The Primary Path Selection Algorithm for Ubiquitous Multi-homing Environments*

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Abstract. The multi-homing technology can provide an extended coverage area via distinct access technologies. Also, it is able to redirect a flow from one interface to another without reinitiating the flow. However, there is no suitable multi-homing technology for ubiquitous network environment at the moment. To provide multi-homing schemes into the ubiquitous environment, various related researches should be studied. Therefore, we proposed primary path selection algorithm which can provide a ubiquitous access and Flow redirection.

1 Introduction

Currently, multi-homing issues[1] are one of the most important factors in ubiquitous network environment. Multi-homing technologies can establish connection more efficiently and reliably between nodes those communicate each other. To adopt multi-homing technologies into the ubiquitous networks, various algorithms such as source address selection, primary path selection and failure discovery must be defined. An efficient algorithm for address selection and failure discovery has been articulated in [2]. However, existing works do not provide suitable path selection algorithms for multi-homing technology in ubiquitous networks which is very important considering the performance of the network. So in this paper our main focus is on primary path selection algorithm to improve the network performance. Our paper is organized as follows. Section 2 introduces related works about multi-homing issues. In section 3, we described the primary path selection algorithm for Ubiquitous network environment. After that we show the simulation results in section 4. Finally, we conclude in section 5.

2 Related Works

The monami6 working group in IETF has defined scenarios so that multiple interfaces and multiple CoA (care of addresses) registration [3] can be used. According to those scenarios, mobile node [5][6] can use multiple types of access technologies such as

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802.11.b, WiBro and Cellular network in order to maintain ongoing communication, especially when it is moving out of coverage area of a specific technology. Moreover, these scenarios described how the mobile node can dynamically redirect flows [3] from one type of access technology to another and how it can also select the best access technology according to traffic characteristics or preferences. In multiple care of addresses registration [2], binding unique identifiers sub option for registration of multiple CoA [5][8] is defined. Although, this group defined well about multi-homing, still there are problems to solve such as source address selection and primary path selection algorithm. These algorithms should be defined as because mobile node must select one of the access technologies and it can change path according to user preference, applications and traffic quality. Therefore, this research focused mainly on primary path selection when mobile node make connection with its' home agent and correspondent node. Moreover it defined the path selection algorithm that can dynamically change primary path according to network state.

3 Path Selection Scheme for Ubiquitous Network Environment

In this section the primary path selection algorithm, binding update with multiple care of address, administration of binding cache and operation of proposed scheme are described.

3.1 Primary Path Selection Algorithm

The primary path selection algorithm is a method that can select primary path by Home Agent and Correspondent Node. When mobile node selects primary path in multi-homing environment, it can allocate primary path using the following algorithm. There are three different factors; which are signal strength, data rate and bandwidth utilization used in this algorithm. Our research considered these factors to compare the most appropriate paths. If signal strength and data rates have higher value, it means network can provide high quality of service to a mobile node. In addition, according to primary path selection algorithm, network states can be separated in eight different cases as shown figure 1. The figure 1 shows the results to measure each signal strength, data rate and bandwidth utilization by mobile node at the same time.
The graphs are analyzed as follows:

① Time 1: The mobile node should select A as a primary path because it has higher value for both signal strength and data rates than B
② Time 2: Although A's signal strength and data rate are higher than the B's, bandwidth at interface a ('a' is connected with access router A)
③ Time 3: If bandwidth utilization of interface 'a' and 'b' are over threshold value, the mobile node can select the A as a primary path which have higher value for data rate and signal strength.
④ Time 4: The mobile node should select the B as a primary path even the A has higher data rate than the B. This is because of the signal strength of A falls under

