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Autonomic Computing Characteristics of Wireless Sensor Networks

[1]Rajani Narayan, [2]Dr. B. P. Mallikarjunaswamy, [3]M. C. Supriya

[1]Research scholar, Department of Computer Science and Engineering, Jnanasahyadri, Kuvempu University, Shankaraghatta, Shimoga, Karnataka, India

[1]Associate Professor, Department of MCA, RNS Institute of Technology, Bangalore

[2]Professor, Dept. of Computer Science and Engineering, Sri Siddhartha Institute of Technology, Tumkur, Karnataka, India
[3]Research scholar, Department of Computer Science and Engineering, Jnanasahyadri, Kuvempu University, Shankaraghatta, Shimoga, Karnataka, India

***Abstract*— Wireless sensor networks (WSN) have become increasingly one of the most promising and interesting areas over the past few years. Wireless networks of sensor nodes are envisioned to be installed in the physical surroundings to monitor a wide assortment of real-world phenomena. Wireless sensor networks (WSN's) are becoming prevalent in military and civilian applications such as surveillance, monitoring, disaster recovery, home automation and many others. Almost any sensor network application requires some form of self-configuration and autonomic functionality. Following IBM's initiatives towards Autonomic computing many architectures and protocols for network self-organization and management have been proposed and being implemented.**

The paper presents a review of some researches which follows concept of Autonomic Computing with respect to Wireless Sensor Network. The paper introduces Wireless sensor network basics, design goals and challenges along with current and future applications. It articulates basic needs of incorporating autonomic computing principles into the design of Wireless Sensor Networks. The paper also outlines recent contributions to Autonomic network architectures, research projects, proposed architectures and routing protocols for Autonomic Wireless Sensor Networks.

Keywords **— Wireless Sensor Network, Autonomic Computing, Self-Management, Self-configuration, Self-Healing, Self-Protection, Self-Optimization.**

I. INTRODUCTION

Wireless sensor networks have critical applications in the scientific, medical, commercial, and military domains. Examples of these applications include environmental monitoring, smart homes and offices, surveillance, and intelligent transportation systems. It also has significant usages in biomedical field. As social reliance on wireless sensor network technology increases, we can expect the size and complexity of individual networks as well as the number of networks to increase dramatically.

The paper introduces a review of Autonomic computing and wireless sensor network concepts. Discusses how the fundamental properties of Autonomic computing comply with the basic design requirements for wireless sensor networks. Proposed protocols for Wireless Sensor Network and their applicability and suitability to Autonomic Wireless Sensor Networks and required improvements. The paper gives brief overview of research projects and architectures for autonomic communication and networking which can be applied to WSNs. The last section focuses on the current and possible future applications of Autonomic Wireless Sensor Networks.

Autonomic Computing–

1. Background

The dramatic increase in computing devices, increased computing capacity and complexity combined with popularity of internet resulted in phenomenal growth in heterogeneous networks and network applications. With this increasing system complexity, network management issues and communication protocols are reaching a level beyond human ability to manage and secure so the stability of current infrastructure, systems, and data is at an increasingly greater risk to suffer outages and general disrepair. Future network algorithms need to be adaptive, robust, and scalable with fully distributed and self-organizing architectures. Automation, self-protection and self-management of wide spread networks may solve the problem till some extent.

As the concept of self-management rooted up, the most direct inspiration one can think of was the *autonomic function of the human central nervous system*, where autonomic controls use motor neurons to send indirect messages to organs at a sub-conscious level. These messages regulate temperature, breathing, and heart rate without conscious thought. Observation and analysis of these complex adaptive systems found in nature became a

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major source of inspiration to design algorithms for self-managed, self-organized, self-configuring and self-protecting systems.

Taking inspiration from autonomic nervous system of the human body IBM created a foundation for autonomic systems by taking initiatives towards Autonomic Computing for relieving humans from the burden of managing computer systems which is growing enormously till the extent of unmanageability.

