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SOME 4-TOTAL PRIME CORDIAL LABELING OF GRAPHS

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ABSTRACT. Let G be a (p, q) graph. Let $f : V(G) \to \{1, 2, \ldots, k\}$ be a map where $k \in \mathbb{N}$ and $k > 1$. For each edge uv, assign the label $\gcd(f(u), f(v))$. f is called k-Total prime cordial labeling of G if $\left|t_f(i) - t_f(j)\right| \leq 1$, $i, j \in \{1, 2, \cdots, k\}$ where $t_f(x)$ denotes the total number of vertices and the edges labelled with x. A graph with a k-total prime cordial labeling is called k-total prime cordial graph. In this paper we investigate the 4-total prime cordial labeling of some graphs.

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1. Introduction

All Graphs in this paper are finite, simple and undirected. Let G_1, G_2 respectively be (p_1, q_1), (p_2, q_2) graphs. The corona of G_1 with G_2, $G_1 \odot G_2$ is the graph obtained by taking one copy of G_1 and p_1 copies of G_2 and joining the i^{th} vertex of G_1 with an edge to every vertex in the i^{th} copy of G_2. The cartesian product of two graphs G_1 and G_2 is the graph $G_1 \times G_2$ with vertex set $V_1 \times V_2$ and two vertices $u = (u_1, u_2)$ and $v = (v_1, v_2)$ are adjacent whenever $[u_1 = v_1$ and u_2 adj $v_2]$ or $[u_2 = v_2$ and u_1 adj $v_1]$. The graph $L_n = P_n \times K_2$ is called ladder. A friendship graph F_n is a graph which consists of n triangles with a common vertex. Ponraj et al. [4], has been introduced the concept of k-total prime cordial labeling and investigate the k-total cordial labeling of certain graphs. Also in [4, 5], we have investigated the 4-total prime cordial labeling for path, cycle, star, bistar, flower graph, gear graph etc. In this paper we investigate the 4-total prime cordiality of some graphs like comb, double comb, triangular snake, double triangular snake, ladder, friendship graph.

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2. Main results

Theorem 2.1. The comb $P_n \odot K_1$ is 4-total prime cordial.

Proof. Let P_n be the path $u_1, u_2, \ldots, u_n$. Let $v_1, v_2, \ldots, v_n$ be adjacent to the pendent vertices $u_1, u_2, \ldots, u_n$. Clearly $|V(P_n \odot K_1)| + |E(P_n \odot K_1)| = 4n - 1$.
Case 1. $n \equiv 0 \pmod 4$.
Let $n = 4t$, $t \in \mathbb{N}$. Assign the label 4 to the vertices $u_1, u_2, \ldots, u_t$ and assign the label 3 to the vertices $u_{t+1}, u_{t+2}, \ldots, u_{2t}$. Next we assign the label 2 to the vertices $u_{2t+1}, u_{2t+2}, \ldots, u_{3t}$ and assign 1 to the vertices $u_{3t+1}, u_{3t+2}, \ldots, u_{n-1}$ respectively. Finally we assign the label 4 to the vertex u_n. Next we consider the vertices $v_1, v_2, \ldots, v_n$. Assign the label 4 to the vertices $v_1, v_2, \ldots, v_t$ and assign the label 3 to the vertices $v_{t+1}, v_{t+2}, \ldots, v_{2t}$ and 2 to the vertices $v_{2t+1}, v_{2t+2}, \ldots, v_{3t}$. Next we assign 1 to the vertices $v_{3t+1}, v_{3t+2}, \ldots, v_{n-1}$ respectively. Finally we assign the label 3 to the vertex v_n. Clearly $t_f(1) = t_f(3) = t_f(4) = 4t$ and $t_f(2) = 4t - 1$.
Case 2. $n \equiv 1 \pmod 4$.
Let $n = 4t + 1$, $t \in \mathbb{N}$. In this case, assign the label to the vertices u_i $(1 \le i \le n - 1)$ and v_i $(1 \le i \le n - 1)$ by in case 1. Next assign the labels 2 and 3 to the vertices u_n and v_n respectively. Here $t_f(1) = t_f(2) = t_f(3) = 4t + 1$ and $t_f(4) = 4t$.
Case 3. $n \equiv 2 \pmod 4$.
Let $n = 4t + 2$, $t \in \mathbb{N}$. As in case 2, assign the label to the vertices u_i $(1 \le i \le n - 1)$ and v_i $(1 \le i \le n - 1)$. Next we assign the labels 4 and 3 to the vertices u_n and v_n respectively. It is easy to verify that $t_f(1) = t_f(2) = t_f(3) = 4t + 2$ and $t_f(4) = 4t + 1$.
Case 4. $n \equiv 3 \pmod 4$.
Let $n = 4t + 3$, $t \in \mathbb{N}$. Assign the label to the vertices u_i $(1 \le i \le n - 3)$ and v_i $(1 \le i \le n - 3)$ as in case 1. Finally we assign the labels 4, 2, 3 to the vertices u_{n-2}, u_{n-1} and u_n and 3, 4, 2 to the vertices v_{n-2}, v_{n-1} and v_n respectively. Here $t_f(1) = t_f(2) = t_f(4) = 4t + 3$ and $t_f(3) = 4t + 2$. □

