Bol. Soc. Paran. Mat.
©SPM – E-ISSN-2175-1188
SPM: www.spm.uem.br/bspm

(3s.) **v. 2026 (44) 14** : 1–11.
ISSN-0037-8712
doi:10.5269/bspm.81733

Laceability Properties in Edge-Tolerant Total Transformation Graphs $G^{\alpha\beta\gamma}$

Nagarathnamma K. G. and Leena N. Shenoy

ABSTRACT: A bipartite graph G is hamiltonian laceable if there is a hamiltonian path between any two vertices of G from distinct vertex bipartite sets. A bipartite graph G is k-edge fault-tolerant hamiltonian laceable if $G - F$ is hamiltonian laceable for every $F \subseteq E(G)$ with $|F| \leq k$. A graph G is k-edge fault-tolerant conditional hamiltonian if $G - F$ is hamiltonian for every $F \subseteq E(G)$ with $|F| \leq k$ and $\delta(G - F) \geq 2$. In this paper, we establish laceability properties in the edge tolerant total transformation graphs $G^{\alpha\beta\gamma}$.

Keywords: Hamiltonian laceable, fault-tolerant, total transformation graph.

Contents

1. Introduction

An interconnection network links the processing units in parallel computing systems. Its structure can be modeled as a graph, where vertices represent processors and edges represent communication links. As a result, the terms graph and network are often used synonymously. Designing an efficient network topology involves balancing multiple conflicting requirements. Among the most widely used topologies is the n-dimensional hypercube, Q_n [14]. However, the hypercube does not achieve the minimal possible diameter given its number of connections. To address this limitation, researchers have developed various modified networks by reconfiguring certain links in hypercubes [1, 8-10].

For graph definitions and notations, we follow [25]. A graph $G = (V, E)$ consists of a finite vertex set V and an edge set $E \subseteq \{\{u, v\} \mid u, v \in V\}$. The neighborhood of a vertex $u \in G$, denoted by $N_G(u)$, is the set $\{v \mid \{u, v\} \in E\}$. The neighbor edges of u are denoted by $NE_G(u) = \{\{u, v\} \mid v \in N_G(u)\}$. The degree of u, written as $\deg_G(u)$, equals $|N_G(u)|$. A graph is k-regular if $\deg_G(u) = k$ for all $u \in V$, and we denote the minimum degree by $\delta(G) = \min\{\deg_G(x) \mid x \in V\}$.

A *Hamiltonian path* spans all vertices of G, and a *cycle* is a closed path with no repeated vertices except the start/end vertex. A *Hamiltonian cycle* traverses every vertex exactly once, and a graph possessing such a cycle is *Hamiltonian*.

A graph is *bipartite* if its vertex set partitions into V_0 and V_1 such that every edge connects V_0 and V_1. A bipartite graph is *Hamiltonian laceable* if there exists a Hamiltonian path between any two vertices from different partitions.

Hsieh et al.[11] introduced *edge fault-tolerant Hamiltonicity* to assess Hamiltonian properties in faulty networks. A graph G is *k-edge fault-tolerant Hamiltonian* if $G - F$ remains Hamiltonian for any $F \subseteq E(G)$ with $|F| \leq k$. For bipartite graphs, G is *k-edge fault-tolerant Hamiltonian laceable* if $G - F$ remains Hamiltonian laceable under the same conditions. Latifi et al. [13] proved that the n-dimensional hypercube Q_n is $(n-2)$-edge fault-tolerant Hamiltonian, while Li et al. [15] showed the n-dimensional star graph S_n is $(n-3)$-edge fault-tolerant Hamiltonian. Edge fault tolerance has been widely examined in networks [10,11,13,15,18,20].

2020 *Mathematics Subject Classification:* 05C40, 05C90.
Submitted February 03, 2026. Published April 30, 2026.

1.1. Total transformation graphs

Wu and Meng [28] have generalized the total graph as follows:

Definition 1.1 *Let $G = (V, E)$ be a graph and α, β, γ be three variables taking values $+$ or $-$. The total transformation graph $G^{\alpha\beta\gamma}$ is a graph having $V(G) \cup E(G)$ as a vertex set, and for $\rho, \mho \in V(G) \cup E(G)$, ρ and $\mho$ are adjacent in $G^{\alpha\beta\gamma}$ if and only if*

1. *$\rho, \mho \in V(G)$, ρ, $\mho$ are adjacent in G if $\alpha = +$ and ρ and $\mho$ are not adjacent in G if $\alpha = -$.*
2. *$\rho, \mho \in E(G)$, ρ, $\mho$ are adjacent in G if $\beta = +$ and ρ and $\mho$ are not adjacent in G if $\beta = -$.*
3. *$\rho \in V(G)$ and $\mho \in E(G)$, ρ, $\mho$ are incident in G if $\gamma = +$ and ρ and $\mho$ are not incident in G if $\gamma = -$.*

