Optimization of Location Estimation Utilizing GDOP Technique with Cooperation of Relay Station

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***Abstract*—Geometric Dilution of Precision (GDOP) has always played an important role in satellite navigation system. This paper presents the extension of GDOP as a location estimation technique to determine the location of a Relay Station (RS). The proposed RS scheme and architecture showed a promising potential in increasing the network coverage and extending the range of a base station. The simulation results indicate that the application of GDOP to optimize RS position has improved the Mobile station (MS) estimation accuracy.**

***Index Terms*—Relay Station; GDOP; IMT-Advanced; Mobile Station; Base Station.**

I. Introduction

International Mobile Telecommunications-Advanced (IMT-Advanced) is defined by the International Telecommunication Union (ITU) for 4G mobile wireless broadband communication systems. The standardization of IMT-Advanced systems was carried out in 2011, and this was followed by the commercialization deployment of IMT-Advanced systems and services in 2015. According to the requirements of the ITU [1], IMT-Advanced systems can support peak data rates of 100 Mb/s and 1 Gb/s in high speed mobility environments (up to 350 km/h) and stationary and pedestrian environments (up to 10 km/h), respectively [2]. The transmission bandwidth of IMT-Advanced systems should be scalable and can change from 20 to 100 MHz, with downlink and uplink spectrum efficiencies in the range of [1.1, 15 b/s/Hz] and [0.7, 6.75 b/s/Hz], respectively. The minimum requirements on voice over IP (VoIP) capacities in high- and low-mobility environments are 30 and 50 active users/sector/MHz, respectively [2]. The latency for control and user planes should be less than 100 ms and 10 ms, respectively in unloaded conditions.

Many of the researches that have been carried out focused on a higher wireless access data rate and better quality of service (QoS) with cost effective systems that are easy to set up. The relay station (RS) is one of the hot research topics with great application potential due to its capability to increase capacity at a lower cost than through the use of more expensive BSs [3]. An RS can be developed as a collaborative communication by forwarding user information from a neighbouring mobile station (MS) or user equipment (UE) to a local base station (BS) or eNode-B (eNB). There are 3 main benefits provided by the RS architecture over a normal BS installation, namely increased coverage, improved throughput and operational cost [4]. The RS is expected to enhance the coverage reliability in geographical areas that are severely shadowed from the BS, and extend the range of a BS. The performance of RS transmissions depends on the relay type, relay partners and effective relay position established for the benefit of the user.

The rest of this journal is organized as follows: Section II introduces the relay transmission schemes and their network architecture in IMT-Advanced systems. Section III discusses the selection of a suitable RS and the geometric dilution of precision (GDOP) technique for determining the effective RS location for improving the coverage of the existing BS. The simulation result and performance analysis are provided in Section IV. Finally, the conclusions are given in Section V.

II. Relay Station Transmission Schemes and Network Architecture

A. Amplify-and-forward (AF)

This type of RS receives the signal from a BS (or MS) in the first phase. In the second phase, the RS amplifies the signal and forwards the received signal to the MS (or BS). The relay is transparent to both the MS and the BS. This AF technique is very simple and has a short delay, but it is only suitable for high signal-to-noise ratio (SNR) environments as it will amplify whatever it receives, including noise and interference [5].

B. Decode-and-forward (DCF)

The RS decodes the received signal from the BS (or MS) in the first phase. Prior to forwarding it to the MS (or BS), it would have performed a cyclic redundancy check (CRC) to make sure that the decoded data is correct. Since this type of relay does not amplify noise and interference, it is useful in low-SNR environments. Although this DCF scheme can effectively avoid propagation error, it has a high processing delay [2].

C. Demodulation-and-forward (DMF)

The RS demodulates the received signal from the BS (or MS) and makes a hard decision in the first phase (without decoding the received signal). It modulates and forwards the new signal to the MS (or BS) in the second phase. This demodulation-and-forward (DMF) scheme has the advantages of simple operation and low processing delay, but it cannot avoid error propagation due to the hard decisions made at the symbol level in phase one [2].

