Blockchain Single and Interval Valued Neutrosophic Graphs

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Abstract. Blockchain Technology (BCT) is a growing and reliable technology in various fields such as developing business deals, economic environments, social and politics as well. Without having a trusted central party this technology, gives the guarantee for safe and reliable transactions using Bitcoin or Ethereum. In this paper BCT has been considered using Bitcoins. Also Blockchain Single and Interval Valued Neutrosophic Graphs have been proposed and applied in transaction of Bitcoins. Also degree, total degree, minimum and maximum degree have been found for the proposed graphs. Further, comparative analysis is done with advantages and limitations of different types of Blockchain graphs.

Keywords: Blockchian Technology, Bitcoins, Fuzzy Graph, Neutrosophic Graphs, Properties

1. Introduction

A completely peer-to-peer form of electronic cash will permit payments through online and direct transaction can be done from one participant to another without facing any financial organization. If a central party wants to avoid double-spending then the main gain will be lost even though digital signatures contribute part of the solution. This issue was the reason of bargain a solution to this problem based on peer-to-peer network. For direct transaction of two willing parties without having a trusted third party, an electronic system using cryptographic proof (signaling code) can be used. Fuzzy logic is introduced by Zadeh to deal uncertainty of the problem. Fuzzy graphs are playing an important role in network where impreciseness exists on the vertices and egdes. Yeh and Banh also proposed the fuzzy graph independently and examined various connectedness theories [1-4].

The universal problems namely sustainable development or transformation of assets can be dealt effectively by Block chain technology than the existing financial systems. The financial sector acquires in various operative costs for the smooth and effective functioning of the entire system. These costs consist of time and money needed for investment in framework, electricity cost spent for operation and from Automated Teller Machines, consumption of water and gas by the employees and wastage production.

Also there is no possibility of creating fiat currency without costs. In order to give assurance in a regular basis in the quality standards for the bank notes in circulation, the used ones are shredded. To find an overview of the overall cost of an existing financial system, the cost for the production of coins and noted will be included. Whereas in BCT, one needs only to connect to the network and do not obtain the electricity cost for any source. Also the production of the crypto currency (a digitalized currency, where encoding method is applied to control the production of currency and funds transference verification) [5-7].

Platforms of Central banking, improvement of business processing, automotive ownership, sharing of health information, deals and voting can be potentially replaced by Block chain Technology. BCT plays an important role, in political components namely governmental interference, control leadership and taxation. Also BCT is very useful in Exchange rates of currency market growth and monetary as an economic component. BCT is very helpful in social components namely environmental situation, culture, behavior of the customer and demand. In the same way, BCT has a potential action in modern technologies and tendency [8-9].

BCT permits an emerging set of participants to continue with a secure and alter–proof ledger for all the activities without having a third trusted party. Here, transactions are not actually documented but instead, every participant keeps a provincial copy of the ledger which is a related listing of blocks and they comprise agreed transactions [19]. Nagoorgani and Radha introduced the concept of degree of fuzzy vertex. A crypto currency is nothing a Bitcoin which is a universal payment system and also the initial decentralized digital currency since the system works without a single administrator or central bank. Bitcoins made as a payment for a process called mining and can be exchanged for different currencies. Nakamoto and Satoshi were introduced the concept of Blockchain and applied as an important component of Bitcoin where it act as a public ledger for all the transactions. To solve double-spending problem, Blockchain for the Bitcoin has been an appropriate choice without the help of trusted third part as a central server. Block chain transactions will be done on the interchangeable ledger data saved at every node [42].

A Blockchain network can be seen as a reliable computer whose private states are auditable by anyone. A ledger of transactions may call as a Blockchain. Generally a physical ledger will be maintained by a centralized party whereas in Blockchain is a distributed ledger which locates on the device of every participants. Bitcoins are believable and best used [40, 45]. A Fuzzy Set (FS) can be described mathematically by assigning a value, a grade of membership to every desirable person in the universe of discourse. This grade of membership associates a degree for the participant is either identical or appropriate to the approach performed by FS. A fuzzy subset of FS, X is a function from membership to non-membership and is defined by $\eta : X \to [0,1]$ continuous rather than unexpected. Fuzzy relationships are popular and essential in the fields of computer chains, decision making, neural network, expert systems etc. Direct relationship and also indirect relationship also will be considered in graph theory.

Model of relation is nothing but a graph which is a comfortable way of describing information about the connection between two objects. In graph, points and relations are defined by vertices and edges respectively. While impreciseness exists in the statement of the phenomenon or in the communication or both, fuzzy graph model can be designed for getting an optimized output. Maximizing the Utility of the application is always done by the researchers during the constructing of a model with a key characteristics reliability, complexity and impreciseness. Among these, impreciseness is a considerable one in maximizing the utility of the technique. This situation can be described by fuzzy sets, introduced by Lotfi. A. Zadeh [24, 25].

