QoS Based Handoff Reduction Algorithm in Small Cell Overlay Networks

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***Abstract*—In small cell wireless networks, fast and seamless vertical handoff decision making algorithms are required to minimize the handoff failures and unnecessary handoff, especially in high-speed scenario. In small cell wireless networks such as WLAN and 5G, shorter traveling time is anticipated for a fast-moving user traversing the cell coverage. This results in frequent handoffs. It leads to poor user experience and wastage of network resources. To overcome this problem, this paper proposed a new handoff decision making algorithm that integrates the traveling distance prediction technique with the bandwidth based handoff algorithm. The simulation results show that the proposed algorithm has successfully reduced the number of unnecessary handoffs and handoff failure in small cell wireless networks.**

Keywords*— Handoff failure, Unnecessary handoff, Small cell networks, Fast-moving.

I. INTRODUCTION

In the world of Internet of Things (IoT) applications, where most of the devices required internet access over heterogeneous wireless technologies [1]. The IoT utilizes wireless technology such as cellular network and Wireless Local Area Network (WLAN) for the best network service [2]. Moreover, in dense heterogeneous wireless networks of WLAN and 5G where numerous small cells are deployed, an efficient handoff between the wireless technologies is required to guarantee that the moving mobile terminal (MT) is continuously connected to the network cells seamlessly. To achieve seamless vertical handoff across different wireless technologies, the Media Independent Handoff (MIH) framework is used, with the main task to find nearby network information, reporting link quality and service to control and manage the chosen network.

We prefer small cell wireless networks such as 5G and WLAN among the wireless networks because of their high bandwidth capacity. But in small coverage cell with high-speed scenarios the MT leaves the cell coverage within a short time. This causes a high rate of unnecessary handoffs and handoff failures which in turn leads to data corruption, packet delay and poor user experience [3]. This paper proposed a handoff decision making algorithm that utilizes Received Signal Strength (RSS) to predict the traveling time within the small cell network and also the bandwidth of the network. The handoff to small cell network is triggered if and only if the estimated traveling time (t) is greater than the total handoff latency for handoff to (T_i) and handoff out from (T_o) the small cell network ($t > (T_i + T_o)$) to ensure the handoff is performed before the MT leaves the small cell network. Handoff failure occurred if MT leaves the targeted network before completing the handoff process, where t is less than T_i. If t less than $T_i + T_o$, it leads to incur of unnecessary handoff, where MT performs handoff out from the serving network just after connecting to it. In such a case, there would be wastage of network resources.

II. RELATED WORKS

A. Prediction based Handoff Algorithms

In many prediction based handoff algorithms, Received Signal Strength (RSS) is predominantly used to estimate the traveling distance. In Paper [4], proposed a scheme that measures the traveling distance in the WLAN using the trigonometric function and two RSS measurements within the WLAN coverage. The scheme performs handoff to the WLAN if the handoff latency is less than the predicted traveling time. The probability of unnecessary handoff was decreased by using this scheme. Nevertheless, this method only predicts for the MT moving in a constant speed. But MT will not have constant speed.

In paper [5] prediction based vertical handoff algorithm whereby prediction is performed before the MT enters the threshold boundary. Fig. 1 shows the scenario when the MT is moving into the WLAN cell coverage. Firstly, the MT will get distance d by multiplying the traveling time from P_b to P_{in} with the velocity of MT. The log-distance method ((13) in [5]) is used for calculating the R and r values. The estimated distance, l is calculated by using Equation (1).

$$l = \frac{R^2 - r^2 - d^2}{d} \qquad (1)$$

The accuracy of traveling distance estimation of this method is high because the prediction process started before it reached the RSS threshold value. However, this method only considers the constant speed situation like the scheme proposed by Bhatt et al. [4]. The authors further improved their method by considering MT moving with variable speed [6], [7]. The improved algorithm maintained the handoff failure and unnecessary handoff rate below 1% in highspeed.

