QoS-Adaptive Router Based on Per-Flow Management over NGN[1]

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Abstract. In the present paper, we designed a specific router which provides the required level of QoS over NGN(Next Generation Network) by controlling data flows. We called this router QoS-Adaptive router, which consists of two parts, a legacy routing part and a QoS guarantee routing part. In order to provide differentiated services, QoS-Adaptive router enables data taking broad bandwidth or data requiring high-level QoS to be processed immediately and not to be affected by other services. And, we used the definition of flow for per-flow management, and assigned new service types to the flow label field of IPv6 header so as to provide differentiated services according to the packet type. By doing this, we designed a distinguishing mechanism in order to adapt to NGN that concentrates upon QoS. We built not only a small network to test QoS-Adaptive router but also a simulation environment called OMNeT++, and we could verify the performance of QoS-Adaptive router supporting QoS based on subscriber and service levels.

Keywords: QoS, NGN(Next Generation Network), Resource Management, Data Flow, User Level, Service Level, Bandwidth

1 Introduction

The requirements of quality of services using the Internet increase continuously. However, there is a limit to QoS because IP transport technology focuses on internet services based on 'best effort'. Therefore, the current network architecture is evolving to NGN(Next Generation Network), which supports guaranteed quality of broadband multimedia services that are integrated with communication, broadcast and the

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internet. According to the main concept of NGN, NGN architecture should support various services requiring high-level QoS such as a real-time service even though users use any kinds of communication networks and terminals. To provide integrated network services, NGN needs different network architecture from the existing network one, and the development of some equipment such as a router, should evolve so as to be suitable for NGN. Therefore, we added a few functions, such as classifying packets, adjusting bandwidth and keeping flows from others, to the existing router in order to support QoS. Furthermore, we extended the role of RACF(Resource and Admission Control Functions) in NGN QoS architecture to communicate with the proposed router.

2 Background

2.1 RACF in NGN QoS Architecture

NGN QoS architecture is made up of ‘Service Stratum’ in charge of application signaling and ‘Transport Stratum’ in charge of packet transmission as shown in Fig. 1 [1].

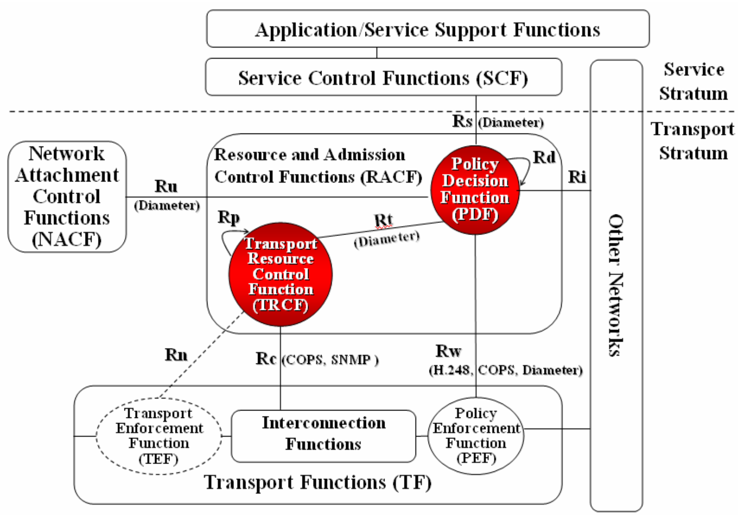

Fig. 1. RACF in NGN QoS Architecture

SCF(Service Control Functions), which implements signaling with terminals, transmits QoS requirements to real networks via RACF in order to provide network services. TCF(Transport Control Functions), which is made up of NACF and RACF, acts as an arbitrator for connecting two strata, Service Stratum and Transport Stratum. NACF (Network Attachment Control Functions) provides a registration function at the access level and an initialization function of end-user functions to access NGN services. These functions provide network-level identification/authentication, and also authenticate an access session. RACF(Resource and Admission Control Functions) provides QoS control functions including a resource reservation, admission control and gate control in order to get desired QoS for communication and permission to access certain resources. RACF is composed of PDF(Policy Decision Function) which exchanges signaling and resources information with SCF, and TRCF(Transport Resources Control Function) which analyzes network resources and status. TF (Transport Functions) is the set of functions that support the transmission of media information and control information [1].

