An adaptive call admission control scheme with load balancing for QoS enhancement in RoF based converged UMTS/WLAN

R. Shankar and P. Dananjayan

Abstract—As universal mobile telecommunications system (UMTS) and wireless local area network (WLAN) have complementary characteristics, convergence of UMTS and WLAN offer seamless wireless access service to users. In a converged UMTS/WLAN enhancing quality of service (QoS) for different services require call admission control and load balancing. This paper analyses the performance of wideband power based (WPB) and throughput based (TB) call admission control schemes in UMTS/WLAN. Further an adaptive call admission control scheme with load balancing for enhancing QoS in hybrid coupled and radio over fiber (RoF) based UMTS/WLAN convergence network is analysed. Simulation results show that adaptive call admission control with load balancing improves QoS in RoF based UMTS/WLAN compared to hybrid coupled UMTS/WLAN convergence network.

***Keywords*—**Admission control, hybrid coupled, RoF, Converged UMTS WLAN, load balancing, QoS.

Manuscript received August 30, 2011.

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I. Introduction

The 3rd generation partnership project (3GPP) has been working on standardisation for integrating cellular and WLAN systems [1, 2], Network architectures for converging UMTS/WLAN systems can be grouped into two categories based on the independence between two networks as, tight coupling and loose coupling. In loose coupling architecture, the two networks are integrated beyond core network (CN) of UMTS and are connected through gateways of internet. Communication between networks are realised through standard internet protocol (IP) and mobility of mobile stations is managed through protocols such as Mobile IP. Loose coupling architecture enables the two networks deployed independently but results in longer delay for signaling and vertical handovers.

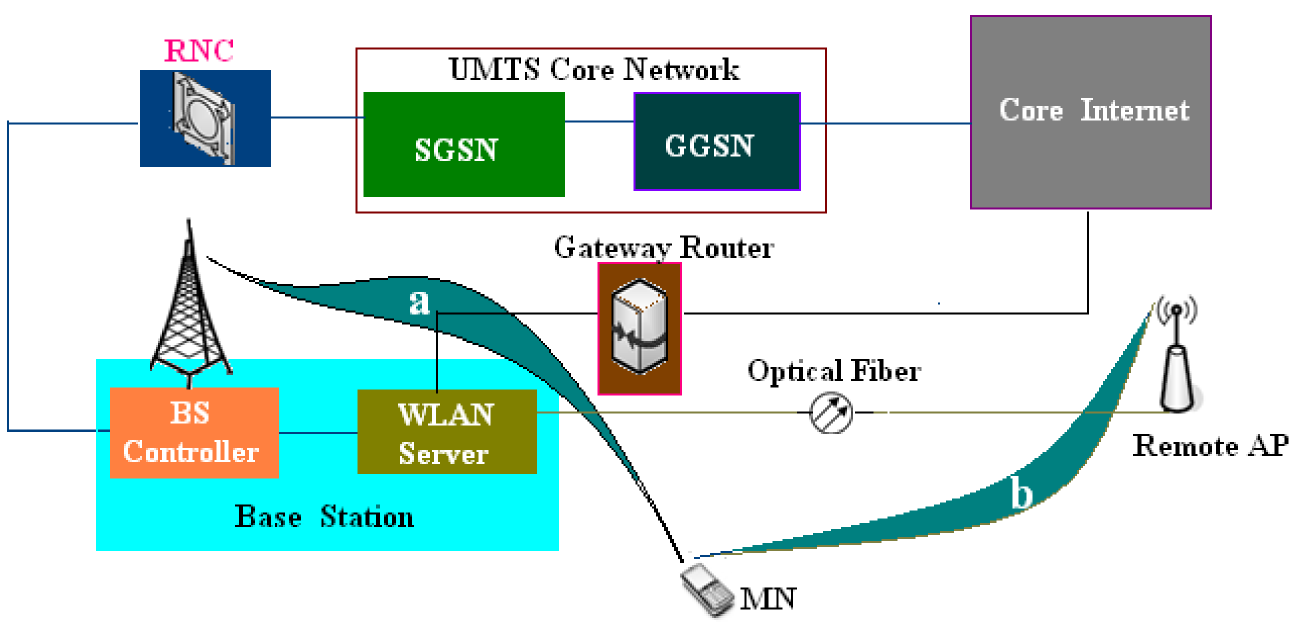

Fig. 1 RoF based convergence architecture

In tight coupling architecture, the two networks are integrated at UMTS's CN, which has lower delay for signaling and vertical handover but has higher implementation complexity. Although above two schemes are used widely, they have their own disadvantages. To overcome their disadvantages hybrid coupling [3, 4] technique was proposed. In order to enhance

QoS, a converging architecture using RoF technique is proposed [5]. Compared with the existing coupling schemes, RoF based convergence network can distribute the signaling and data load on both UMTS core network and core internet and have less handoff latency in vertical handoff process. When a mobile node (MN) is in UMTS cellular network as in Fig. 1, it directly connects with the base station (BS) by wireless link "a".

