Evaluation of Buffer Size for Middleware using Multiple Interface in Wireless Communication

Etsuko Miyazaki
Ochamonizu Univercity
2-1-1 Ohtsuka, Bunkyo-ku 112-8610
Tokyo, Japan
Email: etsuko@ogl.is.ocha.ac.jp

Masato Oguchi
Ochamonizu Univercity
2-1-1 Ohtsuka, Bunkyo-ku 112-8610
Tokyo, Japan
Email: oguchi@computer.org

***Abstract*—Although a variety of wireless interfaces are available on mobile devices, they still provide only low throughput so far. When coverage areas of these different technologies overlap, mobile devices with multiple interfaces can use them simultaneously by mechanism of Bandwidth Aggregation. However, there are some performance problems for Bandwidth Aggregation on Network Layer and lower Layer which derive from TCP congestion control mechanism. We have proposed advanced Bandwidth Aggregation on Middleware for the purpose of avoiding there problems. In this paper, we have evaluated buffer size for receive-side Middleware.**

***Keywords*-component; Multiple interface; Middleware; Buffer Size; IEEE 802.11**

I. INTRODUCTION

The growth of mobile Internet communication stimulate developments of a variety of wireless technologies: for example IEEE 802.11, Bluetooth and WiMAX. Although some of them have relatively broad bandwidth, they still have lower throughput than wired connection such as Ethernet, and are able to be accessed only in limited areas. It is possible to have more efficient mobile Internet service using multiple interfaces simultaneously, when we are in areas covered by several services of wireless technologies. Bandwidth Aggregation which use multiple interface simultaneously is proposed as advanced way to access Internet from mobile node.

Among several research works, seamless vertical handoff from one interface to another has been addressed[1]. However, we have not achieved Bandwidth Aggregation in practical use. Those technologies give us better mobility support, reliability and resource sharing. Thus, we have proposed and evaluated an innovative mechanism of Bandwidth Aggregation in this paper.

II. BACKGROUND OF THIS RESEARCH WORK

A. Bandwidth Aggregation in Various Layer

Bandwidth Aggregation is supposed to be realized on several layers, while they have merits and demerits respectively.

An approach on Datalink layer[2] will give most effective result, will give the most effective result, and upper layer do not need to care about Bandwidth Aggregation. However, we can install it only world using same protocol for datalink layer and have to install specific hardware to their nodes.

An implementation in Network layer will provide efficient Bandwidth Aggregation by intelligent methods. The advantages using Network layer are they perform transparently to widely used Transport protocol such as TCP and UDP. However, TCP may not achieve estimated efficiency due to a possibility that they receive packets in incorrect order. These problems cause congestion control more than required.

In Transport layer, they have congestion window for each path. It enables more effective transport by doing packet distribution and retransmission for each path[3]. However, the system has to be installed into each operation system in all the end-end way.

An implementation on Application layer does not demand to replace current operating systems[4]. However, there are variety of applications and it is difficult to implement aggregation method for all of them. After connections established, we have to consider how to distribute packets for each connection.

B. Packet Loss Problem in Bandwitdth Aggredation on Network Layer

If multiple interfaces are used for concurrent communications, there are possibilities that receiving node may take packets incorrect order. In such a case, receiver recognizes occurring of packet loss incorrectly due to receiving packets different from expected order of packets. Then TCP requests retransmission unnecessarily. This is one of problems in Bandwidth Aggregation on Network Layer.

For the purpose of eliminating this problem, Earliest Delivery Path First (EDPF) was proposed[5]. EDPF is implemented to the node in which path is separated from sender to receiver. EDPF chooses on which path each packet should be sent in consideration of their bandwidth, delay and congestion. EDPF decides the fastest path to transmit the packet to receiver node. All packets are sent by the route on which estimated time is the shortest. Therefore, receiver can receive any packets in correct order. It makes Bandwidth

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Aggregation effective as estimated efficiency in no packet loss circumstances, and its effectiveness has been verified by previous researches.

C. Performance Problem in Bandwidth Aggregation on Network Layer

In the case of wireless communication, there are so many packet losses more than the case of wired communication. When Bandwidth Aggregation is operating on Network layer or lower layer, TCP cannot recognize which path causes the packet loss. Thus, TCP executes congestion control and throughput is degraded more than necessary. This is the second problem in Bandwidth Aggregation on Network Layer.

