Cross-Layer Routing Method for the SCTP with Multihoming MIPv6

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Abstract. The *multihoming* is regarded as a kind of technology to provide wide-band and relaible network service. The protocol called *Stream Control Transmission Protocol* (*SCTP*) [1] can manage the multi-homed nodes to realize a highly-available data transfer capability in the *Transport Layer*. An *SCTP* node may keep a combination of the sets of the eligible source and destination transport addresses. The node can detect if a transport address is out of service by periodical messaging which is called *HEARTBEAT* in *SCTP*. If the *HEARTBEAT* is unacknowledged, the node will change to send data via another transport address which is with a *HEARTBEAT ACK*. The multi-homed mobility nodes, such as the cellphones implemented with both WiFi and 3G, are widely used in the world. *Mobility Support in IPv6* (*Mobile IPv6, MIPv6*) [2] is a protocol to provide a mobility function in IP layer. However the *SCTP* is not a protocol designed for the moving nodes, such as the nodes using the *Mobile IP* (*MIP*). Also there is an enhanced *SCTP* called *mSCTP* [3] which enables the mobility at the *Transport Layer*. But the *mSCTP* is not designed for the multihoming *Mobile IP*. In this paper, we suggest a new cross-layer routing method to use the *SCTP* with the multihoming *MIPv6*. Our proposal is mobile node can use *SCTP* to select an optimized transport peer in real time.

Keywords: multi-homed, Mobile IPv6, SCTP, Binding Update, cross-layer.

1 Introduction

Recently the multi-homed nodes is not just limited in the PCs. Even the cellphones, such as iPhone, are started to implement WiFi and 3G interfaces. Due the multi-homed mobility nodes started to be used widely in the world, the multihoming technology is required to provide a reliable wide-band ubiquitous environment. WiFi and 3G are wireless communication technologies that can keep a mobile node's connection seamlessly while it is moving in a WiFi network or a 3G network. However a mobile node will lose the network connections while switching its wireless interfaces without any upper layer support.

X. Jun Hei and L. Cheung (Eds.): AccessNets 2009, LNICST 37, pp. 179–191, 2010.

Although the *Mobility Support in IPv6* can provide a mobility support in the IP layer, the management of a multi-homed mobile node (*MN*) is beyond the *MIPv6* specification. *SCTP* is a protocol in the Transport Layer that may control the multi-homed nodes. However, a multi-homed mobile node may move around different networks with different IP addresses. In the *MIPv6*, the *Routing Optimization* is used. A node can communicate with an *MN* without the forwarding service supported by the *MN*'s *Home Agent*. Though the *mSCTP* [3] provides the dynamic address reconfiguration[4], it is not designed for the multihoming *Mobile IP*. The multihoming *Mobile IP* is known that may have multiple *Home Addresses* (*HoAs*) or *Care-of Addresses* (*CoAs*).[5] The dynamic address reconfiguration *mSCTP* does not have the mechanism for dynamic updating the relationship between multiple *HoAs* and *CoAs* at the transport layer. A cross-layer routing method is required to manage the IP addresses between the *SCTP* and *MIPv6*.

In Sec.2 this paper describes the issues in the *Steam Control Transmission Protocol*. Sec.3 analyzes the current specification of the *Mobile IPv6*. Our proposal and related experiment results are introduced in Sec.4. Sec.5 shows the evaluation of our proposal and the remaining future works.

2 Stream Control Transmission Protocol: SCTP

SCTP [1] is a connection-oriented protocol in the *Transport Layer*. *SCTP* is able to control the multi-homed nodes which have multiple IP addresses. Fig.1 shows the multi-homed nodes use *SCTP* for transferring the stream.

