Analytical Modeling of Radio Network Performance for 5G (Non-Standalone) and It's Network Connectivity

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Abstract**—**The traffic demand and prediction for the next decade would be mostly affiliated with the Internet of Things (IoT). Various challenges with mobile communication industry will be faced as the demand in high capacity, multi mobile devices (users) connected to the network, uplink power consumption on User Equipment (UE), and its effect on the life span of mobile phone. The major features of 5G as per user experience on the network are Ultra-Reliable Low Latency Communication (URLLC), Internet of Things (IoT), sustaining high rate Enhanced Mobile Broadband (eMBB), and connection density Massive Machine Type Communication (mMTC). This research work focuses on Non-Standalone (NSA) 5G New Radio (NR) early deployment on eMBB for achieving the required throughput. The 5G performance requirement is higher than 4G, which includes the capacity to support user experience downlink throughput with target value of 1 Gbps, millisecond-level of end-to-end latency, and high connection density of 1 million per square kilometer. Optimization is a vast topic, and this paper discusses the problems faced by users latching on 5G NSA network on the downlink and 4G Network on the uplink and suggests its solution.

Index Terms**—**Enhanced Mobile Broadband (eMBB), Massive Machine Type Communication (mMTC), Ultra-Reliable Low Latency Communication (URLLC), Non-Standalone (NSA), 5G.

I. Introduction

In telecommunication research much attention has been given on LTE research and its finding. A resolution for higher data consumer improvement with spectral efficiency, base station deployment for coverage and capacity purposes, Carrier Aggregation (CA), Coordinated Multipoint (CoMP) and Multiple-Input Multiple-Output (MIMO) are needed to control the traffic surge in 4G. Hence, the 5G performance requirement is higher than LTE with the capacity to improve network deployment, operation, and maintenance [1]-[3]. Compared with LTE, the spectrum efficiency of 5G New Radio (NR) is improved by 5~15 times with key performance indicators of user experience, connection density, and latency. The 5G, officially known as IMT 2020, is the fifth generation of mobile communication standard deployed by the International Telecommunication Union (ITU). Traditional 2G, 3G, and 4G services are people-oriented, thereby enhancing the transmission rate is their primary pursuit over the generations. 5G will provide a full spectrum of services [4], [5].

With the way wireless communications have evolved, high system capacity for end-user specifications and requirements has continued to grow. Various solutions, such as bandwidth availability with higher Modulating and Coding Scheme (MCS) index have emerged [6], [7]. Expanding the system bandwidth increases the system capacity but does not adequately improve the spectral efficiency [8]. The gNodeB and UEs use a range of modulation schemes in both the uplink and the downlink [9]. Modulation schemes of different orders produce different modulation efficiencies [10]. Higher-order modulation schemes are more efficient. They allow more bits to be carried per symbol and producing a higher bit rate for a given symbol rate [11].

In NSA Dual Connectivity (DC) scenarios, the base station reports data volume about the NR side to the core network for independent charging of 5G data volume [12]. The NR data volume information can be reported periodically or reported based on events such as bearer release, bearer change, and UE release [4], [5], [13], [14]. During data volume reporting, the bearer differentiates NR uplink and downlink data volumes [15]. The eNodeB or gNodeB measures the data volume on the air interface distributed to the NR side and reports the data volume in a secondary RAT usage report list IE or a secondary RAT data usage report message [16], [17].

Udoh and Srivastava [18] have already analysed that how user/subscriber latched on preferred technology, communicate while mobility takes places without facing drop calls both PS and CS between LTE and 3G network. Thereafter, *Udoh and Srivastava* [19] considered the causes, problems, and analysis of CSFB failures experienced by end users using information/data from a live commercial network. The major factors affecting CSFB have been highlighted. The Key Performance Indicators (KPI) have been extracted and analysed from the customer's network. This present work shows EUTRA NR dual connectivity where User Equipment is connected to LTE network and NR via Radio Resource Control (RRC) reconfiguration process [20], dual connectivity setup with the aid of split bearer when transferring data between LTE and NR [21], [22]. The UE will be communicating with LTE eNodeB and NR gNodeB radio with signaling and data through the LTE

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core network [4], [5], [23]-[29]. Coverage and distance effect on network uplink and downlink data throughput as mobile users move away from coverage of gNodeB. The target for a new 5G radio access technology is to support multi-Gbps and ms latency connectivity simultaneously [30], with the rapid development of the Internet of Things (IoT), various low-cost Machine Type Communications (MTC) devices, and intelligent wearable devices [31], [32]. Multi-antenna technologies such as beamforming and Multiple-Input, Multiple-Output (MIMO) with hybrid beamforming structures in the mm-Wave band are anticipated to play a key role in 5G systems [33], [34]. Since 5G NR brings a significant amount of data rate, reduced symbol time duration, which may cause 5G NR user equipment to consume more power PDCCH [35]. Since Non-Standalone (NSA) is the early phase of 5G deployment and this uses 4G core. Its being noticed from end user side that 5G coverage suddenly diminish during mobility scenario more than 500 meters and does not handover to 4G network (user connection lost due to drop of service resulting to drop PS service) and mobile goes to emergency mode and reselects a frequency based on priority set according to parameter. In this present research work, a drive test live data collection was conducted on a roll out network, showing degradation of data throughput as user drift away from NR sites.