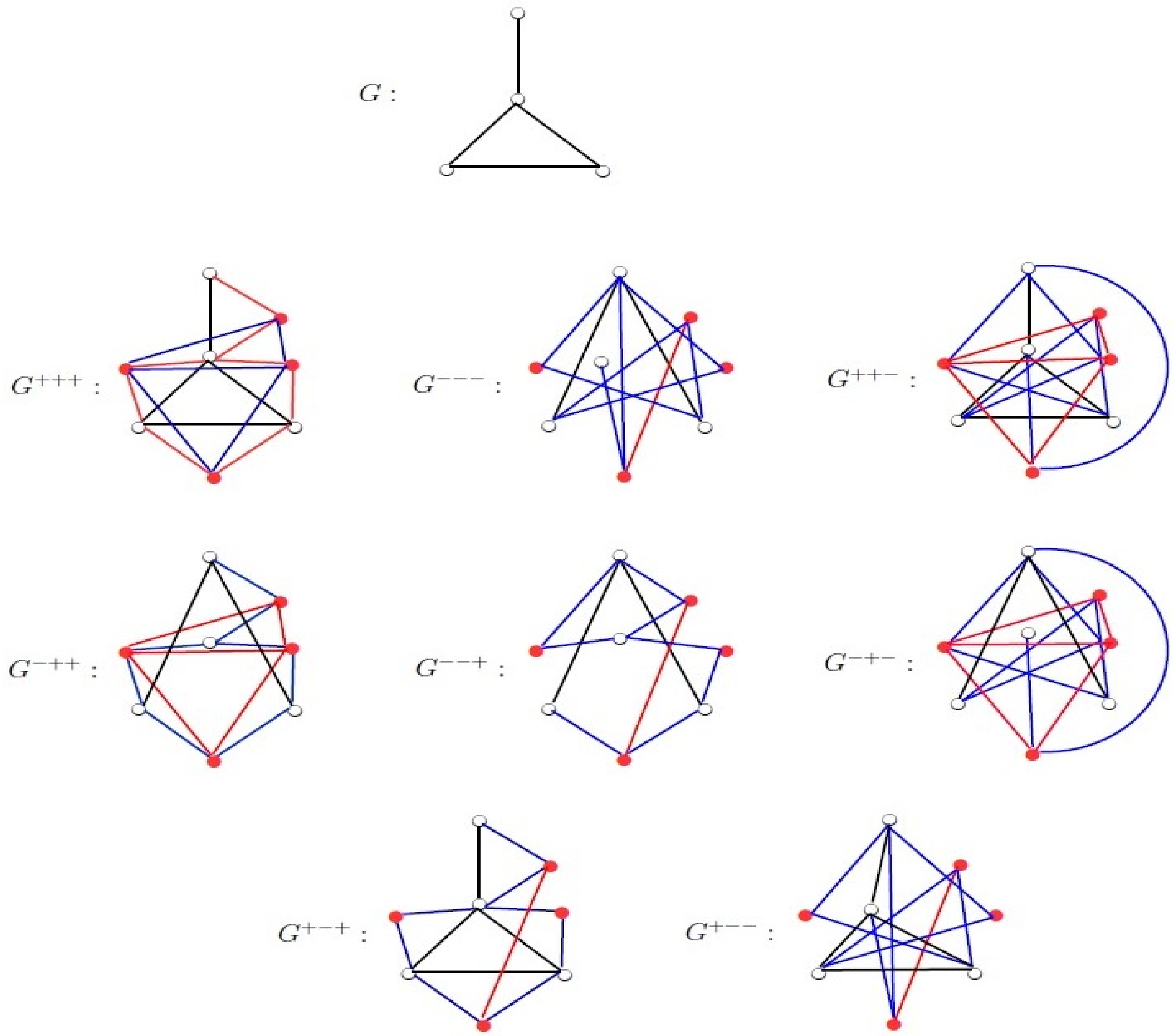

Figure 1. A graph G and its total transformation graph G^{xyz}.

The basic properties of these total transformation can be seen in [28,29].

2. Results

Theorem 2.1 *For $n \geq 2$, the $m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edge fault tolerant graph G^{+++} is Hamiltonian laceable if and only if G is laceable.*

Proof: Let G be a laceable graph of order n and size m such that $V(G) = \{v_1, v_2, v_3, \cdots, v_n\}$ and $E(G) = \{e_1, e_2, e_3, \cdots, e_m\}$. Then by the definition of G^{+++} we have $V(G^{+++}) = V(G) \cup E(G)$. That is $V(G^{+++}) = \{v_1, v_2, v_3, \cdots, v_n, e_1, e_2, e_3, \cdots, e_m\}$. Further, $|V(G^{+++})| = n + m$ and $|E(G^{+++})| = \frac{1}{2}\left[4m + \sum_{i=1}^{n} d_G(v_i)^2\right]$. Since G is laceable, we need to show that G^{+++} is laceable after removal of $m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edges from $E(G^{+++})$. It is easy to observe that for every edge $e = uv \in G$, uve will be a cycle of length three in G^{+++}. A graph is bipartite if and only if it does not contain odd cycle, therefore, G^{+++} is non-bipartite graph and therefore non-laceable. By the definition of G^{+++}, G is an induced subgraph, since G is laceble therefore, G^{+++} is $E(G^{+++}) - E(G)$ edge fault tolerant graph. That is, $m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edge fault tolerant graph G^{+++} is Hamiltonian laceable.

Conversely, assume that G^{+++} is Hamiltonian laceable and G is non-laceable graph. Then G^{+++} does not contain any odd cycle, since by the definition and structural analysis it is easy to observe that C_3 is a subgraph of G^{+++}, a contradiction to our assumption. □

Example 1. The shadow graph is an edge-fault-tolerant t^*-laceable. Therefore, consider the shadow graph of $B(C_4)$ and its total transformation graph B^{+++} is also an edge-fault-tolerant t^*-laceable.

