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ON THE FORCING MONOPHONIC GD, GEODETIC GD AND STEINER GD NUMBER OF A GRAPH

[1]J. Suja and [2]V. Sujin Flower

[1]Register Number 20223042092017, Research Scholar,

Department of Mathematics, Holy Cross College, Nagercoil - 629 001, India.

email: jesinsuja@gmail.com

[2]Assistant Professor, Department of Mathematics,

Holy Cross College, Nagercoil - 629 001, India.

email: sujinflower@gmail.com

Affiliated to Manonmaniam Sundaranar University, Abishekapatti,

Tirunelveli-627 012, Tamil Nadu, India

Abstract

The forcing geodetic, Steiner and monophonic global domination (GD) numbers of a graph are examined in this research. It is established that there is a connected graph G such that $f_{\overline{\gamma}_m}(G) = f_{\overline{\gamma}_g}(G) = f_{\overline{\gamma}_s}(G) = a$, for every integer $a \geq 0$. Moreover, it is established that for every integer $a \geq 0$ there exists a connected graph G such that $f_{\overline{\gamma}_m}(G) = a, f_{\overline{\gamma}_g}(G) = f_{\overline{\gamma}_s}(G) = 0$.

Keywords: Geodetic Number, Monophonic number. Geodetic GD, Steiner number, Steiner GD number, Monophonic GD number.

Introduction

Consider the graph $G = (V, E)$, where the vertex and the edge set is $V(G)$ and $E(G)$ (or V and E). Additionally, we proved that G has size $m = |E(G)|$ and order $n = |V(G)|$. We examine [2] for a list of fundamental graph theoretic terms. A vertex v is regarded as extreme if the subgraph formed by its neighbors is complete. Therefore, a vertex v is a universal vertex if $\deg_G(v) = n - 1$.

Let u and v be the vertices of a graph G that is connected. A $u - v$ geodesic is a substitute for the shortest $u - v$ path. The length of a u-v geodesic in G is the (shortest path) distance and if the graph is obvious from the context, it is represented by the $d(u, v)$ or $d_G(u, v)$. Such that G's diameter is the maximum separation between each pair of vertices is referred as $d(G)$ or d respectively. An edge connecting two non-adjacent vertices of a path P is referred to as a chord. A chord-less $u - v$ path is represented as a monophonic path. All vertices residing in a $u - v$ monophonic path, are included in the closed interval $J[u, v]$ for two vertices v and u. When v and u are next to each other, $J[u, v] = \{u, v\}$. Let $J[M] = \cup_{u,v \in M} J[u, v]$ for a set M of vertices. In such case, $M \subseteq J[M]$. A monophonic set of G is

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described as a set $M \subseteq V(G)$ if $J[M] = V$. The lowest order of a monophonic set of G is its monophonic number $m(G)$. A m-set of G is any monophonic set of order $m(G)$ [1, 2].

Since any vertex in $V \setminus D$ is adjacent to atleast one vertex of D, then the subset $D \subseteq V(G)$ is represented as a dominant set. The lowest cardinality of such dominating sets of G is indicated by the domination number, $\gamma(G)$. Hence, a γ-set of G is a minimum dominant set. In [3], the concept of dominance was examined. If D is a dominating set in G and $\overline{G}$, then a subset $D \subseteq V$ is defined to as a GD set in G. The least cardinality of a minimum GD set in G is the GD number $\overline{\gamma}(G)$. In [3], the idea of GD in graphs was first presented. If M is both a monophonic set and a GD set of G, then $M \subseteq V$ is a monophonic GD set of G. The monophonic GD is referred as $\overline{\gamma}_m(G)$, is the minimal cardinality of a monophonic GD set of G. A $\overline{\gamma}_m$-set of G is a monophonic GD set of cardinality $\overline{\gamma}_m(G)$. In [4], the idea of monophonic globally domination in graphs was first presented. The sequel makes use of the following theorems.

