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SOME MULTIPLICATIVE NEIGHBORHOOD TOPOLOGICAL INDICES OF NANOCONES AND DENDRIMERS

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ABSTRACT

A topological index is a numerical parameter mathematically derived from the graph structure. In this paper, we introduce the modified multiplicative first and second neighborhood indices, multiplicative F-neighborhood index, general multiplicative neighborhood index, multiplicative inverse sum indeg neighborhood index, multiplicative harmonic neighborhood index and multiplicative symmetric division neighborhood index, first and second multiplicative Gourava neighborhood indices of a graph. We compute these newly defined multiplicative neighborhood indices for nanocones and dendrimers.

Keywords: *multiplicative F-neighborhood index, multiplicative harmonic neighborhood index, multiplicative Gourava neighborhood indices, nanocone, dendrimer.*

Mathematics Subject Classification: *05C05, 05C12, 05C90.*

I. INTRODUCTION

A molecular graph is a graph such that its vertices represent to the atoms and the edges to the bonds. Chemical Graph Theory is a branch of Mathematical Chemistry whose focus of interest is finding topological indices of a molecular graph which correlate well with chemical properties of the chemical molecules. Several topological indices have been considered in Theoretical Chemistry and have found some applications, especially in QSPR/QSAR study, see [1, 2, 3].

Let G be a finite, simple, connected graph with vertex set $V(G)$ and edge set $E(G)$. The degree of a vertex u is the number of vertices adjacent to u and it is denoted by $d_G(u)$. Let $N(u) = \{v{:}uv{\in}E(G)\}$. Let $S_G(u) = \sum_{v\in N(u)} d_G(v)$ be the degree sum of neighbor vertices. For undefined term and notation, we refer the book [4].

Recently, some neighborhood indices were introduced and studied such as fifth M_1 and M_2 Zagreb indices [5], fifth hyper M_1 and M_2 Zagreb indices [6], general fifth M-Zagreb indices [6], F-neighborhood index, general first neighborhood index [7], fifth arithmetic-geometric index [8], fifth multiplicative Zagreb indices [9], fifth multiplicative hyper Zagreb indices [10], fifth multiplicative sum and product connectivity indices [10], general fifth multiplicative Zagreb indices [10], fourth multiplicative atom bond connectivity index [11], fifth multiplicative geometric-arithmetic index [9]. Also some neighborhood indices were studied in [12, 13, 14, 15, 16].

The fifth multiplicative M_1 and M_2 Zagreb indices (now we call multiplicative first and second neighborhood indices) were introduced by Kulli in 2017[9], defined as

$$NM_1II(G) = \prod_{uv\in E(G)} \left[S_G(u)+S_G(v)\right], \quad NM_2II(G) = \prod_{uv\in E(G)} S_G(u)S_G(v).$$

The fifth multiplicative hyper Zagreb indices (now we call multiplicative first and second hyper neighborhood indices) were introduced by Kulli in 2018[10], defined as

$$HNM_1II(G) = \prod_{uv\in E(G)} \left[S_G(u)+S_G(v)\right]^2, \qquad HNM_2II(G) = \prod_{uv\in E(G)} \left[S_G(u)S_G(v)\right]^2.$$

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We introduce the modified multiplicative first and second neighborhood indices of a graph G and they are defined as

$$^{m}NM_1II(G)=\prod_{uv\in E(G)}\frac{1}{S_G(u)+S_G(v)}, \quad ^{m}NM_2II(G)=\prod_{uv\in E(G)}\frac{1}{S_G(u)S_G(v)}.$$

The fifth multiplicative sum connectivity index (now we call multiplicative neighborhood sum connectivity index) of a graph was introduced by Kulli in 2018[10], defined it as

$$SNMII(G)=\prod_{uv\in E(G)}\frac{1}{\sqrt{S_G(u)+S_G(v)}}.$$

The fifth multiplicative sum connectivity index (now we call multiplicative neighborhood product connectivity index) of a graph was introduced by Kulli in 2018[10], defined it as

$$PNMII(G)=\prod_{uv\in E(G)}\frac{1}{\sqrt{S_G(u)S_G(v)}}.$$

The general fifth multiplicative Zagreb indices (now we call multiplicative neighborhood sum and product connectivity indices) of a graph were introduced by Kulli in 2018[10], and they are defined as

$$NM_1^aII(G)=\prod_{uv\in E(G)}\left[S_G(u)+S_G(v)\right]^a,$$

$$NM_2^aII(G)=\prod_{uv\in E(G)}\left[S_G(u)S_G(v)\right]^a,$$

where a is a real numbers.

We now introduce the reciprocal multiplicative product connectivity index of a graph G, and it is defined as

$$RPNMII(G)\prod_{uv\in E(G)}\sqrt{S_G(u)S_G(v)}.$$

We introduce some new multiplicative neighborhood indices as follows:

The multiplicative F- neighborhood index of a graph G is defined as

$$FNMII(G)=\prod_{uv\in E(G)}\left[S_G(u)^2+S_G(v)^2\right].$$

The general multiplicative neighborhood index of a graph G is defined as

$$NM^aII(G)=\prod_{uv\in E(G)}\left[S_G(u)^a+S_G(v)^a\right].$$

We introduce the multiplicative inverse sum indeg neighborhood index of a graph G, defined as

$$INMII(G)=\prod_{uv\in E(G)}\frac{S_G(u)S_G(v)}{S_G(u)+S_G(v)}.$$

We propose the multiplicative harmonic neighborhood index of a graph G, defined it as

$$HNMII(G)=\prod_{uv\in E(G)}\frac{2}{S_G(u)+S_G(v)}.$$

We also introduce the multiplicative symmetric division neighborhood index of a graph G, defined as

$$SDNMII(G)=\prod_{uv\in E(G)}\left(\frac{S_G(u)}{S_G(v)}+\frac{S_G(v)}{S_G(u)}\right).$$

We propose first and second multiplicative Gourava neighborhood indices of a graph G, and they are defined as

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$$NGO_1II(G)=\prod_{uv\in E(G)}\left[S_G(u)+S_G(v)+S_G(u)S_G(v)\right],$$

$$NGO_2II(G)=\prod_{uv\in E(G)}\left[S_G(u)+S_G(v)\right]S_G(u)S_G(v).$$

In this study, some new and old neighborhood indices of nanocones and 2 types of dendrimers are computed. For nanocones, dendrimers see 17.

2. RESULTS FOR NANOCONES $C_n[k]$

In this section, we consider nanocones $C_n[k]$. The molecular structure of $C_4[2]$ is shown in Figure 1.

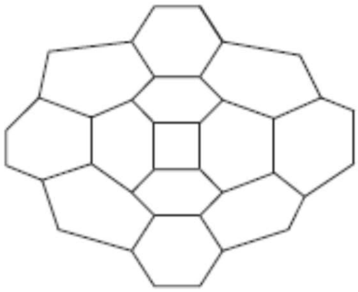

Figure 1. The molecular structure of $C_4[2]$

Let G be the molecular structure of $C_n[k]$. By calculation, G has $n(k+1)^2$ vertices and $\frac{n}{2}(k+1)(3k+2)$ edges. Also by calculation, we obtain that G has five types of edges based on $S_G(u)$ and $S_G(v)$ the degree of end vertices of each edge as given in Table 1.

