A New MAC Design in LTE for MIMO Multiuser Schemes

Reema Imran
University of Jordan
Amman, Jordan
r.imran@ju.edu.jo

Nizar Zorba, Elias Yaacoub
Qatar Mobility Innovation Center
Al-Doha, Qatar
{nizarz, eliasy}@qmic.com

Hossam S. Hassanein
Queen's University
Kingston, Canada
hossam@cs.queensu.ca

Christos Verikoukis
CTTC
Barcelona, Spain
cveri@cttc.es

Abstract— **Long Term Evolution (LTE) supports closed-loop Multiple Input Multiple Output (MIMO) techniques, as a mechanism to improve system performance. An open topic since the appearance of MIMO is whether the feedback load, that is required for its operation, compensates the performance improvement in practical systems. The availability of full Channel State Information at the Transmitter (CSIT) induces a large feedback load, so that any Partial CSIT scheme has a better chance to be considered in practical systems. This paper presents an LTE-MAC design for MIMO Multiuser transmission where Partial CSIT is required. The aim is to achieve simultaneous downlink transmissions to multiple users. Mathematical expressions are provided for the performance evaluation in terms of the system sum rate and throughput.**

I. INTRODUCTION

Long Term Evolution (LTE) [1] is one of the most innovative cellular systems that has been recently specified to meet the increasing performance requirements of mobile broadband [2]. The fundamental targets of this technology are to improve the coverage and system capacity while reducing the connection and operator costs by employing all the cutting edge technologies, like the Multiple Input Multiple Output (MIMO) and the Orthogonal Frequency Division Multiplexing (OFDM) techniques [3], among others.

The integration of MIMO within LTE supports the incorporation of transmission schemes such as transmit diversity, spatial multiplexing and beamforming [4]. Although several MIMO schemes are provisioned in the LTE standard, the specific technique to be applied in each case has been left open in the standard [5], so that each manufacturer/operator may decide on the most suitable option for its scenario/application demands [6].

The most attractive downlink options of MIMO need full CSIT before the transmission starts, which is a handicap due to the feedback load in the Uplink [7]. This problem is even larger in the Multiuser scenarios (e.g., cellular systems), as the CSIT from each user is unaffordable [8]. The application of non-CSIT MIMO schemes in Multiuser scenarios does not provide the required boost in data rate and throughput, so that the partial-CSIT MIMO schemes will be the most implemented ones. The Multibeam Opportunistic Beamforming (MOB) is one of the highest performance and low complexity partial-CSIT schemes in literature [9]. It exploits the multiuser availability and it can provide service to several users at the same time, frequency and code through the transmission over several beams.

For any proposal to be included in LTE, a Medium Access Control (MAC) design must be formulated showing the symbols flow and their distribution over the LTE resources [10]. This paper tackles the MOB scheme and how to include it in the LTE standard. We will design a MAC scheme where the main challenge is the allocation of resources for the feedback load in the uplink and the data flow in the downlink. The objective is to achieve the largest efficiency of the employed resources. As the Transmission Mode (TM-5) in the LTE specifications is devoted for MIMO Multiuser [11], we will adapt it to our objectives, being backward compatible with the LTE standard in any change we introduce.

In this paper, we mathematically formulate the achievable data rate and throughput for our MAC proposal within LTE. The closed form expressions show the impact of each parameter in the system performance. The results from equations are later compared to computer simulations for an LTE scenario, where we see a very close behaviour between the mathematical equations and the simulations.

The remainder of this paper is organized as follows: section II deals with the system model, the beamforming transmission technique at the physical layer, and the Adaptive Modulation and Coding scheme (AMC). A description of the proposed multiuser MAC scheme together with the throughput analysis is presented in section III, followed by the simulations and numerical results in section IV. The paper ends with the conclusions in section V.

