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# Unnecessary Handover Minimization in Two-Tier Heterogeneous Networks

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***Abstract*—Ultra-dense deployment of small cells (SC) can be foreseen in 5G network under the coverage area of the macrocell (MC). A mobile user equipment (UE) should be able to discover adjacent SCs to perform the handover (HO). This process can be done by frequent neighbour cell scanning. However, extensive scanning for every SC in a dense deployment scenario is a resource wasting strategy, which results in a power dissipation of the UE battery and also lowers the throughput gain. This also means that a high number of SCs would be available for the UE to HO to. Hence, the probability of unnecessary HO will increase and in turn degrade the UE's quality of service (QoS). This paper aims to minimize unnecessary HOs in two tier heterogeneous network with dense deployment of SCs. In the proposed method, we utilise the actual distance between the UE and the SCs and the UE angle of movement to construct a shortened candidate list which helps in reducing the signal overhead of scanning and the number of unnecessary HOs. UE's movement velocity threshold based on average human walking speed is used to control the HO to the SC. Simulation results show that the proposed algorithm outperformed the conventional HO method with reduced unnecessary HOs and increased throughput for the network particularly for medium to high speed UEs resulting in good UE QoS.**

## I. Introduction

Data traffic demand around the globe is sharply increasing due to the increasing number of smart UE equipments. Increasing the number of MC base stations is usually costly and inefficient to deal with this demand. One of the most recent methods for capacity boosting and coverage extension is the deployment of SCs. Basically, SCs are recognised by their lower transmit power, smaller coverage, and size [1]. Despite their huge benefits in providing network coverage in the gaps that could not be covered by MCs and their promising capacity enhancements, the dense deployment of SCs is expected to introduce a very high number of HOs because of the high-speed UEs. Hence, the overall QoS of the mobile network would be degraded. There have been some works accomplished to address this problem in the two-tier heterogeneous network. The majority of HO algorithms use the received signal strength (RSS) metric for HO decision. Authors in [2] used an exponential window function to eliminate the rapid RSS changing rate between MC and femtocell. The two windowed RSS of MC and femtocell are then combined to form a HO decision criteria. One of the drawbacks of this algorithm is that the optimization of its performance in real life network deployment is a challenge. In [3] the authors proposed a single-MC single-femtocell scenario for inbound HO to femtocell when the RSRP of femtocell is offset greater than that of the MC and the velocity of the UE is below a predefined threshold. Compared to the traditional methods, this method tends to minimize the probability of unnecessary HO for fast moving UEs. However, the choice of the speed threshold has not been justified. In [4] the authors proposed an adaptive hysteresis margin algorithm to minimize the probability of unnecessary HOs for UE inbound mobility to femtocell. The algorithm compares the received signal quality (RSQ) of the target and serving cells by utilizing an adaptive HO margin (HM). The HM is measured based on the RSQ at the UE side and the path loss. In [5] authors presented a HO decision algorithm that uses an adaptive hysteresis margin which is adjusted periodically according to UE movement. However, the use of these HO metrics in both [4] and [5] have increased the signalling overhead in the network. In this paper, the actual distance between the UE and the SCs and the UE angle of movement are used to extract a shortened candidate list to reduce both scanning process and unnecessary HOs. In addition, signal to noise ratio (SNR), and velocity threshold, which is based on average human walking speed, are used to minimize the unnecessary HO. The time of stay metric is used to evaluate the performance of the proposed method in terms of unnecessary HO.

The rest of this paper is organised as follows. Section II describes the system model. Section III illustrated the proposed HO scheme. While section IV discusses the performance of the proposed algorithm. Finally, section V concludes the paper.

