Optimization Techniques for Data Aggregation in Wireless Sensor Networks

Dr.J. SenthilKumar[1], Mr. R. Gowrishankar[2],
[1]Professor, Department of Information Technology, Sona College of Technology, Tamilnadu
[2]Assistant Professor, Department of Computer Science and Engineering, Nehru Institute ofTechnology, Coimbatore, Tamilnadu.

Abstract— Wireless Sensor Network (WSN) consists extensive sensor hubs which contain a preparing unit, at-least one sensor, a transceiver for information exchange and power unit outfitted with low energy distributed over a geographical area for monitoring our surrounding and physical conditions. It’s been established that vitality is that the most obliging element on the functionality of such systems as they're controlled with constraints and replacement of vitality resources could be difficult. While sending the data in the sensor network, there could be loss of data or error could occur in receiving data during transfer. The precision of data has huge impact on the performance of the network. to reinforce the exactness of sensor information, minimizing vitality utilization and adaptation to internal failure is significant for a few WSN’s applications as they operate in unpredictable conditions and need to stay operational no matter whether a network failure happen. This paper surveys the at hand energy efficient, reliable and fault tolerant approaches in WSNs. It focuses on Residue Numeration System (RNS) and Agent technologies for energy-efficient and fault tolerance in WSNs respectively. However, performance evaluation is done supported the energy consumption, reliability, delay in receiving the transmitted data and efficiency**.**

Keywords— Wireless Sensor Networks, Fault Tolerant, Residue Number System, Power Efficiency and Reliability.

I. INTRODUCTION

Wireless sensor networks (WSNs) comprises of number of remote sensor hubs distributed in a region of interest with one or multiple base stations, where information is collected. They are vitally used in monitoring our environment and for physical conditions. These are small circuit devices which enable the measurements of physical and environmental conditions [1]. WSNs finds its importance in many areas such as patient monitoring in hospital, battle field surveillance, Internet of Things (IoT) and other areas where wireless nodes operate in highly dynamic environments [2]. WSNs are also self-reliable systems that comprises of numerous distributed sensor devices that are scattered over a wide area to monitor physical phenomena, including temperature, humidity, vibrations, etc [3]. WSNs contains distributed network of enormous number of arbitrarily organised sensor hubs, which have inherent computational, storage and transmission capacity that operate in an unfriendly mode and gather information of interest from its surrounding [4] .The principle aim of remote sensor systems is to acquire the detected information from condition and send them to the sink hub where it is to be handled. Figure 1 shows a Wireless Sensor Networks containing wireless nodes and therefore the sink.

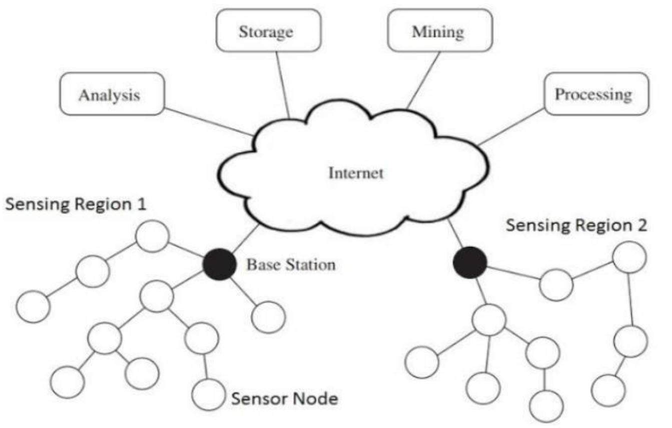
A sensor hub is a small electronic gadget that comprises of three parts: a decision making unit used to process local data, a sensing unit used to acquire data from the physical condition, and a wireless transceiver that transfers the sensing data to the base station. These sensor nodes perform datasensing and processing data and also communicate with each other in the network. In

WSN, sensor node batteries cannot be replaced or recharged frequently, applications and services should be architectured in an energy efficient manner [3]. Adaptation to unexpected failure is imperative for some WSNs applications as they work in dynamic environment and ought to stay operational. Moreover, it is seen that the reliability and availability of WSNs can be affected by risks, including those from radio- wave interference, battery exhaustion, hardware and failures, communication link errors,malicious attacks, etc [3].

