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β* - Locally Closed Sets in Topological Spaces

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Abstract

In this paper we introduce three forms of β*- locally closed sets called β*- LC sets, β*- LC* sets and β*- LC** sets. Properties of these new concepts are studied as well as their relations to the other classes of locally closed sets will be investigated. Additionally, we define β*- Locally continuous function and compare it with other locally continuous functions in topological spaces.

Keywords: β*- LC sets, β*- LC* sets and β*- LC** sets.

I. Introduction

The notion of a locally closed set in a topological space was introduced by kurutowski and seerpinski [10]. According to bourbaki [3] a subset A of a topological space X is called locally closed in X if it is the intersection of an open set and a closed set in X. Ganster and Reilly used locally closed sets to define LC - continuity and LC - irresoluteness. Balachandran, Sundaram and Maki [2] introduced the concept of generalized locally closed sets in topological spaces and introduced some of their properties. Also various authors like, Arockiarani, Gnanambal, Park and Park and Veera Kumar [8] have introduced regular-generalized locally closed sets, semi-generalized locally closed sets and g^*- locally closed sets respectively in topological spaces.

In this paper, we introduce three weaker forms of locally closed sets denoted by β*- LC(X, τ), β*- LC^*(X, τ), β*- LC^{**}(X, τ) each of which contains LC(X, τ) and obtained some of their properties and also their relationships with other locally closed sets.

II. Preliminaries

Definition 2.1: A subset A of a topological space (X, τ) is called locally closed [3], if A = U $\cap$ F. where U $\in \tau$ and F is closed in (X, τ).

Definition 2.2:A subset A of a topological space (X, τ) is called β - locally closed (briefly β - LC) set if A = U $\cap$ V. Where U is β - open and V is β - closed.

Definition 2.3: A subset S of (X, τ) is called g - locally closed set[2] (briefly g- lc) if S = G $\cap$ F. where G is g - open in (X, τ) and F is g - closed in (X, τ) . Every g - closed set (resp. g - open set) is g- lc.

Definition2.4:A function f : X, τ) ⟶ (Y, σ) is called β - continuous if $f^{-1}(O)$ is a β - open of (X, τ) for every open set o of (Y, σ).

Definition2.5: A subset A of a topological space is said to be β*- open if $A \subseteq cl(int^{*}(cl(A)))$.

Definition 2.6: The complement of β*- open set in X is β* - closed set in X.

III. β*- Locally Closed Sets

In this section we introduce three forms of locally closed sets denoted by β*-locally closed sets, β*- LC* sets and β*- LC** sets and obtain some of their properties and also their relationships with g- lc sets, β - locally closed sets.

Definition 3.1: A subset A of a topological space (X, τ) is called a β*- locally closed set if A = S ∩ F. Where S is β*- open and F is β* - closed.

The class of all β*- locally closed sets in (X, τ) is denoted by β*- LC(X, τ).

Example 3.2: Let X = { a, b, c } , τ = {ϕ,{a, b}, X}, β*O(X, τ) = {ϕ, {a},{b},{a, b},{a, c}, {b, c}, X} and β*C(X, τ) = {ϕ , {a}, {b} , {c} ,{a, c} ,{b, c},X}.

Then β*- LC(X, τ) = { ϕ , {a}, {b}, {a, c},{b, c},X}.

Definitions 3.3: A subset A of a topological space (X, τ) is said to be β*- LC* set if there exits β*- open set S and a closed set F of (X, τ) such that A = S ∩ F.

Example 3.4: Let X = { a, b, c, d } , τ = {ϕ,{a},{b},{a, b},{a, b, c}, X}, τ^{c} = {ϕ,{d},{c, d}, {a, c, d},{b, c, d}, X}. β*O(X, τ) = {ϕ, {a},{b},{c},{a, b},{a, c}, {a, d}, {b, c}, {b, d}, {c, d},{a, b, c},{a, b, d},{a, c, d},{b, c, d}, X}.Then β*- LC^{*} (X, τ) = { ϕ , {c, d}, {a, c, d}, {b, c, d},X}.

