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兼具高傳輸效率與容錯韌力之異質多層次多媒體群播服務
研究成果報告(精簡版)

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兼具高傳輸效率與容錯韌力之異質多層次多媒體群播服務
Transport Efficient and Loss Resilient Heterogeneous Multilayer Multimedia Multicasting

John K. Zao (NCTU), Wen-Hsiao Peng (NCTU), Chung-Hsuan Wang (NCTU) and Robert S.Y. Li (CUHK)

I. INTRODUCTION

This technical report described the results of on-going research on *heterogeneous multicasting of H.264 Scalable Video Bitstreams* performed by an NCTU project team consisting of Prof. John K. Zao (NCTU CS, PI), Prof. Wen-Hsiao Peng (NCTU CS, Co-PI), Prof. Chung-Hsuan Wang (NCTU EE, Co-PI) and Chair Prof. Robert S.Y. Li (CUHK IE, Adjunct-PI) supported by the NSC grant, # 97-2221-E-009-076.

Prof. John K. Zao (NCTU CS, PI) and Prof. Wen-Hsiao Peng (NCTU CS, Co-PI) began their collaborated research on SVC multicasting since early 2007. Their work was focused initially on the adaptation of SVC inter-layer dependence relations and bitstream extraction orders so as to attain rate-distortion optimized playback for different viewing devices. After receiving their first NSC grant, they invited Prof. Chung-Hsuan Wang (NCTU EE, Co-PI) and Chair Prof. Robert S.Y. Li (CUHK IE, Adjunct-PI) to join the project team and started exploring the benefit of employing unequal erasure correction and networking coding techniques to enhance the performance of SVC streaming over wireless LANs and the public Internet.

In the past three years, the project team has produced significant results in the following research topics. Only the underlined ones are summarized in this section. Reviewers are referred to the cited publication for details.

- Video Multicasting among Peers with Asymmetric Network Connectivity [1]
- Rate-Distortion Optimized SVC Interlayer Dependency and Bitstream Extraction [6,8]
- Bandwidth Allocation for SVC Multipath Multicasting [2]
- Rate-Distortion Optimized RTP-based SVC Internet Streaming [9]
- BitTorrent Modification for Video Dissemination among Disparate Peers [3]
- Optimal Degree Distribution for Short Data Length LT Code

II. VIDEO MULTICASTING AMONG PEERS WITH ASYMMETRIC NETWORK CONNECTIVITY

II.1 Objectives

In our first work on video multicasting, we tried to confront two issues that often arise when peer-to-peer application layer multicast (ALM) is used to provide video streaming to household users:

1. Peers with asymmetric connectivity for up/down links such as ADSL, VDSL or Cable modem usually have narrower upstream bandwidth. The capacity of peer's upstream bandwidth will influence on how many topological children it can support.
2. Peers, especially the mobile ones that use wireless links, may be disconnected from the network at any time, and thus cause the ALM services they render with unexpected performance degradation.

II.2 Approach

We devised a resilient application layer multicasting (ALM) mechanism, which has several desirable properties. (1) Peers can tolerate a small number of packet delay or loss and they still can receive complete message in time. (2) A sudden breakdown of some peers or links won't disrupt the reception of downstream peers. (3) Streaming data can be retrieved only by the peers subscribing to the ALM service, but not by the peers helping to provide the service.

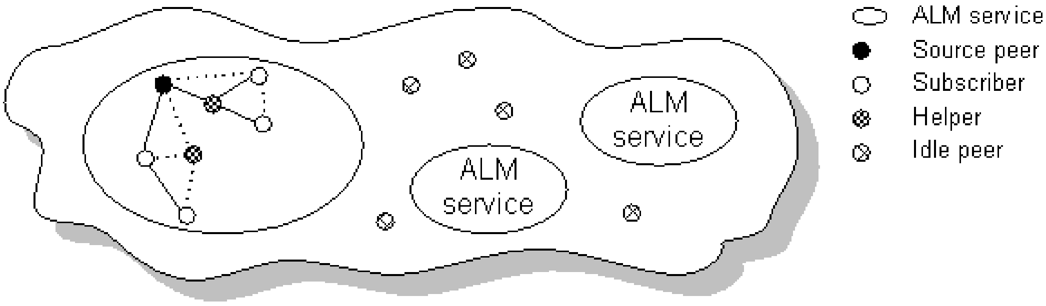


Figure 1 : Application Layer Multicast (ALM) System

We solve the asymmetric connectivity issue by making full use of peers' upstream bandwidth and increasing the total upstream bandwidth of the service. To reach the purpose we described, we use three approaches, which are described in the following paragraphs.

(A) Information Dispersion

Rabin's Information Dispersal Algorithm (IDA) [4] is used to process the message generated from source peer and a message will be divided into several stripes. The peers can't know any content without receiving sufficient number of stripes. There are two meanings. First, it means you can't know any content of the message from one or few stripes. Therefore, if some peers have no authority to read the message, we only need to make sure not to let them receive too many different stripes of the message. Second, it means peers don't need to receive whole stripes of a message and they can still know the complete message. By this characteristic, we can improve the fault tolerance and robustness of data transmission.

(B) Multiple Path Transport

Each message transported from source peer that provide streaming data will be divided into several stripes [5]. In the multicasting tree formation, we not only construct one tree, we construct as many different trees as the number of stripes that one message is divided into. And each tree transmits different stripe of the message. This approach will lead to two advantages. First, each stripe will pass through different path. When one peer leaves or crashed, descendants of the peer will only lose one stripes and they still can receive other stripes. Furthermore, when a hop of the path is congested, it only influences on the reception of one stripe. Second, a stripe is much smaller than a message. The advantage is that a peer with low upstream bandwidth can also support several children because the data it needs to retransmit is small enough. Therefore, every peer can fully utilize their upstream bandwidth.

(C) Helper Recruitment

Because the lack of upstream bandwidth, even we use multiple stripes approach to fully utilize every peer's upstream bandwidth; it is still possible that new peers cannot find the parent in the tree that can provide them smooth streaming data. Therefore, the service will request some peers called helper that still have unnecessary bandwidth to join and share their bandwidth to increase the total upstream bandwidth of the service. With the aid of the helpers, the service can accept more peers and each peer can receive the streaming data smoothly.

II.3 Simulation Results

We combined the three approaches mentioned above and produced a new application layer multicast system[1] as shown in Figure 1. In an ALM system, there are many ALM services and each service provides different streaming data. Every ALM service uses information dispersal algorithm, multiple stripes, and helper approach to operate independently. Each user who joins the system is called a peer. The peer who provides streaming data is called source peer. The peer who wants to receive the streaming data of the service and join it is called subscriber in that service. And for other services, it is a helper. The peer who doesn't join any service of the ALM system is called idle peer. And the idle peer is also a helper for all services in the system.

