IAES International Journal of Artificial Intelligence (IJ-AI)
Vol. 10, No. 3, September 2021, pp. 623~635
ISSN: 2252-8938, DOI: 10.11591/ijai.v10.i3.pp623-635

Empirical Bayesian network to improve service delivery and performance dependability on a campus network

Arnold Adimabua Ojugo[1], Andrew Okonji Eboka[2]
[1]Department of Computer Science, Federal University of Petroleum Resources Effurun, Delta State, Nigeria
[2]Department of Computer Science, Federal College of Education (Technical), Asaba, Delta State, Nigeria

Article Info

Article history:

Received Sep 2, 2020
Revised Jun 1, 2021
Accepted Jun 12, 2021

Keywords:

Bayesian network
Network availability
Network performance
Redundancy
Resilience
Scalability
Throughput

ABSTRACT

An effective systemic approach to task will lead to efficient communication and resource sharing within a network. This has become imperative as it aids alternative delivery. With communication properly etched into the fabrics of today's society via effective integration of informatics and communication technology, the constant upgrades to existing network infrastructure are only a start to meeting with the ever-increasing challenges. There are various criteria responsible for network performance, scalability, and resilience. To ensure best practices, we analyze the network and select parameters required to improve performance irrespective of bottlenecks, potentials, and expansion capabilities of the network infrastructure. Study compute feats via Bayesian network design alongside upgrades implementation to result in a prototype design, capable of addressing users need(s). Thus, to ensure functionality, the experimental network uses known simulation kits such as riverbed modeler edition 17.5 and cisco packet tracer 6.0.1-to conduct standardized tests such as throughput test, application response-time test, and availability test.

Corresponding Author:

Arnold Adimabua Ojugo
Department of Computer Science
Federal University of Petroleum Resources Effurun
Delta State, Nigeria
Email: ojugo.arnold@fupre.edu.ng, arnoldojugo@gmail.com

1. INTRODUCTION

Universities, as citadels of learning-are agents of great change and frontiers for cutting-edge research as well as knowledge sharing. Data sharing, its security, redundancy, non-repudiation, and other feats have become imperative goals in informatics and veritable tools for the modern age. The benefits of computing and networks today, is quite enormous and has arguably, become the largest engineered system to be created. Its benefits can never be over-estimated [1]-[4] as they stem from ease at which networks enhance communication transactions at unprecedented speeds, to their corresponding accuracy, portability, mobility, and reliability [5]-[8].

Many organizations (service industries, government agencies, academic and research institutions) today employ services that adopt robust networks to automate their daily tasks. They thus, employ information and communication technology devices as means to manage, control, and improve the performance of their complex systems cum processes. Thus, contribute to the quest for improved performance and competitiveness, at lowered costs. However, there is the constant need to measure the relevance in improving network's service delivery via measuring its availability, performance, efficiency, quality, on-time delivery, environ/safety needs, and cost effectiveness [9], [10]. The challenge now is to model real time systems-that addresses these feats as mentioned above in relation to the increased complexity while upscaling the system's transparency to its users. This task underlines issues concerning the quantification of model parameters, its representation, propagation, and quantification of uncertainty in system behavior [11]-[14].

System performance and reliability assessments are studied with assumptions that seek to simplify the study. One of such assumption is to focus the study only on technical issues-whereas, such assumptions are no longer valid due to the importance as well as the impact on organizational and human factors contributions [15]-[17]. Innovative studies seek to address the causes (technical, human, and organizational). Also, such analyses are often difficult to achieve as they require a lot of resources-and adds to the complexities involved in system modeling due to interactions between different components with the technical, human, organizational and environmental factors. All of which, are pre-requisites to quantify failure case scenarios. Thus, the issues therein, is to model of a complex system that successfully integrate these aspects [18], [19] as in Figure 1.

In addition, modeling these factors must account for knowledge integration of the diverse natures (qualitative and quantitative) with needed levels of abstraction. Organization and human analyses are modeled with qualitative data represented in failure effects and criticality analysis, hazard operability, and probabilistic risk assessment analysis. Also, the technical level is represented with quantitative data such as failure rates, mean time to failure, and unavailability level [20]. To model these requirements, classical dependability methods can be used such as fault trees, Markov chains, and Bayesian networks (BN), while Bayesian network is not the solution to all problems-it has proven to be relevant in complex systems [21]-[24] and recent studies shows an increased interest to analyze the evolution of BN and its applications on dependability.

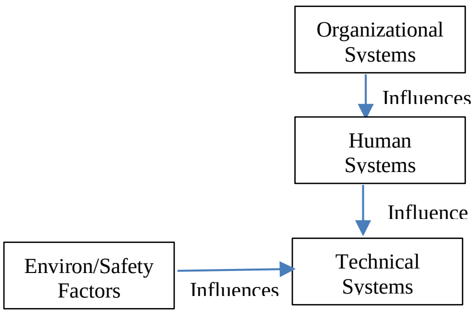


Figure 1. The context of complex system to be modeled

The problem characteristics of the study is geared towards having a network that models as part of its components, a system that assesses availability, performance, and robustness as thus:

- How do we formalize feats like availability, performance, and robustness, modelled as complexities within a campus network with respect to the network's size as a system [11]?
- What combination of uncertainties feats in the parameter estimation-needs to be employed on the network to yield better quality of service, availability, and performance [11]?
- We seek to factor into the network's implementation, the temporal and environmental aspects that will help yield the desired outcome [25].
- We seek to integrate qualitative and quantitative knowledge at the various levels of abstraction [26], [27].
- We seek to factor in the nature of multi-state components within the network infrastructure [28] and,
- We seek to ascertain the inter-dependences between events such as failures, using simulation kits [29].

The goal (with these factors catered for) will improve service delivery via greater network resilience, improved performance, availability, and capability of the network to withstand upward scalability. Thus, will also account for system dynamics and robustness. With these feats met, we can encounter other issues such as: degradations of components, evolution of symptoms in deterioration mechanisms, impact of preventive maintenance acts on degradation, influence of environmental conditions and effects of the operation conditions on the evolution of the component states. Thus, the essence of the computation solution to be modelled in with the appropriate data to support the decision process. This implies that the uncertainty and imprecision in the system parameters not foreseen from the outset-can be accommodate with some degree of tolerance and resilience in the network.

2. SOFT-COMPUTING FRAMEWORK

2.1. Principles of probability

An argument is simply a statement that has a true or false value. Reasoning is the ability to employ an argument in favor of an assumption that provided the facts, the argument can either favor the assumption that everything is either believed false or believed true. However, it is often useful to represent the facts that we believe such event is probably true/false, or it can simply be expressed that such an event is true with a probability of 0.65. Thus, the probability of an event x is true (success) or false (unsuccess) with a value in the range of 0 and 1, denoted as P(x) = 0 < x < 1 [6], [30]-[34] in (1):

$$P(x)\frac{instances\ of\ the\ event\ x}{total\ instance\ or\ sample\ space} \quad (1)$$

Basic probability rules includes: (a) all probabilities have values between 0 and 1 inclusive such that $0 \leq P(x) \leq 1$, (b) sum of all the probabilities in sample space equals 1, (c) the probability of an event occurring equals 1, (d) the probability of the sample space is 1, (e) the probability of any event not in the sample space is 0, and lastly, (f) the probability of an event not occurring is P(x')= 1-P(x'). Probability helps us deal with problems of reasoning that involve randomness, unpredictability, and insufficient data to work out what is true/false. Thus, we have these definitions [7], [12], [30], [35], [36]: (a) probability is the likelihood that an event is successful with P, and unsuccessful with (1-P), (b) an event is the outcome of a probability experiment, (c) a sample space is the set of all outcomes in a probability event, (d) an experiment leads to well-defined results called outcomes, (e) an independent events is such that two events E_1 and E_2 are independent if the probability that E_1 occurs, does not affect the probability of E_2 occurring as well, and (f) mutually-exclusive events is such the occurrence of any events in the set E_1, E_2, $E_3 \ldots E_n$, will automatically implies non-occurrence of the remaining n-1 events.