$S_G(u), S_G(v) \setminus uv \in E(G)$	Number of edges
(5, 5)	n
(5, 7)	$2n$
(6, 7)	$2(k-1)n$
(7, 9)	nk
(9, 9)	$\frac{nk}{2}(3k-1)$

Table 1. Edge partition of $C_n[k]$ based on $S_G(u)$, $S_G(v)$

We compute the multiplicative neighborhood general sum connectivity index of $C_n[k]$.

Theorem 1. The multiplicative neighborhood general sum connectivity index of nanocone $C_n[k]$ is

$$NM_1^aII(C_n[k])=10^{an}\times 12^{2an}\times 13^{2an(k-1)}\times 16^{ank}\times 18^{\frac{ank}{2}(3k-1)}. \quad (1)$$

Proof: Let G be the molecular graph of $C_n[k]$. By using the definition and Table 1, we deduce

$$NM_1^aII(C_n[k])=\prod_{uv\in E(G)}\left[S_G(u)+S_G(v)\right]^a$$

$$=(5+5)^{an}\times(5+7)^{2an}\times(6+7)^{2an(k-1)}\times(7+9)^{ank}\times(9+9)^{\frac{ank}{2}(3k-1)}$$

$$=10^{an}\times 12^{2an}\times 13^{2an(k-1)}\times 16^{ank}\times 18^{\frac{ank}{2}(3k-1)}.$$

The following results are obtained by using Theorem 1.

Corollary 1.1. The multiplicative first neighborhood index of $C_n[k]$ is

$$NM_1II(C_n[k]) = 10^n \times 12^{2n} \times 13^{2n(k-1)} \times 16^{nk} \times 18^{\frac{nk}{2}(3k-1)}.$$

Corollary 1.2. The multiplicative first hyper neighborhood index of $C_n[k]$ is

$$HNM_1II(C_n[k]) = 10^{2n} \times 12^{4n} \times 13^{4n(k-1)} \times 16^{2nk} \times 18^{nk(3k-1)}.$$

Corollary 1.3. The modified multiplicative first neighborhood index of $C_n[k]$ is

$$^{m}NM_1II(C_n[k]) = \left(\frac{1}{10}\right)^n \times \left(\frac{1}{12}\right)^{2n} \times \left(\frac{1}{13}\right)^{2n(k-1)} \times \left(\frac{1}{16}\right)^{nk} \times \left(\frac{1}{18}\right)^{\frac{nk}{2}(3k-1)}.$$

Corollary 1.4. The multiplicative neighborhood sum connectivity index of $C_n[k]$ is

$$SNMII(C_n[k]) = \left(\frac{1}{\sqrt{10}}\right)^n \times \left(\frac{1}{12}\right)^n \times \left(\frac{1}{13}\right)^{n(k-1)} \times \left(\frac{1}{4}\right)^{nk} \times \left(\frac{1}{\sqrt{18}}\right)^{\frac{nk}{2}(3k-1)}.$$

Proof: Put a = 1, 2, –1, –½ in equation (1), we get the desired results.

We determine the multiplicative neighborhood general product connectivity index of $C_n[k]$.

Theorem 2. The multiplicative neighborhood general product connectivity index of nanocone $C_n[k]$ is

$$NM_2^aII(C_n[k]) = 25^{an} \times 35^{2an} \times 42^{2an(k-1)} \times 63^{ank} \times 81^{\frac{ank}{2}(3k-1)}. \quad (2)$$

Proof: By using the definition and Table 1, we derive

$$NM_2^aII(C_n[k]) = \prod_{uv \in E(G)} [S_G(u)S_G(v)]^a$$

$$= (5\times5)^{an} \times (5\times7)^{2an} \times (6\times7)^{2an(k-1)} \times (7\times9)^{ank} \times (9\times9)^{\frac{ank}{2}(3k-1)}.$$

$$= 25^{an} \times 35^{2an} \times 42^{2an(k-1)} \times 63^{ank} \times 81^{\frac{ank}{2}(3k-1)}.$$

We obtain the following results by using Theorem 2.

Corollary 2.1. The multiplicative second neighborhood index of $C_n[k]$ is

$$NM_2II(C_n[k]) = 25^n \times 35^{2n} \times 42^{2n(k-1)} \times 63^{nk} \times 81^{\frac{nk}{2}(3k-1)}.$$

Corollary 2.2. The multiplicative second hyper neighborhood index of $C_n[k]$ is

$$HNM_2II(C_n[k]) = 25^{2n} \times 35^{4n} \times 42^{4n(k-1)} \times 63^{2nk} \times 81^{nk(3k-1)}.$$

Corollary 2.3. The modified multiplicative second neighborhood index of $C_n[k]$ is

$$^{m}NM_2II(C_n[k]) = \left(\frac{1}{25}\right)^n \times \left(\frac{1}{35}\right)^{2n} \times \left(\frac{1}{42}\right)^{2n(k-1)} \times \left(\frac{1}{63}\right)^{nk} \times \left(\frac{1}{81}\right)^{\frac{nk}{2}(3k-1)}.$$

Corollary 2.4. The multiplicative neighborhood product connectivity index of $C_n[k]$ is

$$PNMII(C_n[k]) = \left(\frac{1}{5}\right)^n \times \left(\frac{1}{35}\right)^n \times \left(\frac{1}{42}\right)^{n(k-1)} \times \left(\frac{1}{\sqrt{63}}\right)^{nk} \times \left(\frac{1}{9}\right)^{\frac{nk}{2}(3k-1)}.$$

Corollary 2.5. The reciprocal multiplicative neighborhood product connectivity index of $C_n[k]$ is

$$RPNMII(C_n[k]) = (5)^n \times (35)^n \times (42)^{n(k-1)} \times (\sqrt{63})^{nk} \times (9)^{\frac{nk}{2}(3k-1)}.$$

Proof: Put a = 1, 2, –1, –½, ½ in equation (2), we get the desired results.

