# Edge and Connected Edge domination number of Complement of $B(\overline{K_p}, \overline{L(G)}, NINC)$

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**Abstract**

For any graph G, let V(G) and E(G) denote the vertex set and edge set of G respectively. The Boolean function graph $B(\overline{Kp}, \overline{L(G)}, NINC)$ of G is a graph with vertex set $V(G)\cup E(G)$ and two vertices in $B(\overline{Kp}, \overline{L(G)}, NINC)$ are adjacent if and only if they correspond to two non adjacent edges of G or to a vertex and an edge not incident to it in G. For brevity, this graph is denoted by $B_3(G)$. In this paper, edge domination numbers of Complement of Boolean Function Graph $B(K_p, L(G), INC)$ of some standard graphs and corona graphs are obtained.

Keywords: Boolean Function graph, Edge Domination Number.

## 1. Introduction

Graphs discussed in this paper are undirected and simple graphs. For a graph G, let V(G) and E(G) denote its vertex set and edge set respectively. A graph with p vertices and q edges is denoted by G(p, q). A subset $F \subseteq E(G)$ is called an edge dominating set of G, if every edge not in F is adjacent to some edge in F. The edge domination number $\gamma'(G)$ of G is the minimum cardinality taken over all edge dominating sets of G. The concept of edge domination was introduced by Mitchell and Hedetaiemi[8] and it was studied by Arumugam and Velammal[1]. Complementary edge domination in graphs is studied by Kulli and Soner [7] Jayaram[6]studied the line dominating sets and obtained bounds for the line domatic number. The corona $G_1 o\, G_2$ of two graphs $G_1$ and $G_2$ is defined as the graph obtained by taking one copy of $G_1$ (which has $p_1$ vertices) and $p_1$ copies of $G_2$, and then joining the $i^{th}$ vertex of $G_1$ to every vertex of in the $i^{th}$ copy of $G_2$. For any graph G, $GoK_1$ is denoted by $G^+$.

An edge dominating set F of is called a connected edge dominating set of G, if the induced subgraph $\langle F \rangle$ is connected. The connected edge domination number $\gamma_c'(G)$ of G is the minimum cardinality taken over all connected edge dominating sets of G.

Janakiraman et al., introduced the concept of Boolean function graphs [3 - 5]. For any graph G, let V(G) and E(G) denote the vertex set and edge set of G respectively. The Boolean function graph $B(\overline{Kp}, \overline{L(G)}, NINC)$ of G is a graph with vertex set $V(G) \cup E(G)$ and two vertices in $B(\overline{Kp}, \overline{L(G)}, NINC)$ are adjacent if and only if they correspond to two non adjacent edges of G or to a vertex and an edge not incident to it in G. For brevity, this graph is denoted by $B_3(G)$.

In this paper, edge domination numbers of Complement of $B(K_P, L(G), INC)$ of some standard graphs are obtained.

## 2. Prior Results

**Observation 2.1. [5]**

Let G be a graph with p vertices and q edges.

1. If G has p vertices, then the complete graph on p vertices is an induced subgraph of $\overline{B_3(G)}$. Also L(G) is an induced subgraph.
2. The degree of a vertex $v \in V(G)$ in $\overline{B_3(G)}$ is $p-1+deg_G(v)$ and the degree of a vertex e' of L(G) in $\overline{B_3(G)} = deg_{L(G)}(e')+2$ and hence $\Delta(\overline{B_3(G)}) = p-1+ \Delta(G)$ and $\delta(\overline{B_3(G)}) = \delta'(G) + 2$, where $\delta'(G) = \delta(L(G))$.
3. $\overline{B_3(G)}$ is a connected graph, for any graph G.

## 3. Main Results

In the following, edge domination numbers of $\overline{B_3(P_n)}$, $\overline{B_3(C_n)}$ , $\overline{B_3(K_{1,n})}$ and corona graphs are found and the bounds are obtained.

