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On Semi- $T_{1/2}$ Spaces

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Abstract: In this paper we introduce new types of Semi- $T_{1/2}$ spaces using sg-closed type sets. We define new topological ordered spaces namely semi- $sg_i T_{1/2}$ space, semi- $sg_d T_{1/2}$ space, semi- $sg_b T_{1/2}$ space, semi- $sg_i T_{is,1/2}$ space, semi- $sg_d T_{ds,1/2}$ space and semi- $sg_b T_{bs,1/2}$ space. We also establish relationships between these spaces. **Mathematics subject classification:** 54A05

Keywords: Topological ordered space, i-closed set, d-closed set, b-closed set, sg-closed set, Semi- $T_{1/2}$ space.

I. INTRODUCTION

L.Nachbin [1] initiated the study of Topological ordered spaces (TOS). A topological ordered space is a topological space in which a partial order is available. Using order relation one can think of increasing, decreasing and balanced sets. N. Levine [5] defined generalized closed (briefly g-closed) set in 1970 by slightly weakening the notion of closedness. They are not only the natural generalizations of closed sets but they can suggest more properties of topological spaces. In recent years, some authors have introduced notions which uses both topological and order structure, for example generalized increasing sets.

Let X be a non-empty set. A TOS is a triple (X, τ, \leq) where “ τ ” is a topology and “ \leq ” is a partial order on X . For

any $x \in X$, the sets $[x, \rightarrow]$ and $[\leftarrow, x]$ are defined as $[x, \rightarrow] = \{y \in X / x \leq y\}$ and $[\leftarrow, x] = \{y \in X / y \leq x\}$. A

subset A of a TOS (X, τ, \leq) is said to be increasing if $A = i[A]$ and decreasing if $A = d[A]$ where

$i[A] = \bigcup_{a \in A} [a, \rightarrow]$ and $d[A] = \bigcup_{a \in A} [\leftarrow, a]$. The complement of an increasing set is a decreasing set and vice versa. A

subset of a TOS (X, τ, \leq) is said to be balanced if it is both increasing and decreasing. M.K.R.S.Veera Kumar [2] introduced the study of increasing closed set (briefly i-closed), decreasing closed set (briefly d-closed) and balanced closed set (briefly b-closed) in 2001.

N. Levine [4] introduced semi-open sets. The complement of a semi-open set is a semi-closed set. Bhattacharya & Lahiri [6] introduced and studied semi-generalized sets (briefly sg-closed).

II. PRELIMINARIES

Throughout this paper (X, τ) represent a non-empty topological space on which no separation axioms are assumed unless otherwise mentioned. For a subset A of a topological space (X, τ) , the intersection of all closed sets containing A is called closure of A denoted by $cl(A)$ and the intersection of semi-closed sets containing A is called the semi-closure of A denoted by $scl(A)$. We recall the following definitions.

A. *Definition 2.1.*

A subset A of a topological space (X, τ) is called a semi-open set [4] if $A \subseteq cl(int(A))$ and a semi-closed set if $int(cl(A)) \subseteq A$.

B. *Definition 2.2.*

A subset A of a topological space (X, τ) is called

- 1) a generalized closed set (briefly g-closed)[5] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X, τ) . The complement of a g-closed set is a g-open set.
- 2) a semi-generalized closed set (briefly sg-closed)[6] if $scl(A) \subseteq U$ whenever

$A \subseteq U$ and U is semi-open in (X, τ) . The complement of a sg-closed set is

a sg-open set.

C. Definition 2.3 [7]

A subset A of a topological ordered space (X, τ, \leq) is called

- 1) a semi generalized increasing closed (briefly sgi-closed) set if A is a sg-closed set and an increasing set.
- 2) a semi generalized decreasing closed (briefly sgd-closed) set if A is a sg-closed set and a decreasing set.
- 3) a semi generalized balanced closed (briefly sgb-closed) set if A is a sg-closed set and a balanced set.