II. SYSTEM MODEL

We focus on the LTE downlink channel, where the OFDMA subcarriers are organized into resource blocks RBs with zero interference among them. OFDM guarantees no interference among the RBs. A multiple antenna downlink scenario is considered where the eNB transmitter is equipped with n_t transmit antennas to serve K users, where it is assumed that $K \geq n_t$. To achieve lower complexity and implementation cost at the receiver side, we assume single antenna at each UE. Let $\mathbf{x}(t)$ be the $n_t \times 1$ transmitted vector, then the k^{th} user received signal $y_k(t)$ is given by

$$y_k(t) = \mathbf{h}_k(t)\mathbf{x}(t) + z_k(t) \quad (1)$$

978-1-4673-5307-6/13/$31.00 ©2013 IEEE

where $z_k(t)$ is an additive independent and identically distributed (i.i.d.) complex noise component with zero mean and variance $E\{|z_k|^2\} = \sigma^2$. A channel $\mathbf{h}_{1\times n_t}$ between each of the users and the eNB is considered, following the specular model [12] for flat fading outdoor channel, which is assumed to keep constant through the coherence time T_c and independently changes between consecutive time intervals. A total transmit power constraint of $P_t = 1$ is considered and for ease of notation, time index is dropped whenever possible.

The channel between the k^{th} user and the eNB is defined as

$$\mathbf{h}_k = \frac{1}{\sqrt{P}} \sum_{p=1}^{P} \gamma_{k,p} \mathbf{a}(\theta_{k,p}) \tag{2}$$

where P is the number of paths the signal is assumed to follow from the eNB to the user k. $\theta_{k,p}$ is the angle of incidence of these paths, which are assumed to have gaussian distribution with mean $\overline{\theta_k}$ and angle spread of $AS = \sqrt{E(|\theta_{k,p} - \overline{\theta_k}|^2)}$. $\gamma_{k,p}$ is the gain of the p^{th} path seen by the k^{th} user, which is a zero mean complex gaussian distributed random variable. and $\mathbf{a}(\theta_{k,p})$ is the steering vector defined as:

$$\mathbf{a}(\theta_{k,p}) = \left[1, \exp^{-j2\pi \frac{d\cos(\theta_{k,p})}{\lambda}}, .., \exp^{-j2\pi \frac{(n_t-1)d\cos(\theta_{k,p})}{\lambda}}\right] \tag{3}$$

where d is the distance between the antennas at the eNB and λ is the wavelength.

The transmitter delivers service to a maximum of n_t simultaneous users in each RB. Thus the transmitted signal $\mathbf{x}$ encloses the uncorrelated data symbols s_k to each one of the selected users with $E\{|s_k|^2\} = 1$.

A. Multibeam Opportunistic Beamforming (MOB)

One of the major low complexity transmission techniques in multiuser MIMO scenarios is the MOB technique [13], which aims to improve the system performance by enabling the transmitter at the eNB to serve several users at the same time, through generating several beams at the eNB. In order to maintain the lowest interference between the served users, the generated beams have to be orthogonal which restricts the eNB transmitter to generate a maximum of n_t beams, and it disables any user to obtain more than one beam at a time [8].

The procedure is that, at the beginning of the transmission process, a reference predefined training sequence is transmitted from the eNB and over each one of the available beams; each user in the system calculates its received Signal to Noise and Interference Ratio (SNIR) value corresponding to each beam, and feeds back the maximum measured SNIR value with an integer for the corresponding beam index. The eNB selects the user that has the largest SNIR for each one of the beams (i.e., opportunistic scheduling), and the data flow starts.

This multibeam strategy extracts the spatial multiplexing gain by serving several users at the same time achieving high system sum rate. If n_t users are selected for transmission, the transmitted signal that encloses the data symbols can be expressed as

$$\mathbf{x} = \frac{1}{\sqrt{n_t}} \sum_{m=1}^{n_t} \mathbf{b}_m s_m \tag{4}$$

where s_m is the data symbol for the m^{th} selected user and $\mathbf{b}_m$ is the normalized transmission beam, so that the term $\frac{1}{\sqrt{n_t}}$ makes the transmitted power to be unity.

