Improved Location and Positioning Utilizing Single MIMO Base Station in IMT-Advanced System

A.A.M. Isa, M.H. Othman, Z. Manap, M.S.M. Isa, M. S. I. M. Zin, S. Saat and Z. Zakaria
Centre for Telecommunication Research and Innovation (CeTRI),
Faculty of Electronic and Computer Engineering (FKEKK),
Universiti Teknikal Malaysia Melaka (UTeM), Malaysia.
azmiawang@utem.edu.my

***Abstract*— This paper discusses an improvement of location and positioning estimation using one of the IMT-Advanced systems known as the mobile WiMAX. The Single MIMO Base Station (SMBS) in mobile WiMAX is combined with a virtual technique, known as the Virtual Base Stations, created a novel algorithm for location and positioning (L&P) purposes. This algorithm based on the angle of arrival (AOA) and angle of departure (AOD) measurement parameter completed the new SMBS algorithm with virtual base station (SMVirBS). The developed algorithm includes the effect of the geometric dilution of precision (GDOP) to assist with the location estimation accuracy. The simulation results showed that the proposed SMVirBS technique always outperforms the linear least square (LLS) algorithm in terms of estimated location accuracy. The technique also has the capability to work well in non-line of sight errors (NLOS).**

***Index Terms*— Angle of Arrival, Angle of Departure, Location and Positioning, MIMO.**

I. Introduction

Demand for reliable location and positioning (L&P) estimation for mobile service is exploding and it has become one of the fastest growing segments. A variety of location-based applications, such as emergency services, commercial applications and location-based advertising has derived service provider to give more attention on the need for accurate positioning performance and acceptable operating cost. In the mobile communications industry, it is generally agreed that the IMT-Advanced or 4G systems will include serving the end-users based on anytime-anywhere facilitation with higher data rate and the capability to fulfill the demand for reliable L&P estimation. With the advent of MIMO technology in mobile WiMAX as one of IMT-Advanced features, it has become feasible to adopt the technology into mobile location scenario because of its capability to mitigate NLOS errors [1]. In a wireless MIMO system, the important parameters used in determining the MS's position, such as the angle of arrival (AOA), angle of departure (AOD) and distance of the propagation path of multipath signals (ℓ), can be estimated using an advanced array signal processing. To limit the scope of this work, the estimation process of AOA, AOD [2, 3] and ℓ parameters will not be discussed in this paper.

The estimation of performance location is a function of the number of BSs, and thus the addition of measurements from more available BSs should result in an improved accuracy of the L&P system. It is, however, impractical to install additional BSs just for the sake of L&P accuracy [4]. Furthermore, the improvement in location estimation utilizing MIMO is insufficient due to the multiple signals transmitted from the same location of the BS. There are existing L&P systems which make use of only one BS by exploring TOA[5], AOA and AOD information, in which it can be measured by antenna arrays at both ends of a MIMO system such as in [6,7]. The L&P technique in [6] employs an iterative Taylor series to determine the location of MS. This method, however, requires an initial estimation of the MS position, which may suffer from a convergence problem. The technique in [7] requires prior information about the NLOS path and uses least squares (LS) to calculate the MS position. However, it performs poorly when errors in the AOA, AOD and ℓ parameters are large. The technique in [8] uses a sentinel function derived from a geographical interface system (GIS) database kept in the BS to view certain information about the environment (e.g. buildings and other obstacles) in the neighborhood of BS. The technique only considers fixed obstacles lying within the cell coverage area and the azimuth plane of the BS antenna. It will not give accurate information about the environment if the GIS are not updated and there are obstacles coming from moving objects. As a result, the accuracy of location estimation will deteriorate.

In this paper, based on the estimated multipath signal parameters in the MIMO system described above, a novel method using a single MIMO BS with a virtual BS concept to locate the MS is presented, namely the SMVirBS algorithm. This approach seeks to reduce the error arising from the estimation of multiple paths by positioning the multiple paths at virtual BSS [9]. The remainder of this paper is organized as follows. Section II explains the system model for Single MIMO base station known as SMBS. Section III and IV discuss the algorithm used together with the proposed SMBS techniques using virtual base station. Section V presents performance results and finally section VI concludes the paper.

II. System Model for Single Mimo Base Station (SMBS)

The system model adopts a simplified 3GPP MIMO channel with $N_t \times N_r$ transmission paths between the BS and the MS as proposed in IEEE802.16m [10]. In this work, a macrocellular environment is considered by utilizing a ring of scatterers (ROS) model with each signal travelling from the BS or MS experiences a single bounce only. This mechanism is illustrated in Figure 1. Although only one scatterer is shown in Figure 1, it is assumed that there are many scatterers that correspond to $N_t \times N_r$ transmission paths. The geometry of the ROS model (it can also be referred to as a geometrically based single bounce macrocellular model (SBM)) assumes the scatterers are uniformly distributed within a radius R_{ROS} around the MS [11].