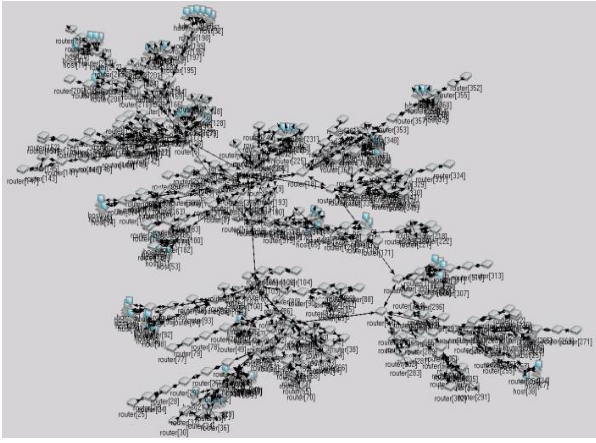


Figure 2: Network topology of *Trickle* simulations

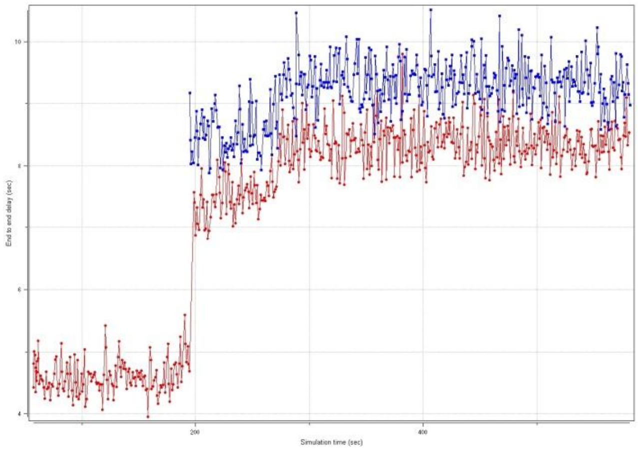


Figure 3: Recovered frame counts at the same two subscribers

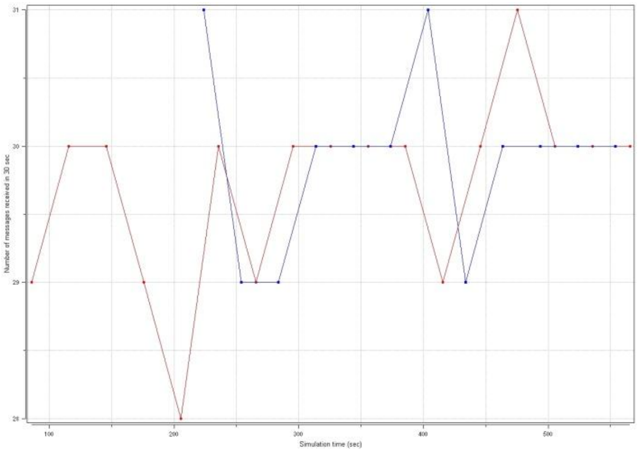


Figure 4: Packet latencies at two dispersed subscribers as more subscribers and helpers were introduced

III. RATE-DISTORTION OPTIMIZED SVC INTERLAYER DEPENDENCY AND BITSTREAM EXTRACTION

H.264-SVC with spatial, temporal and fidelity scalability allows different viewing devices to extract and decode different parts of an SVC bitstream according to their display formats, processing power and network connectivity.

Nonetheless, multiple factors can affect the choice of extracted layers; they may include video content characteristics, encoder parameter settings, display formats and error concealment algorithms used by the viewing devices. Thus, it is a worthy effort to determine the plausible correlations between inter-layer dependencies and rate-distortion optimized extraction of SVC bitstreams. Towards this end, we conducted a series of experiments and published our results in [6,7,8].This section offers a summary of those results.

III.1 Experiments with Inter-layer Dependency

Our first study focused on the combined effects of quantization parameter (*Qp*) and inter-layer (spatial and fidelity) dependence relations in determining coding efficiency and rate-distortion (R-D) performance of an SVC bitstream.

(A) Proper Setting of Quantization Parameters

[1] The ALM simulation network consists of 380 routers and 100 hosts – among them, 10 hosts are subscribers.

The first experiment aimed at finding the proper settings of *Qp* for the sake of obtaining good R-D performance. Two SVC layers are encoded with fixed *Qp* values for the enhancement-layer while the *Qp* value of the base layer sweeps from 0 to 51. Both CGS and spatial scalability were examined. Their R-D performances are shown in Figure 5 (a) and (b) respectively.

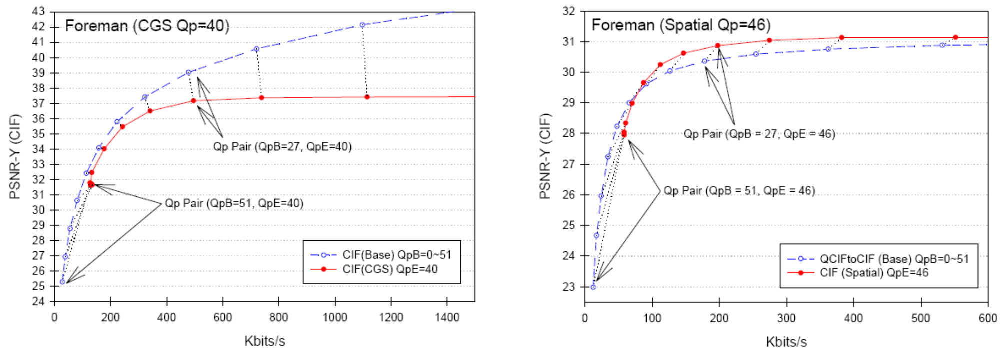
These experiment results made clear that in order to achieve good R-D performance, an SVC layer should depend on another layer of inferior visual quality. This implies that proper *Qp* setting should ensure a *monotonic decrease of distortion levels* as the SVC layers are decoded following their dependence relations.

(B) Proper Choices of Inter-layer Dependency

In the second experiment, the correlation of inter-layer dependencies with both video contents and *Qp* settings was examined. Two test bitstreams (Mobile and Forman) consists of two spatial layers (QCIF and CIF), each of which in turn has three CGS layers (QCIF: A0, A1, A2; CIF: B0, B1, B2) and four temporal levels (3.75Hz – 30Hz). Each bitstream was encoded with the following four dependency settings:

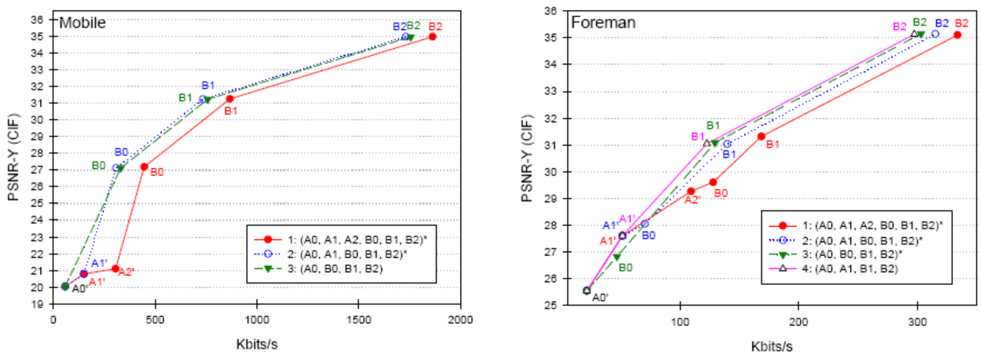
- Setting #1: (A0 ⟵ A1 ⟵ A2), (A2 ⟵ B0 ⟵ B1 ⟵ B2)
- Setting #2: (A0 ⟵ A1 ⟵ A2), (A1 ⟵ B0 ⟵ B1 ⟵ B2)
- Setting #3: (A0 ⟵ A1 ⟵ A2), (A0 ⟵ B0 ⟵ B1 ⟵ B2)
- Setting #4: (A0 ⟵ A1 ⟵ A2), (A1 ⟵ B1 ⟵ B2)

The R-D performance of each encoded bitstream is shown in Figure 6. For the sake of fair comparison, QCIF videos were enlarged to CIF format before their PSNR values were measured. Those measurements are displayed as A0', A1' and A2' in the figure.