Packet-Pair based Earliest-Delivery-Path-First algorithm for TCP applications (PET) and Buffer Management Policy (BMP) were proposed for the purpose of fixing that problems on Network layer[6].

PET has functions estimating which path should be used more strictly and dynamically. BMP is implemented in receiver node, evaluates whether a received packet is needed to line up or caused packet loss. When BMP receives later sequence number packet, it informs packet loss was occurred for sure. Otherwise BMP delivers correct order packets to TCP.

With PET and BMP, more effective communication is realized compared with implemented EDPF, in particular, when packet losses occur. However, in circumstances with a lot of packet losses occur, even PET-BMP cannot exercise efficient Bandwidth Aggregation. This is most difficult problem to solve in Bandwidth Aggregation on Network Layer. Referenced researches claim it is possible to get expected results with eliminating packet losses using other methods. In reality, it is too difficult to eliminate packet losses in wireless communication.

III. Our Proposal for Bandwidth Aggregation

As shown in previous chapters, we face a various obstacles using Bandwidth Aggregation on Network layer and/or lower layer. Thus, we propose Middleware layer that aggregate bandwidth on the middle of Application layer and Transport layer. Figure 1. shows comparison between Bandwidth Aggregation on Network layer and our proposed model.

A. An Overview of Our Proposal

Our proposal model has some TCP connections per each paths and aggregates their connections. Therefore, applications are not required to be conscious of aggregating bandwidth. It has some TCP congestion windows which prevent throughput degradation more than necessary in circumstances with many packet losses per each paths. Its feature avoid the problem in implementation on Network layer. Our previous research work shows their problems on Network layer are solved[7]. The defect which PET-BMP could not solve is overcome by our method, which means that Bandwidth Aggregation on Middleware Layer is effectively than on the other Layers.

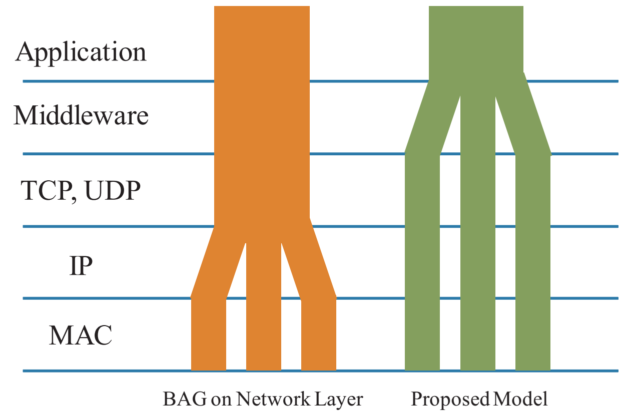

Figure 1. Comparison Between BAG on Network Layer and Our Proposed Model

This approach can also be implemented by modifying TCP which aggregates some connections on Transport layer. However, as an easier way, we can use existing TCP for the purpose of achieving the most efficient Bandwidth Aggregation.

B. The Design of Our Proposed Model

The sender Middleware establishes TCP connections on every possible paths. They receive a packet from an application and give sequence number to a packet. A packet is sent to enabled connection. The receiver Middleware puts received packets in correct order and give them to an appropriate application.

The receiver Middleware has a possibility that some packets arrive by incorrect order and needs to have buffer to restore packets for the purpose of waiting for the packet with expected sequence number. Estimation of required buffer size in each circumstances is one of the important points for designing the Middleware. BMP also considers about buffer size and controls how packets should be deriverd. We propose the method on other layer and suppose that they will behave differently.

IV. Evaluation of queue size with simulation

In this experiments, we are motivated by the advantages that uses Bandwidth Aggregation through simultaneous use of multiple interfaces. We have used simulation software QualNet for their experiments[8].

For the purpose of designing Middleware, the buffer size of Middleware receiver has to be estimated clearly. We have investigated their size under various circumstances.

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A. Scenario 1 - Low Bit Rate Wireless Communications

Node 1 sends some data to Node2 which has 2 interfaces through 2 paths referring to Figure 2.