Theorem 2.2. The double comb $P_n \odot 2K_1$ is 4-total prime cordial.

Proof. Let P_n be the path $u_1 u_2 \ldots u_n$. Let x_i, y_i $(1 \le i \le n)$ be the pendent vertices adjacent to u_i $(1 \le i \le n)$. Obviously $|V(P_n \odot 2K_1)| + |E(P_n \odot 2K_1)| = 6n - 1$.
Case 1. $n \equiv 0 \pmod 4$.
Let $n = 4t$, $t \in \mathbb{N}$. Consider the vertices of path P_n. Assign the label 4 to the vertices $u_1, u_2, \ldots, u_t$ and assign the label 3 to the vertices $u_{t+1}, u_{t+2}, \ldots, u_{2t}$. Next we assign the label 2 to the vertices $u_{2t+1}, u_{2t+2}, \ldots, u_{3t}$ then assign 1 to the vertices $u_{3t+1}, u_{3t+2}, \ldots, u_{n-1}$. Finally we assign the label 3 to the vertex u_n. Next we move to the pendent vertices. Assign the label to the vertices x_i, y_i $(1 \le i \le n-1)$ as in u_i $(1 \le i \le n-1)$. Now we assign the labels 2 to the vertex x_n and 4 to the vertex y_n. Clearly $t_f(2) = t_f(3) = t_f(4) = 6t$ and $t_f(1) = 6t - 1$.
Case 2. $n \equiv 1 \pmod 4$.

Let $n = 4t+1$, $t \in \mathbb{N}$. As in case 1, assign the label to the vertices u_i, x_i, y_i $(1 \le i \le n-1)$. Now we assign the labels 3, 2, 4 to the vertices u_n, x_n and y_n respectively. Here $t_f(1) = t_f(2) = t_f(4) = 6t+1$ and $t_f(3) = 6t+2$.

Case 3. $n \equiv 2 \pmod 4$.

Let $n = 4t+2$, $t \in \mathbb{N}$. Assign the label to the vertices u_i, x_i, y_i $(1 \le i \le n-1)$. Next we assign the labels 4, 2, 3 respectively to the vertices x_n, u_n and y_n. It is easy to verify that $t_f(1) = t_f(2) = t_f(3) = 6t+3$ and $t_f(4) = 6t+2$.

Case 4. $n \equiv 3 \pmod 4$.

