M.S. THESIS

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초고밀도 밀리미터 웨이브 셀룰러 네트워크에서 이중연결 기반 핸드오버 기법

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SEONGJOON KANG

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지도교수 박 세 웅

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2018년 12월

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강 성 준

강성준의 공학석사 학위 논문을 인준함

2018년 12월

위 원 장: 최성현 (인)

부위원장: 박세웅 (인)

위 원: 심병효 (인)

Abstract

Mobile UEs in ultra-dense millimeter-wave cellular networks will experience handover events more frequently than in conventional networks, which will yield increased service interruption time and performance degradation. To resolve this, leveraging multi-connectivity becomes a promising solution in that it can improve the coverage of millimeter-wave communications and support link robustness. In this paper, we propose a dual-connection based handover scheme for mobile UEs in an environment where they are connected simultaneously with two millimeter-wave cells to overcome frequent handover problems, keeping a legacy LTE connection. We compare our dual-connection based scheme with a conventional single-connection based one through ns-3 simulation. The simulation results show that the proposed scheme significantly reduces handover rate, transmission failure ratio and delay. Therefore, we argue that the dual-connection based handover scheme will decrease network controlling overheads, guarantee more reliable transmission and provide better quality-of-service.

keywords: 5G, multi-connectivity, ultra-dense networks, secondary cell handover, ns-3 simulation

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Chapter 1

Introduction

1.1 Motivation

The increasing growth in mobile users and traffic demand requires cellular network operators to provide high network capacity [1]. As a promising technology in the fifth-generation (5G), millimeter-wave (mmWave) communication provides much higher data rate owing to its new spectrum bands with wider bandwidth. In particular, mmWave communication is aggressively pushed ahead by exploiting 28 GHz band first and then higher band [2]. However, the mmWave signal has a short distance transmission range and suffers high penetration losses due to the characteristics of mmWave propagation [3]. In other words, blockages such as buildings, vehicles, and people incur non-line-of-sight (NLOS) connections (i.e., multi-paths) between a mmWave base station (BS) and a user, which greatly lower the signal-to-noise-ratio (SNR) and degrade quality-of-service (QoS). Hence, LOS connections are highly desirable in mmWave communications.

To overcome blockage effects, multi-connectivity can be exploited where a mobile user is simultaneously connected to multiple BSs, which clearly increases the chance of a LOS connection [4]. That connectivity is possible when much higher BS density is given, so ultra-dense network is indispensable for realizing multi-connectivity. Particularly, highly directional beams utilized in mmWave communication enable very dense spatial reuse through spatial/angular isolation and result in no strong intercell interference [5].

However, multi-connections of a user to multiple BSs can give rise to higher handover rate and, consequently, higher network overhead [6, 7]. Specifically, the authors in [8] proposed a mmWave secondary cell handover (SCH) scheme in LTE-mmWave dual-connectivity networks, which basically uses a single mmWave connection in addtion to an LTE connection. In this scheme, a mmWave connection is switched to another mmWave cell that provides a larger signal-to-interference-plus-noise-ratio (SINR) after time-to-trigger (TTT). But, even when dynamic TTT is adopted, if the BS density is very high, a TTT based handover scheme can increase the handover rate to maintain connectivity with better SINR when frequent connection changes occur.

1.2 Related Works

Ultra-dense networks with very short inter-BS distance and mmWave band operation have been investigated as a promising deployment solution to achieve 5G requirement [9, 10]. Multi-connectivity in ultra-dense mmWave networks can achieve low session drop probability so that it could provide robust communication even though there were intensive traffic or blockages [11]. Authors in [12] presented that multi-connectivity in mmWave cellular networks can improve overall network throughput compared with single-connectivity. By conducting extensive ray tracing simulation from using 3D urban building data, the cell coverage and robustness of mmWave urban cellular network was analyzed and the necessity of multi-frequency heterogeneous networks mmWave 5G system was revealed [13].

A mobility handling scheme with multi-connectivity would be quite different from the conventional schemes with single-connectivity. Many recent studies analyzed about handover in ultra-dense network mathematically [7, 14, 15]. In control/user plane separated network, handover probability was investigated [7] and the analytic model of the handover signalling with respect to velocity was proposed [14]. In [15], the handover rate in multi-tier heterogeneous network was analyzed. These works focused only on link level analysis and did not take into account the whole network level performance. Authors in [8] conducted several network level simulations using ns-3 and evaluated the performance of its SCH scheme under single-connection between a mmWave BS and a UE. However, single-connection of mmWave communication cannot guarantee the reliability and delay constraint because its link quality could be severely degraded by blockages or UE mobility. To best of our knowledge, there is no prior works considering network level performance of a mobile UE with multi-connection to mmWave BSs in ultra-dense networks.

1.3 Contributions and Outline

In this paper, we propose a mmWave dual-connectivity scheme that a user equipment (UE) is connected with two mmWave base stations and an LTE base station. By utilizing the two mmWave links in ultra-dense networks, we will get the spatial diversity of the two links, which provides more robust and stable connectivity in a dynamically varying environment due to the characteristics of mmWave propagation channels. We also design new handover scheme based on mmWave dual-connection. Our proposals help decrease the handover frequency in ultra-dense cellular networks, which contributes to the significant reduction in network overhead. We compare our dual-connection based SCH scheme with the single-connection one utilizing ns-3 simulation, when base station density is very high. Simulation results show that our scheme outperforms the single-connection based scheme in terms of QoS, network overhead and spectral efficiency. To the best of our knowledge, we are the first to evaluate the performance of a mobile UE under mmWave dual-connectivity, and propose a handover triggering algorithm suitable for dynamic mmWave cellular networks.