## II. System Model

System model consists of 7 hexagonal MCs as illustrated in Fig.1, and dense open access mode SCs. Indoor SCs are

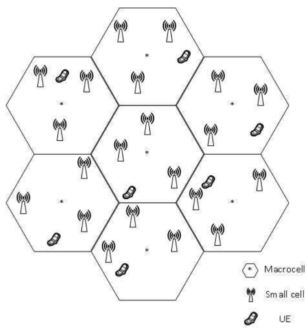


Figure 1: System model

deployed randomly under the MC coverage area. The mobility model of the UE in the simulation area follows a random way point model [6]. The path loss between a UE and a cell is different in different scenarios as detailed in [7]. When a MC UE is outdoor, the path loss between the MC and the UE is

$$\delta = 128.1 + 37.6 \ \log_{10}(d_m), \tag{1}$$

where $d_m$ is the distance between the UE and the MC in kilometres. And its path loss to the SC is calculated as

$$\delta = 37 + 20 \ \log_{10}(d_{sc}) + q_{sc} \cdot W + L, \tag{2}$$

where $d_{sc}$ is the distance between the UE and the SC in metres, $q_{sc}$ is the number of walls between the SC and the UE, $W$ is the wall partition loss, and $L$ is the outdoor penetration loss. When the UE is inside a house (SC UE), its path loss to the SC is

$$\delta = 37 + 20\ \log_{10}(d) + q_{sc} \cdot W. \quad (3)$$

The downlink reference signal received power (RSRP) is

$$P^r_{i \to ue_j} = p^t_{i \to ue_j} + g_{bs} - \delta_{i \to ue_j} - \xi_{i \to ue_j}, \quad (4)$$

where $P^r_{i \to ue_j}$ is the measured RSRP of the target cell at the UE side, $p^t_{i \to ue_j}$ is cell transmitting power, $g_{bs}$ is the base station antenna gain, $\delta_{i \to ue_j}$ is the path loss between UE $j$ and base station $i$, and $\xi_{i \to ue_j}$ is the shadow fading with a log-normal distribution with zero mean and 3 dB standard deviation [8]. The radius of each SC $i$, $R_{sc_i}$, could be estimated when the UE enters the coverage area of the SC [9] i.e. when the UE starts receiving the minimum required signal for service continuity ($P_{th}$), as defined below

$$R_{sc_i} = \Big(\frac{p^t_{i \to ue_j}\ 10^{\xi/10}}{P_{th}}\Big)^{\frac{1}{\beta}}, \quad (5)$$

where $\beta$ is the path loss exponent. From the geometry of Fig.2 we can see the expected distance UE stays inside the cell is between $A$ and $B$. Where $A$ and $B$ are respectively the entry and the exit points of the UE to and from the SC. The UE's angle of entry to the SC, $\theta$, is measured as in (6)

$$\theta = \arctan\Big(\frac{y_2 - y_1}{x_2 - x_1}\Big). \quad (6)$$

The estimated distance of UE $j$ inside SC $i$, $d_{ue_j \to sc_i}$, is

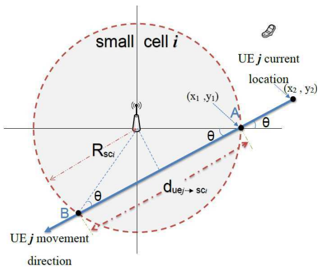


Figure 2: Small cell ToS measurement

$$d_{ue_j \to sc_i} = 2R_{sc_i} \cdot cos(\theta), \quad (7)$$

## III. Proposed Scheme

In this section, we propose a method to minimize the probability of unnecessary HO and to reduce the neighbour cell scanning for SC heterogeneous network. The proposed method uses shortened SC list and different metrics for HO decision including SNR, velocity, and the actual distance between the UE and the SC denoted as ($d_{act}^{ue_j \to sc_i}$). The proposed method pseudo code is shown below

where $V_{ue_j}$ is the velocity of the UE, $V_{th}$ is the HO velocity threshold, $d_{th}$ is the distance threshold to form the SC list, $\alpha_{ue_{ji}}$ is the angle between UE $j$ and the SC $i$, $\alpha_{in,th}$ is the angle threshold at which the SCs are included in the candidate list, $SNR^r_{m \to ue_j}$ is the signal to noise ratio received from the MC at the UE side, and $SNR^r_{sc_i \to ue_j}$ is the signal to noise ratio received from SC at the UE side. From the geometry of Fig.3 we can calculate the angle between UE $j$ and SC $i$, $\alpha_{ue_{ji}}$, based on $\vec{u}$ and $\vec{v}$ vectors as

$$\alpha_{ue_{ji}} = \arccos\Big(\frac{x_u \cdot x_v + y_u \cdot y_v}{\sqrt{x_u^2 + y_u^2} \cdot \sqrt{x_v^2 + y_v^2}}\Big), \forall i = 1, 2, ..., N^*_{sc} \quad (8)$$

where $x_u = x_2 - x_1$, $x_v = x_3 - x_1$, $y_u = y_2 - y_1$, $y_v = y_3 - y_1$, and $N^*_{sc}$ is the total number of SCs that are located within $d_{th}$