Since nodes are prone to error, failure detection and fault recovery approaches are mandatory in WSNs. However, a base station that collects data from each of the sensor nodes to provide fault resistance can be very expensive. To improve the correctness of sensor information, the errors are recognized and risk is calculated. Commotion expulsion in sensor information additionally enhances its quality [1]. The term agent is exceptionally prominent in the registering press as it is inside the computerized reasoning and the software engineering networks. Agent software has continued to attract significant research attention due to their intelligence, mobility and collaborative nature. Agent-based systems play significant roles in the design of various essential industrial applications [5].

However, there is high need of agents processing as a result of quick advancement in computing and information organizing innovation to help those requirements. A multi-agent system (MAS) consists of many cooperative agents that can solve problem impossible for single agent [6]. MAS have a rule that can be effortlessly coordinated in complex frameworks thanks to their completely distributed and intelligent approach. Residue numeration system (RNS) may be a non-weighted number system that provides free, parallel, rapid, and secure and fault tolerant mathematical works. With-in the ancestral decades, residue number system possesses extraordinary consideration. In this system, residues of the amount with reference to module set are represented rather than the first number itself.

Along these lines the amount are going to be part into some littler numbers which are automated and tasks are often distilled on them independently and simultaneously which makes the computations less complex and faster[7]. It provides extraordinary capacity for rapid computation due to their significant properties which make them predominantly helpful in Digital Signal Processing (DSP) applications. RNS can enforce convey constraints and fast number-crunching, error discovery and additionally error recovery applications [8]. As results of these highlights, its utilization in embedment of varied fields is developing quickly. Residue



numeration systems are highly valuable in error recognition and rectification on the grounds that a mistake in one digit doesn't degenerate another digits. This paper presents a survey of the available agent-based fault tolerant and RNS energy efficiency in WSNs. It also performs evaluation supported the facility consumption, reliability, delay within the transfer of knowledge and efficiency for every approach.

A. *Energy-Efficiency and Fault Tolerance in Wireless SensorNetworks*

Energy efficiency in WSNs is the set of procedures to manage various vitality supply mechanisms and then efficient utilization of the power in a sensor node. Energy efficiency involves less power to achieve the same service. A WSN that offers a higher event detection accuracy for less amount of vitality is said to energy-efficient.

It is of prior importance for WSNs because once deployed it is difficult to recharge or replace its power source frequently[3]. Hence, WSN should be planned in a vitality efficient way in order to reduce the usage of at- hand power. The life time of a sensor network can be improved by applying various approaches. Energy efficient algorithms usually aimed at decreasing the vitality consumption during network activities. However, a great amount of energy is used by node components such as CPU, transceiver etc. even if they are inactive. Power management approaches are thus used for switching off hub parts that are not temporarily needed [8]. However, a system is considered fault tolerant if the system works, regardless of the failure of a portion of its parts, is reliable with its details. Fault tolerant systems have the capacity to performs task within the sight of errors. By utilizing adaptation to unexpected failure, numerous potential disappointments are turned away, in this manner extending the dependability and proficiency of the system.

The main aim of adaptation to non-critical failure is to extend the systems accessibility, which is to construct the ideal opportunity for which the system is accessible for clients' administration. Computers can be made more reliable by preventing errors aswell as detecting and rectifying identified errors. Fault is a sort of deformity that prompts an error. An error is defined as inaccurate system state, and such a state may prompt a failure. A failure is the noticeable indication of an error, which happens when the system works against its determined task and cannot convey its proposed purpose [4].In WSNs, fault event likelihood is highly contrasted with traditional networking management. Then again network maintenance and hubs replacement is incomprehensible since its remote deployment. Adaptation to non-critical failure in wireless networks can be grouped into four levels from systemview.

