A NOVEL ROUTING NETWORK ALGORITHM VIA NEUTROSPHIC FUZZY SET APPROACH

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Abstract

Routers steer and bid network data, through packets that hold a variety of categories of data such as records, messages, and effortless broadcasts like web interface. The procedure of choosing a passageway for traffic in a network or between several networks is called routing. Starting from telephone networks to public transportation the principles of routing are applied. Routing is the higher-level decision making that directs network packets from their source en route for their destination through intermediate network nodes by specific packet forwarding mechanisms. The main function of the router is to set up optimized paths among the different nodes in the network. An efficient novel routing algorithm is proposed with the utilization of neutrosophic fuzzy logic in this work addition to many routing algorithms for finding the optimal path in the literature. In this approach, each router makes its own routing decision in the halting time. Various concepts like routing procedures, most expected vector, most expected object, and list of estimated delay are explained.

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1.Introduction

The increasing usage of computerized components in the digital era in every walks of life leads to drastic improvements in network technologies and management techniques to satisfy the customers to receive high excellence service. Due to the overwhelming transmission of data through the computer network, the quality of service expected by the user's started to mortify. To overcome this situation a more effective method for routing data through a computer network is proposed.

Broadband ISDN is the broadband transmission counterpart of Integrated Services Digital Network. B-ISDN standards and technologies are an emerging option for high-speed networking that promises the capabilities of high-speed digital connectivity for homes and businesses. N-ISDN refers to data communication and telecommunications tools, technologies, and services that utilize a narrower set or band of frequencies in the communication channel. B-ISDN was predicted as a supplier of higher bit rates to the user when compared with N-ISDN. The main objectives of B-ISDN are that the stipulation of a broad range of services to a broadband diversity of users consuming a limited set of connection types and multi-purpose user-network interfaces. B-ISDN is designed to use the cell-switching transport technology of Asynchronous Transfer Mode (ATM) together with the underlying physical transport mechanisms of Synchronous Optical Network (SONET). ATM provides functionality that uses features of circuit switching and packet switching networks. It uses asynchronous time-division multiplexing and encodes data into small, fixed-sized network packets. The transport of cells must be at high speed as ATM has to support a wide range of services whose requirements vary over a wide range. Hence the dispensation time at the midway devices like router and the efficient techniques for traffic management must be reduced. Normally the rising traffic loads will obviously show the way to network delays, which will be the reason for many other problems. These network interruptions will cause dropped sessions or lost data, which results in frustrated users. In order to stop this increasing traffic load, optimal routing of messages within a network can be framed which would reduce the difficulties of heavy traffic. With the intention of reducing the network delays a more effective technique of routing can be established.

To transfer packets from source to destination in networks the process of routing is used. The path determination function facilitates a router to estimate the existing paths to a destination and to set up the preferred handling of a packet. Data can take different paths to get from a source to a destination. Traffic between source-destination pair can be split along multiple paths with infinite precision. The optimized paths among the different nodes in the network are formed by a router. Low mean packet delay and high network throughput is obtained by an optimized path. The existing routing algorithms can be broadly classified into static and dynamic algorithms. With static routing, small networks may use physically configured routing tables. Larger networks have multifaceted topologies that can transform rapidly, making the manual edifice of routing tables unfeasible. Based on the information switched among the adjoining routers dynamic routing algorithms make choice concerning the optimized paths independently of other routers. This swap of routing information is carried out occasionally mounting the traffic on the network. Dynamic routing attempts to solve this problem by constructing routing tables automatically, based on information carried by routing protocols, allowing the network to act nearly autonomously in avoiding network failures and blockages and swap routing information occasionally among the adjoining routers. This is meant by periodic updates. This epoch typically varies from few tens of milliseconds to 1 or 2 minutes. If the updates are too frequent, jamming might arise. On the other hand, if updates are too uncommon, routing might not be proficient. Hence these dynamic algorithms add extra traffic due to the exchange of routing information among the routers to the network. This builds the traffic management concern a complex one and hence it is becoming a main field of research. The traffic owing to routers is decreased by implanting neutrosophic fuzzy intelligence into existing adaptive routers. These neutrosophic fuzzy routers are predictable to amplify the speed of routing as compared to present adaptive routers as frequent exchange of routing information.

