

$(1, 2)^*$ - M_{gp} -Closed Sets in Bitopological Settings

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ABSTRACT: In this paper, a new class of set, namely $(1, 2)^*$ - M_{gp} -closed set is introduced in bitopological spaces and compared with different closed sets in Bitopological spaces. We further discuss some basic properties and applications of $(1, 2)^*$ - M_{gp} -closed sets, which defines a new class of space namely $(1, 2)^*$ - T_{Mgp} -space. Also, we establish their link with existing spaces.

I. INTRODUCTION

Topology had become an important area of study within mathematics. A metric space is now considered as a special case of a general topological spaces. A non-empty set X together with two topologies τ_1 and τ_2 is called a bitopological space and it is denoted by (X, τ_1, τ_2) . **Lellis Thivagar** [5] brought a new idea without using pair wise properties, namely $(1, 2)$ -bitopological spaces. In 2005, **Lellis Thivagar and O.Ravi** [6] introduced yet another bitopological space, namely, $(1, 2)^*$ -bitopological spaces.

Levine [7] concept of generalized open sets. Several researches were done and the notion of generalized-semi-closed, generalized-pre-closed and generalized semi-pre-open sets was investigated. In 1968 **Zaitsev** [15] defined π -closed sets. $(1, 2)^*$ - $M_{\delta\pi}$ -closed sets are introduced by **K.Mohana and I.Arockiarani** [8] in Bitopological spaces. **R.Raja Rajeshwari, M.Lellis Thivagar, M.Margaret Nirmala and E.Ekici** [11] defines $(1, 2)^*$ -gpr-closed set. **R.Dhanya, A. Parvathi** [4] introduced πgb^* -closed sets in Bitopological spaces.

The purpose of the present paper is to define a new class of closed sets called $(1, 2)^*$ - M_{gp} -closed sets and we discuss some basic properties of $(1, 2)^*$ - M_{gp} -closed sets in Bitopological spaces. As an application, we obtain a new space called $(1, 2)^*$ - T_{Mgp} -space.

II. PRELIMINARIES

Throughout this paper by a space X and Y represent non-empty bitopological spaces on which no separation axioms are assumed, unless otherwise mentioned. We recall the following definitions and results which are useful in the sequel.

Definition 2.1

- (i) A subset S of a bitopological space X is said to be $\tau_{1,2}$ -open [6], if $S=A \cup B$ where $A \in \tau_1$ and $B \in \tau_2$.
- (ii) A subset S of X is said to be (i) $\tau_{1,2}$ -closed [6], if the complement of S is $\tau_{1,2}$ -open. (ii) $\tau_{1,2}$ -clopen [7], if S is both $\tau_{1,2}$ -open and $\tau_{1,2}$ -closed.

Definition 2.2 In the space X a subset A is said to be $(1, 2)^*$ -pre-open [10], if $A \subseteq \tau_{1,2}\text{-int}(\tau_{1,2}\text{-cl}(A))$. The complement of $(1, 2)^*$ -pre-open is $(1, 2)^*$ -pre-closed.

Definition 2.3 Let S be a subset of the bitopological space X . then

- (1) The $(1, 2)^*$ -pre-interior [10] of S denoted by $(1, 2)^*\text{-pre-int}(S)$ is defined by $\cup\{G: G \subseteq S \text{ and } G \text{ is } (1, 2)^*\text{-pre-open}\}$.
- (2) The $(1, 2)^*$ -pre-closure [10] of S denoted by $(1, 2)^*\text{-pre-cl}(S)$ is defined by $\cap\{F: S \subseteq F \text{ and } F \text{ is } (1, 2)^*\text{-pre-closed}\}$.

Definition 2.4 In a space X , a subset A is said to be $(1, 2)^*$ -regular open [6], if $A = \tau_{1,2}\text{-int}(\tau_{1,2}\text{-cl}(A))$

Definition 2.5 In a space X , a subset A is said to be $(1, 2)^*$ -semi pre open [2], if $A \subseteq \tau_{1,2}\text{-cl}(\tau_{1,2}\text{-int}(\tau_{1,2}\text{-cl}(A)))$

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Definition 2.6 Finite union of $(1, 2)^*$ - regular-open sets is $\tau_{1,2}$ - π -open sets [15]. The complement of $\tau_{1,2}$ - π open set is said to be $\tau_{1,2}$ - π -closed set.

