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Brief communication

Wireless Sensor Networks in Chemistry: Innovations in Real-Time Monitoring for Enhanced Sustainability

SUNEELA KALLAKUNTA* and ALLURI SREENIVAS

Department of Electrical, Electronics and Communication Engineering, GITAM (Deemed to be University), Visakhapatnam, Andhra Pradesh, India.
*Corresponding author E-mail: suneelakallakunta@gmail.com

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ABSTRACT

This study provides an in-depth analysis of critical nodes within Chemistry-Related Wireless Sensor Networks, comprising 20 nodes. The research employed a detailed evaluation using a range of centrality metrics, including local (degree centrality) and global (betweenness, closeness, and Eigenvector centrality) measures. Based on these metrics, nodes were ranked on a scale of 1 to 10, reflecting their relative importance within the network's hierarchy. This exhaustive examination enhances our comprehension of wireless sensor networks, offering crucial insights that aid in network optimization, designing effective strategies, and making well-informed decisions.

Keywords: Graph theory, Centralities, Chemistry-Related Wireless Sensor Networks, Node Rankings.

INTRODUCTION

Wireless Sensor Networks (WSNs) have emerged as a cornerstone in chemistry, offering groundbreaking innovations that impact various sectors, from environmental monitoring to industrial process control and healthcare. These networks consist of autonomously functioning sensors that are spatially distributed, each boasting advanced capabilities in sensing, computing, and communication. These sensors are strategically deployed to monitor critical chemical parameters, making them indispensable in gathering and analysing data. In chemistry, WSNs find applications in diverse fields, enhancing research and operational efficiency. For example, in environmental monitoring, WSNs track vital indicators such as air quality in cities and heavy metal concentrations in rivers, providing essential data that helps assess environmental health and ensures public safety. These networks span various ecosystems, from bustling urban centers to isolated wilderness areas, offering continuous and real-time monitoring capabilities. By accurately measuring pollutants and environmental conditions, WSNs provide insights into ecological dynamics, helping track pollution sources and studying the effects of climate change on natural habitats. In industrial applications, WSNs meticulously monitor complex chemical processes at petrochemical plants or pharmaceutical factories, tracking everything from reactor temperatures to solvent flow rates[1,2]. This constant vigilance ensures that production processes adhere to safety standards and quality controls, optimizing output while minimizing waste and energy consumption. For instance, in chemical plants, WSNs can detect abnormal increases in pressure or temperature, triggering alerts to prevent accidents and maintain operational safety. WSNs play a pivotal role in chemical inventory management in laboratories and manufacturing settings. They track volatile organic compounds' usage and storage conditions, ensuring safe handling and compliance with environmental regulations. Integration with Laboratory Information Management Systems and Enterprise Resource Planning systems automates and optimizes workflows, enhances inventory visibility, and promotes efficient resource utilization[3,4]. Moreover, WSNs act as advanced early warning systems, quickly identifying hazardous conditions like gas leaks or unstable chemical reactions, thereby preventing potential industrial disasters. In scenarios where immediate human intervention is risky or impossible, such as monitoring radioactive substances or biohazard environments, WSNs provide a crucial layer of security. In more inaccessible or dangerous environments, WSNs function as remote scientific explorers. For instance, they monitor volcanic emissions in remote islands or track pollutant dispersal in disaster zones, gathering data vital for scientific research and informing policy decisions for environmental preservation and disaster response. WSNs facilitate a transformative shift toward personalized medicine in healthcare, particularly in medical chemistry. Wearable sensors and implantable devices monitor vital patient metrics, such as glucose levels in diabetics or cardiac rhythms in heart patients, enabling tailored treatment plans and improving patient outcomes. These devices, integrated within WSNs, ensure continuous monitoring, crucial for critical care and chronic condition management. Furthermore, within research laboratories, WSNs speed up data collection and analysis, enabling scientists to observe chemical reactions in real-time[5,6]. This capability is instrumental in fields such as synthetic chemistry and materials science, where understanding reaction dynamics can lead to discovering new materials or drugs. By fostering data sharing and collaboration, WSNs help scientists tackle complex interdisciplinary challenges more effectively[7,8].