(a) (b)

Figure 5: R-D performance of (a) CGS and (b) spatially scalable bitstreams with different *Qp* values



(a) (b)

Figure 6: R-D performance of test sequences (a) Mobile and (b) Forman with different dependency settings

The experiment results not only showed that the effects of inter-layer dependencies vary greatly among different video contents — Mobile worked poorly with spatial interpolation — but also confirmed that it is improper for an SVC layer to depend on another layer of better visual quality.

(C) Comparisons of Coding Efficiency

In the third experiment, we compared the total bit rates of four test sequences (Mobile, Forman, Akiyo and Football) as they were encoded according to the first three dependency settings of the last experiment. When compared with Setting #1, well-adapted inter-layer dependencies increased the bitrates by merely 3% – 11%.

(D) Rules for Decisions

From these experiments, we deduced following two rules for setting *Qp* values and dependency relations among SVC NAL units.

1. *Monotonic Reduction of Distortion following Dependence Order*. For a set of decodable NAL units, a *proper dependency setting* should guarantees that every decodable subset produced by successive refinement [defined below] exhibit a monotonic decrease of distortion values in mean squared errors.
2. *Convexity of Rate-Distortion Curves.* For the same decodable set of NAL units, a *well-adapted dependency setting* should also guarantee that every decodable subset produced by successive refinement exhibit a monotonic decrease in the reduction rates of distortion. Figure 9 illustrates the implication of these two rules as they are applied to an SVC bitstream.

III.2 Experiments with Bitstream Extraction

With potential application of heterogeneous SVC multicasting in mind, we studied the *successive refinement* of an SVC bitstream. It is an extraction procedure that takes a decodable subset of NAL units from the previous set in every step. The extraction sequence of successive refinement defines an *extraction path* that traverses the SVC scalable layers. Our aim was to develop an algorithm to search for the optimal extraction path that can minimize both the distortion and the bitrates of each decoded pictures along the path.

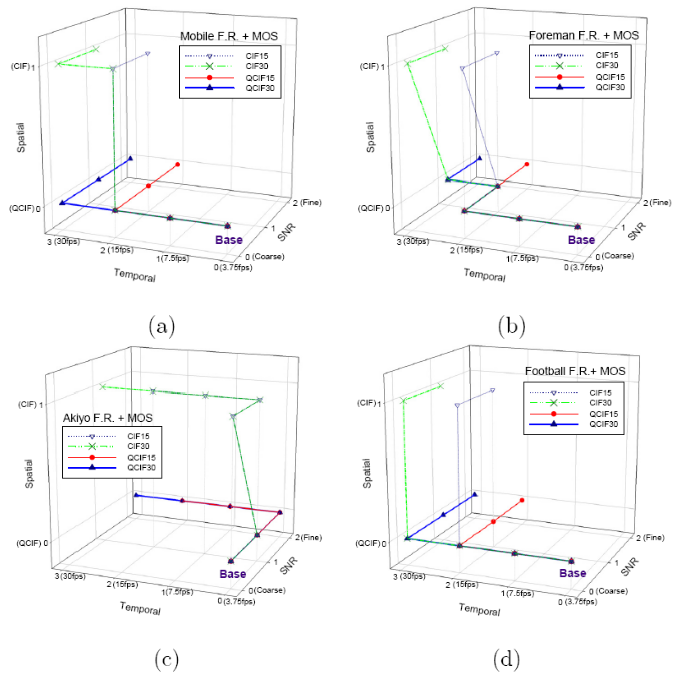


Figure 7: Optimal extraction paths for (a) Mobile, (b) Foreman, (c) Akiyo, and (d) Football

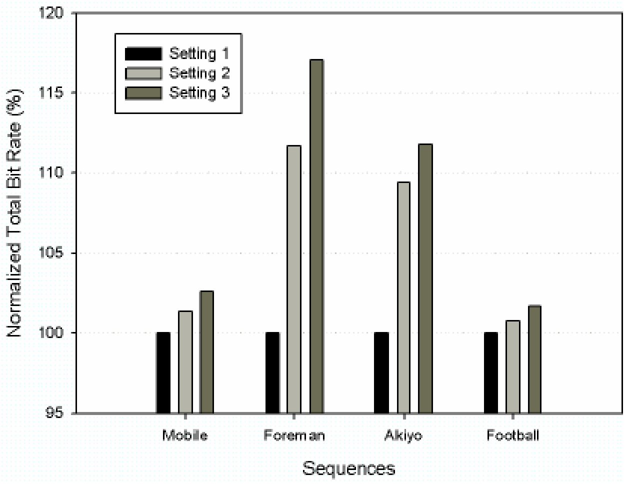


Figure 8: Comparison of coding efficiency based on different inter-layer dependencies

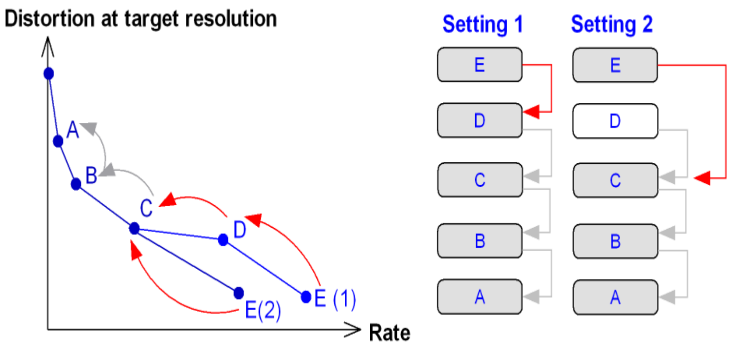


Figure 9: Comparison between (1) ill-adapted and (2) well-adapted SVC bitstreams

In our experiments, the optimal extraction paths for three viewing devices of CIF@30Hz, CIF@15Hz, and QCIF@30Hz formats were constructed by exhaustive search for the four test sequences: Mobile, Forman, Akiyo and Football.

It is worth noting that the optimal extraction paths for different viewing devices actually reveal regular predictable patterns for the same video. The optimal paths for the devices with lower spatial-temporal resolutions are likely to be the projections or truncation of the ones for higher resolutions.

III.3 Search for Optimal/Near-Optimal Extraction Paths

Our proposed method consists of two steps: (1) find out all extraction paths that suit for convex rate-distortion curves; (2) pick out the one has the smallest area below the rate-distortion curve, which will be the target optimal extraction path.

(A) Graphical Tools

We proposed two kinds of graphical tools for searching the optimal extraction path: RD Mesh and Trellis Diagram.

In order to examine how many benefits will be acquired while receiving different parts of bitstreams at each refinement steps, we draw all the rate-distortion curves of extraction paths which fulfill the characteristics of successive refinement in the same graph, and name it as the *RD Mesh* for the SVC bitstream [Figure 10]. In this figure the horizontal axis denotes for bit rate, and the vertical axis denotes for distortion. Points in the grid represent different scalable layers that can be extracted, and those layers are marked as spatial layer L and temporal layer T. Line segments in the grid represents for refinement steps along spatial or temporal dimension, and their slopes indicate the rate-distortion performance of the corresponding extraction paths.