Zadeh formulated, grade of membership in order to handle with impreciseness. Atannasov introduced intuitionistic fuzzy set by including the grade of non-membership in FS as a separate element. Samarandache introduced Neutrosophic set (NS) by finding the membership degree of indeterminacy, it can be viewed from the logical point of view as a self-ruling component to handle with uncertain, undetermined and unpredictable data which are exist in the real world problem. The NSs are defined by the membership functions of truth, indeterminacy and falsity whose values take from the real standard interval. Wang et al. proposed the theoretical concept of single-valued Neutrosophic sets (SVNS) and Interval valued Neutrosophic Sets (IVNSs) as well [26-34].

If uncertainty exists in vertices or edges set or both then the structure turns into a fuzzy graph. It can be established by taking the set of vertices and edges as FS, in the same way one can model any other types of fuzzy graphs [21-15, 32].Graph theory defines the relationship between various individuals and has got many number of applications in different fields namely database theory, modern discipline and technology, neural networks, data scooping cluster analysis, knowledge systems image capturing and control theory. Handling Indeterminacy on the object or edge or both cannot be handled fuzzy graphs and hence Neutrosophic graphs have been introduced. [44, 47-48].

A new perspective for neutrosophic theory and its applications also proposed [49]. There are many methods have been proposed under single valued neutrosophic, interval valued neutrosophic and neutrosophic environments by colloborating with other methods such as TOPSIS, DEMATEL, VIKOR. Also all these hybrid and extension methods applied in the process of decision making. Further, NS-cross entropy, hyperbolic sine similarity measure, hybrid binary algorithm similarity measure method and single-valued co-neutrosophic graphs play an important role in decision making. In fuzzy graph all the edges are represented by fuzzy numbers and that may be interval valued fuzzy number also. Whereas in neutrososphic graph the edges are represented by single valued neutrosophic numbers [50-62].

The remaining part of the paper is organized as follows. In section 2, review of literature is presented. In section 3, basic concepts related to the presented work is given. In section 4, Blockchain single valued and interval valued neutroosphic graphs are proposed and applied for Bitcoin transaction. Also degree, total degree, minimum and maximum degree have been found. In section 5, qualitative analysis has been done with the limitations and advantages of various types of graphs. In section 6, conclusion of the paper is given with the future work.

2. Review of Literature

[Yeh and Bang 1] proposed fuzzy relations, fuzzy graphs and applied them in cluster analysis. [Satoshi 2] presented a solution for the problem of double-sending using a peer-to-peer network. [Leroy 3] portrayed the evolution and proof of linguistic care of an accumulator back-end. [Dey et al.4] have done a vertex colouring of a fuzzy graph. [Dey et al. 5] applied the concept of fuzzy graph in light control in traffic control management. [Ober et al. 6] proposed a model and obscurity of the Bitcoin transaction graph. [Decker and Wattenhofer 7] examined about knowledge reproduction in the network of Bitcoin. [Fleder et al. 8] linked bit coin public keys to real people and commented about the public transaction graph and hence done a graph analysis scheme to find and compiled activity of known as well as unknown users.

[Stanfill and Wholey 9] proposed a transactional graph on the basis of computation with error management. [Ye 10] proposed aggregation operators under simplified neutrosophic environment and applied them in a decision making problem. [Biswas et al. 11] introduced a new methodology for dealing unknown weight information and applied in a decision making problem. [Biswas et al. 12] proposed grey relational analysis based on entropy under single valued neutrosophic setting and applied in a decision making process with multi attribute.

[Mondal and Pramanik 13] introduced a model for clay-brick selection based on grey relational analysis for neutrosophic decision making. [Mondal and Pramanik 14] proposed neutrosophic tangent similarity measure and applied in multiple attribute decision making. [Biswas et al. 15] introduced cosine similarity measure with trapezoidal fuzzy neutrosophic numbers and applied in a decision making problem. [Broumi et al. 16] introduced an extended TOPSIS methodology using interval neutrosophic uncertain linguistic variables. [Greaves and Au 17] investigated the prognostic power of Blockchain network using lineaments on the future price of Bitcoin. [Pilkington 18] clarified the main ethics behind block chain technique and few of its application of cutting edge.

[Bonneau et al. 19] Analyzed invisibility problems in Bitcoin and contribute an evaluation plan for private- enlarging proposals and contributed a new intuition on language disintermediation protocols. [Smarandache and Pramanik 20] introduced a new direction for neutrosophic theory and applications. [Biswas et al. 21] proposed TOPSIS methodology under single-valued neutrosophic setting for multi-attribute group decision making. [Biswas et al. 22] proposed aggregation operators for triangular fuzzy neutrosophic set information and used for a decision making problem. [Biswas et al. 23] introduced a ranking method based on value and ambiguity index using single-valued trapezoidal neutrosophic numbers and its application to decision making problem. [Eyal et al. 24] designed a block chain protocol called Bitcoin –next generation. [Broumi et al. 25] introduced operational laws on interval valued neutrosophic graphs.

