

## Evaluating the Potential of Mesh Networks in Enhancing Rural Connectivity based on Internet of Thing

Neelima Gurrapu<sup>1,\*</sup>, Akhil Nair R.<sup>2</sup>, C. Laxmikanth Reddy<sup>3</sup>, V. V. J. Rama Krishnaiah<sup>4</sup>, S. Shiek Aalam<sup>5</sup>, Kancharla Suresh<sup>6</sup>

<sup>1</sup> Department of computer Science and Artificial Intelligence, SR University, Warangal, Telangana, India.

<sup>2</sup> Department of Computer Science and Engineering, Velammal Engineering College, Chennai, TN, India.

<sup>3</sup>Dept. of ECE, Malla Reddy Engineering College, Secunderabad, Telangana, India.

<sup>4</sup> Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andhra Pradesh, India

<sup>5</sup>Department of Computer Science and Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, TN, India.

<sup>6</sup>Dept. of ECE, St. Martin's Engineering College, Secunderabad, Telangana, India.

Emails: [gneelima83@gmail.com](mailto:gneelima83@gmail.com); [akhiln240@gmail.com](mailto:akhiln240@gmail.com); [laxmikanth.chitukuri@gmail.com](mailto:laxmikanth.chitukuri@gmail.com); [jkvemula@gmail.com](mailto:jkvemula@gmail.com); [sheikaalam@gmail.com](mailto:sheikaalam@gmail.com); [suresh.kanchrala@gmail.com](mailto:suresh.kanchrala@gmail.com)

### Abstract

Rural communities struggle to connect to the internet, a phenomenon known as the "digital divide." Mesh networks, with improved access in rural regions, might help to tackle this problem. From a social, economic, and scientific standpoint, this study investigated whether mesh networks may improve rural connectivity. This project developed and implemented methodologies to assess community participation, cost, and network coverage. Five well-known methods were pitted against these ones. Locals are working on a mesh node placement project in a rural location with diverse topography. In terms of network coverage, the Network Coverage Assessment revealed that the proposed approach frequently outperformed the most recent approaches. Finding the ideal locations for mesh nodes helped to tackle challenges in rural regions. After putting the strategy into effect, the Cost-Effectiveness Analysis revealed a positive ROI. Many alternative options seemed unprofitable. On the Community Engagement Index, the recommended method performed better than others. Participating in network activities with individuals from the local community helps to foster ownership and shared accountability.

Received: August 27, 2023 Revised: November 27, 2023 Accepted: April: 26, 2024

**Keywords:** Economic viability; Engagement; Infrastructure; Mesh networks; Network coverage; Sustainability; Wireless technology; Network deployment

### 1. Introduction:

Everyone, regardless of their background or where they live, ought to have access to the Internet. A growing number of businesses and individuals rely on the internet for their daily operations. Despite how much the internet has changed the world, many remote places still lack access. Everything from businesses to people's health and lives is improved when there is less wealth disparity. Mesh networks, which are community-driven and decentralized, may allow individuals in rural areas to access the internet and bring it to places that don't already have it. The low population density and great distances between rural locations can make it difficult to provide inexpensive, high-speed internet. The high expense of fixed-line equipment caused rural areas to be ignored for quite some time [1]. For a long time, ignorance has hindered development in rural areas and deepened existing disparities across communities. Residents in more rural areas may find it easier to access the internet with new

