Lecture 9

Internet (continued)

By

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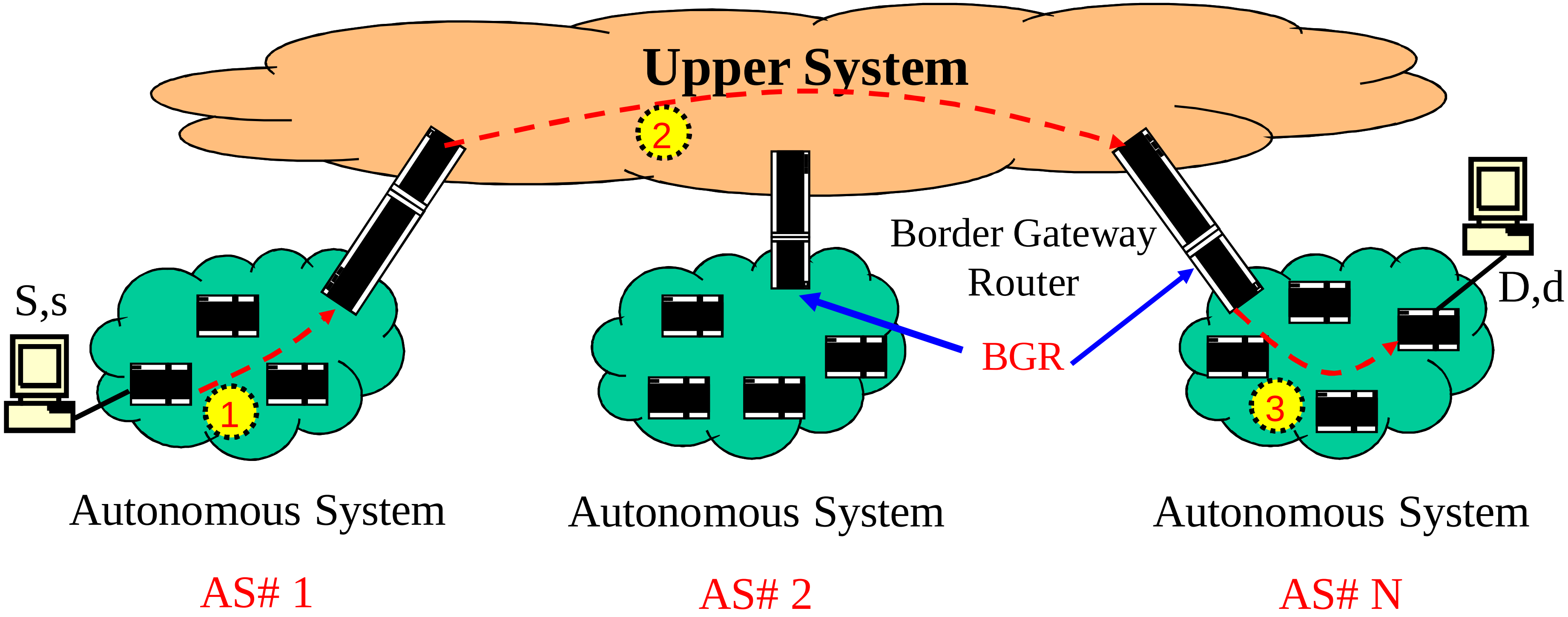
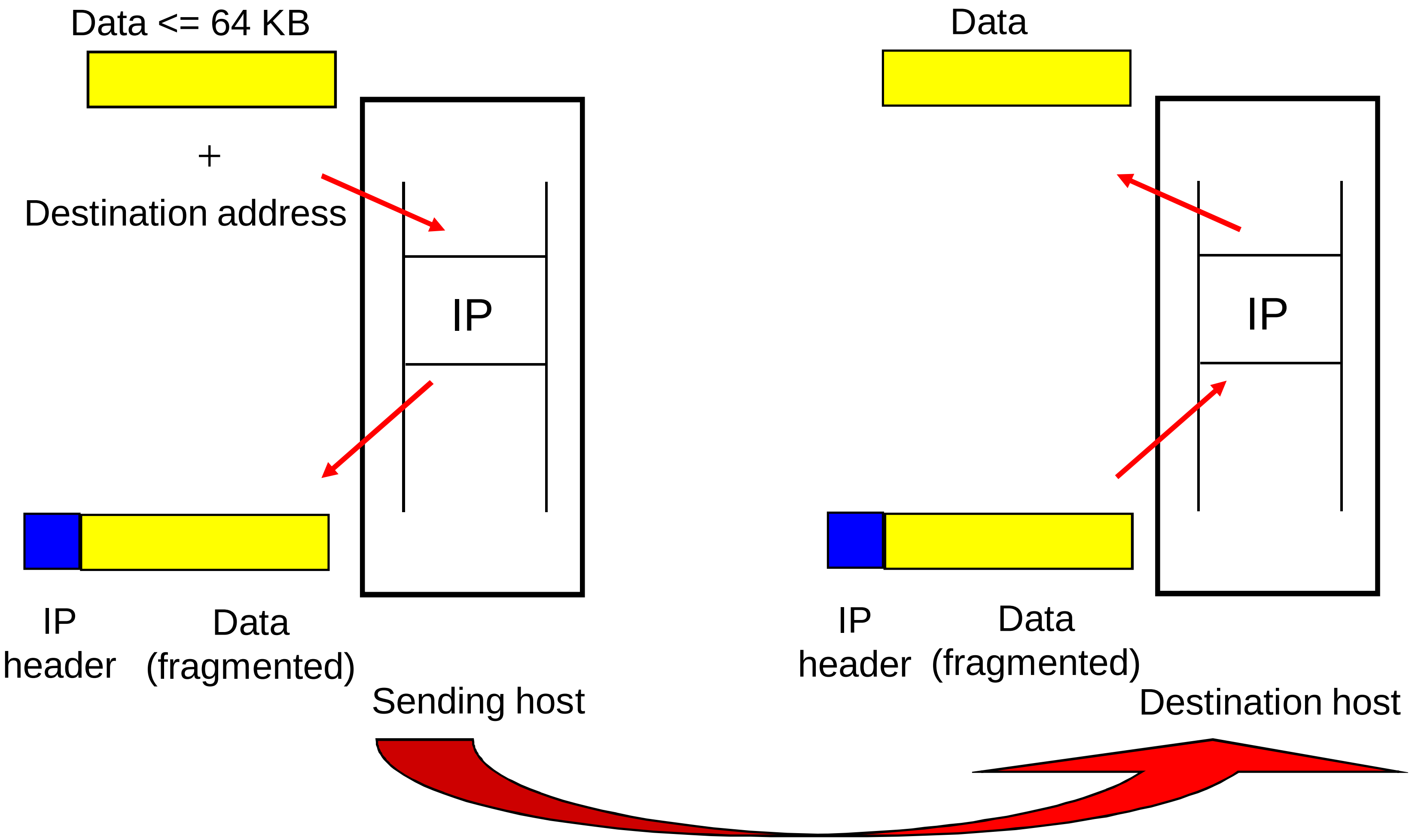
Internet Protocol

