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PRE*GENERALIZED CLOSED SETS IN TOPOLOGICAL SPACES

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ABSTRACT

*In this paper a new class of generalized closed sets, namely p*g-closed sets is introduced in topological spaces. We find some basic properties and characterizations of p*g-closed sets.*

Mathematics Subject Classification: *54A05.*

Key Words: *g-closed sets, p*g-closed sets, g*p-closed sets, πgp-closed sets.*

1. INTRODUCTION

In 1970, N. Levine [8] introduced the concept of generalized closed sets (briefly g-closed). In 1982, Dunham [6] introduced the generalized closure (briefly g-closure). In 1996, H. Maki, J. Umehara and T. Noiri [4, 10] introduced the class of pre generalized closed sets and used them to obtain properties of pre-T1/2 spaces. Selvi [20] introduced pre*closed sets using the g-closure operator due to Dunham. Y. Gnanambal [7], H. Maki, R. Devi, K. Balachandran [9], J. Dontchev [4, 5], Veerakumar [23, 24, 25], N. Palaniappan and K. C. Rao [17], N. Nagaveni [14], J. H. Park [18], S. Muthuvel and R. Parimelazhagan, Milby Mathew [12, 13], Sarsak. M. S. and N. Rajesh [19], introduced and investigated gpr-closed, α-closed, αg-closed, gsp-closed, πg-closed, g*-closed, g*p-closed, pre semi closed, rg-closed, wg-closed, rwg-closed, πgp-closed, α^m-closed, b*-closed, πgsp-closed respectively.

In this paper we introduce a new class of sets called p*g-closed sets. We give characterizations of p*g-closed sets also investigate some fundamental properties of p*g-closed set.

2. PRELIMINARIES

Throughout this paper (X, τ) represents a topological space on which no separation axiom is assumed unless otherwise mentioned. For a subset A of a topological space X, cl(A) and int(A) denote the closure of A and the interior of A respectively. (X, τ) will be replaced by X if there is no changes of confusion. We recall the following definitions and results.

Definition 2.1: Let (X, τ) be a topological space. A subset A of X is said to be generalized closed [8] (briefly g-closed) if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is an open in (X, τ).

Definition 2.2: Let (X, τ) be a topological space and A $\subseteq$ X. The generalized closure of A [6], denoted by cl*(A) and is defined by the intersection of all g-closed sets containing A and generalized interior of A [6], denoted by int*(A) and is defined by union of all g-open sets contained in A.

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Definition 2.3: Let(X, τ) be a topological space and A ⊆ X. Then

(i) A is α-open if A ⊆ int(cl(int(A))) and α-closed if cl(int(cl(A))) ⊆ A [15].
(ii) A is pre open if A ⊆ int(cl(A)) and pre closed if cl(int(A)) ⊆ A [11].
(iii) A is pre*open if A ⊆ int∗(cl(A)) and pre*closed if cl*(int(A)) ⊆ A [20].
(iv) A is regular open if A = int(cl(A)) and regular closed if A = cl(int(A)) [21].
(v) A is semi pre open if A ⊆ cl(int(cl(A))) and semi pre closed if int(cl(int(A))) ⊆ A [1].
(vi) π-closed set [26] if A is a finite intersection of regular closed sets. The complement of a π-closed set is called a π-open set.
(vii) a regular α-open set (briefly rα-open) [22] if there is a regular open set U such that U ⊆ A ⊆ αcl(U).

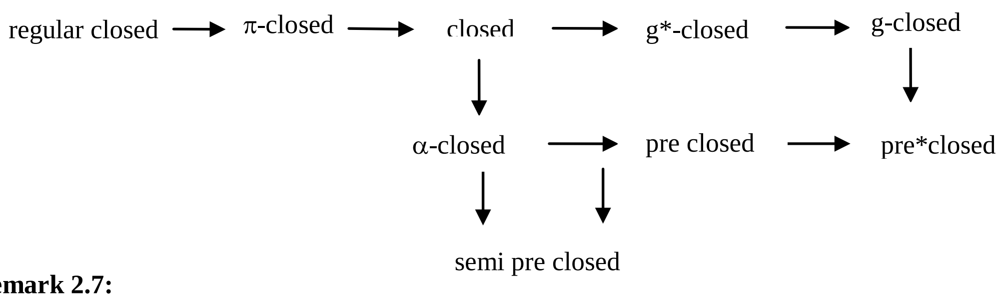
Definition 2.4: Let (X, τ) be a topological space and A ⊆ X. The pre closure of A [11], denoted by pcl(A) and is defined by the intersection of all pre closed sets containing A.

