Survey on Handover Techniques for Heterogeneous Mobile Networks

Adnane El Hanjri, Ikram Ben Abdel Ouahab, and Abdelkrim Haqiq

Abstract—**This paper presents an overview of existing techniques of Handover in Heterogeneous Mobile Networks. It gives an overview of the mobility management processes and mainly focuses on decision-making approaches. The literature has reported many problems with seamless support for mobility management techniques. Failures in the Handover operation are caused by frequent disconnections and ineffective seamless Handovers. Therefore, to provide customers with an acceptable Quality of Service, Heterogeneous Mobile Networks must have an effective mobility management system that allows many wireless networks to collaborate. A single parameter, two or more extra factors, or a mix of both are used by several mobile-controlled Handovers to assess the policy choice. In this paper, We have covered many Handover approaches, as well as advancements that have been achieved throughout time. Almost all of the Handover Techniques over the previous ten years have been covered. Based on the many Advantages and Limitations, we have tabulated all the Handover procedures. The paper will be beneficial to emerging specialists in the sector.**

Index Terms—**Handover, Heterogeneous Mobile Networks, 5G networks, Handover Techniques, Performance.**

I. Introduction

In recent years, mobile cellular communication has grown to be one of the most relevant research areas. With the current cellular system architectures, the constantly rising demand for wireless data services necessitates large network densification.

The current cellular network infrastructure cannot satisfy the necessary needs due to its inadequate coverage area and capacity due to the rising demand for multimedia traffic.

Mobility is one of the key traits that has made wireless cellular communication systems indispensable. The procedure of Handover allows continuous service as a user moves between cells. During cell-crossing or/and signal quality deterioration in the present channel, Handover is required. Handover, in the realm of telecommunications and mobile communication, denotes the seamless transfer of cellular transmission from one base station to another, ensuring uninterrupted connectivity throughout the transition [1]. The emergence of Fifth Generation (5G) [2] technology addresses the rising need for high data bit rates. Key to 5G networks is the integration of Small Cells alongside Macrocells, forming what's known as Heterogeneous Networks (HetNets) [3]. These networks combine cells of varying sizes to deliver ultra-dense coverage within specific geographic zones.

To guarantee that Quality of Service (QoS) is not compromised and needless Handovers are avoided and should occur at the appropriate moment by triggering Handover decisions that take all relevant factors into account.

Various criteria are used in the Handover process as part of the mobility management scheme, which improves system performance at the time of the Handover choice. These metrics are important for evaluating the performance of Handover procedures and identifying potential issues that may affect the performance of the network. By monitoring these metrics, network operators can make adjustments to enhance the performance of the network and provide a better experience for users.

In this work, we present a detailed Survey of Handover Techniques for Heterogeneous Mobile Networks. This article is organized as follows. In Section II, we introduce the Handover definition, phases, and types. Section III provides Handover issues. Section IV, discusses various parameters affecting the performance during the Handover, then the Handover Techniques are presented in Section V. Then, the Handover Management Techniques in 5G Networks are presented in section VI. After that, we introduce the Future Research Directions in Section VII. Finally, in Section VIII, we conclude the article.

II. Handover

A Handover, further known as a handoff, is a crucial concept in wireless cellular communication that allows the User Equipment (UE) to go from one cell to another without losing the session. This process is essential in mobile networks, as it allows a mobile device to maintain a connection while moving between different cells or Base Stations (BSs), where BS is a general term for any Base Station (BTS is a GSM term, NodeB, eNodeB or NR is used in 3G/4G/5G). Handovers are typically performed seamlessly, without interruption to the user's communication.

A. Phases of Handover

Every Handover process contains three phases, see figure 1.

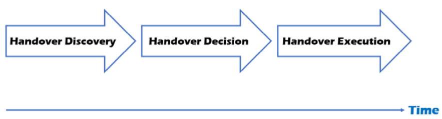

Fig. 1: Phases of Handover

A. El Hanjri Laboratory of Intelligent Systems and Applications (LSIA), Morrocan School of Engineering Sciences (EMSI), Tangier, Morocco. (E-mail: a.elhanjri@emsi.ma)

I. Ben Abdel Ouahab Smart Systems and Emerging Technologies (2SET), Faculty of Science and Techniques, University Abdelmalek Essaadi, Tangier, Morocco. (E-mail: ibenabdelouahab@uae.ac.ma)

A. Haqiq is a Professor at the department of Mathematics and Computer science, Hassan First University, Faculty of Sciences and Techniques, Computer, Networks, Mobility and Modeling laboratory: IR2M, Settat, Morocco. (E-mail: abdelkrim.haqiq@uhp.ac.ma)

DOI: 10.36244/ICJ.2024.3.6

Handover Discovery: A Handover process must start whenever a mobile node requires a move away from its point of attachment to the present network in order to connect to another network where the QoS will be better. Typically, a weak signal or a value for one or more quality of service criteria below a certain threshold may be to blame. The mobile node scans the networks in its immediate area continually throughout this phase in order to get the essential data.

Handover Decision: In this phase, the UE chooses the best access network and gives instructions to the execution phase in order to decide if and how to complete the Handover. Several parameters have been proposed in the research literature for use in the Handover decision algorithms, such as, Handover delay, Number of Handovers, Handover failure probability, and Throughput.

Handover Execution: During this phase, the source BS transmits the handover command to the UE. Following receipt of the handover command, the UE instantly disconnects from the source cell and starts building a downlink synchronization link with the destination cell.

B. Handover Types

There are different types of handovers, including:

Hard Handover: Where the connection to the existing BS is shut down before a new connection is established with a new BS. This type of Handover is typically used in cellular networks and is known for its quick and efficient transfer of data.

Soft Handover: Where the connection to the current BS is maintained while a new connection is established with a new BS. This type of Handover is typically used in cellular networks and is known for its ability to offer a more reliable connection, as the mobile device is connected to multiple BSs simultaneously.

Horizontal Handover: This type of Handover occurs when a mobile device moves between different cells or base stations that are part of the same network.

Vertical Handover: This type of Handover occurs when a mobile device moves between different types of networks, such as a cellular network and a wireless network.

Intra Handover: also known as an intra-cell handover or handover within the same cell, occurs when a mobile device switches between different sectors within the same base station or cell.

Inter Handover: also known as an inter-cell handover, occurs when a mobile device switches its connection from one cell to another within the same or a different eNodeB (Evolved NodeB, a base station in LTE).

III. HANDOVER ISSUES

There are several issues that can arise during the Handover process, which can impact the quality and reliability of the connection, these issues include:

Handover delay: This occurs when there is a delay in the Handover process, which can result in dropped calls or data packets.

Handover delay: This occurs when there is a delay in the Handover process, which can result in dropped calls or data packets.

Handover failure: This occurs when the Handover process fails, resulting in a loss of connection.

Ping-pong effect: This happens when the mobile device switches between BSs multiple times, resulting poor call quality and increased power consumption.

Interference: This occurs when multiple mobile devices are trying to access the same resources, leading to congestion and reduced capacity.

Security: This issue occurs when the Handover process is not properly secured, which can lead to unauthorized access to the network or eavesdropping on communications.

Quality of Service (QoS): During the Handover process, the QoS of the call or data session may be affected, resulting in a lower-quality connection.

Mobility management: This issue is related to the management of the mobile devices in the network, it can cause delays in the Handover process and a lack of resources for the new connection.

