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Support Strongly Edge Irregular FSGs

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Abstract: The discussions on support strongly edge irregular fuzzy soft graph(FSG), support strongly totally edge irregular FSG is made. Necessary condition for a FSG to be both support strongly and support strongly totally edge irregular is given. We also derive the conditions, the FSG satisfies, if it is support strongly and support strongly totally edge irregular.

Key Words: Support edge of FSG, support edge strongly irregular FSG, support edge irregular FSG, support edge totally strongly irregular FSG.

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§1. Introduction

The soft set theory expanded by Molodtstov dealt with uncertainity and unclear objects, and the notion of soft set theory was given by him in 1999 [8]. Maji.et al [7] evolved a new set with soft sets and fuzzy which proved much effective and defined basic operations on them with some applications to it. Akram and Nawaz looked into properties of fuzzy soft graphs [9]. Santhi and Sekar discussed edge irregular fuzzy graphs in [6]. They also worked on strongly edge irregular fuzzy graphs in [5]. Akilandeswari introduced and discussed properties of edge degree in a fuzzy soft graph and edge regular FSG [11]. Somasundari introduced support of a vertex in FSG [13] and discussed support neighbourly irregular FSG. Subha Lakshmi and Santhi Maheswari dealt with support strongly irregular FSG [17]. The support and total support of edge in FSG was introduced by Subha Lakshmi and NRS [18] and some properties of neighbourly edge irregular FSG was also discussed. These promoted the idea to develop support-SEI and support- STEI FSGs.

§2. Preliminaries

Definition 2.1 *A fuzzy graph G is a nonempty set V with functions $\sigma : V \to [0,1]$ and*

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$\mu : V \times V \to [0,1]$*:* $\forall\ u, v \in V$*,* $\mu(uv) \le \sigma(u) \wedge \sigma(v)$*, where* σ *is fuzzy vertex set and* μ *is fuzzy edge set in* G*.*

Definition 2.2 *A pair* (F, A) *is soft set over the universal set* U*, where* $A \subseteq E$ *and* $F : a \to \mathscr{P}(U)$*. That is a soft set over* U *is parameterized collection of subsets of* U*.*

Definition 2.3 *An FSG* $\widetilde{G} = (\mathscr{G}^*, \mathscr{F}, \mathscr{K}, \mathscr{A})$ *is a 4-tuple:*

(1) $\mathscr{G}^*$ *is crisp graph;*
(2) $\mathscr{A}$ *is the parameter set;*
(3) $\widetilde{\mathscr{F}}, \mathscr{A}$ *is fuzzy soft set over vertex set V;*
(4) $\widetilde{\mathscr{K}}, \mathscr{A}$ *is fuzzy soft set over edge set E.*
The pair $\left(\widetilde{\mathscr{F}}(a), \widetilde{\mathscr{K}}(a)\right)$ *is fuzzy (sub)graph of* $\mathscr{G}^*, \forall\ a \in \mathscr{A}$*.*

The membership value of the edge in an FSG is given as

$$\widetilde{\mathscr{K}}(a)(xy) \le \min\left\{\widetilde{\mathscr{F}}(a)(x), \widetilde{\mathscr{F}}(a)(y)\right\}$$

and a FSG $\left(\widetilde{\mathscr{F}}(a), \widetilde{\mathscr{K}}(a)\right)$ is denoted as $\widetilde{\mathscr{H}}(a)$.

Definition 2.4 *If* $\widetilde{G}$ *is an FSG, then the degree of a vertex u is given as*

$$d_{\widetilde{G}}(u) = \sum_{a_i \in A}(\sum_{u \neq v} \widetilde{\mathscr{K}}(a_i)(uv)).$$

Definition 2.5 *If* $\widetilde{G}$ *is an FSG, then degree of edge uv is given as*

$$d_{\widetilde{G}}(uv) = d_{\widetilde{G}}(u) + d_{\widetilde{G}}(v) - 2(\sum_{a_i \in A} \widetilde{\mathscr{K}_{a_i}}(uv)).$$

Definition 2.6 *If* $\widetilde{G}$ *is an FSG, then total degree of edge uv is given as*

$$td_{\widetilde{G}}(uv) = d_{\widetilde{G}}(uv) + \sum_{a_i \in A} \widetilde{\mathscr{K}_{a_i}}(uv).$$