The rest of the paper is organized as follows. Chapter 2 explicates background and system models. Chapter 3 presents our proposed SCH scheme based on dual-connection to mmWave BSs. Chapter 4 accounts for ns-3 implementation and discusses the simulation results. We conclude in Chapter 5.

Chapter 2

Background and System Model

2.1 LTE-MmWave Dual Connectivity and Small Cell Handover

Handover scheme in mmWave cellular network is firstly researched by [8], taking into account the whole network performance. In this study, authors proposed the LTE-mmWave dual connection structure and new handover scheme between mmWave cells which cover smaller area than LTE cell. When one UE is simultaneously connected with LTE eNB and mmWave gNB, the UE is only served by mmWave link. In other words, LTe eNB solely forwards data traffic received from core network to mmWave gNB that connected with the UE.

To support the UE's mobility, sounding reference signal (SRS) is periodically reported to all mmWave gNBs by the UE. After receiving SRS message from UE, each gNB estimates an optimal beam direction and calculates SINR value, and sends them to LTE eNB. Then LTE eNB makes a report table including SINR values and optimal beam direction for each gNB and updates it at regular time intervals. Therefore, LTE eNB plays a role as centralized coordinator and decides whehter UE needs to trigger handover event or not. In this architecture, if there is no connectable mmWave gNB, the UE performs fallback to LTE.

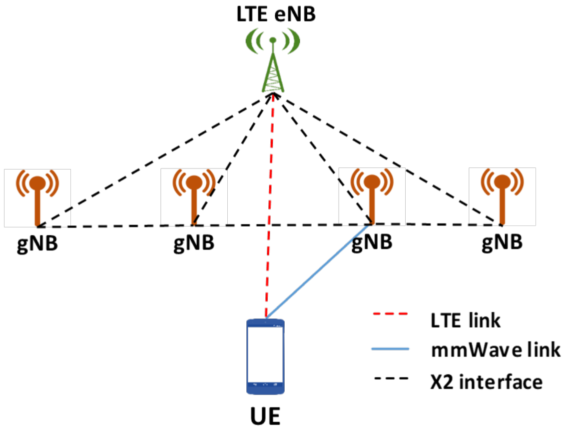

Figure 2.1: LTE-mmWave dual connectivity structure

Handover between mmWave cells is triggered by LTE eNB based on SINR value of each link between a UE and gNBs. LTE eNB makes handover decision whenever finding a better link than the current connected mmWave link. Therefore, it can trigger frequent handover event in the ultra-dense networks.

2.2 Network Model

We take account of the downlink scenario where a UE is connected with one master node (MN) and two secondary nodes (SNs) simultaneously. BSs can be set to MN or SN according to the radio characteristics such as carrier frequency as shown in Fig. 2.2. In this figure, an MN covers the whole area and SNs are placed at regular intervals. A UE with constant speed has single-connection to an MN and dual-connection to SNs simultaneously and moves along the street between SNs. Blockages are randomly scattered on 2-D plane. Also, MN is responsible for forwarding data traffic from the core network to the two SNs via wired links such as X2 interface, and manages control signals toward a UE. On the other hand, an SN is responsible for sending data traffic to a UE with high data rate. Hence, we assume that an MN uses the radio access

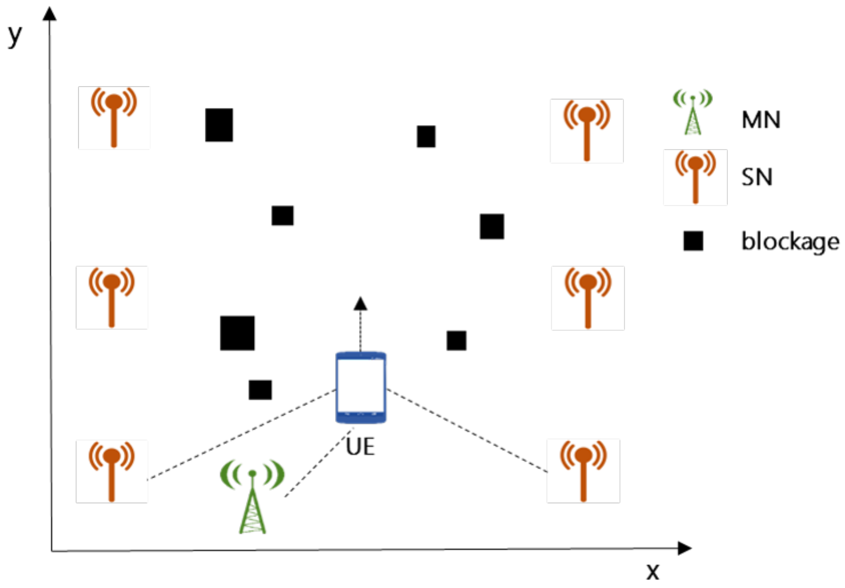

Figure 2.2: Network model

technology (RAT) of low carrier frequency such as LTE in which coverage is larger compared to the case of using SNs only. This is because an SN uses the RAT of high carrier frequency, such as mmWave communication, whose data rate is higher than that of an MN.

