Proactive Hybrid Half and Joint D2D Handover Scheme in Multi-access Mobile Edge Computing (MEC)

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***Abstract*—Reducing the pressure in the core network is the major concern for future mobile networks. Device to Device (D2D) communication is one of the innovative techniques in 5G networks that allows direct communication between nearby devices without relying on a base station or core network. However, the D2D technique faces several technical challenges in mobility management since there is no dedicated procedure in the current standards. Moreover, the studies in the literature show several limitations in the design of half and joint handover algorithms especially in the quality of the link, handover triggering time and D2D pairs movement directions. To overcome these challenges, this paper proposes a proactive half and joint handover solution for D2D communication considering the signal quality between D2D pairs in addition to that between them and the base station. Furthermore, proactive handover minimizes the risk of dropped links or service interruptions since it initiates handover procedure before signal degradation occurs during D2D movement. More importantly, the proposed solution employs Multi-access Mobile Edge Computing (MEC) technique which is operated at the edge network to reduce the processing burden on the core network and speed up the handover process. The simulation implementation reveals the vital performance gain especially in improving D2D mode ratio and reducing D2D handover failure rate.**

***Index terms*—Device to Device Communication, D2D, Multi-access Mobile Edge Computing, MEC, Handover, Proactive, 5G.**

I. Introduction

Today, there is a significant increase in the traffic and data rate in the cellular industry. Therefore, cellular networks need to be developed continuously to obtain the required quality of service (QoS). Future mobile networks aim to deliver ultra-fast speeds, extremely low latency, and enhanced connectivity for a multitude of devices. In this context, the future of the current 5G mobile network (Beyond 5G) tries to modify the current wireless systems and also seeks for new technologies [1]. Combining different 5G key technologies to work together is a major aspect for the next B5G solutions [2].

To provide a variety of services and applications, the upcoming B5G mobile networks need to satisfy the future trends of wireless technologies such as virtual reality, augmented reality, autonomous vehicles, and smart cities. The 5G mobile network introduced several new paradigms to improve the network architecture, such as milli-meter wave (mmWave), massive Multiple Input Multiple Output (massive MIMO), Software Defined Networking (SDN), Device to Device Communication (D2D), Multi-access Edge Computing (MEC), and so on. However, the integration of these key technologies is an open challenge that needs to be solved to achieve successful overall network performance [2]-[4]. Therefore, this paper focuses on development of mobile network architecture by integrating D2D communication and MEC technologies to improve the network performance. Specifically, this paper proposes a mobility management solution for D2D communication in MEC environment.

Basically, D2D communication is a key technology in 5G and B5G networks. This technique enables direct communication between nearby devices in a cellular network without relying on a base station or evolved Node B (eNB in LTE standard) [5]. The core network is essential for a normal mobile communications link, even if the two mobile devices are close to each other. Thus, the peer-to-peer model of D2D communication reduces the pressure on the core of the mobile network due to the direct communication link. However, the communication can occur between two devices or among multiple devices. The D2D technique can serve as a relay to ensure that the signal strength is enough for the users, especially for users who are at the edge of the network. There are several advantages come from using D2D communication technique, such as improving spectral utility, elevating throughput, decreasing delay, and enhancing energy efficiency [6]. Generally, there are two types of D2D communications depending on the spectrum used. In-band D2D communication when using the cellular spectrum and out-band D2D communication when exploiting the unlicensed spectrum provided by the extra interface in mobile devices [7].

Multi-Access Edge Computing (MEC) which is formerly known as Mobile Edge Computing is developed as an extension for the cloud computing technology in mobile networks. In general, the mobile devices typically receive services from cloud servers at the core network which result in a higher communication delay. Therefore, MEC is an innovative approach that is introduced to enhance mobile networks capabilities by bringing cloud computing resources closer to the end users [8]. In terms of the network architecture, the MEC allows edge computing devices to perform some cloud

Manuscript received June 16, 2025; revised July 25, 2025. Date of publication October 22, 2025. Date of current version October 22, 2025. The associate editor prof. Giovanni Giambene has been coordinating the review of this manuscript and approved it for publication.

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Digital Object Identifier (DOI): 10.24138/jcomss-2025-0125

computing tasks which in turn alleviates the burden of the central cloud servers at the core network. Edge servers may be installed in base stations to offer computing services, data processing, network storage, and resource capabilities to edge mobile nodes. Therefore, MEC architecture may significantly reduce network latency, allow real-time processing, faster response times and then improved services and applications. This is particularly crucial for applications that require immediate feedback, such as autonomous driving, augmented reality, and interactive gaming [8], [9].

The B5G mobile networks must be designed to support a vast number of devices with an extensive range of customized applications. This may be done in the shortest time possible and without overloading the infrastructure or core network. Accordingly, D2D and MEC are complementary technologies that can be used together to create innovative and efficient wireless networks. The D2D can be used to offload traffic from the cellular network, while MEC can be used to provide the computing resources needed to support D2D communication. However, to fully realize the potential of these paradigms, it is very crucial to determine the issues associated with the integration of these two mobile networks technologies. Providing seamless connectivity with improved handover solutions is one of the major challenges that must be considered. Even though D2D communication is a key technology in 5G networks, there is no detailed description about D2D handover. Several drawbacks emerged when D2D handover occurs, such as D2D link interruption, extra control signaling, resource wasting, and higher latency. Additionally, the current suggested solutions didn’t consider the availability of MEC technology. Therefore, this work aims to provide an efficient handover scheme for the D2D communication benefiting from MEC technology.

The main contributions of this paper can be summarized as follows:

- The proposed scheme develops a proactive handover strategy to reduce the risk of dropped links or service interruptions. The proactive handover may facilitate rapid and effortless handover preparing and therefore lower handover latency during execution.
- The proposed solution employs a MEC technique to enhance the handover procedure in mobile networks by reducing latency and improving reliability. Since MEC places computing resources closer to the user at the edge network, it enables faster cell selection during handover to ensuring seamless transitions between cells. Thus, the MEC server could expedite the handover procedure at edge network and reduce the processing demand on the core network.
- The proposed scheme utilized Channel Quality Indicator (CQI) to identify the quality of the link between D2D pair and also between (Mobile Node) MNs and the base station. Compared to Reference Signal Received Power (RSRP) used in the literature, CQI may more accurately demonstrate the actual channel situation, and then improved QoS efficiency.
- Unlike earlier research studies that only considered one movement direction to a single target cell, this work suggests a D2D handover mechanism that considers several MN movement directions for diverse nearby cellular cells.