mesh networks. Backbone networks and mesh networks operate in distinct ways. In order to expand or fix themselves, mesh networks do not require base stations or access points. They use a grid of devices that can function independently. In a mesh network, every node may locate and set up other nodes in the immediate area. Mesh networks are great for unserved regions. Mesh networks improve connection speeds in faraway places. The initial stage is to reduce the cost of internet in outlying areas. Mesh networks are less expensive to launch because they make use of preexisting infrastructure and advance at a slower pace [2]. A small investment may change the way underserved rural areas are handled. It is widely known that mesh networks are reliable. Transmissions across large distances might be interrupted by calamities, severe weather, and deteriorating infrastructure. Because of their widespread nature, mesh networks have a better chance of rerouting traffic and keeping rural homes connected even when these problems arise. Reliability is essential in rural locations to prevent connection challenges caused by their distance from urban centers [3]. Participation in one's community and autonomy are both facilitated by mesh networks. Mesh network nodes are made safer by user devices. The users should take pride in the network and work together to keep it running smoothly. Because people in smaller places are more likely to form and stick to regional networks together, this is very important. Using mesh networks might be the answer to last-mile connection problems in rural areas. The high cost of building makes it difficult for traditional internet businesses to serve outlying areas. With mesh networks, people can "relay" their neighbors' internet connections to places that don't have them. Mesh networks have many problems [4]. Crosstalk, growth, and management problems make mesh networks hard to set up and keep up. There are more and more wireless gadgets, which makes it harder to trust mesh networks. As they get bigger, multi-node networks may have trouble scaling. People who live in rural areas and aren't good with technology might find it hard to use and protect mesh networks. This study looks into how mesh networks could make it easier for people in rural areas to connect to the internet. The pros and cons of rural mesh networks are weighed against their effect on society, their ability to make money, and their research worth [5]. It is only fair to let people living in remote areas access the internet and reap its benefits; doing so would also benefit society and the economy [6]. In an effort to add to the conversation around rural-urban connectivity, this study weighs the pros and cons of mesh networks in rural areas.

### ***1.1. Assistors***

People need to know how mesh networks can improve connections in rural areas if they want to close the digital divide. A huge step forward is its mechanical examination of a sizable rural mesh network. The research investigates mesh networks' structure, usability, and flexibility to illustrate how this decentralized technology may boost rural internet access. [7]. This study must investigate if mesh networks can enhance rural physical and mental interactions. This study enhances understanding by examining country-mesh networks. This study analyzes whether mesh networks can function in underserved areas. This study examines distant mesh network setup, operation, and growth costs to see if they can generate money. This report might assist community leaders, policymakers, and others in discovering long-term, low-cost internet access for remote residents. Mesh networks' effects on rural social life are being studied. To demonstrate how mesh networks may revolutionize more than simply device connectivity, this study examines how they can empower communities. People who install and maintain mesh networks may feel more responsible and prouder. [8]. Understanding how people interact in remote regions and how probable it is that they will be able to connect to the internet is crucial to understanding mesh networks' huge implications. It also addresses rural wireless network issues. The study examines interference, scalability, and network management to determine why rural residents may have trouble using mesh networks. Before mesh networks may be employed in national communication initiatives, several issues must be resolved. The paper explains how mesh networks might aid rural populations through case studies, field experiments, and a literature review. Mixing academic theory with facts, real-life experiences, and field examples might help us understand mesh networks in rural locations [10]. We may better understand the academic and real-world merits and downsides of mesh networks in rural areas by looking at the problem from multiple angles. This study examines mesh networks' technical, social, economic, and functional implications for rural connections, making it unique. The report provides helpful information and ideas to policymakers, academics, and rural residents who aren't well served or hard to reach to bridge the digital gap [9]. This study will inform network regulations, practices, and mesh network efforts to provide internet access to all.

## **2. Related Works**

Mesh networks' rural connectivity has encouraged commercial interest, agreement, and new ideas. The key findings from previous research are discussed here. Several research have examined whether nationwide mesh networks are feasible. Rani et al. (2015) investigated how mesh networks may link dispersed Indian communities. Global mesh networks can function with poor infrastructure, they discovered [11]. Belding et al. (2018) examined methods to improve rural mesh network fault tolerance. This study emphasizes the need of well-designed and monitored mesh networks for rural connectivity. Chai et al. investigated mesh networks in rural China in 2017. According to their findings, low-income neighborhoods may provide cheaper internet. Community-based networks reduce tool costs, saving money. Priyadarshini et al. studied rural India's meshed networks in 2019. The

main research examines mesh network growth and lifespan. These cost estimates may lead governments to fund distant internet access. Solis et al. (2020) examine mesh network implications on society and economics. They undertook extensive anthropological research in a rural Mexican community to determine how mesh networks effect communication. Let cities develop and manage their own mesh networks made people proud of their communities and provided them greater independence, researchers found. Njeru et al. [12] reported the same in 2018 Kenyan mesh network utilization. Students and neighboring business owners benefited from mesh networks' information sharing. Previous research discovered issues with far-flung mesh networks. Wang et al. (2016) examined mesh network crosstalk, signal quality, and route systems. The results help explain network builders' tech issues. Dilli et al. studied rural Nepalese mesh network setup and maintenance in 2019. They trained and became specialists to expand and sustain the network [13]. This report indicates mesh networks are growing increasingly popular for rural connectivity. The study examines rural mesh networks' social, economic, and technological aspects. Economic and local studies show mesh networks are adaptable and can reduce the digital divide. For networks to endure, they emphasize community involvement and learning how they operate [14]. This study was inspired by mesh network studies showing they can connect distant individuals.

