

REPORT ITU-R F.2058

**Design techniques applicable to broadband fixed wireless access
systems conveying Internet protocol packets or
asynchronous transfer mode cells**

(2006)

TABLE OF CONTENTS

	<i>Page</i>
1 Introduction	2
2 Types of FWA systems conveying IP packets or ATM cells in terms of radio channel utilization	2
3 Scope	3
4 References	3
5 Abbreviations	5
6 Technical characteristics addressed.....	8
6.1 Modulation and multiple access method	8
6.2 CoS and QoS.....	9
6.3 Transfer delay characteristics	9
6.4 VoIP technique	10
6.5 Efficient spectrum utilization technique.....	10
6.6 Error correction techniques in an ATM-based FWA system	10
ANNEX 1 – Mechanism to ensure QoS or CoS in the broadband FWA systems.....	11
ANNEX 2 – Example calculations of average access protocol delay and delay variation of CSMA/CA-based FWA.....	29
ANNEX 3 – Example calculations of additional waiting time in multiple VoIP flow situations for TDMA-based FWA	34
ANNEX 4 – Example calculations of QoS class 0 network delay	39
ANNEX 5 – Technical characteristics of broadband FWA systems to support VoIP technique.....	43
ANNEX 6 – Techniques to improve spectrum utilization efficiency	50
ANNEX 7 – Error correction techniques in an ATM-based FWA system.....	53

1 Introduction

There is an urgent need for broadband services in the telecommunication market. Users' needs are not uniform but diversified in terms of bit rate and service quality. Internet protocol (IP) and asynchronous transfer mode (ATM) are becoming basic signal transfer methods in recent wired networks in order to cope with such multimedia service demands. This trend also affects the fixed wireless systems used in the access networks. It is generally understood that IP-based and ATM-based fixed wireless access (FWA) systems should desirably have similar quality of service (QoS) or class of service (CoS) control capability to that of wired systems.

Both QoS and CoS are defined as classified categories prescribed by transmission performance parameters. QoS is used for classes of the transmission performance which satisfy users' quality requirements. On the other hand, CoS is generally used for the classes of similar performance which are presented to users as a guideline by a network administrator.

Furthermore, FWA systems are required to achieve objectives of IP or ATM performance parameters in the wired network adopted in ITU-T Recommendations I.356 and Y.1541. For this purpose, PHY layer parameters of FWA systems must be designed to meet these objectives of IP or ATM performance parameters.

Relations between PHY layer parameters and IP layer performance parameters, such as IPTD are given in ITU-T Recommendations Y.1540 and Y.1541. Relations between PHY layer parameters and ATM layer performance parameters, such as the cell loss ratio (CLR) or cell error ratio (CER) are given in ITU-T Recommendation I.356. ATM-based FWA systems should also satisfy the (SESR) objective specified in Recommendation ITU-R F.1668 (performance and availability requirements and objectives for FWA systems connected to PSTN are described in Recommendation ITU-R F.1400).

Both IP and ATM are packet or cell-based technologies operating at a high clock frequency where IP packet or ATM cell transmission may affect the system design and utilization efficiency of the radio-frequency spectrum. Such requirements will lead to design approaches which differ from existing voice-based FWA. Also necessary technologies for IP packets or ATM cells in FWA applications are, in many respects, common to those used in radio local area networks (RLANs).

The purpose of this Report is to provide example design techniques and methods addressing various aspects of FWA systems carrying IP or ATM data.

2 Types of FWA systems conveying IP packets or ATM cells in terms of radio channel utilization

Types of FWA systems conveying IP packets or ATM cells in terms of radio channel utilization can be categorized as follows.

The first type is to allocate an exclusive radio channel to each subscriber permanently or during a call retains. The typical system is point-to-point (P-P) or point-to-multipoint (P-MP) broadband wireless access systems generally using frequency bands above 20 GHz. This type of system is usually used for the leased line access services.

The second type is to allocate a radio resource when a call attempt occurs. The typical system is an FWA system providing PSTN services for mass users. Some of the systems use the technologies of mobile wireless access systems in order to reduce the cost of equipment.

The third type is to allocate a radio channel only when traffic such as IP packets or ATM cells occurs. This type achieves more efficient frequency usage compared with the first types especially for P-MP topology, provided that overhead bits are not too numerous. MP-MP topology is also suitable in this type of FWA.

The typical systems for the second type include those based on RLANs. FWA systems based on RLAN technologies may also have an advantage of reduce equipment costs. A feature of the third type may be explained as follows in case of ATM cell transmission. There are two cases for FWA systems conveying ATM cells:

- a) FWA transmits ATM cells transparently without identifying any information contained in a cell;
- b) FWA identifies information contained in the header portion of an ATM cell and thus controls the treatment of each cell within the radio section.

In case a), the system design method of FWA should basically be identical to systems intended for SDH signal transmission. This corresponds to the first type of FWA systems described above.

On the other hand, in case b), there can be a different approach in transmitting ATM cells over the radio section in order to efficiently utilize radio-frequency spectrum.

Several RLANs, used mostly for nomadic wireless access (NWA) purposes, or other types of wireless access systems using IP packet or ATM cell over the radio are realized as commercial products or examined in standardization bodies of forums. Standards for wireless access systems, both fixed and nomadic, are given in Recommendation ITU-R F.757 and Recommendation ITU-R M.1450.

3 Scope

This Report provides various design techniques applicable to FWA systems based on RLAN or NWA system technologies, which provide IP packets or ATM cell transport with a rate of more than several Mbit/s targeted for ubiquitous penetration.

The design solutions presented in the Annexes to this Report are suggested as one means towards satisfying the particular MAC layer standards set forth in ITU-T Recommendations concerning IP and ATM transmission. It should also be noted that the material presented in Annex 6 is not applicable to IP traffic since the idle cell notion is very specific to ATM.

The FWA discussed in this Report is focused primarily on P-MP applications wherein the capacity of one radio carrier provided by a base station will be shared by several or more terminal stations, although some of the techniques described in the Annexes to this Report are applicable also to P-P and MP-MP applications.

