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A STUDY ON FUZZY LOCALLY b-CLOSED SETS

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ABSTRACT

In this paper the concept of fuzzy locally b-closed sets is introduced and its inter relations with other types of locally closed sets are studied with suitable counter examples. Equivalently the inter relations of fuzzy locally b-continuous functions with other types of fuzzy locally continuous functions are discussed with necessary counter examples. Also the concepts of fuzzy locally b-compact spaces, fuzzy locally b-Lindelof spaces and fuzzy locally b-closed compact spaces are introduced and some of their charecterizations and properties are established.

Key words

fuzzy locally b-closed sets, fuzzy locally b-continuous functions, fuzzy locally b-compact spaces and fuzzy locally b-Lindelof spaces

1. INTRODUCTION AND PRELIMINARIES

1.1 Introduction

The concept of fuzzy sets was introduced by Zadeh [11] in his classical paper. Fuzzy sets have applications in many fields such as information [9] and control [10]. The first step of locally closedness was done by Bourbaki [5]. Ganster and Reilly used locally closed sets in [8] to define Lc - continuity and Lc - compactness. The concepts of r - fuzzy G_δ - $\tilde{g}$ -locally closed sets and fuzzy G_δ - $\tilde{g}$ -locally continuous functions were studied by Amudhambigai, Uma and Roja [1]. The concepts of fuzzy slightly β-continuity, fuzzy β-Lindelof, fuzzy mildly compact and fuzzy countably β-closed compact were introduced by Erdal Ekici [7]. In this paper the concept of fuzzy locally b-closed sets is introduced and its inter relations with other types of locally closed sets are studied with suitable counter examples. Equivalently the inter relations of fuzzy locally b-continuous functions with other types of fuzzy locally continuous functions are discussed with necessary counter examples. Also the concepts of fuzzy locally b-compact spaces, fuzzy locally b-Lindelof spaces and fuzzy locally b-closed compact spaces are introduced and some of their charecterizations and properties are established.

1.2 PRELIMINARIES

Definition : 1.2.2 [2,6] A fuzzy topological space (X, T) is said to be **fuzzy compact** if every fuzzy open cover of (X, T) has a finite subcover.

Definition : 1.2.4 [4] Any $\lambda \in I^X$ in a fuzzy topological space (X, T) is said to be a

(i) **fuzzy α -closed set** (briefly, Fα -cls) if $\lambda \geq$ cl (int (cl (λ))

(ii) **fuzzy pre-closed set** (briefly, Fp-cls) if $\lambda \geq$ cl (int (λ)).

(iii) **fuzzy semi-closed set** (briefly, Fs-cls) if $\lambda \geq$ int (cl (λ)).

Definition : 1.2.7 [3] Any fuzzy set $\lambda \in I^X$ in a fuzzy topological space (X, T) is said to be a **fuzzy b-closed set** (briefly, Fb-cls) if $\lambda \geq$ cl (int (λ)) $\wedge$ int (cl (λ)).

Definition : 1.2.8 [6] Let (X, T) and (Y, S) be any two fuzzy topological spaces. Any function f : (X, T) $\rightarrow$ (Y, S) is said to be a **fuzzy continuous function** if $f^{-1}(\lambda)$ is fuzzy open in (X, T) for each fuzzy open set λ in (Y, S).

Definition : 1.2.9 [7] A fuzzy topological space (X, T) is said to be **fuzzy β -compact** if every fuzzy β -open cover of (X, T) has a finite subcover.

(a) fuzzy countably β -compact if every fuzzy β -open countably cover of (X, T) has a finite subcover.

(b) fuzzy β -Lindelof if every fuzzy β -open cover of (X, T) has a countable subcover.

(c) fuzzy mildly compact if every fuzzy clopen cover of (X, T) has a finite subcover.

(d)fuzzy mildly countably compact if every fuzzy clopen countably cover of (X, T) has a finite subcover.

(e) fuzzy mildly Lindelof if every fuzzy clopen cover of (X, T) has a countable subcover.