Definition 2.7 In a space X , a subset A is said to be $(1,2)^*$ -b-open [1], if $A \subseteq \tau_{1,2} \text{cl}(\tau_{1,2} \text{int}(A)) \cup (\tau_{1,2} \text{int}(\tau_{1,2} \text{cl}(A)))$

Definition 2.8 In a space X , a subset A is said to be $(1,2)^*$ - semi open [2], if $A \subseteq \tau_{1,2} \text{cl}(\tau_{1,2} \text{int}(A))$

Definition 2.9 A subset A of a bitopological space is called

- (1) $(1, 2)^*$ -gp-closed [14], if $(1, 2)^* \text{pcl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $\tau_{1,2}$ -open.
- (2) $(1, 2)^*$ -gpr-closed [11], if $(1, 2)^* \text{pcl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $(1,2)^*$ - regular open.
- (3) $(1, 2)^*$ -g-closed [12], if $\tau_{1,2} \text{cl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $\tau_{1,2}$ -open.
- (4) $(1, 2)^*$ - π gb-closed [13], if $(1, 2)^* \text{bcl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $\tau_{1,2}$ - π -open.
- (5) $(1, 2)^*$ - π gp-closed [9], if $(1, 2)^* \text{pcl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $\tau_{1,2}$ - π -open.
- (6) $(1,2)^*$ - π g β -closed, if $(1, 2)^* \text{spcl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $\tau_{1,2}$ - π -open.
- (7) $(1,2)^*$ - π gs-closed [3], if $(1, 2)^* \text{scl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $\tau_{1,2}$ - π -open.

III. $(1, 2)^*$ - M_{gp} - closed set

DEFINITION: 3.1 A subset A of X is said to be $(1,2)^*$ - M_{gp} - closed set if $(1,2)^* \text{pcl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $(1,2)^*$ -g -open.

PROPOSITION: 3.2 Every $(1,2)^*$ pre closed set is $(1,2)^*$ - M_{gp} - closed set.

REMARK:3.3 The converse of the above proposition is not true as shown in the following example.

EXAMPLE:3.4 Let $X=\{a,b,c,d\}$, $\tau_1=\{X, \emptyset, \{c\}, \{d\}, \{c,d\}\}$, $\tau_2=\{X, \emptyset, \{b\}\}$, Here $\{a,d\}$ is $(1,2)^*$ M_{gp} -closed set, but not $(1,2)^*$ -pre closed set.

PROPOSITION 3.5 Every $(1,2)^*$ - M_{gp} -closed set is $(1,2)^*$ -gp - closed set.

REMARK: 3.6 The converse of the above proposition is not true as shown in the following example.

EXAMPLE: 3.7 Let $X= \{a,b,c,d\}$, $\tau_1=\{X, \emptyset, \{c\}\}$, $\tau_2=\{X, \emptyset, \{d\}\}$. Here $\{b,c\}$, $\{a,d\}$, $\{a,c\}$, $\{b,d\}$, $\{b,c,d\}$ & $\{a,c,d\}$ are $(1,2)^*$ -gp - closed set, but not $(1,2)^*$ - M_{gp} -closed set.

PROPOSITION: 3.8 Every $(1,2)^*$ - M_{gp} - closed set is $(1,2)^*$ - gpr-closed set.

REMARK: 3.9 The converse of the above proposition is not true as shown in the following example.

EXAMPLE: 3.10 Let $X=\{a,b,c,d\}$, $\tau_1=\{X, \emptyset, \{a\}, \{c\}, \{a,c\}\}$, $\tau_2=\{X, \emptyset, \{d\}\}$, Then, $\{a\}$ & $\{a,c,d\}$ are in $(1,2)^*$ - gpr-closed sets, but not $(1,2)^*$ - M_{gp} - closed set.

PROPOSITION: 3.11 Every $(1,2)^*$ - M_{gp} - closed set is $(1,2)^*$ - π gp - closed set.

REMARK: 3.12 The converse of the above proposition is not true as shown in the following example.