4 References

ITU-R Recommendations

Recommendation ITU-R F.757	Basic system requirements and performance objectives for fixed wireless access using mobile-derived technologies offering telephony and data communication services.
Recommendation ITU-R M.1450	Characteristics of broadband radio local area networks.
Recommendation ITU-R F.1668	Error performance objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections.
Recommendation ITU-R F.1704	Characteristics of multipoint-to-multipoint fixed wireless systems with mesh network topology operating in frequency bands above about 17 GHz, 2004.

Recommendation ITU-R F.1763

Radio interface standards for broadband wireless access systems in the fixed service operating below 66 GHz.

ITU-T Recommendations

ITU-T Recommendation Y.1540

Internet protocol communication service – IP packet transfer and availability performance parameters.

ITU-T Recommendation Y.1541

Network performance objectives for IP-based services.

ITU-T Recommendation P.800

Methods for subjective determination of transmission quality.

ITU-T Recommendation P.862

Mapping function for transforming P.862 raw result scores to MOS-LQO.

ITU-T Recommendation I.356

B-ISDN ATM layer cell transfer performance.

ITU-T Recommendation G.107

The E-model, a computational model for use in transmission planning.

ITU-T Recommendation G.113

Transmission impairments due to speech processing.

ITU-T Recommendation G.114

One-way transmission time.

ITU-T Recommendation G.711

Pulse code modulation (PCM) of voice frequencies.

ITU-T Recommendation G.723.1

Dual rate speech coder for multimedia communications transmitting at 5.3 and 6.3 kbit/s.

ITU-T Recommendation G.729

Coding of speech at 8 kbit/s using conjugate-structure algebraic-code-excited linear-prediction (CS-ACELP).

Others

ETSI TS 101 761-1 v1.3.1

Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; Data Link Control (DLC) Layer; Part 1: Basic Data Transport Functions.

ETSI TS 101 856 v1.1.1

Broadband Radio Access Networks (BRAN); Functional Requirements for Fixed Wireless Access systems below 11 GHz: HIPERMAN.

ETSI TS 101 999 v1.1.1

Broadband Radio Access Networks (BRAN); HIPERACCESS; PHY protocol specification.

IEEE standard for local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications – Amendment 1: High-speed physical layer in the 5 GHz band.

IEEE standard for local and metropolitan area network – Specific requirements – Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications.

IEEE standard for local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications – Amendment 4: Further higher-speed physical layer extension in the 2.4 GHz band.

IEEE standard for local and metropolitan area networks – Part 16: Air interface for fixed broadband wireless access systems.

ARIB STD-T70 v1.0 – Low power data communication systems/broadband mobile access communication system (HiSWANa).

Design and considerations for traffic class expediting and dynamic multicast filtering, IEEE Std 802.1D Annex H, IEEE, 1998.

<http://www.ietf.org/html.charters/mps-charters.html>

<http://www.ietf.org/html.charters/diffserv-charter.html>

<http://www.ietf.org/html.charters/rsvp-charter.html>

Wireless medium access control (MAC) and physical layer (PHY) specifications: Medium access control (MAC) enhancements for quality of service (QoS), IEEE std 802.11e/D1, March 2001.

INOUE, Y., SAITOH, S., IIZUKA, M. and MORIKURA, M. [December 2000] A fair data transfer method by using a CoS control mechanism for fixed wireless access systems, The 2000 International Conference on broadband wireless access systems, p. 19-25.

KAGAMI, O., OTHA, A. and HOJO, H. [November 2002] Development of compact wireless access equipment for an AWA system based on HiSWANa standard, *NTT Rev.*, p. 49-53, Vol. 14, No. 6.

TTC Standard JJ-201.01 [2003] A method for speech quality assessment of IP telephony.

ETSI TR 101 329-7 – End-to-end quality of service in TIPHON systems; Design guide for elements of TIPHON connection from an end-to-end speech transmission point of view.

MASUDA, M. and ORI, K. [November 2001] Network performance metrics in estimating the speech quality of VoIP, IEICE APSITT2001, p. 333-337.

ICHIKAWA, T., *et. al.*, *Approximation of characteristics of CSMA/CA based on IEEE 802.11 standard*, B-5-186, Proceedings of the 2003 IEICE Society Conference.

5 Abbreviations

This Report uses the following abbreviations:

ACK	Acknowledge
AIFS	Arbitration inter-frame space
ARQ	Automatic repeat request
ATM	Asynchronous transfer mode
BC	Broadcast channel
BCC	Block convolutional code
BE	Best effort
BEB	Binary exponential backoff
BER	Bit error ratio
BS	Base station
BWA	Broadband wireless access
CBR	Constant bit rate
CBQ	Class based queuing
CDV	Cell delay variation
CER	Cell error ratio
CLR	Cell loss ratio

CMR	Cell misinsertion ratio
CoS	Class of service
CSMA/CA	Carrier sensing multiple access with collision avoidance
CTD	Cell transfer delay
CW	Contention window
CWmin	Contention window minimum
DAMA	Demand assign multiple access
DiffServ	Differentiated service
DIFS	Distributed coordination function inter frame space
DL	Data link
DS	Differentiated service
DSA	Dynamic slot assignment
EDCF	Enhanced distributed coordination function
FCS	Frame check sequence
FDD	Frequency division duplex
FSDD	Frequency switched division duplexing
FEC	Forward error correction
FIFO	First in first out
FTP	File transfer protocol
FWA	Fixed wireless access
GBN	Go-Back-N method
GBR	Guaranteed bit rate
HCF	Hybrid coordination function
HEC	Header error control
HIPERACCESS	High performance radio ACCESS network
HIPERMAN	High performance radio metropolitan area network
HRP	Hypothetical reference path
IEEE	Institute of Electrical and Electronics Engineering
IETF	Internet engineering task force
IP	Internet protocol
IPDV	IP packet delay variation
IPER	IP packet error ratio
IPLR	IP packet loss ratio
IPTD	IP packet transfer delay
ITU-R	International Telecommunication Union – Radiocommunication Sector

ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
LCO	Loss cell outcome
LDP	Label distribution protocol
LSR	Label switching router
MAC	Media access control layer
MC	Multicast
MP	Measurement point
MP-MP	Multipoint-to-multipoint
MPLS	Multi-protocol label switching
MOS	Mean opinion score
NAK	Negative Acknowledge
nrtPS	Non-real-time polling service
OFDM	Orthogonal frequency division multiplexing
PCR	Peak cell rate
PDU	Protocol data units
PHSI	Payload header suppression identifier
PLC	Packet loss concealment
PS	Physical slot
P_{pl}	Packet loss probability
P_{plN}	Packet loss probability in network
P_{plB}	Packet loss probability in jitter absorption buffer
PHB	Per-hop behaviour
PHY	Physical layer
P-P	Point-to-point
P-MP	Point-to-multipoint
PESQ	Perceptual evaluation of speech quality
PSTN	Public switched telephone network
QoS	Quality of service
R	Rating factor
RSVP	Resource reservation protocol
rtPS	Real-time polling service
RTS/CTS	Request to send/clear to send
SLA	Service level agreement
SC	Single carrier
SDH	Synchronous digital hierarchy

SDMA	Space division multiple access
SIFS	Short inter frame space
SR	Selective repeat
TC	Traffic category
TCI	Tag control information
TDD	Time division duplex
TDM	Time division multiplex
TDMA	Time division multiple access
ToS	Type of service
TTC	Telecommunication Technology Committee
UBR	Unspecified bit rate
UGS	Unsolicited grant service
UNI	User network interface
VoIP	Voice over Internet protocol
WAN	Wide area network
WFQ	Weighted fair queuing
WRR	Weighted round robin

6 Technical characteristics addressed

6.1 Modulation and multiple access method

For guidance on preferred methods of multiple access and modulation techniques for broadband FWA systems conveying IP packets or ATM cells, Table 1 can be referred to.

TABLE 1
Methods of multiple access and modulation techniques

Conveyed signal	Multiple access ⁽¹⁾	Modulation
IP packet	TDM-TDD/FDD TDMA-TDD/FDD OFDMA-TDD/FDD DAMA-TDD/FDD CSMA/CA DSSS-OFDM	Adaptive (4-, 16-, and 64-QAM) ⁽²⁾ Adaptive (BPSK, 4-, 16-, and 64-QAM) ⁽²⁾ Adaptive (BPSK, 4-, 16-, 64- and 256-QAM) ⁽²⁾ Presettable (4- and 16-QAM) CCK (QPSK) DSSS (BPSK, QPSK)
ATM cell	TDM-TDD/FDD TDMA-TDD/FDD OFDMA-TDD/FDD DAMA-TDD/FDD	Adaptive (4-, 16-, and 64-QAM) ⁽²⁾ Adaptive (BPSK, 4-, 16-, and 64-QAM) ⁽²⁾ Adaptive (BPSK, 4-, 16-, 64- and 256-QAM) ⁽²⁾ Presettable (4- and 16-QAM)

⁽¹⁾ Including duplex technique.

⁽²⁾ These modulation techniques may be applied in conjunction with OFDM.

6.2 CoS and QoS

In the variety of broadband applications, there is greater demand for services with guaranteed service quality. It is also desirable to adopt service quality guarantee in FWA systems where communications qualities match the various services.

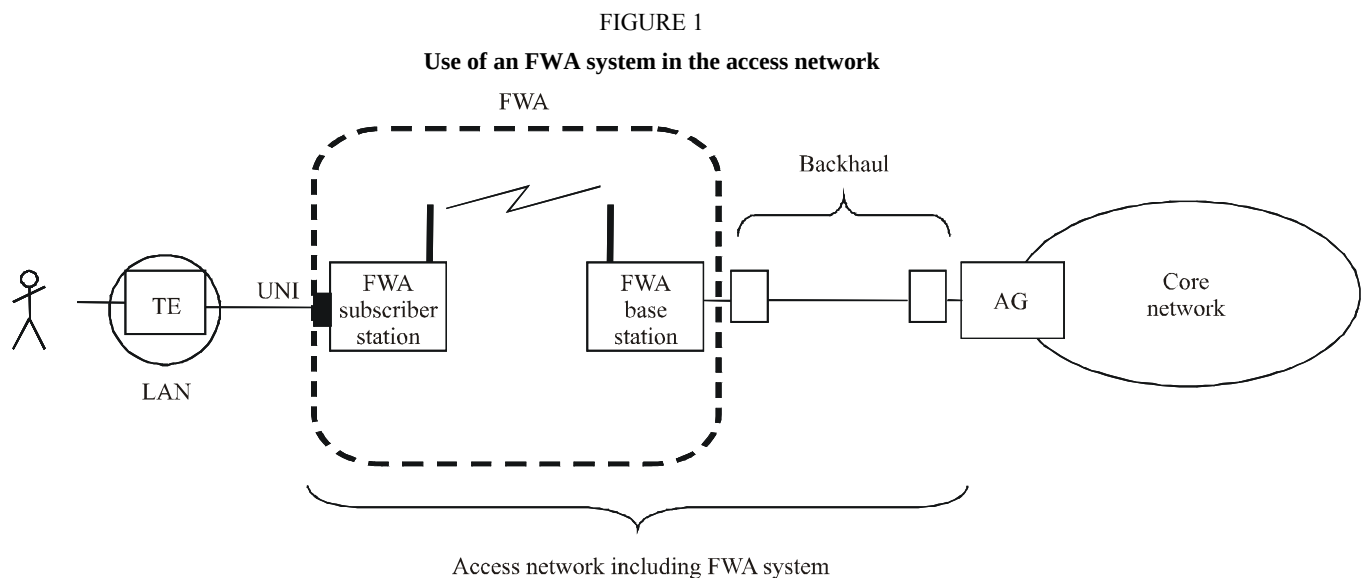
ATM-based FWA has the capability of QoS control which is one of capabilities of the ATM transport. Conversely, CoS control is a realistic solution in the IP-based FWA systems because of the limited bandwidth and characteristics of the radio channel.

Annex 1 describes a mechanism to provide CoS and QoS control in FWA systems using distributed control or centralized control.

6.3 Transfer delay characteristics

ITU-T Recommendation Y.1541 specifies overall IP performance objectives. Among the performance parameters, transfer delay parameters, i.e. IPTD and IPDV defined in ITU-T Recommendation Y.1540, should be taken into account in the design of FWA systems conveying IP packets or ATM cells.