This system has a major drawback that each generated beam causes an interference on non-intended users[1]. The received SNIR value for the k^{th} user that is served by the m^{th} beam is formulated as

$$SNIR_{k,m} = \frac{\frac{1}{n_t}|\mathbf{h}_k \mathbf{b}_m|^2}{\sigma^2 + \sum_{v\neq m}^{n_t} \frac{1}{n_t}|\mathbf{h}_k \mathbf{b}_v|^2} \tag{5}$$

where a uniform power allocation among all the users is considered. The Cumulative Density Function (CDF) for the serving SNIR is formulated as [8]

$$F(\gamma) = \left[1 - \frac{\exp\left(-n_t\gamma\sigma^2\right)}{(1+\gamma)^{n_t-1}}\right]^K \tag{6}$$

Within this scheme there exists the possibility that no user selects the m^{th} beam or all the SNIR values for that beam are below the minimum threshold for correct detection at the receiver side, thus reducing the achievable system sum rate.

B. Adaptive Modulation and Coding (AMC)

Within AMC, the transmitter tracks the changes and fluctuations of a wireless channel, and adapts its employed modulation and code to the channel characteristics, where the employed modulation has to be carefully selected to meet a predefined Symbol Error Rate (SER) value. If we assume that R different modulation and coding schemes are available, then the instantaneous SNIR values are divided into R regions with thresholds defined as $[\gamma_1, ., \gamma_R]$, so if the measured SNIR value lies within the r^{th} region ($\gamma_r \leq SNIR < \gamma_{r+1}$) only the modulation and coding scheme corresponding to that interval can be employed. Using the CDF given in Eqn.(6), the probability that a user lies within the r^{th} region can be obtained as

$$P(r) = F(\gamma_{r+1}) - F(\gamma_r) \tag{7}$$

The partial CSIT concept of AMC is that, as the SNIR value for each user lies within a predefined range, then the user has only to feedback the AMC interval index (through the Channel Quality Indicator (CQI)), and not the SNIR value itself, thus reducing the number of required bits to feedback the SNIR value, and increasing the resources efficiency. The AMC intervals are shown in Table I for the LTE system.

[1]Although the beams ($\mathbf{b}$) are orthogonal, their flows in the channel ($\mathbf{hb}$) are not orthogonal [9].

CQI index	AMC	Efficiency ζ (bps/Hz)	SNIR (dB)
0	No service	0	<-6.7
1	QPSK, 1/4	0.55	-6.7
2	QPSK, 1/3	0.835	-4.7
3	QPSK, 1/2	1.12	-2.3
4	QPSK, 2/3	1.35	0.2
5	QPSK, 3/4	1.69	2.4
6	16-QAM, 1/4	1.98	4.3
7	16-QAM, 1/3	2.56	5.9
8	16-QAM, 1/2	3.045	8.1
9	16-QAM, 2/3	3.43	10.3
10	16-QAM, 3/4	3.815	11.7
11	64-QAM, 1/4	4.2	14.1
12	64-QAM, 1/3	4.585	16.3
13	64-QAM, 1/2	4.97	18.7
14	64-QAM, 2/3	5.355	21
15	64-QAM, 3/4	5.75	22.7

Table I: AMC intervals in LTE

III. Multiuser MAC Layer Scheme

In this section we will present the proposed MAC scheme that accounts for the inclusion of the MOB transmission technique in the LTE standard, that aims to support multiuser downlink transmission. We will show that the required modifications are back-compatible with the LTE standard.

A. Multiuser MAC Algorithm description

The aim of the proposed scheme is to exploit the Multiuser MIMO capabilities, and to opportunistically assign service to the user with the highest SNIR value per beam. These users will share the downlink resource blocks via the MOB transmission technique, thus maximizing the system throughput. This section will explain how MOB technique described in section II fits within the LTE system, while being back-compatible.