2.2. Bayesian networks

BN is based on bayes theorem of conditional and probabilities of random events. It is a machine learning scheme that represents data as graph mathematical structure [37]. It shows probability relations of a set of variables under uncertainty as directed acyclic graph (DAG) and conditional probability tables (CPT) of a random variable - given the occurrence of its parent nodes [38], [39]. In relation to the degree of belief - it measures the plausibility of an event given incomplete knowledge. It states that the probability of an event A conditional on another event B is given by P(A|B). It is different from probability of B conditional on A - denoted as P(B|A). It implies: (a) that Bayes Theorem is the relation between events P(A|B) and P(B|A), (b) it seeks to compute P(A|B) given data about P(B|A), and (c) its outcome uses new data to update conditional probability of event [30], [40]-[49]. So given sample space *s*, with mutually exclusive events $(A_1, A_2, \ldots, A_n)$ from *s*-B is an event of *s* with probability P(B) > 0. Thus, Bayes theorem describes the probabilities that:

$$(A_k|B) = \frac{P(A_k \cap B)}{P(A_1 \cap B) + P(A_2 \cap B) + \cdots + P(A_n \cap B)} \quad (2)$$

So that invoking the facts that: $P(A_k|B) = P(A_k).P(B|A_k)$ - the probability then becomes (3).

$$P(A_k|B) = \frac{P(A_k).P(B|A_k)}{P(A_1).P(B|A_1) + P(A_2).P(B|A_2) + \cdots + P(A_n).P(B|A_n)} \quad (3)$$

BN classifiers are built using training data with structured parameter learning on probability distribution for each node on the network. It uses two learning forms: (a) structured learning (casual discovery) which learns the structure of the networks and the parameters adopted based on observed input data using either of K_2, Hill climbing and Tabu-Search; and (b) probability distribution learning is achieved with algorithms like Bayes Net estimator, Bayesian model averaging (BMA) estimator and multinomial estimator. Once structure learning is complete, parameter learning completes the CPT tables for each feature in the Bayesian network [4], [50]-[52].

3. EXPERIMENTAL BAYESIAN NETWORK

3.1. Experimental framework/implementation

We seek to employ BN to select the appropriate parameters and compute their combination usage to improve the quality of service delivery on a campus network infrastructure, its capacity and performance. Our BN design must also address the goals, conflicts in parameter selection and estimation algorithms. We adopt the hill-climbing search on six parameters for this network on a threshold value of 0.5 [38], [39] as in Figure 2.

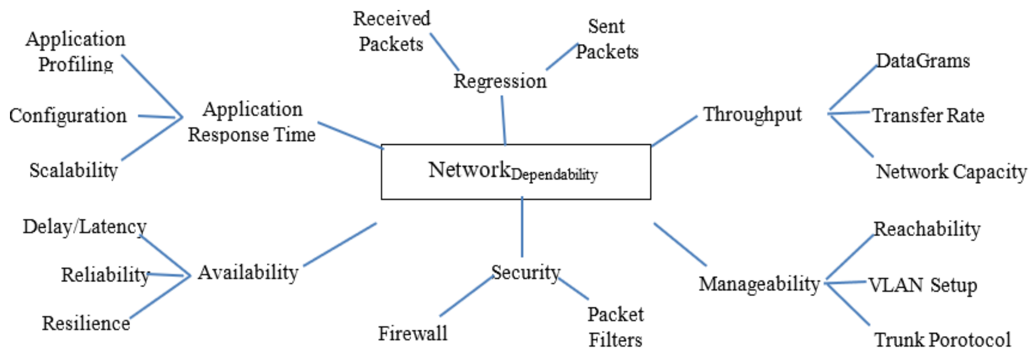


Figure 2. Bayesian network of feats and their selected criterion (s) to improve performance and dependability

3.2. Feature selection, training, and rationale for choice of model

The need to optimize the number of feats employed as input parameters-stems from the fact that an increase in the number of feats used, will add to the computational complexity of the system. Thus, BN is used in selecting feats using (1-3) respectively. Input dataset [14] obtained during feasibility for improving system performance is used. We train the BN as a filter solution-since it uses known predictions and their total occurrences (as scores) to maintain a database; And, based on their occurrences, each value-combination of the parameter is considered as data assigned a criterion or probability score for its capacity of determining an improved case scenario for the network infrastructure.

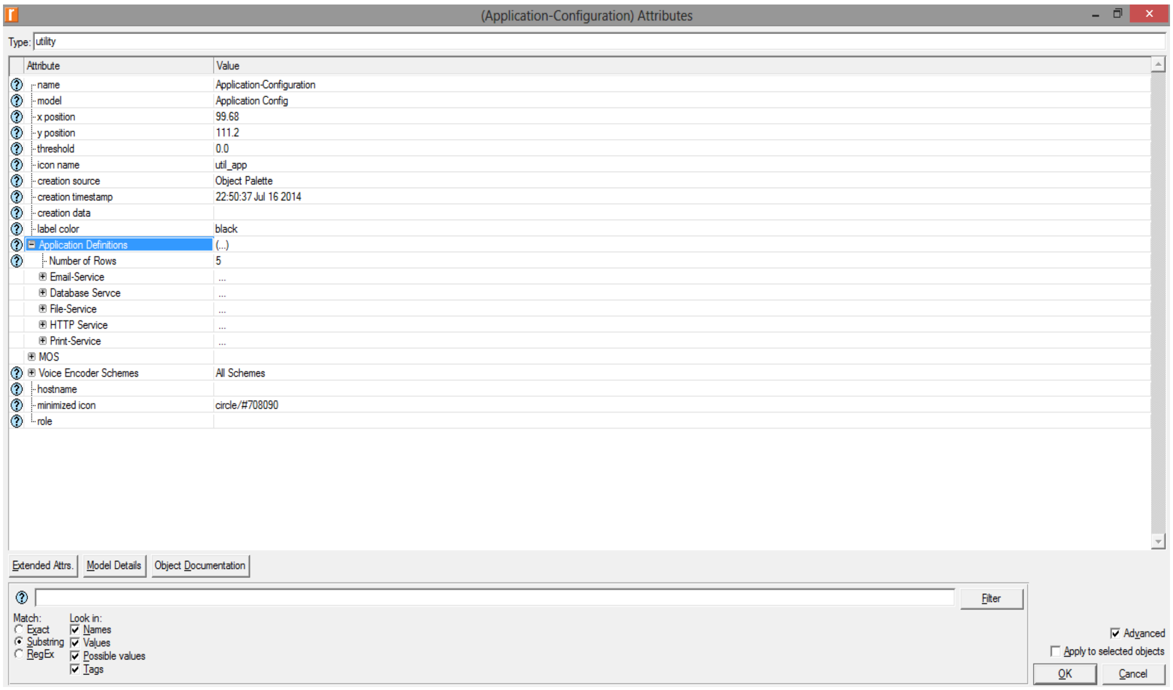
3.3. Rationale for the model of choice used

The certainty-factor model was one of the most popular models of representation and manipulation of uncertain knowledge for rule-based systems. Its place has been taken by the more expressive formalisms of the Bayesian belief network (BN) for the representation and manipulation of uncertain knowledge. BN is a graphic probabilistic model that represents a set of variables and their respective probabilities. It consists of: (a) a set of nodes and corresponding edges showing nodal relations, (b) edges reflects cause-effect relations, (c) the effects are not completely deterministic, and (d) the strength of an effect is modeled as a probability [6], [7], [13], [30].