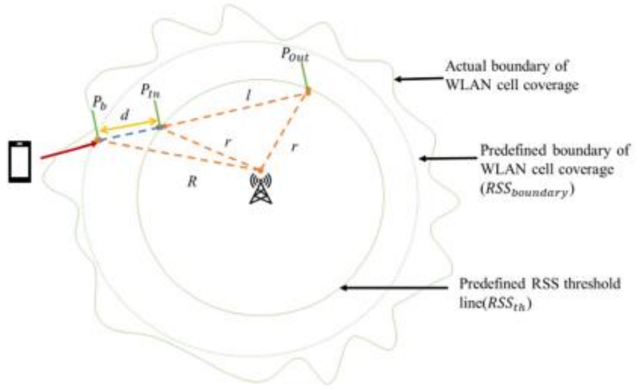


Fig. 1. Handoff from Cellular network to WLAN

B. *Multi-Criteria Based Handoff Schemes*

In paper [8] an adaptive vertical handoff decision (VHD) scheme for the heterogeneous network between the Third Generation (3G) and WLAN based on the cost function. This work aims to have a lower power consumption by estimating the trend of the cost function and RSS values using a double moving average method. In the process phase, the MT collects handoff parameters such as RSS, handoff latency and user's parameters including power consumption, cost and security. The weightage of the handoff parameters is dynamically adjusted based on the user requirements. The proposed cost function computes and chooses the best network. The results of the presented scheme gave a lower number of handoffs, high quality of service (QoS), and use less power consumption. Nevertheless, the author did not consider the speed of MT in the handoff decision making process.

In Paper [9] multi-criteria handoff for Worldwide Interoperability for Microwave Access (WiMAX), WLAN and Long Term Evolution (LTE) as shown in Fig. 2. Four handoff criteria are used: network occupancy, MT speed, cost and RSS. The scheme has shown better performance in terms of lower handoff rate. The scheme has also shown high throughput. Yew et al. [10] proposed a handoff algorithm for handoff between 3G cellular network and WLAN for telecardiology application. The handoff algorithm selects the network based on the user preference as well as health conditions. The parameters used for handoff criteria include cost, QoS and power. This work will have a high number of unnecessary handoff if users are moving at the high-speed because the algorithm will bias to WLAN when the users set a high performance to QoS.

C. *Intelligence-Based Handoff Schemes*

To improve the handoff performance, intelligent based schemes such as Fuzzy Logic and Artificial Neural Networks (ANN) are applied in the vertical handoff process. Yew et al. [11] proposed a fuzzy logic based handoff scheme for cellular network, WiMAX and WLAN. The system ensures that users can be connected to the best network based on user requirements anywhere and anytime. However, this work set the speed threshold for the small cell network. WLAN was not selected when the MT speed is higher than 10 km/h.

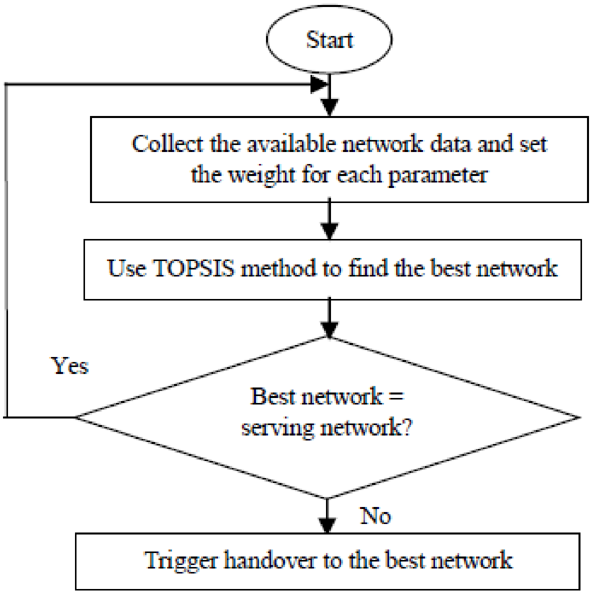


Fig. 2. Topsis based handoff scheme

In paper [12] an adaptive neuro-fuzzy that combines fuzzy logic and artificial neural network for heterogeneous networks on WLAN, WiMAX, and Third Generation (3G) cellular network. The fuzzy logic uses three input parameters which are RSS, throughput and cost function to obtain the training element as the output on the artificial neural network. The artificial neural network of the scheme obtained information from the fuzzy logic. The artificial neural networks output known as Access Point Candidacy Value (APCV) is the result of training elements of the inputs that adjusted the membership functions and rules. With this scheme, once the handoff initiation completes, the APCV of each base station (BS) candidate is compared with the present BS. When the APCV is higher than the current BS, MT triggers handoff to that network. It has been claimed the scheme has minimized the handoff rate through the shortening of the learning phase. However, the scheme only considers the slow moving cases (2.5 km/h). There will be high unnecessary handoff in fast moving cases.

