End-to-End QoS Guaranteed Service in WLAN and 3GPP Interworking Network

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Abstract. In this paper, we model the end-to-end QoS provisioning mechanisms in the WLAN and 3GPP interworking network. For the end-to-end QoS guaranteed service, we model the control plane and user plane considering the WLAN and 3GPP interworking network. And we propose the QoS parameter/class mapping and DPS packet scheduler. By the simulation results, DPS can provide the low end-to-end delay of voice traffic, even though a traffic load increases by 96%. Especially, the end-to-end delay of voice is much smaller than without the QoS provisioning mechanisms when the QoS parameter/class mapping and DPS are applied to the interworking network.

1 Introduction

In recent years, many mobile users are demanding anytime and anywhere access to high-speed multimedia services for next generation communication system. There are many number of communication technologies for next generation system. In order to satisfy the user requirements for the wireless local area network (WLAN) and third generation partnership project (3GPP) interworking network, the 3GPP is concerned about the WLAN and 3GPP interworking [1]. The wide mobility support of 3GPP, the high speed and low cost of WLAN are complementary.

3GPP has been studying and standardizing the WLAN and 3GPP interworking mechanism because of the advantages of WLAN and 3GPP. However, it is insufficient to investigate the quality of service (QoS) provisioning technology in the WLAN and 3GPP interworking network.[2].

There are various challenges to provide the end-to-end QoS guaranteed services through WLAN and 3GPP interworking network [3], [4]. First, there are many differences between their QoS provisioning technologies such as the QoS parameters, service classes and so on. Accordingly, the mapping mechanism is required for a seamless service. Second, a bottleneck may be generated due to the limited capacity and the overload at a gateway linked with backbone network. In order to solve these problems, we define the functional features based on the end-to-end QoS architecture in WLAN and 3GPP interworking network.

We also propose the new QoS provisioning technologies, and then analyze the performance of the proposed mechanism using a simulator.

2 WLAN and 3GPP Interworking Network Proposed by 3GPP

3GPP working groups are enthusiastic about the standardization of the WLAN and 3GPP interworking technologies. They have proposed standard for the WLAN and 3GPP interworking network [2], [5], [6].

2.1 WLAN and 3GPP Interworking Network Architecture

3GPP TR 23.882 defines the WLAN and 3GPP interworking network architecture as shown in Fig. 1. In this network architecture, WLAN is interconnected with 3GPP network based on universal mobile telecommunication system (UMTS) network. The network elements are added to WLAN network to link up with 3GPP network such as WLAN access gateway (WAG) and packet data gateway (PDG). WAG allows visited public land mobile network (VPLMN) to generate charging information for users accessing via the WLAN access network (AN) in the roaming case. WAG filters out packets based on unencrypted information in the packets. PDG is to directly connect to 3GPP data service network. PDG has responsibilities that it contains routing information for WLAN-3GPP connected users and performs address translation and mapping. PDG also accepts or rejects the requested WLAN access point name (W-APN) according to the decision made by the 3GPP AAA Server. In the 3GPP standards, they define the additional WLAN networks as the WLAN Direct IP network and WLAN 3GPP IP access network. The WLAN Direct IP network is directly connected to internet/intranet, and the WLAN 3GPP IP access network including WAG and PDG is connected to 3GPP network [6].

2.2 Research Issues for End-to-End QoS Provisioning

In WLAN and 3GPP interworking network architecture, there are various research issues for the end-to-end QoS guaranteed service.

It is a very important issue to map between the QoS provisioning mechanisms of WLAN and 3GPP. When a WLAN UE transmits packets to a 3GPP subscriber, the QoS provisioning mechanisms of WLAN and 3GPP may not be worked together due to the absence of QoS information of transmitted packets. Especially, the QoS parameter mapping function should be located in the PDG, since the PDG is the edge node linked with 3GPP network.

The other issue is that a bottleneck can be occurred in the PDG when WLAN UEs may forward many packets to a PDG. The bottleneck can be a serious problem, since the end-to-end delay of voice or video traffic can be rapidly increased by the bottleneck. Therefore, we propose two QoS provisioning mechanisms which are the QoS parameter/class mapping function and packet scheduler (DPS).