**Algorithm 1** Proposed Method

```
if Strong neighbor SC detected > P_th then
    Put the SC in a shortened candidate list
    V_uej monitoring
    if V_uej ≤ V_th then
        if ((d_act^{uej→sci} ≤ d_th) ∧ (| α_ueji | ≤ α_in,th)) then
            Keep SC sc_i in the shortened candidates list
        else
            Remove SC sc_i from the shortened candidates list
        end if
    end if
    if maximum ( SNR^r_{sci→uej} ) in the list is > SNR^r_{m→uej} then
        Handover to SC
    end if
end if
```

distance from the UE. The algorithm starts by checking the

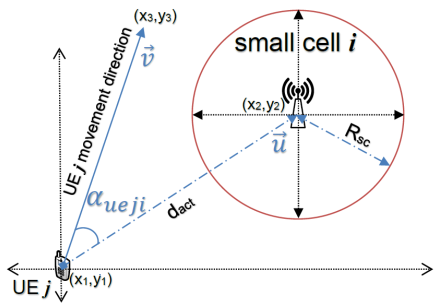


Figure 3: UE angle of movement

neighbouring SCs, if their received RSRP are greater than a threshold, $P_{th}$, a shortened SCs list is formed containing all of these cells. Then the UE's velocity is checked, if it exceeds the threshold, $V_{th}$, which means that the UE is moving very fast and will potentially stay very short time in the SC coverage area, then the UE keeps associated to MC. On the other hand, if the UE's moving velocity is equal to or below the threshold, we form a circle, i.e. model the SC candidate list as a circle, whose center is the UE location and its radius is $d_{th}$. Then, all SCs, within this circle, that are not located within an angle range of $[-\alpha_{in,th}, \alpha_{in,th}]$ from the circle center (i.e. UE location) will be removed from the circle as shown in the blue shaded area of Fig.4. Leaving in the list only the SCs that are located at UE trajectory as shown in the white unshaded area of Fig.4. Hence, the scanned number of SCs by the UE is reduced. The

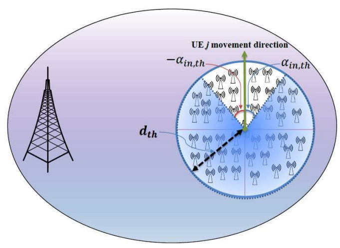


Figure 4: Removing small cells from the list

evaluation of the actual distance between the UEs and the SCs, in one MC, can be described in the following matrix

$$d_{act}^{ue_j \to sc_i} = \begin{pmatrix} d_{act}^{ue_1 \to sc_1} & \cdots & d_{act}^{ue_1 \to sc_{n-2}} & \cdots & d_{act}^{ue_1 \to sc_n} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ d_{act}^{ue_{m-2} \to sc_1} & \cdots & d_{act}^{ue_{m-2} \to sc_{n-2}} & \cdots & d_{act}^{ue_{m-2} \to sc_n} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ d_{act}^{ue_m \to sc_1} & \cdots & d_{act}^{ue_m \to sc_{n-2}} & \cdots & d_{act}^{ue_m \to sc_n} \end{pmatrix}, \tag{9}$$

where $n = 1, 2,..., N_{sc}^*$, $m = 1, 2,..., N_{ue}$, $N_{ue}$ is the total number of UEs, the rows represent the UEs, and the columns represent the SCs. Each element in the matrix is compared against its correspondent SC radius to construct the shortened candidates list. Thus, we can define the set of candidate SCs for UE $j$ in one MC, which is denoted as $S_{sc}$, using the following

