The Effect of Error on Energy Consumption in Packet Switched Wide Area Networks

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***Abstract*—The evolution of networks has been glittered by the increased application of characteristic improvements in essential software and hardware technologies. These technologies are enabling more distributed network design characterised by variety of new services and service capabilities, integrated multiprotocol/multiservice transport capability and the addition of intelligence at the core of WAN. The rapid expansion of the network is the result of five key developments: the ability to specify a guaranteed end-to-end quality of service (QoS), an expanding selection of access technologies, the large amount of distributed information being applied to services, in practical terms continuous ability and explosive growth of bandwidth available in the transport layer.**

This paper presented a general concepts of Error Control and its mechanisms and its application to packet switched wide area networks. An improved model was proposed with reduced error while transmitting packets from one channel to the other

Simulating the model for reducing error control in packet switched wide area networks reduced energy consumption and achieved minimal energy consumption with increased throughput and extended amplitude which is the threshold volume.

Keywords—Error, Packet Switched, Wide Area Networks, Throughput, Amplitude, Dynamic Erasure coding, Energy Consumption

I. INTRODUCTION

The evolution of networks has been glittered by the increased application of characteristic improvements in essential software and hardware technologies. These technologies are enabling more distributed network design characterised by variety of new services and service capabilities, integrated multiprotocol/multiservice transport capability and the addition of intelligence at the core of WAN. The rapid expansion of the network is the result of five key developments: the ability to specify a guaranteed end-to-end quality of service (QoS), an expanding selection of access technologies, the large amount of distributed information being applied to services, in practical terms continuous ability and explosive growth of bandwidth available in the transport layer.

II LITERATURE REVIEW

A Common Network Protocols

Different types of data networks are based on underlying technologies and support different many types of applications. In general, packet switched network can be divided into two which connectionless and connection oriented networks.

1 Transmission Control Protocol (TCP)

Transmission Control Protocol (TCP) makes the source to send data across the sub network (network) to destination or the known destination is on another sub network to a router that will forward the data. It functions a relay to move a block of data from one host (source) through one or more routers to another host (destination). TCP is only implemented in the end systems. It keeps track of blocks of data to assure that all are delivered to the appropriate application.

For successful delivery of packets, every entity in the system must have a unique address. Two levels of addressing are needed. Each host on a subnetwork must have a unique global internet address. This allows the data to be delivered to a proper host. Each process with a host have an address that is unique within the host-to-host to deliver the data to proper process. TCP breaks the block of message into smaller packets to make the message delivered quickly. TCP adds control information known as TCP header forming TCP segment. TCP hands each segment to IP with instructions to transmit to another device.

2 Internetworking Protocol (IP)

The Internetworking Protocol (IP) is the transmission mechanism used by the TCP/IP protocols. It is an unreliable and connectionless protocol-a best-effort delivery service. The term *best effort* means that IP does not or track or check for errors. IP assumes the unreliability of the underlying layers and does its best to get a transmission through to its destination, but with no guarantee. IP transports data in packets called *datagrams,* each of which is transported separately. Datagrams can travel along different routes and can arrive out of sequence or be duplicated. IP does not keep track of the routes and has no facility for reordering datagrams once they arrive at their destination. The limited functionality of

IP should not be considered a weakness, however. IP provides bare-bones transmission functions that free the user to add only those facilities necessary for a given application and thereby allows for maximum efficiency [1].

B Past Research works done on Energy Consumption in Packet Switched Wide Area Networks

The paper [2], presented a new way of energy efficient network design and management system by using the clustering approach based on spectral algorithm to reduce energy consumption of network infrastructure. By this method, it was possible to hibernate or switch off part of network during low traffic hours in order to save energy. Experimental result showed that significant amount of energy could be saved by reorganizing the network switches and clustering the end devices using the spectral algorithm.

Energy Efficiency of CSMA Protocol for Wireless Packet Switched Networks [3] investigated energy efficiency tradeoffs among communication, computation and caching with QoI guarantee in distributed networks. We first formulated an optimization problem that characterizes these energy costs. This optimization problem belongs to the non-convex class of MINLP, which was hard to solve generally. They proposed a variant of the spatial branch-and-bound (V-SBB) algorithm, which solved the MINLP with optimality guaranteed. They also showed numerically that the newly proposed V-SBB algorithm outperforms the existing MINLP solvers, Bonmin, NOMAD and GA. They also observed that C3 optimization framework, which to their knowledge has not been investigated in the literature, but eventually reduced energy consumption by 88% when compared with either of the C2 optimizations which have been widely studied.

The paper [4] investigated the energy efficiency in Career Sense Multiple Access (CSMA) Protocols which could be applied to wireless packet switched networks. Two variants of CSMA: non-persistent and p-persistent was focussed on relating it to throughput and packet delay. For high message generation, by the members of a finite population, they found out that non-persistent CSMA has a markedly higher energy efficiency than p-persistent CSMA for all network configurations, though p-persistent attained a moderately lower packet delay. They also showed that non-persistent CSMA was optimized for energy efficiency, throughput and delay were impacted negatively, whereas p-persistent CSMA could effectively optimize all the three with the same network setting. The results brought up the suitability of each CSMA scheme for various wireless environments and applications.

Paper [5] illustrated methods of optimizing Data processing power consumption by the use of power management policies (static and dynamic policies) that yielded electrical power saving while maintaining the system QoS at acceptable levels. It also illustrated methods to optimize Tlc power consumption by use of power management policies to be adopted in wired and wireless Tlc systems. The electrical power saving of Data processing was without tampering the service quality.

The paper [6] analysed the energy consumption for data transfer when using Bluetooth, WiFi and 3G communication technologies. This is important since devices are becoming more powerful and tasks that they can perform are becoming more complex. That results with the increased demands for energy. Therefore, if device can use several of different communication technologies for data transfer, it was important to know energy consumption characteristics of each of them. The measured data were collected and analyzed. On that basis a simple energy consumption model for Android phones was design. Using their model, they showed how to calculate energy consumption for the Collaborative Downloading service. The main idea behind the service was to combine different communication technologies when downloading files in parts, and reduce the amount of energy required to transfer the entire file to a group of mobile users. Measurements were made using a simple Android application in which we were downloading or uploading data continuously.

Paper [7] proposed a new energy-efficient clustering protocol Decentralized Energy Efficient cluster Propagation (DEEP) that was based on the idea of controlling the geographical dimensions of clusters and distribution of cluster heads. Due to the balanced load among cluster heads, there was no need for frequent re-clustering, but after current cluster heads are out of energy, protocol could rotate the cluster head position among all the sensor nodes. Also, identical distance between a pair of neighboring cluster heads lead to the ease of route setup deployment. After establishing the routes among cluster heads using Inter-Cluster energy conscious Routing (ICR) protocol, results showed that DEEP can reduce the energy consumption and distribute the load as nearly as 8 times better than an existing clustering protocol LEACH. Optimum point of operation, in terms of cluster head density, was about 0.05.

Paper [8] analysed energy consumption of ICT networks worldwide. Data was collected. The approach for cost incentives for implementing energy saving was implemented. Results were launched in Power lib. Some of the incentives were to draft general and practical guidelines to improve energy efficiency and carbon footprint in networks. Major societal and economic challenges were identified. Economic incentives to induce energy aware behaviours of users, equipment manufacturers and operators were provided. Cases considered were Fibre to the Home with home router virtualization as Energy Efficiency solution and Wireless access with network sharing as Energy Efficiency solution. The result for the first case (Fibre to the home) was energy consumption was reduced by 20% and the other case (Wireless access with network sharing), Quality of service was increased and increase roaming price with network sharing of wireless access reduced the consumption of energy.

