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INVESTIGATION INTO PATH LOSS PERFORMANCE FOR LONG TERM EVOLUTION WITH KEY PERFORMANCE INDEX

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ABSTRACT:

This work involved investigation into path loss (PL) performance evaluation for long term evolution (LTE) with key performance index. PL model for prediction of cellular transmission, enhance spectral efficiency relay and channel capacity for three terrains (hilly areas with thick vegetation, hilly terrains with exceptional or uniform vegetation, and smooth terrains or rural area with low vegetation) were evaluated. PL of 114dB and 159dB were obtained for downlink distances of 5km and 20km, respectively for Standford University Interim (SUI) and Cost-231 Hata. The result shows increase in the throughput per user when compared to the average throughput achieved in Cost-231. Again, uplink data traffic from communications equipment towards the network core associated with higher spectral efficiency for uplink PL are 159 and 190dB, respectively for LTE systems. This is attributable to the relative distance between the transmitting and the receiving stations. Hence, higher spectra efficiency utilization for LTE is not currently feasible for Lagos and other major cities in Nigeria.

Keywords: Attenuation, Downlionk, Long Term Evolution, Path Loss, Throughput, Uplink.

INTRODUCTION

The wireless broadband technology is expected to maintain handheld devices and cell phones to support internet access(Ramkumar and Gunasekaran, 2013). The volume of connected devices is estimated to exceed the world population by 2019. Therefore, it essential to make provision for systems that will deliver such projection. Operators are rolling out Long Term Evolution (LTE) to meet the ever-increasing request for sophisticated data rate. To aid spectral efficiency, relay deployment is mobilized to propel and increase the channel capability for the entire network throughput(Hamid and Kostanic, 2013). With high request for sophisticated mobile, broadband channel is increasing rapidly. To meet with the present and future demands for reliable data rates over the mobile networks, the International Telecommunication Union (ITU) set up the International Mobile Telecommunication (IMT)-Advanced, whose key feature is to provide enhanced data rates for outdoors and indoors purposes. IMT-Advanced standards offered efficient modulation and access techniques (Ahmed and Makki, 2010). The transmitting power ratio of the receiving power is recognized as Path Loss (PL). This refers to the highest transmitting power a transmitter can transmit and receive while recovering the original data (Liu et al., 2017). PL is a significant factor in the energy budget of each mobile cell. For this reason, it is important to estimate or measure PL and its performance with accuracy to provide effective and stable connection in the entire region (Atanasov and Kiss'ovski, 2013). 3GPP relay was investigated in LTE networks for the uplink and downlink average throughput for evaluation of antenna model. This work appraises the current LTE network deployment in Lagos, Nigeria. It presents a synopsis of LTE deployment in Lagos using key performance index data obtained from Huawei Nigeria Limited, in order to realize faster data throughputs on the current LTE system.

Various studies have been conducted on PL performance for LTE deployment using different approaches. First generation (1G) is an analog cellular system with circuit switched network architecture. It is suitable for simple telephony but has low capacity and narrow coverage area. Second generation (2G) wireless technology is designed for the capacity enhancement of increasing voice telephony, limited data services and text messaging, and with capability of permitting transmission of other packets with small power range(Mayuri and Manish, 2012). 2.5G is an extension of 2G and offers greater capacity of Radio Frequency channels and sophisticated throughput data rates(Kanojia et al., 2012). Third generation (3G) mobile and wireless technology surpasses 2G technology and precedes the fourth-generation (4G) technology. 4G is a widespread, high-speed wireless service (IEEE LAN/MAN Standards

Committee, 2006). The feature and end user's expectations of 4G networks and the problem of the new trends is discussed in IEEE LAN/MAN Standards Committee(2006), Andrews et al.(2007), Khan (2009) and Kale and Jadhav(2013). 4G LTE gives quality wireless mobile data rate up to 300Mbps, only second to MIMO (Mawjoud, 2013).

