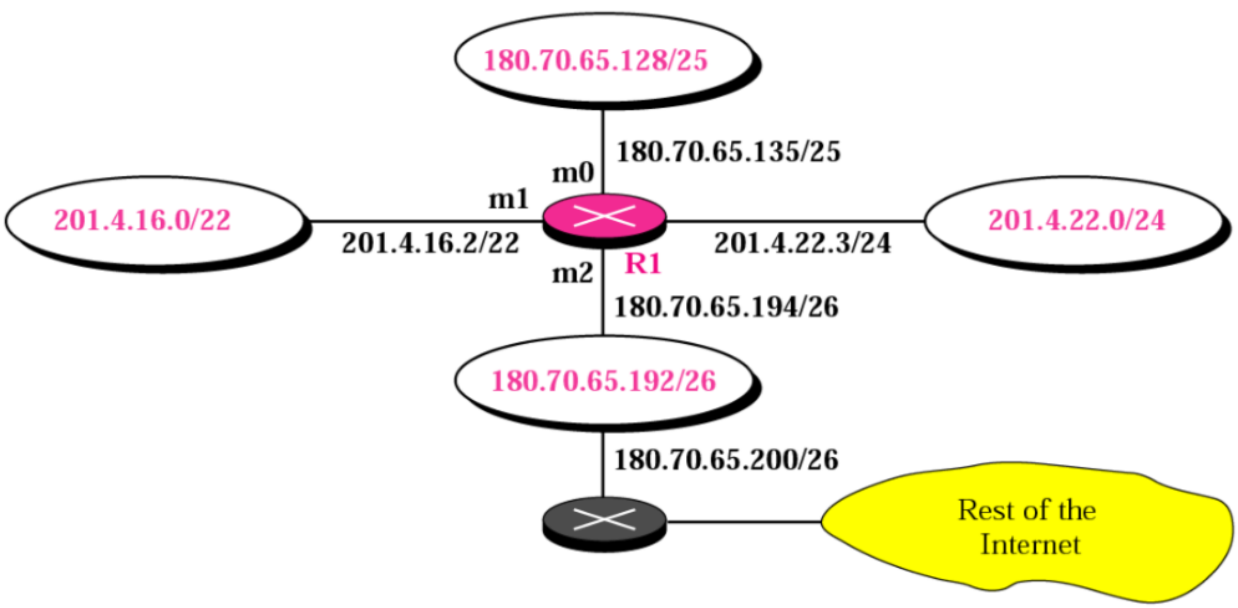
Q.1 The ARP protocol uses the the next-hop address and the interface number, found in the routing table, to find the physical address of the next hop. Consider a certain router Ri whose routing table has only three columns: mask, network address, and next-hop address, i.e. the column with the interface numbers has been deleted. (Note that only the column with the info on the interfaces has been removed not the interfaces themselves, i.e. the network configuration has not changed.) Does the ARP protocol still work? If not, how to modify this protocol to make it work? Does your modification affect the network performance?

A.1 The ARP protocol on certain Router Ri will not work because:-

1) The interface column tells the router which NIC(Network Interface Card) is connected to the appropriate destination network.
2) Technically, the interface column only tells the router the IP address that has been assigned to the NIC that connects the router to the destination network.
3) Thus, the standard ARP protocol will not work without the interface number of routing table.



For instance let us consider a network with a configuration as shown in the above figure, router R1 is connecting various subnets and passing packets to their respective destinations as per the entries in its routing table. The routing table for router R1 is shown below.

Mask	*Network Address*	*Next Hop*	*Interface*
/26	180.70.65.192	-	m2
/25	180.70.65.128	-	m0
/24	201.4.22.0	-	m3
/22	201.4.16.0	....	m1
Default	Default	180.70.65.200	m2

It can be seen that the routing table for router R1 holds the entries for mask that needs to be applied to get the network address of the destination and the next hop address for the particular network addresses. The reason that most of the entries in the next hop column are empty is that the destination address is in the same network to which the router is connected. Thus, the ARP protocol uses the destination address as the next hop address.

Now if we remove the entries of the corresponding interfaces from the routing table of the router R1 it can be seen that ARP protocol would not be able to get the job done. Since, only the entries of the interfaces are being erased from the routing table and not the interfaces themselves we can make few modifications in the traditional ARP protocol to make it work even when there is no entries for interfaces in the routing table. The following section mentions few such modifications.

