Ant Colony Optimization Based Energy Efficient On-Demand Multipath Routing Scheme For Wireless Sensor Networks

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Abstract— Reliable transmission has become one of the major aspects of a wireless sensor network. The current paper provides an Ant Colony Optimization based method for providing multi path routes. These routes are provided on-demand, hence they can be used in any dynamic system. The advantage of this system is that it can provide near optimal results within the stipulated time.
Key words: Ant colony Optimization; Multipath Routing; Wireless Sensor Networks

I. Introduction

A Wireless Sensor Network consists of distributed sensors that are autonomous in nature, which can be used to monitor physical or environmental conditions. These sensors cooperatively pass their data through the network to the base station. Energy is the rarest resource in a WSN further, it determines the lifetime of WSNs. The deployment areas of WSNs include isolated and hostile regions, where ad-hoc communications become mandatory. For this reason, algorithms and protocols need to address the following issues:

(1) Lifetime maximization
(2) Self-configuration
(3) Robustness and fault tolerance

Routing is the process of determining the path that is to be taken by a packet during transmission. Most of the conventional algorithms use the method of single path routing during transmission.

Ant colony optimization algorithm (ACO) is a probability based method for solving computational problems, based on graph analysis. It was proposed by Dorigo in 1992[4]. He proposed an approach that solves the shortest path selection problem in graphs using the distributed approach. He considered the Travelling Salesman Problem (TSP) as the base problem for this approach. It considers individual autonomous agents, the ants to be the processing elements. These ants are initially distributed in the search space and are made to move to cities, that they consider to be the best choices. This movement is controlled by probability [4]. After movement, the ants tend to deposit pheromones on the path. These pheromone deposits function as the basic guidance mechanism for other ants when traversing a path.

Suurballe's algorithm is used for finding two disjoint paths in a weighted directed graph, so that both paths contain the same begin and end nodes and are disjoint, and have minimum total length. The algorithm was conceived by J. W. Suurballe and published in 1974. [7][8][2] The conventionalSuurballe's algorithm usesDijkstra's algorithm to find one path, to modify the weights of the graph edges, and repeat the process again.

II. Related Works

Routing is one of the most important protocols of sensor networks. As sensor networks have an inherent distributed nature, the nodes must be able to forward the information to those devices that need it. Many, if not most sensor network protocols depend on the availability of a routing infrastructure. Its importance makes it a potential target for attackers: most of the attacks can be crafted to hinder the routing processes. As there are many types of routing strategies (e.g. flat routing, data-centric routing, hierarchical routing, location-based routing), it is necessary to find suitable security approaches for every strategy that take into account their specific properties. Nevertheless, it can be possible to define certain generic countermeasures that can provide some security properties to all strategies.

et al, in 2003 have proposed a Directed Diffusion routing protocol which is highly energy efficient since it is on demand and the node does not have to maintain global information about network topology. Nodes can also do aggregation and caching, in addition to sensing.

Some of the existing countermeasures against routing protocol attacks are analyzed by both existing surveys [6] and by drafts of routing standards for sensor networks like Routing over Low power and Lossy Networks [10]. Attackers trying to manipulate the routing discovery mechanisms (using HELLO flood and acknowledgement spoofing attacks) transmit their packets with a higher transmission power. Therefore, nodes can defend themselves by verifying that the link is truly bidirectional, using extra protection mechanisms such as onetime keys if needed. An adversary can also try to overload a sensor node with irrelevant messages, as the lifetime of sensor networks is highly tied to the number of exchanged messages. Nodes can lessen the effects of this attack by introducing traffic quotas if the network seems overloaded.

Evolution in the field of hardware have made it possible to deploy lightweight mobile devices in a real environment. Two types of communications usually exist in sensor networks: between the sensor nodes and between the sensor nodes and base station (BS). Not only the resource-restriction, but also the security-critical applications and security functions play very important roles in WSN. Because of low battery availability in a sensor device, power efficient routing methods are crucial to maximize a lifetime of networks. [9] proposes a power and security aware protocol for sensor networks.

