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Handoff Scheme for 5G Mobile Networks Based on Markovian Queuing Model

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ABSTRACT

Wireless and mobile communication systems are in continuous evolution every day. The fifth generation (5G) is the next major phase of the mobile telecommunication and wireless system which aims to improve Quality of Service (QoS) and integrate human-to-machine and machine-to-human communications. In 5G mobile networks, mobility and small coverage areas are the biggest challenges for mobile users. Mobile users may not have the time required to acquire network resources to transfer from one cell to another, resulting in a large number of handoff failures. In this paper, we propose a handoff scheme for the 5G mobile network to minimize the probability of handoff failures using Markovian queuing model. We use the ECC33 channel propagation model to calculate the received signal strength (RSS) of the different users to decide the handoff users. We evaluate system performance based on blocking probability, overall system delay, and overall system throughput. The results of the proposed system model give a better QoS in the system and significantly affect the system performance.

1. Introduction

The world is in progressive evolution of the mobile wireless network generations. Network data rates are expected to increase 1000 times due to the evolution of the smart devices, application, and exponential increase in wireless data demand [1]. Moreover, upcoming mobile networks are expected to provide flexible mobility and extensive access to the networks [2-4].

The fifth generation (5G) is the next major phase of mobile telecommunication & wireless system that envisioned to enhance the quality of service (QoS) and integrate human-to-machine and machine-to-human communications [5]. 5G networks are expected to deliver peak rates of 20 Gbit/s downlink and 10 Gbit/s uplink, and reduce end-to-end (E2E) latency to less than 5 ms [6]. Moreover, 5G mobile networks make a remarkable evolution of the industry chain and ecosystem (smart manufacturing) and many applications such as, Augmented/Virtual Reality (AR/VR), Internet of vehicles (IoV) and cloud-based AI robotics [7,8]. These new services are characterized by restricted requirements in terms of data rate, end-to-end latency, and reliability. 5G can have a significant

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effect, when combined with other technologies such as cloud, AI and the Internet of Things (IoT), plus other changes such as the adoption of renewable energy sources [9,10].

To achieve these requirements, 5G networks will be much more complex than the current ones. Ultra-Dense Networks (UDNs) become an important solution to meet extremely high-capacity requirements [11-13]. Ultra-Dense Networks (UDNs) are a group of small cells in a specific area including different wireless technologies (LTE, WiMAX, IEEE 802.11, etc.). Small cells could be an optimal solution for the network to guarantee better connection by minimizing the signal attenuation and the noise that could be added to it.

On the other hand, unnecessary, frequent, and back-and-forth handoff (ping pong handoff problem) in UDNs represent a challenge for the network operators due to the small coverage area and the high mobility of the user.

In 5G mobile networks, the handoff process is an important guarantee of service quality and communication continuity. The handoff process in 5G occurs in highly mobile environment and among various small cells with small coverage area. Mobile users may not have the time required to acquire network resources to complete the handoff process, resulting in a large number of handoff failures [14].

In this paper, we propose a handoff scheme for 5G mobile network to minimize the probability of handoff failures by proposing a handoff system model for 5G mobile networks using Markov chain analysis. We consider two different arrival streams. The first one with rate λ_o represents the arrival rate of originating calls, and the second one with rate λ_h represents the handoff calls' effective arrival rate. We utilize ECC33 channel propagation model, to evaluate λ_h for different scenarios. Then, based on queuing model M/M/C/K, we evaluate blocking probability, overall system delay, and overall system throughput. The presented model's output is analysed and compared with another traditional model to demonstrate the impact of our work to the system performance. On the other hand, different mobility schemes will be investigated. In addition, the cell radius effect will be investigated.

The rest of the paper is organized as follows. Section II discusses related work. Section III presents the proposed system model compared with traditional system models. The results are being discussed in Section IV. The paper is concluded in section V.

2. Related Work

Several researches have been performed on minimizing the probability of handoff failure in LTE and 5G mobile networks, using different techniques to analyse the performance of mobile networks in terms of call blocking probability characteristic, throughput and overall delay.

He *et al.,* [2] present a simple and robust vertical handoff decision algorithm for heterogeneous wireless mobile networks. The algorithm takes classification of mobile nodes into account. The authors use dynamic new call blocking probability (DNCBP) to make handoff decision to reduce the number of unnecessary handoffs, reduce handoff delay and avoid connection dropping. Rejeb *et al.,* [3] present LTE mechanism for source allocation and QoS management based on call admission control (CAC), Adaptive Modulation and Coding (AMC), the Random Waypoint (RWP) mobility model and Continuous Time Markov Chain (CTMC) to evaluate the system performance in terms of the blocking probability, throughput, and residence time. Cicioglu [14] present a handoff mechanism for small cells in 5G networks based on two parameters signal-to-noise ratio (SNR) and received signal strength indicator (RSSI) to prevent delays and packet losses by providing base station selection. The effects of Free Space Path Loss and Nakagami channel models are compared and used to analyse the performance of the presented handoff mechanism. Zeng and Agrawal [15] propose a handoff scheme for a homogeneous system based on queuing model. Moreover, they propose a mathematical traffic model using Markov chain technique to evaluate the system performance including average queue length, transmission delay, and call blocking probability. Yonal [16] present a handoff decision algorithm based on mathematical traffic model using Markov chain technique to minimize the probability of handoff failures and unnecessary handoffs and maximize the usage of resources in highly mobile environments. The model depends on two acceptance factors (α) and ($\boldsymbol{\beta}$) and the time that the mobile user needs to perform the handoff process. The model evaluates the system performance in terms of blocking probability, mean queue length and transmission delay. Trivedi *et al.,* [17] present tractable analytic models for wireless mobile networks with hard handoff process including channel failures. Fixed-point iteration scheme is presented to determine the handoff arrival rate and obtaining a closed form to determine the blocking probability for new calls and handoff calls. Kirsal *et al.,* [18] present an analytical model of vertical handoff decision algorithm for highly mobile environments and heterogeneous wireless system. This model is based on two-stage open queuing systems and depends on the deployment of guard channels and buffering at base station to make a framework with accepted levels of QoS. Al-Rubaye *et al.,* [19] present a handoff scheme for a 5G mobile network. It reduces the time interrupted during mobile user re-connection while moving from a macro cell to a micro cell and vice versa. The Call Admission Control (CAC) function is used to set thresholds during handoff request signalling. The model evaluates call blocking probability Using Markov chain and makes a handoff approval for different mobile user requests.