For the time being, there is no specification on how the UNI end-to-UNI end requirements for IPTD and IPDV are sub-divided into individual portions forming the access network. Basically, FWA systems should be designed so that the overall IPTD and IPDV could meet, e.g. in the configuration in Fig. 1, the requirements specified in ITU-T Recommendation Y.1541.



AG: Access gateway
TE: Terminal equipment
UNI: User network interface

Rap 2058-01

In order to achieve the above requirements, the following considerations are noted.

In general, FWA equipment (e.g. subscriber station, base station, and so on) may have some buffers for controlling transmission timings, compensating jitters, formatting frame, and so on. Such buffers lead to delay degradation in FWA systems. Representative access protocols for FWA systems are CSMA/CA and TDMA, and such access protocols may become the dominant factors of delay characteristics in FWA systems.

6.3.1 Considerations on IPTD

In CSMA/CA scheme, for packet collision avoidance, backoff and RTS/CTS sending techniques are adopted. Those techniques cause IPTD degradation, especially when many stations try to send packets simultaneously (see Annex 2).

In TDMA scheme, base stations control the entire bandwidths and assign them to each service flow, so that collision-free connections can be realized in principle. Once an initial connection procedure can be finished, IPTD degradation like CSMA/CA due to collision avoidance like backoff and RTS/CTS may not happen. However, several factors like scheduling algorithm, frame structure, traffic loads and capacity may become causes of IPTD degradation (see Annex 3).

6.3.2 Considerations on IPDV

CSMA/CA-based FWA systems usually adopt BEB scheme. It may cause large IPDV occasionally. This scheme mitigates probability of simultaneous re-transmissions from multiple stations, but incurs IPDV degradation. In addition, especially in case that a long packet occupies the radio channel for a long span, waiting time which happens to other packets to be transmitted will increase. This also leads to IPDV degradation.

In TDMA scheme, base stations can control bandwidths on service flow basis. Thus, low-jitter transmission can be realized compared with CSMA/CA.

For technical guidance and examples of calculation on IPTD and IPDV occurring in wireless system to access portion of the IP network (see Annex 4).

6.4 VoIP technique

VoIP is recently regarded as one of the most attractive solutions of IP-based network.

There are several performance parameters for providing a certain QoS for VoIP. Some of the parameters, such as delay or packet loss ratio, are defined in the ITU-T Recommendations for the end-to-end network (including both wired and wireless sections). Objectives for such performance parameters in wireless sections should also be defined.

Annex 5 provides technical characteristics of broadband FWA systems to support VoIP, as derived from studies of the TTC that can be found in TTC Standard JJ-201.01 – A Method for Speech Quality Assessment of IP Telephony, 2003.

6.5 Efficient spectrum utilization technique

Two possible control methods to utilize the spectrum efficiently consist of PHY layer control technique and MAC layer control technique.

The PHY layer control technique is further classified in two ways. One way is to fill packets or cells full by applying adaptive modulation, adaptive TDD and DAMA. The other way is to increase the efficiency of spectrum utilization by applying SDMA using sector antenna or array antenna.

The MAC layer control technique assigns adequate spectrum to data according to its application or service quality. Data is fragmented or packed to increase the efficiency of data load utility. Annex 6 describes a technology to remove idle cells without introducing CDV for ATM-based FWA to achieve efficient spectrum utilization.

6.6 Error correction techniques in an ATM-based FWA system

In ATM-based FWA systems, ARQ and/or FEC effectively improve error performance.

Annex 7 provides the error correction techniques in an ATM-based FWA system.

Annex 1

Mechanism to ensure QoS or CoS in the broadband FWA systems

1 Introduction

In this Annex, mechanisms to ensure QoS or/and CoS in the broadband FWA systems are described. There are two types of radio channel access schemes. One is the distributed control system and the other is the centralized control system. An example of the distributed control system is the IEEE 802.11 systems. They are packet switching service adopting CSMA/CA. On the other hand, a base station assigns the time slot of the TDMA MAC frame to subscriber terminals or a combined frequency and time partition in OFDMA in the centralized control system. Examples of the centralized control system are ETSI-BRAN HIPERMAN, HIPERACCESS, HIPERLAN, IEEE802.16-2004 or MMAC-HSWA HiSWAN. Full QoS, even in overloading conditions, is achievable only with centralized control systems.

There are two schemes to achieve QoS and CoS. One is the prioritized scheme which offers a priority control among the service classes without specifying service specific parameters. The other is a parameterized scheme to assure required communication quality parameters. Only a parameterized scheme has the possibility to guarantee QoS.

First of all, an overview of CoS control is presented in § 2. Subsequently, queuing and priority management mechanisms to support CoS controls are shown in § 3. Then, a CoS control mechanism for a distributed control scheme and a QoS control mechanism for a centralized control scheme are presented in § 4 and 5, respectively. Finally, a comparison of distributed control scheme system and a centralized control scheme system is shown in § 6.

2 Overview of CoS control

2.1 Airplane model

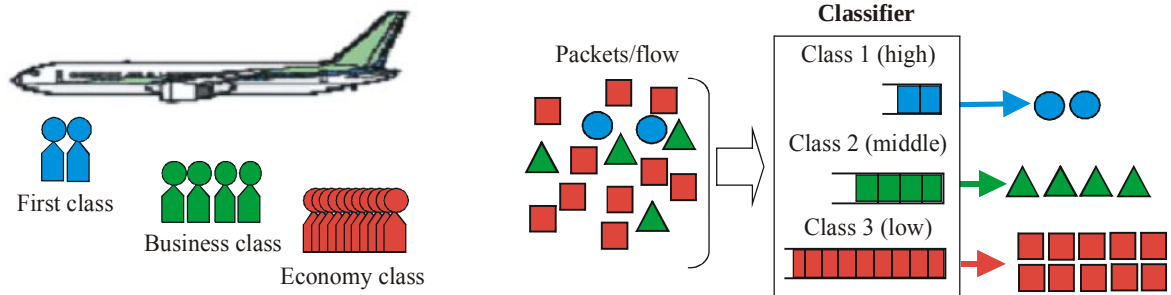
CoS control is often explained by an “airplane model” (see Fig. 2). Service quality is classified into several service classes just like airplane seats which are classified into first, business and economy class. Higher service classes than usual best effort class are used to offer high-level services, e.g. ensuring minimum delay time or available bandwidth. High-quality service is provided if the request from the user is accepted. Admission control or policy control methods are used to determine which service classes are allowed for data transfer. According to the service class, each data transfer is transferred based on that quality. However the amount of traffic carried in such higher service classes is limited because the available bandwidth is limited.

