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Multicasting Effective Video Quality Using QDM

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***Abstract*—In a multirate wireless network, Adaptation of modulation and transmission bit-rates for video multicast is a challenging problem because of network dynamics. Various WLAN multicast protocols have been proposed in order to overcome these problems. Existing multicast protocols, however, are not so efficient. To enhance the reliability and efficiency of multicast services in IEEE 802.11n WLANs, QDM enables selective retransmissions for erroneous multicast frames and efficient adjustments of the modulation and coding scheme (MCS). Easy-to-implement protocol, called QDM, which constructs a cluster-based structure to characterize node heterogeneity and adapts the transmission bit-rate to network dynamics based on video quality perceived by the representative cluster heads. In addition, an extension of QDM, for efficient delivery of scalable video over IEEE 802.11n WLANs**.

***Index Terms:-* Wireless video multicast, rate adaptation, QoS, Multicast, IEEE 802.11n, scalable video coding.**

I. INTRODUCTION

Video streaming is arguably one of the most popular multimedia applications over wireless networks today. With the successful deployment of IEEE 802.11 WLANs and increase in applications that require multicast services such as IPTV and Internet streaming, multicast communications over IEEE 802.11 WLANs have received much attention. However, there are two well-known problems in the multicast protocol of the IEEE 802.11 standard. First, multicast frames are transmitted as a simple broadcasting mechanism without acknowledgments from receivers. Due to the absence of automatic repeat request (ARQ) mechanisms, the reliability of multicast frames cannot be guaranteed, especially when the probability of collisions or bit errors is high. Second, a low and fixed transmission rate is used for multicast transmissions.

Although there have been several rate adaptation mechanisms for unicast transmissions in WLANs, they cannot be directly applied to multicast transmissions since the sender does not receive any feedbacks from receivers. Taking advantage of the wireless broadcast nature, a video source can multicast a video object to a group of multicast members in order to reduce the bandwidth requirement, as compared with unicasting the data to each individual member. However, current commercial network devices typically transmit multicast packets at the base rate in the MAC layer, even though 802.11 standard supports multiple bit-rates up to 11 Mb/s for 802.11b or 54 Mb/s for 802.11 a/g, each of which has a different modulation scheme. This is a waste of wireless bandwidth if certain members in the multicast group are capable of receiving packets at a higher bit rate, and desire a better visual quality. To address this problem, a dynamic rate adaptation scheme with quality-differentiated features to better support heterogeneity in the clients.The rate adaptation schemes measure the loss probability according to feedback acknowledged from the receiver, and predict a rate that can achieve the highest throughput. Such feedback-based schemes cannot be extended to multicast scenarios because concurrent feedback from several multi- cast members can lead to severe collision. To avoid this effect, some multicast rate adaptation schemes select the member who experiences the worst channel condition as the leader of the multicast group, and predict a bit rate that can reach this leader (the worst node). Such a leader-based approach is particularly suitable for applications that need to deliver data to all members reliably, e.g., data dissemination. However, this approach may not be efficient for video multicast because it merely selects the rate that maximizes the throughput of the worst node. In doing so, it penalizes those nodes who can receive data at a higher bit rate.

A visual-quality-based rate adaptation protocol, which makes tradeoff between two goals: providing same video quality for various clients to match their heterogeneous channel conditions and guaranteeing minimum visual quality for each client. Specifically, our goal is to develop a software-based rate scheduling protocol in order to produce the maximal total visual quality for quality-differentiated video multicast under the constraint of ensuring at least minimum visual quality for each member. Due to the heterogeneity among multicast members, different multicast recipients may observe dissimilar link qualities. Recently, several works have focused on how to allocate bandwidth efficiently for broadcasting video streams to clients either with heterogeneous re- sources, e.g., screen resolution or decoding capability, or with multiple access technologies, e.g., 3G and WLAN. Compared to those works that do no take channel condition, packet losses and transmission bit-rates into account, this work allocates bandwidth for video multicasting with consideration of multiple available transmission bit-rates and the corresponding loss probability. Our goal is to provide clients same visual quality matching their channel conditions.

