Some New kinds of Connected Domination in Intuitionistic Fuzzy Graphs

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Abstract :*In this paper, we introduce the concept of some new kinds of connected domination number of an intuitionistic fuzzy graphs. We determine the domination numbers γ_{cs}, γ_{ds} ,γ_{lsc} , γ_{rsc} and the total domination number of γ_{tcs}, $\gamma_{tds}$for several classes of intuitionistic fuzzy graphs and obtain bounds for the same. We also obtain the Nordhaus – Gaddum type result for these parameters.*

Keywords : *Connected strong domination number, disconnected strong domination number, total connected strong domination number, total disconnected strong domination number, left semi connected domination number, right semi connected domination number.*

AMS classification Number : 03E72, 03F55, 05C72, 05C69

I.INTRODUCTION

The study of domination set in graphs was begun by ore and Berge. The connected domination number was first introduced by E.Sampathkumar and H.B.Walikar[8] Rosenfield[6] introduced the notion of fuzzy graph and several fuzzy analogs of graph theoretic concepts such as path, cycles and connectedness. A Somasundram and S.Somasundaram[10] discussed domination in fuzzy graphs. K.T. Atanassov[1] initiated the concept of intuitionistic fuzzy relations and intuitionitic fuzzy graphs. R.Parvathi and M.G. Karunambigai[6] gave a definition of IFG as a special case of IFGS defined by K.T Atanassov and A.Shannon. R.Parvathi and G.Thamizhendhi[7] was introduced dominating set and domination number in IFGS. In this paper, we discuss some new kinds of connected domination number of an intuitionstic fuzzy graphs and obtain the relationship with other known parameters of an IFG G.

II. PRELIMINARIES

Definition :2.1

An Intuitionistic Fuzzy Graph (IFG) is of the form G =(V, E) where

(i) $V = \{V_1, V_2, \ldots , V_n\}$ such that $\sigma_1 : V \to [0, 1]$ and $\sigma_2 : V \to [0, 1]$ denote the degree of membership and non-membership of the element $v_i \in V$ respectively and $0 \leq \sigma_1 (v_i) + \sigma_2 (v_i) \leq 1$, for every $v_i \in V$

(ii) $E \subset V \times V$ where $\mu_1 : V\times V \to [0, 1]$ and $\mu_2 : V \times V \to [0, 1]$ are such that

$\mu_1 (v_i, v_j) \leq \min \{\sigma_1(v_i), \sigma_1(v_j)\}$

$\mu_2 (v_i, v_j) \leq \max \{\sigma_2(v_i), \sigma_2(v_j)\}$

and $0 \leq \mu_1(v_i, v_j) + \mu_2(v_i, v_j) \leq 1$

for every $(v_i, v_j) \in E$.

Note : when $\mu_{1ij} = \mu_{2ij}=0$ for some i and j then there is no edge between v_i and v_j otherwise there exits an edge between v_i and v_j.

Definition : 2.2

An IFG H = (V', E') is said to be an IF subgraph (IFSG) of G = (V, E) if $V' \subseteq E$ and $E' \subseteq E$. That is $\sigma_{1i}^1 \leq \sigma_{1i}$; $\sigma_{2i}^1 \geq \sigma_{2i}$ and $\mu_{1i}^1 \leq \mu_{1i}$; $\mu_{2j}^1 \geq \mu_{2j}$, for everyi = 1, 2….n

Definition : 2.3

The intuitionistic fuzzy subgraph H = (V′, E′) is said to be a spanning fuzzy subgraph of an IFG G = (V, E) if $\sigma_1' (u) = \sigma_1 (u)$ and $\sigma_2' (u) = \sigma_2(u)$ for all $u \in V'$ and $\mu_1^1(u, v) \leq \mu_1 (u, v)$ and $\mu_2^1(u, v) \geq \mu_2(u, v)$ for all $u,v \in V$.

