We have just given a high-level overview of how an institution can employ IPsec to create a VPN. To see the forest through the trees, we have brushed aside many important details. Let's now take a closer look.

8.7.2 The AH and ESP Protocols

IPsec is a rather complex animal—it is defined in more than a dozen RFCs. Two important RFCs are RFC 4301, which describes the overall IP security architecture, and RFC 6071, which provides an overview of the IPsec protocol suite. Our goal in this textbook, as usual, is not simply to re-hash the dry and arcane RFCs, but instead take a more operational and pedagogic approach to describing the protocols.

In the IPsec protocol suite, there are two principal protocols: the **Authentication Header (AH)** protocol and the **Encapsulation Security Payload (ESP)** protocol. When a source IPsec entity (typically a host or a router) sends secure datagrams to a destination entity (also a host or a router), it does so with either the AH protocol or the ESP protocol. The AH protocol provides source authentication and data integrity but *does not* provide confidentiality. The ESP protocol provides source authentication, data integrity, *and* confidentiality. Because confidentiality is often critical for VPNs and other IPsec applications, the ESP protocol is much more widely used than the AH protocol. In order to de-mystify IPsec and avoid much of its complication, we will henceforth focus exclusively on the ESP protocol. Readers wanting to learn also about the AH protocol are encouraged to explore the RFCs and other online resources.

8.7.3 Security Associations

IPsec datagrams are sent between pairs of network entities, such as between two hosts, between two routers, or between a host and router. Before sending IPsec datagrams from source entity to destination entity, the source and destination entities create a network-layer logical connection. This logical connection is called a **security association (SA)**. An SA is a simplex logical connection; that is, it is unidirectional from source to destination. If both entities want to send secure datagrams to each other, then two SAs (that is, two logical connections) need to be established, one in each direction.

For example, consider once again the institutional VPN in Figure 8.27. This institution consists of a headquarters office, a branch office and, say, n traveling salespersons. For the sake of example, let's suppose that there is bi-directional IPsec traffic between headquarters and the branch office and bi-directional IPsec traffic between headquarters and the salespersons. In this VPN, how many SAs are there? To answer this question, note that there are two SAs between the headquarters gateway router and the branch-office gateway router (one in each direction); for each salesperson's laptop, there are two SAs between the headquarters gateway router and the laptop (again, one in each direction). So, in total, there are $(2 + 2n)$ SAs. *Keep in mind, however, that not all traffic sent into the Internet by the gateway routers or by the laptops will be IPsec secured.* For example, a host in headquarters may want to access a Web server (such as Amazon or Google) in the public Internet. Thus, the gateway router (and the laptops) will emit into the Internet both vanilla IPv4 datagrams and secured IPsec datagrams.