JCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-7, Special Issue, 5, March 2019 E-ISSN: 2347-2693

On Variation of Product Cordial Labeling of Subdivision of Flower and Its Path Union

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DOI: https://doi.org/10.26438/ijcse/v7si5.6468 | Available online at: www.ijcseonline.org

Abstract— In this paper, we prove that the subdivision of Flower graph and the Path union of k copies of subdivision of Flower graphs are Product cordial graph and Total product cordial graphs. We also extend to prove that the path union from the outer vertex of the subdivision of Flower admits Product cordial and total product cordial labeling.

Keywords— Product cordial labeling, Total product cordial labeling, Flower graph, Subdivision, Path union.

I. INTRODUCTION

In mathematical discipline of graph theory, a graph labeling is the assignment of labels, traditionally represented by integers, to the edges or vertices, or both, of a graph subject to certain constraints. Graph labeling is one of the most interesting concepts in Graph theory and it was introduced by Rosa [3] in 1960's. Graph labeling draws an effective communication between Number Theory and in analysing the structure of the graphs. Cordial labeling was first introduced by Cahit [1] in 1987. In 2004, Sundaram *et al*[4] introduced the notion of **Product cordial labeling** .Sundaram *et al* [4] proved the various graphs are product cordial graphs such as tree graphs, Triangular snakes, Dragon graphs, Helm, $P_m \cup P_n$, $C_m \cup P_n$, $W_m \cup C_m$. In 2006, Sundaram *et al* [5] introduced the notion of **Total product cordial labeling**. Sundaram *et al* [5] proved the various graphs are Total product cordial graphs such as Tree graphs, all cycles except $C_4, K_{n,2n-1}, C_n$, Wheels, Helms. Let the Flower graph $Fl_n, n \geq 3$, is the graph obtained from the Helm graph H_m by attaching each pendant vertex to the apex of the wheel graph w_n and subdividing each edge by a vertex is called Subdivision of Flower graph. For a detailed survey on Total product cordial graphs one can refer to Gallian [2].

II. MAIN RESULTS

Theorem 2.1:
Subdivision of Flower graph admits Product cordial labeling.

Proof:
Let the Flower graph $S(Fl_n), n \geq 3$ is the graph obtained from the Helm H_m by attaching an edge from each pendant vertex to the apex of the wheel W_n and subdividing each edge by a vertex.

We denotes the vertices of $S(Fl_n), n \geq 3$ as follows:

Let u denotes the apex vertex. Let $w_1, w_2, \dots, w_n$ denotes the vertices obtained by subdividing the edges uu_i . Let $u_1, u_2, \dots, u_n$ denotes the vertices of the cycle of Flower graph. Let $u_i u_{i+1}$ $(1 \leq i \leq n)$ subdivides as the vertices y_i on the cycle c_n. Let $v_1, v_2, \dots, v_n$ denotes the end vertices of the $S(Fl_n)$. Let $x_1, x_2, \dots, x_n$denotes the vertices which is obtained by subdividing the uv_i edges of Flower graph. Let $z_1, z_2, \dots, z_n$ denotes the vertices obtained by subdividing the edges $u_i v_i$ of Flower graph.

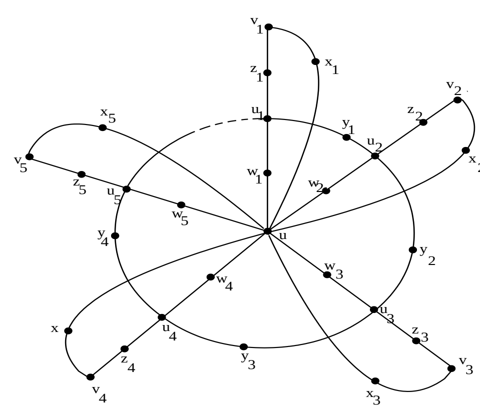

Figure: 2.1 Subdivision of Flower graph

Let $V(S(Fl_n)) = \{u, w_i, u_i, z_i, v_i, x_i, y_i; (1 \leq i \leq n)\}$
Let $E(S(Fl_n)) = \{(uw_i, w_i u_i) \cup (u_i z_i, z_i v_i) \cup (u_i y_i, y_i u_{i+1}) \cup (ux_i, x_i v_i); (1 \leq i \leq n)\}$
The total number of vertices in $S(Fl_n)$ is $6n + 1$ and the total number of edges in $S(Fl_n)$ is $8n$ $(n \geq 3)$.