In view of the above definitions, we have every sgb-closed set is sgi-closed and sgd-closed also. [9]

D. Definition 2.4 [7]

A topological ordered space (X, τ, \leq) is called a *semi-T_{1/2}* space if every sg-closed set is semi-closed.

III. SEMI-T_{1/2} SPACES DEFINED USING SG-CLOSED TYPE SETS

In this section, we introduce new types of Semi-T_{1/2} spaces using sgi-closed, sgd-closed and sgb-closed sets.

A. Definition 3.1: [8]

A topological ordered space (X, τ, \leq) is called

- 1) a *semi-sgi T_{1/2}* space if every sgi-closed set is semi-closed.
- 2) a *semi-sgd T_{1/2}* space if every sgd-closed set is semi-closed.
- 3) a *semi-sgb T_{1/2}* space if every sgb-closed set is semi-closed.

B. Example 3.2.

Consider the set $X = \{a, b, c\}$ with the topology $\tau_8 = \{\phi, X, \{a, b\}\}$ and partial order $\leq_4 = \{(a, a), (b, b), (c, c), (a, b), (c, a), (c, b)\}$. Then, (X, τ_8, \leq_4) is a topological ordered space. Semi-closed sets in this space are $\phi, X, \{c\}$. Increasing sets in this space are $\phi, X, \{b\}, \{a, b\}$. Also, sg-closed sets are $\phi, X, \{c\}, \{b, c\}, \{a, c\}$. Then, sgi-closed sets are ϕ, X . Clearly, every sgi-closed set is a semi-closed set. So, the space (X, τ_8, \leq_4) is a *semi-sgi T_{1/2}* space.

C. Example 3.3

Consider the set $X = \{a, b, c\}$ with the topology $\tau_8 = \{\phi, X, \{a, b\}\}$ and partial order $\leq_1 = \{(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)\}$. Then, (X, τ_8, \leq_1) is a topological ordered space. Semi-closed sets in this space are $\phi, X, \{c\}$. Sg-closed sets are $\phi, X, \{c\}, \{b, c\}, \{a, c\}$ and decreasing sets are $\phi, X, \{a\}, \{a, b\}$. Then, sgd-closed sets are ϕ, X . Clearly, every sgd-closed set in X is a semi-closed set. So, the space (X, τ_8, \leq_1) is a *semi-sgd T_{1/2}* space.

D. Example 3.4

Consider the set $X = \{a, b, c\}$ with the topology $\tau_8 = \{\phi, X, \{a, b\}\}$ and partial order $\leq_1 = \{(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)\}$. Then, (X, τ_8, \leq_1) is a topological ordered space. Semi-closed sets in this space are $\phi, X, \{c\}$. Balanced sets in this space are ϕ, X and sg-closed sets are $\phi, X, \{c\}, \{b, c\}, \{a, c\}$. Then, sgb-closed sets are ϕ, X . Clearly, every sgb-closed set in X is a semi-closed set. So, the space (X, τ_8, \leq_1) is a *semi-sgb T_{1/2}* space.

IV. RELATIONSHIPS BETWEEN SEMI-T_{1/2} SPACES

In this section we establish relationships between *semi-T_{1/2}* and *semi-sgi T_{1/2}*, *semi-sgd T_{1/2}* and *semi-sgb T_{1/2}* spaces. We also establish independency of some of the spaces.

A. Theorem 4.1

Every $semi-T_{1/2}$ space is a $semi-sgi-T_{1/2}$ space but not conversely.

