Video Quality Guarantee for Mobile Users Across WLAN/3G Networks

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***Abstract*—The network-centric CAC schemes try to do resource reservation into networks for mobile connections, observing network status only. This approach can be appropriate for non-real time traffic, but for real-time applications, hasn't showed good results. In this paper, we introduce the PI-CAC, a user-centric L3 CAC scheme, based on user quality of experience for integrating WLAN and 3G networks, with the objective of guarantee the best video quality for users of these networks. Our CAC scheme works at network layer, considering that mobiles are multimode terminals, with L1 and L2 connections always actives. So, the mobile connection request is accepted in networks through brokers, located in network coverage area as multimode clients. These brokers are controlled by networks and use QoS informations received of the networks, at the same time that calculate the QoE of video requested by user. The performance of our solution was evaluated using a testbed implementation into a real scenario and the results were better when compared to solutions based on traditional approaches.**

***Index Terms*—QoS; Wireless; WLAN; 3G; Integration; CAC**

I. Introduction

In the past few years, the demand for high performance services for mobile 3G connections has increased exponentially. Although cellular networks can have high transmission rates, the cost for mounting or adapting the necessary infrastructure is very high. In contrast, WLAN infrastructure has been developed in various countries and offers data rates that are much higher than 3G networks at lower deployment and maintenance costs.

These two networks, therefore, complement each other and, if properly integrated, can provide the user with the appropriate conditions to access services, regardless of the access network being used.

The focus of this paper is to demonstrate the that network-centric CAC schemes based only on networks QoS parameters are not efective when video quality is involved. For this, we consider a scenario where there are WLAN and 3G overlay networks and the mobile is a multimode terminal, linked with both WLAN and 3G networks at layers 1 and 2.

The effectiveness of our proposal is demonstrated through experiments conducted in real environment with a WLAN network, over which we have total manage control, and a 3G network from a local carrier in Brazil, over which we have no manage control.

This paper is organized as follows: Section 2 shows a background about CAC schemes based on traditional approaches used for integrating WLAN/3G networks. Section 3 presents the main related works, discussing solutions for CAC problem in heterogeneous network integration. Section 4 presents our proposal, including details PI-CAC architecture and implementation. Section 5 details testbed and methodology used in the work. Session 6 presents the results and discussion about PI-CAC, comparing it to WLAN-First CAC scheme and Session 7 presents the conclusion of this work.

II. Background

Cellular networks are currently able to provide better mobility to their users without offering high bandwidth for data applications. In contrast, WLANs are known for their relatively high bandwidth but limited mobility. Ubiquitous data services and high data transmission rates across heterogeneous networks can be achieved by using WLAN as a complementary technology to cellular data networks. Today there is great need for efficient mechanisms to enable interworking between WLANs and cellular data networks [1].

However, to integrate WLAN and 3G, a major factor to consider is the network resource reservation. This reservation takes place in order to guarantee the necessary resources to a user during his connection with the network and the consequent use of services.

Thus, emerges as key main in this process, the schemes of Connection Admission Control (CAC). These schemes serves as mediators between the mobile and the networks in order to accept/reject a connection request, based on existing resources in the target network and the resources required for this new connection [2].

We note that the CAC schemes has always acted considering the physical (L1) and logical (L2) resource availability in networks, using QoS metrics to evaluate, statistically/probabilistically, if the network can or can not accept given connection. These tradicional CAC schemes have been adopted in integration architectures for heterogeneous networks in an attempt to ensure to the user a satisfactory level of QoS [3].

However, in video stream transmission, some problems are found. One problem is the treatment given by the network selection schemes adopted by some mobile devices that insist on making the handover always to the network with best signal quality. This can cause a serious problem in the user quality of experience at the reception of the video, since not always the network with best signal, will have better conditions for video delivery [4].

In addition, the network-centric CAC schemes observes metrics as throughput, jitter, delay and packet loss, which can often not be sufficient for that particular video connection can be accepted on the network [5].

In other words, the network-centric CAC schemes always operate under the vision of the network and not of the user. Our work seeks his relavância this point. We focus the PI-CAC in user experience on video reception, where the acceptance of mobile connection is done by network brokers. This network brokers analyze the connection requests of users and based in networks conditions, accept it. Is important remember that in our proposal, the CAC mechanism is located into network brokers, so, out core network. Moreover, the network brokers are fix multimode terminals working as networks clients, allowing the use of QoE video metrics for control of connections acceptance.