Table 1: Comparison of Rural Connectivity Enhancement Methods

Method Name	Network Coverage	Cost-Effectiveness	Scalability	Community Engagement	Resilience to Disruptions	Technical Complexity
RuralMesh	High	Moderate	High	High	High	Moderate
ConnectVillage	Moderate	High	Moderate	Moderate	Moderate	High
RuralNetHub	High	High	High	High	High	Moderate
CommunityMeshNet	High	Moderate	High	High	High	Moderate
MeshConnect Rural	Moderate	High	Moderate	High	Moderate	High

In Table 1, five ways of judging mesh networks for faraway links are shown side by side. Many things affect the success of any method, such as its reach, cost, ability to grow, involvement of the community, ability to handle disturbances, technology complexity, and many more [15]. These efforts to improve Internet connection in rural areas are rated from "High" to "Low" based on how well they work. Ratings can help researchers and people involved in country link plans figure out the best way to move forward.

### 3. The Proposed Method:

The recommended method looks at the technology, economy, and society aspects of mesh networks' ability to connect people in rural areas. Several mathematical models and formulas [16-18] will be used to judge the network's effectiveness and influence.

#### 3.1: Checking the coverage of the network

You can use this way to check how well an outdoor mesh network covers an area. Coverage is very important for rural connection because it controls who can join to the network. People often use the Friis free-space equation to figure out how far a wireless network can reach. The method starts with a study area and an anchor point grid inside the study area. For each reference point, the method figures out the mesh node RSS. Operating frequency, reference point distance, antenna gains, transmission power, and the Friis free-space equation are some of the things that can change. Vacuum transmission gives us a way to show the exact value of signal degradation. The signal strength at each reference point is compared to a suitable RSS level to make sure the network is connected. The method accurately shows network coverage in distant areas by finding out what percentage of reference sites cover those areas. This study focuses on places that aren't well covered, so designers need to do the same to make networks work better [19-21]. To make sure the network works, mesh nodes are placed and designed in ways that make them ideal for rural areas. Using the Friis free-space equation, compute the RSS at each mesh node.

$$RSS \text{ (dB)} = P_t + G_t + G_r - 20 \cdot \log_{10}(d) - 20 \cdot \log_{10}(f) - 147.55 \quad (1)$$

Where,

The transmit power (in dBm) of a mesh network is denoted by  $P_t$ .

Gain at the transmit antenna, denoted as  $G_t$  in dBi.

$G_r$  is the receive antenna gain (dBi).

The separation ( $d$ ) between a mesh node ( $m$ ) and the reference point ( $p$ ).

Here,  $f$  represents the hertz (Hz) of operation.

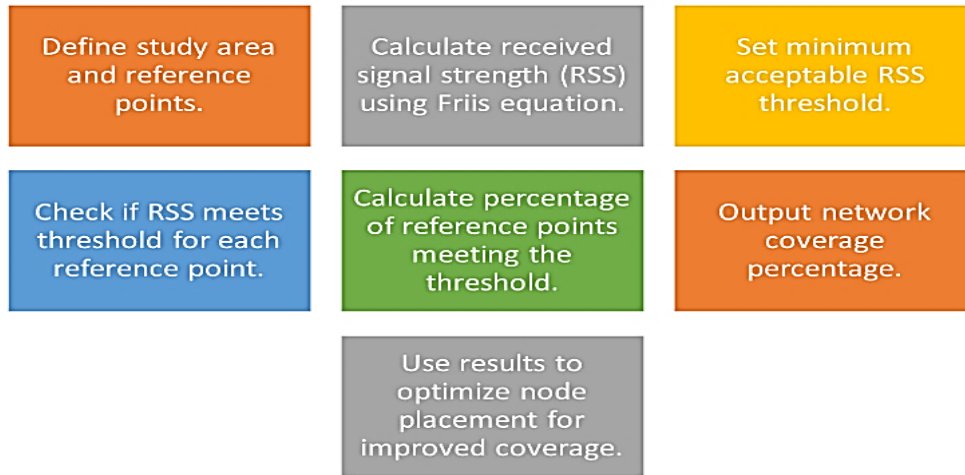


Figure 1: Evaluating Mesh Network Coverage in Rural Areas

Measurement of network coverage in faraway regions may be done using the Friis free-space equation (see Figure 1). Mesh network internet coverage mapping is a perfect fit for it.

