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Re:	IEEE 802.16m-07/040, “Call for Contributions on Project 802.16m System Description Document (SDD)”
Abstract	This contribution proposes a section/subsection in P802.16m SDD to describe the operation and the functional area to support radio resource management for AAS in IEEE 802.16m.
Purpose	Propose to have a section/subsection “Radio Resource Management for AAS” in TGm SDD ToC.
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Radio Resource Management for Adaptive Antenna System (AAS) in Project 802.16m SDD

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I. Introduction

The standards of IEEE 802.16 family [1][2] adopt Adaptive Antenna System (AAS) as an option to enhance cell capacity and coverage. The feature of AAS is its ability to reduce interference by steering the beam to a specific user. As a result, the Signal-to-Interference-and-Noise Ratio (SINR) could be enhanced. Besides, with spatial division multiple access (SDMA), multiple beams can support multiple users at the same time, each resource unit in orthogonal frequency division multiple access (OFDMA) can be utilized by more than one user.

Usually SDMA is combined with other multiple access schemes, such as TDMA [3][4]. In [3], the “spatial grouping” algorithm is proposed to group users according to their spatial separability. Users in the same group are all spatial separable and can be served on the same frequency band at the same time. Different groups of users are served in TDMA scheme by proportional fair scheduler. In [4], a multimedia SDMA/TDMA scheduling algorithm is proposed. The proposed algorithm consists of packet prioritization and packet allocation. Packet prioritization is to minimized packet loss based on Quality of Service (QoS) requirement in terms of timeout values. Packet allocation is to maximize the throughput based on spatial characteristic.

According to [5] [6], AAS can enhance link quality. Different from the aforementioned scheduling algorithm for SDMA on mobile WiMAX, our motivation is to support poor users to guarantee QoS. In this contribution, we make users with poor SINR value have priority to be served by beamforming. Therefore, the two-stage scheduling method is proposed, which consists of prioritization and intra-beam interference avoidance. Finally, the system level performance analysis with AAS-enabled SDMA is presented as well.

The rest of this contribution is organized as follows. The ensuing section briefly reviews adaptive antenna system. In Section III, we described a procedure for system level simulation. Some preliminary simulation results and discussion are given in Section IV. Then, some concluding remarks are given in Section V. Finally, proposed sections/subsections in the table of content (ToC) for IEEE 802.16m SDD are described in the last section.

II. Brief Review on Adaptive Antenna System

➢ Spatial Filtering Interference Reduction (SFIR)

One application of AAS is SFIR shown as Fig. 1. Compared with omni-directional cell, the interference can be significantly suppressed. The purpose of SFIR is to reduce the interference, but its spectral efficiency is low with one adaptive beam only [16].

➢ Spatial Division Multiple Access (SDMA)

A more advance application of AAS is SDMA shown as Fig. 1. It can locate more than one user simultaneously, and allow multiple users to access the resource unit at the same time and frequency. It distinguishes users only by the different impinging angles of signals. The transmitted data from multiple users can be well separated in the receiver as long as users do not locate in a near region. The spectral efficiency of SDMA system is high, and the cell capacity can be significantly improved [16].

