Research Article

Optimal Bandwidth Allocation and Software-Defined Network Aggregation for Heterogeneous Mobile Network

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Abstract: The Software Defined Networking (SDN) defines a promising networking architecture combining network programmability and central management. The optimal bandwidth allocation is not attained in the existing system which results in overall network performance degradation. The Adaptive Genetic Algorithm (AGA) is used for attaining the optimal bandwidth allocation so as to improve the overall network performance. A software-defined network aggregation is used in this system for traffic offloading in LTE-WiFi networks. The SDN and Multipath Transmission Control Protocol (MPTCP) can generate TCP subflows across multiple network connection. A centralized controller id used for connecting SDN directly to the subflows and for aligning the rate of subflows in every radio access network for enhancing integrity and load balancing of many-RAT bandwidth aggregation(MRBA). The controller can receive the status of the network and promote network management. The Quality of Experience (QoE) estimation method is used in this system for enhancing QoE of the multimedia device users. The newly designed AGA-MRBA-QoE architecture can give high performance with regard to lower delay, higher bandwidth, higher packet delivery ratio (PDR), higher throughput and lower energy consumption.

Keywords: Resource management,multipath-based network aggregation, Software defined wireless sensor networking, Adaptive Genetic Algorithm and Bandwidth Allocation

1. Introduction:

As the smart devices are fixed in cellular networks, the mobile traffic is increased [1]. The increased mobile traffic is the main technical challenge faced by the mobile network operators. In fourth generation long term evolution (LTE) networks, the wireless local area network (WLAN) hotspots are integrated with the cellular network through packet data network gateway (P-GW) [2] so that the hotspots can offload the mobile traffic and so the congestion is reduced at LTE access networks like internet protocol (IP) [3]. The newly designed heterogeneous LTE/WLAN multi-radio architecture allows the use of heterogeneous LTE/WLAN radio interfaces in more advanced and systematic manner like continuous flow mobility and bandwidth aggregation [4].

Moreover, the aligning of enhanced heterogeneous bandwidth to multiple radio devices is needed for effective network utilization [5]. Although the operators are improving their networks to withstand the increase in bandwidth, the network capacity is significantly low than the bandwidth [6] and so easy to use and low in cost WLANs are used by the operators for improving the network capacity [7]. In order to maintain better QoE, advanced solution is need to be used in the heterogeneous network.

A large number of users can be able to receive signal from Wi-Fi Access Point (AP) during peak time, as the Wi-Fi APs are used in the hot spot regions. Also the operators cannot be able to switch the interface consistently over Wi-Fi and cellular networks as the load of the Wi-Fi APs is not taken for interface selection. The interface selection is carried out only after the connection is initiated and so the same level of throughput is varied to multiple levels of QoE for the operator. As the interface capacity is shared between multiple flows from multiple users, the QoE is reduced for all the flows [8]. While some studies show that the interface selection is performed for providing temporary or partial solution by assuming that an architecture for continuous switching is present [9].

There are a lot of challenges and practical complications in designing such architecture in addition to theoretical complexity. In some systems, the user data are arranged in Wi-Fi and cellular interfaces so as to restrict to delay-tolerant traffic and to neglect real time videos and images [10]. This system improves the QoE of the user by mapping the user flows to the corresponding network. The network-wide utility is improved by using a practical algorithm for interface selection, and the backhauling traffic from Wi-Fi to LTE network is avoided by using AGA for optimal path selection.

Below are the indications and that are explained: similar work with many work aggregation with QoE systems with SDN network has explained within this method 2, the discussed systems AGA-MRBA-QoE are elaborated with the section 3 then the live resultant through proposed are elaborated with the section 4 then at the resultant the closure work is provided through the section 5.

2. Related Work

In [11] The QoE representing the user's satisfaction of the multimedia device is improved by establishing an optimal resource allocation method for heterogeneous wireless networks. The QoE is effectively measured by considering energy factor (EF) and rate factor (RF) at the same time. The user's QoE is improved with respect to the limitations of power rate, data rate and transmit bandwidth.

In [12] Data-driven self-tuning algorithm is used for attaining traffic steering in order to improve the overall QoE in multi-carrier LTE network. Traffic steering is achieved by varying Reference Signal Received Quality (RSRQ) based inner-frequency margins. In [13] Traffic steering is formulated between WiFi and cellular networks in real-time for improving user experience, balancing the energy consumption and reducing delay. The Lyapunov drift plus penalty optimization is used for achieving effective Wi-Fi/cellular resource management.