General View

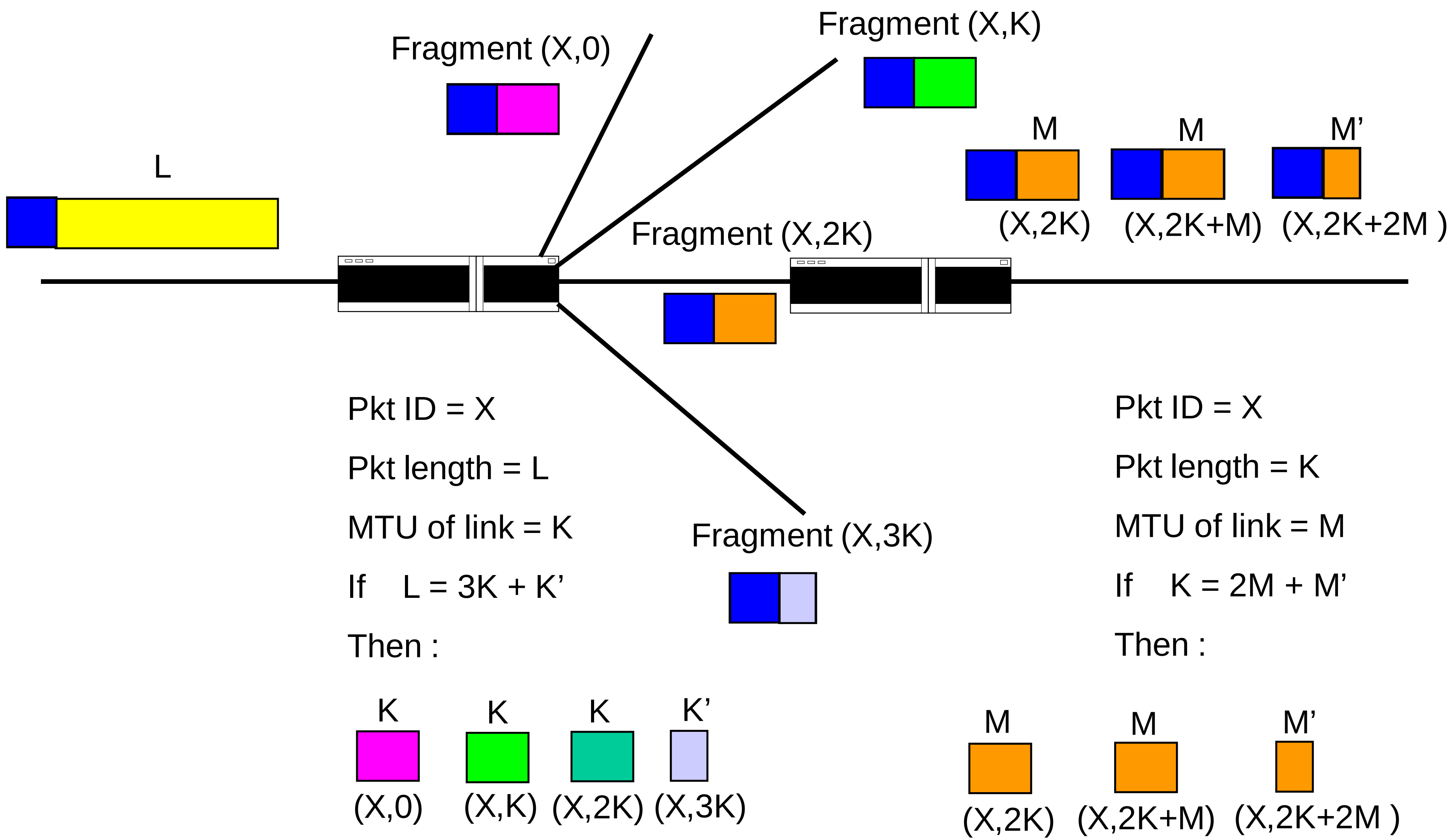


(Inside each AS, routers are governed by the same "Authority".)

Some operational details



Some operational details (continued)



Some operational details (continued)

- IP pkt may NOT arrive at destination, due to :

  * Host being unreachable

  * Looping of pkt in NW

  In this case, source host is informed using ICMP (Internet Control Message Protocol).

- If pkt does NOT arrive at destination due to :

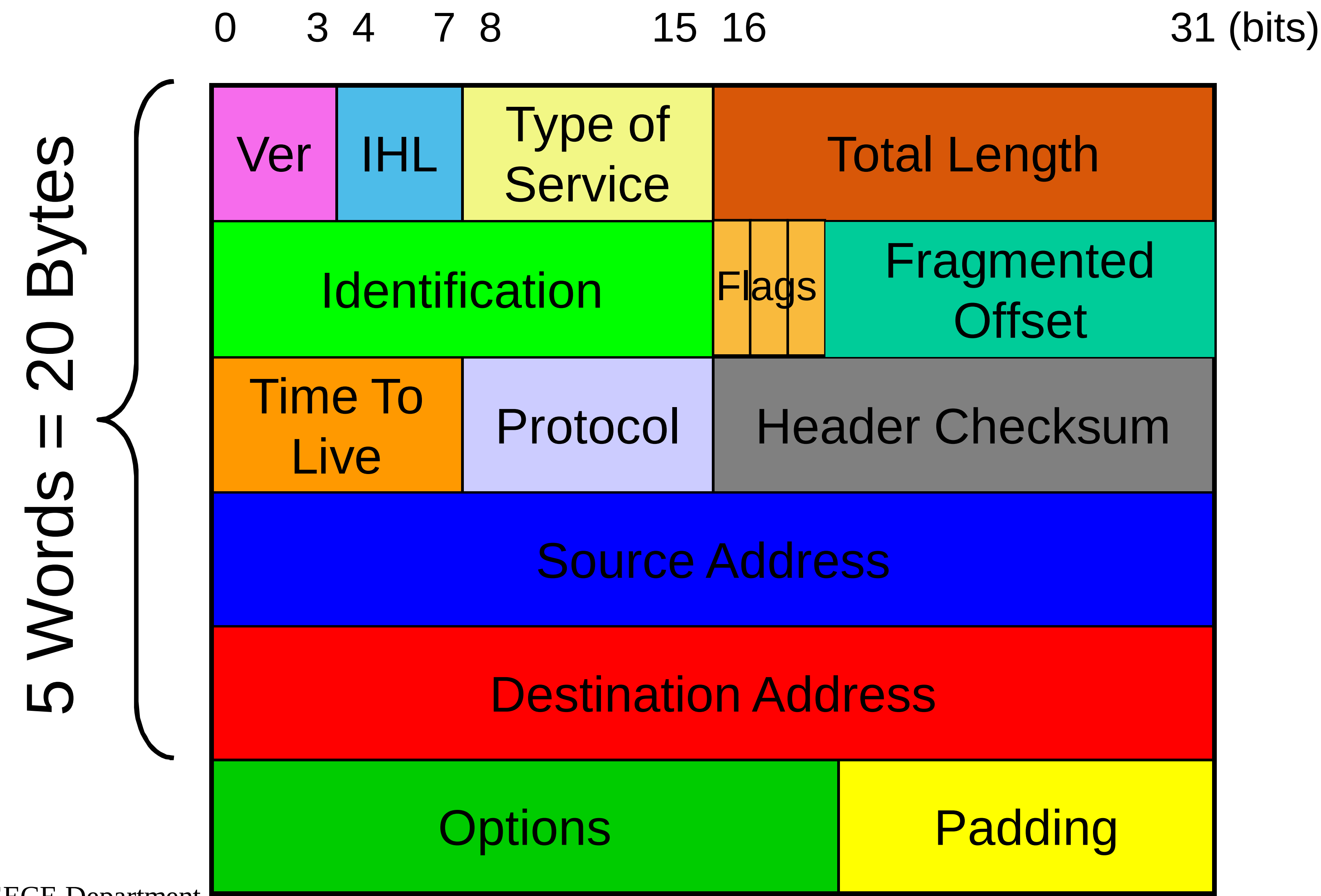
  * Transmission errors affecting header

