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Self-Healing and Self-Configuration in AODV based Wireless Sensor Network

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***Abstract*—WSN technologies present significant potential in several application domains. Given the diverse nature of these domains, it is essential that WSNs perform in a reliable and robust fashion. This paper presents methods of self-configuration based on modulation parameter scaling and error correction codes based self-healing technique. Results show that lifetime and throughput of wireless sensor network can be increased using this methods.**

Keywords—WSN;Self-Configuration;Self-Healing;Error Correction Codes;Modulation Scaling.

I. Introduction

Wireless Sensor Networks (WSNs) have focused on the development of new applications like wireless monitoring and environmental control applications for twenty-first century. Its properties like ad hoc nature and deploy-and-leave vision has gained the interest of researchers in public interest welfares like military, transport, monitoring, medical and safety. These applications have similar operation features like constrained power source and ability to operate in harsh environmental conditions. They are also programmed to work in conditions like failure of node, their mobility and networking over a considerable size of geographical area. Thus for this reason, the maintenance and management approaches of traditional networks are now impractical in this field [1].

WSNs are nothing but the deployment of the tiny sensor nodes that are inexpensive and can be located in any region of interest to collect data relating to one or more variables. These nodes are deployed only to sense, process and communicate the data to the adjacent nodes and ultimately to pre-defined destination.

Sensor nodes maycooperate with their neighbors (within communication range)to form an ad hoc network. WSN topologies are generallydynamic and decentralized.Sensor nodes can also havemobility capabilities which enable them to physically relocatewith relation to neighboring nodes and the environment inwhich they are situated.

In order to build real-time, multi-modal,high resolution monitoring in these systems, WSN applications need to address critical challenges such as *autonomy*: the ability to operate in an unattended (and possibly hostile) area with the minimal aid from base stations and human administrator. *Scalability*: the ability to scaleto, for example, a large number of sensor nodes and alarge amount of data generated by sensor nodes. *Adaptability*: the ability to adapt to dynamic conditions of WSNs (e.g., network traffic and resource availability) andsensor nodes (e.g., sensor readings and power consumption).*Self-healing*: It is the ability to detect and eliminate false positive data from the malfunctioning nodes. *Simplicity*: design simplicity and lightweight in footprint due to resource constraints in sensor nodes [2].

The WSN deployment configuration is crucial to the network satisfying the performance criteria and operationallifetime. Even if the sensor nodes are deployed uniformlyacross the region of interest as time passes, sensor nodes mayfail randomly due to energy exhaustion, malfunction ormalicious destruction. Non-uniform traffic distribution andedge effects will directly influence the energy usage of thesensor nodes. The cumulative result of these factors maycause coverage holes and possibly detach a segment ofthe WSN. The implication of these failures may result inthe WSN performance deteriorating thus preventing theperformance criteria from being met. The net result of thesefailures is a reduced useful lifetime.

II. Realated Work

Several researchers have researched on the above mentioned problem.Hoseung Lee et al [3] proposed a self-configuring sensor network topology scheme, that can achieve scalable, robust and energy efficient sensor network based on distance between active nodes. The idea is based on reduction of number of active nodes so as to make energy efficient network.Boonma et al [4] presented a new middleware called tinyDDS. These according to the network conditions adaptively perform the event publication and balance the performance among conflicting objectives. A modification of the Directed Diffusion routing protocol is presented by the authors of [4] for the reduction in energy consumption of the network in case of failures. The scheme they proposed employs Geocast approach for the broken paths by constructing a new routing tree [5]. Furthermore several researchers also proposed self-healing techniques to mitigate the effect of aforementioned problems. Vlajic et al presentedconcept of self-healing WSNs to improve the performance and network lifetime. Authors investigated the energy aspect of combating routing holes through the deployment of a single mobile (super) node [6].To create the Wireless Sensor Network reliable it is necessary to study the reasons of fault occurrence. The ZigBee specifications states about the self-healing mechanism that relies on tree topology. Once the node in ZigBee fails, the decedents of the node re-align the path to join the network. Instead, Jian et al [7] proposed a scheme efficient enough for the self-healing of node after its failure or in other case only some of the descendants should join the network. This allows the subnet of a fault node to rejoin the network with minimum transaction of communication and thus saving the critical energy [8]. At different levels of WSN fault occurrence is the common issue. Against this the end-user requires the automatic self healing in the pervasive applications. Bourdenas et al studied the two cases of body sensor deployment and evaluated the impact of fault in a WSN node on the activity and gesture classification accuracy.

