International Journal of Mathematics And its Applications
Volume 5, Issue 2–C (2017), 391–401.
ISSN: 2347-1557
Available Online: http://ijmaa.in/

International Journal of Mathematics And its Applications

Subdivisions of Contra Harmonic Mean Graphs

Research Article

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Abstract: A graph $G(V,E)$ is called a Contra Harmonic mean graph with p vertices and q edges, if it is possible to label the vertices $x \in V$ with distinct elements $f(x)$ from $0,1,\ldots,q$ in such a way that when each edge $e = uv$ is labeled with $f(e=uv) = \left\lceil \frac{f(u)^2+f(v)^2}{f(u)+f(v)} \right\rceil$ or $\left\lfloor \frac{f(u)^2+f(v)^2}{f(u)+f(v)} \right\rfloor$ with distinct edge labels. The mapping f is called Contra Harmonic mean labeling of G.

Keywords: Graph, Contra Harmonic mean graph, Path, Comb, Cycle, Triangular Snake, Quadrilateral snake.

1. Introduction

All graphs in this paper are simple, finite, undirected. Let $G(V,E)$ be a graph with p vertices and q edges. For a detail survey of graph labeling we refer to [1]. A general reference for graph-theoretic ideas is [2]. The concept of mean labeling was introduced by S. Somasundaram and R. Ponraj [3] in 2004. S. Somasundram and S.S. Sandhya introduced Harmonic mean labeling [4] in 2012. In this paper we investigate the Subdivision of Contra Harmonic mean labeling for some graphs. The following definition are useful for our present study.

Definition 1.1. *A graph G(V, E) is called a Contra Harmonic mean graph with p vertices and q edges, if it is possible to label the vertices $x \in V$ with distinct elements $f(x)$ from $0,1,\ldots,q$ in such a way that when each edge $e = uv$ is labeled with $f(e=uv) = \left\lceil \frac{f(u)^2+f(v)^2}{f(u)+f(v)} \right\rceil$ or $\left\lfloor \frac{f(u)^2+f(v)^2}{f(u)+f(v)} \right\rfloor$ with distinct edge labels. The mapping f is called Contra Harmonic mean labeling of G.*

Definition 1.2. *A Triangular snake T_n is obtained from a path $u_1 \ldots u_n$ by joining u_i and to a vertex v_i for $1 \le i \le n-1$.*

Definition 1.3. *A Quadrilateral snake Q_n is obtained from a path $u_1 \ldots u_n$ by joining u_i and u_{i+1} to new vertices v_i, w_i, $1 \le i \le n-1$.*

Definition 1.4. *The union of two graphs $G_1 = (V_1,E_1)$ and $G_2 = (V_2,E_2)$ is a graph $G = G_1 \cup G_2$ with vertex set $V = V_1 \cup V_2$ and edge set $E = E_1 \cup E_2$.*

Definition 1.5. *The corona of two graphs G_1 and G_2 is the graph $G = G_1 \odot G_2$ formed by taking one copy of G_1 and $|V(G_1)|$ copies of G_2 where the i^{th} vertex of G_1 is adjacent to every vertex in the i^{th} copy of G_2.*

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Definition 1.6. *If $e = uv$ is an edge of G and w is not a vertex of G then e is said to be subdivided when it is replaced by the edges uw and wv. The graph obtained by subdividing each of a graph G is called the subdivision of G and is denoted by $S(G)$.*

2. Main Results

Theorem 2.1. *$S(P_n \odot K_1)$ is a Contra Harmonic mean graph.*

Proof. Let $u_1u_2\dots u_n$ be a path P_n of length n. Let v_i be the vertex which is joined to the vertex u_i, $1 \leq i \leq n$ of the path P_n. The resulting graph is a comb $P_n \odot K_1$. Let G be graph obtained by subdividing the edges. Here we consider the following cases.

