Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

INTERFERENCE MANAGEMENT USING DIRECT SEQUENCE SPREAD SPECTRUM (DSSS) TECHNIQUE IN LTE-WI-FI NETWORK

A. E. Azhar, A. L. Yusof*, M. A. Zainali and N. Ya'acob

Wireless Communication Technology (WiCoT), Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

ABSTRACT

In this paper, an enhance DSSS technique was proposed which considers both serving and its neighbouring base stations in the network. New coefficients, chip rate coefficient (α) and radius fraction coefficient (β) were applied in DSSS technique in order to improve the SINR value. First, SINR MUE and SINR WUE for the standard DSSS were simulated. Then, by using the obtained analysis, the enhance DSSS technique was proposed. As the results, the SINR at MUE using α-coefficient gives better SINR than standard around 4%~5% improvement. On the other hand, the SINR at WUE using α-coefficient also gives better SINR than standard around 9%~10% improvement. Other than that, by applying both α-coefficient and β-coefficient into the proposed DSSS based on modified interference power, the improvement for SINR MUE increases to 11%~13%. For SINR WUE, the percentage spikes to 74%~84%.

Keywords: DSSS, LTE network; Wi-Fi network; SINR; interference management and interference power.

Author Correspondence, e-mail: laily012001@yahoo.com

doi: http://dx.doi.org/10.4314/jfas.v9i4s.16

1. INTRODUCTION

Long Term Evolution (LTE) [27] is a cellular technology evolved from its predecessor, the Universal Mobile Telecommunications System (UMTS). In the near future, it has been estimated that LTE network will be suffer in network congestion due to tremendous data growth and the increase of user subscribers [1]. Prior to the situation, Wi-Fi integration in LTE network has been studied in order to improve network by offload the traffic to Wi-Fi. The details of the study can be found in 3GPP Release 12.

IEEE802.11 is a standard of WLAN. It is under Wireless Fidelity (Wi-Fi) alliance. The most critical problem in LTE-Wi-Fi network is the co-channel interference [2]. LTE-TDD Band 40 operates in frequency of 2.3 to 2.4-GHz overlapped with Wi-Fi (IEEE802.11b/g/n/ac), which also operates at frequency 2.4-GHz. If the network operator did not take this matter seriously, it can cause interference to the users. These will result in user's service degradations [3]. In [4] investigates the performance of Wi-Fi coexistence in LTE network inside a building using a simulator. Results proof that in LTE network, user throughput has slightly decreased or no impact when LTE is coexistence with Wi-Fi. However, for Wi-Fi, the user throughput was decreased about 70% to 98% for sparse and dense deployment. This is because the Wi-Fi suffers interference from LTE system and interference management is needed.

There were several interference management technique has been proposed in LTE heterogeneous network. Almost Blank Subframe (ABS) is a technique that mutes some subframes. It allows small cell to allocate its band on heterogeneous deployments in such way that the small cells did not suffer severe interference during those silent periods [5-7]. The proposed scheme had improved in total capacity achieved by the system; provided better signal-interference-to-noise ratio (SINR) and improved the capacity achieved by the victim users. However, this technique has one demerit which is the LTE gives up some time to allocate Wi-Fi subframes.

On the other hand, in [8-9] proposed the power control technique by avoiding small cells (Femtocell) to transmit more power than the users. The proposed technique improved in throughput, Packet Loss Ratio (PLR) and SINR. However, this technique is for indoor environment and did not include the macrocells in LTE network. In other research paper, in

[10] proposed interference aware operating point in LTE-Wi-Fi network by using power control technique. The performance of this simulation network was measured by mean user throughput and resulted in improvement of Wi-Fi coexistence and slightly reduces in LTE network. The disadvantage of the proposed technique is it focuses only in indoor network.

Other than that, Spread Spectrum (SS) technique can also be used to mitigate interference as in [11]. This technique was used on the second communication by using the signal-to-interference power ratio (SIR) from the adjacent base station (BS). By using the proposed technique, the UE throughput has been improved. However, this technique not included the interference power from its serving BSs. All these interference management techniques mentioned above have mainly focused on interferences between small cell-to-small cell and macrocell-to-small cell.

In this paper, we extent our investigations made in [11] where we propose Enhance SS technique by derives and simulates Direct Sequence Spread Spectrum (DSSS) in LTE-Wi-Fi network to mitigate co-channel interference in 2.4GHz.

2. DIRECT SEQUENCE SPREAD SPECTRUM

SS system can be defined as the transmitted signal that spreads over a wide frequency band than the minimum bandwidth required to transmit the information being sent. There are two types of SS system known as Frequency Hopped (FHSS) and Direct Sequence (DSSS). FHSS is a technique of transmitting radio signals by quickly switching a carrier among many frequency channels, using a pseudorandom sequence known to both transmitter and receiver. On the other hand, DSSS is technique where the signal is spread over a wider frequency band [12] using a pseudorandom code known as chipping code by directly applied to the data for spreading before the carrier modulation [13].

The DSSS system employs two identical Pseudo Noise (PN) sequence generators i.e. the PN sequence generators that interface with the modulator at the transmitting end and the PN sequence generators that interfaces with the demodulator at the receiving end. These two generators produce a PN sequence, which is used to spread the transmitted signal at the modulator and to de-spread the received signal at the demodulator. The advantages of SS technique are improves the SNR and can treat multipath interference [14]. A typical DSSS transmitter is compose of a binary message denoted by d(t) and a PN code sequence, p(t). The p(t) is generates from PN sequence generator. There are several well-known sequences such as Barker, Kasami, Gold and Hadermard-Walsh Sequence. Next, both signals go through a mixer and produces a m(t) signal. The transmitted signal ends with the m(t) go through a balanced modulator. For the receiver section, to recover the DSSS signal, the signal go through balanced modulator and multiplies with the PN code p(t).

