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ORIGINAL RESEARCH

A comprehensive study of handover mechanism with minimal resources in 5G cellular networks: architecture and challenges

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Abstract

Now days MIMO–OFDM is highly preferred in mobile communication, includes the 5th generation (long term evaluation). The objectives of current research include proposing and designing a high quality 5G cellular network using minimum resources and handover mechanism. The handover mechanism is implemented for the minimization of the time in the performance of the cellular network. The performance of the proposed simulation model for the 5G cellular network is extracted based resource allocation and handover mechanism. This implementation is reducing the handover preparation time and execution time. For the three selected schemes of transmission as – 5 dB, 0 dB, and 5 dB the experiment acts as an active, passive, and clustered. For the 0 dB the transmission acts as an active transmission, for the – 5 dB it acts as a passive, and for the 5db it acts as a clustered mode for the transmission. The present study clearly demonstrated that the 5G network can be communicated within minimum resources, time, space, and usability of the white spectrum with maximum speed. Due to the increasing complexity of network topology in 5G Heterogeneous with the integration of many different base station types, in the 5G architecture mobility management has many challenges. The intense deployment of small cells, along with many advantages it provides, brings important mobility management problems such as frequent Handover (HO), HO failure, HO delays, ping pong HO and high energy consumption which will result in lower user experience and heavy signal loads. The simulation framework was efficiently designed towards the minimum resources and maximum speed objective. The proposed model allowed to reduce the time required for handover mechanism time and its execution time.

Keywords 5G network simulation · Resource allocations · Technology · Cellular network · Handover

1 Introduction

The technology world has witnessed the rapid growth of cellular mobile technology for the last three decades (Kumar et al. 2019). The cellular technology growth is started from 2 to 4G with the help of long term evolution (LTE) (of Mobile Networks) and global system for mobile communications (GSM). The high bandwidth signal transmission relies on the compatibility of the hardware, the connectivity of the network node, the inner channel interface, and scalability. The restraint of the new generation network is based on the improved network capacity and low delay factor for the voice, data, and video signal transmission (Mitra and Agrawal 2015).

In the traditional cellular network, the bandwidth, data rate and security can be improved by the practice of upgrading cellular network using 4G LTE technology. In the current network, the data rate is enhanced to 100 Mbps. However, the bandwidth signal transmission rate is not sufficient for

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current mobile users. It is believed that the 5G network will expect to improve not only the speed of the network, but also the scalability, high connectivity, efficiency, and better security in the cellular network (Zhang et al. 2015). The cellular network customer has triggered the high-quality changes in the requirement of the network concerning security and usability (Barakabitze et al. 2020). For the development objective of the 5G network the physical network has been sliced into a more logical isolated network and structure. The logical dedicated structure is demanding high-quality services for cellular phones and the internet of things (IoT) devices (Chen and Zhao 2014; Abbas and Alcardo 2015). The cellular services are based on the handover mechanism. This service mobility services work based on distance between two cells means the range is passed from one cell station to base station (Niu and Willing 2005; Brahmjit, 2005; Xie and Zhao 2009).The LTE based cellular network provides improved performance in terms of data rate and bandwidth. The LTE provides a fast and seamless handover between two cells to meet the requirement towards the network management.

Its working is based on the switching functionality from base station to active current station in the network (Migaldi et al. 2008). In the 5G network, there are large number of small cells are presents. So prior concern is that there is increment in the handover rate. So system is expensive and time consuming if the appropriate coverage is not obtained which may increases the call blocking or call drop. Different types of handover in 5G network are listed as Xn based handover, N2 or NGAP based handover, and intra & inter frequency handovers.

In the 5G network, based on base station scanning and used topology, the handover can be further classified into hard handover and soft handover. In the hard handover, a through of a break before establishing a connection among the nodes of the network. It is used for time division multiple access (TDMA) and frequency division multiple access (FDMA). Both are used to minimize the channel interference by utilizing different frequency based adjacent channel and frequency ranges. Soft handover is used to establish a new connection between a new base station and previously disconnected based station.

