International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING

ISSN:2147-6799 www.ijisae.org Original Research Paper

Survey: Dynamic Duty Cycle Mechanism of WSN for Mobility and Static Nodes

Hussein A. Jasim[1], Saraa A. Khudhair*[2], Nazik K. Aljbur*[3] , Dhuha Habeeb [4]

Submitted:13/03/2024 **Revised**: 29/04/2024 **Accepted**: 05/05/2024

Abstract: The dynamic duty cycle mechanism in wireless sensor networks (WSNs) is designed to optimize power consumption in both static and mobility nodes. This article provides a comprehensive review to extend the life of the network by adjusting the duty cycle of each node based on its hopping state. In the case of mobility nodes, which refer to nodes that move frequently within the network, the duty cycle is dynamically adjusted to balance power consumption and sensing requirements. When a node is in motion, it typically uses a higher duty cycle to ensure continuous monitoring of its surroundings. However, when the node is stationary, the duty cycle can be reduced to reduce unnecessary energy expenditure. For static nodes, which are fixed within network, the duty cycle is fixed at a lower value because it does not require frequent sensing or communication. This conserves energy and allows stationary nodes to operate for extended periods of time without need for battery replacement. By dynamically adjusting the duty cycle based on the mobility status of nodes, WSN can optimize power usage and maximize network lifetime. This mechanism helps ensure efficient operation of the network while accommodating the power requirements of mobility and static nodes.

Keywords: *Duty cycle, wireless sensor networks (WSNs), Mobility, static nodes, energy efficiency*

1. Introduction

The duty cycle mechanism in Wireless Sensor Networks (WSN) is an important technique for the efficient use of energy among mobility and static nodes. The duty cycle represents the fraction of time a node is active or inactive, and it plays a crucial role in managing the energy consumption of sensor nodes during their operation. In static networks, duty cycling mechanisms are used to maximize the network lifetime by turning off the nodes that are not needed, while in mobile networks such as vehicular sensor networks, duty cycling mechanisms are used to manage the energy consumption of nodes in a mobile environment to ensure efficient data transmission between nodes.

The duty cycle mechanism can be classified into two types: asynchronous and synchronous duty cycle. In asynchronous duty cycling, nodes operate independently and randomly schedule their active and inactive periods. This mechanism is best suited for static networks that do not require strict synchronization. Synchronous duty cycling, on the other hand, is used for mobile networks where nodes are required to synchronize their active and inactive periods to ensure efficient communication.

The use of duty cycle mechanisms is essential in WSNs to manage energy consumption and maximize the network lifetime, especially in situations where the nodes are mobile. Therefore, researchers must focus on studying duty cycling mechanisms to develop efficient and effective techniques that can optimize energy consumption and enhance the performance of WSNs in both static and mobile environments.

It can can sometimes not be practical to change the power sources in WSNs due to the potentially hostile settings in which they may live. These situations include underwater petroleum and natural gas [1] and recovery from disasters [2], among other uses. internet [3]. The relevance of energy-saving solutions that lengthen node and consequently network lifetime is growing as a result. Running a duty cycle of node power, which puts the nodes to sleep while idle, is a technique that WSNs frequently use to address this issue. Although service cycling reduces power consumption, it also causes other problems for wireless networks. Due to the variability of wake schedules inside individual nodes in a WSN caused by the duty cycle, it is challenging to guarantee that those times overlap when nodes are detected and data transfer is possible between them. Neighbor discovery (ND) methods now need to permit nodes in the same area in addition to overlapping in the wake schedule, which might compound this issue if mobility becomes a consideration inside the network. This

[1] Department of Computer Science, College of Computer Science and Information Technology, University of Basrah , Basrah – 64001, IRAQ
ORCID ID : 0009-0008-8158-6168
[2] Department of Intelligent Medical System, College of Computer Science and Information Technology, University of Basrah , Basrah – 64001, IRAQ
ORCID ID : 0009-0006-1234-3686
[3] Department of Intelligent Medical System, College of Computer Science and Information Technology, University of Basrah , Basrah – 64001, IRAQ
ORCID ID : 0009-0005-5465-2033
[4] Department of Computer Engineering, Iraq University College, Basrah – 64001, IRAQ
ORCID ID : 0000-0002-1324-0973
** Corresponding Author Email: hussein.jasim@uobasrah.edu.iq*

could happen if a sinking node is activated to address a particular power and hotspot connectivity problem with static WSNs [4].

This project's goal is to develop a dynamic cycle of duty mechanism for mobile and stationary nodes in wireless sensor networks, where nodes in steady state and mobility are monitored for energy use, packet delivery ratio (PDR), and duty cycle. The sinking and static nodes for sensors, which are the two distinct scenarios used for this, are where the navigation takes place.

The static node cases received special attention from the researchers. A few researchers have looked into the motion of nodes, and they have concluded that static nodes perform better in sensor networks than mobility nodes when it comes to power use PDR, delay, and various other execution statistics that were discovered during the research. In this study, static nodes and other mobile nodes are two possibilities that are examined.

The use of energy is distributed more fairly across the nodes in the WSN whenever the Mobile Sink Node (MSN) is used to move within or across the network. This is because no single node can assume the position of the hotspot for a considerable amount of time. Numerous routing techniques have been created for network-based approaches when considering MSNs. These protocols may generally be split into two groups: those that use floods, which may result in excessive power consumption, and those that use delay-tolerant techniques, which make up for it by using less energy [5-6].

