Achieving QoS Through Network Coding

Marium Jalal Chaudhry, Farhat Saleemi, Fatima Jalal Chaudhry

***Abstract*—Network coding is a novel technique that includes many applications in realistic networking era. Through network coding, intermediary nodes might send out packets that are combinations of incoming information. The basic theme behind network coding is the summation of incoming information traffic through simple XOR. There are many profits of network coding: improved throughput, less number of transmissions, better network management, less BER, minimum delay, less resource consumptions. In this paper we will prove how network coding improves and achieves the Qos of any network. We also discuss the Implementation aspects of network coding like how it may implemented on current infrastructure networks, we also discuss the theoretical and practical results on network coding for improving quality of service parameters using four basic approaches of network coding, Optimal, Deterministic, Random and Heuristic approach.**

***Index Terms*—Network Coding, QoS, Throughput.**

I. INTRODUCTION TO NETWORK CODING

Networking arise in almost all the communication parts like phone networks, internet, peer to peer networks and Ad-Hoc, wireless , sensors networks and all other infrastructures that precedes or follow a passage for information transfer, such systems are being central part of our lives. Network coding is an excellent technique in which we exploit the characteristics of the wireless and wired medium for achieving QoS parameters like to increase the maximum capacity or the throughput of the network. Less delays, minimum number of transmissions, less resources consumptions and many other Qos parameters. This paper studies the applications of the network coding technique for wireless and wired networks. Network coding is totally different with the traditional routing approaches, in which incoming traffic is only forwarded to destinations, but network coding surprisingly makes it possible to apply some very simple mathematical operation on incoming data streams. This paper evaluate the ad- vantage of network coding over the traditional approaches for both wired and wire-less networks for achieving several Qos measures. The recommendations help to identify improvements that network coding techniques is much more than better to existing networks with respect to a number of qualities of services issues. Specifically we are paying attention on Improving delay time and throughput of a network using network coding techniques. [10].

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II. BASIC TECHNIQUES OF NETWORK CODING

In this paper we are using four basic techniques/approaches of network coding.

- Optimal
- Deterministic
- Random
- Heuristic

In random network coding, server/Sender node combines the random numbers of data packets without knowing the status of receiver, and sends that data packets to destinations, the data packets may divide in two categories first is have packets, that are those data packets which receiver already have, and second category is Want packets, that are those packets which receiver don't have and want to recover its compete information set.

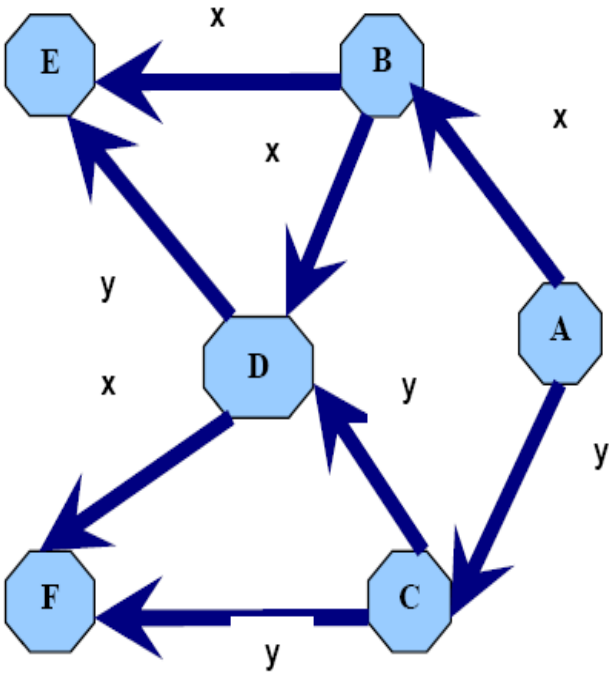

Figure 1. Butterfly Network with one source A and two terminals E and F. Source s wants to transmit two packets X and Y to both terminals . [10]

Network coding can use any multicast sub graph which satisfies min-cut max-flow bound for each receiver. In this approach Random linear combinations of information contents sent out and after reaching destination the Receiver nodes can decode if they receive sufficient independent linear combinations.

The network coding Differs from traditional networking approaches. As in traditional approach server sends out each and every content separately to every receiver client, as many times server sends out information contents every time in every transmission resources like bandwidth, power channel etc consumes.

