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Investigation of Enhanced Particle Swarm Optimization Algorithm for the OFDMA Interference Management in Heterogeneous Network

Mohammad Kamrul Hasan[1], Ahmad Fadzil Ismail[1], Wahidah Hashim[2] and Shayla Islam[1]

[1]Department of Electrical and Computer Engineering, International Islamic University, Jalan Gombak 53100, Malaysia
[2]College of Information Technology, University Tenega Nesional, Malaysia
hasankamrul@ieee.org, af_ismail@iium.edu.my, wahidah@uniten.edu.my, iium19612@hotmail.com

Abstract

In orthogonal frequency division multiplexing Access (OFDMA) systems resource allocation to the subcarrier is essential owing to the insufficient resources available at the base station. In OFDMA, subcarrier and power allocation are not separate; thereby this two allocation are not self-governing. This paper proposes the subcarrier allocation approach through investigating previous methods, and also the Enhanced Particle Swarm Optimization (PSO) algorithm is analyzed. The both of the algorithms cross functionality is analyzed and compared the performance of the subcarrier allocation of OFDMA systems in Heterogeneous Network (HetNet). The simulation results show that the PSO approach efficiently allocates the OFDMA subcarriers.

Keywords*: OFDMA; Particle Swarm Optimization; Heterogeneous Network*

1. Introduction

In the heterogeneous network, HeNodeBs are deployed for the extension of the coverage, and capacity. The main reason of this deployment is to extend the signal quality in the indoor environment. By LTE-Advanced systems, the HeNodeBs extended the downlink capacity to 1.5 GHz, while 500 Mbps for the uplink. Moreover, it is economical since it has the low power (less than 0.1W), and best for the short range (coverage 10 – 50m), CPE-based plug and plays licensed 2.6 GHz Home Base Station[1]. A straightforward model of HeNodeB can serve 4 to 5 HUEs with concurrent voice/information sessions whenever, while an endeavor model can serve up to 11 HUEs [2-4]. The HeNodeB can correspond with the central server system which belongs to mobile operators by broadband association, for example, DSL, link modem or a different remote backhaul channel [5]. HeNodeBs have been created to work with a scope of various cell benchmarks, for example, GSM, UMTS, WIMAX, WCDMA, LTE and LTE-A. Since HeNodeBs are overlaid on the current macrocell system, both constitute the heterogeneous system. Not at all like WiFi, HeNodeB works in authorized range, and either co-channel or devoted channel organization can be made. In dedicated channel allocation, separate subcarriers are employed. Thus, there is no cross-tier interference; it is frightfully wasteful as well as there is the chance for co-tier obstruction under thick HeNodeB organization. In Figure1, the typical co-tier interference scenario is shown in a heterogeneous network.

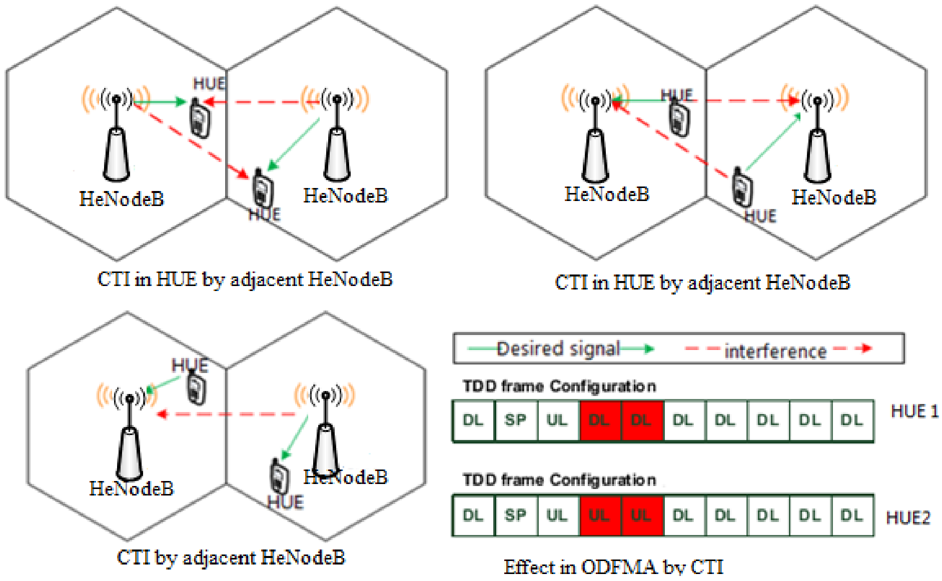

Figure 1. A Typical Interference Scenario in Heterogeneous Network[6]

