Palestine Journal of Mathematics

Vol 15(Special Issue II)(2026) , 206–211

New Perspectives on Binary Multiset Connectedness Structures

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MSC 2010 Classifications: Primary 00A05; Secondary 54B10.

Keywords and phrases: bms separated, bms connectedness, bms disconnectedness.

The authors would like to thank the reviewers and editor for their constructive comments and valuable suggestions that improved the quality of our paper.

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Abstract

This paper introduces new concepts of binary multiset connectedness within binary multiset topological spaces. Some fundamental properties of bms connectedness are established. Furthermore, bms disconnectedness and bms separated in bms topology are discuss their basic properties are proved, and characterizations are analyzed.

1 Introduction

In mathematics, a multiset is a generalization of a classical set that allows multiple occurrences of its elements. This generalization provides a richer framework for studying topological structures by accounting for element multiplicity. In 1989, Blizard [1] introduced the concept of multiset theory in topological spaces and later elaborated on its development [2], describing it as a well-defined collection of distinct objects. Girish and John established in 2011 and 2012 that allowing repeated occurrences of any object in a set results in a multiset (mset) [5, 6]. In multiset topological spaces, standard topological notions such as open m-sets, closed m-sets, and m-connectivity are redefined to incorporate element multiplicity. Various aspects of multiset theory have been studied in different contexts. M-open sets and their applications were introduced in [4], demonstrating the broad applicability of multisets across mathematical branches.

Discrete multiset topological spaces represent the simplest multiset structure, in which every subset is an open m-set. In such spaces, multiset connectedness is trivial the only connected multisets are singletons, since every sub-mset can be separated. Despite their simplicity, discrete spaces serve as an important reference for understanding more complex multiset or binary multiset structures.

The concept of multiset connectedness was formally introduced by Mahalakshmi and Thangavelu [7], who also characterized its properties within multiset topological spaces. Rajish Kumar and Sunil Jacob John [9] studied separation and connectedness in subspace M-topology, comparing different subspaces and analyzing situations in which M-connectedness properties coincide. Their work demonstrated that M-connectedness of a sub-mset in one subspace M-topology does not necessarily imply M-connectedness in another, and identified the conditions required for M-separation in both subspace M-topologies.

Binary topological spaces, introduced in 2011 [10], study the interaction between two sets under basic topological properties such as openness and closedness. A binary topological space from X to Y is a binary structure satisfying axioms analogous to classical topological axioms.

The principle of compactness plays a pivotal role in understanding the behavior of spaces and their subsets. The study of connectedness through generalized open sets has a long history in topology. Shen [11] discussed generalized connectedness in topological spaces, while Tantway et al. [12] explored connectedness in multi-generalized topological spaces. In 2018, Vivekananda Dembre and Sanjay Mali [13] introduced new notions of compactness and connectedness in topological spaces.

Priyalatha et al. [8] introduced a new topology between two multisets, called binary multiset (bms) topology, and investigated its fundamental properties. In bms topology, concepts such as open bms, closed bms , bms connected, and bms separated spaces are extended to handle two multisets simultaneously. bms connectedness examines whether a binary multiset space can be expressed as the union of two disjoint open bms sets. This generalizes classical connectedness and multiset connectedness, allowing the analysis of relationships between pairs of multisets within a unified framework. A bms topology satisfies conditions analogous to the axioms of classical topology, and its properties can be explored through characterization theorems.

This paper focuses on bms connectedness in topological spaces, highlighting its properties through theorems and examples. Additionally, bms separated and bms disconnected spaces are examined in the context of bms topological spaces.

2 Preliminaries

Definition 2.1. [8] Let U,V be two non-empty sets, $[U]^w, [V]^r$ be two m-set spaces on U and V respectively. The ordered pair (M_1, M_2) is called a binary multiset (or bms) where $M_1 \in [U]^w, M_2 \in [V]^r$ are two m-sets drawn from U and V respectively.

Note[8] The power set of a m-set $M_1(resp. M_2)$ is the support set of the power m-set of $M_1(resp. M_2)$, is symbolized by $P^*(M_1)(resp. P^*(M_2))$. We can define $P^*(M_1) \times P^*(M_2) = \{(A_i, B_i) : A_i \in P^*(M_1), B_i \in P^*(M_2)\}$. According this definition, the ordered pair ({A,B}) is called a bms from M_1 and M_2 where $A \subseteq M_1$ and $B \subseteq M_2$. That is, the bms ({A,B}) is an element in $P^*(M_1) \times P^*(M_2)$.