We make an assumption that the MN covers the whole area we interested in. SNs are placed at regular intervals, where the distance between the two SNs depends on the network density. We presume that the two SNs providing the dual-connectivity of a UE have different carrier frequencies to avoid inter-cell interference. A UE moves up and down along the path between the SNs at a constant speed, while it maintains connectivity with the two SNs. Rectangular-shaped obstacles are scattered randomly in a 2-dimensional plane to create blockages.

2.3 Channel and Propagation Model

We use the mmWave channel model given in [16] for a link between an SN and UE, and the LTE channel model for a link betweent an MN and UE. In [16], the authors provide a realistic assessment, including long-term and short-term fading, of mmWave micro- and pico-cellular networks in a dense environment. We assume that mmWave channel matrix, small scale fading and beamforming gain models are the same as the models in [17].

In this paper, we utilize the following pathloss model

$$PL(d)\,[dB] = \alpha + \beta 10 \log_{10}(d) + \xi\,, \quad \xi \sim N(0, \sigma^2) \tag{2.1}$$

where d is the distance between receiver and transmitter, σ^2 is the lognormal shadowing variance, and α and β are the parameter values given in [18].

We measure the channel quality in terms of SINR, which is computed as

$$SINR_{j,UE} = \frac{\frac{P_{TX}}{PL_{j,UE}} G_{j,UE}}{\sum_{k \neq j} G_{k,UE} + W_{tot} \times N_0}, \tag{2.2}$$

where P_{TX} is the total transmit power, $G_{i,UE}$ is the beamforming gain, $PL_{j,UE}$ is the pathloss between BS j and UE, and $W_{tot} \times N_0$ is the thermal noise. SINR values can be classified into three categories: LOS, NLOS, and outage. The classified SINR is used as a criterion for handover decision or path switching in the proposed scheme, which will be described in the following section.

Chapter 3

Secondary Cell Handover Design for Multi-Connectivity

3.1 MmWave-MmWave Dual Connectivity

The multi-connectivity in ultra-dense networks plays an important role in improving performance of mobile users in terms of throughput, handover rate and network overhead [7]. In this paper we take into consideration mmWave dual-connectivity, where a UE is connected with two mmWave SNs, while keeping connection to one MN. Fig. 3.1 shows the proposed network model. In this figure, among two connected mmWave SNs, one is an serving SN, SN_{serve}, and another is an idle SN, SN_{idle}, since we always would use one SN link for receiving data. Also, the two SNs receive sounding reference signal (SRS) periodically from the UE that they serve, and estimate downlink channel state under the assumption that channel reciprocity holds [17]. An MN controls data traffic and makes handover decision by using the channel state information delivered from two SNs.

There are some advantages of using additional mmWave connection. First, connecting with two mmWave SNs enables fast intra-RAT switching so that an MN can determine a mmWave link to serve a UE among the two links without signalling overhead. When the link of SN_{serve} is in NLOS or outage, the alternative SN, SN_{idle}, can serve a UE instead of SN_{serve} by switching data path without generating control mes-

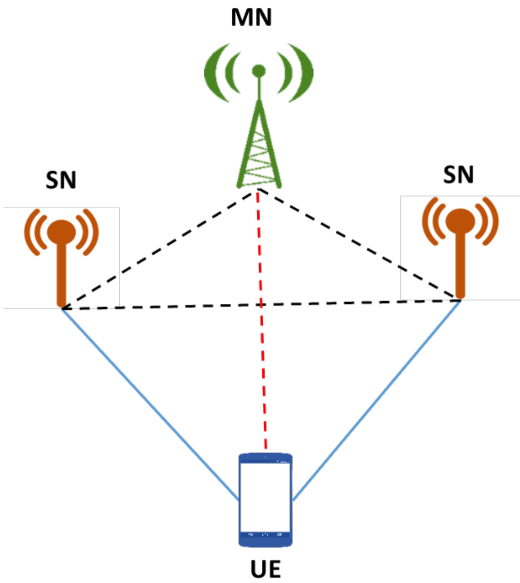

Figure 3.1: Proposed network structure.

sages for handover. This reduces the frequency of handover between SNs and service interruption time. Second, it makes SN_{serve} avoid experiencing buffer overflow problem or data loss in RLC layer by forwarding RLC data to the RLC layer at SN_{idle} via X2 interface. In other words, when the SINR value of SN_{serve} is abruptly dropped by a blockage, it may incur many packet losses and retransmissions. If SN_{serve} quickly perceives its SINR state and forwards its buffered data through X2 interface to SN_{idle} with better link quality, the duration that link quality of the UE is bad could be reduced, which results in preventing a lot of packet losses. Lastly, we can exploit a packet duplication (PD) scheme on dual-connection, where an MN forwards the same data traffic to both SNs to obtain diversity gain. On the condition that two mmWave links have lower SINR values than a certain threshold value or they are unstable, we would get link diversity gain from applying the PD scheme.

3.2 Secondary Cell Handover Scheme

Conventional handover schemes are based on single-connection between a UE and a BS, and they don't take account of the frequent handover problem in ultra-dense networks. To resolve this problem, we propose a new handover scheme, a dual-connection based handover scheme, which achieves high reliability and reduces service interruption time. We introduce the dual-connection based handover procedures as shown in Fig. 3.2, where the RRC reconfiguration message is exchanged between the MN and UE to prevent loss of control message with the help of good coverage of the MN unlike [8].

