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PAIR DIFFERENCE CORDIAL LABELING OF SOME STAR RELATED GRAPHS

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Abstract. In this paper, we investigate the pair difference cordial labeling behaviour of some star related graphs.

Keywords: Banana tree, Lilly graph, Shrub, Star.
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1. Introduction

All graphs are consider here only finite, undirected and simple graphs. The concept of cordial labeling was introduced by Cahit[1]. Varieties of cordial labeling have been studied in [2, 4, 6, 7, 8, 9, 20, 21]. In a similar line the notion of pair difference cordial labeling (PDC-Labeling) of a graph has been introduced in [10]. The PDC- labeling behaviour of several graphs have been investigated in [10 - 17]. In this paper, we investigate the PDC-labeling behaviour of some star related graphs. Terms not defined here are used in the sense of Harary[5]

2. Preliminaries

Definition 2.1. [3] The graph obtained from the $r-$stars $K_{1,l_1}, K_{1,l_2}, K_{1,l_3}, \cdots, K_{1,l_r}$ by joining the central vertices of K_{1,l_j} and $K_{1,l_{j+1}}$ to a vertex w_j for $j = 1, 2, 3, \cdots, r-1$ is denoted by $T(K_{1,l_1} : K_{1,l_2} : K_{1,l_3} : \cdots : K_{1,l_r})$.

Definition 2.2. [3] The graph obtained from the $r-$stars $K_{1,l_1}, K_{1,l_2}, K_{1,l_3}, \cdots, K_{1,l_r}$ by joining a leaf of K_{1,l_j} and a leaf of $K_{1,l_{j+1}}$ to a new vertex w_j for $j = 1, 2, 3, \cdots, r-1$ by an edge is denoted by $T(K_{1,l_1} \circ K_{1,l_2} \circ K_{1,l_3} \circ \cdots \circ K_{1,l_r})$.

Definition 2.3. [3] The graph obtained by connecting a vertex v_0 to the central vertex of each of m number of stars is called the shrub graph and it is denoted by $St((l_1, l_2, l_3, \cdots, l_m)$

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Definition 2.4. [3] The graph obtained by connecting a vertex v_0 to one leaf of each of m number of stars is called the banana tree graph and it is denoted by $Bt(l_1, l_2, l_3, \cdots, l_m)$.

Definition 2.5. [3] The Lilly graph $I_n, n \geq 2$ is constructed by two copy of the stars $2K_{1,n}, n \geq 2$ joining the two copy of the path graphs $2P_n, n \geq 2$ with sharing a common vertex.
Let $V(I_n) = \{u_i, v_i : 1 \leq i \leq n\} \cup \{x_i : 1 \leq i \leq n\} \cup \{y_i : 1 \leq i \leq n-1\}$ and $E(I_n) = \{x_n u_i, x_n y_i : 1 \leq i \leq n\} \cup \{x_i x_{i+1} : 1 \leq i \leq n-1\} \cup \{x_n y_1\} \cup \{y_i y_{i+1} : 1 \leq i \leq n-2\}$. Clearly I_n has $4n-1$ vertices and $4n-2$ edges.

The following theorem is used for the subsequent places.

Theorem 2.6. [10] *The path P_n is PDC for all values of $n \neq 3$.*

3. Main Results

Theorem 3.1. *$T(K_{1,l_1} : K_{1,l_2} : K_{1,l_3} : \ldots : K_{1,l_r})$ is PDC, where $l_1 = l_2 = l_3 = \cdots, l_r = n$ if and only if $n \leq 3$.*

Proof. Let the vertices of n copies of stars be $u_i, u_{ii}, i = 1, 2, 3, \ldots, n$.
Let $V(T(K_{1,n} : K_{1,n} : K_{1,n} : \ldots : K_{1,n})) = \{u_i, u_{ii} : 1 \leq i \leq n\} \cup \{v_i : 1 \leq i \leq n-1\}$ and $E(T(K_{1,n} : K_{1,n} : K_{1,n} : \ldots : K_{1,n})) = \{u_i, u_{ij} : 1 \leq i, j \leq n\} \cup \{u_i v_i, u_{i+1} v_i : 1 \leq i \leq n-1\}$. Clearly $T(K_{1,n} : K_{1,n} : K_{1,n} : \ldots : K_{1,n})$ has $n^2 + 2n - 1$ vertices and $n^2 + 2n - 2$ edges.
There are four cases arises.