Definition 2.2. [8] Let $M_1 \in [U]^w$, $M_2 \in [V]^r$ be two m-sets drawn from U and V respectively. A binary multiset topology (briefly, bms-topology) from M_1 to M_2 is a binary multiset structure $\tau_b \subseteq P^*(M_1) \times P^*(M_2)$ that satisfies the following axioms:

(i) $(\emptyset, \emptyset), (M_1, M_2) \in \tau_b$

(ii) If $(\{A_1, B_1\}), (A_2, B_2) \in \tau_b$, then $(A_1 \cap A_2), (B_1 \cap B_2) \in \tau_b$.

(iii) If $\{(A_\lambda, B_\lambda) : \lambda \in J\} \subseteq \tau_b$, then $(\cup A_\lambda, \cup B_\lambda) \in \tau_b$.
In this case, the structure (M_1, M_2, τ_b) is called bms-topological space(or bms-space).
Note that τ_b is an ordinary set whose elements are bms.

Definition 2.3. [8] For a bms-space (M_1, M_2, τ_b), we have

(i) Each element in τ_b is called an open binary multiset (or open bms) and the complement of open bms is named a closed binary multiset (or closed bms).

(ii) A sub-bms ({A,B}) of a bms-space (M_1, M_2, τ_b) is said to be closed bms if $(\{A, B\})^c = (M_1 \ominus A, M_2 \ominus B)$ is an open bms.

Definition 2.4. [8] Let (M_1, M_2, τ_b) be an bms-topological space and $A \subseteq M_1$, $B \subseteq M_2$. Then ({A,B}) is closed bms in (M_1, M_2, τ_b) if $(M_1 \ominus A, M_2 \ominus B) \in \tau_b$, the complement of closed bms τ_b^c.

Example 2.5. [8]
Consider the two non-empty sets, $U = \{x, y\}, V = \{m, n\}$, and $M_1 = \{2/x, 1/y\}, M_2 = \{1/m, 2/n\}$ two multiset from U and V respectively. Then, $\tau_b = \{(\emptyset, \emptyset), (M_1, M_2), (\{1/x\}, \emptyset), (\{1/x\}, \{1/m\}), (\{1/x\}, \{1/n\}), (\{1/x\}, \{1/m, 1/n\})\}$ is a binary multiset topology from M_1 to M_2. The open binary multiset are, $\{(\emptyset, \emptyset), (M_1, M_2), (\{1/x\}, \emptyset), (\{1/x\}, \{1/m\}), (\{1/x\}, \{1/n\}), (\{1/x\}, \{1/m, 1/n\})\}$. The complement of an open binary multiset known as closed binary multiset, $\{(M_1, M_2), (\emptyset, \emptyset), (\{1/x, 1/y\}, M_2), (\{1/x, 1/y\}, \{2/n\}), (\{1/x, 1/y\}, \{1/m, 1/n\}), (\{1/x, 1/y\}, \{1/n\})\}$.

Definition 2.6. [8] The collection $I = \{(\emptyset, \emptyset), (M_1, M_2)\}$ is known as the indiscrete binary multiset topology from M_1 to M_2 and the structure (M_1, M_2, I) is said to be the indiscrete binary multiset topological space.

Definition 2.7. [8] The collection $D = \mathcal{P}^*(M_1) \times \mathcal{P}^*(M_2)$ is known as the discrete binary multiset topology from M_1 to M_2 and the structure (M_1, M_2, D) is known as the discrete binary multiset topological space.

Remark 2.8. [8] A discrete binary multiset topological space $D = \mathcal{P}^*(M_1) \times \mathcal{P}^*(M_2)$. The power set of (M_1, M_2, D) forms a discrete binary multiset topological space, also known as a trivial binary multiset topological space.

