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User Preference Aware Radio Access Technology Selection Model for Heterogeneous Communication Network

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Abstract:
The future generation of Heterogeneous Wireless Networks (HWNs) will combine various radio access technologies for connecting various mobile subscriber (MS) based on Quality Of Service (QoS) and wireless network parameter and connecting MS to best possible wireless network (WN) has been a hot research trends in HWN. Existing radio access technology (RAT) selection method are designed to meet QoS of network criteria and user preference are neglected. Very limited work is done for RAT selection considering user preference. However, these model are designed considering multimode terminal (MT) running single service at a time under low density network. For overcoming research problems, this paper present User Preference Aware Multi-Objective RAT (UPAMO-RAT) selection method for high dense and dynamic HWNs. The UPAMO-RAT selection first present Preference Aware Weight (PAW) evaluation. Then, present User Preference Aware TOPSIS (UPA-TOPSIS) for selecting ideal RAT for communication. Experiments are conducted for evaluating performance UPAMO-RAT over existing RAT selection method. The UPAMO-RAT selection method attain superior Quality of Experience (QoE) outcome when compared with existing RAT selection method.

Keywords: *Decision making, MADM, QoE, QoS, Heterogeneous wireless communication.*

I. INTRODUCTION

The growth of self-governing and smart robots and vehicle has enabled wide attention across various area for enhancing the data commination and vehicle safety. The smart self-governing vehicle such as Google Car [1] are being constructed using cognitive (observation) architecture/framework that includes various information collected from different on-board sensor and using Artificial intelligence (AI) such Machine learning (ML) and Deep learning (DL) model for smart maneuvering on road with other vehicles. Nonetheless, the smartness of autonomous vehicle can be additionally improved by usage of effective computing and network capability of smart transport system (STS). The vehicle driving safety majorly depends on low-latency and highly reliable wireless communication environment for efficient transmission of control packets (CP) due to constraint of on-board sensors [2]. For provisioning such prerequisite, as of late, different RAT are being modeled with diverse communication features/attributes such as data rate (DT) (i.e., bandwidth (BW)), communication frequency (CF), network coverage (NC), communication delay (CD) etc. For instance, the Universal Mobile Telecommunications System (UMTS) can give a wide scope of NC and lower transmission capacity (i.e., BW). Likewise, communication network such as Worldwide Interoperability for Microwave Access (WiMAX), Long Term Evolution (LTE), and CRAN [3] utilize important and significant communication advancements, to be specific frequency division technique such as multi-input & multi-output (MIMO) and orthogonal frequency division multiplexing (OFDM). These communication advancement aid in enhancing the bandwidth and spectral efficiency (SE) with much larger network coverage [4]. Besides, the wireless network designed using $IEEE$ 802.11 based wireless local area network (WLAN) can offer much higher communication speed with smaller NC [5].

Within certain NC of cellular network (CN) different kind of RAT are conveyed with overlapping section of NC, forming HWN's [6]. Seamless mobility among different RAT is hot research topic of heterogeneous wireless networks. Further, as different RAT has diverse network communication capability with diverse user application QoS prerequisite, it is preliminary to deepened on RAT selection methodology for selecting appropriate RAT for mobile multimode terminal (MT's) (i.e., mobile subscribers) in heterogeneous wireless communication system [7]. Thus, modelling effective vertical handover/handoff (VHO) decision making (DM) method (i.e., RAT selection techniques) has been hot research area in heterogeneous wireless network. Majority of existing RAT selection model are designed based on received signal strength (RSS) parameter. In RSS based RAT selection model the MT select the RAT with highest RSS. The RSS based RAT selection method are much simpler and easy to model. However, they suffers from significant ping-pong effect [8]. A few research work consider RAT selection based on network load (NL) for addressing congestion issues (i.e., for balancing load among different network within HWNs). In spite of the fact that this sort of methodology enhances resource (i.e., bandwidth) utilization performance heterogeneous wireless networks, the methodology doesn't considers the link status, and the subscribers might be associated with the RAT with bad signal/link quality. In this manner, the quality of service prerequisite of MT administration can't be viably/successfully ensured [9].