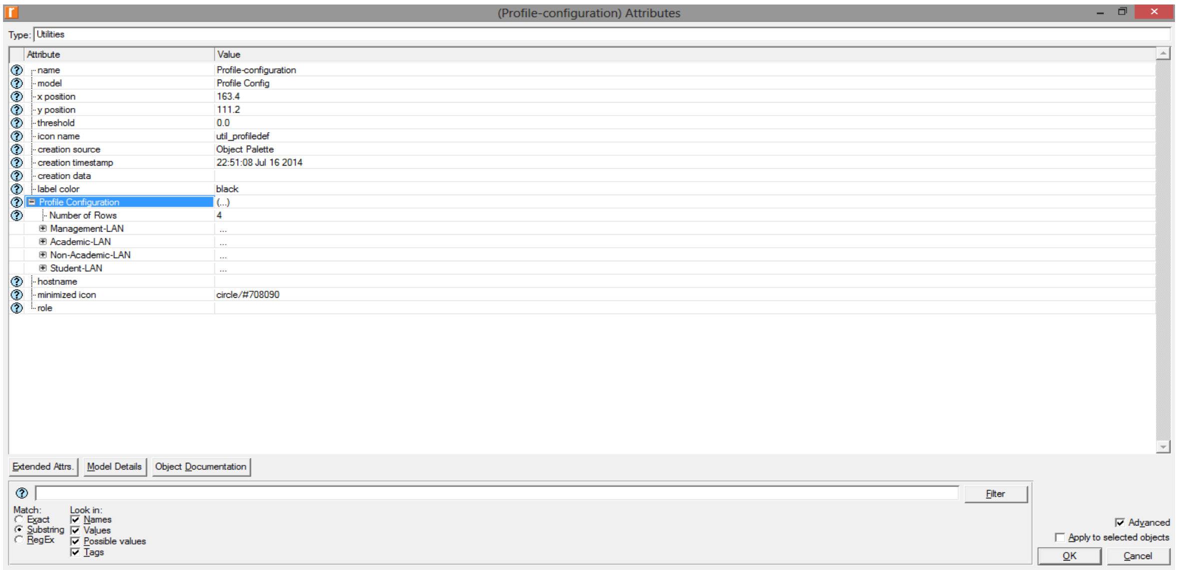
BN is a directed acyclic graph whose added value is linked to probability computation of a nodal state over several variables. BN is a powerful modeling tool for complex systems as they provide modeling benefits such as: (a) BN permit users to merge and model knowledge about dynamic tasks with feedback data from experience or experts' judgment (expressed as logical rules and/or subjective probabilities), (b) it studies the behavior of a system (functional and dysfunctional analysis) and the observations therein, modelling all the complex and abstracted levels of interactions as nodal relations to help further analyze the structure, (c) it helps to establish cause-and-effect relations between nodal tasks using several sources of data to develop the model with a proviso that only a few feedback data relates to dependability [53]. Thus, we adopt an experts' judgment (network infrastructure from an international best practice view)-integrated into the model's structure. A general inference here, is to permit the propagation and diagnostic modules to incorporate the new data (evidence) gathered in a study. Thus, we use BN to allow updating of the set of events´ probabilities according to observed facts and the BN network structure. It makes the strength of this knowledge management tool [16].

4. RESULT FINDING AND DISCUSSION

To effectively conduct tests, scripts were designed and tested using the academic riverbed modeler edition 17.5 for the tests. The software was configured with required applications and user population-using the application cum profile configuration options, as shown in Figure 3. Figures 3(a) and 3(b) show the interfaces of the application and profile configurations respectively of the Riverbed modeler, academic edition 17.5.



(a)

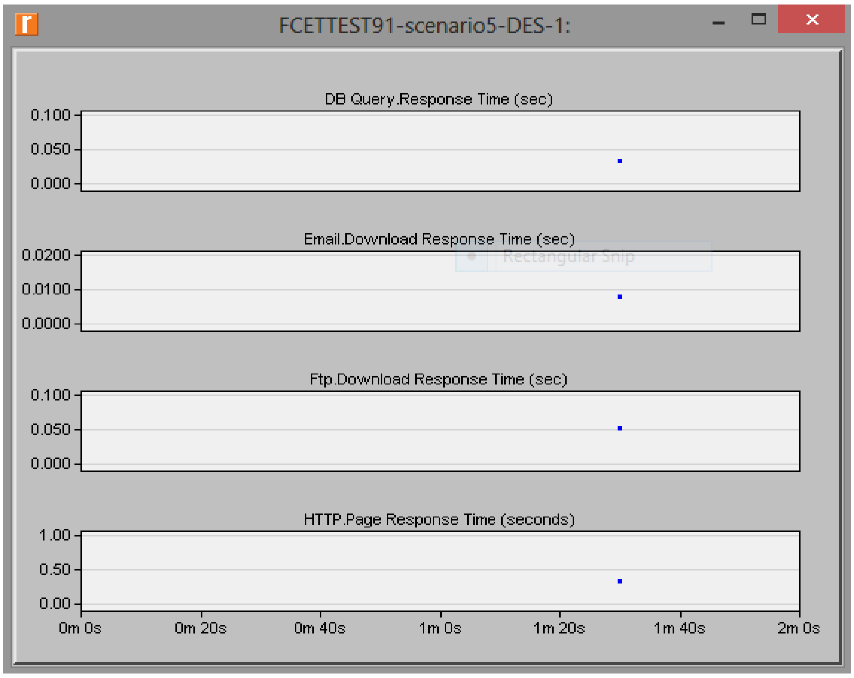


(b)

