Unified Radio Network for Broadcasting and Broadband Wireless Access

Weiwei Wang and Changjia Chen, Beijing Jiaotong University
Yunbao Zeng, Zihua Guo, and Wenchao Ma, Lenovo Corporate Research
Xuemin (Sherman) Shen, University of Waterloo

ABSTRACT

In this article we propose a unified radio network architecture, broadband wireless multimedia (BWM), which integrates broadcasting service and broadband wireless access service at both the application and physical layers. A simple, flexible, and comprehensive radio resource management framework is developed for the unified radio network. It is shown that the proposed radio network architecture has many advantages over existing ones. In addition, the new architecture is currently being considered in China for the system level design.

INTRODUCTION

Traditionally, the communications network and the broadcasting network are separated. With the development of new technologies, in particular IP technology, and the fast growing bandwidth in the wired domain, the boundary between communications and multimedia broadcasting is becoming blurred and convergence is the trend. IPTV, for instance, brings rich video content to the end user via broadcasting/multicasting/unicasting over the Internet backbone. Furthermore, different services over the same radio network are becoming reality: broadband wireless access and mobile broadcasting are moving closer and closer. A converged mobile network will not only affect the user experience, but also significantly impact the industry and technology development. Therefore, significant attention has been paid to designing a new broadband wireless network. For instance, the Third Generation Partnership Project (3GPP) and 3GPP2 have already started work on long-term evolution (LTE) [1] and air interface evolution (AIE) in order to provide services up to 100 Mb/s in the downlink and 50 Mb/s in the uplink at substantially reduced cost compared to current radio access technologies. On the other hand, with the ratification of IEEE 802.16d/e [2] and the deployment of wireless broadband (WiBro) [3], wide cell coverage and seamless services under medium and low mobility could be achieved. In addition, future mobile communication systems should have the features of high data rate transmission and open network architecture.

Recently, mobile TV is becoming one of the most attractive services. Numerous operators, equipment manufacturers, and terminal manufacturers are getting involved. Several mobile TV standards have been proposed, which can be classified into two categories:

- Mobile TV based on existing cellular networks
- Mobile TV based on separate networks that usually include terrestrial and satellite broadcast networks

For the first category, multimedia broadcast multicast service (MBMS) [4] proposed by 3GPP and broadcast and multicast service (BCMCS) proposed by 3GPP2 are the typical representatives. The former supports broadcast and multicast services in wideband code-division multiple access (WCDMA), while the latter is in CDMA2000. The major advantage of this approach is that mobile TV can be supported without any large modification of the current infrastructure and terminal design. However, due to the small capacity in 3G networks, the supported broadcast and multicast services are limited, and the throughput of other services is restricted.

For the second category, the spectrum used for mobile TV is the broadcast frequency. The typical technologies of terrestrial broadcast include digital video broadcast handheld (DVB-H) [5], terrestrial digital multimedia broadcast (T-DMB) [6], digital audio broadcast IP (DAB-IP), forward link only (MediaFLO), and terrestrial integrated services digital broadcast (ISDB-T). Most of them add new technologies used to support the mobility and power saving of user handheld terminals on the basis of the current broadcasting systems. Taking DVB-H as an example, it has been developed based on the terrestrial broadcast system, DVB-T, and basically forms a broadcast network via the single-frequency network (SFN). In the lower layer, it features some key technologies, such as multiprotocol encapsulation forward error correction (MPE-FEC), time slicing, and enhanced mobility support using 4k (number of subcarriers) mode. In China, two kinds of terrestrial-broadcast-based mobile TV systems have been

 0163-6804/07/$20.00

proposed. One is terrestrial mobile multimedia broadcasting (T-MMB) developed by Nufrontsoft, Communication University of China, and Southeast University, and provides compatibility with DAB, T-DMB, and DAB-IP. The other one is digital multimedia/TV broadcast-terrestrial/handheld (DMB-TH) proposed by Tsinghua University based on DMB-T which is the core part of the national standard for digital terrestrial TV (DTTV) transmission in China. The major advantages of these approaches are high spectrum efficiency and large coverage. However, one of the critical problems is the lack of uplink transmission, which is very important for network management, such as authentication, authorization, and accounting (AAA).

Satellite-based mobile TV broadcasting has also attracted a lot of attention, and almost every terrestrial mobile TV broadcast system has a satellite counterpart. Typical representatives include DVB-satellite (DVB-S) proposed in Europe, satellite DMB (S-DMB) proposed in Korea, and satellite and terrestrial interactive multiservice infrastructure (STiMi) proposed in China. They all use satellite to ensure large coverage of broadcast services. For these kinds of networks, the broadcast signal is transmitted by satellite and received by the terminals directly or through terrestrial repeaters. However, as with terrestrial-based mobile TV broadcasting, satellite networks also lack uplink transmission.