The vertex labels for the subdivision of Flower graph are defined below:

$$f: V(S(Fl_n) \rightarrow \{0,1\}$$
$$f(u, w_i, u_i, y_i) = 1$$
$$f(z_i, v_i, x_i) = 0 \text{ where } (1 \leq i \leq n) \qquad (1)$$

The edge labels for the subdivision of Flower graph are defined below:

$$f: E(S(Fl_n) \rightarrow \{0,1\}$$
$$f(uw_i, w_i u_i, u_i y_i, y_i u_{i+1}) = 1$$
$$f(ux_i, x_i v_i, u_i z_i, z_i v_i) = 0 \qquad (2)$$

Using the above equations, the vertex and edge labels are computed as follows:

The number of vertices with label $'0' = v_f(0) = \frac{6n}{2}$

The number of vertices with label $'1' = v_f(1) = \frac{6n}{2} + 1$

The number of edges with label $'0' = e_f(0) = \frac{8n}{2}$

The number of edges with label $'1' = e_f(1) = \frac{8n}{2}$

Let m denotes the number of petals in Flower graph.

Case: m is odd

$$|v_f(0) - v_f(1)| = \left|\frac{6n}{2} + 1 - \frac{6n}{2}\right| = 1$$
$$|e_f(0) - e_f(1)| = \left|\frac{8n}{2} - \frac{8n}{2}\right| = 0$$

The condition for Product cordial labeling is,

$$|v_f(0) - v_f(1)| \leq 1 \text{ and } |e_f(0) - e_f(1)| \leq 1$$

Thus, the condition is satisfied.

Case: m is even

$$|v_f(0) - v_f(1)| = \left|\frac{6n}{2} + 1 - \frac{6n}{2}\right| = 1$$
$$|e_f(0) - e_f(1)| = \left|\frac{8n}{2} - \frac{8n}{2}\right| = 0$$

Therefore, $|v_f(0) - v_f(1)| \leq 1$ and $|e_f(0) - e_f(1)| \leq 1$

Thus, the condition is satisfied.

Hence the subdivision of Flower graph admits product cordial labeling.

Theorem 2.2:

Subdivision of Flower graph admits Total product cordial labeling.

Proof:

Denote the vertices and edges of $S(Fl_n)$ as follows:

Let $V(S(Fl_n)) = \{u, w_i, u_i, z_i, v_i, x_i, y_i; (1 \leq i \leq n)\}$

Let $E(S(Fl_n)) = \{(uw_i, w_i u_i) \cup (u_i z_i, z_i v_i) \cup (u_i y_i, y_i u_{i+1}) \cup (ux_i, x_i v_i); (1 \leq i \leq n)\}$

The total number of vertices in $S(Fl_n)$ is $6n + 1$ and the total number of edges in $S(Fl_n)$ is $8n$ $(n \geq 3)$.

The vertex labels for the subdivision of Flower graph are defined below:

$$f: V(S(Fl_n) \rightarrow \{0,1\}$$
$$f(u, w_i, u_i, y_i) = 1$$
$$f(z_i, v_i, x_i) = 0 \text{ where } (1 \leq i \leq n) \qquad (3)$$

The edge labels for the subdivision of Flower graph are defined below:

$$f: E(S(Fl_n) \rightarrow \{0,1\}$$
$$f(uw_i, w_i u_i, u_i y_i, y_i u_{i+1}) = 1$$
$$f(ux_i, x_i v_i, u_i z_i, z_i v_i) = 0 \qquad (4)$$

Using the above equations, the vertex and edge labels are computed as follows:

The number of vertices with label $'0' = v_f(0) = \frac{6n}{2}$

The number of vertices with label $'1' = v_f(1) = \frac{6n}{2} + 1$

The number of edges with label $'0' = e_f(0) = \frac{8n}{2}$

The number of edges with label $'1' = e_f(1) = \frac{8n}{2}$

The condition for total product cordial labeling is,

$$|v_f(0) + e_f(0) - (v_f(1) + e_f(1))| \leq 1$$

Let m denotes the number of petals in Flower graph.