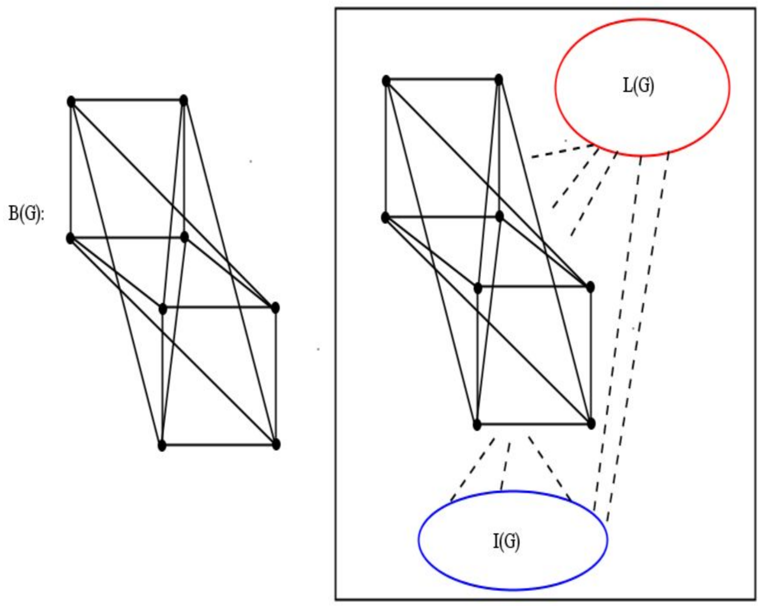

Figure 2. The shadow graph of C_4 and its total transformation graph G^{+++}.

Theorem 2.2 *For $n \geq 2$, the $m(n-2) - m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edge fault tolerant graph G^{++-} is Hamiltonian laceable if and only if G is laceable.*

Proof: Let G be a laceable graph of order n and size m such that $V(G) = \{v_1, v_2, v_3, \cdots, v_n\}$ and $E(G) = \{e_1, e_2, e_3, \cdots, e_m\}$. Then by the definition of G^{++-} we have $E(G^{++-}) = E(G) \cup E(L(G)) \cup (n-2) \cdot E(G)$, $|V(G^{++-})| = m + n$, $|E(G^{++-})| = m = \frac{1}{2}[2m(n-2) + \sum_{i=1}^{n} d_G(v_i)^2]$. Since G is laceable, we need to show that G^{++-} is laceable after removal of $m(n-2) - m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edges from $E(G^{++-})$. It is easy to observe that for every edge $e = uv \in G$, uve will be a cycle of length three in G^{++-}. A graph is bipartite if and only if it does not contain odd cycle, therefore, G^{++-} is non-bipartite graph and therefore non-laceable. By the definition of G^{++-}, G and its line graph (G) are subgraphs, since G is laceble therefore, G^{++-} is

$E(G^{++-}) - E(G)$ edge fault tolerant graph. That is, $m(n-2) - m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edge fault tolerant graph G^{++-} is Hamiltonian laceable.

Conversely, assume that G^{++-} is Hamiltonian laceable and G is non-laceable graph. Then G^{++-} does not contain any odd cycle, since by the definition and structural analysis it is easy to observe that C_3 is a subgraph of G^{++-}, a contradiction to our assumption. □

Example 2. The shadow graph is an edge-fault-tolerant t^*-laceable. Therefore, consider the shadow graph of $B(C_4)$ and its total transformation graph B^{++-} is also an edge-fault-tolerant t^*-laceable due to the fact that $B(G)$ is a subgraph of B^{++-}.

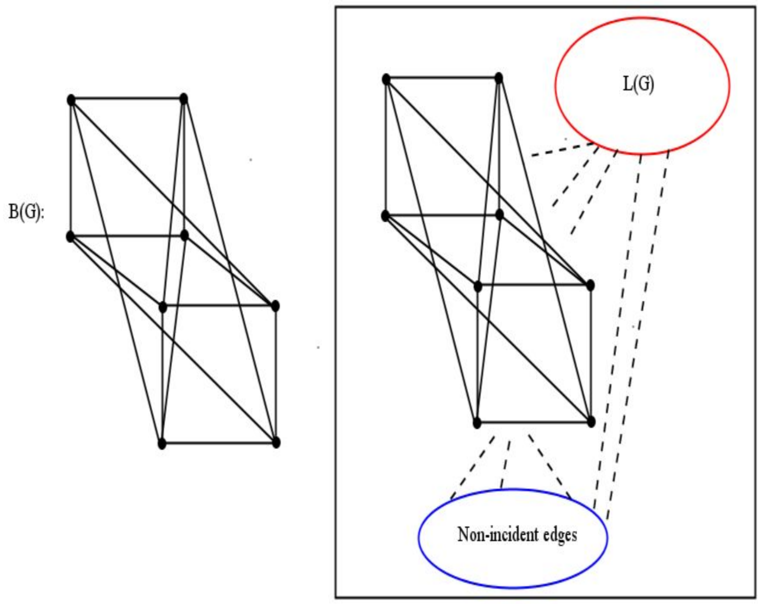

Figure 3. The shadow graph of C_4 and its total transformation graph G^{++-}.

