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Neighborhood Triple Connected Two- Out Degree Equitable Domination Number

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Abstract: *In this paper we introduce a new domination parameter with real life application called neighborhood triple connected two out degree equitable domination number of a graph. A subset D of V of a nontrivial graph G is said to be a neighborhood triple connected two out degree equitable dominating set if D is a two out degree equitable dominating set and the induced sub graph <N(D)> is triple connected. The minimum cardinality taken over all neighborhood triple connected two out degree equitable dominating set is called neighborhood triple connected two out degree equitable domination number and is denoted by $\gamma_{ntc\,2oe}(G)$ We investigate this number for some standard graphs and special graphs*

Key words: *dominating set, equitable, neighborhood Triple connected, two out degree,*
Mathematical Subject Classification*: 05C69*

I. Introduction

By a graph G= (V,E), we mean a finite , unordered with neither loops or multiple edges the order and size of G are denoted by p and q respectively. For graph theoretic terminology we refer to Chartand and Lesniak [1]. A subset D of V is called a dominating set if N[D]=V. The minimum (maximum) cardinality of a minimal dominating set of G is called domination number (upper domination) number of G is denoted by $\gamma(G)[\Gamma(G)]$. An excellent treatment of the fundamentals of domination is the book by Haynes et al [2]. A survey of several advanced topics in domination is given in the book edited by Haynes at el[3]. Various types of domination have been defined and studied by several authors and more than 75 models of domination are listed in the appendix of Haynes et al [3].

Let v ϵV the open neighborhood and the closed neighbourhood of v are donted by N(v)={u ϵV, uvϵE } and N[v]= N(v) ∪ v respectively. If D⊂ V then N(D) $=\cup_{v\epsilon D} N(v)$ and N[D]= N(D) ∪ D. Let G=(V,E) be a graph D⊆V and v be any vertex in D. The out degree of v with respect to D is denoted by $od_D(v)$ and is defined by $od_D(v) = |N(v) \cap V - D|$. A dominating set of D in a graph G is called a two out degree equitable dominating set if for any two vertices u,v ∈ D, $|od_D(u) - od_D(v)| \leq 2$. The minimum cardinality of a two out degree equitable domination number of G is denoted by $\gamma_{2oe}(G)$[4].A subset D of V of a nontrivial graph G is said to be a neighborhood triple connected dominating set, if D is a dominating set and induced sub graph <N(D)> is triple connected. The minimum cardinality taken over all of such set is called neighborhood triple connected domination number and it is denoted by $\gamma_{ntc}(G)$[5]

II. Neighborhood Triple Connected Two- Out Degree Equitable Domination Number

2.1Definition: A subset D of V of a nontrivial graph G is said to be a neighborhood triple connected two out degree equitable dominating set if D is an out degree equitable dominating set and the induced sub graph <N(D)> is triple connected. The minimum cardinality taken overall of such set is called neighborhood triple connected two out degree equitable domination number of G and is denoted by $\gamma_{ntc\,2oe}(G)$. Any neighborhood triple connected two out degree equitable dominating set with $\gamma_{ntc\,2oe}(G)$ vertices is called $\gamma_{ntc\,2oe} -$ set of G.

2.2Example: For the graph G_1in Fig 2.1 S={v_1,v_2} forms a$\gamma_{ntc\,2oe} -$ set of G. hence $\gamma_{ntc\,2oe}(G_1)$=2

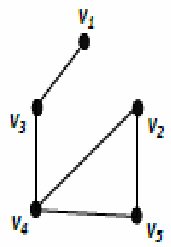


Figure 2.1 Graph with $\gamma_{ntc\,2oe}$ =2

2.3 Remark

Throughout this paper we consider only connected graphs for which neighborhood triple connected two out degree equitable dominating set exists.

2.4 Observation

The complement of a neighborhood triple connected two out degree equitable dominating set D need not be a neighborhood triple connected two out degree equitable dominating set.