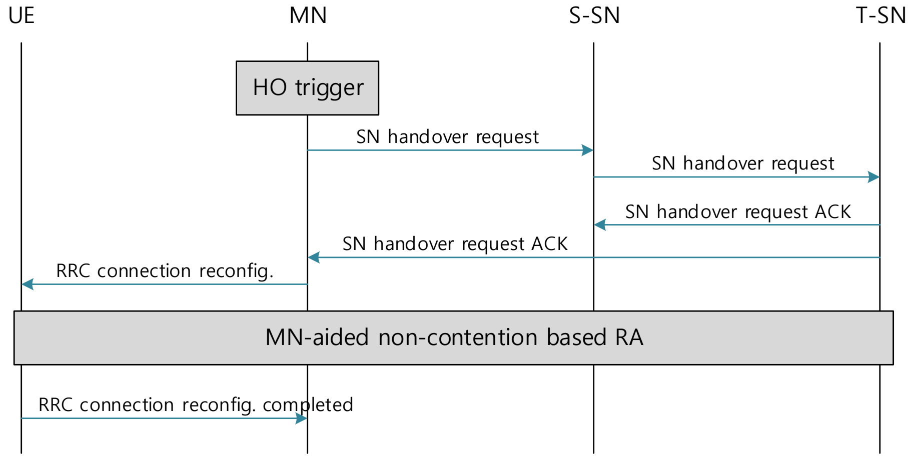

Figure 3.2: SN handover procedures.

Assuming that an MN connected with the UE obtains all channel information between SNs and a UE by periodically receiving the link state information from each SN, all control decisions such as handover, path switch and PD are determined by the MN. We present the decision-making algorithm of the MN for handover and path switching, which is based on SINR values ($SINR_{serve}$, $SINR_{idle}$) reported by the SN_{serve} and SN_{idle} as shown in Algorithm 1.

- The first case (Algorithm 1: line 2 - 9) happens when the SINR vaules of two

Algorithm 1 Handover decision algorithm

while There is at least one connectable SN **do**
  if $SINR_{serve} \leq SINR_{th}$ **and** $SINR_{idle} \leq SINR_{th}$ **then**
    Send the same packets to two SNs during HO
    if $SINR_{serve}^{target} \leq SINR_{idle}^{target}$ **then**
      Handover to SN_{idle}^{target}
      Forward the buffered data to SN_{idle}^{target}
    else
      Handover to SN_{serve}^{target}
    end if
  else if $SINR_{serve} \leq SINR_{th}$ **and** $SINR_{idle} > SINR_{th}$ **then**
    Switch data forwarding path to SN_{idle}
    Forward the buffered data to SN_{idle}
  else if $SINR_{serve} > SINR_{th}$ **and** $SINR_{idle} > SINR_{th}$ **then**
    if $SINR_{idle} > SINR_{serve}$ **then**
      Switch data forwarding path to SN_{idle}
    end if
  end if
end while

SNs are lower than a certain SINR threshold value, $SINR_{th}$. In this case, the MN makes handover decision, if there is a target SN that has better SINR value than the current one. The MN knows the candidates of two SNs (SN_{serve}^{target}, SN_{idle}^{target}) from SRS of neighbor SNs. The MN compares the two target SINR values ($SINR_{serve}^{target}$, $SINR_{idle}^{target}$) and selects one between the two candidates which has a higher SINR value than the other one. If the selected candidate is SN_{idle}^{target}, SN_{serve} will forward buffered data at RLC to SN_{idle}^{target} through X2 interface. Hence, nothing but one SN between the two connected ones will be changed. Because the SINR values of the two mmWave links are expected to be very low, if we transmit data over one path, the packet delay would be quite long during the handover event. So, whenever a handover occurs, the MN sends the same packet to the both SNs via X2 interfaces until all the handover procedures are completed to avoid the long service interruption time.

- The second case (Algorithm 1: line 10 - 12) deals with the case when NLOS or outage occurs in the transmission link being used and the other link has a high SINR value. In this case, the MN knows the channel states and changes the data forwarding path to the other SN connected with the UE. In addition, the MN sends a controlling message to SN_{serve} for triggering the buffer forwarding to SN_{idle} through X2 interface. If the SN_{serve} has the buffered data in RLC layer, then it will forward all buffered data to SN_{idle} via X2 interface.

- The last case (Algorithm 1: line 13 - 16) occurs when the two SINR values are high enough. In this case, the MN selects one SN with a higher SINR value between the two SNs and forward data to it.

In the above three cases, handover occurs only when the SINR values of two SNs are smaller than the $SINR_{th}$, which depends on QoS requirement of a UE, and only one mmWave link is used for data transmission except the case that handover occurs. Therefore, provided that the density of SNs is very high, the handover frequency would be decreased, compared with when a single-connection based handover scheme is applied. If two links are in outage and there is no candidate link to support handover, the UE will fall back to the MN, which is the same as [8].

Frequent handovers can lead to more chance of ping-pong phenomena, which means that data would be repeatedly bounced back and forth between SNs via X2 interface and it consequently make the network performance poor. In our scheme, frequent path switching can bring about ping-pong phenomena. But we averaged SINR value within in a constant time window, which will prevent the possibility of ping-pong.