A few existing work have used multi-objective (i.e., multiple decision (MD)) parameter such as BW, RSS, CD, low jitter, energy dissipation, application service provisioning cost, mobility speed of MT, packet loss ratio (PLR), etc. for modelling RAT selection method. This MD parameter is known as Multiple Attribute Decision Making (MADM) issue [10], [11]. When using MADM for RAT selection in HWN, the MADM first gather information for every decision parameter. Second, the collected decision parameters are normalized and weight of MD parameters are computed. Lastly, the respective (i.e., candidate) RAT are ranked. Along with, the different subscribers have different QOS and QOE prerequisite with similar MD parameter because of diverse nature of subscriber services. Thus, few existing work have designed utility function (UF) for quantifying subscriber satisfactory level with MD parameter [12]. The design of UF based RAT selection method are modeled to design different UF's and convert the MD parameter outcome into UF value for establishing inclusive UF outcome for every competitor RAT, rank these outcomes. Lastly, access the RAT with maximal UF outcomes. Furthermore, a few existing work uses method, for example, Markov chain (MC) [13], game theory (GT) [14] the, and the optimization technique [15] for modelling RAT selection methods.

The vast majority of existing RAT selection method discussed above are generally designed using MADM, UF, RSS, and other RAT selection methodology prerequisite accurate MD parameter. Nonetheless, not every MD parameter can be modeled in accurate manner in heterogeneous wireless network. In addition, so as to adjust to the dynamic condition of heterogeneous wireless networks, the working parameters of existing RAT selection methods should be optimized physically, bringing about the manual optimization procedure and constraining/limiting the usage of these method for practical application usages [16]. Further, majority of existing RAT selection method [17], [18], [19], and [20] are designed considering meeting QoS parameter of network criteria. Very limited work is carried out for RAT selection considering user preference under HWN [21], [22], and [23]. However, these RAT selection method are designed considering single call in the network. However, these model do not consider RAT selection when user running multiple applications at same instance of time. This RAT selection problem is known as multiservice multimode terminals (MMTs). For addressing MMTs RAT selection problems, existing model either considered service requirement or user preference prerequisite. No existing MMT RAT selection brings good tradeoffs between application requirement or user preference prerequisite. For addressing the research issues, this work present a user preference aware multi objective RAT selection method for highly dense and dynamic heterogeneous communication environment. The UPAMO-RAT selection method considers network attributes (QoS) and user preference (QoE) requirement for selecting best RAT among accessible RAT's under HWNs.

The Contribution of research work is as follows:

- This paper presented a user preference aware multi-objective RAT selection method for heterogeneous communication network.
- Presented preference aware weight evaluation method and user preference aware TOPSIS (technique for order preference by similarity to an ideal solution) method for RAT selection under HWNs.
- The proposed UPAMO-RAT selection method attain superior performance than existing RAT selection method in terms of reducing handover number with better packet transmission performance.

The paper organization is as follows: The proposed user preference aware radio access technology selection model for heterogeneous communication network are presented in Section II. The results and experimental analysis are presented in the penultimate section. The concluding remark and future work is discussed in the last section.

II. User Preference Aware Radio Access Technology Selection Model For Heterogeneous Communication Network

This section presents a User preference aware radio access technology (UPA-RAT) selection model for heterogeneous communication network. First the system model of UPAMO-RAT is presented. The proposed UPAMO-RAT selection method combines user preference and MADM method for selecting suitable RAT for future communication. The algorithm flow of proposed UPA-RAT is described in **Fig. 1**.

