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COMPARATIVE STUDY AND ANALYSIS OF MULTIMEDIA TRAFFIC OVER AD HOC NETWORK

JAYESH N. MODI

Department of Computer Science, MCA Program, HNGU, Patan, Gujarat, India

ABSTRACT

Easy configuration and quick deployment of Wireless Ad hoc Networks make such networks more suitable for various applications including multimedia applications (e.g. VOIP, video conferencing etc). The traffic patterns (video and audio streams etc) generated by multimedia applications are more complicated than those of simple voice and data traffic. The available bandwidth for Wireless Ad hoc Networks fails to meet the requirements of multimedia transmission, which results in packets loss, delay and decrease the quality of transmitted multimedia data. Network Coding is a technique which can be used to overcome such problems over Wireless Ad hoc Networks. In Network Coding technique, it allows a node to combine data (packets) received from different input links, encode received data and send encoded data on its output links (instead of just storing and forwarding). In this thesis work, a variant of Network Coding that is Random Linear Network Coding (RLNC) with Multi Generation Mixing (MGM) is employed for MPEG-4 video traffic. In this work, each sender node encodes packet using RLNC with MGM with the aim to provide more protection to I frames. In MGM, mixing set size number of I packets (Intra frames) are encoded together in one generation and enough number of copies is forwarded over the network. In order to provide more protection to packets of I frames, I packets are encoded with P (Predictive frames) packets in another generation and enough copies of mixed IP packets are generated and forwarded over the network. Similarly, I and P packets are encoded with B (Bidirectional frames) packets and enough copies of IBP mixed packets are generated and forwarded over the network. In this thesis work, simulations are carried out by changing protocol parameters and its effects on network parameters and performance parameters are analyzed. Simulation results confirm with intuition that the performance get enhanced using Random Linear Network Coding with MGM.

KEYWORDS: Transmission, Ad Hoc Network, Computer Science

ABBREVIATION

NC	NETWORK CODING
RLNC	RANDOM LINEAR NETWORK CODING
MGM	MULTI GENERATION MIXING
JPEG	JOINT PHOTOGRAPHY EXPERT GROUP
MPEG	MOVING PICTURE EXPERTS GROUP
GoP	GROUP OF PICTURES
POMDP	PARTIALLY OBSERVABLE MARKOV DECISION PROCESS
MBMS	MULTIMEDIA BROADCAST MULTICAST SERVICE
AP	ACCESS POINT

INTRODUCTION

Multimedia transmission over Wireless Ad hoc Networks suffers from limited bandwidth, unreliable channel, change in topology, and nodes with heterogeneity, distributed environment and high packet loss rate. Because of such challenges present in Wireless Ad hoc Networks, it is difficult to meet node's requirements such as multimedia transmission with low delay and low packets loss. In such scenarios, Network Coding and its variants can be used by nodes to meet different requirements. Network coding changes the role of network nodes from traditional routing or store and forward to encode the data packets. Encoding process includes mathematical operations on data packets. This thesis work has considered number of theoretical and practical scenarios where network coding or it's variant applied on multimedia traffic with the aim to improve performance and to provide protection against packet losses. This thesis work has mainly focused on the performance enhancement of Multimedia traffic over Wireless Ad hoc Networks using Random Linear Network Coding with Multi Generation Mixing. Using Multi Generation Mixing, packets of greater importance has got more protection.

NETWORK CODING

Network Coding was introduced as an alternative to traditional routing. In a traditional packet-switched network, data flows in defined, discrete "pieces" from the source to the destination. At the transmitting station, the outgoing message is broken into packets, each of which contains some of the message data intact. The packets do not necessarily all travel along the same route but they all eventually arrive at the same destination, where the receiving computer reassembles them into the original message. The main problem with this method is that when the overall network traffic volume is high; bottlenecks are common, resulting in long delays. Packets tend to bunch up at certain nodes and other routes & nodes may remain under utilized.