EXAMPLE: 3.13 Let $X=\{a,b,c,d\}$, $\tau_1=\{X, \emptyset, \{a\}\}$, $\tau_2=\{X, \emptyset, \{c\}\}$, Then $\{a,b\}$ & $\{a,b,c\}$ are in $(1,2)^*$ - π gp-closed sets, but not $(1,2)^*$ - M_{gp} -closed set.

PROPOSITION: 3.14 Every $(1,2)^*$ - M_{gp} -closed set is $(1,2)^*$ - π gb-closed set.

REMARK: 3.15 The converse of the above proposition is not true as shown in the following example.

EXAMPLE: 3.16 Let $X=\{a,b,c,d\}$, $\tau_1=\{X, \emptyset, \{b\}, \{a,d\}, \{a,b,d\}\}$, $\tau_2=\{X, \emptyset, \{a,c,d\}, \{b,c\}, \{c\}\}$, here $\{b\}$, $\{a,d\}$ are $(1,2)^*$ - π gb - closed sets, but not $(1,2)^*$ - M_{gp} -closed set.

REMARK: 3.17 The following example shows that $(1,2)^*$ - M_{gp} -closed set is independent from $(1,2)^*$ - g-closed set.

EXAMPLE: 3.18 Let $X= \{a,b,c,d\}$, $\tau_1=\{X, \emptyset, \{a,d\}, \{b,d\}, \{d\}, \{a,b,d\}\}$, $\tau_2=\{X, \emptyset, \{b\}\}$
Here $\{a,b,d\}$ is $(1,2)^*$ - g- closed set but not $(1,2)^*$ - M_{gp} - closed set and $\{a\}$ is $(1,2)^*$ - M_{gp} -closed set, but not $(1,2)^*$ - g -closed set.

Therefore $(1,2)^*$ - M_{gp} -closed set and $(1,2)^*$ - g -closed set are independent of each other.

REMARK: 3.19 The following example shows that $(1,2)^*$ - M_{gp} -closed set is independent from $(1,2)^*$ - π g β closed set.

EXAMPLE:3.20 Let $X=\{a,b,c,d\}$, $\tau_1=\{X, \emptyset, \{a\}, \{b\}, \{a,b\}\}$, $\tau_2=\{X, \emptyset, \{a,b,d\}\}$. Here $\{d\}$ is $(1,2)^*$ - M_{gp} -closed set but not $(1,2)^*$ - π g β -closed set. Also the sets $\{a\}, \{b\}, \{a,b\}, \{a,d\}, \{b,d\}$ & $\{a,b,d\}$ are $(1,2)^*$ - π g β - closed set, but not $(1,2)^*$ - M_{gp} -closed set. Therefore, $(1,2)^*$ - M_{gp} -closed set and $(1,2)^*$ - π g β -closed set are independent of each other.

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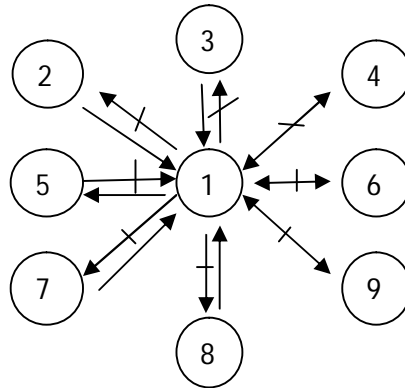
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REMARK: 3.21 The following example shows that $(1,2)^*$ - M_{gp} -closed set is independent from $(1,2)^*$ - π_{gs} -closed set.

EXAMPLE: 3.22 Let $X=\{a,b,c,d\}$, $\tau_1=\{X, \emptyset, \{a\}\}$, $\tau_2=\{X, \emptyset, \{b, c\}\}$. The sets $\{b\}$, $\{c\}$, $\{a,c\}$ are $(1,2)^*$ - M_{gp} -closed set, but not $(1,2)^*$ - π_{gs} -closed set. Also $\{a\}$ is $(1,2)^*$ - π_{gs} -closed set, but not $(1,2)^*$ - M_{gp} -closed set. Therefore, $(1,2)^*$ - M_{gp} -closed set and $(1,2)^*$ - π_{gs} -closed set are independent of each other.

REMARK: 3.23 The following diagram shows the relationships of $(1,2)^*$ - M_{gp} -closed set with other known existing sets. $A \rightarrow B$ represents A implies B , but not conversely.



