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Article

Point Set Domination in Uniform Single-Valued Neutrosophic Graphs for Energy-Efficient Backbone Design in Wireless Sensor Networks

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Abstract: This paper introduces a novel framework for Point Set Domination in Uniform Single-Valued Neutrosophic Graphs (PS-USVNGs) and investigates its application to energy-efficient backbone design in Wireless Sensor Networks (WSNs). A Point Set Neutrosophic Strength (PNS) function, incorporating truth-membership, indeterminacy-membership, and falsity-membership values, is proposed to model domination under uncertainty. Based on this strength function, new concepts of Point Set USVNG domination, dominating sets, and domination numbers are formulated. Several membership-based properties are established to analyze the effects of truth, indeterminacy, and falsity on domination behavior. Furthermore, graph operation results involving union, join, Cartesian product, and complement operations are developed within the PS-USVNG framework. A uniformity theorem is also derived to characterize domination in uniform neutrosophic environments. The proposed model is applied to WSN backbone formation, enabling reliable and uncertainty-aware node selection. Comparative analysis demonstrates that the PS-USVNG approach provides a more comprehensive representation of uncertain communication networks than existing domination models.
Keywords: Point Set Domination, Uniform Single-Valued Neutrosophic Graph, Domination Number, Graph Operations, Wireless Sensor Networks

1. Introduction

Due to their numerous applications in industrial automation, military surveillance, healthcare systems, environmental monitoring, disaster management, and intelligent transportation systems, Wireless Sensor Networks (WSNs) have become one of the most significant technologies in contemporary communication systems. Many sensor nodes work together to gather, process, and send data to a base station in a wireless sensor network. Energy efficiency becomes a critical concern in the design and operation of WSNs since sensor nodes are often powered by finite battery resources.

Building an effective communication backbone is one of the key tactics for lowering energy usage in WSNs. The goal of backbone design is to choose a subset of sensor nodes that can handle routing and communication duties while reducing redundant transmissions and increasing network longevity. Because dominating sets offer effective routing and coverage techniques, graph theoretic domination notions have been widely used in the building of such backbone systems.

However, in wireless communication situations, uncertainty is frequently not adequately represented by standard graph models. Unreliable connectivity, packet loss, interference, unstable links, and node failures can all affect sensor nodes. Fuzzy graphs and intuitionistic fuzzy graphs were developed to deal with such uncertainties. However, these models are unable to simultaneously capture information about truth, indeterminacy, and falsehood.

A more adaptable framework for simulating ambiguous and inconsistent data in complex networks is offered with the introduction of single-valued neutrosophic graphs. Every vertex and edge in a single-valued neutrosophic graph has truth-membership, indeterminacy-membership, and falsity-membership functions. Neutrosophic values preserve uniformity conditions throughout the graph structure in uniform single-valued neutrosophic graphs (USVNGs), a significant subclass.

Domination concepts in neutrosophic graphs have garnered a lot of interest lately. Nevertheless, there hasn't been enough research done on the idea of point set domination in uniform single-valued neutrosophic graphs and how it might be used to construct an energy-efficient backbone for wireless sensor networks.

Inspired by these findings, this study presents the notion of point set domination in USVNGs and explores its theoretical and practical implications for building WSN backbones.

The following is a summary of this paper's primary contributions:

- In Uniform Single-Valued Neutrosophic Graphs, a new notion of point set domination is presented.
- A number of boundaries, attributes, and dominating parameters are established.
- A point set domination-based energy-efficient backbone design model for WSNs is created.
- In neutrosophic settings, a backbone selection algorithm is suggested.
- The efficiency of the suggested paradigm is illustrated with numerical examples and comparative analysis.

2. Literature Review

Due to its numerous applications in wireless sensor networks, network monitoring, communication systems, and routing optimization, dominance theory has emerged as one of the most important fields of graph theory research. In order to find minimum subsets of vertices that could control or cover a complete graph structure, classical dominance notions were first developed. Later, domination-based methods proved to be very successful for building backbones and optimizing routing in wireless communication networks.

Researchers expanded traditional graph models into fuzzy and intuitionistic fuzzy settings in response to the advent of uncertain communication systems. Lotfi A. Zadeh's[14] fuzzy graphs made it possible to communicate uncertainty in graph topologies, and intuitionistic fuzzy graphs added hesitation information. Nevertheless, in complicated network situations, these methods were unable to concurrently capture failure, uncertainty, and reliability information.

Florentin Smarandache[1] developed the idea of neutrosophic sets, which offered a broader framework for managing ambiguous and contradictory data. This idea served as the foundation for the introduction and subsequent substantial development of Single-Valued Neutrosophic Graphs (SVNGs) for uncertain network analysis. Broumi et al. [2] examined the structural characteristics of single-valued neutrosophic graphs and showed how useful they are for simulating uncertain communication.

Domination notions in neutrosophic graph contexts have been greatly enlarged by recent investigations conducted between 2023 and 2026. In Single-Valued Neutrosophic Incidence Graphs, Mohamad et al. (2023) [3] presented new dominance concepts and examined domination relationships along with useful applications in vaccination and communication networks. With an emphasis on network stability in the event of node failure, Sivasankar and Broumi (2023) [4] examined secure dominance and completely secure neutrosophic domination in communication networks.

Advanced uncertain communication modelling has been the subject of subsequent advancements in neutrosophic graph architectures. Graph operations, regular structures, and decision-making applications in extremely unpredictable contexts were investigated in research on complex Fermatean neutrosophic graphs. Smarandache, F., et al.,[5] By directly integrating neutrosophic membership values into domination analysis, recent research on neutrosophic signed domination functions extended classical dominance.

