Internet Routing

Internetworking – Lecture 6

Internet Routing

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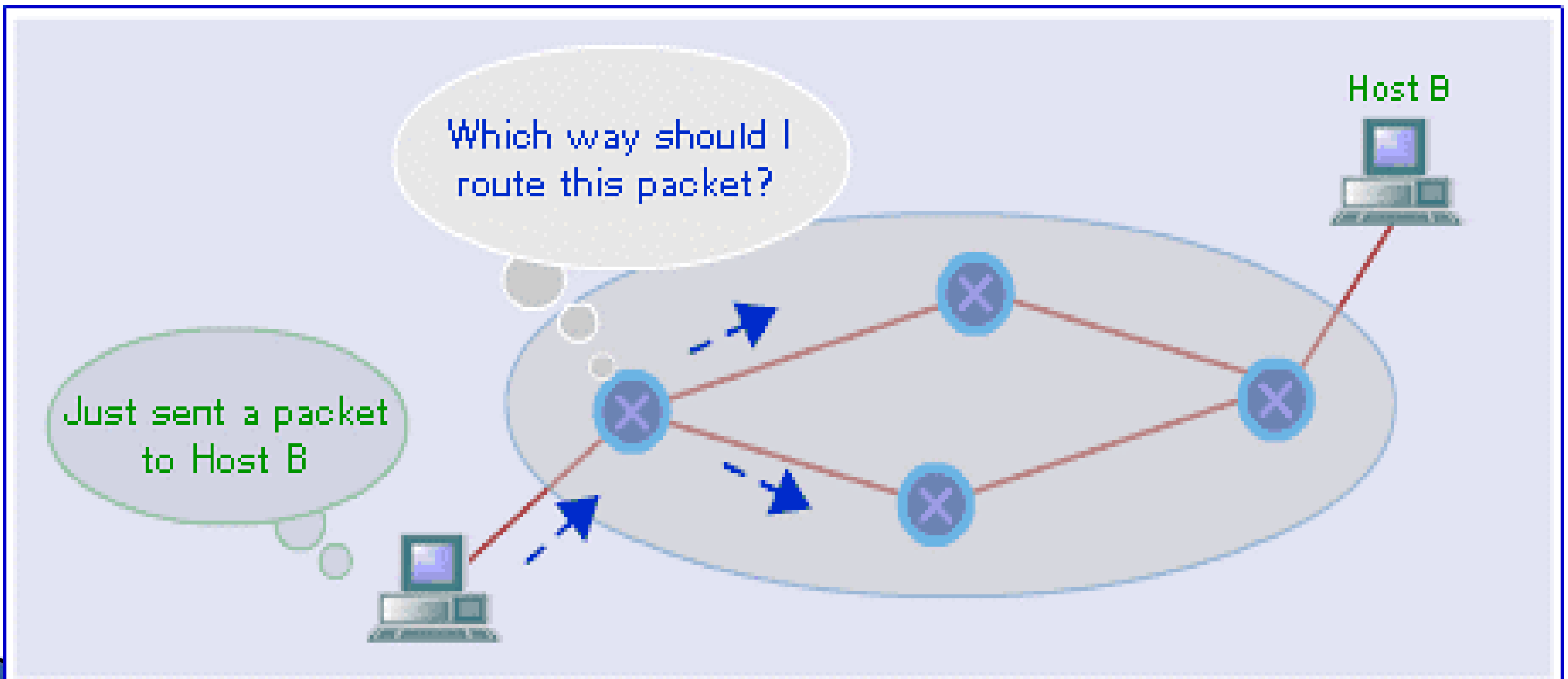
  - What is Routing
  - What if’s – the Complications of Routing
  - Routing Tables
  - An automated routing solution
  - Defining a routing Protocol
  - Design Considerations
  - Metrics of Routing Protocols
  - Categorising Routing protocols

What is Routing?

- The act of forwarding network packets from a source network to a destination network



What If's', Complications of Routing?