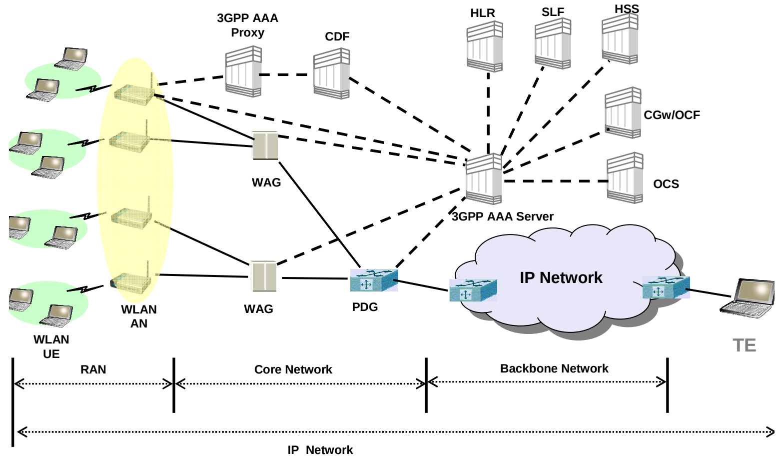

Fig. 1. WLAN and 3GPP interworking end-to-end network architecture

3 Proposed QoS Provisioning Mechanisms

In the conventional WLAN and 3GPP interworking standard, the QoS provisioning mechanisms have not been considered in detail [2]. Therefore, we define the functional features for the end-to-end QoS provisioning based on the end-to-end QoS architecture and model the control and user plane considering the detailed functional features. Besides the control and user plane, we propose QoS parameter/class mapping and packet scheduler (DPS).

3.1 End-to-End QoS Architecture and Functional Features

As shown in Fig. 2, the end-to-end QoS architecture is modeled by 3GPP [2]. However, the functional features are not defined in the 3GPP standard. We define the functional features of each element based on the end-to-end QoS architecture as follows. End-to-End Service provides the end-to-end QoS guaranteed service through the 3GPP IP Access Bearer Service and External Bearer Service. 3GPP IP Access Bearer Service includes the WLAN Bearer Service, since the WLAN Bearer Service can provide a QoS guaranteed service in WLAN. For the QoS guaranteed service in WLAN, we consider the IEEE 802.11e. The External Bearer Service provides the QoS guaranteed service in backbone network. In backbone network, we consider two QoS provisioning mechanisms, such as a differentiated service (DiffServ) and integrated service (IntServ). When the DiffServ mechanism is applied to the backbone network, the PDG has to perform a DiffServ edge function.

3.2 Control and User Plane

Based on the end-to-end QoS architecture, we model control and user plane as shown in Fig. 3 and Fig. 4. In control plane, we define the functional blocks which manage the signal procedure for the resource reservation. In user plane, we define the functional blocks that are needed for QoS guaranteed service when packets are transmitted through the WLAN and 3GPP interworking network. The definition of the functional features is as follows.

Functional features in control plane IP bearer service (BS) Manager allocates the remote IP address for transmitting packets through end-to-end network. Translation Function is applied to WLAN UE and PDG. In WLAN UE, Translation Function translates the QoS information of application data to that of IEEE 802.11e in forward link and vice versa in reverse link. In PDG, Translation Function translates the QoS information of external network to that of 3GPP IP access BS network in forward link and the opposite in reverse link. The Admission/Capability Control is located in the WLAN UE, PDG and WLAN AN. In the WLAN UE and PDG, the Admission/Capability Control decides to admit the received call or not. In the WLAN AN, the call admission control (CAC) applied to manage the wireless resource in IEEE 802.11e. 3GPP IP Access BS Manager requests the QoS information to Translation Function or Admission/Capability and manages the tunneling protocol. Access Network Manager is for routing according to the local IP address. WLAN BS Manager requests the QoS information considering the wireless resource in WLAN network, and interrogates the available resource. WLAN BS Manager manages the negotiation process of traffic specification (TSPEC) defined in IEEE 802.11e. WLAN PHY BS Manager manages the bearer service according to the wireless environment. Wn and Wp Bearer Service manage the bearer service of Wn and Wp respectively.

