ISSN PRINT 2319 1775 Online 2320 7876

Research paper **UGC CARE Listed (Group -I) Journal Volume 11, Iss 12, 2022**

A New Class of Star Generalized Open Sets Weaker than Semi* α - Open Sets

S. Pious Missier
Head & Associate Professor (Retd), Department of Mathematics,
Don Bosco College of Arts and Science,
(Affiliated to Manonmaniam Sundaranar University, Abishekabatti, Tirunelveli)
Keela Eral, Thoothukudi, Tamil Nadu-628 908, India.
E-mail: spmissier@gmail.com

Siluvai A
Research Scholar (Reg.No-18131282091015),
PG and Research Department of Mathematics,
GVN Arts and Science College, (Autonomous),
Kovilpatti, India.
E-mail: siluwin@gmail.com

Abstract:

In this paper we intend to explore the possibility of introducing a novel class, namely $\widehat{S_p}^*$ - Open Sets using pre-open set and generalized closure. An undaunted effort has been made to study its characterization to relate this newly constructed set with the well-established sets that are available by earlier studies. An analysis of the properties of $\widehat{S_p}^*$ open sets have borne interesting results. The results are substantiated with appropriate examples.

Key Words: ***Pre-Open, Generalized Pre Closure,*** **$\widehat{S_p}^*$ - Open Sets, $\widehat{S_p}^*$ interior.**

AMS Subject Classification (2010): 54A05

1. INTRODUCTION

A.S. Mashhour et al, [6] introduced pre-open sets in topological spaces in 1982. Since the introduction of pre-open sets, many topologists generalized various concepts of topology using pre-open sets instead of open sets. In 1970, Levine [4] defined and studied generalized closed sets. Using Levine's generalized closed sets, Dunham [3] introduced the concept of generalized closure and characterized some of its properties. In this paper, analogous to H. Maki, etal's pre-generalized closed sets, we define a new class of sets, namely $\widehat{S_p}^*$-open sets, using the pre-generalized closure operator instead of closure to due to W. Dunham in the definition of pre-open set. We further show that the concept of $\widehat{S_p}^*$-open set is weaker than semii^*-α-open sets but stronger than the concept of semi-pre-open sets (β open set) and is independent of g-open sets, pre-open sets, and $semi^*$-pre-open sets. We study the characterization of $\widehat{S_p}^*$-open sets. We investigate the basic properties of $\widehat{S_p}^*$-open sets. We also define $\widehat{S_p}^*$-interior of a subset and study some of its basic properties. We also establish that the class of $\widehat{S_p}^*$-closed sets are placed between the class of α-closed sets and the class of semi-pre–closed sets.

2. PRELIMINARIES

Definition 2.1 Let A be a subset of a topological space (X,τ). Then

(i) A is semi-open set [4] if there is an open set U in X such that $U \subseteq A \subseteq Cl(U)$ or equivalently if $A \subseteq Cl(Int(A))$.

(ii) A is pre-open set [6] if $A \subseteq Int(Cl(A))$ and pre-closed if $Cl(Int(A)) \subseteq A$.[35]

(iii) A is α-open set [7] if $A \subseteq Int(Cl(Int(A))$ and α-closed if $Cl(Int(Cl(A)) \subseteq A$.[36]

ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 11, Iss 12, 2022

(iv) A is semi pre-open set [11] if A $\subseteq Cl(Int(Cl(A)))$ and semi pre -closed if $Int(Cl(Int(A))) \subseteq A$.

The pre-closure of A, α-closure of A and semi pre closure of A are analogously defined and they are respectively denoted by $PCl(A)$, $\alpha\, Cl(A)$ and $SPCl$(A).

