



Enhancing Network Reliability: A Novel Approach to Error Management in Packet Switched Wide Area Networks

¹Emuejevoke Francis Ogbimi, ¹Paschal Uchenna Chinedu, ²Pascal Adegher, ³Emmanuel John Abah,

⁴Ruth Stephen Bature, ⁵Muyideen Omuya Momoh

¹Department of Information Systems and Technology
Delta State University of Science and Technology, Ozoro, Nigeria

²Department of Computer Science
Nigeria Defence Academy, Kaduna, Nigeria

³Department of Computer Science,
Margaret Lawrence University, Abuja, Nigeria

⁴Department of Information and Communication Technology,
Nigeria Institute of Leather and Science Technology, Zaria, Kaduna State, Nigeria.

⁵Department of Mechatronics Engineering,
Air Force Institute of Technology Kaduna, Nigeria

ABSTRACT

The desire for error-free communication is paramount for both senders and receivers of messages. However, errors frequently occur in networks due to various factors, leading to the loss or alteration of message content. This issue is a significant concern for both the parties involved in communication and network providers. In response to this challenge, we propose a model for error control that aims to reduce transmission errors in packet-switched Wide Area Networks (WANs). By leveraging advanced techniques, this model seeks to enhance the reliability and efficiency of data transmission, ultimately ensuring that messages are delivered accurately and promptly.

ARTICLE INFO

Article History

Received: August, 2024

Received in revised form: September, 2024

Accepted: September, 2024

Published online: December, 2024

KEYWORDS

Packet-Switched, Wide Area Network, Error, Router, Service Rate, Arrival Rate, Entropy

INTRODUCTION

Data communication and networking are determining how we live and transact business. Today, business decision-making is being made speedily so it requires immediate access to reliable data. Businesses also depend on internetworking of data and computing machines. Before asking how fast users could be connected, we have to be informed which prototype meets of the capacity required, what types of automations are available and how networks work. The advancement of the computers brought progresses in learning, research, commerce and manufacturing. Identical changes occurred through information transmission and interconnection. Improvements in technology have made signal transmission faster through high capacity communication links. Call features like audio, call waiting, conference call and call user have been established through the use of internet technologies. Research in data communications and networking has brought a paradigm shift in the way people send and receive messages.

One objective of data communication is to transmit and receive information in different forms from various sources like video, audio, incoming calls, conference and text messages. People aspire to gain access to the web to send and receive information swiftly and precisely at all times.

The rapid growth of data has brought immense tasks of data management and research in data communication. Integrated Data Corporation (IDC, 2012) anticipated that the volume of data generated, replaced and used will increase substantially beyond 2020.

In an ideal situation, all users connected in a particular network are expected to receive the same data, but in practice that is not the situation. This is because data may be corrupted and lead to error in transmission. Therefore, there is need to work to minimize data transmission error. The need to minimize corruption of data (error) became really necessary with the development of the high speed computer which handles large volume of data. Also, large volume of data is handled in military operations, aviation industry and Global

Corresponding author: Emuejevoke Francis Ogbimi

✉ ogbimief@dsust.edu.ng

Department of Information Systems and Technology, Delta State University of Science and Technology, Ozoro, Nigeria.

© 2024. Faculty of Technology Education. ATBU Bauchi. All rights reserved

System Mobile (GSM) communication. Operations that deal with large volume of data demand accuracy and will continue to apply measures that minimize error in data transmission.

Changes in networks are determined by the developments in software and hardware.

Wide Area Networks (WAN) are the interconnection of computer along large region of buildings. WAN are popular in computer and informatics because they are connected across multiple regions and are reliable networks. It is for the popularity of WAN that they are the focus of our effort to contribute to knowledge and skills for minimizing errors in networks.

Error is an important concern in WANs. It occurs when a packet (unit of message/data) does not get to the destination or comes to the destination but some of the bits are erased. Packet switching is a mechanism which ensures that large volume of information is broken down into smaller units of messages, packets to be transmitted more easily to the receiver. Bandwidth is the width of the range of frequencies a signal contains. Packet loss results when there is no sufficient capacity to transmit information input into it. Retransmission means that the sender has to resend the data already sent i.e., transmitting the same message until the receiver gets the message. The sender will not know that the packets have been missing. The sender has to wait for the receiver to respond to data received or missing over an extended period of time. Lost units of messages increase waiting time because more time is required for retransmission. Retransmitting a message takes time and consumes additional energy. If retransmission is not done, messages will be lost. Buffers can be used to keep packets which could have been missing. Consequently, the temporarily stored/missing data has to be resent. Therefore, retransmitted units of message increase energy and cost for both retransmitting and accepting the damaged packets.

