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AN ENHANCED FUZZY BASED APPROACH TO IMPROVE THE QOS & NETWORK LIFETIME OF WIRELESS SENSOR NETWORKS (WSN)

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ABSTRACT

Wireless sensor network (WSN) brings a new paradigm of real-time embedded systems with limited computation, communication, memory, and energy resources that are being used fora huge range of applications. To prolong the function of wireless sensor networks (WSNs), the lifetime of the system has to be increased. WSNs lifetime can be calculated by using a few generic parameters, such as the time until the death of the first node and other parameters according to the application. The nodes in WSN are constrained with limited power for their vital operations since the connectivity of the network will go down as soon as node energy gets exhausted. Node failures due to power constraints cause system failures and hence minimize end-to-end connectivity in the network. And also mobility and congestion of the nodes lead to frequent link failures and packet losses affecting the QoS performance of the protocol. In this work, we used an effective proposed scheme, Balanced and Energy Efficient Multipath Routing with Robust Transmission in WSN to overcome above limitations in mobile ad hoc networks. The proposed scheme which maximizes end-to-end connectivity in the network and minimizes faults at link or/and node level. A set of multiple paths are established from source to multicast destinations using energy efficient neighbor node selection mechanism. It provides effective load balancing at the node and finds a stable path between the source and destination meeting the delay requirement. Simulation results show that the proposed protocol outperforms in terms of packet delivery ratio, throughput, routing overhead and average end to end delay.

Keywords: Wireless Sensor Network (WSN), Network Lifetime, Quality of Service (QoS), Node, Energy Efficient.

1. INTRODUCTION

In recent years, Wireless Sensor Networks (WSNs) are receiving more attention from the research community due to their performing capabilities in the military and civilian application. A WSN is a group of nodes linked with wireless connections.

WSN is one of the emerging networks that have an extensive range of next-generation applications. Hence, WSN plays a significant role in achieving application-based goals. Routing enables the nodes to collaborate and coordinate among them and to establish routes to radio access infrastructure, particularly WSN base station (BS).With a longer route lifetime, the effects of link disconnections and network partitions reduce [1, 2]. The high mobility of NODEs means that network topology can change over time, so discovering and maintaining routes becomes one of the main issues to address. Routing protocols are responsible for finding, establishing, and maintaining routes between two nodes that wish to communicate. These protocols should minimize overhead and bandwidth consumption. The frequent updating of the control information can ensure more accurate information; however, there is a need for a greater use of energy since this reduces the autonomy of the nodes [3]. The results are not in the expected level of the researcher and further it can be improved using the alternative approach of the proposed one. It overcomes the other works presented in the literature.

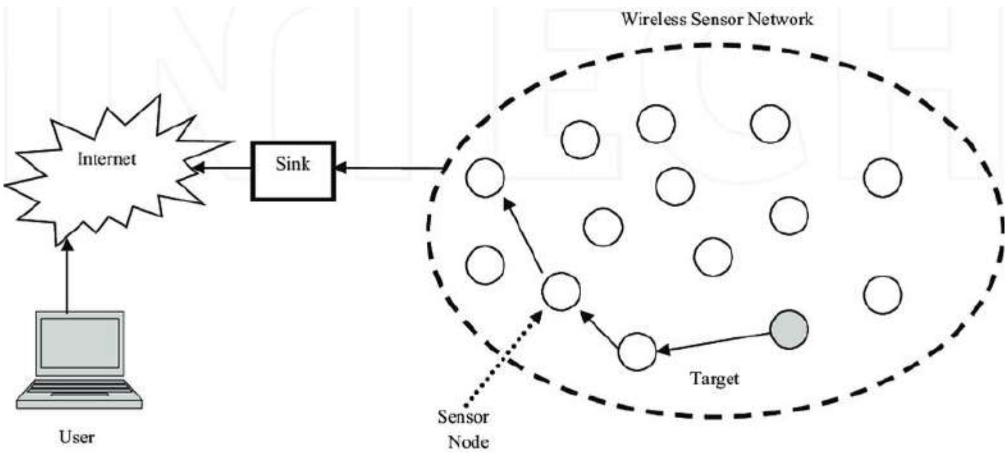

Fig. 1.1: Wireless Sensor Network (WSN)

In wireless sensor networks (WSNs), the energy constraint is a very crucial issue, as sensor nodes are usually operated on limited and irreplaceable battery power. Thus, most research works have focused on how to prolong network lifetime by reducing the energy consumption of sensor nodes [4]. However, research works for guaranteeing network lifetime have rarely been studied despite their impact on network management. Furthermore, since these existing schemes did not concern specific applications, they therefore suffer from adaptability problems in real deployment. Most WSN applications are required to meet specific requirements. In emergency WSN applications, such as radiation monitoring, security surveillance and fire detection, real-time data delivery is essential.