Definition 2.2 Let A be a subset of a topological space (X,τ). Then

(a) A is called a generalized closed set [5] (briefly g-closed) if $Cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X,τ).
(b) A is called a semi generalized closed set [1] (briefly sg-closed) if $SCl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi-open in (X,τ).
(c) A is called a pre generalized closed set [6] (briefly pg-closed) if $PCl(A) \subseteq U$ whenever $A \subseteq U$ and U is pre-open in (X,τ).
(d) A is called a semi star generalized closed set [2] (briefly S^*g-closed) if $SCl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi-open in (X,τ).
(e) A is called a semi generalized star open set [11] (briefly $S_g{}^*$ -open) if there is an open set U in X such that $U \subseteq$ A $\subseteq$ Scl *(U).
(f) A is called a semi star open set [9] (briefly S^*-open) if there is an open set U in X such that $U \subseteq A \subseteq Cl^*(U)$ or equivalently if $A \subseteq Cl^*(Int(A))$.
(g) A is called an alpha star open set [10] (briefly α^*-open) if there is an open set U in X such that $U \subseteq A \subseteq Cl^*(U)$ or equivalently if $A \subseteq Int^*(Cl(Int(A)))$.
(h) A is called a semi star alpha open set [8] (briefly $S^*\alpha$-open) if there is an open set U in X such that $U \subseteq A \subseteq Cl^*(U)$ or equivalently if $A \subseteq Int^*(Cl(Int(A)))$.

3. $\widehat{S_P}^*$ OPEN SETS

Definition 3.1. A subset A of a topological space (X,τ) is called a $\widehat{S_P}^*$-open set, if here is an open set U such that $U \subseteq A \subseteq PCl^*(U)$. The collection of all $\widehat{S_P}^*$-open sets in (X,τ) is denoted by $\widehat{S_P}^*O(X,\tau)$ or $\widehat{S_P}^*O(X)$.

Theorem 3.2. If A is a subset of a topological space (X,τ), then the following statements are equivalent:

(i) A is $\widehat{S_P}^*$- open
(ii) $A \subseteq PCl^*(Int(A))$
(iii) $PCl^*(Int(A)) = PCl^*(A)$
(iv) $PCl^*\left(A \cap Cl(Int(A))\right) = PCl^*(A)$

Proof **(i) ⇒ (ii):** If A is $\widehat{S_P}^*$open, then there is an open set U in X such that $U \subseteq A \subseteq PCl^*(U)$. Now $U \subseteq A$ and U is an open implies $U = Int(U) \subseteq Int(A)$ which implies that $A \subseteq PCl^*(U) \subseteq PCl^*(Int(A))$

(ii) ⇒ (iii): Since PCl^* is a kuratowski closure operator, $A \subseteq PCl^*(Int(A))$ implies $PCl^*(A) \subseteq PCl^*\left(PCl^*(Int(A))\right) = PCl^*(Int(A))$. Since $Int(A) \subseteq A$, $PCl^*(Int(A)) \subseteq PCl^*(A)$. Thus $PCl^*(Int(A)) = PCl^*(A)$

(iii) ⇒ (i): Take $U = Int(A)$. Then U is an open set such that $U \subseteq A \subseteq PCl^*(A) = PCl^*(Int(A)) = PCl^*(U)$. Therefore, by definition 2.1.1, A is $\widehat{S_p}^*$open.

(iii) ⇔ (iv): Follows from the fact that for any subset A, $PInt(A) = A \cap Cl(Int(A))$

Theorem 3.3. Every open set is a $\widehat{S_P}^*$- open set.

Proof: Let A be an open set in X, $Int\,(A) = A$ and $A \subseteq PCl^*(A)$, then we have $A \subseteq PCl^*(Int(A))$. Therefore, A is a $\widehat{S_P}^*$ - open set.

Remark 3.4. The Converse of the above Theorem 3.3 need not be true as can be seen from the following example.

Example 3.5 Consider a topological space (X, τ) where $X = \{a, b, c, d\}$, $\tau = \{X, \phi, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}\}$. Then $\widehat{S_P}^* O(X, \tau) = \{X, \varphi, \{a\}, \{b\}, \{a, b\}, \{a, c\}, \{a, d\}, \{b, c\}, \{b, d\}, \{a, b, c\}, \{b, c, d\}, \{c, d, a\}, \{d, a, b\}\}$. Here the subsets {a, c} and $\{a, d\}$ are $\widehat{S_P}^*$ - open but not open.

Theorem 3.6. Arbitrary union of $\widehat{S_P}^*$ - open sets is $\widehat{S_P}^*$ - open.

