VOL. 16, NO. 1, JANUARY 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

RESOURCE EFFICIENT FOR HYBRID FIBER-WIRELESS COMMUNICATIONS LINKS IN ACCESS NETWORKS WITH MULTI RESPONSE OPTIMIZATION ALGORITHM

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ABSTRACT

Mobile Ad-hoc Network (MANET) is currently popular at demand as a solution in numerous deployments that cover from the combat zone to the user's parlor due to its quickly deployable with adaptive topology and able to function without any infrastructure. However, variable topology is one of the key challenges since the network throughput and energy consumption depends on number of possible connections. This work proposes a Multi response Optimization (MO) algorithm, named MO-LMMHOWAN that apply in Last Mile Mobile Hybrid Optical Wireless Access Network (LMMHOWAN). In this perspective, the paper originally proposes a model and an architecture that roughly combine MANET and FiWi domains based on adaptive data rate transmission of cross layer scheme integrated with Taguchi method: the primary idea is that this MANET and FiWi can route the packet in accordance to the pre-optimized and robust profile drive by the adaptive data rate, thus mutually enhancing their capability of packet transmission over hybrid FiWi-MANET networks. Technically, the effects of seven controlled factors and two uncontrolled factors were investigated by implementing the Orthogonal Arrays (OA) of Taguchi experimental method on a AODVUU routing path in last mile mobile HOWAN. The study here is established on energy consumption, Packet Delivery Ratio (PDR) and throughput metric with varying nodes scenario. This result is compared to the (non-Taguchi) work study which further reduces the variability among routing configuration parameters and shows superior performance improvement with regards to capacity, energy consumption and PDR with values of 77.89%, 33.76%, and 25.44%, respectively.

Keywords: MANET, MO-LMMHOWAN, FiWi-MANET, OA, PDR.

INTRODUCTION

MANET is a fully distributed network with independent nodes that linked via wireless interfaces [1]. This condition has caused a major challenge as the network topology constantly changing due to number of mobile nodes increases which contribute to the number of hops also increased [2]. According to this reason, the dynamic MANET adapted with QoS degradation which leads to node failure in the ad hoc network as well as battery exhaustion due to limited battery lifetime [3]. This situation makes it important to find the optimized routing path with improved QoS network resource consumption which has become a significant issue and this presents the main objective in this paper. Some related work of QoS support in MANET, which mainly focuses on route improvement for the utilization of resources consumption, such as power-aware or bandwidth aware [4] [5]. For example, in Core-Extraction Distributed Ad hoc Routing (CEDAR) [6] [7] the QoS routing which is based on specific QoS metric is obtained by propagating the high bandwidth availability information to an established core node. However, it had neglected the partial QoS path with low bandwidth causing excessive overhead control due to the movement that may burden the core node. In this case, the main point was these implementations have shown the operation of MANET protocols under disparate approaches, showing the difficulties of conducting testbed experimentation where it requires in general a significant amount of logistics for performance evaluation. On top of that, this so called classical experimental design methods are too complex and are not easy to use due to huge number of variables to be optimized. For that reasons, Taguchi method with Design of Experiment (DoE) is introduced which can reduce the optimization time and effort to obtain the desirable conditions [8]. Despite such daunting challenges, it has received more and more attentions where the users' insatiable desire is sparked in accessing the Internet (wired network) which have fueled to the development of Internet-based Mobile Ad hoc Network (IMANET) [9] [10]. This need which calls for an

alternative next-generation of hybrid Internet access network related to Mobile Ad hoc Networks (MANET), such as Internet-based MANET over Fi-Wi concept. The use of MANET in this case is to provide communication beyond a single hop communication of WLAN by extending it to a multihop communication environment [11]. For improved performance and reliability, ad hoc networking can help to extend the next-generation hybrid network system access networks availability by utilizing intelligent devices (where node acts both as host and router). The rest of the paper is organized as follows: Section 2 pronounces the problem formulation. Next, in section 3 accounts the results and their discussion and the conclusion of the work would be the final section.

