Machine learning and Artificial modelling for improved QoS provisioning in wireless sensor networks

Dr Sanjay M Asutkar
Associate Professor, Electronics and Communication Engineering Department,
MIET, Gondia.
asutkarsanjay@yahoo.com

Abstract:
Area surveillance, healthcare monitoring, environmental sensing, and industrial monitoring are just some of the areas that might benefit from Wireless Sensor Network (WSN) research. Quality of Service has emerged as a key concern for WSN deployments due to the increasing importance of this technology. Due to the limitations imposed by the applications running over WSN, achieving guaranteed QoS is challenging. Typically, QoS is measured in terms of network-level metrics like latency, throughput, packet loss, and jitter. A good quality of service network has low packet delivery latency, a high packet receipt ratio, and maximum throughput. Quality of service metrics may be collected at either the application or the network layer.

Keywords: Quality of Service, Wireless Sensor Network,Area surveillance, healthcare monitoring, environmental sensing, packet loss, jitter
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Introduction

As low-power wireless communication devices, sensor technologies, and wireless protocols have rapidly advanced, WSN has benefited and seen more progress. WSN's crucial function is provided byproviding data on environmental and physical events that may be used to better manage and conserve these assets. Weather and climate monitoring, area / military surveillance, home / industry automation, and health care are some of the most common current uses of WSN. Research on WSN has been extensive in many different areas, including architecture and protocol design, power conservation, QoS support, and others. The research community have not yet delved deeply into many QoS-related topics and concerns. New data-analysis methods may help resolve QoS-related problems more effectively. Physical events may be monitored, data can be gathered, light can be processed, and information can be sent wirelessly using a device called a wireless sensor that has been installed in the environment.

Most sensor networks have a large number of nodes, and their ability to communicate with one another is limited. Messages sent to a faraway sink node need a complex path across numerous intermediate nodes. An operational Wireless Sensor Network is shown in Figure 1.1.The base station is known as a sink because of the extra energy, resources, and network connections it requires. Each sensor node participates in data collection through radio links, processes the gathered information, and relays packets on behalf of other sensor nodes to their final destinations. WSNs are vital to achieving the ultimate goal of pervasive computing and smart environments. Wireless sensor networks operate without the need for physical infrastructure. Multi-sink sinks and movable sinks are the two main types of WSN topology. In multi-sink, many nodes share the role of "sink node," whereas in mobile sink, the sink itself is believed to be mobile.

Number of hops: Single-hop for a smaller coverage area, multi-hop for a larger coverage area, and Wireless Mesh Networks for a very wide coverage area. • There are two types of nodes: homogeneous and heterogeneous. In homogeneous networks, all of the nodes' parameters and computing capabilities are the same, but in heterogeneous networks, the nodes' parameters and computation capabilities differ.

Sensor networks with event-driven and time-driven scheduling: When an event happens in an event-driven sensor network, the nodes wake up from sleep mode, sense the data, process it, and send it to the sink; in time-driven sensor networks, the nodes wake up from sleep mode only at regular intervals, sense the data, process it, and transmit it to the sink

WSN connection and link characteristics vary on a regular basis due to their infrastructural architecture. Real-time applications with End-to-End performance assurances are becoming increasingly popular. Information is received at, or almost at, the time it is delivered in real-time communication. Quality of Service (QoS) is required for real-time applications, and there may be a performance scale that is acceptable for that application.

