Module 3 – Network Layer

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Network Layer

The data unit in network layer is known as **Packet.**

The basic function of the network layer is the delivery of the packet from source network to the destination network.

There are algorithms that will help us to determine the path in which the transfer should take place.

Special hardware devices known as **Routers** does this job.

Network Layer operation.

The packets follow a **store and forward** mechansim.

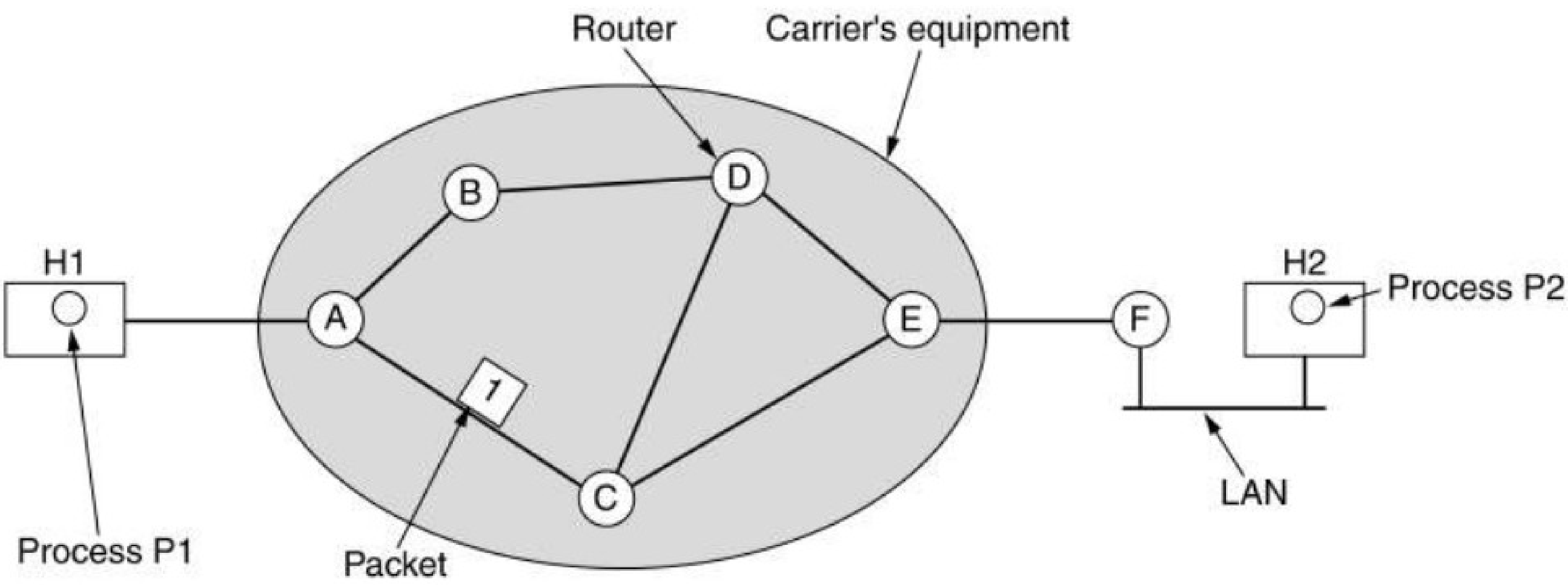
There will be intermediate routers in the path.

The packets that is incoming to the router will be stored and will be forwarded in the best possible path.

This mechanism of delivering the packets on the best possible path is referred to as **switching**.

Since the packets are stored before switching the entire process is known as **store and forward switching.**

Network layer environmment



The establishment of path

A packet needs to travel on the best possible path .

There are two startegies to forward the packet.

Routing algorithms determine the path in both cases.

1.Establish the full path before sending the packet.

- The path is known as **Virtual Circuit subnet**.

-It is a connection oriented service as initial setup is involved.

2.Just forward the packet and determine the best path for individual packets.

-The path is known as **Datagram subnet**.

-It is a connectionless service as no prior setup is involved.

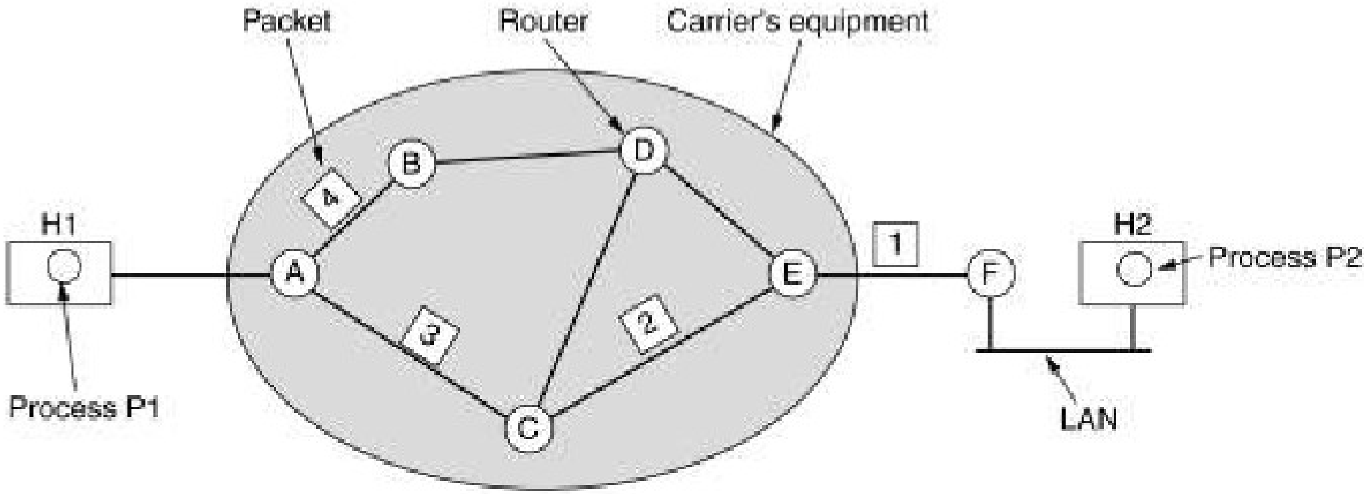
Datagram Subnet

In datagram subnet individual packets from source to destination may follow different paths.

This is because the routing algorithm might have learned about another best path.

Or path older path might have issues such as delay.

Every router maintains a table with the next best path to destination.