This proposed model for error control will reduce the error in transmission of data in packet switched Wide Area Networks.

LITERATURE REVIEW

A. Information Theory

Information theory is the scientific investigation of the measurement, storage, and transmission of digital information [2]. The scope

was basically created by the works of Harry Nyquist and Ralph Hartley, in the 1920s, and Claude Shannon in the 1940s [3]. The field is at the logical product of law of probability, data, computer science, quantum mechanics, information engineering and electrical engineering.

A significant step in information theory is entropy. Entropy is the valuation of the amount of incomplete information before reception [2]. Often called *Shannon entropy*, it was initially conceived by Claude Shannon in 1948 to study the size of data of a delivered message. The definition of information disorderliness is represented in terms of another series of probabilities so that

$$H(s) = - \sum_{i=1}^n P_k \log P_k \quad (1)$$

Where P_k is the probability of number of routers that are accepting packets

In the case of delivered messages, these probabilities were the possibilities that an exact message was exactly delivered, and the disorderliness of the message system was an estimation of the average size of information of a message. For the case of equal possibilities (i.e. each message is equally probable), the Shannon disorderliness (in bits) is just the number of digital questions needed to ascertain the amount of the message [5].

Entropy quantifies the amount of uncertainty involved in the value of a random variable or the result of a random operation. For example, identifying the result of a fair coin flip (having an equal probability of two) provides less information (lower entropy) than specifying the outcome from a roll of a die (having and equal probability of six). Information theory studies the broadcasting, processing, analyzing, drawing out and utilization of information. Abstractly, information can be thought of as the resolution of uncertainty. In the case of communication of information over a noisy channel, this abstract concept was formalized in 1948 by Claude Shannon in a paper entitled *A Mathematical Theory of Communication*, in which information is thought of as a set of possible messages, and the goal is to send these messages over a noisy channel, and to have the receiver reconstruct the message with low probability of error, in spite of the channel noise. Shannon's main result, the noisy-channel coding

theorem showed that, in the limit of many channel uses, the rate of information that is asymptotically achievable is equal to the channel capacity, a quantity dependent merely on the statistics of the channel over which the messages are sent [6].

B. Past Research Works on Entropy in Wide Area Networks

Donelli, Stringer and Stuart [9], decreased the utilization rate and increased the data hold-up period of computer network packets of data. Blocks of data packets were grouped by measuring the disorderliness of the user information. The value of the support was determined according to the disorderliness and other information in the support layer; physical, data connection and the connection layer of the Open System Interconnection (OSI) model of data networking packet layer. Encrypted payloads and reduced packet information often have very high disorderliness due to their randomness. Without cryptography keys, encrypted payloads cannot be decrypted so often. They have storage value compressed packet information often made up of reduced raw information (e.g. movies, television and music) that can be recreated and so they can have low storage value (utility). Moreover reduced packet information may not be eventually reduced. Consequentially, packet data information with high disorderliness (High disorderliness packet information date) could be applied to reduction of packet information to retain memory capacity and increase holding time. Plain text data is readily viewable and often has low entropy. Because the payload data is viewable it can have a high storage value. The low disorderliness block of data is returned further to retain memory and increase holding time.

Iglesias and Zseby [10], proffered a fast, lightly built scheme to distinguish different types of attack found in an IP deep space monitor. The scheme is derived from disorderliness measures of circulation features and artificial intelligence methods. Results from an comprehensive congestion analysis according to packet top-part and details are used as a guidebook to highlight data and to measure the quality of the disaster-based categorization. Full IP dark space traffic captures from a three-week monitoring period in April, 2012, are used to compare the entropy-based classification with extensive traffic analysis. Results show that

several transfer types exhibits a close relationships to the respective flow of data disorderliness signals and can even fit multinomial declination models. Sharp changes in gridlock types caused by recent attacks or attack preparation activities was identified based on entropy variations.

Kompella, Drake, Amante, Henderickx and Yong [11], improved load balancing across MPLS networks using the concept of "entropy labels". They defined the concept, described why entropy labels are useful, enumerated properties of entropy labels that allow maximal benefit, and shows how they can be signaled and used for various applications.

Lawniczak, Hao and Stefano, [12] demonstrated that the entropy function of packet traffic monitored at selected network nodes as a tool in detection of anomalous packet traffic, e.g. DDoS attacks. The method detect changes in "natural" randomness of spatio-temporal distributions of packets among nodes caused by anomalous packet traffic, e.g. (Distributed Denial of Service (DDoS) attacks [13]. This is because for properly selected sets of monitored nodes the values of entropy functions of packet traffic decreases sharply from the "fingerprint" profiles shortly after start of each DDoS attack, with certainty a presence of an infrequent event [14].

