Advanced Logical Superposition Modulation based Video Streaming Multicast System over Wireless Networks

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Abstract— **In this paper, we present an advanced logical superposition modulation based video streaming multicast system over a wireless networks. The traditional logical superposition modulation scheme generates symbols using a pre-fixed modulation scheme to overcome wireless channel diversity. In contrast, our proposed logical superposition modulation determines logical superposition modulation scheme according to time-varying wireless channel conditions in order to maximize overall network throughput, similar to state-of-art adaptive modulation schemes. in addition, two-layer SVC video streams are effectively mapped to the determined superposition modulation scheme to support better quality video streaming. Experimental results show the performance of our proposed system.**

I. INTRODUCTION

The demand for high-quality multimedia services over wireless networks has been increasing rapidly in recent years. It becomes more feasible as result of the fast development of communication/networking technology and smart mobile devices. However, providing seamless high-quality multimedia services over wireless networks is still difficult due to the limited resources. It is well known that multicast technology is essential for delivering the same data services to multiple subscribers with minimal redundancy. In particular, multimedia streaming multicast technology is very important because, as compared to other data services, multimedia streaming services consume a huge amount of network resources. Many advanced communication techniques have been proposed to improve network throughput in time-varying wireless networks. modulation and demodulation (MODEM) technology is one of the key technologies in communication systems. Modulation is the process of translating a data stream into a form suitable for transmission over the physical medium, and its performance is measured by the ability to preserve the accuracy of the encoded data. Adaptive Modulation and Coding (AMC) and Superposition Modulation (SPM) are the main types of modulation considered in this paper. Most state-of-the-art wireless networks, such as WLAN, WiMAX, and LTE, have the functionality required to change their modulation schemes adaptively based on the time-varying wireless channel conditions in order to improve network throughput. For example, IEEE 802.11a provides optional data rates of up to 54Mbps in the 5GHz band [1]. SPM algorithms have been proposed in order to allow a transmitter to effectively send information to multiple receivers simultaneously using a single wireless broadcast signal containing a multi-resolution modulated symbol, and consequently to achieve a higher channel capacity. Superposition Coded Modulation (SPCM) [2], [3] and Logical SPM (LSPM) [4], [5] are representative examples of SPM. SPCM is a modulation scheme that generates a superimposed signal by physically combining two signals. However, SPCM needs additional physical equipment at both the transmitter and the receiver, i.e., the transmitter requires equipment to superimpose multiple signals and the receiver needs SIC equipment to remove the extracted signal from the superimposed signal received. LSPM was proposed to solve this equipment problem. As shown in Figure 1, LSPM is a modulation scheme that logically superimposes signals by mapping modulation symbols to the concoctive bit patterns of the layer 1 and layer 2 data streams. A receiver demodulates the received signal using the corresponding dense demodulation scheme. If the demodulation process is successful, the receiver obtains all of the data from layers 1 and 2. If the demodulation fails, the receiver demodulates the received signal once more using the corresponding sparse demodulation scheme to acquire only layer 1 data. If the secondary demodulation is successful, only layer 1 data are still available. In this paper, we propose an effective advanced LSPM and Scalable Video Coding (SVC) [6] based video streaming multicast system. One of its main features is the fact that, like state-of-the-art wireless networks, the proposed multicast system adaptively changes the modulation scheme and decomposes it into a combination of two sub-modulation schemes by considering the distribution of subscribers in order to maximize overall network throughput. Furthermore, the proposed system provides a better video streaming service to more subscribers by efficiently mapping advanced LSPM and SVC streams.

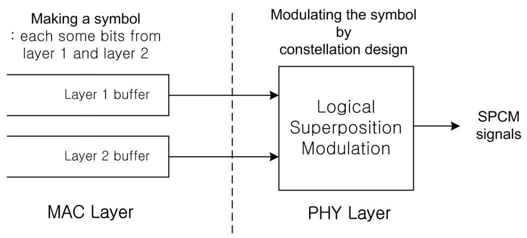

Figure 1. The structure of LSPM.