2. LITERATURE REVIEW

To provide a review of the literature on the dynamic work cycle mechanisms of hopping and static nodes in WSNs, some important studies of recent years can be presented. In a paper titled "Energy-Efficient Data Collection in Mobile Wireless Sensor Networks," the authors proposed a dynamic duty cycle diagram based on node mobility. They are designing an algorithm that adapts the sleep/wake schedules of the mobile nodes based on their speed. By dynamically adjusting the duty cycle, the authors achieve energy efficiency in data collection, taking into account the changing mobility patterns of nodes. Another study titled "Mechanism of Dynamic Duty Cycle Control of Heterogeneous Wireless Sensor Networks" focuses on duty cycle conditioning based on the difference in node energy levels. The authors propose a mechanism that adjusts the duty cycle based on the power status of both fixed and moving nodes. This approach aims to achieve load balancing and extend network life by optimizing power consumption. In addition, a paper titled "Dynamic Energy Conservation Duty Cycle Diagram for Fixed Sensor Nodes in WSNs" addresses duty cycle optimization for fixed nodes. The authors propose an algorithm that modifies the duty cycle based on connection aspects and network traffic load. The scheme aims to conserve power in fixed sensor nodes by reducing unnecessary wake-up times without compromising network performance.

WSNs have utilized smart sensors that have been cleverly designed in recent years and have paid particular attention to the technological specialty of MEMS technology. The sensors are compact and less expensive than traditional sensors, thus they call for compliance and resources. Depending on the choices made and the sensor's architecture, information can be gathered, measured, and conveyed to the user. A sensor places thousands of microcomputers in a specific area. after the data is ready and the homemade sensors are available. In light of a move toward wireless communication, electronic gadgets are altering drastically in practically every aspect of life. Utilizing tiny networks of sensor nodes, it is possible to monitor and analyze some complicated events over wide areas and for extended periods. The most recent developments in networked sensors research have led to the development of small and fake nodes for sensors that can achieve significant offsets for data comprising physical values. Ad hoc networks with many nodes equipped with various sensors are known as WSNs. Thanks to technological advancements, this type of system is made possible by low-power devices wireless connections, and the whole silicon that requires place among various functions. Independent sensors that WSN has configured are used to keep an eye on the physical and environmental conditions. Every sensor node has a transmitter and receiver or another component that may be powered by a tiny power source and a controller [7].

The best path plan is displayed in [8]. This work's alternative method of prioritizing emergency broadcasts is a crucial component. One finding from this study indicates that whenever the abdominal node is close by, the fixed nodes ought to awaken. However, the specifics of how this occurred are not given, and it appears that this is one of the presumptions on which the study's future work has been based. The findings of this study reveal a decrease in network lifetime and transmit delay, proving the value of using sink hopping to modify network behavior. Here, the strategy is to modify the MSN navigating style to conform to the chosen job rotation method. Both the advantages of this strategy and the prospective benefits of connecting pelvis mobility to the company's cycle have been established. The eTrail protocol was proposed by Pazzi et al. [9]. The MSN serves as the cluster's head in this study, and clusters form as the pelvis rotates. The sensor nodes update their routing information, which updates the way to the basin for each node, as MSN delivers signals to follow the route of the basin. Because only local broadcasting is used and this work is done at the level of the network, the authors assert that there are negligible communication costs. We have attempted to eliminate the usage of transmissions and broadcasts of any type in our research due to the increased energy consumption brought on by their use.

Inconsistent power usage and dynamic sensor network designs are better accommodated by Energy Aware Adaptive Low Power Listening (EA-ALPL) [10]. Each sensor node in EA-ALPL can customize its listening mode based on the circumstances local to it. All nodes listen in the initial listening mode since they are uninformed of their neighbors. To first indicate its presence and status, each sensor first transmits recurrent track update signals. To determine how many descendants are present in the routing network, a routing graph is created, and the data is sent through a base station. Each node determines its unique duty cycle based on the quantity of downlink nodes. If a node has a large number of child nodes and runs out of energy, it notifies the child nodes to select a different parent to lessen the node's workload.

According to Tian and Georganas [11], every node is aware of its location and the dimensions of its sensing region. The method is broken down into work cycles, which include a self-scheduling phase and a working phase following. All nodes are operational before the first stage. Each node broadcasts its location using a Position Awareness Message (PAM) and monitors the PAMs of its neighbors throughout the self-scheduling phase of the first phase. It then determines whether or not to rest by figuring out how much coverage its surrounding region is providing. Consider the eligibility rule's contract to see how it operates. A node is eligible to go to sleep to try to lower the network's total power dissipation if its sensing region is completely engulfed by the union group of its neighbors. A detecting and sending module can be disabled by eligible nodes to conserve power.

Having a focus on the sensor node sleep problems, Jemal et al. [12] examined the issue of optimizing sensor network lifetime utilizing network-based sensor networks. It is presumed that the sensors in question have the capacity to cache the sensed data and that there is a mobile base station, that is, a single mobile data collector like an Unmanned Aerial Vehicle (UAV) that operates within the field being tracked, visits the area regularly, and gathers cached data from the nodes already present in the area. These features render unnecessary lengthy, multi-hop routing. The suggested algorithm's fundamental idea is to constantly schedule the sleep-wake frequency by the scheduling requirements for mobile base station traffic.