With increasing user requirements, convergence of the broadcast and mobile communications systems is necessary. This is because:

- The mobile phone is a necessary device for most people; it is natural and convenient to have both mobile TV and communications on the same device.
- It can provide an uplink for the separate mobile TV broadcasting network.

As a result, the separate mobile TV system is currently loosely coupled with the existing cellular network, and some higher-layer protocols are defined for their interaction. For example, in DVB-H, the IP datacast (IPDC) system on top of DVB-H is performed through the 3G cellular network. For many current T-DMB trial systems, the general packet radio service (GPRS)/3G system is used as an uplink for signaling. At the same time, the Open Mobile Alliance (OMA) also defines a framework called OMA BCAST Enabler, where various functions such as service guide, file distribution, streaming distribution, and service protection are defined over a bearer-independent system (e.g., DVB-H or MBMS). However, regardless of OMA BCAST Enabler, IPDC, and so on, convergence is still in the service network part, separate from the radio network part. If a broadband wireless access network and a broadcast network can be converged in a unified radio network, many additional benefits can be obtained. In other words, it is natural to design over the same air interface, to share the same frequency band, and at the same time to obtain the same high spectrum efficiency as the separate broadcast networks. In summary, a unified radio network has the following advantages:

- Since they are in the same radio network, the broadcast part naturally has the reverse link from the broadband wireless access part.
- The broadcast part has the same high spectrum efficiency as the separate network such as DVB-H or T-DMB, thus leaving more scare spectrum to the broadband wireless access part.
- Since both broadcast and wireless access share the same spectrum, the spectrum can be dynamically assigned to achieve higher spectrum utilization.
- Operation is simple since no coordination between different carriers is needed.
- Due to flexible spectrum sharing, the unified radio network can easily be a full broadcasting network or a full broadband wireless access network according to carrier requirements.

In this article we propose a unified radio network architecture named broadband wireless multimedia (BWM), which integrates broadcasting service and broadband wireless access service at both the application and physical layers. A simple, flexible, and comprehensive radio resource management (RRM) framework is developed for the unified radio network. The new architecture is currently being considered in China for the system level design. The rest of the article is organized as follows. We introduce the BWM architecture. We also describe the RRM. Finally, we conclude the research work.

Network Architecture

BWM is an all-IP network, and a unified radio network supporting integrated broadcasting and communications services. The former provides broadcast services very similar to those of T-DMB, DVB-H, and so on; the latter supports traditional data services, such as VoIP, FTP, HTTP, and cell-specific broadcast or multicast services. Moreover, with the radio convergence of these two services, other new services can be provided, such as viewers voting for the best goalkeeper when watching a football game.

In the BWM, the convergence architecture basically has two different modes: broadcasting base station (BS) + cellular BS mode (B-C mode) and cellular BS only mode (C mode). By considering the different requirements, operators can choose different modes for the radio convergence network. Both can well support high-spectrum-efficiency broadcasting and data communications. Due to the different architecture of these two modes, convergence is different at the physical layer. For B-C mode, convergence is via time-division multiplexing (TDM) to share the spectrum between broadcast and data access; while in C mode, both TDM and frequency-division multiplexing (FDM) can be used. The broadcast data and broadband wireless access data jointly form a superframe, described in detail later. In the following, we first present the architecture and then the superframe design.

In the BWM, the convergence architecture has two different modes: broadcasting base station (BS) + cellular BS mode (B-C mode) and cellular BS only mode (C mode). By considering the different requirements, the operators can choose different modes for the radio convergence network.

Overview of the Unified Radio Network Architecture

Figure 1a shows the proposed architecture of BWM including the core network and access network. Two modes, B-C mode (only for TDM) and C mode (for TDM and FDM), are supported in the BWM. The main difference between

Due to the large transmission power, only a few BBSs are needed and they constitute a single frequency network, while the CBSs are set up as the traditional cellular network, and are responsible for the data communication and the reverse link signaling for the broadcasting services.

the two modes is in the access network, which is shown in Fig. 1b.

In Fig. 1a, an IP-based network constitutes the core network of BWM; that is, all packets, including the broadcast data from the broadcast content server (BCS) and the broadband wireless access data are transmitted based on IP in the core network. The broadcast router manager (BRM) is responsible for distributing the broadcast data from different content providers to right service regions. Furthermore, due to the delay-constrained characteristic of most broadcast services, several BRMs may be located in the core network to optimize the route of the broadcast data. Another important management entity in the core network is the radio scheduling center (RSC), which is responsible for resource allocation for the broadcast services and data communication. In each superframe, broadcast and communications data packets coexist, and the portion of each part is determined by the RSC. Once a broadcast service is added or removed to/from the unified radio network, configuration only needs to be performed in the RSC and then reported to all BSs, which makes RRM of the whole system very convenient and flexible. In addition, Dynamic Host Configuration Protocol (DHCP), Domain Name Service (DNS), and AAA, which are needed for the management of the terminals, can be located all together in one network management server (NMS) or in different servers. Due to space limits, only the architecture of the B-C mode is shown in Fig. 1a, where broadcasting BSs (BBSs) and cellular BSs (CBSs) are connected to the core network through a broadcasting gateway (B-GW) and a broadband wireless access gateway (BWA-GW), respectively. The B-GW is mainly for resource management of BBSs; the BWA-GW completes the management of mobility, radio resources for data communication, and so forth. For C mode, the BBS and the corresponding B-GW in Fig. 1a will be removed.