Let $n = 4t+3$, $t \in \mathbb{N}$. As in case 1, assign the label to the vertices u_i, x_i, y_i $(1 \le i \le n-3)$. Now we assign the labels 4, 3, 2, 4, 3, 2, 4, 3, 2 to the vertices x_{n-2}, x_{n-1}, x_n, u_{n-2}, u_{n-1}, u_n, y_{n-2}, y_{n-1} and y_n respectively. Here $t_f(2) = t_f(3) = t_f(4) = 6t+4$ and $t_f(1) = 6t+5$. □

Theorem 2.3. The graph $C_n \odot 2K_1$ is 4-total prime cordial.

Proof. Let C_n be the cycle $u_1u_2\ldots u_nu_1$. Let x_i, y_i $(1 \le i \le n)$ be the pendent vertices adjacent to u_i $(1 \le i \le n)$. It is easy to verify that $|V(C_n \odot 2K_1)| + |E(C_n \odot 2K_1)| = 6n$.

Case 1. $n \equiv 0, 1, 3 \pmod 4$.

Let $n = 4t$,$n = 4t+1$,$n = 4t+3$, $t \in \mathbb{N}$. The vertex labelled in Theorem 2.2 is also a 4-total prime cordial of $C_n \odot 2K_1$.

Case 2. $n \equiv 3 \pmod 4$.

Let $n = 4t+2$, $t \in \mathbb{N}$. Assign the label to u_i, x_i, y_i $(1 \le i \le n)$ as in Theorem 2.2. Finally interchange the labels of u_n and x_n. Obviously this induced vertex labels is a 4-total prime cordial of $C_n \odot 2K_1$. □

Theorem 2.4. The ladder L_n is 4-total prime cordial.

Proof. Let $V(L_n) = \{u_i, v_i : 1 \le i \le n\}$ and $E(L_n) = \{u_iu_{i+1}, v_iv_{i+1} : 1 \le i \le n-1\} \cup \{u_iv_i : 1 \le i \le n\}$. Clearly $|V(L_n)| + |E(L_n)| = 5n-2$.

Case 1. $n \equiv 0 \pmod 4$.

Let $n = 4t$, $t \in \mathbb{N}$. Assign the label 4 to the vertices $u_1, u_2, \ldots, u_t$ and assign the label 2 to the vertices $u_{t+1}, u_{t+2}, \ldots, u_{2t}$. Next we assign the label 3 to the vertices $u_{2t+1}, u_{2t+2}, \ldots, u_{3t}$ then assign the label 1 to the vertices $u_{3t+1}, u_{3t+2}, \ldots, u_{n-1}$. Finally we assign the label 4 to the vertex u_n. Next we consider the vertices v_i $(1 \le i \le n)$. Assign the label 4 to the vertices $v_1, v_2, \ldots, v_t$ and assign the label 2 to the vertices $v_{t+1}, v_{t+2}, \ldots, v_{2t}$. Next we assign the label 3 to the vertices $v_{2t+1}, v_{2t+2}, \ldots, v_{3t}$ then assign the label 1 to the vertices $v_{3t+1}, v_{3t+2}, \ldots, v_{n-1}$. Finally we assign the label 3 to the vertex v_n. Clearly $t_f(1) = t_f(2) = 5t$ and $t_f(3) = t_f(4) = 5t-1$.

Case 2. $n \equiv 1 \pmod 4$.

Let $n = 4t+1$, $t \in \mathbb{N}$. As in case 1, assign the label to the vertices u_i, v_i $(1 \le i \le n-1)$. Next we assign the label 4, 3 respectively to the vertices u_n and v_n. Here $t_f(1) = t_f(3) = t_f(4) = 5t+1$ and $t_f(2) = 5t$.

Case 3. $n \equiv 2 \pmod 4$.

