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Performance analysis of handover management in 5G small cells

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ABSTRACT

In 5G networks, the coverage area of the base stations is smaller and the communications are at higher frequencies. The small cell concept has risen with high mobility and small coverage area. Mobile users can move among the small cells with different service requirements as a result of handover. The frequency of changing the small cell and the considered handover parameters affect the quality of service. In this paper, the handover performance analysis with different metrics and a realistic urban channel model is investigated for 5G small cells. The effect of the traditional handover metrics performance, on the 5G small cell handover procedure, is also shown. This study contributes to the research for developing new procedures on 5G small cell handover.

1. Introduction

The demand for more data traffic by mobile users reveals the need for fast and seamless connection to the base stations. From the first communication network structures to the newest ones, the frequency bands are getting higher allowing the transfer of more data. However, higher frequencies provide a smaller coverage area as a result of carrier frequency wavelengths [1]. These needs reveal the necessity of new generation communication infrastructures. 5G networks will have to deal with various network problems in the 2020s [2]. Although 5G networks are expected to play crucial roles in applications such as healthcare, industry, transportation, etc. [3], while these developments occur, various communication facilities have to be utilized or modified for 5G networks to be viable.

In 5G networks the small coverage area requires an increase in the connection numbers of the access point or base station to maintain mobility. Handover started to take place in communication networks with 2G networks as a result of mobility. If a mobile user moves from one coverage to another, the handover process provides to transport its connection [4]. The mobile user decides to connect to the base station according to selected metrics. Typically, when mobile users move away from base stations they need an increase in the transmit power for signal strength. Thereby causing more energy consumption. Moreover, the interference, fading, and errors affect communication quality with lower received signal strength indicator (RSSI). This value determines the connection quality and triggers the handover process in traditional network cells. If a base station RSSI value falls below a certain threshold, the mobile user disconnects from it, then provides a connection with another base station with a certain RSSI [5].

In current literature, research on the handover process in 5G is planned in two categories. The first one is between micro and macro cells, the other is the handover among various micro cells as small cell handovers. In the near future micro and macro cell handovers as a heterogeneous structure must be taken into consideration, but eventually the 5G small cells may dominate as a homogeneous scheme. For the heterogeneous networks, handover is known as vertical when it is between different wireless networks [6]. Therefore, mobile users have to evaluate various metrics like data rate, monetary cost, RSSI, signal-to-noise ratio (SNR), etc. [7]. In contrast, the homogeneous networks consist of the same wireless technologies and the small cells with small coverage area are in the same environment. In this way, mobile users will decide the handover trigger in as short a time span as possible because increasing the number of evaluation metrics can cause handover delays. In this paper, a fast handover trigger is proposed which has the most important metrics for minimum time span. Mobile users in small cells are illustrated in Fig. 1. Considering that a mobile user walks at a speed of 5 km per hour and the diameter of the small cell coverage area is 200 m, the mobile user will change their cell, approximately, every three minutes.

The handover process begins with the system discovery considering the base stations in the environment. The mobile users then collect the base station statistics as metrics for later evaluations. In the handover decision phase, the gathered metrics are evaluated and the candidacy values of the base stations are determined. Finally, the mobile user makes a decision in the handover execution stage. The handover is a mandatory operation for next-generation wireless 5G networks with the

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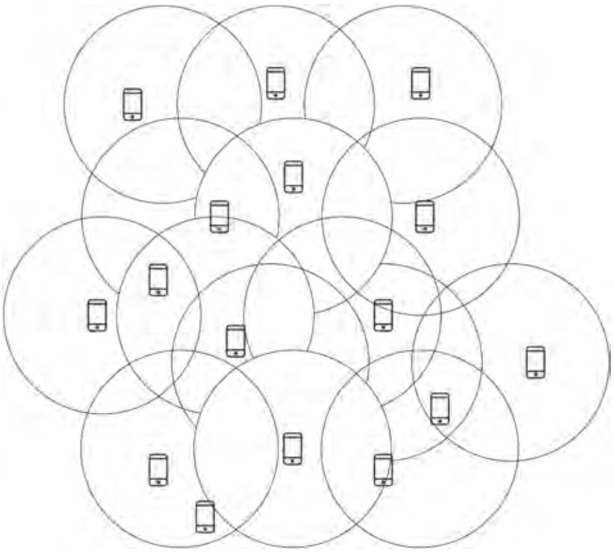

Fig. 1. A number of mobile users in small cells.

aforementioned main phases [8]. In Fig. 2, an illustration shows the possible small cell handovers.

Mobile users discover the base stations or access points via signals spreading to the environment from them. The received signals register as RSSI, which represents the relative quality of a signal, and is an estimated measure of power level. RSSI is usually presented between 0 and -120 dB (decibels). The closer the value to 0, the stronger the signal will be. The traditional handover process uses the RSSI value for the handover trigger. In Fig. 3, the RSSI based handover decision progress is shown. In this approach, the mobile user gathers RSSI information periodically to scan the existence of candidate small cells. This phase is called the discovery phase in handover management. In the discovery phase, the measured RSSI level is compared with the current RSSI value. If the new RSSI level is higher the handover operation is performed. Otherwise, it goes back to the discovery phase. Parameters other than RSSI, like SNR, bandwidth, bit error rate (BER) can be used in this approach. However, these parameters are often not directly involved in the handover decision-making process, they are mostly used to assist the handover procedure. Due to the simplicity and availability of the hardware equipment required for RSSI calculations, it has been used in quite a number of studies in the literature [9–11].

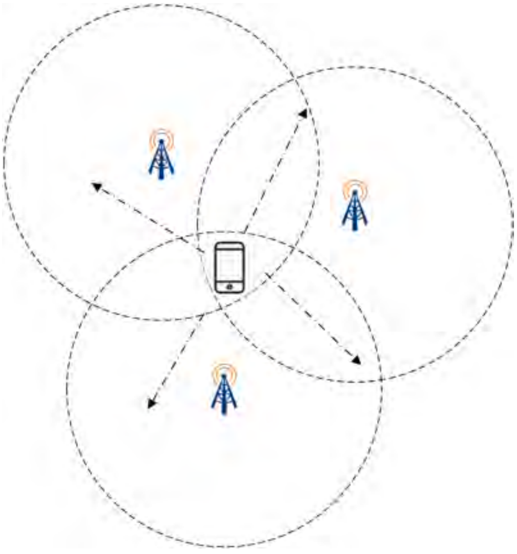

Fig. 2. Possible mobile user movements and handovers among small cells.