  * Buffer overflow in intermediate nodes

  No ICMP messages are generated. BUT, it is up to higher layer (Transport protocol) to detect & correct situation

- ICMP Protocol uses IP

IP header format



OSPF (Open Shortest Path First)

- General facts

  * Determines shortest path from one node of a graph to all other nodes of the graph.

  * Is based on Dijkstra's algorithm

  * Length of path is defined as sum of length of links along the path

- Physical picture

  * nodes Ξ balls (total = N, say), links bet. nodes Ξ strings bet. balls

  * To find shortest path from one node and all other nodes :

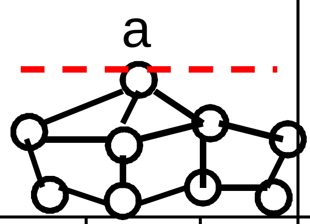
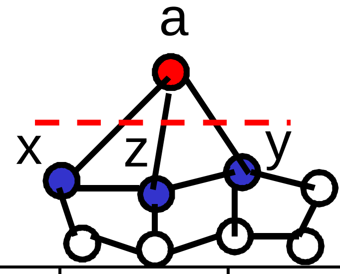
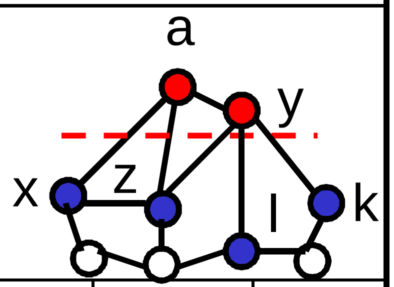
    Place all balls on floor

    - Select ball representing that node, call it ball 1 (b1)
    - Lift b1 from floor, till the next ball is lifted from floor, call it ball 2 (b2).
    - Continue to lift b1 and b2 till the next ball is lifted from floor, call it ball 3 (b3).
    - Clearly, string bet. b1 and b2 is shortest path from b1 to b2

      and shortest path from b1 to b3 = min. {string bet. b1 & b3 (if one exists)

      & string bet. b1 & b2 + string bet. B2 & b3}

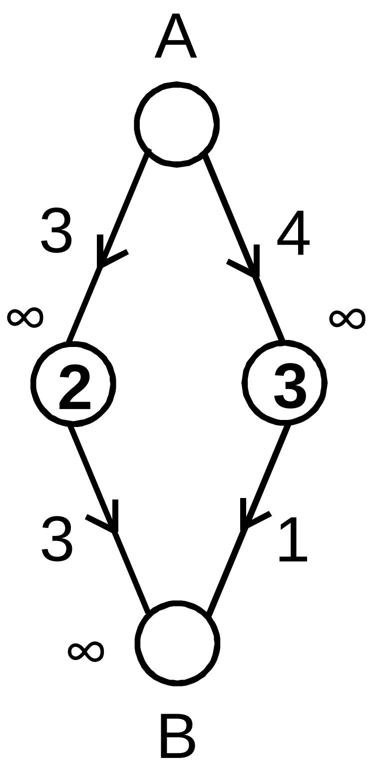
OSPF (Open Shortest Path First) (continued)

Step n		0			1			2		
Topology										
U(n) **Up balls at step n**	i, $d_n(i)$, $p_n(i)$				a	0 N (1)	a	a y	0 d_y N (2)	a a
F(n) Floor balls at step n	i, $d_n(i)$, $p_n(i)$ i = ball id $d_n(i)$ = distance to "root" ball from ball i at step n $p_n(i)$ = path to "root" ball from ball i at step n N(n)= "Floor" balls that are neighbors of "up" balls at step n.	1 2 . a . . N	∞ ∞ . 0 . . ∞	a	x y z 1 . . N	$d_1(x)$ $d_1(y)$ $d_1(z)$ ∞. . ∞	a a a	x z k l 1 . N	$d_2(x)$ $d_2(z)$ $d_2(k)$ $d_2(l)$ ∞ ∞	a a y y

OSPF (Open Shortest Path First) (continued)

- Simple Example

Step 0



Node A is reference

==> distance A --> A is 0

No link bet. A & others yet

==> distance A --> others is ∞

∴ A is smaller value

==> A is first to be lifted (mark RED)

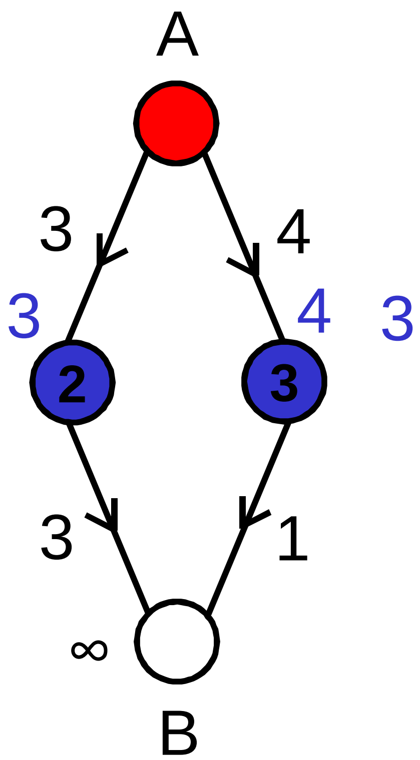
$U(0) = \emptyset$

$F(0) = \{A,2,3,B\}$

OSPF (Open Shortest Path First) (continued)

- Simple Example

Step 1



Lift node A

$U(1) = \{A\}$

$F(1) = \{2,3,B\}$

$N(1) = \{2,3\}$

Two middle nodes (nodes 2 and 3) are now neighbors of A with

node 2, $d_1(2) = 3$, $p_1(2) = A$

node 3, $d_1(3) = 4$, $p_1(2) = A$

while node B has :

node B, $d_1(B) = \infty$

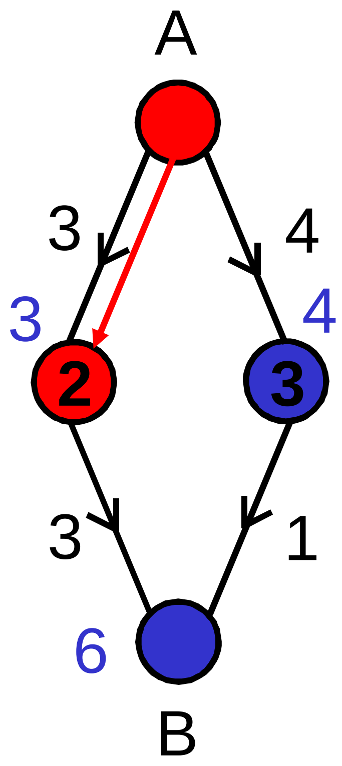
$\therefore$ next node to be lifted is node 2

(it has smallest $d_1(i)$).