III. System Architecture

The current paper uses the evolutionary method of Ant Colony Optimization (ACO) to determine the routes in a Wireless Sensor Network (WSN). The routes are determined on-demand so as to compensate for the dynamic nature of the WSN.

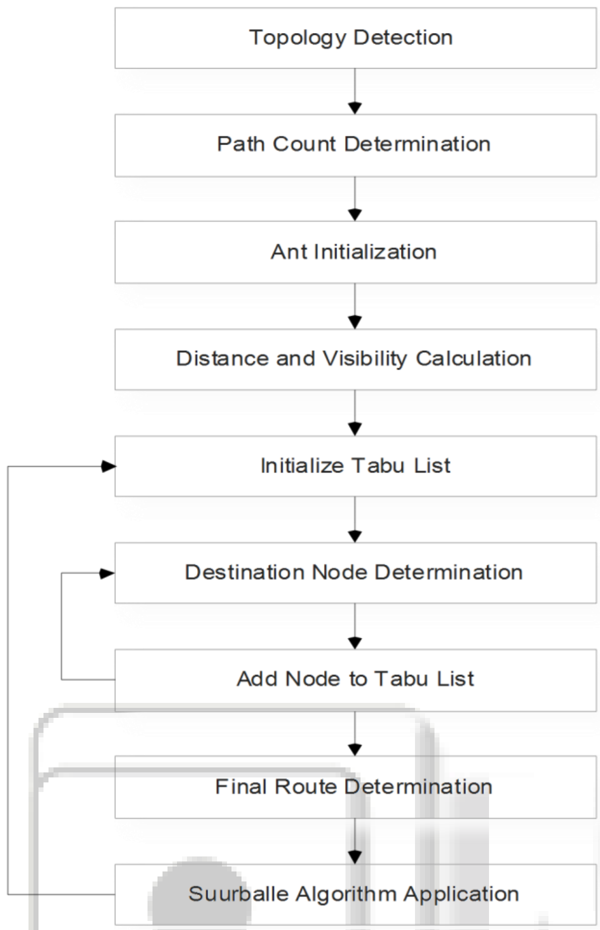


Fig. 1: System Architecture

Figure 1 shows the system architecture of the ACO based Multipath Routing method. When a node demands transmission of data, the current topology of the network is determined and the number of paths to be generated is determined. ACO is applied to the network to determine the route. Suurballe's algorithm is then applied on the topology and ACO is applied again to determine another disjoint route. This process is carried out until the required number of routes are determined.

IV. Ant Colony Optimization Based Energy Efficient On-Demand Multipath Routing Scheme

The current paper proposes an energy efficient routing methodology that uses ACO to determine the routes on-demand i.e. route determination is carried out only when the application requires to transmit data.The process of multi path route determination [3] is carried out in three phases. When a node in the networks wishes to transmit data, it triggers the initial phase and the algorithm operation begins.

A. Topology Detection and Path Count Determination

The initial phase deals with detecting the topology of the WSN. Due to the dynamic nature of the WSN (as considered in the problem definition), this process is to be performed for every transmission request. This can be performed by transmitting *hello* packets in the network, or by external tools of the user's convenience. The next step is to determine the path count. This is application specific. The number routes to be generated is determined by the application based on various factors line; the expected security level, overall node energy, network topology and the type of encryption algorithm being used.

B. ACO Application and Final Path Determination

The process of actual routing is performed in this phase. The Ant Colony Optimization algorithm is used to determine the routes to be taken by the packets.

According to Dorigo's definition, the decision for the next edge to travel is performed in a probabilistic manner, using the relation:

$$P_{ij}^{k}(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}[\eta_{ij}]^{\beta}}{\sum_{l\in J_k(i)}[\tau_{ij}(t)]^{\alpha}[\eta_{ij}]^{\beta}}, if & j\in J_k(i) \\ 0, & j\notin J_k(i) \end{cases} \qquad (1)$$

Here,

P_{ij}^{k}(t)= Probability of travel from i to j node for an ant k.