- 1) *Proof:* Let (X, τ, \leq) be a $semi-T_{1/2}$ space and A be a sgi -closed set in X . Then, A is a sg -closed set. Since X is a $semi-T_{1/2}$ space, A is a semi-closed set. Therefore, every sgi -closed set in X is a semi-closed set. Hence, the space (X, τ, \leq) is a $semi-sgi-T_{1/2}$ space.
- 2) The following example shows that the converse is not true.: Consider the set $X = \{a, b, c\}$ with the topology $\tau_8 = \{\phi, X, \{a, b\}\}$ and partial order $\leq_4 = \{(a, a), (b, b), (c, c), (a, b), (c, a), (c, b)\}$. Then, (X, τ_8, \leq_4) is a topological ordered space. Semi-closed sets in this space are $\phi, X, \{c\}$. Increasing sets in this space are $\phi, X, \{b\}, \{a, b\}$. Also, sg -closed sets are $\phi, X, \{c\}, \{b, c\}, \{a, c\}$. Then, sgi -closed sets are ϕ, X . Clearly, every sgi -closed set is a semi-closed set. So, the space (X, τ_8, \leq_4) is a $semi-sgi-T_{1/2}$ space. The subset $\{b, c\}$ is a sg -closed set but not a semi-closed set. Hence, the space (X, τ_8, \leq_4) is not a $semi-T_{1/2}$ space.

B. Theorem 4.2

Every $semi-T_{1/2}$ space is a $semi-sgd-T_{1/2}$ space but not conversely.

- 1) *Proof:* Let (X, τ, \leq) be a $semi-T_{1/2}$ space and A be a sgd -closed set. Then, A is a sg -closed set. Since X is a $semi-T_{1/2}$ space, A is a semi-closed set. Therefore, every sgd -closed set in X is a semi-closed set. Hence, the space (X, τ, \leq) is a $semi-sgd-T_{1/2}$ space.
- 2) *The following example shows that the converse is not true.:* Consider the set $X = \{a, b, c\}$ with the topology $\tau_8 = \{\phi, X, \{a, b\}\}$ and partial order $\leq_1 = \{(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)\}$. Then, (X, τ_8, \leq_1) is a topological ordered space. Semi-closed sets in this space are $\phi, X, \{c\}$. Sg -closed sets are $\phi, X, \{c\}, \{b, c\}, \{a, c\}$ and decreasing sets are $\phi, X, \{a\}, \{a, b\}$. Then, sgd -closed sets are ϕ, X . Clearly, every sgd -closed set in X is a semi-closed set. So, the space (X, τ_8, \leq_1) is a $semi-sgd-T_{1/2}$ space. The subset $\{b, c\}$ is a sg -closed set but not a semi-closed set. Hence, the space (X, τ_8, \leq_1) is not a $semi-T_{1/2}$ space.

C. Theorem 4.3

Every $semi-T_{1/2}$ space is a $semi-sgb-T_{1/2}$ space but not conversely.

- 1) *Proof:* Let (X, τ, \leq) be a $semi-T_{1/2}$ space and A be a sgb -closed set in X . Then, A is a sg -closed set. Since, X is a $semi-T_{1/2}$ space, A is a semi-closed set. Therefore, every sgb -closed set in X is a semi-closed set. Hence, the space (X, τ, \leq) is a $semi-sgb-T_{1/2}$ space.
- 2) *The converse is not true as shown in the following example.:* Consider the set $X = \{a, b, c\}$ with the topology $\tau_8 = \{\phi, X, \{a, b\}\}$ and partial order $\leq_1 = \{(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)\}$. Then, (X, τ_8, \leq_1) is a topological ordered space. Semi-closed sets in this space are $\phi, X, \{c\}$. Balanced sets are ϕ, X and sg -closed sets are $\phi, X, \{c\}, \{b, c\}, \{a, c\}$. Then, sgb -closed sets are ϕ, X . Clearly, every sgb -closed set in X is a semi-closed set. So, the space (X, τ_8, \leq_1) is a $semi-sgb-T_{1/2}$ space. On the other hand, the subset $\{b, c\}$ is a sg -closed set but not a semi-closed set. Hence, the space (X, τ_8, \leq_1) is not a $semi-T_{1/2}$ space.

space. The following Figure 1 indicates the relationships between the spaces discussed above. Here, $A \longrightarrow B$ indicates A implies B but not conversely.