3. Traditional Queueing System Models

Based on the handoff queuing model used by Zeng and Agrawal [15] and Kirsal *et al.,* [18], the authors assume the shape of the cell to be arbitrary shape and the set of available channels is given by $Y = \{1,2,..,s,..,S\}$ and queue length is given by Q. The maximum number of calls in the system is given by L where $L = S + Q$ as shown in Figure 1.

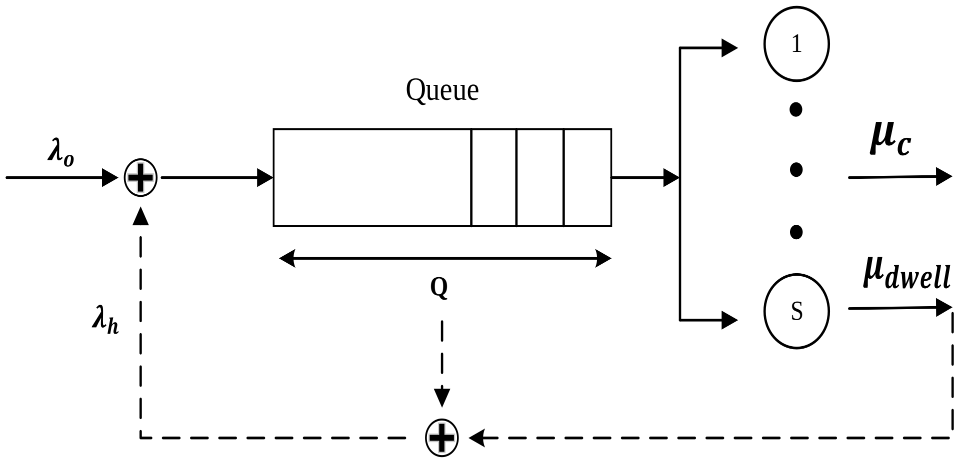

Fig. 1. The traditional handoff queuing system model [15]

There are two types of arrival rates in the system: I) λ_o is the arrival rate of newly generated calls and II) λ_h is the effective arrival rate of handoff calls. The overall arrival rate in the system is given by: $\lambda = \lambda_o + \lambda_h$. the arrival rate of both calls can be assigned to any available channel s in the system, otherwise the incoming call requests will be placed in the queue. Queued channel requests are served by first-in, first-out (FIFO) method. When the queue is full, the incoming calls will be blocked. Also, mobile user may leave the network due to his mobility. Assume T_c is the call holding time in the system and $\mu_c = {}^1/_{T_c}$ is the mean call holding rate. Also, T_{dwell} is the time that the mobile user spends in the cell and $\mu_{dwell} = {}^1/_{T_{dwell}}$ is the mean dwell rate and can be calculated as follows

$$\mu_{\text{dwell}} = \frac{\text{E[v].L}}{\pi.\text{A}} \tag{1}$$

where $E[v]$ is the expected velocity of the mobile users, L is the perimeter of the cell and A is the area of the cell.

The traditional queuing model in Yonal's [16] study is similar to the pervious queueing model. There is a handoff decision algorithm which, determines the time that the mobile user needs before performing the handoff process. It sends both calls in to the system using two acceptance factors α and β ,where α is the acceptance factor of the originating calls and β is the acceptance factor of the handoff calls. The originating and handoff calls are $\lambda_o(1-\alpha)$ and $\lambda_h(1-\beta\ )$ respectively and the total arrival rate in the system is λ =$\lambda_o(1-\alpha)$ +$\lambda_h(1-\beta\ )$ as shown in Figure 2.

