A New Band AMC Scheme for Military Use of Indoor Mobile WiMAX System

Woo-Chan Kim\textsuperscript{a}, Soo-Yong Jeon and Dong-Ho Cho
School of Electrical Engineering and Computer Science
Korea Advanced Institute of Science and Technology (KAIST)
E-mail: wckim@comis.kaist.ac.kr

Abstract—Indoor wireless communication systems have been developed to improve cell coverage and throughput with low cost in indoor environment. Among several indoor wireless communication systems such as Mobile WiMAX (Worldwide Interoperability for Microwave Access) system, WPAN (Wireless Personal Area Network) and WLAN (Wireless Local Area Network), the Mobile WiMAX is one of the promising next-generation wireless communication systems and considered for military use by the U.S. Army. In indoor environment, a band AMC mode which is one of subchannel allocation modes in the Mobile WiMAX system is mainly used since it is appropriate to the fixed or low mobility environments. However, the conventional band AMC mode is optimized for the outdoor environment, so it will cause many problems in the indoor environment. In this paper, we propose a new band AMC operation suited for the indoor environment. The proposed band AMC operation allocates the resource flexibly in indoor environment and it is compatible with the existing Mobile WiMAX standard. The numerical analysis and simulation results show that a channel utilization of the proposed band AMC mode is higher than that of the conventional band AMC mode.

I. INTRODUCTION

The rapidly growing demands for high data rate and multimedia have driven the great development of the wireless mobile internet access. Among many wireless internet access technologies, the IEEE 802.11a/g [1][2] for the wireless local area network (WLAN) provides very high data rate with low cost. However, internet is not accessible anywhere and anytime because the service area is limited and it does not support mobility. On the other hand, the cellular systems like CDMA2000 1X, 1X EV-DO, and WCDMA support very large coverage and mobility. But the bandwidth of these systems is not large enough to support multimedia service to all users. Furthermore, it is very expensive to transmit high volume data in these systems. For the new communication technology supporting high data rate and multimedia service, Mobile WiMAX (IEEE 802.16e) [3] is developed. The Mobile WiMAX system provides larger coverage and more robust mobility compared to the WLAN system as well as higher data rate compared to the cellular system.

The Mobile WiMAX system can be used in the military system due to its many merits. The U.S. Army’s Communications Electronics Research & Development Engineering Center (CERDEC) has been using fixed WiMAX which is based on the IEEE 802.16 [4][5] and researches mobile WiMAX for use in the military system [6][7]. The Mobile WiMAX system is superior to SWLAN (Secure Wireless Local Area Network) which is now used in the U.S. Army in view of coverage and mobility. The Mobile WiMAX standard defines five scheduling services such as Unsolicited Grant Service (UGS), Real-time Polling Service (rtPS), Extended rtPS, Non-real-time Polling Service (nrtPS) and Best effort service (BE) to support QoS (Quality of Service). These scheduling services and high capacity make the mobile multimedia services available in the Mobile WiMAX system with low cost. The Mobile WiMAX also provides robust security by using the 128-bit block-size AES (Advanced Encryption Standard) algorithm.

The Mobile WiMAX system is also suitable for the indoor environments. Although many indoor wireless communication systems such as the IEEE 802.11a/b/g, Bluetooth, IrDA, and ZigBee have been developed to improve cell coverage and throughput, these technologies are not enough efficient in view of compatibility, cost, data rate, etc. However, the indoor Mobile WiMAX system provides high data rate, large coverage and mobility with low cost in the indoor environments. It is also compatible with the outdoor Mobile WiMAX system. Therefore, the indoor Mobile WiMAX system can be used in the army barracks to increase capacity. With this enhanced capacity, QoS can be guaranteed for more users in the military system. Furthermore, users need only to have one device for communication in both indoor and outdoor environments due to the compatibility between the indoor Mobile WiMAX system and the outdoor Mobile WiMAX system, which also minimizes the power consumption.