To avoid these issues, the network should be designed to minimize Handover delay and Handover failure and to ensure that the Handover process is secure and efficient. Additionally, the network should be optimized to provide a good QoS and good management of mobile devices.

IV. FACTORS INFLUENCING PERFORMANCE DURING HANDOVER

The factors determining whether a Handover is necessary are Handover metrics. These metrics can either be dynamic or non-dynamic depending on the source of Handover and the frequency of recurrence, see figure 2.

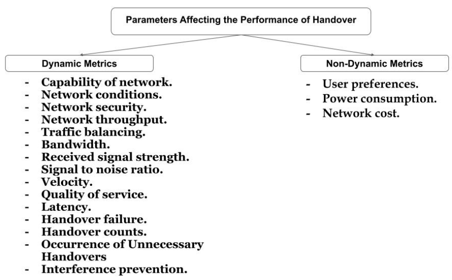

Fig. 2: Parameters Affecting the Performance During Handover

A. Dynamic Metrics

These measures' values fluctuate regularly, which has a significant impact on the decisions relating to Handover. Here are some of the most important dynamic aspects covered.

Capability of Network: In terms of bandwidth support, protocol support, interoperability standards, etc., different networks have varying capacities.

Network Conditions: Network topology and dynamic changes taking place nearby are crucial factors to consider while making handoff decisions.

Network Security: During the Handover decision step, security policies pertaining to integrity, authorization, authentication, confidentiality, and resource modification must be correctly injected.

Network Throughput: The network throughput serves as a gauge for effective data delivery.

Traffic Balancing: The capacity of the cells to carry traffic is reduced due to frequent changes in network loads, which also lowers the QoS requirements.

Bandwidth: Lower call dropping and less call blocking are caused by increased bandwidth.

Received Signal Strength (RSS): The RSS significantly contributes to minimizing the ping-pong effect. Lower RSS numbers result in a greater network load, whereas higher RSS values cause more call drops.

Signal-to-Interference-plus-Noise Ratio (SINR): Quantifies the ratio of the desired Signal strength to the combined strength of Interference and Noise in a communication system.

Velocity: Higher velocity in microcellular networks causes more Handovers to occur often, which raises the overall handover counts.

Quality of Service (QoS): The network performance is certified by QoS levels.

Handover Latency: The QoS metrics are impacted by Handover latency, which also lowers network throughput and performance.

Handover Failure: The main reasons for handoff failure are mobility and a lack of resources at the destination station.

Handover Counts: The value of handover counts should be reduced.

Occurrence of Unnecessary Handovers: Ping-pong effects caused by unnecessary handoffs increase communication and handoff latency overheads.

Interference Prevention: Interference during Handover is extremely undesirable since it lowers the QoS requirements, which in turn makes users less satisfied.

B. Non-Dynamic Metrics

These metrics change far less often than dynamic metrics, which means they have less of an impact on the Handover mechanism. Below is a list of a few non-dynamic factors.

User Preferences: Depending on their preferences and the needs of the application, users may have a variety of options.

Power Consumption: Due to interface activations during the decision phase of the Handover procedure, battery consumption occurs.

Network Cost: It speaks of the whole expense of gaining access to the network throughout the Handover. It is determined using a cost function based on call arrival rates.

V. Handover Techniques

The decision-making process for Handover involves assessing the available wireless access networks. As a result of this procedure, a network is chosen to which a Mobile Terminal should be transferred while taking the information acquired during the system discovery phase into account. Although standards do not specify decision algorithms, there are numerous possibilities in the literature. These algorithms' dependability and complexity depend on how readily available and dynamic the inputs are. We list a selection of the most popular Handover decision-making processes below,

A. RSS based Handover Decision

RSS (Received Signal Strength) based Handover decision works by monitoring the signal strength between the mobile device and the BS, and when the signal strength falls below a certain threshold, a Handover is triggered [4].

Base Stations are designed to cover specific areas efficiently, so they often have multiple cells or sectors. RSS indeed pertains to the signal strength received by the mobile device from a specific transceiver within a cell/sector. It is not a measure of the combined signal strength from all transceivers within the BS. RSS measurements are relevant for all cell sites, whether they have single or multiple cells/sectors. However, when discussing RSS in the context of a specific cell/sector, it is important to understand that it relates to the signal strength from the individual transceivers serving that cell/sector, not from all transceivers within the entire BS.

The RSS-based Handover decision has some advantages, simple to implement and widely used in wireless networks. Additionally, it is based on the signal strength which is a direct measure of the quality of the connection.

However, it has some drawbacks as well, it is only based on the signal strength and it does not take into account other factors such as network congestion, available capacity, and QoS. Moreover, it is sensitive to the environment and the obstacles that may affect the signal strength.

B. Bandwidth based Vertical Handover

In this technique, the mobile device monitors the available bandwidth of different networks, such as cellular networks and wireless networks, and selects the network that can provide the highest bandwidth [5] [6].

The bandwidth-based vertical Handover has some advantages, efficient and flexible as it can adapt to changing network conditions.

However, it has some drawbacks as well, it is dependent on the accurate measurement of the available bandwidth, and the measurement can be affected by some factors such as interference or network congestion. Additionally, it does not take into account other important factors such as security and cost.

C. Cost based Vertical Handover

This technique involves evaluating the costs associated with different network options and selecting the network that provides the best balance of cost and QoS [7] [8] [9].

The cost evaluation can be based on different factors, such as the cost of data usage, the cost of network access, and the cost of device compatibility.

The cost based vertical Handover has some advantages, it is based on the cost-benefit ratio and it is selecting the network that offers the best balance of cost and QoS. Additionally, it is efficient in terms of cost management.

However, it has some drawbacks as well, it may not always prioritize the QoS over the cost and it is not always easy to accurately estimate the costs associated with different network options.

D. Multi Metric Handover Decision

Multi-Metric Handover Decision is a technique that works by taking into consideration multiple metrics, such as signal strength, available bandwidth, network congestion, and QoS when making a Handover decision [10] [11] [12].

In a Multi-Metric Handover Decision, each metric is assigned a weight, and the Handover decision is made based on a combination of these weights and the corresponding metric values.

The Multi-Metric Handover decision has some advantages, it is based on multiple metrics, which provides a more accurate and reliable Handover decision. Additionally, it is efficient and flexible as it can adapt to changing network conditions.

However, it has some drawbacks as well, it is dependent on the accurate measurement of the multiple metrics, and the measurement can be affected by some factors such as interference or network congestion. Additionally, it can be complex to implement and it may require more computation power.

E. Function based Decision Algorithm

Function-based decision algorithm is a technique that works by defining a function, or set of functions, that take into account multiple parameters, such as signal strength, available bandwidth, network congestion, QoS, and use this function to make a Handover decision [13].

This function is typically based on mathematical equations or models, and it is designed to optimize a specific performance metric, such as Handover delay, Handover failure rate, or call/data session drop rate.

Function based decision algorithm has some advantages, it is based on multiple parameters and it uses a function to make a decision, which provides a more accurate and reliable Handover decision. Additionally, it is efficient and flexible as it can adapt to changing network conditions.

However, it has some drawbacks as well, it is dependent on the accurate measurement of the multiple parameters, and the measurement can be affected by some factors such as interference or network congestion. Additionally, it can be complex to implement and it may require more computation power.