A's table

initially		later		C's table		E's table	
A	–	A	–	A	A	A	C
B	B	B	B	B	A	B	D
C	C	C	C	C	–	C	C
D	B	D	B	D	D	D	D
E	C	E	B	E	E	E	–
F	C	F	B	F	E	F	F

Dest. Line

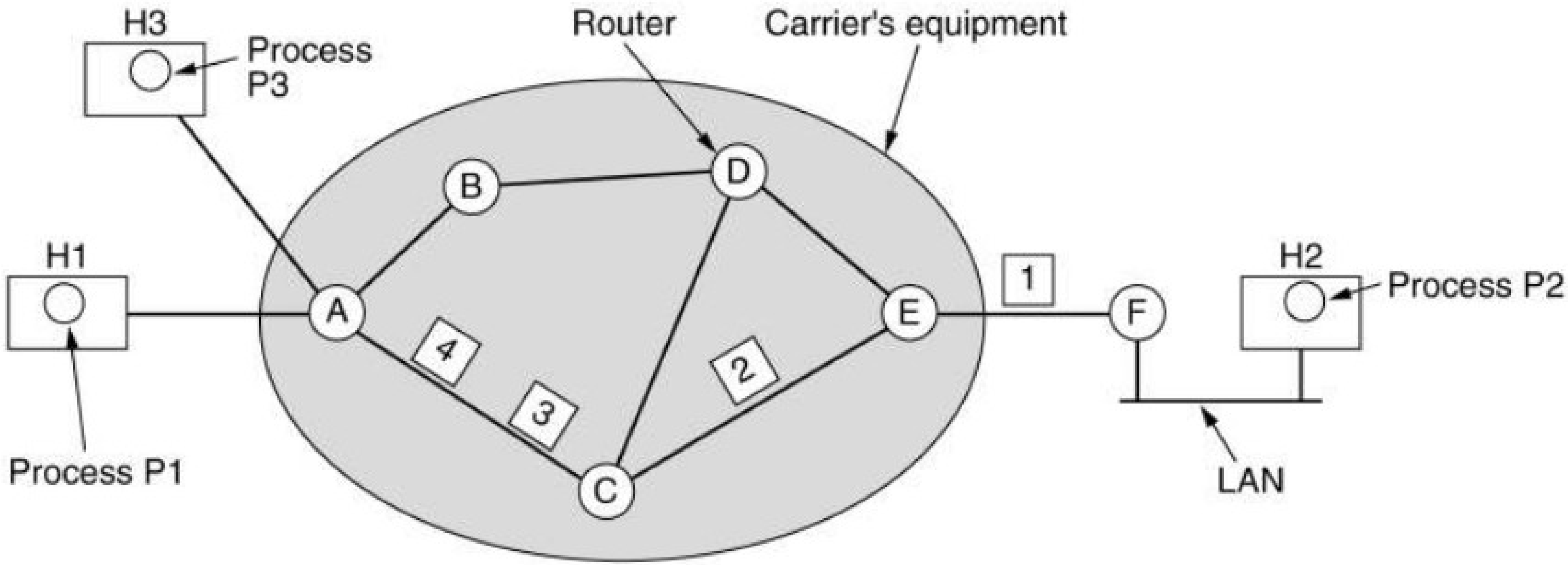
Virtual Circuit Subnet

In virtual circuits every incoming packet will be given an identifier.

The identifiers are chosen by the sending process.

If there are conflicts ,resolution is done by routers.

Intermediate routers forward the packet by looking at the identifiers.



A's table

In		Out	
H1	1	C	1
H3	1	C	2

C's table

A	1	E	1
A	2	E	2

E's table

C	1	F	1
C	2	F	2

Issue	Datagram subnet	Virtual-circuit subnet
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

Routing algorithms

Routing algorithms decide on selecting the best output line for the incoming packets.

If datagram network is used ,this decision has to be taken for each packet.

If virtual circuit is used,this decision is taken initially and is valid for the entire session.**(Session Routing)**

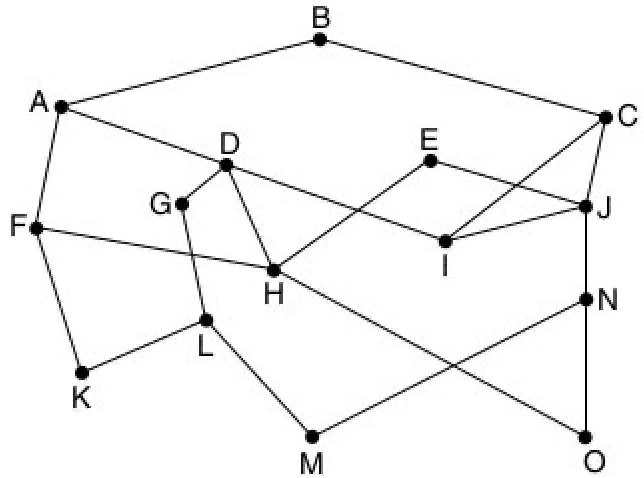
Non Adaptive algorithms -> The decision on best route does not depend upon current network conditions.A precomputed route is used.

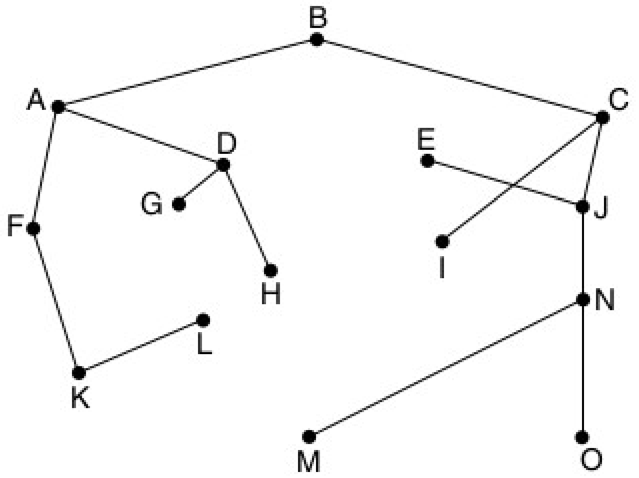
Adaptive algorithms-> Made to adjust to changing topology and network conditions.

The optimality principle

If router **J** is on an optimal path from router **I** to router **K**,then the optimal path from router **J** to router **K** also falls along the same path.

A set of optimal routes from all sources to a destination forms a tree routed at the destination,known as **sink tree**.





Shortest path algorithm

The distance is usually measured in *hops.*

Hop count may be equated to the number of devices.

One such algorithm is **Dijkstras shortest path algorithm** (1959).

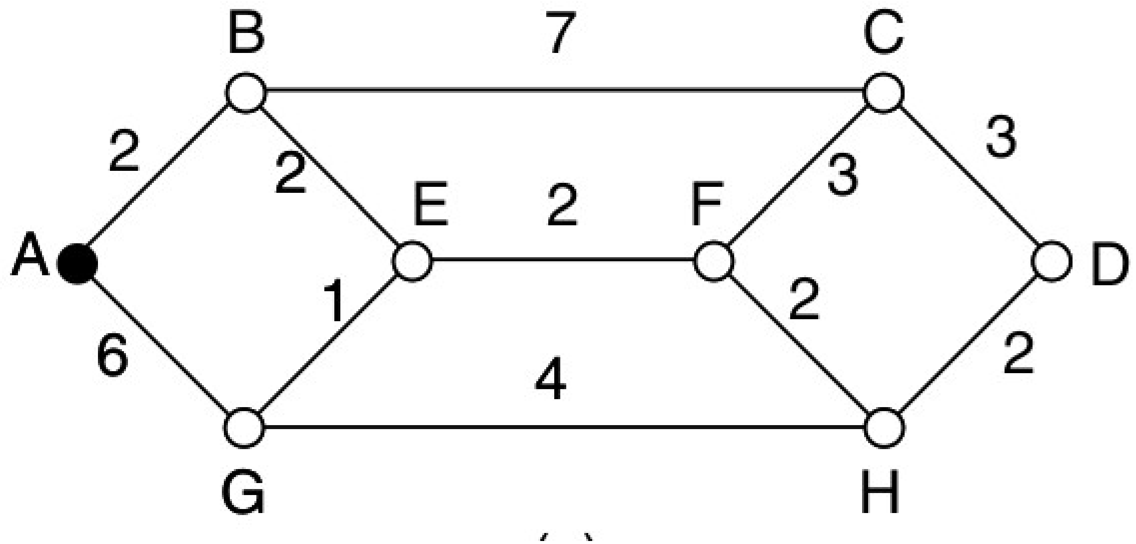
- ✓Considers the network as a directional graph .
- ✓The cost of reaching the neighbouring nodes is known.
- ✓The distance to self is zero and all other nodes are taken as inifinity in the initial condition.
- ✓The shortest distance between two nodes is calculated based on the cost and current node.

