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Long Term Evolution Multiple-Input Multiple-Output Network in Unmanned Air Vehicles Platform

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Abstract**—**Line-of-sight (LOS) information, data rates, good quality, and flexible network service are limited by the fact that, for the duration of any given connection, they experience severe variation in signal strength due to fading and path loss. Wireless system faces major challenges in achieving wide coverage and capacity without affecting the system performance and to access data everywhere, all the time. In this paper, the cell coverage and edge rate of different Multiple-input multiple-output (MIMO) schemes in 20 MHz Long Term Evolution (LTE) system under Unmanned Air Vehicles (UAV) platform are investigated. After some background on the enormous potential of UAV, MIMO, and LTE in wireless links, the paper highlights the presented system model which attempts to realize the various benefits of MIMO being incorporated into UAV platform. The performances of the three MIMO LTE schemes are compared with the performance of 4x4 MIMO LTE in UAV scheme carried out to evaluate the improvement in cell radius, BER, and data throughput of the system in different morphology. The results show that significant performance gains such as bit error rate (BER), data rate, and coverage can be achieved by using the presented scenario.

Keywords**—**BER, LTE, MIMO, path loss, UAV.

I. Introduction

IN many scenario, high uninterrupted bandwidth requires LOS between transmitter and receiver station to minimize path loss attenuation. In non-line-of-sight (NLOS) condition, the accuracy of localization techniques is hampered by multi-path effects due to reflections, scattering, and diffractions. Therefore, it is necessary that NLOS mitigation methods are introduced to overcome the challenges of NLOS propagation [1]-[3]. UAVs can be used as radio cooperative relay such as amplify and forward in environments characterized by poor RF signals or communication range is limited [4]. Those environments can have different morphology and clutter such as lake, forest, valley, dense urban, urban where no LOS exists between transmitter and receiver stations [5]

With the development of smartphones and tablets in recent years, its data usage and the traffic rate increase time to time. For the system aspect it needs larger air interface bandwidths (i.e., high data-rate coverage required). In addition to this, with certain event or disaster, both voice and data traffic increased more than the existing network capacity, especially the system interoperability among network elements (radio, core, IP, and transmission), and power interruption. These results are not sufficient to provide a flexible and accurate communication service to dissemination of warnings, and in the coordination of disaster relief operations. Hence, there is a need for a wireless platform that can mitigate such kind of flexible voice and data service requirement.

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The fourth generation (4G) broadband communication, the growing demand of higher data rate under the constraint of limited available bandwidth, MIMO systems offer the possibility of spatial multiplexing which enables very high spectral efficiencies [6], [7] and also this leads to the development of an appropriate signal processing architecture to support the spectral requirement.

In LTE, MIMO techniques enable radio systems to achieve significant enhancement of throughput [8], cell coverage, spectral efficiency [9], [10]. For more efficiency, MIMO can be integrated into UAV system.

UAV system advantages such as great mobility, ease of transport, safety, easily controlled, low cost and more flexible extreme climate conditions, and this study used the UAV technology to get the real-time aerial data-collection, photogrammetry, videography and observation for ecological, meteorological, geological and hydrological data in disaster situation or some geological environments such as Erta Ale volcanoes area [11]. UAV can be classified in different categories, such as: flight altitude, endurance, speed, size (very small, small, medium, and large), and range (for instance short range and mid-range). In addition to this, many similar terms are used by different literature for example: Drone, UAVs, remotely piloted aerial vehicle (RPAV), Remotely Operated Aircraft (ROA), remotely piloted aircraft system (RPAS), Unmanned Combat Aerial Vehicle (UCAV), Unmanned Vehicle System (UVS), and UAS (Unmanned Aerial System) [12], [13].

From the different phases of LTE network deployment, core and radio design is critical for network performance. LTE system is designed to provide the peak data rate of 100 Mbps in downlink and 50 Mbps in the uplink. The performances of the network are further improved by applying carrier aggregation and enhanced multi-antenna [14], [15].

Cooperative relay such as amplify and forward (AAF) deployment, which is an integral part of LTE-Advanced, is used for diversity advantages, energy efficiency, extend cell coverage area and increases the overall throughput of the network [16]. Moreover, it can be used for cost optimization [17].