Theorem 2.3 *For $n \geq 2$, the $2m + \overline{q}_l$ edge fault tolerant graph G^{+-+} is Hamiltonian laceable if and only if G is laceable, where $\overline{q}_l$ the number of edges in $\overline{L(G)}$.*

Proof: Let G be a laceable graph of order n and size m such that $V(G) = \{v_1, v_2, v_3, \cdots, v_n\}$ and $E(G) = \{e_1, e_2, e_3, \cdots, e_m\}$. Then by the definition of G^{+-+} we have $E(G^{+-+}) = E(G) \cup E(\overline{L(G)}) \cup 2E(G)$, $|V(G^{+-+})| = m + n$ $|E(G^{+-+})| = m = \frac{1}{2}[m(m+7) - \sum_{i=1}^{n} d_G(v_i)^2]$. Since G is laceable, we need to show that G^{+-+} is laceable after removal of $2m + \overline{q}_l$ edges from $E(G^{+-+})$. It is easy to observe that for every edge $e = uv \in G$, uve will be a cycle of length three in G^{+-+}. A graph is bipartite if and only if it does not contain odd cycle, therefore, G^{+-+} is non-bipartite graph and therefore non-laceable. By the definition of G^{+-+}, G and its line graph (G) are subgraphs, since G is laceble therefore, G^{+-+} is $E(G^{+-+}) - E(G)$ edge fault tolerant graph. That is, $2m + \overline{q}_l$ edge fault tolerant graph G^{+-+} is Hamiltonian laceable.

Conversely, assume that G^{+-+} is Hamiltonian laceable and G is non-laceable graph. Then G^{+-+} does not contain any odd cycle, since by the definition and structural analysis it is easy to observe that C_3 is a subgraph of G^{+-+}, a contradiction to our assumption. □

Example 3. The shadow graph is an edge-fault-tolerant t^*-laceable. Therefore, consider the shadow graph of $B(C_4)$ and its total transformation graph B^{+-+} is also an edge-fault-tolerant t^*-laceable due to the fact that $B(G)$ is a subgraph of B^{++-}.

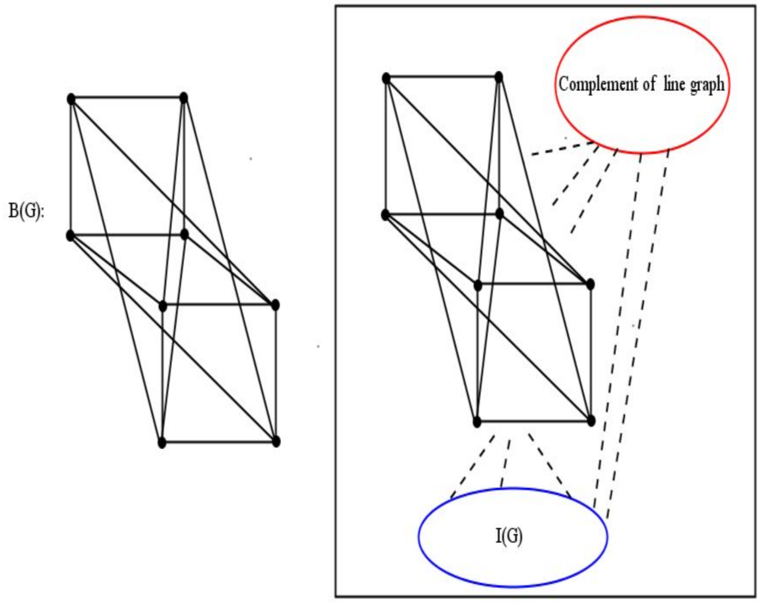

Figure 4. The shadow graph of C_4 and its total transformation graph G^{+-+}.

Theorem 2.4 *For $n \geq 2$, the $2m(n-2)+\overline{q}_l$ edge fault tolerant graph G^{+--} is Hamiltonian laceable if and only if G is laceable, where $\overline{q}_l$ the number of edges in $\overline{L(G)}$.*

Proof: Let G be a laceable graph of order n and size m such that $V(G) = \{v_1, v_2, v_3, \cdots, v_n\}$ and $E(G) = \{e_1, e_2, e_3, \cdots, e_m\}$. Then by the definition of G^{+--} we have $E(G^{+--}) = E(G) \cup E(\overline{L(G)}) \cup (n-2) \cdot E(G)$, $|V(G^{+--})| = m+n$, $|E(G^{+--})| = m = \frac{1}{2}[m(m+2n-1) - \sum_{i=1}^{n} d_G(v_i)^2]$. Since G is laceable, we need to show that G^{+--} is laceable after removal of $2m(n-2)+\overline{q}_l$ edges from $E(G^{+--})$. It is easy to observe that for every edge $e = uv \in G$, uve will be a cycle of length three in G^{+--}. A graph is bipartite if and only if it does not contain odd cycle, therefore, G^{+--} is non-bipartite graph and therefore non-laceable. By the definition of G^{+--}, G and its line graph (G) are subgraphs, since G is laceble therefore, G^{+--} is $E(G^{+--}) - E(G)$ edge fault tolerant graph. That is, $2m(n-2)+\overline{q}_l$ edge fault tolerant graph G^{+--} is Hamiltonian laceable.

Conversely, assume that G^{+--} is Hamiltonian laceable and G is non-laceable graph. Then G^{+--} does not contain any odd cycle, since by the definition and structural analysis it is easy to observe that C_3 is a subgraph of G^{+--}, a contradiction to our assumption. □

Example 4. The shadow graph is an edge-fault-tolerant t^*-laceable. Therefore, consider the shadow graph of $B(C_4)$ and its total transformation graph B^{+--} is also an edge-fault-tolerant t^*-laceable due to the fact that $B(G)$ is a subgraph of B^{+--}.

