

## Mean cordiality of some snake graphs

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**Abstract** Let  $f$  be a function from the vertex set  $V(G)$  to  $\{0, 1, 2\}$ . For each edge  $uv$  assign the label  $\left\lceil \frac{f(u)+f(v)}{2} \right\rceil$ .  $f$  is called a mean cordial labeling if  $|v_f(i) - v_f(j)| \leq 1$  and  $|e_f(i) - e_f(j)| \leq 1$ ,  $i, j \in \{0, 1, 2\}$ , where  $v_f(x)$  and  $e_f(x)$  respectively denote the number of vertices and edges labeled with  $x$  ( $x = 0, 1, 2$ ). A graph with a mean cordial labeling is called a mean cordial graph. In this paper we investigate mean cordial labeling behavior of double triangular snake, alternate triangular snake, double alternate triangular snake.

### 1 Introduction

All graphs in this paper are finite, undirected and simple. The vertex set and edge set of a graph  $G$  are denoted by  $V(G)$  and  $E(G)$  respectively. Let  $p, q$  denotes the number of vertices and edges in  $G$ . Ponraj et al. defined the mean cordial labeling of a graph in [3]. Mean cordial labeling behavior of path, cycle, star, complete graph, wheel, comb,  $mG$ ,  $P_m \cup P_n$ ,  $P_n^2$ , triangular snake etc have been investigated in [3, 6]. Also, Albert William et al. [1] have studied about the mean cordial labeling behaviour of certain graphs like subdivision of a bistar  $S(B_{m,n})$ , particular type of caterpillar, Banana tree and path banana tree. Here we investigate the mean cordial labeling behavior of double triangular snake, alternate triangular snake, double alternate triangular snake. The symbol  $\lceil x \rceil$  stands for smallest integer greater than or equal to  $x$ . Terms and definitions not defined here are used in the sense of Harary [4].

### 2 Preliminary Results

In this section we write some basic definitions and results which are needed for the next section.

**Definition 2.1.** Let  $f$  be a function from  $V(G)$  to  $\{0, 1, 2\}$ . For each edge  $uv$  of  $G$  assign the label  $\left\lceil \frac{f(u)+f(v)}{2} \right\rceil$ .  $f$  is called a mean cordial labeling if  $|v_f(i) - v_f(j)| \leq 1$  and  $|e_f(i) - e_f(j)| \leq 1$ ,  $i, j \in \{0, 1, 2\}$ , where  $v_f(x)$  and  $e_f(x)$  denote the number of vertices and edges labeled with  $x$  ( $x = 0, 1, 2$ ) respectively. A graph with a mean cordial labeling is called a mean cordial graph.

**Definition 2.2.** The triangular snake  $T_n$  is obtained from the path  $P_n$  by replacing each edge of the path by a triangle  $C_3$ .

**Definition 2.3.** An alternate triangular snake  $A(T_n)$  is obtained from a path  $u_1u_2 \dots u_n$  by joining  $u_i$  and  $u_{i+1}$  (alternatively) to new vertex  $v_i$ . That is every alternate edge of a path is replaced by  $C_3$ .

**Definition 2.4.** A double alternate triangular snake  $DA(T_n)$  consists of two alternate triangular snakes that have a common path. That is, a double alternate triangular snake is obtained from a path  $u_1u_2 \dots u_n$  by joining  $u_i$  and  $u_{i+1}$  (alternatively) to two new vertices  $v_i$  and  $w_i$ .