[13] Neutrosophic graph frameworks have also been used recently in Internet of Things (IoT) contexts, graph neural networks, intelligent communication systems, and healthcare risk prediction. In 2025, Advanced Neutrosophic Graph Neural Networks (NGNNs) were proposed to predict disease transmission in unclear epidemiological situations, showcasing neutrosophic graphs' ability to handle partial and faulty network information. Meenakshi, A., et al.,[7] The usefulness of uniform neutrosophic structures in simulating intricate communication dynamics was further highlighted in recent research on uniform neutrosophic topological indices in Internet of Things systems. Rajeshwari, M., et al.,[8] Significant issues with energy consumption, routing overhead, erratic connectivity, and node failures still plague Wireless Sensor Networks (WSNs). Thus, domination-based approaches to backbone creation have garnered a lot of research interest. The significance of graph-theoretic techniques for lowering energy consumption and extending network lifetime in sensor networks has been emphasized by a number of optimization studies [16] Their significance in environmental monitoring and intelligent sensing systems has also been shown by recent domination-based communication models in uncertain environments [6].

Very little research has been done on point set domination in Uniform Single-Valued Neutrosophic Graphs (USVNGs)[15-20], especially for energy-efficient backbone creation in wireless sensor networks, despite the fact that a number of domination ideas have been researched in neutrosophic graph environments. The combination of point set domination with uniform neutrosophic structures and WSN backbone optimization is yet mainly unexplored; current research primarily concentrates on general domination, secure domination, or incidence domination.

Inspired by these research gaps, the current study presents a novel framework of point set domination in Uniform Single-Valued Neutrosophic Graphs and applies it to the development of energy-efficient backbones in wireless sensor networks that operate in unpredictable communication contexts.

3. Preliminaries

Definition 3.1 Graph

A graph is an ordered pair $G = (V, E)$ where:

- V is a non-empty finite set of vertices,
- $E \subseteq V \times V$ is the set of edges connecting pairs of vertices.

The number of vertices in a graph is called the order of the graph.

Definition 3.2 Dominating Set

Let $G = (V, E)$ be a graph. A subset $D \subseteq V$ is called a dominating set if every vertex in $V - D$ is adjacent to at least one vertex in D. The minimum cardinality of a dominating set is called the domination number of G and is denoted by $\gamma(G)$.

Definition 3.3 Single-Valued Neutrosophic Set

Let X be a universe of discourse. A Single-Valued Neutrosophic Set (SVNS) A in X is characterized by:

- truth-membership function $T_A(x)$,
- indeterminacy-membership function $I_A(x)$,
- falsity-membership function $F_A(x)$,

such that $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$ for every $x \in X$.

Definition 3.4 Uniform Single-Valued Neutrosophic Graph

A Uniform Single-Valued Neutrosophic Graph (USVNG) is a special class of SVNG in which neutrosophic membership conditions remain uniform throughout the graph structure.

Uniformity provides:

- balanced graph representation,
- simplified domination analysis,
- and efficient computational implementation.

3.1 Definition 3.5 Path Graph

A path graph P_n is a graph consisting of $n$vertices arranged in a linear sequence such that consecutive vertices are connected by edges.

Definition 3.6 Cycle Graph

A cycle graph C_n is a graph consisting of $n$vertices connected in a closed chain.

Definition 3.7 Star Graph

A star graph S_n is a graph containing one central vertex adjacent to all remaining pendant vertices.

4. Point Set Domination in Uniform Single-Valued Neutrosophic Graphs

This section examines the mathematical features of the concept of point set domination in Uniform Single-Valued Neutrosophic Graphs (USVNGs).

Let $G = (V, E, T, I, F)$ be a Neutrosophic Uniform Single-Valued Graph in which:

The set of vertices is represented by V, the set of edges by E, the truth-membership function by T, the indeterminacy-membership function by I, and the falsity-membership function by F.

Throughout this section, $|V| = n$ represents the order of the graph.

Definition 4.1 Point Set Neutrosophic Strength

Let $G = (V, E, T, I, F)$ be a Point Set Uniform Single-Valued Neutrosophic Graph.

For every edge $uv \in E$, define $PNS(uv) = T(uv) + (1 - I(uv)) - F(uv)$.

where

- $T(uv)$= truth-membership value
- $I(uv)$= indeterminacy-membership value
- $F(uv)$= falsity-membership value

The quantity $PNS(uv)$represents the domination capability of edge uv.

Definition 4.2 Point Set USVNG Dominance

Let $\lambda \in [0,2]$ be a domination threshold. A vertex u is said to Point-Set-USVNG dominate a vertex v if $uv \in E$ and $PNS(uv) \geq \lambda$.

Equivalently, $T(uv) + (1 - I(uv)) - F(uv) \geq \lambda$.

Definition 4.3 Point Set USVNG Dominating Set

A subset $D \subseteq V$ is called a Point Set USVNG Dominating Set if every $v \in V - D$ is Point-Set-USVNG dominated by at least one vertex $u \in D$.

Definition 4.4 Point Set USVNG Domination Number

The minimum cardinality among all Point Set USVNG Dominating Sets is called the Point Set USVNG Domination Number and is denoted by $\gamma_{PSU}(G)$.