Table 1. Pseudo code for primary path selection algorithm

```
If signal strength  A>B
      If data rate A>B
            If  A's signal strength ≠ threshold
                  If  interface a of MN's bandwidth utilization = enough
                              A is selected primary path by mobile node
                  Else if  interface b of MN's bandwidth utilization = enough
                              B is selected primary path by mobile node
                  Else // 'a' and 'b' = threshold
                              A is selected primary path by mobile node
            Else // A's signal strength = threshold
                  B is selected primary path by mobile node
      Else // data rate A<B
            If  B's signal strength ≠ threshold
                  If  interface b of MN's bandwidth utilization = enough
                              B is selected primary path by mobile node
                  Else if  interface a of MN's bandwidth utilization = enough
                              A is selected primary path by mobile node
                  Else // 'a' and 'b' = threshold
                              B is selected primary path by mobile node
            Else // B's signal strength = threshold
                  A is selected primary path by mobile node
                  A is selected primary path by mobile node
End
* A and B are Access Router
* 'a' is a interface of mobile node to connect with A
* 'b' is a interface of mobile node to connect with B
* threshold is a  minimum value which can connect with access router by a MN
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the threshold. It means mobile node moves far from access router so that it can prepare a handover or its' connection can be disconnected with access router.

⑤ Time 5: Although B's signal strength is lower than the A's, the mobile node should select the B as a primary path because the B's data rate is higher than the A's data rate. It means the B can provide a better quality of service than the A.

⑥ Time 6: It has same condition with the Time 5 except bandwidth utilization. In this timing, the B's bandwidth utilization increases over the threshold. Which means it can not provide efficient throughput through the interface 'b' at that time. Therefore, the mobile node should select A as the primary path.

⑦ Time 7: It has similar condition with the time 3. Even though the A's signal strength is higher than the B, but B's data rate is higher than A. So the mobile node should select the B as a primary path.

⑧ Time 8: The mobile node should select A as a primary path because A's signal strength falls under the threshold.

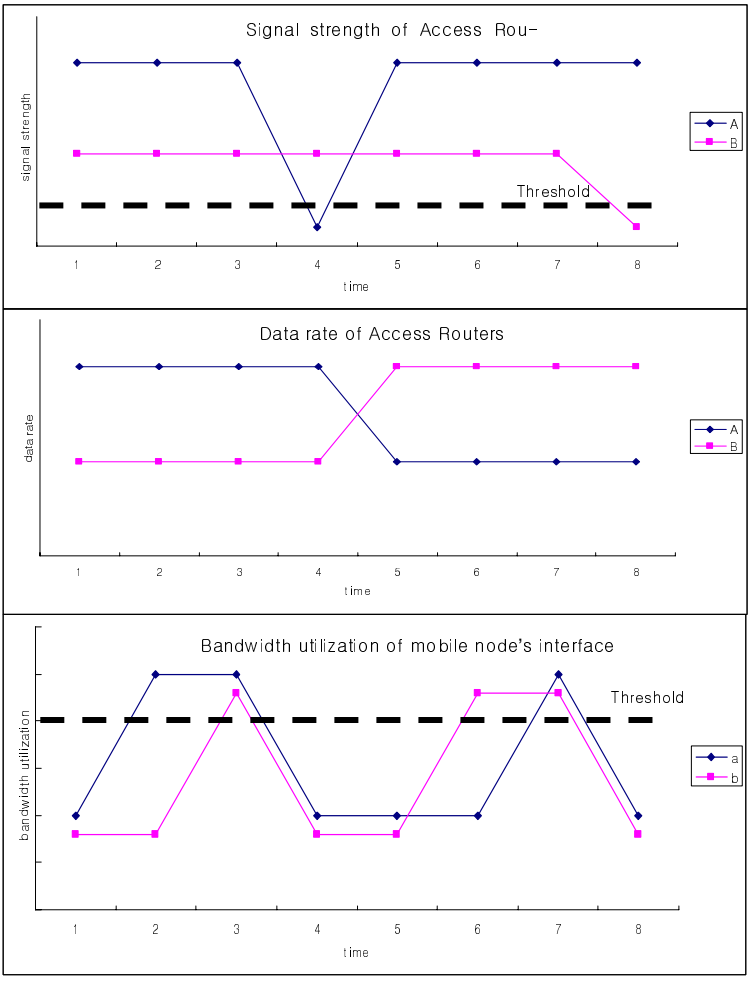

Fig. 1. Eight cases for primary path allocation

3.2 Binding Update with Multiple Care of Address

New binding update [5] fields are defined to accommodate multiple binding and priority value registration. The following additional fields are required in the binding update message. Figure 2 depicts the new binding update message format

