protocol such as memory space (RAM), CPU utilization, and link bandwidth utilization. Higher resource requirements necessitate more powerful hardware to support the routing protocol operation, in addition to the packet forwarding processes.
- **Implementation and maintenance**: Implementation and maintenance describes the level of knowledge that is required for a network administrator to implement and maintain the network based on the routing protocol deployed.
- Following table summarizes the characteristics of each routing protocol.
- ***Table Comparing Routing Protocols***

	Distance Vector	Link-State				
	RIPv1	**RIPv2**	**IGRP**	**EIGRP**	**OSPF**	**IS-IS**
Speed of Convergence	Slow	Slow	Slow	Fast	Fast	Fast
Scalability – Size of Network	Small	Small	Small	Large	Large	Large
Use of VLSM	No	Yes	No	Yes	Yes	Yes
Resource Usage	Low	Low	Low	Medium	High	High
Implementation and Maintenance	Simple	Simple	Simple	Complex	Complex	Complex

Routing Protocol Metrics :

There are cases when a routing protocol learns of more than one route to the same destination. To select the best path, the routing protocol must be able to evaluate and differentiate between the available paths. This is accomplished through the use of routing ***metrics***.

A metric is a measurable value that is assigned by the routing protocol to different routes based on the usefulness of that route. In situations where there are multiple paths to the same remote network, the routing metrics are used to determine the overall "cost" of a path from source to destination. Routing protocols determine the best path based on the route with the lowest cost.

Different routing protocols use different metrics. The metric used by one routing protocol is not comparable to the metric used by another routing protocol. Two different routing protocols might choose different paths to the same destination.

For example, assume that PC1 wants to send a packet to PC2. In fig 12, the RIP routing protocol has been enabled on all routers and the network has converged. RIP makes a routing protocol decision based on the least number of hops. Therefore, when the packet arrives on R1, the best route to reach the PC2 network would be to send it directly to R2 even though the link is much slower that all other links.

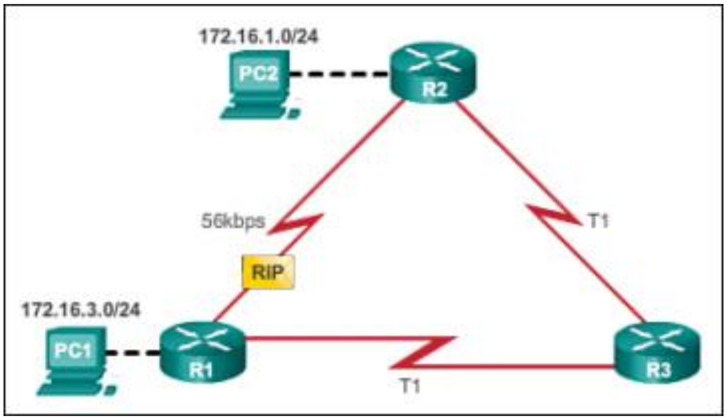

Fig 12: RIP Uses Shortest Hop Count Path

In fig 13, the OSPF routing protocol has been enabled on all routers and the network has converged. OSPF makes a routing protocol decision based on the best bandwidth. Therefore, when the packet arrives on R1, the best route to reach the PC2 network would be to send it to R3, which would then forward it to R2.

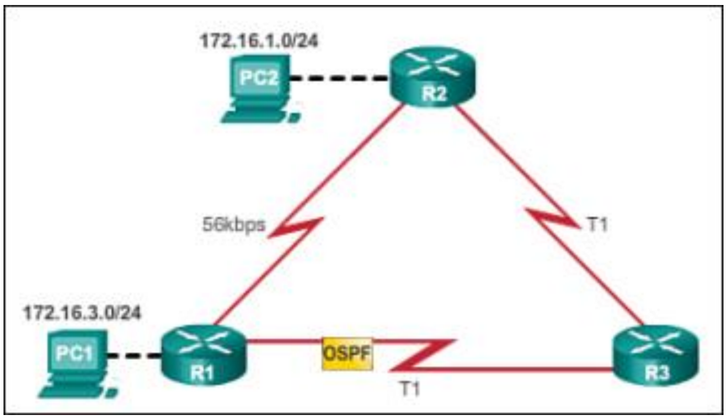

Fig 13: OSPF Uses Faster Links

Conclusion :

Routing protocols are classified as static and dynamic routing protocol. Dynamic routing protocol is classified based on purpose, operation and behaviour. All routing protocols have different metrics and characteristic and for these reason different routing protocols are used in different scenario which distinguishes based on size and speed, classful and classless. Network professionalsmustunderstand when to use static and dynamic routing protocols depends on network scenario and its requirements.

References :

1. www.ciscopress.com
2. www.freeccnastudyguide.com
3. www.en.wikipedia.org

QUIZ (9)

Q-1 The least perfect square, which is divisible by each of 21, 36 and 66 is:

A. 213444 B. 214344 C. 214434 D. 231444

Q-2 A two-digit number is such that the product of the digits is 8. When 18 is added to the number, then the digits are reversed. The number is:

A. 18 B. 24 C. 42 D. 81

Answer of Last Quiz (8)

(D) 16

Solution:- Starting bottom left and moving clockwise around the triangle, numbers follow the sequence of Square Numbers. So correct answer is **(D) 16**

Student Corner:

Topic : Success Poem

Success eludes people,
Who don't try in life,
Success is achieved,
With the right hard-work & strive.
Success come easy to those who want it,
Eventually you will reach your destination,
Which will make your journey a hit.

Anuradha A. Patil
Enrollment No. : 196150307559
Department of Computer Engineering

Article Name:What is Life ?

- *Life is an opportunity,benefit from it.*
- *Life is beauty,admire it.*
- *Life is a dream,realize it.*
- *Life is a challenge, meet it.*
- *Life is a duty, complete it.*
- *Life is a game, play it.*
- *Life is a promise,fulfill it.*
- *Life is a sorrow,overcome it.*
- *Life is a song,sing it.*
- *Life is a struggle,accept it.*
- *Life is a tragedy, confront it.*
- *Life is a adventure,dare it.*
- *Life is luck,make it.*
- *Life is too precious, don't destroy it.*
- *Life is life, fight for it.*

Laxmi Sharma
Enrollment No. : 196150307532
Department of Computer Engineering