Certainly, it can be also expressed as

$$td_{\widetilde{G}}(uv) = d_{\widetilde{G}}(u) + d_{\widetilde{G}}(v) - \left(\sum_{a_i \in A} \widetilde{\mathscr{K}_{a_i}}(uv)\right).$$

Definition 2.7 *An FSG* $\widetilde{G}$ *is irregular if* $\widetilde{\mathscr{H}}(e)$ *is irregular for all* $a \in \mathscr{A}$*.*

Definition 2.8 *The support* $(2 - degree)$ *of a vertex u in an FSG* $\widetilde{G}$ *is the addition of degrees of its adjacent vertices and denoted as* $s_{\widetilde{G}}(u)$*, whereas its total support is given as*

$$ts_{\widetilde{G}}(u) = s_{\widetilde{G}}(u) + \sum_{a_i \in A} \widetilde{\mathscr{F}}(a_i)(u).$$

Definition 2.9 *The support* $(2-degree)$ *of an edge in a FSG is the sum of edge degrees of edges which are adjacent to given edge and can be defined as*

$$s_{\widetilde{G}}(uv) = \sum_{e_i \in N(uv), a_i \in A} \widetilde{\mathscr{K}}(a_i)(uv).$$

Definition 2.10 *The total support of an edge in an FSG is found as*

$$ts_{\widetilde{G}}(uv) = s_{\widetilde{G}}(uv) + \sum_{a_i \in A} \mathscr{K}(a_i)(uv).$$

§3. Support Strongly EI (s-SEI) and Support Strongly Totally EI (s-STEI) FSG

Definition 3.1 *A FSG is support-SEI if all the edges in the graph are adjacent to edges with distinct edge supports,i.e., all the edges in the FSG have different edge supports.*

Example 3.2 Consider the below example $\widetilde{G}$, where $V = \{u, v, w, x, y, z\}$ and $E = \{uv, vw, vx, xy, xz\}$, the parameter set $\mathscr{A} = a_1, a_2$, where $a_1 = \{uv, vw, vx, xy\}$ and $a_2 = \{vw, vx, xy, xz\}$, $\widetilde{\mathscr{H}}(a) = (\widetilde{\mathscr{F}}(a), \widetilde{\mathscr{K}}(a))$ be the fuzzy soft subgraph of $\widetilde{G}$.

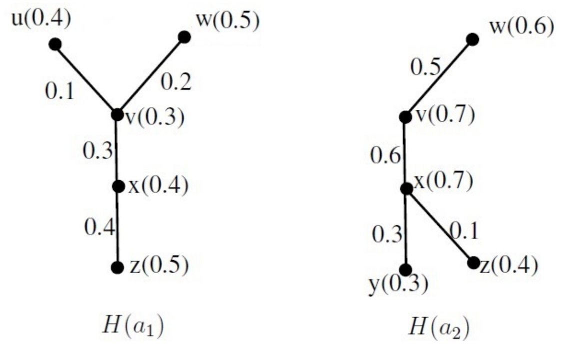

Figure 3.1

$\widetilde{F}$	u	v	w	x	y	z	$\widetilde{K}$	uv	vw	vx	xy	xz
(a_1)	0.4	0.3	0.5	0.4	0	0.5	(a_1)	0.1	0.2	0.3	0	0.4
(a_2)	0	0.7	0.6	0.7	0.3	0.4	(a_2)	0	0.5	0.6	0.3	0.1

Table 3.1

The degree of vertices are respectively given as $d_{\widetilde{G}}(u) = 0.1$, $d_{\widetilde{G}}(v) = 1.7$, $d_{\widetilde{G}}(w) = 0.7$, $d_{\widetilde{G}}(x) = 1.7$, $d_{\widetilde{G}}(y) = 0.3$, $d_{\widetilde{G}}(z) = 0.5$, the degree of the edges are respectively $d_{\widetilde{G}}(uv) = 0.1 + 1.7 - 2(0.1) = 1.6$, $d_{\widetilde{G}}(vw) = 1.0$, $d_{\widetilde{G}}(vx) = 1.6$, $d_{\widetilde{G}}(xy) = 1.4$, $d_{\widetilde{G}}(xz) = 1.2$ and the support of the edges are given as $s_{\widetilde{G}}(uv) = 2.6$, $s_{\widetilde{G}}(vw) = 3.2$, $s_{\widetilde{G}}(vx) = 5.2$, $s_{\widetilde{G}}(xy) = 2.8$, $s_{\widetilde{G}}(xz) = 3.0$. The support of all the edges in the FSG are different, so it is support SEI.

