RESOURCE MANAGEMENT STRATEGY TO SUPPORT REAL TIME VIDEO ACROSS UMTS AND WLAN NETWORKS

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ABSTRACT

The communication world is expecting an environment where a single terminal can support multiple services with pervasive network access. This paper addresses the challenges and resource management strategies to support real time video across UMTS and WLAN networks. A priority based service interworking architecture with Hybrid coupling is proposed to achieve seamless continuity of real time video sessions across the two networks. QoS consistency is an important challenge that needs to be addressed since QoS degradation can occur during vertical handover. The results indicate that QoS consistency can be achieved for real time video sessions with certain conditions and restrictions. The proposed scheme enables WLAN to support more number of UMTS video subscribers with better QoS consistency.

Keywords: Priority based service, Hybrid coupling, QoS consistency, QoS degradation, Vertical handover.

1. INTRODUCTION

In the past decade, there was fast evolution and successful deployment of a number of wireless access networks. Now the focus is turned towards the next generation communication networks [1, 2] which is aimed at seamlessly integrating various existing wireless communication networks [3], such as wireless local area networks (WLANs, e.g., IEEE 802.11 a/b/g and HiperLAN/2), wireless wide area networks (WWANs, e.g., 1G, 2G, 3G, IEEE 802.20), wireless personal area networks (WPANs, e.g., Bluetooth, IEEE 802.15.1/3/4), and wireless metropolitan area networks (WMANs, e.g., IEEE 802.16**).** The Technology of seamlessly integrating various existing wireless networks is called as Convergence Technology. This technology combines different existing access technologies such as cellular, cordless, WLAN type systems, short range wireless connectivity and wired systems on a common platform to complement each other in an optimum way and to provide a multiple possibilities for current and future services [4] and applications to users in a single terminal. The next generation communication network will be heterogeneous and provide multiple services anywhere and anytime with users getting the benefit of seamless internet access with multimode access capability. Seamless integration doesn't mean that the radio access technologies are converged into a single network. Instead the services offered by the existing radio access technologies are integrated. By converging voice, video and data networks onto a single IP based network, a business can lower it's total cost of network ownership by reducing expenditures on equipment, maintenance, network administration and carrier charges while enhancing it's communications capabilities. The goal is set forth and the research today is focused on integrating different combination of existing networks.

As on now, the most popular networks are cellular network and the wireless local area network (WLAN). The interworking [5-8] between third generation (3G) cellular network and WLAN has been considered as the suitable path towards the next generation of wireless networks. To be specific, both radio access networks have their own merits. The cellular networks support both circuit-switched and packet-switched services and have benefits such as global coverage, universal roaming and well defined infrastructure. But it has low data rate and lack of capability to service bandwidth demanding applications. On the other hand, WLAN supports only packet-switched services. It supports high data rate at low cost over local coverage and is very efficient in serving bursty traffic. But it has limitations such as poor mobility management, interference, vague infrastructure and is not suitable for serving time sensitive services. Security is not good either. When real time services are to be supported, WLAN lacks capability to serve them.

This is because WLAN is optimized for local, high rate and low cost data service [9]. Despite WLAN having lot of QoS deficiencies to handle real time services, it doesn't mean WLAN cannot handle it. For WLAN to handle real time services, QoS consistency is the major challenge that needs to be addressed.

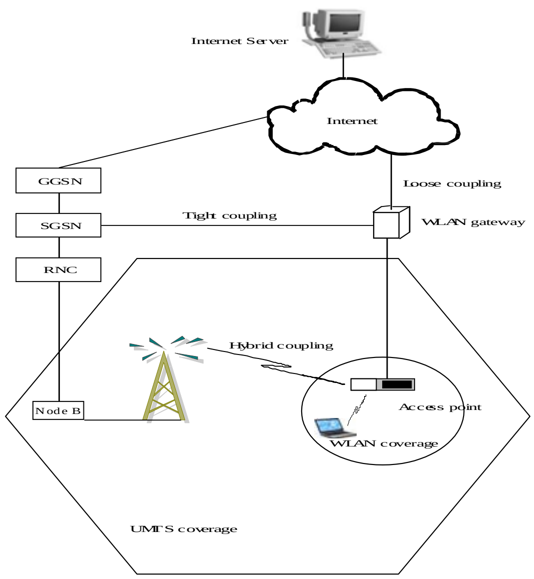

Figure 1. Interworking architectures

2. INTERWORKING ARCITECTURE

To achieve efficient interworking, the architecture plays an important role. The issue is more important when real time services are to be supported across the two networks.