Theorem 3. The general multiplicative neighborhood index of nanocone $C_n[k]$ is

$$NM^aII(C_n[k]) = (2\times5^a)^n \times(5^a+7^a)^{2n}\times(6^a+7^a)^{2n(k-1)}\times(7^a+9^a)^{nk}\times(2\times9^a)^{\frac{nk}{2}(3k-1)}.$$

Proof: Let G be the molecular structure of $C_n[k]$. By using the definition and Table 1, we obtain

$$NM^aII(C_n[k]) = \prod_{uv\in E(G)}\left[S_G(u)^a + S_G(v)^a\right]$$

$$= (2\times5^a)^n \times(5^a+7^a)^{2n}\times(6^a+7^a)^{2an(k-1)}\times(7^a+9^a)^{nk}\times(2\times9^a)^{\frac{nk}{2}(3k-1)}.$$

Corollary 3.1. The multiplicative *F*- neighborhood index of $C_n[k]$ is

$$FNMII(C_n[k]) = (50)^n\times(74)^{2n}\times(85)^{2n(k-1)}\times(130)^{nk}\times(162)^{\frac{nk}{2}(3k-1)}.$$

Theorem 4. The multiplicative inverse sum indeg neighborhood index of $C_n[k]$ is

$$INMII(C_n[k]) = \left(\frac{5}{2}\right)^n\times\left(\frac{35}{12}\right)^{2n}\times\left(\frac{42}{13}\right)^{2n(k-1)}\times\left(\frac{63}{16}\right)^{nk}\times\left(\frac{9}{2}\right)^{\frac{nk}{2}(3k-1)}.$$

Proof: Using the definition and Table 1, we have

$$INMII(C_n[k]) = \prod_{uv\in E(G)}\frac{S_G(u)S_G(v)}{S_G(u)+S_G(v)}$$

$$= \left(\frac{5\times5}{5+5}\right)^n\times\left(\frac{5\times7}{5+7}\right)^{2n}\times\left(\frac{6\times7}{6+7}\right)^{2n(k-1)}\times\left(\frac{7\times9}{7+9}\right)^{nk}\times\left(\frac{9\times9}{9+9}\right)^{\frac{nk}{2}(3k-1)}$$

$$= \left(\frac{5}{2}\right)^n\times\left(\frac{35}{12}\right)^{2n}\times\left(\frac{42}{13}\right)^{2n(k-1)}\times\left(\frac{63}{16}\right)^{nk}\times\left(\frac{9}{2}\right)^{\frac{nk}{2}(3k-1)}.$$

Theorem 5. The multiplicative harmonic neighborhood index of $C_n[k]$ is

$$HNMII(C_n[k]) = \left(\frac{1}{5}\right)^n\times\left(\frac{1}{6}\right)^{2n}\times\left(\frac{2}{13}\right)^{2n(k-1)}\times\left(\frac{1}{8}\right)^{nk}\times\left(\frac{1}{9}\right)^{\frac{nk}{2}(3k-1)}.$$

Proof: Using the definition and Table 1, we deduce

$$HNMII(C_n[k]) = \prod_{uv\in E(G)}\frac{2}{S_G(u)+S_G(v)}$$

$$= \left(\frac{2}{5+5}\right)^n\times\left(\frac{2}{5+7}\right)^{2n}\times\left(\frac{2}{6+7}\right)^{2n(k-1)}\times\left(\frac{2}{7+9}\right)^{nk}\times\left(\frac{2}{9+9}\right)^{\frac{nk}{2}(3k-1)}$$

$$= \left(\frac{1}{5}\right)^n\times\left(\frac{1}{6}\right)^{2n}\times\left(\frac{2}{13}\right)^{2n(k-1)}\times\left(\frac{1}{8}\right)^{nk}\times\left(\frac{1}{9}\right)^{\frac{nk}{2}(3k-1)}.$$

Theorem 6. The multiplicative symmetric division neighborhood index of $C_n[k]$ is

$$SDNMII(C_n[k]) = 2^{n+\frac{nk}{2}(3k-1)}\times\left(\frac{74}{35}\right)^{2n}\times\left(\frac{85}{42}\right)^{2n(k-1)}\times\left(\frac{130}{63}\right)^{nk}.$$

Proof: Using the definition and Table 1, we deduce

$$SDNMII(C_n[k]) = \prod_{uv\in E(G)}\left(\frac{S_G(u)}{S_G(v)}+\frac{S_G(v)}{S_G(u)}\right)$$

$$= \left(\frac{5}{5}+\frac{5}{5}\right)^n\times\left(\frac{5}{7}+\frac{7}{5}\right)^{2n}\times\left(\frac{6}{7}+\frac{7}{6}\right)^{2n(k-1)}\times\left(\frac{7}{9}+\frac{9}{7}\right)^{nk}\times\left(\frac{9}{9}+\frac{9}{9}\right)^{\frac{nk}{2}(3k-1)}$$

$$= 2^{n+\frac{nk}{2}(3k-1)} \times \left(\frac{74}{35}\right)^{2n} \times \left(\frac{85}{42}\right)^{2n(k-1)} \times \left(\frac{130}{63}\right)^{nk}.$$

Theorem 7. The first and second multiplicative Gourava neighborhood indices of nanocone $C_n[k]$ are given by

(i) $NGO_1II(C_n[k]) = 35^n \times 47^{2n} \times 55^{2n(k-1)} \times 79^{nk} \times 99^{\frac{nk}{2}(3k-1)}.$

(ii) $NGO_2II(C_n[k]) = 250^n \times 420^{2n} \times 546^{2n(k-1)} \times 1008^{nk} \times 1458^{\frac{nk}{2}(3k-1)}.$

Proof: By using the definition and Table 1, we deduce

(i) $NGO_1II(C_n[k]) = \prod_{uv\in E(G)} [S_G(u)+S_G(v)+S_G(u)S_G(v)]$

$$= (5+5+5\times5)^{an} \times (5+7+5\times7)^{2an} \times (6+7+6\times7)^{2an(k-1)}$$

$$\times (7+9+7\times9)^{nk} \times (9+9+9\times9)^{\frac{ank}{2}(3k-1)}.$$

$$= 35^n \times 47^{2n} \times 55^{2n(k-1)} \times 79^{nk} \times 99^{\frac{nk}{2}(3k-1)}.$$

(ii) $NGO_2II(C_n[k]) = \prod_{uv\in E(G)} [S_G(u)+S_G(v)]S_G(u)S_G(v)$

$$= [(5+5)5\times5]^n + [(5+7)5\times7]^{2n} \times [(6+7)6\times7]^{2n(k-1)}$$

$$\times [(7+9)7\times9]^{nk} \times [(9+9)9\times9]^{\frac{ank}{2}(3k-1)}.$$

$$= 250^n \times 420^{2n} \times 546^{2n(k-1)} \times 1008^{nk} \times 1458^{\frac{nk}{2}(3k-1)}.$$

2. RESULTS FOR $NS_2[n]$ DENDRIMERS

In this section, we focus on the class of $NS_2[n]$ dendrimers with $n\geq1$. The graph of $NS_2[2]$ is shown in Figure 2.

