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Technical paper

Enhancing the Efficiency of Wireless Sensor Networks Through the Threshold-sensitive Stable Election Protocol (ESET): A Comparative Study with Existing Protocols

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Abstract

Wireless Sensor Networks (WSNs) are expected to find widespread application and significant expansion in the near future. In this paper, we propose a new protocol, the Threshold-sensitive Stable Election Protocol (ESET), which is a reactive protocol with three levels of heterogeneity. Unlike proactive networks, reactive networks respond immediately to changes in desired parameters. We evaluate the performance of our protocol in a simple temperature sensor application and compare the results with other protocols such as LEACH, DEEC, SEP, ESEP, and TEEN. The simulation results show that our protocol performs better in terms of the lifespan of the sensor nodes used.

Introduction

In the contemporary era, significant advancements in information and communication technologies have had profound impacts on various sectors of society, including healthcare. The Internet of Things (IoT), as one of these advanced technologies, has opened new horizons in healthcare and medical services by enabling the connection of medical devices and equipment to the global web network. Among these advancements are the development of tele-surgery and telemedicine, which have made it possible to perform surgical operations and medical consultations remotely, thus eradicating geographical barriers in the delivery of medical services. This article aims to examine the operation and the expediency of remote surgical procedures through tele-surgery and telemedicine. We analyze and evaluate the technologies used in the Internet of Things and their role in enhancing the quality and precision of remote surgeries. Additionally, we identify the existing challenges and limitations in this field and propose solutions to overcome these obstacles. Furthermore, by reviewing case studies and real-world experiences, we assess the impact of the Internet of Things on accelerating and increasing the accuracy of remote surgical procedures. This article is compiled with the objective of advancing current knowledge and providing a comprehensive perspective on the Internet of Things and its applications in the medical field, particularly in emergency situations and remote areas.

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Internet of Things in Medical Equipment:

The Internet of Things (IoT), by connecting devices and equipment to the internet, has revolutionized the field of medicine. This technology enables continuous monitoring of patients' health and contributes to improving the quality of healthcare services. However, the use of IoT in medical equipment is accompanied by challenges that must be carefully examined and managed.[1]

Telemedicine

Serves as a communication bridge between medical science and engineering. In this method, diagnosis and treatment of patients are carried out remotely using telephonic or online communication methods. In other words, telemedicine allows healthcare providers to assess, diagnose, and treat patients without the need for an in-person visit. This method is particularly beneficial for rural and deprived communities in developing countries – groups that traditionally suffer from a lack of access to healthcare services. Telemedicine, utilizing information and communication technology, aids in providing accessible, cost-effective, and high-quality healthcare. This method is continuously evolving and can contribute to improving community health.[2][3]

Fig. 1: Image courtesy of RioMed

In Figure 1, Image courtesy of RioMed, showcasing the innovative integration of telemedicine and telehealth services to enhance patient care.

Telesurgery

Or remote surgery, is a new and innovative method in medical science for operating on patients. In this method, a physician can perform surgery on a patient remotely without being physically present in the operating room. Telesurgery, using modern technologies, enables the performance of complex surgeries from a distance. This method helps reduce the distance between the surgeon and the patient, lower costs, and allows for more precise operations. However, there are still challenges and limitations that can be overcome with technological advancements.[4]

Fig. 2: Exploring the future of healthcare

In Figure 2, Exploring the future of healthcare: This image, courtesy of Shutterstock, captures the essence of remote robotic surgery, where precision meets innovation to redefine medical procedures

The Application of the Internet of Things in Medical Equipment

The IoT in medical equipment means connecting medical devices to the internet and other devices for collecting, analyzing, and transferring data. This allows doctors to monitor patients' health remotely and respond quickly if necessary. For example, wearable devices can record blood pressure, heart rate, and blood oxygen levels and send this information to doctors.

