Final Report **2002-24**

Research

Wireless Transmission of Image and Video Data

Minnesota Guidestar®

Technical Report Documentation Page

<table>
<tr><td>1. Report No.
MN/RC – 2002-24</td><td>2.</td><td colspan="2">3. Recipients Accession No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
WIRELESS TRANSMISSION OF IMAGE AND VIDEO DATA</td><td colspan="2">5. Report Date
April 2002</td></tr>
<tr><td colspan="2">6.</td></tr>
<tr><td colspan="2">7. Author(s)
Vladimir Cherkassky, Xuhao He, Prakash Balasubramanian</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
University of Minnesota
Department of Electrical and Computer Engineering
200 Union Street, S.E.
Minneapolis, MN 55455</td><td colspan="2">10. Project/Task/Work Unit No.</td></tr>
<tr><td colspan="2">11. Contract (C) or Grant (G) No.
c) 74708 wo) 193</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Organization Name and Address
Minnesota Department of Transportation
Office of Research Services
395 John Ireland Boulevard Mail Stop 330
St. Paul, Minnesota 55155</td><td colspan="2">13. Type of Report and Period Covered
Final Report</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplementary Notes</td></tr>
<tr><td colspan="4">16. Abstract (Limit: 200 words)

This project focuses on the issues involved in wireless transmission of video data and addresses two main issues: video compression and quality of service. The report describes the research experiment, analysis, and results.

Researchers compared several compression techniques that are commercially available and recommended wavelet-based compression technique for video compression and network prioritization for issues related to quality of service.</td></tr>
<tr><td>17. Document Analysis/Descriptors
Wireless transmission
Video monitoring
Video compression</td><td>
Wavelet-based compression
Network prioritization</td><td colspan="2">18.Availability Statement
No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161</td></tr>
<tr><td>19. Security Class (this report)
Unclassified</td><td>20. Security Class (this page)
Unclassified</td><td>21. No. of Pages
47</td><td>22. Price</td></tr>
</table>

Wireless Transmission Of Image and Video Data

Final Report

Prepared by:

Vladimir Cherkassky
Xuhao He
Prakash Balasubramanian

Department of Electrical and Computer Engineering
University of Minnesota
Minneapolis, MN 55455

APRIL 2002

Published by:

Minnesota Department of Transportation
Office of Research Services
MS 330
395 John Ireland Boulevard
St. Paul, MN 55155

TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

This project focuses on the issues involved in wireless transmission of image and video data. In this project we focus on the issues of video compression and Network Prioritization which are the key factors to be considered to make efficient use of the limited available bandwidth.

We analyze the above two key factors from the practical implementation point of view. We compared several compression techniques that are available commercially and from our analyses we recommend the use of Wavelet based Compression technique for the needs of Minnesota Department of Transportation (Mn/DOT).

The second key issue is that of Network prioritization. Since the volume of traffic flow is quite high and the available bandwidth is quite low we need to make efficient use of the available bandwidth. Thus we need to prioritize traffic so that time critical applications are given more bandwidth and high priority at times of congestion. For our study we used the commercial network prioritization software, Viziq provided by a local company Envoda. From our analysis we feel that traffic can be organized more easily and efficiently and can be prioritized based on their importance with the help of the software. Hence, we recommend the use of Network Prioritization techniques for the needs of Mn/DOT.

1. INTRODUCTION

Minnesota Department of Transportation (Mn/DOT) is trying to build a traffic video monitoring system based on wireless that can cover the whole highway area within the state for better traffic control and accident instant-reaction. Currently, as an experimental system, the Duluth Transportation Operations and Communications Center (TOCC) Network System is utilizing 2.4 GHz spread spectrum radio link to transmit digitized video from the cameras installed on the highway to the control center. This system uses Motion Joint Photographic Experts Group (JPEG) compression standard for the digitized video which is obtained from fixed and pan tilt zoom cameras. This compression is performed using commercially available AXIS video compression boxes at the source camera. The amount of compression can be set by a privileged operator through the VTOC system and software. The maximum video rate obtained is 15fps. Currently this system does not address any Quality of Service (QoS) issues. The video and other data source go through their dedicated privately owned Local Area Network (LAN).

The growing trend towards wireless transmission of traffic video data places stringent constraints on the transmission of image and video data over low-speed wireless channels.

One obvious way to accommodate this demand is to increase the wireless bandwidth available to all users. Of course, this "solution" is not without technological and economical difficulties. Another way is to reduce the volume of the data that must be transmitted. There has been a tremendous amount of progress in the field of video compression during the past 10 years using wavelet transforms.

Also, to utilize the expensive wireless network resource more efficiently, QoS technologies need to be investigated. QoS refers to the capability of a network to provide better service to selected network traffic.

2. RESEARCH OBJECTIVES

In this project various research issues involved in the wireless transmission of image and video data are explored. These issues will be addressed from the practical implementation point of view. The important issues which are being addressed here are: -

1. Assessing performance of commercial image compression products for wireless transmission.
2. Implementing dynamic priority allocation of computer traffic for wireless transmission environment.
3. Measure / evaluate performance of wireless transmission using realistic prototype system at Intelligent Transportation Systems (ITS) Labs
4. Provide recommendations regarding practical feasibility of wireless image/video transmission with existing commercial products.

2.1 Compression of image/video data

Recently, several commercial products for wavelet-based image compression came up to market. Many of them claim high compression ratio (over 100:1) with extremely small data loss. However, there is little empirical evidence to support these claims for real-life traffic image/video data, because:

- The quality of compressed images is highly application-dependent, so high compression ratios achieved on artificial ‘test’ image data may not be achievable with real traffic video data.
- The quality of compressed image/video data delivered to end - users may be significantly affected by the networking factors. These factors are typically ignored by hardware vendors claiming high data compression ratios for their wavelet compression products.