Case (i): G is obtained by subdividing each edge of the path. Let $t_1t_2\dots t_{n-1}$ be the vertices which subdivide the edges of u_iu_{i+1}. Define a function $f : V(G) \to \{0, 1, \dots, q\}$ by

$$f(u_i) = 3i - 3, \quad 1 \leq i \leq n$$

$$f(v_i) = 3i - 2, \quad 1 \leq i \leq n$$

$$f(t_i) = 3i - 1, \quad 1 \leq i \leq n - 1$$

Then the distinct edge labels are

$$f(u_iv_i) = 3i - 2, \quad 1 \leq i \leq n$$

$$f(u_it_i) = 3i - 1, \quad 1 \leq i \leq n - 1$$

$$f(t_iu_{i+1}) = 3i, \quad 1 \leq i \leq n - 1$$

$\therefore$ f is a Contra Harmonic mean labeling of G. The Contra Harmonic mean labeling pattern of $S(P_7 \odot K_1)$ is

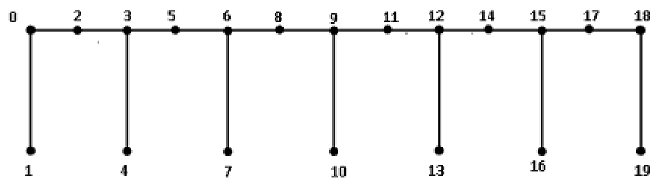

Figure 1.

Case (ii): G is obtained by subdividing the edges u_iv_i. Let w_i be the vertices which subdivide the edges u_iv_i, $1 \leq i \leq n$. Define a function $f : V(G) \to \{0, 1, \dots, q\}$ by

$$f(u_1) = 0,\ f(u_2) = 3,\ f(u_i) = 3i - 2,\ 3 \leq i \leq n.$$

$$f(v_1) = 2,\ f(v_2) = 5,\ f(v_i) = 3i,\ 3 \leq i \leq n.$$

$$f(w_1) = 1,\ f(w_2) = 4,\ f(w_3) = 8,\ f(w_4) = 11,\ f(w_i) = 3i - 1,\ 5 \leq i \leq n.$$

Then the distinct edges labels are

$$f(u_iu_{i+1}) = 3i, \quad 1 \leq i \leq n - 1$$

$$f(u_iw_i) = 3i - 2, \quad 1 \leq i \leq n$$

$$f(w_iv_i) = 3i - 1, \quad 1 \leq i \leq n$$

∴ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(P_5 \odot K_1)$ is shown below.

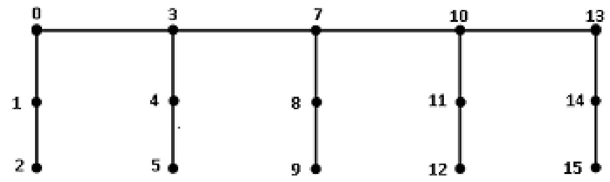

Figure 2.

Case (iii): G is obtained by subdividing all the edges of $P_n \odot K_1$. Let t_i and w_i be the vertices which subdivide the edges u_iu_{i+1} and u_iv_i respectively. Define a function $f : V(G) \to \{0, 1, \ldots, q\}$ by

$$f(u_1) = 0,\ f(u_2) = 4,\ f(u_i) = 4i - 3,\ 3 \le i \le n$$
$$f(v_1) = 2,\ f(v_2) = 6,\ f(v_i) = 4i - 1,\ 3 \le i \le n$$
$$f(t_1) = 3,\ f(t_i) = 4i,\ 2 \le i \le n - 1$$
$$f(w_1) = 1,\ f(w_2) = 5,\ f(w_i) = 4i - 2,\ 3 \le i \le n$$

Then the distinct edge labels are

$$f(u_it_i) = 4i - 1, \quad 1 \le i \le n - 1$$
$$f(t_iu_{i+1}) = 4i, \quad 1 \le i \le n - 1$$
$$f(u_iw_i) = 4i - 3, \quad 1 \le i \le n$$
$$f(w_iv_i) = 4i - 2, \quad 1 \le i \le n$$

∴ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(P_5 \odot K_1)$ is shown below.

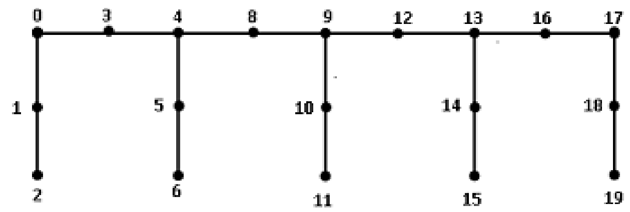

Figure 3.