PL channels at 2300MHz, 2600MHz and 3500 MHz was investigated and modeled by Shabbir et al.(2011) using MATLAB software. The predicted models used are Stanford University Interim (SUI) model, COST (European Cooperation in Science and Technology) 231 Walfisch-Ikegami model, ECC (Electronic Communication Committee)-33/Hata Okumura extended model and COST 231 Hata. Results from various models revealed that minimum PL is achieved with COST-231 Hata prediction model (Sachin and Jadhav, 2013). It was found that the optimum model value is very close to the measured PL data for COST 231 Hata model, with a mean error value lowered to a zero. The models investigated by Shabbir et al. (2011)were examined for city, sub city and remote areas. Again, the findings also showed that COST 231 Hata model presented the least PL for diverse frequencies. However, adaptability to distinct areas by way of suitable modification for different locations is the major advantage of this approach. The result showed that PL is least in the city for the frequencies between 1900 MHz and 2100 MHz with SUI model while COST231 gave the greatest PL. The computation of PL for different WiMAX model at 3500 MHz via MATLAB in urban settings was presented in Taruna and Kaur (2013). The study adopted COST 231 Hata model, SUI model, Ericsson model, ECC-33/Hata Okumura comprehensive model and free space PL model, and the best results were obtained via ECC-33 and SUI models at different heights. In Tchao et al. (2013), deterministic approach for bit error rate (BER) was adopted for MIMO antenna arrangement and several interferers in the Sub-African settings. Despite of the interference problem, poor estimation of average BER were detected for MIMO placements. MIMO antenna was configured efficiently with suppressed side lobes to enhanced BER performance of WiMAX. InCurwen and Whalley(2013), network performances of different network sizes were analyzed using MATLAB. The channel size was simulated with different MIMO schemes against probability error at different signal to noise ratio. The result established that the maximum channel size was attained at the highest decibel. In the case of Gabriel (2017), 9.62Mbps downlink throughput WiMAX network for realistic conditions in Sub-Saharan African region was proposed. The throughput performance was poor when compared to the LTE networks deployment in other continents. However, the results obtained from some European and Asian countries were presented in Kokane(2014) and Mollel and Kisangiri (2014) respectively. In Kokane(2014),the maximum reported measured downlink throughput was 52Mbps whiles a maximum throughput of 32Mbps is reported in Mollel and Kisangiri (2014)

1. RESEARCH METHODOLOGY

Path loss models are useful wireless cellular systems for planning that permits a set of mathematical equations and procedures for radio signal propagation in proposed strategic areas. Basically, there are three types of models available as shown in Figure 1. These are

i. Empirical Model,
ii. Stochastic Model, and
iii. Deterministic Model.

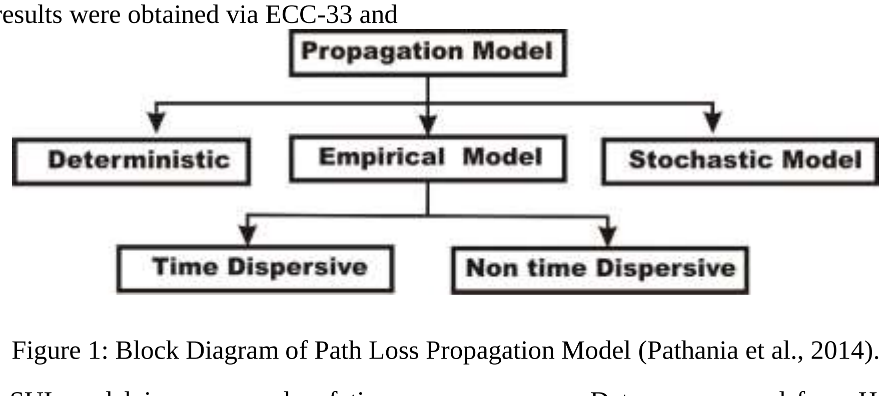


Figure 1: Block Diagram of Path Loss Propagation Model (Pathania et al., 2014).

The SUI model is an example of time dispersive model while Cost 231 Hata model is non-time dispersive model(Pathania et al., 2014). In this work, Empirical Model (EM) was adopted.

2.1. Data Collection

Data was sourced from Huawei Nigeria limited with key parameter index to predict PL model for cellular transmission using Matlab. These parameters are downlink cell traffic volume, LTEdownlink average throughput, uplink data traffic and LTE cell uplink average throughput. All the data were collected in Lagos from one of the mobile network service provides at a frequency of 900/1800/2700 MHz.

