Technology for WiFi/Bluetooth and WiMAX Coexistence

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Mobile Worldwide Interoperability for Microwave Access (Mobile WiMAX) is useful as next-generation wireless broadband access technology based on OFDMA. For it to proliferate, the radio interference between WiMAX, which is operated on the 2.3 GHz and 2.5 GHz bands, and WiFi/Bluetooth, which is located on the Industrial Scientific and Medical (ISM) band (2.4 GHz), needs to be resolved. Fujitsu has developed some proprietary coexistence technology as an effective way to do this, until a countermeasure of enhancing the IEEE specification is deployed in a few years. Our developed coexistence technology does not require any modifications to be made to the current specifications for backward compatibility. It works by using automatic repeat requests (ARQ). There were concerns about the technology's adverse effect on system throughput, but no such effect was observed when operating at 75% of system capacity or less. We evaluated this in a simulation. This paper describes the issues regarding WiFi/Bluetooth and WiMAX coexistence, and Fujitsu's proprietary coexistence technology.

1. Introduction

Along with the recent proliferation of systems such as cell phones (cellular system) and wireless LAN, there has been growing demand for broadband connection by wireless means. As a next-generation wireless broadband technology to address this need, Mobile WiMAX (Worldwide Interoperability for Microwave Access) is attracting attention. Mobile WiMAX is a system based on the Orthogonal Frequency Division Multiple Access (OFDMA) method, and it has already been standardized as IEEE 802.16e.[1),2)] Its specifications have been globally stipulated as the sixth air interface of the 3G mobile telecommunications system (IMT-2000). The system currently covers a wide range of frequency bands from the 2 GHz band to the 3.8 GHz band and its high capabilities have opened up a way for its potential application to an even wider range of frequency bands.

The commercial operation of Mobile WiMAX was started in September 2008 in the U.S., ahead of other countries, and began in Japan in February 2009. The service is operated on the 2.5 GHz band in the two countries and the bandwidth is 10 MHz. Licensed bands are used to operate WiMAX in both cases and planar deployment of base stations is planned as with cellular networks. However, the 2.5 GHz band assigned for Mobile WiMAX is adjacent to the Industrial Scientific and Medical (ISM) band (2.4 GHz), and an adverse effect due to mutual interference between the two systems has been a concern from the beginning.

To resolve this problem, the WiMAX Forum, an industry-led organization that formulates the system's operation specifications, has been discussing whether to add a mechanism to the IEEE Standards[3)] to ensure coexistence between WiMAX and ISM band communication systems.

However, the standardization and revision process has been delayed and the first base station capable of this function will likely appear in the second half of 2010 at the earliest. In addition, base stations with the system coexistence function implemented do not have guaranteed compatibility with the existing base stations and the base stations currently in operation will need to be replaced, which is hindering the proliferation of WiMAX technology. At least for a few years after the service launch, the difficulty of coexistence with the ISM band communication systems, especially with WiFi and Bluetooth that have already been widely applied to consumer products, is expected to be a major problem.

This paper describes Fujitsu's proprietary system coexistence technology to achieve coexistence between ISM band communication systems, especially WiFi and Bluetooth, and WiMAX without the need for modifying the existing specifications so as to fill the gap in service provision due to the difficulty of system coexistence.

2. WiFi/Bluetooth and WiMAX radio interference issue

The operational frequency band for Mobile WiMAX is divided into several frequency bands. **Table 1** shows the Band Class defined by the WiMAX Forum. Among these classes, Band Class 2 (2.3 GHz band) and Band Class 3 (2.5 GHz band) are adjacent to (partially overlap) WiFi (IEEE 802.11b/g) and Bluetooth (IEEE 802.15.1) which operate on the 2.4 GHz band, and this causes mutual radio interference.

Using band-limiting filters is one way to suppress the interference between these systems. However, sufficient frequency intervals required for filtering cannot be ensured between the WiFi and WiMAX systems and the Bluetooth and WiMAX systems, and interference is extremely difficult to suppress.

Table 1
WiMAX/ISM band communication system operational frequency band.

Band Class Index	Frequency band (GHz)	Bandwidth (MHz)
1	2.3–2.4	8.75, 5, 10
2	2.305–2.320, 2.345–2.360	3.5, 5, 10
3	2.496–2.69	5, 10
4	3.3–3.4	5, 7, 10
5	3.4–3.8, 3.4–3.6, 3.6–3.8	5, 7, 10
WiFi (IEEE 802.11b/g)	2.4–2.497	26
Bluetooth (IEEE 802.15.1)	2.402–2.480	1

3. Examples of system coexistence

Inter-system radio interference is likely to cause a problem in applications such as those shown in **Figure 1**.