From the past related research study, it is seen that there are diverse research frameworks that were used for the handover based 5G simulation networks. The simulation-based assessment is one of the extraordinary strategies for achieving the best of the 5G network with the handover framework and resource allocation methodology. The progression of the 5G network is possible using 4G development, LTE, and handover based instruments (Farooq and Rather 2019). There are many new challenges in the mobility management of the 5G communication system, such as signal measurements are not precise, frequent handover, different network layers switching and resource allocation. In this paper, we provide a comprehensive study on the mobility management in 5G, in terms of radion resource control, and also addresses the challenges and suggest possible solutions for the 5G mobility management. The advantages of using mmWave systems in 5G HetNets were mentioned and how these systems will be integrated, the management of beam level mobility and the measurement parameters used for this purpose are explained in detail. Afterwards, various difficulties such as HO problems, signal overhead, power consumption, security and delay are described in detail, along with the solution suggestions presented in the literature.

2 Related work

There are several studies in the literature review for describe and compressive literature review of out the proposed research. The examination from 2016 is expounded as a 5G test system model and the exploration of 2020 is built up as a handover, execution improvement, and ongoing application advancement utilizing 5G networks. The proposed research framework, implementation framework such different applications have been concentrated on this experiment. Extensive studies have been conducted in the literature to overcome management problems in HetNets. The main reason for performing HO from one cell to another is users mobility. Table 1, show a comparison for the literature is depicted, the descriptive information about the survey in the literature is given in the prepared.

3 Methodology

In the present study, we have focused on the lessening of handover time and utilized an advantage reservations method for the progression of 5G simulated networks. This simulation-based experiment is designed and executed in a Matlab simulation environment.

3.1 Research framework

The objective of the proposed model is to reduce the handover interruption time for the communication network in the simulation environment. The development of the simulation needs information and target. The network model design is based on the simulation software environment. The simulated network is verified and validated using the performance evaluation parameter based on resource allocation and handover interruption time.

Table 1 literature survey comparison and properties

Simulator	Properties of simulator
NYUSIM (Anwar and Prasad 2018)	Statistical channel illustrating, recreation code with an easy-to-use interface
	A standalone application, it include GUI (graphical user interface)
	It can run on computers with windows 7 or higher and Mac operating systems
	Carrier frequencies from 2 to 73
Vienna LTE Simulators (Hajiyat et al. 2019)	The statistical channel of 5G arranges for enormous scope, that can incorporate several hubs Parallelization is upheld
	The development of the system architecture, called SAE (system architecture evolution)
	To provide higher spectral efficiency
	More multi-user flexibility
	Multi-level directions
	The code is openly accessible for development
WISE (Larsson et al. 2014)	System-level reenactments of 5G systems for multitier directions
	Available source code for reenactments and approval
GTEC 5G simulator (Tayyab et al. 2019)	Link level reproductions of 5G frameworks for OFDM (orthogonal frequency division) and FBMC (filter bank multicarrier) signals
	Transceiver usage
MmWave	MmWave transmission
	AMC (artificial magnetic conductor)
	User scheduling
	A wavelength range of 10 mm at 30 GHz decreasing to 1 mm at 300 GHz
5G Toolbox by Matlab (Pratschner et al. 2018)	Linkage level simulations
	Strait modeling
	It supports golden reference verification
	It also support test waveform generation
	Signal generation

3.2 Simulation model

This method explains the handover and the resource allocation mechanism. This experiment tested the Matlab software package and its 5G wireless toolbox. The spectrum and frequency passing from one node to another node in the 5G interface were utilized in the designing of the simulation network. The architecture of the 5G is a combination of 3G, GPRS, and LTE. Each technology has its server and a combination of the server towards the development of the 5G is described in Fig. 1. Block diagram consists of the MTS and BTS of the respective cell. Various devices, modules are used as input for the proposed model. BTS is connected various inputs like mobile unit (UE),traffic signal, radio stations, personal computers, etc. From BTS those signal are processed, then transferred to MTS where actual switching and controlling the signal is done. Different servers are connected to network layer which acts as a cloud. There is separate BTS for the each cell named as base station (BS).

The simulator software is simple and provides the user interface for designing and development. The experiment tests for the 5G simulation model.

The software-defined networking (SDN) based architecture of the proposed 5G simulation network is shown in Fig. 2. The proposed architecture, compared to 4G (LTE), enhances the RANs with programmability and transport network layer is realized by Quality of Experience (QoE) services, events, topology and network model, and configuration. The first approach allows incremental enhancements of existing deployed networks. In this case, the SDN controller implements the required standardized interfaces. The real execution system for the SDN based simulation network improvement appears in the above outline. This framework explains the network model, topology, and design of the network test system. The information perception, assessment, and framework based reportage administrations are conceivable utilizing the proposed network.