2.2. Propagation Path Loss Models

These are generally referred to as the reference formulas used in describing the propagation loss encountered in the downlink between transmitters (eNodeB). Lagos state has over hundred thousand eNodebase stations and receivers (Popoola et al., 2017). PL models are used to achieve the objectives of this study.

2.2.1 Cost 231 Hata Model

This Model is broadly used for PL prediction in wireless technology as an extension of Hata-Okumura model. Hata models are designed for frequency range between 500MHz to 2GHz for urban, suburban and rural environments expansion. The frequency is out of range, it is simple and has high access correction factors. This Model call for the base station antenna to be higher than all adjacent rooftop(Moges, 2016). The Cost Hata model is premised on four prediction propagation factors. These are frequency, receiving antenna height, base station height and distance between base station and the receivers' antenna (Popoola et al., 2017). This Model is limited to base station antenna heights greater than 30 meters and the PL can be expressed as follows (AlAmmouri et al., 2017):

$$\mathrm{PL} = \mathrm{A} + \mathrm{B}\log(\mathrm{d}) + \mathrm{C} \quad (1)$$

$$\mathrm{A} = 46.3 + 33.9\, log_{10}(\mathrm{f}_c) - 13.82\, log_{10}(\mathrm{h}_b)\, \mathrm{a}(\mathrm{h}_m) \quad (2)$$

$$\mathrm{B} = 44.9 - 6.55\, log_{10}(\mathrm{h}_b) \quad (3)$$

where A, B and C are factors that depends on frequency and antenna height. C is the environment correction factor, f_c is the carrier frequency of transmission (in MHz), h_b is he height of base station (in meters), and h_m is the hight of mobile station antenna (in meters).The constant, Cis zero and 3 for medium city, and metropolitan centers and urban cities, respectively. The distance, dis approximately between 1 and 20 km. Carrier Frequency ranges between 1.5 and 2 GHz, base station heights are between 18 and 100 meters, while mobile stationheight varies between and10 meters.

2.2.2 SUI Model

The SUI is mutually designed by IEEE 802.16 group and Stanford University for frequency below 11GHz. This model is an extended Hata model for 1900 MHz and higher frequency. Multipoint Microwave Distribution System (MMDS) frequency band is between 2.5to 2.7GHz in some parts of the world. The height of the base station antenna for SUI model is between 10 to 80 meters. The SUI model is applicable to three types of terrains (A, B and C). Terrain A is used in the hilly areas with thick vegetation. This terrain has highest PL considering terrain a highly populated urban area. Terrain B is good for hilly terrains with exceptional vegetation, or uniform vegetation. The intermediate PL scheme is considered for suburban environment. Terrain C is appropriate for smooth terrains or rural area with low vegetation; PL is minimum for this terrain.

2. RESULTS AND DISCUSSION

As shown in the downlink cellular network plots of Figures 2 and 3, which was constructed from the data collected from Huawei Nigeria Limited downlink data traffic given on Table1, the Base Stations (BSs) are spatially distributed according to homogeneous Poisson point (Claesson and Edholm, 2016). It is evident that the dataset is crowded by mobile users. The time of day and the density of population significantly affected the downlink speeds. The downlink speeds are observed to be significantly higher in urban areas when compared to some rural regions.

Table 1 shows Terrains A, B and C for densely populated urban area, suburban environment and flat or rural area respectively.

Table 1: Parameter for Different Terrains for SUI Model

Model Parameter	TerrainA	TerrainB	Terrain C
a	4.6	4	3.6
b	0.0075	0.0065	0.005
c	12.6	17.1	20