- 'M' flag: Mobile node sends multiple care of address in binding update
- 'Priority' field: The priority value is calculated using path selection algorithm by mobile node. It is used by Home Agent and Correspondent Node to select a primary path.

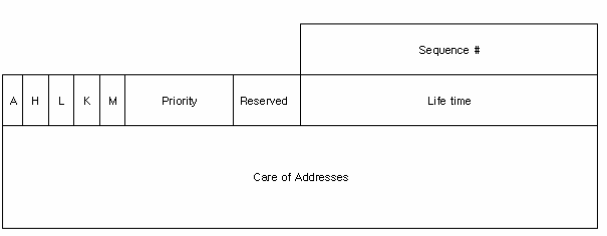

Fig. 2. Binding Update format with multiple Care of Address

3.3 Administration of Binding Cache

The new binding cache entry [5][7][8] that helps both the Home Agent and Correspondent Node to decide primary path is defined in this paper. The binding cache entry which include new priority field is given in table 2. The primary path is selected according to the value of priority field.

Table 2. New binding cache entry in Home Agent

	Home address	Care of Address	Life time	flag	Sequence Number	priority
Path1	a:b:c:d:fff1	1:b:c:fff1	10	1	234	1
Path2	a:b:c:d:fff1	2:b:c:fff1	10	1	252	2

For instance, the mobile node which has a:b:c:d:fff1 address as the home address have got two care of addresses from different access router. So it can send binding update message including priority value to Home Agent. While, Home Agent receives binding update message from mobile node. The binding cache entries could be recorded like the table 2. As a consequence, the Correspondent Node that tries to connect to mobile node has allocated the primary path as path 1 by Home Agent.

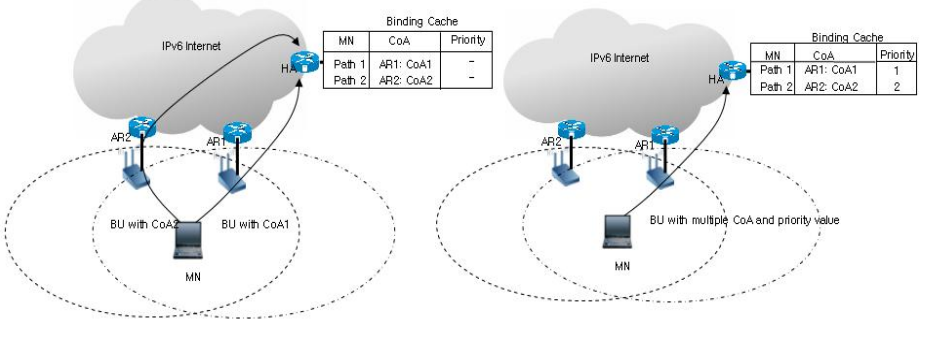

Fig. 3. Normal binding procedure and Binding Update with multiple CoA and Priority values

The mobile node can get binding acknowledgements for each binding update. Then it measures signal strength and data rate for each access router. As a result, it sends binding update which includes multiple CoA and priority value that is calculated by primary path selection algorithm as shown in figure 3. The following figure 4 shows the header format when the mobile node sends binding update to home agent through the AR1.

IPv6	MIPv6: M='1', Priority='1', Address: CoA1	MIPv6: M='1', Priority='2' Address: CoA2

Fig. 4. Packet which is sent to Home Agent through the Access Router 1

The binding cache database is updated by the priority value. It provides two options to Home Agent. First option is that Home Agent can separate traffic according to the traffic class value in the IPv6 header. While, Second option is Home Agent allocates most suitable paths for each correspondent node.

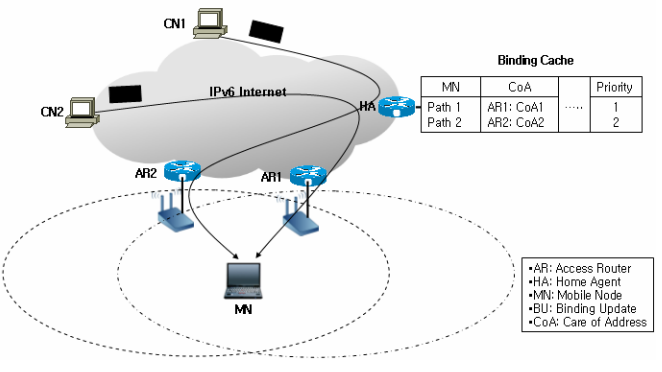

Fig. 5. Path selection according to the traffic specific

Figure 5 shows path selection procedure of Home Agent.

Following figure 6 and 7 shows the header information [4] of each correspondent node.

IPv6 Header traffic class='high value'	data

Fig. 6. Packet which is sent to Home Agent through the Access Router 1

IPv6 Header traffic class='low value'	data

Fig. 7. Correspondent node 2's header

When home agent receives packets from correspondent nodes, it checks the traffic class value in the IPv6 header. Then it allocates primary path for each correspondent node. For instance, when the correspondent node 1 sends packet having high value in