The rest of this paper is organized as follows; Section II describes the relevant related work in the literature highlighting the current challenges and limitations. Section III presents the proposed system design for the handover scheme. The simulation implementation and results obtained are discussed in Section IV. Finally, Section V concludes the paper.

II. Related Works

The importance of D2D communication as a new enabling technology for 5G mobile networks gives it significant attention. A large and growing body of the literature has investigated D2D communication architecture, features, communication modes, and challenges [6], [10]. The authors in [11] thoroughly reviewed D2D communication techniques employed for various phases of efficient D2D communication in 5G heterogeneous networks. Furthermore, this survey study offers an extensive analysis of game-theoretic techniques that are intended to maximize D2D communication performance in 5G. It highlights problems with D2D communication, open challenges, and recommends areas for further study. In depth analysis of multiple communication options for both normal cellular and D2D communication which can be used adaptively depending on the available resources is provided in [12]. In like manner, the authors in [13] studied the coordination between mobility control and radio resource allocations to maintain better QoS for the cellular devices and D2D pairs that operating within the same spectrum. In [14], the authors listed the existing mobility management techniques that may be suitable for D2D communication in cellular networks. A mathematical analysis was contacted to select the best possible solution for handover performance. Recent D2D handover techniques to maintain seamless connectivity and improve network efficiency when devices move or switch connections within 5G and 6G networks are explored in [15]. The authors only focused on machine learning and deep learning algorithms to optimize handover decisions and reduce service disruptions. However, they neither presented any detailed handover protocol or handover mechanism for D2D communications, nor addressed the importance of MEC for 5G/6G mobility management schemes.

On the other hand, a considerable amount of the literature has discussed the importance of MEC as an extension of cloud computing, simple architecture shown in Figure 1 [9], [16]. Additionally, the description of the current trends, features, and challenges can be found in [8]. Authors of [17] provided a comprehensive review of the MEC reference architecture with handover strategies and challenges for MEC recently published in the literature. The authors investigated the challenge of MEC node selection technique during handover between different MEC nodes. Nevertheless, this paper did not take the D2D handover mechanism into account. Similary, the MEC advantages for low latency and fast handover are given in [18]. In [19], the authors surveyed the handover decision-making algorithms in MEC to provide an ultra-low latency response.

The authors examined the integration challenges between computing capacity, communication resources, and mobility management. The authors identified the interdependencies trade-off challenge between handover control messages and computation offloading at MEC. Even though the authors described handover decision-making challenges in MEC, they didn't provide any description of any handover mechanism.

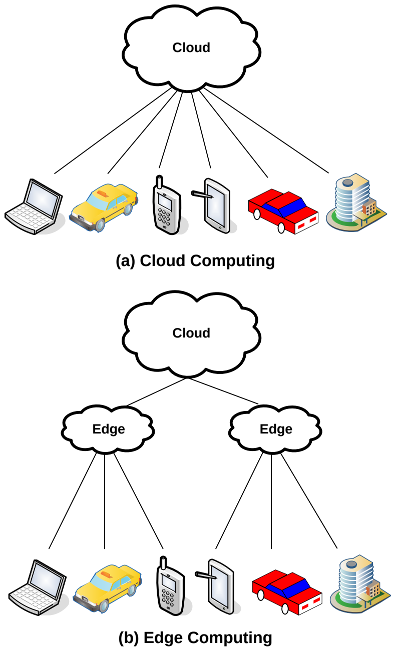

Fig. 1. Cloud Computing vs. Edge Computing Architecture.

A mobility framework for MEC networks that involves the cost and user performance as the main factors influencing mobility management is presented in [20]. The authors develop a distributed mobility management scheme that incorporates game theory. Even the system may give some flexibility, but it produces a higher complexity model. The authors in [21] described the integration of mobility solutions and MEC to serve the future mobile applications and services under 6G mobile networks. The possible integration may provide seamless handover procedure during MN movement from serving base station to target base station. This cooperation may demonstrate how MEC and 6G work together to improve user experience, lower latency, and move networks and services to the edge more effectively. The handover decision schemes with MEC in 6G networks are reviewed systematically in [22]. This study offered a thorough grasp of the most persistent problems and solutions pertaining to mobility management in 6G mobile networks, focusing on machine learning technologies with more consideration for user QoS in heterogeneous networks.

More recently, the literature emerged the possible co-operation between recent 5G technologies to improve the network architecture. For instance, the authors of [2] surveyed the research works for D2D, MEC, and Network Slicing (NC) and focused on the benefits achieved by integrating these concepts for next generation mobile networks. The authors in [23] proposed D2D neighbor discovery protocol by offloading discovery operations to the MEC server. The MEC server identifies nearby devices and keep track of them in a centralized database at the edge network. The obtained results imply that MEC discovery increases D2D communication's scalability and reliability in 5G networks in addition to increasing mobile node energy efficiency. The collaboration between D2D and BS supported with MEC to distribute computing tasks efficiently across the network is studied in [24]. The authors suggested a hierarchical offloading structure that utilizes the strengths of both local device resources of the D2D communication and the infrastructure of BS supported MEC, which can lead to better resource utilization and improved QoS. By dynamically determining the optimal offloading target at various levels, the approach attempts to lower latency and energy usage.

Despite the extensive research on D2D communication, only few works have focused on the handover mechanism during D2D pair movement. A handover mechanism for D2D communication when the mobile nodes move across a cell boundary in LTA-Advanced was proposed by [25]. Even though the authors described half and joint handovers, they only considered the condition when the two mobile nodes are moving to the same new cell. In addition, storing the handover command for next handover trigger is considered the main issue for this work as it may fail to provide the correct time of handover trigger. The authors of [26] attempted to develop a mobility management solution for D2D communication that could be compatible with 5G mobile networks. The authors examined their work through a simplified operation model with several limitations such as the consideration of D2D pairs moving to the same new cell [27]. The work presented in [28] also suffered from the same limitations where the authors provided a numerical model for D2D handover that considers the D2D pair moving to the same target cell benefiting from historical movements of MNs and the received signal condition.