III. PROPOSED SYSTEM

The proposed handoff scheme is a combination of traveling distance prediction technique and bandwidth (BW) based handoff algorithm. The bandwidth based handoff decision making algorithm always selects the network with the highest bandwidth. The Bandwidth based handoff algorithm is selected because it is less complicated compared to the multi-criteria and intelligence based handoff schemes. It will minimize the handoff process time.

The flow process of the proposed scheme is shown in Fig. 3. The small cell network such as WLAN which offers high bandwidth with low cost is highly preferred by the users. If WLAN is detected, the proposed algorithm will initiate the prediction process to estimate the traveling time in the WLAN coverage. The proposed scheme used (1) to predict the traveling distance in the small cell network. The traveling

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 03, March-2023

time (t) within the WLAN cell, can be determined by using (2).

$$t = \frac{l}{v} \qquad (2)$$

where l is the estimated traveling distance(meters) which computed using (1) and v is the velocity of the MT in m/s.

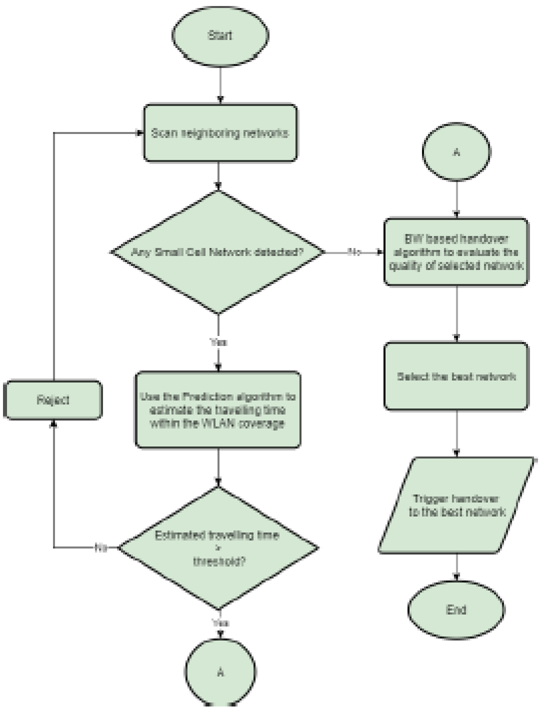


Fig3. Handoff decision making algorithm.

The traveling time estimation process only applied to small cell networks to avoid the unnecessary handoff
The proposed scheme will reject the networks which have predicted traveling time less than the threshold value (t <= 2 seconds). Only the qualified networks (t > 2 seconds) will undergo the network quality evaluation process. Here, the bandwidth based algorithm is used for evaluating the network quality because higher the network bandwidth, the better the network quality. The network with the highest bandwidth will be selected as a handoffr target.

The proposed algorithm monitors the RSS periodically at time interval T_t which is given by D_t / v, where D_t is a distance of 1 m and v is the MT velocity that was set from 40 km/h to 110 km/h. Twenty RSS samples are collected over the time interval T_t and mean value of the RSS samples is used. Mean of RSS values can minimize the impact of RSS fluctuation [8] such as avoid the ping-pong effect.

The actual travel distance, D in WLAN can be calculated by using (3).

$$D = 2\sqrt{r^2 - h^2} \qquad (3)$$

where h = |*AP y coordinate – MT y coordinate*| and r is the radius as shown in Fig. 4. *AP* is the WLAN access point.

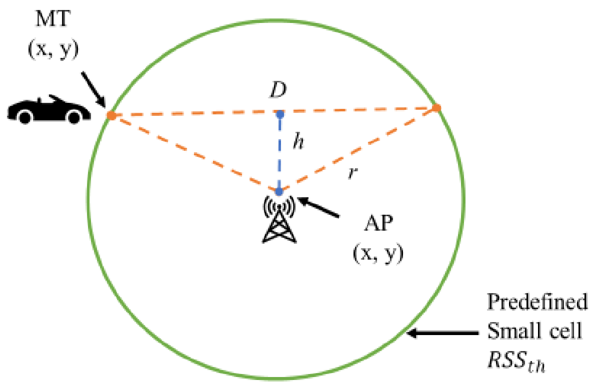


Fig. 4. Actual traveling distance within the small cell network (WLAN).

