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NOVEL ANCHOR-SELECTION SCHEME FOR DISTRIBUTED MOBILITY MANAGEMENT

Abstract *The number of subscribers in mobile networks is growing rapidly, which challenges network management and data delivery. Efficient management and routing are key solutions. One important solution is distributed mobility management (DMM), which handles the mobility of subscribers at the edges of mobile networks and load balancing. Otherwise, mobility anchors are distributed across a network that can manage the handover procedures. In this paper, we propose a novel mobility anchor-selection scheme based on the results of a cost function with three factors to select a suitable cell as well as an anchor for moving subscribers and improving the handover performances of networks. Our results illustrate that the proposed scheme provides significantly enhanced handover performance.*

Keywords cost function, DMM, distributed anchor, handover, mobility management

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1. Introduction

Network technologies are rapidly developing and changing to meet the requirements of customers. On the other hand, 5G network has led to challenges for mobile network operators. Also, new paradigms have been integrated into the 5G network architecture such as network function virtualization, software-defined networks, edge computing, and network slicing [11, 12, 29, 36]. Following these paradigms, the 3GPP's working groups focus on the improvement of a mobile network's performance, developing it towards a distributed and softwarized one [1–3, 22]. As a result, the mobile network architecture is changing from homogeneous to heterogeneous and with increasing complexity.

There are a huge number of mobile subscribers who are generating and transferring massive mobile data traffic, and this is rapidly growing [11]. From a Cisco report, the amount of mobile data traffic grew by 71% in 2017. In addition, this is expected to increase by nearly tenfold by 2022, reaching 77 exabytes per month. Moreover, mobile subscribers and connections grew to 8.6 billion in 2017 [12]. These growths are affecting the signaling overhead of networks.

In a next-generation network, mobility management needs to efficiently manage the mobility of subscribers in heterogeneous and complex networks. However, network management is becoming more difficult due to the integration process, such as the distributed and softwarized technologies in mobile networks [36]. The following issues are challenging the performance of centralized mobility management (CMM).

1. In a dense and heterogeneous network, cells of smaller sizes (such as small cells, femtocells, and picocells) are denser and more uncontrollable [10, 20]. Therefore, mobility management needs changes and features for a heterogeneous network.
2. Many factors affect network performance, including simultaneously executing handovers, mobility speed, the load of the mobility anchors (MAs), the available the radio resources (RRs) of a cell, and the number of active subscribers and their usage. The impact of these factors varies depending on the current network environment.
3. The concentration of subscribers is a cause of overload in a certain section of an access network. At a certain section of the network, the mobility of massive subscribers is a reason for the increased load of a centralized MA; this also decreases the performance of the handover procedure. In other words, a single point of failure is a significant drawback of CMM because the subscriber's mobility is handled by a centralized MA located at the core network.

This paper focuses on the second issue, where a subscriber is moving across distributed anchors. To provide efficient mobility management and solve the above-mentioned issues, a network-based distributed mobility management (DMM) solution is to be developed with a load balance function and handover procedure execution at the edge of a network [9]. In DMM, MAs are distributed across a network, and their serving area is defined by geolocation or a set of cells. The subscribers' registration processes and their data paths are also managed by an MA (such as a data gateway with an MA function).

In cellular networks, there are two types of handover procedures: intra and inter handovers. When subscribers are moving inside the serving area of a current MA, the intra handover procedure is executed between two cells. The inter handover procedure executes between two MAs if the subscriber is leaving the serving area of a current MA. Also, the network begins the inter handover procedure between MAs when load balancing and optimal path selection are necessary. In the existing handover, a selection scheme is important. If the wrong cell or MA is selected, a handover request is dropped by the call admission control and subscriber tries again to start a new handover procedure. This is one of the reasons for high handover delay and unsuccessful handovers (including request drops).

The existing selection scheme is a distance-based scheme in the current development of DMM. For example, the nearest selection scheme (NS) selects an MA that can provide the shortest path between an MA and a subscriber [9]. Also, this path can provide a low-latency connection. However, in order to provide a load balance between MAs, a network will change the MA again after a successful handover procedure. From the above example, a selection scheme with one factor cannot select an optimal connection path with low-latency and load balancing. Furthermore, optimizing the factors is necessary.

In DMM implementation, we defined one possible feature individually, which is a selection scheme that selects a target cell and MA. In other words, a selection scheme selects a cell from a neighbor cell list (NCL) and an MA from the possible sets. Then, the subscriber's data path is established over the selected cell and MA in the handover execution. For example, any cell can establish a connection with any MA to provide an optimized path over the selected cell and MA for a subscriber's connection performance. In the current DMM, a network selects a target cell or MA because the cells have established a fixed connection to the MA.

In this paper, we propose an anchor-selection scheme that is based on multiple factors for DMM called cost-based mobility anchor selection (CMAS) to select a suitable cell and MA for the provision of the QoS of a subscriber's connection. The major contributions of our proposal are twofold: (i) we present a handover with multi-factor-based MA selection that addresses the improvement of handover performance (including decreased request drops) and load balancing in handover execution; and (ii) a simulation model developed to compare our proposal with existing well-known schemes.