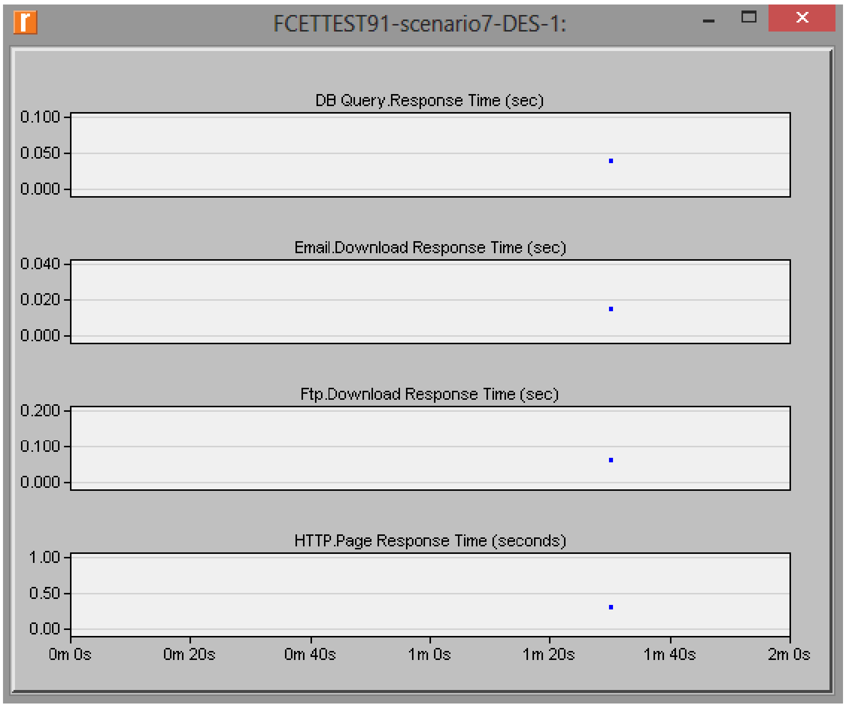
Figure 3. Proposed network for (a) application and (b) profile configuration

4.1. Application response time test

This test is a performance metric that aims to determine the time interval between a user's request and the actual time a response is gotten, as shown in Figure 4. To achieve, the response time from a database Query, a hypertext transfer protocol (HTTP) Page, file downloads from FTP and email server was tracked as in Figures 4(a) and 4(b) respectively using two scenarios. In case 1, the response times for database queries was about 0.38 seconds, 0.008 seconds for email download, 0.052 seconds for file download and 0.32 seconds for HTTP page retrieval. In case 2, a longer response time was seen as it took about 0.40 seconds for database queries, 0.015 seconds for email download, 0.060 seconds for file download and 0.35 seconds for HTTP page retrieval. There was no significant difference in the response time for the various applications in both scenarios. The result concludes that the response time (even with a doubled population) is still fast and system is highly scalable as seen from Table 1.



(a)



(b)

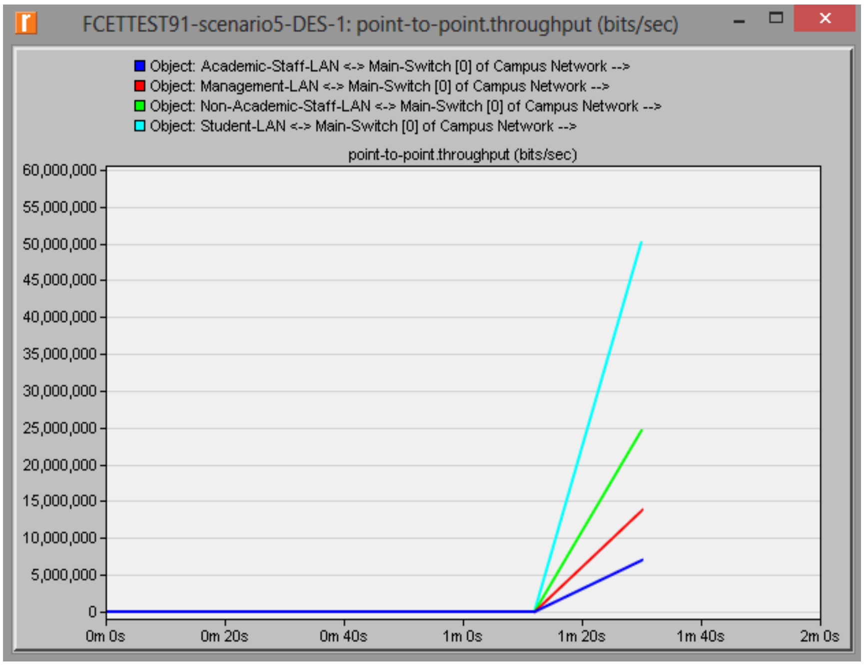
Figure 4. Response time for (a) scenario 1 (actual population) and (b) scenario 2 (doubled population)

Table 1. Application response and network scalability result

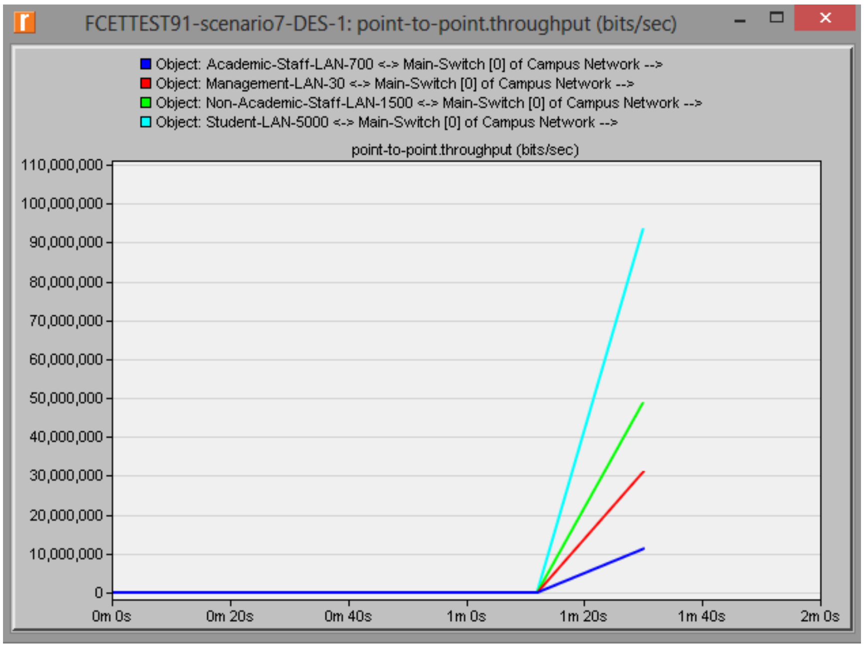
Items	Scenario 1		Scenario 2	
	Time Secs	Population	Time Secs	Population
Database Query	0.38	0.40	3512	7230
Email Download	0.008	0.015	3512	7230
FTP Download	0.052	0.060	3512	7230
HTTP Download	0.32	0.35	3512	7230

4.2. Throughput test

Dye *et al.* [54] defined throughput as data transfer rate over a period in time, as shown in Figure 5. As a performance metrics, it essentially displays the effects of interference and errors on a network's capacity. Data transfer rate of the network traffic the four local area network (LAN) segments were analyzed using both scenarios as in Figure 5(a) and 5(b) respectively. In case 1, the highest data transfer rate was about 47.68 mbps and from student LAN, while the lowest is from management LAN with about 6.68 mbps. In case 2, highest throughput also from student LAN with 89.65 mbps; while the lowest again from management LAN with 11.44 mbps. This is expected. We used a multimode fiber optic cabling with a bandwidth capacity of 9.92 Gbps. As such, the effect of the highest throughput has no negative consequence on the network. With our LAN cabling capacity, optimal performance is expected.



(a)



(b)

Figure 5. Throughput test for (a) scenario 1 and (b) scenario 2

4.3. Availability test

Ping command was used for the reachability of the different nodes. The ping sends internet control message protocol to different devices across the network. Figure 6 shows ping to different nodes with about 80% response rate (first ping), and 100% on subsequent pings shows that the different nodes were reachable.