Bellman [1] proposed the Distance Vector Routing algorithm which is considered as usual dynamic routing algorithm as it is being utilized extensively in the present networks like Routing Information Protocol (RIP) for IP, Cisco's Internet gateway Routing Protocol (IGRP), AppleTalk's Routing Table Maintenance Protocol (RTMP) etc. Zadeh [2] have proposed Fuzzy Sets to deal with the vague data's in uncertain conditions. Ashit Kumar Dutta [3] explained about the application of Intuitionistic Fuzzy in Routing Networks.

The basis of Intuitionistic Fuzzy Sets is presented by Atanassov [4]. Smarandache, [5] proposed Neutrosophic Logic. Neutrosophy, Neutrosophic Set, Neutrosophic Probability etc which reveled the importance of neutrosophy fuzzy over other fuzzy sets. The elementary concepts of Fuzzy Control are offered by Driankovet al [6]. Anti-fuzzy subgroup and its characterizations are proposed by Gayen et al [7]. Kumar et al [8] presented various investigations on Interval-valued Neutrosophic subgroup based on interval-valued triple t-norm. A rule based fuzzy logic to find out the optimum path taking into account the crisp values of hop count metric is proposed by Ka-Wing Wong [9]. The testing and simulation study of the approach is passed out with different traffic loads. It is accomplished that the approach decreases the dispensation overhead and presents a fair distribution of network traffic as compared to other conventional routing methods.

The intelligent fuzzy approach is proposed for routing the tagged cells by Ford and Fulkerson [10] simulation results which demonstrated a development in network consumption. Tahir mahmood et al, proposed the vector similarity measures for simplified neutrosophic hesitant fuzzy set [11]. Neutrosophic shortest path problem and its characteristics were presented by Bromi et al [12]. Qaisar Khan and Tahir Mahmood have deliberated about Interval neutrosophic finite switchboard state machine [13]. Runtong Zhang and Yannis A. Phillis [14] reported the fuzzy routing in queuing systems and computer network routing. Mohsin Ali Khan[15] presented about Q-Single Valued Neutrosophic Sets. A study on transportation problem in neutrosophic environment is deliberated by Pratihar et al [16]. Ullah et al explained about the Single Valued Neutrosophic Finite State Machine and Switchboard State Machine [17].

Shuchitha Upadhayay and Mini Sharma [18] presented a reinforcement of a new fuzzy mixed metric approach through fuzzy routing Algorithms. Fuzzy set delay representation for computer network routing algorithms was proposed by Sridhar et al [19]. Some interesting results in computer networks was established by Tanenbaum. [20]. Fuzzy routing in Adhoc network is presented by Gasim Alandjani [21]. Barolli et al [22] found an intelligent fuzzy routing scheme for improving ATM Network Performance using Violation tagging function. Kumar et al [23] presented an optimal path selection approach for fuzzy reliable shortest path problem. Recently, several researchers have extended crisp and fuzzy routing algorithms to neutrosophic environment [24-32].

An emerging study area is routing in IoT (Internet of Things) devices. Routing is playing a

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indispensable role in IoT devices. Routing is a very tractable visage that occurs in IoT because of its immanent essences. Sometimes routing protocol is named routing policy, which specifies how routing devices communicate with one another within the network, circulating control information that to pick the simplest routes between any two nodes among multiple routes. In routing protocol information (or) data are often shared from a source node through nearest neighbors and reaches the sink node. Based upon algorithms in routing it decide the simplest path between the source and therefore the destination node. Different authors implemented different algorithms and protocols to extend the lifetime of the network, efficiency in routing. In this sense, this paper also will be an improvement for routing issues within IoT devices.

Neutrosophic fuzzy logic is used to hold uncertainties in cluster head communication range estimation. This method is mainly based on neutrosophic fuzzy mathematics to deal with the uncertainties in traffic handling. Some new terminologies in Section 3 are introduced and then Section 4 is initiated with the method of neutrosophic routing. The work reported covers the theoretical aspects of neutrosophic fuzzy routing.