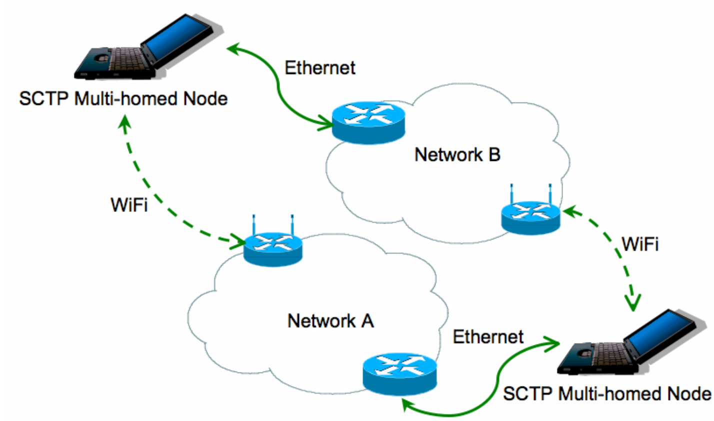


Fig. 1. Multi-homed Nodes Use SCTP

2.1 SCTP Chunks

In *SCTP*, a multi-homed node need to have a set of IP addresses used the same port number. Multiple IP addresses with an SCTP port is treated as a *list of transport addresses*. *SCTP* packets are delivered with a common header and several *chunks*. There are 2 types of *SCTP chunks*, one is *DATA chunk*, and the other is *control chunk*. *HEARTBEAT Request* and *HEARTBEAT Acknowledgement* are used as control trunks in the *SCTP* fault management. According to the *HEARTBEAT* and sharing the same *SCTP* port number as described before, multi-homed nodes can take a quick failover in *SCTP*. As start-up, *Primary Path* is set to transfer data for multi-homed nodes and an alternative path is reserved as a backup of the *Primary Path*. An *SCTP* packet consists of one or more chunks: either *data* or *control*. For the purposes of reliability and congestion control, each *data chunk* in an association is assigned a unique *Transmission Sequence Number* (*TSN*). The *TSN* is similar to the sequence number used in *TCP*. Different from the *TCP*, the *SCTP* is message-oriented and chunks are atomic, *TSN* is associated only with the *data*.

As defined in the *RFC 4960* [1], the *Selective Acknowledgement* (*SACK*) is a chunk sent to the peer endpoint to acknowledge received *DATA* chunks as represented by their *TSNs*. The value of the *Cumulative TSN Ack* parameter is the last *TSN* received before a break in the sequence of received *TSNs* occurs. The next *TSN* value following this one has not yet been received at the endpoint sending the *SACK*.

2.2 mSCTP

Based on the *SCTP Dynamic Address Reconfiguration* [4], *Mobile SCTP for IP Handover Support (mSCTP)* [3] is suggested a mobility option in the Transport Layer. *mSCTP* uses the *SCTP* connection as a multi-homed mobile node's permanent identification while the mobile node is moving among networks. The *SCTP* connection acts a fundamental role in *mSCTP*. In short, a multi-homed mobile node cannot have the mobility option without available *SCTP* connections. It is difficult to use the *mSCTP* for the data transmission which requires a reliable mobility network service, like medical information.

2.3 CMT: Concurrent Multipath Transfer

In the original *SCTP*, the sender is not able to send new data on multiple paths simultaneously. The sender uses the *primary destination* to which all transmissions of new data are sent. *CMT-SCTP* [6] provides a reliable, multihome-aware, SACK-based SCTP. *CMT* uses *SCTP*'s multihoming feature to simultaneously transfer new data across multiple end-to-end paths to the receiver.

3 Mobility Support in IPv6: Mobile IPv6

Different from the *mSCTP*, the *Mobility Support in IPv6* (*Mobile IPv6, MIPv6* [2] is a mobility support in native IP Layer. In *MIPv6*, each *Mobile Node (MN)* have 2 IP addresses. One is for the permanent use, called *Home Address* (HoA). Another one is called *Care-of Address (CoA)* for recording the current location of the mobile node. Literally, the *CoA* is changed frequently. *Home Agent (HA)* is a router for managing the location of a mobile node and routing the packets belong to the mobile node.

In *MIPv6*, a mobile node is required to send *Binding Updates* that includes the mobile node's *HoA* and *CoA* to its *HA* and the *Correspondent Node (CN)* which is communicating with the mobile node. If a *CN* has cached an entry of a *MN*'s *Binding Information*, the *MN*'s *CoA* can be used in the packet transmission between *CN* and *MN* directly. This kind of routing mechanism is called *Routing Optimization* in *MIPv6* (Fig.2). Otherwise, a *CN* without caching an *MN*'s *Binding information* is required to use *Triangular Routing* instead (Fig.3). The packet transmission between *MN* and *CN* is forwarded by the *MN*'s *HA*.

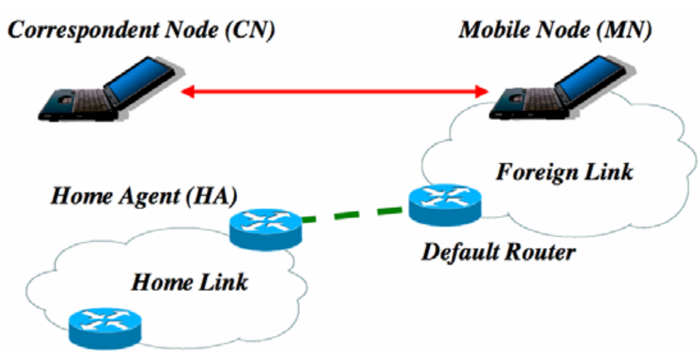


Fig. 2. Routing Optimization

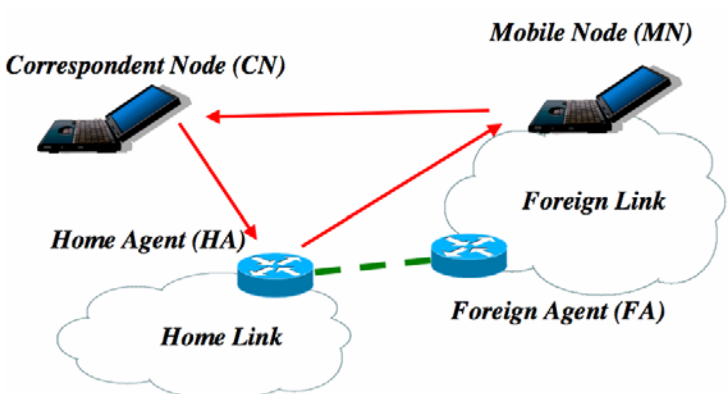


Fig. 3. Triangular Routing

3.1 Multihoming Issues in MIPv6

The management of multi-homed mobile node in *MIPv6* is discussed in the *Internet Engineering Task force* (*IETF*). The investigation of the multihoming use in *MIPv6* is described in the Internet Draft document , *Analysis of Multihoming in Mobile IPv6* [5].