- When should you route a packet?
- What is the best route to take?
  - How do you know?
- Does the topology change?
  - If it does change what then?
- What if there is a fault in the network?
- What if the destination does not exist?
- If a packet has a different network destination network to the host then it is determined that it needs to be forwarded to another network via the IP Address.
- It is the router that holds the internetwork logic to decide how to forward the packet.

Routing a Packet to a Destination ?

- Workstation **A**, sends an email to Workstation **B**

↓

- Workstation **A** determines if Workstation **B** is on the same network by checking the local routing table

↓

- Determines that Workstation **B** is on a different network

↓

- Send packet to the default Gateway

Static Routing

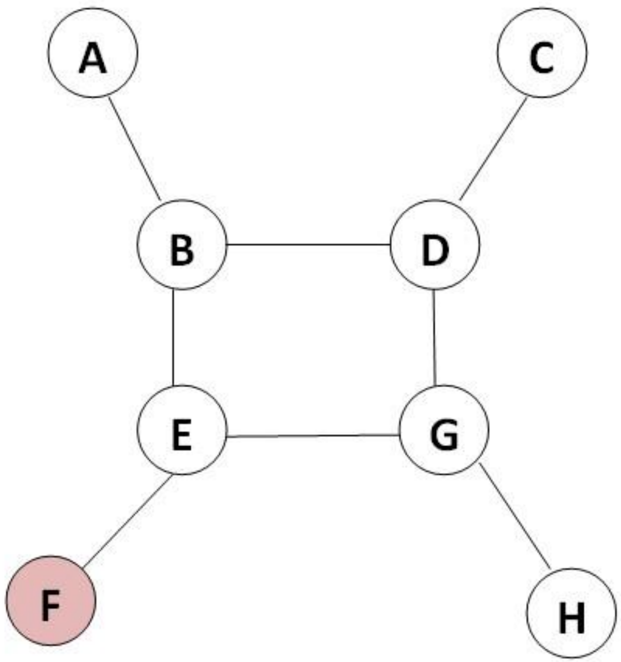
- Manually populated routing tables
- An almost impossible task to maintain in modern networks
- Ideal for small stable networks without redundant network links
- Dynamically routing protocols use up network resources learning where all the nodes are.
- Often static routing is coupled with dynamically routing
- In CISCO static routes can be configured with IP route commands

Anatomy of a Routing Table

Code	Network, Mask	AD/Metric	Next Hop	Interface
O	10.0.0.0/8	110/20	200.1.1.1	S0
O	172.16.0.0/16	100/15	200.1.1.1	S0
O	192.168.1.0/24	100/20	200.2.2.2	S1
C	210.1.1.4/30	0/0	Directly connected	E0

- **Code**: what process discovered the route
- **Network Mask:** address of destination network and its subnet mask
- **Administrative Distance/Metric**: used to select the best route
- **Next Hop:** IP address of the next hop router
- **Interface:** the interface that the packet will be forwarded on

A simple scenario…



- Send a packet from node F to node C
- Which one is the optimal path?
  - What if a link fails?
  - What if a router fails?
- Can you make an informed decision?

An Automated Routing Solution

- We established that static routing is unworkable over the Internet;
- The more complex the networks the harder it would be to manually manipulate the routing tables;
- Therefore an automated approach to the problem is required

Key Features of Dynamic Routing

- Key features of dynamic routing are:
  - They learn about the network
  - Automatically modify the routing tables
  - Dynamic routing should be deployed on any sized network

What is a Routing Protocol?