**Theorem 3.1:** For the Path $P_n$ on n ($n \geq 3$) vertices, $\gamma'(\overline{B_3(P_n)}) = n-1$.

Proof: Let $v_1, v_2, ..., v_n$ be the vertices and $e_1, e_2, ..., e_{n-1}$ be the edges in $P_n$, where $e_i = (v_i, v_{i+1})$ i = 1, 2, ..., n-1. Then $v_1, v_2, ..., v_n, e_1, e_2, ..., e_{n-1} \in V(\overline{B_3(P_n)})$. $\overline{B_3(P_n)}$ has 2n-1 vertices and $((n^2+ 5n-8)/2)$ edges. Let $D' = \bigcup_{i=1}^{n-1}\{(v_i, e_i)\}$. Then $D' \subseteq E(\overline{B_3(P_n)})$. Each edge in $V(\overline{B_3(P_n)})$ - D′ adjacent to atleast one edge in D′. Therefore, D′ is an edge dominating set of $\overline{B_3(P_n)}$ . Hence, $\gamma'(\overline{B_3(P_n)}) \leq |D'| = n-1$. Let D″ be an edge dominating set of $\overline{B_3(P_n)}$ . To dominate edges of the form $(v_i, e_i)$, (i = 1, 2, ...., n-1) and $(v_{i+1}, e_i)$, i = 1, 2, ..., n-1. D″ contains atleast (n-1) edges. These (n-1) edges dominate edges of $K_n$ and $L(P_n)$ in $\overline{B_3(P_n)}$. Therefore, $|D''| \geq n-1$. Hence, $\gamma'(\overline{B_3(P_n)}) = n-1$.

**Remark:**

1. $\gamma'(\overline{B_3(C_n)}) = n$, $n \geq 4$

2. $\gamma'(\overline{B_3(K_{1,n})}) = n$, $n \geq 3$.

**Theorem 3.2:** For the path $P_n$ on n ($n \geq 3$) vertices, $\gamma'(\overline{B_3(P_n^+)}) = 2n-1$.

Proof: Let $V(P_n^+) = \{v_1, v_2, \dots v_n, u_1, u_2, \dots u_n\}$, where $v_1, v_2, \dots v_n$ are the vertices of $P_n$ and $u_1, u_2, \dots, u_n$ are the pendant vertices of $P_n^+$ and $e_i = (v_i, v_{i+1})$ i =1, 2, ..., n-1 and $f_i = (v_i, u_i)$, i=1,2,...., n be the edges of $P_n^+$. Then $v_1, v_2, \dots v_n, u_1, u_2, \dots u_n, e_1, e_2, \dots, e_{n-1}, f_1, f_2, \dots, f_n \in V(\overline{B_3(P_n^+)})$. $\overline{B_3(P_n^+)}$ has 4n-1 vertices and $(2n^2 + 6n - 6)$ edges.

Let $F_1 = \bigcup_{i=1}^{n-1}\{(v_i, e_i)\}$ and $F_2 = \bigcup_{i=1}^{n}\{(u_i, f_i)\}$ and let $D' = F_1 \cup F_2 \subseteq E(\overline{B_3(P_n^+)})$.

$|D'| = n-1+n = 2n-1$. $F_1$ dominates edges of $L(P_n)$ and edges of the form $(e_i, f_i)$, i = 1,2, ..., n-1 and $(e_i, f_{i+1})$, i = 1, 2, ..., n-1. $F_1 \cup F_2$ dominates edges of $K_{2n-1}$ in $\overline{B_3(P_n^+)}$. Therefore, F is an edge dominating set of $\overline{B_3(P_n^+)}$ and as in Theorem 1, F is minimum. D′ is a minimum edge dominating set of $\overline{B_3(P_n^+)}$. Hence, $\gamma'(\overline{B_3(P_n^+)}) = 2n-1$.