The authors in [29] studied the possibility of integrating the D2D communication with the existing handover solutions to get 0 ms handover interruption. The authors exploited the D2D communication to improve conventional handover performance when one of the MNs which is in D2D communication acts as a relay to transfer the data during handover procedure. The authors claimed higher throughput with better user experience. Authors of [30] utilized the advantages of D2D communication to decrease the unnecessary handover. The mechanism focused on reducing switching between normal cellular and D2D communication modes by allowing the D2D communication to continue as far as possible. Considering the case when two MNs move to the same new cell, the analytical evaluation showed reduced number of handovers and D2D failure rate during a high mobility environment. This work suffered from several issues, such as considering the MNs move to the same target cell, especially for half handover case. Also, the stored trigger time for the next half handover might not take place at the appropriate moment and lead to link disruption. In addition, the MNs need to send periodic reports to the base station which may cause signaling overhead. Another study [31] focused on identifying the best operation mode (normal mobile or D2D) to perform seamless handover mechanism. An SDN architecture was used in [32] and in [33] to provide a D2D handover management scheme. The authors argued for enhanced handover performance compared to conventional LTE networks with improved D2D service continuity.

Altogether, the above-mentioned studies provide important insights into the critical behavior of the D2D handover solutions for the upcoming B5G mobile networks. However, these works show several limitations and challenges, such as buffering data, considering the MNs movement into the same new target cell, half handover depending on timer trigger which may fail to trigger handover in correct time, and the MN periodically sends measurement report to base station. Furthermore, no study has been discovered that examines the potential D2D handover mechanism solution while taking the MEC environment into account. Thus, the goal of this work is to design an effective handover mechanism that overcomes the above aforementioned challenges and enables the use of MEC technology for D2D communication.

III. Proposed System Design

Since the D2D communication is a new technology for 5G mobile networks, the D2D handover issue has come to light due to the legacy standard LTE system's inability to support D2D handover. As illustration, considering two MNs performing ongoing D2D communication in the same cellular cell and moving to neighboring cell. One of the MNs may execute standard handover procedure to the target cell, which leads to interrupt and loss the D2D connection. With extra signaling, the D2D link can be resumed when link quality between them is enough for D2D communication. Consequently, providing reliable data communication between two MNs in D2D communication is a challenging task. Thus, there is a critical need to design a D2D handover scheme to cope with these challenges as the research in this field is still going on.

This study aims to design a D2D handover scheme by overcoming the current limitations and challenges in the existing solutions. Consequently, this work proposes a D2D handover scheme taking into account various MNs movement directions for different neighboring cellular cells instead of considering one movement direction to one target cell in previous studies. The proposed scheme also tries to improve the duration of the D2D connection link as much as possible to reduce the pressure on the network and enhance the overall network performance in turn. Additionally, the proposed handover solution benefits from link layer (L2) signaling to sense the quality of connected links in order to provide a proactive handover scheme. Proactive handover initiates handover procedure before signal degradation occurs during MN movement. The proposed algorithm not only measures the signal quality between MN and eNBs or base stations, but also between the two MNs in D2D communication. The proactive handover may give smooth and fast handover preparation and then reduce handover latency during handover execution. Thus, proactive handover can minimize the risk of dropped links or service interruptions. More importantly, the proposed solution employs a MEC server which is located on the edge network to reduce the handover latency significantly since it minimizes the distance of handover control messaging travel during handover. The handover control messages will be exchanged with the MEC server at the edge network instead of with the cloud server at core network, as explained in Figure 2. Furthermore, the MEC server may alleviate the processing burden on the core network and speed up the handover process.

Besides that, the proposed solution relies on specific condition or trigger that prompt the MNs to initiate a handover procedure. The trigger for handover process takes place proactively during handover preparation stage. This trigger-based handover solution can overcome the issues of continuous scanning for the scan-based handovers of the current schemes, which depend on periodically scanning the environment to find better connectivity options. Thus, the proposed trigger-based D2D handover solution may reduce the signaling overhead and power consumption compared to the current scan-based handovers, and also provide faster handover initiation.

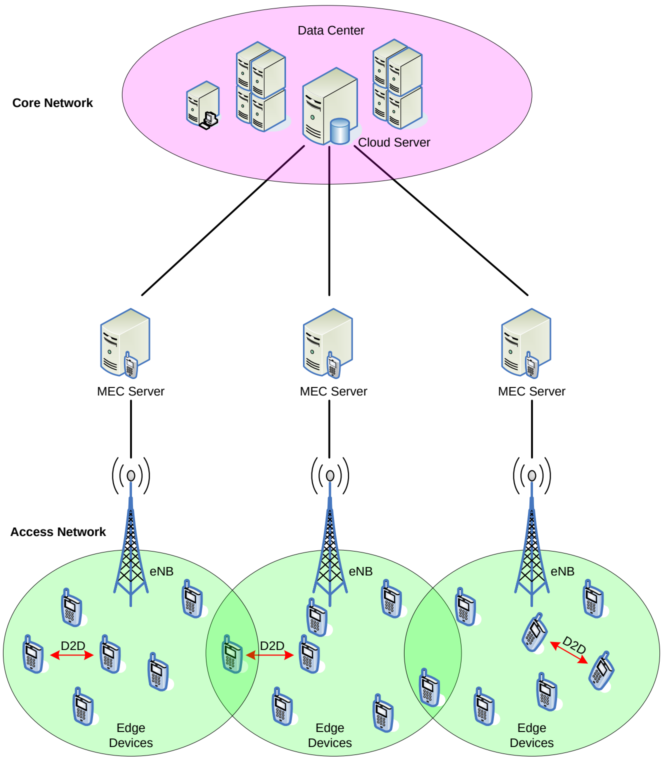

Fig. 2. Integrating D2D Communication and MEC Techniques for Efficient Wireless Networks (B5G).

In detail, the proposed solution works as follows: consider the case of two MNs in D2D communication moving to neighboring cells. Then, if the D2D pair moves to the same neighbor cell, a joint handover may take place as long as the signal quality between these two MNs is suitable for D2D communication. The proposed architecture utilizes the Channel Quality Indicator (CQI) to identify the quality of the link. The CQI may reflect the actual channel condition better than using Received Signal Strength (RSS), or Reference Signal Received Power (RSRP) which depend on received power only. Regardless of the data QoS required, an RSS-based handover decision is made when the D2D devices receiving power reach a threshold value. This indicates that the D2D user QoS is not supported when using RSRP value. The proposed solution lets the MN determine the CQI value based on the Signal to Noise Ratio (SNR) which is calculated from the measurements of the RSS and the noise level. A higher CQI value indicates a better channel quality. Thus, the channel quality between MN and eNB or between two MNs within the range for D2D communication can be determined from CQI value. Consequently, the D2D pair that is in close proximity and moving in the same direction to neighboring cell with appropriate CQI, can simultaneously perform a joint handover to the same target cell with continuous D2D communication services. The D2D communication joint handover procedure is illustrated in Figure 3.

