(1)

"Design of Immune Algorithm Based Tow- Dimensional Recurive Digital Filters using Multi- level ortho gonel Arrays"

Mohammed Abo-Zahhad, Sabah M. Ahmed, Nabil Sabor and Ahmed F. AL-Ajlouni

Abstract:

Taguchi Immune Algorithm (TIA) is based on both features of the biological immune system and the Taguchi method which increases the ability of the Immune Algorithm (IA) to find the global optimal solution in a nonlinear space. In the TIA, the clonal proliferation within hypermutation for several antibody diversifications and the recombination by using the Taguchi method for the local search are integrated to improve the capabilities of exploration and exploitation. Two major tools are used in the Taguchi method; namely the Orthogonal Arrays (OAs) and the Signal to Noise Ratio (SNR). The effect of selecting the number of levels adopted in the construction of OAs on TIA is not studied before. So, this paper addresses the problem increasing the convergence speed of immune algorithm based two-dimensional recursive digital filters design process by adopting two, three and four levels OAs. For seek of comparison, the same computational experiments adopted in [1] are considered. Numerical results show that increasing the number of OA levels yields to faster convergence and better antibody genes selection in order to achieve the potential recombination, and consequently enhance the design process.

Keywords:

Taguchi methods, array signal processing, recursive filters, two-dimensional digital filters

Published In:

28th National Radio science Conference (NRSE 2011) , NULL , PP. 325-332

(2)

"Design of Two-Dimensional Recursive Digital Filters with Specified Magnitude and Group Delay Characteristics using Taguchi-based Immune Algorithm"

Mohammed Abo-Zahhad, Sabah M. Ahmed, Nabil Sabor and Ahmed F. AL-Ajlouni

Abstract:

This paper presents one modern heuristic optimisation algorithm, named Taguchi-Based Immune Algorithm (TBIA), to solve the problem of designing 2D recursive digital filters with specified magnitude and group-delay characteristics. The algorithm is detailed for the design of three recursive filters categories, namely filters with predefined magnitude, delay and magnitude and delay. On the basis of minimising the magnitude and group-delay errors, multi-criterion design combination is employed to obtain optimal recursive filters that satisfy the required specifications. Computational experiments show the ability of the proposed algorithm to obtain more robust stable complex filters compared with previously reported design methods.

Keywords:

two-dimensional digital filters; IA; immune algorithm; Taguchi method; group delay.

Published In:

Int. J. of Signal and Imaging Systems Engineering , Vol. 3 - No. 3 , pp. 222-235

(3)
"The Convergence Speed of Single-And Multi-Objective Immune Algorithm Based Optimization Problems"

Mohammed Abo-Zahhad, Sabah M. Ahmed, Nabil Sabor and Ahmed F. AL-Ajlouni

Abstract:

Despite the considerable amount of research related to immune algorithms and it applications in numerical optimization, digital filters design, and data mining, there is still little work related to issues as important as sensitivity analysis, [1] [4]. Other aspects, such as convergence speed and parameters adaptation, have been practically disregarded in the current specialized literature [7] [8]. The convergence speed of the immune algorithm heavily depends on its main control parameters: population size, replication rate, mutation rate, clonal rate and hyper mutation rate. In this paper we investigate the effect of control parameters variation on the convergence speed for single and multi objective optimization problems. Three examples are devoted for this purpose; namely the design of 2 D recursive digital filter, minimization of simple function, and banana function. The effect of each parameter on the convergence speed of the IA is studied considering the other parameters with fixed values and taking the average of 100 times independent runs. Then, the concluded rules are applied on some examples introduced in [2] and [3]. Computational results show how to select the immune algorithm parameters to speedup the algorithm convergence and to obtain the optimal solution.

