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Lifetime Improvement of WSN by Trust Level based Ant Colony Optimization

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***Abstract*— A Wireless Sensor Network (WSN) is a network that contains numerous sensor nodes for gaining information from the environment and to communicate with other sensor nodes. In this work, we propose to increase the lifetime of a network by trust level computation and Ant Colony Optimization (ACO) algorithm for routing. Initially, the trust level of nodes is computed by the one hop neighbour and then the optimal route is selected by the ACO algorithm. The trust level of nodes is calculated by taking energy and packet delivery ratio into account. Thus, the transmission is made fast and the energy is effectively utilized, which in turn increases the lifetime of the network. This system proves maximum energy efficiency and minimum energy consumption, which is shown in experimental analysis.**

***Key words*—WSN, Trust, ACO, and Network Lifetime.**

I. Introduction

A Wireless Sensor Network (WSN) is a network that contains numerous sensor nodes for gaining information from the environment and to communicate with other sensor nodes. Each sensor node is configured with the signal processing circuits, microcontrollers and wireless transmitters and receiver antenna [1] and so they are bound to limited power, energy and lifetime. The sensor nodes are randomly distributed, even at the area that cannot be accessed easily. Thus, recharging the nodes is not always made possible. Alternative idea of recharging is energy conservation. The idea behind this is that the energy can be conserved at the maximum so as to increase the lifetime of the network rather than battery recharge.

Improving the network lifetime is the hot topic of research in wireless sensor networks, as WSN is being observed with increased number of applications. Major reasons for energy consumption are the listening mode of the nodes that do not involve in any transmission, traffic or congestion and data transmission. There are several ways to improve the lifetime of a network and they are correct placement of device [5], processing of data [6], routing [7-14] and device control [15-17].

Some of the great challenges involved in WSN are dynamic topology and energy limitations. The problem of energy limitations could be addressed by effective utilization of energy and to conserve as much energy as possible. Some of the applications of WSN are traffic monitoring, environment monitoring and home education [2-4]. Apart from this, WSN are employed in remote patient monitoring in medical applications too.

In this work, we propose to increase the lifetime of a network by trust level computation and Ant Colony Optimization (ACO) algorithm for routing. Initially, the trust level of nodes is computed by the one hop neighbour and then the optimal route is selected by the ACO algorithm. The trust level of nodes is calculated by taking energy and packet delivery ratio into account. Energy is considered because an energy drained node cannot transmit messages and the reason for considering packet delivery rate is to determine the rate of perfect packet transmission. This is calculated by the total number of messages sent and the total number of acknowledgements received.

This work is compared with the existing system and our system proves betterment, which is presented in experimental analysis. The main objective of this work is to improve the lifetime of the network by effective utilization of energy.

The remainder of this paper is organized in the following way. Section 2 presents the review of literature and the proposed methodology is presented in section 3. The results and experimental analysis is carried by section 4 and finally the concluding remarks are presented.

II. Review of Literature

A distributed heuristic model by name Distributed Energy-efficient Scheduling for k-Coverage is presented in [18], conserves energy and thereby increase the lifetime of the system, with the requirement of coverage details. This model works in rounds and only one hop neighbour details are required. The works presented in [19-21] concentrate on coverage aware, energy efficient and distributed clustering methods for improving the lifetime of a network.

The impact of sink mobility is studied in [24] and the system has been checked on static and mobile sink scenarios. In [25], an ACO based approach is proposed for improving the lifetime of a heterogeneous network. A heuristic way to reduce energy consumption by ACO is provided for routing in WSN [26].

An ant based autonomous routing algorithm is presented in [27] by considering link quality, energy level and lose rate into account. A routing algorithm based on ant colony is presented in [28]. A survey of power saving and energy optimization techniques for wireless sensor networks is presented in [29].

