

Sensor Communication Network Using Swarm Intelligence

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Abstract - Energy consumption is currently a key issue in research for future sensor networks. This paper presents a novel approach to sensor network routing based on energy consumption. The unique routing algorithm uses swarm intelligence, which is computationally efficient.

Keywords: Communication, Sensor Networks, Routing, Swarm Intelligence, Ant System.

I. INTRODUCTION

Communication routing in a network is a NP hard problem[1] and evolutionary algorithms play an important role in solving routing problems. In this paper, a building sensor network consisting of wired and wireless nodes possessing energy constraints[2] between nodes is considered. Each node in the network has the ability to communicate with any

of its peers. The objective is transferring messages with minimum energy using evolutionary swarm algorithm.

II. BUILDING SENSOR NETWORK

In Figure 1, a graphical representation of an example building sensor network is shown. Where a two building network with four floors and rooms equipped with or without sensors (denoted by shaded circles, and the arrows denotes the route taken by the agents) is shown. The number of sensors is independent of the floor(s) and room(s). Swarm agents set up a communication route incorporating all nodes. The nodes are not homogenous in terms of energy.

During communication the sensor nodes on each floor form clusters in a decentralized manner with no cluster heads and communicate with its peers regardless of the type of their links i.e., wired or wireless (energy loss is dependent

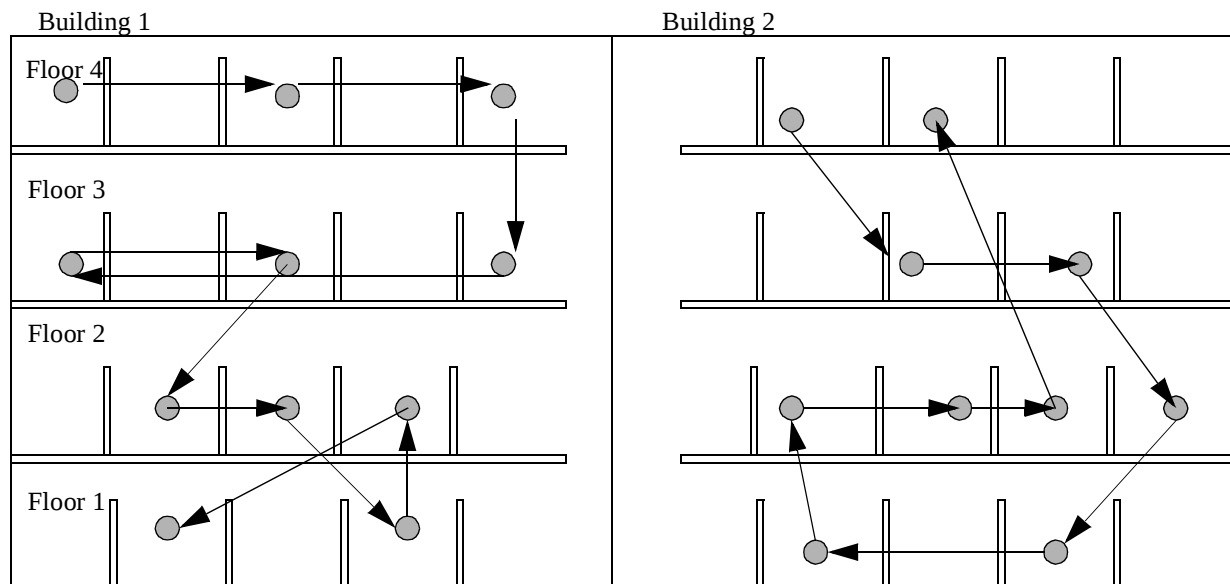


Fig. 1. Communication Routing in a Building Sensor Network Using Swarm Agents

on link type). Using an evolutionary algorithm known as swarm intelligence [3], we optimize the resources achieving optimality and reachability [4]. The swarm algorithm for solving communication routing problem is discussed in the next section. Simulation results provide insight into computational efficiency in the fourth section. The fifth section concludes with a discussion on future progress of the paper.