Case: m is odd

$$\left|\frac{6n}{2} + \frac{8n}{2} - \left(\frac{6n}{2} + 1 + \frac{8n}{2}\right)\right| = 1$$

Thus, the condition is satisfied.

Case: m is even

$$\left|\frac{6n}{2} + \frac{8n}{2} - \left(\frac{6n}{2} + 1 + \frac{8n}{2}\right)\right| = 1$$

Thus, the condition is satisfied.

Hence the subdivision of Flower graph admits Total product cordial labeling.

Theorem 2.3:

Path union of k copies of Subdivision of Flower graph admits Product cordial labeling.

Proof:

Let the Flower graph $S(Fl_n), n \geq 3$ is the graph obtained from the Helm H_m by attaching an edge from each pendant vertex to the apex of the wheel W_n and subdividing each edge by a vertex.

We denotes the vertices of $S(Fl_n)$ as follows:

Let $u'_1, u'_2, \ldots, u'_n$ denotes the apex vertices. Let $w_{1i}, w_{2i}, \ldots, w_{ni}$ denotes the vertices i.e., obtained by subdividing the edges $u'_n u_{ni}$. Let $u_{1i}, u_{2i}, \ldots, u_{ni}$ denotes the vertices of the cycle of Flower graph. Let $u_i u_{i+1}$ $(1 \leq i \leq n)$ subdivides as the vertices $y_{1i}, y_{2i}, \ldots, y_{ni}$ on the cycle c_n. Let $v_{1i}, v_{2i}, \ldots, v_{ni}$ denotes the end vertices of the $S(Fl_n)$. Let $x_{1i}, x_{2i}, \ldots, x_{ni}$ denotes the vertices i.e., obtained by subdividing the $u'_n v_{ni}$ edges of Flower graph. Let $z_{1i}, z_{2i}, \ldots, z_{ni}$ denotes the vertices obtained by subdividing the edges $u_{ni} v_{ni}, (n = 1,2..)$ of Flower graph. Let P'_i denotes the number of vertices in the path. Let p_i denotes the edges in the path.

Here $u'_n = P'_i$

Let $V(S(Fl_n)) = \{u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}, P_i'; (1 \le i \le n)\}$

Let $E(S(Fl_n)) = \{(u_n' w_{ni}, w_{ni} u_{ni}) \cup (u_{ni} z_{ni}, z_{ni} v_{ni}) \cup (u_{ni} y_{ni}, y_{ni} u_{n(i+1)}) \cup (u_n' x_{ni}, x_{ni} v_{ni}); (1 \le i \le n)\}$

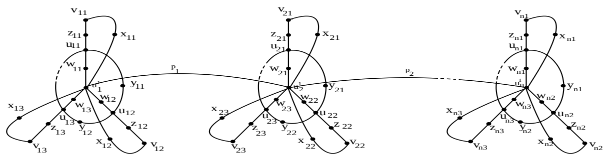

Figure 2.3 Subdivision of Flowers are connected by the path from the apex.

The total number of vertices in $S(Fl_n)$ is $(6n+1)k's$ and the total number of edges in $S(Fl_n)$ is $(8n)k's + p_i$ $(n \ge 3)$

Let k denotes the copies of subdivision of Flower graph.