The increased capacity, broader coverage, and transmission speed are achieved through the introduction of additional MIMO antenna [18]. Moreover, the massive MIMO systems is the most promising technology available to address the ever increasing demand for spectral efficiency and more data traffic requirement of future wireless systems [19], [20].

In Cellular MIMO technologies, the terminals have additional degrees of freedom and can reduce the effects of interference from either an information theory point of view [21] or a system efficiency point of view [22]. The wisdom behind the MIMO systems is the ability to turn multipath propagation, traditionally a pitfall of cellular transmission, into a benefit for the user. MIMO effectively takes the advantage of resistance to multipath fading, and when available, multipath delay spread [23], and support for multiple users.

MIMO delivers the wireless terminals significantly enhance the performance of cooperative relay systems. For this study Maximum ratio combining (MRC) can be used effectively to enhance the benefits of such networks [24], [25].

Uplink and downlink link analysis in LTE system is the most critical step in the dimension phase; such as covered area reliability and service area reliability. In live networks due to non-orthogonal users and single-user detection, the coverage of the cell has an inversely proportional with the number of users in same cell. If there is only one user in the network, the maximum range between a user and a base station is normally limited by the maximum allowable transmission power of the user and the sensitivity of the base station; however, an increase in the number of users in the cell causes more interference in the receiver terminal. In fact, in some cases, antenna tilt and cell power level adjustment minimize the interference effect [26]. This is due to the fact that each user has to contribute for the retention of a certain Signal-to-Interference plus Noise Ratio (SINR) at the receiver for the satisfactory system performance.

The rest of the paper is organized as follows. Section II presents the presented system model. LTE propagation models, especially standard propagation model (SPM), have been discussed in Section III. Section IV provides the simulation results. The conclusion has been provided in Section V.

II. System Model

A. Scenario One

The presented setup is illustrated in Fig. 1. In general, there are two main parts: MIMO LTE system and user equipment (UE) with the received signal. To access network service, the end user can use the UE such as hand-held telephone or laptop equipped with a broadband adapter and they are also used as cooperator for spatial diversity.

The presented UAV platform is the communication facilities. The system consists of M transmit and N receive antennas constitutes M×N MIMO communication system.

MIMO channel consists of M antennas at the transmitter and N antennas at the receiver front end as shown Fig. 2.

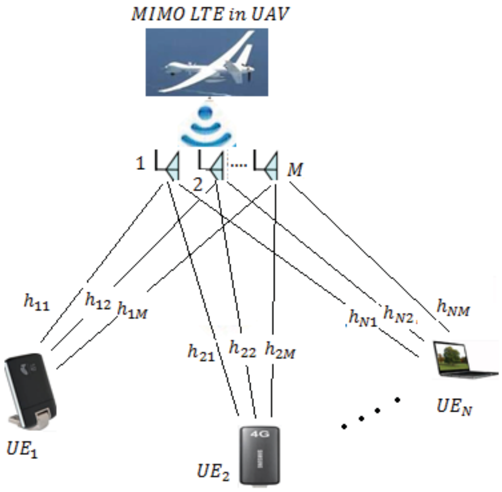

Fig. 1 Scheme of an (M×N) MIMO LTE system under UAV Platform

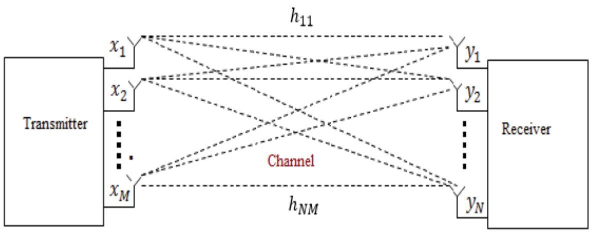

Fig. 2 MIMO Channel

The channel matrix can be expressed as [27], [28].

$$H = \begin{bmatrix} h_{11} & h_{12} \dots & h_{1M} \\ h_{21} & h_{22} \dots & h_{2M} \\ . & . \dots & . \\ . & . \dots & . \\ h_{N1} & h_{M1} \dots & h_{NM} \end{bmatrix} \quad (1)$$

where h_{ij} represents the channel gain (i.e., Complex Gaussian random variable) from transmission antenna j^{th} to the receive antenna i^{th}.

