CS 542 – Computer Networks I – Fundamentals (Section-01)
Fall 2018 - project (**10 points)**

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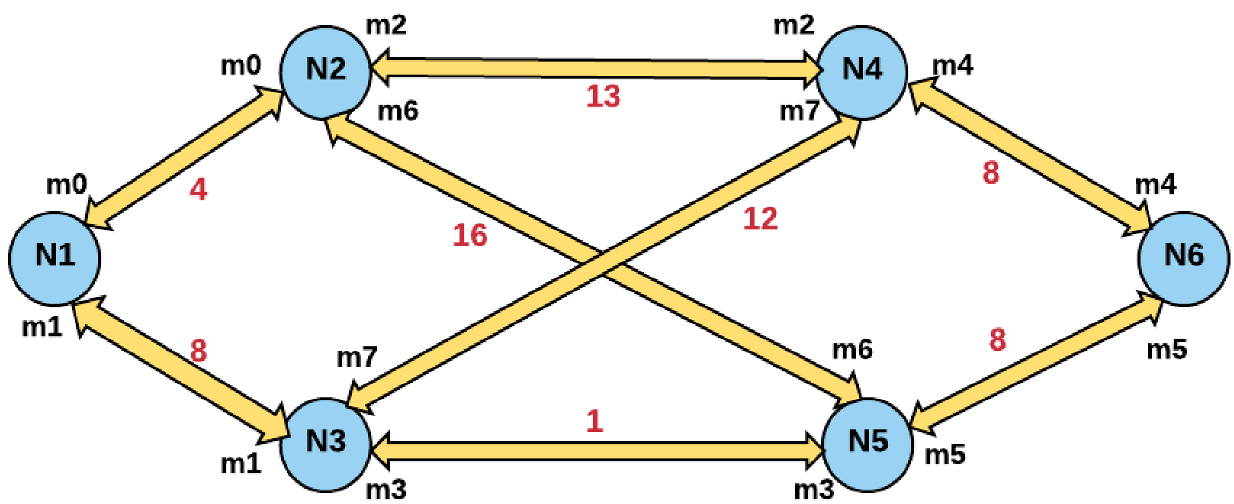
**The objective of this project is to design a new fragmentation protocol that:**

1. Finds an optimal MTU that enables fragmentation of an original packet at a source node only, i.e. the resulting fragments must NOT be fragmented again at intermediate nodes.

2. Determines the next hop IP address for these fragments as they travel to the destination.

**Approach to new fragmentation:**

Consider a network topology of 6 nodes naming *N1, N2, N3, N4, N5, N6* interconnected with bidirectional links $l_{ij}$ where $i$ and $j$ identify the end nodes *Ni* and *Nj* where $l_{ij}$ and $l_{ji}$ denotes the same link as shown below. Note that, here we have considered ***source node as N1 and destination node as N6.***




Based on the above figure, let's figure out an approach to find an optimal MTU from source to destination. The given details are network configuration, MTU size of the bidirectional links connecting the nodes and the neighboring node's information. So, from the neighboring nodes we shall get the information about the MTU size, interface number of its immediate neighbors.

***Iteration 1:***

From the given network topology, we could find that the neighboring nodes of node N1 are N2 and N3. The MTU size between N1 and N2 is 4 and MTU size between N1 and N3 is 8 respectively.

Therefore, the information table for ***Node N1*** based on information given in above network topology is given below,

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| N2 | m0 | 4 | N1→N2 |
| N3 | m1 | 8 | N1→N3 |
| N4 | - | - | - |
| N5 | - | - | - |
| N6 | - | - | - |

***Iteration 2:***

From the given network topology, we could find that the neighboring nodes of node N2 are N1, N4 and N5. The MTU size between (N2, N1) is 4, (N2, N4) is 13 and (N2, N5) is 16 respectively. The detailed ***Node N2*** information is described in the below mentioned table as follows,

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| N1 | m0 | 4 | N2→N1 |
| N3 | - | - | - |
| N4 | m2 | 13 | N2→N4 |
| N5 | m6 | 16 | N2→N5 |
| N6 | - | - | - |

