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Neutrosophic Intelligent Energy Efficient Routing for Wireless Ad-hoc Network Based on Multi-criteria Decision Making

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Abstract: A wireless ad-hoc network is a decentralized ad-hoc network which has no access point earlier time. In this network, data from every node is transferred to another node dynamically based on network connectivity and existing routing algorithm. Many authors introduced various routing techniques to handle the issues in wireless ad-hoc networks. The main concept of this paper is to develop a new network design to improve the service of wireless ad-hoc network by equipping the routes energy efficient using neutrosophic technique. Multi-criteria decision making method under neutrosophic environment is used for making the routes of the network efficiently here. Since neutrosophic set is the generalization of fuzzy and intuitionistic fuzzy sets, the parameters involved in this method like hop-count, data packets, distance and energy are taken from neutrosophic sets. Mathematical analysis for the proposed network design is carried out and results are also discussed here.

Keywords: Neutrosophic set; WANET; Multi-criteria; Neutrosophic energy function; Neutrosophic distance function.

1. Introduction

Ad-hoc is a communication setting that allows computers to communicate with each other directly without a route. Ad-hoc networks play an important role in emergency situations like military conflicts, natural disasters etc., because of its minimal configuration and quick deployment. Ad-hoc networks are analyzed by various features like uncertain connectivity changes; erratic wireless medium etc., According to these features, ad-hoc networks creates numerous types of failures including failure of nodes and links, data transmission errors, congestions and route breakages.

WANET is a self-configured network which can be shared to various devices like sensors, laptops, personal communication systems for weather conditions, airlines schedules etc.[20]WANET has no established infrastructure in advance. Nodes in wanet are dynamic and easily movable. Since wanet is a decentralized one, it helps to improve the network system more efficient than wireless controlled networks [5, 7, 8, 9].Due to lack of energy and physical damages, some nodes of this network will not be able to use and the total system will be affected. In such situations, the lifetime of wanet is reduced. So many authors in [10, 12] established different types of protocols for improving the lifetime of wanet by considering data packets, hop count, energy and distance parameters. The present network design focused on introducing neutrosophic logic for analyzing intelligent energy efficient routing for wanet based on multicriteria decision making and the analysis of the proposed method is compared with one of the existing methods to validate the results.

Neutrosophic set was introduced by Florentine Smarandache [22] which is the generalization of fuzzy set, intuitionistic set fuzzy set, classical set and paraconsistent set etc., In intuitionistic fuzzy sets, the uncertainty is dependent on the degree of belongingness and degree of non-belongingness. In case of neutrosophy theory, the indeterminacy factor is independent of truth and falsity membership-values. Also neutrosophic sets are more general than IFS, because there are no conditions between the degree of truth, degree of indeterminacy and degree of falsity. Multi-criteria decision making in neutrosophic sets are developed in the book [23] edited by Florentine Smarandache and Surapati Pramanik in 2016 and Faruk Karaaslan introduced Gaussian single-valued neutrosophic numbers and its application in multi-attribute decision making in[11]. Also many authors discussed about multi-criteria decision making in neutrosophic sets and its applications in [14,15,16,17,18,19,24].Decision analysis and expert system was developed in[5,13] and various types of shortest route algorithms in neutrosophic environment are established in [1,2,3,4].

The main concept of this paper is to develop a new network design to improve the lifetime of wireless ad-hoc network by equipping the routes energy efficient using neutrosophic technique. Multicriteria decision making method under neutrosophic environment is used for making the routes of the network efficiently here. The parameters involved in this method like hop-count, data packets, distance and energy are taken from neutrosophic sets. Using this method, we can reduce the energy consumption and route breakages due to high level data packet transmission and maximum hop count. The neutrosophic technique is implemented here will give better energy efficient routes for WANET. The rest of the paper is organized as follows: Section 2 provides preliminaries about each of the set theories. Section 3 describes proposed network design with neutrosophic rule matrix and section 4 gives conclusions and future research.

2. Preliminaries

This section includes some basic definitions that are very useful to the proposed network model.

Definition 2.1[22]:

Let E be a universe. Then a fuzzy set X over E is a function defined as follows: $X = (\mu_x(x)/x): x \in E$, where $\mu_x: E \to [0.1]$. Here, μ_x is called membership function of X, and the value $\mu_x(x)$ is called the grade of membership om $x \in E$. The value represents the degree of x belonging to the fuzzy set X.