2. **ROUTING PROCEDURES**

Routing is the progression of promoting a packet in a network so that it attains its intended destination. The core goals of routing are correctness, simplicity, robustness, stability, fairness, and optimality. The routing algorithms may be classified as adaptive routing algorithm, non-adaptive routing algorithm, delta routing and multipath routing etc. Adaptive routing algorithm is further classified into isolated, centralized and distributed. Non-Adaptive routing algorithm is further classified into flooding and random walk**.**

Routing decisions are made based on topology and network traffic. Routing decisions are the static tables. The types of adaptive routing algorithm are centralized, isolation and distributed algorithm. The types of non adaptive routing algorithm are flooding and random walks. A routing algorithm is a set of step-by-step operations used to direct internet traffic efficiently. When a packet of data leaves its source, there are many different paths it can take to its destination. The routing algorithm is applied to determine mathematically the best trail to take.

Normally the information will be alienated into tiny blocks named as packets or cells, which

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will be enthused across some sorts of networks and ends at the distance point in the internet world. Routers, identify the trail throughout which the data packet passes. To commune among the users on different networks the process of routing is applied. The aim of routing is to choose an optimized path between dispatcher and recipient. Non-adaptive and adaptive are the two major groups for routing. Non-adaptive (also called static) algorithms do not base their routing resolutions on capacity or guess of the present traffic. When a router utilizes a non-adaptive routing algorithm it check with a static table in order to determine to which computer it should send a packet of data. This is in contrast to an adaptive routing algorithm, which bases its decisions on data which replicates present traffic circumstances. The parameters which are used in adaptive routing algorithms are distance, hop, estimated transit time and count. Adaptive algorithms, in contrast, change their routing decisions to reflect changes in the topology and traffic. These adaptive algorithms formulate a pronouncement in the routing path found on the information they get from extra routers. The main dissimilarity in the existing algorithms will be different from each other in the technique they receive information, when they alter the routes and what limit is employed for optimization namely distance, number of hops, or estimated transit time, reliability, bandwidth, load etc.

To accept several input constraints that are uncertain and imprecise in nature fuzzy inference system is applied in routers. When broadcasting usual data, fuzzy-logic-based data-differentiated service sustained routing protocol has accomplished maximum optimum and extended network lifetime than that of parallel algorithms. The recent extension of fuzzy is neutrosophic fuzzy which deals with proper truth-membership function, indeterminacy- membership function, and falsity - membership function. The intention of this work is to decrease the traffic due to routers and to extend the network lifetime using neutrosophic fuzzy intelligence by proposing F-CTP protocol taking into account a multi-objective optimization problem which is based on the fuzzy logic algorithm. The main advantages of neutrosophic fuzzy routers are expected to boost the rapidity of routing as evaluated to conformist adaptive routers as a recurrent swap of routing information is not needed.

In distance vector routing, each router preserves a routing table including one entry for each target in the network. Distance-vector routing protocols estimate the distance by the number of routers a packet has to pass, one router counts as one hop. This ingress enlightens the ideal outgoing line to employ for that destination. The router knows the “distance” which means the number of hops, queue length or delay to each of its neighbors. Once every t msec, each router

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sends to each neighbor a list of its predictable delays to each destination. A router can find which route seems the best and updates its routing table. This routing table will be used by the router to route the packets for next T msec (T >> t), after which routing information will be switch over again and this procedure is repeated. Thus for every t msec, routing information will be exchanged among the adjacent routers which leads to increased traffic on the network. But the benefit of the algorithm is that it updates routing information dynamically for every fixed time interval and to reduce the traffic due to exchange of routing information.

3. PRELIMINARIES

Definition 3.1:

Let X be a space of points with generic elements in X denoted by x is the neutrosophic set A is an object having the form, A = $\{\langle x : T_A(X), I_A(X), F_A(X)\rangle, x \in X\}$, where the functions T,I,F : X→]$^-$0,1$^+$[define respectively the truth-membership function, indeterminacy- membership function and falsity - membership function of the element , $x \in X$ to the set A with the condition $^-0 \leq T_A(X) + I_A(X) + F_A(X) \leq 3^+$ .The functions are real standard or non standard subsets of]$^-$0,1$^+$ [.

