International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-6, August, 2019

Dominations In Semigraphs

D. Narmatha , N. Murugesan

Abstract: ***The semigraph generalization is more closely related to the axiom that the two edges in a semigraph have atmost one vertex in common, where as the hypergraph generalization is based on the consideration of an edge as a subset of two elements of the set of vertices of graphs. The concept of domination is an important parameter in graph theory. They provide a lot of space to the theoretical development of graphs and their applications. The dominations in semigraphs have no exception. In this paper, we study various dominations of semigraphs arising out of the corresponding adjacencies exist in semigraphs.***

ndex Terms: $a-$ ***Domination,*** $ca-$ ***Domination,*** $e-$ ***Domination,*** $1e-$ ***Domination, Independent Domination, Semigraph.***

I. INTRODUCTION

The dominating set plays an important role in computer and communication networks. Mainly mobile network, Wireless Sensor network and social network.

Let S is a pair (V,X) with nonempty set of vertices S and set of ordered n-tuples $n \geq 2$ of different vertices called edges of S satisfying the following conditions hold good :

i. every two edges have at most one vertex in common place.

ii. the edges $E_1=(u_1,u_2,.....u_m)$ and $E_2=(v_1,v_2,....v_n)$ are said to be identical iff

a. $m=n$ and

b. either $u_i=v_i$ or $u_i=v_{n-i+1}$ for $1\leq i\leq n$.

Revised Manuscript Received on October 30, 2019.
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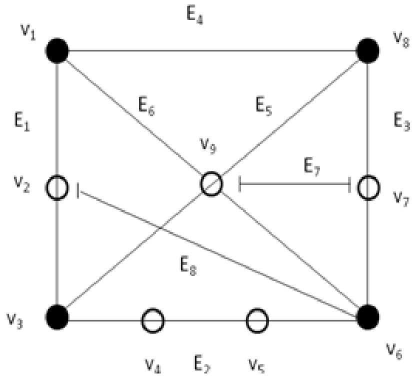

Consider a semigraph S where $V=\{v_1,v_2,....v_9\}$ and

$$X=\begin{Bmatrix}(v_1,v_2,v_3),(v_1,v_4,v_5,v_6),(v_6,v_7,v_8),(v_1,v_8)\\(v_8,v_9,v_3),(v_1,v_9,v_6),(v_9,v_7),(v_2,v_6)\end{Bmatrix}$$

The vertices v_1,v_3,v_6,v_8 are end vertices, v_4,v_5 are middle vertices and v_2,v_7,v_9 are middle-end vertices.

The order and size of a semigraph S is respectively denoted by the numbers $|V|$ and $|X|$. The number of vertices in E is represented as $|E|$, we also write, $V=V_e\cup V_m\cup V_{me}$ where V_e, V_m and V_{me} respectively represent the set of end, middle and middle-end vertices.

Semigraphs are introduced by E. Sampath kumar [10] in the year 2000, since then it has been an interesting field of research in graph theory. B. D. Acharya [1] discussed construction of semigraph from square matrices. B. Y. Bam and N. S. Bhave [3] have studied different types of degree sequences in semigraphs. S. P. Subbiah [11] have studied the relationship between topologies and discrete semigraphs. In 1998, N. Murugesan et.al [4] studied semigraphs and its properties. N. Murugesan and D. Narmatha [5,6,7,8] studied characteristic polynomials for e and r- adjacency matrix. Murugesan and D. Narmatha [9] studied ca-dominations for Cartesian product of path semigraphs.

II. PROPOSED METHODOLOGY

In this paper, $a-$ domination, $ca-$ domination, $e-$ domination, $1e-$ domination of path semigraphs and cycle semigraphs. Based on that, we find the above four types of dominations for semigraphs as well as independent dominations for all the semigraphs.

III. TYPES OF DOMINATIONS IN SEMIGRAPH

A. Four Types of Vertex Dominations in Semigraphs

B. Definition

A subset D of V is called $a-$dominating set of S if for all $v \in V-D$ there exist $u \in D$ such that u and v are adjacent. The minimum cardinality of an $a-$dominating set is called $a-$domination number of S and isrepresented by $\gamma_a(S)$. If D is $a-$dominating set of S and it has no proper subset is called minimal $a-$dominating set.

