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Exploration of CCD-Number for Some Specific Graphs

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Abstract

Objectives: A dominating set S of a graph G is said to be a complementary corona dominating set (CCD-set) if every vertex in $< V-S >$ is either a pendent vertex or a support vertex. The smallest cardinality of a CCD-set is called the CCD-number and is denoted by $\gamma_{CCD}(G)$. In this article, we explore the CCD-number for some specific graphs. **Methods:** We are finding the upper bound of $\gamma_{CCD}(G)$ and the lower bound of $\gamma_{CCD}(G)$. We prove that both the upper and lower bound are equal for the given graphs. **Findings:** In this article, we obtained the CCD-number for some specific graphs. **Novelty:** Complementary corona dominating set is a vertex set such that the induced subgraph of the complementary set is isomorphic to corona virus.

Keywords: Dominating Set; Corona Dominating Set; Support And Pendent Vertex; Butterfly Graph; Dumbbell Graph; Coconut Tree Graph; Peacock Head Graph; Sunlet Graph; Spider Graph; Firecracker Graph; Uniform g-ply graph

1 Introduction

This study considers a simple undirected graph with no loops or multiple edges. Typically V and E stand for the number of vertices and edges in a graph G respectively. A graph vertex's degree is determined by counting the number of edges that incident on it, twice accounting for loops. The notation deg(v) represents a vertex v degree. A graphs maximum and minimum degrees are indicated by the symbols $\triangle(G)$ and $\delta(G)$, respectively. G. Mahadevan et al.[1] proposed the idea of corona domination in graphs and L. Praveen Kumar et al.[2] introduced the idea of CD-number of graphs. S. Anuthiya et al[3] introduced the concept for exploration of CPCD Number for power graph. M. Vimala Suganthi et al[4] motivated by this paper CCD-number of a graphs.

A butterfly graph $BF_{s,g}$[5] two even C_g of the same order with s pendent edge attaching common vertex. The graph joining two disjoint cycles $(x_1,x_2,x_3,\ldots x_g,x_1)$and $(y_1,y_2,y_3,\ldots,y_g y_1)$ by an edge x_1y_1 is called dumbbell graph[6] and it is denoted by Db_g. The coconut tree[7] is created by joining s pendant edges to an end vertex of a path called P_g . It is denoted by $CT_{g,s}$. The peacock head graph is a graph obtained from $C_g = (x_1,x_2,\ldots,x_g,x_1)$ by attaching y pendent edges to a vertex x_1 of C_g and it is denoted by $PC_{g,s}$. The sunlet graph[8] S_g is a cycle C_g attaching a pendant vertices. The spider graph $S(g,s)$[9] is obtained from $K_{1,s}$ by pasting an end vertex of P_g to each pendant of $K_{1,s}$. A $(g,k)-$firecracker graph[10] $P_g = (x_1,x_2,x_3,\ldots,x_g)$ by combining the root vertex of k-star [star graph with k vertices] to $x_i; 1 \leq i \leq g$ by an edge denoted by $F_{g,k}$. A uniform g-ply graph is obtained from r distinct paths $P_s,\ s \geq 3$ by joining all the initial vertices to a new vertex u by a edge and all the terminal vertices to a new vertex v by an edge and is denoted by $P_g(s)$.

2 Methodology

In this paper we are finding the exact value of exploration of CCD-number for some specific graphs. We prove the upper and lower bound of the parameter for the given graphs.

3 Result and Discussion

Theorem:3.1

If $g \geq 4$, then

$$\gamma_{CCD}(BF_{s,g}) = \begin{cases} 2\left\lceil \frac{g}{3} \right\rceil + s - 1 & \text{if } g \equiv 0 \text{ or } 1(\bmod 3) \\ 2\left\lceil \frac{g}{3} \right\rceil + s + 1 & \text{otherwise.} \end{cases}$$

Proof:

Let $V(BF_{s,g}) = \{v_1, v_2, \ldots, v_g, v_1', v_2', \ldots, v_g', w_1, w_2, \ldots, w_s\}$ and

$$E(BF_{s,g}) = \left(v_i v_{i+1} :, v_i' v_{i+1}' : 1 \leq i \leq g-1\right\} \cup \left(v_1 v_g, v_1' v_g'\right\} \cup \{v_1 w_i : 1 \leq i \leq s\},$$

$v_1 = v_1'$ be the common vertex. Let $A = \{v_i, v_i' :\ i \equiv 1\ (mod\ \ 3)\} \cup \{w_i : 1 \leq i \leq s\}$.