[Broumi et al. 26] proposed the formulas to find degree, size and order of a single valued neutrosophic graphs. [Pramanik et al. 27] proposed hybrid similarity measures under neutrosophic environment and applied them in decision making problem. [Dalapati et al. 28] introduced IN-cross entropy for interval neutrosophic set environment and applied in multi attribute group decision making process. [Broumi et al. 29] proposed uniform single valued neutrosophic graphs. [Cocco et al. 30] paid attention at the threats and opportunities of carrying out Blockchain mechanism across banking. [Jeoseph et al. 31] reviewed the approval and future use of block chain technology.

[Chan and Olmsted 32] proposed a design for prevailing transactions from Ethereum into a graph database namely leveraging graph computer. [Illgner 33] proposed a blockchian to fix all Blockchains. [Swan and Filippi 34] explained about the philosophy of Bockchain technology. [Banuelos et al. 35] proposed an advanced method to implement business developments on top of commodity Blockchain technology. [Dinh et al. 36] surveyed the case of the art targeting on private Blockchain where the parties are authenticated. [Desai 37] analysed industry application and have legal perspectives for Blockchain technology. [Jain et al. 38] analyzed asymmetrical associations using fuzzy graph and finding hidden connections in Facebook. [Raikwar et al. 39] proposed a framework of Blockchain for insurance processes.

[Ramkumar 40] proposed Blockchain integrity framework. [Hill 41] presented a review on Blockchain [Arockiaraj and Charumathi 42] introduced the Blockchain fuzzy graph and its concepts and properties. [Halaburda 43] answered for the question, Blockchain transformation without the Blockchain. [Gupta and Sadoghi 44] explained about Blockchain process in detailed manner. [Ramkumar 45] accomplished large scale measure in Blockchian. [Asraf et al. 46] proposed Dombi fuzzy graphs. [Marapureddy 47] introduced fuzzy graph for the semi group. [Quek et al. 48] introduced a few of the results for complex Neutrosophic sets on graph theory. [Smarandache and Pramanik 49] introduced a new perspective to neutrosophic theory and its applications.

[Basset et al. 50] proposed an extended neutrosophic AHP-SWOT analysis for critical planning and decision making. [Basset et al. 51] proposed association rule mining algorithm to analyze big data. [Basset et al. 52] introduced Group ANP-TOPSIS framework under hybrid neutrosophic setting for supplier selection problem. [Basset et al. 53] presented a hybrid approach of neutrosophic sets and DEMATEL method to enhance the criteria for supplier selection. The same authors presented a series of article[63-69]. ([Pramanik et al. 54] proposed NS-cross entropy under single valued neutrosophic environment and applied in a MAGDM problem. [Biswas et al. 55] proposed neutrosophic TOPSIS method and solved group decision making problem.

[Pramanik and Mallick 56] proposed VIKOR method using trapezoidal neutrosophic numbers and solved MAGDM problem using proposed method. [Biswas et al. 57] solved MADM problem by introducing distance measure using interval trapezoidal neutrosophic numbers. [Biswas et al. 58] introduced TOPSIS strategy for solving MADM problem with trapezoidal numbers. [Biswas et al. 59] solved MAGDM problem using expected value of neutrosophic trapezoidal numbers. [Mondal et al. 60] introduced hyperbolic sine similarity measure based MADM strategy under single valued neutrosophic environment. [Mondal et al. 61] proposed hybrid binary algorithm similarity measure under single valued neutrosophic set assessments for MAGDM problem. [Dhavaseelan et al. 62] proposed single-valued co-neutrosophic graphs.

The above literature survey motivated to propose Blockchain single and interval valued Neutrosophic Graphs and applied them in Blockchain technology using Bitcoins.

3. Basic Concepts

Some basic concepts needed for the proposed concepts and their application, are listed below.

3.1 Bitcoins [40]

Bitcoin is the digital currency and worldwide payment system and are believable and best used when,

- There are a series of transaction
- Need to be recorded
- Need to be verified with respect to purity of the information and the order of the events.

3.2 Blockchain [42]

A Blockchain is a network and can be seen as a reliable computer whose private states are auditable by anyone. It can also be defined as follows.

- Cryptographic approach for modeling an unalterable append-only public ledger
- It includes a methodology for obtaining an open general agreement on each entry
- Ledger entries are mappings of the states of processes by the Blockchain network.

Uses of Blockchain

- A uniform approach to execute a variety of application processes
- Reliable and efficient Low upward approaches for stakeholders/users namely states with query application and audit correctness of changes of states.

3.3 Graph [46]

A mathematical system $G=(V,E)$ is called a graph, where a vertex set is $V=V(G)$ and an edge set is $E=E(G)$. In this paper, undirected graph has been considered and hence every edge is considered as an unordered pair of different vertices.