III. Related Works

The proposals of admission control found in the previous literature [6], [5], [7], [3], [2], [8], [4] treat their schemes as part of a QoS architecture by considering a scenario involving coupling between the networks. This reflects the need in such cases to include the proposed mechanisms in the core of existing networks, thereby increasing the complexity and cost of deploying the solution.

This is partly due to the fact these schemes help to control the network access, preventing new entries that would impact the quality of already admitted connections, and to prevent quality problems in new connections, considering that this schemes has access and control over the network. In addition, CAC schemes have been developed to ensure network access for users as well as access to network resources throughout the period of user activity on network.

This allocation serves to allow the CAC to decide whether to accept a new connection. Thus, information about the number of active connections, channels and available bandwidth are commonly used by CAC mechanisms, reinforcing the need of CAC scheme to be controlled by a network provider.

The CAC schemes have been used as mechanisms for accepting or rejecting connections from mobile devices on networks in handovers process, which in turn tends to block connection attempts and thus negatively impact the quality of services offered to mobile users. Moreover, in the particular case of WLAN and 3G overlay networks, it is common for multimode devices to perform the handover from 3G to WLAN, depending on which signal quality is better. In most cases, the WLAN signal is better than the 3G signal, causing the saturation of WLAN because signal quality is not always reflected in connection and service quality.

So, we propose in this work, an user-centric scheme for CAC, based in real network conditions, evaluated considering the vision of users, in order for garantee a good quality of user experience in video stream access. This propose is detailed in next session.

IV. Proposal

We propose an alternative form of CAC. The PI-CAC scheme is formed by Network Brokers (NBs) into of an architecture with Specialized Mobile IP (S-MIP) [9] as manager mobility in layer 3, Transport Control Protocol (TCP) as video transport protocol in layer 4, a Session Proxy (SP) [10] as cache video frames in layer 5 and a mobile portion for implement network selection, according with Figure 1.

The idea of the PI-CAC is to provide users with access to WLAN and 3G cellular networks under an alternative form of admission control based on video quality experience offered in network, using the NBs for mensure this quality based on PSNR metric.

To this end, NBs acts as multimode terminals of these networks, and, as customers, aiming to capture both QoE and QoS information without requiring changes in core of the network provider infrastructure.

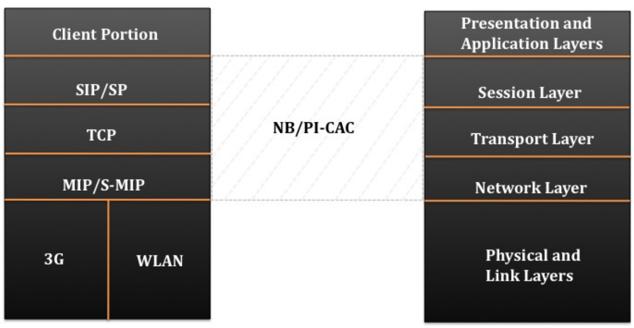

Figure 1. Proposal Architecture [9]

If NBs is controlled by network operator, its can receive this informations from network. Otherwise, the NBs can capture information on networks using an implementation based on unix sockets. To make this catch, NBs perform UDP requests for video servers indicated in connection request of mobile, in order to calculate the quality of video received using the QoE metrics PSNR and well-known QoS metrics (i.e., throughput, delay, loss and jitter).

This information is then used for decide if accept or reject video connection request of mobile. The advantage of having the reception quality information on each network according with user's viewpoint (considering the NBs as network users), is that we can effortlessly determine whether that network offers a good standard quality given the services offered during the period of observation and without changing the infrastructure of the networks involved.

The PI-CAC can often be used for help the network selection procedure of the mobile. The mobile, as multimode terminal, verifies continousaly the RSSI and packet loss rate of its interfaces and, according with nível defined in [10], tiggered SP cache and connection admission request to other network, with the objective of decide when to do soft handover proactively, using physical parameters, QoS network parameters and user experience parameters.

Although unusual, this approach is eficience, helping the integration between WLAN and 3G networks, while maintaining video session continuity after a handover. However, in the CAC scheme known as WLAN-first [2], the connection requests are primary directed to WLAN network due to the bandwidth values and costs involed in this network standard.

