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TOPOLOGICAL INTEGER ADDITIVE SET- LABELING OF SIGNED GRAPHS

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ABSTRACT

The objective of this paper is to extend the existing concept of integer additive set- labeling of signed graphs over topology and give the extension as topological integer additive set -labeled signed graphs. Here, in this paper, we also work on different graph classes such that a topological integer additive set- labeling can be obtained with the signed function for which motive of the paper can be fulfilled.

INTRODUCTION

The labeling of graphs seems to be a mile stone in the path of illuminating practical world of mathematics. Graph Labeling is the process to assign the labels (numbers) to the elements (vertices and edges) of the graphs. The Sun of Graph Labeling shines in sixties when Rosa [1] introduced the concept of $\beta - valuation$ of graphs. Later many authors introduced various types of graph labeling and obtained thousands of interesting results. Acharya[3] initiated a general study of labeling of vertices and edges of a graph by assigning the subsets of the set. Acharya established a relation between graph theory and point set-topology by introducing the concept of topological set-indexers [4]. Germina and Anandavally[14] introduced the concept of integer additive set-valuation of graphs by assigning the subset of non-negative integers to the elements with additive operation. Sudev and Germina[17] extended this concept over different graph classes and graph operations. The sumset of sets A and B is denoted as A+B. It is defined as A+B= $\{a+b: a \in A, b \in B\}$.

The concept of signed theory took birth by the social relations. Cartwright and Harary[7] gave birth to a new concept by representing the dyadic relationship between the persons. They considered such graphs in which vertices represent persons and the edges represent symmetric relations amongst persons each of which is designated as being positive or negative according to whether the nature of the relationship is positive (friendly, like) or negative (hostile, dislike). Such a network S is called a signed graph (Chartrand[11], Harary et al. [10]). Signed graphs are much studied in literature because of their extensive use in modeling a variety of socio-psychological processes (Acharya[5,6], Katai and Iwai[18] etc.). Further, Sudev and Germina[15] extended the concept of integer additive set-valuations over signed graph and gave integer additive set-valuations of signed graphs.

Motivated from their study, we introduce the concept of topology over integer additive set-valuations of signed graphs and produce topological integer additive set-labeling of signed graphs.

Preliminaries

All the terms and conditions are not mentioned in this paper, for more details we refer to [8, 13]. Here, we considered X as a non empty finite subset of N_0 where N_0 is a set of natural number containing zero also.

Definition [14]:- An integer additive set-labeling (IASL) is an injective function $f : V(G) \rightarrow P(X) - \{\emptyset\}$ such that the induced function $f^+ : E(G) \rightarrow P(X) - \{\emptyset, \{0\}\}$ is defined by $f^+(uv) = f(u) + f(v)\ \forall\ uv \in E(G)$. A graph G which admits an

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IASL is called an integer additive set-labeled graph (IASL graph).

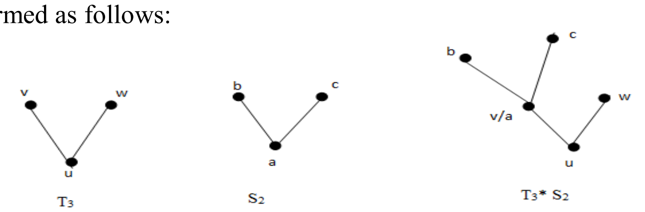
Definition [19, 20]:- A signed graph denoted by $\Sigma(G, \sigma)$, is a graph G(V, E) together with a function $\sigma : E(G) \rightarrow \{+, -\}$ that assigns a sign, either + or −, to each ordinary edge in G. The function σ is called the signature or sign function of Σ.

Definition [9, 12]:- A simple cycle (or path) of a signed graph Σ is said to be balanced if the product of signs of its edges is +. A signed graph is said to be a balanced signed graph if it contains no half edges and all of its simple cycles are balanced.

Definition [15]:- Let $X \subseteq N_0$ and let Σ be a signed graph, with corresponding underlying graph G and the signature σ. An injective function f: $V(\Sigma) \rightarrow P(X) - \{\emptyset\}$ is said to be an integer additive set-labeling (IASL) of Σ if f is an integer additive set-labeling of the underlying graph G and the signature of Σ is defined by $\sigma(uv) = (-1)^{|f(u)+f(v)|}$ $\forall$ uv ∈ E(Σ). A signed graph which admits an integer additive set-labeling is called an integer additive set-labeled signed graph (IASL signed graph) and is denoted by Σ_f.