The Mobile WiMAX system is based on OFDMA (Orthogonal Frequency Division Multiplexing Access) and TDD (Time Division Duplex) scheme at 2.3GHz. In the OFDMA, frequency bandwidth is divided into several orthogonal subcarriers which constitute subchannels and these subcarriers are shared by multiple users. There are two types of subchannel allocation modes in the Mobile WiMAX system: diversity and band AMC modes. In the diversity mode, a subchannel consists of several subcarriers randomly distributed over the entire bandwidth. Fig. 1(a) shows the composition of subchannels in the diversity mode. In this case, the channel quality of each subchannel takes the average channel quality of the entire bandwidth. Therefore, the overhead caused by channel quality reporting is very low, and this characteristic is efficient especially under the fast fading channel condition which suffers in every frame from channel variation. On the other hand, a
subchannel consists of adjacent subcarriers in the band AMC mode. Fig. 1(b) shows the composition of subchannels in the band AMC mode. In this case, the total system throughput can be increased since each user selects only good subchannels. However, the overhead caused by channel quality reporting is larger compared to that of the diversity mode since each SS (Subscribe Station) must report the channel qualities of each subchannel. Therefore, the band AMC mode is appropriate to a fixed or low mobility environment, not incurring too much overhead caused by channel quality reporting.

The band AMC mode can be operated efficiently in the indoor Mobile WiMAX system since the channel quality is stable and users are moving slowly in that case. However, the preferred bands of the SSs are similar since almost SSs will be operated in the band AMC mode due to the channel characteristic of the indoor environments [8][9]. This similarity of preferred bands of the SSs leads to poor channel utilization and long delay for channel allocation. To solve this problem, we propose a flexible band AMC allocation scheme. Our proposed band AMC scheme enhances the channel utilization and it is compatible with the conventional band AMC mode.

The rest of this paper is organized as follows. Section II describes the conventional band AMC operation of Mobile WiMAX system and section III describes the proposed band AMC operation and the compatibility with the existing Mobile WiMAX system. Section IV analyzes the performance of the proposed band AMC operation and section V compares the performance of the proposed band AMC operation with that of the conventional band AMC operation. Finally, last section concludes this paper.

II. EXISTING BAND AMC OPERATION

In the Mobile WiMAX system, it is necessary to report the channel quality of an SS to a BS (Base Station) and this reporting procedure is conducted by a CQICH (Channel Quality Indicator CHannel). That is, the BS allocates the CQICH to the SS, and the SS transmits its own channel quality to the BS through the CQICH. There are three CQICH codewords: C1(0b111101), C2(0b111110) and C3(0b111111). Theses codewords are transmitted from the SS to the BS and indicates the transmission between the diversity mode and the band AMC mode. First, the C1 codeword is used for the transition from the diversity mode to the band AMC mode. Second, the C2 codeword is transmitted to confirm the transmission of the bitmap information about the five best bands. Finally, the C3 codeword is used for the transition from the band AMC mode to the diversity mode.

Fig. 2 shows the flow chart of the transition from the diversity mode to the band AMC mode. First, an SS which is operated in diversity mode transmits the C1 codeword to a BS through the CQICH. Then, the BS receives the C1 codeword from the SS and transmits the REP-REQ (report request) message to the SS, and the SS transmits the REP-RSP (report response) message which informs the best five bands and the BS, and indicates the transmission between the diversity mode and the band AMC mode. Then, the BS receives the REP-RSP message and the C2 codeword from the SS, and allocates the band AMC subchannels among the five best
bands reported by the SS to the SS. After that, the SS transmits the differential value of the CINR (Carrier to Interference and Noise Ratio) of the reported five best bands to the BS periodically. When the SS which is operated in the band AMC mode wants to change the allocated bands, it transmits the REP-RSP message which contains the bitmap information of the new best five bands and the C2 codeword to the BS. And then, the BS allocates the band AMC subchannels among the five best bands just reported by the SS to the SS.