In 2000, decisive work has been done by Ahlswede et al to introduce the network coding model for the problem of communicating information in networks. On the other hand, as per some other web references the concept of network coding was first introduced by R. W. Yeung and Z. Zhang in 1999 as an alternative to routing. But they showed the extended capabilities of intermediate nodes to code incoming packets to give greater information throughput than in the traditional routing scheme. NC is considered as a field of information theory and coding theory. NC can be used to attain the maximum possible information flow in a network. The core notion of NC is to allow and encourage mixing of data at intermediate network nodes. A receiver receives encoded data packets and deduces from them the packets those were originally intended for the receiver. Network Coding has been shown to provide an elegant solution to scheduling problems and also reduces the number of control messages exchanged in the network.

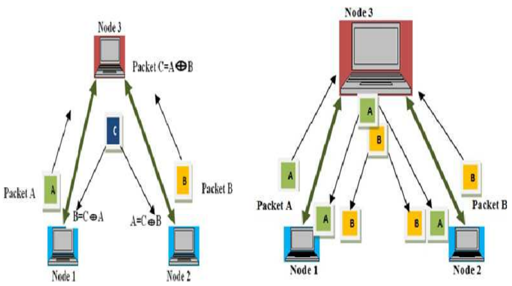

Figure 1: Concept of Packet Transmission Using Network Coding and without Using Network Coding

Network Coding technique can be used in wired as well as in wireless networks to improve the performance of network. Network Coding can be used for performance improvement in terms of achievable throughput, resource consumption and load balancing for uni-cast, multicast and broadcast flow of traffic.

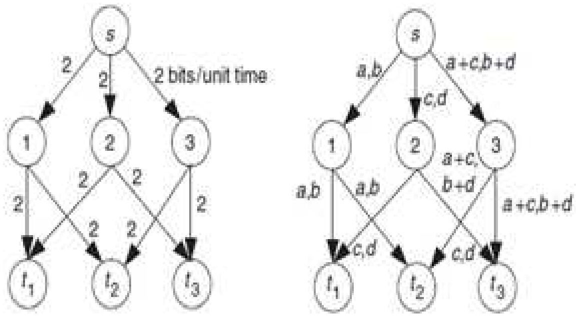

Figure 2: Shows Capacity of Each Link Represents Network Coding

In Figure 2 the capacity of each link is shown and the source S should send four bits (a, b, c and d) to t1, t2 and t3 simultaneously. In Figure 2 network coding is shown and '+' denotes modulo 2 addition. In this example, information is coded at the source node. At t2, c can be recovered from a and a+c and d can be recovered from b and b+d. a, b, c and d can also be recovered at t3. The benefit of network coding which can be known from this example is the transmission rate achieves 4 by using network coding. If network coding is not allowed, a, b, c and d cannot be sent to t1, t2 and t3 in unit time. So using network coding increases the throughput.

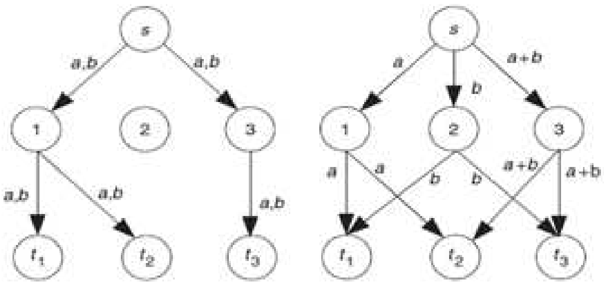

Figure 3: Conventional Routing Represents Network Coding

Random Linear Network Coding (RLNC)

Random Linear Network Coding is a variant of Network Coding. Random Linear Network Coding works well over Wireless Networks to improve performance of multimedia transmission. In RLNC, the node Combines number of packets (each Packet of length L exactly) it has received or created into one or several outgoing packets of L exactly, that's why it is called Linear. It is called Random because nodes draw coefficients (these coefficients are sent to the destination in the packet header) at random from a finite field to form Random Linear combinations. It can be implemented in a distributed fashion, which makes it particularly suitable as a framework for dynamic and unstable networks. In RLNC, outgoing packets are Linear combinations of the original packets, where addition and multiplication are performed over the field F2s. An encoded packet carries information about several original packets.