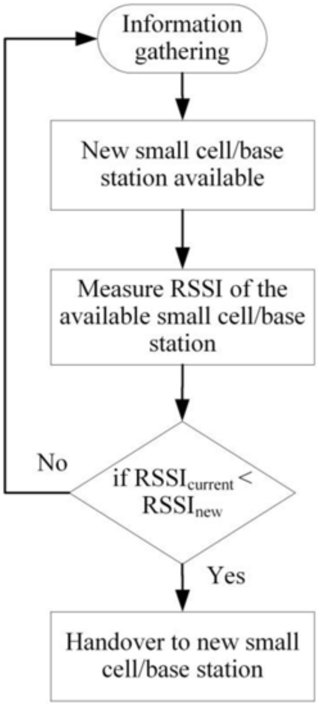

Fig. 3. General scheme of RSSI based decision mechanism.

SNR is defined as the ratio of signal power to noise power, and it is another important parameter for handover strategies in wireless communications. SNR is usually measured in decibels and defines the communication channel quality. A higher SNR value means the errors and inference will have less impact on the signals.

RSSI is an inevitable parameter in the handover decision phase, however, this parameter alone is not enough in wireless communication environments. The most important reason for this is that RSSI cannot adequately reflect the conditions of a wireless communication environment. When only the RSSI is taken into account, it can cause an increase in the number of handovers and a decrease in network performance. Therefore the SNR, which is one of the important parameters for quality of service (QoS), should also be used in the handover decision phase.

Generally, RSSI and SNR are known as similar parameters. The RSSI aims to provide connections to mobile users. However, SNR reflects the current conditions (e.g. bandwidth efficiency, user density, etc.) of the wireless communication environment and serves as an important parameter to meet the QoS expectations of mobile users.

In this paper, the aforementioned RSSI and SNR values are taken into consideration for the handover management process. The rest of the paper is organized as follows. The paper continues with a literature review in Section 2. Section 3 covers the handover strategies in detail. The simulations and the performance analysis are given in Section 4. Finally, the conclusion is given in Section 5.

2. Related works

The small cell concept will be an essential component of 5G networks since it increases network capacity, density, and coverage, especially indoors [12]. To the best knowledge of the authors, there are only a few survey papers about 5G small cells and their simulation, and a limited number of papers about micro and macro cell handover.

A comprehensive survey about small cell handover, simulation researches, and open issues is given in [5]. The simulation in their paper shows that the utilization of standard LTE-A measurements allows the doubling of the macro cell offloading gain, improving the uplink capacity, and decreasing the interference at the user equipment level. In [13], a review on small cell antenna design is proposed and the role of small cell concept is explained in detail. In [14], an ultra-dense small cell survey is considered and the authors summarize and compare some of the recent achievements and research findings in the literature. The authors in [15] propose a comparative summary of the key decision parameters and features of several handover algorithms.

The authors in [16] develop a scheme coordinating a group of neighbouring small cells to suggest a local anchor-based handover architecture, and associated novel handover schemes employing a local mobility anchor based on Markov chain modeling. The simulation is performed with Monte-Carlo simulation of a small cell cluster with several mobile users using MATLAB. In [17], a multi-directional path loss model is offered to analyze the impact of the anisotropic path loss exponent on performance in 5G fractal small cell networks. They conclude that the resulting heavy handoff overhead is emerging as a new challenge for 5G fractal small cell networks. In [18], a novel heterogeneous architecture for the efficient integration of small cell technology in future mobile networks, called “Advanced Heterogeneous Mobile Network” is developed. Their network consists of macro cell, and metro cells for outdoor, and femtocell for indoor, traffic.

The authors in [19] propose a new handover scheme using a cooperation based cell clustering scheme for reducing handover overhead in the core network and also signaling overhead among small cells. In [20], various handover parameters are considered for improving mobility in heterogeneous networks. The simulations are performed with the authors’ developed MATLAB simulator which follows the “Third Generation Partnership Project (3GPP)” specified evaluation methodology.

The authors in [21] focus on small cell handover in macro cell and propose the state-dependent handover decision algorithm. Their proposed algorithm improves not only the performance of the user equipment but also the small cell utilization. In [22], a distributed mobility robustness optimization algorithm is developed for handover failures. Their algorithm uses the time to trigger and offset parameters for radio link failures in the handover decision. They classify the handover failures and optimize handover parameters in their study. The authors in [23] propose self-optimization of handover parameters issue for dynamic small-cell networks. Their method detects the radio link failures and adjusts the handover parameters. The authors in [24] investigate the inbound handover confusion in the two-tier macro cell-small cell networks with the help of mobility prediction. They model the activity status of the small cells.

The authors in [25] propose movement aware coordinated multi-point handover approach. They developed a smart algorithm that estimates the dwell time in the small cells and assigns it to the macro cell or small cell according to the movement tendency of the mobile user. The authors in [26] propose a new handover procedure using Apollonian circles and the straight-line geometric elements and analyze its performance. They develop an optimal handover mechanism to minimize both radio link failure and ping-pongs effects together.

In [27], a new data-driven handover optimization is proposed to reduce the problems associated with mobility such as handover delay, early handover, wrong selection of target cell and frequent handover. Their study is based on gathering the information from the network and developed a model to determine the relationship between the gathered dataset (time interval for the last handover, threshold value, radio link failure, new target cell ID, previous serving cell ID) and key performance indicator (KPI) expressed as the weighted average of mobility problem ratios.

The authors in [28] propose a new approach that can detect two important functions mobility load balancing (MLB) and mobility robustness optimization (MRO) conflict in a timely manner for handover management. Alpha-beta pruning technique [29], one of the game-theoretic approaches, is used for this process. After finding small cells with the possibility of MLB and MRO conflict, the two-dimensional Markov chain has been used to eliminate the fluctuations that cause this conflict.