Let $'n'$ denotes the vertex labels for the subdivision of Flower graph is defined below:

Case: n is even

$$f(u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}) = \begin{cases} 1, & \left\lceil \frac{k(6n+1)}{2} \right\rceil \\ 0, & otherwise \end{cases} \quad (5)$$

Case: n is odd

$$f(u_n', w_{ni}, u_{ni}, y_{ni}) = 1$$
$$f(z_{ni}, v_{ni}, x_{ni}) = 0$$
$$f(u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}) = \begin{cases} 1, \left[\frac{k-1}{2}(6n+1)\right] \\ 0, \left[\frac{k-1}{2}(6n+1)\right] \\ 1,0; \left[\frac{(6n+1)}{2}\right] \end{cases}$$

(6)

Using the above equations, the vertex and edge labels are computed as follows:

The number of vertices with label $'0' = v_f(0) = \frac{6n}{2}$

The number of vertices with label $'1' = v_f(1) = \frac{6n}{2} + 1$

The number of edges with label $'0' = e_f(0) = \frac{8n}{2} + p_i$

The number of edges with label $'1' = e_f(1) = \frac{8n}{2} + p_i$

Case: k is odd

$$|v_f(0) - v_f(1)| = \left|\frac{6n}{2} - \frac{6n}{2} - 1\right| = 1$$

$$|e_f(0) - e_f(1)| = \left|\frac{8n}{2} + p_i - \frac{8n}{2} + p_i\right| = 0$$

The condition for Product cordial labeling is,

$$|v_f(0) - v_f(1)| \le 1 \text{ and } |e_f(0) - e_f(1)| \le 1$$

Thus, the condition is satisfied.

Case: k is even

$$|v_f(0) - v_f(1)| = \left|\frac{6n}{2} - \frac{6n}{2} - 1\right| = 0$$

$$|e_f(0) - e_f(1)| = \left|\frac{8n}{2} + p_i - \frac{8n}{2} - p_i\right| = 1$$

Therefore, $|v_f(0) - v_f(1)| \le 1$ and $|e_f(0) - e_f(1)| \le 1$

Thus, the condition is satisfied.

Hence the path union of k copies of subdivision of Flower graph admits product cordial labeling.

Theorem 2.4:

Path union of k copies Subdivision of Flower graph admits Total product cordial labeling.

Proof:

Denotes the vertex and edges of path union of k copies of $S(Fl_n)$ as follows:

Let $V(S(Fl_n)) = \{u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}, P_i'; (1 \le i \le n)\}$

Let $E(S(Fl_n)) = \{(u_n' w_{ni}, w_{ni} u_{ni}) \cup (u_{ni} z_{ni}, z_{ni} v_{ni}) \cup (u_{ni} y_{ni}, y_{ni} u_{n(i+1)}) \cup (u_n' x_{ni}, x_{ni} v_{ni}); (1 \le i \le n)\}$

The total number of vertices in $S(Fl_n)$ is $(6n+1)k's$ and the total number of edges in $S(Fl_n)$ is $(8n)k's + p_i$ $(n \ge 3)$

Let k denotes the copies of subdivision of Flower graph.

Let $'n'$ denotes the vertex labels for the subdivision of Flower graph is defined below:

Case: n is even

$$f(u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}) = \begin{cases} 1, & \left\lceil \frac{k(6n+1)}{2} \right\rceil \\ 0, & otherwise \end{cases} \quad (7)$$

Case: n is odd

$$f(u_n', w_{ni}, u_{ni}, y_{ni}) = 1$$
$$f(z_{ni}, v_{ni}, x_{ni}) = 0$$
$$f(u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}) = \begin{cases} 1, \left[\frac{k-1}{2}(6n+1)\right] \\ 0, \left[\frac{k-1}{2}(6n+1)\right] \\ 1,0; \left[\frac{(6n+1)}{2}\right] \end{cases}$$

(8)

Using the above equations, the vertex and edge labels are computed as follows:

The number of vertices with label $'0' = v_f(0) = \frac{6n}{2}$

The number of vertices with label $'1' = v_f(1) = \frac{6n}{2} + 1$

The number of edges with label $'0' = e_f(0) = \frac{8n}{2} + p_i$

The number of edges with label $'1' = e_f(1) = \frac{8n}{2} + p_i$

The condition for total product cordial labeling is,

$$|v_f(0) + e_f(0) - (v_f(1) + e_f(1))| \le 1$$

Case: k is odd

$$\left|\frac{6n}{2} + \left(\frac{8n + p_i}{2}\right)k - \left(\frac{6n}{2} + 1 + \left(\frac{8n + p_i}{2}\right)k\right)\right| = 1$$

Thus, the condition is satisfied.