While the MN is in WLAN, it connects with remote AP by wireless link "b". The remote AP transmits radio signal to WLAN server by RoF technique and builds up a connection with WLAN. RoF convergence architecture has following advantages: The BS controller of UMTS cellular network and server of WLAN are located nearer, as a result interchanging traffic between them will not burden core networks. MN is always connected with BS, the process of vertical handoff becomes simpler and communication is not disrupted during vertical handoff. The bandwidth of optical fiber is much broader than radio signal; consequently signals only occupy a little bandwidth of optical fiber. The hardware requirement for converging UMTS and WLAN networks is mainly to build dual mode user equipment (UE) which has capability to access either network. After such a dual mode UE (DMUE) [6] is available and software at each network's operational components are updated, a ubiquitous wireless environment with high data rate enabled in hot spot areas can be set up. To support various integrated services like voice, video, file transfer protocol (FTP), email etc. with QoS [7-9] in a UMTS/WLAN convergence network, resource provisioning like load balancing is a major issue in the converged environment. Call admission control with load balancing is an important solution because it is essential to maintain QoS in such converged network by having minimum call blocking and call dropping probabilities and at the same time efficiently utilise the available resources.

The rest of the paper is organised as follows: admission control and load balancing is detailed in section 2, system model is described in section 3, simulation scenario and results are discussed in section 4, conclusion of this paper is presented in section 5.

II. Admission Control and Load Balancing

A. Wideband Power Based (WPB) Scheme

Every time a new user seeks admission into the system, it adds certain amount of interference to the system. The criterion for uplink admission of the connection is based on comparison of interference the new user would add to system, if admitted, to an interference threshold value I_T. This value should not be exceeded by the admission of a new user. If existing interference in system is I_S and interference new user would bring to the system is ΔI, then uplink criterion is

$$\mathrm{I_S} + \Delta I \le I_T \tag{1}$$

While uplink is interference limited, downlink in system is power limited. Considering downlink direction, user is admitted if new total downlink transmission power does not exceed a predefined target value set by network operator:

$$\mathrm{P_S} + \Delta \mathrm{P} > P_T \tag{2}$$

The load increase in downlink can be estimated on the base of initial power, which depends on distance from base station. The load increase depends on distance of mobile from base station.

B. Throughput Based (TB) Scheme

In uplink, a new user is admitted only if sum of existing uplink load factor [10] η_{UL} and increase in load factor Δ_{UL} does not exceed a predetermined threshold limit η_{ULT}.

$$\eta_{UL} = (1+i)\sum_{j=1}^{N} \frac{1}{1 + \dfrac{w}{(\dfrac{E_b}{N_0})_j . R_j . v_j}} \tag{3}$$

where N is number of stations, v_j is active factor of station j at physical layer, E_b/N_0 is signal energy per bit divided by noise spectral density, W is chip rate, R_j is bit rate of station j and i is other cell to own cell interference ratio seen by base station receiver.

$$\eta_{\mathrm{UL}} + \Delta_{\mathrm{UL}} \le \eta_{\mathrm{ULT}} \tag{4}$$

The criterion in the downlink is similar to that of uplink, downlink load factor η_{DL} defined as

$$\eta_{\mathrm{DL}} = \sum_{j=1}^{N} v_j . \frac{(E_b / N_0)_j}{W / R_j} .[(1-\gamma_j) + i_j] \tag{5}$$

where γ_j is orthogonality of channel of station j and i_j is ratio of other cell to own cell base station received by user j.

$$\eta_{\mathrm{DL}} + \Delta_{\mathrm{DL}} \le \eta_{\mathrm{DLT}} \tag{6}$$

where, increase in downlink load factor Δ_{DL} does not exceed a predetermined threshold limit η_{DLT}.

The basis for this research was to apply WPB and TB schemes initially to UMTS and WLAN respectively in the converged UMTS/WLAN and changes them to TB and WPB in addition to load balancing, with varying percentages of data and voice users and study the performance. Sufficient preliminary results obtained on these schemes on the network consistently showed a trend of preferential treatment. It was observed that WPB scheme reduces voice blocking probability (pb_{voice}) more effectively than throughput based scheme whereas throughput based scheme works better in reducing data blocking probability (pb_{data}). Because, WPB is more power limited in downlink, voice users require lower power to be reached than data users. Hence the downlink forms a bottleneck for data users in WPB. For TB scheme uplink is capacity limited and data users are fewer in number at any point of time than voice users. Hence uplink forms a bottleneck for voice users in TB. Based on preliminary results, the need for a call admission control scheme that would minimise if not totally eliminates this bias was identified. An adaptive call admission control with load balancing that utilises both WPB and TB schemes depending on the number of users at a particular instant of time in the system is analysed for converged WLAN/ UMTS.