Hence, our objective is to compare off-the-shelf technologies for wavelet compression using representative traffic data, in a realistic networking environment for wireless image data transmission. These comparisons will be performed in the ITS Laboratory of the Center for Transportation Studies at the University of Minnesota.

2.2 System Architecture and Prototype System Configuration

In order to investigate feasibility of wireless transmission of image/video data, one needs to specify networking architecture for this application. Based on our discussions with Ted Morris, Manager of ITS Lab, we decided on image/video transmission over Internet Protocol (IP) as a general solution approach. Based on this approach, we developed and installed a complete prototype system (housed at ITS Lab) comprising a dedicated wireless network, router/switch gear and several PCs with video wavelet compression/decompression boards. The source inputs will come from loop backs from the ITS Lab video wall. This prototype system allows direct visual comparison of quality of service with ‘real’ live traffic data.

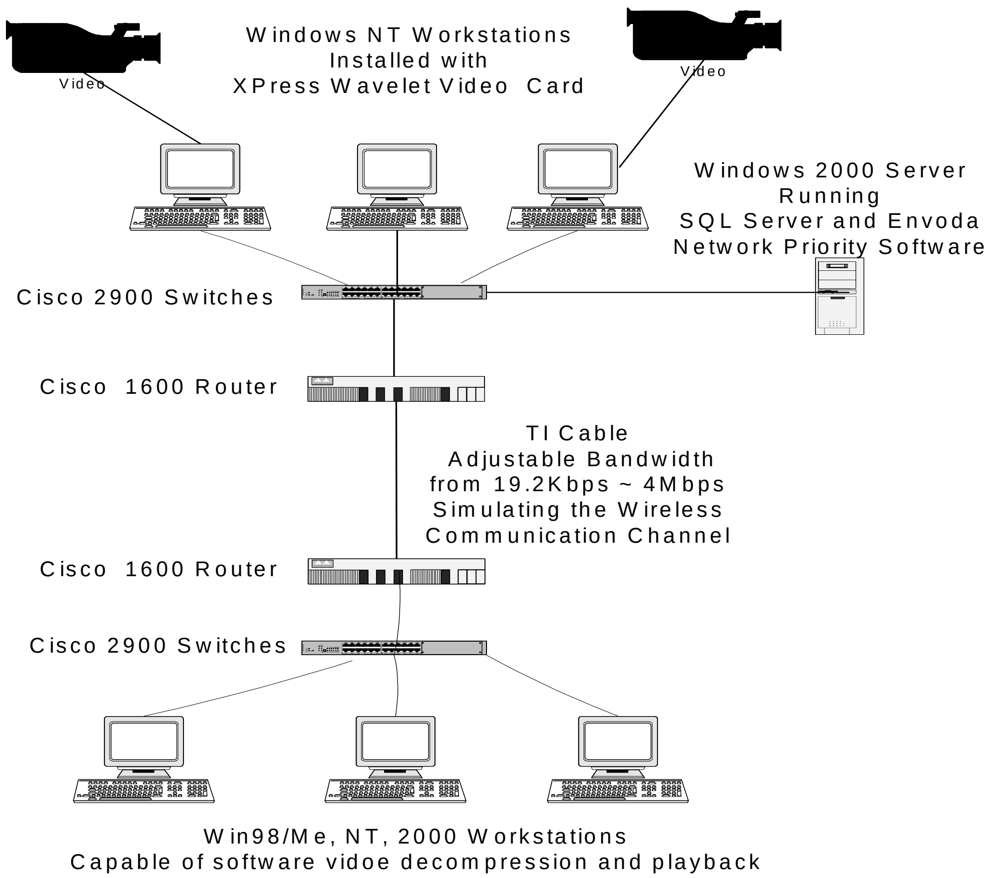


Figure 1: System Prototype

As shown in Figure 1, live video is captured and compressed with wavelet cards installed in Windows NT workstations. The compressed video stream will be transmitted over wireless channels. Right now, a Wide Area Network (WAN) connection between two Cisco 1600 routers simulates the wireless channel. The bandwidth of this link can be varied and set to any value between 19.2Kbps to 4Mbps, which can be set to simulate low-speed Cellular Digital Packet Data (CDPD) analog (at 19.2 kbps) or digital Code Division Multiple Access (CDMA) 1X (144 kbps) or a typical T-1 connection. At the client side the compressed video data which is received is decompressed and displayed. There is no need for any special hardware for decompressing data on the client side since it is performed using a software. This solution in turn decreases the cost of the system as there is no cost involved in getting any new hardware for system expansion. In this prototype system we use *FirstLine Xpress Lite* Wavelet cards manufactured by *Integral Tech Inc.* for performing Wavelet based compression on the server side.

2.3 Networking issues

There are different possible solution approaches to the networking issues for real-time delivery of compressed video data. One possible solution approach is to allocate additional bandwidth as needed. For example, in the case of Duluth TOCC there is no QoS related issue involved since the available bandwidth is enough to handle the video traffic. But, when the number of video sources is increased then the Network traffic is also increased which might result in congestion. It is under this setting that QoS issues play a prominent role and helps in managing network resources. Another solution approach is to introduce priority for different types of network traffic. That is, to allocate sufficiently high priority/ quality-of-service parameters to the traffic data, in order to ensure its real-time delivery over the wireless network infrastructure. Since the network infrastructure is shared by many classes of traffic, it is important to treat different traffic sources based on the policies that can be customized for different types of applications. The main research issue here is to investigate the trade off between the image/video quality and real-time delivery (of this data) to end users for realistic networking configuration shown in Figure 1. In a typical computer network there are different types of data flowing simultaneously. A variety of applications generates this data. Due to unpredictable (statistical) nature of data generated by various applications, there is no guarantee that a particular (time-sensitive) data will reach the destination on time. This is because the existence of several data flows may result in network congestion and unpredictable delays. Hence, it is necessary to provide certain assurance or guarantee to ensure that a particular data will always reach the destination within a given time interval. This is made possible by incorporating Quality of Service techniques in the network. This mechanism is needed to ensure that mission-critical data reaches the destination on time since; delayed transmission may render them useless. Therefore, in such situations Quality of Service techniques play a key role in providing reliable and quality service. In this project we used a software developed by a local Minnesota company *ENVODA*, to study this issue. The software named *Viziq*, provides dynamic priority allocation schemes and can be used to study QoS related issues.