The Contiki-ng [13] Linux operating system and the Cooja emulation are widely regarded as the most recent technologies for creating IEEE 802.15.4 utilities and applications. This work, however, has a different purpose than the Contiki-ng effort and is primarily intended to increase the features of the ns-3 simulator. Similar to Contiki-ng, the Ns-3 simulation protocol stack is based on IEEE 802.15.4-2011 and supports IPV6's low-power and Loss Routing Protocol on top of its MAC level. Contrary to Contiki-ng, ns-3 can create various well-known communication accommodations, including Thread, Zigbee pro, and Zigbee IP, all of which call for IEEE 802.15.4-2011 or older. It is important to keep in mind that protocol stacks like Zigbee Pro offer an alternative to RPL's IP-based routing implementation. The work presented in this paper can therefore be used by ns-3 users to assist in the creation of their very own non-IP routing algorithms that are comparable to Zigbee Pro [14].

Collision-free protocols for MAC are ideal for preventing power loss due to unnecessary transportation and duty cycles for wireless elements that conserve power when there isn't any communication action [15]. Provides a fantastic and recent evaluation of energy-efficient MAC techniques. For a single-hop group, coordinating the time of all nodes is extremely simple, but in mesh networks, it is much more challenging. WRTP is a distributed, efficient, and fair token ring technique. Although [16] made improvements to it, its robustness still has to be proven. According to [17], the standard code-passing method is more reliable and ideal for production environments. Additionally, the previously suggested TOMAC-WSN protocol [18] makes use of the token-passing notion.

To establish sensor energy utilization and lower the amount of energy used during the diffusion phase, the authors of [19] suggested diffusion algorithms. They also take node utilization and mobility into account.

The PADRA [20] and DARA [21] represent two recent implementations of controlled hopping-based contact maintenance methods. Through the regulated transfer of migrating nodes, these algorithms can detect possible splits in networks of sensors and players and reestablish network connectedness [22]. Presents a more theoretical analysis in which the authors take into account two metrics for Quality of Coverage (QoC) in mobile sensing systems: the proportion of events collected and the likelihood of an event to be recorded. They offer analytical findings on how these two measures assess performance in terms of the number of sensors used, velocity trends, and event dynamics. To reduce the likelihood of missing an incident from above, they are also creating a system to plan the motion of the sensors.

The use of portable, controllable parts in network infrastructure as a means of lowering energy usage is covered by the authors in [23]. They demonstrate that having a portable base station decreases energy utilization in comparison to a system of permanent nodes, increasing node density. Although the trajectory of the mobile node's navigation pattern is fixed, the velocity profile that follows through the route is flexible.

By shifting nodes to form new links, the authors of [24] change the structure of a multi-hop wireless connection. They outperform the alternative strategy of boosting the capacity of the busiest links in the network in terms of reducing the average delay from end to end of the network. The network structure, the wireless nodes' coordinates, and the overall network load are all inputs to the centralized algorithm. After that, it tries to alter the network link by gradually relocating the loose network nodes. It occurs to ensure the network stays connected at each stage and that its typical timeline shortens. The authors of [25] collected data using mobile nodes. They first demonstrated the existence of an entire NP issue for the scheduling of several mobile devices with no data loss, after which they assessed the efficiency of several computing techniques with single and multi-mobile devices about of duplication and data collecting delay.

Table 1 lists some of the earlier work in addition to the kind of wireless connection under investigation and the study's objectives for the sake of a higher ranking.

Table 1. Comparison of some previous studies of dynamic duty cycle mechanism in WSNs

Ref.	***Method***	***Objective***	***Structure of Connection***	***Mobility Category of Managed Devices***	***Diagram***
[15]	MAC techniques	Avoid wasting energy	WSN	Automated	Released/ Distributed
[19]	Deploying Methodologies	The implementation	WSN	Flexible	Released/ Distributed
[20]	PADRA	Being connected	WSAN	Flexible	Released/ Distributed
[21]	DARA	Being connected	WSAN	Flexible	Released/ Distributed
[22]	Action which Adapts	Expenditure of power	WSN	Automated	--
[23]	CD	Durational delayed	WN multi-hop	Flexible	Controlled
[24]	MES	Zero loss of data	WSN	Flexible	Released/ Distributed
[25]	BELP	The level of exposure	WSN	Automated	Controlled

3. Challenges and Constraints

The dynamic work cycle mechanic in WSNs presents both mobile and static nodes with certain challenges. The dynamic task cycle aims to conserve energy in WSNs. However, managing power consumption effectively becomes challenging when dealing with both mobile and fixed nodes. Ensuring that nodes maintain an optimal work cycle while keeping in mind their navigation patterns can be complex.

One of the most important challenges with a dynamic work cycle is that the work cycles of neighboring nodes must be synchronized to reduce idle listening and collisions. Achieving synchronization in WSNs with mobile nodes requires additional mechanisms to adapt to node movements and changing network structures. In mobile WSNs, nodes may move frequently, resulting in unexpected changes in the network topology. Dynamic task cycling algorithms must be able to adapt to these changes and adjust work cycles accordingly to maintain network connectivity.

The dynamic duty cycle also involves a trade-off between lower power consumption and lower latency. While longer periods of sleep conserve energy, they also increase delays in data transmission. Striking the right balance to optimize both factors can be challenging, especially in scenarios where latency is critical. WSNs may consist of heterogeneous nodes with different capabilities and traffic patterns. It can be difficult to design dynamic task rotation mechanisms to accommodate this variance while using network resources efficiently.