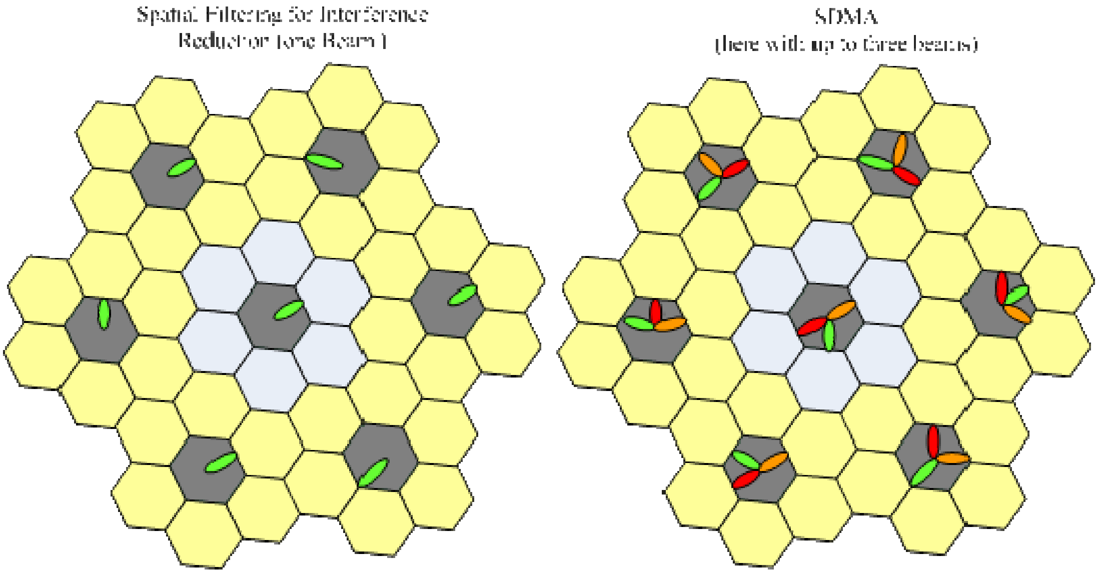


Figure 1. Illustration for SFIR and SDMA

➢ Benefit of AAS

1. Interference suppression/concealing

AAS system is capable of detecting the DoA of the signals and interference. With beamforming, interference suppression and SINR enhancement can be achieved, which is described in section above. This is also the main advantages when applying AAS.

2. Increasing the cell capacity/coverage

As compared with omni case, beamforming can save the wasted energy and increase the received power of MS, and the interference can be significantly reduced. As the result, the MS suffering bad RF condition can be supported with better connection quality especially for cell edge users. With the support of poor users, the cell capacity can be promoted as well.

3. High bandwidth efficiency

SDMA can be enabled by AAS. Besides the frequency and time, there is another dimension of resource units being considered. With the utilization of the space, the carried data on each resource units can be higher without increasing power and bandwidth. This is much important for throughput enhancements.

4. Reuse frequency reduction

Increasing reuse factor is a well known method to reduce the interference with the tradeoff of the bandwidth efficiency. Remind the main purpose of applying AAS is to suppress the interference so that the interference level might be decreased by beamforming under the same reuse factor. This is also improved the system bandwidth efficiency.

- **Limitation and implementation concern**

1. **Element failure**

As aforementioned, the performance is related to the array elements. If antenna elements fail, it will decrease the DoF of the system, and the beamwidth is broaden as well, which cause the interference level is larger. As the result, the serving user may suffer more interference than expected performance.

2. **Computation complexity**

Real time adaptive weights computation is not suitable for high speed application. Especially for multi-carrier system, the weights need to be computed on each subcarrier/subchannel. Simplifying the adaptive algorithm and the improvement of hardware computation speed can be the solution of this problem.

3. **Steering vector error**

Remind the spatial beamforming, the DoA estimation works under insignificant Azimuth spread. If the environment is Line Of Sight, the steering vector error may mislead system to believe that the interference is the desired signal. The simplest way is to broaden the beamwidth, but the interference is increase.

4. **Suitable for symmetric traffic**

AAS system needs the estimation and received training sequence of MS. If the DL and UL channel state are de-correlated or not reciprocal for TDD mode, the feedback information in uplink might not be reliable for downlink transmission [8]. This may happened in packet-oriented and connectionless services due to unpredictable time of request to transmit. If the packet-oriented service is applied, the traffic channel for uplink and downlink might be different so that the reciprocal property for TDD mode no longer exists, so does the connectionless service. Besides, if the beamformer is only on BS, the downlink beamforming is harder to be constructed than uplink beamforming. In uplink beamforming, the weights are directly updated to the current user and interference situation since the received signals have propagated through channel enabling channel estimation and optimum array weights to be computed. This is not possible on the downlink since the channel is generally unknown.