The router in the present paper sets itself up with QoS policies, and communicates with TRCF in order to receive QoS policies and report the data flow status which this router collects and analyzes. TRCF, which received the status from this router, also communicates with PDF.

2.2 Legacy Router vs. Flow-Based Router

A legacy router accepts input data irrespective of its bandwidth, and this router is not responsible for the result such as packet loss, delay, and so forth. In NGN environment, however, if some services affected by one abnormal flow bring about a falloff in router's whole quality, it will be a serious problem because NGN is on the assumption that NGN should guarantee QoS. Therefore, if NGN consists of only these legacy routers, the whole service quality cannot be guaranteed.

A flow-based router, on the other hand, manages data stream as several flows. The definition of a flow is a sequence of packets with the same 5-tuple: source IP address, destination IP address, protocol number, source port, and destination port. This router's whole bandwidth is divided into several bandwidths called 'flow', and the number and the bandwidth capacity of flows are controlled. That is, a flow-based router keeps several flows, and the flows that are not allocated by packets are managed as the left resource. If the problem that one flow affects others happens in the flow-based router, this router adjusts bandwidth, after the packets that have problems are dropped in advance. The stable state can be kept up because this process does not allow one flow to affect others. In addition, if an abnormal flow appears, this router just can drop this flow so that other flows are not affected by this one. Therefore, this per-flow management makes QoS providing to be easier [2].

In the present paper, we propose 'QoS-Adaptive router' including specific features which are composed of a few advantages of a legacy router and a flow-based one.

3 Requirements and Design

3.1 RACF's Information Collection

CPE(Customer Premises Equipment) sends service request signaling to SCF(Service Control Functions), and then SCF informs PDF of QoS requirements from CPE. Once receiving a resource requirement, PDF collects information about the subscriber and available resources. In order to get the subscriber information, PDF communicates with NACF(Network Attachment Control Functions) which provides control functions about network attachments based on the information of subscriber's registration such as a subscriber level and security level, and of a terminal used by the subscriber. To obtain the network resources information, PDF gets a message from TRCF periodically. This message is the information that TRCF makes up of by receiving and analyzing messages from QoS-Adaptive router. In this way, PDF can get two kinds of reports; one is about subscriber's level from NACF, and the other is about network information from TRCF, actually QoS-Adaptive router. PDF makes a decision about whether this service can be accepted or not, and about QoS policies if it is accepted. Fig. 2 shows the relationship of RACF's parts and QoS-Adaptive router as stated above.

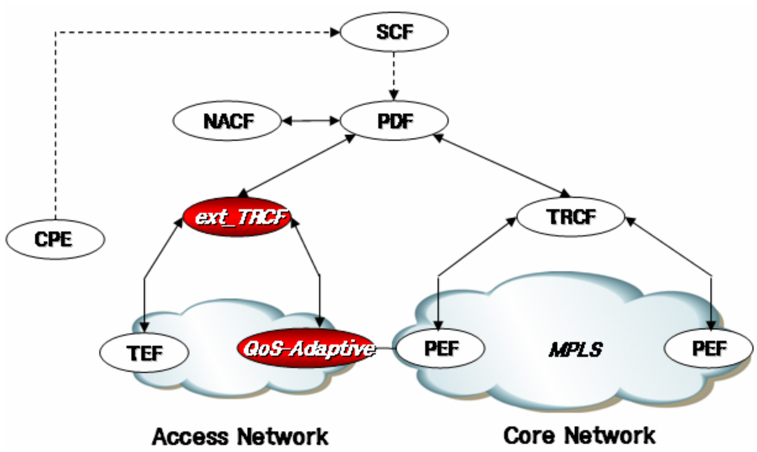

Fig. 2 Relationship between RACF's Parts and QoS-Adaptive router

To support QoS for NGN, a core network is made up of MPLS(Multi Protocol Label Switching) and QoS-Adaptive router is located at each edge, a traffic ingress point [4]. We also designed TRCF including some extended roles such as to communicate with several parts in QoS-Adaptive router, to make up new messages, and to inform PDF of the network's status. We call this TRCF 'ext_TRCF'.

