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Case-Agent Based System for Designing Wireless Sensor Network

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Abstract

Recently, using Wireless Sensor Networks (WSNs) has great growth in many application areas. But, the design of these WSNs still suffers from important challenges especially the complexity appeared in designing the modern complex and critical networks. Therefore, this research aims to incorporate the agents based methodology into the case based systems (CBS) to improve their performance for the designing process. Thus, CBS can simplify the design tasks. While, agents-based systems can model the distributed and autonomous complex systems such as WSNs. So, the proposed system exploits the advantages of both the CBSs and agents based approach for designing WSN architectures. This suggested system has been applied for a simulated WSN that used in detecting radiated objects in a determined area. Its results have proved great success to be applied in the real-time applications.

Keywords: Wireless Sensor Networks, Case based Systems Design, Agent Systems.

1. Introduction

Wireless sensor networks (WSNs) are wireless dynamic networks structured from a large number of sensor nodes those have continuous sensing, data processing and communication capabilities [1].

These nodes are automatically distributed in certain defined area. Each sensor node can detect its environmental conditions such as sound, temperature, the presence of certain objects ... etc. [2].

WSNs are widely used in many applications such as military, environmental, health, smart spaces applications, … etc. [3]. But, designing these networks face with some limitations such as: needs for using high number of nodes, limited resources, power consumption of the sensors, limitation of changing the network topology [4].

Researchers have developed many methods to overcome these limitations of designing the WSNs. But, this domain still has some important problems especially in methodologies of designing the complex WSNs' systems and their applications [3].

However, in the last years, agents-based systems have proved to be one of the successful technologies used to solve the modern complex design problems. Agents-based systems are good for modeling the distributed and autonomous complex systems such as WSNs.

From another side, case-based reasoning has become a great powerful methodology for overcoming the complexity of the modern design problems based on the old experiences for solving similar cases. They can use some old versions of the product to be designed and adapt their features till achieve the new required design. Thus, CBR systems can simplify the complexity of solving the design problem starting from scratch.

Therefore, the present research proposes a new algorithm that integrates the case based system and the agents architecture for designing WSNs. The reminder of this paper can be organized as: Section 2

represents the agents- based architecture. Section 3 deals with the case based reasoning systems. Section 4 represents the designing of wireless sensor networks. Section 5 introduces the proposed system. Section 6, handles the applicability of the proposed system and its results. While, section 7 presents the conclusion.

2. Agent-based Architecture

An agent is a computational entity that is situated in a dynamic environment and is capable of exhibiting autonomous and intelligent behavior [4]. Group of agents can communicate in an environment. The community of interacting agents, as a whole, operates as a multi-agent system [5]. The agents have the ability to operate in environments those are only partly known, observable and predictable. There are different types of agents such as:

1- *Autonomous agents*: they have the opportunity and ability to make decisions of their own.

2- *Rational agents*: they act in such a way to be suitable for the situation at hand and do the best they can do for themselves. Hence, they maximize their expected utility given their own local goals and knowledge [6].

3. Case Based Reasoning

Case-Based Reasoning (CBR) is developed to re-use past experience. It aims to solve new problems based on past experience (solutions) of similar previous problems stored in a case-base. After solving these problems, they are stored as new cases in the case base to be used in the future [7].

The process of CBR is generally composed of four phases as given in Fig. (1): retrieval, reuse, revise and retain. Firstly, the new problem is represented in such a way that it becomes compatible with the contents and retrieval methods of the case-base. The task of retrieving phase is to search and restore the most similar case(s) for the current problem in the case-base. The goal of the reuse phase is evaluating the retrieved solution of the similar case for the problem and using it when having closed matching. Otherwise, if the retrieved case(s) has/have not complete matching with the new problem, its/their solution(s) is/are become unsatisfactory. So, it (they) will be adapted in the revision phase. CBR modifies the solution(s) of the retrieved case(s) to build a solution for the new problem. Finally, the retained step allows storing the new case (problem + its solution) and updating the knowledge of the case base [8].

CBR systems have a great success in solving many engineering problems, such as: design, diagnosis, planning, etc. However, design problem considered one of the main important problem areas can be solved by the CBR systems [9].