Proof: Let $\{A_\beta : \beta \in \Delta\}$ be a collection of $\widehat{S_P}^*$ - open sets in X. Since each A_β is $\widehat{S_P}^*$-open, there is an open set U_β in X such that $U_\beta \subseteq A_\beta \subseteq PCl^*(U)$. Hence, $\cup\, U_\beta \subseteq \cup\, A_\beta \subseteq \cup\, PCl^*(U_\beta) \subseteq PCl^*(\cup\, U_\beta)$. Since each U_β is open, $\cup\, U_\beta$ is open and hence by Definition 3.1, $\cup\, A_\beta$ is $\widehat{S_P}^*$-open.

Remark 3.7. The intersection of any two $\widehat{S_P}^*$ - open sets need not be $\widehat{S_P}^*$ - open as can be seen from the following example.

Example 3.8. Consider a topological space (X, τ) where $X = \{a, b, c\}, \tau = \{X, \phi, \{a\}, \{b\}\}$. Here $\{a, c\}$ and $\{b, c\}$ are $\widehat{S_P}^*$ - open but their intersection $\{c\}$ which is not $\widehat{S_P}^*$ - open.

Theorem 3.9. If A is a $\widehat{S_P}^*$ - open set and B is an open set in a topological space (X, τ), then $(A \cup B)$ is $\widehat{S_P}^*$ - open set.

Proof: The proof follows from Theorem 3.6.

Theorem 3.10. Let $A \subseteq B \subseteq PCl^*(A)$. If A is $\widehat{S_P}^*$ - open in the topological space (X, τ), then B is also $\widehat{S_P}^*$-open.

Proof: Suppose A is $\widehat{S_P}^*$ - open in X, then there is an open set U in X such that $U \subseteq A \subseteq PCl^*(U)$. Since $A \subseteq B, U \subseteq A$ and $U \subseteq B$ which implies $PCl^*(U) \subseteq PCl^*(B)$. Therefore, $U \subseteq B \subseteq PCl^*(U)$ and hence B is $\widehat{S_P}^*$ - open.

Theorem 3.11. If A is a $\widehat{S_P}^*$ - open set in X and B is an open set in X, then $A \cap B$ is a $\widehat{S_P}^*$ - open set in X.

Proof: Since A is $\widehat{S_P}^*$ - open in X, there is an open set U in X such that $U \subseteq A \subseteq PCl^*(U)$. Since B is open in X, $U \cap B$ is also open. Therefore, $(U \cap B) \subseteq (A \cap B) \subseteq PCl^*(U) \cap B \subseteq PCl^*(U \cap B)$. Thus, by Definition 3.1 $A \cap B$ is $\widehat{S_P}^*$ - open.

Theorem 3.12. Every α-open set in X is a $\widehat{S_P}^*$ - open set.

Proof: Let A be an α-open set in X, then $\alpha Int(A) = A$and hence $A \subseteq PCl^*(A) = PCl^*(\alpha Int\,(A)) = PCl^*(Int(A))$. By involving Theorem.3.2, A is $\widehat{S_P}^*$-open.

Remark 3.13. The Converse of the above theorem is not true as can be seen from the following example.

Example 3.14. Consider a topological space (X, τ) where $X = \{a, b, c\}$,$\tau = \{X, \phi, \{a\}, \{b\}\}$.Then the subsets $\{a\}$, $\{b\}$, and $\{a, b\}$ are α-open sets and they are $\widehat{S_P}^*$ - open sets but the $\widehat{S_P}^*$-open sets $\{a, c\}$ and $\{b, c\}$ are not α-open sets.

ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 11, Iss 12, 2022

Theorem 3.15. Every $semi^*$- open set in topological space (X,τ), is $\widehat{S_P}^*$- open.
Proof: Let A be a $semi^*$- open set. Then $A \subseteq Cl^*\big(Int(A)\big) \subseteq PCl^*\big(Int(A)\big)$ which implies $A \subseteq PCl^*(Int(A))$. Hence A is $\widehat{S_P}^*$- open set.

Remark 3.16. The converse of the above theorem need not be true from the following example.

Example 3.17. Consider a topological space (X,τ) where $X = \{a,b,c\}$, $\tau = \big\{X, \phi, \{a\}\big\}$ the subset $\{a\}$ is a $semi^*$-open set which is also a $\widehat{S_P}^*$-open set but not a $semi^*$- open set.