Definition 3.2:

Let $R_N = \langle [R_T, R_I, R_M, R_E,](T_R, I_R, F_R)\rangle$ and $S_N = \langle [S_T, S_I, S_M, S_E,](T_S, I_S, F_S)\rangle$ be two trapezoidal neutrosophic numbers (TpNNs) and $\theta \geq 0$,then

$R_N \oplus S_N = \langle [R_T + S_T, R_I + S_I, R_M + S_M, R_E + S_E](T_R + +T_s - T_R T_S, I_R I_S, F_R F_S)\rangle$

$R_N \otimes S_N = \langle [R_T . S_T, R_I . S_I, R_M . S_M, R_E . S_E]\left(T_R . T_S, I_R + I_s - I_R . I_S, F_R + F_S - F_R . F_S\right)\rangle$

$\theta R_N = \langle [\boldsymbol{\theta} R_T, \boldsymbol{\theta} R_I, \boldsymbol{\theta} R_M, \boldsymbol{\theta} R_E,]\left(1-(1-T_R)\right)^{\theta}, (I_R)^{\theta}, (F_R)^{\theta})\rangle$

4. NEUTROSOPHIC MOST EXPECTED VECTOR (NMEV)

In this section, some preliminaries on neutrosophic most expected vector is presented.

A. Generated Vector (GV)

Let $U_1, U_2, \ldots, U_k$ be k number of n-dimensional vectors,

$$U_{j=}\begin{bmatrix} U_{i1} \\ U_{i2} \\ \cdot \\ \cdot \\ U_{in} \end{bmatrix}$$

i=1, 2, 3…, k

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For each j, (j = 1, 2, . ., n), we will do here n number of extrapolations by using Newton's Backward Interpolation formula, for the n tables given by to find $U_{k+1,j}$, j = 1, 2, 3, …, n.

Thus a new vector is generated, which is

$$\overline{U_{k+1}} = \begin{bmatrix} \overline{U_{k+1,1}} \\ \overline{U_{k+1,2}} \\ . \\ . \\ \overline{U_{k+1,n}} \end{bmatrix}$$

The above vector is stated as Generated Vector (GV) by $U_1, U_2 \ldots, U_k$.

B. **Neutrosophic Fuzzy Vector (NFV)**

The Neutrosophic Fuzzy Vector (NFV) is represented as,

$$\widetilde{U}_{k+1} = \begin{bmatrix} \widetilde{U}_{k+1,1} \\ \widetilde{U}_{k+1,2} \\ . \\ . \\ \widetilde{U}_{k+1,n} \end{bmatrix}$$

where each of $\widetilde{U}_{k+1,1}, \widetilde{U}_{k+1,2} \ldots, \widetilde{U}_{k+1,n}$ is a neutrosophic fuzzy number corresponding to the precise numbers $\overline{U_{k+1,1}}, \overline{U_{k+1,2}} \ldots.. \overline{U_{k+1,n}}$.

We call it an NFV generated by the vectors $U_1, U_2, \ldots.., U_k$ and denote it by the notation.

$$\text{NFV}\ (U_1, U_2, \ldots.., U_K) = U_{K+1}$$

C. **Most Expected Object (MEO)**

Suppose that A is an NFS of a set X with membership function μ_A and non-membership function υ_A. 'Most Expected Object (MEO)' refers to element of X which has the maximum membership value and represented by MEO (A),

Thus, MEO (A) = yp, where yp ∈ Y and

θ(yp) = max { θ(yi) : yi ∈ Y}, where

$$\theta(y_i) = \begin{cases} \frac{\mu_A(y_i)}{\upsilon_A(y_i)} & if\ \upsilon_A(y_i) \geq \pi_A(y_i) \\ \frac{\mu_A(y_i)}{\pi_A(y_i)} & otherwise \end{cases}$$

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D. **Neutrosophic Most Expected Vector (NMEV)**

Suppose that NFV ($U_1, U_2 \ldots U_k$) $=\widetilde{U}_{k+1}$

$$U_{k+1} = \begin{bmatrix} \widetilde{U}_{k+1,1} \\ \widetilde{U}_{k+1,2} \\ \cdot \\ \cdot \\ \widetilde{U}_{k+1,n} \end{bmatrix}$$

