A MADM-based Handover Management in Software-defined 5G Network

Xu Liya[1,2], Deng Anyuan[1], Ge Mingzhu[1,2], Shi Jiaoli[1,2], Gao Guangyong[1]

Abstract— The network densification is one of the key components of 5G to satisfying high data traffic. However, dense deployment of small cells introduces numerous challenges. Such as frequent handovers, inconsistent, interfaces, and so on. The software-defined 5G network is one important technique to solve these problems. Due to the separation of control plane and data plane, the handover management also should be redesigned in layers. In the paper, we have proposed a handover management strategy based on Multiple Attribute Decision Making (MADM) in Software-defined 5G network. The handover operations are managed by the handover controller in control plane. According to the simulation results, the proposed handover management strategy has the less delays and handover failure ratios than the conventional LTE[1].

***Index Terms*—Handover, MADM, Software-defined 5G network, SDN**

I. INTRODUCTION

The unprecedented growth in the number of mobile nodes, connected devices, and data traffic lead to wireless traffic explosion. In 2014, the global mobile traffic experienced around 70% growth[1]. Only 26% smart phones (of the total global mobile devices) are responsible for 88% of total mobile data traffic[1]. Cisco's Visual Networking Index (VNI) forecasts that more than half of the devices connected to the mobile networks are smart devices by 2019. The dense deployment of small cells is a solution to the wireless traffic explosion. By deploying large number of low power small BSs inside the deployment area of a single macrocell, the network capacity, spectrum efficiency and date rates are significantly improved and the coverage is extended to coverage holes.

The migration to such dense 5G deployment is a complex challenge. The dense deployment of evolved node BSs(eNBs) will also increases the interference and energy consumption of the network. Software Design Network(SDN)[2] offers a simplified solution for this challenge. There is a separated architecture for control and date planes in 5G network. And handover operation in 5G network should also be re-designed in both tiers for the better performance.

In this paper, we only focused on handover management.

Firstly, the dense deployment of eNBs and the great number of mobile node will increase the handover count. The frequent handovers may result in deterioration in communication performance. Specifically, if the frequent handovers occur between the target and serving cells continuously, the ping-pong handover problem will be observed. Furthermore, the increase in handover will consume more network resources and energy. There are a lot of studies to solve these problems. In the papers [3]-[5], the handover skipping techniques are proposed to reduce the handover count. A handover management technique, based on self-organizing maps is proposed in [6] to reduce unnecessary handovers for indoor users in two tier cellular networks. Several other techniques to reduce unnecessary handovers are studied in [7]-[9] for two tiers downlink cellular networks. However, none of the aforementioned studies are designed in the SDN-based Architecture of communication network.

Secondly, the dense deployment of eNBs will also increase the time of handover preparation phase. All the handover management approaches need a lot of network status information to make the handover decision. So UE has to collect the information in the handover preparation phase. For example, in the LTE handover standards mobile nodes measure the RRM parameters and send the measurement reports to the serving eNB, then the serving eNB make the handover decision by using these results[10]. Furthermore, in order to choose the best or suitable eNB to handover, other information is embedded into the approaches to support the handover decision, such as velocity, trajectory, preference and so on. For example, the velocity of the UE and locations of small cells are also needed to make the handover decision[11]. The paper [12] proposed a vertical handover technique for heterogeneous networks including vehicular wireless communications. The information needed for handover consists of trajectory, throughput, packet loss ratio, latency per packet and so on.

We have proposed a novel handover management strategy for SDN-based 5G networks. The main aim of this strategy is to choose the optimal eNB to handover under the SDN-based architecture. The main contribution is to reduce the time of the handover preparation phase and the communication during handover process.

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(Advance online publication: 20 November 2019)