The handover process starts proactively when one of the two MNs in D2D communication senses a low RSS from serving eNB. Thus, the handover procedure is initiated due to low signal strength trigger. This trigger-based handover allows MNs to scan the medium for targets eNBs one time compared to continuous scanning of the scan-based handover. Hence, as the MN moves, it searches the wireless medium for nearby eNBs that are available. The MN can identify the potential target eNBs for handoff based on the CQI measured from various eNBs. As the MNs move away from the serving eNB, a more signal degradation occurs until reaching to the limit that MN may inform the serving eNB with Link Going Down Message. The serving eNB then transmits a Radio Resource Control (RRC) measurement control message to the MNs of the D2D pairs via the RRC connection between the source eNB and D2D pairs. The MNs of the D2D pairs reply with RRC measurement reports that may include the required measurement information such as measurement ID, measurement object, uplink and downlink channels, COI, and so on. After that, the serving eNB which is supported with MEC services can make a smart handover decision using an intelligent decision engine benefiting from MEC server capabilities. By processing handover decisions locally, the MEC server reduces the latency involved in the handover process, ensuring a seamless transition for the user. Although we focus on using CQI for selecting the target eNB, numerous factors, including load balancing, application type, QoS, CQIs with different possible target eNBs, and others, can be considered by the MEC. However, machine learning or deep learning algorithms can be used for handover decision method [15] which is out of the scope of this work.

After selecting the target eNB for D2D pair, the serving eNB transmits a Handover Request to target eNB accompanied with D2D pair context information. The target eNB reserves resources for D2D pair and replies with Handover Acknowledgement. This occurs after the admission control process using two control messages to update the information of Mobility Management Entity (MME) and authenticate identification for D2D pair. Once the handover preparation stage is completed, A D2D Joint Handover Command message is sent by the source eNB containing all the necessary information for the D2D pair to execute handover for the target eNB. As a consequence, the D2D pair detaches from source eNB and access the target eNB. After synchronization and D2D resources allocation, the target eNB can send and receive packets. As a result, the D2D pair can now use target eNB resources to conduct D2D communication after sending RRC Complete message. Finally, the target eNB may update MME flow table to modify the data path.

However, when the two MNs in ongoing D2D communication are not in close proximity and may move in two different directions, but link quality between them is still suitable for D2D communication, a half handover can be performed. This case occurs when only one of the MNs needs to handover to a neighboring cell. Thus, a half handover procedure is introduced to maintain the D2D service continuity.

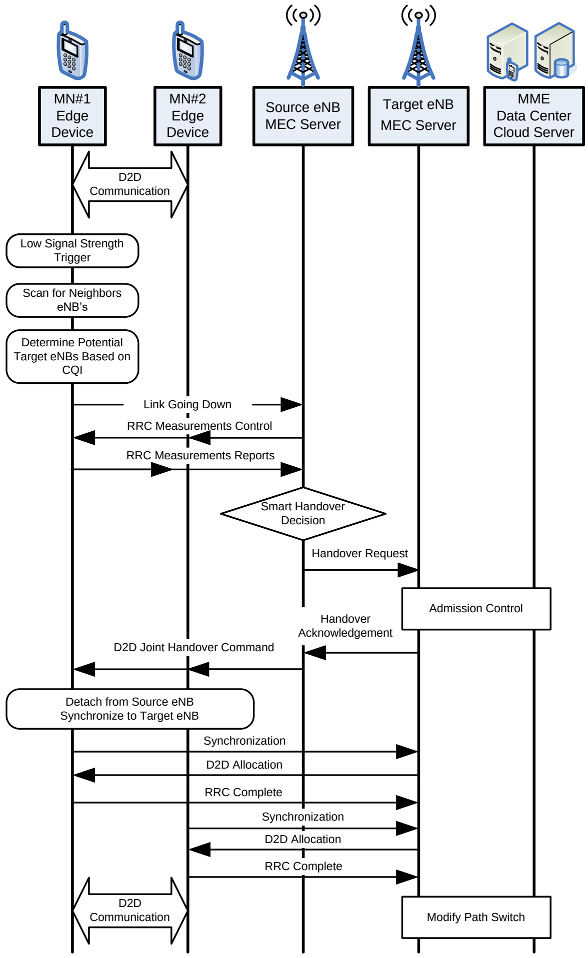

Fig. 3. Joint D2D Communication Handover Procedure.

This is because one of MNs handed over to target eNB while the other device remains in the source eNB. Figure 4 presents the half handover procedure. A proactive handover process is carried out where the handover preparation stage is similar to that explained in joint handover, but only for the required device. With the main exception of using a D2D Half Handover Command message sent by the source eBN to the intended MN, the detailed operation steps are identical to joint handover. Consequently, after making a decision for the target eNB, this MN then detached from source eNB and synchronized with target eNB. When the first half handover completed, one of MNs of the D2D pair handover to the target eNB, while the other one keeps connected with source eNB.

In the meanwhile, there are four possible cases after executing first half handover process depending on the movement direction of the second MN. This device may stay in the coverage area of the source eNB while moving, and thus there is no need for second half handover until D2D communication ends. Alternatively, the device either performs another half handover to the same target eNB of first MN, or handed to a new target eNB while still accomplishing ongoing

D2D communication. The most appropriate target eNB can be selected from several candidates using a smart decision engine. Otherwise, the D2D communication link may disconnect and the MNs return to normal communication mode when the link quality can't provide the suitable CQI for direct D2D communication.

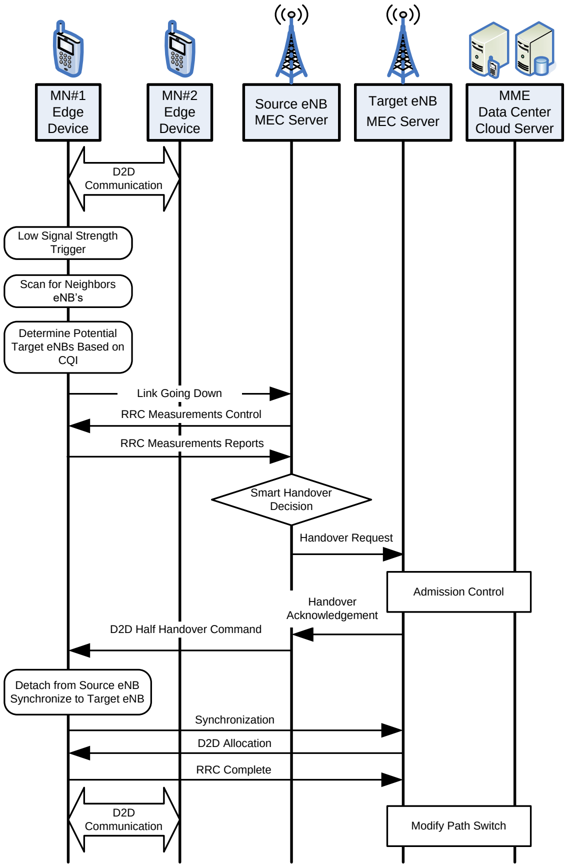

Fig. 4. Half D2D Communication Handover Procedure.