The Neutrosophic most expected vector (NMEV) of $\widetilde{U}_{k+1}$ is the vector, represented by

$$U_{k+1} = \begin{bmatrix} MEO(\widetilde{U}_{k+1,1}) \\ MEO(\widetilde{U}_{k+1,2}) \\ \cdot \\ \cdot \\ MEO(\widetilde{U}_{k+1,n}) \end{bmatrix} = \begin{bmatrix} U_{k+1,1} \\ U_{k+1,2} \\ \cdot \\ \cdot \\ U_{k+1,n} \end{bmatrix}$$

This is denoted by NMEV ($U_1, U_2, \ldots, U_k$)

5. **Neutrosophic Fuzzy Routing**

The proposal for neutrosophic fuzzy routing is presented in this work. This is an extension of the application of Atanassov's theory of IFS in routing, as neutrosophic logic is more generalized than intuitionistic fuzzy logic. In Intuitionistic fuzzy logic, a certain amount of incomplete information or indeterminacy is allowed but neutrosophic fuzzy overcomes this constraint that's why it is being applied in recent works. Let the size of the network is r (the number of routers or nodes) and all the routers are active with the metric is measured by delay.

Procedure:

The working procedure of the routers is explained here. Let n be the number of lists and T be the time in hour. Each router sends to each of its neighbors a "list of estimated delay" (LED) to reach every router of the network for every t msec. After sending n number of such lists, it stops the progress for T hours. The router again sends a fresh set of LED after T hours; and so on. Each LED is evidently an r-dimensional vector. In this paper, an optimal method for generating an innovative type of LED called neutrosophic Fuzzy LED (NFLED) is presented.

Let us consider the subnet consisting of the routers A, B, C, D, E, F, G. H and I, as shown in fig 1,

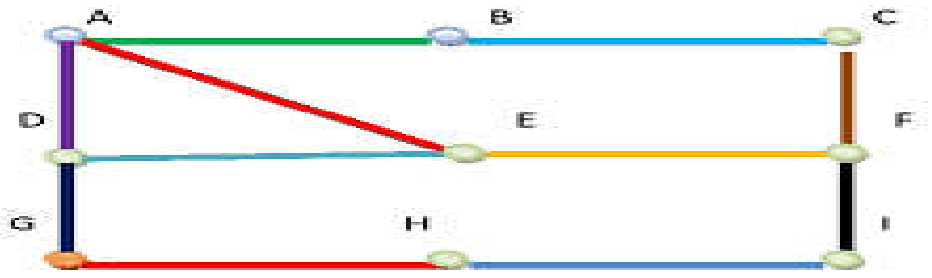

Fig: 1. Subnet with routers

From the above subnet, consider any router, say E. It has three neighbors A, B and D. These three neighbors alone can send LED to the router E. Suppose that at some instant τ, and then at the regular instants (τ + t), (τ + 2t)… (τ + (n-1)t), the router G receives the following sets of three LEDs from A, B, and D respectively.

Table: 1.LED information received by the router E

Instant	LED received from A	LED received from B	LED received from D
τ	U_0^A	U_0^B	U_0^D
τ + t	U_1^A	U_1^B	U_1^D
τ +2t	U_2^A	U_2^B	U_2^D
…	…	…	…
τ +(n-1)t	U_{n-1}^A	U_{n-1}^B	U_{n-1}^D

Each entry vector in the above table is r-dimensional (in this example r = 9).

For example (hypothetical) $U_3^C = \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ x_r \end{bmatrix}$

then it means that the optimal delay from C to the router R_1 is y_1, the optimal delay from C to the router R_2 is y_2, etc.

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Now let us find the following three vectors:

(1) NMEV $(U_0^A, U_1^A, U_2^A, , , , , , U_{n-1}^A) = U_n^A$,(say)

(2) NMEV $(U_0^B, U_1^B, U_2^B, , , , , , U_{n-1}^B) = U_n^B$,(say)

(3) NMEV $(U_0^D, U_1^D, U_2^D, , , , , , U_{n-1}^D) = U_n^D$,(say)

The collection of these three vectors is called Neutrosophic Fuzzy LED (NFLED). During the computation of these three vectors, router E will be functioning according to the previous NFLED. The new NFLED now will remain valid to the router E for T hours next, until the next NFLED is computed. With the help of this NFLED, routing will be done by E. Once an NFLED is computed, the previous NFLED gets replaced.