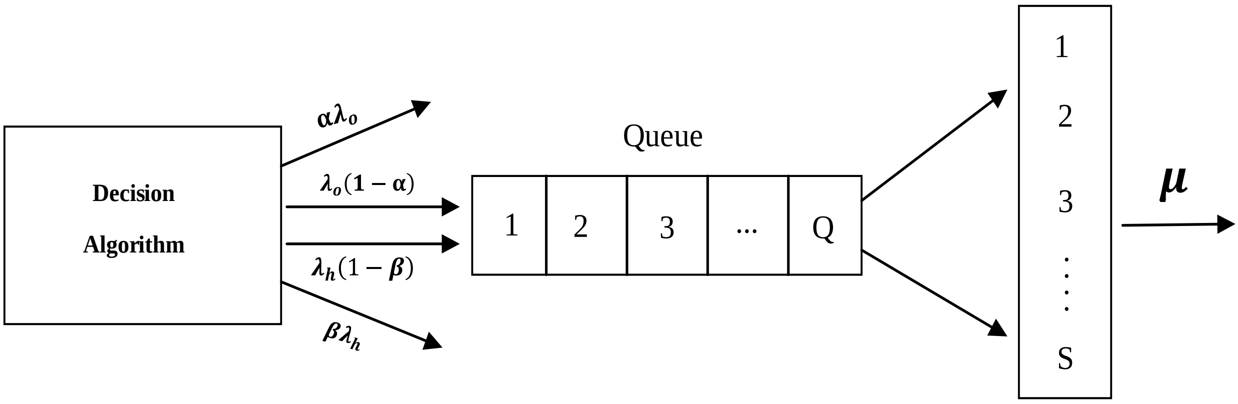

Fig. 2. The traditional handoff queuing system model with acceptance factors α and β [16]

4. The Proposed System Model

The proposed model is a handoff decision algorithm for a 5G mobile network. We use the channel propagation model (ECC33) to calculate λ_h with respect to different operating parameters and scenarios such as cell radius as well as user velocity. We use a one-dimensional Markov chain technique and M/M/C/K queuing model to evaluate the system's performance in terms of overall system throughput, blocking probability, and overall system delay.

4.1 ECC33 Channel Propagation Model

The proposed scheme receives the requests sent by different mobile users. Based on ECC33 propagation model, which is suitable for 5G technology [20].

Assuming the user count in the cell is 100 users, the proposed algorithm calculates the pass loss propagation for each user from the given equation

$$P_{l_{db}} = A_{FS} + A_{Bm} - G_t + G_r \tag{2}$$

where A_{FS} is the free space attenuation and can be calculated as follows

$$A_{FS} = 92.4 + 20\log(d) + 20\log(f) \tag{3}$$

where $f = 3.6$ GHz for downlink, $f = 3.5$ for uplink and d is T-R separation in Km.

A_{Bm} is the basic medium path loss and can be calculated using the following equation

$$A_{Bm} = 20.41 + 98.3\log(d) + 7.89\log(f) + 9.56[\log_{10}(f)]^2 \tag{4}$$

G_t is the BS height gain factor given by

$$G_t = \log\left(\frac{h_b}{200}\right)[13.958 + 5.8(\log_{10}(d))^2] \tag{5}$$

G_r is the Received antenna height gain factor given by

$$G_r = 0.759h_r - 1.862 \tag{6}$$

h_b is the antenna height of the base station and has different values depending on the geographic area as shown in Table 1 below

Table 1
Antenna heights

Area	Height (m)
Urban	23.56
Suburban	34.64
Rural	23.76

h_r is the antenna height of the mobile and it's 1.5 meters.

The received signal strength (Rss) for each user can be calculated using the following equation

$$Rss_{dBm} = P_{t_{dBm}} - P_{l_{dB}} + G_{t_{dB}} + G_{r_{dB}} \tag{7}$$

where $P_{t_{dBm}}$ is the transmitted power of all users.

4.2 The Proposed Handoff Decision Algorithm

The proposed algorithm compares Rss for each user with a specific threshold based on 3GPP standards to get the average number of handoff users H to calculate the effective handoff request arrivals λ_h with respect to different operating parameters and scenarios such as cell radius as well as user velocity. This will be more realistic and significantly affected to the system performance than using assumed acceptance ratios [16]. The proposed algorithm depends on the time required for the mobile user to join the system or make a handoff decision : I) $T_{current}$ is the current time of the mobile user while moving towards the system, II) T_{dwell} is the spending time of the mobile user in the cell, III) T_c is the call holding time of the mobile user, IV) T_E is the estimated time of the mobile user before handoff process and V) T_r is the time channel release time of the mobile user.

As shown in Figure 3, three possible conditions are proposed to reduce handoff failure and unnecessary handoff.

i. First condition: $(T_r)_{n-1} < (T_E)_n$
If the current user's estimated time $(T_E)_n$ is greater than the being served user's release time $(T_r)_{n-1}$, which clarifies that the current user has the necessary time to join the system and get served.

ii. Second condition: $(T_E)_{n-1} < (T_E)_n$ and $(T_r)_{n-1} < (T_r)_n$
In this condition, users use the channels or wait in the queue for service. In other words, if the being served user's release time $(T_r)_{n-1}$ and/or the user's waiting time in the queue is greater than the current user's released time $(T_r)_n$, then the system is partly busy and the current user (n) can join the system after a short period of time.

iii. Third condition: $(T_E)_{n-1} < (T_E)_n$ and $(T_r)_{n-1} > (T_r)_n$
If the being served user's release time $(T_r)_{n-1}$ is greater than the current user's released time $(T_r)_n$, subsequently the system is busy during the current user's traveling time. Thus, the current user (n) can not join the system because all the channels and the queue are busy then increment λ_h by 1.

