A Load Balancing Algorithm with QoS Support over Heterogeneous Wireless Networks

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Abstract—**Coexistence of different wireless networks is a common phenomenon in today's smart communication infrastructure. Now, the big issue is to explore benefits from the heterogeneous nature of communication technology. Load balancing among the heterogeneous wireless networks is the primary goal of this paper. Load balancing without considering Quality of Service (QoS) merely inadequate in convergence of resource utilization and grade of service. So, this paper proposed a load balancing algorithm with QoS provisioning. This paper is based on a semi-distributed load balancing architecture. Firstly, IP-flow dividing ratio based soft load balancing approach is discussed for high speed features of next generation wireless networks. Secondly, an admission control function of QoS requirements is developed. Thirdly, a joint optimization function is derived and a load balancing algorithm is proposed by using the cost function. Finally, simulation results are presented for performance appraisal.**

Keywords-load balancing; QoS provisioning; heterogeneous wireless networks; semi-distributed architecture.

I. INTRODUCTION

Networks with multiple radio access technologies would become one of the most prevalent features in next generation mobile networks [1]. From machine to machine communication to body area networks and from smart grid to cellular communication, coexistence of different access technologies is must for smooth communication.

The delivery of quality of service(QoS)-demanding applications such as in voice over WLAN (VoWLAN) is very challenging in the context of future IP based wireless networking scenario where hotspots of multiple access point are physically collocated [9]. Uniform distribution of traffic loads is the main objective of load balancing algorithm, but uniform distribution sometimes degrades QoS metric. Conversely, maintaining higher QoS may create imbalance of loads among different access networks. So, a joint optimization is the solution to optimize the performance of load balancing algorithm. Here, a joint optimization function is derived using min-max principle and linear weight constraint.

The rest of the paper is organized as follows. Related works are reviewed in section II. The load balancing architecture is depicted in section III. The protocol description and a soft load balancing algorithm are presented in section IV. Joint optimization function based load balancing algorithm is presented in section V. The simulation results are illustrated in section VI. Finally, we conclude the paper in section VII.

II. LITERATURE REVIEW

Load balancing with QoS provisioning in heterogeneous wireless networks is the contemporary research issue as wireless communications are expanded day by day and multiple wireless networks are deployed on the same grid.

The authors of reference [16] proposed a soft load balancing algorithm based on IP-flow dividing ratio. They have shown lower call blocking probability and uniform load balancing of heterogeneous wireless nodes but they didn't consider the QoS requirements. An adaptive network selection algorithm (ANSA) is proposed in reference [17]. The proposed algorithm is based on user profile i.e user mobility, power of the mobile terminals, service costs, and application profile i.e application type, connection delay, network bandwidth etc. To ensure QoS they designed a dynamic cost function considering both user and application profile parameters.

A novel load balancing schema for QoS provisioning is proposed by the authors of reference [18]. In their paper they have shown load related admission control and vertical handover process, and balance loads according to the joint optimization function. In their algorithm, they derived admission control function only considering the bandwidth requirements without considering interference, channel gain and transmission efficiency.

III. THE SEMI-DISTRIBUTED ARCHITECTURE

A distributed architecture for wireless network is appealing due to the single point of failure of centralized design. Our proposed load balancing algorithm is based on the semi distributed architecture, which is free from the huge signaling overhead.

In the architecture, a number of adjacent hexagonal cells create a basic grid. Since the system is heterogeneous, each cell may consist of different access network. For simplicity we consider only three types of access networks i.e UMTS, WLAN and WiMax. In paper [7][8], we have presented the detail description of the semi-distributed architecture.

IV. OPTIMAL FLOW DIVIDING RATIO TO SUPPORT SOFT LOAD BALANCING

To manage control signal from different access networks, a general link layer is employed in LMMs to support a soft load approach. Detail protocol description and soft load balancing algorithm is presented in our another paper [16].