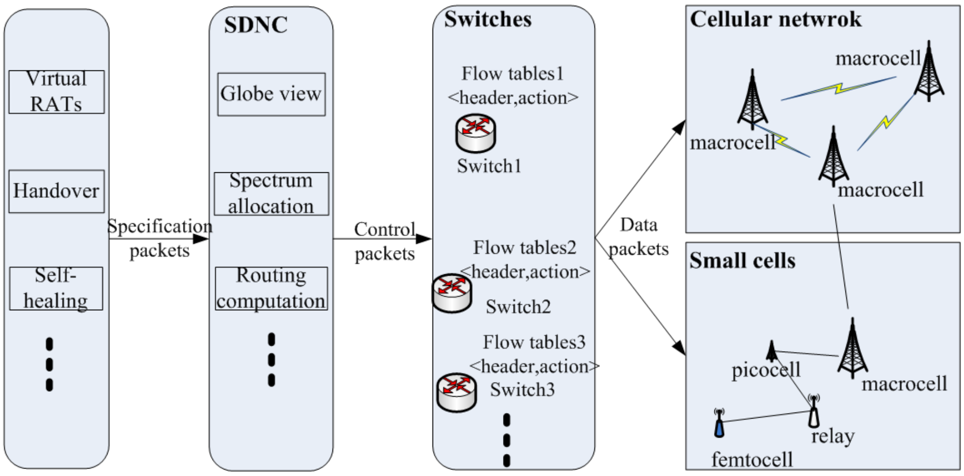


Fig.1 Architecture of SDN-based 5G network

II. SDN-based Architecture of 5G networks

As Fig.1 shows, there is an architecture of SDN-based 5G network[13]. With the application of technology of SDN in the mobile communication network, the control plane is separated from the date plane. The control logic and programmability are given to the SDN controller (SDNC) in the control plane. The SDNC executed the operations and functions in the control plane. Then the switches and routers in the date plane follow the instruction from the SDNC. Moreover, with the ability of programmability, innovations or modifications can be achieved smoothly by adding corresponding modules onto the SDNC. In the SDN-based Architecture of 5G network, the information needed for handover can be obtained from the SDN Controller (SDNC) which is located in a mobile operator or a server. In this way, the SDNC is able to manage the handover more efficiently.

The architecture of network is divided into Part A and Part B. Part A is a traditional macro-coverage-based cellular network. Complementary to Part A, Part B is constituted of small cell to meet 5G requirements. Both parts are controlled by a centralized SDNC[13].

III. Proposed Handover Management Approach

A. Handover Controller

In the SDNC, we added a controller whose name is Handover Controller to the control plane. It consists of eNB attribute quantization Engine and eNB selection engine. The handover controller collects the network state information and quantifies eNB's attributes. It calculates the priority of each neighbor eNBs. The eNB with highest priority is selected to be target eNB to handover. Then the handover controller assigns the UE to handover to the target eNB from source eNB. The handover procedure would also send to the switches which are located on the route of the User Equipment (UE).

eNB attribute quantization Engine: This module collects the network state information and quantifies eNB's attributes. These attributes would be used to select the most appropriate eNB by the handover management module.

(1) eNB load. This value is the probability of target eNB having the available resource. It is calculated for each of the neighbor eNB with call arrival and termination rates. If the eNB has a large number of available resources, the probability of target eNB having the available resource is high. And handover failures and delay will be low. Otherwise, if the value of probability is small, the target eNB would be congested. It leads to the higher probability of handover failures and delay.

TABLE 1
DESCRIPTION OF VARIABLES AND ABBREVIATIONS

NAME	DEFINITION
eNB	evolved node base station
UE	User Equipment
SDN	Software Design Network
SDNC	SDN Controller
RSSI	Received Signal Strength Indication
HoTime	handover time
HisHoTime	historical average of switching time
$T_{U\text{-}S}$	the time to send the packets such as Measure Control, Measure Report and Handover Command between UE and Source eNB
T_{CM}	the time UE measured the channel
$T_{S\text{-}T}$	the time to send the packets such as Handover Req and handover Ack between Source eNB and Target eNB
$T_{U\text{-}T}$	the time to send packet of Handover Confirm from UE to Target eNB
T_H	the time UE changed the communication from Source eNB to target eNB
T_{HD}	the time eNB made the handover decision
T_{update}	the time to update the mobile related information in the Controller

In order to facilitate the study, we assume that each eNB has n resources initially. It means that the max number of simultaneous connection to each eNB is *N*. Furthermore, if a new connection is accepted by the eNB, the resource number minus 1. And the resource numbers of the eNB will plus 1 if a connection is terminated.

$$P_i = 1 - \frac{1}{1+\sum_{i=1}^{\infty}\prod_{i=1}^{N}\frac{\lambda_{i-1}}{\mu_i}}, \forall i = 1,2,... \quad (1)$$

(2)Average handover time. The average handover time T_{a_i} is the historical average time (*HisHoTim*) that UE switching to a_i .

