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Quality of Service in bandwidth adapted hybrid UMTS/WLAN interworking network

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Abstract

Integration of Universal Mobile Telecommunications System (UMTS) and Wireless Local Area Network (WLAN) result in ubiquitous connection for end users. In the integrated network, ensuring the quality of service to users and enhancing capacity of network are prominent issues. Bandwidth adaptation technique is one of the solutions to overcome these issues. Bandwidth adaptation based on per flow and per class schemes were proposed for loosely coupled interworking network. In this paper, hybrid coupled UMTS and WLAN interworking network is analyzed with bandwidth adaptation based on per flow and per class schemes and the performances have been compared. Simulation result shows that the proposed hybrid coupled interworking network with bandwidth adaptation based on per class scheme performs better with enhanced quality of service and network capacity.

Keywords: *call blocking probability, dynamic UMTS/WLAN, opnet, QoS adaptive network, throughput*

1. Introduction

The increase in demand for data communication through mobile phone, paved the way for the migration of, Global System for Mobile (GSM), a circuit switched system to General Packet Radio Service (GPRS) and 3rd Generation (3G) networks, which have the packet switched functionality. Recent trend is that networks like UMTS and WLAN are integrated to provide a universal all Internet Protocol (IP) platform which can provide much useful applications to the end users. The all IP platform can provide end users with benefits such as lower cost of transmission and higher bandwidth with roaming features and pervasive aspects. WLAN systems provide high data rates at a relatively low cost compared to UMTS, but it has a limited coverage area and less support for high speed mobility. WLAN have been widely deployed in places like airports, hotels and campuses. The 3rd generation partnership project (3GPP) has been working on standardization for integrating cellular and WLAN systems [1, 2], Network architectures for converging UMTS/WLAN systems can be grouped into two categories based on the autonomy between two networks such as, tight coupling and loose coupling [3].

In loose coupling, 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 IP and mobility of mobile stations is managed through protocols such as Mobile IP. Loose coupling architecture enables the two networks to be deployed separately as shown in Figure 1, but the limitation is longer delay for signaling and vertical handovers. In tight coupling architecture, the two networks are integrated at CN of UMTS as shown in Figure 2, which has lower delay for signaling and vertical handover but has more implementation complexity. To overcome these disadvantages hybrid coupled UMTS/WLAN interworking architecture was proposed [4, 5]. Compared with the existing coupling schemes, hybrid coupled interworking network can distribute the signaling and data load on both UMTS CN and core internet. It offered less handoff latency in vertical handoff process [6].

When the Mobile Node (MN) is present in UMTS network as shown in Figure 3, it is directly connected with the Base Station (BS) by wireless link "a". If the MN is present in WLAN then it connects with remote access point (AP) by wireless link "b" and in turn remote AP is connected to WLAN server. The dual mode User Equipment (UE) hardware is used for converged UMTS and WLAN networks which have capability to access either network [7, 8]. Many difficulties emerge when attempting to provide Quality of Service (QoS) solutions for

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integrated WLAN and cellular networks, because of the unbalanced capacity of the two systems, issues raised by handover and the unreliable communication in wireless media [9]. To enable efficient use of the scarce resources provided by the cellular networks while maintaining strong QoS guarantees, a generic reservation based QoS model has been proposed for the loosely coupled integrated cellular and WLAN network [10]. Bandwidth adaptation based on per flow algorithm adjusts the QoS to maintain ongoing sessions at a satisfactory level with efficient use of the system resources [11]. The QoS management with bandwidth adaptation based on per class algorithm provides better fairness than bandwidth adaptation based on per flow algorithm [12]. By adapting the bandwidth, as and when demand arises, a greater number of users could be served with acceptable level QoS [13-15]. In this paper, hybrid coupled UMTS/WLAN interworking network with bandwidth adaptation based on per flow and per class algorithm is analysed, their performances are compared with the existing non adaptative scheme via simulation. The rest of this paper is organised as follows. Section 2 reviews the adaptive QoS framework. Bandwith adaptation based on per class algorithm is analysed in section 3. Performance analysis in section 4 describes the simulation scenario and discusses the simulation results. Finally, section 5 summarises this study and gives concluding remarks.