2. A STUDY ON FUZZY LOCALLY b-CLOSED SETS

Definition 2.1 Let (X, T) be a fuzzy topological space. Any $\lambda \in I^X$ is called a **fuzzy locally closed set** (briefly, **FLcls**) if $\lambda = \mu \wedge \gamma$, where μ is a fuzzy open set and γ is a fuzzy closed set. Its complement is called a **fuzzy locally open set.**

Definition 2.2 Let (X, T) be a fuzzy topological space. Any $\lambda \in I^X$ is called a **fuzzy locally α -closed set** (briefly, **FLα -cls**) if $\lambda = \mu \wedge \gamma$, where μ is a fuzzy open set and γ is a fuzzy α -closed set. Its complement is called a **fuzzy locally α -open set.**

Definition 2.3 Let (X, T) be a fuzzy topological space. Any $\lambda \in I^X$ is called a **fuzzy locally semi-closed set** (briefly, **FLs-cls**) if $\lambda = \mu \wedge \gamma$, where μ is a fuzzy open set and γ is a fuzzy semi-closed set. Its complement is called a **fuzzy locally semi-open set.**

Definition 2.4 Let (X, T) be a fuzzy topological space. Any $\lambda \in I^X$ is called a **fuzzy locally pre-closed set** (briefly, **FLp-cls**) if $\lambda = \mu \wedge \gamma$, where μ is a fuzzy open set and γ is a fuzzy pre-closed set. Its complement is called a **fuzzy locally pre-open set.**

Definition 2.5 Let (X, T) be a fuzzy topological space. Any $\lambda \in I^X$ is called a **fuzzy locally b-closed set** (briefly, **FLb-cls**) if $\lambda = \mu \wedge \gamma$, where μ is a fuzzy open set and γ is a fuzzy b-closed set. Its complement is called a **fuzzy locally b-open set.**

Proposition 2.1 Every fuzzy locally closed set is fuzzy locally α -closed.

Remark 2.1The converse of the above Proposition 2.1 need not be true.

Example 2.1 Let X = {a, b} and $\lambda_1, \lambda_2, \lambda_3 \in I^X$ be defined as follows : λ_1(a) =0.5, λ_1(b) = 0.4; λ_2(a) = 0.5, λ_2(b) = 0.2; λ_3(a) = 0.7, λ_3(b) = 0.9. Define the fuzzy topology T = { 0, 1, $\lambda_1, \lambda_2, \lambda_3$ }. Clearly (X, T) is a fuzzy topological space. Let $\gamma \in I^X$ be defined as γ(a) = 0.5, γ(b) = 0.7. Then γ is fuzzy α -closed. Thus, for $\lambda_3 \in$ T, $\lambda_3 \wedge \gamma$ = (0.5, 0.7) = λ is **fuzzy locally α -closed. But, λ is not a fuzzy locally closed set,**

Proposition 2.2 Every fuzzy locally α -closed set is fuzzy locally semi-closed.

Remark 2.2 The converse of the above Proposition 2.2 need not be true.

Example 2.2 Let X = { a, b } and $\lambda_1, \lambda_2, \lambda_3 \in I^X$ be defined as follows : λ_1(a) =0.3, λ_1(b) = 0.4; λ_2(a) = 0.4, λ_2(b) = 0.4; λ_3(a) = 0.8, λ_3(b) = 0.9.Define the fuzzy topology T = { 0, 1, $\lambda_1, \lambda_2, \lambda_3$ }. Clearly (X, T) is a fuzzy topological space. Let $\gamma \in I^X$ be defined as γ(a) = 0.6, γ(b) = 0.5. Then γ is fuzzy semi-closed. Thus, for $\lambda_3 \in$ T, $\lambda_3 \wedge \gamma$ = (0.6, 0.5) = λ is **fuzzy locally semi-closed. But, λ is not a fuzzy locally α -closed set**.

Proposition 2.3 Every fuzzy locally semi-closed set is fuzzy locally b-closed.

Remark 2.3The converse of the above Proposition 2.3 need not be true.

Example 2.3 Let X = { a, b } and $\lambda_1, \lambda_2, \lambda_3 \in I^X$ be defined as follows : λ_1(a) = 0.6, λ_1(b) = 0.8; λ_2(a) = 0.5, λ_2(b) = 0.4; λ_3(a) = 0.7, λ_3(b) = 0.9.Define the fuzzy topology T = { 0, 1, $\lambda_1, \lambda_2, \lambda_3$ }. Clearly (X, T) is a fuzzy topological space. Let $\gamma \in I^X$ be defined as γ(a) = 0.6, γ(b) = 0.7. Then γ is fuzzy b-closed. Thus, for $\lambda_3 \in$ T and for the fuzzy b-closed set γ, $\lambda_3 \wedge \gamma$ = (0.6, 0.7) = λ is **fuzzy locally b-closed. But, λ is not a fuzzy locally semi-closed set.**

Proposition 2.4 Every fuzzy locally closed set is fuzzy locally pre-closed.

