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A NEW CLASS OF CLOSED SETS IN GENERALIZED TOPOLOGICAL SPACES

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ABSTRACT

In this paper we introduce the concept of $\pi_{b\mu}$-closed sets and study some of their properties in generalized topological spaces. The notion of ($\pi_{b\mu}$, λ)-continuous functions and ($\pi_{b\mu}$, $\pi_{b\lambda}$)-irresolute functions are defined in generalized topological spaces and some of their characterizations are investigated.

Keywords: *$\pi_{b\mu}$ -closed set, ($\pi_{b\mu}$, λ)-continuous function, ($\pi_{b\mu}$, $\pi_{b\lambda}$)-irresolute function.*

1. INTRODUCTION

Á.Császár [1] introduced the concepts of generalized neighborhood systems, concepts of continuous functions and associated interior and closure operators on generalized neighborhood systems and generalized topological spaces. In particular, he investigated characterizations for generalized continuous functions. In [2], he introduced and studied the notions of g- α - open sets, g-semi-open sets, g -pre open sets and g- β- open sets in generalized topological spaces. W.K.Min introduced the weak continuity and almost continuity and studied their relationship on Generalized Topology. After the introduction of the concept of generalized closed set by Levine [8] in a topological spaces, several other authors gave their ideas to the generalizations of various concepts in topology.

The purpose of this paper is to introduce the concept of $\pi_{b\mu}$-closed sets and study some of their properties in generalized topological spaces. The notion of ($\pi_{b\mu}$, λ)-continuous functions and ($\pi_{b\mu}$, $\pi_{b\lambda}$)-irresolute functions are defined in generalized topological spaces and some of their characterizations are investigated.

Throughout this paper, π-generalized b-closed sets, π-generalized b-closure, b-closure of A and b-interior of A on generalized topological spaces are denoted by $\pi_{b\mu}$-closed, $c\pi_{b\mu}$, $c_b(A)$ and $i_b(A)$ respectively. The union of regular μ-open sets on GT is called π_μ-open.

2. PRELIMINARIES

Definition 2.1 [2]: Let X be a nonempty set and μ be a collection of subsets of X. Then μ is called a generalized topology (briefly GT) if Ø ∈ μ and arbitrary union of elements of μ belongs to μ.

Elements of μ are called μ -open sets. A subset A of X is said to be μ -closed if X −A is μ -open. The pair (X, μ) is called a generalized topological space (GTS).

By a space (X, μ) we will always mean a GTS (X, μ). A space (X, μ) is said to be a quasi-topological space [3], if μ is closed under finite intersection. If A is a subset of a space (X, μ), then $c_\mu(A)$ is the smallest μ-closed set containing A and $i_\mu(A)$ is the largest μ-open set contained in A. For every subset of A of a generalized topological space (X, μ), $X - i_\mu(A) = c_\mu(X - A)$.

Definition 2.2: A subset A of a space (X, μ) is said to be

(i) μ-α-open [4] if $A \subset i_\mu c_\mu i_\mu(A)$.
(ii) b $_\mu$-open[16] $A \subset i_\mu c_\mu(A) \cup c_\mu i_\mu(A)$.
(iii) β $_\mu$-open[4] $A \subset c_\mu i_\mu c_\mu(A)$.
(iv) μ -semi-open[4] if $A \subset c_\mu i_\mu (A)$
(v) μ –pre-open[4] if $A \subset i_\mu c_\mu(A)$

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Definition 2.6: A subset A of generalized topological space (X, μ) is said to be g_μ -closed [9], if c_μ (A) $\subseteq$ M whenever A $\subseteq$ M and M is μ -open in X.

Definition 2.7: A function f: (X, μ) $\rightarrow$ (Y, λ) is said to be, (μ, λ) -continuous [2], if f^{-1} (U) $\in \mu$ for each U $\in \lambda$.

Definition 2.8: Let (X, μ) and (Y, λ) be GTS's. Then a function f: X$\rightarrow$ Y is s aid to be, (σ, λ) -continuous [10], if for each λ -open set U in Y, f^{-1}(U) is μ -semi open in (X, μ).