To this point, an effective overall handover algorithm is required to maintain different handover possibilities. The proposed algorithm employs some variables such as CQI_{TH} which refers to the threshold value of CQI to apply efficient communication link. Handover Margin (HOM) refers to the threshold of the difference between CQI of the source eNB and COI of the target eNB to ensure the selection of most proper cell for the device. Figure 5 explains the mechanism operation for proposed algorithm. Given that two MNs are in normal communication mode, the proximity services of the D2D communications try to measure CQI between these devices. The D2D communication can be enabled if the CQI between D2D pair greater than CQI_{TH} for proper D2D communication. During D2D pair movement, a handover may be required when the CQI of the serving cell degrades. If the CQI of the target eNB for the two MNs are greater than the current source eNB, a joint handover may take place. Otherwise, a half handover may occur for one device and leave the other device to perform the appropriate action depending on the CQI quality of the signal. This action may be no handover required, doing a half handover to the same target eNB, handing to a new target eNB, or switching to normal communication mode.

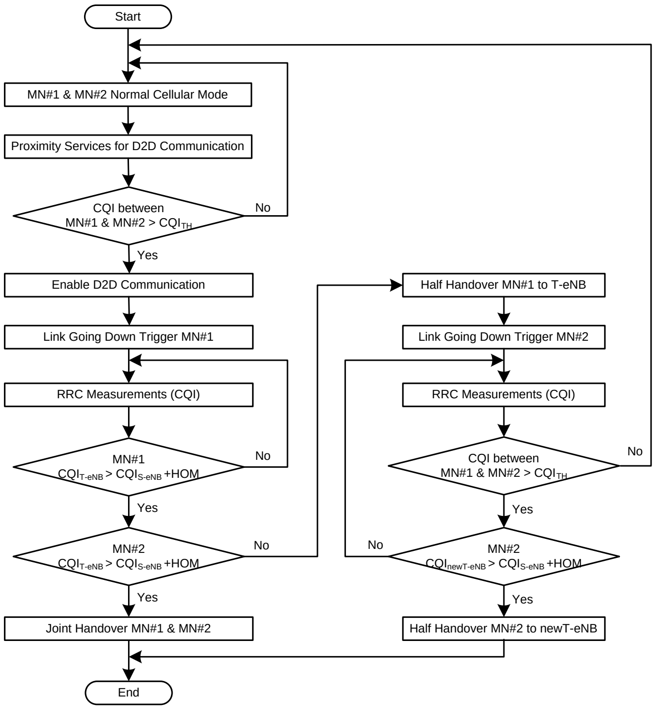

Fig. 5. Proposed Handover Mechanism.

IV. SIMULATION RESULTS AND DISCUSSION

The system model development for the proposed algorithm has been implemented using NS2 network simulator supported with simulation of urban mobility (SUMO) simulator [34]. Thus, the simulation evaluation has been collected by integrating NS2 simulator with SUMO considering a dense network environment. The network topology of the proposed system is illustrated in Figure 6. The simulation scenario is developed similar to that presented in Chen [25] and Balaji [30] with required modifications to compare the performance of the proposed algorithm with them. The proposed system model involves cloud server at the core network and MEC server at edge network. The default link delay between cloud server and gateway Router is considered 5 msec which is larger than the delay between MEC server and gateway Router, which considered 1 msec. Moreover, the network consists of sixteen cellular cells connected to Router, and the default link delay between Router and each cell is considered 1 msec. The default simulation parameters are summarized in Table I.

TABLE I
DEFAULT SIMULATION PARAMETERS

Parameter	*Default Value*
Simulation Area	2000 meters×2000 meters
Propagation Model Type	Two Ray Model
Routing Protocol Type	DSDV
Carrier Frequency	2 GHz
Mobile Device Speed	5 m/s
Packet Size of Constant Bit Rate	1000 Bytes
Packet Interval of Constant Bit Rate	0.01 second
Radius of Mobile Cell	200 m
Number of D2D Pairs	100
Gateway to Core/Cloud Server Delay	5 ms
Gateway to MEC Server Delay	1 ms
Transmission Link Bandwidth	100 Mbps

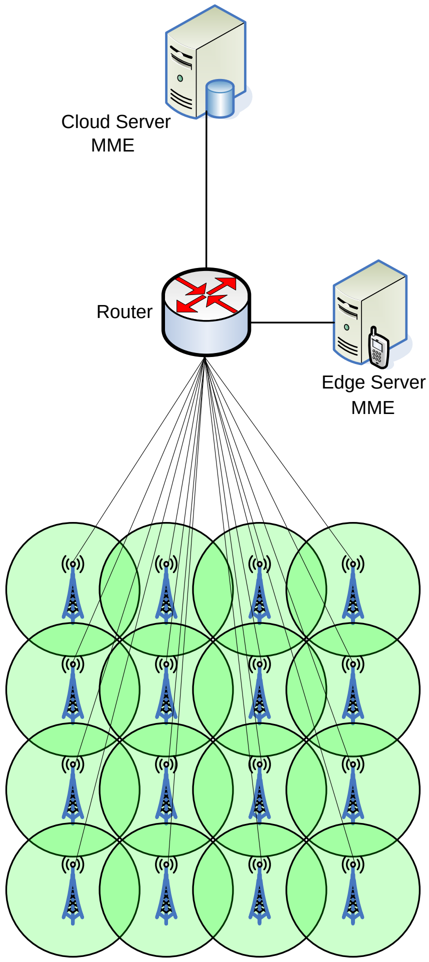

Fig. 6. Network Topology Implemention for Simulation Model.

The simulation evaluation considers the D2D mode ratio, D2D handover failure rate, mode switch, and access to core network delay as the main performance metrics compared to existing literature. The D2D mode ratio measures the time of D2D communication mode to the total simulation time. The D2D handover failure rate refers to the ratio of the number of D2D handover failures to the total number of D2D handovers, meanwhile the mode switch defines the number of triggers for normal mobile mode switch during total simulation time. Finally, the effect of the access to core delay which refers to the location of cloud and MEC servers on the handover response time also presented.