Remark 2.4 The converse of the above Proposition 2.4 need not be true.

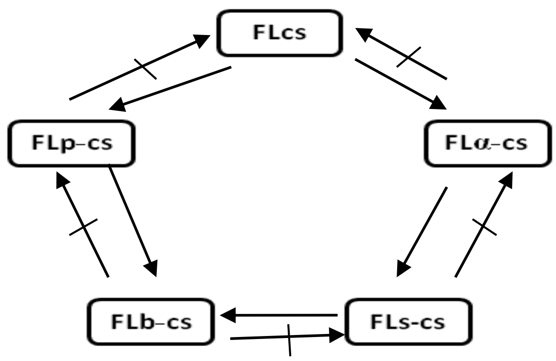
Example 2.4 Let X = { a, b } and $\lambda_1, \lambda_2, \lambda_3 \in I^X$ be defined as follows : λ_1(a) =0.5, λ_1(b) = 0.6; λ_2(a) = 0.4, λ_2(b) = 0.3; λ_3(a) = 0.9, λ_3(b) = 0.8.Define the fuzzy topology T = { 0, 1, $\lambda_1, \lambda_2, \lambda_3$ }. Clearly (X, T) is a fuzzy topological space. Let $\gamma \in I^X$ be defined as γ(a) = 0.7, γ(b) = 0.5. Then γ is fuzzy pre-closed. Thus, for $\lambda_3 \in$ T and for the fuzzy pre-closed set γ, $\lambda_3 \wedge \gamma$ = (0.7, 0.5) = λ is **fuzzy locally pre-closed. But, λ is not a fuzzy locally closed set.**

Proposition 2.5 Every fuzzy locally pre-closed set is fuzzy locally b-closed.

Remark 2.5 The converse of the above Proposition 2.5 need not be true.

Example 2.5 Let X = { a, b } and λ_1, λ_2, $\lambda_3 \in I^X$ be defined as follows: λ_1(a) = 0.3, λ_1(b) = 0.2; λ_2(a) = 0.4, λ_2(b) = 0.3; λ_3(a) = 0.5, λ_3(b) = 0.9.Define the fuzzy topology T = { 0, 1, λ_1, λ_2, λ_3 }. Clearly (X, T) is a fuzzy topological space. Let $\gamma \in I^X$ be defined as γ(a) = 0.7, γ(b) = 0.5. Then γ is fuzzy b-closed. Thus, for $\lambda_3 \in$ T and for the fuzzy b-closed set γ, $\lambda_3 \wedge \gamma$ = (0.5, 0.5) = λ is **fuzzy locally b-closed. But, λ is not a fuzzy locally pre-closed set**.

Remark 2.6 Clearly the above discussions give the following implications :



4. A STUDY ON FUZZY LOCALLY b-CONTINUOUS FUNCTION

Definition 4.1 Let (X, T) and (Y, S) be any two fuzzy topological spaces. Any function f : (X, T) → (Y, S) is said to be a **fuzzy locally continuous function** (briefly, **FLcf**) if $f^{-1}(\lambda) \in I^X$ is fuzzy locally closed and for each fuzzy closed set $\lambda \in I^Y$.

Definition 4.2 Let (X, T) and (Y, S) be any two fuzzy topological spaces. Any function f : (X, T) → (Y, S) is said to be a **fuzzy locally α -continuous function** (briefly, **FLα -cf**) if $f^{-1}(\lambda) \in I^X$ is fuzzy locally α -closed for each fuzzy closed set $\lambda \in I^Y$.

Definition 4.3 Let (X, T) and (Y, S) be any two fuzzy topological spaces. Any f : (X, T) → (Y, S) is said to be a **fuzzy locally semi-continuous function** (briefly, **FLs-cf**) if $f^{-1}(\lambda) \in I^X$ is fuzzy locally semi-closed and for each fuzzy closed set $\lambda \in I^Y$.

Definition 4.4 Let (X, T) and (Y, S) be any two fuzzy topological spaces. Any function f : (X, T) → (Y, S) is said to be a **fuzzy locally pre-continuous function** (briefly, **FLp-cf**) if $f^{-1}(\lambda) \in I^X$ is fuzzy locally pre-closed and for each fuzzy closed set $\lambda \in I^Y$.