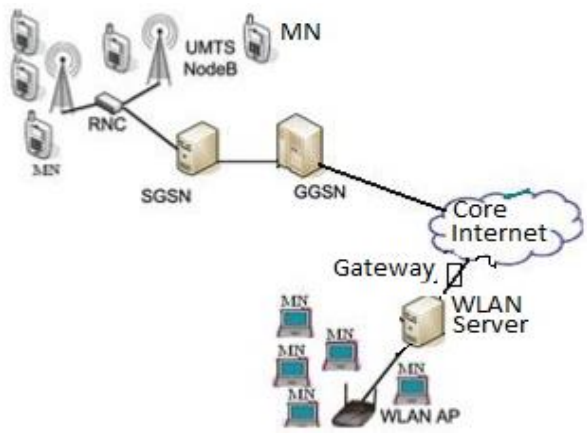

Figure 1. Loose coupling architecture

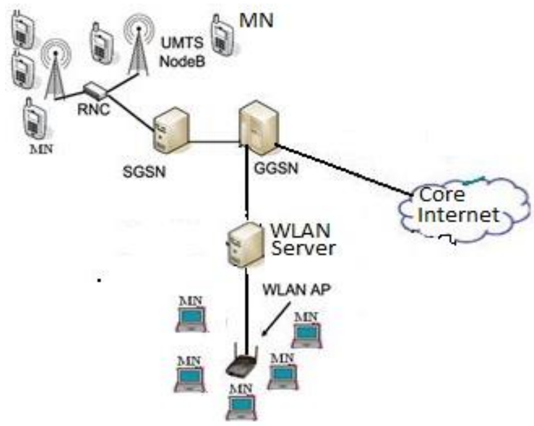

Figure 2. Tight coupling architecture

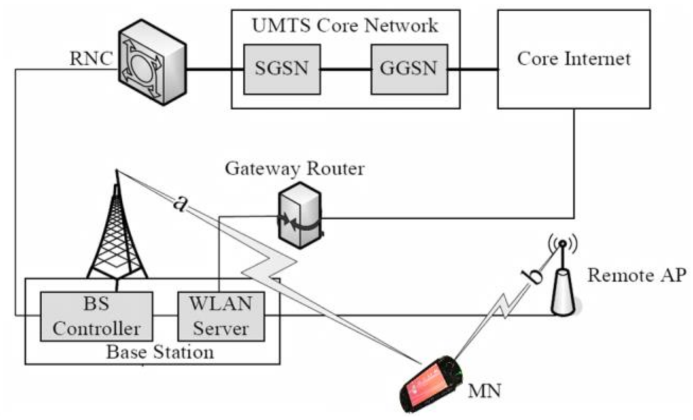

Figure 3. Hybrid coupled UMTS/WLAN interworking architecture

2. Adaptive QoS Framework

WLAN and UMTS networks have different transmission capacities; Consider the significant difference in transmission capacity between the two systems especially when user handoff takes place therefore, handoff between the two systems makes it very hard to maintain the enough QoS for on going connections. Also, WLAN operates on ISM band and has a lot of uncontrollable interference. The spread spectrum technique is used to reduce the interference. To support QoS, in packet switching networks the network load must be kept under a threshold. The third problem is that the achievable QoS levels in WLAN and UMTS do not match each other. UMTS is very well designed with careful network planning and mature admission control algorithms. Therefore, the achievable QoS level is relatively high in UMTS, while 802.11e WLAN works within a less controlled environment and it is difficult to achieve hard QoS. The QoS framework based on an adaptive approach [9] for integrated WLAN and UMTS addresses the above issues and provides practical and user-satisfied QoS. It adapts the long duration calls in the system based on their state information, because they have a greater probability of quitting the system thus leaving fewer adapted connections in the system. Use of adaptation profile can guarantee the satisfied QoS level to the end user and adapting the long duration calls can minimise the QoS reduction of the entire system. Figure 4 describes the bandwidth adaptation algorithm based on per flow scheme.

```
New call arrivals

if (New RBW Bi < SAB)
        assign Bi;
else
    if (New RBW Di < SAB)
        assign Di;
    else
        while (un-adapted, call exists & Di > SAB)
        adapt long duration call;
        if (Di < SAB)
            assign Di;
        else
            reject the call;
        end
    end
end

Handoff call arrivals

if (Handoff RBW Bi < SAB + GB)
    assign Bi;
else
    if (Handoff RBW Di < SAB + GB)
        assign Di;
    else
        while (un-adapted, call exists & Di>SAB+ GB)
            adapt long duration call;
        if (Di < SAB + GB)
            assign Di;
        else
            reject the call;
        end
    end
end

Departures

while (SAB > 0)
find the adapted call with shortest duration;
assign Bi for this call;
```