**Definition 2.5.** A double triangular snake  $D(T_n)$  consists of two triangular snakes that have a common path.

**Theorem 2.6.** [5] The triangular snake  $T_n$  ( $n > 1$ ) is mean cordial iff  $n \equiv 0 \pmod{3}$ .

### 3 Main Results

**Theorem 3.1.** Mean cordial labeling behaviour of Alternate triangular snake  $A(T_n)$  is given below:

- a. Mean cordial if the triangle starts from  $u_2$  and ends with  $u_{n-1}$ .
- b. Mean cordial if the triangle starts from  $u_1$ , ends with  $u_n$  and  $n \equiv 0 \pmod{3}$ .
- c. Not Mean cordial if the triangle starts from  $u_1$ , ends with  $u_n$  and  $n \equiv 1, 2 \pmod{3}$ .
- d. Mean cordial if the triangle starts from  $u_2$ , ends with  $u_n$ .

*Proof. Case a.* The triangle starts from  $u_2$  and ends with  $u_{n-1}$ .

In this case  $p = \frac{3n-2}{2}, q = 2n - 3$ .

**Sub case 1.**  $n \equiv 1 \pmod{3}$ .

Let  $n = 3t + 1, t > 1$ . Assign the label '0' to  $t + 1$  path vertices  $u_1, u_2, \dots, u_{t+1}$ . Then assign '2' to the next  $t$  path vertices; assign '1' to the remaining path vertices. Then we move to the vertices of degree 2. Label the vertices  $v_1, v_2, \dots, v_{t-2}$  by '0'. Then assign the label '2' to the vertices  $v_{t-1}, v_t, \dots, v_{2t-3}$ . Finally assign the label '1' to the vertices  $v_{2t-2}, v_{2t-1}, \dots, v_{3t-5}$ . The above vertex labeling  $f$ , satisfies the mean cordial condition by table 1.

$i$	0	1	2
$v_f(i)$	$\frac{n}{2}$	$\frac{n-2}{2}$	$\frac{n}{2}$
$e_f(i)$	$\frac{2n-5}{3}$	$\frac{2n-2}{3}$	$\frac{2n-2}{3}$

**Table 1.**

When  $t = 1$ , the corresponding mean cordial labeling of  $A(T_4)$  is given in figure 3.1.

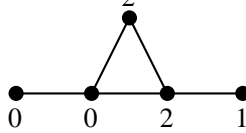


Figure 3.1

**Sub case 2.**  $n \equiv 2 \pmod{3}$ .

Let  $n = 3t + 2$ . Assign the label '0' to the vertices of the first  $\frac{t}{2}$  triangles and then '1' to the next  $\frac{t}{2}$  triangles. Then assign the label '2' to the vertices of the remaining  $\frac{t}{2}$  triangles. Finally assign the label '0', '2' to the pendent vertices  $u_1$  and  $u_n$  respectively. In this case the vertex and edge condition is given in table 2.

$i$	0	1	2
$v_f(i)$	$\frac{n}{2}$	$\frac{n-2}{2}$	$\frac{n}{2}$
$e_f(i)$	$\frac{2n-4}{3}$	$\frac{2n-4}{3}$	$\frac{2n-1}{3}$

**Table 2.**

**Sub case 3.**  $n \equiv 0 \pmod{3}$ .

Let  $n = 3t$ . Assign the labels to the vertices as in sub case 2 then relabel the vertices  $u_1$  by 2 and the vertex  $u_{2t+1}$ , a vertex of  $t^{th}$  triangle by 2. The table 3 shows that the above vertex labeling  $f$  is a mean cordial labeling.

$i$	0	1	2
$v_f(i)$	$\frac{n}{2}$	$\frac{n}{2}$	$\frac{n-2}{2}$
$e_f(i)$	$\frac{2n-3}{3}$	$\frac{2n-3}{3}$	$\frac{2n-3}{3}$

**Table 3.**

For the cases b & c,  $p = \frac{3n}{2}$  and  $q = 2n - 1$ .

**Case b.** The triangle starts from  $u_1$ , ends with  $u_n$  and  $n \equiv 0 \pmod{3}$ .

Let  $n = 3t$ . Assign the label '0' to the vertices of the first  $\frac{t}{2}$  triangles. Then '1' to the vertices of the next  $\frac{t}{2}$  triangles. Finally assign the label '2' to the vertices of the remaining  $\frac{t}{2}$  triangles. The table 4 establishes that the above vertex labeling  $f$ , satisfies the mean cordiality condition.

