Cost Threshold Approach of Network Association in 5G Non-Standalone System

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***Abstract*—5G as the latest generation of wireless communication has been an interesting research topic, with a promise to provide a higher data rate and lower latency to user. 5G uses mmWave band to transmit and receive data. Thus, 5G transmission band resides in different band compared to LTE Macrocell. The mmWave has been utilized due to its ability to provide larger bandwidth to user. In spite of the merit, mmWave also brings challenges. The cell range of mmWave is smaller than previous 3G/4G macro cell. Furthermore, the mmWave channels may not reliable, thus it would be preferable to have microwave band as a carrier used to send important control signaling to user. In this case, it should be connected to two network, the main and the secondary network for a user to have a reliable connection. In 3GPP specification, this concept is known as dual connectivity. In this paper, a method based on threshold value for initiating dual connectivity to 5G BS, with LTE BS as the master node and 5G BS as a secondary node has been proposed. The method considered throughput requirement of user, distance to 5G BS and macrocell as criteria for the input parameters to make decision. The algorithm designed to be simple since it will run on the user terminal. Our analysis showed that the proposed method reflects MS distance to 5G AP and load of both LTE Macrocell and 5G AP, in term of cost calculation; thus, it can reduce unnecessary overhead, while at the same time provide user with a required throughput.**

***Index Terms*—5G; non stand alone; mmWave; user association.**

I. INTRODUCTION

The future trends reported by industries and research companies around the world show us that there is a necessity to have network which can provide higher throughput, better coverage and lower latency in the future. This trend is driven by the popularity of recent topics such as IoT, autonomous driving, virtual reality, industry 4.0 and many others. The next generation of wireless communication, 5G, promises to be the solution to support the ever increasing demand of higher throughput. One of the key factors that makes 5G to be the solution for future network are the mmWave [1], which inherently have higher bandwidth compared to microwave used by previous generation of wireless technology (2G, 3G and 4G). The physical limitation caused by mmWave is overcome by using an array of antennas that is able to perform directional beamforming. The beamforming is important in 5G as it enables the mmWave frequency band to function as a medium for data transmission.

The effort to make a standard for 5G has been initiated by 3GPP and the first draft has already been available under the specification number 38.912 Release 15 entitled “Study on New Radio Access Technology” [2]. The standard covers all aspects making 5G to fulfill all requirements of IMT-2020 as the next generation network.

According to 5G standard, the Radio Access Network (RAN) architecture shall support two kinds of connectivity scheme. The first is the non-standalone scheme, which supports the deployment of LTE eNB connected to the EPC with Non-standalone New Radio (NR). The second is the connectivity that supports non-standalone (NSA) and standalone (SA) scheme. In this scheme, the deployment of 5G AP will connect to the Next Generation Core either as Standalone (SA) or Non- standalone (NSA) air interface, and deployment with LTE eNB will connect to the Next Generation Core either as SA or NSA NR.

In SA architecture, the RAN and core network for 5G runs on top of its own protocol stack and uses mmWave band. The solution from macrocell, microcell, femtocell and picocell are fully developed in mmWave. Thus, this architecture is able to control a fully built plane on mmWave solution. If the user is connected to LTE and wants to connect to 5G AP, the user should perform Handover.

In NSA architecture, the control plane is built on top of LTE network. The protocol is based on dual connection in LTE standard, which are Master eNB (MeNB) and Secondary eNB (SeNB). The NSA is compatible with the current protocol of LTE for control signaling. NSA is considered in the first place since the usage of mmWave channel has several limitations, which are huge propagation loss and weak diffraction ability. It is also very sensitive to blockage, in which the signal power can drop around 40.1 dB and 28.3 dB, if the signal is blocked by tinted glass or brick materials [3]. Therefore, the channel might not be too reliable. NSA has the control plane, which is built on top of LTE network. When a user is in 5G AP coverage, the system will decide if it needs to perform association with 5G AP to allow the user to use channel resources of 5G AP.