Several authors [1, 2, 9-12] used fuzzy set theory in ad-hoc network and wireless sensor network to solve routing problems. The logic in fuzzy set theory is vastly used in all fields of mathematics like networks, graphs, topological space etc.

Definition 2.2[20]:

Intuitionistic Fuzzy Sets are the extension of usual fuzzy sets. All outcomes which are applicable for fuzzy sets can be derived here also. Almost all the research works for fuzzy sets can be used to draw information of IFSs. Further, there have been defined over IFSs not only operations similar to those of ordinary fuzzy sets, but also operators that cannot be defined in the case of ordinary fuzzy sets.

Definition 2.3[20]:

Adroit system [3,4] is a computer program that efforts to act like a human effect in a particular subject area to give the solution to the particular unpredictable problem. Sometimes, adroit systems are used instead of human minds. Its main parts are knowledge based system and inference engine. In that the software is the knowledge based system which can be solved by artificial intelligence technique to find efficient route. The second part is inference engine which processes data by using rule based knowledge.

Definition 2.4[20]:

Let E be a universe. A neutrosophic sets A in E is characterized by a truth-membership function T_A, a indeterminacy-membership function I_A and a falsity-membership function F_A. $T_A(x)$; $I_A(x)$ and $F_A(x)$ are real standard elements of [0,1]. It can be written as

$$A = \{< x, (T_A(x), I_A(x), F_A(x)) >: x \in E, T_A(x), I_A(x), F_A(x) \in]^-0, 1^+[\}$$

There is no restriction on the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$, so $0^- \leq T_A(x) + I_A(x) + F_A(x) \leq 3^+$.

Definition 2.5[20]:

Let E be a universe. A single valued neutrosophic sets A, which can be used in real scientific and engineering applications, in E is characterized by a truth-membership function T_A , a indeterminacy-membership function I_A and a falsity-membership function F_A. $T_A(x)$; $I_A(x)$ and $F_A(x)$ are real standard elements of [0,1]. It can be written as

$$A = \{< x, (T_A(x), I_A(x), F_A(x)) >: x \in E, T_A(x), I_A(x), F_A(x) \in [^-0, 1^+]\}$$

There is no restriction on the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$, so $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

Definition 2.6[20]:

Let $\tilde{a} =< (a_1, b_1, c_1); \widetilde{w_a}, \widetilde{u_a}, \widetilde{y_a} >$, and $\tilde{b} =< (a_2, b_2, c_2); \widetilde{w_b}, \widetilde{u_b}, \widetilde{y_b} >$ be two single valued triangular neutrosophic numbers and $\gamma \neq 0$ be any real number. Then,

1. $\tilde{a} + \tilde{b} =< (a_1 + a_2, b_1 + b_2, c_1 + c_2);$ $\widetilde{w_a}$â^§$\widetilde{w_b}$, $\widetilde{u_a}$â^¨$\widetilde{u_b}$, $\widetilde{y_a}$â^¨$\widetilde{y_b}$ >
2. $\tilde{a} - \tilde{b} =< (a_1 - c_2, b_1 - b_2, c_1 - a_2);$ $\widetilde{w_a}$â^§$\widetilde{w_b}$, $\widetilde{u_a}$â^¨$\widetilde{u_b}$, $\widetilde{y_a}$â^¨$\widetilde{y_b}$ >

Definition 2.7[20]:

Let $\widetilde{A_1} =< T_1,\ I_1,\ F_1 >$ be a single valued neutrosophic number. Then, the score function $s(\widetilde{A_1})$, accuracy function$a(\widetilde{A_1})$, and certainty function $c(\widetilde{A_1})$ of an single valued neutrosophic numbers are defind

1. $s(\widetilde{A_1}) = (T_1 + 1 - I_1 + 1 - F_1)/3$
2. $a(\widetilde{A_1}) = T_1 - F_1$
3. $c(\widetilde{A_1}) = T_1$

3. Proposed Network Protocol

The proposed system is neutrosophic intelligent energy efficient routing for WANET based on multicriteria decision making, which divides the entire system into three stages. These three stages are assessed by intelligent system through multicriteria rule based system. The above three stages are as follows:

(i). Neutrosophic multicriteria intelligent

(ii). Construction of neutrosophic intelligent route (iii). Selection of neutrosophic energy efficient route

Stage (i) describes the neutrosophic membership functions of hop counts, data packets, distance and energy for the proposed system briefly.

