

A Wireless Sensor Networks Low-Latency Routing Protocol Which Examines Energy

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Abstract

Wireless sensor networks (WSNs) have been employed in a number of applications with large-scale automation where human involvement might be lethal or impractical. The limiting of the network lifespan and system delay is one of the biggest problems that wireless sensor networks encounter. Since wireless sensor networks are often battery-powered, their energy usage is limited. Lesser network lifespan and more frequent system halts to refuel depleted power sources would result from increased energy usage. As a result, routing methods that use less energy are constantly sought for. The minimizing of latency is a crucial component of wireless sensor network architecture. The mechanism loses sensitivity the larger the delay or latency.

When it comes to time-sensitive applications, this might prove to be quite important. In the proposed work, the clustering is determined dynamically for each iteration by applying particle swarm optimization to minimize the inter and intra cluster distances. The capacity to tackle complicated multivariate problems with strict bound limiting criteria and no single solution is the heart of the particle swarm optimization method. It is also well known that the redundant nature of the data detected and broadcast by WSNs can result in duplicate data transfers, which consume a lot of energy. By choosing and establishing a cap or threshold of the felt values, this is reduced to a minimum. Retransmissions are not carried out until the cap or threshold is exceeded. Based on network factors including the system's energy consumption, one hop, and network delay, the suggested strategy based on a PSO-threshold optimization is assessed. It has been established that, in terms of the intended wireless sensor network's performance assessment parameters, the suggested system performs better than the prevailing approach.

Keywords: Wireless Sensor Networks, Dynamic Routing, Particle Swarm Optimization, , Latency, Energy Consumption, Network Lifetime

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Introduction

The field of wireless sensor networks is expanding quickly and has assumed a key position in the wireless sensor network ecosystem. Numerous businesses as well as the overall economy have benefited from the use of wireless sensor technology. The globe is switching to wireless technology progressively and gradually [1]. The sensors play a critical role in wireless communication via the WSN and assist in signal transmission. Wireless sensors are included in wireless sensor networks as well [2]. With regard to wireless sensor networks, there are some factors that affect performance. Another performance statistic connected to the WSN is the power saver parameter [31]. In the context of daily communication, wireless communication is crucial. The vast bulk of communication in modern times takes place wirelessly. The corresponding signals are converted by the wireless sensors and sent to the wireless indicators. These sensors are a crucial component of wireless communication [4].

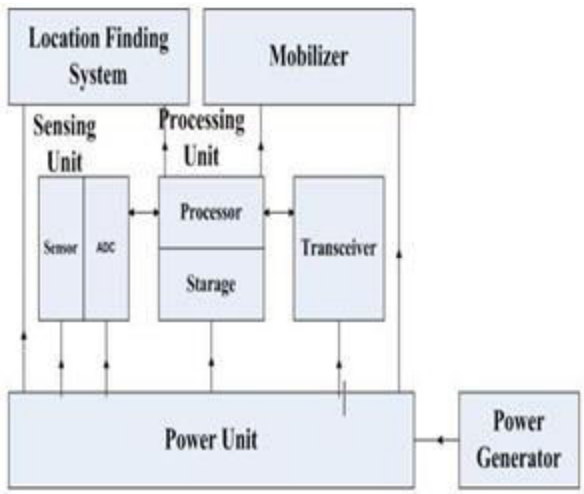

Fig. 1.1 Basic Architecture of Wireless Sensor Network

Wireless Sensor Networks History and Types

It is possible to trace the history of the Wireless Sensor Network back to the 1950s. It took the shape of a sophisticated surveillance system. The US military developed it for the purpose of looking into Russian submarines. Other types of electronic devices were also used in the seas of the Atlantic. As a result, the usage of WSNs dates back to the early days, when wireless communications were still a relatively new idea. Then, a paradigm change in the communication arena was brought about by the introduction of cordless phones and the development of mobile phones, which sparked the rise of wireless sensor networks. DARPA also began investigating WSN [33].

The four fundamental types of wireless sensor networks are depicted in the diagram above. It encompasses terrestrial, mobile, multimedia, underground, and underwater wireless sensor networks. In every area of wireless communications, these key WSN types have several uses. These networks are made up of several sensors grouped in clusters to produce high performance [5]–[6].