Case 1. $n = 1$.
In this case the given graph is isomorphic to P_2, hence by Theorem 2.6 the given graph is PDC.

Case 2. $n = 2$.
Label the vertices $u_{11}, u_{12}, u_{21}, u_{22}$ respectively by the integers $1, 3, -1, -2$. Next label the intergers $2, -3, 2$ respectively to the vertices u_1, u_2, v_1.

Case 3. $n = 3$.
Label the vertices $u_{11}, u_{12}, u_{13}, u_{21}, u_{22}, u_{23}, u_{31}, u_{32}, u_{33}$ by the integers $1, 3, 4, -7, -6, 7, -4, -3, -1$ respectively. Next label the interger values $2, 6, -2, 5, -5$ respectively to the vertices u_1, u_2, u_3, v_1, v_2.

Case 4. $n \geq 4$.
Since the edge label is the absolute difference of vertex labels, the maximum possible number of the edges get the label 1 is

$$\Delta_{f_1} = \begin{cases} 2n+1, & \text{when } n \text{ is even} \\ 2n, & \text{when } n \text{ is odd.} \end{cases}$$

Subcase 1. n is even, $n \geq 4$.
$\Delta_{f_1} \leq 2n+1$. This implies $\Delta_{f_1^c} \geq n^2+2n-2-2n-1$. This implies $\Delta_{f_1^c} \geq n^2-3$. Hence $\Delta_{f_1^c} - \Delta_{f_1} \leq n^2 - 2n - 4 > 1$, a contradiction.

Subcase 2. n is odd, $n \geq 5$.
$\Delta_{f_1} \leq 2n$. This implies $\Delta_{f_1^c} \geq n^2 + 2n - 2 - 2n$. This implies $\Delta_{f_1^c} \geq n^2 - 2$. Hence $\Delta_{f_1^c} - \Delta_{f_1} \leq n^2 - 2n - 2 > 1$, a contradiction.

□

Example 3.2. *PDC-labeling of $T(K_{1,3} : K_{1,3} : K_{1,3})$ is given in Figure 1.*

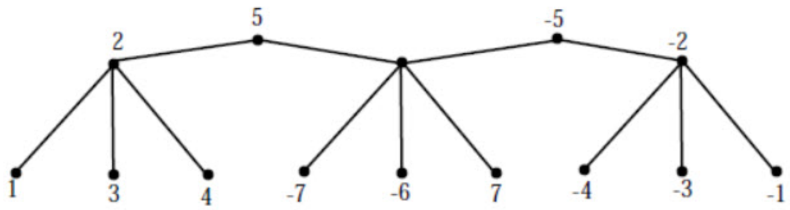

FIGURE 1. $T(K_{1,3} : K_{1,3} : K_{1,3})$

Theorem 3.3. *$T(K_{1,l_1} \circ K_{1,l_2} \circ K_{1,l_3} \circ \ldots \circ K_{1,l_r})$ is PDC, where $l_1 = l_2 = l_3 = \ldots, l_r = n$ if and only if $n \leq 5$.*

Proof. Let the vertices of n copies of stars be $u_i, u_{ii}, (1 \leq i \leq n)$.
Let $V(T(K_{1,n} \circ K_{1,n} \circ K_{1,n} \circ \ldots \circ K_{1,n})) = \{u_i, u_{ii} : 1 \leq i \leq n\} \cup \{v_i : 1 \leq i \leq n-1\}$ and $E(T(K_{1,n} \circ K_{1,n} \circ K_{1,n} \circ \ldots \circ K_{1,n})) = \{u_i, u_{ij} : 1 \leq i, j \leq n\} \cup \{u_{in}v_i, u_{(i+1)1}v_i : 1 \leq i \leq n-1\}$. Clearly $T(K_{1,n} \circ K_{1,n} \circ K_{1,n} \circ \ldots \circ K_{1,n})$ has $n^2 + 2n - 1$ vertices and $n^2 + 2n - 2$ edges.
There are three cases arises.
Case 1. $n = 1$.
In this case the given graph is isomorphic to P_2, hence by Theorem 2.6 the given graph is PDC.