C. a-Dominations in Semigraphs

A vertex u in D is said to be $a-$ isolate in D, if no v in D such that u and v are $a-$ adjacent.

D. Lemma

An $a-$ dominating set $D \subseteq V_m$ is minimal iff every $u \in D$ is an $a-$isolate vertex in D.

The following is an important theorem in domination theory.

E. Ores Theorem[12]

An $a-$dominating set $D \subseteq V$ of S is minimal iff for all $u \in D$ one of the properties following holds good:

i. u is an $a-$isolate vertex of D.

ii. there exists another v in V such that $N_a(v) \cap D = \{u\}$.

F. Lemma

$\gamma_a(S-e) = \gamma_a(S)+k$, where $0 \le k \le |e|-1$.

Proof:

Consider a semigraph S. v is a minimal $a-$ dominating set and $|V| = n$. Suppose if S is disconnected and has a component contains only an edge e. In this case, consider the semigraph $S-e$. Surely, V contains exactly one vertex say u of e. In $S-e$, all vertices of e become $a-$isolates and hence all vertices of e are strongly dominated vertices in $S-e$. Suppose e contains the vertices $U = \{u, u_1, u_2, \ldots, u_m\}$ then $V \cup U$ is a minimal dominating set. Hence $\gamma_a(S-e) = |V|+|U|-1$, since u occurs twice as a member of V and also as a member of U. Hence $\gamma_a(S-e) = |V|+|U|-1 = \gamma_a(S)+|e|-1$. Therefore, $k = |e|-1$, where the edge e itself is a component in the disconnected semigraph S.

Suppose, if u is a strongly dominated vertex in e then in this case also $\gamma_a(S-e) = \gamma_a(S)+|e|-1$. Otherwise, if u is a strongly $a-$ dominated vertex but not in edge e, then $\gamma_a(S-e) = \gamma_a(S)$, i.e., $k=0$. This is also true when u is a weakly $a-$dominated. If u is a weakly $a-$dominated, and v is the alternative vertex u, and v is $a-$adjacent to the all the vertices of e, then $\gamma_a(S-e) = \gamma_a(S)$. Suppose if there are m vertices in e, not adjacent to v then $\gamma_a(S-e) = \gamma_a(S)+m$, where $m < |e|$ - number of vertices in e adjacent to v.

G. Lemma

Le $S=(V,X)$ be a simple connected semigraph only with p number of principal edges then $\gamma_a(S) \le \left\lceil \frac{p}{2} \right\rceil$. Equality arises iff S is a cycle semigraph.

Proof :

Cosider a simple connected semigraph containing only p number of principal edges. Then we have two cases.

i. there are exactly two end vertices of degree one.

ii. the degree of all the end vertices are of degree two.

Suppose if the semigraphs do not have any middle-end vertices, then they are simply paths or cycles. In this case $\gamma_a(S) < \left\lceil \frac{p}{2} \right\rceil$. If every edge has atleast one middle vertex then $\gamma_a(S) = \left\lceil \frac{p}{2} \right\rceil$.

H. Theorem

$\gamma_a(S) = \gamma(S_a)$

Proof :

Let S be a semigraph. Also let $\gamma_a(S) = n$, and $D = \{v_1, v_2, \ldots, v_n\}$ is a minimal $a-$ dominating set of S. Either v_i, $i = 1,2,\ldots,n$ is an $a-$ isolate in D otherwise there exists another v_j in D such that $N_a(v_j) \cap D = \{v_i\}$. In other words, every v_i in D is either $a-$isolate or there is atmost only one vertex in D in the neighbourhood of v_i. Let S_a be the adjacency graph of S. Any two vertices are adjacent in S_a iff the vertices are adjacent in S. If the vertices $v_1, v_2, \ldots., v_n$ are all end or middle-end vertices in S, then they are also in S_a, and form a minimal dominating set in S_a. Suppose, if a vertex v_i in S is a middle vertex in $E_i = (v_s, v_{s+1}, \ldots., v_i, \ldots, v_t)$, then we show that replacing v_i with v_s or v_t in D does not affect the minimum cardinality of the set D. If v_i is $a-$isolate in D, then the including v_s or v_t in place of v_i in D, play the role of dominating set with minimum cardinality. Note that if v_i is not an $a-$isolate in D, and there is a v_j in D such that $N(v_j) \cap D = \{v_i\}$, then v_j definitely should be either a middle vertex or a middle-end vertex, otherwise, $D - \{v_j\}$ is also a $a-$ dominating set. Hence , v_j must be an end vertex or middle-end vertex. In