C. Problems Encountered in Error Control Techniques

In view of the many efforts aimed at solving the problem of error and packet loss in data transmission, there still exists many problems. Some of these problems are (1) **ARQ** has a crucial problem for broadcast support as the sender cannot solve the problem of retransmission missing or corrupt packets for many users in the network. The transmission complexity of packets is proportional to the number of receivers even if only negative acknowledgements are used. The sender waits for a NAK from every receiver before dropping an Error Correcting bit [15-17]. (2) Waiting time may become large, even for low rates because group size of codes is proportional to the number of requests. (3) The capacity is significantly reduced if the sender becomes active resending retransmissions or pointer buffer fills at the top. (4) For Forward Error Correction, because of complexity of available FEC computations, it is very expensive to implement. Erasure codes with

emphasis on burst erasure coding, does not record contents in a clear form. It is difficult to build and slow. Decoding the robin approach, multiplying a matrix by the given matrix to obtain a unit matrix has to be estimated before the interpretation begins, the implementation is only effective if the deletions are in a stationary location.

METHODOLOGY

A. Model Development

Erasure coding is applied by source node. In this network, the packets are lost on the links joining node 1 to node 2 with probability of p_{12} and on the line joining nodes 2 and node 3 with probability of p_{23} and it continues until it gets to the last node. An erasure code is applied at node 1 to send messages at an information rate of $(1 - p_{12})(1 - p_{23}) \dots (1 - p_{nm})$ packets per unit time.

Essentially erasure channels with erasure probability of $1 - (1 - p_{12})(1 - p_{23}) \dots (1 - p_{nm})$ can be achieved by a suitably design code. The erasure codes is applied over the link joining the nodes from 1 and 2 and another joining 2 and 3 up to nodes joining m and n which makes us use many stages of erasure coding with decoding and recoding at nodes 2 to n. Messages can be between nodes 1 to 2 at $1 - p_{12}$ packets and between nodes 2 and 3 at rate of $1 - p_{23}$ up to nodes m and n $(1 - p_{mn})$ packets per unit time. Messages can also be sent between nodes 1 and n at $\min(1 - p_{12})(1 - p_{23}) \dots (1 - p_{nm})$ which in general is greater than $1 - p_{12})(1 - p_{23}) \dots (1 - p_{nm})$. Applying extra stages of erasure coding is a special form of error control which is coding between intermediate nodes.

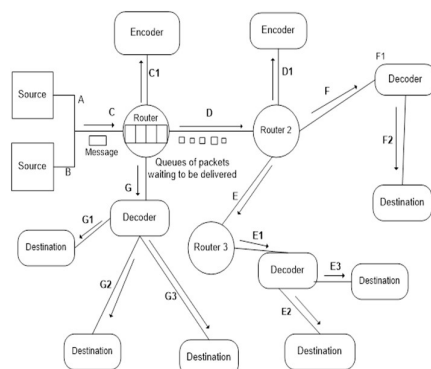


Figure 1: Flow diagram of the Proposed Model

Figure 1 shows a broader concept of dynamic erasure coding for error control in packet switched WAN. This involves multiple senders sending information to multiple receivers where encoders encrypts information from senders and decoders decrypts the information to receivers in the network.

B. Application of Queuing Model

Queuing model is applied to packet switched WAN [18-20]. The parameters of the queuing model were adjusted and solved to reduce error. Following the modified parameters:

The priority framework for movement of packets in packet switched WAN was analysed

Λ = Packet Throughput

μ = Packet Service rate

L_s = Number of messages across network.

L_q = Number of messages in queue.

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

W_s = Delay of 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

λ_{eff} = efficient throughput of packets in the network. It is equal to the nominal throughput λ when the entire packets are transmitted into the network. If the network cannot accommodate all the packets at the same time, then $\lambda_{eff} < \lambda$.

There is no limit on the maximum number of users in the network for a single server model ($n = 1$), The model assumes an infinite source. Incoming packets take place at the speed of k users per time scale. In this circumstances, $\rho < 1$ and $c < m\mu$. If throughput is greater than the service rate, then the exponential progression will not meet and the state of equilibrium likelihood will not exist. The queue length range will increase continually and no steady state will be reached in the network.