Case 2. $2 \leq n \leq 5$.
A PDC-labeling of $T(K_{1,n} \circ K_{1,n} \circ K_{1,n} \circ \ldots \circ K_{1,n}), n = 2, 3, 4, 5$ is shown in Tables 1 , 2 , 3 and 4.

n	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{21}	x_{22}	x_{23}	x_{24}	x_{25}
2	1	3				-1	-1			
3	1	3	4			6	-1	-2		
4	1	3	4	5		7	9	10	11	
5	1	3	4	5	6	8	10	11	12	13

Table 1

n	x_{31}	x_{32}	x_{33}	x_{34}	x_{35}	x_{41}	x_{42}	x_{43}	x_{44}	x_{45}
3	-3	-5	-6							
4	-11	-10	-9	-8		-5	-4	-3	-1	
5	16	17	-17	-16	-15	-13	-12	-11	-10	-8

Table 2

n	x_{51}	x_{52}	x_{53}	x_{54}	x_{55}
5	-6	-5	-4	-3	-1

Table 3

n	x_1	x_2	x_3	x_4	x_5	y_1	y_2	y_3	y_4
2	2	-2				-3			
3	2	7	-7			5	-4		
4	2	8	-7	-2		6	1	-6	
5	2	9	15	-9	-2	7	14	-14	-7

Table 4

Case 3. $n \geq 6$.
The maximum possible number of the edges get the label 1 is

$$\Delta_{f_1} = \begin{cases} 4n-3, & \text{when } n \text{ is even} \\ 4n-2, & \text{when } n \text{ is odd.} \end{cases}$$

Subcase 1. n is even, $n \geq 6$.
$\Delta_{f_1} \leq 4n-3$. This implies $\Delta_{f_1^c} \geq n^2+2n-2-4n+3$. This implies $\Delta_{f_1^c} \geq n^2-2n+1$. Hence $\Delta_{f_1^c} - \Delta_{f_1} \leq n^2-6n+4 > 1$, a contradiction.

Subcase 2. n is odd, $n \geq 7$.
$\Delta_{f_1} \leq 4n-2$. This implies $\Delta_{f_1^c} \geq n^2+2n-2-4n+2$. This implies $\Delta_{f_1^c} \geq n^2-2n$. Hence $\Delta_{f_1^c} - \Delta_{f_1} \leq n^2-6n+2 > 1$, a contradiction.

□

Example 3.4. *PDC-labeling of* $T(K_{1,3} \circ K_{1,3} \circ K_{1,3})$ *is given in Figure 2.*

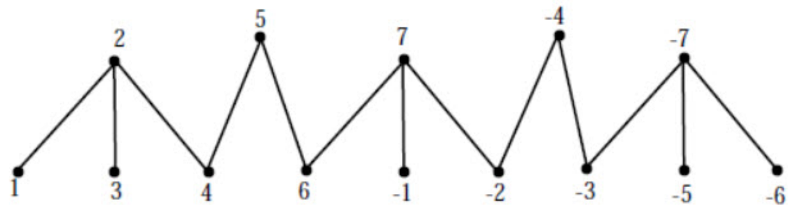

FIGURE 2. $T(K_{1,3} \circ K_{1,3} \circ K_{1,3})$

Theorem 3.5. *$St(n, n)$ is PDC if and only if $n \leq 4$.*

Proof. Let $V(St(n, n)) := \{x, x_i, y, y_i, z : 1 \leq i \leq n\}$ and $E(St(n, n)) := \{xx_i, yy_i : 1 \leq i \leq n\} \cup \{xz, yz\}$. Clearly $St(n, n)$ has $2n + 1$ vertices and $2n + 2$ edges.
There are three cases arises.