A geodesic is a $x - y$ path of length $d(x, y)$. A $u - v$ geodesic is a $u - v$ path of length $d(u, v)$. If v is an internal vertex of P, then v is said to reside on a geodesic P. For a non-empty set $S \subseteq V(G)$, $I[S] = \cup_{x,y \in S} I[x, y]$. The closed interval $I[x, y]$ is composed of x, y, and all vertices lying on some $x - y$ geodesic of G. A geodetic set of G has a geodetic number, denoted as $g(G)$, which is its lowest cardinality. If $I[S] = V(G)$ then a set $S \subseteq V(G)$ in a connected graph G is a geodetic set of G. In [1, 3, 4], the geodetic idea was examined. The term "geodetic GD set of G" refers to a geodetic set W of a linked graph G that is both a geodetic set and a GD set is represented by $\overline{\gamma}_g(G)$, is the lowest cardinality of a geodetic GD set.

The Steiner distance d(W) of a connected graph's nonempty collection W of vertices When a connected subgraph of G contains W, its smallest size is G. A subgraph that is a tree by necessity is called a Steiner tree with respect to W, or Steiner W-tree. Such that when $W = \{u, v\}$ then $d(W) = d(u, v)$. $S(W)$ represents the set of all vertices of G that are located on a Steiner W-tree. If $S(W) = W$ then $G[W]$ is connected. Therefore W is referred to as a Steiner set for G if $S(W) = V$.

The Steiner set of minimum cardinality, or Steiner number $S(G)$ of G, is often referred to as an s-set of G or a minimum Steiner set. These concepts were studied in [1,2,4,5,6]. In G, the set $D \subseteq V$ of vertices is called a dominating set when each vertex $x \in V$ is either a member of D or near an element of D. A subset $D \subseteq V$ is called a GD set in G if it is a dominating set of both G and $\overline{G}$. For a GD set in G, the GD number $\overline{\gamma}(G)$ is its lowest cardinality. These concepts were studied in [3,8,9]. If W is both a Steiner set and a GD set of G, then a Steiner GD set of a linked graph G is defined as a Steiner set W of G. A Steiner GD set's lowest cardinality is represented by the Steiner GD number, which is written as $\overline{\gamma}_s(G)$. In [7], these ideas were examined. The sequel makes use of the following theorems.

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Theorem 1.1. [7] Each Steiner GD set of G contains every extreme vertex of a connected graph G.

Theorem 1.2. [7] Assume that G is a connected graph and that W is the collection of all geodetic GD sets of G. Subsequently $f_{\overline{\gamma}_g}(G) \leq \overline{\gamma}_g(G) - |W|$.

Theorem 1.3. [7] Every geodetic global dominating set of a connected graph G contains every extreme vertex (universal vertex).

On The Forcing Monophonic Global Domination, Geodetic Global Domination and Steiner Global Domination Number of a Graph

Theorem 2.1. For any integer $a \geq 0$, there exists a connected graph G such that $f_{\overline{\gamma}_m}(G) = f_{\overline{\gamma}_g}(G) = f_{\overline{\gamma}_s}(G) = a$.

Proof. Assume $P: x, y, z$ be a three-vertex path. On two vertices, consider $P_i: u_i, v_i$ $(1 \leq i \leq a)$ be duplicates of the path. Let H be the graph is formed by adding the edges yu_i and zv_i $(1 \leq i \leq a)$ to P and to each P_i $(1 \leq i \leq a)$. Let G be the graph obtained from H by adding the vertices $z_1, z_2, \dots, z_{b-a-1}$ and presenting the novel edge, z_i $(1 \leq i \leq b - a - 1)$ (Figure 1).