The organization of this paper is as follows: Section II discusses the 5G non-standalone system architecture and its procedure. The Section III explains beam forming management. The Section IV has the process for MIMO pairing, uplink and downlink power control features with performance comparison. Finally, Section V concludes the work and recommends the future aspects.

II. 5G NSA System Architecture, Interfaces And Procedure

The 5G radio and core networks can be independently evolved and networked. That is, 4G and 5G base stations can be connected to 4G and 5G core networks, respectively [2], [5], [26], [27], [36]-[38]. In addition, the dual-connection technology issued to ensure that 4G and 5G converged networks can be quickly implemented, an LTE network access is required to maintain continuity after a user has accessed a 5G high-frequency small cell. In independent networking and non-independent networking, the dual-connection technology can fully utilize the existing resources and achieve smooth evolution. 5G networking structure can be classified into standalone networking and non-standalone networking. In standalone networking 5G core network & base station should be in existence, and are connected through the control (signalling) plane.

While Non-Standalone (NSA) networking reuses existing LTE network coverage advantages and provides signalling plane connections to solve the 4G and 5G interoperability problems caused by discontinuous coverage of 5G deployment. The device still uses 4G Architecture but with the implementation of 5G gNodeB as a secondary node for dual connectivity without 5G core network. NSA sees the existing LTE Architecture and its NAS signalling in addition to a 5G radio carrier.

Since there is no 5G core network for NSA and it depends on LTE core network, this solution only provides for eMBB that are internet-browsing rate with high speed, augmented reality, visual reality, and broadband. Therefore, the three key performance indicators for 5G that are URLLC and mMTC cannot be achieved until the implementation of standalone with 5G core network. In terms of connectivity to the network, there are different interfaces involved from the UE, gNB, eNB, and to the core network, which are UU, X2, and S1-U interfaces. Since this research work is concerned about Non-Standalone, authors have focus on the 5G interface connecting to the 4G eNodeB [39], [40].

The UU Interface is responsible for downlink and uplink connectivity between the user equipment and the new radio with protocol stack, which is user plane and control plane. The user plane differentiates data streams of circuit switch, packet switch, and broadcast control domains while the control plane carries network signalling messages. The X2 Interface, which will be connecting the Master eNodeB and the secondary gNodeB, its function includes adopting EN-DC and flow control for split bearer on a Non-standalone operation, this will be supporting the X2 application protocol and X2 user plane E-UTRAN Radio Access Bearer (ERAB) configurations. The Flow control function for DC Split bearer is used to split downlink data when using the radio resources of multi RAN nodes. The information exchanged between gNodeB and eNodeB is further enhanced to optimize the flow control for Non-standalone operation.

At the early stage of 5G, authors have recommended the non-standalone architecture for networking, which can reuse the existing LTE network, shown in Fig. 1. The gNodeB supports S1-U connectivity to the Evolved Packet Core (EPC) only (no control plane). The EPC is not compatible with the New Radio protocol, therefore, the EPC cannot connect to the gNB through the control plane. However, the NGC is compatible with 4G access, therefore, NGC can connect to either gNB or eNB through the control plane.

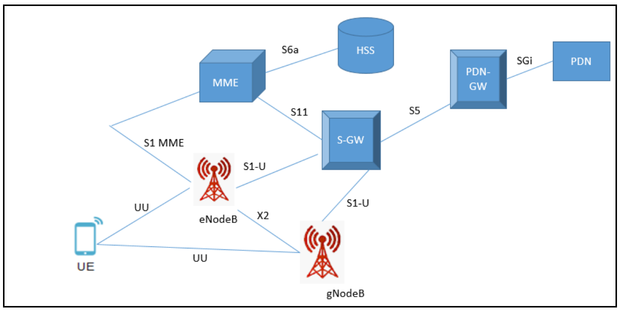

Fig. 1. 5G Non-Standalone architecture.

