Performance Enhancement of 4G LTE Network During Rainy Weather by Bit Error Rate (BER) Reduction

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Abstract : 4G LTE is the most widely used technology in the world of mobile communication. It creates new capabilities for users in terms of quality of experience as it offers much higher bandwidth (speed of data transfer), lower latency (faster response times from the network) and improved spectrum efficiency (increasing overall network capacity). Like any other technology, 4G LTE is susceptible to a number of factors that decreases the quality of service. In this research paper we would evaluate the Bit Error Rate (BER) of the radio signal propagation in 4G technology based upon massive MIMO **[1]** systems during rainy weather. We would also discuss how the absorption and scattering by rain causes a reduction in the transmitted signal amplitude which will lead to the reducing of the availability, reliability and performance on the communications link. The purpose of the research is to find the optimum solution for faster and noiseless communication, most importantly in an energy-efficient way.

Keywords : 4G LTE, BER, MIMO, Smart Antenna, Radio Wave Propagation, Rain Attenuation, OFDM, RSL, E-Utran, Green Communication, SNR.

I. INTRODUCTION

Mobile broadband is a real possibility today and is growing fast, as members of the internet generation accustomed to having internet connection access wherever each goes increases, and not merely at home or in the office and the need for this high speed in wireless communication systems, a new wireless data networks has been emerged and standardized by the 3rd Technology Partnership Project (3GPP). This kind of new standard is known as 4G Long Term Evolution (LTE).

In LTE, The wireless data velocity and data throughput are increased by using a combo of a number of book technologies namely Multiple-Input Multiple Output (MIMO) antennas.

This technique of using multiple antennas at both ends in the communication system can be combined with OFDM to achieve spectral efficiency as well as reliability. MIMO used along with OFDM is a very well known combination used in WLAN, WMAN and 4G cellular standards. It is also considered as an attractive combination for the design and development of next-generation wireless networks, demanding higher data transmission rates.

Standard MIMO networks use two or four antennas. Massive MIMO, on the other hand, is a MIMO system with a huge number of antennas. There's no set figure for what constitutes a Massive MIMO set-up, but the description tends to be applied to systems with tens or even hundreds of antennas. For example, Huawei, ZTE, and Facebook have demonstrated the use of Massive MIMO systems with as many as 96 to 128 antennas.

When data is transmitted over a data link, there is a possibility of errors being introduced into the system. If errors are introduced into the data, then the integrity of the system could also be compromised. As a result, it is necessary to assess the performance of the system, and bit error rate, BER, provides an ideal way in which this can be achieved.

As the name implies, a bit error rate is defined as the rate at which errors occur in a transmission system. This can be directly translated into the number of errors that occur in a string of a stated number of bits.

The bit error rate, BER parameter is usually quoted for many communications systems and it is a key parameter used in determining what link parameters should be used, everything from power to modulation type.
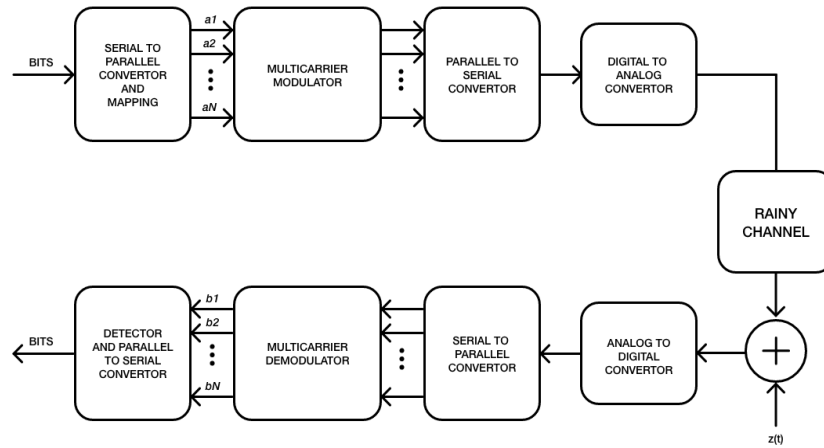
Figure 1: Architecture of 4G LTE communication through Rainy Channel

II. EFFECT OF RAIN ON 4G LTE

BER (Bit Error Rate) can be affected by a number of factors [2]. During the rainy season, rain drops absorb and scatter transmitted signals which degrades the reliability and performance of communication links. Effects of rainfall are dependent on frequency, rain rate, drop size distribution and drop shape, which are determined by the type of rain. By manipulating the variables that can be controlled it is possible to optimise a system to provide the performance levels that are required. This is normally undertaken in the design stages of a data transmission system so that the performance parameters can be adjusted at the initial design concept stages.