OSPF (Open Shortest Path First) (continued)

- Simple Example

Step 2



Lift node 2

$U(2) = \{A,2\}$

$F(2) = \{3,B\}$

$N(2) = \{3,B\}$

Nodes 3 and B are now neighbors of nodes A and 2 :

node 3, $d_2(3) = 4$, $p_1(3) = A$

node B, $d_2(B) = 6$, $p_2(B) = 2$

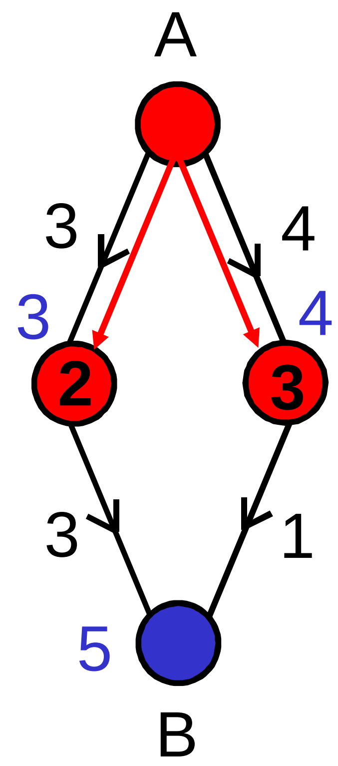
➊ next node to be lifted is node 3

(It has smallest $d_2(i)$).

OSPF (Open Shortest Path First) (continued)

- Simple Example

Step 3



Lift node 3

$U(3) = \{A,2,3\}$

$F(3) = \{B\}$

$N(3) = \{B\}$

Node B is now neighbor of nodes A, 2, and 3 :

node B, $d_3(B) = 5$, $p_2(B) = 3$

($d_3(B) = \min \{d_2(B)$ & $d(3) + L(3,B)\}$)

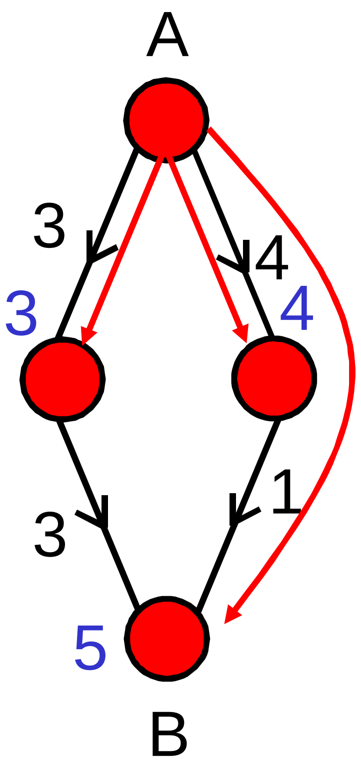
$\therefore$ next node to be lifted is node 4

(The only remaining node).

OSPF (Open Shortest Path First) (continued)