**Remark:** $\gamma'(\overline{B_3(C_n^+)}) = 2n$, $n \geq 4$.

**Theorem 3.3:** For the star $K_{1,n}$ on n+1 vertices, $\gamma'(\overline{B_3(K_{1,n}^+)}) = 2n+1$, $n \geq 3$.

Proof: Let $V(K_{1,n}^+) = \{v, v_1, v_2, \dots v_n, u, u_1, u_2, \dots u_n\}$, where v is the central vertex and $< \{v_1, v_2, \dots v_n\} > \cong K_{1,n}$ and $u_1, u_2, \dots, u_n$ are the pendant vertices of $K_{1,n}^+$ and $e_i = (v, v_i)$ i =1, 2, ..., n and $f = (v, u)$, $f_i = (v_i, u_i)$ i=1, 2, ...., n be the edges of $K_{1,n}^+$. Then $v, v_1, v_2, \dots v_n, u, u_1, u_2, \dots u_n, e_1, e_2, \dots, e_n, f_1, f_2, \dots, f_n \in V(\overline{B_3(K_{1,n}^+)})$. $\overline{B_3(K_{1,n}^+)}$ has (4n+1) vertices and $((5n^2 + 15n + 4)/2)$ edges.

Let $F_1 = \bigcup_{i=1}^{n}\{(v_i, u_i)\}$ $F_2 = \bigcup_{i=1}^{n}\{(e_i, f_i)\}$ and $F_3 = \{(v, f)\}$.

Let $D' = F_1 \cup F_2 \cup F_3 \subseteq E(\overline{B_3(K_{1,n}^+)})$. $|D'| = n + n+1 = 2n+1$. $F_1 \cup F_3$ dominates all the edges of $K_{2n+2}$ induced by $v, v_1, ..., v_n, u, u_1, ..., u_n$ and edges of the form $(v_i, e_i)$, $(v_i, f_i)$, $(u_i, f_i)$ (i = 1, 2, ..., n) and (u, f). $F_2$ dominates the edges of $L(K_{1,n}^+)$. Therefore, F is an edge dominating set of $\overline{B_3(K_{1,n}^+)}$ and is minimum. Hence, $\gamma'(\overline{B_3(K_{1,n}^+)}) = 2n+1$, $n \geq 3$.

**Theorem 3.4:** Let G be a (p, q) graph with $p \geq 3$. Then

(i) $\gamma'(\overline{B_3(G)}) \leq \gamma'(K_p) + \gamma'(L(G))$.

(ii) $\gamma'(\overline{B_3(G)}) \leq \max(p, q)$, if $\delta(G) \geq 1$.

Proof:

(i) Since $K_p$ and L(G) are induced subgraphs of $\overline{B_3(G)}$, $\gamma'(\overline{B_3(G)}) \leq \gamma'(K_p) + \gamma'(L(G))$.

(ii) **Case 1:** $p \geq q$.

Since $\delta(G) \geq 1$, G has no isolated vertices and each vertex in G is incident with atleast one edge in G.

Let $v_1, v_2, ..., v_p$ be the p vertices of G and $e_i$ be incident with $v_i$, for i=1, 2, .., p.

Then $(v_i, e_i) \in E(\overline{B_3(G)})$, i = 1,2, ..., p and $\{(v_i, e_i)/ i=1,2, ...,p\}$ is an edge dominating set of $\overline{B_3(G)}$ and $\gamma'(\overline{B_3(G)}) \leq p$.

**Case 2:** $p < q$.

Let $e_1, e_2, ..., e_q$ be the edges in G and $v_j$ be incident with $e_j$, j = 1,2, ...,q.

Then $\{(v_i, e_i)/ i=1,2, ...,q\}$ is an edge dominating set of $\overline{B_3(G)}$ and $\gamma'(\overline{B_3(G)}) \leq q$.

Therefore, $\gamma'(\overline{B_3(G)}) \leq \max(p, q)$.

In the following, the graphs for which $\gamma'(\overline{B_3(G)}) = 1, 2$ (or) 3 are characterized.

**Observation 3.1:** $\gamma'(\overline{B_3(G)}) = 1$ if and only if G is one of the following graphs: $2K_1$, $3K_1$, $K_2$ and $K_2 \cup K_1$.