Let $n = 4t+2$, $t \in \mathbb{N}$. Assign the label to the vertices u_i, v_i $(1 \le i \le n-4)$ by in case 1. Now we assign the label 1, 4, 3, 4 to the vertices u_{n-3}, u_{n-2}, u_{n-1} and u_n respectively. Finally we assign 3, 2, 3, 4 respectively to the vertices v_{n-3}, v_{n-2}, v_{n-1} and v_n. It is easy to verify that $t_f(1) = t_f(2) = t_f(3) = t_f(4) = 5t + 2$.
Case 4. $n \equiv 3 \pmod 4$.
Let $n = 4t + 3$, $t \in \mathbb{N}$. In this case, assign the label to the vertices u_i, v_i $(1 \le i \le n-6)$ by in case 1. Then we assign the labels 4, 4, 3, 2, 1, 1 to the vertices u_{n-5}, u_{n-4}, u_{n-3}, u_{n-2}, u_{n-1} and u_n respectively. Finally we assign 4, 3, 3, 2, 1, 1 respectively to the vertices v_{n-3}, v_{n-3}, v_{n-3}, v_{n-2}, v_{n-1} and v_n. Here $t_f(2) = t_f(3) = t_f(4) = 5t+3$ and $t_f(1) = 5t + 4$. □

Theorem 2.5. The triangular snake T_n is 4-total prime cordial.

Proof. Let P_n be the path $u_1u_2\dots u_n$. Let $v_1, v_2, \dots, v_{n-1}$ be the vertices such that v_i is adjacent to both u_i and u_{i+1} $(1 \le i \le n-1)$. It is easy to verift that $|V(T_n)| + |E(T_n)| = 5n - 4$.
Case 1. $n \equiv 0 \pmod 4$.
Let $n = 4t$, $t \in \mathbb{N}$. Assign the label 4 to the vertices $u_1, u_2, \dots, u_t$ and assign the label 2 to the vertices $u_{t+1}, u_{t+2}, \dots, u_{2t}$. Next we assign the label 3 to the vertices $u_{2t+1}, u_{2t+2}, \dots, u_{3t}$ then we assign 1 to the vertices $u_{3t+1}, u_{3t+2}, \dots, u_{n-1}$. Finally we assign the label 3 to the vertex u_n. Next we consider the vertices v_i $(1 \le i \le n-1)$. Assign the label 4 to the vertices $v_1, v_2, \dots, v_t$ and assign the label 2 to the vertices $v_{t+1}, v_{t+2}, \dots, v_{2t-1}$ and we assign the label 3 to the vertices $v_{2t}, v_{2t+1}, \dots, v_{3t-1}$. Next we assign 1 to the vertices $v_{3t}, v_{3t+1}, \dots, v_{n-3}$. Finally, we assign the labels 2, 4 to the vertices v_{n-2} and v_{n-1} respectively. Here $t_f(1) = t_f(2) = t_f(3) = t_f(4) = 5t - 1$.
Case 2. $n \equiv 1 \pmod 4$.
Let $n = 4t + 1$, $t > 1$ $t \in \mathbb{N}$. As in case 1, assign the label the vertices to $u_i(1 \le i \le 3t)$, v_i $(1 \le i \le 3t-1)$. Next we assign the labels 4, 3, 2 to the vertices $u_{3t+1}, u_{3t+2}, u_{3t+3}$ respectively. Assign the label 1 to the remaining vertices of the path P_n. Now we assign the labels 1, 3, 4 to the vertices v_{3t}, v_{3t+1} and v_{3t+2} respectively. Finally we assign the label 1 to the vertices $v_{3t+3}, v_{3t+4}, \dots, v_{n-1}$. Clearly $t_f(1) = t_f(2) = t_f(4) = 5t$ and $t_f(3) = 5t+1$. For $n = 5$ a 4-total prime cordial labelling of T_5 is shown in Figure 1.