- *Interference:* The interference levels present in a system are often set by rain droplets and cannot be changed by the system design. However it is possible to vary the power of the transmitted signal. By increasing the power the level of interference can be reduced.

- *Increase transmitter power:* It is possible to increase the power level of the system so that the power per bit is increased. This has to be balanced against factors including the interference levels to other users and the impact of increasing the power output on the size of the power amplifier and overall power consumption and battery life.

- *Lower order modulation:* Lower order modulation schemes can be used, but this is at the expense of data throughput.

It is necessary to balance all the available factors to achieve a satisfactory bit error rate. Normally it is not possible to achieve all the requirements and a few trade-offs are required. However, even with a bit error rate below what is ideally required, further trade-offs can be made in terms of the levels of error correction that are introduced into the data being transmitted.

III. DETERMINATION OF RAIN ATTENUATION

Specific Attenuation α is given by,

$$\alpha = a.(R_p)^b \text{ dB/km} \qquad \text{(eq. 1)}$$

where, a & b depend on the frequency and polarization. Their values can be obtained from a number of sources. R_p is the percentage time (denoted by p) and the rain rate.

Once the specific attenuation is found, total attenuation can be determined as,

$$A = \alpha.(L_{eff}) \text{ dB} \qquad \text{(eq. 2)}$$

where, L_{eff} is the effective path length of the signal through the rain. Because the rain density is unlikely to be uniform over the actual length, an effective length must be used rather than the actual (geometric) length.

The effective path length can be computed by,

$$L_{eff} = L.a(R_p)^b = L.\gamma \qquad \text{(eq. 3)}$$

where, L is the link distance in km and γ is the path reduction factor.

The attenuation of radio waves caused by rain increases with the number of raindrops along the radio path, the size of the drops, and the length of the path through the rain. For simplicity the effect of drops size and other factors pertaining to the drops haven't been considered.

IV. SOLUTION

We performed a literature review for basic knowledge as well as advanced knowledge of interference problems and interference mitigation techniques, especially for the 4g LTE technology. This has helped us to get the idea about the gaps in the current technology being used and the algorithms were developed using Scilab.

The best technique and algorithm that enhances the quality of signals which is technologically and economically feasible with the least harmful effects on the environment is identified.

The best technique which is currently in use and fits our requirements is the Massive MIMO, comprising hundreds of antennas and has various advantages such as, high spectrum efficiency due to large multiplexing gain as well as antenna array gain, high reliability due to large diversity gain, simple scheduling scheme and robustness to individual element failure due to large number of antenna array elements. But it also has a few disadvantages like sensitivity to beam alignment and is also prone to the interference of transmitted signals during rainy weather as the rain droplets get deposited on the antennas that are close to each other. Moisture formed between the transmitters and receivers in a massive MIMO system could cause refraction and reflection of radio signal waves which results in signal loss and increased BER (Bit Error Rate).

To overcome the latter, we propose a solution by using smart antennas we can increase the signal power which in turn would reduce the bit error rate.To observe rain effects, we need to differentiate between any impact not due to the precipitation and the impact caused by the precipitation phenomena. For this reason we need to calibrate the system by measuring the RSL data in no-rain conditions in order to calculate the reference RSL level that includes the impact of all attenuation sources except the rain; once the reference level is calculated, all the measured RSL values must be normalized as shown by the equation