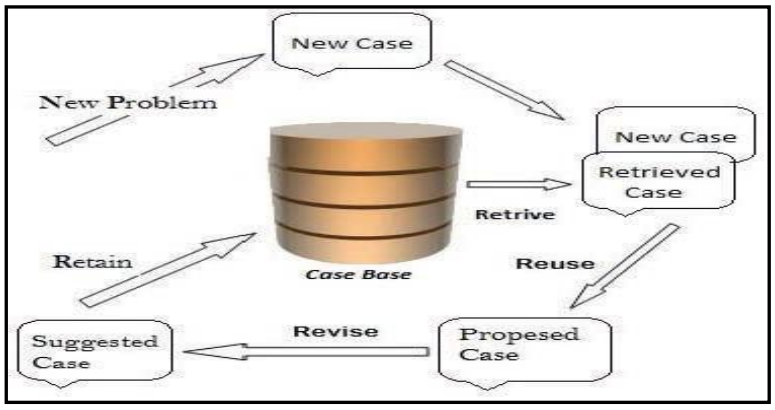

Fig. (1): Case-based reasoning cycle

Many modern case-based systems have integrated CBR with agent-based approach to solve some importantproblems in many application areas. These integrated systems can be classified into two main categories:

1- The agent-based systems in which each agent uses the case based reasoning internally to their own needs. POMAESS's system is used in e-service field and CBR framework that is applied for personalizing the route planning.

2- The agent-based systems whose distribute some/all steps of the CBR cycle among several agents. This type of approach might be better than the first. As the agents can benefit from the other agents capabilities, cooperate with each other for better prediction of the situation. For example, PROCLAIM system is applied in argumentation field, and the Multi-Agent Systems CBR-TEAM agents in a parametric design task [10].

4. Designing of Wireless Sensor Networks

In the last decade, both the scale and the scope of engineering design had been changed and much enlarged. Recently, the design of the wireless sensor networks and their applications are appeared as popular design processes of the modern technology.

But, designing and simulating this type of networks are very complex tasks. The designer must deal with many complex parameters for guaranteeing a good performance of network's operation [11].

These parameters can be determined as: nodes hardware and software requirement, deployment, communication, energy, management, Quality of Services (QoS) and security [12]. Each requirement has its own properties which can differ from an application to another.

To simplify the design process of the WSNs the agent-based approach is used. Agents are suitable for maintaining distributed, and for locally incomplete representations of design objects as well [13].

However, agent-based approach can be used for presenting the WSNs. It uses a facilitator agent, a console agent and some service agents. The facilitator is used to decompose and dispatch the tasks, and to resolve conflicts of poor designs. The console agent acts as an interface between designers and the system. Each service agent is used for modeling different product development phases [14].

Researchers have developed many systems for designing the wireless sensor networks. They tried to cover the gap in autonomous systems and WSN design. For example: J. P. Jamont and M. Occello are used the agents-based for designing the embedded systems and have been validated with the development of WSN application [15]. E. Meshkova, et. al., discuss a design methodology based on the service-oriented architecture and agile development principles for wireless embedded and sensor networks [16]. E. P. de Freitas, et. al., have presented an agent- based framework acting as an integral part of a middle- ware to support autonomous setup and adaptation of sensor networks [17]. R. Fuentes-Fernández, et. al., have proposed an architecture for the design of WSN based on the INGE- NIAS modeling language [18]. F. Y. Xiong and L. Bai have introduced an interoperable model provided generalized frameworks to address some critical issues existed in the WSN such as interoperability, time synchronization, power management and distributed computation [19].

However, almost the previous introduced architectures and frameworks concern with particular parts of WSN design and applications and only few works have been interested in deriving a general architecture. This area still needs more work. The suggested work can share in this objective. It introduces a general purpose system and cover almost WSN’s application requirements having different kind of network topologies and nodes architectures.

5. Proposed System

The widely spread of the wireless sensor networks in a great number of applications drives to develop several approaches to face the requirements of these designs.

The present research has suggested a new algorithm that has integrated two of the modern artificial intelligence techniques for designing the wireless sensor networks. It incorporates the agents-based technique into the case based systems for these designing tasks. However, it can simplify the computational complexity of the WSN designing process and improve its performance. Thus, the proposed system can have both the advantages of the two approaches. It has the benefits of the agents those have proved to be powerful problem-solving computational entities for simplifying and managing the operation in dynamic and open environments like WSNs. Also, the suggested system can simplify the design process and decrease its complexity and run-time by using CBR systems.

The proposed system belongs to the agent-based systems those distribute some/all steps of the CBR cycle among several agents group. To implement and simulate it for designing the WSN, many agents have been proposed. These agents can be defined as:

• **User-Agent:** The proposed system uses this agent to handle different types of interfaces can be used to communicate between multiple users and the network.

• **Case-Description Agent:** It is used to represent the structural of cases in the case-base and work with the user-agent to collect the information from the user.

• **Case-Retrieval Agent:** It uses to retrieve the similar cases for the new design.

• **Case-Adaptation Agent:** It uses to adapt the most similar retrieved case for the new problem till find its needed design (solution).

• **Case-Retain Agent:** It uses to store the new problem and its achieved design as a new case in the case base.