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DOI: 10.35940/ijeat.F8060.088619
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this case, replace v_i with the other end vertex present in E_i. Hence $\gamma_a(S)=\gamma(S_a)$.

I. Observations

If S has no $a-$isolates then $\gamma_a(S)\le\frac{n}{2}$, where $n=\frac{|V(S)|}{2}$. In particular

i. $\gamma_a(S)\le\frac{|V_e(S)|}{2}$

ii. If $\deg(v)=|V_e(S)|-1$, $v\in V_e(S)$, then $\gamma_e(S)=1$.

iii. In particular, $\gamma_a(S)=\frac{|V_e(S)|}{2}$, if $|V_e(S)|$ is even, and $\deg(v)=2$, for all $v\in V_e(S)$.

J. Lemma

$$\gamma_a(P_{s(n)})=\begin{cases}\frac{n}{2} & \text{if } n \text{ is even}\\ \frac{n+1}{2} & \text{if } n \text{ is odd}\end{cases}$$

Proof :

Consider a path semigraph $P_{s(n)}$ with $n=2k,\ k=1,2,...$ edges, say $E_1,E_2,....,E_{2k}$, and $2k+1$ end vertices say $v_1,v_2,....,v_{2k+1}$, such that v_i,v_{i+1} are the end vertices of the edge E_i. First, it can be noticed that no $a-$ dominating set containing middle vertices cannot be a minimal $a-$ dominating set. Let $u_i\in E_i$ is a middle vertex then the set $D=\{u_1,u_2,...,u_{2k}\}$ is a $a-$dominating set in $P_{s(n)}$. Since, each neighbourhood of middle vertex contains all other vertices in that particular edge, the set D is a weakly $a-$dominating set in $P_{s(n)}$.

Also the vertex in u_i, $a-$dominates only the vertices present in the edge E_i, and none of the vertices in the adjacent edges E_{i-1} or E_{i+1}. It can also be seen that both of the u_i, $u_{i+1}\in N(V_{i+1})$, where $i=2r-1,\ r=1,2,...,k$. Hence $D'=\{v_2,v_4,...,v_{2k}\}$ is a minimal $a-$ dominating set and therefore $\gamma(P_{s(n)})=k=\frac{n}{2}$.

Suppose, if $n=2k-1,\ k=1,2,..$, then $P_{s(n)}$ will have $2k-1$ edges, say $E_1,E_2,...,E_{2k-1}$ and $2k$ end vertices $v_1,v_2,....,v_{2k}$ such that v_i,v_{i+1} are the end vertices. By similar argument as above it can be found that $D'=\{v_2,v_4,...,v_{2k}\}$ is a minimal $a-$dominating set. Hence $\gamma(P_{s(n)})=k=\frac{n+1}{2}$.

K. Lemma

$$\gamma_a(C_{s(n)})=\begin{cases}\frac{n}{2} & \text{if } n \text{ is even}\\ \frac{n+1}{2} & \text{if } n \text{ is odd}\end{cases}$$

Proof :

Let $n=2k$, then $P_{s(n)}$ has $n+1$ end vertices and $C_{s(n)}$ has n end vertices. The only difference between $P_{s(n)}$ and $C_{s(n)}$ is that the edges E_1 and E_n are adjacent in $C_{s(n)}$, but E_1 and E_n has one end vertex with degree one. The semigraphs $P_{s(n)}$ has $2k+1$ end vertices and $C_{s(n)}$ has $2k$ end vertices. In particular the vertex V_{2k+1} is present in $P_{s(n)}$, but it is not in $C_{s(n)}$. Hence the strong $a-$dominating set $D'=\{v_2,v_4,...,v_{2k}\}$ of $P_{s(n)}$ is also $a-$dominating set in $C_{s(n)}$.