A. NSA EN-DC Data Split ERAB Configuration

The UE connects to the eNodeB and gNodeB at the same time in a dual connection scenario. One is termed the master node, other is the secondary node as shown in Fig. 2. The determinant of the master or secondary node depends on the anchor of the control plane; the base station that has a control plane with the core network is the master node [41]. There are four different ERAB configurations, which are:

- Master Cell Group (MCG): The ERAB flows from the Serving Gateway to the master node and directing to the UE without any involvement with the secondary RAN Node.
- Master Cell Group Split Bearer: At the Master node, splitting of data will take place with the secondary node for transmission, this shows significant improvement in data rate.
- Secondary Cell Group (SCG): The UE receives 5G data rate using this configuration, ERAB flow of user plane data from the Serving gateway to the secondary node gNB and directly to the UE without splitting data with the master node.
- Secondary Cell Group Split Bearer: The secondary node splits data it receives from the core network with the master node.

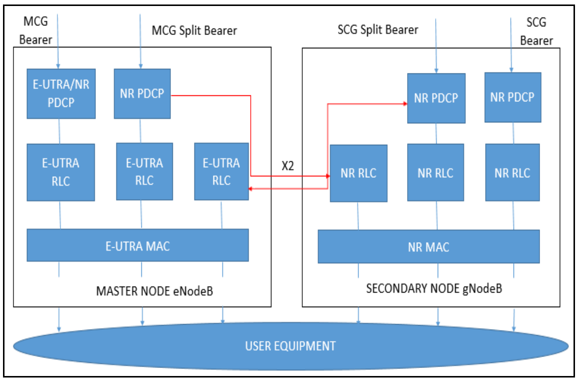

Fig. 2. EN-DC split data of non-standalone UE perspective.

The highest throughput and data rate seen with this approach is actively using dual connectivity, depending on network configuration, services, and scenario; it might not be desirable to work on certain split bearer users based on network requirements. With the dual connection networking, the control plane is provided by the eNodeB. The NR only has a user plane, which can solve the problem of discontinuous coverage at the initial stage. The user plane traffic distribution solution varies according to the architecture:

- Option 3: Data is offloaded from the eNodeB. PDCP split on LTE BBU, the user plane is anchored on the eNodeB side, which reduces the user plane interruption caused by mobility. The gNodeB does not need a connection with the EPC.
- Option 3a: Static offload without RAN state awareness, data is split from the EPC
- Option 3x: PDCP Split on NR BBU, no impact on legacy LTE. The user plane is anchored in the gNB, may change frequently. Data is offloaded from the gNB.

B. 5G NSA Uplink and Downlink Decoupling Features

A vast majority of global operators have selected the C-band spectrum as the preferential 5G frequency band. Comparing the signal level and propagation for DL and UL vice versa on the C-band, the Tx power for DL aid in improving its coverage better on the NR as shown in Fig. 3. The C-band can provide at least 200 Mbps global bandwidth, which will become the main spectrum of 5G Network.

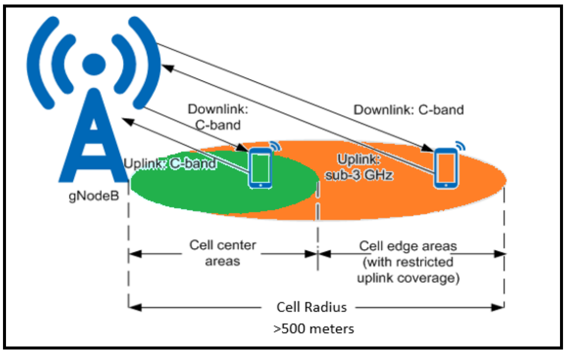

Fig. 3. The UL/DL decoupling and mapping.

The C-band spectrum allows transmission and reception on the same channel, which is ideal for NR-5G Enhanced Mobile Broadband (eMBB) services. Its known features and merits are antenna radiating pattern to specific UE user and reference signal of a cell. These help in path balance in coverage between NR and UE and vice versa, thereby not allowing possible means of interference within users [42].

The UL and DL decoupling feature defines a new-paired spectrum for areas with restricted uplink coverage, propagation model using this high frequency of C Band is complex and requires LOS with no obstacle bridging NR and UE due to its wavelength. Fig 3 describes UL and DL users and distance from NR [43]. In the early stages of 5G commercial use, if no dedicated sub-3 GHz spectrum is available for 5G, then LTE FDD and NR Uplink Spectrum Sharing can be enabled to allow NR to share sub-3 GHz spectrum with LTE FDD.

The new radio base station uses a high-frequency band for downlink transmission. For uplink, the frequency band could be selectively shared with LTE low-frequency band depending on User Equipment coverage. Decoupling between uplink and downlink spectrum allows uplink data transmission on either the NUL or the SUL carriers. For UEs whose uplink data transmission is carried on Supplementary Uplink (SUL), the random access, power control, scheduling, link management, and mobility management differ from the procedures for UEs whose uplink and downlink data transmission are carried on C-band.

