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Influence of Mobility Models in Precision Spray Aided by Wireless Sensor Networks

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Abstract. Precision Spray is a technique to increase performance of Precision Agriculture. This spray technique may be aided by a Wireless Sensor Network, however, for such approach, the communication between the agricultural input applicator vehicle and network is critical due to its proper functioning. Thus, this work analyzes how the number of nodes in a wireless sensor network, its type of distribution and different areas of scenario affects the performance of communication. We performed simulations to observe system's behavior changing to find the most fitted non-controlled mobility model to the system.

1. Introduction
Precision Agriculture (PA) aim to increase the efficiency of resource management and productivity of crops, resulting in better and less expensive products [1]. A technique used for PA is Precision Spray (PS) of agricultural inputs, because the distribution of such materials affects the quality of grown products. The use of Unmanned Aerial Vehicles (UAVs) aided by Wireless Sensor Network (WSN) is an approach for PS in which the WSN report, ongoing, to UAV details of distribution, allowing to improve the efficiency of the process [2]. However, proper functioning of this PS technique depends the communication efficiency between UAV and WSN.

The aim of this work is to observe the behavior of network and find the mobility model, among Random Walk, Random Waypoint, Random Direction and Manhattan Grid, have better performance on this system.

This paper is organized as follow: In Section 2 is commented some theoretical base about concepts of PA, WSN and Mobile Sink (MS), in Section 3 are detailed the parameters of simulations, in section 4 we present the results and discuss about. Conclusions are shown in section 5, followed by references in section 6.

2. Concepts in precision agriculture aided by WSN and mobile sink
PA is one of most prosperous fields for use of WSN [3]. Since PA is based in a big volume of data from the crop, WSN may aim PA collecting data such as micrometeorological, soil conditions [4], presence of nutrients, vegetal health conditions [1] and agricultural inputs distribution [2].

A MS, also called Data Mule, is a concept initially developed for collecting data from nodes or groups of nodes unconnected of others. A MS travel the sensored area collecting data from nodes at its communication range. It consists of a node with improved energetic and data storage capabilities, attached to a mobility agent [5].

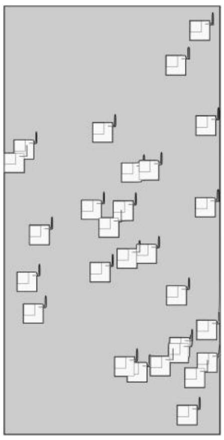
PA may be better executed by use of PS, because PS distributes more properly agricultural inputs at the crop. An approach for PS consists in to have a UAV as applicator vehicle and it be aided by a WSN, in which this WSN reports to UAV how the distribution has made, allowing ongoing corrections [2].

3. Materials and Methods

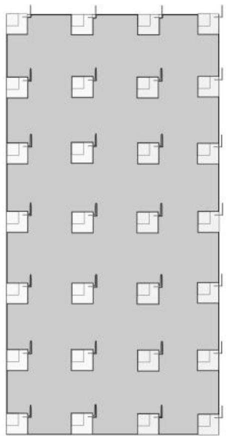
Movement of a MS affects how many and with which this MS is connected on a moment, may interfering directly on network efficiency. To know which mobility model has better performance on the system we made experiments by simulations. We used the network simulator OMNet++ [6] with the framework MiXiM. For generate the mobility models outputs we used the software BonnMotion [7].

Each simulation had duration of 600 seconds. We varied two parameters individually: The number of nodes and the scenario area, called experiments 1 and 2, respectively. The number of nodes was varied by 28, 45, 66, 91 and 120, for a area of 1.8x10^5 m². These values were chosen by complete a grid with equal distance between its intersections with same proportion of scenario, 1:2. The area was varied by 4.24x10^5, 2.64x10^5, 1.8x10^5, 1.3x10^5 and, 9.89x10^4 m², keeping the density values from experiment 1; and used 66 nodes, median of values of varied number of nodes on experiment 1. Each experiment was performed with random and grid node distributions, as shown on Figure1.

The main metric used is the Communication Efficiency (*Ef*). Ef is calculated by *Ef*=*Ru*/*Ts*, where *Ru* is the number of messages received by UAV and *Ts* is the sum of messages sent by nodes. The mobility models were parameterized so that its behaviors were as similar as possible, as commented in [8].



(a)



(b)

Figure 1. Examples of node distributions with 28 nodes for experiments made: (a) Represents a possible random node distribution. (b) Represents a grid node distribution.

The follow assumptions were taken in this work: UAV had constant speed at 20 m/s, has not the capacity of static planning over a region; all nodes, including the UAV, are in the same plan; nodes work the same manner during all the simulation time; all energetic sources and buffers were considered unlimited and; do not existed elements that could affect the signal at specific parts of scenario (e.g. trees, buildings).

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4. Results and discussion

Simulation results are presented on Figures 2, 3, 4 and 5. The results were calculated by me mean of 32 executions of each simulation with different random number seeds. Figures 2 and 4 correspond to random node distribution simulations, and Figures 3 and 5 correspond to grid node distribution simulations. Figures 2 and 3 correspond to number of nodes variation simulations, Figures 4 and 5 corresponds to area variation simulations.