2.5 Example:

For the graph G_2 in the Fig 2.2 D= $\{v_1, v_5, v_6\}$ is neighborhood triple connected two out degree equitable dominating set. But the complement $V - D = \{v_2, v_3, v_4\}$ is not a neighborhood triple connected two out degree equitable dominating set

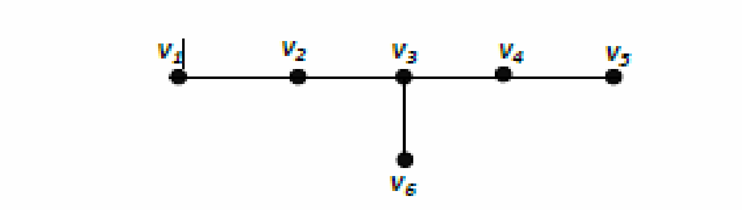


Figure 2.2 G_2

2.7 Observation:

Every neighborhood triple connected two out degree equitable dominating is two out degree equitable dominating set but not conversely.

2.8 Example:

For the graph G_3, in the Fig 2.3 D=$\{v_1, v_2\}$ is a neighborhood triple connected two out degree equitable dominating set as well as two out degree equitable dominating set . For the graph H_3, in the Fig 2.3 D=$\{v_1, v_2\}$ is a two out degree equitable dominating set but not a neighborhood triple connected two out degree equitable dominating set.

Figure 2.3

III. Neighborhood Triple Connected Two- Out Degree Equitable Domination Number For Some Standard Graphs

3.1 Observation

For any graph G with p vertices $2 \leq \gamma_{ntc\,2oe}(G) \leq p$

3.2 Theorem

For any complete graph of order $p \geq 4$. Then $\gamma_{ntc\,2oe}(K_p) = 2$

Proof:

Let V= $\{v_1, v_2, v_3 ------v_p\}$ be the vertices of K_p and D= $\{v_i, v_j\}$ and
V-D= $\{v_1, v_2, v_3 ----v_{i-1}, v_{i+1} ----- v_{j-1}, v_{j+1}---- v_p\}$ since N(v_i)=V for all i
$od_D(v_i) = |N(v) \cap V - D|$=|V-D|
$= p - 2$
Similarly $od_D(v_j) = p - 2$
$|od_D(v_i) - od_D(v_j)| = 0 \leq 2$
So D is two out degree equitable dominating set
<N (D)> = V is triple connected
There fore D is neighborhood triple connected two out degree equitable dominating set.

$\gamma_{ntc\,2oe}(G) \leq 2$and $2\leq \gamma_{ntc\,2oe}(G)$
Hence $\gamma_{ntc\,2oe}(G) = 2$

3.3 Theorem
For the star $K_{1,p}$, the neighborhood triple connected two –out degree equitable domination number is :$\gamma_{ntc\,2oe}(K_{1,p})$ =$p-2$.

Proof:
Let {v,u_1,u_2,u_3----------u_p} be the set of vertices in $K_{1,p}$
Let D= {v,u_1,u_2,u_3----------u_{p-2}} and V-D={u_{p-1},u_p}
By the definition of star $K_{1,p}$, N (u_i) =v for i=1, 2, -----p and N (u_i) ∩ V-D = ∅
Therefore $od_D(u_i)$= |N(u_i)∩ V-D| = 0
Then N (v) = {u_1,u_2,u_3----------u_p} and V-D ⊆ $N(v)$ so N(v) ∩ V-D = V-D
Therefore $od_D(v)$= |N(v)∩ V-D| = $|V-D|$ =2
So $|od_D(u) - od_D(v)| = 2 \leq 2$
So D is two degree equitable dominating set and induced sub graph <N (D)>=V
<N (D)> is triple connected
Hence $\gamma_{ntc\,2oe}(K_{1,p}) \leq$ p-2. And clearly $p-2 \geq \gamma_{ntc\,2oe}(K_{1,p})$
Then:$\gamma_{ntc\,2oe}(K_{1,p})$ =p-2.

