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A Review of Computer Network Reliability

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***Abstract*—Network reliability, as a field, is focused on questions of topological disconnection between data nodes. Computer network reliability problem is primarily resolved by calculating the probability that specific set of nodes in understudied network can *speak* with each other at a given time. Network reliability analysis cuts across the design, deployment and testing of computer networks. Review reveal two major approaches to reliability analysis of computer network these are Path/cute numeration and Case analysis which utilizes the concept of graph decomposition. The measures of computer network reliability analysis include issues on connectivity, capacity and travel time. The different parameters used in defining the reliability of computer-communication system include; Failure Rate, Mean Time To Repair, Mean Time Between Failures, Mean Time To Failure and Availability.**

Keywords-reliability analysis; computer network; reliability index; network reliability

I. INTRODUCTION

Effective communications is critical in determining the economic, social, innovative and military prowess of modern day society; this is hinged on the fact that effective communications is a key stone in all human activities. This communication is majorly effected by data nodes. A data node could be a mobile phone, information centers, encrypting and decrypting machines which have evolved into what we call computers in today's world. Thus, the design and deployment of reliable data nodes has been given a high priority and this has enhanced the study of Computer Network reliability analysis as a field on its own. Network reliability is concerned with the topological disconnection between data nodes. Computer network reliability problem is primarily resolved by calculating the probability that specific set of nodes in understudied network can *speak* with each other at a given time. Network reliability analysis cuts across the design, deployment and testing of computer networks.

As communication is now centered on computer networks, the design of reliable computer networks is much needed. Reliability analysis of a computer-communication network gives "worthiness test" of the infrastructure or relevant components that constitute the computer network and as such, seeks to evaluate the relevance of the computer network to its intended design expectations.

There have been efforts by researchers using various approaches in determining the reliability of a computer network and as such are view to classify the approaches and define most suitable method of analyzing understudied Computer network is needed.

In this paper a review of computer network reliability analysis is carried out and presented in five subheadings.

Section 2 gives the different approaches to reliability analysis of computer networks, section 3 give an overview of related works, section 4 describe the model used, section 5 describes the measures of reliability analysis, section 6 gives a description of different parameters that can affect network reliability, section 7 gives the evaluation of the reliability index and conclusion is presented in section 8.

II. DIFFERENT APPROACHES TO RELIABILITY ANALYSIS OF COMPUTER NETWORKS

Network Reliability defines the probability that an understudied Network can perform its stated function to an acceptable level of performance for some given period of time [1]. Any specific measure of reliability, thus, depends on the nature of the desired function and what levels of performance are acceptable. Earliest works on Network reliability was around 1950, with connectivity of networks been used as there liability index [2].

Different set of algorithms are employed in reliability analysis of computer networks. The algorithms used can be grouped into two:

A. Path/Cut Enumeration:

This entails the listing of all the simple paths between end nodes. These represent a complete set of favorable (unfavorable) non-disjoint events. Simple paths are links in the network that connect set of nodes while prime cut sets are links in the network which when disconnected cause the network to fail. The simple paths are considered assets of favorable events while the prime cuts as set of unfavorable events. Reliability analysis entails summing the terminal reliabilities of these paths which is an indication that each node communicates with a designated node. To obtain the computer network reliability, the inclusion-exclusion techniques of path and cuts is carried out. More efficient techniques based on Boolean algebra, can be utilized [2]–[7].

B. Case analysis:

Case analysis uses the method of graph decomposition. This entails the creation of subsets from the path sets, either around a reference edge or around a number of edges/links/paths. A reference edge is simply the node from which the factoring is anchored. When more than one edge is considered, graph decomposition is restricted to a conservative policy as against an exhaustive one. Using a conservative policy minimizes the number of disjoint events in the analysis. Disjoint events are simple paths that are not connected or have common node. This decomposition simplifies the analysis and helps cancel out occurrence of parallel links.

III. OVERVIEW OF RELATED WORKS

Most of the works reviewed evaluate the reliability of understudied Networks by the methods of minpaths and mincuts. A minpath is the shortest distance/path/ number of hops between nodes needed to keep them up and communicating while mincut is the smallest break in the link/network that renders the link/network ineffective. An aggregation of paths between nodes is called pathsets while an aggregation of cuts in the network is called cutsets.