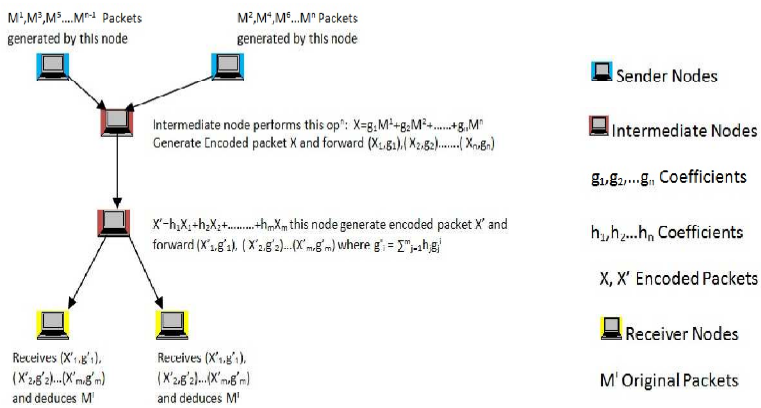

Figure 4: Represents Random Linear Network Coding

Encoding

M1, ...,Mn are original packets generated by one or more sources. The encoded packet X = Pn i=0 giMi, where sequence of coefficients g1, .., gn are chosen uniformly at random over the field F2s . The summation is to be done for every symbol in a vector of L/s symbols in a packet, i.e., Xk = Pn i=0 giMi k, where Mi k and Xk is the kth symbol of Mi and X respectively. Coefficients vector g = (g1, .., gn) are also sent in the encoded packet along with encoded data X. Forwarding nodes can also do encoding on already encoded packets. Consider a node that has a set (g1,X1), ..., (gm,Xm) of encoded packets, where gj is the encoding vector of the jth packet and Xj is the information vector of jth packet. This node can generate a new encoded packet (g',X') by selecting uniformly at random a set of coefficients h1, ..., hm and computing the linear combination X' = Pm j=1 hjXj . Since the coefficients are with respect to the original packets, the corresponding vector g' is given by g'i =Pm j=1hjgj i.

Decoding

Consider a node has received the set (g1,X1), ..., (gm,Xm). To retrieve original packets, it needs to solve the system of M linear equations Xj = Pn i=0 gj iMi with Mis as unknowns. If m = n, i.e., number of received packets are equal to number of original packets, we can recover all the original packets provided all the encoded packets are linearly independent. But there is a possibility that some of the encoded packets are linearly dependent.

Network Coding at Different Layers

In this survey Network Coding technique can be applied at different layers and enhances the performance of wireless Networks.

Table 1: Survey of Various Papers where Network Coding is Applied at Different Layers

Layer	Work Done at this Layer	Results
Physical Layer [18]	With PNC, signal scrambling, causes packet collisions in the MAC can be eliminated	(PNC) significantly enhances the through- put performance of multi-hop WNs
MAC layer [19]	To Improve TCP Performance by applying the TCP- ACK packet within the TCP-DATA packet, NC at MAC	Significant improvements in TCP performance by reducing no. of transmissions and speed up TCP-ACK
Network & MAC Cross layer [20]	Network layer uses the PHY information & performs symbol-level NC over the clean symbols	High throughput without compromising end-to-end reliability
Transport layer [13]	Proposes a TCP/NC, inserts a new layer of NC between TCP and IP & RLNC masks link losses from the TCP to avoid window back off again	Results in higher good put
Application Layer [21]	Topology between nodes can be dynamically created or torn down for better performance	End to end through- put significantly in- creases

Single Generation & Multi Generation Mixing

The issues discussed in this survey give birth to the concept of Generation & Multi Generation Mixing.