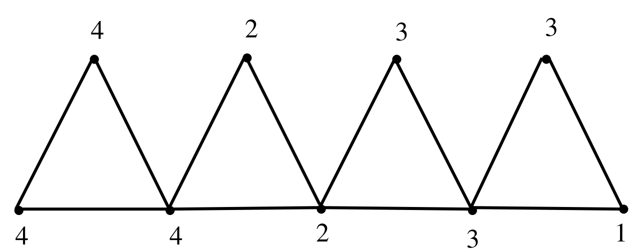

Figure 1

Case 3. $n \equiv 2 \pmod 4$.
Let $n = 4t+2$, $t > 1$ $t \in \mathbb{N}$. As in case 2, we assign the label to the vertices to u_i $(1 \le i \le 3t+2)$, v_i $(1 \le i \le 3t-1)$. Then we assign the labels 4, 2 to the vertices u_{3t+3}, u_{3t+4} respectively. Finally we assign the label 1 to the remaining vertices of the path P_n. Then we assign the labels 4, 3, 2 respectively to the vertices v_{3t}, v_{3t+1} and v_{3t+2}. Finally we assign the label 1 to the vertices $v_{3t+3}, v_{3t+4}, \ldots, v_{n-1}$. It is easy to verify that $t_f(1) = t_f(3) = 5t+1$ and $t_f(2) = t_f(4) = 5t+2$. When $n = 6$ a 4-total prime cordial labelling of T_6 is shown in Figure 2.

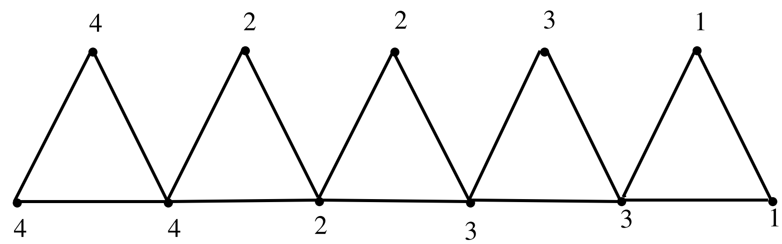

FIGURE 2

Case 4. $n \equiv 3 \pmod 4$.
Let $n = 4t+3$, $t > 1$ $t \in \mathbb{N}$. Assign the label to the vertices to u_i $(1 \le i \le 3t+2)$, v_i $(1 \le i \le 3t+2)$ by case 3. Next we assign the label 2, 3, 4, 3 respectively to the vertices u_{3t+3}, u_{3t+4}, u_{3t+5} and u_{3t+6}. Then the remaining vertices of path labelled by 1. Now we assign the label 2 to the vertex v_{3t+3}. Finally we assign the label 1 to the vertices $v_{3t+4}, v_{3t+5}, \ldots, v_{n-1}$. Clearly $t_f(1) = t_f(2) = t_f(3) = 5t+3$ and $t_f(4) = 5t+2$. When $n = 7$ a 4-total prime cordial labelling of T_7 is shown in Figure 3.

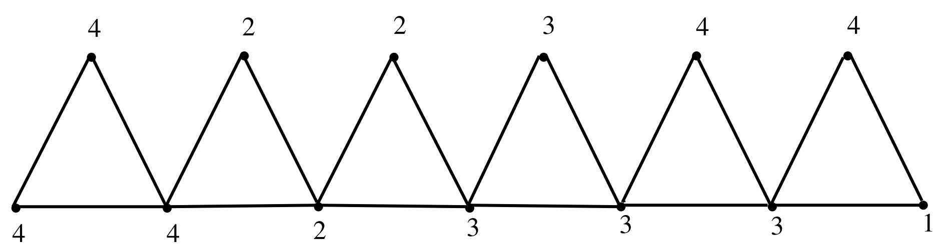

FIGURE 3

□

Theorem 2.6. The double triangular snake $D(T_n)$ is 4-total prime cordial.

