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Analysis of Call Admission Control Schemes for WLAN Coupled to 3G Network

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***Abstract*— Convergence of wireless local area network (WLAN) and third generation (3G) wireless network is expected to create new markets for service providers and tender enhanced services to the integrated network users. In this paper, call admission control (CAC) schemes viz., throughput (TP) based CAC and dynamic partitioning (DP) CAC with service differentiation for WLAN coupled to 3G network have been analysed. The 3G/WLAN convergence network with TP based admission control is developed for loose, tight and hybrid coupled network. DP scheme, a resource allocation mechanism is also implemented, in which the differentiation between the data and voice calls are made by using different thresholds. The performance parameters such as delay, throughput, voice and data call blocking probabilities are analysed for different coupled networks.**

***Index Terms*—3G/WLAN convergence network, call admission control, inter-networking.**

I. INTRODUCTION

Wireless cellular networks have experienced great deployment in recent years and the demand continues to grow, as different application requirements exist with the fast converging technology [1]. There has been an explosive growth in the use of different communication technologies, as mobile telephony has offered mobile communication between people; wireless networking has provided flexible communication between computers. It is widely accepted that next generation wireless networks (NGWN) will be heterogeneous in nature with multiple wireless access technologies [2]. While the heterogeneity poses new challenges to achieve interoperability among different wireless networks, their complementary characteristics can be exploited with the interworking to enhance service provisioning [3, 4]. The popular 3G cellular network and WLAN are two most promising technologies and the cellular/WLAN interworking has attracted much research attention from both the industry and academia [5, 6].

Successful deployment of 3G networks based on universal mobile telecommunication system (UMTS) in some countries with the springing up of WLAN in many hotspots such as campuses, hotels, airports, restaurants etc. necessitates the interworking of the two complementary networks. Mobile technologies such as global system for mobile communication (GSM), general packet radio service (GPRS) and UMTS offer high mobility with low rates. In contrast, WLAN offer high data rates such as 11Mbps, 54Mbps and more but the mobility available is low. The services span from traditional conversational audio to conversational video, voice messaging, telnet, etc. No single radio system can effectively cover all these services from a multi-service point of view, if QoS requirements are to be met. The developments towards interworking between complementary radio systems provide unparalleled level of services. Interworking aims at providing heterogeneous mobile data network which provides WLAN users with always-on and ubiquitous connectivity, even outside the WLAN coverage area. Conversely, interworking will also enable 3G wireless users to seamlessly use WLAN. This will also provide 3G users with lower cost and higher data rate whenever the users are within the range of the WLAN network. Therefore, the integration of these dissimilar technologies using a common framework can enable a potential user to freely roam from one network to another.

In the recent years, much research has been done in the area of interworking between various wireless data networks such as WLAN, 3G cellular i.e., UMTS and CDMA2000, worldwide interoperability for microwave access (WiMAX). By and large, these internetworking architectures can be categorised as tight coupling, loose coupling and hybrid coupling. In the tight coupling architecture, the WLAN is directly connected to the UMTS core network [7]. Thus the WLAN data traffic gets routed via the UMTS core network before reaching the external packet data networks (PDNs). Therefore, UMTS mobility management techniques may be directly applied in this method. On the other hand, the loosely coupled architecture exchanges signaling between the WLAN and the UMTS core network while the data flows via independent internet protocol (IP) based networks. Since the data traffic is routed directly via an IP network this method may help avoiding a potential traffic bottleneck. Nevertheless, in this method, the handoffs are less efficient and therefore real time session mobility may not always be guaranteed. The hybrid coupling framework can be described as coupling the 3G cellular network and the WLAN, in which the combination of loose coupling and tight coupling exits for the network. The traffic can be routed either to the 3G cellular network or the WLAN network based on the intensity and type of traffic, thus making the system more complex but efficient.

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Interworking UMTS and WLAN network are associated with many technical challenges such as network security, seamless vertical handover, session continuity, consistent QoS, common authentication and management of the available radio resource among the different network users. To reduce the network congestion and to ensure QoS capabilities, the problem of managing the resource efficiently acquire additional complexity in the interworked network.