PROBLEMFORMULATION

The problem analysis and formulation was initiated with an analytical idea of the ongoing resource constraint in MANET. A comprehensive literature review on the MANET networking challenges was discussed to give a clear understanding of the development of the resource efficient ad hoc network routing in MANET. The literature review gave an outlook and direction to solve the existing issues of MANET leading to the construction of a solid research problem. In particular, in high dense mobile ad hoc network condition and the nature of the nodes in such network, the resource consumption is limited and inefficient. The poor MANET network condition and unreliable nature of mobile ad hoc nodes must be improved to utilize the resources effectively in order to ensure high reliable and robust link transmission [12].

The optimized resource efficient ad hoc network routing is suggested to reduce the degradation of the MANET performance by making efficient use of the local network state information in enabling high network connectivity with reduced delay in packet transmission to the Internet. Furthermore, the implementation of the established optical wireless infrastructure mode in the ad hoc networks can divert the traffic of mobile nodes and relay through wired backbone [13]. The wired backbone division would increase reliability and stability in comparison to the wireless ad hoc division. This feature has the potential of improving the overall performance. The proposal of the optimized resource efficient ad hoc routing of wireless domain under the unified of wire and wireless domains is based on the current ad hoc network routing focusing on the network resource management. In this case, the efficient QoS is related to PDR, throughput, energy, packet loss probability and delay.

The modification on the optimized resource efficient ad hoc routing of the wireless domain under the unified of wire and wireless domains is able to solve the inherent conflict between optimizing transmission utilization and achieving fairness in the shared channel wireless ad hoc network [14] [15]. Also as mentioned before, the current ad hoc network routing with infrastructure mode does not address the nodes with mobility in the distributed network. If a node under this ad hoc protocol is moved, the regular and up-to-date routing table is requested which demands considerable messaging overhead, that results in power and bandwidth consumption. This situation thus leads to a decrease in throughput where the proposed of optimized ad hoc network routing of infrastructure mode is needed to promote efficient QoS resource consumption. Once the research problems were formulated, the proposed network algorithm was designed.

PROPOSED ALGORITHM THRU TAGUCHI METHOD

Robust Design (Taguchi Method)

In general usage, the Design of Experiments (DoE) or experimental design is the design framework of any information-gathering exercises where variation is present, either under the full control of the experimenter or vice versa. All possible combinations of input values are tested once by using the non-Taguchi method based on DoE without knowing it exits or not. However, in statistics such as Taguchi method, these terms are usually used for controlled experiments. In a DoE Taguchi test, the only certain combination which is tested for several times with the use of noise factor. Figure-1 that is based on the common steps Design of Experiment with one of the Taguchi method application in [16] [17] shows the brief technical process flowchart. This test is undertaken based on the Taguchi method for LMMHOWAN, which takes place in OMNet++. The additional tools that are required in this step are MINITAB and EXCEL.

According to Figure-1, the first step is taken based on human factor to perform a gap analysis in the resource consumption such as energy or capacity of the mobile ad hoc wireless network before any design simulation levels occur. Hence, the gap between the variation of data and performance will become smaller when the performance improves. Usually setting up a well-planned experiment required excessive high number of experiments and time [18] [19]. In order to save time, the brainstorming step is performed in which the designer's creative ideas and his knowledge play a vital role by defining its objective of optimizing the resource consumption more efficiently and identifying all design parameters of interest to obtain systematic data. Specifically, in the experimental stages, Taguchi design approach is chosen since this method is related to find the potential control design parameters to obtain the best values to make the problem less sensitive to the variations in uncontrollable environments during offline mode using the MINITAB software with Taguchi method and analysis. Under the session window output for a Taguchi design, MINITAB calculates the response tables and linear model results. It also generates the main effects plus the interaction plots for the Signal-to-Noise ratios (S/N ratios). This ratio provides a measure of robustness versus the control factors. Moreover, it provides further information about the interaction between the controllable design parameters and the variations in uncontrollable design parameters.

