CHALLENGES IN CROSS LAYER ADAPTATION FOR MULTIMEDIA TRANSMISSION

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ABSTRACT

Over the last years a number of new protocols have been developed for multimedia applications in the whole OSI layer's scale. In order to support better wireless user the cross layer design paradigm has been proposed. This paper presents the challenges in design and implementation of cross layer adaptation schemes for multimedia transmission over wired and wireless networks. In addition, the paper proposes the basic aspects of a cross-layer adaptation framework for multimedia transmission over wired and wireless networks. The main concept is based on a "holistic approach" in which all layers participate to the adaptation process and make its own contributions. Finally, the proposed framework can support both wired and wireless receivers in one platform.

KEYWORDS

Cross layer adaptation, Multimedia transmission, Wireless and Mobile Networking

1. INTRODUCTION

Multimedia data transmission experience a number of constrains that result to low Quality of Service (QoS) that is offered to the end user. These constrains have mainly to do with the nature of multimedia applications, which are characterized by three main properties: the demand for high data transmission rate (bandwidth-consuming applications), the sensitiveness to packet delays (latency and jitter) and the tolerance to packet losses (packet-loss tolerant applications), when compared to other kind of applications. The above properties introduce new design challenges to the networking world as it is in fact difficult to combine guaranteed high bit rates and an acceptable packet loss ratio with low latency and jitter. In wireless networks multimedia data transmission inherits also all the characteristics and constrains related to the propagation to the free space. All the above factors have led both the research community and the industry to develop and propose a number of new protocols and optimization techniques targeting at mitigating delay and packet loss ratio during the transmission of multimedia data. Most of these efforts are based on the classic layered approach in which the various layers try to optimize its performance by adapting its behavior to constantly varying network parameters and provide its best services to upper layers. Under this layered approach, communication occurs between two adjacent layers without taking, however, into consideration the specific characteristics of multimedia applications. Although this layered approach has been the fundamental factor for the growth of the wired networks and the World Wide Web (WWW) it seems to pose serious constrains when attempting to adapt protocol's behavior to multimedia applications characteristics and to wireless network conditions.

Under the OSI model all protocols that function in the various layers communicate only with other protocols that belong to the same layer, while ignoring the existence of other protocols that function in different layers. When, however, looking at the OSI model from a different angle and from some distance we can vision it as a system. In an organized system the various system elements should develop a high level of cooperation through knowledge sharing so that the system as a whole can perform its tasks in a more effective and efficient way. Therefore, we could increase any system's performance if we developed such mechanisms that could increase the level of cooperation and communication amongst the various elements. Here is where the whole concept of cross-layer adaptation is encapsulated; to design those mechanisms without altering the layered model.

This paper presents the challenges in design and implementation of cross layer adaptation schemes for multimedia transmission over wired and wireless networks. In addition, this paper proposes the basic aspects of a cross-layer adaptation framework for multimedia transmission over wired and wireless networks. The main concept is based on a "holistic approach" in which all layers participate to the adaptation process and make its own contributions. Moreover, the proposed framework can support both wired and wireless receivers in one platform. We strongly believe that any cross-layer adaptation effort is incomplete when only some of the layers take part in the adaptation process because all layers belong to the same system. However, further research will guide us to the most appropriate adaptation scheme, as many factors, which are involved, have to be investigated and evaluated through deeper studies and evaluation.

2. RELATED WORK

Over the last years a number of new protocols have been developed for multimedia applications in the whole OSI layer's scale. The family of MPEG protocols, which have been standardized, have been designed for encoding and compression of multimedia data. The MPEG-4 protocol with the latest enhancement of the FGS (Fine Granularity Scalability) (Li, 2001) provides adaptive video coding by taking into account the available bandwidth and is expected to be used by many multimedia applications.

Apart from the above developments in the protocol and the architectural fields there have been a number of proposals for improving QoS in multimedia applications through cross layer adaptation strategies. In Van der Schaar, 2005 the need of a cross-layer optimization is examined and an adaptation framework is proposed amongst the APP, the MAC and the Physical (PHY) layers.

In Shakkottai, 2003 the issue of cross-layer design in wireless networks is addressed. The focus is on the way that higher layers share knowledge of the PHY and MAC layers conditions in order to provide efficient methods to allocate network resources over the Internet.

In Van der Schaar, 2003 a joined APP and MAC adaptation scheme is proposed with the use of MPEG-4 and the latest Fine Granularity Scalability (FGS) extension. In this work, packets containing multimedia data are classified into different classes and in the light of poor network conditions only packets with high value are transmitted. The network conditions are jointly measured by combining the information obtained by the retransmission number of a lost MAC frames (ARQ) and the information provided by the RTCP protocol. This work is a good example of quality optimization through the cross-layered adaptation concept, although adaptation at the PHY layer is avoided for simplicity.

