We have covered that routers have an IP address and a MAC address for each network they are connected to. Routers have routing tables – map of every network (populated by direct connect, static routes, dynamic routes).

Routers also have ARP tables – mapping of layer 3 to layer 2 addresses – everything with an IP address has an ARP table

A screenshot of a computer program

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Look at router 1 ARP table. It doesn’t include its own IP to MAC; it contains the network contents IP to MAC. For example, on the right side is the 10.0.44.x network and there is host A with IP address of 10.0.44.9 and MAC address of a9a9 so in the ARP table it will be 10.0.44.9--->a1a1. Then on the left side is the 10.0.55.x network which has host B with IP address of 10.0.55.8 and MAC address of b8b8. There is also router 2 which IP address of 10.0.55.2 and MAC address of eee2. So, the R1 ARP table it will also have 10.0.55.8--->b8b8 and 10.0.55.2--->eee2. The same applies to the ARP table for router 2.

One key difference between routing tables and ARP tables is that routing tables must start populated (from the 3 ways) and ARP tables start out empty. If routing table isn’t populated ahead of time, if router receives packets that don’t know how to deliver it, the packet will be dropped. With ARP tables, they get populated as data goes through the network.

A computer screen with a diagram

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Host A wants to send data to host C. the packet is SRC 10.0.44.9 DST 10.0.66.7. host A will compare the DST IP address to its own IP address and subnet mask and realise that the DST IP address is on a foreign network. This means that the packet must be sent onto host A’s default gateway (the local router IP address). Since this is the first packet being sent, host A does not know R1’s MAC address so it cannot create the layer 2 header. As of right now the layer 2 header looks like this SRC a9a9 DST ????. So now host A has to do ARP to figure out R1’s MAC address. The ARP is like this ‘if anyone has IP 10.0.44.1, send me your MAC, my IP:MAC is 10.0.44.9:a9a9’. Host A will also have an ARP table. When R1 receives the ARP request, R1 will populate its ARP table.

Now R1 will have its first ARP table entry which is 10.0.44.9--->a9a9. R1 learns the ARP mapping of the sender of the ARP request. R1 sends a response which is like this ‘I am 10.0.44.1, my MAC is eee1’. SRC eee1 DST a9a9. When host A receives the ARP response, host A can populate its ARP table. Host A’s ARP table will have its first entry which is 10.0.44.1-->eee1. Now that host A has the MAC address of its default gateway, it can construct the layer 2 heading to send the data across. Now the data is like this:

Data:

Layer 2 header:

SRC a9a9

DST eee1

Layer 3 header:

SRC 10.0.44.9

DST 10.0.66.7

Now host A can send the frame to the router, when R1 receives it, it will discard the layer 2 header. Now R1 will look at the DST IP address and it can see that in its routing table that there is a match. It looks at the static route 10.0.66.x network and knows that it has to forward the packet to the 10.0.55.2 IP address which is R2. Now R2 needs to make a layer 2 header for this hop. The problem is that router 1 does not have the MAC address of 10.0.55.2, the R1 ARP table does not include it yet.

A computer screen shot of a program

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So this means that R1 has to do ARP request for 10.0.55.2. the ARP request: ‘if anyone has the IP address 10.0.55.2 send me your MAC, my IP:MAC is 10.0.55.1:eee3. When R2 receives the ARP request, R2 can populate its ARP table with 10.0.55.1--->eee3. R2 now learns that the IP address 10.0.55.2 has the MAC address eee3. Now R2 will send an ARP response: ‘I am 10.0.55.2, my MAC is eee2’. This is the ARP mapping which R1 was trying to discover. When R1 receives it, R1 can populate its ARP table with 10.0.55.2--->eee2. Now the layer 2 header can be made for the data which is SRC eee3 DST eee2. Now the frame can be sent from the current NIC (eee3) to the other NIC on the R2 router (eee2). Then R2 will discard the layer 2 header. Then R2 will look at the DST IP address to determine what to do with the packet. R2 will check its routing table and see that the 10.0.66.x network is on the left side. Since it knows that the left side is a directly connected route, it knows that this is the final hop because the DST IP address exists in a directly connected network. So R2 will create a layer 2 header. But R2 does not know host C’s MAC address because the entry isn’t in the R2 ARP table meaning it cant create the layer 2 header. As of now the layer 2 header is SRC eee4 DST ????. R2 must send an ARP request which is ‘if anyone has IP 10.0.66.7, send me your MAC, my IP:MAC is 10.0.66.2:eee4. Then host C will receive the ARP request and in host C’s ARP table it will populate with 10.0.66.2--->eee4. Then host C will send an ARP response which is ‘I am 10.0.66.7, my MAC is c7c7. R2 will receive the ARP response so now it can populate its ARP table with this entry which is 10.0.66.7--->c7c7. Now the layer 2 header can be created because now we know the MAC address of the DST IP address (host C). the layer 2 header is SRC eee4 DST c7c7. The frame is sent to host C, it will discard the layer 2 header, then it will discard the layer 3 header, then it will process the data.

A screenshot of a computer

AI-generated content may be incorrect.

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Now we will go through how host C will send a response to host A, however this will be much quicker because we now have the necessary ARP entries.

Host C wants to send data to host A, it will create a layer 3 header with the source IP address as its own IP address and the destination IP address of host A’s IP address so SRC 10.0.66.7 DST 10.0.44.9. since host C knows that the destination IP address is on a foreign network, host C knows that the packet needs to be sent to its default gateway which is R2. Since host C has the MAC address of R2 (from host C ARP table), it can send the frame to R2. The data will look like this:

Data:

Layer 2 header:

SRC c7c7

DST eee4

Layer 3 header:

SRC 10.0.66.7

DST 10.0.44.9

When R2 receives the frame it will discard the layer 2 header. Then it will look up the DST IP address in its routing table. It can see that it is a static route to get to the network, so it has to send the packet to 10.0.55.1 which is R1’s IP address. The layer 2 header can be created because the MAC address is shown in the R2 ARP table. Layer 2: SRC eee2 DST eee3. Now R2 will send the packet to R1, R1 will now discard the layer 2 header. Then R1 will look up the DST IP address in its routing table and it can see that the 10.0.44.x network is on the right hand side which is a directly connected route. Since R1 has the ARP mapping, it has the MAC address of host A. so now the layer 2 header can be made: SRC eee1 DST a9a9. Host A will receive the data, then it will discard the layer 2 header, then it will discard the layer 3 header, then it will process the data.