IPv6 traffic class field to the mobile node, the home agent allocates path 1 to correspondent node 1 according to a traffic class value. In contrast, when the correspondent node 2 sends packet having low value in IPv6 traffic class field to the mobile node, the home agent allocates path 2 to correspondent node 2 according to a traffic class value.

The mobile node can send the binding update with multiple CoA and priority value after it receives packets of correspondent nodes from the home agent as shown figure 8. After that the correspondent nodes update their binding cache database like figure 9.

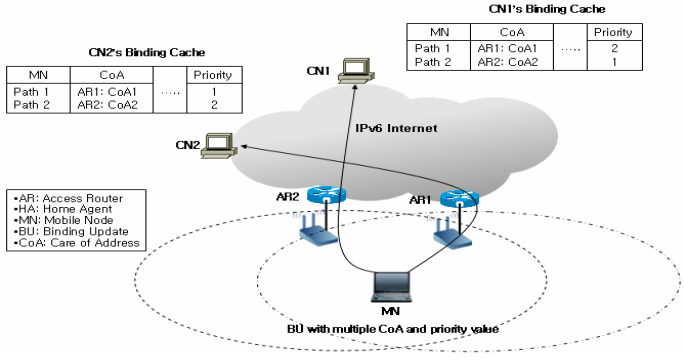

Fig. 8. Binding Update with multiple CoA and priority value

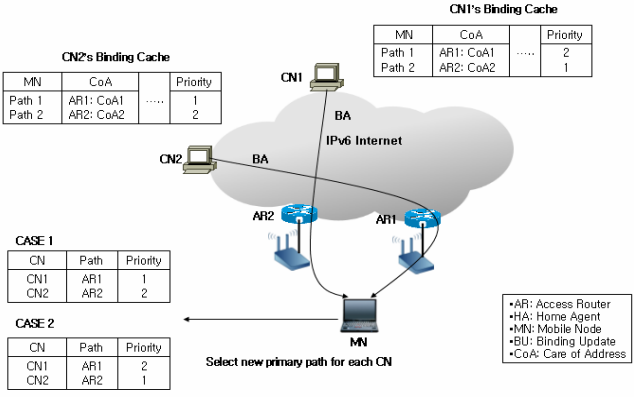

Fig. 9. Primary path selection for each correspondent node

When mobile node receives binding acknowledgements from each correspondent node, it executes primary path selection algorithm and the result could be like figure 8. There are two expected results as shown in case 1 and case 2 in figure 9. Figure 9 shows that, although, the primary path is selected as AR2 for correspondent node 1, the mobile node can change primary path as AR1 for correspondent node 1 according to the result of primary selection algorithm.

The following algorithm describes the process of registering a care of address to home agent:

① Mobile node creates care of addresses which are based on prefix information received from Access Router 1 and Access Router 2.
② MN sends binding update messages through AR 1 and AR 2.
③ When Home Agent receives binding update messages from the mobile node, care of addresses are registered on the Home Agent's binding cache database after address validation.
④ Home Agent then, sends binding acknowledgement messages to each care of address.
⑤ When the mobile node receives binding acknowledgement messages from Home Agent, it decides the primary path using primary path selection algorithm.
⑥ Then, the mobile node sends binding update message which includes multiple care of addresses through the primary path.
⑦ When the Home Agent receives binding update message, it marks the primary path value into the primary care of address's record.

3.4 Operation of Correspondent Node

The following procedure describes the alteration of primary path by the mobile node:
① The correspondent node 1 sends data having high flow level value in the IPv6 field to mobile node.
② In contrast, the correspondent node 2 sends data having low flow level value in the IPv6 field to mobile node.
③ When HA intercepts each packet which is sent by correspondent nodes, it decides correspondent node 1's path and correspondent node 2's path according to the primary path value. Therefore, correspondent node 1's packet sends to mobile node through the primary path and correspondent node 2's packet sends to mobile node through the secondary path.
④ After returning from routing and binding procedure, mobile node can make decision to allocate different primary paths for each correspondent nodes using primary path selection algorithm.