Case 1. $n = 1$.
In this case $St(1, 1)$ is isomorphic to P_4, by Theorem 2.6 the given graph is PDC.

Case 2. $2 \leq n \leq 4$.
A PDC-labeling of $St(n, n), n = 2, 3, 4$ is shown in Table 5 .

n	x_1	x_2	x_3	x_4	y_1	y_2	y_3	y_4	x	y	z
2	1	3			-2	-3			2	-1	2
3	1	3	4		-1	-3	-4		2	-2	2
4	1	3	4	5	-1	-3	-4	-5	2	-2	1

TABLE 5

Case 3. $n \geq 5$.
The maximum possible number of the edges get the label 1 is $\Delta_{f_1} \leq 5$.
This implies $\Delta_{f_1^c} \geq 2n + 2 - 5$. Therefore $\Delta_{f_1^c} \geq 2n - 3$. Hence $\Delta_{f_1^c} - \Delta_{f_1} \leq 2n - 3 - 5 = 2n - 8 > 1$, a contradiction.

□

Theorem 3.6. *$St(n, n, n)$ is PDC if and only if $n \leq 3$.*

Proof. Let $V(St(n, n, n)) = \{x, x_i, x_{ij} : 1 \leq i \leq 3, 1 \leq j \leq n\}$ and $E(St(n, n, n)) = \{xx_i, x_ix_{ij} : 1 \leq i \leq 3, 1 \leq j \leq n\}$. There are two cases arises.

Case 1. $1 \leq n \leq 3$.
A PDC-labeling of $St(n, n, n), n = 1, 2, 3$ is shown in Tables 6 and 7 .

n	x_{11}	x_{12}	x_{13}	x_{21}	x_{22}	x_{23}	x_{31}	x_{32}	x_{33}
1	2			-2			-3		
2	1	3		-1	-3		5	-6	
3	1	3	4	-1	-3	-4	6	6	-5

Table 6

n	x_1	x_2	x_3	x
1	1	-1	3	2
2	2	-2	6	-5
3	2	-2	5	-6

Table 7

Case 2. $n \geq 4$.

Subcase 1. n is even, $n \geq 4$.
In this case $\Delta_{f_1} \leq 6$. This implies $\Delta_{f_1^c} \geq 3n+3-6$. This implies $\Delta_{f_1^c} \geq 3n-3$. Hence $\Delta_{f_1^c} - \Delta_{f_1} \leq 3n - 3 - 6 = 3n - 9 > 1$, a contradiction.

Subcase 2. n is odd, $n \geq 5$.
Here $\Delta_{f_1} \leq 7$. Therefore $\Delta_{f_1^c} \geq 3n + 3 - 7$. This implies $\Delta_{f_1^c} \geq 3n - 4$. Hence $\Delta_{f_1^c} - \Delta_{f_1} \leq 3n - 4 - 7 = 3n - 11 > 1$, a contradiction.

□

Example 3.7. *PDC-labeling of $St(3, 3, 3)$ is given in Figure 3.*

Theorem 3.8. *$St(1, 2, n)$ is PDC if and only if $n \leq 8$.*

Proof. Let $V(St(1, 2, n)) = \{x, x_i : 1 \leq i \leq 3\} cup \{x_{31}, x_{21}, x_{22}\} \cup \{x_{1j} : 1 \leq j \leq n\}$ and $E(St(1, 2, n)) = \{xx_i, x_1x_{1j} : 1 \leq i \leq 3, 1 \leq j \leq n\} \cup \{x_2x_{21}, x_2x_{22}, x_3x_{33}\}$. There are three cases arises.

Case 1. $1 \leq n \leq 4$.
A PDC-labeling of $St(n, n, n), n = 1, 2, 3, 4$ is shown in Tables 8 and 9 .

Case 2. $5 \leq n \leq 8$.
A PDC labeling of $St(1, 2, n), n = 5, 6, 7, 8$ is shown in Table 10 and 11 .