The effect of MN speed on the D2D mode ratio is shown in Figure 7. It can be noted that as the MNs increases, the duration of MNs staying in D2D communication mode decreases. This is because when the speed of D2D pair is slow, the probability of remaining in the same cell increases and the chance of handover occurrence is reduced. Thus, the possible D2D mode switch is reduced as a result for lower D2D link interruption. On the contrary, increasing MNs speed increases the possibility of moving to another cell, which causes more rapid handovers. This leads to lower D2D mode ratio since the MNs stay in D2D communication mode duration reduced. Even though the work [30] gives better performance compared to [25], the proposed scheme outperformed them. This is related to the proactive handover solution and the handover mechanism provided by the proposed scheme that considers different MNs movement directions. More importantly, using CQI in the proposed solution reflects the actual channel condition better than RSRP used in the existing solutions. This improves the time duration for D2D communication mode to continue for a longer time considering the signal quality between the two devices. Accordingly, the proposed scheme maintains a higher D2D communication period. Practically, at low MN speed of 5 m/s, the proposed scheme shows 38.8% better D2D mode ratio compared to [30], meanwhile it gives around 28% greater ratio at higher MN speed of 50 m/s.

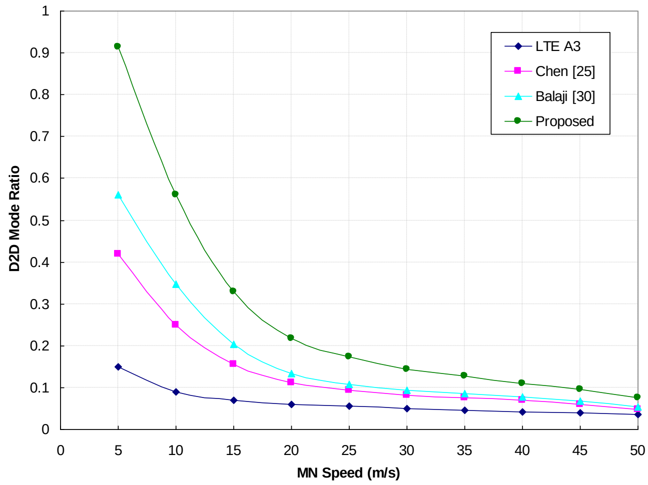

Fig. 7. Impact of MN Speed on D2D Mode Ratio.

Figure 8 illustrates the D2D handover failure rate as a function MNs speed. It can be seen that as the MNs speed increases, the MNs in D2D communication mode moving to a new cell making half or joint handover increases, and then the possibility of D2D handover failure rate increases in turn. Note that as the MNs increase, the time to perform all mobility control messages before interruption is reduced. A successful handover operation takes place when the half or joint handover procedures completed without interruption, otherwise a handover failure may occur. It appears clearly that the proposed scheme provides lower D2D handover failure compared to existing solutions. This outcome can be attributed to the fact that the proposed scheme uses a proactive handover procedure during handover preparation, which may give sufficient time to perform handover execution without the risk of losing the D2D link connection. Moreover, the proposed scheme supports MEC services for different MNs movement directions in the simulation methodology compared to one movement direction to dedicated target cell in the existing literature. However, the proposed scheme reduces the D2D handover failure rate by approximately 63% compared to [30] at lower MNs speed of 5 m/s and about 82% at higher MNs speed of 50 m/s. Notably, the normal LTE A3 handover generates higher D2D handover failure rate since it does not support D2D handover mechanism. On the other hand, authors of [30] calculate the distance between D2D links with RSRP compared to using RSRP only in [25]. That is why the approach presented in [30] gives better

D2D handover failure rate performance compared to that presented in [25].

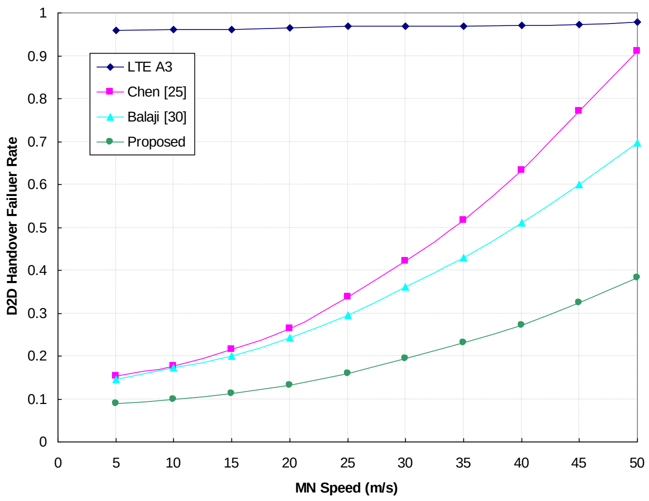

Fig. 8. Impact of MN Speed on D2D Handover Failure Rate.

The influence of MNs speed on mode switch is depicted in the Figure 9. The MNs in D2D communication mode remains using direct D2D link as long as the CQI between them is suitable for direct communication, even after performing half or joint handovers. Once the CQI of the link degrades during MNs movements in different directions, a mode switch from D2D mode to normal cellular mode is required, as explained in detailed mechanism of Figure 5. It can be observed that the mode switch increased rapidly with MNs speed increases. Practically, the proposed scheme produces 62% to 67% lower mode switches compared to [30] as the MNs speed increases from 5 m/s to 50 m/s. Therefore, the proposed scheme keeps the D2D mode for maximum duration considering various possible half or joint handovers for same or different cells, meanwhile it forces to normal cellular mode only when the link quality degrades lower than the threshold for direct D2D communication.

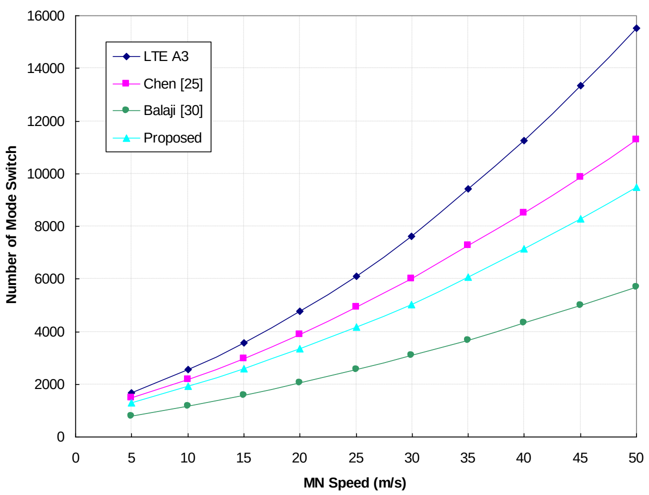

Fig. 9. Impact of MN Speed on D2D Mode Switch.