Definition 2.5: Let (X, τ) be a topological space. A subset A of X is said to be

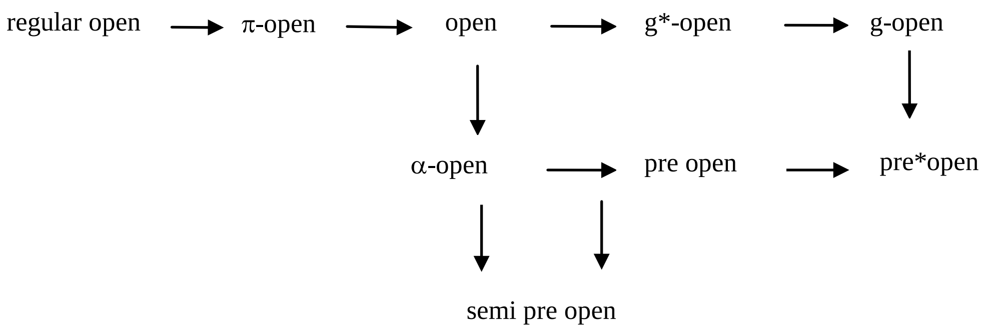
1. α-generalized closed set (briefly αg-closed) [9] if αcl(A) ⊆ U whenever A ⊆ U and U is open in (X, τ).
2. generalized pre closed set (briefly gp-closed) [10] if pcl(A) ⊆ U whenever A ⊆ U and U is open in (X, τ).
3. strongly generalized closed set (briefly g∗closed) [23] if cl(A) ⊆ U whenever A ⊆ U and U is g-open in (X, τ).
4. generalized*pre closed set (briefly g∗p-closed) [24] if pcl(A) ⊆ U whenever A ⊆ U and U is g-open in (X, τ).
5. regular generalized closed set (briefly rg-closed) [17] if cl(A) ⊆ U whenever A ⊆ U and U is regular open in (X, τ).
6. weakly generalized closed set (briefly wg-closed) [14] if cl(int(A)) ⊆ U whenever A ⊆ U and U is open in (X, τ).
7. generalized pre regular closed set (briefly gpr-closed) [7] if pcl(A) ⊆ U whenever A ⊆ U and U is regular open in (X, τ).
8. generalized semi preclosed set (briefly gsp-closed) [5] if spcl(A) ⊆ U whenever A ⊆ U and U is open in (X, τ).
9. pre semi closed set [25] if spcl(A) ⊆ U whenever A ⊆ U and U is g-open in (X, τ).
10. πgp-closed set [18] if pcl(A) ⊆ U whenever A ⊆ U and U is π-open in (X, τ).
11. regular weakly generalized closed set (briefly rwg-closed) [14] if cl(int(A)) ⊆ U whenever A ⊆ U and U is regular open in (X, τ).
12. b-closed set [13] if cl(int(A)) ∩ int(cl(A)) ⊆ A.
13. b*-closed set [13] if int(cl(A)) ⊆ U whenever A ⊆ U and U is b-open in (X, τ).
14. α^m-closed set [12] if int(cl(A)) ⊆ U whenever A ⊆ U and U is α-open in (X, τ).
15. π-generalized semi pre closed set [19] (briefly πgsp-closed) if spcl(A) ⊆ U whenever A ⊆ U and U is π-open in (X, τ).

The complements of the above mentioned closed sets are their respective open sets.

Remark 2.6:



Remark 2.7:



Theorem 2.8: **[3]** Let (X, τ) be a topological space. Then pcl(A∩B) ⊆ pcl(A) ∩ pcl(B).

Lemma 2.9: [1] For any subset A of X, pcl(A) = A ∪ cl(int(A)).

Lemma 2.10: [2] If A is semi closed in X, then pcl(A∪B) = pcl(A) ∪ pcl(B).

