International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-05, Issue-02, May 2019

Nδĝ Closed Sets in Nano Topological Spaces

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Abstract: **In this paper a new class of sets, namely Nδĝ -closed sets is introduced in nano topological spaces. We prove that this class lies between the class of Nδ-closed sets and the class of Nδg -closed sets. Also we find some basic properties and characterisation of Nδĝ- closed sets. Applying this sets to introduce an new space namely N$T_{3/4}$ -space and N$\hat{T}_{3/4}$ -space.**

Keywords*: *Nδg-closed sets, Nδ- closure, N$\hat{g}$-open sets, N$\delta\hat{g}$-closed sets,* N$T_{3/4}$*-space and* N$\hat{T}_{3/4}$*–space.

I. Introduction

M. Lellis Thivagar and Carmel Richard [6] introduced nano topological space (or simply NTS) with respect to a subset X of a universe which is defined in terms of lower and upper approximation of X. He has also defined nano closed sets (briefly N-CS), nano interior and nano closure of a set. In 2013, M. Lellis Thivagar and Carmel Richard [6] introduced nano semi-open, nano regular-open, nano pre open, nano α-open. R. Lalitha and Dr. A. Francina shalini [5] introduced N$\hat{g}$-closed set in nano topological spaces. The purpose of this present paper is to define a new class of nano closed sets called N$\delta\hat{g}$-closed sets and also we obtain some basic properties of N$\delta\hat{g}$-closed sets in nano topological space. Applying these sets, we obtain a new space which is called N$T_{3/4}$-space, N$\hat{T}_{3/4}$-space.

II. Preliminaries

Throughout this paper, (U, τ_R(X)) (or simply U) represent Nano Topological Spaces on which no separation axioms are assumed unless otherwise mentioned. For a set A in a NTS (U, τ_R(X)), Ncl(A), Nint(A) and A^c denote the nano closure of A, the nano interior of A and the nano complement of A respectively. Let us recall the following definitions, which are useful in the sequel.

Definition 2.1. [8] Let U be a non-empty finite set of objects called the universe and R be an equivalence relation on U named as the indiscernibility relation. Elements belonging to the same equivalence class are said to be indiscernible with in another. The pair (U, R) is called the approximation space.

Remark 2.2. [8] Let (U, R) be an approximation space and X ⊆ U. Then

(i)The lower approximation of X with respect to R is the set of all objects, which can be for certain classified as X with respect to R and it is denoted by L_R(X). That is, $L_R(X) = \cup\{R(x) : R(x) \subseteq X, x \in U\}$, where R(x) denotes the equivalence class determined by x.

(ii) The upper approximation of X with respect to R is the set of all objects, which can be possibly classified as X with respect to R and it is denoted by U_R(X). That is, $U_R(X) = \cup \{R(x) : R(x) \cap X \neq \phi , x \in U\}$.

(iii) The boundary region of X with respect to R is the set of all objects, which can be classified neither as X nor as not X with respect to R and it is denoted by B_R(X). That is, $B_R(X) = U_R(X) - L_R(X)$.

Definition 2.3. [6] Let U be the universe, R be an equivalence relation on U and $\tau_R(X) = \{\phi, U, L_R(X), U_R(X), B_R(X)\}$ where X⊆ U. Then τ_R(X) satisfies the following axioms.

(i) U and $\phi \in \tau_R(X)$.

(ii) The union of the elements of any subcollection of τ_R(X) is in τ_R(X).

(iii) The intersection of the elements of any finite subcollection of τ_R(X) is in τ_R(X).

That is, τ_R(X) forms a topology on U called as the Nano topology on U with respect to X. We call (U, τ_R(X)) as the Nano topological space. The elements of τ_R(X) are called as Nano open sets (briefly N -OS).

Definition 2.4. [6] A subset A of a NTS (U, τ_R(X)) is called a

(i) nano semi-open set (briefly Ns -OS) if A⊆ Ncl(Nint(A)). (ii) nano pre-open set (briefly Np -OS) if A ⊆ Nint(Ncl(A)). (iii) nano α− open set (briefly Nα -OS) if A⊆ Nint(Ncl(Nint(A))) .