Keywords:

Immune Algorithm, Convergence, Mutation, Hypermutation, Population Size, Clonal Selection

Published In:

Signal Processing: An International Journal , Vol. 4- No. 5 , pp. 247-266

(4)

"Digital Filters Design Educational Software Based on Immune, Genetic and Quasi-Newton Line Search Algorithms"

Mohammed Abo-Zahhad, Sabah M. Ahmed, Nabil Sabor and Ahmed F. AL-Ajlouni

Abstract:

This paper presents educational software developed for designing FIR and IIR digital filters using two evolutionary algorithms (EAs); namely immune algorithms (IAs) and genetic algorithms (GAs),together with quasi-Newton line search algorithm (QNLS). This software provides the user the ability to design one- and two-dimensional; low-pass, high-pass, band-pass and band-stop digital filters with arbitrary magnitude and group delay specifications. The software is evaluated by making the assessment quizzes for electrical engineering students and instructors. Students responses are very positive. A number of recommendations are made in this work based on instructor observation and students evaluations.

Keywords:

digital filters; evolutionary algorithms; EAs; immune algorithm; IAs; genetic algorithm; GAs; quasi-Newton line search algorithm; QNLS; blending teaching and learning.

Published In:

Int. J. of Innovation and Learning , Vol. 9 - No. 1 , pp. 35-62

(5)

"A New Method for Fastening the Convergence of Immune Algorithms Using an Adaptive Mutation Approach"

Mohammed Abo-Zahhad, Sabah M. Ahmed, Nabil Sabor and Ahmad F. Al-Ajlouni

Abstract:

This paper presents a new adaptive mutation approach for fastening the convergence of immune algorithms (IAs). This method is adopted to realize the twin goals of maintaining diversity in the population and sustaining the convergence capacity of the IA. In this method, the mutation rate (pm) is adaptively varied depending on the fitness values of the so-lutions. Solutions of high fitness are protected, while solutions with sub-average fitness are totally disrupted. A solution to the problem of deciding the optimal value of pm is obtained. Experiments are carried out to compare the proposed approach to traditional one on a set of optimization problems. These are namely: 1) an exponential multi-variable func-tion; 2) a rapidly varying multimodal function and 3) design of a second order 2-D narrow band recursive LPF. Simula-tion results show that the proposed method efficiently improves IA□s performance and prevents it from getting stuck at a local optimum.

Keywords:

Adaptive Mutation; Immune Algorithm; Convergence; Traditional Mutation

Published In:

Journal of Signal and Information Processing , Vol.3 , PP.86-91

(6)

"Wavelet Threshold-Based ECG Data Compression Technique Using Immune Optimization Algorithm"

Mohammed Abo-Zahhad, Sabah M. Ahmed, Nabil Sabor and Ahmed F. AL-Ajlouni

Abstract:

In this paper, a new ECG compression method called Wavelet Threshold Based Immune Algorithm (WTBIA) is proposed. This method based on finding the best threshold level for each wavelet subband using Immune Algorithm (IA). The WTBIA algorithm consists of three main steps: 1) Applying 1-D Discrete Wavelet Transform (DWT) on ECG signal; 2) Thresholding of wavelet coefficients in each subband; and 3) Minimization of the Percent Root mean square Difference (PRD) and maximization of the Compression Ratio (CR) using IA. The main advantage of this method is finding the best threshold level for each subband based on the required CR and PRD. The compression algorithm was implemented and tested upon records selected from the MIT-BIH arrhythmia database [6] using different wavelets such as Haar, Daubechies, Coiflet, Symlet and Biorthogonal. Simulation results show that the proposed algorithm leads to high CR associated with low distortion level relative to previously reported compression algorithms.

Keywords:

Electrocardiogram, Data Compression, Wavelet Transform, Immune Algorithm

Published In:

International Journal of Signal Processing, Image Processing and Pattern Recognition , Vol. 8 - No. 2 , pp. 347-360

(7)

"On autonomous and nonautonomous modified hyperchaotic complex Lü systems"

G. M. Mahmoud, M. E. Ahmed N. Sabor

Abstract:

In this paper autonomous and nonautonomous modified hyperchaotic complex L¨ usystemsare proposed. Our systems have been generated by using state feedback and complex periodic forcing. The basic properties of these systems are studied. Parameters range for hyperchaotic attractors to exist are calculated. These systems have very rich dynamics in a wide range of parameters. The analytical results are tested numerically and excellent agreement is found. A circuit diagram is designed for one of these hyperchaotic complex systems and simulated using Matlab/Simulink to verify the hyperchaotic behavior.