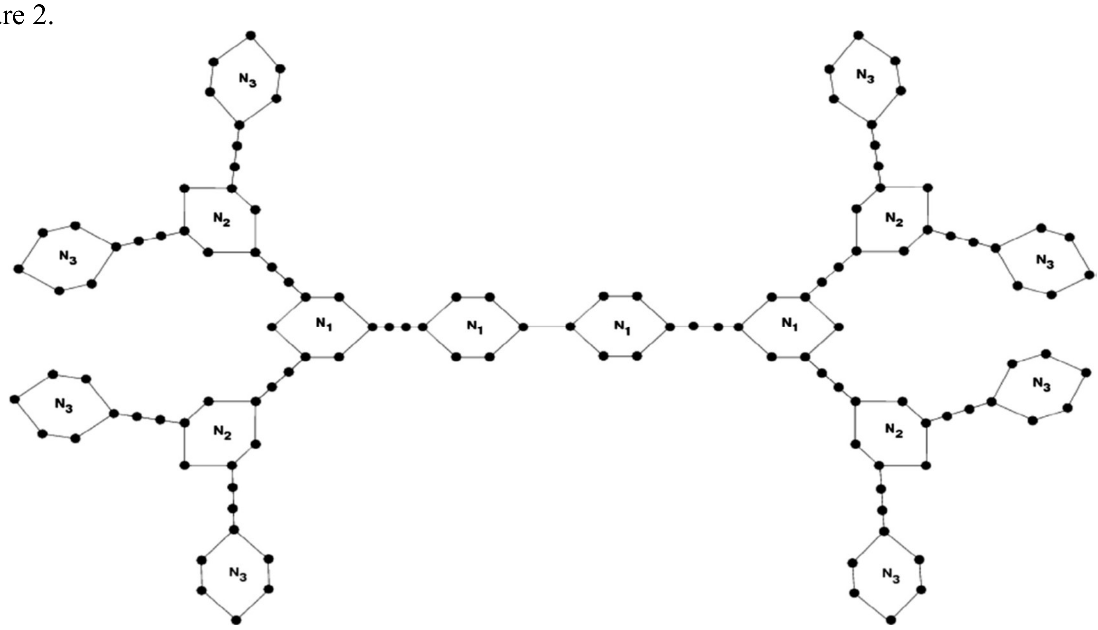

Figure 2. The graph of $NS_2[3]$

Let G be the graph of $NS_2[n]$. By calculation, G has $16\times2^n - 4$ vertices and $18\times2^n - 5$ edges. Also by calculation, we obtain that G has seven types of edges based on $S_G(u)$, $S_G(v)$ the degree of end vertices of each edge as given in Table 2.

$S_G(u), S_G(v) \setminus uv \in E(G)$	(4, 4)	(5, 4)	(5, 5)	(5, 6)	(7, 7)	(5, 7)	(6, 6)
Number of edges	2×2^n	2×2^n	$2\times2^n+2$	6×2^n	1	4	$6\times2^n-12$

Table 2. Edge partition of $NS_2[n]$ based on $S_G(u)$ and $S_G(v)$

We compute the multiplicative neighborhood general sum connectivity index of $NS_2[n]$.

Theorem 8. The multiplicative neighborhood general sum connectivity index of a dendrimer $NS_2[n]$ is

$$NM_1^aII(NS_2[n]) = 8^{a(2\times2^n)}\times9^{a(2\times2^n)}\times10^{a(2\times2^n+2)}\times11^{a(6\times2^n)}\times14^a\times12^{a(6\times2^n-8)} \quad (3)$$

Proof: Let G be the molecular graph of $NS_2[n]$. Using definition and Table 2, we deduce

$$NM_1^aII(NS_2[n]) = \prod_{uv\in E(G)}\left[S_G(u)+S_G(v)\right]^a$$

$$=(4+4)^{a(2\times2^n)}\times(5+4)^{a(2\times2^n)}\times(5+5)^{a(2\times2^n+2)}\times(5+6)^{a(6\times2^n)}\times(7+7)^a\times(5+7)^{4a}\times(6+6)^{a(6\times2^n-8)}$$

$$=8^{a(2\times2^n)}\times9^{a(2\times2^n)}\times10^{a(2\times2^n+2)}\times11^{a(6\times2^n)}\times14^a\times12^{a(6\times2^n-8)}$$

The following results are obtained from Theorem 8.

Corollary 8.1. The multiplicative first neighborhood index of $NS_2[n]$ is

$$NM_1II(NS_2[n]) = 8^{2\times2^n}\times9^{2\times2^n}\times10^{2\times2^n+2}\times11^{6\times2^n}\times14\times12^{6\times2^n-8}$$

Corollary 8.2. The multiplicative first hyper neighborhood index of $NS_2[n]$ is

$$HNM_1II(NS_2[n]) = 8^{4\times2^n}\times9^{4\times2^n}\times10^{4\times2^n+4}\times11^{12\times2^n}\times14^2\times12^{12\times2^n-16}$$

Corollary 8.3. The modified multiplicative first neighborhood index of $NS_2[n]$ is

$${}^mNM_1II(NS_2[n]) = \left(\frac{1}{8}\right)^{2\times2^n}\times\left(\frac{1}{9}\right)^{2\times2^n}\times\left(\frac{1}{10}\right)^{2\times2^n+2}\times\left(\frac{1}{11}\right)^{6\times2^n}\times\frac{1}{14}\times\left(\frac{1}{12}\right)^{6\times2^n-8}.$$

Corollary 8.4. The multiplicative neighborhood sum connectivity index of $NS_2[n]$ is

$$SNMII(NS_2[n]) = \left(\frac{1}{\sqrt{8}}\right)^{2\times2^n}\times\left(\frac{1}{3}\right)^{2\times2^n}\times\left(\frac{1}{\sqrt{10}}\right)^{2\times2^n+2}\times\left(\frac{1}{\sqrt{11}}\right)^{6\times2^n}\times\frac{1}{\sqrt{14}}\times\left(\frac{1}{\sqrt{12}}\right)^{6\times2^n-8}.$$

Proof: Put a = 1, 2, –1, –½ in equation (3), we obtain the desired results.

We compute the multiplicative neighborhood general product connectivity index of $NS_2[n]$.

Theorem 9. The multiplicative neighborhood general product connectivity index of dendrimer $NS_2[n]$ is

$$NM_2^aII(NS_2[n]) = 16^{a\times2\times2^n}\times20^{a\times2\times2^n}\times25^{a(2\times2^n+2)}\times30^{a\times6\times2^n}\times49^a\times35^{4a}\times36^{a(6\times2^n-12)}. \quad (4)$$

Proof: By using the definition and Table 2, we obtain

$$NM_2^aII(NS_2[n]) = \prod_{uv\in E(G)}\left[S_G(u)S_G(v)\right]^a$$

$$=(4\times4)^{a\times2\times2^n}\times(5\times4)^{a\times2\times2^n}\times(5\times5)^{a(2\times2^n+2)}\times(5\times6)^{a\times6\times2^n}\times(7\times7)^a\times(5\times7)^{4a}\times(6\times6)^{a(6\times2^n-12)}.$$

$$=16^{a\times2\times2^n}\times20^{a\times2\times2^n}\times25^{a(2\times2^n+2)}\times30^{a\times6\times2^n}\times49^a\times35^{4a}\times36^{a(6\times2^n-12)}.$$

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The following results are obtained by using Theorem 9.