Modifications:

1) We can modify the protocol by enqueuing local broadcast ARP request(To each and every interface connected to the router) and will wait for the ARP reply

2) The ARP request will then check in the cache table for the corresponding entry.
3) If the entry is resolved then a new entry is not added in cache table.
4) As we get the ARP reply the address is resolved of the next hop or the destination network address.
5) Thus, the state is resolved with the update of MAC address in the cache table.
6) In the above step we will find the MAC address because as mentioned in the question only the Interface number column of routing table is deleted but the network configuration is same and thus we have NIC at each destination network connected to router Ri.
7) The router is smart enough to find the appropriate destination network.
8) The only thing is "The time" which it will take to find the interface between itself and destination network.

Effect of modification in network:-

1) As it is a broadcast request to each interface connected to the router, resource hogging takes place.
2) Time for the ARP reply may increase and thus will slow down the network.
3) Also congestion comes into picture as the ARP request is broadcasted to whole network connected to the router.

Q.2 The ARP reply is used to update the ARP cache table. Can the ARP request be also used to update this table? If so, how?

A.2 Yes, the ARP request does play a role in updating the ARP cache table.
Since computers cannot send broadcast messages every time they need to connect with another network device, they store the IP addresses and the corresponding MAC addresses of systems they frequently communicate with. This addresses are stored in cache table with specific format as mentioned below:-

State	Queue	Attempt	Timeout	Protocol Address	Hardware Address
R	5		100	180.3.6.1	ACAE32457342
P	2	3		129.34.4.8	
F					
P	8	4		156.12.34.5	

Table 2.1

When it comes to the Layer 2 communications between networked systems, IP address is not used. So, within a LAN segment computers identify each other and communicate with each other using the MAC address. So, when Computer (C1) gets the target IP address of the Computer (C2) it wants to communicate with. Suppose the above cache table is at Computer(C1)-

- It first looks at its own ARP cache (which is a table that contains the IP addresses and their corresponding MAC addresses for computers/ systems within a network) to see if it already has the MAC address for the computer (C2), it wants to communicate with.
- If the MAC address of C2 is present in its ARP cache table, it can then append the message with the corresponding MAC address and send it over the network
- If the MAC address of C2 is not present in its ARP cache table, C1 will broadcast an ARP request message to all the computers / systems in the

network indicating that it wants the MAC address for the IP address in its possession.

- When a destination's corresponding entry is not available in the cache table a new entry is made after generating an ARP request as mentioned above. This updates the cache table with by making a entry.
- Firstly, a new entry is added when a free entry is available it is used to add a new entry.
- As we can see in Table 2.1, there is a free entry available and with state "F". This state changes to pending "P" as we add an entry and it is enqueued with certain index of queue.
- ARP request packet holds the protocol address which is fetched into the table.
- As this is a first attempt, the attempt number is set to 1. Thus, for every attempt this count increases and is NULL when a MAC address is resolved with a ARP reply.

State	**Queue**	**Attempt**	**Timeout**	**Protocol Address**	**Hardware Address**
R	5		100	180.3.6.1	ACAE32457342
P	2	3		129.34.4.8	
P	9	1		IP address(C2)	
P	8	4		156.12.34.5	

Table 2.2

- .The columns in the above cache table(Table 2.2) that are updated with a ARP request are:-

I. State → It holds pending as the request has not been resolved yet.

II. Queue → Holds information regarding the queue assigned to this particular request

III. Attempt Number → The number of times a request has been sent

IV. Protocol Address → Holds the address of the destination in terms of the protocol being used.

Q.3 Two network administrators argue about setting an optimal time-out T for the ARP cache table of a certain router. The first administrator thinks that T=t1 is satisfactory, the other one claims that T=t2 is much better. Propose a set of criteria to evaluate which of them is right. (Maybe both are wrong?) Which of these criteria is the most important from your point of view?

A.3 Let us assume that the two time-out values t1 and t2 are like that $t1 < t2$. Then we can consider the following aspects.

Aspect I: t1 is very small in magnitude
In this case if the network traffic is not prominent then the ARP entries will keep getting erased from the cache table and every time the data is to be sent, a new ARP request would be generated. Hence, hogging resources of the network.

Aspect II: t2 is very large in magnitude
If the timeout value is set to be too high then there are chances that the entries in the ARP cache table would go stale. There are chances that due to the long timeout value in ARP cache may represent old information.

Aspect III: When the difference between t1 and t2 is significant enough
In this case we consider the fact that the timeout values vary from t1 to t2 and can be changed at any given point of time. Initially all the entries would be assigned t1 as the timeout value. As the traffic may increase for the entries the timeout values would also increase. Thus, the entries that are needed more will have a greater value for timeout as compared to other entries. This technique not only gives the ability to introduce some flexibility in the ARP cache table but also decreases the probability of regenerating ARP requests for destinations that are being used more often.

The most important criteria is that the timeout value shouldn't be too small as this would increase the probability of the cache entries getting erased. On the other hand longer timeout can be tolerated. As it doesn't affect the network performance on a greater level.