Keywords:

Hyperchaotic attractors; chaotic; complex; fixed points; stability

Published In:

International Journal of Bifurcation and Chaos , Vol. 21 - No. 7 , pp. 1913-1926

(8)

"A New Energy-Efficient Adaptive Clustering Protocol Based on Genetic Algorithm for Improving the Lifetime and the Stable Period of Wireless Sensor Networks"

Mohammed Abo-Zahhad, Sabah M Ahmed, Nabil Sabor and Shigenobu Sasaki

Abstract:

This paper presents a new Genetic Algorithm-based Energy-Efficient adaptive clustering hierarchy Protocol (GAEEP) to efficiently maximize the lifetime and to improve the stable period of Wireless Sensor Networks (WSNs). The new protocol is aimed at prolonging the lifetime of WSNs by finding the optimum number of cluster heads (CHs) and their locations based on minimizing the energy consumption of the sensor nodes using genetic algorithm. The operation of the GAEEP is broken up into rounds, where each round begins with a set-up phase, when the base station finds the optimum number of CHs and assigns members nodes of each CH, followed by a steady-state phase, when the sensed data are transferred to CHs and collected in frames; then these frames are transferred to the base station. The performance of the GAEEP is compared with previous protocols using Matlab simulation. Simulation results show that GAEEP protocol improves the network lifetime and stability period over previous protocols in both homogeneous and heterogeneous cases. Moreover, GAEEP protocol increases the reliability of clustering process because it expands the stability period and compresses the instability period.

Keywords:

Wireless Sensor Networks, Genetic Algorithm, Clustering Protocols, Network Lifetime, Homogeneous and Heterogeneous Networks

Published In:

International Journal of Energy, Information & Communications , Vol. 5 - No. 3 , pp. 47-72

(9)

"Coverage maximization in mobile Wireless Sensor Networks utilizing immune node deployment algorithm"

Mohammed Abo-Zahhad, Sabah M Ahmed, Nabil Sabor and Shigenobu Sasaki

Abstract:

A Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensors with sensing, computation and wireless communication capabilities. Each sensor generally has the task to monitor, measure ambient conditions, and disseminate the collected data towards a base station. One of the key points in the design stage of a WSN that is related to the sensing attribute is the coverage of the sensing field. The coverage issue in WSNs depends on many factors, such as the network topology, sensor sensing model, and the most important one is the deployment strategy. The sensor nodes can be deployed either deterministically or randomly. Random deployment of the sensor nodes can cause coverage holes formulation; therefore, in most cases, random deployment is not guaranteed to be efficient for achieving the required coverage. In this case, the mobility feature of the nodes can be utilized in order to maximize the coverage. This is Non-deterministic Polynomial-time hard (NP-hard) problem. So in this paper, the Immune Algorithm (IA) is used to relocate the mobile sensor nodes after the initial configuration to maximize the coverage area with the moving dissipated energy minimized. The performance of the proposed algorithm is compared with the previous algorithms using Matlab simulation. Simulation results show that the proposed algorithm improves the network coverage and the redundant covered area with minimum moving consumption energy.

Keywords:

Wireless Sensor Network, Immune Algorithm, moving consumption energy, Coverage

Published In:

2014 IEEE 27th Canadian Conference on Electrical and Computer Engineering (CCECE) , NULL , pp. 1-6

(10)
"Mobile Sink-Based Adaptive Immune Energy-Efficient Clustering Protocol for Improving the Lifetime and Stability Period of Wireless Sensor Networks"

Mohammed AboZahhad, Sabah M. Ahmed, Nabil Sabor and Shigenobu Sasaki

Abstract:

Energy hole problem is a critical issue for data gathering in wireless sensor networks. Sensors near the static sink act as relays for far sensors and thus will deplete their energy very quickly, resulting energy holes in the sensor field. Exploiting the mobility of a sink has been widely accepted as an efficient way to alleviate this problem. However, determining an optimal moving trajectory for a mobile sink is a non-deterministic polynomial-time hard problem. Thus, this paper proposed a mobile sink-based adaptive immune energy-efficient clustering protocol (MSIEEP) to alleviate the energy holes. A MSIEEP uses the adaptive immune algorithm (AIA) to guide the mobile sink-based on minimizing the total dissipated energy in communication and overhead control packets. Moreover, AIA is used to find the optimum number of cluster heads (CHs) to improve the lifetime and stability period of the network. The performance of MSIEEP is compared with the previously published protocols; namely, low-energy adaptive clustering hierarchy (LEACH), genetic algorithm-based LEACH, amend LEACH, rendezvous, and mobile sink improved energy-efficient PEGASIS-based routing protocol using MATLAB. Simulation results show that MSIEEP is more reliable and energy efficient as compared with other protocols. Furthermore, it improves the lifetime, the stability, and the instability periods over the previous protocols, because it always selects CHs from high-energy nodes. Moreover, the mobile sink increases the ability of the proposed protocol to deliver packets to the destination.

Keywords:

Wireless sensor networks, immune algorithm, clustering protocols, mobile sink, energy hole problem

Published In:

IEEE Sensors Journal , Vol. 15 - No. 8 , pp. 4576 - 4586

(11)

"Rearrangement of mobile wireless sensor nodes for coverage maximization based on immune node deployment algorithm"

Mohammed Abo-Zahhad, Sabah M. Ahmed, Nabil Sabor and Shigenobu Sasaki

Abstract:

One of the primary objectives of Wireless Sensor Network (WSN) is to provide full coverage of a sensing field as long as possible. The deployment strategy of sensor nodes in the sensor field is the most critical factor related to the network coverage. However, the traditional deployment methods can cause coverage holes in the sensing field. Therefore, this paper proposes a new deployment method based on Multi-objective Immune Algorithm (MIA) and binary sensing model to alleviate these coverage holes. MIA is adopted here to maximize the coverage area of WSN by rearranging the mobile sensors based on limiting their mobility within their communication range to preserve the connectivity among them. The performance of the proposed algorithm is compared with the previous algorithms using Matlab simulation for different network environments with and without obstacles. Simulation results show that the proposed algorithm improves the coverage area and the mobility cost of WSN.

Keywords:

Wireless mobile sensor network, Coverage holes, Multi-objective immune algorithm, Deployment strategies, Connectivity, Mobility cost

Published In:

Computers & Electrical Engineering , Vol. 43 , pp. 76-89

(12)

"Immune Node Deployment Algorithm for Mobile Wireless Sensor Networks with Limited Mobility based on Probabilistic Sensing Model"

Mohammed Abo-Zahhad, Sabah M. Ahmed, Nabil Sabor and Shigenobu Sasaki

Abstract:

Coverage has direct effect on the network performance, thus it considered as the measure of quality of service in WSNs. The deployment strategy of sensor nodes in the sensor field is the most critical factor related to the network coverage. So, in this paper a centralized deployment algorithm based on immune optimization algorithm is proposed to improve the coverage of mobile sensor networks. The proposed algorithm redeploys the random deployed sensor nodes to maximize the coverage area based on a probabilistic sensing model. Moreover, the proposed algorithm limits the moving distance of mobile sensor nodes to reduce the dissipated energy in mobility and to ensure the connectivity among the sensor nodes. The performance of the proposed algorithm is compared with the CSAPO algorithm using MATLAB simulation. Simulation results show that the proposed algorithm outperforms the CSAPO algorithm in terms of the network coverage, mobility cost and convergence speed.

Keywords:

Wireless Sensor Network; Immune Optimization Algorithm; Coverage Problem; Nodes Deployment; Coverage Holes Problem.