2.1. Theoretical Part

For DSSS Transmitter, the DSSS transmitted signal can be written as [15]:

$$\mathrm{x(t)} = [d(t) \times p(t)] \bullet \cos(\omega_0 t) \qquad (1)$$

where d(t): data stream representing the information having the values ±1, p(t): a PN sequence having the values ±1 and ω_o: carrier frequency or $\omega_o = 2\pi f_c$.

At receiver, AWGN noise, n(t) is added to the transmitted signal m(t). The received signal, y(t) can be written as [16]:

$$y(t) = m(t) + n(t) \qquad (2)$$

Then, the y(t) is going through de-modulator becomes (z(t)) and de-spread by using the PN sequence (p(t)) to retrieve the data signal back.

At DSSS Receiver, the final received signal (r(t)) can be written as:

$$r(t) = [z(t) \times p(t)] + n(t) \qquad (3)$$

where z(t): signal after de-modulator, p(t): a PN sequence having the values ±1 and n(t): an additive white Gaussian noise.

In [17], the expected signal power for DSSS is given by:

$$\text{Expected Signal Power} = \mathrm{SF}^2 \mathrm{P_k} \qquad (4)$$

where SF is spreading factor and $\mathrm{P_k}$ is received signal power for user, k.

The expected interference power for DSSS can be defined as:

$$\text{Expected Interference Power} = \mathrm{SF} \sum_{\substack{i=1 \\ i \neq k}}^{N} \mathrm{P_i} \qquad (5)$$

where $\mathrm{P_i}$ is interference power.

For expected noise power for DSSS is given as:

$$\text{Expected Noise} = \mathrm{E}\{c_k^T n^H c_k\} R_c \quad (6)$$

$$= \mathrm{SFN}_0 R_c \quad (7)$$

where R_c is the chip rate.

Therefore, the SINR for user k for DSSS scheme can be expressed as:

$$SINR_k = SF \times P_k / P_i + N_0 R_c \quad (8)$$

From Equation (8), the received power (P_k) for the user can be defined as the difference of power transmitted (P_t) by a BS to the path loss (PL) and log normal shadowing in mobile network (σ_{SF}).

$$P_{k[dBm]} = Pt[dBm] - PL[dB] - \sigma SF[dB] \quad (9)$$

In LTE-Wi-Fi network, there are two types of SINR which are for Macro User Equipment (MUE) and Wi-Fi User Equipment (WUE). Equations in (8) and (9) consider the serving BS only.

2.2. Propose DSSS

For the propose DSSS technique, we focus on chip rate (R_c). We introduced new coefficient known as chip rate coefficient (α). The chip rate is the number of pulses per seconds. For LTE, the chip rate value is 3.8Mbps. On the other hand, chip rate for 802.11b is 11Mbps. By multiplying α to the chip rate for both LTE and Wi-Fi, the SINR of UE can be improves. The value of α is set between 0 and 1 ($0 < \alpha < 1$).

From Equation (8), the SINR with α-coefficient can be written as:

$$SINR_{UE} = (10\log_{10}[SF]+P_k)-(P_i+N_0+10\log_{10}[\alpha \times R_c]) \quad (10)$$

From the equation, the best value of α will be chosen for next calculation. The chosen α will gives the better SINR compares to the standard DSSS. Equation (10) will be applied for both MUE and WUE.

The standard DSSS only considers interference power from its serving BS. According to 3GPP Technical Report 36.922, the maximum interference power is -25dBm. For the propose DSSS, we modify interference power by considering the interferer BSs. In 2.4-GHz LTE-Wi-Fi network, the Downlink interference cases are as illustrated in Fig. 1.

- Case 1: I_MBS_WUE: WUE near the premise of MBS could strongly interfere to WBS-2 Downlink.
- Case 2: I_WBS_WUE: WUE in the edge of the WBS-3 could strongly interfere to neighbouring WBS-2 Downlink.
- Case 3: I_WBS_MUE: MUE near the premise of WBS-1 (Wi-Fi Base Station) could strongly interfere to MBS (Macro Base Station) Downlink.