Another important consideration in designing the handover scheme is the TTT value that a UE should wait until handover event starts. If the mmWave signal is highly attenuated during the TTT time, too many packet losses and resulting retransmissions may occur. The TTT value affects the frequency of handover a lot in single-connection based handover schemes. However, our dual-connection based scheme is not affected by the TTT value that much since the handover event is mainly dependent on the states of the two link states but not a single link. In other words, even though the TTT values are very low, unless the SINR values of two links are less than $SINR_{th}$, handover does not occur.

Chapter 4

Implementation and Performance Evaluation

4.1 ns-3 Simulator Implementation

We modified the uplink based initial access scheme (IA) of NYU simulator [16] to make a UE simultaneously connect one MN and two SNs by adding one more SN connection procedure. Two network devices of connected SNs with a UE use mmWave channel class whose carrier frequencies are different to avoid inter-cell interference. While a UE is moving with dual-connection, the UE should periodically determines its optimal directions to SNs to find new beam directions. To this end, we developed beam alignment scheme suitable for dual-connection. Fig. 4.1 shows the user-plane protocol models in ns-3 for enabling dual-connection to two SNs. We add all the control procedures related to handover or data path switching into RRC classes in MN and UE. In addition, network device of a UE is equipped with protocol stacks corresponding to two SNs and one MN, and all data traffic received from each RLC layer are aggregated in PDCP class at UE. Also, we implemented PDCP reordering function standardized in [19], which will be used for evaluating TCP performance.

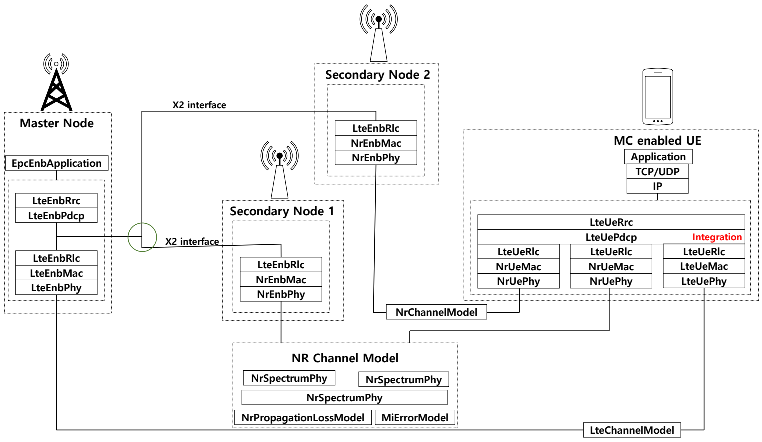

Figure 4.1: User-plane protocol models in ns-3 simulator

4.2 Simulation Setting and Scenario

The parameters we used in simulations are based on realistic system design and are summarized in Table 4.1. In simulations, low carrier frequency is employed for MNs while ultra high carrier frequency is employed for SNs on the grounds that the coverage of MN is needed to be more broad than that of SN to provide stable control signalling with a UE. Specifically, LTE and mmWave protocols are installed at MNs and SNs, respectively. Also, two different mmWave carrier frequencies were alternately placed in adjacent SNs to reduce inter-cell interference. We take account of UDP and RLC AM protocols for removing unnecessary delay and supporting file transmission reliability. Considering the coverage of mmWave BS in dense urban region [13], we emulate the dense deployment of mmWave BSs, where six BSs are located in a square area of 100×100 m^2, that is, setting the inter-BS distance as 50 m. We set UE speed as 10 m/s and make a UE move along the street between mmWave BSs. Small blockages indicating human, tree, vehicle and etc., are randomly scattered on simulation area to make mmWave channel more dynamic. The small blockages have the shape of rectangular and its widths are uniformly generated between 1.0 and 2.0 m.

Table 4.1: Simulation parameters

Parameter	Value
mmWave BS TX power (dBm)	30
mmWave bandwidth (MHz)	1000
mmWave BS antenna configuration	8×8 ULA
UE antenna configuration	4×4 ULA
Inter-BS distance (m)	50
RLC mode	RLC AM
RLC buffer size (MB)	100
LTE bandwidth (MHz)	20
UE speed (m/s)	10
LTE downlink carrier frequency (GHz)	2.1
X2 link delay (ms)	1.0
file size for downloading (MB)	0.1, 1, 10, 100, 200
file transmission interval (ms)	120
blockage size (m)	x, y dimensions $\in (1.0,\ 2.0)$
blockage density (blockages/km^2)	1000, 2000, 4000, 6000
TTT (ms)	20
$SINR_{th}$ (dB)	20

For the comparison, we take into account the handover scheme proposed in [8] as the single-connection based handover scheme. To evaluate the benefits of using dual-connection over single-connection, we simulate the file download scenario and measure the performance metrics such as file download completion time, radio resource usage, handover rates and file download failure ratio. In each simulation, the serving SN periodically sends the fixed size of the file to the UE with regular time interval of 120 ms. We conduct several simulations and show the results as a function of (i) file size when the value of blockage density is fixed at 4000 blockages/km^2 and (ii) blockage density when file size is set to 1 Mbyte to assess the aforementioned performance metrics.

4.3 Simulation Results and Discussion

4.3.1 File download completion time

In simulation, we measured file download completion time as a function of the file size as shown in Fig. 4.2. We observe that the dual-connection based handover scheme achieves smaller file download completion time by reducing the number of outlier points, which is interpreted as service interruption events. From these results, we noticed that utilizing an additional mmWave link improves QoS performance. In particular, when the file size is too large such as 100 or 200 Mbytes, the file download completion time using single-connection is much longer than that of using dual-connection, which means that large file transmission on single-connection is unlikely to guarantee QoS.