This probability is dependent on several factors like,

$\tau_{ij}(t)$=Pheromone intensity.

$\eta_{ij}(t)$= Pheromone visibility.

α= Importance of pheromone intensity.

β=Importance of pheromone visibility

$J_k(i)$=Neighborhood node set for ant k.

Pheromone updates are dependent on relation,

$$\Delta\tau_{ij}^{k} = \begin{cases} \frac{Q}{L_k}, & if\ (i,j)\epsilon\ tour \\ 0, otherwise \end{cases} \qquad (2)$$

Here

$\Delta_{\tau_{ij}^{k}}$= Amount of pheromone updated by ant k while traveling from node i to j.

Q=Constant.

L_k=Total path length covered by ant k.

Pheromone updates finally happens with this equation,

$$\tau_{ij}^{k} = \tau_{ij}^{k} + \Delta\tau_{ij}^{k} \qquad (3)$$

And pheromone decay is dependent on the equation,

$$\tau_{ij} = (1-\rho) \qquad (4)$$

Here

τ_{ij}=Pheromone intensity on edge joining node i and node j

ρ=Evaporation parameter of the graph.

C. Modified Suurballe Algorithm Application

A single optimal path is obtained from ACO. Since the necessity is to determine multiple paths, the network topology graph is altered using the modified Suurballe's algorithm. The base network graph and the determined path is passed to the modified Suurballe's algorithm. Suurballe's algorithm perform the process of eliminating the directed edges contained in the path, from the network topology graph. Hence the topology graph now becomes a modified graph containing some bidirectional edges and some unidirectional edges.

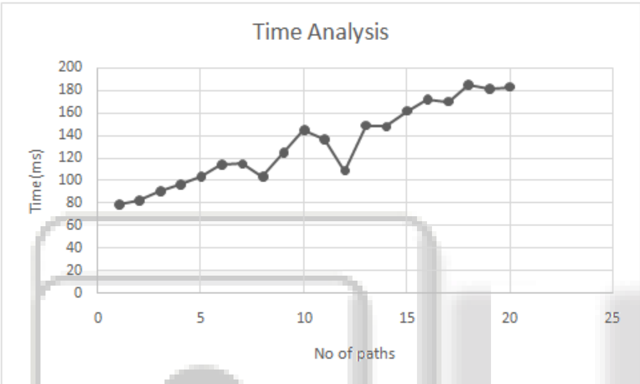
This graph is again passed to the ACO [5] application phase to determine thenext path. This method is repeated until the appropriate number of paths have been obtained.

V. Results And Discussion

A. Simulation setup

All the experimental simulations were performed on a desktop, with the following configuration: Intel® Core™ i3-4130 Processor (3.40GHz), 4GB DDR3 SDRAM 20 MB Cache, 32 GB ECC RAM in a Windows 7 - 64 bit environment. Implementation was done in C# language using the Visual Studio 2012 development environment.

Simulations were created with 30 nodes, and ACO was applied to them to generate multipath routes.



Fig, 2: ACO Time Analysis

From the graph we can see only a very meagre change in the time when the number of paths is increased. Considering just a part of the graph for analysis, we can infer that the time taken for generating 10 paths is approx. 145ms, while an increase of 100%, i.e. 20 paths has increased the time to 180ms, which is an increase of 40ms. The increase is very small and can be compromised for the increased efficiency provided by ACO.

VI. Conclusion

The current method provides best results when incorporated with a dynamic WSN, but it can also be used in a static WSN environment to leverage its capability of energy efficiency. The advantage of this algorithm is that it can be modified for a static environment with minor changes, hence is flexible in nature. In future, this method can be extended such that the routes that were determined earlier can be stored and can be reused, instead of generating new routes for every transmission.

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