- Simple Example

Step 4



Lift node B

U(4) = {A,2,3,B}

F(4) = Ø

node A, d(A) = 0 , p(A) = A

node 2, d(2) = 3 , p(2) = A

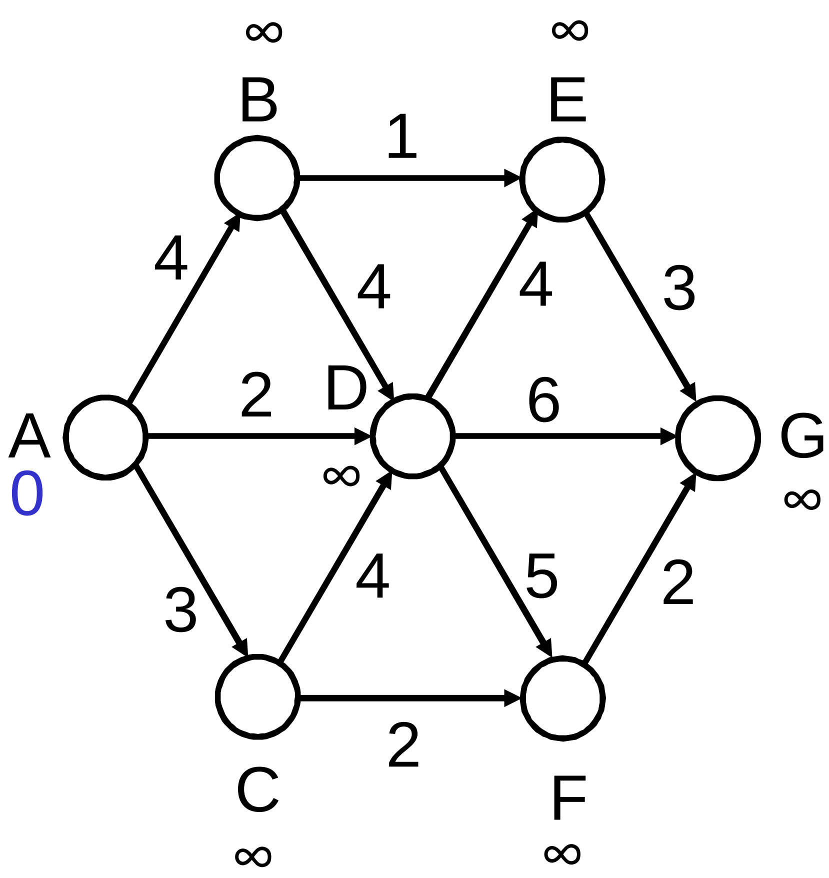
node 3, d(3) = 4 , p(3) = A

node B, d(B) = 5 , p(B) = 3

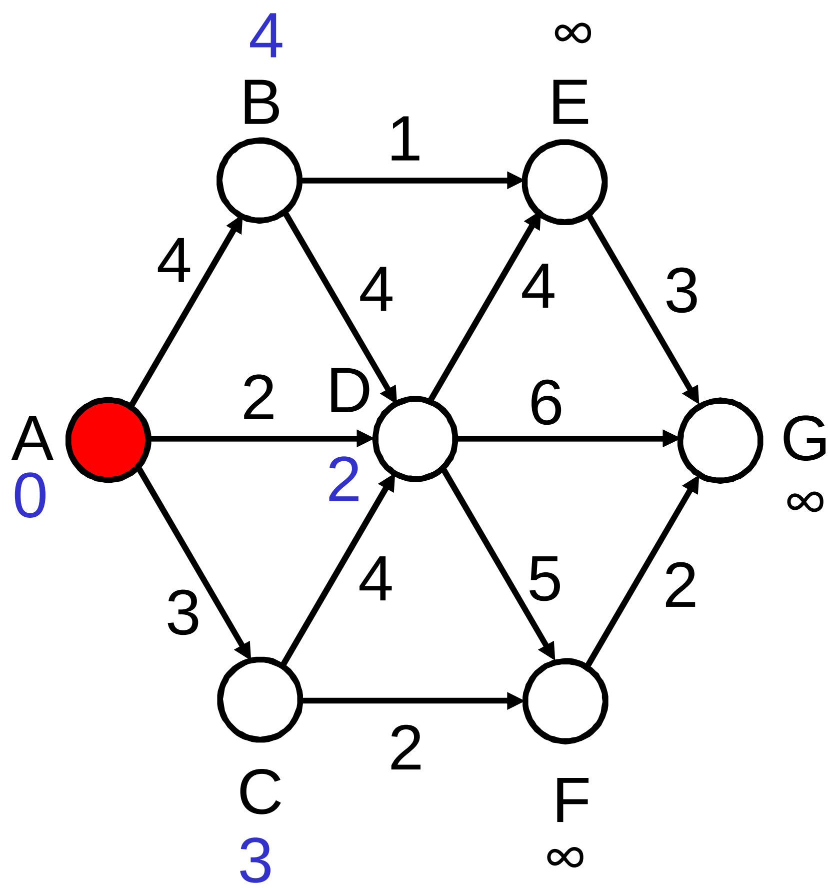
OSPF (Open Shortest Path First) (continued)