Definition 2.9. [8] The ordered pair $(\{A_1, B_1\})^*, (A_2, B_2)^*$ is called bms closure of ({A,B}) is defined as the intersection of all closed bms containing in ({A,B}) denoted by $cl_b(\{A, B\})$ is bms topolgical space (M_1, M_2, τ_b) where $(\{A, B\}) \subseteq (M_1, M_2)$, $cl_b(\{A, B\}) or (\{\overline{A}, \overline{B}\}) = \cap\{(\{G, H\}) \subseteq (M_1, M_2) : (\{G, H\})$is a closed bms and ({A,B}) $\subseteq$ ({ G,H})}.

Definition 2.10. [8] An ordered pair $(\{A_1, B_1\})^\circ, (A_2, B_2)^\circ$ is called bms interior, its defined as union of open bms contained in $(\{A, B\})$. Its denoted by $int_b(\{A, B\})$. It's defined $int_b(\{A, B\}) = \cup\{(\{G, H\}) \subseteq M : (\{G, H\})$is open bms an and $(\{G, H\}) \subseteq (\{A, B\})\}$.

Definition 2.11. [6] Let $M \in [X]_w$ be a multiset, and (M, τ) be an m-topological space. Two submultisets $A, B \subseteq M$ are said to be m-separated if $C(x) \cap mcl(A) \cap B = A \cap mcl(B) = 0, \quad \forall x \in M^*$.

Definition 2.12. [6] Let $M \in [X]_w$ be a multiset, and (M, τ) be an m-topological space. Let $S \subseteq M$ be a submultiset. Then the submultiset S is said to be m-connected if $C_S(x) = C_A \cup B(x)$, where A and B are m-separated, implies $C_A(x) = 0$ or $C_B(x) = 0, \quad \forall x \in M^*$. The space (M, τ) is said to be m-connected if M is a connected multiset of itself.

3 Binary Multiset Connectedness

In this section, the new forms of binary multiset connectedness, binary multiset disconnectedness, binary multiset components and the properties are dicussed.

Definition 3.1. Let (M_1, M_2, τ_b) be a binary multiset topological space and (A,B),(C,D) $\subseteq (M_1, M_2)$ is a two non-empty sub-binary multiset. Then (A,B) and (C,D) are binary multiset separated if $(A, B) \cap \overline{(C, D)} = (\emptyset, \emptyset)$ or $\overline{(A, B)} \cap (C, D) = (\emptyset, \emptyset)$.

Example 3.2. Let $M_1 = \{4/a, 8/r\}$, $M_2 = \{3/c, 1/d\}$ be a multiset and $(A, B) \subseteq M_1$ and $(C, D) \subseteq M_2$. The ordered pairs of (A, B) and (C, D) are disjoint and binary multiset separated. Consider the $(\overline{A}, \overline{B}) = (\{2/a, 4/r\})$, $(C, D) = (\{2/c, 1/d\})$ and $(A, B) \cap \overline{(C, D)} = (\emptyset, \emptyset)$. Hence, $(\{2/a, 4/r\}) \cap (\{2/c, 1/d\}) = (\emptyset, \emptyset)$, are binary multiset separated.

Theorem 3.3. *Let (M_1, M_2, τ_b) be a binary multiset topological space. If (A, B) and (C, D) are binary multiset separated, then any sub-binary multiset $(A_1, B_1) \subseteq (A, B)$ and $(C_1, D_1) \subseteq (C, D)$ are also binary multiset separated.*

Proof. From the definition 3.1., $(\overline{A}, \overline{B}) \cap (C, D) = (\emptyset, \emptyset)$ or $(A, B) \cap (\overline{C}, \overline{D}) = (\emptyset, \emptyset)$.....(1), such that $(A_1, B_1) \subseteq (A, B)$, and $(\overline{A_1}, \overline{B_1}) \subseteq (\overline{A}, \overline{B})$. Since, $(\overline{A_1}, \overline{B_1}) \cap (C_1, D_1) \subseteq (\overline{A}, \overline{B}) \cap (C, D)$ from (1), the right-hand side is empty, such that $(\overline{A_1}, \overline{B_1}) \cap (C_1, D_1) = (\emptyset, \emptyset)$....(2). Similarly, $(C_1, D_1) \subseteq (C, D)$ and $(\overline{C_1}, \overline{D_1}) \subseteq (\overline{C}, \overline{D})$. Thus $(\overline{C_1}, \overline{D_1}) \cap (A_1, B_1) \subseteq (\overline{C}, \overline{D}) \cap (A, B)$ from(1), $(\overline{C_1}, \overline{D_1}) \cap (A_1, B_1) = (\emptyset, \emptyset)$...(3), from (2) and (3). Hence (A_1, B_1) and (C_1, D_1) are binary multiset separated. □

Theorem 3.4. *Let (A, B) and (C, D) be a two binary multiset separated of sub-binary multiset in a binary multiset topological space (M_1, M_2, τ_b). Then,*

(i) If $(A, B) \cup (C, D)$ is a closed binary multiset , then both (A, B) and (C, D) are closed binary multiset.

