Characterization of Randomly Deployed Wireless Sensor Networks

Maximum points 100

General information

This project studies randomly deployed Wireless Sensor Networks (WSNs) with respect to several topological metrics.

Maximum group size 3.

Any programming language can be used for the implementation.

The reports of the project should be submitted in hardcopy to the Instructor the day of the deadline. Additionally, the reports and the code should be submitted to the TA electronically the day of the deadline.

The project should be discussed with the TA within 1 week from the deadline of the second report.

Wireless Sensor Networks

A WSN is composed by small and cheap devices endowed with sensing and communication capabilities. These devices can generally sense physical quantities such as temperature, pressure or light intensity. Communications are performed wirelessly and it is generally assumed that a sensor node can communicate within a communication range R.

Application of WSNs include hazard and inaccessible fields, where sensors cannot be deployed manually. As a result, sensors are generally thrown from an aircraft over the Area of Interest (AoI), generating in a random deployment.

The goal of this project is to study several topological aspects of a randomly deployed WSN with respect to the number of sensors deployed and of the communication range R.

Model and metrics

The WSN is modeled as a random geometric graph \( G=(V,E) \). In particular, each node is assigned a random position \((x,y)\) in the AoI. There is an edge between two nodes \( u \) and \( v \) if their Euclidean distance is less or equal to \( R \), i.e. there is an edge if \( u \) and \( v \) are able to communicate wirelessly. The resulting graph is obviously undirected.
We are interested in the following characteristics of $G$ as a function of the number $N$ of sensors deployed and the radius $R$:

- **Number of connected components**
- **Size of the largest connected component**: connected component with the maximum number of nodes.
- **Average node distance**: average length of shortest paths between each pair of nodes (in the case of multiple connected components consider only the pair of nodes belonging to the same component).
- **Diameter of the network**: length of the longest shortest path.

**Implementation and evaluation**

The project requires the development of a program to generate the random geometric graph $G$ and to evaluate the metrics described above.

The node deployment can be generated as follows. The AoI can be assumed to be a square of size $500 \times 500m^2$. Given the number of nodes $N$ and the transmission range $R$, first assign to each node a random position $(x,y)$ by selecting a random value for both components in the interval $(0,500)$. Once all nodes have been deployed, the distance between each pair of nodes should be evaluated and edges added accordingly.

The graph can be represented using an adjacent matrix or an adjacent list. These structures should be extended or supported by other structures to maintain the information on node positions.

Given the graph $G$ calculated as described above, functions should be developed to calculate the metrics of interest. Each metric should be calculated with respect to the number of sensors and the transmission range $R$ as discussed in the following.

Results should be averaged over at least 5 random generated graphs for each point represented in the graphical results.

**Increasing number of sensors**

Assume a transmission range of 20m and increase the number of sensors $N$. Similarly to the previous project, increase this number in a range that provides meaningful results. As an example, you may vary $N$ from 50 to 1000 increasing every time $N$ by 50.

Four graphs should be generated:

- The trend of the number of connected components by increasing the number of nodes $N$
- The trend of the size of the largest connected component by increasing the number of nodes $N$
- The trend of the Average node distance by increasing the number of nodes $N$
- The trend of the Diameter of the network by increasing the number of nodes $N$
Increasing transmission range

Assume a number of sensor \( N = 200 \), and increase the transmission range \( R \) in a range that provides meaningful results. As an example, you may vary \( R \) from 5 to 50m increasing every time \( R \) by 5.

Four graphs should be generated:

- The trend of the number of connected components by increasing \( R \)
- The trend of the size of the largest connected component by \( R \)
- The trend of the Average node distance by increasing \( R \)
- The trend of the Diameter of the network by increasing \( R \)

Reports

Two reports should be prepared. The first report does not require implementation and should include at least the following sections:

- Abstract: Summary of the following sections
- Definition of the metrics of interest: formally define the metrics of interest given the graph \( G \).
- Proposed solutions: Pseudo-code, description and complexity analysis of the proposed algorithms to calculate the metrics of interest.
- Plan of experiments: Description of the methodology which is planned to use in the experiments, significance and expected results.

The second report requires implementation and describes the implementation and results. It should include at least the following sections:

- Abstract: Summary of the following sections and results
- Implementation: Description of the methodology used for implementing the proposed solutions (e.g. relevant classes and data structures, structure of the program, etc.).
- Experiments: Description of the experiments performed and obtained results. Results should be represented in a graphical form as well as described in the writing.
- Conclusions: Summary of the work and final considerations.