To ensure the availability of the SUL carrier for uplink data transmission, gNodeBs must transmit the SUL carrier information to UEs [44]. The information is contained in the *ServingCellConfigCommon* Information Element (IE) of the RRC reconfiguration message. The SUL carrier information includes the following:

- Frame structure, system bandwidth, and NARFCN.
- Physical Uplink Shared Channel (PUSCH) common configuration.
- Physical Uplink Control Channel (PUCCH) common configuration.
- Physical Random Access Channel (PRACH) configuration: time-frequency resource configuration, including the *NRDUCellSul.Rsrp.Thld.Parameter*

C. Secondary Harmonic Interference Avoidance

Developing and co-existing of 5G radios with other technologies e.g. LTE, military and commercial wireless devices, Wi-Fi, etc. is useful, hence, it brings various network challenges. Network planners and optimization ensures users operate within the given spectrum, and QoS are guaranteed the need to reduce internal band and outside emission in order to meet key performance goals without causing interference with itself and or other technologies signals in the channel or with signals in adjacent spectrum.

When a user equipment uplink data transmission is carried on the supplementary uplink link carrier, and its downlink data transmission is carried on the NUL carrier, the uplink transmit frequency multiplied by two overlaps the downlink receive frequency and interferes with the reception of downlink signals. Hence, the self-interference signal generated by the UE during uplink and downlink data transmission is *secondary harmonic* [45]. This is represented in Fig. 4.

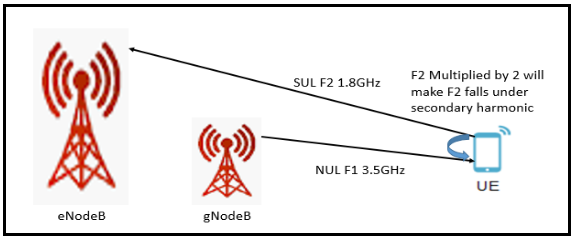

Fig. 4. Secondary harmonic co-existence.

The operation of 5G NR mid and high band are in the same or adjacent spectrum with another wireless communication system, with various devices operating at multiple bands, the risk for sideband interference or new-shared spectrum is high. If the SUL frequency band of an NR cell multiplied by two overlaps the downlink NUL frequency band, select the *SEC_HARMONIC_INTRF_AVOID_SW* option of the NRDUCellSul.*UlDlDecouplingAlgoSwitch* parameter to enable the gNodeB to schedule the uplink and downlink data in coordination for UEs for which UL and DL decoupling takes effect. This reduces interference from UEs uplink signals to downlink signals.

The need for 5G NR devices to operate in the same spectrum or adjacent as existing wireless communication without interference will show significant impact on network user side which are:

- Increased number of UEs admitted to NR cells: this expands the uplink coverage of NR cells and allows more UEs to be admitted to NR cells.
- Improved NR cell throughput: this improves the uplink and downlink throughput of NR cells.

III. Beam Forming and It's Management

A single-wide beam is used to cover an entire cell of a LTE TDD network. This is not the same scenario in NR network where the cell is covered using a series of narrow beams broadcast at different angles and at different moments (Fig. 5). The UE scans each of these individual narrow beams to identify the best beam to use for synchronization and system message demodulation. Static beams are inherent to the cells. They are defined by the arrangement of antenna elements. Dynamic factors such as user locations, user movement speed, or channel quality are not affected by the static beam [1], [3], [6], [22]-[27], [36]-[38]. Weighted signals are transmitted in narrow beams directed towards target UEs or a specified direction. This process is termed as beamforming. It enables beams to accurately direct towards UEs to improve coverage performance, beams refer to the shape and direction of electromagnetic wave propagation.

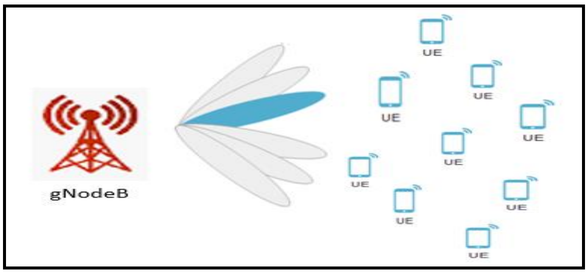

Fig. 5. NR Broadcast beam scanning process.

The management of scanning, reporting, and maintenance of static beams refers to beam management. It enhances cell coverage and reduces system overhead. The purpose of beam management is to select the most appropriate static beams for each channel. Beamforming uses weighting for transmitting signals and forms them into narrow beams directed at target UEs or in other specific directions. If the weighting used for beamforming is present, beam management is required. If dynamic weighting is used, beam management is not required.