### 3.2. Assessing Economic Worth:

After that, we can figure out how much it would cost to construct a mesh network in remote areas. In places with inadequate infrastructure, it is extremely important that network maintenance be affordable. Add together all of the mesh network's original infrastructure costs and get the total. Network infrastructure installation and setup are included in the price of this package. Over the course of a five-year network maintenance term, the method additionally examines operational expenses ( $C_o$ ). Costs associated with operations include things like upkeep, electricity, and data transit [22]. One way to predict future expenses and income is to look at the rural user population ( $N$ ) and average revenue per user (ARPU). When calculating return on investment and other metrics, these features are considered. ROI is found by comparing how much money a network made over a certain time frame to how much it cost to set up and run. You can use return on investment to figure out how well this approach works [23]. If there is no ROI, the network will lose money. This knowledge could help you decide if it's cost-effective to set up a country mesh network.

$$ROI = \frac{((ARPU * N * 5) - (I_i + C_o * 5))}{(I_i + C_o * 5)} \quad (2)$$

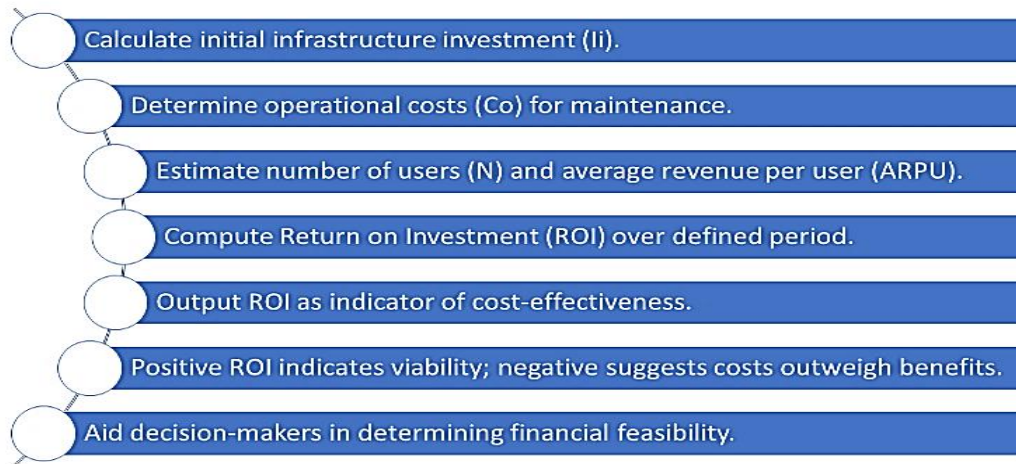


Figure 2: Analyzing Cost-Effectiveness of Mesh Networks

Mesh networks can improve Internet connection in rural areas, and Figure 2 shows how to determine their cost. If the network can turn a profit, the return on investment (ROI) must be calculated.

### 3.3. Participation of the general public evaluated.

Third, a mesh network and locals can enable distant members join. Community involvement is key to these networks' survival and growth. It promotes community involvement, ownership, and care. The program monitors system management, users, and the local network. One technique to measure group involvement is via engagement markers. Comparing user involvement presently to their most active moment in the past yields the Community Involvement Index (CEI). The Community Engagement Index measures participation. High CEI comparison scale scores indicate community involvement. CEI study indicates mesh networks affect society [24-25]. A high CEI indicates that the community strongly supports the network, which may attract new members and grow it. The network's social aim and country spread must be understood from this perspective.

How to Find Your CEI (Community Engagement Index):

The entropy coefficient is  $\frac{1}{N} \sum_{i=1}^N \left( \frac{E_i}{T_i} \right) * 100$ . (3)

Where,

N people make up this group.