Dijkstras Algorithm

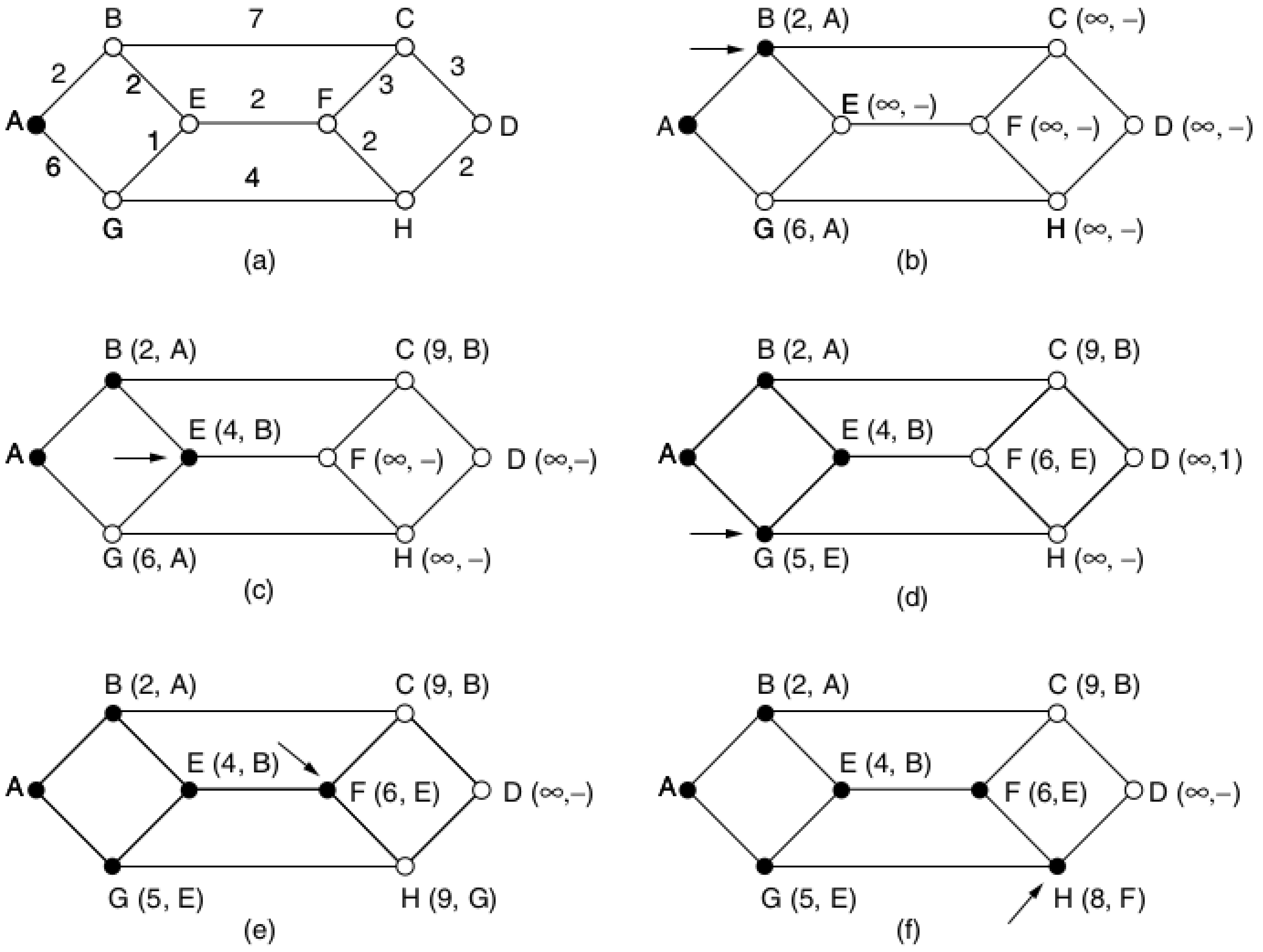
```
S = {};    d[s] = 0;     d[v] = infinity for v != s
While S != V
        Choose v in V-S with minimum d[v]
        Add v to S
        For each  w in the neighborhood of v
                d[w] = min(d[w], d[v] + c(v, w))
```

Example

Source **A**. Destination **D**



Final output



Distance Vector Algorithm

Each router maintains seperate table with distance to other routers.

This information is shared periodically and recalculations are done.

The algorthim is dynamic in nature as updations are send to neighbouring nodes.

Distance vectors are calculated using bellman ford algorithm.

Takes time to converge to optimal path

Iterative, asynchronous:

each local iteration caused by:

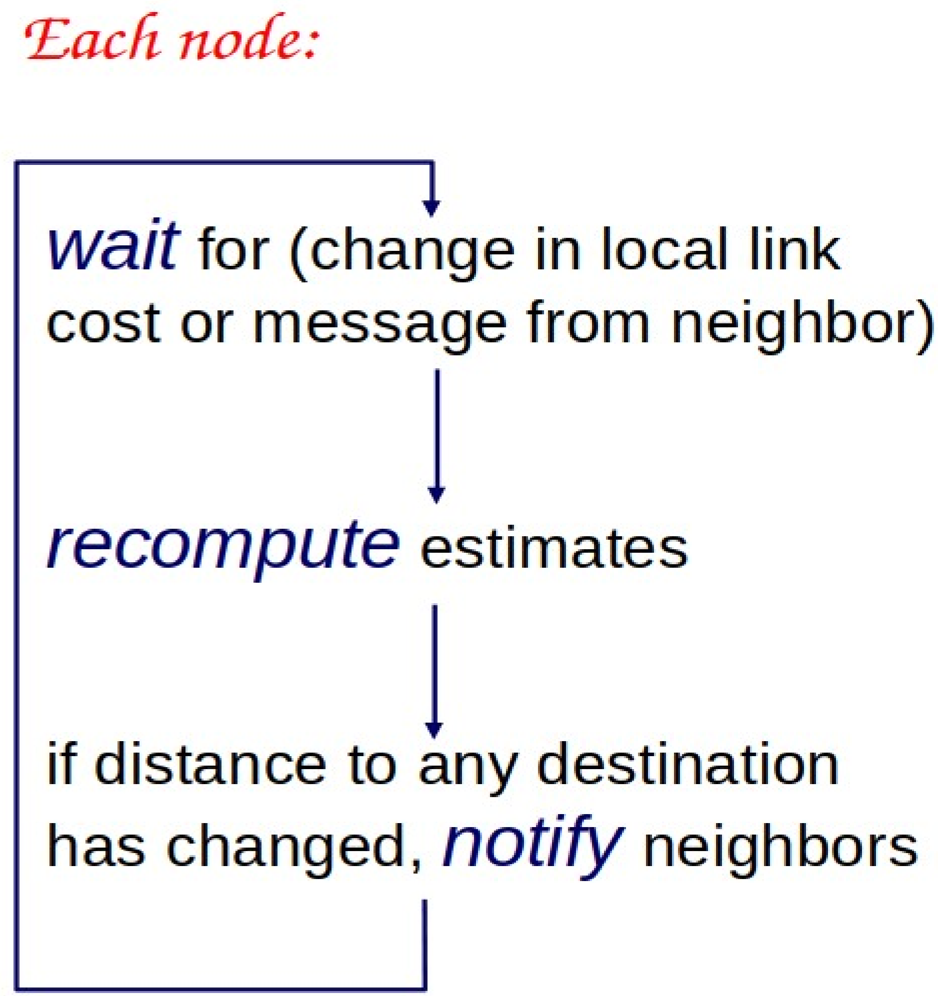
Local link cost change

Distance vector update message from neighbor

Distributed:

Each node notifies neighbors *only* when its DV changes

Neighbors then notify their neighbors if necessary



$$D_x(y) = \min\{c(x,y) + D_y(y),\ c(x,z) + D_z(y)\} = \min\{2+0\ ,\ 7+1\} = 2$$

$$D_x(z) = \min\{c(x,y) + D_y(z),\ c(x,z) + D_z(z)\} = \min\{2+1\ ,\ 7+0\} = 3$$

node x table

from \ cost to	x	y	z
x	0	2	7
y	∞	∞	∞
z	∞	∞	∞

from \ cost to	x	y	z
x	0	2	3
y	2	0	1
z	7	1	0

from \ cost to	x	y	z
x	0	2	3
y	2	0	1
z	3	1	0

node y table

from \ cost to	x	y	z
x	∞	∞	∞
y	2	0	1
z	∞	∞	∞

from \ cost to	x	y	z
x	0	2	7
y	2	0	1
z	7	1	0

from \ cost to	x	y	z
x	0	2	3
y	2	0	1
z	3	1	0

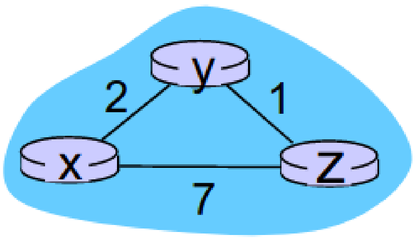
node z table

from \ cost to	x	y	z
x	∞	∞	∞
y	∞	∞	∞
z	7	1	0

from \ cost to	x	y	z
x	0	2	7
y	2	0	1
z	3	1	0

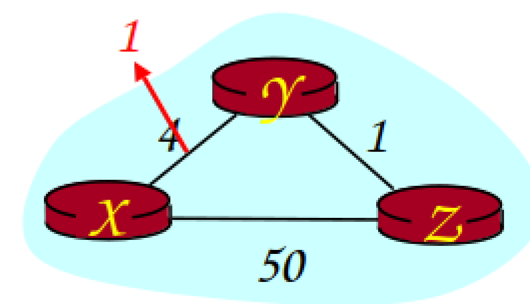
from \ cost to	x	y	z
x	0	2	3
y	2	0	1
z	3	1	0

time



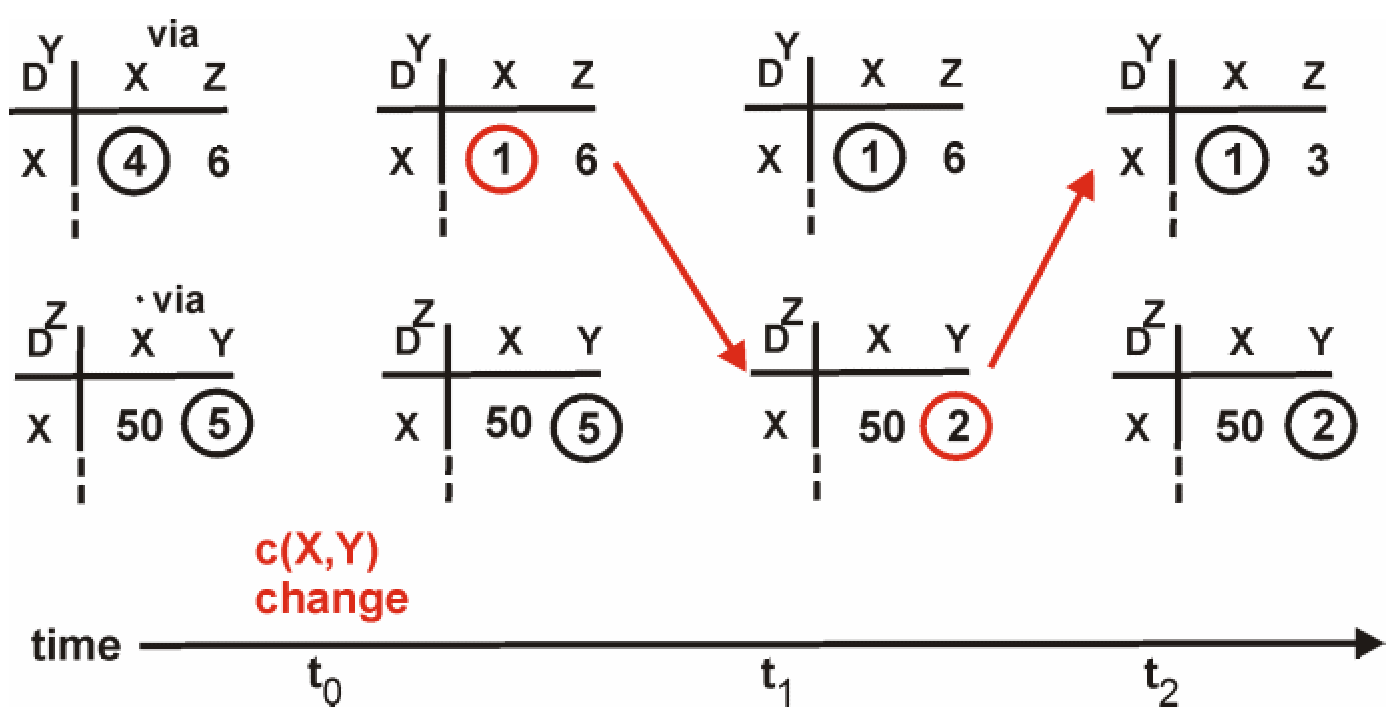
Distance Vector link cost changes

Link cost changes:



- Node detects local link cost change
- Updates the distance table
- If cost change in least cost path, notify neighbors

"good news travels fast"