3. Software Development and Implementation

For the purpose of studying the issues involved in the wireless transmission of video, a software called WaveNet was developed. The purpose of this software is to provide a visual medium for comparison of various factors affecting the transmission of video in a wireless environment. The WaveNet implementation uses the following system platform: -

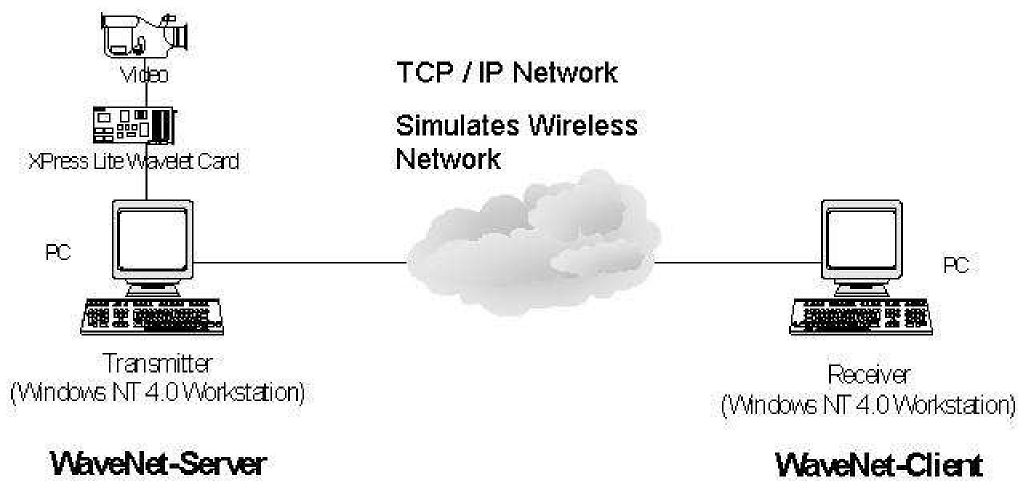


Figure 2: WaveNet System

The system is built upon a hardware platform described as below:

1) IBM-Compatible PC, configured with Pentium III 555Hz CPU, 128M PC133 Memory, Intel 801 Video Card, 100M Ethernet Card

2) First Line XPress Lite Wavelet card, manufactured by Integral Technology Inc.[6]

The PCs are running Windows NT 4.0 Workstation, patched with Service pack 6.0. The software development tool is Microsoft Visual C++ 6.0. MFC class library and C++ language are used so WaveNet is a typical MFC Windows application.

3.1 Functional Specifications

WaveNet-Server is running on the transmitter side. The main function of WaveNet-Server includes:

1) Compress and Display Video in Real-time

The XPress Lite wavelet card is capable of digitizing the input analog video according to CCIR 601 standard. The digital video signal is then compressed using the hardware wavelet encoder at the rate of 30 fields per seconds. All these operations are performed in real-time. XPress SDK is used to integrate the function of this wavelet card into WaveNet-Server. The input video needs to be previewed on the screen.

2) Transmit Compressed Video Data over IP Network

Since User Datagram Protocol (UDP) protocol can reserve the message boundary, it's suitable for transmit the compressed video frame by frame. UDP doesn't guarantee the transmission of service packet. But this doesn't matter since the wavelet compression of XPress card is done on each individual frame with no inter-frame dependency. The loss of one frame doesn't affect the correctness of the decompression of subsequent frames. A UDP connection will be set up between WaveNet-Server and WaveNet-Client to transmit the compressed video data.

3) Control Transmission Frame Rate and Compression Ratio

For traffic monitoring purpose, we don't need to transmit at 30 frames per second. So the Server should have control on the transmission frame rate according to the network bandwidth. Also, the server should be able to change the image quality in response to clients' requests. With wavelet compression, the image quality can be easily controlled through changing the compression ratio.

4) Exchange Control Message between WaveNet-Server and WaveNet-Client

The WaveNet-Server and WaveNet-Client need a communication channel to exchange control information such as WaveNet-Client UDP port number, the compression ratio and the client requested play back frame rate. We can use the UDP connection used for video data to transmit such control information. But, since UDP doesn't guarantee end to end delivery, losing such critical information is not acceptable. So we need a separate Transmission Control Protocol (TCP) connection for these control messages. In implementation, the WaveNet-Server will create a thread to listen on a pre-determined TCP port. WaveNet-Client then can connect to this port and create a TCP connection with the server.

This connection will be alive through out the lifetime of the client and it is used by the client to transmit to the server critical control messages such as client UDP port number, client preferred image compression ratio and frame rate.

WaveNet-Client is running on the receiver side as a client to receive wavelet-compressed video data from the server side. The functions of WaveNet-Server are:

1) Setup Communication Channels with WaveNet-Server

The client needs to create a UDP socket and binds it to a dynamically chosen UDP port. This UDP socket is used to receive video data from the server. The client also needs a TCP socket to connect to the server to setup a TCP connection. Through this connection, the client can let the server know its IP address and UDP port number. With these two pieces of information, the server knows where to send the video data. Also, all other control messages will go through this TCP connection.