Definitions 3.5: A subset A of a topological space (X, τ) is said to be β*- LC^{**} - set if there is an open set S and a β*- closed set F of (X, τ) such that A = S ∩ F.

Example 3.6: Let X = { a, b, c, d } , τ = {ϕ,{a},{b},{c},{a, b},{a, c},{b, c},{a, b, c}, X}, β*C(X, τ) = {ϕ, {a},{b},{c}, {d},{a, b},{a, c}, {a, d}, {b, c}, {b, d},{c, d},{a, b, d}, {a, c, d},{b, c, d}, X}.Then β*- LC^{**} (X, τ) = { ϕ , {a},{b}, {c},{a, b}, {a, c},{b, c},X}.

Theorem 3.7: If a subset A of (X, τ) is locally closed then it is β*- LC(X, τ) , β*- LC^{*} (X, τ), β*- LC^{**}(X, τ) set.

Proof : Let A = P ∩ Q Where P is open and Q is closed in (X, τ). Since every open set is β*-open and every closed is β*- closed, A is β*- LC(X, τ) , β*- LC^{*} (X, τ), β*- LC^{**}(X, τ).

Remark 3.8 : The Converse of the above theorem need not be true as seen from following example.

Example 3.9: Let X = { a, b, c, d } , τ = {ϕ,{a},{b, c, d}, X}, τ^{c} = {ϕ,{a},{b, c, d}, X}. β*O(X, τ) = {ϕ, {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}, X}. β*C(X, τ) = {ϕ, {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}, X}. Then β*- LC (X, τ) = {ϕ, {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}, X} and LC (X, τ) ={ϕ,{a},{b, c, d}, X}.Here{b},{c}, {d}, {a, b},{a, c}, {a, d}, {b, c}, {b, d},{c, d}, {a, b, c},{a, b, d},{a, c, d} is β*- LC (X, τ) but not LC (X, τ).

Example 3.10: Let X = { a, b, c} , τ = {ϕ,{b},{c},{a, b},{b, c},X}, τ^c = {ϕ,{a},{c},{a, b}, {a, c}, X}. β*O(X, τ) = {ϕ, {a},{b},{c}, {a, b},{a, c},{b, c}, X}. β*C(X, τ) = {ϕ, {a},{b},{c}, {a, b},{a, c},{b, c}, X} Then β*- LC^*(X, τ) = {ϕ, {a}, {c},{a, b},{a, c}, X} and LC (X, τ) ={ϕ,{c},{a, b}, X}.Here{a},{a, c} is β*- LC^* (X, τ) but not LC (X, τ).

Example 3.11: Let X = { a, b, c, d } , τ = {ϕ,{a},{b},{c},{a, b},{a, c},{b, c},{a, b, c}, {a, b, d},X}, τ^c = {ϕ,{c},{d},{a, d},{b, d},{c, d},{a, b, d},{a, c, d},{b, c, d}, X}. β*O(X, τ) = {ϕ, {a},{b},{c}, {a, b},{a, c}, {a, d}, {b, c}, {b, d},{a, b, c},{a, b, d},{a, c, d}, {b, c, d}, X}. β*C(X, τ) = {ϕ, {a},{b},{c}, {d}, {a, c}, {a, d}, {b, c}, {b, d},{c, d}, {a, b, d},{a, c, d},{b, c, d}, X}. Then β*- LC^{**} (X, τ) = {ϕ, {a},{b},{c},{a, c},{b, c}, {a, b, d}, X} and LC (X, τ) ={ϕ,{c},{a, b, d}, X}.Here{a},{b}, {a, c},{b, c} is β*- LC^{**} (X, τ) but not LC (X, τ).

Theorem 3.12: If a subset A of (X, τ) is β*- LC^*- set then it is β*- LC - set.