3.4 Fuzzy Graph [47]

Consider a non-empty finite set V , λ be a fuzzy subsets on V and δ be a fuzzy subsets on $\mathrm{V}\times\mathrm{V}$ .A fuzzy graph is a pair $\mathrm{G}=(\lambda,\delta)$ over the set V if $\delta(a,b)\le\min\{\lambda(a),\lambda(b)\}$ for all $(a,b)\in\mathrm{V}\times\mathrm{V}$ where λ is a fuzzy vertex and δ is a fuzzy edge. Where:

1. A fuzzy subset is a mapping $\lambda:\mathrm{V}\to[0,1]$ of V .
2. A fuzzy relation is a mapping $\delta:\mathrm{V}\times\mathrm{V}\to[0,1]$ on λ of V if $\delta(a,b)\le\min\{\lambda(a),\lambda(b)\}$
3. If $\delta(a,b)=\min\{\lambda(a),\lambda(b)\}$ then G is a strong fuzzy graph.

3.5 Blockchain Fuzzy Graph (BCFG) [42]

The pair $\mathrm{G}=(\lambda,\delta)$ is a BCFG, where λ is a fuzzy vertex set and δ is symmetric on λ such that $\delta(a,b)\le\min\{\lambda(a),\lambda(b)\}$, $\forall\ a,b\in\mathrm{V}$ with the following criterion.

1. If $i\ne j$ then $\sum\left[\delta(a_i,b_j)\le\min\left(\lambda(a_i),\lambda(b_j)\right)\right]=1$
2. If $i\ne j$ then $\sum\left[\delta(a_i,b_j)\le\max\left(\lambda(a_i),\lambda(b_j)\right)\right]=1$
3. If $i=j$ then $\sum\left[\delta(a_i,b_j)\le\min\left(\lambda(a_i),\lambda(b_j)\right)\right]=0$

3.6 Single Valued Neutrosophic Graph (SVNG) [26]

A pair $G=(R,S)$ is SVNG with elemental set V . Where:

1. Grade of truth, indeterminacy and falsity memberships of $a_i \in \mathbf{V}$ are defined by $T_R:V\to[0,1]$, $I_R:V\to[0,1]$ and $F_R:V\to[0,1]$ respectively and $0\le T_R(a_i)+I_R(a_i)+F_R(a_i)\le 3, \forall a_i\in\mathbf{V}, i=1,2,3,...,n$
2. The above three memberships of the edge $(a_i,b_j)\in\mathbf{E}$ are denoted by $T_S:E\subseteq V\times V\to[0,1]$, $I_S:E\subseteq V\times V\to[0,1]$ and $F_S:E\subseteq V\times V\to[0,1]$ respectively and are defined by
   - $T_S(\{a_i,b_j\})\le \min[T_R(a_i),T_R(b_j)]$
   - $I_S(\{a_i,b_j\})\ge \max[I_R(a_i),I_R(b_j)]$
   - $F_S(\{a_i,b_j\})\ge \max[F_R(a_i),F_R(b_j)]$

where $0\le T_S(\{a_i,b_j\})+I_S(\{a_i,b_j\})+F_S(\{a_i,b_j\})\le 3, \forall\{a_i,b_j\}\in\mathbf{E}(i,j=1,2,...,n)$.

Also Rand S are the single valued Neutrosophic vertex and edge set of V and **E** respectively. S is symmetric on R.

3.7 Interval Valued Neutrosophic Graph (IVNG) [25]

A pair $G=(R,S)$ is IVNG, where $R=\langle[T_R^L,T_R^U],[I_R^L,I_R^U],[F_R^L,F_R^U]\rangle$, is an IVN set on V and $S=\langle[T_S^L,T_S^U],[I_S^L,I_S^U],[F_S^L,F_S^U]\rangle$ is an IVN edge set on **E** satisfying the following conditions:

1. Here the lower and upper memberships functions of $a_i\in\mathbf{V}$ are defined by $T_R^L:V\to[0,1]$, $T_R^U:V\to[0,1]$, $I_R^L:V\to[0,1]$, $I_R^U:V\to[0,1]$ and $F_R^L:V\to[0,1]$, $F_R^U:V\to[0,1]$ respectively and $0\le T_R(a_i)+I_P(a_i)+F_P(a_i)\le 3, \forall a_i\in\mathbf{V}, i=1,2,3,...,n$
2. And the same for edge $(a_i,b_j)\in\mathbf{E}$ are denoted by $T_S^L:V\times V\to[0,1]$, $T_S^U:V\times V\to[0,1]$ $I_S^L:V\times V\to[0,1]$, $I_S^U:V\times V\to[0,1]$ and $F_S^L:V\times V\to[0,1]$, $F_S^U:V\times V\to[0,1]$ respectively and are defined by
   - $T_S^L(\{a_i,b_j\})\le \min[T_R^L(a_i),T_R^L(b_j)]$
   - $T_S^U(\{a_i,b_j\})\le \min[T_R^U(a_i),T_R^U(b_j)]$
   - $I_S^L(\{a_i,b_j\})\ge \max[I_R^L(a_i),I_R^L(b_j)]$
   - $I_S^U(\{a_i,b_j\})\ge \max[I_R^U(a_i),I_R^U(b_j)]$
   - $F_S^L(\{a_i,b_j\})\ge \max[F_R^L(a_i),F_R^L(b_j)]$
   - $F_S^U(\{a_i,b_j\})\ge \max[F_R^U(a_i),F_R^U(b_j)]$

where $0\le T_S(\{a_i,b_j\})+I_S(\{a_i,b_j\})+F_S(\{a_i,b_j\})\le 3, \forall\{a_i,b_j\}\in\mathbf{E}(i,j=1,2,...,n)$.