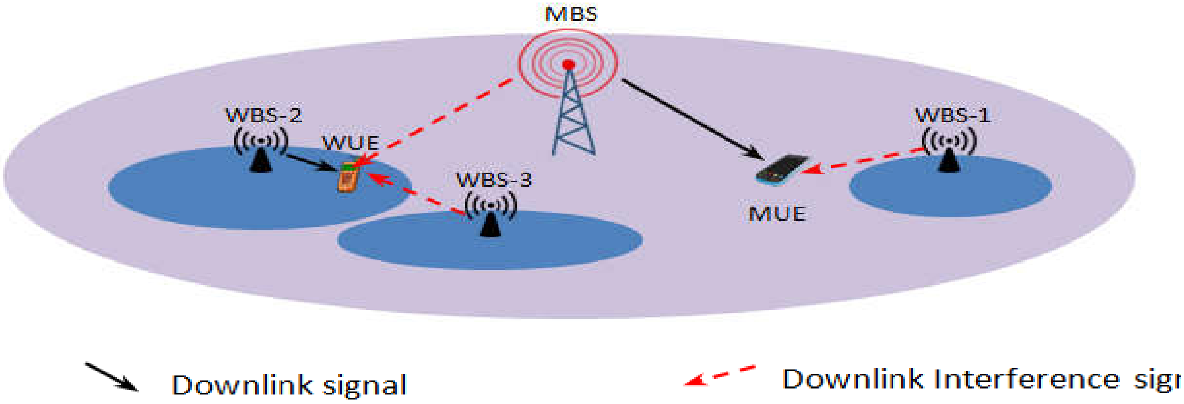


Fig.1. Interference cases in LTE-Wi-Fi network

From this illustration, the SINR at MUE and WUE based on interference power can be expressed. At MUE, it only considered interference power from WBS-1. The modified interference power for MUE is:

Pi_{MUE} = I_WBS_MUE (11)

Therefore, the SINR MUE can be written as:

$SINR_{MUE} = (10\log_{10}[SF]+P_k)-(I\_WBS\_MUE+N_0+10\log_{10}[\alpha \text{ x } R_c])$ (12)

For SINR at WUE, the interference power considers two interferers which are from MBS and WBS-3. In [18], the total interference power for an UE is the total interfering power that user received from its dominant interfering sectors whether from the sectors of same BS and different BS. The modified interference power for WUE can be expressed as:

Pi_{WUE} = I_MBS_MUE+I_WBS_WUE (13)

Therefore, the SINR WUE can be written as:

$SINR_{WUE} = (10\log_{10}[SF]+P_k)-([I\_MBS\_MUE+I\_WBS\_WUE]+N_0+10\log_{10}[\alpha\text{x } R_c])$ (14)

In previous works, the interference power can be defined by using 3-D space model [19-20]. This technique is preferable than 2-D space because it appears to approximate the actual deployment, more accurate and also more tractable. The LTE BS is assumes to use omni-directional antennas to perform beam-forming in the LTE downlink network [21]. According to [22], the interference power can be expressed as:

$$\mathrm{Pi} = 2\pi \times \rho \times \mathrm{P_{EIRP}} \times \left[\frac{\lambda}{4\pi}\right]^2 \times \left[\frac{d_0^2}{r_{\mathrm{min}} + d_0}\right] \tag{15}$$

where $\mathrm{P_{EIRP}}$: Effective Isotropic Radiation Power (EIRP) in dBm, λ: Wavelength of the signal calculated using frequency (f = 2.4GHz), r_{min}: Minimum radius of the hemisphere which there are no transmitters, d_0: The breakpoint distance [23] and ρ: Density of transmitters per unit volume.

$$\rho = \frac{N}{\frac{2}{3}\pi \times [r_{\mathrm{max}}^3 - r_{\mathrm{min}}^3]} \tag{16}$$

where N is the number of transmitter(s) and r_{max} is the maximum radius in a network.

For the propose DSSS, we focus on ρ. The value of ρ is correlated with the interference power of BSs. Lower ρ will gives the lower interference power in mobile network. Hence, we introduce new coefficient known as radius fraction (β) to the radius difference. By applying the β-coefficient, the SINR at UE will be improves. The value of β is set between 0 and 1 ($0 < \beta < 1$). The modified density of transmitters per unit volume can be rewritten as:

$$\rho_{\mathrm{modified}} = \frac{N}{\frac{2}{3}\pi \times \beta[r_{\mathrm{max}}^3 - r_{\mathrm{min}}^3]} \tag{17}$$

From this modified equation, we will choose the best value of β which gives the highest SINR. This modified equation is for both MBS and WBS.

3. RESULTS AND DISCUSSION

In this section, the mathematical formulation for SINR of DSSS technique derived in Equation (8) was simulated by different of spreading factor (SF) which are SF = 1 and SF = 8 as refer to [11] to see the effect of SINR between higher and lower SF using the propose DSSS technique. For SINR at MUE, two types of propagation loss are used to see the difference between standard PL and 2400MHz in urban macro network.

For standard PL, COST231 HATA Urban Macro is used in LTE network [24]:

$$\mathrm{PL}_{[\mathrm{dB}]} = 34.5 + 35\log_{10}[\mathrm{d}] \tag{18}$$

where d is the distance in meter.

For 2400MHz, Modified COST231 HATA in LTE network is used [25]:

$$\mathrm{PL}_{[\mathrm{dB}]} = (44.9 - 6.55\mathrm{log10}[\mathrm{hBS}])\ \mathrm{log10}[\mathrm{d}/1000] + 45.5 + (35.6 - 1.1[\mathrm{hMS}])\mathrm{log10}[\mathrm{fc}] - 13.82\mathrm{log10}[\mathrm{hBS}] + 0.7[\mathrm{hMS}] + \mathrm{C} \tag{19}$$

where h_{BS}: BS antenna height in meters with value of 32m, h_{MS}: MS antenna height in meters with value of 1.5m, f_c: Carrier frequency in MHz with value of 2400MHz, d: Distance between the BS and MS in meters and C: Constant factor with value of 3dB for urban macro.