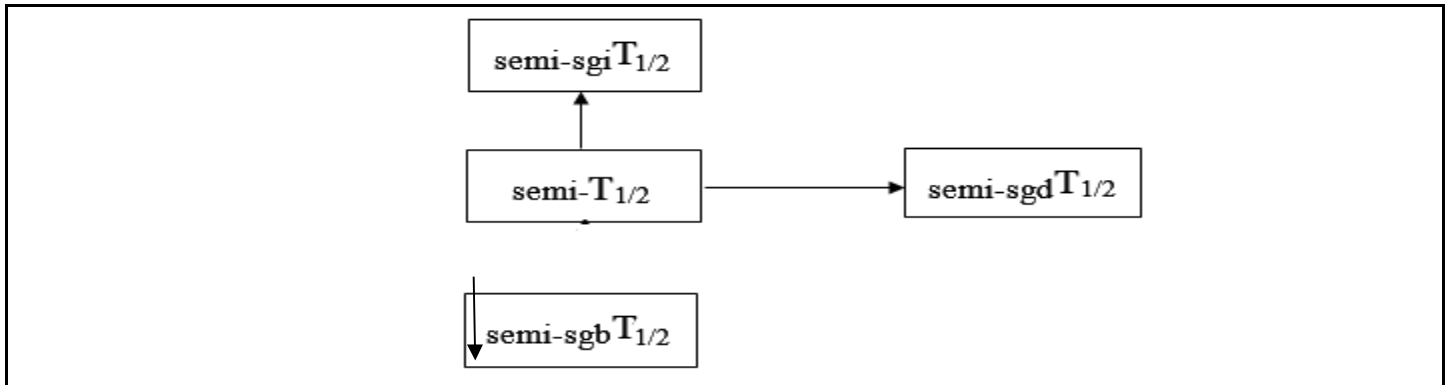


Fig. 1

V. RELATIONSHIPS BETWEEN SEMI- $T_{1/2}$ TYPE SPACES

In this section we establish relationships between $semi-T_{1/2}$ spaces defined by sgi-closed, sgd-closed and sgb-closed sets. We also establish independency of some of these spaces.

A. Theorem 5.1

Every $semi-sgi T_{1/2}$ space is a $semi-sgb T_{1/2}$ space but not conversely.

- 1) *Proof:* Let (X, τ, \leq) be a $semi-sgi T_{1/2}$ space and A be a sgb-closed set in X. So, A is a sgi-closed set. Since X is a $semi-sgi T_{1/2}$ space, A is a semi-closed set. Hence, the space (X, τ, \leq) is a $semi-sgb T_{1/2}$ space.
- 2) *The following example shows that the converse is not true.:* Consider the set $X = \{a, b, c\}$ together with the topology $\tau_8 = \{\phi, X, \{a, b\}\}$ and partial order $\leq_1 = \{(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)\}$. Then, (X, τ_8, \leq_1) is a topological ordered space. Semi-closed sets in this space are $\phi, X, \{c\}$. Increasing sets in this space are $\phi, X, \{c\}, \{b, c\}$ and sg-closed sets are $\phi, X, \{c\}, \{b, c\}, \{a, c\}$. Then, sgi-closed sets are $\phi, X, \{c\}, \{b, c\}$. Balanced sets in this space are ϕ, X . So, sgb-closed sets are ϕ, X . Thus, every sgb-closed set in X is a semi-closed set. Hence, the space (X, τ_8, \leq_1) is a $semi-sgb T_{1/2}$ space. Clearly, the subset $\{b, c\}$ is a sgi-closed set but not a semi-closed set. So, the space (X, τ_8, \leq_1) is not a $semi-sgi T_{1/2}$ space.

B. Theorem 5.2

Every $semi-sgd T_{1/2}$ space is a $semi-sgb T_{1/2}$ space but not conversely.