3.4 Theorem:
The ntc2oe number of a complete bipartite graph is $\gamma_{ntc\,2oe}(k_{s,t}) = \begin{cases} 2 & if\ |s-t| \leq 2 \\ s+t & otherwise \end{cases}$

Proof:
Let V={$u_1, u_2, u_3 - - - - - u_s, v_1, v_2, v_3, - - - - - v_t$} be the vertices set of $k_{s,t}$ and {$u_1, u_2, u_3 - - - - - u_s$} and {$v_1, v_2, v_3, - - - - - v_t$} be the partition of V.

Case (i) $|s-t| \leq 2$
Let D= {u_i, v_j} be a dominating set of G and
$V-D$=$\{u_1, u_2, u_3 - - - u_{i-1}, u_{i+1} - - - - u_s, v_1, v_2, v_3, - - - - v_{j-1}, v_{j+1} - - - v_t\}$
Now, $u_i \epsilon D$ then $od_D(u_i) = |N(u_i) \cap V-D|$
= $|\{v_1, v_2, v_3, - - - - v_{j-1}, v_{j+1} - - - v_t\} - \{u_1, u_2, u_3 - - - u_{i-1}, u_{i+1} - - - u_s, v_1, v_2, v_3, - - - - vj-1, vj+1 - - - vt$
=$|\{v_1, v_2, v_3, - - - - v_{j-1}, v_{j+1} - - - v_t\}|$=$t-1$
$if\ v_j \epsilon D$ then $od_D(v_j) = |N(v_j) \cap V-D|$
=$|\{u_1, u_2, u_3 - - - u_{i-1}, u_{i+1} - - - - u_s\} \cap \{u_1, u_2, u_3 - - - u_{i-1}, u_{i+1} - - - - us, v1, v2, v3, - - - - vj-1, vj+1 - - - vt$
=$|\{u_1, u_2, u_3 - - - u_{i-1}, u_{i+1} - - - - u_s\}|$= $s-1$
$|od_D(u_i) - od_D(v_j)| = t-1-s+1 \leq 2$
Then $|od_D(u_i) - od_D(v_j)| \leq 2$. For any $u_i, v_j \epsilon D$
So D is two out degree equitable dominating set
N(D)=N(u_i) ∪ $N(v_j)$
= V
<N(D)>=V and <V> is triple connected in $k_{s,t}$
So <N(D)> is connected
$\gamma_{ntc\,2oe}(k_{s,t}) \leq 2$and $2\leq \gamma_{ntc\,2oe}(k_{s,t})$
$\gamma_{ntc\,2oe}(k_{s,t}) = 2$
Case (ii) $|s-t| \geq 2$ and s,t≥ 3
Let V={$u_1, u_2, u_3 - - - - - u_s, v_1, v_2, v_3, - - - - - v_t$} be the vertices set of $k_{s,t}$
Let D={$u_1, u_2, u_3 - - - - - u_s, v_1, v_2, v_3, - - - - - v_t$} be the dominating set of $k_{s,t}$
And $V-D$= ∅
Clearly V is ntc2oe-set
Then $\gamma_{ntc\,2oe}(k_{s,t}) \leq s+t$. and $s+t \leq \gamma_{ntc\,2oe}(k_{s,t})$
Then $\gamma_{ntc\,2oe}(k_{s,t}) = s+t$
3.5 Theorem:

For any cycle C_P then $\gamma_{ntc\,2oe}(C_P) = \begin{cases} \left\lfloor \frac{p}{2} \right\rfloor & p \equiv 3\ (mod\ 4) \\ \left\lceil \frac{p}{2} \right\rceil & otherwise \end{cases}$

Proof:
Let V=$\{u_1, u_2 - - - - - u_p\}$ be the vertices set of C_P
Let D be two out degree equitable dominating set of C_P