In this case, these interactions are essential to ensure robustness of routing in distributed networks under

OMNet++ simulation which uses off-line experimentation as a means of improving quality. After designing the experiment with pre-optimized desired optimum design parameters, the particular framework is reconfigured online as a confirming experiment with factors set at the optimal levels for actual running and analysis that meet the defined objective. Hence, for simplicity reason, the Taguchi's Two Level Designs of the linear function is implemented that ease the performance analysis later on. Meanwhile, the Signal-to-Noise ratio (S/N) is analyzed in the Taguchi method to identify the optimal set of processed parameters values. From the statistical point of view of quality, there are three formulas of quality characteristics in the measurement of S/N output, these being the (i) "nominal the best", (ii) "smaller the better-for the case of minimizing the occurrences of some undesirable product performance characteristics and (iii) "larger the better- for the case of maximizing the system response or characteristics" of equations 3.0, 3.1, and 3.2. [20]. The next process is to obtain the preferred factor by the control or noise factor for the maximum appropriate S/N ratio.

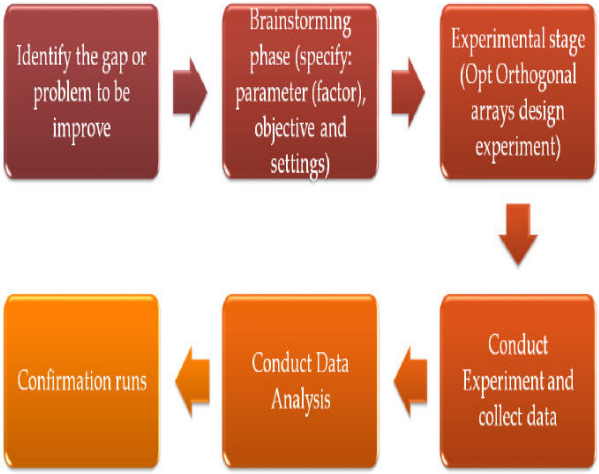

Figure-1. Taguchi Methodology phases.

- For nominal-the-best situation case, where a specified value is most desired, the S/N ratio is calculated using Equation 1:

$$SN_i = 10\log(\frac{\bar{y}_i^2}{S_i^2}) \quad \text{Equation 1}$$

- For the case of minimizing the performance of the system, the following S/N ratio, which is known as the smaller-the-better is calculated using Equation 2:

$$SN_i = -10\log(\sum_{u=1}^{N_i}\frac{y_u^2}{N_i}) \quad \text{Equation 2}$$

- For the case of maximizing the performance characteristics, the following S/N ratio, which is known as the larger-the-better is calculated using Equation 3:

$$SN_i = -10\log[\frac{1}{N_i}\sum_{u=1}^{N_i}\frac{1}{y_u^2}) \quad \text{Equation 3}$$

PROPOSED ALGORITHM

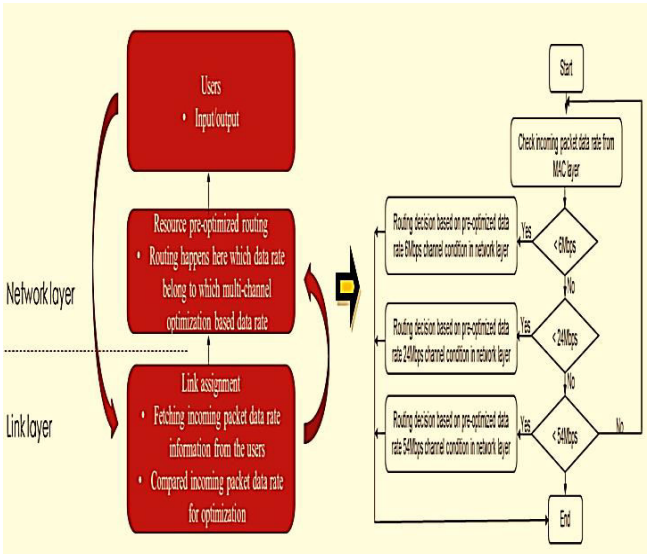

Figure-2. Flowchart for optimized cross-layer scheme of self-configured multiple rate control in AODV-UU routing