In conclusion, the beamforming is more suitable for circuit switch system or symmetric service such like VoIP service or UGS service for mobile WiMAX. If the downlink beamforming is implemented, it might need the additional overhead in the uplink to feed back the training information.

III. System Level Simulation

Algorithm Description

In this section, the proposed two-stage scheduling algorithm is described. Different from other algorithms for SDMA on mobile WiMAX [3][10], the intention of this algorithm is to support poor channel condition users and to ensure link quality improvement after beamforming. These can be realized in two stages: prioritization and intra-beam interference avoidance.

In the first stage, the prioritization is based on user’s channel condition and packet’s deadline. All AAS users are categorized into groups according to their channel condition, assessed by modulation scheme. Higher priority is given to groups with worse channel condition. Users in the same group are prioritized by their packet deadlines. The deadline of the packet is defined as

$$deadline = DB - Age - T_t, \tag{1}$$

where DB denotes delay bound, Age is the time the packet stayed in MAC layer, and T_t is the transmission time for this packet in the current frame. For non-real-time service, a "soft delay bound" is used as the delay bound [7] and is defined as

$$soft\ delay\ bound = \frac{packet\ size}{minimum\ reserved\ traffic\ rate} \tag{2}$$

User with earlier deadline should have higher priority. The beamforming list would be determined in the second stage based upon the intra-beam interference.

The objective of the second stage is to avoid intra-beam interference. Assuming one beam is dedicated for only one user, users which might cause intra-beam interference to higher priority user are not allowed being served by beamforming. In other words, for users which are too close to spatially separable, the beam would only be assigned to the user with highest packet priority. Besides, after beam assignment, the channel condition of each user is re-exam. If the channel condition of beam-assigned user is not improved, which means that even beamforming cannot benefit this user or beamforming cause severer interference to the user, then the user would be deleted from the beamforming list and try to serve the user in the regular non AAS zone.

SINR Calculation

The SINR value is important for radio resource management (RRM). The SINR calculation for non SDMA and SDMA cases is shown as

$$SINR_{m,nonSDMA} = \frac{P_j G_{120^\circ} Pl_{jm} Shadow_{jm}}{Noise + \sum_{i=0,i\neq j}^{18} P_i G_{120^\circ} Pl_{im} Shadow_{im}}$$

$$SINR_{m,SDMA} = \frac{\frac{P_j}{Beamnumber} G_K Pl_{jm} Shadow_{jm}}{Noise + \sum_{i=0,i\neq j}^{18} \sum_{k=1}^{Beamnumber} \frac{P_i}{Beamnumber} G_k Pl_{im} Shadow_{im}}$$

where j is serving BS index, i is interfering BS index, and k is beam number index, P is denoted as transmitted sector power, G represents the antenna pattern gain, Pl is pathloss degraded between BS and MS, and *shadow* is denoted as the shadowing effect.