III. SWARM AGENTS & BUILDING NETWORK

Swarm intelligence[3] is the collective behavior from a group of social insects, namely ant, birds, etc., where the agents (ants) communicate in the system either directly or indirectly using a distributed problem solving approach. This approach supports an optimized routing design, avoids stagnation, and prevents centralization of the network nodes. Routing in wireless network is never static; hence this intelligent sensor approach provides a solution to dynamic and distributed optimization problems. Thus making the network robust, flexible, decentralized, coherent and self organized.

Swarm agents (ant agents) [5], [6], [7] are randomly placed over the network. The ant agents have three features; Pheromone Level, Transition Probability and the Tabu-Lists. Real life ants deposit a chemical substance called pheromone, which serves as a trail for the other ants to follow. The ant system mimics this pheromone deposition by laying pheromones depending on both energy level at the sensor node and the distance from one node to another (Pheromone Level).

The agents travel through the nodes following pheromones and dissipating energy. The pheromone is updated upon completing a tour by every agent by

$$\Psi_{ij}(t) = \rho(\Psi_{ij}(t-1)) + \frac{Q}{D_t \cdot E_t} \quad (1)$$

where Ψ_{ij} is the pheromone deposition with i as the source, j as the destination, ρ and Q arbitrary constants, D_t the total distance of the current tour and E_t the energy dissipation at that node. The transition probability for wired network is computed as

$$P_{ij} = \frac{(\Psi_{ij})^\alpha \cdot \left(\frac{1}{D_{ij}}\right)^\beta \cdot (E_{ij})^\alpha}{\sum_k \left((\Psi_{ik})^\alpha \cdot \left(\frac{1}{D_{ik}}\right)^\beta \cdot (E_{ik})^\alpha \right)} \quad (2)$$

Where, D_{ij} is the euclidean distance, E_{ij} is the energy level at that node and α , and β are arbitrary constants. The transition probability gives the movement of ant with respect to the pheromone deposition and the energy level of the node at that time. Using these two conditions the node with energy level less than the threshold is avoided thereby reducing the pheromone deposition at that node rendering that route the least taken in the network. This scheme of routing provides a

robust network as the failed nodes are avoided by the agents thereby avoiding a total failure of the network.

The third feature of the AS is tabu-list which serves as a visit log that maintains information about each visit to a node, the distance taken and the energy level at that node. With these updates of the environment, the ant agent takes an efficient route which makes them robust and computationally simpler.

The energy level is calculated by means of the euclidean distance D_{ij} . The estimation of energy dissipation includes a link budget constant k and distance D_{ij} ,

$$D_{ij} = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2} \quad (3)$$

For a wired link the energy dissipation is estimated as

$$\Delta E = k \cdot D_{ij} \quad (4)$$

and for a wireless link, the change in energy is

$$\Delta E = k \cdot D_{ij} \quad (5)$$

The energy dissipation for a tour is calculated as the energy at that node with respect to the energy dissipated an agent during a tour in data transfer.