The model is based on the assumption that in macrocell environments, where BS antenna heights are relatively high, there will be no signal reflecting from locations near the BS. Let n denotes the number of multiple transmission paths between the BS and the MS, i.e. $n = N_t \times N_r$. As illustrated in Figure 1, $(x_1, y_1), (x_u, y_u)$ and (x_{S_i}, y_{S_i}) define the position of BS, MS and *i*th scatterer respectively. Note that the MS is assumed to be relatively static; hence the Doppler shift effect can be ignored. Each propagation path is parameterized by three components, namely $\theta_{T_i}, \theta_{R_i}$ and δ_i , where θ_{T_i} , θ_{R_i} and δ_i stand for AOD, AOA and the distance for the *i*th propagation path from the BS and MS respectively. It is further assumed that the BS has knowledge of the number of paths corresponding to the MS, and of the parameters associated with each path. However, the coordinates of (x_u, y_u) and (x_{S_i}, y_{S_i}) are not known.

According to SBM, as shown in Figure 1, the measured range between the serving BS and the MS can be given as:

$$\delta_{i,n}(t_i) = r_{LOS_{i,n}}(t_i) + NLOS_{i,n}(t_i) + \eta_{i,n}(t_i) \tag{1}$$

where $r_{i,n}(t_i)$ is the true range between BS_i and MS, $NLOS_{i,n}(t_i)$ is the NLOS error range and $n_{i,n}(t_i)$ is a Gaussian measurement of noise at time sample t_i . $i = 1$ denotes a single available BS and $n = 1, 2, ..., N_t \times N_r$ where N_t is the number of antenna at the transmitter and N_r is the number of antenna at the receiver. Let us assume that the measurement noise is a zero mean AWGN, which is negligible in comparison with NLOS noise. Furthermore, we assume that the NLOS error distribution is positive. Therefore Equation (1) can be modified as:

$$\begin{aligned} \delta_{i,n}(t_i) &= r_{LOS_{i,n}}(t_i) + NLOS_{i,n}(t_i) \\ &= r_{T_{i,n}}(t_i) + r_{R_{i,n}}(t_i) \end{aligned} \tag{2}$$

where $r_{T_{i,n}}$ and $r_{R_{i,n}}$ represent the range between the BS and the scatterer, and the distance between the scatterer and the MS respectively.

Likewise, the AOD measured at the BS can be modelled as:

$$\hat{\theta}_{T_i} = \theta_{T_i} + \eta_{AOD} \tag{3}$$

where θ_{T_i} denotes the true AOD and η_{AOD} represents the error in AOD measurement at the BS due to NLOS effects. Next, the AOA measured at the MS can be modelled as:

$$\hat{\theta}_{R_i} = \theta_{R_i} + \eta_{AOA} \tag{4}$$

where θ_{R_i} and η_{AOA} denote the true AOA and the error in the AOA measurement at the MS.

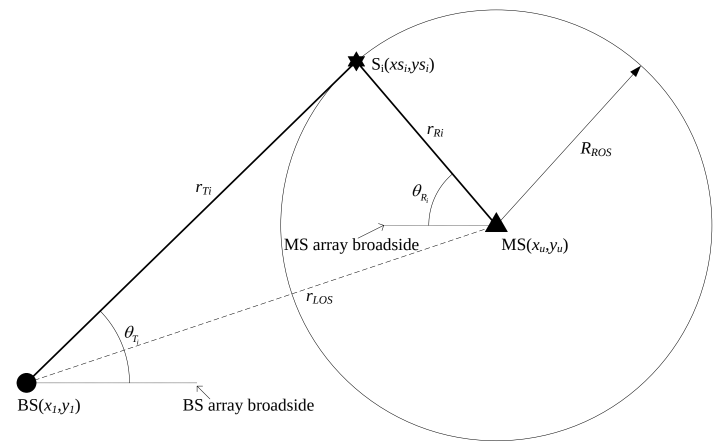

Figure 1: Simplified 3GPP channel model for MIMO Simulations Using SBM with a Ring of Scatterers (ROS) for a MIMO communication system