F. User Centric Decision Algorithm

User Centric Decision Algorithm is a technique that works by taking into account the preferences and needs of the user, in addition to network-related parameters, such as signal strength, available bandwidth, network congestion, and QoS, when making a Handover decision [14] [15].

The User Centric Decision Algorithm has some advantages, it is based on the user's preferences and needs, which can provide a more satisfactory experience for the user. Additionally, it is efficient and flexible as it can adapt to the changing user's preferences and needs.

However, it has some drawbacks as well, it is dependent on the accurate measurement of the user's preferences and needs, and it can be affected by some factors such as the user's behavior change. Additionally, it can be complex to implement and it may require more computation power.

G. Context Aware Handover Decision

The context data contains information on mobile stations, such as their capacity, battery life, location, and mobile velocity. To keep up an elevated standard of customer satisfaction, vertical handover decisions are thought to be best made using user-based information such as preferred network, cost, and application-based information such as the type of service (conversational, background, streaming, etc.).

These approaches improve system flexibility and efficient service continuity [17] [16]. meanwhile, the decision is based on global knowledge and results in computational delays, the designed solutions are centralized and require a lengthy processing time.

H. Media Independent Handover Decision

The key concept behind Media Independent Handover Decision (MIH Decision) [18] is to enable a mobile device or user equipment to make intelligent handover decisions autonomously or with the assistance of network entities. It allows the device to assess the available networks or technologies and determine the optimal handover strategy based on predefined policies or algorithms.

The accuracy of the network state information affects how effective this algorithm is. The routing information contains the gateway along with cost and metrics like data rate, throughput, and latency under network conditions, whereas the network parameters include mode, authentication, and cost [19].

I. Multiple Attributes Decision Making

Multiple attributes decision making (MADM) [20] is a technique that works by taking into account multiple attributes, such as signal strength, available bandwidth, network congestion, QoS, cost, and security, when making a Handover decision [21].

MADM has some advantages, it is based on multiple attributes, which provides a more comprehensive and reliable Handover decision. Additionally, it is efficient and flexible as it can adapt to changing network conditions.

However, it has some drawbacks as well, it is dependent on the accurate measurement of the multiple attributes, and the measurement can be affected by some factors such as interference or network congestion. Additionally, it can be complex to implement and it may require more computation power.

J. Markov based Decision Algorithm

In this technique [22], the network states can be defined based on various parameters such as signal strength, available bandwidth, network congestion, QoS, cost, and security. The transition probabilities between these states are determined using historical data and statistical analysis.

When a Handover is necessary, the algorithm uses the current state and the transition probabilities to determine the next state, which is the network that offers the best performance.

Markov-based decision algorithm has some advantages, it is based on historical data and statistical analysis, which provides a more accurate and reliable Handover decision. Additionally, it's efficient and flexible as it can adapt to changing network conditions.

However, it has some drawbacks as well, it is dependent on the accurate measurement of the multiple attributes, and the measurement can be affected by some factors such as interference or network congestion. Additionally, it can be complex to implement and it may require more computation power.

K. Computational Handover Decision

In computational Handover decisions [23] [24] [25], the algorithm or model is trained on a set of data that includes information about network conditions, such as signal strength, available bandwidth, and network congestion, as well as information about Handover outcomes, such as Handover delay and Handover failure rate. The algorithm or model can then be used to analyze new data and make a Handover decision.

Computational Handover decision has some advantages, it is based on a mathematical algorithm or model that is trained on a set of data, which can provide a more accurate and reliable Handover decision. Additionally, it is efficient and flexible as it can adapt to changing network conditions.

However, it has some drawbacks as well, it is dependent on the accuracy of the data used to train the algorithm or model and it is also dependent on the quality of the algorithm or models and it can be complex to implement.

L. Game Theoretic Approach for Decision Making

Several game theory methodologies, such as cooperative games, non-cooperative games, hierarchic games, and evolutionary games, could be used to simulate the Vertical Handover decision problem.

A cooperative bandwidth allocation technique based on the bankruptcy game is proposed by Niyato et al. in [26]. In this N-person cooperative game, networks work together to use coalition form and characteristic function to create new connections with the necessary bandwidth. By employing the fundamental idea, the stability of the allocation is examined. Each network aims to make the most of the available bandwidth in order to increase revenue from new connections. The same authors refer to the issue of bandwidth allotment as an oligopoly market rivalry in [27]. This market competition is modeled using a Cournot game, and Nash equilibrium is thought to offer a stable resolution. Iterative and search techniques are recommended for obtaining the Nash equilibrium. In both articles, the other authors offered an admission control mechanism based on the suggested bandwidth allocation system to supply new connections with high QoS for both vertical and Horizontal Handover.

Haddad et al. invent a hierarchical distributed learning framework for decision-making during Vertical Handover in Heterogeneous cognitive networks in [28]. They use a Nash-Stackelberg fuzzy Q-learning model to represent the issue. The mobile nodes are seen as followers who want to maximize their QoS while the network is seen as the leader who wants to maximize its revenue.

In [29], Dusit et al. model the Vertical Handover decision problem as a dynamic evolutionary game where various user groups in various service areas compete to share the finite quantity of bandwidth on the available networks. It is believed that the evolutionary equilibrium is the answer to this game. The population evolution method and the reinforcement-learning algorithm are the two network selection algorithms the authors suggest. The first system achieves evolutionary equilibrium more quickly, but it needs a central controller to collect, process, and broadcast data on users within a certain service area. The second technique, however, enables a user to gradually learn and modify the network selection choices to reach evolutionary equilibrium without any user intervention. Then, a Nash equilibrium result derived from a traditional non-cooperative game model is compared to the suggested evolutionary game model.

M. Reputation based Decision Making

In this approach [30] [31], the mobile device maintains a reputation value for each available network, based on feedback from other users or network entities. The Handover decision is made based on the reputation value of the available networks, with the mobile device choosing to connect to the network with the highest reputation value.

This technique can be useful in situations where traditional Handover decision methods may not be able to capture the quality of the network, such as network congestion or QoS.

Reputation-based decision-making has some advantages, it is based on the reputation of the network, which can provide a more accurate and reliable Handover decision by taking into account the quality of the network. Additionally, it is efficient as it can adapt to changing network conditions.

However, it has some drawbacks as well, it is dependent on the accurate measurement of the reputation of the network, and the measurement can be affected by some factors such as false or unreliable feedback. Additionally, it can be complex to implement and it may require more computational resources.

N. Cross Layer based with Predictive RSS Approach

Cross-layer-based with predictive RSS approach is a technique that combines the information from different layers of the protocol stack, such as the physical, data link, and network layers, and uses a predictive algorithm to make a Handover decision [32] [33].

The predictive algorithm uses the RSSI to predict the future signal strength of a network, based on the historical data of the RSSI. The Handover decision is made based on the predicted future signal strength and the information from other layers of the protocol stack.

This technique has some advantages, it is based on a combination of information from different layers of the protocol stack, which can provide a more comprehensive and reliable Handover decision. Additionally, it's efficient as it can predict future signal strength and adapt to changing network conditions.

However, it has some drawbacks as well, it is dependent on the accurate prediction of the future signal strength, and the prediction can be affected by some factors such as uncertainty or lack of data. Additionally, it can be complex to implement and it may require more computational resources.