Fig. 3 shows the flow chart of the transition from the band AMC mode to the diversity mode. First, an SS which is operated in band AMC mode transmits the C3 codeword to a BS through the CQICH to transit to the diversity mode, and then the SS transmits the average value of the CINR of the whole bandwidth to the BS. The SS transmits the C3 codeword and the average value of the CINR of the whole bandwidth to the BS repeatedly until the BS allocates the subchannels to the SS. After the BS allocates the diversity subchannel, the SS transmits the average value of the CINR of the whole bandwidth to the BS periodically.

The conventional band AMC operation of the Mobile WiMAX system is optimized for the outdoor environments. In general, the bands preferred by each SS are uniformly distributed in the whole bands in case of the outdoor environments. However, the possibility that the preferred bands of the SS are overlapped each other becomes high in the indoor environments, since the SSs are close together and move slowly. If the SS requests the bands already used by other SS, the SS can not transit to the band AMC mode although there are other good bands. Therefore, if the conventional band AMC scheme is used as it is in the indoor environments, it leads the poor channel utilization. However, the band AMC operation is very important since most SSs are operated in the band AMC mode in the indoor Mobile WiMAX system. Therefore, we propose a new band AMC operation which is suited to the indoor Mobile WiMAX system.

III. PROPOSED BAND AMC OPERATION

The poor channel utilization in the conventional band AMC operation in the indoor Mobile WiMAX system is caused by the similarity of the best bands of the SSs. Therefore, the channel utilization could increase if we allocate good bands to the SSs occasionally instead of allocating the best bands only. Therefore, in the proposed band AMC scheme, the SS reports the worst bands to the BS, and the BS allocates the bands excluding the reported worst bands to the SS. The best bands could not be allocated to the SS although it is available, but the degradation of the throughput can be minimized since the BS does not allocate the worst bands to the SS. Therefore, the proposed band AMC operation is more useful than the conventional band AMC operation in the indoor environments since it increases the channel utilization.

To achieve the backward compatibility with the existing Mobile WiMAX system, we add new TLV (Type, Length, Value) fields in the REP-REQ message and the REP-RSP message. Table I shows the added TLV fields. In the REP-REQ message, the type 1.9 is used for the request of the information about the worst bands from a BS to an SS and the type 1.10 informs the bitmap information of the five bands to be allocated to an SS. In the REP-RSP message, the type 7.1 informs the bitmap information of the worst five bands from an SS to a BS.

Fig. 4 shows a flow chart of the transition from the diversity mode to the band AMC mode in the proposed band AMC operation. This operation is similar to the conventional operation. First, an SS which is operated in the diversity mode transmits the C1 codeword to a BS through the CQICH to transit to the band AMC mode. The BS which receives the C1 codeword from the SS transmits the REP-REQ message to the SS, and the SS transmits the REP-RSP message which informs the worst five bands and transmits the C2 codeword. Then, the BS which receives the REP-RSP message and the C2 codeword from the SS allocates the band AMC subchannels except the worst five bands reported by the SS to the SS, and transmits the REP-REQ message which informs the bitmap information of the allocated bands. The SS which receives the REP-REQ message transmits the REP-RSP message which informs the CINR measurement of the allocated bands and the C4 codeword which is a new CQICH codeword for the confirmation of the transmission of the CINR measurement of the allocated bands in the proposed band AMC scheme. After that, the SS transmits the differential value of the CINR of the allocated band to the BS periodically to inform it in real-time. The operation of the change of the allocated bands of the SS which is operated in band AMC mode is the same as the conventional scheme.