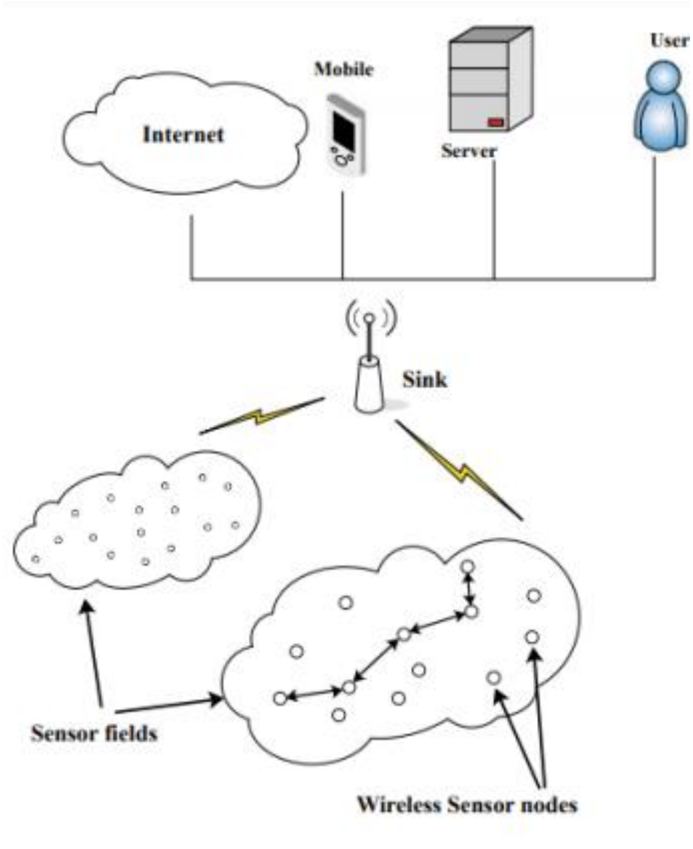

Figure 1.1 Schematic View of a Wireless Sensor Network

In a WSN-based video surveillance programme, for example, the user should be able to see a certain video resolution without any data latency. These QoS needs at the user level should be translated to network-level QoS characteristics such as bandwidth and latency. The goal of this scheme's application design is to provide information in a timely, trustworthy, and comprehensive manner. Furthermore, the system's overall life cycle should be extended without the need to replace sensors. However, meeting QoS criteria in a resource constrained context presents new problems for WSN routing. Most routing systems prioritize energy efficiency over real-time communication or presume that traffic speeds are adequate to fulfillQoS standards. As a result, WSN applications require routing algorithms that account dependability, latency, network throughput, and power efficiency for various QoS criteria. These goals can be translated into QoS performance metrics

Architecture of Sensor Node

The hardware architecture of a sensor node is depicted in Figure. 1.2. The sensor nodes include numerous hardware modules that play particular functions in the sensor device's operation. The Electricity Unit draws power from a battery or a solar panel to power subsystems. Sensing, connectivity, and data processing all use power in a sensor node. Data communication needs more power than sensing and data processing. Batteries or capacitors can be used to store energy. The major source of power for sensor nodes is batteries. Mica2 Mote, for example, is powered by two AA batteries. Because batteries have a restricted capacity, reducing energy usage is always a prioritythroughout WSN operations. Environmental energy (e.g., sun, wind) is converted to electrical energy using renewable energy systemsthroughout WSN operations. Environmental energy (e.g., sun, wind) is converted to electrical energy using renewable energy systems.