A summary of the Handover decision-making processes are briefly mentioned in Table I:

TABLE I
ADVANTAGES AND DISADVANTAGES OF EXISTING HANDOVER DECISION SCHEMES

Existing Handover Decision schemes	Advantages	Disadvantages
RSS based	Simple design	Increased unnecessary handover, increase ping pong effect
Bandwidth based	Good throughput performance, good network selection	Inefficient bandwidth computation
Cost based	Less call drop probability reduced ping pong effect	Increased system overload
Multi metric based	Very less call-drop blocking, good context collection	Complex design leads to implementation issues
Function based	Minimum degradations in high load and congestion situations	Time consuming if services and/or available access points increase.
User-Centric based	Maximizes users' utility, High user consideration and low implementation complexity	No real-time support, simple rate prediction method
Context-Aware Handover Decision	Improve system flexibility and efficiency	Time Consuming, computational delays
Media Independent Handover Decision	Seamless Connectivity, Optimal Network Selection, Optimization and Efficiency	Complexity and Standardization, Increased Device Complexity, introduces additional delay and latency during handovers
MADM	Multi criteria consideration, better decision on dynamic parameters	Medium implementation complexity, Performance dependence on traffic class
Markov based	Adaptive and applicable to a wide range of conditions, Better delay performance	Implementation complexity
Computational Handover Decision	Makes decisions in an automatic way consider multi-criteria, reduced handover delay	Complexity increases if additional input parameters are considered
Game theory based	Efficient resource management, Improves the individual efficiency of mobile users	Additional decision parameters are required in practice to ensure a better quality of service
Reputation based	Faster handover decision	Reputation sustainability need to be addressed in more depth
Cross-Layer based	Adapt to dynamic network conditions by continuously monitoring and analyzing various metrics, including signal strength, channel conditions, congestion levels, and available resources	Lack standardized guidelines and protocols, making it difficult to ensure interoperability and compatibility across different network devices and vendors

VI. HANDOVER MANAGEMENT TECHNIQUES IN 5G NETWORKS

A. Radio Access based Techniques

The following section explains the radio access-based techniques used to control the handover procedures in 5G heterogeneous networks.

Zhang et al. [34] proposed cooperative interference mitigation and handover management in a Heterogeneous cloud small cell network (HCSNet), where a cloud radio access network is combined with small cells. An effectively coordinated multi-point (CoMP) clustering method using affinity propagation was devised to decrease interference from cell edge users. In HCSNet, the signaling procedure of a low-complexity handover management scheme is presented and reviewed. Based on numerical findings, it is possible to greatly enhance the capacity of HCSNet while maintaining the quality of service for users with the suggested network architecture, CoMP clustering scheme, and handover management system.

Maksymyuk et al. [35] [36] created the converged access network for the handover mechanism in the 5G heterogeneous network. In this instance, the wireless access segments and the optical backhaul were both a part of the radio access network. Additionally, the presented technique provides good bandwidth granularity allocation. Further, by employing this method, the radio signals between the remote radio head and baseband processing unit can be adjusted within the same resource blocks by the cloud radio access network channel. Moreover, the multicast data transmission to the complex eNodeB was also constructed through the collaborative efforts of resource elements for diverse cells. The invention of this data transmission, which greatly reduces backhaul traffic, was made possible by the changeover mechanism. Its drawback is that it leads to network congestion.

A generalized Random-Access Channel Handover (RACH) technique was created by Choi and Shin [17] for handover in a 5G heterogeneous network. In the absence of a synchronized network, this created approach achieved perfect mobility. This new RACH approach incorporated the make-before-break (MBB) handover and the RACH-less transfer. Smooth mobility was made possible by the well-established RACH technology by going from the serving cell to the user equipment. Since no other delay causes are impacted by the created method's important elements, they work with the long-term evaluation handover. The developed method did not, however, include the use of packet duplication to improve path switching.

B. Self Optimization based Techniques

The handover procedure for 5G heterogeneous networks' usage of self-optimization techniques is covered in detail in this subsection. Boujelben et al. [37] employed the handover self-optimization technique in the 5G heterogeneous network. The authors proposed a new Handover self-optimization method that is mainly designed to reduce network energy usage. When selecting the Handover destination cell, the received signal power, user speed, and the load of surrounding cells are all taken into account. The results of the performance evaluation demonstrate that, for all the specific user speed scenarios, the proposed algorithm significantly lowers the energy consumption in the network. The main difficulty with the developed approach is inter-cell interference.

C. Software Defined Network based Techniques

This section describes approaches of the Software Defined Network (SDN) based handover techniques used in the handover mechanism for the 5G heterogeneous network.

Tartarini et al. [38] developed a combination of a software-defined handover decision engine and a software-defined wireless networking method to improve the handover in a 5G heterogeneous network. Here, the wireless controller was used by the baseband pool to receive the handover information. The controllers' distribution of the communication information enabled the handover choice to be carried out optimally for each user. The candidate network selection strategy was also created as a technique for resolving binary integer linear programming optimization difficulties. Additionally, the user equipment mobility patterns and the adaptive timing technique were employed to reduce handover errors and restrict undesired handovers, respectively. The effectiveness of the created method has not been increased by implementing less-than-ideal solutions. The developed approach failed to enhance network performance when there was a wider variety of network types.

Rizkallah and Akkari [39] introduced a SDN for the vertical handover method in 5G heterogeneous networks. The data plane and the control plane were separated by utilizing the SDN. Utilizing the SDN also decreased the handover signaling message. The software-defined controller was then used to gather network data after that. The optimum handover choice was made based on the software-defined controller, which also helped to raise each network's quality of service.

Duan and Wang [40] developed the SDN for the handover mechanism in the heterogeneous network. The suggested method was used to facilitate the transfer of authentication and privacy protection. Protection for privacy was enabled among the connected access points. The created software-defined network also lowers the authentication handover latency and offers a platform for network management that can be customized. They assessed the use rates and the latency for authentication. The single point failure and security is the challenge of the Software Defined Network handover approach [41] [42].

D. Authentication based Techniques

This section illustrates authentication-based techniques used with various handover mechanisms now in use for 5G heterogeneous research.

Cao et al. [43] introduced the secure and efficient re-authentication and the group-based handover authentication procedure for 5G heterogeneous networks. This method was utilized to obtain strong security protection. In order to achieve the ensuing communications, a detached session key was finally incorporated into the network and the machine-type communication devices. Better security was attained with perfect effectiveness. Only some of the unidentified attacks are protected by the developed approach.

Fan et al. [44] employed a secure region-based handover technique in the 5G heterogeneous network. With no fundamental network components, the newly created region-based rapid authentication protocol was used to lower transmission and computation costs. The technique also guarantees that no other communication footprints are identical to anonymity. After that, user membership could be revoked using a gathered one-way hash, which removed the need for computational work in the 5G heterogeneous system. Through region-based secure handover, our newly designed solution successfully reduced the handover delay. This cutting-edge approach also met each user's security requirements. On the other hand, the developed approach omitted security-providing performance analytics and key management.

E. Evolved NodeB based Techniques

The eNodeB-based approaches in the handover mechanism for the 5G heterogeneous networks are detailed in this section.

Bilen et al. [45] developed the optimal eNodeB selection approach. The gain function was computed with dynamic weights for selecting the candidate cells. To select the best eNodeB in this case, the spatial estimation autoregressive approach evaluated the Kriging Interpolator and Semivariogram analysis. The best modeling performance is provided by the statistical and stochastic behaviors of Kriging Interpolations. Through the definite values of neighbor user equipment, the unidentified indicator value of mobile user equipment was also calculated. The created eNodeB estimate object, which correlates with every network node, was used to carry out every activity. These evaluations were also used separately in the control and data channels. They decreased the likelihood of needless, frequent, and ping-pong handovers, while the throughput remained the same.