- 1) *Proof:* Let (X, τ, \leq) be a $semi-sgd T_{1/2}$ space and A be a sgb-closed set. So, A is a sgd-closed set. Since X is a $semi-sgd T_{1/2}$ space, A is a semi-closed set. Hence, the space (X, τ, \leq) is a $semi-sgb T_{1/2}$ space.
- 2) *The following example shows that the converse is not true.:* Consider the set $X = \{a, b, c\}$ together with the topology $\tau_8 = \{\phi, X, \{a, b\}\}$ and partial order $\leq_2 = \{(a, a), (b, b), (c, c), (a, b), (c, b)\}$. Then, (X, τ_8, \leq_2) is a topological ordered space. Semi-closed sets in this space are $\phi, X, \{c\}$. Decreasing sets in this space are $\phi, X, \{a\}, \{c\}, \{a, c\}$ and balanced sets are ϕ, X . Also, sg-closed sets with respect to the topology τ_8 are $\phi, X, \{c\}, \{b, c\}, \{a, c\}$. Then, sgd-closed sets are $\phi, X, \{c\}, \{a, c\}$. The sgb-closed sets are ϕ, X . Clearly, every sgb-closed set in X is a semi-closed set. So, the space (X, τ_8, \leq_2) is a $semi-sgb T_{1/2}$ space.

space. The subset $\{a, c\}$ is a sgd -closed set but not a semi-closed set. So, the space (X, τ_8, \leq_2) is not a $semi-sgd T_{1/2}$ space.

C. Theorem 5.3

The notions $semi-sgi T_{1/2}$ and $semi-sgd T_{1/2}$ are independent.

1) Proof: To prove the independency it is enough to exhibit an example of a $semi-sgi T_{1/2}$ space which is not a $semi-sgd T_{1/2}$ space and a space which is a $semi-sgd T_{1/2}$ space but not a $semi-sgi T_{1/2}$ space.

For the first part, consider the set $X = \{a, b, c\}$ with the topology $\tau_8 = \{\phi, X, \{a, b\}\}$ and partial order $\leq_4 = \{(a, a), (b, b), (c, c), (a, b), (c, a), (c, b)\}$. Then, (X, τ_8, \leq_4) is a topological ordered space. Semi-closed sets in this space are $\phi, X, \{c\}$. Increasing sets are $\phi, X, \{b\}, \{a, b\}$ and decreasing sets are $\phi, X, \{c\}, \{a, c\}$. The sg -closed sets are $\phi, X, \{c\}, \{b, c\}, \{a, c\}$. Then, sgd -closed sets are $\phi, X, \{c\}, \{a, c\}$ and sgi -closed sets are ϕ, X . Clearly, every sgi -closed set in X is a semi-closed set. So, the space (X, τ_8, \leq_4) is a $semi-sgi T_{1/2}$ space. The subset $\{a, c\}$ is a sgd -closed set but not a semi-closed set. So, the space (X, τ_8, \leq_4) is not a $semi-sgd T_{1/2}$ space.

For the other part, consider the set $X = \{a, b, c\}$ with the topology $\tau_8 = \{\phi, X, \{a, b\}\}$ and partial order $\leq_1 = \{(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)\}$. Then, (X, τ_8, \leq_1) is a topological ordered space. Semi-closed sets in this space are $\phi, X, \{c\}$. Increasing sets are $\phi, X, \{c\}, \{b, c\}$ and sg -closed sets are $\phi, X, \{c\}, \{b, c\}, \{a, c\}$. Decreasing sets in this space are $\phi, X, \{a\}, \{a, b\}$. Then, sgi -closed sets are $\phi, X, \{c\}, \{b, c\}$. The sgd -closed sets are ϕ, X . Clearly, every sgd -closed set in X is a semi-closed set. So, the space (X, τ_8, \leq_1) is a $semi-sgd T_{1/2}$ space. On the other hand, the subset $\{b, c\}$ is a sgi -closed set but not a semi-closed set. So, the space (X, τ_8, \leq_1) is not a $semi-sgi T_{1/2}$ space.