In [14] The user's QoE in heterogeneous wireless networks is maximized by designing an optimal bandwidth and power allocation method. In [15] An efficient resource allocation method is implemented by optimization based decision making algorithm for reducing energy consumption. The resource allocation method is used for forming clusters in wireless video sensor using RAS-HO algorithm. Also, the user flows will be continuously moved between LTE and Wi-Fi and the existing connection will not be interrupted by the framework, even though the IP address is changed during the live session of the user. Thus, it is difficult to find the dynamic solution for over the top (OTT) traffic and user QoE. Therefore, it is necessary to find dynamic, scalable and continuous traffic management solution and to build an end-end system that is effectively run in any user's network without requiring high data plane integration between LTE and Wi-Fi networks.

3. Proposed methodology

In this paper, QoE based bandwidth aggregation method is designed for maximizing the user's QoE. By considering both the data rate and energy consumption, the efficient QoE measurement is performed. The optimal path selection is carried out using AGA algorithm. Also, the end user's QoE utility is improved using QoE based bandwidth aggregation method with regard to service requirement and transmission limitations.Further, optimal bandwidth aggregation for end users is effectively achieved in MRAT systems. The AGA-MRBA-QoE structure with traffic engineering is explained in the figure given below FIG 1.

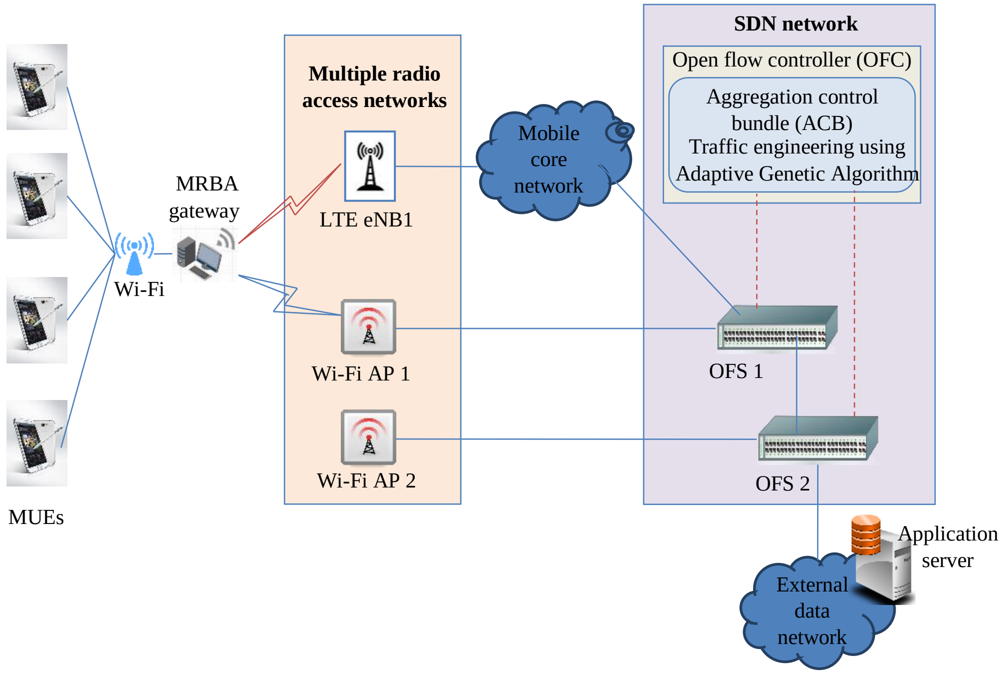

Fig. 1. The Proposed AGA-MRBA-QoEwith Traffic Engineering

In Fig. 1 the AGA-MRBA-QOE with Traffic Engineering has various radio processing networks (e.g.WiFi and LTE networks and SDN network). The UE is managed through many-RAT Client (mRC) which has large number of the wireless network processing interfaces like LTE and WiFi. With the MRBA pathway structure, every UEs combines with WiFI, so that the pathway can utilize MRBA function by removingthetrafficand the load balancebetweentheLTEand the WiFi networks. Thus, UE combines with LTE station referred aseNB andWiFi access point (AP) through SDN network. The Wi-Fi APs contacts with open flow switches (OFS),where the LTE depending methods are controlled with SDN system along with the core in mobile connectivity. Thus the open flow switches have been handled through the open flow controller (OFC). The calculated control bundle (ACB) is establishedwithin the open flow handler, for finding the stocks byimplementing flow permit through the packet routing with open flow modification by utilizing Dijkstra and by ignoring traffic. Thus these packets have been moved towards application server outside the data network through the open flow switches.