Proof: Let A be a β*- LC^*- set. Let P be a β*- set in (X, τ) and Q be closed set in (X, τ).Since A is β*- LC^*- set by definitions, A=P∩Q. Since every closed set is β* - closed then Q is β*- closed. Then A is β*- LC- set.

Remark 3.13: The converse of the above theorem need not be true as seen from the following example.

Example3.14: Let X = { a, b, c, d } , τ = {ϕ,{a},{b},{a, b},{a, b, c}, X}, τ^c = {ϕ,{d},{c, d}, {a, c, d},{b, c, d}, X}. β*O(X, τ) = {ϕ, {a},{b},{c}, {a, b},{a, c}, {a, d}, {b, c}, {b, d}, {c, d},{a, b, c},{a, b, d},{a, c, d},{b, c, d}, X}. β*C(X, τ) = {ϕ, {a},{b},{c}, {d}, {a, b}, {a, c}, {a, d}, {b, c}, {b, d},{c, d},{a, b, d},{a, c, d},{b, c, d}, X}. Then β*- LC (X, τ) = {ϕ, {a},{b},{c},{a, b}, {a, c},{a, d},{b, c},{b, d}, {c, d},{a, b, d}, {a, c, d},{b, c, d}, X} and β*- LC^* (X, τ) ={ϕ,{c, d},{a, c, d}, {b, c, d}, X}.Here{a},{b}, {c},{a, b},{a, c}, {a, d},{b, c}, {b, d},{a, b, d} is β*- LC (X, τ) but not β*- LC^* (X, τ).

Theorem 3.15: Every β*- LC^{**} (X, τ) is β*- LC (X, τ) .

Proof: It follows from the definitions 3.1 and 3.3.

Remark 3.16: The converse of the above theorem need not be true as seen from the following example.

Example 3.17 : Let X = { a, b, c, d } , τ = {ϕ,{a},{b}, {c},{a, b},{a, c},{b, c},{a, b, c}, X}, τ^c = {ϕ,{d},{a, d},{b, d},{c, d},{a, b, d}, {a, c, d},{b, c, d}, X}. β*O(X, τ) = {ϕ, {a},{b},{c}, {a, b},{a, c}, {a, d}, {b, c}, {b, d},{c, d},{a, b, c},{a, b, d},{a, c, d},{b, c, d}, X}. β*C(X, τ) = {ϕ, {a},{b},{c}, {d}, {a, b},{a, c}, {a, d}, {b, c}, {b, d},{c, d},{a, b, d},{a, c, d},{b, c, d}, X}. Then β*- LC (X, τ) = {ϕ, {a},{b},{c}, {a, b}, {a, c},{a, d},{b, c},{b, d}, {c, d},{a, b, d}, {a, c, d},{b, c, d}, X} and β*- LC^{**} (X, τ) ={ϕ, {a},{b},{c},{a, b},{a, c}, {b, c}, X}. Here {a, d},{b, d}, {c, d},{a, b, d},{a, c, d},{b, c, d} is β*- LC (X, τ) but not β*- LC^{**}(X, τ).

Theorem 3.18: If a subset A of (X, τ) is β - LC set then A is β*- LC - set.

Proof: Let $A = P \cap Q$. Where P is β - Open, Q is β - Closed in (X, τ). Since, every β - Open set is β*- Open and every β - Closed set is β*- Closed. Therefore, A is β*- LC - set in (X, τ).

Remark 3.19: The Converse of the above theorem need not be true as seen from the following example.