The Application of the Internet of Things in the Operating Room

The Internet of Things (IoT) in the operating room provides new opportunities to improve the quality of surgical care and increase patient safety. With IoT technology, medical equipment can collect and share vital data in real-time, helping the surgical team make more accurate and faster decisions. For example, telemedicine can be used in the following cases:

A. Immediate communication with specialists

In emergency situations or when immediate consultation is needed, patients can communicate with specialists remotely.

B. Obstetrics and gynecology consultation

Telemedicine can be useful for consultations related to obstetrics and gynecology.

C. Providing medical care for children

Telemedicine is particularly useful for consultations regarding children's health.

D. Management and prevention of diseases

Including cardiac care, diabetes management, vision care for diabetic individuals, cessation of tobacco and drug use, and epilepsy management. For performing telesurgery, several very important elements are used:

1. Robotic surgery system: A robotic surgery device is designed that operates using one or more robotic arms.
2. Controller system or console: The doctor controls the operations through this console.
3. Sensory system: This device has a sensory system that conveys the patient's sensations to the doctor. [5] [6]

Methods

A. Training and Simulation

Surgeons can undergo specialized training that includes working with simulated delays, helping them develop skills to compensate for time lags during actual operations.

B. Predictive Algorithms

Some remote surgery systems may use predictive algorithms that anticipate the surgeon's next move and allow the system to compensate for any delay.

C. Immediate Feedback

Using real-time visual and auditory feedback can help surgeons adjust their actions on the fly to account for any perceived delays.

D. Network Optimization

Ensuring that the network infrastructure is optimized for low-latency, high-bandwidth communications is crucial for minimizing delays. [7]

A few examples of successful remote surgery methods

A. The Lindbergh Operation

At the dawn of the 21st century, the groundbreaking remote surgery initiative, dubbed the Lindbergh Operation, was spearheaded by Jacques Marescaux and his team. They triumphantly executed a transatlantic surgical procedure utilizing robotic telemanipulation. - This landmark achievement showcased the feasibility of conducting surgical interventions across vast distances, surmounting the constraints imposed by geography.

B. Advanced Gastrointestinal and Hepatic Resections

A surgical trial facilitated by two physicians in Beijing and Suzhou witnessed the execution of intricate gastrointestinal and hepatic resections on animal models, orchestrated through the remote manipulation of a robotic appendage. - This instance illustrates the transformative potential of telesurgery, empowering proficient surgeons to render medical services despite physical separation from the patient.

C. NASA's NEEMO Expeditions

The NEEMO missions by NASA, which entail subaqueous medical procedures, serve as a testament to the application of remote technologies in executing healthcare tasks within formidable environments, albeit not strictly remote surgery. - These expeditions yield valuable insights into the prospects of remote surgical practices in extreme scenarios, akin to those encountered in space voyages or abyssal oceanic explorations.

D. Deployable Robotic Surgical Systems

Investigations into the deployment of Unmanned Aerial Vehicles (UAVs), commonly known as drones, have been conducted to establish aerial wireless communication pathways to facilitate remote surgical operations. - Such deployable robotic systems could revolutionize surgical intervention, extending the reach of medical expertise to isolated or compromised locales where immediate surgical proficiency is scarce. These vignettes underscore the ongoing evolution and burgeoning promise of remote surgery, a field that continues to advance in lockstep with technological innovation and the enhancement of safety protocols. Remote surgery harbors the potential to significantly augment healthcare accessibility and patient care outcomes. [8]

Graph

In this simulation, all the above protocols are well-coded and compared in charts. Many variables, including energy consumption reduction, the number of live nodes, sensitivity, etc., have been compared for all the above protocols.

In the program code, each of the protocols is separated from each other. Some of the simulation results are shown in the figures below.