**Case c.** The triangle starts from  $u_1$ , ends with  $u_n$  and  $n \equiv 1, 2 \pmod{3}$ .

$i$	0	1	2
$v_f(i)$	$\frac{n}{2}$	$\frac{n}{2}$	$\frac{n}{2}$
$e_f(i)$	$\frac{2n-3}{3}$	$\frac{2n}{3}$	$\frac{2n}{3}$

**Table 4.**

**Sub case 1.**  $n \equiv 1 \pmod{3}$ .

Suppose  $f$  is a mean cordial labeling, then  $v_f(0) = v_f(1) = v_f(2) = \frac{n}{2}$ . This forces the maximum value of  $e_f(0)$  is  $\lfloor \frac{2n-1}{3} \rfloor - 1$ . That is  $e_f(0) \leq \lfloor \frac{2n-1}{3} \rfloor - 1$ . Since the size of  $A(T_n)$  is  $2n - 1$ ,  $f$  can not be satisfies the edge condition of the mean cordial labeling.

**Sub case 2.**  $n \equiv 2 \pmod{3}$ .

Suppose  $f$  is a mean cordial labeling, then  $v_f(0) = v_f(1) = v_f(2) = \frac{n}{2}$ . In this case  $e_f(0) \leq \frac{2n-4}{3}$ , a contradiction.

**Case d.** The triangle starts from  $u_2$ , ends with  $u_n$ .

Here  $p = \frac{3n-1}{2}$ ,  $q = 2n - 2$ .

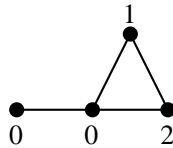
**Sub case 1.**  $n \equiv 0 \pmod{3}$ .

Let  $n = 3t$ ,  $t > 1$ . Assign the label '0' to the first  $t + 1$  vertices  $u_1, u_2, \dots, u_{t+1}$  of the path. Then label the next  $t - 1$  vertices  $u_{t+2}, u_{t+3}, \dots, u_{2t}$  by '1' and assign the label '2' to the remaining vertices of the path. Now we move to the vertices with degree 2. Assign the label '0' to the first  $\frac{t-1}{2}$  vertices and then the next  $\frac{t+1}{2}$  vertices receives the label '1'. Finally assign the label '2' to the remaining  $\frac{t-1}{2}$  vertices. From the table 5, we can conclude that the above vertex labeling, say  $f$ , is a mean cordial labeling.

$i$	0	1	2
$v_f(i)$	$\frac{n+1}{2}$	$\frac{n-1}{2}$	$\frac{n-1}{2}$
$e_f(i)$	$\frac{2n-3}{3}$	$\frac{2n-3}{3}$	$\frac{2n}{3}$

**Table 5.**

When  $t = 1$ , the mean cordial labeling of  $A(T_3)$  is given in figure 3.2.



**Figure 3.2**

**Sub case 2.**  $n \equiv 1 \pmod{3}$ .

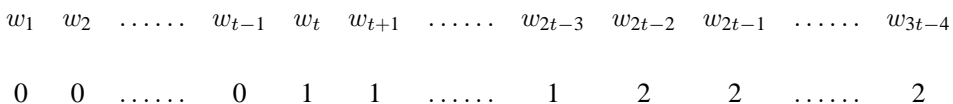
Let  $n = 3t + 1$ . Assign the label '0' to the first  $\frac{t}{2}$  triangles and then label the vertices of the next  $\frac{t}{2}$  triangles by '1'. Then assign the label '2' to the vertices of the remaining  $\frac{t}{2}$  triangles. Finally assign the label '0' to the vertex  $u_1$ . The vertex and edge conditions of the above labeling  $f$  is given in table 6.