In Fig. 1b, for B-C mode, the broadcast and data services are transmitted by BBSs and CBSs, respectively, through TDM. Therefore, terminals in this mode should receive broadcast and broadband wireless access services from different BSs in different time slots. Due to the large transmission power, only a few BBSs are needed, and they constitute a single frequency network (SFN); the CBSs are set up as a traditional cellular network, and are responsible for data communication and reverse link signaling for the broadcasting services. In Fig. 1 (b.1), assuming the CBSs utilize a frequency reuse factor (FRF) of 7, the whole system bandwidth is $f(f = \Sigma_{i=0}^{6} f_i)$. Then TDM for each superframe is as follows. First, all the BBSs transmit the same content in the whole spectrum, f, for some duration simultaneously, then stop the transmissions (denoted $t_{f+silence}$); correspondingly, the $CBS_i(i = 0, \ldots, 6)$ keeps silent for a while first and then transmits in f_i (denoted $silence+tf_i$). Obviously, in B-C mode, the broadcast part is very similar to current independent broadcast systems such as DVB-H, where the SFN is used to achieve high broadcast spectrum efficiency. In C mode, only CBSs are active, therefore, both the broadcasting and communications data are transmitted by them through TDM or FDM scheme, which are shown in Fig. 1 (b.2) and (b.3), respectively. For TDM in Fig. 1 (b.2), all CBSs in the network transmit the same broadcasting content using the entire system bandwidth, $f(f = \Sigma_{i=0}^{6} f_i)$ for some duration simultaneously, and then perform normal data communications in each $f_i(i = 0, \cdots, 6)$. For FDM in Fig. 1 (b.3), all CBSs simultaneously transmit broadcast and communications packets. The total system bandwidth is $f_b + \Sigma_{i=0}^{6} f_i$. For each CBS, f_b+f_i $(i = 0, \cdots, 6)$ means f_b is used for broadcasting services in the whole time domain, while f_i is used for communications services. In other words, all CBSs in the network transmit the same broadcasting packets simultaneously through the same partial spectrum f_b, and the normal communications through frequency reuse factor of 7 within the rest spectrum. Apparently, in C mode, whether using TDM or FDM for the broadcast service, an SFN is formed which results in the same high broadcasting spectrum efficiency as the independent broadcasting network. In addition, in Fig. 1b, we assume all CBSs transmit the data communication with a reuse factor of 7; however, by using the techniques of intercell interference (ICI) coordination/randomization/cancellation [7], the reuse factor among CBSs could reach 1, which could improve the spectrum efficiency of data communications greatly in BWM.

To compare the B-C mode and C mode, we have the following observations:

For B-C mode:

- Only a few broadcast towers are needed to cover the whole city; thus, only a few pieces of network equipment are needed.
- It can easily switch to a pure broadcast or pure broadband wireless access network based on the operator's requirement.
- Two sets of BSs are required, one for broadcast and one for broadband wireless access.

For C mode:

- Only one set of BSs is needed for broadcast and broadband wireless access.
- Since the broadcast data should be delivered to each cellular BS, much more broadcast equipment, such as edge routers and servers, is needed. In addition, it may also degrade to a pure broadcast or broadband wireless network.

SUPERFRAME DESIGN

The design of the superframe structure is of paramount importance to the performance of the BWM network. Since broadcast and communications services coexist, a long superframe may affect link adaptation algorithm (e.g., adaptive modulation and control, AMC, or power control) design due to very long mutation. At the same time, a short superframe may cause relatively large overhead due to the header and guard time (discussed later). With respect to the ratio of the broadcast and communications in each superframe, the system bandwidth should be taken into account. In addition, power consumption in the terminal is one of the most crucial factors, in particular for terminal receive-only video broadcasting. Thus, the frame design should take power consumption into con-

