Network Science for Communication Engineering

7

Sudhir K. Routray
https://orcid.org/0000-0002-2240-9945
Bule Hora University, Bule Hora, Ethiopia

INTRODUCTION

Network science is associated with the study, analysis, modeling and applications of networks. Networks are not limited to any one or two disciplines. Rather, networks are found in almost every field in different forms. For instance, in electrical engineering we have electrical circuits which are known as networks. In communication engineering, we have communication networks of different types such as access networks, regional networks, core networks and the Internet. Computer networks are very much identical to the communication networks these days. In fact, unification of communication and computing has given birth to the Internet. Power distribution networks are found throughout the world. They are huge in size and directly affect the human activities across the world these days. In our society, we have different types of social networks. Social networks through the communication platforms have given birth to the online social networks such as LinkedIn and Facebook. However, the social networks are very much older than the current social networks found online. The social networks were started along with the civilizations. However, their studies in psychology were started much later in the twentieth century (Moreno, 1934). Transportation networks are formed through the roads connecting cities, towns and villages. These transportation networks are also found over the water and air as the shipping and airline networks. Based on the economic activities between different countries and regions, trade and economic networks are formed.

In the nature, many different types of networks are found in various forms. Human brain is a complex network of neurons. In the human body there are some other networks as well such as blood circulation network and the lymphatic networks. In genetics, we can find out the link between generations and different clans. It is also a complex network. Based on the genetics, doctors classify different diseases and utilize them for advanced research and clinical treatments. This branch of medicine is commonly known as network medicine. Metabolism of organisms follows different sequences of processes which forms a metabolic network. Rivers and streams form natural water supply networks. In the modern world, there are several resource supply and distribution networks. Structural networks are found in different mechanical designs and civil architectures. In scientific collaborations we find the citation networks.

Complex systems are the large and randomly related with their components. The components of these systems are complexly related with each other. In other words, these systems are made up of many heterogeneous and non-identical elements connected through several diverse interactions. In every complexity, we always find a network is associated (Albert & Barabási, 2002). In order to understand the complexities, the underlying networks have to be understood properly. As we have seen above, every discipline has complex issues. Mapping the complexities accurately we can find a network which has the potential to simplify its understanding (Albert & Barabási, 2002). This is the main reason behind the popularity of network science.

DOI: 10.4018/978-1-7998-3479-3.ch065

Network Science: Origin and Background

Network science is being treated as the study of networks using different scientific methods. Its popularity and widespread applications are very much recent. However, the discipline has been developed quite clandestinely since a long time. The exact beginning of network related study is not known. Regular networks were being studied in geometry in several old civilizations. These principles were also being used in the building and structural architectures. However, graph theory which is considered as the mathematical basis of networks was started by Euler in 1735. His visit to Königsberg was the key in the development of graph theory (Alexanderson, 2006). The famous "Seven Bridges of Königsberg" puzzle was solved by Euler and it was the foundation of graph theory. Since then, graph theory became a systematic branch of mathematics. The first application of graph theory in engineering was found in the study and analysis of electrical networks in circuit theory. Early applications of network science are recorded in Psychology (Travers & Milgram, 1967) in which the psychologists tried to explain the social behavior of people. In the 1930s Moreno used the principles of networks to analyze the social networks (Moreno, 1934). The mathematical models for the networks other than the graph theory came quite late in the late 1950s. The mathematical model for the random networks was developed by Erdös and Renyi in 1959 (Erdős & Rényi, 1960). This was the first model to analyze the real networks. Their formulation assumed that every real network is random in nature as their nodal degrees follow Poisson's distribution. In the late 1960s and early 1970s, communication networks were studied rigorously as their size and applications got expanded. The Grannovettor network model was developed in 1973 which was very much fundamental like the random network model developed by Erdös and Renyi (Grannovetter, 1977). Ecological networks and several biological networks were brought in to the picture in the late 1970s. After these practical applications, network science attracted researchers from almost every field. Two papers by the network scientists in the late 1990s opened the floodgate of research in this discipline. They are: the paper of Albert and Barabási (Albert & Barabási, 1999) in Science, on the scaling of the Internet published in 1999; and the paper of Watts and Strogatz (Watts &Strogatz, 1998) in Nature, regarding the small world networks published in 1998. These two papers showed the essence of network science in the modern scientific and technological analysis.

Since the publications of those two ground breaking papers in the late 1990s, network science became considered as a fundamental discipline in the study of networks and their applications to understand the natural complexities. Complex systems such as the Internet and human brain are built over large networks. In order to understand their principles, it is essential to understand their underlying network. Several branches of science, arts, and commerce now use network science as one of their main tools to analyze the complexities. For instance, in physics, chemistry, biology, communication engineering, material science, psychology, medicine, economics, and political science network science is used as a tool to explain the underlying complexities. In communication engineering, network science is used to study the dynamics and stability of the networks (Routray et al., 2015). The use of statistical modeling in the analysis of optical networks is found in Waxman (1988) in which the nodal degrees of the core networks were found to follow Poisson's distribution. A complete statistical formalism for the fast estimation of optical network parameters was developed in Korotky (2004). A similar fast estimation of mesh optical networks was developed in Labourdette et al. (2005). Optical network topologies can be developed using the statistical principles of the optical networks (Pavan et al., 2010). Following the successes of these models several statistical models for different parameters of core and access networks have been developed in the recent years (Routray et al., 2015). Network economics can also be analyzed using network science approaches (Routray et al., 2017). The social networks are really complex and