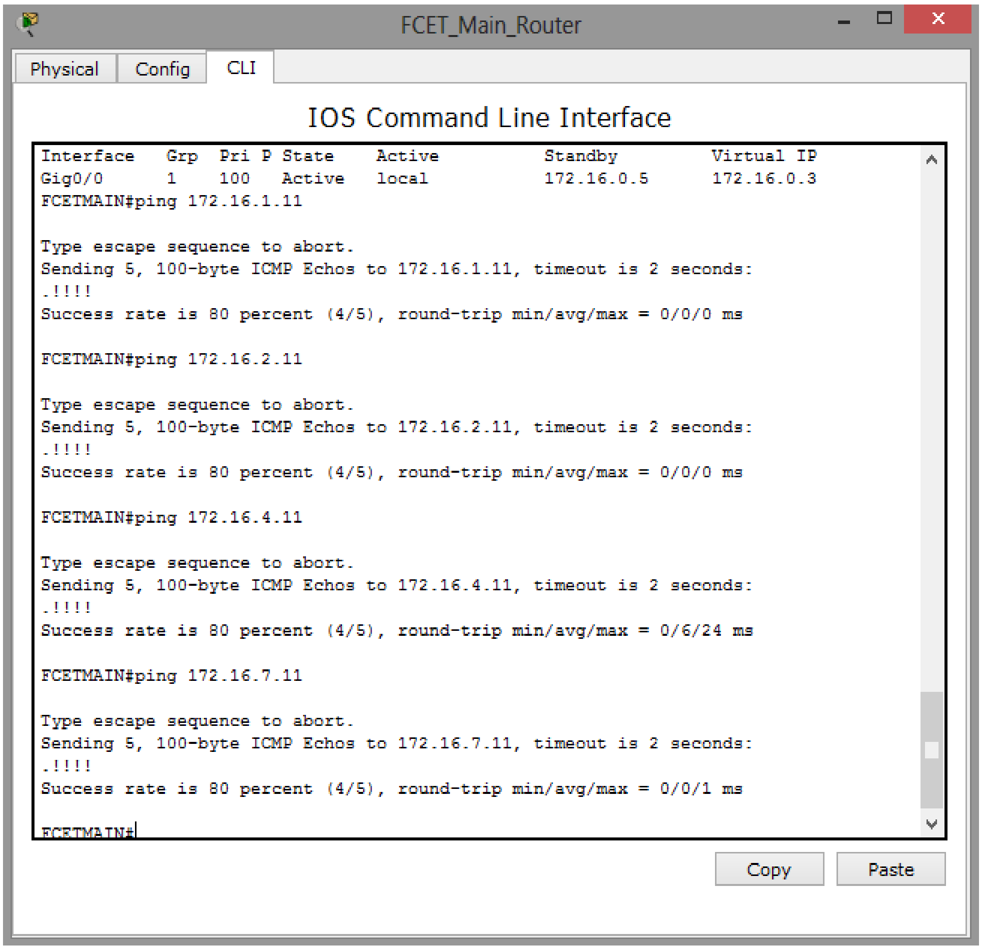


Figure 6. Reachability test for proposed network

4.4. Network security

To conduct security test for proposed network, we use the Riverbed OPNET to test the effectiveness of our firewall. The test consisted of two scenarios; the first case allowed external users to have unrestricted access to the network resources, while the second scenario restricted external users from having access the web and database servers. We used regression test to ensure that all network devices and applications from the existing network were fully incorporated and functional in the proposed network. As shown in Figure 7, existing switches were used at the access layer of the network and were found to be functional. We also tested the backup router to ascertain its capability in the event and failure of the main router. To achieve this, we have the scenario of using the existing router and switches as in Figure 7.

Figure 8 shows the results from web traffic to external users and red line indicates amount of data received per second by a user, while blue line shows that no access was granted to the external users by the web server. Figure 9 shows the database server and other applications granted access to the external users with traffic still filtered. Figure 10 shows data traffic flow from the file server to the external users.