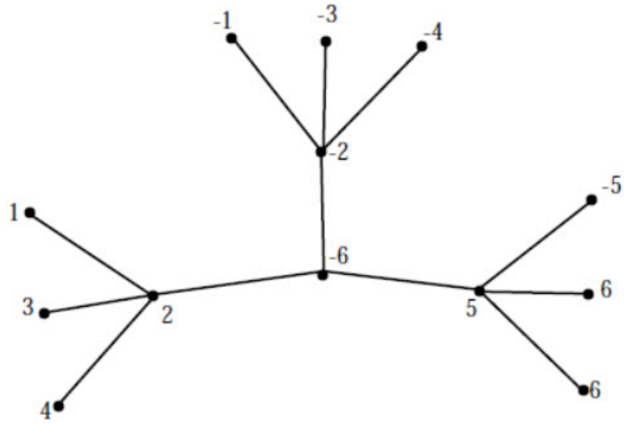

FIGURE 3. $St(3,3,3)$

n	x_{11}	x_{12}	x_{13}	x_{14}	x_{21}	x_{22}	x_{31}
1	-3				1	3	-4
2	-1	-3			1	3	5
3	-2	-3	-4		1	3	5
4	-2	-3	-4	-5	1	3	-4

TABLE 8

n	x_1	x_2	x_3	x
1	-2	2	4	-1
2	-2	2	-4	4
3	-1	2	-4	4
4	-1	2	5	4

TABLE 9

n	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}
5	1	3	4	5	6			
6	1	3	4	5	6	6		
7	1	3	4	5	6	7	-7	
8	1	3	4	5	6	7	-7	3

TABLE 10

Case 3. $n \geq 9$.
There are two cases arises.

n	x_{21}	x_{22}	x_{31}	x_1	x_2	x_3	x
5	-6	-1	-3	2	-2	-5	-4
6	-6	-1	-3	2	-2	-5	-4
7	-6	-1	-3	2	-2	-5	-4
8	-6	-1	-3	2	-2	-5	-4

TABLE 11

Subcase 1. n is even, $n \geq 10$.
The maximum possible value of Δ_{f_1} is 7. Therefore $\Delta_{f_1^c} \geq n+6-7$. This implies $\Delta_{f_1^c} \geq n-1$. Hence $\Delta_{f_1^c} - \Delta_{f_1} \leq n-1-7 = n-8 > 1$, a contradiction.

Subcase 2. n is odd, $n \geq 9$.
The maximum possible value of Δ_{f_1} is 6. Therefore $\Delta_{f_1^c} \geq n+6-6$. This implies $\Delta_{f_1^c} \geq n$. Hence $\Delta_{f_1^c} - \Delta_{f_1} \leq n-6 > 1$, a contradiction.

□

Theorem 3.9. *$Bt\,(n,n)$ is PDC if and only if $2 \leq n \leq 5$.*

Proof. Let $V\,(Bt\,(n,n)) = \{a_1, a_{i,1}, a_{i,2}, \ldots, a_{i,n} : 1 \leq i \leq n\}$ and $E\,(Bt\,(n,n)) = \{a_1 a_{1,i}, a_{1,i} a_{2,i} : 1l1eqi \leq n\} \cup \{a_{2,j} a_{i,j} : 3 \leq i \leq n, 1 \leq j \leq n\}$.

Case 1. $n = 1$.
Since $B(1,1) \cong P_3$, by Theorem 2.6 $Bt(1,1)$ is not PDC.

Case 2. $2 \leq n \leq 5$.
A PDC-labeling of $Bt(n,n), n = 2,3,4,5$ is shown in Tables 12 , 13 and 14.

n	a_1	$a_{1,1}$	$a_{1,2}$	$a_{1,3}$	$a_{1,4}$	$a_{1,5}$	$a_{2,1}$	$a_{2,2}$	$a_{2,3}$	$a_{2,4}$	$a_{2,5}$
2	1	1	-1				2	-2			
3	-5	1	-1	4			2	-2	5		
4	-4	6	7	-6	-7		2	-2	5	-5	
5	-12	-9	-10	-11	-13	13	2	-2	6	-6	10

TABLE 12

Case 3. $n \geq 6$.
The maximum possible number of the edges get the label 1 is $\Delta_{f_1} \leq 2n+2$. This implies $\Delta_{f_1^c} \geq n^2-2n-2$. Therefore $\Delta_{f_1^c} - \Delta_{f_1} \leq n^2-2n-2-2n-2 = n^2-4n-4 > 1$, a contradiction.