As previously described in Section I, the RS has been proposed as a solution for extending the coverage of a single BS, but it can also be used for the purpose of positioning. The technique used to determine the position of the MS is the same as with other positioning methods, where the trilateration method is applied based on at least three base stations. However, this paper only focused on one of the IMT-Advanced systems, namely WiMAX, and 3 BSs with assisted RSs being proposed, which means that the MS can be estimated within a cell by using the serving BS with the assistance of the RSs, as shown in Figure 1. In this paper, a fixed RS with the AF scheme was used in the relay-based WiMAX cellular network architecture.

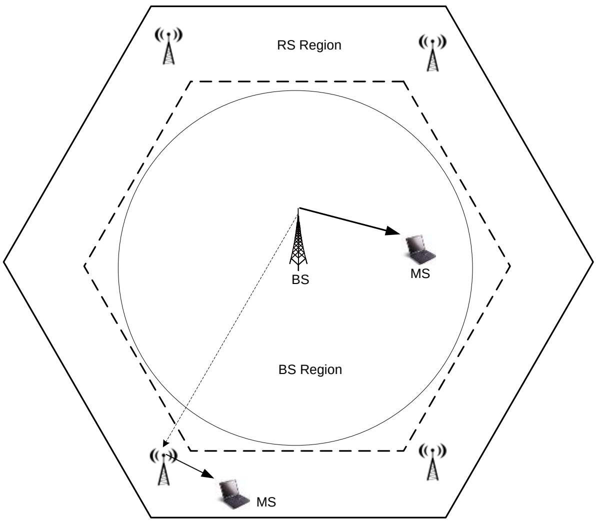

Figure 1: Network Architecture for Mobile Multi-Hop Relay (MMR)

Figure 1 shows the MMR network architecture, where the whole cell is divided into two regions: the BS region and the RS region. The users near the base station, who belong to the BS region, are connected directly to the BS, while users in the relay region, outside the BS region, are connected to the RS. Here, the RS pretends to be an MS for the BS and to be a BS for the MS. Therefore, it is important to determine the optimum position of the RS in order to get the accurate position of the MS, as will be discussed in the next section.

III. SELECTION OF SUITABLE RS LOCATION

A. Geometric Dilution of Precision (GDOP) Technique

GDOP is a geometric calculation of errors in a measurement that can affect the final location estimation. This technique is widely used in satellite navigation systems, and it plays a major role in determining the precision in L & P estimations. When visible navigation satellites are close together in the sky, the geometry is said to be weak and the GDOP value is high; when they are far apart, the geometry is strong and the GDOP value is low. Other factors that can increase the effective GDOP are obstructions such as nearby mountains or buildings, which create a non-line-of-sight (NLOS) environment. The same concept is used in determining the optimized RS position for L & P purposes [6]. Consider two overlapping rings or annuli with different centres. If they overlap at right angles, the greatest extent of the overlap is much smaller than if they overlap in near parallel. Thus, a low GDOP value represents a better positional precision due to the wider angular separation between the satellites used to calculate the position of a unit [7]. A large GDOP value corresponds to poor geometry topology, which will result in inferior performance by adopting most of the existing location algorithms. Conversely, however, the smaller the GDOP value, the more accurate is the location estimation that can be achieved. It has been shown in [4] that a larger GDOP value will result in poor location estimation accuracy. The work in [8] described the effect and cost resulting from a network topology with significant GDOP values. To illustrate this, consider the location of the MS under 2-D coordinates, where the GDOP value obtained at the true position of the MS can be represented as:

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

where *trc* and *T* indicate the traces (i.e. the sum of the diagonal elements) and the transpose of the matrix, respectively; and the matrix *G* is given by:

$$\boldsymbol{G} = \begin{bmatrix} \frac{x_u - x_1}{r_1} & \frac{y_u - y_1}{r_1} \\ \frac{x_u - x_2}{r_2} & \frac{y_u - y_2}{r_2} \\ \vdots & \vdots \\ \frac{x_u - x_i}{r_i} & \frac{y_u - y_i}{r_i} \end{bmatrix} \tag{2}$$