$$RSL_n = \frac{RSL_m}{RSL_{nr}} \qquad \text{(eq. 4)}$$

where:
RSL_n is the normalised RSL
RSL_m is the measured RSL
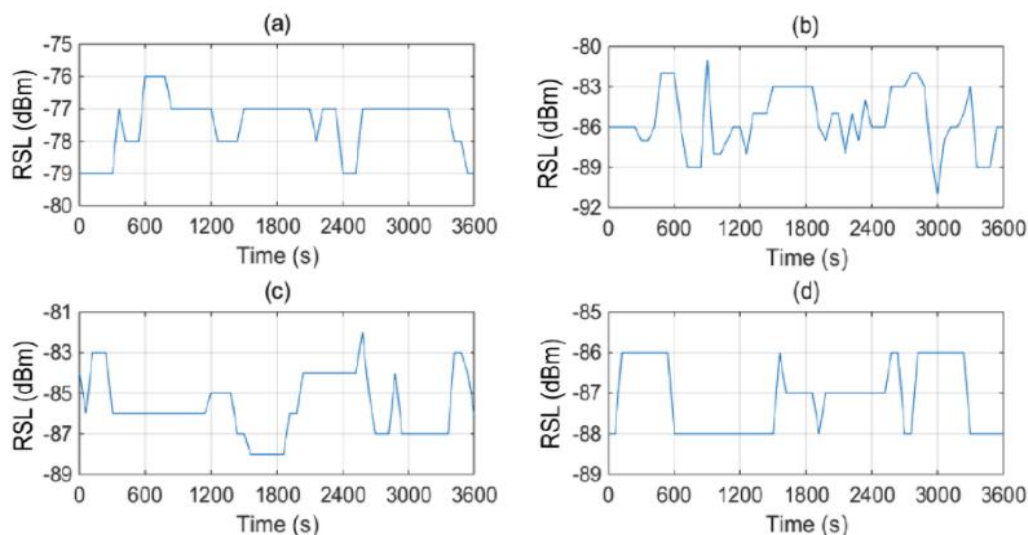RSL_{nr} is the average RSL measured in no-rain conditions

Figure 2: Different rain conditions: (a) No rain, (b) weak, (c) moderate and (d) heavy rain conditions for 1 hour [3]

Smart antennas would periodically monitor the RSL(Received Signal Level) of the User Equipment (UE) and would accordingly increase the power of the signal transmitted during rainy weather conditions.

The Transmitting Antenna (E-Utran) can further be equipped with Rain Sensors which would detect the onset of rainfall and would send a pilot signal to get the RSL value. This would help remove the ambiguity of sending the pilot signal periodically and would further improve the efficiency and would contribute to Green Communication.

An increase in the power of the transmitted signal will result in increased energy consumption thus depleting natural resources. Carbon dioxide emissions are a major cause of the degrading environment and rain or bad weather conditions increase power consumption at both ends. Smart antennas are used for monitoring the power consumption depending upon rain and adjust the signal power transmitted accordingly. Another important aspect addressed here is to make use of smart antennas for prolonging the battery lifetime of mobile terminals, thereby optimizing the network performance and thus green communication has been sloganized as a solution to address this concern.
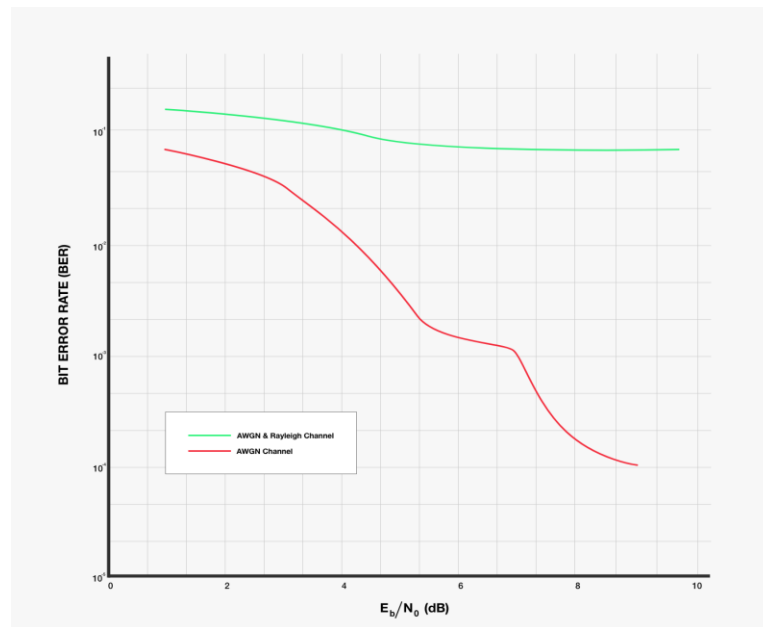
V. RESULTS AND DISCUSSION

