Organization model for Mobile Wireless Sensor Networks inspired in Artificial Bee Colony

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Abstract. The purpose of this study is to find a self-organizing model for MWSN based on bee colonies in order to reduce the number of messages transmitted among nodes, and thus reduce the overall consumption energy while maintaining the efficiency of message delivery. The results obtained in this article are originated from simulations carried out with SINALGO software, which demonstrates the effectiveness of the proposed approach. The BeeAODV (Bee Ad-Hoc On Demand Distance Vector) proposed in this paper allows to considerably reduce message exchanges whether compared to AODV (Ad-Hoc On Demand Distance Vector).

1. Introduction

The current industrial automation systems are typically characterized by a high degree of spatial distribution. Due to the complexity of production operations, solutions that help improving the productivity and efficiency of these systems are current challenges in the area. The use of WSN to monitor and control industrial applications has some advantages, such as facility of deployment and configuration, distance control and cost savings in infrastructure maintenance. However, the physical layout of large equipment and standards of operation make a very hostile environment for the characteristics of a WSN, and may have a large number of nodes failures, which makes its measurements unreliable [1]. Another issue to be addressed is the fact that in industrial environments wireless networks operating in the 2.4 GHz band are highly used, directly interfering in the transmission process of WSN. According to [2] in large and dense WSN networks, we can use fusion techniques of competitive data. The technique described in [3] defines that not all nodes have to operate at the same time, thus being possible to disconnect the radio module when the nodes are properly configured and in sleep state, therefore increasing the WSN life time and reducing the use of the communication channel. Real-time applications require constant monitoring of events in the environment for rapid decision-making, but the large number of messages exchanged between all nodes generates bumps and miscommunications, directly interfering the performance of the WSN, as described in [4]. The approach of this paper aims to reduce energy consumption by introducing the idea of mobile nodes, using techniques of bio-inspired algorithms and simulating the operation of a bee hive, where mobile nodes can efficiently communicate reducing power consumption.

2. Problem statement

Mobile Wireless Sensor Networks (MWSN) are an interesting alternative to circumvent the limited communication range of the nodes in a WSN. In [5] the authors present the BeeAdHoc, a routing algorithm for mobile ad hoc networks. It is based on the principles of a bee colony and uses mainly two types of agents, scouts and foragers, for doing routing in mobile ad hoc networks. This is a reactive routing algorithm that consumes less energy if compared to existing routing algorithms in the literature, because it operates with less control packets. The results presented in [5] show that BeeAdHoc consumes less energy as compared to DSR [6, 7], AODV [8] and DSDV [9]. When compared, the gains of BeeAdHoc and AODV, one realizes that there is a performance improvement. A comparison of the most used protocols in WSN was presented in [10]. However, this performance gain can be increased with the proposed self-organization for MWSN inspired by bee colony that will be presented in this article. It maintains network performance by reducing the number of messages exchanged between nodes, which makes it more effective to reduce approximately 30% of exchanged messages. The solution also reduces the overall energy consumption of MWSN.

3. Related works

The MWSN is based on routing and a high exchange of messages to maintain connectivity between nodes. Thus, if a node experiences problems (such as physical damage, interference with the media or lack of battery) and can no longer perform its task in the network, other nodes can rearrange their positions supplying the absence of the failed node. Several projects are being conducted in this area. It may be noted that the field of MWSN applications is broader than that of static networks, and with it, new challenges have emerged for the improvement of this technology, among them, the need to add an algorithm for mobility, minimize energy consumption (since mobile nodes consume more battery than fixed nodes) and synchronize the data collected [11]. One of the biggest challenges to overcome is the efficiency in the exchange of messages between nodes and base stations. For this new data transmission protocols are being developed and researched by proposing solutions to ensure such efficiency and communication security. Algorithms such as AODV are being prepared for the pursuit of energy efficiency for the realization of such communication as shown in [8, 12]. Bio-inspired algorithms, specifically regarding communication among colonies of insects such as bees and ants [13, 14], are seen as possible solutions to the communication in MWSN [15]. We can quote the ABC [16] and the ACA [12] as examples of bio-inspired algorithms that improve communication among mobile nodes. BeeAdHoc algorithm consumes less energy than the traditional AODV and other algorithms found in the literature, such as DSDV and DSR [5].

4. Algorithm description

The MWSN organization model presented in this project is inspired by the hierarchical operation of a bee colony. In nature, bees are organized in different roles in the hive. In this proposal, it is assumed three different functions: the queen, attendants and scouts. In Figure 1 is presented an overview of the organizational model proposed for the network. In a similar approach, the fixed base station acts as the queen, the attendants area is equivalent to the hive space, and the nodes located in this area correspond to the attendant bees. The search area corresponds to the region where the scout bees look for food for the hive. In the proposed organization model, when a node needs to transmit information (”food”), it sends a message to the base station. This message is then transmitted among explorer nodes until it is received by an attendant node. The attendant node that receives the message has to send it to the base station. In Fig. 2 is shown the overall implementation of the network, from initial configuration to the BeeAODV algorithm itself.