Two experiments were conducted based on the cell layout scenarios as shown in Fig. 5 and Fig. 6 (top view of WLAN cells arrangement).

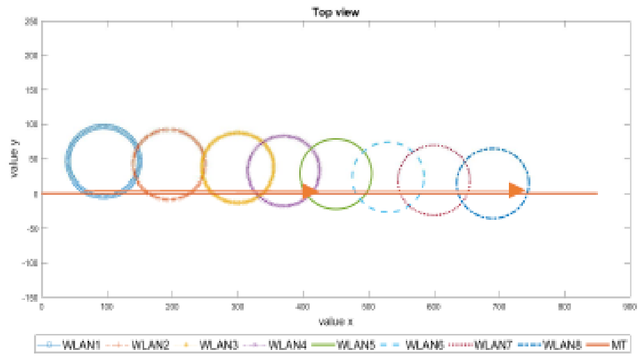


Fig. 5. First scenario

Both scenarios have eight WLAN access points with a similar length of the radius and all these WLAN cells are covered by an LTE network. The second scenario (Fig. 6) is more complicated compared to the first scenario (Fig. 5).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 03, March-2023

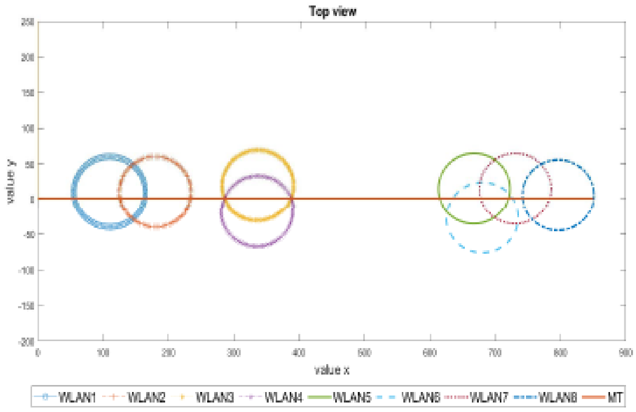


Fig. 6. Second scenario.

In the second scenario, MT will detect equal traveling distance and network bandwidth at both WLAN 3 and WLAN 4. The handoff decision making algorithm must be smart enough to choose only one AP. Otherwise, it will lead to a ping-pong effect where MT will continuously trigger handoff between WLAN3 and WLAN4. The simulation parameters of these experiments are listed in Table I.

TABLE I. SIMULATION PARAMETERS

Parameters	Value
LTE carrier frequency	1800 MHz
WLAN carrier frequency	2.4 GHz
Unnecessary handover threshold	2 seconds [6]
Handover failure threshold	1 second [6]
LTE RSS threshold	-96
WLAN Threshold	-90
LTE coverage radius	2 km
R	55 m
r	50 m
MT Speed (*v*)	40 k/m to 110 k/m
Adaptive sensing time interval	1/*v*

IV. PERFORMANCE ANALYSIS

The performance of the proposed method is compared against the conventional bandwidth based handoff. Assumed MT is moving from left to right in both the scenarios (Fig. 5 and Fig. 6). Table II and III show the comparison results of total handoff, handoff failure and unnecessary handoff for the first scenario and second scenario, respectively, at the range of the speed of from 40 km/h to 110 km/h. The simulation results shows that the proposed algorithm has significantly reduced the handoff rate in both the first and second scenarios. The conventional bandwidth (BW) based handoff algorithm is biasing to WLAN. It performed handoff to WLAN whenever WLAN is available. The high number of unnecessary handoffs and handoff failures of conventional bandwidth based handoff algorithm also due to the ping-pong effect caused by the fluctuation of RSS.