Example 3.20: Let X = { a, b, c, d } , τ = {ϕ,{a},{b},{a, b}, {a, b, c}, X}, $τ^c$ = {ϕ,{d}, {c, d},{a, c, d},{b, c, d}, X}. β*O(X, τ) = {ϕ, {a},{b},{c}, {a, b},{a, c}, {a, d}, {b, c}, {b, d},{c, d},{a, b, c},{a, b, d},{a, c, d},{b, c, d}, X}. β*C (X, τ) = {ϕ, {a},{b},{c}, {d}, {a, b},{a, c}, {a, d}, {b, c}, {b, d},{c, d},{a, b, d},{a, c, d},{b, c, d}, X}.
βO (X, τ) = {ϕ, {a},{b},{a, b},{a, c}, {a, d}, {b, c}, {b, d},{a, b, c},{a, b, d},{a, c, d},{b, c, d}, X}, βC (X, τ) = {ϕ, {a},{b}, {c},{d},{a, c}, {a, d}, {b, c}, {b, d},{c, d},{a, c, d},{b, c, d}, X},Then β*- LC (X, τ) = {ϕ, {a},{b},{c}, {a, b}, {a, c},{a, d},{b, c},{b, d}, {c, d},{a, b, d}, {a, c, d},{b, c, d}, X} and β - LC (X, τ) ={ϕ, {a},{b},{a, c},{a, d},{b, c}, {b, d},{a, c, d}, {b, c, d}, X}.Here {c}, {a, b},{a, d}, {c, d},{a, b, d} is β*- LC (X, τ) but not β - LC(X, τ).

Remark 3.21: Intersection of two β*- LC sets (resp, β*- LC^*- sets, β*- LC^{**} -sets) need not be a β*- LC (resp, β*- LC^* - sets, β*- LC^{**}- sets) as seen from the following example.

Example 3.21: Let X = { a, b, c, d } , τ = {ϕ,{a},{b},{c},{a, b},{a, c},{b, c}, {a, b, c}, X}, $τ^c$ = {ϕ,{d}, {a, d},{b, d},{c, d},{a, b, d}, {a, c, d},{b, c, d}, X}. β*O(X, τ) = {ϕ, {a},{b},{c}, {a, b},{a, c}, {a, d}, {b, c}, {b, d},{c, d},{a, b, c},{a, b, d},{a, c, d},{b, c, d}, X}. β*C (X, τ) = {ϕ, {a},{b},{c}, {d}, {a, b},{a, c}, {a, d}, {b, c}, {b, d},{c, d},{a, b, d},{a, c, d},{b, c, d}, X}.Then β*- LC (X, τ) = {ϕ, {a},{b},{c}, {a, b}, {a, c},{a, d},{b, c},{b, d}, {c, d},{a, b, d}, {a, c, d},{b, c, d}, X}. Here {a, d},{b, c, d} is in β*- LC (X, τ) but {a, d} ∩ {b, c, d}= {d} is not in β - LC(X, τ). Also β*- LC^* (X, τ) = {ϕ,{a, d},{b, d}, {c, d},{a, b, d}, {a, c, d},{b, c, d}, X}. Here {a, d},{b, d} is in β*- LC^* (X, τ) but {a, d} ∩ {b, d}= {d} is not in $β^*$ - LC^* (X, τ).

IV. β*- LC Continuous Function in Topological Space

In this section we introduce the concept of β*- LC continuous and β*- LC^* Continuous and β*- LC^{**} Continuous functions maps are defined and some of their properties are obtained.

Definition 4.1: Let f : (X, τ) ⟶ (Y, σ) be a map. Then *f* is called

(i) β*- LC continuous if f^{-1} (V) ∈ β*- LC (X, τ) for each V ∈ (Y, σ)

(ii) β*- LC^* continuous if f^{-1} (V) ∈ β*- LC^* (X, τ) for each V ∈ (Y, σ)

(iii) β*- LC^{**} continuous if f^{-1} (V) ∈ β*- LC^{**} (X, τ) for each V ∈ (Y, σ)

Example 4.2 : Let X = Y = { a, b, c} , τ = {ϕ,{a, b},X}, $τ^c$ = {ϕ,{c}, X}, σ ={ ϕ,{a},Y}, $σ^c$={ ϕ,{b, c},Y}. β*O(X, τ) = {ϕ, {a},{b}, {a, b},{a, c},{b, c}, X}.