Definition :2.4

Let G = (V, E) be an IFG. Then the vertex cardinality of G is defined by

$$P = |V| = \sum_{v_i \in v} \frac{1}{2}\left(1 + \sigma_1(v_1) - \sigma_2(v_2)\right) \text{ for all } v_i \in V$$

Definition :2.5

Let G = (V, E) be an IFG. Then the edge cardinality of E is defined by

$$q = |E| = \sum_{v_i v_j \in E} \frac{1}{2}\left(1 + \mu_1(v_i, v_j) - \mu_2(v_i, v_j)\right) \text{ for all } (v_i, v_j) \in E$$

Definition :2.6

Let G = (V, E) be an IFG. Then the cardinality of G is defined to be |G| = |V| + |E| = p +q

Definition :2.7

The number of vertices is called the order of an IFG and is denoted by O(G). The number of edge is called size of IFG and is denoted by S(G).

Definition :2.8

The vertices v_i and v_j are said to the neighbors in IFG either one of the following conditions hold

(i) $\mu_1 (v_i, v_j) > 0$, $\mu_2 (v_i, v_j) > 0$

(ii) $\mu_1 (v_i, v_j) = 0$, $\mu_2 (v_i, v_j) > 0$

(iii) $\mu_1 (v_i, v_j) > 0$, $\mu_2 (v_i, v_j) = 0$, $v_i, v_j \in V$

Definition :2.9

A path in an IFG is a sequence of distinct vertices $v_1, v_2, \ldots v_n$ such that either one of the following conditions is satisfied.

(i) $\mu_1 (v_i, v_j) > 0$, $\mu_2 (v_i, v_j) > 0$ for some i and j

(ii) $\mu_1 (v_i, v_j) = 0$, $\mu_2 (v_i, v_j) > 0$ for some i and j

(iii) $\mu_1 (v_i, v_j) > 0$, $\mu_2 (v_i, v_j) = 0$ for some i and j

Note : The length of the path $P = v_1, v_2, \ldots v_{n+1}$ $(n > 0)$ is n

Definition :2.10

Two vertices that are joined by a path is called connected.

Definition :2.11

An edge e=(x,y) of an IFG G = (V, E) is called an effective edge if $\mu_1 (x, y) = \min \{\sigma_1(x), \sigma_1(y)\}$ and $\mu_2 (x, y) = \max \{\sigma_2(x), \sigma_2(y)\}$.

Definition :2.12

An IFG G = (V, E) is said to be complete IFG if $\mu_{1ij} = \min \{\sigma_{1i}, \sigma_{1j}\}$ and $\mu_{2ij} = \max \{\sigma_{2i}, \sigma_{2j}\}$ for every $v_i, v_j \in V$.

Definition :2.13

The complement of an IFG, G = (V, E) is an IFG, $\bar{G} = (\bar{V}, \bar{E})$, where

(i) $\bar{V} = V$

(ii) $\overline{\sigma_{1i}} = \sigma_{1i}$ and $\overline{\sigma_{2i}} = \sigma_{2i}$, for all i = 1, 2, … n

(iii) $\overline{\mu_{1ij}} = \min\{\sigma_{1i}, \sigma_{1j}\} - \mu_{1ij}$

(iv) $\overline{\mu_{2ij}} = \max\{\sigma_{2i}, \sigma_{2j}\} - \mu_{2ij}$ for alli = 1, 2, … n

Definition :2.14

An IFG, G = (V, E) is said to bipartite the vertex set V can be partitioned into two non empty sets V_1 and V_2 such that

(i) $\mu_1 (v_i, v_j) = 0$ and$\mu_2 (v_i, v_j) = 0$ if $v_i, v_j \in V_1$ (or) $v_i, v_j \in V_2$

(ii) $\mu_1 (v_i, v_j) > 0$ and $\mu_2 (v_i, v_j) > 0$ if $v_i \in V_1$and $v_j \in V_2$ for some i and j or
$\mu_1 (v_i, v_j) = 0$ and $\mu_2 (v_i, v_j) > 0$ if $v_i \in V_1$ and $v_j \in V_2$ for some i and jor
$\mu_1 (v_i, v_j) > 0$ and $\mu_2 (v_i, v_j) = 0$ if $v_i \in V_1$ and $v_j \in V_2$for some i and j