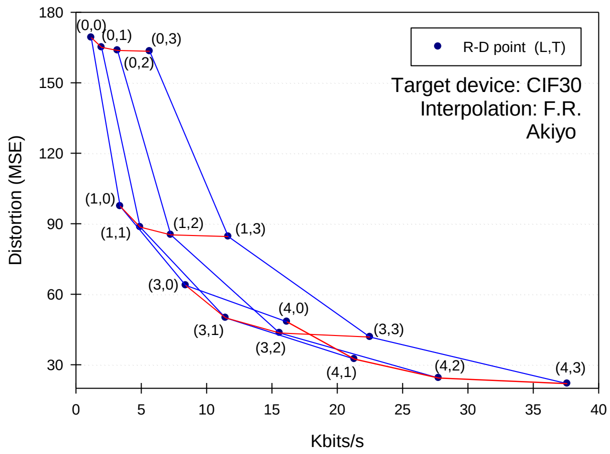


Figure 10: RD Mesh

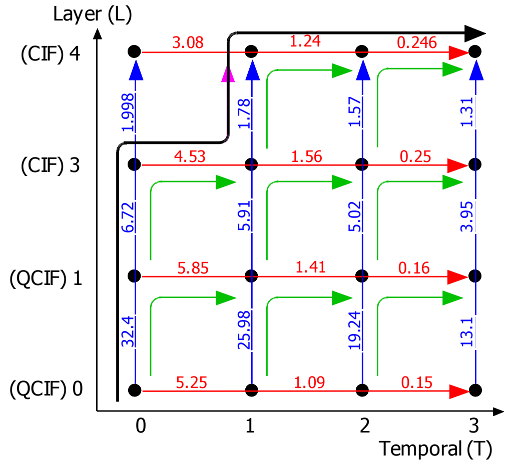


Figure 11: Corresponding Trellis Diagram of R-D Mesh in Figure 10

Also, *Trellis Diagram* is another kind of representation [Figure 11]. Every scalable layer in the bitstream is expanded in grid style, with its time dimension as the horizontal axis, space/fidelity dimension as the vertical axis. The points in the grid are the extractable scalable layers, and the connected line segments are refinement steps receiving one more layer along both axis. Finally the rate-distortion performances acquired from each step are marked in the graph. In this way, the problem of finding the optimal extraction path can be turned into the problem of finding the optimal path in the Trellis Diagram. In the optimal path problem for Trellis Diagram, the starting point is the scalable layer at lower left corner with the minimal time and space magnitude, the end point is the upper right corner with the highest level, and the directions of path can only be right or up. This model helps to explore efficient solutions.

(B) Optimal / Near-Optimal Extraction Path of the search strategy

When searching for optimal extraction path, the most intuitive method is extracting and decoding every extractable scalable layer in the bitstream. In this way the complete RD Mesh and Trellis Diagram information are acquired, therefore all the extraction paths with successive refinement characteristic can be drawn. Consequently, the extraction path with the convex rate-distortion curve and the smallest below area will be the final answer. Although Exhaustive Search can obtain the optimal solution, its huge consumption of time and complexity is unacceptable. Under different conditions, we proposed fast search strategies that can save amount of time on finding optimal extraction path, with average 50% complexity savings.

(1) Global Conditions

In order let the extraction path achieves the style of convex rate-distortion curve, the possibly basic requirement is: no matter locating at any scalable layer, while extracting one more scalable layer along the dimension of time or space, let the path has the characteristic of rate-distortion reduction for refinement steps. In other words, the one with higher performance is first to be extracted. We call this *Global Condition.*

(2) Strong Local Conditions

In the path from the base layer to the target layer, there must be conversions of receiving different dimensions of scalable layers. In Trellis Diagram, the path from bottom left corner to up right corner in every single grid represents the receiving process of one additional space and time scalable layers, but the receiving order will caused the rate-distortion performance differences.

In addition to fulfilling Global Condition, there must be at least one Convex Segment in each single grid to ensure the existence of optimal extraction path for the SVC bitstream. If there is only one convex extraction path in every single grid in the Trellis Diagram represented by the SVC bitstream, the bitstream is called to satisfy *Strong Local Conditions.* This condition is met when one of time and space dimension in a single grid can dominate the local rate-distortion performance.

The study found that for bitstreams that meet the Global Condition and Strong Local Conditions, since some extraction path styles do not exist due to the confliction of limitation of two conditions, convex sections in every grids show the same concentration trends. If we put the ones with better performance while receiving temporal scalable layer in the up left corner, put the ones with better performance while receiving spatial scalable layer in the bottom right corner, the line intersecting the two is the solution [Figure 12].

In this ideal situation, the search strategy of best extraction path can be simplified as Steepest Descent, which at each of the extraction procedures takes the one with highest current rate-distortion performance. Therefore the optimal extraction path can be acquired without additional future information. This search strategy is the most streamlined algorithm considering complexity. The more scalable layer exists, the more savings on bitstream extraction and decoding complexity. In our experiments, on average the reduction of scalable layer decoding requirements is about half.

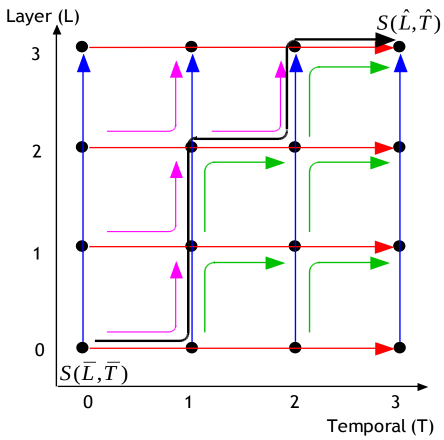


Figure 12: he Trellis Diagram of the bitstream meets the Strong Local Conditions

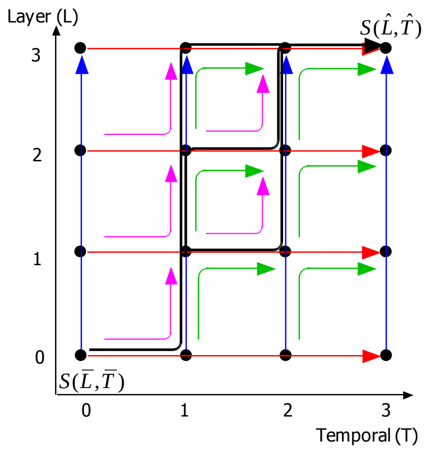


Figure 13: The Trellis Diagram of the bitstream meets the Weak Local Conditions

(3) Weak Local Conditions

If the convex extraction paths are existed in every grid in the Trellis Diagram of the SVC bitstream, but for some regions there are two available path with convex-type Characteristics to choose since there is no dominance in neither space nor time dimension for the rate-distortion performance in single grid, the bitstream is called to satisfy *Weak Local Conditions* [Figure 13]. In this case, the grids with two convex extraction paths often gather at the intersecting line generated by the Strong Local Conditions. Also, the rate-distortion performances within the single grid are close. At this time although the Steepest Descent algorithm cannot guaranteed to find the best extraction path, it can also obtain the sub-optimal extraction path with the same or similar performance as brute force.