Theorem 3.18. Every $S^*\alpha$ - open in a topological space (X,τ) is $\widehat{S_P}^*$-open set.
Proof: Let A be a $S^*\alpha$ - open set in a topological space (X,τ). Then $A \subseteq Cl^*\left(\alpha\big(Int(A)\big)\right)$ which implies that $A \subseteq PCl^*\big(Int(A)\big)$. Hence A is $\widehat{S_P}^*$-open set.

Remark 3.19. The converse of the above theorem is not true as seen from the following example.

Example 3.20. Consider a topological space (X,τ) where $X = \{a,b,c,d\}$, $\tau = \{X, \phi, \{a\}, \{b\}, \{a,b\}, \{a,b,c\}\}$. Then the subsets $\{a,c\}$ and $\{b,c\}$ are $\widehat{S_P}^*$-open sets but are not $S^*\alpha$-open sets.

Theorem 3.21. Every S_g^*- open set is a $\widehat{S_P}^*$- open set.
Proof: Let A be a S_g^* - open set in a topological space (X,τ). Then $A \subseteq SCl^*\big(Int(A)\big) \subseteq PCl^*\big(Int(A)\big)$ which implies $A \subseteq PCl^*(Int(A))$. Hence A is a $\widehat{S_P}^*$- open set.

Remark 3.22. The converse of the above theorem is not true as shown in the following example.

Example 3.23. Consider a topological space (X,τ) where $X = \{a,b,c,d\}$, $\tau = \big\{X, \phi, \{a\}, \{b\}, \{a,b\}, \{a,b,c,\}\big\}$. Then the subset $\{a,b\}$ is a S_g^*- open set and is also $\widehat{S_P}^*$-open set but the subsets $\{a,c\}, \{d\}$ are $\widehat{S_P}^*$ open but not S_g^*-open.

Theorem 3.24. Every $\widehat{S_P}^*$-open set in a topological space (X,τ) is α^*-open set.
Proof: Let A be a $\widehat{S_P}^*$-open set. Then it follows from Theorem 2.1.35 every $\widehat{S_P}^*$-open set is a pre^*-open set. And we know that every pre^*-open is α-open. Therefore, $\widehat{S_P}^*$-open is α^*-open.

Remark 3.25. Converse of the above theorem is not true as seen from the following example.

Example 3.26. Consider a topological space (X,τ) where $X = \{a,b,c\}$, $\tau = \{X, \phi, \{a\}, \{a,b\}\}$. Then the subset $\{a\}$ is an α^*-open set but not a $\widehat{S_P}^*$- open set.

Theorem 3.27. Every $\widehat{S_P}^*$- open set in a topological space (X,τ) is a sg-open set.
Proof: It follows that every $\widehat{S_P}^*$- open set is semi-open and every semi-open is semi-generalized open. Therefore every $\widehat{S_P}^*$- open set is semi-generalized open.

Remark 3.28. Converse of the above theorem is not true as seen from the following example.

Example 3.29. Consider a topological space (X,τ) where $X = \{a,b,c\}$, $\tau = \{X, \phi, \{a,b\}\}$. Then the subsets $\{a\}$ and $\{b\}$ are semi-generalized open sets but not $\widehat{S_P}^*$-open sets.

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Remark 3.30. The concept of $\widehat{S_P}^*$-open set is independent of the concepts of pre-open sets as seen from the following example.

Example 3.31. Consider a topological space (X,τ) where $X = \{a,b,c\}$, $\tau = \{X,\phi,\{a,b\}\}$, the subset $\{b,c\}$ is a pre-open set but not a $\widehat{S_P}^*$- open set. However, in the topological space (X,τ), where $X = \{a,b,c\}$, $\tau = \{X,\phi,\{a\},\{b\}\}$, the subset $\{b,c\}$ is a $\widehat{S_P}^*$- open set but not a pre-open set. Hence pre-open set and $\widehat{S_P}^*$-open set are independent.

Remark 3.32. The concept of $\widehat{S_P}^*$- open set is independent of the concepts of g-open sets as seen from the following example.

