

## Pairwise $s^{**}gO$ - compact spaces in bitopological spaces

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### ABSTRACT

Balachandran [1] introduced the notion of GO-compactness by involving  $g$ -open sets. Quite recently, Caldas et al. in investigated this class of compactness and characterized several of its properties. In this paper we introduced a new type of compact spaces called pairwise  $s^{**}gO$  - compact spaces and study its properties.

**Keywords:** pairwise  $s^{**}gO$  - compact, pairwise pre  $s^{**}g$  - closed.

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### 1. INTRODUCTION

The notions of compactness is useful and fundamental notions of not only general topology but also of other advanced branches of mathematics. Many researchers have investigated the basic properties of compactness. The productivity and fruitfulness of these notions of compactness motivated mathematicians to generalize these notions. In the course of these attempts many stronger and weaker forms of compactness have been introduced and investigated. Balachandran, Sundaram and Maki [1] introduced a class of compact space called GO-compact space and GO-connected space using  $g$ -open cover.

In 1995,  $sg$  - compact spaces were introduced by Caldas [3]. According to him, a topological space  $(X, \tau)$  is called  $sg$  - compact if every cover of  $X$  by  $sg$  - open sets has a finite sub cover. Devi, Balachandran and Maki [11] defined the same concept and they used the term  $SGO$  - compactness. Recently, the notions of pairwise  $S^{*}GO$  - compact spaces were introduced by K.Kannan [8] in bitopological spaces in 2009. In this section we define and study the concept of pairwise  $s^{**}gO$  - compact spaces in bitopological spaces.

The main focus of this paper is to introduce a new type of compact spaces called pairwise  $s^{**}gO$  - compact spaces and study its properties.

### 2. PRELIMINARIES

**Definition 2.1 [8]:** A bitopological space  $(X, \tau_1, \tau_2)$  is *pairwise  $S^{*}GO$  - compact* if every pairwise  $s^{*}g$  - open cover of  $X$  has a finite sub cover .

**Definition 2.2:** A function  $f: (X, \tau_1, \tau_2) \rightarrow (Y, \sigma_1, \sigma_2)$  is *pairwise pre semi - closed* if  $f: (X, \tau_1) \rightarrow (Y, \sigma_1)$  and  $f: (X, \tau_2) \rightarrow (Y, \sigma_2)$  are pre semi closed .

**Definition 2.3:**  $(X, \tau)$  is called an  *$s$  - normal space* if given two disjoint closed sets  $A$  and  $B$  in  $X$  , there exist disjoint semi open neighbourhoods  $U$  and  $V$  of  $A$  and  $B$  respectively .

**Definition 2.4 [6]:** A bitopological space  $(X, \tau_1, \tau_2)$  is said to be pairwise compact in the sense of Fletcher, Hoyle and Patty [FHP] ( to be abbreviated as **FHP compact** ) if every pairwise open cover  $\mu$  of  $X$  has a finite subcover.

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### 3. PAIRWISE $s^{**}gO$ - COMPACT

In the year 2013,  $s^{**}g$  - closed sets were introduced by K.Kannan [9]. In this section we define and study the concept of pairwise  $s^{**}gO$  - compact spaces in bitopological spaces.

**Definition 3.1:** A nonempty collection  $\zeta = \{A_i, i \in I; \text{an index set}\}$  is called a *pairwise  $s^{**}g$  - open cover* of a bi space  $(X, \tau_1, \tau_2)$ . If  $X = \cup A_i$  and  $\zeta \subseteq \tau_1 - s^{**}gO - (X, \tau_1, \tau_2) \cup \tau_2 - s^{**}gO(X, \tau_1, \tau_2)$  and  $\zeta$  contains atleast one member of  $\tau_1 - s^{**}gO - (X, \tau_1, \tau_2)$  and one member of  $\tau_2 - s^{**}gO - (X, \tau_1, \tau_2)$ .

**Definition 3.2:** A bitopological space  $(X, \tau_1, \tau_2)$  is *pairwise  $s^{**}gO$  - compact* if every pairwise  $s^{**}g$  - open cover of  $X$  has a finite subcover.

