

## Chapter 1

# Applications of Network Optimization

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### 1. Introduction

Highways, telephone lines, electric power systems, computer chips, water delivery systems, and rail lines: these physical networks, and many others, are familiar to all of us. In each of these problem settings, we often wish to send some good(s) (vehicles, messages, electricity, or water) from one point to another, typically as efficiently as possible – that is, along a shortest route or via some minimum cost flow pattern. Although these problems trace their roots to the work of Gustav Kirchhoff and other great scientists of the last century, the topic of network optimization as we know it today has its origins in the 1940's with the development of linear programming and, more broadly, optimization as an independent field of scientific inquiry, and with the parallel development of digital computers capable of performing massive computations. Since then, the field of network optimization has grown at an almost dizzying pace with literally thousands of scientific papers and multitudes of applications modeling a remarkably wide range of practical situations.

Network optimization has always been a core problem domain in operations research, as well as in computer science, applied mathematics, and many fields of engineering and management. The varied applications in these fields not only occur 'naturally' on some transparent physical network, but also in situations that apparently are quite unrelated to networks. Moreover, because network optimization problems arise in so many diverse problem contexts, applications are scattered throughout the literature in several fields. Consequently, it is sometimes difficult for the research and practitioner community to fully appreciate the richness and variety of network applications.

This chapter is intended to introduce many applications and, in doing so, to highlight the pervasiveness of network optimization in practice. Our coverage is

not intended to be encyclopedic, but rather attempts to demonstrate a range of applications, chosen because they are (i) 'core' models (e.g., a basic production planning model), (ii) depict a range of applications including such fields as medicine and the molecular biology that might not be familiar to many readers, and (iii) cover many basic model types of network optimization: (1) shortest paths; (2) maximum flows; (3) minimum cost flows; (4) assignment problems; (5) matchings; (6) minimum spanning trees; (7) convex cost flows; (8) generalized flows; (9) multicommodity flows; (10) the traveling salesman problem; and (11) network design. We present five applications for each of the core shortest paths, maximum flows, and minimum cost flow problems, four applications for each of the matching, minimum spanning tree, and traveling salesman problems, and three applications for each of the remaining problems.

The chapter describes the following 42 applications, drawn from the fields of operations research, computer science, the physical sciences, medicine, engineering, and applied mathematics:

1. System of difference constraints;
2. Telephone operator scheduling;
3. Production planning problems;
4. Approximating piecewise linear functions;
5. DNA sequence alignment;
6. Matrix rounding problem;
7. Baseball elimination problem;
8. Distributed computing on a two-processor computer;
9. Scheduling on uniform parallel machines;
10. Tanker scheduling;
11. Leveling mountainous terrain;
12. Reconstructing the left ventricle from X-ray projections;
13. Optimal loading of a hopping airplane;
14. Directed Chinese postman problem;
15. Racial balancing of schools;
16. Locating objects in space;
17. Matching moving objects;
18. Rewiring of typewriters;
19. Pairing stereo speakers;
20. Determining chemical bonds;
21. Dual completion of oil wells;
22. Parallel saving heuristics;
23. Measuring homogeneity of bimetallic objects;
24. Reducing data storage;
25. Cluster analysis;
26. System reliability bounds;
27. Urban traffic flows;
28. Matrix balancing;
29. Stick percolation problem;
30. Determining an optimal energy policy;