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ON sbĝ - CLOSED SETS IN TOPOLOGICAL SPACES

K. BALA DEEPA ARASI[1], S. NAVANEETHA KRISHNAN[2]

[1]Assistant Professor of Mathematics,
A. P. C. Mahalaxmi College for Women, Thoothukudi, (T.N.), India.

[2]Associate Professor of Mathematics,
V. O. Chidambaram College, Thoothukudi, (T.N.), India.

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ABSTRACT

*In this paper, we introduce a new class of sets called sbĝ-closed sets in topological spaces. A subset A of X is said to be sbĝ-closed if sCl(A) $\subseteq$ U whenever A $\subseteq$ U and U is **bĝ** -open in X. Also we study some of its basic properties and investigate the relationship with other existing closed sets in topological space. As an application, we introduce two new spaces namely, $T_{sb\hat{g}}$ and $T^{\alpha}_{sb\hat{g}}$.*

Keywords: *bĝ-open sets, semi-closure, semi-closed sets, sbĝ-closed sets, $T_{sb\hat{g}}$-space and $T^{\alpha}_{sb\hat{g}}$–space.*

AMS Mathematics Subject Classification (2010): *54A05.*

1. INTRODUCTION

N. Levine [6] introduced semi-open sets in Topology and studied its properties in 1963. In 1970, N.Levine[7] introduced generalized closed (briefly g-closed) sets and studied their basic properties. b-open sets have been introduced and investigated by Andrijevic[2] in 1996. M.K.R.S. Veerakumar[14] defined ĝ-closed sets in Topological Spaces and studied their properties. Also, R.Subasree and M.MariaSingam[13] introduced bĝ-closed sets and studied its properties in 2013.

Now, we introduce the concept of sbĝ-closed sets and sbĝ-open sets in Topological space and study some of their properties. Applying these sets, we obtain two new spaces namely $T_{sb\hat{g}}$-space and $T^{\alpha}_{sb\hat{g}}$-space.

2. PRELIMINARIES

Throughout this paper (X, τ) (or simply X) represents topological spaces on which no separation axioms are assumed unless otherwise mentioned. For a subset A of (X, τ), Cl(A), Int(A) and A^c denote the closure of A, interior of A and the complement of A respectively. We are giving some definitions.

Definition 2.1: A subset A of a topological space (X, τ) is called

1. a semi-open set[6] if A $\subseteq$ Cl(Int(A)).
2. an α-open set[10] if A $\subseteq$ Int(Cl(Int(A))).
3. a b-open set[2] if A $\subseteq$Cl(Int(A)) ∪ Int(Cl(A)).
4. a regular open[12] set if A = Int(Cl(A)).

The complement of a semi–open (resp.α–open, b–open, regular-open) set is called semi-closed (resp.α–closed, b–closed, regular-closed) set.

The intersection of all semi-closed (resp.α-closed, b-closed, regular-closed) sets of X containing A is called the semi-closure (resp.α-closure, b-closure, regular closure) of A and is denoted by sCl(A) (resp.αCl(A), bCl(A), rCl(A)). The family of all semi-open (resp. α-open, b-open, regular-open) subsets of a space X is denoted by SO(X) (resp. αO(X), bO(X), rO(X)).

Corresponding Author: K. BalaDeepa Arasi[*1], [1]Assistant Professor of Mathematics,
A. P. C. Mahalaxmi College for Women, Thoothukudi, (T.N.), India.*

Definition 2.2: A subset A of a topological space (X, τ) is called

1) a generalized closed set (briefly g-closed)[7] if Cl(A) ⊆ U whenever A ⊆ U and U is open in X.
2) asg-closed set[4] if sCl(A) ⊆ U whenever A ⊆ U and U is semi-open in X.
3) ags-closed set[3] if sCl(A)⊆ U whenever A ⊆ U and U is open in X.
4) agb-closed set[1] if bCl(A) ⊆ U whenever A ⊆ U and U is open in X.
5) arb-closed set[9] if rCl(A) ⊆ U whenever A ⊆ U and U is b-open in X.
6) a g*b-closed set[16] if bCl(A) ⊆ U whenever A ⊆ U and U is g-open in X.
7) aĝ-closed set[14] if Cl(A) ⊆ U whenever A ⊆ U and U is semi-open in X.
8) abĝ-closed set[13] if bCl(A) ⊆ U whenever A ⊆ U and U is ĝ-open in X.
9) a αbĝ-closed set[11] if αCl(A) ⊆ U whenever A ⊆ U and U is bĝ-open in X

The complement of a g-closed (resp. sg-closed, gs-closed, gb-closed, rb-closed, g*b–closed, ĝ-closed, bĝ-closed and αbĝ-closed) set is called g-open (resp. sg-open, gs-open, gb-open, rb-open, g*b–open, ĝ-open, bĝ-open and αbĝ-open) set.