1. $(1,2)^*$ - M_{gp} -closed set, 2. $(1,2)^*$ -pre-closed set, 3. $(1,2)^*$ -gp-closed set, 4. $(1,2)^*$ -g-closed set, 5. $(1,2)^*$ -gpr-closed set, 6. $(1,2)^*$ - π_{gb} -closed set, 7. $(1,2)^*$ - π_{gp} -closed set, 8. $(1,2)^*$ - π_{gb} -closed set, 9. $(1,2)^*$ - π_{gs} -closed set.

PROPOSITION: 3.24 The union of two $(1,2)^*$ - M_{gp} -closed set is $(1,2)^*$ - M_{gp} -closed set.

Proof: Let A & B be $(1,2)^*$ - M_{gp} -closed set. To prove $A \cup B$ is $(1,2)^*$ - M_{gp} -closed set. Let $A \cup B \subseteq U$ where U is $(1,2)^*$ -g-open. Now to prove $(1,2)^*$ -pcl($A \cup B$) $\subseteq U$. Here A & B are $(1,2)^*$ - M_{gp} -closed set; $A \subseteq U$ and $B \subseteq U$. $\Rightarrow A \cup B \subseteq U$. Also $(1,2)^*$ -pcl(A) $\subseteq U$ and $(1,2)^*$ -pcl(B) $\subseteq U$. Therefore $(1,2)^*$ -pcl(A) \cup $(1,2)^*$ -pcl(B) $\subseteq U$. Hence $(1,2)^*$ -pcl($A \cup B$) $\subseteq U$. The union of $(1,2)^*$ - M_{gp} -closed set is $(1,2)^*$ - M_{gp} -closed set.

REMARK: 3.25 Intersection of any two $(1,2)^*$ - M_{gp} -closed sets in X need not be $(1,2)^*$ - M_{gp} -closed set.

EXAMPLE: 3.26 Let $X=\{a,b,c,d\}$, $\tau_1=\{X, \emptyset, \{c\}, \{d\}, \{c, d\}\}$, $\tau_2=\{X, \emptyset, \{a\}, \{c, d\}, \{a, c, d\}\}$

Here $\{\{a,b,d\}, \{a,c,d\}\}$ are $(1,2)^*$ - M_{gp} -closed sets. Therefore $\{a,b,d\} \cap \{a,c,d\} = \{a,d\}$ is not $(1,2)^*$ - M_{gp} -closed set.

PROPOSITION: 3.27 Let A be $(1,2)^*$ - M_{gp} -closed set. Then $(1,2)^*$ -pcl(A) does not contain any non-empty $(1,2)^*$ -g-closed set.

Proof: Suppose that A is $(1,2)^*$ - M_{gp} -closed set. Let F be $(1,2)^*$ -g-closed set contained in $(1,2)^*$ -pcl(A)- A . Now F^c is $(1,2)^*$ -g-open set of X such that $A \subseteq F^c$. Since A is $(1,2)^*$ - M_{gp} -closed set of X then $(1,2)^*$ -pcl(A) $\subseteq F^c$. Thus $F \subseteq [(1,2)^* - \text{pcl}(A)]^c$. Also $F \subseteq (1,2)^*$ -pcl(A)- A . Therefore $F \subseteq [(1,2)^* - \text{pcl}(A)]^c \cap [(1,2)^* - \text{pcl}(A)] = \emptyset$. Hence $F = \emptyset$.

PROPOSITION: 3.28 If A is $(1,2)^*$ -g-open set and $(1,2)^*$ - M_{gp} -closed subset of X , then A is an $(1,2)^*$ -pre closed subset of X .

Proof: Since A is $(1,2)^*$ -g-open and $(1,2)^*$ - M_{gp} -closed set, $(1,2)^*$ -pcl(A) $\subseteq A$. Hence A is $(1,2)^*$ -pre closed set.

PROPOSITION: 3.29 The intersection of $(1,2)^*$ - M_{gp} -closed set and $(1,2)^*$ -pre closed set is always $(1,2)^*$ - M_{gp} -closed set.