B. Suitable Location of RS

The selection of a suitable position for the RS (which means the shortest distance) will guarantee improvements in the estimation accuracy of the L & P. In this work, a network consisting of M fixed RSs uniformly distributed in a serving BS cluster of diameter D metres was considered. It was further assumed that the data/signal transmission from the BS to the MS was achieved through a two-hop relay link using R RSs among the M competitive RSs, and the serving BS, RSs and MS equipped with a single antenna. It was difficult to estimate the exact position of the MS in the initial stage due to the NLOS propagation. Therefore, it was assumed that the position of the MS was estimated exactly by the GPS. Moreover, it was assumed that the MS was moving through a trajectory of K metres along the x-axis, and that the location information of the N RSs as well as of the MS was available at the BS. By using the location information, the BS selected (and updated each in m metres) the R RSs necessary to perform the L & P technique by computing the respective distances between the M RSs and the MS, each in m metres. The R selected RSs were chosen according to:

$$\ell = \arg\min\left\{\sqrt{d_{R_i}^2 + d_M^2 - 2d_{R_i}d_M\cos\left(\theta_{R_i}\right)}\right\} \tag{3}$$

where d_(R_i) denotes the range between the serving BS and the ith RS, d_(M) represents the distance between the serving BS and MS, and θ_(R_i) denotes the direction of angle (DOA) at the ith RS.

IV. Simulation Result and Performance Analysis

A. Simulation Result

The position of the relay station depends on the optimized location based on the GDOP geometric calculation. As mentioned in the previous chapter, GDOP describes the effect of the geometry on the relationship between the measurement error and the position determination error. GDOP is a dimensionless expression if all the measurements use the same unit as the position unit (e.g. metres). The GDOP expression can be relatively simple if all the measurements exhibit the same RMS error. The GDOP value is employed as a metric to determine the geometric effect on the precision of the location estimation for the MS. This system model was used to investigate the GDOP effect. In order to design a suitable location for the RS, a cell layout with three time of arrival (TOA) measurements was considered, as shown in Figure 2. The location of the MS was designed to be within the enclosed square formed by the three BSs.

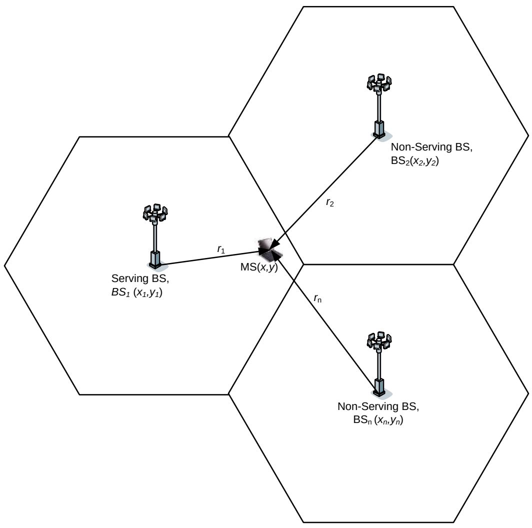

Figure 2: A Cell Network with 3 TOA Measurements

Figure 3 shows the simulation result of the GDOP effect with three TOA measurements coming from 3 WiMAX BSs. It was observed that the GDOP effect was worse (i.e. higher GDOP values) around the area close to the BS compared to the other areas within the measured region. The lowest GDOP value was 1.19, which was located at the middle region of the three BS areas. Based on the lowest GDOP value, the optimum position for the RS could be determined. To further observe the GDOP effect, it is possible to provide an additional RS with an adjustable location within the BS cell.

Figure 4 and Figure 5 show the GDOP contours using 3 BSs with the assistance of 1 and 2 RSs, respectively. It was shown that the GDOP values were decreased by the additional RSs within the MR-BS cell. For the GDOP comparison, the location of the MS was fixed at (x = 1800, y = 3750) metres. It could be seen that the GDOP for 3 BSs only gave a result of 1.2247, followed by a value of 1.0045 for 3 BSs with the assistance of 1 RS, and that the lowest value was 0.9182 for 3 BSs with the assistance 2 RSs. It was observed that with an additional RS located at the lowest GDOP value, the accuracy of the MS location estimation could be improved, as will be discussed in the next section.