For the basic understanding of **random network coding** suppose we have a network that is a directed graph, where the ends be a symbol of paths for data transmission. Using the max-flow min-cut theorem, we can estimate the maximum quantity of data transmission that can be accepted through this network between a sender and many receivers. It is very clear in this network shown that that it is possible to attain the maximum flow, but using traditional routing it is not even possible.[1] The basic theme of network coding is to permit mixing of incoming data packets on intermediate nodes. At destination nodes the receiver receives these data packets and decodes its required data packet from them.

In the butterfly figure above, it is very clear that no routing scheme can achieve the maximum flow, but by using a simple network coding scheme, maximum flow can be achieved.

The network coding will achieve the max-flow in any multicast (each and every destination node receives all the source sanded information).

Theory In random network coding approach each node generate new data packet, which is a linear combination of the previous received data packets from the leading edges, the random mixing is to form coefficients.

In **optimal network** coding approach sender/server send the information that is very accurate and only consists of required packets of each and every client separately for this approach server already have the knowledge of clients “have “ and “required” packets, using that information server only send required packets therefore consumes less resources.

Third approach is **Deterministic approach**; in this very simple approach sender/server send the determined combinations of “have” and “required” packet sets. This approach is not very optimal but it is much better than random and other traditional routing approaches, and consumes fewer resources as compared to random and heuristic approaches.

The last approach we have user in this experimental work is **Heuristic Approach,** that is not accurate as much as optimal and deterministic but it is obviously much better than traditional approaches it some times on some specific \conditions operates very well and gives very excellent results but at the same time for another condition it does not work as excellent it is time dependent approach basically, it consumes less time but gives average results. In heuristic approach server send the linear combinations of packets in very straightforward fashion using shortest path from sender to receiver and utilizes each and every available transmission opportunity.

Our paper will examine all these approaches discussed above on a single butterfly network and will result in categorization of all four approaches in terms of achieved QoS.

Butterfly Network.

In the butterfly network, here are one source A, A wants to send two data packets X and Y to destination nodes E and F, each destination receiver want to receive both X and Y. Each edge can only hold only a single packet. [10]

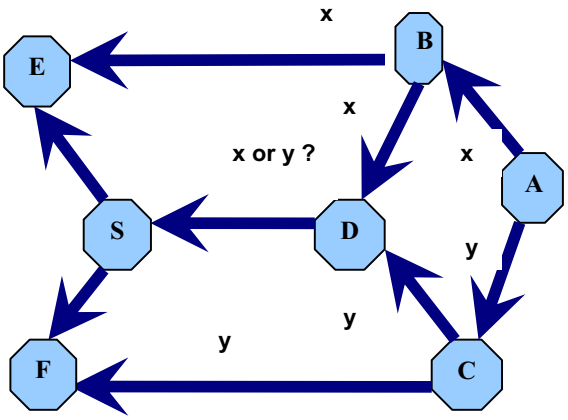

Figure 2. By conventional approach Source A transmits packet Y to terminal F and X to terminal E while it can send either packet X or packet Y on terminals F,E due to which only one of the terminals is bale to recover both packets and other will obvously get only one . [10]

If we use traditional routing, the central edge would be able to carry X or Y, but not both Packets. Source send X through the central edge; then the left receiver will receive X twice and will not receive Y at all.

In case of Sending Y the similar problem occurs for the right Receiver. Finally in this case routing is inadequate because no routing scheme can send out both X and Y simultaneously to both Receivers. by using simple network coding approach as shown in figure 3 , receivers do get both X and Y simultaneously by using sending the sum of the data packets through the central node (Encoding of X and Y using the XOR as "X+Y". The left Receiver F receives X and X+Y, and can decode Y by subtracting the two X+Y. as it is a linear coding because the encoding and decoding are linear settings. In the central node of the butterfly network, 3 messages are being transmitted (X, X+Y, Y). On the other hand 4 messages are received at the receiver nodes. Another efficient feature of network coding is a packet can be stored in the central edge and router could store packets X and Y and can provide all 4 packets to the receivers. [10]

III. Motivation and Scope

The scope of network lies in day-to-day problems coming along with the traditional networking schemes. In the current network schemes the overall capacity of the network is far from a dream, whereas the delay that a receiver has to face is sometimes more than annoying as in some delay sensitive applications it can bring about a significant decline in quality of service. This paper will show the power of network coding to practically solve a number of qualities of service related issues that are crucial for the internet market and users. This paper examines the usability of network coding in application where coding is used to achieve network capacity. Another important aspect is to concentrate on reducing time delays for the information packets at the receivers.