$$E_i(t) = E_i(t-1) - \sum_j \Delta E_{ij} \quad (6)$$

IV. SIMULATION RESULTS

The building sensor network considered here has two

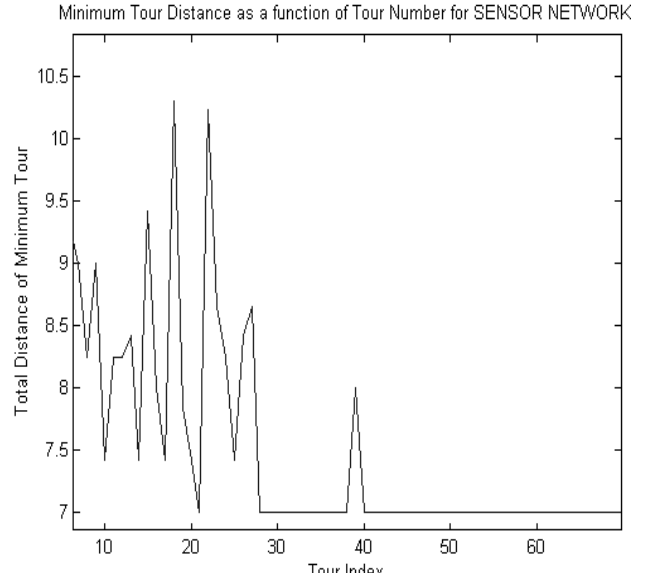


Fig. 2. Optimal Distance of a Building Sensor Network

floors with 5 and 3 sensors on each floor, respectively. These are placed using two-dimensional cartesian co-ordinates. The sensor's energy at each node is initialized to the distance between the nodes with a factor of 100, the pheromone level is initialized to a constant (10) and the threshold at all nodes

is set to 50. Figure 1 shows the network under zero node failure.

In Figure 2 optimal distance is achieved by the agent by sharing their knowledge of the system with their neighbors using the tabu-list. The mean and standard deviation of this problem is 8.5467 and 0.4288 respectively.

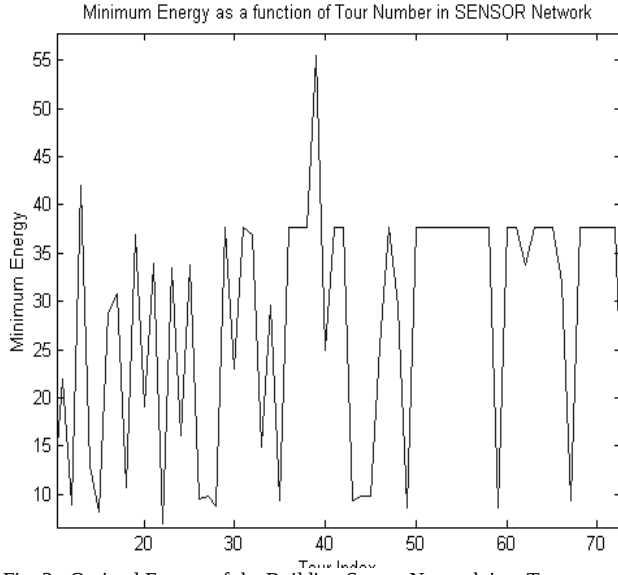


Fig. 3. Optimal Energy of the Building Sensor Network in a Tour

In Figure 3, the minimal energy dissipation of a sensor network is shown. Where the energy dissipation is reduced gradually over a period of time.

Figure 4 gives the average energy level of the sensor network which gives a detail insight of the energy level available in the network and the ability of nodes to communicate.

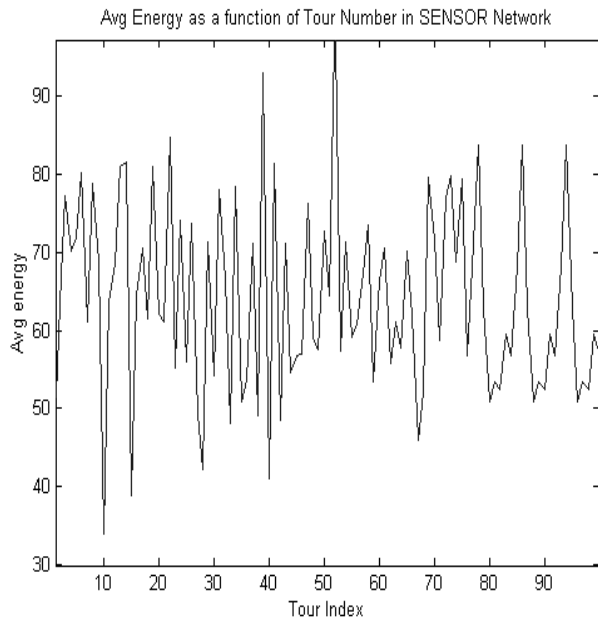


Fig. 4. Average Energy of the Building Sensor Network in a Tour

The route taken by the last ant agent is shown in Figure 5, when compared with the agents previous