On the other side, the suggested system uses another group of agents' models to handle many WSNs' topologies and protocols, and nodes architectures. So, the proposed system can decompose the tasks of the WSN into multiple agents, such as:

• **The interface agent**: This agent is responsible about collecting the user requests, and querying the sensors' network. These interface agents are located on the traditional input devices such as desktops and PDAs.

• **The regional Agent:** It is used as a gateway between the sensor nodes and the internal layers of the networks.

• **The cluster Agent:** the system can use this agent to transfer the query for its suitable part in the network.

• **The query Agent:** This type of agents is used to locate on the data collecting sensor nodes to perform data acquisition and local computation.

• **Data processing Agent**: It is used to perform some processes on the data gathered by the sensors of the WSN such as: analysis, compression, encryption, etc.

• **Deployment Agent:** This agent is responsible about deploying the mobile nodes and re-organizing the WSN. The deployment agent gathers information about the state of the network and the nodes used to control other agents to perform tasks such as localization, positioning and clustering.

• **Localization Agent:** the role of a localization-agent is to calculate the geographic position of the nodes.

• **Positioning Agents:** its role is to change the geographic position of the mobile nodes in the network.

• **Updating Agent:** An update-agent can be used to install some software updating in the nodes.

• **Communication Agents:** These agents implement the protocols of communication used for the selection of the efficient multi-hop path that data take from the nodes to the base stations. This agent is responsible for managing the process of communication. It can determine which role to play by each node involved in the communication according to the topology of the network.

• **Energy Management Agents:** As the energy resources of the sensor nodes are limited. The energy management agent has knowledge about the state of the nodes' energies. So, it can manage other nodes.

• **QoS Management Agents**: QoS agents try to guarantee the efficiency for real-time and high-level of availability for the WSN applications. This agent collaborates with other agents (deployment, query, energy, communication) in order to manage the quality of some nodes.

- **Security Management Agents**: The main roles ensured by these agents are: public key management, authentication, data encryption and malicious nodes detection.
- **System Control Agent:** A system control agent is used to control the operations of the WSN. This agent reasons according to the user needs achieved via the interface and make the suitable decisions for the state at hand. It can also order some commands for the other agents of the system to execute the required tasks, ensure an efficient deployment, organization and control the WSN' nodes, preparing queries and receiving responses, managing communications, energy consumption, QoS and security. Figure (2) represents the flow chart for the proposed system's operation.