IV. Quality of Service for a Network

Quality of Service (QoS) is a broad term used for quality measurement, with many alternative definitions depending on application that are goal specific. For computers, wired and wireless networks there are following QoS parameters which we will address [11].

A. QoS Parameters

QoS can be defined in several parameters. All these parameters can be used for evaluate different networks. For the computer, wireless and Wired network following parameters determine QoS

- Capacity of a network
- Data rate
- Time delay

V. The Problem

As Wireless, wired and all other networks are highly resource constrained the Bandwidth is the most expensive and the Power is sometimes an issue too.and the Serious problems for networks are How to optimise throughput? And can we send more information? Can we reduce bandwidth requirement? Do both at the same time?

VI. Previous Work

Network coding has envisioned the concept of networking in an unusual fashion that comes with great deal of achieving network capacity. To be specific, network coding extends the concept of network operations beyond traditional routing i.e. or store- and-forward approach. In traditional networks, coding is done at source nodes for compression or to protection against data loss. This theme is borrowed by the traditional definition of the network i.e. a medium to transport, unmodified information supplied by source nodes. Whereas network coding brings in light the mixing of data as if the data are mathematical objects and any network node can participate in coding or mixing of information packets to accommodate more data on same

Links and hence increasing throughput. In addition to allow different packets to share links it has also shown to be helpful in increasing the security and decreasing the losses by providing power of recovering data from the mixed packets.

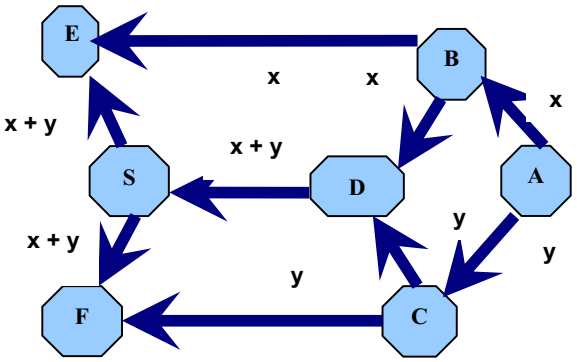

Figure 3. by means of network coding Source A transmits packet X and packet Y to terminals F and E respectively and XY for both terminals.[10]

The first example highlighting the very notion of network coding was given by Ahlswede et al. Figure shows the well known example of a network for which coding in the intermediate nodes of the network is necessary in order to send data packets at the maximum possible multicast transmission rate. Ahlswede et al. showed that coding within a network node helps a source to send information at a rate equal to the min-cut between the source and any receiver. Koetter and Medard. Presented an algebraic framework for a solution to linear network coding for any arbitrary networks and also extended their results to show the robustness achieved by this technique and proved the feasibility of the solution in accordance with the famous min-cut max-flow bound for networks with delay and cycles. The work by Koeter also showed the validity of a network coding solution in terms of transfer matrices, which is extended to show mapping of the same problem to the bipartite matching and network flows problem. Sanders et al. and Jaggi et al. Picked up example of single-source multicast networks to calculate the bound on the field size used for coding operations, and suggesting a centralized deterministic for finding feasible network coding solutions. A heuristic solution by relating network coding to graph coloring problem has been reported by Fragouli et al. Characterization of such networks for which network coding yields feasible solution is studied by Rasala Lehman and Lehman showed important results on the undirected networks by proving that network coding gain in undirected graphs are bounded by factor of 2.[10]

VII. Brief Overview of some Conventional Networks Techniques

A. Hot Potato's

Provides traffic duplication. (Duplicate traffic). Provides duplicate packets at receiving node.

B. Fish Bone Network

Provides more than one route for single packet transmission. (More than one paths for single packets, sanded redundant packets in parallel streams).

C. N-To-N Network Technique

Very latest Technique provides packets duplication at both nodes (sender & receiver).presented by CISCO, not implemented yet working on Algorithm generation.