Definition :2.15

A bipartite IFG, G = (V, E) is said to be complete if

$\mu_1 (v_i, v_j) = \min \{\sigma_1(v_i), \sigma_1(v_j)\}$
$\mu_2 (v_i, v_j) = \max \{\sigma_2(v_i), \sigma_2(v_j)\}$
forall $v_i \in V_1$ and $v_j \in V_2$.
It is denoted by $K_{(\sigma_1\sigma_2,\ \mu_1\mu_2)}$

Definition :2.16

A vertex $u \in V$ of an IFG G = (V, E) is said to be an isolated vertex if $\mu_1 (u, v) = 0$ and $\mu_2 (u, v) = 0$, for all $v \in V$. That is $N (u) = \phi$. Thus an isolated vertex does not dominate any other vertex in G.

Definition :2.17

Let G = (V, E) be an IFG on V. Let $u, v \in V$, we say that u dominate v in G if there exitsaeffective edge between them.

Definition :2.18

Let G = (V, E) be an intuitionistic fuzzy graph G on the vertex set V.Let $x , y \in V$,

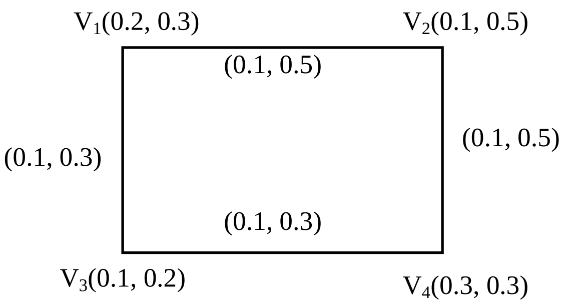
we say that x dominates y in G if $\mu_1 (x, y)=\min\{\sigma_1(x), \sigma_1(y)\}and\mu_2(x,y)= \max \{\sigma_2(x), \sigma_2(y)\}$.A subset D of V is called a dominating set in IFG G if for every $v \in V - D$, there exists $u \in D$ such that u dominates v.A dominating set D of an IFG is said to be minimal dominating set if no proper subset of D is a dominating set.

III. INTUITIONISTIC FUZZY CONNECTED STRONG DOMINATION NUMBER

Definition :3.1

Let G = (V, E) be a IFG without isolated vertices. A subset D_{cs} of V is said to be an intuitionistic fuzzy connected strong domination set if both induced subgraphs<D_{cs}> and <V-D_{cs}> are connected. The intuitionistic fuzzy connected strong domination number $\gamma_{cs}(G)$ is the minimum intuitionistic fuzzy cardinality taken over all connected strong dominating sets of G.

Example :3.1.1



<D_{cs}> and <V-D_{cs}> are connected

$\gamma_{cs}(G) = 0.75$

Definition : 3.2

Let G = (V,E) be an IFG. A subset D_{cs} of V is said to be an intuitionistic fuzzy total connected strong domination set if

(i) D_{cs} is connected strong dominating set

(ii) $N[D_{cs}] = V$

The intuitionistic fuzzy total connected strong domination number $\gamma_{tcs}(G)$ is the minimum intuitionistic fuzzy cardinality taken over all total connected strong dominating sets in G.

Proposition 3.1

$\gamma_{cs}(P_n)$=Min{½(1+{p_1-$\sigma_1(v_1)$-p_2-$\sigma_2(v_1)$}},½{1+{p_1-$\sigma_1(v_n)$- p_2-$\sigma_2(v_n)$}}

Proposition 3.2

$$\gamma_{cs}(C_n) = \tfrac{1}{2}\left\{1+\min\left\{\sum_{i=1}^{n-2}\sigma_1(v_i),\sum_{i=2}^{n-1}\sigma_1(v_i),\ldots,\sum_{i=n-2}^{1}\sigma_1(v_i)\right\} - \max\left\{\sum_{i=1}^{n-2}\sigma_2(v_i),\sum_{i=2}^{n-1}\sigma_2(v_i),\ldots,\sum_{i=n-2}^{1}\sigma_2(v_i)\right\}\right.$$