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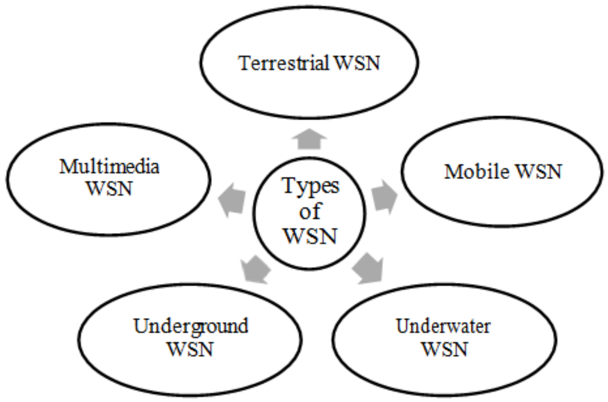

Fig. 1.2 Five Basic Types of Wireless Sensor Networks

Literature Reveiw

Design of WSN and Topologies

Different topologies are used in the construction of wireless sensor networks, or WSNs. The star, mesh, and tree topologies are among them. For WSN, there are certain particular design metrics. The Wireless Sensor Networks must be developed using these ideal metrics. These are listed below [:-

Reliability Dimension

One important parameter for wireless sensor networks is dependability. Sensitive signal transmission to the control station is the sensors' main task. The dependability requirements must be met via the sensor nodes' communication. The communication must adhere to two types of metrics, namely, packet and hop-by-hop metrics.

Size and Network Density

Another crucial factor and indicator of a sound design is the WSN's size and density. The effectiveness of the communication is significantly influenced by the sensor size. The thickness of the sensor nodes needs to be carefully considered and correctly built. The cluster's sensor node density has an impact on the network's performance as well [33].

The network's density is determined as follows:- (R) =(NR2)/A (1.1)

Where A and R denote the radio signal transmission range, N stands for the distributed sensor nodes in that region, and (R) produces the number of nodes that are present within each node's transmission range in area A.

Topology of a sensor network [31]

The topology of the wireless sensor network is also crucial. It has a significant and profound impact on the WSN's overall architecture as well as the effectiveness of its network. Any topology that is employed, such as the star, tree, or mesh, must be carefully designed and applied. The node clusters, in turn, depend on the topology of the WSN, which in turn depends on the routing quality.

WSN Energy Consumption

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The energy consumption statistic for any WSN setup is a very noticeable and important component. Every WSN must have a low network usage as its main objective. Since the sensor nodes run on batteries, the WSN's longevity depends on the quantity and quality of the batteries.

Hardware specifications

Another factor for the proper operation of the WSN is the required hardware. The WSN is often made up of several types of sensor nodes. Base stations and network sensor nodes are also included. The network is primarily in charge of keeping track of any changes in physical conditions like temperature. As a result, the sensor node is the central component of the hardware. Therefore, for an effective outcome, the sensor node hardware must meet many performance requirements.

Strength of the Connection

The WSN's connection quality is also crucially important. The WSN's connection quality and strength have a significant impact on how well the routing system as a whole works. The quality of the connection has a significant impact on the information transfer procedure.

WSN Service Quality

Another factor that affects how well the WSN performs is service quality. The whole plan must adhere to the time restrictions. The service needs to be reliable and meet the prerequisites.

Communication Medium

The WSN's protocol design places a significant emphasis on the transmission medium. There are many popular transmission modes and techniques, but the mode selection must be made so that the performance is ideal when all parameters are taken into account.

Objective

The main goal of the proposed work is to extend the network lifetime of wireless sensor networks by lowering energy consumption and performing performance optimization on it. The major objective is to create a system model that optimizes energy use while improving overall performance. Numerous studies have been conducted in this area in the past, but an improved solution must be sought in order to build a stable system for the increased performance of wireless sensor networks. For the suggested system to operate, the network lifespan must be extended and a low latency method must be acquired.

Problem Formulation

Challenges Associated with WSN Design:

The challenges associated with the WSN design can be sue to the following inherent limitations of WSNs:

1. Energy Consumption: The key challenge is to minimize the energy consumption of the proposed routing algorithm. As the number of nodes increase in the WSN, the energy required to aggregate and transmit the data also increases resulting in the increase of energy consumption. This leads to the degradation of network lifetime of the system which is detrimental to the system performance [5]-[7].
2. Dead Nodes: This is also an associated problem which occurs due to the energy depletion or degradation of the nodes which makes them incapable to transmit or receive data [8]- [10]. This makes parts or the entire network dysfunctional.