The remainder of the paper is organized as follows: In Section 2, we review related works. The details of our proposed cost function are presented in Section 3. In Section 4, we introduce the proposed selection scheme. We describe the network model and set up to study the performance of the proposed scheme in Section 5. Finally, Section 6 concludes the paper.

2. Related works

In this section, we review some mobility solutions and classify the related works into DMM and anchor-selection schemes. The DMM paradigm has been developed by IETF [9]. DMM is an important paradigm for mobile network architecture.

Recently, researchers have proposed some DMM architectures: partial, full, and hybrid solutions. The partial DMM solution is proposed in [18]. The results of this solution showed the reduced signaling messages by 30 percent. In [6], a fully distributed solution is introduced and discussed. In [8,26,28], the authors proposed hybrid mobility management that is a combination of DMM and PMIPv6. In the hybrid approach, a centralized MA can provide communications and information exchanging among regional MAs that are to control its connected macro-cells and the cell-level mobility of UEs. In [25], the authors proposed a DMM solution with Double-NAT that separated an identifier from locator and distributed anchors routing the packets in the transport network. Also, the authors of [32] proposed dynamic mobility anchoring, which can dynamically anchor a user's traffic by routers in an access network.

IPv6 and its mobility approach are presented in [13]. PMIPv6 is a network layer protocol that is meant to support mobility management by a local mobility anchor (LMA). Actually, an LMA is a centralized management node that manages the mobility of subscribers across mobile access gateways (MAGs). The researchers have proposed the LMA discovery and selection schemes in [36, 22]. These schemes provide two main improvements: (1) the load balancing of LMAs and MAGs; and (2) a reduced number of dropped handovers at LMA/MAG. In order to meet 5G's mobility requirements, PIMPv6 replaces a centralized LMA with a control mobility database (CMD) that includes the rules between the distributed anchors and routers [6,8,38].

The integration of SDN and DMM has recently been presented. Publications such as [23,35] introduced SDN-based DMM solutions. In addition, [23] introduced an SDN controller, which included two functions: location, and handover management. In [31], a DMM solution with two controllers is presented. These controllers are a local controller for cell-level mobility and a regional controller for handover from a serving cell controlled by an MA to a target cell controlled by another MA. Also, in [31], the authors presented the characteristics of inter and intra handovers (the same as LTE mobility management).

In [27], the author introduced a method of using SDN-based DMM in 5G networks and compared the existing DMM proposals with the proposed SDN-based DMM. The authors placed their proposed DMM on top of an SDN controller as an application server. The result of this solution showed that the complexity of the control plane decreased and became more scalable in terms of handover procedure delay and transmission delay. The integration of SDN and DMM can manage mobile data traffic by MAs and gateways that are located at the edges of access networks. Two main advantages can improve the handover performance in an SDN-based DMM [19]; these are a fast handover procedure and an SDN controller's optimal data path selection.

In [34], the author introduced and evaluated a novel SDN/OpenFlow-based DMM approach that could be applied to virtualized LTE systems. In the proposed approach, an X2 interface was used for handover procedures between P-GWs, and network traffic could be seamlessly propagated by a target P-GW. Simulation results showed that the handover time was less than 150 ms, which meets the requirements of LTE and LTE-A networks. In [4], the researchers introduced the possible use-cases of an MA-selection approach based on three different contexts (mobile, application, and network). However, they have not introduced the use-case of the hybrid approach that is the multiple factor-based approach. A dynamically MA selection approach is presented in [7]. This approach can provide minimized packet delay and a balanced load of switches. However, the author's proposed mobility management is only for SDN-enabled networks.

In [21], anchor selection is presented to provide load balancing. The main proposal is a middle point, which is an optimal location of an anchor between the corresponding and mobile nodes. The blocking and dropping probability of new call and handover requests are presented with reduced values in the numerical results. This approach can only provide load balance.

However, the other performance factors of the network are uncertain. In [14], the introduced context-aware anchor selection includes handover procedures and two-queued anchoring. The main feature is re-selection after the handover procedures. All of the works discussed above introduce MA selection. Furthermore, distance and load-based MA selections for multicast and distributed anchors are presented in [17].

3. Cost function

In this section, we describe the cost function with three normalized functions that calculate the cost of all of the possible combinations of MAs and cells. In the other words, our proposal is focused on achieving efficient mobility management with MA selection, taking advantage of improved handover performance and load balancing.

In [24], the authors proposed an adaptive handover hysteresis based on a cost function with the following factors: 1) a difference in the load information between the serving and target cells; 2) the moving speed of subscribers; and 3) the subscribers' active services. Based on these factors, the handover triggering is optimized to decrease unsuccessful handovers (including radio link failures). In our previous work [15, 16], we proposed an adaptive hysteresis that was based on multiple factors. Also, we defined the cost function to provide the relationship between these factors, such as the speed of a subscriber, the loads of the cells, and the service type of the subscriber's active sessions. The simulation results of our previous work show a reduction in the radio link failures that affected the handover performance. Also, the cost function and these factors are related to special environments such as high-speed mobility and centralized management.

In this paper, we redefined the cost function for DMM. Our proposed solution is based on several factors: the load information of candidate MAs, the available

RRs of candidate cells, and handover performance. The first two factors mean those indicators that are the number of dropped handover requests at the MA or cell, and handover performance is an indicator of other handover failures.