C. Adaptive Call Admission Control (ACAC) Scheme

In the ACAC scheme, updates of number of voice and data users in the system in periodic intervals of time τ, help determine which scheme WPB or TB it needs to switch to, by calculating number of each type of user present in system at the end of a previous period and number of each type of user's estimated arrival in next period. If there are more voice users, ACAC switches to WPB and if there are more data users, it switches to TB. This prediction depends on α, which is the parameter used to influence the number of predictions in upcoming period and β, which influences total number of calls that have originated in the system since start-up. Simulations have shown that since video and FTP calls tend to persist in the system causing self-similarity, β improves performance of ACAC. α and β vary between 0 and 1. The prediction for α, β and τ are clearly very critical. They can be found either adaptively or statistically. In this paper adaptive i.e., trial and error methods through many simulation runs are used. Though α, β and τ are determined heuristically, it has been observed that they are robust to variation in simulation scenarios for a certain link budget. The prediction is done in the following way for voice and data calls in the upcoming period:

$$V_f = \alpha V_n + (1-\alpha)V_m + \beta V_{total} \quad (7)$$

$$D_f = \alpha D_n + (1-\alpha)D_m + \beta D_{total} \quad (8)$$

where V_f and D_f are the predicted number of call arrivals in the coming period. V_n/D_n and V_m/D_m are originated and predicted voice/data calls in the previous period respectively and V_{total}/D_{total} is total number of voice/data calls that have originated in system since start up [11].

D. Load balancing function for the UMTS/ WLAN

Given the current uplink load factor, η_{UL}, a load balancing function $L_{UL}(\eta_{UL})$ can be constructed [6]

$$L_{UL}(\eta_{UL}) = B_{UL}.(1-\frac{\eta_{UL}}{\eta_T}) \quad (9)$$

where B_{UL} is maximum uplink bandwidth and η_T *is* total load factor

Also, given the current downlink load factor, the linear load balancing function for downlink,

$$L_{DL}(\eta_{DL}) = B_{DL}.(1-\frac{\eta_{DL}}{\eta_T}) \quad (10)$$

where B_{DL} is the maximum downlink bandwidth.

Thus, utility function of the uplink/downlink provides an estimation how much bandwidth is available in uplink/downlink. Then the load balancing function for UMTS network is designed as

$$L_{UMTS} = L_{UL}(\eta_{UL}) + L_{DL}(\eta_{DL}) \quad (11)$$

WLAN does not have explicit QoS control, achieves less throughput when the network is saturated than that when network is not saturated. As traffic load i.e., number of stations increases, severe collisions occur, which results in that the stations can barely transmit a packet successfully. Thus, WLAN network should be closely monitored such that the network is not overbusy. An indicator reflecting WLAN utilisation adopted is busyness ratio, which is defined as the ratio of time that the network is sensed busy. So stations are handovered to a WLAN network only when its busyness ratio R_b is less than a threshold, say R_{th}.

Given the current busyness ratio R_b and its upper bound R_{th}, utility function for WLAN indicating available bandwidth to accommodate new stations is

$$L_{WLAN} = \frac{EP(R_{th} - R_b)}{T_S} \quad (12)$$

which is derived from [12]. In equation (12) *EP* is average data packet size and T_s that depends on distributed coordinated function (DCF) inter frame space (DIFS) and short interframe space (SIFS) is the average time associated with a successful transmission. For the case that request to send/ clear to send (RTS/CTS) is not used,

$$T_S = DIFS + T[EP] + SIFS + ACK \quad (13)$$

and for the case that RTS/CTS mechanism is used,

$$T_S = DIFS + RTS + CTS + T[EP] + 2SIFS + ACK \quad (14)$$

where *T*[*EP*], *RTS,CTS* and *ACK* are time for transmitting a packet with payload size *EP*, transmitting RTS, CTS and ACK packet, respectively.