From case (i) and (ii), it is clear that $S(P_n \odot K_1)$ is a Contra Harmonic mean graph. □

Theorem 2.2. *$S(C_n \odot K_1)$ is a Contra Harmonic mean graph.*

Proof. Let $u_1u_2 \ldots u_n$ be a cycle C_n of length n and let v_i be the pendant vertices adjacent to u_i, $1 \le i \le n$. The resulting graph is $C_n \odot K_1$. Let $G = S(C_n \odot K_1)$ be the graph obtained by subdividing the edges. Here we consider the following cases.

Case (i): Let G be a graph obtained by subdividing each edge of the cycle $u_1u_2\dots u_n$. Let w_i, $1 \le i \le n$ be the vertices which subdivide the edges of the cycle $u_1u_2\dots u_n$. Define a function $f : V(G) \to \{0, 1, 2\dots, q\}$ by

$$f(u_i) = 3i - 3, \quad 1 \le i \le n$$
$$f(v_i) = 3i - 2, \quad 1 \le i \le n$$
$$f(w_i) = 3i - 1, \quad 1 \le i \le n-1 \quad \text{and } f(w_n) = 3n$$

Then the distinct edge labels are

$$f(u_iv_i) = 3i - 2, \quad 1 \le i \le n$$
$$f(u_iw_i) = 3i - 1, \quad 1 \le i \le n$$
$$f(w_iu_{i+1}) = 3i, \quad 1 \le i \le n$$

$\therefore$ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(C_5 \odot K_1)$ is shown below.

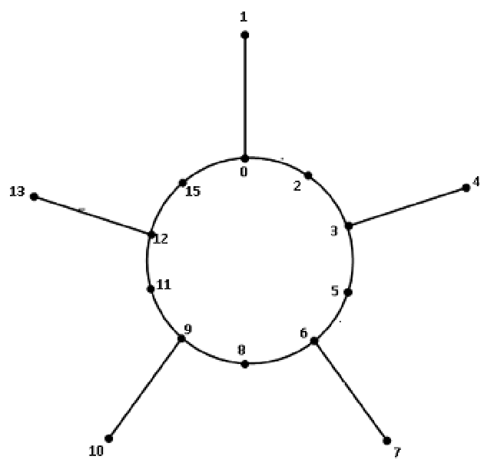

Figure 4.

Case (ii) : Let G be a graph obtained by subdividing the edge u_iv_i of $C_n \odot K_1$. Let t_i, $1 \le i \le n$ be the vertices which subdivide u_i and v_i. Define a function $f : V(G) \to \{0, 1, \dots, q\}$ by

$$f(u_1) = 0, \ f(u_2) = 3 \text{ and } f(u_i) = 3i - 2, \quad 3 \le i \le n$$
$$f(v_1) = 2, \ f(v_i) = 3i, \quad 2 \le i \le n$$
$$f(t_1) = 1, \ f(t_i) = 3i - 1, \quad 2 \le i \le n$$

Then the distinct edge labels are

$$f(u_iu_{i+1}) = 3i, \ 1 \le i \le n-1, \ f(u_nu_1) = 3n - 1,$$
$$f(t_iv_i) = 3i - 1, \ 1 \le i \le n-1, \ f(t_nv_n) = 3n$$

$\therefore$ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(C_5 \odot K_1)$ is shown below.

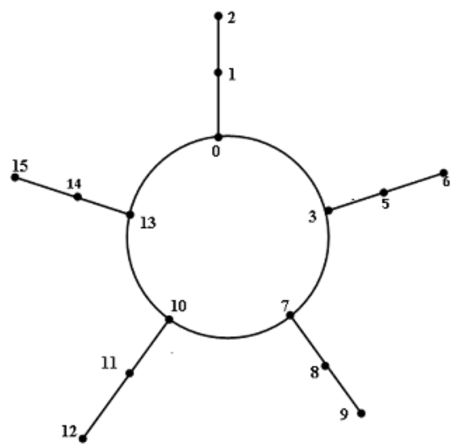

Figure 5.