In general, unlike other protocols, an improved AODV-UU protocol with self-configured based optimized routing setting is the key to "coding awareness" in this respective resource efficient effort of radio-and-optical access network. In particular, this protocol takes variable multiple control data rate information from the lower layer that is MAC layer to be processed at the network layer. Figure-2 shows the cross-layer scheme for this proposed work of data link layer over network layer. The MO-LMMHOWAN scheme determines the optimum representation for different pre-optimized AODV-UU link settings based on three standard packet data rate every time during the initial packet flow. In this way, a mobile end device in MANET can operate on varying channels condition and automatically adjust their transmission rates for more efficient utilization. This MO-LMMHOWAN also adaptively embraces multiple data rate control to avoid the congestion level in the local mobile user nodes. This approach provides a stable mobility wireless condition, which enables the proposed work of constrained data rate mechanism required to offer a better quality of experience for mobile user nodes. Implemented at the mobile station, the predetermined optimized of AODV-UU protocol improves the network performance such as

energy consumption, delay, packet loss probability, Packet Delivery Ratio (PDR) and capacity consumption. Therefore, it permits a more efficient bandwidth to be delivered to each mobile nodes client in a resource constraint MANET, which is crucial for obtaining good IP-Optical streams quality in unpredictable wireless over fiber environments.

SIMULATION RESULTS AND ANALYSIS

This segment delivers an analysis of the main results obtained depending on the evaluation metrics which include energy consumption, throughput and Packet Delivery Ratio (PDR). The results are then compared with the previous works on MANET area [21] called the oRiG scheme.

- **Evaluation Metrics**

The evaluation metrics considered for analyzing the performance of existing and proposed methods are described in this section.

a) Capacity

Capacity is defined as the total data rate that was successfully received at the server within definite time duration in a communication channel.

b) Packet delivery ratio (PDR)

It can be measured as the relationship of the number of packets received at the target end to those sent from the sources.

c) Energy consumption

This is defined as the sum of energy consumed for all individual mobile nodes when the nodes use a limited power in the active state.

Following by these definitions, this paper offer three sets of optimized parameter output graphs to be analyzed as follows:

- **Capacity**

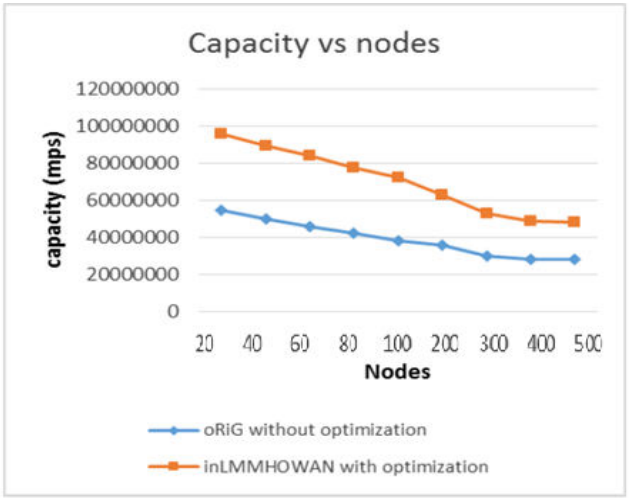

Figure-3. Capacity performance of oRiG and MO-LMMHOWANwith self-configure mechanism.

As shown in Figure-3, the capacity increases to 77.89 % achievable by the proposed MO-LMMHOWAN algorithm under the random waypoint profile mobility. Figure-3 also shows the poor sustainability of the on-demand protocols at a high number of nodes such as link, which becomes saturated from 300 to 500 number of nodes. This results show an increase in energy consumption to route packets that will be dropped downstream. In addition, Figure-3 also displays that larger S/N ratios is better in the Taguchi analysis which meets the objective to obtain optimum capacity as possible with the best fit parameters setting through the parameter screening step.