Corollary 9.1. The multiplicative second neighborhood index of $NS_2[n]$ is

$$NM_2II(NS_2[n]) = 16^{2\times 2^n} \times 20^{2\times 2^n} \times 25^{2\times 2^n+2} \times 30^{6\times 2^n} \times 49 \times 35^4 \times 36^{6\times 2^n-12}.$$

Corollary 9.2. The multiplicative second hyper neighborhood index of $NS_2[n]$ is

$$HNM_2II(NS_2[n]) = 16^{4\times 2^n} \times 20^{4\times 2^n} \times 25^{4\times 2^n+4} \times 30^{12\times 2^n} \times 49^2 \times 35^8 \times 36^{12\times 2^n-24}.$$

Corollary 9.3. The modified multiplicative second neighborhood index of $NS_2[n]$ is

$${}^mNM_2II(NS_2[n]) = \left(\frac{1}{16}\right)^{2\times 2^n} \times \left(\frac{1}{20}\right)^{2\times 2^n} \times \left(\frac{1}{25}\right)^{2\times 2^n+2} \times \left(\frac{1}{30}\right)^{6\times 2^n} \times \left(\frac{1}{49}\right) \times \left(\frac{1}{35}\right)^4 \times \left(\frac{1}{36}\right)^{6\times 2^n-12}.$$

Corollary 9.4. The multiplicative neighborhood product connectivity index of $NS_2[n]$ is

$$PNMII(NS_2[n]) = \left(\frac{1}{4}\right)^{2\times 2^n} \times \left(\frac{1}{\sqrt{20}}\right)^{2\times 2^n} \times \left(\frac{1}{5}\right)^{2\times 2^n+2} \times \left(\frac{1}{\sqrt{30}}\right)^{6\times 2^n} \times \frac{1}{7} \times \left(\frac{1}{\sqrt{35}}\right)^4 \times \left(\frac{1}{6}\right)^{6\times 2^n-12}.$$

Corollary 9.5. The reciprocal multiplicative neighborhood product connectivity index of $NS_2[n]$ is

$$RPNMII(NS_2[n]) = 4^{2\times 2^n} \times \left(\sqrt{20}\right)^{2\times 2^n} \times 5^{2\times 2^n+2} \times \left(\sqrt{30}\right)^{6\times 2^n} \times 7 \times \left(\sqrt{35}\right)^4 \times (6)^{6\times 2^n-12}.$$

Proof: Put a = 1, 2, –1, –½, ½ in equation (4), we obtain the desired results.

Theorem 10. The general multiplicative neighborhood index of dendrimer $NS_2[n]$ is

$$NM^aII(NS_2[n]) = (2\times 4^a)^{2\times 2^n} \times (5^a + 4^a)^{2\times 2^n} \times (2\times 5^a)^{2\times 2^n+2} \times (5^a + 6^a)^{6\times 2^n}$$
$$\times (2\times 7^a) \times (5^a + 7^a)^4 \times (2\times 6^a)^{6\times 2^n-12}.$$

Proof: Using the definition and Table 2, we deduce

$$NM^aII(NS_2[n]) = \prod_{uv\in E(G)} \left[S_G(u)^a + S_G(v)^a\right]$$
$$= (2\times 4^a)^{2\times 2^n} \times (5^a + 4^a)^{2\times 2^n} \times (2\times 5^a)^{2\times 2^n+2} \times (5^a + 6^a)^{6\times 2^n}$$
$$\times (2\times 7^a) \times (5^a + 7^a)^4 \times (2\times 6^a)^{6\times 2^n-12}.$$

From Theorem 10, we establish the following result.

Corollary 10.1. The multiplicative *F*-neighborhood index of $NS_2[n]$ is

$$FNMII(NS_2[n]) = 32^{2\times 2^n} \times 41^{2\times 2^n} \times 50^{2\times 2^n+2} \times 61^{6\times 2^n} \times 98 \times 74^4 \times 72^{6\times 2^n-12}.$$

Theorem 11. The multiplicative inverse sum indeg neighborhood index of $NS_2[n]$ is

$$INMII(NS_2[n]) = 2^{2\times 2^n} \times \left(\frac{20}{9}\right)^{2\times 2^n} \times \left(\frac{5}{2}\right)^{2\times 2^n+2} \times \left(\frac{30}{11}\right)^{6\times 2^n} \times \frac{7}{2} \times \left(\frac{35}{12}\right)^4 \times 3^{6\times 2^n-12}.$$

Proof: By using the definition and Table 2, we deduce

$$INMII(NS_2[n]) = \prod_{uv\in E(G)} \frac{S_G(u)S_G(v)}{S_G(u)+S_G(v)}$$
$$= \left(\frac{4\times 4}{4+4}\right)^{2\times 2^n} \times \left(\frac{5\times 4}{5+4}\right)^{2\times 2^n} \times \left(\frac{5\times 5}{5+5}\right)^{2\times 2^n+2} \times \left(\frac{5\times 6}{5+6}\right)^{6\times 2^n} \times \left(\frac{7\times 7}{7+7}\right)^1 \times \left(\frac{5\times 7}{5+7}\right)^4 \times \left(\frac{6\times 6}{6+6}\right)^{6\times 2^n-12}$$
$$= 2^{2\times 2^n} \times \left(\frac{20}{9}\right)^{2\times 2^n} \times \left(\frac{5}{2}\right)^{2\times 2^n+2} \times \left(\frac{30}{11}\right)^{6\times 2^n} \times \frac{7}{2} \times \left(\frac{35}{12}\right)^4 \times 3^{6\times 2^n-12}.$$

Theorem 12. The multiplicative harmonic neighborhood index of $NS_2[n]$ is

$$HNMII(NS_2[n]) = \left(\frac{1}{4}\right)^{2\times2^n} \times \left(\frac{2}{9}\right)^{2\times2^n} \times \left(\frac{1}{5}\right)^{2\times2^n+2} \times \left(\frac{2}{11}\right)^{6\times2^n} \times \frac{1}{7} \times \left(\frac{1}{6}\right)^{6\times2^n-8}.$$

Proof: By using the definition and Table 2, we derive

$$HNMII(NS_2[n]) = \prod_{uv\in E(G)} \frac{2}{S_G(u)+S_G(v)}$$

$$= \left(\frac{2}{4+4}\right)^{2\times2^n} \times \left(\frac{2}{5+4}\right)^{2\times2^n} \times \left(\frac{2}{5+5}\right)^{2\times2^n+2} \times \left(\frac{2}{5+6}\right)^{2\times2^n} \times \left(\frac{2}{7+7}\right)^{1} \times \left(\frac{2}{5+7}\right)^{4} \times \left(\frac{2}{6+6}\right)^{6\times2^n-12}$$

$$= \left(\frac{1}{4}\right)^{2\times2^n} \times \left(\frac{2}{9}\right)^{2\times2^n} \times \left(\frac{1}{5}\right)^{2\times2^n+2} \times \left(\frac{2}{11}\right)^{6\times2^n} \times \frac{1}{7} \times \left(\frac{1}{6}\right)^{6\times2^n-8}.$$

Theorem 13. The multiplicative symmetric division neighborhood index of $NS_2[n]$ is

$$SDNMII(NS_2[n]) = 2^{10\times2^n-9} \times \left(\frac{41}{20}\right)^{2\times2^n} \times \left(\frac{61}{30}\right)^{6\times2^n} \times \left(\frac{74}{35}\right)^{4}.$$