In the co-channel assignment, the recurrence groups are shared between the large scale macro-eNodeB coverage and HeNodeB coverage. Despite the fact that it is frightfully proficient one, there is more plausibility for cross-level obstruction [4]. Even so, because of licensed spectrum substantial cost high cost, co-channel might be interesting by sharing the resources in OFDMA. For that reason, the effect of frequency-reusing in an awkward arbitrary design acquaints possibly harmful interference with the framework, both in full-scale macro-eNodeB and HeNodeB tiers. Hence, the Cross-tier (CSI) and Co-tier (CTI) occurs in the typical Heterogeneous network. Two types of access technology have been applying in HeNodeB deployment such as Closed Access Group (CSG) and Open Access Group (OAG)[7, 8]. In open get to, all clients of the porTable administrator might be permitted to associate with a customer possessed femtocell. In CSG access just a subset of the clients, which is characterized by the femtocell proprietor, can associate with the femtocell. In half and half get to, a constrained measure of the HeNodeB assets are accessible to all clients, while the rest are worked in a CSG way. At the point when the CSG strategy hinders the utilization of the femtocell assets to a subset of the clients inside of its scope region, another arrangement of cross-level meddling signs is indeed characterized in such territory and makes the issue of obstruction moderation significantly more unpredicTable. The various access technologies for HeNodeBs is depicted in Fig 2. Conversely, the open access strategy would comprehend this point, however conveying security and sharing worries to the client. Henceforth the determination of an entrance control system to femtocells has an incredible impact on the execution of the general scheme, for the most part because of its role on the meaning of obstruction by interference and handover endeavors.

This aim of this paper is to analyses the performance of the PSO based dynamic subcarrier allocation approach. It is also investigates the impact of the system performance in co-channel deployed Heterogeneous network.

The rest of the paper organizes as: Section 2 presents the related works. Section 3 discusses the co-tier interference model for the heterogeneous network. Section 4 analyses the performance of the PSO based dynamic subcarrier allocation approach. Section 5 concludes the paper.

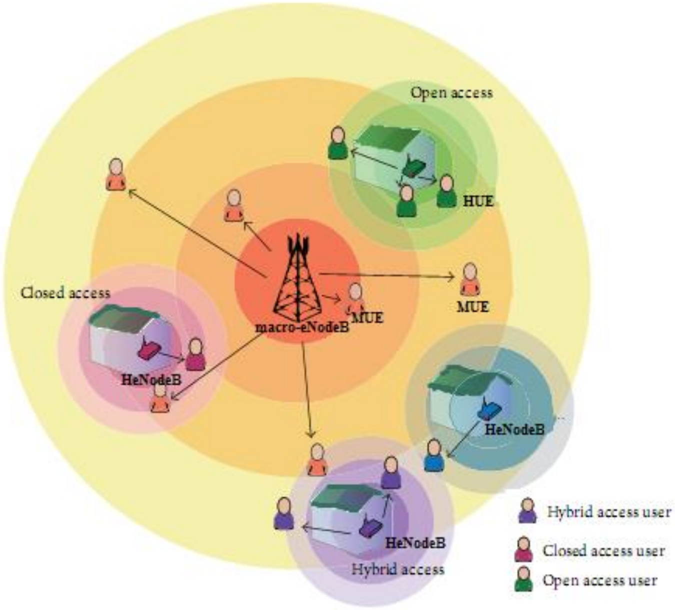

Figure 2. HeNodeB's Access Mechanism[9]

2. Related Works

A distributed interference alleviation method has proposed by applying the recurrence reuse with a specific end goal to guarantee the Quality of Service (QoS). The examination recommends that, the plan that was connected multipath channel blurring and Nakagami blurring to accomplish the enhanced blackout rate and higher ghostly adequacy. Additionally, settled edge and besides signal transmission/gathering were utilized to identify the blank ranges furthermore to recognize interferer. Subsequently, the casualty MUE applies the limit furthermore permitting to different HeNodeBs (interferer) to reuse field. A diversion hypothesis based impedance relief procedure has proposed which is mostly vitality based and utilizes the handover bolstered convention [12]. The impedance has decreased by the shared guide to diminish energy utilization which focuses on enhancing channel state and also building framework limit. In any case, by utilizing the forced assignment can be decreased up to the certain level whereas in functional this would be difficult to deal with the power portion progressively on interest. The system design and the resource administration, for the most part, rely on upon the extent of existing femtocell deployment, existing system framework, and future expansion planning. The CTI need to be completely minimized. Nonetheless, it is conceivable to moderate the impedance. To acquire the best employments of profiTable assets (recurrence and data transfer capacity). Appropriate radio resource administration (RRM) strategies for Interferences mitigation are required. The recurrence OFDMA resource assignment is the key elements to alleviate interference [10-12]. The thickness of femtocells orders the deployable femtocell zones, and conjunction of femtocells and macrocell to moderate, diverse wellsprings of impedances and to guarantee the best usage of the range[6].