Similarly we can see that the weak dominating set $D'=\{v_1,v_3,...,v_{2k-1}\}$ of $P_{s(n)}$, when n is odd which is also a minimal $a-$dominating set of $C_{s(n)}$.

L. Definition

An $a-$ independent dominating set is a set of vertices in S which is both $a-$ dominating and $a-$independent. The minimum size of an $a-$independent dominating set is called $a-$ independent domination number which is noted as $i_a(S)$. Similarly we can define $i_e(S)$, $i_{ca}(S)$ and $i_{1e}(S)$. R.B. Allan et. Al [2] studied independent domination number in 1978.

M. Lemma

$$i_a(P_{s(n)})=\begin{cases}\frac{n}{2} & \text{if } n \text{ is even}\\ \frac{n+1}{2} & \text{if } n \text{ is odd}\end{cases}$$

Proof :

The minimal $a-$dominating set identified for $P_{s(n)}$, is also a minimal $a-$ independent set. Hence, for path semigraph the independent number is same as $a-$domination number. Hence the lemma.

N. Lemma

$$i_a(C_{s(n)})=\begin{cases}\frac{n}{2} & \text{if } n \text{ is even}\\ \frac{n+1}{2} & \text{if } n \text{ is odd}\end{cases}$$

Proof :

We know that cycle semigraph $C_{s(n)}$ can be obtained from the path semigraph $P_{s(n)}$, by making E_1 and E_n are adjacent.

The minimal $a-$ dominating set identified for $P_{s(n)}$ when n is even, is also a $a-$ independent set. Therefore, $a-$ domination number is same as independent number for $C_{s(n)}$, when n is even. But the minimal $a-$dominating set obtained for $P_{s(n)}$, when n is odd is also a minimal $a-$ dominating set for $C_{s(n)}$, the set is also independent in $P_{s(n)}$, but it is not independent set in $C_{s(n)}$.

In $P_{s(n)}$, when n is odd, the minimal $a-$dominating set is the weak $a-$ dominating set $D' = \{v_1, v_3, ..., v_{2k-1}\}$ and the end vertices v_1 and v_{2k-1} are adjacent in $C_{s(n)}$. It can be seen that the vertex v_{2k-1} is included in D', only to cover the vertices present in E_{2k-2}. Hence if we include only middle vertex in E_{2k-2}, in place of v_{2k-1} in D', the resulting set is also a $a-$dominating set, and also an independent set. Hence the $a-$ domination number is same as independent number in $C_{s(n)}$, when n is odd. Hence the lemma.

IV. CA-DOMINATIONS IN SEMIGRAPHS

Let S be a semigraph. A subset D of V is called a $ca-$dominating set, if for all vertex $v \in V - D$, there exists $u \in D$ such that u and v are adjacent and consecutive as well. The set V is also called as $\gamma_{ca} -$ set of G.

The minimum number of a $ca-$dominating set is called as $ca-$ domination number of S, which is represented by $\gamma_{ca}(S)$.

A. Lemma

For any semigraph S, $\gamma_{ca}(S) = \gamma(S_{ca})$.

Proof :

We know that u, v are consecutively adjacent if the vertices are adjacent (i.e., they belong to same edge) and consecutive as well. Also we know that u, v are adjacent in S_{ca} if the vertices are consecutively adjacent in S. Hence $|V(S)| = |V(S_{ca})|$.

Also, for $u \in S$, if $N_{ca}(u) = \{u_1, ..., u_s\}$ in S, then $N(u)$ is also the set $\{u_1, ..., u_s\}$ in S_{ca}, and vice versa. Therefore, if $D = \{v_1, v_2, ..., v_n\}$ is a minimal $ca-$dominating set in S, $D = \{v_1, v_2, ..., v_n\}$ is a dominating set in S_{ca}. Hence $\gamma_{ca}(S) = \gamma(S_{ca})$.

B. Lemma

For any semigraph S, $\gamma_a(S) \le \gamma_{ca}(S)$.