**Definition 3.3:** A set  $A$  of a bitopological space  $(X, \tau_1, \tau_2)$  is *pairwise  $s^{**}gO$  - compact relative to  $X$*  if every pairwise  $s^{**}g$  - open cover of  $B$  by has a finite subcover as a subspace.

**Example 3.1:** Let  $\mathcal{C} = \{G_\alpha : \alpha \in \Lambda\}$  be a pairwise  $s^{**}g$  - open covering for  $X$  so that each  $G_\alpha$  is a pairwise  $s^{**}g$  - open set and  $X = \cup \{G_\alpha : \alpha \in \Lambda\}$ .  $G_\alpha^c$  is the complement of  $G_\alpha$  is a finite set by definition of cofinite topology . Therefore,  $G_\alpha^c = \{x_1, x_2, \dots, x_n\}$  i.e. a finite set . Now each element of  $G_\alpha^c$  is also an element of  $X$  whose cover is  $\mathcal{C}$  and hence each member of  $G_\alpha^c$  is contained in one or other member of  $G_\alpha$  . At the most for each  $x_i \in G_\alpha^c \exists$  a set  $G_{\alpha_i}$  in  $\mathcal{C}$  such that  $x_i \in G_{\alpha_i}$ . Hence  $G_{\alpha_i}^c \subset G_{\alpha_1} \cup G_{\alpha_2} \cup \dots \cup G_{\alpha_n}$ . Above relation shows that the finite collection  $\mathcal{C}^* = \{G_{\alpha_n}, G_{\alpha_1}, \dots, G_{\alpha_n}\}$  is a finite pairwise  $s^{**}g$  - open covering for  $X$  & hence  $(X, \tau_1, \tau_2)$  is pairwise  $s^{**}gO$  - compact .

**Theorem 3.1:** If  $(X, \tau_1)$  and  $(X, \tau_2)$  are Hausdorff and  $(X, \tau_1, \tau_2)$  is pairwise  $s^{**}gO$  - compact then  $\tau_1 = \tau_2$ .

**Proof:** Let  $(X, \tau_1)$  and  $(X, \tau_2)$  be Hausdorff and  $(X, \tau_1, \tau_2)$  is pairwise  $s^{**}gO$  - compact. Since every  $s^{**}gO$  - compact space is pairwise compact we have  $(X, \tau_1)$  and  $(X, \tau_2)$  are Hausdorff and  $(X, \tau_1, \tau_2)$  is pairwise compact. Let  $F$  be  $\tau_1$  - closed in  $X$ . Then  $F^c$  is  $\tau_1$  - open in  $X$ . Let  $\zeta = \{A_i, i \in I; \text{an index set}\}$  be the  $\tau_2$  - open cover for  $X$ . Therefore,  $\zeta \cup F^c$  is the pairwise open cover for  $X$  . Since  $X$  is pairwise compact,  $X = F^c \cup A_1 \cup \dots \dots \dots \cup A_n$ . Hence  $F = A_1 \cup \dots \dots \dots \cup A_n$ . Hence  $F$  is  $\tau_2$  - compact. Since  $(X, \tau_2)$  is Hausdorff we have  $F$  is  $\tau_2$  - closed. Similarly, every  $\tau_2$  - closed set is  $\tau_1$  - closed. Therefore,  $\tau_1 = \tau_2$ .

**Theorem 3.2:** If  $Y$  is  $\tau_i - s^{**}g$  closed subset of a pairwise  $s^{**}gO$  - compact space  $(X, \tau_1, \tau_2)$  then  $Y$  is  $\tau_j - s^{**}gO$  - compact .

**Proof:** Let  $X$  be a pairwise  $s^{**}gO$  - compact space. Let  $\zeta = \{A_i, i \in I; \text{an index set}\}$  be the  $\tau_j - s^{**}g$  open cover of  $Y$ . Since  $Y$  is  $\tau_i - s^{**}g$  closed subset,  $Y^c$  is  $\tau_i - s^{**}g$  open. Also  $\zeta \cup A^c = Y^c \cup \{A_i, i \in I; \text{an index set}\}$  be a pairwise  $s^{**}g$  - open cover of  $X$ . Since  $X$  is pairwise  $s^{**}gO$  - compact,  $X = Y^c \cup A_1 \cup \dots \dots \dots \cup A_n$ . Hence  $Y = A_1 \cup \dots \dots \dots \cup A_n$ . Therefore,  $Y$  is  $\tau_j - s^{**}gO$  - compact.