Allowing $\rho = \frac{\lambda}{\mu}$, the formula for p_n in the

extensive formula reduces to

$$P_k = p^k p_0, n = 0, 1, 2, \dots, j+1$$

(2)

To find out the value of p_0 we identify that

$$p_0 = 1 + \rho + \rho^2 + \dots + \rho^k$$

(3)

Under the condition of $\rho < 1$, $(\frac{1}{1-\rho})$ the series sum to infinity

$$S_k = \frac{a}{1-r} \quad \text{for } a = 1 \text{ and } r = \rho \text{ then,}$$

$$S_k = \frac{1}{1-\rho}$$

(4)

$P_k = 1$ for $k = 0$. Thus the steady state probability

$$\sum_{n=0}^{\infty} P_k = 1 \quad (5)$$

Substitute equation (2) in equation (5) gives for steady state probability $P_k = 1$

$$[\sum_{n=0}^{\infty} \rho^k] P_0 = 1 \quad (5)$$

$$P_0 = \left[\sum_{n=0}^{\infty} \rho^k \right]^{-1} \quad (6)$$

Substitute equation (4) in equation (6)

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

$$P_0 = 1 - \rho$$

(7)

in this case $\rho < 1$ sum to infinity,

$$S_k = \frac{a}{1-r}$$

$$S_k = \frac{\rho}{1-\rho} \quad (8)$$

With $\lambda_{\text{eff}} = \lambda$, for the present situation, that is when the entire throughput of messages are transmitted into the network, the remaining measures of performance are computed using this relationships.

For multiple server model which is the area of focus, there are c erased channels each serving messages ($c > 1$). The arrival rate is λ and the service rate of packets per host is μ . There is no hindrance on the number of routing machines across the network. With Kendall's notation M/M/c is the c host waiting line with Poisson arrivals and geometric shared acknowledged time. All queue disciplines are generalised distributions that satisfied all of its provisions. The parameters considered were throughput (λ), service rate (μ), number of servers (c), probability of number of routers not accepting packets (P_0). Throughput remains the same as M/M/1 queues but service rate depends on the number of channels. When the number of

servers exceed m , the service rate become $m\mu$ as shown in Figure 2.

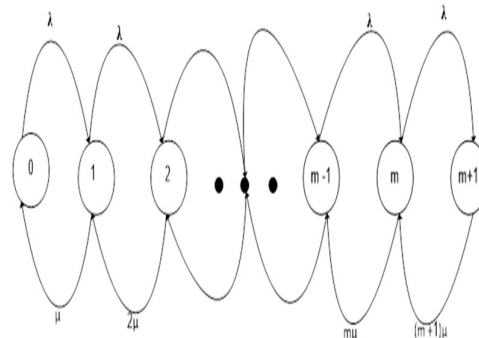


Figure 2: Transition of states in M|M|c Queuing Model, Source: Taha, (2008)

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

$$\sum_{k=0}^{\infty} P_k = 1. \quad (9)$$

N_q was found out in Multiple Input and Multiple Output (MIMO) systems

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

The service rate $m\mu$ will be $m\mu =$

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

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

$$\text{Then, } P_k = \frac{\lambda^k \times P_0}{\mu \times 2\mu \times 3\mu \times \dots \times k\mu}$$

(10)

$$P_k = \frac{\lambda^k}{k! \mu^k} * P_0 \quad k \leq m \quad (11)$$

$$P_k = \frac{1}{m!} \left(\frac{\lambda}{m\mu} \right)^{k-m} \left(\frac{\lambda}{\mu} \right)^m P_0$$

$$= \frac{1}{m!} \left(\frac{\lambda}{m\mu} \right)^k \cdot \left(\frac{\lambda}{m\mu} \right)^{-m} \left(\frac{\lambda}{\mu} \right)^m P_0$$

$$P_k = \frac{\lambda^m}{m! m^{k-m} \mu^m} * P_0 \quad k \geq m \quad (12)$$

These are the measurement of performances in multiple servers and several waiting lines in a packet switched wide area networks.

From equation (11) and (12) we get the following equations.

$$P_k = \left\{ P_0 \frac{(m\rho)^k}{k!} \quad k \leq m \quad (13) \right.$$

$$P_k = \left\{ P_0 \frac{m^m(\rho)^k}{k!} \quad k \geq m \quad (14) \right.$$

Put equations (2) and (7) in equation (1)

$$H(s) = - \sum_{i=1}^k \rho^k (1 - \rho) \log \rho^k (1 - \rho) \quad (15)$$

$$\frac{d(H(p))}{dp} = k\rho^{k-1} - k\rho^k - k^2\rho^{k-1} \log \frac{1}{\rho} + k(k+1)\rho^k \log \frac{1}{\rho} \quad (16)$$

C. Model Validation

Validation and verification of the simulation model occurred throughout the process of simulating the model in Matlab. The important procedures taken were:

1 Analytical Validation of Entropy in Packet switched Wide Area Networks using MatLab

Graphs were produced from entropy. Entropy was produced from service rate of packets and number of erasures (channels). Two cases of probability considered were good channels are greater than the erased channels (erased channels) and the erased channels are greater than the good channels. The entropy produced arose from two cases of probability. The Different speeds of service rate of packets, number of erasures and network utilization were varied with entropy of wide area networks produced. The entropy was computed.