Let $D_1 = \begin{cases} D & if\ \ p \equiv 0\ (mod\ 4) \\ D \cup \{v_p\} & if\ \ p \equiv 1\ or\ 2\ (mod\ 4) \\ D \cup \{v_{p-1}\} & if\ \ p \equiv 3\ (mod\ 4) \end{cases}$

Clearly D_1 is ntc2oe-set of C_P then <N(D)> contains atmost one isolated verteces
And <N (D)>= $\begin{cases} c_p & if\ \ p \equiv 0\ (mod\ 4) \\ p_{p-1} & otherswise \end{cases}$
Then <N (D)>is triple connected
Hence |D| $\geq \gamma_{ntc\,2oe}(C_P) = \begin{cases} \left\lfloor \frac{p}{2} \right\rfloor & p \equiv 3\ (mod\ 4) \\ \left\lceil \frac{p}{2} \right\rceil & otherwise \end{cases}$
Hence the theorem

3.6 Theorem:
For any Path P_p, $\gamma_{ntc\,2oe}(P_p)$ = $\left\lceil \frac{p}{2} \right\rceil$

Proof:
Let P_p=$\{v_1, v_2, v_3 - - - - - v_p\}$
If p not ≡ 1 (mod 4)

Then D= $\{v_j, j = 2k, 2k + 1 and\ k\ is\ odd\}$
Since G is path, then deg (v) ≤ 2, clearly D is two out degree equitable dominating set
N<D> is triple connected
So D is a ntc2oe-set of P_p
If p ≡ 1 (mod 4)
Then $D_1 = D \cup \{v_{p-1}\}$ is a a ntc2oe-set of P_p
Hence $\gamma_{ntc\,2oe}(P_p)$≤ $\left\lceil \frac{p}{2} \right\rceil$
Since $\gamma_{nc}(G)$ =$\left\lceil \frac{p}{2} \right\rceil$ and $\gamma_{nc}(G) \leq\ \gamma_{ntc\,2oe}(G)$
We have $\left\lceil \frac{p}{2} \right\rceil \leq \gamma_{ntc\,2oe}(G)$ and $\left\lceil \frac{p}{2} \right\rceil \leq \gamma_{ntc\,2oe}(P_n)$
$\gamma_{ntc\,2oe}(P_p)$ = $\left\lceil \frac{p}{2} \right\rceil$

3.7 Theorem:
For the WheelW_m, the neighborhood triple connected two –out degree equitable domination number is:
$\gamma_{ntc\,2oe}(W_p) = \begin{cases} 2 & if\ p = 4,5 \\ p - 4 & if\ p \geq 6 \end{cases}$

Proof:
Let W_p be a when with $p - 1$ vertices on the cycle and a single vertex at the center. Let V (W_p) = {u,v_1,v_2,v_3----------v_{p-1}}, where u is the center and v_i (1≤ $i \leq m - 1$) is on the cycle. Clearly deg (v_i) = 3 for all 1≤ $i \leq p - 1$ and deg (u) $= p - 1$.
Clearly p≥ 4. We have the following cases

Case 1. p=4 and 5
If p=4 then W_4 forms a complete graph then by theorem 3.1 $\gamma_{ntc\,2oe}(W_4) = 2$
If p=5. Let us take D= {u,v_i} and $V - D = \{v_i, v_i, - - - - v_{i-1}, v_{i+1} - - - - v_{p-1}\}$ since u is adjacent with v_i for all i 1≤ $i \leq 4$, $V - D \subset$ N (u) so N(u)∩ $V - D \subset V - D$
$od_D(u)$= |N(u)∩ $V - D$| = |$V - D$|=3
Now for v_i