IV. NUMERICAL ANALYSIS

To analyze the performance of the proposed band AMC scheme, we assume that there are $N_{subch}$ band AMC subchannels and the BS allocates maximum $N_{alloc}$ subchannels to each SS which transits from the diversity mode to the band AMC mode. Also, we assume that every band allocation holds for one frame and the new resource allocation procedure restarts in the next frame. And the number of SSs which request band AMC subchannels in one frame is $N_{SS}$. To consider the channel correlation, we define a subchannel correlation coefficient, $\varepsilon$, of which range is from 0 to 1. The channel state of each SS is more similar as the value of $\varepsilon$ is bigger, so each SS chooses the bands to report randomly if $\varepsilon$ is 0 and every SS reports the same bands to the BS if $\varepsilon$ is 1.

<table>
<thead>
<tr>
<th>Message</th>
<th>Type</th>
<th>Length</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>REP-REQ</td>
<td>1.9</td>
<td>1 Byte</td>
<td>Type of channel measurement to be reported in worst reporting mode</td>
</tr>
<tr>
<td>REP-RSP</td>
<td>7.1</td>
<td>2 Bytes</td>
<td>Band indicating bitmap of the worst band AMC</td>
</tr>
</tbody>
</table>

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We use a channel utilization ($U_{ch}$) as a performance metric. The channel utilization is defined as the ratio of the average number of utilized subchannels over the number of the whole subchannels. To calculate the channel utilization, we use a Discrete Time Markov Chain (DTMC) technique.

In the conventional band AMC operation, the SS reports five best bands to the BS according to the Mobile WiMAX standard. So, if $N_{Rep}$ is the number of bands reported by an SS, the value of $N_{Rep}$ is 5. $N_{Rep}$ is equal to the number of bands which can be allocated to SSs when the value of $\varepsilon$ is 1. Then, we divide the $N_{subch}$ bands into $g_1$ and $g_2$, where $g_1$ consists of $N_{Rep}$ bands which can be allocated to the SS when the subchannel correlation coefficient is 1 and $g_2$ consists of remaining $N_{subch} - N_{Rep}$ bands. Let $P(g_1)$ and $P(g_2)$ be the probability that an SS selects one band in $g_1$ and in $g_2$ respectively, then we can derive $P(g_1)$ and $P(g_2)$ as follows according to the value of $\varepsilon$ in general.

$$P(g_1) = \frac{N_{Rep}}{N_{subch}} + \frac{N_{subch} - N_{Rep}}{N_{subch}} \varepsilon. \quad (1)$$

$$P(g_2) = \frac{N_{subch} - N_{Rep}}{N_{subch}} - \frac{N_{subch} - N_{Rep}}{N_{subch}} \varepsilon. \quad (2)$$

If the value of $\varepsilon$ is 1, $P(g_1)$ is 1 and $P(g_2)$ is 0, and the values of $P(g_1)$ and $P(g_2)$ are the same in case that $\varepsilon$ is 0.

To use DTMC model in this analysis, we define the state of the DTMC as $(s_1, s_2)$, where $s_1$ is the number of utilized subchannels in $g_1$ and $s_2$ is that in $g_2$. Let $k_1$ be the number of allocated bands to the SS in $g_1$ and $k_2$ be that in $g_2$ by the BS. Then, $k_1 + k_2$ is less than $N_{alloc}$ since the BS allocates maximum $N_{alloc}$ bands to the SS. The state of the DTMC is changed whenever an SS which transits to the band AMC mode requests bands to the BS and the BS allocates bands to the SS. If $P_1$ is the transition probability matrix of this DTMC, one-step transition probability $P_1(s_1, s_2), (s_1 + k_1, s_2 + k_2)$ represents the probability that a process of the DTMC will, when in state $(s_1, s_2)$, next make a transition into state $(s_1 + k_1, s_2 + k_2)$.