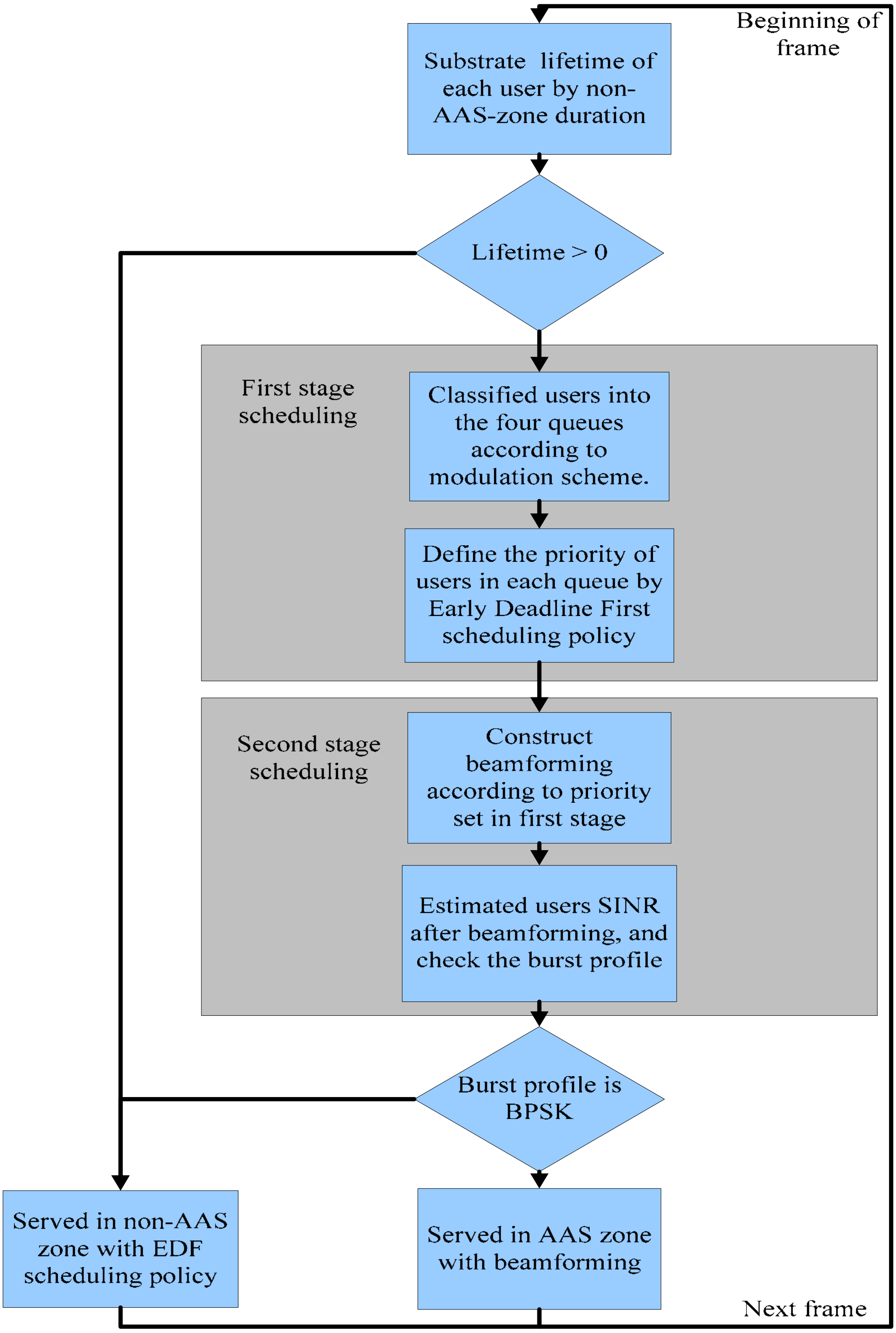


Figure 2. Simulation Flow

Traffic Model

Table 1. FTP traffic model

File size (S)	Truncated Lognormal	A=0.35, u =14.45, M=5m
Reading time (D_{pc})	Exponential	L=1/180

Table 2. VoIP traffic model

codec	Framesize(byte)	Interval(ms)	Rate(bps)	Delay bound(ms)
G729-1	20.0	20.0	8k	20.0