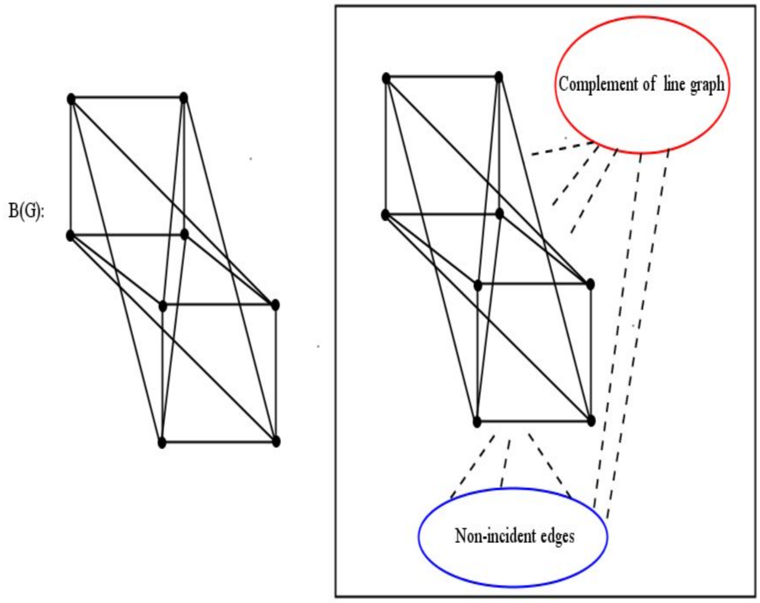

Figure 5. The shadow graph of C_4 and its total transformation graph G^{+--}.

Theorem 2.5 *For $n \geq 2$, the $m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edge fault tolerant graph G^{-++} is Hamiltonian laceable if and only if $\overline{G}$ is laceable.*

Proof: Let G be a laceable graph of order n and size m such that $V(G) = \{v_1, v_2, v_3, \cdots, v_n\}$ and $E(G) = \{e_1, e_2, e_3, \cdots, e_m\}$. Then by the definition of G^{-++} we have $E(G^{--+}) = E(\overline{G}) \cup E(\overline{L(G)}) \cup 2E(G)$, $|V(G^{-++})| = m + n$, $|E(G^{-++})| = m = \frac{1}{2}[n(n-1) + \sum_{i=1}^{n} d_G(v_i)^2]$. Since G is laceable, we need to show that G^{-++} is laceable after removal of $m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edges from $E(G^{-++})$. It is easy to observe that for every edge $e = uv \in G$, uve will be a cycle of length three in G^{-++}. A graph is bipartite if and only if it does not contain odd cycle, therefore, G^{-++} is non-bipartite graph and therefore non-laceable. By the definition of G^{-++}, G and its line graph (G) are subgraphs, since G is laceble therefore, G^{-++} is $E(G^{-++}) - E(G)$ edge fault tolerant graph. That is, $m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edge fault tolerant graph G^{-++} is Hamiltonian laceable.

Conversely, assume that G^{-++} is Hamiltonian laceable and G is non-laceable graph. Then G^{-++} does not contain any odd cycle, since by the definition and structural analysis it is easy to observe that C_3 is a subgraph of G^{-++}, a contradiction to our assumption. □

Example 5. The shadow graph is an edge-fault-tolerant t^*-laceable. Therefore, consider the complement of the shadow graph of $\overline{B(C_4)}$ and its total transformation graph B^{-++} is also an edge-fault-tolerant t^*-laceable due to the fact that $\overline{B(G)}$ is a subgraph of B^{-++}.

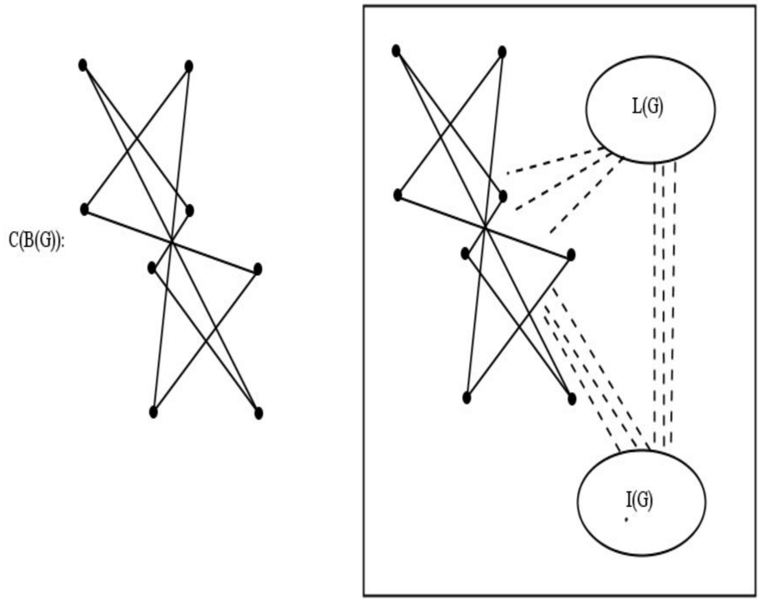

Figure 6. The complement of shadow graph of C_4 and its total transformation graph G^{-++}.