- More sophisticated network

Step 0

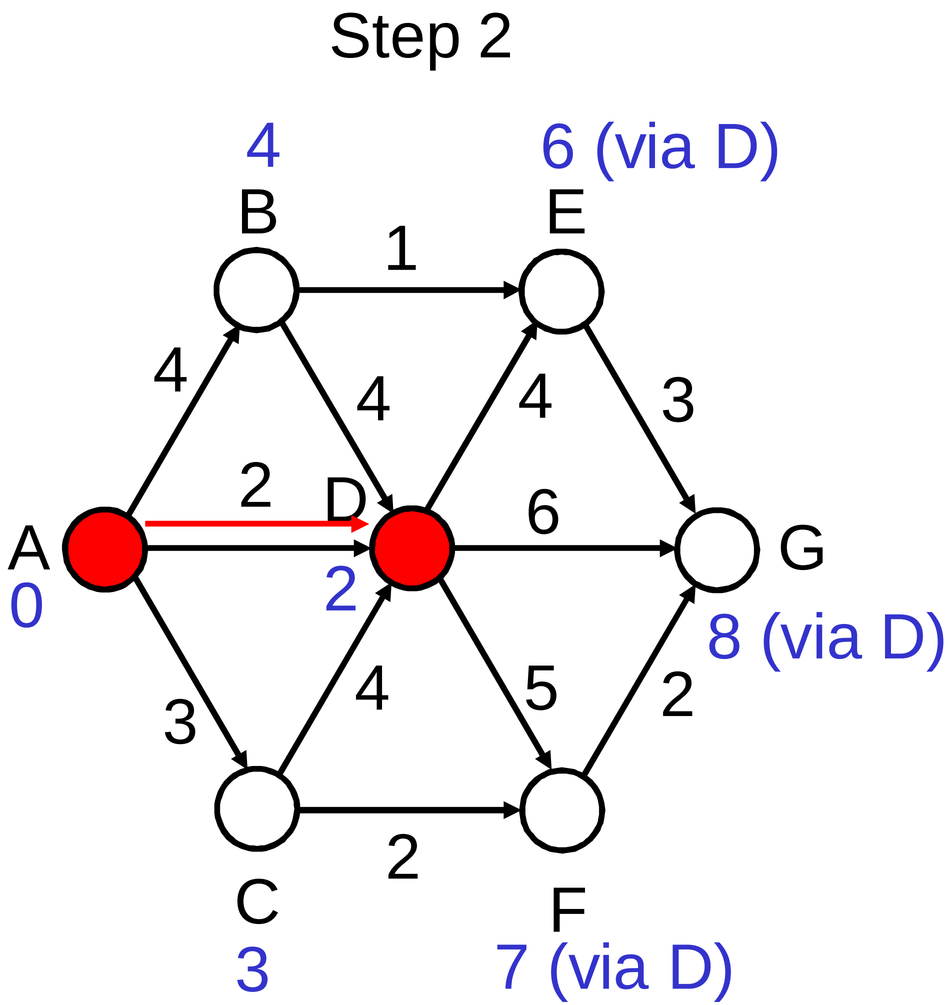


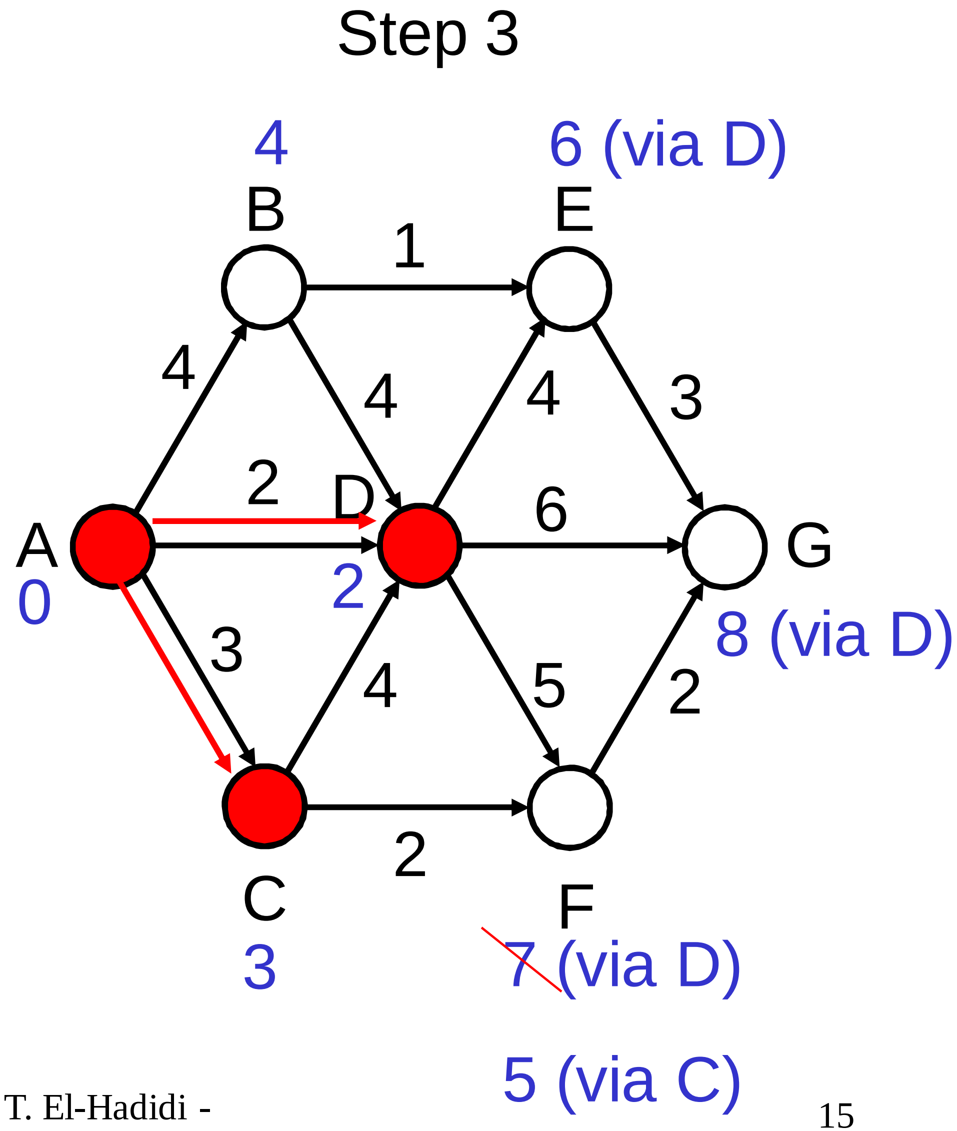
Step 1



OSPF (Open Shortest Path First) (continued)

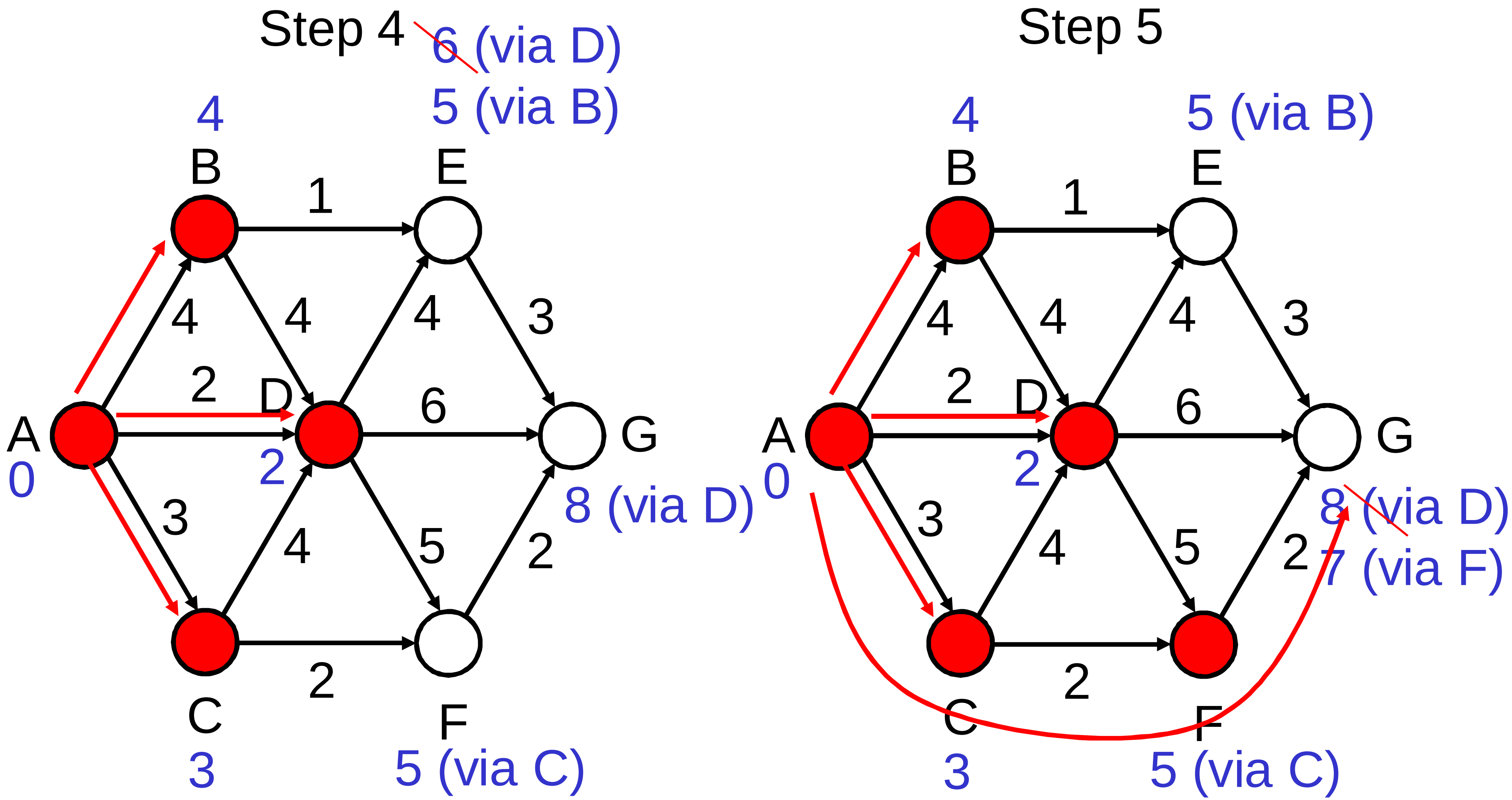
- More sophisticated network





OSPF (Open Shortest Path First) (continued)