However, in our scenario where have overlay networks, without proper integration, the WLAN-first scheme has presented underperforms if compared with the PI-CAC. This happen because, in WLAN-First, all connections are routed to WLAN until its limit, while the others connections are sent to 3G network, considering physical limits only.

Our proposal is based on qualitative information, measures in the application and network layer by NBs that has the behaviour of users on the available networks, requiring video stream transmission services under a wireless network. NBs thus, measure the reception quality of services using QoE metrics (PSNR) and QoS (i.e., throughput, delay, loss and jitter).

The work of the architecture is showed in figure 2. We show the flow of procedures performed by mobile and PI-CAC modules, considering that SP and S-MIP modules was descripted in [10] and [9] respectively.

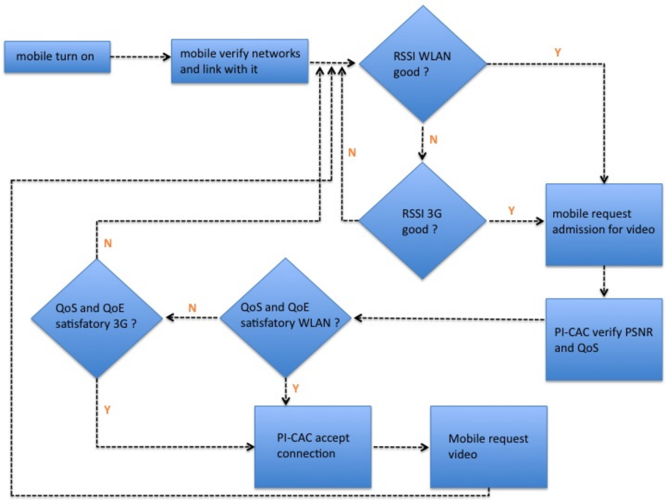

Figure 2. Procedure of Work Proposal

Firt, mobile turn on and verify all interfaces into device and active its, choosing WLAN interface as default. Second, the mobile verify RSSI of interfaces after request PI-CAC admission. Third, the mobile request PI-CAC admission to NB, informing the its features connections: requested video, througput, packet loss, delay, jitter and mainly the video PNSR. The NB of PI-CAC, then, verify if network can be serve the mobile using the one of two strategies: i) NB verify the QoS parameters and video QoE doing same video request done by mobile (in this case, the mobile operation is independent of the network operator); ii) NB receive the QoS parameters of network operator and verify the video QoE the same way as in i). Depending of the PSNR measured in WLAN of NB, the request video connection of mobile is accepted on WLAN network or rejected and forwarded to 3G network.

Note that if RSSI is good and PSNR bad in WLAN, the connection request is rejected by WLAN and forwarding to 3G, if PSNR in this network is good. If the PSNR in both WLAN and 3G networks is bad, the video request of mobile if rejected and needs to be done again.

The mobile portion of our architecture, work in conjunction with NB for perform soft handover between WLAN and 3G, according with the admission negotiation (in layer 3) into network. These procedures is showed in figure 3.

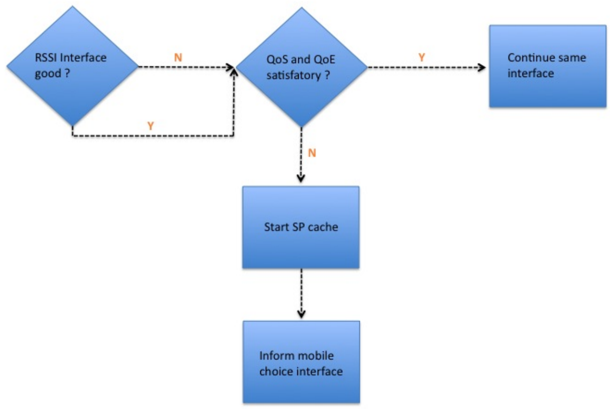

Figure 3. Procedure of Client Portion of our Proposal

V. Methodology

For conduce the experiments, we consider multimode mobile terminals containing two network interfaces (i.e., WLAN and 3G). In addition, an access point based on Linux was implemented to generate the WLAN coverage. The testbed used by this work is descripted in [9].

For experiments and comparison, we implemented the WLAN-first assuming a network saturation limit based on the maximum throughput expected for standard G WLAN (24 MB). The measurement of throughput was made according to the AP; once the number of connections reaches the limit, the AP does not accept any more connections.