They are: hardware layer, programming layer, networking layer and application layer [5]. Generally, to detect the error if any occurs during transmission of data certain measure of overhead in term of additional parity bits which are added to the total transmitted data. These additional bits are used by thereceiver to check for faults on the progression of data that mayoccur in the midst of the transmission. Adaptation to non- critical failure is imperative for some WSNs applications as they work in unstable dynamic conditions and ought to stay operational . WSN failures for example caused by dropped bundles of data because of remote impedance, over-burden, hub or connect failures, and distributed systems [6]. To have the capacity to maintain effective tasks, WSNs must be flexible to these systems flow. The extraordinary case is with the end goal that requires a crisis reaction during disaster for example, in fire, surge, volcanic eruption, tsunami and military reconnaissance. It is, therefore, necessary to automate fault management techniques in wireless sensor networks. One of the main objectives of the remote sensor systems is to enrich dependable information accumulation to meet the goals of the applications. Giving predominantly quality is a critical issue to address since dominant part of the sensor systems are remotely operated with next to no human interaction once sent; and the maintenance is added infeasible now and again. The sensor network is naturally presented to inconsistencies for example, errors from equipment fault, correspondence errors, errors in sensors, and so forth, requiring the requirement for predominant quality components [7].

B. *Fault Propagation in WSN's Applications*

Wireless sensor systems are regularly conveyed in uncertain condition and are prone to faults in few layers of the network. Figure 2 illustrates layered order of the network in WSN which may cause issues [3]. A fault in each layer has the vulnerability to spread over every one of the other levels. Hubs have few equipment and programming parts has deficiencies. The confined area can endure effects and uncover the equipment of the sensor hub to the antagonistic states of the earth, for example, presentation to coordinate contact with water will cause short-circuits. Likewise, at the point when the battery of a sensor drains off, sensor readings may wind up erroneous. Equipment failures will prompt programming errors. A Data Acquisition application will notperform correctly if the hidden sensors are providing error readings. At all situation, equipment failures do not influence every one of the administrations in the sensor hub. In spite of the fact that the hub cannot be utilized to adjust sensor readings, it can be used to give consolidated output in the sensor network. Programming bugs are a typical wellspring of error in WSNs. Bug could cause the longest nonstop system blackout taking the system offline for a long time until the point when thehubs could be reinvented manually.

At the network layer, routing is a major factor that is fundamental in the collecting the sensor information, information about programming and design updates, and coordination among the hubs and this could likewise have some pitfalls. Faults on the routing layer can be due to loss of data or altered messages, or unsuitable delays in the transmission. Interference can likewise make the link between hubs wind up broken. Another issue of link failure is thecollision of messages. A sink hub collects the majority of the information produced in the system and transmits it to the back-end system. It is additionally responsible for faults in its segments. When a failure occurs at the sink and fault-tolerant measures have not been adopted, the after effect of the failure spreads to all nodes of network, resulting in sensor nodes cannot be accessed. Atjilast, the database that stores the information gathered from the system, processes them and sends them to the back-end system, is also liable to bugswhich when display, can prompt loss of information during the time when the fault happened.

II. LITERATURE REVIEW

There have been a few investigations on error controlprotocols in wireless systems and particularly in mobile systems, none of them are specifically set for Wireless Sensor Networks (WSNs). Also many energy conservation methods have been proposed aimed at reducing the power consumption of the radio interface. The two main techniques are: Duty Cycling and In-Network Aggregation [8-9]. In Duty Cycling techniques the radio transceiver will be in the sleep mode whenever point correspondences are not required. In all cases, vitality sparing harms the expanded hub unpredictability and system dormancy occurs.

In In- Network Aggregation technique consolidates routing and information accumulation strategies went for reduce the number of transmissions. Multipath routing algorithms are generally utilized. Altogether multiple paths could remarkably consume more power than the shortest path because a few duplicates of a similar bundle could reach the destination. Moreover, to increase reliability, Automatic Repeat Request (ARQ) in which the receiving node detects lost data and then request the sending node to resend the packets was proposed [10]. In Forward Error Correction (FEC) the aggregator must disentangle the received data, total them with new information and encode with parity bits before sending them to sink [10]. Both reason a critical end-to-end deferral and high vitality utilization which reduces the system lifetime. And also no single technique gives broad adaptation to non-critical failure covering a wide range of flaws that a WSN hub is exposed to. Therefore, it is a need to develop an efficient, fast and reliable fault tolerant WSNs while still preserving the limited energy of the network.