Also R and S are the interval valued Neutrosophic vertex and edge set of V and **E** respectively. S is symmetric on R.

4. Proposed Concepts

In this section, Blockchian single valued neutrosophic graph is proposed and applied in Blockchain technology with Bitcoin transaction.

4.1 Blockchain Single Valued Neutrosophic Graph (BCSVNG)

A pair $G=(R,S)$ is BCSVNG with elemental set V . Where:

1. $T_R:V\to[0,1]$, $I_R:V\to[0,1]$ and $F_R:V\to[0,1]$ and $0\le T_R(x_i)+I_R(x_i)+F_R(x_i)\le 3, \forall x_i\in\mathbf{V}, i=1,2,3,...,n$
2. $T_S:E\subseteq V\times V\to[0,1]$, $I_S:E\subseteq V\times V\to[0,1]$ and $F_S:E\subseteq V\times V\to[0,1]$ are defined by

Case (i): If $i \neq j$ then

$$\sum\left[T_S\left(x_i, y_j\right) \leq \min\left[T_R(x_i), T_R\left(y_j\right)\right]\right] = 1$$

$$\sum\left[I_S\left(x_i, y_j\right) \geq \max\left[I_R(x_i), I_R\left(y_j\right)\right]\right] = 1$$

$$\sum\left[F_S\left(x_i, y_j\right) \geq \max\left[F_R(x_i), F_R\left(y_j\right)\right]\right] = 1$$

Case (ii): If $i = j$ then the above values are 0.

Where, $0 \leq T_S\left(\left\{x_i, y_j\right\}\right) + I_S\left(\left\{x_i, y_j\right\}\right) + F_S\left(\left\{x_i, y_j\right\}\right) \leq 3, \forall \left\{x_i, y_j\right\} \in \mathbf{E}(i, j = 1, 2, ..., n)$

Also R is a single valued Neutrosophic vertex of V and S is a single valued Neutrosophic edge set of $\mathbf{E}$. S is a symmetric single valued Neutrosophic relation on R.

4.1.1 Blockchain Single Valued Neutrosophic Graph in Bitcoin Transaction

Let us consider there are 4 persons in the Blockchain and everyone is doing a transaction using Bitcoin and they are saving 40% and investing the remaining 60% in Bitcoin.

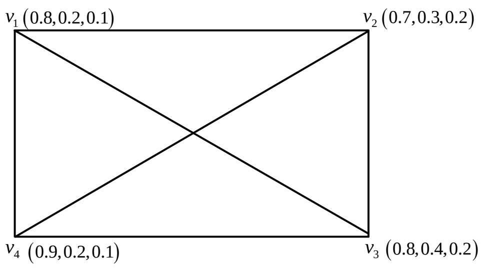

Figure 1: BCSVNG

Party 1: investing 20 lakhs and doing 3 transactions
Party 2: investing 15 lakhs and doing 3 transactions
Party 3: investing 10 lakhs and doing 3 transactions
Party 4: investing 5.5 lakhs and doing 3 transactions
For example, assume that the party-1 (v_1) has the total amount of 20 lakhs, from this he is saving 40% and invest the remaining 60% as Bitcoins for his crypto currencies.

The following are the transactions of Party-1:

Transaction 1: Party-1 to Party-2 : (v_1 to v_2)

$(0.7, 0.3, 0.2) \times 12,00,000$

$= \left\langle \left(1-(1-T_R)^k\right), \left(1-(1-T_R)^k\right), \left(1-(1-T_R)^k\right) \right\rangle$ **,** $k > 0$ (any arbitrary number) **[10]**

$= \left\langle \left(1-(1-0.7)^{12,00,000}\right), \left(1-(1-0.3)^{12,00,000}\right), \left(1-(1-0.2)^{12,00,000}\right) \right\rangle$

$= \left\langle \left(1-(1-0.7)^{12,00,000}\right), \left(1-(1-0.3)^{12,00,000}\right), \left(1-(1-0.2)^{12,00,000}\right) \right\rangle$

$= \langle 1, 1, 1 \rangle$

Similarly for other transactions namely

Transaction 2: Party-1 to Party-3 : (v_1 to v_3)
Transaction 3: Party-1 to Party-4 : (v_1 to v_4)

All the possible transaction are listed out in Table 1 with the sum value of each row.