II. PROPOSED VIDEO STREAMING MULTICAST SYSTEM

The goal of the proposed system is to enable better quality video streaming multicast services to more subscribers over wireless networks. The architecture of the proposed system is depicted in Figure 2. In the following, ms denotes the modulation scheme of the downlink. A dense modulation symbol constellation can be represented by a two-dimensional convolution of two sparse sub-modulation symbol constellations, as shown in Figure 3, called the base sub-modulation scheme (ms_B) and the enhancement sub-modulation scheme (ms_E) of LSPM, respectively. In general, more combinations of sub-modulation schemes can be made for a denser modulation scheme as shown in Table I. By adaptively selecting a combination based on the distribution of subscribers, the proposed system can improve the overall network throughput for all subscribers. In addition, LSPM has a structure that is appropriate for two-layer SVC video stream transmission (i.e., a base sub-modulation scheme for the SVC base layer and an enhancement sub-modulation scheme for the SVC enhancement layer). In the proposed system, the video streaming server provides SVC video streams to the BS (Base Station) and each subscriber reports the current wireless channel condition to BS. Then, the BS estimates the wireless channel condition on the basis of the received channel feedback information. Using this estimated condition, the BS determines the base sub-modulation scheme and the enhancement sub-modulation scheme of LSPM among the possible candidates of sub-modulation scheme combinations in order to maximize the overall network throughput. The base layer video stream and the enhancement layer stream of the SVC are then mapped primarily to the base sub-modulation scheme and the enhancement sub-modulation scheme, respectively. The symbols are produced by logically superimposing the corresponding two symbols. The subscriber then demodulates the received signal in order to obtain the symbols. If the demodulation process is successfully performed in the first stage, both the base and enhancement layer video streams are extracted based on these symbols. Otherwise, (i.e., if demodulation fails), the subscriber executes the demodulation process once more to acquire only a base sub-modulation symbol. If this is successful, the subscriber can obtain the base layer video stream only. In this case, a minimum quality video service is still provided.

TABLE I. POSSIBLE LSPM COMBINATIONS OF BASE SUB-MODULATION SCHEME AND ENHANCEMENT SUB-MODULATION SCHEME.

Combination No.	ms	ms_B	ms_E
1	QPSK	QPSK	-
2	16QAM	QPSK	QPSK
3	64QAM	QPSK	16QAM
4		16QAM	QPSK
5	256QAM	QPSK	64QAM
6		16QAM	16QAM
7		64QAM	QPSK

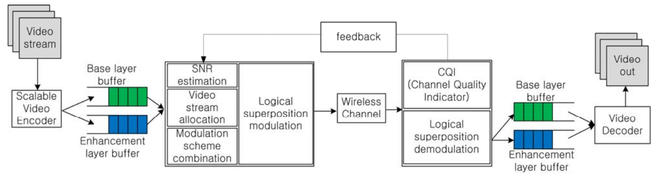

Figure 2. Architecture of the proposed video streaming multicast system.

A. Problem Description

WiMAX, one of the strong candidates that support video streaming multicast, is considered in this paper although the proposed video streaming multicast system can be employed in any wireless network that supports adaptive modulation functionality. In the WiMAX network, BPSK, QPSK, 16QAM, and 64QAM are supported (BPSK is used only for the uplink). The modulation scheme is dynamically adjusted according to wireless channel conditions. Now, let b_{ms} be the number of bits included in a symbol, and b_{ms_B} and b_{ms_E} signify the numbers of bits included in a base sub-modulation symbol and a enhancement sub-modulation symbol, respectively. When the symbol constellation of ms is expressed by the two-dimensional convolution of the two symbol constellations of ms_B and ms_E , the following equation is satisfied.

$$b_{ms} = b_{ms_B} + b_{ms_E} \tag{1}$$

The i_{th} subscriber demodulates the superimposed symbols from the BS. The demodulation success probability of the superimposed modulation scheme is denoted by $P_{B+E}\left(ms_B, ms_E, \widetilde{SNR}(i)\right)$, where $\widetilde{SNR}(i)$ is the estimated SNR of the i_{th} subscriber. If the demodulation process fails, the i_{th} subscriber performs the demodulation again to get only the base sub-modulation symbol. In this case, the demodulation success probability is represented by $P_B\left(ms_B, ms_E, \widetilde{SNR}(i)\right)$. Now we can formulate the goal as follows.

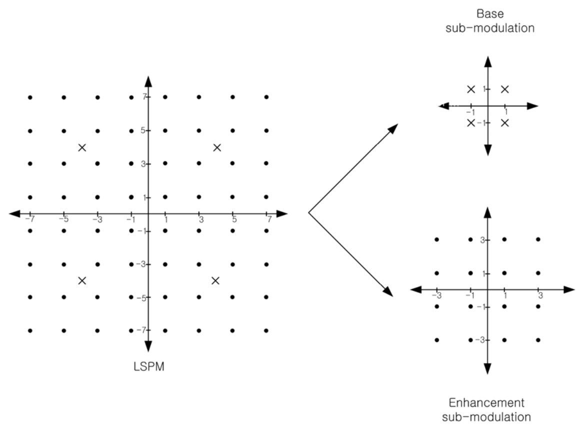

Figure 3. Symbol constellation convolution of the base sub-modulation scheme (ms_B) and the enhancement sub-modulation scheme (ms_E) of LSPM: the convolution of (QPSK, 16QAM).

