On a class of αg^{**}-closed sets in topological spaces and some mappings

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Abstract- In this paper, we introduced the concepts of αg^{**}-closed sets as well as αg^{**}-open sets and studied some of their basic properties. Further we defined αg^{**}-continuous mappings and investigated their basic properties. In addition we obtained αg^{**}-irresolute mappings and some of their properties are derived.

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I. Introduction

The concept of generalized closed (g-closed) sets in a topological space was introduced by Levine [8] and concept of $T_{1/2}$ spaces was initiated by Dunham [5] further investigated the properties of $T_{1/2}$ spaces and defined a new closure operator cl^* by using generalized closed sets. We begin with some basic concepts. A subset A of a topological space (X, τ) is called α-open[12] (resp. semi open[9]) if $A \subseteq int(cl(int(A)))$ (resp. $A \subseteq cl(int(A))$). Also A is said to be α-closed (resp. semi closed) if X – A is α-open (resp. semi open). The collection of all α-open (resp. semi open) subsets in (X, τ) is denoted by τ^α (resp. SO(X)). The α-closure (resp. semi closure) of a subset A is smallest α-closed (resp. semi closed) set containing A and this is denoted by $\alpha cl(A)$ (resp. scl(A)) in the present paper. We recall definitions of some generalized closed sets. A subset A is called $g\alpha$-closed[10] (resp. αg-closed [10], $g^\#\alpha$-closed[13]) if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is an α-open (resp. open, g-open) set in (X, τ). Moreover G. Sai Sundara Krishnan et.al [16] introduced the concept of g^{**}-open sets and defined a subset A of X is said to be g^{**} - open if and only if there exist an open set U of X such that $U \subseteq A \subseteq cl^{**}(U)$. Also its complement is called g^{**}-closed. A topological space (X, τ) is said to be a g^{**}-$T_{½}$ space if every g^{**}-closed set is closed. J.Chitra and D.Saravanakumar [2] introduced the concept of sg^{**}-closed sets and defined a subset A of X is said to be sg^{**} - closed if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is a g^{**}-open set in (X, τ).

In this paper we introduced the concept of αg^{**}-closed sets, which is analogous to α-generalized closed sets and introduced the notion $\alpha G^{**}C(X)$ which is the set of all αg^{**}-closed sets in a topological space. In addition, we defined the concept of αg^{**}-open sets and studied of its some basic properties. Finally we introduced the concept of αg^{**}-continuous and αg^{**}-irresolute maps in a topological space and investigated relationship between them. Throughout this paper we denoted cl^* by cl^{**} and we represented the topological spaces (X, τ), (Y, σ) and (Z, η) as X, Y and Z respectively. Unless otherwise no separation axiom mentioned.

II. αg^{**}-CLOSED SET

In this section we introduce a new class of closed set called αg^{**}-closed set and study further some of their properties.

Definition 2.1. Let A be subset of a topological space X. It is called αg^{**}-closed set if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is g^{**}-open. The set of all αg^{**}-closed sets denoted by $\alpha G^{**}C(X)$. A subset A of X is called αg^{**}-open if X – A is αg^{**}-closed in X.

Example 2.1. If X = {a, b, c, d}, $\tau = \{\emptyset, X, \{c, d\}\}$, then αg^{**}-closed sets of X are {∅, X, {a}, {b}, {a, b}, {a, c}, {a, d}, {b, c}, {b, d}, {a, b, c}, {a, b, d}, {a, c, d}, {b, c, d}}.

Remark 2.1. The concepts of α-open and g^{**}-open are independent.

Let X = {a, b, c} and $\tau = \{\emptyset, X, \{a\}, \{b\}, \{a, b\}\}$. Then {a, c} and {b, c} are g^{**}-open sets but not α-open.

Let X = {a, b, c} and $\tau = \{\emptyset, X, \{a\}\}$. Then {a, b} and {a, c} are α-open sets but not g^{**}-open.