Jingyuan et al [9] presented the scheme for self-healing of nodes in WSN that is dependency constraint directed. The author also stated that in the duration of self-healing, invocation, parameter consistency, certain dependency constraints, control and implicit dependencies are required to be indentified and studied carefully.

III. Autonomic Sensor Networks

Autonomic computing brings together different disciplines of computer science to promoteself-managing systems that adapt to their operating environment and user needs. To this end, different systems exhibit different degrees of adaptation to dynamic environmentswithout manual administration. Autonomic computing is defined by its properties self-configuration, self-healing, self-protection and self-optimization, also referred as the self-*attributes. Self-* attributes are not orthogonal. For instance, in order for a network to heal adefective component, it should be able to reconfigure itself and possibly optimize the use of itsresources to allow for alternative solutions.

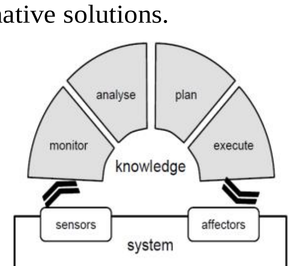


Figure 1:Closed feedback control-loop in Autonomic systems

Common among autonomic systems is a closed feedback control-loop pattern that consists of four distinct steps-monitoring, analyses, planning and execution,the monitoring step collects performance metrics to measure the condition of different systemcomponents. The analysis phase processes information collected in order to infer the system'sstatus. Analysis of monitored attributes may identify node or sensor failures, poor or failedcommunication links, low battery levels or poor quality of service due to overloaded processorsor communication links. The planning phase constructs an alternative system configuration,based on observed symptoms and identifies actions necessary to counter defects and to transitionto a better state. Finally, the execution phase applies the reconfiguration plan that has been produced. This process implies a dynamic system infrastructure that enables in-situreorganization without disrupting operations.

Sensor networks are structured in three layers, which present the functionalarchitecture of a wireless sensor network (WSN) application. The bottom layer, sensing, samplesthe environmental attributes and extracts features such as the mean or variance of sensorreadings, e.g. sensing room temperature for air-conditioning control in buildings. The middlelayer, analysis, processes events, e.g. change of room temperature, to infer system context. For instance, a node may infer room condition by fusing information from extracted features. Informationfusion is not, however, restricted to features but extends to decisions as well. A decisionfusion process combines localized or low-level decisions with domain-specific knowledge to inferhigher level concepts, e.g. based on local decisions of several rooms it may be inferred thatthe air-conditioning in the conference room under-performs. The top layer, network, involvesnode management and orchestration. The functional role of the node manager is to organize the flow of information, e.g. the dissemination of decision from fusion centers to other ends ofthe network, as well as the nodes' structure in the network, e.g. ad-hoc, hierarchical, clusteredcommunications, etc. The network manager finally assigns tasks among nodes and orchestratestheir interactions.

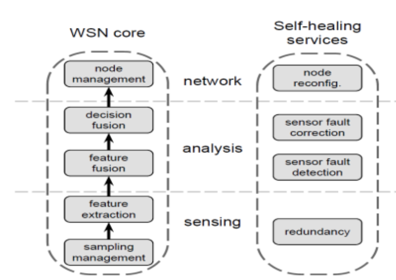


Figure 2: Functional architecture of a self-healing wireless sensor network

Faults in this architecture propagate upwards affecting decision quality in higher layers. Consequently, faults need to be identified and contained as close to their source as possible. We look at extending services in different layers of the architecture that allow the network to toleratefaults and heal.

In the sensing layer redundancy of resources, i.e. sensing devices deployed,provisions for fault tolerance. Fault detection and correction mechanisms can be deployed inthe analysis layer based on features extracted from sensors and domain-specific knowledge ofthe application environment. Finally, at the network layer a reconfiguration mechanism is required to handle identified failures, which will be able to restore broken communication links,reallocate assigned tasks of failed components or redistribute available resources.