Definition 2.9: A GTS (X, μ) is a μ- $T_{1/2}$ -space [11] if every g_μ -closed subset of (X, μ) is μ -closed in (X, μ).

Definition 2.10: A function f: (X, μ) $\rightarrow$ (Y, λ) is (μ, λ) -open [5] (resp. (μ, λ) -closed [5]) when the image of μ -open (resp. μ -closed) sets in (X, μ) is always λ -open (λ -closed) in (Y, λ).

Definition 2.11: A subset A of a generalized topological space (X, μ) is said to be μ -nowhere dense [6] if $i_\mu(c_\mu(A)) = \emptyset$.

Definition 2.12: A generalized topology is said to be quasi-topology [7] (briefly QT) iff M, M′ $\in\mu$ implies M$\cap$ M′ $\in \mu$. If X$\in\mu$, (X, μ) is called a strong generalized topological space [9].

Lemma 2.13[10]: Let (X, μ) be a quasi-topological space. Then c_μ (A$\cup$B)=c_μ(A)$\cup c_\mu$(B) for every subsets A and B of X.

3.$\pi_{b\mu}$ -closed sets

Definition 3.1: Let (X, μ) be a generalized topological space. A subset A of X is said to be $\pi_{b\mu}$ -closed if c_b(A)$\subseteq$U and U is π_μ-open in (X, μ). By πGBC_μ we mean the family of all $\pi_{b\mu}$ -closed subsets of the generalized topological space (X, μ).

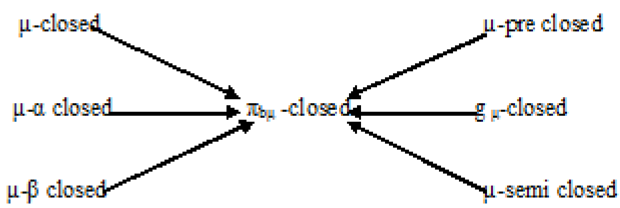
A set A$\subset$X is called $\pi_{b\mu}$ -open if and only if its complement is $\pi_{b\mu}$ -closed.

Theorem 3.2: In generalized topological space (X, μ)
(i) Every μ-closed set is $\pi_{b\mu}$ -closed.
(ii) Every μ-semi closed set is $\pi_{b\mu}$ -closed.
(iii) Every μ-pre closed set is $\pi_{b\mu}$ -closed.
(iv) Every μ-β closed set is $\pi_{b\mu}$ -closed.
(v) Every μ-α closed set is $\pi_{b\mu}$ -closed.
(vi) Every g_μ-closed is $\pi_{b\mu}$ -closed.

Remark 3.3: Converse of the above need not be true as shown in the following examples

Example 3.4: Let X= {a, b, c}, μ= {Φ,{a}}Then A={a} is $\pi_{b\mu}$ -closed but not μ-closed.

Example 3.5: Let X= {a, b, c}, μ= {ϕ, {a, b}, {b, c}, X}, Then A= {b} is $\pi_{b\mu}$ -closed but not g_μ-closed, μ-semi closed, μ-α closed. Also B={a, b) is $\pi_{b\mu}$ -closed but not μ-β closed, μ-pre closed.



Theorem 3.6: Let (X, μ) be a generalized topological space. Then a subset A of X is $\pi_{b\mu}$ -closed if c_b(A)-A does not contain any non empty π_μ-closed set.

Proof: Let A be $\pi_{b\mu}$ -closed set. Let F be a non empty π_μ-closed set such that F$\subset c_b$(A)-A. Since A is $\pi_{b\mu}$ -closed, A$\subset$X-F where X-F is π_μ-open. This implies c_b(A)$\subseteq$X-F. Hence F$\subset$X- c_b(A).Now F$\subset$ c_b(A)$\cap$ (X- c_b (A)).Hence F=ϕ which is a contradiction. This implies c_b(A) does not contain any non empty π_μ-closed set.

Theorem 3.7: Let (X, μ) be a generalized topological space, A and B be subsets of X. If A$\subset$B$\subset c_b$ (A) and A is $\pi_{b\mu}$ -closed, then B is $\pi_{b\mu}$ -closed set.