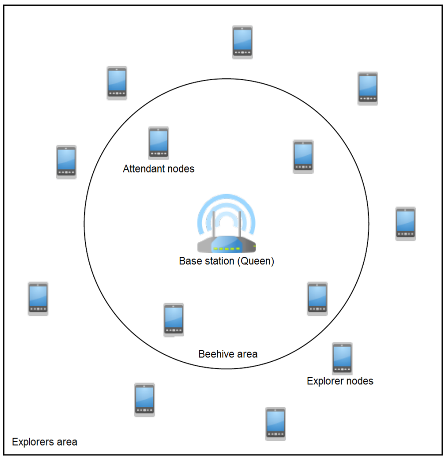

Figure 1. Overview of the organizational model proposed for the network.

```
Read k
Nodes are arranged in the initial distribution
Adjusting transmission power
node[0] = Queen
for n = 1 TO n < number_of_nodes, n++ do

    if (distance_between_node[n] AND Queen) < range_transmission then
        node[n] = NodeAttendant;
    else
        node[n] = Explorer
    end if
end for
while Network running do

    for n = 1 TO n< number_of_nodes, n++ do

        if n = 0 and existence_time_of_routing_table > 1second then
            Send Hello messages
        else

            if node[n] detects changes in the environment then
                node[n] sends messages destined to the Queen
            end if
        end if
    end for
end while
```

Figure 2. Operation of BeeAODV algorithm.

5. Methodology

For evaluating the efficiency of the algorithm, it was performed simulations using SINALGO software. The tests were conducted in a simulated rectangular area of 300 x 600 m, with a base station located in the center. The communication module adopted in the simulations was XBee, which uses the IEEE 802.15.4 communication protocol. When set at maximum power, it reaches a transmission range of approximately 90 m. The nodes were initially arranged in a distribution grid and then we performed a comparison between the traditional AODV algorithm and the organizational model proposed in this paper. Besides the base station that was present in all test cases with 50, 75, 100, 125, 150 and 200 nodes were simulated. Each simulation took 5 minutes to be executed. The data collected was the total number of transmitted messages and the time at which the node remained disconnected to the base. The ”Hello Messages” were sent with 1 second interval.

6. Results

In Fig. 3 is shown the performance of the proposed organizational model BeeAODV compared to AODV, where we can observe that performance with a smaller amount of nodes is almost identical, but with the increase of nodes BeeAODV protocol becomes more efficient by sending a minor amount of messages. The time that the nodes are disconnected from the base station can be analyzed in Fig. 4, where, due to reduced transmission power, the algorithm proposed BeeAODV maintains some stability regardless of the amount of nodes, while the reliability of AODV tends to be 100% as the number of nodes is increased, once it is operated with maximum power transmission. Finally, in Fig. 5 it is shown that, statistically, the BeeAODV protocol is more stable in the exchange of ”Hello Messages”, when compared to AODV. The standard deviation of the number of messages in the simulations is significantly lower in BeeAODV model.

7. Conclusion

Simulation results point out that there was a significant reduction in the number of messages generated by the network. Consequently, this positively affects network performance and service life. Also due to the reduction in nodes transmission power, the overall energy consumption is even smaller, without compromising its reliability. The proposed algorithm BeeAODV proved to be a stable algorithm.

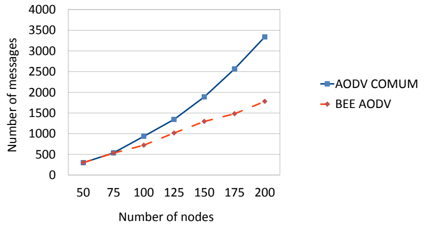

Figure 3. Comparison of the number of "Hello Messages" exchanged (AODV and BeeAODV).

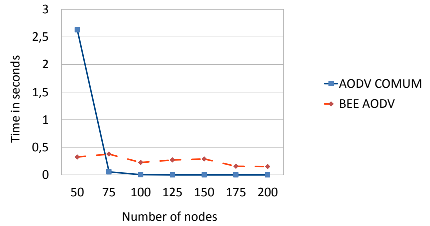

Figure 4. Comparison of time that the node is disconnected from the base station between BeeAODV and AODV protocols.

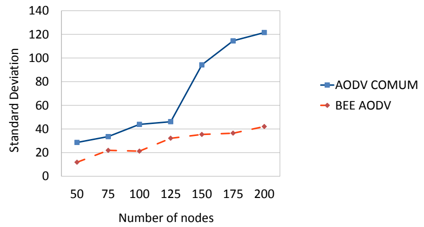

Figure 5. Default deviation for "Hello Messages" sent in simulations.

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