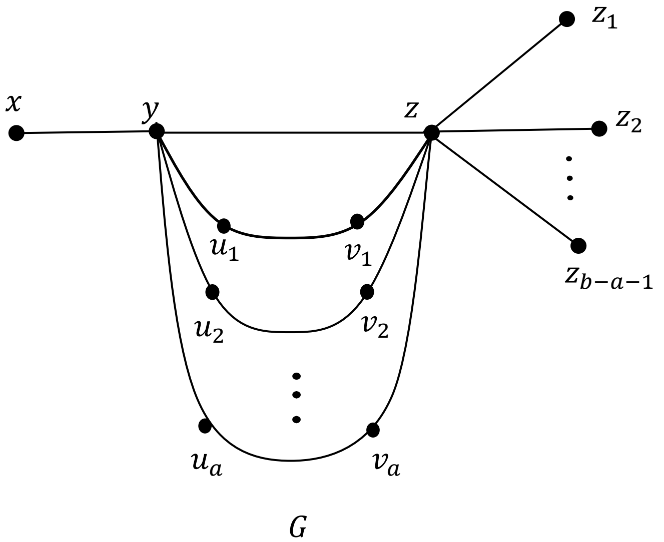

Figure 1. Forcing Monophonic Global Domination of G

Initially, it is demonstrated that $\overline{\gamma}_m(G) = b$. Let $Z = \{x, z_1, z_2, \dots, z_{b-a-1}\}$ constitute the set of end vertices of G. For any monophonic GD set of G, Z is a subset, by Theorem 1.1, so $\overline{\gamma}_m(G) \geq b - a - 1 + 1 = b - a$. However, $J[Z] \neq V(G)$, Z is not a monophonic global dominant set of G. Such that, $H_i = \{u_i, v_i\}$ $(1 \leq i \leq a)$. Every, H_i $(1 \leq \mathrm{i} \leq a)$ has at least one vertex, making it an easily global monophonic dominant set. Therefore $\overline{\gamma}_m(G) \geq b - a + a = b$, such that $M = Z \cup \{u_1, u_2, \dots, u_a\}$. Therefore, if M is a monophonic GD set of G, then $\overline{\gamma}_m(G) = b$.

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It is demonstrated that, $f_{\overline{\gamma}_m}(G) = a$. Then $f_{\overline{\gamma}_m}(G) \le \overline{\gamma}_m(G) - |Z| = b-(b-a) = a$, according to Theorem 1.2, Given that $\overline{\gamma}_m(G) = b$ and that each $\overline{\gamma}_m$-set of G contains Z, it is evident that each $\overline{\gamma}_m$-set of G has the form $M = Z \cup \{c_1, c_2, \ldots, c_a\}$, where $c_i \in H_i$ $(1 \le i \le a)$. With $|T| < a$, let T be a proper subset of M. Next, a vertex, c_j $(1 \le j \le a)$ such that $c_j \notin$ T exists. Consider b_j to be a vertex of H_j that is different from c_j. Therefore, M_1=$\{ b_j \cup (M - \{c_j\}) \}$ is a $\overline{\gamma}_m$-set that correctly contains T. Thus M is not the unique $\overline{\gamma}_m$-set containing T. Hence, T is not a subset of M that is forced. This holds true for every minimum $\overline{\gamma}_m$-set of G, so, $f_{\overline{\gamma}_m}(G) = a$. Analogously, $f_{\overline{\gamma}_g}(G) = f_{\overline{\gamma}_s}(G) = a$.

Theorem 2.2. For any integer $a \ge 0$, there exists a connected graph G such that $f_{\overline{\gamma}_m}(G) = 0, f_{\overline{\gamma}_g}(G) = f_{\overline{\gamma}_s}(G) = a$.

Proof. Consider a path on three vertices, $P: u, v, w$. On two vertices, let, $P_i: x_i, y_i$ $(1 \le i \le a)$ be a duplicate of the path. Let H be the graph that is generated by combining the edges ux_i and wy_i $(1 \le i \le a)$ to P and P_i $(1 \le i \le a)$. Consider G to be the graph that is generated by taking H and adding the additional vertex $z_1, z_2, \ldots, z_{b-a-1}$ and the edge wz_i $(1 \le i \le b-a-1)$ (Figure 2).