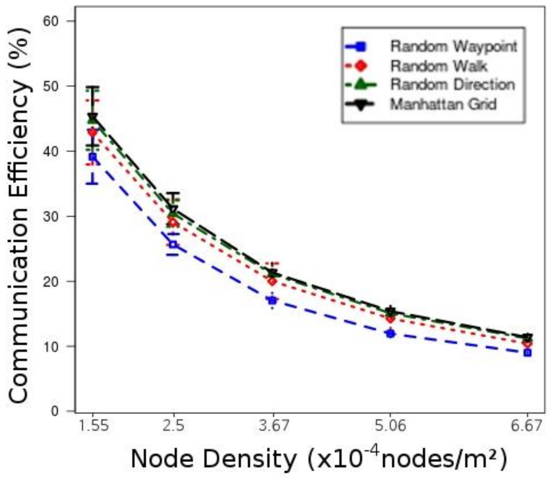

Figure 2. Communication efficiency for experiment 1 with random node distribution.

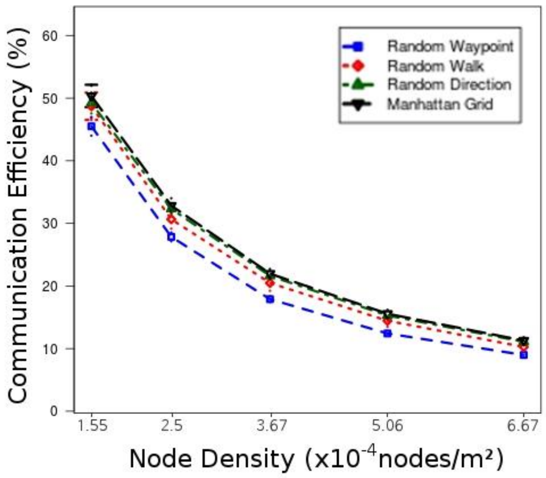

Figure 3. Communication efficiency for experiment 1 with grid node distribution.

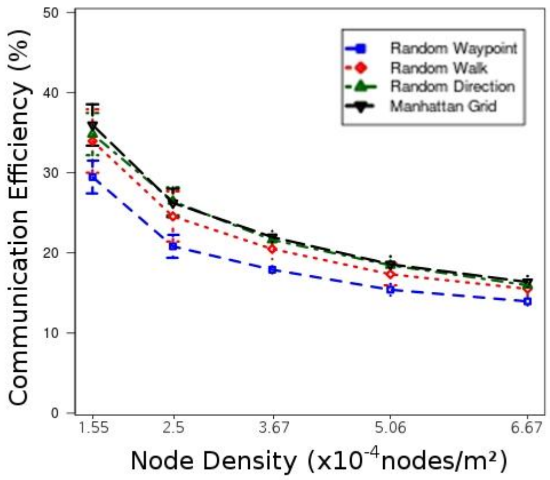

Figure 4. Communication efficiency for experiment 2 with grid node distribution.

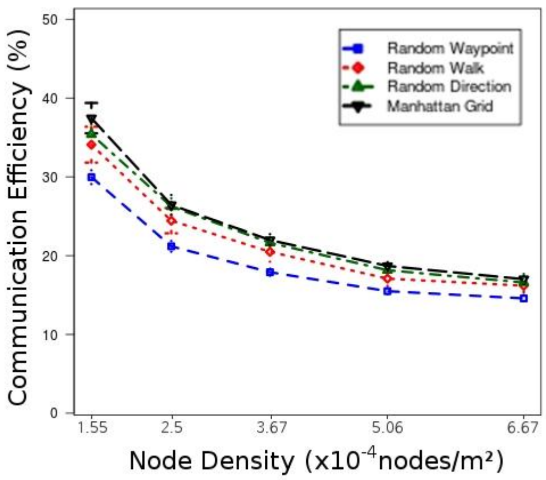

Figure 5. Communication efficiency for experiment 2 with grid node distribution.

Ef curves for random and grid node distribution had respectively average 22.75% and 23.74%. Thus, the average of Ef for random distributions (heterogeneous) present 95.8% of relative efficiency compared with average of grid distributions (homogeneous).

Network behavior for experiment 1 (Figures 2 and 3) had average Ef equals 24.14% and for experiment 2 (Figures 4 and 5) had average Ef equals 22.36%. It, initially, shows a better performance for node variation over area variation, however, the rates of efficiency decrease with increase of density in experiment 1 are from 15.74% until 3.85%, with average 8.82%, while for experiment 2 these rates are from 9.34% until 1.63%, with average 4.53%. It implies the average Ef decreases 1.94 times faster for experiment than experiment 2.

Since the curves for each mobility model presented similar behavior in all cases we may observe their average Efs. Average Efs for Random Waypoint, Random Walk, Random Direction and Manhattan Grid are, respectively, 20.56%, 23.24%, 24.35% and 24.83%. Thus, Manhattan Grid mobility model was the one with better average Ef, and then better fitted to the problem. Mobility models Random Waypoint, Random Walk and Random Direction had relative efficiencies compared to Manhattan Grid respectively 82.80%, 93.60% and 98.03%.

5. Conclusion

The node distribution slightly affected the network efficiency, with homogeneous network subtly more efficient than heterogeneous network. Node variation simulations, despite had been better average network performance than area variation simulations, had bigger efficiency degradation rate than area variation simulations. Manhattan Grid mobility model had better performance on the system. As this model executes grid mobility, Random Direction mobility model may be used for similar systems that require multi directional mobility, once it had almost the same efficiency.

6. References

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