C. Lemma

If m is the maximum number of middle vertices in an edge, then for $k = 1,2,3,...$

$$\gamma_{ca}(P_{s(n)}) = \begin{cases} n\left(\left\lceil \frac{m}{3} \right\rceil + 1\right) & \text{if } m = 3k-1 \\ n\left(\left\lceil \frac{m}{3} \right\rceil + 1\right) & \text{if } m = 3k \\ n\left(\left\lceil \frac{m}{3} \right\rceil\right) & \text{if } m = 3k+1 \end{cases} \quad \text{where } k = 1,2,..$$

D. Lemma

$$\gamma_{ca}(C_s) = \begin{cases} n\left(\frac{m}{3}\right) + 2 & \text{if } n = 3k \\ n\left\lceil \frac{m}{3} \right\rceil & \text{if } n = 3k-1, 3k-2 \end{cases}$$

$$\text{where } k = 1,2,3,...$$

…

V. E AND 1E- DOMINATIONS IN SEMIGRAPHS

A. Definition

Consider a semigraph. A subset D of V is called an $e-$dominating set, if for an end vertex $v \in V - D$, there exists $u \in D$ such that u and v are end vertices of an edge. $\gamma_e(S)$ is the $e-$domination number of S.

B. Lemma

$$\gamma_e(P_{s(1)}) = \gamma_e(P_{s(2)}) = 1$$

$$\gamma_e(P_{s(n)}) = \begin{cases} \frac{n}{3} + 1 & \text{if } n = 3k, \\ \left\lceil \frac{n}{3} \right\rceil & \text{if } n = 3k+1, 3k+2 \end{cases} \quad \text{where } k = 1,2,...$$

C. Lemma

$$\gamma_e(C_{s(n)}) = \left\lceil \frac{n}{3} \right\rceil$$

D. Definition

Let S be a semigraph. A subset D of V is called an $1e-$dominating set, if for an end vertex $v \in V - D$, there exists $u \in D$ such that u and v belong to the same edge and atleast one of them is an end vertex of that edge.

$\gamma_{1e}(S)$ is the minimum $1e-$domination number of S.

E.Lemma

$$\gamma_{1e}(P_{s(n)}) = \begin{cases} \frac{n}{2} & \text{if } n \text{ is even} \\ \frac{n+1}{2} & \text{if } n \text{ is odd} \end{cases}$$

$$\gamma_{1e}(C_{s(n)}) = \begin{cases} \frac{n}{2} & \text{if } n \text{ is even} \\ \frac{n+1}{2} & \text{if } n \text{ is odd} \end{cases}$$

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DOI: 10.35940/ijeat.F8060.088619
Journal Website: www.ijeat.org

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Proof :

The proof is similar to $a-$ dominating set. Since, in $a-$ dominating set alternate end vertex dominates all the other vertices. Similarly, in $1e-$ dominating set alternate end vertices is enough for dominate all the end vertices. Hence

The following lemma is discussed in [12].

F. Lemma

$$\gamma_a(S) = \gamma_{1e}(S)$$

G. Lemma

Consider a semigraph $S=(V,X)$ such that $|X|=1$; $|V|=n$. Then $\gamma_a(S)=\gamma_e(S)=\gamma_{1e}(S)=1$ and $\gamma_{ca}(S)=\left\lceil \frac{n}{3} \right\rceil$.

Proof:

Let $X=|E|$, and $E=(u_1,u_2,\ldots\ldots,u_n)$. Then $D=\{u_1\}$ is a minimal dominating set with respect to the definitions of adjacent, $1e-$adjacent, and $e-$adjacent.

It can be found that the sets $D_1=\{u_2,u_5,\ldots\ldots,u_n\}$, $D_2=\{u_2,u_5,\ldots\ldots,u_{n-1}\}$, $D_3=\{u_2,u_5,\ldots\ldots,u_{n-1}\}$ are minimal $ca-$ dominating sets when $n=3r+1,3r+2,3r+3$, $r=2,3,4\ldots.$ respectively. Also when $n=2,3$ the set $\{u_2\}$, and $n=4,5$ the set $\{u_2,u_4\}$, and $n=6$, the set $\{u_2,u_5\}$ are minimal $ca-$ dominating sets. Hence $\gamma_{ca}(S)=\left\lceil \frac{n}{3} \right\rceil$.