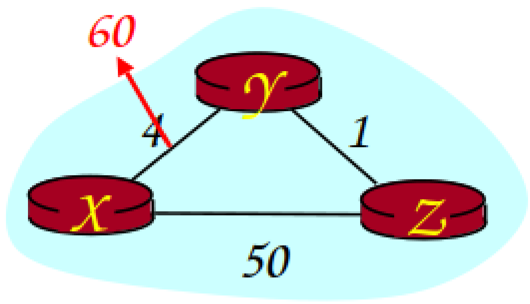


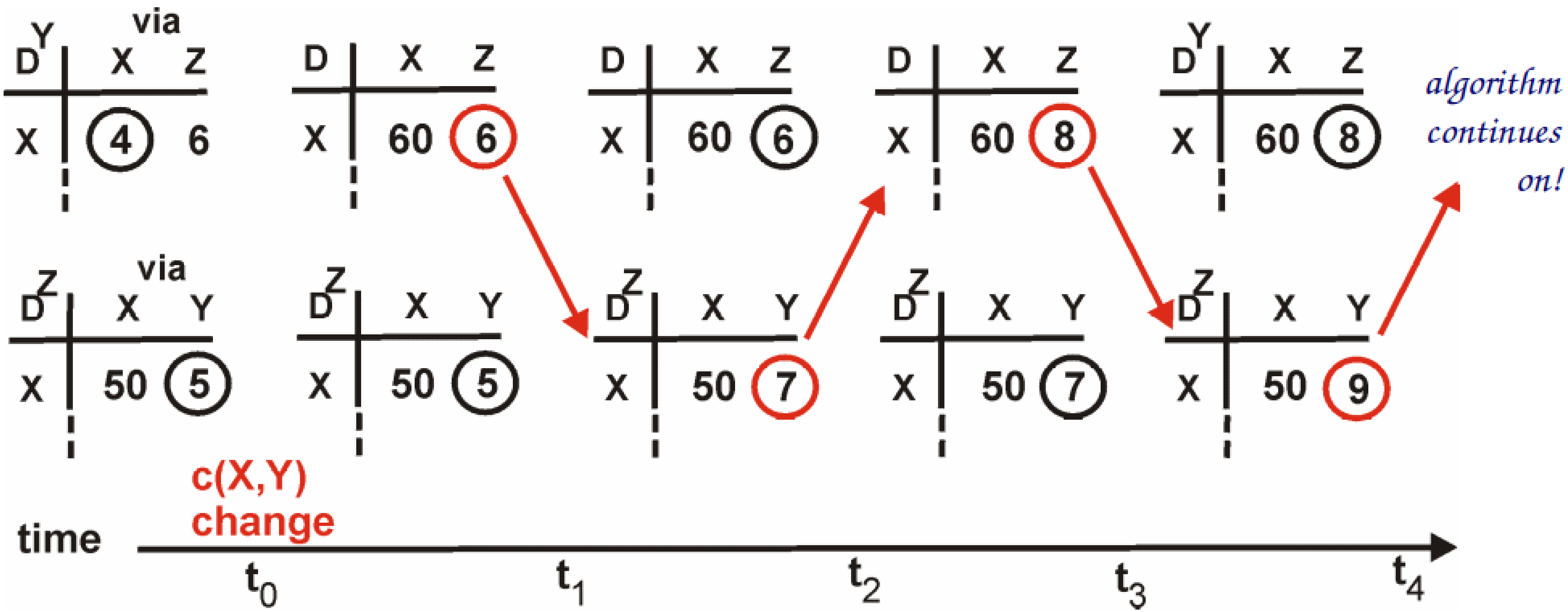
algorithm terminates

Count to inifinity problem

Link cost changes:

- Good news travels fast
- Bad news travels slow - “count to infinity” problem!

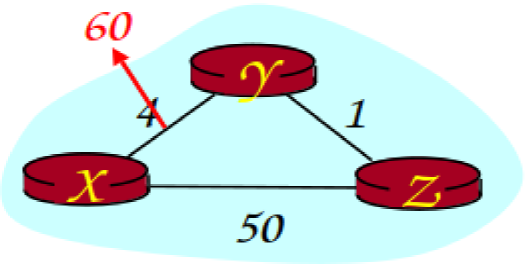


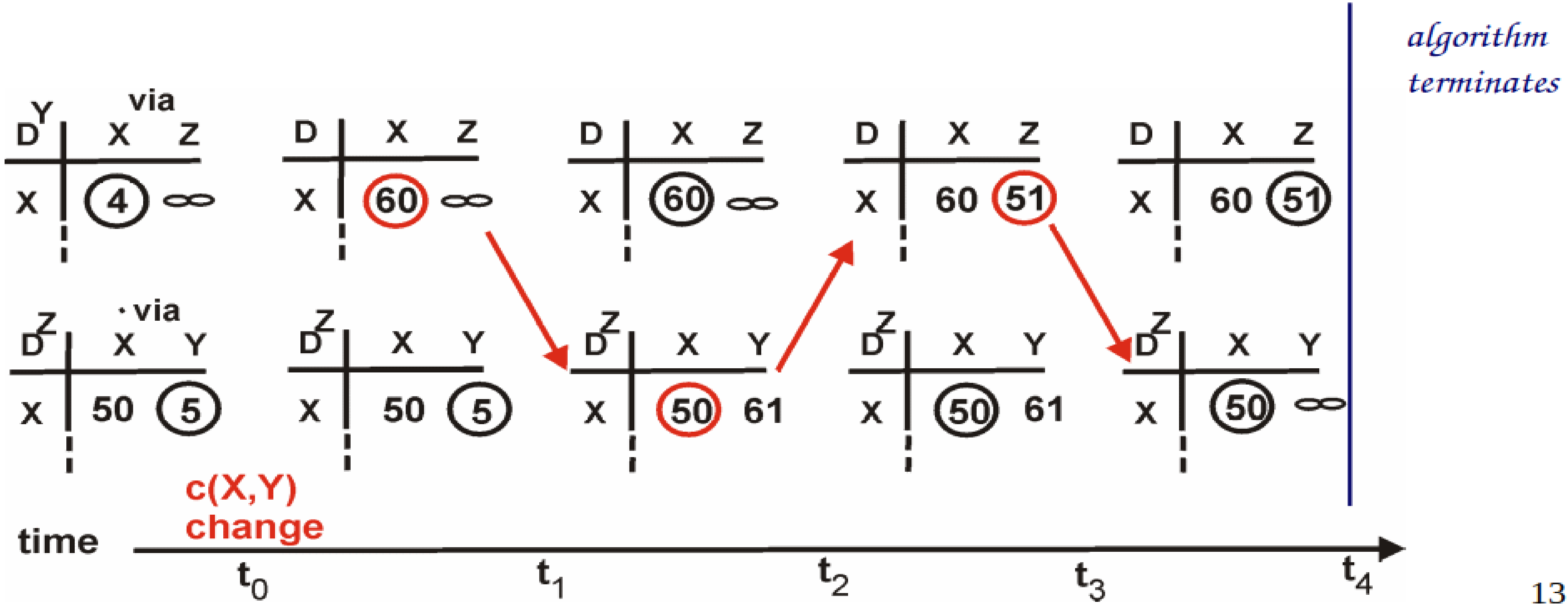


Solution -Poisoned Reverse

If Z routes through Y to get to X :

- Z tells Y its (Z's) distance to X is infinite (so Y won't route to X via Z)
- Still, can have problems when more than 2 routers are involved





Flooding

Probably one of the easiest ways to route the data.

"SEND TO ALL ".

Leads to a large number of duplicate packets.

Solution

-Include serial numbers.

-Include a counter which gets decremented on each hop.

Link State Routing

The Distance vector routing protocol takes a large time to converge.

Each router has to do five primary tasks.