An MA's load is a new influential factor for performing a successful handover in DMM. An MA's total capacity and the size of all active traffic can predict the quality of service (QoS) after a successful handover. If an MA with a high load is selected, the network may begin the handover procedure because of the load-balancing function. Also, a handover request drops by an MA with a full load.

The available RR at the target cell affects the number of dropped handovers at the beginning of the handover procedure. For example, a target cell rejects the handover request because the number of available RRs is fewer than the necessary RRs for the active traffic of a subscriber. If a handover request is dropped at a target cell, the number of wrong cells (handover failure) increases, and the handover procedure restarts anew.

The handover performance of an MA is the ratio of unsuccessful to successful handovers. This determines the behavior and the performance history of the MA based on the attempted handovers that were directed to the MA. This factor contributes to a suitable MA selection. For example, we will increase the weight of the handover performance because it is more important than others are when all MA loads are light or ample for all of the connected subscribers.

Our CMAS is proposed to calculate the cost of candidate MAs based on cost function $f(CMAS)$, which includes three normalized functions: (i) $f(rr)$ is a function of the available RRs of a target cell; (ii) $f(l)$ is a function of MA load; and (iii) $f(hp)$ is a function of the handover performance of an MA. Weights (w)s are used by the normalized functions to define the priority of the factors. Here, proposed function $f(CMAS)$ can be simplified by the following equation:

$$f_n = \begin{Bmatrix} w_l f(l) + w_{rr} f(rr) + w_{hp} f(hp) & if \quad l_s \geq l_{thr} \\ f(rr) & if \quad l_s < l_{thr} \end{Bmatrix} \tag{1}$$

where w_l, w_{rr}, and w_{hp} represent the weights of functions $f(l)$, $f(rr)$, and $f(hp)$, respectively. The sum of all weights is equal to one ($w_l + w_{rr} + w_{hp} = 1$); l_s and l_{thr} are the current loads of the serving MA and the threshold for MA selection, respectively; l_{thr} is a key parameter for handover-type selection: intra and inter handovers. The normalized functions are explained in detail in the following three subsections.

3.1. Function based on load

The function $f(l)$ represents the differences between a target MA's availability and the requirement of the subscriber's sessions. A target MA's availability is defined as the ratio of the sum of the subscribers' traffic flows to the capacity of the MA. Here, the capacity of the MA is defined by the number of supported traffic flows and subscribers. From the viewpoint of hardware, the capacity is the maximum size of the data receive/send sessions over a network adapter. Therefore, a function of MA i load can be simplified by the following equation:

$$f_i(l) = \frac{\sum_{n=1}^{m}(\sum_{u=1}^{t} f_u) - \sum_{h}^{t} f_h^t}{C_i} \tag{2}$$

where C_i is the capacity of MA i, m the number of current subscribers in MA i, f_u^t the total flow of subscriber u, and h is an incoming subscriber.

Note that an MA with a high load is not suitable for a subscriber. A light-load MA is more suitable because it can provide high-quality services for a subscriber's active sessions after a successful handover.

3.2. Function based on available radio resources of target cell

The function $f(rr)$ represents the differences between the ratios of the available RRs before and after a handover. This factor defines a target cell that is better than the others.

In a baseline handover of LTE [7], the serving cell makes an NCL based on the signal-to-noise-plus-interference ratio (SNIR) of the candidate cells that are listed in a subscriber's measurement report. However, our proposal uses the RR calculation instead of SNIR-based sorting, thus reducing the handover-dropping probability. When a handover begins, a serving cell exchanges the context information with its neighbors and re-sorts the NCL based on the available RRs. Based on the context information, $f(rr)$ determines whether target cell j can provide the required RRs for a subscriber's sessions according to the following equation:

$$f_j(rr) = \frac{RR_h}{RR_{max}} - \frac{RR_j}{RR_{max}} = \frac{RR_h - RR_j}{RR_{max}} \tag{3}$$

where RR_h, RR_j, and RR_{max} are the available RRs after and before a handover and the maximum number of RRs of cell j, respectively.

3.3. Function based on handover performance of anchor

The function $f(hp)$ represents the ratio of successful to unsuccessful handovers that are destined to an MA. Now, we define the handover performance of MA i as follows:

$$f_i(hp) = \frac{HF_i + PP_i + RLF_i}{HO_{succ}} \tag{4}$$

where HO_{succ} is the number of successful handovers. HF_i, PP_i, and RLF_i are the handover failures (including handover failures at the execution and completion steps), ping-pong handovers, and radio-link failures (too-late handovers), respectively. All of these parameters (defined in [10,11]) are the results of the handover procedures that are executed from any MA to MA i.

4. Anchor and cell selection

In DMM, one of the most significant issues is the mechanism that is needed to select a suitable candidate from the distributed MAs to provide improved handover performance and good QoS for subscriber sessions. In this section, we present the proposed MA and cell-selection strategy. Depending on the type of handover, our proposed algorithm selects the target cell or both an MA and a cell. For example, if the current MA's load is high, our algorithm selects both an MA and a cell. On the other hand, the target cell is selected.

In the following subsections, we introduce our proposed algorithm and two versions of the handover procedure.

