Inter Layer Communication in Wireless Sensor Network

Ramesh M.Badiger., S.V.Niranjana Murthy

Abstract— In the last few years, the Internet throughput, usage and reliability have increased almost exponentially. The introduction of broadband wireless mobile ad hoc networks (MANETs) and cellular networks together with increased computational power have opened the door for a new breed of applications to be created, namely real-time multimedia applications. Delivering real-time multimedia traffic over a complex network like the Internet is a particularly challenging task since these applications have strict quality-of-service (QoS) requirements on bandwidth, delay, and delay jitter. Traditional IP-based best effort service will not be able to meet these stringent requirements. The time-varying nature of wireless channels and resource constrained wireless devices make the problem even more difficult. To improve perceived media quality by end users over wireless Internet, QoS supports can be addressed in different layers, including application layer, transport layer and link layer. Cross layer design is a well-known approach to achieve this adaptation. In cross-layer design, the challenges from the physical wireless medium and the QoS-demands from the applications are taken into account so that the rate, power, and coding at the physical layer can adapted to meet the requirements of the applications given the current channel and network conditions. A number of propositions for cross-layer designs exist in the literature. In this paper, an extensive review has been made on these cross-layer architectures that combine the application-layer, transport layer and the link layer controls.

Keywords— *Content Aware Networks , Cross-Layer Design, A Cross-Layer Scheduling Algorithm, Cross Layer Adoption Layers, Quality Of Service (Qos).*

1 INTRODUCTION

In this evolving environment, new transport protocols, new multimedia encoding schemes, cross-layer and in-network adaptation, machine-to-machine communication, rich 3D content as well as community networks and the use of peer-to-peer (P2P) overlays are expected to generate new models of interaction and cooperation. Furthermore, this will enable the support of enhanced Perceived Quality of Service (PQoS) and innovative applications "on the move", like In this context, the interaction with content combined with interactive/multimedia search capabilities across distributed repositories, opportunistic P2P networks and the dynamic adaptation to the characteristics of diverse mobile terminals are expected to contribute towards such a vision.

2 Content-aware Access Network Architecture

Even in the near future, the access network (even the evolved one) will remain the weaker part of the network. Moreover, in Peer-to-Peer (P2P) networks the end-to-end path may be unknown or time variant. Thus, it is desirable to have as much information and adaptation at the lower layers (up to the network layer) as possible, along with scalability functionality coming with the media codecs. Certain functions such as content caching in the network, content adaptation and cross-layer optimization would certainly need knowledge of the network conditions and characteristics.

In order to overcome this problem, wherever applicable in the network architecture, we introduce intelligent media/network-aware nodes. In general content-aware MANEs can offer multimedia storage, dynamic content adaptation and enriched PQoS by dynamically combining multiple multimedia content layers from various sources. Moreover, as they have knowledge of the underlying networks, this information on the network conditions/characteristics can be provided to and utilized by cross-layer control mechanisms and adapt the multimedia streams to the next network in the delivery path. This is an extremely important point for low bandwidth but with guaranteed QoS mobile networks as well as for the broadband but best effort P2P topologies.

Introducing the content-aware nodes at the edges of the networks also enables us to realize a Peer-to-Peer (P2P) overlay topology as shown in Figure 1. Given content protection and management is in place, network operators and service providers may offer value-added streaming services with remarkable PQoS.

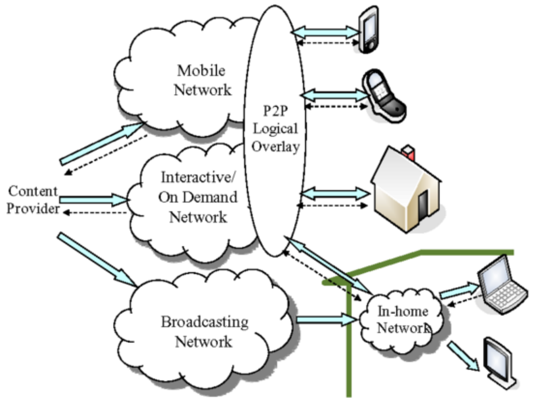

Figure 1: The Concept Of P2P Overlay Architecture

Moreover, individuals may produce their own (real-time) content and make it publicly available to a larger audience, without having to rely on a specific, expensive networking infrastructure. In this environment, video streaming scalability, resilience and PQoS may be increased, as multiple sources may stream video segments, enriching the content on the fly, either at the network and/or at the end-user terminal.