3.2 QoS-Adaptive Router Architecture

Two NGN objects for QoS are to provide differentiated quality services and to protect services from others. These will make most of subscribers be satisfied with the QoS over NGN. Therefore, QoS-Adaptive router, that can guarantee QoS and differentiated services, will be a meaningful component of NGN.

QoS-Adaptive router consists of a legacy part that acts as a legacy router and a flow part which supports QoS and controls bandwidth. As Fig. 3 depicts, QoS-Adaptive router needs Classifier to classify packets according to their own levels, Premium Processor to handle some high-level packets, and Legacy Processor to handle the others. In addition, to communicate with each other or ext_TRCF in RACF, a few communication passages are needed.

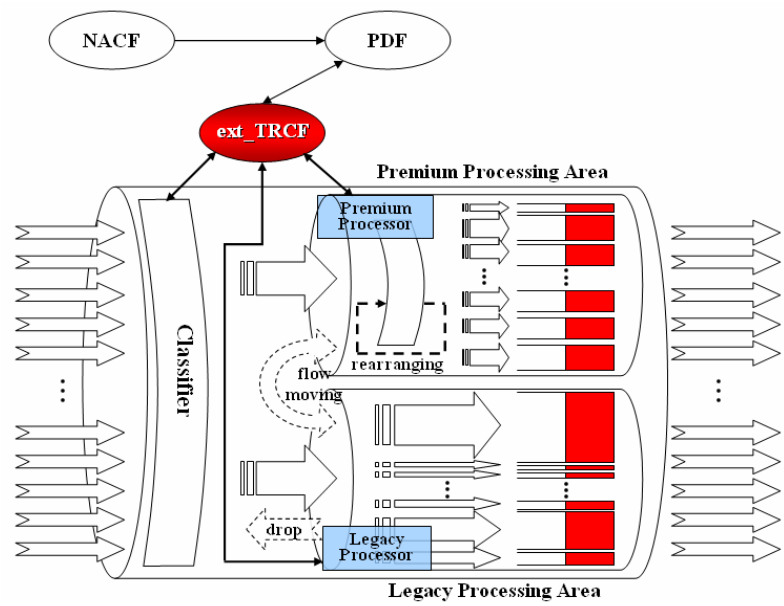

Fig. 3. QoS-Adaptive Router Architecture

1) Classifier

Discriminative transport can be done according to the designated value of the flow label as a newly added field in IPv6, which can support real-time traffic controls or packets that require the same processing [3]. Classifier, as a module in a data input part, classifies packets into several types of packets referring to the flow label field in IPv6 header. We used just low 9-bit of the flow label field. We assigned an urgent mark to 1 bit, types of service to 4 bits, and the rest 4 bits are for subscriber levels in our mechanism. - The detailed contents like using more bits can be adjusted according to the policy by service providers and administration or RACF manager.

Classifier communicates with ext_TRCF periodically in order to obtain a classification policy which is applied in classifying packets, and to report real information about the component ratio of packets. For example, A level's rate is 15%, B level's rate is 23%, and so on. There is the information on messages between Classifier and ext_TRCF in Table 1.

Table 1. Information between Classifier and ext_TRCF

Information		Description
Message ID		Message Identification (Including a mark that this message is from Classifier, Premium Processor or Legacy Processor)
Sequence No.		Sequence Number
Total Stream		Total number of stream in each processor or Classifier
Information	Level	Level type (for instance, 'A')
	Rate	Component rate of this packets' stream
	Loss	Packet loss of this stream
	Level	Level type (for instance, 'B')
	Rate	Component rate of this packets' stream
	Loss	Packet loss of this stream
	…	…

(a) From Classifier to ext_TRCF

Information	Description
Message Type	General Processing / Emergency Processing
Stream Information (Level)	If processing for a general or warning message from Legacy Processor, the minimum level of stream moving into Premium Processing Area. If processing for an emergency message from Premium Processor, the level of stream that should move into Legacy Processing Area or dropped.
Bandwidth	Initial bandwidth value to move streams from Legacy Processing Area to Premium Processing Area If processing to an emergency message from Premium Processor, this information is not needed.