Theorem 2.11: [20] Arbitrary union of pre*open sets is pre*open.

3. PRE*GENERALIZED CLOSED SETS

Definition 3.1: A subset A of a topological space (X, τ) is called pre∗generalized closed (briefly p∗g-closed) if pcl(A) ⊆ U whenever A ⊆ U and U is pre∗open in (X, τ).

Theorem 3.2: Let (X, τ) be a topological space. Then every closed set is p∗g-closed.

Proof: Let A be a closed set. Let A ⊆ U, U is pre*open. Since A is closed , cl(A) = A ⊆ U. But pcl(A) ⊆ cl(A). Thus we have pcl(A) ⊆ U whenever A ⊆ U and U is pre∗open. Therefore, A is p∗g-closed.

Remark 3.3: The converse of the above theorem need not be true, as seen from the following example.

Example 3.4: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {c}, X}. Then {a} and {b} are p∗g-closed but not closed.

Theorem 3.5: Let (X, τ) be a topological space. Then every regular closed set is p∗g-closed.

Proof: Let A be a regular closed set. Let A ⊆ U, U is pre*open. By Remark 2.6, pcl(A) ⊆ rcl(A) = A ⊆ U. Thus we have pcl(A) ⊆ U whenever A ⊆ U and U is pre∗open. Therefore, A is p∗g-closed.

Remark 3.6: The converse of the above theorem need not be true, as seen from the following example.

Example 3.7: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {a, b}, {c}, X}. Then {b, c} and {a} are p∗g-closed but not regular closed.

Theorem 3.8: Let (X, τ) be a topological space. Then every α-closed set is p∗g-closed.

Proof: Let A be a α-closed set. Let A ⊆ U, U is pre*open. By Remark 2.6, pcl(A) ⊆ αcl(A) = A ⊆ U. Thus we have pcl(A) ⊆ U whenever A ⊆ U and U is pre∗open. Therefore, A is p∗g-closed.

Remark 3.9: The converse of the above theorem need not be true, as seen from the following example.

Example 3.10: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {a, b}, X}. Then {a}, {b} are p∗g-closed but not α-closed.

Theorem 3.11: Let (X, τ) be a topological space. Then every p*g-closed set is gp-closed.

Proof: Let A be a p*g-closed set. Let A ⊆ U, U is open. Then by Remark 2.7, U is pre∗open. Since A is p*g-closed, pcl(A) ⊆ U. Thus we have pcl(A) ⊆ U whenever A ⊆ U and U is open. Therefore, A is gp-closed.

Remark 3.12: The converse of the above theorem need not be true, as seen from the following example.

Example 3.13: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {c}, X}. Then {a, c} and {b, c} are gp-closed but not p*g-closed.

Theorem 3.14: Let (X, τ) be a topological space. Then every p*g-closed set is gpr-closed.

Proof: Let A be a p*g-closed set. Let A ⊆ U, U is regular open. Then by Remark 2.7, U is pre∗open. Since A is p*g-closed, pcl(A) ⊆ U. Thus we have pcl(A) ⊆ U whenever A ⊆ U and U is regular open. Therefore, A is gpr-closed.

Remark 3.15: The converse of the above theorem need not be true, as seen from the following example.

Example 3.16: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {a, b}, X}. Then {a, b} is gpr-closed but not p*g-closed.

Theorem 3.17: Let (X, τ) be a topological space. Then every p*g-closed set is wg-closed.

Proof: Let A be a p*g-closed set. Let A ⊆ U, U is open. Then by Remark 2.7, U is pre*open. Since A is p*g-closed, pcl(A) ⊆ U. By Lemma 2.9, A ∪ cl(int(A)) ⊆ U. Thus we have cl(int(A)) ⊆ U whenever A ⊆ U and U is open. Therefore, A is wg-closed.

Remark 3.18: The converse of the above theorem need not be true, as seen from the following example.

Example 3.19: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {c}, X}. Then {a, c} and {b, c} are wg-closed but not p*g-closed.

Theorem 3.20: Let (X, τ) be a topological space. Then every p*g-closed set is rwg-closed.