3 Cross-Layer Design and Architecture

In this section, some of the cross layer design frameworks and algorithms currently existing in the literature are described in brief. Salient features of some of these schemes are presented highlighting their contributions and areas of applications.

3.1 A Cross-Layer QoS Support Architecture for Multimedia over Wireless Networks

Figure 2 depicts the architecture, where the multimedia server, base station (BS) (gateway) with media proxy, and heterogeneous mobile clients are deployed. Application-layer, transport-layer, and link-layer control mechanisms are all taken into account and suitably placed into this generic architecture, to achieve a good end-to-end quality of multimedia services. In Figure 3, the application is transmitted via TCP or UDP in the Internet part based on the traffic characteristics. IP packets arriving in the downlink to the UMTS network are transported to the radio network controller (RNC). Appropriate header compression techniques are applied to the packets in the packet data convergence protocol (PDCP) layer of the UMTS stack. The compression technique in the PDCP layer can vary depending on the implementation.

The PDCP layer compresses the packets and attaches a header and further forwards them. It uses the service provided by a lower layer called radio link control (RLC) layer. The RLC layer is employed to support reliable upper layer protocols such as transmission control protocol (TCP). RLC uses sophisticated retransmission schemes. To perform partial error recovery at the link layer, thus hiding transmission errors from upper layers and reducing the chances of performance degradation of upper layer protocols.

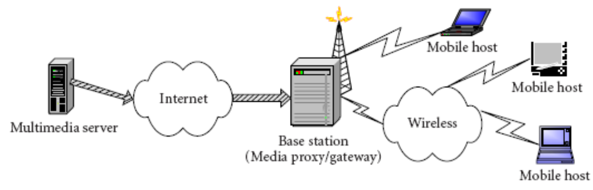

Figure 2: A General Architecture For Multimedia Delivery Over Wireless Internet.

The RLC protocol data units (PDU) of a particular IP connection are served by the MAC layer. In deterministic transmission time intervals (TTIs), the MAC layer entities ask the corresponding RLC layer entities for a certain number of RLC PDUs, which are then transferred through the radio interface in MAC frames. TTI refers to the length of an independently decodable transmission on the radio link. It is related to the size of the data blocks passed from the higher network layers to the radio link layer. In order to be able to adapt quickly to changing conditions in the radio link, shorter TTIs are preferable. However, in order to benefit more from the effect of interleaving and to increase the efficiency of error-correction and compression techniques, a system must have longer TTIs. Thus determination of TTI value is an optimization problem.

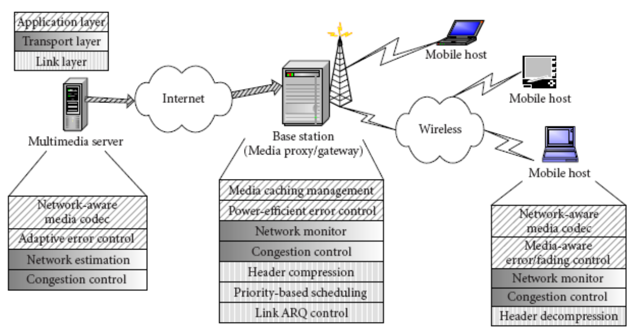

Figure 3. A Cross-Layer Architecture for Multimedia Delivery Over Wireless Internet.

3.2 A Cross-Layer Scheduling Algorithm

A priority function (PRF) is defined for each connection admitted in the system. This priority function is updated dynamically depending on the wireless channel quality, QoS satisfaction, and services across all layers. The connection with highest priority is scheduled each time. Each connection is assigned a priority, which is updated dynamically based on its channel and service status. The connection with the highest priority is scheduled each time. At the MAC layer, each connection belongs to a single service class and is associated with a set of QoS parameters that quantify its characteristics. Following IEEE 802.16 standard, four QoS classes are provided: (i) unsolicited grant services (UGS), (ii) real-time polling service, (iii) non real-time polling service and (iv) Best effort service.

The unsolicited grant service supports constant bit rate (CBR) and fixed throughput connections and provides guarantees on latency, and jitter. Real-time polling service provides guarantees on throughput and latency but with more tolerance on latency as compared to unsolicited grant service. Non-real time polling service provides guarantees in terms of throughput only and is suitable for data applications, such as FTP.