Definition 4.5 Let (X, T) and (Y, S) be any two fuzzy topological spaces. Any function f : (X, T) → (Y, S) is said to be a **fuzzy locally b-continuous function** (briefly, **FLb-cf**) if $f^{-1}(\lambda) \in I^X$ is fuzzy locally b-closed and for each fuzzy closed set $\lambda \in I^Y$.

Definition 4.6 Let (X, T) be a fuzzy topological space. For a fuzzy set λ of X, the **fuzzy locally α -closure** (briefly, FLα -cl) and **fuzzy locally α -interior** (briefly, FLα -int) of λ are defined respectively, as

FLα -cl (λ) = $\wedge$ { $\mu \in I^X$: $\mu \geq \lambda$; μ is fuzzy locally α -closed set } and

FLα -int (λ) = $\vee$ { $\mu \in I^X$: $\mu \leq \lambda$; μ is fuzzy locally α -open set }.

Proposition 4.1 Let (X, T) and (Y, S) be any two fuzzy topological spaces. Then for any function f : (X, T) $\rightarrow$ (Y, S) the following statements are equivalent :

(a) f is fuzzy locally α -continuous.

(b) For every $\lambda \in I^X$, f (FLα -cl (λ)) $\leq$ cl (f (λ)).

(c) For every $\lambda \in I^Y$, f^{-1}(cl (λ)) $\geq$ FLα -cl (f^{-1}(λ)).

(d) For every $\lambda \in I^Y$, f^{-1}(int (λ)) $\leq$ FLα -int (f^{-1}(λ)).

Proposition 4.2 Every fuzzy locally continuous function is fuzzy locally α -continuous.

Remark 4.1 The converse of the above Proposition 4.2 need not be true.

Example 4.1 Let X = { a, b } and let λ_1, λ_2, $\lambda_3 \in I^X$ be defined as follows : λ_1(a) = 0.5, λ_1(b) = 0.4; λ_2(a) = 0.5, λ_2(b) = 0.2; λ_3(a) = 0.7, λ_3(b) = 0.9. Define the fuzzy topology on X as T = { 0, 1, λ_1, λ_2, λ_3 }. Define the fuzzy topology on Y as S = {0, 1, λ }, where $\lambda \in I^X$ is defined as λ(a) = 0.3, λ(b) = 0.5. Clearly (X, T) and (Y, S) are fuzzy topological spaces. Define f : (X, T) $\rightarrow$ (Y, S) as f(a) = b, f (b) = a. Then, f^{-1} $(1-\lambda)$ = (0.5, 0.7) is fuzzy α -closed. Thus, for $\lambda_3 \in$ T and for the fuzzy α -closed set $f^{-1}(1-\lambda)$, $\lambda_3 \wedge f^{-1}$ $(1-\lambda)$= $f^{-1}(1-\lambda)$ is fuzzy locally α -closed but not fuzzy locally closed in (X, T).

Therefore, **every fuzzy locally α -continuous function need not be fuzzy locally continuous.**

Proposition 4.3 Every fuzzy locally α -continuous function is fuzzy locally semi- continuous.

Remark 4.2 The converse of the above Proposition 4.3 need not be true.

Example 4.2 Let X = { a, b } and let λ_1, λ_2, $\lambda_3 \in I^X$ be defined as follows : λ_1(a) = 0.3, λ_1(b) = 0.4; λ_2(a) = 0.4, λ_2(b) = 0.4; λ_3(a) = 0.8, λ_3(b) = 0.9. Define the fuzzy topology on X as T = { 0, 1, λ_1, λ_2, λ_3 }. Define the fuzzy topology on Y as S = { 0, 1, λ }, where $\lambda \in I^X$ is defined as λ(a) = 0.5, λ(b) = 0.4. Clearly (X, T) and (Y, S) are fuzzy topological spaces. Define f : (X, T) $\rightarrow$ (Y, S) as f(a) = b, f(b) = a. Then, f^{-1} $(1-\lambda)$ = (0.6, 0.5) is fuzzy semi-closed. Thus, for $\lambda_3 \in$ T and for the fuzzy semi-closed set $f^{-1}(1-\lambda)$, $\lambda_3 \wedge f^{-1}(1-\lambda)$ = $f^{-1}(1-\lambda)$ is fuzzy locally semi-closed but not fuzzy locally α -closed in (X, T). Therefore, **every fuzzy locally semi-continuous function need not be fuzzy locally α -continuous.**

Proposition 4.4 Every fuzzy locally semi-continuous function is fuzzy locally b-continuous.