Assume

$$S = \begin{cases} \text{A} & \text{if } g = 3q \text{ or } 3q+1 \\ \text{A} \cup \left\{\text{v}_\text{g}, \text{v}_\text{g}'\right\} & \text{if g} = 3\text{q}+2 \end{cases}$$

Then S is a CCD-set of $BF_{s,g}$ and hence

$$\gamma_{CCD}(BF_{s,g}) \leq |S| = \begin{cases} 2\left\lceil \frac{g}{3} \right\rceil + s - 1 & \text{if } g \equiv 0 \text{ or } 1(\bmod 3) \\ 2\left\lceil \frac{g}{3} \right\rceil + s + 1 & \text{otherwise.} \end{cases}$$

Since any dominating set D of cardinality at most

$$k = \begin{cases} 2\left\lceil \frac{g}{3} \right\rceil + s - 2 & \text{if } g \equiv 0 \text{ or } 1(\bmod 3) \\ 2\left\lceil \frac{g}{3} \right\rceil + s & \text{otherwise} \end{cases}$$

contains at least one isolated vertex in $< V - D >$, we have

$$|D| \geq k+1 = \begin{cases} 2\left\lceil \frac{g}{3} \right\rceil + s - 1 & \text{if } g \equiv 0 \text{ or } 1(\bmod 3) \\ 2\left\lceil \frac{g}{3} \right\rceil + s + 1 & \text{otherwise.} \end{cases}$$

Hence the Proof.

Theorem:3.2

If $g \geq 3$, then

$$\gamma_{CCD}(Db_g) = \begin{cases} 2\left[\frac{g}{3}\right] & \text{if } g \equiv 0 \text{ or } 1(\bmod 3) \\ 2\left[\frac{g}{3}\right] + 2 & \text{otherwise.} \end{cases}$$

Proof:

Let $V(Db_g) = \{v_1, v_2, \ldots, v_g, v_1', v_2', \ldots, v_g'\}$ and $E(Db_g) = \left(v_i v_{i+1}, v_i' v_{i+1}' : 1 \leq i \leq g-1\right\} \cup \left(v_1 v_g, v_1' v_g'\right\} \cup \{v_1 v_1'\}$. Let $A = \{v_i, v_i' :\ i \equiv 1\ (mod\ \ 3)\}$.

Assume

$$S = \begin{cases} \text{A} & \text{if } g = 3q \text{ or } 3q+1 \\ A \cup \left\{v_g, {v_g}'\right\} & \text{if } g \equiv 3q+2 \end{cases}$$

Then S is a CCD-set of Db_g and hence

$$\gamma_{CCD}(Db_g) \leq |S| = \begin{cases} 2\left\lceil \frac{g}{3} \right\rceil & \text{if } g \equiv 0 \text{ or } 1(\bmod 3) \\ 2\left\lceil \frac{g}{3} \right\rceil + 2 & \text{otherwise.} \end{cases}$$

Since any dominating set D of cardinality at most $k = \begin{cases} 2\left\lceil \frac{g}{3} \right\rceil - 1 & \text{if } g \equiv 0 \text{ or } 1(\bmod 3) \\ 2\left\lceil \frac{g}{3} \right\rceil + 1 & \text{otherwise,} \end{cases}$

contains at least one isolated vertex in $< V - D >$, we have

$$|D| \geq k+1 = \begin{cases} 2\left\lceil \frac{g}{3} \right\rceil & \text{if } g \equiv 0 \text{ or } 1 (\bmod 3) \\ 2\left\lceil \frac{g}{3} \right\rceil + 2 & \text{otherwise.} \end{cases}$$

Hence the Proof.

Theorem:3.3

If $g \geq 2$, then

$$\gamma_{CCD}\left(CT_{g,s}\right) = \begin{cases} \left\lceil \frac{g}{3} \right\rceil + \text{s if g} \equiv 0 \text{ or } 1 (\bmod 3) \\ \left\lceil \frac{g}{3} \right\rceil + \text{s} + 1 \text{ otherwise.} \end{cases}$$

Proof:

Let $V(CT_{g,s}) = \{v_1, v_2, \ldots, v_g, v_1', v_2', \ldots, v_s'\}$ and $E\left(CT_{g,s}\right) = (v_i v_{i+1}\} : 1 \leq i \leq g-1\} \cup \{v_g v_i' : 1 \leq i \leq s\}$. Let $A = (v_i : i = 3q+1\} \cup \{v_i' : 1 \leq i \leq s\}$.