- **Energy Consumption**

The feature of multiple transmission packet rates over the Taguchi method have important prospective since the decreasing of the network energy consumption occurred when compared with the non-transmission rate optimized situations. After applying this algorithm, it has resulted in 34.31% in energy reduction improvement that is achievable as compared to the oRiG mechanism's parameters setting, as shown in Figure-4. This is due to the twofold positive design effects; the transmission rate optimization reduces unnecessary or inefficient energy consumptions in MANET; and the proposed adaptive encryption approach does not incur extra traffic overhead

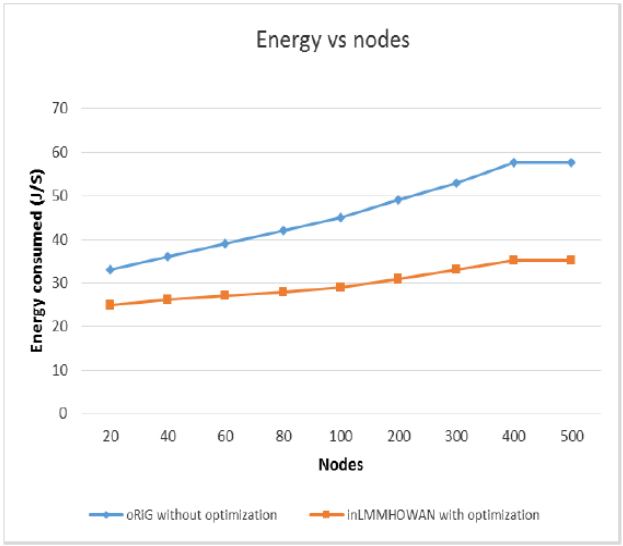

Figure-4. Energy consumption performance of oRiG and MO-LMMHOWAN with self-configure mechanism.

- **Packet Delivery Ratio (PDR)**

Figure-5 shows that the integrated MANET optical backhaul (MO-LMMHOWAN) had a significant effect over the MANET with DSL backhaul (oRi) as per the Taguchi method for PDR (in this case, the larger values of PDR, the better), which is achievable at 50.69% improvement on average. This condition occurs since the integrated MANET optical backhaul (MO-LMMHOWAN) scheme is more reliable due to less link maintenance compared to oRi scheme based MANET.

Specifically, the deployment of Wavelength Division Multiplexing (WDM) based multiplexer is the best choice that allows the transmission of the bidirectional communication over one standard fiber, as well as multiplication of capacity [22] [23]. This can avoid network congestion and make better use of the channel utilization.

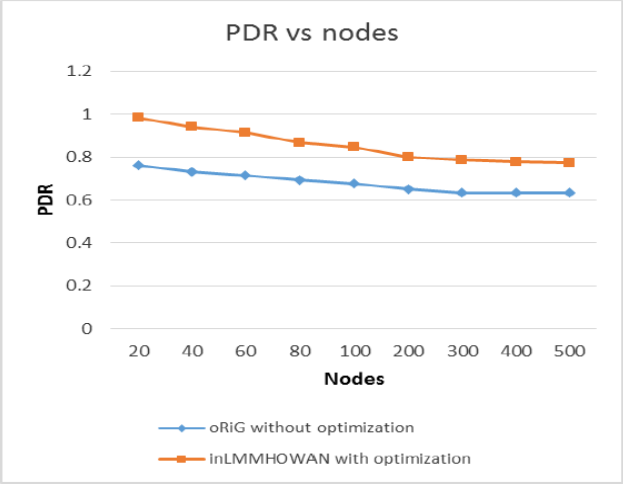

Figure-5. PDR performance of oRiG and MO-LMMHOWAN with self-configure mechanism.