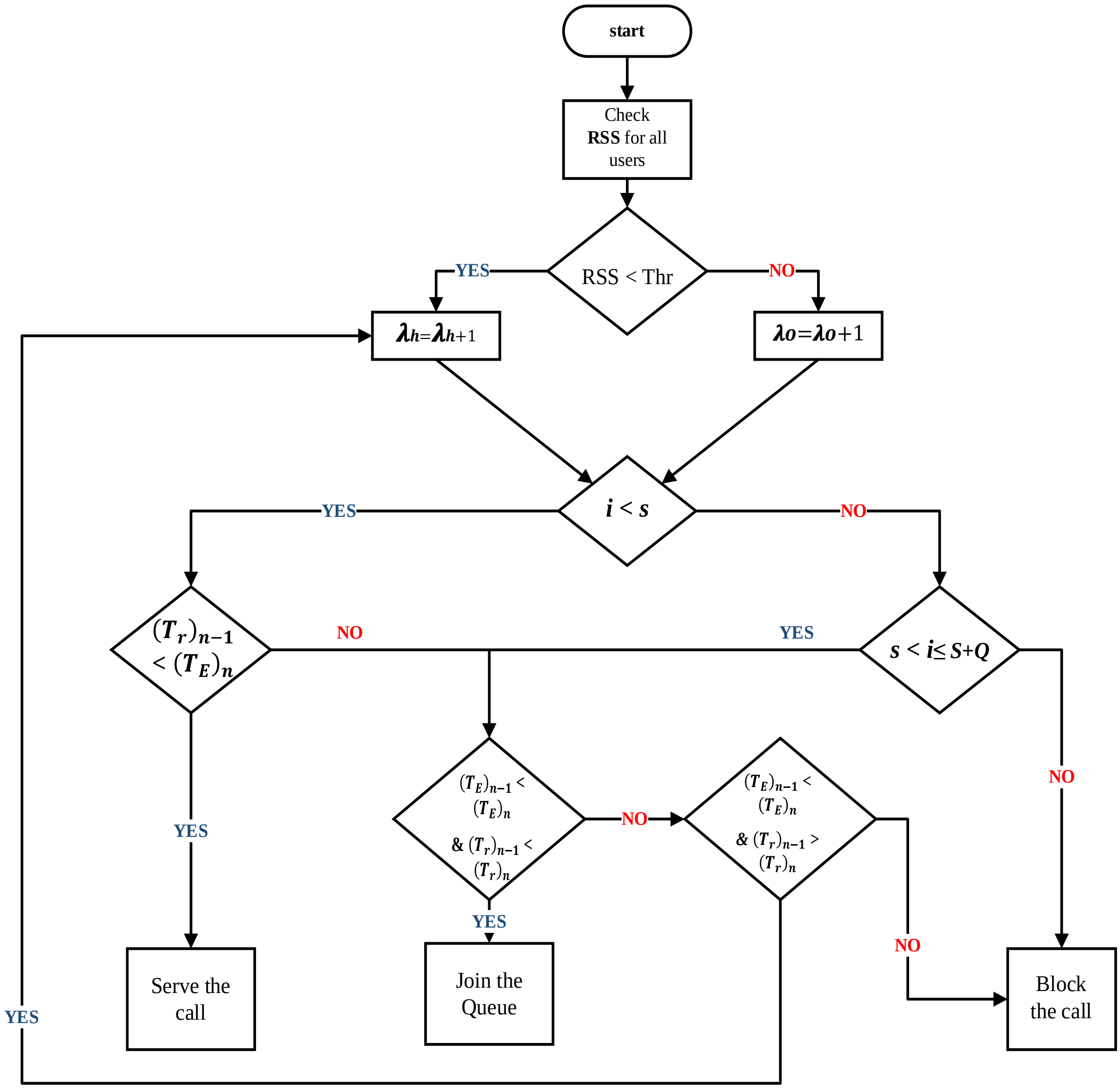

Fig. 3. The proposed handoff decision algorithm

4.3 The Proposed Handoff Queueing Model

According to the decision algorithm that used to distinguish the calls $\frac{\lambda_o}{\lambda_h}$ .The originating and the handoff calls can join the queue with arrival rates λ_o and λ_h respectively. Hence, the effective arrival rate of handoff calls denoted by λ_h and can be calculated as follows

$$\lambda_h = \left(\frac{H}{T-H}\right).\lambda_o \tag{8}$$

where λ_o is the arrival rate of the originating calls, H is the average number of handoff requests and T is the total number of users.

As shown in Figure 4, the queuing system has S number of channels. The system's queuing capacity is Q which dedicated to originating calls and handoff requests in case of all channels are busy. Channel requests are served by FIFO method and the inter-arrival time of the consecutive requests follows the Poisson process, which can be distributed as an exponential distribution with total arrival rate λ.

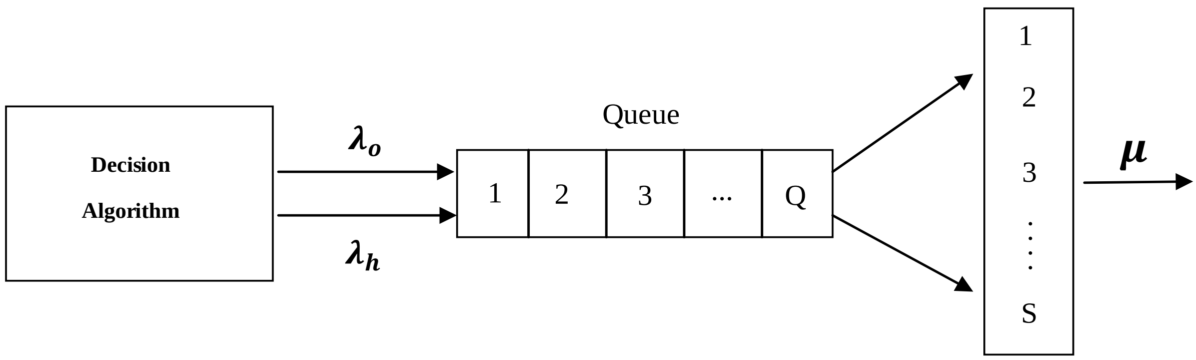

Fig. 4. The proposed handoff queueing system model

The proposed model can be obtained using a one-dimensional Markov chain as shown in Figure 5 and using $M/M/C/K$ queuing model to evaluate the performance of the system.