Assume

$$S = \begin{cases} A \text{ if } g = 3q \text{ or } 3q+1 \\ A \cup \{v_g\} \text{ if } g \equiv 3q+2 \end{cases}$$

Then S is a CCD-set of $CT_{g,s}$ and hence

$$\gamma_{CCD}\left(CT_{g,s}\right) \leq |S| = \begin{cases} \left\lceil \frac{g}{3} \right\rceil + \text{s if g} \equiv 0 \text{ or } 1 (\bmod 3) \\ \left\lceil \frac{g}{3} \right\rceil + \text{s} + 1 \text{ otherwise.} \end{cases}$$

Since any dominating set D of cardinality at most $k = \begin{cases} \left\lceil \frac{g}{3} \right\rceil + \text{s} - 1 & \text{if g} \equiv 0 \text{ or } 1 (\bmod 3) \\ \left\lceil \frac{g}{3} \right\rceil + \text{s} & \text{otherwise.} \end{cases}$

contains at least one isolated vertex in $< V - D >$, we have

$$|D| \geq k+1 = \begin{cases} \left\lceil \frac{g}{3} \right\rceil + \text{s if g} \equiv 0 \text{ or } 1 (\bmod 3) \\ \left\lceil \frac{g}{3} \right\rceil + \text{s} + 1 \text{ otherwise.} \end{cases}$$

Hence the Proof .

Theorem:3.4

If $g \geq 2$, then $\gamma_{CCD}\left(PC_{g,s}\right) = \begin{cases} \left\lfloor \frac{g}{3} \right\rfloor + \text{s if g} \equiv 0 \text{ or } 1 (\bmod 3) \\ \left\lceil \frac{g}{3} \right\rfloor + \text{s} + 1 \text{ otherwise.} \end{cases}$

Proof:

Let $V\left(PC_{g,s}\right) = (v_1, v_2, v_3, \ldots, v_g, v_1', v_2', v_3', \ldots, v_s'\}$ and $E\left(PC_{g,s}\right) = (v_i v_{i+1}\}, v_1 v_g v_1 v_j' : 1 \leq i \leq g-1; 1 \leq j \leq g\}$. Let $A = (v_i : i \equiv 0 \ (mod\ 3)\} \cup \{v_i' : 1 \leq i \leq s\}$.

Assume $S = \begin{cases} A \text{ if } g = 3q \text{ or } 3q+1 \\ A \cup \{v_{g-1}\} \text{ if } g = 3q+2 \end{cases}$

Then S is a CCD-set of $PC_{g,s}$ and hence

$$\gamma_{CCD}\left(PC_{g,S}\right) \leq |S| = \begin{cases} \left\lfloor \frac{g}{3} \right\rfloor + \text{s if g} \equiv 0 \text{ or } 1 (\bmod 3) \\ \left\lceil \frac{g}{3} \right\rfloor + \text{s} + 1 \text{ otherwise.} \end{cases}$$

Since any dominating set D of cardinality at most

$k = \begin{cases} \left\lfloor \frac{g}{3} \right\rfloor + \text{s} - 1 & \text{if g} \equiv 0 \text{ or } 1 (\bmod 3) \\ \left\lceil \frac{g}{3} \right\rfloor + \text{s} & \text{otherwise,} \end{cases}$

contains at least one isolated vertex in $< V - D >$, we have

$$|D| \geq k+1 = \begin{cases} \left\lfloor \frac{g}{3} \right\rfloor + \text{s if g} \equiv 0 \text{ or } 1 (\bmod 3) \\ \left\lceil \frac{g}{3} \right\rfloor + \text{s} + 1 \text{ otherwise.} \end{cases}$$

Hence the Proof.

Theorem:3.5

If $g \geq 2$, then $\gamma_{CCD}(S_g) = \left\lceil \frac{g}{5} \right\rceil + \mathrm{g}$.

Proof:

Let $E(S_g) = \left\{ v_i v_{i+1}, v_1 v_g, v_j v_j' : 1 \leq i \leq g-1, 1 \leq j \leq g \right\}$. and $E(S_g) = \left\{ v_i v_{i+1}, v_1 v_g, v_j v_j' : 1 \leq i \leq g-1, 1 \leq j \leq g \right\}$. Let $A = \{v_i : i \equiv 1 \ (mod\ 5)\} \cup \{v_i' : 1 \leq i \leq r\}$.