The simulation topology for the designing work of cellular networks in the Matlab simulator environment is described in Fig. 3. The topology model is composed of a Server responsible for testing the four QoS classes defined by the 3GPP—one MME/S-GW, two eNBs, and UEs. In this final stage, the reception agents for UDP and TCP traffic were coupled. In this way, the services were defined as conversational (VoIP), streaming (Video), interactive (HTTP),

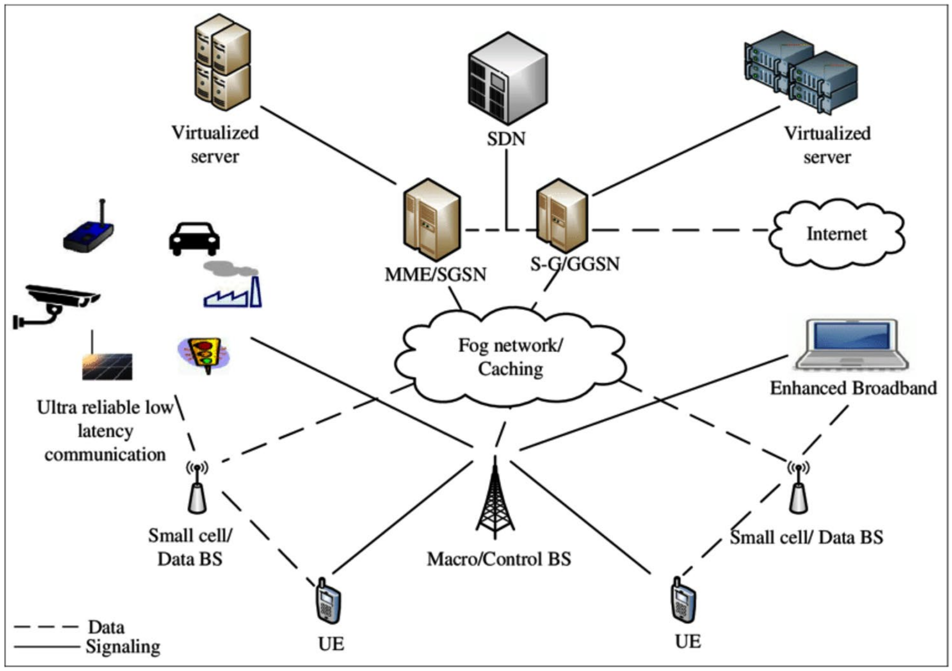

Fig. 1 General 5G technology architecture for different services supported

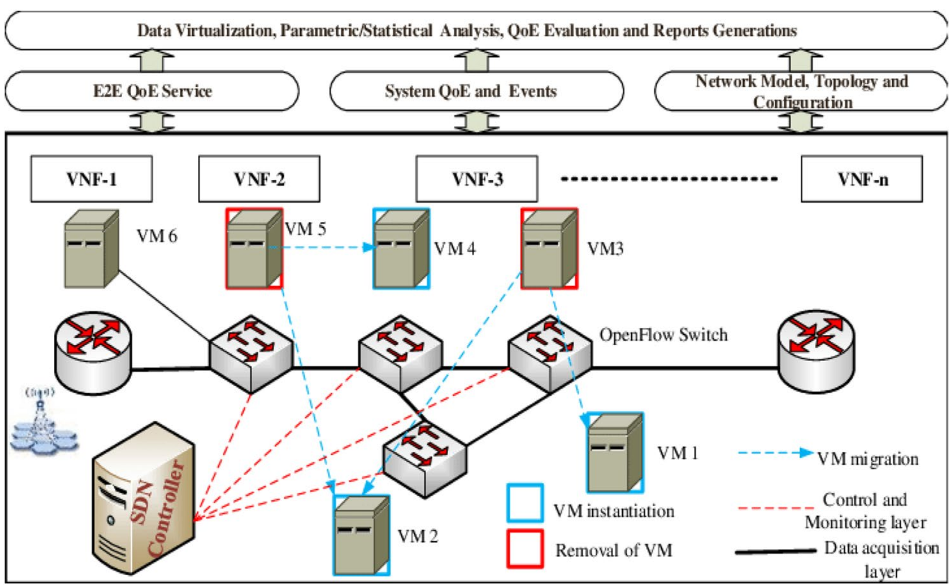

Fig. 2 The scenario of the network using SDN and wireless control

and background (FTP). The parameter was used as simulation time, several UEs, confidence interval, and propagation model.