A *MN* has 2 IP addresses, *CoA* and *HoA*. It causes that the relation between *HoA* and it CoA is estimated to be complex in the multi-homed *MN*. The mapping patterns, 1:1, 1:n, n:1 and n:n are possible in the multihoming use in *MIPv6*.

3.2 Multihoming Proposals in MIPv6

As described above, a multi-homed *MN* may have multiple *CoAs* in *MIPv6*. A new field called *Binding identification number* (*BID*) is added to the original *MIPv6 Binding Information* for managing the multiple *Binding Updates* sent by a multi-homed *MN* in the *IETF Internet Draft*, *Multiple Care-of Addresses Registration* [7]. The new field shown in Fig.4 is called *BID Mobility Option*.

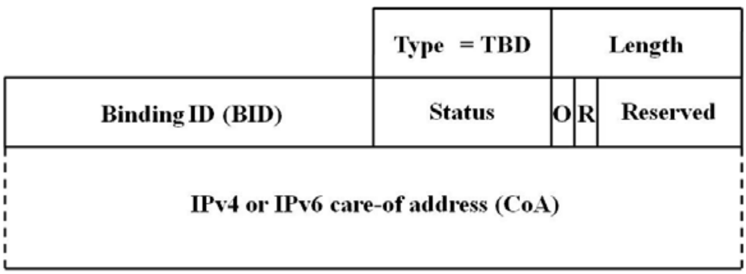


Fig. 4. BID Mobility Option

4 Cross-Layer Routing Method

This paper suggests a new routing method that enables the *SCTP* for the multi-homed *MN* in *MIPv6*. As an *MN*, it moves around different networks and changes its location frequently. An *n-CoAs-to-1-HoA* multi-homed *MIPv6* model is supposed to be used for the *SCTP* transmission.

4.1 Extension on the Binding Data Structure

The multihoming *MIPv6* network used in this paper is a *n-CoAs-to-1-HA* model. The *BID* introduced in Sec.3.2 is used to manage the multiple *Binding Information* entries sent by the different multi-homed *MN*'s *CoAs*. In this paper, the similar field is implemented in the simulation with a name, *MN's Yet another Interface* (*MYIF*). However there is a lack of the consideration for the *CN*

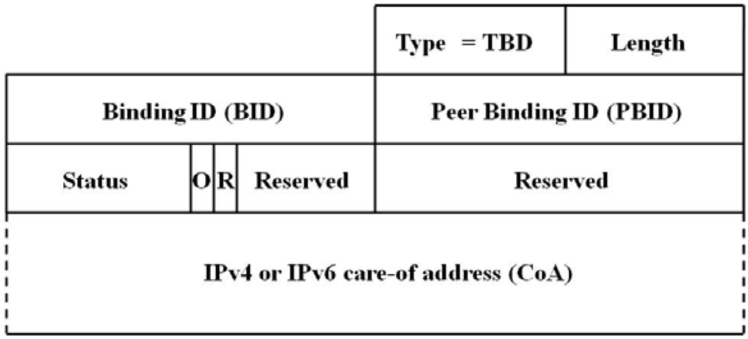


Fig. 5. New PBID tag on the BID Mobility Option

which is a *multi-homed MIPv6 MN* in the *IETF I-D*, *Multiple Care-of Address Registration* [7].

As shown in the Fig.5, we extended the binding data structure with a new tag, called *Peer Binding ID* (*PBID*). In our simulation, the new *PBID* is implemented with a name, *PEERIF*.

4.2 Enhanced Binding Update Procedure

In order to manage the multi-homed *MN*, our proposal has modified the original *Binding Information* messages used in the *Binding Update* procedure.The multi-homed *MN* proceeds *Binding Update* procedure for each of its *interface* individually. This kind of the modification can coexist with the *Return Routerability* security function well.

Fig.6 shows 2 new functions in the *MIPv6 Binding Update Procedure*. One is a function for the *HA* and the other one is for the *CN*. When the *HA* is required to forward a packet to a multi-homed *MN*, the *HA* is designed to forward the packet to the multiple valid *CoAs* of the multi-homed *MN* in this paper. It is easy for the *HA* to distinguish multi-homed*MN* between single *MN*. A multi-homed *MN* is required to start the *Binding Update* procedures to the *CN* individually by its different network interfaces, when the *MN* finds a new *CN* which is not in the *Binding Update List* of the *MN*.