Single Generation

- Generation means grouping sender packets into chunks of packets, where encoding is done among packets belonging to same generation.[6] In other words, Generation means how long and for how many packets a node should wait before encoding a packet and this criterion defines the generation size.
- If NC is applied and one node or set of nodes is/are interested in sending information of a large volume to one receiver then in that case to decode complete information successfully at the receiver requires receiving complete information.

- Information is in the form of packets encoded using randomly generated coefficients over finite field. So, receiver needs to store packets and coefficients until the last packet successfully received by the receiver which introduces delay.
- So, in this case packets of one or more sender can be grouped in to chunks of packets which will reduce storage requirements at the receiver and reduces delay this concept called Generation.[6, 2]

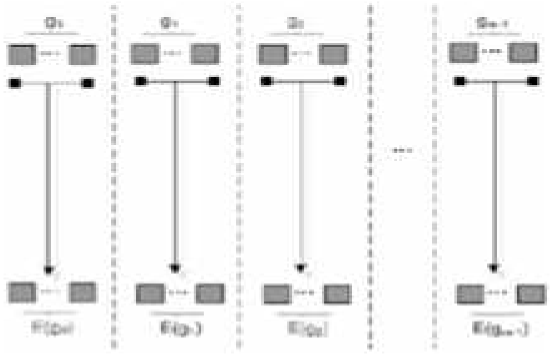

Figure 5: Single Generation Mixing of Packets

Figure 5: Generation by Generation encoding of packets.

- There exist a trade off between Generation size (number of packets to encode), delay and performance. If a node defines a generation size a big number then node needs to wait for those many packets which introduce delay (if too large then may result in retransmission) and loss of such generation can be very expensive.
- If Generation size is too small in that case reduces efficiency. If generation size is 3 then upon receiving any 3 packets of that generation receiver will be able to decode 3 original packets.

Multi Generation Mixing

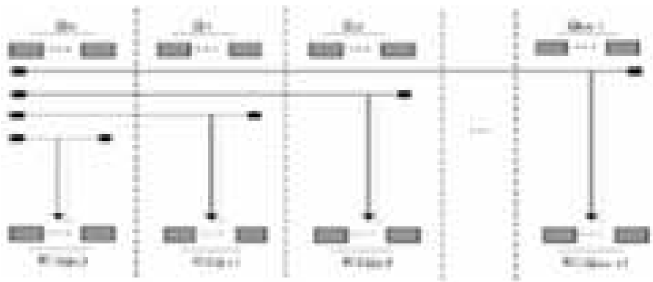

Figure 6: Multi Generation Mixing of Packets

- High losses and sparse connectivity are the main degrading factors on the performance of network coding.
- In case of video transmission over wireless networks loss of one frame may result in loss of many frames. Video is a sequence of Group of Pictures (GoP). GoP is composed of I (Intra), B (Bidirectional) and P (Predictive) frames. I frame is referenced by P and B frames. If I - frames of multiple GoPs are encoded in one encoded packet and loss of such encoded packet results in loss of many frames. This can be overcome through the concept of Multi Generation Mixing. For video transmission over wireless networks, if packets of I-frames of same generation are encoded with the encoded packets of P frames then with B frames then loss of one encoded packet will not results in loss of video because receiving any (enough) packets can recover I frames. Such Multi Generation Mixed packet provides protection to packets of I frames and improves performance even though there is high losses of packet.[2]

Suggested Implementation Flow

In this work, each sender encodes packets using RLNC with single generation wise and Multi Generation Mixing wise. At Application Layer each sender generates encoded data which is of type APPDATA. And using Application layer Agent and Sendmsg method, it sends this APPDATA to Transport layer. At Transport layer, its Agent (target) sets APPDATA in packet's payload and sends the packet to the Network Layer. At the receiver side, Network layer passes the received encoded packet to the Transport layer.