1. Discover its neighbors and learn their network addresses.
2. Set the distance or cost metric to each of its neighbors.
3. Construct a packet telling all it has just learned.
4. Send this packet to and receive packets from all other routers.
5. Compute the shortest path to every other router.

When ever the router is booted special HELLO Packets are send to neighbouring routers.

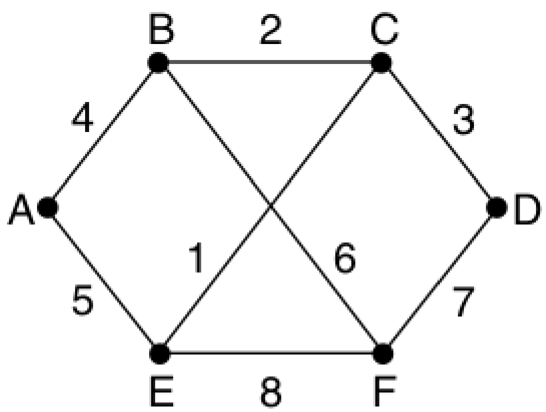
The other routers are expected to reply with their identifiers.

The HELLO messages are generally send as brodcast messages.

So inorder to limit the transmission , an aging factor is added to the packet.

The link cost can generally be the delay which is measured from special ECHO packets send out.

The path calculation is done using dikstras algorithm.



Link State Packets

A		B		C		D		E		F	
Seq.		Seq.		Seq.		Seq.		Seq.		Seq.	
Age		Age		Age		Age		Age		Age	
B	4	A	4	B	2	C	3	A	5	B	6
E	5	C	2	D	3	F	7	C	1	D	7
		F	6	E	1			F	8	E	8

Hierarchial Routing

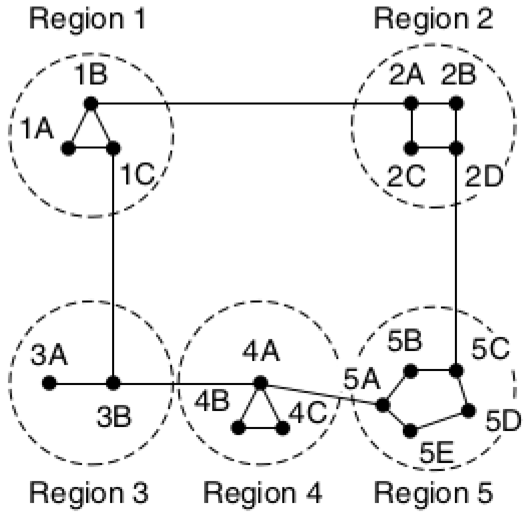
When the number of router grow it will become difficult to store all the informations on the router.

The routing table needs to be stored on the router to make decisions.

This can be only be a certain size.

To overcome this issue routers are organized as regions or in a hierarchial manner.

There could be atleast one router in a region which knows how to reach other regions.



Full table for 1A

Dest.	Line	Hops
1A	–	–
1B	1B	1
1C	1C	1
2A	1B	2
2B	1B	3
2C	1B	3
2D	1B	4
3A	1C	3
3B	1C	2
4A	1C	3
4B	1C	4
4C	1C	4
5A	1C	4
5B	1C	5
5C	1B	5
5D	1C	6
5E	1C	5

Hierarchical table for 1A

Dest.	Line	Hops
1A	–	–
1B	1B	1
1C	1C	1
2	1B	2
3	1C	2
4	1C	3
5	1C	4

Broadcasting

Routing decisions when the same data has to reach multiple destinations.

One way is by using flooding.

Since there are wastages,other ways are used.

1. Reverse Path Forwading.

Router will not forward the information on the line in which it received the data.

2.Construct spanning tree.

Multicasting

Used when data has to be routed to a subset of routers.

The routers which desire to be in part of the scheme has to send special join messages.

Messages will be forwarded to those who are part of the group.

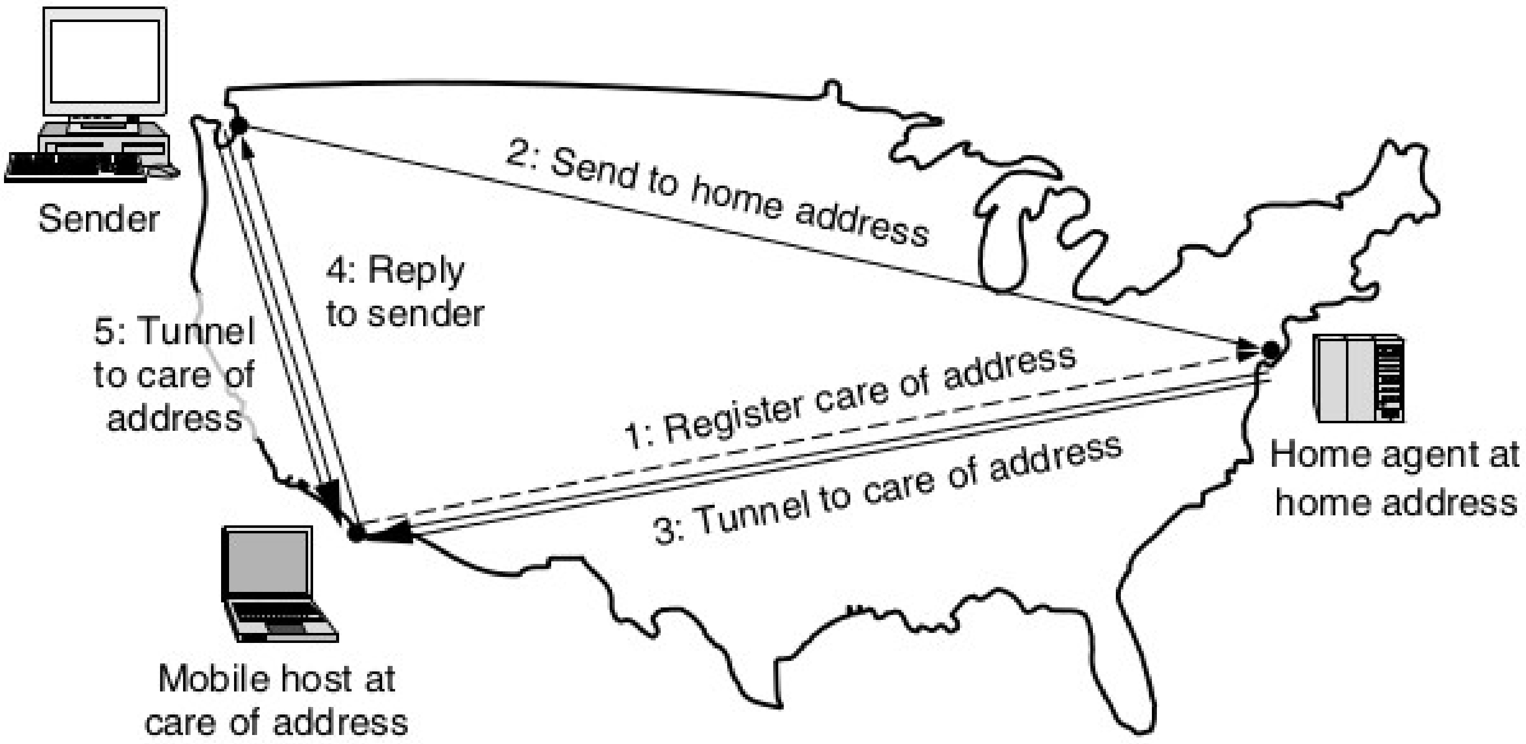
Routing in mobile host

A device with an IP address in one place will get another IP address in another place.