$i$	0	1	2
$v_f(i)$	$\frac{n+1}{2}$	$\frac{n-1}{2}$	$\frac{n-1}{2}$
$e_f(i)$	$\frac{2n-2}{3}$	$\frac{2n-2}{3}$	$\frac{2n-2}{3}$

**Table 6.**

**Sub case 3.**  $n \equiv 2 \pmod{3}$ .

Let  $n = 3t + 2$ . Consider the path vertices  $u_1, u_2, \dots, u_n$ . Assign the label '0' to the vertices  $u_1, u_2, \dots, u_{t+1}$  and label the next  $t + 1$  vertices  $u_{t+2}, u_{t+3}, \dots, u_{2t+2}$  by '1'. Then assign the label '2' to the vertices  $u_{2t+3}, u_{2t+4}, \dots, u_{3t+2}$ . Then we move to the vertices of degree 2. These are labeled in the following pattern.



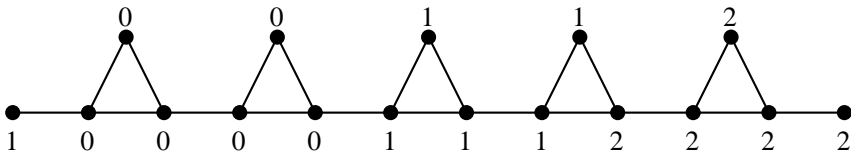
Finally assign the label '0' to the pendent vertex. In this case the following table 7 shows that the above vertex labeling  $f$ , is a mean cordial labeling.

$i$	0	1	2
$v_f(i)$	$\frac{n+1}{2}$	$\frac{n-1}{2}$	$\frac{n-1}{2}$
$e_f(i)$	$\frac{2n-4}{3}$	$\frac{2n-1}{3}$	$\frac{2n-1}{3}$

**Table 7.**

□

A mean cordial labeling of  $A(T_{12})$  with the condition that the triangle starts from  $u_2$ , ends with  $u_{n-1}$  is given in figure 3.3



**Figure 3.3**

**Theorem 3.2.** Mean cordial labeling behaviour of double alternate triangular snake  $DA(T_n)$  is given below:

- a.  $DA(T_n)$  is mean cordial if the triangle starts from  $u_2$  and ends with  $u_{n-1}$  and  $n \equiv 0, 2 \pmod{3}$ .
- b. Not mean cordial if the triangle starts from  $u_2$ , ends with  $u_{n-1}$  and  $n \equiv 1 \pmod{3}$ .
- c. Mean cordial if the triangle starts from  $u_1$ , ends with  $u_n$ ,  $n > 2$ . In this case  $DA(T_2)$  is not mean cordial.
- d. Mean cordial if the triangle starts from  $u_2$ , ends with  $u_n$  and  $n \equiv 1 \pmod{3}$ .
- e. Not mean cordial if the triangle starts from  $u_2$ , ends with  $u_n$  and  $n \equiv 0, 2 \pmod{3}$ .

*Proof.* For the cases a & b,  $p = 2n - 2$  and  $q = 3n - 5$ .

**Case a.** The triangles starts from  $u_2$  and ends with  $u_{n-1}$  and  $n \equiv 0, 2 \pmod{3}$ .

**Sub case 1.**  $n \equiv 0 \pmod{3}$ .

noindent Assign the label to the vertices of the first  $\frac{t}{2}$  double triangles by '0', next  $\frac{t}{2}$  double triangles by '1' and the last  $\frac{t-2}{2}$  double triangles by '2'. Then replace the label of the vertex  $u_{2t+1}$  by '2'. Finally assign the label '2' to the pendent vertices. The labeling  $f$  given in above is mean cordial from table 8.