Figure 4. Pseudo code of per flow adaptation algorithm, where Bi represents the required bandwidth, Di denotes the minimum bandwidth request defined in the connection degradation profile, RBW is requested bandwidth, SAB is system available bandwidth, and GB is guard bandwidth

3. A Dynamic Bandwidth Management Scheme

In wireless communication networks, negotiation between different network flows is an effective way to improve overall system performance. The bandwidth adaptation algorithm as the key factor of the adaptive QoS framework decides how to adjust the QoS connections, since mobile users should be able to seamlessly maintain their ongoing sessions at a satisfied level.

This can be done in two ways. One is to adapt a flow to its same level, when it migrates from one system into another. Ideally, each call in the system should be allocated the maximum allowable bandwidth. However, WLAN and UMTS have different transmission capacity; a session that consumes a moderate amount of bandwidth in WLAN system can be greedy and therefore could be rejected in the UMTS. A connection switched from cellular network to WLAN needs to level up its bandwidth otherwise it will lose the meaning of the integration. The other way is to adapt flows to use the system resource more efficiently in a single system or both to accommodate more new arrivals and handoff calls. The bandwidth adaptation based on per flow method adapts the long duration calls in the system based on their state information with a good hope that those flows have a bigger probability to quit the system and leave fewer adapted connections in the system [10]. The management of per flow algorithm is very complex as the Call Admission Control (CAC) must search for the longest duration call in the system each time. It can create unfairness because if the system state does not change frequently, it can have some connections adapted for long time while others are going at full or at high speed.

In the bandwidth adaptation scheme, which is based on per class degradation [12], when a new user arrives and there are no enough resources in the system, the system should ask all connections in the lowest priority level to adapt until they reach their minimum acceptable level and if the resources is still not enough the process continues with the next priority level (class). If all connections that have lower or equal priority to the new connection have adapted to their minimum and still there is no enough resource, this new connection will be rejected. The adaptation algorithm based on per class scheme is described in Figure 5. By using this per class method, better fairness is ensured between the connections of the same class. The above idea also can improve the scalability of the scheme and reduce the computation complexity.

```
New Call Arrivals

if (New Requested Bandwidth Bi < SAB)
            assign Bi;
                else
                     if (New Requested Band Di < SAB)
                        assign Di;
                        else
                        WHILE (un-adapted, class exists & Di > SAB)
                        adapt lowest priority class;
                             if (Di < SAB)
                               assign Di;
                             end
                           end
                end
```

Figure 5. Pseudo code of per class adaptation algorithm

4. Performance Analysis

The simulations are carried out in OPNET 14.5 [16] with the simulation parameters mentioned in Table 1. Simulation network created for hybrid coupled WLAN and UMTS interworking network is shown in Figure 6. AP of WLAN is connected to Internet server through IP backbone which is routed through a router. Node B of UMTS is connected to the server through RNC, Serving Gateway Support Node (SGSN) and GPRS Gateway Support Node (GGSN) of UMTS network that is connected to IP backbone, which is path of a loosely coupled architecture. Also, WLAN AP is connected to server through GGSN of UMTS, which is the path of tight coupled architecture. Thus, in hybrid coupled architecture the WLAN AP is connected to Internet server through the paths present in loose coupled as well as tight coupled scenarios.

Table 1. Simulation Parameters

Sl. No	Parameter	Value	Sl. No	Parameter	Value
1	UMTS Capacity (U)	2Mb/s	4	WLAN to UMTS Handoff	0.01
2	WLAN Capacity (W)	11Mb/s	5	Session Time	180s
3	UMTS to WLAN Handoff	0.05	6	Simulation Time	180s