Case: k is even

$$\left|\frac{6n}{2}+\left(\frac{8n+p_i}{2}\right)k-\left(\frac{6n}{2}+1+\left(\frac{8n+p_i}{2}\right)k\right)\right|=1$$

Thus, the condition is satisfied.

Hence the path union of k copies of subdivision of Flower graph admits Total product cordial labeling.

Theorem 2.5:

Path union of k copies of Subdivision of Flower graph admits Product cordial labeling when k is even.

Proof:

Let the Flower graph $S(Fl_n), n \geq 3$ is the graph obtained from the Helm H_m by attaching an edge from each pendant vertex to the apex of the wheel W_n and subdividing each edge by a vertex.

We denotes the vertices of $S(Fl_n)$ as follows:

Let $u_1', u_2', \dots, u_n'$ denotes the apex vertices. Let $w_{1i}, w_{2i}, \dots, w_{ni}$ denotes the vertices i.e., obtained by subdividing the edges $u_n' u_{ni}$. Let $u_{1i}, u_{2i}, \dots, u_{ni}$ denotes the vertices of the cycle of Flower graph. Let $u_i u_{i+1}$ $(1 \leq i \leq n)$subdivides as the vertices $y_{1i}, y_{2i}, \dots, y_{ni}$ on the cycle c_n. Let $v_{1i}, v_{2i}, \dots, v_{ni}$ denotes the end vertices of the $S(Fl_n)$. Let $x_{1i}, x_{2i}, \dots, x_{ni}$ denotes the vertices i.e., obtained by subdividing the $u_n' v_{ni}$ edges of Flower graph. Let $z_1, z_2, \dots, z_n$ denotes the vertices obtained by subdividing the edges $u_{ni} v_{ni}, (n = 1,2..)$ of Flower graph. Let P_i' denotes the number of vertices in the path. Let p_i denotes the edges in the path.

Here $v_{ni} = P_i'$

Let $V(S(Fl_n)) = \{u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}, P_i'; (1 \leq i \leq n)\}$

Let $E(S(Fl_n)) = \{(u_n' w_{ni}, w_{ni} u_{ni}) \cup (u_{ni} z_{ni}, z_{ni} v_{ni}) \cup (u_{ni} y_{ni}, y_{ni} u_{n(i+1)}) \cup (u_n' x_{ni}, x_{ni} v_{ni}); (1 \leq i \leq n)\}$

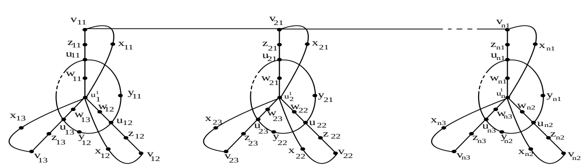

Figure: 2.5 Subdivision of Flowers are connected by the path from the outer vertex.

Let k denotes the copies subdivision of Flower graph.

The total number of vertices in $S(Fl_n)$ is $(6n+1)k's$ and the total number of edges in $S(Fl_n)$ is $(8n)k's + p_i$ $(n \geq 3)$.

Let $'n'$ denotes the vertex labels for the subdivision of Flower graph is given below:

Case: n is even

$$f(u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}) = \begin{cases} 1, & \left[\frac{k(6n+1)}{2}\right] \\ 0, & otherwise \end{cases} \quad (9)$$

Case: n is odd

$$f(u_n', w_{ni}, u_{ni}, y_{ni}) = 1$$
$$f(z_{ni}, v_{ni}, x_{ni}) = 0$$

$$f(u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}) = \begin{cases} 1, \left[\frac{k-1}{2}(6n+1)\right] \\ 0, \left[\frac{k-1}{2}(6n+1)\right] \\ 1,0; \left[\frac{(6n+1)}{2}\right] \end{cases}$$

(10)

Using the above equations, the vertex and edge labels are computed as follows:

The number of vertices with label $'0' = v_f(0) = \frac{6n}{2}$

The number of vertices with label $'1' = v_f(1) = \frac{6n}{2} + 1$

The number of edges with label $'0'$ $= e_f(0) = \frac{8n}{2} + p_i$

The number of edges with label $'1'$ $= e_f(1) = \frac{8n}{2} + p_i$

The condition for Product cordial labeling is,

$$|v_f(0) - v_f(1)| \leq 1$$
$$|e_f(0) - e_f(1)| \leq 1$$

When k is even

$$|v_f(0) - v_f(1)| = \left|\frac{6n}{2} - \frac{6n}{2} - 1\right| = 0$$

$$|e_f(0) - e_f(1)| = \left|\left(\frac{8n}{2} + p_i\right)k - \left(\frac{8n}{2} + p_i\right)k\right| = 1$$

Therefore, $|v_f(0) - v_f(1)| \leq 1$ and $|e_f(0) - e_f(1)| \leq 1$

Thus, the condition is satisfied.

Hence the path union k copies of subdivisions of Flower graph admits product cordial labeling when k is even.

Theorem 2.6:

Path union of k copies of Subdivision of Flower graph admits Total product cordial labeling when k is even.

Proof:

Denotes the vertex and edges of Path union of even number $S(Fl_n)$ as follows:

Let $V(S(Fl_n)) = \{u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}, P_i'; (1 \leq i \leq n)\}$

Let $E(S(Fl_n)) = \{(u_n' w_{ni}, w_{ni} u_{ni}) \cup (u_{ni} z_{ni}, z_{ni} v_{ni}) \cup (u_{ni} y_{ni}, y_{ni} u_{n(i+1)}) \cup (u_n' x_{ni}, x_{ni} v_{ni}); (1 \leq i \leq n)\}$

Let k denotes the copies of subdivision of Flower graph.

The total number of vertices in $S(Fl_n)$ is $(6n+1)k's$ and the total number of edges in $S(Fl_n)$ is $(8n)k's + p_i$ $(n \geq 3)$.

Let $'n'$ denotes the total number of vertices for the subdivision of Flower graph is given below:

Case: n is even

$$f(u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}) = \begin{cases} 1, & \left[\frac{k(6n+1)}{2}\right] \\ 0, & otherwise \end{cases} \quad (11)$$

Case: n is odd

$$f(u_n', w_{ni}, u_{ni}, y_{ni}) = 1$$
$$f(z_{ni}, v_{ni}, x_{ni}) = 0$$

$$f(u_n', w_{ni}, u_{ni}, z_{ni}, v_{ni}, x_{ni}, y_{ni}) = \begin{cases} 1, \left[\frac{k-1}{2}(6n+1)\right] \\ 0, \left[\frac{k-1}{2}(6n+1)\right] \\ 1,0; \left[\frac{(6n+1)}{2}\right] \end{cases}$$

(12)

Using the above equations, the vertex and edge labels are computed as follows:

The number of vertices with label $'0' = v_f(0) = \frac{6n}{2}$

The number of vertices with label $'1' = v_f(1) = \frac{6n}{2} + 1$

The number of edges with label $'0' = e_f(0) = \frac{8n}{2} + p_i$

The number of edges with label $'1' = e_f(1) = \frac{8n}{2} + p_i$

The condition for total product cordial labeling is,

$$|v_f(0) + e_f(0) - (v_f(1) + e_f(1))| \le 1$$

When k is even

$$\left|\frac{6n}{2} + \left(\frac{8n + p_i}{2}\right)k - \left(\frac{6n}{2} + 1 + \left(\frac{8n + p_i}{2}\right)k\right)\right| = 1$$

Thus, the condition is satisfied.

Hence the path union of k copies of subdivisions of Flower graph admits Total product cordial labeling when k is even.

III. CONCLUSION

In this paper, we have proved that the Product cordial labeling and total product cordial labeling of subdivision of Flower graph and the path union of subdivision of Flower graph admits Product cordial labeling and total product cordial labeling. Also, we can prove for any other subdivisions of graphs are Product cordial and Total product cordial labeling.

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