To gain the best load balancing effect, the optimal flow dividing ratio, $\omega^*_{i,m}$ of user *i* in system *m* is derived by,

$$\left[\omega^*{}_{i,m}\right] = \arg\min\left|\Delta_{i,x,y}\right| \tag{1}$$

Where, Δ = Relative load difference among the wireless access networks, Here, $x=\{1,2,3\}$ and $y=\{1,2,3\}$ but $x \neq y$.

and $\omega_{i,m} = LB(\omega^*{}_{i,m})$; $0 \le \omega_{i,m} \le 1$.

The optimal flow dividing ratio for load balancing *LB()* function can be obtained by the following three equations:

$$\omega_{i,1} = \frac{R_i.C_{0,i,1,j_1}.W_{T,1} + C_{0,i,1,j_1}.C_{0,i,2,j2}.C_{0,i,3,j_3}.(L_{2.j_2.i}.W_{T,2} + L_{3.j_3.i}.W_{T,3} - L_{1.j_1.i}.W_{T,1})}{R_i.(C_{0,i,1,j_1}.W_{T,1} + C_{0,i,2,j2}.W_{T,2} + C_{0,i,3,j_3}.W_{T,3})} \tag{2}$$

$$\omega_{i,2} = \frac{R_i.C_{0,i,2,j_2}.W_{T,2} + C_{0,i,1,j_1}.C_{0,i,2,j2}.C_{0,i,3,j_3}.(L_{1.j_1.i}.W_{T,1} + L_{3.j_3.i}.W_{T,3} - L_{2.j_2.i}.W_{T,2})}{R_i.(C_{0,i,1,j_1}.W_{T,1} + C_{0,i,2,j2}.W_{T,2} + C_{0,i,3,j_3}.W_{T,3})} \tag{3}$$

$$\omega_{i,3} = \frac{R_i.C_{0,i,3,j_3}.W_{T,3} + C_{0,i,1,j_1}.C_{0,i,2,j2}.C_{0,i,3,j_3}.(L_{2.j_2.i}.W_{T,2} + L_{1.j_1.i}.W_{T,1} - L_{3.j_3.i}.W_{T,3})}{R_i.(C_{0,i,1,j_1}.W_{T,1} + C_{0,i,2,j2}.W_{T,2} + C_{0,i,3,j_3}.W_{T,3})} \tag{4}$$

Where, R_i be the required data rate of MS *i;* $C_{0,i,m,j}$ is the transmission efficiency according to Shannon Informatics as the maximum transmission rate got by MS *i* located in the j^{th} cell of system *m;* $W_{T,,m}$ is the total bandwidth requirement of system *m*.

V. LOAD BALANCING WITH QOS PROVISIONING

Load balancing with QoS provisioning ensures grade of service with rational balancing of system loads. Even distribution of load sometimes degrades the QoS performance metric. To maintain tradeoff between QoS and load balancing, we formulate a joint optimization function. So, it is required to define the objective function of QoS parameters. Objective function of load balancing *LB()* has already defined in section IV.

A. QoS Admission Control Function

QoS performance requirements like system bandwidth, packet loss, delay and delay jitter varies from one application service to another. In paper [17], authors have presented some application type and performance requirements.

We consider the QoS parameters as a vector $P=(p_1,p_2...p_n)$ of *n* dimension and a weight vector $V=(v_1,v_2,v_3...v_n)$ of *n* dimension for assigning weights of each parameter. The integrated quality of service requirement is: $Q_0=(v_1p_1, v_2p_2,...v_np_n)$, where $\Sigma v_i = 1$ and $v_i > 0$. If we consider the measured actual QoS value of network *m* as the vector $A=(a_{m1}, a_{m2}...a_{mn})$ then the integrated actual QoS is $Q_m = (v_1a_{m1}, v_2a_{m2},...v_na_{mn})$.