There could be situations when the old IP needs to be used.

A special entity known as Home Agent takes care of this issue.

Home Agent knows your present address and routes the information .


Sender
2: Send to home address
4: Reply to sender
5: Tunnel to care of address
1: Register care of address
3: Tunnel to care of address
Home agent at home address
Mobile host at care of address

Things to think

- Routing in Mobile phones.

-Routing in modile adhoc devices

-These are small low power devices

Congestion Control Mechanism

The presence of too many packets in the network creates Congestion.

Congestion occurs when the source produces more packets than the destination could process.

This inturn affects the routers as they have to manage more traffic than they can handle.

All routers have buffers to temporarily store data.

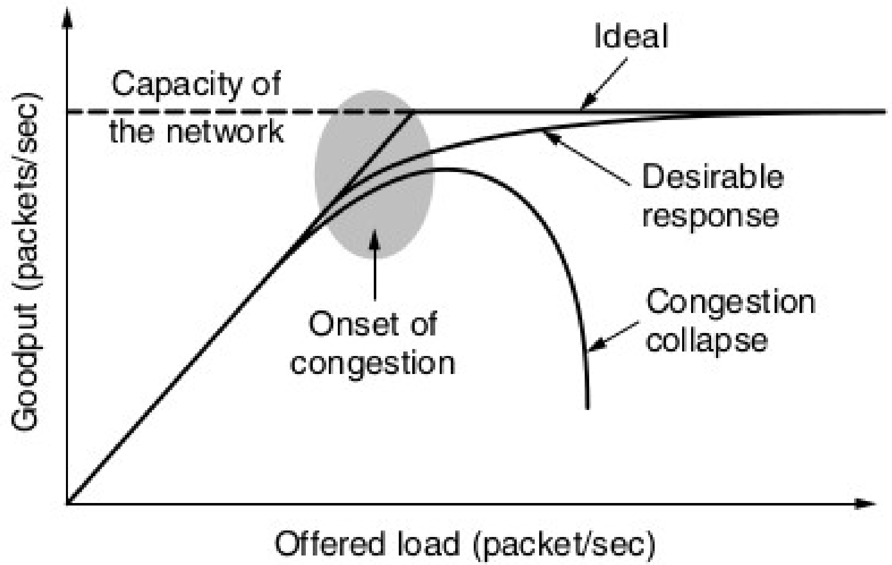
Once this buffer gets filled up data will be lost.

As a result there will be performance degradation.

When congestion increase delay increase.

When delay grows beyond a certain extent the packets ar[e] of no use.

The sender may resen[d] the data ,which adds up the congestion.



Solutions ???

Can we increase the speed of the router.??

Can we design a router with a large buffer ??

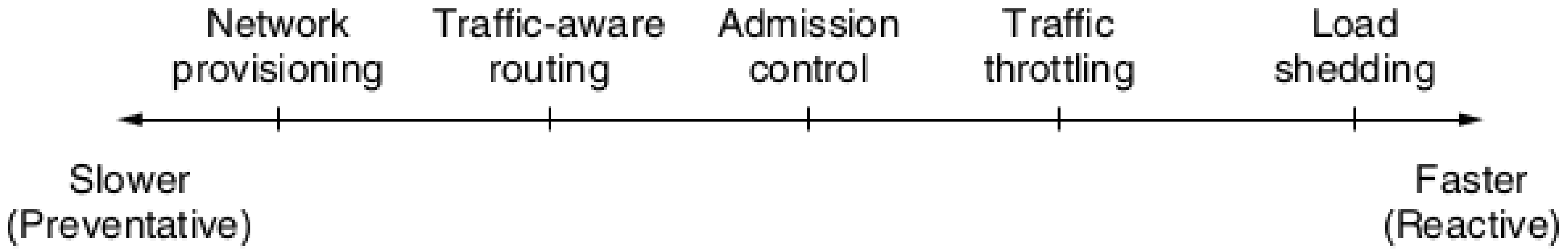
Can we use a faster medium ??

Solutions for dealing with congestion.

The basic idea is to design a network that can handle the load.

But that is not a single step process.

Many factors determine the transmission of the data.



Network Provisioning

Identify the weak points in the network and add resources is the key.

If there are known burst of activities at a certain period extra resources may be utilized.

If no such prior information is available this scheme will not be that effective.

Traffic aware routing.

Routers should asses the factors such as bandwidth,delay etc

The packets should be routed based on analysing conditions so as to avoid congestion.

The parameters has to be decided carfeully.

If load alone is considered.

-New path taken will redue the load.

-Once the load is less confusion arises on which route to take again.

Admission Control

This is particularly applicable in virtual circuits where the path is pre established.

When the request for a new path arrives,this can be denied if the path is already congested.

There could be denial based on services which could generate a large amount of data packets.

Traffic throttiling

A way to avoid congestion is to detect the onset of congestion and take steps so that the data flow is controlled.

One metric is to measure the time spend by packets in a buffer.

$$d_{\text{new}} = \alpha d_{\text{old}} + (1 - \alpha)s$$

Known as exponentially weighted moving average

Traffic throttiling

1.Using Choke Packets

The sender is informed about the congestion by sending a special choke packets.

The sender has to reduce the data rate once the choke packet is received.

2.Explicit Congestion Notification.

Rather than sending new packet, special bits are set in the packet.

Once it reaches the receiver ,congestion information is carried back on the reply message.

Traffic throttiling

3.Hop by Hop back pressure.

The information about the congestion may time to reach the sender.

The intermediate routers which see the congestion information are also made aware of the situation.

Load Shedding

The worst case.

Drop the packets if congestion happens.

The decision on which packet to drop depends on the application.

For video streaming present data is more important tahn old data.

Random Early detection

When the router finds that the queue length has grown beyond a treshold ,it will drop packets.

Packets are chosen at random

It is assume that faster sender will notice the drop and will resend.

The transport layer protocol has mechanisms to slow down the sending.

Quality of service

As far as any network is concerned ,users require to get data within minimum time.

They do not tolerate any loss of data also.

There are four parameters that define the Quality of service.

1.Bandwidth

2.Delay

3.Loss

4.Jitter --> Variations in delay

Contd

A stream of packets that move from source to destination is know as **flow**.

Every application sends a stream of information to the destination.

The QoS parameters will vary based on the application.

For example a video conference application will be highly sensitive to jitter,delay,low bandwidth and loss

Meanwhile a file transfer service will be less sensitive to the parameters.

Traffic shaping

One major problem that is encountered is sudden burst of packet flow. (Bursty traffic)

They cause the incoming data rate to fluctuate at the routers.

As a result the routers may not be able to handle some data resulting in loss and delays.

One solution is to make the sender transmit data onto the network at a constant rate

Traffic shaping

Leaky Bucket Algorithm

Imagine a bucket with a small hole in the bottom.

When there is water in the bucket the output flow will be at a constant rate **R.**

When there is more water there will be spillage and loss.

Translate water to data.