Theorem 4.5 Membership Monotonicity Theorem

Let $G_1 = (V, E, T_1, I, F)$ and $G_2 = (V, E, T_2, I, F)$ be two Point Set USVNGs having identical vertex and edge sets. Suppose $T_1(uv) \leq T_2(uv)$ for every edge $uv \in E$, while $I(uv), F(uv)$ remain unchanged. Then $\gamma_{PSU}(G_2) \leq \gamma_{PSU}(G_1)$.

Proof:

For any edge uv, $PNS_1(uv) = T_1(uv) + (1 - I(uv)) - F(uv)$ and

$PNS_2(uv) = T_2(uv) + (1 - I(uv)) - F(uv)$.
Since $T_1(uv) \leq T_2(uv)$, we obtain $PNS_1(uv) \leq PNS_2(uv)$.

Hence every edge satisfying $PNS_1(uv) \geq \lambda$ also satisfies $PNS_2(uv) \geq \lambda$. Therefore every Point Set USVNG dominating set in G_1 is also a dominating set in G_2. Consequently the minimum Point Set USVNG domination number cannot increase.

Thus $\gamma_{PSU}(G_2) \leq \gamma_{PSU}(G_1)$.

Theorem 4.6 Indeterminacy Effect

Let $G_1 = (V, E, T, I_1, F)$ and $G_2 = (V, E, T, I_2, F)$ be Point Set USVNGs. If $I_1(uv) \leq I_2(uv)$

for every edge, then $\gamma_{PSU}(G_1) \leq \gamma_{PSU}(G_2)$.

Proof:

Using the Point Set Neutrosophic Strength, $PNS(uv) = T(uv) + (1 - I(uv)) - F(uv)$. Since $I_1(uv) \leq I_2(uv)$, it follows that $1 - I_1(uv) \geq 1 - I_2(uv)$.

Therefore $PNS_1(uv) \geq PNS_2(uv)$. Hence more edges satisfy the domination threshold in G_1.

Consequently fewer dominating vertices are required in G_1. Therefore $\gamma_{PSU}(G_1) \leq \gamma_{PSU}(G_2)$.

Theorem 4.7 Falsity Effect

Let $G_1 = (V, E, T, I, F_1)$ and $G_2 = (V, E, T, I, F_2)$ be Point Set USVNGs. If $F_1(uv) \leq F_2(uv)$

for every edge, then $\gamma_{PSU}(G_1) \leq \gamma_{PSU}(G_2)$.

Proof:

For every edge $PNS_1(uv) = T(uv) + (1 - I(uv)) - F_1(uv)$ and

$PNS_2(uv) = T(uv) + (1 - I(uv)) - F_2(uv)$.
Since $F_1(uv) \leq F_2(uv)$, we have $PNS_1(uv) \geq PNS_2(uv)$. Therefore more edges satisfy the domination threshold in G_1. Hence a smaller Point Set USVNG dominating set is sufficient. Thus $\gamma_{PSU}(G_1) \leq \gamma_{PSU}(G_2)$.

Theorem 4.8 Union Operation

Let G_1 and G_2 be disjoint PS-USVNGs. Then $\gamma_{PSU}(G_1 \cup G_2) = \gamma_{PSU}(G_1) + \gamma_{PSU}(G_2)$.

Lemma 4.8.1

Let G_1 and G_2 be two disjoint PS-USVNGs. Then no vertex of G_1 can Point-Set-USVNG dominate any vertex of G_2.

Proof

Since G_1 and G_2 are disjoint, $V(G_1) \cap V(G_2) = \emptyset$. Further, $E(G_1) \cap E(G_2) = \emptyset$. Hence for every $u \in V(G_1), v \in V(G_2)$, there exists no edge uv. Therefore $PNS(uv)$ is undefined.

Consequently u cannot dominate v. Consequently $\gamma_{PSU}(G_1 \cup G_2) = \gamma_{PSU}(G_1) + \gamma_{PSU}(G_2)$.

Proof of the theorem:

Let D_1 be a minimum Point Set USVNG dominating set of G_1, and D_2 be a minimum Point Set USVNG dominating set of G_2. By Lemma 4.8.1, vertices of G_1 cannot dominate vertices of G_2. Hence every dominating set of $G_1 \cup G_2$ must contain both D_1 and D_2.

Therefore $D = D_1 \cup D_2$ is a minimum dominating set. Thus $|D| = |D_1| + |D_2|$. Hence

