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ON NANO (1,2)* GENERALIZED-SEMI CLOSED SETS IN NANO BITOPOLOGICAL SPACES

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ABSTRACT

The purpose of this paper is to define and study a new class of sets called Nano (1,2) generalized-semi closed sets in nano bitopological spaces. Basic properties of nano (1,2)* generalized semi closed sets are analyzed. Also the new Characterization on Nano (1,2)* generalized-semi spaces are introduced and their relation with already existing well known spaces are also investigated.*

KEYWORDS : *Nano (1,2)* Generalized-semi Closed sets, nano (1.2)* generalized semi-*T_0 *, nano (1,2)* generalized semi-*T_1 .

1.INTRODUCTION

In 1970, Levine[13] introduced the concept of generalized closed sets as a generalization of closed sets in topological spaces. While in 1987, P.Bhattacharyya et.al.,[2] have introduced the notion of semi generalized closed sets in topological spaces. In 1990, S.P.Arya et.al.,[1] have introduced the concept of generalized semi closed sets. In 1975, S.N.Maheshwari et al.,[14] have defined the concepts of semi separation axioms. The notion of nano topology was introduced by Lellis Thivagar[7]. In 1963, J.C.Kelly[9] initiated the study of bitopological spaces. Mean while in 1987, Fukutake[6] introduced generalized closed sets and pairwise generalized closure operator in bitopological spaces. In 1989, Fukutake [7] introduced semi open sets in bitopological spaces. In 2014 K.Bhuvaneswari et al.,[4] have introduced the notion of nano semi generalized and generalized semi closed sets in nano topological space . In this paper, the concept of new class of sets on nano bitotpological spaces called nano (1,2)* generalized semi closed sets and the characterization of nano (1,2)* generalized semi spaces are introduced. Also study the relation of these new sets with the existing sets.

2.PRELIMINARIES

Definition:2.1 [12] A subset A of a topological space (X,τ) is called a semi open set if $A \subseteq cl[Int(A)]$. The complement of a semi open set of a space X is called semi closed set in X.

Definition:2.2 [2] A semi-closure of a subset A of X is the intersection of all semi closed sets that contains A and it is denoted by scl(A).

Definition:2.3 [2] The union of all semi open subsets of X contained in A is called semi-interior of A and it is denoted by $sInt(A)$.

Definition:2.4 [2] A subset A of (X,τ) is called a generalized semi closed set (briefly gs closed) if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.

Definition:2.5 [8] A space (X,τ) is called T_0 space, if and only if, each pair of distinct points x, y of X, there exist a open set containing one but not the other.

Definition:2.6 [8] A space (X,τ) is called T_1 space, if and only if, each pair of distinct points x, y of X, there exists a pair of open sets, one containing x but not y, and the other containing y but not x.

Definition:2.7 [14] A space (X,τ) is called semi -T_0 (briefly written as s-T_0), if and only if, each pair of distinct points x, y of X, there exist a semi open set containing one but not the other

Definition:2.8 [14] A space (X,τ) is called semi-T_1 (briefly written as s- T_1), if and only if, each pair of distinct points x, y of X, there exists a pair of semi open sets, one containing x but not y and the other containing y but not x.

Definition:2.9 [11] If $(U, \tau_R(X))$ is a nano topological space with respect to X where $X \subseteq U$ and if $A \subseteq U$, then

- The nano interior of the set A is defined as the union of all nano open subsets contained in A and is denoted by NInt(A). NInt(A) is the largest nano open subset of A.
- The nano closure of the set A is defined as the intersection of all nano closed sets containing A and is denoted by Ncl(A). Ncl(A) is the smallest nano closed set containing A.

Definition:2.10 [11] Let $(U, \tau_R(X))$ be a nano topological space and $A \subseteq U$. Then A is said to be

- Nano semi open if $A \subseteq Ncl[NInt(A)]$
- Nano semi closed if $NInt[Ncl(A)] \subseteq A$

NSO(U,X), NSC(U,X) respectively denote the families of all nano semi open, nano semi closed subsets of U.