Proof: Let $B \subset U$ and U is π_μ-open. Given $A \subset B$ implies $A \subset U$. Since A is $\pi_{b\mu}$ -closed, $A \subset U$ implies $c_b(A) \subseteq U$. By assumption, $c_b(B) \subseteq c_b(A) \subseteq U$. Hence B is $\pi_{b\mu}$ -closed.

Theorem 3.8: If A is π_μ-open and $\pi_{b\mu}$ -closed, then A is b_μ-closed.

Proof: Let A be π_μ-open and $\pi_{b\mu}$ -closed. Let $A \subset A$ where A is π_μ-open. Since A is $\pi_{b\mu}$ -closed, $c_b(A) \subseteq A$. Then $A = c_b(A)$.Hence A is b_μ-closed.

Definition 3.9: For a generalized topological space (X, μ), $\mu_{\pi b}^* = \{U \subset X: c\pi_{b\mu}(X-U) = X-U\}$.

Theorem 3.10: Let (X, μ) be a generalized topological space. Then
(i) Every $\pi_{b\mu}$ -closed set is b_μ-closed if and only if $\mu_{\pi b}^* = BO(X, \mu)$
(ii)Every $\pi_{b\mu}$ -closed set is closed if and only if $\mu_{\pi b}^* = \mu$.

Remark: 3.11 $c_b(X-A) = X-i_b(A)$
By πGBO_μ, we mean the family of all $\pi_{b\mu}$-open subsets of the generalized topological space (X, μ).

Theorem 3.12: A subset A of a generalized topological space (X, μ) is $\pi_{b\mu}$ -open if and only if $F \subset i_b(A)$ whenever $F \subset \pi_\mu$-closed and $F \subset A$.

Theorem 3.13: Let $i_b(A) \subset B \subset A$ and A is $\pi_{b\mu}$ -open, then B is $\pi_{b\mu}$ -open.

Proof: Assume that $i_b(A) \subset B \subset A$. Then $X-A \subset X-B \subset X-i_b(X-A)$.Since X-A is $\pi_{b\mu}$ -closed,

By theorem 3.7, $X-A \subset X-B \subset c_b(X-A)$.Then X-B is $\pi_{b\mu}$ -closed. Hence B is $\pi_{b\mu}$ -open.

Remark 3.14: For any $A \subset X$, $i_b(c_b(A)-A) = \phi$.

Theorem 3.15: Let (X, μ) be a generalized topological space. If a subset A of X is $\pi_{b\mu}$ -closed, then
$c_b(A)-A$ is $\pi_{b\mu}$ -open.

Proof: Let A be $\pi_{b\mu}$ -closed and F be π_μ-closed such that $F \subset c_b(A)-A$. By theorem 3.6, $F = \phi$.

Hence $F \subset i_b(c_b(A)-A)$.This implies $c_b(A)-A$ is $\pi_{b\mu}$ -open.

Definition 3.16: For a subset A of (X, μ), we define π-generalized b-closure of A as $c\pi_{b\mu}(A) = \cap\{F: F$ is $\pi_{b\mu}$ -closed in $X, A \subset F\}$.

Lemma 3.17: Let A and B be subsets of (X, μ), then we have
a) $c\pi_{b\mu}(\phi) = \phi$ and $c\pi_{b\mu}(X) = X$
b) If $A \subset B$, then $c\pi_{b\mu}(A) \subset c\pi_{b\mu}(B)$
c) $c\pi_{b\mu}(A) = c\pi_{b\mu}(c\pi_{b\mu}(A))$
d) $c\pi_{b\mu}(A \cup B) \supset c\pi_{b\mu}(A) \cup c\pi_{b\mu}(B)$
e) $c\pi_{b\mu}(A \cap B) \subset c\pi_{b\mu}(A) \cap c\pi_{b\mu}(B)$

Example 3.18: Let X be a generalized topological space and X= {a, b, c, d, e}, μ= {X, ϕ,{e},{a, e}, {c, d}, {a, c, d}, {c, d, e}, {a, c, d, e}, X}, Then A={a, c, d} and B={e}, $c\pi_{b\mu}(A) = A$ and $c\pi_{b\mu}(B) = B$. $c\pi_{b\mu}(A) \cup c\pi_{b\mu}(B) = \{a, c, d, e\}$ but $c\pi_{b\mu}(A \cup B) = X$. Hence $c\pi_{b\mu}(A \cup B) \supset c\pi_{b\mu}(A) \cup c\pi_{b\mu}(B)$.