In [30], an algorithm that reduces the number of unwanted handovers is proposed for ultra-dense heterogeneous networks. In the algorithm developed based on the mobility behavior of mobile user, it is categorized as the frequent handover-experienced by users as either fast-moving or slow-moving. Fast-moving users are transferred to the macro layer, while slow-moving users are managed by adjustment of handover parameters (dwelling time, velocity). Slow-moving users that cause ping-pong handovers are transferred to the macro layer as well. In this way, unnecessary handovers are avoided.

3. Handover analysis of small cells

The general working mechanism of the proposed SNR based handover decision scheme is given in Fig. 4. First, the mobile user constantly senses the environment and takes the necessary parameters. Here the RSSI parameter is important for the handover trigger module. It is decided whether to make a handover by comparing the RSSI parameter received from the base stations with a predefined threshold value. When an RSSI value below the threshold value is encountered, a check is run for a backup base station remaining from the previous connection process. If there is a backup base station, handover operation is performed. However, if the connection quality is not sufficient or there is no backup base station, the base station scanning process is started for the new connection. At this stage, known as the decision module, the process

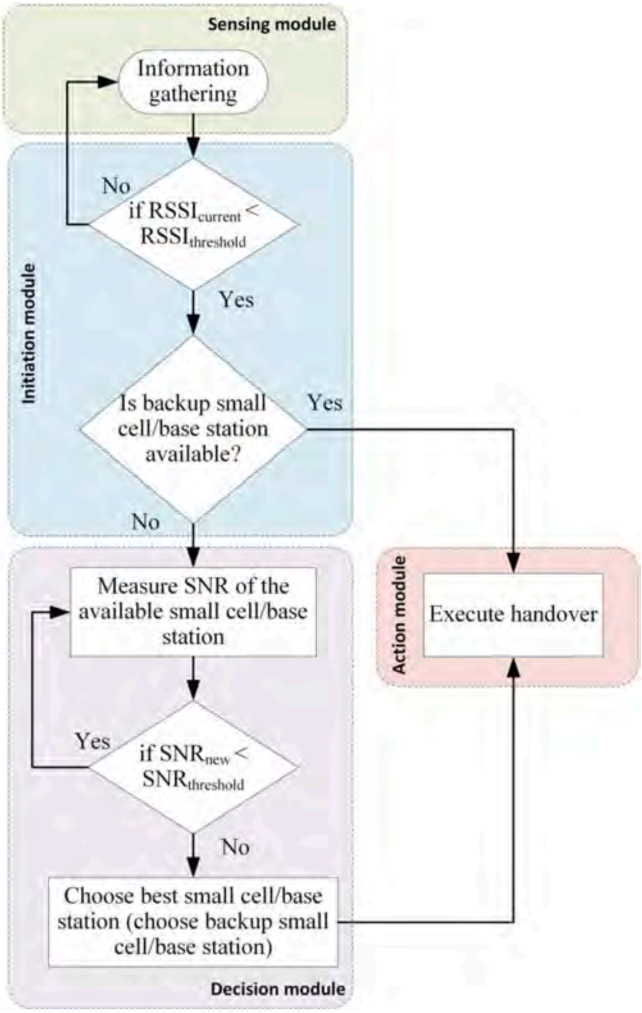

Fig. 4. Scheme of the proposed SNR based decision mechanism.

continues according to the SNR parameter. The scanning process performs with the beacon packets that are taken periodically from the base stations. The SNR values of the base stations are compared again over a predefined threshold value and the most suitable base station and backup base station are selected. The communication continues by performing the handover operation periodically.

3.1. Channel model

The circumstances of a wireless medium affect the performance of wireless communication. The propagation path can be complex due to many obstacles between the mobile nodes. Many environmental conditions such as line-of-sight, complex terrain, buildings, trees have an impact on the propagation. Unstable wireless channels are also difficult to analyze, as they change randomly and are difficult to predict.

Channel propagation of the physical layer has a prominent impact in wireless communication. There are alternative channels in various physical conditions. Path loss, slow fading, fast fading, and multipath fading parameters are taken into account in decisions about the condition of the channels. Riverbed Modeler is an important simulation software that can implement the entire network communication process including` all details. Although this software can implement various medium access control protocols, it only includes the Free Space Path Loss model as the channel model. However, different channel models are needed to obtain more realistic simulation results [31,32]. For this reason, the Nakagami Channel Model was preferred in our study, for the physical layer of wireless communication, instead of Free Space Path Loss. The Nakagami channel model, which is a combination of Rayleigh and Rician channel models, can decide to use the Rayleigh channel or Rician channel through different channel parameters [33].

3.1.1. Free space path loss channel model

The Free Space Path Loss channel model is the simplest path loss model. It is basically based on the Line-of-Sight (LOS) assumption that there are no obstacles to affect wireless communication between the nodes. The received power is calculated by the Friis power transmission equation (Eq. (1)) as follows [34];

$$P_r(d) \approx P_t\beta_t\beta_r\left(\frac{\lambda}{4\pi d}\right)^2 \tag{1}$$

While P_r represents the received power in this equation, it varies depending on the distance between receiver and transmitter. P_t expresses the transmit power, β_t and β_r are the antenna gains of transmitter and receiver antennas, and λ is the wavelength determined by the signal frequency. Although this model is ideal, in reality propagation loss can be affected by many reasons.

3.1.2. The Nakagami channel model

This channel model is developed to model the attenuation of wireless signals passing through multiple paths and to examine the effect of fading channels on wireless communication. Distinct environmental conditions such as complex terrain or disaster situations may provide differing obstacles and even these can be mobile. This model, which is widely preferred for modeling physical fading radio channels, is a more general fading model that can be adjusted to different channel models. The formula of this model, shows that the decrease in signal amplitude in radio wave propagation can be modelled properly with probability density function, and the equation is given as follows [35];

$$P_R = \frac{2m^m R^{2m-1}}{\Gamma(m)\Omega^m} exp^{-(m/\Omega)R^2} \text{ where } \Omega = \overline{R^2} \text{ and } m \geq 0.5 \tag{2}$$

where m is the key parameter that controls the severity or depth of amplitude fading and Γ(.) is the Gamma function. In this model, the value m determines the fading type. If m value is less than one, it is more severe than Rayleigh fading, and if m value is greater than one, it causes less fading than Rayleigh fading. However, if m is close to positive infinity, there will be no fading and the channel model is considered an AWGN (additional white Gaussian noise) channel [36,37]. In Eq. (2), Ω represents the average received power and R represents the signal envelope. The Nakagami Channel Model has been used in order to obtain more realistic results in simulating the scenarios we recommend. More detailed information about this model can be found in the relevant references [35,36].