2. Autonomic System

Autonomic System is a system which works independently on predefined policies and rules without any human interaction and manage and configure itself on its own based on predefined rules and gained knowledge over the time. IBM has defined the following four functional areas for self-management of Autonomic System:

- *Self-Configuration:* Automatic configuration of components.
- *Self-Healing:* Automatic discovery, and correction of faults.
- *Self-Optimization:* Automatic monitoring and control of resources to ensure the optimal functioning with respect to the defined requirements.
- *Self-Protection:* Proactive identification and protection from arbitrary attacks.

A. Structure of Assessment

The edifice steps of this paper is as follows. The Introductory Section ends with a brief introduction of wireless sensor network and autonomic principles.

In Section II, we address the Autonomic behaviour described by various authors, and demonstrate that autonomic behaviour is not restricted to resource-rich system, as typified by large servers, but can be incorporated into distributed and computationally challenged devices. Methods regarding how wireless sensor networks can benefit from the use of autonomic techniques without being overburdened with additional computing costs will be discussed.

Section III addresses the properties of self-configuration in wireless sensor network, and covers a range of behaviours from the better-clustering performance of the Localized method to the more energy-efficient operation of the methods.

In Section IV, we analyse the properties of self-Healing in wireless sensor network, and demonstrate that Self-Healing Routing is an efficient fault-tolerant protocol that performs well even with spontaneous network topology changes.

Section V explains the properties of self-Protection in wireless sensor network, Self-protection problem focuses on using sensor nodes to provide protection to themselves instead of the target objects or certain target area, so that the sensor nodes can resist the attacks targeting on them directly.

Section VI shows experiments on self-Optimizing of wireless sensor networks, Advancements in sensor networks enable a wide range of environmental monitoring and object tracking applications. Moreover, multi-hop routing in WSN is affected by new nodes constantly entering or leaving the network. Therefore, nature based self-optimized and independent mechanism is required to tackle problems arise in WSN, Section VII shows the application, and future work regarding the topic and a general conclusion of the paper is in Section VIII, at the last tabular comparison for different sections are presented before references.

III. A General Autonomic Behaviour for Sensor Networks

"Autonomic computing is an approach to self-managed computing systems with a minimum of human interference". Given this definition, the challenge is to design WSNs that are self-managing, self-diagnostic, and transparent to the monitoring entity. This new computing paradigm, when applied to a WSN, means that the design of such a network should aim to embed autonomic capabilities in sensor nodes.

Author in [1] presents a new data dissemination algorithm for wireless sensor networks is presented. The key idea of the proposed solution is to combine concepts presented in trajectory-based forwarding with the information provided by the energy map of the network to determine routes in a dynamic fashion, according to the energy level of the sensor nodes. This is an important feature of an autonomic system, which must have the capacity of adapting its behavior according to its available resources. Fault tolerance becomes one of the important design factors, and fault tolerance techniques become a critical aspect of research associated with WSN, an author in [2] study state-of-the-art fault tolerance and intrusion tolerance techniques

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for WSN and propose a new fault-intrusion tolerant routing mechanism called MVMP (multi-version multi-path) for WSN. Before that, they made an attempt to unify fault tolerance and intrusion tolerance in a systematic way for WSN by developing an integrated fault-intrusion tolerance framework called WSN-TUM [3]. The WSN-TUM incorporates both conventional non-security fault and intrusion fault management. Specifically, the WSN-TUM identifies four types of faults that can occur in WSN: hardware faults, software faults, middleware faults, and intrusion faults.

Until now, it is unrealistic to prevent DoS attacks, but compromised nodes may be designed to self-recover to reduce the harm of DoS attacks. In this direction, Chunguang Ma et al [4] develop an agent based self-recovery model (ABSR) was presented on the use of autonomic computing, which can recover itself in the approach of anomaly monitoring, anomaly deciding and node recovery. As a possible extension of this work could be to consider other monitoring and recovery methods used for different attacks using ABSR. And they are planning to study how to monitor different attacks and recover to normal in WSN. Future work along these lines could be to prove the effectiveness of ABSR rigorously and universally.