- A set of rules that allow 2 or more routers to exchange information about the networks they are connected to.
- It is based on an algorithm to solve the communication problem
- Therefore… it is **a process that runs on the router**
- Algorithms used are based on <u>graph theory</u>
  - e.g. the router is the dot and they link the networks

Historical Links

- Early protocols are based on work by R.Bellman; L.R.Ford; Edsger Dijkstra
- Bellman–Ford – Distance Vector algorithms
- Dijkstra – Shortest Path first algorithm

- **No one protocol has solved all the routing problems to-date!**

Routing Protocols Design Considerations

- What networking issues need to be taken into consideration?
- How does the router collate the network data to populate the routing table?
  - The router needs to be able to communicate with others
  - It needs to pass its own knowledge of networks to another router
  - It must be able to receive this data
  - A common language of communication is required
  - Needs to communicate with routers, identify its status and its known routes

Routing communication

- The language and vocabulary used is unique to a particular protocol
- Communication can only be between routers using the same protocol
- Routers supporting different protocols can't communicate between each other

Routing Paths – Convergence

- If a change to the network occurs, it means the routing table needs updating. The time it takes until this happens is called “CONVERGENCE”

- What changes triggers an update?
  - If one or more network links fail, every other router needs to be informed
  - If a router crashes it can have a serious impact on the network.

Characteristics of a Routing Protocol

- A routing Protocol must incorporate:
  - –Robustness
  - –Optimisation
  - –Flexibility
  - –Speed of convergence
  - –Avoidance of routing loops
  - –Support for classless addressing
  - –Simplicity

Metric of Routing Protocols

- How a routing protocol decides which route is best especially if more than 1 route is discovered
  - Each route is assigned a metric value
  - There are numerous factors that the protocols may take into consideration when assigning a metric value

Metric of Routing Protocols

- **Hop Count**:
  - Number of routers to traverse in order to reach the destination
- **Path Length**:
  - A refinement of the hop count, Sum of per-link costs
- **Bandwidth**:
  - Speed of the link between routers
- **Delay**:
  - Time in milliseconds to cross a link
- **Load**:
  - Congestion on link due to traffic
- **Reliability**:
  - Based on bit error rates of path

- <u>Not all routing protocols use all the variables</u>

Categorising Dynamic Routing Protocols

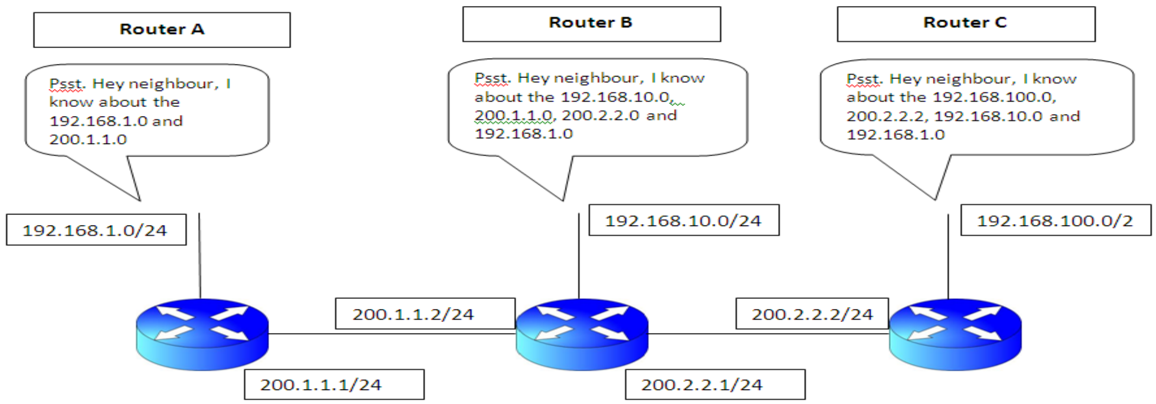
- Routing protocols are categorised by its designed purpose
- **Interior Gateway Protocols:**
  - Developed to facilitate routing **within** autonomous systems
- **Exterior Gateway Protocols**:
  - Developed to facilitate routing **between** autonomous systems
- Most protocols are interior protocols
  - (Autonomous Systems is a system under a single administration control – e.g the university network)

Distance Vector

"Routing by Rumour"

- Routing information is received from immediate router neighbours only
- Sent as routing update packets via broadcasting
- These updates are then added to the router tables
- Then pass this information to their own neighbouring routers
- Finally, all routers learn the path to all networks – network is converged

