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Research Paper

Impact of accelerometer based in physical layer wireless networks

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Abstract

The initial deployments of antenna in the handset consist of fixed non-rotated antenna for transmitting and receiving the signal in the wireless communication scenario. However, link correlation at the UE shows very bad performance when the handset rotates in landscape position. This paper evaluates the impact of accelerometer on the downlink propagation channel of 3G smartphone for non-line-of-sight links. The performance average received signal power is studied for user equipment. Results show that the exploitation of an accelerometer provide better performance in terms of received signal power when the handset rotated from portrait to landscape position. It can be concluded that the deployment of accelerometer can be used to improve existing 3G smartphone received signal. Results also indicate that accelerometer can be used to improve downlink throughput since the signal-to-noise-power is increased by approximately 16%.

1. Introduction

Complete knowledge of an antenna's far-field radiation pattern in terms of its magnitude, phase and polarization as a function of 3D angle is required when exploring the performance of cellular networks. This information is important when dealing with user interactions with the handset. The impact of base station antennas on the macro-cellular LTE downlink was analysed in [1]. The results exposed an impact on the path gain and cell edge peak mean throughputs. In [2], the downlink performance for an 802.11n WLAN system was discussed for indoor environments. The results showed significant throughput sensitivity to antenna pattern and orientation.

According to the mobile data traffic statistics reported in [3] as shown in Fig.1, smartphones represented only 27 percentages of total global handsets in use in 2013 but represented 95 percent of total global handset traffic. In 2013, the typical smartphone produced 48 times more mobile data traffic (529 MB per month) than the typical basic-feature cell phone (which generated only 11 MB per month of mobile data traffic). The most obvious growth is predicted to occur in smartphones, tablets, followed by machine-to-machine connections (M2M). Even 3G network holds for the majority (60 percent) of mobile data traffic today, 4G will develop to signify over half of all mobile data traffic by 2018. This measurements impact to this undertaking to redesign the current handset with 3G innovation abilities and enhancing the user performance as far as signal quality and capacity. It shows that 1000 times more capacity is predicted over 10 year's period.

One of the key contributors to global mobile traffic growth is the transitioning to smarter mobile devices. Most UE or mobile devices nowadays have fix antenna (internal) mounted on the device, it is embedded inside the housing of the device. The antenna is designed to be in a specific spot where it can contribute/received signal at its stable point. Some UE antenna are position on top of the device, others like the Apple iPhone 4s cellular antenna is position on the right side running around almost three quarters of the phone. User Equipment (UE) positioning has significant impact on the propagation characteristics based on studies [4].

The initial deployments of antenna in the handset consist of fixed non-rotated antenna for transmitting and receiving the signal in the wireless communication scenario. However, link correlation at the UE shows very bad performance when the UE tilts in landscape position [5].

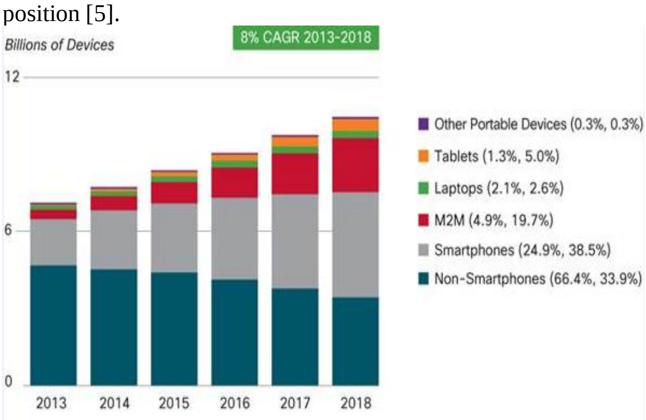

Fig. 1: Global mobile devices and connections growth [1].

The results also showed considerable throughput sensitivity to antenna pattern and orientation as the handset tilt from horizontal to vertical position. Antenna orientations are known to have a major influence on the performance of a wireless communications link. An analysis of the impact of antenna tilt on LTE coverage and capacity was analyzed in [6] where system performance was affected by different combinations of electrical and mechanical tilt. The downlink performance of an 802.11n system with antenna pattern orientation was also addressed in [7].