TABLE II. FIRST SCENARIO

MT speed, km/h	Total Handover		Unnecessary Handover		Handover Failure	
	BW based VHD	Proposed scheme	BW based VHD	Proposed scheme	BW based VHD	Proposed scheme
40	68	9	59	0	58	0
50	68	9	59	0	59	0
60	69	9	60	0	60	0
70	63	9	54	0	53	0
80	51	7	44	0	44	0
90	53	7	46	0	46	0
100	73	7	66	0	65	0
110	72	6	66	0	64	0

TABLE III. SECOND SCENARIO

MT speed, km/h	Total Handover		Unnecessary Handover		Handover Failure	
	BW based VHD	Proposed scheme	BW based VHD	Proposed scheme	BW based VHD	Proposed scheme
40	71	9	63	0	63	0
50	52	9	44	0	44	0
60	70	9	62	0	62	0
70	73	9	65	0	65	0
80	59	9	51	0	51	0
90	79	9	71	0	71	0
100	77	9	69	0	69	0
110	70	9	63	0	62	0

Table IV shows the comparison of estimated (using (1)) and actual (using (3)) traveling distance in the WLAN cells of both first scenario and second scenario for the range of MT speed from 40 km/h to 100 km/h. The highest error rate is observed at WLAN2 in the first scenario which is at 3.645%.

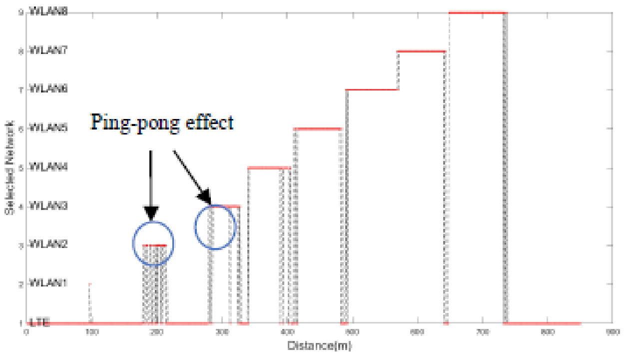
TABLE IV. ESTIMATED TRAVEL DISTANCE ERROR RATE

Access Point (AP)		1st Scenario		2nd Scenario	
		40 km/h	100 km/h	40 km/h	100 km/h
WLAN1	*l* (m)	0	0	96	96
	D (m)	0	0	97.98	97.98
	ER (%)	0	0	2.020	2.020
WLAN2	*l* (m)	42	42	96	96
	D (m)	43.59	43.59	97.98	97.98
	ER	3.645	3.645	2.020	2.020
WLAN3	*l* (m)	58	60	90	90
	D (m)	60	60	91.65	91.65
	ER	3.333	0	1.802	1.802
WLAN4	*l* (m)	70	70	90	90
	D (m)	71.41	71.41	91.65	91.65
	ER	1.980	1.980	1.802	1.802
WLAN5	*l* (m)	78	80	94	94
	D (m)	80	80	95.39	95.39
	ER	2.5	0	1.461	1.461
WLAN6	*l* (m)	86	86	78	80
	D (m)	86.60	86.60	80	80
	ER	0.6958	0.6958	2.500	0
WLAN7	*l* (m)	90	90	94	94
	D (m)	91.65	91.65	95.39	95.39
	ER	1.802	1.802	1.461	1.461
WLAN8	*l* (m)	94	94	98	98
	D (m)	95.39	95.39	99.50	99.50
	ER	1.461	1.461	1.506	1.506

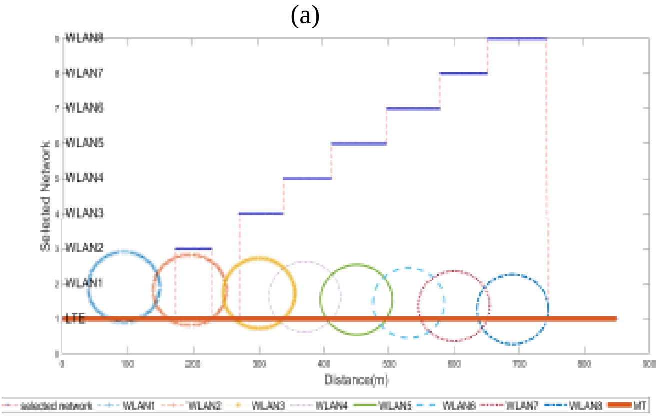
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 03, March-2023

l = Estimated distance in WLAN by (1)
D = Estimated distance in WLAN by (2)
ER = Error rate (%).