4.1. Proposed mobility anchor selection

In our CMAS, the MA selection depends on the cost of the combination, which is defined as the possible collaboration of MAs and cells. If the serving MA's load is above a certain threshold, the decision is made according to the type of handover procedure shown in Algorithm 1. Hence, the algorithm calculates the cost of all possible combinations if an inter handover is necessary. Then, the combination with the lowest cost is selected. The algorithm then sends the handover requests to the selected MA and cell.

Algorithm 1 Proposed CMAS

Input : $M \Leftarrow$ List of MAs and $S \Leftarrow$ Cells in NCL
Output : Selected a combination f_{ij} or only target cell j

if $l_s \geq l_{thr}$ **then** ▷ If inter handover is necessary
  for $MAi \in M$ **do**
    for $j \in S$ **do** ▷ Calculate a cost of combinations of MA i and all cells in NCL
      $f_{ij} = w_l f_i(l) + w_{rr} f_j(rr) + w_{hp} f_i(hp)$
    end for
  end for
  $MA_{selection} = min\{f_{ij}\}$
  return : $MA_{selection}$
else if $l_s < l_{thr}$ **then**
  $Time \Leftarrow$ an average value of cell residence time
  for $j \in S$ **do** ▷ If intra handover is necessary
    $f_j(rr) = \frac{RR_h - RR_j}{RR_{max}}$ ▷ RR's availability of cell j
  end for
  $T_{cell} = max\{SNIR \times f_j(rr) \times Time\}$
  return : T_{cell}
end if

4.2. Proposed cell selection

Our Algorithm 1 selects an only cell based on factors that are related to the neighbor cells, while the current MA can continue a subscriber's connection with high QoS. We assume that the cell selection knows two facts regarding the cells in the NCL: the available RRs, and the SNIR. Thus, the output of the cell selection can be expressed as follows:

$$T_{cell} = max \{SNIR \times f(rr)\} \tag{5}$$

.

Then, a handover request is sent to the target cell. Note that SNIR is an additional factor only if a cell selection is needed.

4.3. Handover procedures

Now, we describe handover preparation with the proposed CMAS. We defined two versions of the handover procedure with an additional option to control and decide about handovers for subscribers. It is possible to move the handover decision from a serving cell to the MA. Hence, the handover procedure using the different methods and the flowchart of handover messages related to the MA or serving cell. We define our proposed handover procedure, which adds and modifies messages on the baseline handover of LTE networks.

4.3.1. MA and cell selection developed at cells

We introduce the cell and MA selections that are placed on the serving cell in Figure 1. The neighbor cells exchange the messages about the RR's information (including the RR availability of the cell). Also, the messages of context information exchanged between MAs include the load and other information. The serving cell controls the radio signal strength of the subscribers as a baseline handover.

If the Event A3 condition is satisfied, the serving cell exchanges the context information with the serving MA (subscriber anchored) and begins the MA and cell-selection step. Then, the serving cell sends a handover request to the target cell. Also, it sends a handover request to the target MA via the serving MA if inter handover is necessary (see the solid blue box in Figure 1). Finally, the serving cell sends a handover command to the subscriber with the target's information for establishing the connection.

4.3.2. MA and cell selection developed at gateways

When the Event A3 condition is satisfied, the serving cell sends a handover necessary message (which includes the availability of the neighbor cells). Based on the result of Algorithm 1, the serving MA sends a handover request to a target cell if an intra handover is necessary. However, the serving MA sends a handover request to a target MA only if an inter handover is necessary (see the solid blue box in Figure 2). Finally, a handover command with the target's information is sent to a subscriber via the serving cell.

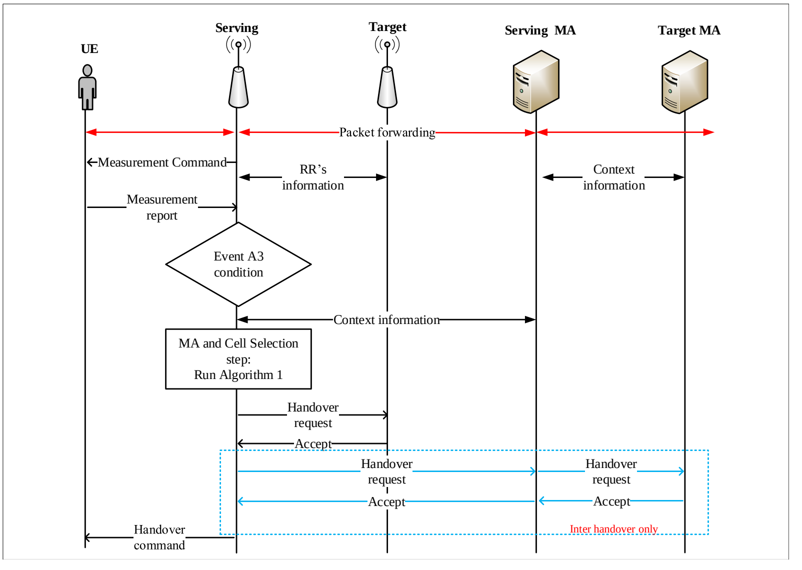

Figure 1. Messages of handover preparation, cell, and MA selection run on serving cell