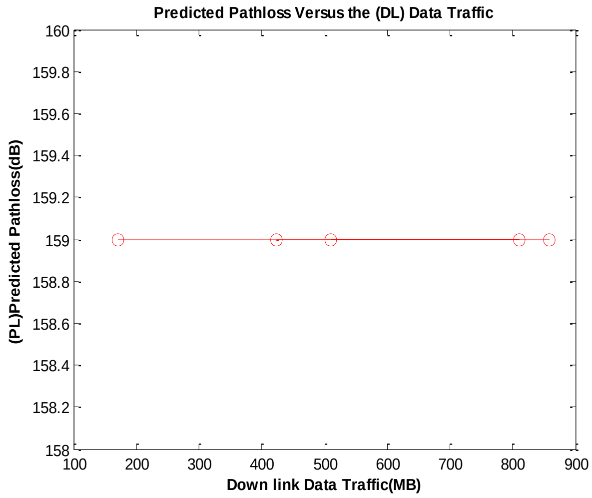


Figure 2: PL for Down Link Data Traffic

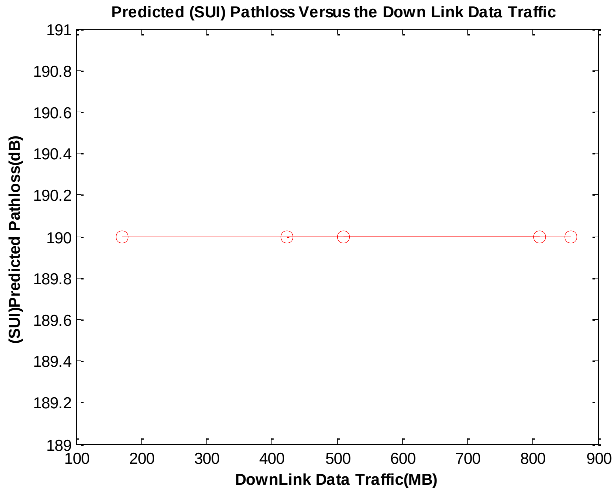
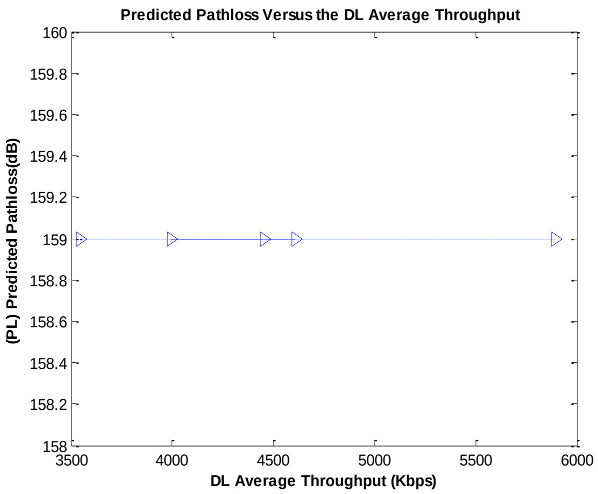
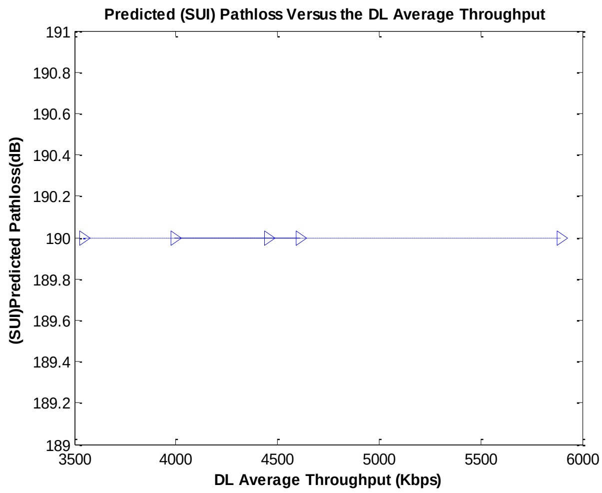


Figure 3: SUI for Down Link Data Traffic

Again, results for the predicted PL were obtained at 159dB. This is the amount of signal loss (i.e, attenuation) between a typical receiver and transmitter. Path loss of 114dB and 159dB were obtained for distances of 5km and 20km, respectively. This is attributable to the relative

receiving stations.From Figures 4 and 5, the factors governing the efficiency of downlink throughput are bandwidth, MIMO usage, modulation and coding. The relative poor performance in this regard could be associated to the relative far distance between the transmitting antenna and the





distance between the transmitting and the

Figure 4: PL for Average Throughput

receiving antenna.

Figure 5: SUI for Average Throughput

Figures 6 and 7 showed that uplink data traffic (from a ground station up to a satellite) from data communications equipment towards the network core is associated with higher spectral efficiency. This higher spectral efficiency is not achievable in Lagos due to higher PL obtained values of 159 and 190dB, respectively, especially for LTE network operated at 800 and 1800MHz.