We consider 250 connections requests of Marley YUV sequence with QCIF format, located into a video server in LabTVDI/UnB laboratory. We used the both WLAN-First and PI-CAC schemes. The experiments procedures was conduced with the mobile multimode terminal always connected in the two networks, with WLAN as active default network. After this, the procedures are detailed in figure 1.

VI. RESULTS

Observing the quality of connections accepted by the WLAN-first and PI-CAC schemes, we can observe the slight superiority of PI-CAC in the tables I II.

Type	ACW	ACWpsnrG	ACWpsnrL
WLAN-First	250	111	139
PI-CAC	143	143	0

Table I
COMPARATION WITH PI-CAC AND WLAN-FIRST IN WLAN ACCEPTED CONNECTIONS

Type	AC3G	AC3GpsnrG	AC3GpsnrL
WLAN-First	0	0	0
PI-CAC	107	107	0

Table II
COMPARATION WITH PI-CAC AND WLAN-FIRST IN 3G ACCEPTED CONNECTIONS

We can observe in table I, that ACW (number of connections accepted in WLAN network), is 250 and ACWpsnrG (number of connections accepted in WLAN when PSNR measured in this network was greater than PSNR measured in 3G network), is 111 and ACWpsnrL (number of connections accepted in WLAN when PSNR measured in this network was less than PSNR measured in 3G network) is 139, showing that WLAN-First consider RSSI only, accepting all time, the connection video request, without observe the quality of video delivery to user.

In other hand, the same information for PI-CAC show $ACW = 143$, $ACWpsnrG = 143$ and $ACWpsnrL = 0$. This fact is due the PI-CAC consider the PSNR offered in networks as mainly parameter for connection acceptance. In table II, we can see that AC3G (number of connection accepted in 3G network), is 107. This show that the connections not accepted in WLAN, was accepted in 3G, considering its PSNR value.

Thus, as WLAN-First continues to accept connections up to the limit set by the AP, even though the 3G network may offer better conditions of service, all requests connection was accepted in WLAN by WLAN-First, considering that the physical limit of WLAN not achieve.

Using the PI-CAC, we observe that when the quality of video, measured by NB in WLAN, begins to decrease compared with mobile connection requirements, the mobile connections are not accepted on network, indicating to mobile device that may migrate to the 3G network due it offers better quality of the video service required.

We can observe that CAC schemes in general consider network parameters, as verified at layers 1 and 2, and reflect network quantitative aspects only, thereby making the use of solutions dependent on the operator's decision. Thus, heterogeneous networks are controlled by the same operators, reducing the effectiveness of solution deployment.

A. Handover Decision

The handover decision for the client portion test was considered as a soft handover. If mobile connection is not accepted in a network, its request is forwarding to other network. If this new network has conditions for accept the mobile connection, the mobile is informed and changes active interface. In case where connections is accepted in a network (for example, WLAN) and video stream is in progress, mobile portion of our proposal continues receiving informations from NBs about PSNR measured in both networks. This, together with RSSI measured in mobile interfaces [10], help the mobile in handover decision.

Although QoS parameters (i.e., throughput, loss, delay and jitter) are available, our client implementation exclusively considers QoE (PSNR) information. Thus, the mobile handover decision is made based on the analysis presented in Table III.

Alfa	Beta	Gama
$RSSI > 40$	$RSSI \leq 40$ and $RSSI > 30$	$RSSI \leq 30$
$PSNR > 35$	$29 > PSNR > 26$	$PSNR < 18$

Table III
PARAMETERS FOR HANDOVER DECISION

Accordingly, the mobile device can verify the level at which a handover should occur; when it reaches this BETA level [10], it informs the SP to begin frame cache.

When the mobile device reaches the GAMA level [10], a handover to another network with a better level occurs. In the experiments, all handovers were made to network with better conditions with respect to RSSI and PSNR, as is exemplified in Table IV.

RSSI WLAN	RSSI 3G	PSNR WLAN	PSNR WLAN 3G	VHO Wlan->3G
42	36	24	16	no
34	29	21	13	no
44	32	13	19	yes
33	37	22	12	no

Table IV
HANDOVER DECISION

Note that that in the first case, the mobile device decides not to implement a handover because RSSI of WLAN is 42, RSSI of 3G is 36 and PSNR of WLAN is greater than of 3G, according with mobile portion and NB informations.