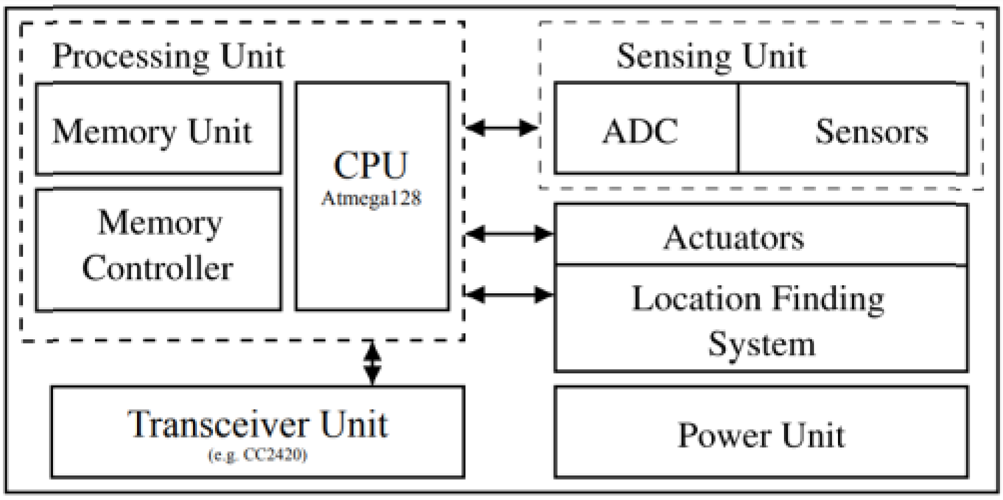

Figure 1.2 Sensor Node Architecture

The Sensing Unit is made up of analogue sensors and A/D converters that sample data and send it to the processing unit; this module generally comprises many sensors. When a sensor detects a change in temperature, pressure, or light, it generates a response signal. An ADC detects and digitizes the continuous analogue signal before sending it to the embedded CPU for processing. Because of the restricted power supply, the connected sensors should be small and waste less energy. One or more types of sensors can be integrated in or linked to a node in a sensor. The sensor's activities are controlled by the Processing Unit. An embedded processor's job at a sensor node is to line up jobs, process data, and control other hardware components. Microcontroller, Digital Signal Processor, and Application Specific Integrated Circuit are some of the embedded processors that may be utilized in a sensor node. Because of its flexibility to link to other devices and its inexpensive cost, the microcontroller has been widely utilized for sensor nodesProgram code and data are saved in the Memory Units. A sensor node's memories include in-chip flash memory, microcontroller RAM, and external flash memory. The ATMega128L microcontroller, for example, has 4-Kbyte static RAM and 128-Kbyte flash programme memory when operating on Mica2 Mote. The Transceiver Unit allows you to communicate with other sensor nodes more easily. A sensor node's wireless communication is handled by a transceiver. Radio frequency and infrared are two different types of wireless communication medium. The majority of WSN applications rely on radio frequency transmission. Transmit, Receive, Idle, and Sleep are the four operating modes of a transceiver. The Actuators Unit is in charge of moving, controlling, and steering the mobile sensor nodes. The Operating System (OS) mission is to stimulate the development of dependable application software by providing a pleasant and safe abstraction of the hardware. Because of the unique needs of WSN applications and the limitations of WSN hardware platforms, operating systems for WSN nodes are simpler than general-purpose operating systems. TinyOS is the first operating system created specifically for WSNs. It's been ported to a variety of platforms and sensor boards. This operating system is used in simulation by WSN project developers all around the globe to create and test various algorithms and protocols.

Research Motivation

Timeliness, high dependability, availability, and integrity are all important QoS criteria for emerging WSNs. The capacity of a WSN to meet certain QoS criteria defines its competence. The accuracy and timeliness of data transferred between sensors and control stations is critical, particularly in real-time settings. The Deadline Miss Ratio (DMR), which is defined as the proportion of packets that fail to reach the end-to-end deadline, should be kept as low as possible. Sensor nodes are generally powered by batteries. As a result, while implementing QoS protocols for WSNs, energy economy and load balancing are essential goals. Cluster heads provide optimization features such as data fusion and Time Division Multiple Access (TDMA) communication. High-power nodes can analyze sensed data and interact with other nodes in clustering, whilst low-power nodes are utilized for sensing. Clustering is an effective method for increasing energy efficiency, lifespan, and scalability. By include fault tolerance and bandwidth in protocol measurements, the network's QoS may be enhanced.

The dependability of Wireless Sensor Networks is influenced by a number of factors, including the random nature of the communication channel, collision, congestion, and the presence of interference. Current research focuses on improving reliability using packet loss avoidance and packet loss rehabilitation approaches, which may be implemented per-hop or end-to-end. Long transmission routes, radio interference, packet collisions, and poor link propagation owing to damaged connections are all issues that these recovery approaches face in practice. These approaches work well in a small network, but their efficacy in enhancing dependability decreases as the network grows larger owing to collisions and congestion.

Sensor node failure compromises the network's quality of service with high density of sensors in the network; the chances of a sensor node failing increase. Locating and removing such faults is critical for maintaining QoS pathways in the event of a breakdown. The objective is to provide algorithms that can provide QoS to apps while using the least amount of energy possible. The idea of multi-channel MAC systems is to increase the capacity of wireless access approaches. Wireless connections having multi-channel access may serve several broadcasts at the same time without colliding. In the MAC layer, multichannel scheduling MAC assignment can reduce interference between various channels and result in collision-free transmission. Each node may only broadcast during the slots that have been allotted to it. Because there is less retransmission and a greater delivery ratio, the collision avoidance approach increases effective channel use and saves energy. The Admission Control Scheme (ACS) analyses if the available resource in WSNs can accommodate new streams while maintaining the existing streams' Quality of Service

Research Objectives

The overall aim of this research work is to propose a method to enhance the QoS in the network by selecting an optimal route with high throughput.

The conventional routing path selection is done with hop count or the routing path length, link stability value, and link availability. But these route selection approaches are not sufficient to ensure the QoS within the networkInitial research was focused on developing and implementing a better path selection strategy in WSN routing based on PRR predictions for enhancing the QoS in the network. Using regression techniques the PRR of a particular path is predicted and the path with optimal PRR value is chosen to provide better quality of service in the network.

The prediction is made based on the Received Signal Strength (RSS), the link quality indicator, noise floor over the respective multi hop path, transmission and reception rate in the MAC layer, and the routing path length. The second contribution of the research focused on estimating the probability of the link availability using statistical parameters and utilizes the same to select an optimal routing path for data transmission.