(iv) nano regular open set (briefly Nr -OS) if A = Nint(Ncl(A)).

The complement of a nano semi-open (resp. nano pre-open, nano α -open, nano regular open) set is called nano semi-closed (resp. nano semi-closed, nano α- closed, nano-regular closed).

 DOI : 10.35291/2454-9150.2019.0129

Definition 2.5. [1] The Nδ−interior of a subset A of U is the union of all nano regular open set of U contained in A and is denoted by $NInt_{\delta}$(A). The subset A is called Nδ−open if A = $NInt_{\delta}$(A), i.e. a set is Nδ−open if it is the union of nano regular open sets. The complement of a Nδ−open is called Nδ−closed. Alternatively, a set A ⊆ (U, τ_R(X)) is called Nδ−closed if A=Ncl_{δ}(A), where $NInt_{\delta}$ (A)= {x∈U: NInt(Ncl(M))∩A ≠ ϕ, M∈ τ_R(X) and x∈ M }.

Definition 2.6. A subset A of a NTS (U, τ_R(X)) is called

(i) nano generalized closed set (briefly Ng − CS) [3] if Ncl(A)⊆M and M is a N – OS in (U, τ_R(X)) .

(ii) nano sg − closed set (briefly Nsg -CS) [2] if Nscl(A) ⊆M whenever A ⊆ M and M is a Ns -OS in (U, τ_R(X)).

(iii) nano gs − closed set (briefly Ngs -CS) [2] if Nscl(A) ⊆M whenever A ⊆M and M is a N –OS in (U, τ_R(X)).

(iv) nano αg − closed set (briefly Nαg -CS) [10] if Nαcl(A) ⊆ M whenever A⊆ M and M is a N − OS in (U, τ_R(X)).

(v) nano gα − closed set (briefly Ngα -CS) [10] if Nαcl(A) ⊆ M whenever A ⊆M and M is a Nα –OS in (U, τ_R((X)).

(vi) nano ĝ−closed set (briefly Nĝ -CS) [5] if Ncl(A) ⊆ M whenever A ⊆ M and M is a nano semi open set in

(U, τ_R(X)).

(vii) nano δg − closed set (briefly Nδg -CS) [1] if Ncl_{δ}(A) ⊆ M whenever A ⊆ M and M is a nano open set in (U, τ_R(X)).

The complement of a Ng−closed (resp. Nsg-closed,, Ngs-closed, Nαg-closed, Ngα-closed, Nĝ-closed and Nδg-closed) set is called Ng- open (resp. Nsg-open, Ngs-open, Nαg-open, Ngα-open, Nĝ- open and Nδg-open).

Theorem 2.7. [5] Every nano open set is Nĝ – open

Proof. Let A be an nano open set in U. Then A^c is nano closed. Therefore, Ncl (A^c) = A^c ⊆ U whenever A^c⊆ U and U is nano semi-open. This implies A^c is Nĝ – closed. Hence A is Nĝ – open.

Definition 2.8. [7] A subset A of a space (X, τ) is called δĝ – closed if cl_{δ}(A) ⊆ U whenever A ⊆ U and U is a ĝ-open set in (X , τ).

Definition 2.9. A space (X , τ) is called a

(i) $T_{3/4}$ − space [4] if every δg - closed set in it is δ -closed.

(ii) $\hat{T}_{3/4}$− space [7] if every δĝ -closed set in it is δ -closed.

Definition 2.10. A NTS (U, τ_R(X)) is called a N $T_{1/2}$ - space [9] if every Ng - closed set in it is N-closed.

III. Nδĝ− CLOSED SETS

In this section we define the following definition.

Definition 3.1. A subset A of a space (U, τ_R(X)) is called Nδĝ-closed if Ncl_{δ}(A) ⊆ V whenever A ⊆ V and V is a Nĝ- open set in (U, τ_R(X)) .

Proposition 3.2. Every Nδ -closed set is Nδĝ-closed set.