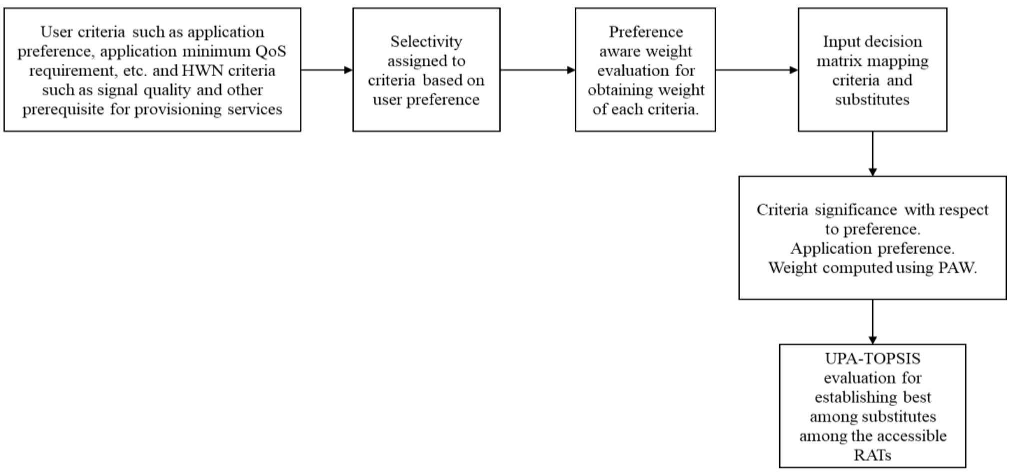

Fig. 1. The flow diagram of proposed UPAMO-RAT selection method.

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a) System model for UPAMO-RAT:

This work consider heterogeneous wireless network as described in Fig. 2. The HWN is composed of UMTS, LTE, WiMAX, and LTE. The architecture provide seamless mobility considering high mobile terminal density environment. The NC of all WN generally overlap each other. Along with, there are higher number of MS that are deployed randomly and moves around in random manner in particular direction within NC. These MS are also considered as MMT with capability of accessing different WN. For selecting appropriate RAT involves following stage such as RAT identification, RAT selection DM, and RAT access execution (i.e., handoff). This work assumes that each MS can obtain MD attribute data of every RAT within it NC of heterogeneous wireless networks. Further, MS can rank the candidature RAT based on collected information and by using RAT selection method the corresponding RAT selection execution is completed. This work considers two important network attributes such as Radio signal strength (RSS) and bandwidth. Along with, considers three user preference attributes such as packet loss rate (PLR), jitter (J), and latency (L). Along with, as different MS services have diverse sensitivity within same RAT attribute (i.e., for data based service require larger BW, for video based services, the resolution of video are adjusted in accordance with BW availability, and in audio based service (i.e., calls) requires minimal BW assurance and so on. Thus, this work therefore segment the MS application services into following category in accordance with application services features such as perfectly elasticity (i.e., data based application service), partially elasticity (i.e., video based application service), and inelasticity (i.e., audio based application services). Along with, this paper considers that end MS use any one of these application services.