**Theorem 3.5:** $\gamma'(\overline{B_3(G)}) = 2$ if and only if G is one of the following graphs: $P_3$, $C_3$, $4K_1$, $K_2 \cup 2K_1$, $P_3 \cup K_1$, $2K_2$, $5K_1$, $K_2 \cup 3K_1$ and $2K_2 \cup K_1$.

Proof:

**Case 1:** G contains no isolated vertices.

If G contains $C_4$ as a subgraph, then $\gamma'(\overline{B_3(G)}) \geq 4$, since $\gamma'(\overline{B_3(C_4)}) = 4$.

If G contains $K_{1,3}$ as a subgraph, then $\gamma'(\overline{B_3(G)}) \geq 3$, since $\gamma'(\overline{B_3(K_{1,3})}) = 3$.

If G contains $P_4$ as a subgraph, then $\gamma'(\overline{B_3(G)}) \geq 3$, since $\gamma'(\overline{B_3(P_4)}) = 3$.

Therefore, G is one of the graphs $K_2$, $P_3$, $C_3$, $2K_2$ and $P_3 \cup K_2$. But, $\gamma'(\overline{B_3(K_2)}) = 1$ and $\gamma'(\overline{B_3(P_3 \cup K_2)}) = 3$. Hence, $G \cong P_3$, $C_3$ (or) $2K_2$.

**Case 2:** G contains isolated vertices.

If $G \cong nK_1$ , $n \geq 6$, then $\gamma'(\overline{B_3(G)}) \geq 3$, since $K_6$ is an induced subgraph of $\overline{B_3(G)}$ and $\gamma'(K_6) = 3$. If $G = 2K_1$(or) $3K_1$, then $\gamma'(\overline{B_3(G)}) =1$.Therefore, $G \cong 4K_1$ (or) $5K_1$.

Let G be not totally connected. Then G contains atleast one edge and $\delta(G) \geq 0$. If $G \cong K_2 \cup mK_1$, $m \geq 4$ (or) $P_3 \cup K_1$, $2K_2 \cup nK_1$ for $n \geq 2$, then $\gamma'(\overline{B_3(G)}) \geq 3$.Therefore, $G \cong K_2 \cup 2K_1$, $K_2 \cup 3K_1$, $P_3 \cup K_1$ (or) $2K_2 \cup K_1$. If $G \cong C_3 \cup K_1$, then $\gamma'(\overline{B_3(G)}) = 3$.

From Case 1 and Case 2, G is one of the following graphs: $P_3$, $C_3$, $2K_2$ , $4K_1$, $5K_1$, $K_2 \cup 2K_1$, $K_2 \cup 3K_1$, $P_3 \cup K_1$ and $2K_2 \cup K_1$ . Conversely, if G is one of the graphs given above, $\gamma'(\overline{B_3(G)}) = 2$.

In the same way, the following theorem can be proved.

**Theorem 3.6:** $\gamma'(\overline{B_3(G)}) = 3$ if and only if G is one of the following graphs: $6K_1$, $7K_1$, $K_2 \cup 4K_1$, $K_2 \cup 5K_1$, $P_3 \cup 2K_1$ , $C_3 \cup K_1$, $C_3 \cup 2K_1$, $P_4 \cup K_1$, $K_{1,3} \cup K_1$, $P_3 \cup K_2$, $P_4$, $K_{1,3}$ and $K_4 - e$.

## 4. Connected edge domination number of $\overline{B_3(G)}$

In the following, Connected edge domination numbers of $\overline{B_3(P_n)}$, $\overline{B_3(C_n)}$ , $\overline{B_3(K_{1,n})}$ are found and an upperbound is obtained.

**Theorem 4.1:** For the path $P_n$ ($n \geq 4$) on n vertices, $\gamma_c' \overline{(B_3(P_n))} = \left\lfloor \frac{3n-3}{2} \right\rfloor$ .