Since every  $\tau_i - s^{**}g$  - closed set is  $\tau_j$  - closed. We have the following

**Theorem 3.3:** If  $Y$  is  $\tau_i$  - closed subset of a pairwise  $s^{**}gO$  - compact space  $(X, \tau_1, \tau_2)$  then  $Y$  is  $\tau_j - s^{**}gO$  - compact.

**Theorem 3.4:** Pairwise  $s^{**}g$  - continuous image of a pairwise  $s^{**}gO$  - compact space is pairwise  $s^{**}gO$  - compact.

**Proof:** Let  $(X, \tau_1, \tau_2)$  be a pairwise  $s^{**}gO$  - compact. Let  $f : (X, \tau_1, \tau_2) \xrightarrow{\text{onto}} (X^*, \tau_1^*, \tau_2^*)$  be a pairwise  $s^{**}g$  - continuous. Let  $\{G_i\}$  be a pairwise  $s^{**}g$  - open cover of  $X^* \Rightarrow \{f^{-1}(G_i)\}$  is pairwise  $s^{**}g$  - open cover of  $X \Rightarrow \exists$  a finite sub cover of  $X$  [ because  $X$  is pairwise  $s^{**}gO$  - compact ]  $\{f^{-1}(G_1), f^{-1}(G_2), \dots, f^{-1}(G_n)\} \Rightarrow G_1, \dots \dots \dots, G_n$  is a subcover of  $G_i \Rightarrow X^*$  is pairwise  $s^{**}gO$  - compact .

**Definition 3.4:** A bitopological space  $(X, \tau_1, \tau_2)$  is said to be *pairwise  $s^{**}g$  - Hausdorff* if for each pair of distinct points  $x$  and  $y$  of  $X$ , there exist  $U \in \tau_1 - s^{**}gO$  and  $V \in \tau_2 - s^{**}gO$  such that  $x \in U, y \in V$  and  $U \cap V = \phi$ .

**Definition 3.5:** A map  $f : X \rightarrow Y$  is called  $\tau_1 \tau_2 - s^{**}g$  continuous if the inverse image of each  $\sigma_1 \sigma_2 - s^{**}g$  closed in  $Y$  is  $\tau_2$  - closed in  $X$ .

**Remark 3.1:** Pairwise  $s^{**}gO$  - compact space & pairwise  $s^{**}g - T_2$  - space which is not pairwise  $s^{**}g$  - connected. The following example supports our claim.

**Example 3.2:** Let  $X = \{a, b, c\}$ ,  $\tau_1 = \{\emptyset, X, \{a\}\}$  and  $\tau_2 = \{\emptyset, X, \{a\}, \{b, c\}\}$ . Let  $\zeta = \{\{a\}, \{c\}, \{a, c\}, \{b, c\}\}$ . Since  $(X, \tau_1, \tau_2)$  is pairwise  $s^{**}gO$  - compact we have  $X$  is finite. Since  $X$  is pairwise  $s^{**}g - T_2$ ,  $\exists$  a  $\tau_1 - s^{**}g$  open set  $U = \{a\}$  &  $\tau_2 - s^{**}g$  open set  $V = \{b, c\}$  such that  $a \in U, b \in V$  &  $U \cap V = \emptyset$ .  $\Rightarrow X = U \cup V$  with  $U \cap V = \emptyset$ . Hence  $X$  is pairwise  $s^{**}g$  - disconnected.

**Remark 3.2:** A pairwise  $s^{**}gO$  - compact subset of a bitopological space  $X$  is need not be  $\tau_2 - s^{**}g$  closed. The following example supports or claim.

**Example 3.3:** Let  $X = \{a, b, c\}$ ,  $\tau_1 = \{\emptyset, X, \{a, c\}\}$  and  $\tau_2 = \{\emptyset, X, \{a\}, \{b, c\}\}$ . Let  $\zeta = \{\{a\}, \{c\}, \{a, c\}, \{b, c\}\}$ . Let  $A = \{a, c\}$ . Now  $A \subset \{a\} \cup \{b, c\}$ . Hence by definition  $A$  is pairwise  $s^{**}gO$  - compact set. But  $A$  is not  $\tau_2 - s^{**}g$  closed its complement  $\{b\}$  is not  $\tau_2 - s^{**}g$  open.