Since 5G AP has smaller coverage than the macrocell, the user association is performed inside the Heterogeneous Network. The traditional approach uses Received Signal Strength Indicator (RSSI) as a parameter as a trigger to connect to certain AP or BS. However, this might not be the correct solution for Heterogeneous Network (HetNet), because the macrocell would always have the highest signal, compared to smaller cell [4]. In NSA architecture, user can use either macrocell resources or 5G AP resources to fulfill the demand rate. However, there are some tradeoffs, in which if the user decided to use 5G AP resources, it might have much larger bandwidth compared to use the macrocell BS. However, if the user only uses an application that does not need high demand rate, it is not necessary to connect to 5G

BS as it causes some unnecessary signaling. However, when deciding to whether to associate to 5G, user needs to consider the load of both 5G AP and macrocell BS, channel condition to each AP, and user's demand. In [5], Shokri-Ghadikolaei et al. argued that these aforementioned criteria need to be included in the association procedure. Several works have been presented earlier on how to perform association in mmWave environment. Zhang et al. performed user association in mmWave using utility function of power consumption in user terminal [6]. Similarly, in [7], Athanasiou et al. proposed user's association based on cost function of power consumption and RSSS.

Previous research of network association used a biased user condition to compensate the high-powered signal received from macrocell. Singh et al. [8] considered a two- tier topology, to address the optimization problem of bias value between small cell and to propose a certain throughput. Bao et al. [9] addressed optimization problem by maximizing UE data rate, considering the spectrum partitioning and user association bias values. Lin et al. [10] proposed an optimal user association bias and spectrum partitioning, motivated by the concern for fairness of network.

In this paper, a systematic approach to perform network association to 5G network for NSA architecture is proposed. The method considers dual connectivity, in which user needs to connect to BS and 5G AP, with LTE BS as Master eNB and 5G AP as the Secondary eNB. The focus of the work is based on the 5G NSA architecture that aims to address the issue of reliability, when using the link to 5G only. Thus, user needs to have main connection with LTE BS. The cost for performing the network association to 5G BS is calculated. If the cost is lower than certain threshold, the user will initiate the network association. The algorithm used throughput requirement of user to initiate connection with 5G BS, considering the condition, macrocell still can serve mobile user with requested QoS. In this case, connection to 5G BS is considered redundant, leading to unnecessary signaling and inefficiency power consumption. The proposed scheme can reduce unnecessary signaling, while at the same time provide user with a new demand throughput. Since the algorithm will be running on user mobile terminal, it is necessary for the algorithm to have a low calculation complexity. Further, in relation to the current conditions, the parameters used in our algorithm are dynamic as they can be obtained from the user terminal itself and the network. The algorithm is designed with low complexity, while still reflecting the current condition of network in terms of load and data rate. This algorithm run on user terminal and functioned to make decision whether or not to perform network association to 5G AP by comparing gain between 5G and LTE BS.

The rest of the paper is organized as follows. In Section II, Non-Stand Alone (NSA) Architecture of 3GPP standard is presented. In Section III, the system model is explained. In Sections IV, the proposed scheme is presented. In Section V, and VI, numerical analysis along with result and discussion are presented. Finally, conclusions are given in Section VI.

II. 3GPP SPECIFICATION

A. LTE Dual Connection

The dual connection of LTE was firstly proposed in Rel 12 version. According to 3GPP Specification, a user in RRC CONNECTED can have multiple of Rx Tx with two eNBs. A user can have two active connections, which are Master eNB and Secondary eNB. There are three bearers: Master Cell Group Bearers, Secondary Group Bearers and Split Bearers. The control plane connected the user and MeNB. The control signaling can also be sent to the user through SeNB through X2 interface. For the user plane, user can connect to MeNB or SeNB.

B. 3GPP NR Specification

In [11], the dual connectivity between LTE and NR are explained. The Dual connectivity of LTE and NR has three deployment scenarios, as mentioned below.

Scenario 1 uses the existing EPC of LTE. All the control signaling for gNB are sent through LTE eNB. LTE eNB and gNB are connected through Xx-C interface for control signaling. For user plane, S-GW can send data directly through S1-U to gNB. Scenario 2 uses NGC GW, which are connected to both gNB and eLTE NB. The control signaling is sent from NGC core to gNB, which is connected to eNB. The NG core can send data to gNB and eLTE eNB. Scenario 3 uses NGC GW that is connected to eLTE eNB, which is connected to gNB. Among these three deployment scenarios, Scenario 1 supports non-standalone architecture only. Scenario 2 supports non-standalone and standalone architecture.