Proof. Let A be an Nδ-closed set and V be any Nĝ -open set containing A. Since A is Nδ -closed, Ncl_{δ}(A) = A for every subset A of U. Therefore Ncl_{δ}(A) ⊆ V and hence A is Nδĝ -closed set.

Remark 3.3. The converse of the above theorem is not true in general as shown in the following example.

Example 3.4. Let U = {a, b, c} with U/R = {a, b} and X= {a} with nano topology τ_R(X) = {U, ϕ, {a, b}}, Nδ -closed= {U, ϕ }, Nδĝ−closed = {U, ϕ, {c}, {a, c}, {b, c}}. Here {a, c} is Nδĝ-closed but not Nδ-closed in (U , τ_R(X)) .

Proposition 3.5. Every Nδĝ -closed set is Ng –closed.

Proof. Let A be an Nδĝ-closed set and V be an any nano open set containing A in (U, τ_R(X)). Since every nano open set is Nĝ− open and A is Nδĝ-closed, Ncl_{δ}(A)⊆V for every subset A of U. Since Ncl(A)⊆ Ncl_{δ}(A) ⊆V, Ncl(A)⊆V and hence A is Ng -closed.

Remark 3.6. An Ng−closed set is not Nδĝ-closed set in general as shown in the following example.

Example 3.7. Let U = {a, b, c} with U/R = {{a}, {c}, {a, b}} and X= {a, c} with nano topology τ_R(X) = {U, ϕ, {a, c}, {b}}, Ng -closed= {U, ϕ, {a}, {b}, {c}, {a, b}, {a, c}, {b, c}}. Nδĝ − closed = {U, ϕ, {b}, {a, c}}. Then the set {a} is Ng−closed but not Nδĝ-closed in (U, τ_R(X)).

Proposition 3.8. Every Nδĝ closed set is Ngs -closed.

Proof. Let A be an Nδĝ -closed and V be any nano open set containing A in (U, τ_R(X)). Since every nano open set is Nĝ-open, Ncl_{δ}(A) ⊆ V for every subset A of U. Since Nscl(A) ⊆ Ncl_{δ}(A) ⊆ V, Nscl(A)⊆V and hence A is Ngs− closed .

Remark 3.9. A Ngs -closed set is not Nδĝ-closed in general as shown in the following example.

Example 3.10. Let U = { a, b, c} with U/R = {{c}, {a, b}} and X= {a, c} with nano topology τ_R(X) = {U, ϕ, {c}, {a, b}} . Then the set {b} is Ngs-closed but not Nδĝ-closed in (U, τ_R(X)) .

Proposition 3.11. Every Nδĝ -closed set is Nαg -closed.

Proof. It is true that Nαcl(A) ⊆Ncl_{δ}(A) for every subset A of U .

Remark 3.12. A Nαg-closed set is not Nδĝ-closed in general as shown in the following example.

Example 3.13. Let U = {a, b, c} with U/R = {{a}, {b, c}, {b}} and X= {a, b} with nano topology τ_R (X) = {U, ϕ, {

 DOI : 10.35291/2454-9150.2019.0129

ISSN : 2454-9150 Vol-05, Issue-02, May 2019

a, b}, {c}}. Then the set {a, c} is $N\alpha g$ -closed but not $N\delta\hat{g}$-closed in (U, $\tau_R(X)$) .

Proposition 3.14. Every $N\delta\hat{g}$-closed set is $N\delta g$ -closed.

Proof. Let A be an $N\delta\hat{g}$-closed set and V be any nano open set containing A. Since every nano open set is $N\hat{g}$-open, $Ncl_\delta(A)\subseteq V$, whenever $A\subseteq V$ and V is $N\hat{g}$-open. Therefore $Ncl_\delta(A)\subseteq V$ and V is nano open. Hence A is $N\delta g$ -closed.

Remark 3.15. A $N\delta g$-closed set is not $N\delta\hat{g}$-closed in general as shown in the following example.