Definition [14]:- An integer additive set-labeled graph G is said to be Topological integer Additive Set-Labeled if f(V(G)) forms a topology.

Definition [2]:- A merge graph $G_1 * G_2$ can be formed from two graphs G_1 and G_2 by merging a node of G_1 with a node of G_2. Here we define merging as, let us consider T_3, a tree with three vertices and S_2, a star on three vertices then $T_3 * S_2$ is formed as follows:



Definition [16] (n; m)-Ladle Graph: Let G be a graph on n vertices and let P_m be a path of order m that has no common vertex with G, then the graph obtained by identifying one vertex of G and one end vertex of P_m as (n; m)-ladle graph.

Definition [16] (n; m)-Tadpole Graph: If G is a cycle C_n, then the ladle graph is called an (n; m)-tadpole graph or a dragon graph. If m = 1 in a tadpole graph, then G is called an n-pan graph.

MAIN RESULTS

Motivated by the labeling defined in [15], we define topological integer additive set-labeling of signed graphs. Here we also characterize the property for the corresponding graph.

Definition: Let S = (V, E, s) be an IASL signed graph with corresponding graph G= (V, E) and the signature function s. Here, G is an integer additive set-labeled graph having function f as f: $V(G) \rightarrow P(X) - \{\emptyset\}$ is an injective function produced another injective function $g_f : E(G) \rightarrow P(X) - \{\emptyset, \{0\}\}$ defined by $g_f(uv) = f(u) + f(v)$ for every uv ∈ E(G), where X is the subset of non-negative integers and P(X) is its power set and the signature function defined as s: E(G) → {+,-} such that s(uv)= $-\mathbf{1}^{|f(u)+f(v)|}$ for all uv ∈ E(G). If f(V(G)) ∪ {∅} forms a topology on X then the signed graph S is called Topological Integer Additive Set-Labeled signed graph (T–IASL signed graph).

Definition: If the labeling defined on the signed graph S becomes topological integer additive set- labeling then the graph S becomes T-IASL signed graph.

Now, we proceed to study about the different graphs and graph classes those satisfy topological integer additive set- labeling of signed graphs properties by defining the corresponding mapping.

Theorem: Every star graph $K_{1,n}$ is Topological Integer Additive Set-labeled signed graph.

Proof: Let $K_{1,n}$ be a star graph with central vertex v of degree n and pendant vertices $u_1, u_2, \ldots, u_n$ adjacent with v. If X is the ground set containing the non-negative integers whose subsets are to be assigned among the vertices of the graph.

The labeling corresponding to the elements of G will be as follows:

If f: $V(K_{1,n}) \rightarrow P(X) - \{\emptyset\}$ be defined as
f (v) ={0}

Case 1*:-* If n is even.

$$f(u_i) = \begin{cases} \{\mathbf{1}, \mathbf{2}, \ldots, \boldsymbol{i}\} & \mathbf{1} \le \boldsymbol{i} \le \frac{\boldsymbol{n}}{\mathbf{2}} \\ \{\mathbf{0}, \mathbf{1}, \mathbf{2}, \ldots, \boldsymbol{i} - \left(\frac{\boldsymbol{n}}{\mathbf{2}}\right)\} & \frac{\boldsymbol{n}+\mathbf{2}}{\mathbf{2}} < i \le n \end{cases}$$

Where X = {0, 1, 2,......, $\frac{n}{2}$}

Case 2:- If n is odd.

$$f(u_i) = \begin{cases} \{\mathbf{1}, \mathbf{2}, \ldots, \boldsymbol{i}\} & \mathbf{1} \le \boldsymbol{i} \le \left\lceil \frac{\boldsymbol{n}}{\mathbf{2}} \right\rceil \\ \{\mathbf{0}, \mathbf{1}, \mathbf{2}, \ldots, \boldsymbol{i} - \left(\frac{\boldsymbol{n}-\mathbf{1}}{\mathbf{2}}\right)\} & \left\lceil \frac{\boldsymbol{n}}{\mathbf{2}} \right\rceil < i \le n \end{cases}$$

Where X = {0, 1, 2,......, $\frac{n+1}{2}$ } and the mapping corresponding to the edges are as:

$g_f : E(K_{1,n}) \rightarrow P(X) - \{\emptyset, \{0\}\}$defined $g_f(u_i v) = f(u_i) + f(v)$ for every $u_i v \in E(K_{1,n})$, $1 \le i \le n$. The signature function defined on G = $K_{1,n}$ as s: E(G) → {+,-} such that s(u_i v)= $-1^{|f(u_i)+f(v)|}$ for all u_i v ∈ E(G), $1 \le i \le n$. Hence, by assigning the set-labeling among the elements of G in above pattern, we get S = (G, s) as Topological Integer Additive Set-Labeled signed graph.