In addition, we take into consideration the case utilizing two mmWave serving links simultaneously connected with the UE and forwarding the same data from LTE eNB to mmWave gNB. In this case, RLC buffer forwarding between two connected mmWave gNBs does not occurs, and handover procedure is the same with our dual-connection based one. Fig. 4.2 shows that under mmWave-mmWave dual connectivity leveraging two serving mmWave links results in the performance degradation, even though its radio resource usage and power consumption are doubled. This is because always using two mmWave link would cause the increase of RLC AM retransmission buffer size. In order words, LTE eNB can trigger handover event for one gNB that has better SINR value and large RLC AM buffer size since another gNB's SINR value is very low or its target gNB's SINR value is much lower. So new target gNB will receive a lot of buffered data from one gNB, and another gNB's link might be in poor channel conditions, which also yield the increase of buffer size.

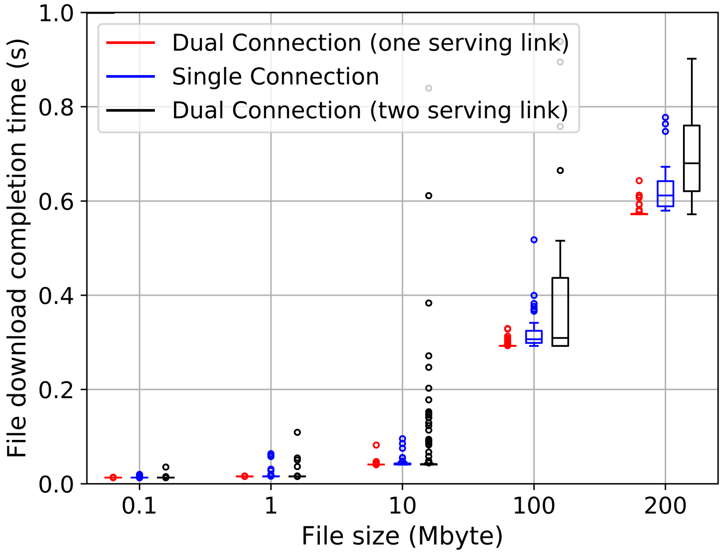

Figure 4.2: File download completion time.

Finally, even in the dual-connection based scheme, there are a few service interruption events. The reason is that the channel state information reported from SNs does not always help to predict the link state perfectly. In other words, the received SINR values may change a lot after SRS reporting when wireless environment is too dynamic.

4.3.2 Radio resource usage in user-plane

We investigated how much dual-connection based scheme wastes radio resources in user-plane and compared it with that of single-connection based scheme. Fig. 4.3 shows the sum of all transport block size allocated by MAC scheduler for only transmitting data over total simulation time. We observe the resource usage reduction of 1.5, 4.6, 2.3, 3.1 and 3.1% for each file size, when using dual-connection. This resource saving explicates that dual-connection achieves better spectral efficiency than single-connection. We traced the RLC AM retransmission buffer size during the simulation when the file size is 100 Mbyte as shown in Fig. 4.4. This figure claims that using single-connection increases the number of retransmissions because the handover event more frequently occurs in single-connection than in dual-connection. Many handover events would increase the probability that a UE stays in a poor mmWave connection, which results in the increase of the number of retransmissions. In order words, before handover event, although a connected mmWave link is very poor, a UE should wait for TTT, and total amount of this waiting time (TTT) during the whole simulation time depends on number of handover events. But the proposed scheme reduces number of TTT before handover event by replacing it with path switching.

4.3.3 Handover rate and file download failure ratio

Next, the handover rate and transmission reliability are evaluated under the different values of blockage density. We define the handover rate as the total number of handovers divided by the whole simulation time. Although the BS density is high, under the environment with high blockage density, it would be difficult to make stable connection between a UE and BS on account of frequent handovers or falling back to MN. If we have an extra link, we can use the spatial diversity and reduce the control signalling overhead caused by handover or falling back. Fig. 4.5 shows the handover rate for single- and dual-connection. Our dual-connection based handover scheme remarkably reduces the number of handovers and accordingly the overall network over-

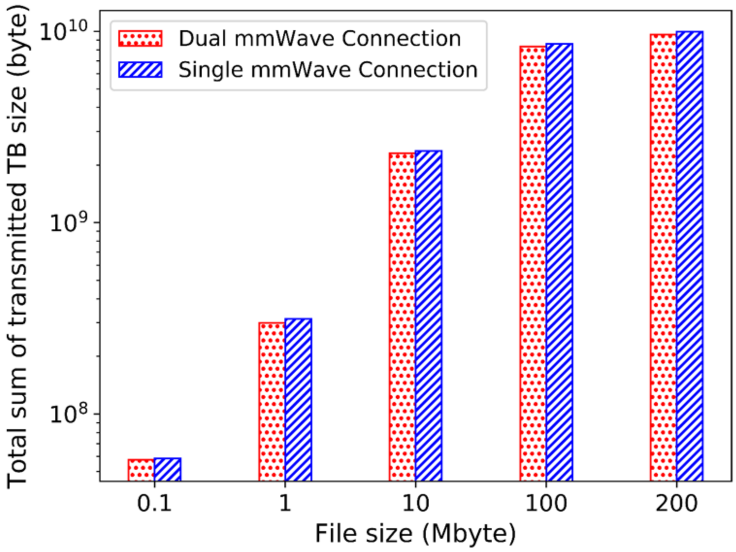

Figure 4.3: Radio resource usage.