The proposed 5G simulation model has used the handover framework which decreases the handover management and execution time. The simulation framework software is direct and gives the UI to arranging and progression. The simulation investigation was done using the Matlab simulation stage. The basic initial parameters used for the handover based simulation network are finalized.

The network layout consists of 2 tier 19 cells (total no of channels = T/C, where T = Total no of duplex channels, C = cell cluster size i.e. 4, 7, 12 or 21). The cell radius, bandwidth, and peak data rate were 1 km, 5 MHz, and 20 Mbps, respectively. Omni direction type of antenna was used. Transmit power, shadowing standard deviation and default hysteresis (H) were 46dBm, 6.5 dB and 3.5 dB, respectively. The report period and trigger time (T) were 100 and 300 mSec, respectively.

3.3 The 5G recommendation standardizes as follows

(1) For peak data rate: Downlink: 20 Gbit/s, Uplink: 10 Gbit/s, (2) for peak spectral efficiencies: downlink: 30

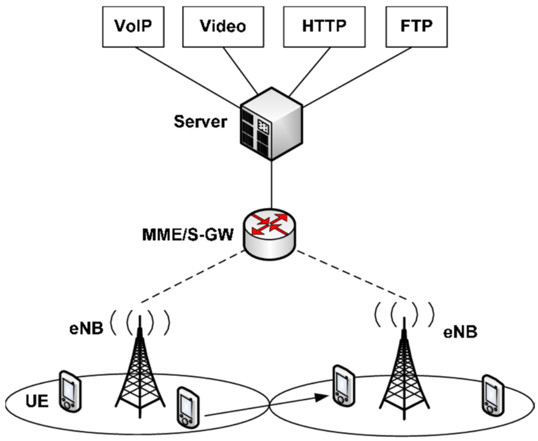

Fig. 3 The simulation topology for the experimental analysis

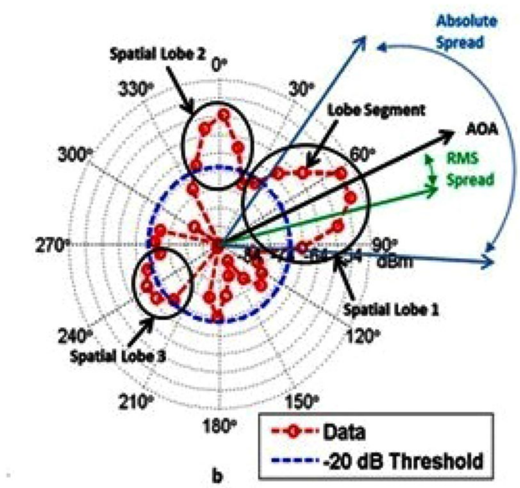

Fig. 4 Handover overlapping channel models

bit/s/Hz, Uplink: 15 bit/s/Hz, (3) user plane latency (single user, small packets): 4 ms for embb, 1 ms for URLLC, (4) control plane latency (idle = > active): 10–20 ms, (5) maximum aggregated system bandwidth: at least 100 MHz, up to 1ghz in higher frequency bands (above 6ghz), (6) mobility: up to 500 km/h in rural embb.

The Fig. 4, represents the handover request, measurement, report of handover, traffic before resource allocation. The topology is foremost and a challenging task for the simulation model. The overlapping model based on threshold and data is graphically drawn and shown in Fig. 4. The representation is shown based on root-mean-square (RMS) and power and delay time RMS spread parameter. Here, three lobs are presented which actually represent the signal strength in the particular direction.

Root mean square (RMS) spread is defined as the square root of the second central moment of power delay profile. Mathematically it is represented as: $\sigma_T = \sqrt{\bar{T^2} - \left(\bar{T}\right)^2}$

$$\bar{T^2} = \frac{\sum_i P(T_i) T_i^2}{\sum_i P(T_i)}$$

3.4 Selected parameters

The experiment was done in the metlab simulation software package using a 5G toolbox. Various parameters were used for the experiment such as, for the simulation experiment, the grid area is selected as a 300×300 m^2 as per dense for the development of the handover based model. For reference signal the selected values of parameter were harmonized in the Matlab simulator. The position based and cell-specific signal was distinguished by model of synchronization. For the handover simulations performance based assessment the experiment was arranged and tested for approaches of − 5db, 0db and 5db SNR. The experiment results of handover mechanism in the 5G simulation network were evaluated based on three parameters which are that were throughput, delay and handoff failure.