III. SMBS ALGORITHM USING LINEAR LEAST ESTIMATION

In order to estimate the position of the MS, it is necessary to have knowledge about the positions of the scatterers, $S(x_S, y_S)$. As shown in Figure 1, it is straightforward to acquire the SBM parameters of $\theta_{T_i}, \theta_{R_i}$ and δ_i as a function of the positions of the MS and scatterers, which are given as follows:

$$\theta_{T_i} = \begin{cases} \tan^{-1}\left(\dfrac{y_{S_i} - y_1}{x_{S_i} - x_1}\right) , & \dfrac{y_{S_i} - y_1}{x_{S_i} - x_1} > 0 \\ \tan^{-1}\left(\dfrac{y_{S_i} - y_1}{x_{S_i} - x_1}\right) + \pi, & \dfrac{y_{S_i} - y_1}{x_{S_i} - x_1} < 0 \end{cases} \tag{5}$$

$$\theta_{R_i} = \begin{cases} \tan^{-1}\left(\dfrac{y_{S_i} - y_u}{x_{S_i} - x_u}\right) , & \dfrac{y_{S_i} - y_u}{x_{S_i} - x_u} < 0 \\ \tan^{-1}\left(\dfrac{y_{S_i} - y_u}{x_{S_i} - x_u}\right) + \pi, & \dfrac{y_{S_i} - y_u}{x_{S_i} - x_u} > 0 \end{cases} \tag{6}$$

for $i = 1, 2, ..., n$ where $n = N_t \times N_r$. Similarly, as we know the distance between the BS and the MS represented by δ , is measured as a propagation delay time (TOA), τ multiple of the light velocity, c and the TOA, then τ can be computed as:

$$\tau_i = \frac{r_{T_i} + r_{R_i}}{c}, \quad i = 1, 2, ..., n \tag{7}$$

where:

$$r_{T_i} = \left\| \boldsymbol{x_1} - \boldsymbol{x}_{\boldsymbol{S}_i} \right\| = \sqrt{\left(x_1 - x_{S_i}\right)^2 + \left(y_1 - y_{S_i}\right)^2} \tag{8}$$

$$r_{R_i} = \left\| \boldsymbol{x_u} - \boldsymbol{x}_{\boldsymbol{S}_i} \right\| = \sqrt{\left(x_u - x_{S_i}\right)^2 + \left(y_u - y_{S_i}\right)^2} \tag{9}$$

Hence, the distance between the BS and MS for the *i*th propagation path is given as follows:

$$\delta_i = r_{T_i} + r_{R_i} \tag{10}$$

Therefore, the possible coordinates of the scatterers found along θ_{T_i} for the first *n*, are:

$$x_{S_i} = x_1 + r_{T_i} \cos\theta_{T_i} \tag{11}$$

$$y_{S_i} = y_1 + r_{T_i} \sin\theta_{T_i} \tag{12}$$

and the coordinates of the MS are expressed as:

$$x_u = x_{S_i} - r_{R_i} \sin\theta_{R_i} \tag{13}$$

$$y_u = y_{S_i} - r_{R_i} \sin\theta_{R_i} \tag{14}$$

It follows that by substituting Equation (11) and (12) into Equation (13) and (14) respectively, the possible positions of the MS can be described as follows:

$$x_u = x_1 + r_{T_i} \cos\theta_{T_i} - r_{R_i} \cos\theta_{R_i} \tag{15}$$

$$y_u = y_1 + r_{T_i} \sin\theta_{T_i} - r_{R_i} \sin\theta_{R_i} \tag{16}$$

It was explained earlier that the scatterers are uniformly distributed on a ring centered on the MS with radius R_{ROS}. Therefore, the distance between the coordinates of the scatterers and the MS's position is assumed to be similar to the radius of R_{ROS}.

$$r_{R_i} = R_{ROS} \tag{17}$$

Manipulating Equation (17) into (10) and then replacing it into Equation (15) and (16) gives:

$$x_u = x_1 + \left(d_i - R_{ROS}\right)\cos\theta_{T_i} - R_{ROS}\cos\theta_{R_i} \tag{18}$$

$$y_u = y_1 + \left(d_i - R_{ROS}\right)\sin\theta_{T_i} - R_{ROS}\sin\theta_{R_i} \tag{19}$$

For simplicity, the position of the MS can be determined using a Least Squares (LS) approach and the above linear equations can be written in matrix form as:

$$\boldsymbol{Gx} = \boldsymbol{H} \tag{20}$$

where:

$$\boldsymbol{G} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ \cdots & \cdots \\ 1 & 0 \\ 0 & 1 \\ \cdots & \cdots \\ & \vdots \\ \cdots & \cdots \\ 1 & 0 \\ 0 & 1 \end{bmatrix}, \quad \boldsymbol{x} = \begin{bmatrix} x_u \\ y_u \end{bmatrix}$$