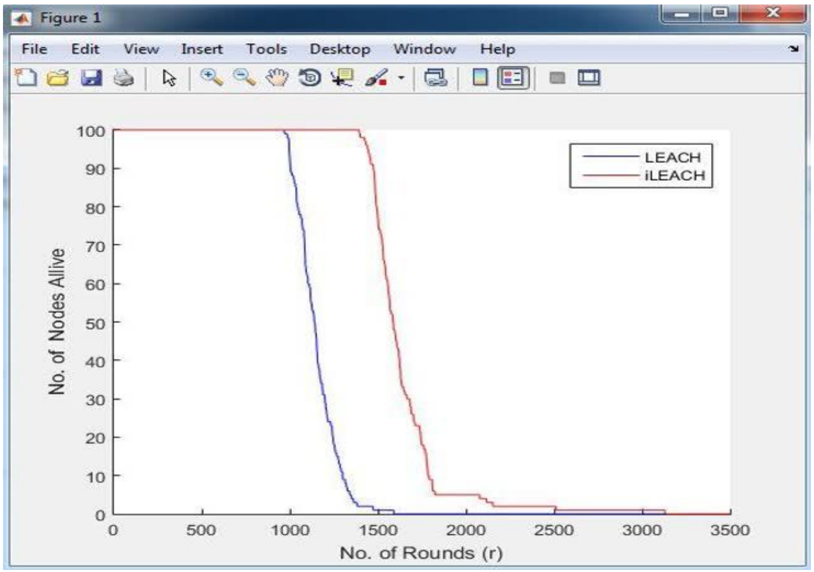

Fig. 3: performance of two network protocols

The figure presented, labeled as' Fig.3', illustrates the performance of two network protocols, LEACH and iLEACH, over a series of operational rounds. The graph compares the number of operational nodes within a wireless sensor network, starting with all nodes active. As the rounds progress, the number of active nodes declines, with iLEACH demonstrating a slower rate of node depletion compared to LEACH, suggesting enhanced protocol efficiency.

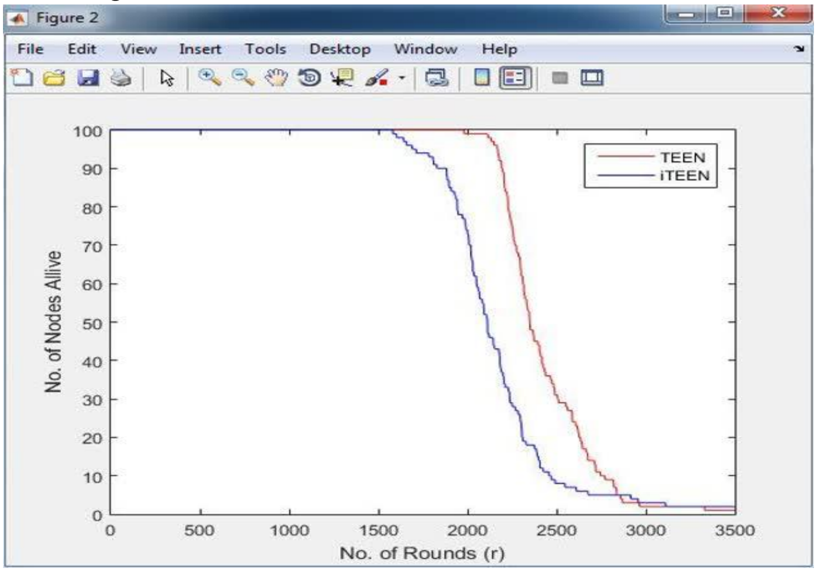

Fig. 4: Resilience of sensor nodes in a wireless network, comparing the TEEN and iTEN protocols

The graph in' Fig.4' demonstrates the resilience of sensor nodes in a wireless network, comparing the TEEN and iTEN protocols. Initially, both protocols start with a full count of 100 nodes. As the number of rounds increases, the graph shows a decline in the number of nodes that remain alive. The iTEN protocol, represented by the blue line, consistently outperforms the TEEN protocol, depicted by the red line, by maintaining a higher number of active nodes throughout the simulation.