As a network enlarges and nodes increase, the number of minpaths and mincuts increase exponentially. Effective analysis of these sets needed to keep the network up or down via optimization methods help in estimating the reliability of understudied networks.

Genetic algorithm as an optimization tool was used in evaluating the reliability of networks [8]-[11].

Wei-Chang Yeh [12] in his work used Particle Swarm Optimization and Monte Carlo Simulation in analyzing the pathsets in order to evaluate the reliability

Monte Carlo simulation was also employed in [13] [14] to analyze the pathsets/cutsets in order to evaluate the reliability understudied network.

Wei Hou [15] in his thesis, analyzed the reliability of networks with software and hardware failures. He developed models; MORIN – Modelling Reliability for Integrated Networks and SAMOT – Simplified Availability Modeling Tool, with which he used in analyzing the Network.

Boolean reduction technique was also used in evaluating the reliability of understudied network [16] – [21]

Mathematical Analysis are also employed in the reliability analysis of networks [22] – [23].

An overview of works reviewed shows that little have been done on reliability analysis of Ring topology networks (this might be a ripple-effect from the fact that most computer networks implement the mesh topology for its obvious advantages).

Earlier works seem to use survivability, availability, susceptibility, connectivity and reliability interchangeably. These mentioned parameters are distinct and a field of study on themselves.

Modern communication networks are made up of reliable components and failed components are quickly repaired. Multiple connections which allow for rerouting of traffic when network failure occurs is also a common feature. With the afore-stated in mind, it is important to take into account the connection ports, links and state of the nodes (this should cater for issues of power supply, equipment malfunctioning and working environment) in the reliability analysis of computer networks

It is important to note that Failures in computer networks cannot be completely eliminated and, hence, reliability can never be 100 percent. In order to reduce their negative impact on end-to-end connectivity, redundancy techniques are implemented on network routing so as to ensure a proper alternate (backup) path is available upon failure of the primary working path.

Performances of networks can be measured by comparing with the reliability index. The reliability index represents the probability that a network operates. The performance of a design can be studied by changing the topology of the network. This is achieved by adding, removing or replacing some components so as to augment the reliability or for satisfying certain specifications.

IV. MODELS USED IN COMPUTER NETWORK RELIABILITY

Models used to describe computer networks help to define a frame in which the network could be studied. From papers researched, the common model used for Computer Network is the Stochastic Model.

A stochastic network [24] describes a physical system in which each node and/or each edge (directed or undirected) can fail independently and failure one element does not affect another network element. A number representing the non-failure probability is assigned to the element. With this model, the network reliability analysis problem is solely calculating the probabilities of failure/operation for the edges and/or nodes needed to establish link connectivity [25].

In the Reliability analysis of Computer Networks (especially Ring Networks) [37], the following assumptions are made (depending on the number of components understudied):

- Components are either operational or failed at any given time and Component state is a random event, s, independent of any other.
- The reliability of a network component is the probability that it is operational at a given time.
- The Channel Capacity, C, is fixed and C » B (where B is the provisioned Bandwidth/Capacity for the Network).
- Failure of any electronic component in a station, including the power supply, causes the station to fail
- Network reliability does not include the probability for failure of attached hosts since they are external to the understudied communications subnetwork.

The components used to define the node in the understudied network are the link, port and station itself. The station define the system health and caters for power issues in the node. Failure/success probabilities of these component are independent of each other but have an overall effect on the state of the node.

The port comprises the transmitter, receiver and the inbound/outbound link used in effecting self-healing when a fault occurs.

V. MEAURES OF COMPUTER NETWORK RELIABILITY

A good index for measuring the utilization of a computer network reflects that a network fails gradually and that some nodes (links) are more important than others. The stated index is not also based on traffic patterns. Measures with the above requirements include; terminal, "capacity-related", and "travel-time related" reliability measures.

A. Terminal Reliability

Terminal Reliability is the probability that there exists an end-to-end connection between two or more nodes in a computer network needed to keep the network up and running [9]. There are basically 3variants;K-Terminal,2-Terminal and All-Terminal Reliabilities.

1) K-Terminal Reliability: The predominant measures of reliability when applied to computer networks are mainly specialized cases of k-terminal reliability. This is defined as the probability that a path exists and connects k-terminals (nodes) within the network [26] -[28].This reliability is the sum of the probabilities of disjoint success paths [29].