4.3 Cross-Layer Route Method in SCTP with MIPv6

Our suggestion adds a new additional function to inform the upper layer *SCTP* by the lower layer *MIPv6* while the *Binding Information* is updated. This process realizes the cross-layer sharing of the *Binding Information* of a multi-homed *MN* between *SCTP* and *MIPv6*. The original *SCTP* regards the *n-CoAs-to-1-HoA* multi-homed *MIPv6 MN* as a "single" node because there is only 1 *HoA* used in the multihoming *MIPv6*.

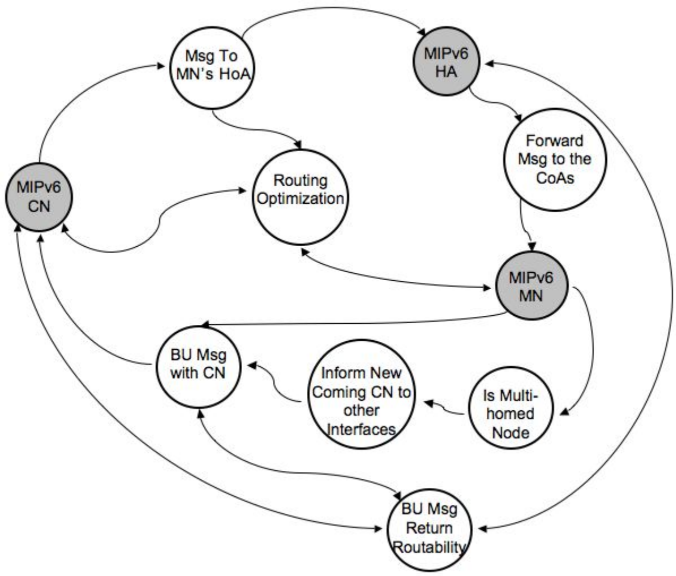


Fig. 6. Modified State Transition of MIPv6

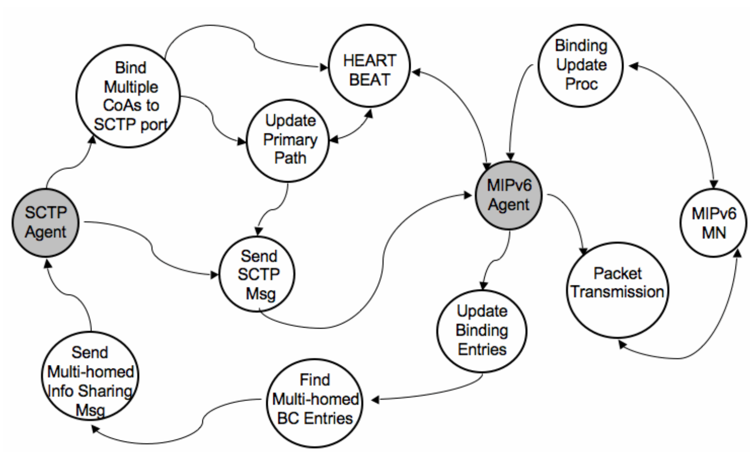


Fig. 7. Modified State Transition in an SCTP-MIPv6 node

Fig.7 shows an *SCTP and MIPv6* aware node is implemented a new function for sharing the *Binding Information* of a multi-homed *MN*. There are 2 processes in the new function. One is used to monitor the *Binding Information* of a multi-homed *MN*. Another one is for informing the upper layer, *SCTP* agent. It is an interface between *MIPv6* and *SCTP*. By using the interface, *SCTP* shares the

CoAs and *Hop Limits* information of the multi-homed *MN* cached in the *Binding Information* of the *MIPv6* .

The *Cross-layer Routing* mechanism suggested in the paper requires the *SCTP* to use the *MIPv6 Routing Optimization* for the multi-homed *MN*. The *SCTP* is modified to share the multiple IP addresses of a multi-homed *MN* from the *Binding Information* cached by itself in the lower layer, MIPv6. The sharing interface is added to both *MIPv6* and *SCTP*. Also, our proposal coexists with the original *HEARTBEAT* mechanism used in *SCTP*. The *SCTP control and data chunks* are transferred to the *multi-homed MN* by the *MIPv6 Routing Optimization*.

In our modified mechanism, the *Binding Information* sent by the multi-homed *MN* and *CN* can be cached by the *CNs* and *HAs* can be cached properly. With the enhanced cross-layer method suggested in the paper, the upper layer *SCTP* can share the *Binding Information* which are cached in the lower layer *MIPv6* and all *SCTP chunks* are able to be sent to the multi-homed *MN*'s *CoAs* directly. This paper realized an *end-to-end SCTP multihoming transmission* for the *n-CoAs-to-1-HoA MIPv6*.

4.4 Simulation

We use the simulation tool called *Network Simulation 2* (*NS*) to simulate our proposal. The *MN* and *CN* are implemented to provide the *MIPv6* functions via IEEE 802.11, the wireless bandwidth is 2Mbps. Other wired networks are connected by the 100 Mbps Ethernet. Fig. 8 shows the network topology of our simulation environment.