Proof:

**Case 1:** n is odd.

Let $A_1 = \bigcup_{i=1}^{n-2}\{(v_i, v_{i+1})\}$, $A_2 = \bigcup_{i=1}^{(n-1)/2}\{(v_{2i-1}, e_{2i-1})\}$ and $A_3 = \{(v_{n-1}, e_{n-1})\}$.

Let $A = A_1 \cup A_2 \cup A_3$ and $|A| = (3n-3)/2$. The set $A_1$ dominates all the edges of $K_n$ in $\overline{B_3(P_n)}$. The set $A_2 \cup A_3$ dominates all the edges of $L(P_n)$ and the edges of the form (v, e) in $\overline{B_3(P_n)}$. Therefore A is an edge dominating set of $\overline{B_3(P_n)}$. Also, < A> is a tree obtained from $P_{n-1}$ by attaching a pendant edge at $v_{2i-1}$ (i = 1,2, ..., (n-1)/2) and at $v_{n-1}$. Therefore, A is a connected edge dominating set of $\overline{B_3(P_n)}$ and $\gamma_c'\overline{(B_3(P_n))} \le |A| = ((3n-3)/2)$.

Let D′ be a minimum edge dominating set of $\overline{B_3(P_n)}$. Since $\gamma_c'(K_n) = n-2$, to dominate edges of $K_n$ in $\overline{B_3(P_n)}$, D′ contains (n-2) edges. These edges dominate the edges of the form (v, e) in $\overline{B_3(P_n)}$. To dominate edges of $\overline{L(P_n)}$ and to maintain connectedness of < D′ >, atleast ((n+1)/2) edges are to be added to D′. Therefore, D′ contains atleast (n-2)+((n+1)/2) = ((3n-3)/2) edges.

Hence, $\gamma_c'\overline{(B_3(P_n))} \ge ((3n-3)/2)$

**Case 2:** n is even.

Let $A_4 = \bigcup_{i=1}^{n/2}\{(v_{2i-1}, e_{2i-1})\}$ . Then the set $A_1 \cup A_4$ is an minimum edge dominating set of $\overline{B_3(P_n)}$ and < $A_1 \cup A_4$ > is a tree obtained from $P_{n-1}$ by attaching pendant edge at $v_{2i-1}$, i = 1, 2, ..., (n/2). Therefore, $A_1 \cup A_4$ is a connected edge dominating set of $\overline{B_3(P_n)}$. As in Case1, $A_1 \cup A_4$ is minimum. Hence, $\gamma_c'\overline{(B_3(P_n))} = |A_1 \cup A_4| = (n-2)+n/2 = (3n-4)/2 = \left\lfloor\frac{3n-3}{2}\right\rfloor$.

By Case 1 and Case 2, $\gamma_c'\overline{(B_3(P_n))} = \left\lfloor\frac{3n-3}{2}\right\rfloor$, $n \ge 4$.

**Observation:** $\gamma_c'\overline{(B_3(P_3))} = 2$.

**Theorem 4.2:** For the cycle $C_n$ ($n \ge 3$) on n vertices, $\gamma_c'\overline{(B_3(C_n))} = \left\lfloor\frac{3n-1}{2}\right\rfloor$.

Proof: Let $D_1 = \bigcup_{i=1}^{n-1}\{(v_i, v_{i+1})\}$

**Case 1:** n is odd.

Let $D_2 = \bigcup_{i=1}^{(n+1)/2}\{(v_{2i-1}, u_{2i-1})\}$. Then the set $D_1 \cup D_2$ is an edge dominating set of $\overline{B_3(C_n)}$ and

< $D_1 \cup D_2$ > is a tree obtained from by attaching a pendant edge at $v_i$, i=1, 2, ...,(n+1)/2.

Therefore, $D_1 \cup D_2$ is a connected edge dominating set of $\overline{B_3(C_n)}$ and is minimum, as in Case 1 of Theorem 4.1.