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3. Latency: This the time lag corresponding to the time the event to be captured occurs and the time the data is sent to the control station. Larger latencies makes the system slow and less responsive to input changes [11]-[14].
4. Mobility of sinks: This is also a challenge if the sink or the control station is mobile. This makes it mandatory to re-route the data through nodes which are nearer to the sink [15]. Typically, the data to be routed through the nodes near to sink is considerably larger than the data that is routed through sinks which are far away from the sinks. There clearly exists a trade-off between the data quantity and the latency [16]-[18].The visual representation of the mobile sink situation is depicted in the figure below:

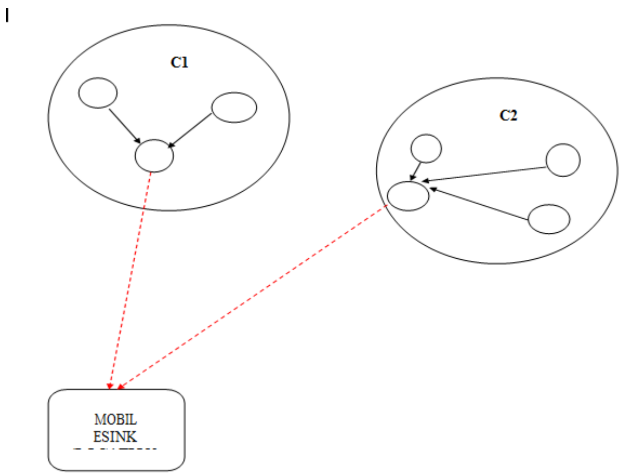
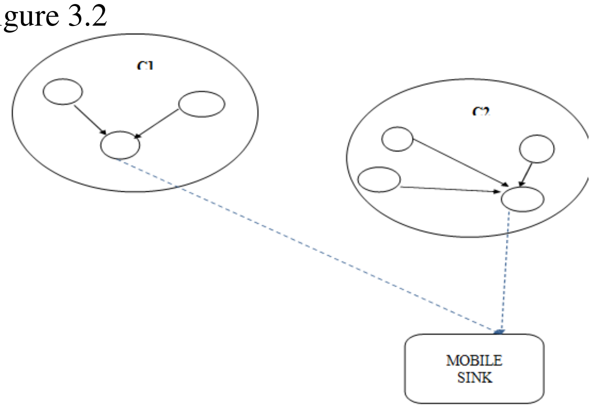


Fig. 3.1The mobile sink situation with sink at location -1

The figure above depicts the mobile sink location for the sink at location -1 and the cluster sizes and heads chosen accordingly.The configuration of the WSN needs to be changed when the sink changes as shown by figure 3.2



Research Gap with regards to previous work

The research gap with regards to previous work is cited here so as to find out the shortcomings of previously existing techniques.

- In [1], only the energy consumption of the system was more compared to what was anticipated. This is one area that could improve for better performance.
- In [2], the system faced a network delay that was major problem. The delay in network impacts the overall network performance so it needs to be reduced.

- In [3], an area unaddressed was the distribution of the cluster of nodes. The node cluster distribution has to be robust for the WSN system to work efficiently.
- In [4], fixed clustering topologies were used but the topology could be used in a hybrid approach for better functioning of the cluster heads.
- In [5], the cluster functioning could be more optimized to make the topology work in its favour. The clusters of nodes that perform the sensing work need to be arranged very well for seamless performance.
- In [6], no latency minimization for multi-hop network was analysed. Minimum network delay has to be maintained for the WSN to yield better performance and perform to its optimal level.
- In [7], the energy consumption was not reduced. The security was significantly enhanced but it also increased the power consumption. Measures need to be taken to reduce the power consumption in the WSN; otherwise this could lead to dead noses impairing the system performance.
- In [8], the inter and intra-cluster distances were not simultaneously reduced in accordance to each other thereby increasing the distance of transmission and hence the delay and energy consumption of the network.
- In [9], the network lifetime was increased and improved. The cluster heads used less power due to the optimization. But there existed reliable connection issues. The quality of the transmission and connection was not up-to the mark that needed further manoeuvre.
- In [10], the one thing that hindered the performance was the high data congestion during transmission that led to more network delay and one hop delays. Delays in the WSN massively impact the performance and functioning capacity. Hence it required improvement.

Thus two major facets were seen in the WSN routing protocols:

1. If the number of nodes in a cluster was increased, the energy consumption would go down but the delays would increase [24].
2. Decreasing the nodes in a cluster would increase the energy consumption of the system.
3. Thus a trade-off existed between the cluster size, energy consumption and the delay of the system which needed optimization as the key solution. This paves the path for the design of the proposed approach.

Proposed Methodology

Quite often, wireless sensor networks are categorized as homogenous networks and heterogeneous networks. Commonly, conditions of heterogeneity exist in WSNs [32]. The heterogeneity in wireless sensor networks can be in several aspects such as initial energy, computation and clustering, duty cycle etc. The variation in the parameters resulting in heterogeneity impacts the performance or output parameters of the wireless sensor networks and overall functioning.