Wireless sensor networks are used in dynamically changing environments that can change rapidly over time. The dynamic behaviour of sensors is still a major challenge for data routing, energy constraints, coverage, link quality, and quality of service. The motivation of this research is to enhance the lifetime of the sensors in real-time scenarios. Sensors have a limited lifespan due to energy constraints [5]. In order to improve the lifespan of the sensors, hierarchical routing with optimal clustering using the fuzzy system (HROCF) protocol is proposed. This research shows that the proposed novel approach can be employed as a powerful tool to facilitate a delay-constrained path selection algorithm and a fuzzy based optimization method which requires only the local channel information and outdated messages to optimize different parameters. This research can be extended to investigate other real-world problems of different domains. The proposed work deals the challenge in WSN design is how to save energy while maintaining the desirable network behavior. As it is obvious that WSN falls under wireless networks that too in ad hoc scenario is really a challenging task to perform cluster based routing. Also another one challenging area is choosing the adaptive routing solution. It is well known that, several category of routing schemes is available, choosing the right solution is always a difficult task. The proposed work implements congestion aware clustered mechanism with adaptive optimized routing strategy for delay constrained WSNs. The results show that the proposed model is capable of maintaining the QoS standards and also helps the nodes to conserve their energy without promising on the performance.

2. RELATED WORK

The issues related to various categories of WSN are discussed in [11]. The major issues are platform and operating systems, communication protocol stack, deployment, and network services. To overcome these issues, various routing protocols need to be designed. As for network lifetime, much of the research literature has studied this in the last few decades. In this section, we briefly describe the related research works for energy consumption and network lifetime. Several techniques have been suggested to reduce the energy consumption of sensors and to prolong network lifetime. As a centralized approach for scheduling and prolonging a WSN lifetime, the concept of utilizing artificial intelligence (AI) or computational intelligence (CI) techniques to support the decisionmaking process is widely used in the recent literature to obtain more efficient WSN algorithms. Several protocols applied AI or CI techniques to design energy-efficient WSNs and routing algorithms [12]. Such techniques emphasized the efficiency and performance of WSN routing protocols by merging sensed data obtained from nodes and their communication in order to improve network performance.

Lata, S., et al, (2020), proposed the LEACH-Fuzzy Clustering (LEACH-FC) protocol and implemented a fuzzy logic-based cluster head selection and cluster formation to maximize the lifetime of the network [6]. The authors addressed the problem of to prolong the function of wireless sensor networks (WSNs), the lifetime of the system has to be increased. WSNs lifetime can be calculated by using a few generic parameters, such as the time until the death of the first node and other parameters according to the application. For selections of cluster head and formation of the cluster, we have used a centralized approach instead of distributed ones. We have also employed fuzzy logic in the selection of vice cluster head, which is also a centralized approach. The proposed algorithm has been found to be effective in balancing the energy load at each node thereby enhancing the reliability of WSN. It outperforms other proposed algorithms for improving network lifetime and energy consumption.

Kumaran, R. S., et al, (2022), resolved the energy issues of WSN, clustering and proper routing are the two major procedures that have to be focused on [7]. The authors introduced a hierarchical routing with optimal clustering using a fuzzy system (HROCF) for network lifetime enhancement in WSNs. This proposed scheme uses two phases: selection of a cluster leader with a fuzzy inference system and the hierarchical routing strategy are implemented for routing to consume the energy of the sensors resourcefully. During the first phase, a proper cluster leader can be nominated through the fuzzy inputs, namely: residual energy, cost, and position. In the second phase, hierarchical routing can communicate the information from the lower region to the sink node through the cluster leaders in higher regions. These two phases help to prolong the lifetime. The simulation analysis demonstrates that the HROCF scheme reduces the overall energy spent in the network and supports an increase in the lifespan in terms of more alive sensors compared to the existing schemes.

Manoharan, J. S. (2023), proposed a simple two-phase technique of route creation and maintenance to ensure route reliability by employing nature-inspired ant colony optimization followed by the fuzzy decision engine (FDE) [8]. Benchmark methods such as PSO, ACO and GWOare compared with the proposed HRCM's performance. However, choosing optimal cluster heads and similarity measures for clustering significantly increases computing time and cost. The objective has been focused towards establishing the superiority of proposed work amongst existing optimization methods in a standalone configuration. An average of 15% improvement in energy consumption followed by 12% improvement in latency reduction is observed in proposed hybrid model over standalone optimization methods.