Problem formulation: Determine ms_B and ms_E to maximize

$$\sum_{i=1}^{N_{ss}} \left\{ \begin{array}{l} \left(P_{B+E}\left(ms_B, ms_E, \widetilde{SNR}(i)\right) \times b_{ms}\right) \\ +\left(\left(1-P_{B+E}\left(ms_B, ms_E, \widetilde{SNR}(i)\right)\right) \times P_B\left(ms_B, ms_E, \widetilde{SNR}(i)\right) \times b_{ms_B}\right) \end{array} \right\}, \quad (5)$$

$$\text{subject to } ms_B \le ms\left(\arg\min_{1\le i\le N_{ss}}\left(\widetilde{SNR}(i)\right)\right), \quad (6)$$

where N_{ss} is the number of subscribers in a cell who are participating in the multicast session, and $ms\left(\arg\min_{1\le i\le N_{ss}}\left(\widetilde{SNR}(i)\right)\right)$ is the modulation scheme determined on the basis of the worst channel condition among the subscribers.

B. The Sub-Modulation Scheme Combination Determination Process

The proposed advanced LSPM system determines the combination of ms_B and ms_E according to the distribution and the mobility of subscribers.

Step 0: Observe the current wireless channel condition of each subscriber and estimate the subsequent wireless channel condition based on the observed values.

Step 1: Calculate $P_{B+E}\left(ms_B, ms_E, \widetilde{SNR}(i)\right)$ and $P_B\left(ms_B, ms_E, \widetilde{SNR}(i)\right)$ based on the $\widetilde{SNR}(i)$ values (for a detailed derivation, refer to [4]).

Step 2: Search for all possible base sub-modulation scheme candidates considering $ms\left(\arg\min_{1\le i\le N_{ss}}\left(\widetilde{SNR}(i)\right)\right)$.

Step 3: Search for all possible combinations of base sub-modulation scheme candidates and the corresponding enhancement sub-modulation scheme candidates.

Step 4: Calculate Eq. (5) for all the above possible combinations. The combination with the highest value is selected as the solution.

C. Allocating Video Stream to Logical Superposition Modulation Scheme

The video data are encoded into two-layer SVC video streams (i.e. the base layer video stream and the enhancement layer video stream). The base layer video stream for the minimum quality should be transmitted with the sparsest sub-modulation scheme to support the multicast service for as many subscribers as possible. Hence the encoding rate of the base layer is set to the data rate of the sparsest sub-modulation scheme, and the encoding rate of the enhancement layer is fixed to the data rate of the densest sub-modulation scheme. The encoded base and enhancement layer video streams encoded at fixed target encoding rates are transmitted. Since the data rate of the modulation scheme is changing when the combination of the base sub-modulation scheme and the enhancement sub-modulation scheme are being determined, we need to solve this mismatch between the target encoding rate and the data rate while allocating video streams to the base sub-modulation scheme and the enhancement sub-modulation scheme. One way to handle this mismatch is given in Figure 4. Figure 4 (a) shows the case when the target encoding rate of the video streams is the same as the data rate of sub-modulation schemes. In this case, the symbols of the base sub-modulation and the enhancement sub-modulation are mapped to the base layer video stream and the enhancement layer video stream, respectively. The symbols of the base sub-modulation and the enhancement sub-modulation are then logically superimposed to generate the LSPM symbols. In Figure 4 (b), the data rate of the base sub-modulation scheme is greater than the target encoding rate of the base layer video stream. As a result, base layer buffer underflow may occur. To avoid this resource wastage, a part of the enhancement layer video stream is allocated to the base sub-modulation symbols.

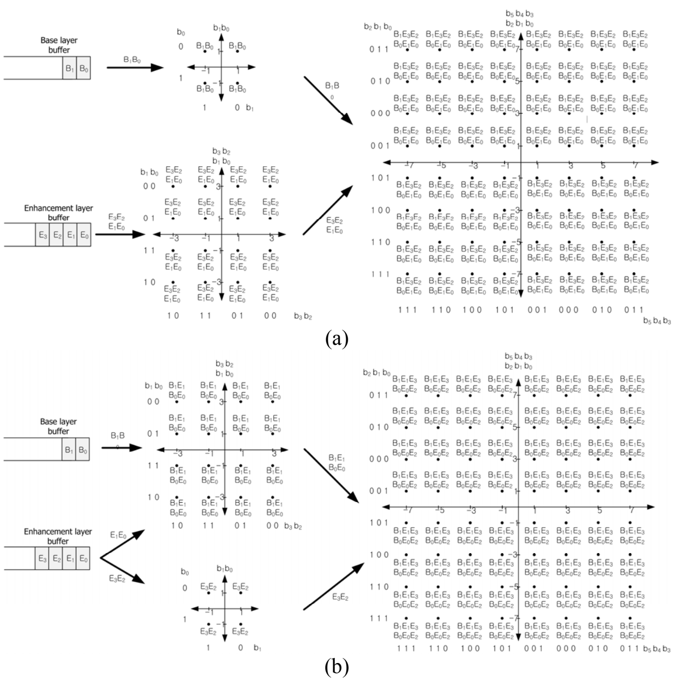

Figure 4. Mapping of video data with symbol constellations of sub-modulation schemes: (a) (QPSK, 16QAM) and (b) (16QAM, QPSK).