$$S_{sc} = \{sc_i \in N_{sc} \mid (d_{act}^{ue_j \to sc_i} \leq d_{th}) \wedge (\mid \alpha_{ue_{ji}} \mid \leq \alpha_{in,th})\}, \tag{10}$$

where $N_{sc}$ is a set represents all SCs in one MC base station. The HO is performed to the SC, $sc_i$ from the set $S_{sc}$, with the maximum SNR providing that this SNR is greater than the serving one i.e. $SNR^r_{sc_i \to ue_j} > SNR^r_{m \to ue_j}$. Since the SC radius, $R_{sc_i}$, is environment-dependent i.e. depends on the path loss, shadowing distribution and the transmit power, then the distance threshold, $d_{th}$, is also environment-dependent because it is a function of the SC radius ($d_{th} = 2R_{sc_i}$). In this way, the UEs only need to initiate the HO to a certain SC in a shortened list which only contains certain number of SCs that have a sufficient RSRP level and are located in the UE's trajectory. Hence, the possibility of unnecessary HO will be reduced.

The UE expected time of stay (ToS) inside the SC is measured to evaluate the probability of unnecessary HO. The ToS is compared against the time threshold $T_{threshold}$. When the UE's ToS is less than the $T_{threshold}$, the HO is considered as unnecessary HO. The expected time of stay inside a SC $i$ for UE $j$, $ToS_{UE_{ji}}$, can be calculated using UE velocity, $V_{ue_j}$, and the expected traveling distance, $d_{ue_j \to sc_i}$, and is expressed as

$$\begin{aligned} ToS_{UE_{ji}} &= \frac{d_{ue_j \to sc_i}}{V_{ue_j}} \\ &= \frac{2R_{sc_i} \cdot cos(\theta)}{V_{ue_j}}. \end{aligned} \tag{11}$$

Depending on the hand-in and hand-out times, the time threshold is chosen so that it is equal to the sum of two HO times (hand-in and hand-out). The RSRP measurement and HO execution take about 360ms. Therefore, two HOs time (hand-in and hand-out) is approximately equal to 720ms.

## IV. Performance Evaluation and Analysis

System level simulation has been carried out to evaluate the performance of the proposed algorithm. Table I gives a summary of simulation parameters used.

Table I: Basic Simulation Parameters

| | |
|---|---|
| System bandwidth | 5 MHz |
| Macrocell antenna gain | 15 dBi |
| Macrocell transmit power | 45 dBm |
| Macrocell radius | 500 m |
| Small cell antenna gain | 0 dBi |
| Small cell transmit power | 2 dBm |
| Number of SCs within MC | 100 |
| Outdoor penetration loss ($L$) | 10 dB |
| Number of walls ($q_{sc}$) | Random |
| $P_{th}$ | -70 dBm |
| $V_{th}$ | 5, 15, 20 km/h |
| $d_{th}$ | $2R_{sc_i}$ |
| $\alpha_{in,th}$ | $20^o$,$30^o$,$60^o$ |

We define the number of HOs per MC, $HO_n$, as

$$HO_n = \sum_{i=1}^{N_{sc}} HO_{n \to i}, \tag{12}$$

where $HO_{n \to i}$ is the number of HOs from MC $n$ to SC $i$. Whereas the number of HOs in all deployed MCs, $NHO_m$, will be

$$NHO_m = \sum_{n=1}^{N_m} HO_n, \tag{13}$$

where $N_m$ is the total number of MC base stations in the network. For high-speed UEs, the HO is happening between two neighbouring MC following the strongest received power strategy. Therefore, the number of HOs for high-speed UEs, $NHO_{m \to m}$, is expressed as

$$NHO_{m \to m} = \sum_{k=1}^{N_m} HO_{m,k}, \tag{14}$$

where $HO_{m,k}$ is the number of HOs between two adjacent MC base stations. Finally, the total number of the HOs in the network, $HO_{total}$, is

$$HO_{total} = NHO_m + NHO_{m \to m}. \tag{15}$$

We express the probability of successful HO to SCs, $P_{HO}$, as

$$P_{HO} = \Pr\Big[\; V_{ue_j} \leq V_{th} \;\;\wedge\;\; d_{act}^{ue_j \to sc_i} \leq d_{th} \;\;\wedge\;\; \mid \alpha_{ue_{ji}} \mid \leq \; \alpha_{in,th} \;\wedge\; SNR^r_{sc_i \to ue_j} > SNR^r_{m \to ue_j} \Big]. \tag{16}$$