In stage (ii), rating of each and every neutrosophic route is established with the help of skilled system using rating formula.

Stage (iii) handles the selection process of neutrosophic energy efficient route using rule matrix after rating of neutrosophic routes.

3.1. Stage(i): Neutrosophic multicriteria intelligence

In this stage, neutrosophic membership functions of hop count, data packets, distance and energy are given as the input variables and the rating scale of neutrosophic routes as output variable. These input and output variables are categorized as the linguistic variables(low, medium and high). In this network model, the input variables hop count, data packet, distance and energy are considered as 30 (Nos.), 600(Mbps), 260(Meters) and 80(Joules).The membership functions of input variables are given in Table1, Table 2, Table 3, and Table 4 and output variable inTable 5.

Table:1 Neutrosophic membership function of hop count(Nos.)

Linguistic Values	Notation	Neutrosophic Range	Neutro. Base value
Low	H_L^N	$[H_{L1}^N, H_{L2}^N]$	(0,0,15)(0,0,30)(0,0,45)
Medium	H_M^N	$[H_{M1}^N, H_{M2}^N]$	(0,15,30)(0,15,45)(0,15,60)
High	H_H^N	$[H_{H1}^N, H_{H2}^N]$	(15,30,30)(10,30,45)(9,30,60)

Table:2 Neutrosophic membership function of Data packet(Mbps)

Linguistic Values	Notation	Neutrosophic Range	Neutro. Base value
Low	DP_L^N	$[DP_{L1}^N, DP_{L2}^N]$	(0,0,300)(0,0,600)(0,0,900)
Medium	DP_L^N	$[DP_{M1}^N, DP_{M2}^N]$	(0,300,600)(150,300,750)(270,300,900)
High	DP_L^N	$[DP_{H1}^N, DP_{H2}^N]$	(300,600,600)(500,600,800)(700,600,850)

Table:3 Neutrosophic membership function of Distance(Meters)

Linguistic Values	Notation	Neutrosophic Range	Neutro. Base value
Low	D_L^N	$[D_{L1}^N, D_{L2}^N]$	(0,0,100)(0,0,200)(0,0,250)
Medium	D_L^N	$[D_{M1}^N, D_{M2}^N]$	(40,100,220)(70,100,250)(90,100,270)
High	D_L^N	$[D_{H1}^N, D_{H2}^N]$	(140,260,260)(170,260,290)(190,260,300)

Table4: Neutrosophic membership function of Energy(Joules)

Linguistic Values	Notation	Neutrosophic Range	Neutro. Base value
Low	E_L^N	$[E_{L1}^N, E_{L2}^N]$	(0,0,32)(0,0,64)(0,0,96)
Medium	E_M^N	$[E_{M1}^N, E_{M2}^N]$	(8,40,72)(16,40,82)(24,40,92)
High	E_H^N	$[E_{H1}^N, E_{H2}^N]$	(48,80,80)(68,80,90)(78,80,100)

The rating scale of different neutrosophic routes are classified in the following table.

Table5: Neutrosophic membership function of Energy(Joules)

Linguistic Variable	Very Bad	Bad	Satisfactory	Medium	Less Good	Good	Very Good	Excellent	Very Excellent
Notation	$R^N{}_{VB}$	$R^N{}_B$	$R^N{}_S$	$R^N{}_M$	$R^N{}_{LG}$	$R^N{}_G$	$R^N{}_{VG}$	$R^N{}_E$	$R^N{}_{VE}$

3.2. Stage(ii): Construction of neutrosophic intelligent

In stage(ii), the rules and formulas for construction of neutrosophic intelligent routes are established. Usually, in ad-hoc networks while sending and receiving data packets energy consumption is occurred.Also the total network system is affected and lifetime of network is reduced at the time of power failure. The amount of input variables should be reduced in order to give the energy efficient routes for improving lifetime and performance of network system in such situations. Since energy plays an important role in network performance, the other input variables(hop count, data packet, distance) are combined with energy and the rules are framed for construction of intelligent route as follows:

Table 6: Rules for construction of neutrosophic route)