(b) From ext_TRCF to Classifier

Bandwidth allocation in Legacy Processing Area is done by PDF, and PDF decides which level's packets move into Premium Processing Area. This information is sent to Classifier that classifies real packets. After applying a policy from PDF, Classifier observes packet streams that move into Premium Processing Area and into Legacy Processing Area for a while, and then reports a classified packets' ratio to PDF via ext_TRCF. This process is done periodically. PDF controls the whole bandwidth in QoS-Adaptive router based on this report continually.

2) Legacy Processor

General data move through Legacy Processing Area. Specific data, however, should move through Premium Processing Area by the flow label field in IPv6 header. There are a few cases that data streams move from Legacy Processing Area to Premium Processing Area.

Packet is urgent one or requiring high quality. Data, which are urgent or require high quality, should move from Legacy Processing Area into Premium Processing Area, since these kinds of data should be transmitted immediately even though the performance of QoS-Adaptive router may slow down. For this, we designed an urgent mark and level marks in IPv6 header, and Classifier makes these packets move into Flow Processing Area based on packets' flow label field.

There is little bandwidth in Legacy Processing Area. When almost all of the bandwidth in Legacy Processing Area is used, Legacy Processor should make a stream using the largest bandwidth move into Flow Processing Area. In this case, Legacy Processor sends a warning message to ext_TRCF. After getting this warning message, ext_TRCF sends this status to PDF. And then, PDF regulates the amount of bandwidth in Legacy Processing Area which should be left, and sends a reply with a new policy including the level bound, which should be moved into Premium Processing Area, to ext_TRCF which takes a role of communicating with Classifier in order to apply this new policy. This process is done in large-bandwidth order until the amount of bandwidth in Legacy Processing Area appointed by PDF is left. This mechanism not only allows the bandwidth used in Legacy Processing Area to lower, but also guarantees the QoS in this area. Table 2 tells us the information that Legacy Processor sends to ext_TRCF.

Table 2. Information from Legacy Processor to ext_TRCF

Information		Description
Message ID		Message identification (Including a mark that this message is from Classifier, Premium Processor or Legacy Processor)
Sequence No.		Sequence Number
Message Type		General message / Warning message
Level		The highest level among packets' levels which are through this area to find out level boundary.
Information	Stream ID and Level	Stream's identifier and its level (For instance, '0001' and 'A')
	Loss	Packet loss of this stream
	Bandwidth	Bandwidth size of this stream
	Stream ID and Level	Stream's identifier and its level (For instance, '0011' and 'B')
	Loss	Packet loss of this stream
	Bandwidth	Bandwidth size of this stream
	…	…

3) Premium Processor

Data which move through Premium Processing Area are managed as flows of a flow-based router. There are three cases where data move into Premium Processing Area. First, if a packet includes a high quality level mark in IPv6 header, this packet moves into Premium Processing Area. Soon after CPE sends service request signaling to SCF, this high level is decided by PDF based on the subscriber and service information. This means that the packet's level is assigned before this packet comes into QoS-Adaptive router. Second, if a packet is an urgent one, this packet moves into Premium Processing Area irrespective of its level. In our mechanism, this packet has priority over the packets in the first case, and this urgent sign also is marked in the flow label field of IPv6 header. Last, if there is little bandwidth which is left in Legacy Processing Area, a stream holding the largest bandwidth moves into Premium Processing Area. Since this stream is taking big bandwidth but the service level is not high, the bandwidth of this stream should be lowered in order not to affect other streams. To this management, this stream should move from Legacy Processing Area into Premium Processing Area. Premium Processor allocates some bandwidth to this stream based on the surplus bandwidth in Premium Processing Area and the level of this stream. In most cases, Premium Processor allocates lower the amount of bandwidth than the amount which this stream required.