One of the most important problem occurs in wsn is, Owing to the deployment of large number of sensor nodes in uncontrolled hostile or harsh environments and unmonitored operation, it is common that a node becomes inactive due to a node failure or exhaustion of the respective energy resource. Many author propose algorithms to make a wireless sensor network more efficient, by considering energy as a crucial parameter or by applying an intelligent behaviour in sensor networks, like level based approach proposed in [5], the work can also be done by considering heterogeneity in network and making a cluster network steady as done in [het]. Mainly [6] present a dynamic energy efficient real-time job allocation algorithm called ERTJA for handling such node failures in a cluster. This relies on the other cluster nodes to handle the node failure.

Some researchers also motivates us to add another “S” in our autonomic structure, like Self-address Collision Detection and solving [7], Self-Security in network as mentioned by Rabindra Bista et al [8] which Providing an efficient data aggregation scheme with preserving data privacy is a challenging problem in the research of wireless sensor networks, and Self-Configuration as done in [9] and [10].

Self-configuration mainly define in terms of Clusters, Data Aggregation, and Authentication. One author [12] make an algorithm in hybrid sense, it incorporates the best features of two other recently proposed self-configuring protocols for sensor networks: the Localized protocol and the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol. LLC covers a range of behaviors from the better-clustering performance of the Localized method to the more energy-efficient operation of the LEACH method, to achieve the desired goal. Self-Configuration mainly apply in routing mechanism like TDMA, MAC protocols. One of the key research in the era was “Self-Configuration TDMA Protocol for Wireless Sensor Networks” [13], the main design goal of SC-TDMA is to solve collision, overhearing, idle listening and control packet overhead problems which are the main sources of power consumption for sensors.

Other considerations can also be taken to make an autonomic structure much powerful like adding the issues like stability, scalability, as developed in researchers like Volker Turau et al [14], Hongwei Zhang et al [15], their algorithm enables network nodes in a 2D plane to configure themselves into a cellular hexagonal structure where cells have tightly bounded geographic radius and the overlap between neighboring cells is low. Also a problem-independent transformations for algorithms that stabilize under the central daemon scheduler such that they meet the demands of a WSN.

III. SELF-CONFIGURATION BEHAVIOUR FOR SENSOR NETWORKS

Here, we describe some important innovations in achieving self-configuration behaviour in wireless sensor networks, mainly points Automatic discovery, and correction of faults.

Localization is an important building block for sensor networks and is itself a sensor network. We use it as our example to motivate the need for automatic self-configuration through adaptive localized algorithms. A

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localized algorithm is a distributed computation in which sensor nodes achieve a desired global objective while constraining their communication to sensors within some neighbourhood.

Pervasive networks of micro-sensors and actuators offer to revolutionize the ways in which we understand and construct complex physical systems. Sensor networks must be scalable, long-lived and robust systems, over- coming energy limitations and a lack of pre-installed infrastructure. Nirupama Bulusu et al [11] first explore three themes in the design of self-configuring sensor

Networks: tuning density to trade operational quality against lifetime; using multiple sensor modalities to obtain robust measurements; and exploiting fixed environmental characteristics.

IV. SELF-HEALING BEHAVIOUR FOR SENSOR NETWORKS

Wireless sensor networks (WSNs) and pervasive systems are increasingly used for applications such as building monitoring and control, health-care and environmental monitoring. The users are frequently non-technical and devices may not be easily accessible, thus their management and complexity should be transparent to the users.

To this extent, the systems need to be self-healing, able to respond to failures. Sensor networks are structured in three layers, which presents the functional architecture of a wireless sensor network (WSN) application.

The bottom layer, sensing, samples the environmental attributes and extracts features such as the mean or variance of sensor readings, e.g. sensing room temperature for air-conditioning control in buildings. The middle layer, 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.

Most of the autonomic researches in WSN are done in the field of self-healing, as we know it is highly desirable that these natural deteriorations can be monitored continuously and can be corrected with self-healing when necessary. Jingyuan Li et al [16] reveal that when self-healing services are being composed, certain dependency constraints, including invocation, parameter consistency, control and implicit assumption dependencies must be carefully identified and respected, and we analyse that this research is also a key to energy efficient self-healing.