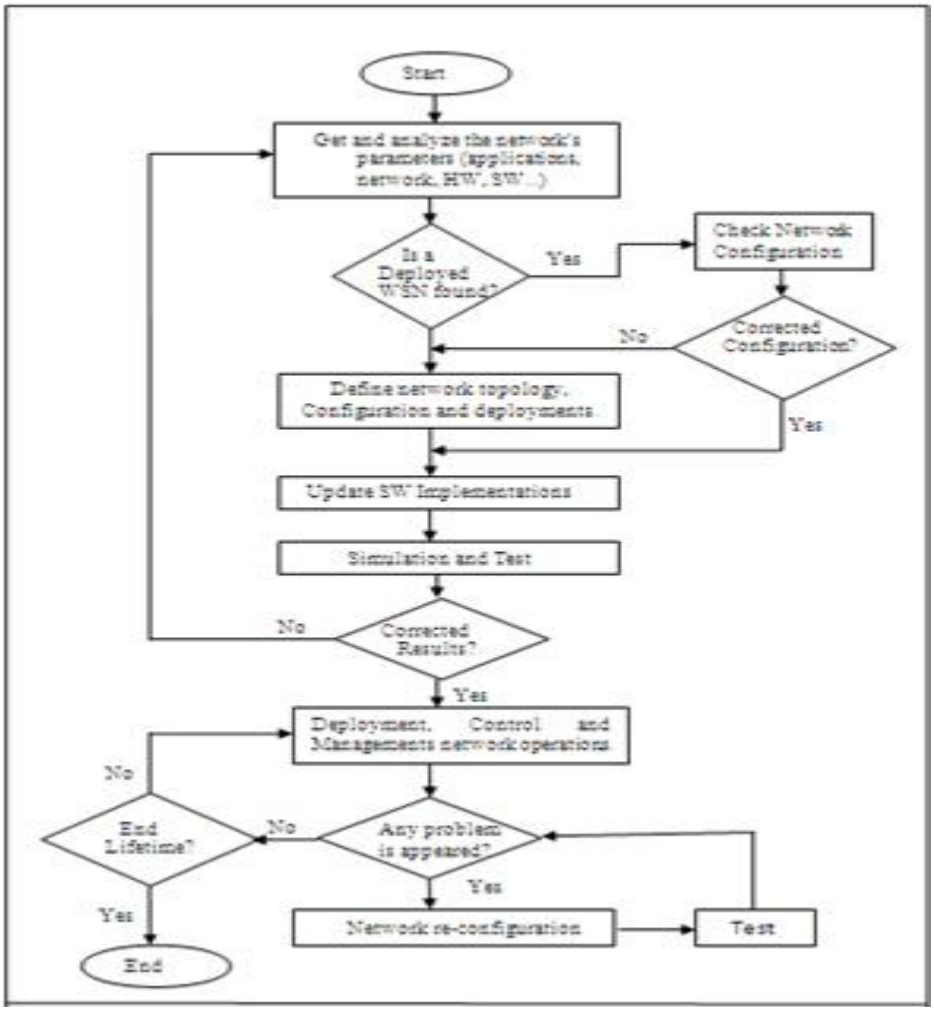

Fig. (2): Flow chart of the proposed system Operation

6. Applicability of the Proposed System and Its Results

The proposed system is a general purpose system that incorporates the agent-based approach into the case based reasoning systems to solve the design problem of wireless sensor networks. It can be used for designing different types of WSNs.

In the present research, it has been applied for design a WSN used for communicating between monitored area and its control system to detect the presence of radiated objects inside it as a case of study.

To evaluate the performance of the proposed system, its results are compared with those obtained from two traditional case base design systems and two traditional agent based system [20-23]. The suggested system has applied all the tested systems for designing the same WSN at hand inside the same area.

Figure (3-6) show comparisons between the accuracy and time results obtained from the proposed system and two traditional design CBR systems for different number of cases in the case based and agents.

While, fig. (7-10) present comparisons between the accuracy and the time of the suggested system and two traditional agent based systems when using different numbers of nodes and agents.

It is found that, the proposed system can increase the accuracy and significantly decrease the run-time of the designing process of the tested wireless sensor network.

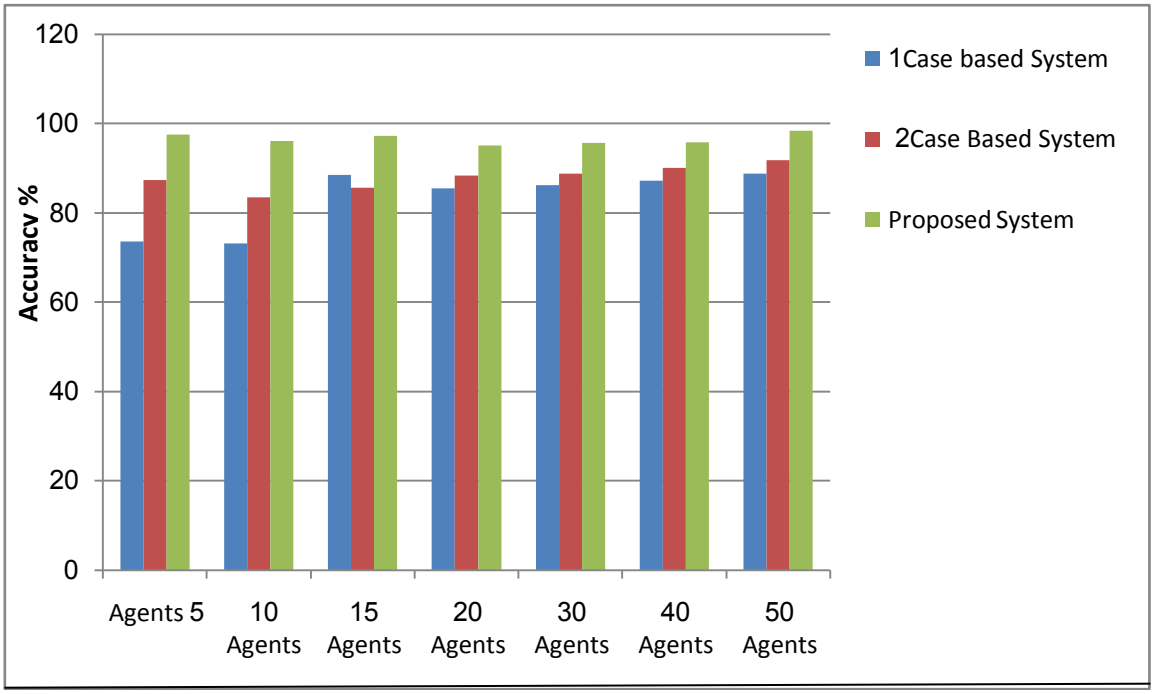

Fig. (3): A Comparison between accuracy of the proposed system and the two traditional case based systems at different number of agents.