In each frame scheduling time T_F the eNB generates n_t random beams and sends cell specific reference signals over each one of the n_t beams. This is performed to support channel estimation and enabling each user to calculate its received SNIR value for each one of the n_t beams [15]. After that, the user selects the beam showing the largest SNIR value and searches the AMC interval where it falls. Then the corresponding CQI value plus an identifier for the beam index are fed back to the eNB.

Based on the CQI feedback, the eNB selects the user with the highest CQI on each beam, determines the appropriate modulation and coding scheme, and then transmits simultaneously the data for all the selected users. Finally, each user receives its data and sends an ACK indicator to acknowledge the correct reception [10].

LTE supports Multiuser MIMO within the Transmission Mode (TM-5) [11], where the user is asked to report 1-bit rank Indicator (RI), 3-bits Precoding Matrix Indicator (PMI) together with 4-bits CQI [11], which add up to a total of 8 bits from each user. Our scheme requires to feedback $\left(4+\log_2(n_t)\right)$ bits from each user, 4 of them for the CQI and the $\left(\log_2(n_t)\right)$ as the beam index (i.e., when the eNB is equipped with 2 transmit antennas the UE has to feedback 1-bit, 2-bits for 4 transmit antennas, and so on). Any number of antennas at the eNB can be considered within our proposal, but MIMO commercial deployment results have shown that the best results are obtained by using only a subset of 2 antennas to provide service to 2 users at each time, code and frequency block, and any increase in the number of serviced users shows negligible benefit as the multiplexing gain will not compensate the problem of interference and channel correlations. Therefore we will consider that two beams are generated, where our scheme saves 3 bits. Obviously, increasing the number of considered beams would decrease the amount of saved feedback bits. We will assume to use both CQI and PMI, while the RI is saved.

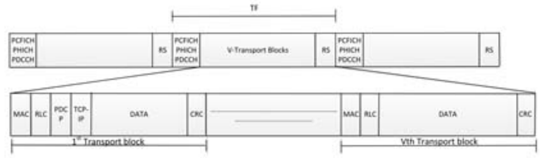

Fig. 1. LTE Frame structure.

The proposed LTE frame is shown in Fig. (1), where the first OFDM symbols are reserved for control signaling within each frame duration, while the data packets are organized into V transport blocks available for transmission. Notice that if the length of the data to be transmitted is greater than the maximum transport block length, segmentation is done at the Radio Link Control (RLC) layer [14]. Reference signals (RS) are sent over each Transmission Time Intervals (TTI) within the frame from the n_t beams to keep the compatibility with the standard [15]. We assume that whenever the SNIR is above the minimum threshold, we have error free data transmission, so that the Automatic Repeat reQuest (ARQ) retransmissions are not considered within the analysis nor the simulations.

B. System Sum Rate

As our proposal is based on AMC, then the achievable data rate is affected by the instantaneous reported SNIR values and their allocation to the different AMC intervals. Furthermore as we stated in section II, the system sum rate is also affected if no user selects a given beam for transmission. The probability that there is a transmission on a given beam equals the probability that at least one user selects a given beam, which can be described as

$$P_{r_{beam}} = 1 - \left[1 - \frac{1}{n_t}\right]^K \tag{8}$$

Thus, using the formulated CDF in section II and Eqn.(8), the achievable sum Data Rate (DR) we calculate it as

$$DR = BW n_t \left(1 - \left[1 - \frac{1}{n_t}\right]^K\right) \sum_{r=1}^{R} \zeta(r)\left[F_\gamma\left(\gamma_{r+1}\right) - F_\gamma\left(\gamma_r\right)\right] \tag{9}$$

where ζ is the spectral efficiency of bps/Hz and for each one of the AMC intervals from Table I; while BW is the available bandwidth that is composed of Q RBs. Using Eqns. (6) and (9), we represent the average system sum rate with all the involved parameters in the top of next page.

