Judges' Commentary: The Fusaro Award for the Repeater Coordination Problem

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Introduction

MCM Founding Director Fusaro attributes the competition's popularity in part to the challenge of working on practical problems. "Students generally like a challenge and probably are attracted by the opportunity, for perhaps the first time in their mathematical lives, to work as a team on a realistic applied problem," he says. The most important aspect of the MCM is the impact it has on its participants and, as Fusaro puts it, "the confidence that this experience engenders." The Ben Fusaro Award for the 2011 discrete problem went to a team from the University of Electronic Science and Technology (UES&T), Web Sciences Center, in Chengdu, Sichuan, China. This solution paper was in the top group, the Outstanding papers. Characteristics it exemplified were:

- Presented a high-quality application of the complete modeling process.
- Demonstrated noteworthy originality and creativity in the modeling effort to solve the problem as given.
- Written clearly and concisely, making it a pleasure to read.

The Problem

This year's problem dealt with finding the number of repeaters needed to create a VHS network to cover a circular region of radius 40 miles and

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simultaneously serve first 1,000 users, then 10,000 users. The approaches that different teams took could be broken down into two categories. Some papers focused first on covering the area, others on covering the population. This team did both. Students found many publications related to this topic. While to receive an Outstanding or Meritorious designation it was important for a team to review the literature, teams had to address all the issues raised and come up with a solution that demonstrated their own creativity.

The University of Electronic Science and Technology Paper

One-Page Summary Sheet

This team did an outstanding job with its executive summary. Although it was a bit long with very small print, in one page they motivated the reader and provided the reader with a precise summary of what they had accomplished. It gave an overview of everything from the assumptions, to the modeling and how it was done, to the testing of their models, and finally, to the analysis of the accuracy of their results and limitations of their models. It was well written and among the best examples of what an executive summary should be. The team's executive summary was followed by a one-page abstract. Typically, an executive summary contains more information (and often more sensitive information) than the abstract does.

Assumptions

As was the case with many teams, this team began with the assumption that the distribution of users in the area was uniform. Other teams considered a variety of other distributions as well, but this team did not. The second assumption stated the conditions under which repeaters would interfere with each other and the third was that the wireless signals can fade freely. Of critical importance, the team showed how their assumptions were used in the development of their model.

The Model and Methods

The team proposed a two-tiered network model consisting of user nodes and repeater nodes. As many teams did, they covered the circle with a sufficient number of hexagons to yield transmission among users based on the maximum communication distances for each type of node. However, they also used Voronoi diagrams to optimize communication with the least number of repeaters. Spanning trees were used to assign frequencies in the desired ranges and private line (PL) tones.

Testing Their Models

After determining the communication distances for their users and repeaters, along with the maximum capacity for a repeater, the UES&T team computed lower bounds for the number of repeaters that would be needed for each population size. They then developed an algorithm to place the users and repeaters within the designated circle of radius 40 miles and subdivided the area using Voronoi diagrams. They refined their algorithm to make certain that in the Voronoi regions, no repeater had users beyond its threshold capacity. Then they tested their models—not with just one size region, but with many, for user numbers of 1,000 and 10,000. By analyzing their results, they were able to comment on the sensitivity and robustness of their models. This was something that very few papers were able to do, and it is a very important step in the modeling process.

Recognizing Limitations of the Model

Recognizing the limitations of a model is an important last step in the completion of the modeling process. The students recognized that their algorithms would have to be modified if the terrain were not flat or if the users were distributed differently.

References and Bibliography

The list of references used was fairly thorough, but specific documentation of where those references were used was not always clear. Precise documentation of references used should have been included throughout the paper.

Conclusion

The careful exposition in the development of the mathematical models made this paper one that the judges felt was worthy of the Outstanding designation. The team members are to be congratulated on their analysis, their clarity, and on using the mathematics they knew to create and justify their own model for the Repeater Coordination Problem.

About the Author

Marie Vanisko is a Mathematics Professor Emerita from Carroll College in Helena, Montana, where she taught for more than 30 years. She was also a Visiting Professor at the U.S. Military Academy at West Point and taught for five years at California State University Stanislaus. She chairs the Board of Directors at the Montana Learning Center at Canyon Ferry and serves on the Engineering Advisory Board at Carroll College. She has been a judge for both the MCM and HiMCM.