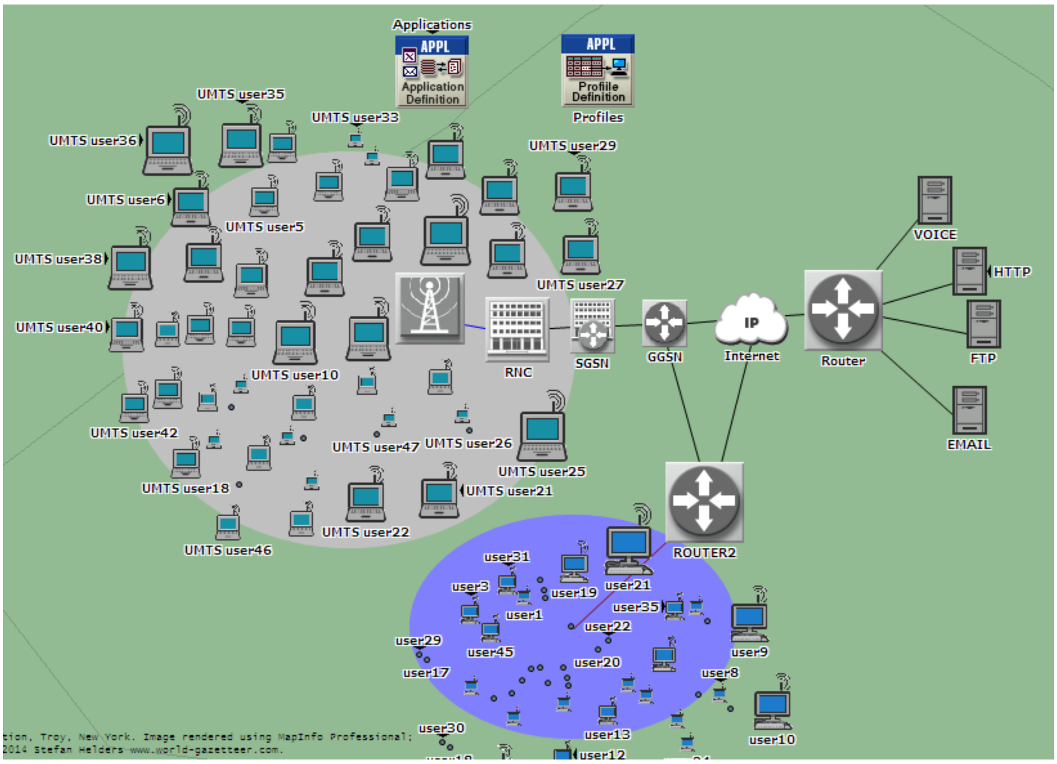

Figure 6. Hybrid coupled UMTS and WLAN integrated network

Call arrivals in the simulation follow an independent Poisson process and the session time of each connection is exponentially distributed. It is well known that dropping an established communication is worse than rejecting a new call. Therefore, UMTS reserve a guard bandwidth for the handoff calls to reduce the handoff dropping probability. The reserved guard bandwidth can be either static or dynamic [17, 18]. The dynamic approach often outperforms the static at the expense of generating more control overheads [19-22]. However, the static approach is often attractive in practice owing to its design simplicity. In the simulation, a static guard bandwidth, 5% of the system capacity is employed to deal with handoff calls. The integrated network in the simulation consists of one UMTS and one WLAN hotspot. As WLAN has higher capacity and is cheaper than UMTS, handoff probability from UMTS to WLAN is 5 times as much as that from WLAN to UMTS. The simulation results demonstrate the effectiveness of the bandwidth adaptation in the interworking network. The hybrid coupled interworking network that works under same traffic load and normal operation condition with non-adaptive, per flow and per class framework respectively were simulated. Each simulation was executed until the system reaches its stable state. To measure the system performance merits, throughput and delay [23-27] were observed. QoS parameters such as call blocking probabilities and data blocking probabilities were also examined.

4.1. Throughput

The throughput of existing hybrid coupled interworking network with non-adaptive bandwidth and the network with proposed adaptive bandwidth schemes is shown in Figure 7. It is observed from the figure that the hybrid architecture with per class adaptation offers high throughput compared to non-adaptive and per flow counterparts.

It is due to the traffic of users flow through two paths present between the users and internet. Moreover, the per class hybrid coupled architecture offered traffic, for considerably more users with higher bandwidth than per flow and non-adaptive schemes, it is observed that the throughput in per class is 5% and 7% higher than non-adaptive and per flow adaptive schemes respectively. The throughput is moderate in non-adaptive scheme as it accommodates fewer users whose bandwidth is not modified than per flow and per class counter parts. It is due to increased users with less bandwidth in the network, per flow scheme has least throughput.