Proof: Let A be a p*g-closed set. Let A ⊆ U, U is regular open. Then by Remark 2.7, U is pre∗open. Since A is p*g-closed, pcl(A) ⊆ U. By Lemma 2.9, A ∪ cl(int(A)) ⊆ U. Thus we have cl(int(A)) ⊆ U whenever A ⊆ U and U is regular open. Therefore, A is rwg-closed.

Remark 3.21: The converse of the above theorem need not be true, as seen from the following example.

Example 3.22: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {a}, {b}, {a, b}, X}. Then {a, b} is rwg-closed but not p*g-closed.

Theorem 3.23: Let (X, τ) be a topological space. Then every p*g-closed set is πgp-closed.

Proof: Let A be a p*g-closed set. Let A ⊆ U, U is π-open. Then by Remark 2.7, U is pre∗open. Since A is p*g-closed, pcl(A) ⊆ U. Thus we have pcl(A) ⊆ U whenever A ⊆ U and U is π-open. Therefore, A is πgp-closed.

Remark 3.24: The converse of the above theorem need not be true, as seen from the following example.

Example 3.25: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {a}, {b}, {a, b}, X}. Then {a, b} is πgp-closed but not p*g-closed.

Theorem 3.26: Let (X, τ) be a topological space. Then every p*g-closed set is gsp-closed.

Proof: Let A be a p*g-closed set. Let A ⊆ U, U is open. Then by Remark 2.7, U is pre∗open. Since A is p*g-closed, pcl(A) ⊆ U. But spcl(A) ⊆ pcl(A) ⊆ U. Thus we have spcl(A) ⊆ U whenever A ⊆ U and U is open. Therefore, A is gsp-closed.

Remark 3.27: The converse of the above theorem need not be true, as seen from the following example.

Example 3.28: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {a}, {a, b}, X}. Then {a, c} is gsp-closed but not p*g-closed.

Theorem 3.29: Let (X, τ) be a topological space. Then every p*g-closed set is πgsp-closed.

Proof: Let A be a p*g-closed set. Let A⊆U, U is π-open. Then by Remark 2.7, U is pre∗open. Since A is p*g-closed, pcl(A) ⊆ U. But spcl(A) ⊆ pcl(A) ⊆ U. Thus we have spcl(A) ⊆ U whenever A ⊆ U and U is π-open. Therefore, A is πgsp-closed.

Remark 3.30: The converse of the above theorem need not be true, as seen from the following example.

Example 3.31: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {a, b}, X}. Then {a, b} is πgsp-closed but not p*g-closed.

Theorem 3.32: Let (X, τ) be a topological space. Then every p*g-closed set is pre semi closed.

Proof: Let A be a p*g-closed set. Let A ⊆ U, U is g-open. Then by Remark 2.7, U is pre∗open. Since A is p*g-closed, pcl(A) ⊆ U. But spcl(A) ⊆ pcl(A) ⊆ U. Thus we have spcl(A) ⊆ U whenever A ⊆ U and U is g-open. Therefore, A is pre semi closed.

Remark 3.33: The converse of the above theorem need not be true, as seen from the following example.

Example 3.34: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {c}, {b, c}, X}. Then {a, c} is pre semi closed but not p*g-closed.

Theorem 3.35: Let (X, τ) be a topological space. Then every p*g-closed set is g*p-closed.

Proof: Let A be a p*g-closed set. Let A ⊆ U, U is g-open. Then by Remark 2.7, U is pre∗open. Since A is p*g-closed, pcl(A) ⊆ U. Thus we have pcl(A) ⊆ U whenever A ⊆ U and U is g-open. Therefore, A is g*p-closed.

Remark 3.36: The converse of the above theorem need not be true, as seen from the following example.

Example 3.37: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {c}, {b, c}, X}. Then {a, c} is g*p-closed but not p*g-closed.

Theorem 3.38: Let (X, τ) be a topological space. If A and B are two p∗g-closed in X, then A∩B is p∗g-closed.