Published In:

32nd NATIONAL RADIO SCIENCE CONFERENCE(NRSC 2015) , NULL , pp. 259 - 267

(13)

A centralized immune-Voronoi deployment algorithm for coverage maximization and energy conservation in mobile wireless sensor networks

Mohammed Abo-Zahhad, Nabil Sabor, Shigenobu Sasaki, Sabah M. Ahmed

Abstract:

Saving energy is a most important challenge in Mobile Wireless Sensor Networks (MWSNs) to extend the lifetime, and optimal coverage is the key to it. Therefore, this paper proposes a Centralized Immune-Voronoi deployment Algorithm (CIVA) to maximize the coverage based on both binary and probabilistic models. CIVA utilizes the multi-objective immune algorithm that uses the Voronoi diagram properties to provide a better trade-off between the coverage and the energy consumption. The CIVA algorithm consists from two phases to improve the lifetime and the coverage of MWSN. In the first phase, CIVA controls the positions and the sensing ranges of Mobile Sensor Nodes (MSNs) based on maximizing the coverage and minimizing the dissipated energy in mobility and sensing. While the second phase of CIVA adjusts the radio (sleep/active) of MSNs to minimize the number of active sensors based on minimizing the consumption energy in sensing and redundant coverage and preserving the coverage at high level. The performance of the CIVA is compared with the previous algorithms using Matlab simulation for different network configurations with and without obstacles. Simulation results show that the CIVA algorithm outperforms the previous algorithms in terms of the coverage and the dissipated energy for different networks configurations.

Keywords:

Mobile wireless sensor networks; Immune algorithm; Voronoi Diagram; Coverage area; Node deployment

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Information Fusion , Vol. 30 , 36-51

(14)

An Unequal Multi-hop Balanced Immune Clustering protocol for wireless sensor networks

Nabil Sabor Mohammed Abo-Zahhad Shigenobu Sasaki Sabah M. Ahmed

Abstract:

In multi-hop routing, cluster heads near the base station act as relays for far cluster heads and thus will deplete their energy very quickly. Thus, hot spots in the sensor field result. This paper introduces a new clustering algorithm named an Unequal Multi-hop Balanced Immune Clustering protocol (UMBIC) to solve the hot spot problem and improve the lifetime of small and large scale/homogeneous and heterogeneous wireless sensor networks with different densities. UMBIC protocol utilizes the Unequal Clustering Mechanism (UCM) and the Multi-Objective Immune Algorithm (MOIA) to adjust the intra-cluster and inter-cluster energy consumption. The UCM is used to partition the network into clusters of unequal size based on distance with reference to base station and residual energy. While the MOIA constructs an optimum clusters and a routing tree among them based on covering the entire sensor field, ensuring the connectivity among nodes and minimizing the communication cost of all nodes. The UMBIC protocol rotates the role of cluster heads among the nodes only if the residual energy of one of the current cluster heads less than the energy threshold, as a result the time computational and overheads are saved. Simulation results show that, compared with other protocols, the UMBIC protocol can effectively improve the network lifetime, solve the hot spot problem and balance the energy consumption among all nodes in the network. Moreover, it has less overheads and computational complexity.

Keywords:

Hot spot problem; Unequal clustering; Multi-hop routing; Multi-objective immune algorithm; Homogeneous and heterogeneous networks

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Applied Soft Computing , Vol. 43 , pp. 372389

(15)

A Comprehensive Survey on Hierarchical-based Routing Protocols for Mobile Wireless Sensor Networks: Review, Taxonomy and Future Directions

Nabil Sabor , Shigenobu Sasaki , Mohammed. Abo-Zahhad , Sabah. M. Ahmed

Abstract:

Introducing mobility to Wireless Sensor Networks (WSNs) puts new challenges particularly in designing of routing protocols. Mobility can be applied to the sensor nodes and/or the sink node in the network. Many routing protocols have been developed to support the mobility of WSNs. These protocols are divided depending on the routing structure into hierarchical-based, flat-based, and location-based routing protocols. However, the hierarchical-based routing protocols outperform the other routing types in saving energy, scalability, and extending lifetime of Mobile WSNs (MWSNs). Selecting an appropriate hierarchical routing protocol for specific applications is an important and difficult task. Therefore, this paper focuses on reviewing some of the recently hierarchical-based routing protocols that are developed in the last five years for MWSNs. This survey divides the hierarchical-based routing protocols into two broad groups, namely, classical-based and optimized-based routing protocols. Also, we present a detailed classification of the reviewed protocols according to the routing approach, control manner, mobile element, mobility pattern, network architecture, clustering attributes, protocol operation, path establishment, communication paradigm, energy model, protocol objectives, and applications. Moreover, a comparison between the reviewed protocols is investigated in this survey depending on delay, network size, energy-efficiency, and scalability while mentioning the advantages and drawbacks of each protocol. Finally, we summarize and conclude the paper with future directions.