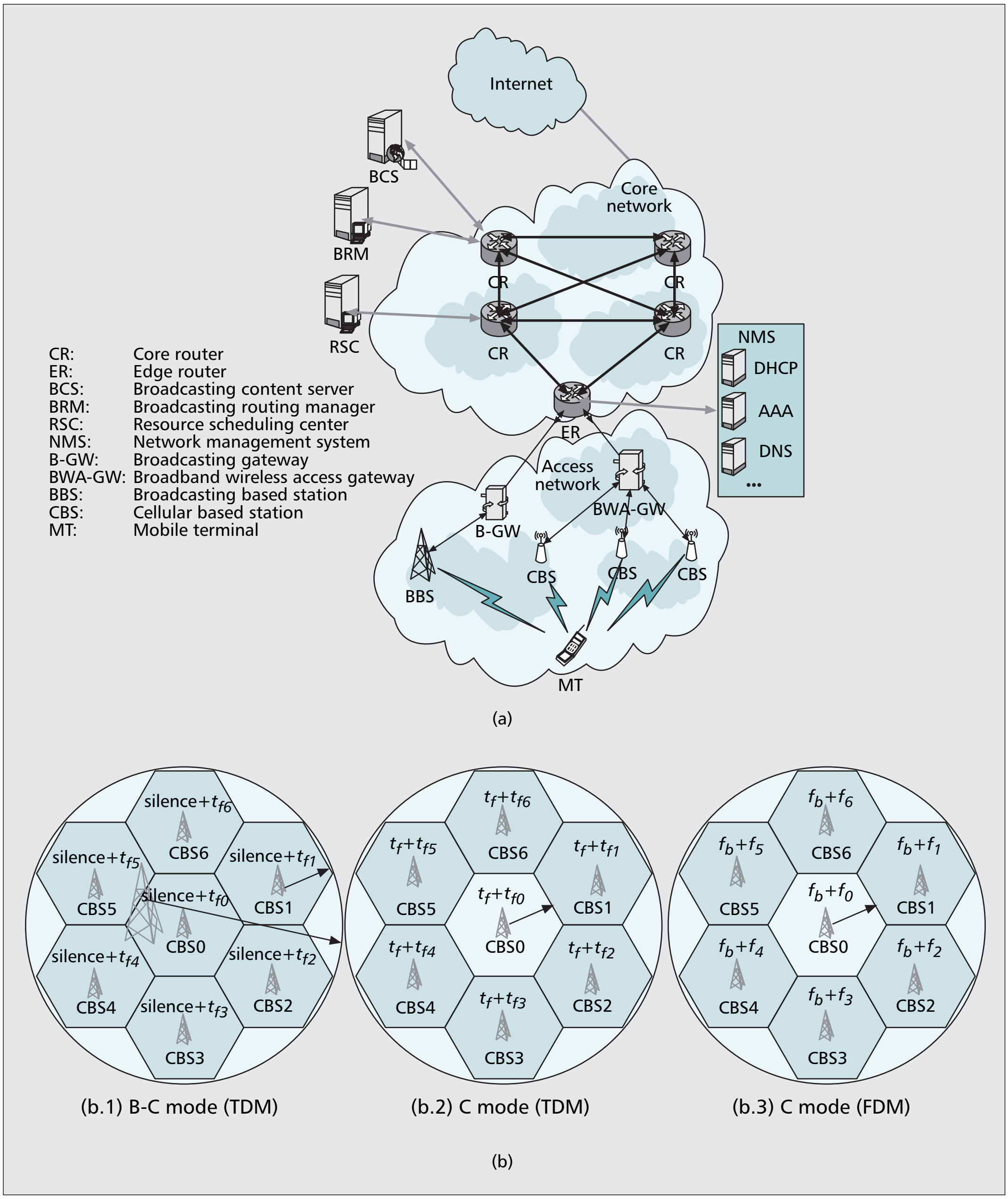


Figure 1. *The architecture of the BWM system: a) overall architecture; b) networking architecture of the access network.*

The design of the superframe structure is of paramount importance to the performance of BWM network. Since broadcasting and communications services coexist, long length of the superframe may affect the link adaptation algorithm design due to very long mutation.

sideration. Consequently, a three-level frame structure is proposed in the BWM network. The first frame level is classified into a broadcast frame (B-frame) for broadcast services and a data frame (D-frame) for communications services. The second frame level is a superframe consisting of several B-frames and D-frames. Usually, only a small part of one superframe is used for broadcast services, and the rest is for data communications and reverse link transmission of broadcast services. The portion of broadcast and communications can be changed dynamically to fully utilize the scarce spectrum, as we describe in detail next. The third frame level is the superframe group, which includes several superframes in the time domain, and all broadcast channels are serviced at least once in one superframe group; then another superframe group follows. In the following, we describe TDM and FDM superframe structures, respectively.

TDM — Figure 2a shows the superframe structure in B-C or C mode of a TDM scheme. n superframes constitute one superframe group. For simplicity, we assume each broadcast channel is transmitted once during one superframe group to reduce the terminal wakeup time. The portion of the broadcast service can be changed dynamically to meet the different video channel bandwidth requirements. For instance, suppose 10 video channels are designed for the system. Initially, the operator may only use six channels; thus, the other four B-frame time slots in the superframe group could be occupied by the D-frames. From the viewpoint of the superframe

The D-frames in each superframe are used for the broadband wireless access services, which has the similar function as the traditional broadband wireless access system. That is, any technology in current wireless communications network can be used in this time slot.