To derive $P_1$, we define two events associated with the band selection of an SS and the subchannel allocation of a BS. First, $E_1(a_1, b_1 | i, j)$ is the event, which is associated with the band selection of an SS, that the number of bands which are not yet allocated among the reported bands by an SS is $a_1$ in $g_1$ and $b_1$ in $g_2$ given that there are $i$ bands which are already allocated in $g_1$ and $j$ bands in $g_2$. The BS can allocate bands only among these $a_1 + b_1$ bands to the SS. We call this allocatable band as a candidate band. Fig. 5 shows an example of the state of bands after an SS selects bands to report. To derive the probability of this event, $P(E_1(a_1, b_1 | i, j))$, we consider two probabilities, $p_1(a_2, b_2)$ and $p_2(a_1, b_1 | i, j; a_2, b_2)$. $p_1(a_2, b_2)$ is the probability that the number of bands which are reported by an SS is $a_2$ in $g_1$ and $b_2$ in $g_2$, and $p_2(a_1, b_1 | i, j; a_2, b_2)$ is the probability that the number of candidate bands is $a_1$ in $g_1$ and $b_1$ in $g_2$ given that there are $i$ bands which are already allocated in $g_1$ and $j$ bands in $g_2$. The SS requests $a_2$ bands in $g_1$ and $b_2$ bands in $g_2$. Then, $P(E_1(a_1, b_1 | i, j))$ is represented as the product of the two probabilities $p_1(a_2, b_2)$ and $p_2(a_1, b_1 | i, j; a_2, b_2)$ as follows.

$$P(E_1(a_1, b_1 | i, j)) = \sum_{a_2, b_2} p_1(a_2, b_2) \cdot p_2(a_1, b_1 | i, j; a_2, b_2) \quad (3)$$

where $a_2 + b_2 = N_{Rep}$, $0 \leq a_2, b_2 \leq N_{Rep}$.

We use another DTMC model to derive $p_1(a_2, b_2)$. We define the state of the DTMC as $(n_1, n_2)$, where $n_1$ is the number of reported bands by an SS in $g_1$ and $n_2$ is that in $g_2$. In this DTMC model, the state is changed whenever the SS reports a band. If $P_2$ is the transition probability matrix of this DTMC, one-step transition probability $P_2(n_1, n_2), (n_1 + n_2 + \varepsilon, n_2 + \varepsilon)$ represents the probability that a process of the DTMC will, when in state $(n_1, n_2)$, next make a transition into state $(n_1 + n_2 + \varepsilon, n_2 + \varepsilon)$.
To derive P2, we define two probabilities associated with the band selection of an SS. Let $f_1$ be the probability that an SS selects a band to report in $g_1$ and $f_2$ be the probability that the SS selects a band to report in $g_2$ when the number of bands which are not yet selected by the SS is $\alpha$ in $g_1$ and $\beta$ in $g_2$. Then, we can derive following equations.

$$\alpha f_1 + \beta f_2 = 1.$$  \hfill (4)

$$f_1 : f_2 = P(g_1) : P(g_2).$$  \hfill (5)

Using (4) and (5), we can calculate $f_1$ and $f_2$ as follows.

$$f_1 = \frac{P(g_1)}{\alpha P(g_1) + \beta P(g_2)},$$  \hfill (6)

$$f_2 = \frac{P(g_2)}{\alpha P(g_1) + \beta P(g_2)}.\hfill (7)$$

If there are $n_1$ bands in $g_1$ and $n_2$ bands in $g_2$, the number of bands which are not yet selected in $g_1$ is $N_{\text{Rep}} - n_1$ and that in $g_2$ is $N_{\text{subch}} - N_{\text{Rep}} - n_2$. Hence, $P_{2}(n_1,n_2),(n_1 + \kappa_1, n_2 + \kappa_2)$ becomes (8).