The manner in which data about the aquarium is gathered and reported may change over time. Consider a sizable sensor network that is event-driven in nature. An interesting event triggers a node nearby to begin time-drivingly broadcasting information toward the sink about it at a predetermined rate. Such occurrences can happen in unexpected locations. Identifying an individual in a surveillance application, based on a value that is observed up to the limit in a watched scene, can be one way to start it off. This can be translated into data transmission in connection with mobility, i.e., the transfer of data gathered by a mobile sensor from a stationary node out from the network's coverage area.

Mobility is anticipated to be an extremely viable approach for increasing connection overall [26], extending the reach of networks [27]. Due to the surroundings where they function, sensor nodes can also move from their present placements. Mobile sensors will undoubtedly pass through complex networks of stationary sensor nodes to get correct data. Mobile nodes must be incorporated into the communication table of their neighbors in this situation. When a timetable between static nodes has already been established, this can be particularly problematic. In some circumstances, like tracking targets or monitoring applications, as described in [28], the data collected and submitted by mobile nodes could be essential.

Addressing these challenges requires the development of advanced algorithms and adaptive techniques that take into account the specific requirements and characteristics of the WSN, such as navigation patterns and application scenarios.

Two primary and separate groups of applications are revealed by the type of transfer of data. Table 2 provides a summary of them. Ecosystems and environments are within the first grouping of deployments that attempt to continuously monitor phenomena. With these deployments, samples are taken often over a lengthy period in an effort to better comprehend the situation. Sensor nodes transmit their measurements to the drain in a time-driven way. Deployments that gauge a person's reaction to stimuli are under the second type. This includes, for instance, monitoring systems for intrusion detection and structural health. It is occasionally possible to simultaneously observe long-term and sporadic phenomena by combining the two groups.

Table 2. The primary usage restrictions are placed on WSNs nowadays.

Gp.	***The case study***	***Particular constraints***	***Strategy for collecting data***
1	monitoring the surroundings	Robustness, vigor	Time-driven
	Environmental surveillance	The energy that is barely perceptible and unobtrusive	Time-driven
2	Monitoring apparatus	Security and power	Query-driven/Event-driven
	Fundamental health surveillance	Power, extreme frequency sampling	Query-driven/Event-driven
1+2	Automating the house	Heterogeneity, Cybersecurity	Time-driven/ Event-driven

4. Problem Formulation

The current dynamic duty cycle mechanism in WSNs aims to address the challenges posed by both mobile and static nodes. Problem formulation typically involves optimizing node duty cycles to increase energy efficiency while meeting system requirements. The main goal of the system is to maximize network life or reduce power consumption while ensuring reliable data transmission. It is proposed to develop an existing energy model that captures the energy consumption patterns of both mobile and fixed nodes. Taking into account factors such as transmit power, receive power, idle power, and the power required to navigate the node. For mobile nodes, a mechanism has been included to predict their future locations and movement patterns. This can be based on current historical data, existing location-tracking algorithms, or other predictive technologies. An existing optimization problem that defines optimal duty cycles for each node has also been formulated, taking into account power constraints and communication requirements. A duty cycle is the part of the time that a node is actively engaged in sensing, processing, and transmitting data. In addition to determining an appropriate optimization method, such as mathematical programming or inference, to solve the formulated problem. Consider algorithms that can handle both static and dynamic optimization with changing network conditions. Finally, we evaluated the performance of the proposed dynamic duty cycle mechanism through current simulations or real-world experiments.

By formulating the problem taking into account the portability and characteristics of both static and mobility nodes, a dynamic duty cycle mechanism can help optimize energy utilization in WSNs while accommodating the diverse requirements of the network [29].

Pre-sampling-based protocols operate more simply in dynamic networks since neither time synchronization nor schedule propagation is necessary and they are not dependent on an ensemble or agenda at the network level. Since each node may independently pick its active schedule, theoretically each could be able to transmit on the medium at any time. Preamble usage, however, decreases the number of available channels, increasing node competition.

The preamble in wireless communication serves as a synchronization signal that helps receivers detect the start of a transmission and synchronize their clocks with the transmitter's clock. the preamble affects the number of available channels indirectly by contributing to channel contention. As more nodes use preambles, the competition for channels during the preamble transmission phase increases, reducing the effective number of channels available for data transmission.

Collisions can occur often and entail retransmissions, aggravating contention, and using more power, according to the network congestion and regularity of data gathering. Portable sensors may incur significant delays in achieving the average while traveling to such congested places. They also intensify competition for the shared medium since they add to the number of emitters in the area they migrate to. The period required for entering a channel must be shortened because the moving sensor won't remain close to the perceiving event indefinitely and might not be able to keep a lot of information in the queue. Additionally, the mobile sensor can be prevented from moving on to the next step by adjusting the average arrival delay linked to the node's movement. In reality, as demonstrated in Figure 1, the intended peer may become inaccessible after the information package has been successfully conveyed on the channel because several factors such as move unpredictably of nodes, interference, signal attenuation, battery power, or processing capabilities [30-31].