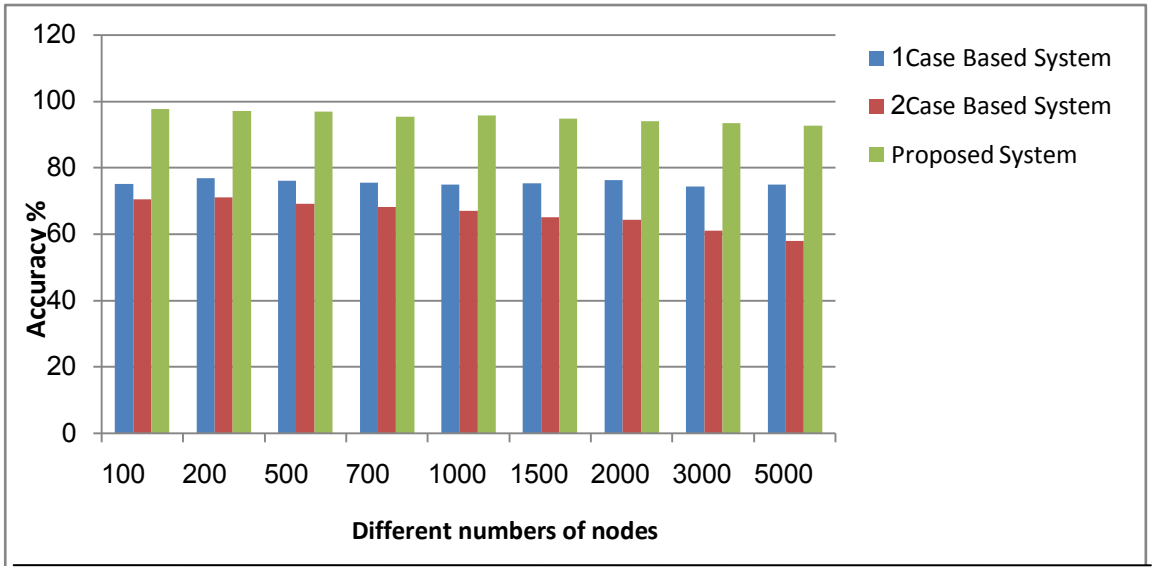

Fig. (4): A Comparison between accuracy of the proposed system and the two traditional case based systems at different number of cases.

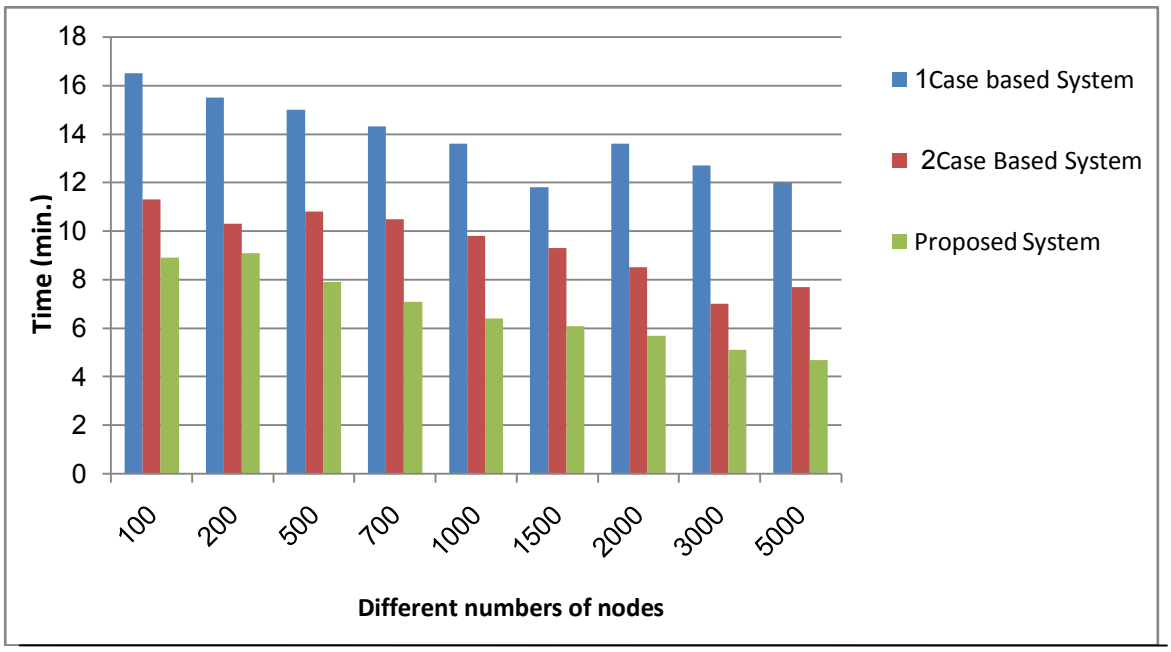

Fig. (5): A Comparison between time of the proposed system and the two traditional case based systems at different number of cases.