Figure 10 shows the effect of the delay between the edge network (where the MEC server is located) and the core network (where the cloud server is located) on the handover average response time. The delay between the edge network and the core network may escalate due to the increase in distance or number of intermediate routers between them. It is clearly seen that the average response time for cloud server escalates linearly with edge to core networks delay increases, meanwhile, the average response time for edge server remains constant since it is located at the edge network, and hence doesn't affect by the change in the delay. However, the MEC server gives around 16% to 29% lower response time than cloud server when the delay between edge and core networks is 5 and 10 msec, respectively. Accordingly, the MEC server may provide faster handover response compared to cloud server and this reduces the possibility of handover interruption and reduces handover failure rate.

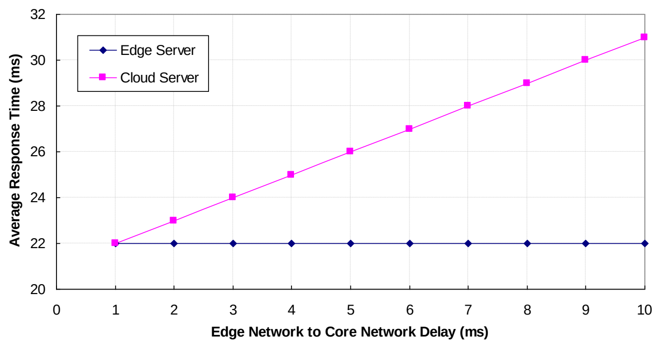

Fig. 10. Impact of Edge Network to Core Network Delay on Average Response Time.

Despite the previous notable performance outcomes, an investigation for signaling overhead of the proposed scheme should be taken into account. The signaling overhead refers to the extra control signaling exchanged between MNs and base stations or between base stations and other network elements during the handover procedure [35]. Evaluating signaling cost for D2D handover involves analyzing the overhead introduced when control messages are exchanged to maintain seamless connectivity between mobile devices. The signaling cost involves all the necessary control signals during handover preparation, execution, and completion to provide mobility support [36][37]. Generally, the signaling cost is proportional to the control message size and the hop distance between network elements. Analytically, the signaling cost C_{sig} can be expressed as [37]:

$$C_{sig} = M_{msg} . H_{avg} . N_{Ho} . S_{size} \quad (1)$$

where C_{sig} refers to the total signaling cost, M_{msg} is the number of signaling messages for handover procedure, H_{avg} is the number of average hop distance between network elements, N_{HO} is the average number of handovers, and S_{size} is the size of the handover control messages. To simplify the analytical model, we assume the network model includes several circular cells with many MNs distributed on the network. Each cell with radius R integrated with a centralized base station. Then, the area of each cell is given by $A = \pi R^2$. Considering the MN stays within the cell with an exponential distribution random variable, and the movement is a fluid flow model with a uniformly distributed direction and an average speed of *V*. Then, the handover occurs when MN moves from one cell to another, and the number of handovers can be given by [14], [37]:

$$N_{HO} = \frac{2V}{\sqrt{\pi.A}} = \frac{2V}{\pi.R}. \quad (2)$$

Now, by employing all handover stages of perpetration, execution, and completion for successful handover procedure; the total signaling cost can be expressed by [38]:

$$C_{sig} = C_{pre} + C_{exe} + C_{comp}. \quad (3)$$

Accordingly, the C_{sig} for the current schemes in [25][30] considering joint D2D handover, it can be expressed by:

$$C_{sig}^{current} = \left(12H_{wireless}^{MN-eNB} + 2H_{edge}^{eNB-eNB} + 2H_{core}^{MME}\right).N_{HO}.S_{size} \quad (4)$$

where total messages M_{msg} consists of 16 handover messages, distributed as 12 wireless signals between MNs and eNBs, two signals between eNBs, and two signals with MME at the core network. On the other hand, referring to Figure 3 for the proposed solution, the C_{sig} can be expressed by:

$$C_{sig}^{proposed} = \left(13H_{wireless}^{MN-eNB} + 2H_{edge}^{eNB-eNB} + 2H_{edge}^{MME}\right)N_{HO}S_{size} \quad (5)$$

where M_{msg} involves 17 handover messages, which includes 13 wireless signals due to one additional control signal used for triggering proactive handover solution (Link Going Down Message), and two signals between eNBs, in addition to the other two signals with MME at the edge network.
Table II lists the default parameters values [36], [37] that used to demonstrate the numerical results obtained from the analytical equations.

TABLE II
DEFAULT PARAMETERS FOR ANALYTICAL MODEL

Symbol	*Description*	*Default Value*
V	Average MN speed	5 m/s
R	Radius of mobile cell	3000 m
$H_{wireless}$	Average Hop distance between MN and eNB	1
H_{edge}	Average Hop distance between two eNBs at edge network	6
H_{core}	Average Hop distance between eNB at edge and MME at the core network	12
M_{msg}	Average number for handover control signal	12/13
S_{size}	Average packets Size of the handover control signal	76 Bytes

The effect of the average wireless hop distance on the total signaling cost C_{sig} is presented in Figure 11. The C_{sig} increases linearly with average wireless hop distance increases. It can be noted that the C_{sig} of the proposed solution shows lower C_{sig} than that of the current scheme in [25], [30]. This result is attributes to the number of hops for the two communication messages with MME. In the proposed solution, the handover procedure needs to communicate with the MME at the edge server which is located at the edge network with lower average hops number. Meanwhile, the current schemes communicate with MME at the cloud server in the core network, which involves higher hops number. However, the proposed solution is more affected by the average wireless hop distance due to the additional wireless signal used for the proactive handover procedure. Numerically, the C_{sig} of the proposed solution gives 29.7% reduction in total signaling cost with lower wireless hops of one, and about 1.3% reduction as the wireless hops increased to 10.