For Wi-Fi network, the Wi-Fi outdoor propagation loss was used [26]. This path loss is for small cell in high rise urban environment which is using 3D space model technique. It assumed that each UE communicates with the nearest small cell.

$$\mathrm{PL}_{[\mathrm{dB}]} = \mathrm{PL}(\mathrm{d0}) + [10 \text{ x } \alpha\mathrm{pathloss} \text{ x } \mathrm{log10}[\mathrm{d}/\mathrm{d0}]] + \mathrm{FAF} \tag{20}$$

where d: Distance between the WBS and MS in meters, $PL_{(d0):}$ Path loss of the first meter (d_0 =1 m) with value of 40 dB for 2.4 GHz and $\alpha_{pathloss}$: Path loss exponent with value of $3 < \alpha_{pathloss} < 5$. According to [26], the value of α is fixed to 4 and FAF: Floor Attenuation Factor with value of 45 dB.

Next, the SINR of DSSS is simulated by using the chip rate coefficient (α) for both MUE and WUE. The values of α are 0.2, 0.4, 0.6 and 0.8. The propose DSSS technique is compares with the standard DSSS (without α) to see the improvement to the SINR values. Table 1 and 2 summarize the parameters for MBS and WBS.

Table 1. Parameters for MBS

Parameter	**Value**
P_{t_MBS}	46 dBm
σ_{SF_MBS}	8 dB
SF	1 and 8
P_i	-25 dBm
N_0	-174 dBm
R_C	3.84 Mbps

Table 2. Parameters for WBS

Parameter	Value
P_{t_WBS}	30 dBm
σ_{SF_WBS}	8 dB
SF	1 and 8
P_i	-25 dBm
N_0	-174 dBm
R_C	11 Mbps for Barker

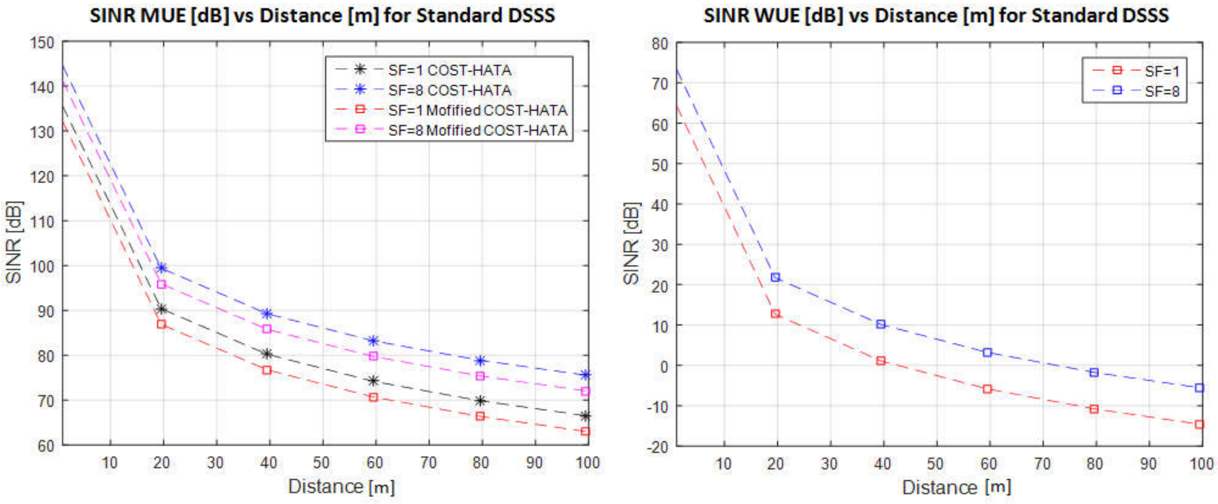
This section shows the results of SINR simulations for both standard and the proposed DSSS.

3.1. Standard DSSS

The result demonstrated that in Fig. 2 (a) and Fig. 2 (b) show the SINR values decreases as the distance increases. The reason behind this result is the SINR drop when the UE moves away from its serving BS. Both graphs also show that the SINR for both MUE and WUE with SF = 8 give higher SINR values compare to SF = 1. It is due to no SS transmission is applied in standard DSSS when SF = 1. In terms of path loss on SINR, for MUE, the result demonstrated that the SINR using Modified COST231 HATA has lower values compare to SINR using COST231 HATA. The reason is the modified COST231 HATA uses frequency of 2.4GHz instead the standard COST231 HATA that uses 1.9GHz. Other than that, by comparing both graphs, SINR WUE gives the lowest SINR compares to SINR MUE. The reason is path loss in Wi-Fi network includes the large value of path loss at d = 1m and the FAF value. Table 3 shows the SINR values at d = 1 for standard DSSS.

Table 3. SINR values by using standard DSSS

SINR [dB]	SF = 1	SF = 8
MUE (standard PL)	136	145
MUE (Modified PL)	133	142
WUE	65	74



(a) (b)