F. Neural network based Techniques

This section serves as an illustration of research that made use of neural network-based methods.

Maksymyuk and Shubyn [35] employed the Recurrent Neural Network (RNN). Here, user mobility information was used to implement the neural network in the most effective way possible. As a result, the generated system's performance was improved by applying the gated recurrent unit-based neural network. Additionally, a cell individual offset parameter was located and used to carry out the mobility load balance. The gated recurrent unit-based neural network was also modified to find the subscriber's movement. They were only able to estimate the traffic in the Neural Network with an accuracy of less than 90%. In addition, benchmark data are not used, nor are network parameters analyzed to determine efficiency.

Morghare and Mishra [46] presented the neural network-based handover approach. Here, the neural network design was combined with the Particle Swarm Optimization (PSO) method. To improve system efficiency, the created method was used for quick delivery handover routes and network selection. However, to increase the effectiveness of the system, a sizable number of secondary users were also taken into consideration. Additionally, an optimization challenge and network selection issues were resolved using the created neural network method. Finally, the network selection for the free route and changeover path for data transfer was determined. Taking into account the interference and the population size, they were able to improve fitness with fewer iterations. When handing over the mobile terminal, the technique neglected to take network security and harmful assaults into account.

G. Blockchain based Techniques

This section shows the blockchain-based solutions that have been gathered from the numerous handover strategies already in use in 5G heterogeneous network research projects.

Ma and Lee [47] developed the blockchain scheme for the 5G heterogeneous network handover process. The Parallel Block-chain Key Derivation Function (PB-KDF), which regulates the fundamentals of the Bitcoin blockchain for structurally supporting the key derivation process, was used in this method. Additionally, the PB-KDF aids in improving handover performance. After that, the system's security was enhanced by using the blockchain outside of the cryptocurrency space. The mining procedure takes advantage of the handover key in this instance to allow both complete backward and full forward partitions. Consequently, the new PB-KDF technique improves both the performance and security of the handover. However, because key management creates computing costs and is not included in the processing phase, they did not take the computation difficulty into account and instead focused on improving security during intracellular handover.

Yazdinejad et al. [48] employed the blockchain-enabled authentication handover method in the 5G heterogeneous network. The software-defined network and heterogeneous network management were also used to increase programmability. The user's security and privacy were both preserved using this strategy, which also made use of encryption resources. Additionally, in recurrent changeover among heterogeneous networks, the introduced technique was used to reduce the avoidable re-authentication. In order to provide intelligent control among the diverse cells and safeguard user privacy, the software-defined network was also employed. Energy efficiency and scalability goals are met, however, the system's disadvantage is that security, data leakage, and handover delays still occur.

H. Blind Handover Technique

Blind handover is a technique used in wireless networks to perform Handover without the need for explicit signaling between the mobile device and the network. In this technique, the mobile device continuously monitors the signal strength of available networks and selects the network with the strongest signal to connect to, without consulting the network.

This technique is commonly used in wireless networks, such as WiFi and cellular networks, to ensure a seamless Handover between different access points or base stations. The mobile device uses the received signal strength indicator (RSSI) to measure the signal strength of available networks and select the network with the strongest signal.

In [49] [50] EL Hanjri et al. propose a new approach, to have an efficient, blind, and rapid Handover just by analyzing the received signal density function instead of demodulating and analyzing the received signal itself in classical Handover. The proposed approach exploits some mathematical tools like Kullback Leibler Distance, Akaike Information Criterion, and Akaike Weight.

The blind Handover technique has some advantages, simple to implement and does not require any explicit signaling between the mobile device and the network. Additionally, it's efficient as it can perform handover quickly, which can reduce the interruption of communication.

However, it has some drawbacks as well, it is dependent on the accurate measurement of the signal strength, and the measurement can be affected by some factors such as interference or network congestion. Additionally, it may not always select the network that offers the best Quality of Service (QoS) or the lowest cost, which might lead to poor call quality or dropped calls in case the mobile device connects to a network with poor signal strength.

A summary of The Handover Management Techniques in 5G Network with their Advantages and Limitations are briefly mentioned in Table II:

TABLE II
THE HANDOVER MANAGEMENT TECHNIQUES IN 5G NETWORK WITH THEIR ADVANTAGES AND LIMITATIONS

Handover Management Techniques in 5G Network	**Advantages**	**Limitations**
Radio Access-based	Increase the capacity while maintaining users' quality of service, reduce the backhaul traffic	Creates congestion in the network, failed to use packet duplication for path switching optimization
Self-Optimization-based	Reduce the energy consumption in the network	Inter-cell interference
Software-defined network-based	minimize the handover failures, eliminate the unwanted handover, reduce the authentication handover latency	Failed to improve network performance when higher diversity of network types
Authentication-based	Achieved better security with ideal efficiency, reduce communication and computation costs	Did not include performance analytics and key management for providing security
Evolved NodeB-based	Reduce the unnecessary, frequent, and ping-pong handover risk	Does not change the throughput
Neural network-based	Achieve a better fitness value with a reduced number of iterations while considering the interference and the population size	Fail to consider the security and the malicious attacks of the network while handovering the mobile terminal
Blockchain-based	Enhance the handover performance and improve the security of the system	Fail to consider the computation complexity
Blind Handover	Simple to implement and does not require any explicit signaling between the mobile device and the network, can perform handover quickly, which can reduce the interruption of communication	May not always select the network that offers the lowest cost

VII. FUTURE RESEARCH DIRECTIONS

Target criteria for mobile users will undergo significant development in the next-generation wireless networks. However, when the UE switches between cells in an extremely dense HetNet, adequate consideration must be given throughout the Handover procedure. The following subsections provide more details on a few of the probable future study fields that are briefly mentioned in Table III.

TABLE III
THE FUTURE ENABLER TECHNOLOGIES WITH THEIR ADVANTAGES AND LIMITATIONS

Future Technology	**Advantages**	**Limitations**
SDN	Flexible, programmable, and efficient way to manage and control networks with reduced operational costs	Complexity, Lack of standardization, and Lack of well-defined algorithms
ML and DL	The mobility management can be controlled by using machines	A state of the art Handover Decision Algorithms are required
Optimized Load Balancing	Achieve higher throughput and better QoS	The use of Dual Connectivity in a 5G Non-Standalone architecture

A. Software Defined Network

A method for managing the dynamic nature of various network topologies and their rising complexity is the SDN idea [51]. The Handover process is the primary management challenge for many network designs.

For instance, publication [52] describes a Handover mechanism for extremely dense 5G mobile networks based on SDN. SDNs struggle with numerous pointless Handovers. Decoupling network functions from specialized hardware devices to make them into tasks carried out by software-based programs is known as network function virtualization [53].

By executing layer 2 and layer 3 on the software-based application, virtual base stations enable operators to carry out operations from various mobile network technologies with a single virtual base station. Four stages make up the proposed Handover scheme: data collection, data processing, V-cell construction, and Handover execution. The phase of data gathering involves the control plane acquiring information about the state of the network. Measurement reports from the mobile node, serving base station, and potential Handover base stations are among the data that have been gathered. To choose the optimal set of target base stations for mobile users with various behaviors, the collected data is then processed to generate QoS for each base station coverage region.