Proof. Let P_n be the path $u_1u_2\dots u_n$. Let v_i, w_i be the vertex adjacent to u_i and u_{i+1}. Obviously $|V(D(T_n))| + |E(D(T_n))| = 8n - 7$.
Case 1. $n \equiv 0 \pmod 4$.
Let $n = 4t$, $t \in \mathbb{N}$. Assign the label 4 to the vertices $u_1, u_2, \dots, u_t$ and assign the label 2 to the vertices $u_{t+1}, u_{t+2}, \dots, u_{2t}$. Next we assign the label 3 to the vertices $u_{2t+1}, u_{2t+2}, \dots, u_{3t}$ then we assign 1 to the vertices $u_{3t+1}, u_{3t+2}, \dots, u_{n-1}$. Finally we assign the label 3 to the vertex u_n. Next we consider the vertices v_i, w_i $(1 \le i \le n-1)$. Assign the label 4 to the vertices $v_1, v_2, \dots, v_t$ and $w_1, w_2, \dots, w_t$. Then assign the label 2 to the vertices $v_{t+1}, v_{t+2}, \dots, v_{2t-1}$ and $w_{t+1}, w_{t+2}, \dots, w_{2t-1}$. Next we assign the label 3 to the vertices $v_{2t}, v_{2t+1}, \dots, v_{3t-1}$ and $w_{2t}, w_{2t+1}, \dots, w_{3t-1}$. Now we assign 1 to the vertices $v_{3t}, v_{3t+1}, \dots, v_{n-3}$ and $w_{3t}, w_{3t+1}, \dots, w_{n-3}$. Finally, we assign the labels 2, 4, 2, 4 to the vertices v_{n-2}, v_{n-1}, w_{n-2} and w_{n-1} respectively. Clearly $t_f(1) = t_f(2) = t_f(3) = 8t - 2$ and $t_f(4) = 8t - 1$.
Case 2. $n \equiv 1 \pmod 4$.
Let $n = 4t + 1$, $t \in \mathbb{N}$. As in case 1, assign the label to the vertices u_i $(1 \le i \le n-3)$, v_i $(1 \le i \le n-1)$ and w_i $(1 \le i \le n-3)$. Next we assign the labels 2, 3, 4, 2, 3 respectively to the vertices u_{n-2}, u_{n-1}, u_n, w_{n-2} and w_{n-1}. Here $t_f(1) = t_f(3) = t_f(4) = 8t$ and $t_f(2) = 8t + 1$.
Case 3. $n \equiv 2 \pmod 4$.
Let $n = 4t + 2$, $t \in \mathbb{N}$. As in case 2, assign the label to the vertices u_i $(1 \le i \le n-4)$, v_i $(1 \le i \le n-4)$ and w_i $(1 \le i \le n-2)$. Now we assign the labels 2, 3, 3, 4, 4, 4, 4, 2 to the vertices u_{n-3}, u_{n-2}, u_{n-1}, u_n, v_{n-3}, v_{n-2}, v_{n-1} and w_{n-1} respectively. It is easy to verify that $t_f(1) = t_f(2) = t_f(4) = 8t + 2$ and $t_f(3) = 8t + 3$.
Case 4. $n \equiv 3 \pmod 4$.
Let $n = 4t + 3$, $t \in \mathbb{N}$. As in case 3, assign the label to the vertices u_i $(1 \le i \le n-1)$, v_i $(1 \le i \le n-2)$ and w_i $(1 \le i \le n-2)$. Finally we assign the labels 4, 3, 2 respectively to the vertices u_n, v_{n-1} and w_{n-1}. Clearly $t_f(1) = t_f(3) = t_f(4) = 8t + 4$ and $t_f(2) = 8t + 5$. □

Theorem 2.7. The friendship graph $C_3^{(t)}$ is 4-total prime cordial iff $t \equiv 0, 1, 2 \pmod 4$.