Rule	Energy and Hop Count level	Rating of Neutrosophic Route
R1	Low energy and high hop count	Very Bad
R2	Low energy and medium hop count	Bad
R3	Low energy and low hop count	Satisfactory
R4	Medium energy and high hop count	Medium
R5	Medium energy and medium hop count	Less Good
R6	Medium energy and low hop count	Good
R7	High energy and high hop count	Very Good
R8	High energy and medium hop count	Excellent
R9	High energy and low hop count	Very Excellent
	Energy and Data Packet level	
R10	Low energy and high data packet	Very Bad
R11	R11 Low energy and medium data packet	Bad
R12	Low energy and low data packet	Satisfactory
R13	Medium energy and high data packet	Medium
R14	R14 Medium energy and medium data packet	Less Good
R15	Medium energy and low data packet	Good
R16	High energy and high data packet	Very Good
R17	High energy and medium data packet	Excellent
R18	High energy and low data packet	Very Excellent
	Energy and Distance level	
R19	Low energy and high distance	Very Bad
R20	Low energy and medium distance	Bad
R21	Low energy and low distance	Satisfactory
R22	Medium energy and high distance	Medium
R23	Medium energy and medium distance	Less Good
R24	Medium energy and low distance	Good
R25	High energy and high distance	Very Good
R26	High energy and medium distance	Excellent
R27	High energy and low distance	Very Excellent

In Table 7, different types of neutrosophic states are established by using the formula
NR_{pq} = mean value of neutrosophic energy / mean value of other parameters

Rating of neutrosophic routes(Table.8) is calculated by using neutrosophic states in Table 7 and by using Table.8, the ascending order of rating of neutrosophic routes and linguistic nature of different neutrosophic rating of routes are calculated and given in Table.9 and Table.10.

Table 7: Different types of neutrosophic states

Neutro. Energy and Hop count		**Neutro. Energy and Data packet**		**Neutro. Energy and Distance**	
Neutro.State	Neutro.Value	Neutro. State	Neutro.Value	Neutro. State	Neutro.Value
NS11	2.133	NS21	0.10665	NS31	0.349
NS12	1.0665	NS22	0.0537	NS32	0.1548
NS13	0.7412	NS23	0.03458	NS33	0.09013
NS14	5.4	NS24	0.27	NS34	0.8836
NS15	2.7	NS25	0.1361	NS35	0.39192
NS16	1.8765	NS26	0.0875	NS36	0.2281
NS17	7.822	NS27	0.3911	NS37	1.2799
NS18	3.911	NS28	0.19719	NS38	0.5677
NS19	2.7182	NS29	0.1268	NS39	0.3305

Table 8: Different types of neutrosophic rating of routes

Neutro. Energy and Hop count		**Neutro. Energy and Data packet**		**Neutro. Energy and Distance**	
Neutro.Route	Neutro. Rating	Neutro.Route	Neutro. Rating	Neutro. Route	Neutro.Rating
NS11	3.911	NS21	0.19555	NS31	0.63995
NS12	1.955	NS22	0.097775	NS32	0.25598
NS13	1.3036	NS23	0.06518	NS33	0.159987
NS14	0.9777	NS24	0.04888	NS34	1.59987
NS15	0.48885	NS25	0.02444	NS35	0.6399
NS16	0.3259	NS26	0.01629	NS36	3.99968
NS17	0.6518	NS27	0.03258	NS37	2.5598
NS18	0.16295	NS28	0.00814	NS38	1.02392
NS19	0.1086	NS29	0.00543	NS39	0.63995

Table 9: Ascending order of rating of neutrosophic routes

Based on hop count rating
NR11 > NR12 > NR13 > NR14 > NR17 > NR15 > NR16 > NR18 > NR19
Based on data packets rating
NR21 > NR22 > NR23 > NR24 > NR27 > NR25 > NR26 > NR28 > NR29
Based on distance rating
NR36 > NR37 > NR34 > NR38 > NR35 > NR31;NR39 > NR32 > NR33

Table 10: Linguistic nature of di_erent neutrosophic rating of routes

S.No.	Linguistic nature	Neutrosophic Rating
1	NRV E	NR11, NR21, NR36
2	NRE	NR12, NR22, NR37
3	NRV G	NR13, NR23, NR34
4	NRG	NR14, NR24, NR38
5	NRLG	NR17, NR27, NR35
6	NRM	NR15, NR25, NR31, NR39
7	NRS	NR16, NR26, NR32
8	NRB	NR18, NR28, NR33
9	NRV B	NR19, NR29