2) Receive Wavelet-compressed Video Data and Playback

The client needs a thread to wait on the UDP socket. Once it receives a compressed frame encapsulated in a UDP packet, it needs to decompress it and get bitmap stored in a buffer. Then it needs to display this image on the screen. The above steps when repeated will produce a continuous sequence of frames on the screen.

The decompression is performed by software installed on the client side. The time taken for decompressing and displaying the video data on the screen is limited by the Client's hardware configuration. If the processing speed of the client is slow then it can act as a bottleneck and affect the data rate. So, the playback frame rate depends on the receiver system's configuration also. For example, if the client can playback only 10 frames per seconds, then there is no need for the server to send data at a rate higher than 10fps. This can in turn prevent the server from flooding the network and can help save limited network resources. In this case, the hardware configuration of the client acts as a bottleneck in determining the maximum data rate that can be achieved by the system.

3) Compression Ratio Adjustment

The decompressed image will be displayed on the screen and seen by end users. The user can judge the image quality subjectively. Good quality images need more network bandwidth to transmit. When network bandwidth is limited, the user needs to make a choice between better image quality and faster frame rate. Thus, Bandwidth requirement is a function of Frame rate and Compression Ratio. For a given data rate bandwidth requirement can be reduced by increasing the Compression ratio. This in turn affects the quality of the video. Similarly, for a given compression ratio bandwidth requirement can be reduced by decreasing the data rate. This in turn affects the continuous motion of the image on the screen and can result in bad video quality. Hence, proper tradeoffs are necessary to adjust the data rate and compression ratio depending on the bandwidth requirement and the quality of the video requested by the user. For this purpose the user should have control over the compression ratio and/or the frame rate. Therefore, the client can then transmit the user requested video settings to the server. The server will then adjust certain parameters that will affect the video quality. This feature can be applied to different application settings. For example, when the available bandwidth is quite high, say 4MB and the maximum data generated by the applications is hardly 2-3MB then there is no need for any compression and hence, the compression factor can be set quite low. On the other end if an application setting has a limited bandwidth say 2MB and the video data generated by many applications could easily exceed the limit then compression could be of great help. The compression ratio for this application can be set so that they can be transmitted within the available bandwidth limit.

3.2 Screen shots of the WaveNet System

Figure 3 shows the window of a running WaveNet-Server. The image displayed in the window is the original one (uncompressed). The WaveNet-Server displays the live video in this window while doing compression and data transmission in the background.

Figure 3: WaveNet-Server Main Window

For traffic monitoring purpose, it's not necessary to transmit 30 frames per seconds. The WaveNet-Server can let the operator control the transmission frame rate. This can be done by choosing the menu **Tool-> Set Sending Rate …**, so a dialog box will pop up to let the operator to choose how many frames to send to the client per second. See Figure 4.

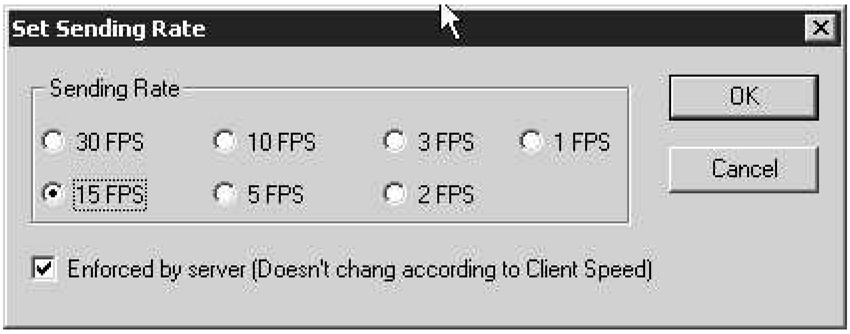


Figure 4: Illustration of frame rate control on the server side

Figure 5 shows the running window of WaveNet-Client. The image is compressed at ratio 50:1.

Figure 5: WaveNet-Client Main Window

Because the client users will see the compressed image, they can judge the quality of the image subjectively. WaveNet system leaves the control of the image compression ratio to the client users. Choose menu **Settings ->Compression Ratio**, a dialog will popup to let the user adjust the compression ratio accordingly. See Figure 6

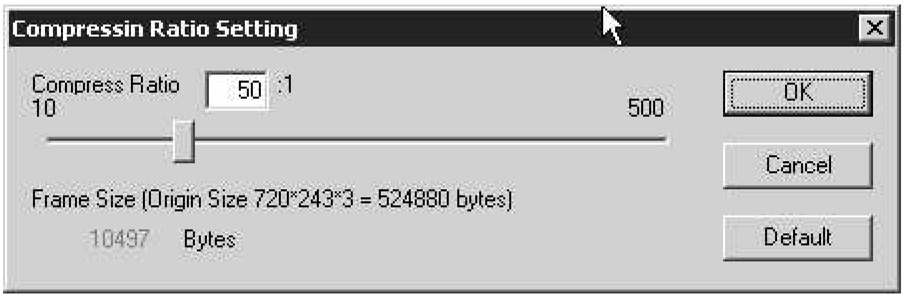


Figure 6: Illustration of compression ratio control on the client side

WaveNet system satisfies the objectives mentioned and can be used as a tool for testing the Qos related issues.

4. DISCUSSION OF WAVELET COMPRESSION

In this project various compression techniques image and video data was studied. It was found that wavelet based compression technique is better suited for this type of application. The following discussion briefly summarizes the advantages of Wavelet compression over other compression techniques.

