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On 2-SuperHyperLeftAlmostSemihypergroups

Pairote Yiarayong[1,*]

[1]Department of Mathematics, Faculty of Science and Technology, Pibulsongkram Rajabhat University, Phitsanulok 65000, Thailand; E-mail: pairote0027@hotmail.com

[*]Correspondence: pairote0027@hotmail.com

Abstract. The aim of this paper is to extend the concept of hyperideals to the SuperHyperAlgebras. In this paper, we introduce the concept of 2-SuperHyperLeftAlmostSemihypergroups which is a generalization of $\mathcal{LA}$-semihypergroups. Furthermore, we define and study 2-SuperHyper-$\mathcal{LA}$-subsemihypergroups, SuperHyper-Left(Right)HyperIdeals and SuperHyperHyperIdeals of 2-SuperHyperLeftAlmostSemihypergroups, and related properties are investigated. We give an example to show that in general these two notions are different. Finally, we show that every SuperHyperRightHyperIdeal of 2-SuperHyper-$\mathcal{LA}$-semihypergroup S with pure left identity is SuperHyperHyperIdeal.

Keywords: SuperHyperAlgebra; $\mathcal{LA}$-subsemihypergroup; 2-SuperHyperLeftAlmostSemihypergroup; SuperHyperHyperIdeals; SuperHyperLeft(Right)HyperIdeal.

1. Introduction

The concept of left almost semihypergroups ($\mathcal{LA}$-semihypergroups), which is a generalization of $\mathcal{LA}$-semigroups and semihypergroups, was introduced by Hila and Dine [9] in 2011. They defined the concept of hyperideals and bi-hyperideals in $\mathcal{LA}$-semihypergroups. Until now, $\mathcal{LA}$-semihypergroups have been applied to many fields [2, 4–6, 13, 16, 18]. In 2013, Yaqoob et al. [17] have characterized intra-regular $\mathcal{LA}$-semihypergroups by using the properties of their left and right hyperideals and investigated some useful conditions for an $\mathcal{LA}$-semihypergroup to become an intra-regular $\mathcal{LA}$-semihypergroup. In 2014, Amjad et al. [1] generalized the concepts of locally associative $\mathcal{LA}$-semigroups to hypergroupoids and studied several properties. They defined the concept of locally associative $\mathcal{LA}$-semihypergroups and characterized a locally associative $\mathcal{LA}$-semihypergroup in terms of (m, n)-hyperideals. In 2016, Khan et al. [10] proved that an $\mathcal{LA}$-semigroup S is $0(0, 2)$-bisimple if and only if S is right 0-simple. In 2018, Azhar et al. [3] applied the notion of $(\in, \in \vee q_k)$-fuzzy sets to $\mathcal{LA}$-semihypergroups. They introduced the notion of $(\in, \in \vee q_k)$-fuzzy hyperideals in an ordered $\mathcal{LA}$-semihypergroup and then derived their basic properties. In 2019, Gulistan et al. [8] presented a new definition of generalized fuzzy hyperideals, generalized fuzzy bi-hyperideals and generalized fuzzy normal bi-hyperideals in an ordered $\mathcal{LA}$-semihypergroup. They characterized ordered $\mathcal{LA}$-semihypergroups by the properties of their $(\in_\gamma, \in_\gamma \vee q_\delta)$-fuzzy hyperideals, $(\in_\gamma, \in_\gamma \vee q_\delta)$-fuzzy bi-hyperideals and $(\in_\gamma, \in_\gamma \vee q_\delta)$-fuzzy normal bi-hyperideals. In 2021, Suebsung et al. [12] have introduced the notion of left almost hyperideals, right almost hyperideals, almost hyperideals and minimal almost hyperideals in $\mathcal{LA}$-semihypergroups. In 2022, Nakkhasen [11] characterized intra-regular $\mathcal{LA}$-semihyperrings by the properties of their hyperideals.