View of Distance Vector Protocol Communication



- Each router informs its neighbour of its directly connected network
- Includes networks the router has learned from other neighbours
- Share the metrics of the routes it knows
- In distance vector protocols the metrics is distance initially hop count – e.g. how many routers the packet has to cross to reach its destination, 3 hops = the metric 3

Distance Vector Protocol

- If two or more paths are discovered for the same destination, the route with the lowest hop count would win and be added to the routing table

- Others have used bandwidth and delay to determine the metric value

Vectors

- In distance vector protocols, vectors are direction of the next hop
- Router stores the IP address of the (next hop) router with the lower cost path
- Next hop is the next location (router) packets will be forwarded towards the destination

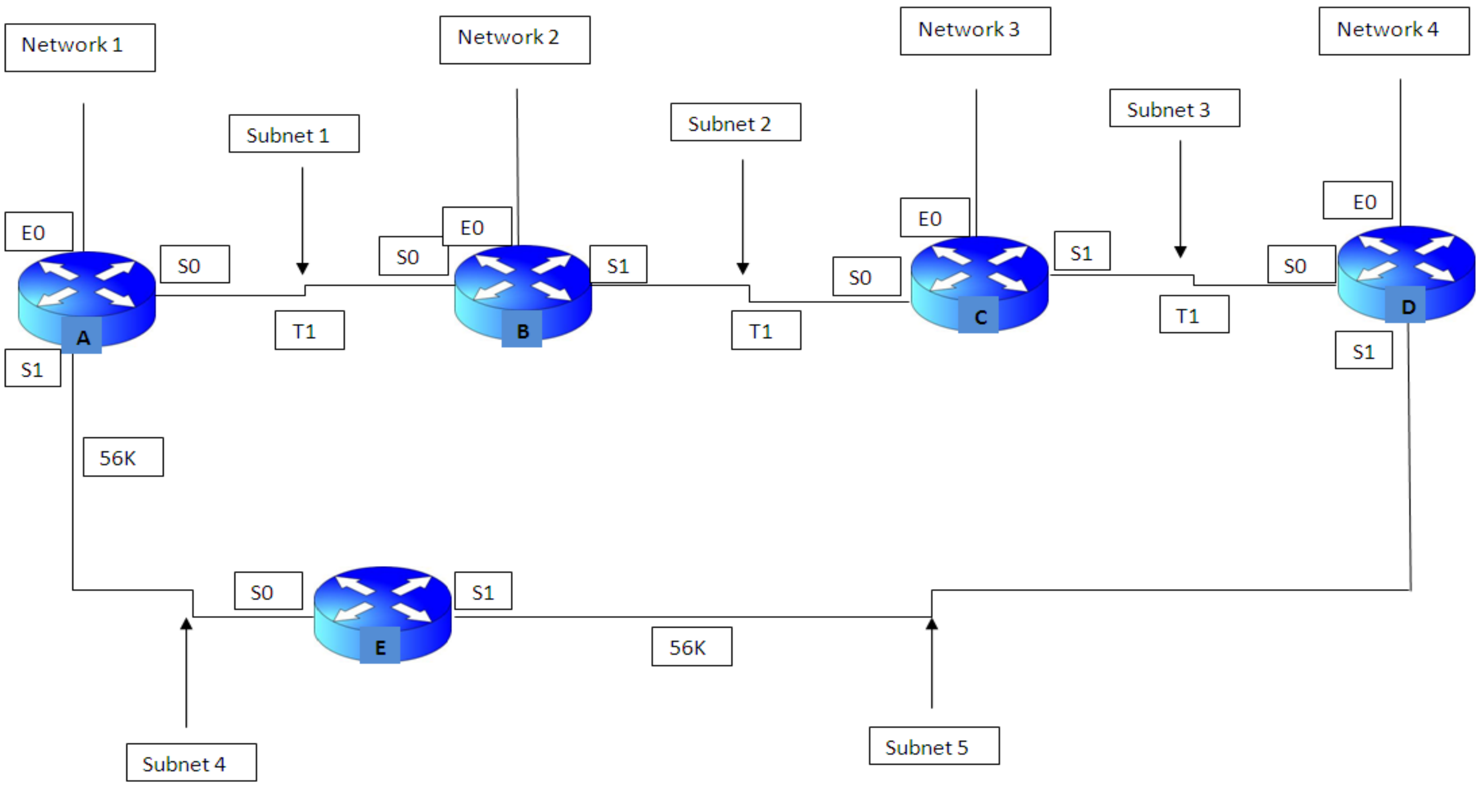
- Metric = distance
- Direction = vector