Fig.2. SINR for (a) MUE and (b) WUE versus distance for standard DSSS

3.2. Proposed DSSS

3.2.1. α-Coefficient

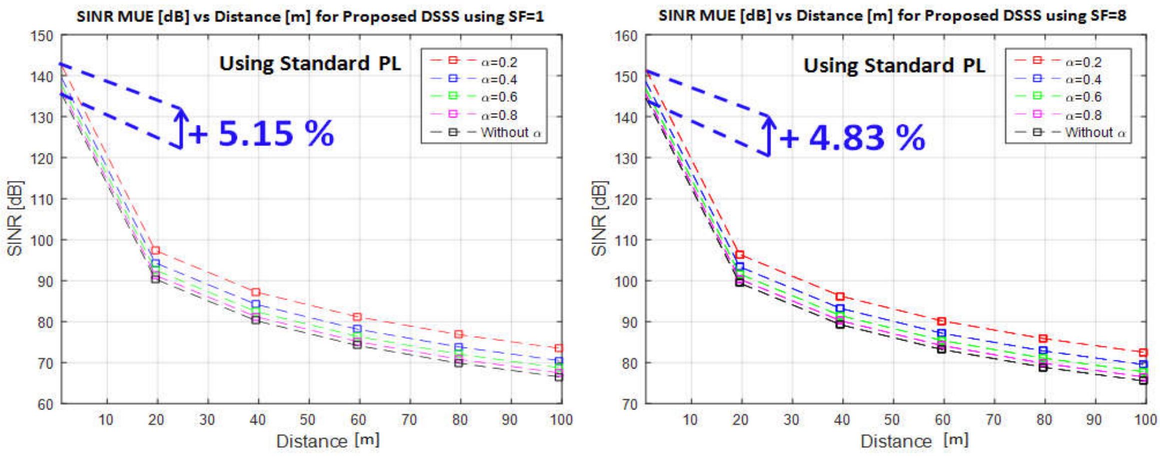
In terms of value α on SINR, the result in Fig. 3-Fig. 5 demonstrated that the SINR using variable chip rate coefficient has higher values compare to without using α (standard DSSS). The reason is the chip rate coefficient gives lower value of noise power, hence increases the SINR. Among the chip rate coefficient values, α = 0.2 gives the highest SINR compare to others. Table 4 and Table 5 show the SINR values at d = 1 for α = 0.2 for MUE and WUE respectively. We found that by added the α, the SINR UE were improves as much as 4~5% for MUE and 9~10% improvement for WUE compare to the standard technique.

Table 4. SINR MUE values for proposed DSSS by applying α

SINR [dB]	**SF = 1**		**SF = 8**	
	α = 0.2	**% Δ**	**α = 0.2**	**% Δ**
MUE (standard)	143	+5.15%	152	+4.83%
MUE (Modified)	140	+5.26%	149	+4.93%

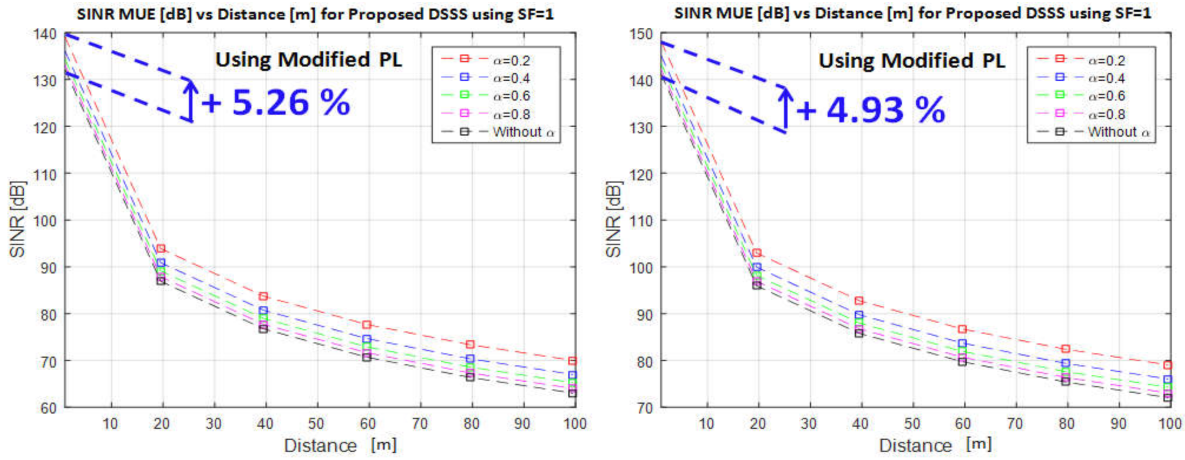
Table 5. SINR WUE values for proposed DSSS by applying α

SINR [dB]	**SF = 1**		**SF = 8**	
	α = 0.2	**% Δ**	**α = 0.2**	**% Δ**
WUE	72	+10.77%	81	+9.46%



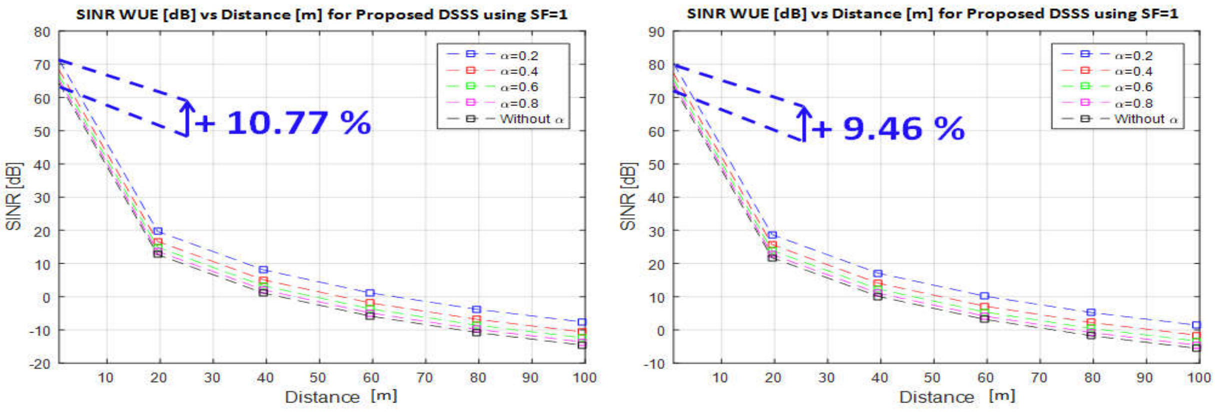
(a) (b)