The paper [9] presented a model of energy consumption of current and future access networks using published specifications of representative commercial equipment. We analyzed the energy consumption of DSL, HFC, PONs, FTTN, point-to-point optical systems, UMTS (WCDMA), and WiMAX. Passive optical networks and point-to-point optical networks are the most energy-efficient access solutions at high access rates.

III SOLUTION OF THE MODEL

Queuing model is applied to packet switched WAN [10]. The parameters of the queuing model were modified and solved to reduce error. Following modified parameters:

The queuing model for packet flow in packet switched WAN was analysed

$\boldsymbol{\lambda}$ = Packet Throughput

μ = Packet Service rate

L_s = Number of messages in the network.

L_q = Number of messages in the queue.

W_q = Waiting time of packets spend in the queue to be transmitted to other networks.

W_s = Waiting time the packets spend in the network

P_n = Probability of routers accepting packets

$\frac{1}{\mu}$ = service time (time packets are acknowledged and transmitted)

$\bar{c}$ = Expected number of servers that reject packets

c = number of servers

ρ = network utilization

$$L_s = \sum_{n=1}^{\infty} n p_n. \qquad (1)$$

The relationship between W_s and L_s (also W_q and L_q) is known as Little's law which states that the number of packets is directly proportional to the product of average rate of packets and the time taken to deliver the packets.

$$L_s = \boldsymbol{\lambda}_{eff} W_s \qquad (2)$$

$$L_q = \boldsymbol{\lambda}_{eff} W_q \qquad (3)$$

For multiple server models which is the case of interest, there are c erased channels each serving messages (c>1). The arrival rate is λ and the service rate per server is µ. There is no limit on the number of routers in the network. With Kendall's notation M/M/c is the c server queue with Poisson arrivals and exponentially distributed service time. All queue disciplines are generalised distributions that satisfied all conditions. The parameters considered were throughput (**λ**), service rate (µ), number of servers (c), probability of number of routers not accepting packets (P_o). Throughput remains the same as M/M/1 queues but service rate depends on the number of channels. When the number of channels exceed m, the service rate become µm as shown below.

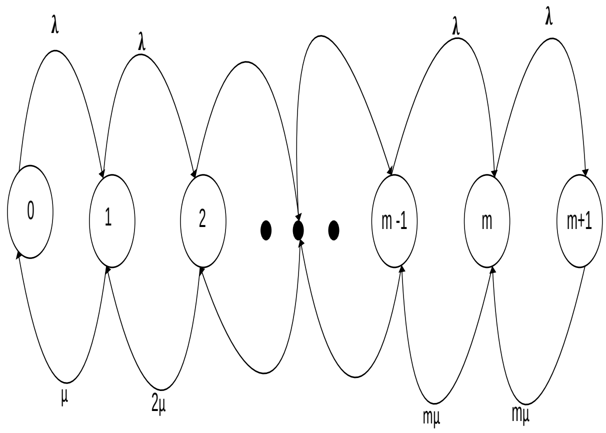

Figure 1: *Transition of states in M|M|c Queuing Model*

If $\rho = {}^{\lambda}/_{m\mu}$ and assuming ${}^{\rho}/_{m} < 1$, the value gotten from

$$\sum_{k=0}^{\infty} P_k = 1. \qquad (4)$$

N_q was determined in Multiple Input and Multiple Output (MIMO) systems

If $\rho = {}^{\lambda}/_{m\mu}$ (k = 0, 1, 2,....., j+1).

The service rate $m\mu$ will be

$$m\mu = \begin{cases} n\mu & k < m \text{ for } k = 1,2,3, \dots \dots \dots, m \\ m\mu & k > m \; for \; k = m, m+1, \dots \dots m+k \end{cases}$$

Probability of having n messages in the network can be written in a similar way with M/M/1 using revised service rate.

$$\text{Then, } P_k = \frac{\lambda^k \times P_0}{\mu \times 2\mu \times 3\mu \times ---------\times k\mu} \qquad (5)$$

$$P_k = \frac{\lambda^k}{k!\mu^k} * P_0 \qquad k \le m \qquad (6)$$

$$P_k = \frac{\lambda^m}{m! m^{k-m} \mu^m} * P_o \qquad n \ge m \qquad (7)$$

These are the measurements of performances in a multiple server and multiple queue in a packet switched wide area networks.

From equation (6) and (7) we get the following equations.

$$P_k = \left\{ P_0 \frac{(m\rho)^k}{k!} \quad k \le m \right. \qquad (8)$$

$$\left\{ P_0 \frac{m^m (\rho)^k}{k!} \quad k \ge m \right. \qquad (9)$$

From equation (1)

$$L_s = \sum_{n=1}^{\infty} k p_k$$

$$= P_0 \rho \frac{m^m}{m!} \left(\frac{1}{(1-\rho)^2} \right)$$

(10)

Case 1: Number of messages having erased channels.

$$L_q = \frac{m^m}{m!} \frac{\lambda}{m\mu - \lambda}$$

When 0 ≤ k ≤ m (The Erased channels are more than the normal working channels)

$$L_s = \frac{m^m}{m!} \frac{\lambda}{m\mu - \lambda}$$

When number of running channels is greater than the erased channels

Case 2: Number of messages having erasure channels

$$L_s = \frac{m^m}{m!}\frac{\lambda}{m\mu - \lambda} \quad (11)$$

Case 3: Total number of messages with erased channels

$$L_s = \frac{m^k}{k!}\frac{\lambda}{m\mu - \lambda} + \frac{m^m}{m!}\frac{\lambda}{m\mu - \lambda} \quad (12)$$

Case 4: For dynamic erasure code we differentiate with respect to code utilization ρ to see the effect on the number of messages produced in the network

$$dL_s = \frac{m^k}{k!}\frac{m^2\mu^2}{m^2\mu^2 - 2m\mu\lambda + \lambda^2} + \frac{m^m}{m!}\frac{m^2\mu^2}{m^2\mu^2 - 2\lambda m\mu + \lambda^2} \quad (13)$$

Probability of messages in queue and all channels busy and forced to wait in queue

$$\sum_{k=m}^{\infty} P_n = \sum_{k=m}^{\infty}\frac{p_0 m^m \rho^n}{m!}$$

$$\sum_{k=m}^{\infty} P_n = \left(\frac{\lambda}{\mu}\right)^m \frac{1}{m!} \quad (14)$$

Average number of customer in queue

$$L_q = \sum_{k=0}^{\infty} k p_{k+m}$$

$$= \left(\frac{\lambda}{\mu}\right)^m \frac{1}{m!}\frac{\lambda}{m\mu - \lambda} \quad (15)$$

Expected Number of messages waiting in queue (not in service) = L_q

$$L_q = (m - k)P_n$$

$$= \frac{(k\rho)^k}{k!}\frac{\rho}{1-\rho} \quad (16)$$

$$W_q = \frac{\frac{\left(\frac{\lambda}{\mu}\right)^k}{k!}\frac{\lambda}{k\mu - \lambda}}{\lambda}$$

$$W_q = \left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!}\frac{1}{k\mu - \lambda} \quad (17)$$

$$W_s = \frac{1}{\mu} + \left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!}\frac{1}{k\mu - \lambda} \quad (18)$$

B ENERGY CONSUMPTION IN PACKET SWITCHED WIDE AREA NETWORKS

Electricity consumption is an important issue in telecommunication networks. The worldwide telecommunication networks electricity consumption (which include customer premises network equipment, network equipment and operator networks) has been estimated to 350 TWh in 2012, accounted for 1.8% of the total worldwide electricity consumption in the same yea [11]. While it can be argued that this number in itself is relatively small, it is significant and increasing at a rate of 10% per year. Moreover it is relative contribution to the worldwide electricity consumption is increasing as well (from 1.3% in 2007 to 1.8% in 2012). As such, a research problem interest is to improve the energy-efficiency of telecommunication networks and it is very important for environmental (reducing the carbon footprints), technical (reducing the associated heat dissipation) and economic (reducing the energy cost) reasons.