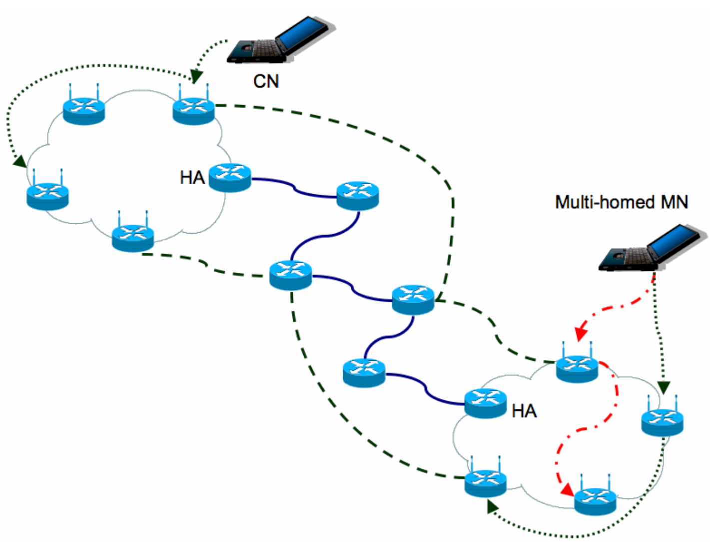
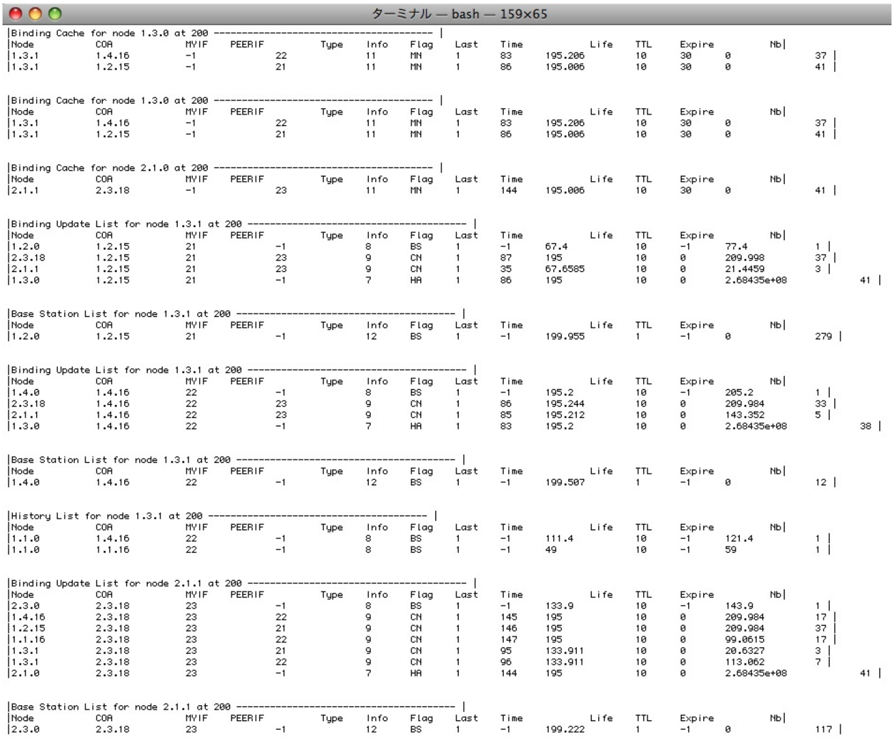


Fig. 8. Network Topology of the Simulation



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ターミナル — bash — 159×65
|Binding Cache for node 1.3.0 at 200 --------------------------------------- |
|Node      COA       MYIF  PEERIF      Type  Info  Flag  Last  Time           Life  TTL  Expire           Nb|
|1.3.1     1.4.16    -1        22            11    MN    1     83    195.206        10   30      0              37 |
|1.3.1     1.2.15    -1        21            11    MN    1     86    195.006        10   30      0              41 |

|Binding Cache for node 1.3.0 at 200 --------------------------------------- |
|Node      COA       MYIF  PEERIF      Type  Info  Flag  Last  Time           Life  TTL  Expire           Nb|
|1.3.1     1.4.16    -1        22            11    MN    1     83    195.206        10   30      0              37 |
|1.3.1     1.2.15    -1        21            11    MN    1     86    195.006        10   30      0              41 |

|Binding Cache for node 2.1.0 at 200 --------------------------------------- |
|Node      COA       MYIF  PEERIF      Type  Info  Flag  Last  Time           Life  TTL  Expire           Nb|
|2.1.1     2.3.18    -1        23            11    MN    1     144   195.006        10   30      0              41 |