The probability of unnecessary HO, $P_{unHO}$, is defined as

$$P_{unHO} = \Pr\Big[ ToS_{UE_{ji}} \leq T_{threshold} \Big], \tag{17}$$

where $T_{threshold}$ is the minimum time required for hand-in and hand-out. For the overall network throughput measurements, the following formula is used

$$\text{Throughput} = \sum_{c \in X} \text{BW} \cdot \log_2\left(1 + \frac{P^r_{c \to ue}}{\sigma^2}\right), \tag{18}$$

where set $X$={1,2,...,$N_{sc}$,$N_m$}, and $\sigma$ is the thermal noise density. In this section, we compare the performance of our proposed HO algorithm with that of the conventional methods. The HO for the conventional method happens when the RSRP of the target cell, $P^r_{sc_i \to ue_j}$, is greater than the RSRP of the serving cell, $P^r_{m \to ue_j}$, i.e. ($P^r_{m \to ue_j} < P^r_{sc_i \to ue_j}$) and can be described as

$$\eta := \{sc_i \mid P^r_{sc_i \to ue_j} > P^r_{m \to ue_j}\} \tag{19}$$

$$sc^*_{conv} = \arg \max_{sc_i \in N^*_{sc}} P^r_{sc_i \to ue_j} \in \eta, \tag{20}$$

where $\eta$ represents the set of all SCs within the candidate list circle of $d_{th}$ radius, and $sc^*_{conv}$ is the best SC in set $\eta$ in term of downlink received power.

Whereas the HO criteria of our proposed method can be presented as

$$\zeta := \{sc_i \mid SNR^r_{sc_i \to ue_j} > SNR^r_{m \to ue_j}\} \quad (21)$$

$$sc^*_{pro} = \arg \max_{sc_i \in S_{sc}} SNR^r_{sc_i \to ue_j} \in \zeta, \quad (22)$$

where $\zeta$ represents the set of all SCs within the white unshaded area of Fig.4, and $sc^*_{pro}$ is the optimal SC in set $\zeta$ which satisfies the conditions in lines (5) and (11) of the algorithm pseudo code.

A) The Ratio of the Small Cells in the List

We evaluate the ratio of the candidate SCs in a list as a function of the distance threshold, $d_{th}$, taking into account the SC radius. Given that $d_{th}$ is defined as a function of $R_{sc_i}$, we can define the ratio of the SCs in a shortened candidate list, denoted $\rho_{sc}$, as

$$\rho_{sc} = \frac{Number\ of\ candidate\ small\ cells\ within\ [-\alpha_{in,th}, \alpha_{in,th}]}{Total\ number\ of\ small\ cells} \times 100\% \quad (23)$$

As depicted in Fig.5, the ratio of the candidate SCs in the conventional method is always the higher, compared to our proposed method, because its shortened list contains all the SCs within the UE range (i.e. all SCs within a circle of $d_{th}$ radius). On the other hand, our proposed method has reduced the number of candidate SCs in the list for different $\alpha_{in,th}$ values. The higher the value of $\alpha_{in,th}$ the higher the ratio of SCs. The impact of the SC list radius, $d_{th}$, is obvious in Fig.5, the ratio of SCs slightly increases with the increase in $d_{th}$. We can clearly see from Fig.5 an achieved improvement of the ratio of the candidate SCs in our proposed method compared to the conventional method, for example at $d_{th} = 3R_{sc}$, we have an improvement of 20%, 25%, and 27% when setting $\alpha_{in,th}$ to $60^o$, $30^o$, and $20^o$ respectively.