In the second case, RSSI of WLAN=45, RSSI of 3G is 29 and PSNR WLAN is 21, while PSNR 3G is 13, reforcing the mobile decision of not perform handover. In other hand, in third case collected in experiments and showed in IV, the RSSI of WLAN is 44, RSSI of 3G is 32, but the PSNR of 3G (19) is greater than the PSNR of WLAN (13), informing the mobile that handover need be performed to 3G network because its PSNR is better. This fact shows that for our proposal, the choice based on PSNR as the base handover parameter was correct.

B. Video Quality Impacts

Using the PI-CAC, a significative improvement in the video quality after vertical handovers was verified, considering objectives metrics of video quality.

Due to the characteristics of WLAN-Firt scheme, the request conections are accepted to WLAN while the fisical limit is not achieve. Thus, the quality of video received is damaged due to traffic generated in WLAN.

Furthermore, with the PI-CAC, the quality of received video is the main parameter for the mobile acceptance (or not) of remains in that the network, although it has been accepted. The figures 4 and 5 show this difference.

Figure 4. Quality of Received Video in WLAN-Firt Scheme

Figure 5. Quality of Received Video in PI-CAC Scheme

VII. Conclusions and Future Works

The use of a PI-CAC mechanism based on user-centric network-checking, can help mobile devices to choose a network, thereby reducing the effects caused by CAC mechanisms only based on level 2 measures [5].

Our work develops the concept as well as presents the implementation of a new pro-active and user-centric CAC scheme that accept video request connections from mobile, based in quality of video possible in networks. In addition, the PI-CAC even help mobile in soft handover decision, toward select a better network based on the PSNR of transmitted videos in a network.

Our solution does not require any additional developments by 3G operators. As such, it is a free-of-charge option for additional transmission services and continuous video streaming.

As a continuation of this present, we are currently developing tests using our PI-CAC mechanism, with the objective of comparing it with JCAC and other probabilistic CAC mechanisms. We hope to develop an analytical model to validate the PI-CAC.

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References

[1] K. Munasinghe and A. Jamalipour, "Interworking of WLAN-UMTS networks: an IMS-based platform for session mobility," *IEEE Communications Magazine*, vol. 46, no. 9, pp. 184–191, 2008.

[2] W. Song, H. Jiang, and W. Zhuang, "Performance analysis of the WLAN-first scheme in cellular/WLAN interworking," *IEEE Transactions on Wireless Communications*, vol. 6, no. 5, pp. 1932–1952, 2007.

[3] W. Song, W. Zhuang, and Y. Cheng, "Load balancing for cellular/WLAN integrated networks," *IEEE Network*, vol. 21, no. 1, pp. 27–33, 2007.

[4] C. de Castro Monteiro and P. de Lira Gondim, "Improving video quality in 802.11 networks," in *Proceedings of the 28th IEEE international conference on Computer Communications Workshops*. IEEE Press, 2009, pp. 188–193.

[5] S. Lee, K. Kim, K. Hong, D. Griffith, Y. Kim, and N. Golmie, "A probabilistic call admission control algorithm for WLAN in heterogeneous wireless environment," *IEEE Transactions on Wireless Communications*, vol. 8, no. 4, p. 1673, 2009.

[6] J. Fernandez, T. Taleb, M. Guizani, and N. Kato, "Bandwidth aggregation-aware dynamic QoS negotiation for real-time video streaming in next-generation wireless networks," *IEEE Transactions on Multimedia*, vol. 11, no. 6, pp. 1082–1093, 2009.

[7] W. Song, H. Jiang, W. Zhuang, and X. Shen, "Resource management for QoS support in cellular/WLAN interworking," *IEEE network*, vol. 19, no. 5, pp. 12–18, 2005.

[8] Q. Song and A. Jamalipour, "A quality of service negotiation-based vertical handoff decision scheme in heterogeneous wireless systems," *European Journal of Operational Research*, vol. 191, no. 3, pp. 1059–1074, 2008.

[9] M. Claudio de Castro and G. Paulo Roberto de Lira, "An Alternative QoS Architecture for Integrating WLAN/3G Networks," *The Sixth International Conference on Wireless and Mobile Communications*, vol. 2010, 2010.

[10] M. Claudio de Castro, G. Paulo Roberto de Lira *et al.*, "Seamless Video Session Handoff between WLANs," *Journal of Computer Systems, Networks, and Communications*, vol. 2010, 2010.