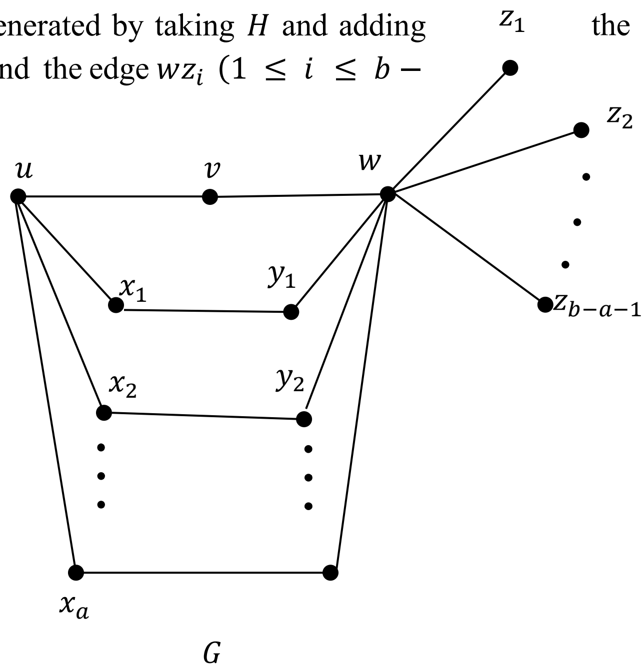

Figure 2. Geodetic Global Domination of *G*

Initially, it is demonstrated that $f_{\overline{\gamma}_m}(G) = 0$. Letting $Z = \{z_1, z_2, \ldots, , z_{b-a-1}\}$ represent the set of G's end end vertices. Z is a subset of each monophonic GD set of G, by Theorem 1.1. Additionally, $\overline{\gamma}_m(G) \ge b-a-1$ since $J[Z] \ne V(G)$, Z is not a monophonic GD set of G. Since $Z \cup \{x\}$, $x \notin Z$ is not a monophonic GD set of G, it can be readily confirmed that $\overline{\gamma}_m(G) \ge b-a-1$. Let, $Z_1 = Z \cup \{u, w\}$. In such case $\overline{\gamma}_m(G) = 0$. Since Z_1 is the only $\overline{\gamma}_m$-set of G and Z is a subset of all geodetic GD sets of G by Theorem 1.3, $\overline{\gamma}_g(G) \ge b-a-1$.

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Consider the following $Q_i = \{x_i, y_j\}$ $(1 \leq i \leq a)$. Clearly, every GD set has at least one vertex from Q_i $(1 \leq i \leq a)$ and the vertex, u. Consequently $\overline{\gamma}_g(G) \geq b - a - 1 + 1 + a = b$. Considering that $S = Z \cup \{u\} \cup \{x_1, x_2, \ldots, x_a\}$. If S is a $\overline{\gamma}_g$-set of G, then $\overline{\gamma}_g(G) = b$, $f_{\overline{\gamma}_g}(G) \leq b - |Z \cup \{u\}| = a$ for Theorem 1.3. Since $\overline{\gamma}_g(G) = b$ and every $\overline{\gamma}_g$-set of G contains $Z \cup \{u\}$, it is evident that each $\overline{\gamma}_g$-set of G is of the form $M = Z \cup \{u\} \cup \{c_1, c_2, \ldots, c_a\}$, where, $c_i \in H_i$ $(1 \leq i \leq a)$. With $|T| < a$, let T be a proper subset of M. Next, a vertex, c_j $(1 \leq j \leq a)$ such that, $c_j \notin$ T exists. Consider, b_j to be a vertex of H_j, that is different from c_j. Therefore, $M_1 = (M - \{c_j\}) \cup \{b_j\}$ is a $\overline{\gamma}_g$-set that correctly contains T. Hence, T is not a forcing subset of M. This holds true for every minimum $\overline{\gamma}_g$-set of G, so $f_{\overline{\gamma}_g}(G) = a$. In a similar manner, it shows that $f_{\overline{\gamma}_s}(G) = a$.

Theorem 2.3. For every integers $a \geq 0$, there exists a connected graph G with respect to $f_{\overline{\gamma}_m}(G) = a, f_{\overline{\gamma}_g}(G) = f_{\overline{\gamma}_s}(G) = 0$.

Proof. Consider a path on three vertices, $P: x, y, z$. Let $(1 \leq i \leq a)$ be a duplicate of the path on three vertices, and let, $P_i: r_i, s_i, t_i$. Let H be the graph that is produced by adding the edges xr_i and yt_i $(1 \leq i \leq a)$ to P and P_i $(1 \leq i \leq a)$. Let G be the graph obtained from H by inserting the edge yz_i $(1 \leq i \leq b - a - 1)$ and the new vertices $z_1, z_2, \ldots, z_{b-a-1}$. Figure 3 shows the graph G.