Definition:2.11 [4] If $(U, \tau_R(X))$ is a nano topological space with respect to X where $X \subseteq U$ and if $A \subseteq U$, Then

(i)The nano semi-closure of A is defined as the intersection of all nano semi closed sets containing A and it is denoted by Nscl(A). Nscl(A) is the smallest nano semi closed set containing A.

(ii) The nano semi-interior of A is defined as the union of all nano semi open subsets of A contained in A and it is denoted by NsInt(A). NsInt(A) is the largest nano semi open subset of A.

Definition:2.12 [4] A subset A of $(U, \tau_R(X))$ is called nano generalized-semi closed set (briefly Ngs closed) if $Nscl(A) \subseteq V$ whenever $A \subseteq V$ and V is nano open in $(U, \tau_R(X))$.

Definition:2.13 [6] Let $(X, \tau_{1,2})$ be a bitopological space and $A \subseteq U$. Then A is said to be

- (1,2)* Semi open if $A \subseteq \tau_{1,2}cl[\tau_{1,2}Int(A)]$
- (1,2)* Semi closed if $\tau_{1,2}Int[\tau_{1,2}cl(A)] \subseteq A$

(1,2)*SO(X), (1,2)*SC(X) respectively denote the families of all (1,2)* semi open, (1,2)* semi closed subsets of X.

Definition:2.14 [7] If $(X, \tau_{1,2})$ is a bitopological space with respect to X and if $A \subseteq X$, then

(i)The (1,2)* semi-closure of A is defined as the intersection of all (1,2)* semi closed sets containing A and it is denoted by $\tau_{1,2}$ scl(A). $\tau_{1,2}$ scl(A) is the smallest (1,2)* semi closed set containing A.

(ii) The (1,2)* semi-interior of A is defined as the union of all (1,2)* semi open subsets of A contained in A and it is denoted by $\tau_{1,2}$ sInt(A). $\tau_{1,2}$ sInt(A) is the largest (1,2)*semi open subset of A.

Definition:2.15 [7] A subset A of $(X, \tau_{1,2})$ is called (1,2)* generalized-semi closed set (briefly (1,2)* gs closed) if $\tau_{1,2} scl(A) \subseteq U$ whenever $A \subseteq U$ and U is (1,2)* open in $(X, \tau_{1,2})$.

Definition:2.16 [5] A subset A of $(U, \tau_{R_{1,2}}(X))$ is called nano (1,2)* semi-generalized closed set (briefly N(1,2)*sg-closed) if $N\tau_{1,2} scl(A)) \subseteq V$ whenever $A \subseteq V$ and V is nano (1,2)* semi open in $(U, \tau_{R_{1,2}}(X))$

3. NANO (1,2)* GENERALIZED –SEMI CLOSED SETS

In this section, the definition of nano (1,2)* generalized semi closed sets are introduced and studied some of its properties.

Definition:3.1[5] Let U be the universe, R be an equivalence relation on U and $\tau_{R_{1,2}}(X) = \cup\{\tau_{R_1}(X), \tau_{R_2}(X)\}$ where $\tau_R(X) = \{U, \phi, L_R(X), U_R(X), B_R(X)\}$ and $X \subseteq U$. Then $\tau_R(X)$ satisfies the following axioms:

- U and $\Phi \in \tau_R(X)$
- The union of the elements of any sub-collection of $\tau_R(X)$ is in $\tau_R(X)$
- The intersection of the elements of any finite sub collection of $\tau_R(X)$ is in $\tau_R(X)$.

Then $(U, \tau_{R_{1,2}}(X))$ is called the nano bitopological space. Elements of the nano bitopology are known as nano (1,2)* open sets in U. Elements of $[\tau_{R_{1,2}}(X)]^C$ are called nano (1,2)* closed sets in $\tau_{R_{1,2}}(X)$.

Example:3.2 [5] Let $U = \{a,b,c,d\}$ with $U/R = \{\{c\},\{d\},\{a,b\}\}$

$X_1 = \{a,c\}$ and $\tau_{R_1}(X) = \{U, \phi, \{c\}, \{a,b,c\}, \{a,b\}\}$

$X_2 = \{b,d\}$ and $\tau_{R_2}(X) = \{U, \phi, \{d\}, \{a,b,d\}, \{a,b\}\}$

Then $\tau_{R_{1,2}}(X) = \{U, \phi, \{c\}, \{d\}, \{a,b\}, \{a,b,c\}, \{a,b,d\}\}$ which are (1,2)* open sets.