$$\gamma_{PSU}(G_1 \cup G_2) = \gamma_{PSU}(G_1) + \gamma_{PSU}(G_2).$$

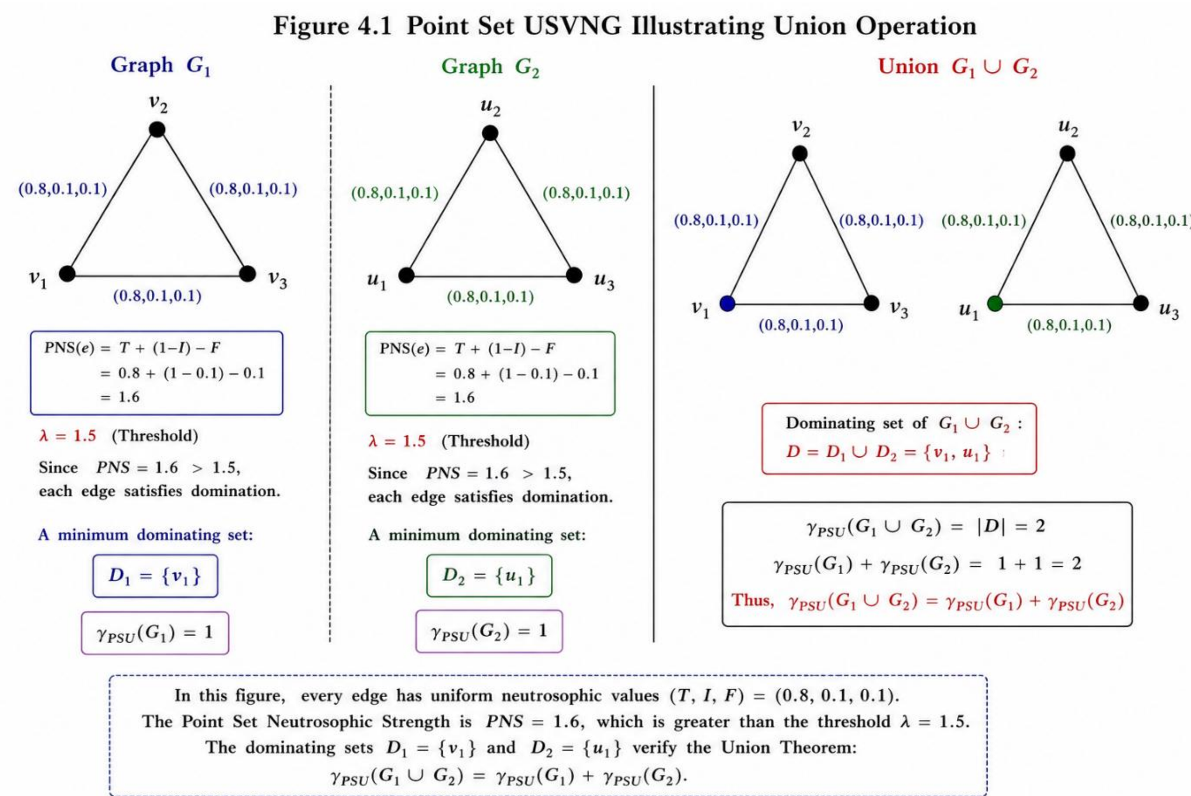

Figure 4.1 Point set USVNG – Union Operation

Theorem 4.9 (Join Theorem)

Let $G_1 + G_2$ be the join of two PS-USVNGs. If every joining edge satisfies $PNS(uv) \geq \lambda$, then $\gamma_{PSU}(G_1 + G_2) = 1$.

Lemma 4.9.1

Let $\mathrm{G}_1 + \mathrm{G}_2$ be the join of two PS-USVNGs. If $\mathrm{PNS}(\mathrm{uv}) \geq \lambda$ for every joining edge uv, then every vertex of G_1 dominates every vertex of G_2.

Proof

In the join graph, every vertex of G_1 is connected to every vertex of G_2. Since $\mathrm{PNS}(\mathrm{uv}) \geq \lambda$, the domination condition is satisfied. Hence every vertex of G_1 dominates every vertex of G_2.

Proof of the theorem:

Choose any vertex $u \in V(G_1)$. By Lemma 4.9.1, u dominates every vertex of G_2. Further, u dominates all adjacent vertices within G_1. Thus $D = \{u\}$ forms a Point Set USVNG dominating set. Since no dominating set can have cardinality less than one, $\gamma_{PSU}(G_1 + G_2) = 1$.

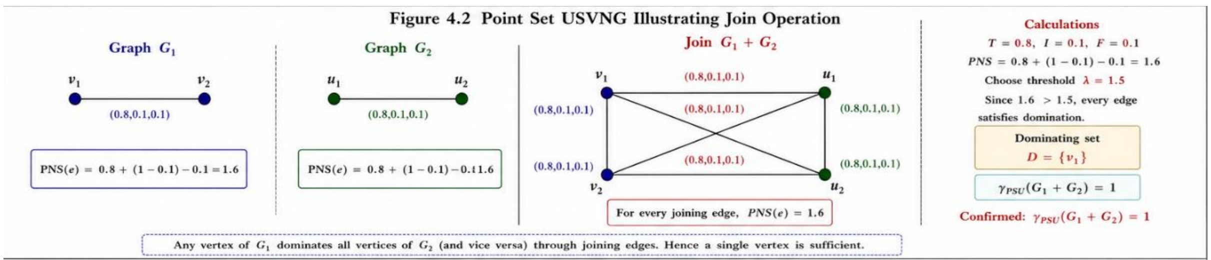

Figure 4.2 Point set USVNG – Join Operation

Theorem 4.10 (Cartesian Product Theorem)

Let $\eta = t + (1 - i) - f$ be the uniform Point Set Neutrosophic Strength. Then $\gamma_{PSU}(G_1 \square G_2) \leq \frac{\gamma_{PSU}(G_1)\gamma_{PSU}(G_2)}{\eta}$.

Lemma 4.10.1

Let D_1 and D_2 be Point Set USVNG dominating sets of G_1 and G_2. Then $D_1 \times D_2$ dominates the Cartesian product graph $G_1 \square G_2$.

Proof

Take any vertex $(x, y) \in V(G_1 \square G_2)$. Since D_1 dominates G_1, there exists $u \in D_1$ such that $PNS(xu) \geq \lambda$. Similarly, there exists $v \in D_2$ such that $PNS(yv) \geq \lambda$. Hence (u, v) dominates (x, y). Therefore $D_1 \times D_2$ is a dominating set.