3.4.1 Throughput (*T*)

It is a KPI (key performance indicator) for cellular operators, that may be utilized to show interplay among capacity gain and HO cost applied by network densification. Here we calculate the effect of rate of HO and the effect of every HO skipping schemes, upon throughput of average user. The throughput indicated as T, is denoted as unit packet/second. T is tested for 3 approaches of − 5db, 0db and 5db SNR. $T = WR(1 - D)$ Where, W: The complete bandwidth and denotes the erotic efficiency of spectrum.

3.4.2 Delay (*D*)

This can be calculated as connection switching time taken and transfer of data on the another access point. This handover delay time is main influenced parameter that directly impact the network performance. Calculations may be performed as—$D = \min\left(H_t \times d, 1\right)$ where, H_t: the rate of handover per unit time, D: the rate of handover per handover delay in seconds.

3.4.3 Handoff failures parameter

These parameters explain a handoff failures number which occurs in the system.

4 Results and discussion

The main objective of the handover based 5G network simulation experiment is to achieve the extreme broadband rate and reliable latency in communication technology.

4.1 5G simulation network parameters

The numerical outcome of the simulating transmission scheme for the − 5db, 0db, and + 5db SNR at 30 kHz is described below. From the start of the transmission, it shows the failed because this time is used for requesting the handover in the communication. From the table − 5db SNR noise is passed from the source to target node communication. From the 0db SNR mechanism means there is no noise in the transmission or communication among the nodes. The initial transmission is passed means that they successfully communicate among sources to the target node. The simulated experimental results for the 5db noise is shown below, which are passed from the source to target node communication.

1. Channel SNR: − 5db, initial transmission failed: 40% rotate vector (RV) = 0, retransmission passed: 42.5% RV = 2
2. Channel SNR: 0db, initial transmission failed: 2.00% RV = 0, retransmission passed 2.50% RV = 2
3. Channel SNR: + 5db, initial transmission failed: 1.50% RV = 0, retransmission passed: 2.50% RV = 2

The performance of the handover mechanism is extracted based on Throughput. For the three selected schemes of transmission as − 5 dB, 0db, and 5db the experiment acts as an active, passive, and clustered. For the 0db the transmission acts as an active transmission, for the − 5db it acts as a passive, and for the 5db it acts as a clustered mode for the transmission. Based on data rate and the number of nodes is represented in Fig. 5. This pattern is observed because of the cellular structure the cell with no 7, 14, 21 etc. Hence at switching we observed this pattern for data rate. When the same frequencies have strong enough strength of signal at the same time, then it gives a constant graph. If the same switching frequency band is not much stronger then it weakens the data rate (for passive and clustering transmission).

The delay factor is estimated depend on the node number in the transmission using the mathematical equation. The number of nodes used for the delay calculation is categorized as an active, passive, and clustered node. Clustered node is the node used run time means a combination of active and passive nodes.

The graphical representation of delay for three schemes of transmission extracted from the simulation experiment is shown in Fig. 6. Delayed time actually represents the cell switching time. If frequency band is not available in another cell when the UE changes the geographic location from one cell to another, delayed pattern is observed. If required frequency is available in another cell then it takes small time for handover and if frequency is not viable it take more time for handover as it losses more time to search required band or check the viability of required band.