The following figure 2 indicates the relationships between the spaces discussed above. Here, $A \longrightarrow B$ (A \implies B) indicates A implies B but not conversely (A and B are independent notions).

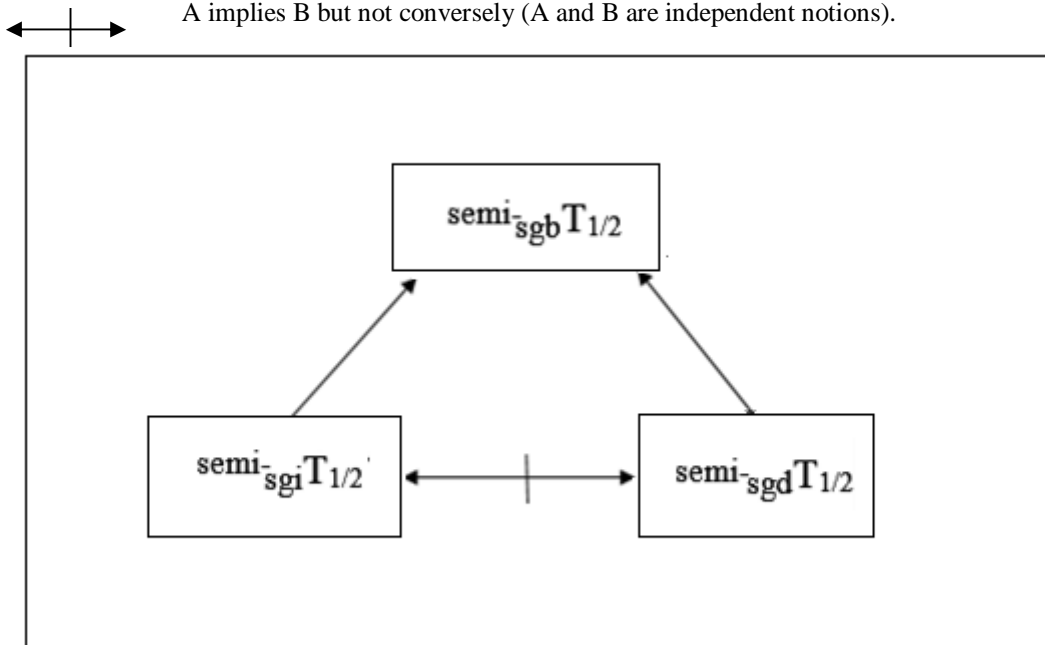


Fig. 2

VI. SOME MORE NEW SPACES

In this section we introduce some more new topological ordered spaces using semi-closed sets, increasing, decreasing and balanced closed sets.

We introduce the following definitions.

A. Definition 6.1: [8]

A topological ordered space (X, τ, \leq) is called

- 1) a $semi-sgi T_{is,1/2}$ space if every sgi-closed set is i-semi-closed.
- 2) a $semi-sgd T_{ds,1/2}$ space if every sgd-closed set is d-semi-closed.
- 3) a $semi-sgb T_{bs,1/2}$ space if every sgb-closed set is b-semi-closed.

B. Example 6.2

Let $X = \{a, b, c\}$ with the topology $\tau_1 = \{\phi, X, \{a\}, \{b\}, \{a, b\}\}$ and partial order $\leq_1 = \{(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)\}$. Then, (X, τ_1, \leq_1) is a topological ordered space. Increasing sets in this space are $\phi, X, \{b, c\}, \{c\}$ and semi-closed sets are $\phi, X, \{a\}, \{b\}, \{c\}, \{b, c\}, \{a, c\}$. Then, i-semi-closed sets are $\phi, X, \{b, c\}, \{c\}$. Also, sg-closed sets are $\phi, X, \{a\}, \{b\}, \{c\}, \{b, c\}, \{a, c\}$. Then, sgi-closed sets are $\phi, X, \{b, c\}, \{c\}$. Clearly, every sgi-closed set is an i-semi-closed set. So, the space (X, τ_1, \leq_1) is a $semi-sgi T_{is,1/2}$ space.