So, the QoS based admission control function is as follows [18]:

$$QS(Q_0, Q_m) = 1 - \frac{\|Q_0 - Q_m\|}{\|Q_0\|} \tag{5}$$

$$= 1 - \frac{\sqrt{(v_1p_1 - v_1a_{m1})^2 + (v_2p_2 - v_2a_{m2})^2 + ... + (v_np_n - v_na_{mn})^2}}{\sqrt{(v_1p_1)^2 + (v_2p_2)^2 + ... + (v_np_n)^2}}$$

Where, $0 \le QS(Q_0,Q_m) \le 1$

B. Joint Optimization Function

The cost function should be a linear combination of the objective function, where $0 \le \lambda \le 1$:

$$J(\lambda, m) = \lambda.QS(Q_0, Q_m) + (1-\lambda).LB(\omega^*{}_{i,m}) \tag{6}$$

Here, for a given value of λ there exists a value of *m*, which provides the optimum value of cost function $J(\lambda,m)$. The value of *m*, for which the function *J()* returns largest value, will be chosen. The value of *J* should be $0<J_{th}<1$. Thus, call from MS *i*, will be dropped for its smaller value of $J<J_{th}$.

C. Load Balancing Algorithm with QoS Provisioning

Step 1: When an MS *i* requests a wireless AP to access or to handover, RI searches for the available AP's to serve MS *i*.

Step 2: RI determines the channel gain, transmission efficiency and QoS admission control function $QS(Q_0,Q_m)$ for MS *i* of cell *j* and system *m*. Then, it sends the measured result to corresponding LMM.

Step 3: If LMM finds that the MS *i* resides within the basic grid then LMM calculates $J(\lambda,m)$ according to the equation number (6). If $J < J_{th}$ then LMM denies its access to the solicited network. Otherwise, LMM calculates the optimal flow-dividing ratio for MS *i* according to (2), (3) and (4).

Step 4: If LMM finds that the MS *i* reached at the border of adjacent grid then LMM communicates with neighboring LMMs and calculates $J(\lambda,m)$ according to the equation number (6). If $J < J_{th}$ then LMM denies its access to the solicited network. Otherwise, LMM calculates the optimal flow-dividing ratio for MS *i* according to the equation (2), (3) and (4).

Step 5: LMM allows MS *i* to access networks according to the optimal flow dividing ratio.

The flow diagram of proposed load balancing approach with QoS provisioning has shown in Fig. 1.

VI. SIMULATION STUDY

MATLAB simulator is used to simulate the proposed load balancing algorithm and exiting novel load balancing scheme (Novel QoS) for QoS provisioning [18]. Furthermore, we also simulated the load uniformity and packet loss rate of adaptive network selection algorithm (ANSA) [17] for comparison purpose.

A. Simulation Scenario

The assumed simulation parameters are summarized in Table I. To simulate QoS provisioning model, we consider the weights of different applications of QoS parameters presented in paper [18]. We assume the value of λ as 0.5. To simulate QoS based admission control function, we assume that all the parameters of QoS are normalized [20].