The receiver antenna type and features defined for the physical layer in the Riverbed Modeler simulation software have been revised for the Nakagami channel model. There is a C based file (dra_power.ps.c) for the receiver antenna power model in the simulation program. This attribute specifies the name of a pipeline procedure capable of computing the received power level for incoming radio transmission. The codes in this file have been revised according to Eq. (2) for the Nakagami Channel Model.

4. Simulation results

In this section, the simulation scenarios are discussed in detail. One mobile user and eleven small cells are utilized for comparative performance analysis of traditional RSSI and SNR based handover schemes in the Riverbed Modeler simulation software. The mobile user moves at a speed of 5 km/h for 3600 s as shown in Fig. 5. The performance analysis of the mobile user handover process among the coverage area of the small cells in two different scenarios is realized in terms of throughput, end to end delay, bit error rate (BER), and packet loss ratio (PLR). One of the most important advantages of Riverbed Modeler is that it allows different channel models to be implemented in C language for wireless communication. In this study, the Nakagami channel model is used to make simulation results more realistic and compared to the Free Space Path Loss Model. All simulation results are based on the antenna structure proposed by the Nakagami channel model. Simulation parameters are given in Table 1.

The Riverbed Modeler [38] is an object-oriented simulation software package, widely accepted and used by academics, researchers and developers in modeling a variety of communication networks. Performance evaluation scenarios of the network systems are programmed with discrete state simulation occurrences. This software, with hierarchical modeling layers pertaining to networks in terms of protocol layers, protocols, nodes, connection lines, and data packets, etc. to be used in the network environment, is prepared as separate procedures using the editor functions in the simulator package. Riverbed Modeler software supports a variety of innovative approaches in simulating network environments by designing a new protocol model with the help of editors and adding the pre-designed models and protocols from the software library.

4.1. Comparison of channel models

All results in Fig. 6-11 show the variations of the handover decision mechanism according to different channel models. Generally, in the analysis of the handover decision algorithms proposed in many studies in the literature, channel models are not mentioned and analysed in simulation environments for different channel models.

On the other hand, the performance results can be examined through the default and simplest channel model such as Free Space Path Loss channel model in the Riverbed Modeler simulation software. However, this channel model produces misleading results for real application environments. In this context, in order to obtain more realistic results, the Nakagami channel model has been proposed in this study. The Nakagami channel model is programmed with the help of C language in Riverbed Modeler simulation software.

In order to perform comparative analysis, the simulation results obtained using both channel models are investigated. According to Nakagami and Free Space Path Loss channel models, average

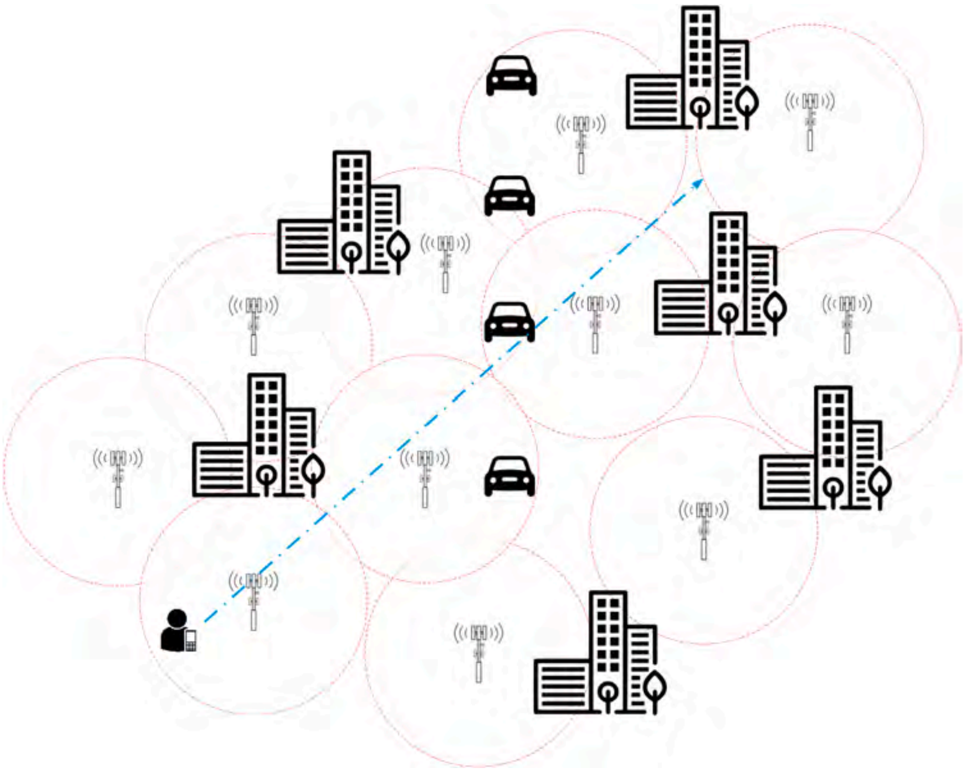

Fig. 5. Simulation environment with a mobile user and eleven small cells.

Table 1
Simulation parameters.

Parameter	Value
Simulation time	3600 s
Network coverage area	5000 m x 5000m
Number of small cell	1–15
Number of mobile users	1
Mobile user mobility model	Random waypoint
Bandwidth (MHz)	10
Small cell communication protocol	802.11 (CSMA/CA)
Tx power for small cells	30 dBm
Radius of small cells	200 m
BS status transmission period	100ms
Path Loss	Free Space Path Loss Nakagami Channel Model
$SNR_{threshold}$	35 dB
$RSSI_{threshold}$	−70 dBm
Mobil user speed	2–6 km/h

throughput results in Fig. 6, end-to-end delay results in Fig. 7, bit error rate results in Fig. 8, packet loss rates in Fig. 9, received signal noise/ratio results in Fig. 10, and received power results Fig. 11 for BS1, BS2, and BS3 are given for comparative performance analysis. From these results, it is seen that the Nakagami channel model gives more realistic results compared to the Free Space Path Loss channel model.

