Evolutionary Computing Approach for Ad-Hoc Networks

Prayag Narula
University of Delhi, India

Sudip Misra
Yale University, USA

Sanjay Kumar Dhurandher
University of Delhi, India

INTRODUCTION

Wireless ad-hoc networks are infrastructureless networks in which heterogeneous capable nodes assemble together and start communicating without any backbone support. These networks can be made truly dynamic and the nodes in these networks can move about freely while connecting and disconnecting with other nodes in the network. This property of ad-hoc networks to self-organize and communicate without any extrinsic support gives them tremendous flexibility and makes them perfect for applications such as emergencies, crisis-management, military and healthcare.

For example, in case of emergencies such as earthquakes, often most of the existing wired network infrastructure gets destroyed. In addition, since most of the wireless networks such as GSM and IEEE 802.11 wireless LAN use wired infrastructure as their backbone, often they are also rendered useless. In such scenarios, ad-hoc networks can be deployed swiftly and used for coordinating relief and rescue operations. Ad-hoc networks can be used for communication between various stations in the battle-field, where setting up a wired or an infrastructure-based network is often considered impractical.

Though a lot of research has been done on ad-hoc networks, a lot of problems such as security, quality-of-service (QoS) and multicasting need to be addressed satisfactorily before ad-hoc networks can move out of the labs and provide a flexible and cheap networking solution.

Evolutionary computing algorithms are a class of bio-inspired computing algorithms. Bio-inspired computing refers to the collection of algorithms that use techniques learnt from natural biological phenomena and implement them to solve a mathematical problem (Olario & Zomaya, 2006). Natural phenomena such as evolution, genetics, and collective behavior of social organisms and functioning of a mammalian brain teach us a variety of techniques that can be effectively employed to solve problems in computer science which are inherently tough.

In this Chapter and the chapter entitled, “Swarm Intelligence Approach for Wireless Ad Hoc Networks” of this book, we present some of the currently available important implementations of bio-inspired computing in the field of ad-hoc networks. This chapter looks at the problem of optimal clustering in ad-hoc networks and its solution using Genetic Programming (GP) approach. The chapter entitled, “Swarm Intelligence Approaches for Wireless Ad Hoc Networks” of this book, continues the same spirit and explains the use of the principles underlying Ant Colony Optimization (ACO) for routing in ad-hoc networks.

BACKGROUND

The first infrastructureless network was implemented as packet radio (Toh, 2002). It was initiated by the Defense Advanced Research Projects Agency (DARPA) in 1970s. By this time the ALOHA project (McQuillan & Walden, 1977) at the University of Hawaii had demonstrated the feasibility of using broadcasting for sending / receiving the data packets in single-hop radio networks. ALOHA later led to the development of Packet Radio Network (PRNET), which was a multi-hop multiple-access network, under the sponsorship of Advanced Research Projects Agency (ARPA). PRNET had the design objectives similar to the current day ad-hoc networks such as flow and error control over multi-hop communication route, deriving and maintaining network topology information and mechanism to handle router mobility and power and size requirements, among others. However, since the electronic devices were huge then, the packet radios were not easily movable, leading to limited mobility. In addition, the network coverage was slow and since Bellman-Ford's shortest path algorithm was used for routing, transient loops were present. Since then, a lot of research has been done on ad-hoc networks and a number of routing algorithms have been developed which provide far greater performances and are loop free. The rapid development of silicon technology has also led to ever shrinking devices with increasing computation power. Ad-hoc networks are deliberated for use in medical, relief-and-rescue, office environments, personal networking, and many other daily life applications.

Bio-inspired algorithms, to which the evolutionary computing approaches such as genetic algorithms belong, have been around for more than past 50 years. In fact, there have been evidences that suggest that the Artificial Neural Networks are rooted in the unpublished works of A. Turing (related to the popular *Turing Machine*) (Paun, 2004). Finite Automata Theory was developed about a decade after that based on the neural modeling. This ultimately led to the area that is currently known as Neural Computing. This can effectively be called as the initiation of bio-inspired computing. Since then, techniques such as GP, Swarm Intelligence and Ant Colony Optimization and DNA computing have been researched and developed as nature continues to inspire us and show us the way for solving the most complex problems known to man.

MAIN FOCUS OF THE CHAPTER

This chapter and the the chapter entitled, "Swarm Intelligence Approaches for Wireless Ad Hoc Networks" of this book, in combination, present an introduction to various bio-inspired algorithms and describe their implementation in the area of wireless ad-hoc networks. This chapter primarily presents the GP approach to ad-hoc networks. We first give a general introduction to GP and explain the concepts of genes and chromosomes. We also explain the stochastic nature of GP and the process of mutation and crossover to provide optimal solution to the problem using the GP approach. We then present the Weighted Clustering Algorithm given by (Chatterjee, Das & Turgut, 2002) that are used for clustering of nodes in mobile ad-hoc networks, as an instantiation of this approach.

GP

GP is a popular bio-inspired computing method. The concepts in genetic algorithms are inspired by the phenomenon of life and evolution itself. Life is a problem whose solution includes retaining those who have strong enough characteristics to survive in the environment and discarding the others. This exquisite process can provide solutions to complex analytical problems awaiting the most "fitting" result.

The basics include the role of chromosomes and genes. Chromosomes carry the genes which contain the parameters/characteristics that need to be optimized. Hence, GP starts with declaration of data structures that form the digital chromosomes. These digital chromosomes contain genetic information where each gene represents a parameter to be optimized. The gene could be represented as a single bit, which could be '1' (ON) or '0' (OFF). So, a chromosome is a sequence of 1's and 0's and a parameter is either totally present or totally absent. Other abstractions could represent the presence of a parameter in relative levels. For instance, a gene could be represented using 5 bits where the magnitude of the binary number tells about the magnitude of the presence of a parameter in the range '0' (00000) to '31' (11111).

First, these digital chromosomes are created using stochastic means. Then their fitness is tested either by static calculation of fitness using some method or dynamically by modelling fights between the chromosomes. The chromosomes with a set level of fitness are retained and allowed to produce a new generation of chromosomes. This can be done either by genetic recombination that is new chromosomes are produced with combination of present chromosomes, or by mutation, that is new chromosomes are produced by randomly producing changes in present chromosomes. This process of testing for fitness and creating new generations is repeated until the fittest chromosomes are deemed as optimized enough for the task, which the genetic algorithm was created for. The process is described in Figure 1.

Related Content