2.2 CoS control mechanism for the best effort flows in the FWA environment

2.2.1 Priority control for the CoS control

At least two CoS are necessary to offer CoS control. Priority is associated to the CoS and service differentiation is made according to the priority. The base station (BS) must determine the CoS for each best effort transfer. A subscriber needs to know the CoS in transmitting its best effort data. The methods by which CoS is determined and translated to the subscriber are introduced in the following paragraphs.

FIGURE 2
Airplane model



2.2.2 Priority determination

There are several ways to determine the CoS for transmitting best effort data between the base station and a subscriber station. The business users or high end customers may have higher priority in transmitting the best effort data than others. In this case, an authentication mechanism is used to determine the CoS of the subscriber. The base station may control the bandwidth allocated to a subscriber that occupies the system resources by transmitting or receiving a greater amount of data. To protect the systems resources from greedy subscribers, the base station may change the CoS for such a subscriber to low. In this case, the base station checks the amount of data transmitted and/or received by each subscriber and changes the CoS based on the amount of data and determined threshold.

In both cases, it is the role of the base station to determine the CoS of a subscriber. In the former case, the base station can ask the authentication server or may check the internal database. In the latter case, the base station can control the CoS offered for each subscriber.

2.2.3 Notification of the CoS to subscribers

To make CoS control in both forward and reverse directions, the base station needs to note the CoS of each subscriber. For this purpose, outbound or inbound signalling is used.

In the outbound signalling scheme, the base station sends the service class information to each subscriber before data transfer occurs. In this case, the base station must also notify a subscriber of any changes to its CoS.

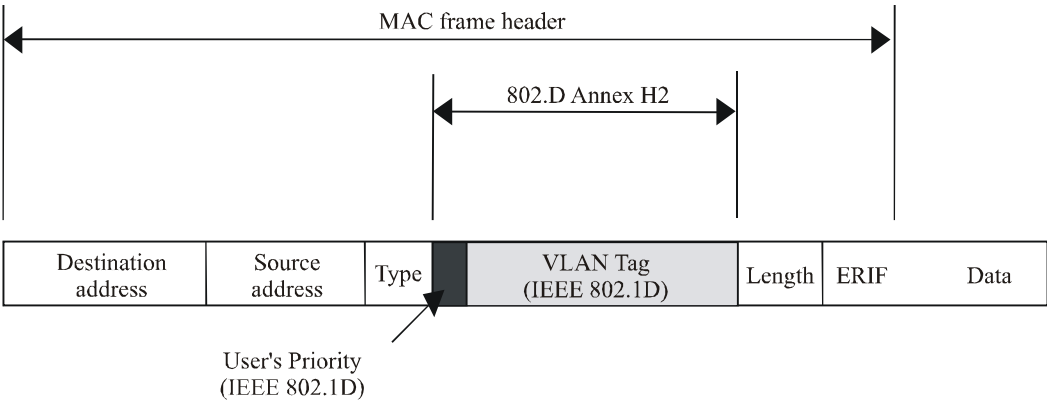
Another alternative is the inbound signalling scheme where the base station sends the determined information on the CoS together with the data by using a similar mechanism defined in like IEEE 802.1D Annex H2 standard as shown in Fig. 3. The base station sets the priority of a frame in the frame header. Since the priority is associated with the CoS, the subscriber can recognize the CoS from the priority information.

As in Fig. 4, the subscriber sets the same priority information with the latest received data frame.

The determined CoS must be considered in the access control method. Although there are many random access methods, most of them do not support such functionality. A CSMA/CA-based method has been proposed to offer prioritized transmission.

A priority control scheme by the inbound signalling scheme seems to be a realistic solution for CoS control in the FWA systems as it does not need too much bandwidth compared to the outbound signalling scheme.

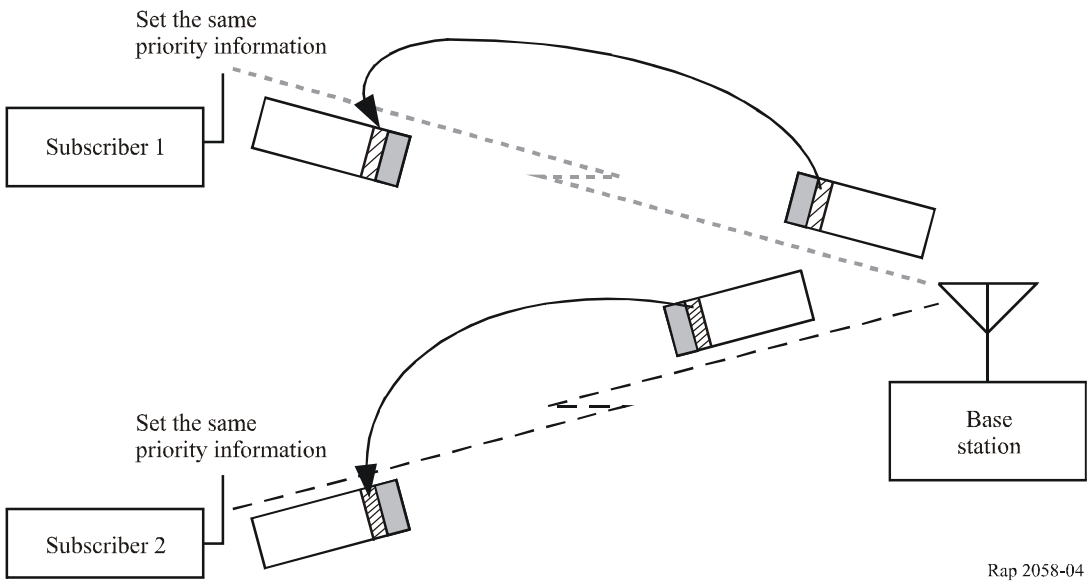
FIGURE 3
Priority control with frame tagging



ERIF: embedded routing information field

Rap 2058-03

FIGURE 4
CoS notification by the inbound signalling scheme



Rap 2058-04

2.3 Effect of CoS control

2.3.1 Fair access

One useful way of CoS control is to prevent a specific user from occupying the limited bandwidth of the wireless channel and to provide fair access for all subscribers. By making a lower service class than the usual best effort class, a subscriber who consumes most of the frequency resource alone will be forced to degrade the service class.