The output will be at a constant rate.

Additional buffers may be employed at source to prevent loss.

Traffic shaping

Token Bucket algorithm

Here the bucket is filled at a constant rate.

And tokens or data are retreived from the bucket.

The removal follows a pattern.

In both the cases ,the overall idea is to reduce uneven flow rate.

As a result there could be addition of minimal delay.

Packet Scheduling

The routers are required to store and process packets before transmitting them.

There are three resources that needs to be allocated

1. CPU
2. Bandwidth.
3. Buffer space.

There could be buffer selection algorithms that select packets from buffer.

Packets could be selected using FIFO.

But there could be packets belonging to delay sensitive applications.

The routers may use multiple queues.

Specific weight could be given to queues also.

Admission Control

Applications are required to provide the Quality parameters .

This scheme works well in a virtual circuit scheme.

Routers can determine if they can meet the requirement .

If the requirements are within range connection is allowed.

There are specific protocols to negotiate the parameters.(RFC 2210,2211

Resource Reservation Protocol (RSVP)

Mainly used in multicast networks.

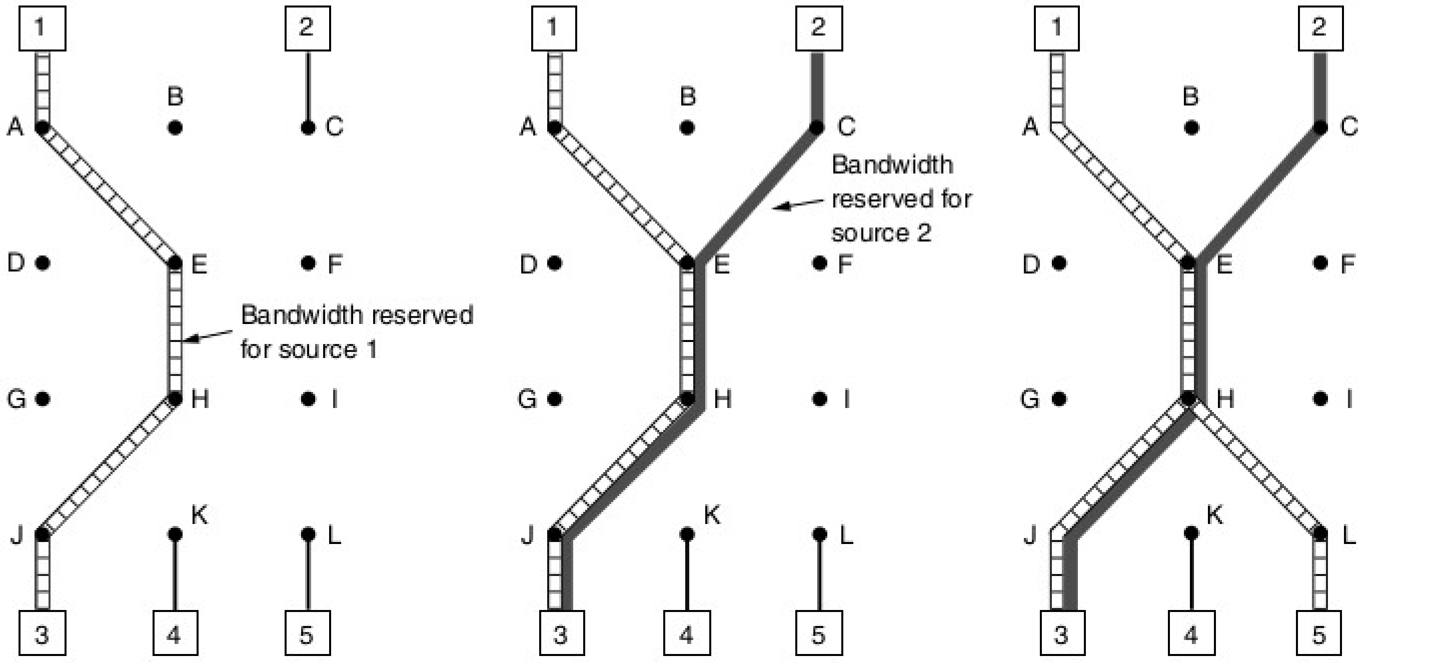
Multicast receivers may require to switch between applications.

Protocol uses a multicast spanning tree.

The transmission is done by specifying group address as destination.

Any receiver in the group can send up reservation request using reverse path forwarding.

Routers which get the data try to allocate resources.


1
2
B
A
C
D
E
F
Bandwidth reserved for source 1
G
H
I
J
K
L
3
4
5
1
2
B
A
C
Bandwidth reserved for source 2
D
E
F
G
H
I
J
K
L
3
4
5
1
2
B
A
C
D
E
F
G
H
I
J
K
L
3
4
5

Differentiated Service

Users are added to different classes.

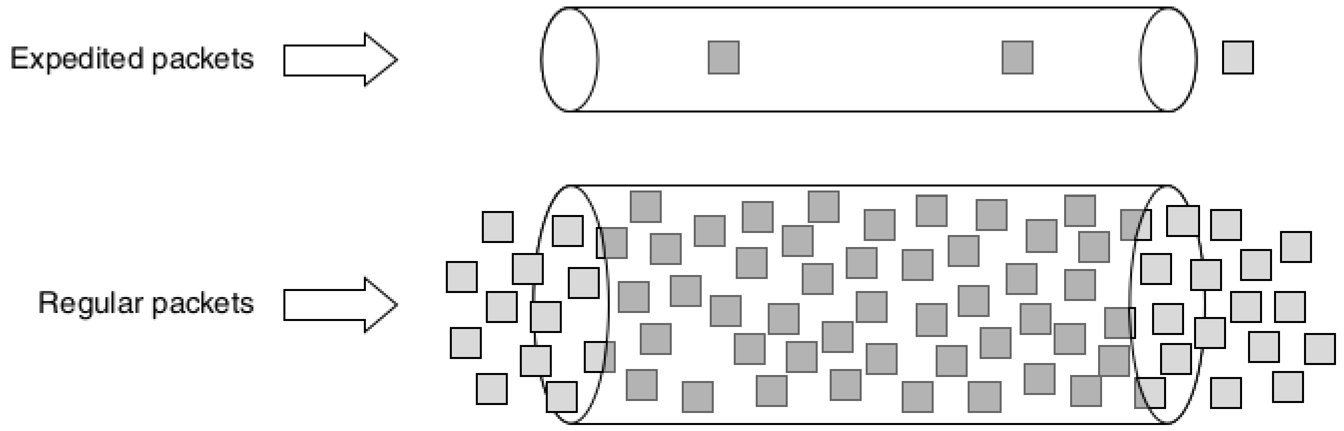
Each class of service given specific QoS parameters.

The classes are defined as per hop behaviour.

This may not be true among all the routers.

For Example Gold class customers getting less delay,more bandwidth.

RFC 3246 defined expedited and regular flow.



Application	Bandwidth	Delay	Jitter	Loss
Email	Low	Low	Low	Medium
File sharing	High	Low	Low	Medium
Web access	Medium	Medium	Low	Medium
Remote login	Low	Medium	Medium	Medium
Audio on demand	Low	Low	High	Low
Video on demand	High	Low	High	Low
Telephony	Low	High	High	Low
Videoconferencing	High	High	High	Low