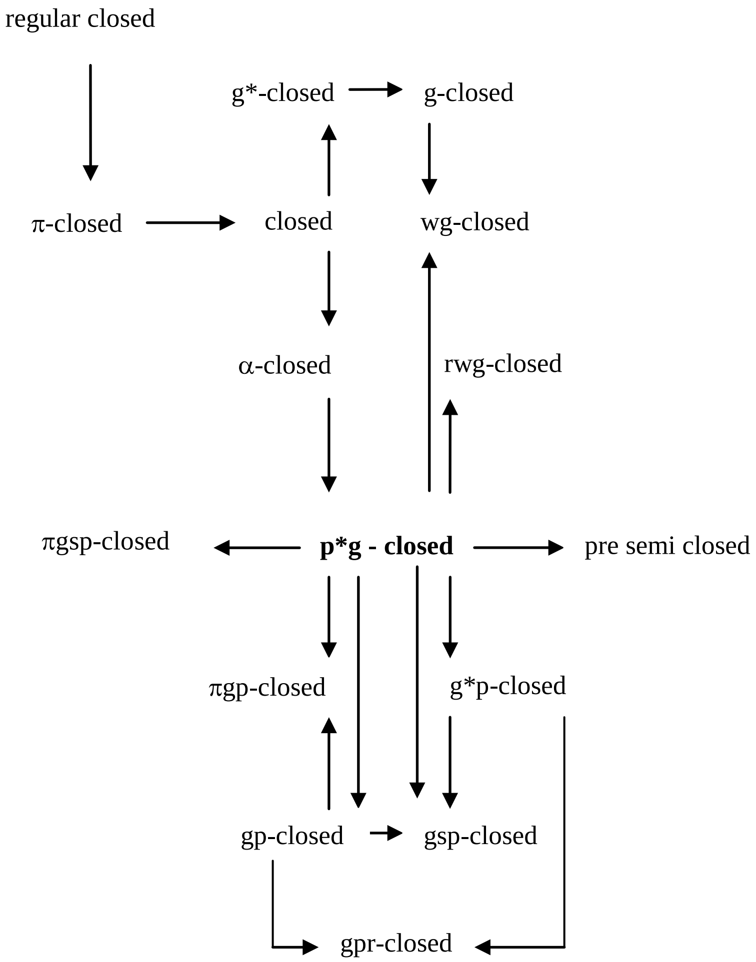
Proof: Let U be pre*open such that A∩B ⊆ U. Then by Theorem 2.11, U ∪ (X-B) is pre*open containing A. Since A is p*g-closed, pcl(A) ⊆ U ∪ (X-B).

Now pcl(A ∩ B) ⊆ pcl(A) ∩ pcl(B) ⊆ pcl(A) ∩ cl(B) = pcl(A) ∩ B ⊆ (U ∪ (X-B)) ∩ B = U ∩ B ⊆ U. Thus we have pcl(A∩B) ⊆ U, U is pre*open and A∩B ⊆ U. Therefore A∩B is p*g-closed.

Remark 3.39: In general, union of any two p*g-closed sets in (X, τ) need not be a p*g-closed set, as seen from the following example.

Example 3.40: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {a, b}, X}. Here, {a} and {b} are p∗g-closed. But their union {a, b} is not p∗g-closed.

Remark 3.41: The above discussions are summarized in the following implications.



Remark 3.42: p*g-closedness and rg-closedness are independent concepts as we illustrate by means of the following example.

Example 3.43: Let X = {a, b, c, d} and τ = {ϕ, {a}, {b}, {a, b}, {b, c}, {a, b, c}, X}. Then the set {c} is p*g-closed but not rg-closed and also {a, b} is rg-closed but not p*g-closed.

Remark 3.44: p*g-closedness and g-closedness are independent concepts as we illustrate by means of the following example.

Example 3.45: Let X = {a, b, c} and τ = {ϕ, {a}, {a, b}, X}. Then the set {b} is p*g-closed but not g-closed and also {a, c} is g-closed but not p*g-closed.

Remark 3.46: p*g-closedness and g*-closedness are independent concepts as we illustrate by means of the following example.

Example 3.47: Let X = {a, b, c} and τ = {ϕ, {a}, {a, b}, X}. Then the set {b} is p*g-closed but not g*-closed and also {a, c} is g*-closed but not p*g-closed.

Remark 3.48: p*g-closedness and αg-closedness are independent concepts as we illustrate by means of the following examples.