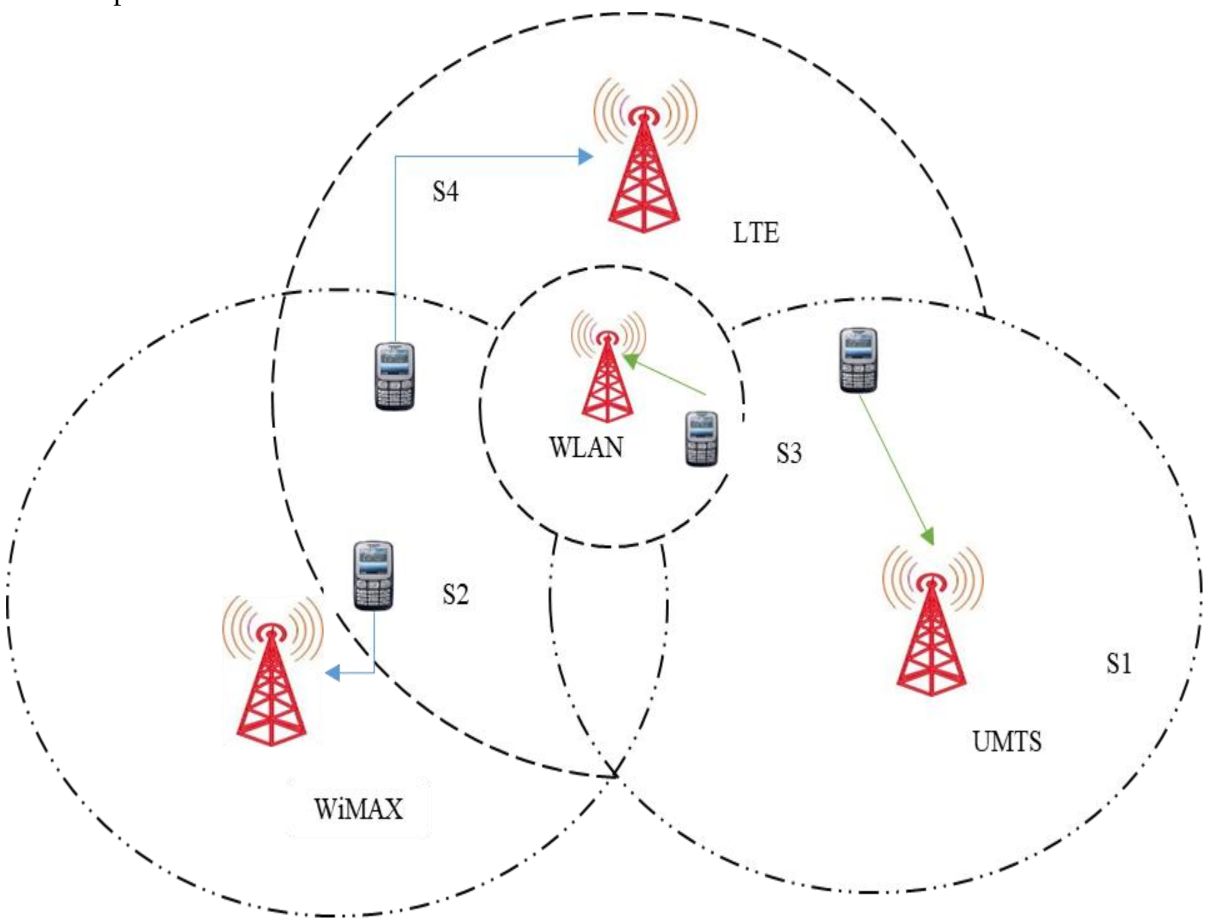

Fig. 2. The architecture of heterogeneous wireless network.

The proposed UPA-RAT selection method is composed of two phase. First, the criteria weights according to communication network criteria and user applications preferences. Second, decision making (DM) is carried out in accordance with criteria and accessible RATs organization. In first phase, the usefulness of criteria weight in accordance with user applications priority/selectivity is measured. The input pair-wise matrix (PM) are built in accordance with criteria with respect to criteria mapping using user preference aware weight. More detail of user preference based weight evaluation is discussed in section a. Then, RAT ranking is carried out using mapping of accessible RAT with respect with qualified criteria that forms decision matrix (DM). Post that user preference aware TOPSIS (UPA-TOPSIS) is modelled for obtaining ranking lists of RAT's. The rank list structure describe the ideal RAT when selecting it in descending order. More detail of RAT ranking method are discussed in section b. The user preference aware multi-objective based RAT (UPAMO-RAT) selection model is discussed in **Algorithm 1**.

Algorithm 1: User preference aware multi-objective radio access technology selection method.

Step 1. Start.

Step 2. Input preference aware associative criteria.

Step 3. Build PM correlating criteria with respect to other criteria.

Step 4. PM is normalized.

Step 5. Then, by using preference aware weight evaluation method the weight vector is obtained.

Step 6. The pairwise matrix consistency (PMC) is estimated for validating weight consistency.

Step 7. If $PMC < \mu$ **then**

Step 8. Return to **step 7**.

Step 9. Else

Step 10. Return to **step 3**.

Step 11. End if

Step 12. DM is created by associating the criteria over accessible RATs.

Step 13. Apply normalization for ease of computing matrix using UPA-TOPSIS.

Step 14. The UPA-TOPSIS is used on normalized DM for obtaining the ranking vector (RV) using weight obtained from **step 5**.

Step 16. The RAT with maximum weight in RV is selected as the best RAT.

Step 17. Stop.