6.CONCLUSION

A new method of routing called neutrosophic fuzzy routing is proposed. In intuitionistic fuzzy logic, the indeterminacy is ignored, while in Neutrosophic logic the indeterminacy is taken into consideration. The distance vector routing with neutrosophic fuzzy tools is applied in this work to compute NFLED. The neutrosophic fuzziness in the value of the almost equal mean of traffic is to be dealt with proper truth-membership function, indeterminacy-membership function, and falsity-membership function. Both dynamic, as well as the static method, is proposed and this method works on updated information. These results is a gain in the reduction of resource management traffic. The neutrosophic fuzziness diminishes to fuzziness and then the neutrosophic fuzzy routing will be reduced to 'fuzzy routing' as a particular case. The developments in the paper are strong possible candidates for future directions to use in IoT mechanisms and devices. We will also extend the work and other routing and IoT based problems with numerical values.

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References

[1] R. E. Bellman, “Dynamic Programming”, NJ, Princeton University Press, 1957.

[2] L. Zadeh, “Fuzzy Sets”, Information and Control, 8, 338-353.1965.

[3] A. K. Dutta, A. R. W. Sait, “An Application of Intuitionistic Fuzzy in Routing Networks”, International Journal of Advanced Computer Science and Applications,*Vol. 3, No.6, 2012.*

[4] K. T. Atanassov, “Intuitionistic fuzzy sets”,Fuzzy Sets and Systems, 20, 87-96, 1986.

[5] F. Smarandache, “A Unifying Field in Logics: Neutrosophic Logic. Neutrosophy, Neutrosophic Set,

DOI: 10.5281/zenodo.4308543

Neutrosophic Probability", American Research Press, Rehoboth, NM, 1999.

[6] D. Driankov, H. Hellendoorn, M. Reinfrank, "An Introduction to Fuzzy Control", Springer-Verlag, Berlin, New York, 1993.

[7] S .Gayen, S. Jha, M. Singh, R.Kumar, "On a generalized notion of anti-fuzzy subgroup and some characterizations", International Journal of Engineering and Advanced Technology, 8, 385-390, 2019.

[8] S. Gayen, F. Smarandache, S. Jha, R. Kumar, "Interval-valued neutrosophic subgroup based on interval-valued triple t-norm", Neutrosophic sets in decision analysis and operations research; IGI Global, pp 215-243,2020.

[9] K. Wong, "Fuzzy routing control of service request messages in an individual computing environment", Proc. of the 1995 *ACM Symposium on Applied Computing, Nashville* (USA), pp 548-551,1995.

[10] L. R. Ford, D.R. Fulkerson, "Flows in Networks", Princeton,NJ; *Princeton University Press*, 1962.

[11] T. Mahmood, Q. Khan, K.Ullah, N.Jan, "Single Valued Neutrosophic Finite State Machine and Switchboard State Machine", ViXra*,* 2018.

[12] R. Kumar, A. Dey, S. Broumi, F.Smarandache, "A study of neutrosophic shortest path problem",In Neutrosophic Graph Theory and Algorithms; IGI Global,148-179,2020.

[13] T. Mahmood , Q. Khan, M. A. Khan, "Q-Single Valued Neutrosophic Sets", Journal of New Theory, 13 ,10-25,2016.

[14] R. Zhang, Y. A. Phillis, "Fuzzy Routing of Queueing Systems with Heterogeneous Servers", Proc. of IEEE Intl. Conference on Robotics and Automation Albuquerque, New Mexico, pp. 2340-2345, April 1997.

[15] T. Mahmood, Q. Khan, "Interval neutrosophic finite switchboard state machine", Afrika Matematika , 27 ,7-8 , 1361-1376, 2016.

[16] J. Pratihar, R. Kumar, A. Dey, S. Broumi, "Transportation problem in neutrosophic environment", NeutrosophicGraph Theory and Algorithms;IGI Global, 180-212,2020.

[17] T. Mahmood, J. Ye, Q. Khan, "Vector similarity measures for simplified neutrosophic hesitant fuzzy set and their applications", Journal of Inequalities and Special Functions, Volume 7, Issue 4,176-194, 2016.