Checking the amount of transferred data for each subscriber at the base stations, the operator can know the activity of each user. There will be some ways to check the amount of transferred data for each subscriber. For example, IP address may be enough to distinguish the heavy user. Of course, the operator can check the traffic flow in more detail.

The service provider must have a policy control mechanism to protect the system resources from a user who intentionally overly occupies the system resources.

2.3.2 End-to-end CoS control

To offer CoS controls in the end-to-end region, FWA base stations and/or their upper routers need to have CoS handling functions and, if possible, subscriber terminals should also have a corresponding functionality. Whether CoS control is accomplished or not depends on the available bandwidth. To meet the various users' requirements of subscribers, the system needs much greater bandwidth than necessary for usual best effort services. Although the bandwidth limited and the radio channel is not so reliable, certain level of CoS control will nevertheless be offered.

3 Queuing and priority management mechanisms to support CoS controls in the FWA systems

3.1 Introduction

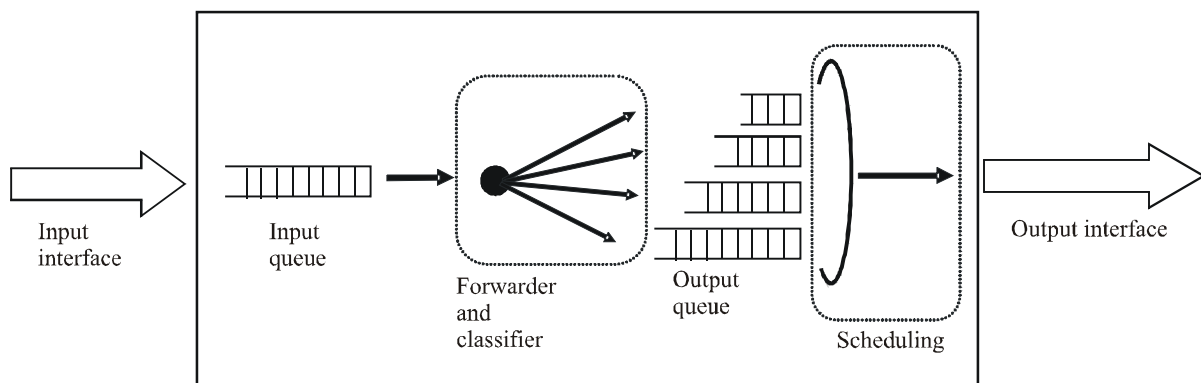
This paragraph introduces the queuing mechanisms and the priority management scheme that support CoS controls in the FWA systems. A queuing mechanism that offers priority control and/or fair data transmissions will be used to make service differentiation according to service classes. Some kinds of priority queuing mechanisms are briefly described. Moreover, the priority management scheme is proposed to make fair data transfer by using the CoS control mechanism.

3.2 Queuing mechanisms for FWA systems

CoS control is the mechanism to ensure the communications quality of each data transfer according to its service class. CoS control is achieved when all nodes between the end systems have the function to make service differentiation according to the service class. The basic mechanism for this purpose is the queuing.

Queuing can be seen as a buffering operation to reorder the IP packets and plays a very important role in the forwarding nodes. This operation is carried out when a node relays a packet from the input queue of an interface to the output queue of another interface as in Fig. 5. In this process, the packet classification and the packet scheduling of the output queue plays a very important role in supporting CoS control. In this paragraph, the output queuing methods, i.e. the packet scheduling methods, are considered and some basic mechanisms are briefly introduced.

FIGURE 5
Queuing and packet scheduling in a forwarding node



Rap 2058-05

3.2.1 First in First out (FIFO) queuing

FIFO queuing is the standard method in carrying the IP packet from input interface to the output interface in a store and forward manner. In FIFO queuing, incoming packets are put into the queue in the order of arrival and the packets are sent to the output interface in the same order.

FIFO queuing is the most popular mechanism and many vendors implement it in their products. Although the FIFO queuing is simple and fast mechanism, it suffers from queuing delay when the traffic load increases. Moreover, it cannot make service differentiation and therefore has difficulty to support CoS control functions.

3.2.2 Priority queuing

In the priority queuing, high-priority packets are always handled before the others. Recognizing the traffic type and putting the high-priority packet to the head of output queue achieve priority queuing. Several output queues corresponding to the offered traffic classes may be used. In the priority queuing, arrived packets are put into the output queue according to the determined order. Therefore, the higher-priority packets are transmitted before the lower priority ones.

3.2.3 Class based queuing (CBQ)

In the CBQ, traffic in the network is classified into some classes which are defined by the network operator to make different forwarding operations according to the traffic types. A packet is forwarded according to its traffic class. The forwarding nodes have output queues for each traffic class and the operator can schedule the outgoing traffic for each queue. On the contrary to priority queuing, CBQ gives every packet a chance to be forwarded according to the classified level of transmission.

3.2.4 Weighted fair queuing (WFQ)

WFQ is a combined mechanism of priority queuing and fair queuing. It realizes fair data transfer considering the priority and the amount of traffic for each traffic class.

3.3 CoS control schemes on layer 3 or higher

To support CoS control between end users, some mechanisms have been proposed which work on the IP layer. These schemes are effective to provide end-to-end CoS control. If the FWA base stations or the routers in the system support the functionality, various multimedia services can be provided. Current CoS control methods for layer 2 and 3 or higher are shown in Table 2.