Example 3.16. Let U = {a, b, c} with U/R = {{a}, {b, c}} and X= {a, c} with nano topology $\tau_R(X)$ = {U, ϕ, {a}, {b, c}}. Then the set {c} is $N\delta g$-closed but not $N\delta\hat{g}$-closed in (U, $\tau_R(X)$) .

Remark 3.17. The class of $N\delta\hat{g}$-closed sets is properly placed between the classes of $N\delta$-closed and $N\delta g$ -closed sets.

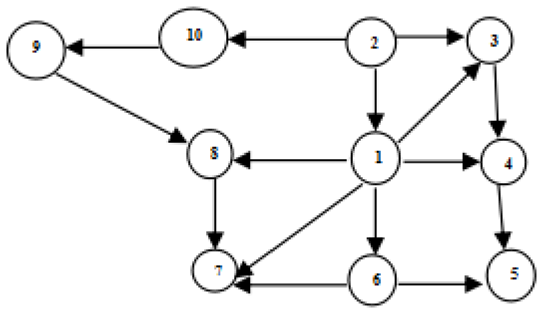
Remark 3.18. The following examples show that $N\delta\hat{g}$ -closeness is independent from $N\hat{g}$-closeness, Nsg-closeness and $Ng\alpha$-closeness.

Example 3.19. Let U = {a, b, c} with U/R = {{a}, {b, c}} and X = {a}, with nano topology $\tau_R(X)$ = {U, ϕ, {a}}. Then the set {a, b} is $N\delta\hat{g}$ –closed but neither $N\hat{g}$ -closed nor Nsg-closed and the set {a, c} is $N\delta\hat{g}$-closed but not $Ng\alpha$ -closed.

Also the another example, Let U = {a, b, c} with U/R = {{a, b}, {a}, {c}} and X ={a, c} with nano topology

$\tau_R(X)$ = {U, ϕ, {a, c}, {b}}. Then the set {c} is $N\hat{g}$-closed, Nsg -closed, $Ng\alpha$ -closed but not $N\delta\hat{g}$ -closed.

Remark 3.20. The following diagram shows the relationships of $N\delta\hat{g}$ –closed sets with other known existing sets. A→B represents A implies B but not conversely.



1. $N\delta\hat{g}$ -closed, 2. $N\delta$-closed, 3. $N\delta g$-closed, 4. Nsg-closed,

5. Ngs -closed, 6. $N\hat{g}$ -closed, 7. $N\alpha g$-closed, 8. $Ng\alpha$-closed, 9. $N\alpha$ -closed, 10. N-closed.

IV. CHARACTERISATION

Theorem 4.1. The finite union of $N\delta\hat{g}$-closed sets is $N\delta\hat{g}$-closed.

Proof. Let {Ai/i =1, 2, ...n} be a finite class of $N\delta\hat{g}$-closed subsets of a space (U, $\tau_R(X)$). Then for each $N\hat{g}$ -open set Vi in U containing Ai. $Ncl_\delta(Ai)\subseteq Vi$, i∈ {1, 2, ..., n}. Hence ∪iAi ⊆∪ iVi = W. Since arbitrary union of $N\hat{g}$−open sets in (U, $\tau_R(X)$) is also $N\hat{g}$-open set in (U, τR(X)) , W is $N\hat{g}$-open in (U, $\tau_R(X)$). Also $\cup iNcl_\delta(Ai)=Ncl_\delta(\cup iAi)\subseteq W$. Therefore ∪iAi is $N\delta\hat{g}$-closed in (U, $\tau_R(X)$) . □

Theorem 4.2. The arbitrary intersection of $N\delta\hat{g}$-closed sets is $N\delta\hat{g}$- closed.

