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ON L-FUZZY ω-BASICALLY DISCONNECTED SPACES

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Abstract. In this paper L-fuzzy ω-closed and L-fuzzy ω-open sets are introduced. Also a new class of L-fuzzy topological space called L-fuzzy ω-basically disconnected space is introduced. Several characterizations and some interesting properties are also given.

1. Introduction

The fuzzy concept has invaded almost all branches of Mathematics since the introduction of the concept by Zadeh[14]. Fuzzy sets have applications in many fields such as information [10] and control [11]. The theory of fuzzy topological spaces was introduced and developed by Chang [3] and since then various important notions in classical topology have been extended to fuzzy topological spaces. Rodabaugh [7] discussed normality and the L-fuzzy unit interval. He [8] also studied fuzzy addition in the L-fuzzy real line. Hoeche [6] studied the characterizations of L-topologies by L-valued neighbourhoods. An L-fuzzy normal spaces and Tietze extension theorem were discussed by Tomash Kubiak [13]. The concept of ω-open set was studied in [9]. The purpose of this paper is to introduce L-fuzzy ω-closed, L-fuzzy ω-open sets and a new class of L-fuzzy topological spaces called L-fuzzy ω-basically disconnected space. In this connection several characterizations and some interesting properties are also given.

2. Preliminaries

Definition 2.1. ([1]) Let (X,T) be a fuzzy topological space and λ be a fuzzy set in (X,T). λ is called a fuzzy G_δ-set if $\lambda = \bigwedge_{i=1}^{\infty} \lambda_i$ where each $\lambda_i \in T, i \in I$.

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Definition 2.2. ([1]) Let (X, T) be a fuzzy topological space and λ be a fuzzy set in (X, T).λ is called a fuzzy F_σ-set if $\lambda = \bigvee_{i=1}^{\infty} \lambda_i$ where each $1 - \lambda_i \in T, i \in I$.

Definition 2.3. ([2]) Throughout this paper $(L, \leq, ')$ stands for an infinitely distributive lattice with an order reversing involution. Such a lattice being complete has a least element 0 and a greatest element 1. Let X be a non-empty set. An L-fuzzy set in X is an element of the set L^X of all functions from X to L.

Definition 2.4. The L-fuzzy real line $R(L)$[4] is the set of all monotone decreasing elements λ in L^R satisfying $\vee\{\lambda((t)/t \in R\} = 1$ and $\wedge\{\lambda(t)/t \in R\} = 0$, after the identification of $\lambda, \mu \in L^R$ iff $\lambda(t-) = \mu(t-)$ and $\lambda(t+) = \mu(t+)$ for all $t \in R$ where $\lambda(t-) = \wedge\{\lambda(s)/s < t\}$ and $\lambda(t+) = \vee\{\lambda(s)/s > t\}$. The natural L-fuzzy topology on $R(L)$ is generated from the subbases $\{L_t, R_t/t \in R\}$, where $L_t(\lambda) = \lambda(t-)'$ and $R_t(\lambda) = \lambda(t+)$. The L-fuzzy unit interval $I(L)$[5] is a subset of $R(L)$ such that $[\lambda] \in I(L)$ if $\lambda(t) = 1$ for $t < 0$ and $\lambda(t) = 0$ for $t > 1$. It is equipped with the subspace L-fuzzy topology.

Definition 2.5. ([13]) If $A \in L^X$ is crisp, then (A, T_A) is an L-fuzzy topological space called a crisp subspace of (X, T), where $T_A = \{U/A | U \in T\}$ is called the subspace L-fuzzy topology.

Definition 2.6. ([9]) A subset of a topological space (X, T) is called ω-closed in (X, T) if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi-open in (X, T).A subset A is called ω-open in (X, T) if its complement, A^C is ω-closed.

Definition 2.7. ([12]) Let (X, T) be any fuzzy topological space. (X, T) is called fuzzy basically disconnected if the closure of every fuzzy open F_σ set is fuzzy open.

