# Genetic Algorithms for Self-Spreading Nodes in MANETs *


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## ABSTRACT

We present a force-based genetic algorithm for self-spreading mobile nodes uniformly over a geographical area. Wireless mobile nodes adjust their speed and direction using a genetic algorithm, where each mobile node exchanges its genetic information of speed and direction encoded in its chromosomes with the neighboring nodes. Simulation experiments show encouraging results for the performance of our force-based genetic algorithm with respect to normalized area coverage.



## Categories and Subject Descriptors

**G.I.6 [Optimization]: Unconstrained optimization**; **I.2.8 [Artificial Intelligence]: Problem Solving, Control Methods, and Search**; **I.2.m [Artificial Intelligence: Miscellaneous]: Genetic algorithms**

## General Terms

**Algorithms**

## Keywords

**Genetic Algorithms, MANET, Mobile Agents.**


## 1. INTRODUCTION

We present a distributed genetic algorithm (GA) run by every node in a MANET to obtain a uniform distribution over a given geographical area by adjusting the nodes' speed and direction. Using the principle of the equilibrium of the molecules in physics, this GA for self-spreading mobile nodes is inspired by the algorithm introduced by Heo and Varshney [1]. In this paradigm, each molecule tries to be in the balanced position and to spend minimum energy to protect its own position. To evaluate the effectiveness of our force-based GA with different applications, we conducted simulation experiments to measure metrics such as instantaneous and total area coverage. The results show that our force-based GA provides a satisfactory coverage of a given geographical area and converges faster to a uniform distribution compared to either random walk or Hill Climbing.

## 2. GA FOR SELF-SPREADING AGENTS

### 2.1 Area Coverage and Mean Node Degree

The geographical area is partitioned into equivalent hexagonal cells, where a node is capable of moving to one of possible six directions [3, 4]. For simplicity, the communication range ($R_{com}$) is assumed to be the same for each mobile node. Normalized Area Coverage ($NAC$) is defined as a point to be covered if the point is located at the hexagonal sensing radius of at least one mobile node. A cell is covered by a mobile node if and only if $(x - x_i) + (y - y_j) \leq R_{com}$, where $(x, y)$ shows the position of a mobile node, and $(x_i, y_j)$ is a hexagonal cell's location in the geographical area $(i, j \epsilon Z^+)$. $NAC$ is calculated as $(\sum_{i=1}^{d_{max}} \sum_{j=1}^{d_{max}} c_{i,j})/A$, where $c_{i,j}$ is the area covered by a hexagonal cell located at coordinate $(i, j)$, and $A$ is the total area of the geographical terrain. If a cell area is already covered by another node, or located outside the given geographical area, it is not included in the calculation.

*Mean Node degree* ($\overline{N}$) is defined as the best possible number of neighbors to construct the fitness function for a given network density, $R_{com}$, and geographical area [2]. The best fitness value of 1.0 is obtained if a node has either $(\overline{N}-1)$, $\overline{N}$, or $(\overline{N}+1)$ number of neighbors. If a node has either $(\overline{N}-2)$ or $(\overline{N}+2)$ neighbors, its fitness value is defined as 0.5. A node's fitness is 0.0 for any other number of neighbors.

### 2.2 Obtaining Uniform Node Distribution

**GA Using Force (FGA):** A mobile node uses the total force applied to it by the neighboring nodes located in its communication range to decide for its next movement direction and speed. The optimal location of a node is *deterministically* calculated in [1]. In our $FGA$ implementation, each node runs a GA to find the best next position, direction and speed, using a fitness function. The absolute force value for each node is ordered and the smallest value shows a better position for the node. The fitness function $F(n)$ for a node $n$ is calculated as:

$$F(n) = \sum_{i=0}^{k} \sum_{j=0}^{k} \overline{N}(R_{com} - |((x - x_i) + (y - y_j))|) \qquad (1)$$

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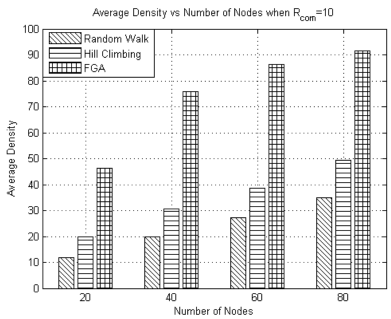