Optimizing Chemistry-Related Wireless Sensor Networks: Identifying Key Nodes through Centrality Measures

Achieving optimal efficiency in WSNs designed for chemical applications hinges on identifying key nodes by applying graph theory and centrality measures[9,10]. Nodes represent sensors placed to monitor specific chemical parameters, while edges symbolize the communication links that facilitate data exchange. Centrality measures such as Degree (DC), Betweenness (BC), Closeness (CC), and Eigenvector (EVC) centrality are crucial for evaluating the significance of individual nodes within the network.

Degree centrality, for example, may highlight a node positioned at a critical junction in a manufacturing process, such as where raw materials are combined in a pharmaceutical plant, impacting overall production flow. Betweenness centrality can identify nodes that act as crucial communication bridges in a sprawling industrial complex, ensuring an efficient relay of safety alerts across the network. Closeness centrality might emphasize nodes in a densely packed laboratory environment, where rapid dissemination of contamination alerts is critical. Eigenvector centrality offers insights into nodes that, although not centrally located, influence key processes due to their connectivity to other significant nodes.

Understanding these metrics allows stakeholders to pinpoint essential nodes that perform critical functions such as real-time data collection, transmission, and analysis. This understanding not only aids in resource allocation but also ensures network resilience and robust performance, facilitating the integration of WSNs into complex chemical processes and thus driving efficient, safe, and optimized operational outcomes.

Chemistry-Related Wireless Sensor Network with 20 nodes

This research article explores the dynamics of a Chemistry-Related WSN consisting of 30 nodes. Our study delves into the critical task of identifying key nodes within the network by employing advanced centrality measures to assign rank nodes based on their importance. Drawing upon the rich framework of graph theory, we analyze the intricate interconnections between sensors deployed in a chemical environment, recognizing the pivotal role of specific nodes in facilitating data collection, transmission, and processing. By integrating centrality analysis into our investigation, we aim to provide valuable insights into optimizing network performance and enhancing the efficiency of chemical processes. Through meticulous examination and ranking of nodes, our study sheds light on the strategic allocation of resources and the establishment of resilient communication pathways essential for the seamless operation of WSNs in chemistry-related applications. Our findings contribute to the growing body of knowledge in the field, offering practical guidance for researchers and practitioners in designing and managing WSNs for monitoring and control in chemical environments.

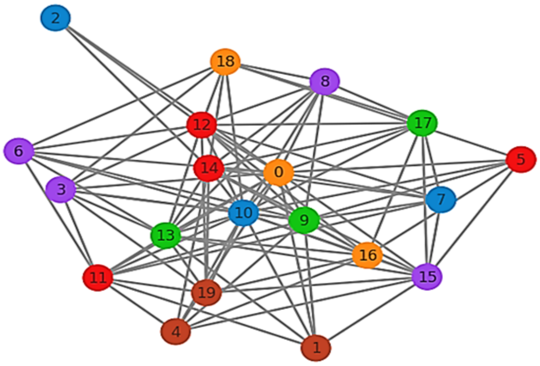
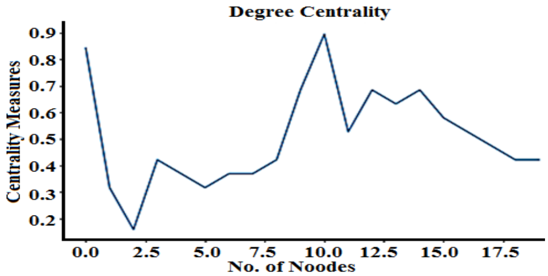
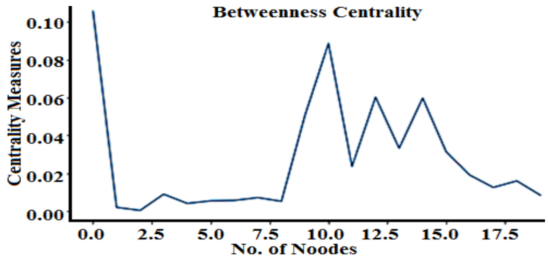
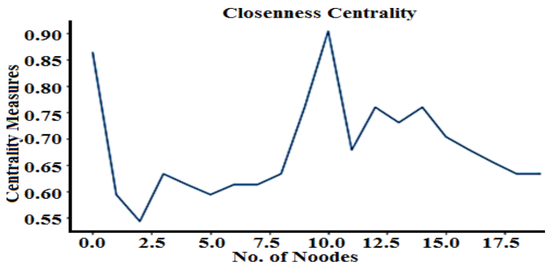