Handover time. The time spent to complete the handover operation process. And the UE can send and receive data packets.

After the successful handover of each UE, a packet will be sent to the primary access point, including the handover time (*HoTime*) and the new access point ID.

HisHoTime will be updated after access point receiving HoTime.

$$HisHoTime = \alpha \times HisHoTime + \beta \times HoTime$$

Where $\alpha + \beta = 1$. Take the compromise value between α and β. If the current network status pays more attention on the current network environment, set $0 < \alpha < \beta < 1$.In particular, if the HisHoTime is empty, that is, the first time to receive handover time sent by the target access point, $HisHoTime = HoTime$.

(3)Deflection angle. The value of deflection angle reflects probability of UE accessing the coverage of eNB and the residence time in eNB coverage. The larger value means a longer residence time. The deflection angle φ is shown in the fig.2.

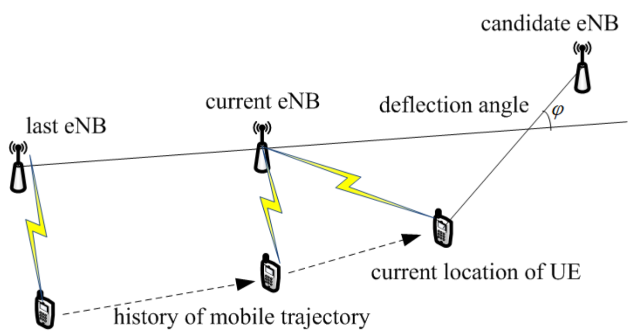


Fig.2 deflection angle

In the proposed approach, the residence time prediction based on the history of mobile trajectory has not been adopted. The handover procedure is managed by centralized SDNC. If the every UE upload the location every once in a while, It will bring a lot of extra network overhead. So the deflection angle related to the historical trajectory is used to calculate the most appropriate eNB.

(4)RSSI. The value of RSSI is measured by UE when handover operation initialized. However, the observed values may also be erroneous due to interference and other factors. Therefore, it is inaccurate to use the value of RSSI at a given time as an important handover attribute. And it is also not an ideal method to calculate a historically weighted average by using multiple observations of the network state in the recent period.

The RSSI of eNB over the recent period can be regard as an infinite population, and the sample is the observe value of RSSI every once in a while. As UE can not send and receive data when scanning channels, and the more samples will lead to extra network overhead. It is impossible to reduce sampling errors by increase sample size.

UE observer the RSSI of eNB every Δt , and $\{r_1, r_1, \ldots r_k\}$ .As the RSSI is particularly susceptible to interference, there may be differences between the observation value and real value. Moreover, the existing research have proved that the RSSI basically obeys the normal distribution. So we can set the confidence degree α to calculate the RSSI confidence interval $(\bar{r} - z_{\alpha/2}\frac{\sigma}{\sqrt{k}}, \bar{r} + z_{\alpha/2}\frac{\sigma}{\sqrt{k}})$.

$$\begin{cases} r_{ij}^L = \bar{r} - z_{\alpha/2}\dfrac{\sigma}{\sqrt{n}} \\ r_{ij}^R = \bar{r} + z_{\alpha/2}\dfrac{\sigma}{\sqrt{n}} \end{cases} \tag{2}$$

While α is the mean value of k times observation value and σ is the is the total variance. The confidence degree α is set in advance. The confidence degree refers to the probability that the real value falls in a certain area of sample statistics. The higher the confidence degree, the larger the confidence interval is. Obviously, the confidence interval cannot be arbitrarily expanded. It is necessary to set a relatively reasonable confidence level to eliminate the impact of some instantaneous peaks on handover decision-making, so that attribute intervals can more accurately reflect the real state of the network.

eNB selection engine： This module gets the quantized attributes of neighbor eNBs from the eNB attribute quantization Engine to calculate the priority of eNBs. Then select the most optimal eNB.

The handover decision policy is based on TOPSIS in this paper, and the decision attributes are $\{G_1, G_2, G_3, G_4\}$. The specific meaning is shown in Table 2.