A coverage optimization protocol to increase the lifetime of heterogeneous wireless sensor networks is presented in [30]. The scheduling of this system is carried out by rounds and each round has got four phases. They are information exchange, leader election, decision and sensing.

Motivated by these works, we propose a system that is based on trust level and ACO algorithm. The trust level is computed by considering the energy level and the packet delivery ratio. This trust level is fed into the ACO, in order to arrive at an optimal route.

III. PROPOSED SCHEME OF TLACO

In this work, we propose to extend the lifetime of a network by incorporating trust level computation and a modified ACO algorithm into a new protocol Trust Level based Ant Colony Optimization (TLACO). TLACO employs ants to come up with a short, energy efficient and trustworthy route. Our routing algorithm is quite successful because of the computation of short route with trustworthy nodes.

A node is claimed as trustworthy by two deciding parameters and they are packet delivery rate and its energy level. The packet delivery is calculated by total number of packets (n_p) being sent by the node to the total number of acknowledgements (n_a) being received by that node. If $(n\_p) = (n\_a)$, then the node is pretty trustworthy. Energy threshold is calculated and the number of nodes that are above the energy threshold along the path is calculated. This yields effective routing and thus the lifetime is improved.

A. Trust Level Computation

The trust level of every node is calculated by the one hop neighbour in order to determine its trust and the trust level is updated in the trust_table maintained by every node. The trust level is calculated for every period of time and is overwritten in the trust_table, so as to save memory. The trust_threshold is found by the average of all trust values of the nodes. The trust level is calculated by taking energy and packet delivery rate into account. Packet delivery rate is the rate of packets being sent by the node and the total number of acknowledgements being received for the sent packets. The node energy is calculated by the below assumption.

1. If the node is fully energized, then the energy value is 1.
2. A half energized node is given the energy value of 0.5.
3. A completely energy drained node energy value is 0.

The average energy value (e_v) between every two nodes is computed and the value obtained is the energy threshold. The packet delivery rate is computed by the one hop neighbour and the values are normalized between [0, 1]. The packet delivery rate is calculated by

1. If $snt_{pk} = t_{ack}$, then the packet delivery rate is fixed as
2. If $snt_{pk} = t_{ack}/2$, then the packet delivery rate is 0.5
3. If $t_{ack} = 0$, then the packet delivery rate is 0.

Both these values are integrated and the trust value is computed by the below given formula.

$$Tr_{xy} = \frac{e_v + p_{tr}}{2} \qquad (1)$$

Where e_v and p_{tr} are the energy and packet delivery rate of two nodes and the value of T_{xy} lies in between 0 and 1.

B. Ant Colony Optimization Algorithm

ACO algorithm is well-suited for combinatorial optimization problems. The routing algorithm based on ant colony optimization well suits the wireless sensor networks. The work principle of ACO is provided below.

1. A forward ant f is triggered from every node, in order to find a path to reach its destination, at every period of time. The address of the nodes that are reached by f, is stored in memory M_f.
2. The next hop node is selected by the ant, at every node by a probabilistic rule.

$$p_f(s,d) = \begin{cases} \frac{[T(s,d)]^{\alpha}[E(d)]^{\beta}}{\sum_{u \notin M\_f}[T(s,u)]^{\alpha}[E(u)]^{\beta}} & if\ d \notin M\_f \\ 0 & otherwise \end{cases} \qquad (2)$$

In (2), $p_f(s,d)$ is the probability rate of f to start from s and reach d, T is the routing table of each node that saves the concentration of pheromone from s to d. E is the visibility function, which can be computed by $1/(ie - ae_s)$, where ie is the initial energy of node and ae_s is the actual energy of the node s. α and β are the controlling parameters of trail vs visibility.

3. When the destination is reached by the ant, it becomes a backward ant b and its task is to update the pheromone through which it reached the destination and is stored in memory.
4. The destination node estimates the amount of pheromone that is to be spent by the ant.

$$\Delta T_f = \frac{1}{N - td_f} \qquad (3)$$

Here, N is the total number of nodes and td_f is the distance travelled by forward ant f.