Keywords:

Mobile Wireless Sensor Networks, Mobile Sink, Hierarchical-based Routing, Classical-based Routing, Optimized-based Routing.

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Wireless Communications and Mobile Computing Journal , Vol. 2017 , pp. 1-23

(16)
A Graphical-based educational simulation tool for Wireless Sensor Networks Authors

Nabil Sabor ,Shigenobu Sasaki,Mohammed Abo-Zahhad,Sabah M Ahmed

Abstract:

Many routing protocols have been developed to improve the lifetime, bandwidth reusability and scalability of the Wireless Sensor Networks (WSNs). The operation of routing protocols is difficult to understand and some problems may occur while developing these protocols. Simulation is a relatively fast way of estimating these protocols and understating what is happening in the network. Thus, this paper presents an open source Graphical-based educational simulation tool called Gbest-WSN for simulating routing protocols of the static and mobile, homogeneous and heterogeneous WSNs. Gbest-WSN tool has a user-friendly interface that helps the user to select the routing protocol and define the network configuration. It is provided with four routing protocols; namely LEACH, LEACH-Mobile, immune algorithm-based and genetic algorithm-based routing protocols. Also, it allows the user to update the existing routing protocols and add a new routing protocol. Gbest-WSN is provided with radio, coverage and mobility models for modeling the hardware of the sensor node. It shows a detailed 2D and 3D graphical perception for what is happing during the routing process. Also, it has the ability to compare the simulation results of different simulation methods or different network configurations. In addition, it allows the user to save and load simulation scenarios and also exports the graphical results on PDF files and the statistical results on excel or mat files. Moreover, Gbest-WSN is provided with html help documents to help the user how to use it. The illustrative simulation examples clarified that the Gbest-WSN is a helpful tool for the students, teachers and researchers who work in the field of WSNs.

Keywords:

Wireless Sensor Networks; Routing protocols; Genetic algorithm; Immune algorithm; Open source software; Command-line; Graphic; Educational software

Published In:

Simulation Modelling Practice and Theory , Vol. 69 , pp. 55-79

(17)

An Immune-Based Energy-Efficient Hierarchical Routing Protocol for Wireless Sensor Networks

Nabil Sabor Shigenobu Sasaki1 Mohammed Abo-Zahhad Sabah M. Ahmed

Abstract:

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Keywords:

NULL

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SERSC International Journal of Future Generation Communication and Networking (IJFGCN) , vol. 9, no. 9 , pp. 47-66

(18)

Utilization of Multi-Objective Immune Deployment Algorithm for Coverage Area Maximization with Limit Mobility in Wireless Sensors Networks

M. Abo-Zahhad S. M. Ahmed N. Sabor S. Sasaki

Abstract:

Coverage is one of the most important performance metrics for wireless sensor network (WSN) since it reflects how well a sensor field is monitored. The coverage issue in WSNs depends on many factors, such as the network topology, sensor sensing model and the most important one is the deployment strategy. Random deployment of the sensor nodes can cause coverage holes formulation. This problem is non-deterministic polynomial-time hard problem. So in this study, a new centralised deployment algorithm based on the immune optimisation algorithm is proposed to relocate the mobile nodes after the initial configuration to maximise the coverage area. Moreover, the proposed algorithm limits the moving distance of the mobile nodes to reduce the dissipation energy in mobility and to ensure the connectivity among the sensor nodes. The performance of the proposed algorithm is compared with the previous algorithms using Matlab simulation. Simulation results clear that the proposed algorithm based on binary and probabilistic sensing models improves the network coverage and the redundant covered area with minimum moving consumption energy. Furthermore, the simulation results show that the proposed algorithm also works when obstacles appear in the sensing field.