Figure 4: Network topology

Best effort service provides no guarantee on delay or throughput and is used for HTTP and email applications. The designed scheduler has the following features:

- Efficient bandwidth utilization is achieved so that the scheduler does not assign a time slot to the connection with bad channel quality and multiuser diversity can be exploited.
- Delay bound is provided for applications that are based on real-time polling service.
- Throughput is guaranteed for non real-time polling service connections if sufficient bandwidth is available.
- Implementation complexity is low because the priority-based scheduler simply updates the priority of each connection per frame and allocates maximum time slots to the connection with the highest priority.
- The scheduler is flexible as it does not depend on any traffic or channel model. Scalability is achieved.

4 Adaptations at Different Layers of the Protocol Stack

Different types of adaptations are required at different layers of the standard protocol stack for providing a robust QoS support to multimedia applications over wireless networks. In Section 1, it has already been seen that wireless channels pose a number of challenges in this aspect. Considering the limitation of bandwidth in wireless systems, the most important target at the link layer is to increase link utilization. It is known that RTP/UDP/IP and TCP/IP have the problem of large header overhead on bandwidth-limited links. Header compression has been proven to be efficient for using those protocols. To handle the severe bandwidth and delay fluctuation in wireless Internet, available network condition estimation and congestion control are key issues needed to be addressed in the transport layer.

4.1 Link Layer Adaptation Mechanisms

There are several currently existing approaches for link layer adaptation under varying wireless channel conditions. The important ones in this category are: (i) application adaptive ARQ, (ii) priority-based scheduling, (iii) channel-aware scheduling. These are described in detail in the following.

Application Adaptive ARQ: To overcome packet loss, a technique called Automatic Repeat Request (ARQ) is used for packet retransmissions. ARQ uses acknowledgments and timeouts to achieve reliable data transmission. The receiver sends an acknowledgement (ACK) to the transmitter to indicate that it has correctly received a data frame or packet. The sender waits for a predefined period (timeout) for the ACK to arrive. If ACK arrives then the sender sends the next packet. Otherwise, it resends the earlier packet until it receives an ACK or exceeds a predefined number of retransmissions. ARQ can be implemented at the application/transport layer as well as the link-layer. Link-layer ARQ is more effective than application/transport layer ARQ because – (i) it has a shorter control loop and hence can recover lost data more quickly, (ii) it operates on frames that are much smaller than the IP datagram and (iii) it might be able to use local knowledge that is not available to end hosts, to optimize delivery performance for the current link conditions. This information can include information about the state of the link and channel, e.g., knowledge of the current available transmission rate, the prevailing error environment, or available transmit power in wireless links.

Priority-based Scheduling: In priority-based schedulers, packets are grouped into several classes with different priority according to their QoS requirements i.e. the MAC layer is made aware of the application layer QoS. Packets belonging to higher priority classes are more likely to be transmitted first. Packets in the same class are served in a FIFO manner. Based upon the priority scheduling mechanism, each QoS class will have some sort of statistical QoS guarantees.

Channel-aware Scheduling: In a multiple access wireless network, the radio channel is normally characterized by time-varying fading. To exploit the time-varying characteristic, a kind of channel-state dependent scheduling, called multiuser diversity, can be exploited to improve system performance .For a wireless communication system with multiple MSs having independent time-varying fading channels, we can assume that the channels are either ON i.e. one packet can be transmitted successfully to the mobile user during the time-slot or OFF i.e. unsuitable for transmission. The scheduler at the BS MAC layer gets the channel state information from its PHY layer. The scheduler at the BS transmits to a user whose channel is in the ON state. In case more than one user channel is in ON state, the scheduler selects a user channel randomly. No data is sent by the BS when all the channels are OFF. For a 3-user case, all the channels will be in OFF state only for 1/8 of the time on average. Thus, total data rate achieved by the scheduler is (1-1/8) = 7/8 packets per slot. Hence average data rate per user is (7/8)/3 = 7/24 packets/slot. For round-robin scheduling with 3 users, each user will get 1/3 slot time. Since the user channels are equally likely to be ON or OFF in each timeslot, each user will get a data rate of (1/3)/2 = 1/6 packets/slot which is almost half that of the channel-aware multi-user diversity scheduler. Thus, overall resource utilization can be improved by using channel-aware scheduling mechanism.

4.2 Transport Layer Adaptation Mechanisms

The wireless medium is very dynamic in nature due to the motion of the wireless devices, interference or fading. This fast changing, small-scale channel variations result in burst error at the receiver. In addition, there's a large-scale channel variation where the average channel state condition depends on users' In order to deliver multimedia over wireless networks, it's necessary to estimate the condition of the underlying network so that the strict QoS constraints for multimedia applications can be adhered to. Congestion may occur within a network when routers are overloaded with traffic which in turn causes their queues to build up and eventually overflow, leading to high delays and packet losses. Network conditions can be assessed mainly through congestion estimation based on - packet loss and current available bandwidth.