In Premium Processing Area, following problems can happen, and Premium Processor should handle these cases.

Abnormal flow takes almost bandwidth. If the problem that one abnormal flow takes almost bandwidth in Premium Processing Area happens, once Premium Processor has to drop this flow in advance, and then rearrange its bandwidth based on the surplus bandwidth in this area. This is to protect normal flows from an abnormal flow. This status is reported to PDF via ext_TRCF.

There is little bandwidth in Premium Processing Area. In this case, Premium Processor sends an emergency message to ext_TRCF. ext_TRCF analyzes the status of Legacy Processing Area, and distributes some flows' bandwidth in Premium Processing Area into Legacy Processing Area in low-grade order if there is extra bandwidth in Legacy Processing Area. However, if there is no extra bandwidth, to protect high level services, Legacy Processor starts dropping the lowest level stream until there is the amount of bandwidth settled by PDF.

The information from Premium Processor to ext_TRCF is similar to Table 2. Just two different things are that there is emergency information in a message from Premium Processor instead of warning information, and this message is processed first. And the information of 'Level' is the lowest level among packets' levels which are through this area.

3.3 Procedure of QoS-Adaptive Router

Fig. 4 shows us the whole procedure of QoS-Adaptive router.

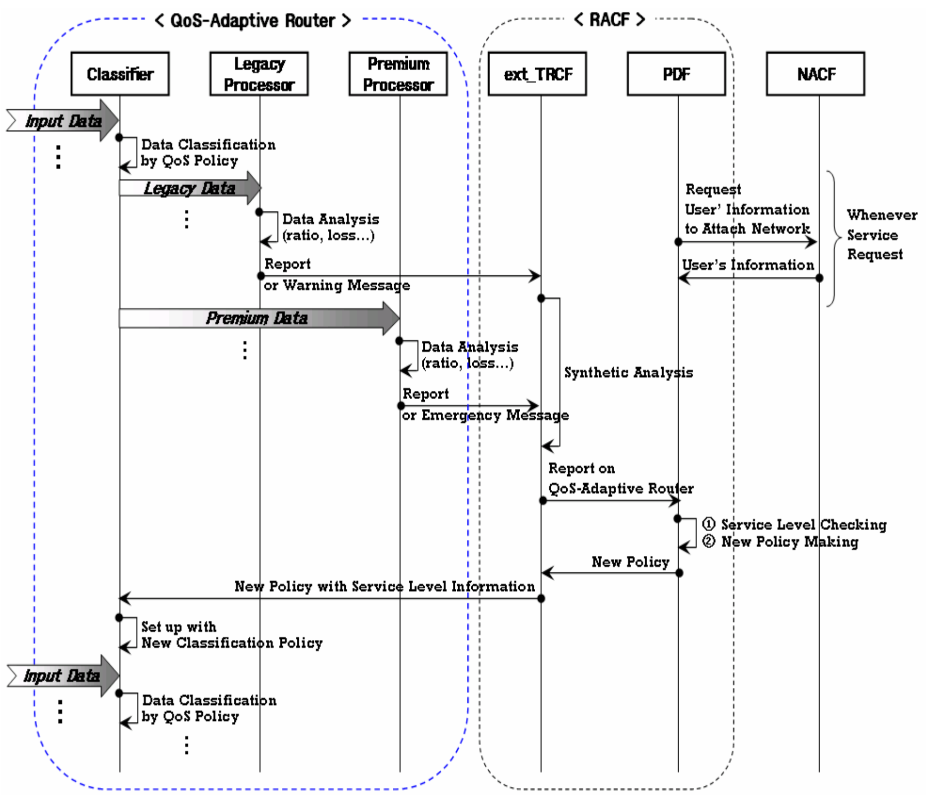

Fig. 4. Procedure of QoS-Adaptive router

This procedure is repeated periodically. As a matter of fact, general reports are sent to each destination by periodic, but a warning message from Legacy Processor or an emergency message from Premium Processor is reported to ext_TRCF immediately so as to be managed without delay.