Definition 2.3: sCl(A) is defined as the intersection of all semi-closed sets containing A.

Definition 2.4: A space (X, τ) is called a

(i) a T_b– space[5] if every gs-closed set in X is closed.
(ii) aT_{gs} – space[1] if every gb-closed set in X is b-closed.
(iii) a$T_{b\hat{g}}$ – space[13] if every bĝ-closed set in X is b-closed.
(iv) a$T^*_{b\hat{g}}$ – space[13] if every bĝ-closed set in X is closed.
(v) a$T^c_{\alpha b\hat{g}}$ – space[11] if every αbĝ-closed set in X is closed.

3. sbĝ-CLOSED SETS

We introduce the following definition.

Definition 3.1: A subset A of a topological space (X, τ) is called a sbĝ-closed set if sCl(A) ⊆ U whenever A ⊆ U and U is bĝ-open in X. The family of all sbĝ-closed sets of X are denoted by sbĝ-C(X).

Definition 3.2: The complement of a sbĝ-closed set is called sbĝ-open set. The family of all sbĝ-open sets of X are denoted by sbĝ-O(X).

Example 3.3: Let X = {a, b, c} and τ = {X, ϕ,{a},{b},{a, b},{a, c}} then {X, ϕ,{b},{c},{a, c},{b, c}} are sbĝ-closed sets and {X, ϕ,{b},{a},{a, c},{a, b}} are sbĝ-open sets in X.

Proposition 3.4: Every closed set is sbĝ-closed set

Proof: Let A be any closed set in X and U be any bĝ-open set in X such that A ⊆ U. Since A is closed, Cl(A) = A for every subset A of X. Therefore, sCl(A) ⊆Cl(A) = A ⊆ U. Hence, A is sbĝ-closed set.

The following example shows that the converse of the above proposition need not be true.

Example 3.5: Let X = {a, b, c} and τ = {X, ϕ, {a}}.sbĝ-C(X) = {X, ϕ,{b},{c},{b, c}}. Here, {b}, {c} are sbĝ-closed sets but not closed sets in X.

Proposition 3.6: A subset A of (X, τ) is semi-closed set in X iff A is sbĝ-closed set in X.

Proposition 3.7: Every α-closed set is sbĝ-closed set.

Proof: Let A be any α-closed set in X such that A ⊆ U where U is bĝ-open. Since A is α-closed set, sCl(A) ⊆ αCl(A) ⊆ U. Therefore, sCl(A) ⊆ U. Hence, A is sbĝ-closed set.

The converse of the above proposition need not be true as shown in the following example.

Example 3.8: Let X = {a, b, c} and τ = {X, ϕ,{a},{c},{a, c},{b. c}}.α-C(X) = {X, ϕ,{a},{a, b},{b, c}} and sbĝ-C(X) = {X, ϕ,{a},{b},{a, b},{b, c}}. Here, {b} is sbĝ-closed set but not α-closed set in X.

Proposition 3.9: Every regular closed set is sbĝ-closed set.

Proof: Let A be any regular closed set in X such that A ⊆ U where U is **bĝ**-open. Since A is regular closed set, sCl(A) ⊆ rCl(A) ⊆ U. Therefore, sCl(A) ⊆ U. Hence, A is sbĝ-closed set.

The reverse implication does not hold as shown in the following example.

Example 3.10: Let X = {a, b, c} and τ = {X, ϕ, {b}}.r-C(X) = {X, ϕ} and sbĝ-C(X) = {X, ϕ, {a}, {c}, {a, c}}. Here, {a}, {c}, {a, c} are sbĝ-closed sets but not regular closed sets in X.

Proposition 3.11: Every sbĝ-closed set is b-closed set.

Proof: Let A be any ĝsb -closed set in X such that A ⊆ U where U is **bĝ**-open. Since A is **sbĝ**-closed set, bCl(A) ⊆ sCl(A) ⊆ U. Therefore, bCl(A) ⊆ U. Hence, A is sbĝ-closed set.