TABLE 2
HANDOVER DECISION ATTRIBUTES

NAME	DESCRIPTION
G_1	eNB load
G_2	average handover time
G_3	deflection angle
G_4	Received Signal Strength Indication(RSSI)

For a UE with *m* candidate access schemes $\{X_1, X_2, X_3 \ldots, X_m\}$ and 4 decision attributes, the decision matrix is established as follows:

$$X = \begin{bmatrix} X_1 \\ \vdots \\ X_m \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} \\ \ldots & & & \\ x_{m1} & x_{m2} & x_{m3} & x_{m4} \end{bmatrix} \tag{3}$$

As the units, dimensions and orders of magnitude of 4 decision attributes are different, normalization is needed for all judgment indicators.

$$y_{ij}=\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}},1\le i\le m,\ 1\le j\le 4 \quad (4)$$

Then we get the standard matrix $\mathrm{Y}=\left[\mathrm{y}_{\mathrm{ij}}\right]_{m\times 3}$

$$Y=\left(\mathrm{y}_{\mathrm{ij}}\right)_{m\times 3}=\begin{bmatrix} y_{11} & y_{12} & y_{13} & y_{14} \\ \dots & & & \\ y_{m1} & y_{m2} & y_{m3} & y_{m4} \end{bmatrix} \quad (5)$$

The weight vector is set as follows according to users' preset preference,

$$w=(w_1,w_2,w_3,w_4),\sum_{j=1}^{4} w_j=1 \quad (6)$$

In reality, the definition of users' preference for network properties possesses ambiguity and vagueness, and the introduction of fuzzy set theory can implement the conversion between linguistic variables and fuzzy numbers through membership function. However, traditional fuzzy multi-attribute decision-making has the problem of complete calculation when using fuzzy number in fuzzy logic operation, which brings adverse impact on handoff performance and has higher demands on the computing power of mobile nodes.

Chen and Hwang proposed a multi-attribute decision-making method which is able to effectively solve the problem [14]. In the method proposed by Chen and Hwang, we synthesize and revise the research of several scholars, propose eight semantic scales, and represent semantic items by triangular and trapezoidal fuzzy number, which is suitable for two to eleven semantic items representatively. In this paper, we adopt five linguistic variables to characterize the user's preferences: very low, low, medium, high, very high. According to the formula $\mu_T=\left[\frac{\mu_R(M)+1-\mu_L(M)}{2}\right]$ (where $\mu_R(M)$ and $\mu_L(M)$ are the boundary values around fuzzy number M), the fuzzy number is converted into the corresponding exact value:" 0.091, 0.283, 0.5, 0.717, 0.909." Bring them to formula (6), and normalize them.

The weighted normalized decision matrix is established, and matrix V is obtained by multiplying each column of the matrix Y by the corresponding weights. Thus the weighted normalized decision matrix V is as follows:

$$V=\begin{bmatrix} v_{11} & v_{12} & v_{13} & v_{14} \\ \vdots & & & \\ v_{m1} & v_{m2} & v_{m3} & v_{m4} \end{bmatrix}=\begin{bmatrix} w_1y_{11} & w_2y_{12} & w_3y_{13} & w_4y_{14} \\ \vdots & & & \\ w_1y_{m1} & w_2y_{m2} & w_3y_{m3} & w_4y_{m4} \end{bmatrix}$$
(7)

Determine the ideal solution and the negative ideal solution. X^+ and X^- represent the ideal solution and the negative ideal solution respectively:

$$X^+=\begin{cases} \{(\min_i v_{ij}\}=\{v_1^+,v_2^+,v_3^+\} \\ [v_4^{L+},v_4^{R+}]=[\max_i v_{i4}^L,\max_i v_{i4}^R]=\{v_4^+\} \end{cases} \quad (8)$$

$$X^-=\begin{cases} \{(\max_i v_{ij}\}=\{v_1^+,v_2^+,v_3^+\} \\ [v_4^{L-},v_4^{R-}]=[\min_i v_{i4}^L,\min_i v_{i4}^R]=\{v_4^-\} \end{cases} \quad (9)$$

Where J is the benefit index, and J' is the cost index.