II. RELATED WORK

1. Feedback-Based Schemes: The rate adaptation schemes for unicast video streaming measure the loss probability according to feedback acknowledged from the receiver, and predict a rate that can achieve the highest throughput. Such feedback-based schemes cannot be extended to multicast scenarios because concurrent feedback from several multi- cast members can lead to severe collision.
2. The Leader-Based Protocol: The first leader-based approach proposed to overcome the problem of feedback collision. It selects the worst node as the leader to acknowledge multicast packets. Other members can issue negative acknowledgements to collide the acknowledgement sent by the leader and, thus, trigger the sender to retransmit the lost packets. The goal of LBP is to support reliability by a single feedback. However, it does not adapt the transmission bit rate to dynamic channel conditions, but only sends data at the base rate. Thus, the rate adaptation algorithms, such as RAM [13] and ARSM [15], are proposed for the leader-based multicast protocol. They estimate link quality of the leader and determine a proper rate that can better reach the leader. Both of these techniques let each receiver embed the information about it receiving SNR value in the CTS frame. The sender can infer the leader's SNR upon receiving the CTS frames, and predict a suitable rate accordingly.

In A Rate-Adaptive MAC Protocol for Multi-Hop Wireless Networks[1], Gavin Holland and Nitin Vaidya proposed that the topic of optimizing performance in wireless local area networks using rate adaptation. Presented a new approach to rate adaptation, which differs from previous approaches in that it uses the RTS/CTS protocol to enable receiver-based rate adaptation. Using this approach, a protocol based on the popular IEEE 802.11 standard was presented, called the Receiver-Based AutoRate (RBAR) protocol. Simulation results were then presented comparing the performance of the proposed protocol against the performance of an existing 802.11 protocol for mobile nodes across Rayleigh fading channels.

In Modulation Rate Adaptation in Urban and Vehicular Environments [2]: Cross-layer Implementation and Experimental Evaluation, Joseph Camp and Edward Knightly proposed a custom cross-layer rate adaptation framework which has high levels of interaction and observability between MAC and PHY layers. They are the first to implement SNR-based rate adaptation at MAC time scales comparable to commercial systems and evaluate protocol accuracy compared to optimal rate selection on a packet-by-packet basis. Using this cross-layer implementation, they found that loss-triggered mechanisms under select in the presence of fast-fading and interference and are unable to track channel changes in mobile environments. Further, they found that in-situ training of SNR-triggered protocols to overcome their coherence time sensitivity allows significant throughput gains. They show that even in static topologies in practical outdoor environments, coherence time training is necessary. Finally, they show that a mechanism designed to equally share throughput in the hidden terminal scenario has a severe imbalance in throughput sharing with only slight heterogeneity in average link quality of competing transmitters.

In Efficient Channel-aware Rate Adaptation in Dynamic Environments [3], Glenn Judd and Xiaohui Wang proposed that their results in highly dynamic wireless channels, which can affect the performance of many aspects of the mobile device. Adaptation is critical to overall system performance. They have developed a channel-aware rate adaptation algorithm (CHARM) that quickly obtains accurate channel state information, and, unlike earlier channel-aware efforts, leverages channel reciprocity to eliminate the need for RTS/CTS exchanges. They use time-aware signal prediction technique to predict current channel information based on past observations, thus avoiding the pitfall of using stale channel information. In addition, they have developed techniques for automatically calibrating SINR thresholds. Our implementation of CHARM in the MadWifi driver for Atheros cards considers many practical issues such as antenna diversity and support for legacy nodes. Experiments show that in dynamic signal propagation environments, i.e. when the wireless devices are mobile or when there is a lot movement in the area, CHARM's rapid adaptation allows it to dramatically outperform probe-based techniques.