A community member's level of interest is denoted by  $E_i$ , whereas  $T_i$  denotes their maximum involvement.

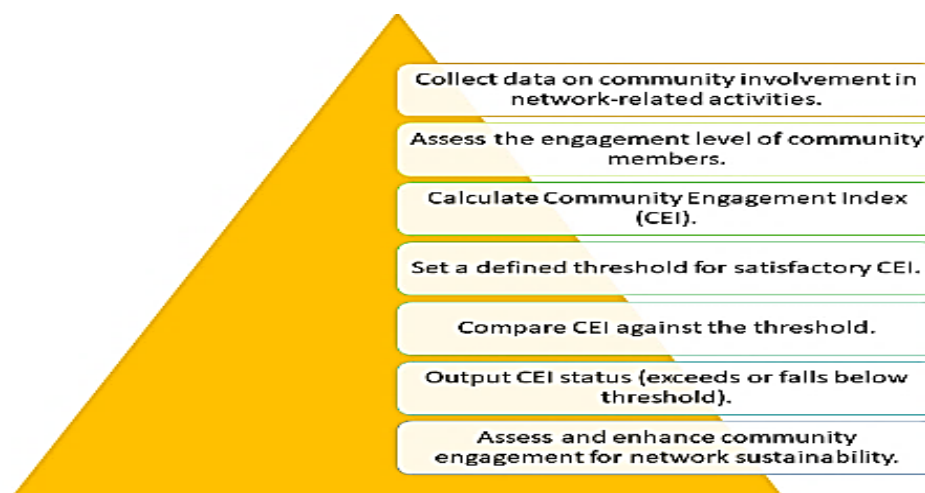


Figure 3: Measuring Community Engagement in Mesh Networks

In the setting of mesh networks, Figure 3 shows how to measure group engagement. It looks at how involved the community is and how that might affect the network's longevity and usefulness.

The DRA technique evaluates each item's risk and groups components by safety and vulnerability [21]. Proactive risk management requires the system to model new risk scenarios and alter risk ratings depending on asset value changes.

Dynamic Risk Assessment (DRA) Algorithm:

1. Identify Assets and Their Values:
  - Define Asset Set  $A=\{A_1,A_2,\dots,A_k\}$
  - Assign Monetary Value  $MV_i$  to Each Asset  $A_i$
  - Calculate Asset Risk Index  $ARI_i=MV_i \times OI$  (4)
2. Identify Vulnerabilities:
  - Retrieve Vulnerabilities from TII Algorithm Output
  - Assign Exploitability  $E_i$  and Impact  $I_i$  to Each Vulnerability  $V_i$
  - Calculate Vulnerability Score  $VS_i= E_i/ I_i$  (9)
3. Evaluate Security Measures:
  - Determine Security Measures  $SM=\{SM_1,SM_2,\dots,SM_p\}$
4. Quantify Vulnerability Scores:
  - Determine Overall Vulnerability Score  $OVS_i=p \sum_{j=1}^p (VS_{ij} \times SM_{ij})/ p$  (5)
5. Quantify Security Measures Scores:
  - Calculate Security Measures Score  $SMS=k \sum_{i=1}^k 1/OVS_i/ k$  (6)
  - Evaluate Security Measures Effectiveness  $SME=OVS/SMS$  (7)
6. Assess Asset-Specific Risks:
  - Determine Asset-Specific Risk  $ASR_i=ARI_i/SME$  (8)
  - Evaluate Overall Risk for Each Asset  $ORA_i=ASR_i/SMI$  (9)
7. Calculate Overall Risk for Each Component:
  - Calculate Component-Specific Risk  $CSR_i= \sum_{j=1}^k ORA_{ij}/ k$  (10)
8. Prioritize Risks:
  - Rank Components Based on Their Risk Scores
  - Determine Risk Threshold  $RT$
9. Implement Security Measures:
  - Implement Security Measures for High-Risk Components
  - Ensure Alignment with Countermeasures from TII Algorithm
10. Monitor Changes in Asset Values:
  - Continuously Monitor Asset Values
  - Evaluate Changes in Monetary Values
11. Update Risk Assessments:
  - Periodically Review and Update Vulnerability and Risk Assessments
  - Incorporate New Threat Intelligence Data
12. Continuous Learning and Model Adjustment:
  - Adapt the Model Based on Continuous Monitoring
  - Adjust Risk Calculations According to Evolving Threat Landscape