III. AGENT-BASED FAULT TOLERANT APPROACHES IN WSNS

An agent is software embedded in the node that is arranged in some condition, and it has an ability of performing self-sufficiently in that condition to meet its planed goal. Satellites autonomously sense the earth and react appropriately [2]. In earlier days, MAS are utilized in many domains, for example, reproduction, and artificial intelligence and robotic, image processing and so forth and are incorporated into the WSNs, on account of their significance. MAS applied to the WSN for the capturing information, and also directing, andthe discovery of knowledge which is used in decisions making.

In reality, adding multi-agent approaches in WSN many ideas are presented at various levels and working angles. Agent technology has been successfully deployed in WSNs at various layers such as application, middleware, database and network. In DMWSN, a distributed monitoring system for WSNs used in multi-agent system was proposed with the main objective of software design and the organization of the network topology to be self sufficient and self reliant [11]. Moreover, the aim was to reduce error in the network and increase its usage time. This was deployed in Castalia simulator based on the simulator Omnet++. Additionally, error detection and correction that was based on multi agent system was proposed in MFTS. Energy conservation was done with multi-agent and mobile agent configuration was simulated with Java.

EDFBRP, proposes an operator based routing protocol for remote sensing systems, in view of determining the possibility of volatile hubs [12]. The steering calculation is linked with vitality and separation elements of every hub. The primary target was to extend the lifetime of the network while not trading off information consistency. JADE was used as operator structure. Also, MACB-WSN, designed multi-agent which involves clustering of WSN using two mathematical models [13]. The first model Data aggregation (Multi Agent Controlled Dynamic Routing Protocol - MACDRP) where one Base Station in each round; and data is changeable in any direction. The second model (Multi-agent and Base Stations Route Clustering -MABCDCP), Cluster Heads are selected and then sensor nodes send the information to the Cluster Heads and then Cluster Head transmits the collaborated information to the nearest sink. The proposed models improved security in synchronization, better coverage and in turn reliability. Besides, in IWSNM-MAS, intelligent multi agent that used mobile agent to collect data in a cluster was proposed. It is designed in such a way each sensor node has processing capability with an agent each for local data processing [14]. The nodes were grouped with a cluster head using Local Closest First (LCF) protocol to determine a method for nodes belonging to the same group. Network Simulations done using C++ Builder. The results show decrease in power consumption and increased in packet delivery rate. A multi-agent architecture that will enhance the mapping of parameters between heterogeneous systems, call affirmation control and handover administration with the goal of certification end-to-end delivery and QoS was proposed [12]. The extraordinary standpoint of this system is an enhanced execution of the remote correspondence supported the very fact that the simplest system is chosen by the QoS parameters. In conclusion, multi-agent technology was used in wireless sensor network with space keeping to adjust programming engineering, and to streamline its monitoring tasks [13]. Agent based algorithm for adoptation to internal failure and topology control in a remote sensor organize was proposed. This consists of embedding an agent at every hub that is responsible for choosing its parent or the following bounce to the sink node while exchanging packets. The fundamental promise is the proposition of another following procedure of evolving parent, which depends on the calculation of an adaptation to internal failure rate, found each time by the agent in participation with its neighbouring hubs. The results of simulation demonstrate that this technique for changing parent permits an upgraded lifetime, and arrange adaptation to non-critical failure.

IV. RNS-BASED ENERGY EFFICIENCY IN WSNS:

A lot of research has been completed to investigate diverse areas in energy efficient and fault tolerant wireless sensorsystems, those researches have brought new challenges in creating secure and reliable data storage and access facility in WSNs.One of the most benefits of residue numeration system is that they facilitate the detection and correction of errorbecause all the digits are independent [16]. However, there are several approaches that are studied for fault tolerant wireless sensor network, a number of which are discussed. Low Energy Adaptive Clustering Hierarchy (LEACH) is the primary and best energy-efficient hierarchical clustering scheme for WSNs that was proposed for reducing power consumption [18]. In LEACH protocols, the sensor nodes are divided into clusters, then sensor node with higher resources is chosen as upcluster head (CH).