III. System Model

DMUE is simulated in OPNET which can switch between UMTS and WLAN networks. The DMUE is different from dual mode terminal (DMT) [13] in which DMUE can be adopted in loose coupling interworking systems where UMTS and WLAN networks are connected by a router, whereas DMT is only applicable in tight coupling interworking systems. The protocols in UMTS and WLAN are relatively independent. The packets arriving at the router are routed according to subnet address of each network. Once packets are being delivered in UMTS or WLAN network, the delivery follows individual protocol. The main difference of UMTS and WLAN mobile station is in medium access control (MAC) layer [14] and physical layer. In DMUE, a new software layer, called IP switch layer is created, just below IP layer. Each DMUE has multiple IP addresses which access to different networks. When a data packet comes from the IP layer, the IP switch layer will make a decision based on WPB, TB or ACAC with load balancing and send out this data packet through corresponding physical layers. Each AP of WLAN and Node-B of UMTS uses TB and WPB initially to accommodate users present in converged area, which will provide maximum room for voice users and data users in UMTS and WLAN respectively.

As time varies, when Node B of UMTS and AP of WLAN finds more data users and voice users, ACAC switches TB and WPB in WLAN and UMTS to WPB and TB respectively with load balancing function which will calculate available bandwidth in UMTS and WLAN in converged WLAN/UMTS for broadcasting. Once a station receives the load balancing function from either UMTS or WLAN network, it will compare received value with that of host network to decide whether to swap network, after a random time, for each user before swap to avoid imbalance in network. Thus, resources of integrated networks are fully utilised meanwhile load balancing among networks is achieved.

IV. SIMULATION SCENARIO AND RESULT

Simulation of hybrid coupled and RoF based UMTS/WLAN convergence network is carried out using OPNET 14.5 [15], with the simulation parameters mentioned in table 1.

Hybrid coupling is the combination of loose coupling and tight coupling and so WLAN router is connected with both IP cloud and UMTS CN, as in Fig. 2a. Here, AP router and WLAN router are connected with ethernet cable. This consists of Node-B, serving voice, video and FTP users.