In Cross-Layer Wireless Bit Rate Adaptation [4], Mythili Vutukuru and Hari Balakrishnan proposed chieves throughput gains of up to 2 over frame-based protocols such as SampleRate and RRAA, 20% over SNR-based protocols trained on the operating environment, and 4 over untrained SNR-based protocols. The key idea is to expose per-bit confidences called SoftPHY hints from the physical layer, using them to estimate the interference-free BER of received frames. Picking bit rates using the BER thus estimated enables SoftRate to react quickly to channel variation without requiring any environment-specific calibration. Moreover, SoftRate's idea of estimating BER from SoftPHY hints can be applied to a variety of wireless cross-layer protocols that, for example, allocate frequency or transmit power, or perform efficient error recovery.

III. SYSTEM DESIGN

QDM exploits the cluster-based structure that provides same video quality for various clients. QDM, a practical video multicast framework including three components: 1) cluster construction: it clusters clients according to their channel conditions in order to characterize the heterogeneity of clients; 2) sample-based rate scheduling: it predicts the rate schedule by real-time sampling, and, thus, can estimate visual quality. 3) two-stage rate adaptation: using the finite-state machine, it adapts the rate schedule to variable video bit rates and channel conditions, and, at the same time, avoids the unnecessary sampling overhead.

Advantages of Proposed System:

- Compared with the Feedback-Based and The Leader-Based Protocol, QVM provides The incremental quality of all received frames.
- It maximizes the overall video quality for the entire group.
- It increases the Video bit rate.

IV. SYSTEM ARCHITECTURE

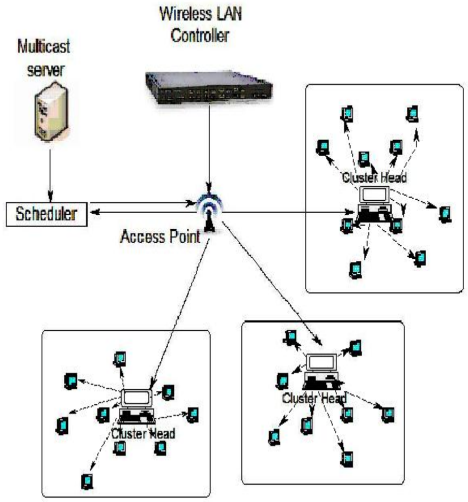


Figure 1 System Architecture

4.1 Analysis Of Channel Condition

Due to the heterogeneity among multicast members, different multicast recipients may observe dissimilar link qualities.

Compared to previous works that do not take channel condition, packet losses and transmission bit-rates into account, this work allocates bandwidth for video multicasting with consideration of multiple available transmission bit-rates and the corresponding loss probability.

Goal is to provide clients homogeneous visual quality matching their channel conditions. First, focus on the video streaming application, and provide different clients homogeneous visual quality by assigning each video frame a different transmission bit-rates based on its importance. Second, our work considers a single-AP scenario where AP cannot cooperate with each other.

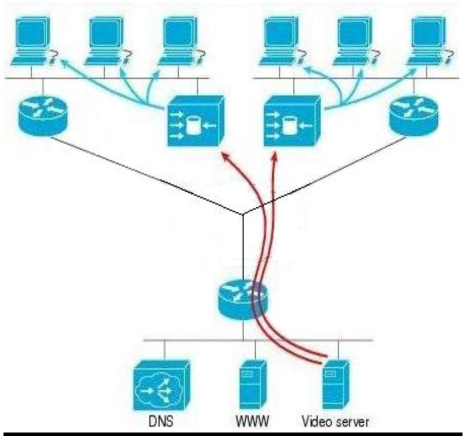


Figure 2 Analysis Of Channel Condition

4.2 Bit-Rate Scheduling Framework

SARM constructs a SRN-PSNR table that maps a SNR to a visual quality for each video content. Hence, it can predict the rate that provides everyone a minimum visual quality. ARSM proposes a variant, called H-ARSM, to select another best node who has the best channel condition. It then selects a bit-rate for the base layer of a stream according to the channel quality of the worst node, while transmits the enhancement layer at another bit rate based on the channel quality of the best node.Consider an environment where the video servers forward the stream to AP that can help broadcast data to all multicast members. Assume that AP and the video server are interconnected by wired networks, which are not the bottleneck; hence, only focus on transmission between AP and multicast members.