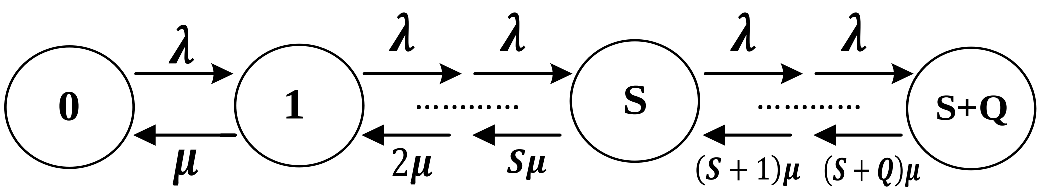

Fig. 5. State transition diagram of the proposed model [11]

The $M/M/C/K$ queue model is a variant of a multi-server system and only a maximum of K customers are eligible to remain in the system. Assuming the system is in steady state, we obtain the steady state probabilities P_i using the birth and death process.

Define state i (i =0,1,2, 3…, $S+Q$) as the number of calls in the system at time t. Assuming that the arrival rate is constant for all requests. On the other hand, the rate of service completions depends on the number of calls in the system based on the analysis.

Users are served by the channels in the system with rate $\mu = \mu_{dwell} + \mu_c$. All channels are busy when requests are equal to or greater than S. The total service rate of the proposed system is a combination between $S\ (\mu_{dwell} + \mu_c)$ and $i\ (\mu_{dwell} + \mu_c)$ if $i < S$.
Therefore, μ_i can be calculated as

$$\mu_i = \begin{cases} i(\mu_{dwell} + \mu_c) & 0 \leq i < S \\ S(\mu_{dwell} + \mu_c) & S \leq i \leq S+Q \end{cases} \tag{9}$$

The steady state probabilities P_i can be obtained as follows

$$P_i = \begin{cases} \frac{[\lambda_o+\lambda_h]^i}{i!(\mu_{dwell}+\mu_c)^i}.Po & , \ 0 \leq i < S \\ \frac{[\lambda_o+\lambda_h]^i}{S^{i-S}\, S!(\mu_{dwell}+\mu_c)^i}.Po & , S \leq i \leq S+Q \end{cases} \tag{10}$$

Po is the normalization condition and can be calculated by

$$Po = \left[\sum_{i=0}^{S-1} \frac{[\lambda_o+\lambda_h]^i}{i!(\mu_{dwell}+\mu_c)^i} + \sum_{i=S}^{S+Q} \frac{[\lambda_o+\lambda_h]^i}{S^{i-S}\, S!(\mu_{dwell}+\mu_c)^i}\right]^{-1} \tag{11}$$

The average number of packets in the system, MQL can be calculated by

$$MQL = \sum_{i=0}^{S+Q} i.p_i \tag{12}$$

which gives

$$MQL = \left[\sum_{i=0}^{S-1} i \frac{[\lambda_o+\lambda_h]^i}{i!(\mu_{dwell}+\mu_c)^i} + \sum_{i=S}^{S+Q} i \frac{[\lambda_o+\lambda_h]^i}{S^{i-S}\, S!(\mu_{dwell}+\mu_c)^i}\right].Po \tag{13}$$

Similarly, the blocking probability P_B can be calculated as follows

$$P_B = \left[\frac{[\lambda_o+\lambda_h]^{S+Q}}{S^Q\, S!(\mu_{dwell}+\mu_c)^{S+Q}}\right].Po \tag{14}$$

In addition, the average queue length LQ is

$$LQ = \sum_{i=S+1}^{S+Q} (i-S).p_i \tag{15}$$

Using Littles' formula, the overall normalized waiting time or the mean transmission delay of the channel requests in the queue is calculated by

$$T_D = \frac{LQ}{\lambda_o+\lambda_h} \tag{16}$$

Also use Shannon's formula to calculate the average sum rate R_i as follows

$$R_i = B * \log_2(1+SINR) \tag{17}$$

where B is the bandwidth of the channel in hertz and $SINR$ is signal-to-noise ratio between users and can be calculated as follows

$$\mathrm{SINR} = \frac{\mathrm{P_{r_i}}}{\mathrm{N}+\sum \mathrm{I_i}} \tag{18}$$

where P_{r_i} is the average received signal power, N is the variance or noise spectral density per hertz, and $\sum I_i$ is the interference power of all users on user i which is calculated by

$$\mathrm{I_i} \; = \mathrm{R_{SS_i}} * (\text{channel gain})_{\mathrm{j}} \;, \; \mathrm{j} \neq \mathrm{i} \tag{19}$$

5. Results and Analysis

To evaluate the performance of the proposed model, we used MATLAB version R2016a. We construct a mobile network with a single mega cell. We assume that the shape of the cell is circular. Table 2 below summarizes the parameters used in the proposed model.