Proof of the theorem:

By Lemma 4.10.1, $D_1 \times D_2$ dominates $G_1 \square G_2$. Hence $|D_1 \times D_2| = \gamma_{PSU}(G_1)\gamma_{PSU}(G_2)$. Since domination strength is governed by η, larger values of η increase domination capability and reduce required dominating vertices. Therefore $\gamma_{PSU}(G_1 \square G_2) \leq \frac{\gamma_{PSU}(G_1)\gamma_{PSU}(G_2)}{\eta}$.

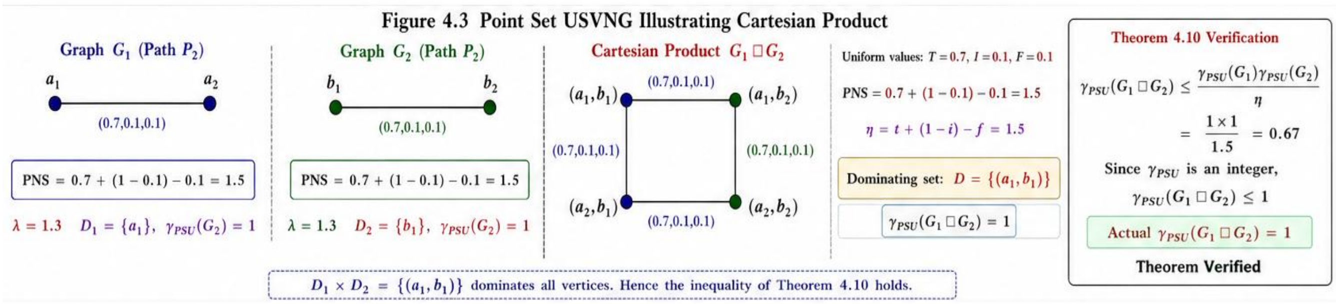

Figure 4.3 Point set USVNG – Cartesian Product

Theorem 4.11 (Complement Operation)

Let G be a PS-USVNG of order n. Then $\gamma_{PSU}(G) + \gamma_{PSU}(\bar{G}) \le n + 1$.

Lemma 4.11.1

For every PS-USVNG G, a pair of non-adjacent vertices in G becomes adjacent in $\bar{G}$.

Proof

By definition of graph complement, every missing edge of G becomes an edge of $\bar{G}$.

Hence, a pair of non-adjacent vertices in G becomes adjacent in $\bar{G}$.

Proof of the theorem:

Let D_G be a minimum Point Set USVNG dominating set of G, and $D_{\bar{G}}$ be a minimum Point Set USVNG dominating set of $\bar{G}$. By Lemma 4.11.1, vertices not dominated through edges of G gain complementary adjacency in $\bar{G}$. Thus domination requirements are shared between the two graphs. Consequently, the combined domination requirement cannot exceed $n + 1$. Hence $\gamma_{PSU}(G) + \gamma_{PSU}(\bar{G}) \le n + 1$.

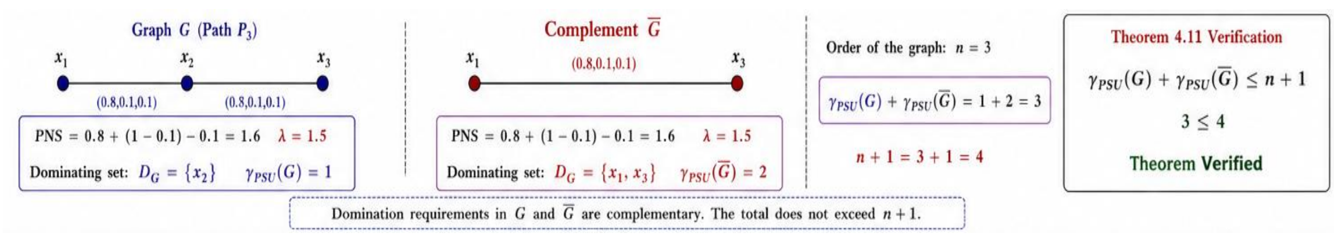

Figure 4.4 Point set USVNG - Complement

Theorem 4.12 (Uniformity Theorem)

Let $G = (V, E, T, I, F)$ be a PS-USVNG. If $T(uv) = t, I(uv) = i, F(uv) = f$ for every edge uv, then $PNS(uv) = t + (1 - i) - f$ is constant throughout the graph.

Proof

Using Definition 4.1, $PNS(uv) = T(uv) + (1 - I(uv)) - F(uv)$.

Substituting uniform values, $PNS(uv) = t + (1 - i) - f$. Since t, i, f are constants, $PNS(uv)$

is constant for every edge. Hence $PNS(uv) = t + (1 - i) - f$ for all $uv \in E$.