Remark 2.2. The concepts of g-closed sets and αg^{**}-closed sets are independent.

Let X = {a, b, c, d} and $\tau = \{\emptyset, X, \{b\}, \{b, c\}, \{a, b, c\}, \{b, c, d\}\}$. Then {a, b, d} is a g-closed set but not αg^{**}-closed. Also {c}, {a, c} and {c, d} are αg^{**}-closed sets but not g-closed.

Theorem 2.1. Let A be a subset of a topological space X and if A is a α-closed set in X, then A is αg^{**}-closed.

Proof: Let A be a α-closed set in X and $A \subseteq U$ where U is g^{**}-open. Since A is α-closed, $\alpha cl(A) = A \subseteq U$. Hence A is αg^{**}-closed in X.
The reverse implication does not hold.

Example 2.2. Let X = {a, b, c, d} and $\tau = \{\emptyset, X, \{a\}, \{b\}, \{a, b\}, \{b, c, d\}\}$. Then {b, c} is a αg^{**}-closed set but not α-closed.

Theorem 2.2. Let A be a subset of a topological space X and if A is a αg^{**}-closed set in X, then A is αg-closed.

Proof: Let A be a αg-closed set in X and $A \subseteq U$ where U is open. Since every open set is g^{**}-open and A is αg^{**}-closed, $\alpha cl(A) \subseteq U$. Hence A is αg-closed in X.

The reverse implication does not hold.

Example 2.3. Let X = {a, b, c, d} and τ = {∅, X, {a}, {a, b}, {a, c}, {a, b, c}, {a, b, d}}. Then {a, c, d} is a αg-closed set but not αg^{**}-closed.

Remark 2.3. The concepts of gα-closed and αg^{**}-closed are independent.

Let X = {a, b, c} and τ = {∅, X, {a}}. Then {a, b} and {a, c} are αg^{**}-closed sets but not gα-closed.

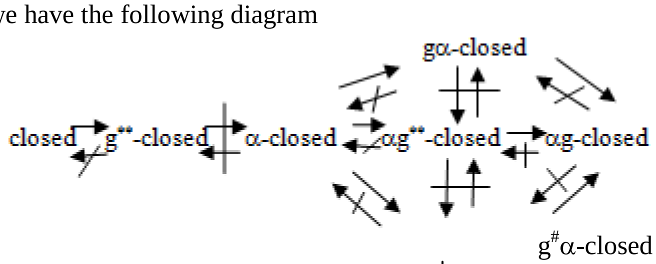
Let X = {a, b, c, d} and τ = {∅, X, {a}, {a, b}, {c, d}, {a, c, d}}. Then {b, c} and {b, d} are gα-closed sets but not αg^{**}-closed.

Remark 2.4. The concepts of $g^{\#}\alpha$-closed and αg^{**}-closed are independent.

Let X = {a, b, c, d} and τ = {∅, X, {a}, {b}, {a, b}, {b, c, d}}. Then {b, c} and {a, b, c} are αg^{**}-closed sets but not $g^{\#}\alpha$-closed.

Let X = {a, b, c, d} and τ = {∅, X, {b}, {b, c}, {a, b, c}, {b, c, d}}. Then {a, b, d} is a $g^{\#}\alpha$-closed set but not αg^{**}-closed.

Remark 2.5. From the Theorems 2.1, 2.2 and Remarks 2.3, 2.4, we have the following diagram



where A → B represents A imply B, A $\not\rightarrow$ B represents A does not imply B.

Theorem 2.3. If A is a αg^{**}-closed set in X, then it is sg^{**}-closed.

Proof: Let A be a αg^{**}-closed set such that $A \subseteq U$, where U is g^{**}-open. By Definition 2.1, we have $\alpha cl(A) \subseteq U$. Since $\alpha cl(A)$ is a semi closed set and scl(A) is the least semi closed set containing A, we have $scl(A) \subseteq \alpha cl(A) \subseteq U$. Hence A is sg^{**}-closed.