From **algorithm 1** it can be seen using UPAMO-RAT for choosing the ideal RAT and established as future communication network for serving user application traffic demand. This is accomplished by employing UPA-TOPSIS which is designed using standard MADM method according to Euclidean Theory (ET) that converse the selected RAT (output) is a suboptimal strategy with significant difference with respect with negative best strategy. The prerequisite of network and user cooperate to establish preference aware information. The selectivity of criteria is allocated based on user's application traffic load and QoS requirement. Along with, selectivity of weight parameters are computed using preference aware weight (PAW) evaluation method. The computed weight describes the quailed significances of criteria in DM of RAT selection considering preference aware element (**rule**). The PAW is composed of intra RAT information for carrying out HO operation. The UPA-TOPSIS method is used for establishing future RAT according to inter evaluation of criteria and RAT accessible based on preference within a communication domain environment.

a) User preference based criteria weight evaluation method:

This section present user preference based criteria weight evaluation method for decision making. The decision making process is composed of two phases. In first phase, objective prerequisite and decision impact (DI) B PM $(o * o)$ are established by associating/correlating criteria among each other. Let $D = [D_k; k = 1,2, \dots, o]$ depicts criteria sets. The

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respective $(o * o)$ PM B in which each feature/component $b_{jk}\,(j,k = 1,2,\dots,o)$ are the denominator of the criteria weight (CW). The selectivity given are of varied dimensions. Thus, the parameters are normalized and transformed it into a dimensional representation. The feature sets of constructed PM are weighted over each with respect to application QoS prerequisite. The Pm can be mathematically denoted using following equation

$$B = \begin{bmatrix} b_{11} & b_{12} & \vdots & b_{1n} \\ b_{21} & b_{22} & \vdots & b_{2n} \\ \cdots & \cdots & \dots & \dots \\ b_{n1} & b_{n2} & \cdots & b_{nn} \end{bmatrix} where, b_{jj} = 1, b = \frac{1}{b_{jk}} \quad (1)$$

where b_{jk} depicts the significance of criteria sets with respect to another criteria sets in the created PM B according to the strength of significance considered. Establishing association among criteria with respect other criteria's are known. Then in each strength, the DI are compared in the PM in accordance with their strength. In second phase, normalization and weight sets correlation is computed. The PM is composed of varied dimensional value of different units. Thus, it is normalized for ease of computation. Using Eq. (1), the normalized matrix (NM) B are created. That, is, divide every feature of the correlated matrix B by its corresponding column summation for obtaining feature sets of the NM in Eq. (2)

$$B = \begin{bmatrix} \frac{b_{11}}{\sum b_{j1}} & \frac{b_{12}}{\sum b_{j2}} & \vdots & \frac{b_{1n}}{\sum b_{jn}} \\ \frac{b_{21}}{\sum b_{j1}} & \frac{b_{22}}{\sum b_{21}} & \vdots & \frac{b_{2n}}{\sum b_{jn}} \\ \cdots & \cdots & \dots & \dots \\ \frac{b_{n1}}{\sum b_{j1}} & \frac{b_{n2}}{\sum b_{j2}} & \dots & \frac{b_{nn}}{\sum b_{jn}} \end{bmatrix} where, b_{jj} = 1, b = \frac{1}{b_{jk}} \quad (2)$$

Computing CW, the DI, X_j are estimated using following equation

$$X_j = \frac{\sum_o^{k=1} b_{jk}}{o}, X = \begin{bmatrix} X_1 \\ X_2 \\ \cdot \\ \cdot \\ \cdot \\ X_o \end{bmatrix} \quad (3)$$

where o depicts the size of similar criteria. The pairwise matrix consistency (PMC) is evaluated using following equation

$$PMC = \frac{\mathcal{C}}{\mathcal{R}} \quad (4)$$

where $\mathcal{C}$ depict consistency index parameter and $\mathcal{R}$ is a random parameter which depend on the number of criteria considered. The consistency parameter (CP) and random parameter can be estimated using following set of equations

$$\beta = \frac{B * X}{X} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \cdot \\ \cdot \\ \cdot \\ \beta_o \end{bmatrix} \quad (5)$$

$$\beta_{\uparrow} = \frac{\beta_1 + \beta_2 + \cdots + \beta_o}{o} \quad (6)$$

$$CP = \frac{\beta_{\uparrow} - o}{o - 1} \quad (7)$$

The pairwise similarity is ideal when PMC value is lesser than μ (i.e., 0.1). Thus, the qualified weights are computed by establishing W with respect with largest $\beta_{\uparrow}$.