A new architecture is proposed for the interworking of cellular network and the WLANs. But the most promising ones are Tight coupling, Loose coupling and Hybrid coupling. In Tight coupling, the coupling is such that WLAN appears to the cellular core network as another cellular access network. In Loose coupling, WLAN and cellular networks are completely separated and are connected through the Internet. But both coupling schemes [10-12] have drawbacks such as static routing of traffic, high latency during vertical handover [13-15] and increased burden for core networks. In order to overcome these shortcomings, Hybrid coupling architecture is developed. In Hybrid coupling, a new wireless link using IEEE 802.16 standard is created between base station (BS) in cellular network and 802.11 WLAN within a same cell area. Figure 1 illustrates the three coupling schemes**.** Hybrid coupling has advantages including dynamically reducing signaling cost and handoff latency [16, 17] and relieving the burden of core networks through dynamically distributing traffic in low level network, and enhancing the robustness of the integrated networks through adding a new wireless link.

2.1 SUPPORT FOR REAL TIME VIDEO SERVICE

When real time packet switched video is to be supported across the cellular network and WLAN, the vital component that needs to be maintained is the QoS consistency for the service. This is because to ensure seamless continuity [18], the QoS level for the service has to be maintained in the two network domains. But it is a very challenging issue because IEEE 802.11 WLAN was initially developed without paying much attention to QoS aspects, aimed primarily at simple and cost-effective data service. Even with the recent IEEE 802.11e developments, WLAN QoS still exhibits several deficiencies with respect to 3G QoS. It is a difficult task for WLAN to support real time video service because of QoS deficiencies. The deficiencies include equal error protection across different media streams, no control on residual BER and MAC service data unit, no dedicated radio channels and no soft handover can be achieved. Nevertheless, the QoS deficiencies of WLANs do not necessarily mean that seamless session continuity from UMTS to WLAN cannot be supported. UMTS subscribers admitted to WLAN are called as UMTS roamers. When a video session initiated in 3G network transits to a WLAN environment, the video session should continue seamlessly without any noticeable change in quality of service (QoS). In this regard, not only is 3G-based access control required, but also access to 3G-based services is needed over the WLAN network.

2.2 CONDITIONS FOR SEAMLESS CONTINUITY

To ensure seamless continuity of video sessions, WLAN can accept UMTS roamers as long as the two conditions are satisfied.

i. The video streams of all UMTS roamers admitted to the WLAN must experience at least the same QoS level as negotiated in the UMTS network i.e., the MAC SDU (MSDU) loss rate in the WLAN must not exceed the corresponding UMTS SDU error ratio (10^{-3}). The terminals of UMTS roamers make every effort to transmit all video packets within their delay bound, which is considered equal to 40 ms for consistency with UMTS. However, if a video packet is delayed for more than 40 ms, it is dropped. This policy guarantees that the delay experienced by all successfully transmitted video packets will be smaller than 40 ms.

ii. At the same time, the bandwidth available to WLAN data users must not diminish below a predefined threshold. The admission policy may need to ensure that WLAN data users have at least 'L' Mbps of bandwidth available no matter how many UMTS roamers are admitted into the WLAN. So the admission policy will reject further association requests from UMTS roamers when the bandwidth reservation limit is reached.