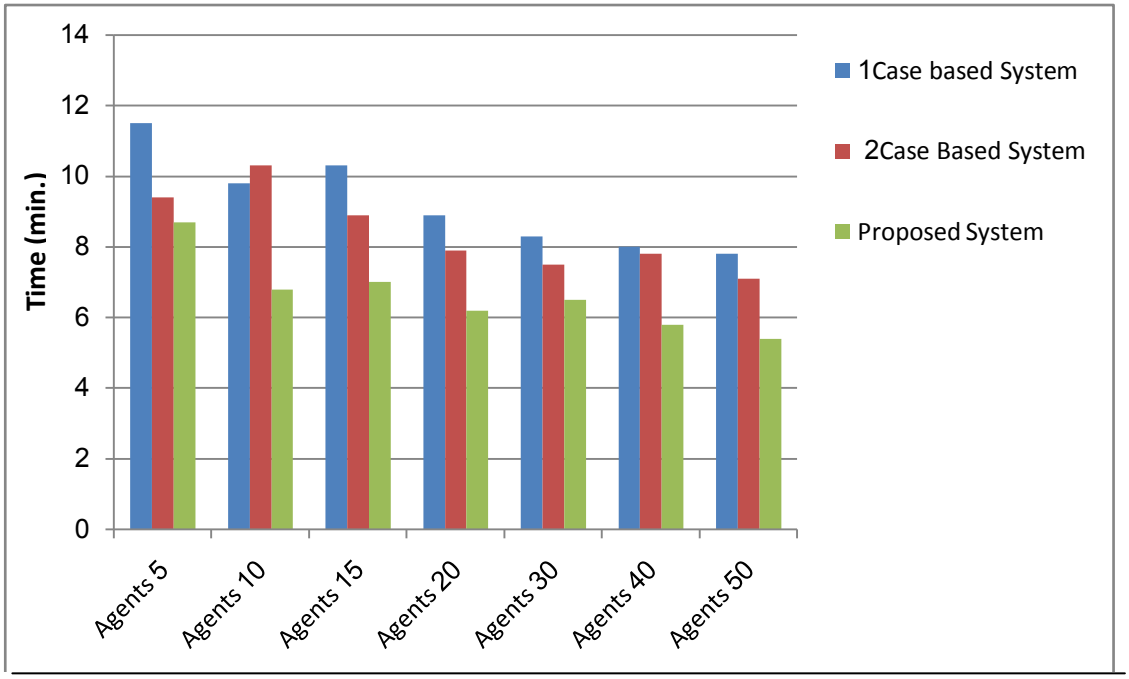

Fig. (6): A Comparison between time of the proposed system and the two traditional case based systems at different agents.

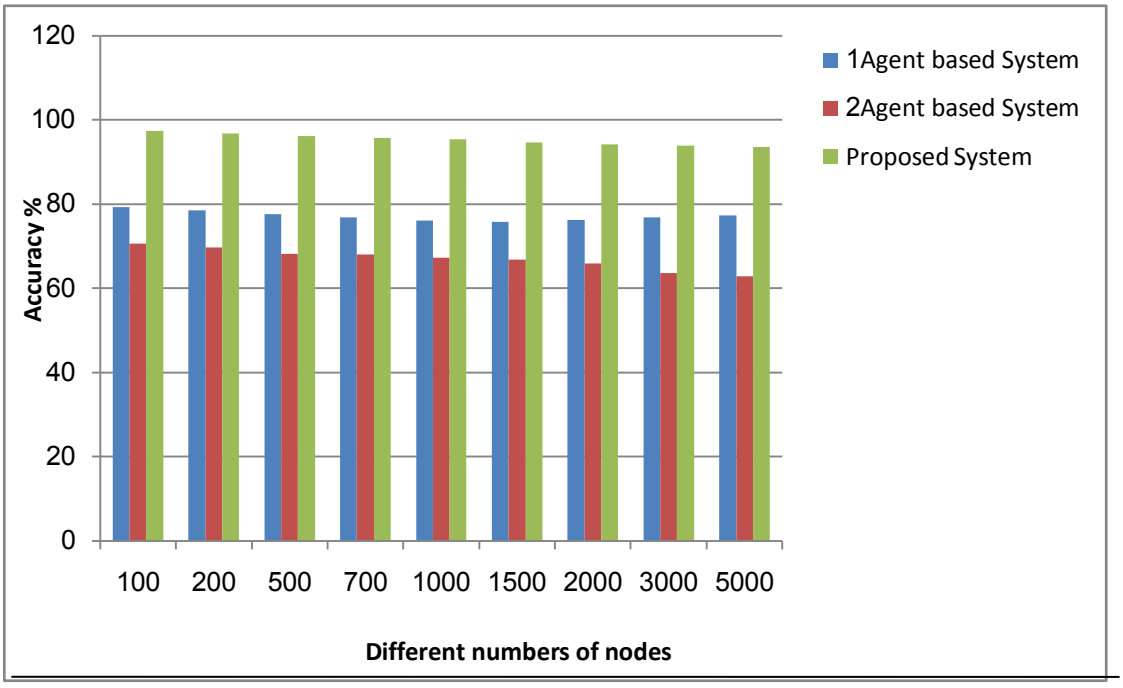

Fig. (7): A Comparison between accuracy of the proposed system and the two traditional agent based systems at different sensor nodes.