|Binding Update List for node 1.3.1 at 200 --------------------------------------- |
|Node      COA       MYIF  PEERIF      Type  Info  Flag  Last  Time           Life  TTL  Expire           Nb|
|1.2.0     1.2.15    21        -1            8     BS    1     -1    67.4           10   -1    77.4             1 |
|2.3.18    1.2.15    21        23            9     CN    1     87    195            10   0     209.998          37 |
|2.1.1     1.2.15    21        23            9     CN    1     35    67.6585        10   0     21.4459          3 |
|1.3.0     1.2.15    21        -1            7     HA    1     86    195            10   0     2.68435e+08          41 |

|Base Station List for node 1.3.1 at 200 --------------------------------------- |
|Node      COA       MYIF  PEERIF      Type  Info  Flag  Last  Time           Life  TTL  Expire           Nb|
|1.2.0     1.2.15    21        -1            12    BS    1     -1    199.955        1    -1      0              279 |

|Binding Update List for node 1.3.1 at 200 --------------------------------------- |
|Node      COA       MYIF  PEERIF      Type  Info  Flag  Last  Time           Life  TTL  Expire           Nb|
|1.4.0     1.4.16    22        -1            8     BS    1     -1    195.2          10   -1    205.2            1 |
|2.3.18    1.4.16    22        23            9     CN    1     86    195.244        10   0     209.984          33 |
|2.1.1     1.4.16    22        23            9     CN    1     85    195.212        10   0     143.352          5 |
|1.3.0     1.4.16    22        -1            7     HA    1     83    195.2          10   0     2.68435e+08          38 |

|Base Station List for node 1.3.1 at 200 --------------------------------------- |
|Node      COA       MYIF  PEERIF      Type  Info  Flag  Last  Time           Life  TTL  Expire           Nb|
|1.4.0     1.4.16    22        -1            12    BS    1     -1    199.507        1    -1      0              12 |

|History List for node 1.3.1 at 200 --------------------------------------- |
|Node      COA       MYIF  PEERIF      Type  Info  Flag  Last  Time           Life  TTL  Expire           Nb|
|1.1.0     1.4.16    22        -1            8     BS    1     -1    111.4          10   -1    121.4            1 |
|1.1.0     1.1.16    22        -1            8     BS    1     -1    49             10   -1    59               1 |

|Binding Update List for node 2.1.1 at 200 --------------------------------------- |
|Node      COA       MYIF  PEERIF      Type  Info  Flag  Last  Time           Life  TTL  Expire           Nb|
|2.3.0     2.3.18    23        -1            8     BS    1     -1    133.9          10   -1    143.9            1 |
|1.4.16    2.3.18    23        22            9     CN    1     145   195            10   0     209.984          17 |
|1.2.15    2.3.18    23        21            9     CN    1     146   195            10   0     209.984          37 |
|1.1.16    2.3.18    23        22            9     CN    1     147   195            10   0     99.0615          17 |
|1.3.1     2.3.18    23        21            9     CN    1     95    133.911        10   0     20.6327          3 |
|1.3.1     2.3.18    23        22            9     CN    1     96    133.911        10   0     113.062          7 |
|2.1.0     2.3.18    23        -1            7     HA    1     144   195            10   0     2.68435e+08          41 |

|Base Station List for node 2.1.1 at 200 --------------------------------------- |
|Node      COA       MYIF  PEERIF      Type  Info  Flag  Last  Time           Life  TTL  Expire           Nb|
|2.3.0     2.3.18    23        -1            12    BS    1     -1    199.222        1    -1      0              117 |
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Fig. 9. Binding Information with IF Identifiers

In the simulation, both *CN* and multi-homed *MN* moves around and assigned to different networks. *MN* sends *Binding Update* with different *CoAs* which are allocated to the different interfaces to the *CN* and *HA*. *CN* is a normal *MIPv6* mobile node. It also sends *Binding Update* to the multi-homed *MN* and its *HA*. Due to the movement of the *CN* and the multi-homed *MN*, the end-to-end shortest path changes. The end-to-end distance is measured and cached during our modified *Binding Update* procedure. By using our new *Cross-layer Routing Method*, the modified *SCTP* enables to use the *MIPv6 Routing Optimization* for the multi-homed *MNs.*

As shown in Fig. 9, the multi-homed *MN* has 2 interfaces, one is the interface *21* and the other one is *22*. The Interfaces *21* and *22* are assigned to the same *HoA*, 1.3.1. Our proposal is implemented on the simulation called Network Simulation 2 (NS2). [1] In the simulation, the *CN* is an *MN* with its *HoA*, 2.1.1, and it is currently allocated with an *CoA*, 2.3.18. Fig.9 shows that the entries of the

[1] The IP address in the simulation NS2 is different from the real hexadecimal IPv6 address. This kind of IP address architecture does not affect the essential MIPv6 mechanism in NS2.

