

Minimum Edge Compact Spanner Problem

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Abstract

We introduce and study the Minimum Edge Compact Spanner (MECS) problem on a simple undirected graph. The MECS problem deals with finding a sparse subgraph of an input graph, such that the of average distance or average path length (APL) is preserved to a constant factor. From the perspective of network communication efficiency and robustness, APL can be viewed as a measure of robustness of a communication network in the sense that the shorter the APL, the fewer hops information transmission paths contain on average, thus enhancing robustness of a network with respect to potential transmission errors or disruptions on network links. As a result, such problems have applications in areas where one wants to substitute a dense graph with a sparse subgraph while maintaining a low cost of communication. For example, in the World Wide Web, a short APL enables the rapid transfer of information between websites, thereby reducing communication costs. Similarly, in road networks, a short APL ensures efficient transportation by minimizing the average number of intersections or turns needed to travel between two locations, leading to reduced travel time and fuel consumption. We prove computational complexity results related to the considered problem, design exact and heuristic algorithms for solving the problem, and provide the respective computational results.

Keywords

Network Optimization, Spanner, Average Distance, Exact MIP Formulations, Heuristic Algorithms.

Biographies

Dr. Mukherjee is an associate professor in the Computer Science department at UAH. He received MS and PhD in Computer Science from Florida State University, Tallahassee, FL. His research interests are broadly in Cyber Security and Malware Analysis with applications to national defense. Dr. Mukherjee is also an expert on Machine Learning and uses techniques from Machine Learning for building intelligent and autonomous systems having applications in national defense. He is also interested in integrating Machine Learning and Cyber Security for building the next generation of systems for cyber offense and defense.

Dr. Veremyev received his B.S. degree in mathematics and applied mathematics from Moscow State University, Moscow, Russia in 2002 and the Ph.D. degree in industrial and systems engineering from the University of Florida, Gainesville, FL, in 2011. From 2011 to 2012 he was an Adjunct Assistant Professor at the University of Florida, Industrial and Systems Engineering Department. Then he was an NRC Research Associate at the Air Force Research Laboratory, Munitions Directorate, Eglin AFB, FL from 2012 to 2014. From 2014 to 2017 he was a Research Assistant Scientist with the Industrial and Systems Engineering Department, University of Florida. Since 2017, he has been a Research Assistant Professor with the Industrial Engineering and Management Systems Department, University of Central Florida, Orlando, Florida. His research interests include mathematical modeling, development and analysis of efficient methods for solving various combinatorial optimization problems in complex networks. Dr. Alexander Veremyev was a recipient of the National Research Council Research Associateship award in 2012.

Dr. Boginski received the B.S. degree in applied mathematics from Moscow Institute of Physics and Technology, Russia, in 2000, and the M.S. degree and the Ph.D. degree in industrial and systems engineering from University of Florida, Gainesville, FL, USA, in 2003 and 2005, respectively. From 2015 till present, Dr. Boginski has been with the Industrial Engineering and Management Systems department at the University of Central Florida, Orlando, FL, USA (Associate Professor since 2015, Professor since 2020). He previously served as an Assistant Professor of Industrial and Systems Engineering at the University of Florida (Gainesville, FL, USA) and Florida State University (Tallahassee, FL, USA). Dr. Boginski's research interests primarily focus on using mathematical modeling and optimization techniques in the interdisciplinary area of network science. He has co-authored over 90 publications, including 50 refereed journal articles. He is a member of Institute for Operations Research and Management Sciences (INFORMS), where he has previously served as the Vice-chair for Networks at the INFORMS Optimization Society (2013-2015) and as a member of council at the INFORMS Telecommunications and Network Analytics Section (2016-2020). In 2018, he was selected by the U.S. National Academy of Engineering (NAE) as a participant of the Japan-America Frontiers of Engineering symposium, which brought together sixty of the most promising early career engineers from Japan and the United States.

Dr. Semenov is a Research Assistant Professor at Herbert Wertheim College of Engineering, University of Florida. Dr. Semenov holds a PhD in computer science from the University of Jyväskylä, Finland. His research interests include network science, efficient algorithms, analysis of large datasets, optimization, and machine learning. Dr. Semenov has previously worked at the University of Jyväskylä and for multiple startup companies in the fields of e-commerce and transportation. Dr. Semenov has co-authored over 60 peer-reviewed publications and has been a recipient of multiple research grants. He is currently an Associate Editor for the Journal of Combinatorial Optimization, IET Blockchain Journal, Energy Systems, and member of editorial board at Scientific Reports.

Dr. Pasilio received the B.S. degree in mechanical engineering from Columbia University, New York, NY, USA, in 1992, the M.S. degree in coastal and oceanographic engineering and the Ph.D. degree in industrial and systems engineering from University of Florida, Gainesville, FL, USA, in 1995 and 2003, respectively. Dr. Pasilio is currently a Research Engineer at the Air Force Research Laboratory. His research interests are in the areas of graph theory, combinatorial optimization, discrete mathematics, network science, and machine learning. He has co-authored over 100 peer-reviewed journal and conference publications. He has been a member of American Institute for Aeronautics and Astronautics (AIAA) and Institute for Operations Research and Management Sciences (INFORMS).