Definition 3.3 *A FSG is support-STEI when no edge in the graph is adjacent to edges with same total edge support. In other words, all the edges in the FSG have different total edge support.*

Example 3.4 Consider the example, with parameters $\mathscr{A} = \{a_1, a_2\}$, where $a_1 = \{uv, vw, wx\}$, $a_2 = \{uv, vw, wx\}$.

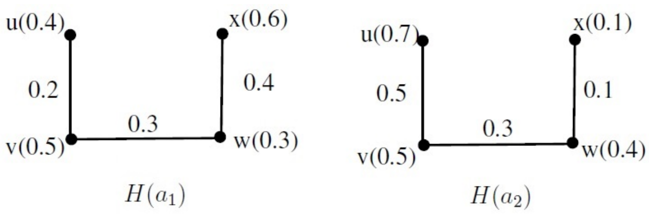

Figure 3.2

$\widetilde{F}$	**u**	**v**	**w**	**x**	$\widetilde{K}$	**uv**	**vw**	**wx**
(a_1)	0.4	0.5	0.3	0.6	(a_1)	0.2	0.3	0.4
(a_2)	0.7	0.5	0.4	0.1	(a_2)	0.5	0.3	0.1

Table 3.2

The degree of vertices and edges are found respectively to be $d_{\widetilde{G}}(u) = 0.7$, $d_{\widetilde{G}}(v) = 1.3$, $d_{\widetilde{G}}(w) = 1.1$, $d_{\widetilde{G}}(x) = 0.5$, $d_{\widetilde{G}}(uv) = 0.6$, $d_{\widetilde{G}}(vw) = 1.2$, $d_{\widetilde{G}}(wx) = 0.6$. And the support of the above edges are $s_{\widetilde{G}}(uv) = 1.2$, $s_{\widetilde{G}}(vw) = 1.2$, $s_{\widetilde{G}}(wx) = 1.2$. Thus, the total support of the above edges $ts_{\widetilde{G}}(uv) = 1.9$, $ts_{\widetilde{G}}(vw) = 1.8$, $ts_{\widetilde{G}}(wx) = 1.7$ are all not same, so it is support-STEI.

Remark 3.5 A support-SEI FSG need not be support-STEI, and vice versa.

Example 3.6 Consider below example, with parameters $\mathscr{A} = \{a_1, a_2, a_3\}$, where $a_1 = \{uv, uw\}$, $a_2 = \{uv, uw\}$, $a_3 = \{uv, uw, vw\}$.

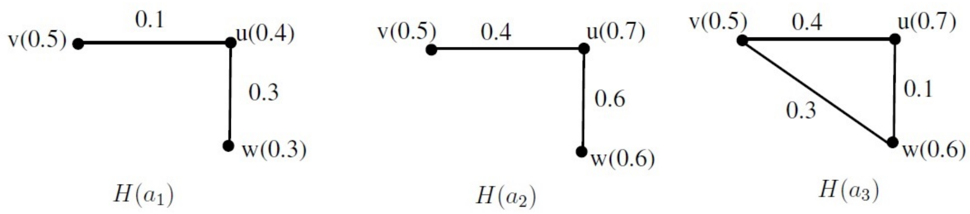

Figure 3.3

$\widetilde{\mathscr{F}}$	**u**	**v**	**w**	$\widetilde{\mathscr{K}}$	**uv**	**vw**	**wu**
(a_1)	0.4	0.5	0.3	(a_1)	0.1	0	0.3
(a_2)	0.7	0.5	0.6	(a_2)	0.4	0	0.6
(a_3)	0.7	0.5	0.6	(a_2)	0.4	0.3	0.1

Table 3.3

The support of the edges are distinct here, and consider the total support of the edges given as $ts_{\widetilde{G}}(uv) = 4.0$, $ts_{\widetilde{G}}(vw) = 4.5$, $ts_{\widetilde{G}}(wu) = 4.5$, where the edges vw and uw have same total edge support, so it is not support-STEI, but support-SEI.

Example 3.7 Consider the example 3.4, which is support-STEI, but not support-SEI.

Example 3.8 Consider the below example which is both support-SEI and support-STEI. The FSG is with the parameters $A = \{a_1, a_2\}$, where $a_1 = \{uv, vw, wu\}$, $a_2 = \{uv, vw, wu\}$.