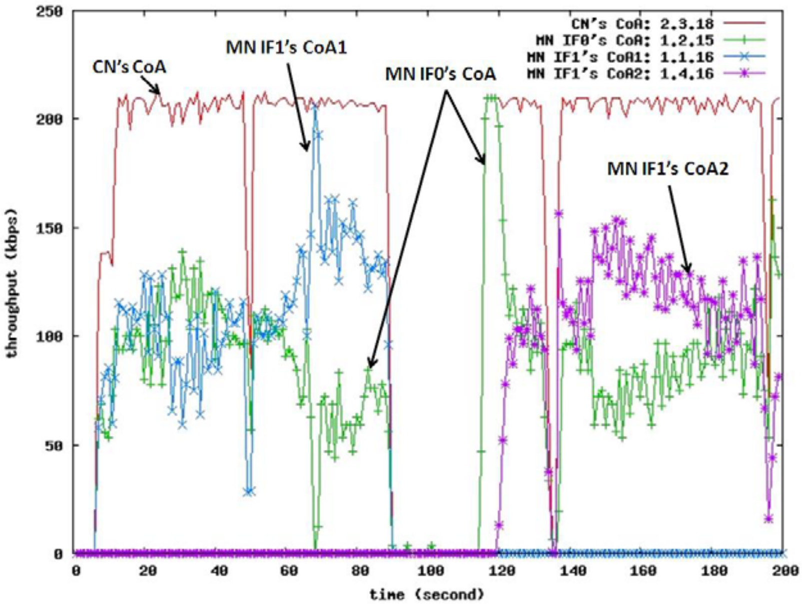

Fig. 10. Throughput of MIPv6 SCTP (CMT) + MIPv6

Binding Information from the multi-homed *MN* are cached by the *HA*, *CN* and *BS* correctly.[2]

In this simulation, *Concurrent Multipath Transfer (CMT)* [6] is in use. The line titled to "CN's CoA", shows the *SCTP* throughput of the single node, *CN*. The line with a title "MN IF0's CoA" shows the throughput of the multi-homed *MN*'s interface *IF0*. And the lines with the titles "MN IF1's CoA1" and "MN IF1's CoA2" show the throughput of the multi-homed *MN*'s interface *IF1* while the *IF1* is moving around different networks. In the simulation, *SCTP* chunks are sent by the *MIPv6 Routing Optimization*. Because of the movement of the *IF1* at the *Second 89*, *SCTP* handover and *MIPv6 overlap issues* [8] occurred. At the *Second 114*, the *SCTP Data* chunk starts to be sent by the *IF0* only. At the *Second 120*, the *IF1* is recovered. Fig.10 shows that the multi-homed *MN* increases the throughput successfully while the *MN* is changing one of its *CoAs* from *1.1.16* to *1.4.16* comparing with the single-homed *MNs*. All of the *SCTP* streams are transferred by the *MN*'s *IF0*.

The Fig. 11 shows the throughput performance was improved while the *MN* moves cross the cell coverage overlap faster, comparing the throughput with the Fig.10. The *MIPv6 overlap issue* affects the *SCTP CMT* throughput performance even in the multihoming *MIPv6*. [3]

Fig. 12 and Fig.13 show the *Windows Size* (*cwnd*), *Slow-Start Threshold* (*ssthresh*) and the *Transmission Sequence Number* (*TSN*) measured at the

[2] The *MYIF* or *PEERIF* with a number -1 means, the node is not multi-homed.
[3] In the Fig.11 we let the *MN* moves faster at the overlapped cells.