2.3 PRIORITIZED CHANNEL ACCESS

For WLAN to support real time video sessions, the channel access mechanism plays a major role. Traditional IEEE 802.11 WLAN have DCF (Distributed co-ordination function) and PCF (Point co-ordination function) as the channel access mechanism [19]. DCF does not have any provision to support QoS. All data traffic is treated in a first come first serve, best-effort manner. All STAs (stations) in the BSS (basic service set) contend for the wireless medium with the same priority. This causes asymmetric throughput between uplink and downlink, as the AP (Access point) has the same priority as other STAs but with much higher throughput requirement. There is also no differentiation between data flows to support traffic with QoS requirements. When the number of STAs in a BSS increases, probability of collisions becomes higher and results in frequent retransmissions. Therefore QoS decreases as well as overall throughput in the BSS. Although PCF was designed to support time-bounded traffic, many inadequacies have been identified. These include unpredictable beacon delays resulting in significantly shortened CFP (Contention free period), and unknown transmission duration of polled STA making it very difficult for the AP to predict and control the polling schedule for the remainder of the CFP. In addition there is no management interface defined to setup and control PCF operations. So neither DCF nor PCF provide sufficient facility to support traffic with QoS requirements. So enhancements such as EDCA (Enhanced distributed channel access) and HCCA (Hybrid controlled channel access) are made in IEEE 802.11e [20-22]. The enhancements are made to provide priority for a particular service. To provide priority the maximum backoff time for the service is made minimum, thereby increasing the chance for that particular type of service users to access the channel.

3. PERFORMANCE EVALUATION

The performance of the coupling schemes are analyzed for both contention based and contention free channel access.

3.1 Contention Based Channel Access

In Contention based channel access [23], both UMTS roamers and WLAN data users contend with each other to access the channel. Here, the UMTS roamers can be admitted to the system as long as the WLAN can support L Mbps of data traffic and the QoS experienced by the video streams meets or exceeds the QoS negotiated in the UMTS environment. To support real time video sessions, the channel access is invoked by giving priority to a particular type of users (i.e., either WLAN data users or UMTS roamers).

3.2 Priority to WLAN Data Users

The priority can be given to particular type of users by changing the maximum backoff time during their contention for channel access. Users possessing high priorities are given less backoff time than the users possessing low priority. By assigning priorities, the low priority users have to wait long time to access the channel. This mechanism helps high priority users to have more opportunities to access the channel than the users having low priority. When WLAN data users are given preferential access to the channel, the limiting factor for the maximum number of UMTS roamers in the WLAN is not the bandwidth reservation constraints but rather the MSDU loss rate of video streams.

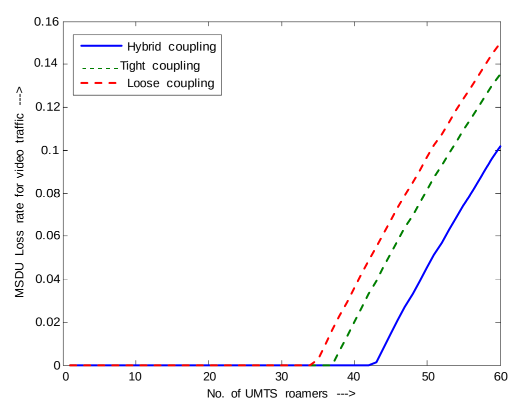

Figure 2. MSDU Loss rate for video traffic (L= 7 Mbps) vs. No. of UMTS roamers

Figure 2 reveals that when the WLAN data traffic (L) is 7 Mbps, the MSDU loss rate for video traffic reaches the UMTS negotiated value (10^{-3})

when there are 34, 37 and 43 UMTS roamers in case of Loose coupling, Tight coupling and Hybrid coupling respectively. Figure 3 reveals that when the WLAN data traffic (L) is 5 Mbps, the number of UMTS roamers that can be accepted to WLAN are 39, 42 and 50 in case of Loose coupling, Tight coupling and Hybrid coupling respectively.