Example 3.33. Consider a topological space (X,τ) where $X = \{a,b,c,d\}$, $\tau = \{X,\ \phi,\ \{a\},\ \{b\},\ \{a,b\},\{a,b,c\}\}$, the subset $\{b,c,d\}$ is not a g-open set but $\widehat{S_P}^*$-open set and subset $\{c\}$ is a g-open set but not a $\widehat{S_P}^*$- open set.

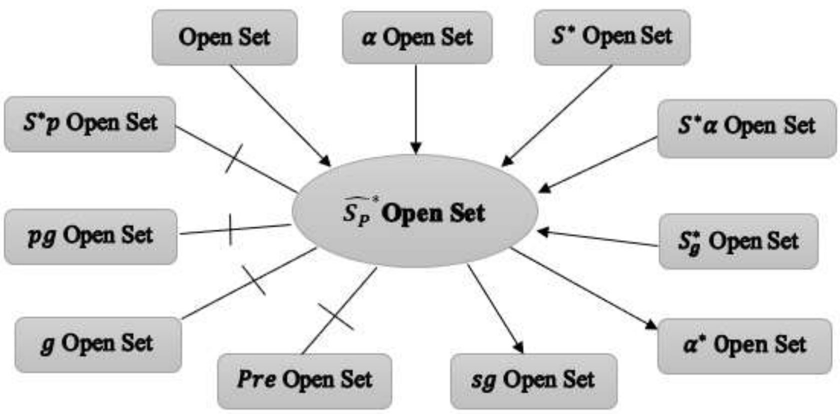
Remark 3.34. The concept of $\widehat{S_P}^*$-open set is independent of the concepts of pg-open sets as seen from the following example.

Example 3.35. Consider a topological space (X,τ) where $X = \{a,b,c\}$, $\tau = \{X,\phi,\{a\},\{b\}\}$. Then the subsets $\{a,c\}$ and $\{b,c\}$ are $\widehat{S_P}^*$-open sets and not pre-generalized-open sets. However, in the topological space (X,τ) where $X = \{a,b,c\}$, $\tau = \{X,\phi,\{a,b\}\}$, the subsets $\{a\}$, $\{b\}$, $\{a,c\}$ and $\{b,c\}$ are pre-generalized-open sets but not $\widehat{S_P}^*$-open sets. Hence pg open set and $\widehat{S_P}^*$-open set are independent.

Remark 3.36. The concept of $\widehat{S_P}^*$-open set is independent of the concepts of $semi^*$-pre-open sets as seen from the following example.

Example 3.37. Consider a topological space (X,τ) where $X = \{a,b,c\}$, $\tau = \{X,\phi,\{a,b\}\}$, the subset $\{a,c\}$ is a $semi^*$-pre-open set but not a $\widehat{S_P}^*$-open set. However, in the topological space (X,τ), where $X = \{a,b,c\}$, $\tau = \{X,\phi,\{a\},\{b\}\}$, the subset $\{a,c\}$ is a $\widehat{S_P}^*$-open set but not a $semi^*$-pre-open set. Hence $semi^*$-pre-open set and $\widehat{S_P}^*$-open set are independent.

Remark 2.1.38. From the above discussions we have the following diagram.



4. $\widehat{S_P}^*$ - INTERIOR

ISSN PRINT 2319 1775 Online 2320 7876
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In this section we introduce the concept of $\widehat{S_P}$ -interior of a subset and investigate its characterization. We also define $\widehat{S_P}^*$-interior point of a subset. We also give the characterizations for a subset to be $\widehat{S_P}^*$-open.

Definition 4.1. The $\widehat{S_P}^*$-interior of A is defined as the union of all $\widehat{S_P}^*$- open sets of X that are contained in A and is denoted by $\widehat{S_P}^* Int(A)$.

Definition 4.2. Let $A \subseteq X$. A point x in X is called a $\widehat{S_P}^*$- interior point of A if A contains a $\widehat{S_P}^*$open set containing x.

Theorem 4.3. Let A be a subset of a topological space X then

(i) $\widehat{S_P}^* Int(A)$ is the largest $\widehat{S_P}^*$open set contained in A.