3.1. SDN-Multi-RAT Model with Problem formulation

SDN method allows the individuals to control the data in traditional network and uses SDN switches for transmitting data. Therefore, the handle system is decoupled through its switches and is forwarded through the centralized SDN handler. These switches are handled by the SDN handler through the predefined communication system external Flow (external Networking start-up, 2014), which is named as Open Flow switches (OFSs) and Open Flow controller (OFC), hence, this method creates the handler with high network estimation and adaptability. The SDN are integrated through multi-RAT bandwidth calculation consisting of *M* active MUEs and *N* available RATs. The multi–RAT stabilizing defects can be managed approximately through centralized open flow handler. The user equipments (UEs) system is enabled using single network interface, and also the UE can withstand with the switching system networks for the given time. The UE is integrated with MRBA by generating multi-RAT client (MRC) between LTE and WiFi networks. In UEs the application services have been processed through discussed method. Thus the MRC gives an undefined radio network interfaces through the IP stage accessed by the host, like the system gets combinedwith the radio links(e.g. in between the Wi-Fi and the LTE). Thus, the open flow has been handled by Aggregation Control Bundle (ACB) through managing many RAT calculated bandwidth. The detailed explanation of MRC and ACB is given in this section. The QoE of the end users in the MRAT system is calculated as below:

$$\max_{band,Energ} U(band, Energ) = \sum_{i=1}^{M} U_i(band_i, Energ_i)$$

$$\sum_{i=1}^{M} band_{ij} \le Bd_i^{max}, \forall i$$

$$\sum_{j=1}^{N} Energ_{ij} \le Ey_j^{max}, \forall j$$

$$ADR_i \ge Service_i^{min}, \forall i\ ;\ band_{ij} \ge 0, Energ_{ij} \ge 0$$

In which U($band, Energ$) is the QoE utility function of the end users,Bd_i^{max} refers to the total subsystem bandwidth of MRAT system, $Service_i^{min}$is the minimum power rate of MUE, ,Ey_j^{max} is the maximum power rate of MUE,, $Energ_i$ is the energy allocation matrix from RATs to MUEs, $band_i$ is the bandwidth allocation matrix and ADR_i is the attainable data rate of MUE_iwhich is given as:

$$\sum_{i=1}^{M} ADR_i = \sum_{j=1}^{N} band_{ij} tr_j \log_2 \left(1 + \frac{\left|Channelgain_{ij}\right|^2 Energ_{ij}}{N_{ij} band_{ij}}\right)$$

here N shows the total number of RATs used by MUE,, $band_{ij}$refers the bandwidth allocated to $MUE_i$from $MRAT_j$, $Energ_{ij}$is the energy transmitted by MUE_i through $MRAT_j$and tr_j (0 < tr_j< 1) shows the transmission efficiency achieved by $MRAT_j$ to MUEs. The QoE utility is evaluated with high precision by using multiplicative exponent weighing (MEW) method. The factors like energy consumption and data rate are utilized for obtaining QoE utility function which is measured as,

$$U_i(band, Energ) = \prod_{k=1}^{n} [u_k(band, Energ)]^{w_k}$$

Whereas w_k shows the weight factors, $u_k(band, Energ)$ refers to elementary utility factor k and n shows the total number of considered factors. The rate and energy factors are utilized simultaneously for finding QOE. The $U_i(band, Energ)$ can be expressed as:

$$U(band, Energ) = \sum_{i=1}^{M} \{[\mathfrak{K}\mathfrak{F}_i(band_i, Energ_i)]^{w_1} \cdot [\mathfrak{E}\mathfrak{F}_i(band_i, Energ_i)]^{w_2}\}$$

$$= \sum_{i=1}^{M} \left\{ \left[\frac{r_i}{Ub_i}\right]^{w_1} \cdot \left[1 - \frac{\sum_{j=1}^{N} Energ_{ij}}{Ey_j^{max}}\right]^{w_2} \right\}$$

$$U(band, Energ) = \sum_{i=1}^{M} \{[\mathfrak{K}\mathfrak{F}_i(band_i, Energ_i)]^{w_1} \cdot [\mathfrak{E}\mathfrak{F}_i(band_i, Energ_i)]^{w_2}\}$$

$$= \sum_{i=1}^{M} \left\{ \left[\frac{r_i}{Ub_i}\right]^{w_1} \cdot \left[1 - \frac{\sum_{j=1}^{N} Energ_{ij}}{Ey_j^{max}}\right]^{w_2} \right\}$$

In which Ub_ishows the upper bound transmit rate for MUEi, which is measured as given below,

$$Ub_i = \log_2 e. Ey_j^{max} . \frac{\left|Channelgain_{ij}\right|^2}{N_{ij}}$$

The QoE measurement in $\max_{band,Energ} U(band, Energ)$ is performed by considering the weight parameters w_1 and w_2 of the selected factors as $w_1 + w_2 = 1$, values of weight parameter w1 is increased with the transmission rate and the value of w2 is changed according to the energy consumption. Additionally, the optimal path detection is performed using AGA with the objective function.