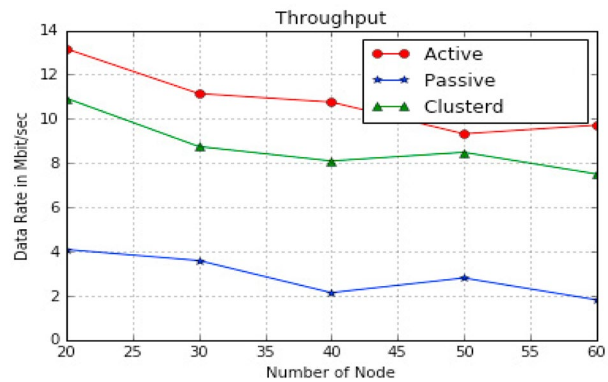

Fig. 5 Overall throughputs for three schemes of transmission

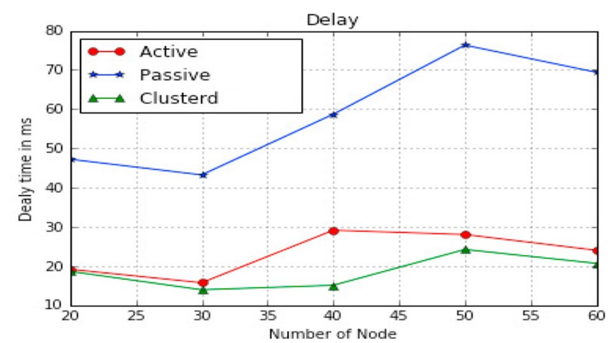

Fig. 6 Overall delays in the transmission scheme

The failure of the handoff directly affects data transmission in the network. The failure is occurring due to interrupt time in the handover and the error occurred to connect new nodes in the transmission. The graphical representation of the handover failure of the transmission is shown in Fig. 7.

From Fig. 7, it is observed that the number of nodes is minimum the active, passive, and clustered nodes are grouped in the minimum category.

4.2 Performance of resource allocation in network

For resource allocation, two types of models are used such as uplink and downlink. The generated waveform was achieved concerning the frequency and channel capacity of the 500 MHz was extracted using NRB coefficient values of

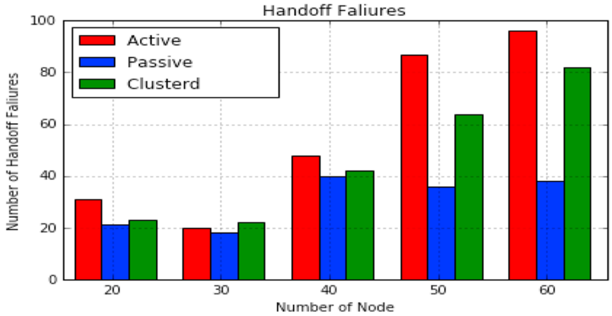

Fig. 7 Overall handoff failures in the transmission scheme

270 and 133 for the uplink waveform and the frequency of the parameter values was extracted and graphically represented for the 40 MHz channel capacity for downlink waveform. The graphical representation of the uplink waveform, resources used, its allocation and bandwidth is shown in Fig. 8.

For the resource allocation multiplexing is used to send the data over the network. Allocated lots are 0 and 1. Each period slot is consists of the 5 slots. First two slots consist of the 3 symbols while actually allocated slots consist of the 8 symbols (0 to 7). The resource allocation is allocated using the traditional sub-carrier swift algorithm but it has the limitation of minimum information decoding rate indirect channel communication. The graphical representation of the downlink waveform, resources used, its allocation and bandwidth id shown in Fig. 9.

Physical resource block (PRB) means resources utilized in the cellular network. The uplink model elaborates on the bandwidth and distance, but the downlink resource allocation was done based on the priority of the resources. The performance of the downlink resource allocation was better as compared to uplink because there was a chance to execute the highest priority resources early. The simulation-based was needed to wait for the allocation of the overall resources. The adaptation of the information rate for respective channel capacity and the link adaptation process at the BS, constructed on the CSI received on a feedback channel from the MS, selects the MCS to be used in the next TTI. MS is the mobile station, MCS is a main controlling station, TTI is a transmission time interval. TTI is the encapsulation of the information or data from high order layer to radio link in the frame form. The present study, we presumed that the BS was taken from M = 15 set. M are the number of MCS (main controlling) station. LTE/LTE-Advanced systems were used in MCSs (Table 2). Furthermore, as it was complete in LTE/LTE-Advanced networks, a scheduled user was prescribed to transmit the code word of the spatial stream using the same MCS on all allocated RBs. The parameter values for the resource allocation using downlink are elaborated in Table 2. The Resource Consumption Model (RCM) was calculated based on the modulation with respective time of task $T(1)$, $T(4)$ and $T(25)$. T is the total number of duplex channels.