Hence, $\gamma_c{}' \overline{(B_3(C_n))} = | D_1 \cup D_2| = (n-1)+((n+1)/2) = (3n-1)/2$.

**Case 2:** n is even.

Let $D_3 = \bigcup_{i=1}^{n/2}\{(v_{2i-1}, u_{2i-1})\}$. Then the set $D_1 \cup D_3$ is an edge dominating set of $\overline{B_3(C_n)}$ and

$< D_1 \cup D_3 >$ is a tree obtained from $P_n$ by attaching a pendant edge at $v_i$, i=1, 2, ...,(n/2).

Therefore, $D_1 \cup D_3$ is a connected edge dominating set of $\overline{B_3(C_n)}$ and is minimum.

Hence, $\gamma_c{}' \overline{(B_3(C_n))} = | D_1 \cup D_3| = (n-1)+(n/2) = (3n-2)/2 = \left\lfloor \frac{3n-1}{2} \right\rfloor$.

By Case 1 and Case 2, $\gamma_c{}' \overline{(B_3(C_n))} = \left\lfloor \frac{3n-1}{2} \right\rfloor$, $n \geq 3$.

**Theorem 4.3:** For the star $K_{1,n}$ ($n \geq 3$) on (n+1) vertices, $\gamma_c{}' \overline{(B_3(K_{1,n}))} = 2n-1$ .

Proof: Let $F_1 = \bigcup_{i=1}^{n-2}\{(v_i, v_{i+1})\}$, $F_2 = ( \bigcup_{i=1, i\neq 2}^{n}\{(v_i,e_i)\})$, $F_3 = \{(v, v_1), (v, e_n)\}$.

Then the set $F_1 \cup F_2 \cup F_3$ is an edge dominating set of $\overline{B_3(K_{1,n})}$ and

$< F_1 \cup F_2 \cup F_3 >$ is a tree obtained from $P_n$ by attaching a pendant edge at all vertices, except at $v_2$. Therefore, $F_1 \cup F_2 \cup F_3$ is a connected edge dominating set of $\overline{B_3(K_{1,n})}$ and is minimum.

Hence, $\gamma_c{}' \overline{(B_3(K_{1,n}))} = | F_1 \cup F_2 \cup F_3| = (n-2)+(n-1)+2 = 2n-1$.

**Theorem 4.4:** Let G be a connected (p, q) graph. Then $\gamma_c{}' \overline{(B_3(G))} \leq p-1+\alpha_0(L(G))$.

Proof: $K_p$ is an induced subgraph of $\overline{B_3(G)}$ . Let T be a spanning tree in $K_p$, |E(T)|= p-1. Let D be a minimum point cover of L(G). Then, $|D|= \alpha_0(L(G))$. Assume $D =\{e_1, e_2, ...,e_k\}$, where $k = \alpha_0(L(G))$ and let $e_i \in E(G)$ be incident with $v_i \in E(G)$, i = 1,2, ...., k . Then $(v_i, e_i) \in \overline{B_3(G)}$, i = 1, 2, ..., n and the set $\{(v_i, e_i)/ i=1,2, ..., k\} \cup E(T)$ is a connected edge dominating set of $\overline{B_3(G)}$. Therefore, $\gamma_c{}' \overline{(B_3(G))} \leq k + p-1= p-1+\alpha_0(L(G))$.

Equality holds, if $G \cong C_n$, $n \geq 3$. Since $\alpha_0(L(C_n)) = \alpha_0(L(C_n)) = \left\lceil \frac{n}{2} \right\rceil$.

**Remark:**

1. If $\gamma_c' \overline{(B_3(G))} = 2$ if and only if $G \cong P_3$.

2. If $\gamma_c' \overline{(B_3(G))} = 3$ if and only if $G \cong K_{1,2}$ (or) $P_3$.

## 5. Conclusion

In this paper, Edge and Connected edge domination numbers of B( $\overline{Kp}$ , $\overline{L(G)}$, NINC) of path, cycle, stars and corona graphs are obtained.

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