4 Performance Evaluation

We implemented a simulation using a network simulator named OMNeT++ to evaluate the performance in a broader range [9]. For QoS-Adaptive router, we configured a network environment as shown in Fig. 5.

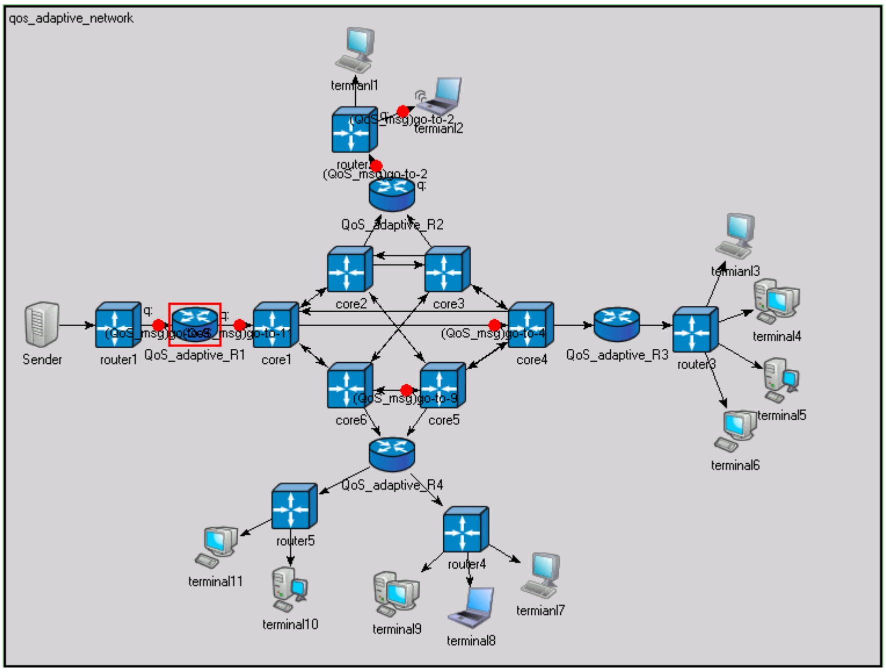

Fig. 5. QoS-Adaptive Network to be Simulated

We adopted delays between each QoS-Adaptive Router and an access router in each access network, differently from 5 ms to 20 ms considering real network's features. Therefore, there are differences of packet loss, latency, and so forth in each access network.

Source node is a packet generator that generates several types of packets including their own service level and destination. Simulation operator can control the ratio of levels and the speed of generation. We generated each level's packet randomly. QoS-Adaptive Routers are located in front of general routers and on the border of core networks. Each terminal receives its own data including each level. In our test, we sent 1st level data to terminal 2, 4 and 7, 2nd level data to terminal 3 and 11, 3rd level data to terminal 1, 6 and 8, and 4th level data to terminal 5, 9 and 10. And we made the level of data to terminal 5 be upgraded to the 2nd level in course of the test.

Fig. 6 illustrates the queuing time to arrive at each terminal as a result of our simulation. There were few data in the early stage of the test. As the number of data increases, however, the difference of queuing time to reach each terminal can be checked. The queuing time of the data including 1st level mark is short, whereas the one of the data including 4th level mark is rather long. Also, we can check that the queuing time of upgraded data diminished abruptly.