TABLE 2
Current/CoS control methods

Layer	Method		Standardization
Layer 2	IEEE 802.1D Annex H2	IEEE 802.1D Annex H2 Tagging	IEEE 802 Committee
Layer 3-4	MPLS	Label Switching	IETF
	DiffServ	Use of DS field (IP ToS field)	IETF
	RSVP	RSVP signalling	IETF

3.3.1 Multi-protocol label switching (MPLS)

The label switching technique is used to make high-speed packet forwarding. A label which can be referred from the data link layer is assigned to the data flow to distinguish from the others. LSRs are used in MPLS in which packet forwarding is carried out not by the layer 3 but by the layer 2 checking the label in the frame header of the packets. Therefore, high-speed packet switching is enabled because IP header analysis is not necessary except for the first packet.

When assigning a label to a data transfer, service quality for that transfer can also be assigned. The label for a data transfer is propagated to other LSRs by the LDP. At this time, service class is also distributed, and CoS is provided by the LSRs. To support end-to-end CoS control, an edge router, the LSR which connects a conventional router and other LSRs must also support DiffServ model.

3.3.2 Differentiated services (DiffServ)

In the DiffServ model, service levels are distinguished by ToS field in the IP packet header. ToS field is not used in IPv4 and the meaning of that field is redefined in the DiffServ model. Policy or rule based traffic control is offered in the DS domain, which is constructed by the DS capable nodes. The operations of DS nodes such as packet forwarding manner for each data flow of the specific CoS is defined by the PHB.

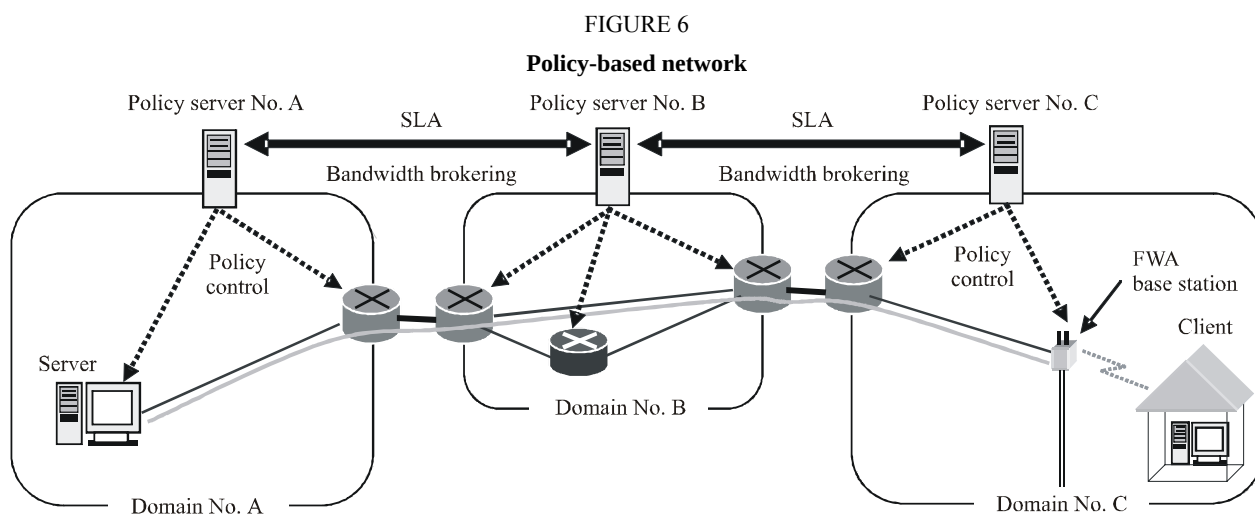
When transferring data over DS domains with specific service quality, policy servers of those DS domains negotiate with each other. Necessary bandwidth for the data transfer is acquired by a bandwidth broker if the SLA is accomplished.

3.3.3 Policy-based network management for CoS provision

To determine a priority of a data transfer according to the requirement of subscriber or to control a subscriber's priority, policy or rule-based network management is necessary. The policy controller and admission controller will be used to manage the network resources or the subscribers' priority.

When policy-based network management is employed, centralized access control mechanism is desired at the layer 2 protocol in FWA systems. Although random access, such as CSMA or variations of it, may be enough to provide best effort services, centralized access mechanisms, such as a polling based protocol, will be necessary to propagate and ensure the determined CoS for the data flow.

An example is illustrated in Fig. 6.



Rap 2058-06

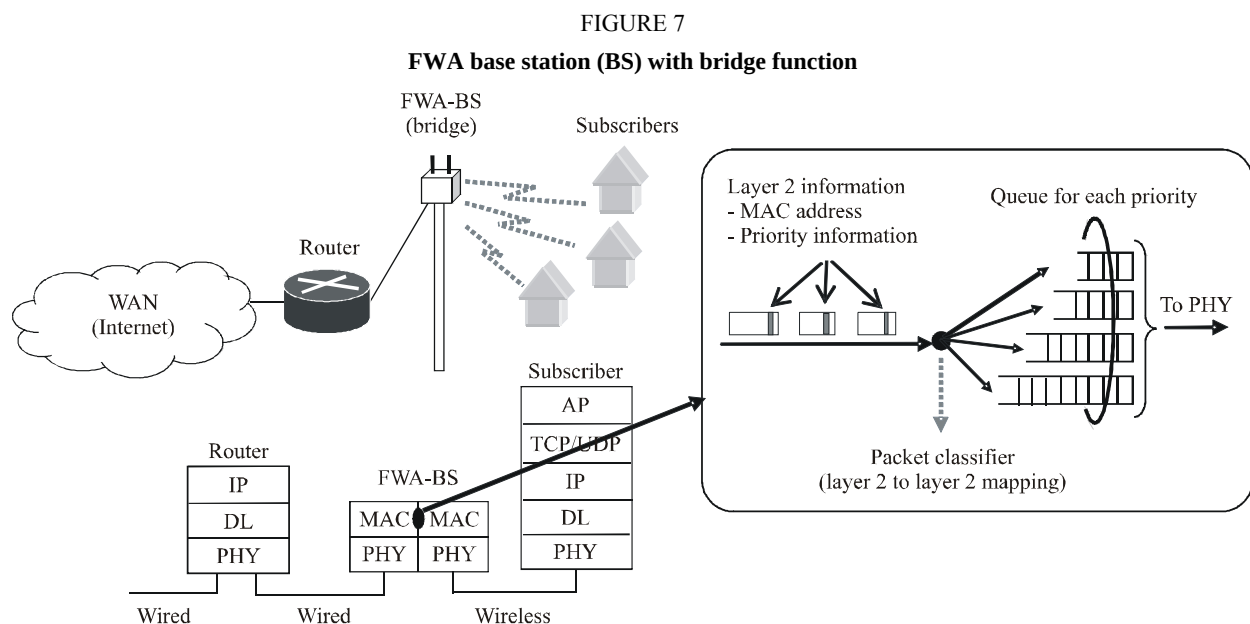
3.3.4 CoS control mechanism in the FWA systems