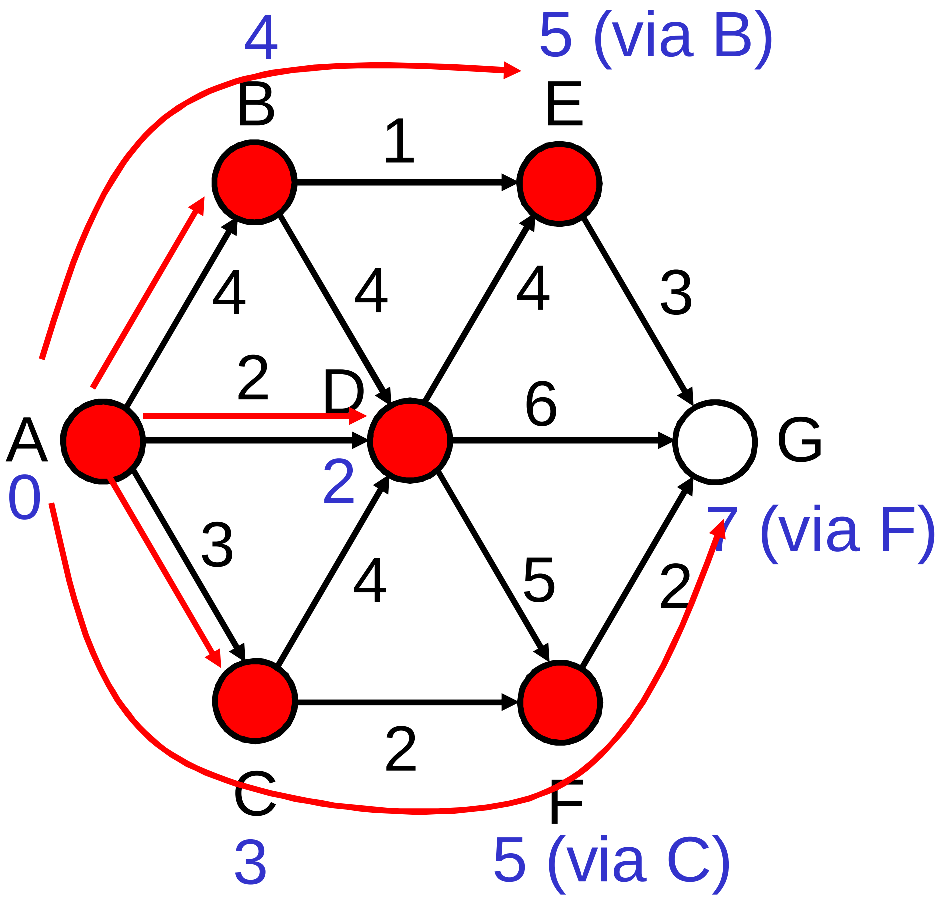
- More sophisticated network



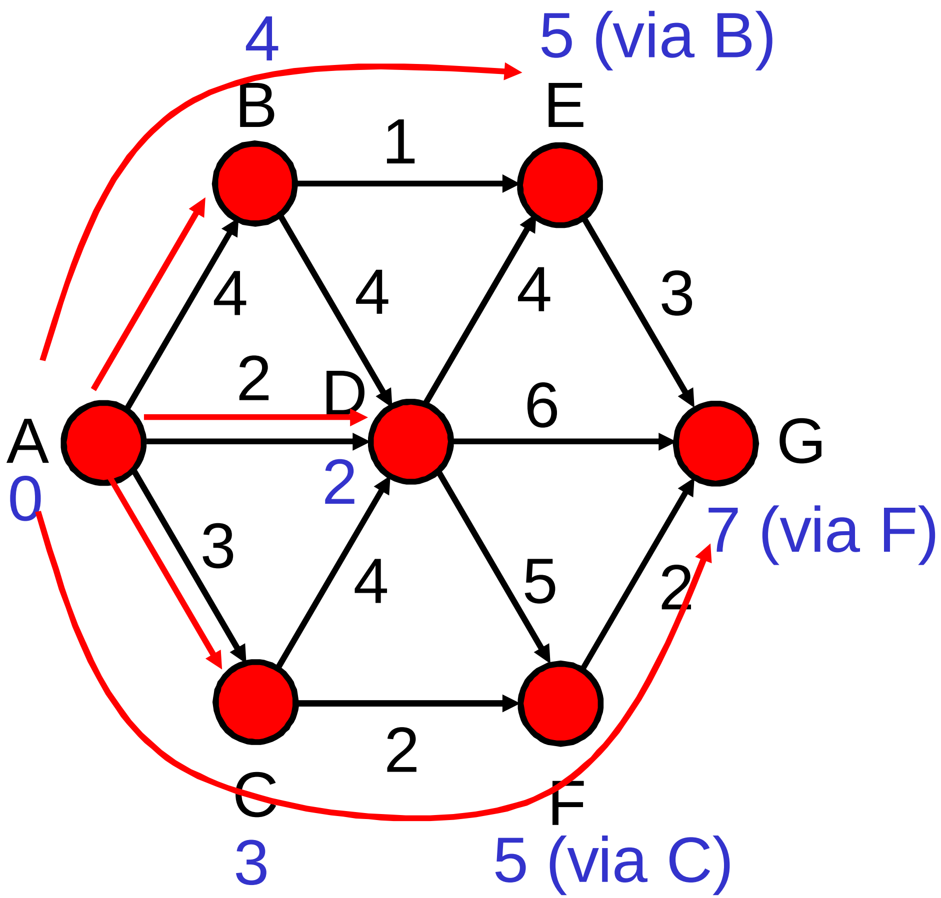
OSPF (Open Shortest Path First) (continued)

- More sophisticated network

Step 6



Step 7



BGP

- BGP differs from OSPF in TWO aspects :

a) BGP router has – in general – different network information to that of another BGP router.

==> BGP is a distributed protocol

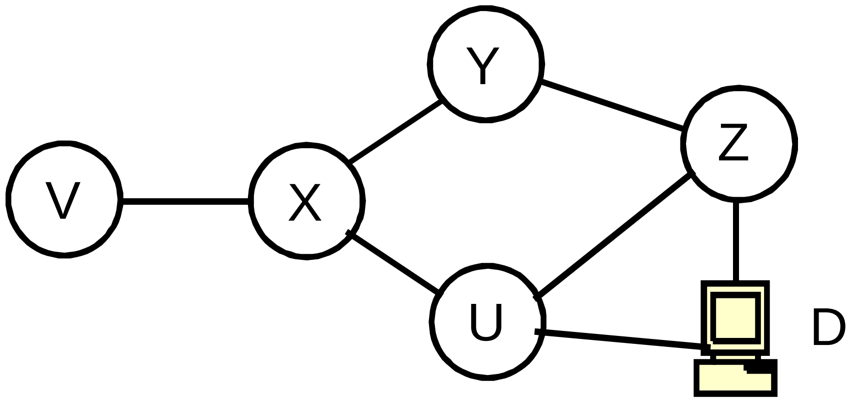
b) BGP router makes a decision based on preferred path (as opposed to OSPF which bases its decision on a metric).

==> BGP uses a <u>preferred path algorithm</u>

- Physical view :

* Consider a host D that is to be reached by an AS X.

* Assume that X is connected to a number of AS's as shown



BGP (continued)

* Let at some time, both AS Y & AS U have developed certain

  preferred paths to D :

AS Y to D : [Y , X , U ; 17]

AS U to D : [U ; 18]

Some metric. E.g. delay in msec

* Both AS Y & AS U will advertise these preferred paths to D,

  to other AS's including AS X.

* At AS X, it receives preferred paths to D :

If X <u>decides</u> to choose preferred path of Y (because metric is <u>smaller</u>) ==>

BG router in X sends to BG router in Y then BG router in Y sends to BG router in X

∴ have a loop !!!

Hence, X will decide to choose – as its preferred path to D – the path via U.

* The resulting preferred path to D from AS X will be :

[X , U ; 23] 23 = 18 + 5

18 = Metric from U to D

5 = Metric representing delay bet. 2 boundary pts. on X. E.g. (entry to X from V) to (exit from X to U)

* The above preferred path will next be advertised by AS X.