In this paper, we extend the concept of hyperideals to the SuperHyperAlgebras. In this paper, we introduce the concept of 2-SuperHyperLeftAlmostSemihypergroups which is a generalization of $\mathcal{LA}$-semihypergroups. Furthermore, we define and study 2-SuperHyper-$\mathcal{LA}$-subsemihypergroups, SuperHyperLeft(Right)HyperIdeals and SuperHyperHyperIdeals of 2-SuperHyperLeftAlmostSemihypergroups, and related properties are investigated. We give an example to show that in general these two notions are different. Finally, we show that every SuperHyperRightHyperIdeal of 2-SuperHyper-$\mathcal{LA}$-semihypergroup S with pure left identity is SuperHyperHyperIdeal.

2. **Preliminaries and Basic Definitions**

In this section, we give some basic definitions and properties of left almost semihypergroups and classical-type Binary SuperHyperOperations that are required in this study.

Recall that a mapping $\circ : S \times S \to \mathcal{P}^*(S)$, where $\mathcal{P}^*(S)$ denotes the family of all non empty subsets of S, is called a **hyperoperation** on S. An image of the pair (x, y) is denoted by $x \circ y$. The couple $(S, \circ)$ is called a **hypergroupoid**.

Let x be an elements of a non empty set of S and let A, B be two non empty subsets of S. Then we denote $A \circ B = \bigcup\limits_{a \in A, b \in B} a \circ b, x \circ B = \{x\} \circ B$ and $A \circ x = A \circ \{x\}$.

In 2011, Hila and Dine [9] introduced the concept and notion of left almost semihypergroup as a generalization of semigroups, $\mathcal{LA}$-semigroups and semihypergroups.

Definition 2.1. [9] A hypergroupoid $(S, \circ)$ is called a **left almost semihypergroup ($\mathcal{LA}$-semihypergroup)** if $\circ$ is left invertive law, that is $(x \circ y) \circ z = (z \circ y) \circ x$ for every $x, y, z \in S$.

Clearly, every $\mathcal{LA}$-semihypergroup is $\mathcal{LA}$-semigroup. If $(S, \circ)$ is an $\mathcal{LA}$-semihypergroup, then $\bigcup\limits_{a \in x \circ y} a \circ z = \bigcup\limits_{b \in z \circ y} b \circ x$ for all $x, y, z \in S$.

The concept of classical-type binary SuperHyperOperation was introduced by Smarandache [14, 15].

Definition 2.2. [14, 15] Let $\mathcal{P}_*^n(S)$ be the n^{th}-powerset of the set S such that none of $\mathcal{P}(S), \mathcal{P}^2(S), \ldots, \mathcal{P}^n(S)$ contain the empty set. A **classical-type binary SuperHyperOperation $\bullet_n$** is defined as follows:

$$\bullet_n : S \times S \to \mathcal{P}_*^n(S)$$

where $\mathcal{P}_*^n(S)$ is the n^{th}-power set of the set S, with no empty set.

An image of the pair (x, y) is denoted by $x \bullet_n y$. The couple $(S, \bullet_n)$ is called a **2-SuperHyperGroupoid**.

The following is an example of Examples of classical-type binary SuperHyperOperation (or 2-SuperHyperGroupoid).

Example 2.3. [14] Let $S = \{a, b\}$ be a finite discrete set. Then its power set, without the empty-set $\emptyset$, is: $\mathcal{P}(S) = \{a, b, S\}$ and $\mathcal{P}^2(S) = \mathcal{P}^2(\mathcal{P}(S)) = \mathcal{P}^2(\{a, b, S\}) = \{a, b, S, \{a, S\}, \{b, S\}, \{a, b, S\}\}$. The classical-type binary SuperHyperOperation defined as follows, $\bullet_2 : S \times S \to \mathcal{P}_*^2(S)$

$\bullet_2$	a	b
a	$\{a, S\}$	$\{b, S\}$
b	a	$\{a, b, S\}$

Then $(S, \bullet_2)$ is a 2-SuperHyperGroupoid and is not a hypergroupoid.