The distance between all alternatives and ideal alternative is measured by 3 dimensional Euclidean distances:

$$D_i^+=\sqrt{\sum_{j=1}^{4}(d_{ij}^+)^2},\quad 1\le i\le m \quad (10)$$

$$D_i^-=\sqrt{\sum_{j=1}^{4}(d_{ij}^-)^2},\quad 1\le i\le m \quad (11)$$

$$d_{ij}^+=\begin{cases} v_j^+-v_{ij} & ,\quad j=1,2,3 \\ \max(\left|v_4^{L+}-v_{ij}^L\right|,\left|v_4^{R+}-v_{ij}^R\right|) & ,\quad j=4 \end{cases} \quad (12)$$

$$d_{ij}^-=\begin{cases} v_{ij}-v_j^- & ,\quad j=1,2,3 \\ \max(\left|v_{ij}^L-v_4^{L-}\right|,\left|v_{ij}^R-v_4^{R-}\right|) & ,\quad j=4 \end{cases} \quad (13)$$

The relative closeness of ideal solution C_i^+ is:

$$C_i^+=\frac{1}{\frac{D_i^+}{D_i^-}+1},0<C_i^+<1,i\in M \quad (14)$$

When C_i^+ approaches 1, and scheme X_i approaches X^+

Then for *m* candidate access scheme $\{X_1,X_2,X_3\dots,X_m\}$, the objective function of the multi-objective decision making method corresponding to k decision attributes is as follows:

$$\underset{\forall a_i}{Max}(C_i^+)$$

The algorithm of eNB selection is shown in Table 3.

TABLE 3
THE ALGORITHM OF ENB SELECTION

Algorithm1: CLOSED-DEGREE(List)
input: list of eNBs, the performance of eNBs
output: the optimal eNB
V can be updated using formula (7)
FOR (i=1;i<=M;i++)
FOR (j=1;j<=4;j++)
IF j !=3 **THEN**
IF $v_{ij}>v_j^-$ **THEN** $v_j^-=v_{ij}$ **END IF**
IF $v_{ij}<v_j^+$ **THEN** $v_j^+=v_{ij}$ **END IF**
END IF
IF j=3 **THEN**
IF $v_{ij}<v_j^-$ **THEN** $v_j^-=v_{ij}$ **END IF**
IF $v_{ij}>v_j^+$ **THEN** $v_j^+=v_{ij}$ **END IF**
END IF
END FOR
END FOR
the C_i^+ of each access point can be updated using formula
RETURN max(C_i^+);

B. The handover procedure

There are two conditions that UE handover to a new eNB: ①the RSSI of current eNB is lower than the low threshold value; ②the performance of the current eNB cannot meet the user's demand for QoS.

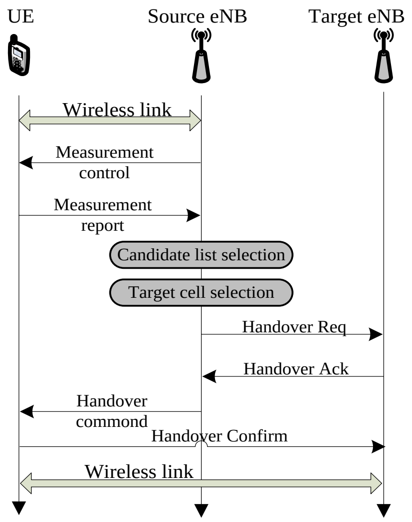


Fig.3 LTE handover procedure

In the traditional mobile communication technology such as 3GPP, UE has to measure the radio resource management (RRM) in the handover preparation phase. UE sends the measurement reports to the source eNB, and the source eNB makes the handover decision by these results. Then the source eNB sends the handover request to the target eNB[12]. The handover process is summarized in Fig.3. There are two principal questions: ① The UE does not have the status information of network, and it has to measure the channels. The process increases the handover delay. ② The complicated handover algorithms which is focus on selecting the best target eNB for UE to handover will also increase the handover delay. The reason is that more status information should be collected to calculate the priority of eNBs in the handover preparation phase.

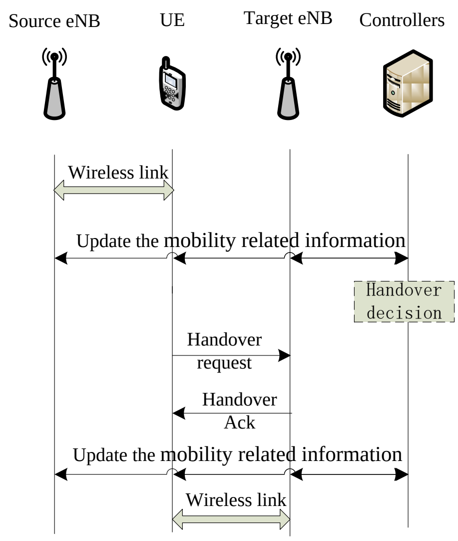


Fig.4 proposed handover procedure

The SDNC keeps monitoring the whole network and performing normal operations such as executing the virtual RATs or handover mechanisms. The handover controller can get the information needed for handover from data plane or other controllers of SDNC in control plane, such as status information of eNBs, mobile node subscription information, mobile identification, tracking area updates and so on.