The converse of the above proposition need not be true as shown in the following example.

Example 3.12: Let X = {a, b, c} and τ = {X, ϕ,{c},{a, b}}. bC(X) = {X, ϕ,{a},{b},{c},{a, b},{a, c},{b, c}} and sbĝ-C(X)= {X, ϕ,{c},{a, b}}. Here, {a},{b},{a, c},{b, c} are sbĝ-closed sets but not b-closed sets.

Proposition 3.13: Every sbĝ-closed set is sg-closed set

Proof: Let A be any sbĝ-closed set in X and U be any semi-open set in X such that A ⊆ U. Since "Every semi-open set is bĝ-open set", we have sCl(A)⊆ U where U is semi-open. Hence, A is sg-closed.

Every sg-closed set need not be **sbĝ**-closed set as shown in the following example.

Example 3.14: Let X = {a, b, c} and τ = {X, ϕ,{a, c}}. sg-C(X) = {X, ϕ,{b},{a, b},{b, c}} and sbĝ-C(X) = {X, ϕ,{b)}. Here, {a, b},{b, c} aresg-closed sets but not sbĝ-closed sets.

Proposition 3.15: Every **sbĝ**-closed set is gs-closed set

Proof: Let A be any **sbĝ**-closed set in X and U be any open set in X such that A ⊆ U. Since "Every open set is bĝ-open set", we have sCl(A)⊆ U where U is open. Hence, A is gs-closed.

The following example shows that the converse of the above proposition need not be true.

Example 3.16: Let X = {a, b, c,} and τ = {X, ϕ,{a},{b, c}}. gs-C(X) = {X, ϕ,{a},{b},{c},{a, b},{a, c},{b, c}} and sbĝ-C(X) = {X, ϕ,{a},{b, c}}. Here, {b}, {c},{a, c},{a, b}are gs-closed sets but not sbĝ-closed sets.

Proposition 3.17: Every sbĝ-closed set is gb-closed set.

Proof: Let A be any sbĝ -closed set in X. Let U be open set such that A ⊆ U. Since, "Every open set is bĝ –open", we have bCl(A) ⊆ sCl(A) ⊆ U. Therefore, bCl(A)⊆ U where U is open in X. Hence, A is gb-closed set.

The converse of the above proposition need not be true as shown in the following example.

Example 3.18: Let X = {a, b, c} and τ = {X, ϕ, {a},{a, b}}. gb-C(X) = {X, ϕ,{b},{c},{a, c},{b,c}} and sbĝ-C(X) = {X, ϕ,{b},{c},{b, c}}. Here, {a, c} is gb-closed set but not sbĝ-closed set.

Proposition 3.19: Every rb-closed set is sbĝ-closed set.

Proof: Let A be any rb-closed set in X. Let U be any b-open set in X such that A ⊆ U. Since "Every b-open set is bĝ-open set", we have sCl(A) ⊆ rCl(A) ⊆ U where U is bĝ-open. Therefore, sCl(A) ⊆ U. Hence, A is sbĝ-closed set.

The reverse implication does not hold as shown in the following example.

Example 3.20: Let X = {a, b, c, d} and τ = {X, ϕ, {a},{a, c},{a, b, d}}. rb-C(X) = {X, ϕ,{b, c, d}} and sbĝ-C(X) = {X, ϕ,{b),{c},{d},{b, c},{b, d},{c, d},{b, c, d}}. Here,{b},{c},{d},{b, c},{c, d},{b, d} are sbĝ-closed sets but not rb-closed sets.

Proposition 3.21: Every sbĝ-closed set is g*b-closed set.

Proof: Let A be any sbĝ -closed set in X. Let U be g-open set such that A ⊆ U. Since, "Every g-open set is bĝ –open set", we have bCl(A) ⊆ sCl(A) ⊆ U. Therefore, bCl(A)⊆ U where U is g-open in X. Hence, A is g*b-closed set.

The following example shows that the converse of the above proposition need not be true

Example 3.22: Let X = {a, b, c,} and τ = {X, ϕ,{c},{a, b}}. g*b-C(X) = {X, ϕ,{a},{b},{c},{a, b},{a, c},{b, c}} and sbĝ-C(X) = {X, ϕ,{c},{a, b}}. Here,{a},{b},{a, c},{b, c} are g*b-closed sets but not sbĝ-closed sets.

Proposition 3.23: Every sbĝ-closed set is bĝ-closed set.