3.2. Adaptive Genetic Algorithm based Routing Path detection

A hybrid method has been created by utilizing Multi-RAT for forwarding collective packets so as tocalculate the traffic. Hence, the network lagging value is limited through transmitting packets along the network. The discussed method has been at aim through search lesser way through Thepacketsare transferred from the sender node to receiver node with better traffic density and low network lagging value. The mutation probability and cross-over probability can be mechanically adjusted by the AGA algorithm with the alternating environmental factors. The drawback like lower convergence speed, rapid drop down of local optimum value and large calculation can be eliminated by AGA algorithm

Path planning ensures avoiding colliding with obstacles running in the shortest path which is ensured by retaining each path point in the shortest distance while moving from starting to ending points [6]. The distance between the node and obstacle should be larger than the sum of their circumference radius so as to avoid collision and so an invalid path point can also be avoided. The maximum value of fitness function can be measured as follows:

$$fitness = \alpha \frac{1}{\max_{band,Energ} U(band, Energ)} + \beta \sum_{i=1}^{M} dist_{min}$$

Inwhich$dist$,represents the shortest distance between obstacle and the path point.The coefficient of path point and obstacles is mentioned asα and β . AGA based path detection performance is given as follows.

Selection and duplication: The fitness result can be measured according to the individual path. The probability expression (Pi) is calculated by identifying the ratio of individual and sum of all fitness. The Pi is calculated as follows,

$$P_i = \frac{fitness_i}{\sum_{i=0}^{m} fitness_i}$$

Crossover:

Crossover is a process of generating new individuals and determining the capacity of global search. Initially, the group of individuals is generated with random association. The chromosomes in each individual are switched so as to generate new individualsbased on the crossover probability$P_{crossover}$.The crossover probability$P_{crossover}$ is calculated as follows,

$$P_{crossover} = \begin{cases} \frac{k_1(fitness_{max} - fitness')}{fitness_{max} - fitness_{avg}} & fitness' > fitness_{avg} \\ k_2 & fitness' \leq fitness_{avg} \end{cases}$$

Mutation: Mutation is the process of generating new individualsand determining the capacity of local search.The capacity of the local search is improved. Crossover is not usable for local search. The diversity of the individuals is maintained effectively by mutation and also the premature convergence can be avoided. The mutationprobability$P_{mutation}$ is determined as follows:

$$P_{mutation} = \begin{cases} \dfrac{k_3(fitness_{max} - fitness')}{fitness_{max} - fitness_{avg}} & fitness > fitness_{avg} \\ k_4 & fitness \leq fitness_{avg} \end{cases}$$

In which $fitness_{max}$ represents the maximum fitness value of individual group, $fitness'$ represents the largest fitness value between two individuals,, $fitness_{avg}$is the average fitness value of the individuals and wherek_1, k_2, k_3, k_4 represents the constant values such as 0 and 1. The weight values of $\alpha = 0.9$ and $\beta = 0.1$. The initial values of crossover probabilities are $P_{crossover1} = 0.8$ and $P_{crossover2} = 0.6$, and the initial values of mutation probabilities are $P_{mutation1} == 0.01$,, $P_{mutation1} = 0.001$.AGA method is utilized to attain the optimal values of the bandwidth.Particularly, the update expressions for the bandwidth is calculated as below,

$$band_{ij}^{k+1} = \left[band_{ij}^{k} + \frac{\delta \partial band}{\partial band_{ij}}\right]^{+}, \forall i, j$$

where $\left[band_{ij}^{k} + \frac{\delta \partial band}{\partial band_{ij}}\right]^{+} = \max\left\{\left[band_{ij}^{k} + \frac{\delta \partial band}{\partial band_{ij}}\right], 0\right\}$ and $\delta$is the step size for primal variable band_{ij}. By solving the optimization problem of the MRAT system in MRBA, the total end-user'sQoE utility can be improved. The flowchart of AGA based path detection is shown in Fig.2.