3.3. Stage(iii): Selection of neutrosophic energy efficient route

Neutrosophic energy efficient route is evaluated using neutrosophic rule matrix in Table.11, Table.12 and Table.13. These three matirices are framed by combining energy with other parameters hop count, data packet and distance. Each route selected by these matrices have a particular value in the proposed ad-hoc network. After evaluated the routes using rule matrices, it is analysed that if the source node is in the positions NR19 or NR29 having lowest neutrosophic energy with high neutrosophic hop count or high neutrosophic data packets or long distance from destination, then it will receice the lowest neutrosophic rating value NR_{VB} and if the source node is in the positions NR11, NR21 or NR36 having high neutrosophic energy with low neutrosophic hop count or low neutrosophic data packets or shortest distance from the destination, then it will receive highest neutrosophic rating value NR_{VE}.

Table 11: Neutrosophic rule matrix based on energy and hop count

Neutro. energy / Hop count	**H_L^N**	**H_L^N**	**H_L^N**
E_L^N	NR_S	NR_B	NR_{VB}
E_M^N	NR_G	NR_{LG}	NR_M
E_H^N	NR_{VE}	NR_E	NR_{VG}

Table 12: Neutrosophic rule matrix based on data packet and energy

Neutro. energy / Hop count	**DP_L^N**	**DP_L^N**	**Dp_L^N**
E_L^N	NR_S	NR_B	NR_{VB}
E_M^N	NR_G	NR_{LG}	NR_M
E_H^N	NR_{VE}	NR_E	NR_{VG}

Table 13: Neutrosophic rule matrix based on distance and energy

Neutro. energy / Hop count	**D_L^N**	**D_L^N**	**D_L^N**
E_L^N	NR_S	NR_B	NR_{VB}
E_M^N	NR_G	NR_{LG}	NR_M
E_H^N	NR_{VE}	NR_E	NR_{VG}

Finally, by analysing the the different types of neurtrosophic energy efficient rating of routes as given in figure.1, the process of wanet is improved in this stage by identifying the neutrosophic intelligent energy efficient route.

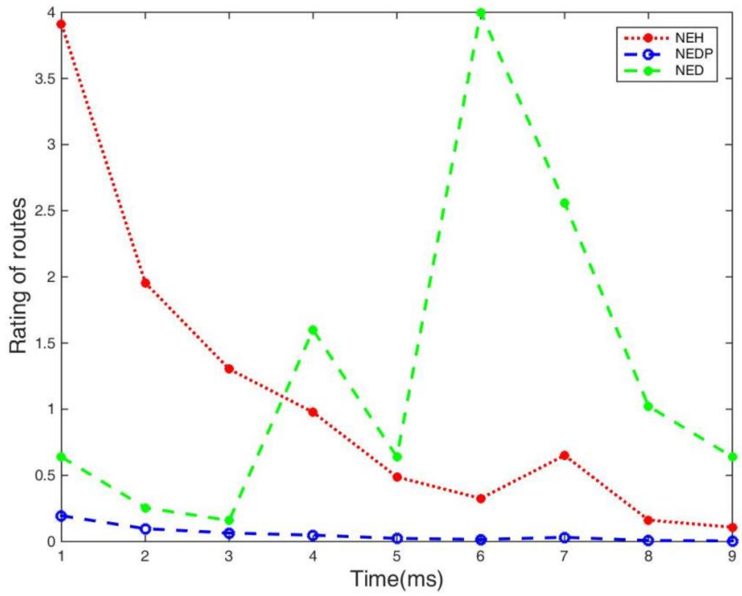

Figure 1: Analysis of neutrosophic intelligent energy efficient rating of routes.

4. Conclusions

In this paper, a new network design is developed to improve the service of wireless ad-hoc network by equipping the routes energy efficient using neutrosophic technique. Multi-criteria decision making method under neutrosophic environment is used for making the routes of the network efficiently here. From the mathematical analysis of the proposed network design, we conclude that the neutrosophic route is very efficient when source node is in the position NR11, NR21 or NR36, since the node with low energy, high hopcout, high transmitted data packets and long distance from the destination causes breakage of route and data packet retransmission. This neutrosophic energy efficient routing for wanet under multi-criteria decision making is better than other existing methods in uncertain environment. Various protocols for the efficiency of ad-hoc network system using neutrosophic sets will be established in future.

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