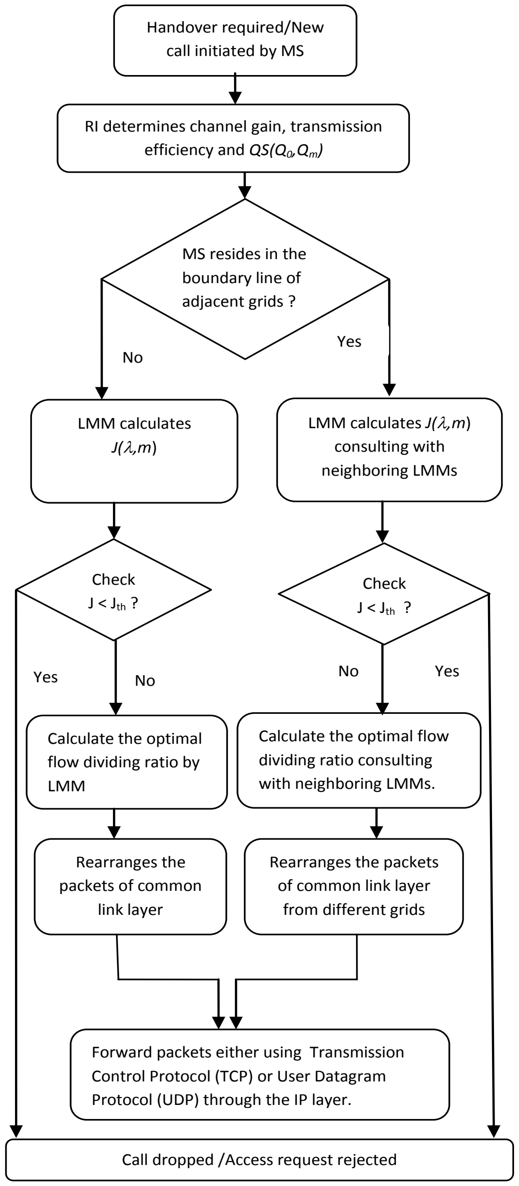

Figure 1. Flow diagram of proposed load balancing algorithm with QoS provisioning

TABLE I. SIMULATION PARAMETERS

Parameters	Access technology 1	Access technology 2	Access technology 3
Radius	1.5 km	0.75km	30 m
Bandwidth	5MHz	10MHz	20MHz
TX power of AP	46 dBm	43 dBm	24dBm
Noise Power	-174 dbm/Hz	-170 dbm/Hz	-118 dBm/Hz
Required BER	10-3		
Subscriber speed	120km/h		
Traffic rate	Follows uniform distribution from 500 kb/s to 1000 kb/s		
Traffic interval	Follows poison distribution with mean of 1 s		

B. *Simulation Results*

We simulate our proposed joint optimization function in three different forms 1) Soft load balancing (SLB) (without QoS provisioning) 2) Load balancing only with the QoS admission function (LBQoSAF) 3) Load balancing with QoS provisioning (LBWQoS). We also compare our proposed algorithm with adaptive network selection (ANSA) [17] algorithm with respect to normalized loads and packet loss rate.

Fig. 2 shows that the call blocking probability is increasing with the number of subscribers' increment. The call blocking probability of LBQoSAF is higher than other load balancing methods, because in this approach if the cellular system fails to provide QoS requirements, it blocks those calls.

However, the call blocking probability of the proposed load balancing with QoS provisioning algorithm is always lower than the existing novel QoS load balancing scheme. The reason behind the lower blocking probability is its optimal joint function, which is formulated by QoS requirement parameters' as well as optimal flow dividing ratio.

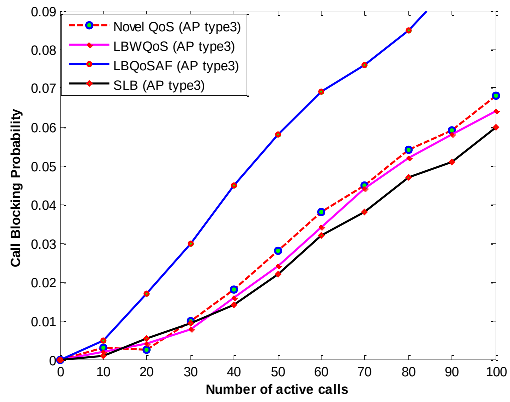

Figure 2. Call blocking probability of different load balancing approaches

Fig. 3 shows that the load balancing with QoS provisioning (LBWQoS) algorithm, distributes load more uniformly than the existing novel QoS provisioning algorithm. Because the proposed LBWQoS algorithm always tries to balance loads among the available access technologies using IP flow dividing ratio.