3. 2-SuperHyperLeftAlmostSemihypergroups

In this section, we generalize this concept in left almost semihypergroup and introduce SuperHyperLeft(Right)HyperIdeals of 2-SuperHyper-$\mathcal{LA}$-semihypergroups and study their properties.

The 2-SuperHyperLeftAlmostSemihypergroups is generated with the help of left almost semihypergroups and classical-type binary SuperHyperOperations. So we can say that 2-SuperHyperLeftAlmostSemihypergroup is the generalization of previously defined concepts related to binary SuperHyperOperations. We consider the SuperHyperLeftAlmostSemihypergroup as follows.

Definition 3.1. A 2-SuperHyperGroupoid $(S, \bullet_n)$ is called a **n-SuperHyperLeftAlmostSemihypergroup (2-SuperHyper-$\mathcal{LA}$-semihypergroup)** if it satisfies the SuperHyperLeftInvertive law; $(x \bullet_n y) \bullet_n z = (z \bullet_n y) \bullet_n x$ for all $x, y, z \in S$.

The following is an example of a 2-SuperHyper-$\mathcal{LA}$-semihypergroup S.

Example 3.2. Let $S = \{a, b\}$ be a finite discrete set. The classical-type binary SuperHyperOperation defined as follows, $\bullet_2 : S \times S \to \mathcal{P}_*^2(S)$

$\bullet_2$	a	b
a	$\{a, S\}$	b
b	$\{b, S\}$	$\{a, b, S\}$

Then, as is easily seen, $(S, \bullet_2)$ is a 2-SuperHyper-$\mathcal{LA}$-semihypergroup. Since

$$\begin{aligned}(a \bullet_2 a) \bullet_2 b &= \{a, S\} \bullet_2 a \\ &= (a \bullet_2 a) \cup (S \bullet_2 a) \\ &= \{a, S\} \cup \bigcup_{x \in S} x \bullet_2 a \\ &= \{a, S\} \cup (a \bullet_2 a) \cup (b \bullet_2 a) \\ &= \{a, S\} \cup \{a, S\} \cup \{b, S\} \\ &= \{a, b, S\} \\ &\neq b \\ &= a \bullet_2 b \\ &= a \bullet_2 (a \bullet_2 b),\end{aligned}$$

we have $\bullet_2$ is not Strong SuperHyperAssociativity.

Theorem 3.3. *Every 2-SuperHyper-$\mathcal{LA}$-semihypergroup S satisfies the **SuperHyperMedial law**, that is, for all $a, b, c, d \in S$, $(a \bullet_n b) \bullet_n (c \bullet_n d) = (a \bullet_n c) \bullet_n (b \bullet_n d)$.*

Proof. Let a, b, c and d be any elements of S. Then we have

$$\begin{aligned}(a \bullet_n b) \bullet_n (c \bullet_n d) &= ((c \bullet_n d) \bullet_n b) \bullet_n a \\ &= ((b \bullet_n d) \bullet_n c) \bullet_n a \\ &= (a \bullet_n c) \bullet_n (b \bullet_n d).\end{aligned}$$

This completes the proof. □

Theorem 3.4. *If S is a 2-SuperHyper-$\mathcal{LA}$-semihypergroup, then $(a \bullet_n b)^2 = a^2 \bullet_n b^2$ for all $a, b \in S$.*

Proof. Let a and b be any elements of S. Then by Theorem 3.3,

$$\begin{aligned}(a \bullet_n b)^2 &= (a \bullet_n b) \bullet_n (a \bullet_n b) \\ &= (a \bullet_n a) \bullet_n (b \bullet_n b) \\ &= a^2 \bullet_n b^2.\end{aligned}$$

□

An element e of a 2-SuperHyper-$\mathcal{LA}$-semihypergroup S is called **left identity (resp., pure left identity)** if for all $a \in \mathcal{N}(S), a \in e \bullet_n a$ (resp., $a = e \bullet_n a$). The following is an example of a pure left identity element in 2-SuperHyper-$\mathcal{LA}$-semihypergroups.