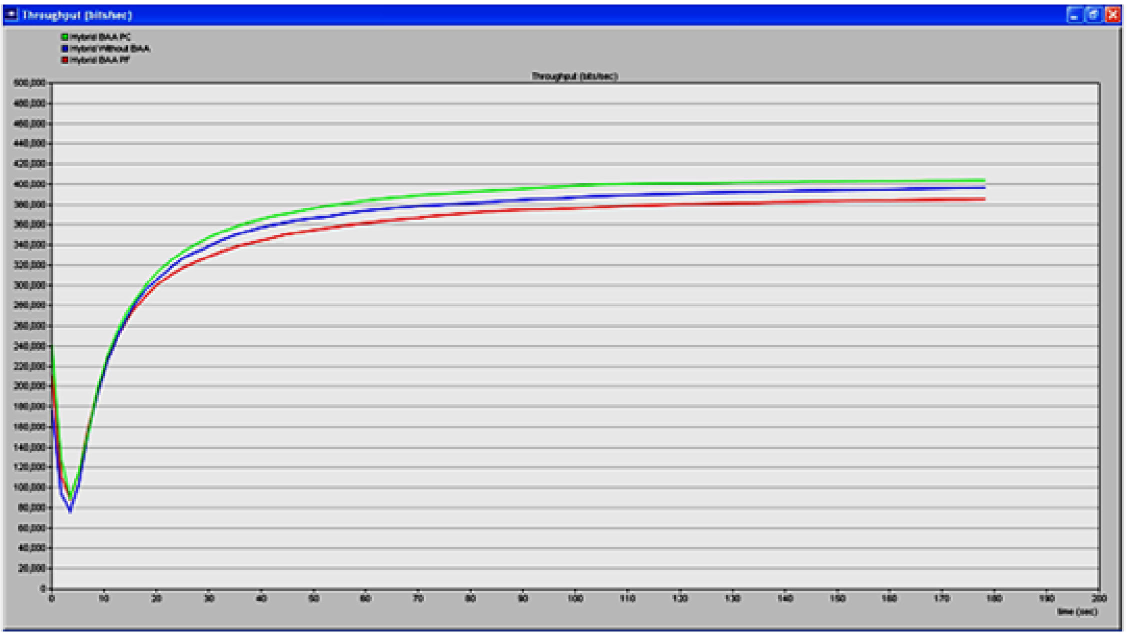

Figure 7. Throughput comparison

4.2. Delay

The end to end delay of existing hybrid coupled interworking network with non-adaptive bandwidth and the network with proposed adaptive bandwidth schemes is shown in Figure 8, it is evident from the figure that the delay is moderate in per class scheme which is 1.4% lesser and 2.8% higher than per flow and non-adaptive schemes respectively, as it takes comparatively lesser time for adaptation in per class than per flow scheme and in non-adaptation hybrid coupling time is not required. It is also evident that delay is 4.2% higher in per flow than non-adaptive scheme as in per flow more complex algorithm is involved which search for the flow that are present in the system for longer duration.