B. Machine Learning (ML) and Deep Learning (DL)

To help the 5G wireless network achieve its objectives, a number of cutting-edge technology and networking strategies have been put forth. However, these solutions have also created a new set of issues, making the network's administration issues more complicated. For instance, HetNets has made it more difficult to govern many operations, such as mobility management, while still offering better coverage. Another essential component of the 5G wireless network, proactive data-driven models must replace traditional reactive-based models to increase the productivity of these models. Future innovations in 5G HetNet technologies and architectures will heavily rely on machine learning-based algorithms [54].

The most alluring method with the biggest potential for the 5G mobile network is machine learning [55]. Machine Learning based techniques are necessary in HetNets to correctly implement Handover judgments. These algorithms give the system the ability to automatically change parameters in response to UE demands and specifications. Thus, frequent handovers can be effectively decreased.

Machine Learning based algorithms give systems the ability to learn on their own, improving performance through encounters without having their roles defined beforehand. Systems may actively monitor, learn, and predict network behavior using data from the dynamic nature of network parameters thanks to machine learning-based techniques. To complete the required tasks, machine learning-based algorithms propose data-driven approaches to model system parameters and their impacts on complex systems.

Deep Learning is a branch of AI that teaches machines to perform tasks on their own. It is a strategy that has recently received a lot of attention and is quite promising. Artificial neural network techniques, a sophisticated technology for tackling complex problems, are also used in deep learning. In order for autonomous vehicles to recognize stop signs and distinguish between pedestrians and lampposts, deep learning is a crucial component. It makes voice control possible for household electronics including hands-free speakers, tablets, smartphones, and televisions. Recently, deep learning has drawn a lot of attention, and for good reason. It is reaching results that weren't possible before. Deep Learning models have the potential to achieve cutting-edge accuracy, frequently beating humans. Massive amounts of labeled data and multilayer neural network topologies are used to train the models. Better recognition accuracy than ever is delivered by deep learning. In safety-sensitive applications like driverless vehicles, this makes it possible for consumer electronics to live up to user expectations. Deep learning has recently advanced to the point where it is now superior to humans at some tasks, such as classifying objects in pictures [56].

C. Optimised Load Balancing

Potential methods for adjusting radio resources in the HetNet context of a mobile cellular network include self-optimization and load balancing. By moving the load from a high-density cell to a low-density cell, great throughput can be attained.

The load balancing techniques that can be employed in the 5G HetNet generally include the Cloud Radio Access Network, Cell Types, and Dynamic Handover parameters [57]. In the next generation of wireless communication systems, balancing data traffic and optimizing QoS, latency, and energy consumption are the major goals.

VIII. Conclusion

The review offered in this work indicates that typical vertical Handovers utilizing a single criterion are frequent. When either velocity or Handover signaling delay exceeds the preset value of the RSS threshold, it has been observed that the likelihood of a Handover failure increases. A thorough investigation into network selection with access to a wide range of contextual data reveals that user preference is a key factor in QoS. Network coverage information updates still aren't included in the decision-making process, though. To maintain connection, an optimization method for selecting the optimal candidate network throughout the vertical Handover process is crucial. The main goal is to offer effective smooth vertical Handover with optimal bandwidth allocation, improved QoS support in terms of delay measure, decreased Handover failure, and zero-level ping-pong impact. Additionally, vertical Handover is a problem that needs to be solved and requires energy efficiency just like in other networks. The plans should function on the network-controlled side, where the difficulties posed by mobile-initiated Handovers, such as a lack of power and knowledge of the network, may be overcome.

References

[1] M. Tayyab, X. Gelabert and R. Jäntti, "A Survey on Handover Management: From LTE to NR," in *IEEE Access*, vol. 7, pp. 118 907–118 930, 2019, doi: 10.1109/ACCESS.2019.2937405.

[2] John Baghous, "5G system throughput performance evaluation using Massive-MIMO technology with Cluster Delay Line channel model and non-line of sight scenarios," in *Infocommunications Journal*, vol. 13, no. 2, pp. 40–45, January 2021, doi: 10.36244/ICJ.2021.2.6.

[3] Kotaru Kiran and D. Rajeswara Rao, "Analytical Review and Study on Various Vertical Handover Management Technologies in 5G Heterogeneous Network", *Infocommunications Journal*, vol. XIV, No 2, June 2022, pp. 28–38., doi: 10.36244/ICJ.2022.2.3

[4] S. Mohanty and I. F. Akyildiz, "A Cross-Layer (Layer 2 + 3) Handoff Management Protocol for Next-Generation Wireless Systems," in *IEEE Transactions on Mobile Computing*, vol. 5, no. 10, pp. 1347–1360, Oct. 2006, doi: 10.1109/TMC.2006.142.

[5] S. Lee, K. Sriram, K. Kim, Y. H. Kim and N. Golmie, "Vertical Handoff Decision Algorithms for Providing Optimized Performance in Heterogeneous Wireless Networks," in *IEEE Transactions on Vehicular Technology*, vol. 58, no. 2, pp. 865–881, Feb. 2009, DOI: 10.1109/TVT.2008.925301.

[6] M. M. Q. Al-Ghadi, I. M. Ababneh, W. E. Mardini, "Performance study of SINR scheme for Vertical Handoff in wireless networks," in *Information & Communication Systems*, 2011, vol. 137.

[7] D. W. Lee, G. T. Gil, D. H. Kim, "A cost-based adaptive handover hysteresis scheme to minimize the handover failure rate in 3GPP LTE system," in *EURASIP Journal on Wireless Communications and Networking*, 2010, DOI: 10.1155/2010/750173

[8] K. H. Hong, S. K. Lee, L. Y. Kim, et al, "Cost-based vertical handover decision algorithm for WWAN/WLAN integrated networks," in *EURASIP Journal on Wireless Communications and Networking*, 2009, DOI: 10.1155/2009/372185

[9] D. He, C. Chi, S. Chan, et al, "A simple and robust vertical handoff algorithm for heterogeneous wireless mobile networks," in *Wireless Personal Communications* 59, pp. 361–373, 2011, DOI: 10.1007/s11277-010-9922-x.

[10] R. M. Rodriguez-Dagnino, H. Takagi, "Application of renewal theory to call handover counting and dynamic location management in cellular mobile networks," in *European Journal of Operational Research*, 2010, 204(1): 1-13.

[11] E. A. Alyousfi, M. M. Alkhawlani, "Optimization of vertical handover performance using elimination-based MCDM algorithm," in *Journal of Science & Technology*, 2016, 21(1).

[12] Hwang, Wen-Shyang, Teng-Yu Cheng, Yan-Jing Wu, and Ming-Hua Cheng, "Adaptive Handover Decision Using Fuzzy Logic for 5G Ultra-Dense Networks", in *Electronics*, 2022, 11(20):3278, DOI: 10.3390/electronics11203278

[13] G. Koundourakis, D. Axiotis, M. Theologou, "Network-based access selection in composite radio environments," in *IEEE, Wireless Communications and Networking Conference*, March 2007, pp. 3877–3883.

[14] O. Ormond, P. Perry, J. Murphy, "Network selection decision in wireless heterogeneous networks," in *IEEE 16th International Symposium on Personal Indoor and Mobile Radio, Communications*, vol. 4, September 2005, pp. 2680–2684.