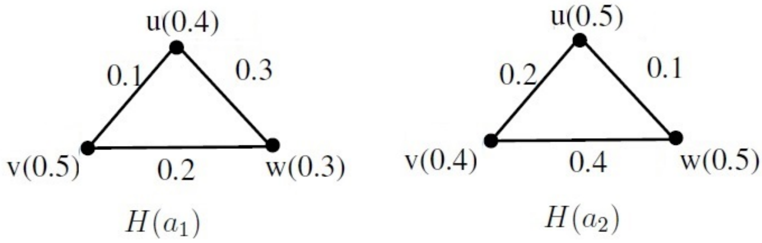

Figure 3.4

$\widetilde{F}$	**u**	**v**	**w**	$\widetilde{K}$	**uv**	**vw**	**wu**
(a_1)	0.4	0.5	0.3	(a_1)	0.1	0.3	0.3
(a_2)	0.5	0.4	0.5	(a_2)	0.2	0.4	0.1

Table 3.4

The degree of vertices are given as $d_{\widetilde{G}}(u) = 0.3 + 0.4 = 0.7$, $d_{\widetilde{G}}(v) = 0.9$, $d_{\widetilde{G}}(w) = 1.0$ and the edge degrees are given as $d_{\widetilde{G}}(uv) = 0.7 + 0.9 - 0.6 = 1.0$, $d_{\widetilde{G}}(vw) = 0.7$, $d_{\widetilde{G}}(uw) = 0.9$. The support of the edges are $s_{\widetilde{G}}(uv) = 1.6$, $s_{\widetilde{G}}(vw) = 1.9$, $s_{\widetilde{G}}(wu) = 1.7$.

The total support of the edges are $ts_{\widetilde{G}}(uv) = 1.9$, $ts_{\widetilde{G}}(vw) = 2.5$, $ts_{\widetilde{G}}(wu) = 2.1$ and they are all different so it is support-STEI.

§4. Properties of Support-SEI and Support-STEI FSGs

Theorem 4.1 *A FSG $\widetilde{G}$, is support-SEI, if its fuzzy soft (sub)graph $\widetilde{H}(a) = (\widetilde{F}(a), \widetilde{K}(a))$ is support-SEI, for all $a \in A$.*

Remark 4.2 The converse of Theorem 4.1, namely if G, is support-SEI, then its fuzzy subgraphs need not be s-SEI.

Example 4.3 Examine Example 3.2, which is support-SEI, while taking $\widetilde{H}(a_1)$, the support of the edges are $s_{\widetilde{H}(a_1)}(uv) = 2.2$, $s_{\widetilde{H}(a_1)}(vw) = 2.8$, $s_{\widetilde{H}(a_1)}(vx) = 4.8$, $s_{\widetilde{H}(a_1)}(xy) = 2.4$, $s_{\widetilde{H}(a_1)}(xz) = 2.2$ are all not distinct, so $H(a_1)$ is not support-SEI.

Theorem 4.4 *A FSG $\widetilde{G}$, is support-STEI, if its fuzzy soft (sub)graphs $\widetilde{H}(a) = (\widetilde{F}(a), \widetilde{K}(a))$ is support-STEI, for all $a \in A$.*

Remark 4.5 The converse need not be true.

Example 4.6 Given a FSG as below.

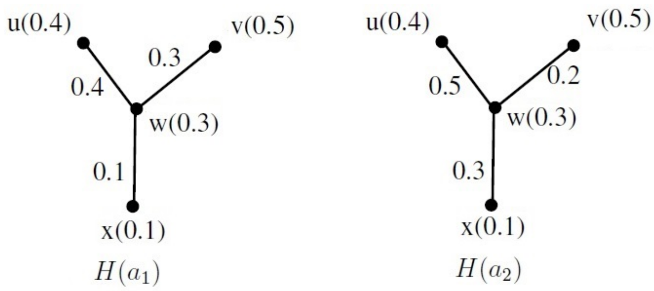

Figure 4.1

This FSG is support-STEI, but while considering $\widetilde{H}(a_1)$, the total support of the edges vw and vx are same, so it is not support-STEI.