(4) Violation of Local Conditions

Although the Global Condition may be designed to fulfill, local conditions might locally cause the situation that there is no convex extraction path in single grid that violates the local condition. That is due to effect of image characteristics, distortion measurement, or time and space interpolation. Violation of local conditions may not only make the best extraction path does not exist, but also mislead the Steepest Descent algorithm’s judgment, as a result optimal solution cannot be obtained

[Figure 14]. However, through the observation of large experiments, this violation merely happens. Although it occurs, since Steepest Descent algorithm always receives the current best performance one, if the tolerance of slight deviation in convex curve is added, the approximate optimal extraction path can be obtained.

(5) Tolerance for Deviation from Convexity

If there exists grids in Trellis Diagram that violate local conditions, they may make the Steepest Descent algorithm choose the wrong path, or the path with the smallest area under the curve (best rate-distortion performance) does not have convex rate-distortion curve characteristics. For this situation we propose the formula for the tolerance of convex curve deviation, it will see the acceptable extraction paths with minor deviation as the one meets convex curve features, therefore take into the choice of optimal path in order to obtain approximate optimal extraction path [Figure 15].

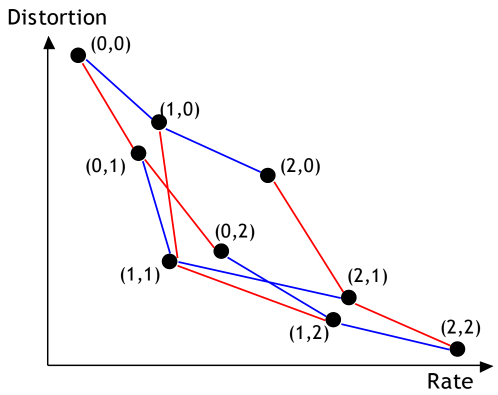


Figure 14: RD Mesh that violates local condition

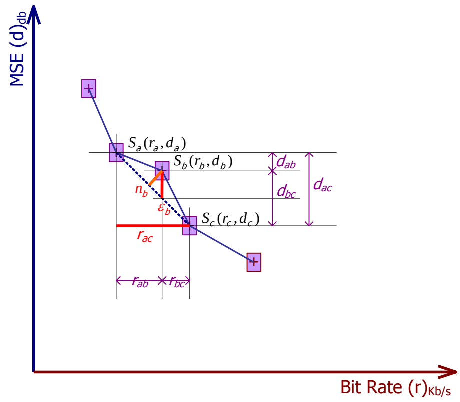


Figure 15: Schematic diagram of convex curve deviation tolerance

III.4 Summary

The SVC bitstreams designed to meet the Global Condition, can obtain their optimal extraction path by Steepest Descent algorithm in Strong Local Conditions. Although only the Weak Local Conditions are met, sub-optimal solutions with similar performance can be found. And when the local conditions are violated, the use of tolerance calculation for the convex curve deviation can find the approximate optimal solution.

After the appropriate cross-layer dependence and quantization parameter settings during the compression of the SVC bitstreams, Steepest Descent can be used as a high performance algorithm for the best extraction path search strategy.

IV. Rate-Distortion Optimized RTP-based SVC Internet Streaming

In this thesis [9],we aim to build a rate-distortion estimation model. The expected rate and distortion can be calculated through our estimation model with a given packet loss rate and a transmission policy under certain transmission scenario.

Many details need to be tackled when streaming via RTP over the wired Internet are taken into account in our estimation model. This model is build for SVC video streaming under receiver-driven retransmission and receiver-driven aggressive retransmission.

The results show that the difference of RD points between different transmission policies become larger when the packet loss rate increase. As the maximum retransmission times increase, the improvement of distortion becomes less obvious.

We also propose transmission policy optimization algorithms. For a given bit rate, we can find the optimal transmission policy with minimum expected distortion through our optimization algorithms.

IV.1 Rate-distortion Estimation Model

In this research, our Rate-Distortion Estimation Model is based on Chou's model. First at all, we consider two kinds of retransmission mechanism.

- Receiver-driven Retransmission
  The retransmission is controlled by receiver. When receiver wants to receive a multimedia data unit, receiver will send a request message to sender ask for the data unit. If in next time slot, receiver dose not receive the data unit, receiver will decide whether resend a request message to sender or not depends on the transmission policy.
- Receiver-driven Aggressive Retransmission
- The different with Receiver-driven Retransmission is that sender will send the data unit continuously until receiver sends an ACK message which represents receiver received the data unit.
- Rate-distortion Estimation
  Expected Distortion Value

$$D_{(L,T)}(\boldsymbol{\pi}) = D_0 - \sum_{\aleph_G(L',T') \in S(L,T)} \Delta D_{(L',T')} \prod_{\aleph_G(L'',T'') \preccurlyeq \aleph_G(L',T')} \left(1 - \epsilon_{\pi(L'',T'')}\right) + \mathcal{C}_{(L,T)}$$

  Expected Transmission Cost Value

$$R_{(L,T)}(\boldsymbol{\pi}) = \sum_{\aleph_G(L',T') \in S(L,T)} \left(B_{(L',T')} + H \cdot N_{(L',T')}\right) \rho_{\pi(L',T')}$$

IV.2 *Transmission Policy Optimization*

- Optimization Algorithm 1

  We used Greedy algorithm to find next possible policies according to extraction path. And then compute the expected rate and distortion choose the optimal improvement from these policies as our next policy. Find out the next policy step by step. Finally, we can get the optimized policy.

- Optimization Algorithm 2

  Algorithm 2 is also greedy but it did not take the extraction paths into account. When we tried to find the next policy, the algorithm will regard all possible policies as candidates even if some of them do not have any dependency with the data units that receiver has already received. Use this algorithm we find out another possible optimized solution.

IV.3 Estimation Results

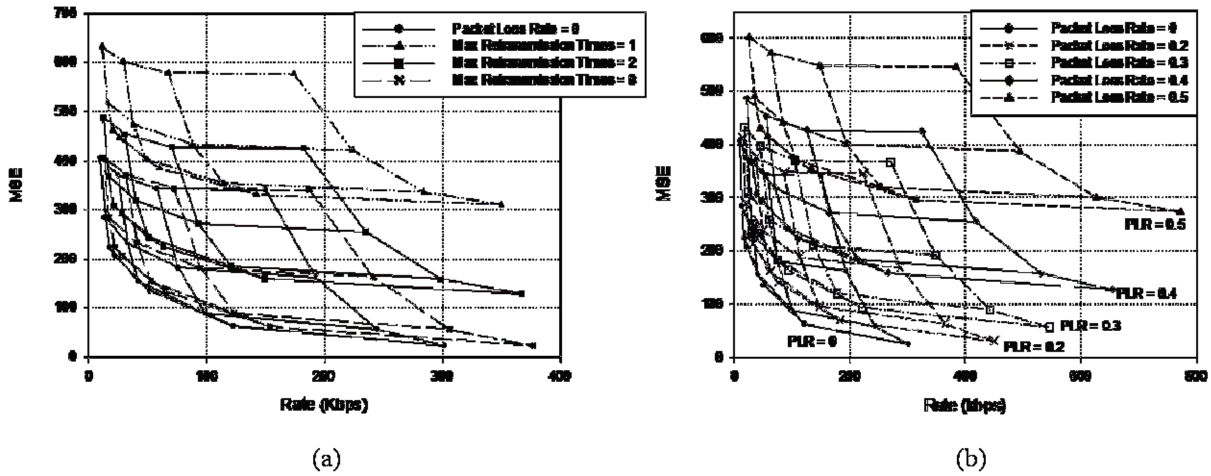


Figure 16: (a) RD Trellis of Different Policies, Packet Loss Rate = 0.2 in Receiver-driven Retransmission. (b) Policy 1, Different Packet Loss Rate in Receiver-driven Aggressive Retransmission