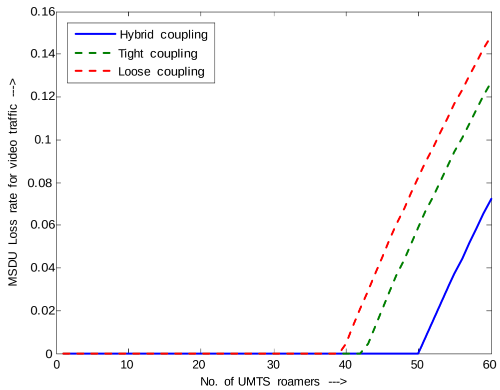

Figure 3. MSDU Loss rate for video traffic (L= 5 Mbps) vs. No. of UMTS roamers

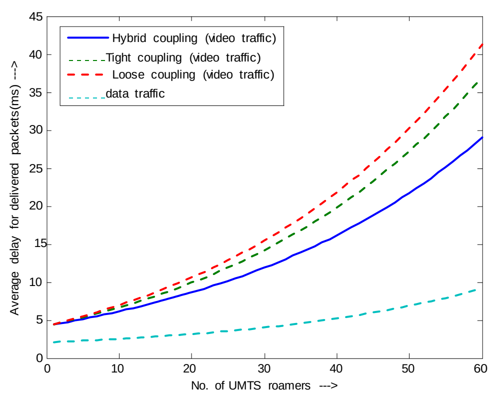

Figure 4. Average delay for delivered packets (L= 7 Mbps) vs. No. of UMTS roamers

When the WLAN offered data traffic is high, the number of WLAN data users are more and thereby results in accepting less number of UMTS roamers and vice versa. From Figure 2 and Figure 3, it is clear that the number of UMTS roamers accepted is more for Hybrid coupling than Loose coupling and Tight coupling. This is due to the wireless link established between the base station and WLAN Access point (AP) within the same macro cell area to achieve dynamic distribution of traffic. But the traffic distribution is static incase of Loose coupling and Tight coupling.

When WLAN data users are given preferential access to the channel, the delay for video packets will be larger than the delay of data packets. This is because the data packets are served with high priority than the video packets. Figure 4 and Figure 5 illustrates the average delay for delivered packets for different WLAN offered data traffic (i.e., for 7 Mbps and 5 Mbps).

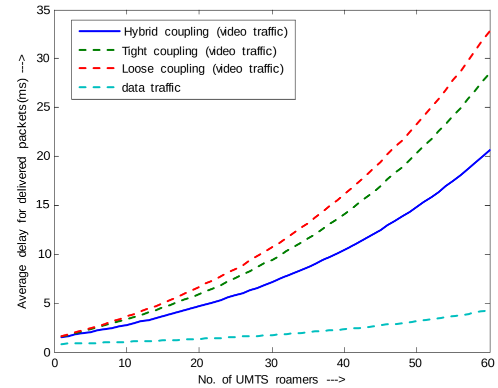

Figure 5. Average delay for delivered packets (L= 5 Mbps) vs. No. of UMTS roamers

It is also clear that the delay for data packets is less compared to video packets and also the delay for video packets in Hybrid coupling architecture is less compared to both loose coupling and tight coupling architectures.

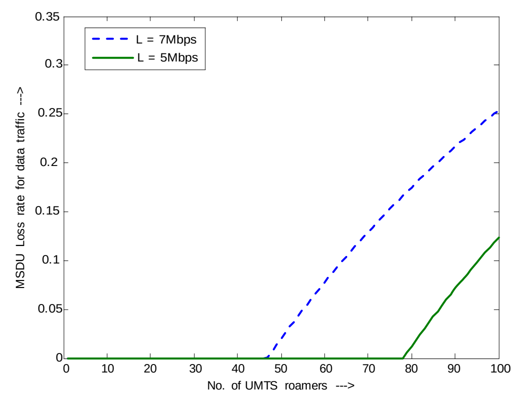

Figure 6. MSDU Loss rate for data traffic vs. No. of UMTS roamers

3.3 Priority to UMTS roamers

When UMTS roamers are given preferential access to the wireless medium, the loss rate experienced by video packets is almost negligible since the UMTS roamers are given preferential access to the wireless medium. Therefore, the limiting factor for the maximum number of UMTS roamers in the WLAN is not the loss rate of video streams but rather the bandwidth reservation constraints. In order to respect the WLAN data users, they are given a bandwidth threshold. So WLAN can accept UMTS roamers as long as the bandwidth reservation policy is respected.