3. Characterizations and properties of L-fuzzy ω-basically disconnected spaces

In this section a new class of set called L-fuzzy ω-closed set and thereby a new class of space called L-fuzzy ω-basically disconnected space is introduced. Some interesting properties and characterizations are also discussed.

Definition 3.1. Let (X, T) be any L-fuzzy topological space and λ be any L-fuzzy set in (X, T).λ is called

(a) an L-fuzzy G_δ set if $\lambda = \bigwedge_{i=1}^{\infty} \lambda_i$ where each λ_i is L-fuzzy open.

(b) an L-fuzzy F_σ set if $\lambda = \bigvee_{i=1}^{\infty} \lambda_i$ where each $(1 - \lambda_i)$ is L-fuzzy open.

Definition 3.2. Let λ be any L-fuzzy set in the L-fuzzy topological space (X, T). Then we define

$$L - int(\lambda) = \vee\{\mu/\mu \leq \lambda \text{ and } \mu \text{ is } L - \text{fuzzy open}\},$$
$$L - cl(\lambda) = \wedge\{\mu/\mu \geq \lambda \text{ and } \mu \text{ is } L - \text{fuzzy closed}\}.$$

Definition 3.3. Let λ be any L-fuzzy set in the L-fuzzy topological space (X, T). λ is called L-fuzzy semi-open if $\lambda \leq L\text{-}cl(L\text{-}int(\lambda))$.

Definition 3.4. An L-fuzzy set λ of an L-fuzzy topological space (X, T) is called L-fuzzy ω-closed in (X, T) if $L\text{-}cl(\lambda) \leq \mu$ whenever $\lambda \leq \mu$ and μ is L-fuzzy semi-open in (X, T). The complement of L-fuzzy ω-closed set is L-fuzzy ω-open.

Note 3.1. (a) Let (X, T) be an L-fuzzy topological space. An L-fuzzy set λ in (X, T) which is both L-fuzzy ω-open and L-fuzzy F_σ is denoted by L-fuzzy ω-open F_σ.

(b) Let (X, T) be an L-fuzzy topological space. An L-fuzzy set λ in (X, T) which is both L-fuzzy ω-closed and L-fuzzy G_δ is denoted by L-fuzzy ω-closed G_δ.

Notation 1. An L-fuzzy set λ which is both L-fuzzy ω-open F_σ and L-fuzzy ω-closed G_δ is denoted by L-fuzzy ω-$COGF$.

Definition 3.5. Let (X, T) be an L-fuzzy topological space. For any L-fuzzy set λ in (X, T), L-fuzzy ω^*-closure of λ **(briefly,** $L\omega^*$**-**$cl(\lambda)$ is defined as $L\omega^*\text{-}cl(\lambda) = \wedge\{\mu : \mu \geq \lambda$ and μ is L-fuzzy ω-closed $G_\delta\}$.

Definition 3.6. Let (X, T) be an L-fuzzy topological space. For any L-fuzzy set λ in (X, T), L-fuzzy ω^*-interior of λ **(briefly,** $L\omega^*$**-**$int(\lambda)$) is defined as $L\omega^*\text{-}int(\lambda) = \vee\{\mu : \mu \leq \lambda$ and μ is L-fuzzy ω-open $F_\delta\}$.

Remark 3.1. Let (X, T) be an L-fuzzy topological space. For any L-fuzzy set λ in (X, T)

(a) $1 - L\omega^*\text{-}int(\lambda) = L\omega^*\text{-}cl(1 - \lambda)$,
(b) $1 - L\omega^*\text{-}cl(\lambda) = L\omega^*\text{-}int(1 - \lambda)$.

Definition 3.7. Let (X, T) and (Y, S) be any two L-fuzzy topological spaces. A mapping $f : (X, T) \to (Y, S)$ is called L-fuzzy ω^*-continuous if $f^{-1}(\lambda)$ is L-fuzzy ω-closed G_δ in (X, T) for every L-fuzzy closed and L-fuzzy G_δ set λ in (Y, S).