Distance Vector

Metric

- Some protocols use hope count as the determinate of the distance to the destination, e.g. the lower the hop count the better the route
- Works well on networks with a stable transmission speed on network links – smaller controlled systems
- In larger complex systems with varying bandwidth, hop counts in isolation does not work.

Determine the best path using the hop count



Router A

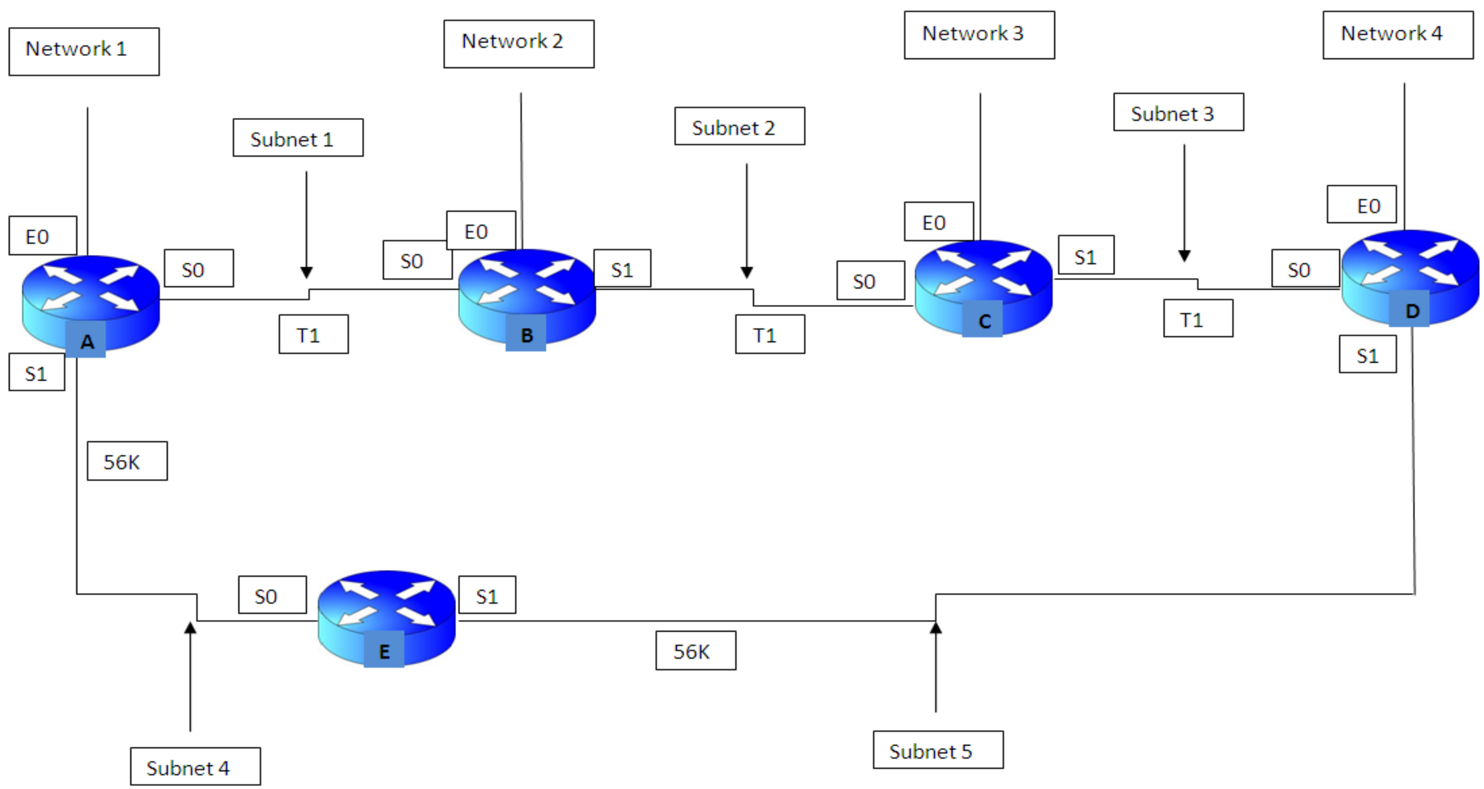
- What does router A know?
- Its connected to network 1 via Ethernet (port) 0
- Its connected to subnet1 via serial (port) 0
- Its connected to subnet 4 via serial 1
- Network 2 is 1 hop away via serial 0
- Network 2 is 4 hops away via serial 1
- Network 3 is 2 hops away via serial 0
- Network 3 is 3 hops away via serial 1
- Network 4 is 3 hops away via serial interface 0
- Network 4 is 2 hops away via serial 1