[18] S. Upadhayay, M. Sharma, "Reinforcement of a new fuzzy mixed metric approach through fuzzy routing Algorithms", IJCNS, 8,2, 271 – 276,2008.

[19] S. Pithani, A. S. Sethi, "A fuzzy Set Delay Representation for Computer Network Routing Algorithms", Proc. Second Intl. Symposium on Uncertainty Modeling and Analysis, College Park, MD pp. 286-293, 1993.

[20] A. S. Tanenbaum, "Computer Networks", Prentice-Hall, Englewood Cliffs, NJ, 1988.

[21] Gasim Alandjani and Eric. E.Johnson, "Fuzzy routing in Ad hoc networks", IEEE, 2003.

[22] L. Barolli , A.Koyama ,T.Yamada, S. Yokoyama, "An Intelligent fuzzy routing scheme for improving ATM Network Performance using Violation tagging function", IEEE Proceedings on Database and expert system application, pp. 5 -9, 2000.

[23] R. Kumar, S. A. Edalatpanah, H. Mohapatra, "Note on "Optimal path selection approach for fuzzy reliable shortest path problem", Journal of Intelligent & Fuzzy Systems (Preprint), pp.1-4, 2020.

DOI: 10.5281/zenodo.4308543

[24] S. Broumi, M. Talea, A. Bakali et al., "Shortest path problem in fuzzy intuitionistic fuzzy and neutrosophic environment: an overview", *Complex Intell. Syst.*, vol. 5, no. 4, pp. 371-378, 2019.

[25] S. Broumi, D. Nagarajan, A. Bakali et al., "The shortest path problem in interval valued trapezoidal and triangular neutrosophic environment", *Complex Intell. Syst.*, vol. 5, no. 4, pp. 391-402, 2019.

[26] S. Broumi, A. Bakali, M. Talea et al., "Shortest path problem under interval valued neutrosophic setting", Int. J. Adv. Trends Comput. Sci. Eng., vol. 8, no. 1, pp. 216-222, 2019.

[27] R. Liu, “Study on single-valued neutrosophic graph with application in shortest path problem”, CAAI Transactions on Intelligence Technology, Vol. 5, Iss. 4, pp. 308–313, 2020.

[28] R. P. Tan, W.D. Zhang, S. Broumi, Solving methods for the shortest path problem based on trapezoidal fuzzy neutrosophic numbers. Control Decis, 34, pp. 851–860, 2019.

[29] L. Yang, D. Lin, R. P. Tan, Shortest Path Solution of Trapezoidal Fuzzy Neutrosophic Graph Based on Circle-Breaking Algorithm, Symmetry, 12(8), 1360, 2020 ; https://doi.org/10.3390/sym12081360.

[30] E. Çakır, Z. Ulukan, “A* Algorithm Under Single-Valued Neutrosophic Fuzzy Environment” In: Kahraman C., Cevik Onar S., Oztaysi B., Sari I., Cebi S., Tolga A. (eds) Intelligent and Fuzzy Techniques: Smart and Innovative Solutions. INFUS 2020. Advances in Intelligent Systems and Computing, vol 1197, 2021. Springer, Cham. http://doi-org-443.webvpn.fjmu.edu.cn/10.1007/978-3-030-51156-2_36.

[31] E. Çakır, Z. Ulukan, Bipolar Neutrosophic Fuzzy Dijkstra Algorithm and Its Application” In: Kahraman C., Cevik Onar S., Oztaysi B., Sari I., Cebi S., Tolga A. (eds) Intelligent and Fuzzy Techniques: Smart and Innovative Solutions. INFUS 2020. Advances in Intelligent Systems and Computing, vol 1197.,2021. Springer, Cham. http://doi-org-443.webvpn.fjmu.edu.cn/10.1007/978-3-030-51156-2_37.

[32] S. Broumi, M. Talea, A. Bakali, F. Smarandache, S. K. Patro, On the Neutrosophic Counterpart of Bellman-Ford Algorithm In: Ezziyyani M. (eds) Advanced Intelligent Systems for Sustainable Development (AI2SD’2019). AI2SD 2019. Advances in Intelligent Systems and Computing, vol 1106, 2020. Springer, Cham. http://doi-org-443.webvpn.fjmu.edu.cn/10.1007/978-3-030-36677-3_13.

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