Since deg (v_i) =3 and v_i is adjacent to u∈D then N (v_i) = {u,v_j ,v_k}
and $N(v_i)$∩ $V - D$= {v_j ,v_k}
$od_D(v_i)$= |N(u)∩ $V - D$| = 2
$|od_D(u) - od_D(v_i)| = 1 \leq 2$and clearly <N(D)>= V is triple connected
So N(D) is neighborhood triple connected two degree equitable dominating set
Hence $\gamma_{ntc\,2oe}(W_n) \leq 2$ and $2 \leq \gamma_{ntc\,2oe}(G)$
Hence $\gamma_{ntc\,2oe}(W_p)$ =2

Case 2.p≥6
In this case deg (u) =p, while deg (v_i) =3 for all i, 1≤ $i \leq 5$,
Let us take D= {u,v_1,v_2,v_3----------v_{p-4},} be a dominating set and $V - D = \{v_{p-3}, v_{p-2,} v_{p-1,} v_p\}$ since u is adjacent with v_i for all i, $V - D \subset$ N(u)
so$N$(u)∩ $V - D \subset V - D$
$od_D(u)$= |N(u)∩ $V - D$| = 4
Now for v_i and v_j
If v_i and v_j is adjacent N(v_i)= {u,v_j,v_k} and N(u)∩ $V - D$= {v_k}
$od_D(v_i)$= |$N(v_i)$∩ $V - D$| = 1
If v_i and v_j are not adjacent but v_i and v_j are adjacent with u so N(u)∩ $V - D$ contains two elements so $od_D(v_i)$= |$N(v_i)$∩ $V - D$| = 2
So for any elements u,v∈ D $|od_D(u) - od_D(v)| \leq 2$and clearly <N(D)>= V is triple connected
So D is neighborhood triple connected two degree equitable dominating set
Hence $\gamma_{ntc\,2oe}(W_p)$=$p - 4$

IV. Exact Values For Some Special Graphs

4.1Peterson graph
The neighborhood triple connected two out degree equitable domination number of Peterson graph is 5

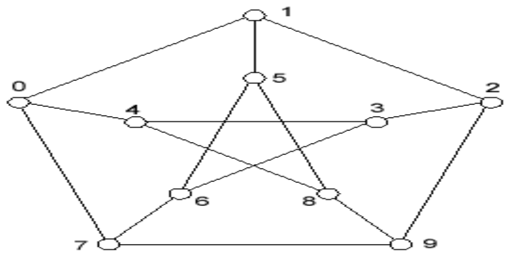


Figure 4.1

For any Peterson graph $\gamma_{ntc\,2oe}$(G)=5
In the above graph D= {3,4,5,6,8} is a neighborhood triple connected two out degree equitable dominating sets

4.2 Diamond Graph
The diamond graph is a planer undirected graph with 4 vertices and 5 edges as show in Fig 4.2 is consist of a complete graph K_4 minus one edge

For any diamond graph G of order 4. $\gamma_{ntc\,2oe}(G)$=2

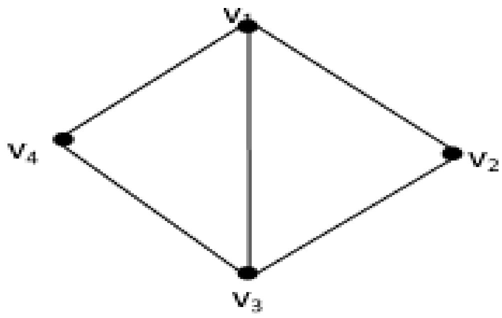


Figure 4.2
In the Fig 3.2 D= {v_1, v_2} is neighborhood triple connected two out degree equitable dominating set.

4.3 Fan graph

A Fan graph $F_{r,s}$ defined as the graph join $\overline{k_p} + P_q$,where$\overline{k_p}$ is the complete graph on p vertices and P_q is the path graph on q vertices . The case p-1 corresponds to the usual fan graphs.