β*C(X, τ) = {ϕ, {a},{b},{c}, {a, c},{b, c}, X} Then β*- LC(X, τ) = {ϕ, {a}, {b},{a, c},{b, c}, X}. Then the function f : (X, τ) ⟶ (Y, σ) defined by f(a) = b, f(b) = c, f(c) = a. Clearly f is β*- LC continuous.

Example 4.3 : Let X = Y = { a, b, c} , τ = {ϕ,{c},{a, b},X}, $τ^c$ = {ϕ,{c},{a, b},X}, σ ={ ϕ, {a, b},Y}, $σ^c$ ={ ϕ,{c},Y}. β*O(X, τ) = {ϕ, {a},{b},{c}, {a, b},{a, c},{b, c}, X}.

β*C(X, τ) = {ϕ, {a},{b},{c},{a, b}, {a, c},{b, c}, X} Then β*- LC(X, τ) = {ϕ, {c}, {a, b}, X}. Then the function f : (X, τ) ⟶ (Y, σ) defined by f(a) = a, f(b) = b, f(c) = c. Clearly f is β*- LC^* continuous.

Example 4.4 : Let X = Y = { a, b, c, d} , τ = {ϕ, {a},{b},{c},{a, b},{a, c},{b, c},{a, b, c},X}, $τ^c$ = {ϕ,{d},{a, d}, {b, d},{c, d},{a, b, d},{a, c, d}, {b, c, d},X}, σ ={ ϕ,{a, b},Y}, $σ^c$ ={ ϕ, {c, d},Y}. β*O(X, τ) = {ϕ, {a},{b},{c}, {a, b},{a, c},{a, d}, {b, c},{b, d},{c, d},{a, b, c}, {a, b, d},{a, c, d},{b, c, d}, X}. β*C(X, τ) = {ϕ, {a},{b},{c}, {d},{a, b},{a, c},{a, d}, {b, c},{b, d},{c, d}, {a, b, d},{a, c, d},{b, c, d}, X} Then β*- LC^{**} (X, τ) = {ϕ, {a},{b},{c}, {a, b},{a, c},{b, c}, X}. Then the function f : (X, τ) ⟶ (Y, σ) defined by f(a) = b, f(b) = c, f(c) = a. Clearly f is β*- LC^{**} continuous.

Theorem 4.5: Let f : (X, τ) ⟶ (Y, σ) be a function. Then we have the following

1. If *f* is LC - continuous then *f* is β*- LC continuous, β*- LC^* continuous, β*- LC^{**} continuous.
2. If *f* is β*- LC^* continuous (or) β*- LC^{**} continuous function the f is β*- LC continuous.

Proof:

1. Suppose that *f* is LC – continuous. Let V be an open set of (X, τ). Then $f^{-1}(V)$ is locally closed in (X, τ). Since every locally closed set is β*- LC set, β*- LC^*- set, β*- LC^{**}- set, it follows that *f* is β*- LC continuous, β*- LC^* continuous, β*- LC^{**} continuous.

2 .Let f : (X, τ) ⟶ (Y, σ) be a β*- LC^* continuous (or) β*- LC^{**} continuous function. Since every β*- LC^* - set is β*- LC - set and every β*- LC^{**} - set is β*- LC - set. Therefore the proof follows.

Remark 4.6: The converse of the above theorem need not be true as seen from the following example.

Example 4.7:

1) Every β*- LC continuous is not LC continuous:

Let X={a, b, c, d},Y={a, b, c, d} τ ={X, ϕ,{a},{b, c, d}} & σ={X, ϕ,{a},{a, b, c}}, β*- LC(X, τ) = {X, ϕ, {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}}. Let f : (X, τ) ⟶ (Y, σ) define by f(a) = a, f(b) = b, f(c) = c, f(d) = d. Clearly f is β*- LC continuous but not locally closed, since f^{-1} {a, b, c}= abc is not LC in X.