(ii) If $(A, B) \cup (C, D)$ is an open binary multiset , then both (A, B) and (C, D) are open binary multiset.

Proof. (i) Since (A, B) and (C, D) are binary multiset separated, by definition 3.1, $(\overline{A}, \overline{B}) \cap (C, D) = (\emptyset, \emptyset)$ or $(A, B) \cap (\overline{C}, \overline{D}) = (\emptyset, \emptyset)$.....(1).
Such that $(A, B) \cup (C, D)$ is closed binary multiset, its binary multiset closure codition are satisfies, $(\overline{A}, \overline{B}) \cup (\overline{C}, \overline{D}) = (A, B) \cup (C, D)$. Such that, $(\overline{A}, \overline{B}) = (A, B)$ and $(\overline{C}, \overline{D}) = (C, D)$.

Hence, both (A, B) and (C, D) are closed binary multiset.
(ii) If $(A, B) \cup (C, D)$ is an open binary multiset and union of any open binary multiset is open binary multiset, and (A, B) and (C, D) are disjoint sub-binary multiset, both are individually open binary multiset. □

Definition 3.5. Let (M_1, M_2, τ_b) be a binary multiset topological space over (M_1, M_2) is said to be binary multiset connected (briefly, binary multiset $\mathfrak{C}$), if there exist a ordered pair of (A,B) and (C,D) of non-empty disjoint union of open binary multiset in (M_1, M_2, τ_b), such that $\tau_b = (\overline{A}, \overline{B}) \cup (C, D)$. Otherwise, (M_1, M_2, τ_b) is said to be binary multiset disconneccted. In this case, the ordered pair of (A,B) and (C,D) is called the binary multiset disconnected (briefly, binary multiset $\mathfrak{DC}$) over M_1 and M_2.

Definition 3.6. Let (M_1, M_2, τ_b) be a binary multiset topolgical space and sub-binary multiset of (A,B) and (C,D) is a binary multiset connected if it is binary multiset connected as binary multiset sub-space.

Definition 3.7. A binary multiset topological space (M_1, M_2, τ_b) is binary multiset disconnected (respt. binary multiset connected) if and only if there exist (respt. does not exist) two non-empty sub-binary multiset (A,B) and (C,D) which is both open binary multiset and closed binary multiset in (M_1, M_2, τ_b).

Definition 3.8. A binary multiset topological space (M_1, M_2, τ_b) any two binary multIipoints $(\{k/u\}, \{m/v\})$ is a binary multiset connected points in a binary multiset topological space if they are contained in a binary multiset of sub-binary multiset (A,B) and (C,D) of (M_1, M_2).

Example 3.9. Let $M_1 = \{3/x\}, M_2 = \{2/a\}$ be a multiset and $\tau_b = \{(M_1, M_2), (\emptyset, \emptyset), (\{2/x\}, \{1/a\}), (\{1/a\}, \{1/x\})\}$ is binary multiset topology and sub-binary multiset $(A, B) = (\{1/a\}, \{1/x\})$ is open binary multiset. Since the complement of $(\{2/x\}, \{1/a\})$ is a closed binary multiset of $(\{1/a\}, \{1/x\})$ is also known as open binary multiset. Therefore two non-empty sub-binary multiset of (A, B) which is both open binary multiset and closed binary multiset such as (M_1, M_2, τ_b) is binary multiset disconnected.