$$\boldsymbol{H} = \begin{bmatrix} x_1 + c\tau_1 \cos\theta_{T_1} - R_{ROS_1}\left(\cos\theta_{T_1} + \cos\theta_{R_1}\right) \\ y_1 + c\tau_1 \sin\theta_{T_1} - R_{ROS_1}\left(\sin\theta_{T_1} + \sin\theta_{R_1}\right) \\ \cdots\cdots\cdots \\ x_1 + c\tau_2 \cos\theta_{T_2} - R_{ROS_2}\left(\cos\theta_{T_2} + \cos\theta_{R_2}\right) \\ y_1 + c\tau_2 \sin\theta_{T_2} - R_{ROS_2}\left(\sin\theta_{T_2} + \sin\theta_{R_2}\right) \\ \cdots\cdots\cdots \\ \vdots \\ \cdots\cdots\cdots \\ x_1 + c\tau_i \cos\theta_{T_i} - R_{ROS_i}\left(\cos\theta_{T_i} + \cos\theta_{R_i}\right) \\ y_1 + c\tau_i \sin\theta_{T_i} - R_{ROS_i}\left(\sin\theta_{T_i} + \sin\theta_{R_i}\right) \end{bmatrix}$$

The LS solution for (20) is given by:

$$\boldsymbol{x} = \left(\boldsymbol{G}^T\boldsymbol{G}\right)^{-1}\boldsymbol{GH} \tag{21}$$

IV. PROPOSED SMBS ALGORITHM WITH VIRTUAL BASE STATIONS

It has been proven in [6-8, 12] that the position of MS can be estimated by using only one BS with a supporting MIMO system. However, with the existing single BS, the geometric factor was not considered when estimating the MS in previous studies. The development of a single BS with MIMO system starts a new era in L&P systems, though the systems have poor geometrical topology. The effects of geometric topology associated with L&P accuracy can be observed using geometric dilution of precision (GDOP) [13, 14]. The GDOP is defined as an index to observe the location precision of the MS under various geometries within networks. A large GDOP corresponds to a poor geometric layout established by the MS and its associated BS, which consequently results in increased location estimation error. In contrast, as the GDOP becomes smaller, the effect of the geometric relationship on location estimation accuracy becomes trivial; hence there is an improved location estimation. These GDOP effects can be a dominant factor in location estimation accuracy if the location and number of BSs in the coverage area are not carefully planned [15].

The concept of the proposed algorithm is based on the technique that a virtual BS is developed in order to improve poor geometrical topology. It has been shown that when the number of available BSs increases, the accuracy of location estimation is also improved, with a provision that the location of the BS is proper. However, the algorithm proposed only considers the range (TOA) measurements, whereas this proposed technique utilizes both range (ℓ) and angle (AOD and AOA) measurements to calculate the location of MS. Under the assumption of a single bounced scattering model, as shown earlier in Figure 1, the proposed SMBS algorithm with VirBS is depicted in Figure 2. With scatterers regarded as virtual observation stations, the problem of single BS location can be converted into a problem of multi-BS location with the development of virtual BSs. This can be achieved by initially determining a suitable location for a virtual BS. The number of virtual BS corresponds to $N_t \times N_r$ transmission paths. It is known that in order to design a VirBS location, it requires the initial MS. In this case, the initial MS can be obtained using the LS method. Then, the location of the VirBS can be computed so that the minimal value of GDOP is attainable with respect to the initial location estimate of MS. As stated earlier, the GDOP value obtained at the MS's true position can be represented as [16, 17]:

$$GDOP = \sqrt{trc\left(G^T G\right)^{-1}} \tag{22}$$

where *trc* and *T* indicate the traces (i.e. sum of the diagonal elements) and the transpose of the matrix respectively as well as the matrix *G* for range measurement (TOA) is given by [13].

$$G_{TOA} = \begin{bmatrix} \frac{x_e - x_1}{\ell_1} & \frac{y_e - y_1}{\ell_1} \\ \frac{x_e - x_{v_1}}{\ell_{v_1}} & \frac{y_e - y_{v_1}}{\ell_{v_1}} \\ \vdots & \vdots \\ \frac{x_e - x_{v_n}}{\ell_{v_n}} & \frac{y_e - y_{v_n}}{\ell_{v_n}} \end{bmatrix} \tag{23}$$

Instead of depending only on the TOA measurements to calculate GDOP, we also define the counterpart GDOP expression for angle measurements. With this technique, we consider that the first arrival of signal (TOA) will be maintained at a physical BS, whereas the remaining receiving signals will be converted to VirBSs.