The reverse implication does not hold.

Example 2.4. Let X = {a, b, c, d} and τ = {∅, X, {a}, {b}, {a, b}, {a, b, c}}. Then {a}, {b}, {a, c} are sg^{**}-closed sets in X but not αg^{**}-closed.

Theorem 2.4. Let A be a αg-closed set in a topological space X. Then A is αg^{**}-closed if X is g^{**}-$T_{1/2}$.

Proof: Let A be a αg-closed set in X and $A \subseteq U$ where U is g^{**}-open. Since X is a g^{**}-$T_{1/2}$ space and A is αg-closed, every g^{**}-open set is open and hence $\alpha cl(A) \subseteq U$. Therefore A is αg^{**}-closed in X.

Corollary 2.1. If X is g^{**}-$T_{1/2}$, then every gα-closed set is αg^{**}-closed.

Proof: Follows from the above Theorem 2.4.

Corollary 2.2. If X is g^{**}-$T_{1/2}$, then every $g^{\#}\alpha$-closed set is αg^{**}-closed.

Proof: Follows from the above Theorem 2.4.

Theorem 2.5. Let $\{A_i : i \in J\}$ be the collection of αg^{**}-closed sets in a topological space X. Then $\cup_{i\in J} A_i$ is also a αg^{**}-closed set in X.

Proof. Let $\cup_{i\in J} A_i \subseteq U$ where U is g^{**}-open. Then $A_i \subseteq U$ for each $i \in J$. Since A_i is αg^{**}-closed for each $i \in J$, we have $\alpha cl(A_i) \subseteq U$ for each $i \in J$. This implies that $\alpha cl(\cup_{i\in J} A_i) = \cup_{i\in J} \alpha cl(A_i) \subseteq U$. Hence $\cup_{i\in J} A_i$ is αg^{**}-closed in X.

Remark 2.6. (i) Intersection of two αg^{**}-closed sets need not be αg^{**}-closed.

Let X = {a, b, c}, τ = {∅, X, {a}}. Then αg^{**}-closed sets of X are {∅, X, {b}, {c}, {a, b}, {a, c}, {b, c}}.

If A = {a, b} and B = {a, c}, then the sets A and B are αg^{**}-closed but $A \cap B$ = {a} is not αg^{**}-closed.

Theorem 2.6. If a set A is αg^{**}-closed in X, then $\alpha cl(A) - A$ contains no non-empty g^{**}-closed set.

Proof: Let F be a g^{**}-closed set such that $F \subseteq \alpha cl(A) - A$. Since $X - F$ is g^{**}-open and $A \subseteq X - F$, from the definition of αg^{**}-closed set it follows that $\alpha cl(A) \subseteq X - F$. Thus $F \subseteq X - \alpha cl(A)$. This implies that $F \subseteq \alpha cl(A) \cap (X - \alpha cl(A)) = \emptyset$.

Corollary 2.3. Let A be a αg^{**}-closed set in X. Then A is α-closed if and only if $\alpha cl(A) - A$ is g^{**}-closed.

Proof: Necessity. Let A be α-closed in X. Then $\alpha cl(A) \subseteq A$. This implies that $\alpha cl(A) - A = \emptyset$. Therefore $\alpha cl(A) - A$ is g^{**}-closed.

Sufficiency, Suppose $\alpha cl(A) - A$ is g^{**}-closed. Then by Theorem 2.6, $\alpha cl(A) - A$ contains does not contain any non-empty g^{**}-closed set and hence $\alpha cl(A) - A = \emptyset$. This implies that $\alpha cl(A) = A$. Therefore A is α-closed in X.

Theorem 2.7. Suppose that X is an α-space (i.e., $\tau = \tau^{\alpha}$). A αg^{**}-closed set A is α-closed in X if and only if $\alpha cl(A) - A$ is α-closed in X.