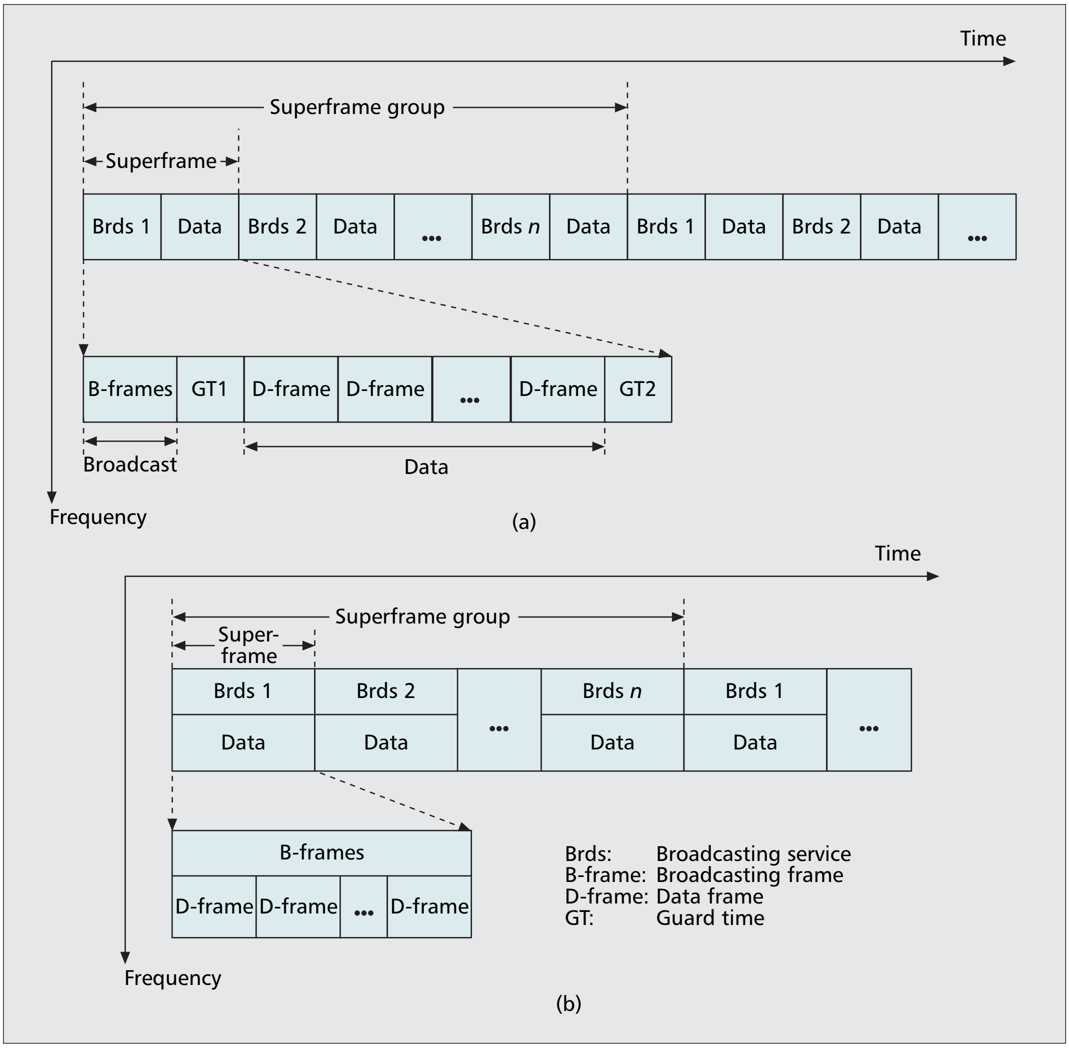


Figure 2. *Superframe structure of a) TDM; b) FDM.*

group, transmission of the video broadcast has a similar time-slicing pattern to that of DVB-H. As a result, any terminal, after obtaining one broadcast channel, could sleep for the duration of one superframe group to save battery power as long as no communications data are needed. Each superframe may include multiple B-frames and D-frames. In a B-frame for one broadcasting channel, the next time indicator for obtaining this channel should be included. The D-frames in each superframe are used for broadband wireless access services, which has a similar function to the traditional broadband wireless access system. That is, any technology in current wireless communications network can be used in this time slot, such as time-/frequency-division duplex (TDD/FDD) or time-/orthogonal frequency-division multiple access (TDMA/OFDMA).