Referring to Figure 2, the angle that measures the LOS between the BS and MS relative to the baseline is defined as θ_i for $i = 1,2 \ldots N_t \times N_r$. Thus, the following equation can be established:

$$\sin(\theta) = \frac{y_u - y_i}{\ell_i} \qquad \cos(\theta) = \frac{x_u - x_i}{\ell_i} \tag{24}$$

Following a procedure similar to Equation (23), matrix *G* for AOA measurements becomes [18].

$$G_{AOA} = \begin{bmatrix} \frac{-\sin\theta_1}{\ell_1} & \frac{\cos\theta_1}{\ell_1} \\ \frac{-\sin\theta_2}{\ell_2} & \frac{\cos\theta_2}{\ell_2} \\ \vdots & \vdots \\ \frac{-\sin\theta_n}{\ell_n} & \frac{\cos\theta_n}{\ell_n} \end{bmatrix} \tag{25}$$

From Equation (22), multiplying G_{AOA}^T by G_{AOA} produces:

$$G_{AOA}^T G_{AOA} = \begin{bmatrix} \sum_{i=1}^{n} \frac{\sin^2\theta_i}{\ell_i^2} & \sum_{i=1}^{n} \frac{-\sin\theta_i\cos\theta_i}{\ell_i^2} \\ \sum_{i=1}^{n} \frac{-\sin\theta_i\cos\theta_i}{\ell_i^2} & \sum_{i=1}^{n} \frac{\cos^2\theta_i}{\ell_i^2} \end{bmatrix} \tag{26}$$

It can be shown that $G_{AOA}^T\ G_{AOA}$ is a positive definite matrix, and that its inverse matrix exists. Following the 2x2 matrix in Equation (26), we have:

$$trc\left(G_{AOA}^T G_{AOA}\right)^{-1} = \frac{trc\left(G_{AOA}^T G_{AOA}\right)}{\left|G_{AOA}^T G_{AOA}\right|} \tag{27}$$

After some algebraic manipulation, the numerator and denominator of Equation (27) can be simplified to:

$$trc\left(G_{AOA}^T G_{AOA}\right) = \sum_{i=1}^{n} \frac{1}{\ell_i} \tag{28}$$

and:

$$\left|G_{AOA}^T G_{AOA}\right| = \sum_{i=1}^{n-1}\sum_{k=i+1}^{n} \frac{1}{\ell_i^2 \ell_k^2} \sin^2\left(\theta_k - \theta_i\right) \tag{29}$$

Therefore, GDOP for AOA measurements can be derived as:

$$GDOP_{AOA} = \sqrt{\frac{\sum_{i=1}^{n} \frac{1}{\ell_i}}{\sum_{i=1}^{n-1}\sum_{k=i+1}^{n} \frac{1}{\ell_i^2 \ell_k^2} \sin^2\left(\theta_k - \theta_i\right)}} \tag{30}$$

It can be seen from Equation (30) that GDOP is affected by the distance between the BS and the estimated MS. When the number of BSs (physical BSs and VirBSs) is constant and the distance between any BS and the MS is the same, the best angles to place the virtual BS can be derived by solving Equation (31):

$$\left(\theta_1, \theta_2, ..., \theta_n\right) = \underset{(\theta_1, \theta_1, ..., \theta_n)\in[0,2\pi]}{\arg\max} \sum_{i=1}^{n-1}\sum_{k=i+1}^{n} \sin^2\left(\theta_k - \theta_i\right) \tag{31}$$

To acquire the lowest GDOP, the BSs (physical BSs and VirBSs) are uniformly scattered and centred on the MS, which fulfills the following conditions and is illustrated in Figure 3:

$$\theta_{v_1} - \theta_1 = \theta_{v_2} - \theta_{v_1} = \theta_{n-1} - \theta_{n-2} = \frac{\pi}{n} = \phi \tag{32}$$

and:

$$\ell_1 = \ell_2 = ... = \ell_n = \delta \tag{33}$$

Therefore, for the available *i* VirBSs, the position of the VirBSs can be obtained as:

$$\boldsymbol{x}_{v_i} = \left[\delta\cos\phi_1^m .....\delta\cos\phi_i^m, \delta\sin\phi_1^m ....\delta\sin\phi_i^m\right]^T + \left[x_e, y_e\right]^T \tag{34}$$

and the new set of BSs (physical BSs and VirBSs) for the location estimation is obtained as:

$$BS_{x_v}^i = \left\{\boldsymbol{x}_1, \boldsymbol{x}_{v_1}, ..., \boldsymbol{x}_{v_i}\right\} \tag{35}$$

where $\boldsymbol{x}_1 = \left[x_1, y_1\right]$ denotes the physical BS, and $\boldsymbol{x}_{v_i} = \left[x_{v_1}, y_{v_i}\right]$ represents the location of the *i*th VirBS for $i = 1,2,\dots,n-1$. Following the new set of locations of BSs given in (35) and the measurement parameters of range, $\delta_{i,n} = \left(\delta_{1,1}, \delta_{1,2}, ..., \delta_{1,n}\right)$, AOD, $\theta_{T_{i,n}} = \left(\theta_{T_{1,1}}, \theta_{T_{1,2}}, ..., \theta_{T_{1,n}}\right)$ and AOA, $\theta_{R_{i,n}} = \left(\theta_{R_{1,1}}, \theta_{R_{1,2}}, ..., \theta_{R_{1,n}}\right)$, a new estimate of the MS's location, can be calculated. However, the AOD and AOA are changed due to the location of the VirBSs. These values can be solved by finding the locations of the scatterers with respect to the VirBS location. Referring to Figure 2, it is assumed that the first parameters of $\theta_{T_{1,1}}$, $\theta_{R_{1,1}}$ and $\delta_{1,1}$, are used by the physical BSs, while the second parameters will be employed by the first VirBS.