From the Table 2, a total of 15 resources are shown with their bandwidth modulating. The simulated allocated slots were shown using T values. The three allocated slots for the resource allocation with their distance values were shown in the Table 2. In the 4G LTE network, the interruption time is approximately 30–60 ms based on the structure and frequency conditions. The main objective for reducing the handover interruption time is continuous communication among the nodes of the network. The proposed solution is utilized for the reduction of interruption time in the handover management (Fig. 10).

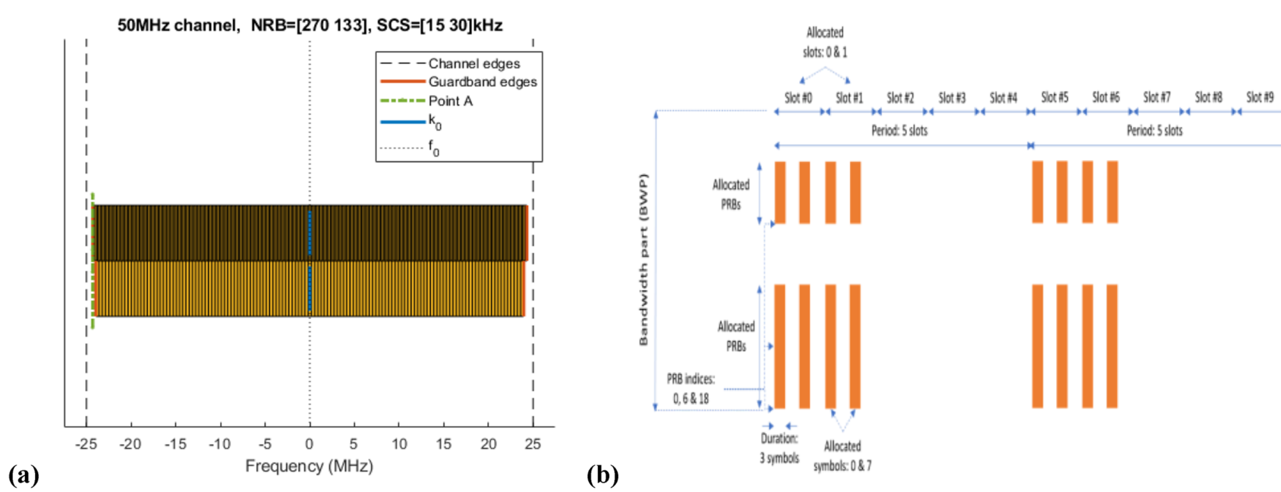

Fig. 8 Uplink waveform generation and its allocated resources. **a** Uplink waveform generation; **b** Allocated resources using uplink model

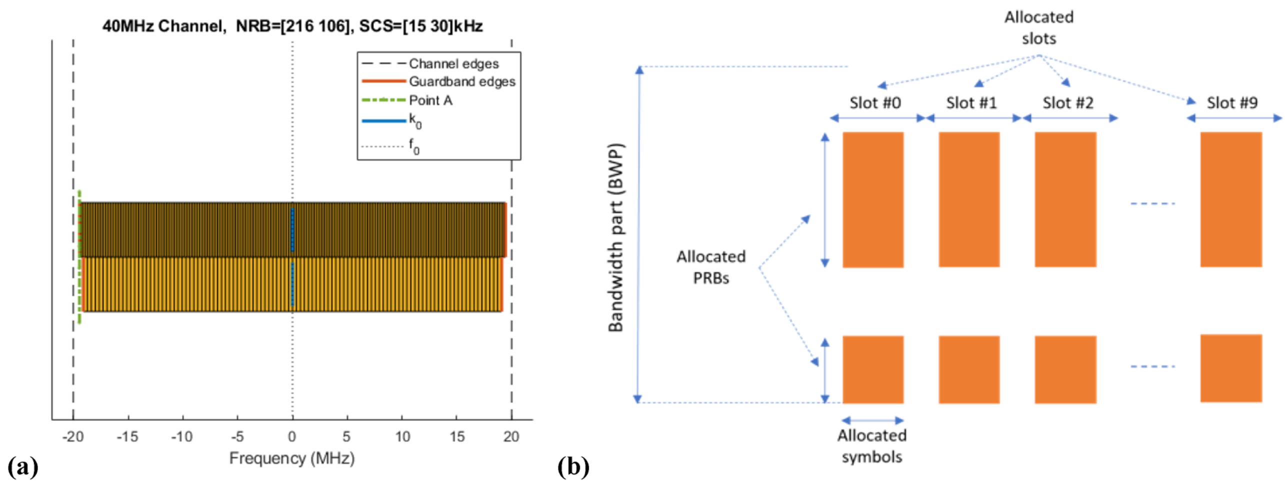

Fig. 9 Downlink waveform generation and its allocated resources. **a** Downlink waveform generation; **b** Allocated resources using downlink model