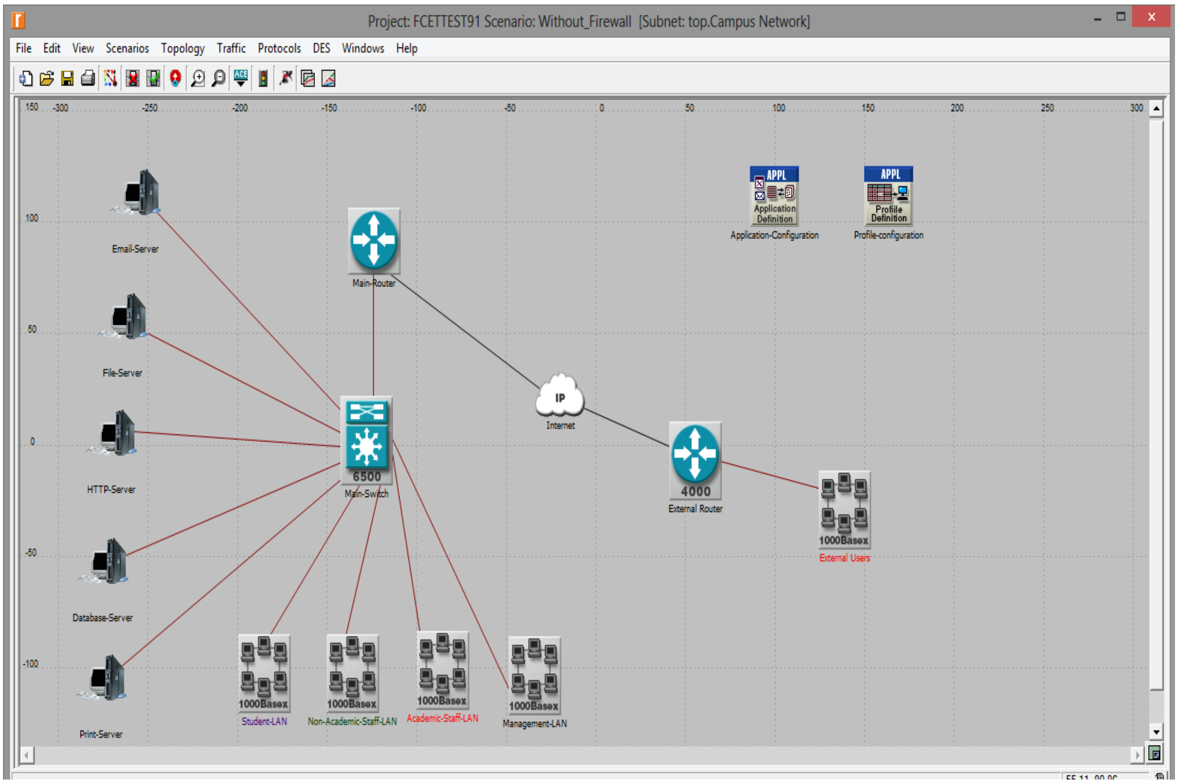


Figure 7. Security with firewall for framework design

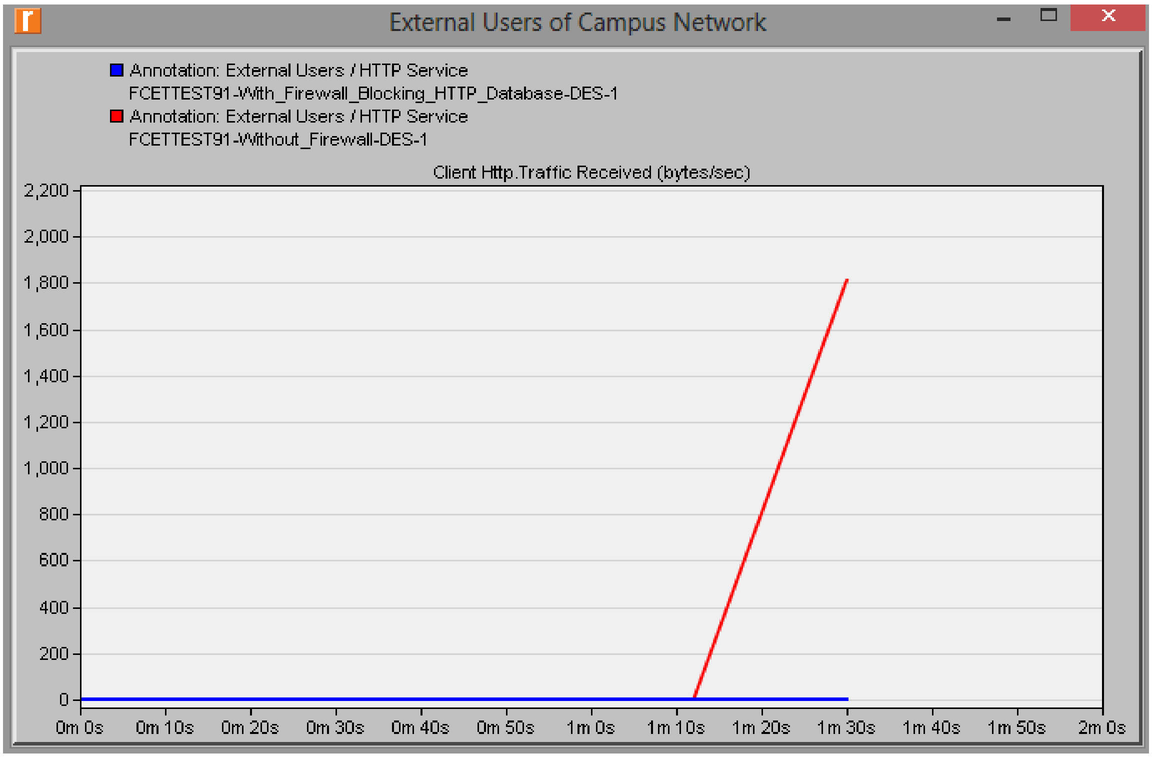


Figure 8. Firewall on HTTP service

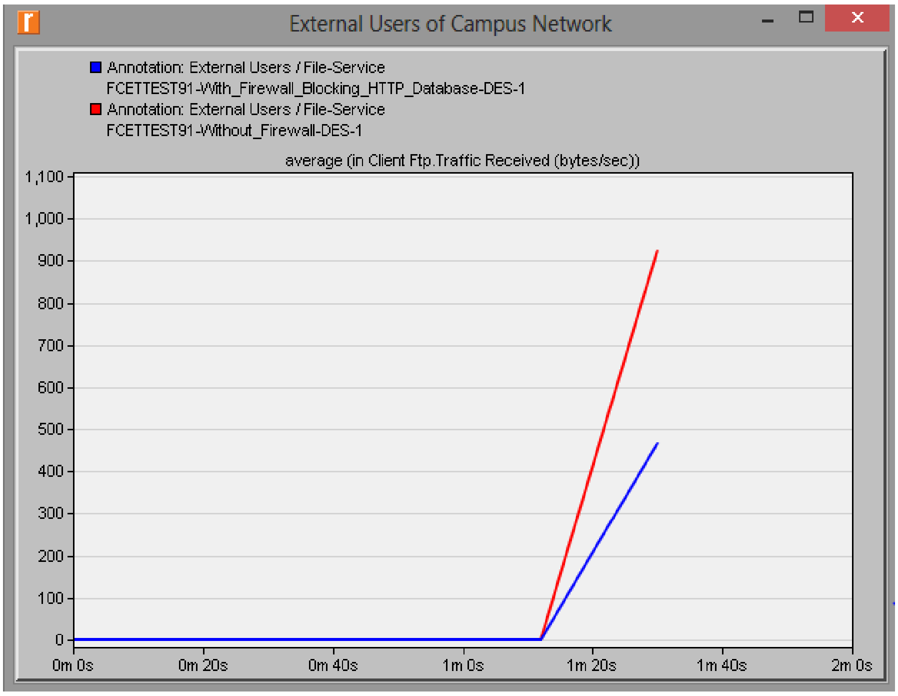


Figure 9. Firewall on database service

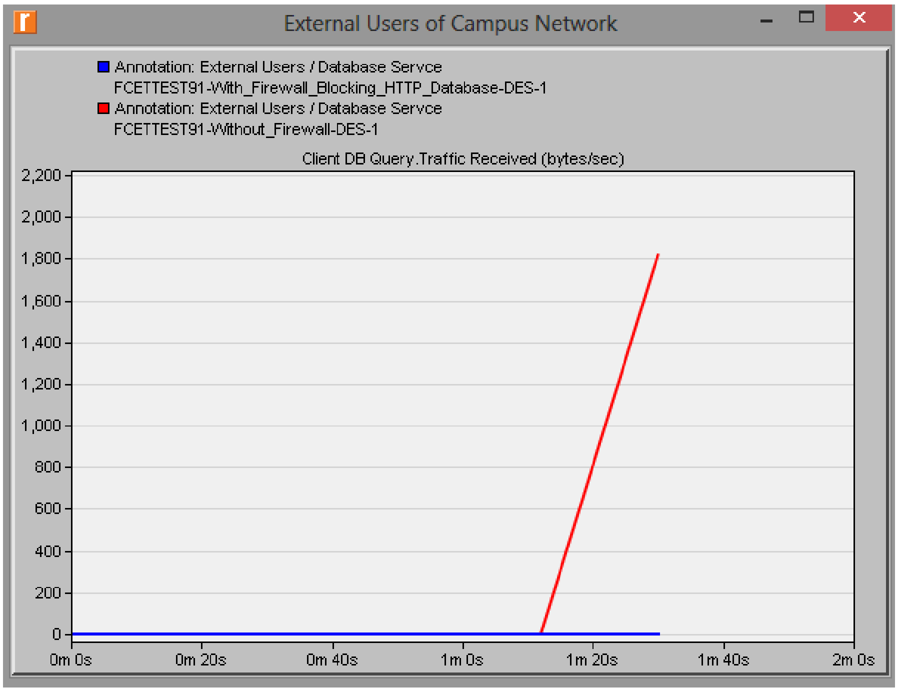


Figure 10. Firewall on filtering FTP traffic

5. CONCLUSION

From the tests, the basic functionalities of the proposed network are working as stipulated and in tandem with the study objectives. We opine that the deployment of this network meets the needs of the stakeholders. Study employed a standardized approach to network analysis, design, optimization and testing to deliver a network that met the requirements of its stakeholders. It ensured that users' requirements were met via a top down design, which formed the basis for the network topology, applications, devices, and protocols chosen. Furthermore, qualitative, and quantitative methods were utilized in collection/analysis of data. The constraints of time, energy and resources that previously made it impractical to explore the benefits a network can offer any organization were considered via the implementation of four applications namely centralized data storage, file transfers, web services and e-mail services. We recommend also other possible implementation(s) such as voice over internet protocol and cloud computing for internal communication and external data storage respectively-all of which will further guarantee an optimal utilization of the network infrastructure, provide a reliable platform for data recovery and network agility required by organizations in today's competitive world.