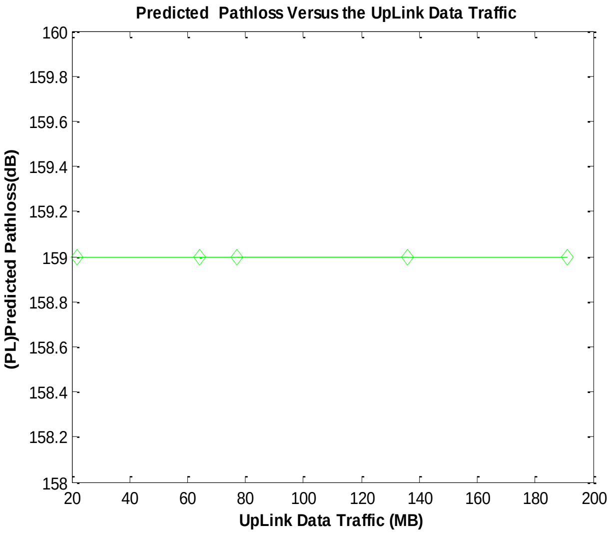


Figure 6: PL for Uplink Data Traffic

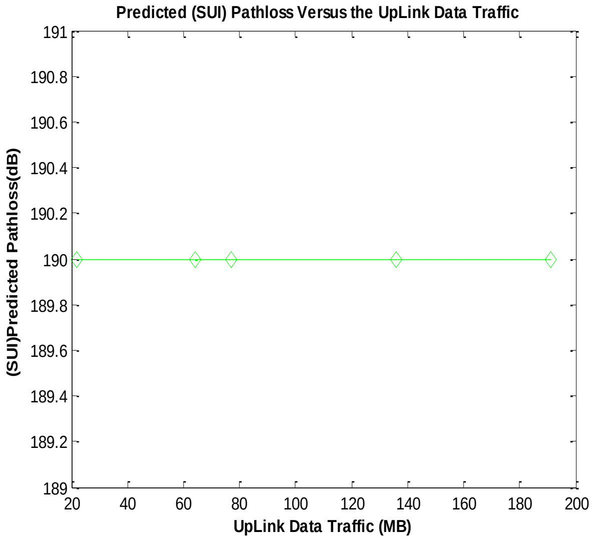


Figure 7: SUI for Uplink Data Traffic

Furthermore, comparing the PL parameters obtained with respect to the uplink average throughput data obtained at 159 and 190dB as shown in Figures 8 and 9, it is appropriate to conclude that spectral efficiency is underutilized.