From the given network topology, we could find that the neighboring nodes of node N3 are N1, N4 and N5. The MTU size between (N3, N1) is 8, (N3, N4) is 12 and (N3, N5) is 1 respectively. The detailed ***Node N3*** information is described in the below mentioned table as follows,

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| N1 | m1 | 8 | N3→N1 |
| N2 | - | - | - |
| N4 | m7 | 12 | N3→N4 |
| N5 | m3 | 1 | N3→N5 |
| N6 | - | - | - |

Now, consider the new neighboring nodes of N2, it is clear from the figure that its new neighboring nodes N4 and N5 are connected via links $l_{24}$, $l_{25}$. Similarly, the new neighboring nodes of N3 are N4 and N5 are connected via links $l_{34}$, $l_{35}$. As we see from the above network topology, the MTU of link $l_{24}$ is 13 and MTU of link $l_{34}$ is 12.

Let’s figure out, the criteria for selecting optimal MTU to reach N4 from the source node N1. The possible ways to reach N4 from N1 is via N2 and N3 respectively.
Now consider via N2, (N1 → N2 →N4)

**The MTU of N2→N1 is 4 from table Node N2**. The MTU of $l_{24}$ is 13.
Now, consider the minimum MTU from N1 → N4 because we can transfer a fragment of size lesser than or equal to 4 that is, min(N2, N2→N4) = min(4,13) = 4

Now consider via N3, (N1 → N3 →N4)

**The MTU of N3→N1 is 8 from table Node N3.** The MTU of $l_{34}$ is 12.
Now consider the minimum MTU from N1 → N4 because we can transfer a fragment of size lesser than or equal to 8 that is min(N3, N3→N4) = min(8,12) = 8

To find the optimal MTU from N1 to N4, consider the maximum MTU of the possible ways discussed above to reach N4 from source N1.
That is, max(4,8) =8
Therefore, based on above observation, the optimal MTU is 8 via N1→N3→N4.
Now, let’s update the information table for Node N1 with optimal MTU to reach N4 via **N3**.

***Updation of Node N1 after iteration 2,***

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| N2 | m0 | 4 | N1→N2 |
| N3 | m1 | 8 | N1→N3 |
| **N4** | **m1** | **8** | **N1→N3→N4** |
| N5 | - | - | - |
| N6 | - | - | - |

***Iteration 3:***
Let’s figure out, the criteria for selecting optimal MTU to reach N5 from the source node N1. The possible ways to reach N5 from N1 is via N2 and N3(currently discovered at end of iteration 1) respectively.

Now consider via N2, (N1 → N2 →N5)

The MTU of N1→N2 is 4 from information table Node N2. The MTU of $l_{25}$ is 16.
Now consider the minimum MTU from N1 → N5 because we can transfer a fragment of size lesser than or equal to 4 is min(N2, N2→N5) = min(4,16) = 4.

Now consider via N3, (N1 → N3 →N5)

The MTU of N3 is 8 from table Node N3. The MTU of $l_{35}$ is 1.

Now consider the minimum MTU from N1 → N5 because we can transfer a fragment of size lesser than or equal to 1 is min(N3, N3→N5) = min(8,1) = 1.
To find the optimal MTU from N1 to N5, consider the maximum MTU of the possible ways to reach N5 from source N1.
That is, max(4,1) = 4
Therefore, based on above observation, the optimal MTU is 4, via N1 →N2→N5.
Now, let's update the table for Node 1 with optimal MTU to reach N5 via **N2**.
Now, let's update the information table for Node N1 with optimal MTU to reach N5 via **N2**.

***Updation of Node N1 after iteration 3,***

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| N2 | m0 | 4 | N1→N2 |
| N3 | m1 | 8 | N1→N3 |
| **N4** | **m1** | **8** | **N1→N3→N4** |
| **N5** | **m0** | **4** | **N1→N2→N5** |
| N6 | - | - | - |

***Iteration 4:***

From the given network topology, we could find that the neighboring nodes of node N4 are N2, N3 and N6. The MTU size between N4, N2 is 13 and MTU size between N4, N3 is 12 and the MTU size between N4, N6 is 8 respectively. Therefore, the information table for ***Node N4*** based on information given in above network topology is given below,

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| N1 | - | - | - |
| N2 | m1 | 13 | N4→N2 |
| N3 | m7 | 12 | N4→N3 |
| N5 | - | - | - |
| N6 | m4 | 8 | N4→N6 |

Similarly, form the given topology, we could find that the neighboring nodes of node N5 are N2, N3 and N6. The MTU size between N5, N2 is 16 and MTU size between N5, N3 is 1 and the MTU size between N5, N6 is 8 respectively.