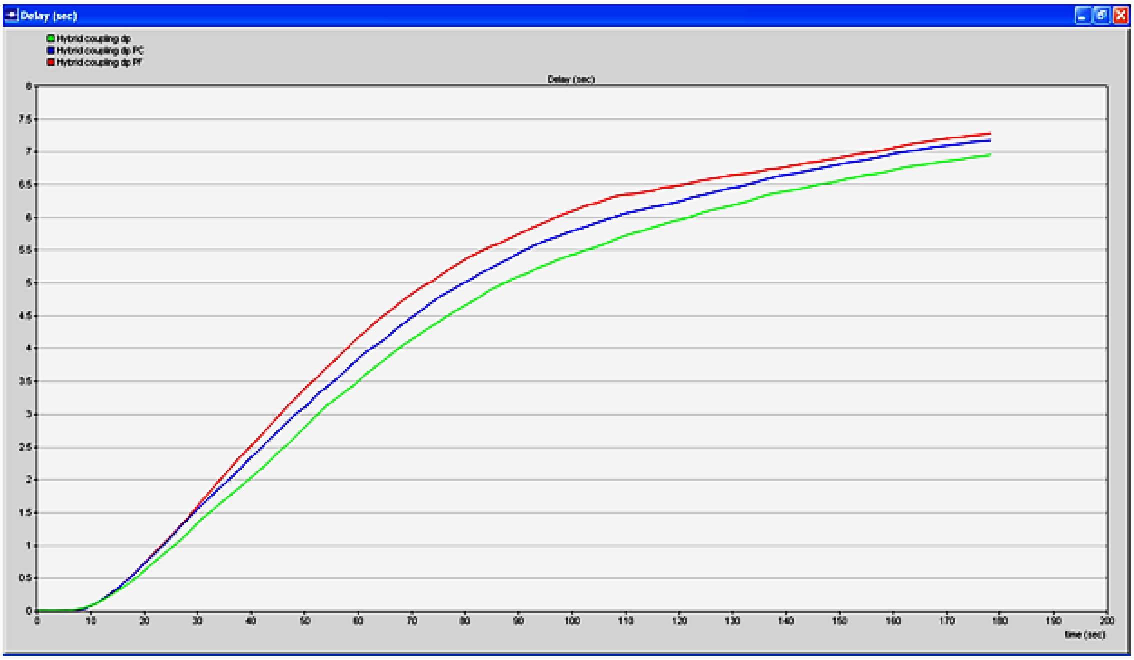

Figure 8. Delay comparison

4.3. Call Blocking Probability (CBP)

Blocking probability represents the amount of traffic blocked by the network, when users attempt to get the service from the network. Ratio of total voice calls served to total voice calls attempted, in the network is known as Call Blocking Probability (CBP). Figure 9 shows the evaluated CBP with respect to users, based on Erlang B for 1200 users. From the figure, it is evident that as many as 800 users can be accommodated in the network with non-adaptive scheme without any blocking whereas it is possible to accommodate 1000 users in the case of per flow method with zero blocking probability, also it is observed that more than 1000 users can be accommodated in per class scheme with very less blocking probability. It is observed that the per class hybrid coupling has 27.2% lesser CBP than non-adaptive network and it is 12.9% less than per flow hybrid coupling. The better performance of per class hybrid coupling is due to the offered capacity is large as compared to per flow and non-adaptive architectures. In per flow hybrid coupling, the CBP is 14.3% less compared to non-adaptive scheme of hybrid network, thus it can accommodate lesser number of users than per class hybrid coupled network and higher number of user than non-adaptive hybrid network.