Initially, it is established that, $f_{\overline{\gamma}_m}(G) = a$. Assuming $Z = \{x, z_1, z_2, \ldots, z_{b-a-2}\}$ represent the set of G's end vertices. Such that Z is a subset of each monophonic GD set of G, by Theorem 1.1 and so $\overline{\gamma}_m(G) = b - a - 1$. There is no monophonic global dominant set of G since $J[Z] \neq V(G)$. Suppose that, $H_i = \{s_i, t_i\}(1 \leq i \leq a)$. Clearly, any global monophonic dominant set has atleast one vertex from any $H_i(1 \leq i \leq a)$ of the following such that $\overline{\gamma}_m(G) \geq b - a - 1 + 1 + a = b$. Consider $M = Z \cup \{z\} \cup \{s_1, s_2, \ldots, s_a\}$ instead. Consequently, M is a global monophonic dominant set of G, hence $\overline{\gamma}_m(G) = b$.

It is then verified that, $f_{\overline{\gamma}_m}(G) = a$. Hence according to Theorem 1.2, $f_{\overline{\gamma}_m}(G) \leq \overline{\gamma}_m(G) - |Z| \cup \{x\} = b - (b - a + 1 - 1) = a$. Following that $\overline{\gamma}_m(G) = b$ and each $\overline{\gamma}_m$-set of G contains $Z \cup \{x\}$, it is evident that every $\overline{\gamma}_m$-set of G is of the type $M = Z \cup \{x\} \cup \{c_1, c_2, \ldots, c_a\}$, where $c_i \in H_i$ $(1 \leq i \leq a)$. With, $|T| < a$, consider T be a proper subset of M. Next, a vertex, c_j $(1 \leq j \leq a)$ such that, $c_j \notin$ T exists. Consider, b_j to be a vertex of H_j that is different from, c_j. Therefore, $M_1 = (M - \{c_j\}) \cup \{b_j\}$ is a $\overline{\gamma}_m$-set that correctly contains T. Hence, T is not a subset of M that is forced. This holds true for any minimum $\overline{\gamma}_m$-set of G, so $f_{\overline{\gamma}_m}(G) = a$.

Following that, it is established that, $f_{\overline{\gamma}_g}(G) = 0$. A subset of each global geodetic set of G is Z, from Theorem 1.3. Therefore, $J[Z] \neq V(G)$, Z is not a geodetic set of G. There is no doubt that every global geodetic set of G only has the vertex S_i, from any $H_i(1 \leq i \leq a)$. Consequently, $\overline{\gamma}_g(G) \geq -1 + 1 + a + b - a = b$. Suppose $S = Z \cup \{x\} \cup \{s_1, s_2, \ldots, s_a\}$.

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Thus, S is a unique $\overline{\gamma}_g$-set of G since $\overline{\gamma}_g(G) = b$ and$f_{\overline{\gamma}_g}(G) = 0$. Similarly, it can be demonstrated that $f_{\overline{\gamma}_s}(G) = 0$.

Theorem 2.4. For each integer $a \geq 0$, there exists a connected graph G with respect to $f_{\overline{\gamma}_m}(G) = 0, f_{\overline{\gamma}_g}(G) = a, f_{\overline{\gamma}_s}(G) = 0$.

Proof. Consider a path on six vertices, $P: u, v, w, x, y, z$. Let $(1 \leq i \leq a)$ be a replica of the path on three vertices, and let $P_i: u_i, v_i, w_i$. Let H be the graph formed from P and P_i $(1 \leq i \leq a)$ by adding the edges uu_i, yw_i, wu_i, wv_i and ww_i $(1 \leq i \leq a)$. Let G be the graph that is generated by taking H and adding the new vertices $z_1, z_2, \ldots, z_{b-a-2}$, and adding the edge yz_i $(1 \leq i \leq b-a-2)$.