One of the radio resource management techniques for efficient allocation of traffic users into the network is the implementation of CAC algorithms. CAC in single service networks have been extensively studied. Haun Chen *et al*. proposed the guard channel based CAC for homogenous network based on birth and death process, which results in the increase of the new call blocking probability. Bin Li *et at*. proposed the resource utilisation for a wireless cellular system based on partitioning the channel available for different traffic sets. In a heterogeneous network, a balance in the resource utilisation between different network users is to be provided. The users should be allocated with the network that has the highest probability of providing the best QoS for a particular service request.

In this paper TP and DP CAC schemes for WLAN coupled with 3G network is implemented and their performances are analysed. The rest of the paper is organised as follows, section 2 unveils the interworking issues in 3G/WLAN convergence network, section 3 elaborates throughput and dynamic partitioning based CAC schemes, section 4 presents the performance analysis of IEEE 802.11e WLAN [8] coupled to 3G network with TP and DP CAC schemes, section 5 summaries the inferences arrived from the simulation results in conclusion.

II. INTERWORKING ISSUES

Despite recent attempts for providing efficient network usage, many open and unresolved issues still exist in converged 3G/WLAN.

A. Seamless Roaming across 3G Cellular Networks and WLANs

The first of which is the issue of session mobility across WLAN and UMTS networks. Taking into account the distinct mobility management mechanisms employed in cellular networks and WLANs, it is a rather challenging task to support seamless roaming across the two networks. Either the cellular networks or WLANs should have inherent mechanisms for location and handoff management.

B. Enhanced Security Level

For 3G/WLAN interworking, if comparable security cannot be provided by both networks, adversaries can break into the system through the weakest component in the security chain and in turn defeat all security goals of the entire system. In other words, the two networks must be integrated in such a manner to achieve an enhanced (instead of impaired) security level. Also, appropriate independence between them should be maintained to minimise the security exposure.

C. Consistent End to End QoS Guarantee

There exist differences in QoS provisioning of 3G and WLAN network, based on the differences, different services can be admitted to either the cellular network or the WLAN according to their traffic characteristics and QoS requirements [9]. For example, real-time services such as voice telephony can be well carried by the cellular network to satisfy the strict delay requirement, whereas the delay tolerant data traffic can be admitted to the WLAN to enjoy the high throughput. It is also an important issue to maintain consistent or smoothly adapted QoS during vertical handoff (i.e., handoff between the cellular network and the WLAN).

D. Authentication and Authorisation Support

It is expected that in a 3G/WLAN integrated network the wireless terminal will be dual-mode, which means that the terminal will be equipped with network interfaces to both 3G networks and WLANs. However, only one subscription is needed with a 3G operator or a WLAN service provider, who has roaming agreements to support the interworking.

E. Radio Resource Management across 3G Network and WLANs

The problem of managing resources acquires additional complexity in the framework of heterogeneous networks. Initial radio access technologies (RAT) selection, CAC, resource allocation and handovers should be carried out jointly to make the best out of the available technologies and resources.

CAC is one of the key radio resource management (RRM) strategies. CAC algorithm in heterogeneous networks provides a decision, as to which of the available wireless access technologies to use. It is implemented to reduce network congestion, meanwhile ensure the QoS and enhance the utilization of network resources.

III. CAC SCHEMES

In communication system, the call admission control scheme is a strategy for QoS provisioning and network congestion reduction. Arriving calls are granted or denied based on predefined system criteria. Due to limited spectrum resource and growing popularity of usage in wireless cellular networks, CAC has been receiving a lot of attentions for QoS provisioning and its main features are extended to cover signal quality, blocking probability of new call, handoff dropping probability, data rate, etc. The converged WLAN and 3G cellular networks pose a great challenge to the CAC design due to heterogeneous network features, such as varied access techniques, resource allocation priorities, QoS provisioning levels, vertical handoffs, etc.

In general, CAC can be grouped into two categories: parameter based (proactive) and measurement based (reactive). Parameter based admission control schemes use a priori traffic specification to determine the parameters of deterministic or stochastic models. On the other hand, measurement based admission control offers QoS to users, without requiring priori traffic specifications or online policing. It depends on the measurement of actual traffic load in the network in making admission decisions. As a result, it shifts the task of traffic specification from the user to the network and relieves the network from the burden of traffic policing.