Example 3.5. 1. Let $S = \{a, b\}$ be a finite discrete set. The classical-type binary SuperHyperOperation defined as follows, $\bullet_2 : S \times S \to \mathcal{P}^2_*(S)$

$\bullet_2$	a	b
a	a	$\{a, b, S\}$
b	$\{b, S\}$	S

Then, as is easily seen, $(S, \bullet_2)$ is a 2-SuperHyper-$\mathcal{LA}$-semihypergroup with left identity a.

2. Let $S = \{a, b\}$ be a finite discrete set. The classical-type binary SuperHyperOperation defined as follows, $\bullet_2 : S \times S \to \mathcal{P}^2_*(S)$

$\bullet_2$	a	b
a	a	b
b	b	S

Then, as is easily seen, $(S, \bullet_2)$ is a 2-SuperHyper-$\mathcal{LA}$-semihypergroup with pure left identity a.

Theorem 3.6. *A 2-SuperHyper-$\mathcal{LA}$-semihypergroup S with pure left identity e satisfies the* ***SuperHyperParamedial law****, that is, for all $a, b, c, d \in S$, $(a \bullet_n b) \bullet_n (c \bullet_n d) = (d \bullet_n c) \bullet_n (b \bullet_n a)$.*

Proof. Let a, b, c and d be any elements of S. Then we have

$$\begin{aligned}
(a \bullet_n b) \bullet_n (c \bullet_n d) &= [(e \bullet_n a) \bullet_n b] \bullet_n (c \bullet_n d) \\
&= [(b \bullet_n a) \bullet_n e] \bullet_n (c \bullet_n d) \\
&= [(c \bullet_n d) \bullet_n e] \bullet_n (b \bullet_n a) \\
&= [(e \bullet_n d) \bullet_n c] \bullet_n (b \bullet_n a) \\
&= (d \bullet_n c) \bullet_n (b \bullet_n a).
\end{aligned}$$

This completes the proof. □

The following may be noted from the above definitions.

Lemma 3.7. *If S is a 2-SuperHyper-$\mathcal{LA}$-semihypergroup with pure left identity, then $a \bullet_n (b \bullet_n c) = b \bullet_n (a \bullet_n c)$ holds for all $a, b, c \in S$.*

Proof. Let a, b and c be any elements of S. Then by Theorem 3.3,

$$\begin{aligned}
a \bullet (b \bullet_n c) &= (e \bullet_n a) \bullet (b \bullet_n c) \\
&= (e \bullet_n b) \bullet (a \bullet_n c) \\
&= b \bullet_n (a \bullet_n c).
\end{aligned}$$

This completes the proof. □

Now, we give the concept of 2-SuperHyperLeftAlmostSemihypergroups (2-SuperHyper-$\mathcal{LA}$-subsemihypergroup) of 2-SuperHyper-$\mathcal{LA}$-semihypergroups.

Definition 3.8. A nonempty subset A of a 2-SuperHyper-$\mathcal{LA}$-semihypergroup S is called **2-SuperHyperLeftAlmostSemihypergroup (2-SuperHyper-$\mathcal{LA}$-subsemihypergroup)** if $A \bullet_n A \subseteq A$.

The following may be noted from the above definitions.

Proposition 3.9. *Let A and B be two 2-SuperHyper-$\mathcal{LA}$-subsemihypergroups of a 2-SuperHyper-$\mathcal{LA}$-semihypergroup S. If $A \cap B \neq \emptyset$, then $A \cap B$ is a 2-SuperHyper-$\mathcal{LA}$-subsemihypergroup of S.*

Proof. Let A and B be two 2-SuperHyper-$\mathcal{LA}$-subsemihypergroups of S such that $A \cap B \neq \emptyset$. Then have that

$$\begin{aligned}(A \cap B) \bullet_2 (A \cap B) &= [A \bullet_n (A \cap B)] \cap [B \bullet_n (A \cap B)] \\ &= (A \bullet_n A) \cap (A \bullet_n B) \cap (B \bullet_n A) \cap (B \bullet_n B) \\ &\subseteq (A \bullet_n A) \cap (B \bullet_n B) \\ &\subseteq A \cap B,\end{aligned}$$

and so $A \cap B$ is a 2-SuperHyper-$\mathcal{LA}$-subsemihypergroup of S. □

Now we mention some special class of 2-SuperHyper-$\mathcal{LA}$-subsemihypergroups in a 2-SuperHyper-$\mathcal{LA}$-semihypergroup.