Table 2
Network simulation parameters

Parameters	Setting
Number of channels (S)	16 channels
Queue length (Q)	50 channels
Cell radius (R)	1000 m
Expected is call holding time ($\mathrm{E}[T_c]$)	120 sec
normalized arrival rate per user (λ_o)	0.01 – 0.6 packets/sec

To calculate the received signal strength for each user we used ECC33 propagation model as explained in subsection 4.1. Table 3 summarizes the parameters used in the aforementioned propagation model [12].

Table 3
Simulation parameters of the proposed propagation model

Link	UL	DL
Cable loss (dB)	0	0
Noise figure (dB)	3.5	7
Interference margin (dB)	2	7
Building penetration loss per indoor wall (dB)	20	20
Transmission power (dBm)	23	39.5
Fading margin (dB)	4.5	4.5
Antenna gain (dB)	17	17
Rain/Ice margin (dB)	0	0
Receiver sensitivity (dB)	-109.70	-106.66
Threshold level for base station	-102	-110

5.1 Traditional Model Verification Results

Figure 6 and Figure 7 show the verified results of the traditional model presented by Yonal [16]. The results are monotonically the same.

Figure 6 and Figure 7 show the Mean Queue Length MQL and blocking probability P_B respectively as a function in arrival rate of newly generated calls λ_o for different values of β. For a given value of

β, as the λ_o increases the number of the users waiting for a new channel in queue increase. This leads to increasing the mean length of the queue (MQL) as shown in Figure 6. Moreover, increasing the length of the queue will increase the probability of the blocked calls as shown in Figure 7. In addition, as β increases the overall effective arrival rate of handoff calls $(1-\beta)\lambda_h$ decreases, subsequently, the MQL decreases as illustrated in Figure 6 and the blocking probability P_B decreases as in Figure 7.

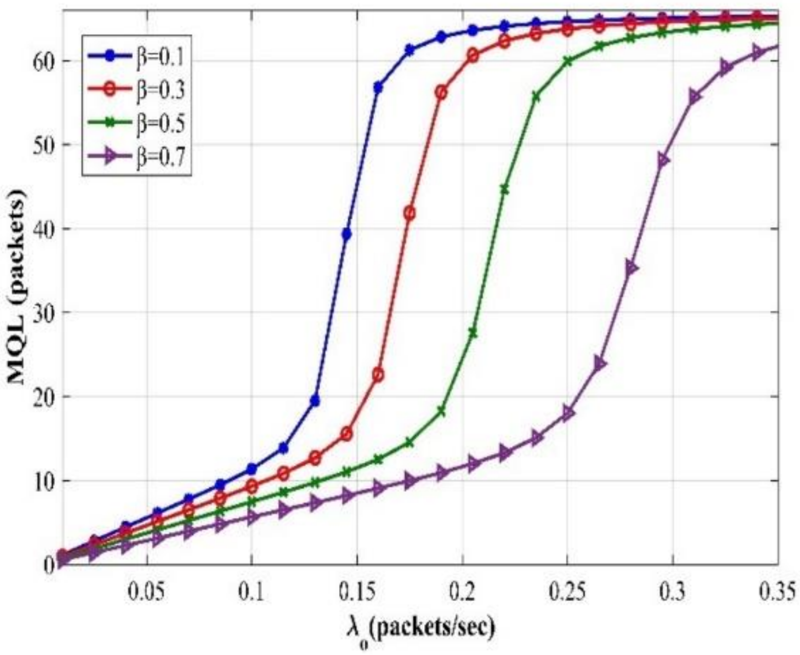

Fig. 6. Mean queue length results as a function of λ_o for different values of β

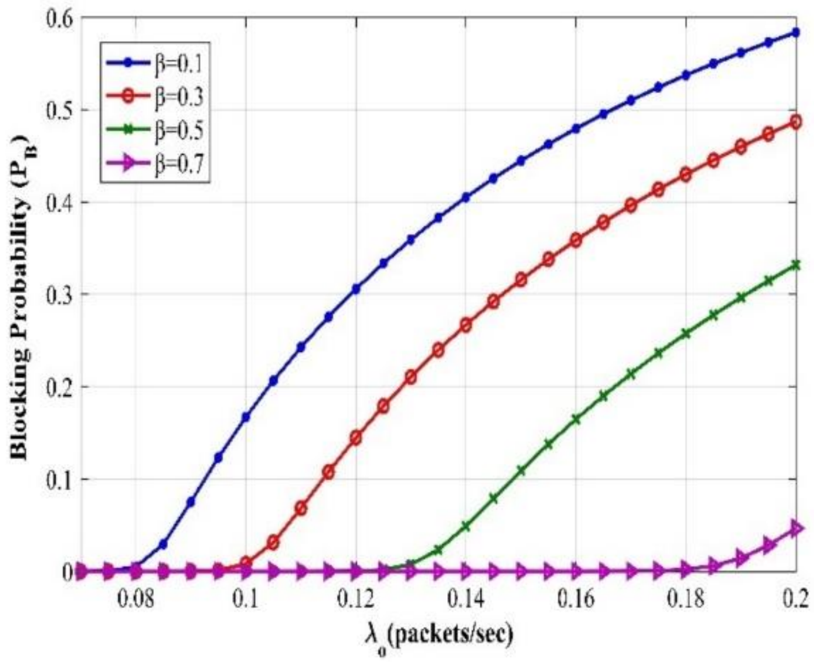

Fig. 7. Blocking probability results as a function of λ_o for different values of β

5.2 The Proposed Model Results

Figure 8 shows the blocking probability P_B as a function of λ_o for different cell $R = 1000\ m$, $R = 500\ m$ and $R = 300\ m$. We assume the maximum velocity $120\ m/sec$. The result show that decreasing the cell radius for a given value of λ_o the number of handoff requests increase, subsequently, the number of users in the queue waiting for handoff channels increases. This will lead to increasing the probability of blocked calls.