ACKNOWLEDGEMENTS

We appreciate the Provost of the Federal College of Education Technical Asaba, Dr. Josephine Anene-Okeawa, and the Vice Chancellor Prof. Rim-Rukeh Akpofure who has extended research as way of life in the Federal University of Petroleum Resources, Effurun – under the guidance of Prof. Akii Ibhadode. Thank you for the vision. We acknowledge all staff of the ICT Unit at the Federal College of Education Technical, Asaba for providing server log files and other materials necessary for this research.

REFERENCES

[1] J. Kurose and K. Ross, *Computer Networking: A Top-Down Approach*. M. Hirsch and E. Snider, ed., 6th edition, Boston: Pearson Education Limited, 2013.

[2] M. Lanxiaopu, "An Investigation and Comparison on Network Performance Analysis," MS thesis, Network and System Administration, Oslo University College, 2012.

[3] A. A. Ojugo, A. O. Eboka, E. O. Okonta, R. E. Yoro, and F. Aghware, "Genetic algorithm rule-based intrusion detection system," *Journal Emerging Trends in Computing and Information Systems*, vol. 3, no. 8, pp. 1182-1194, 2012.

[4] A. A. Ojugo, E. Ben-Iwhiwhu, O. Kekeje, M. Yerokun, and I. Iyawah, "Malware propagation on social time vary network: a comparative study," *International Journal Modern Education Computer Science*, vol. 6, no. 8, pp. 25-33, 2014, doi: 10.5815/ijmecs.2014.08.04.

[5] J. Segovia, E. Calle, and P. Vila, "Availability analysis of GMPLS connections based on physical network topology," in *2008 International Conference on Optical Network Design and Modeling*, 2008, pp. 1-6, doi: 10.1109/ONDM.2008.4578418.

[6] R. Iqbal and W. Xingang, "Network Planning and Management," 2014. [Online] Available: http://cumoodle.coventry.ac.uk/course/view.php?id=10062.

[7] A. A. Ojugo and A. O. Eboka, "*Memetic algorithm for short messaging service spam filter text normalization and semantic approach*," *International Journal of Informatics and Communication Technology (IJ-ICT)*, vol. 9, no. 1, pp. 13-27, 2019, doi: 10.11591/ijict.v9i1.

[8] A. A. Ojugo and D. O. Otakore, "Intelligent cluster connectionist recommender system using implicit graph friendship algorithm for social networks," *International Journal of Artificial Intelligence (IJ-AI)*, vol. 9, no. 3, pp. 497-506, 2020, doi: 10.11591/ijai.v9.i3.pp497-506.

[9] I. Alsyouf, "The role of maintenance in improving companies' productivity and profitability," *International Journal of Production Economics*, vol. 105, no. 1, pp. 70-78, 2007, doi: 10.1016/j.ijpe.2004.06.057.

[10] K. Kutucuoglu, J. Hamali, Z. Irani, and J. Sharp, "A framework for managing maintenance using performance measurement systems," *International Journal of Operations and Production Management*, vol. 21, no. 1, pp. 173-194, 2001, doi: 10.1108/01443570110358521.

[11] E. Zio, "Reliability engineering: Old problems and new challenges," *Reliability Engineering and System Safety*, vol. 94, pp. 125-141, 2009, doi: 10.1016/j.ress.2008.06.002.

[12] A. Ali, M. Elfaki, and D.N.A. Jawawi, "Using Naïve Bayes and Bayesian Network for prediction of potential problematic cases in tuberculosis," *International Journal of Information and Communication Technology (IJ-ICT)*, vol. 1, no. 2, pp. 63-71, 2012.

[13] P. Sharma, "Top-Down Network Design: Analysis Business Goals and Constraints," 2012. [Online]. Available: http://www.slideshare.net/ciscohite/top-down-network-design.

[14] A. A. Ojugo and A. O. Eboka, "Mitigating technical challenges via redesigning campus network for greater efficiency, scalability and robustness: a logical view," *International Journal of Modern Education & Computer Science*, vol. 6, pp. 29-45, 2020, doi: 10.5815/ijmecs.2020.06.03.

[15] N. Leveson, N. Dulac, K. Marais, and J. Carroll, "Moving Beyond Normal Accidents and High Reliability Organizations: A Systems Approach to Safety in Complex Systems," *Organization Studies*, vol. 30, no. 2-3, pp. 227-249, 2009, doi: 10.1177/0170840608101478.

[16] P. Weber, G. Medina-Oliva, and S. B. Iung, "Overview on Bayesian network applications for dependability, risk analysis and maintenance areas," *Engineering Applications of Artificial Intelligence*, April 2012, doi: 10.1016/j.engappai.2010.06.002.

[17] A. G. Wilson and A. V. Huzurbazar, "A Bayesian networks for multilevel system reliability," *Reliability Engineering and System Safety*, vol. 92, no. 10, pp. 1413-1420, 2007, doi: 10.1016/j.ress.2006.09.003.