C. System Throughput

In order to make a fair comparison in terms of the data rate of MOB to other schemes in the literature and/or the

$$DR = BWn_t\left(1-\left[1-\frac{1}{n_t}\right]^K\right)\sum_{r=1}^{R}\zeta(r)\left\{\left[1-\frac{e^{-n_t\gamma_{r+1}\sigma^2}}{(1+\gamma_{r+1})^{n_t-1}}\right]^K-\left[1-\frac{e^{-n_t\gamma_r\sigma^2}}{(1+\gamma_r)^{n_t-1}}\right]^K\right\} \quad (10)$$

standard, the feedback load must be included in the data rate formulation. An interesting metric is the throughput (Th) that accounts for the effective rate at which the data can be sent through a communication channel, taking into consideration the control signaling and feedback overhead. Remember that the MOB scheme is based on the availability of several users and on selecting the one with the largest SNIR value for each beam, thus increasing the number of available users would increase MOB performance but at the expenses of larger feedback load in the system. Beside the improvement in DR, the operator is also interested by the resources it has to employ in order to achieve such an improvement.

We formulate a metric that jointly accounts for the control signaling (i.e., PDCCH, RS, etc.), the header within the PDSCH (i.e., MAC, RLC, etc.), and the feedback as CQI, PMI and ACK in the performance evaluation. Even the feedback load is sent via the PUCCH [15] and not on the same downlink shared channel, but it should be included in the performance evaluation.

As the proposed downlink frame is organized into Q RBs in frequency domain and a scheduling period of T_F, then a total number of resource elements $(RE_{tot} = 12 \cdot Q \cdot 14 \cdot T_F)$ exists within each frame, where a resource element can be defined as one allocated subcarrier in one OFDM symbol. As we stated earlier a number of the available REs are reserved for the downlink control signaling (RE_{DLC}); while (RE_{ULC}) are composed of the bits employed for the feedback in the physical channel PUCCH and they must be included in our calculations, making the percentage of REs available for data transmission RE_{data} to be formulated as

$$RE_{data} = \frac{(RE_{tot} - RE_{DLC})}{(RE_{tot} + RE_{ULC})} \quad (11)$$

where RE_{ULC} is sent each frame duration (T_F). To mathematically formulate RE_{ULC} notice that it consists of CQI bits (b_{CQI}), PMI bits (b_{PMI}) and ACK bits (b_{ACK}) all of them modulated into QPSK complex symbols (i.e., 2 bits per symbol) before mapping them into REs [14]. Then we obtain RE_{ULC} as

$$RE_{ULC} = \frac{K \cdot b_{CQI} + K \cdot b_{PMI} + n_t \cdot b_{ACK}}{2} \quad (12)$$

where K is the number of users in the system and n_t selected users at the same frame. It remains to obtain the expression for the number B of bits sent within each frame through the PDSCH, that using the previous expression we express it as

$$B = DR\frac{(RE_{tot} - RE_{DLC})}{RE_{tot}}T_F \quad (13)$$

where the DR is given in Eqn.(10). B_h bits out of B are employed as header (i.e., MAC, RLC, etc) and looking to Fig. (1), we formulate them as

$$B_h = TCP + PDCP + V\Big(RLC + MAC + CRC\Big) \quad (14)$$

With all above expressions, we can state the throughput expression as

$$Th = DR\left(1-\frac{B_h}{B}\right)RE_{data} \quad (15)$$

IV. Simulations and Results

In order to check the behavior of the proposed scheme within LTE, its performance is presented by Monte Carlo computer simulations. A multiuser MIMO scenario is considered where the eNB transmitter is equipped with any number of antennas, but only 2 beams are generated and a total number of $K = 15$ users are available in the cell. All the users are assumed to have the same average channel characteristics, and showing the same distribution for the maximum SNR value, so that each user has the same probability to be selected. If this is not the case (e.g. heterogeneous users distribution in the cell, with some users far from the eNB), then a channel normalization (e.g. division by the path loss) can be accomplished for such a scenario.