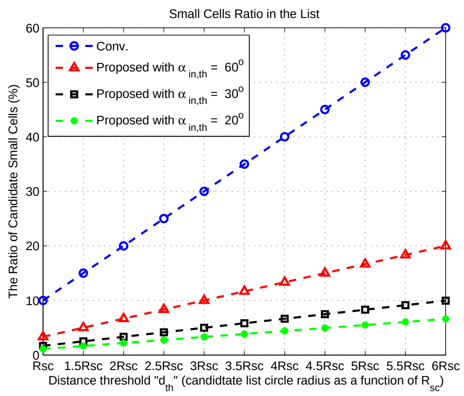


Figure 5: Ratio of the Candidate Small Cells in the List as a Function of $d_{th}$ with Different Values of $\alpha_{in,th}$

B) Probability of Handover

The probability of HO is depicted in Fig.6. Generally, the probability of HO for the two methods increases with the increase in velocity. The conventional method has the highest increase owing to the fact that it depends only on RSRP for HO decision. The proposed method shows lower level of HO for low speed UEs compared to the conventional one because of the signal to noise ratio metric. At the velocity limits, 5km/h 15km/h and 20km/h, we can see that the probability of HO for the proposed method sharply goes down before it starts to climb again because the HO to SC only happens for the UEs with a velocity less than or equal to the velocity threshold. For high-speed UEs, above the velocity threshold, the HO is happening between two adjacent MC base stations. In the proposed method, the effect of the velocity threshold is obvious, fewer HOs are taking place for low-speed UEs with a lower velocity threshold (5 km/h). Moreover, the proposed method shows lower level of HO probability (for all $V_{ue} < V_{th}$) because of the introduction of shortened SC list. Hence, fewer HO target cells will result in lower HO probability and will also reduce the extensive scanning for neighbouring SCs which will eventually minimize the UE battery power consumption.

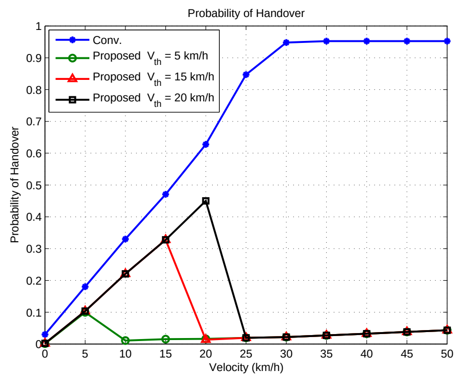


Figure 6: Probability of Handover with $\alpha_{in,th} = 30^o$

C) Unnecessary Handover Probability

Fig.7 illustrates the probability of unnecessary HO for both the conventional and the proposed methods. The performance of the proposed method outperformed that of the conventional one by showing a lower level of unnecessary HO probability. The conventional method shows a higher level of unnecessary HOs and this level slightly increase when the velocity of the UE increases owning to the fact that the conventional method depends only on the RSRP level for neighbourhood scanning and HO decision which degrades the end UE QoS by consuming the UE's battery power. The introduction of shortened SC list has a great influence on the performance of the algorithm. By using this list a plenty of unnecessary HOs have been avoided because a fewer number of target SCs are nominated and the one with highest SNR is selected as a possible HO target making the scanning process less power consuming. As clearly shown in the figure, when using different velocity thresholds in the proposed method the unnecessary HOs are very low for SC UEs compared to the conventional method. The utilization of the angle, $\alpha_{in,th}$, has reduced the number of SCs in the shortened list and in turn minimizes the unnecessary HO for different velocity thresholds. For example, when adjusting the velocity threshold to 5k/m, fewer unnecessary HOs are happening for low to medium-speed UE (0km/h-to-25km/h). The higher the velocity threshold, the higher the unnecessary HO for low to medium-speed UEs (0km/h-to-25km/h). Thus, our method has increased the proper utilization of SCs and prevented the unnecessary HO from MC UEs to the SC (i.e. has eliminated the HO for fast UEs). Fig.8 shows the influence of different angle thresholds, $\alpha_{in,th}$, on the probability of unnecessary HO. The solid curves represent the scenario with $\alpha_{in,th} = 30^o$, whereas the dotted curves represent the scenario with $\alpha_{in,th} = 20^o$. As clearly illustrated in Fig.8, for different