$i$	0	1	2
$v_f(i)$	$\frac{2n}{3}$	$\frac{2n-3}{3}$	$\frac{2n-3}{3}$
$e_f(i)$	$n - 1$	$n - 2$	$n - 2$

**Table 8.**

**Sub case 2.**  $n \equiv 2 \pmod{3}$ .

Label the vertices of  $DA(T_n)$  as in subcase 1 and assign the label 2 to the vertices of the last double triangles. Then replace the label of the vertex  $u_{t+1}$  by '0'. The vertex condition and edge condition of the labelings  $f$  is shown in table 9.

$i$	0	1	2
$v_f(i)$	$\frac{2n-1}{3}$	$\frac{2n-4}{3}$	$\frac{2n-1}{3}$
$e_f(i)$	$n - 2$	$n - 1$	$n - 2$

**Table 9.**

**Case b.** The triangles starts from  $u_2$ , ends with  $u_{n-1}$  and  $n \equiv 1 \pmod{3}$ .

Suppose  $f$  is a mean cordial labeling. Then  $v_f(0) = v_f(1) = v_f(2) = \frac{2n-2}{3}$ . But  $e_f(0) \leq \lfloor \frac{3n-5}{3} \rfloor - 1$ . This is a contradiction.

**Case c.** The triangles starts from  $u_1$ , ends with  $u_n$ .

In this case  $p = 2n$  and  $q = 3n - 1$ .

Consider the graph  $DA(T_2)$ . Suppose  $f$  is a mean cordial labeling. Then we have two cases.  $v_f(0) = 2$  or  $v_f(0) = 1$ . If  $v_f(0) = 1$  then  $e_f(0) = 0$ , a contradiction. Suppose  $v_f(0) = 2$ . Note that the label '0' should be assigned to the adjacent vertices (otherwise  $e_f(0) = 0$ ). Then  $e_f(0) = e_f(2) = 1, e_f(1) = 3$  or  $e_f(0) = 1, e_f(1) = 4, e_f(2) = 0$ , a contradiction. Therefore  $DA(T_2)$  is not mean cordial.

**Sub case 1.**  $n \equiv 0 \pmod{3}$ .

Assign the label to the vertices of the first  $\frac{t}{2}$  double triangles by '0'. Put the label '1' to the vertices of the next  $\frac{t}{2}$  triangles. Finally assign the label '2' to the vertices of the last  $\frac{t}{2}$  double triangles. The table 10 shows that  $f$  is a mean cordial labeling.

$i$	0	1	2
$v_f(i)$	$\frac{2n}{3}$	$\frac{2n}{3}$	$\frac{2n}{3}$
$e_f(i)$	$n - 1$	$n$	$n$

**Table 10.**

**Sub case 2.**  $n \equiv 1 \pmod{3}$ .

Assign the label '0' to the first  $t + 1$  path vertices then assign the label '1' to the next  $t$  vertices of the path. The remaining  $t$  vertices of the path are labeled by '2'. The vertices  $v_i$  and  $w_i$  are labeled as given below.

$v_1$	$v_2$	.....	$v_t$	$v_{t+1}$	$v_{t+2}$	.....	$v_{2t}$	$v_{2t+1}$	$v_{2t+2}$	.....	$v_{3t-1}$
0	0	.....	0	1	1	.....	1	2	2	.....	2
$w_1$	$w_2$	.....	$w_{t-1}$	$w_t$	$w_{t+1}$	.....	$w_{2t-1}$	$w_{2t}$	$w_{2t+1}$	.....	$w_{3t-1}$
0	0	.....	0	1	1	.....	1	2	2	.....	2

The values of  $v_f(i)$  and  $e_f(i)$  are given in table 11

$i$	0	1	2
$v_f(i)$	$\frac{2n+1}{3}$	$\frac{2n+1}{3}$	$\frac{2n-2}{3}$
$e_f(i)$	$n - 1$	$n$	$n$

**Table 11.**

**Sub case 3.**  $n \equiv 2 \pmod{3}$ .

Assign the label '0' to the vertices of first  $\frac{t+2}{2}$  double triangles then assign the label to the next  $\frac{t}{2}$  vertices of the double triangles by '1' and the last  $\frac{t}{2}$  triangles by 2. Finally replace the labels of the vertices  $u_{t+2}, w_{\frac{t+2}{2}}, u_{2t+2}, w_{t+1}$  by 1, 1, 1, 2 respectively. The following table 12 shows that the above vertex labeling  $f$  is a mean cordial labeling.