Theorem 4.7 *If $\widetilde{G}$ is support-SEI FSG, then it is support-EI.*

Proof Given the FSG $\widetilde{G}$ is support-SEI, $\Rightarrow$ the support of all the edges in the graph are distinct, $\Rightarrow$ there exist at least one edge with edge support different from others, thus it is support-EI FSG. □

Theorem 4.8 *If $\widetilde{G}$ is support-STEI FSG, then it is support-TEI.*

Proof Given the FSG $\widetilde{G}$ is support-STEI, $\Rightarrow$ the total support of all the edges in the graph are distinct, $\Rightarrow$ there exist atleast one edge with total edge support different from others, thus it is support-TEI FSG. □

Remark 4.9 It is not necessary for a FSG, which is support-EI, to be support-SEI.

Remark 4.10 It is not necessary for a FSG, which is support-TEI, to be support-STEI.

Theorem 4.11 *If $\widetilde{G}$ is support-SEI FSG, then it is support edge neighbourly irregular.*

Proof Consider the given FSG, $\widetilde{G}$ is support-SEI. Then the support of all the edges are different, $\Rightarrow$ no two adjacent edges in $\widetilde{G}$ have same edge support. Therefore, it is support NEI FSG. □

Theorem 4.12 *If $\widetilde{G}$ is support-STEI FSG, then it is support edge totally neighbourly irregular.*

Proof Consider the given FSG, $\widetilde{G}$ is support-STEI. Then the total support of all the edges are distinct, $\Rightarrow$ no two adjacent edges in $\widetilde{G}$ have same total edge support. Therefore, it is support edge totally neighbourly irregular FSG. □

Remark 4.13 A support edge neighbourly EI FSG, not necesaarily be support-SEI.

Remark 4.14 A support edge totally neighbourly irregular FSG, not necesaarily be support-STEI.

Example 4.15 Consider the below example with parameters $A = \{a_1, a_2\}$, where a_1 =

$\{uv, vw, vx\}$, $a_2 = \{vw, vx, xy, xz\}$.

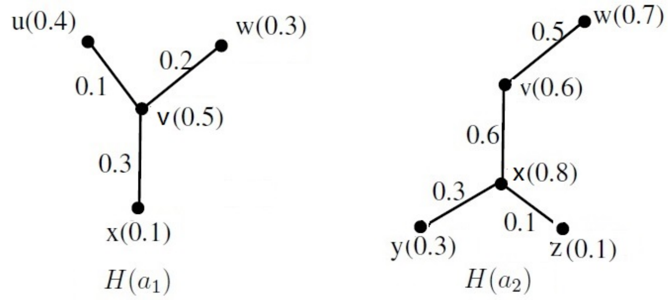

Figure 4.2

The support of the edges are given as $s_G(uv) = 2.2$, $s_G(vw) = 2.8$, $s_G(vx) = 4.8$, $s_G(xy) = 2.4$, $s_G(xz) = 2.2$. Whereas the total support of the edges are $ts_G(uv) = 2.3$, $ts_G(vw) = 3.5$, $ts_G(vx) = 5.7$, $ts_G(xy) = 2.7$, $ts_G(xz) = 2.3$. The given example is support edge NI, and support edge totally NI, but not support-SEI and support-STEI.

Theorem 4.16 *A FSG, whose edges have same support, then it is support-STEI iff* $\sum \widetilde{\mathscr{K}}(a)(e_i)$ *are all different,* $\forall a_i \in A$ *and* $e_i \in E$.

Proof Suppose $\widetilde{G}$, a FSG in which the support of all the edges are same, let that be $s_{\widetilde{G}}(e_i) = m$, for all $e_i \in E$. Given $\widetilde{G}$, is support-STEI, $\Rightarrow$ all the edges have different total edge support. $\Rightarrow$ no edges which are adjacent have same total edge support. Let e_j and e_{j+1} be adjacent edges, $\Rightarrow ts_{\widetilde{G}}(e_j) \neq ts_{\widetilde{G}}(e_{j+1})$.

And so,

$$\Rightarrow s_{\widetilde{G}}(e_j) + \sum \widetilde{K}(a_i)(e_j) \neq s_{\widetilde{G}}(e_{j+1}) + \sum \widetilde{K}(a_i)(e_{j+1})$$

$$\Rightarrow m + \sum \widetilde{K}(a_i)(e_j) \neq m + \sum \widetilde{K}(a_i)(e_{j+1}).$$

This implies

$$\sum \widetilde{K}(a_i)(e_j) \neq \sum \widetilde{K}(a_i)(e_{j+1}),$$

this holds for all the edges in $\widetilde{G}$.

