5G SA Network Performance Evaluation for Different Modulation Schemes

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Abstract— **The main objective of radio technology has always been to achieve higher data rate. Data services are now part of the key applications that users expect, with high speed and low latency. Thus, one of the elements that can influence this quality of service is the type of modulation used. In light of this, this article describes the results of laboratory tests on 5G smartphones to evaluate the impact of various QAM modulation settings on data transfer rate (throughput). According to the findings of the tests, the greater the order of modulation, the higher the throughput and the less time spent on transfer. The 256-QAM scenario increased the transfer rate by up to 190% while reducing the time by around 4 minutes.**

Keywords— **5G, Modulation, Throughput, Laboratory.**

I. Introduction

The fifth generation of mobile networks, or 5G, represents substantial advancement over previous mobile networks. The next generation of mobile network introduced new features as Ultra-Reliable Low-Latency Communications (URLLC), enhanced Mobile Broadband (eMBB), and massive Machine Type Communications (mMTC). To offer those advances, 5G continues to use the same modulation techniques as 4G usage, by the orthogonal frequency division multiplexing (OFDM) method [1] [2]. OFDM allows data to be transmitted on multiple sub-carriers simultaneously, each with a very narrow bandwidth. Each sub-carrier should use different modulation scheme, such as Quadrature Amplitude Modulation (QAM) [1].

QAM is a digital data transmission method applied in wireless communication systems to allow high-speed data transfer while maintaining excellent spectral efficiency. In QAM modulation, digital information is expressed by a set of points on a quadrature amplitude plane. Each point represents a binary amplitude in-phase and quadrature amplitude combination. The number of bits that can be conveyed in each sign grows in relation to the number of points in the constellation. The number of bits delivered per symbol in different QAM modulations grows in direct proportion to the data transfer rate in communication networks [1]. However, increasing the number of bits per symbol while using the same amount of transmission power can result in a loss of signal quality or Signal-to-Noise Ratio (SNR), but if the signal quality is maintained, increasing the number of bits per symbol results in an increase in data transfer rate [3] [4].

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Some studies in the literature have already evaluated scenarios that involved different modulations. In [5], the authors explore several modulation scenarios by modifying the SNR in terms of the BER. In addition, in [6] an analysis is performed using a variant of the channel quality indicator while maintaining the modulation in 256 QAM. All of these research studies are based on simulations, with no collected data, and take account of LTE scenarios. To the best of the authors' knowledge, few studies consider realistic measurements in 5G Standalone (SA) scenarios. Then, this paper presents results of laboratory test on high-end mobile devices to evaluate the impact of different QAM configurations on data transfer rate, considering a 5G SA scenario.

This document is structured in: Section II discusses the essential elements of the 5G, including modulation methods. Section III presents the methodology used to assess the performance of scenario variations. Section IV show the results from all measurements. Section V presents the final considerations.

II. Key Concepts

A. 5G New Radio

5G technology aims to provide more reliable connectivity to connect not only people, but also smart devices and systems. The 5G system combines new technologies such as smart antennas, adaptive modulation, and network virtualization to provide greater bandwidth, lower latency, and increased connection capacity. 5G networks can support a wide range of wireless technologies. One of the key technologies used in 5G is adaptive modulation, which allows the network to change the data modulation rate in real-time based on network conditions to ensure Quality of Service (QoS) [7].

B. Modulation Schemes

QAM modulation has several variants that differ in their constellation and number of bits per symbol. For example, 16-QAM modulation employs 16 points in its constellation, allowing for the transmission of 4 bits per symbol. 64-QAM modulation employs 64 points in its constellation to transmit 6 bits each symbol. Finally, 256-QAM modulation employs 256 points in its constellation to transmit 8 bits each symbol. The increase in the number of bits transferred per symbol in different QAM modulations is directly proportional to the increase in the data rate in communication systems. The greater the number of bits transmitted per symbol, the more data may be transferred in a given time frame [1].