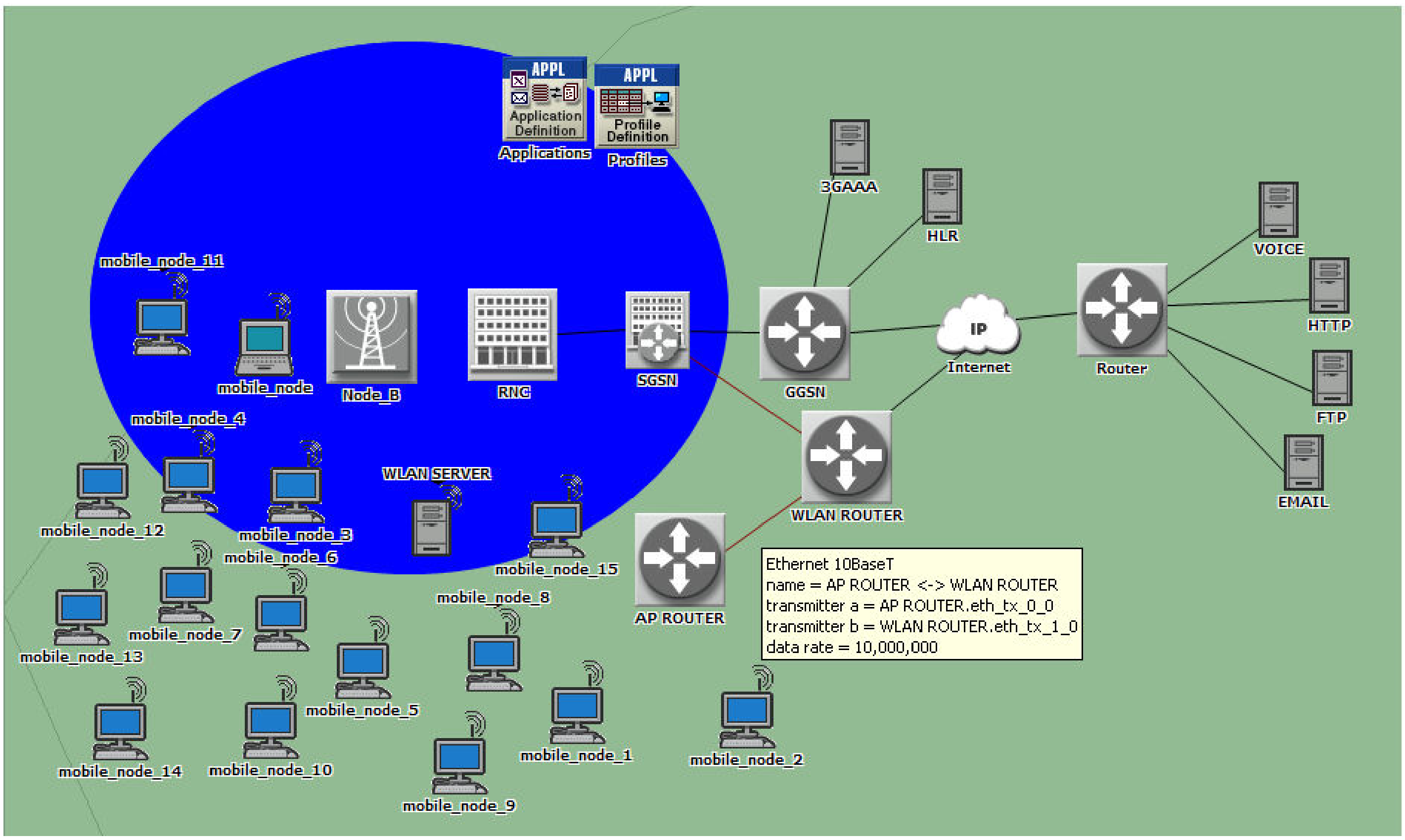

Fig. 2a Hybrid coupled WLAN/UMTS

The RoF convergence network adopts RoF technique [5] that directly transmits radio signal on optical fiber. In this architecture, WLAN server and access point (AP) are connected with fiber distributed data interface (FDDI) cable as in Fig. 2b. The AP transmits the radio signal to WLAN server by RoF technique. Thus mobile node builds up a connection with WLAN.

TABLE I
SIMULATION PARAMETERS

PARAMETERS	VALUES
B_{UL}, B_{DL}	1 Mbps
WLAN data rate	54 Mbps
SIFS	10 µs
DIFS	50 µs
Phy header	192 bits
MAC header	224 bits
DATA packet	12000 bits + Phy header + MAC header
RTS	160 bits + Phy header
CTS, ACK	112 bits + Phy header
Traffic frame size	34560 bytes
Utility gap	10000 bits
Simulation time	1000 seconds