			$(0.8,0.2,0.1)$	$(0.7,0.3,0.2)$	$(0.8,0.4,0.2)$	$(0.9,0.2,0.1)$	sum
			v_1	v_2	v_3	v_4	
	$(0.8,0.2,0.1)$	v_1	0	$(0.4,0.38,0.3)$	$(0.3,0.41,0.4)$	$(0.3,0.21,0.3)$	$(1,1,1)$
	$(0.7,0.3,0.2)$	v_2	$(0.4,0.38,0.3)$	0	$(0.4,0.37,0.3)$	$(0.2,0.25,0.4)$	$(1,1,1)$
	$(0.8,0.4,0.2)$	v_3	$(0.3,0.41,0.4)$	$(0.4,0.37,0.3)$	0	$(0.3,0.54,0.3)$	$(1,1,1)$
	$(0.9,0.2,0.1)$	v_4	$(0.3,0.21,0.3)$	$(0.2,0.25,0.4)$	$(0.3,0.54,0.3)$	0	$(1,1,1)$
sum			$(1,1,1)$	$(1,1,1)$	$(1,1,1)$	$(1,1,1)$	

Table 1: Transaction Table for BCSVNG

Where sum= $\sum(v_i, v_j)$

4.1.2 Properties of Blockchain Single Valued Neutrosophic Graph

In this section, degree, total degree, minimum and maximum degrees are found for Blockchain Single Valued Neutrosophic Graph.

(i). Degree of Single Valued Neutrosophic Graph (SVNG)

$d(v_1)=(d_T(v_1),d_I(v_1),d_F(v_1))$ **[26]**

$=(1,1,1)$

Where, $d_T(v_1)=T_S(v_1,v_2)+T_S(v_1,v_3)+T_S(v_1,v_4)\ =0.4+0.3+0.3=1$

$d_I(v_1)=I_S(v_1,v_2)+I_S(v_1,v_3)+I_S(v_1,v_4)\ =0.38+0.41+0.21=1$

$d_F(v_1)=F_S(v_1,v_2)+F_S(v_1,v_3)+F_S(v_1,v_4)\ =0.3+0.4+0.3=1$

Similarly $d(v_2)=(d_T(v_2),d_I(v_2),d_F(v_2))=(1,1,1)$

$d(v_3)=(d_T(v_3),d_I(v_3),d_F(v_3))=(1,1,1)$

$d(v_4)=(d_T(v_4),d_4(v_4),d_F(v_4))=(1,1,1)$

And $\sum d(v_1)=\left(2\sum_{v_1\neq v_j} T_S(v_1,v_j),2\sum_{v_1\neq v_j} I_S(v_1,v_j),2\sum_{v_1\neq v_j} F_S(v_1,v_j)\right)$

$=(2(1),2(1),2(1))=(2,2,2)$

(ii). Total Degree of SVNG

$td(v_i)=(td_T(v_i),td_I(v_i),td_F(v_i))$ **[26]**

Where $td_T(v_i)=\sum T_S(v_i,v_j)+T_R(v_i)$

$td_T(v_1)=\sum T_S(v_1,v_j)+T_R(v_1)\ =1+0.8=1.8$

$td_I(v_1)=\sum I_S(v_1,v_j)+I_R(v_1)\ =1+0.2=1.2$

$td_F(v_1)=\sum F_S(v_1,v_j)+F_R(v_1)\ =1+0.1=1.1$

Therefore, $td(v_1)=(td_T(v_1),td_I(v_1),td_F(v_1))=(1.8,1.2,1.1)$

Similarly, $td(v_2)=(td_T(v_2),td_I(v_2),td_F(v_2))=(1.7,1.3,1.2)$

$$td(v_3) = (td_T(v_3), td_I(v_3), td_F(v_3)) = (1.8, 1.4, 1.2)$$
$$td(v_4) = (td_T(v_4), td_I(v_4), td_F(v_4)) = (1.9, 1.2, 1.1)$$

(iii). Minimum degree of SVNG

It is $\xi(\mathrm{G}) = (\xi_T(\mathrm{G}), \xi_I(\mathrm{G}), \xi_F(\mathrm{G}))$, where
$\xi_T(\mathrm{G}) = \min\{d_T(v)/v \in \mathrm{V}\}$, $\xi_I(\mathrm{G}) = \min\{d_I(v)/v \in \mathrm{V}\}$ and $\xi_F(\mathrm{G}) = \min\{d_F(v)/v \in \mathrm{V}\}$ **[15]**

For the Fig. 1,
$\xi_T(\mathrm{G}) = \min\{d_T(v)/v \in \mathrm{V}\} = 1$
$\xi_I(\mathrm{G}) = \min\{d_I(v)/v \in \mathrm{V}\} = 1$
$\xi_F(\mathrm{G}) = \min\{d_F(v)/v \in \mathrm{V}\} = 1$