Proof. Let {Ai/i =1, 2,....} be a arbitrary class of $N\delta\hat{g}$-closed subsets of a space (U, $\tau_R(X)$). Then for each $N\hat{g}$ -open set Vi in U containing Ai, $Ncl_\delta(Ai)\subseteq Vi$, i∈ {1, 2, ...,}. Hence ∩iAi ⊆∩ iVi = W. Since arbitrary intersection of $N\hat{g}$− open sets in (U, τ_R (X)) is also $N\hat{g}$-open set in (U, $\tau_R(X)$), W is $N\hat{g}$-open in(U, $\tau_R(X)$). Also $\cap iNcl_\delta(Ai) = Ncl_\delta(\cap iAi)\subseteq W$. Therefore ∩iAi is $N\delta\hat{g}$-closed in (U, $\tau_R(X)$) . □

Proposition 4.3. Let A be a $N\delta\hat{g}$ -closed set of (U, $\tau_R(X)$). Then $Ncl_\delta(A)-A$ does not contain a non-empty $N\hat{g}$ closed set.

Proof. Suppose that A is $N\delta\hat{g}$-closed, let F be a $N\hat{g}$-closed set contained in $Ncl_\delta(A)-A$. Now F^c is $N\hat{g}$-open set of (U, $\tau_R(X)$) such that $A\subseteq F^c$. Since A is $N\delta\hat{g}$−closed set of (U, $\tau_R(X)$), then $Ncl_\delta(A)\subseteq F^c$. Thus $F\subseteq (Ncl_\delta(A))^c$. Also $F\subseteq Ncl_\delta(A)-A$. Therefore $F\subseteq (Ncl_\delta(A))^c\cap(Ncl_\delta(A))=\phi$. Hence F = ϕ .

Proposition 4.4. If A is $N\hat{g}$-open and $N\delta\hat{g}$-closed subsets of (U, $\tau_R(X)$), then A is an $N\delta$-closed subset of (U, $\tau_R(X)$) .

Proof. Since A is $N\hat{g}$-open and $N\delta\hat{g}$-closed, $Ncl_\delta(A)\subseteq A$. Hence A is $N\delta$−closed . □

Proposition 4.5. If A is a $N\delta\hat{g}$-closed set in a space (U, $\tau_R(X)$) and $A\subseteq B\subseteq Ncl_\delta(A)$, then B is also a $N\delta\hat{g}$-closed set.

Proof. Let V be a $N\hat{g}$ − open set of (U, $\tau_R(X)$) such that $B\subseteq V$. Then $A\subseteq V$. Since A is $N\delta\hat{g}$– closed set, $Ncl_\delta(A)\subseteq V$. Also since $B\subseteq Ncl_\delta(A)$, $Ncl_\delta(B)\subseteq Ncl_\delta(Ncl_\delta(A)) = Ncl_\delta(A)$. Hence $Ncl_\delta(B)\subseteq V$. Therefore B is also a $N\delta\hat{g}$-closed set.

Theorem 4.6. Let A be $N\delta\hat{g}$-closed of (U, $\tau_R(X)$). Then A is $N\delta$-closed iff $Ncl_\delta(A)-A$ is $N\hat{g}$ -closed.

Proof. **Necessity:** Let A be a $N\delta$-closed subset of U. Then $Ncl_\delta(A)=A$ and so $Ncl_\delta(A)-A=\phi$ which is $N\hat{g}$-closed.

Sufficiency: Since A is $N\delta\hat{g}$-closed, by proposition 4.3, $Ncl_\delta(A)-A$ does not contain a non-empty $N\hat{g}$-closed set. But $Ncl_\delta(A)-A=\phi$. That is $Ncl_\delta(A)=A$. Hence A is $N\delta$–closed. □

V. APPLICATIONS

In this section we define the following definition.

Definition 5.1. A space (U, $\tau_R(X)$) is called a

(i) $NT_{3/4}$-space if every $N\delta g$-closed set in it is $N\delta$-closed.

 DOI : 10.35291/2454-9150.2019.0129

ISSN : 2454-9150 Vol-05, Issue-02, May 2019

(ii) $N\hat{T}_{3/4}$ -space if every $N\delta\hat{g}$-closed set in it is an $N\delta$ -closed.

Theorem 5.2. For a nano topological space $(U, \tau_R(X))$, the following conditions are equivalent.

(i) $(U, \tau_R(X))$ is a $N\hat{T}_{3/4}$-space.

(ii) Every singleton $\{x\}$ is either $N\hat{g}$-closed or $N\delta$ –open.