D Simulation with Matlab

The proposed model for correcting error in packet switched broadband Networks was demonstrated using Matlab. Matlab is an information technology program created specifically for engineers and scientists to analyse and design algorithms and results that transform our world. Matlab allows for the natural expression of computational mathematics. An algorithm was used to model the entropy of packet in wide area networks. The parameters used were number of erasures, entropy in the network, and network utilization. The script was divided into steps. The initial phase was to develop the equations for different cases of probability. The second step was to obtain entropy of probability of routers accepting

packets in the system for both erasure coding and dynamic erasure coding model. The number of erasures were varied using service rate of packets and network utilization and the entropy of packets received was produced.

The proposed model of the number of erasures was compared with a past erasure method for analysing the effect of erased channels on entropy. The proposed model determined the performance of the network.

RESULTS AND DISCUSSIONS

This section presents the findings of the evaluation and characterization of the Dynamic Erasure Coding developed in Section III. The evaluation was conducted by analyzing the entropy of the number of erased channels, which was determined based on the packet rate and network utilization, with a focus on the number of erased channels.

TABLE 1: Entropy of Packet Switched WAN at Service rate of 500 Mb/ s

Erased Channel	Entropy	
	ERCM	DECM
2	1.09E-22	-1.40E+00
4	3.84E-21	-3.00E+00
6	5.50E-20	-6.29E+00
8	4.32E-19	-1.08E+01
10	2.17E-18	-1.65E+01
12	7.65E-18	-2.34E+01
14	2.02E-17	-3.15E+01
16	4.21E-17	-4.07E+01
18	7.20E-17	-5.12E+01
20	1.05E-16	-6.29E+01

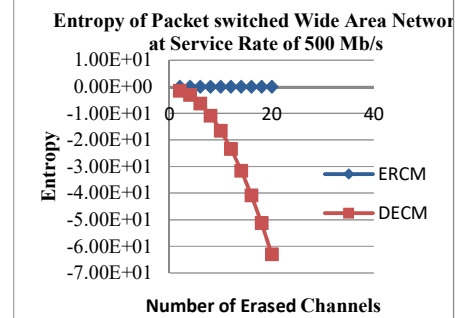


Figure 3: Entropy of Packet switched Wide Area Networks at Service Rate of 500 Mb/s

Corresponding author: Emuejevoke Francis Ogbimi

✉ ogbimief@dsust.edu.ng

Department of Information Systems and Technology, Delta State University of Science and Technology, Ozoro, Nigeria.

© 2024. Faculty of Technology Education. ATBU Bauchi. All rights reserved

Figure 3 shows the relationship between the entropy produced and number of erased channels at Service rate of 500 Mb/s. The blue graph showed the result of Erasure Coding method (ERCM) on entropy. The graph maintained almost a flat curve. The brown coloured graph showed the Dynamic Erasure Coding method (DECM). The graph deviate significantly downward, this is because of service rate and good channels as denominators in the entropy function. The results of the two models showed that when the erased channel is increased, the entropy neither increases or decreases in ERCN. For the DECM, the entropy increases which means there is more disorderliness when number of erasure increases. The higher efficiency of ECM can be attributed to two reasons: i) the closeness of the model to the real problem. The problem of information/data transmission and congestion/data loss/error is a queuing problem like automobiles queue up when too many automobiles try to use a particular road at the same time. Hence the DECM developed from queuing theory has a closer relationship between the model and the problem. ii) the DECM adopts the tools of recovery and retransmitting lost messages. The very high speed of light ensures that recovery of lost messages and retransmitting many times do not lead to significant delays in getting all the message to the receiver.