For any fan graph of order n≥ 4, $\gamma_{ntc\,2oe}\,(F_{1,p-1})= \begin{cases} 2 \;\; if\; p = 4,5 \\ p-2 \; if \; p \geq 6 \end{cases}$

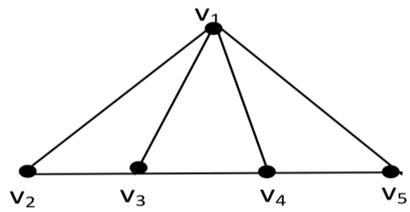


Figure 4.3(a)

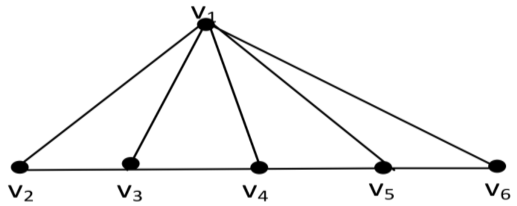


figure 4.3 (b)

In Fig 4.3(a) D= $\{v_1, v_2\}$ is neighborhood triple connected two out degree equitable dominating set so$\gamma_{c2oe}\,(F_{1,4})$=2

In Fig 4.3(b) D= $\{v_1, v_{2,} v_3, v_4\}$ is neighborhood triple connected two out degree equitable dominating set so$\gamma_{c2oe}\,(F_{1,5})$=4

4.4 Moser spindle

The Moser spindle is an undirected graph with seven vertices and eleven edges as show in Fig

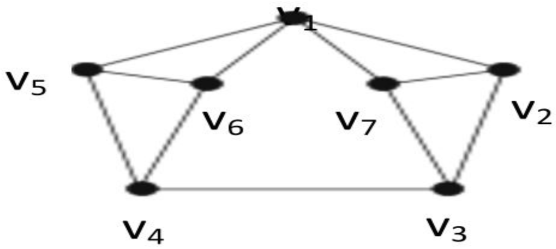


Figure 4.4

In above Fig 4.4 D= $\{v_1, v_{2,} v_5\}$ is a neighborhood triple connected two out degree equitable dominating set so$\gamma_{ntc\,2oe}\,(G)$=3

4.5 Bidiakis cube

The Bidiakis cube is a 3 regular graph with 12 vertices and 18 edges as shown in Fig 4.5

For the Bidiakis cube graph $\gamma_{ntc\,2oe}\,(G)$=6

In above Fig 4.5 D= $\{v_1, v_{3,} v_4, v_6, v_{7,} v_8\}$ is a neighborhood triple connected two out degree equitable dominating set so $\gamma_{ntc\,2oe}\,(G)$=6

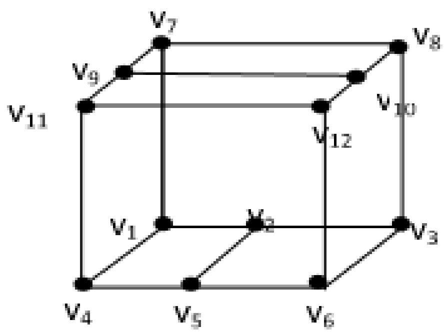


Figure 4.5

4.6 Chvatal Graph

Chavatal graph is an undirected graph with 12 vertices 24 edges discovered by VactavChavatel

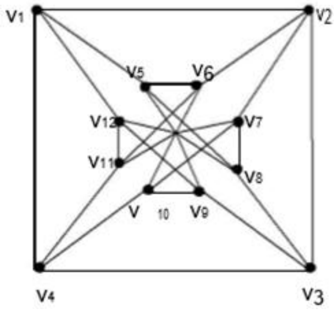


Figure 4.6

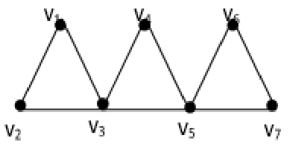
The neighborhood triple connected two out degree equitable domination number is 4

In above Fig $\{v_1, v_2, v_3, v_4\}$is a neighborhood triple connected two out degree equitable dominating set