The above statistics influence this paper to upgrade the existing smartphone with 3G technology capabilities and to improve the user performance in terms of signal quality. Even the statistics is based on global forecast; the trend will follow up in Malaysia within years as technology grows. In this paper, we extend previous work by considering a sensor deployment (i.e. an accelerometer sensor) and evaluate the impact of an accelerometer and antenna positioning in 3G handset system. This paper makes the following key contributions:

- An analysis the impact of the accelerometer in 3G smartphone for downlink multipath propagation.
- An analysis of the performance of average received signal power for SISO deployments using horizontal and vertical UE array configurations.
- An analysis of user Signal-to-Noise-Ratio (SNR) for horizontal and vertical UE array configuration

The remainder of the paper is structured as follows. In section 2, the system design and parameters is presented. The experimental setup is given in section 3. Results in terms of user performance evaluation in received signal power and signal-to-noise-ratio (SNR) are presented and discussed in section 4. Section 5 concludes the paper.

2. System design and parameters

A channel bandwidth of 10 MHz and a carrier frequency of 2.6 GHz are used. The physical layer parameters for the SISO link are based on a baseband LTE-A link level simulator. Distributed subcarrier mapping with turbo channel coding and a 1024 IFFT size is used. The system noise temperature was 290K and a receive noise figure (NF) of 7 dB was assumed at the user equipment (UE) [8].
In this paper, the range of SISO system configurations used to match the link throughput to the SNR and maximum tolerable PER. The RBIR algorithm is used to determine the optimal MCS mode for each user [9]. This technique has previously been validated against the LTE-A link-level simulator [10]. The PER for each of the MCS modes shown in Fig. 2 is now simulated on a per-user basis using a SCM 3GPP LTE channel model.
The transmission date rate is expressed as

$$R_b = N_{ss}(N_d R_c b N_s / t_{slot}) \quad (1)$$

where NSS denotes the number of spatial streams, N_d is number of data subcarriers, rc is the coding rate, b is the number of coded bits per subcarrier, Ns is the number of OFDMA symbols per time slot and tslot is the duration of a time slot. The PHY layer throughput can be obtained from

$$\text{Throughput} = (1 - \text{PER}) \times R_b \quad (2)$$

where Rb represents the peak error-free transmission rate and PER is the residual packet error rate for a given MCS mode. For each UE location, the mode with the highest throughput (assuming PER < 10%) is chosen. The selection is optimal since it is derived by exhaustively simulating the throughput of all MCS modes for each UE location.

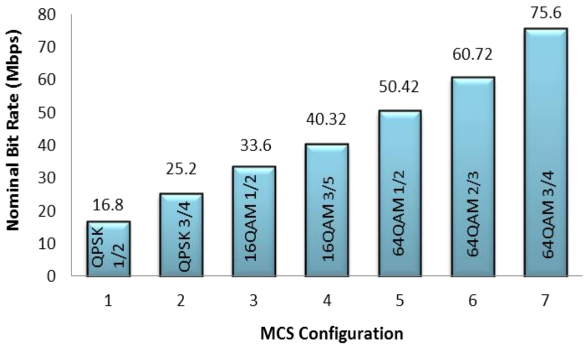

Fig. 2: MCS PHY layer in 10 MHz bandwidth.

3. Experimental setup

In this paper, the MPU-6050 sensor is used to measure the tilt angle of the UE in different axis respect to gravitational value. The MPU-6050 sensor data converts into digital value through analog digital conversion (ADC). The accelerometer gives the tile angle value of roll and pitch in instantaneous time, while gyroscope meter gives the angular speed of roll and pitch. This is where Kalman Filter is applied, to fuse accelerometer result and gyroscope result, producing more accurate instantaneous tilt angle rotation of the output servo motor that holds the antenna. The overall configuration of this work is illustrated as in Fig.3.
An accelerometer sensor in the UE detects an orientation changes whether in portrait (antenna in horizontal) or landscape (antenna in vertical) position. The accelerometer sensor will send the data to the Arduino microcontroller for processing. Fig. 4 shows the antenna radiation pattern with its vertical and horizontal polarization components for the UE antenna tilted in elevation (x-z plane) by 0° (portrait) and 90° (landscape) as in this paper only portrait and landscape will be considered.
The servo motor rotates the antenna to horizontal orientation. UE antenna radiates an omnidirectional radio wave power uniformly in all directions in one plane, with the radiated power decreasing with elevation angle above or below the plane, dropping to zero on the antenna's axis. This radiation pattern is often described as "doughnut shaped". It can be seen that when the UE is tilted towards 90° angle, the antenna pattern performance is worst. The UE with and without the integrated sensor will be tested and analyzed in terms of average received signal power.