3. System Model

In HetNet, the macro-eNodeBs andHeNodeBs are shared the same entire frequency band. This is because of the limited spectrum resources, and to achieve the maximum spectral efficiency. Moreover, due to the same spectrum allocation, the frequency is overlapped whichcan be stretchedbetter cell group average throughput, nonetheless, the cell edge throughput is deteriorated adversely due to the CTI effects. Therefore, the subcarrier allocation approach is necessary for the HetNet. As a result, to mitigate such type of CTI interference, the system approachcan be represented in Figure 3. The PSO-based subcarrier allocation optimization algorithm is discussed and analyzed for the dynamic subcarrier allocation in LTE-A HetNet. The network connectivityof the j^{th} HeNodeB and i^{th}HUEs in a HetNet is desired/permissible entity. On the other hand, if the adjacent HeNodeBs are the cause of the interference with HUEs in the downlink. The received power perceived by HUE at subcarrier can be written in Equation (1).

$$\mathcal{R}_s^{HUE} = P_{HUE_i,s}^{\mathrm{H}_j} \sum_{n}^{N} h_{n,,s}^{\mathrm{H}_j} + \sum\nolimits_{HUE_i \in H_{int,s}}^{Z} \left| h_{\mathrm{H}_j,s}^{HUE_i} \right|^2 \mathrm{P}_{HUE_i,s}^{\mathrm{H}_j} + \sum\nolimits_{HUE_i \in I_{int,s}}^{S} \left| h_{HUE_i,z}^{H_j} \right|^2 p_s^{HUE_i} \sigma^2 \tag{1}$$

As a result, the SINR of HUE get effected and the co-tier interference occurred, which can be presented below.

$$\Upsilon_{HUE_i,s}^{SINR} = \frac{P_{HUE_i,s}^{\mathrm{H}_j} \quad h_{HUE_i,s}^{\mathrm{H}_j} \quad \varphi_{HUE_i,s} \mathcal{Z}_{HUE_i \leftrightarrow H_j}}{\sum_{HUE_i \in H_{int,s}}^{Z} \left| h_{\mathrm{H}_j,s}^{HUE_i} \right|^2 \mathrm{P}_{HUE_i,s}^{\mathrm{H}_j} + \sum_{HUE_i \in I_{int,s}}^{S} \left| h_{HUE_i,z}^{H_j} \right|^2 p_s^{HUE_i} + \sigma^2} \tag{2}$$

Applying the Shannon's capacity law, we get the capacity in the following Equation.

$$\forall_{s,i} = \sum_{s=1}^{S} \frac{\omega_{i,s}}{S} \log_2 \left(\frac{1 + \\ P_{HUE_i,s}^{\mathrm{H}_j} \quad h_{HUE_i,s}^{\mathrm{H}_j} \quad \varphi_{HUE_i,s} \mathcal{Z}_{HUE_i \leftrightarrow H_j}}{\sum_{HUE_i \in H_{int,s}}^{S} \left| h_{\mathrm{H}_j,s}^{HUE_i} \right|^2 \mathrm{P}_{HUE_i,s}^{\mathrm{H}_j} + \sum_{HUE_i \in I_{int,s}}^{S} \left| h_{HUE_i,s}^{H_j} \right|^2 p_s^{HUE_i} + \sigma^2} \right) \tag{3}$$

The fitness problemof the subcarriers can be formedas below.