Remark 4.3 The converse of the above Proposition 4.4 need not be true.

Example 4.3 Let X = { a, b } and let λ_1, λ_2, $\lambda_3 \in I^X$ be defined as follows : λ_1(a) = 0.6, λ_1(b) = 0.8; λ_2(a) = 0.5, λ_2(b) = 0.4; λ_3(a) = 0.7, λ_3(b) = 0.9. Define the fuzzy topology on X as T ={0, 1, λ_1, λ_2, λ_3 }. Define the fuzzy topology on Y as S ={0, 1, λ }, where $\lambda \in I^X$ is defined as λ(a) = 0.3, λ(b) = 0.4. Clearly (X, T) and (Y, S) are fuzzy topological spaces. Define f :(X, T)$\rightarrow$(Y, S) as f(a) = b, f(b) = a.

Then, $f^{-1}(1-\lambda)$ =(0.6, 0.7) is fuzzy b-closed. Thus, for $\lambda_3 \in$ T and for the fuzzy b-closed set $f^{-1}(1-\lambda)$, $\lambda_3 \wedge f^{-1}(1-\lambda) = f^{-1}(1-\lambda)$ is fuzzy locally b-closed but not fuzzy locally semi-closed in. Therefore, **every fuzzy locally b-continuous function need not be fuzzy locally semi-continuous.**

Proposition 4.5 Every fuzzy locally continuous function is fuzzy locally pre-continuous.

Remark 4.4 The converse of the above Proposition 4.5 need not be true.

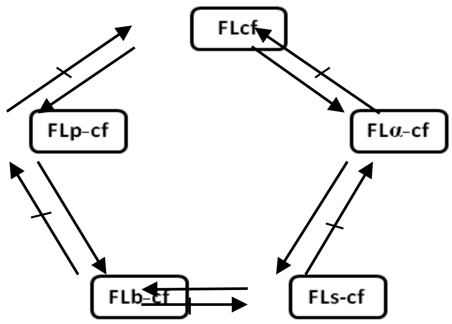
Example 4.4 Let X = { a, b } and let $\lambda_1, \lambda_2, \lambda_3 \in I^X$ be defined as follows : λ_1(a) = 0.5, λ_1(b) = 0.6; λ_2(a) = 0.4, λ_2(b) = 0.3; λ_3(a) = 0.9, λ_3(b) = 0.8. Define the fuzzy topology on X as T = { 0, 1, λ_1, λ_2, λ_3 }. Define the fuzzy topology on Y as S = { 0, 1, λ }, where $\lambda \in I^X$ is defined as λ(a) = 0.5, λ(b) = 0.3. Clearly (X, T) and (Y, S) are fuzzy topological spaces. Define f : (X, T) → (Y, S) as f(a) = b, f(b) = a. Then, $f^{-1}(1-\lambda)$ = (0.7, 0.5) is fuzzy pre-closed. Thus, for $\lambda_3 \in$ T and for the fuzzy pre-closed set $f^{-1}(1-\lambda)$, $\lambda_3 \wedge f^{-1}(1-\lambda) = f^{-1}(1-\lambda)$ is fuzzy locally pre-closed but not fuzzy locally closed in (X, T) . Therefore, **every fuzzy locally pre-continuous function need not be fuzzy locally continuous.**

Proposition 4.6 Every fuzzy locally pre-continuous function is fuzzy locally b-continuous.

Remark 4.5 The converse of the above Proposition 4.6 need not be true.

Example 4.5 Let X = { a, b } and let $\lambda_1, \lambda_2, \lambda_3 \in I^X$ be defined as follows : λ_1(a) = 0.3, λ_1(b) = 0.2; λ_2(a) = 0.4, λ_2(b) = 0.3; λ_3(a) = 0.5, λ_3(b) = 0.9. Define the fuzzy topology on X as T = { 0, 1, λ_1, λ_2, λ_3 }. Define the fuzzy topology on Y as S = { 0, 1, λ }, where $\lambda \in I^X$ is defined as λ(a) = 0.5, λ(b) = 0.5. Clearly (X, T) and (Y, S) are fuzzy topological spaces. Define f : (X, T) → (Y, S) as f(a) = b, f(b) = a. Then, $f^{-1}(1-\lambda)$ = (0.5, 0.5) is fuzzy b-closed. Thus, for $\lambda_3 \in$ T and for the fuzzy b-closed set $f^{-1}(1-\lambda)$, $\lambda_3 \wedge f^{-1}(1-\lambda) = f^{-1}(1-\lambda)$ is fuzzy locally b-closed but not fuzzy locally pre closed in (X, T). Therefore, **every fuzzy locally b-continuous function need not be fuzzy locally pre continuous.**