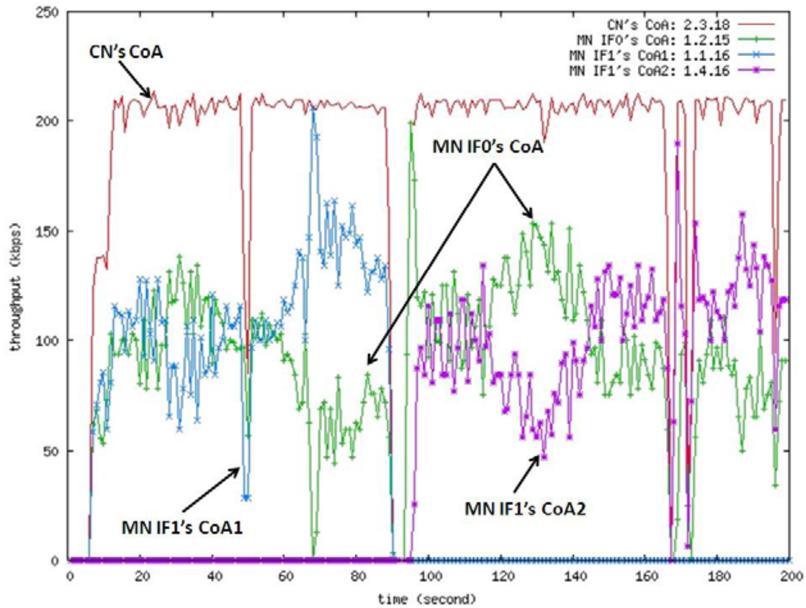

Fig. 11. Throughput of SCTP (CMT) + MIPv6: Overlap Issue

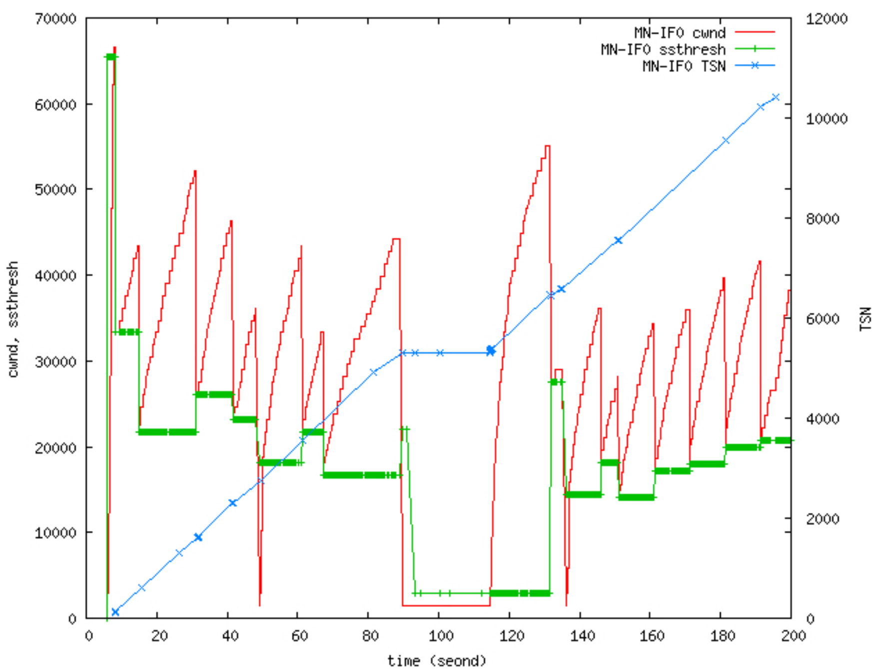

Fig. 12. Experiment of the Multi-homed MIPv6 MN, IF0

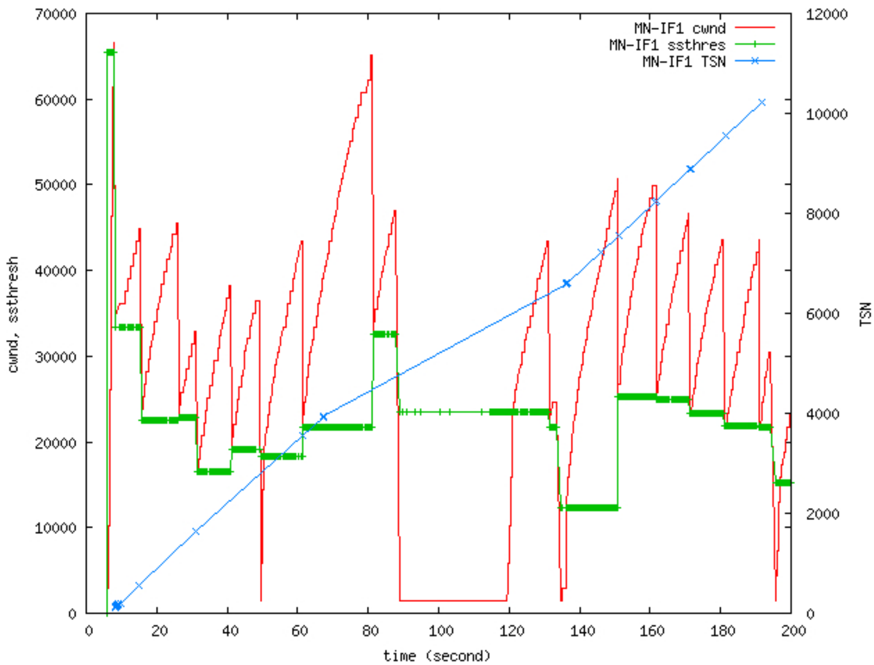

Fig. 13. Experiment of the Multi-homed MIPv6 MN, IF1

interface *IF0* an interface *IF1* of the multi-homed *MN*. Because of the movement of *IF1*, the *cwnd* is increased for the handoff recovery as shown in the Fig.12.

5 Conclusion and Future Work

This paper suggests a cross-layer routing method for using the *SCTP* via multihoming *MIPv6*. We modified the original *Binding Update* procedure and added the interfaces between the *MIPv6* and *SCTP* for the cross-layer management. The measurement based on the modified simulation shows that our proposal let the *SCTP* work with the multihoming *MIPv6* correctly. The nodes in our simulation can use the *MIPv6 Routing Optimization* to send the *SCTP* chunks. While the handover occurs on one of the multi-homed *MN*'s interfaces, another proper interface can keep on the transmission for the end-to-end *SCTP* association.

In this paper, we suppose an n-CoAs-to-1-HoA multihoming MIPv6 model. As the future work, we need to extend this routing method to provide the remaining multihoming MIPv6 network topologies, *n-CoAs-to-n-HoAs* and *1-CoA-to-n-HoAs*.

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