Example 3.10. Let $M_1 = \{3/s, 4/e, 6/f\}, M_2 = \{7/x, 8/y, 1/z\}$ be a multiset and $\tau_b = \{(M_1, M_2), (\emptyset, \emptyset), (\{3/s, 3/f\}, \{2/x, 1/z\}), (\{2/e\}, \{4/y\}), (\{3/s, 3/f, 2/e\}, \{2/x, 1/z, 4/y\})\}$ is a bianry multiset topology and $(\{3/s, 3/f\}, \{2/x, 1/z\}), (\{2/e\}, \{4/y\}), (\{3/s, 3/f, 2/e\}, \{2/x, 1/z, 4/y\})$ is a open binary multiset and their complement open binary multiset does not contained in τ_b. Hence, it is binary multiset connected.

Theorem 3.11. *Every binary multiset connected topological space (M_1, M_2, τ_b) is multiset connected.*

Proof. Let (A,B) and (C,D) be two non-empty disjoint open binary multiset in (M_1, M_2, τ_b). Since every open binary multiset is open binary multiset. Therefore (A,B) and (C,D) are non-empty disjoint open binary multiset in (M_1, M_2) and (M_1, M_2) is binary multiset connected. Hence $(M_1, M_2) = (A, B) \cap (C, D)$. Therefore (M_1, M_2, τ_b) is binary multiset connected. □

Theorem 3.12. *Let (M_1, M_2, τ_b) be a binary multiset topological space. Then the following statements are equivalents,*
(i) If (M_1, M_2, τ_b) is a binary multiset connected.
(ii) A sub-binary multiset of (M_1, M_2, τ_b) which are both open binary multiset and closed are empty set $(\emptyset, \emptyset)$ and (M_1, M_2).

Proof. (i)→ (ii) Let (A,B) be a non-empty open binary multiset and the complement of open binary multiset is a closed binary multiset of $(M_1, M_2.\tau_b)$. Thus, $(M_1, M_2) - (A, B)$ is also both open binary multiset and closed binary multiset. Since, $(M_1, M_2) = (A, B) \cup ((M_1, M_2) - (A, B))$ is a disjoint union of two non-empty open binary multiset, which cotradicts the (M_1, M_2, τ_b) is binary multiset conneccted. Hence $(A, B) = (\emptyset, \emptyset)$ or $(A, B) = (M_1, M_2)$.
(ii)→(i) Suppose that $(M_1, M_2) = (A, B) \cup (C, D)$ where, (A,B) and (C,D) are disjoint two non-empty open sub-binary multiset of (M_1, M_2, τ_b). Such that $(A, B) = (M_1, M_2) - (C, D)$, and (A,B) is both open binary multiset and closed binary multiset. Therefore, $(A, B) = (\emptyset, \emptyset)$ or $(A, B) = (M_1, M_2)$, which is a contradicts of hypothesis. Hence (M_1, M_2, τ_b) is binary multiset connected. □

Theorem 3.13. *Let (A,B) and (C,D) be a sub-binary multiset of binary multiset disconnected in binary multiset topological space* (M_1, M_2, τ_b) *and (E,F) is a binary multiset connected of sub-binary multiset of* (M_1, M_2, τ_b)*. Then (E,F) is contained in (A,B) or (C,D).*

Proof. Suppose that (E,F) is neither contained in (A,B) nor in (C,D). Then $(E, F) \cap (A, B) \neq (\emptyset, \emptyset)$ and $(E, F) \cap (C, D) \neq (\emptyset, \emptyset)$ are both non-empty open sub-binary multiset in (E,F) such that $[(E, F) \cap (A, B)] \cap [(E, F) \cap (C, D)] = (\emptyset, \emptyset)$, and $[(E, F) \cap (A, B)] \cup [(E, F) \cap (C, D)] = (E, F)$. Such that $((E, F) \cap (A, B), (E, F) \cap (C, D))$ is a binary multiset disconnected of (E,F), which is a contradicts oh hypothesis of (E,F) is binary multiset connected. □

Theorem 3.14. *Let* (C, D) *be a sub-binary multiset of binary multiset connected in binary multiset topological space* (M_1, M_2, τ_b)*, and* (A, B) *is a sub-binary multiset such that* $(C, D) \subseteq (A, B) \subseteq Cl_b(C, D)$*. Then* (A, B) *is binary multiset connected .*