Remark 4.6 Clearly the above discussions give the following implications :



5. A VIEW ON FUZZY LOCALLY b-COMPACTNESS

Definition 5.1 Let (X, T) be a fuzzy topological space. The collection { $\lambda_i \in I^X$: λ_i is fuzzy locally b-open, i ∈ J } is called the fuzzy locally b-open cover of (X, T) if $\bigvee_{i \in J} \lambda_i = 1$.

Definition 5.2 Let (X, T) be a fuzzy topological space. The collection { $\lambda_i \in I^X$: λ_i is fuzzy locally b-closed, i $\in$ J} is called the fuzzy locally b-closed cover of (X, T) if $\bigvee_{i \in J} \lambda_i = 1$.

Definition 5.3 A fuzzy topological space (X, T) is said to be

(a) fuzzy locally b-compact if every fuzzy locally b-open cover of (X, T) has a finite subcover.

(b) fuzzy locally countably b-compact if every fuzzy locally b-open countable cover of (X, T) has a finite subcover.

(c) fuzzy locally b-Lindelof if every fuzzy locally b-open cover of (X, T) has a countable subcover.

(d) fuzzy locally b-closed-compact if every fuzzy locally b-closed cover of (X, T) has a finite subcover.

(e) fuzzy locally countably b-closed-compact if every fuzzy locally b-closed countable cover of (X, T) has a finite subcover.

(f) **fuzzy locally b-closed-Lindelof** if every fuzzy locally b-closed cover of (X, T) has a countable subcover.

Definition 5.4 Let (X, T) and (Y, S) be any two fuzzy topological spaces. Any function f : (X, T) → (Y, S) is said to be **fuzzy locally b-continuous** if $f^{-1}(\rho) \in I^X$ is a fuzzy locally b-open set for every fuzzy open set $\rho \in I^Y$.

Definition 5.5 Any fuzzy topological space (X, T) is said to be a **fuzzy locally b-$T_{1/2}$ space** if every fuzzy locally b-open set in (X, T) is a fuzzy open set.

Proposition 5.1 Let (X, T) and (Y, S) be any two fuzzy topological spaces and let f : (X, T) → (Y, S) be a fuzzy locally b-continuous surjection. If (X, T) is fuzzy locally b–compact, then (Y, S) is fuzzy mildly compact.

Proposition 5.2 Let (X, T) and (Y, S) be any two fuzzy topological spaces and let f : (X, T) → (Y, S) be a fuzzy locally b-continuous surjection. If (X, T) is fuzzy locally b-Lindelof, then (Y, S) is fuzzy mildly Lindelof.

Proposition 5.3 Let (X, T) and (Y, S) be any two fuzzy topological spaces and let f : (X, T) → (Y, S) be a fuzzy locally b-continuous surjection. If (X, T) is fuzzy locally countably b-compact, then (Y, S) is fuzzy mildly countably compact.

Proposition 5.4 Let (X, T) and (Y, S) be any two fuzzy topological spaces and let f : (X, T) → (Y, S) be a fuzzy locally b-continuous surjection. If (X, T) is fuzzy locally b-closed-compact. Then (Y, S) is fuzzy mildly compact.

Proposition 5.5 Let (X, T) and (Y, S) be any two fuzzy topological spaces and let f : (X, T) → (Y, S) be a fuzzy locally b-continuous surjection. If (X, T) is fuzzy locally b-closed-Lindelof, then (Y, S) is fuzzy mildly Lindelof.

Proposition 5.6 Let (X, T) and (Y, S) be any two fuzzy topological spaces and let f : (X, T) → (Y, S) be a fuzzy locally b-continuous surjection. If (X, T) is fuzzy locally countably b-closed-compact, then (Y, S) is fuzzy mildly countably compact.

Proposition 5.7 Let (X, T) and (Y, S) be any two fuzzy topological spaces. If (X, T) is a fuzzy compact and fuzzy locally b-$T_{1/2}$ space and f : (X, T) → (Y, S) is a fuzzy locally b-continuous surjection, then (Y, S) is also a fuzzy compact space.

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