Functional features in user plane In user plane, we define the functional features when packets are transmitted through WLAN 3GPP IP access network. Classification Function classifies the packet which is received from the external network or application layer. Traffic Conditioner controls the uplink or downlink traffic using the QoS information. Mapping Function performs the service class

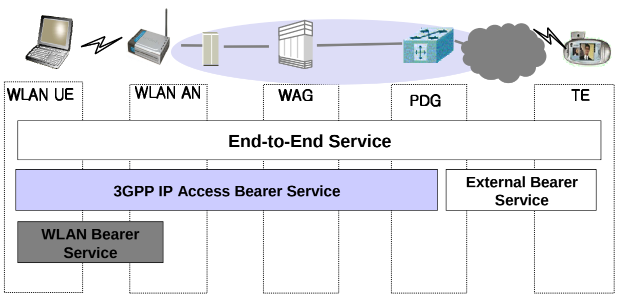

Fig. 2. End-to-end QoS architecture in WLAN and 3GPP interworking network

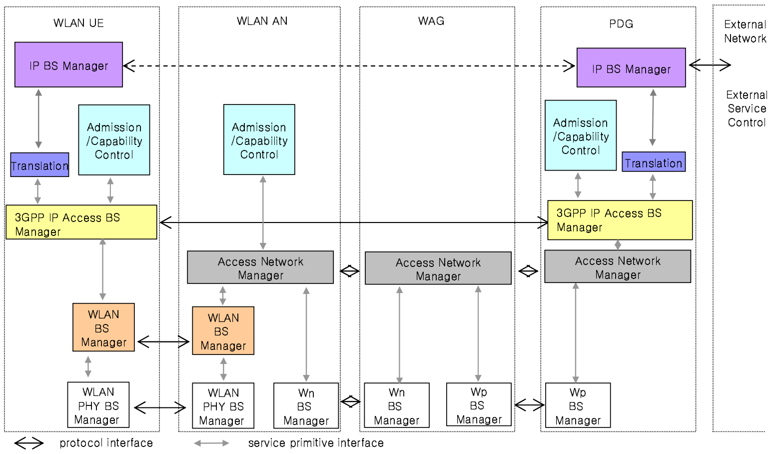

Fig. 3. Control plane based on the end-to-end QoS architecture

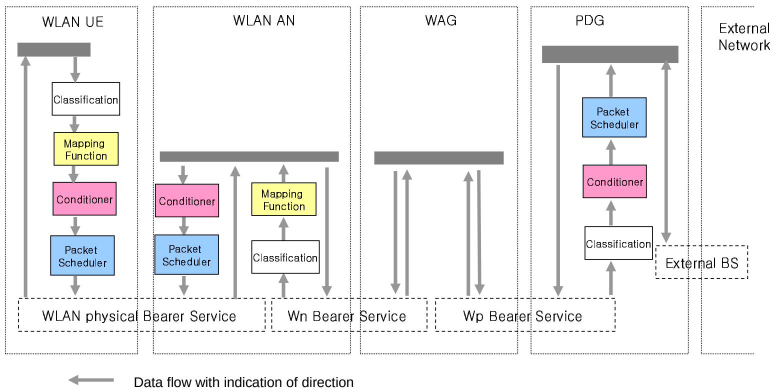

Fig. 4. User plane based on the end-to-end QoS architecture

mapping of QoS parameters among WLAN, IP and 3GPP. Packet Scheduler rearranges the transmission order according to the service class.

3.3 QoS Provisioning Technologies

For the QoS provisioning, we propose the QoS parameter/class mapping technology and DPS packet scheduler based on the control plane and user plane. The QoS parameter and class mapping technologies are used to translate the QoS information in the control plane and user plane. The packet scheduler is applied to manage the data flow in user plane. In this paper, we evaluate the performance of the QoS parameter/class mapping algorithm and packet scheduler in section 4.