TABLE 2: Entropy of Packet Switched Wide Area Networks at Service rate of 2000 Mb/s

Erased Channel	Entropy	
	ERCM	DECM
2	9.50E-24	-5.23E-01
4	3.46E-23	-1.06E+00
6	6.00E-23	-2.30E+00
8	7.36E-23	-3.94E+00
10	7.81E-23	-6.03E+00
12	7.91E-23	-8.55E+00
14	7.92E-23	-1.15E+01
16	7.92E-23	-1.49E+01
18	7.92E-23	-1.87E+01
20	7.92E-23	-2.30E+01

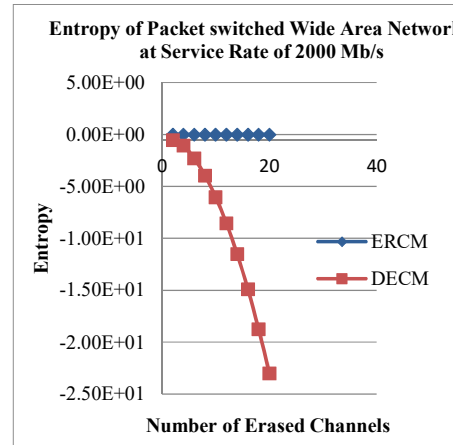


Figure 4: Entropy of Packet switched Wide Area Networks at Service Rate of 2000 Mb/s

Figure 4 shows the relationship between the entropy produced and number of erased channels at Service rate of 2000 Mb/s. The blue graph showed the result of Erasure Coding method (ERCM) on entropy. The graph maintained almost a flat curve. The brown coloured graph showed the Dynamic Erasure Coding method (DECM). The graph significantly sloped downward, this is because of service rate of packets and good channels as denominators of the change in the entropy function. The results of the two models showed that when the erased channel is increased, the entropy neither increases or decreases in ERCN. For the DECM, the entropy increases which means there is more disorderliness when number of erasure increases. The graph confirmed the trend as when the speed of receiving packet increases, the lower the entropy for DECM and the higher the entropy for ERCM. The four graphs demonstrated a trend that the higher the speed of receiving packet, the lower the entropy for DECM and the higher the entropy for ERCM.

TABLE 3: Entropy of Packet Switched Wide Area Networks at Network Utilization of 0.1

Erased Channels	Entropy	
	ERCM	DECM
2	-2.116	-0.6029
4	-2.6413	-0.0286
6	-2.7817	-6.78E-04
8	-2.6658	-1.24E-05
10	-2.6552	-1.96E-07
12	-2.6546	-2.85E-09
14	-2.6546	-3.90E-11
16	-2.6546	-5.12E-13
18	-2.6546	-6.51E-15
20	-2.6546	-8.66E-17

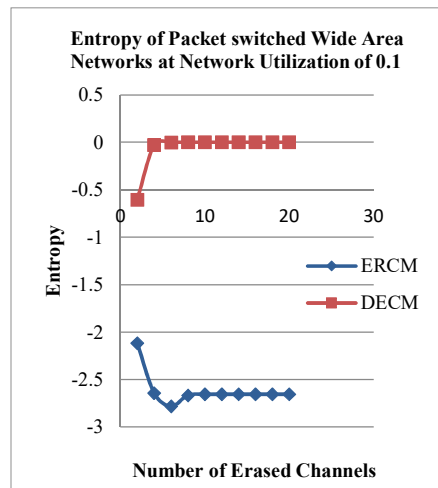


Figure 5: Entropy of Packet switched Wide Area Networks at Network Utilization of 0.1

Figure 5 illustrates how the number of lost channels influences the entropy at network utilization of 0.1. The blue graph showed the result ERCM on entropy. The graph sloped down from -2.1160 to -2.7817, rose to -2.6552 and became uniform although at -2.6546 to the last point. The brown graph showed the DECM method. The graph rose from -0.6029 Joules and rose steadily up to the last point of -8.6633×10^{-17} Joules. The graph showed that the entropy for DECM was lower compared to ERCM model. The composite plots showed that the DECM was more efficient than ERCM. The sensitivity of DECM was responsible for the lower entropy. It is also responsible for the closeness of the true situation in transmitting data.

TABLE 4: Entropy of Packet switched Wide Area Networks at Network Utilization of 0.5

Erased Channels	Entropy	
	ERCM	DECM
2	-88.5191	-0.1534
4	-1.57E+03	-0.2699
6	-8.63E+03	-2.31E-01
8	-2.43E+04	-1.20E-01
10	-4.42E+04	-5.12E-02
12	-6.04E+04	-1.94E-02
14	-6.94E+04	-6.80E-03
16	-7.30E+04	-2.30E-03
18	-7.40E+04	-7.40E-04
20	-7.43E+04	-2.32E-04