Table 2 Parameter utilized in the resource allocation

MCS	Modulation	RCM	Bit/symbol	*T*(1)	*T*(4)	*T*(25)
0	–	–	–	$-\infty$	$-\infty$	$-\infty$
1	4QAM	0.76	1.32	−6.76	−6.93	−725
2	4QAM	0.117	0.677	−485	−5.21	−7.58
3	4QAM	0.452	1.012	0.463	−5.33	−5.78
4	4QAM	0.465	1.025	0.78	−1.45	−3.76
5	4QAM	0.987	1.547	0.9	0.48	−177
6	4QAM	0.463	1.023	0.34	2.35	0.17
7	64QAM	0.78	1.34	0.325	0.67	6.45
8	64QAM	0.9	1.46	2.33	5.33	0.34
9	64QAM	0.34	0.9	6.7	6.78	11.43
10	64QAM	0.325	0.885	9.761	12.09	2.54
11	64QAM	0.554	1.114	3.65	11.98	11.99
12	64QAM	0.678	1.238	8.23	13.43	17.56
13	64QAM	0.854	1.414	1.43	15.45	17.89
14	64QAM	0.878	1.438	2.09	17.54	17.332
15	64QAM	0.936	1.496	19.56	14.76	19.67

4.3 Steps in handover process:

(1) Communication started, (2) initialize handover request as the cell is going to change, (3) forward this request to BTS of another cell, (4) do the handover decision according to availabilities of the frequency bands, (5) buffer or hold the data till the handover request is processed. If the handover request is processed successfully, then a handover takes place and release the source cell connection with proper transmission and reception in the target cell.

The diagram represents the performance of the network for a 30 kHz frequency level. From the given experiment, we can observe that reducing the handover interrupt time is directly increasing the performance of the simulation network. In the 5G network, everyone wants the data on one single fraction of the time. If we have high throughput without failure and with high quality, it means it has a high signal to noise ratio (strong strength of signal while weakest noise signal). This aspect puts the conclusion that interrupts time is inversely proportional to the throughput as well as SNR.

5 Conclusions

The novelty of current research is to use a resource reservation algorithm for the above objective of high quality cellular network with minimum resources. The reservation of the resources, considers the uplink and downlink model.

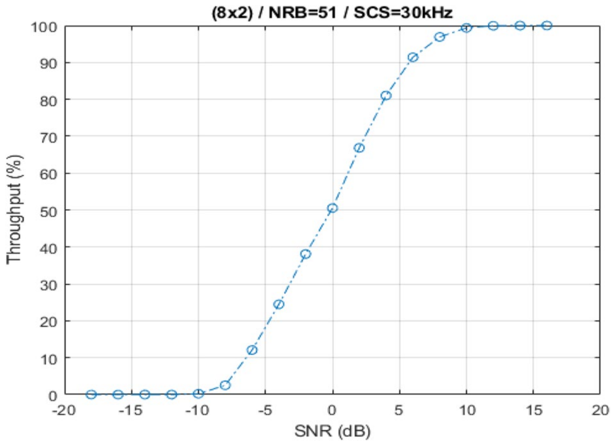

Fig. 10 The performance of the simulation after reducing the handover interrupts time

The implement the handover mechanism which reduces the handover preparation time and execution time. The present study clearly demonstrated that the 5G network can be communicated within minimum resources, time, space, and usability of the white spectrum with maximum speed. The simulation framework was efficiently designed towards the minimum resources and maximum speed objective. Using downlink algorithm resource allocation was improved to accept continuous handover requests along with the minimum resources transmission. The resource allocation has been continuously done by the scheduling basis of the index values and request from the target node. Finally, the description and comprehensive review about 5G mobility management, that highlighted in this paper and understanding the mobility management in recent generation as architecture and challenges. There are several challenges have been addressed as HO issues, signaling overhead, power consumption, security and latency.

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