Proof: Necessity. If A is α-closed in X, then $\alpha cl(A) \subseteq A$. This implies that $\alpha cl(A) - A = \emptyset$, we have $\alpha cl(A) - A$ is α-closed in X.

Sufficiency, Suppose that A is αg^{**}-closed and $\alpha cl(A) - A$ is α-closed. It follows from the assumption that $\tau = \tau^{\alpha}$. Then $\alpha cl(A) - A$ is g^{**}-closed in X. By Theorem 2.6, we have $\alpha cl(A) - A = \emptyset$ this implies that $\alpha cl(A) = A$. Hence A is α-closed in X

Theorem 2.8. Let A be a αg^{**}-closed set in X. If A is g^{**}-open, then $\alpha cl(A) - A = \emptyset$.

Proof: Let A be g^{**}-open in X. Since A is αg^{**}-closed, $\alpha cl(A) \subseteq A$. This implies that $\alpha cl(A) - A = \emptyset$.

Theorem 2.9. Every subset is αg^{**}-closed in X if and only if every g^{**}-open set is α-closed.

Proof: Necessity. Let A be g^{**}-open in X. Then by hypothesis A is αg^{**}-closed in X. By Theorem 2.8 $\alpha cl(A) - A = \emptyset$. Hence A is α-closed.

Sufficiency. Let A be a subset of X and U a g^{**}-open set such that $A \subseteq U$. Then by hypothesis, U is α-closed. This implies that $\alpha cl(A) \subseteq \alpha cl(U) = U$. Hence A is αg^{**}-closed.

Theorem 2.10. If A is a αg^{**}-closed set in X and $A \subseteq B \subseteq \alpha cl(A)$, then B is αg^{**}-closed in X.

Proof: Let $B \subseteq U$ where U is g^{**}-open. Since A is αg^{**}-closed in X and $A \subseteq U$, it follows that $\alpha cl(A) \subseteq U$. By hypothesis, $B \subseteq \alpha cl(A)$ and hence $\alpha cl(B) \subseteq \alpha cl(A)$. Consequently, $\alpha cl(B) \subseteq U$ and B becomes αg^{**}-closed in X.

Theorem 2.11. For each $x \in X$, $\{x\}$ is g^{**}-closed or its complement $X - \{x\}$ is αg^{**}-closed in a space X.

Proof: Suppose that $\{x\}$ is not g^{**}-closed in X. Since $X - \{x\}$ is not g^{**}-open, the space X itself is only g^{**}-open set containing $X - \{x\}$. Therefore, $\alpha cl(X - \{x\}) \subseteq X$ holds and so $X - \{x\}$ is αg^{**}-closed.

III. αg^{**}-OPEN SET

In this section, we introduce a new class of open set called αg^{**}-open set and study some of their properties.

Definition 3.1. A subset A of a topological space is called semi g^{**}-open (briefly αg^{**}-open) if and only if $X - A$ is αg^{**}-closed. The set of all αg^{**}-open set denoted by $\alpha G^{**}O(X)$.

Theorem 3.1. Let $\{A_i : i \in J\}$ be the collection of αg^{**}-open sets in a topological space X. Then $\cap_{i\in J} A_i$ is also a αg^{**}-open set in X.

Proof. Since A_i is αg^{**}-open in X for each $i \in J$. This implies that $X - A_i$ is αg^{**}-closed in X for each $i \in J$. Then by Theorem 2.5, we have $X - \cap_{i\in J} A_i = \cup_{i\in J} (X - A_i)$ is also αg^{**}-closed in X. Hence $\cap_{i\in J} A_i$ is αg^{**}-open in X.

Remark 3.1. Union of two αg^{**}-open sets need not be αg^{**}-open.