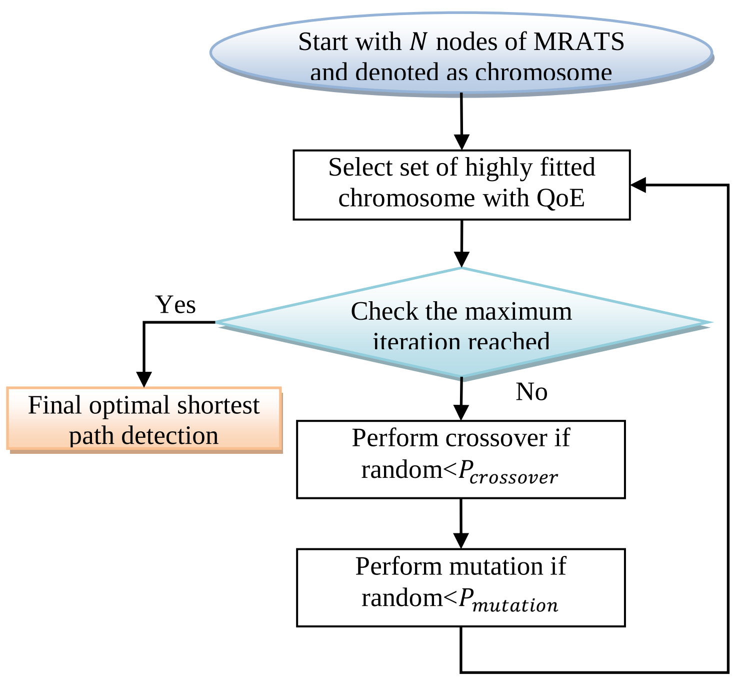

Fig.2. The flowchart of AGA based path detection

3.3. SDN-based multi-RAT bandwidth aggregation procedure

The SDN-based MRBA structure is detailedwithin the flow- dependant bandwidth calculation system. In MRBAthe information is shared easily from ACB using LTE networkthan Wi-Fi. Also the mobility management is better in LTE than Wi-Fi. Thus, the information can be effectively delivered with LTE in MRBA. Moreover, the UE utilizes the well organised control port of control IPtodeliver the messages in control mannerthan the targeted IP. The Port numbers as well as IP addresses are identified through OFSs, so that the information is passed towards ACB.

Registration procedure: The information in the UE is forwarded with ACB through theLTE network. The IP addresses of LTE andeNBare interlinked through UE. The operation of WiFi and the contacting of WiFi and UE will takesplacesimultaneously.Thus the UE transfers the detailed information with OFSI along with LTE andeNB. Also, the targeted IP gets enhanced through handler , the packet anda control port, thus the packets gets transferred to OFCthrough OFSI. The IPs of the UE is interlinked with the packet IP's of Wi-Fi and LTE through BSSID. Thusthepackets are connected with current flow permit in OFSI. Below are the restrictions for present flow permit: At the beginning IP address of targeted port transfers the packets with OFC through PACKET_IN information.

Thereforethe filed permits get transferred with the ACB with OFC. The ACB is identified through IP messages, so as tochoose the calculated point (e.g. OFSI) and to perform alignment with IP using interface in virtual network through user equipment.Thus ACB transfers the saved messages with PACKET_OUT information through OFSI for adding the information like IP_UE and saved output (e.g. success). OFSI gets the PACKET_OUT information through the UE.Also the UEsequences IP_UE through the interface virtual networkinstead of the saving the reacting packets. After saving the packets, ACB receives the required UE information interface by interlinking IP addresses of Wi-Fi and LTE with Wi-Fi Aps general service set Identifier (BSSID).Also, OFSI gets the primary packet of the data, thus the PACKET_IN information has been shared through ACB so as to find the starting IP of the UE, thus the similar routing limitations are carried out from OFC to OFS1through AGAfor transferring packet.

Flow-based bandwidth aggregation procedure: Fig..3 displaysthe information flow-by-flow based on bandwidth calculation. This system gets induced through its primary packets through Wi-Fi and LTE getting through OFS. Within certain area, thus the OFS have not getting how the packet gets forwards. The flow-depending bandwidth calculation is started for allowing UE to emit the various data applications of Wi-Fi and LTE simultaneously.The flow of data is enabled through Wi-Fi and LTE by the port_1 then port_2, accordingly. The bandwidth calculation method isdetailed as below.

Step 1. The UE started network handling through LTE.

Step 2. Thus, the data packets are shared to OFS1 through LTE eNB along MRBA pathway.

Step 3. The initially reaching data packet starts table-miss function through OFSI for transferring packets information PACKET_IN to OFC through ACB.

Step 4. ThusACB finds the packet through the starting IP, the UE messages are transferred through UMF and the routing path is calculated by FCF using AGA**.**

Step 5. The flow permit is made by ACB through OFSI for transmitting FLOW_MOD to OFSI**.**Thepacket at IP_UE changes the starting IP and the IP is allocated to the new OFS (e.g.OFS2). The targeted IP replaced by packetat IP_LTE and the replaced IP is shared to LTE eNB.

Step 6. By transmitting FLOW_MOD by means of OFS2 which allows ACB additional flow. By using the OFS1 and the targeted IP packet IP_UE the packet moves to the application server with the internet.