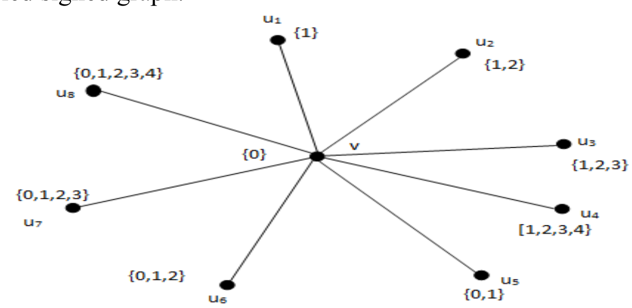


Illustration Figure 1 shows $K_{1,8}$ as T-IASL signed graph

Theorem: Every double star graph $S_{m,n}$ is Topological Integer Additive Set-labeled signed graph.

Proof: Let G = $S_{m,n}$ be a double star graph with central vertices u and v. Let $\{u_1, u_2, \ldots, u_m\}$ and $\{v_1, v_2, \ldots, v_n\}$ be sets of pendant vertices adjacent to the vertices u and v respectively. If X is finite non-empty ground set containing the non-negative integers and the mapping defined as follows:

If f: V $(S_{m,n}) \rightarrow P(X) - \{\emptyset\}$ be defined as

Case 1:- If m ≥ n

$f(u) = \{0\}$, $f(v) = \{0,1\}$, $f(u_i) = \{0,1,\ldots, i+1\}$, $1 \le i \le m$
$f(v_j) = \{1,\ldots, j\}$, $1 \le j \le n$ with $X = \{0,1,2,\ldots\ldots, m+1\}$

Case 2:- If m < n

$f(u) = \{0,1\}$, $f(v) = \{0\}$, $f(u_i) = \{0,1,\ldots, i\}$, $1 \le i \le m$
$f(v_j) = \{1,\ldots, j+1\}$, $1 \le j \le n$ with $X = \{0,1,2,\ldots\ldots, n+1\}$ and the labeling for the edges are:

$g_f : E(S_{m,n}) \rightarrow P(X) - \{\emptyset, \{0\}\}$ defined by
$g_f(u_iv_j) = f(u_i) + f(v_j)$ for every $u_iv_j \in E(S_{m,n})$, $1 \le i \le m$ and $1 \le j \le n$. The signature function defined on $S_{m,n}$ as s: $E(S_{m,n}) \rightarrow \{+,-\}$ such that s $(u_iv_j) = -1^{|f(u_i)+f(v_j)|}$ $\forall$ $u_iv_j \in E(S_{m,n})$, $1 \le i \le m$, $1 \le j \le n$. Hence, By assigning the set-labeling among the elements of $S_{m,n}$ in above pattern, we get S = $(S_{m,n}, s)$ as Topological Integer Additive Set- Labeled signed graph.

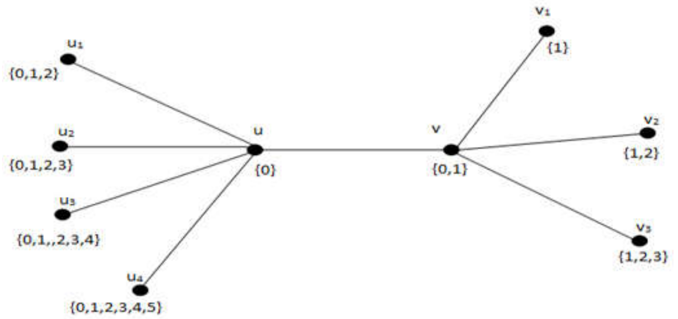


Illustration: Figure 2 shows $S_{4,3}$ as T-IASL signed graph

Theorem: Every path graph P_n is Topological Integer Additive Set-labeled signed graph.