IV. Self-Configuration in AODV Wireless Sensor Network

Today, the WSN are deployed in several military and civil services on a heavy scale. The reason is the scalability of WSN services in the remote conditions and harsh environment. Since the major limitation of sensor network is the battery life of a sensor node hence algorithms to maximize the life of battery and lowering power consumption is crucial as it nearly impossible to change the battery of the sensor network nodes [6]. Also the reliability of the data collected, processed and forwarded by the sensor node has to be assured. As a result of this the low energy consumption and high reliability has become the crucial issues when dealing with the WSN.

Energy Efficiency is a major fact of anxiety in operation of any WSN. The large scaleof such networks and the necessity of unattended operation over a long period of time require careful management of the energy resources. In addition, wireless communication is a major source of power consumption during system operation, the ratio of the energy spent in sending one bit of information to the energy spent in executing one instruction is typically around several orders of magnitude [11]. It is crucial to develop low power radio modules to increase network lifetime. Modulation scaling is a new paradigm, which is an effective technique to reduce radio power consumption by adopting modulation level to match the traffic load. Consider multihop communication as presented in [12], here we developed modulation scaling approach for AODV WSN as self-configuration mechanism.

Let communication path involves n nodes,$S_1 \rightarrow S_2 \rightarrow S_3 \rightarrow . . . \rightarrow S_n$and consider a packet size s is needed to transmit from S_1 to $S_n$in a given time interval [0,T].

By fixing the symbol rate R_i for each hop, the time duration for transmission over can be modeled as: $S_1 \rightarrow S_{i+1}, \tau_i$ can be modeled as:

$$\tau_i = \frac{s}{b_i * R_i} \qquad (1)$$

Further, the corresponding energy dissipation for sending the packetE_i can be modeled as:

$$E_i = (P_i + D_i.R_i) * \tau_i = [C_i.(2^{bi} - 1) + D_i].\frac{s}{b_i} \qquad (2)$$

Where $P_i$is the transmission power; $C_i$is determined by the quality of transmission, in terms of Bit Error Rate, and the noise power; $D_i$is a device-dependent parameter that determines the power consumption of electronic circuitry; b_i is the constellation size in number of bits per symbol.

By substituting $b_i = \frac{s}{\tau_i * R_i}$, in above equation it can be shown that E_i is non-negative, monotonically decreasing function of τ_i.

Let $\omega_i(\tau_i)$ denotes energy function. $\vec{\tau} = \{\tau_i, i = 1,2,3, \ldots. n-1\}$, is feasible if the transmission latency,$\sum_{i=1}^{n-1} \tau_i$, is within T. Consider that the energy functions of all the hops are known a priori. Then the algorithm can be defined as:

Given *a series of consecutive single-hop communication links*$S_1 \rightarrow S_2 \rightarrow S_3 \rightarrow . . . \rightarrow S_n$ and packet size s, find *a feasible schedule of packet transmission*$\vec{\tau}$, *so as tominimize the maximal energy dissipation over all nodes*:

$$OBJ_{\vec{\tau}} = \max_{i=1}^{n-1} \omega_i(\tau_i) = \max_{i=1}^{n-1} \left[C_i.\left(2^{\frac{s}{\tau_i * R_i}} - 1\right) + D_i\right].\tau_i.R_i$$

The node S_i that satisfies $\omega_i(\tau_i) = OBJ_{\vec{\tau}}$ is called the *critical node* for τ_i or simply critical node. In general, critical node may not be unique.

The necessary and sufficient conditions for optimality are:

1. $\sum_i \tau_i = T$; and
2. $\omega_1(\tau_1) = \omega_2(\tau_2) = \cdots \omega_{n-1}(\tau_{n-1})$

The value of $b_i$can be derived from equation 1 based on the final value ofτ_i. Hence by variations in latency modulation parameter can be changed.

V. Self-Healing in AODV based Wireless Sensor network

The WSN consists of number (100s-1000s) of spatially distributed autonomous sensor nodes. Each sensor node is able to sense the physical or environmental conditions, process it and communicate it in the network using RF transceiver. Sensor nodes are deployed in different geographical area and due to the lack of any other power supply the sensor nodes are operated by battery. Modulation scheme, operating frequency, channel condition and inter-node distance and ECC has significant effect on the consumption of energy of the sensor node. The maximum amount of energy is consumed during communication.