Fig. 1. Graphical Representation of a Wireless Sensor Network Comprising 20 Nodes







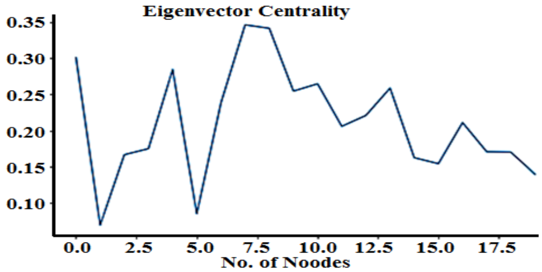


Fig. 2. Graphical Representation of Centrality Measures in a 20-Node Network as Shown in Figure 1

Table 1: Node rankings based on network centrality measures in a 20-Node Network as Shown in Figure 1

Rank	DC	BC	CC	EVC
1	10	0	10	10
2	0	10	0	0
3	9, 12, 14	12	9, 12, 14	9
4		14		14
5		9		12
6	13	13	13	13
7	15	15	15	15
8	11, 16	11	11, 16	16
9		16		11
10	3, 8, 18, 19	18	17	8

CONCLUSION

This study leveraged Python and centrality metrics such as degree, betweenness, closeness, and eigenvector centrality to analyze critical nodes within a 20-node Wireless Sensor Network. Our comprehensive analysis has elucidated the roles of individual nodes in influencing network behavior, underscoring the significance of understanding the importance of nodes for enhancing network efficiency and performance. The insights gained are particularly relevant in environmental and chemical engineering contexts, where optimizing network dynamics can lead to significant advancements in areas such as pollution monitoring and process control systems.

Moving forward, we plan to extend our research to encompass networks of varying sizes and complexities. We aim to refine our analytical methods to efficiently manage larger and more complex networks, employing scalable algorithms and techniques developed from our initial findings. This expanded research will enhance our comprehension of network dynamics and furnish researchers and practitioners in environmental and chemical engineering with robust tools and insights, facilitating the management and optimization of diverse network configurations.

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Conflict of interest

The author declare that we have no conflict of interest.

REFERENCES

1. Capella, J. V.; Bonastre, A.; Ors, R.; Peris, M. A Wireless Sensor Network Approach for Distributed In-Line Chemical Analysis of Water., *Talanta.*, **2010**, *80*(5), 1789-1798.
2. Diamond, D.; Coyle, S.; Scarmagnani, S.; Hayes, J. Wireless Sensor Networks and Chemo-/Biosensing., *Chem. Rev.*, **2008**, *108*(2), 652-679.
3. Pule, M.; Yahya, A.; Chuma, J. Wireless Sensor Networks: A Survey on Monitoring Water Quality., *J. Appl. Res. Technol.*, **2017**, *15*(6), 562-570.
4. Dargie, W.; Wen, J.; Panes-Ruiz, L. A.; Riemenschneider, L.; Ibarlucea, B.; Cuniberti, G. Monitoring Toxic Gases Using Nanotechnology and Wireless Sensor Networks., *IEEE Sens. J.*, **2023**, *23*(11), 12274-12283.
5. Manjarrés, C.; Garizado, D.; Obregon, M.; Socarras, N.; Calle, M.; Jimenez-Jorquera, C. Chemical Sensor Network for pH Monitoring., *J. Appl. Res. Technol.*, **2016**, *14*, 1-8.
6. Paavola, M.; Leivisk, K. Wireless Sensor Networks in Industrial Automation. InTech., **2010**.
7. Mbiya, S. M.; Hancke, G. P.; Silva, B. An Efficient Routing Algorithm for Wireless Sensor Networks Based on Centrality Measures., *Acta Polytech. Hung.*, **2020**, *17*(1), 83-99.
8. Vázquez-Rodas, A.; de la Cruz Llopis, L. J. A Centrality-Based Topology Control Protocol for Wireless Mesh Networks., *Ad Hoc Netw.*, **2015**, *24*, 34-54.
9. Gómez, S. Centrality in Networks: Finding the Most Important Nodes. In Business and Consumer Analytics: New Ideas; Moscato, P., de Vries, N., Eds.; Springer: Cham., **2019**.
10. Njotto, L. L. Centrality Measures Based on Matrix Functions., *Open J. Discrete Math.*, **2018**, *8*, 79-115.