The major work in the field is done by Themistoklis Bourdenas el al [17], he identify and define sensor readings' fault models extracted from long-running, real-world sensor deployments. Author describe a fault detection mechanism for sensor readings based on heuristic and Bayesian probabilistic approaches that accurately identifies error occurrences in readings and minimises false positives. The work propose by Markus Lanthaler et al [18] In his work a failure detection scheme and a service management approach using the autonomic computing paradigm and some concepts of the IT Infrastructure Library (ITIL) will be evaluated. The presented approach aims to employ self-healing services, allowing them to discover, examine, diagnose and react to malfunctions.

WSN applications need to address critical challenges such as autonomy, scalability, self-healing and simplicity. Based on the observation that various biological systems have developed mechanisms to meet these challenges, BiSNET (Biologically inspired architecture for Sensor networks) implements key biological mechanisms such as energy exchange, pheromone emission, replication and migration to design WSN applications [19]. While dealing with the efficiency parameters of a self-Healing Network, the main parameters are system Efficiency and Resiliency of Data Delivery in Wireless Sensor Network, to make a system better one option is to make protocol uses broadcast communication and a prioritized transmission back-off delay scheme as done in [20]. But in case of opportunistic multi-hop wireless communication consist of Adhoc devices, we should have to follow some terms as followed by Joel W. Branch et al [21]. In it, broadcast communication and a prioritized slotted transmission back-off delay scheme to empower a receiving node to use its hop distance from the destination to autonomously decide whether to forward a packet. That's why this enables dynamic traversal of the shortest available routes without requiring nodes to explicitly decide to which neighbors to forward packets. To study a general behaviour of self-Healing, [22] writer follows an initial approach to self- healing in WSN and describes experiments with two case studies of body sensor deployment. In the contemporary section, many techniques

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are evolved like Immune-Inspired Self-Healing in Wireless Sensor Networks [23], An Efficient and Sustainable Self-healing Protocol for Unattended Wireless Sensor Networks [24].

V. SELF-PROTECTING BEHAVIOUR FOR SENSOR NETWORKS

Since the sensors themselves are important and critical objects in the network, a natural question is whether they need certain level of protection, so as to resist the attacks targeting on them directly. If this is necessary, then who should provide this protection, and how it can be done? We refer to the above problem as self-protection, as we believe the sensors themselves are the best (and often the only) candidates to provide such protection.

There's very less attention paid by researchers in this particular domain, but it's a key element to build an autonomic structure in wsn, for the first time dan wang et al [25] present a formal study on the self-protection problems in wireless sensor networks. We show that, if we simply focus on enhancing the quality of field or object covering, the sensors might not necessarily be self-protected, which in turn makes the system extremely vulnerable

Another author yu wang et al [26] develop an Efficient Self-Protection Algorithms for Static Wireless Sensor Networks, which is more efficient as compare with existing approaches. He also extend his experiment to simple wireless sensor network [27].

Most of the existing geographic routing protocols have not been designed to work effectively in scenarios with malicious nodes. Some protocols use cryptographic schemes, reputation schemes and other sorts of complex and costly (especially for a wireless sensor network) solutions to provide security to the routing protocols. Moreover, these schemes are not able to deal with attacks from legitimate nodes compromised (insider attacks). Author [28] analyse in detail the effects of insider attacks (Sybil and Sinkhole) in beaconless geographic routing protocols and propose a Self-Protected Beaconless Geographic Routing protocol. Here we review that just enhancing the forwarding logic of our routing protocol to make additional transmissions when suspicious traffic is detected, we can deal with these insider attacks without the extra cost and overhead of deploying complex reputation systems. Figure below shows a basic Architecture of a Self-protecting WSN described by [29]. Some other Efficient Self-protection algorithms we found are [30], [31], and [32]. They consider that, due to their open nature of the wireless medium an adversary can easily eavesdrop and replay or inject fabricated messages. Authors explained that Different cryptographic methods can be used to defend against some of such attacks. But here we analyse that for node compromised those methods can do little, which is another major problem of WSN security as it allows an adversary to enter inside the security perimeter of the network, which raised a serious challenge for WSNs.