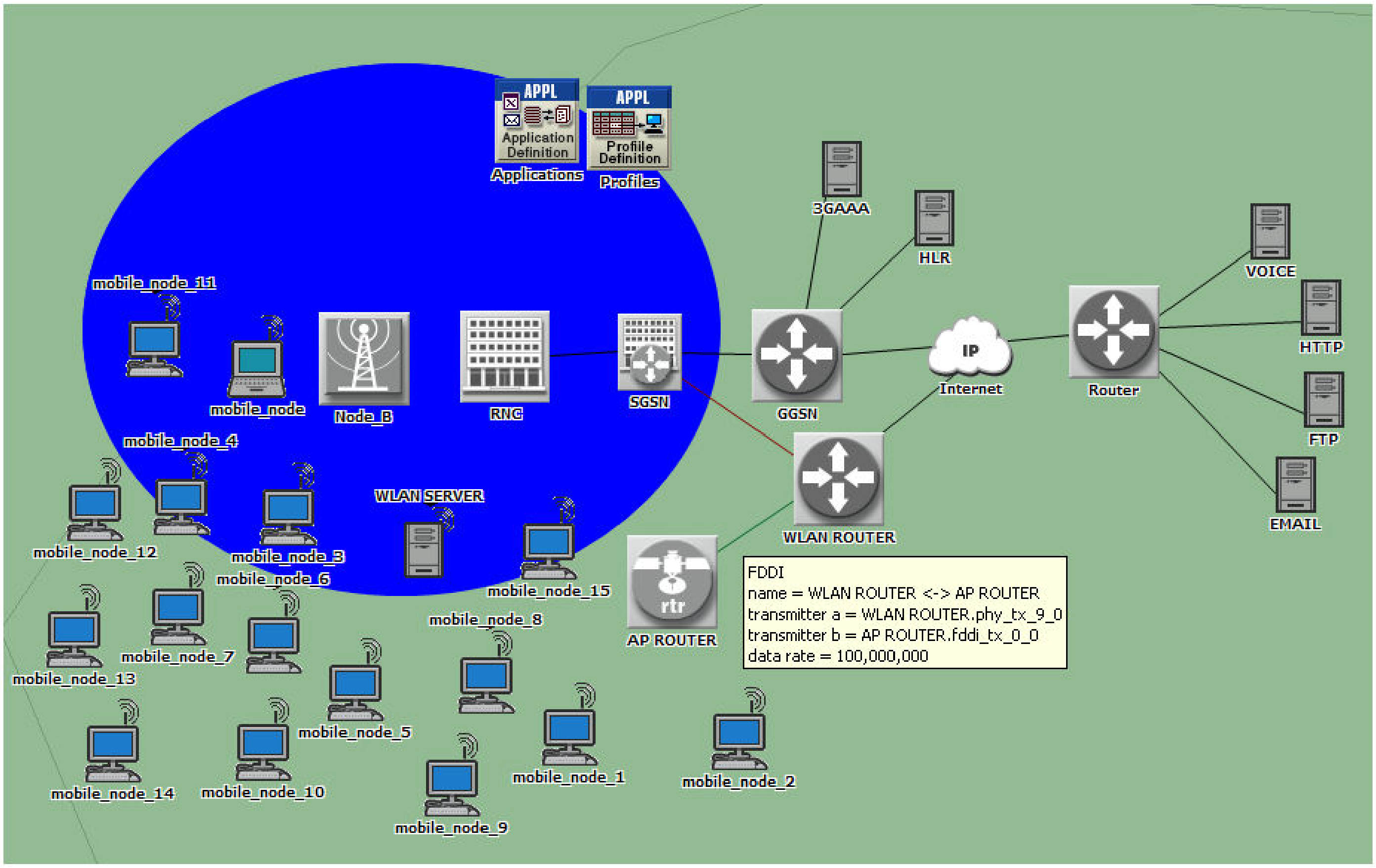

Fig. 2b RoF based WLAN/UMTS convergence network

Both WLAN and UMTS networks are considered to be IPv6 based networks [16] and each node in the network have unique IP address. This consists of Node-B, serving voice, video and FTP users. The traffic generated is assumed to be similar as is the pattern of mobility. These systems have an approximately equal number of voice and data calls generated at the end of a period. Video and FTP users are referred as data users. Mobile nodes move with a velocity of approximately 40 km/hr.

The input to system is based on traffic i.e., arrival rate or service rate that each type of service (ToS) provides rather than the average number of users. The output is observed as the blocking and the dropping probability.

Voice users have ON and OFF periods Poisson distributed but with mean 0.65 and 0.35 seconds respectively. Voice and data users have durations that are uniformly distributed between 3−5 minutes and 15−30 minutes respectively. FTP users have pareto distributed file size for self-similarity. Having a ToS helps to prioritize calls since priority can be considered to be another type of QoS.

Voice, video and FTP users have ToS of interactive voice, global system for mobile (GSM) quality voice -priority 0, streaming multimedia, video conferencing light -priority 1 and best effort, file transfer light -priority 2 respectively.

DMUE has two IP addresses, one is for UMTS, and other is for WLAN. An application of UDP video uploading from each DMUE to server is applied. Each video frame size is 34560 bytes, and it has an interarrival time with a Poisson distribution.

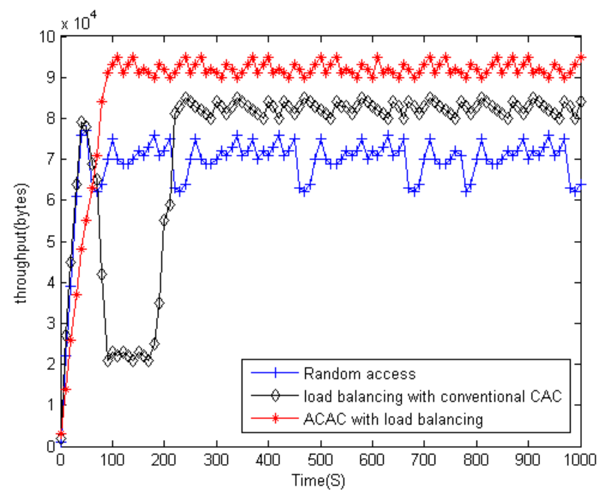

Fig. 3a Throughput in hybrid coupled UMTS/WLAN

In case 1 of hybrid coupled and RoF based UMTS/WLAN convergence scenario, in the initiation, all the DMUEs randomly connect to either UMTS network or WLAN and switching never happen. In case 2, all the DMUEs initially connect to WLAN, the network access decision algorithm based on the load balancing with conventional call admission control (CAC) works in whole simulation duration. In case 3, all DMUEs in the converging area are admitted into UMTS or WLAN through ACAC with load balancing function to efficiently utilise the resource of converged WLAN/UMTS.

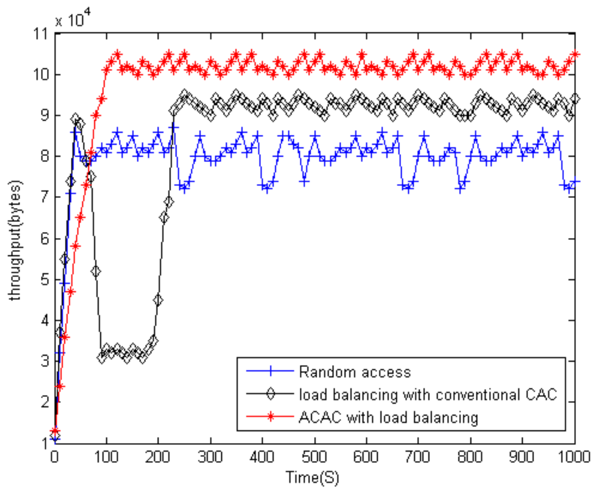

Fig. 3b Throughput in RoF based UMTS/WLAN

From the simulation result shown in Fig. 3a, 3b, 4a and 4b which are measured at the server side, overall throughput [17-18] for 110Kb, 10Mb data in ACAC with load balancing approach is larger than one with random access and load balancing with conventional CAC in hybrid coupled and RoF based UMTS/WLAN convergence network respectively, further it can be inferred that the throughput is higher in RoF convergence network than hybrid coupled UMTS/WLAN.