Fig. 7 shows the handoff performed by the conventional bandwidth based handoff algorithm and also the proposed handoff algorithm in the first scenario at the speed of 60 km/h. The conventional bandwidth based handoff algorithm induced a high number of unnecessary handoffs. These unnecessary handoffs are due to the algorithm handoff to WLAN whenever it detected WLAN because WLAN has higher bandwidth than LTE. Furthermore, the fluctuation of RSS caused the ping-pong effect at the boundary of WLAN during handoff to and out from the WLAN. On the other hand, the proposed scheme has no ping-pong effect because it used average RSS values. With the prediction method, the proposed algorithm did not handoff to WLAN1 because the traveling time in WLAN1 is less than 2 seconds at the speed of 60 km/h. The MT just touched the RSS threshold line of WLAN1. The actual traveling distance within the WLAN1 of the first scenario is zero meter as shown in Table IV.



(a)

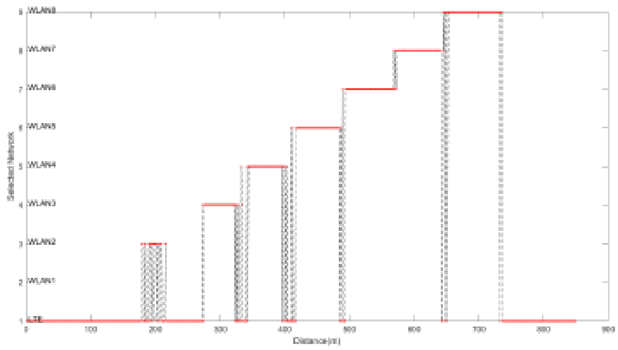


(b)

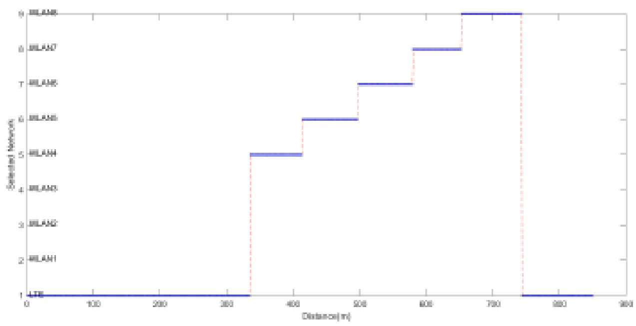
Fig. 7. Handoff performance at the speed of 60 km/h in the first scenario (a) conventional bandwidth based handoff algorithm (b) proposed handoff algorithm

The traveling time became shorter while the MT traverses the network at a higher speed. The performance of the conventional bandwidth based handoff algorithm while the MT is traveling at the speed of 110 km/h was shown in Fig. 8. Obviously, there was a ping-pong effect. The MT handoff to WLAN2 till WLAN8 even though the traveling time within the WLAN2 and WLAN3 was less than 2 seconds. However, for the proposed scheme, MT only connected to WLAN4 to WLAN8 at a speed of 110 km/h. It ignores the WLANs that have traveling time less than 2 seconds such as WLAN1, WLAN2 and WLAN3. For instance, the traveling time within the WLAN3, in the first scenario can be calculated by dividing the actual distance (*D*) within the WLAN3 with MT speed (*v*) (as given in Equation (4)).

$$t_{w3} = \frac{D}{v} = \frac{60}{110km/h} = \frac{60}{30.56\,m/s} = 1.96\,s \qquad (4)$$



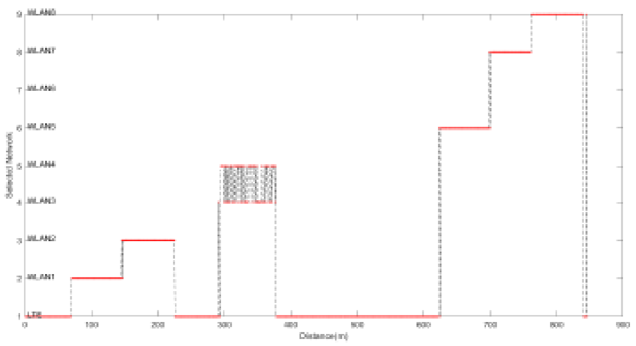
(a)