VI. SELF-OPTIMIZATION BEHAVIOUR FOR SENSOR NETWORKS

Advancements in WSN enable a wide range of environmental monitoring and object tracking applications. Moreover, multi-hop routing in WSN is affected by new nodes constantly entering or leaving the network, also power & energy management are also the key issues in wireless networks. Therefore, the self-optimized and self-aware mechanism is required to handle the problems arise very frequently in WSNs.

Mainly Metaheuristic optimization schemes are used in wireless sensor network to make it self-optimized. In computer science, metaheuristic designates a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. Some of the important algorithms are genetic algorithm, particle swarm optimization, simulated annealing algorithm, ant colony/bee colony algorithm. A.R.Pinto et al [33] presents a Self-Optimization of Dense Wireless Sensor Networks which is based on Simulated Annealing, Here authors main goal is the achievement of a certain level of communication efficiency in an autonomic way.

As multi-hop routing in WSN is affected by new nodes constantly entering or leaving the network. Therefore, nature based self-optimized and independent mechanism is required to tackle problems arise in WSN. The ant inspired routing has shown an excellent performance for WSNs. In [34], the model of self- optimized autonomous routing algorithm BIOSARP with cross layer architecture for WSN. Similar research done by an author in [35], and in [36] name as Biological Inspired Self-Optimized Routing Algorithm for Wireless Sensor Networks.

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Other researches include Evaluating a Transmission Power Self-Optimization Technique for WSN in EMI Environments presented in [37], A

Transmission Power Self-Optimization Technique for Wireless Sensor Networks in [38], Self-Optimized Collaborative Data Communication in Wireless Sensor Networks in [39], here the author focus on the fact that during the collaboration, a receiver node aggregates the signals of the collaborative nodes separately.

VII. CONCLUSION & DISCUSSION

Wireless Sensor Network technology offers significant potential in numerous application domains. Given the diverse nature of these domains, it is essential that WSNs perform in a reliable and robust fashion. I believe, wireless sensor network has proved its usage in the future distributed computing environment. However, there are significant amount of technical challenges and design issues those needs to be addressed. One of the biggest challenges is the designing of efficient network management architecture to continuously support WSNs for providing services for various sensor applications.

The unique features of WSNs make the design and implementation of such management architecture different enough from the traditional networks which can be satisfied by concept of Autonomic Computing. There is still no particular generic network management architecture so taking inspiration from IBMs Autonomic Computing concept and Biological neural network system many different research projects are currently being executed.

In this paper, we discussed review of concepts of Autonomic computing, Wireless Sensor Networks (WSN's). Design criteria for WSN and how it matches basic Autonomic principles. Then we overviewed few architectures and routing protocols suitable for WSN and ongoing research work of Autonomic communication and network management architectures which can be applied to WSNs. Finally, we summarized some of the WSN applications along with future usages, the tabular results below shows the comparative description of different researches in different autonomic structure in wireless sensor network.

TABLE I. Comparison table of different researches in section II

Author	Research	Description
Max do Val Machado	Data Dissemination in Autonomic Wireless Sensor Networks	A new data dissemination algorithm for wireless sensor networks is presented. The key idea of the proposed solution is to combine concepts presented in trajectory-based forwarding with the information provided by the energy map of the network to determine routes in a dynamic fashion, according to the energy level of the sensor nodes.
Carlos Ribeiro	WSN Self-address Collision Detection and Solving	A solution to detect address collisions in dynamic scenarios wasting a minimum level of energy (i.e. without periodic beacons or any other kind of message), and we describe a collision solving protocol which minimizes the impact on the already established routes, which also minimizes energy loss.
Chunguang Ma	An Agent based Self-Recovery Model for Wireless Sensor Network	An agent based self- recovery model (ABSR) was presented on the use of autonomic computing, which can recover itself in the approach of anomaly monitoring, anomaly deciding and node recovery.