Initially, it is illustrated that $f_{\overline{\gamma}_m}(G) = 0$. Considering $Z = \{u, z_1, z_2, \ldots, , z_{b-a-2}\}$ represent the collection of G's end vertices. Every monophonic GD set of G has a subset of Z, according to Theorem 1.1. Because $J[Z] \neq V(G)$, Z is not a monophonic GD set of G, $\overline{\gamma}_m(G) = b - a - 2$. It is simple to confirm that x is a member of all global monophonic dominant sets. Assume that $Z_1 = Z \cup \{x\}$. The global monophonic dominating set of G is then Z_1. Hence $\overline{\gamma}_m(G) = 0$, since Z_1 is a dominating set of G and $\overline{G}$. Thus Z_1 is a unique minimal GD set of G. It is then established that $\overline{\gamma}_g(G) = a$. The fact that Z_1 is a subset of each geodetic GD set of G is readily apparent. The geodetic GD set of G is not $I[Z_1] \neq V(G)$, Z_1. Consider the following $H_i = \{u_i, v_i, w_i\}$ $(1 \leq i \leq a)$. The presence of at least one vertex from each, H_i $(1 \leq i \leq a)$ in every global geodetic dominating set can be readily confirmed, and thus $\overline{\gamma}_g(G) \geq b - a + a = b$. For example, let, $S_1 = Z_1 \cup \{u_1, u_2, \ldots, u_a\}$. Therefore S_1 is a $\overline{\gamma}_g$-set of G, hence $\overline{\gamma}_g(G) = b$.

Following that, $f_{\overline{\gamma}_g}(G) = a$ is proved. By Theorem 1.3, $f_{\overline{\gamma}_g}(G) \leq \overline{\gamma}_g(G) - |Z_1| = b - (b - a) = a$. Such that, $\overline{\gamma}_g(G) = b$ and any $\overline{\gamma}_g$-set of G contains Z_1, it is evident that each $\overline{\gamma}_g$-set of G has the form $S = Z_1 \cup \{u_1, u_2, \ldots, u_a\}$, where, $u_i \in H_i$ $(1 \leq i \leq a)$. Since T is a valid subset of S with $|T| < a$. Then, a vertex like u_i $(1 \leq i \leq a)$ there exists $u_i \notin$ T. In contrast to, c_j, let, b_j be a vertex of H_j. This means that $\overline{\gamma}_g$-set that correctly contains T is $S_1 = (S - \{u_i\}) \cup \{b_j\}$. Consequently, T is not a forcing subset of S. It follows that, $f_{\overline{\gamma}_g}(G) = a$, hence this is true for all minimum $\overline{\gamma}_g$-set of G.

It is demonstrated that $\overline{\gamma}_s(G) = 0$. The fact that Z_1 is a subset of each Steiner GD set of G is readily apparent. There is no Steiner global dominant set of such that $S(Z_1) \neq V(G)$, Z_1. It is readily apparent that the vertex v_i, from each H_i $(1 \leq i \leq a)$. Then W is the only element present in every Steiner GD set of G. For instance, consider $W = Z_1 \cup \{v_1, v_2, \ldots, v_a\}$. After that, W is the only Steiner GD set of G that is unique, therefore $\overline{\gamma}_s(G) = 0$.

Theorem 2.5. For every integer $a \geq 0$, there exists a connected graph G such that $f_{\overline{\gamma}_m}(G) = 0, f_{\overline{\gamma}_g}(G) = 0, f_{\overline{\gamma}_s}(G) = a$.

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Proof. Consider a path on nine vertices, $P: r_1, r_2, r_3, r_4, r_5, r_6, r_7, r_8, r_9$. Let, $P_i: x_i, y_i, u_i, v_i, w_i$ $(1 \leq i \leq a)$ as a duplicate of the path on five vertices. Consider H be the graph that is generated from P and P_i $(1 \leq i \leq a)$ by adding the edges yy_i, yu_i, yv_i, r_2x_i and r_8w_i $(1 \leq i \leq a)$. Let G be the graph that is generated by taking H and adding the new vertices x and z, as well as the edge yz, xr_5. Figure 3 displays the graph G.