5. When the backward ant is back to the source node s from d, then the routing table is updated by the following

$$p_f(s,d) = (1-\rho)\, p_f(s,d) + \Delta T_f \qquad (4)$$

Where ρ is the coefficient and $(1-\rho)$ indicates the evaporation of trail, since the last updated version of $p_f(s,d)$.

6. When the ant reaches the node at which its journey started, the goal is attained and the ant is eliminated.

After several iterations, the node can identify the best neighbours for sending packets to a specific destination [23].

C. Work Principle of TLACO

In this paper, the lifetime of a network is extended by considering the trust level of nodes. The trust of nodes is computed by considering energy and packet delivery ratio. The trust level is computed by eqn (1). This is passed into the ACO as input. By calculating the trust level, the malicious nodes are weeded out from the system. The nodes with the trust value greater than or equal to the threshold, can only participate in routing.

The probability of data packet transmission from the source to destination node through the best route is given by (1)

$$p(s,d) = \left\{ \frac{[Tr(s,d)]^{\alpha} [\frac{1}{d_{sd}}]^{\beta} (\psi_{f_{sd}})^{\gamma}}{\sum_{v_n} [Tr(s,v_n)]^{\alpha} [\frac{1}{d_{sv_n}}]^{\beta} (\psi_{f_{sv_n}})^{\gamma}} \right. \quad (5)$$

Where $Tr(s,d)$ is the trust level of nodes between s and d, d_{sd} is the distance between the source and the destination node, $\psi_{f_{sd}}$ is the amount of pheromone between s and d. v_n are the valid nodes. α, β and γ are constants that belongs to [0,1].

When the backward ant is back to the source node s from d, then the routing table is updated by the following

$$p_f(u) = (1-\rho)\, p_f(u-1) + \frac{N_{sd}}{d_{sd}} \quad (6)$$

ρ is the evaporation constant that belongs to [0,1].

With this algorithm, the optimal route is identified. Obviously, the energy consumption is very low, when the packet gets transmitted without any overhead. When the energy consumption is low, the lifetime of a network is maximized. Thus, TLACO improves the lifetime of network by employing trust and modified ACO.

IV. Experimental Analysis

In this work, we compare our system with the existing system in terms of packet delivery ratio, end-to-end delay, path detection time, throughput, energy efficiency and energy consumption. The graphical results are presented from fig 1-6.

1. Packet delivery rate: Packet delivery rate is the rate of packets sent to the destination with the total number of packets.

$$Packet\_delivery\_rate = \frac{Successfully\ sent\ packets}{Total\ number\ of\ packets} \times 100 \quad (7)$$

2. End-to-end delay: End-to-end delay is the time taken by the packet to reach its destination from the source node.

$$End-to-end\ delay = \frac{Arrival\ time - sent\ time}{Total\ number\ of\ connections} \quad (8)$$

3. Detection Time Analysis: Detection time is the time it takes to find an optimal path and is given by time at which the route is found subtracted from the start time of route discovery.

4. Throughput: Throughput is the amount of data transferred per unit of time.

$$Throughput = \frac{Number\ of\ transferred\ bits}{Time\ taken\ (secs)} \quad (9)$$

5. Energy consumption VS time: This calculates the total energy consumed by the node with respect to time.

Energy consumption=Present Energy-Initial Energy (10)

6. Energy Efficiency: Energy efficiency of the system can be calculated by

$$Energy\ Efficiency = \frac{Output\ Energy}{Input\ Energy} \times 100 \quad (11)$$