The proposed method estimates the overall probability of the link availability for all the node links present within the routing path under consideration. The route with highest probability will be considered for transmission of the data packets. This helps to ensure the QoS in the network by limiting the overhead caused due to frequent link failure when unstable links are selected for transmission. This research proposed solution for enhancing QoS in a Wireless multi-hop network by adopting a multi-channel communication and following a multi-path routing along with packet aggregation. The objective is to balance the load within the network by distributing the traffic to multiple hops and reduce the probability of bottleneck nodes. This investigated the advantage of cluster based routing and proposed a QoS aware Cluster based Routing (QoS-CR) technique for WSN. The proposed QoS-CR involves three main processes, namely clustering, routing and maintenance. At the earlier stage, Fuzzy logic Based Clustering (FBC) technique gets executed to organize the nodes into clusters and selects Cluster Heads (CHs) effectively. Then, a Firefly with a Levy (FF-L) algorithm is employed for identifying the optimal paths between two CHs or CHs to BS. Finally, the maintenanceprocess is invoked to balance the load and energy consumption throughout the network evenly

QoS is an important mechanism which guarantees the achievement of multiple generic and unique requirements of a variety of applications. QoS related issues and challenges can be categorized in to either application or network specific. The network specific issues are concerned with efficient utilization of network resources such as energy and bandwidth for satisfying the requirements of the application. This chapter presents an optimal route selection strategy for enhancing the QoS in the network by predicting the PRR. The PRR is predicted based on the mean values of the following parameters namely receiver signal strength, LQI, noise floor, routing path length, transmission rate, and receive rate. The main function of sensor nodes is to collect data from various nodes within the network and send it to the base station in a systematic manner. The dependability of Clustering algorithms that can organize a huge number of data points could be used to reinforce such networks. Organizing wireless sensor networks into interconnected groups extends the life of the networks. The interspace between the nodes and the base station, as well as the space between the nodes and the base station, are important aspects of a wireless sensor network. The energy utilization and therefore the longevity of the system are heavily influenced by the distance between the interconnected nodes

Methodology

The overall aim of this research work is to propose a method to enhance the QoS in the network by selecting an optimal route with high throughput. In various literatures it is mentioned that TCP throughput is inversely proportional to the square root of the Packet-Reception-Rate in a multi hop links environment.

The optimal route selections are based on multiple criteria including the mean RSSI, mean LQI over the multi-hop links, and predicted PRR. Moreweightage is given to the PRR when compared to other two parameters. Each routing path is assigned one numerical value P based on the following equation. The Figure 1.3 shows the block diagram of the various tasks involved in the route selection process

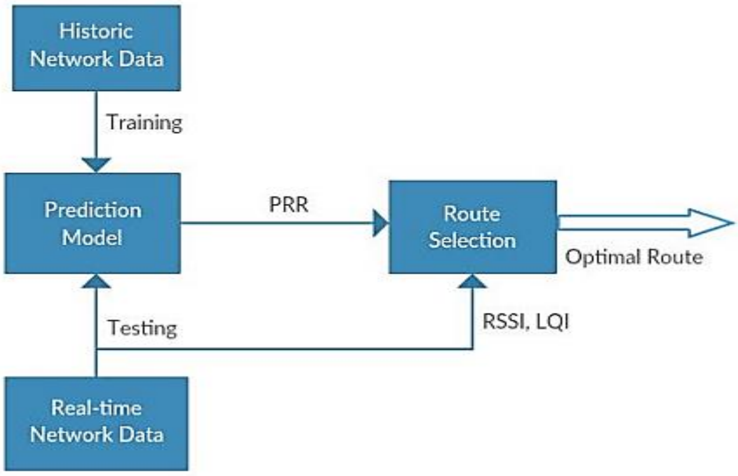

Figure 1.3Block Diagram of Route Selection Process

Link Assessment in WSN

The assessment of link quality between two nodes becomes crucial when selecting routes in a multi-hop environment. A dependable link possesses certain attributes, including minimal energy consumption, high stability, optimal throughput, low latency, reliability in retransmissions, and infrequent changes in neighboring nodes. To counter energy waste, link quality estimation typically involves a limited number of samples, as selecting an incorrect route could lead to packet loss. Opting for an unstable link with dynamically changing neighboring nodes can lead to simultaneous transmissions, causing interference. Interference in a link also impacts the quality of neighboring links. Several techniques for link quality estimation have been proposed, such as Link Quality Indication Based on Metric (LQIBM), Expected Transmission Count (ETX), Required Number of Packets (RNP), LQI based ETX (LETX), and the Kalman Filter algorithm (KLE).