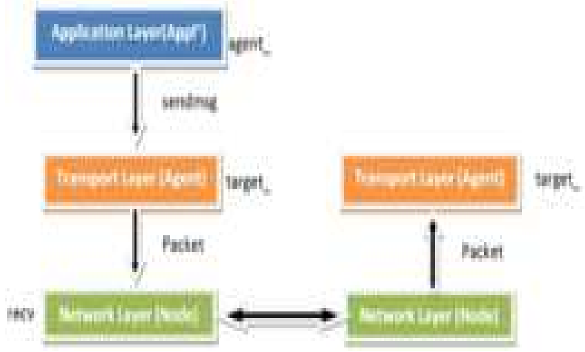

Figure 7: Suggested Implementation Flow

NS-2

NS-2 in its different versions is one of the most popular simulation environments for research. It has a hybrid approach to programming simulations with both C++ and an object-oriented version of Tcl scripting called OTcl. This duality can lead to confusion when not familiar with the system, but it proves to be very convenient once the user becomes acquainted with it. The modules are developed using C++, in order to provide higher simulation speeds by the use of compiled code. C++ modules are configured and executed via OTcl scripts, which provide the description of the simulation environment and the configuration parameters for each module involved. This OTcl scripts are not compiled but interpreted by the ns software. This makes the set-up of simulations very easy and convenient to batch, as there is no compilation needed to run the scripts, and these contain all the required configuration parameters for the C++ modules. This duality becomes critical when it comes to develop or modify modules.

The modules have two parts: one programmed using C++ and other OTcl. This is required to provide the usability features previously mentioned. There is an All-in-One package available for most of the releases. These versions include the network simulator, network animator –NAM– and xGraph in the latest version available at the moment of the creation of the package. The installation is not quite straightforward if you are not using one of the systems supported out-of-the-box for that version, but is easy to find community-developed scripts to compile and install the software properly. The installation of extra modules may require additions and modifications in the configuration files in order to work, being usually simple and well documented.

RESULTS AND ANALYSIS

Graph represents effect of changing network parameter - Number of Connections on Performance parameter - Packet Delivery Fraction for MGM, single Generation and Without Network Coding. Here, simulation is carried out by changing number of connections (from 1 to 5 different connections). For this simulation, queue length is fixed and it is 8000. Number packets sent in all cases is fixed ant it is 27000 packets. For this simulation, simulation time is 560 seconds. It is clear from the graph that the Packet Delivery Fraction at achieved Number of Connections for MGM and Single generation is better than that of without using Network Coding.

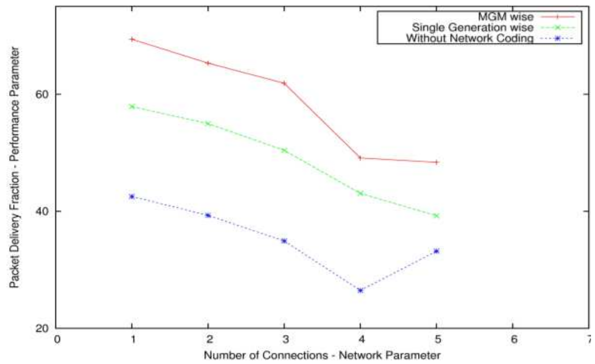

Figure 8: Graph for Number of Connections V/S Packet Delivery Fraction for MGM, Generation and without Network Coding

Graph represents effect of changing protocol parameter - Number Of Copies on Performance parameter - Packet Delivery Fraction for MGM and single Generation. Here, simulation is carried out by changing number of redundant copies (from 1.0 to 2.0). For this simulation, queue length is fixed and it is 8000. For this simulation, simulation time is 560 seconds. For simulation, 3 connections are created. It is clear from the graph that the Packet Delivery Fraction achieved for different values of number of copies is better for Single generation compare to that of MGM.