The basic beam management feature enables the gNodeB only to support the default coverage scenario of broadcast beams. For broadcast channels, beams can be configured differently for different coverage scenarios. With the use of 3D coverage pattern, a gNodeB supports a range of broadcast beam configurations to meet different coverage requirements. Operators can select the beam configuration best suited to their own coverage requirements to enhance cell coverage and reduce interference from neighbouring cells. In addition to the default scenario, 3D coverage pattern enables the gNodeB to support another 16 different broadcast beam coverage scenarios. In different coverage scenarios, broadcast beams have different tilts, azimuths, horizontal, and vertical beamwidths. This feature resolves issues of insufficient cell coverage and neighbouring cell interference in different scenarios [46].

The coverage area of a cell depends on the tilt and azimuth of the antenna. After the tilt or azimuth is adjusted, the coverage radius and coverage shape of the cell change as:

- When the 3D coverage pattern feature is not activated, the gNodeB (8T/32T/64T) supports only the default scenario.
- When the 3D coverage pattern feature is activated, the gNodeB (8T/32T/64T) supports the default scenario and other coverage scenarios.

Multiple narrow beams are used at the user level. The best possible narrow beam set needs to be selected first for the PUCCH, PUSCH, PDCCH, PDSCH, CSI-RS, and TRS. The UE needs to scan these narrow beams to identify the best beam set. The gNodeB then maintains the best beam set reported by the UE and selects the best beam set for each channel.

Static beams for uplink channels (PUCCH/PUSCH) are selected based on SRS measurements. After SRS measurement, the Reference Signal Received Power (RSRP) values are organized and the beams with the largest RSRP values are selected for these channels. Generally, the coverage of a data channel (PDSCH/PUSCH) is the area covered by a user-level static beam. It remains unchanged. The direction of a user-level static beam is not affected by the azimuth and tilt adjustment of a broadcast beam.

On low frequency bands, SRSs are used to measure the RSRPs of static beams for downlink channels (PDCCH/PDSCH/CSI-RS/TRS). The beams with the largest RSRP values are selected for downlink channels. On low frequency bands, either wide or barrow beams can be used for UE TRS beams. The type of beam used depends on the setting of the *NRDUCellTrpBeam.TrsBeamPattern* parameter.

- A singlewide beam is used. It is recommended that PATTERN1 be configured for 64T, 32T (16H2V), 16T, or 8T AAUs.
- Two smaller beams are used when set to PATTERN 2.

The NR broadcast channels use narrow-beam scanning to direct the transmit energy at target users, which increases their demodulation SNR and improves the transmission success rate. This also improves the control channel coverage, thereby increasing the cell radius. NR user-level beam management maintains, selects, and filters the best beam sets to improve the accuracy of static beam directions, increasing the demodulation SNR of target users and improving the transmission success rate. This also improves the user-level channel coverage.

Different broadcast beam scenarios can be selected based on network conditions and user distribution to ensure maximum coverage gains. The tilt and azimuth adjustments can reduce overshoot coverage, reduce inter-cell interference, and improve coverage gains in multiple scenarios, such as public squares or high-rise buildings. Users can remotely adjust the antenna down tilt (Electrical) and horizontal azimuth by specifying the *NRDUCellTrpBeam.Tilt* parameter and the *NRDUCellTrpBeam.Azimuth* parameter. This can reduce the difficulty in site selection planning and site optimization, decrease the optimization and coordination costs, and better address inter-cell interference issues. The gNodeB supports the tilt and horizontal azimuth adjustment of narrow beams on broadcast channels in degrees. More beam directions can be used by means of tilt and horizontal azimuth adjustment, which helps meet different coverage requirements and allows for more flexible networking.

IV. MIMO Pairing, Downlink, Uplink, Power Control, and Performance Comparision

The use of MIMO involves various antennas transmitting and receiving with different techniques for signal processing, which all combine to improve user experience.

A. *MU MIMO Pairing and SU-MIMO Layers and Features*

The MIMO allows gNodeBs to use multiple antennas to transmit and receive signals. The TDD gNodeBs working on low frequency bands support 64T64R, 32T32R, and 8T8R. gNodeBs use beamforming to transmit signals in the downlink. Beamforming is supported only in TDD mode. In the uplink, gNodeBs receive UE signals over multiple antennas. Massive MIMO increases the number of arrays and uses narrow bean with higher concentration to replace the previous wide beam, unlike the traditional antennas. Higher enablement gain can be achieved if the beam weight of Massive MIMO is adjusted [33], [47].