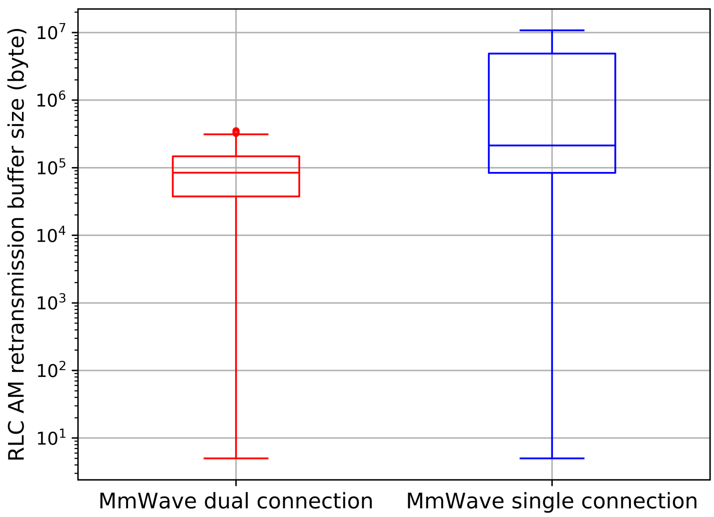

Figure 4.4: RLC AM retransmission buffer size.

head. We observe that the UE doesn't need handover especially when the blockage density is very low (1000 blockages/km^2) because it is enough to switch the data path between the two connected links.

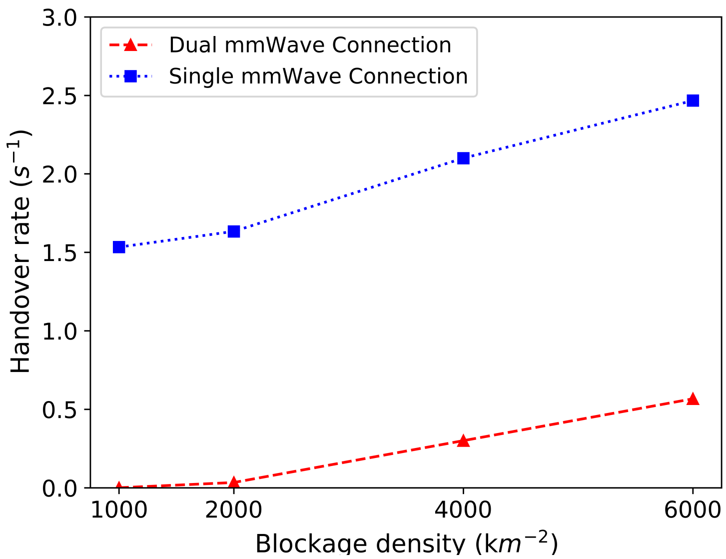

Figure 4.5: Handover rate.

To see transmission reliability, we take into account the file download transmission failure ratio, which is defined as the number of file download failures divided the total number of file transmissions. We consider the delay constraint to assess whether a file is successfully downloaded or not. In other words, if a file does not arrive within delay constraint, it is regarded as transmission failure. Fig. 4.6 shows the file download failure ratio when blockage density changes and indicates that dual-connection make the file transmission more reliable, which means we can achieve more stable QoS by applying dual-connection.

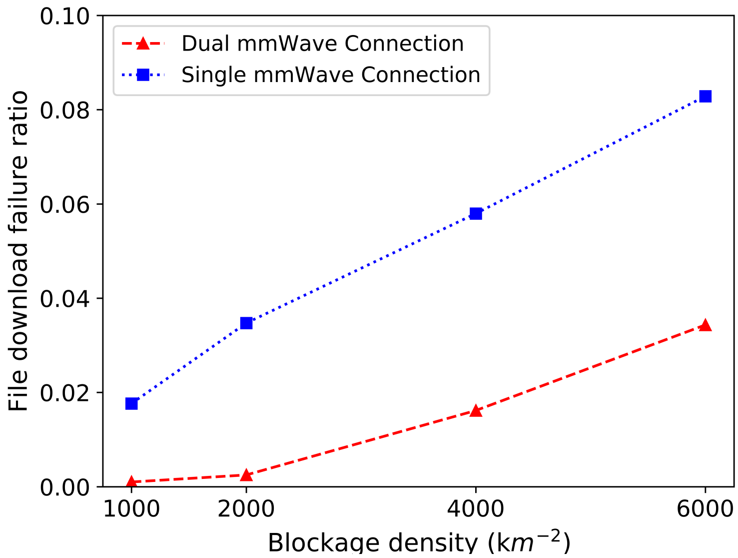

Figure 4.6: File download failure ratio.

4.3.4 TCP performance

We evaluated TCP (NewReno) performance in the same scenario and simulation setting; a UE moved up and down with a constant speed under blockage density of approximately 4000 blockages/km^2. Also, a remote server constantly transmits data to the UE with 200 Mbps data rate during simulation time, and PDCP reordering function is enabled for aggregating packets received from two paths . Fig. 4.7 and Fig. 4.8 represent that our proposed dual-connection handover scheme outperforms the single-connection based one in terms of data throughput and tcp cwnd variation. This is because proposed scheme decreases service interruption time caused by frequent handover.