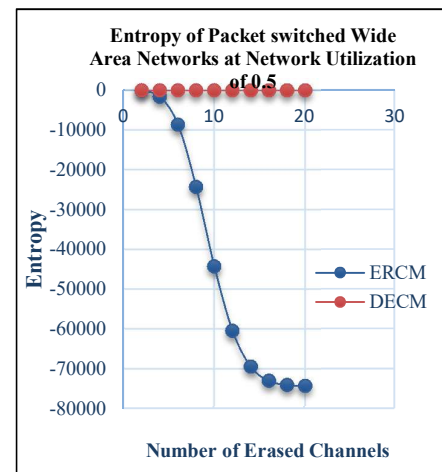


Figure 6: Entropy of Packet switched Wide Area Networks at Network Utilization of 0.5

Figure 6 illustrates how the number of erased channels affects the entropy at network utilization of 0.5. The blue graph showed the result ERCM on entropy. The graph sloped downwards from -0.1534 to -74260. The brown graph showed the DECM method. The graph maintained a flat curve from the first point to the last point because the entropy is very small. The graph showed that the entropy for ERCM was higher compared to DECM model. The model DECM demonstrated a trend in entropy with higher network utilization comparing figures 5, 6 added to the information that the higher the network utilization of packets, the more lower the

entropy. For ERCM, The entropy was getting higher with higher network utilization of packets.

TABLE 5: Table showing Entropy of Erasure Coding at Network Utilization of 0.9

Erased Channels	Entropy	
	ERCM	DECM
2	-17.258	0.3128
4	-3.12E+03	0.4452
6	-5.47E+04	4.66E-01
8	-4.48E+05	4.23E-01
10	-2.18E+06	3.47E-01
12	-7.10E+06	2.58E-01
14	-1.69E+07	1.68E-01
16	-3.14E+07	8.65E-02
18	-4.78E+07	1.55E-02
20	-6.24E+07	-4.29E-02

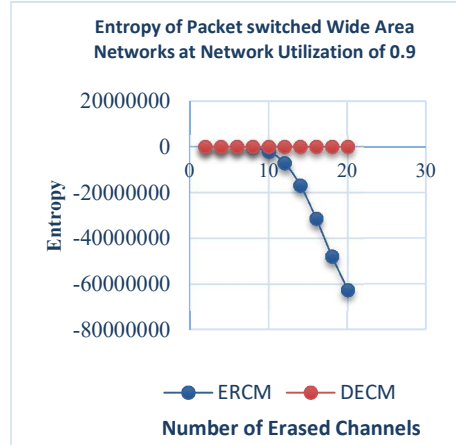


Figure 7: Entropy of Packet switched Wide Area Networks at Network Utilization of 0.9

Figure 7 illustrates how the number of erased channels affects the entropy of packet switched wide area networks at network utilization of 0.9. The blue graph showed the result of ERCM entropy. The graph made a downward slope from 0.3128 to -62431000 passing through 8 points the brown graph showed the DECM. The graph maintained a flat curve from the first to the last point. The graph confirmed the trend that when the network utilization of data transmission is very high, the entropy increases for ERCM and reduces for DECM. The three graphs, figures 5, 6, and 7

have confirmed the trend that the higher the network utilization, the entropy for ERCM and the lower the entropy for DECM.

The three graphs have confirmed a trend that the higher the network utilization, the lower the entropy in DECM and the higher the entropy on ERCM.

An increase in network utilization produced reduces the entropy for the model. In a network where there is error in transmission, the packet has to be retransmitted. Retransmission in networks involves resending the same packets to the receiver until the sender gets a reply from the receiver of successfully received packets. With this proposed method (DECM), retransmission will not be observed because movement of packet which is in form of electrons move with the speed of light. It is as if packets are transmitted normally as it should in the network because the proposed method have reduced error which makes the sender retransmit packets to destination.

CONCLUSION

The challenges associated with error management in packet-switched Wide Area Networks (WANs) are significant and multifaceted. This study highlights the critical need for effective error control mechanisms to ensure reliable data transmission. The proposed Dynamic Erasure Coding Model (DECM) demonstrates a promising approach to mitigating transmission errors by utilizing principles from queuing and information theory. By enhancing the entropy of packet traffic and reducing disorderliness within the network, the DECM not only improves the efficiency of data transmission but also addresses the complexities of retransmission and packet loss. As technology continues to evolve, the implementation of such innovative models will be essential in meeting the growing demands for accurate and timely communication in increasingly complex network environments.

REFERENCES

- [1] Integrated Data Corporation, (2012), "IDC's Digital Universe Study", Sponsored by EMC; White Paper, December, 2012.
- [2] C. E. Shannon (1949), "Communication Theory of Secrecy Systems", "Bell System Technical Journal", Volume 28, Issue 4, pages 656-715.