CONCLUSIONS

The current social life in the 21st century is increasingly becoming digital that drive the rapid growth of mobile Internet access and mobile devices. It is important to provide smooth network connectivity and ICT services to meet the increasingly demand from end user to create sustainable growth and to provide improved quality of life. Henceforth, in this article, it emphasizes on possible areas of improvement for the research to develop innovative simulation models that can improve telecommunication in next generation wireless access network. Subsequently, the work here had identified several factors or parameters through the DoE-based Taguchi Method that significantly affect the performance of last-mile telecommunication networks for next generation wireless access networks. Furthermore, the paper also introduced a multi-rate network scheme to accommodate a wide range of channel conditions to improve the resource utilization in a wireless Mobile Ad-hoc network (MANET). This is carried out via a unique and robust optimized profile-based data rate algorithm based on Taguchi method. The proposed MO-LMMHOWAN scheme under the LMMHOWAN framework of routing improvement, when compared to the previous study of oRiq scheme achieved the average improvement of 77.89% in capacity, 50.69% in PDR and 34.31% in energy consumption under the scenario of varying number of nodes.

ACKNOWLEDGMENT

The authors would like to thank Centre for Research and Innovation Management (CRIM) for the support given to this research by Universiti Teknikal Malaysia Melaka (UTeM). We thank also those who contributed in any other forms for providing their continuous support throughout this work.

REFERENCES

[1] Rasa Bruzgiene, Lina Narbutaite and Tomas Adomkus. May 11th 2017. MANET Network in Internet of Things System, Ad Hoc Networks, Jesus Hamilton Ortiz and Alvaro Pachon de la Cruz, IntechOpen, DOI: 10.5772/66408.

[2] Hara, Takahiro. 2017. Data management issues in mobile ad hoc networks. Proceedings of the Japan Academy. Series B, Physical and biological sciences. 93(5): 270-296. doi:10.2183/pjab.93.018.

[3] M. Vanjale, J. S. Chitode and S. Gaikwad. 2018. Residual Battery Capacity Based Routing Protocol for Extending Lifetime of Mobile Ad Hoc Network. 2018 International Conference on Advances in Communication and Computing Technology (ICACCT), Sangamner. pp. 445-450, doi: 10.1109/ICACCT.2018.8529412.

[4] Jamil Abedalrahim Jamil Alsayaydeh, Mohamed Nj, Syed Najib Syed Salim, Adam Wong Yoon Khang, Win Adiyansyah Indra, Vadym Shkarupylo and Christina Pellipus. 2019. Homes Appliances Control Using Bluetooth. ARPN Journal of Engineering and Applied Sciences. 14(19): 3344-3357.

[5] A. Younis, T. X. Tran and D. Pompili. 2018. Bandwidth and Energy-Aware Resource Allocation for Cloud Radio Access Networks. in IEEE Transactions on Wireless Communications. 17(10): 6487-6500, doi: 10.1109/TWC.2018.2860008.

[6] Adam Wong Yoon Khang, Arnidza Ramli, Shamsul J. Elias, J. Pusppanathan, Jamil Abedalrahim Jamil Alsayaydeh, Fatin Hamimi Mustafa, Win Adiyansyah Indra, Johar Akbar Mohamat Gani. 2020. Self-configuration and self-optimization process with taguchi method in hybrid optical wireless network. Indonesian Journal of Electrical Engineering and Computer Science. 19(2): 870-878.

[7] N. Sivapriya & Dr. T. N. Ravi. 2018. QoS Routing Protocols in MANET: A Survey. International Journal of Pure and Applied Mathematics. 119(12): 16573-16579.

[8] J. O. Abe, O. M. Popoola, A. P. I. Popoola, E. Ajenifuja, D. I. Adebiyi. 2019. Application of Taguchi design method for optimization of spark plasma sintering process parameters for Ti-6Al-4V/h-BN binary composite. Eng. Res. Express. 1, pp. 1-20.