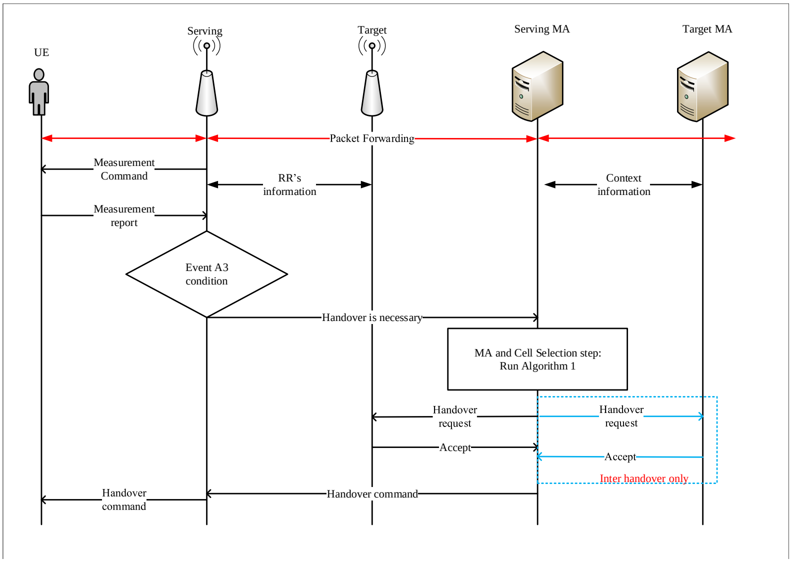

Figure 2. Messages of handover preparation, cell, and MA selection run on serving MA

5. Simulation model and results

In this section, we present a comparative study of our proposed CMAS in terms of handover-dropping probabilities, handover failures, and signaling costs. We separate the handover failures from the handover request dropping because the request-dropping metric represents the performance of the MA selection (target cell and MA). For example, if the MA-selection scheme selects a bad MA, the handover request is dropped at the target MA, and the serving MA needs to begin the measurement again (by the subscriber) and make a new handover preparation.

5.1. Simulation setting

For analysis, we used the NS-3.24 open-source simulator with a LENA module. We modified the cells and MAs that added the functions for the cost calculation and exchange of the context information. Figure 3 shows a simulation area and network topology with 1 P-GW (PDN gateway), 8 S-GWs (serving gateways) with MA function, and 37 macrocells. The P-GWs can route the packets to subscribers via their registered S-GWs. However, the S-GW forwards the buffered packets of a subscriber to other S-GWs if an inter handover is successful. Hence, all of the S-GWs are located at the network edge, and the neighbor S-GWs are connected by the wired links.

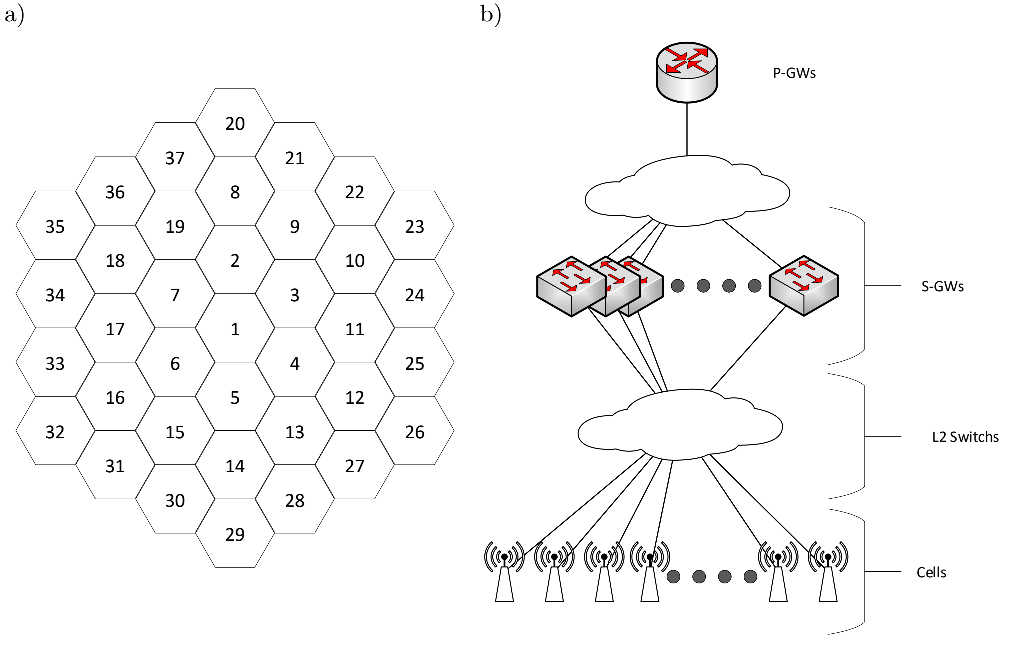

Figure 3. Network model: a) simulation area and cell structure; b) network topology

Twenty-four L2 Switches are placed between the MAs and the cells for wired links with a full-duplex mode with a 1-Gbps bandwidth. In the simulations, subscribers are randomly placed in the cells. All subscribers move according to a random way-point mobility model in which the mobility speed is randomly selected within a range of 3 km/h to 60 km/h. The speeds of the subscribers can affect the number of attempted handovers.