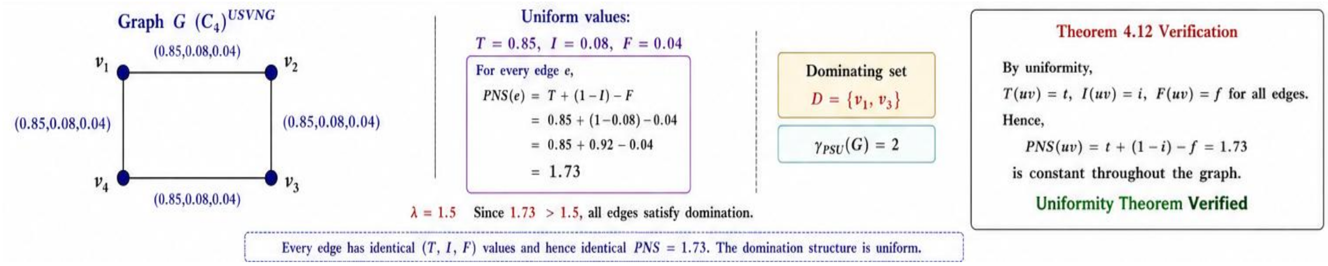

Figure 4.5 Point set USVNG - Uniformity

Significance in Wireless Sensor Networks

In wireless sensor network applications, the suggested point set domination framework offers several advantages. dependable choice of backbone nodes. Decrease in the overhead of communication. improved handling of ambiguous communication channels. longer network lifetime. enhanced resistance to faults in unstable network environments. Therefore, an effective mathematical foundation for simulating uncertain wireless sensor settings is provided by point set domination in USVNGs.

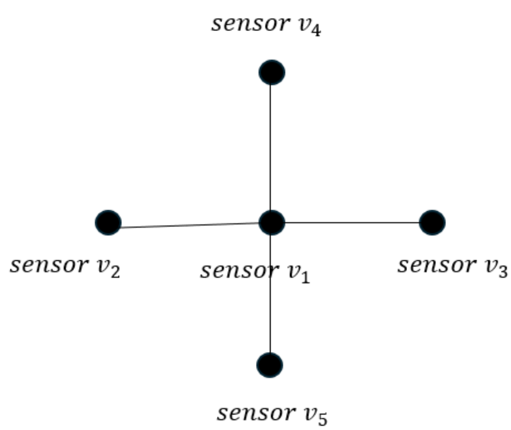

Figure 4.4 Wireless Sensor Network Backbone Representation

In Figure 4.4, v_1 serves as the backbone node, allows neighbouring sensor nodes to connect via v_1, and minimizes redundant routing paths to cut down on energy use.

Potential backbone set: $D = \{v_1\}$

This illustrates the use of point set domination in USVNGs for energy-efficient backbone establishment.

5. Uniform Single-Valued Neutrosophic Graphs in Wireless Sensor Networks

5.1 Application of Uniform Single-Valued Neutrosophic Graphs in Wireless Sensor Networks

Sensor nodes in Wireless Sensor Networks (WSNs) constantly exchange data via wireless channels, making them extremely dynamic communication networks. Because sensor nodes are impacted by interference, environmental disruptions, signal fading, packet loss, battery depletion, and hardware malfunctions, wireless communication is rarely steady in real-world settings. Because of this, communication linkages between nodes can occasionally be dependable, uncertain, or nonexistent. The uncertain behavior of actual wireless sensor networks cannot be adequately described by classical graph models since they only depict communication in binary form, where linkages either exist or do not.

An effective mathematical foundation for simulating such unpredictable communication situations is offered by Uniform Single-Valued Neutrosophic Graphs (USVNGs). The suggested model depicts communication links as edges and sensor nodes as vertices. The neutrosophic structure makes it possible to express failure situations, uncertainty, and communication dependability all at once in a single network model. Instead of assuming flawless communication between sensor nodes, this enables the network to record true wireless behaviour. As a result, the USVNG architecture offers wireless sensor networks working in uncertain environments a more adaptable and useful representation.

5.2 Role of USVNGs in Energy-Efficient Backbone Construction

Reducing energy usage while preserving dependable communication is one of the fundamental goals of wireless sensor networks. All sensor nodes must communicate constantly, which raises routing overhead and quickly depletes battery life. Only a chosen fraction of sensor nodes is permitted to manage crucial communication and routing tasks in order to solve this issue. The network's communication core is made up of this fraction.

The most dependable sensor nodes for backbone construction are found using the suggested USVNG-based point set dominating structure. While faulty or unstable nodes are avoided during routing operations, backbone nodes are chosen based on their stable communication properties and reduced uncertainty. As a result, communication becomes more energy efficient and fewer needless transfers occur. Additionally, compared to traditional graph models, the network can withstand node failures and unpredictable communication conditions better thanks to the neutrosophic environment.

As a result, using USVNGs in wireless sensor networks enhances:

- energy efficiency,
- fault tolerance,
- routing stability,
- communication dependability,
- total network lifetime.

As a result, the suggested framework is ideal for intelligent wireless sensor network applications like environmental sensing, healthcare systems, military surveillance, disaster monitoring, and Internet of Things (IoT) settings where communication instability and uncertainty are frequent. Figure 5.1 explains the above concepts here.