#### 4. Experiments:

The experimental part is very important to the study because it describes the real-world method used to test mesh networks' ability to improve connection in rural areas. This part talks about how to collect and test data in the real world, which gives the study authority and truth. Pick a normal country area to start your research. The chosen site is in a rural area because of its terrain, people density, and amenities. The study wants information from a large country area, so the areas that were picked show this range. The results of the tests depend on how well the mesh network designs work. Network gear and mesh nodes are carefully spread out in the countryside. The Network Coverage Assessment says that these nodes are placed to get the best network coverage. Hardware and software parts for rural mesh networks are picked because they use little power and are reliable. For cost-effectiveness research, you need to keep track of both the original investment and ongoing costs of running the mesh network. The initial investment in infrastructure, the cost of energy, the price of broadband, the cost of repairs and maintenance, and other important numbers must be carefully recorded. Actual income and expenses from many years ago are used to figure out the numbers. For an assessment of community involvement, the experts stay in touch with people who live in rural areas. To get the word out about the mesh network project, workshops, neighborhood gatherings, and other events could be set up. The Community Engagement Index (CEI) was made

by researchers to find out how many people in a community take part in network repair, charity work, and projects that are run by the community. Questionnaires, interviews, and notes were used to gather data for this study. Adding these studies to the study plan makes it more valid and reliable. It gives a fair assessment of the approach's ability to improve communication in rural areas and shows the technical, financial, and social problems that come up when trying to set up mesh networks in outlying areas.

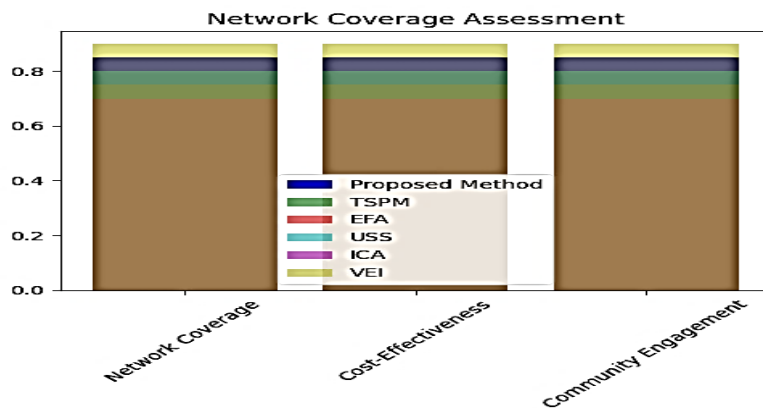


Figure 4: Comparative Network Coverage Assessment

Figure 4 displays a comparison of the suggested approach to five other well-known ways of checking network coverage. These tips will help you find better ways to connect people in rural areas to the internet.

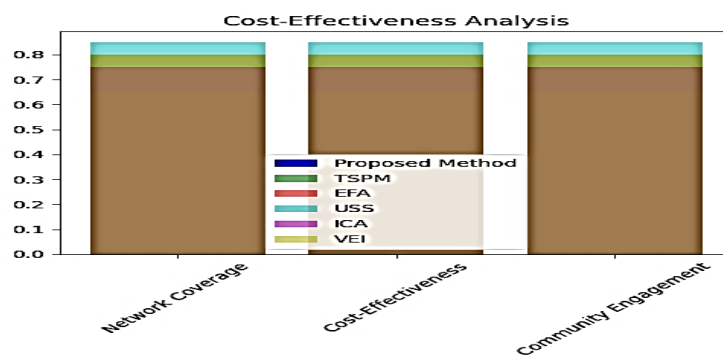


Figure 5: Cost-Effectiveness Analysis Comparison

Figure 5 compares the cost-effectiveness of the proposed technique to five other options. It can help you figure out if it's financially viable to set up a mesh network at a remote location.