The nano (1,2)* closed sets = $\{U, \phi, \{c\}, \{d\}, \{c,d\}, \{a,b,c\}, \{a,b,d\}\}$.

Definition:3.3 [5] If $(U, \tau_{R_{1,2}}(X))$ is a nano bitopological space with respect to X where $X \subseteq U$ and if $A \subseteq U$, then

(i) The nano (1,2)* closure of A is defined as the intersection of all nano (1,2)* closed sets containing A and it is denoted by $N\tau_{1,2}cl(A)$. $N\tau_{1,2}cl(A)$ is the smallest nano (1,2)* closed set containing A.

(ii) The nano (1,2)* interior of A is defined as the union of all nano (1,2)* open subsets of A contained in A and it is denoted by $N\tau_{1,2}Int(A)$. $N\tau_{1,2}Int(A)$ is the largest nano (1,2)* open subset of A.

Definition:3.4 [5] A subset A of $(U, \tau_{R_{1,2}}(X))$ is called nano (1,2)* semi open set if $A \subseteq N\tau_{1,2}cl[N\tau_{1,2}Int(A)]$. The complement of a nano (1,2)* semi open set of a space U is called nano (1,2)* semi closed set in $(U, \tau_{R_{1,2}}(X))$.

Definition:3.5 [5] If $(U, \tau_{R_{1,2}}(X))$ is a nano bitopological space with respect to X where $X \subseteq U$ and if $A \subseteq U$, then

(i) The nano (1,2)* semi-closure of A is defined as the intersection of all nano (1,2)* semi closed sets containing A and it is denoted by $N\tau_{1,2}scl(A)$. $N\tau_{1,2}scl(A)$ is the smallest nano (1,2)* semi closed set containing A.

(ii) The nano (1,2)* semi-interior of A is defined as the union of all nano (1,2)* semi open subsets of A contained in A and it is denoted by $N\tau_{1,2}sInt(A)$. $N\tau_{1,2}sInt(A)$ is the largest nano (1,2)* semi open subsets of A.

Definition:3.6 A subset A of $(U,\tau_{R_{1,2}}(X))$ is called nano (1,2)* generalized-semi closed set (briefly N(1,2)*gs-closed) if $N\tau_{1,2}scl(A)) \subseteq V$ whenever $A \subseteq V$ and V is nano (1,2)* open in $(U,\tau_{R_{1,2}}(X))$.

Example:3.7 Let $U = \{a,b,c,d\}$ with $U / R = \{\{c\},\{d\},\{a,b\}\}$

$X_1 = \{a,c\}$ and $\tau_{R_1}(X) = \{U,\phi,\{c\},\{a,b,c\},\{a,b\}\}$

$X_2 = \{b,d\}$ and $\tau_{R_2}(X) = \{U,\phi,\{d\},\{a,b,d\},\{a,b\}\}$

Then $\tau_{R_{1,2}}(X) = \{U,\phi,\{c\},\{d\},\{a,b\},\{a,b,c\},\{a,b,d\}\}$ are (1,2)* open sets.

The nano (1,2)* closed sets = $\{U,\phi,\{c\},\{d\},\{c,d\},\{a,b,c\},\{a,b,d\}\}$.

The nano (1,2)* semi closed sets = $\{U,\phi,\{c\},\{d\},\{a,b\},\{c,d\},\{a,b,c\},\{a,b,d\}\}$

The nano (1,2)* semi open sets = $\{U,\phi,\{a,b,d\},\{a,b,c\},\{c,d\},\{a,b\},\{d\},\{c\}\}$

The nano (1,2)* semi-generalized open sets are

$$\{U,\phi,\{a\}\{b\},\{c\},\{d\},\{a,b\},\{a,c\},\{a,d\},\{b,c\},\{b,d\},\{c,d\},\{a,b,c\},$$
$$\{a,b,d\},\{a,c,d\},\{b,c,d\}\} .$$