QoS parameter mapping The QoS parameter mapping function is located in WLAN UE and PDG. It translates between the QoS parameters of WLAN and 3GPP. There are many QoS parameters which are similarly defined by WLAN and 3GPP. For example, Maximum Bit-Rate and Maximum service data unit (SDU) Size defined in 3GPP is similar to the Peak Data Rate and Maximum MAC service data unit (MSDU) Size defined in WLAN respectively. Therefore, we propose the QoS parameter mapping table considering the relation of the QoS parameters of WLAN and 3GPP as Table 1.

QoS service class mapping We should consider QoS service class mapping among WLAN, IEEE 802.1D (IP) and 3GPP for the packet scheduling, because the data packet would be transmitted through WLAN, IP, and 3GPP network. Since the QoS service classes of them are defined for each service requirement, we can make the QoS service class mapping table considering the similar service requirements like Table 2.

Dynamic processor sharing (DPS) The DPS is proposed for the QoS guaranteed service. DPS can keep the delay bound of voice traffic by the resource allocation for voice traffic. In addition, DPS can provide the fairness for the others. The DPS is shown in Fig 5 and the explanation of DPS operation is as follows. We define the service classes as class1, class2, class3, and class4 according to the priority. Class1 indicates the highest priority traffic class which is very sensitive to delay such as voice of internet protocol (VoIP). To support the class1, the resource manager allocates the resource to guarantee the delay bound when the class1 is generated. Class2 is also sensitive to delay, but the tolerance of delay is larger than class1 like video streaming. Class3 and class4 are insensitive to delay, but they are critical to the packet drop probability such as hyper text transfer protocol (HTTP) and file transfer protocol (FTP) respectively. Therefore, the weighted round robin (WRR) is applied to the class2, class3, class4 to keep the QoS and fairness. The weight should be selected considering the traffic load for the efficiency of capacity. Since class1 occupies the resource, the fairness problem may be occurred if the resource limitation is not defined. To solve this fairness problem, the CAC is applied to the class1.

Table 1. The QoS parameter mapping of WLAN and 3GPP

3GPP QoS parameters (3GPP TS 23.107)	WLAN QoS parameters (TSPEC)
Maximum bit rate (kbps)	Peak data rate (bps)
Maximum SDU size (octects)	Maximum MSDU size (octects)
SDU format information	Burst size (octects)
Transfer delay (ms)	Delay bound (μsec)
Traffic handling priority	User priority

Table 2. The service class mapping of WLAN, 3GPP, and IP

802.1D	3GPP	WLAN
7,6	Conversational	Continuous time QoS traffic (HCCA)
5,4	Streaming	Controlled-access CBR traffic (HCCA)
0,3	Interactive	Bursty traffic (HCCA)
2,1	Background	Unspecified non-QoS traffic (HCCA)

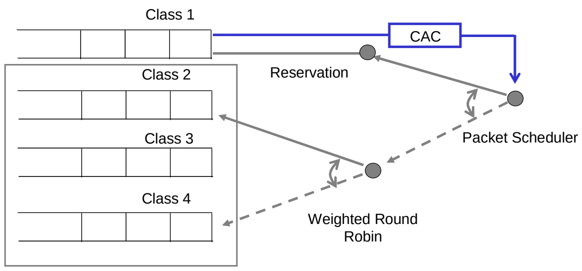

Fig. 5. DPS

4 Performance Evaluation

In this section, we present the network model and results of the performance evaluation for our proposed QoS provisioning technologies. We built the simulator for the QoS provisioning technologies using OPNET.

4.1 Network Model

For the performance evaluation, we simply model the end-to-end reference network architecture which consists of WLAN UEs, three APs, a WAG, a PDG, a gateway, and an internet server. The WLAN UE and AP include the IEEE 802.11, but we do not consider the IEEE 802.11e in this simulation. We connect the PDG with the gateway by a PPP-E1 link for implementing the bottleneck phenomenon. We can expect that the performance of the system rapidly decreases as the total traffic load approaches about 2Mbps.