[15] A. Calvagna, G. Di Modica, "A user-centric analysis of vertical handovers," in *Proceedings of the Second ACM international workshop on Wireless mobile applications and services on WLAN hotspots*, ser. WMASH '04. New York, USA: ACM, 2004, pp. 137–146, DOI: 10.1145/1024733.1024751.

[16] P. Bellavista, A. Corradi, L. Foschini, "Context-aware handoff middleware for transparent service continuity in wireless networks," in *Pervasive and Mobile Computing*, 2007, 3(4): 439-466, DOI: 10.1016/j.pmcj.2007.04.006.

[17] J. H. Choi, D. J. Shin, "Generalized RACH-Less Handover for Seamless Mobility in 5G and Beyond Mobile Networks", in *IEEE Wireless Communications Letters*, vol. 8, no. 4, pp. 1264–7, May 2019, DOI: 10.1109/LWC.2019.2914435

[18] O. Khattab, O. Alani, "A survey on media independent handover (MIH) and IP multimedia subsystem (IMS) in heterogeneous wireless networks," in *International Journal of Wireless Information Networks*, 2013, 20(3): pp. 215–228, DOI: 10.1007/s10776-013-0213-9

[19] J. Varga, A. Hilt, J. Bíró, C. Rotter, and G. Jaro, "Reducing operational costs of ultra-reliable low latency services in 5G," in *Infocommunications Journal*, vol.X, pp. 37–45, 2018, DOI: 10.36244/ICJ.2018.4.6.

[20] Liu, Q., Kwong, C.F., Zhang, S. et al, "A fuzzy-clustering based approach for MADM handover in 5G ultra-dense networks," in *Wireless Netw 28*, pp. 965–978 (2022), DOI: 10.1007/s11276-019-02130-3

[21] R. Chai, W.-G. Zhou, Q.-B. Chen, L. Tang, "A survey on vertical handoff decision for heterogeneous wireless networks," in *IEEE Youth Conference on Information, Computing and Telecommunication*, September 2009, pp. 279–282.

[22] E. Stevens-Navarro, V. Wong, Y. Lin, "A vertical handoff decision algorithm for heterogeneous," in *wireless networks*, March 2007, pp. 3199–3204, DOI: 10.1109/WCNC.2007.590

[23] M. A. Ben-Mubarak, B. M. Ali, N. K. Noordin, et al, "Fuzzy logic based self-adaptive handover algorithm for mobile WiMAX," in *Wireless Personal Communications*, 2013, 71(2): pp. 1421-1442, DOI: 10.1007/s11277-012-0883-0

[24] J. Zhou, C. Y. Zhu, "Compensatory analysis and optimization for MADM for heterogeneous wireless network selection," in *Journal of Electrical and Computer Engineering*, 2016, DOI: 10.1155/2016/7539454.

[25] V. Kantubukta, S. Maheshwari, S. Mahapatra, et al, "Energy and quality of service aware FUZZY-technique for order preference by similarity to ideal solution based vertical handover decision algorithm for heterogeneous wireless networks," in *IET Networks*, 2013, 2(3), DOI: 10.1049/iet-net.2012.0183.

[26] D. Niyato, E. Hossain, "A cooperative game framework for bandwidth allocation in 4g heterogeneous wireless networks," in *IEEE International Conference on Communications*, ICC '06, vol. 9, June 2006, pp. 4357– 4362, DOI: 10.1109/ICC.2006.255766

[27] Dusit Niyato and Ekram Hossain, "Bandwidth allocation in 4g heterogeneous wireless access networks: a noncooperative game theoretical ap- proach," in *IEEE Global Telecommunications Conference GLOBECOM '06*, December 2006, pp. 1–5.

[28] M. Haddad, Z. Altman, S. E. Elayoubi, E. Altman, "A Nash-Stackelberg fuzzy qlearning decision approach in heterogeneous cognitive networks," in *GLOBECOM'10*, 2010, pp. 1–6.

[29] D. Niyato, E. Hossain, "Dynamics of network selection in heterogeneous wireless networks: an evolutionary game approach," in *IEEE Transactions on Vehicular Technology 58* (4) (2009) pp. 2008–2017, DOI: 10.1109/TVT.2008.2004588.

[30] M. Zekri, B. Jouaber, D. Zeghlache, "On the Use of Network QoS Reputation for Vertical Handover Decision Making," in *IEEE Globecom, Workshop on Advances in Communications and Networks (ACN 2010)*, vol. 12, Miami, Florida, USA, 2010, pp. 2006–2011, DOI: 10.1109/GLOCOMW.2010.5700296

[31] R. Trestian, O. Ormond, G. M. Muntean, "Reputation-based network selection mechanism using game theory," in *Physical Communication* (2011), DOI: 10.1016/j.phycom.2011.06.004

[32] R. A. Howard, "Dynamic Programming and Markov Processes," Hoboken, NJ: Wiley, 1960.

[33] Ben-Jye Chang and Jun-Fu Chen, "Cross-Layer-Based Adaptive Vertical Handoff With Predictive RSS in Heterogeneous Wireless Networks," in *IEEE Transactions on Vehicular Technology*, vol. 57, Issue: 6, November 2008, DOI: 10.1109/TVT.2008.921619.

[34] H. Zhang, C. Jiang, J. Cheng, V. C. Leung, "Cooperative interference mitigation and handover management for heterogeneous cloud small cell networks", in *IEEE Wireless Communications*, vol. 22, no. 3, pp. 92–9, July 2015, DOI: 10.1109/MWC.2015.7143331.

[35] T. Maksymyuk, O. Krasko, M. Kyryk, V. Romanchuk, R. Kolodiy, "Designing the new backhaul for 5G heterogeneous network based on converged optical infrastructure", in *Acta Electrotechnical et Informatica*, vol. 17, no. 4, pp. 9–13, January 2017, DOI: 10.15546/aeei-2017-0028.

[36] B. Shubyn, T. Maksymyuk, "Intelligent Handover Management in 5G Mobile Networks based on Recurrent Neural Networks", in *Proceedings of 3rd International Conference on Advanced Information and Communications Technologies (AICT),* pp. 348–351, July 2019, DOI: 10.1109/AIACT.2019.8847734

[37] M. Boujelben, S. B. Rejeb, S. Tabbane, "A novel green handover self-optimization algorithm for LTE-A/5G HetNets", in *Proceedings of International Wireless Communications and Mobile Computing Conference (IWCMC)*, pp. 413–418, August 2015, DOI: 10.1109/IWCMC.2015.7289119

[38] L. Tartarini, M. A. Marotta, E. Cerqueira, J. Rochol, C. B. Both, M. Gerla, P. Bellavista, "Software-defined handover decision engine for heterogeneous cloud radio access networks", in *Computer Communications*, vol. 115, pp. 21–34, January 2018, DOI: 10.1016/j.comcom.2017.10.018

[39] J. Rizkallah, N. Akkari, "SDN-based vertical handover decision scheme for 5G networks", in *Proceedings of IEEE Middle East and North Africa Communications Conference (MENACOMM)*, pp. 1–6, April 2018, DOI: 10.1109/MENACOMM.2018.8371040

[40] Duan X, Wang X, "Authentication handover and privacy protection in 5G hetnets using software-defined networking", in *IEEE Communications Magazine*, vol. 53, no. 4, pp. 28–35, April 2015, DOI: 10.1109/MCOM.2015.7081072