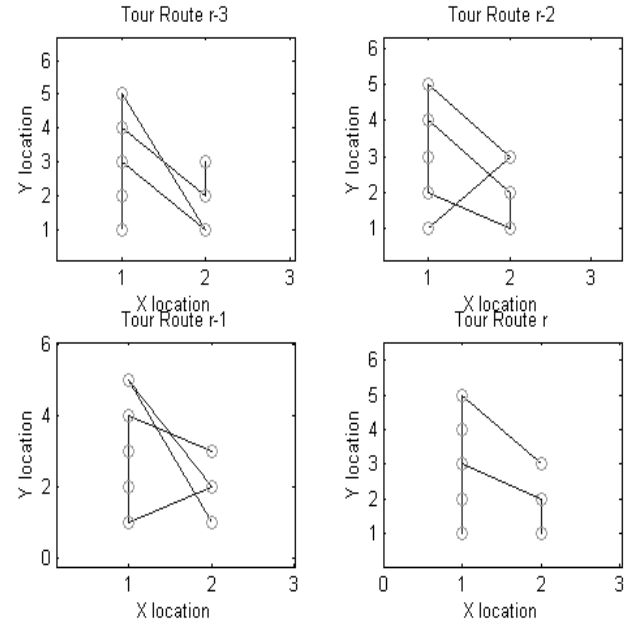


Fig. 5. Routing in Building Sensor Network - The last agent's route 8 Sensors

routes r-3 and the last route r, the efficient route is picked by the agent. Thus obtaining an optimal solution.

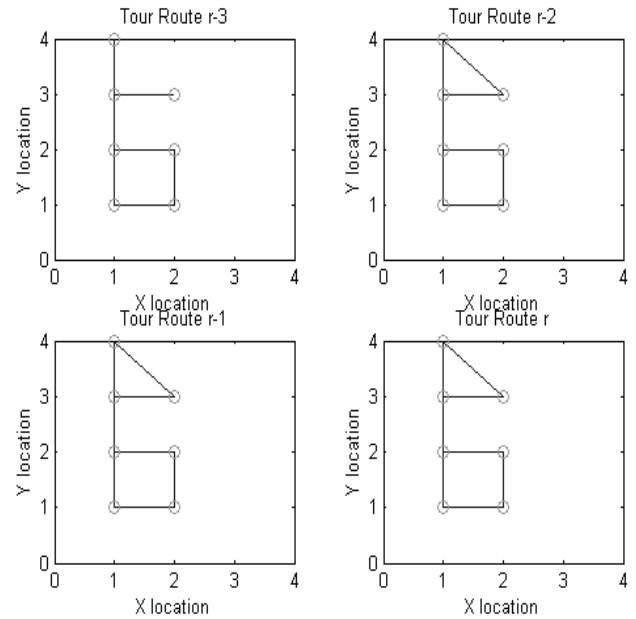


Fig. 6. Identical Routes of the agent -Routing in Building Network with 7 Sensors

When identical routes are taken by three agents we define convergence as shown in Figure 6.

The results are summarized in Table I , where for a given problem set the mean and the standard deviation of the distance and energy is listed. As the number of tours increases the global solution with minimum distance and energy is achieved.

TABLE I. PERFORMANCE VS. NO OF RUNS USING AGENTS

No Of Runs	Mean of Distance	Mean of Energy	SD of Distance	SD of Energy
5	11.8980	0.9483	1.6566	0.1705
15	13.0534	0.9418	1.9542	0.1643
30	10.7995	0.9170	2.0674	0.1575
55	8.6058	0.8968	1.9492	0.1334
105	8.3467	0.8328	1.2504	0.1310
180	8.1124	0.8152	0.5722	0.1222
280	7.9271	0.7218	0.4540	0.0908
1280	7.6180	0.7074	0.6607	0.0727

V. CONCLUSION AND FUTURE WORK

The evolutionary algorithm used under the above circumstance reaches optimality with respect to routing, energy dissipation and robustness.