The free space path loss channel is the simplest path loss model, which is available in the Riverbed Modeler simulation software. It is assumed that the signal is transmitted to the receiver in an environment where there is no line of sight obstacle between receiver and transmitter nodes. Briefly, it is an ideal Line-of-Sight (LOS) that there are no obstacles to affect a wireless communication channel. The communication channel is affected by many factors such as propagation loss and fading. On the other hand, the Nakagami channel model states that the conditions in the wireless environment change randomly and the mobility of the obstacles should not be ignored. It can adapt Rayleigh, AWGN, or Rician channel models according to the channel condition in the environment. In our study, the Nakagami and the Free Path Loss channel models are compared and their effects are observed. The main difference between these two models is that the Nakagami channel model assumes an environment with obstacles and does not ignore the mobility situations. Referring to the result analysis as exemplified in Figs. 6-11, it is concluded that the Nakagami channel model gives more accurate results.

4.2. *Comparison of handover schemes*

In this study, two scenarios have been developed for two different handover schemes. In the first scenario, the simulation results of the traditional RSSI based handover decision scheme are shown in Fig. 12-15. The result of the mobile user's movement between the start and endpoints are analysed according to the Nakagami channel model [35, 36]. The traditional method is based on the comparison of old and new RSSI values according to the beacon packet sent by each base station every 100 ms. The RSSI parameter allows only connection to the base stations. However, the current condition of the base stations (bandwidth, user density, etc.) is neglected. This negligence can often lead to delays, packet losses, or even communication interruption.

In the second scenario, the simulation results of the SNR based handover decision scheme are shown in Fig. 12-15. The result of the mobile user's movement between the start and endpoints are examined according to the Nakagami channel model. In this scenario, the base stations send a beacon packet in 100 ms and the handover process is based on comparing the current and threshold RSSI values. However, this comparison is used only to trigger the handover process. In the traditional approach where the current condition of the base stations is neglected, the SNR value, which is one of the most important QoS parameters, is analysed to solve this problem. The SNR parameter is used to meet the QoS requirements of mobile users in the handover decision phase. In the proposed algorithm, the candidate base station's SNR value is compared with the threshold value in the handover decision. If the SNR value is below this threshold, the discovery process is started for a

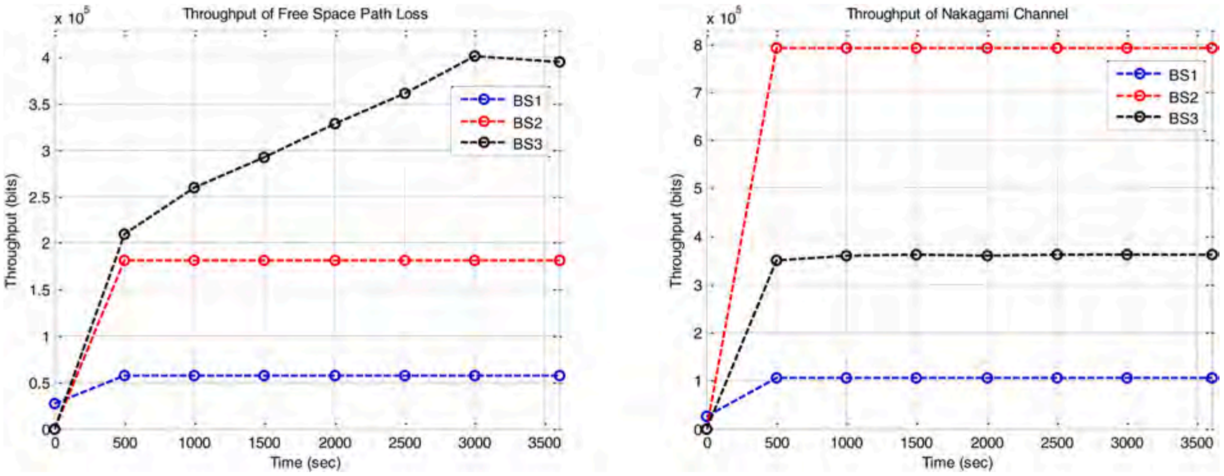

Fig. 6. Average throughput results for the different channel model.

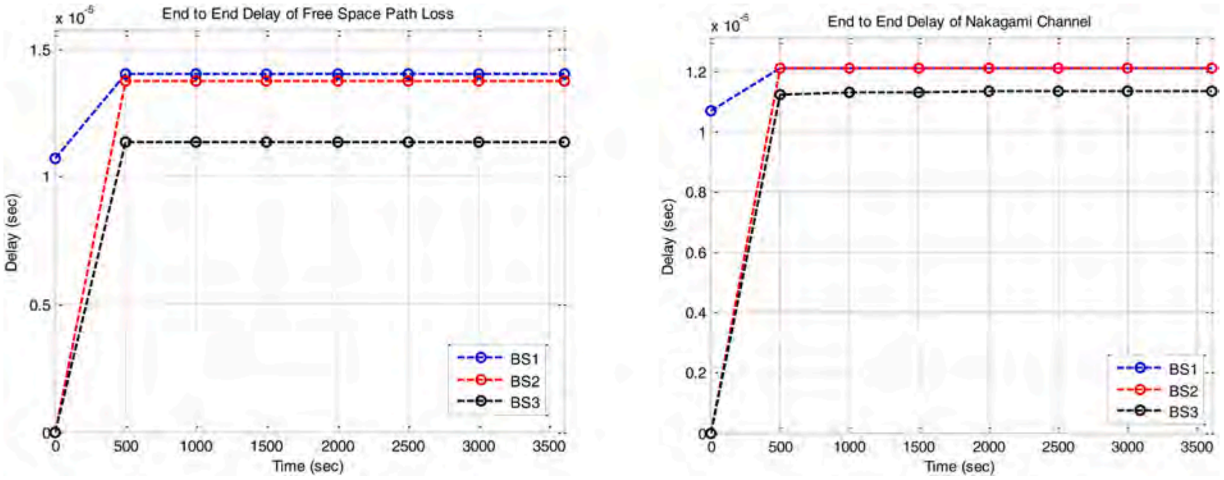

Fig. 7. End to end delay results for the different channel model.