The frame structure of TDM mode could be used for B-C mode and C mode. For B-C mode, the BBSs are used to transmit the same broadcast data simultaneously, while the CBSs service the terminals in each cell. Since the broadcast data and wireless access data are transmitted by BBSs and CBSs separately, guard times (e.g., GT1 and GT2) in each superframe, as shown in Fig. 2a, are necessary to ensure synchronization between terminals and BBSs/CBSs. Usually, GT1 is larger than GT2. For GT1, the terminals switch from BBSs to CBSs. Because the largest distance from the terminals to the BBSs is usually tens of kilometers, GT1 should be long enough to address this issue. For GT2, the terminals switch from CBSs to BBSs. Since the coverage of the CBSs is usually only a few kilometers, GT2 is relatively smaller than GT1. In the BWM system, GT1 is defined to be around 50–100 μs, satisfying the large coverage range of BBS (15–30 km) and other parameter adjustments; GT2 is set to be around 5–10 μs. At the same time, due to the overhead caused by GT1 and GT2, it is preferred to have only one D-frame and B-frame time slot in each superframe. For C mode, there is no essential change in the superframe structure. The only difference is that GT1 and GT2 are very small since the terminal does not need to switch the BS.

FDM — Figure 2b shows the superframe structure in FDM mode, which is only supported in C mode because in B-C mode, the higher transmitting power of BBSs can capture that of CBSs in FDM mode. In each superframe, some frequency resources are used for transmission of broadcast services and the rest for broadband wireless access services. For the access service, it is compatible with current wireless communications systems, and many multiple access technologies (e.g., TDD or FDD) are applicable. Similar to TDM, during one superframe group in FDM, all supported broadcast channels should be serviced at least once. The radio resources reserved for broadcast can also be used by broadband wireless access if necessary.

Flexibility in Superframe Design — The superframe structure provides the flexibility to improve spectrum efficiency and utilization. First, under the constraint of the maximum duration for broadcasting services due to the communications link adaptive algorithms in the physical layer, the B-frame could be allocated flexible resources to satisfy:
- The TV channel bandwidth
- Different link adaptation technologies in the physical layer

Therefore, different operators can set different resource allocations. Second, to address the different bandwidth requirements of various broadcast services, splitting and multiplexing of broadcast services could be performed in the B-frame. For instance, newspaper broadcast takes up very little resources, so several newspaper broadcast services could be multiplexed in one B-frame in the superframe group, while for some high-quality video services, the higher bandwidth requirements may require two or more B-frames in a superframe group. Third, when fewer broadcast channels are supported in the BWM network at the initial stage, several B-frames in one superframe group could be substituted by D-frames. Note that these benefits mainly come from convergence in the radio access network instead of at a higher layer. These flexibilities could improve spectrum efficiency significantly, and the configuration to implement this can be performed by an RSC once every two or three months when the TV channel changes.

Superframe Design — In this subsection we use an example to illustrate superframe design in TDM mode; for FDM mode, a similar approach could be applied. We assume each superframe includes one broadcasting channel. As a result, the length of the superframe group is mainly determined by the bandwidth requirements of the supported broadcast services, which can be denoted by the following inequality:

$$\frac{T_{bcst} \cdot t_{bcst}}{t_{SFG}} \geq V_B, \quad (1)$$

where T_{bcst} and t_{bcst} are the downlink throughput and time duration of the broadcast part in the superframe, respectively. V_B, expressed in kilobits per second, is the bandwidth requirement of each broadcasting service. t_{SFG} is the time duration of the superframe group, which could be calculated by

$$t_{SFG} = N(t_{bcst} + t_{data} + GT1 + GT2), \quad (2)$$

where N is the number of superframes in the superframe group; in other words, N broadcasting channels are included in the system. t_{data}, $GT1$, and $GT2$ are the time duration of the data communication part and guard times, as in Fig. 2a, respectively.

System BW (MHz)	T_{bcst} (Mb/s)	t_{bcst} (ms)	T_{data} (Mb/s)	t_{data} (ms)	N	t_{SF} (ms)
1.25	2	3	1	11.89	2	15
	2	4	1	5.89	4	10
5	10	4	5	15.89	10	20
	10	4.5	5	10.39	15	15
10	20	5	10	19.89	20	25
	20	5	10	14.89	25	20

Table 1. *Results of frame design.*

In the superframe, for the broadcasting part, the modulation and coding rate scheme are 16-quadrature amplitude modulation (QAM) and 3/4, respectively; for the data part, due to AMC technology in the physical layer, we assume the average throughput is equivalent to that achieved by the modulation and coding rate scheme with quaternary phase shift keying (QPSK) and 3/4. V_B, which is a mobile TV channel bandwidth, is 200 kb/s, Table 1 gives some results on frame design with different system bandwidths.