At the beginning of the simulation, the macrocells establish a connection to the P-GW using the location information that is the nearest selection scheme. However, any macrocell can establish a connection to any S-GW with an MA function. Also, the user's equipment (UE) is randomly located in the simulation area and registers to the nearest cell based on the SNIR. During the simulation, the UE often used the real-time services for three minutes. A first-in-first-out queue was used in the call admission control that executes the cell and MA actions (request accepting or dropping) on the handover request order by the received time.

The P-GW locates a core network that manages the S-GWs and provides an internet connection. In Table 1, the parameters that are used in this paper are listed based on 3GPP specifications and the NS-3 LENA module [5].

Table 1
Simulation Parameters

Parameters	Value
Number of subscribers	100 to 1,000
Number of MAs	8
Simulation time	36,000 s
Mobility model	Random-Waypoint (ADD) [30]
Carrier frequency	2.4 GHz
The number of cells	37
Path loss model	128.1+37.6 log10d
Shadow fading deviation	2 dB
Radius of cells	500 m
Handover overlap area	30 % of cell radius
Speed of subscribers	random (between 3 and 60 km/h)

We ran two simulation scenarios for the handover types with our proposed CMAS. The first one ran the proposed CMAS on the cells, while the second ran it on the MAs. Note that the handover decision is made based on the Event A3 condition. Once this condition becomes true (is satisfied), the serving cell or MA starts to prepare a handover with the proposed CMAS by a handover-request message to the targets.

5.2. Simulation results

The results below show an analytical calculation based on the simulation runs. In this subsection, the performance of the proposed CMAS scheme is explained and compared with the existing schemes in terms of the signaling costs, handover failures, and request dropping in 50 simulation runs. First, our CMAS is compared to the nearest selection (NS), load-based selection (LS), and hybrid selection (HS). The NS scheme is based on the distance between an MA and a subscriber. A traditional selection scheme such as an NS for a DMM solution provides low-latency between the MA and the subscriber. Then, we compared CMAS with the major DMM solutions, PMIPv6-based DMM, and SDN-based DMM. We confirm that we have rebuilt these solutions to the simulation environments; however, the originality of these solutions may be changed.

The LS scheme only chooses the lightest-load MA. For our comparison, we redefine the HS scheme whose MA is selected based on the result of the minimum function of the load and distance (Equation 6).

$$HS_{MA} = min\{load \times distance\} \tag{6}$$

5.2.1. Signaling cost

The number of subscribers affected the load on the MAs and cells during the simulation time. Figure 4 shows the handover signaling cost versus the number of subscribers when the selection scheme is placed at the cells. The signaling cost that is related to handovers of CMAS was lower than the others were when the number of subscribers is changed up to 1,000. There is a slight difference that can be observed between the CMAS and the HS when the number of subscribers is between 100 and 700. The reason for this is that the proposed CMAS and HS are selected as light-load MAs. However, the proposed CMAS maintains the reduction of the handover signaling cost even when the number of subscribers is increased.

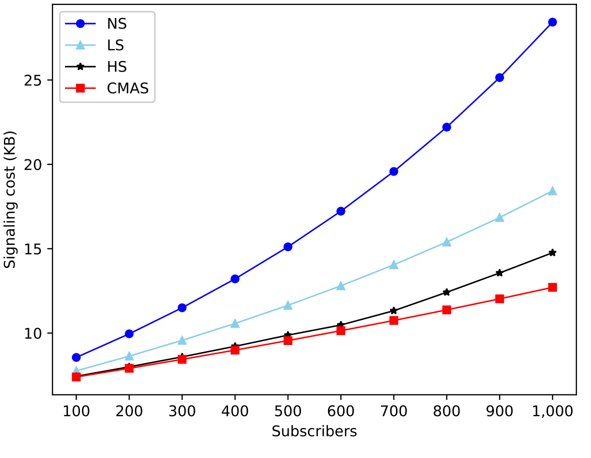

Figure 4. Handover signaling cost versus number of UE. Serving cell runs selection scheme

Figure 5 shows the handover signaling cost versus the number of subscribers when the selection scheme is placed at the MAs. In this figure, the proposed CMAS shows the perceptible reduction of the handover signaling cost. The reason for this reduction is that the target MA and cell can be simultaneously selected in the proposed CMAS. The distance calculation of the NS and HS is the reason for the increased signaling cost.

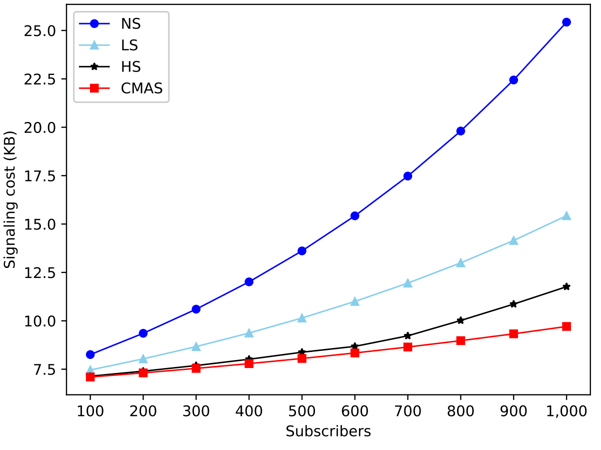

Figure 5. Handover signaling cost versus number of UE. Serving MA runs selection scheme