**Figure 1: Average** $NAC$ **(**$R_{com} = 10$**)**

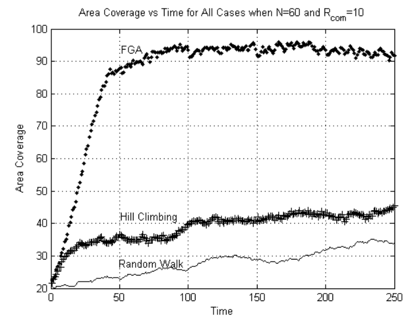


**Figure 2:** $NAC$ **(**$R_{com} = 10$**)**

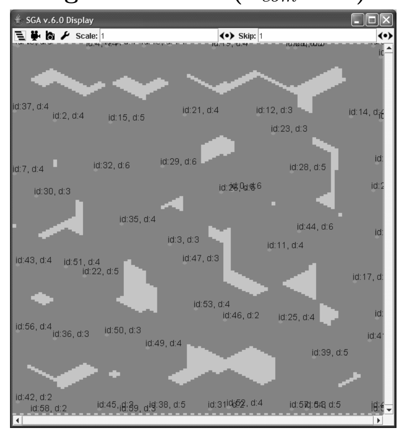

**Figure 3: Node distribution after** 250 **iterations**

where $k$ is the total number of neighbors, $(x, y)$ is the coordinates of the node, and $(x_i, y_j)$ is the location of a neighbor cell of the node.

**Random Walk:** A mobile node can randomly move to any of its six neighboring cells and adjust their speeds without a GA or any other type of intelligence. Each node decides the next speed and direction based on a discrete time random walk model [2].

**Hill Climbing:** The distributed Hill Climbing that we use in our simulations to compare with $FGA$ employs a *goal function* which is defined in terms of its node degree and mean node degree [2]. A mobile node moves to a new position if and only if it yields a better goal function value than its current position; otherwise, it stays in the same location.

# 3. SIMULATION EXPERIMENTS

The simulation experiments were run for different network densities ($N = 20, 40, 60$, and 80) and $R_{com} = 10$. Each experiment was performed for $T_{max} = 250$ steps and repeated 15 times to obtain more accurate results in coverage area.

*Normalized Area Coverage (NAC)*: In performance evaluation of our $FGA$, $NAC$ is a key metric in the simulation experiments, To represent realistic applications, the nodes are initially randomly placed at the northwest corner of the second quadrant of the given area (as opposed to randomly spread throughout the entire area). The mean $NAC$ values obtained for different network densities are shown in Fig. 1. $FGA$ yields a coverage ranging from 45% for sparse networks to 90% for dense networks. As expected, $FGA$ achieves a better performance than deterministic Hill Climbing since Hill Climbing may stop at a local maximum whereas $FGA$ searches for a global maximum point. Random walk, which does not use any intelligence in the movement decisions, is used as a base to compare the results from $FGA$ and Hill Climbing. The instantaneous $NAC$ values obtained for a single run are shown in Fig. 2. $FGA$ achieves twice better coverage than Hill Climbing and three times better than the random walk. As also seen from Fig. 2, the cases $FGA$ and Hill Climbing reach their respective steady $NAC$ values after approximately $T = 100$ iterations.

*Final Node Distribution*: Starting with the initial random node distribution concentrated at the northwest corner of the area, the final node distribution after $T = 250$ iterations are given by the screen shot in Fig. 3. In this experiment, the number of mobile nodes in MANET and the communication range are set to $N = 60$ and $R_{com} = 10$, respectively. Dark gray areas in Fig. 3 represent the cells located within the communication range of at least one mobile node, whereas the light gray areas are the cells which are not covered by any node. Since in $FGA$ each node applies a force to its neighbors calculated by Eq. 1 minimizing the intersection of the coverage for each node, $FGA$ converges to an almost uniform distribution.

# 4. CONCLUSIONS

We present a force-based GA approach to self-spreading mobile nodes in a MANET, where each node has a limited range of communication. Each node makes its decisions for the movement direction and speed based on a fitness function inspired from the molecular force equilibrium defined in physics. The main objective of $FGA$ is to increase the area coverage with the least number of nodes and with the least area overlap among the nodes' communication ranges. The simulation experiment results show that $FGA$ performs satisfactorily especially for dense networks towards achieving a uniform distribution over a given geographical terrain.

# 5. REFERENCES


[1] N. Heo and P.K. Varshney. A distributed self spreading algorithm for mobile wireless sensor networks. *In IEEE Wireless Communications and Networking*, pp.1597-1602,2003.

[2] M.U. UYAR, I. HOKELEK, and M. A. FECKO. Random-walk based analysis of virtual backbone in manets. *In Proc. of IASTED/CCN 2005*, pp.132-137,2005.

[3] E. URREA, C.S. SAHIN, M.U. UYAR, M. CONNER, I. HOKELEK, G. BERTOLI, and C. PIZZO. Simulation experiments for knowledge sharing agents using genetic algorithms in manets. *In Proc. of Int. Conference on Artificial Intelligence and Pattern Recognition*, pp.369-376,2007.

[4] E. URREA, C.S. SAHIN, M.U. UYAR, M. CONNER, I. HOKELEK, G. BERTOLI, and C. PIZZO. Uniform manet node distribution for mobile agents using genetic algorithms. *In Proc. of the 2007 Int. Conference on Genetic and Evolutionary Methods*, pp.24-30,2007.