Definition 3.10. A nonempty subset L of a 2-SuperHyper-$\mathcal{LA}$-semihypergroup S is called **SuperHyperLeft(Right)HyperIdeal** if

$$S \bullet_n L \subseteq L\,(R \bullet_n S \subseteq R).$$

A nonempty subset I of S is called a **SuperHyperHyperIdeal** of S if it is both a SuperHyperLeft and a SuperHyperRightHyperIdeal of S.

Proposition 3.11. *Let $\mathcal{N}(S)$ be a 2-SuperHyper-$\mathcal{LA}$-semihypergroup with pure left identity. Then the following properties hold.*

(1) *If L is a SuperHyperLeftHyperIdeal of S, then $S \bullet_n L = L$.*
(2) *If $\mathcal{N}(R)$ is a SuperHyperRightHyperIdeal of S, then $R \bullet_n S = R$.*
(3) *$S \bullet_n S = S$.*

Proof. 1. Since L is a SuperHyperLeftHyperIdeal of S, we have $S \bullet_n L \subseteq L$. On the other hand, let a be an element of S such that $a \in L$. Then we have $a = e \bullet_n a \in S \bullet_n L$ and hence $S \bullet_n L = L$.

2. Since R is a SuperHyperRightHyperIdeal of S, we have $R \bullet_n S \subseteq R$. On the other hand, let a be an element of S such that $a \in R$. Then we have

$$\begin{aligned} a &= e \bullet_n a \\ &= (e \bullet_n e) \bullet_n a \\ &= (a \bullet_n e) \bullet_n e \\ &\subseteq (R \bullet_n S) \bullet_n S \\ &\subseteq R \bullet_n S. \end{aligned}$$

Therefore we obtain that $R \subseteq R \bullet_n S$ and hence $R \bullet_n S = R$.

3. The proof is similar to the proof of (2). □

By applying the above definition, we state the following result.

Theorem 3.12. *Let S be a 2-SuperHyper-$\mathcal{LA}$-semihypergroup with pure left identity. Then the following properties hold.*

(1) *If x is an element of S, then $x \bullet_n S$ is a SuperHyperLeftHyperIdeal of S.*

(2) *If x is an element of S, then $S \bullet_n x$ is a SuperHyperLeftHyperideal of S.*

(3) *If x is an element of S, then $S \bullet_n x \cup x \bullet_n S$ is a SuperHyperRightHyperIdeal of S.*

Proof. 1. Let x be an element of S. By Lemma 3.7 and Proposition 3.11 (3), we have

$$\begin{aligned} S \bullet_n [x \bullet_n S] &= x \bullet_n [S \bullet_n S] \\ &= x \bullet_n S. \end{aligned}$$

Therefore we obtain that $x \bullet_n S$ is a SuperHyperLeftHyperIdeal of S.

2. Let x be an element of S. By Theorem 3.6 and Proposition 3.11 (3), we have

$$\begin{aligned} S \bullet_n (S \bullet_n x) &= (S \bullet_n S) \bullet_n (S \bullet_n x) \\ &= (x \bullet_n S) \bullet_n (S \bullet_n S) \\ &= [(S \bullet_n S) \bullet_n S] \bullet_n x \\ &= S \bullet_n x. \end{aligned}$$

Therefore we obtain that $S \bullet_n x$ is a SuperHyperLeftHyperIdeal of S.

