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# Judge's Commentary: The Outstanding Communications Network Papers

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The Communications Network Problem provided contestants with a fascinating example of how a real-world problem can submit to a range of mathematical analyses, spanning the simple to the sophisticated. It provided sufficient detail to clearly define the problem in both a numerical sense and a graph-theoretical sense and to appeal to the practical intuition of contestants. Based on the number of entries for this problem, these qualities apparently were not lost on the audience.

As in past years, the diverse backgrounds of the undergraduate contestants motivated many interesting modeling approaches, making the judging of these papers a formidable task indeed. Rather than simply characterizing the qualities of the outstanding papers and adding to the plethora of modeling checklists available in the literature, it is instructive to also include some comments regarding common shortcomings observed among the entries.

As many teams discovered, the numerical aspects of the Communications Network Problem could be solved directly using hand calculations. However, although a direct approach allowed many teams to obtain appropriate numerical results for this specific problem instance, in several cases it severely limited a team's ability to generalize their modeling approach to a larger class of networks, or to suggest possible improvement reconfigurations for the network. Consequently, their results possessed limited applicability to other communications network problems whose parameters varied from those presented.

By and large, the exceptional papers provided conclusive evidence that their teams had dedicated a substantial amount of time discussing and conceptualizing the problem prior to deciding on a modeling methodology. Rather than leaping head-first into an exhaustive literature search hoping to find a problem exactly like the one presented, they tended to characterize the problem in a more general sense and then identify several different modeling approaches to the problem. Lest this point be misinterpreted, it is not to say that "more is better" with regards to the number of models applied to this problem. The best papers appropriately recognized the time available

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for analysis, and presented a sufficiently complete treatment to convince the reader of their depth of understanding independent of the number of models that they used.

In contrast, papers that attempted a "partial-credit" or "core-dump" approach to their modeling effort, by briefly addressing many different models, detracted from the overall quality of their submission. It was far better to have presented one or two well-developed approaches than to dedicate one paragraph each to several different techniques with the sole intention of demonstrating an awareness of these techniques.

Nearly all of the papers attempted computer implementations of their algorithms in order to examine the algorithm's performance on larger problem instances. Several of the outstanding papers used their computer implementation to try to expose underlying structural properties of the problem in a more general context. One paper was able to characterize the distribution of the file-transfer times as a uniform distribution by using statistical tests. Given the number of readily accessible off-the-shelf computer simulation programs, it was important to identify exactly why a computer was being used to support analysis. There is little value in having run 10,000 simulations of a random network when there is no rationale given for the underlying probability distribution, the design of and motivation for the simulation, or the general structure of the network being simulated. Repetition is not the mother of invention, nor the supreme arbiter of scientific correctness.

The vast majority of superior papers recognized the applicability of Vizing's theorem and were able to develop specific graph-theoretical solution algorithms to take advantage of this fact. They also identified critical processors in the network that were limiting the optimal performance of the network file-transfer process. One paper was able to quantify cleverly the critical characteristic of these processors by developing a ranking structure for each node in the network, based upon layered sums of linked-computer capacities.

Several inferior papers presented modeling approaches so specifically tailored to this instance of the problem that they rendered generalization next to impossible. The better papers maintained a perspective that this problem was one instance in a class of problems. These papers sought first to identify the general class, next develop an algorithm addressing this larger class, and then narrow the scope of the algorithm to the instance at hand. These papers explicitly recognized the limitations of an enumeration-based approach for larger problems and attempted to develop more efficient approaches, hoping to avoid the computational burden imposed by the combinatorial nature of the problem.

Although the exceptional papers all expressed a healthy respect for the difficulty in attempting to identify an algorithm that works for all networks, several other papers repeatedly overstated their results, perhaps in response

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to the excitement of finding a useful algorithmic approach that supported their intuition. Claims to have found "the optimal solution"—without verifying uniqueness—or to extending results to "any arbitrary network"—after demonstrating a very restrictive applicability—diluted the credibility of their analysis. In spite of achieving logical and seemingly correct results, one must also recognize that optimality and uniqueness are not synonymous.

Lastly, the finer papers were consistently characterized by clear, logical, well-supported presentations that illuminated the team's underlying analytical reasoning. Those papers that were well-written had very few grammatical errors, conveyed their results in well-designed tables and graphics, and presented a complete summary typically made their point more effectively.

The Communications Network Problem was challenging, and many excellent solutions were offered. Five papers stood out from all the others, and those teams should feel proud of their accomplishment.

# About the Author

Patrick J. Driscoll completed his undergraduate studies at the U.S. Military Academy at West Point in 1979, where he majored in engineering with a minor in mathematics. After serving in the infantry for eight years, Pat went on to earn a master's degree in operations research and a master's degree in engineering economic systems at Stanford University in 1989 and a Ph.D. in industrial and systems engineering at Virginia Tech in 1995. He has been a member of the faculty in the Dept. of Mathematical Sciences at West Point since 1989. His current research interests focus on discrete optimization in mathematical programming. Pat was an associate judge for the Communications Network Problem.