Figure 3: Graph of Bit Error Rate (BER) vs Signal to Noise Ratio E_b/N_0 (dB) in AWGN and AWGN & Rayleigh Channel

Based on Figure 3, we can observe the simulated performance curve of a signal passed through an AWGN & Rayleigh Channel there is a significant increase in BER which results in decrease of SNR.
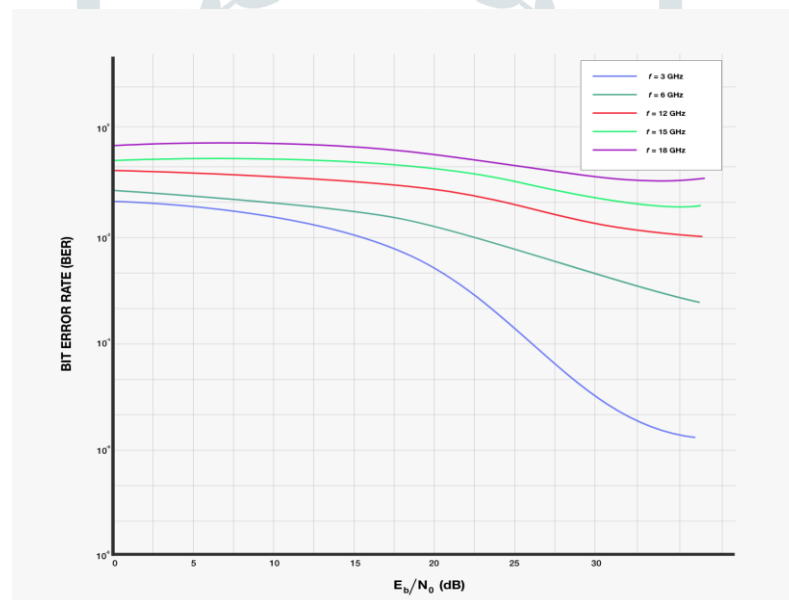

Figure 4: Graph of Bit Error Rate (BER) vs Signal to Noise Ratio E_b/N_0 (dB) through rainy channel

Based on Figure 4, we can observe the signals of different frequencies of 4G LTE network and the relation between their respective BER and SNR. On the basis of this, we can conclude that an increase in signal frequency results in increased BER which results in increased signal power loss.
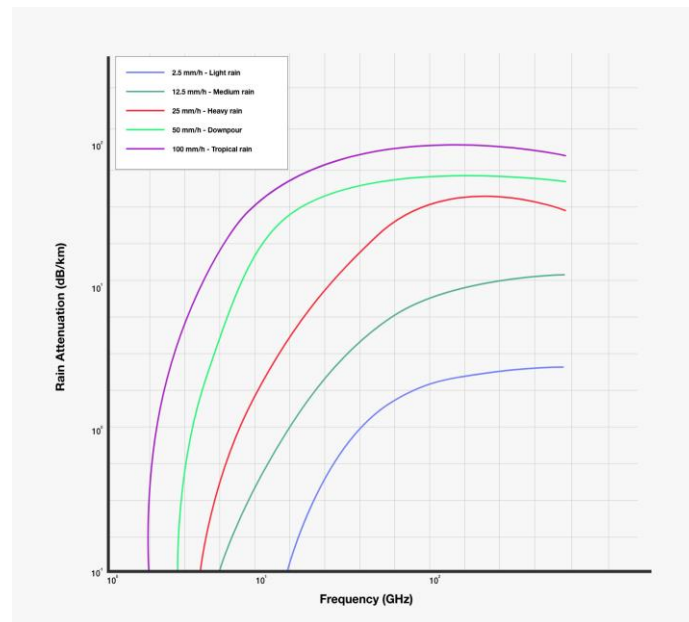
Figure 5: Rain Attenuation (dB/km) vs Frequency (Ghz) through rainy channel