Proof: Using the definition and Table 2, we obtain

$$SDNMII(NS_2[n]) = \prod_{uv\in E(G)} \left(\frac{S_G(u)}{S_G(v)} + \frac{S_G(v)}{S_G(u)}\right)$$

$$= \left(\frac{4}{4}+\frac{4}{4}\right)^{2\times2^n} \times \left(\frac{5}{4}+\frac{4}{5}\right)^{2\times2^n} \times \left(\frac{5}{5}+\frac{5}{5}\right)^{2\times2^n+2} \times \left(\frac{5}{6}+\frac{6}{5}\right)^{6\times2^n} \times \left(\frac{7}{7}+\frac{7}{7}\right)^{1} \times \left(\frac{5}{7}+\frac{7}{5}\right)^{4} \times \left(\frac{6}{6}+\frac{6}{6}\right)^{6\times2^n-12}$$

$$= 2^{10\times2^n-9} \times \left(\frac{41}{20}\right)^{2\times2^n} \times \left(\frac{61}{30}\right)^{6\times2^n} \times \left(\frac{74}{35}\right)^{4}.$$

Theorem 14. The first and second multiplicative Gourava neighborhood indices of nanocone $NS_2[n]$ are

(i) $NGO_1II(NS_2[n]) = 24^{2\times2^n} \times 29^{2\times2^n} \times 35^{2\times2^n+2} \times 41^{6\times2^n} \times 63 \times 47^4 \times 48^{6\times2^n-12}$.

(ii) $NGO_2II(NS_2[n]) = 128^{2\times2^n} \times 180^{2\times2^n} \times 250^{2\times2^n+2} \times 330^{6\times2^n} \times 686 \times 420^4 \times 432^{6\times2^n-12}$.

Proof: By using the definitions and Table 2, we obtain

(i) $$NGO_1II(NS_2[n]) = \prod_{uv\in E(G)} \left[S_G(u)+S_G(v)+S_G(u)S_G(v)\right]$$

$$= (4+4+4\times4)^{2\times2^n} \times (5+4+5\times4)^{2\times2^n} \times (5+5+5\times5)^{2\times2^n+2} \times (5+6+5\times6)^{6\times2^n}$$
$$\times (7+7+7\times7)^{1} \times (5+7+5\times7)^{4} \times (6+6+6\times6)^{6\times2^n-12}.$$
$$= 24^{2\times2^n} \times 29^{2\times2^n} \times 35^{2\times2^n+2} \times 41^{6\times2^n} \times 63 \times 47^4 \times 48^{6\times2^n-12}.$$

(ii) $$NGO_2II(NS_2[n]) = \prod_{uv\in E(G)} \left[S_G(u)+S_G(v)\right]S_G(u)S_G(v)$$

$$= [(4+4)4\times4]^{2\times2^n} \times [(5+4)5\times4]^{2\times2^n} \times [(5+5)5\times5]^{2\times2^n+2} \times [(5+6)5\times6]^{6\times2^n}$$
$$\times [(7+7)7\times7]^{1} \times [(5+7)5\times7]^{4} \times [(6+6)6\times6]^{6\times2^n-12}.$$
$$= 128^{2\times2^n} \times 180^{2\times2^n} \times 250^{2\times2^n+2} \times 330^{6\times2^n} \times 686 \times 420^4 \times 432^{6\times2^n-12}.$$

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4. RESULTS FOR $NS_3[n]$ DENDRIMERS

In this section, we focus on another type of dendrimers $NS_3[n]$ with $n \geq 1$. The molecular structure of $NS_3[2]$ is presented in Figure 3.

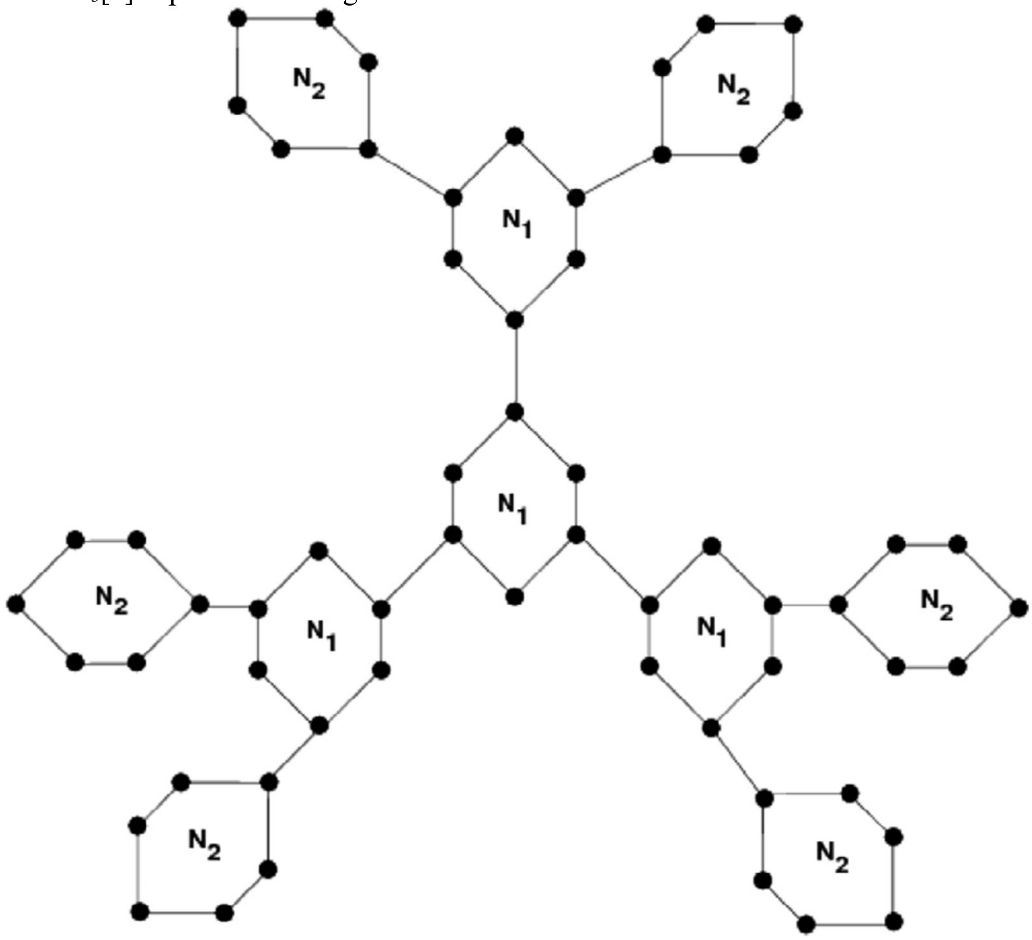

Figure 3. The structure of $NS_3[2]$

Let G be the molecular graph of $NS_3[n]$. By calculation, we obtain that G has $18\times2^n - 12$ vertices and $21\times2^n - 15$ edges. Also by calculation, we get that G has five types of edges based on $S_G(u)$ and $S_G(v)$ the degree of end vertices of each edge as given in Table 3.