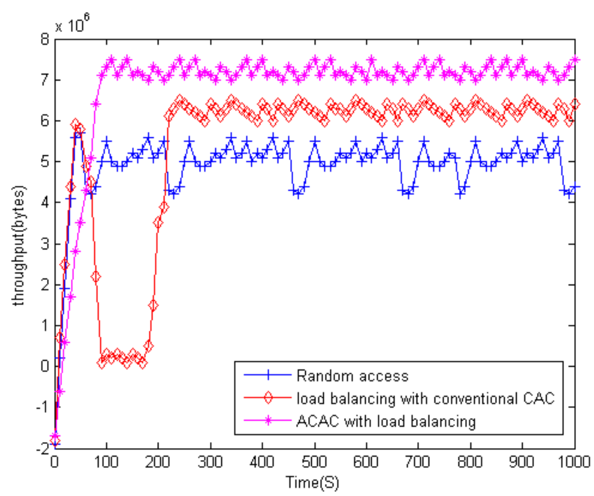

Fig. 4a Throughput in hybrid coupled UMTS/WLAN

Fig. 5a and 5b shows the performance of TB, WPB, ACAC without load balancing and ACAC scheme with load balancing for blocking probability (P_B) of hybrid coupled and RoF based UMTS/WLAN convergence network respectively.

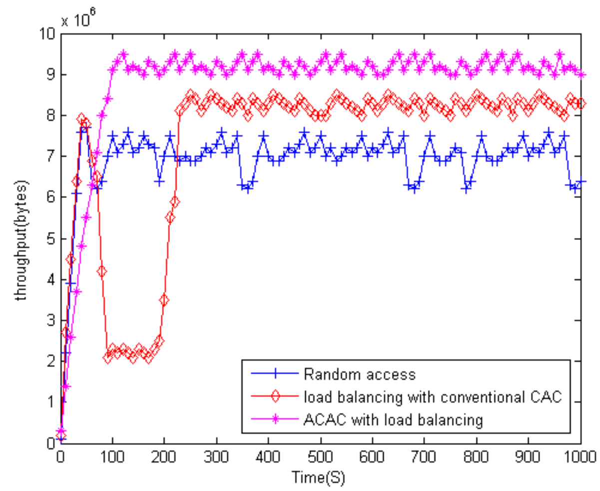

Fig. 4b Throughput in RoF based UMTS/WLAN

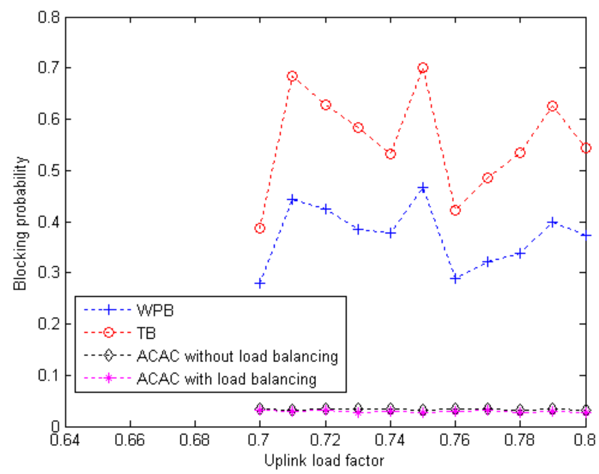

Fig. 5a Blocking probability of hybrid coupled UMTS/WLAN

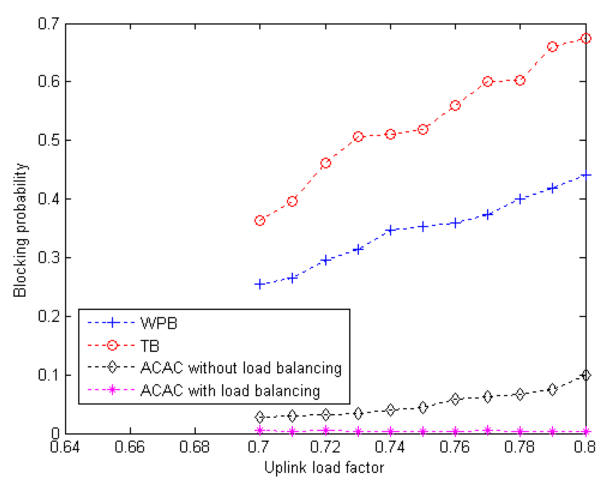

Fig. 5b Blocking probability of RoF based UMTS/WLAN

The results are obtained from an average of several runs of simulation for an uplink loading factor (η_{UL}) of 0.70 to 0.80 as most UMTS uses 0.75 as uplink and downlink load factors.