The main criterion used in evaluating any CAC algorithm must be how well it fulfills its primary role of ensuring that service commitments are not violated.

The second evaluation criterion is how well a level of network utilization, a CAC can achieve while still meeting its service commitments. The third evaluation criterion is how high the implementation and operation cost of an algorithm is. Thus the implementation cost of a CAC should not be prohibitive. Other criteria are optimality, stability and scalability.

A. Throughput based Call Admission Control 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}.

$$\eta_{UL} = (1+i)\sum_{j=1}^{N} \frac{1}{1+\frac{W}{(\frac{E_b}{N_0})_j . R_j . v_j}} \quad (1)$$

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.

$$\eta_{UL} + \Delta_{UL} \leq \eta_{ULT} \quad (2)$$

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

$$\eta_{DL} = \sum_{j=1}^{N} v_j . \frac{(E_b/N_0)_j}{W/R_j} . [(1-\gamma_j)+i_j] \quad (3)$$

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*.

$$\eta_{DL} + \Delta_{DL} \leq \eta_{DLT} \quad (4)$$

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

In an ideal single cell CDMA system, downlink channels are perfectly code multiplexed, i.e., codes have a degree of orthogonality between them. However in a real CDMA system, the set of codes is modulated by the multipath channel. As a result codes arrive at the users with a lesser degree of orthogonality. This produces downlink interference, which is modeled as a downlink orthogonality factor [11].

The admission criterion for throughput based scheme depends on the loading factor of the system. The performance can be analysed based on the equations (1) and (4) given above. When the limit of loading increases the threshold by the addition of new user (ΔL), then the new call will not be allowed into the system, thus call blocking occurs. Throughput based scheme works better in reducing the data blocking probability (p_{bdata}). For the scheme, the uplink is capacity limited and data users are fewer in number at any point of time than voice users. Hence the uplink forms a bottleneck for voice.

B. Dynamic Partitioning CAC Scheme

This is a complete partition scheme, in which the bandwidth within a cell is divided into separate pools for each traffic type. In this scheme, the boundary for the partition is movable and, thus, can effectively deal with the traffic changes in the system. However, handoff calls are not differentiated from new calls and the specified requirement of handoff dropping probability is not met. Furthermore, it is assumed that the data requires one unit of bandwidth. In this paper, this scheme is extended to differentiate between handoff calls and also take into account the different bandwidth requirements. In the DP scheme, as shown in Fig.1, K_1 out of C channels are reserved exclusively for new/handoff voice calls (voice only area) and K_2 channels are reserved exclusively for new/handoff data calls (data only area). The other ($C-K_1-K_2$) channels (shared area) are shared in fair manner by both voice and data calls. In order to maintain a low handoff dropping probability for voice calls, it is further restricted, that new voice calls can only use the K_3 out of K_1 voice channels (i.e., guarded channel policy). owever, K_1 handoff voice calls can use all the channels.

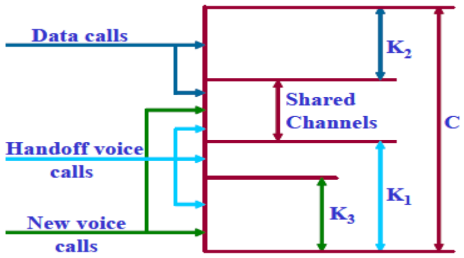

Fig 1 Dynamic partitioning scheme

The admission control of DP scheme is described as follows. For a new voice call request, a channel is searched for in the voice only area. If there is no available channel there, the shared area will be searched. Likewise, a data call assignment will be first attempted in the data only area and if that is not possible, the shared area will be examined. When a handoff voice call arrives, if there is no channel available in both the voice only area and the shared area, it will be dropped. When a new voice call arrives, if the channel occupancy exceeds the threshold in the voice only area and there is no idle channel in the shared area, it will be blocked. When a data call (new or handoff) arrive, if the number of idle channels in the data only area or in the shared area is less than B that is the fixed number of channels for data service, it will be blocked.