$S_G(u), S_G(v) \setminus uv \in E(G)$	(4, 4)	(5, 4)	(5, 7)	(6, 7)	(7, 7)
Number of edges	3×2^n	3×2^n	3×2^n	$9\times2^n-12$	$3\times2^n-3$

Table 3. Edge partition of $NS_3[n]$ based on $S_G(u)$ and $S_G(v)$

We compute the multiplicative neighborhood general sum connectivity index of $NS_3[n]$.

Theorem 15. The multiplicative neighborhood general sum connectivity index of a dendrimer $NS_3[n]$ is given by

$$NM_1^a II\left(NS_3[n]\right) = 8^{a\times3\times2^n} \times 9^{a\times3\times2^n} \times 12^{a\times3\times2^n} \times 13^{a\left(9\times2^n-12\right)} \times 14^{a\left(3\times2^n-3\right)}. \quad (5)$$

Proof: Let G be the molecular graph of $NS_3[n]$. By using definition and Table 3, we deduce

$$NM_1^a II(NS_3[n]) = \prod_{uv\in E(G)} [S_G(u)+S_G(v)]^a$$
$$= (4+4)^{a\times 2\times 2^n} \times (5+4)^{a\times 3\times 2^n} \times (5+7)^{a\times 3\times 2^n} \times (6+7)^{a(9\times 2^n-12)} \times (7+7)^{a(3\times 2^n-3)}$$
$$= 8^{a\times 3\times 2^n} \times 9^{a\times 3\times 2^n} \times 12^{a\times 3\times 2^n} \times 13^{a(9\times 2^n-12)} \times 14^{a(3\times 2^n-3)}.$$

We establish the following results from Theorem 15.

Corollary 15.1. The multiplicative first neighborhood index of $NS_3[n]$ is

$$NM_1II(NS_3[n]) = 8^{3\times 2^n} \times 9^{3\times 2^n} \times 12^{3\times 2^n} \times 13^{9\times 2^n-12} \times 14^{3\times 2^n-3}.$$

Corollary 15.2. The multiplicative first hyper neighborhood index of $NS_3[n]$ is

$$HNM_1II(NS_3[n]) = 8^{6\times 2^n} \times 9^{6\times 2^n} \times 12^{6\times 2^n} \times 13^{2(9\times 2^n-12)} \times 14^{2(3\times 2^n-3)}$$

Corollary 15.3. The modified multiplicative first neighborhood index of $NS_3[n]$ is

$${}^{m}NM_1II(NS_3[n]) = \left(\frac{1}{8}\right)^{3\times 2^n} \times \left(\frac{1}{9}\right)^{3\times 2^n} \times \left(\frac{1}{12}\right)^{3\times 2^n} \times \left(\frac{1}{13}\right)^{9\times 2^n-12} \times \left(\frac{1}{14}\right)^{3\times 2^n-3}.$$

Corollary 15.4. The multiplicative neighborhood sum connectivity index of $NS_3[n]$ is

$$SNMII(NS_3[n]) = \left(\frac{1}{\sqrt{8}}\right)^{3\times 2^n} \times \left(\frac{1}{3}\right)^{3\times 2^n} \times \left(\frac{1}{\sqrt{12}}\right)^{3\times 2^n} \times \left(\frac{1}{\sqrt{13}}\right)^{9\times 2^n-12} \times \left(\frac{1}{\sqrt{14}}\right)^{3\times 2^n-3}.$$

Proof: Put $a = 1, 2, -1, -½$ in equation (5), we obtain the desired results.

We determine the multiplicative neighborhood general product connectivity index of $NS_3[n]$.

Theorem 16. The multiplicative neighborhood general product connectivity index of dendrimer $NS_3[n]$ is given by

$$NM_2^a II(NS_3[n]) = 16^{a\times 3\times 2^n} \times 20^{a\times 3\times 2^n} \times 35^{a\times 3\times 2^n} \times 42^{a(9\times 2^n-12)} \times 49^{a(3\times 2^n-3)}. \quad (6)$$

Proof: Using the definition and Table 3, we obtain

$$NM_2^a II(NS_3[n]) = \prod_{uv\in E(G)} [S_G(u)S_G(v)]^a$$
$$= (4\times 4)^{a\times 3\times 2^n} \times (5\times 4)^{a\times 3\times 2^n} \times (5\times 7)^{a\times 3\times 2^n} \times (6\times 7)^{a(9\times 2^n-12)} \times (7\times 7)^{a(3\times 2^n-3)}.$$
$$= 16^{a\times 3\times 2^n} \times 20^{a\times 3\times 2^n} \times 35^{a\times 3\times 2^n} \times 42^{a(9\times 2^n-12)} \times 49^{a(3\times 2^n-3)}.$$

We establish the following results by using Theorem 9.

Corollary 16.1. The multiplicative second neighborhood index of $NS_3[n]$ is

$$NM_2II(NS_3[n]) = 16^{3\times 2^n} \times 20^{3\times 2^n} \times 35^{3\times 2^n} \times 42^{9\times 2^n-12} \times 49^{3\times 2^n-3}.$$

Corollary 16.2. The multiplicative second hyper neighborhood index of $NS_3[n]$ is

$$HNM_2II(NS_3[n]) = 16^{6\times 2^n} \times 20^{6\times 2^n} \times 35^{6\times 2^n} \times 42^{18\times 2^n-24} \times 49^{6\times 2^n-6}.$$

Corollary 16.3. The modified multiplicative second neighborhood index of $NS_3[n]$ is

$${}^{m}NM_2II(NS_3[n]) = \left(\frac{1}{16}\right)^{3\times 2^n} \times \left(\frac{1}{20}\right)^{3\times 2^n} \times \left(\frac{1}{35}\right)^{3\times 2^n} \times \left(\frac{1}{42}\right)^{9\times 2^n-12} \times \left(\frac{1}{49}\right)^{3\times 2^n-3}.$$

Corollary 16.4. The multiplicative neighborhood product connectivity index of $NS_3[n]$ is

$$PNMII(NS_3[n]) = \left(\frac{1}{4}\right)^{3\times 2^n} \times \left(\frac{1}{\sqrt{20}}\right)^{3\times 2^n} \times \left(\frac{1}{\sqrt{35}}\right)^{3\times 2^n} \times \left(\frac{1}{\sqrt{42}}\right)^{9\times 2^n-12} \times \left(\frac{1}{7}\right)^{3\times 2^n-3}.$$

Corollary 16.5. The reciprocal multiplicative neighborhood product connectivity index of $NS_3[n]$ is

$$RPNMII(NS_3[n]) = 4^{3\times2^n} \times (\sqrt{20})^{3\times2^n} \times (\sqrt{35})^{3\times2^n} \times (\sqrt{42})^{9\times2^n-12} \times 7^{3\times2^n-3}$$

Proof: Put a = 1, 2, −1, −½, ½ in equation (6), we obtain the desired results.