**Remark 3.3:** A pairwise  $s^{**}gO$  - compact space which is not pairwise  $s^{**}g$  - Hausdorff.

**Definition 3.6:** A function  $f : (X, \tau) \rightarrow (Y, \sigma)$  is **pre  $s^{**}gO$  - closed** if  $f(U)$  is  $s^{**}g$  - closed in  $Y$  for every  $s^{**}g$  - closed set in  $X$ .

**Definition 3.7:** A function  $f : (X, \tau_1, \tau_2) \rightarrow (Y, \sigma_1, \sigma_2)$  is **pairwise pre  $s^{**}g$  - closed** if  $f : (X, \tau_1) \rightarrow (Y, \sigma_1)$  and  $f : (X, \tau_2) \rightarrow (Y, \sigma_2)$  are pre  $s^{**}g$  - closed .

**Definition 3.8:** A function  $f : (X, \tau_1, \tau_2) \rightarrow (Y, \sigma_1, \sigma_2)$  is **pairwise  $s^{**}g$  - continuous** if the inverse image of each  $\sigma_2$  - closed set in  $Y$  is  $\tau_1 \tau_2 - s^{**}g$  - closed set in  $X$ .

**Theorem 3.5:** Let  $f : (X, \tau_1, \tau_2) \rightarrow (Y, \sigma_1, \sigma_2)$  be pairwise  $s^{**}g$  - continuous, bijective and pairwise pre  $s^{**}g$  - closed. Then the image of a pairwise  $s^{**}gO$  - compact space under  $f$  is pairwise  $s^{**}gO$  - compact.

**Proof:** Let  $f : (X, \tau_1, \tau_2) \rightarrow (Y, \sigma_1, \sigma_2)$  be pairwise  $s^{**}g$  - continuous, bijective and pairwise pre  $s^{**}g$  - closed. Let  $X$  be a pairwise  $s^{**}gO$  - compact. Let  $\zeta = \{A_i, i \in I ; \text{an index set}\}$  be the  $\tau_2 - s^{**}g$  open cover of  $Y$ . Then  $Y = \cup A_i$  and  $\zeta \subseteq \sigma_1 - s^{**}gO - (X, \tau_1, \tau_2) \cup \sigma_2 - s^{**}gO - (X, \tau_1, \tau_2)$  and  $\zeta$  contains atleast one member of  $\sigma_1 - s^{**}gO - (X, \tau_1, \tau_2)$  and one member of  $\sigma_2 - s^{**}gO - (X, \tau_1, \tau_2)$ . Therefore,  $X = f^{-1}(\cup A_i) = \cup f^{-1}(A_i)$  and  $f^{-1}(\zeta) \subseteq \tau_1 - s^{**}gO - (X, \tau_1, \tau_2) \cup \tau_2 - s^{**}gO - (X, \tau_1, \tau_2)$  and  $f^{-1}(\zeta)$  contains atleast one member of  $\tau_1 - s^{**}gO - (X, \tau_1, \tau_2)$  and one member of  $\tau_2 - s^{**}gO - (X, \tau_1, \tau_2)$ . Therefore,  $f^{-1}(\zeta)$  is the pairwise  $s^{**}g$  - open cover of  $X$ . Since  $X$  is pairwise  $s^{**}gO$  - compact, we have  $X = f^{-1}(\cup A_i), i = 1 \text{ to } n. \Rightarrow Y = f(X) = \cup A_i, i = 1 \text{ to } n$ . Hence  $\zeta$  has the finite subcover. Therefore,  $Y$  is the pairwise compact.

**Theorem 3.6:** If  $(X, \tau_1, \tau_2)$  is pairwise  $s^{**}gO$  - compact space then both  $(X, \tau_1)$  and  $(X, \tau_2)$  are  $s^{**}gO$  - compact.