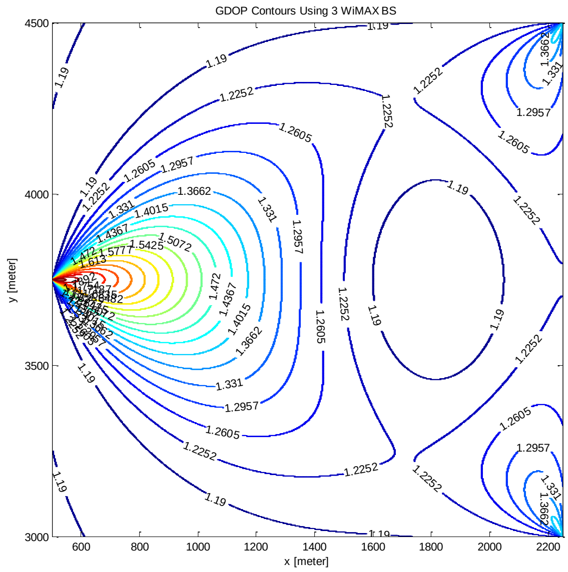

Figure 3: GDOP Contours using Three TOA Measurements for 3 BSs

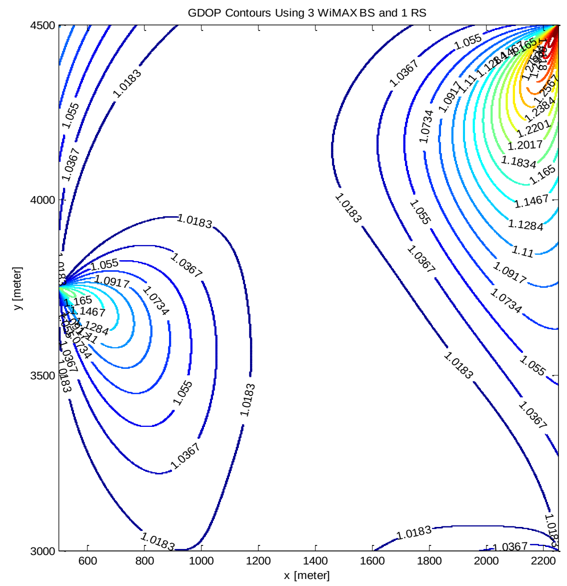

Figure 4: GDOP Contours using 3 BSs with the assistance of 1 RS

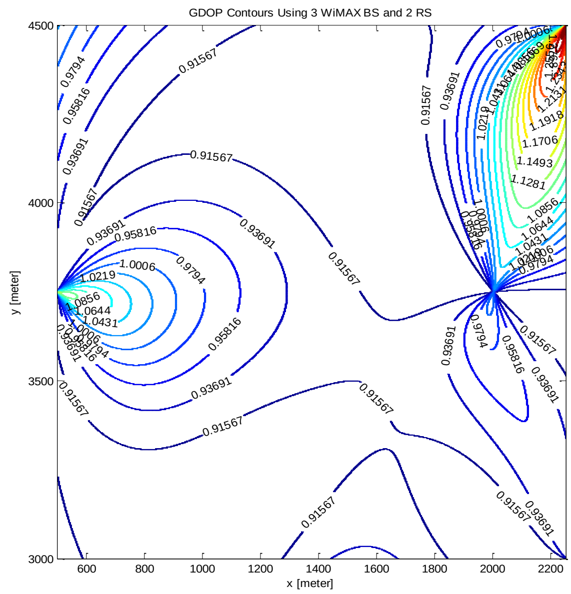

Figure 5: GDOP Contours using 3 BSs with the assistance of 2 RSs

B. Performance Analysis

Figure 6 shows the CDF of the location error using 3 different case scenarios, namely with 3 BSs, 3 BSs with 1 RS, and 3 BSs with 2 RSs, with regard to the simulation that was carried out in the previous section. The selection for the cumulative probability, P = 0.67, was in accordance with the FCC regulation, which requires a specific system to identify a caller location within 100 m for 67% of the time. It was shown in this figure that for a cumulative probability of P = 0.67 in case #1, the average RMSE was 80 m, followed by 58 m and 55 m in case #2 with 1 RS and 2 RSs, respectively. All the combinations were within the FCC regulation, being below the RMSE average of 100 m for a cumulative probability of P = 0.67. The performance analysis showed that the optimum location of the RS can improve the MS estimation, with the average improvement being close to 30%.