Definition 3.8. Let (X, T) and (Y, S) be any two L-fuzzy topological spaces. A mapping $f : (X, T) \to (Y, S)$ is called L-fuzzy ω^*-irresolute if the inverse image of every L-fuzzy ω-open F_σ set in (Y, S) is L-fuzzy ω-open F_σ in (X, T).

Definition 3.9. Let (X, T) and (Y, S) be any two L-fuzzy topological spaces. A mapping $f : (X, T) \to (Y, S)$ is said to be L-fuzzy ω^*-open if the image of every L-fuzzy ω-open F_σ set in (X, T) is L-fuzzy ω-open F_σ in (Y, S).

Proposition 3.1. *Let (X,T) and (Y,S) be any two L-fuzzy topological spaces. Then $f:(X,T)\to(Y,S)$ is L-fuzzy ω^*-irresolute iff $f(L\omega^*\text{-}cl(\lambda))\leq L\omega^*\text{-}cl(f(\lambda))$, for every L-fuzzy set λ in (Y,S).*

Proposition 3.2. *Let (X,T) and (Y,S) be any two L-fuzzy topological spaces and let $f:(X,T)\to(Y,S)$ be an L-fuzzy ω^*-open surjective function. Then $f^{-1}(L\omega^*\text{-}cl(\lambda))\leq L\omega^*\text{-}cl(f^{-1}(\lambda))$, for each L-fuzzy set λ in (Y,S).*

Definition 3.10. Let (X,T) be any L-fuzzy topological space. (X,T) is called L-fuzzy ω-basically disconnected if the L-fuzzy ω^*-closure of every L-fuzzy ω-open F_σ set is L-fuzzy ω-open F_σ.

Proposition 3.3. *For an L-fuzzy topological space (X,T) the following statements are equivalent:*

(a) *(X,T) is an L-fuzzy ω-basically disconnected space,*
(b) *For each L-fuzzy ω-closed G_δ set λ, $L\omega^*\text{-}int(\lambda)$ is L-fuzzy ω-closed G_δ,*
(c) *For each L-fuzzy ω-open F_σ set λ, $L\omega^*\text{-}cl(\lambda)+L\omega^*\text{-}cl(1-L\omega^*\text{-}cl(\lambda))=1$,*
(d) *For every pair of L-fuzzy ω-open F_σ sets λ and μ such that $L\omega^*\text{-}cl(\lambda)+\mu=1$, we have $L\omega^*\text{-}cl(\lambda)+L\omega^*\text{-}cl(\mu)=1$.*

Proof. **(a)⇒(b)** Let λ be any L-fuzzy ω-closed G_δ set. Then $1-\lambda$ is L-fuzzy ω-open F_σ. Now $L\omega^*\text{-}cl(1-\lambda)=1-L\omega^*\text{-}int(\lambda)$. By (a),$L\omega^*\text{-}cl(1-\lambda)$ is L-fuzzy ω-open, which implies that $L\omega^*\text{-}int(\lambda)$ is L-fuzzy ω-closed G_δ.
(b)⇒ (c) Let λ be any L-fuzzy ω-open F_δ set. Then

$$L\omega^*–cl(\lambda)+L\omega^*–cl(1-L\omega^*–cl(\lambda))=L\omega^*–cl(\lambda)+L\omega^*–cl(L\omega^*–int(1–\lambda)). \quad (3.1)$$

Since λ is L-fuzzy ω-open F_σ , $1-\lambda$ is L-fuzzy ω-closed G_δ. Hence by (b), $L\omega^*\text{-}int(1-\lambda)$ is L-fuzzy ω-closed G_δ. Therefore by 3.1,

$$\begin{aligned} L\omega^*-cl(\lambda)+L\omega^*-cl(1-L\omega^*-cl(\lambda)) &= L\omega^*-cl(\lambda)+L\omega^*-int(1-\lambda)\\ &= L\omega^*-cl(\lambda)+1-L\omega^*-cl(\lambda)\\ &=1. \end{aligned}$$