The standard formula for the Shannon maximum capacity of the channel, in bps/Hz, is given by [29], [30]:

$$C_{SISO} = \log_2(1 + \rho.|H|^2) \quad (2)$$

where ρ is the average signal-to-noise ratio at each receiver branch. H normalized complex gain of a fixed wireless channel value.

For M RX and N TX antennas the capacity of a MIMO channel can be expressed as [31]

$$C_{MIMO} = E\left[\log_2 \det(I_N + \frac{\rho}{M} HH^H)\right] [b/s/Hz] \quad (3)$$

where $\rho = \frac{p}{No}$ represents the SINR, and H is the channel transfer function. The operator $\{.\}^H$ represents the Hermitian transpose operation. Foschini and Gans [32] and Telatar [33] both demonstrated that the capacity in (3) grows linearly with

$m = \min(M, N)$ rather than logarithmically (2). This result can be intuited as follows: the determinant operator yields a product of nonzero eigenvalues of its (channel-dependent) matrix argument, each eigenvalue characterizes the SNR over eigenmode of the channel (also called an eigenchannel).

If $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_{\min}$ are the (random) order singular values of the channel matrix H, then we can express (3) as

$$C_{MIMO} = E\left[\sum_{i=1}^{n_{min}} \log_2(1 + \frac{\rho}{M}\lambda i^2)\right]$$
$$= \sum_{i=1}^{n_{min}} E\left[\log_2(1 + \frac{\rho}{M}\lambda i^2)\right] \text{[b/s/Hz]} \quad (4)$$

where $n_{min} = \min(M, N)$.

Since the product HH^H is positive semi define with positive eigenvalues $(\lambda_{1,}\lambda_{2,}, \lambda_{3,}, \ldots . \lambda_{v,})$ at the squares of the non-zero singular values of H (i.e., $\lambda_{1,=}\sigma_1^2, \lambda_{2,} = \sigma_2^2, \ldots . \lambda_v = \sigma_v^2$), it can be diagonalized by using a unitary matrix W as $HH^H = W\Lambda W^H$, where Λ diagonal matrix containing the eigenvalues $\lambda_{1,}\lambda_2, \lambda_3, \ldots . \lambda_{v,}$. Noting that [34], [35]:

$$\text{logdet}(I_N + \frac{\rho}{M}HH^H) = \text{logdet}(I_N + \frac{\rho}{M}W\Lambda W^H)$$
$$= \text{logdet}(W(I_N + \frac{\rho}{M}\Lambda)W^H) \quad (5)$$

We obtain

$$C = \sum_{i=1}^{v} \log(1 + \frac{\rho}{M}\lambda_i) \quad (6)$$

B. Signal-to-Interference-Plus-Noise-Ratio (SNIR)

A SINR is a measure of LTE signal quality. Usually, it is used by operators. Throughput over the channel becomes affected by variable SINR due to fading, path loss, and interference. In the LTE system, the uplink data rate of a user depends on the SINR over the resource block. UEs typically use SINR to calculate the Channel Quality Indicator (CQI) and it can be calculated as

$$SINR_n^m(t,k,c) = \frac{Pl_n^m(c)|h_n^m(t,k,c)|^2}{I_{oth}(t,k,c) + N_o} \quad (7)$$

where P is the transmitted power, $l_n^m(c)$ is the linear-valued of the path loss, and $h_n^m(t,k,c)$ are the complex channel gains, and N_o is the noise power, c is the carrier component, k is PRB, t is sub-frame, and $I_{oth}(t,k,c)$ is the received power from the interfering cells [36] and can be expressed as

$$I_{oth}(t,k,c) = \sum_{q=1,q\neq m}^{M} Pl_n^q \left|h_n^q(t,k,c)\right|^2 \quad (8)$$

Then, the variance of the interference σ^2 is set as

$$\sigma^2 = E\left[\sqrt{I_{oth}}(t,k,c)F\right] \quad (9)$$

where F $(0 \leq F \leq 1)$ is the load factor that associated with each eNodeB [36]. Indeed, SINR would simply be [37]

$$SINR = \frac{S}{I+N} \quad (10)$$

where S is the average received power (W) and mainly reference signal and physical downlink shared channels involved, I is the average inference power, and N is the background noise.