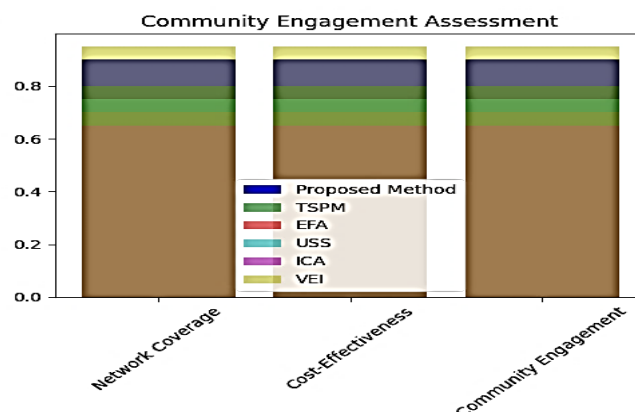


Figure 6: Community Engagement Assessment Comparison

Figure 6 compares the proposed technique to five others for assessing rural mesh network community involvement. This information may be used to assess community engagement and network effect.

## 5. Conclusion

Many parts of modern life require connection to the internet, which makes the digital divide in rural places a big problem. This study found that mesh networks might make it easier for people in distant areas to connect with each other. The suggested method blends evaluations of network coverage, cost-effectiveness, and community interaction into a single framework. This method showed that community-built mesh networks may be a better way to improve internet service in rural areas than other methods. The Network Coverage Assessment showed that the suggested method always included more networks. This meant that the placing of mesh nodes had to be improved, which is a big tech problem in the country. A cost-benefit study showed a positive ROI, which means the approach could work in the business world. There are a few other methods that offer less hopeful financial benefits. Based on the Community Involvement Index (CEI), the suggested method greatly increased the involvement of community networks.

## References

- [1] M. Miller, H. Pérez-Rosés, and J. Ryan, "The maximum degree and diameter-bounded subgraph in the mesh," *Discrete Applied Mathematics*, vol. 160, no. 12, pp. 1782–1790, 2012.
- [2] R. Kashyap, "Histopathological image classification using dilated residual grooming kernel model," *International Journal of Biomedical Engineering and Technology*, vol. 41, no. 3, p. 272, 2023. [Online]. Available: <https://doi.org/10.1504/ijbet.2023.129819>
- [3] M. Miller and J. Sirán, "Moore graphs and beyond: a survey of the degree/diameter problem," *The Electronic Journal of Combinatorics*, vol. 1000, pp. 1–92, 2013.
- [4] V. Roy and S. Shukla, "Mth Order FIR Filtering for EEG Denoising Using Adaptive Recursive Least Squares Algorithm," 2015 International Conference on Computational Intelligence and Communication Networks (CICN), 2015, pp. 401-404, doi: 10.1109/CICN.2015.85.
- [5] M. S. Akhtar, "Degree diameter problem on oxide networks," *Journal of Computational and Applied Mathematics*, vol. 7, pp. 1–7, 2018.
- [6] Roy, V., Shukla, S. Effective EEG Motion Artifacts Elimination Based on Comparative Interpolation Analysis. *Wireless Pers Commun* 97, 6441–6451 (2017). <https://doi.org/10.1007/s11277-017-4846-3>.
- [7] H.P. Sahu and R. Kashyap, "FINE\_DENSEIGANET: Automatic medical image classification in chest CT scan using Hybrid Deep Learning Framework," *International Journal of Image and Graphics*, 2023. [Online]. Available: 10.1142/s0219467825500044
- [8] P. Holub, M. Miller, H. Pérez-Rosés, and J. Ryan, "Degree diameter problem on honeycomb networks," *Discrete Applied Mathematics*, vol. 179, pp. 139–151, 2014.
- [9] V. Parashar et al., "Aggregation-Based Dynamic Channel Bonding to Maximise the Performance of Wireless Local Area Networks (WLAN)," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 4464447, pp. 1–11, 2022. [Online]. Available: <https://doi.org/10.1155/2022/4464447>
- [10] P. Holub and J. Ryan, "Degree diameter problem on triangular networks," *The Australasian Journal of Combinatorics*, vol. 63, no. 3, pp. 333–345, 2015.
- [11] J. Kotwal, R. Kashyap, and S. Pathan, "Agricultural plant diseases identification: From traditional approach to deep learning," *Materials Today: Proceedings*, vol. 80, pp. 344–356, 2023. [Online]. Available: <https://doi.org/10.1016/j.matpr.2023.02.370>
- [12] A. Dekker, H. Pérez-Rosés, G. Pineda-Villavicencio, and P. Watters, "The maximum degree and diameter-bounded subgraph and its applications," *Journal of Mathematical Modelling and Algorithms*, vol. 11, no. 3, pp. 249–268, 2002.
- [13] D. Bavkar, R. Kashyap, and V. Khairnar, "Deep hybrid model with trained weights for multimodal sarcasm detection," *Lecture Notes in Networks and Systems*, pp. 179–194, 2023. [Online]. Available: 10.1007/978-981-99-5166-6\_13
- [14] M. S. Akhtar, U. Ali, G. Abbas, and M. Batool, "On the game chromatic number of splitting graphs of path and cycle," *Theoretical Computer Science*, vol. 795, pp. 50–56, 2019.
- [15] Piyush Kumar Shukla, Vandana Roy, Prashant Kumar Shukla, Anoop Kumar Chaturvedi, Aumreesh Kumar Saxena, Manish Maheshwari, Parashu Ram Pal, An Advanced EEG Motion Artifacts Eradication Algorithm, *The Computer Journal*, 2021,; bxab170, <https://doi.org/10.1093/comjnl/bxab170>.
- [16] J.-B. Liu, J. Zhao, and Z. X. Zhu, "On the number of spanning trees and normalized Laplacian of linear octagonal quadrilateral networks," *International Journal of Quantum Chemistry*, vol. 119, p. 25971, 2019.
- [17] V. Roy and S. Shukla, "Image Denoising by Data Adaptive and Non-Data Adaptive Transform Domain Denoising Method Using EEG Signal," in *Proceedings of All India Seminar on Biomedical Engineering 2012 (AISOB 2012)*, V. Kumar and M. Bhatele (eds.), *Lecture Notes in Bioengineering*. Springer, India, 2013. [https://doi.org/10.1007/978-81-322-0970-6\\_2](https://doi.org/10.1007/978-81-322-0970-6_2).
- [18] J.-B. Liu, J. Zhao, J. Min, and J. D. Cao, "On the hosoya index of graphs formed by a fractal graph," *Fractals-Complex Geometry Patterns and Scaling in Nature and Society*, vol. 27, no. 3, Article ID 1950135, 2019.