4.7 Triangular Snake graph

The Triangular Snake graph is obtained from a path $v_1, v_2, v_3 ------v_p$ by joining v_i and v_{i-1} to a new vertex w_i for i=1,2,3-----p and denoted by mC_3 (where m denotes the number of times the cycle C_3) snake as shown in Fig 4.7

For the Triangular Snake G, $\gamma_{ntc\,2oe}\,(G\,)$=m



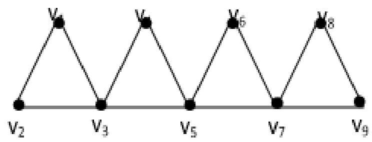


Figure 4.7(a) **Figure 4.7 (b)**

In Fig 4.7 (a) D= $\{v_1, v_4, v_6\}$ is a neighborhood triple connected two out degree equitable dominating set . In Fig 4.7 (b) D= $\{v_1, v_4, v_6, v_8\}$ is a neighborhood triple connected two out degree equitable dominating set.

4.8 Crown graph

Any cycle with a pendent edge attached at each vertex is shown in Fig 4.8 is called Crown graph and is denoted by $C^+{}_p$

For the Crown graph, $\gamma_{ntc\,2oe}\,(C^+{}_p\,)$=p

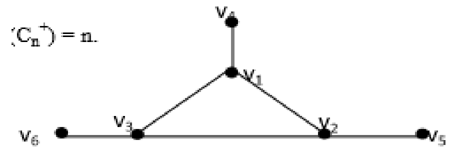


Figure 4.8

In Fig 4.8 D= $\{v_4, v_5, v_6\}$ is a neighborhood triple connected two out degree equitable dominating set .

4.9 Franklin graph

The Franklin graph 3- regular graph with 12 vertices and 18 edges as shown below in figure 4.9

For the Franklin graph G, $\gamma_{ntc\,2oe}\,(G\,)$=6

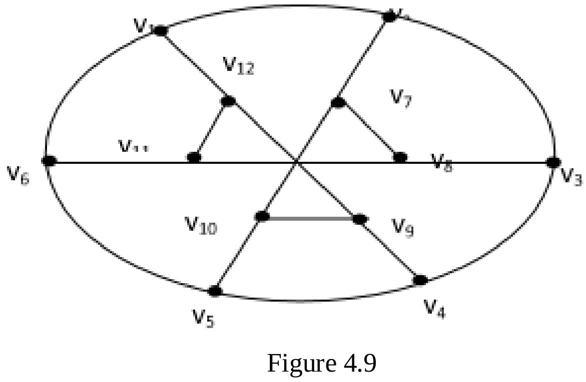


Figure 4.9

In fig.9 D= $\{v_7, v_8, v_9, v_{10}, v_{11}, v_{12}\}$ is a neighborhood triple connected two out degree equitable dominating set.

4.10Wagner graph

The Wagner graph is a 3- regular graph with 8 vertices and 12 edges as shown in figure 4.10. It is the 8 vertex Mobius ladder graph. Mobius ladder is a cubic circulant graph with an even number 'p' vertices formed from an n-cycle by adding edges connecting opposite pair of vertices in the cycle.

For the Wagner graph G, $\gamma_{ntc\,2oe}(G)$=3

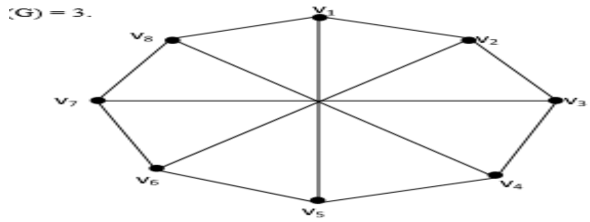


Figure 4.10

In Fig D= $\{v_1, v_2, v_3\}$ is a neighborhood triple connected two out degree equitable dominating set.