(iv). Maximum degree of SVNG

It is defined by $\eta(\mathrm{G}) = (\eta_T(\mathrm{G}), \eta_I(\mathrm{G}), \eta_F(\mathrm{G}))$, where
$\eta_T(\mathrm{G}) = \max\{d_T(v)/v \in \mathrm{V}\}, \eta_T(\mathrm{G}) = \max\{d_T(v)/v \in \mathrm{V}\}, \eta_F(\mathrm{G}) = \max\{d_F(v)/v \in \mathrm{V}\}$ **[26]**
For the Fig. 1,
$\eta_T(\mathrm{G}) = \max\{d_T(v)/v \in \mathrm{V}\} = 1$
$\eta_I(\mathrm{G}) = \max\{d_I(v)/v \in \mathrm{V}\} = 1$
$\eta_F(\mathrm{G}) = \max\{d_F(v)/v \in \mathrm{V}\} = 1$
For the Fig. 1,
$\eta_T(\mathrm{G}) = \max\{d_T(v)/v \in \mathrm{V}\} = \eta_T(\mathrm{G}) = \max\{d_T(v)/v \in \mathrm{V}\} = \eta_F(\mathrm{G}) = \max\{d_F(v)/v \in \mathrm{V}\} = 1$

4.2 Blockchain Interval Valued Neutrosophic Graph (BCIVNG)

A pair $\mathrm{G} = (R, S)$ is BCIVNG, where $R = \langle [T_R^L, T_R^U], [I_R^L, I_R^U], [F_R^L, F_R^U] \rangle$, is an IVN set on V and $S = \langle [T_S^L, T_S^U], [I_S^L, I_S^U], [F_S^L, F_S^U] \rangle$ is an IVN edge set on $\mathbf{E}$ satisfying conditions 1 and 2 as in the definition of IVNG and with the following criterions.

Case (i): If $i \neq j$ then

$$\sum \left[T_S^L(x_i, y_j) \le \min\left[T_R^L(x_i), T_R^L(y_j) \right] \right] = 0.5$$

$$\sum \left[T_S^U(x_i, y_j) \le \min\left[T_R^U(x_i), T_R^U(y_j) \right] \right] = 0.5$$

$$\sum \left[I_S^L(x_i, y_j) \ge \max\left[I_R^L(x_i), I_R^L(y_j) \right] \right] = 0.5$$

$$\sum \left[I_S^U(x_i, y_j) \ge \max\left[I_R^U(x_i), I_R^U(y_j) \right] \right] = 0.5$$

$$\sum \left[F_S^L(x_i, y_j) \ge \max\left[F_R^L(x_i), F_R^L(y_j) \right] \right] = 0.5$$

$$\sum \left[F_S^U(x_i, y_j) \ge \max\left[F_R^U(x_i), F_R^U(y_j) \right] \right] = 0.5$$

Case (ii): If $i = j$ then the above six values are 0.
Where $0 \le T_S(\{x_i, y_j\}) + I_S(\{x_i, y_j\}) + F_S(\{x_i, y_j\}) \le 3, \forall \{x_i, y_j\} \in \mathbf{E}(i, j = 1, 2, \ldots, n)$

Also R is an interval valued Neutrosophic vertex of V and S is an interval valued Neutrosophic edge set of $\mathbf{E}$. S is a symmetric interval valued Neutrosophic relation on R.

4.2.1 Blockchain Interval Valued Neutrosophic Graph in Bitcoin Transaction

Let us consider there are 3 persons in the Blockchain and everyone is doing a transaction using Bitcoin and they are saving 40% and investing the remaining 60% in Bitcoin.

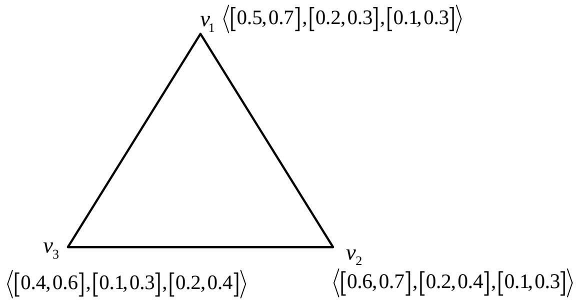

Figure 2: BCIVNG

Party 1: investing 20 lakhs and doing 2 transactions
Party 2: investing 15 lakhs and doing 2 transactions
Party 3: investing 10 lakhs and doing 2 transactions

For example, assume that the party-1 (v_1) has the total amount of 20 lakhs, from this he is saving 40% and invest the remaining 60% as Bitcoins for his crypto currencies.

