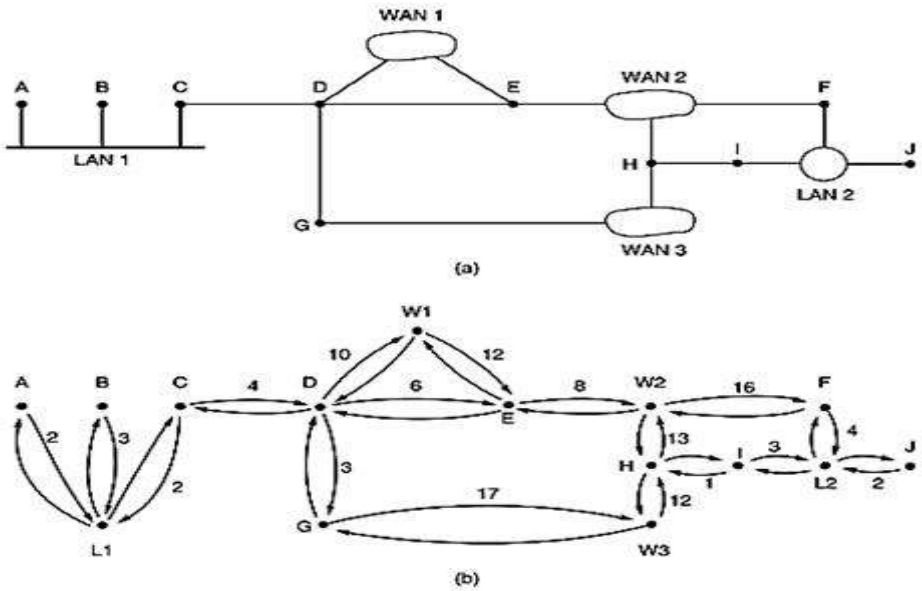

Figure: (a) An autonomous system. (b) A graph representation of (a).

v. Operation and its graph representation:

- OSPF operates by abstracting the collection of actual networks, routers, and lines into a directed graph in which each arc is assigned a cost (distance, delay, etc.).
- It then computes the shortest path based on the weights on the arcs.
- A serial connection between two routers is represented by a **pair of arcs**, one in each direction.
- Figure shows the graph representation of the network of Fig. (a).
- What OSPF fundamentally does is represent the actual network as a graph like this and then compute the shortest path from every router to every other router.
- OSPF allows them to be divided into numbered areas, where an area is a network or a set of contiguous networks.

Figure 5-66. The five types of OSPF messages.

Message type	Description
Hello	Used to discover who the neighbors are
Link state update	Provides the sender's costs to its neighbors
Link state ack	Acknowledges link state update
Database description	Announces which updates the sender has
Link state request	Requests information from the partner

BGP-The Exterior Gateway Routing Protocol

Within a single AS, the recommended routing protocol is OSPF (although it is certainly not the only one in use). Between ASes, a different protocol, BGP (Border Gateway Protocol), is used. The following section elaborates the BGP in details.

BGP:

- Pairs of BGP routers communicate with each other by establishing TCP connections.
- Operating this way provides reliable communication and hides all the details of the network being passed through.
- BGP is fundamentally a distance vector protocol, but quite different from most others such as RIP.
- Instead of maintaining just the cost to each destination, each BGP router keeps track of the path used.
- Similarly, instead of periodically giving each neighbor its estimated cost to each possible destination, each BGP router tells its neighbors the exact path it is using.
  As an example, consider the BGP routers shown in Fig. In particular, consider F's routing table. Suppose that it uses the path FGCD to get to D. When the neighbors give it routing information,

they provide their complete paths, as shown in Fig. (b) (for simplicity, only destination D is shown here).

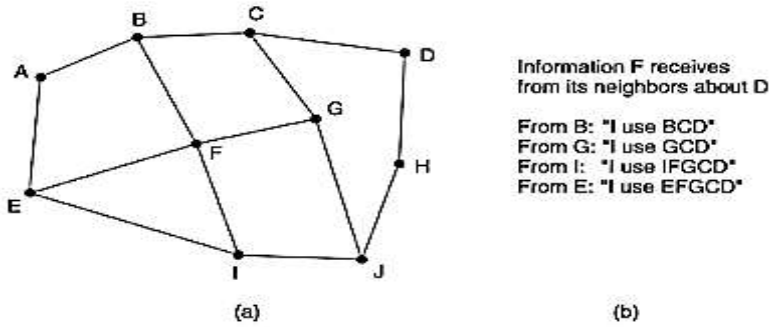

Figure (a) A set of BGP routers. (b) Information sent to F.

After all the paths come in from the neighbors, F examines them to see which is the best.
It quickly discards the paths from I and E, since these paths pass through F itself.
The choice is then between using B and G.

- Every BGP router contains a module that examines routes to a given destination and scores them, returning a number for the "distance" to that destination for each route.
- Any route violating a policy constraint automatically gets a score of infinity.
- The router then adopts the route with the shortest distance.
- The scoring function is not part of the BGP protocol and can be any function the system managers want.
- BGP easily solves the count-to-infinity problem that plagues other distance vector routing algorithms.

Internet Multicasting

For some applications it is useful for a process to be able to send to a large number of receivers simultaneously. Examples are updating replicated, distributed databases, transmitting stock quotes to multiple brokers, and handling digital conference (i.e., multiparty) telephone calls.

Multicasting:

- IP supports multicasting, using class D addresses.
- Each class D address identifies a group of hosts.
- Twenty-eight bits are available for identifying groups, so over 250 million groups can exist at the same time.
- When a process sends a packet to a class D address, a best-efforts attempt is made to deliver it to all the members of the group addressed, but no guarantees are given.
- Some members may not get the packet.
- Two kinds of group addresses are supported: permanent addresses and temporary ones.
- A permanent group is always there and does not have to be set up.
- Each permanent group has a permanent group address.
- Some examples of permanent group addresses are:

224.0.0.1	All systems on a LAN
224.0.0.2	All routers on a LAN
224.0.0.5	All OSPF routers on a LAN
224.0.0.6	All designated OSPF routers on a LAN

- Temporary groups must be created before they can be used.
- A process can ask its host to join a specific group. It can also ask its host to leave the group.
- When the last process on a host leaves a group, that group is no longer present on the host. Each host keeps track of which groups its processes currently belong to.

Implementing Multicasting:

- Multicasting is implemented by special multicast routers, which may or may not be collocated with the standard routers.