Table 3. Simulation Parameters

Parameters	**Value/Comment**
Cell layout	Hexagonal grid, 19 cells (wrap around)
Sectors per cell	3
Frequency reuse factor	1x1, 1x3
Available bandwidth	10MHz in 1x1, 70 MHz in 1x7 reuse
Antenna pattern (Θ_{3dB} , A_m) in non-AAS zone	(70° , 20 dB)
Antenna pattern (Θ_{3dB} , A_m) in AAS zone	(8.75°,29 dB)
Beamwidth in non-AAS zone	120°
Antenna bore-sight gain in non-AAS zone	3 dB
Beamwidth in AAS zone	15°
Antenna bore-sight gain in AAS zone	12dB
Beam number per sector for SDMA application	3 beams / sector
Served user per beam for SDMA application	1 user / beam
Tx power per beam	Divided equally by beam number per cell (9)
Cell radius	1 km

Transmitter/Receiver	Downlink (from BS to MSs)
Duplex	TDD mode
DL/UL subframe ratio	1:1
Frame length	5ms
Frame structure	1024-FFT OFDMA downlink carrier allocations with PUSC
OFDMA symbol length	102.9 µs
OFDMA symbols per slot	2 symbols
BS Tx power	46dBm (40 Watt)
BS Antenna gain	17 dBi
BS back off	5 dB
Thermal Noise Density	-173.93 dB/Hz
MS Noise Figure	9dB
MS Antenna gain	3 dBi
Pathloss model	35.0log(d[m])+31.5, 50m<d<5km
Shadow fading model	Log-normal distribution with STD=8dB and Gudmundson's correlation model
Mobility model	MS speed : 30 km/hr Probability to change direction : 0.2 Max. angle for direction update : 45^o
BS Power contol	Max power
AMC	QPSK+CC 1/2, 16-QAM+CC 1/2, 64-QAM+CC 1/2
Channel assignment	Frequency first
Scheduling control	Early Deadline First (EDF)
Handoff	Hard handoff
Traffic model	FTP VoIP

IV. Preliminary Simulation Results and Discussion

In this section, the performance of MAC throughput, outage probability, unsatisfied rate and packet loss rate is evaluated with the implementation of proposed algorithm in AAS-enabled SDMA WiMAX system.

From Fig. 3, the MAC throughput for FTP service scenario has been improved significantly in both reuse-factor 1 and 3. This is because more resource units are available. The cross point occurs because it is lack of multiuser diversity when cell loading is low and the extra overhead required by implementing AAS.

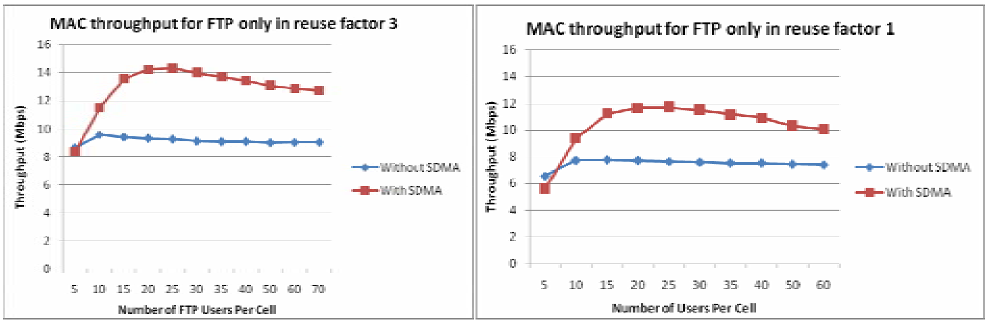
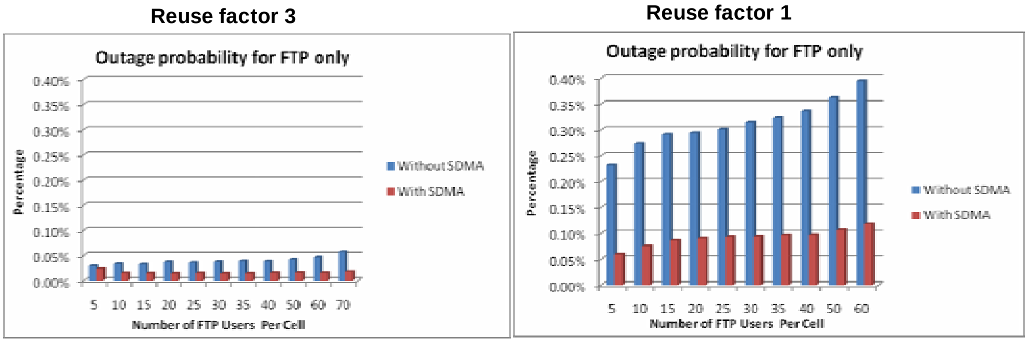