• Graceful degradation at high compression ratios

Wavelet-compressed video provides good video quality even at high compression ratios. The wavelet algorithm is run on the entire frame at once, which tends to eliminate distracting artifacts that are characteristic of other compression schemes. Many other compression schemes, namely JPEG and Moving Picture Experts Group (MPEG) standards, use the discrete cosine transform (DCT), which must be run on small blocks within an image to meet the computational constraints. Although the DCT performs very well at lower compression ratios, block-shaped artifacts become highly visible at high compression ratios. A comparison of wavelet compression methods and JPEG is shown in Figure 7.
(Ref: http://www.seas.upenn.edu/~ksl/Classes/TCOM502/Wavelets)

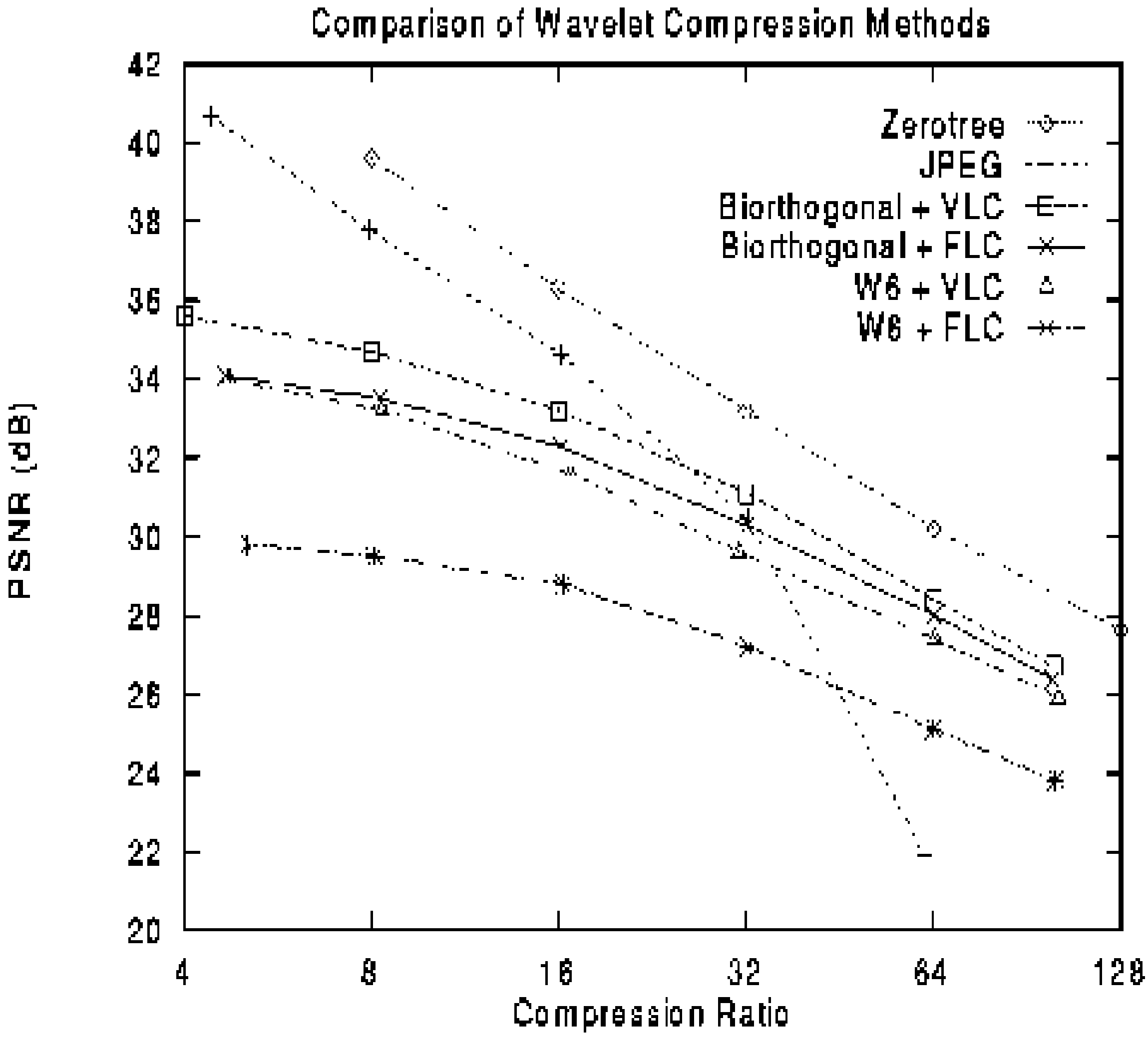


FIGURE 7: Comparison of Image Compression Results

It can be seen from the above figure that JPEG performs well for low compression ratios. But, when the compression ratio exceeds 30, Peak Signal to Noise Ratio (PSNR) of JPEG decreases drastically while wavelet-compressed images degrade more gracefully.

A comparison for real images is shown in Figure 8. The first image is the original one. The second image is compressed using wavelet at 64:1. The third image is JPEG compressed to match file size of the wavelet compressed image.

(a) Original Image

(b) Image compressed by DWT

(c) Image compressed by JPEG

Figure 8: Comparison of images Compressed by DWT and JPEG

• Motion detection

Wavelet compression lends itself well to motion detection; some of the video information that is obtained through the compression process may also be used to detect motion at a minimal additional cost. This feature helps in traffic monitoring and motion detection. For example it can be used to detect unauthorized movement of vehicles in restricted zones. The motion detection may even be localized to a particular area of the picture, allowing a program to detect motion in some areas of the picture while ignoring other areas. This feature provides flexibility since certain portions of the frame can be highlighted and can be used to monitor traffic.