For non-standalone architecture, all control signaling are destined for user/ 5G gNB, which is sent through LTE eNB. Thus, the protocol involved with control plane shall be decided carefully because it can cause overhead for LTE eNB, including network association. Fig. 1 shows all interfaces in the non-standalone architecture, which has been the main focus for this work.

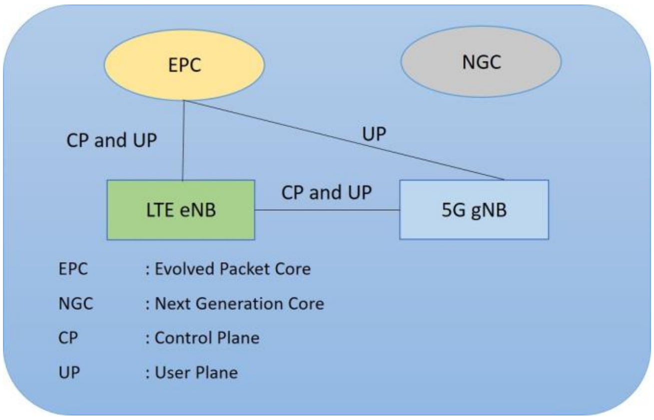

Figure 1: 5G Non-Standalone Architecture

III. SYSTEM MODEL

In this work, a system model of two-tier network consisting of one macrocell and 5G APs is considered. The load of BS and AP is indicated as L_{BS} and L_{AP}. A user is assumed to request more traffic demand, which is equal to 1000 Mpbs and served by LTE macrocell with distance 100 m to 2000 m, with respect to LTE Macrocell

A well-known propagation model COST 231 Hata for urban environment was used with a shadowing effect that follows log normal distribution for LTE Macrocell. The propagation model for 5G follows the specification in [12]. The scenario to analyze our proposed scheme is the Urban Macro (UMa) scenario with LOS between BS and MS. Based on our designed algorithm, a user would decide to perform association with 5G AP to meet the new demand rate or use currently connected LTE Macrocell resources.

IV. PROPOSED SCHEME

A user-centric algorithm to perform user association mechanism with 5G AP is proposed. Even though the decision is made by UE, the parameters in the algorithm reflect the current load and channel condition of macrocell and 5G AP.

The algorithm uses cost ratio metric Ct_j, which is used to compare the cost of staying in current AP and the cost of performing handover to new AP.

Algorithm 1 Cost ratio based Algorithm

```
for every subframe do
    read UE rate demand
    if UE rate demand > UE current rate then
        calculate cost
        if cost < th then
        perform network association with new AP
        end if
    end if
end for
```