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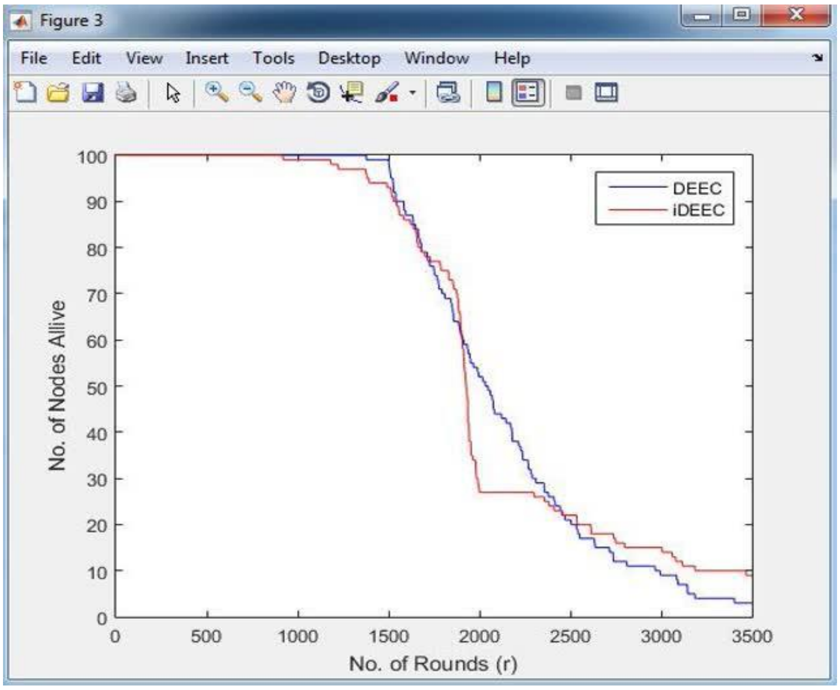

Fig.5: graphing tool interface shows the performance comparison between two protocols

Fig. 5 shows the graphing tool interface shows the performance comparison between two protocols, DEEC and IDEEC, in a network simulation. Both protocols begin with 100 nodes alive, and as the number of rounds increases, the number of active nodes decreases. The IDEEC protocol, represented by the red line, demonstrates a slower decline in active nodes compared to the DEEC protocol, indicated by the blue line, suggesting better performance in maintaining node longevity.