The electricity consumption in the core networks is expected to rise considerably. The major part of the power consumption is attributed to the wired aggregation and access networks and mobile radio networks in the telecommunication operator networks. The core network in contrast is estimated to account (in 2012) for only about 8% of the total operator network consumption (which includes wired aggregation and access, mobile radio and backbone network [11]. High growth rates in the backbone energy consumption are expected increase of traffic volume, potentially even overtaking the access network's consumption [13]. For this reason it is important to respond quickly to the energy issue of backbone's network.

In this paper we compared different scenarios of the packet switched network when there are Higher number and lower number of errors affecting number of messages produced

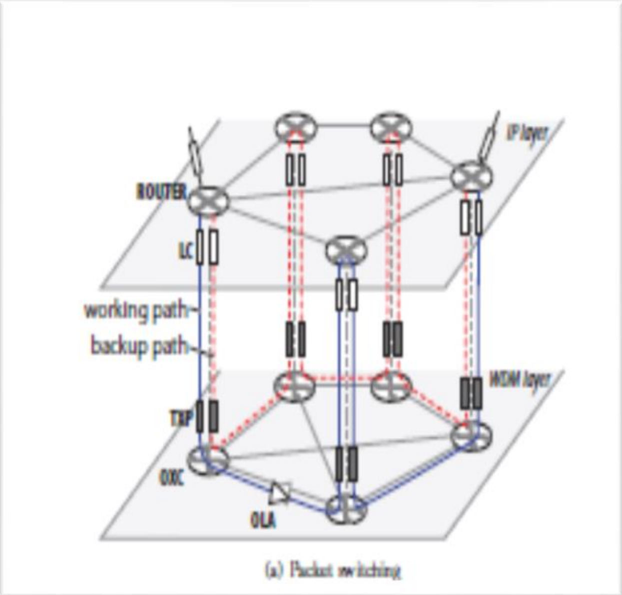

Figure 2: *Figure Showing Architecture for Packet Switched Networks for Energy Consumption*

Consumed Energy by nodes during packet transmission were be divided into two parts. The first part represented the energy consumed in the processing circuit of the transmitter (baseband processing). The second part represented the energy consumed by the power amplifier of the transmitter to generate the required output power for data transmission through the wire. At the same time, the energy consumed by a node to receive a packet could be obstructed by only one part, which is the energy consumed by receiving the circuit including the low noise amplifier of the receiver.

Let (k, m) denotes the connection between sender and receiver. Let r be the rate at which packets transmit data over the physical link (k, m). Pt is the power needed to run the processing circuit of the transmitter. Pr is the power to run the receiving circuit, $P_{k,\,m}$ be the transmission power from k to m and κ be the efficiency of the power amplifier. The energy consumed by u to send a packet of length x bits over (k, m) is

$$\varepsilon_{k,m}(x,r) = \left(P_t + \frac{P_{k,m}}{\kappa}\right)T = \left(P_t + \frac{P_{k,m}}{\kappa}\right)\frac{\mathrm{x}}{\mathrm{r}} \qquad (19)$$

The transmission power $P_{k,m}$ could be maximum transmission power as a consequence of transmission power control scheme.

If there is no acknowledgement received by the sender, packets are then retransmitted or packet loss is acknowledged. The sender retransmits packets until it receives acknowledgement. The actual consumed energy to exchange a packet over must include the total energy consumed as well.

Let $\chi \in \{0,1,2,\ldots,M\}$ be the Number of messages transmitted including first transmission and and $y \in \{0,1,2,\ldots,N\}$be the Number of messages acknowledged. The assumption is energy consumed by the receiver and decoding a corrupt packet is the same as consumed energy for receiving an error free packet.

1. EXPECTED NUMBER OF CODEWORDS IN PACKET SWITCHED WIDE AREA NETWORKS

A message would be transmitted several times and if there are erased channels, from equations (16) and (17), P_k is the probability of number of messages transmitted over (m, k) and ρ is the code utilization of messages. **λ** is the message transmitted at this speed and µ is the message acknowledged.

From equation 1 we have

$$\mathrm{E(L_s)} = \sum_{\mathrm{k=0}}^{\infty} \mathrm{kP_k} \qquad (1)$$

Equation (1) has already been derived earlier using $\sum_{k=0}^{\infty} \rho^k = \frac{\rho}{1-\rho}$ and in this case ρ < 1 and also since it is a multi channel queue, we used ρ = $\frac{\lambda}{m\mu}$ and **λ** < µ which is convergent, the limit is small. It signifies that for any limited values of k and m, ρ < 1.

Next, P_k was be determined which has already be done earlier. If channels are lost during all possible transmission attempts, no acknowledgement would be sent for the lost message. Hence P_o = 1–ρ. At the same time, an acknowledgement would be sent many times for code transmission if the message is received correctly for every transmission attempt if there are no bad k channels.

Let us calculate the time for transmitting messages for different cases of higher erasures, lower erasures, total number of erasures and dynamic number of erasures and acknowledgement. An acknowledgement is transmitted to sender only when message is received correctly after a number of transmission attempts. If there is no acknowledgement for the message lost, the sender will retransmit the messages. Hence another acknowledgement will be retransmitted if the data message was received correctly after a number of attempts. There is no limit on the number of transmission attempts which adds to the complexity of the analysis.

To determine the probability of number of bad channels and good channels, two cases were considered. The first case is that the number of erased channels greater than the good channels. In the first case, transmission of packets never occurred because the sender received an acknowledgement for the packets before reaching the maximum transmission attempts. In such cases, packets are transmitted from the first k channels, For all {m, m+1,……,m+k)} transmission attempts of the data packets could be successful but all m-1 acknowledgements transmitted for it are lost. The transmission of data messages must be successful and its acknowledgement must also be received successfully. The no of unused message that is idle is

$$L_q = \frac{\left(\frac{\lambda}{\mu}\right)^k \left(\frac{\lambda}{k\mu}\right)}{k!\,(1 - \frac{\lambda}{k\mu})} \qquad (16)$$

And response time

$$\mathrm{W_q} = \left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!}\,\frac{1}{k\mu - \lambda} \qquad (17)$$

In the second case, the sender transmits messages many times to the receiver. The sender did not receive acknowledgement after many attempts. This is because there are bad channels or erased channels in the system. It also means that the acknowledgements are lost. The bad channels are more than the good channels using equation (9) to illustrate

$$\mathrm{P_k} = \left\{ P_0 \, \frac{(m\rho)^k}{k!} \quad k \le m \right. \qquad (9)$$

The second part of the equation is most of the messages transmitted are successfully transmitted without or with minimal error and acknowledgements are transmitted for successfully transmitted messages. The good channels are more than the bad channels.

$$\mathrm{P_k} = \left\{ \mathrm{P_0} \, \frac{m^m(\rho)^k}{k!} \quad k \ge m \right. \qquad (8)$$

The total probability of message a bad channel and a good channel transmit a message and a dynamic erasure coding will also be computed and waiting time which would be varied with the energy consumption in a given network. Given ρ and 1 – ρ, The Average number of messages and also time used in transmitting and acknowledging. There is no limitation on the number of transmission attempts and acknowledgement attempts of a message, error channels are varied. In such cases a packet can be transmitted many times until the receiver receives the messages successfully. The expected rate of arrival is 1/λ and expected rate of service is 1/µ. The expected energy consumed by bad and good channel will be computed arising from response time of different cases of erased channels.