It is considered that, all cells have the same number of channels and experience the same new and handoff call arrival rates. In each cell, the arrivals of new voice calls, new data calls, handoff voice calls, and handoff data calls are Poisson distributed with arrival rate λ_{vn} ,λ_{dn}, λ_{vh} and λ_{dh} respectively. Thus, the total voice call arrival rate and data call arrival rate are $\lambda_v = \lambda_{vn} + \lambda_{vh}$ and $\lambda_d = \lambda_{dn} + \lambda_{dh}$, respectively. Since data can usually tolerate some degree of service degradation, new data calls and handoff data calls are not distinguished. Call duration times or call holding times of voice and data are exponentially distributed with the average call duration time $1/\mu_{vr}$ and $1/\mu_{dr}$. In addition, the cell residence time for voice and data calls is exponentially distributed with mean, $1/\mu_{vh}$ and $1/\mu_{dh}$, respectively. Thus, the channel occupancy times for voice and data calls are exponentially distributed with mean $1/\mu_v = 1/(\mu_{vr} + \mu_{vh})$ and $1/\mu_d = 1/(\mu_{dr} + \mu_{dh})$, respectively. Also, define $\rho_d = \lambda_d/\mu_d$ and likewise for voice calls.

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The above sets of assumptions have been found reasonable as long as the number mobile is much larger than the number of channels in a cell.

The DP scheme can be modeled as a three-dimensional Markov chain. If a Markov chain is ergodic, then it is possible to find the stationary distribution of the states (i.e., the equilibrium state probabilities) in the Markov chains. Let P_{ijk} be the steady probability that there are, i new voice calls, j handoff voice calls, and k data calls in the system.

Case (i)

$i=j=k=0$. No arrival of new voice and data call. The channel is free.

Case (ii)

If $0 \leq i+j \leq K_1$ and $0 \leq k < [(C - K_1) / B]$, all voice calls (new and handoff) and data calls will be accepted.

Case (iii)

If $0 < i + j < K_3$ and $k = [(C - K_1) / B]$, voice calls (new and handoff) will be accepted, but data calls will be rejected.

Case (iv)

If $K_3 \leq i + j < K_1$ and $k = [(C - K_1) / B]$, only handoff voice calls will be accepted, new voice calls and data calls will be rejected.

Case (v)

If $i + j = K_1$ and $k = [(C - K_1) / B]$, or $k < i + j < C - K_2$ and $k = [(C - i - j) / B]$, all new/handoff voice calls and data calls will be rejected.

Case (vi)

If $i + j = C - K_2$ and $k < K_2 / B$, data calls will be accepted, but new and handoff voice calls will be rejected.

Based on the above conditions, the voice and data call blocking probability is calculated by,

Voice call blocking probability:

$$P_{vb} = \sum_{K_3 \leq i+j \leq K_1} P_{ijk} + \sum_{K_1 \leq i+j \leq C-K_2} P_{ijk} + \sum_{i+j=c-K_2} P_{ijk} \qquad (5)$$

Data call blocking probability:

$$P_{db} = \sum_{K_3 \leq i+j \leq K_1} P_{ijk} + \sum_{K_1 \leq i \leq C-K_2} P_{ijk} \qquad (6)$$

where,

Total number of channels = C

K_1 channels out of C for new and handoff voice calls

K_2 channels for data calls

C-K_1-K_2 for shared channel

K_3 out of K_1 for new voice calls

IV. PERFORMANCE ANALYSIS

The 3G/ WLAN interworking network for loose coupling, tight coupling and hybrid coupling architecture are developed using OPNET with the simulation parameters listed in table I.

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Table I. Simulation Parameters