b) *User preference based TOPSIS method for RAT ranking:*

TOPSIS is a well-known MADM method that is designed using Euclidian theory (ET). The TOPSIS model consider that selected output is close to finest ideal strategy and the same time they are far away from negative ideal strategy. This work incorporated preference aware methodologies into TOPSIS for building user preference aware TOPSIS (UPA-TOPSIS). The DM is established by mapping of suitable substitute with criteria described by a component. The UPA-TOPSIS method performs very efficiently for ranking accessible RAT at

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instance of DM. The UPA-TOPSIS permits dynamism for input criteria and at the same time aid in choosing ideal RAT. The preference contextual parameter depicts to the condition of DM for association prerequisite of the communicating devices. The process for computing the ranking of RAT using UPA-TOPSIS is as follows. The DM E are established by associated mapping of substitutes RAT with respect with qualified criteria. Each component is the association (i.e., interconnect) of the substitute B with the corresponding criteria D i.e., $B_j D_k$ where $j = 1, \dots, 4$ and $k = 1, \dots, 5$.

$$E = \begin{bmatrix} B_1 D_1 & \cdots & \cdots & B_1 D_n \\ \cdots & \cdots & \cdots & \cdots \\ \dots & \dots & \dots & \dots \\ B_n D_1 & \cdots & \cdots & B_n D_n \end{bmatrix} \quad (8)$$

The pairwise DM normalization process is as follows. The DM is normalized for applying UPA-TOPSIS method using Eq. (9)

$$S_{jk} = \frac{e_{jk}}{\sqrt{\sum_{j=1}^{n} .}} \; where, j = 1, \dots n; k = 1, \dots, o \quad (9)$$

e_{jk} are dependent on the outcome of action j for k in DM. Then, just multiply the normalized decision criteria sets S_{jk} with its given weights X_l the construction of NM is done. The weights obtained from user preference based criteria weight evaluation method described in section a is used as the input parameter for obtaining matrix W_{jk}. Here W_{jk} depicts the real information that is obtained by combining or cumulating substitutes and criteria weights. Further, the ideal positive ($+ve$) and ideal negative ($-ve$) strategy for the established information are computed using Eq. (10) to (Eq. (18).

$$W_{jk} = S_{jk} * X_l \; where, \sum_{l=1}^{n} X_l = 1 \quad (10)$$

Establishing $+ve$ ideal strategy B^+ and $-ve$ ideal strategy B^- is done using below equations

$$B^+ = W_1^+, \dots, W_n^+ \quad (11)$$

$$B^- = W_1^-, \dots, W_n^- \quad (12)$$

The prerequisite qualified criteria are obtained using following equations

$$W_1^+ = \max W_{jk}, k = 1, \dots, o \quad (13)$$

$$W_1^- = \min W_{jk}, k = 1, \dots, o \quad (14)$$

Similarly, the unqualified criteria are obtained using following equations

$$W_1^+ = \min W_{jk}, k = 1, \dots, o \quad (15)$$

$$W_1^- = \max W_{jk}, k = 1, \dots, o \quad (16)$$

The similarity distance (SD) is computed using following equation

$$T_k^+ = \sqrt{\sum_{k=1}^{o} \left(W_j^+ - W_{jk}^-\right)^2} \; where, k = 1, \dots o \quad (17)$$

$$T_k^- = \sqrt{\sum_{k=1}^{o} \left(W_{jk}^+ - W_j^-\right)^2} \; where, k = 1, \dots o \quad (18)$$

After obtaining $+ve$ and $-ve$ ideal strategies, the final ranking vector D is established using Eq. (19). The parameter D defines the rank order of the RATs among the accessible RAT. Finally, the best RAT among them is selected in descending order with respect to rank. The RAT with maximum value are considered as the best RAT.

$$D_k^* = \frac{T_k^-}{T_k^+ + T_k^-} \; where, k = 1, \dots, o \quad (19)$$

The proposed user preference based RAT selection method attain superior result when compared with existing RAT selection method which is experimentally shown below.