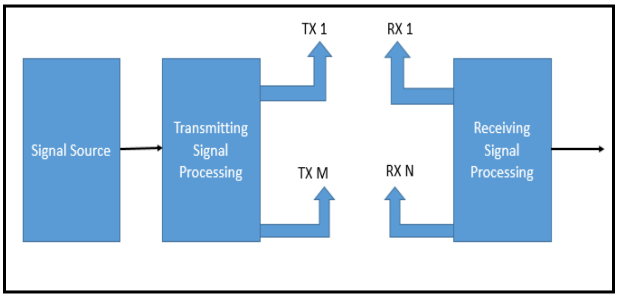

Fig. 6. MIMO in time division duplex mode.

Multi-User MIMO (MU-MIMO) allows for spatial multiplexing (Transmission techniques transmitting encoded data signals) of the same OFDM time-frequency resources by multiple UEs in uplink and downlink data transmission (Fig. 6). This improves uplink and downlink capacity and spectral efficiency. The selection of multiple UEs for MU-MIMO is called pairing. Currently, only PDSCHs, physical downlink control channels (PDCCHs), and PUSCHs support MU-MIMO. Uplink receive diversity enables gNodeBs to enhance reception by taking advantage of space diversity and coherent reception to receive UE signals over multiple antennas. The overall uplink receive diversity procedure is as follows:

- A gNodeB receives SRSs from a UE over multiple antennas, estimates the uplink channel characteristics, and then sends Downlink Control Information (DCI) to the UE, notifying the UE of the optimal PMI/rank value.
- The UE uses that PMI value to precode PUSCH data and transmits it to the gNodeB.
- The gNodeB uses multiple antennas to receive the PUSCH data, improving the signal-to-noise ratio (SNR) and stability of received signals, and increasing uplink user throughput.

B. Downlink and Uplink SU-MIMO Layers

The SU MIMO uses multi-antenna technologies to support spatial multiplexing of time-frequency resources in uplink and downlink data transmission for a single UE. This enables multi-layer data transmission in both the uplink and the downlink for that UE [44], which boosts the single UE peak rate (Fig. 7). The DL SU MIMO uses multi-antenna technologies to enable downlink multi-layer data transmission for a single UE [48]. The maximum number of downlink data layers for a single UE depends on the following factors:

- The smaller value between the number of gNodeB transmit antennas and the number of UE receive antennas
- 3GPP specifications, which stipulate that a single UE supports a maximum of eight data layers in the downlink
- Restriction of the maximum number of downlink layers in a cell.

The *NRDuCellPdsch.MaxMimoLayerNum* parameter specifies the maximum number of downlink layers in a cell.

The UL SU MIMO uses multi-antenna technologies to enable uplink multi-layer data transmission for a single UE. The maximum number of uplink data layers for a single UE depends on the following factors:

- The smaller value between the numbers of gNodeB receive antennas and the number of UE transmit antennas.
- 3GPP specifications, which stipulate that a single UE support a maximum of four data layer in the uplink.
- Restriction of the maximum number of uplink layers in a cell.

The *NRDuCellPusch.MaxMimoLayerCnt* parameter specifies the maximum number of uplink layers in a cell.

For DL SU MIMO with a 64T64R gNodeB, a 2T4R UE can support data transmission over up to 4 layers in the downlink. For UL SU MMO with a 64T64R gNodeB, a 2T4R UE supports data transmission over a maximum of 2 layers in the uplink.

The MU-MIMO is recommended for large traffic scenarios. The network traffic is considered large when either of the following conditions is met:

- The uplink or downlink PRB usage is at least 50%.
- High number of UE in connected mode

The throughput gains depend on the number of layers for spatial multiplexing. When there are more layers, the gains are greater. For full buffer service, this function provides a theoretical throughput gain of N x 100 %, where N is the number of layers for spatial multiplexing.

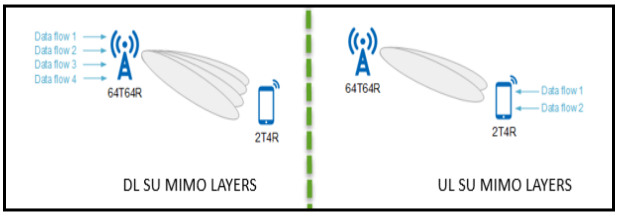

Fig. 7. DL / UL-SU MIMO multiple layers.

C. Uplink and Downlink Power Control

The gNodeB and UE power adjustment aid in satisfying and compensation of coverage for users without distortion from the effect of obstacles, in order to reduce the interference between 5G intra-frequency cells, while also helping meet coverage and capacity requirements. There are two types of power control in an NR system, which are uplink power control and downlink power control.

In the NR system, downlink power control is used to control channel and signal power. Downlink power control is applicable to the Physical Broadcast Channel (PBCH), Synchronization signal (SS), Physical downlink control channel (PDCCH), Physical downlink shared channel (PDSCH), and CSI Reference Signal (CSI-RS).