Fig.3. SINR MUE versus distance for proposed DSSS using COST231 HATA PL for (a) SF = 1 and (b) SF = 8



(a) (b)

Fig.4. SINR MUE versus distance for proposed DSSS using modified COST231 HATA PL for (a) SF = 1 and (b) SF = 8



(a) (b)

Fig.5. SINR WUE versus distance using proposed DSSS for (a) SF = 1 and (b) SF = 8

3.2.2. α-Coefficient and β-Coefficient

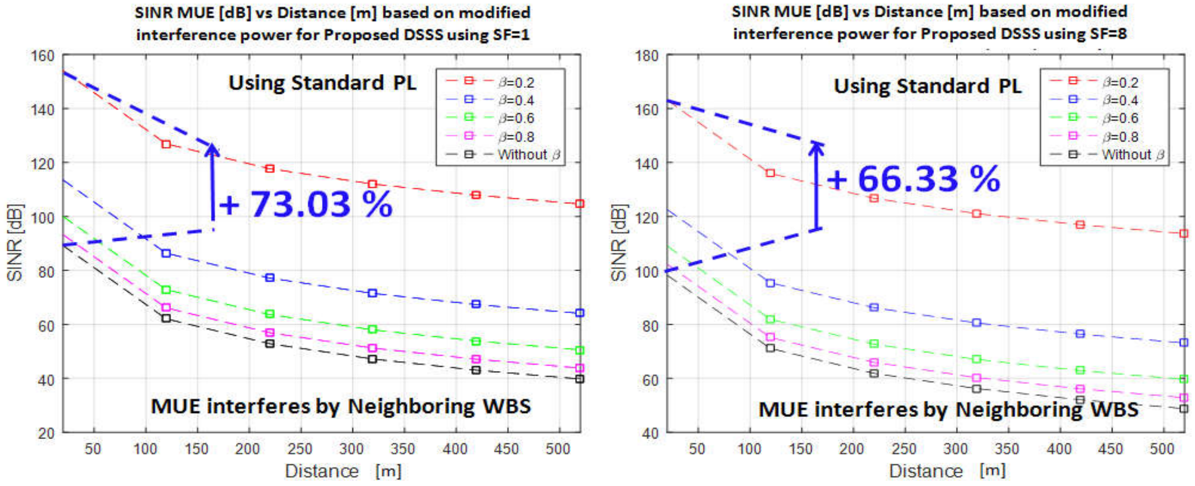
Fig. 6 and Fig. 7 show the SINR at MUE which is interferes by the WBS. On the other hand, Fig. 8 shows the SINR at WUE which is interferes by two interferers (MBS and WBS). The value α is fixed at 0.2 for both SINR. In terms of value β on SINR, the results demonstrated that the SINR using β coefficient has higher values compare to SINR without it. The reason is the β coefficient gives lower value of interference power, hence increases the SINR. Amongst the β coefficient values, β = 0.2 gives the highest SINR compares to others. Table 6 and Table 7 show the SINR values at d = 1 for β = 0.2 for MUE and WUE respectively. In addition, we found that by added the β, the SINR UE are improves as much as 66%~76% for MUE and 111%~130% for WUE compare to without β.

Table 6. SINR MUE values for proposed DSSS by applying β = 0.2

SINR[dB]	**SF = 1**			**SF = 8**		
	β = 0.2	**w/o β**	**% Δ**	**β = 0.2**	**w/o β**	**% Δ**
MUE (standard)	154	89	+73.03	163	98	+66.33
MUE (Modified)	150	85	+76.47	159	94	+69.15

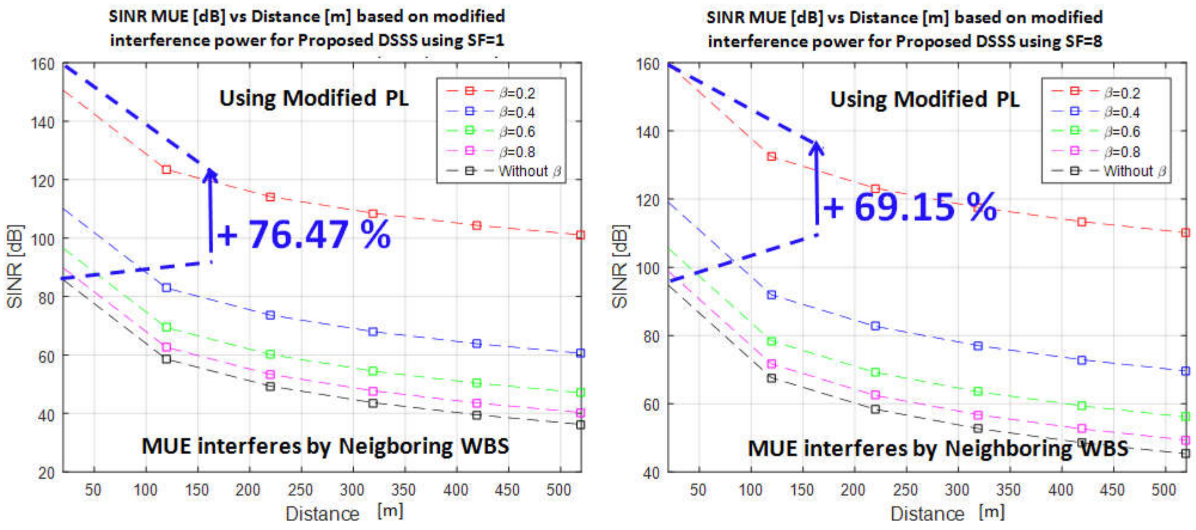
Table 7. SINR WUE values for proposed DSSS by applying β = 0.2