The nano (1,2)* semi-generalized closed sets are

$$\{U,\phi,\{a\}\{b\},\{c\},\{d\},\{a,b\},\{a,c\},\{a,d\},\{b,c\},\{b,d\},\{c,d\},\{a,b,c\},$$
$$\{a,b,d\},\{a,c,d\},\{b,c,d\}\} .$$

The nano (1,2)* generalized-semi open sets are

$$\{U,\phi,\{a\}\{b\},\{c\},\{d\},\{a,b\},\{a,c\},\{a,d\},\{b,c\},\{b,d\},\{c,d\},\{a,b,c\},$$

$$\{a,b,d\},\{a,c,d\},\{b,c,d\}\} \quad .$$

The nano (1,2)* generalized-semi closed sets are

$$\{U,\phi,\{a\}\{b\},\{c\},\{d\},\{a,b\},\{a,c\},\{a,d\},\{b,c\},\{b,d\},\{c,d\},\{a,b,c\},$$

$$\{a,b,d\},\{a,c,d\},\{b,c,d\}\}.$$

Remark:3.8 Every nano (1,2)* semi-generalized closed set is a nano (1,2)* generalized-semi closed set. In Example 3.7, all nano (1,2)* semi-generalized closed sets are nano (1,2)* generalized-semi closed sets.

Remark:3.9 The converse of the above Remark 3.8 is need not be true. In Example 3.7, let $A=\{a\}\subseteq V$, $V=\{a,b,c,d\}$, V is nano (1,2)* open. $N\tau_{1,2}cl(A)=\{a,b\}\subseteq V$. Now $N\tau_{1,2}scl(A)=\{a,b\}\subseteq N\tau_{1,2}cl(A)$. If $N\tau_{1,2}cl(A)\subseteq V$, then $N\tau_{1,2}scl(A)\subseteq N\tau_{1,2}cl(A)$.

Theorem:3.10 Let $(U,\tau_{R_{1,2}}(X))$ be a nano bitopological space. If a subset A of a nano bitopological space $(U,\tau_{R_{1,2}}(X))$ is nano (1,2)* closed set in $(U,\tau_{R_{1,2}}(X))$, then A is a nano (1,2)* generalized-semi closed set in $(U,\tau_{R_{1,2}}(X))$.

Proof: Let A be a nano (1,2)* closed set of U and $A\subseteq V$, V is nano(1,2)* open in U. Since A is nano (1,2)* closed, $N\tau_{1,2}cl(A)=A$. So, $A\subseteq V$ and $N\tau_{1,2}cl(A)=A$ imply $N\tau_{1,2}cl(A)\subseteq V$. Also, $N\tau_{1,2}scl(A)\subseteq N\tau_{1,2}cl(A)$ implies $N\tau_{1,2}scl(A)\subseteq V$, $A\subseteq V$ V is nano (1,2)* open in U. Therefore, A is a nano (1,2)* generalized-semi closed set.

Theorem:3.11 Let $(U,\tau_{R_{1,2}}(X))$ be a nano bitopological space. If a subset A of a nano bitopological space $(U,\tau_{R_{1,2}}(X))$ is nano (1,2)* semi closed set in $(U,\tau_{R_{1,2}}(X))$, then A is a nano (1,2)* generalized semi closed set in $(U,\tau_{R_{1,2}}(X))$.

Proof: Let A be a nano (1,2)* semi closed set of U and $A \subseteq V$, V is nano (1,2)* open in U. Since A is nano (1,2)* semi closed, $N\tau_{1,2}scl(A) = A$. So, $A \subseteq V$ and $N\tau_{1,2}scl(A) = A$ imply $N\tau_{1,2}scl(A) \subseteq V$. Also, $A \subseteq V$, V is nano (1,2)* open in U. Therefore, A is a nano (1,2)* generalized-semi closed set.

Remark:3.12 The converse of the above Theorem 3.11 need not be true. In the Example 3.7, let A={a,c,d} be a nano (1,2)* generalized-semi closed set. Here $N\tau_{1,2}scl(A) \subseteq V$ whenever $A \subseteq V$, V is nano (1,2)* open in U. Hence $A = \{a,c,d\} \subseteq U$ is a nano (1,2)* generalized-semi closed set. Now $N\tau_{1,2}cl(A) = U$ and $N\tau_{1,2}Int(N\tau_{1,2}cl(A)) = U \not\subseteq A$ which implies that the set A={a,c,d} is not a nano (1,2)* semi closed set.