Case (iii) : Let G be a graph obtained by subdividing all the edges of $C_n \odot K_1$. Let t_i, w_i be the vertices which subdivide the edges of the cycle $u_1u_2 \dots u_n$ and the edges u_i and v_i for $1 \leq i \leq n$ respectively. Define a function $f : V(G) \to \{1, 2, \dots, q\}$ by

$$f(u_1) = 0,\ f(u_i) = 4i - 3,\ 2 \leq i \leq n$$
$$f(v_1) = 2,\ f(v_i) = 4i - 1,\ 2 \leq i \leq n$$
$$f(w_1) = 1,\ f(w_i) = 4i - 2,\ 2 \leq i \leq n$$
$$f(t_1) = 3,\ f(t_i) = 4i,\ 2 \leq i \leq n$$

Then the distinct edge labels are

$$f(u_iw_i) = 4i - 3, \quad 1 \leq i \leq n$$
$$f(w_iv_i) = 4i - 2, \quad 1 \leq i \leq n$$
$$f(u_it_i) = 4i - 1, \quad 1 \leq i \leq n$$
$$f(t_iu_{i+1}) = 4i, \quad 1 \leq i \leq n$$

$\therefore$ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(C_5 \odot K_1)$ is shown below. From the above cases we

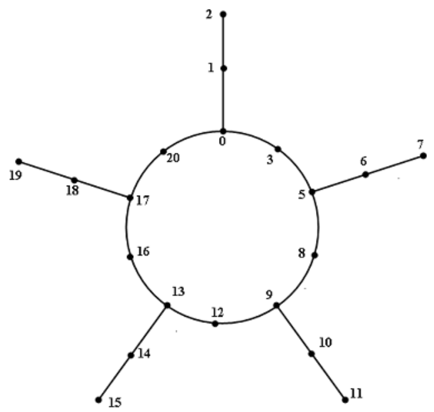

Figure 6.

conclude that $S(C_n \odot K_1)$ is a Contra Harmonic mean graph. □

Theorem 2.3. *$S(T_n)$ is a Contra Harmonic mean graph.*

Proof. Let $u_1u_2\ldots u_n$ be a path of length n. Let T_n be a triangular snake obtained by joining u_i and u_{i+1} to a new vertex v_i, $1\le i\le n-1$. Let us subdivide the edges of T_n. We consider the following cases.

Case (i) : G is obtained by subdividing each edge of the path. Let $t_1,t_2,\ldots,t_{n-1}$ be the vertices which subdivide the edge u_iu_{i+1}. Define a function $f:V(G)\to\{0,1,2,\ldots,q\}$ by

$$f(u_i)=4i-4,\quad 1\le i\le n$$

$$f(v_i)=4i-3,\quad 1\le i\le n-1$$

$$f(t_i)=4i-2,\quad 1\le i\le n-1$$

Then the distinct edge labels are

$$f(u_it_i)=4i-2,\quad 1\le i\le n-1$$

$$f(t_1u_2)=3,\quad f(tiu_{i+1})=4i,\ 2\le i\le n-1$$

$$f(u_iv_i)=4i-3,\quad 1\le i\le n-1$$

$$f(v_1u_2)=4,\ f(v_iu_{i+1})=4i-1,\quad 2\le i\le n-1$$

$\therefore$ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(T_6)$ is

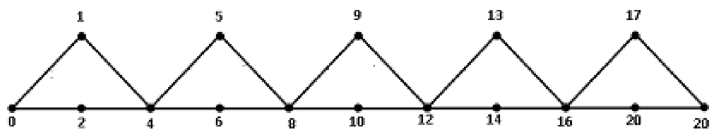

Figure 7.

Case (ii) : G is obtained by subdividing the edges u_iv_i and $u_{i+1}v_i$. Let t_i and s_i be the two vertices which subdivide the edges u_iv_i and $u_{i+1}v_i$, $1\le i\le n-1$ respectively. Define a function $f:V(G)\to\{0,1,2,\ldots,q\}$ by