2) Every β*- LC* continuous is not LC continuous:

Let X = {a, b, c}, Y= {a, b, c}, τ = { X, ϕ, {b}, {c}, {a, b},{b ,c}}& σ={X, ϕ, {a},{a, b},

{a, c}}, β*- LC* (X, τ) = { X, ϕ, {a}, {c}, {a, b},{a ,c}} . Let $f: X \to Y$ defined by f(a)= a , f(b)= b, f(c) = c. Cleary f is β*- LC*continuous but f^{-1} {a, c} = ac is not LC in X. Hence f is not LC continuous in X.

3) Every β*- LC continuous is not LC - continuous:**

Let X = {a, b, c}, Y= {a, b, c}, τ = { X, ϕ, {b}, {c}, {a, b},{b ,c}}& σ={X, ϕ,{a, b}},

β*- LC** (X, τ) = { X, ϕ, {b}, {c}, {a, b},{b ,c}} . Let $f: X \to Y$ defined by f(a) = c , f(b) = a, f(c) = b. Cleary f is β*- LC** continuous but f^{-1} {a, b}= bc is not LC in X. Hence f is not LC continuous in X.

4) Every β*- LC continuous is not β*- LC* continuous:

Let X = Y = {a, b, c}, τ={X, ϕ,{b},{c},{a, b} ,{b, c}} σ = {X, ϕ, {c}, {a, c}, {b, c}} β*- LC (X, τ) = {X, ϕ, {a}, {b}, {c}, {a, b}, {a, c}, {b, c} }, β*- LC* (X, τ) = { X, ϕ, {a}, {c}, {a, b}, {a, c}}. Let f: X→Y f(a) = a, f(b) = b, f(c) = c. Clearly f is β*- LC continuous but not β*- LC* continuous since f^{-1} {b, c} = {b, c} is not in β*- LC*.

5) Every β*- LC continuous is not β*- LC continuous:**

Let X= Y= {a, b, c, d} , τ = {X , ϕ ,{a}, {b},{c},{a, b},{a, c},{a, b, c}, {a, b, d}}. β*- LC (X, τ) = {X, ϕ,{a},{b},{c},{d},{a, b},{a, c}, {b, c}, {c, d},{a, d},{b, d},{a, b, c},{b, c, d},

{a, b, d},{a, c, d}}. β*- LC** (X, τ) ={X, ϕ,{ a},{b},{c},{a, c}, {b, c},{a, b, d}}.

σ={X, ϕ,{a},{a, b, c}},Let f:X→Y f(a) = a, f(b) = d, f(c) = b, f(d) = c . Clearly f is

β*- LC continuous but not β*- LC**.

Theorem 4.8: If $f: (X,\tau) \to (Y,\sigma)$ is β*- LC continuous and $g: (Y,\sigma) \to (Z,\eta)$ is continuous, then $g \circ f: (X,\tau) \to (Z,\eta)$ is β*- LC continuous function.

Proof: Let F be a closed set in (Z,η). Then $g^{-1}(F)$ is closed in (Y,σ). Since g is continuous, then $f^{-1}(g^{-1}(F))$ is β*- LC set in (X,τ) as f is β*- LC continuous then $g \circ f: (X,\tau) \to (Z,\eta)$ is β*- LC continuous function.

Theorem 4.9 : If $f: (X,\tau) \rightarrow (Y,\sigma)$and $g: (Y,\sigma) \rightarrow (Z,\eta)$ be any two functions. Then

(i) $g \circ f$ is β*- LC*.- continuous if f is β*- LC*.- continuous and g is continuous.

(ii) $g \circ f$ is β*- LC**.- continuous if f is β*- LC**.- continuous and g is continuous.

Proof: The proof is similar to that of Theorem 4.8.

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