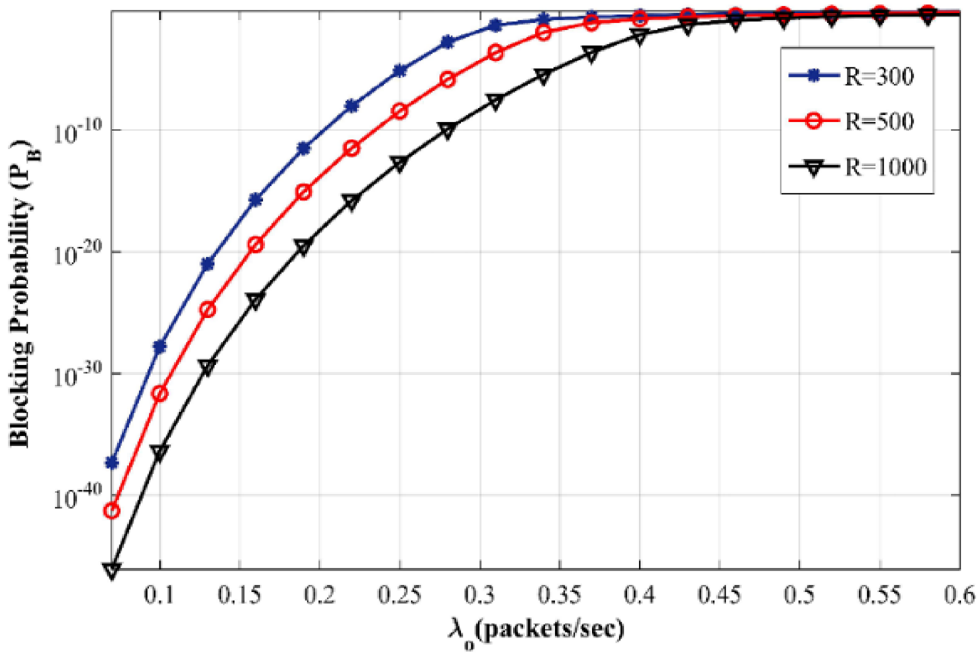

Fig. 8. Blocking probability results as a function of λ_o for different radii values

Figure 9 shows the blocking probability P_B versus λ_o. We assume three different velocities $E[v] = 30\ km/hr$, $E[v] = 60\ km/hr$ and $E[v] = 120\ km/hr$. The results show that the blocking probability increases as the velocity increases. This can be explained by that as the velocity increase the handoff requests increase. Therefore, the length of the queue increases as the users are waiting for the handoff channels. Increasing the length of the queue leads to increasing the probability of blocked calls.

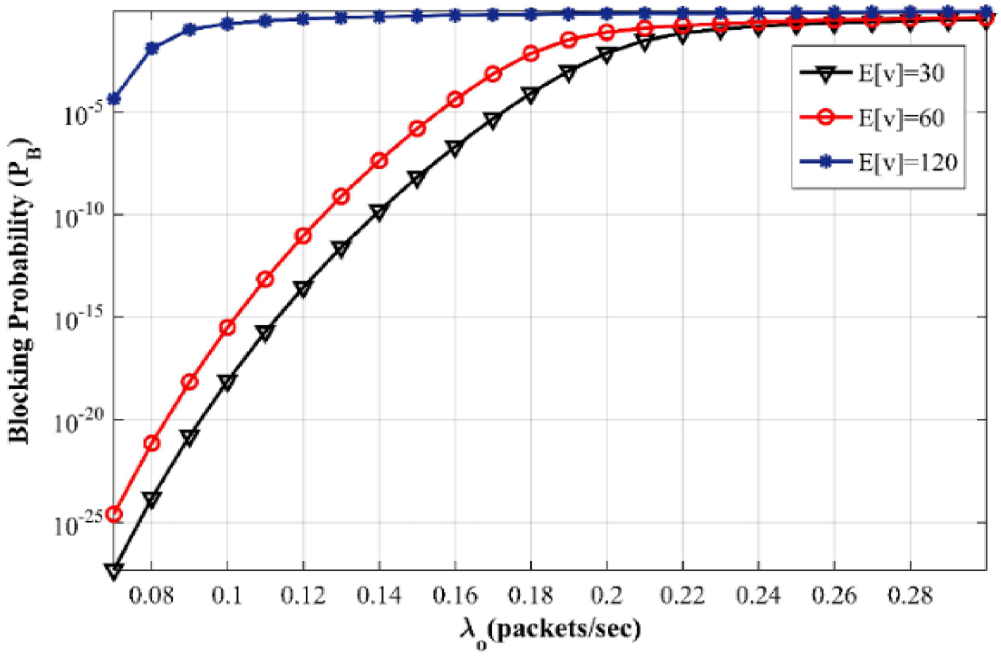

Fig. 9. Blocking Probability results as a function of λ_o for different velocity values

Figure 10 shows the normalized overall delay T_D versus velocity. We assume five different arrival rates of the originating calls $\lambda_o = 0.1$, $\lambda_o = 0.5$, $\lambda_o = 0.6$, $\lambda_o = 0.7$,and $\lambda_o = 0.9\ packets/sec$. The results show that the normalized overall delay increases as the velocity increases. This can be explained by the fact that the handoff requests increase as the velocity increases. Therefore, the length of the queue increases as the users are waiting for the handoff channels. Increasing the length of the queue leads to increasing the overall delay of the system. In addition, as λ_o increases, the overall delay of the system also increases.