Proof: Let A be any sbĝ-closed set. By proposition 3.11, A is b-closed set in X. By proposition 3.3 in [13], A is bĝ-closed set in X.

The converse of the above proposition need not be true as shown in the following example.

Example 3.24: Let X = {a, b, c, d} and τ = {X, ϕ, {b}, {a, b}, {b, c, d}}. bĝ-C(X) = {X, ϕ,{a},{c},{d},{a, c}, {a, d}, {c, d}, {a, b, c},{a, b, d},{a, c, d}} and sbĝ-C(X) = {X, ϕ,{a},{c},{d},{a, c},{a, d},{c, d},{a, c, d}}. Here {a, b, c}, {a, b, d} are bĝ-closed sets but not sbĝ-closed sets.

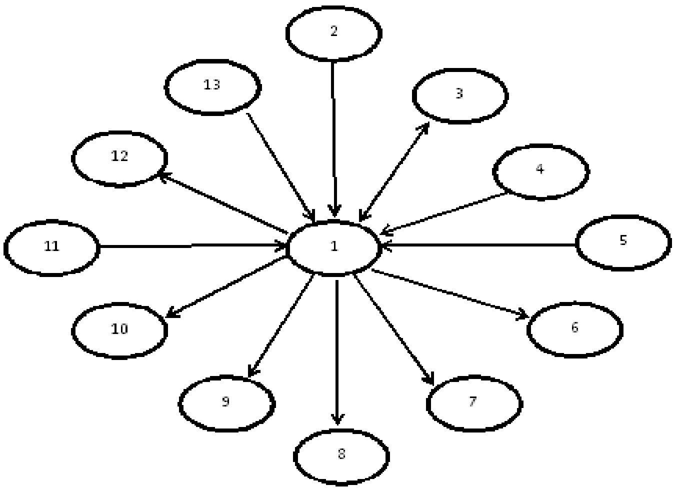
Proposition 3.25: Every αbĝ-closed set is sbĝ-closed set.

Proof: Let A be any αbĝ-closed set. Let U be any bĝ-open set in X such that A ⊆ U. To prove that, A is sbĝ-closed set. Now, sCl(A) ⊆ αCl(A) ⊆ U where U is bĝ-open set. Therefore, A is sbĝ-closed set.

The converse of the above proposition need not be true as shown in the following example.

Example 3.26: Let X = {a, b, c,} and τ = {X, ϕ,{a},{b},{a, b}}. αbĝ-C(X) = {X, ϕ,{c},{a, c},{b, c}} and sbĝ-C(X) = {X, ϕ, {a}, {b},{c},{a,c},{b,c}}. Here, {a},{b} are sbĝ-closed sets but not αbĝ-closed sets.

Remark 3.27: The following diagram shows the relationship of sbĝ-closed sets with other known existing sets. A → B represents A implies B but not conversely.



1. sbĝ-closed	2. closed	3. semi-closed	4. α-closed
5. regular-closed	6. b-closed	7. gs-closed	8. sg-closed
9. gb-closed	10.g*b-closed	11.rb-closed	12.bĝ-closed
13. αbĝ-closed.			

4. CHARACTERIZATION

Lemma 4.1: The finite union of sbĝ-closed sets is sbĝ-closed set.

Lemma 4.2: The finite intersection of sbĝ-closed sets is sbĝ-closed set.

Proposition 4.3: Let A be a sbĝ-closed set of X. Then sCl(A)-A does not contain a non-empty bĝ-closed set.

Proof: Suppose A is a sbĝ-closed set. Let F be a bĝ -closed set contained in sCl(A)-A. Now F^c is a bĝ -open set of X such that A ⊆ F^c. Since A is sbĝ-closed, we have sCl(A) ⊆ F^c. Hence, F ⊆ $(sCl(A))^c$. Also, F ⊆ sCl(A)-A. Therefore, F ⊆ sCl(A) ∩ $(sCl(A))^c$ = ϕ. Hence, F must be ϕ.

Proposition 4.5: If A is bĝ-open and sbĝ-closed set of X, then A is semi-closed.

Proof: Since A is bĝ-open and sbĝ-closed, we have sCl(A) ⊆ A. Hence, A is semi-closed.

Proposition 4.6: The intersection of a sbĝ-closed set and a semi-closed set of X is always sbĝ-closed set.