5.2.2. Handover request dropping

Figures 6 and 7 show the ratio of the request dropping for the number of attempted handover requests when selecting an MA. The handover request dropping can represent the performance of decisions in the handover preparation. If the wrong MA or cell is selected, the handover request is dropped by that MA or cell in the handover preparation. In the figures, our proposed CMAS scheme provides a reduction in handover request dropping. When the number of the UE is low, the difference among the four schemes is visible because light-load MAs and cells with a high availability of RRs provide a higher acceptance rate of incoming handover requests. However, as the number of the UE increases, only our proposed CMAS provides a low value of handover request dropping, as one of the three normalized functions of the proposed CMAS is handover performance, which can provide an improvement in the network's performance. For example, it may be possible that an MA with a light load is not selected if the handover performance is high. However, the NS, LS, and HS schemes select an MA based on distance and load only. Otherwise, when the UE was moved from the same location to the same target cell at different simulation times, the NS and HS schemes generally selected the same MA when inter handover was necessary. However, our proposed CMAS directs the handover request to a suitable MA and target cell based on their cost.

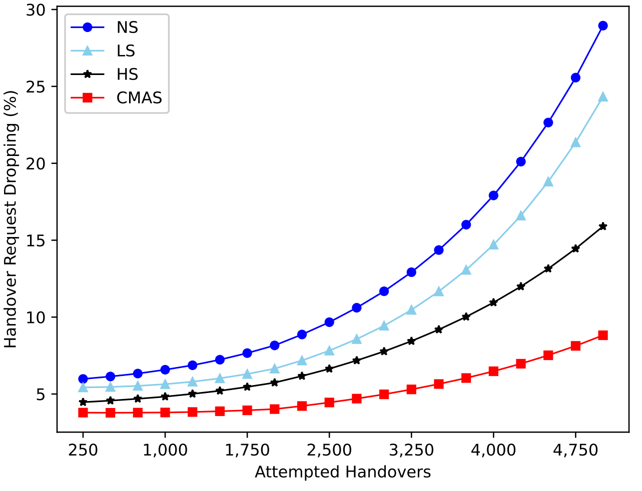

Figure 6. Handover request dropping comparison with number of subscribers. MA selection schemes placed at cells

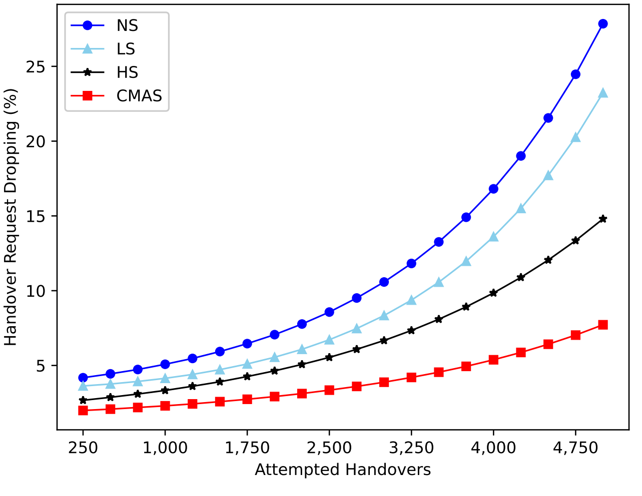

Figure 7. Handover request dropping comparison with number of subscribers. MA selection schemes placed at MAs

5.2.3. Handover failures

Figures 8 show the ratio of handover failures for a number of attempted handovers when the MA selection is placed at the gateways. When the number of attempted handovers increased, our proposed CMAS demonstrated fewer handover failures than the other three cases did.

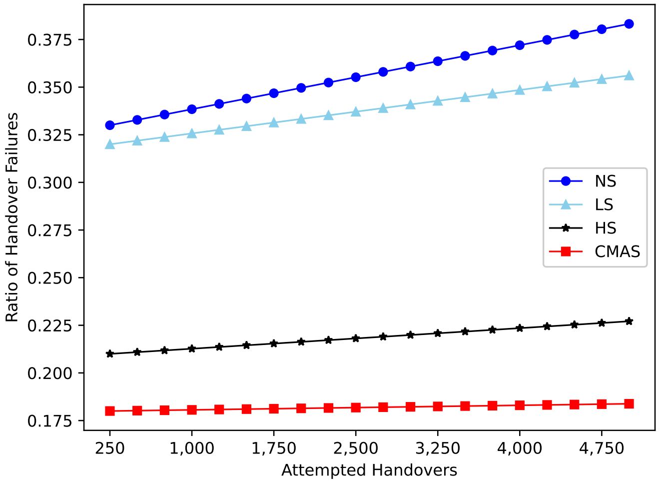

Figure 8. Ratio of handover failures for number of attempted handovers

This reduction can be explained by the result of two normalized functions: (i) the function based on MA load affected the cost of the MA as follows: an MA with an optimal load and good handover performance is selected with a high probability; and (ii) the function of handover performance must be recalculated after a handover procedure has finished (using the next handover procedure). Then, the proposed CMAS scheme selects a different MA and cell when subscribers simultaneously begin a handover procedure as well as in the case where the candidates listed in the NCL are the same.