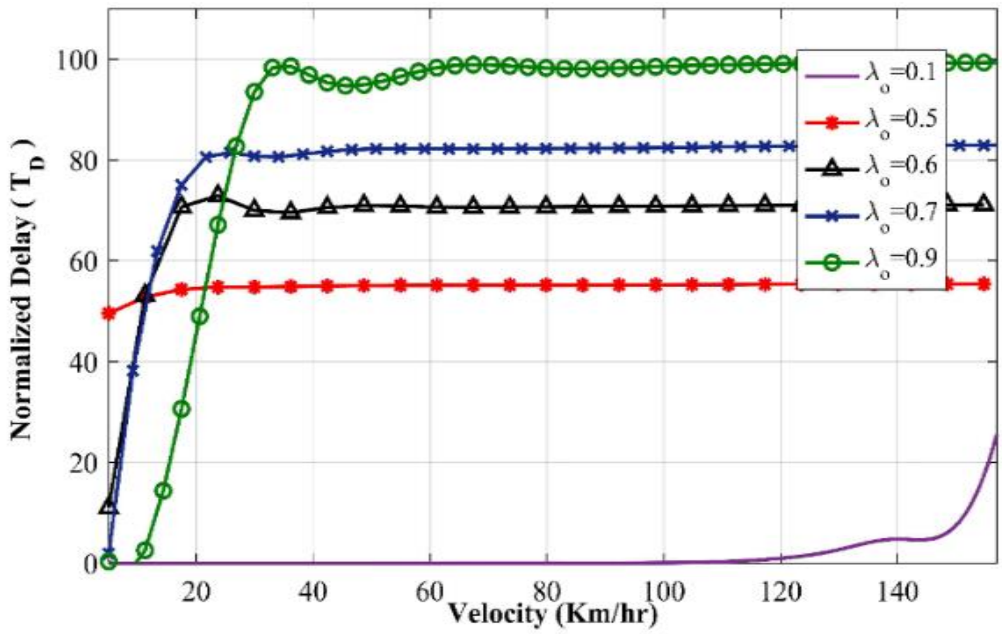

Fig. 10. The overall delay results vs different velocity values at specific arrival rates

Figure 11 the total averaging sum rate versus different user's velocity. The results show that the total averaging sum rate decreases with the increase in user's velocity. This can be explained by that as the velocity increase the number of handoff requests increase. Subsequently, the probability of the calls failure increase then the total sum rate decrease.

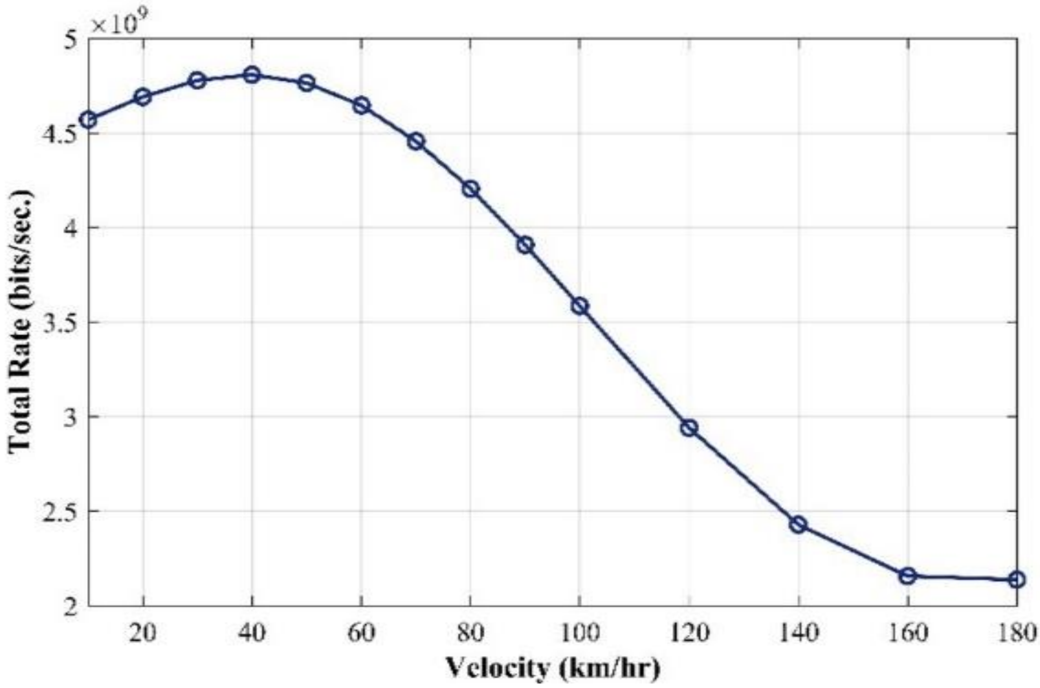

Fig. 11. The total averaging sum rate for different values of velocities

6. Conclusion

In this work, we proposed a handoff scheme for the 5G mobile network to minimize the probability of handoff failure. The handoff scheme is based on Markov chain traffic model. We used 5G ECC33 channel propagation model to calculate received signal strength of the different users to decide the handoff users. The system performance is evaluated Overall system throughput, blocking probability, and overall system delay.

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