Therefore, $L\omega^*\text{-}cl(\lambda)+L\omega^*\text{-}cl(1-L\omega^*\text{-}cl(\lambda))=1$.
(c)⇒ (d) Let λ and μ be L-fuzzy ω-open F_σ sets such that

$$L\omega^*-cl(\lambda)+\mu=1. \quad (3.2)$$

Then by (c),

$$1=L\omega^*-cl(\lambda)+L\omega^*-cl(1-L\omega^*-cl(\lambda))=L\omega^*-cl(\lambda)+L\omega^*-cl(\mu).$$

Therefore, $L\omega^*\text{-}cl(\lambda)+L\omega^*\text{-}cl(\mu)=1$.
(d)⇒(a) Let λ be any L-fuzzy ω-open F_σ set. Put $\mu=1-L\omega^*\text{-}cl(\lambda)$. Then $L\omega^*\text{-}cl(\lambda)+\mu=1$. Therefore by (d), $L\omega^*\text{-}cl(\lambda)+L\omega^*\text{-}cl(\mu)=1$. This implies $L\omega^*\text{-}cl(\lambda)$ is L-fuzzy ω-open F_σ and so (X,T) is L-fuzzy ω-basically disconnected. □

Proposition 3.4. *Let (X,T) be any L-fuzzy ω-basically disconnected space and (Y,S) be any L- fuzzy topological space. Let $f:(X,T)\to(Y,S)$ be L-fuzzy ω^*-irresolute, L-fuzzy ω^*-open and surjective function. Then (Y,S) is L-fuzzy ω-basically disconnected.*

Proof. The proof follows from the concepts of L-fuzzy ω^*-irresolute, L-fuzzy ω^*-open maps and by the Propositions 3.1 and 3.2. □

Definition 3.11. Let $\{(X_\alpha,T_\alpha)/\alpha\in\Delta\}$ be a family of disjoint L-fuzzy topological spaces. Let $X=\bigcup_{\alpha\in\Delta} X_\alpha$. Define $T=\{\lambda\in L^X/\lambda/X_\alpha$ is L-fuzzy ω-open F_σ in $(X_\alpha,T_\alpha)\}$. Then (X,T) is an L-fuzzy topological space called the L-fuzzy topological sum of $\{(X_\alpha,T_\alpha)/\alpha\in\Delta\}$.

Proposition 3.5. *Let $\{(X_\alpha,T_\alpha)/\alpha\in\Delta\}$ be a family of disjoint L-fuzzy ω-basically disconnected spaces and let (X,T) be their L-fuzzy topological sum. Then (X,T) is L-fuzzy ω-basically disconnected.*

Proof. Let λ be an L-fuzzy ω-open F_σ set in (X,T). Then λ/X_α is L-fuzzy ω-open F_σ in (X_α,T_α). Since (X_α,T_α) is L-fuzzy ω-basically disconnected, $L\omega^*$-$cl_{X_\alpha}(\lambda/X_\alpha)$ is L-fuzzy ω-open F_σ in (X_α,T_α). Now $L\omega^*$-$cl_X(\lambda)/X_\alpha=L\omega^*$-$cl_{X_\alpha}(\lambda/X_\alpha)$, which implies that $L\omega^*$-$cl_X(\lambda)$ is L-fuzzy ω-open F_σ in (X,T). Therefore (X,T) is L-fuzzy ω-basically disconnected. □

Definition 3.12. Let (X,T) be an L-fuzzy topological space. A mapping $f:X\to R(L)$ is called lower (resp. upper) L-fuzzy ω^*-continuous if $f^{-1}(R_t)$ (resp. $f^{-1}(L_t)$) is L-fuzzy ω-open F_σ (resp. L-fuzzy ω-open F_σ/L-fuzzy ω-closed G_δ), for each $t\in R$.