Clustered Networks

The need for clustering in a wireless sensor network is of fundamental importance. It helps to regularize the network and decrease the energy consumption [25]-[26]. The concept of data transfer with and without clustering is shown in the figure below:

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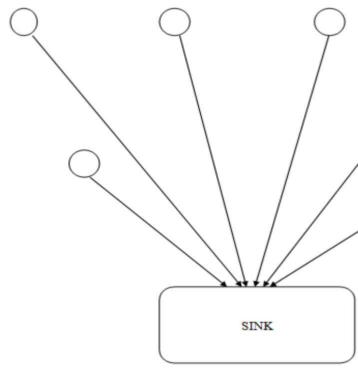

Fig. 4.2 Data Transfer without clustering

The discrete transfer of data from individual nodes to the sink consumes more energy compared to clustered network in which the following operations take place [27]-[28]:

1. Nodes are grouped into clusters
2. Each cluster is allotted a cluster head (CH)
3. Cluster heads aggregate the data and transmit to the sink.

The process is depicted in the figure below:

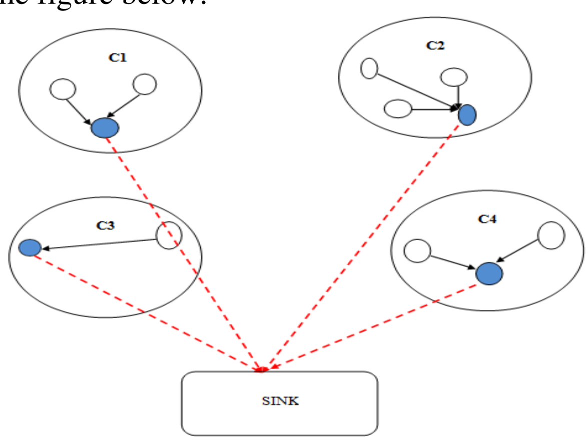

Fig. 4.3 Data Transfer in Clustered Networks

Proposed Algorithm

The proposed approach can be understood as the sequential implementation of the following steps:

1) Decide the cluster size dynamically so as to distributed nodes in a manner to minimize inter cluster and intra-cluster distances. The number of nodes in a cluster need not be fixed in each iteration of data transfer.
2) The cluster heads of each iteration change and is based on the average residual energy of each node in a cluster. Thus the CH of a cluster „n" for an iteration „t" would depend on the following mathematical condition:

   (,) = max[(1, 2 … … … … … …),]

   Here,

   m is the number of nodes in the particular cluster, which may vary from cluster to cluster n is the cluster index

   k is the iteration number

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E denotes the maximum energy

3) Since the inter-cluster and intra-cluster distances need to be optimized in each iteration based on a new cluster head, hence all the three parameters vary randomly in each iteration. This optimization problem becomes challengingly non-trivial for large number of nodes and clusters which is typically the case for most practical wireless sensor networks. The solution to point 3 lies in the use of a optimization technique to be adopted. The approach adopted here is the particle swarm optimization.
4) Since the data sensed is generally redundant and quasi static in nature, hence the energy can be saved by minimizing re-transmission of redundant data samples. This is done by deciding a cap or threshold percentage for the transmission to occur.
5) Compute evaluation parameters such as energy consumption and latency.

Conclusion

With large scale automation, several applications have seen the use of wireless sensor networks (WSNs) being used where human intervention can be fatal or infeasible in approach. Several such application can be large scale industrialization, climate monitoring, defence, healthcare etc. One of the major challenges which wireless sensor networks face is the limitation of the network lifetime and latency of the system. The wireless sensor networks are typically battery operated and hence are constrained in terms of energy. More energy consumption would mean lesser network lifetime and frequent stalling of the operative system to replenish the drained out power sources. Hence routing algorithms which consume less energy are always sought after. Another critical aspect of the design of wireless sensor network is the latency minimization. There is some finite amount of time which elapses between the moment the data is sensed by the sensing nodes and the moment the data reaches the sink. If this delay or latency is large, then the system becomes less sensitive to changes in the environment where the WSN is installed. This can prove to be of serious importance for time critical applications. The proposed approach tries to address both the issues. In the proposed work, the inter and intra cluster distances are minimized by using the particle swarm optimization to decide the clustering dynamically for each iteration. The essence of the particle swarm optimization is its capability to solve complex multivariate problems with tight bound limiting conditions and no unique solution. The redundancy in the data sensed and transmitted in WSNs is also a known fact and this can be lead to redundant data transmissions and hence large energy expenditure. This is minimized by deciding and setting up of a cap or threshold of the sensed values. Till the cap or threshold is crossed, re-transmissions are not done. The evaluation of the proposed approached based on a PSO-threshold optimization is done based on the network parameters such as the energy consumption, the one hop and network delay of the system. The simulation or experimental results are obtained after designing and implementing the system on matlab 2018a. It has been shown that the proposed system outperforms the previously existing technique in terms of the performance evaluation parameters of the designed wireless sensor network.

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