Figure 3. MAC throughput for FTP service with/without SDMA


Reuse factor 3

Reuse factor 1

Figure 4. Outage probability for FTP service with/without SDMA

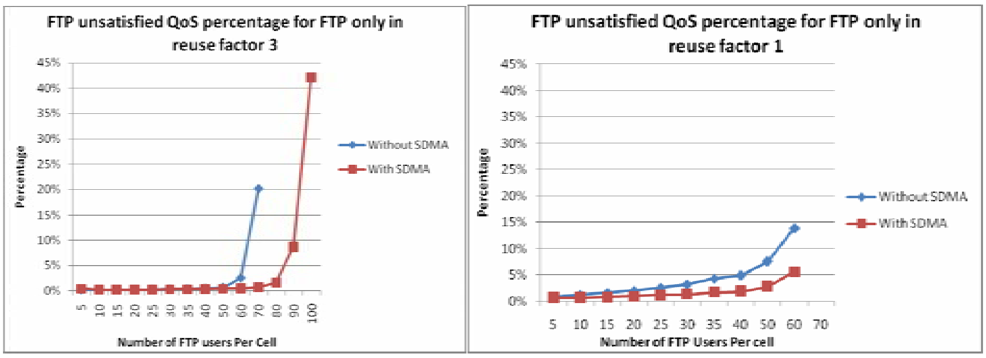
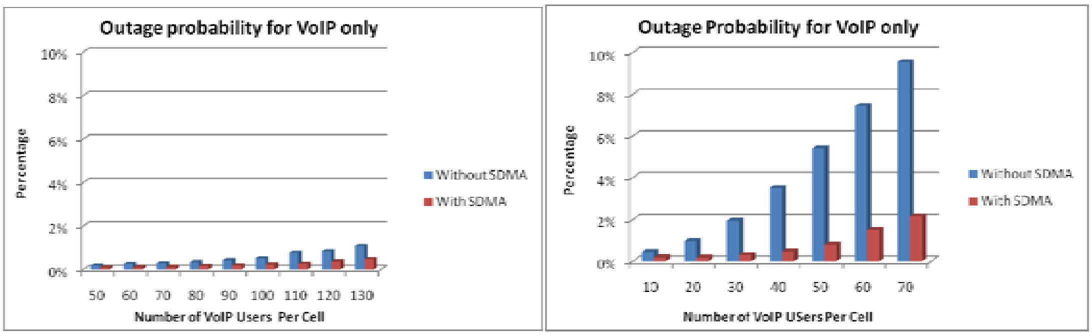


Figure 5. The QoS unsatisfied percentage for FTP service with/without SDMA

As for the outage probability, the percentage of users fail to achieve QPSK, is shown in Fig. 4. Due to long delay margin of non-real-time services, the outage probability of FTP service is quite low (less than 0.4%) in both reuse factor 1 and 3 cases. For the unsatisfied rate shown in Fig. 5, the percentage of packets exceed the soft delay bound is improved by more than 40% due to the AAS-enabled SDMA can create more available resource units.