The following are the transactions of Party-1:

Transaction 1: Party-1 to Party-2: (v_1 to v_2)

$$\langle[0.6,0.7],[0.2,0.4],[0.1,0.3]\rangle \times 12,00,000$$

$$=\left\{\left[1-\left(1-T_R^L\right)^k,1-\left(1-T_R^U\right)^k\right],\left[\left(I_R^L\right)^k,\left(I_R^U\right)^k\right],\left[\left(F_R^L\right)^k,\left(F_R^U\right)^k\right]\right\}$$ **[25]**

$$=\left\{\left[1-(1-0.6)^{12,00,000},1-(1-0.7)^{12,00,000}\right],\left[(0.2)^{12,00,000},(0.4)^{12,00,000}\right],\left[(0.1)^{12,00,000},(0.3)^{12,00,000}\right]\right\}$$

$$=\left\{\left[1-(0.4)^{12,00,000},1-(0.3)^{12,00,000}\right],\left[(0.2)^{12,00,000},(0.4)^{12,00,000}\right],\left[(0.1)^{12,00,000},(0.3)^{12,00,000}\right]\right\}$$

$$=\{[1-0,1-0],[0,0],[0,0]\}$$

$$=\{[1,1],[0,0],[0,0]\}$$

Transaction 2: Party-1 to Party-3: (v_1 to v_3) $=\{[1,1],[0,0],[0,0]\}$

Table 1represent all possible transactions from one vertex to all other verteices. Here edge represents the transaction and the vertex represents the parties.

		$\langle[0.5,0.7],$ $[0.2,0.3],$ $[0.1,0.3]\rangle$	$\langle[0.6,0.7],$ $[0.2,0.4],$ $[0.1,0.3]\rangle$	$\langle[0.4,0.6],$ $[0.1,0.3],$ $[0.2,0.4]\rangle$	$\sum(v_i,v_j)$
		v_1	v_2	v_3	
$\langle[0.5,0.7],$ $[0.2,0.3],$ $[0.1,0.3]\rangle$	v_1	0	$\langle[0.217,0.283],$ $[0.211,0.289],$ $[0.302,0.313]\rangle$	$\langle[0.281,0.282],$ $[0.198,0.199],$ $[0.208,0.209]\rangle$	$(1,1,1)$
$\langle[0.6,0.7],$ $[0.2,0.4],$ $[0.1,0.3]\rangle$	v_2	$\langle[0.217,0.283],$ $[0.211,0.289],$ $[0.302,0.313]\rangle$	0	$\langle[0.28,0.283],$ $[0.197,0.198],$ $[0.208,0.209]\rangle$	$(1,1,1)$
$\langle[0.4,0.6],$ $[0.1,0.3],$ $[0.2,0.4]\rangle$	v_3	$\langle[0.281,0.282],$ $[0.198,0.199],$ $[0.208,0.209]\rangle$	$\langle[0.217,0.283],$ $[0.302,0.313],$ $[0.292,0.302]\rangle$	0	$(1,1,1)$
$\sum(v_i,v_j)$		$(1,1,1)$	$(1,1,1)$	$(1,1,1)$	

Table 2: Transaction Table for BCIVNG

From table 1 and table 2 it is observed that sum of all single /interval valued Neutrosophic edges of a particular Neutrosophic vertex is equal to (1, 1, 1). Hence the proposed method is an optimized one to deal indeterminacy of the data in Bitcoin transaction.

5. Comparative Analysis (Qualitative)

Blockchain approach has been applied in various fields as a growing technique. Here the advantages and limitations are listed out for Blockchian crisp, fuzzy and Neutrosophic graphs. This analysis will be very useful to understand the concept of Blockchian under different environments.

Type of Blockchain Graph	Advantages	Limitations
Blockchian Crisp Graph	• Faster Process with purity and detectable • Process clarity • Data will be permanent	• Unable to handle uncertainties • Size of the network will decide the security level
Blockchain Fuzzy Graph	• Can handle uncertainty exists in the vertex and edge sets • Invariable data	• Incapable to handle indeterminacy of the data and interval data • Large network will give more level of security
Blockchain Interval Valued Fuzzy Graph	• Can able to deal with data in terms of range	• Inadequate to handle undetermined data
Blockchain Single Valued Neutrosophic Graph	• Able to handle indeterminacy of the data	• Unfit to handle interval data
Blockchain Interval Valued	• Capable to handle interval	• Unsuited to handle criterion

Neutrosophic Graph	data as the participant's decision is always lie in a range.	insufficient information of the weights.

6. Conclusion

Reliability and assurance of the dealing is very important for any business transaction. Blockchain technology is such a technology and recently it is widely applied in many fields. In any field uncertainty is unavoidable one as the human behavior always uncertainty in nature. Also indeterminacy does not deal in any area field of mathematics whereas Neutrosophic set deals indeterminacy and hence an optimized solution can be obtain for any problem. In this paper Blockchain network has been used in terms of Bitcoin transaction where the vertex and edges have been considered as single and interval valued Neutrosophic sets. Also the degree, total degree, minimum and maximum degree have been found for the proposed Blockchain single valued Neutrosophic graph. In addition to this, contingent study has been done for various types of Blockchain graphs.

Notes

Compliance with Ethical Standards

Conflict of Interest

The authors declare that they have no conflict of interest

Ethical Approval

The article does not contain any studies with human participants or animal performed by any of the authors

Informed Consent

Informed consent was obtained from all individual participants included in the study

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Received: December 30, 2018, Accepted: March 02, 2019