Example 3.49:

i. Let X = {a, b, c} and τ = {ϕ, {a, b}, X}. Then the set {a} and {b} are p*g-closed but not αg-closed.
ii. Let X = {a, b, c} and τ = {ϕ, {c}, X}. Then the set {a, c} and {b, c} are αg-closed but not p*g-closed.

Remark 3.50: p*g-closedness and regular α-closedness are independent concepts as we illustrate by means of the following example.

Example 3.51: Let X = {a, b, c} and τ = {ϕ, {a}, {b}, {a, b}, X}. Then {c} is p*g-closed but not regular α-closed and also {a} and {b} are regular α-closed but not p*g-closed.

Remark 3.52: p*g-closedness and b*-closedness are independent concepts as we illustrate by means of the following examples.

Example 3.53:

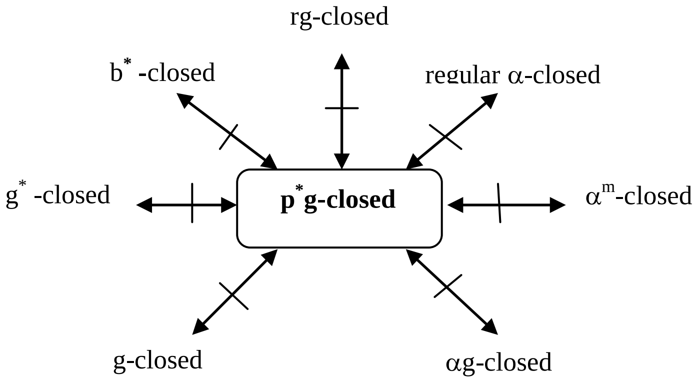
i. Let X = {a, b, c} and τ = {ϕ, {a, b}, X}. Then the set {a} and {b} are p*g-closed but not b*-closed.
ii. Let X = {a, b, c} and τ = {ϕ, {a}, {b}, {a, b}, X}. Then {a} and {b} are b*-closed but not p*g-closed.

Remark 3.54: p*g-closedness and α^m-closedness are independent concepts as we illustrate by means of the following examples**.**

Example 3.55:

i. Let X = {a, b, c} and τ = {ϕ, {a, b}, X}. Then the set {a} and {b} are p*g-closed but not α^m-closed.
ii. Let X = {a, b, c} and τ = {ϕ, {a}, {b}, {a, b}, X}. Then {a} and {b} are α^m-closed but not p*g-closed.

Remark 3.56:



4. CHARACTERIZATION

In this section, we investigate some basic characterization of p*g-closed set in topological spaces.

Theorem 4.1: If A is g-closed and p*g-closed, then A is wg-closed.

Proof: Suppose A is g-closed and p*g-closed. By Remark 2.6, pcl(A) $\subseteq$ cl(A) which implies pcl(A) $\subseteq$ cl(A) $\subseteq$ U. By Lemma 2.9, A $\cup$ cl(int(A)) $\subseteq$ U. Thus we have cl(int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is open. Therfore, A is wg-closed.

Remark 4.2: The converse of the above theorem need not be true, as seen from the following example.

Example 4.3: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {c}, X}. Here, {a, c} and {b, c} are both g-closed and wg-closed but not p*g-closed.

Theorem 4.4: If A is g-closed and p*g-closed, then A is g*p-closed.

Proof: Suppose A is g-closed and p*g-closed. By Remark 2.6, pcl(A) $\subseteq$ cl(A) which implies pcl(A) $\subseteq$ cl(A) $\subseteq$ U and by Remark 2.7, U is g-open. Thus we have pcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is g-open. Therefore, A is g*p-closed.

Remark 4.5: The converse of the above theorem need not be true, as seen from the following example.

Example 4.6: Consider the space (X, τ) where X = {a, b, c} and τ = {ϕ, {c}, {b, c}, X}. Here, {a, c} is both g-closed and g*p-closed but not p*g-closed.

Theorem 4.7: Let A be any p*g-closed set in (X, τ). If A $\subseteq$ B $\subseteq$ pcl(A), then B is also a p*g-closed set.