The rate scheduler can be installed either in the video server that collocates with the AP or in multiple proxy servers that share the workload of scheduling. It can alternatively be implemented as a driver run in the AP. The rate scheduler, which is run in user space, can then notify the network driver of AP, which is usually run in kernel, to send each packet at the selected transmission bit-rate.

QDM Formulation Approach

The model in the last section is proposed to find the most efficient solution, which needs complete information about the loss probability and incremental quality of each frame. QDM, a practical video multicast framework including three components:

1) Cluster construction: it clusters clients according to their channel conditions in order to characterize the heterogeneity of clients.

2) Sample-based rate scheduling: it predicts the rate schedule by real-time sampling, and, thus, can estimate visual quality even if information about incremental quality is not given.

*3) Two-state rate adaptatio*n: using the finite-state machine, it adapts the rate schedule to variable video bit rates and channel conditions, and, at the same time, avoids the unnecessary sampling overhead.

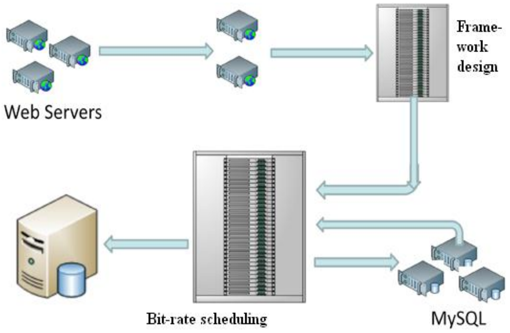


Figure 3 Bit-Rate Scheduling Framework

4.3 Formation Of Cluster

The design of QDM is to separate members to multiple clusters such that the receivers with similar channel conditions can be classified into the same cluster. Let us denote the best rate of member ‘m’ if it can receive the maximal throughput from AP. Those who have the same best rate ‘r’ can be grouped into cluster Ci.

Hence, a multicast group can be divided to |R| clusters, each of which can select the one in Ci who experiences the worst channel condition as the cluster head (CH) of Ci (denoted by CHi) to represent all members in Ci.

The scheduler can collect heterogeneous channel conditions from the CHs, and reduce the overhead of information exchange significantly. Based on the performance reported by the representative nodes (i.e., CHs), the scheduler can approximate the overall video quality of a multicast group.

4.4 Two -State Rate Adaptation

Since the sampled rate (i.e., a higher and a lower rate of the current rs) may not be suitable for the multicast group, QDM should avoid unnecessary samples if both of the network topology and the video rate are static. Specifically, the scheduler must adjust the sampling interval so as to adapt the rate to network dynamics and variable video bit rates; however, it must keep the selected rate unchanged if the environment is stable.

Here, propose a two-state rate adaptation scheme, which is a finite-state machine designed to determine the size of the sampling interval that can reflect variation of channel conditions or video bit rates. there are two states and two transition functions in the proposed two-state machine. Expect that the system stays in the active state if it still needs to search a suitable rate due to unstable environments (i.e., network dynamics or variable video rates); otherwise, the system can stay in the static state, and use the currently selected rs and ne.

Even though the cluster heads must respond the mask more frequently, however, the size of a mask (i.e., x bits for x packets) is much smaller than the size of supplementary frames Fs in a sample GOP. If the scheduler samples inappropriate rs during the sampling procedure, receivers may not achieve an adequate video quality. In this case, transmission of Fs in sample GOPs at an inappropriate rate can be deemed as a sampling overhead. That is, the scheduler may was significant sampling overhead if it executes the sampling procedure when the environment is stable and suitable to use the current rate rs.