$$f(u_i)=5i-5,\quad 1\le i\le n$$

$$f(v_1)=2,\ f(v_i)=5i-2,\quad 2\le i\le n-1$$

$$f(t_1)=1,\ f(t_i)=5i-3,\quad 2\le i\le n-1$$

$$f(s_1)=3,\ f(s_i)=5i-1,\quad 2\le i\le n-1$$

Then the distinct edge labels are

$$f(u_1u_2)=5,\ f(u_iu_{i+1})=5i-2,\quad 2\le i\le n-1$$

$$f(u_it_i)=5i-4,\quad 1\le i\le n-1$$

$$f(t_iv_i)=5i-3,\quad 1\le i\le n-1$$

$$f(v_1s_1)=3,\ f(v_is_i)=5i-1,\quad 2\le i\le n-1$$

$$f(s_1u_2)=4,\ f(s_iu_{i+1})=5i,\ 2\le i\le n-1$$

$\therefore$ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(T_5)$ is shown below.

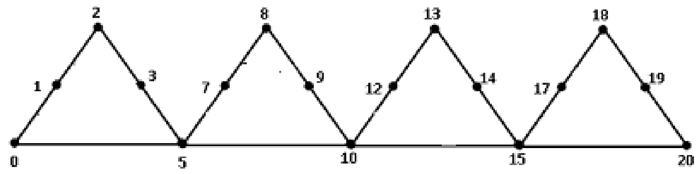

Figure 8.

Case (iii) : G is obtained by subdividing all the edges of T_n. Let x_i, y_i and t_i be the vertices which subdivide the edges u_iv_i, v_iu_{i+1} and u_iu_{i+1} respectively. Define a function $f : V(G) \to \{0, 1, \ldots, q\}$ by

$$f(u_i) = 6i - 6, \quad 1 \le i \le n$$

$$f(v_1) = 2, \; f(v_i) = 6i - 3, \quad 2 \le i \le n - 1$$

$$f(t_1) = 3, \; f(t_i) = 6i - 2, \quad 2 \le i \le n - 1$$

$$f(x_1) = 1, \; f(x_i) = 6i - 4, \quad 2 \le i \le n - 1$$

$$f(y_1) = 4, f(y_i) = 6i - 1, \quad 2 \le i \le n - 1$$

Then the distinct edge labels are

$$f(u_it_i) = 6i - 3, \quad 1 \le i \le n - 1$$

$$f(t_iu_{i+1}) = 6i - 1, \quad 1 \le i \le n - 1$$

$$f(u_ix_i) = 6i - 5, \quad 1 \le i \le n - 1$$

$$f(x_iv_i) = 6i - 4, \quad 1 \le i \le n - 1$$

$$f(v_iy_i) = 6i - 2, \quad 1 \le i \le n - 1$$

$$f(y_iu_{i+1}) = 6i, \quad 1 \le i \le n - 1$$

$\therefore$ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(T_5)$ is shown below.

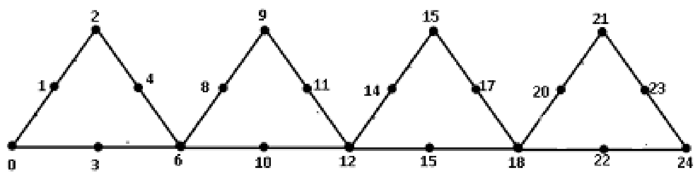

Figure 9.

From Case (i), Case (ii), Case (iii) it can be seen that $S(T_n)$ is a Contra Harmonic mean graph. □

Theorem 2.4. *$S(Q_n)$ is a Contra Harmonic mean graph.*

Proof. Let $u_1u_2 \ldots u_n$ be a path of length n. Join u_i and u_{i+1} to new vertices v_i and w_i, $1 \le i \le n - 1$ respectively and then join v_i and w_i. The resulting graph is a Quadrilateral snake Q_n. Let G be the graph obtained by subdividing the edges of Q_n. Here we consider the following cases.