- **Controllable data rate**

The wavelet compression algorithm is flexible, and it can be used to achieve a wide range of compression ratios. This feature enables a user to specify a limit on the size of data that can be transmitted. Hence, the video data can be compressed according to the specified limit. This flexibility enables automatic change of compression ratio depending on the available bandwidth. Hence, compression ratio can be set high during network congestion and low during light network load.

- **Frame preservation**

The wavelet algorithm is run on each individual frame with no inter-frame dependency, which allows for camera switching between frames and makes video less blurry. In contrast, MPEG-based compression exploits temporal redundancy—that is, portions of one frame are used to generate the next frame. This scheme does not work well when there is a high degree of motion because one frame “bleeds” into the next.

The proposed software implementation (of compression) can be applied (in principle) to other compression schemes such as JPEG based compression which is used in the Duluth TOCC. However, certain features of the software are quite useful when applied in a setting which makes use of Wavelet based compression. For example, the feature “client controllable compression ratio” is quite useful under a Wavelet based scheme since it offers a wide range of compression factors.

5. WaveNet System for Wireless Transmission of Traffic Video

The WaveNet system can implement the trade-off between the frame rate (fps or frames-per-second) and the image compression ratio for transmission of video data over limited bandwidth wireless channels. Since both factions (fps and compression ratio) affect the bandwidth this trade-off depends on the video quality as determined by application needs.

Some applications require continuous video flow and higher frame rate, at the expense of higher compression rate. This can be achieved by increasing the frame and at the same time increasing the compression factor, in order to satisfy limited bandwidth constraints.

Other situations may demand clearer video, that is video with low compression factor. For example, the video quality should be clear enough to see the license plate of the vehicle. In this case high compression ratio might cause blurring of the license plate. Hence, it is necessary to maintain a low compression factor. Lowering the compression factor requires lowering the frame in order to satisfy the bandwidth constraint.

From our study we found that the compression rate of 60:1 and the data rate of 10fps would be acceptable for most of the traffic monitoring applications. This setting would require a bandwidth less than half of a typical T1 connection.

6. Issue of Network Prioritization

In a typical IP based computer network congestion is unavoidable when the network bandwidth is limited (as in the case of wireless networks). This issue comes into greater focus during transmission of video or image data that require a lot of bandwidth. The solution approach being investigated in this project is based on downgrading of certain types of network traffic (including video), which in turn may affect the visual quality of the video data received. This approach leads to the need for dynamic prioritization the traffic so that certain types of traffic are least affected during congestion at the expense of others. This is achieved by allocating high priority to certain important mission-critical applications at the cost of downgrading others.

In this project, which is concerned with video over wireless there is a possibility that video from more than one source may share the same network bandwidth. If all sources of the video data are downgraded uniformly, that would degrade the video quality received from all sources. This is where the issue of prioritization comes into play. In most situations we are not worried about the video data from all the sources. We are interested in particular about one or two of the video source. For example, if there is an accident, we might be interested in that particular video source where the accident occurred. So, we might want that particular video to be of high quality. For this we might have to increase the frame rate and decrease the compression ratio to improve the video quality. This in turn results in increased bandwidth requirement for that particular video source. Since we are not interested in the quality of other video sources at this time we can degrade these video sources and provide higher bandwidth to the video source where the accident occurred. This can be done by assigning high priority to that particular video source. Therefore, all other video sources will be downgraded to provide Quality of Service to the high priority source.

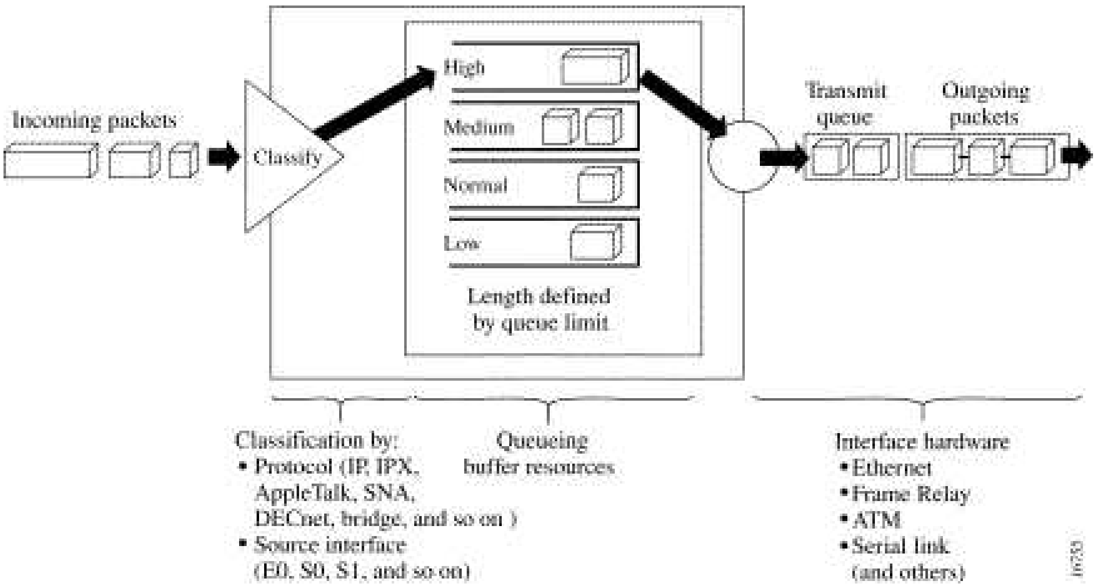
In order to provide such functionality we use a commercially available dynamic priority allocation software called *Viziq* provided by a local company *Envoda*. This software provides the option of allocating six different priority levels to different network connections based on the destination IP address and port number. Using this software we can configure our application in such a way that a particular video source receives higher priority than other sources during congestion. Under such a configuration during congestion the high priority traffic is allocated more bandwidth and this yields a visually good quality video at the expense of downgrading other video sources.