4.3 Application Layer Adaptation Mechanisms

Due to real-time nature, multimedia services typically require QoS guarantees like large bandwidth, stringent delay bound and relatively error-free video/audio/speech quality. Multimedia services over the wireless channels become very challenging due to the dynamic uncertain nature of the channel resulting in variable available bandwidths and random packet losses. The main objectives of the application layer QoS control for multimedia communication over wireless networks are –(i) to avoid bursty losses and excessive delay (caused by network congestion) that have a devastating effect on multimedia presentation quality, and (ii) to maximize multimedia quality even when packet loss occurs in a wireless communication network. There have been a number of approaches currently existing in the literature in this regard. First, two important cross-layer approaches e.g., Joint Design of Source Rate Control and QoS-aware Congestion Control and Joint Design of Source Coding and Link Layer FEC/ Retransmission are described. Some other propositions are also described later.

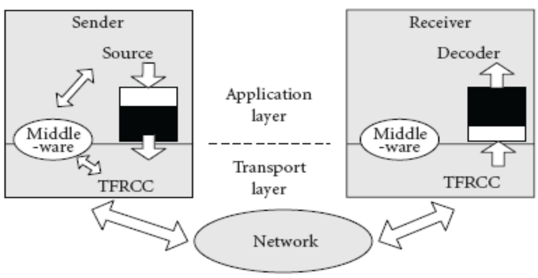

Figure 5: The System Architecture for Source Rate Control And Congestion Control

5 CONCLUSION

Cross-layer adaptations are essential for guaranteeing QoS supports in real-time multimedia traffic over wireless networks. In this paper, various adaptation mechanisms at the application layer, transport layer and link layer are discussed based on the currently existing propositions in the literature. More specifically, network-aware adaptive media source coding, dynamic estimation of the varying channel, adaptive and energy-efficient application and link-level error control, efficient congestion control, adaptive ARQ and priority-based scheduling are explicitly reviewed. However, cross-layer design is an extremely challenging task and lots of other issues need to be taken into consideration for an efficient design. QoS support in a multicast media streaming is one such area which requires attention. Mobility of the users will bring in another dimension of complexity which will call for an efficient handling of the problem related to handoff while guaranteeing the application QoS. In mobile ad hoc networks (MANETs), changes in the topology of the network graph and the interference due to simultaneous communications will pose serious challenges too. Multi-path media streaming and QoS-aware MAC design are two cross-layer design approaches proposed in the literature for providing QoS support in MANETs. However, any cross layer design should take a cautious and careful approach as some adverse impact on the system performance can occur in certain situations due to cross layer interactions. Unbridled and extensive cross layer interactions can lead to a complex spaghetti design and thwart further innovations. Also such design will lack standardization and compatibility and portability features. This calls for a careful impact analysis and design of the cross layer protocol stack.

REFERENCES

[1] H. Jiang, W. Zhuang and X. Shen, "Cross-layer design for resource allocation in 3G wireless networks and beyond", *IEEE Communications Magazine*, Vol 43, No 12, December 2005, pp. 120-126.

[2] W. Kumwilaisak, Y. Thomas Hou, Q. Zhang, W. Zhu, C.-C. Jay Kuo, Ya-Qin Zhang, "A cross-layer qualityof-service mapping architecture for video delivery in Wireless networks", *IEEE Journal On Selected Areas In Communications*,Vol 21,No 10, December 2003, pp. 1685-1698.

[3] P. Zhu, W. Zeng, and C. Li, "Cross-layer QoS support for multimedia delivery over wireless Internet", *EURASIP Journal on Applied Signal Processing* Vol 2005 No 2, pp. 207-219, Hindawi Publishing Corporation.

[4] G. Xylomenos, G.C. Polyzos, P. Mahonen, and M. Saaranen, "TCP performance issues over wireless links," *IEEE Communications Magazine*, Vol. 39, No. 4, April 2001, pp. 52-58.

[5] G. Fairhurst and L. Wood, "Advice to link designers on link automatic repeat request (ARQ)", IETF RFC 3366, August 2002.

[6] S.Shakkottai, T. S. Rappaport, and P. C. Karlsson, "Cross-layer design for wireless networks", *IEEE Communications Magazine*, Vol 41, No 10, October 2003, pp. 74-80.

BIOGRAPHIES

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