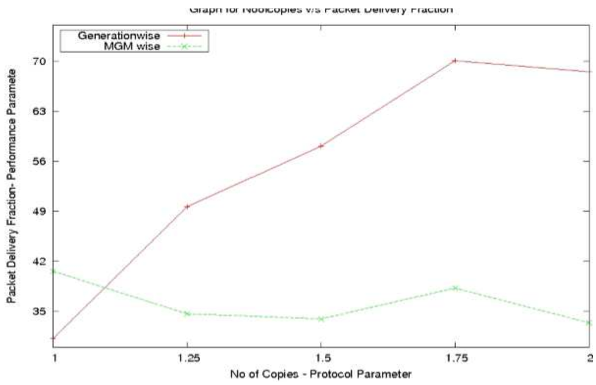

Figure 9: Number of Copies V/S Packet Delivery Fraction by Forwarding Different No of Redundant Copies for MGM and Generation

Graph represents effect of changing network parameter - Number of Connections on Performance parameter - Delay for MGM, single Generation and Without Network Coding. Here, simulation is carried out by changing number of connections (from 1 to 5 different connections). For this simulation, queue length is fixed and it is 8000. Number packets sent in all cases is fixed ant it is 27000 packets. For this simulation, simulation time is 560 seconds. It is clear from the graph that the Delay for Number of Connections for MGM is greater than that of without using Network Coding and Single generation.

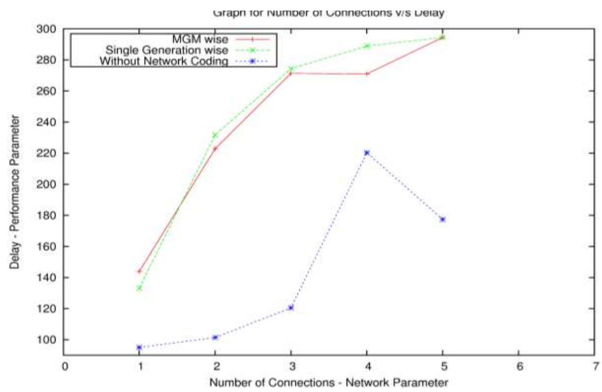

Figure 10: Graph for Number of Connections V/S Delay for MGM, Generation and without Network Coding

Graph represents effect of changing protocol parameter - Number Of Copies on Performance parameter - Block Delay for MGM and single Generation. Here, simulation is carried out by changing number of redundant copies (from 1.0 to 2.0). For this simulation, queue length is fixed and it is 8000.

For this simulation, 3 connections are created. For this simulation, simulation time is 560 seconds. It is clear from the graph that the Block Delay for different values of number of copies is almost similar for MGM and Single generation

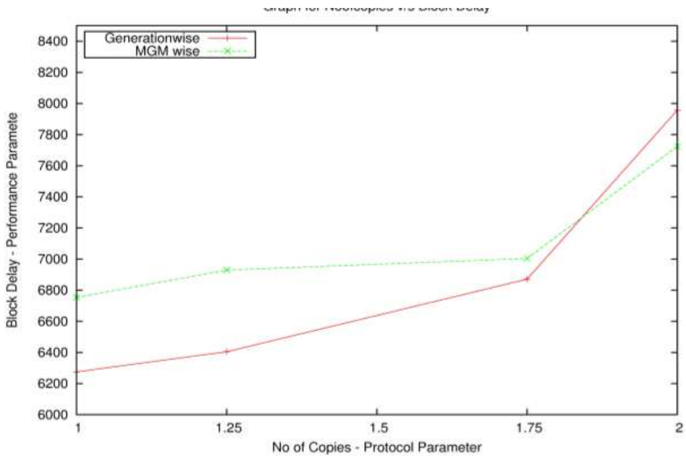

Figure 11: Number of Copies V/S Block Delay by Forwarding Different No of Redundant Copies for MGM and Generation

Graph represents effect of changing protocol parameter -Number Of GoPs on Performance parameter - Packet Delivery Fraction for MGM and single Generation. Here, simulation is carried out by changing number of GoPs (from 2 to 5). For this simulation, queue length is fixed and it is 8000.