1) Voice (VoIP) service using Bluetooth headsets [Figure 1 (a)]

VoIP is an important application for realizing voice communication in Mobile WiMAX that provides packet services, and it can be assumed that existing cell phones have achieved VoIP applications using Bluetooth. However, Mobile WiMAX and Bluetooth use adjacent frequency bands, which means some measures are required to suppress interference. The existing specifications do not assume the need to avoid interference between the Bluetooth and WiMAX systems and their simultaneous use in the present conditions is difficult.

2) WiFi-WiMAX seamless handover [Figure 1 (b)]

With Mobile WiMAX, video streaming that takes advantage of Mobile WiMAX's high transmission rate is also likely to prove a useful application. Meanwhile, WiFi is widespread as an indoor communication system, and it can be used for providing a cost-free broadband environment via an access point located at the user's home.

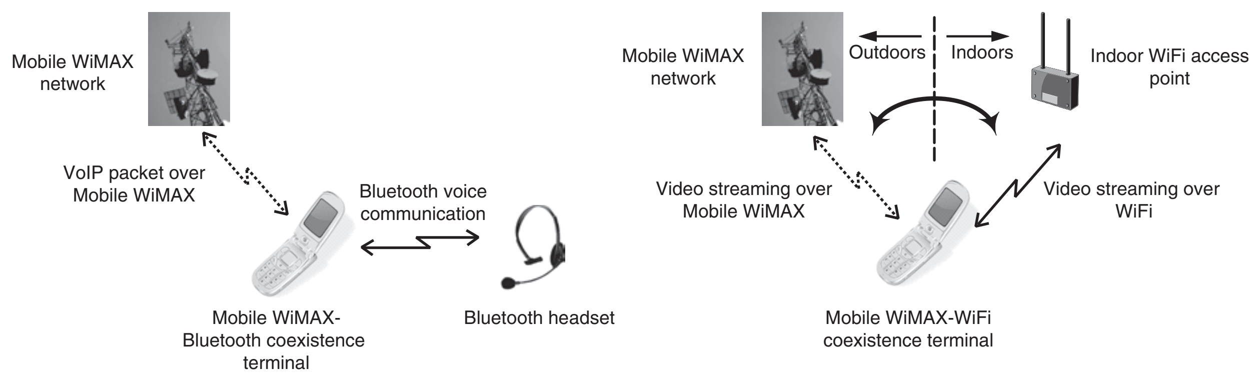
Using WiFi to seamlessly maintain a video streaming session that has been started outdoors by using Mobile WiMAX indoors essentially requires a seamless handover between the systems. As with the previous case, however, the two systems use neighboring operational frequency bands and simultaneous operation to achieve a handover is extremely difficult because of the interference factor.

4. Enhancement of standard

The system coexistence method discussed by the WiMAX Forum prevents radio interference by controlling the coexisting multiple communication systems by applying time-division multiplexing (TDM) as shown in **Figure 2**.

The system coexistence terminal and Mobile WiMAX base station (BS) deliberately stop the operation of the Mobile WiMAX mobile station (MS) on the terminal, by exchanging TDM control frame information called Bit Map. One bit of the Bit Map corresponds to a subframe of the Down Link (DL) and Up Link (UL) of Mobile WiMAX frames and the Mobile WiMAX system (BS/MS) functions when Bit = '1'.

The TDM control frames create intermittent stop states of the Mobile WiMAX and, during



(a) Voice (VoIP) service using Bluetooth headset

(b) WiFi-WiMAX seamless handover

Figure 1
Use cases of system coexistence.

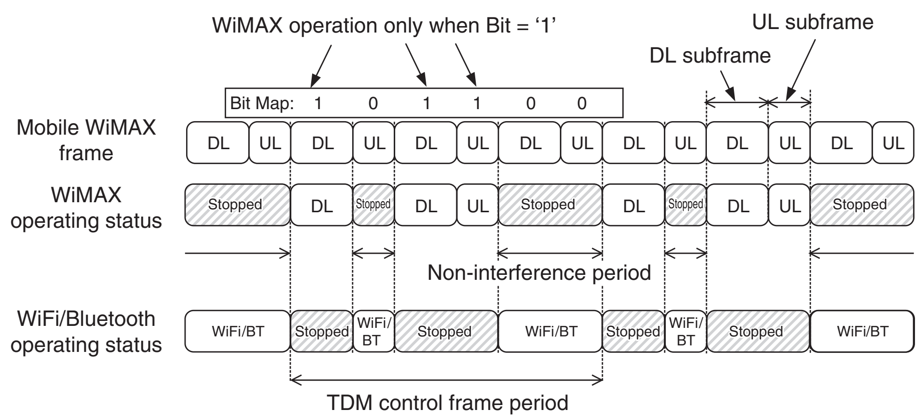


Figure 2
IEEE 802.16e Rev.2 coexistence specification.

these stop periods without interference, WiFi/Bluetooth communication takes place. Conversely, WiFi/Bluetooth transmission is stopped during the Mobile WiMAX operation periods. The TDM control frame period depends on the required throughput for the respective application.