The system downlink throughput (υ) is given by

$$\upsilon = \frac{N_{bs}}{Hz} x N_s x \frac{N_{SF}}{T_{SF}} \quad (11)$$

where N_{bs} is the number of bits per symbol, N_S is the number of subcarriers, and N_{SF} is the number of symbols in sub frames [38].

Assuming that the maximum available transmission power is equally divided over the cell bandwidth, the LTE average received power (AveRxPowerDL) in the bandwidth allocated to the user is derived as:

$$\text{AveRxPowerDL} = \frac{P_T}{Link\ Loss\ DL} \quad (12)$$

where P_T is the total link loss in downlink (W), $Link\ Loss\ DL$ is a product of allocated bandwidth of LTE network cell (MHz) and total link loss in the downlink. In the LTE system, several different Maximum NodeB transmitter Powers deployed depend on the channel bandwidth, and Scalable channel bandwidths of LTE are: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, and 20 MHz in both the downlink and the uplink [37]. Specifically, the Maximum Node transmitter power in LTE network is usually 20 W or 40 W [38].

C. Scenario Two

Cooperative relay network with MIMO enabled source (*S*), UAV relay (*R*) and destination (*D*) having *N*, *L*, and *M* antennas, respectively (Fig. 3). For simplicity, N=L=M.

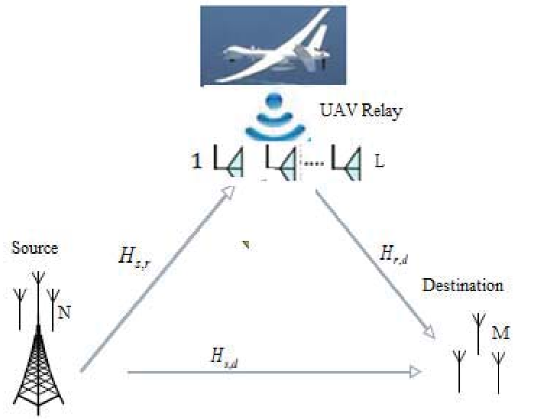

Fig. 3 Scheme of an (M × N) MIMO cooperative system under UAV Platform

Using maximal ratio combining technique (MRC), the signals received at the UAV relay and destination are given by

$$Y_r = \sqrt{P_s} H_{s,r} X_s + w_r \quad (13)$$

$$Y_d^{(1)} = \sqrt{P_s} H_{s,d} X_s + w_d^{(1)} \quad \text{(Phase one)} \quad (14)$$

$$Y_d^{(2)} = \sqrt{P_r} H_{r,d} X_r + w_d^{(2)} \qquad \text{(Phase two)} \tag{15}$$

respectively, where P_s is the transmission power of the source, $H_{s,r}, H_{s,d}$ are $L \times N$ and $M \times N$ channel matrices of the S-R and S-D links, and $w_r \sim CN(O_L, \sigma_r^2 I_{L\times L}), w_d^{(1)} \sim CN(O_M, \sigma_r^2 I_{M\times M})$ are the AWGN at the UAV relay and destination, respectively [39]-[41]. $H_{r,d}$ is an $M \times L$ channel matrix, and $w_d^{(2)} \sim CN(O_M, \sigma_d^2 I_{M\times M})$, is the AWGN at the destination in phase 2.

The signal transmitted by the UAV relay is given by

$$X_r = F Y_r \tag{16}$$

where F is an Lχ L pre-coding matrix and can be calculated as

$$F = 1/\sqrt{tr(\sigma_r^2 I_{Mr} + (P_s/M_s)} H_{s,r} H_{s,r}^H \tag{17}$$

By considering the mutual information theory and cooperative scheme between source and destination, the capacity of the AAF MIMO UAV relay channel is given by

$$C = \frac{1}{2} log_2 \left(\frac{\det\left(I_L + \left(I_L + \frac{P_s}{N\sigma_d^2} H_{s,r} H_{s,r}^H \right) \frac{P_r \sigma_r^2}{\sigma_d^2} F^H H_{r,d}^H H_{r,d} F \right)}{\det\left(\frac{P_r \sigma_r^2}{\sigma_d^2} F^H H_{r,d}^H H_{r,d} F \right)} \right) \tag{18}$$