As Fig.4 shows, when the handover is triggered, the UE sends the request to the controller. The handover controller makes the handover decision by quantifying eNB's attributes and calculating the priority of candidate eNBs. The handover controller manages the whole handover procedure, and UE handover from the source eNB to the target eNB. Then the control information is updated the by OpenFlow protocol to make the new connection.

IV. Theoretical Analysis

A. The analysis Handover Delay

The handover delay is defined as the time spent to handover from source eNB to Target eNB. The time is an important index to measure the actual performance of the handover algorithm. The smaller the value is, the faster the handover operation is completed. And the handover failure ratios would be lower too.

In the traditional mobile communication technology such as 3GPP, UE sends the measurement reports to the source eNB, and the source eNB makes the handover decision by these results. Then the source eNB sends the handover request to the target eNB. The handover process is summarized in Fig.2.

In LTE, the time from UE initializing handover to starting to send a packet through target eNB is as follows:

$$HDelay_1 = 3T_{S-U} + T_{CM} + T_{HD} + 2T_{S-T} + T_{U-T} + T_H \tag{13}$$

Where T_{S-U} is the time to send the packets such as Measure Control, Measure Report and Handover Command between UE and Source eNB. T_{CM} is the time UE measured the channel. T_{S-T} is the time to send the packets such as Handover Req and handover Ack between Source eNB and Target eNB. T_{U-T} is the time to send packet of Handover Confirm from UE to Target eNB. T_H is the time UE changed the communication from Source eNB to target eNB. T_{HD} is the time eNB made the handover decision.

The time from UE initializing handover to starting to send a packet through target eNB in proposed approach is as follows:

$$HDelay_2 = T_{U-C} + T_{HD} + 2T_{U-T} + T_H + 2T_{update} \tag{14}$$

Where T_{update} is the time to update the mobile related information in the Controller. And it is affected by the network load, the location of the Controller and so on. T_{U-T} is the time to send packet of Handover Req and Handover Ack between UE and Target eNB.

It is well known that 5G is characterized by high speed, low delay and high capacity. The time of sending packets is relatively short, and T_{CM} in handover delay represents a significant proportion. Furthermore, the dense deployment of eNBs would exacerbate this situation.

B. Algorithmic Time Complexity Analysis

As the Table 3 shown, the time complexity of algorithm of eNB selection is $O(M)$. The time cost of handover decision is related to the number of candidate eNBs.

V. SIMULATION

A. The comparison of performance parameters

TABLE 4
SIMULATION PARAMETERS

PARAMETER NAME	VALUE
number of macrocells	20
number of small cells	100-500
number of UE	100-1000
Resource number(N)	50
speed of UE	0-30m/s
Radius of macrocells	1000m
Radius of small cells	200m
Densification ratio	10-100
Bandwidth	10MHz
TXPOWER of macrocells	50db
TXPOWER of small cells	30db

In order to test and verify the performance of the proposed algorithm, we focus on analyzing the following parameters:

Waiting times: UE should search the channel and get the network state information in the handover preparation phase.

Average handoff delay: the time spent to handover from source eNB to Target eNB.

Average handoff times: the sum of handoff times for each UE.

Average handover failure ratios: the average handover failure ratios for each UE.

The simulation software adopts MATLAB. The main simulation parameters are given in the TABLE 4.

