Chapter 1
What is Multicast Routing?

Consider a telecommunications network consisting of a set of nodes connected by arcs. The network might be, e.g., the Internet, or the private network offered by a service provider such as AT&T. A node represents a physical device, such as a switch or router, connected to other devices. The term switch is typically used to refer to a device performing layer 2 data link functionality (e.g., Asynchronous Transfer Mode (ATM) or Frame Relay) in the OSI model [102], while a router performs layer 3 network functionality in the OSI model. For brevity, by node we mean either a switch or a router. An arc represents a communications pathway, such as a fiber optic cable or a radio (wireless) link. Suppose a given source node in the network wishes to send the same data stream, composed of packets, to one or more destination nodes in the network. The data stream might be, e.g., an all-employee broadcast, software distribution, a file transfer, financial information, video on demand, or emergency management communications.

We want to determine the path that should be used to send the stream to each destination node. When there is a single destination node, this problem is known as unicast routing, and is typically solved by computing a shortest path between the source and the destination. The path might be computed by a link state method such as ISIS [52], Open Shortest Path First (OSPF) [77], or Private Network-Network Interface (PNNI) [8], or by a distance vector method such as RIP [68]. (In link state methods, each node has its own view of the network topology, and computes routes to all destinations; the classic link-state method is Dijkstra’s method [5]. In distance vector methods, nodes exchange and update routing tables; the classic distance vector method is the Bellman-Ford method [5].) The source node forwards each packet to the next node on the shortest path, this second node forwards the packet to the third node, and this hop-by-hop forwarding terminates when the packet is received by the destination node (a hop is a synonym for an arc). Unicast routing is “easy,” since the complexity of computing a shortest path in a network with $N$ nodes and $A$ arcs is, e.g., $O(N^2)$ for Dijkstra’s method for dense networks, and $O(A + N \log N)$ for a Fibonacci heap implementation [5] (a function $f(x)$ is said to be $O(g(x))$ if there is a positive constant $c$ such that $|f(x)| \leq c|g(x)|$ for all $x \geq 0$).

When the stream is required to be transmitted to every other node in the network, the problem is known as broadcast routing or simply broadcasting. Broadcasting is used, e.g., in ad-hoc mobile networks, where node mobility causes frequent link failures [56]. When the stream is required to be transmitted to only a specified subset of nodes in the network, the problem is called
multicast routing or simply multicasting. Thus unicast is the special cast of multicast where there is one destination, and broadcast is the special case where all nodes are destinations.

1.1 Groups, Sources, and Receivers

In multicast routing, the basic constructs are sources, receivers, and groups. A source is an end user that originates a data stream. A receiver is an end user wishing to receive a data stream. Each source is locally connected to (i.e., subtends) a nearby node, typically either by a direct connection or by an Ethernet Local Area Network (LAN). A source might also be connected to a second nearby node, in case the connection to the first node, or the first node itself, fails. Similarly, each receiver subtends a nearby node, typically by a direct connection or Ethernet LAN, and might also be connected to a second nearby node. We refer generically to an end user source or receiver as a host. There may be no hosts subtending some nodes; such nodes are called via nodes.

A multicast group is a set of receivers with a common interest. Note that this definition makes no mention of a source. For example, if the group is the set of students registered for an online course offered by a university, the receivers are the computers of the online students, and the source might be the router connected to the video camera in the classroom where the instructor is teaching. A second example is a financial institution such as a brokerage house, where the group is the set of stock traders, distributed around the globe, who communicate with each other about stock offerings. The set of receivers is the entire set of computers used by the traders; since each trader typically needs to send financial data to other traders, the set of sources is also the entire set of computers used by the traders.

In the first example, there is a single source, and the set of receivers is relatively static for the duration of the online lecture, since students must pre-register for the online course (although some students might sign-in late or sign-off early). In the second example, both the set of sources and the set of receivers are dynamic, depending on which traders are working that day, or are interested in some stock offer. The financial institution might have multiple multicast groups, e.g., one for bond traders and one for stock traders.

In the any source multicast (ASM) model [31], there is no limit on the number of multicast groups, or on the number of sources and receivers for a group. (While the ASM model assumes no limits, in practice equipment vendors may impose limits due to, e.g., processing or memory limitations.) Group membership is dynamic; receivers can join or leave a multicast group at any time. Similarly, the set of sources for a group can vary over time.