For this simulation, 3 connections are created. For this simulation, simulation time is 560 seconds. It is clear from the graph that the Packet Delivery Fraction for different values of GoPs results are better for MGM compare to that of Single generation.

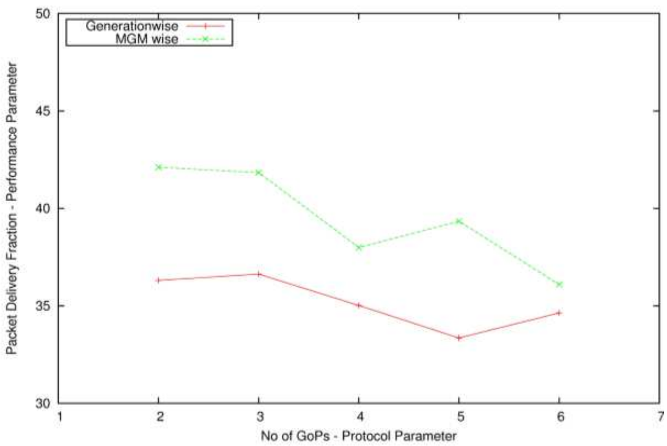

Figure 12: Number of GoPs Vs Packet Delivery Fraction for Different No of GoPs for MGM and Generation

Graph represents effect of changing protocol parameter - Number Of GoPs on Performance parameter - Block Delay for MGM and single Generation. Here, Simulation is carried out by changing number of GoPs(from 2 to 5). For this simulation, queue length is fixed and it is 8000.

For this simulation, 3 connections are created. For this simulation, simulation time is 560 seconds. It is clear from the graph that the Block Delay for different values of GoPs results is similar for MGM and Single generation.

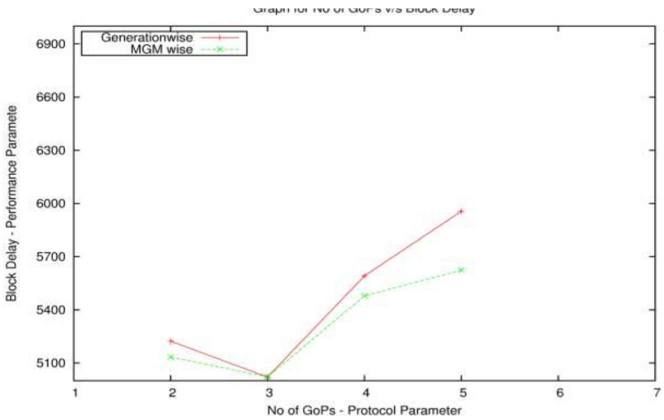

Figure 13: Number of GoPs Vs Block Delay for Different No of GoPs for MGM and Generation

CONCLUSIONS

Mixing of different packets by means of Random Linear Network Coding with MGM increases the Packet Delivery Fraction as well as reduces Packet Drop Rate and Block Delay of multimedia transmission over wireless ad hoc networks at the available bandwidth. In case of RLNC with MGM, loss of one or more I packets are recovered through successful decoding of either IP packets or IBP packets. In some scenarios of RLNC with MGM, to provide more protection to I frames by transmitting more and more number of redundant copies of encoded packets results in burst traffic in the network and slightly reduces its performance.

FUTURE WORK

In this thesis work, Video Traffic Model is used to generate video traffic frames as I,B and P at the specified frame rate and these frames are encoded using RLNC with single generation and MGM. In this work, no real video traffic is used for transmission, so in future it is an open direction to simulate real video traffic over wireless ad hoc networks using Network Coding. In Ad hoc networks, on receiving less number of encoded packets then the required gives birth to partial decoding of packets or in future one can solve issue of decoding packets over multiple generations of same set.

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