Case (i) : G is obtained by subdividing the edges of the path. Let $t_1 t_2 \ldots t_{n-1}$ be the vertices which subdivide the edge $u_i u_{i+1}$, $1 \leq i \leq n-1$. Define a function $f : V(G) \to \{0, 1, \ldots, q\}$ by

$$f(u_i) = 5i - 5, \quad 1 \leq i \leq n$$
$$f(v_1) = 1, \ f(v_i) = 5i - 3, \quad 2 \leq i \leq n-1$$
$$f(t_1) = 3, \ f(t_i) = 5i - 1, \quad 2 \leq i \leq n-1$$
$$f(w_1) = 2, \ f(w_i) = 5i - 2, \quad 2 \leq i \leq n-1$$

Then the distinct edge labels are

$$f(u_i t_i) = 5i - 2, \quad 1 \leq i \leq n-1$$
$$f(t_i u_{i+1}) = 5i, \quad 1 \leq i \leq n-1$$
$$f(u_i v_i) = 5i - 4, \quad 1 \leq i \leq n-1$$
$$f(w_i u_{i+1}) = 5i - 1, \quad 1 \leq i \leq n-1$$
$$f(v_i w_i) = 5i - 3, \quad 1 \leq i \leq n-1$$

$\therefore$ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(Q_5)$ is shown below.

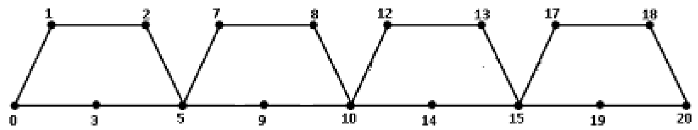

Figure 10.

Case (ii) : G is obtained by subdividing all the edges of Q_n. Let t_i, x_i, y_i, z_i be the vertices which subdivide the edges $u_i u_{i+1}$, $u_i v_i$, $v_i w_i$ and $w_i u_{i+1}$ respectively. Define a function $f : V(G) \to \{0, 1, \ldots, q\}$ by

$$f(u_i) = 8i - 8, \quad 1 \leq i \leq n$$
$$f(v_1) = 2, \ f(v_i) = 8i - 5, \quad 2 \leq i \leq n-1$$
$$f(w_1) = 4, \ f(w_i) = 8i - 3, \quad 2 \leq i \leq n-1$$
$$f(t_1) = 5, \ f(t_i) = 8i - 2, \quad 2 \leq i \leq n-1$$
$$f(x_1) = 1, \ f(x_i) = 8i - 6, \quad 2 \leq i \leq n-1$$
$$f(y_1) = 3, \ f(y_i) = 8i - 4, \quad 2 \leq i \leq n-1$$
$$f(z_1) = 6, \ f(z_i) = 8i - 1, \quad 2 \leq i \leq n-1$$

Then the distinct edge labels are

$$f(u_1 t_1) = 5, \ f(u_i t_i) = 8i - 4, \quad 2 \leq i \leq n-1$$
$$f(t_i u_{i+1}) = 8i - 1, \quad 1 \leq i \leq n-1$$
$$f(u_i x_i) = 8i - 7, \quad 1 \leq i \leq n-1$$

$$f(x_iv_i) = 8i - 6, \quad 1 \le i \le n-1$$

$$f(v_iy_i) = 8i - 5, \quad 1 \le i \le n-1$$

$$f(y_1w_1) = 4, \; f(y_iw_i) = 8i - 3, \quad 2 \le i \le n-1$$

$$f(w_iz_i) = 8i - 2, \quad 1 \le i \le n-1$$

$$f(u_{i+1}z_i) = 8i, \quad 1 \le i \le n-1$$

∴ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(Q_5)$ is shown below.

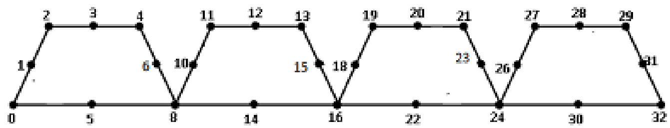

Figure 11.

From case (i) and case (ii), it is clear that S(Q $_n$) is a Contra Harmonic mean graph.

□

Theorem 2.5. *$S(P_n \odot K_3)$ is a Contra Harmonic mean graph.*

Proof. Let $u_1u_2\ldots u_n$ be the path of length n. Let v_i, w_i be the vertices of K_2 which are joined to the vertex u_i of the path P_n, $1 \le i \le n$. The resultant graph is $P_n \odot K_3$. Let G be a graph obtained by subdividing all the edges of $P_n \odot K_3$. Here we consider the following cases.