□

n	$a_{3,1}$	$a_{3,2}$	$a_{3,3}$	$a_{3,4}$	$a_{3,5}$	$a_{4,1}$	$a_{4,2}$	$a_{4,3}$	$a_{4,4}$	$a_{4,5}$
3	3	-3	-4							
4	1	-1	4	-4		-3	-3	6	-6	
5	1	-1	5	-5	-9	3	-3	7	-7	11

TABLE 13

n	$a_{5,1}$	$a_{5,2}$	$a_{5,3}$	$a_{5,4}$	$a_{5,5}$
5	4	-4	8	-8	12

TABLE 14

Example 3.10. *PDC-labeling of $Bt\,(4,4)$ is given in Figure 4.*

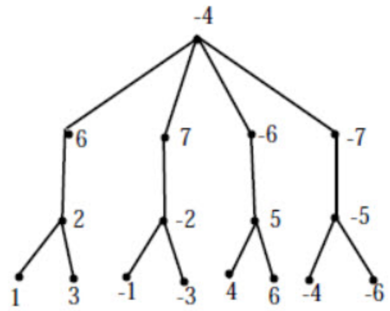

FIGURE 4. $Bt\,(4,4)$

Theorem 3.11. *I_n is PDC for all values of n.*

Proof. Take the vertex and edge set from Definition 2.6.

First we label the vertices $x_1, x_2, x_3, \ldots, x_n$ by the integers $1, 2, 3, \ldots, n$ respectively and next using labels $n+1, n+2, n+3, \ldots, 2n-1$ to the vertices $y_1, y_2, y_3, \ldots, y_{n-1}$ respectively.

Secondly assign the labels $-1, -2, -3, \ldots, -n$ respectively to the vertices $u_1, u_2, u_3, \ldots, u_n$ and label the vertices $v_1, v_2, v_3, \ldots, v_{n-1}$ respectively by the integers $-(n+1), -(n+2), -(n+3), \ldots, -(2n-1)$.
Finally asign the label $n-1$ to the vertex v_n. Here $\Delta_{f_1} = \Delta_{f_1^c} = 2n-1$. □

Example 3.12. *PDC labeling of I_5 is given in Figure 5.*

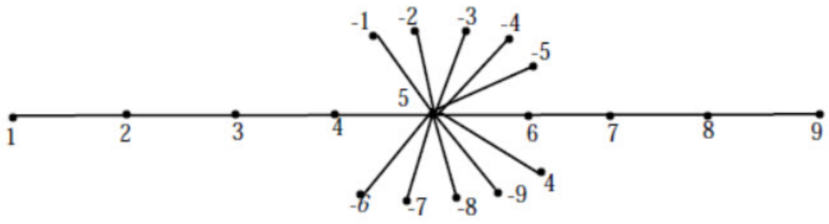

FIGURE 5. I_5

4. Limitation of Research

Presently, it is difficult to investigate the PDC-labeling behaviour of rigid ladders, twisted cylinder,hybrid quadrilatral snake and swastik graph.

5. Conclusion

The pair sum labeling was introduced in [18]. Also the notion of the difference cordial labeling of graphs was introduced in [19]. With the background of these two labeling concepts, we have defined a new labeling the PDC labeling of graphs. A consequential hypothesis arising in this context is that all graphs can be expected to possess the property of PDC labeling. However, this is a formidable hypothesis. Examining this hypothesisfor a general graph poses computational complexities. Therefore, one may consider specific graphs and examine this property. Accordingly,the PDC labeling behaviour of some star related graphs like Banana tree, Lilly graph, Shrub have been investigate in this paper. The PDC-labeling behaviour of m- copies of some special graphs are the open problems.

6. Aknowledgement

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