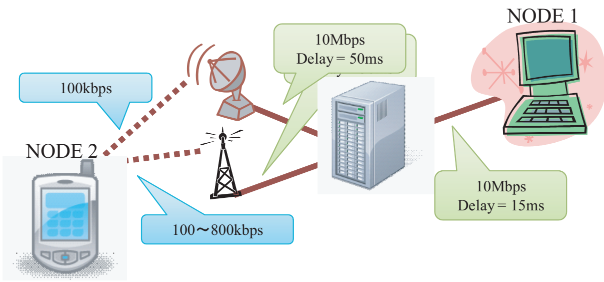

Figure 2. An Overview of Scenario 1

The bandwidths at wired connection are 10Mbps. One of wireless connection is fixed to 100kbps and the other is varied from 100kbps to 800kbps. The rate of two bandwidth of wireless connection is varied from 1:1 to 1:8. Transport protocol is set to TCP new Reno, and parameters are configured by following Table 1.

Table I
TCP PARAMETERS

MSS	1460Bytes
Send buffer	65535Bytes
Receive buffer	65535Bytes

B. Scenario 2 - High Bit Rate Wireless Communications

Node 1 sends some data to Node2 which has 2 interfaces through 2 paths referring to Figure 2.

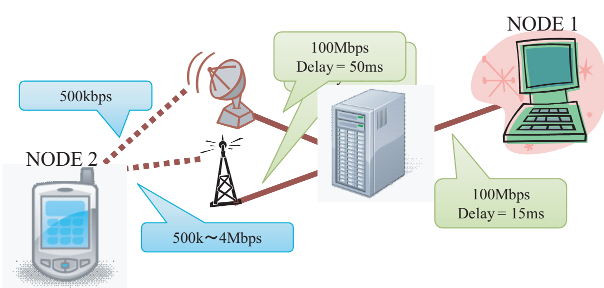

Figure 3. An Overview of Scenario 2

The bandwidths at wired connection are 100Mbps. The one of wireless connections is fixed to 500kbps and the other one is varied from 500kbps to 4Mbps. The rate of two bandwidth of wireless connection is varied from 1:1 to 1:8. Transport protocol and TCP parameters are configured same as Scenario 1.

C. Term of Steady State and Unsteady State

Figure 4. shows throughputs of two connections and buffer size of receiver middleware when bandwidth of wireless connections are set to 100kbps and 300kbps.

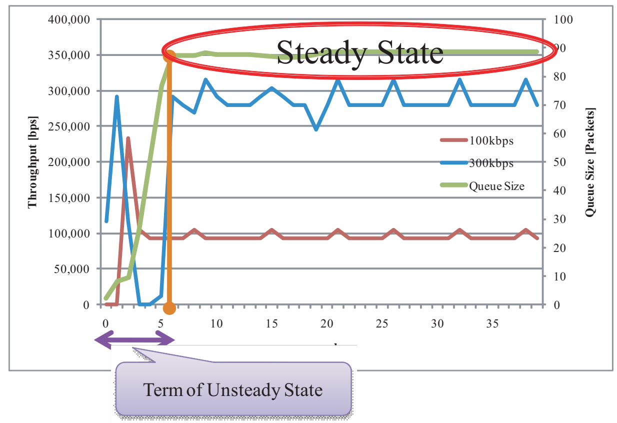

Figure 4. Throughputs and Queue Size

After a short while, two of wireless connection's throughput show efficient communication. Queue size of receiver Middleware is growing at first and settle down at a value. We call the state that buffer size is stable "Steady Term", and the time of until being Steady Term "Term of Unsteady State". We focus on their values at various circumstances.

D. Aasociation Between Rate of Bandwidths and Required Buffer Size

Figure 5. shows buffer size at Steady Term in Scenario 1. when rate of two bandwidths are changed.