2 ENERGY CONSUMPTION ARISING FROM AMPLITUDE AND RESPONSE TIME USED IN TRANSMITING PACKETS BETWEEN CHANNELS

The receiver with the signal transmitted is synchronized. This is because both transmitter and receiver are simultaneously designed; they also use the same value for the packet interval T. Coordination of processes could occur because the transmitter starts by sending with a reference packet which is usually changes. The receiver knows what the sequence of the synchronizing sequence of packet is and uses it to determine when packet boundaries occur. The receiver of a packet stream derives the clock – when packet boundary occurs from the input signal. Because the receiver does not determine which of the packets are sent until process coordination occurs, it does not know when the preamble is obtained during synchronization. The transmitter indicates the end of the synchronizing sequence by switching to other channel sequence. The second synchronizing sequence informs the receiver that the data packets are about to come and that preamble is almost over.

Once processes are coordinated and packets of data are transmitted, the receiver must determine every T seconds what packet was transmitted during the previous packet interval. The data communication aspect is the focus of the research.

The receiver duplicates the received packet by each of the possible members of the signal set of the transmitter, combines the product over the bit interval, and compares the result. Whichever path through the receiver yields the largest value corresponds to the receiver's decision as to what code was sent during the previous code interval. Mathematically, Energy consumed while transmitting packets with an amplitude A in a period of time which is waiting time used in transmitting messages for different cases of higher/lower erasures, when system is idle, when system is in use, total number of erasures and the proposed one (Dynamic Erasure Coding).

Energy Consumed, $E = A^2T$ where A represents amplitude and T represents response time for each number of erasures.

$$E = A^2T \qquad (19)$$

The First Set of tables and graph below Shows the Energy consumed for different levels of Higher and Lower erasures and idle network and network in use at P_t = 100 mW and $P_{k,m}$ = 200 mA and κ = 1 with different throughput varying waiting time.

TABLE I: TABLE SHOWING ENERGY CONSUMPTION OF PACKETS AT THROUGHPUT OF 100 MB/S

Erase Chann	Idle Net	Net. in use	H/L Erase	No of Erase	Dy. Erase
2	9.62-E08	0.0001501	0.00084	0.0987	21.8223
4	9.90E-12	0.0001501	0.00840	0.1063	23.4861
6	5.47E-16	0.0001501	0.03400	0.1316	29.0883
8	1.83E-20	0.0001501	0.07340	0.1707	37.7340
10	4.06E-25	0.0001501	0.09860	0.1958	43.2780
12	6.40E-30	0.0001501	0.09100	0.1958	41.4750
14	7.53E-35	0.0001501	0.06010	0.1576	34.8270
16	6.86E-40	0.0001501	0.03030	0.1280	28.2870
18	5.00E-45	0.0001501	0.01200	0.1098	24.2670
20	2.95E-50	0.0001501	0.00380	0.1017	22.4760

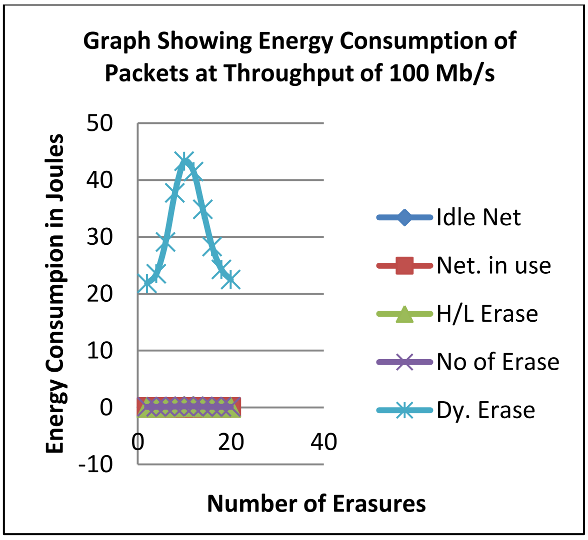

Figure 3: *Graph Showing Energy Consumption of Packets at Throughput of 100 Mb/s*

The blue graph shows the idle network which means that when network is not in use. The graph sloped down from 9.62×10^{-8}, rose from 9.90×10^{-12} to 5.47×10^{-16} and became slightly uniform. The higher the number of erasures, the more uniform the graph which means that the number of erasures do not have much effect on energy consumption in packet switched wide area networks. The wine coloured graph shows the network in use. The graph is uniform all through the number of erasures. The higher the number of erasures, the minimal the energy consumption of error in packet switched wide area networks.

The green graph shows the Higher/Lower erasures in the network. The graph rose from 8.40×10^{-4} passing through three points to 9.86×10^{-2} Joules and sloped down through four points to 3.80×10^{-3}.

The Purple graph shows total number of erasures in the network. The graph rose from 9.87×10^{-2} passing through three points to 1.96×10^{-1} Joules and sloped down through three points to 1.02×10^{-1}.

The sky blue graph shows the proposed model (Dynamic Erasure coding network). The graph rose from 2.18×10^{1} passing through three points to 4.33×10^{1} and slopped down through four points to 2.25×10^{1}.

The result of the five graphs at 100 Mb/s shows that the first two graphs are not affected by the number of erased channels. The last three graphs show that when the Good channel is higher than the erased channel, the energy consumption will be lower and when the erased channel is higher than the good channel, the energy consumption increases. The further the good/erased channel, the higher the energy consumption and the closer the good/erased channel, the lower the energy consumption.