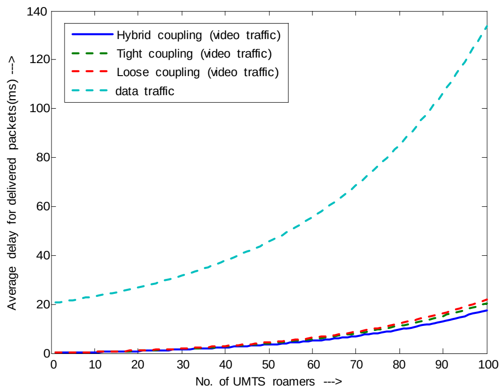

Figure 7. Average delay for delivered packets (L= 7 Mbps) vs. No. of UMTS roamers

Figure 6 illustrates that when the WLAN offered data traffic (L) is 7Mbps, the MSDU loss rate for data traffic is equal to zero up to 47 UMTS roamers. Up to this number, the capacity offered to the WLAN data users is indeed 7 Mbps and hence the bandwidth reservation policy is respected. But, when more than 47 UMTS roamers are admitted to the WLAN, the bandwidth reservation policy cannot be satisfied as the bandwidth utilized by WLAN data users is quickly diminished. So the maximum roamers that can be accepted to WLAN are 47.

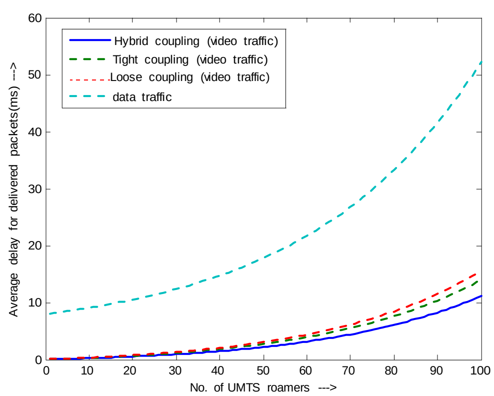

Figure 8. Average delay for delivered packets (L= 5 Mbps) vs. No. of UMTS roamers

When the WLAN offered data traffic is reduced (i.e., L = 5 Mbps), the number of UMTS roamers accepted increases to 78. This is because, when WLAN offered data traffic increases, more number of WLAN data users will be present in WLAN and thereby leaving less bandwidth for the acceptance of UMTS roamers. It is also clear that the number of UMTS roamers accepted is more for the channel access mechanism where the UMTS roamers are given preferential access to the channel. This is because the video packets are served with higher priority and thereby enhance acceptance of more UMTS roamers.

When UMTS roamers are given preferential access to the medium, the video packets are served with high priority. Therefore the delay for the delivery of video packets will be very much lesser than the delay negotiated in UMTS domain. Since Hybrid coupling enables dynamic distribution of traffic with the wireless link established between BS and WLAN in the same cell area, the delay for video packets will be much lesser than the delay for both tight coupling and loose coupling interworking architectures. So the data packets are served with less priority which results in increased delay for delivery. But the delay for data service is not an issue since data service requires reliability rather than delay for delivery. So the video packets will be delivered with less delay, when the UMTS roamers are given preferential access to the medium.

Figures 7 and 8 reveal that when UMTS roamers are given preferential access to the WLAN channel, the delay experienced by video packets is very small for all coupling schemes. So the advantage of this type of channel access is the acceptance of more number of UMTS roamers and decrease in the delay of video packets. But this gain is achieved at a cost in delay performance of WLAN data users.