Signaling issues between the layers for cross-layer optimization over wireless networks are examined in Wang, 2003. The authors propose a new signaling framework in which signaling can be done between two non-neighboring layers, through light-weighted messages and the use of a message control mechanism to avoid message dissemination overflow. Although this proposal avoids heavy ICMP messages for out-bound signaling between the layers that is proposed in Sudame, 2001, it introduces very high complexity.

In Chen, 2004 a joined adaptation scheme of the APP, MAC and PHY layers is presented. Packet transmission is made with a novel-scheduling algorithm at the MAC layer whose function is based on the user and application priority levels. Priorities are assigned to users on the basis of paid services, in which users are classified into groups with different QoS levels. The MAC layer selects the appropriate combination of transmission power and modulation type of the packets for each user based on the present channel conditions and the QoS level that is associated to the user.

Finally, Carneiro, 2004 outlines the need for new cross-layer architecture to address known problems of mobility, packet losses and delay that are observed in wireless networks. The main idea of a cross-layer manager is discussed in which all layers send notification messages to the manager who is responsible for intra layer co-ordination. Therefore, the various layers adopt their behavior to current network conditions, including required QoS of a specific application, mobility, security and finally channel interference. This reference endorses our concept for a "holistic" participation of all layers in a cross-layer design.

3. PROPOSED FRAMEWORK

In this section we describe the proposed framework for cross-layer adaptation. Figure 1 presents the usage scenario of the proposed framework. The proposed framework consists of four entities: The sender which represents the multimedia server, the proxy which is located at the edge of the wired network, the AP which co-located with the proxy and can be integrated with the proxy and finally the wired and wireless receivers.
This proposed framework separates the wired from the wireless part of the network by introducing a new entity named "proxy" between the sender and the receiver. The sender transmits multimedia data to the wired receivers and the proxy by using the wired part of the network and the proxy is responsible to transmit the multimedia data received by the sender to the wireless receivers. The transmission in the wired part can benefit either by QoS features (IntServ / DiffServ (Blake, 1998)) of the network (if the network domains involved in the multimedia transmission offer QoS) or by congestion control mechanisms that are especially designed for multimedia data transmission in wired networks (Handley, 2003). For the transmission of multimedia data in the wired network multicast is used. The Proxy entity is responsible to collect wireless users requirements and send them to the sender in order to perform the cross layer adaptation.

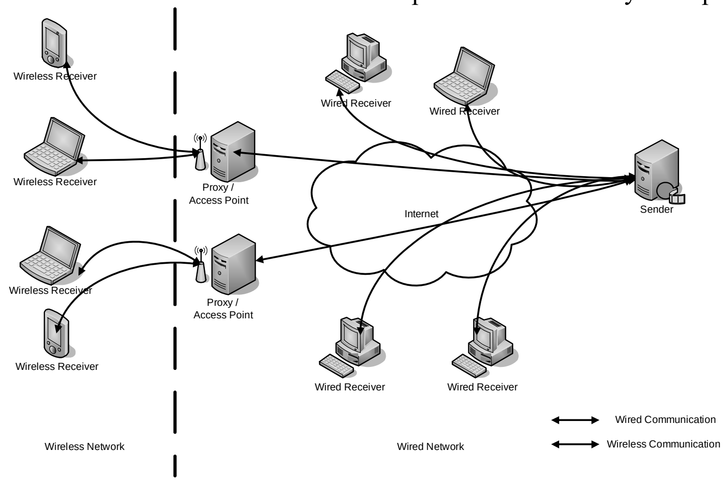

Figure 1.Usage scenario of the proposed framework

This approach is more efficient than any other mentioned in the literature in which cross layer adaptation is realized only in the wireless portion of the network for the following reasons: Firstly, the cause of packet losses is different in wired and wireless networks and therefore different error and congestion control mechanisms are needed accordingly. Secondly, in the wired portion existing adaptation and optimization mechanisms (extensively tested and evaluated during the last years) can be applied along with new protocols that have been especially designed for multimedia data transmission in wired networks. Thirdly, this architecture minimizes the distance in terms of the number of hops between the multimedia source and the wireless receiver. To explain this let us consider the situation in which the wireless receiver detects the loss of an RTP packet in the RTP stream. The wireless receiver will attempt to retrieve the lost RTP packet from the sender. However, time constrains of the multimedia application (e.g. real time video transmission) make the retransmission of the lost RTP packet from the sender untimely in a multi-hop network such as the Internet. With the use of the proxy and depending of its buffer size the retransmission of the lost RTP packet from the proxy instead of the sender can meet the time constrains of the application as the distance between the proxy and the wireless receiver is only one hop. To conclude the above arguments for the usefulness of the proxy in the proposed framework let us recall the services provided by the Content Distribution Networks (CDNs). The CDNs were introduced to bring closer the multimedia data to the users, as they are located at the edge of the Internet. With the use of the proxy we can emulate, in some way, the services provided by the (CDNs).