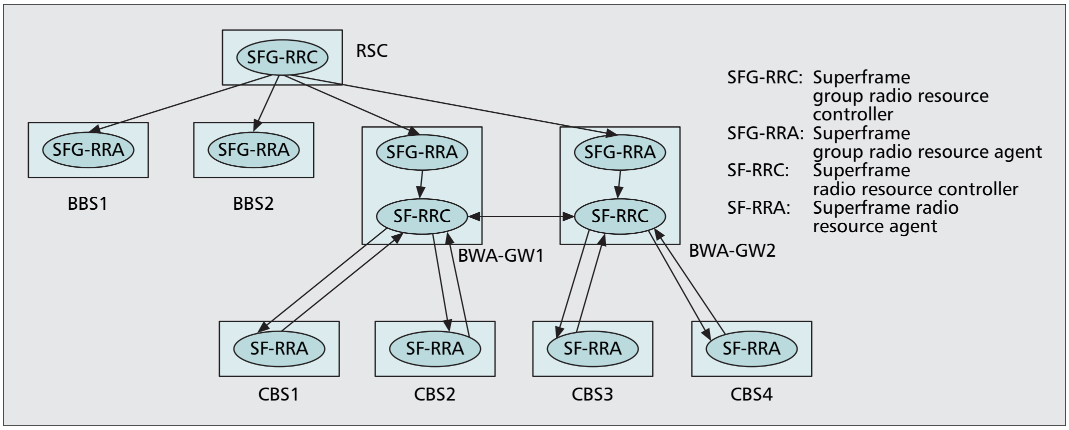
In Table 1, T_{data} is the throughput of the data part in the superframe, and t_{SF} is the duration of the superframe. The interpretation of the table is as follows. In the last line, assume an operator obtains 10 MHz spectrum. If it uses 20 percent of the resource (a 5 ms broadcasting slot out of 25 ms superframe length), the operator can support 20 TV channels, each at a rate of 200 kb/s; meanwhile, if it uses 25 percent (5 of 20 ms) of the resource, the operator can support 25 TV channels. Thus, once the broadcast part throughput is given,depending on the obtained spectrum, physical/medium access conrol (PHY/MAC) technology, and so forth, the broadcast slot length, superframe length, and TV channel number depend on each other. The operator can flexibly choose the parameters to meet its requirement.

Radio Resource Management

To develop a simple, flexible, and comprehensive RRM framework is one of the most important tasks in such a unified radio network. In BWM, considering the integration of the broadcasting and wireless access services, a two-level RRM framework is proposed. Due to space limitations, in Fig. 3 only the framework in B-C mode is shown.

Four entities, SFG-RRC, SFG-RRA, SF-RRC, and SF-RRA, constitute the RRM framework in BWM. SFG-RRC and SFG-RRA, as the first level of RRM, manage resource allocation in a superframe group. Specifically, SFG-RRC, located in RSC, performs configuration of the resource allocation of the broadcast and

The natural coexistence of broadcasting and broadband wireless access in the same radio network enables many new applications. For future work, more details such as the converged MAC and physical layer technology, superframe header, signaling, synchronization, etc., will be presented.



■ **Figure 3.** *RRM framework for B-C mode.*

communications services in the superframe group, and then sends the superframe group indicators including the structure information of the superframe group to SFG-RRAs residing in BBSs and the BWA-GW. SF-RRC and SF-RRA, as the second level of RRM, are responsible for not only the transmission and processing of the superframe group indicators but also the resource management for data services in each cell, which is similar to that of current broadband wireless access networks such as WiMax [8]. They may be collocated in the same CBS or reside separately in a BWA-GW and a CBS. SF-RRC receives the superframe group indicators from SFG-RRA through the proprietary interface when located in a BWA-GW or through a standard interface when residing in a CBS and then sends it to SF-RRA. Also, SF-RRC exchanges the data radio resource indicators with SF-RRA located in a CBS. SF-RRA collects radio resource information, such as the neighbor BSs and the interference in each channel, from the population of terminals registered to it, and then allocates the resource in the D-frames to each terminal. In addition, the information collected from terminals is reported to SF-RRC through data radio resource indicators. In SF-RRC, a database of radio resources is maintained for optimizing resource allocation. Furthermore, an SF-RRC may communicate with other SF-RRCs through the standard interface to coordinate with other cells. Similar to B-C mode, the RRM framework for C mode can be obtained by removing the BBSs in Fig. 3.

Conclusions

In this article an architecture for access network convergence supporting both broadcast and broadband wireless access services has been presented. The convergence includes B-C mode for TDM, and C mode for TDM and FDM. In addition, RRM has also been discussed. The natural coexistence of broadcast and broadband wireless access in the same radio network enables many new applications. For future work, more details such as the converged MAC and physical layer technology, superframe header, signaling, and synchronization will be presented.