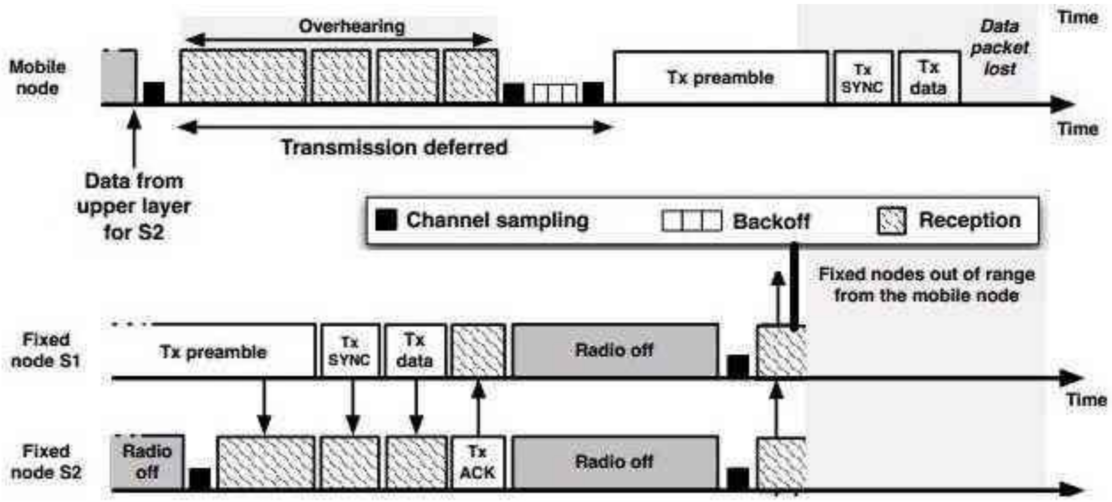

Fig 1. Content networks give the **static** and **mobile** nodes a bit of time to anticipate their next move.

5. Methodology

The current dynamic duty cycle mechanism employs several existing methods, including threshold-based, learning-based, and control techniques. The threshold-based method uses a static threshold value to determine when the node should wake up or sleep. The threshold value changes as per current network requirements, but the method imposes considerable overhead in terms of energy consumption. The learning-based method adjusts the duty cycle based on the network's existing history, i.e., the node learns to identify patterns in the data packets and accordingly calculates the duty cycle. The control techniques regulate the power consumption in the node by controlling its existing operating parameters. The dynamic duty cycle is crucial for optimizing the power consumption of WSN nodes, especially in current mobile and static nodes. The method enables nodes to adjust their power consumption based on existing network requirements and data traffic to extend the network's current lifetime and performance. Multiple methods can be employed, including existing threshold-based, learning-based, and control techniques, to achieve efficient power consumption. The dynamic duty cycle mechanism forms an essential aspect of energy-efficient WSN, and further current development and optimization of this mechanism will play a vital role in ensuring sustainable and intelligent WSN deployments.

The basic equation can be expressed as follows: (%).

$$Dt = (Pw/m) * 100\% \quad (1)$$

Similarly, the duty period (ratio) can be written as.

$$Dt = (Pw/m) \quad (2)$$

Where “Pw” represents the power consumption during the "on" cycle of the mechanism,” m” represents the mass of the system or device, and Therefore,” Dt” time during the duty cycle.

The present time utilized by a functioning signal in an existing electrical device, like the switch for power in a source of power, can be determined or described using duty cycles. We may additionally employ duty cycles to express the physiological possibilities of the activity discovered by a living thing in the present environment, for instance, a neuron. Although it is possible to define the duty factor for periodic signals using the same concept [32][33], it is occasionally scaled to an order of magnitude value instead of 100% [34].

According to Figure 2. For comparison, a mobile node's rate of operation is typically 12.2% (0.12), which indicates that its radio is running at 126ms per second while a static node is not delivering data on the medium. This is consistent with the fact that a data packet is sent every second by the mobile phone sensor. Even in low-density networks, where there is intense channel competition, the B-MAC (Berkeley-Medium Access Control) threshold is surpassed by more than 35%. The mobile node must transmit an initial for every packet of data that is on its waiting list, which is the primary cause. As a result, the phone is always in receiving mode [35].

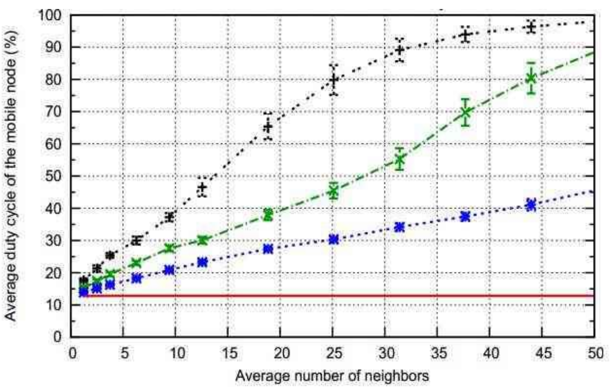

Fig 2. The average amount of neighbors of a mobile sensor employing a B-MAC, which represents the radio duty cycle on average.