For the triangle formed by the BS, the scatterer and the MS are based on the second parameters and the application of the law of cosines result to:

$$\alpha_2 = \cos^{-1}\left(\frac{r_{T_2}^2 + r_{LOS}^2 - r_{R_2}^2}{2 r_{T_2} r_{LOS}}\right) \tag{36}$$

The angle at VirBS should have a similar value to Equation (36);

$$\hat{\alpha}_2 = \alpha_2 \tag{37}$$

Next, the angle between the x-axis is acquired and the line from the estimated MS to the VirBS is:

$$\hat{\gamma}_2 = \arctan\left(\frac{y_e - y_{v_1}}{x_e - x_{v_1}}\right) \tag{38}$$

Therefore, the angle between the broadside and the line from the VirBS to the scatterer can be obtained as follows:

$$\hat{\theta}_{T_2} = \hat{\alpha}_2 + \hat{\gamma}_2 \tag{39}$$

Finally, the new scatterer coordinates VirBS are given by:

$$\begin{aligned} \hat{x}_{S_2} &= \hat{r}_{T_2}\cos\hat{\theta}_{T_2} + x_{v_1} \\ \hat{y}_{S_2} &= \hat{r}_{T_2}\sin\hat{\theta}_{T_2} + y_{v_1} \end{aligned} \tag{40}$$

It is noted that the value of $\hat{r}_{T_2}$ is similar to r_{T_2}.