Proposition 3.3

$\gamma_{cs}(w_n)$ = ½{1+$\sigma_1(v)$ - $\sigma_2(v)$} ,
v is the centre vertex = $|v_i|$

Proposition 3.4

$\gamma_{cs}(k_n)$ = ½{1+$\sigma_1(v)$ - $\sigma_2(v)$} ,
v is the vertex of minimum cardinality.

Proposition 3.5

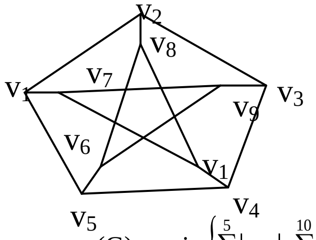
γ_{cs} (star) = ½ (1+$\sigma_1(v_i)$ - $\sigma_2(v_i)$ + ½ (1+$\sigma_1(v_j)$ - $\sigma_2(v_j)$)
= $|v_i| + |v_j|$,v_i is a vertex adjacentwith all other vertices and v_j is the all pendent vertices of minimum cardinality, except one pendent vertex has maximum cardinality.

Proposition 3.6

$\gamma_{cs}(K_{\sigma 1\sigma 2,\mu 1\mu 2})$ = min {$|v_i|$} + min {$|v_j|$} where $v_i \in V_1$ and $v_j \in V_2$.
Where |v|= ½ (1+$\sigma_1(v)$-$\sigma_2(v)$)

Proposition 3.7

Let G be the Peterson graph, (i) If all intuitionistic fuzzy vertices having equal membership and non-membership value then
$\gamma_{cs}(G) = 5|v_i|= 5/2\ (1+\sigma_1(v_i) – (\sigma_2(v_i))$, i=1to10
(ii)If an unequal intuitionistic fuzzy vertex cardinality then,



$$\gamma_{cs}(G) = \min\left\{\sum_{i=1}^{5}|v_i|,\sum_{i=6}^{10}|v_i|\right\}$$

Theorem 3.1

A connected strong dominating set D_{cs} of an IFG is a minimal dominating set iff for each vertex d $\in D_{cs}$, one of the following condition holds

i. $N(d) \cap D_{cs} = \phi$

ii. There exist $c \in V – D_{cs}$ such that $N(c) \cap D_{cs} = \{d\}$

Proof :

Suppose that D_{cs} is minimal and there exist a vertex v $\in D_{cs}$ such that v doesnot satisfy any one of the above conditions. Then by condition (i) and (ii),D′ = D_{cs} – {v} is a dominating set of IFG G, This implies that D′ is connected strong dominating set of G, which is contradiction.

Theorem 3.2

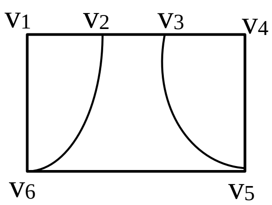
For any IFG, G = (V,E),$\gamma_{cs}(G) \le \gamma_{tcs}(G) \le 2\gamma_{cs}(G)$

Proof :Since every total connected strong dominating set is a connected strong dominating set. Therefore $\gamma_{cs}(G) \le \gamma_{tcs}(G)$. Let D_{cs} be a connected strong dominating set with finite vertices say $\{v_1,v_2,\ldots,v_n\}$. For each $v_i \in D_{cs}$, choose one vertex $u_i \in V\text{-}D_{cs}$ such that v_i and u_i are adjacent.

This is possible since G has no isolated vertices. Now the set $\{v_1,v_2,\ldots v_n, u_1,u_2,\ldots u_n\}$ is a total connected strong dominating set of IFGG.

$\therefore \gamma_{cs}(G) \le \gamma_{tcs}(G) \le 2\gamma_{cs}(G)$.