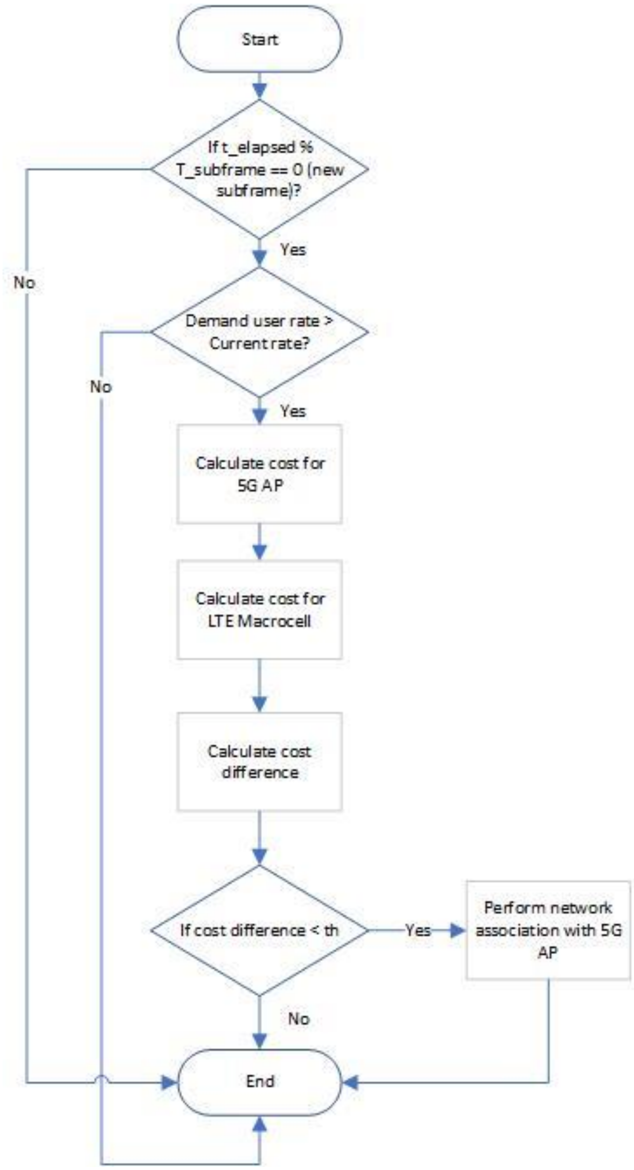

Figure 2: Flowchart for proposed algorithm

Ct_j is defined as the cost of performing handover to new AP.

$$Ct_j = Ch_j - Cs \tag{1}$$

in which Cs is the cost of staying in current serving AP and Ch_j is the cost of performing handover to AP j. If Ct_j is smaller than a threshold value, then handover is performed. Otherwise, stay in current serving AP.

The cost of staying in current AP is denoted as Cs is calculated as follows. ΔR is defined as the difference between the last allocated rate and the demanded rate.

$$\Delta R = R_{demand} - Rcurrent \ |\Delta R > 0 \tag{2}$$

The formula for calculating the cost of accommodate the demanded rate of UE in current AP is

$$C_s = \frac{\Delta R}{R_s} \tag{3}$$

where Rs is formulated based on well-known Shannon-Hartley capacity formula as follows:

$$R_s = B_{servingAP} log(1 + SINR_s) \tag{4}$$

The cost of doing handover to AP_j, Ch_j is formulated in a similar fashion with Cs, with $SINR_j$ indicated SINR to AP_j. For Chj calculation, R_{demand} is used to calculate the cost since $R_{current}$ is initially zero.

$$Ch_j = \frac{R_{demand}}{R_j} | \ j \ \in [1, L] \tag{5}$$

where

$$R_j = B_{newAP} log(1 + SINR_s) \tag{6}$$

The network association should consider the load of serving 5G and new AP as well. If load serving AP and new AP were considered, the equations become

$$R_s = (1 - load_{servingAP}) B_{servingAP} log(1 + SINR_s) \tag{7}$$

$$R_j = (1 - load_{newAP}) B_{newAP} log(1 + SINR_j) \tag{8}$$

where $load_{servingAP}$ and $load_{newAP}$ indicate the load of serving AP and new AP respectively.

V. NUMERICAL RESULT AND DISCUSSION

The numerical analysis of the proposed scheme was performed using system model as explained in Section II. For our analysis, the serving AP is LTE Macrocell and new AP is 5G AP. The parameters can be found in Table I. The analysis tool used is Octave-5.2.0.

Table 1
Simulation Parameters

Parameter	Symbol	Value
MS Distance to 5G AP		100 m - 2000 m
Frequency carrier AP	fc_{AP}	28 GHz
Frequency carrier LTE Macrocell		900 MHz
Bandwith AP	B_{AP}	100 MHz
Bandwidth LTE Macrocell	B_{LTE}	20 MHz
Height BS	hbs	25 m
Height UT	hut	5 m
Propagation velocity	c	3 x 10^8 m/s

In 3GPP model, the distance from MS to 5G AP is described in Fig. 2. From now on, the distance from MS to BS is referred to d3d as shown in Figure 3.

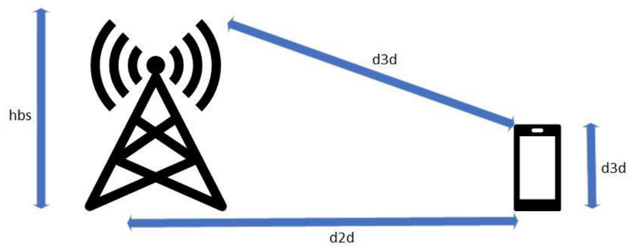

Figure 3: Distances in 5G Analysis

Firstly, SINR was calculated. SINR value for MS with distance 100 m to 2000 m with respect to LTE Macrocell BS. The SINR value was calculated based on RSRP, path loss and shadowing. The maximum capacity for MS at each distance related with function of SINR and BS load were calculated. For the LTE Macrocell to have fair comparison with 5G AP, the best-case scenario was considered, when MS has SINR higher than 31 dB. The reason is that MS is able to select the highest Index Modulation and Coding Scheme MCS with 64 QAM and coding rate 0.8. The required SINR is 31 dB, which was interpolated from [13]. The best-case scenario was when MS is located 100 m from LTE Macrocell. MS was then set to request a new demand rate equal to 1000 Mbps.