[9] Jamil Abedalrahim Jamil Alsayaydeh, Adam Wong Yoon Khang, Win Adiyansyah Indra, J. Pusppanathan, Vadym Shkarupylo, A. K. M. Zakir Hossain, Saravanan S/O Saminathan. 2019. Development of Vehicle Door Security using Smart Tag and Fingerprint System. International Journal of Engineering and Advanced Technology (IJEAT). 9(1): 3108-3114. DOI: 10.35940/ijeat.E7468.109119.

[10] R. U. Zaman, K. u. R. Khan, M. A. Waseem, A. Farokhi and A. V. Reddy. 2016. Traffic priority based gateway selection in Integrated Internet-MANET. 2016 2nd International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT), Bangalore. pp. 18-21, doi: 10.1109/ICATCCT.2016.7911958.

[11] T. Hara. 2017. Data management issues in mobile ad hoc networks. Proceedings of the Japan Academy. 93(5): 270-296.

[12] S. M. Al-Shehri and P. Loskot. 2018. Enhancing Reliability of Tactical MANETs by Improving Routing Decisions. in J. Low Power Electron. Appl.

[13] Malik, Suman, and Prasant Kumar Sahu. 2019. A comparative study on routing protocols for VANETs. Heliyon, Vol. 5, 8 e02340. doi:10.1016/j.heliyon.2019.e02340.

[14] Jamil Abedalrahim Jamil Alsayaydeh, Win Adiyansyah Indra, Adam Wong Yoon Khang, Vadym Shkarupylo, Dhanigaletchmi A/P P Jkatisan. 2019. Development of Vehicle Ignition Using Fingerprint. ARPN Journal of Engineering and Applied Sciences. 14(23): 4045-4053.

[15] Moyaba M. Velempini and S. Dlamini. 2018. A Joint MAC and Network Layer QoS Scheme which Mitigates Primary and Secondary Users' Interference. 2018 International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD), Durban. pp. 1-8, doi: 10.1109/ICABCD.2018.8465429.

[16] Adam Wong Yoon Khang,Jamil Abedalrahim Jamil Alsayaydeh, Win Adiyansyah Indra, J. Pusppanathan, Shamsul J. Elias. 2019. Taguchi based Self-configure Data Rate Optimization AODVUU Routing Parameters in MANET over Optical Network Performances. International Journal of Engineering and Advanced Technology. 8(5): 316-322.

[17] Sa'ed J. A., Amer M., Bodair A., Baransi A., Favuzza S., Zizzo G. 2019. A Simplified Analytical Approach for Optimal Planning of Distributed Generation in Electrical Distribution Networks. Appl. Sci. 9, 5446.

[18] R. Davis, P. John. 2018. Application of of taguchi-based design of experiments experiments for industrial chemical processes. Stat Approaches Emphas Des Exp Appl Chem Process. pp. 137-155.

[19] Jamil Abedalrahim Jamil Alsayaydeh, Adam Wong Yoon Khang, Win Adiyansyah Indra, Vadym Shkarupylo and Jayananthinii Jayasundar. 2019. Development of smart dustbin by using apps. ARPN Journal of Engineering and Applied Sciences. 14(21): 3703-3711.

[20] Banerjee S., Sharif H. 2016. A Survey of Wireless Communication Technologies & Their Performance for High Speed Railways. J. Transp. Technol. 6, 15.

[21] Lakshman Naik L., R. U. Khan & R. B. Mishra. 2015. Analysis of Performance Enhancing Parameters of AODV Using NS-3. African Journal of Computing & ICT. 8(2, 2).

[22] He K. 2013. Fusion network performance experiment. M.Sc. thesis, Department of Telematics, Norwegian University of Science and Technology (NTNU).

[23] Jamil Abedalrahim Jamil Alsayaydeh, Win Adiyansyah Indra, Adam Wong Yoon Khang, A. K. M. Zakir Hossain, Vadym Shkarupylo and J. Pusppanathan. 2020. The experimental studies of the automatic control methods of magnetic separators performance by magnetic product. ARPN Journal of Engineering and Applied Sciences. 15(7): 922-927.