Figure 5 shows the increase in the Rain Attenuation (dB/km) as the frequency of the signal is increased. under varying intensities of rainfall i.e Light Rain (2.5 mm/h), Medium Rain (12.5 mm/h), Heavy Rain (25 mm/h), Downpour (50 mm/h) and Tropical Rain (100 mm/h)
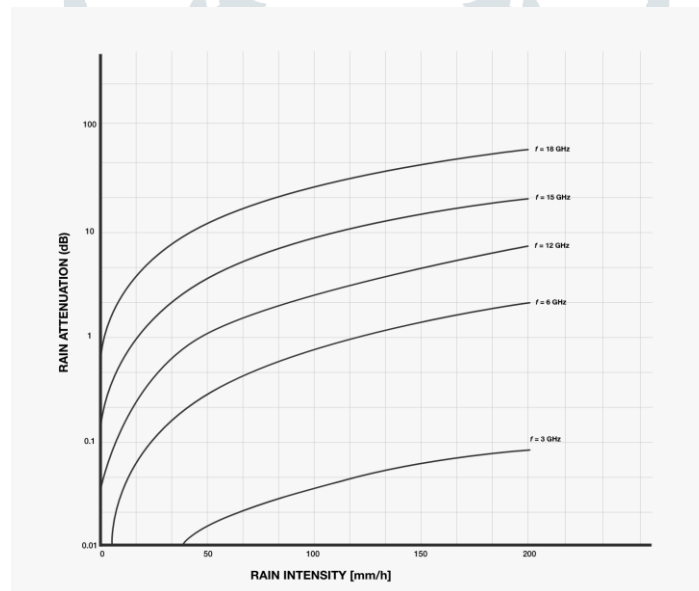

Figure 6: Graph of Rain Attenuation (db) vs Rain Intensity [mm/h]

In figure 6, we observed the impact of varying intensity of rainfall over signal attenuation. The RSL value observed under such varying conditions can be compared with RSL value under ideal channel conditions without rainfall and the difference as calculated by the Smart Antennas can be compensated by increasing the signal power level accordingly which will help to avoid the unnecessary wastage of energy, hence contributing to Green Communication.

VI. CONCLUSION

In our research work we optimized BER in massive MIMO-OFDM which resulted in increased data rate thus enhancing performance of 4G LTE Network System. Unwanted terminations of an on-going wireless conversation have become the biggest issue of the whole world. Call drop degrades the voice call quality and impacts the quality of service of the network so this optimized system design aims to maximize the performance of high-signal-to-noise ratio (SNR) which solves the above problem.

The trade-off of parameters has been simulated in SCILAB which was also used to generate customizable waveforms to verify conformance to the latest 4G LTE standards. We are proposing the usage of smart antennas, which are antenna arrays with smart signal processing algorithms used to identify rain droplets and use them to calculate signal power for transmission from one end to

another. Our project is feasible as it achieves energy-efficient communication by using the existing technologies only and is primarily developed for addressing the unnecessary energy loss during extreme weather conditions.

REFERENCES

[1] M. R. D. P. V. David Borges, "Energy Efficient Massive MIMO Point-to-Point Communications with Physical Layer Security: BPSK vs QPSK Decomposition," *Springer, Cham,* p. 10, 2019.

[2] S. S. A. A. a. Z. I. Roslan Umar, "Radio frequency interference: The study of rain effect on radio signal attenuation," *Research Gate,* vol. 19, no. 5, p. 6, 2015.

[3] G. C. G. L. S. C. N. a. F. S. F. Beritelli, "Rainfall Estimation Based on the Intensity of the Received Signal in a LTE/4G Mobile Terminal by using a Probabilistic Neural Network," *IEEE Access,* p. 10, 2017.

[4] "Research Gate," [Online]. Available: Researchgate.com.

[5] S. S. a. D.-Y. Choi, "Characterization of Rain Specific Attenuation and Frequency Scaling Method for Satellite Communication in South Korea," *Hindawi,* p. 21, 2017.

[6] P. a. U. C. N. Nweke F. U., "Weather Variation and its Effect on," *International Journal of Scientific & Engineering Research,* vol. 6, no. 6, p. 3, 2015.

[7] P. H. S. a. D. Desai, "http://spoken-tutorial.org/NMEICT-Intro," 2020. [Online]. Available: file:///C:/Users/Gaurav/Downloads/Mobile%20Communication_Prof_Hetal%20Shah.pdf.