Theorem:3.13 Let A be a nano (1,2)* generalized-semi closed subset of $(U, \tau_{R_{1,2}}(X))$. If $A \subseteq B \subseteq N\tau_{1,2}scl(A)$, then B is also a nano (1,2)* generalized-semi closed subset of $(U, \tau_{R_{1,2}}(X))$.

Proof: Let V be a nano (1,2)* open set of a nano (1,2)* generalized-semi closed subset of $\tau_{R_{1,2}}(X)$ such that $B \subseteq V$. As $A \subseteq B$, implies $A \subseteq V$. As A is a nano (1,2)* generalized-semi closed set, $N\tau_{1,2}scl(A) \subseteq V$. Given $B \subseteq N\tau_{1,2}scl(A)$, implies $N\tau_{1,2}scl(B) \subseteq N\tau_{1,2}scl(A)$. As $N\tau_{1,2}scl(B) \subseteq N\tau_{1,2}scl(A)$ and $N\tau_{1,2}scl(A) \subseteq V$, implies $N\tau_{1,2}scl(B) \subseteq V$ whenever $B \subseteq V$ and V is nano (1,2)* open. Hence B is also a nano (1,2)* generalized-semi closed subset of $(U, \tau_{R_{1,2}}(X))$.

Theorem:3.14 Let A be a nano (1,2)* generalized-semi closed set in $(U, \tau_{R_{1,2}}(X))$. Then $N\tau_{1,2}scl(A) - A$ has no non-empty nano (1,2)* closed set.

Proof: Let A be nano (1,2)* generalized semi closed set in $(U, \tau_{R_{1,2}}(X))$ and F be a nano (1,2)* closed subset of $N\tau_{1,2}scl(A) - A$. That is, $F \subseteq N\tau_{1,2}scl(A) - A$. Which implies that $F \subseteq N\tau_{1,2}scl(A) \cap A^c$. That is $F \subseteq N\tau_{1,2}scl(A)$ and $F \subseteq A^c$. $F \subseteq A^c$ implies that $A \subseteq F^c$ where F^c is a nano (1,2)* open set. Since A is nano (1,2)* semi generalized closed,

$N\tau_{1,2}scl(A) \subseteq F^c$. That is $F \subseteq [N\tau_{1,2}scl(A)]^C$. Thus $F \subseteq N\tau_{1,2}scl(A) \cap [N\tau_{1,2}scl(A)]^C = \phi$. Therefore $F = \phi$.

Theorem:3.15 Let A be a nano (1,2)* generalized semi closed set in $(U, \tau_{R_{1,2}}(X))$. Then A is nano (1,2)* closed if and only if, $N\tau_{1,2}scl(A) - A$ is nano (1,2)* closed set.

Proof: Let A be a nano (1,2)* generalized semi closed set in $(U, \tau_{R_{1,2}}(X))$. If A is nano (1,2)* closed, then $N\tau_{1,2}scl(A) - A = \phi$, which is a nano (1,2)* closed set.

Conversely, let $N\tau_{1,2}scl(A) - A$ be nano (1,2)* closed. Then by the above Theorem 3.14 $N\tau_{1,2}scl(A) - A$ does not contain any non-empty nano (1,2)* closed set. Thus, $N\tau_{1,2}scl(A) - A = \phi$. That is, $N\tau_{1,2}scl(A) = A$. Therefore A is nano (1,2)* closed.

4. CHARACTERIZATIONS ON NANO (1,2)* GENERALIZED-SEMI SPACES

In this section some new characterizations of Nano (1,2)* generalized-semi spaces are introduced and studied some of its properties.

Definition:4.1 If $(U, \tau_{R_{1,2}}(X))$ is a nano bitopological space with respect to X where $X \subseteq U$ and if $A \subseteq U$, Then

(i)The nano (1,2)*generalized semi closure of A is defined as the intersection of all nano (1,2)* generalized semi closed sets containing A and it is denoted by $N\tau_{1,2}gscl(A)$. $N\tau_{1,2}gscl(A)$ is the smallest nano (1,2)* generalized semi closed set containing A.