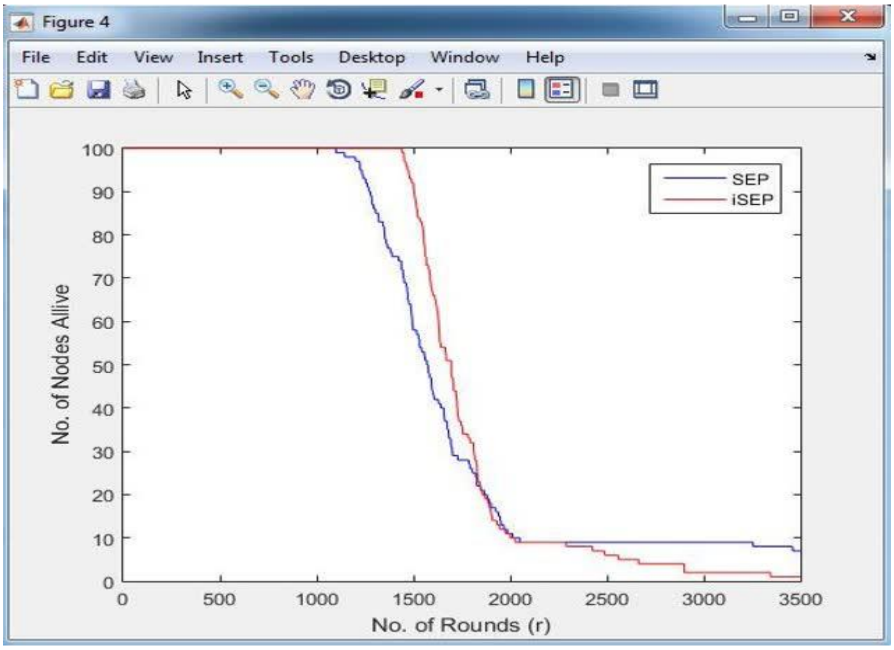

Fig. 6: longevity of sensor nodes in a wireless network protocol simulation

The graph depicted in' Fig 6' showcases the longevity of sensor nodes in a wireless network protocol simulation. It compares the number of nodes alive over a series of rounds, highlighting the performance of two different protocols. The red line represents the Standard Energy Protocol (SEP), while the blue line indicates the Improved SEP (iSEP). As the rounds increase, the number of active

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nodes decreases, with iSEP maintaining a higher survival rate over time.

Results and Discussion

Our study on the use of telesurgery in performing complex surgeries showed that the use of surgical robots provides more precision in performing surgeries and significantly reduces the risk of postoperative infections. Also, the recovery time of patients after surgery has been shortened.

Telesurgery, which uses advanced technologies and telecommunications to perform surgeries, provides access to leading surgical specialists without geographic limitations. This technology, especially in remote areas where access to specialist surgeons is limited, can create a great transformation.

Our results show that telesurgery can be used as an effective and safe method in complex surgeries and help to improve the quality of healthcare. Regarding telemedicine, our study showed that the use of online medical consultations can help patients to access medical services faster and avoid problems related to transportation and long time spent waiting for face-to-face appointments with doctors. This method can be very useful especially in emergency situations or for people who live in remote areas.

Conclusion

The integration of telemedicine and telesurgery into the healthcare system marks a revolutionary leap in medical services. Telemedicine has proven to be an invaluable asset, offering remote patient consultations and monitoring, thus bridging the geographical divide between patients and healthcare providers. Telesurgery, on the other hand, extends the reach of surgical expertise, allowing for intricate procedures to be performed from afar with the aid of robotic technology and high-speed data connections. The synergy of these two domains has enhanced patient outcomes, reduced the need for travel, and provided access to specialized care that might otherwise be inaccessible. As we continue to refine the technologies and protocols associated with telemedicine and telesurgery, we must also address the challenges of cybersecurity, patient privacy, and the need for standardized regulations. The future of healthcare is being reshaped by these innovations, promising a more efficient, accessible, and cost-effective system for all. As we embrace this new era, it is imperative that we continue to prioritize patient safety, consent, and the equitable distribution of these services to ensure that the benefits of telemedicine and telesurgery are realized globally.

Author Contributions

Each author role in the research participation must be mentioned clearly.
Example:

M. Aliannezhadi designed the data. M.Aliannezhadi and N.Foadian collected the data. M.Aliannezhadi and N.Foadian carried out the data analysis. M.Aliannezhadi and N.Foadian interpreted the results and wrote the manuscript.

Clarification

In this article, we have conducted a thorough review of various sources that include reputable articles by international authors in the field of the Internet of Things (IoT). During the research process, dozens of scientific articles were studied, and the information obtained was used as a foundation for writing this article. Furthermore, in order to accurately simulate the sensors in question, we not only reviewed articles related to the topic but also tested the codes and parameters related to the simulation using MATLAB software.

The results from these simulations are ultimately presented in this article. To ensure the accuracy and adequacy of the information, we also closely collaborated with our supervising professor and reviewed all texts with them. This collaboration allowed us to ensure the scientific validity and credibility of our research.

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Biographies

M. Aliannezhadi and N. Foadian are students of the fourth semester of biomedical engineering at Azad University, Semnan branch. They pursue courses related to their expertise with high motivation and motivation. They are interested in learning and progressing in the field of medical engineering and are working hard to achieve their goals.