Example :3.2.1



$\sigma_1(v_i) = 0.1$, $\sigma_2(v_i) = 0.1$, for all $v_i \in V$
$\mu_1(v_i,v_j) = 0.1$, $\mu_2(v_i,v_j) = 0.1$, for all $(v_i,v_j) \in E$

$D_{cs} = \{v_2,v_3\}$, $\gamma_{cs} = 0.5$
$D_{tcs} = \{v_2,v_3\}$, $\gamma_{tcs} = 0.5$
$\therefore \gamma_{cs}(G) \le \gamma_{tcs}(G) \le 2\gamma_{cs}(G)$

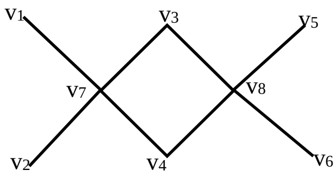
Theorem 3.3

If G = (V,E) is a connected intuitionistic fuzzy graph, then,

$$\gamma_{cs}(G) \le |v| - \left\{\frac{1}{2}(1+\sigma_1(v_i)-\sigma_2(v_i)) + \frac{1}{2}(1+\sigma_1(v_j)-\sigma_2(v_j))\right\}$$

$$= |v| - \tfrac{1}{2}\left\{2+(\sigma_1(v_i)+\sigma_1(v_j))-(\sigma_2(v_i)+\sigma_2(v_j))\right\}$$

Where v_i,v_j are the vertex having first two maximum intuitionistic fuzzy cardinality among the all vertices.



Theorem 3.4

If G = (V,E) is a fuzzy graph then

$|v_i| \le \gamma_{cs}(G) \le |V| - |v_i|$

ii) $2|v_i| \le \gamma_{cs}(G) - |v_i| \le |V|$, v_i is the vertices of intuitionistic fuzzy minimum cardinality.

Proof :

Let G = (V,E) be an IFG.
By definition of intuitionistic fuzzy dominating set, $\gamma(G) \le |V|$
Clearly $\gamma(G) \le \gamma_{cs}(G)$
Suppose all fuzzy vertices are isolated then $\gamma(G) = |V|$, clearly $\gamma_{cs}(G) < |V|$.
Therefore, $|v_i| \le \gamma_{cs}(G)$ when G is complete or not
$\therefore |v_i| \le \gamma_{cs}(G) \le |V| - |v_i|$

Theorem 3.5

If G = (V,E) is an intuitionistic fuzzy path, all connected strong dominating set are minimal dominating sets.

Proof : By theorem 2.5, G has exactly two different connected strong dominating sets.

ie) $D_1=\{v_1,v_2,\ldots v_{n-1}\}$
$D_2=\{v_2,v_3,\ldots v_n\}$

Obviously D_1-$\{v_i\}$ is not a connected strong dominating set, for all $v_i \in D_1$.

Hence D_1 is a minimal connected strong dominating set. Similarly for D_2.

$\therefore$Both D_1 and D_2 are minimal connected strong dominating sets of an IFG.

Theorem 3.6

If G = (V, E) is an intuitionistic fuzzy path then G has exactly two connected strong dominating set.

Proof :

Let $V = \{v_1,v_2,\ldots v_n\}$ be an intuitionistic fuzzy vertex set of G, by definition 3.1

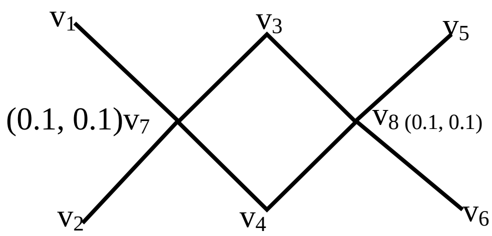
Clearly $D_1 = \{v_1,v_2,\ldots v_{n-1}\}$ and $D_2 = \{v_2,v_3,\ldots v_n\}$ are the two intuitionistic fuzzy connected strong dominating sets.