Proof. Suppose that, $Cl_b(C, D)$ is binary multiset connected in binary multiset topological space. The contradiction of $Cl_b(C, D)$ is binary multiset disconnected there exists a binary multiset disconnected $((E, F), (G, H))$ of $Cl_b(C, D)$. The intersection of $(E, F) \cap (C, D), (G, H) \cap (C, D)$ are open sub-binary multiset of (C, D) such that $[(E, F) \cap (C, D)] \cap [(G, H) \cap (C, D)] = [(E, F) \cap (G, H)] \cap (C, D) = (\emptyset, \emptyset)$, and $[(E, F) \cap (C, D)] \cup [(G, H) \cap (C, D)] = [(E, F) \cup (G, H)] \cap (C, D) = (C, D)$. Therefore, $((E, F) \cap (C, D), (G, H) \cap (C, D))$ is a binary multiset disconnected of (C, D), which is contradicts our assumption (C, D) is binary multiset connected. Hence, $Cl_b(C, D)$ binary multiset connected, and (A, B) is binary multiset connected. □

Theorem 3.15. *If binary multiset topological space* (M_1, M_2, τ_b) *is binary multiset disconnected if and only if there exists a non-empty sub-binary multiset of (A,B) and (C,D) which is both open binary multiset and closed binary multiset .*

Proof. Let (A, B) be a both open binary multiset and closed binary multiset and (A,B) is a closed binary multiset so that $\overline{(A, B)} = (A, B)$...(1). Therefore (A,B) is open binary multiset, $(A, B)^c$=(C,D) is closed binary multiset, such that $\overline{(C, D)} = (C, D)$...(2). Since (C,D)is complement of (A,B)in (M_1, M_2) , $(A, B) \cup (C, D) = (M_1, M_2)$ and there exist $(A, B) \cap (C, D) = (\emptyset, \emptyset)$. Thus, $(A, B) \cap (C, D) = (\emptyset, \emptyset)$,$\overline{(A, B)} \cap (C, D) = (\emptyset, \emptyset)$ and $(A, B) \cap \overline{(C, D)} = (\emptyset, \emptyset)$. Hence, (M_1, M_2) is binary multiset binary multiset disconnected. The converse part of this theorem, (M_1, M_2) is binary multiset disconnected, there exsits two non-empty sub-binary multiset $(M_1, M_2) = (A, B) \cup (C, D)$, and $\overline{(A, B)} \cap (C, D) = (\emptyset, \emptyset), (A, B) \cap \overline{(C, D)} = (\emptyset, \emptyset)$....(3),therefore $(A, B) \subseteq \overline{(A, B)}, \overline{(A, B)} \cap (C, D) = (\emptyset, \emptyset)$ such that $(A, B) \cap (C, B) = (\emptyset, \emptyset)$....(4). To show that $(M_1, M_2) = (A, B) \cup (C, D)$ and $(A, B) \cap (C, D) = (\emptyset, \emptyset)$, $(A, B) = (M_1, M_2) - (C, D)$. Thus (A,B) is a sub-binary multiset of (M_1, M_2) and $(C, D) \subseteq \overline{(C, D)}$, $(A, B) \cup (C, D) = (M_1, M_2), (A, B) \cup \overline{(C, D)} = (M_1, M_2)$ and $(C, D) \subseteq \overline{(C, D)}$, $(A, B) \cap (C, D) = (\emptyset, \emptyset), (A, B) \cap \overline{(C, D)} = (\emptyset, \emptyset)$.... (5). Thus, $(A, B) = (M_1, M_2) - \overline{(C, D)}$ and (C,D) is a closed binary multiset, therefore $(A, B) = (M_1, M_2) - \overline{(C, D)}$...(6). Similarly, $(C, D) = (M_1, M_2) - \overline{(A, B)}$ is open binary multiset and $(A, B) = (M_1, M_2) - (C, D)$, where (C,D) is open binary multiset. Since (A,B) is closed binary multiset from (6) therefore (A,B) is open binary multiset. Hence (A,B) is a non-empty sub-binary multiset which is both open binary multiset and closed binary multiset. □

4 Conclusion remarks

. This paper explores the definition of bms connectedness within bms topological spaces, along with the concepts of bms separation and bms disconnectedness. A comprehensive discussion on the properties and characteristics of bms disconnectedness has also been provided. The study of bms connectedness and disconnectedness offers a foundation for further investigations in binary multiset topology and its applications.

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