As channel propagation model for 5G network, UMa scenario with LOS viewed from 3GPP specification was used. There are two path loss model based on the value of d'_{bp}

$$PL_{LOS} = \begin{cases} PL1_{LOS}, for\ d2d < d'_{bp} \\ PL2_{LOS}, for\ d2d > d'_{bp} \end{cases} \quad (9)$$

In which $d'bp$ is defined as.

$$d'_{bp} = 4(hbs)(hut)(fc_{AP})/c \quad (10)$$

The formulas for are $PL1_{LOS}$ and $PL2_{LOS}$ are

$$PL1_{LOS} = 28 + log_{10}(d3d) + 20log_{10}(fc) \quad (11)$$

$$PL2_{LOS} = 28 + 40log_{10}(d3d) + 20log_{10}(fc) - 9log_{10}({d'_{bp}}^2 + (hbs - hut)^2)) \quad (12)$$

Figure 3 shows the relation between cost *Ctj* and distance of MS to 5G AP. The load of BS was set to be 10%, which means 90 percent of resources can be used for accommodating demand of user. The observation was made that the *Ctj* is increased exponentially from 1.197 to 49.572 for distance 100 m to 2000 m. In the simulation, if *th* set to 100, MS up to 400.66 m can perform network association to 5G AP.

The performance of proposed method based on the load of LTE Macrocell and 5G AP was also observed. The result is shown in Fig. 4. First, the load of 5G AP set from 50 percent to 90 percent, while keeping the load of LTE Macrocell to 50 percent. The observation was made that the cost of performing network association to 5G AP increased proportionally to the load of 5G AP increased for the same distance. At 432 m, for AP load 50 perecent, the cost is 114.98, while for AP load 90 percent, the cost is 582.56. Based on the results, the proposed method also reflects the load of both 5G AP and LTE Macrocell well.

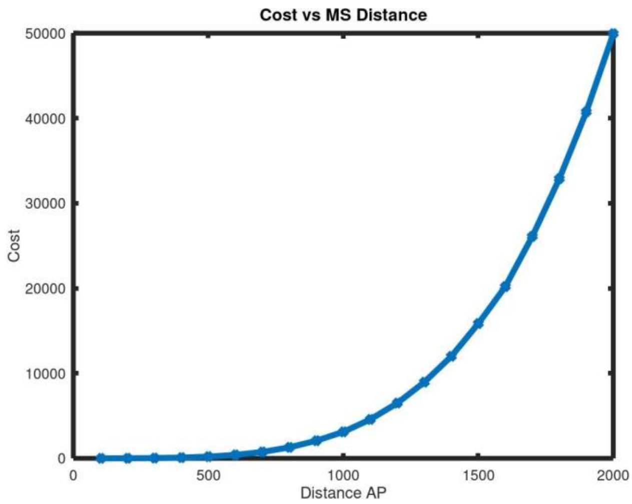

Figure 4: Simulation results for cost vs MS distance to 5G AP

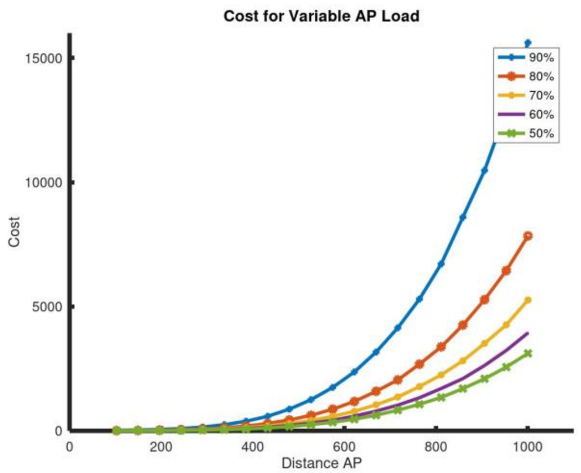

Figure 5: Simulation results for cost vs varied load of 5G AP with BS load 50%

The next simulation was done to compare the performance when the load of BS set to 80 percent, while varied the load of 5G AP set from 50 percent to 90 percent. The result is shown in Figure 5. In general, the trend of cost respective to variable AP load and distance is similar with the previous simulation. However, slightly different cost compared to the previous one was observed. At 432 m, for AP load 50 percent, the cost is 115.18, while for AP load 90 percent, the cost is 587.05. Thus, the cost is slightly lower compared to when LTE Macrocell load is 50 percent. This is because since the load of LTE Macrocell increased, 5G AP would slightly prefer compared to LTE Macrocell.