SINR [dB]	**SF = 1**			**SF = 8**		
	β = 0.2	**w/o β**	**% Δ**	**β = 0.2**	**w/o β**	**% Δ**
WUE	120	51	+127.45	129	60	+108.33



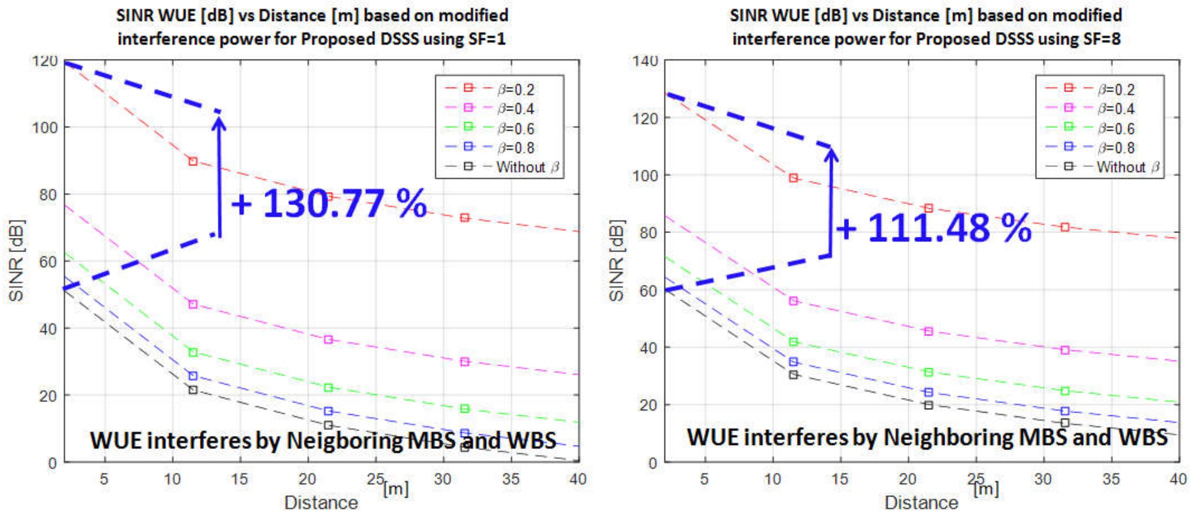
(a) (b)

Fig.6. SINR MUE versus distance using proposed DSSS for (a) SF = 1 and (b) SF = 8



(a) (b)

Fig.7. SINR MUE versus distance using proposed DSSS for (a) SF = 1 and (b) SF = 8



(a) (b)

Fig.8. SINR WUE versus distance using proposed DSSS for (a) SF = 1 and (b) SF = 8

From the simulation results, we compares the propose DSSS (α-coefficient and β-coefficient) with the standard DSSS. For both MUE and WUE, the propose DSSS has better SINR than standard DSSS. The reason is by using propose DSSS, it gives lower interference power than the maximum interference power value given by 3GPP specification. Table 8 shows the improvement percentage for MUE. We found that for SINR MUE the percentage of improvement increase to 12%-13% and 11%-12% for standard and modified COST231 HATA respectively. Table 9 shows the improvement percentage for WUE. We found that for SINR WUE the percentage spike to 74%-84%.

Table 8. Improvement percentage for SINR MUE

SINR [dB]	**SF = 1**	**SF = 8**
	% Δ	**% Δ**
MUE (standard)	+13.23	+12.41
MUE (Modified)	+12.78	+11.97

Table 9. Improvement percentage for SINR WUE

SINR [dB]	**SF = 1**	**SF = 8**
	% Δ	**% Δ**
WUE	+84.62	+74.32

4. CONCLUSION

This paper investigated the SINR at MUE and WUE using standard and propose DSSS in LTE-Wi-Fi network. The standard scheme only considers its serving BS only. On the other hand, the propose DSSS considers both its serving and the neighbouring BSs which interfere the UE by applying α and β. The simulation results show that the SINR for both MUE and WUE improve significantly compare to the standard DSSS. The propose DSSS did not considering path loss from its neighboring BSs. Hence, for the future studies, we will consider the path loss of neighboring BSs to improve SINR for both MUE and WUE.

5. ACKNOWLEDGEMENTS

This paper is part of research work that supported by Geran Inisiatif Penyeliaan (GIP) file no.: 600-IRMI/GIP 5/3 (0012/2016) and Faculty of Electrical Engineering, UiTM Shah Alam.