Keywords:

NULL

Published In:

IET Wireless Sensor Systems , vol. 5, no. 5 , pp. 250261

(19)

ARBIC: An Adjustable Range Based Immune hierarchy Clustering protocol supporting mobility of Wireless Sensor Networks

Nabil Sabor, Sabah M Ahmed, Mohammed Abo-Zahhad, Shigenobu Sasaki

Abstract:

Introducing the mobility to Wireless Sensor Networks (WSNs) puts new challenges in designing an energy-efficient routing. Improving the network lifetime and the packet delivered rate are the most important issues in designing of the Mobile Wireless Sensor Networks (MWSNs). MWSN is more difficult to deal with than its stationary counterpart because it does not have a fixed topology. This increases the complexity of routing due to the frequent link breaks between clusters and their members. Various clustering protocols are developed to support mobility of the nodes in the WSNs. However, these protocols suffer from some limitations in connectivity, energy-efficient, fault tolerance, load balancing and mobility adaption because they organize the network into fixed size clusters and select the heads of these clusters randomly. Thus, this paper proposes an Adjustable Range-Based Immune hierarchy Clustering protocol (ARBIC) with mobility supporting to deliver the sensory data of the MWSN to the base station in an efficient way for a long-time. The operation of ARBIC protocol depends on organizing the network into optimum clusters and adjusting the size of these clusters based on the speed of the mobile sensor nodes to preserve the cluster connectivity. ARBIC protocol utilizes the immune optimization algorithm to determine the best positions of the clusters heads that optimize the trade-off among the mobility factor, energy consumption, connectivity, residual energy and link connection time. In order to save the overhead packets and the computational time, the ARBIC protocol runs the clustering process if and only if the residual energy of any cluster head is less than a predefined energy threshold. Moreover, it performs a fault tolerance mechanism after sending each frame to reduce the packets drop rate by maintaining the stability of links between the clusters heads and their member nodes. Mathematical analyses are established to analyze the computational and overhead complexities of the ARBIC protocol. Simulation results show that, compared with other protocols, the ARBIC protocol can effectively improve the packet delivery ratio while simultaneously offering lower energy consumption and delay by using sensor nodes with adjustable transmission ranges.

Keywords:

Mobile Wireless Sensor NetworksMobility factorMulti-Objective optimizationImmune AlgorithmAdjustable transmission rangeLink Connection Time

Published In:

Pervasive and Mobile Computing , Vol.43 , PP.27-48

(20)

An Unequal Multi-hop Balanced Immune Clustering protocol for wireless sensor networks

Sabor, Nabil; Abo-Zahhad, Mohammed; Sasaki, Shigenobu; Ahmed, Sabah M.

Abstract:

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Applied Soft Computing Journal , NULL , NULL

(21)

A comprehensive survey on hierarchical-based routing protocols for mobile wireless sensor networks: Review, taxonomy, and future directions

Sabor, Nabil; Sasaki, Shigenobu; Abo-Zahhad, Mohammed; Ahmed, Sabah M.

Abstract:

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Keywords:

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Wireless Communications and Mobile Computing , NULL , NULL

(22)

A Graphical-based educational simulation tool for Wireless Sensor Networks

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A centralized immune-Voronoi deployment algorithm for coverage maximization and energy conservation in mobile wireless sensor networks

Abo-Zahhad, Mohammed; Sabor, Nabil; Sasaki, Shigenobu; Ahmed, Sabah M.

Abstract:

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Keywords:

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Information Fusion , NULL , NULL

(24)

C19. Immune node deployment algorithm for mobile wireless sensor networks with limited mobility based on probabilistic sensing model

Abo-Zahhad, Mohammed; Ahmed, Sabah M.; Sabor, Nabil; Sasaki, Shigenobu

Abstract:

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Keywords:

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Published In:

National Radio Science Conference, NRSC, Proceedings , NULL , NULL