In the future the link layer will be merged with the network layer to perform optimization and energy conservation simultaneously. Further, the swarm agents will be incorporated with a life factor to determine effectiveness of the algorithm versus the survivability of the agents in the network.

VI. REFERENCES

- [1] J.C. Chen, C.S. Chen, B.J. Chen, M.Lay, L.Liu, B.Lee, S.Huang, W.Chang and D.Huang, " Application of Vehicle Routing Problem with Hard Time Window Constraints ", The 29th International Conference Computers and Industrial Engineering, Nov. 2000.
- [2] W. Heinzelman, J. Kulik, and H. Balakrishnan, "Adaptive Protocols for Information Dissemination in Wireless Sensor Networks ", Proc. 5th ACM/IEEE Mobicom Conference (MobiCom '99), Seattle, WA, August, 1999
- [3] Kennedy J, Shi Y. and Eberhart R.C., "Swarm Intelligence", Morgan Kaufmann Publishers, San Francisco, 2001.
- [4] Rajani Muraleedharan and Lisa Ann Osadciw, "Balancing The Performance of a Sensor Network Using an Ant System ", 37th Annual Conference on Information Sciences and Systems, John Hopkins University, 2003.
- [5] Luca Maria Gambardella and Marco Dorigo, "Solving Symmetric and Asymmetric TSPs by Ant Colonies", IEEE Conference on Evolutionary Computation(ICEC'96), May20-22,1996,Nagoya,Japan.
- [6] Marco Dorigo, "The Ant System: Optimization by a Colony of Cooperating Agents", IEEE Transactions on Systems, Man and Cybernetics-Part B, Vol-26, No. 1, Sept1996,pp 1-13.
- [7] Dorigo and L.M. Gambardella, "Ant colony system: a co operative learning approach to the travelling salesman problem", IEEE Transactions on Evolutionary Computation, Vol 1, no.1, 1997, pp.53-66, JOURNAL.
- [8] Percy P.C. Yip and Yoh-Han Pao, " Combinatorial Optimization with Use of Guided Evolutionary Simulated Annealing ", IEEE Transactions on Neural Network, Vol. 6, May 1999, pp. 968-972.
- [9] Yun-Chia Liang and Alice E. Smith, " An Ant system approach to redundancy allocation," Proceedings of the 1999 Congress on Evolutionary Computation, Washington D.C., IEEE, 1999, 1478-1484.8]
- [10] Kennedy J and Eberhart R. C., " Particle Swarm Optimization ", Proc of the 1995 IEEE International Conference on Neural Networks, vol 4, IEEE Press, pp. IV: 1942-1948.
- [11] H. Van Dyke Parunak," Go To The Ant: Engineering Principles from Naturla Multi-Agent System", Forthcoming in Annals of Operations Research, special issue on Artificial Intelligence and Management Science, 1997, pp. 69-101.
- [12] Shi Y. and Eberhart R.C., " Empirical Study of Particle Swarm Optimization ", Proc of the 1999 IEEE International Conference on Evolutionary Computation, Vol 3, 1999 IEEE Press, pp 1945-1950.
- [13] H. Van Dyke Parunak, Sven Brueckner, " Ant like Missionaries and Cannibals : Synthetic Pheromones for Distributed Motion Control ", Proc of the 4th International Conference on Autonomous Agents(Agents 2000), pp. 467-474.
- [14] H. Van Dyke Parunak, Sven Brueckner, " Entropy and Self-Organization in Multi-Agent Systems", Proc of the 5th International Conference on Autonomous Agents, May2001, pp. 124-130.