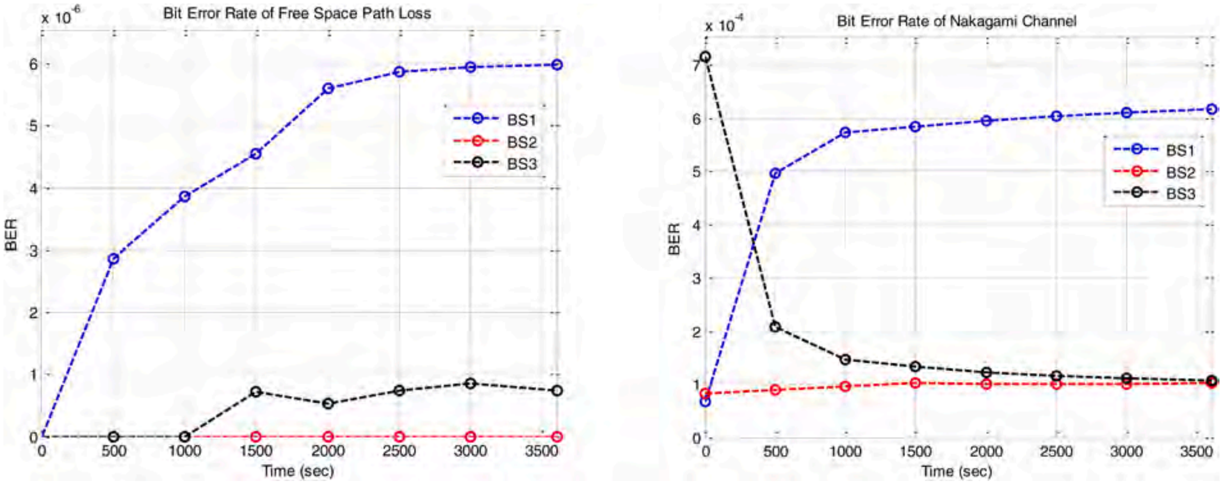

Fig. 8. Bit error rate results for the different channel model.

new base station. However, if the SNR value is above this threshold value, the base station is selected and handover operation is started. In addition, in this scenario, the selection of a backup base station is an important approach to continue communication without fail in the event of a problem. As a result, these two methods are compared according to the simulation results of throughput, end-to-end delay, BER and PLR, in two different scenarios.

In Fig. 12, the mobile user throughput results are given for BS1, BS2,

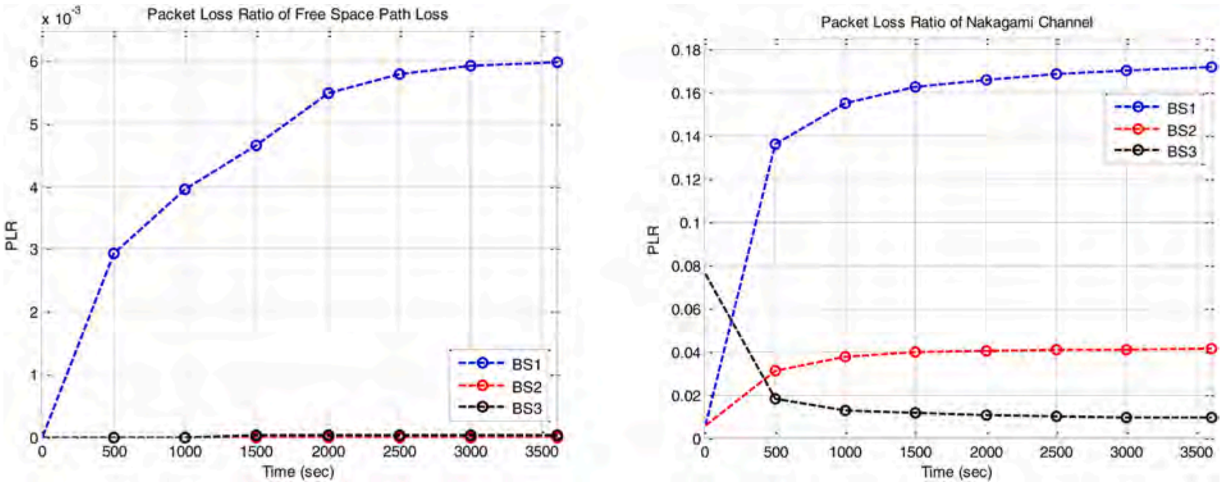

Fig. 9. Packet loss ratio results for the different channel model.

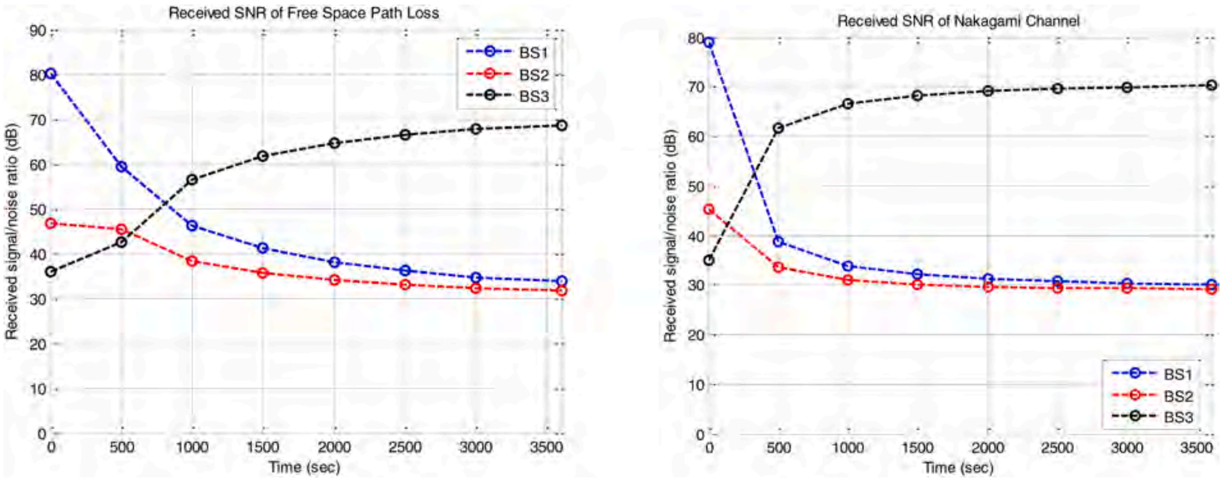

Fig. 10. Received signal noise/ratio results for the different channel model.