**Proof:** To prove  $(X, \tau_1)$  is  $s^{**}gO$  - compact space we must prove for any  $s^{**}g$  - open cover of  $X$  has a finite sub cover. Let  $\{U_i, i \in \Lambda$  is a  $s^{**}g$  - open cover of  $X$ , implies  $f^{-1}(U_i), i \in \Lambda$  is a  $s^{**}g$  - open cover of  $X$ , so  $(X, \tau_1)$  is  $s^{**}gO$  - compact. And by the same way we prove  $(X, \tau_2)$  is  $s^{**}gO$  - compact.

**Theorem 3.7:** If  $f : (X, \tau_1, \tau_2) \rightarrow (Y, \sigma_1, \sigma_2)$  is a pairwise  $s^{**}g$  - continuous and  $X$  is pairwise  $s^{**}g$  - connected , then  $Y$  is pairwise  $s^{**}g$  - connected.

**Proof:** Suppose that  $Y$  is not pairwise  $s^{**}g$  - connected. Let  $Y = A \cup B$  where  $A$  and  $B$  are disjoint non-empty  $\sigma_1 - s^{**}g$  open &  $\sigma_2 - s^{**}g$  open sets in  $Y$ . Since  $f$  is pairwise  $s^{**}g$  - continuous and onto,  $X = f^{-1}(A) \cup f^{-1}(B)$  where  $f^{-1}(A)$  and  $f^{-1}(B)$  are disjoint non-empty  $\tau_1$  - open and  $\tau_2$  - open sets in  $X$ . This contradicts the fact that  $X$  is  $s^{**}g$  - connected. Hence  $Y$  is connected.

**Proposition 3.8:** If  $A$  and  $B$  are two pairwise  $s^{**}gO$  - compact subsets of a bitopological space  $(X, \tau_1, \tau_2)$  then  $A \cup B$  is pairwise  $s^{**}gO$  - compact subset of  $X$ .

**Proof:** Given  $A$  and  $B$  are two pairwise  $s^{**}gO$  - compact subsets of a bitopological space  $(X, \tau_1, \tau_2)$ . We shall prove that  $A \cup B$  is pairwise  $s^{**}gO$  - compact subset of  $X$ , We have to prove that for any pairwise  $s^{**}g$  - open cover of  $A \cup B$  has a finite sub cover .

Let  $\{U_i / i \in \Lambda\}$  be any pairwise  $s^{**}g$  - open cover of  $A \cup B$ . Then  $A \cup B \subseteq \{\cup U_i / i \in \Lambda\}$  and therefore  $A \subseteq \cup U_i$  and  $B \subseteq \cup U_i$ , which implies that  $\{\cup U_i / i \in \Lambda\}$  is an pairwise  $s^{**}g$  - open cover of  $A$  and  $B$ , where  $i, j = 1, 2$  and  $i \neq j$ . But  $A$  and  $B$  are pairwise  $s^{**}gO$  - compact subsets. Therefore there exist  $i_1, i_2, \dots, i_n \in \Lambda$  and

$t_1, t_2, \dots, t_n \in \mathcal{A}$  such that  $\{U_{i_1}, U_{i_2}, \dots, U_{i_n}\}$  and  $\{U_{t_1}, U_{t_2}, \dots, U_{t_n}\}$  is a finite sub cover of A and B respectively, then  $\{U_{i_1}, U_{i_2}, \dots, U_{i_n}\} \cup \{U_{t_1}, U_{t_2}, \dots, U_{t_n}\}$  is a finite sub cover of  $A \cup B$ . Therefore  $A \cup B$  is an pairwise  $s^{**}gO$  - compact subset of X.

**Theorem 3.9:** Every pairwise  $s^{**}gO$  - compact subset of a pairwise  $s^{**}g$  - Hausdorff space is pairwise  $s^{**}g$  - closed.