IV. INTUITIONISTIC FUZZY DISCONNECTED STRONG DOMINATING NUMBER

Definition 4.1

Let G = (V, E) be an IFG without isolated vertices. A subset D_{ds} of V is said to be an intuitionstic fuzzy disconnected strong dominating set if both induced subgraphs$\langle D_{ds}\rangle$ and $\langle V\text{-}D_{ds}\rangle$ are disconnected. The intuitionistic fuzzy disconnected strong domination number $\gamma_{ds}(G)$ is the minimum intuitionistic fuzzy cardinality taken over all disconnected strong dominating sets of G.

Example :4.1



$\sigma_1(v_i) = 0.1$, $\sigma_2(v_i) =0.1$, for all $v_i \in V$
$\mu_1(v_i,v_j) = 0.1$, $\mu_2(v_i,v_j) = 0.1$, for all $(v_i,v_j) \in E$
$D_{ds} = \{v_7,v_8\}$, V- $D_{ds} = \{v_1,v_2,v_3,v_4,v_5,v_6\}$
$\langle D_{ds}\rangle$ and$\langle V\text{-}D_{ds}\rangle$ are disconnected.
$\gamma_{ds}(G) =1$

Proposition : 4.1

$\gamma_{ds}(P_n) = \left\lfloor \frac{n}{2} \right\rfloor |v_i|$, Each v_i having equal intuitionistic fuzzy cardinality, n is the order of an IFG.

Proposition : 4.2

$\gamma_{ds}(C_n) = \left\lceil \frac{n}{3} \right\rceil |v_i|$, each v_i having equal intuitionistic fuzzy cardinality, $n \ge 4$.

Proposition : 4.3

$$\gamma_{ds}(K_{\sigma1\sigma2,\mu1\mu2}) = \min\left\{\sum_{i=1}^{m}|v_i|, \sum_{j=1}^{n}|v_j|\right\}$$

Where$v_i \in V_1$and $v_j \in V_2$.

Theorem 4.1

For any IFG, G = (V,E)
$|V| - |E| \leq \gamma_{ds}(G) \leq |V| - \Delta$

Proof : Let V be a vertex of an intuitionistic fuzzy graph, such that $dN(v) = \Delta$,then $V/N(v)$ is a dominating set of an intuitionistic fuzzy graph G.

So that $\gamma_{ds}(G) \leq |V/N(v)| = |V| - \Delta$

Definition : 4.2

Let G(V,E) be an IFG G, A subset D_{tds} of V is said to be an intuitionistic fuzzy total disconnected strong dominating set if

i) D_{tds} is disconnected strong dominating set
ii) $N[D_{tds}] = V$

The intuitionistic fuzzy total disconnected strong dominating number γ_{tds} is the minimum cardinality taken over all total disconnected strong dominating set in G.

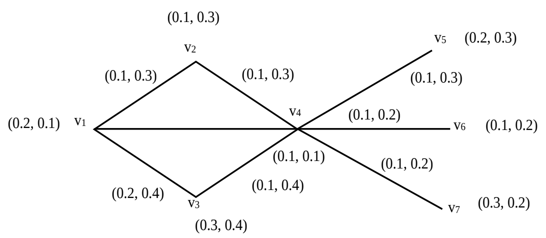
V. INTUITIONISTIC FUZZY LEFT SEMI CONNECTED DOMINATION NUMBER

Definition 5.1

Let G = (V,E) be an intuitionistic fuzzy graph without isolated vertices. A subset D_{lsc} of V is said to be a fuzzy left semi connected strong dominating set if the induced intuitionistic fuzzy subgraph$\langle D_{lsc}\rangle$ is connected and induced intuitionistic fuzzy subgraph$\langle V-D_{lsc}\rangle$ is disconnected.

The intuitionistic fuzzy left semi connected domination number $\gamma_{lsc}(G)$ is the minimum intuitionistic fuzzy cardinality taken overall left semi connected dominating sets of G.