6.1 Brief discussion of *Viziq*

Viziq is a network traffic management system that enables enterprises to take control of their communications networks and elevate them to a strategic level. Viziq works by monitoring network traffic and prioritizing those applications an organization deems most critical. Network managers achieve end-to-end QoS, greater insight and control of their networks, and enable network convergence through the deployment of cost-saving technologies.

Network traffic is managed by creating policy-based classes of service that discriminate among the business-critical traffic on the network, recognizing that various applications have different needs and/or requirements. Policies are based on users, applications, and time of day. It is possible to exert extreme control over network resources. For example, a policy could be created for a specific user, a specific application for any hour of the year. Moreover, the system provides real-time network monitoring, modeling, analysis, and reprioritization to resolve bandwidth contention in real time.

Typically traffic is classified based on different criteria based on their required priority. It basically uses the concept of Weighted Fair Queuing. The Cisco router through which the traffic is routed is configured to categorize the incoming traffic and give more bandwidth to high priority traffic. The Figure 9 illustrates this approach: -



Courtesy: Cisco (www.cisco.com)

Figure 9: Illustration of Network Prioritization

Thus using *Viziq* Network prioritization software the traffic can be classified and highly important emergency traffic can be given a high priority in terms of more bandwidth at the expense of not so important traffic. This in turn makes sure that congestion does not degrade the performance and delay high time sensitive traffic.

To study the effect of network prioritization on a traffic monitoring system, we configured a couple of servers to transmit video from the same video source. We then configured several clients to receive the video data. Using the traffic prioritization software we assigned a high priority to one of the client and low priority to the other client. We then used a traffic generator to introduce traffic in the Network. Initially we set the bandwidth to 4Mbps. For both the source the compression ratio was set to 60:1 and the sending frame rate was set to 10fps. The data generated in this case was approximately 1.4Mbps which is much less than the available bandwidth. Hence, the video quality at both the clients was good. We then slowly increased the amount of traffic and monitored the corresponding change in video quality in the two clients. When the bandwidth is sufficient to handle the incoming traffic then the video on the both the clients continued to be smooth. At one stage we then increased the traffic so that the amount of data produced is greater than the available bandwidth of 4Mbps. At this state the bandwidth available is too small to handle the traffic and hence resulted in congestion. During congestion we found that the traffic to the high priority client continued to flow and the video quality was smooth but, the video quality of the low priority client was very bad and it occasionally freezes.

This is because we have configured the system to provide bandwidth to the high priority traffic before allowing other not so important traffic to utilize the bandwidth. The behavior of the system during congestion is shown in Figure 10: -

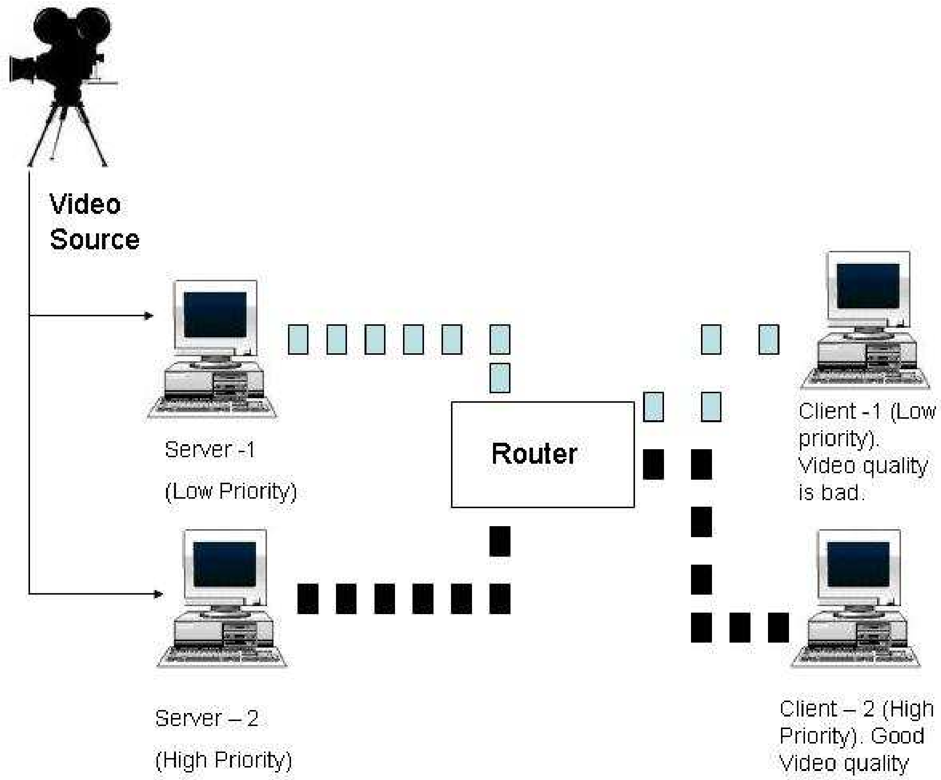


Figure 10: Illustration of system behavior during congestion

As can be seen from the above figure, when there is congestion the router gives preference to the high priority video traffic. Hence, the high priority video data is given a bulk of the bandwidth and preference over the low priority data. The leftover bandwidth is utilized to send the low priority data. As a result, many data packets of the low priority client gets timed out and dropped or does not reach the client on time. Hence, the video quality of the client is very bad. But, this in turn ensures that the high priority data reaches the client on time and hence, the video quality of the high priority client is relatively good.