Let $X = \{a, b, c\}$, $\tau = \{\emptyset, X, \{a\}\}$. Then αg^{**}-open sets of X are $\{\emptyset, X, \{a\}, \{b\}, \{c\}, \{a, b\}, \{a, c\}\}$

If $A = \{b\}$ and $B=\{c\}$. Then the sets A and B are αg^{**}-open but $A \cup B = \{b, c\}$ is not αg^{**}-open.

Theorem 3.2. A set A is αg^{**}-open in X if and only if $F \subseteq \alpha int(A)$ whenever F is g^{**}-closed and $F \subseteq A$.

Proof: Necessity, Let A be αg^{**}-open and suppose $F \subseteq A$ where F is g^{**}-closed. By Definition 3.1, $X - A$ is αg^{**}-closed. Also $X - A$ is contained in the g^{**}-open set $X - F$. This implies that $\alpha cl(X - A) = X - \alpha int(A)$. Hence $X - \alpha int(A) \subseteq X - F$. Therefore $F \subseteq \alpha int(A)$.

Sufficiency. If F is a g^{**}-closed set with $F \subseteq \alpha int(A)$ whenever $F \subseteq A$, it follows that $X - A \subseteq X - F$ and $X - \alpha int(A) \subseteq X - F$. Thus $\alpha cl(X - A) \subseteq X - F$. Hence $X - A$ is αg^{**}-closed and A becomes αg^{**}-open. This proves the theorem.

Theorem 3.3. If $\alpha int(A) \subseteq B \subseteq A$ and A is αg^{**}-open in X, then B is αg^{**}-open.

Proof: By hypothesis, $X - A \subseteq X - B \subseteq X - \alpha int(A)$. Thus $X - A \subseteq X - B \subseteq X - (X - \alpha cl(X - A)) = \alpha cl(X - A)$. Now $X - A$ is αg^{**}-closed and hence by Theorem 2.10, $X - B$ is αg^{**}-closed. Hence B is αg^{**}-open in X.

IV. αg^{**}-CONTINUOUS MAP and αg^{**}-IRRESOLUTE MAP

In this section we introduce the concepts of αg^{**}-continuous map and αg^{**}-irresolute map and study relationship between some other mappings.

Definition 4.1. A map $f : X \to Y$ is called αg^{**}-continuous if $f^{-1}(V)$ is αg^{**}-closed in X for every closed set V of Y.

Definition 4.2. A map $f : X \to Y$ is called αg^{**}-irresolute if $f^{-1}(V)$ is αg^{**}-closed in X for every αg^{**}-closed set V of Y.

Theorem 4.1. Let $f : X \to Y$ be αg^{**}-continuous. Then f is αg-continuous but not conversely.

Proof: Let V be a closed set in Y. Then $f^{-1}(V)$ is αg^{**}-closed in X since f is αg^{**}-continuous. By Theorem 2.2, every αg^{**}-closed set is αg-closed. Therefore $f^{-1}(V)$ is αg-closed in X. Hence f is αg-continuous. The converse need not be true as seen from the following example.

Example 4.1. Let X = {a, b, c, d}, τ = {$\varnothing$, X, {b}, {b, c}, {a, b, c}, {b, c, d}}, Y = {1, 2, 3, 4} and σ = {$\varnothing$, Y, {1}, {2}, {1, 2}, {2, 3, 4}}. Define a map f : X $\to$ Y by f(a) = 3, f(b) = 2, f(c) = 1, f(d) = 4. Then f is αg-continuous. $f^{-1}(\{2, 3, 4\})$ = {a, b, d} is not αg^{**}-closed in X for the closed set {2, 3, 4} of Y. So f is not αg^{**}-continuous.

Theorem 4.2. Let f : X $\to$ Y be a mapping from a topological space X into a topological space Y. Then the following statements are equivalent.
(i) f is αg^{**}-continuous;
(ii) the inverse image of each open set in Y is αg^{**}-open in X.

Proof: Straight forward from the Definition 3.1.

Definition 4.3. A space X is called αg^{**}-$T_{1/2}$ space if every αg^{**}-closed set is g^{**}-closed.