6. REFERENCES

[1] Ericsson, Ericsson mobility report June 2017. 2017, https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf

[2] Southgate Amateur Radio News. Ofcom: Interference to 2400 MHz from LTE. 2014, http://www.southgatearc.org/news/2014/april/interference_to_2400mhz_from_lte.htm

[3] Chaves F S, Cavalcante A M, Almeida E P, Abinader Jr F M, Vieira R D, Choudhury S, Doppler K. LTE/Wi-Fi coexistence: Challenges and mechanisms. In XXXI Simposio

Brasileiro De Telecomunicacoes, 2013, pp. 1-5

[4] Cavalcante A M, Almeida E, Vieira R D, Chaves F, Paiva R C, Abinader F, Choudhury S, Tuomaala E, Doppler K. Performance evaluation of LTE and Wi-Fi coexistence in unlicensed bands. In IEEE 77th Vehicular Technology Conference, 2013, pp. 1-6

[5] Almeida E, Cavalcante A M, Paiva R C, Chaves F S, Abinader F M, Vieira R D, Choudhury S, Tuomaala E, Doppler K. Enabling LTE/WiFi coexistence by LTE blank subframe allocation. In IEEE International Conference on Communications, 2013, pp. 5083-5088

[6] Lopez-Porez D, Claussen H. Improved frequency reuse through sector offset configuration in LTE Heterogeneous Networks. In IEEE International Conference on Communications, 2014, pp. 2338-2343

[7] Singh R, Mishra S, Murthy C S. A multi-tier cooperative resource partitioning technique for interference mitigation in heterogeneous cellular networks. In 12th IEEE International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks, 2014, pp. 181-187

[8] Iturralde M, Yahiya T A, Wei A, Beylot A L. Interference mitigation by dynamic self-power control in femtocell scenarios in LTE networks. In IEEE Global Communications Conference, 2012, pp. 4810-4815

[9] Alexiou A, Billios D, Bouras C. A power control mechanism based on priority grouping for small cell networks. In 8th IEEE International Conference on Broadband and Wireless Computing, Communication and Applications, 2013, pp. 170-176

[10] Chaves F S, Almeida E P, Vieira R D, Cavalcante A M, Abinader F M, Choudhury S, Doppler K. LTE UL power control for the improvement of LTE/Wi-Fi coexistence. In IEEE 78th Vehicular Technology Conference, 2013, pp. 1-6

[11] Yoshizaki G, Mori K, Naito K, Kobayashi H. Enhanced inter-cell carrier aggregation with spread spectrum technique for next generation mobile systems. In 21st IEEE International Conference on Telecommunications, 2014, pp. 379-383

[12] Guo W, Healy W M, Zhou M. Impacts of 2.4-GHz ISM band interference on IEEE 802.15. 4 wireless sensor network reliability in buildings. IEEE Transactions on

Instrumentation and Measurement, 2012, 61(9):2533-2544

[13] Amin M S, Reaz M B, Jalil J, Rahman L F. Digital modulator and demodulator IC for RFID tag employing DSSS and Barker code. Journal of Applied Research and Technology, 2012, 10(6):819-825

[14] Dowluri T, Kumari S U. A novel approach for frequency hopping CDMA technique. International Journal of Advanced and Innovative Research, 2012, 1:147-151

[15] Chung S H, McLane P J. Code hopping-direct sequence spread spectrum to compensate for intersymbol interference in an ultra-wideband system. In IEEE International Conference on Communications, 2006, pp. 1501-1507

[16] Aly O A. Enhancing the performance of spread spectrum techniques in different applications. Phd thesis, Magdebur: Otto-von-Guericke-University of Magdebur, 2006

[17] NTT Docomo Inc. Principles of DS-CDMA. 2017, https://www.nttdocomo.co.jp/english/corporate/technology/rd/tech/network/multiple_access/05/

[18] Yan R, Zhang G, Li B, Ren P, Du Q. An effective semi-static interference coordination scheme for wireless cellular systems. In IEEE Wireless Telecommunications Symposium, 2013, pp. 1-6

[19] Mallipeddy S R, Kshetrimayum R S. Impact of UWB interference on IEEE 802.11 a WLAN system. In IEEE National Conference on Communications, 2010, pp. 1-5

[20] Shi X. A pulse design method for the compatibility of UWB and IEEE 802.11 a WLAN systems. In IEEE International Conference on Network Computing and Information Security, 2011, pp. 130-133

[21] Rathore S, Paulus R, Jaiswal A K, Agrawal A. Ultra-wideband antenna for WLAN, WiMAX and LTE applications. International Journal of Computer Applications, 2015, 121(7):27-30

[22] Cabral O, Meucci F, Mihovska A, Velez F J, Prasad N R, Prasad R. Integrated common radio resource management with spectrum aggregation over non-contiguous frequency bands. Wireless Personal Communications, 2011, 59(3):499-523

[23] Federal Communications Commission (FCC). Rules and regulations for title 47.

Washington DC: FCC, 2017

[24] Howard H. 3GPP technical report 25.996. 2017, http://www.3gpp.org/ftp//Specs/archive/25_series/25.996/

[25] Faruque S. Radio frequency propagation made easy. Berlin: Springer, 2014

[26] Pan Z, Zhu Q. Modeling and analysis of coverage in 3-D cellular networks. IEEE Communications Letters, 2015, 19(5):831-834

[27] Ramli H A, Rizman Z I. Novel scheduling algorithm for optimizing real-time multimedia performance in Long Term Evolution-Advanced. Turkish Journal of Electrical Engineering and Computer Sciences, 2017, 25(1):247-253.

How to cite this article:
Azhar AE, Yusof AL, Zainali MA, Ya'acob N. Interference management using direct sequence spread spectrum (dsss) technique in lte-wi-fi network. J. Fundam. Appl. Sci., 2017, *9(4S), 276-292.*