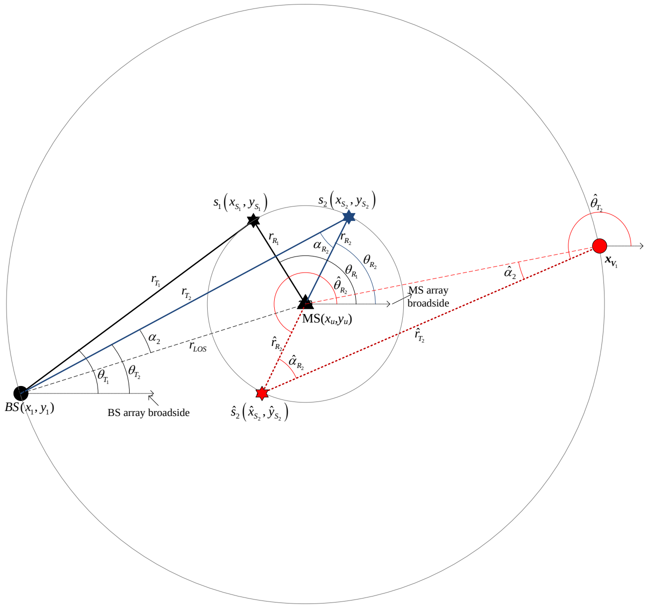

Figure 2: Geometry of SMVirBS Based Location System

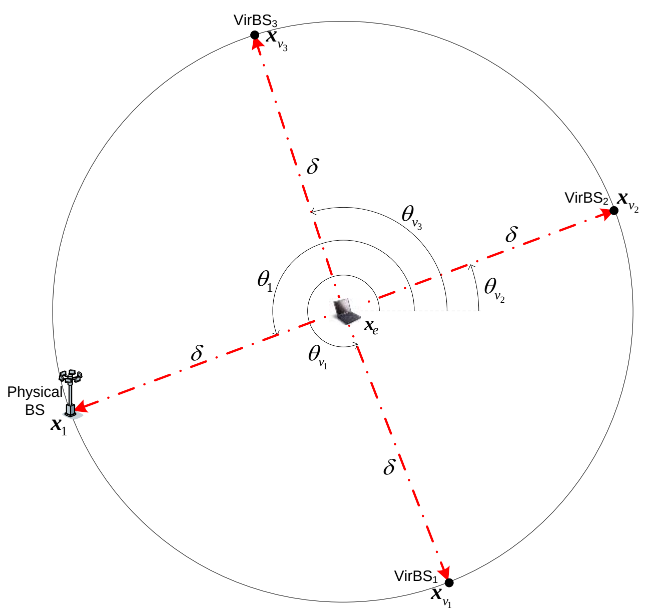

Figure 3: Relation between the BS, VirBSs and the MS

V. PERFORMANCE ANALYSIS FOR THE SMVIRBS ALGORITHM

The performance analysis presents the results of the simulation which seek to investigate the effectiveness of the proposed SMVirBS algorithm under various MIMO antenna configurations and where a comparison with the existing LLS algorithm has been performed. The simulation scenario is performed under macrocellular environments, according to the system model described in Section II. The physical BS is assumed to be positioned at $BS_1(x_1 = 500, y_1 = 4750)$ in a two-dimensional (2-D) plane and the cell is modelled as a regular hexagonal shape with a radius of 1km. The geometric coordinates of the true MS are set to $MS(x_u = 1500,\ y_u = 3750)$. The specific coordinates location of the physical BS and true MS are for the simulation purpose only. The range and angle related measurements are in metres and degrees respectively. To investigate the performance of our proposed SMVirBS algorithm, the BS and MS are equipped with MIMO 2x2, MIMO 4x2, and MIMO 4x4 with a half-wavelength distance between adjacent antennas. It is assumed that the number of multipath (consisting of range, AOD and AOA parameters) to be equal to the number obtained by multiplying the number of transmitter antenna N_t by the number of receiver antenna N_r.

The first simulation was to study the effects of several MIMO antenna mode configurations utilizing the proposed SMVirBS algorithm with L&P estimation of errors. In this simulation, the parameters for NLOS errors, such as radius of ROS, R_{ROS}, AOD SD and AOA SD, are fixed at 500m, 10 degrees and 5 degrees respectively.

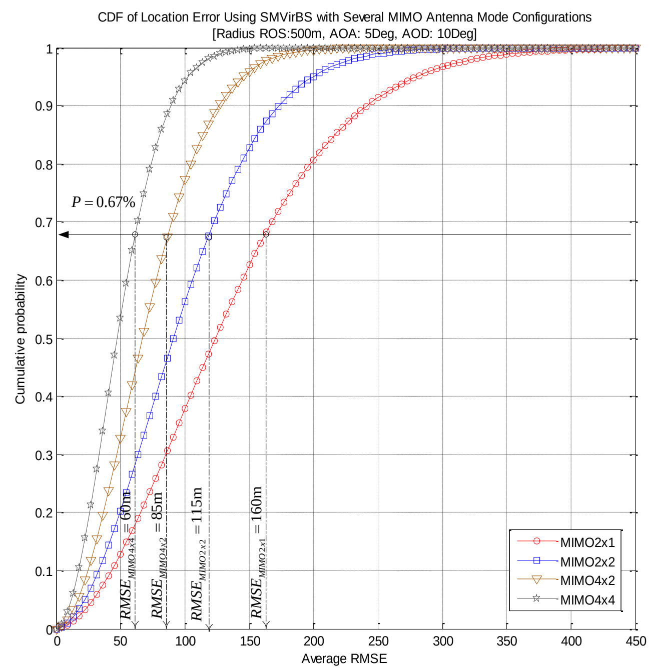

Figure 4: CDF Comparison of Location Errors for several MIMO Antenna Arrays [Radius of ROS, Rr: 500m, AOD SD: 10 degrees, AOA SD: 5 degrees]

The improvement in the L&P estimation provided by the hybrid SMVirBS schemes can be observed in the cumulative distribution function (CDF) of average root mean square error (RMSE), as illustrated in Figure 4. It can be observed that with an augmentation of the MIMO antenna mode configurations, this will reduce the average location error. For example, for cumulative probability $P = 0.67$, the MIMO 2x1 antenna has an average of $RMSE$ = 160 meters. However, for the same cumulative probability, RMSE is reduced to 115 meters if

MIMO 2x2 is employed, 85 meters if MIMO 4x2 is used, and 60 meters if MIMO 4x4 is utilized for the L&P estimation.

Figure 5 represents the effects of the radius of the ROS, R_{ROS} , on the location of estimation performance between the SMVirBS and LLS schemes that utilize several antenna mode configurations. In this simulation, the values of AOD SD and AOA SD are fixed at 5 and 3 degrees respectively. It can be seen that the performance of location estimation at any MIMO antenna is considered to perform better as the radius of ROS, R_{ROS} decreases for the proposed SMVirBS and LLS algorithms. On the other hand, it needs to be highlighted that the proposed SMVirBS always outperforms the LLS scheme and that the gap in RMSE error becomes larger as the radius of R_{ROS} increases. For instance, in MIMO4x4 antenna mode, the average RMSE measured at R_{ROS} of 500m for the proposed SMVirBS is about 85 metres and increases to 236 metres when utilizing the LLS algorithm which produces about a 150 metres gap (about a 64 per cent improvement). Meanwhile, when R_{ROS} is set at 100m., the average RMSE for the SMVirBS and LLS algorithms is 33 metres and 53 metres, respectively, leaving a gap of about 20 metres (about a 38 per cent improvement).