Proof: Let P_n be a path graph with n vertices $u_1, u_2, u_3, \ldots, u_n$ and X is the ground set containing finite natural no. including 0. If the labeling defined corresponding to the elements of graph as follows then the graph become T-IASL signed graph. Without loss of generality, we can assume that X itself is assigned to u_1 and $\{0\}$ is assigned to u_2 which is adjacent to u_1. The labeling of vertices of P_n will be defined by the function as follows:-

Let f: V $(P_n) \rightarrow P(X) - \{\emptyset\}$ be defined as:-
$f(v_3) = \{1\}$

Case 1:- If n is even.

$$f(v_i) = \begin{cases} \{0,1,2,\ldots,i-3\} & 4 \le i \le \frac{n+4}{2} \\ \{1,2,\ldots,i-\left(\frac{n+2}{2}\right)\} & \frac{n+4}{2} < i \le n \end{cases}$$

Where X = {0, 1, 2,......, n-2}

Case 2:- If n is odd.

$$f(v_i) = \begin{cases} \{0,1,2,\ldots,i-3\} & 4 \le i \le \frac{n+5}{2} \\ \{1,2,\ldots,i-\left(\frac{n+3}{2}\right)\} & \frac{n+5}{2} < i \le n \end{cases}$$

Where X = {0, 1, 2,......, n-2} then f (V(G)) ∪ { ϕ } forms a topology on X. The remaining labeling g_f and s corresponding to edges will be same as in above Theorem 3.4.

Hence, P_n admits a Top-IASL signed labeling and graph becomes T-IASL signed graph.

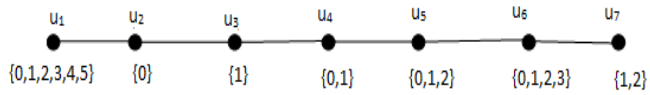


Illustration Figure 3 shows P_7 as T-IASL signed graph

Theorem: If P_n and S_m are two T-IASL signed graphs then merging of both graphs as G= P_n* S_m also admits Topological Integer Additive Set-Labeled signed labeling (T-IASL signed labeling).

Proof: Let $\{u_1, u_2, \ldots, u_n\}$ and $\{v_1, v_2, \ldots, v_m, v\}$ are the vertices set of P_n and S_m graphs respectively. Now, in merging of the graph both graphs are joined together with a single vertex. Without loss of generality, we can assume that u_n vertex of P_n is merge with the central vertex v of S_m. If n=1,2 then P_1* S_m and P_2* S_m becomes S_m and S_{m+1} star graphs respectively for any arbitrary value of m. Hence, the labeling will be same as in Theorem 3.4. The labeling corresponding to the remaining values of n will be defined as:

Let f : $V(P_n) \rightarrow P(X) - \{\emptyset\}$ be defined as:-
$f(u_1) = X$, $f(u_2) = \{0\}$, $f(u_3) = \{1\}$

Case 1:- If n=3 and m has any arbitrary value.

$$f(v_j) = \begin{cases} \{0,1,\ldots,j\}, & 1 \le j \le \left[\frac{m}{2}\right]+1. \\ \left\{1,2,\ldots,\left(j-\frac{m}{2}\right)\right\}, & \left[\frac{m}{2}\right]+1 \le j \le m \text{ and } m \text{ is even.} \\ \left\{1,2,\ldots,\left(j-\frac{m-1}{2}\right)\right\}, & \left[\frac{m}{2}\right]+1 \le j \le m \text{ and } m \text{ is odd.} \end{cases}$$

Case 2:- If n ≥ 4 and m has any arbitrary value.

$f(u_i) = \{0,1,\ldots,i-3\}$, $4 \le i \le n$.

Case (a):- If n is even.

$$f(v_j) = \begin{cases} \{1,2,\ldots,j+1\} & 1 \le j \le \left[\frac{n+m}{2}\right]-2. \\ \left\{0,1,2,\ldots,\left(j-\left[\frac{m}{2}\right]+\left(\frac{n-1}{2}\right)\right)\right\} & \left[\frac{n+m}{2}\right]-1 \le j \le m. \end{cases}$$

Case (b):- If n is odd.

$$f(v_j) = \begin{cases} \{1,\ldots,j+1\}, & 1 \le j \le \left[\frac{n+m}{2}\right]-2. \\ \left\{0,1,2,\ldots,\left(j+\left[\frac{n-m}{2}\right]\right)\right\}, & \left[\frac{n+m}{2}\right]-1 \le j \le m \text{ and } m \text{ is even.} \\ \left\{0,1,2,\ldots,\left(j+\left[\frac{n-m}{2}\right]-1\right)\right\}, & \left[\frac{n+m}{2}\right]-1 \le j \le m \text{ and } m \text{ is odd.} \end{cases}$$

with corresponding ground set X. Hence, by defining the function in above manner we will get the labeling as T-IASL signed graph and the remaining mapping corresponding to the edges will be as in Theorem 3.4.