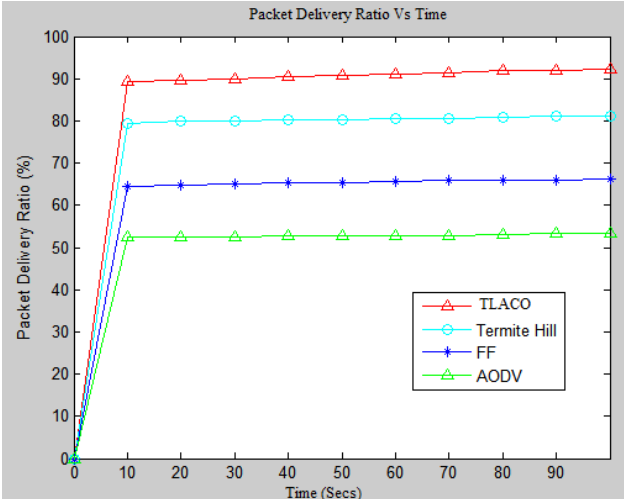

Fig 1: Packet Delivery Ratio Analysis

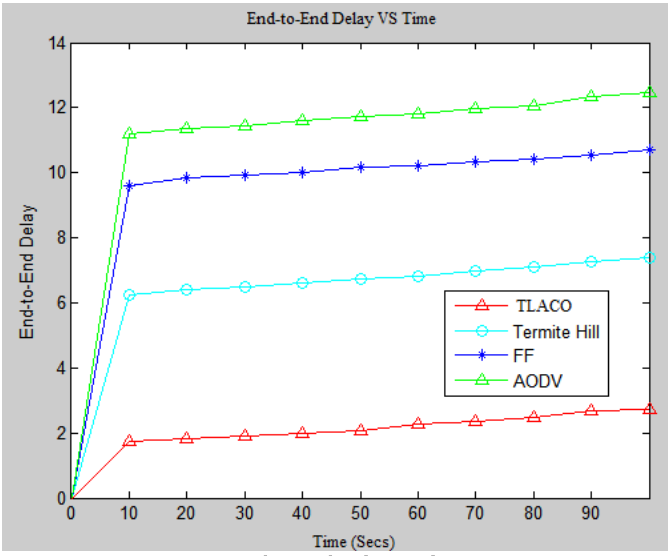

Fig 2: End-to-End Delay Analysis

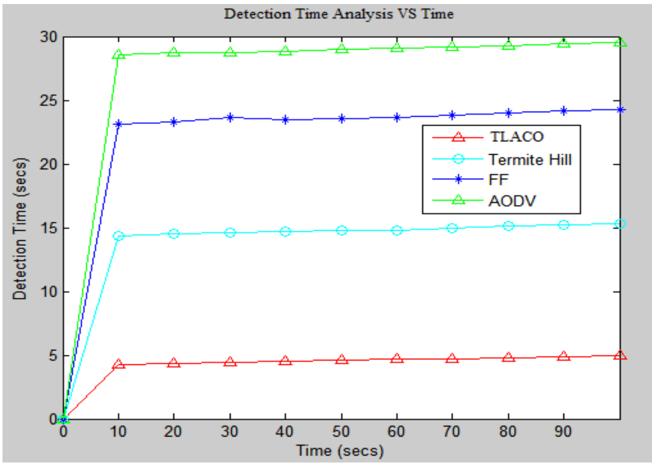

Fig 3: Detection Time Analysis

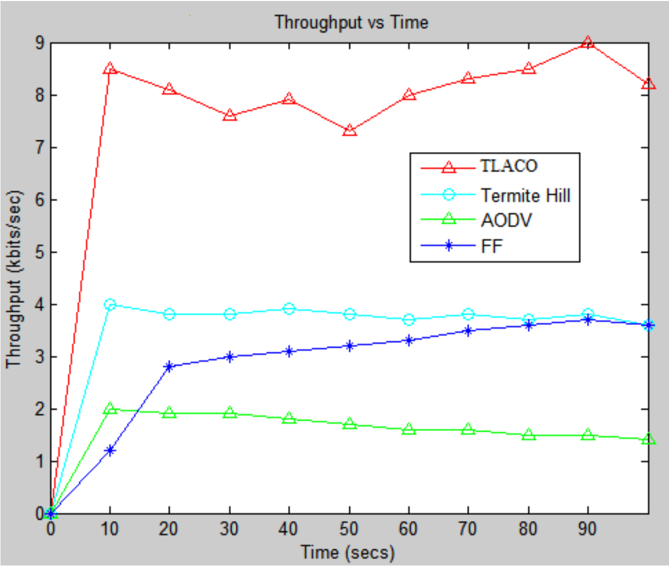

FIG 4: THROUGHPUT VS TIME ANALYSIS

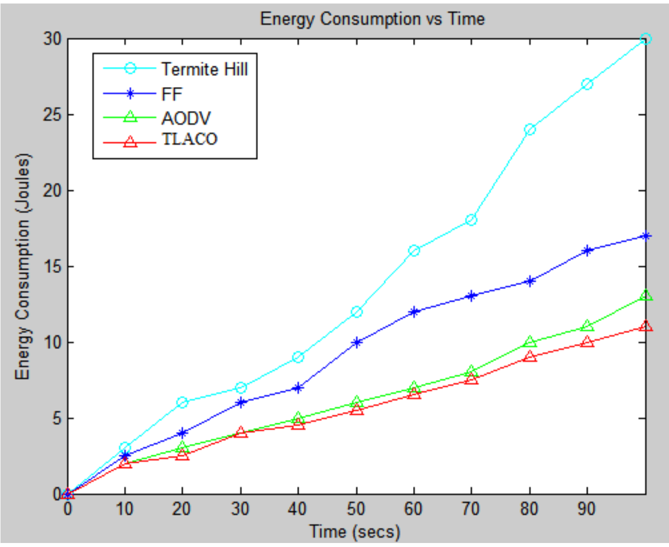

Fig 5: Energy Consumption VS Time Analysis

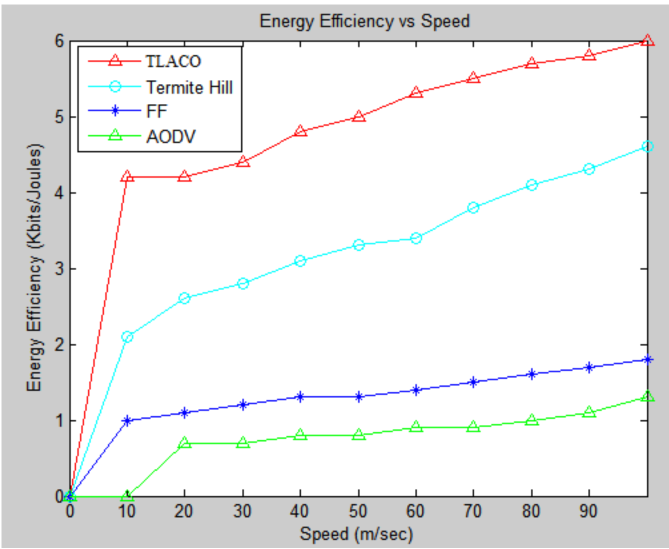

Fig 6: Energy Efficiency VS Speed Analysis

From the performance analysis, it is proven that the proposed protocol Trust Level based Ant Colony Optimization (TLACO) outperforms all the existing methodologies with the maximum energy efficiency and minimum energy consumption. By achieving this, the lifetime of the network is considerably increased.

V. CONCLUSIONS

In this work, we propose a protocol by name Trust Level based Ant Colony Optimization (TLACO), by computing trust level and modified Ant Colony Optimization algorithm. The trust level is computed by considering energy and packet delivery ratio. The computed trust level is provided as the input to the ACO, which helps in finding valid nodes for packet transmission. Thus, the transmission is made fast and the energy is effectively utilized, which in turn increases the lifetime of the network.

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