TABLE II: TABLE SHOWING ENERGY CONSUMPTION OF PACKETS AT THROUGHPUT OF 500 MB/S

Erase Chann	Idle Net	Net. in use	H/L Erase	No of Erase	Dy. Erase
2	2.49E-06	0.00015268	0.00084	0.1006	4.5282
4	6.51E-09	0.00015010	0.00850	0.1082	4.8738
6	8.85E-12	0.00015010	0.03440	0.1341	6.0360
8	7.32E-15	0.00015010	0.07430	0.1739	7.8306
10	4.04E-18	0.00015010	0.09990	0.1995	8.9808
12	1.59E-21	0.00015010	0.09160	0.1912	8.6064
14	4.66E-25	0.00015010	0.06090	0.1605	7.2270
16	1.06E-28	0.00015010	0.03070	0.1304	5.8704
18	1.92E-32	0.00015010	0.01220	0.1118	5.0358
20	2.84E-36	0.00015010	0.00390	0.1036	4.6644

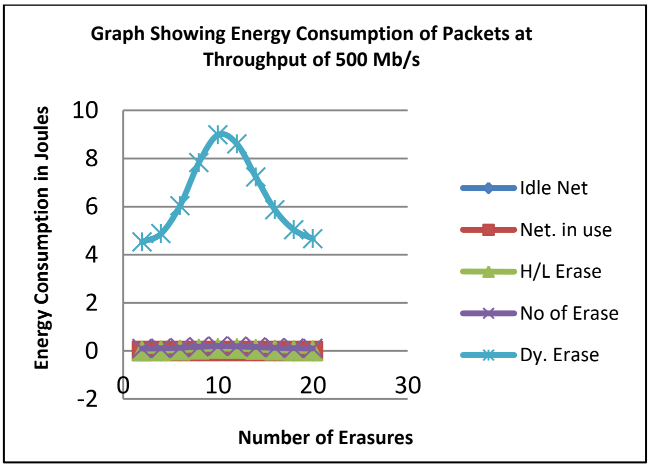

Figure 4: *Graph Showing Energy Consumption of Packets at Throughput of 500 Mb/s*

The blue graph shows the idle network which means that when network is not in use. The graph sloped down from 2.49×10^{-6} to 6.51×10^{-09} to 8.85×10^{-12} and became slightly uniform. The higher the number of erasures, the more uniform the graph which means that the number of erasures do not have much effect on energy consumption in packet switched wide area networks. The wine coloured graph shows the network in use. The graph sloped down from 1.53×10^{-4} to 1.50×10^{-4} and became uniform all through the number of erasures. The higher the number of erasures, the minimal the energy consumption of error in packet switched wide area networks.

The green graph shows the Higher/Lower erasures in the network. The graph rose from 8.40×10^{-4} passing through three points to 9.99×10^{-2} Joules and sloped down through four points to 3.90×10^{-3}.

The Purple graph shows total number of erasures in the network. The graph rose from 1.01×10^{-1} passing through three points to 2.00×10^{-1} Joules and sloped down through three points to 1.04×10^{-1}.

The sky blue graph shows the proposed model (Dynamic Erasure coding network). The graph rose from 4.53 Joules passing through three points to 8.98 Joules and slopped down through four points to 4.66.

The result of the five graphs at 500 Mb/s shows that the first two graphs are not affected by the number of erased channels. The last three graphs show that when the Good channel is higher than the erased channel, the energy consumption will be lower and when the erased channel is higher than the good channel, the energy consumption increases. The further the good/erased channel, the higher the energy consumption and the closer the good/erased channel, the lower the energy consumption.

TABLE III: TABLE SHOWING ENERGY CONSUMPTION OF PACKETS AT THROUGHPUT OF 1000 MB/S

Erase Chann	Idle Net	Net. in use	H/L Erase	No of Erase	Dy. Erase
2	1.25E-05	1.6250E-04	0.00087	0.1030	2.3730
4	1.11E-07	1.5011E-04	0.00870	0.1108	2.5542
6	5.92E-10	1.5011E-04	0.03510	0.1373	3.1635
8	1.94E-12	1.5011E-04	0.07590	0.1781	4.1037
10	4.25E-15	1.5011E-04	0.10210	0.2042	4.7067
12	6.65E-18	1.5011E-04	0.09360	0.1957	4.5105
14	7.78E-21	1.5011E-04	0.06220	0.1643	3.7875
16	7.06E-24	1.5011E-04	0.03140	0.1335	3.0765
18	5.11E-27	1.5011E-04	0.01240	0.1145	2.6394
20	3.02E-30	1.5011E-04	0.00400	0.1061	2.4494

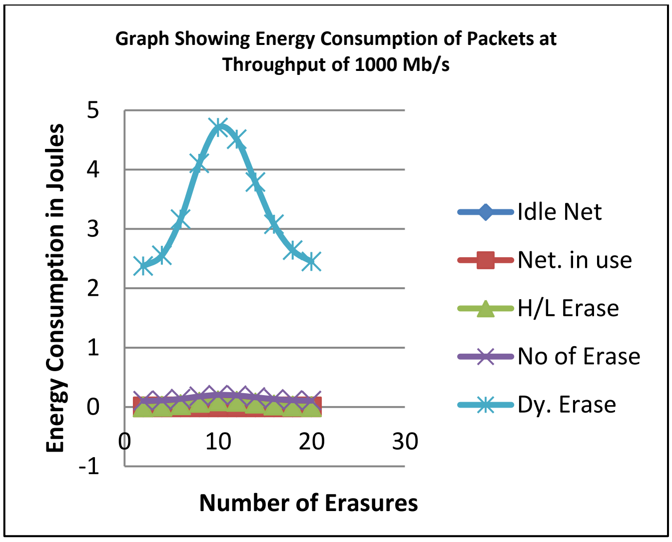

Figure 5: *Graph Showing Energy Consumption of Packets at Throughput of 1000 Mb/s*

The blue graph shows the idle network which means that when network is not in use. The graph sloped down from 1.25×10^{-5} to 1.11×10^{-7} to 5.92×10^{-10} and became slightly uniform. The higher the number of erasures, the more uniform the graph which means that the number of erasures do not have much effect on energy consumption in packet switched wide area networks. The wine coloured graph shows the network in use. The graph sloped down from 1.63×10^{-4} to 1.50×10^{-4} Joules and became uniform all through the number of erasures. The higher the number of erasures, the minimal the energy consumption of error in packet switched wide area networks.

The green graph shows the Higher/Lower erasures in the network. The graph rose from 8.70×10^{-4} passing through three points to 1.02×10^{-1} Joules and sloped down through four points to 4.00×10^{-3}.

The Purple graph shows total number of erasures in the network. The graph rose from 1.03×10^{-1} passing through three points to 2.04×10^{-1} Joules and sloped down through three points to 1.06×10^{-1}.

The sky blue graph shows the proposed model (Dynamic Erasure coding network). The graph rose from 2.37 Joules passing through three points to 4.71 Joules and slopped down through four points to 2.45 Joules.

The result of the five graphs at 1000 Mb/s shows that the first two graphs are not affected by the number of erased channels. The last three graphs show that when the Good channel is higher than the erased channel, the energy consumption will be lower and when the erased channel is higher than the good channel, the energy consumption increases. The further the good/erased channel, the higher the energy consumption and the closer the good/erased channel, the lower the energy consumption.