Kumar, H., & Singh, P. K. (2021), focused on rising the network lifetime, throughput and decreasing the energy utilization to make the network more reliable, robust and more responsive for a longer period of time [9]. The proposed approach is based on multilevel heterogeneity inspired by SEP (Stable Election Protocol). First node dead in the network plays a vital role in network lifetime because if the first node dead after a long period then definitely network lifetime becomes better. To get better the network life time, the proposed approach is another effort to make the network more responsive. Proposed approach compared with NEECP (Novel Energy-Efficient clustering protocol), ICACO (Inter Cluster Ant Colony optimization) and DCHSM (Dynamic Cluster Head Selection Method) gives the improved outcome in conditions of Network lifetime and throughput.

Hemavathi, S., & Latha, B. (2023), introduced a novel QoS improvement framework for the WSN-IoT networks, and the objective of this work is twofold [10]. In the first phase, we utilize an Aquila optimizer (AO) for an efficient and reliable Cluster Head selection which is based on different factors such as node level, distance to the sink node, energy level. In the next phase, the Hybrid Fuzzy Levy Flight PSO algorithm (HFLPSO) is presented to enhance the QoS of the network even further by identifying a set of optimal paths to route the packets and measure the reliability of each path via different metrics. The proposed model is capable of improving the QoS of the WSN-IoT networks when compared to the different state-of-art methodologies.

3. PROBLEM SPECIFICATION

Drastic changes in network topology of Wireless Sensor Networks (WSNs) result in the instability of the single-hop delay and link status accordingly. Therefore, it is difficult to implement the congestion control with delay-sensitive traffic according to the instantaneous link status [13]. There are two main causes of congestion in WSN, the low node capacity and the wireless channel design. Congestion can lead to packet drops and retransmission either at the MAC or upper layers. The congestion control mechanism cannot handle the properties of a shared wireless multihop channel well. The congestion exists mainly in WSN nodes due to its limited memory, slow processor and limited node power. WSN is subsequently congested throughout the networks due to the nature of the network, event, interference with the channels and reporting rate. Routing must cater to two main characteristics of WSNs that reduce the route lifetime. Firstly, the collaboration nature requires the nodes to exchange messages and to coordinate among themselves, causing high energy consumption. Secondly, the mobility pattern of the nodes is highly dynamic and they may be spaced far apart, causing link disconnection.

4. RESEARCH CONTRIBUTION

WSN provides a better sustainable network as it serves as a subnet in an IoT system; however, it suffers from redundancies such as packet loss during data transmission, more delay, minimized network lifetime, and increased energy consumption of nodes [14]. Therefore, to address these issues, a novel approach is described using the fuzzy based clustering approach.

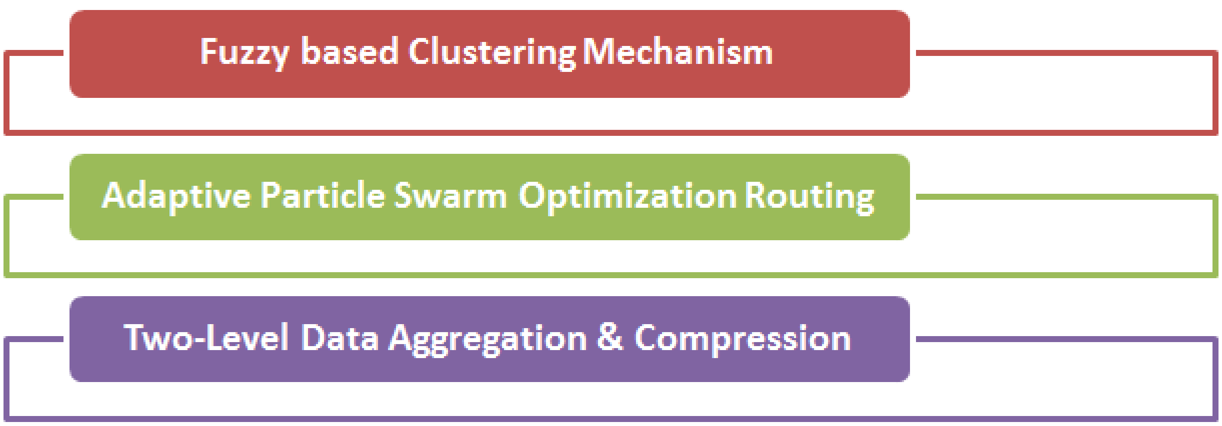

Fig. 4.1: Workflow of Proposed Research

The main contribution of this work is presented as follows,

- **Phase 1: - Fuzzy based Clustering Mechanism.**
- **Phase 2: - Adaptive Particle Swarm Optimization Routing.**
- **Phase 3: - Two-Level Data Aggregation & Compression Approach.**