$$Max\left(\mathcal{Q}_{i,s}, P_{i,s}^{\mathrm{H}_j}\right) = \sum_{i}^{J} \sum_{s=1}^{S} \mathcal{w}_{i,s} \left[\frac{\omega_{i,s}}{S} \log_2 \left(\frac{1 + \\ P_{HUE_i,s}^{\mathrm{H}_j} \quad h_{HUE_i,s}^{\mathrm{H}_j} \quad \varphi_{HUE_i,s} \mathcal{Z}_{HUE_i \leftrightarrow H_j}}{\sum_{HUE_i \in H_{int,s}}^{S} \left| h_{\mathrm{H}_j,s}^{HUE_i} \right|^2 \mathrm{P}_{HUE_i,s}^{\mathrm{H}_j} + \sum_{HUE_i \in I_{int,s}}^{S} \left| h_{HUE_i,s}^{H_j} \right|^2 p_s^{HUE_i} + \sigma^2} \right) \right] \tag{4}$$

4. Dynamic Subcarrier Allocation

In the dynamic subcarrier allocation, two types of variation *e.g.* Inertia weight, as well as constriction factor model, was considered for PSO based allocation [13]. This is to achieve higher throughput as well as average performance. To ensure the faster convergence, PSO constriction factor model has been used. In PSO, the Inertia weight as well as compression element updates the velocity of each particle conferring to the finest two known positions such as the personal best position (pbest) for HeNodeB and the neighbor HeNodeBs best position (npbest). The pbest stated particles the best position and npbest is for the correspondence in between the particle and the neighbor HeNodeB. The npbest was also deliberated as the global-best (g-best) when the total swarm is considered. This position was also considered due to the demand of faster convergence. Therefore, it has been identified that the g-best particle and the positions were shared once each generation is completed. To circumvent unnecessary sharing of particle position for HeNodeBs, the positions are divided if there is a substantial fitness value gap, concerning the current as well as the previous generation. The framework of PSO-based subcarrier allocation follows the steps as below point-wise:

- At the beginning the algorithm generates swarm particles (as subcarrier) with position and velocity.
- Estimate the fitness of the subcarrier usingposition and velocity.
- Evaluates the fitness of each position of particles in order to get the neighbor best position
- Apprise the velocity and position of respectivesubcarrier
- Select the subcarriers and mutate the crossover subcarriers.
- Check the circumstance of subcarrier fitness (see Equation 3)
- Share the subcarriers based on the velocity and position of each particle

  For the faster convergence the updated velocity is estimated in Equation (5). The In Equation (6), we introduced a parameter distance of the neighbor particles. Therefore, the enhanced PSO (ePSO) algorithm is proposed to search and share the subcarriers among the HeNodeBs in HetNet environment.

$$\partial_s^{new} = \partial_s + \alpha\omega(pbest_s - \varphi_s) + \beta\omega(pbest_s - \varphi_s) \quad (5)$$
$$s = 1,2,\dots,S$$
$$\varphi_s^{new} = \frac{\varphi_s + \partial_s^{new}}{d_s} \quad (6)$$

where, α and β are termed as acceleration coefficients whose job is to control the influence in the search process. The number of particles in a swarm is represented by P. $\omega$is the random factorsof the interval between 0 to 1 {0,1}. And, P_s, ∂_s^{new} , P_s^{new} and s represents the current and updated position and velocity of the s^th particle. In the ePSO algorithm the set of subcarrier is shared the OFDMA subcarriers. The enhanced algorithm is focused with the performance metrics of throughput of the HeNodeBs, and capacity with respect to SINR distribution.

5. Performance Analysis

Given subcarrier allocation, the consequences are simulated, where 35 HUEs, 35 HeNodeBs are considered. The 500 iteration processes are considered for the subcarrier allocation. The simulation is carried out using MATLAB based simulator. Table 1 listed the simulation parameters.[6, 14, 15].

Table 1. LTE-A HeNodeB Operation Specification

Description	Specification
Frequency band	2.6 GHz
Number of HeNodeBs	*50*
System Bandwidth	*20MHz*
Number of subcarriers	*720*
Distance between HeNodeBs	*20m*
Transmission power of macro-eNodeB	*46 dBm*
Transmission power of HeNodeB	*23dBm*
Penetration wall loss	*20dB*
Intersite distance	*500m*
Thermal noise factor	*-174 Bm/Hz*
shadowing correlation	*0.7dB*
Number of HUE	*35*
SINR threshold	*-8dB*
Exponent factor	*3*
Modulation	*64QAM*
Sub frame time duration	*1ms*
Apartment dimension	*10 x 10m^2*
BER	*10^{-6}*

The expedient or interfering link in between HUE and HeNodeB [2], [13-14] need to be estimated for the path-loss. The path-loss ($\ell^{path-loss}$) model includes the indoor wall penetration loss (ℓ_W), distances which is expressed in Equation (7).