TABLE IV: TABLE SHOWING ENERGY CONSUMPTION OF PACKETS AT THROUGHPUT OF 2000MB/S

Erase Chann	Idle Net	Net. in use	H/L Erase	No of Erase	Dy. Erase
2	7.50E-05	2.25E-04	0.0009	0.1081	1.3083
4	2.0833-06	1.52E-04	0.0092	0.1164	1.4081
6	4.1667E-08	1.50E-04	0.0369	0.1441	1.7439
8	5.3145E-10	1.50E-04	0.0797	0.1896	2.2623
10	4.5930E-12	1.50E-04	0.1072	0.2144	2.5946
12	2.8468E-14	1.50E-04	0.0983	0.2055	2.4866
14	1.3235E-16	1.50E-04	0.0653	0.1726	2.0879
16	4.7796E-19	1.50E-04	0.0329	0.1402	1.6959
18	1.3182E-21	1.50E-04	0.0130	0.1202	1.4549
20	3.2451E-24	1.50E-04	0.0041	0.1114	1.3475

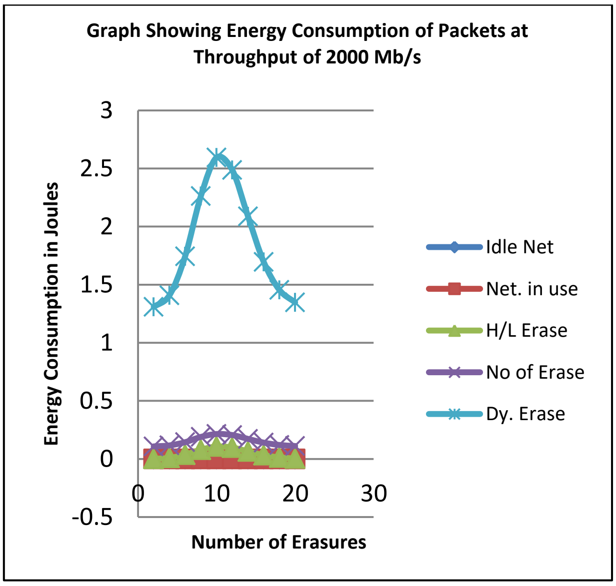

Figure 6: *Graph Showing Energy Consumption of Packets at Throughput of 2000 Mb/s*

The blue graph shows the idle network which means that when network is not in use. The graph sloped down from 7.50 × 10^{-5} to 2.06 × 10^{-6} to 4.17 × 10^{-8} and became slightly uniform. The higher the number of erasures, the more uniform the graph which means that the number of erasures do not have much effect on energy consumption in packet switched wide area networks. The wine coloured graph shows the network in use. The graph sloped down from 2.25 × 10^{-4} to 1.52 × 10^{-4} and to 1.50 × 10^{-4} Joules and became uniform all through the number of erasures. The higher the number of erasures, the minimal the energy consumption of error in packet switched wide area networks.

The green graph shows the Higher/Lower erasures in the network. The graph rose from 9.00 × 10^{-4} passing through three points to 1.07 × 10^{-1} Joules and sloped down through four points to 4.10 × 10^{-3}.

The Purple graph shows total number of erasures in the network. The graph rose from 1.03 × 10^{-1} passing through three points to 2.04 × 10^{-1} Joules and sloped down through three points to 1.06 × 10^{-1}.

The sky blue graph shows the proposed model (Dynamic Erasure coding network). The graph rose from 1.31 Joules passing through three points to 2.59 Joules and slopped down through four points to 1.35 Joules.

The result of the five graphs at 2000 Mb/s shows that the first two graphs are not affected by the number of erased channels. The last three graphs show that when the Good channel is higher than the erased channel, the energy consumption will be lower and when the erased channel is higher than the good channel, the energy consumption increases. The further the good/erased channel, the higher the energy consumption and the closer the good/erased channel, the lower the energy consumption.

The Second Set of tables and graph below Shows the Energy consumed for different levels of Higher and Lower erasures and idle network and network in use at Throughput of 2000 Mb/s and Service rate of 2000 Mb/s with different Amplitudes with varying waiting time.

TABLE V: TABLE SHOWING ENERGY CONSUMPTION OF PACKETS AT AMPLITUDE OF 40 METRES

Erase Chann	Idle Net	Net. in use	H/L Erase	No of Erase	Dy. Erase
2	0.4000	1.2000	4.80	576.64	6977.60
4	0.0111	0.8111	48.80	620.64	7509.60
6	2.22E-04	0.8007	196.80	768.64	9300.80
8	2.83E-06	0.8000	425.28	1011.2	12065.60
10	2.45E-08	0.8000	571.84	1143.68	13837.60
12	1.52E-10	0.8000	524.16	1096.00	13261.60
14	7.06E-13	0.8000	348.48	920.32	11135.20
16	2.55E-15	0.8000	175.68	747.52	9044.80
18	7.35E-18	0.8000	69.44	641.28	7759.20
20	1.73E-20	0.8000	22.08	593.92	7186.40

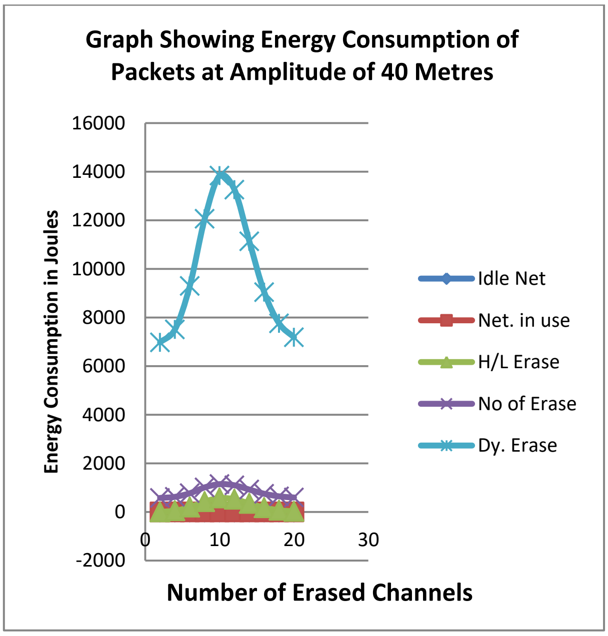

Figure 7: *Graph Showing Energy Consumption of Packets at Amplitude of 40 Metres*

The blue graph shows the idle network which means that when network is not in use. The graph sloped down from 4.00 × 10^{-1} to 1.11 × 10^{-2} to 2.22 × 10^{-4} Joules and became slightly uniform. The higher the number of erasures, the more uniform the graph which means that the number of erasures do not have much effect on energy consumption in packet switched wide area networks. The wine coloured graph shows the network in use. The graph sloped down from 1.20 to 8.11 × 10^{-1} to 8.01 × 10^{-1} and to 8.00 × 10^{-1} Joules and became uniform all through the number of erasures. The higher the number of erasures, the minimal the energy consumption of error in packet switched wide area networks.

The green graph shows the Higher/Lower erasures in the network. The graph rose from 4.8 Joules passing through three points to 572 Joules and sloped down through four points to 22.1 Joules.

The Purple graph shows total number of erasures in the network. The graph rose from 5.77 × 10^{2} Joules passing through three points to 1.14 × 10^{3} Joules and sloped down through three points to 5.94 × 10^{2} Joules.

The sky blue graph shows the proposed model (Dynamic Erasure coding network). The graph rose from 6.98 × 10^{3} Joules passing through three points to 1.38 × 10^{4} Joules and slopped down through four points to 7.19 × 10^{3} Joules.

The result of the five graphs at amplitude of 40 metres shows that the first two graphs are not affected by the number of erased channels. The last three graphs show that when the Good channel is higher than the erased channel, the energy consumption will be lower and when the erased channel is higher than the good channel, the energy consumption increases. The further the good/erased channel, the higher the energy consumption and the closer the good/erased channel, the lower the energy consumption.