$p_1(a_2,b_2)$ is the probability that a process of the DTMC in state $(0,0)$ will be in state $(a_2,b_2)$ after $N_{\text{Rep}}$ transitions by its definition. Hence, $p_1(a_2,b_2)$ can be derived as follows by using the $n$-step transition probability.

$$p_1(a_2,b_2) = P_{2}(0,0),(a_2,b_2).$$  \hfill (9)

Using Chapman-Kolmogorov equation [10], we can re-write $p_1(a_2,b_2)$ as follows.

$$p_1(a_2,b_2) = \sum_{\lambda_1=0}^{N_{\text{Rep}}-N_{\text{subch}}} \sum_{\lambda_2=0}^{N_{\text{Rep}}-N_{\text{subch}}} P_{2}(0,0),\lambda_1,\lambda_2) P_{2}(\lambda_1,\lambda_2),(a_2,b_2).$$  \hfill (10)

where $N_{\text{Rep}} + N_{\text{subch}} = N_{\text{Rep}}, 0 \leq N_{\text{Rep},1}, N_{\text{Rep},2} \leq N_{\text{Rep}}$.

Next, $p_2(a_1,b_1 | i,j; a_2,b_2)$ can be derived intuitively as (11).

The second event $E_2(k_1, k_2 | a_1,b_1)$ is associated with the subchannel allocation of a BS. This is the event that the BS allocates $k_1$ bands among the $a_1$ candidate bands in $g_1$ and $k_2$ bands among the $b_1$ candidate bands in $g_2$ to the SS. The probability of this event, $P\{E_2(k_1, k_2 | a_1,b_1)\}$, is calculated as follows.

$$P\{E_2(k_1, k_2 | a_1,b_1)\} = \binom{a_1}{k_1} \binom{b_1}{k_2} \binom{a_1+b_1}{k_1+k_2}.$$  \hfill (12)

Now, we can derive $P_{1}(s_1,s_2),(s_1+k_1,s_2+k_2)$ using the probabilities of the defined two events, $P\{E_1(a_1,b_1 | i,j)\}$ and $P\{E_2(k_1, k_2 | a_1,b_1)\}$, as (13).

(13) means the probability that the number of the utilized subchannels is changed from $s_1$ to $s_1 + k_1$ in $g_1$ and that is changed from $s_2$ to $s_2 + k_2$ in $g_2$ after the resource allocation of an SS. However, we are interested in the state of subchannels when the number of SSs which complete the resource allocation is $N_{SS}$. This can be calculated by using the $n$-step transition probability, $P_{1}(N_{SS},(0,0),(s_1,s_2))$, which means the probability that the number of utilized subchannels is $s_1$ in $g_1$ and $s_2$ in $g_2$ when the number of SSs which complete the resource allocation is $N_{SS}$. The initial state is $(0,0)$ since the resource allocation restarts every frame. We can derive the $n$-step transition probability, $P_{1}(N_{SS},(0,0),(s_1,s_2))$, as follows by using Chapman-Kolmogorov equation [10].

$$P_{1}(N_{SS},(0,0),(s_1,s_2)) = \sum_{\lambda_1=0}^{N_{SS,1}} \sum_{\lambda_2=0}^{N_{SS,2}} P_{1}(0,0),\lambda_1,\lambda_2) \sum_{\lambda_1=0}^{N_{SS,1}} \sum_{\lambda_2=0}^{N_{SS,2}} (s_1 + s_2) \times P_{1}(N_{SS},(0,0),(s_1,s_2)).$$  \hfill (14)

The channel utilization of the proposed band AMC operation also can be calculated in the way similar to that of the conventional band AMC operation. However, the subchannels excluding the five worst bands reported by the SS are allocated to the SS in the proposed band AMC operation. By this characteristic, the proposed band AMC operation is the same as the conventional band AMC operation if the number of bands which are reported by an SS is not 5 but $N_{\text{subch}} - 5$ in this analysis. Therefore, we can apply the analysis of the conventional band AMC scheme to the proposed band AMC scheme by replacing the value of $N_{\text{Rep}}$ with $N_{\text{subch}} - 5$.

V. SIMULATION RESULTS AND DISCUSSION

In order to evaluate the performance of the proposed band AMC operation, we perform simulation and compare the performance with the conventional band AMC operation in view of channel utilization. In this simulation, we assume that there are 12 subchannels located at different bands. We do not consider the signaling overhead. The number of SSs varies between 1 and 12. Each SS reports five bands - the five best bands are chosen in the conventional band AMC operation, and the five worst bands in the proposed band AMC operation. And the BS allocates the two bands among the reported five best bands in the conventional band AMC mode but the two bands among the remaining bands except the reported five worst bands in the proposed band AMC mode to the SS.