4.11 Frucht graph

The Frucht graph is a 3-regular graph with 12 vertices 18 edges and non trival symmetric show in Fig 4.11.For the Frucht graph G, $\gamma_{ntc\,2oe}(G)$=5

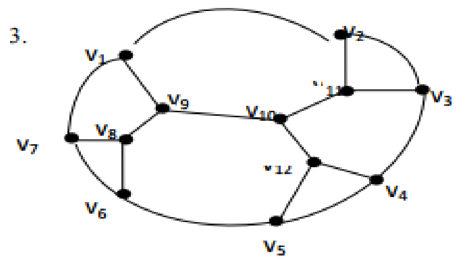


Figure 4.11

In Fig 4.11 D=$\{v_8, v_9, v_{10}, v_{11}, v_{12}\}$ is a neighborhood triple connected two out degree equitable dominating set.

4.12 Diigor Graph

The Diigor Graph is obtained cubic graph with 12 vertices and 18 edges as shown in Fig 4.12

For Diigor Graph G, $\gamma_{ntc\,2oe}(G)$=6

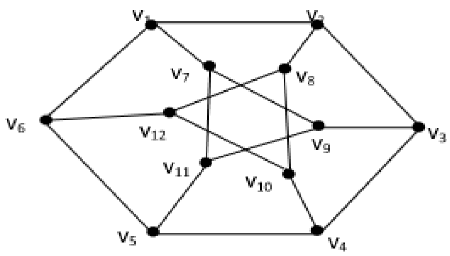


Figure 4.12

In Fig D=$\{v_7, v_8, v_9, v_{10}, v_{11,} v_{12,}\}$ is a neighborhood triple connected two out degree equitable dominating set.

4.13 Herschel graph

The Herschel graph is a bipartite undirected graph with 11 vertices and 18 edges shown in figure 4.13

For Herschel Graph G, $\gamma_{ntc\,2oe}(G)$=6

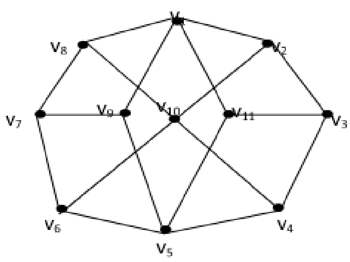


figure 4.13

In Fig 4.13 D=$\{v_1, v_9, v_{10}, v_{11}\}$ is a neighborhood triple connected two out degree equitable dominating set.

4.14 Hoff man tree

Any path with pendent edge attached at each vertex as shown in Fig 4.14 is called Hoff man tree and denoted by P_p^+ For any Hoffman tree $\gamma_{ntc\,2oe}(P_p^+)$=p

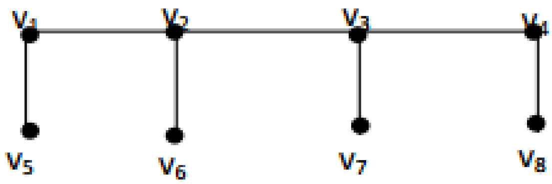


Figure 4.14

In above Fig D= $\{v_5, v_6, v_7, v_8\}$ is a neighborhood triple connected two out degree equitable dominating set.

V. Conclusion

We conclude the paper with a real life application. Suppose we are manufacturing a product and need to distribute the products in different major cities and sub cites so that we give dealership to each city and declare in that city distribute our products in to sub cities. The major cities may or may not be connected. It we draw this situation as a graph by considering the major cities and sub cities as vertices and the roadways connecting the cities as edges, the cities denote the dominating set say D of a constructed graph. If <N(D)> is triple connected in the constructed graph means the customer in the sub cites or any one of the other sub cities. And also the minimum cardinality of D minimizes that total cost. The above situation describes one of the real life applications of neighborhood triple connected two out degree equitable dominating set and neighborhood triple connected two out degree equitable domination of a graph. In this paper we find neighborhood triple connected two out degree equitable domination number for standard and some special graphs.

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