Our research results shows that this prioritization of network traffic is essential when the bandwidth is limited and the data flowing through this limited bandwidth is quite huge which is typical of a wireless environment. Also, with the help of this scheme it is possible to multiplex traffic from different sources onto a single channel.

7. Combining Compression and Prioritization

As discussed in the previous two sections, the issue of compression and prioritization if handled carefully can result in better and efficient use of the networks resources. However, several issues and tradeoffs are involved in combining the above two issues. There is a limit beyond which compression has no effect on the size of data. Also, beyond a certain compression limit the quality of video might be so bad that it would be of no use. Hence, depending on the application requirements a limit on the compression value has to be set.

Similarly, the issue of prioritization also affects the fps of the video. For example, in order to give a high priority to one of the video client the router may drop or delay the packets to other video clients which in turn decrease the fps of the other video clients. Hence, this issue involves various trade-offs between compression and prioritization. This issue can be resolved based on the application needs. For example, in a typical traffic monitoring system in case of emergency if video quality from a particular source is important then, we can lower the compression ratio thereby increasing the quality and increase the prioritization thereby maintaining the data rate (fps). In certain situations it might be enough if we get a continuous and high data rate with not much emphasis on the video quality. In such situations it is enough to increase the priority of the video source to maintain a high fps keeping the compression value to a constant.

As can be seen from the above situations depending on the application requirement at a particular point of time the priority and compression can be set. This is determined based on the available bandwidth. Increasing the priority of a particular video source decreases the fps of the other video sources for a given bandwidth. Whereas, increasing the compression reduces the video quality but increases the available bandwidth.

8. CONCLUSION AND RECOMMENDATION

This study was broadly divided into two parts.

In the first part of our project we studied various compression techniques and demonstrated the use of Wavelet based compression product (called Xpress Lite) for the needs of Mn/DOT. This product is offered commercially by Integral Technology Inc.

In the second part of our project we investigated Networking (Quality of Service) issues. In particular we implemented network prioritization solution approach (using commercial software) to address QoS issues for video data transmission. From our study we think that prioritizing traffic makes efficient use of limited available bandwidth as in the case of wireless medium. Therefore, we recommend the use of network prioritization software for the needs of Mn/DOT.

We have investigated various trade-offs between the bandwidth requirement and video quality, using the experimental prototype system. In particular, there is a trade-off between the video frame rate and the compression ratio for given (available) bandwidth.

As mentioned earlier in section 5 there may be two application settings corresponding to different application requirements.

For the application setting where the frame rate is important, fps can be set to 15fps and compression ratio to 60. This requires a bandwidth of approx. 1 Mbps. The bandwidth can be further reduced to one half of T1 (750Kbps) by increasing the compression ratio to 90:1.

For the application setting where the image clarity is of importance, compression ratio can be set to 40 and frame rate to 10 fps. This requires a bandwidth of approx. 1Mbps. The bandwidth can be reduced to one half or T1 by decreasing the frame rate to 7fps.

9. FUTURE WORK

Future work in this area would include investigation of practical usability of video/image transmission over 'typical' wireless channels. This will be mainly concerned with investigating alternative forms of streaming video as described as follows.

The practical utility of quasi-real-time-video, i.e. short bursts of "full motion" followed by seconds or minutes of still motion can be studied. This is one of the solution approaches to overcoming bandwidth constraints of the wireless medium. Another interesting possibility is to investigate 'on-demand' video transmission, where the traffic monitoring authority can effectively control video quality. That is, the system will support low quality video transmission which is adequate for low-bandwidth connections unless a human operator requests a 'full motion' video.

Also, the future work may be concerned with trying reducing the bandwidth constraint further by considering alternative options for video transmission. For example, delayed or deferred video transmission can be considered where the video that is seen by the end-user is not the actual 'live' video. This may be quite useful in preventing or avoiding network congestion and the video can be deferred for transmission when the network load is normal.

The present Duluth based TOCC does not address any QoS issues. As the number of video source is increased or expanded this might prove to be a problem, since efficient use of bandwidth is needed. Duluth based TOCC can be used as an experimental system to study the above-mentioned alternatives.

References

- Amara Graps, "An Introduction to Wavelets," IEEE Computational Science and Engineering, vol. 2, no. 2, Summer 1995.

- Jerome M. Shapiro, "Embedded Image Coding Using Zerotrees of Wavelet Coefficients," IEEE Transactions on Signal Processing, vol. 41, no. 12, pp. 3445-3462, Dec. 1993.

- Michael L. Hilton, Bjorn D. Jawerth, and Ayan Sengupta, "Compressing Still and Moving Images with Wavelets," Multimedia Systems, vol. 2, no. 3.

- Po-Yuen Cheng, Jin Li, and C. C. Kuo, "Video Coding Using Embedded Wavelet Packet Transform and Motion Compensation," University of Southern California.

- Robi Polikar, "The Engineer's Ultimate Guide to Wavelet Analysis."

- Integral Technology Inc., “XPress Software Development Kit Manual”, October 1999

- David J. Kruglinski, “Programming Visual C++ Fifth Edition”, Microsoft Express, 1998

- DirectDraw reference
  http://www.gamedev.net/reference/articles/article608.asp

- Wavelets Reference
- http://www.seas.upenn.edu:8080/~ksl/Classes/TCOM502/Wavelets/

- Viziq Network Prioritization Software Documenation,
  http://www.envoda.com/includes/ViziqExecutiveOverview.pdf

- Cisco congestion Management overview
  http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fqos_c/fqcprt2/qcfconmg.htm

- Cisco 1600 Series routers Documentation
  http://www.cisco.com/univercd/cc/td/doc/product/access/acs_mod/1600/index.htm

- Intel Networking – TrafficPrioritization
  http://www.intel.com/network/white_papers/priority_packet.htm