Theorem 2.6 *For $n \geq 2$, the $2m(n-2)+\overline{q}_l$ edge fault tolerant graph G^{--+} is Hamiltonian laceable if and only if $\overline{G}$ is laceable, where $\overline{q}_l$ the number of edges in $\overline{L(G)}$.*

Proof: Let G be a laceable graph of order n and size m such that $V(G) = \{v_1, v_2, v_3, \cdots, v_n\}$ and $E(G) = \{e_1, e_2, e_3, \cdots, e_m\}$. Then by the definition of G^{--+} we have $E(G^{--+}) = E(\overline{G}) \cup E(\overline{L(G)}) \cup 2E(G)$, $|V(G^{--+})| = m+n$, $|E(G^{--+})| = m = \frac{1}{2}[m(m+n)+n(n+1)-\sum_{i=1}^{n} d_G(v_i)^2]$. Since G is laceable, we need to show that G^{--+} is laceable after removal of $2m(n-2)+\overline{q}_l$ edges from $E(G^{--+})$. It is easy to observe that for every edge $e = uv \in G$, uve will be a cycle of length three in G^{--+}. A graph is bipartite if and only if it does not contain odd cycle, therefore, G^{--+} is non-bipartite graph and therefore non-laceable. By the definition of G^{--+}, G and its line graph (G) are subgraphs, since G is laceble therefore, G^{--+} is $E(G^{--+}) - E(G)$ edge fault tolerant graph. That is, $2m(n-2)+\overline{q}_l$ edge fault tolerant graph G^{--+} is Hamiltonian laceable.

Conversely, assume that G^{--+} is Hamiltonian laceable and G is non-laceable graph. Then G^{--+} does not contain any odd cycle, since by the definition and structural analysis it is easy to observe that C_3 is a subgraph of G^{--+}, a contradiction to our assumption. □

Example 6. The shadow graph is an edge-fault-tolerant t^*-laceable. Therefore, consider the complement of the shadow graph of $\overline{B(C_4)}$ and its total transformation graph B^{--+} is also an edge-fault-tolerant t^*-laceable due to the fact that $\overline{B(G)}$ is a subgraph of B^{--+}.

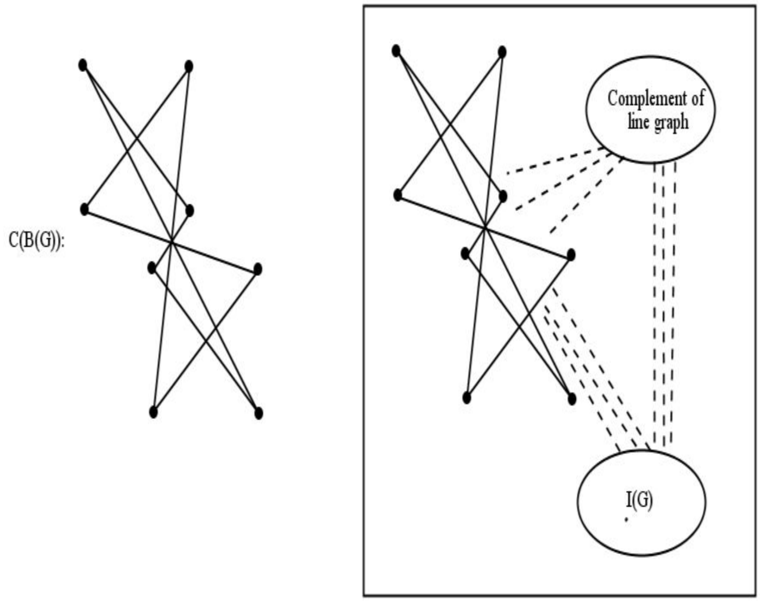

Figure 7. The complement of shadow graph of C_4 and its total transformation graph G^{--+}.

Theorem 2.7 *For $n \geq 2$, the $2m(n-2) - m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edge fault tolerant graph G^{-+-} is Hamiltonian laceable if and only if $\overline{G}$ is laceable.*

Proof: Let G be a laceable graph of order n and size m such that $V(G) = \{v_1, v_2, v_3, \cdots, v_n\}$ and $E(G) = \{e_1, e_2, e_3, \cdots, e_m\}$. Then by the definition of G^{-+-} we have $E(G^{-+-}) = E(\overline{G}) \cup E(L(G)) \cup (n-2) \cdot E(G)$, $|V(G^{-+-})| = m+n$, $|E(G^{-+-})| = m = \frac{1}{2}[n(m+n-1) + m(n-8) + \sum_{i=1}^{n} d_G(v_i)^2]$. Since G is laceable, we need to show that G^{-+-} is laceable after removal of $2m(n-2) - m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edges from $E(G^{-+-})$. It is easy to observe that for every edge $e = uv \in G$, uve will be a cycle of length three in G^{-+-}. A graph is bipartite if and only if it does not contain odd cycle, therefore, G^{-+-} is non-bipartite graph and therefore non-laceable. By the definition of G^{-+-}, G and its line graph (G) are subgraphs, since G is laceble therefore, G^{-+-} is $E(G^{-+-}) - E(G)$ edge fault tolerant graph. That is, $2m(n-2) - m + \frac{\sum_{i=1}^{n} d_G(v_i)^2}{2}$ edge fault tolerant graph G^{-+-} is Hamiltonian laceable.

Conversely, assume that G^{-+-} is Hamiltonian laceable and G is non-laceable graph. Then G^{-+-} does not contain any odd cycle, since by the definition and structural analysis it is easy to observe that C_3 is a subgraph of G^{-+-}, a contradiction to our assumption. □

Example 7. The shadow graph is an edge-fault-tolerant t^*-laceable. Therefore, consider the complement of the shadow graph of $\overline{B(C_4)}$ and its total transformation graph B^{-+-} is also an edge-fault-tolerant t^*-laceable due to the fact that $\overline{B(G)}$ is a subgraph of B^{-+-}.