TDM control by standardization, which is an operation coordinated by the system and which means that BS can recognize the system coexistence terminal in advance, can be said to be the most effective coexistence technology since it does not influence frequency resources. However, to use this method the existing BS needs to be replaced or revised and there is a major problem in terms of compatibility due to the system's lack of operability with the existing system.

5. Fujitsu's proprietary system coexistence method

To fill the gap in service provision due to the difficulty of system coexistence, Fujitsu Laboratories has developed its own system coexistence method that can be realized without modifying the current specifications.

As with the standard enhancement measure, Fujitsu's proprietary system coexistence method prevents radio interference by TDM control, which is shown in **Figure 3**. With the proprietary system, however, exchange of TDM control frame information between the BS and MS as in the enhanced standard is not required, and TDM control is achieved only with the operation of the system coexistence terminal (MS). With Mobile WiMAX the BS handles all of the band control, and TDM control requires coordination between the BS and MS, which is achieved by exchanging TDM control frame information in the enhanced standard. The proprietary method, on the other hand, deliberately has the BS issue a repeat request to the MS to provide multiple transmit/receive opportunities. Transmit/receive takes place intermittently, which frees the remaining periods for use by other systems, thereby applying TDM control. This realizes system coexistence by using repeat control, which is the existing

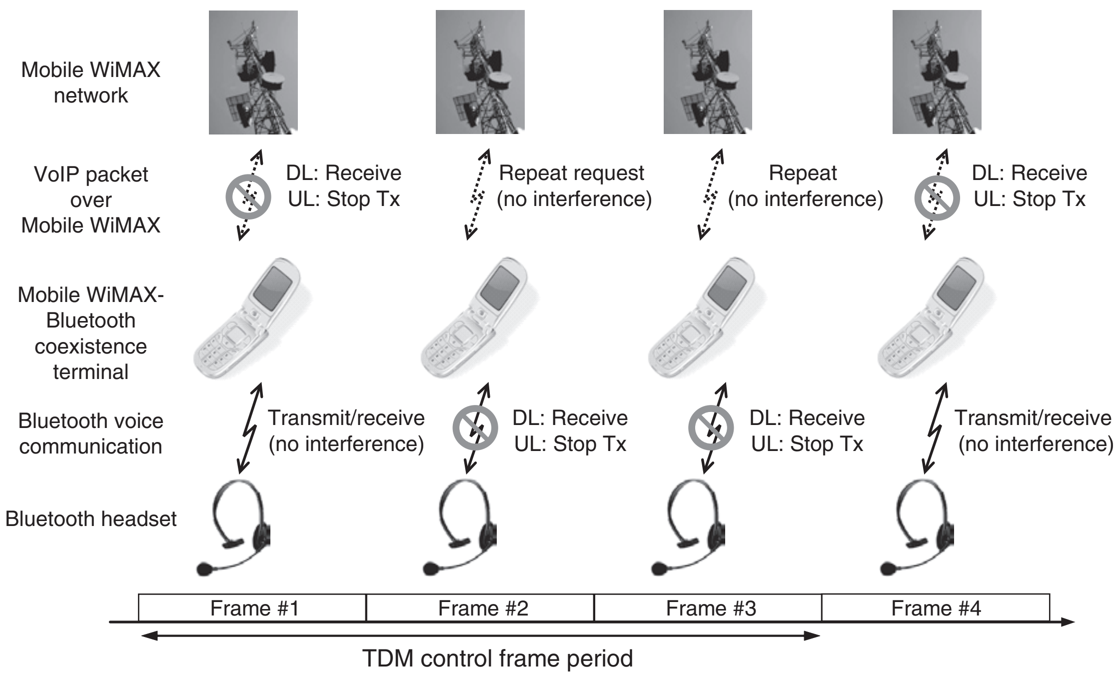


Figure 3
Fujitsu's proprietary system coexistence method.

specification, as it is.

In Frame #1, the MS autonomously stops WiMAX UL transmission, which already reserves a frequency band between the BS and MS, and this frame, a non-interference period, is used for Bluetooth communication. The stopped UL data is handled by the BS as an ordinary lost frame in a propagation path.

In Frame #2, control to stop transmission from the MS to Bluetooth takes place and, during this non-interference period, the MS receives a repeat request for the WiMAX UL data lost in Frame #1. It transmits a repeat request for DL data in Frame #1 as required.