The capacity of the amplify-and-forward MIMO relay channel with direct link (S-D) is given by

$$C = \frac{1}{2} log_2 \det\left(I_M + \frac{P_s}{N\sigma_d^2} H_{s,d} H_{s,d}^H \right) + \frac{1}{2} log_2 (I_M + \frac{P_s P_r}{N} H_{r,d} F H_{s,r} \left(I_N + \frac{P_s}{N\sigma_d^2} H_{s,d} H_{s,d}^H \right)^{-1} \times H_{s,r}^H F^H H_{r,d}^H (P_r \sigma_r^2 H_{r,d} F F^H H_{r,d}^H + \sigma_d^2 I_M)^{-1}) \tag{19}$$

BER formulation for an ideal MRC is obtained by using the optimum weights [42]-[44].

BER over the Rayleigh fading channels $H_{s,r}, H_{s,d}$ and, $H_{r,d}$ is formulated as

$$P_b = \frac{1}{16\pi} \int_{-\pi}^{\pi} f(\theta)\, \mathcal{M}_{\gamma 1}(\theta) \mathcal{M}_{\gamma 2}(\theta) d\theta \tag{20}$$

where $\mathcal{M}_{\gamma 1}(\theta) = \int_{-\infty}^{\infty} e^{-\alpha(\theta)\lambda} P_{\gamma i} d\lambda$ denotes the moment generating function (MGF) of the SNR $\gamma_i = 1,2$.

For Rayleigh independent fading channels, $|H_{s,d}|^2, |H_{s,r}|^2$ and $|H_{r,d}|^2$ are independent exponential random variable with parameter $1/\sigma_{s,d}^2$, $1/\sigma_{s,r}^2$ and $1/\sigma_{r,d}^2$, respectively. Thus

$$\mathcal{M}_{\gamma 1}(\theta) = \frac{1}{1 + K_{s,d}(\theta)} \tag{21}$$

where $K_{s,d}(\theta) \cong \alpha(\theta) P_s \sigma_{s,d}^2 / No$

$$\mathcal{M}_{\gamma 2}(\theta) = \frac{1}{1+K_{s,r}(\theta)} (1 + \frac{K_{s,r}(\theta)}{1+K_{s,r}(\theta)} \frac{P_s \sigma_{s,r}^2 + No}{P_r} \times \frac{1}{\sigma_{r,d}^2} \int_0^{\infty} \frac{\exp(-u/\sigma_{r,d}^2)}{u + R(\theta)} du) \tag{22}$$

where

$$R(\theta) \cong \frac{P_s \sigma_{s,r}^2 + No}{P_r (1 + K_{s,r}(\theta))} \tag{23}$$

III. Link Budget and Propagation Model

A. Link Budget

The link budget is one of the steps performed in the cell planning process. Radio link budget is the key concept for planning and design that allows the test of path loss and peak data rates required against the target of coverage level. The link budgets determine the maximum propagation loss and fade margin that allows users located on the edges of the cells to be able to use the system. The LTE link budget tool supports the analysis for down link (DL) Traffic, Upper link (UL) Traffic, and signaling channel and is used to determine cell range and number of base station. In order to formulate LTE link budget equation, the uplink shared data channel (PUSCH) has first priority since it is our limiting link [45].

$$L = P_t + G_t - L_t - SINR + G_r - L_r + G_{div} - N \text{ (dB)} \tag{24}$$

where, L (dB) =maximum path loss (down/up), P_t = is the transmitted power (dBm), G_t = is the transmitting antenna gain (dBi), G_r = is the receving antenna gain (dBi), $SINR$ =Signal to interference and noise ratio, L_t =is the transmitter loss (dB), L_r = is the receiver loss (dB), G_{div} =is the diversity gain (dB), N =Receiver Noise (dBm).