B-MAC, data sending period of 1 s on the fixed nodes (with 90% confidence interval)

B-MAC, data sending period of 2 s on the fixed nodes (with 90% confidence interval)

B-MAC, data sending period of 3 s on the fixed nodes (with 90% confidence interval)

B-MAC, fixed sensors not sending data

In this study, a search operation was conducted using the development of the inductive speculative technique [36]. The research process is carried out in the manner of a scientific inquiry, starting with the formation of a fictitious research aim and progressing to a greater objective via experiment and debate on a person's study contributions. The outcomes of experimenting were not biased by observation. To highlight research contributions [37][38], solutions have been evaluated and published with a high degree of confidence in the observed outcomes. Figure 3 shows the search procedure, which goes as follows:

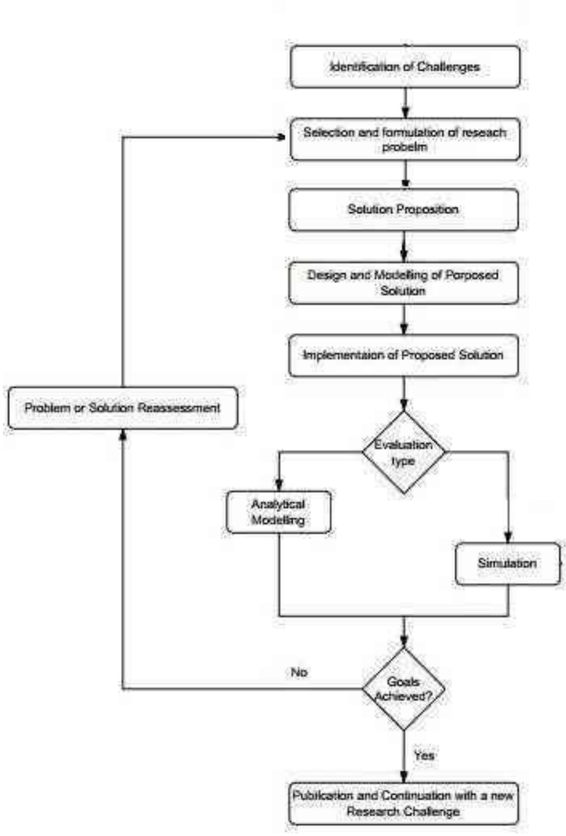

Fig 3. Research Process

Identify issues. Following the initial questionnaire, we went on to find, gather, and record a list of possible study issues. This aided in the methodological prioritizing of obstacles and the focus on tempting oneself first in terms of the study purpose.

Decision-making and issue formulation. Based on early thoughts and discussions with supervisors, specific challenges or a set of difficulties were chosen. Furthermore, the breadth of the issue's description and exact definitions are used to develop and validate the challenges.

Proposed Solution. A practical solution has been thought of, and analyzed in terms of benefits and drawbacks, and a suggestion for modelling and carrying it out has been made. We put up a plan of action to opportunistically overcome the obstacles and difficulties and raise the bar for the current norm [39].

Planning and Instruction. Depending on the sort of solution, the answer provided can be represented as a mathematical approach, process progression, or message sequence. The crucial elements, their connections, and their general organization as they relate to the design of an architectural structure, with comparisons between central and scattered architectural styles.

Implementation. The inclusion of genuine interfaces for networks, topologies of networks, optimized network components, and genuine electromagnetic mediums in the simulation is the primary distinction between experimental simulation and event-based mathematical modeling. Software technologies including the Linux idea of virtual networking, Mininet-WiFi wireless network simulator, and WSN Contiki Cooja emulator were utilized for simulation [40].

Evaluation. Based on a software test, we assess a prototype or implemented solution that addresses one or more WSN use cases like mobility, density, or heterogeneity. The evaluation techniques comprise:

- Analytical modeling. Depending on the use case, the mathematical solution for networking management is iteratively tested with various inputs. Here, we iterated the formula through various test scenarios using Python scripts.

- Simulation. Development of a modeling environment for evaluation of implementation utilizing industrial software and computer-assisted simulation tools. The study has been constructed in iterations here so that factors like node mobility and node count may be changed, and heterogeneity can be tested by integrating the subsystems of several wireless domains. A system stability test and trust in the outcomes of a best-effort genuine WSN replication were done as part of the evaluation.

Compilation of findings and discussion. Results of measurements of network performance for various parameter iterations were gathered after validation. The correlation between the outcomes and the trend between the parameters and the metrics was then noted [41].

6. Conclusion

WSNs are widely used to monitor physical or environmental conditions by using sensor nodes that communicate with each other through wireless communication. Some sensor nodes in WSNs are static, while others are mobile. The dynamic nature of these networks requires a mechanism that can adjust their duty cycle, which is the percentage of time a node stays active during a cycle, and optimize their energy consumption. The dynamic duty cycle focuses on optimizing the network performance by reducing the on-time for nodes that are far from the sink node and increasing the on-time for nodes that are closer to the sink node. Hence, it effectively balances the energy consumption of both mobile and static nodes, thus extending the life of the network. The usage of a dynamic duty cycle is essential to enhance the performance of WSNs operating in harsh and dynamic environments, improving both energy consumption and network lifetime.

The solutions that have been put forth thus far to solve the problem globally hardly ever satisfy all criteria simultaneously since they only take into account the sharing of load or failed reaction methods. We concentrate on modifying an online gateway for mobile nodes in networks in this contribution. Our system suggests load balancing, dynamic forwarding, and failover strategies for equitable utilization of all mobile network resources, where Load balancing involves distributing incoming network traffic across multiple servers to ensure no single server is overwhelmed, thereby improving performance, reliability, and redundancy, Dynamic forwarding involves dynamically routing traffic based on real-time network conditions, such as link quality, congestion, or latency, and for Failover strategies involve automatically switching to a redundant or standby system when the primary system fails. Additionally, the method does not call for changing any of the mobile subnet's current client nodes.

We'll keep concentrating our research efforts on creating a single network administration framework for WSN. The basic idea is to assist smart grids or decision-making regarding routing, resource coordination, and other things by having a programmable, open, and programmatic administration structure based on Software Defined Networking (SDN) technology. We intend to continue our study on combining multiple operations in IoT networks or limited WSNs in light of the future trend toward application knowledge in IoT networks.