Theorem 4.3. Let f : X $\to$ Y be a map. If f is αg^{**}-continuous, then f is g^{**}-irresolute where X is αg^{**}-$T_{1/2}$ and Y is g^{**}-$T_{1/2}$.

Proof: Let V be g^{**}-closed in Y. Since Y is g^{**}-$T_{1/2}$, we have V is closed in Y. Then $f^{-1}(V)$ is αg^{**}-closed in X, since f is αg^{**}-continuous. But X is αg^{**}-$T_{1/2}$ and so $f^{-1}(V)$ is g^{**}-closed. Hence f is g^{**}-irresolute.

Theorem 4.4. Let f : X $\to$ Y be a map. If f is g^{**}-continuous, then f is αg^{**}-irresolute where X is g^{**}-$T_{1/2}$ and Y is αg^{**}-$T_{1/2}$.

Proof: Let V be g^{**}-closed in Y. Since Y is αg^{**}-$T_{1/2}$, we have V is g^{**}-closed in Y. Then $f^{-1}(V)$ is g^{**}-closed in X, since f is g^{**}-continuous. But X is g^{**}-$T_{1/2}$ and so $f^{-1}(V)$ is αg^{**}-closed. Hence f is αg^{**}-irresolute.

Note that if f : X $\to$ Y and g : Y $\to$ Z are both αg^{**}-continuous, then the composition g o f : X $\to$ Z is not αg^{**}-continuous mapping.

Example 4.2. Let X = Y = Z = {a, b, c}, τ = {$\varnothing$, X, {a}, {b}, {a, b}}, σ = {$\varnothing$, Y, {a}} and η = {$\varnothing$, Z, {a}, {a, b}, {a, c}}. Define f : X $\to$ Y by f(a) = c, f(b) = a and f(c) = b and define g : Y $\to$ Z by g(a) = a, g(b) = c, g(c) = b. Then f and g are αg^{**}-continuous mappings. The set {b} is closed in Z. $(g \circ f)^{-1}(\{b\}) = f^{-1}(g^{-1}(\{b\})) = f^{-1}(\{c\})$ = {a} which is not αg^{**}-closed in X. Hence g o f is not αg^{**}-continuous.

Theorem 4.5. Let f : X $\to$ Y and g : Y $\to$ Z be two mappings.
(i) If f is αg^{**}-irresolute and g is αg^{**}-continuous, then the composition g o f is αg^{**}-continuous;
(ii) If f and g are αg^{**}-irresolute, then the composition g o f is αg^{**}-irresolute;
(iii) Let a space Y be αg^{**}-$T_{1/2}$. If f : X $\to$ Y is g^{**}-irresolute g : Y $\to$ Z is g^{**}-continuous, then the composition g o f : X $\to$ Z is g^{**}-continuous.

Proof: (i) Let V be closed in Z. Then αg^{**}-continuity of g implies that $g^{-1}(V)$ is αg^{**}-closed in Y. Since f is αg^{**}-irresolute, it follows that $f^{-1}(g^{-1}(V))$ is αg^{**}-closed in X. Hence g o f is αg^{**}-continuous.

(ii) Let V be αg^{**}-closed in Z. Then αg^{**}-irresolute of g implies that $g^{-1}(V)$ is αg^{**}-closed in Y. Since f is αg^{**}-irresolute, it follows that $f^{-1}(g^{-1}(V))$ is αg^{**}-closed in X. Hence g o f is αg^{**}-irresolute.

(iii) Let V be closed in Z. Then αg^{**}-continuity of g implies that $g^{-1}(V)$ is αg^{**}-closed in Y. Thus $g^{-1}(V)$ is g^{**}-closed in Y since Y is αg^{**}-$T_{1/2}$. Therefore $f^{-1}(g^{-1}(V))$ is g^{**}-closed in X, because f is g^{**}-irresolute. Hence g o f is g^{**}-continuous.

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