$$\ell^{path-loss} = 15.3 + 37.6 \log_{10}(d) + \ell_W \tag{7}$$

The channel gain model among transmitter and receiver, perceived at receive antenna is represented in Equation (8) below:

$$C^{i,S}_{j_n,S} = \left| h^{j_n}_{q,s} \right|^2 \ 10^{(-\ell \ \ (d)+Ye)/10} \tag{8}$$

where. $\ell \ \ (d)$ is the distance dependent path-loss, Ye is the log-normal shadowing, channel variation is represented thru $h^{j_n}_{q,s}$. The channel vibes usually show the time as well as frequency dispersions, channel variations in a certain resource block. The system level simulator is used to simulate the approach. The simulation scenarios are depicted based on 3GPP and ITU standards. The designed scenarios are an average of 1000 autonomous simulations. The assumed system parameter for the simulation is given in Table 1. Modulation 64-QAM represents 6 bits per symbol. Hence, 10MHz be able to offer a raw symbol rate of 54Mbps, which empowers the system to sort the data through average numbers of subcarriers. Figure 3 presents the simulation scenario.

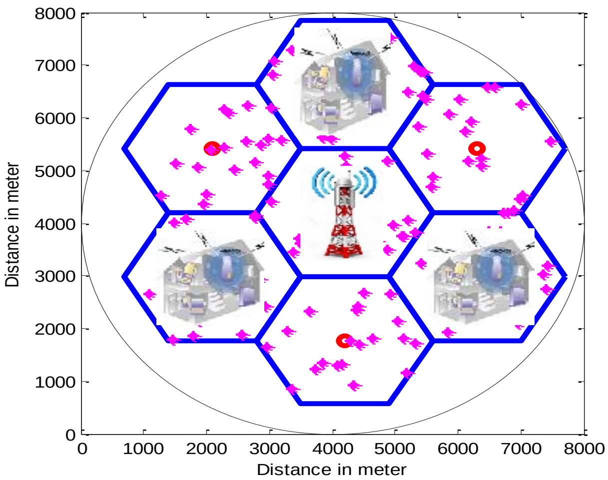

Figure 3. HeNodeB and Macro-eNodeB HetNet Scenario

The performance of an ePSO based resource allocation approach is assessed based on the different deployment of HeNodeBs compactness in HetNet. Radio sign quality gets weaker rapidly because of the distance varieties. In Figure Four the bitrate is shown over the distances. With the different distance between HeNodeB and macro-eNodeB, the achieved bitrate performance is characterized. If the distance is increased, then the bit rate is lower. Initially, the ePSO achieved minimum bitrate is achieved 3.8bps/Hz while distance is 1km. However, if the distance is 30km the bitrate is nearly 0.4 bps/Hz. Therefore, it is viewed that the signal-to-noise ratio gets worse as distance increases.