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Ruiping Ma	Fault-Intrusion Tolerant Techniques in Wireless Sensor Networks	Problem with state-of-the-art fault tolerance and intrusion tolerance techniques for WSN and propose a new fault-intrusion tolerant routing mechanism called MVMP (multi-version multi-path) for WSN
Hamid Karimi	Energy-Efficient Cluster-Based Scheme for Handling Node Failure in Real-Time Sensor Networks	Present a dynamic energy efficient real-time job allocation algorithm called ERTJA for handling such node failures in a cluster. ERTJA relies on the other cluster nodes to handle the node failure.
Hung-Chi Chu	A Level-based Energy Efficiency Clustering Approach for Wireless Sensor Networks1	Here, Each cluster replaces its cluster head and re-clusters periodically according to the established energy level. A cluster head is a node that has more residual energy and lower communication cost compared to other nodes.
Rabindra Bista	A New Approach to Secure Aggregation of Private Data in Wireless Sensor Networks	Network suffers from one main problem which is the high communication cost due to unnecessary traffics in the network during data transmissions. The proposed scheme applies the additive property of complex number to unite sensor data and for their privacy during their transmissions to a sink node.
Alberto Cerpa	ASCENT: Adaptive Self-Configuring sensor Networks Topologies	The work is parts in some phase, like When a node first initializes, it enters into a listening-only phase called neighbor discovery phase, If a node decides to join the network for a longer time, it enters into an active phase and starts sending routing control and data messages. If a node decides not to join the network, it enters into the adaptive phase, where it turns itself off for a period of time, or reduces its transmission range.
Bozena Kaminska	Self-communicating and self-configuring wireless sensor environment for independent living support	The target requirement is to deliver reliable and sustainable operation of a WSN. The factors of environmental conditions, changing behavior and perturbations need to be part of the definition of a WSN architecture and mode of operation.

TABLE II. Comparison table of different researches in section III

Author	Research	Description
Nirupama Bulusu	Scalable Coordination for Wireless Sensor Networks: Self-Configuring Localization Systems	Three themes in the design of self-configuring sensor networks: tuning density to trade operational quality against lifetime; using multiple sensor modalities to obtain robust measurements; and exploiting fixed environmental characteristics.
Maleq Khan	Self-configuring Clusters, Data Aggregation, and Authentication in Micro-sensor Networks	The main contribution of this paper is a generalized self- clustering protocol, called Low-energy Localized Clustering (LLC). It incorporates the best features of two other recently proposed self-configuring protocols for sensor networks: the Localized protocol and the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol.
Lih-Chyau Wuu	Self-Configuration TDMA Protocol for Wireless Sensor Networks	The design goal of SC-TDMA is to solve collision, overhearing, idle listening and control packet overhead problems which are the main sources of power consumption for sensors.

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Volker Turau	Randomized Self-stabilizing Algorithms for Wireless Sensor Networks	Proposes problem-independent transformations for algorithms that stabilize under the central daemon scheduler such that they meet the demands of a WSN. The transformed algorithms use randomization and are probabilistically self-stabilizing.
Hongwei Zhang	scalable self-configuration and self-healing in wireless sensor networks	A distributed algorithm for scalable self-configuration and self-healing in multi-hop wireless sensor networks. The algorithm enables network nodes in a 2D plane to configure themselves into a cellular hexagonal structure where cells have tightly bounded geographic radius and the overlap between neighboring cells is low.

TABLE III. Comparison table of different researches in section VI

Author	Research	Description
A.R.Pinto	Self-Optimization of Dense Wireless Sensor Networks based on Simulated Annealing	The deployment of hundreds of nodes can overcome the low dependability of individual nodes, however this strategy introduces a lot of challenges regarding network management, real-time requirements and self-optimization. This paper present a simulated annealing approach that self- optimize large scale WSN.
Behnam Banitalebi	Self-Optimized Collaborative Data Communication in Wireless Sensor Networks	Propose a new self-optimized collaborative algorithm which minimizes the energy consumption by de- creasing the number of collaborative nodes and at the same time guarantees the demanded quality. To do this, author focus on the fact that during the collaboration, a receiver node aggregates the signals of the collaborative nodes separately.
F. Lavratti	A Transmission Power Self-Optimization Technique for Wireless Sensor Networks	Trading off power optimization and reliability insurance has become one of the most important concerns when dealing with modern systems based on WSN. In this context, author present a transmission power self-optimization (TPSO) technique for WSNs.
F. Lavratti	Evaluating a Transmission Power Self-Optimization Technique for WSN in EMI Environments	Same Approach as above.
Kashif Saleem	Biological Inspired Self-Optimized Routing Algorithm for Wireless Sensor Networks	Multi-hop routing in WSN is interrupt by new nodes constantly entering/leaving the system. Therefore, biologically inspired algorithms are reviewed and enhanced to tackle problems arise in WSN. Ant routing has shown an excellent performance for sensor networks. In this paper, the design and work on ant based autonomous routing method for wireless sensor network are presented.