4 Simulation

In this section, we describe the simulation environment and show the simulation results. For the simulation, we used the Network Simulator version 2 (NS-2) [9].

4.1 Simulation Environment

For the simulation, we configured the network topology as shown in figure 10. There are four wired nodes which are connected with 5Mbps data rate and 200ms link delay and one mobile node which are connected with node 2 and node 3. Node 2 and node 3 are connected through a wireless link (path 1) of 0.5Mbps and 600ms delay. While

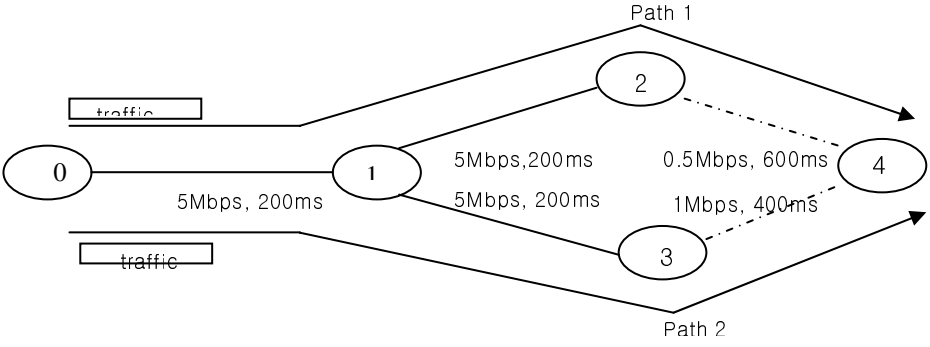

Fig. 10. Simulation environment

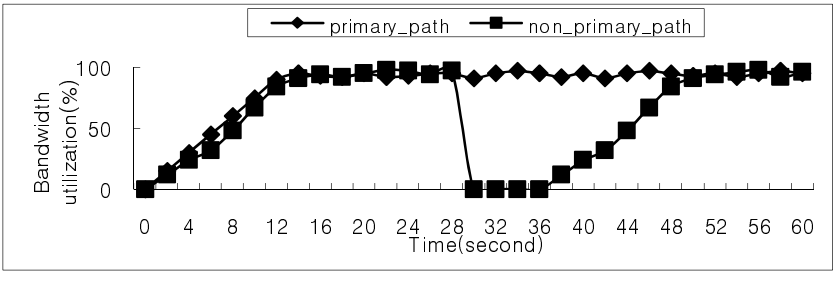

Fig. 11. Bandwidth utilization

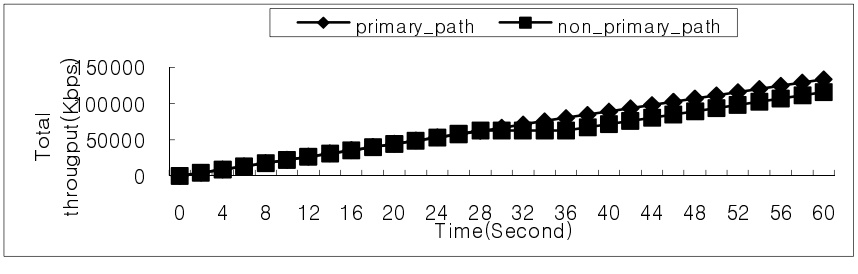

Fig. 12. Throughput

node 3 and node 4 has a wireless link (path 2) of 1Mbps and 400ms delay between them. In order to measure the performance of proposed scheme, we have generated two different size traffics at the node 0. The traffic which has 0.5Mbps rate is sent to the node 4 through the path 1 by the node 0. Other traffic which has 2Mbps rate is sent to the node 4 through the path 2 by the node 0. The simulation scenario is that node 0 sends two different size traffics to node 4 through the node 2 and node 4 for 60 seconds. During the simulation, we have configured that mobile node moves near to node 3 so that connection of the mobile node and the node 2 is disconnected for 6

seconds. And then, the mobile node returns to original position. Figure 11 shows bandwidth utilization of the mobile node measured during simulation. From the figure we conclude that, primary path scheme and non-primary path scheme both have same bandwidth utilization except disconnected time. Also, we have got total throughput as shown the figure 12. It shows that the proposed scheme's total throughput is better than normal scheme's because when the mobile node is disconnected from an access router, the mobile node can make new path through other access router immediately.

5 Conclusion

Multi-homing has become one of the most crucial issues in ubiquitous network environment. As a consequence, recent literature has enriched by a number of proposed multi-homing schemes. Most of the schemes have come up with abstract concepts and scenarios of ubiquitous network. To provide an extended coverage area via distinct access technologies anywhere, anytime and anyone, we propose the primary path selection algorithm for ubiquitous multi-homing environment. We also defined new binding update and binding cache entry. Therefore, a mobile node can select suitable path for data transmission. In addition, it can change primary path when wireless network environment is changed such as a mobile node moves from one place and another place and a mobile node find better access router than current access router. From the simulation results we can conclude that primary path selection algorithm improves the network performance.

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