Proof: Let A be $(1,2)^*$ - M_{gp} -closed set and F be $(1,2)^*$ -pre closed set. If U is an $(1,2)^*$ -g-open set with $A \cap F \subseteq U$, then $A \subseteq F^c$. Now $(1,2)^*$ -pcl($A \cap F$) $\subseteq U$. Hence $A \cap F$ is $(1,2)^*$ - M_{gp} -closed set.

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PREPOSITION: 3.30 If A is a $(1,2)^*$ - M_{gp} -closed set in a space X and $A \subseteq B \subseteq (1,2)^*$ -pcl(A), then B is also $(1,2)^*$ - M_{gp} -closed set.

Proof: Let U be $(1,2)^*$ -g-open set of X such that $B \subseteq U$. Then $A \subseteq U$. Since A is $(1,2)^*$ - M_{gp} -closed set, $(1,2)^*$ -pcl(A) $\subseteq U$. Also, since $B \subseteq (1,2)^*$ -pcl(A), $(1,2)^*$ -pcl(B) $\subseteq (1,2)^*$ -pcl(A) = $(1,2)^*$ -pcl(A). Hence $(1,2)^*$ -pcl(A) $\subseteq U$. Therefore B is also a $(1,2)^*$ - M_{gp} -closed set.

PROPOSITION: 3.31 Let A be $(1,2)^*$ - M_{gp} -closed set of X , then A is $(1,2)^*$ -pre closed if and only if $(1,2)^*$ -pcl(A) - A is $(1,2)^*$ -g-closed set.

Proof: Necessity: Let A be $(1,2)^*$ -pre closed subset of X . Then $(1,2)^*$ -pcl(A) = A and so $(1,2)^*$ -pcl(A) - $A = \emptyset$ which is $(1,2)^*$ -g-closed set. **Sufficiency:** Since A is $(1,2)^*$ - M_{gp} -closed set, by the theorem 3.27. $\Rightarrow (1,2)^*$ -pcl(A) - A does not contain a nonempty $(1,2)^*$ -g-closed set. But $(1,2)^*$ -pcl(A) - $A = \emptyset$ (i.e.) $(1,2)^*$ -pcl(A) - A . Hence A is $(1,2)^*$ -pre closed set.

IV. $(1,2)^*$ - T_{Mgp} -SPACES

DEFINITION: 4.1 A space X is called $(1,2)^*$ - T_{Mgp} -space, if every $(1,2)^*$ - M_{gp} -closed set in it is an $(1,2)^*$ -pre closed set.

PROPOSITION: 4.2 For a bitopological space X , the following conditions are equivalent.

(i). X is an $(1,2)^*$ - T_{Mgp} -space.

(ii). Every singleton $\{x\}$ is either $(1,2)^*$ -g-closed or $(1,2)^*$ -pre open.

Proof: (i) \Rightarrow (ii). let $x \in X$, suppose $\{x\}$ is not a $(1,2)^*$ -g-closed set of X . Then $X - \{x\}$ is an $(1,2)^*$ - M_{gp} -closed set of X . Since X is $(1,2)^*$ - T_{Mgp} -space, $X - \{x\}$ is an $(1,2)^*$ -pre closed set of X . (i.e) $\{x\}$ is $(1,2)^*$ -pre open set of X . (ii) \Rightarrow (i). let A be an $(1,2)^*$ - M_{gp} -closed set of X . let $x \in X$, $(1,2)^*$ -pcl(A), by (ii), $\{x\}$ is either $(1,2)^*$ -g-closed or $(1,2)^*$ -pre open. **Case (i):** Let $\{x\}$ be $(1,2)^*$ -g-closed set. If we assume that $x \notin A$ then we would have $x \in (1,2)^*$ -pcl(A) - A , which cannot happen according to theorem 3.27. Hence $x \in A$. **Case (ii):** Let $\{x\}$ be $(1,2)^*$ -pre open set. since $x \in (1,2)^*$ -pcl(A), then $\{x\} \cap A \neq \emptyset$. This shows that $x \in A$. So in the both cases, we have $(1,2)^*$ -pcl(A) $\subseteq A$. Trivially, $A \subseteq (1,2)^*$ -pcl(A). This implies $A = (1,2)^*$ -pcl(A) or equivalently A is $(1,2)^*$ -pre closed. Hence X is a $(1,2)^*$ - T_{Mgp} -space.