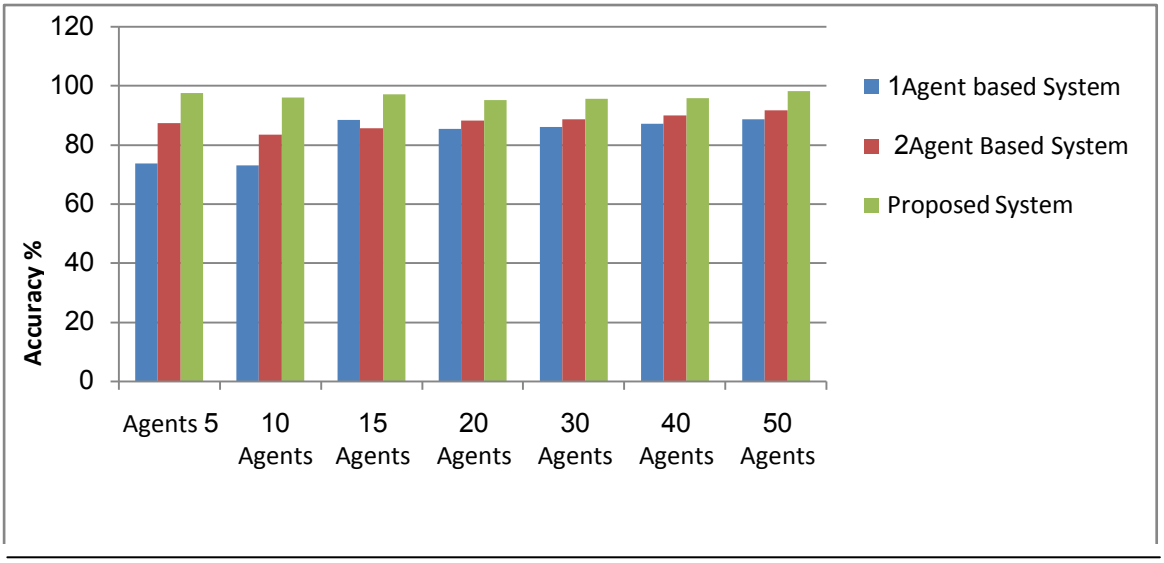

Fig. (8): A Comparison between accuracy of the proposed system and the two traditional agent based systems at different number of agents.

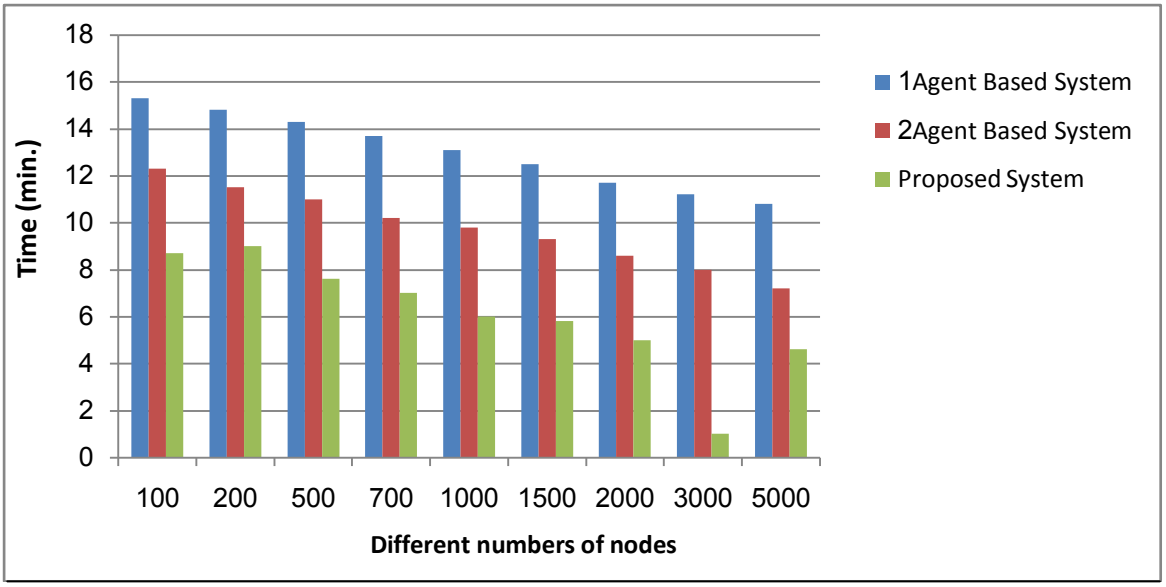

Fig. (9): A Comparison between time of the proposed system and the two traditional agent based systems at different cases.