Fig. 6 shows the channel utilization versus the subchannel correlation coefficient in case that there are 9 SSs which transit the band AMC mode. When the value of $\varepsilon$ is equal to or close to 0, the channel utilization of the proposed band AMC operation is similar to that of the conventional band AMC operation - it is close to 1 in both cases - since the BS can allocate subchannels uniformly over the whole bands to the SSs. However, the proposed band AMC scheme shows better performance as the value of $\varepsilon$ is bigger since the BS gets more allocatable bands in the proposed band AMC operation than in the conventional band AMC operation as the $\varepsilon$ is closer to
\[ P_{2(n_1,n_2),(n_1+s_1,n_2+s_2)} = \begin{cases} 
\binom{N_{Rep} - n_1}{n_1} f_1 |_{\alpha = N_{Rep} - n_1, \beta = N_{subch} - N_{Rep} - n_2}, \\
\binom{N_{subch} - N_{Rep} - n_2}{n_2} f_2 |_{\alpha = N_{Rep} - n_1, \beta = N_{subch} - N_{Rep} - n_2}, \\
1, \\
0. \end{cases} \]

\[
p_2(a_1, b_1 | i, j; a_2, b_2) = \frac{\binom{N_{Rep} - i}{a_1}}{\binom{N_{Rep}}{a_1}} \binom{i}{a_2 - a_1} \cdot \frac{\binom{N_{subch} - N_{Rep} - j}{b_1}}{\binom{N_{subch} - N_{Rep}}{b_1}} \binom{j}{b_2 - b_1}. \tag{11} \]

\[
P_{1(s_1,s_2),(s_1+k_1,s_2+k_2)} = \begin{cases} 
\sum_{a_1} \sum_{b_1} P\{E_1(a_1, b_1 | s_1, s_2)\} \cdot P\{E_2(k_1, k_2 | a_1, b_1)\}, & \text{if } k_1 + k_2 \leq N_{alloc} \\
0, & \text{otherwise} \end{cases} \tag{13} \]

Fig. 6. Channel utilization according to channel correlation coefficient in case that the number of SSs is 9.

1. The maximum difference of the channel utilization between the two schemes is about 40% when the value of \( \varepsilon \) is 1.

Fig. 7 shows the channel utilization versus the number of SSs in case that the subchannel correlation coefficient is 0.8. The proposed band AMC scheme shows better performance than the conventional band AMC scheme in terms of channel utilization when the number of SSs is greater than 3. The maximum difference of the channel utilization between the two schemes is about 12% when the number of SSs is 9.

The channel state of SSs in indoor environments may be similar each other compared to that in outdoor environments. Therefore, the value of \( \varepsilon \) in the indoor environments is bigger than that in the outdoor environments. Also, most SSs are trying to be operated in band AMC mode due to the stable channel condition in indoor environments. Considering these characteristics of indoor environments, we can see that the proposed band AMC scheme is more efficient compared to the conventional band AMC scheme in the indoor environments from the numerical and simulation results.

VI. CONCLUSIONS

In this paper, we proposed a new band AMC operation for military use of the indoor Mobile WiMAX system. In the proposed band AMC operation, the SS reports the worst bands to the BS and the BS allocates the band AMC subchannels flexibly. The proposed band AMC scheme increases the channel utilization with minimizing the degradation of capacity since the BS allocates the subchannels excluding the worst bands reported by the SS. Also, the proposed band AMC operation is compatible with the existing Mobile WiMAX standard. The numerical analysis and simulation results show that the proposed band AMC operation has a better performance in...
terms of the channel utilization than the conventional band
AMC operation in the indoor environments.

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