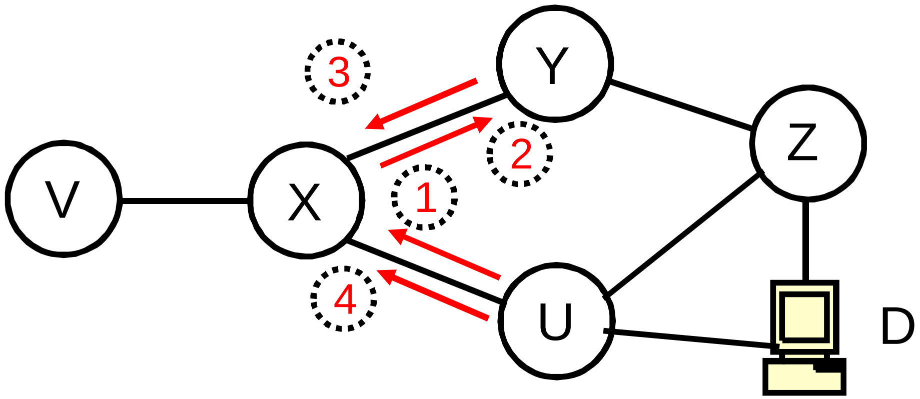
BGP (continued)

* To explain the inconsistency bet. :

metric of preferred path to D (by Y) which is 17

& metric of preferred path to D (by U) which is 18

despite the implication of topology, consider the following scenario:



Step 1 : U advertises preferred path to D [U ; 12]

Step 2 : X repeats advertisement of U

Step 3 : Y uses advertised preferred path of U to deduce its preferred path to D [Y , X , U ; 17]

Step 4 : U sends a new advertisement of its path to D [U ; 18]

Changed due to congestion developing at U

Mobile IP

- Idea :

To *allow a host to be temporarily connected* to a new network (& getting an IP address associated with this new network) *while at the same time* to *forward messages* that are normally sent to his permanent network, *to his NEW (temporary) location*.

- Implementation :

Uses a special protocol – called Mobile IP – which involves TWO agents :

Home Agent (HA); located at permanent (Home) network

Remote Agent (RA); located at network being visited

BGP (continued)

- Implementation

  * Though an AS may have several border routers, AS manager selects one border router to implement BGP (called BGP speaker)

  * Usually, an AS maintains a list of other AS's it does not want to send pkts through.

    (can belong to competitors ==> not secure or reliable)

  * Each AS advertises its preferred paths of destinations only to its neighbor AS's

    ==> minimized amount of information is exchanged

    (in case of OSPF, routing information may flood network)

  * Since using metric information alone can cause looping, advertised information contain both (path & metric)

DHCP (Dynamic Host Configuration Protocol)

- Idea :

  To allow a host to have a real IP address for a limited time.

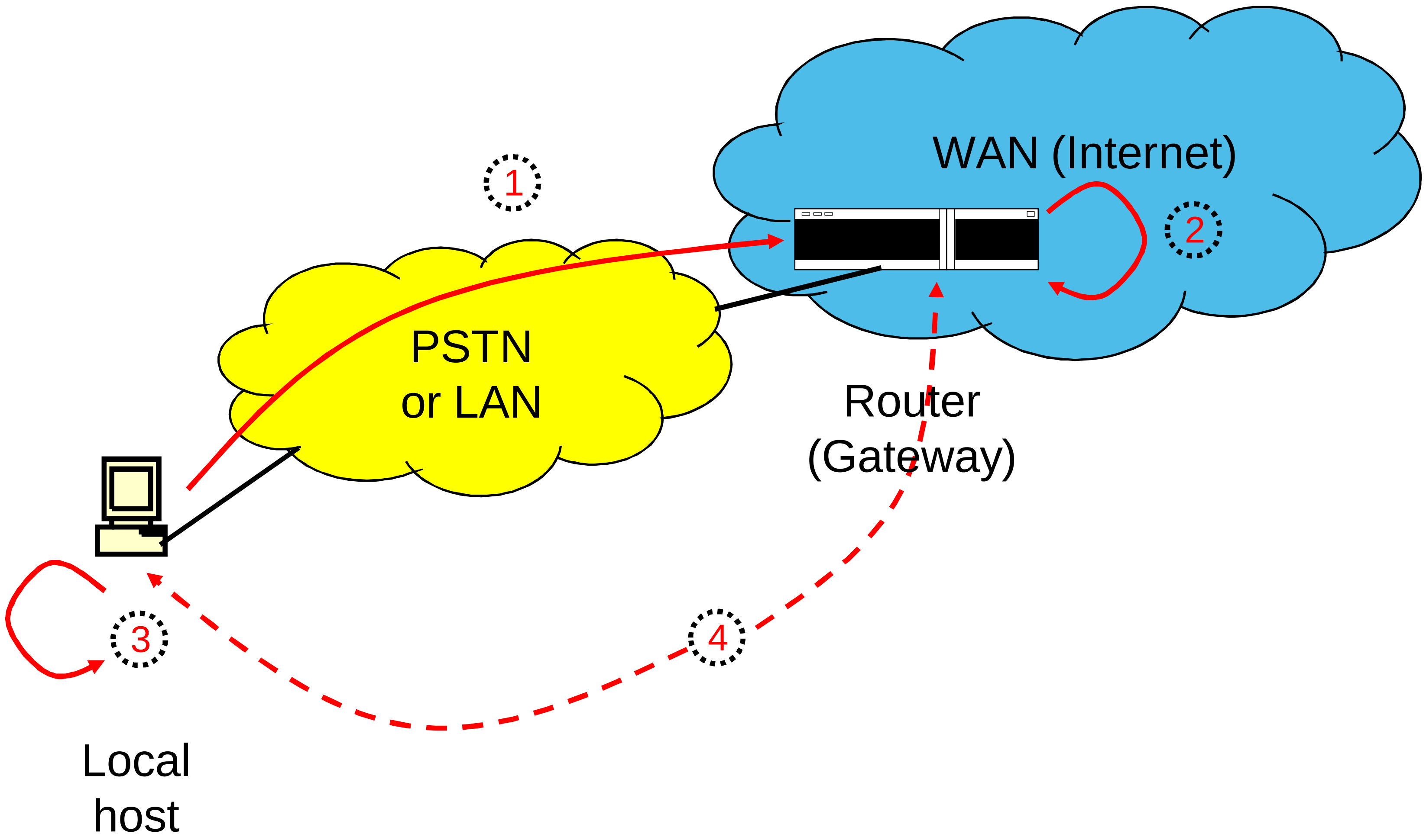
  (Typical situation : Attaching a Laptop to an Ethernet port to get E-Mail, browse WWW, and transfer files. These applications do not require registering a user/host name & its IP address permanently).

- Implementation :

  Uses a special protocol – called DHCP – which assigns an IP address from a pool of free IP addresses to a requester, for a limited time (timeout).

DHCP (Dynamic Host Configuration Protocol) (continued)

- Steps :



Mobile IP (continued)

- Steps :