Determine the Path

- If packet X is at network 1 and its destination is network 4

- Router A identifies 2 paths:
  - Path 1: 3 hops away serial 0
  - Path 2: 2 hops away serial 1
- With distance vector protocols path 2 will be chosen based on hop count, even though path 1 is faster.
- The limitations of this was identified therefore bandwidth was used

Determine the best path now using both hop and bandwidth



Router A

- Its connected to network 1 via Ethernet 0
- Its connected to subnet1 via serial 0
- Its connected to subnet 4 via serial 1
- Network 2, 1,544kbps via serial 0
- Network 2, 2 X 56K links and two 1,544kbps via serial 1
- Network 3 1,544kbps via serial 0
- Network 3 2 X 56k, 1 X 1,544kbps via serial 1
- Network 4 3 X 1,544kbps serial 0
- Network 4 2 X 56K via serial 1
- Using bandwidth and hops, the 3 hops on 1,544kbps links would be selected

Distance Vector problems..

- Hop count and bandwidth does improve the efficiency of the routing
- One problem is distance vector consume network resources since the full routing tables can be broadcast every 30 seconds by default
- Routing tables can be very large
- This process can also affect convergence due to delay incurred in sending so many update packets
- Distance vector protocols are prone to loops
- Routing loops are when two routers point to each other as the path to a network
- Therefore the packets bounce between the two routers