Theorem 17. The general multiplicative neighborhood index of dendrimer $NS_3[n]$ is

$$NM^aII(NS_3[n]) = (2\times4^a)^{3\times2^n} \times (5^a+4^a)^{3\times2^n} \times (5^a+7^a)^{3\times2^n} \times (6^a+7^a)^{9\times2^n-12} \times (2\times7^a)^{3\times2^n-3}.$$

Proof: By using the definition and Table 3, we deduce

$$NM^aII(NS_3[n]) = \prod_{uv\in E(G)} \left[S_G(u)^a + S_G(v)^a\right]$$

$$= (2\times4^a)^{3\times2^n} \times (5^a+4^a)^{3\times2^n} \times (5^a+7^a)^{3\times2^n} \times (6^a+7^a)^{9\times2^n-12} \times (2\times7^a)^{3\times2^n-3}.$$

From Theorem 17, we obtain the following result.

Corollary 17.1. The multiplicative F-neighborhood index of $NS_3[n]$ is

$$FNMII(NS_3[n]) = 32^{3\times2^n} \times 41^{3\times2^n} \times 74^{3\times2^n} \times 85^{9\times2^n-12} \times 98^{3\times2^n-3}.$$

Theorem 18. The multiplicative inverse sum indeg neighborhood index of $NS_3[n]$ is

$$INMII(NS_3[n]) = 2^{3\times2^n} \times \left(\frac{20}{9}\right)^{3\times2^n} \times \left(\frac{35}{12}\right)^{3\times2^n} \times \left(\frac{42}{13}\right)^{9\times2^n-12} \times \left(\frac{7}{2}\right)^{3\times2^n-3}.$$

Proof: By using the definition and Table 2, we deduce

$$INMII(NS_3[n]) = \prod_{uv\in E(G)} \frac{S_G(u)S_G(v)}{S_G(u)+S_G(v)}$$

$$= \left(\frac{4\times4}{4+4}\right)^{3\times2^n} \times \left(\frac{5\times4}{5+4}\right)^{3\times2^n} \times \left(\frac{5\times7}{5+7}\right)^{3\times2^n} \times \left(\frac{6\times7}{6+7}\right)^{9\times2^n-12} \times \left(\frac{7\times7}{7+7}\right)^{3\times2^n-3}$$

$$= 2^{3\times2^n} \times \left(\frac{20}{9}\right)^{3\times2^n} \times \left(\frac{35}{12}\right)^{3\times2^n} \times \left(\frac{42}{13}\right)^{9\times2^n-12} \times \left(\frac{7}{2}\right)^{3\times2^n-3}.$$

Theorem 19. The multiplicative harmonic neighborhood index of $NS_3[n]$ is

$$HNMII(NS_3[n]) = \left(\frac{1}{4}\right)^{3\times2^n} \times \left(\frac{2}{9}\right)^{3\times2^n} \times \left(\frac{1}{6}\right)^{3\times2^n} \times \left(\frac{2}{13}\right)^{9\times2^n-12} \times \left(\frac{1}{7}\right)^{3\times2^n-3}.$$

Proof: By using the definition and Table 2, we derive

$$HNMII(NS_3[n]) = \prod_{uv\in E(G)} \frac{2}{S_G(u)+S_G(v)}$$

$$= \left(\frac{1}{4}\right)^{3\times2^n} \times \left(\frac{2}{9}\right)^{3\times2^n} \times \left(\frac{1}{6}\right)^{3\times2^n} \times \left(\frac{2}{13}\right)^{9\times2^n-12} \times \left(\frac{1}{7}\right)^{3\times2^n-3}.$$

Theorem 20. The multiplicative symmetric division neighborhood index of $NS_3[n]$ is

$$SDNMII(NS_3[n]) = 2^{6\times2^n-3} \times \left(\frac{41}{20}\right)^{3\times2^n} \times \left(\frac{74}{35}\right)^{3\times2^n} \times \left(\frac{85}{42}\right)^{9\times2^n-12}.$$

Proof: By using the definition and Table 3, we deduce

$$SDNMII(NS_3[n]) = \prod_{uv\in E(G)}\left(\frac{S_G(u)}{S_G(v)}+\frac{S_G(v)}{S_G(u)}\right)$$
$$=\left(\frac{4}{4}+\frac{4}{4}\right)^{3\times2^n}\times\left(\frac{5}{4}+\frac{4}{5}\right)^{3\times2^n}\times\left(\frac{5}{7}+\frac{7}{5}\right)^{3\times2^n}\times\left(\frac{6}{7}+\frac{7}{6}\right)^{9\times2^n-12}\times\left(\frac{7}{7}+\frac{7}{7}\right)^{3\times2^n-3}$$
$$=2^{6\times2^n-3}\times\left(\frac{41}{20}\right)^{3\times2^n}\times\left(\frac{74}{35}\right)^{3\times2^n}\times\left(\frac{85}{42}\right)^{9\times2^n-12}.$$

Theorem 21. The first and second multiplicative Gourava neighborhood indices of dendrimer $NS_3[n]$ is

(i) $NGO_1II(NS_3[n]) = 24^{3\times2^n}\times29^{3\times2^n}\times47^{3\times2^n}\times55^{9\times2^n-12}\times63^{3\times2^n-3}.$

(ii) $NGO_2II(NS_3[n]) = 128^{3\times2^n}\times180^{3\times2^n}\times420^{3\times2^n}\times546^{9\times2^n-12}\times686^{3\times2^n-3}.$

Proof: By using the definitions and Table 3, we derive

(i) $$NGO_1II(NS_3[n]) = \prod_{uv\in E(G)}\left[S_G(u)+S_G(v)+S_G(u)S_G(v)\right]$$
$$=(4+4+4\times4)^{3\times2^n}\times(5+4+5\times4)^{3\times2^n}\times(5+7+5\times7)^{3\times2^n}$$
$$\times(6+7+6\times7)^{9\times2^n-12}\times(7+7+7\times7)^{3\times2^n-3}$$
$$=24^{3\times2^n}\times29^{3\times2^n}\times47^{3\times2^n}\times55^{9\times2^n-12}\times63^{3\times2^n-3}.$$

(ii) $$NGO_2II(NS_3[n]) = \prod_{uv\in E(G)}\left[S_G(u)+S_G(v)\right]S_G(u)S_G(v)$$
$$=[(4+4)4\times4]^{3\times2^n}\times[(5+4)5\times4]^{3\times2^n}\times[(5+7)5\times7]^{3\times2^n}$$
$$\times[(6+7)6\times7]^{9\times2^n-12}\times[(7+7)7\times7]^{3\times2^n-3}$$
$$=128^{3\times2^n}\times180^{3\times2^n}\times420^{3\times2^n}\times546^{9\times2^n-12}\times686^{3\times2^n-3}.$$

CONCLUSION

In this study, we have introduced some multiplicative neighborhood indices. Furthermore, we have determined some new and old multiplicative neighborhood indices for nanocones and two types of dendrimers.

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