Proposition 3.6. *Let (X,T) be an L-fuzzy topological space. Then (X,T) is L-fuzzy ω-basically disconnected iff for all L-fuzzy ω-open F_σ set λ and an L-fuzzy ω-closed G_δ set μ such that $\lambda\le\mu, L\omega^*$-$cl(\lambda)\le L\omega^*$-$int(\mu)$.*

Proof. Let λ be L-fuzzy ω-open F_σ and μ be L-fuzzy ω-closed G_δ with $\lambda\le\mu$.Then by (b) of Proposition 3.3, $L\omega^*$-$int(\mu)$ is L-fuzzy ω-closed G_δ. Also since λ is L-fuzzy ω-open $F_\sigma, L\omega^*$-$cl(\lambda)\le L\omega^*$-$int(\mu)$. Conversely let μ be any L-fuzzy ω-closed G_δ set. Then $L\omega^*$-$int(\mu)$ is L-fuzzy ω-open F_σ in (X,T) and $L\omega^*$-$int(\mu)\le\mu$. Therefore by assumption,$L\omega^*$-$cl(L\omega$-$int(\mu))\le L\omega^*$-$int(\mu)$. This implies that $L\omega^*$-$int(\mu)$ is L-fuzzy ω-closed G_δ. Hence by (b) of Proposition 3.3, it follows that (X,T) is L-fuzzy ω-basically disconnected. □

Remark 3.2. Let (X,T) be an L-fuzzy ω-basically disconnected space. Let $\{\lambda_i, 1-\mu_i/i\in N\}$ be a collection such that λ_i's, are L-fuzzy ω-open F_σ and μ_i's are L-fuzzy ω-closed G_δ and let λ,μ are L-fuzzy ω-COGF. If $\lambda_i\le\lambda\le\mu_j$ and $\lambda_i\le\mu\le\mu_j$ for all $i,j\in N$, then there exists an L-fuzzy ω- COGF set γ such that $L\omega^*$-$cl(\lambda_i)\le\gamma\le L\omega^*$-$int(\mu_j)$, for all $i,j\in N$.

Proposition 3.7. *Let (X,T) be an L-fuzzy ω-basically disconnected space. Let $\{\lambda_r\}_{r\in Q}$ and $\{\mu_r\}_{r\in Q}$ be monotone increasing collections of L-fuzzy ω-open F_σ sets and L-fuzzy ω-closed G_δ sets of (X,T) and suppose that $\lambda_{q_1} \leq \mu_{q_2}$ whenever $q_1 < q_2$ (Q is the set of all rational numbers).Then there exists a monotone increasing collection $\{\gamma_r\}_{r\in Q}$ of L-fuzzy ω-COGF sets of (X,T) such that $L\omega^*\text{-}cl(\lambda_{q_1}) \leq \gamma_{q_2}$ and $\gamma_{q_1} \leq L\omega^*\text{-}int(\mu_{q_2})$ whenever $q_1 < q_2$*

Proposition 3.8. *Let (X,T) be any L-fuzzy topological space; let $\lambda \in L^X$ and let $f : X \to R(L)$ be such that*

$$f(x)(t) = \begin{cases} 1, & if \quad t < 0 \\ \lambda(x), & if \quad 0 \leq t \leq 1 \\ 0, & if \quad t > 0. \end{cases}$$

for all $x \in X$. Then f is lower(resp.upper) L-fuzzy ω^*-continuous iff λ is L-fuzzy ω-open F_σ (resp.L-fuzzy ω-open F_σ/L-fuzzy ω-closed G_δ).

Remark 3.2, Proposition 3.7 and Proposition 3.8 can be established by the concepts of L-fuzzy ω-COGF set, L-fuzzy ω^*-interior, L-fuzzy ω^*-closure and the lemmas given in [13] with some slight suitable modifications.

Definition 3.13. The characteristic function of $\lambda \in L^X$ is the map $\chi_\lambda : X \to I(L)$ defined by $\chi_\lambda(x) = (\lambda(x)), x \in X$.

Proposition 3.9. *Let (X,T) be an L-fuzzy topological space and let $\lambda \in L^X$ Then χ_λ is lower (resp.upper) L-fuzzy ω^*-continuous iff λ is L-fuzzy ω-open F_σ (resp. L-fuzzy ω-open F_σ/L-fuzzy ω-closed G_δ).*

Proof. The proof follows from Proposition3.8. □

Definition 3.14. Let (X,T) and (Y,S) be any two L-fuzzy topological spaces. A mapping $f : (X,T) \to (Y,S)$ is called strong F_σ L-fuzzy ω^*-continuous if $f^{-1}(\lambda)$ is L-fuzzy ω-COGF set of (X,T), for every L-fuzzy ω-open F_σ set λ of (Y,S).