Proof. (i)⇒(ii) Let $x \in U$. Suppose $\{x\}$ is not a $N\hat{g}$-closed set of $(U, \tau_R(X))$. Then $U-\{x\}$ is not a $N\hat{g}$-open set. Thus $U-\{x\}$ is an $N\delta\hat{g}$–closed set of $(U, \tau_R(X))$. Since $(U, \tau_R(X))$ is $N\hat{T}_{3/4}$-space, $U-\{x\}$ is an $N\delta$–closed set of $(U, \tau_R(X))$, i.e . $\{x\}$ is $N\delta$ -open set of $(U, \tau_R(X))$.

(ii) ⇒(i) Let A be an $N\delta\hat{g}$-closed set of $(U, \tau_R(X))$. Let $x \in Ncl_\delta(A)$. By (ii), $\{x\}$ is either $N\hat{g}$ -closed or $N\delta$ -open.

Case(i): Let $\{x\}$ be $N\hat{g}$-closed. If we assume that $x \notin A$, then

we would have $x \in Ncl_\delta(A)-A$, which cannot happen according to proposition 4.3. Hence $x \in A$.

case(ii): Let $\{x\}$ be $N\delta$-open. Since $x \in Ncl_\delta(A)$, then $\{x\} \cap A \neq \phi$. This shows that $x \in A$.

So in both cases we have $Ncl_\delta(A) \subseteq A$. Trivially $A \subseteq Ncl_\delta(A)$. Therefore $A = Ncl_\delta(A)$ or equivalently A is $N\delta$ -closed. Hence $(U, \tau_R(X))$ is a $N\hat{T}_{3/4}$ - space.

Theorem 5.3. Every $NT_{3/4}$ -space is a $N\hat{T}_{3/4}$ -space.

Proof. The proof is straight forward since every $N\delta\hat{g}$ -closed set is $N\delta g$ -closed set. □

Remark 5.4. The converse of the above theorem is not true in general as it can be seen from the following example.

Example 5.5. Let U={a, b, c} with U/R={{a}, {b, c}} and X = {a, c} with nano topology $\tau_R(X) = \{U, \phi, \{a\}, \{b, c\}\}$. $(U, \tau_R(X))$ is a $N\hat{T}3/4$ -space but not a $NT3/4$ -space.

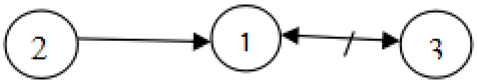
Remark 5.6.$N\hat{T}_{3/4}$–space and $NT_{1/2}$-space are independent of one another as the following example show.

Example 5.7. Let U={a, b, c} with U/R = {{a}, {b, c}} and X={a, c} with nano topology $\tau_R(X) = \{U, \phi, \{a\}, \{b, c\}\}$. $(U, \tau_R(X))$ is a $N\hat{T}_{3/4}$-space but is not a $NT_{1/2}$ -space.

Example 5.8. Let U={a, b, c} with U/R={{a, c}, {b}, {a}} and X = {a} with nano topology $\tau_R(X) = \{U, \phi, \{a\}, \{a, c\}, \{c\}\}$. $(U, \tau_R(X))$ is $NT_{1/2}$-space but not a $N\hat{T}_{3/4}$ -space.

Remark 5.9. The following diagram shows the relationships

$N\hat{T}_{3/4}$-space with other known existing spaces. A → B and A ↮ B represent A implies B but not conversely and A & B are independent respectively.



1. $N\hat{\hat{T}}_{3/4}$-space, 2. $NT_{3/4}$-space, 3. $NT_{1/2}$-space .

VI. CONCLUSION

In this paper we introduced $N\delta\hat{g}$– closed sets, properties and characterisation. Applying this sets to introduce an new space namely $NT_{3/4}$-space and $N\hat{\hat{T}}_{3/4}$-space. Further using this sets we introduce $N\delta\hat{g}$–continuous functions and $N\delta\hat{g}$– homeomorphism. Also this type of $N\delta\hat{g}$–continuous functions has a wide variety of applications in real life.

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