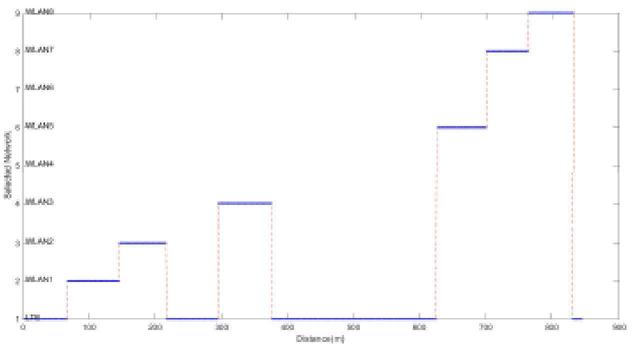
(b)

Fig. 8. Handoff performance at the speed of 110 km/h in the first scenario (a) conventional bandwidth based handoff algorithm (b) proposed handoff algorithm.

Fig. 9 shows the handoff performed in the second scenario at the speed of 70 km/h. Similar to the first scenario, conventional bandwidth based handoff has a high number of unnecessary handoffs as shown in Fig. 9(a). The MT was non-stop switching between WLAN3 and WLAN4 (ping-pong effect) while it was traversing the overlap region of WLAN3 and WLAN4. However, the number of unnecessary handoffs has significantly reduced by using the proposed handoff decision making algorithm, as shown in Fig. 9(b). The proposed algorithm randomly chose either one network while more than one WLANs provided a similar traveling time and bandwidth, to avoid inducing of the ping-pong effect at WLAN3 and WLAN4. Fig. 9(b) also shown that the MT was able to perform handoff in the overlapping region of multiple WLAN cells (WLAN5 to WLAN8). WLAN 6 was not connected due to the MT directly handoff to WLAN7 after disconnected from WLAN5. The experiment results at the speed of 110 km/h in the second scenario were shown in Fig. 10. The proposed scheme is outperformed the conventional bandwidth based handoff algorithm.

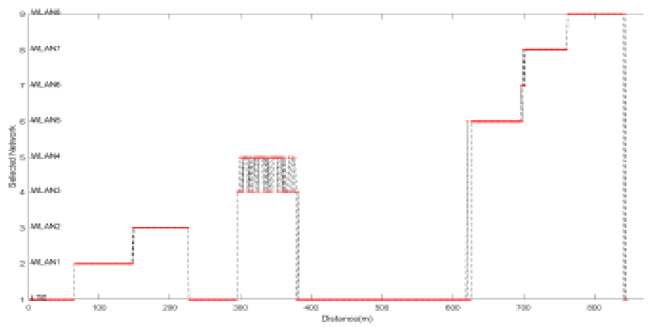


(a)



(b)

Fig. 9. Handoff performance at the speed of 70 km/h in second scenario (a) conventional bandwidth based handoff algorithm (b) proposed handoff algorithm.



(a)

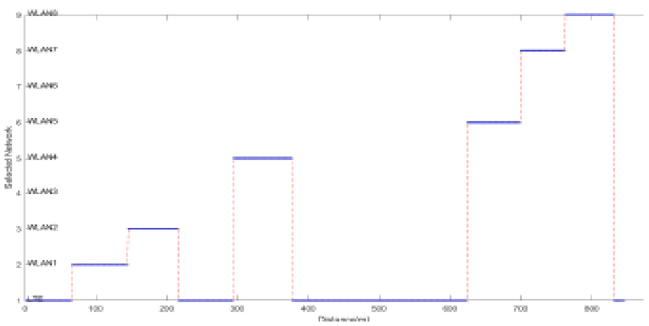


Fig. 10. Handoff performance at the speed of 110 km/h in the second scenario (a) conventional bandwidth based handoff algorithm (b) proposed handoff algorithm

V. CONCLUSION

This paper has presented a new handoff scheme to reduce the unnecessary handoff and handoff failure in the small cell wireless networks. The results show that the proposed handoff scheme has better performance than the conventional bandwidth based handover algorithm in terms of reduction number of unnecessary handoffs and handoff failures while MT is traveling at the high speed (40 km/h to 10 km/h). The accuracy of traveling distance prediction is up to 96%. The proposed scheme can improve the network connectivity. It can be applied to the telemedicine system where nurse transmits the real-time patient's health data from a fast-moving ambulance to hospital emergency centre. In future 5G parameters can be used instead of WLAN.

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