To increase the traffic load in this simulation, we increase the number of voice user and video traffic load. We model the service traffic based on the traffic models provided by OPNET as shown in Table 3. Since we are interested in the performance of the QoS parameter/class mapping and DPS, we compare the various packet schedulers applied to the PDG. We consider the packet schedulers as first in first out (FIFO), WRR, strict priority (SP), and DPS. We set up the weight ratio according to the traffic load ratio for DPS and WRR.

4.2 Simulation Results

We present our simulation results to evaluate the DPS through comparing it with FIFO, WRR, and SP.

Table 3. The service traffic models

Service class	Parameters
Voice	Voice encoder scheme : G.711
	PHY throughput of a voice user : 174 kbps
	Silence : exponential (0.65)
	Talk spurt : exponential (0.35)
	Session duration : constant (30 sec)
Voice	Frame inter-arrival time : 10 frame/sec
	PHY throughput : 1Mbps, 1.3Mbps, 1.5Mbps, and 1.7Mbps
FTP	Inter-request time : exponential (30 sec)
	File size : 5000 bytes
HTTP	HTTP spectification : HTTP 1.1
	Page inter-arrival time : exponential (60 sec)
	Number of objects : constant (6)

In our simulation, we evaluate packet schedulers for three cases. First, we analyze the voice/video end-to-end delay with increasing a voice traffic load. In Fig. 6, a total traffic load increases as 62.3%, 70.8%, 79.33%, 87.8%, and 96.3% according to the increase of the number of voice user. Fig. 6 presents that DPS can provide the low voice end-to-end delay under 10msec even though a traffic load increases above 96.3%. The reason is that DPS gives the highest priority for the voice packet. We can also analogize that DPS is not poor at the video end-to-end delay from Fig. 6, because the performance difference between others is very small. Therefore, we found that DPS is suitable for the packet scheduler of PDG irrespective of the voice traffic load.

Second, we analyze the voice/video end-to-end delay with increasing a video traffic load. In this case, we can confirm the robustness of DPS according to the increase of the video traffic. Since DPS gives a highest priority to a voice packet, the voice end-to-end delay does not increase though the video traffic increases. In Fig. 7, when a PHY throughput of video traffic increases from 1Mbps to 1.7Mbps, the voice end-to-end delay of DPS does not change at all. And there are very few differences among packet schedulers for the video end-to-end delay. Therefore, DPS is extremely suitable to be applied to the packet scheduler of the PDG compared with FIFO and WRR. The last case is the comparison between SP and DPS. SP is very similar to DPS, because SP also gives a highest priority to a voice packet when a voice packet arrives at the PDG. However, SP can not guarantee the fairness when the number of voice user rapidly increases. If a number of voice users connect and transmit a number of voice packets to the PDG, the end-to-end delay of video steaming, FTP and HTTP traffic may increase because of the unfairness of SP. Unlike SP, DPS is able to guarantee the fairness because of the CAC applied to DPS. For example, if we limit the maximum number of voice user in DPS, DPS can drop the voice call when the number of voice user is over the maximum number. Fig. 8 presents the video end-to-end delay when the maximum number of voice user is equal to 3 using

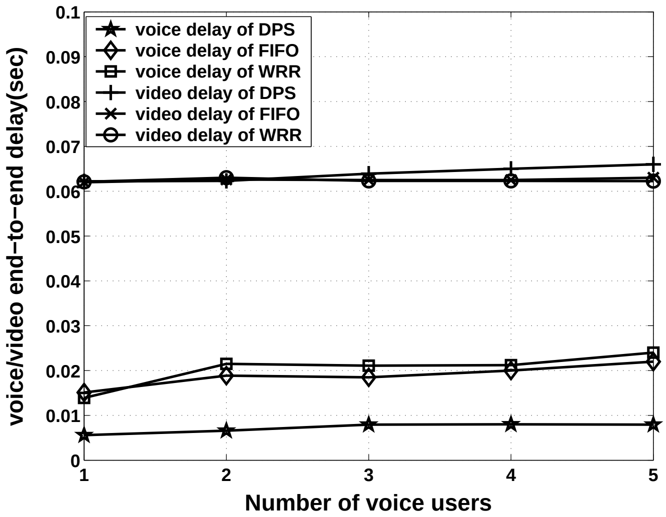

Fig. 6. End-to-end delay of voice and video traffic according to the packet schedulers and the number of voice users