Proof: Let A be a sbĝ-closed set and B be a semi-closed set. Since A is sbĝ-closed, sCl(A) ⊆ U whenever U is bĝ-open. Let B be such that A∩B ⊆ U where U is bĝ -open. Now, sCl(A∩B) ⊆sCl(A) ∩ sCl(B) ⊆ U ∩ B ⊆ U. Hence, A∩B is sbĝ-closed set. Therefore, intersection of any sbĝ-closed set and a semi-closed set of X is always sbĝ-closed set.

5. APPLICATIONS

As an applications of sbĝ-closed sets, we introduce two new spaces namely, $T_{sb\hat{g}}$ - space and $T^{\alpha}_{sb\hat{g}}$- space.

Definition 5.1: A Space (X, τ) is called a $T_{sb\hat{g}}$-space if every sbĝ-closed set in X is closed.

Definition 5.2: A Space (X, τ) is called a $T^{\alpha}_{sb\hat{g}}$-space if every sbĝ-closed set in X is α-closed.

Proposition 5.3: Every T_b-space is $T_{sb\hat{g}}$-space.

Proof: Let (X, τ) be T_b-space. Let A be sbĝ-closed set in (X, τ). By proposition 3.15, A is gs-closed. Since (X, τ) is T_b-space, A is closed. Hence, (X, τ) is $T_{sb\hat{g}}$-space.

The converse of the above proposition need not be true as shown in the following example.

Example 5.4: Let X = {a, b, c} and τ = {X, ϕ,{c},{a, b}}
sbĝ-C(X) = {X, ϕ,{c},{a, b}
gs-C(X) = {X, ϕ,{a},{b},{c},{a, b},{a, c},{b, c}}
C(X) = {X, ϕ,{c},{a, b}}
Here, (X, τ) is $T_{sb\hat{g}}$ space but not T_b-space.

Proposition 5.5: Every $T_{sb\hat{g}}$-space is T_{gs}-space.

Proof: Let (X, τ) be $T_{sb\hat{g}}$-space. Let A be sbĝ -closed set in (X, τ). By Propositon 3.17, A is gb-closed. Since every closed set is b-closed set, A is b-closed set in X. Therefore, (X, τ) is T_{gs}-space.

The converse of the above proposition need not be true and is explained in the following example.

Example 5.6: Let X = {a, b, c} and τ = {X, ϕ, {a}, {b}, {a, b}}
sbĝ-C(X) = {X, ϕ,{a},{b},{c},{a, c},{b, c}}
gb-C(X) = {X, ϕ,{a},{b},{c},{a, c},{b, c}}
bC(X) = {X, ϕ,{a},{b},{c},{a, c},{b, c}}
C(X) = {X, ϕ,{c},{a, c},{b, c}}
Here (X, τ) is T_{gs}-space but not $T_{sb\hat{g}}$-space.

Proposition 5.7: Every $T_{sb\hat{g}}$-space is $T_{b\hat{g}}$-space.

Proof: Let (X, τ) be $T_{sb\hat{g}}$-space. Let A be sbĝ -closed set in (X, τ). By Propositon 3.23, A is bĝ -closed. Since every closed set is b-closed set, A is b-closed set in X. Therefore, (X, τ) is $T_{b\hat{g}}$-space.

The reverse implication does not hold as shown in the following example.

Example 5.8: Let X = {a, b, c} and τ = {X, ϕ,{a},{b},{a, b}}
sbĝ-C(X) = {X, ϕ,{a},{b},{c},{a, c},{b, c}}
bĝ-C(X) = {X, ϕ,{a},{b},{c},{a, c},{b, c}}
bC(X) = {X, ϕ,{a},{b},{c},{a, c},{b, c}}
C(X) = {X, ϕ,{c},{a, c},{b, c}}
Here, (X, τ) is $T_{b\hat{g}}$- space but not $T_{sb\hat{g}}$-space.

Proposition 5.9: Every $T^{*}_{b\hat{g}}$-space is $T_{sb\hat{g}}$-space.

Proof: Let (X, τ) be $T^{*}_{b\hat{g}}$-space. Let A be sbĝ-closed set in (X, τ). By Propositon 3.23, A is bĝ -closed. Since (X, τ) is $T^{*}_{b\hat{g}}$–space, A is closed set in X. Therefore, (X, τ) is $T_{sb\hat{g}}$-space.

The reverse implication need not be true as shown in the following example.