Some strategies can be considered to implement the CoS control mechanism in the FWA systems according to the functionality of the FWA base station. Basically, the MAC layer will have CoS control functionality for a data flow in the wireless region because the access procedure is defined there.

3.3.4.1 When an FWA base station is a bridge

When an FWA base station works as a bridge as shown in Fig. 7, a straightforward way to realize CoS is to have some queue corresponding to each service class. From the priority information in the MAC frame header, the base station judges the priority of the frame and queues it appropriately. If the base station relays the frame from the wired region to wireless, or vice-versa, protocol conversion may be required and the above operation will be accomplished in that process. When transmitting the buffered frame, the base station takes a frame from the buffer according to the determined algorithm and then sends it to the channel. One method to ensure CoS may be the queuing and priority management methods.

Other approaches to realize CoS is for further study.



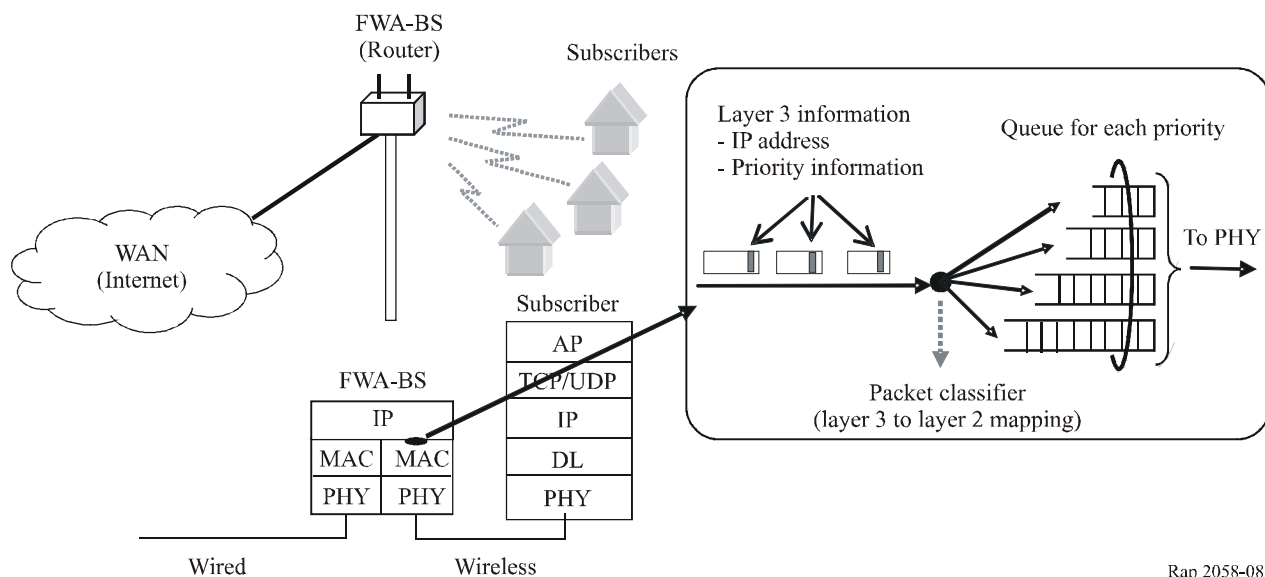
BS: base station

Rap 2058-07

3.3.4.2 When an FWA base station is a router

When an FWA base station works as a router, an example to provide CoS control is described in Fig. 8. In this case, the base station must handle the priority information between the different layers, i.e. layer 3 and layer 2. In many schemes, an inbound signalling method is employed to distinguish the high priority packet from the usual best effort packets. In this case, the priority information is written in the packet header. An FWA base station is assumed to have priority queuing functionality in the MAC layer and mapping of the service class in the layer 3 and priority in the layer 2 is accomplished.

FIGURE 8
FWA BS with router function



Rap 2058-08

3.3.4.3 Subscriber terminals

A subscriber terminal of the FWA system will require some mechanisms for CoS controls.

When receiving a data frame, the MAC layer of the subscriber terminal must understand the priority information in the frame and pass it to the upper layer. If a subscriber wants to send high priority data, the MAC layer of the terminal must set the priority information of the frame.

When a subscriber terminal is the source of high priority data, it may be required to have the functionality to negotiate with the policy server, the router or the base station to reserve the bandwidth for the data.

4 CoS control mechanism of FWA systems using a distributed control scheme

4.1 Extension of CSMA/CA protocol to support CoS controls

CSMA-based methods are widely used as distributed MAC mechanism in the LAN environment. The IEEE 802.11 wireless LAN system employs CSMA/CA protocol as its basic access method. CSMA/CA protocol provides equal opportunity to transmit data for the stations and priority of data is not considered. To support CoS controls, CSMA/CA protocol must be modified to make service differentiation considering the priority of transmitting data. Data priority is established by changing the backoff procedure of CSMA/CA protocol. The original and modified CSMA/CA protocol is briefly explained in this paragraph.

4.2 Original CSMA/CA protocol

In the CSMA/CA protocol, both the base station and subscribers continuously sense the channel to know whether the channel is available. The channel is deemed idle if the station does not detect a signal for a specified time interval called DIFS.

When data arrives at a station, it starts to transmit the data immediately if the channel is sensed idle. If the channel is busy at the time of arrival, the station carries out a backoff procedure once the channel becomes idle in order to avoid collisions. In the backoff procedure, a station that is ready to transmit data generates a random backoff time before transmission by generating a random number