Figure 2 shows the block diagram of our proposed framework.

The sender of the proposed framework consists of the following modules:

- *Video Source:* Video source consists of a set of hard disks in which the video files are stored. The sender application supports the MPEG video format.
- *Feedback analysis / layer encoding:* This module is responsible for the analysis of feedback information from the proxy and the other wired receivers. The role of this module is to determine the network condition both in wired and wireless networks based on the received feedback reports. After the examination of network condition, the feedback analysis module informs the layer encoding module in order to fine-tune the MPEG layered encoding.
- *Congestion Control:* It is responsible for the congestion control during the transmission of the multimedia data in the wired part of the network. This module is based on a TCP friendly transmission mechanism for multimedia data.
- *Sender buffer:* This module is responsible for the encapsulation of multimedia information in the RTP packets. In addition, this module is responsible for the transmission of the RTP packets in the network. In order to smooth accidental problems to the transmission of the multimedia data from the sender to the network; we use an output buffer on the sender.

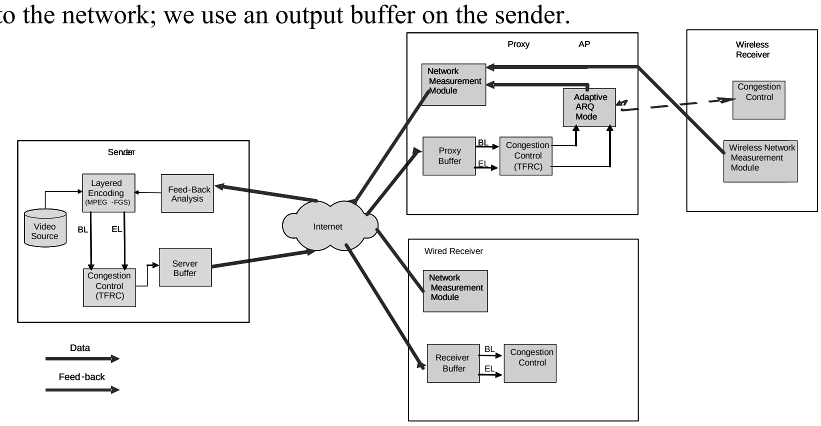

Figure 2. Block diagram of the proposed framework

The wired receiver entity of the proposed framework consists of the following modules:

- *Network Measurement:* This module is responsible of monitoring the transmission quality of the data and informs the sender. The monitoring of the transmission quality is based on RTCP receiver reports that the receiver sends to the sender. With the above information the feedback analysis module of the sender determines the network's condition.
- *Congestion Control:* It is responsible for the congestion control during the transmission of the multimedia data in the wired part of the network. This module is based on a TCP friendly transmission mechanism for multimedia data.
- *Receiver buffer:* The use of the buffer on the receiver for the implementation of streaming applications is very important. The receiver stores the incoming data to the buffer before starting presenting the data to the user. The presentation of the multimedia data to the user starts only after the necessary amount of the data is stored in the buffer.

The proxy / access point entity of the proposed framework consists of the following modules:

- *Network Measurement:* This module is responsible of monitoring the transmission quality of the data and informs the sender. The Proxy entity monitors both the wired part of the network (as the other wired receivers) and the wireless part of the network. The monitoring of the transmission quality is based on RTCP receiver reports that the client sends to the sender. The Proxy entity is using the APP

RTCP packets in order to transmit feedback information regarding the wireless part of the network to the Sender. With the above information the feedback analysis module of the sender determines the network's condition.

- *Congestion Control:* It is responsible for the congestion control during the transmission of the multimedia data in the wired part of the network. This module is based on a TCP friendly transmission mechanism for multimedia data.
- *Adaptive ARQ:* This module is responsible for the selected retransmission of the missing or corrupted MAC frames in the wireless part of the network.
- *Proxy buffer:* Same operations like the wired receiver buffer.

The wireless receiver entity of the proposed framework consists of the following modules:

- *Wireless Network Measurement:* This module is responsible of monitoring the transmission quality of the data in the wireless part of the network and informs the Proxy.
- *Congestion Control:* It is responsible for the congestion control during the transmission of the multimedia data in the wireless part of the network.

4. CONCLUSION / FUTURE WORK

This paper presents the challenges in designing and implementing cross layer adaptation schemes for multimedia transmission over wired and wireless networks. In addition, this paper proposes the basic aspects of a cross-layer adaptation framework for multimedia transmission over wired and wireless networks. The main concept is based on a “holistic approach” in which all layers participate to the adaptation process and make its own contributions. Moreover, the proposed framework can support both wired and wireless receivers in one platform. Our future work includes the detail investigation of all the aspects of the proposed framework and the evaluation of the proposed framework through a number of simulations. Main target of the simulations will be the examination of the proposed framework behavior to a heterogeneous group of wired and wireless receivers.

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