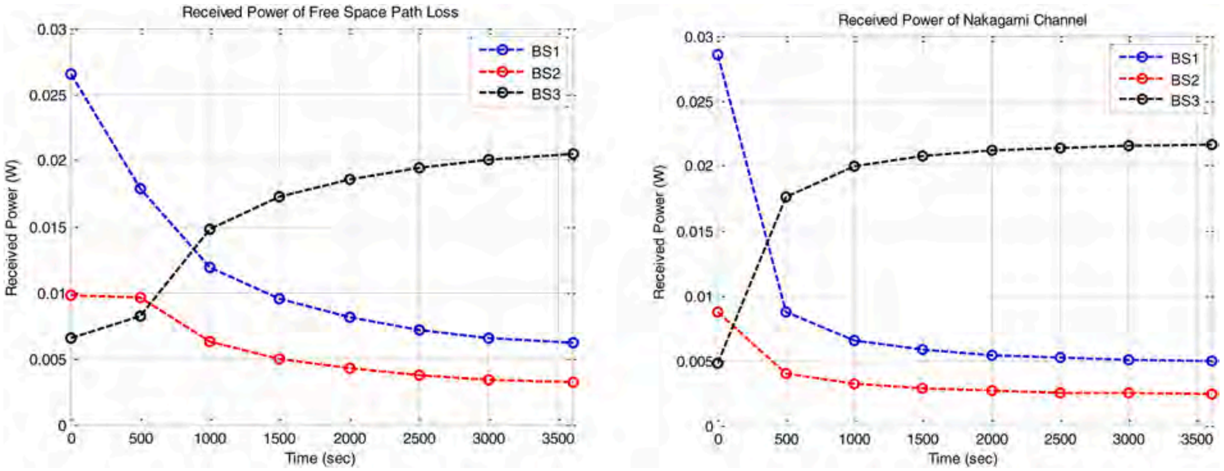

Fig. 11. Received power results for the different channel model.

and BS3 from eleven base stations during the simulation period. These results are obtained by comparing traditional RSSI and SNR based handover decision algorithms according to the Nakagami Channel Model. The mobile user starts communication by selecting BS1. After a while, the mobile user begins to scan a new BS because of the decreasing RSSI value from BS1. Finally, the communication is carried out through BS2 and then BS3 base stations, respectively.

As seen in Fig. 12, when comparing RSSI and SNR based handover decision schemes, it is seen that the SNR based scheme gives more successful results in terms of throughput. The main reason for this result

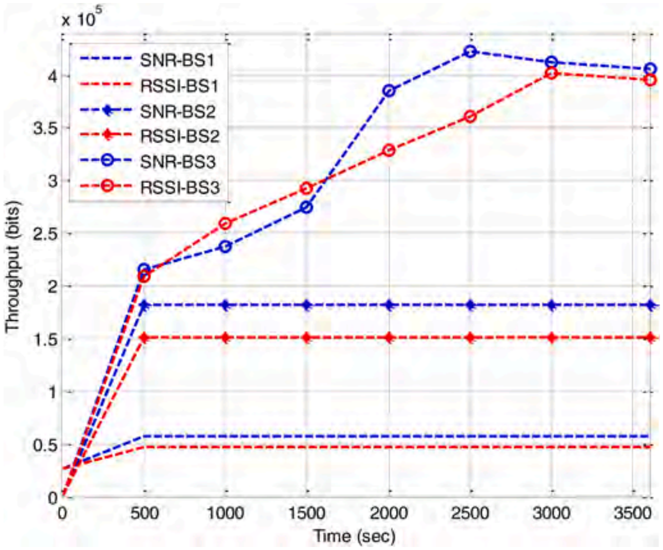

Fig. 12. Average throughput of BS1-BS2-BS3 for the SNR and RSSI based schemes.

is that the traditional approach only takes into account the RSSI parameter. However, the SNR based handover decision process considers not only RSSI but also SNR. While the RSSI parameter acts as a handover trigger with a threshold value, the SNR parameter is used in the selection of the base station that can meet the QoS expectations of the mobile user. In addition, a backup base station is selected to prevent communication from being interrupted, which is used when there are not enough frequency bands assigned to the mobile user or radio link failure. It is observed that the SNR based handover mechanism works more efficiently when the results of the throughput that occurred in three different base stations during the simulation period according to both approaches. These results are consistent with studies in the literature [39,40].

In Fig. 13, the average delay results in the handover process of the mobile user according to both scenarios are given. The SNR based handover decision scheme has a lower delay, while the RSSI based handover scheme has a higher latency. One of the most important expectations for 5G is to minimize delays. This result clearly shows that only the RSSI parameter is not sufficient in the handover decision process. In this context, it is seen that the SNR parameter, which reflects the current conditions of the wireless communication environment and base stations, should be used in the handover decision process.

The main reason for the delay in the RSSI based handover scheme is the frequent handover experience. Considering only the RSSI value and ignoring current differences between base stations by the mobile user causes frequent handover experience among small cells. In addition, the direction and speed of movement of the mobile user also affects this process negatively. While this approach causes unnecessary handover, it also causes packet delays and packet losses. However, the proposed approach compares the RSSI value with a threshold value for handover triggering, while the SNR values of candidate base stations are used in the handover decision. If the SNR level of the new base station is below this threshold, the handover operation does not take place. In this way, unnecessary handover process and delays are prevented. As can be observed from Fig. 13, the SNR based handover decision scheme has a lower delay.