Therefore, the information table for ***Node N5*** based on information given in above network topology is given below,

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| N1 | - | - | - |

| | | | |
|---|---|---|---|
| N2 | m6 | 16 | N5→N2 |
| N3 | m3 | 1 | N5→N3 |
| N4 | - | - | - |
| N6 | m5 | 8 | N5→N6 |

Since we have information about neighboring nodes of N4 and N5 from previous iteration since there is a path from N4 →N2 and N5→N2 we shall check whether is an optimal path to reach N2 from source node N1 using the nodes N4 and N5.
Let's figure out, the criteria for selecting optimal MTU to reach N2 from N4 and N5. The possible ways to reach N2 are N1→N3→N4→N2 and N5 →N2.

Now consider via N4, (N4 → N2)
The MTU of N1→N3→ N4 is 8 as per updation of information table Node N1 after iteration 3. The MTU of $l_{42}$ is 13. Now, consider the minimum MTU from N4 → N2 because we can transfer a fragment of size lesser than or equal to 8, that is min(N4, N4→N2) = min(8,13) = 8

Now consider via N5, (N5 → N2)
The MTU of N1→N2→N5 is 4 as per updation of information table Node N1 after iteration 3. The MTU of $l_{52}$ is 16. Now, consider the minimum MTU from N5 → N2 because we can transfer a fragment of size lesser than or equal to 4, that is min(N5, N5→N2) = min(4,16) = 4

As we know, the MTU of old node N2 is 4. To find the optimal MTU to reach N2, consider the maximum MTU of the possible ways to reach N2.
That is, max (8,4,4) =8

Therefore, based on above observation, the optimal MTU of N2 is 8 via N1→N3→N4→N2.
Now, let's update the information table for Node 1 with optimal MTU for N2 is changed to 8 via **N4**.

***Updation of Node N1 table after iteration 4,***

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing path*** |
|---|---|---|---|
| **N2** | **m0** | **8** | **N1→N3→N4→N2** |
| N3 | m1 | 8 | N1→N3 |
| N4 | m1 | 8 | N1→N3→N4 |
| N5 | m0 | 4 | N1→N2→N5 |
| N6 | - | - | - |

***Iteration 5:***

Let's figure out, the criteria for selecting optimal MTU to reach N3 from N4 and N5. The possible ways to reach N3 are N4 →N3 and N5 →N3.

Now consider via N4, N4→N3.

The MTU to reach N4 from source node N1 is 8 as per updation of information table Node N1 after iteration 3. The MTU of $l_{43}$ is 12. Now, consider the minimum MTU from N4 → N3 because we can transfer a fragment of size lesser than or equal to 8, that is min(N4, N4→N3) = min(8,12) = 8

Now consider via N5, N5 → N3.

The MTU to reach N5 from source node N1 is 4 as per updation of information table Node N1 after iteration 3. The MTU of $l_{53}$ is 1.

Now, consider the minimum MTU from N5 → N3 because we can transfer a fragment of size lesser than or equal to 1, that is min (N5, N5→N3) = min(4,1) = 1

As we know, the MTU of old node N3 is 8 from N1. To find the optimal MTU to reach N3, consider the maximum MTU of the possible ways to reach N3.

That is, max (8,1,8) =8

Therefore, based on above observation, the optimal MTU of N3 is 8 via N4.

As the MTU for N3 has not changed the table remains the same as above information table Node N1 after iteration 5 is given below,

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| N2 | m0 | 8 | N1→N3→N4→N2 |
| N3 | m1 | 8 | N1→N3 |
| N4 | m1 | 8 | N1→N3→N4 |
| N5 | m0 | 4 | N1→N2→N5 |
| N6 | - | - | - |

***Iteration 6:***

Since we have updated the MTU size to reach N2 from source node N1 from last iteration, so we shall check we could update the MTU size to reach N5 from source node N1 via N2. As we could find a link from N2→N5 now let's check whether there is an optimal way to reach N5 from source node N1. Now, let's update N5 as it has link to N2.