A gNodeB calculates the Transmit Power Control (TPC) value, no dominant, and overshooting cells [49]. The gNodeB then issues a TPC command to the UE through the PDCCH. According to 3GPP TS 38.213, the UE converts the power adjustment amount based on the TPC command. Then, the UE determines its transmit power based on factors including its own maximum transmit power, the nominal power of the cell, the path loss, the modulation and coding scheme (MCS), and the number of radio resources [50].

D. PDCCH Power Control

In the event that the demodulation performance of PDCCH power control cannot be ensured for CEUs, control channel element (CCE) power can be increased to correctly demodulate PDCCH signals. PDCCH power control can be PDCCH static power control and PDCCH dynamic power control. Implementation of PDCCH power control is done on the gNodeB. The PDCCH static and dynamic power control functions improve the PDCCH coverage performance for CEUs. In a situation where CEU's are high, and the PDCCH static and dynamic power control values are set high, the coverage gain will increase, resulting in high downlink interference among neighbouring cells [51]. Thus, the formula for calculating static and dynamic transmit power (dBm) on the common PDCCH is:

$$\text{ReferencePwr}+\text{MaxCommonDciPwrOffset}+10*\text{Log10}(\text{RFChannelNum}) \quad (1)$$

$$\text{ReferencePwr}+\text{MaxDedicatedDciPwrOffset}+10*\text{Log10}(\text{RFChannelNum}) \quad (2)$$

where Reference power is cell reference power *MaxCommDciPwrOffset* is the maximum DCI power offset in common searching space CSS *MaxDedicatedDciPwrOffset* is the maximum value of the Dci power offset in UE specific searching space USS RF Channel Num is the number of RF physical channel.

The PDCCH static power control optimizes the PDCCH coverage performance of the cell. This function includes common PDCCH static power control and UE-specific PDCCH static power control.

E. 5G NSA Procedure for Adding Serving gNodeB

The UE accesses the network using UL-SCH allocation to send the RRC connection request message to the eNodeB, after accessing, the eNodeB responds to the preamble with random access response and RRC connection setup request message on the DL-SCH [52]. After the completion of the RRC connection, the UE carries NAS attach a message, which is signalled to the core network through the initial UE message. The DCNR bit in UE network capability IE is set, this signals to the core network of the 4G that the user equipment supports dual connectivity with NR and LTE [26], [27], [36], [37]. This process has been shown in Fig. 8.

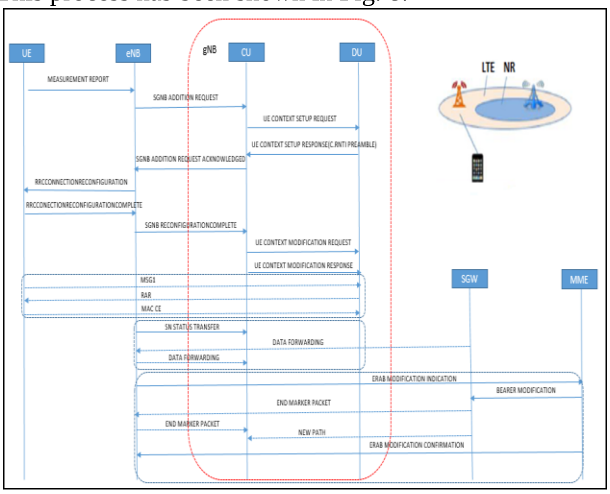

Fig. 8. Procedure for adding serving gNodeB.

The eNodeB decides to request the gNodeB (CU) to allocate radio resources for the specific ERAB indicating the characteristics of the ERAB parameters, TNL address information corresponding to the bearer type. The CU sends a UE CONTEXT SETUP REQUEST message including information such as GTP-U tunnel established with the EPC, S1 UL TNL address, and security configuration. The DU uses the configuration provided by the CU to return the UE CONTEXT SETUP RESPONSE message containing at least the S1 downlink TNL address and F1 uplink TNL address, rejection of some bearers from the DU side may occur due to insufficient resources. If the DU and CU are both combined, the signaling messages of both cannot be traced.

F. 5G NSA Downlink Performance Comparing Throughput and Distance Away From gNodeB

The important service scenario at the initial stage of network deployment is eMBB, the need to consider the target throughput at the edge of coverage during network planning should be the requirement. Network drive test measurement was carried out for this paper to compare variation of downlink and uplink throughput when user equipment is in mobility state drifting away from gNodeB (Fig. 9).