III. Result And Discussion

This section present performance evaluation of proposed UPAMO-RAT over existing RAT selection method. The implementation and simulation parameter considered are described below [22], [23], and [24]. The $IEEE$ 802.11 radio access technology is considered for UMTS, WiMAX, LTE, and WLAN. Three different kind of services such voice, video, and data (i.e., web browsing) are considered for experiment analysis. Each access network is given equal priority. For evaluating performance of UPAMO-RAT under dynamic mobility environment this work used *IEEE* 802.11 standard MAC designed in SIMITS simulator [25]. For modelling cellular network, the channel is composed of additive white Gaussian noise (AWGN). Then, multipath fading and log-normal shadowing model are used for modelling path loss model. Lastly, power control are ideal. Then, IEEE 802.11 is used for modelling WLAN, Rayleigh channel model are used, and bandwidth are set to 3-27 Mbps. The mobile subscriber are distributed uniformly random across HWN environment. New mobile subscriber and HO subscribers will obeys Poisson distribution. Lastly, 3 types of services are considered which composed of 40% of video service, 30% of audio services, and 30% of data services. The performance of UPAMO-RAT and existing RAT selection method is evaluated in terms of throughput, number of handover, and packet loss rate.

a) Throughput performance of UPAMO-RAT over existing RAT selection method:

This section present throughput performance attained of proposed UPAMO-RAT selection method over existing RAT selection method. Fig. 2 shows the throughput outcome attained be proposed UPAMO-RAT selection method over existing RAT selection method [22], [23] considering varied mobile terminal. The UPAMO-RAT improves throughput by 16.794%, 21.65%, and 18.821% over existing RAT selection method considering 100, 200, and 400 mobile terminal, respectively. From result it can be seen throughput increase with respect increase in mobile terminal size. This is because more number of packet is being transmitted in network. An average throughput performance improvement of 19.088% is attained by proposed UPAMO-RAT over existing RAT selection method. From overall result attained it can be seen, the proposed RAT selection is robust and scalable with respect to mobile terminal size in attaining good throughput.

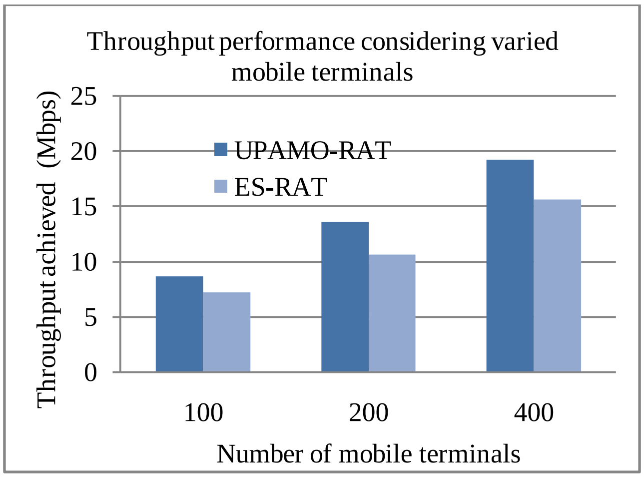

Fig. 2. Throughput performance evaluation considering varied iteration.

b) Packet loss rate performance of UPAMO-RAT over existing RAT selection method:

This section present packet loss rate performance attained of proposed UPAMO-RAT selection method over existing RAT selection method. Fig. 3 shows the packet loss rate outcome attained be proposed UPAMO-RAT selection method over existing RAT selection method [22], [23] considering varied mobile terminal. The UPAMO-RAT reduce packet loss in network by 82.47%, 47.67%, and 31.602% over existing RAT selection method considering 100, 200, and 400 mobile terminal, respectively. From result it can be seen packet loss rate increase with respect increase in mobile terminal size. This is because challenges exist in finding suitable substitute RAT for communication of dynamic mobile terminal. An average packet loss rate performance improvement of 53.91% is attained by proposed UPAMO-RAT over existing RAT selection method. From overall result attained it can be seen, the proposed RAT selection is robust and scalable with respect to mobile terminal size in attaining good packet loss rate performance.