The error induced in the communicated data by noise during transmission can be corrected by two techniques one is to request the sender to resend the data (ARQ) and the second technique is to add some extra bits to the original data at the transmitter these extra bits will detect and correct the errors induced in the data at the receiver (ECC).

ECC provides better BER at the same SNR as compared to uncoded system i.e. provides coding gain. To maintain the BER within its specified limit either transmitter power can be increased or ECC can be used. ECC reduces the required transmitter signal energy due to its coding gain on the other hand extra bits added to data by ECC requires extra energy for encoding , transmitting and decoding. Therefore at very small distances < 10 m using ECC is less efficient .but if the distance is more 50-100m and above then using ECC is energy efficient as coding gain will keep the transmitter power low for the same BER. Choice of particular ECC depends upon type of application and other sensor network constraints such as environmental conditions, type of modulation scheme, number of nodes, distance requirements. A procedure for the selection of ECC for a specific WSN application and limitations is developed or shown where energy consumption of different ECCs is calculated using energy simulator and configuration energy is compared with other error code performance then an optimum ECC is selected by comparing the power consumption.

The energy consumed in WSN can be computed as

$$E_{TOTAL} = E_{enc} + \sum_{i=1}^{m} N_b E_{TX} + \sum_{i=1}^{m-1} N_b E_{rx} \quad (3)$$

$$E_{TX} = E_{RX} = E_{te} + E_{ta} d^{\alpha} \quad (4)$$

$$E_{ta} = \frac{(SNR)_{r(i)} NF_{RX} N_0 BW \left(\frac{4\pi}{\lambda}\right)^{\alpha}}{G_{ant}\, \eta_{amp}\, R_{Bit}} \quad (5)$$

Where

E_{enc} : Energy consumed by the encoder.

N_b : Total number of bits transmitted.

E_{TX} : Energy consumed in transmitting single bit from a node.

E_{rx} : Energy consumed in receiving single bit by a node.

$(SNR)_{r(i)}$: Desired SNR at ith receiving node.

NF_{RX} : Receiver Noise Figure.

N_0 : Thermal noise of the receiver.

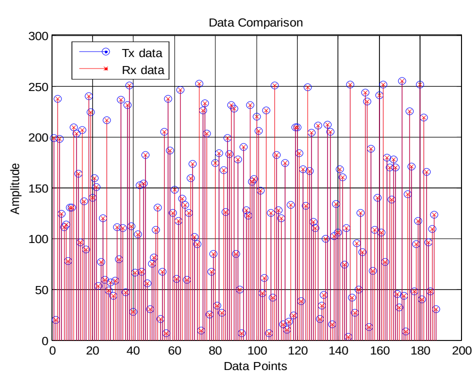
BW: Bandwidth of Noise in channel.

G_{ant} : Gain of transmitting antenna.

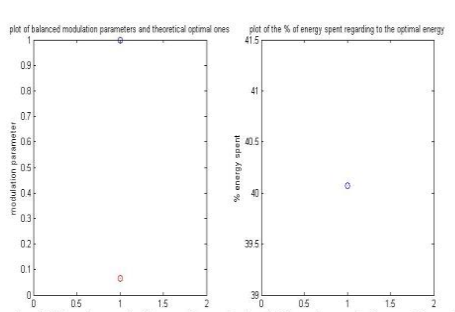
η_{amp} : Transmitter Efficiency.

R_{Bit} : Channel bit rate.

VI. RESULT



Self-Healing in WSN



Self-Configuration In WSN

D	7.0000e-010
energy	-2.3000e-004
Eused	5.6000e-007
ratio	0.4007
omega	0.4000
gamma	3
NON-AWARE protocol: number of total tx	1429
AWARE Protocol: number of total tx was	14422

IX. CONCLUSION

The paper proposes a novel method for autonomic computing in WSN by self-configuration and Self-Healing. The proposed approach for self-configuration uses modulation parameter scaling to enhance network lifetime. Result shows the original and scaled modulation parameter to meet optimum system requirement. ECC based approach is proposed for self-healing in WSN system. As depicted from result it is clear that deploying error correction mechanism can improve the performance. Simulation has been carried out on MATLAB. The overall impact of aforementioned schemes is to provide Transactional security and to enhance network lifetime by applying autonomic characteristics to WSN.

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