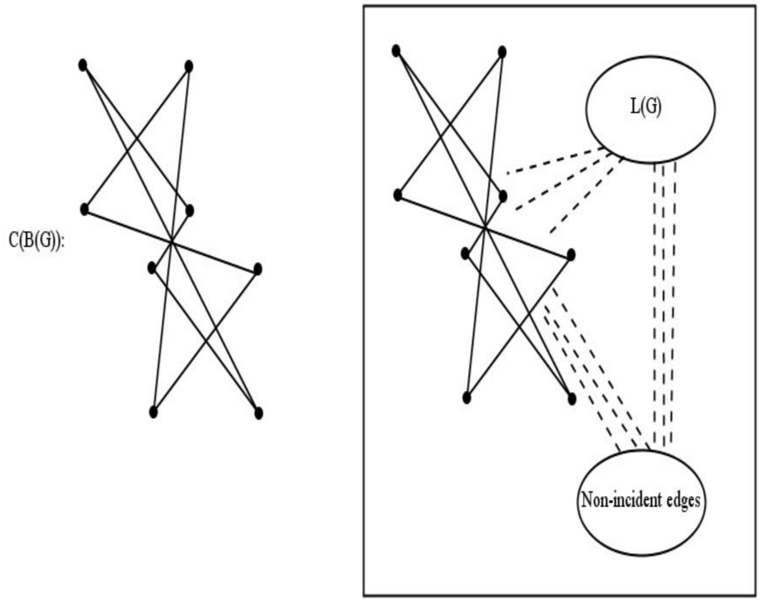

Figure 7. The complement of shadow graph of C_4 and its total transformation graph G^{-+-}.

Theorem 2.8 *For $n \geq 2$, the $2m(n-2)+\overline{q}_l$edge fault tolerant graph G^{---} is Hamiltonian laceable if and only if $\overline{G}$ is laceable, where $\overline{q}_l$ the number of edges in $\overline{L(G)}$.*

Proof: Let G be a laceable graph of order n and size m such that $V(G) = \{v_1, v_2, v_3, \cdots, v_n\}$ and $E(G) = \{e_1, e_2, e_3, \cdots, e_m\}$. Then by the definition of G^{---} we have $E(G^{---}) = E(\overline{G}) \cup E(\overline{L(G)}) \cup (n-2) \cdot E(G)$, $|V(G^{---})| = m+n$, $|E(G^{---})| = m = \frac{1}{2}[(m+n-1)(m+n) - 4m - \sum_{i=1}^{n} d_G(v_i)^2]$. Since G is laceable, we need to show that G^{---} is laceable after removal of $2m(n-2)+\overline{q}_l$ edges from $E(G^{---})$. It is easy to observe that for every edge $e = uv \in G$, uve will be a cycle of length three in G^{---}. A graph is bipartite if and only if it does not contain odd cycle, therefore, G^{---} is non-bipartite graph and therefore non-laceable. By the definition of G^{---}, G and its line graph (G) are subgraphs, since G is laceble therefore, G^{---} is $E(G^{---}) - E(G)$ edge fault tolerant graph. That is, $2m(n-2)+\overline{q}_l$ edge fault tolerant graph G^{---} is Hamiltonian laceable.

Conversely, assume that G^{---} is Hamiltonian laceable and G is non-laceable graph. Then G^{---} does not contain any odd cycle, since by the definition and structural analysis it is easy to observe that C_3 is a subgraph of G^{---}, a contradiction to our assumption. □

Example 8. The shadow graph is an edge-fault-tolerant t^*-laceable. Therefore, consider the complement of the shadow graph of $\overline{B(C_4)}$ and its total transformation graph B^{---} is also an edge-fault-tolerant t^*-laceable due to the fact that $\overline{B(G)}$ is a subgraph of B^{---}.

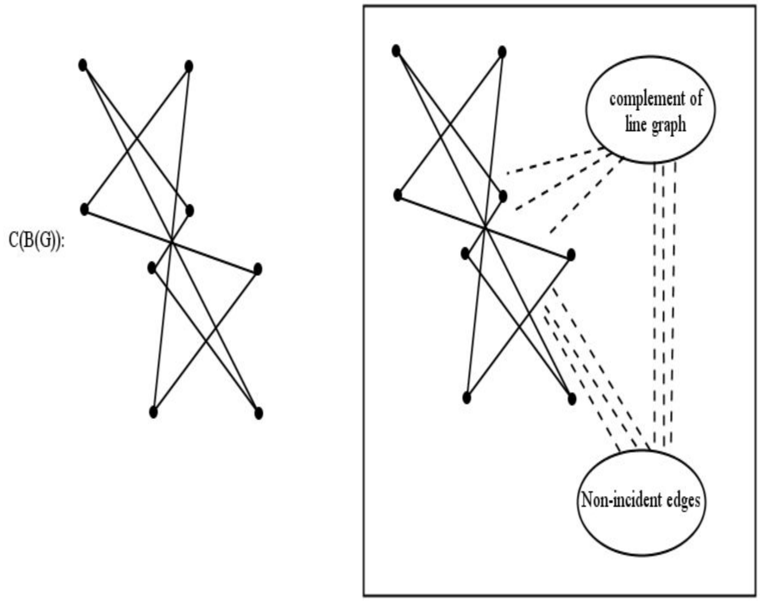

Figure 8. The complement of shadow graph of C_4 and its total transformation graph G^{---}.