In Fig. 14, bit error rates in the handover process of the mobile user are given according to both scenarios. As seen in Fig. 14, it is observed that the SNR based handover scheme gives more successful results compared to the RSSI based handover scheme in terms of bit error rate. The differences between the base stations also necessitate the selection of the most suitable base station. However, RSSI based handover decision neglects these differences in the selection process of the base station. Unlike the RSSI based scheme, SNR based handover, which is an inference parameter for the QoS expectations of the mobile user, has a positive effect for BER in the decision process.

In Fig. 15, the packet loss rates in the handover process of the mobile user according to both scenarios are given. While the packet loss rates are high in the RSSI based scheme, this value is low in the SNR based scheme. The most important reason for this result is that the SNR parameter is used in the SNR based handover decision scheme as well as RSSI and the backup base station is quickly involved in a possible problem.

5. Conclusions

This paper provides comprehensive expression and simulation of the handover management in small cells for 5G networks. RSSI and SNR based handover mechanisms are simulated and their comparative performance analysis has been made according to various parameters. Basic handover management procedures have been proposed to develop fast and seamless connections for 5G and beyond networks. The parameter

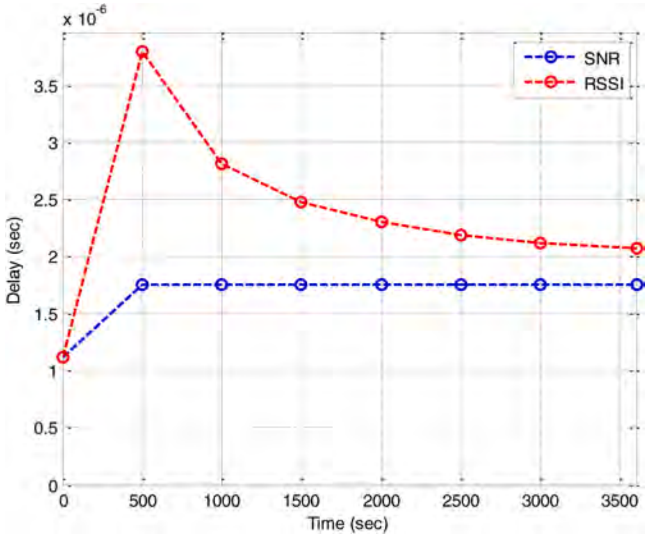

Fig. 13. Average packet delay of mobile user for the SNR and RSSI based schemes.

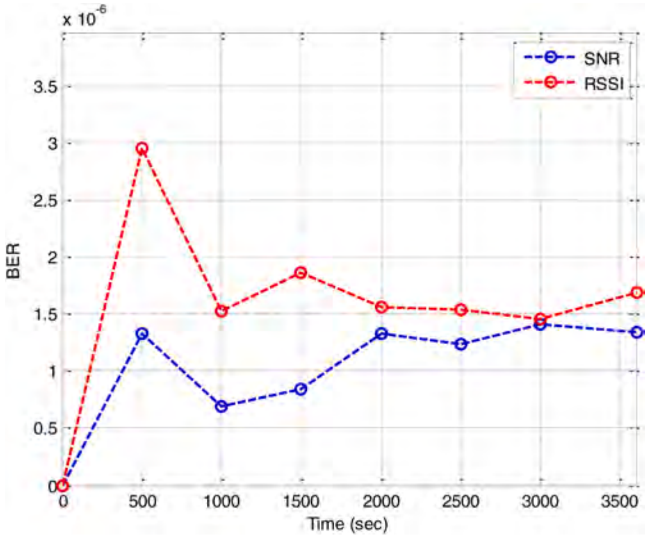

Fig. 14. Bit error rate of mobile user for the SNR and RSSI based schemes.

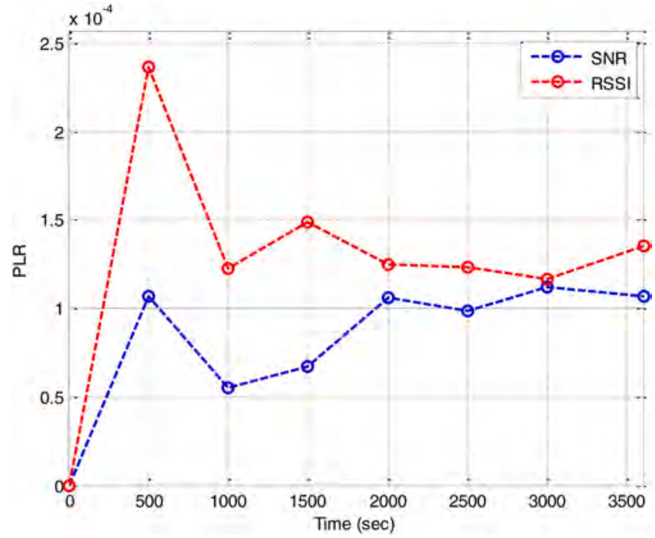

Fig. 15. Packet loss ratio of mobile user for the SNR and RSSI based schemes.

evaluation for handover triggering is the most crucial phase and the selection of the parameters is very important for reliable connection of the optimal base station. For this reason, unlike the traditional approach, SNR, which is an important QoS parameter, is used with the RSSI parameter, and a new handover mechanism is developed to provide the most appropriate base station selection. In addition, in order to prevent delays and packet losses, a faster handover is provided with the selection of a backup base station. The effects of Free Space Path Loss and Nakagami channel models in handover management are compared and the Nakagami channel model is used to analyze the performance of the developed handover mechanism in a more realistic environment. According to the simulation results, it is seen that the proposed approach gives more successful results than the traditional approach in terms of throughput, average packet delays, bit error rate and packet loss rates.

In future works, new handover mechanisms for various wireless environments according to the environment specifications will be planned and ultra-dense 5G networks will be considered in terms of load balancing optimization. In addition, a new handover approach will be planned using a software-defined networking approach.

CRediT authorship contribution statement

Murtaza Cicioğlu: Conceptualization, Methodology, Software, Investigation, Writing - original draft, Writing - review & editing, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.csi.2020.103502.

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