VIII. Input of this work

So far network coding has been invented as theoretic perception in networks with multi-cast, wireless, wired and unicast approaches. The objective of this paper is to discover the more practical characteristic of the network coding by taking into account its applications in wired and wireless network. The center of this paper is to present methods for improving quality of service issues. The input of paper is further divided into sub parts initially, a graph theoretical model has been developed to appropriately compute the parameters of apprehension at the same time as maintenance model as secure as rational by avoiding needless assumptions that obstruct it from turn into a practical job. Secondly based on model a straightforward and well-designed algorithm has been prepared that can work for any original common network. Thirdly due to rigid personality of network coding the basic problem is to device intelligent option by affecting from deterministic to random network coding resolution. Very last, paper presents widespread simulation outcomes for realistic channel setting for both wired and wireless network and will result in terms of quality of service parameters are proposed.

A. Areas where network coding may implement

- Wireless
- Wired
- P2P
- Ad-Hoc networks

And money more.

B. QoS Parameters

In the ground of computer networking and additional telecommunication networks, the quality of service (QoS) is distinct as the traffic engineering phrase that refers to supply reservation control mechanisms relatively than the achieved service quality. However the concept of quality of service that meets together the resource reservation at its best and achieving the service quality both is new and old with the rising idea of network coding. In network coding the links, routers and other important resources in the network is permitted to shared among different transmissions, terminals for combining packets which makes the resource reservation as most excellent as it is can be thought of but of course it comes with the worth of some extra factor that have to be well in the new equation of resource reservation like additional calculation control is essential at the middle nodes/routers which is not as much cost competent as the conventional routers and mechanism of the network. This inbuilt attractiveness of network coding is more attractive by the probable increase in the following *QoS* parameters:

Routers and components of the network. This intrinsic beauty of network coding is prettier by the probable increase in the following *QoS* parameters:

- Time delay
- Throughput
- Data rate
- Security
- Fault-tolerant

Within this paper we are particularly focusing and analyzing the time delay and throughput of network beneath thoughtfulness.

C. Network Coding for Improving QoS

Think about the example shown. Network coding helps in:

- Achieving maximum capacity: By min-cut-max flow theorem the maximum capacity of this network from source to any destination is 2 using conventional routing it is not possible to achieve this capacity but applying network coding it is possible to achieve this maximum capacity
- Dropping delay: In case of conventional routing 2 time slots are required to transport packets “x” and “y” to destination “E” and “F”. while network coding is capable in tarnsporting both the packets to both the destinations in a single time unit
- Amplified data rate: Network coding is capable of amplifying data rate. With conventional approach the data rate was 1 while when network coding is used it is 2.

D. Experimental Steps

- A random graph is formed where nodes and their connections (edges) are all random. A source and number of terminals are selected at random using uniform distribution.
- Find min-cut of the network
- Identify network coding nodes
- Apply simple XOR over incoming packets and forward it on outgoing links.
- Calculate time and throughput using both network coding and traditional routing.
- I have conducted a set of experiment for 2 3 and 4 terminal nodes and have generated random topologies check how network coding works as compared to the traditional approach. I have been focusing on two most important factors i.e. Time taken by all terminals to decode and throughput of the network. the results are shown in Fig 26 for Throughput and Fig 27 for Time response.

IX. Simulation Results and Findings

For numerical results we performed a number of experiments to categorize and to calculate the coding gains as well as the performance number of experiments using four basic approaches of network coding that are

- Optimal Network Coding
- Deterministic Network Coding
- Heuristic Network Coding
- Random Network Coding
- Traditional Routing Approach

In every part of our experiments shown below, the quantity of clients is equal to the number of packets. In the initial testing, we evaluate the coding gain of a wireless and wired system with seven clients. particularly, we generated more than 50 experiments sets of in each situation the set "have" of each client is at random chosen. The outcome of the testing are shown in fig and the observation is the best possible approach is optimal network coding which has maximum throughput, the second best possible approach is deterministic and the third is random in which we have average throughput and at the heuristic arrives at the last position because it may works for some problems for some and may not work for others it entirely dependent on time.

Figure 4. Shows the results of achieved throughput of maximum 60 clients that shows the throughput for each number of clients, the major observation is that the majority of the experiments, there is a major increase in throughput /coding gain (more than 1200 Kbps) which is only achievable by optima network coding approach and heuristic at the same time comes on last position.

The third set of experiments is similar to the first and second one, but shows the average delay in terms of time and number of consumers using four basic approaches optimal, deterministic, random and heuristic, results shows that optimal approach consumes lesser time for decoding maximum data as compared to other approaches as a final observation optimal network coding approach is more advantageous than others but at the same time as compared to traditional routing remaining three approaches are also much more than beneficial in terms of throughput/coding gain, time delay, data rate, and fault tolerance as quality of service parameters.