TABLE VI: TABLE SHOWING ENERGY CONSUMPTION OF PACKETS AT AMPLITUDE OF 80 METRES

Erase Chann	Idle Net	Net. in use	H/L Erase	No of Erase	Dy. Erase
2	1.60	4.8000	19.20	2306.56	27910.4
4	0.0444	3.2444	195.20	2482.56	30038.4
6	8.89E-04	3.2000	787.20	3074.56	39203.2
8	1.13E-05	3.2000	1701.12	4044.8	48262.4
10	9.80E-08	3.2000	2287.36	4574.72	55350.4
12	6.07E-10	3.2000	2096.64	4384.00	53046.4
14	2.84E-12	3.2000	1393.92	3681.28	44540.8
16	1.02E-14	3.2000	702.72	2990.08	36179.2
18	2.94E-17	3.2000	277.76	2565.12	31036.8
20	6.92E-20	3.2000	88.32	2375.88	28745.6

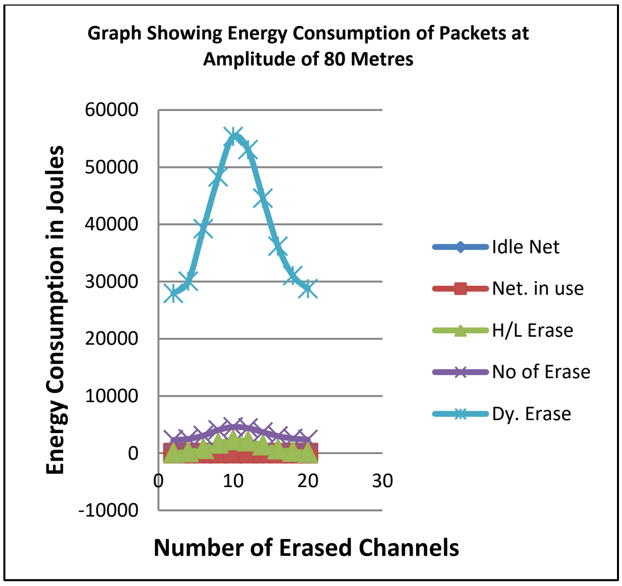

Figure 8: *Graph Showing Energy Consumption of packets at Amplitude of 80 Metres*

The blue graph shows the idle network which means that when network is not in use. The graph sloped down from 1.60×10^{-1} to 4.44×10^{-2} to 8.89×10^{-4} Joules and became slightly uniform. The higher the number of erasures, the more uniform the graph which means that the number of erasures do not have much effect on energy consumption in packet switched wide area networks. The wine coloured graph shows the network in use. The graph sloped down from 4.80 to 3.24 to 3.20 Joules and became uniform all through the number of erasures. The higher the number of erasures, the minimal the energy consumption of error in packet switched wide area networks.
The green graph shows the Higher/Lower erasures in the network. The graph rose from 4.8 Joules passing through three points to 572 Joules and sloped down through four points to 22.1 Joules.

The Purple graph shows total number of erasures in the network. The graph rose from 2.31×10^{3} Joules passing through three points to 4574.72 Joules and sloped down through three points to 2375.88 Joules.
The sky blue graph shows the proposed model (Dynamic Erasure coding network). The graph rose from 2.79×10^{4} Joules passing through three points to 55350.4 Joules and slopped down through four points to 28745.6 Joules.
The result of the five graphs at amplitude of 80 metres shows that the first two graphs are not affected by the number of erased channels. The last three graphs show that when the Good channel is higher than the erased channel, the energy consumption will be lower and when the erased channel is higher than the good channel, the energy consumption increases. The further the good/erased channel, the higher the energy consumption and the closer the good/erased channel, the lower the energy consumption.

TABLE VII: TABLE SHOWING ENERGY CONSUMPTION OF PACKETS AT AMPLITUDE OF 120 METRES

Erase Chann	Idle Net	Net. in use	H/L Erase	No. of Erase	Dy. Erase
2	3.6000	10.8000	43.20	5189.76	62798.4
4	0.1000	7.2999	439.20	5585.76	67586.4
6	0.0020	7.2059	1771.20	6917.76	83707.2
8	2.55E-05	7.2000	3827.52	9100.8	108590.4
10	2.20E-07	7.2000	5146.56	10293.12	124538.4
12	1.37E-09	7.2000	4717.44	9864.00	119354.4
14	6.35E-12	7.2000	3136.32	8282.88	100216.8
16	2.29E-14	7.2000	1581.12	6727.68	81403.2
18	6.62E-17	7.2000	624.96	5771.52	69832.8
20	1.56E-19	7.2000	198.72	5345.28	64677.6

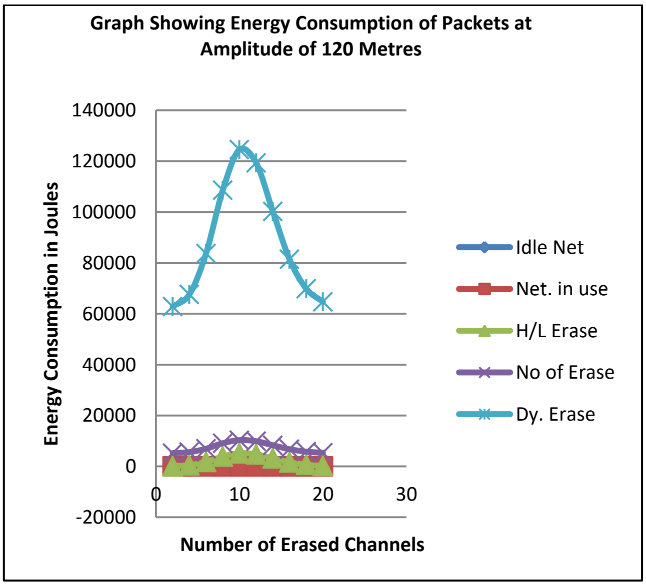

Figure 9: *Graph Showing Energy Consumption of Packets at Amplitude of 120 Metres*

The blue graph shows the idle network which means that when network is not in use. The graph sloped down from 3.60 × 10^0 to 1.00 × 10^{-1} to 2.00 × 10^{-3} Joules and became slightly uniform. The higher the number of erasures, the more uniform the graph which means that the number of erasures do not have much effect on energy consumption in packet switched wide area networks. The wine coloured graph shows the network in use. The graph sloped down from 10.80 to 7.30 to 7.21 Joules to 7.20 Joules and became uniform all through the number of erasures. The higher the number of erasures, the minimal the energy consumption of error in packet switched wide area networks.

The green graph shows the Higher/Lower erasures in the network. The graph rose from 43.2 Joules passing through three points to 5146.56 Joules and sloped down through four points to 198.72 Joules.

The Purple graph shows total number of erasures in the network. The graph rose from 5.190 × 10^3 Joules passing through three points to 10293.12 Joules and sloped down through three points to 5345.28 Joules.

The sky blue graph shows the proposed model (Dynamic Erasure coding network). The graph rose from 6.28 × 10^4 Joules passing through three points to 124538.4 Joules and slopped down through four points to 64677.6 Joules.

The result of the five graphs at amplitude of 120 metres shows that the first two graphs are not affected by the number of erased channels. The last three graphs show that when the Good channel is higher than the erased channel, the energy consumption will be lower and when the erased channel is higher than the good channel, the energy consumption increases. The further the good/erased channel, the higher the energy consumption and the closer the good/erased channel, the lower the energy consumption.