References

[1] H. Ekström et al., "Technical Solutions for the 3G Long-Term Evolution," *IEEE Commun. Mag.*, vol 44, no. 3, Mar. 2006, pp. 38–45.
[2] C. Eklund et al., "IEEE Standard 802.16: A Technical Overview of the WirelessMAN™ Air Interface for Broadband Wireless Access," *IEEE Commun. Mag.*, vol. 40, no. 6, June 2002, pp. 98–107.
[3] S. Lee et al., "The Wireless Broadband (WiBro) System for Broadband Wireless Internet Services," *IEEE Commun. Mag.*, vol. 44, no 7, July 2006, pp. 106–12.
[4] S. Parkvall et al., "Evolving 3G Mobile Systems: Broadband and Broadcast Services in WCDMA," *IEEE Commun. Mag.*, vol. 44, no. 2, Feb. 2006, pp. 30–36.
[5] ETSI, "Digital Video Broadcasting (DVB): DVB-H implementation guidelines," doc. TR 102 377, Feb. 2005.
[6] ETSI, "Digital Audio Broadcasting (DAB); DMB Video Service; User Application Specification," doc. TS 102 428 V1.1.1, June 2005.
[7] 3GPP 25.814, "Evolved UTRA Physical Layer Aspects," 2005.
[8] "WiMAX End-to-End Network Systems Architecture-Stage 2: Architecture Tenets, Reference Model and Reference Points," WiMAX Forum, Dec. 2005.

Biographies

Weiwei Wang (comeonwww1981@yahoo.com.cn) received a B.S. degree in communication engineering from Beijing Jiaotong University, China, in 2003 and is working toward his Ph.D. in the field of future wireless communications at the same university. His research interests includes WiMax, B3G, and 4G.

Yunbao Zeng (zengyb@lenovo.com) received B.S and M.S degrees from Harbin University of Science and Technology, China, in 2000 and 2003, respectively, and the Ph.D. degree from Beijing University of Posts and Telecommunications (BUPT). He is now with Lenovo Corporate Research, Beijing. His research interests include TDS-CDMA, B3G, and 4G.

Zihua Guo (guozh@lenovo.com) received B.S and M.S degrees from the University of Science and Technology, Beijing, China, in 1995 and 1998, respectively. He received a Ph.D. degree from the Hong Kong University of Science and Technology in 2001. His research interests include wireless communications and networking, 3G and beyond technologies, multimedia communications, and signal processing. He is now with Lenovo Corporate Research, Beijing.

Wenchao Ma [S'99, M'04] (mawc@lenovo.com) received his B.S. and M.S. degrees from BUPT in 1995 and 1998, respectively, and a Ph.D. degree from the University of Florida, Gainesville, in 2003. From 1998 to 1999 he was an engineer with China Telecom. From 1999 to 2000 he was with the Electrical and Computer Engineering Department, New Jersey Institute of Technology, Newark. He also worked with Microsoft Research Asia before 2005 as an associate researcher and currently works with Lenovo Corporate Research & Development as a senior researcher. His research interests include wireless multimedia networks,

mobility management, mobile computing, mobile IP, P2P technology, and broadband wireless access.

XUEMIN SHEN [M'97, SM'02] (xshen@bbcr.uwaterloo.ca) received a B.Sc.(1982) degree from Dalian Maritime University, China, and M.Sc. (1987) and Ph.D. (1990) degrees from Rutgers University, New Jersey, all in electrical engineering. He is a professor and university research chair, and associate chair for graduate studies, Department of Electrical and Computer Engineering, University of Waterloo, Canada. His research focuses on mobility and resource management in interconnected wireless/wired networks, UWB wireless communications systems, wireless security, and ad hoc and sensor networks. He is a co-author of three books, and has published more than 300 papers and book chapters in wireless communications and networks, control, and filtering. He serves as Technical Program Committee Chair for IEEE GLOBECOM '07, General Co-Chair for Chinacom '07 and QShine '06, and Founding Chair of IEEE Communications Society Technical Committee on P2P Communications and Networking. He also serves as a Founding Area Editor for *IEEE Transactions on Wireless Communications*; Editor-in-Chief for *Peer-to-Peer Networking and Application*; Associate Editor for *IEEE Transactions on Vehicular Technology*; *KICS/IEEE Journal of Communications and Networks*, Computer Networks; *ACM Wireless Networks*; and *Wireless Communications and Mobile Computing* (Wiley), among others. He has also served as Guest Editor for *IEEE JSAC*, *IEEE Wireless Communications*, and *IEEE Communications Magazine*. He received an Excellent Graduate Supervision Award in 2006 and an Outstanding Performance Award in 2004 from the University of Waterloo, the Premier's Research Excellence Award (PREA) in 2003 from the Province of Ontario, Canada, and a Distinguished Performance Award in 2002 from the Faculty of Engineering, University of Waterloo. He is a registered Professional Engineer of Ontario, Canada.

CHANGJIA CHEN (chenchangjia@sina.com.cn) received a B.S degree from Harbin Engineering University in 1975, an M.S degree from Institute of Electronics, Chinese Academy of Sciences in 1981, and a Ph.D. degree from the University of Hawaii in 1986. He is a professor at the School of Electronics and Information Engineering, Beijing Jiaotong University. His research focuses on P2P networks, network measurements, and broadband access networks.