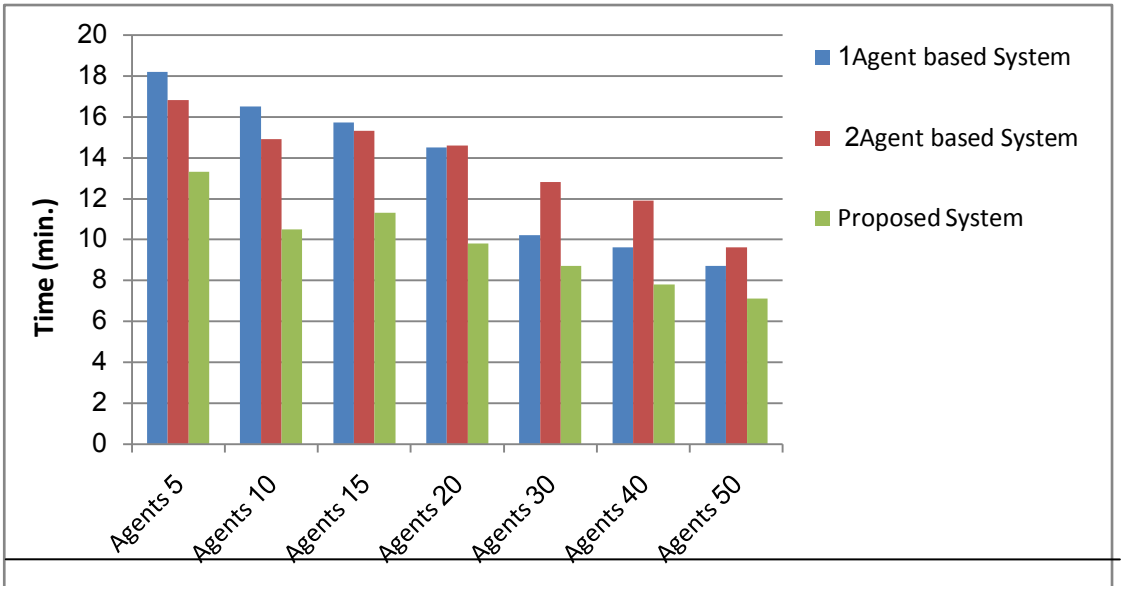

Fig. (10): A Comparison between time of the proposed system and the two traditional agent based systems at different agents.

From the obtained results, it is found that:

1- The proposed system can increase the accuracy and decrease the time of operation rather than the two traditional case base systems or the two agent based systems.

2- The proposed system can increase the accuracy of the design system rather than the two traditional case-based or agent-based systems by increasing the number of sensor nodes of the WSN.

3- The proposed system can decrease the time of the design system rather than the two traditional case-based or agent-based systems by increasing the number of sensor nodes of the WSN.

4- The proposed system can increase the scalability of the design process of more complex WSNs.

5- The proposed system can increase the management and reliability of the design process of more complex WSNs.

6- The proposed system can simplify the operation of the case based system in solving the designing problems by using the agent-based method.

7. Conclusion

The last decade has a great increasing in the modern communication technology. In this manner, wireless sensor networks have widely used in many application areas. But, their designing processes face many challenges till now.

The present research has suggested a novel system that has incorporated the modern agent-based methodology into the case based systems.

Thus, case based systems have proved their powerful in solving the design process. On the other side, the agent –based approach has proved their success in simplifying the complexity of designing the modern wireless sensor networks.

The proposed system has proved their goodness in the following features:

1- It can use the case based reasoning system to reuse and adapt the previous experience stored in the case bases to solve the new problems rather than start from scratch.

2- It uses the multi-agents to manage and simplify the complexity of the design process of complex modern WSNs.

3- It can deal with designing the larger-sized WSNs.

4- It has the advantages of both simplifying the design process by using the old experiences of CBR and handle the agent based approach for it.

5- It can decrease the time for designing the complex systems.

6- It can increase the accuracy of the designing process.

The proposed system has been applied for designing a simulated WSN that uses in the detecting a presence of radiated objects in its determined area. Its obtained results have compared with two traditional CBR and two agent-based systems. It is found that, the suggested system has a good performance, simplifying the complexity, and increasing the accuracy of the design process. However, the proposed system can be successfully applied for the practical sites.

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