The CH manages all the activities within its cluster. it's also the responsibility of CH to obtain information from cluster nodes, aggregate and take away between gathered data so as toscale back the energy requirements for sending data packets from the CH to a different CH or to the base station [18]. In any case, an approach that relays on a packet-splitting algorithm based CRT that's featured by an easy modulo division between integers was proposed [17] which has low overhead in calculation, correspondence and capacity, immune to DoS assault. A trade-off between vitality effectiveness and dependability of the CRT sending plan when obligation cycling systems are considered was explored [10]. This was accomplished with an immediate update within the general multifaceted nature and with low overhead. Redundant moduli that assume no part choose the dynamic range was presented. This was utilized as a neighbourhood of WSNs to diminish renew information sending by means of happen error in information packet which was centred around low many-sided quality error detection techniques which was executed with low information repetition and productive vitality devouring in remote sensor hub utilizing residue number systems. A novel vitality proficient and rapid error control conspire that depends on the Redundant Residue number system (RRNS) during a real-time use of WSNs was proposed [10]. The hypothetical outcomes sponsored by recreation tests affirm that the arrangement outflanks famous error control techniques for WSNs regarding error controllability, vitality productivity, and reduce of end-to-end delay. Authors in [19], Likewise proposed information transmission convention that gave dependable association amongst hubs and sink. Residue number system and a couple of redundant modules were utilized to furnish security in transmission concerning vitality in sensors and ideal course is additionally chosen.

The author in[10] considers simultaneous wireless information and power transfer (SWIPT) technique and routing technique, and applying them to multi-hop clustered wireless sensor networks (MCWSN), where each node can decode information and harvest energy from a received radio- frequency signal. And the relay nodes in MCWSN can use the harvest energy to forward data to their next hop nodes consistently with the routing protocol. First, design an energy-efficient routing problem of MCWSN with SWIPT.

Then, a heuristic energy efficient cooperative SWIPT routing algorithm (EECSR) is presented to find a transmission path with the utmost energy efficiency. Specifically, in EECSR, the resource allocation problem in each hop of the path is transformed to an equivalent convex optimization problem, which are resolved through dual decomposition. Added, a distributed routing protocol supported EECSR is proposed. As far as we know, this is the first solution that considers energy efficiency optimization based on routing and SWIPT in MCWSN. Simulation results show that the EECSR algorithm has high energy efficiency and best robustness. And the distributed routing protocol has better real-time performance than traditional protocols.

V. COMPARISON ANALYSIS

A great amount of research effort has been put on the development of various techniques to detect faults that may occur in wireless sensor networks. Besides, all these effort has been limited almost completely to a particular faults in sensor networks, no technique provides extensive fault tolerant support covering all types of faults that WSNs node is exposed to. It was also seen that none of the researches on review of fault tolerant WSNs reviewed two techniques altogether. There are a few researchers think about WSNs with the point of streamlining the vitality utilization of hubs utilizing new inventive protection procedures to enhance execution speed, including the extension of its life. Overall, vitality preservation is at last to locate the best trade-off between the different vitality.

VI. CONCLUSION

Survey on various techniques and schemes for providing efficient fault tolerant wireless sensor networks were discussed. The cause and the effects of faults in WSNs were also identified and discussed. Different algorithms and/or techniques that were used to prevent, detect, identify, isolate, and treat faults and failures in WSNs were summarized. The existing research works with the notion of improving reliability and energy efficiency were studied elaborately based on their performance and reliability measures. Besides, it is been observed that no single technique or algorithm can provide a completely reliable solution for the fault tolerant problem in WSNs. It is suggested that a multi-level approach for providing fault tolerant, reliability and energy efficiency is needed.

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