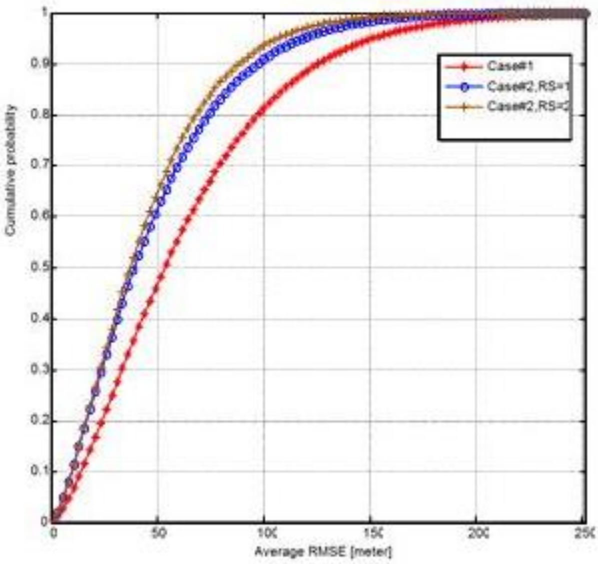

Figure 6: CDF of Location Error for 3 Different Cases

V. CONCLUSIONS

In this paper, an approach was proposed for the determination of the optimized RS position. The use of the GDOP technique to assist the BS in the location of the RS showed an improvement in the CDF of the location error. This indicated the important role that played by GDOP in determining the best RS location within a cell network. Computer simulations in 3 different cases revealed that the GDOP technique really improved the performance of the RS in enhancing the BS coverage and location estimation accuracy.

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REFERENCES

[1] “ITU-R Rep M. 2134 ‘Requirement Related to Technical Performance for IMT-Advanced Radio Interface(s),’” 2008.

[2] Y. Yang, H. Hu, J. Xu, and G. Mao, “Relay Technology for WiMAX and LTE-Advanced Mobile System,” *IEEE Communication Magazine, Oct 2009*, 2009.

[3] M. Iwamura, H. Takahashi, and S. Nagata, “Relay Technology in LTE-Advanced,” *NTT DOCOMO Tech. J.*, Vol 12, 2010.

[4] K. Mubeen Ahmad and K. O. Prakash, “Analysis of Relay Station in WiMAX Networks,” *International Journal Computer Technology & Application*, Vol 3 (4), pp. 1431–1434, 2012.

[5] C. Hoymann, W. C. Juan, Montojo, A. Golitschek, and X. Shen, “Relay Operation in 3GPP LTE Challenges and Solution,” *IEEE Communication Magazine, Oct. 2009*.

[6] A. A. M. Isa, M.H. Othman, M. S. I. M. Zin, I. M.S.M, S. S, N. Z. Haron, and Z. Z, “Improved Location and Positioning in WiMAX Networks with Virtual Multiple Input Multiple Output Base Stations,” *Advanced Science Letters*, vol. 20, no. 10–12, pp. 1846–1850, 2014.

[7] C. Hung Wu, W. Han Su, and Y. Wei Ho, “A Study on GPS GDOP Approximation Using Support-Vector Machines,” *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 1, pp. 137–145, 2011.

[8] A. A. M. Isa, M. . Othman, Manap.Z, I. M.S.M, M. S. I. M. Zin, S. S, and Z. Z, “Improved Location and Positioning Utilizing Single MIMO Base Station In IMT-Advanced System,” *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, vol. 8, no. 1, 2016.