Proof. Let $V(C_3^{(t)}) = \{u, u_i, v_i : 1 \le i \le n\}$ and $E(C_3^{(t)}) = \{uu_i, uv_i, u_iv_i : 1 \le i \le n\}$.
Case 1. $t \equiv 0 \pmod 4$.
Let $t = 4m$, $m > 4$ $m \in \mathbb{N}$.
Subcase 1. m is even.
Assign the label 4 to the central vertex u. Next assign the label 4 to the vertex $u_1, u_2, \dots, u_m$ and $v_1, v_2, \dots, v_m$. Next assign 2 to the vertices $u_{m+1}, u_{m+2}, \dots, u_{2m}$ and $v_{m+1}, v_{m+2}, \dots, v_{2m}$. Next assign the label 3 to the vertices $u_{2m+1}, u_{2m+2}, \dots,$ $u_{\frac{7m}{2}}, \dots, u_{4m}$ and $v_{2m+1}, v_{2m+2}, \dots, v_{\frac{7m}{2}}$. Finally assign the label 1 to the remaining vertices.

Subcase 2. m is odd.
As in subcase 1, assign the label to the vertices u_i, v_i $(1 \leq i \leq \frac{7m+1}{2})$. Next assign the label 3 to the vertices $v_{\frac{7m+1}{2}}, \ldots, v_{4m}$ and assign the label 1 to the remaining vertices. Clearly $t_f(1) = t_f(2) = t_f(3) = 5m$ and $t_f(4) = 5m + 1$.
Case 2. $t \equiv 1 \pmod 4$.
Let $t = 4m + 1$, $m > 4$ $m \in \mathbb{N}$. As in case 1, assign the label to the vertices u_i, v_i $(1 \leq i \leq 4m - 1)$. Finally assign the labels 3, 2 to the vertices u_n and v_n respectively. Clearly $t_f(1) = t_f(2) = 5m + 2$ $t_f(3) = t_f(4) = 5m + 1$.
Case 3. $t \equiv 2 \pmod 4$.
Let $t = 4m + 2$, $m > 4$ $m \in \mathbb{N}$. Assign the label to the vertices u_i, v_i $(1 \leq i \leq 4m - 2)$ by case 1. Next we assign the labels 4, 2, 3, 3 respectively to the vertices u_{4m-1}, v_{4m-1}, u_{4m} and v_{4m}. It is clear that $t_f(1) = 5m + 2$ and $t_f(2) = t_f(3) = t_f(4) = 5m + 3$.
Case 4. $t \equiv 3 \pmod 4$.
Let $t = 4m+2$, $m > 4$ $m \in \mathbb{N}$. Clearly $\left|V(c_3^{(t)})\right| + \left|E(c_3^{(t)})\right| = 20m+16$. Suppose f is a 4-total prime cordial of $C_3^{(t)}$.
Subcase 1. $f(u) = 1$ or 3.
In this case, either $t_f(2) < 5m + 4$ or $t_f(4) < 5m + 4$.
Subcase 2. $f(u) = 4$.
To get edge label 3, 3 should be labelled to the adjacent vertices. So far the maximum possibility 3 is the label of the adjacent vertices. To get the edge label 2, either 2 is labelled to the adjacent vertices or 2 and 4 are labelled on the adjacent vertices. Thus for the maximum possibility of 4 is the labels of the adjacent vertices and 2 is the labels of the adjacent vertices. But in this case $t_f(4) > 5m + 4$, a contradiction.
Subcase 3. $f(u) = 2$.
Similar to subcase 2.
Case 2. $t = 2, 4, 5, 6, 8$.
A 4-total prime cordial labeling is given in Table 1.

n	2	4	5	6	8
u	4	2	2	2	2
u_1	4	4	4	4	4
u_2	2	4	4	4	4
u_3	3	4	4	4	4
u_4	3	3	4	4	4
u_5		3	3	3	4
u_6		3	3	3	4
u_7		4	3	3	3
u_8		3	3	3	3
u_9			2	2	3
u_{10}			1	3	3

u_{11}				4	3
u_{12}				3	3
u_{13}					4
u_{14}					3
u_{15}					2
u_{16}					1

Table 1:

□

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