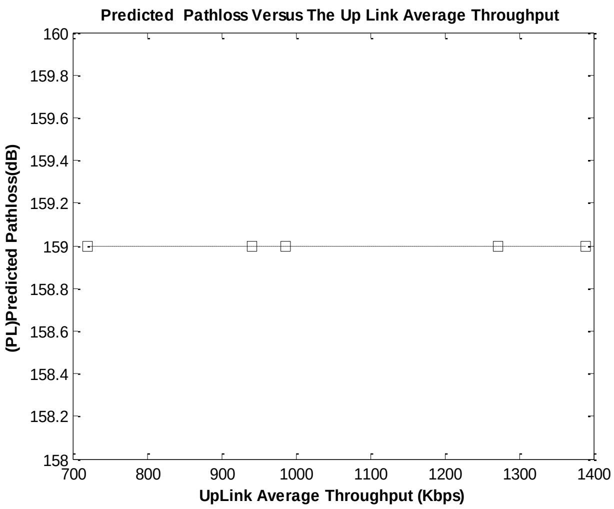


Figure 8: PL for Uplink Average Throughput

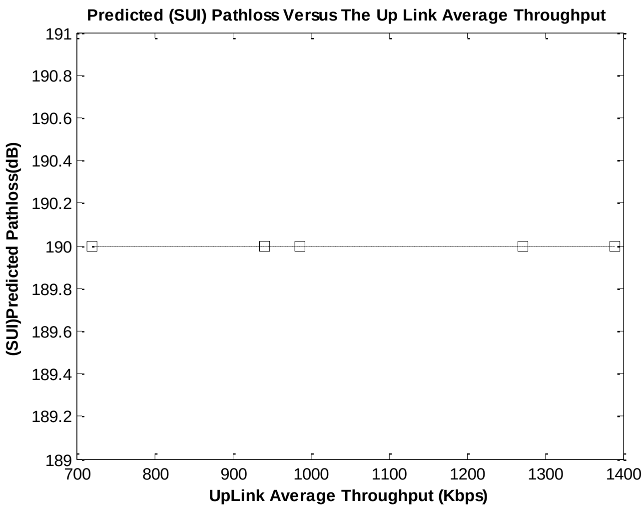


Figure 9: SUI for Uplink Average Throughput

The throughput of a user equipment in a physical segment at distance from the base station or receiver station, given a number of transmitting and receiving antennas, the cell center users are users who do not need relay station, and transmitting data directly to eNodeB with higher data rate than when using receiving station.
The correction factors and mathematical model is formulated and presented by Popoola et al. (2017) as:

$$\mathrm{PL} = \mathrm{A} + 10\,\gamma \log(\mathrm{d/do}) + \mathrm{X_f} + \mathrm{X_h} + \mathrm{S} \quad (4)$$

PL is measured in decibel (dB), d represents the distance between the transmitter and the receiver, d_0 is the reference distance (taken as 100m), X_f is the frequency modification factor, $\mathrm{X_h}$ is the modification factor for base station height, S represents shadowing and γ represents the PL component. Furthermore, d is the space between BS and mobile antenna, in meters, λ is the wavelength in meters, log is the distributed factor S, for the propagations path fading, with values ranging between 8.2 and 10.6 dB(AlAmmouri et al., 2017). Comparing this model with other empirical models, the model in Equation (4) is found to be suitable for PL predictions. To determine fading scale and the receiver signal strength, a value between 1 to 20 km is suitable for mobile channel characterization for technologies like GSM (Global System for Mobile

Communications). From Pathania et al. (2014),

$$A = 20\ log\ (4\pi d_o/\pi) \quad (5)$$

Also, the PL exponent γ is given by

$$\gamma = a - b\ \mathrm{h}_b + (\frac{c}{h_b}) \quad (6)$$

where, the parameter $\mathrm{h}_b$is the base station antenna height, in meters. The height is between 10 and 80 meters. The parameters a, b, and c are determined by the terrain category**,** the parameter $\gamma = 2$ for free space propagation, the frequency modification factor X_f and the modification for receiver antenna height $\mathrm{X_h}$ for the model are expressed by AlAmmouri et al.(2017) as:

$$X_f = 6.0\ log(\frac{f}{2000}) \quad (7)$$

$$\mathrm{X_h} = -10.8\ log\ (\frac{hr}{2000}) \quad \text{for terrain types A and B} \quad (8)$$

where, f is the operating frequency in MHz, and receiver antenna height is h_r(m). These correction factors facilitate extended the applicability of this model in the prediction of PL for all three types of terrains in rural, urban and suburban environments.

3. CONCLUSION

PL performance evaluation for LTE systems were investigated using key performance index. Notwithstanding the deployment of the LTE systems in major cities of Nigeria, slow internet speed information download has continued to be a pointer to the perennial challenge confronting Internet users in Nigeria.

Furthermore, PL for SUI model was evaluated using the average throughput per user in a narrower but higher range of 0.75-1.8 Mbps. The result shows increase in the throughput per user when compared to the average throughput achieved in Cost-231. For this, radio access technology was observed to present lower to the throughput of wide area network. Again, for a typical node, throughput approached a ratio between the capacities of low coverage and high throughput radio access technologies to the high coverage. Hence, Cost -231 Hata model PL prediction was obtained at 159dB at 5km while SUI model gave a predicted DL PL of 190dB, translating to a maximum attenuation of 114dB between receiver and transmitter, for same 5km distance. As a result, higher spectra efficiency utilization for LTE is not currently feasible for Lagos and other major cities in Nigeria. To achieve this, relevant optimization techniques are required to manage the tradeoffs between power level, frequency reconfiguration and other spectrum efficiency. There is urgent need for Nigerian Communication Commission (NCC)to design appropriate pricing model that would encourage mobile network operators and Internet Service Providers. However, subscribers should be ready and willing to pay more for improved reliability, efficiency and faster data rates.

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