Step7. With the help of OFS2 flow entry data packets are transferred to the application server in the OFS1. The uplink and downlink flow (i.e. bi-directional flow) allows OFS1 and OFS2, then the next available data packets are transmitted using LTE and UE network.

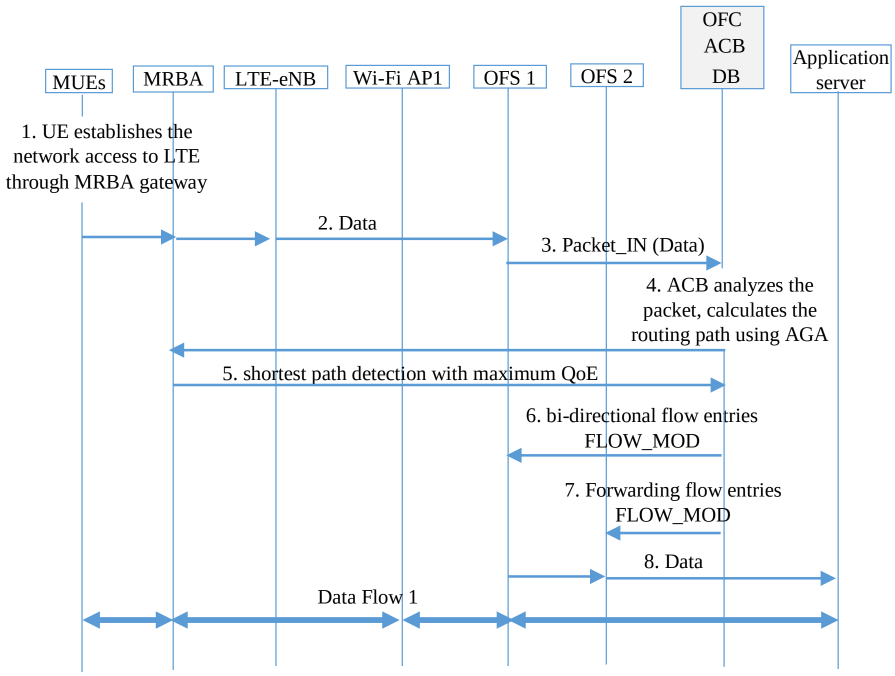

Fig.3. The flow-based bandwidth aggregation procedure with QoE of Multi-RAT

4. Experimental Results and Discussion

In this portion, the improvement attained by SDN-based multi-RAT architecture is discussed. An ns-3vbased evolution platform is developed with the designed architecture which is named as AGA-MRBA-QoE for measuring the system performance. The developed platform modifies the operation of LTE and Wi-Fi base stations and converts them into data plane nodes. A multi-RAT controller module collects the bandwidth operation of RATs and aligns the data path based user defined policy. The existing multi-RAT architecture provides network information only within a specific RAT but the newly designed architecture provides information of LTE BS and Wi-Fi Access point (AP) along with overlapping coverage area. The throughputs, latency of data traffic are measured using simple techniques in the newly designed architecture. The simulation parameters for Wi-Fi and LTE are illustrated in Table 1:

Table 1:Multi-RAT network model for LTE and Wi-Fi

Parameter	Value
Data rate for single LTE user	5 Mbps
Single User Service Mean Time	60 s
Path loss	128.1+37.6 log (R), R in kms
Wi-Fi bit rate	54 Mbps
Tx power for LTE (d)BS	46 dBm
Tx power for AP and Wi-Fi dBS	23 dBm
Tx power for UE	23 dBm