For different distances between the serving BS and target MS, the improvement in location estimation accuracy with the proposed methods can also be seen in Figure 6. In this simulation, the NLOS parameters for the radius of ROS, AOD SD and AOA SD are fixed at 300m., 5 degrees and 3 degrees respectively. In general, it can be observed that average RMSE obtained by both proposed SMVirBS and LLS algorithms increases as the distance between the MS and serving BS becomes large.

However, the SMVirBS algorithm gives better results than the LLS algorithm for any MIMO antenna configuration considered. It also needs to be highlighted that larger antenna mode configurations are less affected by the increments in distance between the BS and MS. For example, for a MIMO 4x4 utilizing the SMVirBS algorithm, the average location error at a distance of 1km to 2km increases by about 10 metres whereas for a MIMO 2x2 the average location error increases by about 30 metres for the same distances.

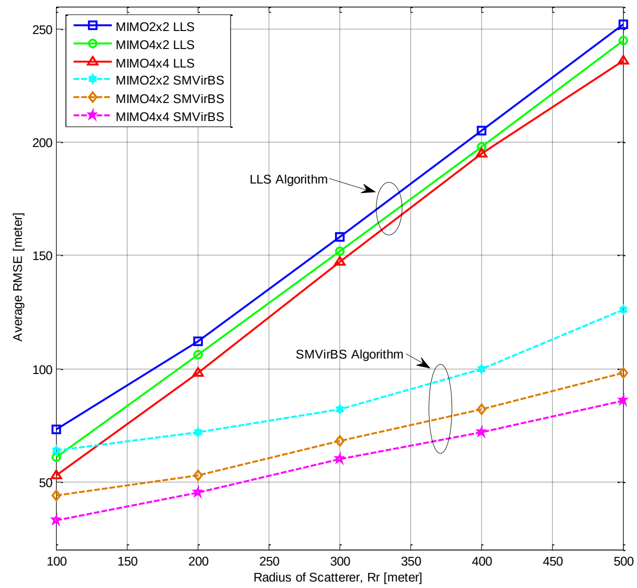

Figure 5: Effect of the radius of ROS on average RMSE performance between the proposed SMVirBS and LLS algorithms utilising several Antenna Mode Configurations [AOD SD: 5 Degrees, AOA SD: 3 Degrees].

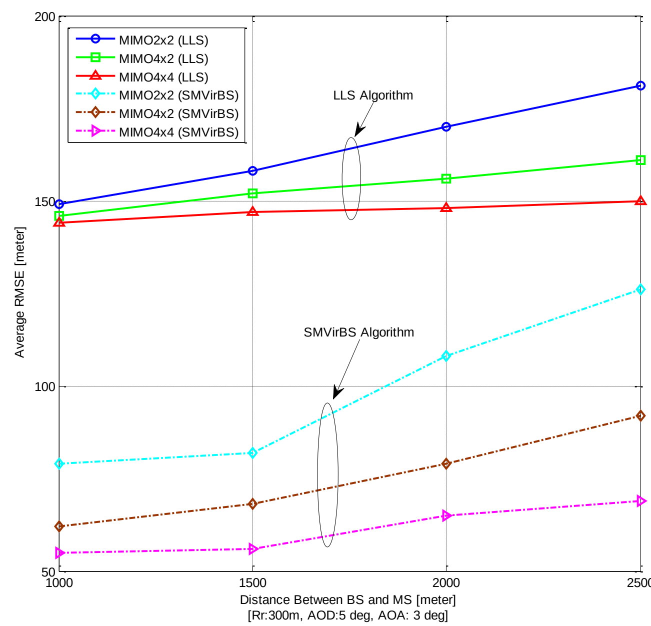

Figure 6: Comparison of Average RMSE for the SMVirBS and LLS Algorithms with Different Radius of BS to MS [Radius of ROS: 300m., AOD SD: 5 Degrees, AOA SD: 3 Degrees].

VI. CONCLUSION

In this paper, an improvement for location and positioning using one of the IMT-Advanced systems has been discussed. A new L&P scheme utilizing only one WiMAX base station with MIMO capability together with a virtual BS has been presented. Here, the new system model has been developed using the LLS method. The algorithm determined the locations of its virtual BSs based on the lowest GDOP value. With only one base station combined together with a virtual base station concept

(SMVirBS), the accuracy of the mobile station has improved. The simulation results showed the effectiveness of the proposed SMVirBS scheme even with the NLOS problem without additional expenditure on network architecture.

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