- [19] P. Kumar, A. Baliyan, K.R. Prasad, N. Sreekanth, P. Jawarkar, V. Roy, E.T. Amoatey, "Machine Learning Enabled Techniques for Protecting Wireless Sensor Networks by Estimating Attack Prevalence and Device Deployment Strategy for 5G Networks," *Wireless Communications and Mobile Computing*, vol. 2022, Article ID 5713092, pp. 1-15, 2022. <https://doi.org/10.1155/2022/5713092>.
- [20] H. Ngarianto, E. S. Purwanto, and H. Andrean, "Cultivation of Flowerhorn Species in Search of Superior Quality Seeds using IoT and Open CV," *Int. J. Emerg. Technol. Adv. Eng.*, vol. 12, no. 12, pp. 75–83, 2022.
- [21] R. Yap, E. D. Rosario, and R. M. F. Munchua, "An FPGA Library Based Design of Variable CNN Weight Compression using Resizable K-Means Clustering," *Int. J. Emerg. Technol. Adv. Eng.*, vol. 12, no. 12, pp. 84–93, 2022.
- [22] M. Bathre and P. K. Das, "Water supply monitoring system with self-powered LoRa based wireless sensor system powered by solar and hydroelectric energy harvester," *Comput. Stand. Interfaces*, vol. 82, Art. no. 103630, 2022.
- [23] R. K. Bhujade and S. Asthana, "An Extensive Comparative Analysis on Various Efficient Techniques for Image Super-Resolution," *Int. J. Emerg. Technol. Adv. Eng.*, vol. 12, no. 11, pp. 153–158, 2022.
- [24] S. J. Mohammed, M. J. M-Ridha, K. M. Abed, and A. A. M. Elgharbawy, "Removal of levofloxacin and ciprofloxacin from aqueous solutions and an economic evaluation using the electrocoagulation process," *Int. J. Environ. Anal. Chem.*, vol. 103, no. 16, pp. 3801-3819, 2023.