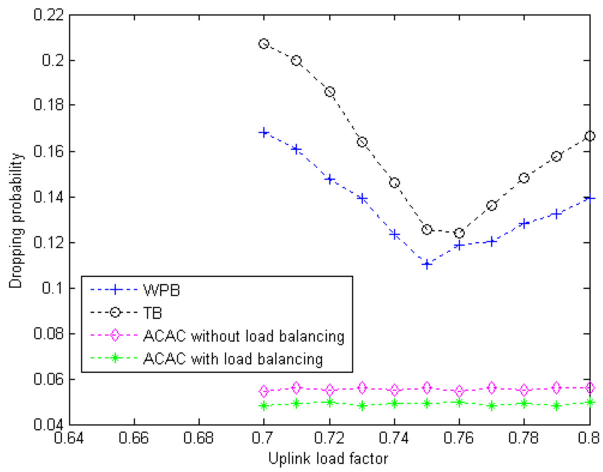

Fig. 6a Dropping probability of hybrid coupled UMTS/WLAN

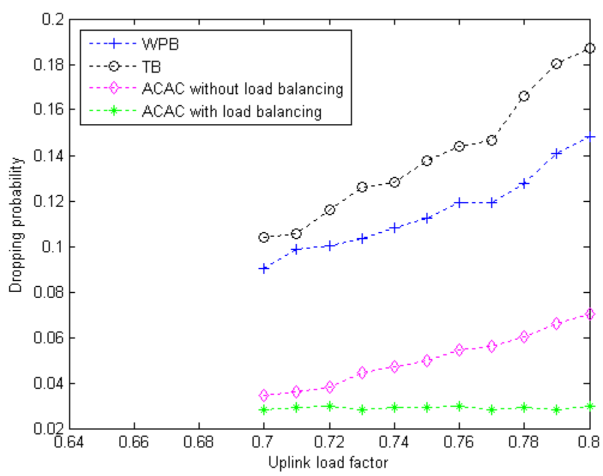

Fig. 6b Dropping probability of RoF based UMTS/WLAN

Fig. 6a and 6b show the performance of TB, WPB, ACAC without load balancing and ACAC scheme with load balancing for dropping probability (P_D) of hybrid coupled and RoF based UMTS/WLAN convergence network respectively.

It is observed that ACAC with load balancing has the lowest values and they remain stable through different η_{UL} values. This is attributed to the fact that call admission control is a bi-directional scheme. Increase in η_{UL} might cause an increase in admitted users but might not meet requirement for downlink and viceversa. Also, P_B and P_D values of ACAC with load balancing are statistically different from WPB, TB and ACAC in hybrid and RoF based UMTS/WLAN convergence network. It is observed that RoF based UMTS/WLAN convergence network has linear variation in the blocking and dropping probability than hybrid coupled UMTS/WLAN in addition to reduced P_b and P_d that enhances QoS of the system.

In a scenario where there are a dominant number of voice users or data users, ACAC will work as good as WPB or TB respectively but lags in balancing the load between WLAN/UMTS. But it is not seen in today's trend that UMTS systems where traffic generated by data users are rising up to match that of the voice users. Due to this ACAC with load balancing is required, which will give tremendous improvement in performance and will work best under most conditions. Thus it is inferred that ACAC scheme with load balancing works best and enhances QoS [19-21] by minimising preferential treatment that is shown by WPB, TB schemes and ACAC without load balancing that lags in balancing load when used in hybrid coupled and RoF based WLAN/UMTS convergence network.

V. CONCLUSION

In this paper, wideband power based, throughput based call admission control scheme and an adaptive call admission control with load balancing is analysed to enhance QoS in hybrid coupled and RoF based WLAN/UMTS convergence network. The simulation results show that the adaptive call admission with load balancing performs significantly better in terms of QoS than throughput based, wideband power based, random network selection, adaptive call admission control without load balancing and load balancing scheme with conventional CAC. It is also observed that when using adaptive call admission control with load balancing, RoF based UMTS/WLAN convergence network outperforms hybrid coupled convergence network in terms of QoS.

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