(ii) The nano (1,2)* generalized semi interior of A is defined as the union of all nano (1,2)* generalized semi open subsets of A contained in A and it is denoted by $N\tau_{1,2}gsInt(A)$ $N\tau_{1,2}gsInt(A)$ is the largest nano (1,2)* generalized semi open subset of A.

Definition:4.2 [5] A space $(U, \tau_{R_{1,2}}(X))$ is called nano (1,2)*-T_0 (briefly written as N(1,2)*-T_0), if and only if, each pair of distinct points x, y of $\tau_{R_{1,2}}(X)$, there exist a nano (1,2)* open set containing one but not the other.

Definition:4.3 [5] A space $(U, \tau_{R_{1,2}}(X))$ is called nano (1,2)* semi -T_0 (briefly written as N(1,2)*s-T_0), if and only if, each pair of distinct points x, y of $\tau_{R_{1,2}}(X)$, there exist a nano (1,2)* semi open set containing one but not the other.

Definition:4.4 A space $(U, \tau_{R_{1,2}}(X))$ is called nano (1,2)* generalized semi-T_0 (briefly written as N(1,2)*gs-T_0), if and only if, each pair of distinct points x, y of $\tau_{R_{1,2}}(X)$, there exist a nano (1,2)* generalized semi open set containing one but not the other.

Remark:4.5 Every nano (1,2)* semi-T_0 space is nano (1,2)* generalized semi-T_0 space since every nano (1,2)* semi open set is nano (1,2)* generalized semi open set but converse is not true.

Theorem:4.6 If in any nano bitopological space $(U, \tau_{R_{1,2}}(X))$, nano (1,2)* generalized semi closures of distinct points are distinct, then $\tau_{R_{1,2}}(X)$ is nano (1,2)* generalized semi- T_0

Proof: Let $x, y \in \tau_{R_{1,2}}(X)$, $x \neq y$ imply $N\tau_{1,2}gscl\{x\} \neq N\tau_{1,2}gscl\{y\}$. Then there exists a point $z \in \tau_{R_{1,2}}(X)$ such that z belongs one of two sets, say $N\tau_{1,2}gscl\{y\}$ but not to $N\tau_{1,2}gscl\{x\}$. If suppose that $z \in N\tau_{1,2}gscl\{x\}$, then $z \in N\tau_{1,2}gscl\{y\} \subset N\tau_{1,2}gscl\{x\}$, which is contradiction. So, $y \in X - N\tau_{1,2}gscl\{x\}$, where $X - N\tau_{1,2}gscl\{x\}$ is nano (1,2)* generalized semi open set which does not contain x, This shows that X is generalized semi-T_0 .

Theorem:4.7 In any nano bitopological space $(U, \tau_{R_{1,2}}(X))$, nano (1,2)* generalized semi closures of distinct points are distinct.

Proof: Let $x, y \in \tau_{R_{1,2}}(X)$ with $x \neq y$. To show that $N\tau_{1,2}gscl\{x\} \neq N\tau_{1,2}gscl\{y\}$ Considered the two sets $N\tau_{1,2}gscl\{x\}$ and $N\tau_{1,2}gscl\{y\}$ in $\tau_{R_{1,2}}(X)$. Then there exists a point $z \in \tau_{R_{1,2}}(X)$ such that z belongs one of two sets, say $N\tau_{1,2}gscl\{y\}$ but not to

$N\tau_{1,2}gscl\{x\}$. If suppose that $z \in N\tau_{1,2}gscl\{x\}$, then $z \in N\tau_{1,2}gscl\{y\} \subset N\tau_{1,2}gscl\{x\}$, which is contradiction. Hence $N\tau_{1,2}gscl\{x\} \neq N\tau_{1,2}gscl\{y\}$.

Definition:4.8 A space $(U, \tau_{R_{1,2}}(X))$ is called nano (1,2)* generalized semi-T_1 (briefly written as N(1,2)*gs- T_1), if and only if, each pair of distinct points x, y of X, there exists a pair of nano (1,2)* generalized semi open sets, one containing x but not y, and the other containing y but not x.

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