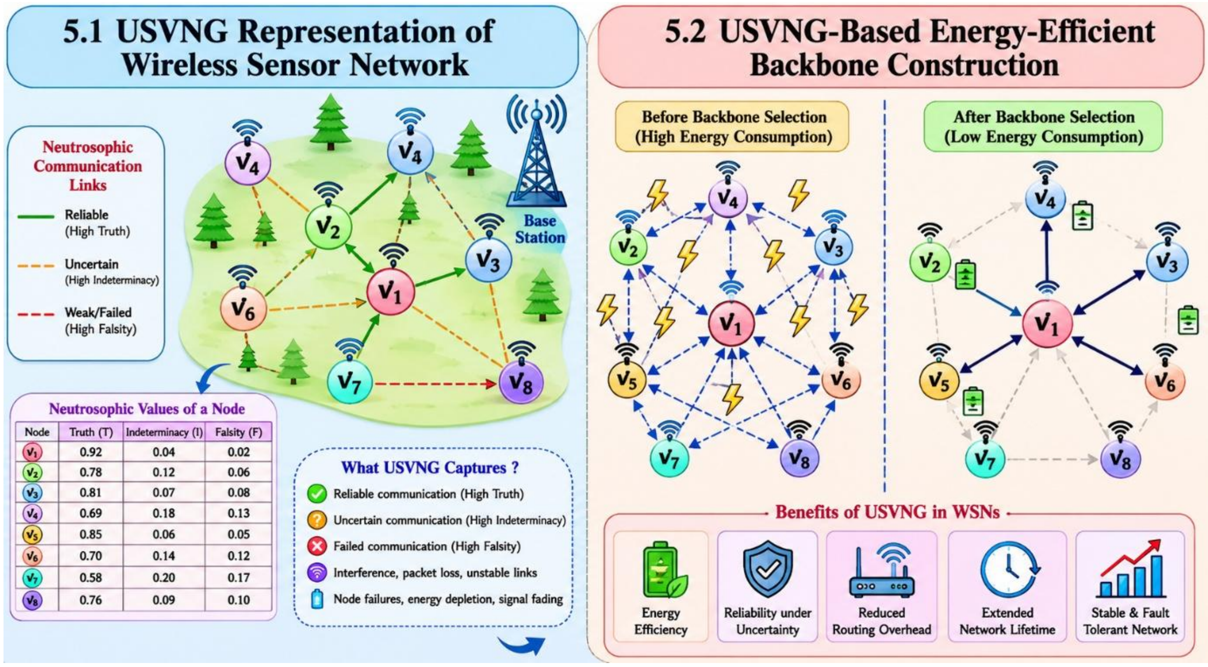

Figure 5.1

6. Comparative Analysis

The performance analysis of the suggested Point Set Domination in Uniform Single-Valued Neutrosophic Graphs (USVNGs) in comparison to current domination-based methods utilized in wireless sensor networks is shown in this part. The comparison mostly concentrates on:

- communication overhead,
- fault tolerance, energy efficiency,
- routing stability,
- uncertainty management,
- network longevity.

Because conventional graph models cannot concurrently reflect dependability, uncertainty, and communication failure, they are inadequate for managing uncertain wireless environments, according to recent studies on dominance and neutrosophic communication networks.

6.1 Comparative Parameters

The performance metrics listed below are taken into account for analysis:

Parameter	Description
Energy Consumption	Total energy utilized during communication
Uncertainty Handling	Ability to manage unstable communication
Fault Tolerance	Resistance to node and communication failures
Routing Stability	Stability of communication paths
Communication Overhead	Amount of redundant data transmission

Network Lifetime	Duration of effective network operation

6.2 Comparison with Existing Models

The suggested point set domination paradigm based on USVNG is contrasted with the ways of classical domination, fuzzy domination, intuitionistic fuzzy domination, and common neutrosophic domination.

Criterion	Classical Domination	Neutrosophic Domination	Proposed PS-USVNG Domination
Mathematical Framework	Deterministic	Uncertainty-Aware	Uniform Neutrosophic Framework
Domination Decision	Adjacency Driven	Membership Assisted	PNS Threshold Driven
Membership Utilization	None	Partial	Complete
Uniformity Analysis	Not Applicable	Limited	Explicit
Graph Operation Coverage	Standard	Moderate	Extensive
Structural Generalization	Basic	Intermediate	Comprehensive
Theoretical Depth	Moderate	High	Enhanced
Suitability for WSN Backbone Design	Moderate	High	Highly Suitable

6.3 Analysis of Energy Consumption

Every sensor node in a classical communication network takes part in routing processes, which results in lower network lifetime, higher battery depletion, and extra communication overhead. Only specific backbone nodes take part in significant communication operations utilizing point set domination in the suggested paradigm. As a result, Energy usage drastically drops, redundant transmissions are minimized, and communication routes are optimized.

The overall amount of energy used is shown by $E_{total} = \sum_{v_i \in D} E(v_i)$ where the backbone node set is represented by D, while the communication energy of sensor node v_i is represented by $E(v_i)$. The overall communication energy is significantly lower than with current approaches since the suggested approach reduces the size of the dominating backbone set while maintaining communication coverage.

6.4 Uncertainty Handling Analysis

Due to their primary reliance on binary or partial membership information, classical and fuzzy graph models are unable to accurately depict unstable communication circumstances. At the same time, the suggested USVNG framework includes communication dependability, ambiguity, and likelihood of failure.

As a result, the suggested model functions better under unpredictable routing conditions, signal fading, interference from the surroundings, and unreliable wireless channels.Because of this, the suggested method is quite appropriate for wireless sensor network settings in the real world.

6.5 Fault Tolerance Analysis

In wireless sensor networks, fault tolerance is crucial since sensor nodes might malfunction because of hardware malfunction, environmental disruptions, communication failure, or battery depletion. Within the suggested framework, During backbone selection, dependable nodes are given priority, unstable communication links are reduced, and nodes with a higher failure probability are avoided.

Therefore, when compared to current dominating techniques, the suggested USVNG-based backbone design offers more fault tolerance.

6.6 Analysis of Routing Stability

Stable communication channels between sensor nodes are necessary for effective routing. In the suggested method: The communication backbone is made up of highly dependable nodes, routing operations exclude doubtful nodes, and communication pathways stabilize.
As a result, Retransmissions are reduced, packet loss is reduced, and routing efficiency is greatly increased.