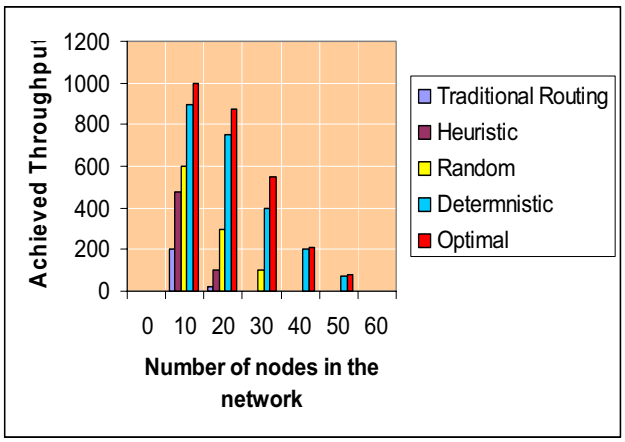

Figure 4. Shows the results of achieved throughput of maximum 60 clients that shows the throughput for each number of clients approache used are optima network coding, deterministic network coding, random network coding and trditional routing .,

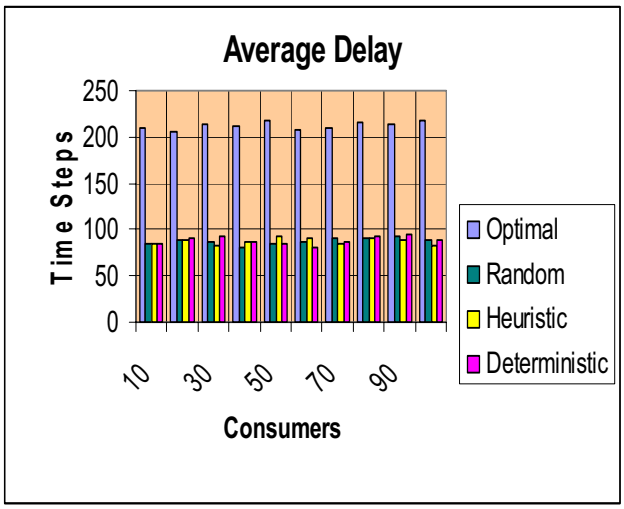

Figure 5. shows the average delay in terms of time and number of consumers approache used are optima network coding, deterministic network coding, random network coding and trditional routing .,

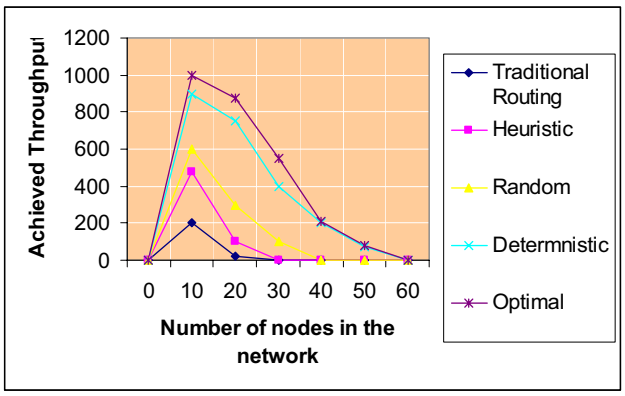

Figure 6. approache used are optima network coding, deterministic network coding, random network coding and trditional routing .,

I. CONCLUSION

This paper presents the overlook and solution of basic problems of today wireless and wired networks "improving Quality of service while sticking on same infrastructure "to achieve QoS we have compute, analyze and achieve optimal throughput in data networks using different number of clients and data rates in diverse environments. Results of network coding amazed us that how it is able to make the design of proficient solutions to this primary and many secondary problems that was previously viewed as very rigid to solve. Results also show the observation and conclusion that; the most important advantage of network coding is not to attain higher optimal throughput/Coding gain but also to achieve such optimality in currently existing infrastructure. We also categorize the four basic approaches of network coding that are optimal, deterministic, random and heuristic for random numbers of clients and different data rates and shows that which approach is best for some certain conditions of clients, data rates, delay and fault tolerance and network type. These results are very useful for practical implementation of network coding for diversity of networks like overlay networks, Ad-Hoc networks, peer to peer networks and many others for achieving quality of service.

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