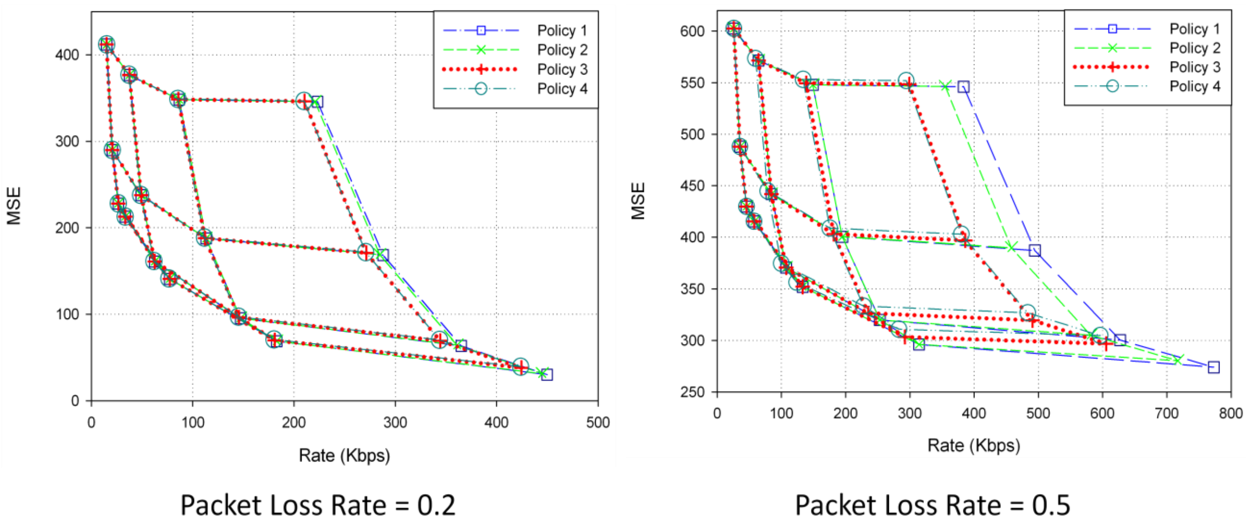


Figure 17: Different Policies, Different Packet Loss Rate in Receiver-driven Aggressive Retransmission

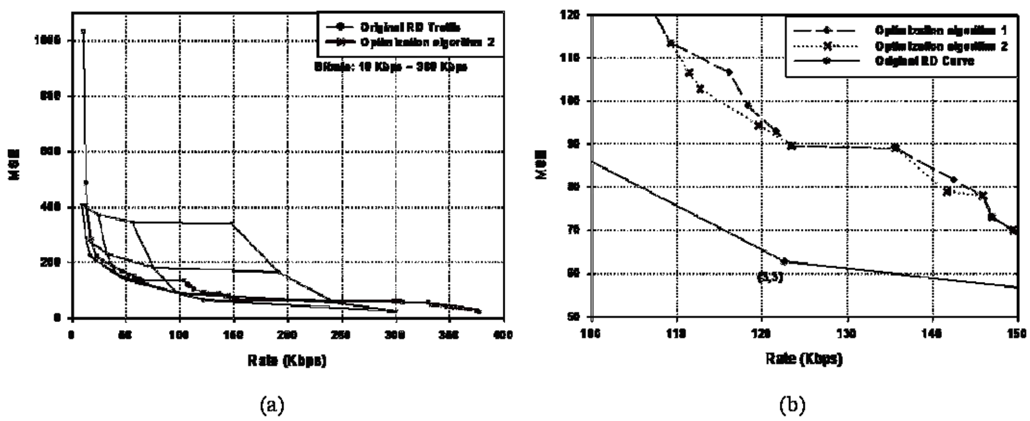


Figure 18: (a) Optimization Algorithm 2 RD Curve of optimal policies. (b) Compare Algorithm 1 to Algorithm 2 Min MSE at Different Bit Rate

V. OPTIMAL DEGREE DISTRIBUTION FOR SHORT-LENGTH LT CODES VIA CMA-ES

An important step in the development of Rateless UEP Channel Codes is to design short data length Rateless Erasure Corrections Codes that exhibit good tradeoff between received symbol counts and decoding failure rates. Since the beginning of 2009, the research team has been trying to design these codes by searching for the optimal degree distribution of short data length LT codes using an evolutionary strategy based on covariance matrix adaptation (CMA-ES).

(A) Algorithm Design

In our initial experiments with the goal to find the optimal degree distribution we set the number of tags equal to 10. The tag values (e.g. 1, 2, 3, 4, 5, 7, 9) represent the number of input symbols connected to one output symbol and were assigned to numbers (mainly primes) between 1 and 200 with dense distribution at the beginning. As the values of tags become higher the tag distribution is becoming more and more spars (according to empirical results this pattern seems to be the most suitable). In all our experiments were LT blocks consisting of 1000 symbols.

(B) Optimization Attributes and Parameter Adjustment

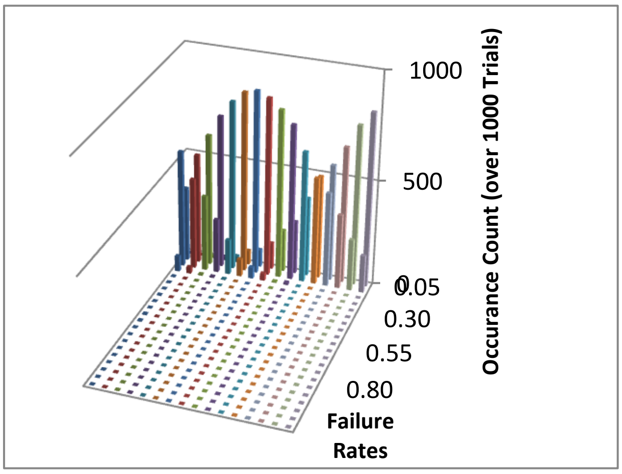
We performed experiments with various optimization criteria and parameter values. Four experiments with the promising results are summarized in the table below.