2) Two Terminal Reliability: This is the probability that a path exists between end pair of nodes in the network [30]-[32].

3) All Terminal Reliability: This is the probability that the nodes in a network are communicating with each other [33][34]. Two terminal and all- terminal reliability are modifications on the K- Terminal measure where K=2 and K=n (n is the number of nodes in the network), respectively.

B. Capacity-Related Network Reliability

This field is an extension or specialization of the research in computer network reliability. It is acknowledge that not all links (edges) may have the same capacity (weight, bandwidth). Further, it is also considered that the capacity demanded of the network is variable. Capacity-Related computer network reliability defines the network reliability in terms of the bandwidth (variable or fixed) needed to establish efficient data-throughput between nodes [35] [36]. It places a bench mark requirement (bandwidth) needed for connectivity between node shaving fixed or variable link capacities. It is used when the data requirement is same or more than the channel bandwidth and/or subscribed bandwidth.

C. Travel Time Network Reliability

This basically defines the time taken for data to travel between link ends or nodes. It also describes the time taken for a hand shake to occur between specific nodes in a network and uses this as an index to measure reliability

VI. COMPUTER NETWORK RELIABILITY PERFORMANCE PARAMETERS

Network reliability cannot be fully defined without taking into consideration some parameters that affect computer network performance. Different parameters that affect network reliability of a computer-communication system are described below [37]. They include failure rate, Meantime to repair, mean time between failures, mean time to failure and availability.

- Failure Rate (FR) is the number of failures experienced or expected for a device divided by the total equipment operating time.
- Mean Time to Repair (MTTR) is the total time taken to effect corrective maintenances divided by the total number of these repairs.
- Mean Time between Failures (MTBF) is the mean
- time expected between failures, measured in hours. For constant failure rate systems, MTBF is the inverse of the Failure Rate.
- Equation 1givesthemathematical formula for evaluating MTBF

$$MTBF = 1/FR \tag{1}$$

- Mean Time to Failure (MTTF) is the mean time expected before the first failure of a piece of equipment. It is meant to be the mean over a long period of time and a large number of units.
- Availability (A) is the probability of a system to being operational when called upon to perform its function. Availability and unavailability (1-A) are often expressed as probabilities.

Equation 2 gives the mathematical formula for determining the availability of the network.

$$A = MTBF/(MTBF + MTTR) \tag{2}$$

VII. EVALUATION OF COMPUTER NETWORK RELIABILITY INDEX

Reliability analysis of a computer network invariably leads to evaluating a reliability index for the network. This is implied sincere liability, like availability, is expressed as probabilities. A reliability index defines a scale on which the reliability of a computer network can be measured. This scale ranges from 0–1. A value of zero implies a failed network while one means an "excellent" reliable network. The computer network reliability performance parameters described above are used in the evaluation of Reliability (R) index of the network.

Computationally we have;

$$MTBF = \int_0^{\infty} R(T)dT \tag{3}$$

$$R(T) = e^{-(\frac{T}{MTBF})} \tag{4}$$

('T' is the number of hours)

For multiple components;

$$MTBF = 1/(FR1 + FR2 + FR3 + - - -FRn) \tag{5}$$

('n' is the number of components in the system)

$$R(T) = \sum_{i=1}^{n} Ri(T) \tag{6}$$

The reliability of a computer network is invariably a sum of the probabilities of the individual components of the communications aspect of the Computer communication network understudied (Equation 6).

VIII. CONCLUSION

The objective of a typical computer network reliability analysis is to obtain an index against which the reliability of the understudied network can be measured. Though a review of computer network reliability has been carried out in this paper, further work is been done on implementing the above stated discourse on an existing computer network. The intent of this is to observe and document (if any) variations from the review, give recommendations for future expansion and deployment of network facilities and evaluate the reliability of the understudied network.

This analysis can be carried out for a proposed network and an existing network. This is to ensure better choices of network components, network topology deployment and flexibility in expansion and upgrading of network. The Reliability analysis of Computer Networks forms a veritable tool in defining the worth of a network to its intended design expectations and as such seeks to give a measure for user satisfaction. It invariably forms an mportant criteria to enhancing Quality of Service– QoS.

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