Example 3.19: Let X be a generalized topological space and X= {a, b, c, d, e}, μ= {X, ϕ, {e}, {a, e}, {c, d}, {a, c, d}, {c, d, e}, {a, c, d, e}, X},Then A={a, c, d, e} and B={b, c, d}, $c\pi_{b\mu}(A) = X$ and $c\pi_{b\mu}(B) = B$. $c\pi_{b\mu}(A) \cap c\pi_{b\mu}(B) = \{b, c, d\}$ but $c\pi_{b\mu}(A \cap B) = \{c, d\}$.Hence $c\pi_{b\mu}(A \cap B) \subset c\pi_{b\mu}(A) \cap c\pi_{b\mu}(B)$.

Lemma 3.20: Let A be a subset of (X, μ) and $x \in X$. Then $x \in c\pi_{b\mu}(A)$ if and only if $V \cap A \neq \phi$ for every $\pi_{b\mu}$ -open set V containing x.

4. $(\pi_{b\mu}, \lambda)$-continuous and $(\pi_{b\mu}, \pi_{b\lambda})$-irresolute functions

Definition 4.1: A function $f: (X, \mu) \rightarrow (Y, \lambda)$ is $(\pi_{b\mu}, \lambda)$-continuous if $f^{-1}(U)$ is $\pi_{b\mu}$ -closed in (X, μ) for every λ-closed set U in (Y, λ).

Definition 4.2: A function f: $(X, \mu)\to(Y, \lambda)$ is said to be
(i) $(\pi_{b\mu}, \pi_{b\lambda})$-irresolute if the inverse image of every $\pi_{b\mu}$ -closed set in (Y, λ) is $\pi_{b\mu}$-closed in (X, μ).
(ii) pre-$(\pi_{b\mu}, \lambda)$ continuous if $f^{-1}(V)$ is $\pi_{b\mu}$-closed in (X,μ) for every b_λ -closed set of (Y, λ).

Definition 4.3: A generalized topological space is said to be $\pi_{b\mu}$-$T_{1/2}$ -closed if every $\pi_{b\mu}$ - closed set is b_μ-closed.

Theorem 4.4: For a generalized topological space, the following are equivalent
(i) X is $\pi_{b\mu}$-$T_{1/2}$
(ii) For every subset A of X, A is $\pi_{b\mu}$ -open if and only if A is b_μ-open.

Remark 4.5
(i) If $\mu_{\pi b}^* = \mu$ in X, then (μ , λ)-continuity and $(\pi_{b\mu} , \lambda)$-continuity coincide.
(ii) Every $(\pi_{b\mu} , \lambda)$-continuous function defined on $\pi_{b\mu}$-$T_{1/2}$ is (b_μ, λ)-continuous.

Theorem 4.6: Every (μ , λ) continuous function is $(\boldsymbol{\pi_{b\mu}}, \lambda)$-continuous but not conversely.

Example 4.7: Let X= {a, b, c}, μ= Φ,{a},{a, b},{b, c},X}, Y= {a, b, c}, and λ=Φ,{a}}. Define a function $f:(X, \mu)\to(Y, \lambda)$ by f(a)=c, f(b)=a, f(c)=b. Then f is $(\pi_{b\mu}, \lambda)$-continuous but not (μ, λ)-continuous because $f^{-1}(b, c)=\{a,c\}$ is not μ-closed in (X, μ).

Theorem 4.8: If f: X→Y is $(\pi_{b\mu}, \lambda)$-continuous, then $f(c\pi_{b\mu}(A))=c_\mu(f(A))$ for every subset A of generalized topological space X.

Proof: Let A be a subset of X. Since f is $(\pi_{b\mu},\lambda)$-continuous and $A\subset f^{-1}(c_\mu(f(A)))$,we get $c\pi_{b\mu}(A)\subset f^{-1}(c_\mu f(A))$.Then $f(c\pi_{b\mu}(A))\subset c_\mu(f(A))$.