Acknowledgements

The authors acknowledge University of Basrah for the support in conducting the research and producing this paper using the facilities in the communication research site.

Author contributions

Hussein A. Jasim: Conceptualization, Methodology, Software, Field study **Saraa A. Khudhair:** Data curation, Writing-Original draft preparation, Software, Validation., Field study **Nazik K. Aljbur:** Visualization, Investigation, Writing-Reviewing and Editing **Dhuha Habeeb:** Proofreading and Writing-Reviewing

Conflicts of interest

The authors declare no conflicts of interest.

References

[1] Ali, S.; Ashraf, A.; Qaisar, S.B.; Kamran Afridi, M.; Saeed, H.; Rashid, S.; Felemban, E.A.; Sheikh, A.A.

SimpliMote: A Wireless Sensor Network Monitoring Platform for Oil and Gas Pipelines. IEEE Syst. J. 2018, 12, 778–789, doi:10.1109/JSYST.2018.2597171.

[2] Ahmed, A.; Bakar, K.A.; Channa, M.I.; Khan, A.W.; Haseeb, K. Energy aware and secure routing with trust for disaster response wireless sensor network. Peer-to-Peer Network. Appl. 2017, 10, 216–237, doi:10.1007/s12083-015-0421-4.

[3] Kim, M.; Park, S.; Lee, W. Energy and Distance-Aware Hopping Sensor Relocation for Wireless Sensor Networks. Sensors 2019, 19, 1567, doi:10.3390/s19071567.

[4] Tang X.; Xie L. Data Collection Strategy in Low Duty Cycle Wireless Sensor Networks with Mobile Sink. Int. J. Commun. Netw. Syst. Sci. 2018, 10, 227–239, doi:10.4236/ijcns.2018.105B023.

[5] Shelby Z.; Chakrabarti S.; Nordmark E.; Bormann C. RFC6775: Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs). Available online: http://www.hjp.at/doc/rfc/rfc6775.html (accessed on 2019).

[6] Wang J.; Gao Y.; Liu W.; Sangaiah A.K.; Kim H.J. Energy Efficient Routing Algorithm with Mobile Sink Support for Wireless Sensor Networks. Sensors 2019, 19, 1494, doi:10.3390/s19071494.

[7] A. Kamble, V. S. Malemath, and D. Patil, “Security attacks and secure routing protocols in RPL-based Internet of Things: Survey,” 2017 Int. Conf. Emerg. Trends Innov. ICT, ICEI 2017, pp. 33–39, 2017.

[8] Tang, X.; Xie, L. Data Collection Strategy in Low Duty Cycle Wireless Sensor Networks with Mobile Sink. Int. J. Commun. Netw. Syst. Sci. 2017, 10, 227–239, doi:10.4236/ijcns.2017.105B023.

[9] Pazzi, R.W.; Boukerche, A.; De Grande, R.E.; Mokdad, L. A clustered trail-based data dissemination protocol for improving the lifetime of duty cycle-enabled wireless sensor networks. Wirel. Netw. 2017, 23, 177–192, doi:10.1007/s11276-015-1089-7.

[10] Jurdak, R., Baldi, P. and Lopes, C.V. “Energy-Aware Adaptive Low Power Listening for Sensor Networks” In Proceedings of the Second International Workshop on Networked Sensing Systems, San Diego, CA, 2018.

[11] D. Tian and N. D. Georganas, “A Node Scheduling Scheme for Energy Conservation in Large Wireless Sensor Networks,”in Wireless Communication Mobile Computing 2017; 3:271–290.

[12] J. H. Abawajy, S. Nahavandi and F. Al-Neyadi, “Sensor Node Activity Scheduling Approach,” in IEEE, 2019 International Conference on Multimedia and Ubiquitous Engineering (MUE'07).

[13] Oikonomou, G.; Duquennoy, S.; Elsts, A.; Eriksson, J.; Tanaka, Y.; Tsiftes, N. The Contiki-NG open source operating system for next generation IoT devices. SoftwareX 2022, 18, 101089.

[14] Connectivity Standards Alliance. Zigbee Specification. 2017. Available online: https://csa-iot.org/all-solutions/zigbee/ (accessed on 22 July 2022).

[15] Kumar, A., Zhao, M., Wong, K.J., Guan, Y.L., Chong, P.H.J. A Comprehensive Study of IoT and WSN MAC Protocols: Research Issues, Challenges and Opportunities. In IEEE Access, December 27th 2018.

[16] Pre La Joux. (2019) https://www.remontees-mecaniques.net/ bdd/reportage-tsd6-de-pre-la-joux-leitner-132.html, last visit on 17th 2019.

[17] Ren, P.. Virtual TokenPassing Protocol Applicable to Manufacturing Sensor Networks Appl. Math. Inf. Sci. 9, No. 3, 1435-1444, 2017.

[18] Lepage, F., Docquier, T., Lecuire, V., Georges, J.P. TOMAC-WSN: A new WSN efficient protocol for monitoring big distributed mechanical systems. 3rd IFAC CESCIT 2018, 2018, Faro, Portugal.

[19] S. Abdel-Mageid and R.A. Ramadan, “Efficient deployment algorithms for mobile sensor networks,” in IEEE International Conference of Autonomous and Intelligent Systems (AIS), 2017.