Conversely assume $\sum \widetilde{K}(a_i)(e_i)$ are all distinct $\forall e_i \in E$. Suppose $\widetilde{G}$ is not support-STEI, $\Rightarrow$ there is at least a pair of edges with same total edge support. Let e_n and e_{n+1} be such edges, then

$$ts_{\widetilde{G}}(e_n) = ts_{\widetilde{G}}(e_{n+1}) \Rightarrow s_{\widetilde{G}}(e_n) + \sum \widetilde{K}(a_i)(e_n) = s_{\widetilde{G}}(e_n) + \sum \widetilde{K}(a_i)(e_{n+1}),$$

implies that

$$m + \sum \widetilde{K}(a_i)(e_n) = m + \sum \widetilde{K}(a_i)(e_{n+1}) \Rightarrow \sum \widetilde{K}(a_i)(e_n) = \sum \widetilde{K}(a_i)(e_{n+1}),$$

which $\Leftrightarrow$, thus $\widetilde{G}$ is support-STEI. □

Theorem 4.17 *A FSG,* $\widetilde{G}$*, in which* $\sum \widetilde{K}(a_i)(e_i)$ *are same for all* $e_i \in E$*, then* $\widetilde{G}$ *is not* *support-EI and support-edge totally irregular FSG.*

Proof Let $\widetilde{G}$ be a FSG, where

$$\sum \widetilde{K}(a_i)(e_i) = k, \quad \forall e_i \in E.$$

Let us consider a path in the graph $uvwx$, such that we have edges uv, vw, wx, where

$$\sum \widetilde{K}(a_i)(uv) = \sum \widetilde{K}(a_i)(vw) = \sum \widetilde{K}(a_i)(wx) = k.$$

The degree of the edges are $d_{\widetilde{G}}(uv) = d_{\widetilde{G}}(vw) = d_{\widetilde{G}}(wx) = k$. Then the support of these edges are $s_{\widetilde{G}}(uv) = s_{\widetilde{G}}(vw) = s_{\widetilde{G}}(wx) = k$, hence it is not support EI, also the total support of the edges are also same, hence not support edge totally irregular also. □

Theorem 4.18 *If a FSG, $\widetilde{G}$ is support-SEI and $\sum \widetilde{K}(a_i)(e_i)$ are different for all edges in E, then the given FSG is support-STEI.*

Proof Given that $\widetilde{G}$ is support-SEI, then no edge in the FSG has same support, i.e., $s_{\widetilde{G}}(e_i)$ are distinct for all $e_i \in E$. Let us consider the edges e_k and e_{k+1} having different edge supports. The support total of these edges are

$$s_{\widetilde{G}}e_k + \sum \widetilde{K}(a_i)(e_k) \text{ and } s_{\widetilde{G}}e_{k+1} + \sum \widetilde{K}(a_i)(e_{k+1}),$$

respectively. It is given that $\sum \widetilde{K}(a_i)(e_i)$ are different for all the edges, so $ts_{\widetilde{G}}e_k \neq ts_{\widetilde{G}}e_{k+1}$, this holds for all pairs of edges in the given FSG. Thus we conclude that $\widetilde{G}$ is support-STEI.□

Theorem 4.19 *A FSG $\widetilde{G}$ is suppport-STEI, and $\sum \widetilde{K}(a_i)(e_i)$ is same for all the edges, then it is support-SEI, when $s_{\widetilde{G}}(e_i)$ are all distinct.*

Proof Given a FSG, $\widetilde{G}$ which is support-STEI. $\Rightarrow ts_{\widetilde{G}}(e_i)$ are different $\forall e_i \in E$. Given that

$$\sum \widetilde{K}(a_i)(e_i) = k, \quad \forall e_i \in E,$$

consider any pair of edges (say) e_n and e_m, then

$$ts_{\widetilde{G}}(e_n) \neq ts_{\widetilde{G}}(e_m) \;\Rightarrow\; s_{\widetilde{G}}(e_n) + \sum \widetilde{K}(a_i)(e_n) \neq s_{\widetilde{G}}(e_m) + \sum \widetilde{K}(a_i)(e_m),$$

$$s_{\widetilde{G}}(e_n) + k \neq s_{\widetilde{G}}(e_m) + k \;\Rightarrow\; s_{\widetilde{G}}(e_n) \neq s_{\widetilde{G}}(e_m).$$

This implies support of any pair of edges are distinct, thus $\widetilde{G}$ is support-SEI. □

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