$i$	0	1	2
$v_f(i)$	$\frac{2n+2}{3}$	$\frac{2n-1}{3}$	$\frac{2n-1}{3}$
$e_f(i)$	$n - 1$	$n$	$n$

**Table 12.**

For the cases  $d$  &  $e$ ,  $p = 2n - 1$  and  $q = 3n - 3$ .

**Case d.** The triangle starts from  $u_2$ , ends with  $u_n$  and  $n \equiv 1 \pmod{3}$ .

Assign the label '0' to the vertices of the first  $\frac{t}{2}$  double triangles, '1' to the vertices of the next  $\frac{t}{2}$  double triangles and '2' to the vertices of the last  $\frac{t}{2}$  double triangles. Put the label '0' to the pendent vertex  $u_1$ . Table 13 establish that the labeling  $f$  given above is a mean cordial labeling.

**Case e.** The triangle starts from  $u_2$ , ends with  $u_n$ .

**Sub case 1.**  $n \equiv 0 \pmod{3}$ .

$i$	0	1	2
$v_f(i)$	$\frac{2n+1}{3}$	$\frac{2n-2}{3}$	$\frac{2n-2}{3}$
$e_f(i)$	$n-1$	$n-1$	$n-1$

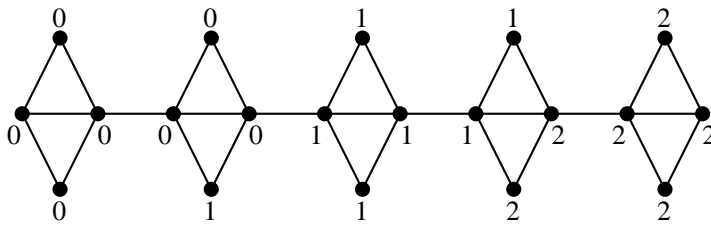
**Table 13.**

Suppose  $f$  is a mean cordial labeling. In this case, either  $v_f(0) = \frac{2n}{3}$  or  $\frac{2n-3}{3}$ . In both cases  $e_f(0) \leq n-2$ , a contradiction.

**Sub case 2.**  $n \equiv 2 \pmod{3}$ .

Here  $v_f(0) = \frac{2n-3}{3}$ . But  $e_f(0) \leq n-2$ . This contradiction proves that there does not exist a mean cordial labeling.  $\square$

A mean cordial labeling of  $DA(T_{10})$  with the condition that the triangles starts from  $u_1$ , ends with  $u_n$  is given in figure 3.4



**Figure 3.4**

**Theorem 3.3.** *The double triangular snake  $D(T_n)$  is mean cordial iff  $n > 3$ .*

*Proof.* **Case 1.**  $n = 2$ .

Follows from case c of theorem 3.2.

**Case 2.**  $n = 3$ .

In this case,  $v_f(0) = 2$  or  $3$ . If  $v_f(0) = 2$  then  $e_f(0) \leq 1$  which is not possible. If  $v_f(0) = 3$  then '0' should be labeled to the vertices of any triangle. Otherwise the value of  $e_f(0)$  lower than 3. In the case of '0' labeled in the vertices of the triangle, the value  $e_f(2)$  is not greater than 2. This is a contradiction to the size. Hence  $D(T_3)$  is not mean cordial.