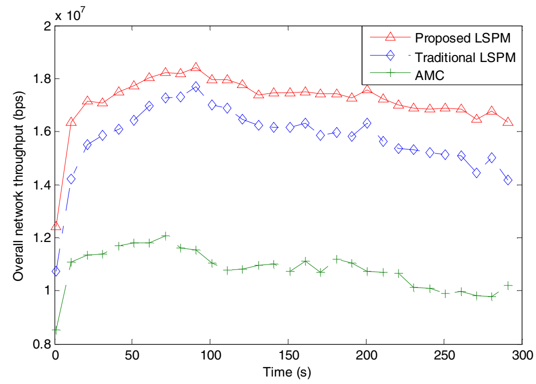

Figure 5. The overall network throughput according to mobility of subscribers.

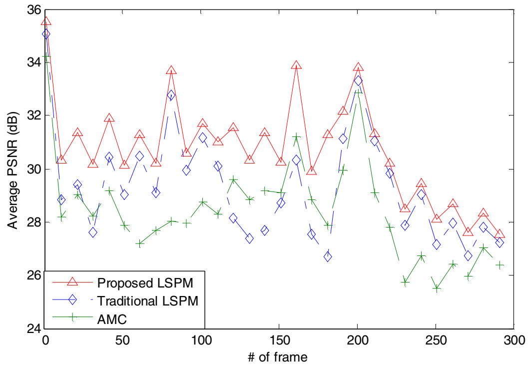

Figure 6. Average PSNR plots of all subscribers (The test video sequence used was CIF Foreman).

III. Experimental Results

An NS-2 simulator and H.264 Joint Scalable Video Model (JSVM) were employed for this experiment. The Additive White Gaussian Noise (AWGN) wireless channel model was utilized. The number of subscribers in each cell was set to 10. and each video streams was encoded at 30 fps. The test video sequences used were CIF-sized Foreman, Harbour, and City, and encoded in SVC two layers.

A. Performance Comparison according to Mobility of Subscribers

The experiment was performed with the subscribers randomly moving in a cell. During the experiment, the subscribers were moving at 10-20 m/s according to the Random waypoint Model. The overall network throughput plots are given in Figure 5. It is apparent that AMC provided a lower overall network throughput than both the proposed system and the traditional LSPM since AMC selects its modulation scheme for the subscriber with the worst channel condition. The proposed system can support higher overall network throughput than the traditional LSPM by adaptively choosing a combination of the base sub-modulation and the enhancement sub-modulation according to the wireless channel condition.

B. Objective and Subjective Video Quality Comparison

Based on the above values for overall network throughput, the achievable quality of video streaming was compared objectively and subjectively. The Peak SNR (PSNR) plots of Foreman are shown in Figure 6. It can clearly be seen that the proposed system supports streaming multicast services at a

(a) (b) (c)

Figure 7. Subjective video quality comparison of the 79_{th} frame of the CIF Foreman video sequence: (a) Proposed advanced LSPM, (b) Traditional LSPM, and (c) AMC.

Table II. Average PSNR values of test video sequences.

Modulation \ Test seq.	Foreman	Harbour	City
Proposed LSPM	30.04 dB	26.48 dB	27.62 dB
Traditional LSPM	28.80 dB	25.79 dB	27.44 dB
AMC	27.88 dB	24.42 dB	26.86 dB

higher PSNR than the traditional LSPM and AMC. The resulting average PSNR values are summarized in Table II. The PSNR improvement was approximately 0.8~2.2 dB compared to AMC and approximately 0.2~1.2 dB compared to the traditional LSPM. For the subjective comparison, the 79_{th} frame of the Foreman video sequence was captured as shown in Figure 7.

IV. Conclusion

In this paper, we have proposed an effective advanced LSPM and SVC based video streaming multicast system that considers the distribution of subscribers over wireless networks. By selecting an efficient combination of a base sub-modulation scheme and an enhancement sub-modulation scheme according to the wireless channel conditions, the proposed system can increase the overall network throughput in a cell. Furthermore, the proposed system provides considerably better video streaming multicast services by integrating LSPM and SVC two-layer streams. Experimental results are confirmed the performance of the proposed system.

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