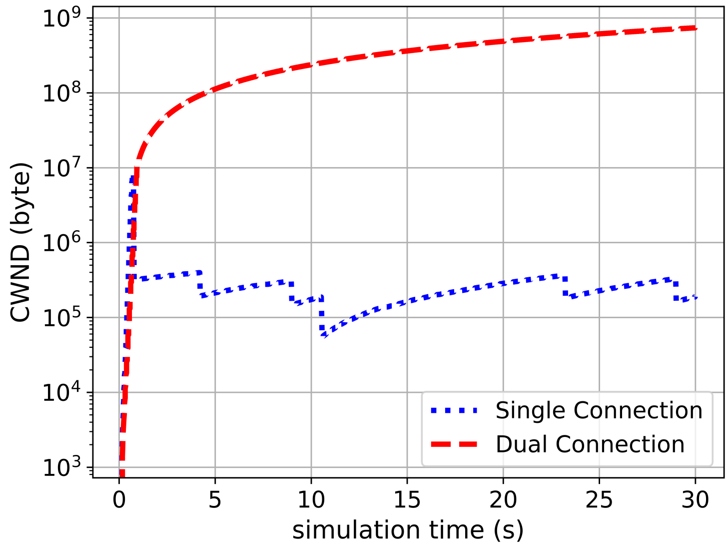

Figure 4.7: TCP CWND variation.

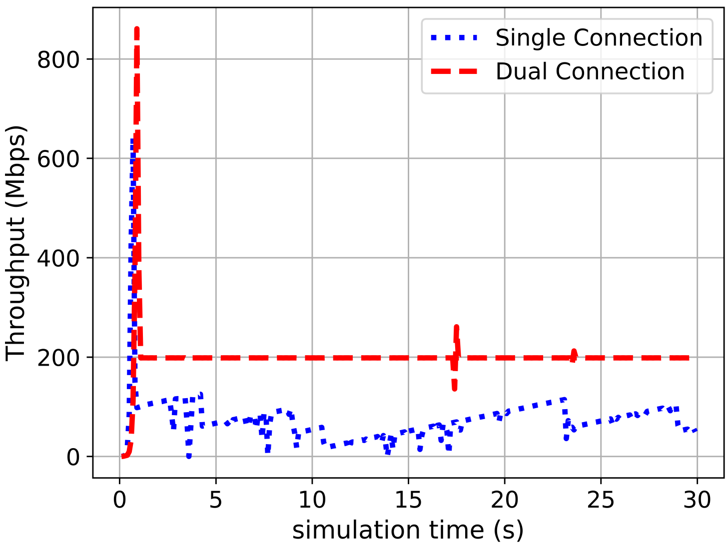

Figure 4.8: TCP throughput.

Chapter 5

Conclusion

In this paper, we proposed a mmWave-mmWave dual connection-based handover scheme and evaluated its performance through ns-3 simulation. For doing this, we modified the mmWave ns-3 modules that have been implemented by NYU. Our handover scheme takes into account the case that a UE is connected to two mmWave BSs. In simulation, we compared the performance of the dual-connection based handover scheme with that of the single-connection based one. To verify the performance of our proposed scheme, we measured the file download completion time according to the file size. The dual-connection based scheme reduces service interruption time and utilizes wireless resources more efficiently than the single-connection based one. We also examined performance in terms of handover rate in different blockage densities and observed our proposal achieves much lower handover rate in ultra-dense networks. Using the dual-connection based scheme reduces the file download failure ratio, which means that our proposed scheme is robust and reliable. Lastly, we conducted a simulation for evaluating TCP performance and substantiated that dual-connection based handover shows better TCP performance than single-connection based one.

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초 록

밀리미터 웨이브를 사용하는 초고밀도 셀룰러 네트워크에서 이동하는 단말은 기존의 네트워크보다 더 많은 핸드 오버를 경험할 것이며, 이는 서비스 중단 시간의 증가와 그로 인한 성능저하를 야기할 것이다. 이런 문제점을 해결하기 위한 솔루션으로서 다중연결성은 밀리미터 웨이브의 통신 범위를 향상시키고 링크를 보다 견고하게 할 수 있다는 점에서 현재 많이 각광 받고 있는 기법 중 하나이다. 본 논문에서는 한 개의 단말이 기존의 LTE 셀과의 연결을 유지하면서 두 개의 밀리미터 웨이브 셀과 동시에 연결하는 새로운 네트워크 구조를 제안하며, 이러한 연결성에 의존하는 단말의 이동성을 보장하며 핸드오버의 수를 감소시키기 위하여 이중연결 기반 핸드오버 기법을 제시하였다. 또한 논문에서는 제시한 이중연결기법 기반의 핸드오버 기법과 기존의 단일 연결 기반의 핸드오버 기법을 ns-3 시뮬레이션을 통해 구현하고 비교하였다. 시뮬레이션 결과는 제안 된 기법이 핸드 오버 비율, 전송 실패율 및 전송 지연 시간을 크게 감소시킨다는 것을 보여주었다. 따라서 본 논문은 이중 연결 기반 핸드 오버 기법이 네트워크의 부담을 줄여주고 더 안정적인 전송을 보장하며 보다 나은 서비스 품질을 제공 할 것이라고 주장한다.

주요어: 5G, 다중연결성, 초고밀도 네트워크, 스몰셀 핸드오버, ns-3 시뮬레이션
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