Theorem 4.9: Let f: X→Y be a function of generalized topological space. Then the following statements are equivalent.
(i) For each x∈X and each μ-open set V containing f(x),there exists a $\pi_{b\mu}$ -open set U containing x such that $f(U)\subset V$
(ii) For every subset A of X, $f(\pi_{b\mu}(A))\subset c_\mu(f(A))$
(iii) Suppose $\mu_{\pi b}^*$ is a generalized topology, the function f :$(X, \mu_{\pi b}^*)\to(Y, \sigma)$ is continuous.

Theorem 4.10: Let (Y, σ) be a generalized topological space such that $\sigma_{\pi b}^* =\sigma$. If f:$(X, \mu)\to(Y, \sigma)$ is $(\pi_{b\mu}, \lambda)$ and g: $(Y, \sigma)\to(Z, \eta)$ is $(\pi_{b\sigma}, \eta)$-continuous functions, then $g\circ f$: $(X, \mu)\to(Z, \eta)$ is also $(\pi_{b\mu} ,\eta)$-continuous.

Definition 4.11: A generalized topological space is said to be $\pi_{b\mu}$-$T_{1/2}$ -closed if every $\pi_{b\mu}$ - closed set is b_μ-closed.

Theorem 4.12: A function f: $(X, \mu) \to(Y, \lambda)$ is $(\pi_{b\mu}, \lambda)$-continuous if and only if $f^{-1}(U)$ is $\pi_{b\mu}$ -open in (X, μ) for every λ-open set in (Y, λ).

Remark 4.13: Composition of $(\pi_{b\mu}, \lambda)$-continuity and $(\pi_{b\lambda}, \eta)$-continuity need not be $(\pi_{b\mu}, \eta)$-continuity.

Example 4.14: Let X=Y=Z={a, b, c}, μ= Φ,{a},{b},{a, b}, X}, λ= {Φ,{a},{a, b}} and η=Φ,{c}}. Define f:$(X, \mu)\to(Y, \lambda)$ and g:$(Y, \lambda)\to(Z, \eta)$ to be identity functions. Then f is $(\pi_{b\mu},\lambda)$-continuous and g is $(\pi_{b\lambda},\eta)$- continuous but $(g\circ f)^{-1}(\{a, b\}=f^{-1}(g^{-1}(\{a, b\})=f^{-1}(\{a, b\})=\{a, b\}$ is not $\pi_{b\mu}$ -closed in (X, μ).

Definition 4.15: A generalized topological space (X, μ) is called $\boldsymbol{\pi_{b\mu}}$ - space if every $\pi_{b\mu}$ -closed set is μ -closed.

Theorem 4.16: Let (X, μ) and (Z, η) be generalized topological space and (Y, λ).be a μ- $\pi_{b\mu}$ -space. If the function f: $(X, \mu)\to(Y, \lambda)$ is $(\pi_{b\mu}, \lambda)$-continuous and g: $(Y, \lambda)\to (Z, \eta)$ is $(\pi_{b\lambda}, \eta)$- continuous, then $g\circ f$: $(X, \mu) \to (Z, \eta)$ is $(\pi_{b\mu}, \eta)$-continuous.

Theorem 4.17: Let f: $(X, \mu)\to(Y, \lambda)$ be $(\pi_{b\mu}, \lambda)$-continuous and g: $(Y, \lambda)\to (Z, \eta)$ is (λ , η) - continuous, then $g\circ f$: $(X, \mu) \to (Z, \eta)$ is $(\pi_{b\mu}, \eta)$-continuous.

Theorem 4.18: If a function f: $(X, \mu) \to(Y, \lambda)$ is $(\pi_{b\mu}, \pi_{b\lambda})$-irresolute, then it is $(\pi_{b\mu}, \lambda)$-continuous but not conversely.

Example 4.19: Let X=Y={a,b,c}, μ= {Φ,{a},{b},{a, b},X},λ= {Φ,{a},{a, b},{b, c}} Define f:$(X, \mu)\to(Y, \lambda)$ to be an identity function. Then f is $(\pi_{b\mu}, \lambda)$-continuous but not $(\pi_{b\mu}, \pi_{b\lambda})$-irresolute because {a, b} is $\pi_{b\lambda}$ –closed in (Y, λ) but $f^{-1}(\{a, b\})=\{a, b\}$ is not $\pi_{b\mu}$ -closed in (X, μ).