Assume $S = \begin{cases} \{\mathrm{A} - \{\mathrm{v_{g-1}}\}\} \cup \{\mathrm{v_{g-2}}\} \text{ if } \mathrm{g} \equiv 2(\bmod 5) \\ \mathrm{A} \text{ otherwise.} \end{cases}$

Then S is a CCD-set of S_g and hence $\gamma_{CCD}\ (S_g) \leq |S| = \left[\frac{g}{5}\right] 5 + g$.

Since any dominating set D of cardinality at most $k = \left[\frac{g}{5}\right] + g - 1$, contains at least one isolated vertex in $< V - D >$, we have $|D| \geq k + 1 = \left[\frac{g}{5}\right] + g$.

Hence the Proof.

Theorem:3.6

If $g \geq 2$ and $s \geq 3$ then $\gamma_{CCD}(S(g,s)) = \begin{cases} \left\lceil \frac{g}{3} \right\rceil \mathrm{s} + 1 \text{ if } \mathrm{g} \equiv 0 \text{ or } 1(\bmod 3) \\ \left[\frac{g}{3}\right] \mathrm{s} + \mathrm{s} + 1 \text{ otherwise.} \end{cases}$

Proof:

Let $V(S(g,s)) = \{u, x_1^i, x_2^i, x_3^i, \ldots, x_g^i : 1 \leq i \leq s\}$ and $E(S(g,s)) = \{ux_1^i : 1 \leq i \leq s\} \cup \left\{x_j^i x_{j+1}^i\right\} : 1 \leq i \leq s; 1 \leq j \leq g-1\}$. Let $A = \left\{x_j^i : j \equiv 0 \ (mod\ \ 3) : 1 \leq i \leq s\right\} \cup \{u\}$.

Assume $S = \begin{cases} \mathrm{A} \text{ if } \mathrm{g} = 3\mathrm{q} \\ \mathrm{A} \cup \left\{\mathrm{x_g^i} : 1 \leq \mathrm{i} \leq \mathrm{s}\right\} \text{ if } \mathrm{g} \equiv 3\mathrm{q} + 1 \\ \mathrm{A} \cup \left\{\mathrm{x_{g-1}^i}, \mathrm{x_g^i} : 1 \leq \mathrm{i} \leq \mathrm{s}\right\} \text{ if } \mathrm{g} \equiv 3\mathrm{q} + 2 \end{cases}$

Then S is a CCD-set of $S(g,s)$ and hence

$\gamma_{CCD}(S(g,s)) \leq |S| = \begin{cases} \left[\frac{g}{3}\right] \mathrm{s} + 1 \text{ if } \mathrm{g} \equiv 0 \text{ or } 1(\bmod 3) \\ \left[\frac{g}{3}\right] \mathrm{s} + \mathrm{s} + 1 \text{ otherwise.} \end{cases}$

Since any dominating set D of cardinality at most $k = \begin{cases} \left\lceil \frac{g}{3} \right\rceil \mathrm{s} \text{ if } \mathrm{g} \equiv 0 \text{ or } 1(\bmod 3) \\ \left[\frac{g}{3}\right] \mathrm{s} + \mathrm{s} \text{ otherwise.} \end{cases}$

contains at least one isolated vertex in $< V - D >$, we have

$|D| \geq k + 1 = \begin{cases} \left[\frac{g}{3}\right] \mathrm{s} + 1 \text{ if } \mathrm{g} \equiv 0 \text{ or } 1(\bmod 3) \\ \left[\frac{g}{3}\right] \mathrm{s} + \mathrm{s} + 1 \text{ otherwise} \end{cases}$

Hence the Proof.

Theorem:3.7

If $g \geq 2$ then $\gamma_{CCD}(F_{g,k}) = \begin{cases} 2\left\lfloor \frac{g}{3} \right\rfloor + (\mathrm{k} - 1)\mathrm{g} + 1 & \text{if } \mathrm{g} \equiv 1(\bmod 3) \\ \left\lceil \frac{g}{3} \right\rceil + (\mathrm{k} - 1)\mathrm{g} & \text{otherwise} \end{cases}$

Proof:

Let $V(F_{g,k}) = \{x_1', x_2', \ . \ . \ . \ , x_g', y_1^i, y_2^i, \ . \ . \ . \ , y_k^i : 1 \leq i \leq g\}$ and $E(F_{g,k}) = \{x_i' x_{i+1}' : 1 \leq i \leq g-1\} \cup \{x_i' y_1^i : 1 \leq i \leq g\} \cup \{y_1^i y_j^i : 1 \leq i \leq g; 2 \leq j \leq k\}$. Let $A = \{x_i', y_1^i : i = 3q + 2\} \cup \{y_j^i : 1 \leq i \leq g; 1 \leq j \leq k\}$.