Example 5.10: Let X = {a, b, c} and τ = {X, ϕ,{a},{b, c}}
sbĝ-C(X) = {X, ϕ,{a},{b, c}}
bĝ-C(X) = {X, ϕ,{a},{b},{c},{a, b},{a, c},{b, c}}
C(X) = {X, ϕ,{a},{b, c}}
Here, (X, τ) is $T_{sb\hat{g}}$- space but not $T^*_{b\hat{g}}$-space.

Proposition 5.11: Every $T^*_{b\hat{g}}$ -space is $T^\alpha_{sb\hat{g}}$ -space.

Proof: Let (X, τ) be $T^*_{b\hat{g}}$ -space. Let A be sbĝ- closed set in (X, τ). By Proposition 3.23, A is bĝ-closed. Since (X, τ) is $T^*_{b\hat{g}}$–space, A is closed set in X. Since every closed set is α-closed set, A is α-closed in X. Therefore, (X, τ) is $T^\alpha_{sb\hat{g}}$ -space.

The following example shows that the converse of the above proposition need not be true.

Example 5.12: Let X = {a, b, c} and τ = {X, ϕ, {a}}
sbĝ-C(X) = {X, ϕ,{b},{c},{b, c}}
bĝ-C(X) = {X, ϕ,{b},{c},{a, b},{a, c},{b, c}}
αC(X) = {X, ϕ,{b},{c},{b, c}}
C(X) = {X, ϕ, {b, c}}
Here, (X, τ) is $T^\alpha_{sb\hat{g}}$-space but not $T^*_{b\hat{g}}$-space.

Proposition 5.13: Every $T_{sb\hat{g}}$-space is $T^c_{\alpha b\hat{g}}$- space.

Proof: Let (X, τ) be $T_{sb\hat{g}}$-space. Let A be αbĝ-closed set in (X, τ). By Proposition 3.25, A is sbĝ-closed. Since (X, τ) is $T_{sb\hat{g}}$-space, A is closed. Therefore, (X, τ) is $T^c_{\alpha b\hat{g}}$- space.

The converse of the above proposition need not be true and is explained in the following example.

Example 5.14: Let X = {a, b, c} and τ = {X, ϕ,{a},{b},{a, b}}
sbĝ-C(X) = {X, ϕ,{a},{b},{c},{a, c},{b, c}}
αbĝ-C(X) = {X, ϕ,{c},{a, c},{b, c}}
C(X) = {X, ϕ, {c}, {a, c}, {b, c}}
Here, (X, τ) is $T^c_{\alpha b\hat{g}}$-space but not $T_{sb\hat{g}}$-space.

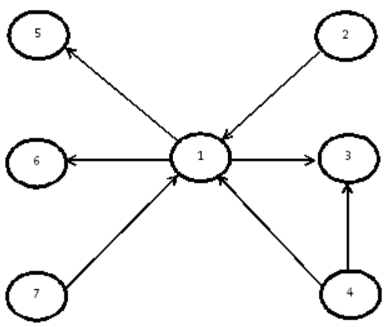
Proposition 5.15: Every $T_{sb\hat{g}}$ -space is $T^\alpha_{sb\hat{g}}$ - space.

Proof: Let (X, τ) be $T_{sb\hat{g}}$ -space. Let A be sbĝ-closed set in (X, τ). Since (X, τ) is $T_{sb\hat{g}}$ -space, A is closed. Since every closed set is α-closed set, A is α-closed set in X. Therefore, (X, τ) is $T^\alpha_{sb\hat{g}}$ - space.

The following example shows that the converse of the above proposition need not be true.

Example 5.16: Let X = {a, b, c} and τ = {X, ϕ, {b}}
sbĝ-C(X) = {X, ϕ,{a},{c},{a, c}}
αC(X) = {X, ϕ,{a},{c},{a, c}}
C(X) = {X, ϕ,{a, c}}
Here, (X, τ) is $T^\alpha_{sb\hat{g}}$ -space but not $T_{sb\hat{g}}$-space.

Remark 5.17: The following diagram shows the relationship about $T_{sb\hat{g}}$-space and $T^\alpha_{sb\hat{g}}$-space with other known existing spaces.



1. $T_{sb\hat{g}}$-space
2. $T^{c}_{\alpha b\hat{g}}$-space
3. $T^{\alpha}_{sb\hat{g}}$- space
4. $T^{*}_{b\hat{g}}$-space
5. $T_{b\hat{g}}$-space
6. T_{gs}-space
7. T_{b}-space.

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