[18] P. Trucco, E. Cagno, F. Ruggeri, and O. Grande, "A Bayesian Belief Network modelling of organisational factors in risk analysis: A case study in maritime transportation," *Reliability Engineering and System Safety*, vol. 93, no. 6, pp. 845-856, 2008, doi: 10.1016/j.ress.2007.03.035.
[19] M. C. Kim, P. H. Seong, and E. Hollnagel, "A probabilistic approach for determining the control mode in CREAM," *Reliability Engineering and System Safety*, vol. 91, no. 2, pp. 191-199, 2006, doi: 10.1016/j.ress.2004.12.003.
[20] W. Røed, A. Mosleh, J. E. Vinnem, and T. Aven, "On the Use of Hybrid Causal Logic Method in Offshore Risk Analysis," *Reliability Engineering and System Safety*, vol. 94, no. 2, pp. 445-455, 2008, doi: 10.1016/j.ress.2008.04.003.
[21] H. Langseth, "Bayesian Networks in Reliability: The Good, the Bad and the Ugly," in *Advances in Mathematical Modeling for Reliability*, Amsterdam, Netherland: IOS Press, 2008.
[22] S. Mahadevan, R. Zhang, and N. Smith, "Bayesian networks for system reliability reassessment," *Structural Safety*, vol. 23, no. 3, pp. 231- 251, 2001, doi: 10.1016/S0167-4730(01)00017-0.
[23] H. Boudali and J. B. Dugan, "A discrete-time Bayesian network reliability modeling and analysis framework" *Reliability Engineering and System Safety*, vol. 87, no. 3, pp. 337-349, 2005, doi: 10.1016/j.ress.2004.06.004.
[24] H. Langseth and L. Portinale, "Bayesian net in reliability," *Reliability Engineering and System Safety*, vol. 92, no. 1, p. 92, 2007, doi: 10.1016/j.ress.2005.11.037.
[25] P. E. Labeau, C. Smidts, and S. Swaminathan, "Dynamic reliability: towards an integrated platform for probabilistic risk assessment," *Reliability Engineering and System Safety*, vol. 68, pp. 219-254, 2000, doi: 10.1016/S0951-8320(00)00017-X.
[26] I. Papazoglou, J. Bellamy, A. Hale, O. Aneziris, B. Ale, and J. I. Post, "I-Risk: Development of an integrated technical and management risk methodology for chemical installations," *Journal of Loss Prevention in the Process Industries*, vol. 16, no. 6, pp. 575-591, 2003, doi: 10.1016/j.jlp.2003.08.008.
[27] F. Delmotte, "A socio-technical framework for integration of human and organizational factors in project management and risk analysis," Master thesis, Industrial and Systems Engineering, Faculty of the Virginia Polytechnic Institute and State University, 2003.
[28] W. F. Griffith, "Multistate reliability models," *Journal of Application in Probability*, vol. 17, no. 3, pp. 735-744, 1980, doi: 10.2307/3212967.
[29] J. G. Torres-Toledano and L. E. Sucar, "Bayesian Networks for Reliability Analysis of Complex Systems," in *Lecture Notes in Computer Science; 1484. Proc. of 6th Ibero-American Conf. on AI: Progress in Artificial Intelligence*, pp. 195-206, 1998, doi: 10.1007/3-540-49795-1_17.
[30] A. A. Ojugo and R.E. Yoro, "Extending three-tier constructivist learning model for alternative delivery: ahead covid-19 pandemic in Nigeria," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 21, no. 3, pp. 1673-1682, doi: 10.11591/ijeecs.v21.i3.pp1673-1682, 2021.
[31] P. Coddington, "Constraint satisfaction problems," in Computer Lecture notes, cs. Adelaide. Edu. (Accessed Feb 13, 2013).
[32] F. Bacchus, "Constraint satisfaction problem," University of Toronto: Lecture notes on Computer Science. Available: www.cs.toronto.edu/~ fbacchus/ (Accessed Feb. 13, 2015).
[33] H. Y. Al Tarawneh and M. Ayob, "Using Tabu search with multi-neighborhood structures to solve University Course Timetable UKM case study (Faculty of Engineering)," in *2011 3rd Conference on Data Mining and Optimization (DMO)*, Putrajaya, Malaysia, 2011, pp. 208-212, doi: 10.1109/DMO.2011.5976529.
[34] A. A. Ojugo, J. E. Emudianughe, R. E. Yoro, E. O. Okonta, and A. O. Eboka, "Hybrid ANNGSA for runoff modeling," *Progress in Intelligence Computing Applications*, vol. 2, no. 1, pp. 22-33, 2013, doi: 10.4156/pica.vol2.issue1.2.
[35] J. Kazmierska and J. Malicki, "Application of the Naive Bayesian Classifier to optimize treatment decisions," *Radiother Oncol*, vol. 86, pp. 211-6, 2008, doi: 10.1016/j.radonc.2007.10.019.
[36] D. A. Oyemade and A. A. Ojugo, "A property oriented pandemic surviving trading model", *International Journal of Advanced Trends in Computer Science and Engineering*, vol. 9, no. 5, pp. 7397-7404, 2020, doi: 10.30534/ijatcse/2020/71952020.
[37] J. M. Kizza, *Guide to Computer Network Security*. Second. London: Springer, 2013
[38] A. A. Ojugo and R.E. Yoro, "Forging a deep learning neural network intrusion detection framework to curb the distributed denial of service attack", *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 11, no. 2, pp 1498-1509, 2021, doi: 10.11591/ijece.v11i2.pp1498-1509.
[39] R. Markus, S. Wunderlich, and D. Grudl, "Flow-based benchmark data sets for intrusion detection," in *Proceedings of the 16th European Conference on Cyber Warfare and Security (ECCWS), to appear*, 2017, pp. 361-369.
[40] S. C. Brailsford, C. N. Potts, and B. M. Smith, "Constraint satisfaction problem: algorithms and applications," *European Journal Operation Research*, vol. 119, pp. 557-581, 1998, doi: 10.1016/S0377-2217(98)00364-6.
[41] H. Tarkesh, A. Atighehchian, and A. S. Nookabadi, "Facility layout design using virtual multi-agent system," *Journal of Intelligent Manufacturing*, Springer, vol. 20, no. 4, pp 347–357, 2009, doi: 10.1007/s10845-008-0109-1.
[42] M. Kisan, S. Sangathan, J. Nehru, and S.G. Pitroda, "Management and Productivity Sectional Committee," MSD 4, 2011. [Online]. Available: https://law.resource.org/pub/in/bis/S07/is.iso.31000.2009.pdf.
[43] M. James, *Common Network Protocol-CompTIA Network+ N10-004: 1.1*. (Jul 17, 2010). [Online Video]. Available: http://www.youtube.com/watch?v=QnilcNeh97c.
[44] H. A. Bashir and R. S. Neville, "Hybrid evolutionary computation for continuous optimization," *arxiv: 1303.3469*, 2013.

[45] J. Lassig and D. Sudholt, “Adaptive population model for offspring population and parallel evolutionary algorithms,” *arxiv: 1102.0588*, 2011.
[46] A.A. Sakr, “QoS Routing Protocol Using GA’s,” *International Journal of Science and Advanced Technology,* vol. 1, no. 3, 78–85, 2011. [Online]. Available: http://www.ijsat.com/admin/download/[11-01-02-014].pdf.
[47] Y. Miaji and M. M. Ebedon, “Novel Performance Enhancement of University’s Network Exploiting Cisco Network Design Model: Study Case on IUKL Network,” in *International Conference on Computer Security and Digital Investigation,* Malaysia, 2014, pp. 36–41.
[48] Z. Michalewicz, “A survey of constraint handling techniques in Evolutionary computation methods,” *Evolutionary programming*, vol. 4, pp. 135-155, 1995, doi: 10.7551/mitpress/2887.003.0018.
[49] A. G. Nikolaev, S. H. Jacobson, S. N. Hall, and D. Henderson, “A framework for analyzing sub-optimal performance of local search algorithms,” *Computational Optimization and Applications*, vol. 49, no. 3, pp. 407-433, 2011, doi: 10.1007/s10589-009-9290-1.
[50] L. Kianmehr, D. Becker, and A. Kamali, “The Importance of Written Security Policy for Any Network Connection,” in *Information Systems Educators Conference,* vol. 28, no. 1774, 2011, 1–7.
[51] A. A. Ojugo, A. O. Eboka, R. E. Yoro, M. O. Yerokun, and F. N. Efozia, “Hybrid Model for Early Diabetes Diagnosis,” in *2015 Second International Conference on Mathematics and Computers in Sciences and in Industry (MCSI),* Sliema, Malta, 2015, pp. 55-65, doi: 10.1109/MCSI.2015.35.
[52] D. Smith, “Five Principles for Research Ethics,” *American Psychological Association*, vol. 34, no. 1, pp. 56, 2003. [Online]. Available: http://www.apa.org/monitor/jan03/principles.aspx.
[53] G. Celeux, F. Corset, A. Lannoy, and B. Ricard, “Designing a Bayesian network for preventive maintenance from expert opinions in a rapid and reliable delay,” *Reliability Engineering and System Safety*, vol. 91, no. 7, pp. 849-856, 2006, doi: 10.1016/j.ress.2005.08.007.
[54] M. A. Dye, R. W. McDonald, and A. Rufi, *Network fundamentals: CCNA exploration companion guide*, 1st ed. Indianapolis, Indiana, US: Cisco Press, 2008.