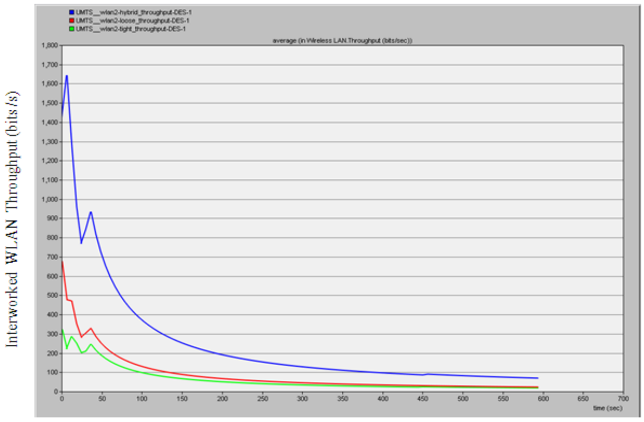
Simulation Parameters	Values
Uplink power control efficiency	0.85
Uplink loading factor	0.75
Downlink loading factor	0.75
Path loss model	Hata small- medium city
WLAN data rate	54 Mbps
Traffic frame size	128000 bytes
Simulation runtime	10 minutes

The performance such as throughput and delay for the network is analysed for the admission control schemes

A. *Throughput based CAC*

The TB scheme is developed by assigning the admission control in the RNC of the UMTS network. The uplink and the downlink loading factor define the load of the link due to the addition of new users. The increase in load factor by the addition of a user is included in the system evaluation. The uplink and downlink loading factors are fixed for the admission control scheme as 0.75, and the power control efficiency parameter is set to 0.8.The simulation is run for 10 minutes and the performance parameter such as throughput and delay are obtained.

The scheme depends on the uplink and down link loading factor of the system taking into consideration the power efficiency, since UMTS is a CDMA system with signal to interference having the great impact of the network performance.



Simulation runtime (s)

Fig. 2 Interworked WLAN throughput in throughput based CAC

Fig.2 shows the throughput obtained in an WLAN network which is interworked with the UMTS network. From the result obtained it can be observed that hybrid coupling scheme performs better in than the other coupling schemes, since the traffic can take the WLAN or the UMTS network. The loose coupling network with independent resource utilization has a better throughput when compared to the tight coupling network, with the least performance since the entire network load is through the SGSN of UMTS network.

The throughput degradation are effective in an wireless environment due to the three factors such as propagation delay, user's idle period (not transmitting), and packet collision because of overlapping of transmissions from multiple user. The delay of the network is shown in Fig. 3. The loose coupling network has the higher delay when compared to tight coupling since signal traffic needs to traverse long paths which cause high handoff latency, affecting the real-time services.

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The hybrid coupling network has a moderate delay. It performs as a better choice for selecting the path for the traffic to be sent (i.e. either through the UMTS or the WLAN network) based on the intensity.

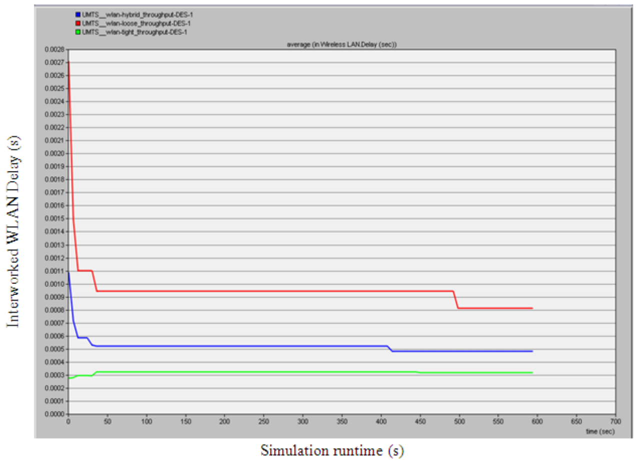

Fig. 3 Interworked WLAN delay – throughput based CAC

B. Dynamic Partitioning CAC Scheme

DP Scheme is based on the partitioning the available channels to support for different traffic services. Voice calls are given higher priority than the data service. The data services can be in queue if there is no available resource present in the network. The voice services are real time services which are delay sensitive and should be served immediately without affecting the information transferred.

The DP scheme is implemented in the RNC of the network. Admission requests received are collected at BS and transmitted to the RNC. The differentiation between handover and new calls is then made by prioritization function.

Furthermore different traffic classes are differentiated by using different thresholds. Threshold values are adjusted dynamically by the system in order to respond to changing traffic conditions. Admission decision is based on guaranteeing QoS requirements for each call. The available bandwidth is divided into data and voice and handover voice and some shared channel.