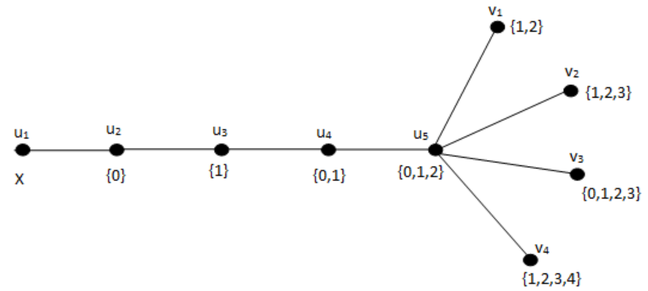


Illustration: Figure 4 shows P_5* S_4 as T-IASL signed graph

Theorem:- Every n-pan graph is T- IASL signed graph.

Proof:- Let G be an n-pan graph. Let $v_1, v_2, v_3, \ldots, v_n$ be the vertices of C_n and u be the vertex of P_1. Let X be the ground set containing finite natural no. including 0. Without loss of generality, we can assume that X itself is assigned to u and {0} is assigned to v_1 which is adjacent to u. The labeling of vertices of C_n will be defined by the function as follows:
Let $f : V(C_n) \rightarrow P(X)$ be defined as
$f(v_1) = \{0\}$, $f(v_2) = \{1\}$

Case 1:- If n is even.

$$f(v_i) = \begin{cases} \{0,1,2,\ldots,i-2\} & 3 \le i \le \frac{n+4}{2} \\ \{1,2,\ldots,i-\left(\frac{n+2}{2}\right)\} & \frac{n+4}{2} < i \le n \end{cases}$$

Where X = {0, 1, 2,......, n-1}

Case 2:- If n is odd.

$$f(v_i) = \begin{cases} \{0,1,2,\ldots,i-2\} & 3 \le i \le \frac{n+3}{2} \\ \{1,2,\ldots,i-\left(\frac{n+1}{2}\right)\} & \frac{n+3}{2} < i \le n \end{cases}$$

Where X = {0, 1, 2,......, n-2} then f (G) ∪ { ϕ } forms a topology on X and the labeling for the edges will be same as defined in Theorem 3.5. Hence, every pan graph has T- IASL signed labeling and the graph becomes T-IASL signed graph.

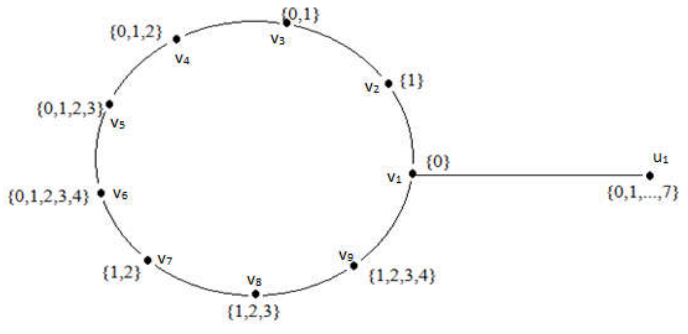


Illustration: Figure 5 shows 9-Pan graph as T-IASL signed graph.

Theorem:- Every (n;2)- Tadpole graph is Top- IASL signed graph.

Proof:- let G be a (n;2)- Tadpole graph. Let $\{v_1, v_2, \ldots, v_n\}$ and $\{u_1, u_2\}$ be the vertices set of C_n and P_2 graph respectively. W.L.G., we can assume that u_1 is the pendant vertex of P_2 and u_2 is the adjacent vertex of v_1. Now, X is the ground of non-negative integers assigned to u_1 and {0} is assigned to u_2.