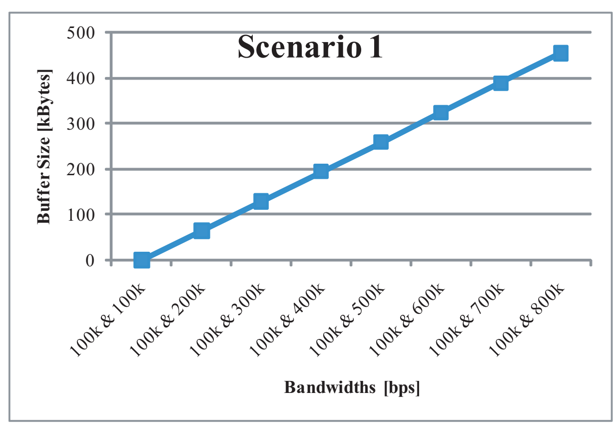

Figure 5. Queue Size in Scenario 1

The value of buffer size when two interfaces has same bandwidths is 0. It is proportional to the ratio of one interface's bandwidth to other interface's bandwidth.

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Figure 6. shows buffer size at Steady Term in Scenario 2. when rate of two bandwidths are changed.

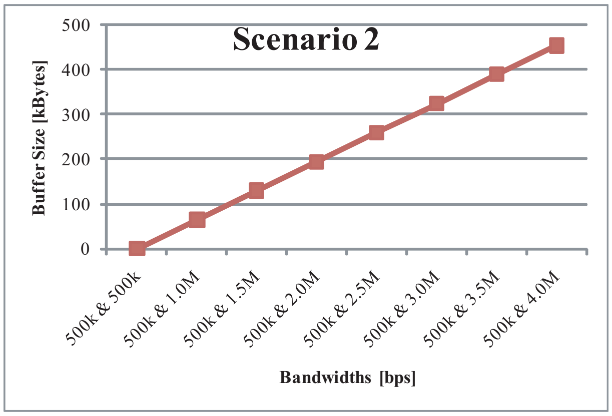

Figure 6. Queue Size in Scenario 2

The value is proportional to the ratio of one interface's bandwidth to other interface's bandwidth as well as Scenario 1. Although Scenario 1. and Scenario 2. have different bandwidth and different rate of bandwidth between wired and wireless, buffer size is resolved by rate of two bandwidth of wireless connection.

E. Association Between Rate of Bandwidths and Time of Unsteady State

Figure 7. shows time of Unsteady State in Scenario 1. and Scenario 2. when rates of two wireless connections' bandwidth are changed.

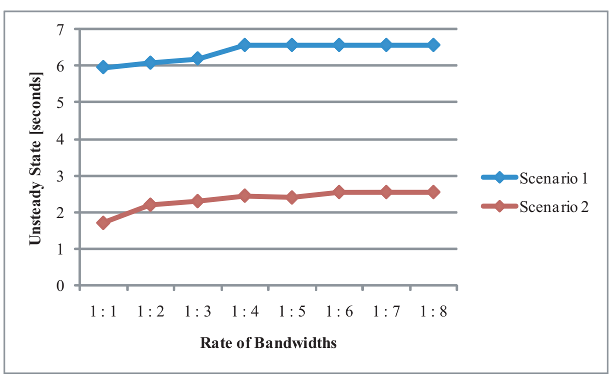

Figure 7. Unsteady Time

The time of Unsteady State in Scenario 2. which has high bit rate is shorter than its in Scenario 1. which has low bit rate in whole. The rates of bandwidth between two wireless connection do not affect their time.

V. Conclusion and Future Work

In this paper, we have experimented with network simulator for the purpose of evaluation of the communication using multiple interfaces simultaneously. The methods of Bandwidth Aggregation on network layer still have problems, for instance, they can not recognize which path cause the packet loss. We have proposed the model of Bandwidth Aggregation on Middleware in order to eliminate their problem. Their effect are verified compared with previous method since we can get comparable throughput as well as aggregating throughput of multiple connection. The receiver Middleware needs to have buffer to restore the order of packets' sequence number. We have investigated how large buffer is needed in various situations. The mobile node which has two interfaces varies one of interface's bandwidth and observes the buffer size. The result shows it proportional to the ratio of one interface's bandwidth to other one.

In the future, we will implement the feature of buffer size that demonstrated by the experiments and function on the sender Middleware considering how to distribute each packets to the paths. Moreover, we will suppose that mobile node can have three or many wireless interfaces and study the result in that cases. In addition, we try to achieve more efficient Bandwidth Aggregation in a various situations, for instance, occurring packet losses, various pattern of lower layer, and dynamically-changed bandwidth.

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