(ii) A is $\widehat{S_P}^*$open if and only if $\widehat{S_P}^*\big(Int(A)\big) \subseteq A$

(iii) $\widehat{S_P}^*\big(Int(A)\big)$ is the set of all $\widehat{S_P}^*$interior points of A

(iv) A is $\widehat{S_P}^*$open if and only if every point of A is $\widehat{S_P}^*$ interior point of A

Proof: (i) Since $\widehat{S_P}^*\big(Int(A)\big)$ is the union of $\widehat{S_P}^*$open subsets of A, by Theorem 3.6, $\widehat{S_P}^*\big(Int(A)\big)$ is a $\widehat{S_P}^*$open set that is contained in A. Also, it contains every $\widehat{S_P}^*$open subset of A. Hence $\widehat{S_P}^*\big(Int(A)\big)$ is the largest $\widehat{S_P}^*$open set contained in A.

(ii) Suppose A is $\widehat{S_P}^*$open and since $A \subseteq A$ implies $\widehat{S_P}^* Int(A)$ follows from definition. Conversely suppose that $\widehat{S_P}^*\big(Int(A)\big) = A$. By (i) above, $\widehat{S_P}^*\big(Int(A)\big)$ is $\widehat{S_P}^*$open and hence A is $\widehat{S_P}^*$open.

(iii) By the definition of $\widehat{S_P}^*$interior, a point $x \in \widehat{S_P}^*\big(Int(A)\big)$ if and only if x belongs to some $\widehat{S_P}^*$open subset of A. That is, if and only if x is a $\widehat{S_P}^*$- interior point of A.

(iv) Follows from (ii) and (iii)

Theorem 4.4. In any topological space X, the following statements hold

(i) $\widehat{S_P}^* Int(\phi) = \phi$

(ii) $\widehat{S_P}^* Int(X) = X$

(iii) $\widehat{S_P}^* Int(A) \subseteq A$

(iv) For any subsets A and B of a topological space X, $A \subseteq B$ implies $\widehat{S_P}^* Int(A) \subseteq \widehat{S_P}^* Int(B)$

Proof: Clearly (i), (ii), (iii) and (iv) follow from the Definition 4.1.

Theorem 4.5 In any topological spaces (X, τ),the following statements hold:

(i) $\widehat{S_P}^* Int(A) \cup \widehat{S_P}^* Int(B) \subseteq \widehat{S_P}^* Int(A \cup B)$

(ii) $\widehat{S_P}^* Int(A \cap B) \subseteq \widehat{S_P}^* Int(A) \cap \widehat{S_P}^* Int(B)$

(iii) $Int(\widehat{S_P}^* Int(A)) = Int(A)$

(iv) $\widehat{S_P}^* Int\big(Int(A)\big) = Int(A)$

Proof: (i) Since $A \subseteq (A \cup B)$, using theorem 4.4 (iv), we have $\widehat{S_P}^* Int(A) \subseteq \widehat{S_P}^* Int(A \cup B)$. Similarly, $\widehat{S_P}^* Int(B) \subseteq \widehat{S_P}^* Int(A \cup B)$. Thus (i) is proved.

(ii) Since $A \cap B \subseteq A$, from Theorem 4.4 (iv), we have $\widehat{S_P}^* Int(A \cap B) \subseteq \widehat{S_P}^* Int(A)$. Similarly, $\widehat{S_P}^*\big(Int(A \cap B)\big) \subseteq \widehat{S_P}^*\big(Int(B)\big)$ and proves (ii)

(iii) By Theorem 4.4 (iii), we have $Int(A) \subseteq \widehat{S_P}^*\big(Int(A)\big)$ and so $Int\big(Int(A)\big) \subseteq Int\left(\widehat{S_P}^* Int(A)\right)$ and hence $Int(A) \subseteq Int\left(\widehat{S_P}^* Int(A)\right)$. This proves (iii).

(iv) Since $Int(A)$ is open, by Theorem 3.12, every α-open set is $\widehat{S_P}^*$open set. $Int(A)$ is $\widehat{S_P}^*$-open and hence by involving Theorem 4.3 (ii) $\widehat{S_P}^*\left(Int\left(Int(A)\right)\right) = Int(A)$. Thus (iv) is proved.

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