A straightforward and effective method for estimating link quality is the Window-Mean-with-EWMA (WMEWMA) estimator, widely utilized in Wireless Sensor Networks (WSNs). This approach calculates link quality based on the current packet delivery rate and historical values, employing a weighted moving average filter. This filter negates the impact of fluctuations in the Packet Reception Rate (PRR). Importantly, the estimation process takes place on the receiver side, preventing an increase in overhead.

QoS Provisioning in wireless sensor Network

After various advancements in pervasive computing and miniature sensor devices, the applications of wireless sensor networks have expanded to encompass areas such as healthcare, agriculture, industrial automation, and urban infrastructure. Guaranteeing and maintaining Quality of Service (QoS) in this diverse application landscape is challenging due to the networks' dynamic topology and the distinctive attributes of sensor nodes, primarily their constrained resources. At the network layer, methods tailored to specific domains for QoS provisioning have captured substantial interest within the research community. This study conducts a structured evaluation of the assorted approaches put forth in literature to ensure QoS within the network.

Enabling dynamically adaptive routing decisions sensitive to the network's conditions is attainable through a robust model of network awareness and information dissemination across the IEEE 802.15.4 protocol stack. Conversely, incorrect data supplied by a sophisticated (intruder) node could lead to losses in links or packets within the network, resulting in a decline in QoS and heightened energy consumption. In this context, the ongoing learning of network patterns, dynamic parameters, node analysis, network conditions, along with strategic path planning, could play a pivotal role in achieving energy efficiency and furnishing QoS.

Moreover, since wireless sensor networks function as cooperative protocols, they frequently confront opposition in the form of malicious nodes aiming to manipulate routing decisions, delete data packets, and obstruct services. This leads to data loss, retransmissions, delays, QoS breaches, and energy depletion. A strategy involving route selection based on the availability of links has been proposed to ensure QoS. This approach outperforms traditional metrics like hop count and network stability in terms of route selection. The stability of the routing path is more pronounced in scenarios with limited mobility, while heightened mobility results in a decrease in the likelihood of network availability.

The progress in pervasive computing and miniature sensor technology has widened the scope of applications for wireless sensor networks. Upholding QoS across diverse applications necessitates tailored methodologies. Effective QoS assurance involves adaptive routing aware of network conditions, addressing the influence of rogue nodes, and countering adversarial nodes to minimize data loss, delays, and energy drain.

Route Selection Process and its Impact

Wireless Sensor Networks (WSNs) have garnered significant interest, particularly following the remarkable advancements in Micro Electro Mechanical System (MEMS) technology. WSNs utilize a diverse array of versatile sensors to establish interconnected networks. A primary constraint of WSNs stems from their reliance on battery-powered sensor devices. In most applications, the deployment locations for these sensors are often inaccessible. To surmount this challenge within the network, strategies for optimizing resources come into play. Beyond energy considerations, the network must manage other critical resources such as network bandwidth, memory capacity, and Quality of Service (QoS) parameters, which include factors like end-to-end delay, packet latency, and link reliability. To extend the overall lifespan of a WSN, optimization algorithms are employed. The goal of QoS provisioning is to ensure reliable packet transmission to the intended destination node within an acceptable delay threshold and without incurring packet loss.

Since the nodes operate on batteries, the energy levels across the network's nodes are not uniform due to differences in remaining power. Additionally, because nodes can move erratically, the links between intermediate nodes might break due to low battery or node mobility. Quality of Service (QoS) aims to ensure stable link selection by estimating link availability using data from the MAC and data link layers at the network and transport layers. This prevents unnecessary energy wastage.

In the typical network communication protocol, a modular structure is employed. Each layer has specific responsibilities: the MAC layer handles node communication scheduling, the network layer forwards data packets from source to destination, and the physical layer modulates data for wireless transmission. The widely used OSI layering model provides the structure for these protocol layers. However, an alternate approach called cross-layer communication is employed instead of sharing information strictly among the layers. Unlike the OSI model where non-adjacent layers don't interact, cross-layer design enables interaction between non-adjacent layers to function cohesively as a system..

Conclusion

A multichannel interference-aware topology control and QoS-enhanced routing in an IEEE 802.11-based multichannel WSN are examined. A probability-based routing system is created, which allows the transmitting network nodes to find the routing route one hop at a time. The suggested solution is accomplished via cross-layer design, as the network allocation vector read from the MAC layer is sent to the routing layer for computing the sending probability. This strategy takes into account the interference at both ends of the transmission and estimates a routing metric to use in selecting the next hop node. The simulation results revealed the higher performance of the suggested technique when compared to a standard multi-path routing protocol.

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