4.1. Throughput Analysis

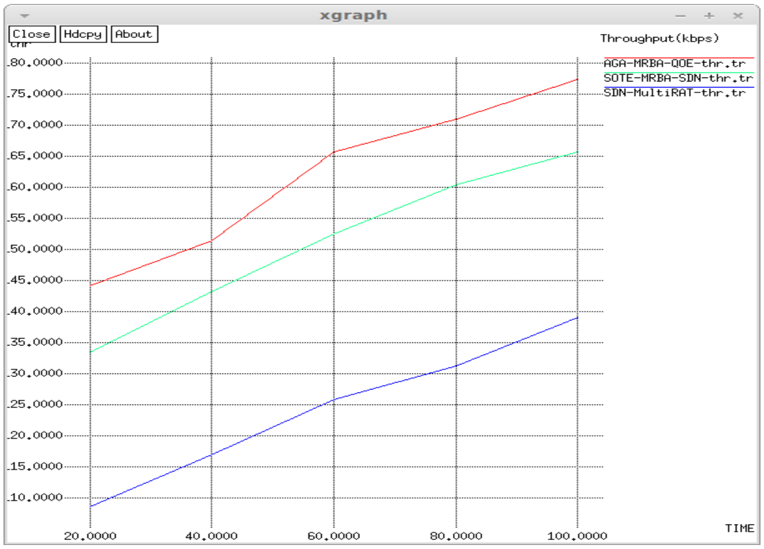

Fig.4.Throughput Comparison results

In the above Fig.4, The solid curves indicates the performance of SDN base SOTE-MRBA-SDN, Multi RAT and AGA-MRBA-QoE networks. The performance value of the newly designed method is -77kbps. However, the traditional SDN-MultiRAT and SOTE-MRBA-SDN only reduces thethroughput performance with the values of -65kps and -39kps because in the existing SDN-Multi RAT network, the specific RAT does not have the load information of the other RATs. These results indicate that the newly formulated method gives high bit rate transmission. TheAGA-MRBA-QoEarchitecture facilitates faster connection towards local maximaso as to improve the total system throughput.

4.2. Delay Results

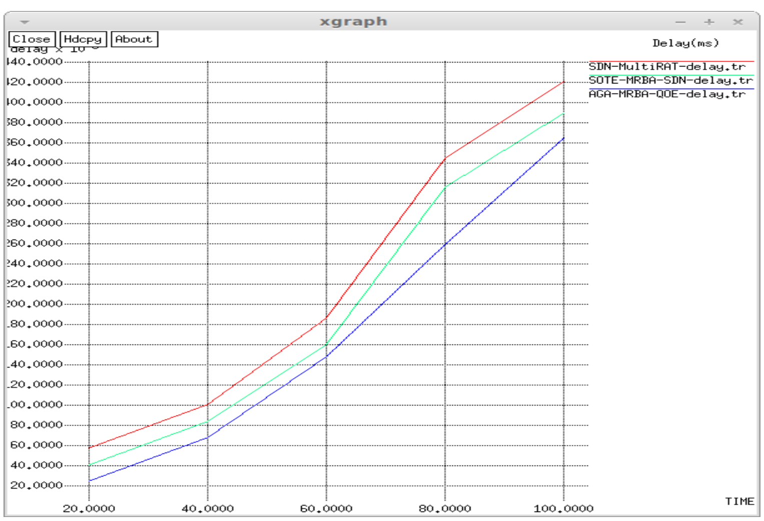

Fig.5.Delay Comparison results

Fig.5shows the delay results of the SDN-based MultiRAT, SOTE-MRBA-SDN and AGA-MRBA-QoEnetworks with the corresponding time. Once if the time of data user arrival rate increases, there is a linear increase in the delay rate. It is also found that the delay is decreased in the AGA-MRBA-QoE framework with the value of 370ms.Also, the delay values in SDN-based MultiRAT, SOTE-MRBA-SDN network attains high results of 420ms and 390ms respectively. Hence, AGA-MRBA-QoE algorithm assures exorbitant global QoE utility and it represent the possibility and reasonability of distributed optimization process for MRAT system.

4.3. Energy results

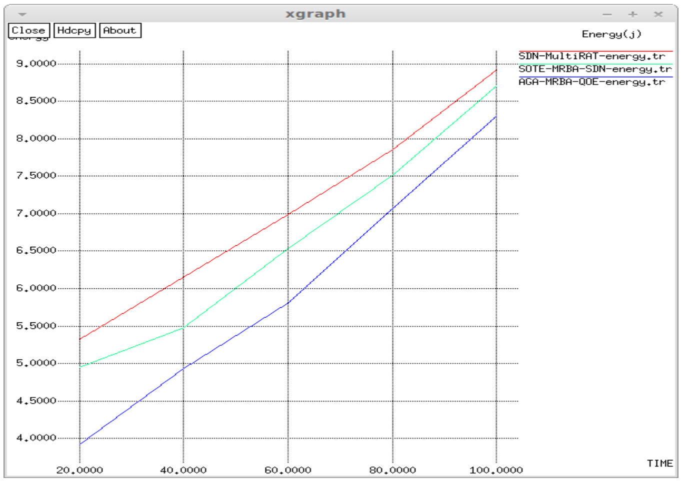

Fig.6.Energy Comparison results

The above Fig,6, shows the energy of service request in SDN-multi RAT network accumulates with probability of the LTE service request with the value of 8.9000J. In addition, SOTE-MRBA-SDN network obtain high energy value of 8.7000J. When the input service requests are inconsistent, the response time of the service request will be affected terribly. The input service request sent to LTE eNB and Wi-Fi based on the network load due to AGA-MRBA-QoE network achieved less energy value of 8.3000J. The AGA-MRBA-QoE architecture uses the network functions suitably so that the energy in the MRBA gateway didn’t affected under several arrival rates, in such a way that the efficiency is progressed with low energy consumption.