Proposition 3.10. *Let (X,T) be an L-fuzzy topological space. Then the following statements are equivalent :*

(a) *(X,T) is an L-fuzzy ω-basically disconnected space.*
(b) *If $g,h : X \to R(L)$ where g is lower L-fuzzy ω^*-continuous,h is upper L-fuzzy ω^*-continuous, then there exists $f \in C_{F_\sigma}L\omega(X)$ such that $g \leq f \leq h$. $[C_{F_\sigma}L\omega(X)$ = collection of all strong F_σ L-fuzzy ω^*-continuous function on X with values in $R(L)]$.*
(c) *If λ is L-fuzzy ω-closed G_δ and μ is L-fuzzy ω-open F_σ sets such that $\mu \leq \lambda$, then there exists a strong F_σ L-fuzzy ω^*-continuous function $f : X \to I(L)$ such that $\mu \leq (1-\lambda_1)f \leq R_0 f \leq \lambda$.*

Proof. **(a)⇒ (b)** can be established by the concept of L-fuzzy ω-COGF set and the theorem 3.7 of Kubiak [13] with some slight suitable modifications.

(b)$\Rightarrow$ (c) Suppose λ is L-fuzzy ω-closed G_δ and μ is L-fuzzy ω-open F_σ such that $\mu \leq \lambda$. Then $\chi_\mu \leq \chi_\lambda$ whereχ_μ, χ_λ are lower and upper L-fuzzy ω^*-continuous respectively. Hence by (b), there exists a strong F_δ L-fuzzy ω^*-continuous function $f : X \to R(L)$ such that, $\chi_\mu \leq f \leq \chi_\lambda$. Clearly $f(x) \in I(L)$, for all $x \in X$ and $\mu = (1 - L_1)\chi_\mu \leq (1 - L_1)f \leq R_0 f \leq R_0\chi_\lambda = \lambda$. Therefore $\mu \leq (1L_1)f \leq R_0 f \leq \lambda$.
(c)$\Rightarrow$ (a) $(1 - L_1)$ f and $R_0 f$ are L-fuzzy ω-COGF sets. By Proposition3.6, (X, T) is an L-fuzzy ω-basically disconnected space. □

Proposition 3.11. *Let (X, T) be an L-fuzzy ω-basically disconnected space and let $A \subset X$ be such that χ_A is L-fuzzy ω^*-open. Let $f : (A, T/A) \to I(L)$ be strong F_σ L-fuzzy ω^*-continuous. Then f has a strong F_σ L-fuzzy ω^*-continuous extension over (X, T).*

Proof. Let $g, h : X \to I(L)$ be such that $g = f = h$ on A and $g(x) = \langle 0 \rangle$, $h(x) = \langle 1 \rangle$ if $x \notin A$. We now have

$$R_t g = \begin{cases} \mu_t \wedge \chi_A, & if \quad t \geq 0 \\ 1, & if \quad t < 0 \end{cases}$$

where μ_t is L-fuzzy ω-open F_σ and is such that $\mu_t/A = R_t f$ and

$$L_t h = \begin{cases} \lambda_t \wedge \chi_A, & if \quad t \leq 1 \\ 1, & if \quad t > 1 \end{cases}$$

where λ_t is L-fuzzy ω-open F_σ/L-fuzzy ω-closed G_δ and is such that $\lambda_t/A = L_t f$. Thus g is lower L-fuzzy ω^*-continuous h is upper L-fuzzy ω^*-continuous and $g \leq h$. By Proposition 3.10, there is a strong F_σ L-fuzzy ω^*-continuous function $F : X \to I(L)$ such that $g \leq F \leq h$. Hence $F \equiv f$ on A. □

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