Initially, it is verified that, $f_{\overline{\gamma}_m}(G) = 0$. Consider that the set of end vertices of G is $Z = \{x, z, r_1, r_9, r_5, y\}$. Every monophonic global dominant set of G has a subset of Z, according to Theorem 1.1. Considering that $J[Z] = V(G)$, Z is the only monophonic set of G, and therefore $f_{\overline{\gamma}_m}(G) = 0$.

It is established that $f_{\overline{\gamma}_g}(G) = 0$. Every geodetic GD set of G has a subset of Z, according to Theorem 1.3. Considering that $I[Z] = V(G)$, Z is the only geodetic set of G, $f_{\overline{\gamma}_g}(G) = 0$.

Afterward, it is established that, $f_{\overline{\gamma}_s}(G) = a$. Z is a subset of each Steiner GD set of G. There is no Steiner set of G such that $S(Z) \neq V(G)$, Z. For example, let, $H_i = \{y_i, u_i, v_i\}$ $(1 \leq i \leq a)$. The fact that each Steiner GD set of G has exactly one vertex from each of the following is readily apparent: $(1 \leq i \leq a)$ and so $\overline{\gamma}_s(G) \geq a + b$. Consider $W = Z \cup \{y_1, y_2, \dots, y_a\}$. Therefore $S(Z) =\neq V(G)$ hence $\overline{\gamma}_s(G) = a$.

Following that, it is demonstrated that $f_{\overline{\gamma}_s}(G) = a$. As per the Theorem 1.3, $f_{\overline{\gamma}_s}(G) \leq b + a - |Z| = b + a - b = a$. Since, $\overline{\gamma}_g(G) = a + b$ and for any $\overline{\gamma}_s$-set of G contains, Z_1, it is evident that every, $\overline{\gamma}_s$-set of G has the form $W = Z \cup \{y_1, y_2, \dots, y_a\}$, where, $y_i \in H_i$ $(1 \leq i \leq a)$. Assume that T is a valid subset of W when $|T| < a$. Afterwards, a vertex y_i $(1 \leq i \leq a)$ exists, $y_i \notin$ T. Let b_j be a vertex of H_j distinct from c_j. This means that a $\overline{\gamma}_s$-set that correctly contains T is $W_1 = (W - \{y_i\}) \cup \{b_j\}$. Consequently, T is not a forcing subset of W. It follows that, $f_{\overline{\gamma}_s}(G) = a$. Therefore it is minimum $\overline{\gamma}_s$-set of G.

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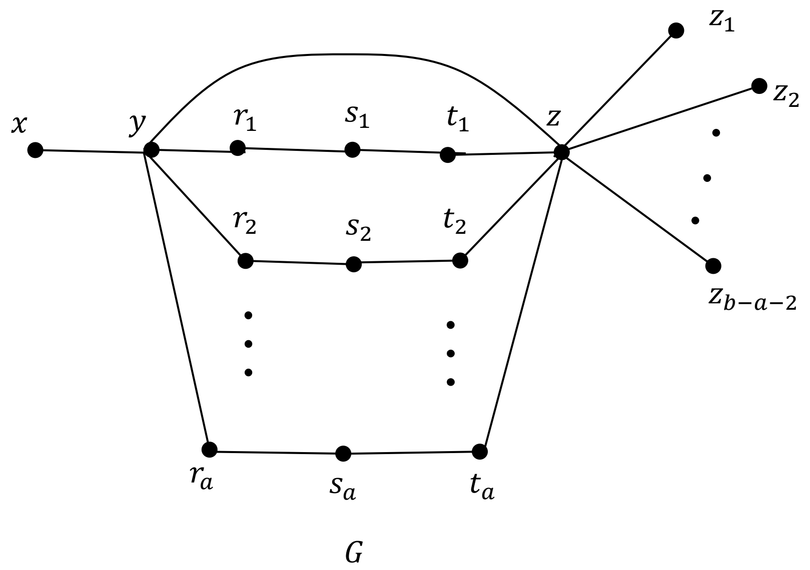

Figure 3. Steiner Global Domination Number of G

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