[41] P. K. Mangipudi and J. McNair, "SDN enabled Mobility Management in Multi Radio Access Technology 5G networks: A Survey", in *arXiv-CS-Systems and Control*, 2023, DOI: 10.48550/arXiv.2304.03346

[42] R. Ahmad, E. A. Sundararajan, and A. Khalifeh, "A survey on fem to cell handover management in dense heterogeneous 5G networks," in *Telecommun Syst 75*, 481–507 (2020), **DOI**: 10.1007/s11235-020-00718-1

[43] J. Cao, M. Ma, H. Li, Y. Fu, X. Liu, "EGHR: Efficient group-based handover authentication protocols for mMTC in 5G wireless networks", in *Journal of Network and Computer Applications*, vol. 102, pp. 1–6, January 2018, **DOI**: 10.1016/j.jnca.2017.11.009

[44] C. I. Fan, J. J. Huang, M. Z. Zhong, R. H. Hsu, W. T. Chen, J. Lee, "ReHand: secure region-based fast handover with user anonymity for small cell networks in 5G", pp. 1806–03406, June 2018, **DOI**: 10.1109/TIFS.2019.2931076

[45] T. Bilen, T.Q. Duong, B. Canberk, "Optimal eNodeB estimation for 5G intra-macrocell handover management", in Proceedings of the 12th ACM Symposium on QoS and Security for Wireless and Mobile Networks, pp. 87–93, November 2016, **DOI**: 10.1145/2988272.2988284

[46] O. P. Mishra, G. Morghare, "An Efficient approach Network Selection and Fast Delivery Handover Route 5G LTE Network", in Proceedings of 3rd International Conference on Trends in Electronics and Informatics (ICOEI), pp. 857–862, April 2019, **DOI**: 10.1109/ICOEI.2019.8862791

[47] H. Lee, M. Ma, "Block chain-based mobility management for 5G", in *Future Generation Computer Systems*, August 2019, **DOI**: 10.1016/j.future.2019.08.008

[48] A. Yazdinejad, R. M. Parizi, A. Dehghantanha, K. K Choo, "Blockchain-enabled authentication handover with efficient privacy protection in SDN-based 5G networks", in *IEEE Transactions on Network Science and Engineering*, August 2019, **DOI**: 10.1109/TNSE.2019.2937481

[49] A. El Hanjri, A. Hayar, and A. Haqiq, "Blind handover detection based on KLD and channel capacity, outage probability estimation for rice and Nakagami models," in *IAENG International Journal of Computer Science*, 48: pp. 1087–1094, 2021.

[50] A. El Hanjri, A. Hayar, and A. Haqiq, "Features detection based blind handover using Kullback Leibler distance for 5G Hetnets systems," in *IAES International Journal of Artificial Intelligence*, pp. 193–202, 2020.

[51] A.A. Ateya, A. Muthanna, A. Vybornova, A. D. Algarni, A. Abuarqoub, Y. Koucheryavy, A. Koucheryavy, "Chaotic salp swarm algorithm for SDN multicontroller networks," in *Engineering Science and Technology, an International Journal* 22 (4) (2019) pp. 1001–1012.

[52] A. Gharsallah, F. Zarai, M. Neji, "SDN/NFV-based handover management approach for ultradense 5G mobile networks," in *International Journal of Communication Systems* 32 (17) (2019).

[53] G. Járó, et al, "Evolution towards Telco-Cloud: Reflections on Dimensioning, Availability and Operability", in *IEEE 42nd Telecommunications and Signal Processing Conference*, 2019, **DOI**: 10.1109/TSP.2019.8768807

[54] B. M. Eldowek, S. M. Abd El-atty, E.-S. El-Rabaie, Fathi E. Abd El-Samie, "3D nonstationary vehicle-to-vehicle MIMO channel model for 5G millimeter-wave communications," in *Digital Signal Processing* 95 (2019).

[55] A. Kececi, A. Yildirak, K. Ozyazici, G. Ayluctarhan, O. Agbulut, I. Zincir, "Implementation of machine learning algorithms for gait recognition," in *Engineering Science and Technology, an International Journal* 23 (4) (2020) 931–937.

[56] A. Haghrah, M. P. Abdollahi, H. Azarhava et al, "A survey on the handover management in 5G-NR cellular networks: aspects, approaches and challenges," in *Wireless Com Network* 2023, 52 (2023), **DOI**: 10.1186/s13638-023-02261-4

[57] A. El-atty, M. Saied, Z. M. Gharsseldien, K. A. Lizos, "Predictive reservation for handover optimization in two-tier heterogeneous cellular networks," in *Wireless Personal Communications* 98 (2) (2018) 1637–1661.

Adnane El Hanjri has a High Study Degree and a PhD degree (Doctorat d'Etat) in the field of Applied Mathematics from the Faculty of Sciences and Techniques, University Hassan First, Settat, Morocco. He is a professor of Mathematics at Morrocan School of Engineering Sciences (EMSI), Tangier, Morocco. He is a member of Laboratory of Intelligent Systems and Applications (LSIA) and a member of the International Association of Engineers (IAENG). He participated in many international conferences, and has published many scientific papers in collaboration with the Laboratory team.

Ikram Ben Abdel Ouahab an assistant professor at the computer science department of the Faculty of Sciences and Techniques of Tangier, Morocco. She is a member of Data & Intelligent Systems research Team. She received her PhD degree in the field of Cybersecurity and AI at FSTT, University Abdelmalek Essaâdi, Tangier, Morocco. She participated in many international conferences, and have published many scientific papers in collaboration with the Laboratory team. Her main research interests include cybersecurity, malware analysis, artificial intelligence, and IoT.

Abdelkrim Haqiq has a High Study Degree and a PhD degree (Doctorat d'Etat), both in the field of modeling and performance evaluation of computer communication networks, from the Faculty of Sciences, Rabat, Morocco. He is a full professor at the department of Applied Mathematics and Computer at the Faculty of Sciences and Techniques, Settat, Morocco, and the Director of Computer, Networks, Mobility and Modeling laboratory. He is an IEEE senior member. He is also a member of Machine Intelligence Research Labs, Washington, USA and a member of the International Association of Engineers (IAENG).

He was a codirector of a NATO Multi-Year project entitled "Cyber Security Analysis and Assurance using Cloud-Based Security Measurement system", having the code: SPS-984425. Prof. Abdelkrim Haqiq's interests lie in the areas of modeling and performance evaluation of communication networks, mobile communications networks, cloud computing and security, emergent technologies, Markov Chains and queueing theory, Markov decision processes theory, and game theory. He is the author and co-author of more than 230 papers (international journals and conferences/workshops).

He is an associate editor of the International Journal of Computer International Systems and Industrial Management Applications (IJCISM), an editorial board member of the International Journal of Intelligent Engineering Informatics (IJIEI) and of the International Journal of Blockchains and Cryptocurrencies (IJBC), an international advisory board member of the International Journal of Smart Security Technologies (IJSST) and of the International Journal of Applied Research on Smart Surveillance Technologies and Society (IJARSSTS). He is also an editorial review board of the International Journal of Fog Computing (IJFC) and of the International Journal of Digital Crime and Forensics (IJDCF).

Prof. Abdelkrim Haqiq was a chair and a technical program committee chair/member of many international conferences and scientific events. He was also a Guest Editor and Co-Editor of special issues of journals, books, and international conference proceedings.