Types of semigraph	γ_a	γ_e	γ_{1e}	γ_{ca}
Regular Semigraph	$\leq \left\lceil \frac{m}{2} \right\rceil$	$\leq \left\lceil \frac{n_e}{3} \right\rceil$	$\leq \left\lceil \frac{n_e}{3} \right\rceil$	$\leq \left\lceil \frac{n}{3} \right\rceil$
r- Unifrom Semigraph	$\leq \left\lceil \frac{n}{3} \right\rceil$	$\leq \left\lceil \frac{n_e}{2} \right\rceil$	$\leq \left\lceil \frac{n_e}{2} \right\rceil$	$\leq \left\lceil \frac{n}{3} \right\rceil$
Edge Complete Semigraph	≤ 2	1	1	$\geq \left\lceil \frac{n}{3} \right\rceil$
Forest Semigraph	$\leq m$	$\leq m$	$\leq m$	$\leq \frac{n}{2}$
Star Semigraph	1	$\leq \frac{n}{2}$	1	$\leq \left\lceil \frac{n}{3} \right\rceil$
Wounded Spider Semigraph	$\leq t-2$	$\leq t-2$	$\leq t-2$	$\leq \left\lceil \frac{n}{2} \right\rceil$
Claw Semigraph	1	3	1	$\leq \left\lceil \frac{n}{2} \right\rceil$
Dendroid Semigraph	$\leq m$	$\leq m$	$\leq m$	$\leq \frac{n}{2}$

Table : Domination numbers of special graphs

VI. RESULTS

In this paper, the generalized dominating sets for path and cycle semigraphs are calculated and proved and it shown below.

$$\gamma_a(P_{s(n)})=\gamma_a(C_{s(n)})=\begin{cases}\frac{n}{2} & \text{if } n \text{ is even}\\ \frac{n+1}{2} & \text{if } n \text{ is odd}\end{cases} \quad \text{and}$$

$$i_a(P_{s(n)})=i_a(C_{s(n)})=\begin{cases}\frac{n}{2} & \text{if } n \text{ is even}\\ \frac{n+1}{2} & \text{if } n \text{ is odd}\end{cases}$$

$$\gamma_{ca}(P_{s(n)})=\begin{cases} n\left(\left\lceil \frac{m}{3}\right\rceil+1\right) & \text{if } m=3k-1\\ n\left(\left\lceil \frac{m}{3}\right\rceil+1\right) & \text{if } m=3k\\ n\left(\left\lceil \frac{m}{3}\right\rceil\right) & \text{if } m=3k+1\end{cases}$$

$where\, k=1,2,..$

$$\gamma_{ca}(C_s)=\begin{cases} n\left(\frac{m}{3}\right)+2 & \text{if } n=3k\\ n\left\lceil \frac{m}{3}\right\rceil & \text{if } n=3k-1,3k-2\end{cases}$$

$$\gamma_e(P_{s(1)})=\gamma_e(P_{s(2)})=1$$

$$\gamma_e(C_{s(n)})=\left\lceil \frac{n}{3}\right\rceil$$

$$\gamma_e(P_{s(n)})=\begin{cases}\frac{n}{3}+1 & \text{if } n=3k,\\ \left\lceil \frac{n}{3}\right\rceil & \text{if } n=3k+1,3k+2\end{cases}$$

$where\, k=1,2,\ldots$

$$\gamma_{1e}(P_{s(n)})=\gamma_{1e}(C_{s(n)})=\begin{cases}\frac{n}{2} & \text{if } n \text{ is even}\\ \frac{n+1}{2} & \text{if } n \text{ is odd}\end{cases}$$

VII. CONCLUSION

The four types of domination numbers are defined in this paper. Special properties of these domination numbers and independent domination numbers have been studied. The nature of domination numbers of some special semigraphs have also been discussed.

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DOI: 10.35940/ijeat.F8060.088619
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