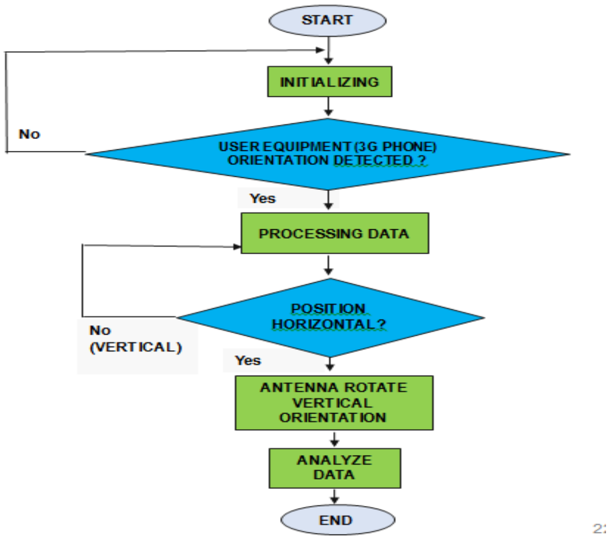

Fig. 3: Process configuration.

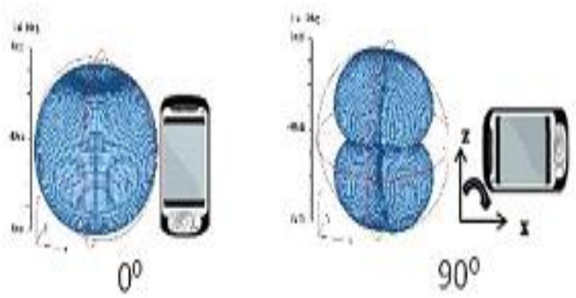

Fig. 4: The effect of elevation tilt by 0^0 (portrait) and 90^0 (landscape).

The propagation data for this paper was acquired for an urban area of Kuala Lumpur donates as UE1, UE2, UE3, UE4 and UE5 for Wangsa Maju, Gombak, Selayang, Sentul and Kepong respectively. All the measurement of the signal strength (before & after) the implementation of the smart UE antenna is taken and recorded. The data is then analyzed to differentiate the difference in signal strength (dBm) in both portrait (0º) and landscape (90º) UE's position.

4. Results and discussion

4.1. Smart UE antenna prototype

The final prototype with integrated sensor is shown in Fig.5. There are 3 levels involved in the prototype construction which consist of top level (smartphone), middle level (circuits) and the bottom level (antenna). These levels are designed and created to make the prototype look more uniform and neat. It has been constructed in order to make sure all the components and hardware is properly aligned and fit the correct frame. The prototype is designed to be as small as possible to create the user experience of a normal size smartphone that can be handled by a single hand.

Fig. 5: The handset with integrated sensor.

To test the functionality of the prototype product, a number of tests are set up to observe the output process and the response time between each UE angle rotation. The test is conducted when the UE tilts at 0º and 90º elevation angles as shown in Fig. 6. At 0° elevation tilts, the UE and the antenna are both aligned with each other, the antenna should be vertically stable at all times as the antenna should be lock at this reference angle even if the UE tilts at any angle. It can be seen that when the UE tilts at 45º, the antenna is vertically stable and response time of servo from the UE rotation is acceptable. The antenna is aligned with the reference angle i.e. at 0º when the UE tilts at 90º.

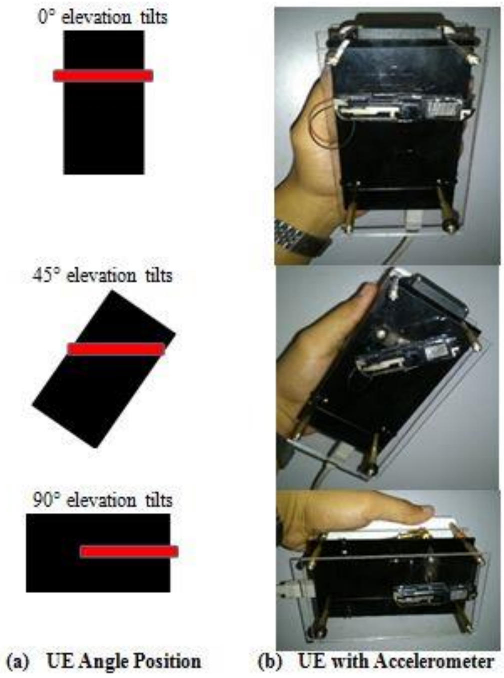

Fig. 6: UE elevation tilts.