Reuse factor 3

Reuse factor 1

Figure 6. Outage probability for VoIP service with/without SDMA

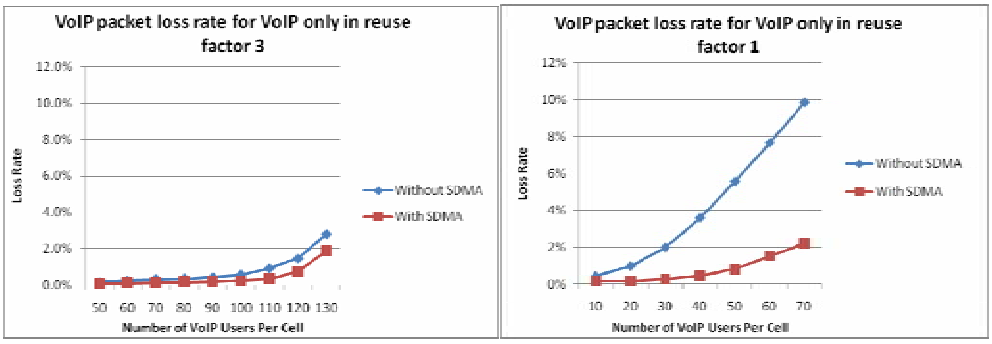


Figure 7. Packet loss rate for VoIP service with/without SDMA

For VoIP services, without SDMA, the outage probability grows significantly in reuse factor 1 case, as shown in Fig. 6. The same observation also applied to the packet loss rate, shown in Fig. 7. In reuse factor 1, the employment of SDMA is necessary because of the suppression of the excessive interfernece. On the other hand, for reuse factor 3, even without SDMA, the performance for voice is still acceptable. There is olny a minor improvement by implementing the AAS-enabled SDMA.

We observed that for FTP services, which have large packet sizes and delay tolerance, the performance enhancement is contributed by creating more available radio resources in AAS zone. However, in the VoIP case, if the interference is not high (reuse factor of 3), additional radio resources can not improve system performance due to its small packet size and low utilization of radio resources. Instead, when the interference level is high (reuse factor of 1), for VoIP services, the performance is improved significantly. In that case, the interference suppression technique becomes advantageous.

V. Conclusion

The performance of AAS-enabled SDMA is investigated. Basically, regardless of interference levels, FTP services with longer delay margin will have low outage probability and the throughput can be improved by additional radio resources exploited by SDMA technique. For VoIP services, the capacity is improved only when the environment suffers from high interference. In that scenario, the proposed two-stage interference avoidance scheduling algorithm and interference suppression contributed by AAS-enabled SDMA can effectively reduce the interference and enhance poor users in time. As a result, more VoIP users can be supported.

VI. Proposed Sections/Subsections in the Table of Content (ToC)

This contribution is to present a scheme of Radio Resource Management for AAS-enabled SDMA, which manages and distributes the radio resources exploited by beamforming techniques to each user based on their channel condition and QoS requirements, and show that appropriate Radio Resource Management for AAS can achieve significant performance improvement, especially for services with small packet size, such as VoIP, in high interference environment. According to IEEE 802.16 documents, AAS works as an optional mode. In order to keep QoS above a certain level for each user, it is suggested to include AAS into IEEE 802.16m system as mandatory functionality together with Radio Resource Management. Required modifications to current system and proposed sections/subsections in ToC are shown as follows.

Proposed sections/subsections in ToC:

--Start of the Text--

[*Adopt the following text in the ToC of P802.16m System Description Document (SDD)*]

x.y MAC AAS support

x.y.z Radio Resource Management for AAS

[*In the IEEE 802.16e-2005 standard, AAS works as an optional mode. The frame structure, private messages, and network entry procedure for AAS transmission can be modified in new system. The messages associated with AAS controls includes AAS preamble, AAS compressed MAP, AAS Downlink Frame Prefix (AAS-DLFP), AAS Alert Slot, and some AAS exchanging messages (AAS_FBCK_REQ/RSP, AAS_BEAM_SELECT, AAS_SDMA_DL_IE, etc).*]

--End of the Text--

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