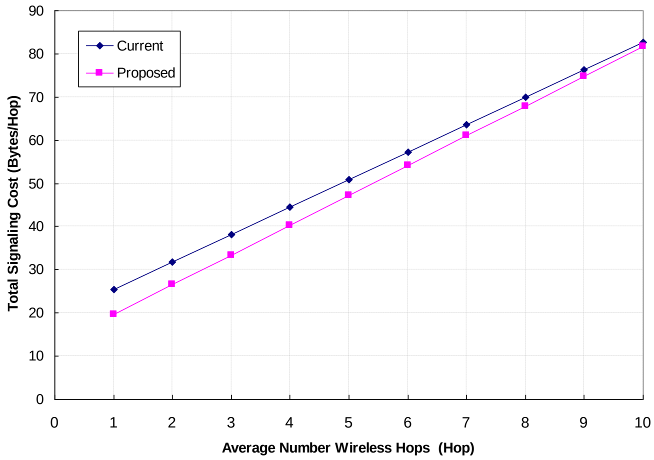

Fig. 11. Impact of Wirless Hops Number on Signaling Cost.

Figure 12 depicts the variation of the average hop number of core networks on the total signaling cost. Although the C_{sig} of the current schemes increases linearly with average core hop distance, the proposed solution does not affect. This is related to the fact that the proposed solution does not have any handover control signaling with the core network. However, the proposed solution gives a 2.7% increase compared to the current schemes when the average core hop distance equals that of the edge network. This is due to one extra wireless signal for triggering proactive handover. Meanwhile, the proposed solution shows a 46% reduction when the average core hop distance reaches 15.

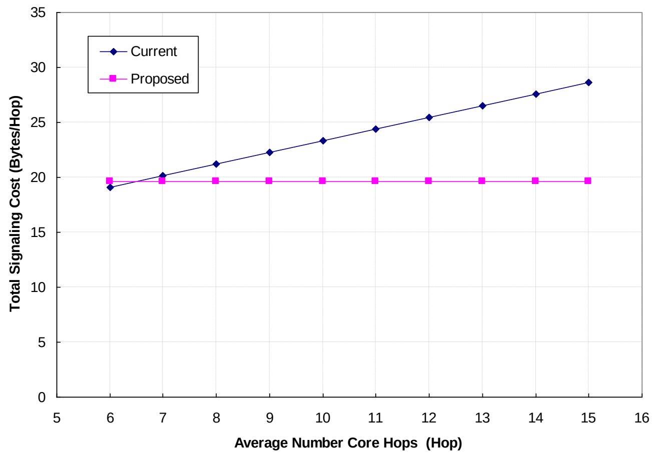

Fig. 12. Impact of Core Hops Number on Signaling Cost.

The impact of the cell radius R on total signaling cost C_{sig} is shown in Figure 13. It can be observed that the C_{sig} deceases as the cell radius R increases. This is because when the radius increases, the number of handovers N_{HO} deceases. However, the proposed solution produces an average of 29.7% reduction in the C_{sig} compared to the current schemes. Figure 14 illustrates the effect of MN speed on the total signaling cost C_{sig}. Since the number of handovers N_{HO} is proportional to the MN speed, then the C_{sig} increases linearly with MN increases. However, the proposed solution also gives an average of 29.7% reduction in the C_{sig} compared to the current schemes.

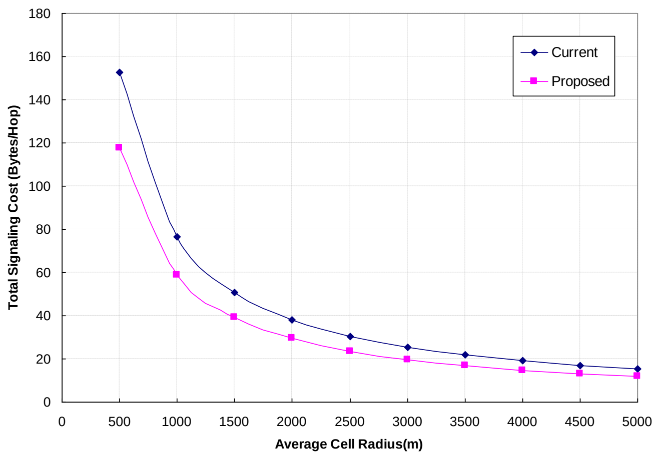

Fig. 13. Impact of Cell Radius on Signaling Cost.

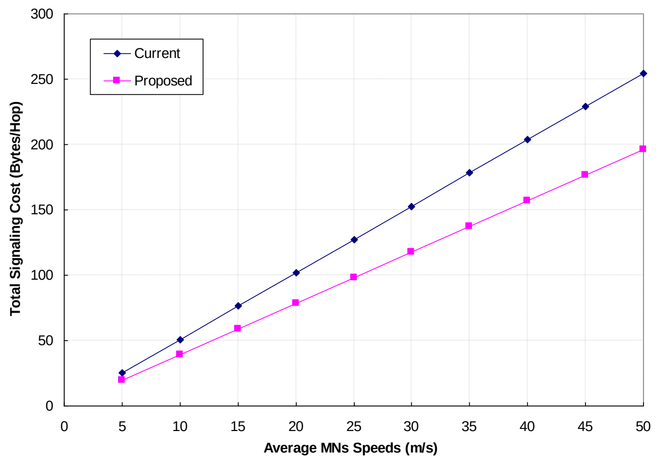

Fig. 14. Impact of MN Speed on Signaling Cost.

V. CONCLUSION AND FUTURE WORKS

This paper proposes a proactive handover scheme for D2D communication in B5G networks by examining the challenges of the current handover schemes. The proposed solution addresses the idea of integrating D2D communication and MEC concepts to achieve maximum benefits from their individual gains. The MEC can supply the processing power required to enable D2D communication, while D2D can be utilized to offload traffic from the cellular network. The proposed solution introduces link layer proactive messages to initiate handover procedure before signal degradation occurs during MN movement. This gives sufficient time to reduce handover execution latency and minimize the risk of dropped links or service interruptions. More importantly, the utilization of CQI may identify the quality of the link better than RSRP, especially between MNs in D2D communication mode and also between them and the base station. Moreover, the proposed scheme offers an effective overall handover mechanism that involves different possible cases for joint handover, half handover, or normal cellular mode condition. The analysis of the results obtained from simulation implementation reveal the notable outcomes of the proposed solution compared to existing one. The proposed solution gives a remarkable improvement in D2D mode ratio, notable reduction in D2D handover failure rate and mode switch. In addition, the MEC server reduces handover response time effectively compared to cloud server. Additionally, analytical modeling demonstrates that the proposed solution's signaling overhead outperformed the existing schemes. Future research should focus on varying mobility patterns, network density, radio interference, heterogeneous cell types and other MEC capabilities of the system.

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