5.2.4. Analysis of DMM solutions

In this subsection, we compared our solution with other related solutions for DMM that are PMIPv6-based DMM solution (PMIPv6-DMM) [6, 33], and SDN--based DMM solution (SDN-DMM) [19]. In PMIPv6-DMM, the LMA/MAG selection scheme can provide a load balance between anchors but cannot select an optimal path. Also, the controller selects a path with low-latency in SDN-DMM. However, the load-balancing function works after the handover procedures.

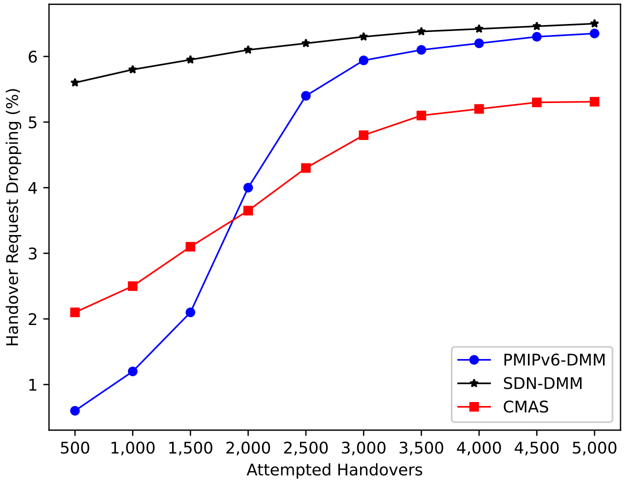

Figure 9. Ratio of handover request dropping versus number of attempted handovers

Figure 9 depicts the effect that increasing the attempted handovers has on the request dropping rate. The results show that the percentage of the handover request dropping of SDM-DMM is significantly increased. PMIPv6-DMM and CMAS show a low percentage of handover request dropping when the number of attempted handovers is low. When the number of handovers increases, CMAS keeps a lower percentage of handover request dropping than PMIPv6-DMM. This is due to a load of an MA that is defined as a factor in the handover decision phase of CMAS. Also, the result of PMIPv6-DMM can be explained by the load balancing function and LMA/MAG selection function. In addition, SDN-DMM cannot provide load balancing in the handover procedures.

5.3. Impact of weight configuration

In this subsection, we study the impact of weight configuration. Figure 10 shows the percentage of handover request dropping for the number of attempted handovers. We reconfigured the weights as shown in Table 2.

Table 2
Weight configuration

Cases	Values
1	$w_l = 0.2$, $w_{rr} = 0.2$ and $w_{hp} = 0.6$
2	$w_l = 0.4$, $w_{rr} = 0.2$ and $w_{hp} = 0.4$
3	$w_l = 0.6$, $w_{rr} = 0.2$ and $w_{hp} = 0.2$

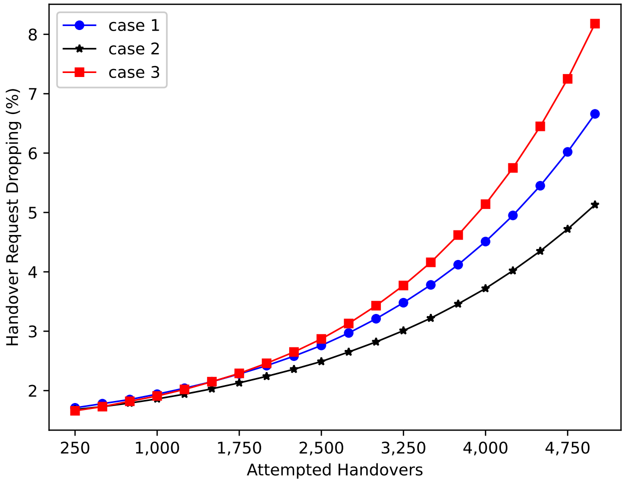

Figure 10. Handover request dropping versus number of attempted handovers

From Figure 10, the handover signaling cost of the three configurations of weights is almost identical (at about 3%) when the number of attempted handovers is between 250 and 2,500. However, when the number of attempted handovers is greater than 3,000, the handover request dropping increases significantly. Then, when the number of attempted handovers is greater than 3,000, the handover request dropping of Case 2 is around 4%. In addition, the handover request dropping of Cases 1 and 3 is increased by up to 7%.

6. Conclusions

In this paper, we propose and analyze a cost function-based MA selection for DMM architecture. The proposed CMAS can select a suitable MA and cell in the handover-preparation step. First, we compared our proposed scheme with three simple solutions – distance-based, load-based, and hybrid solutions. Simulation results such as signaling cost, handover request dropping, and handover failures show the feasibility of CMAS. The proposed CMAS was analyzed and shown to have better handover performance than that of the other three solutions. In addition, our proposal reduces the ratio of handover request dropping, as CMAS gives the subscriber a better chance at succeeding with the first attempted handover. Second, we compared major solutions such as PMIPv6-based DMM, SDN-based DMM, and CMAS. Our CMAS maintains lower handover request dropping when the number of attempted handovers increases.

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