TABLE VIII: TABLE SHOWING ENERGY CONSUMPTION OF PACKETS AT AMPLITUDE OF 160 METRES

Erase Chann	Idle Net	Net. in use	H/L Erase	No. of Erase	Dy. Erase
2	6.4000	19.2000	76.80	9226.24	111641.6
4	0.1778	12.9777	780.80	9930.24	120153.6
6	0.0036	12.8105	3148.80	12298.24	148812.8
8	4.54E-05	12.8000	6804.48	16179.2	193049.6
10	3.92E-07	12.8000	9149.44	18298.88	221401.6
12	2.43E-09	12.8000	8386.56	17536.00	212185.6
14	1.13E-11	12.8000	5575.68	14725.12	178163.2
16	4.08E-14	12.8000	2810.88	11960.32	144716.8
18	1.18E-16	12.8000	1111.04	10260.48	124147.2
20	2.77E-19	12.8000	353.28	9502.72	114982.4

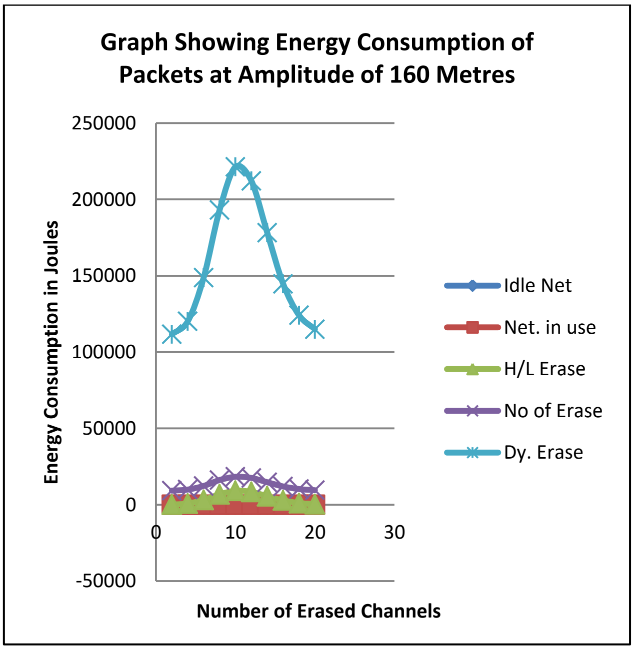

Figure 10: *Graph Showing Energy Consumption of packets at Amplitude of 160 Metres*

The blue graph shows the idle network which means that when network is not in use. The graph sloped down from 6.40 × 10^{-1} to 1.78 × 10^{-1} to 3.60 × 10^{-3} Joules and became slightly uniform. The higher the number of erasures, the more uniform the graph which means that the number of erasures do not have much effect on energy consumption in packet switched wide area networks. The wine coloured graph shows the network in use. The graph sloped down from 19.20 to 12.9777 to 12.8105 Joules to 12.8000 Joules and became uniform all through the number of erasures. The higher the number of erasures, the minimal the energy consumption of error in packet switched wide area networks.

The green graph shows the Higher/Lower erasures in the network. The graph rose from 7.68 Joules passing through three points to 9149.44 Joules and sloped down through four points to 353.28 Joules.

The Purple graph shows total number of erasures in the network. The graph rose from 9.23 × 10^3 Joules passing through three points to 18288.88 Joules and sloped down through three points to 9502.72 Joules.

The sky blue graph shows the proposed model (Dynamic Erasure coding network). The graph rose from 1.12 × 10^5 Joules passing through three points to 221406.4 Joules and slopped down through four points to 114982.4 Joules.

The result of the five graphs at amplitude of 160 metres shows that the first two graphs are not affected by the number of erased channels. The last three graphs show that when the Good channel is higher than the erased channel, the energy consumption will be lower and when the erased channel is higher than the good channel, the energy consumption increases. The further the good/erased channel, the higher the energy consumption and the closer the good/erased channel, the lower the energy consumption.

TABLE IX: TABLE SHOWING ENERGY CONSUMPTION OF PACKETS AT AMPLITUDE OF 200 METRES

Erase Chann	Idle Net	Net. in use	H/L Erase	No of Erase	Dy. Erase
2	10.0000	30.0000	120.00	14416	174440
4	0.2778	22.9777	1220.00	15516	187740
6	0.0056	20.2776	4920.00	19216	232520
8	7.09E-05	20.0164	10632.00	25280	301640
10	6.12E-07	20.0000	14296.00	28592	345940
12	3.80E-09	20.0000	13104.00	27400	331540
14	1.76E-11	20.0000	8712.00	23008	278380
16	6.37E-14	20.0000	4398.00	18688	226120
18	1.84E-16	20.0000	1736.00	16032	193980
20	4.33E-19	20.0000	552.00	14848	179660

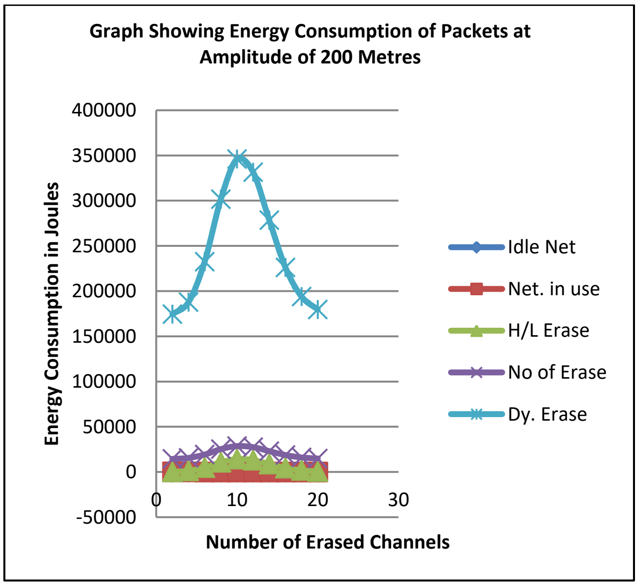

Figure 11: *Graph Showing Energy Consumption of Packets at Amplitude of 200 Metres*

The blue graph shows the idle network which means that when network is not in use. The graph sloped down from 1.00×10^{-1} to 2.78×10^{-1} to 5.60×10^{-3} Joules and became slightly uniform. The higher the number of erasures, the more uniform the graph which means that the number of erasures do not have much effect on energy consumption in packet switched wide area networks. The wine coloured graph shows the network in use. The graph sloped down from 30 to 22.9777 to 20.2776 Joules to 20.0164 and finally to 20.0000 Joules and became uniform all through the number of erasures. The higher the number of erasures, the minimal the energy consumption of error in packet switched wide area networks.

The green graph shows the Higher/Lower erasures in the network. The graph rose from 120 Joules passing through three points to 14296 Joules and sloped down through four points to 552 Joules.

The Purple graph shows total number of erasures in the network. The graph rose from 1.44×10^4 Joules passing through three points to 28592 Joules and sloped down through three points to 14848 Joules.

The sky blue graph shows the proposed model (Dynamic Erasure coding network). The graph rose from 1.74×10^5 Joules passing through three points to 345940 Joules and slopped down through four points to 179660 Joules.

The result of the five graphs at amplitude of 200 metres shows that the first two graphs are not affected by the number of erased channels. The last three graphs show that when the Good channel is higher than the erased channel, the energy consumption will be lower and when the erased channel is higher than the good channel, the energy consumption increases. The further the good/erased channel, the higher the energy consumption and the closer the good/erased channel, the lower the energy consumption.

IV CONCLUSION

This paper has shown that Dynamic Erasure Coding method can achieve minimal Energy consumption with increase in throughput and increase in amplitude which is the threshold value. It will save the data society and economy which has all the time increase in volume while transferring data.

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