For the next simulation, the new demand data rate was varied and observation for the effect respective to MS distance to 5G AP was made. The load of 5G AP set to 50% and the load of LTE Macrocell is 50 percent for the distance 10 to 100 m. The result is shown in Figure 6. The results show for variable demand rates with distance up to around 85 m, higher new demand rate resulted in lower cost. For example, in 84.253 m, cost for demand rate 3000 Mpbs is 0.18, while for demand rate 1000 Mbps, cost is -0.05. However, when the distance reaches 104.23 m, the cost for new demand rate 3000 Mbps is 2.139, while for new demand rate 1000 Mbps is 0.73.

The reason for this is that as the distance increased, the pathloss for 5G AP increased in a faster rate, thus to fulfill the demand rate for higher demand rate cost higher than lower demand rate. While for shorter distance, the gain of larger bandwidth related with data rate exceeds the effect pathloss, thus the cost of higher new demand rate is lower.

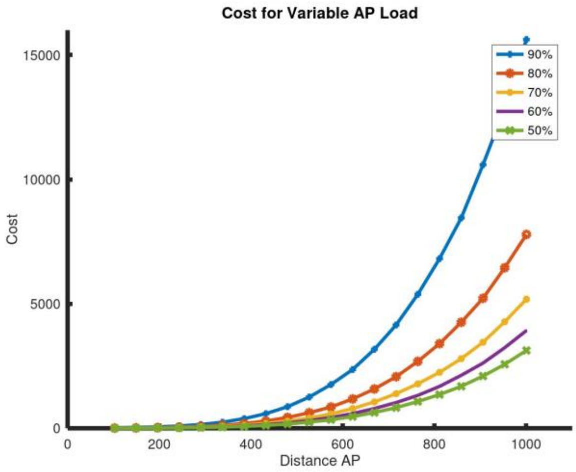

Figure 6: Simulation results for cost vs varied load of 5G AP with BS load 80%

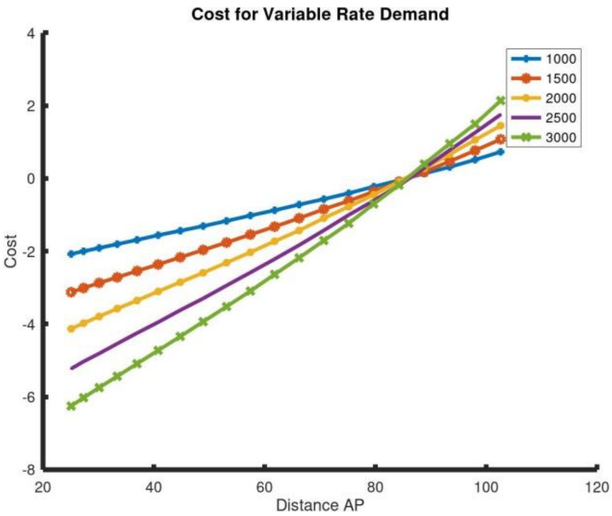

Figure 7: Simulation result for variable demand rate vs cost

VI. CONCLUSION

In this paper, a method to perform network association based on cost-based threshold has been proposed. Since the algorithm aims to be used in User Equipment, it is designed to have low complexity and easy to implement. The equations to perform calculation of costs for both serving LTE Macrocell and 5G AP are presented. The proposed method considers the difference between these costs for making decision. From the numerical result and discussion, it is shown that the cost to perform network association is proportional to distance of MS to 5G AP and load of 5G AP; thus, the algorithm is dynamic and adaptable to both parameters. For future work, the optimal cost threshold of the proposed method for various environment such as indoor, outdoor, urban, and suburban area will be the main focus.

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