Thus, prefer to let the system enter the static state, which may need a few overheads of responding the masks, but significantly save the sampling overhead.

By controlling the size of the sampling interval, the two-state machine can adapt rs to network dynamics with a reasonable sampling overhead.

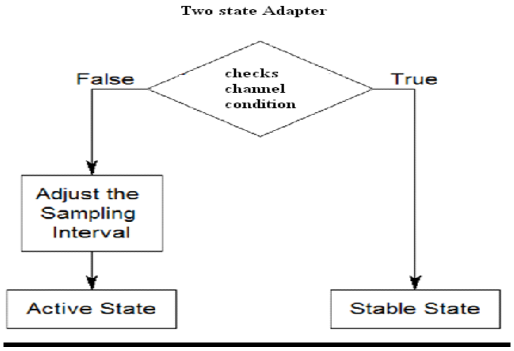


Figure 4 Two -State Rate Adaptation

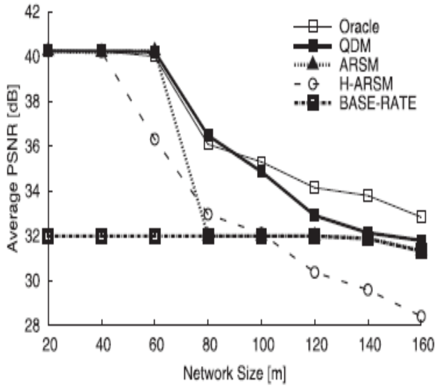
The functions of two states and two transitions are specified as follows:

- *Active state:* The system stay in the active state if the clients are mobile or the video bit-rate varies with time. In this state, repeat the sampling procedure for each sampling interval, which is set to a fixed size (e.g., set to six GOPs in our simulations). Hence, the system can sample a better rate periodically.
- *static state:* The system stops sampling, and uses the selected rs and ne for the following GOPs.

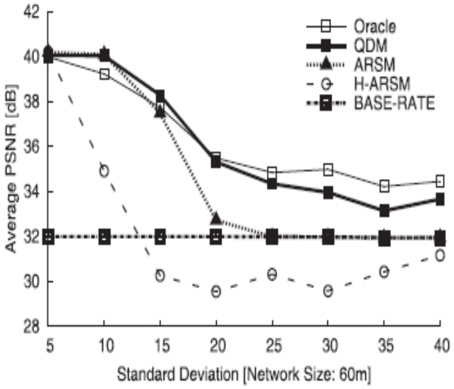
V. PERFORMANCE EVALUATIONS

Evaluate the performance of QDM in terms of PSNR total and the CDF of PSNR perceived by each client.Compare the following schemes:

1. *Oracle:* the dynamic-programming-based solution with oracle information.
2. *QDM:* the proposed quality-differentiated multicast;
3. *ARSM:* the leader-based solution, which selects the transmission bit-rate based on the worst node;
4. *H-ARSM:* the two-level solution, which selects the rate for the base layer according to the channel condition of the worst node, while selects the rate for the enhancement layer based on the best node;
5. *BASE-RATE:* the baseline scheme that always sends packets at the base rate.



(a) Uniform Distribution



(b) Normal Distribution

VI. CONCLUSIONS

This paper investigated the rate-scheduling problem of video multicast for heterogeneous clients over wireless environments. A rate-scheduling model that solves the theoretical optimal solution by dynamic programming. A practical protocol, called QDM, was further presented for real-time video streaming even with- out preprocess on computing the rate-distortion function and estimating the loss probability of each wireless link. In QDM, exploit a cluster-based structure to provide differentiated qualities for heterogeneous clients. Based on the information reported by cluster heads, the sender can estimate the total video quality and explore a suitable rate for each video frame based on a sample-based scheme.

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