Hybrid coupling scheme provides the higher throughput as shown in Fig. 4, when compared to the loose and tight coupling network. DP scheme performs better for hybrid coupling network since the traffic is sent to different partition level based on the traffic service. Since hybrid scheme has connection to both WLAN and UMTS and the channel is divided for data and voice separately, data call can be through WLAN and voice call can be through UMTS network leading to higher throughput.

Fig. 5 shows the WLAN delay in an interworking network. The loose coupling network with no load balancing [12] is provided for applications with specific QoS requirements and it does not support seamless services. Similar to previous architecture, tight coupling does not support efficient usage of resource, since the service are classified and routed to the channel allocated for the particular service only through a single network. Hybrid coupling which gives access to both the UMTS and WLAN network can reduce the delay in transmission. Thus hybrid coupled network has the minimum delay compared to the other networks.

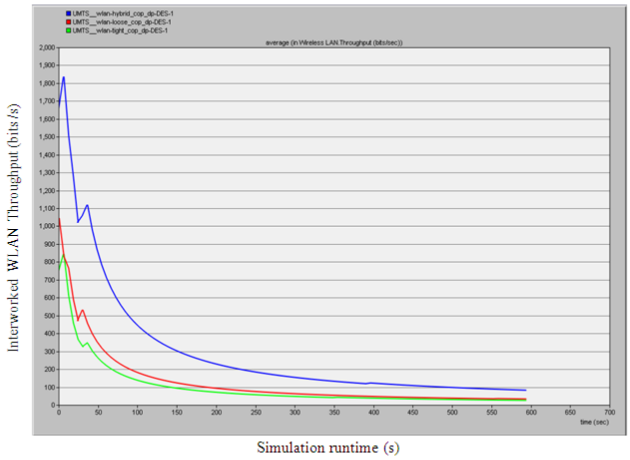

Fig. 4 Interworked WLAN throughput - DP scheme

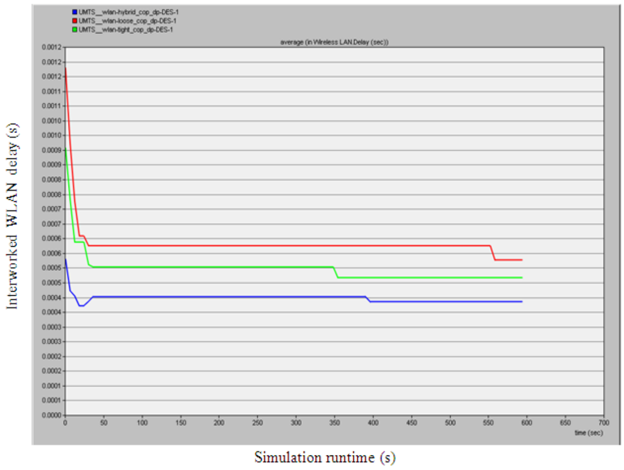

Fig. 5 Interworked WLAN delay - DP scheme

Comparing the performance metric for the different coupling schemes, hybrid scheme has the optimal performance in throughput and delay.

Loose coupling network has the lowest throughput and highest delay. A loosely-coupled architecture allows a WLAN to bypass the 3G core network and interface directly to the core IP network via a WLAN gateway. This approach completely separates the data paths in the WLAN and UMTS networks. Therefore the WLAN data traffic is never injected into the UMTS core network. It allows for independent deployment of WLAN and UMTS networks. This lead to the loss of packet due to congestion or queuing in the network is there is no much availability of resource.

Tight coupling has the lowest throughput among the network. The WLAN is directly connected to the UMTS core network. Consequently, all the WLAN traffic is injected into the UMTS core data network. As a result, the traffic must be routed either through the UMTS or WLAN network. The tight coupling network acts to function as a single network and leading to less efficient sharing of the resource available. This approach is only feasible when both WLAN and UMTS networks belong to the same operator.

C. Comparison of Throughput based and DP CAC

Table II shows the comparison in the throughput and delay values between the TP scheme and the DP scheme.