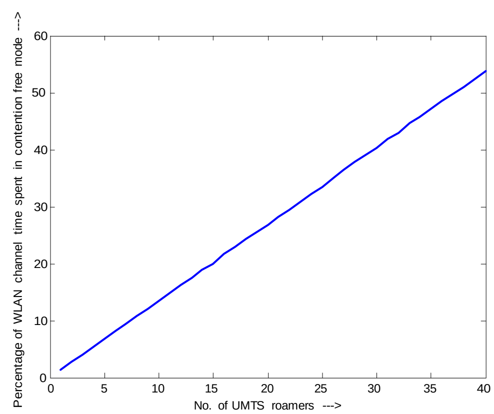

Figure 9. Percentage of WLAN channel time spent in contention free mode vs. No. of UMTS roamers

3.4 Contention Free Channel Access

In Contention free channel access, the UMTS roamers do not contend with the WLAN data users. The channel access is managed by the AP and occurs in a centric fashion. The Access point control the access to the wireless channel by assigning transmission opportunities (TXOPs) to requesting WLAN terminals. Since access to the channel is centrally controlled and there is no contention or collision and this mode is appropriate for providing parameterized QoS services. But the consequence is the poor channel utilization. This is because; the AP tries to respect the negotiated delay bounds and allocates more radio resources to a UMTS roamer than required.

When the WLAN offered data traffic is 7 Mbps, almost 35% of channel time can be spent in contention free mode. It can be revealed from the Figure 9 that when the number of UMTS roamers increases, the percentage of WLAN channel time spent in contention free mode increases linearly and for 35% of channel time, the number of UMTS roamers supported is 26 and is less compared to contention based channel access. This is due to the poor management of the channel by Access point and thereby leads to inefficient channel utilization. When the WLAN offered data traffic reduced to 5 Mbps, 37 UMTS roamers are accepted. This is because, when the WLAN offered data traffic is reduced, more channel time is available for UMTS roamers. The video packets are not lost because the AP tries to respect the negotiated delay bounds. Therefore, the QoS experienced by the UMTS roamers in this mode is affected only by the delay characteristics and not loss rate.

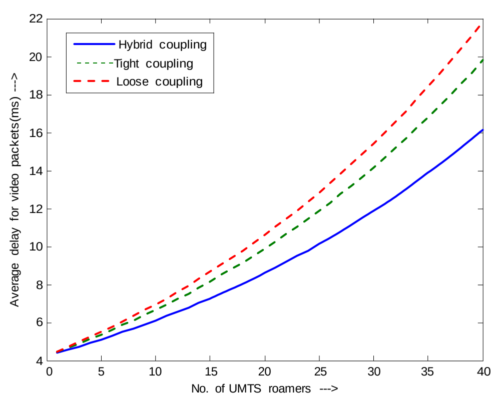

Figure 10. Average delay for video packets vs. No. of UMTS roamers

Figure 10 illustrates the average delay experienced by the delivered video packets and is below the delay bound negotiated in the UMTS domain (40 ms). The average delay experienced by video packets is less for Hybrid coupling. This is because of the dynamic distribution of traffic. It is interesting to note, that average delay for contention free channel access is larger than the corresponding delay in the contention-based channel access. This is due to the inefficient TXOP allocation of the AP and it makes a worst case estimation and allocates more channel time to the polling stations so as to accommodate the largest MSDU size.

4. CONCLUSION

The simulation results show that the number of UMTS roamers accepted to WLAN is more for contention based channel access than contention free channel access and the count is maximum for channel access mechanism when UMTS roamers are given preferential access to the medium. In contention free channel access, the resource utilization is poor because the AP provides more resources to the users than required. So this paves way towards the acceptance of less number of UMTS roamers. The average delay for video packets is also low in the channel access mechanism when UMTS roamers are given preferential access to the medium. This is because, when UMTS roamers are given priority to access the medium, the video packets are served with high priority and thereby require small delay for delivery. But the consequence is that, the delay for the delivery of data packets increases. The attained delay for data packets is accepted because data service requires reliability rather than delay. The proposed scheme suggests that WLAN can support seamless continuity of video sessions for only a limited number of UMTS subscribers, which depends on bandwidth reservations, WLAN access parameters, and the QoS requirements of video sessions. The results also depicts that the proposed scheme accept more roamers than tight coupling and loose coupling architectures. This is because, Hybrid coupling dynamically distributes traffic by the wireless link created between the base station in UMTS network and 802.11 WLAN within a same cell area.

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