Throughput Loss Over Standalone 5G Networks

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***Abstract*— This paper aims to assess the performance of Standalone 5G under scenarios of power (PW) restrictions. The presented analysis is performed experimentally through lab tests, in which different modulations and transmission schemes are exploited. The results of this study attested to the higher sensitivity of the higher-order modulations and also showed the impact of the transmission scheme, which may result in 100% of throughput (THP) loss. Then, it is demonstrated that technologies envisioned for 5G to achieve higher data rates may not be applied in all scenarios.**

***Index Terms*— 5G; Performance; Throughput; Cell-edge.**

I. INTRODUCTION

THE advent of mobile communications is currently in its fifth generation (5G), which is a technological paradigm that differs from its predecessors, i.e., up to the fourth generation (4G). With an air interface standardised as New Radio (NR), 5G was basically designed for supporting services that can be subdivided into three categories: 1) Enhanced mobile broadband (eMBB), by increasing the signal bandwidths and exploiting higher frequency bands, i.e., millimeter waves. 2) Ultra-reliable low-latency communication (URLLC), for lower latency and high reliability applications, such as autonomous vehicles driving and medical surgeries, in which delays and data packets loss may be harmful and, 3) massive Machine type communications (mMTC) application, for massive Internet of things (IoT) low cost devices, with lower data rates.

Although still under deployment, 5G is being released in some countries and, according to [1], the number of subscriptions are expected to reach 3.5 billion worldwide. However, as a new technology, there is an uncertainty regarding 5G operation and achievable performance. Currently, some papers answer several questions regarding 5G performance. In [2], authors conducted a performance analysis and network verification. Through the presented analysis, the authors concluded that, under higher-density coverage scenarios, interference cases may occur when using high-frequency bands. Thus, the performance of 5G may decrease at least 14.7 %. The work in [3] proposes an architecture for local 5G operators, whose performance and feasibility are analyzed and compared to the traditional mobile network operator (MNO), in factory environments. The results of these work revealed that the proposed architecture can provide low end-to-end (E2E) latency compared to an MNO 5G, where the core network is located outside the factory premises. In [4], the authors assess the 5G air-to-ground links of low-height unmanned aerial vehicles (UAVs) in suburban scenarios, through system-level simulations. Then, it was observed that the loss of performance with respect to the distance may be negligible in higher Signal to Noise Ratio (SNR) scenarios, e.g., greater than 0 dB. However, the performance tends to decreases for lower SNR values.

This paper provides a throughput (THP) loss analysis of 5G user equipment (UE) under scenarios of received power restrictions, e.g., the edge of the cell. Our analysis is performed through laboratory experiments using commercially available smartphones, which makes this analysis more realistic. Furthermore, the presented analysis may contribute for 5G network planning by the carriers, e.g., by providing the minimum received power (PW) required for each modulation to perform reliably, it is possible to estimate the coverage of 5G.

II. ANALYSIS METHODOLOGY

This paper analyses THP loss when the mobile device operates at the cell edge. Basically, the metric used for this analysis is the average throughput loss (THP_{loss}), which is given in percentage, and calculated through: $THP_{loss}(\%) = 100 - 100 \times (THP/THP_{max})$. Where, THP and THP_{max} are the instantaneous throughput and the maximum achievable throughput, respectively, both obtained through measurements. Thus, after connecting the UE into a 5G network, the signal transmitted by the test station is adjusted to the maximum power. In this case, the THP measured in the UE reaches its maximum value THP_{max}, for which THP_{loss} corresponds to 0%. Then, the transmitted PW is gradually reduced, while the Reference Signal Received Power (RSRP) is measured by the UE. These procedure is performed until the UE is disconnected, due to the lower recieved PW, i.e., with THP_{loss} of 100%. For each measurement, 120 samples are collected for analysis. Furthermore, two different modulation schemes are analyzed, 64QAM and 256QAM, besides considering SISO, MIMO 2x2 and MIMO 4x4 antennna configuration. Then, the measured THP is compared to the THP loss threshold of 30%, i.e., $100\% - 70\% = 30\%$, where 70% is the THP requirement as defined in [5], to ensure good performance of 5G. This study focus on downlink transmission. The uplink analysis is in progress and will be reported in future works.

III. MEASUREMENT SETUP

The measurement setup, as shown in Figure 1, is composed by: 1) 5G test station (TS), Anritsu MT8000A, which emulates a 5G cell, 2) Control PC, which controls the TS

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through the Smart Studio New Radio (SSNR) tool. This tool allows the setting up of the parameters for the 5G Base station. Also, an IP data server, Dell EMC Power Edge running iPerf, is used to generate downlink IP data.