4.4. Overhead comparison

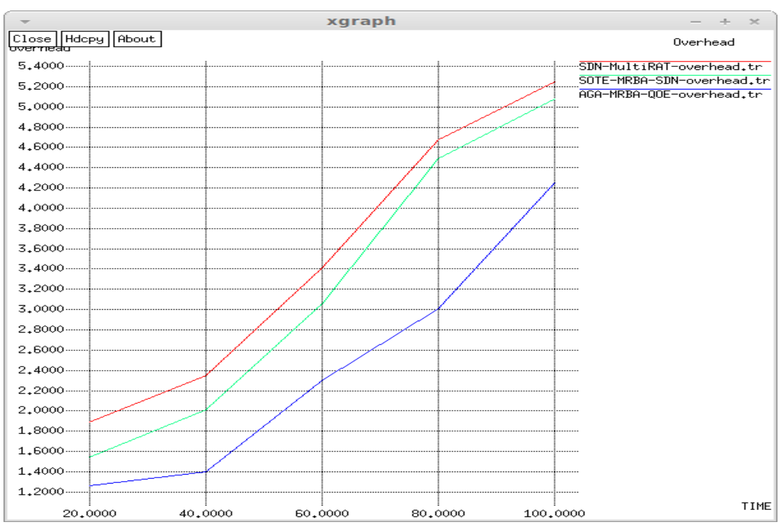

Fig. 7. The performance comparison of overhead

In Fig.7theoverheadperformance of thedesigned AGA-MRBA-QoE algorithm compared with the SDN-based MultiRAT, and SOTE-MRBA-SDN algorithms is shown. The AGA-MRBA-QoE algorithm provides higher QoE utility compared with SDN-based MultiRAT and SOTE-MRBA-SDN.It is found that the overheadperformance value ofAGA-MRBA-QoE frameworkis decreased with the value of 4.2500 when compared with the overhead performance values in the SDN-based MultiRAT, SOTE-MRBA-SDN are of 5.2500 and 5.1000 respectively.The

SDN-based MultiRAT and SOTE-MRBA-SDN algorithms are related to the number of MUEs and RATs, so that the overhead performance is degraded.

4.5. Packet delivery Ratio (PDR) comparison

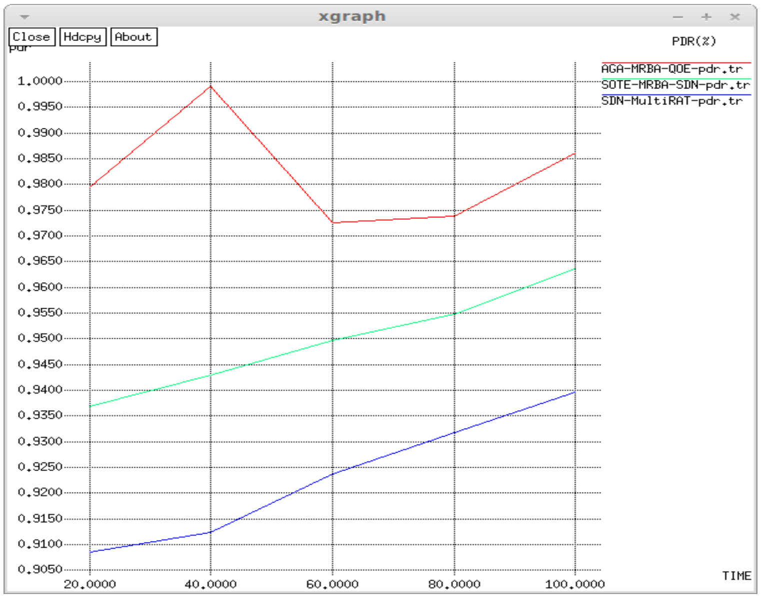

Fig. 7. The performance comparison of PDR

In Fig.7, illustrates that performance of PDR of the newlydesigned AGA-MRBA-QoE algorithm over the SDN-based MultiRAT and SOTE-MRBA-SDN algorithms.It is found that the PDR is increased in the AGA-MRBA-QoE framework with the value of 9.860% when compared with the overhead values in SDN-based MultiRAT, and SOTE-MRBA-SDN networks are of 0.9400% and 0.9630% respectively. So that, this AGA-MRBA-QoEalgorithmperforms well, and guarantees maximizedglobal QoE utility with high PDR.

5. Conclusion and Future Work

In this research, the optimal bandwidth aggregation is attained with low energy consumptionby the efficient QoE measurement. The QOE of end-users is optimized effectively using this AGA-MRBA-QoE architecture. This newly designed architecture will extend in future as finding the local and global optimum solution for resource allocation at user level and network selection strategies using QoE utility function in multiple environments at user level.

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