References

1. Abraham, S. and Padmanabhan, K., *The twisted cube topology for multiprocessors: a study in network asymmetry*, Journal of Parallel and Distributed Computing 13, 104-110, (1991).
2. Bondy, J. A. and Murty, U. S. R., *Graph theory with applications*, North Holland, New York, (1980).
3. Chan, M. Y. and Lee, S. J., *On the existence of hamiltonian circuits in faulty hypercubes*, SIAM Journal on Discrete Mathematics 4, 511-527, (1991).
4. Chang, C. H., Lin, C. K., Huang, H. M. and Hsu, L. H., *The super laceability of the hypercube*, Information Processing Letters 92, 15-21, (2004).
5. Chen, Y. C., Tan, J. J. M., Hsu, L. H. and Kao, S. S., *Super-connectivity and super-edge-connectivity for some interconnection networks*, Applied Mathematics and Computation 140, 245-254, (2003).
6. Chen, Y. C., Tsai, C. H., Hsu, L. H. and Tan, J. J. M., *On some super fault-tolerant hamiltonian graphs*, Applied Mathematics and Computation 148, 729-741, (2004).
7. Cull, P. and Larson, S. M., *The Möbius cubes*, IEEE Transactions on Computers 44, 647-659, (1995).
8. Efe, K., *A variation on the hypercube with lower diameter*, IEEE Transactions on Computers 40, 1312-1316, (1991).
9. Efe, K., *The crossed cube architecture for parallel computing*, IEEE Transactions on Parallel and Distributed Systems 3, 513-524, (1992).
10. Hsieh, S. Y., Chen, G. H. and Ho, C. W., *Fault-free hamiltonian cycles in faulty arrangement graphs*, IEEE Transactions on Parallel and Distributed Systems 10, 223-237, (1999).
11. Hsieh, S. Y. and Chen, C. H., *Pancyclicity on Mobius cubes with maximal edge faults*, Parallel Computing 30, 407-421, (2004).
12. Latifi, S., Zheng, S. Q. and Bagherzadeh, N., *Optimal ring embedding in hypercubes with faulty links*, Proceedings of the IEEE Symposium on Fault-Tolerant Computing, 178-184, (1992).
13. Leighton, F. T., *Introduction to parallel algorithms and architectures: arrays • trees • hypercubes*, Morgan Kaufmann, CA, San Mateo, (1992).
14. Li, T. K., Tan, J. J. M. and Hsu, L. H., *Hyper hamiltonian laceability on the edge fault star graph*, Information Sciences 165, 59-71, (2004).
15. Park, C. D. and Chwa, K. Y., *Hamiltonian properties on the class of hypercube-like networks*, Information Processing Letters 91, 11-17, (2004).
16. Tsai, C. H., *Linear array and ring embeddings in conditional faulty hypercubes*, Theoretical Computer Science 314, 431-443, (2004).
17. Tsai, C. H., Chang, S. H. and Sheu, J. P., *Fault-free ring embedding in a star graph with both link and node failure*, IEEE Transactions on Parallel and Distributed Systems 8, 1185-1195, (1997).

18. Vaidya, A. S., Rao, P. S. N. and Shankar, S. R., *A class of hypercube-like networks*, Proceedings of the Fifth IEEE Symposium on Parallel and Distributed Processing, 800-803, (1993).

19. Xu, J. M., Du, Z. Z. and Xu, M., *Edge-fault-tolerant edge-bipancyclicity of hypercubes*, Information Processing Letters 96, 146-150, (2005).

20. Xu, J. M., Xu, M. J. and Du, Z. Z., *Edge-fault-tolerant properties of hypercubes and folded hypercubes*, Australasian Journal of Combinatorics 35, 7-16, (2006).

21. Chang, J. M., Chen, W. E. and Miao, J. J., *Panconnectivity, fault-tolerant Hamiltonicity and Hamiltonian-connectivity in alternating group graphs*, Theoretical Computer Science 407, 66-77, (2008).

22. Alspach, B., Chen, C. C. and McAvaney, K., *On a class of Hamiltonian laceable 3-regular graphs*, Discrete Mathematics 151, 19-38, (1996).

23. Anitha, R. and Lekshmi, R. S., *N-Sun Decomposition of Complete, Complete Bipartite and Some Harary Graphs*, International Journal of Mathematical Sciences 2, 33-38, (2008).

24. Balakrishnan, R. and Ranganathan, K., *A Textbook of Graph Theory*, Universitext, Springer New York, (2012).

25. Harary, F., *Graph Theory*, Addison-Wesley series, USA, (1969).

26. Gomathi, P. and Murali, R., *Laceability properties in edge tolerant shawdow graphs*, Bulletin of International Mathematical Virtual Institute 9, 463-474, (2019).

27. Thimmaraju, S. N. and Murali, R., *Hamiltonian-n^*-laceable graphs*, Journal of Intelligent System Research 3, 17-35, (2009).

28. Wu, B. and Meng, J., *Basic properties of total transformation graphs*, Journal of Mathematical Study 34, 109-116, (2001).

29. Xu, L. and Wu, B., *Transformation graph G^{-+-}*, Discrete Mathematics 308, 5144-5148, (2008).

Nagarathnamma K. G.,
Department of Mathematics,
Bapuji Institute of Engineering and Technology, Davanagere -577 004
India.
and
Research Scholar
Visveswaraya Technological University, Belagavi-590018
E-mail address: nagarathnammakg777@gmail.com

and

Leena N. Shenoy,
Department of Mathematics,
B.N.M. Institute of Technology, Bengaluru-560070
India.
and
Visveswaraya Technological University, Belagavi-590018
E-mail address: leenanshenoy@bnmit.in