[20] K. Akkaya, F. Senel, A. Thimmapuram and S. Uludag, “Distributed Recovery from Network Partitioning in Movable Sensor/Actor Networks via Controlled Mobility,” in IEEE Transactions on Computers, vol. 59, no. 2, pp. 258-271, 2018.

[21] A. A. Abbasi, M. Younis and K. Akkaya, “Movement-Assisted Connectivity Restoration in Wireless Sensor and Actor Networks,” in IEEE Transactions on Parallel and Distributed Systems, Volume 20 Issue 9, 2019.

[22] N. Bisnik, A. Abouzeid and V. Isler, “Stochastic Event Capture Using Mobile Sensors Subject to a Quality Metric,” in IEEE Transactions on Robotics, Volume:23, Issue:4, Page(s):676-692, 2017.

[23] A.A. Somasundara, A. Kansal, D.D. Jea, D. Estrin and M.B. Srivastava, “Controllably mobile infrastructure for low energy embedded networks,” in IEEE Transactions on Mobile Computing, Volume:5, Issue:8, Page(s):958-973, 2017.

[24] A. Basu, B. Boshes, S. Mukherjee and S. Ramanathan, “Network Deformation: Traffic-Aware Algorithms for Dynamically Reducing End-to-end Delay in Multi-hop Wireless Networks,” in Proceedings of ACM MobiCom, Page(s):100-113, 2017.

[25] A.A. Somasundara, A. Ramamoorthy and M.B. Srivastava, “Mobile Element Scheduling with Dynamic Deadlines,” in IEEE Transactions on Mobile Computing, Volume:6, Issue:4, Page(s):395-410, 2019.

[26] K. Dantu, M. Rahimi, H. Shah, S. Babel, A. Dhariwal, and G. S. Sukhatme. Robomote: Enabling mobility in sensor networks. In IPSN ’05: 4th International Symposium on Information Processing in Sensor Networks, pages 404–409. ACM, 2017.

[27] M. Zhang, X. Du, and K. Nygard. Improving coverage performance in sensor networks by using mobile sensors. In MILCOM ’05: Military Communications Conference, volume 5, pages 3335–3341. IEEE, 2017.

[28] J. Leguay, M. Lopez-Ramos, K. Jean-Marie, and V. Conan. An efficient service-oriented architecture for heterogeneous and dynamic wireless sensor networks. In SensApp ’08: 3rd International Workshop on Practical Issues in Building Sensor Network Applications. IEEE, 2018.

[29] R. Kuntz, J. Montavont, and T. Noël. Improving the medium access in highly mobile wireless sensor networks. In Submitted to MASS ’10: 8th International Conference on Mobile Ad-hoc and Sensor Systems, San Francisco, CA, USA, 2017. IEEE.

[30] C. Merlin and W. Heinzelman. Schedule adaptation of low-power listening protocols for wireless sensor networks. IEEE Transactions on Mobile Computing, 9(5):672 –685, 2017.

[31] B. Yahya and J. Ben-Othman. An adaptive mobility-aware and energy-efficient MAC protocol for wireless sensor networks. In ISCC ’09: IEEE Symposium on Computers and Communications, pages 15–21. IEEE, 2018.

[32] Habeeb, Ibtisam & Ali, Hussein & Hashim, Mustafa. Balance energy based on duty cycle method for extending wireless sensor network lifetime. Bulletin of Electrical Engineering and Informatics. 12. 3105-3114. 10.11591/eei.v12i5.4980, 2023.

[33] H. A. Jassim, M. H. Hashim and A. K. Daraj, "Radio Spectrum Predicts Primary User Transmission Status Over The Licensed Band," 2022 Iraqi International Conference on Communication and Information Technologies (IICCIT), Basrah, Iraq, 2022, pp. 293-297, doi: 10.1109/IICCIT55816.2022.10010629.

[34] G. Glissa, A. Rachedi, and A. Meddeb, “A secure routing protocol based on RPL for internet of things,” 2017 IEEE Glob. Commun. Conf. GLOBECOM 2017 - Proc., 2017.

[35] Senslab consortium. Senslab, the very large-scale open wire-less sensor network testbed. http://www.senslab.info.

[36] A. Berguiga, A. Harchay, A. Massaoudi, and H. Youssef. Fpmipv6-s: A new network-based mobility management scheme for 6lowpan. Internet of Things, 13:100045, 2021.

[37] I. J. Habeeb, A. K. Daraj and H. A. Jasim, "Dynamic System Based on RSSI for Indoor localization Using Multi-Bands," 2022 Iraqi International Conference on Communication and Information Technologies (IICCIT), Basrah, Iraq, 2022, pp. 137-141, doi: 10.1109/IICCIT55816.2022.10010652.

[38] Jasim, Hussein Ali. Dynamic duty cycle mechnism for mobility in wireless sensor networks. Diss. Universiti Tun Hussein Onn Malaysia, 2020.

[39] R. Fontes and C. Rothenberg. Wireless Network Emulation with Mininet-WiFi. Christian Esteve Rothenberg, 2019.

[40] J. Kim and J. Jeong. Design and performance analysis of an industrial iot-based mobility management for smart manufacturing. In 2020 IEEE 10th

[41] G. Elhayatmy, N. Dey, and A. S. Ashour. Internet of things based wireless body area network in healthcare. In Internet of things and big data analytics toward next-generation intelligence, pages 3–20. Springer, 2018.