B. Propagation Model

During the propagation in a wireless channel, transmitted signals experience three basic mechanisms of electromagnetic wave propagation; namely, diffraction, reflection, and scattering. Many path loss models have been developed for different environments to be able to estimate the radio wave propagation as accurately as possible between the transmitter and receiver [46]. The accuracy prediction of path losses is used extensively in network planning and optimization particularly for conducting feasibility studies, frequency assignments and interference estimations especially during initial deployment [47]-[49]. LTE uses several propagation models [50] for different terrains: rural, dense urban, and suburban. In this paper, SPM is considered.

1. Free Space Path Loss Model (FSPL)

FSPL is the loss of the transmitted RF signal encountered by an electromagnetic wave, which results from a clear line of sight path between transmitter and receiver. Mathematically, the path loss experienced by the RF signal with the distance and frequency is given by [51].

$$\mathrm{PL_{dB}} = 20\log(\mathrm{d_{Km}}) + 20\log(\mathrm{f_{MHz}}) + 32.46 \tag{25}$$

where $\mathrm{d_{Km}}$ = distance between the transmitter and receiver in km $\mathrm{f_{MHz}}$ = frequency of operation in MHz.

2. Standard Propagation Model (SPM)

The SPM is an extension of Hata model designed to cover a distances ranging from 1-20 km and used for the prediction of path loss for GSM, UMTS, and LTE network. SPM includes two main parameters to provide better performance, i.e. the clutter loss and diffraction loss [52], [53]. The equation for SPM is expressed as:

$$P_r = \{K_1 + K_2 \log(d) + K_3 \log(h_t) + K_4.\text{Diffraction Loss} + K_5 \log(d).\log(h_t) + K_6 h_r + K_7 \log(h_r) + K_{clutter} f_{clutter} + K_{hill}\} \quad (26)$$

where P_r is received power (dBm), P_t is transmitted power (dB), d is the distance between transmitter and receiver station in meters, h_t is the effective height of the transmitting antenna in meters, h_r is the effective height of the receiving antenna in meters, K_1 is the frequency constant, K_2 is the distance attenuation constant, K_3 and K_4 are the correction coefficients of height of mobile station antenna, K_5 and K_6 are the correction coefficients of height of base station antenna, K_7 is the multiplying factor for $\log(h_r)$, $K_{clutter}$ is the multiplying factor for $f_{clutter}$, K_{hill} the is corrective factor for hilly region, and $f_{clutter}$ is the average of the weighted losses due to clutter [54]-[56].

IV. Simulation and Results Analysis

A. Simulation Assumption

TABLE I
SIMULATION PARAMETER

Parameter	Value
Edge MSC	QPSK 1/3 and 16QAM 2/3, 4/5
Carrier Frequency (MHz)	700,1800, and 2600
Area Coverage probability (%)	90%
Sectorization	3 sector
Antenna Schemes (MIMO)	1x2, 2x2, and 4x4
System Bandwidth (MHz)	10
UAV speed (km/h)	300
UE location	indoor
UAV (km)	5
IBLER (%)	10
Shadow Fading Margin (dB)	3.56

B. Simulation Results Analysis

In this section, the effects of LTE performance in MIMO UAV platform for each morphology and radio relay have been investigated. Four transmission modes are considered; namely, 1x2, 2x2 MIMO, 4x4 MIMO, and 4x4 MIMO in UAV platform. During the whole simulation, all users (UE) at indoor locations. The simulations were done by assuming rural, suburban, urban and dense urban macro cell environment. Path loss is calculated by using SPM.

Fig. 4 shows how the cell coverage can be increased by using MIMO with UAV system. The comparison between four scenarios shows that the cell coverage for 4x4 MIMO LTE in UAV system provides better coverage enhancement than the other schemes for the same input requirement. For example, the cell coverage was enhanced to 3.5 km in 4x4 LTE MIMO under UAV platform in the rural area, which is the largest value comparing both 1x2, 2x2, and 4x4 MIMO scheme.

Table II compares the SINR of 20 MHz at LTE 700 MHz in different morphology. It can be observed from the table that both Physical Downlink Shared Channel (PDSCH) and Physical Uplink Shared Channel (PUSCH) SINR more value in rural area compare suburban. In addition to this the SINR required to achieve the same throughput and cell coverage decreased comparing 1x2 and 2x2 configuration. The minimum required SINR seen for LTE 700 MHz system was at 3.06 dB for suburban 2x2 configurations. More results are obtained when applying 4x4 MIMO, and the best result is achieved by using 4x4 MIMO LTE in UAVs since we can get significant link budget advantage with large cells where LOS links are required.