**Proof:** Suppose that A be a pairwise  $s^{**}gO$  - compact subset of a pairwise  $s^{**}g$  - Hausdorff space X. Since X is pairwise  $s^{**}g$  - Hausdorff, the subspace A is pairwise  $s^{**}g$  - Hausdorff. By hypothesis, A is a pairwise  $s^{**}gO$  - compact. Hence A is pairwise compact. Let  $x \in X - A$ . For every  $a \in A$  we have  $a \neq x$ . But X is pairwise  $s^{**}g$  - Hausdorff. Hence there exist  $\tau_i$  -  $s^{**}g$  open nbds  $U_a$  of a and a  $\tau_j$  -  $s^{**}g$  open nbds  $V_a$  of x such that  $U_a \cap V_a = \phi$  ... (1), where  $i, j = 1, 2$  and  $i \neq j$ . But then the collection  $\mathcal{C} = \{U_a : a \in A\}$  is an pairwise  $s^{**}g$  - open cover of A. But A is pairwise compact. Hence  $\mathcal{C}$  has a finite sub collection  $\{U_{a_1}, U_{a_2}, \dots, U_{a_n}\}$  covering A. Put  $U = U_{a_1} \cup U_{a_2} \cup \dots \cup U_{a_n}$ . Then U is an  $\tau_i$  -  $s^{**}g$  open set with  $A \subset U$ . Consider the corresponding  $\tau_j$  -  $s^{**}g$  open sets  $V_{a_1}, V_{a_2}, \dots, V_{a_n}$ . Write  $V = V_{a_1} \cap V_{a_2} \cap \dots \cap V_{a_n}$ . Then V is an  $\tau_j$  -  $s^{**}g$  open set with  $x \in V$ . By virtue of (1),  $U \cap V = \phi$ .  $\Rightarrow x \in U \subset X - V \subset X - A \Rightarrow x \in U \subset X - A \Rightarrow X - A$  is  $\tau_i$  -  $s^{**}g$  open  $\Rightarrow A$  is  $\tau_i$  -  $s^{**}g$  closed. Similarly, A is  $\tau_j$  -  $s^{**}g$  closed. Hence A is pairwise  $s^{**}g$  - closed.

**Theorem 3.10:** A pairwise  $s^{**}g$  - closed subset of pairwise  $s^{**}gO$  - compact space is pairwise  $s^{**}gO$  - compact relative to X.

**Proof:** Let A be a pairwise  $s^{**}g$  - closed subset of a pairwise  $s^{**}gO$  - compact space X. Then  $A^c$  is pairwise  $s^{**}g$  - open in X. Let S be a cover of A by pairwise  $s^{**}g$  - open sets in X. Then,  $\{S, A^c\}$  is a pairwise  $s^{**}g$  - open cover of X. Since X is pairwise  $s^{**}gO$  - compact, it has a finite subcover, say  $\{G_1, G_2, \dots, G_n\}$ . If this subcover contains  $A^c$ , we discard it. Otherwise leave the subcover as it is. Thus, we have obtained a finite pairwise  $s^{**}g$  - open subcover of A and so A is pairwise  $s^{**}gO$  - compact relative to X.

**Theorem 3.11:** Suppose that A is a pairwise  $s^{**}gO$  - compact subset of a pairwise  $s^{**}g$  - Hausdorff space X. Let  $x \in X - A$ . Then there exist disjoint  $\tau_1$  -  $s^{**}g$  open neighborhood U of A and  $\tau_2$  -  $s^{**}g$  open neighborhood V of X respectively.

**Proof:** By hypothesis, X is pairwise  $s^{**}g$  - Hausdorff. Let  $a \in A$  arbitrarily. Then there exist disjoint  $\tau_1$  -  $s^{**}g$  open neighborhoods  $U_a$  of A and  $\tau_2$  -  $s^{**}g$  open neighborhoods  $V_x$  of X respectively. The collection  $\mathcal{C} = \{U_a : a \in A\}$  is a pairwise  $s^{**}g$  - open cover of A. But A is pairwise  $s^{**}gO$  - compact. Accordingly, this collection  $\mathcal{C}$  has a finite sub cover  $\{U_{a_1}, U_{a_2}, \dots, U_{a_n}\}$ . Let  $U = U_{a_1} \cup \dots \cup U_{a_n}$ . Put  $V = V_{a_1} \cap \dots \cap V_{a_n}$ . Then  $A \subset U$  and  $x \in V$ . Also U is  $\tau_1$  -  $s^{**}g$  open and V is  $\tau_2$  -  $s^{**}g$  open. Since  $U_{a_i} \cap V_{a_i} = \phi$  for  $1 \leq i \leq n$ . We obtain that  $U \cap V = \phi$ . We have proved the result.

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