Table II. Comparison of throughput and delay

Coupling scheme	Throughput (bits/s)		Delay (s)	
	Throughput based CAC	*DP CAC*	*Throughput based CAC*	*DP CAC*
Loose coupling	90	190	0.00095	0.00058
Tight coupling	80	130	0.00035	0.0005
Hybrid coupling	400	420	0.00058	0.00045

Hybrid coupling network has a greater efficiency in sharing the resource of both network. This leads to utillisation of the UMTS or the WLAN network depending upon the traffic intensity. Thus the coupling network has better throughput performance.

Comparing the CAC Schemes DP scheme has a good performance since this has a complete partitioning of the traffic service based on the threshold fixed.

TP scheme is based on the loading factor of uplink and downlink. It is based on the interference in the system and leads to soft capacity (i.e. the call blocking or dropping will be due to the increase in the interference level of the system by additional number of users entering the system, and not due to the scarcity of radio resource).

DP scheme having service differentiation based on the traffic type and the channels are divided for supporting the traffic type, data all is routed first to the WLAN network and voice call is routed to the UMTS network. This makes efficient usage of the radio spectrum available. Thus the scheme offers better delay and throughput performance.

The CAC performance metric [13-15] such as voice call blocking probability and dropping call probability are calculated for DP CAC scheme from the system analysis equation given in (5) and (6) respectively are shown in Figs. 6 and 7.

The user intensity is varied from 6 to 16 and the simulation is performed. The traffic sent, traffic received is obtained from the simulation results and the average of 50 run is taken to calculate the blocking probability.

Due to the nature of complete partition, these voice only channels cannot be shared by data calls. Thus, when the voice call intensity is low, much lower voice call dropping probability can be achieved.

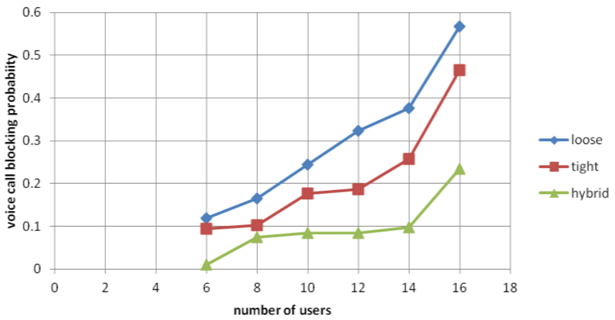

Fig. 6 Voice call blocking probability

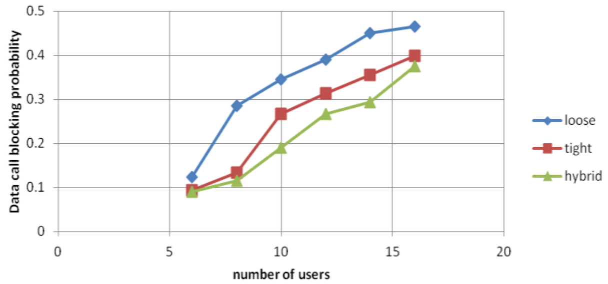

Fig. 7 Data call blocking probability

Hybrid coupling with more efficient resource utilization provides less blocking probability. The user entering the network depending on the service type can be routed to the specified network based on the priority. Since in hybrid coupling the user has the advantage of using both the interworked network resource effectively, more number of users is allowed to share the resource in an efficient way. Tight coupling has the moderate blocking probability due to its less utilisation to the network resource availability. In Loose coupling architecture, with common management functionalities and less sharing of resource, the users based on service differentiation has less utilisation of resource, results in highest blocking probability.

V. CONCLUSION

The principle purpose of efficient admission control algorithm is very important for future networks, since it allows maximum utilization of the network, preventing overloading situations and ensuring that users are served with the best QoS. The interworking network can be better utilized by efficient CAC algorithms, by which end-to end QoS can be achieved leading to minimized call blocking and dropping probability. Hybrid mobile networks like those formed by WLANs and 3G cellular data networks should guarantee seamless connectivity to users.

In this paper efficient CAC such as TB and DP scheme for interworking environment of UMTS and WLAN has been developed. The TP scheme, which depends on soft capacity of the network, provides lesser system performance, since there is no service differentiation. DP scheme with the service differentiation has better utilization of the network resource.

From the results it is observed that hybrid gives better performance than loose and tight coupling. DP Scheme performs better than TP scheme in terms of throughput and delay.

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