Assume $S = \begin{cases} A \ \text{ if } g = 3q \text{ or } 3q + 2 \\ A \cup \{y_1^g\} \text{ if } g \equiv 3q + 1. \end{cases}$

Then S is a CCD-set of $F_{g,k}$ and hence

$\gamma_{CCD}(F_{g,k}) \leq |S| = \begin{cases} 2\left\lfloor \frac{g}{3} \right\rfloor + (\mathrm{k} - 1)\mathrm{g} + 1 & \text{if } \mathrm{g} \equiv 1(\bmod 3) \\ \left\lceil \frac{g}{3} \right\rceil + (\mathrm{k} - 1)\mathrm{g} & \text{otherwise} \end{cases}$

Since any dominating set D of cardinality at most

$k = \begin{cases} 2\left\lfloor \frac{g}{3} \right\rfloor + (\mathrm{k} - 1)\mathrm{g} \text{ if } \mathrm{g} \equiv 1(\bmod 3) \\ \left\lceil \frac{g}{3} \right\rceil + (\mathrm{k} - 1)\mathrm{g} - 1 \text{ otherwise,} \end{cases}$

contains at least one isolated vertex in $< V-D >$, we have

$$|D| \geq k+1 = \begin{cases} 2\left\lfloor \frac{g}{3} \right\rfloor + (k-1)g+1 & \text{if } g \equiv 1(\bmod 3) \\ \left\lceil \frac{g}{3} \right\rceil + (k-1)g & \text{otherwise} \end{cases}$$

Hence the Proof.

Theorem:3.8

If $g \geq 2$ then $\gamma_{CCD}\left(P_g(s)\right) = \begin{cases} \left\lceil \frac{s}{3} \right\rceil g+2 & \text{if } s \equiv 0(\bmod 3) \\ \left\lfloor \frac{s}{3} \right\rfloor g+2 & \text{otherwise} \end{cases}$

Proof:

Let $V\left(P_g(s)\right) = \left\{u, v, x_1^i, x_2^i, \ldots, x_s^i\right\}$ and $E\left(P_g(s)\right) = \left\{x_j^i x_{j+1}^i : 1 \leq i \leq g; 1 \leq j \leq s-1\right\} \cup \left\{ux_1^i, vx_s^i : 1 \leq i \leq g\right\}$. Let $A = \left\{x_j^i : j = 3q : 1 \leq i \leq g\right\}$.

Assume $S = \begin{cases} A \cup \{u, v\} \text{ if } s = 3q \text{ or } 3q+2 \\ A \cup \{u\} \cup \left\{x_s^1\right\} \text{ if } s \equiv 3q+1 \end{cases}$

Then S is a CCD-set of $P_g(s)$ and hence $\gamma_{CCD}\left(P_g(s)\right) \leq |S| = \begin{cases} \left\lceil \frac{s}{3} \right\rceil g+2 & \text{if } s \equiv 0(\bmod 3) \\ \left\lfloor \frac{s}{3} \right\rfloor g+2 & \text{otherwise} \end{cases}$

Since any dominating set D of cardinality at most $k = \begin{cases} \left\lceil \frac{s}{3} \right\rceil g+1 \text{ if } s \equiv 0(\bmod 3) \\ \left\lfloor \frac{s}{3} \right\rfloor g+1 \text{ otherwise.} \end{cases}$

contains at least one isolated vertex in $< V-D >$, we have

$$|D| \geq k+1 = \begin{cases} \left\lceil \frac{s}{3} \right\rceil g+2 & \text{if } s \equiv 0(\bmod 3) \\ \left\lfloor \frac{s}{3} \right\rfloor g+2 & \text{otherwise.} \end{cases}$$

Hence the Proof.

4 Conclusion

Throughout in this article, we found the CCD-number for $BF_{s,g}$, Db_g, $CT_{g,s}$ $PC_{g,s}$, S_g, $S_{g,s}$, $F_{g,k}$ and $P_g(s)$. For the future work, we extend this parameter for trees, product related graphs, power graphs and comparing other parameter which will be prove the subsequent papers.

Declaration

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