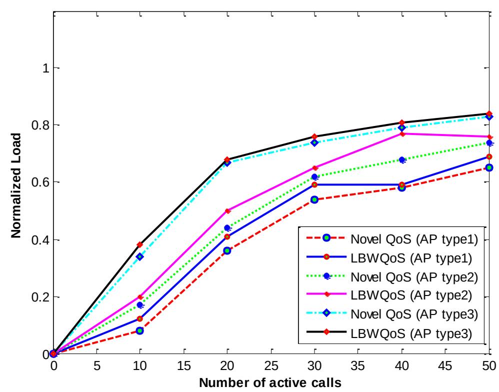

Figure 3. Normalized loads among different access technologies

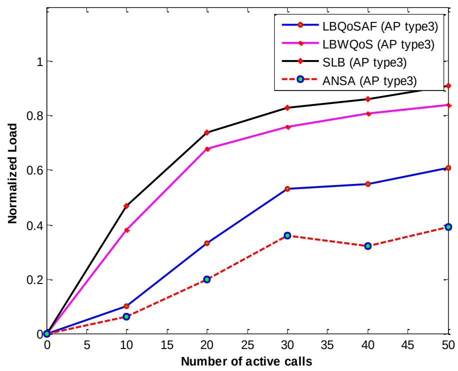

Figure 4. Normalized loads using different load balancing approaches

Fig. 4 shows pitiable performance of load balancing of both LBQoSAF and ANSA. Here, LBQoSAF only tries to maintain QoS other than balancing loads uniformly within available wireless networks. In the same way, ANSA fails to balance loads evenly among the access networks because of the user profile constrains. Conversely, LBWQoS performs well with maintaining optimal QoS requirements.

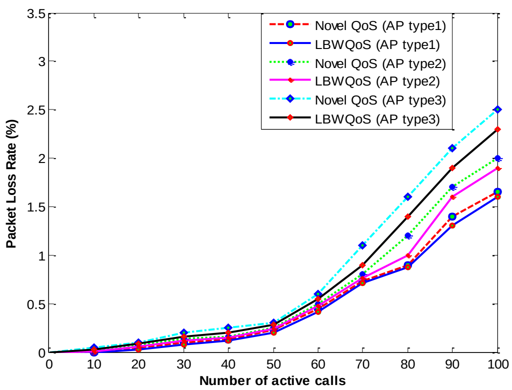

Figure 5. Packet loss rate of different access technologies

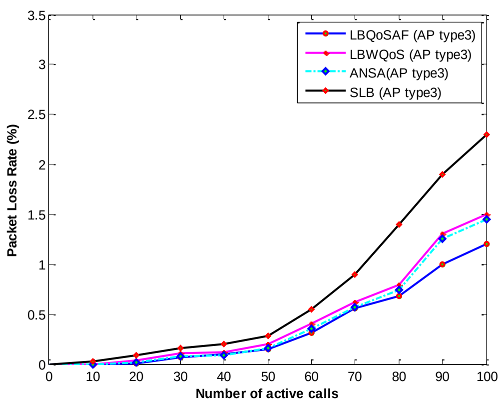

Figure 6. Packet loss rate of different load balancing approaches

It can be seen in Fig. 5 that the packet loss rate is always higher in novel QoS approach. Because it considers only the load related admissions control function, whereas LBWQoS considers channel gain, transmission rate and SNR.

In case of real time data transmission, any packet loss may create huge congestion due to retransmission traffic. So, packet loss rate without considering QoS requirement becomes higher (Fig. 6). Packet loss rate of ANSA is almost similar to LBWQoS because ANSA considers user profile along with the QoS application parameters to design its cost function whereas LBWQoS considers QoS and *LB()* function to design its joint optimization function. Load balancing only with QoS admission function experiences lower packet loss rate. But in that case, the system becomes imbalance.

VII. CONCLUSION

The proposed QoS support load balancing algorithm focused on semi-distributed architecture, optimizes call blocking probability and packet loss rate with upholding QoS requirements. The simulation results also articulate its uniform distribution of loads among different access technologies. Perceptibly the proposed load balancing algorithm conducts a balanced tradeoff between QoS and normalized loads in heterogeneous wireless networks. Resource utilization, uplink-downlink power consumption, handoff requirements are still subject to study towards its effective operation.

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