DEFINITION: 4.3: A space X is called a $(1,2)^*$ - T_{gp} -space if every $(1,2)^*$ -gp-closed set in it is $(1,2)^*$ -pre closed.

PROPOSITION: 4.4 Every $(1,2)^*$ - T_{gp} -space is a $(1,2)^*$ - T_{Mgp} -space.

Proof: The proof is straight forward, since every $(1,2)^*$ - M_{gp} -closed set is $(1,2)^*$ -gp-closed set.

REMARK: 4.5 The converse of the proposition is not true as shown from the following example.

EXAMPLE: 4.6 Let $X = \{a, b, c, d\}$, $\tau_1 = \{X, \emptyset, \{a\}, \{a, b, d\}\}$, $\tau_2 = \{X, \emptyset, \{c\}, \{b, c, d\}\}$

Then X is a $(1,2)^*$ - T_{Mgp} -space but not a $(1,2)^*$ - T_{gp} -space.

DEFINITION: 4.7 A space X is called $(1,2)^*$ - T_{gpr} -space if every $(1,2)^*$ -gpr-closed set in it is $(1,2)^*$ -pre-closed set.

PROPOSITION: 4.8 Every $(1,2)^*$ - T_{gpr} -space is $(1,2)^*$ - T_{Mgp} -space.

Proof: The proof is straight forward, since every $(1,2)^*$ - M_{gp} -closed set is $(1,2)^*$ -gpr-closed set.

REMARK: 4.9 The converse of the proposition is not true as it can be seen from the following example.

EXAMPLE: 4.10 Let $X = \{a, b, c, d\}$, $\tau_1 = \{X, \emptyset, \{a\}\}$, $\tau_2 = \{X, \emptyset, \{b\}\}$, Then X is a $(1,2)^*$ - T_{Mgp} -space but not a $(1,2)^*$ - T_{gpr} -space.

DEFINITION: 4.11 A space X is called $(1,2)^*$ - $T_{\pi gp}$ -space if every $(1,2)^*$ - πgp -closed set in it is $(1,2)^*$ -pre-closed set.

PROPOSITION: 4.12 Every $(1,2)^*$ - $T_{\pi gp}$ -space is a $(1,2)^*$ - T_{Mgp} -space.

Proof: The proof is straight forward, since every $(1,2)^*$ - M_{gp} -closed set is $(1,2)^*$ - πgp -closed set.

REMARK: 4.14 The converse of the proposition is not true as it can be seen from the following example.

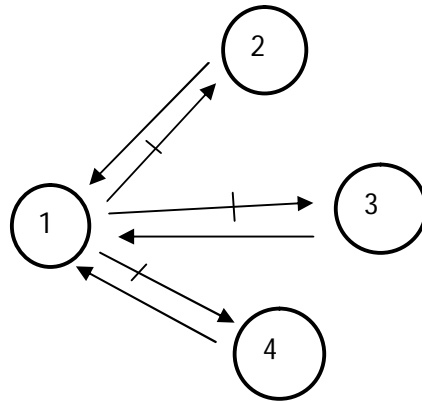
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EXAMPLE: 4.15 Let $X = \{a, b, c, d\}$, $\tau_1 = \{X, \emptyset, \{a, d\}\}$, $\tau_2 = \{X, \emptyset, \{a, b, d\}\}$. Therefore X is $(1, 2)^*$ - T_{Mgp} -space but not $(1, 2)^*$ - $T_{\pi gp}$ space.

REMARK: 4.16 The following diagram shows the relationships of $(1, 2)^*$ - T_{Mgp} -space with other known Existing spaces. $A \rightarrow B$ represents A implies B , but not conversely.



1. $(1, 2)^*$ T_{Mgp} space, 2. $(1, 2)^*$ T_{gp} space 3. $(1, 2)^*$ T_{gpr} space, 4. $(1, 2)^*$ $T_{\pi gp}$ space

V.CONCLUSION

A new class $(1, 2)^*$ - M_{gp} -closed set is studied in bitopological spaces and compared with different closed sets. We also discussed the basic properties and their applications of $(1, 2)^*$ - M_{gp} -closed sets, which defined a new class of space namely $(1, 2)^*$ - T_{Mgp} -space. Further, With the light of newly formed sets we will study some applications in soft sets.

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