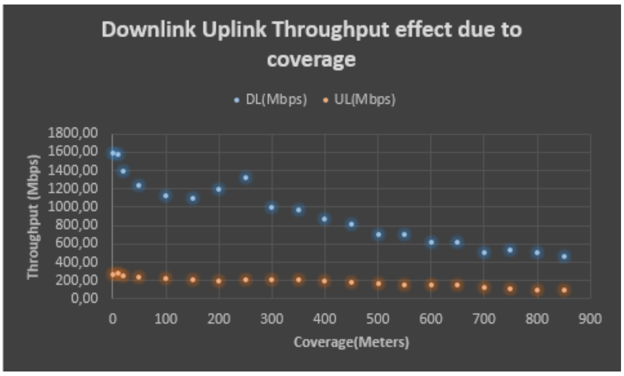

Fig. 9. Comparison of DL and UL throughput vs. distance.

The measurement event of the New Radio is delivered on the LTE side in the Non-Standalone scenario. The UE in mobility state moves from one serving gNodeB to another SgNB change as it drift from serving area to a better and stronger cell PSCELL. The measurement control information of the NR module is transmitted on the LTE through the X2 interface; the LTE delivers the measurement control information to the UE. The measurement information of the UE is reported to the LTE, and the LTE sends the measurement report information to the NR through the X2 interface.

According to the on-site test shown, intra frequency mobility management is triggered based on coverage. After the EN-DC UE is connected, then the eNodeB updates measurement configuration. There is a huge gap in throughput degradation as users drift away from gNodeB, since NR operates on mm waves; more sites are needed at close proximity for coverage and capacity.

Mobility mode experienced during data collection showing *NRSCellAbnormalRelease* and *LTEERABAbnormalRel* messages after event A3 measurement (between UE and NR) signifying handover as 5G coverage weakens. There was network disconnection and PS service was dropped, user equipment eventually reselected and latched on LTE network during download. It has been shown in Fig. 10. It is recommended for NR to LTE Handover configuration to avoid Anchor issues and KPI degrade there by affecting subscribers.

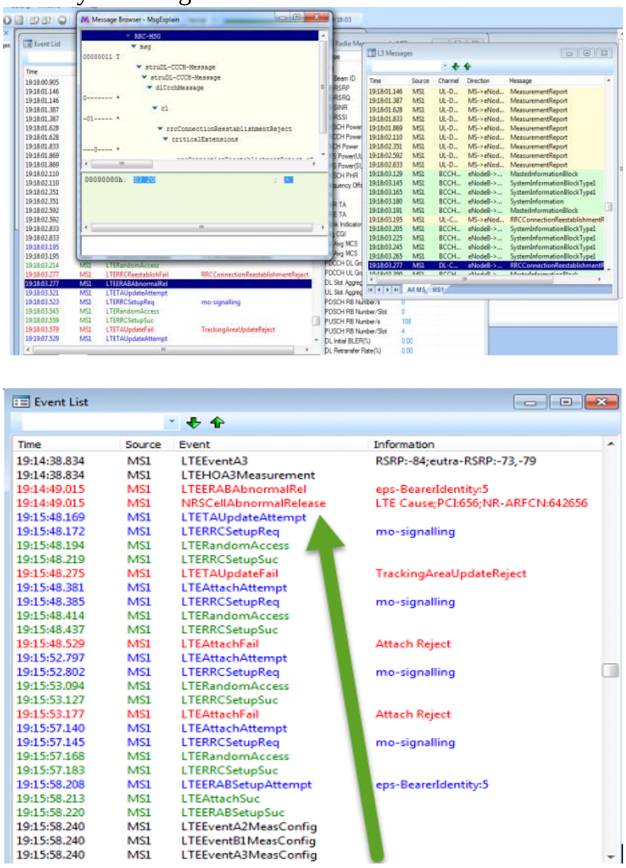

Fig. 10. Radio signalling layer messages during data collection.

V. Conclusions and Future Aspects

Non-standalone focuses on eMBB services at the early stage of 5G deployment as LTE core serves as an anchor, and EPC can be reused. This research was carried out on an active network deploying NSA. Mm wave is high with a low penetration rate due to shorter wavelengths. Network operators should quickly deploy Standalone NR without 4G Core. To improve frequency efficiency, F-OFDM feature can control the leakage of transmitting signals outside the system bandwidth, can control the impact of out-band interference on the NR system, and enable more spectrum to become the downlink transmission bandwidth, hence increase the cell capacity and provide good downlink coverage with user experience.

The uplink and downlink cell throughput value for large traffic scenarios can be enhanced with MU MIMO which is dependent on the number of layers for spatial multiplexing. The deployment of 5G New Radio with its core on commercial network will fully maximize the desired features of 5G KPI's which are mMTC- IoT and URLLC.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Sylvester J. Udoh (SJU) and Viranjay M. Srivastava (VMS) conducted this research; SJU designed and analyzed the model with data and wrote the paper; VMS has verified the result with the designed model; all authors had approved the final version.

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