Proof: Let B $\subseteq$ U where U is pre*open in (X, τ). Then A $\subseteq$ U. Also since A is p*g-closed, pcl(A) $\subseteq$ U. Since B $\subseteq$ pcl(A), pcl(B) $\subseteq$ pcl(pcl(A)) = pcl(A) $\subseteq$ U. This implies, pcl(B) $\subseteq$ U. Thus B is a p*g-closed set.

Theorem 4.8: If a set A is p*g-closed in X, then pcl(A) - A contains no non empty pre*open set in X.

Proof: Let U $\subseteq$ pcl(A) - A be a non empty pre*open set. Then U $\subseteq$ pcl(A) and A $\subseteq$ X - U, we have pcl(A) $\subseteq$ X-U. So U $\subseteq$ X - pcl(A). Therefore U $\subseteq$ pcl(A) $\cap$ (X - pcl(A)) = {ϕ}. Hence pcl(A) - A contains no non empty pre*open set in X.

Remark 4.9: The converse of the above theorem need not be true, as seen from the following example.

Example 4.10: If pcl(A) - A contains no non empty pre*open set in X, then A is not a p*g-closed set. Consider X = {a, b, c} with the topology τ = {ϕ, {a}, {b}, {a, b}, X} and A = {a, b}. Then pcl(A) – A = X - {a, b} = {c} contains no non empty pre*open set in X, but A is not a p*g-closed set in X.

Theorem 4.11: For every element x in a space X, the set X - {x} is p*g-closed or pre*open.

Proof: Suppose X - {x} is not pre*open. Then X is the only pre*open set containing X - {x}. This implies pcl(X - {x}) $\subseteq$ X. Hence X - {x} is p*g-closed.

Theorem 4.12: Let A and B be p*g-closed sets in (X, τ) such that cl(A) = pcl(A) and cl(B) = pcl(B). Then A$\cup$B is p*g-closed.

Proof: Let A$\cup$B $\subseteq$ U, where U is pre*open. Then A $\subseteq$ U and B $\subseteq$ U. Since A and B are p*g-closed, pcl(A) $\subseteq$ U and pcl(B) $\subseteq$ U. Now cl(A$\cup$B) = cl(A) $\cup$ cl(B) = pcl(A) $\cup$ pcl(B) $\subseteq$ U. But pcl(A$\cup$B) $\subseteq$ cl(A$\cup$B). So, pcl(A$\cup$B) $\subseteq$ cl(A$\cup$B) $\subseteq$ U. Therefore pcl(A$\cup$B) $\subseteq$ U whenever A$\cup$B $\subseteq$ U, U is pre*open. Hence A$\cup$B is p*g-closed.

Theorem 4.13: The union of two p*g-closed sets is p*g-closed if at least one of them is semi closed.

Proof: Let A and B be two p*g-closed sets in X. Suppose A is semi closed. To prove that A$\cup$B is p*g-closed. Let A$\cup$B $\subseteq$ U and U is pre*open. Then A $\subseteq$ U and B $\subseteq$ U. Since A and B are p*g-closed, pcl(A) $\subseteq$ U and pcl(B) $\subseteq$ U. Therefore, pcl(A) $\cup$ pcl(B) $\subseteq$ U. Since by Lemma 2.10, pcl(A$\cup$B) $\subseteq$ U. Thus we have pcl(A$\cup$B) $\subseteq$ U whenever A$\cup$B $\subseteq$ U and U is pre*open. Therefore A$\cup$B is p*g-closed.

Theorem 4.14: If A $\subseteq$ Y $\subseteq$ X and A is p*g-closed in X then A is p*g-closed relative to Y.

Proof: Given that A $\subseteq$ Y $\subseteq$ X and A is a p*g-closed set in X. To prove that A is p*g-closed set relative to Y. Let us assume that A $\subseteq$ Y$\cap$U, where U is pre*open in X. Since A is p*g-closed, A $\subseteq$ U. This implies that pcl(A) $\subseteq$ U. It follows that Y $\cap$ pcl(A) $\subseteq$ Y $\cap$ U. That is, A is p*g-closed relative to Y.

5. CONCLUSION

The present paper has introduced a new concept of p*g-closed set in topological spaces. It also analyzed some of the properties. The implication shows the relationship between p*g-closed sets and the other existing sets.

6. REFERENCES

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