

knows the IP address of the school's gateway router (68.85.2.1) via the DHCP ACK message in step 5 above, it doesn't know the gateway router's MAC address. In order to obtain the MAC address of the gateway router, Bob's laptop will need to use the **ARP protocol** (Section 5.4.1).

10. Bob's laptop creates an **ARP query** message with a target IP address of 68.85.2.1 (the default gateway), places the ARP message within an Ethernet frame with a broadcast destination address (FF:FF:FF:FF:FF:FF) and sends the Ethernet frame to the switch, which delivers the frame to all connected devices, including the gateway router.
11. The gateway router receives the frame containing the ARP query message on the interface to the school network, and finds that the target IP address of 68.85.2.1 in the ARP message matches the IP address of its interface. The gateway router thus prepares an **ARP reply**, indicating that its MAC address of 00:22:6B:45:1F:1B corresponds to IP address 68.85.2.1. It places the ARP reply message in an Ethernet frame, with a destination address of 00:16:D3:23:68:8A (Bob's laptop) and sends the frame to the switch, which delivers the frame to Bob's laptop.
12. Bob's laptop receives the frame containing the ARP reply message and extracts the MAC address of the gateway router (00:22:6B:45:1F:1B) from the ARP reply message.
13. Bob's laptop can now (*finally!*) address the Ethernet frame containing the DNS query to the gateway router's MAC address. Note that the IP datagram in this frame has an IP destination address of 68.87.71.226 (the DNS server), while the frame has a destination address of 00:22:6B:45:1F:1B (the gateway router). Bob's laptop sends this frame to the switch, which delivers the frame to the gateway router.

### 5.7.3 Still Getting Started: Intra-Domain Routing to the DNS Server

14. The gateway router receives the frame and extracts the IP datagram containing the DNS query. The router looks up the destination address of this datagram (68.87.71.226) and determines from its forwarding table that the datagram should be sent to the leftmost router in the Comcast network in Figure 5.32. The IP datagram is placed inside a link-layer frame appropriate for the link connecting the school's router to the leftmost Comcast router and the frame is sent over this link.
15. The leftmost router in the Comcast network receives the frame, extracts the IP datagram, examines the datagram's destination address (68.87.71.226) and determines the outgoing interface on which to forward the datagram towards the DNS server from its forwarding table, which has been filled in by Comcast's intra-domain protocol (such as **RIP**, **OSPF** or **IS-IS**, Section 4.6) as well as the **Internet's inter-domain protocol, BGP**.
16. Eventually the IP datagram containing the DNS query arrives at the DNS server. The DNS server extracts the DNS query message, looks up the name www.google.com in its DNS database (Section 2.5), and finds the **DNS resource**