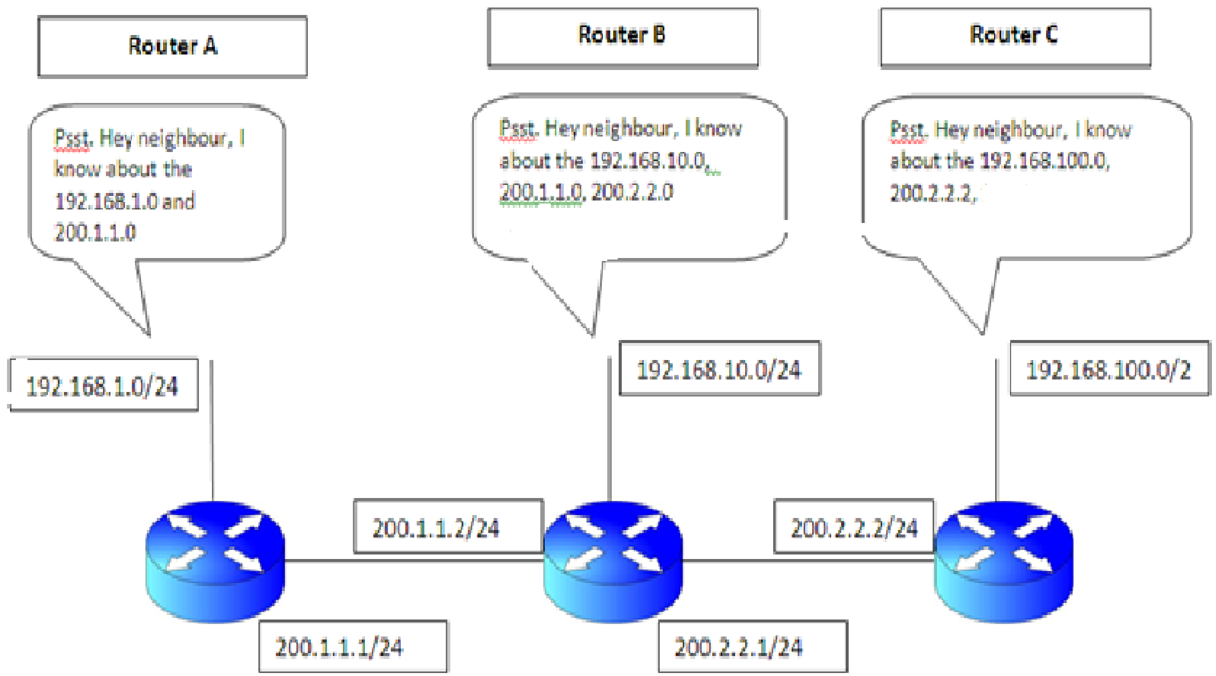
Link state Routing Protocols

- Known as shortest path first
- Based on the Dijkstra algorithm
- Works on first-hand information not "routing by Rumours"
- Data is transmitted via Link State Advertisement (LSA)
- It includes the state of the directly connected routers Links
- Link state determines how many routers are out there and what networks are connected to them
- Each router ends up with a topology map of the system

Link-State Routing Protocols

- As only the link state is communicated and not the whole routing table,
  - Speed of convergence is improved!
- Table updates are initiated on a change of a link state only
  - Minimises unnecessary use of available bandwidth
- When the Dijkstra algorithm is run the shortest quickest route is determined to populate the routing table
- This is less prone to routing loops as each router has a complete map of the system
- Routers are not tricked into routing packets back to themselves.

Link state Routing Protocols



Benefits of Link State algorithms..

- Update packets can be sent via multicast rather than broadcast
- Reduces processing requirements on routers
- Can be configured in a hierarchical fashion
- Reduces unnecessary traffic
- Eliminates Routing Loops

Multiple Routing Paths?

- Multiple paths to a network may exist
- Not all routing protocols can actually install multiple paths
- If only one path can be installed into the routing table it should be the best path. If this failed then the next best would be installed
- If a multipath routing protocol is used a primary path can be identified also packets can be routed via multipaths to reduce throughput and load balancing – multiplexing
- This improves network performance and reliability

Hierarchical Routing

- To reduce routing update on network bandwidth, routers can be configured in a hierarchical topology
- Thereby routers are grouped into AREAS and some of the updates are confined to those areas
- Areas will communicate as well but the updates are segregated on a need to know basis
- Helps with the management of the network resources

Route Summarisation

- The concept of reducing the number of entries in route tables while still facilitating paths to all known networks
- Using subnetting means the route table increases
- Collating the routing data takes up network resources e.g. bandwidth
- Large route tables means the lookup process takes longer
- It also requires larger memory and CPU resources
- Route summarisation defines a single path to multiple subnets
  - Reduces the table size

Route Summarisation

- Summarisation can be employed at the address assignment level and organisation level
- Auto-summarisation is available – the routing protocol summarises routes by default
  - Auto-summarisation can be disabled

Routing issue

- A key problem in routing is a routing-loop
  - A packet travelling endlessly around the network without reaching its destination
  - The routing table does not hold the most up to date information
  - Routing decisions are based on incomplete/incorrect information
  - delay in network convergence is often the main cause of this.

Summary

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- Routing Tables
- An automated routing solution
- Defining a routing Protocol
- Design Considerations
- Metrics of Routing Protocols
- Categorising Routing protocols