Example 5.1



$D_{lsc} = \{v_1,v_4\}$,
$\langle D_{lsc}\rangle$ is connected
$\langle V- D_{lsc}\rangle$ is disconnected
$\gamma_{lsc}(G) = 1.0$

Proposition 5.1

$\gamma_{lsc}(P_n) = |V| – (|v_1| + |v_n|)$

Proposition 5.2

$\gamma_{lsc}(w_n) = 3|v_i|$, all v_i's having equal intuitionistic fuzzy cardinality.

Proposition 5.3

$\gamma_{lsc}(star) = |v_i|$, where v_i is the intuitionistic fuzzy vertex having maximum effective degree.

Proposition 5.4

$\gamma_{lsc}(k_{\sigma1\sigma2,\mu1,\mu2}) =$
min

$$\left\{\sum_{i=1}^{m}(u_i)+\min\left\{|v_j|, j=1 \text{ to } n\right\}, \sum_{i=1}^{n}|v_j|+\min\left\{|v_i|, i=1 \text{ to } m\right\}\right\}$$

Theorem 5.1

For any intuitionistic fuzzy graph G, $\gamma(G) \leq \gamma_{lsc}(G)$

Theorem 5.2

Let G = (V,E) be an intuitionistic fuzzy connected graph, and H = (V′,E′) be an intuitionistic spanning fuzzy subgraph of G, if H has a left semi connected dominating set then $\gamma_{lsc}(G) \leq \gamma_{lsc}(H)$.

Theorem 5.3

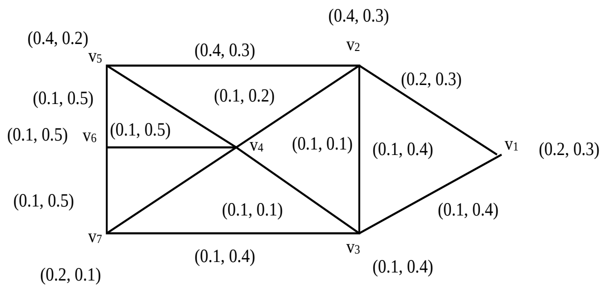
For any intuitionistic fuzzy graph G = (V,E), $\gamma_{lsc}(G) + \gamma_{lsc}(\overline{G}) \leq 2|V|$, where $\gamma_{lsc}(\overline{G})$ is the left semi connected domination number of $\overline{G}$ and equality holds iff$0 \leq \mu_1(u,v) < \sigma_1(u) \wedge \sigma_1(v)$ and $0 \leq \mu_2(u,v) > \sigma_2(u) \vee \sigma_2(v)$ for all $u,v \in V$.

VI. INTUITIONISTIC FUZZY RIGHT SEMI CONNECTED DOMINATION NUMBER

Definition 6.1

Let G = (V,E) be an intuitionistic fuzzy graph without isolated vertices. A subset D_{rsc} of V is said to be an intuitionistic fuzzy right semi connected dominating set if the induced intuitionistic fuzzy subgraph$\langle D_{rsc}\rangle$ is disconnected and induced intuitionistic fuzzy subgraph$\langle V-D_{rsc}\rangle$ is connected. The intuitionistic fuzzy right semi connected domination number $\gamma_{rsc}(G)$ is the minimum intuitionistic fuzzy cardinality taken over all right semi connected dominating sets of G.

Example :6.1



$D_{rsc}= \{v_1,v_4\}$,
$V-D_{rsc} = \{v_2,v_3,v_5,v_6,v_7\}$
$\langle D_{rsc}\rangle$ is disconnected and
$\langle V-D_{rsc}\rangle$ is connected
$\gamma_{rsc}(G) = 0.95$

Proposition 6.1

$$\gamma_{rsc}(P_n) = \min\left\{\sum_{i=1}^{n-3} |v_i| + |v_n|, \sum_{i=4}^{n} |v_i| + |v_1|\right\}$$

Proposition 6.2

$\gamma_{rsc}(P_n) = \left\lceil \frac{n}{3} \right\rceil |v_i|$, $\forall$ v_i's having equal intuitionistic fuzzy cardinality

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