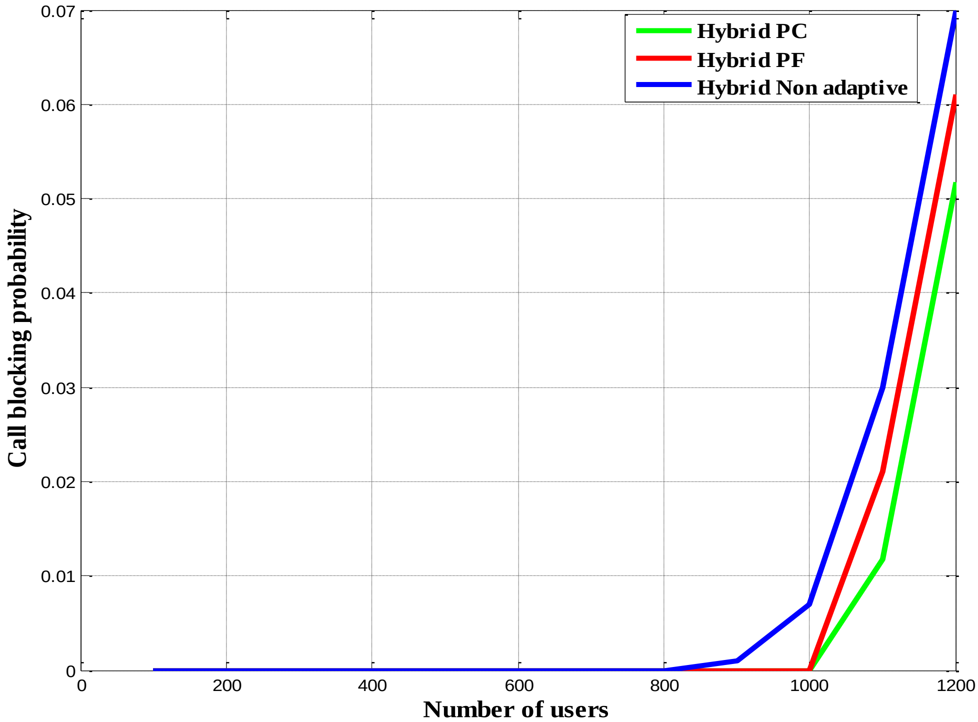

Figure 9. CBP

4.4. Data Blocking Probability (DBP)

DBP is the ratio of total data served by the network to the total data attempted in the network. Figure 10 shows the analyzed DBP against number of users. From the figure, it is observed that the per class hybrid coupled network offered lesser DBP due to its increased capacity compared to per flow and non-adaptive hybrid architectures. From the figure, it is evident that more than 850 data users can be accommodated in the network with non-adaptive scheme without any blocking whereas it is possible to accommodate 1000 users in the case of per flow method with zero blocking probability, also it is observed that more than 1000 users can be accommodated in per class scheme with very less blocking probability. Thus, the network with per class scheme has 18.2% lesser DBP than non-adaptive network and 9% less than per flow hybrid coupling. In per flow adaptation, the DBP is 9% less compared to non-adaptive hybrid coupling, as it can accommodate lesser number of users than per class hybrid coupling network and higher number of user than non-adaptive network.

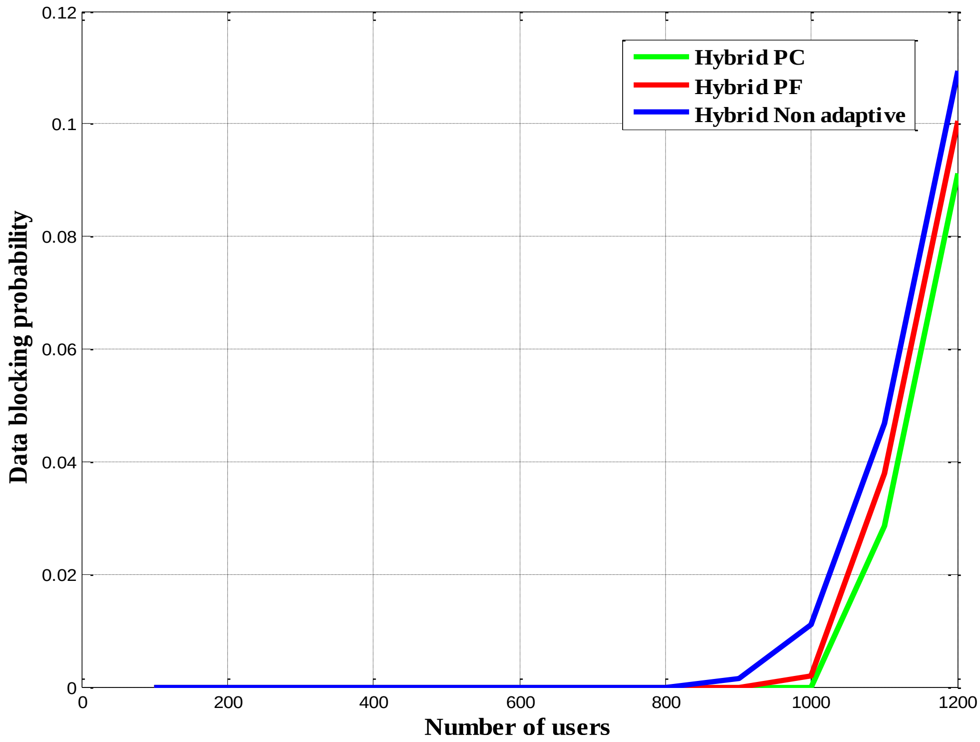

Figure 10. DBP

5. Conclusion

Integrating WLAN and UMTS networks efficiently with QoS support is a challenging task. Proposed hybrid coupled interworking network is efficient compared to loosly and tight coupled network. The generic reservation based QoS model for the loosly coupled cellular and WLAN interworking network uses bandwidth adaptation based on per flow and per class mechanism for ensuring enhanced QoS. In this paper, hybrid coupled UMTS and WLAN based interworking network with bandwidth adaptation based on per flow and per class algorithm are analysed and their performance is compared. The results show that per class method adapts all the flows in certain class and offered better performance than per flow. It is evident from the higher throughput which is 5 and 7 percent higher, than per flow and non-adaptive schemes. It also provides computation simplicity and executes faster, which is important for an admission control component that can be understood from the moderate end to end delay present that is 1.4 percent lesser delay than in per flow scheme. Per class method uses the system resources more efficiently than the per flow method since it adapted the connections based on requirement of the new connection, which is observed from the least call and data blocking probability which are 27.2, 12.9 percent and it is 18.2, 9 percent lesser than non-adaptive and bandwidth adaptation based on per flow scheme respectively.

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