B. Performance comparison

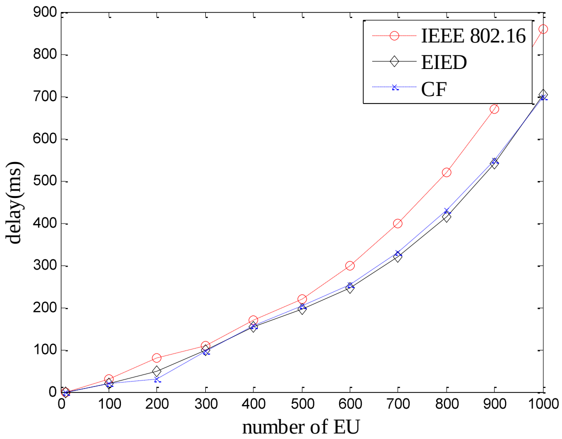


Fig.5 waiting time before handover

As mentioned earlier, the dense deployment of eNBs can significantly improve the network capacity, spectrum efficiency and date rates. But the dense deployment of eNBs will also increase the interference and energy consumption of the network. SDN is a simplified solution for dense deployment of eNBs in next generation mobile communication network. The date plane of SDN based 5G networks consists of a great many of dummy small cells and UEs. In order to show the densification level of the date plane and study the relationship between densification level and handover performance, we defined the densification ratio $\psi = \delta_{UE} / \delta_{SCell}$ .Where δ_{UE} is the number of UEs per unit area, and δ_{SCell} is the number of small cells per unit area.

In the conventional handover procedure, UE has to search the channel and get the network state information in the handover preparation phase. It is a distributed control method and will increase the expenditure of energy and reduce throughput. Furthermore, when the number of UEs is large, waiting time in the queue will become rather long. The result is shown in Fig.5[15].

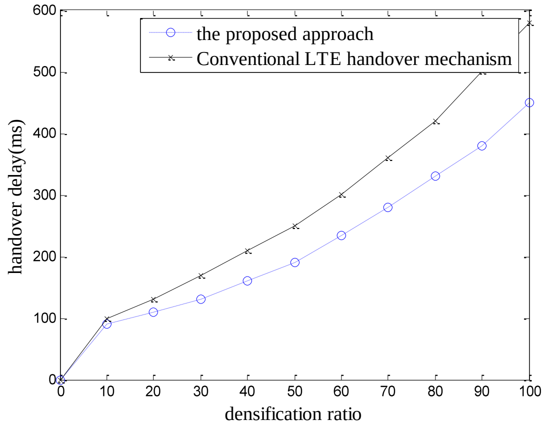
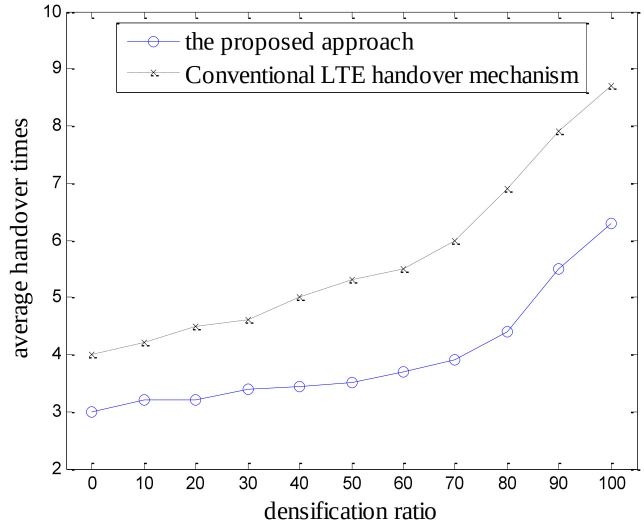
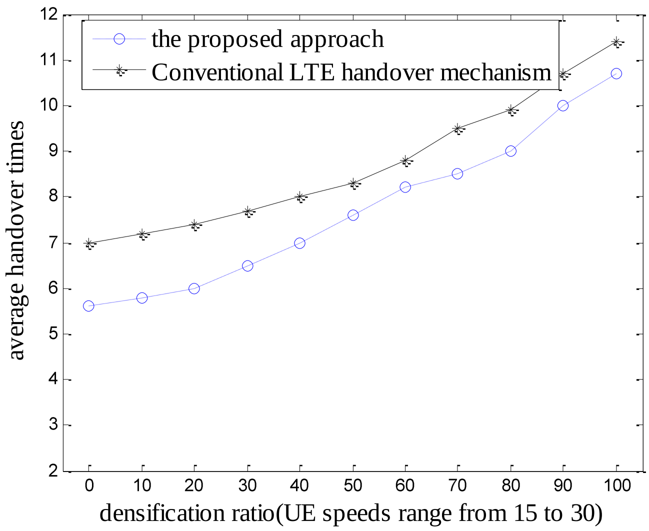