4.1. Fuzzy based Clustering Mechanism

Recently, there are good numbers of research efforts towards the optimisation of standard communication paradigms for such networks. The traditional (WSN) design has never paid attention to constraints such as the limited or scarce energy of nodes and their computational power [9]. Also, in WSN paths can change overtime, because of time-varying characteristics of links, local contention level and nodes reliability. These problems are essential, especially in a multi-hop scenario, where nodes also do at the routing of other nodes' packets.

In order to minimise the number of data transmission between the source and sink nodes; aggregation is used in clustering. Then the CH collects the data from other nodes and sends them to the BS in the next level. Hence, at a level, the node with the highest residual energy is the CH. The Cluster Head Selection Probability (CHSP) is estimated using Fuzzy logic, based on the distance between the node and BS, remaining battery energy and network traffic. After this, the number of neighbouring nodes was also considered as input. The inclusion of the degree of the neighbouring nodes showed improved performance compared to their earlier work.

4.2. Adaptive Particle Swarm Optimization Routing

In this proposed work, a Adaptive Particle Swarm Optimization (APSO) algorithm is proposed where three different adaptive strategies are used. Particle Swarm Optimization algorithm has been proved to be a very efficient algorithm for the solution of routing type problems. At first, the performance of classical PSO algorithm is enhanced using the proposed adaptive PSO (APSO) algorithm. Different from the traditional PSO algorithm, the optimal solution is searched through cooperating four best vector types into three velocity updating strategies.

Particle Swarm Optimization (PSO) is a common method for NODE path planning. Its main defects are: slow convergence in the later stage, easy to fall into the local optimal solution. In order to overcome this defect, an adaptive particle swarm optimization (APSO) algorithm is proposed by adding an adaptive adjustment algorithm to the particle swarm optimization algorithm, adjusting the inertia weight and two learning factors at the same time.

On this basis, the fitness function and route planning algorithm flow of adaptive particle swarm optimization algorithm are designed. In order to test the effectiveness of APSO algorithm, path planning simulation experiments of NODE are carried out by using APSO algorithm and traditional PSO algorithm respectively.

4.3. Two-Level Data Aggregation & Compression Approach

In WSNs, data aggregation is required because of two primary reasons. The first reason is the large amount of data produced by each node and a large number of nodes in each network, which gives a stack of data to process and analyses. This data must be converted into information relevant and valuable to the data consumer.

CH aggregates the data generated by the nodes in its cluster and then send such data to the BS. There are two kinds of provenance in WSNs. One is a simple provenance, where data is generated at a leaf node and forwarded by nodes CH; Second is an aggregated provenance, where data are aggregated at CH and forwarded to the BS.

Since the CH which collects data from its members has high residual energy and applies compressed aggregation, the intra-cluster energy consumption is balanced. Similarly, while selecting the next hop CH, the CH with high residual energy and the least load is selected, thereby balancing the inter-cluster energy consumption also.

5. EXISTING METHODOLOGY

In previous work, we used a stable and energy-efficient routing technique. In the proposed method, quality of service (QoS) monitoring agents collect and calculate the link reliability metrics such as link expiration time (LET), probabilistic link reliable time (PLRT), link packet error rate (LPER) and link received signal strength (LRSS). In addition, residual battery power (RBP) is implemented to maintain the energy efficiency in the network [15]. Finally, route selection probability (RSP) is calculated based on these estimated parameters using fuzzy logic. Simulation results show that the proposed routing technique improves the packet delivery ratio and reduces the energy consumption.

In this technique, the QoS monitoring agents collect and estimate the link reliability metrics link expiration time (LET), probabilistic link reliable time (PLRT), link packet error rate (LPER) and link received signal strength (LRSS) [17] in order to ensure stable routing [16]. These metrics are used to find reliable links in MANET. In addition, they reduce the number of route reconstructions in the wireless network. Next, the residual battery power (RBP) of a node is also estimated for providing energy conservation.