Fig. 1: Measurement setup

Finally, 3) a Shield-box is used to provide over-the-air (OTA) environment. The mobile device used in this analysis is a 5G smartphone, running an iperf server. The 5G cell is configured according to the following parameters: maximum transmission PW of -14 dBm; signal bandwidth of 100 MHz; transmission frequency is 3.5 GHz (N78 band). Also, both the 64 QAM and 256 QAM modulations are analyzed considering SISO and MIMO 4x4 antenna configuration.

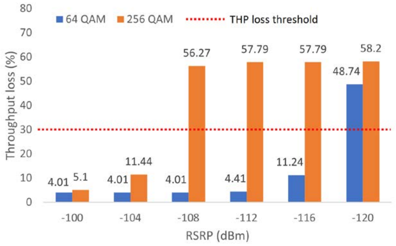
IV. RESULTS

THP loss in 5G is presented in Figure 2. To emulate the cell edge, the RSRP range varies between -120 dBm and -100 dBm. The measured THP_{max} in each scenario, i.e., with maximum transmission PW, is shown in Table I.

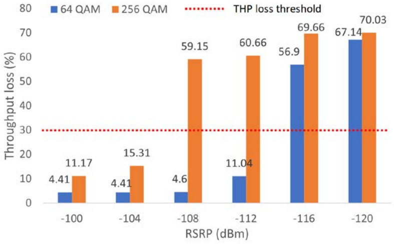
TABLE I: Measured maximun throughput

Transmission scheme	Modulation	Maximum Throughput
SISO	64 QAM	281.130 Mbps
	256 QAM	378.590 Mbps
MIMO 2x2	64 QAM	610.060 Mbps
	256 QAM	826.993 Mbps
MIMO 4x4	64 QAM	1124.609 Mbps
	256 QAM	1513.344 Mbps

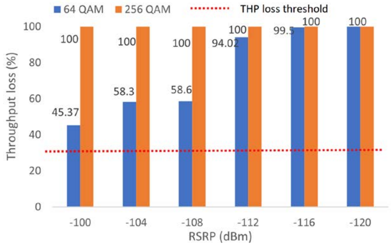
Then, Figure 2 (a), (b) and (c) show the THP_{loss} of 5G using SISO, MIMO 2x2 and MIMO 4x4, respectively. In general, THP_{loss} tends to increase when the received $RSRP$ at the UE decreases. Also, 64 QAM modulation has lower THP_{loss} compared to 256 QAM. For SISO configuration, THP_{loss} remais below the threshold up to -116 dBm (11.24%) and -104 dBm (11.44%), for 64 QAM and 256QAM, respectively. In both cases, for $RSRP$ of up to -120 dBm, THP_{loss} remains above the threshold of 30%, i.e., 5G operates with degraded performance (48.74 % and 58.2 %). In case of MIMO 2x2 configuration, THP_{loss} remais below the threshold up to -112 dBm (11.04%) and -104 dBm (15.31%), for 64 QAM and 256QAM, respectively. However, when $RSRP$ reaches -116 dBm, the THP_{loss} remains above the threshold of 30%, i.e., 56.9% and 69.66%, respectively. Finally, in case of MIMO 4x4 configuration, the THP_{loss} increases significantly for both 64 QAM and 256 QAM modulations and it remains above the threshold in the whole analyzed range of $RSRP$, e.g., when the $RSRP$ is -100 dBm, the THP_{loss} is 45.37% for 64QAM. In addition, for the $RSRP$ of up to -116 dBm, the THP_{loss} is 100% for both 64 QAM and 256 QAM, i.e., total loss of THP. Note that, 256 QAM presents total loss of THP in the whole the analyzed range of $RSRP$.



(a) SISO



(b) MIMO 2x2



(c) MIMO 4x4

Fig. 2: Throughput loss of the UE at the Cell edge.

V. CONCLUSIONS

The presented results attested to the high sensitivity of higher-order modulation techniques, i.e., these techniques make 5G more susceptible to the loss of performance. Furthermore, these results also show the impact of the multi-antenna configuration, which may also result in THP loss. Therefore, it can be concluded that in some scenarios, e.g., cell edge operation, it is not advantageous to use advanced techniques in 5G, such as spatial multiplexing and high order modulations. Otherwise, it may result in a total loss of the user´s throughput. Ideally, these technologies should be exploited in scenarios where good signal power is reported.

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