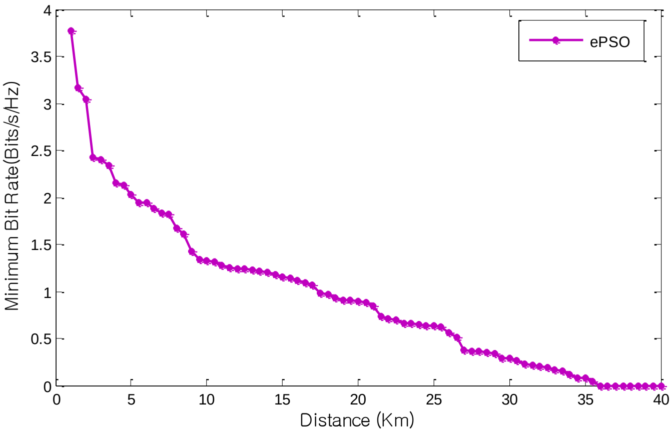

Figure 4. HeNodeB and Macro-eNodeB HetNet Scenario

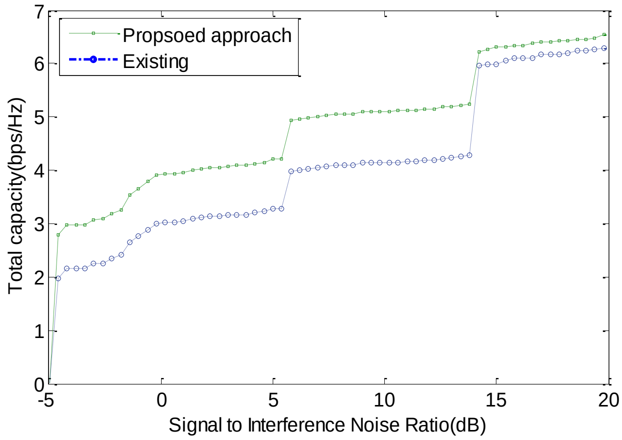

Figure 5. Total Capacity vs. SINR

The total capacity over the SINR is presented in Figure 5. The performance is observed from the Fig 5 that, with the lower rate of SINR the capacity is lower also, which can satisfy Shannon's capacity law. It is viewed that, the proposed approach provides the better SINR ratios with better-enhanced capacity towards MUEs. It has happened due to the subcarrier sharing among the HeNodeBs resources, after that, the HeNodeB's allocates the subcarriers to the MUEs. Therefore, if the data rates and capacity is higher, hence the interference possibilities are lower.

6. Conclusion

The deployment of HeNodeB cost is very lower since these are customer premises equipment. HeNodeBs are not only extended coverage in indoor but also increases the bandwidth capacities for HUEs. This is because it shared the both of radio access, and frequency bands with macro-eNodeB as well as HUEs. The subcarrier allocation in OFDMA is vital since the co-channel deployment faced challenges. As a result of the system, throughput becomes worst. This paper enhances PSO based dynamic the subcarrier allocation algorithm in OFDMA based Heterogeneous Network. The results are suggesting that the enhanced algorithm can maximize the SINR distribution as well as throughput. Though, the subcarrier allocation algorithm needs to be enhanced to achieve better performance.

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Authors

Mohammad Kamrul Hasan, he is currently a PhD candidate in Communication Engineering at the department of Electrical and Computer Engineering in International Islamic University, Malaysia. He achieved his received his Masters in Communication Engineering from International Islamic University, Malaysia in 2012. His current research interests include OFDMA, Interference, Cognitive Network, Optimization, Big Data, Smart Grid Computing, and Data Communication and Networking. He published more than 50 papers in international journals and conferences. He is a Member of Institute of Electrical and Electronics Engineers (MIEEE), and Member of Institution of Engineering and Technology (MIET).

Ahmad Fadzil Ismail, he currently an Associate Professor at Department of Electrical and Computer Engineering, Faculty of Engineering, International Islamic University Malaysia (IIUM). He completed his bachelor degree studies in Electrical Engineering at Gannon University, Pennsylvania, USA with Cum Laude Latin honors. He holds MSc and PhD from University of Essex, UK and University of Bath, UK, respectively. He is registered with Board of Engineering Malaysia as a Professional Engineer and also a senior member of IEEE. His research interests include development of active and passive target tracking algorithms, radio frequency and wireless systems and microwave and millimeter wave technology.

Wahidah Hashim, she received her bachelor degree in Information Technology, Business Management and Language from University of York, UK in 1999. She then pursued her MSc in Multimedia Technology at University of Bath, UK. She completed her PhD studies fromKing's College London, UK in the field of TelecommunicationEngineering. She is currently at Universiti Tenaga Nasional, system and networking department, College of Computer Science and Information Technology as a principle lecturer since 2014.Apart from her main task in doing research in cognitive radio, WLAN, OFDM, MIMO systems, IoT, Big Data and wireless system, she is actively involved in the development of Malaysia technical specification, standard and guidelines of wireless devices, International Mobile Telecommunication (IMT) systems and sensor network for Malaysian Communications and Multimedia Commission (MCMC). She had represented Malaysia at International Telecommunication Union (ITU) working party 5D meeting for IMT-Advanced technology as well as a member to ITU Focus Group on Aviation Cloud Computing and Asia Pacific Telecommunity Standardization Program (ASTAP). Dr. Wahidah has published several publications and filed several patents on her research findings. She is a member of the IEEE and IACSIT.

Shayla Islam, she received PhD in Computer and Information Engineering, at the department of Electrical and Computer Engineeringin International Islamic University, Malaysia in 2016. She competed herMSc at the department of Electrical and Computer Engineeringin International Islamic University, Malaysia in 2012. She completed her BSc in Computer Science and Engineering from International Islamic University Chittagong, Bangladesh in 2007.She was appointed as a lecturer in Green University of Bangladesh (GUB) from 2007 to 2009. Her current research interests include network mobility, computer networks and wireless communication. She published more than 35 papers in international journals and conferences. She works as a reviewer for many international conferences.