In stable multipath route discovery phase, an enhanced stable path collection mechanism based on source routing and adaptive ad hoc on-demand multipath distance vector (AOMDV) is designed to discover multiple paths between the source and the destination. For selection of optimal routes, a fuzzy logic-based selection technique is applied. Here, the LET, PLRT, LPER and LRSS and RBP are taken as input for the fuzzy logic engine and based on the results of fuzzy rules, the route selection probability is estimated as output. In pre-emptive route repair phase, the moving node, which is responsible for the occurrence of communication grey zone, is detected based on the above designed metrics. An appropriate node is selected to do route repair and start fast local route repair.

Disadvantages:

- It suffers from too many route breaks and route rediscovery procedures due to the occurrence of communication grey zone.
- The extra computation for link stability factor causes the slightly higher delay.
- The route reconstruction is reduced only up to 50%.
- Here the data and encoding packets has higher packet overhead.
- Due to lack of link capacity resources, flows that could have been routed across sufficiently robust routes cannot be accommodated and are blocked.

6. PERFORMANCE EVALUATION

The proposed approach of Fuzzy based CH selection and Cluster Formation is evaluated through NS (Network Simulator)-3 under network simulations environment. The simulation analysis of wireless sensor network is exhibited into the connected dominating set with Bi-partite graph. NS-3 is used to simulate the proposed protocol since it is most widely used for wireless environment [17].

Depending on the user's purpose for an OTcl simulation script, simulation results are stored as trace files, which can be loaded for analysis by an external application:

- A NAM trace file (file.nam) for use with the Network Animator Tool
- A Trace file (file.tr) for use with XGraph or TraceGraph

Ns-2uses Toolkit Command Language (Tcl) scripts to configure the simulator such as to construct the network to simulate specify the protocol to use, and specify traffic sources [18]. Tcl is the language used to provide a linkage between C++ and OTcl. Tcl provides linkage for class hierarchy, object instantiation, variable binding and command dispatching. C++ is used for defining the internals of NS2. In contrast, OTCL is used to control the simulation as well as to schedule discrete events. After the simulation, NS2 outputs either text-based or animation-based simulation results. In order to interpret these results, graphically and interactively, tools such as NAM and XGraph are used.

1. Network Lifetime (NL)

The lifetime of the network is defined as the operational time of the network during which it is able to perform the dedicated task(s). It is the amount of time that a Wireless Adhoc Network would be wholly operative. One of the most used definitions of a network lifetime is the time at which the first network node runs out of energy to send a packet because to lose a node could mean that the network could lose some functionality.

$$T(n) \times \frac{E_{re}}{E_{in}} \qquad \text{if } n \in G \qquad \ldots \text{equ } (4.7)$$

2. Residual Energy (RE)

Residual energy is the ordinary energy spent by node during each round throughout the network. A node looses a particular amount of energy for every packet transmitted and every packet received. As a result, the value of initialEnergy_ in a node gets decreased. The current value of energy in a node after receiving or transmitting routing packets is the residual energy.

$$ResEng = \frac{Eg_{ini}}{Eg_{Rem}} \qquad \ldots \text{equ}(4.8)$$

3. Number of Alive Nodes Per Round (AN)

If more number of nodes are alive and are available in the WSN, then a large amount of information can be collected from the target area. The presence of hierarchical heterogeneity, as the first node dies after a significantly higher number of rounds (i.e. Longer stability period) compared to the heterogeneous case (mo =0. 4 and β = 2). The lifetime of the network is also increased.

4. Number of Clusters Formed (NC)

The optimal number of the cluster can be defined as follow: Compute fuzzy-based clustering mechanism for different values of the variable, for instance, by varying the variable from 1 to 10 clusters. For each variable, calculate the total within-cluster sum of square (WSS). Since the nodes are closer to the base station in the region the cost associated with direct transmission is lesser. Hence more cluster gets get elected. However, as the distance from the base station increases the number of clusters decreases.

7. CONCLUSION

Wireless network is considered as most common service used in industrial and commercial application due to its technological enhancement in the process, interaction and utilisation of low power embedded computational devices. Energy consumption and lifespan are the most vital concerns in heterogeneous WSN as it increases the energy consumption equilibrium and hence increase in the lifespan of network. In the current study, the fuzzy based algorithm is implemented to improve the lifetime of the WSN network. Compared to other models having crisp values, fuzzy logic maintains a high accuracy level and balanced energy consumption among sensor nodes in the network field. This helps the proposed scheme to adjust each node's energy consumption approximately at the optimal energy consumption rate to achieve the objective. Furthermore, the design of the fuzzy-logic system is simple and easy, which allows users/applications to define different variables, sets and rules, depending on each particular environment and the sensor features.

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