The labeling of the vertices of C_n are defined as follows:-
Let $f : V(C_n) \rightarrow P(X)$ be defined as
$f(v_1) = \{1\}$

Case 1:- If n is even

$$f(v_i) = \begin{cases} \{0,1,2,\ldots,i-1\} & 2 \le i \le \frac{n+2}{2} \\ \{1,2,\ldots,i-\left(\frac{n}{2}\right)\} & \frac{n+2}{2} < i \le n \end{cases}$$

where X = { 0,1,2,..., n-1}

Case 2:- If n is odd

$$f(v_i) = \begin{cases} \{0,1,2,\ldots,i-1\} & 2 \le i \le \frac{n+3}{2} \\ \{1,2,\ldots,i-\left(\frac{n+1}{2}\right)\} & \frac{n+3}{2} < i \le n \end{cases}$$

where X = {0,1,2,..., n}

Then f (V(G)) ∪ { ϕ } forms a topology on X with the mapping defined along the edges are same as defined in Theorem 3.5. Hence, graph G is T- IASL signed graph.

Theorem 3.9:- Every Tadpole graph is T- IASL signed graph.

Proof:- l et G be a (n;m)- Tadpole graph. Let $\{v_1, v_2, \ldots, v_n\}$ and $\{u_1, u_2, u_3, \ldots, u_m\}$ be the vertices set of C_n and P_m graphs respectively. Now, X is the ground set of finite non negative natural no. including {0}. Now, labeling assigned to the vertices of P_m is defined as:-

W.L.G., we can assume that X is assigned to the pendant vertex u_1 of P_m, u_2 is adjacent to u_1 have label {0}, u_3 is assigned label {1} and remaining are as follows:-
$g : V(P_m) \rightarrow P(X)$ be defined as
$g(u_j) = \{0,1,2,\ldots,i-3\}$ $\forall$ $j \ge 4$.

Now, the mapping along the vertices of C_n as follows:-
Case 1:- If n & m both are even or odd and m ≥ 3.
Let $f : V(C_n) \rightarrow P(X)$ be defined as
If n ≥ m

$$f(v_i) = \begin{cases} \{0,1,2,\ldots,i+m-3\} & 1 \le i \le \frac{n-m+4}{2} \\ \{1,2,\ldots,i-\left(\frac{n-m+2}{2}\right)\} & \frac{n-m+4}{2} < i \le n \end{cases}$$

If n < m but n ≠ m-2

$f(v_i) = \{1,2,\ldots, i-(\frac{n-m+2}{2})\}$ $\forall$ $1 \le i \le n$.
Where X = {0, 1, 2,..., n+m-3}.
Then f (G) ∪ {ϕ } forms a topology.

Case 2:- If n & m either one is even or other is odd.
Let $f : V(C_n) \rightarrow P(X)$ be defined as

If n ≥ m

$$f(v_i) = \begin{cases} \{0,1,2,\ldots,i+m-3\} & 1 \le i \le \frac{n-m+5}{2} \\ \{1,2,\ldots,i-\left(\frac{n-m+3}{2}\right)\} & \frac{n-m+5}{2} < i \le n \end{cases}$$

Where X = {0, 1, 2,..., n+m-2}.

If n < m but n ≠ m-3

$f(v_i) = \{1,2,\ldots, i-(\frac{n-m+3}{2})\}$ $\forall$ $1 \le i \le n$.
Where X = {0, 1, 2,..., n+m-4}.

Then f (G) ∪ {ϕ} forms a topology along with the defined mapping along the edge function and signature function according to the theorem 3.5. Hence, the labeling becomes T-IASL signed labeling and the graph become T- IASL signed graph.

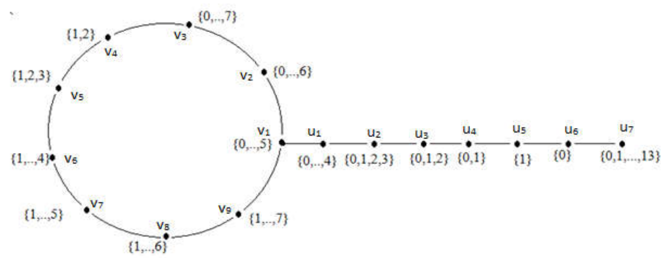


Illustration: Figure 6 shows (9;7)-Tadpole graph as T-IASL signed graph

CONCLUSION

The concept of topology over integer additive set-valuations of signed graphs has been already introduced in this paper. Here, we also discussed the graph classes with T-IASL signed graphs. Even now there is a large scope of further study to find the answer of these questions. What is the minimal cardinality of ground set required for the graph having T-IASL signed mapping? What are the necessary and sufficient conditions for the graphs to become T-IASL signed graphs? Find the graph classes having T-IASL balanced signed graph property? Also find the necessary and sufficient conditions for the graphs have T-IASL balanced signed graphs? Verify the existence of T-IASL signed labeling for different graphs operations and graph products.

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