**Case 3.**  $n > 3$ .

**Sub case 1.**  $n \equiv 1 \pmod{3}$ .

Let  $n = 3t + 1$ . Assign the label '0' to  $v_i$  ( $1 \leq i \leq t$ ), '1' to  $v_{t+i}$  ( $1 \leq i \leq t$ ) and '2' to  $v_{2t+i}$  ( $1 \leq i \leq t + 1$ ). Label the vertices  $u_i$  ( $1 \leq i \leq t + 1$ ) by '0',  $u_{t+1+i}$  ( $1 \leq i \leq t$ ) by 1 and  $u_{2t+1+i}$  by 2. Then we move to the vertex  $w_i$ . Assign the labels to  $w_i$  as in  $v_i$ . The following table 14 shows that the above labeling  $f$  is a mean cordial labeling.

$i$	0	1	2
$v_f(i)$	$n$	$n-1$	$n-1$
$e_f(i)$	$\frac{5n-5}{3}$	$\frac{5n-5}{3}$	$\frac{5n-5}{3}$

**Table 14.**

**Sub case 2.**  $n \equiv 0 \pmod{3}$ .

Let  $n = 3t$ ,  $t > 1$ . Assign the label '0' to the vertices  $u_i$  ( $1 \leq i \leq t + 1$ ),  $v_i$  ( $1 \leq i \leq t$ ) and  $w_i$  ( $1 \leq i \leq t - 1$ ). Put the label '1' to the vertices  $u_j$  ( $t + 2 \leq j \leq 2t$ ),  $v_j$  ( $t + 1 \leq j \leq 2t$ ) and  $w_j$  ( $t \leq j \leq 2t - 1$ ). Finally assign the label '2' to the vertices  $u_r$  ( $2t + 1 \leq r \leq 3t$ ),  $v_r$  ( $2t + 1 \leq r \leq 3t - 1$ ) and  $w_r$  ( $2t \leq r \leq 3t - 1$ ). The table 15 given below shows that the above labeling  $f$  is a mean cordial labeling.

$i$	0	1	2
$v_f(i)$	$n$	$n-1$	$n-1$
$e_f(i)$	$\frac{5n-6}{3}$	$\frac{5n-6}{3}$	$\frac{5n-3}{3}$

**Table 15.**

**Sub case 3.**  $n \equiv 2 \pmod{3}$ .

Let  $n = 3t + 2$ . First we consider the path vertices. Assign the label '0' to  $u_i$  ( $1 \leq i \leq t + 1$ ), '1' to  $u_j$  ( $t + 2 \leq j \leq 2t + 2$ ) and 2 to  $u_r$  ( $2t + 3 \leq r \leq 3t$ ). Now we move to the vertices  $v_i$  ( $1 \leq i \leq n - 1$ ). The first  $t + 1$  vertices are labeled by '0' and the vertices  $v_i$  ( $t + 2 \leq i \leq 2t + 1$ ) are labeled by 1 then the last  $t$  vertices of  $v_i$  are labeled by '2'. The vertex labeling of  $w_i$  ( $1 \leq i \leq n - 1$ ) is given below.

$$\begin{array}{cccccccccccccccc}
 w_1 & w_2 & \dots & w_t & w_{t+1} & w_{t+2} & \dots & w_{2t} & w_{2t+1} & w_{2t+2} & \dots & w_{3t-1} \\
 0 & 0 & \dots & 0 & 1 & 1 & \dots & 1 & 2 & 2 & \dots & 2
 \end{array}$$

Let  $f$  be the labeling defined above. The values  $e_f(i)$  and  $v_f(i)$  where  $i = 0, 1, 2$  given in table 16 proves that  $f$  is a mean cordial labeling.

$i$	0	1	2
$v_f(i)$	$n$	$n - 1$	$n - 1$
$e_f(i)$	$\frac{5n-7}{3}$	$\frac{5n-4}{3}$	$\frac{5n-4}{3}$

**Table 16.**

□

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