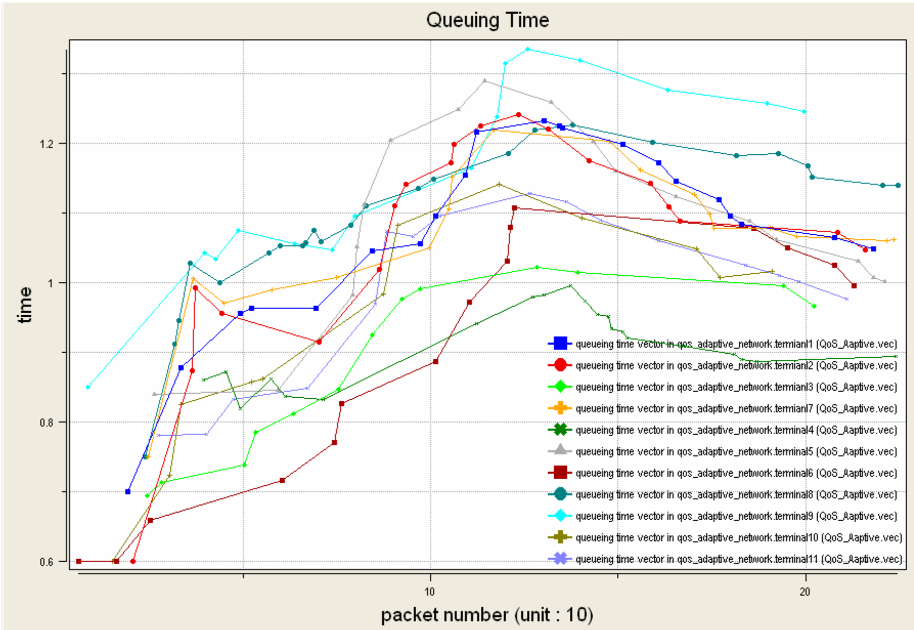

Fig. 6. Simulation Result (1) - Queuing Time

Also, we can see the result of packet loss in each terminal shown in Fig. 7, and this was simulated for 10 days in simulation time. When network overhead happens, high level flows can be guaranteed because these ones have priority over the others, and are processed first by QoS-Adaptive router.

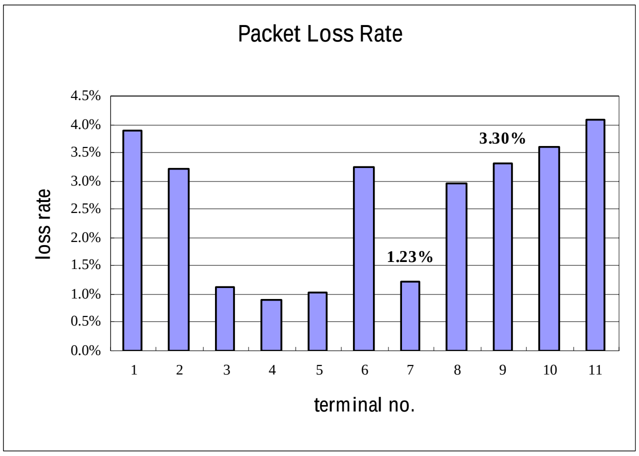

Fig. 7. Simulation Result (2) – Packet Loss

This bar graph tells us that there are numerical differences of packet loss between high level data and low level data. For example, terminal 7 and terminal 9 are in the same access network, and the level of terminal 7 is much higher than terminal 9. As Fig. 7 illustrates the result, the packet loss of terminal 7 is low, 1.23%. However, the result of terminal 9 shows rather high packet loss, 3.30%.

5 Conclusion

To guarantee QoS, RACF in NGN QoS architecture was proposed and has been studied in many ways. We not only designed QoS-Adaptive router to combine the features of legacy routing and flow-based routing, and a new packet type to mark levels, but also extended the role of TRCF in RACF to enable PDF and a QoS-Adaptive router to communicate with each other. By this mechanism, we could provide per-flow management which is based on subscriber and service level, and is suitable for QoS characteristics. As a result, QoS-Adaptive router takes charge of a QoS supporter over NGN by working based on subscriber and service levels.

This mechanism could be used in any network services for guaranteeing QoS such as real-time services. In addition, one main aspect of NGN services is to grasp the receiver’s situation and feeling of satisfaction about services in order to analyze and provide QoE(Quality of Experience). QoE means end-to-end QoS in subscriber’s point of view, and makes subscribers be served with suited services for each one. Our mechanism will help this work. Also, Quality Management Center, which acts on behalf of specific service or content providers and NGN Managers, can obtain the service and network status from QoS-Adaptive routers, and this information will be used to regulate a NGN policy, fix the price of the service, create new services, and so on.

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