Large-scale P2P VoIP/Video Application (TD3c-06)

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Project Overview

Introduction

Network coding provides significant benefits for achieving a high quality and smooth video streaming under Peer-to-peer (P2P) environment, it is an innovative mechanism proposed to improve the throughput utilization of a given network topology. The principle behind network coding is to allow intermediate nodes to encode its received packets before forwarding it to achieve the maximum flow bound on the information transmission rate in a multicast scenario.

Project Objective

This project aims at designing and implementing a network coding mechanism in Microsoft Foundation Class (MFC) to support P2P Video Streaming such that the video information could be propagated efficiently in a large scale P2P network topology.

Advantages of Network Coding

1. Achieve load balancing
2. Attain maximum information flow in a network
3. Enable better resource utilization
4. Compress video information
5. Save bandwidth to transmit video information

Block Diagrams

On the encoder side, it consists of four keys components:

1. Seed Generator
2. Matrix Generator
3. Combiner
4. A standalone media player

Figure 1 – A system diagram of encoder
On the decoder side, an Invertible Matrix Generator has been implemented, which is the necessary component to decode video blocks. On the other hand, a virtual server has been implemented, as the additional feature, to communicate with Window Media Player (WMP) to play live videos.

Figure 2 – A system diagram of decoder

Methodology

Encoding Process

\[
\begin{pmatrix}
\begin{bmatrix}
C_{11} & C_{12} & \cdots & C_{1n} \\
C_{21} & C_{22} & \cdots & C_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
C_{n1} & C_{n2} & \cdots & C_{nn}
\end{bmatrix}

X_1 \\
X_2 \\
\vdots \\
X_n
\end{bmatrix}
\begin{bmatrix}
F_1 \\
F_2 \\
\vdots \\
F_n
\end{bmatrix}
= 
\begin{bmatrix}
F_1 \\
F_2 \\
\vdots \\
F_n
\end{bmatrix}
\]

N-by-N Coefficient matrix Video segment Encoded block matrix

Figure 3 – Linear combination of video blocks in encoding process

Encoded packet can be represented as one row in the matrix

\[
F = \sum_{i \in N} C_i X_i
\]

\[
F_1 = C_{11} X_1 + C_{12} X_2 + C_{13} X_3 + \cdots + C_{1n} X_n \\
F_2 = C_{21} X_1 + C_{22} X_2 + C_{23} X_3 + \cdots + C_{2n} X_n
\]

Decoding Process

\[
\begin{pmatrix}
\begin{bmatrix}
C_{11} & C_{12} & \cdots & C_{1n} \\
C_{21} & C_{22} & \cdots & C_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
C_{n1} & C_{n2} & \cdots & C_{nn}
\end{bmatrix}^{-1}

F_1 \\
F_2 \\
\vdots \\
F_n
\end{bmatrix}
\begin{bmatrix}
X_1 \\
X_2 \\
\vdots \\
X_n
\end{bmatrix}
= 
\begin{bmatrix}
X_1 \\
X_2 \\
\vdots \\
X_n
\end{bmatrix}
\]

Inversed coefficient matrix Encoded block matrix Recovered video block

Figure 4 – Recovering of video blocks in decoding process

\[
X = \sum_{i \in N} C'_i F_i
\]

Where \( C'_i \) be the coefficient in the inversed coefficient matrix
Figure 5 and figure 6 show that the performance of the network coding highly depends on data block size and matrix size. The larger the size of video block (or matrix), the longer the encoding time (or decoding time) consumed in the encoder (or decoder). According to figure 6, the decoding process consumes more time than that in the encoding process if a large matrix size (>=200) is used.

When network coding is applied to improve the efficiency in video streaming, there is always a trade-off among the factor of matrix size, video block size, video bit rate as well as the encoding and decoding time.

Diagram 1 – The graphical user interface (GUI) of the encoder

Diagram 2 – The GUI of the decoder