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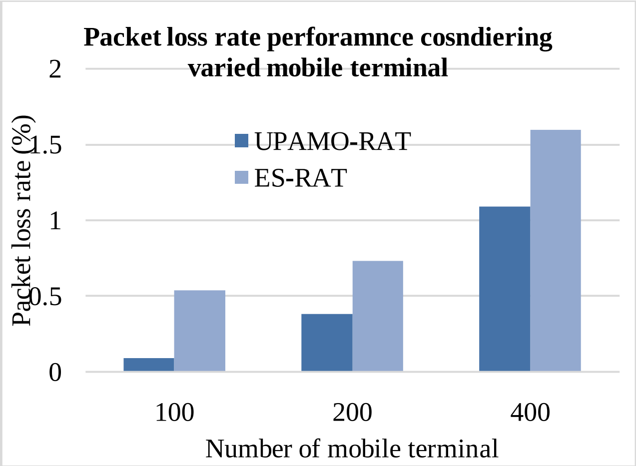

Fig. 3. Packet loss rate performance evaluation considering varied mobile terminal.

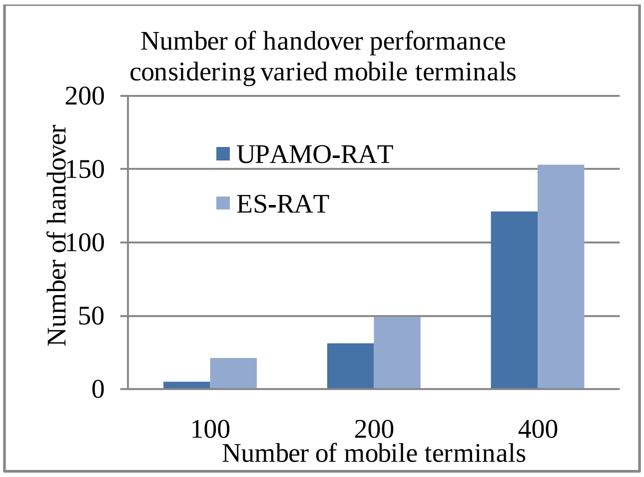

Fig. 4. Number of handover performance evaluation considering varied mobile terminal.

c) Number of Handover performance of UPAMO-RAT over existing RAT selection method:

This section present number of handover performance attained of proposed UPAMO-RAT selection method over existing RAT selection method. Fig. 4 shows the number of handover outcome attained be proposed UPAMO-RAT selection method over existing RAT selection method [22], [23] considering varied mobile terminal. The UPAMO-RAT reduce number of handover in network by 76.19%, 36.73%, and 20.91% over existing RAT selection method considering 100, 200, and 400 mobile terminal, respectively. From result it can be seen number of handover increase with respect increase in mobile terminal size. This is because challenges exist in finding suitable substitute RAT for communication of dynamic mobile terminal. An average number of handover performance improvement of 44.61% is attained by proposed UPAMO-RAT over existing RAT selection method. From overall result attained it can be seen, the proposed RAT selection is robust and scalable with respect to mobile terminal size in attaining good number of handover performance.

IV. Conclusion

Presenting efficient RAT selection under multi-service multi-terminal heterogeneous wireless network. First, this work conducted extensive survey of various existing RAT selection for HWN. From survey it is seen MADM with combination of Fuzzy, Markov Decision (i.e., reinforcement Leaning), Deep learning are some method used for RAT selection in HWN. Most of existing RAT selection method are designed without considering user QOE and preferences. Further, very limited work is carried out considering provisioning user preference considering multi-service HWN environment. This work presented user preference aware multi-objective RAT selection method for HWN. First, a decision matrix is built using preference aware weight. Then, ideal RAT is selected using preference aware TOPSIS for carrying out handover operation and communication. Experiments are carried out to evaluate the performance of proposed UPAMA-RAT method over existing RAT selection method in terms of throughput, packet loss rate, and number of handover. From result attained it can be seen the UPAMA-RAT improves throughput performance by 19.088%, improves packet loss rate performance by 53.91%, and number of handover performance by 44.61% over existing RAT selection method considering varied mobile terminals. From result attained it can been the UPAMO-RAT selection method attain superior Quality of experience (QoE)

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outcome when compared with existing RAT selection method. Future work would further considering more dynamic service and incorporate soft computing technique such as Fuzzy, Markov decision or particle swarm intelligence for building better decision matrix and RAT selection. Along with consider more complex environment similar to VANET where frequent handoffs occurs.

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