C. Example 6.3

Consider the set $X = \{a, b, c\}$ with the topology $\tau_1 = \{\phi, X, \{a\}, \{b\}, \{a, b\}\}$ and partial order $\leq_2 = \{(a, a), (b, b), (c, c), (a, b), (c, b)\}$. Then, (X, τ_1, \leq_2) is a topological ordered space. Decreasing sets in this space are $\phi, X, \{a, c\}, \{c\}, \{a\}$ and semi-closed sets are $\phi, X, \{a\}, \{b\}, \{c\}, \{b, c\}, \{a, c\}$. Also, d-semi-closed sets in this space are $\phi, X, \{a, c\}, \{c\}, \{a\}$ and sg-closed sets are $\phi, X, \{a\}, \{b\}, \{c\}, \{b, c\}, \{a, c\}$. Then, sgd-closed sets are $\phi, X, \{a, c\}, \{c\}, \{a\}$. Clearly, every sgd-closed set in this space is a d-semi-closed set. So, the space (X, τ_1, \leq_2) is a $semi-sgd T_{ds,1/2}$ space.

D. Example 6.4

Let $X = \{a, b, c\}$ with the topology $\tau_1 = \{\phi, X, \{a\}, \{b\}, \{a, b\}\}$ and partial order $\leq_3 = \{(a, a), (b, b), (c, c), (a, b), (a, c)\}$. Then, (X, τ_1, \leq_3) is a topological ordered space. Balanced sets in this space are ϕ, X and semi-closed sets are $\phi, X, \{a\}, \{b\}, \{c\}, \{b, c\}, \{a, c\}$. Also, b-semi-closed sets in this space are ϕ, X . Sg-closed sets are $\phi, X, \{a\}, \{b\}, \{c\}, \{b, c\}, \{a, c\}$. Then, sgb-closed sets are ϕ, X . Clearly, every sgb-closed set in X is a b-semi-closed set. So, the space (X, τ_1, \leq_3) is a $semi-sgb T_{bs,1/2}$ space.

E. Theorem 6.5

Every $semi-sgi T_{is,1/2}$ space is a $semi-sgi T_{1/2}$ space.

- 1) *Proof:* Let (X, τ, \leq) be a $semi-sgi T_{is,1/2}$ space and A be a sgi-closed set. Since X is a $semi-sgi T_{is,1/2}$ space, the set A is an i-semi-closed set. So, A is a semi-closed set. Therefore, every sgi-closed set in X is a semi-closed set. Hence, the space (X, τ, \leq) is a $semi-sgi T_{1/2}$ space.

F. Theorem 6.6

Every $semi-sgd T_{ds,1/2}$ space is a $semi-sgd T_{1/2}$ space.

1) *Proof:* Let (X, τ, \leq) be a $semi-sgd T_{ds,1/2}$ space and A be a sgd -closed set in X . Since X is a $semi-sgd T_{ds,1/2}$ space, A is a d -semi-closed set. So, A is a semi-closed set. Therefore, every sgd -closed set in X is a semi-closed set. Hence, the space (X, τ, \leq) is a $semi-sgd T_{1/2}$ space.

G. Theorem 6.7

Every $semi-sgb T_{bs,1/2}$ space is a $semi-sgb T_{1/2}$ space.

1) *Proof:* Let (X, τ, \leq) be a $semi-sgb T_{bs,1/2}$ space and A be a sgb -closed set in X . Since X is a $semi-sgb T_{bs,1/2}$ space, A is a b -semi-closed set. So, A is a semi-closed set. Therefore, every sgb -closed set in X is a semi-closed set. Hence, the space (X, τ, \leq) is a $semi-sgb T_{1/2}$ space.

VII. CONCLUSION

In this paper we introduced new types of Semi- $T_{1/2}$ spaces using sg -closed type sets. We studied relationships between these spaces. We also established the independency of some of these topological ordered spaces.

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