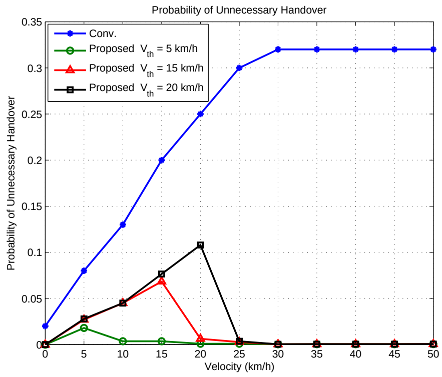


Figure 7: Probability of Unnecessary Handover with $\alpha_{in,th} = 30^o$

velocity thresholds, the unnecessary HO for lower angle threshold is lower than that of the higher angle threshold (almost 50% reduction in the unnecessary HO is achieved with lower angle threshold). This is due to the fact that lower angle threshold will produce shorter SC list and hence low unnecessary HO.

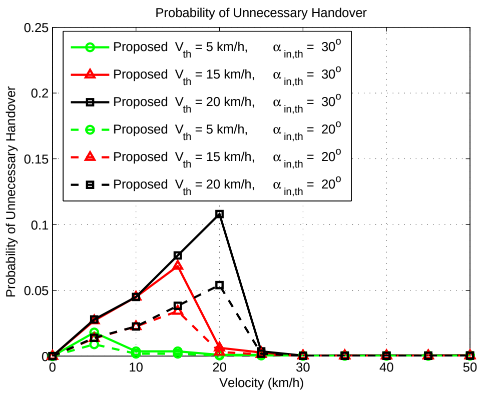


Figure 8: Probability of Unnecessary Handover for Different Values of $\alpha_{in,th}$

D) Throughput

Fig.9 illustrates the network throughput for both the proposed and the conventional methods against the velocity. For both methods, the throughput decreases with the increase in velocity. The conventional method has always the lowest throughput compared to the proposed method. The proposed method has outperformed the conventional method in terms of throughout by holding higher capacity for fast moving UEs because the fast moving UEs do not have to perform frequent HOs to the small coverage area SC. Fig. 9 reveals that our proposed method, in addition to the unnecessary HO reduction, has increased the network throughput. At (5km/h) velocity, the throughput of the proposed method is about 23Kbps higher than that of the conventional scheme. Moreover, the proposed method continues to produce higher throughput for high-speed UEs, e.g. at (50km/h), the throughput is 46Kbps higher than the conventional method because the high-speed UEs are always associated to the MC. Hence, higher capacity is held for fast moving UEs because the signal to noise ratio for these UEs (served by MC) are nearly steady and are not fluctuated due to high-speed mobility.

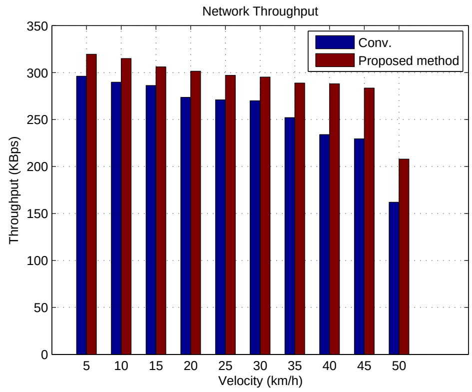


Figure 9: Network Throughput with $\alpha_{in,th} = 30^o$

## V. Conclusion

In this paper, a HO algorithm for two-tier heterogeneous network was proposed and compared against the conventional HO algorithm which depends only on RSRP for HO decision. Different velocity thresholds are used to control the HO to SC. In order to identify the shortened candidate SC list, the actual distance and SC radius, in addition to the UEs angle of movement, were used to form the most realistic SC HO targets. Moreover, the expected UE's ToS is taken into consideration to evaluate the unnecessary HO. Simulation results showed that our proposed method reduces the number of candidate SCs in the shortened list. The proposed method also shows a low number of HOs for all UE's velocities compared to the conventional method. On the other hand, the probability of unnecessary HOs for the proposed method is less than the conventional method due to the incorporation of the shortened SC list which in turn reduced the overall scanning for neighbouring SCs. Hence, reducing the UE battery power dissipation. Results show, the network throughput also increased for the proposed method comparing to the conventional method.

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