Chapter 10

Autonomously Evolving
Communication Protocols
The Case of Multi-Hop Broadcast

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ABSTRACT

While traditional telecommunication still relies on rigid, highly regulated, and highly controlled communication protocols, with the emergence of new forms of networks (mobile ad hoc and delay-tolerant networks, lacking central infrastructure and strict regulations) bio-inspired communication protocols have also found their way to success. In this chapter we introduce a nontraditional way of creating and shaping communication protocols, through an autonomous machine intelligence model, built upon on-line evolutionary methods such as natural selection and genetic programming. Creating a genetic programming language and a selection mechanism for multi-hop broadcast protocols in ad hoc networks, we show that this kind of approach can outperform traditional ones under given circumstances, offering a powerful alternative in the future.

INTRODUCTION

Communication protocols are always of high concern in telecommunication networks, especially in ad hoc networks. While too chatty protocols waste resources such as bandwidth and processing power, unnecessarily tight-lipped communication strategies hinder the flow of information and as a consequence, impede the effective operation of the system. Recent studies indicate that while there is no clear answer for the protocol selection riddle in general, it makes sense to evaluate
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the goodness of communication protocols for a certain problem case (Williams and Camp 2002; Dai and Wu 2004; Cheng, Huang, Li, Wu, and Du 2003; Al Hanbali, Ibrahim, Simon, Varga, and Carreras 2009).

The idea of protocol selection or protocol switching has been present for many years in other areas (e.g. cryptography). Our proposal follows this line, but goes one step further: we do not only select but create and shape the protocols.

Imagine a system where communication protocols are not rigid, pre-deployed parts, instead, the protocol logic itself emerges dynamically and improves flexibly according to the current needs of the communicating parties. What could this idea of evolving protocols mean? As a main advantage, the evolution mechanism removes the burden of designing communication protocols manually. The application of machine intelligence for this task not only reduces costs, but with a suitable model, also guarantees the emergence of successful protocols in the end.

Evolutionary programming comes naturally as an implementation tool for the protocol evolution. However, finding the right representation is non-trivial; it is not just operational parameters what we want to optimize, we aim at optimizing the protocol logic itself.

The objective of the chapter is to elaborate on the idea of autonomously evolving protocols through a concrete example showing how such a model could work. The demonstrative example, the challenge of multi-hop broadcast in ad-hoc networks, is a real problem today. We created a concrete evolutionary model with a pilot implementation for this problem case, and excessive simulation was used, alongside with data mining on the results, in order to explore various aspects.

In our previous work (Simon, Bérces, Varga and Bacsárdi. 2009) we used natural selection to achieve self-adaptation of multi-hop broadcast protocols in ad hoc networks, through automatically selecting the optimal one from a predefined set of protocols. Now we introduce an on-line Genetic Programming framework that extends our previous ideas: protocol candidates are generated via evolution.

The structure of the chapter is the following. First, we give a short summary on the background of broadcasting in mobile ad-hoc networks – our guinea pig – and the applied toolset such as machine learning, genetic programming and natural selection algorithms. Then, in the main trust of chapters, we discuss the questions and solutions of the evolutionary approach for the multi-hop-broadcast problem. We describe the details of the model, the abstractions, and the genetic programming language itself. Then, various aspects of the model are examined via simulation; a large amount of collected simulation data was analyzed using data mining techniques. Finally, we discuss interesting future directions.

BACKGROUND

It is a common task in ad hoc networks to distribute messages globally to all, or almost all, participants of the network. This is basically an extension of local broadcast, usually referred to as multi-hop broadcast. By nature, this kind of service consumes a significant amount of resources (channel usage, collisions), therefore it is an important objective to optimize the protocol used for multi-hop broadcast.

Various literature sources investigate the possible protocols and their performance characteristics (Williams and Camp 2002; Dai and Wu 2004; Cheng, Huang, Li, Wu, and Du 2003; Al Hanbali, Ibrahim, Simon, Varga, and Carreras 2009), but measurements show that there is no definite winner – the behavior of protocols depend heavily on the parameters of the environment. These parameters include mobility patterns, node speed, node density, transmission technology and traffic models. Selecting the suitable protocol, therefore, requires deep and exact knowledge about the actual environment – which is generally hard to acquire, given the complex factors involved, such