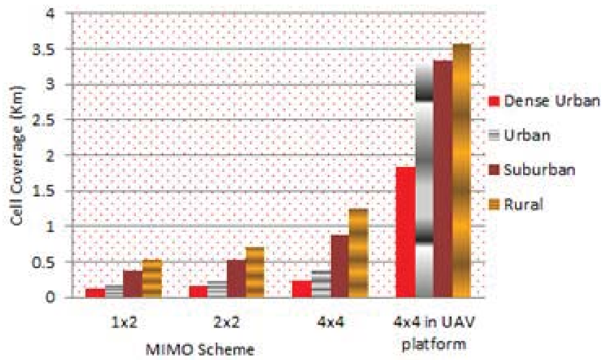

Fig. 4 Cell Coverage versus MIMO channel for a different morphology environment based on SPM propagation and FSPL model in LTE and 4x4 MIMO LTE in UAV system respectively

TABLE II
REQUIRED SINR WHEN SYSTEM FREQUENCY BAND LTE 700 MHZ

Morphology	Rural		Suburban	
MIMO	1x2	2x2	1x2	2x2
Required SINR(dB)-PDSCH	3.98	3.08	3.84	3.06
Required SINR(dB)-PUSCH	3.59	3.59	3.62	3.62
Edge Rate (kbps)	10862	1060	8166	5160

From Fig. 4 and Table II, it can be concluded that the 4x4 MIMO LTE in UAV platform shows better performance using 16QAM 1.33 and 16QAM 1.22 downlink and uplink, respectively.

Fig. 5 compares the BER of LTE of the different scheme and also shows the impact of different antenna configurations on the BER (see, scenario two proposed method). In this case, system model scenario two considered. This figure shows that, for direct transmission, the BER is higher than the relaying MIMO system, and when the value of Eb/No is 10 dB, the BER is approximately $10^{-1.75}$ and $10^{-3.5}$ for AAF without direct link and UAV relay with 4x4 MIMO schemes, respectively. UAV relay with MIMO scheme can significantly enhance the performance of the communication system by reducing the probability of error of the system and increasing the capacity.

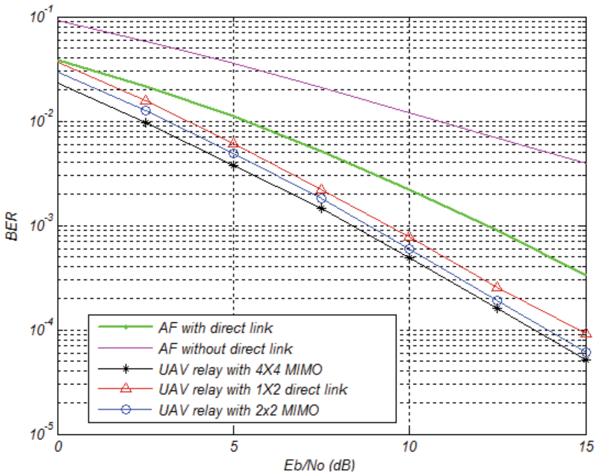

Fig. 5 Performance analysis of UAV relay with MIMO in LTE network

V. Conclusions

The presented scheme supports to provide high data rates, better quality of service, in flexible and safe communication framework. In this paper, the key aspects of the MIMO 4G cellular network deployed in UAV systems have been described including a discussion of propagation models and link budget approaches. These results describe the large increase in cell radius, capacity, and decrease in BER that can be achieved by using in presented methods. This shows a single MIMO LTE in UAV platform can cover wider area, efficient usage of bandwidth and replace a large number of terrestrial masts, along with their associated costs, environmental impact, and backhaul constraints. The presented model offers line of sight connectivity between the transmitter and receiver station. Thus, a proportion of users can get a high quality communication as low propagation delay and low blocking from the UAV. A MIMO LTE in UAV can be quickly deployed in the sky within a matter of hours. It has clear advantages when it is used in post disaster, emergency services, or special event.

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