III. Methodology

The environment of test employed a high-end smartphone for the measurement campaign, with the chip-set Snapdragon 8 Gen 1 and Modem Snapdragon X65 with 5G SA capability, in Single-Input-Single-Output (SISO) configuration. To simulate the best measurement environment, we used the Anritsu Signaling Tester MT8000A, able to emulate 5G base station functions, together with Anritsu MA8161A shield box, for avoiding external radio interference. Three measurement scenarios were created for the testing, and all of them were evaluated in terms of throughput. The scenarios were set up with the following parameters: band NR 7, bandwidth of 20 MHz, sub-carrier spacing (SCS) of 15 kHz, packet size 1GB, Modulation and Coding Scheme (MCS) of 10, 19, 27 for modulation of 16, 64, and 256 QAM, respectively. Furthermore, all of the data gathered was the outcome of a average of three measurements for each scenario.

IV. Results

The results were achieved with the promise that modulation would be the predominant change in all three scenarios. SNR was then set to the same value in all instances to prevent affecting the results. The level is approximately the same in all QAM modulation settings. Considering the preceding explanation, Figure 1 depicts the throughput profile for three modulation order scenarios: 16 QAM, 64 QAM, and 256 QAM. The results show that throughput (TPUT) improves with modulation order, i.e., when the scenario employs 256 QAM, the TPUT is considerably higher than with 64 QAM and 16 QAM. Modulation of 256 QAM reached up to 92.2 Mbps, 64 QAM reached 63.38 Mbps, and the 16 QAM scenario obtained 31.71 Mbps.

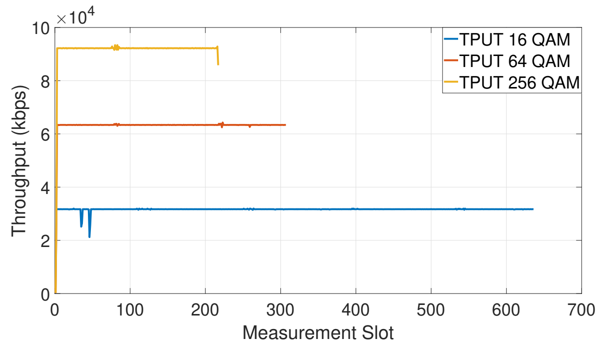

Fig. 1. Throughput for different QAM modulations.

Figure 1 additionally illustrates that the highest modulation, 256 QAM, performs the download faster than other scenarios since the data was collected from the moment the TPUT occurred and because the TPUT for three scenarios was fixed in 1GB download. This may be demonstrated by comparing 256 QAM to 64 QAM and 16 QAM in terms of sample measurement.

Figure 2 indicates that the modulation variation results in a 66% decrease between 256 QAM and 16 QAM and a 31% decrease when 64 QAM is considered. In terms of time, there is a reduction of approximately 4 minutes between the scenarios of 256 QAM and 16 QAM and around 1 minute when examining the 64 QAM scenario.

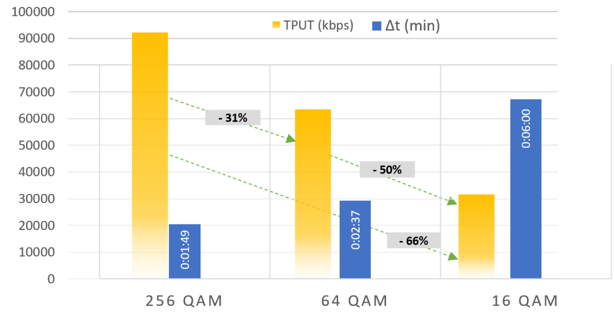

Fig. 2. Comparison between measured QAM scenarios

V. Conclusion

This paper aimed to evaluate the impact of modulation variation in 5G SA, considering three modulation scenarios (16, 64, and 256 QAM) during a 1GB download. With the result of measurements in the emulated environment, as well as expected, the scenario with the highest modulation order obtained better result. In terms of the throughput achieved from each modulation scenario, the 256 QAM obtained values that were up to 190% greater than the 16 QAM scheme and 45% higher than the 64 QAM. Comparing the 64 QAM scenario with that of 16 QAM obtained a data rate of approximately 99% higher. Concerning download time, the modulation scenarios completed the download in 1.49, 2.37, and 6 minutes for 256, 64, and 16 QAM, respectively. In conclusion, it is feasible to analyze that the higher-order modulation scenario outperforms the others, indicating that a set between device and network that provide 256 QAM scheme could improve the quality of service for users.

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