DPS. DPS guarantees the QoS for a video streaming even though the number of voice user rapidly increases.

5 Conclusion

In this paper, we defined the functional features of the network elements and designed the control plane and user plane considering the end-to-end QoS architecture. We proposed the QoS parameter/class mapping and DPS to provide the end-to-end QoS guaranteed service. We also built the simulation model and verified the performance of the proposed technologies. The simulation results show that DPS is superior to FIFO, WRR and SP for the multimedia services such as voice and video.

Since the WLAN and 3GPP interworking technology is the newly embossed issue, our proposed end-to-end QoS mechanisms are expected to be a significant reference. Contributions of this paper are as follows.

- Define the functional features of network elements
- Design the control and user plane
- Propose the QoS parameter/class mapping and DPS
- Build the simulation model using OPNET for the WLAN and 3GPP interworking network

For the future works, we would like to add details of IEEE 802.11e to our simulation, and build the control plane. Finally, this framework can be applied to the other heterogeneous network between WiMAX and 3GPP.

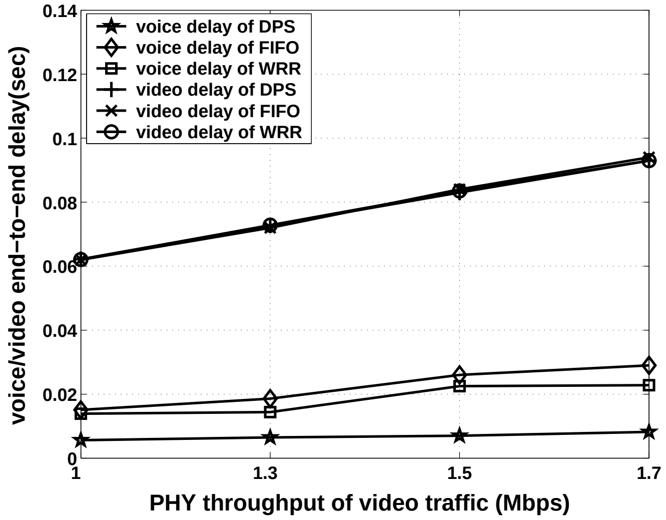

Fig. 7. End-to-end delay of voice and video traffic according to the packet schedulers and the video traffic load

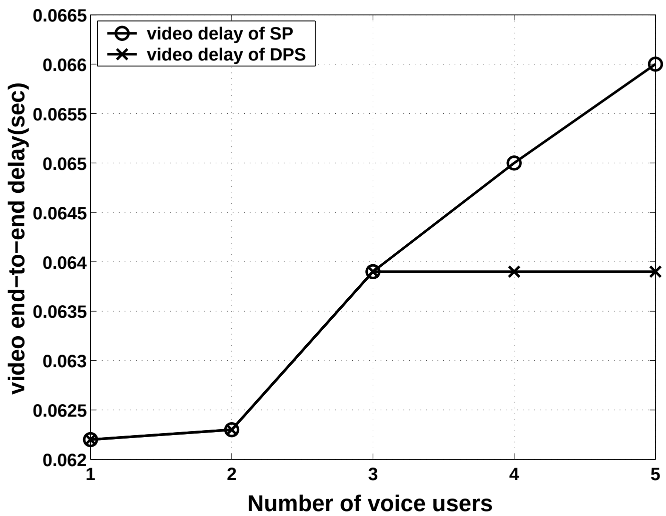

Fig. 8. End-to-end delay of video traffic according to the number of voice users

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