Fig.6 handover delay

Different from the conventional handover approaches, the proposed handover approach is designed in the SDN-based mobile communication network. As the SDNC keeps monitoring the whole network and performing normal operations, there is little handover preparation phase. UE only needs to handover to the target eNBs accordin to the handover decision made by handover controller. In order to observe the effects of network densification level on handover delay, we investigate the delays of the proposed handover approaches with different densification ratio. As shown in the Fig. 6, although handover delay increases with the higher densification ratio, adverse effects are still acceptable. Compared with Fig. 5, the waiting time before handover is still less than the conventional handover procedure. The reasons are as follows: ① the number of OpenFlow table entries and the packet transmission delay are increasing with the growth of densification ratio. ②UE has to search the channel and get the network state information in the handover preparation phase. ③ Collecting network information by UE is more time-consuming than acquiring network information from SDNC.

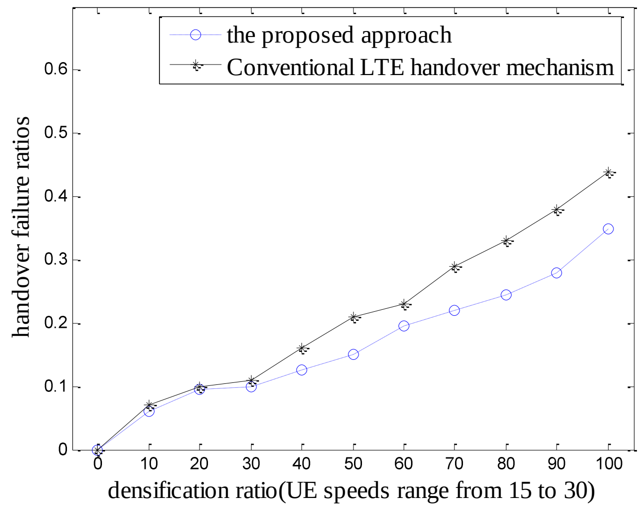


(a) UE speeds range from 0 to 1

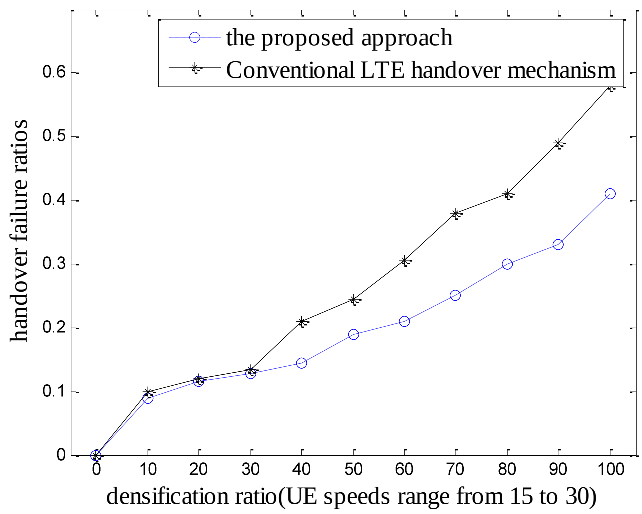


(b) UE speeds range from 15 to 30

Fig.7 average handover times



(a) UE speeds range from 0 to 15



(b) UE speeds range from 15 to 30

Fig.8 handover failure ratios

We also compared the performance of the proposed and conventional approaches. First, we counted the handover times of the proposed approach and conventional LTE handover mechanism according to the increased densification ratio. As shown in Fig.7, the numbers of handover times are obviously different. The handover times of conventional LTE handover mechanism are more than the proposed approach. Then, the handover failure ratios of the proposed and conventional LTE handover mechanism are further investigated. As shown in Fig.8, the handover failure ratios of the proposed approach are less than the conventional LTE handover mechanism. The reasons are as follows: The UE in LTE network makes the handover decision according to Reference Signal Receiving Power (RSRP), and it does not have other status information of network such as eNB load, historical handover delay and so on. But the eNB with the strongest RSSI may not be the appropriate one. The inappropriate eNB may lead to more handover times or handover failure.

VI. Conclusion

In this paper, we proposed a handover management strategy for software-defined 5G network. In SDN, the SDNC keeps monitoring the whole network and performing normal operations. All the operations are managed by the handover controller in the proposed strategy. During the handover procedure, the devices of data plane are notified by OpenFlow tables. According to the simulation results, the proposed handover management strategy has the less delays and handover failure ratios.

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