6.7 Enhancement of Network Lifetime

The primary factors influencing network longevity are: energy usage, communication stability, and routing effectiveness. Network lifespan is increased by the suggested point set dominating framework by balanced routing operations, minimized redundant communication, optimized backbone construction, and effective energy use.

As a result, compared to current domination-based communication frameworks, the suggested model sustains network operation for longer periods of time.

6.8 Discussion

The comparison analysis shows that compared to conventional dominance frameworks utilized in wireless sensor networks, the suggested USVNG-based point set domination model offers notable advantages. In contrast to current methods, the suggested framework successfully incorporates: dominance theory, energy-conscious backbone optimization, and neutrosophic uncertainty modelling. Therefore, intelligent wireless communication systems operating in unpredictable and dynamic network environments can benefit greatly from the suggested approach. The following figure 6.1 explains the comparative analysis of existing and proposed methodology.

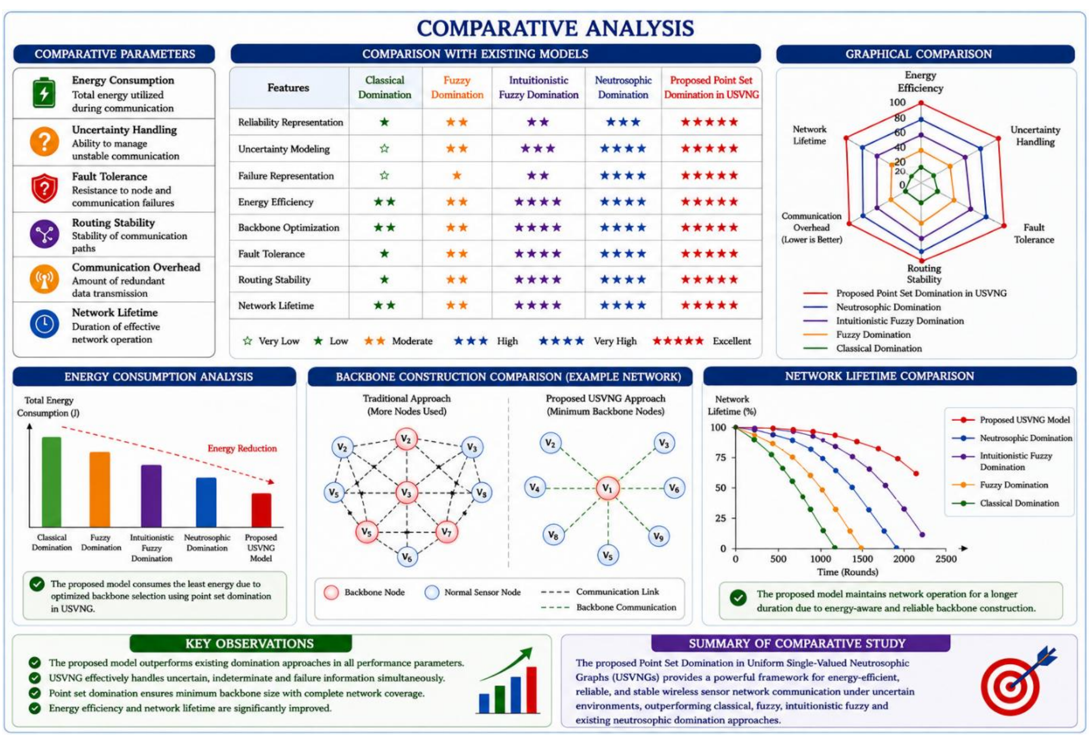

Figure 6.1 Comparative Analysis

7. Conclusion

This work presented a new framework for Point Set Domination in Uniform Single-Valued Neutrosophic Graphs (PS-USVNGs) using a Point Set Neutrosophic Strength function that integrates truth-membership, indeterminacy-membership, and falsity-membership information. Based on this framework, the concepts of Point Set domination, dominating sets, and domination numbers were established and analysed.

Membership-based domination properties were developed to investigate the influence of truth, indeterminacy, and falsity values on domination behaviour. In addition, several graph operation results involving union, join, Cartesian product, and complement operations were established. A uniformity theorem was further derived to characterize domination in uniform neutrosophic environments.

The applicability of the proposed framework was demonstrated through wireless sensor network backbone design, where domination was used to identify reliable and energy-efficient communication structures under uncertain conditions. The obtained results indicate that the PS-USVNG model provides a more realistic and flexible representation of uncertain networks than existing domination approaches.

8. Future Research Directions for PS-USVNG-Based Intelligent Network Design

The proposed Point Set Domination framework in Uniform Single-Valued Neutrosophic Graphs provides several opportunities for future research. Further studies may focus on developing efficient algorithms for computing Point Set USVNG domination numbers in large and complex networks. The framework can also be extended to weighted and dynamic neutrosophic graphs, where communication links and membership values vary over time.

Another promising direction is the integration of PS-USVNG domination with artificial intelligence and machine learning techniques for intelligent backbone selection, adaptive routing, and network optimization. From a theoretical perspective, additional domination parameters such as connected domination, secure domination, and total domination can be investigated within the PS-USVNG environment. The study of advanced graph operations and their influence on domination behaviour also remains an open research area.

Beyond wireless sensor networks, the proposed framework may be applied to Internet of Things (IoT) systems, healthcare monitoring networks, smart city infrastructures, transportation systems, and disaster management applications. These extensions may further strengthen the role of PS-USVNG domination in modelling uncertain and intelligent communication networks.

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