Now consider via N2, N2 →N5.

The MTU to reach N2 from N1 is 8 as per information table node N1. The MTU of l25 is 16.

Now consider the minimum MTU from N2 → N5 because we can transfer a fragment of size lesser than or equal to 8, that is min(N2, N2→N5) = min(8,16) = 8

As we know, the MTU of old node N5 is 4. To find the optimal MTU to reach N5, consider the maximum MTU of the possible ways to reach N5.
That is, max (8,4) = 8
Now, let's update the table for Node N1 with optimal MTU for N5 is changed to 8.

***Updation of information table N1 after iteration 6,***

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| N2 | m0 | 8 | N1→N3→N4→N2 |
| N3 | m1 | 8 | N1→N3 |
| N4 | m1 | 8 | N1→N3→N4 |
| **N5** | **m0** | **8** | **N1→N3→N4→N2→N5** |
| N6 | - | - | - |

***Iteration 7:***
From the given network topology, we could find that the neighboring nodes of node N6 are N4 and N5. The MTU size between N4, N6 is 8 and MTU size between N5, N6 is 8 respectively.

Therefore, the information table for ***Node N6*** based on information given in above network topology is given below,

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| N1 | - | - | - |
| N2 | - | - | - |
| N3 | - | - | - |
| N4 | m4 | 8 | N4→N6 |
| N5 | m5 | 8 | N5→N6 |

Let's figure out, the criteria for selecting optimal MTU to reach N6 from N4 and N5.

Now consider via N4, N4 → N6
The MTU of N4 from source node N1 is 8 as per the information table Node N1. The MTU of $l_{46}$ is 8. Now, consider the minimum MTU from N4 → N6 because we can transfer a fragment of size lesser than or equal to 8, is min(N4, N4→N6) = min(8,8) = 8

Now consider via N5, N5 →N6

The MTU of N5 from source node N1 is 8. The MTU of $l_{56}$ is 8. Now, consider the minimum MTU from N5 → N6 because we can transfer a fragment of size lesser than or equal to 8, is min(N5, N5→N6) = min(8,8) = 8

To find the optimal MTU to reach N6, consider the maximum MTU of the possible ways to reach N6 via N4→N6 and N5→N6.
That is, max (8,8) = 8

Therefore, based on above observation, the optimal MTU of N6 is 8 via N4→N6 and N5→N6. Now, let's update the information table for Node N1 with optimal MTU for N6 as 8 via N4 and N5.

***Updation of Node N1 Table after iteration 7:***

| ***Next hop address*** | ***Interface number*** | ***MTU Size*** | ***Routing Path*** |
|---|---|---|---|
| **N2** | **m0** | **8** | **N1→N3→N4→N2** |
| **N3** | **m1** | **8** | **N1→N3** |
| **N4** | **m1** | **8** | **N1→N3→N4** |
| **N5** | **m0** | **8** | **N1→N3→N4→N2→N5** |
| **N6** | **m1** | **8** | **N1→N3→N4→N6 (or) N1 → N3 → N4 → N2 → N5 → N6** |

The two optimal MTU paths to reach from source N1 to destination N6 are:
***N1 → N3 → N4 → N6***
(OR)
***N1 → N3 → N4 → N2 → N5 → N6***

Therefore, the optimal MTU path to reach from source N1 to destination N6 is:
***N1 → N3 → N4 → N6*** (since it has minimum number of hops from source to destination)

**Conclusion:**
Therefore, from the above network topology, the optimal MTU from source node N1 to reach destination node N6 is 8, because we can transfer only one fragment of size lesser than or equal to 8 and this is achieved via N1→N3→N4→N6 since it has minimum number of hops from source to destination. The updation of the neighboring node's information shall be ***stopped*** when the source node gets information about all the neighboring links (MTU Size) of all the nodes in the network topology.