Within the semi-persistent scheduling, the transmitted data in terms of transport blocks are organized into frames of $T_F = 20ms$ duration, and the selected users through MOB are assigned the whole resource blocks within the 20 ms interval. The control information (scheduling information) for all the selected users are transmitted via PDCCH within the first OFDM symbol. The data headers such as PDCP, RLC and MAC for all the selected users are transmitted within each transport block on the PDSCH. It is assumed that the system is saturated, so that there is always available packets for all the associated users. The simulation parameters are summarized in Table II.

We will compare three different schemes. The first one is the benchmark single serviced user scheme, where one beam is generated at the transmitter to serve only one randomly

Parameter	Single-user	Two-users
Bandwidth	3MHz	3MHz
Number of subcarriers	180	180
Number of RBs	15	15
Frame duration	20ms	20ms
Transmitted power	1W	1W
Max.size of transport block	6144	6144
Control signaling overhead	8.4%	23.9%
TCP-IP header	8 bytes	16 bytes
PDCP header	4 bytes	8 bytes
RLC header	2 bytes	4 bytes
MAC header	2 bytes	4 bytes
CRC (Cyclic Redundancy Check)	3 bytes	6 bytes
CQI	4 bits / 20ms	8 bits / 20ms
PMI-beam index	-	1 bit / 20ms / user
ACK	1 bit / 4ms	1 bit / 4ms / user

Table II: LTE Simulation parameters.

selected user, so that after the eNB randomly selects a user for transmission, that user will feedback a CQI based on its measured Signal to Noise Ratio (SNR) value to allow the eNB to apply AMC; this strategy is the one with lowest feedback requirement. The second scheme is the opportunistic single user service, where only one beam is generated and each user in the system feeds back its CQI then the eNB selects the best user. Lastly, the third one is our proposed scheme where the eNB generates two orthogonal beams, each user feeds back the CQI and PMI corresponding to the selected beam, then the eNB selects the best user for each one of the beams. Notice that AMC is employed according to Table I within the LTE systems.

The throughput performance of the three schemes is shown in Fig. (2) for a scenario with a variable number of active users. All the systems use the same energy restriction for a fair comparison in performance. The figure illustrates that our proposal outperforms the opportunistic single user scenario (i.e., scheme 2) for realistic number of users. Although our scheme induces a feedback load that enlarges as the number of users increases together with control signaling, but it is obvious that also greater diversity and multiplexing gain are obtained, which translates into a larger system throughput. Notice that the figure shows very good matching between the simulations and the mathematically obtained results.

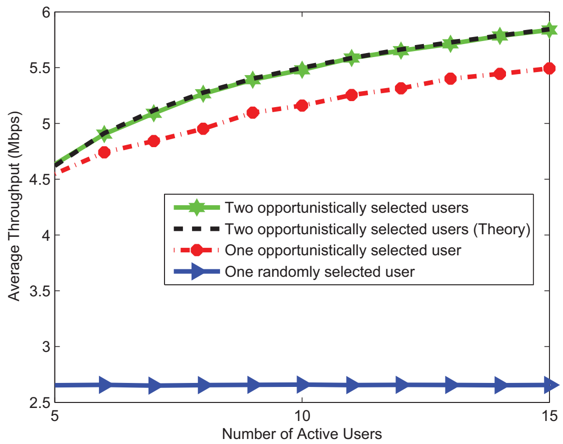

Fig. 2. Throughput comparison for the different schemes within an LTE scenario

Finally, to present the performance of our proposed scheme within different environments. Fig. (3) displays the throughput for different values of angle spread (AS) when there are 10 active users in the system, which shows the good performance of our scheme for all kinds of AS (i.e., covering both indoor and outdoor channels).

V. Conclusion

In this paper we present a new MAC scheme that supports Multiuser MIMO transmission, which is combined with MOB and AMC at the physical layer. To exploit the capabilities of the Multiuser MIMO scenario, opportunistic selection of the best set of users for transmission is accomplished. The simulation results show that although our scheme requires feedback payload at the MAC layer to simultaneously serve many users, it shows improved performance compared to single user techniques, while being back-compatible with the LTE specs. We formulate the throughput of our proposal through closed form expressions that match the computer-based simulations.