TABLE IV. Comparison table of different researches in section IV

Author	Research	Description
Themistoklis Bourdenas	Towards Self-healing in Wireless Sensor Networks	Paper discusses our initial approach to self- healing in WSN and describes experiments with two case studies of body sensor deployment.

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Kamil Wasilewski	Self-Healing Routing: A Study in Efficiency and Resiliency of Data Delivery in Wireless Sensor Networks	The protocol uses broadcast communication and a prioritized transmission back-off delay scheme to empower a receiving mote to use its hop distance from the destination to decide autonomously whether to forward a packet. When severed routes are encountered, the protocol dynamically and locally re-routes packets so they traverse the surviving shortest route.
Themistoklis	Self-healing in Wireless Sensor Networks	Present a middleware for constrained platforms, which supports dynamic adaptation of network components imposing small overheads.
Markus Lanthaler	Self-Healing Wireless Sensor Networks	A failure detection scheme and a service management approach using the autonomic computing paradigm and some concepts of the IT Infrastructure Library (ITIL) is evaluated.
Joel W. Branch	Self-Healing Routing for wireless ad hoc sensor networks	The protocol uses broadcast communication and a prioritized slotted transmission back- off delay scheme to empower a receiving node to use its hop distance from the destination to autonomously decide whether to forward a packet.
Jingyuan Li	Predictive Dependency Constraint Directed Self-Healing for Wireless Sensor Networks	Introduce a dependency constraint directed self-healing scheme for wireless sensor networks.
TiongHoo Lim	Immune-Inspired Self-Healing in Wireless Sensor Networks	Propose an immune-inspired self-healing system where an individual node can detect degradations in network performance, perform diagnostic tests, and provide automated immediate response to recover the network to a stable state.
Alberto Cerpa	An Efficient and Sustainable Self-healing Protocol for Unattended Wireless Sensor Networks	Present a novel sustainable node self-healing protocol for UWSNs. Author also generate unpredictable random data for key update and thus the node self-healing capability doesn't decrease when the number of attack rounds increases.
Pruet Boonma	An Adaptive, Scalable and Self-Healing Sensor Network Architecture for Autonomous Coastal Environmental Monitoring	This paper describes major system components in BiSNET and shows recent simulation results to evaluate BiSNET for oil spill detection in the coastal environment.

TABLE V. Comparison table of different researches in section V

Author	Research	Description
Yu Wang	Efficient Self-Protection Algorithms for Wireless Sensor Networks	Further study the p-self-protection for wireless sensor networks and discuss several aspects that have not been considered or cannot be addressed in previous problem.
Yu Wang	Efficient Self-Protection Algorithms for Static Wireless Sensor Networks	Author study the self-protection problem for static wireless sensor networks in this paper
Rafael Marin-Perez	A Simple Self-Protected Beaconless Geographic Routing for Wireless Sensor Networks	Due to their open nature of the wireless medium an adversary can easily eavesdrop and replay or inject fabricated messages. Different cryptographic methods can be used to defend against some of such attacks.
Dan wang	The Self-Protection Problem in Wireless Sensor Networks	For the first time present a formal study on the self-protection problems in wireless sensor networks. Author show that, if we simply focus on enhancing the quality of field or object covering, the sensors might not necessarily be self-protected, which in turn makes the system extremely vulnerable.
Hosam Soleman	Architecture for Application Autonomic Protection Principles in Wireless Sensor Network	A framework that embeds autonomic capabilities into WSN systems is proposed. The proposed framework provides self-protection features in cases of unauthorized, inadvertent and intentional change in security parameters.

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