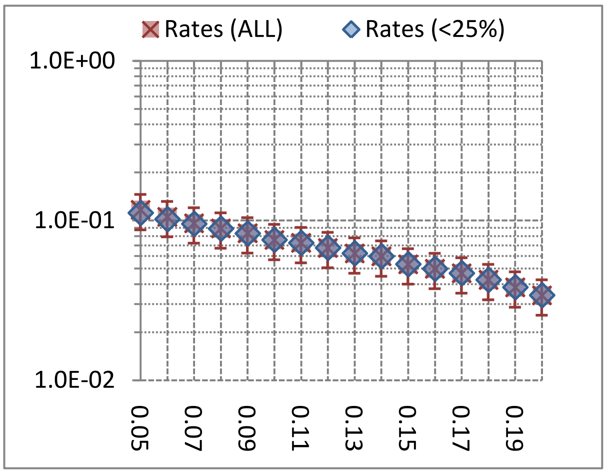
<table>
<tr><th>No</th><th>Optimization (minimization) attribute</th><th>ϵ</th></tr>
<tr><td>1</td><td>Failure rate (number of undecoded symbols within block) of LT blocks, which after decoding had at least half of the symbols correct (500 out of 1000).</td><td>0.05</td></tr>
<tr><td>2</td><td>Failure rate (number of undecoded symbols within block) of all the LT blocks.</td><td>0.15</td></tr>
<tr><td>3</td><td>Cumulative failure rate after taking into consideration following weights:
<table>
<tr><td>Failure Rate</td><td><200</td><td><200</td><td><200</td><td><200</td><td>>200</td><td>>200</td><td>>200</td><td>>200</td></tr>
<tr><td>ϵ</td><td>0.05</td><td>0.1</td><td>0.15</td><td>0.2</td><td>0.05</td><td>0.1</td><td>0.15</td><td>0.2</td></tr>
<tr><td>Weight</td><td>1</td><td>2</td><td>3</td><td>4</td><td>6</td><td>7</td><td>8</td><td>10</td></tr>
</table></td><td>0.05, 0.1, 0.15, 0.2</td></tr>
<tr><td>4</td><td>Cumulative failure rate after taking into consideration following weights:
<table>
<tr><td>Failure Rate</td><td><200</td><td><150</td><td><100</td><td><50</td><td>>200</td><td>>150</td><td>>100</td><td>>50</td></tr>
<tr><td>ϵ</td><td>0.05</td><td>0.1</td><td>0.15</td><td>0.2</td><td>0.05</td><td>0.1</td><td>0.15</td><td>0.2</td></tr>
<tr><td>Weight</td><td>1</td><td>1</td><td>1</td><td>1</td><td>4</td><td>4</td><td>4</td><td>4</td></tr>
</table></td><td>0.05, 0.1, 0.15, 0.2</td></tr>
</table>

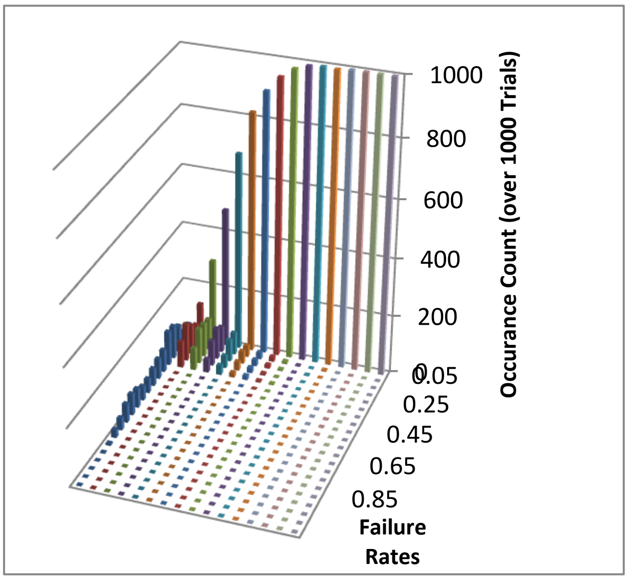
(C) Preliminary Results

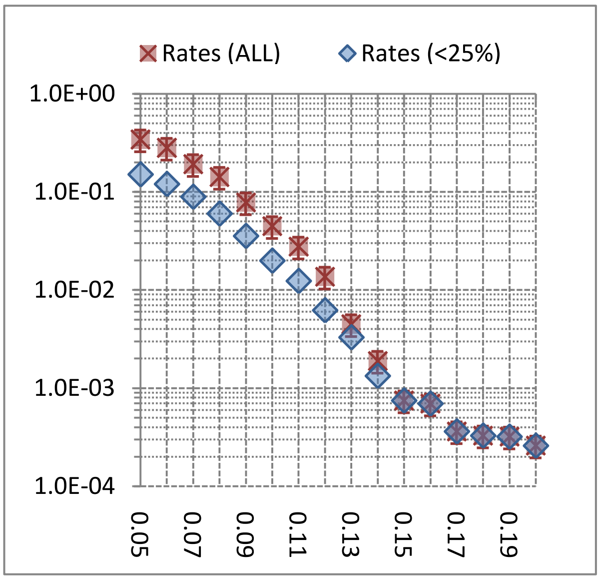
Following diagrams show in the same vcertical order the failure rates of the four cases mentioned in the previous section.