Theorem 4.20: Let (X, μ) be a generalized topological space, (Y, λ) be a $\pi_{b\lambda}$ -space and f: (X, μ) →(Y, λ) be a ($\pi_{b\mu}$, λ)-continuous, then f is ($\pi_{b\mu}$, $\pi_{b\lambda}$)-irresolute.

Proof: Let U be a $\pi_{b\lambda}$ -closed in (Y, λ).Since (Y, λ) is a $\pi_{b\lambda}$ -space, U is a λ-closed set in (Y, λ). By hypothesis, f^{-1}(U) is $\pi_{b\mu}$ -closed in (X, μ).Hence f is ($\pi_{b\mu}$, $\pi_{b\lambda}$)-irresolute.

Proposition 4.21:
a) If f is ($\pi_{b\mu}$, $\pi_{b\lambda}$) irresolute, then it is pre- $\pi_{b\mu}$ –continuous
b) If f is pre-($\pi_{b\mu}$,λ) continuous, then it is ($\pi_{b\mu}$,λ)-continuous.

Theorem 4.22: If f: (X, μ)→(Y, λ) and g: (Y, λ)→ (Z, η) be a function. Then
(i) Let f be ($\pi_{b\mu}$, $\pi_{b\lambda}$)-irresolute and g is ($\pi_{b\lambda}$, η)-continuous. Then g∘f is ($\pi_{b\mu}$, η)-continuous.
(ii) If f be ($\pi_{b\mu}$, $\pi_{b\lambda}$)-irresolute and g is ($\pi_{b\lambda}$, $\pi_{b\eta}$)-irresolute, then g∘f is ($\pi_{b\mu}$, $\pi_{b\eta}$)- irresolute.
(iii) Let (Y, λ) be a $\pi_{b\lambda}$ -space. If f is ($\pi_{b\mu}$, λ)-continuous and g is ($\pi_{b\lambda}$, η)-continuous then g∘f is ($\pi_{b\mu}$, η)-continuous.

Theorem 4.23: Let (X, μ) be a $\pi_{b\mu}$ -space. If f: (X, μ) →(Y, λ) is surjective, (μ, λ)-closed and ($\pi_{b\mu}$, $\pi_{b\eta}$)- irresolute, then (Y, λ) is a $\pi_{b\lambda}$ -space.

Proof: Let F be a $\pi_{b\lambda}$ -closed subset of (Y, λ).Since f is ($\pi_{b\mu}$, $\pi_{b\eta}$)- irresolute,f^{-1}(F) is $\pi_{b\mu}$ -closed subset of (X, μ).Since (X, μ) is a $\pi_{b\mu}$ -space,f^{-1}(F) is a μ-closed subset of (X, μ).By hypothesis, it follows that F is λ-closed of (Y, λ).Hence (Y, λ) is a $\pi_{b\lambda}$ -space.

Theorem 4.24: Let f: (X, μ)→(Y, λ) be a function. Then the following statements are equivalent.
(i) The function f is ($\pi_{b\mu}$, λ)-continuous.
(ii) The inverse of each λ-open set in Y is $\pi_{b\mu}$ -open in X.
(iii) For each x in (X, μ), the inverse of every λ-nhd of f(x) is $\pi_{b\mu}$ -nhd of x.
(iv) For each x in (X, μ),and every λ-open set U containing f(x),there exists a $\pi_{b\mu}$ -open set V containing x such that f(V)⊆U.
(v) f($c\pi_{b\mu}$ (A))⊆c_λ(f(A)) for every subset A of X.
(vi) $c\pi_{b\mu}$ (f^{-1}(B)⊆f^{-1}(c_λ(B)) for every subset B of Y.

Theorem 4.25: If f is bijective, π_μ-open, pre- $\pi_{b\mu}$ -continuous in generalized topological space, then f is ($\pi_{b\mu}$, $\pi_{b\lambda}$)-irresolute.

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