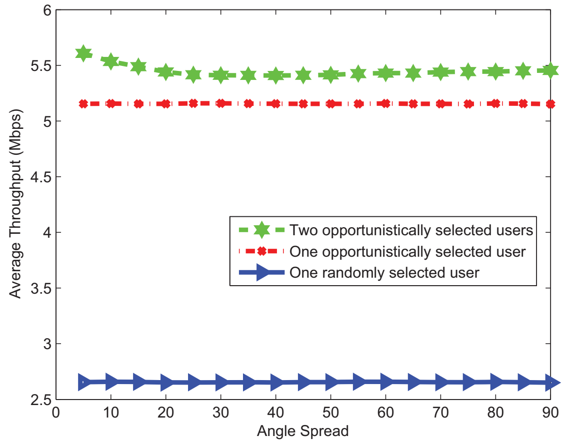

Fig. 3. Throughput comparison for the different angle spread values within an LTE scenario

Acknowledgement

This work was made possible by NPRP grant 09-406-2-153 from the Qatar National Research Fund (a member of The Qatar Foundation). The statements made herein are solely the responsibility of the authors.

References

[1] M. Mustaqim *et al.*, “LTE-Advanced: Requirements and Technical Challenges for 4G Cellular Network,” *CIS Journal*, vol. 3, no. 5, May 2012.
[2] D. Astely *et al.*, “LTE: the evolution of mobile broadband,” *IEEE Communications Magazine*, vol. 47, no.4, pp. 44 - 51, April 2009.
[3] S. Saha and R.Quazi, “Priority-coupling-a semi-persistent MAC scheduling scheme for VoIP traffic on 3G LTE,” *10th International Conference on Telecommunications*, pp. 325 - 329, June 2009.
[4] H. Zhang *et al.*, “MIMO downlink scheduling in LTE systems,” *IEEE INFOCOM 2012*, pp. 2936 - 2940, March 2012
[5] Q. Li *et al.*, “MIMO Techniques in WiMAX and LTE: A Feature Overview,” *IEEE Communications Magazine*, vol. 48, May 2010.
[6] R. Kwan and C. Leung, “A survey of scheduling and interference mitigation in LTE,” *Journal of Electrical and Computer Engineering*, vol. 2010, no.1, January 2010.
[7] T. Samarasinghe *et al.*, “The Feedback-Capacity Tradeoff for Opportunistic Beamforming,” *IEEE ICC*, Kyoto, June 2011.
[8] M. Sharif and B. Hassibi, “On the Capacity of MIMO Broadcast Channel with Partial Side Information,” *IEEE Trans. Inform. Theory*, vol. 51, no. 2, February 2005.
[9] N. Zorba and A.I. Perez-Neira, “CAC for Multibeam Opportunistic Schemes in Heterogeneous WiMax Systems Under QoS Constraints,” *IEEE Globecom*, New Orleans, November 2007.
[10] A. Larmo *et al.*, “The LTE link-layer design,” *IEEE Communications Magazine*, vol. 47, no. 4, pp. 52 - 59, April 2009.
[11] 3GPP TS 36.213, “Evolved Universal Terrestrial Radio Access (E-UTRA) Physical layer procedures,” Rel. 9.
[12] D. Gesbert *et al.*, “Transmit Correlation-aided Scheduling in Multiuser MIMO Networks,” *IEEE ICASSP*, May 2006.
[13] P. Viswanath *et al.*, “Opportunistic beamforming using dumb antennas,” *IEEE Trans. Inform. Theory*, vol.48, pp. 1277 - 1294, 2002.
[14] 3GPP TS 36.212, “Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding,” Rel. 11.
[15] 3GPP TS 36.211, “Evolved Universal Terrestrial Radio Access (E-UTRA) Radio Physical Channels and Modulation,” Rel. 11. 2012.