3. Let x be an element of S. By Theorem 3.6, Lemma 3.7 and Proposition 3.11 (3), we have

$$\begin{aligned} (S \bullet_n x \cup x \bullet_n S) \bullet_n S &= [(S \bullet_n x) \bullet_n S] \cup [(x \bullet_n S) \bullet_n S] \\ &= [(S \bullet_n x) \bullet_n (S \bullet_n S)] \cup [(S \bullet_n S) \bullet_n x] \\ &= [(S \bullet_n S) \bullet_n (x \bullet_n S)] \cup (S \bullet_n x) \\ &= [x \bullet_n ((S \bullet_n S) \bullet_n S)] \cup (S \bullet_n x) \\ &= S \bullet_n x \cup x \bullet_n S. \end{aligned}$$

Therefore we obtain that $S \bullet_n x \cup x \bullet_n S$ is a SuperHyperRightHyperIdeal of S. □

For that, we need the following theorem.

Theorem 3.13. *Let S be a 2-SuperHyper-$\mathcal{LA}$-semihypergroup with pure left identity. Then the following properties hold.*

(1) *If x is an element of S, then $x^2 \bullet_n S$ is a SuperHyperHyperIdeal of S.*

(2) *If x is an element of S, then $S \bullet_n x^2$ is a SuperHyperHyperIdeal of S.*

(3) *If x is an element of S, then $S \bullet_n x \cup x \bullet_n S$ is a SuperHyperHyperIdeal of S.*

Proof. 1. Let x be an element of $\mathcal{N}(S)$. By Theorem 3.12 (1), we have that $x^2 \bullet_n S$ is a SuperHyperLeftHyperIdeal of $\mathcal{N}(S)$. Since

$$\begin{aligned}\left(x^2 \bullet_n S\right) \bullet_n S &= (S \bullet_n S) \bullet_n x^2 \\ &= x^2 \bullet_n (S \bullet_n S) \\ &= x^2 \bullet_n S,\end{aligned}$$

we have $x^2 \bullet_n S$ is a SuperHyperRightHyperIdeal of S and so $x^2 \bullet_n S$ is a SuperHyperHyperIdeal of S.

2. The proof is similar to the proof of (1).

3. Let x be an element of S. By Theorem 3.12 (3), we have that $S \bullet_n x \cup x \bullet_n S$ is a SuperHyperRightHyperIdeal of $\mathcal{N}(S)$. By Theorem 3.6, Lemma 3.7 and Proposition 3.11 (3), we have

$$\begin{aligned}S \bullet_n (S \bullet_n x \cup x \bullet_n S) &= [S \bullet_n (S \bullet_n x)] \cup [S \bullet_n (x \bullet_n S)] \\ &= [(S \bullet_n S) \bullet_n (S \bullet_n x)] \cup [x \bullet_n (S \bullet_n S)] \\ &= [(x \bullet_n S) \bullet_n (S \bullet_n S)] \cup (x \bullet_n S) \\ &= [((S \bullet_n S) \bullet_n S) \bullet_n x] \cup (x \bullet_n S) \\ &= S \bullet_n x \cup x \bullet_n S.\end{aligned}$$

Therefore we obtain that $S \bullet_n x \cup x \bullet_n S$ is a SuperHyperLeftHyperIdeal of S and hence $S \bullet_n x \cup x \bullet_n S$ is a SuperHyperHyperIdeal of S. □

Theorem 3.14. *Every SuperHyperRightHyperIdeal of 2-SuperHyper-$\mathcal{LA}$-semihypergroup S with pure left identity is SuperHyperHyperIdeal.*

Proof. Let R be a SuperHyperRightHyperIdeal of S. By Theorem 3.6, Lemma 3.7 and Proposition 3.11 (3), we have

$$\begin{aligned}S \bullet_n R &= (S \bullet_n S) \bullet_n R \\ &= (R \bullet_n S) \bullet_n S \\ &\subseteq R \bullet_n S \\ &\subseteq R.\end{aligned}$$

Therefore we obtain that R is a SuperHyperLeftHyperIdeal of S and hence R is a SuperHyperHyperIdeal of S. □

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