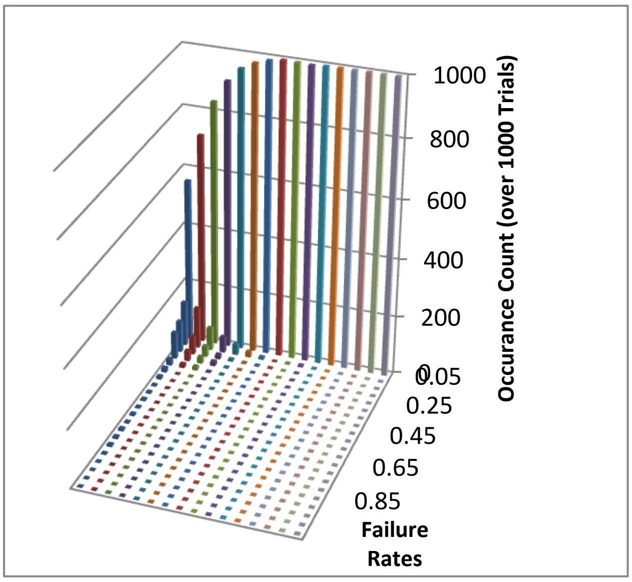
Histograms	Trends

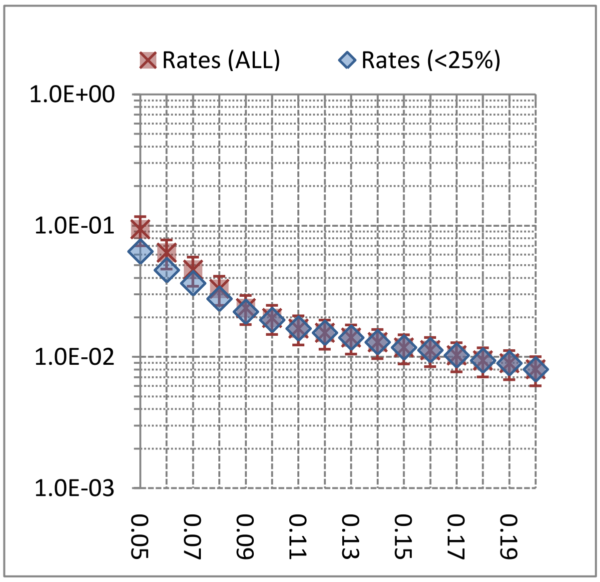


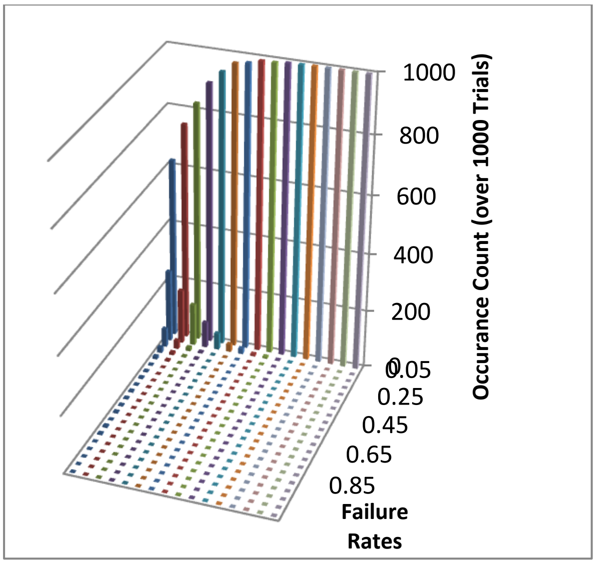


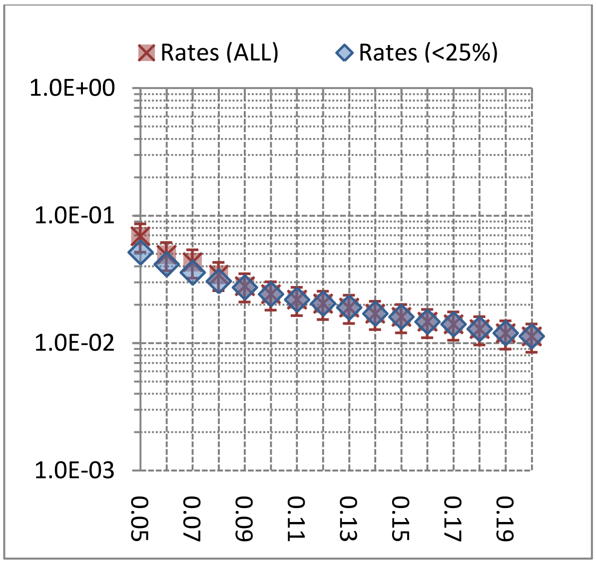




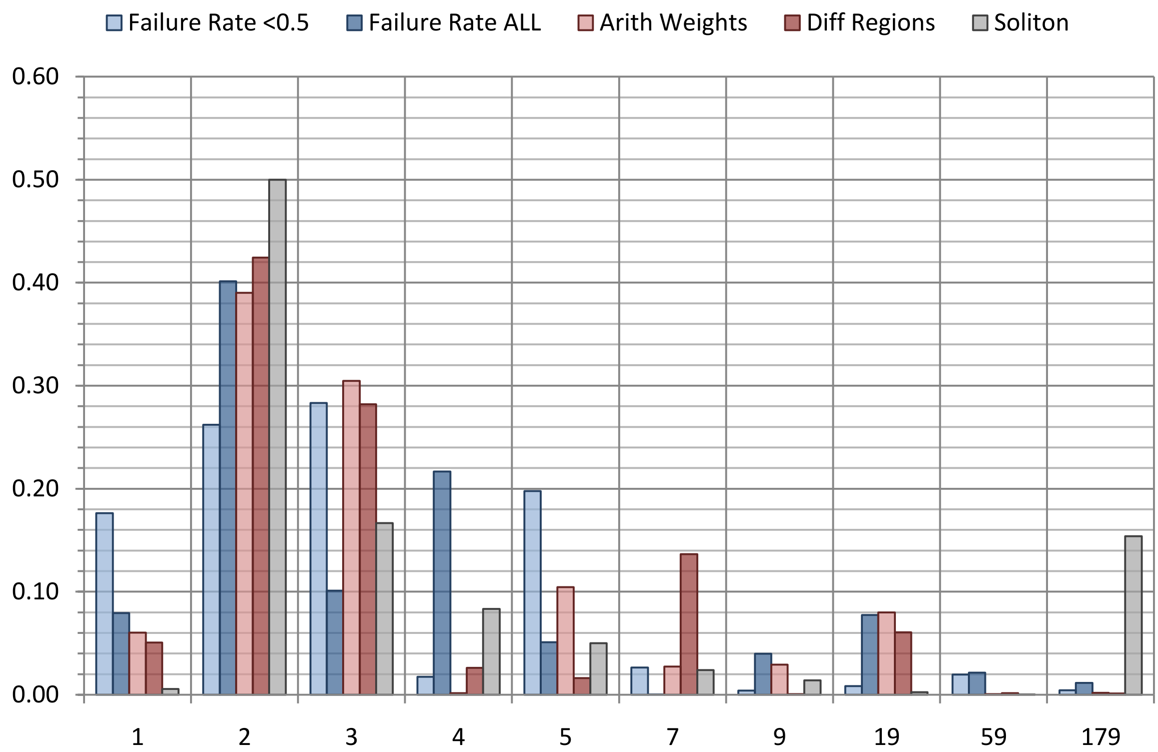








The degree distributions produced by the four experiments as well as that of the Soliton distribution are shown in the following diagram.



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國科會補助專題研究計畫項下赴國外(或大陸地區)出差或研習心得報告

日期：99(2010)年 7 月 21 日

計畫編號	NSC 97-2221-E-009-076		
計畫名稱	兼具高傳輸效率與容錯韌力之異質多層次多媒體群播服務 Transport Efficient and Loss Resilient Heterogeneous Multilayer Multimedia Multicasting		
出國人員姓名	邵家健	服務機構及職稱	國立交通大學 資訊工程學系(所)
出國時間	2008/7/30 – 2008/8/2 2009/11/2 – 2009/11/4	出國地點	香港 (Hong Kong)

一、 國外(大陸)研究過程

This project team began our collaboration with Prof. Robert S.Y. Li's Network Coding Research Center at the Chinese University of Hong Kong (CUHK) since the summer of 2008. During the period of this project, Prof. John K. Zao (PI) visited the research center twice to discuss technical ideas and research plan with Prof. Li and his colleague, Prof. Raymond Young, and their students. Each visit lasted three days with an open lecture on the research being delivered in the 1st or 2nd day. Extensive discussions were conducted after the lecture.

二、 研究成果

The first visit in the early August of 2008 along with Prof. Wen-Hsiao Peng (Co-PI) and Prof. Chung-Hsuan Wang (Co-PI) was meant to establish basic understanding of the two project teams. Prof. Zao, Prof. Peng and Prof. Wang delivered lectures on *heterogeneous multimedia multicasting*, *H.264 SVC video compression standard* and *punctured convolutional codes with unequal erasure protection (UEP) capability* respectively on the first day. Discussions on possible ways to develop Network Codes with Unequal Erasure Protection (UEP) capability and employ these codes in heterogeneous multimedia multicasting were held on 2nd and 3rd days. A road map for collaboration was drawn during this visit.

The second visit at the end of 2009 was a trip to launch the exchange of researchers between the two project teams. Specifically, a PhD candidate from our project team, Mr. Kuo-Kuang Yen (**顏國光**), began his two three-month research internship at CUHK immediately after this visit. In this visit, we proposed three concrete approaches to develop Randomized Linear Network Codes (RLNC) with Unequal Erasure Protection (UEP) capability and started the work on the first two approaches. The results of this research effort will be published by the end of this year.

三、 建議

I sincerely hope that the procedures to establish research collaboration with the universities in Hong Kong will be greatly simplified in the near future.

無研發成果推廣資料

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

　　□實驗失敗

　　□因故實驗中斷

　　□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

Real-time video multicasting over public wired and wireless Internet is widely acclaimed to produce the next wave of Internet "killer apps". This project, along with its predecessor and successors, aimed at developing the key technology for bandwidth efficient and error resilient multicasting applications using the emerging H.264/SVC video compression standard.