In Frame #3, the process of stopping Bluetooth transmission to provide non-interference periods, WiMAX UL transmit in response to the repeat request, and DL receive continues. Frames #1 to #3 constitute a TDM control frame period and this TDM control is subsequently repeated. The TDM control frame period is determined according to the throughput required of Bluetooth.

In this way, a mechanism of repeat control can be used to realize MS-led TDM control.

Table 2
Simulation parameters.

Item	Condition
No. of users	150/sector
Channel	PB3
TDM control frame period	VoIP: 5 frames Video streaming: 4 frames
WiMAX UL transmission stop period	1 frame
Placement count	1
HARQ combining	Takes place except during UL send stop periods
Symbol configuration	PUSC
DL/UL	32/15
Cell/sector	7 cells/3 sectors
Reuse factor	1
Ack delay	1
No. of ARQ channels	∞
Maximum repeat count	Unlimited
Traffic model	VoIP: VoIP (AMR CODEC) Video streaming: full buffer
Antenna configuration	SISO
Simulation period	1500 frames
LLS conditions	Channel: PB3 Antenna configuration: SISO Real Channel Estimation Instantaneous SNR based

6. Impact on WiMAX system

Unlike the standard enhancement method, with Fujitsu's proprietary system coexistence method, the MS autonomously stops UL transmission without coordination with the BS and provides TDM control. For this reason, the BS does not recognize (is not notified of) the system coexistence terminal and UL band reservation with no transmission is generated. In reality, the transmission operation is stopped in the MS and a band is reserved that is degradation in terms of system throughput, which is a disadvantage. To address this issue, we have assumed that the applications are VoIP (delay oriented) and video streaming (throughput oriented) and evaluated the system impact. For this performance evaluation we used a Wireless Link Level Simulator (LLS), which was used in the performance evaluation conducted by the WiMAX Forum, and a System Level Simulator (SLS) used in the IEEE 802.16j standardization (both were self-developed).

Table 2 shows the simulation conditions. We set the number of users at 150 (per sector), which presents the maximum throughput. As a traffic model, 12.2 kb/s AMR has been used for VoIP and full buffer for video streaming.

Table 3 shows the results of our simulation. We confirmed that the VoIP satisfies the

Table 3
SLS/LLS simulation results.

Application	% of satisfied users
VoIP (Max. allowable delay: 50 ms)	90% min.
Video streaming (Required throughput: 384 kb/s)	75% min.

specifications, namely a maximum allowable delay of 50 ms, for 90% of all users. In addition, we confirmed that video streaming is capable of providing the required throughput of 384 kb/s for 75% of all users.

The results mentioned above have revealed that a traffic load of 75% or more of the system capacity may cause an impact on a WiMAX system.

Because the average traffic load designed by operators is not 100% and there is likely to be a low load traffic at the launch of Mobile WiMAX services due to factors such as the low initial diffusion rate, we expect the suggested method will show excellent potential for realizing system coexistence with little system impact.

7. Conclusion

Simultaneous operation of WiFi/Bluetooth and WiMAX, which operate on adjacent frequency bands, in co-location or proximity may produce inter-system radio interference, which will have a considerable impact on users in terms of service provision.

To address this issue, we suggest having TDM control by system coordination that can be established when the standards are next revised. However, we expect the dissemination of TDM control will still require much more time because of the delay in the standardization activities and non-compatibility. As an effective way to fill this gap in service provision, Fujitsu Laboratories has established its own system coexistence technology capable of TDM control by MS operation alone, and applied it to a Mobile WiMAX system.

Our proprietary method is capable of achieving system coexistence while maintaining compatibility with no need to modify the existing specifications. At the same time, however, there is concern that the system throughput may be affected.

Our simulation has quantitatively demonstrated that, in high-speed real-time applications such as video streaming, a traffic load of up to 75% of the system capacity causes no impact. We plan to conduct further effectiveness verification in the future including throughput evaluation in the field by using actual equipment.

References

1) IEEE Standard 802.16-2004, IEEE Standard for Local and Metropolitan Area Networks—Part 16: Air Interface for Fixed Wireless Access Systems.
2) IEEE Standard 802.16e-2005, Amendment to IEEE Standard for Local and Metropolitan Area Networks—Part 16: Air Interface for Fixed Broadband Wireless Access Systems—Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands.
3) P802.16Rev2/D9 January 2009 (Revision of IEEE Std 802.16-2004 and consolidates material from IEEE Std 802.16e-2005, IEEE Std 802.16-2004/Cor1-2005, IEEE Std 802.16f-2005 and IEEE Std 802.16g-2007).

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