5. Received signal power and SNR performance analysis

All the measurement of the signal strength (before & after) the implementation of the smart UE antenna is taken and recorded. The data is then analyzed to differentiate the difference in signal strength (dBm) in both portrait (0º) and landscape (90º) UE's position. The data that is collected for all 10 UE's locations have been selected randomly. The map shows that the area of the city is about three square kilometers (3km2). The geographical forms have different surface area to distinguish from one data to another. The data collected is in terms of received signal power/signal strength (dBm). Table 6 illustrates the locations of the data measurement taken for this paper.

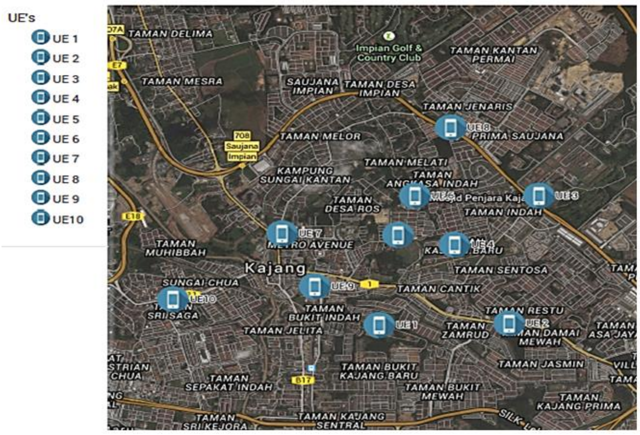

Fig. 6: Example of the UE at various locations.

Fig. 7 present UE's average received signal power at numerous locations with and without the accelerometer. It can be seen that the UE achieved better performance with the integrated sensor. The UE average received signal power increased approximately 6dBm to 8dBm at landscape position with the integrated sensor. This is due to the accelerometer maintaining the antenna position to its horizontal position even though the handset is rotated to 90° elevation tilts.

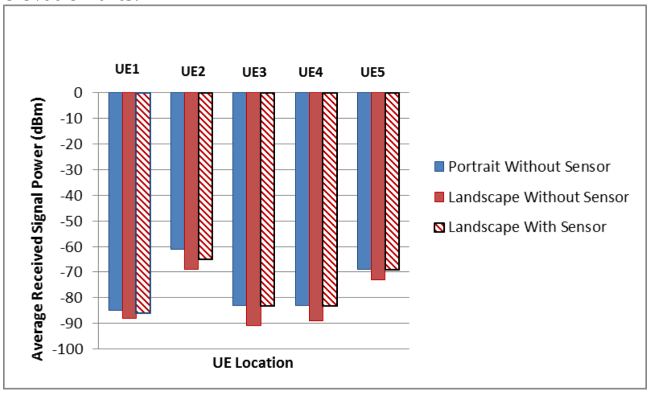

Fig. 7: UE's Average Received Signal Power at various locations.

Table 1 compares the peak received SNR for each location of UE when it in landscape position with and without accelerometer-based. It can be seen that the UE peak SNR is increased when the accelerometer is integrated. The results show that the UE optimal throughput can be improved when the peak. Results also indicate that accelerometer can be used to improve downlink throughput since the signal-to-noise-power is increased.

Table 1: UE Performance

	SNR (dB)	
	Portrait	Landscape
Location	Without Accelerometer-Based	Without/With Accelerometer-Based
UE1	12.5	9.5/11.5
UE2	36.5	28.5/32.5
UE3	14.5	6.5/14.5
UE4	14.5	8.5/14.5
UE5	28.5	24.5/28.5

6. Conclusions

This paper has presented a study of the impact of accelerometer-based on the link propagation channel of SISO 3G system. Results show that the average received signal power increased by 6dBm to 8dBm when the UE embedded with accelerometer. It can be concluded that the deployment of accelerometer can be used to improve existing 3G smartphone received signal. Results indicate that it can be used to improve downlink throughput, particularly for cell-edge users, since the average received signal power is much higher.

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