Case (i) : Let G be a graph obtained by subdividing each edge of the path. Let $t_1t_2\ldots t_{n-1}$ be the vertices which subdivide the edge u_iu_{i+1}. Define a function $f : V(G) \to \{0, 1, \ldots, q\}$ by

$$f(u_1) = 0, \; f(u_i) = 5i - 4, \quad 2 \le i \le n$$

$$f(v_1) = 1, \; f(v_i) = 5i - 3, \quad 2 \le i \le n$$

$$f(w_1) = 3, \; f(w_i) = 5i - 1, \quad 2 \le i \le n$$

$$f(t_1) = 4, \; f(t_i) = 5i, \quad 2 \le i \le n-1$$

Then the distinct edge labels are

$$f(u_it_i) = 5i - 1, \quad 1 \le i \le n-1$$

$$f(t_it_{i+1}) = 5i, \quad 1 \le i \le n-1$$

$$f(u_iv_i) = 5i - 4, \quad 1 \le i \le n$$

$$f(u_1w_1) = 3, \; f(u_iw_i) = 5i - 3, \quad 2 \le i \le n$$

$$f(v_1w_1) = 2, \; f(v_iw_i) = 5i - 2, \quad 2 \le i \le n$$

Then f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(P_4 \odot K_3)$ is

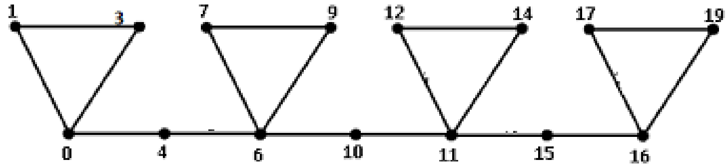

Figure 12.

Case (ii): Let G be a graph obtained by subdividing all the edges of $(P_n \odot K_3)$. Let t_i, x_i, y_i, s_i be the vertices which subdivide the edges u_iu_{i+1}, u_iv_i, u_iw_i and v_iw_i respectively. Define a function $f : V(G) \to \{0, 1, \ldots, q\}$ by

$$f(u_1) = 2,\ f(u_i) = 8i - 5, \quad 2 \le i \le n$$

$$f(v_1) = 0,\ f(v_i) = 8i - 9, \quad 2 \le i \le n$$

$$f(s_1) = 3,\ f(s_i) = 8i - 6, \quad 2 \le i \le n$$

$$f(w_i) = 8i - 4, \quad 1 \le i \le n$$

$$f(t_i) = 8i + 1, \quad 1 \le i \le n - 1$$

$$f(x_1) = 1,\ f(x_i) = 8i - 8, \quad 2 \le i \le n$$

$$f(y_i) = 8i - 2, \quad 1 \le i \le n$$

Then the distinct edge labels are

$$f(u_it_i) = 8i - 1, \quad 1 \le i \le n - 1$$

$$f(t_iu_{i+1}) = 8i + 3, \quad 1 \le i \le n - 1$$

$$f(u_ix_i) = 8i - 6, \quad 1 \le i \le n$$

$$f(u_iy_i) = 8i - 3, \quad 1 \le i \le n$$

$$f(x_1v_1) = 1,\ f(x_iv_i) = 8i - 8, \quad 2 \le i \le n$$

$$f(y_iw_i) = 8i - 2, \quad 1 \le i \le n$$

$$f(v_1s_1) = 3,\ f(v_is_i) = 8i - 7, \quad 2 \le i \le n$$

$$f(s_iw_i) = 8i - 4, \quad 1 \le i \le n$$

$\therefore$ f is a Contra Harmonic mean labeling of G. The labeling pattern of $S(P_4 \odot K_3)$ is shown below.

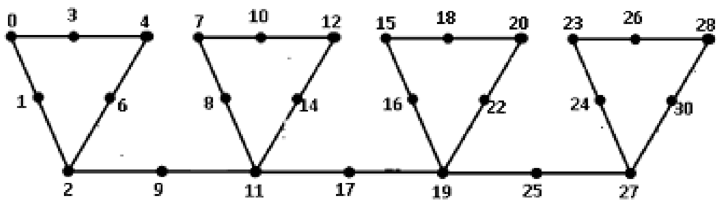

Figure 13.

From case (i), case (ii) it can be seen that $S(P_n \odot K_3)$ is a Contra Harmonic mean graph. □

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