Corresponding author: Emuejevoke Francis Ogbimi

✉ ogbimief@dsust.edu.ng

Department of Information Systems and Technology, Delta State University of Science and Technology, Ozoro, Nigeria.

© 2024. Faculty of Technology Education. ATBU Bauchi. All rights reserved



- [3] C. E. Shannon and W. Weaver (1998), "The Mathematical Theory of Communication", "Bell System Technical Journal" 27, 379–423, 623–656, University of Illinois Press.
- [4] B. Roger (2004). "Entropy, a Protean concept". In Dalibard, Jean (ed.). "Poincaré Seminar 2003: Bose-Einstein condensation – entropy". Basel: Birkhäuser. pp. 119–144. ISBN 978-3-7643-7116-6.
- [5] R. Frigg and C. Werndl, "Entropy – A Guide for the Perplexed". In *Probabilities in Physics*; Beisbart C. and Hartmann, S. Eds; Oxford University Press, Oxford, 2010.
- [6] F. Rieke, D. Warland, R. Ruyter van Steveninck and W. Bialek (1997). *Spikes: "Exploring the Neural Code"*, The MIT press, ISBN 978-0262681087.
- [7] R. Morris (1988), "Time's Arrows: Scientific Attitudes Toward Time". Simon and Schuster, Inc.
- [8] <http://entropysimple.oxy.edu/>
- [9] S. F. Donnelly, J. Stringer, and S. Wilson (2018), "Network recorders with Entropy and Value based Truncation", Endace Technology Limited, Hamilton, U.S.A.
- [10] Iglesias F. and Zseby T., "Entropy-Based Characterization of Internet Background Radiation", *Entropy* 2015, 17, 74-101; doi:10.3390/e17010074.
- [11] K. Kompella, J. Drake, S. Amante, W. Henderickx and L. Yong (2012), "The Use of Entropy Labels in MPLS Forwarding", Internet Engineering Task Force (IETF), Request for Comments: 6790, ISSN: 2070-1721.
- [12] A. T. Lawniuczak, W. Hao, B.N. Stefano (2009), Detection of Anomalous Behaviour via Information Entropy, "International workshop on Complex networks", Catania, Italy.
- [13] A.E. Adedokun, M.B. Abdulrazak, M.M. Omuya, H. Bello-Salau, and B.O. Sadiq, (2019). A spatio-temporal based frame indexing algorithm for qos improvement in live low-motion video streaming. *ATBU Journal of Science, Technology and Education*, 7(3), pp.305-315.
- [14] P. U. Chinedu, W. Nwankwo, D. Aliu, S. M. Shaba, and M. O. Momoh. "Cloud security concerns: assessing the fears of service adoption." *Archive of Science and Technology* 1, no. 2 (2020): 164-174.
- [15] D. Towsley and J. K. Wolf, (1979). "On the Statistical Analysis of Queue Length and Waiting times for Statistical Multiplexers with ARQ Retransmission schemes", *IEEE Transaction on Communications*, VOL COM-27, No. 4, March 1979.
- [16] M. S. Saliu, M. O. Momoh, P. U. Chinedu, W. Nwankwo, & A. Daniel (2021). Comparative Performance Analysis of Selected Routing Algorithms by Load Variation of 2-Dimensional Mesh Topology Based Network-On-Chip. *ELEKTRIKA-Journal of Electrical Engineering*, 20(3), 1-6.
- [17] I. J. Umoh, G. O. Marufat, Y. Basira, A. D. Abdulfatai, & M. O. Muyideen (2019). BANM: A Distributed Network Manager Framework for Software Defined Network-On-Chip (SDNoC). *Covenant Journal of Informatics and Communication Technology*.
- [18] K. Raman and V. Viswanathan (2015), *Entropy and Telecommunications Systems*. "Journal of Telecommunications System and Management", Volume 4, Issue 1: e114. doi:10.4172/2167-0919.1000e114.
- [19] B. A. Forouzan, (2007), "Data Communications and Networking", 4th Edition, McGraw Hill, Higher Education, New York, U.S.A.
- [20] H. A. Taha, (2008), "Operations Research, An Introduction", Pearson Hall, New Jersey, 07458, U.S.A.

Corresponding author: Emuejevoke Francis Ogbimi

✉ ogbimief@dsust.edu.ng

Department of Information Systems and Technology, Delta State University of Science and Technology, Ozoro, Nigeria.

© 2024. Faculty of Technology Education. ATBU Bauchi. All rights reserved