Applications of Automatic Control Methods in Wireless Networks

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Abstract

The performance of wireless networks is limited by the features such as mobility, unstability, interference or so, therefore capable tools to solve the problems are expected. Automatic control methods can be such tools in the sense that they can be applied to the network models and such tools are mature and being studied. In this project, such a problem is studied that what automatic control methods can be applied, how they can be applied and what problems can be solved by applying these methods.

KEYWORD: AUTOMATIC CONTROL METHODS WIRELESS NETWORKS

1 INTRODUCTION

The problem about how to improve performance of wireless networks has always been the most principal problem in this domain. Wireless systems have some features, such as the mobility of users, interference, difficulty to schedule the network, resource allocation and so on. Such features determine that resources cannot be utilized completely, which limit the performance of the network. So we are eager to find such tools which can be applied to the network models, and can perform well in solving such problems. Mathematic tools, economic tools and automatic tools are all excellent choices, since they are suitable for the models, all quite mature and being studied so that the tools themselves are improving too. In this paper, we want to focus on automatic control methods.

The procedure of the work is as follows: if we want to study such methods, we have to know what automatic control methods are, so in the first session, automatic control methods are collected and classified. After collecting such methods, papers in wireless communication domain which use automatic control methods are searched and collected according to the methods found. Then the papers are studied individually, and detailed report about each of them is written. Finally, by summarizing the papers read and reports written, we find out what automatic control methods can be applied and what problems they can solve. So the rest of the paper is organized as follow: in Section II, automatic control methods are collected, and a classification of them is done. In Section III, cases utilizing automatic control methods are stated and analyzed, categorized by automatic methods. Finally in Section IV, a summarization is given about the applications of automatic control methods.

2 AUTOMATIC CONTROL METHODS

The collection of automatic control methods can be easily done if there is a systematic classification of the methods, like the Mathematic Manual in Mathematic domain. But unfortunately, there is no such thing in the domain of Automatic Control. So the methods are collected individually, and I have to classify them according to some specific rules. Finally I found a reasonable classification rule, and classify the automatic control methods into CLASSIC AUTOMATIC CONTROL METHODS and MODERN AUTOMATIC CONTROL METHODS. In the category of modern automatic control methods, there is an important subcategory called intelligence algorithm. The classification of the methods collected is given in the figure 1:

In this classification, the classic automatic control methods are not so widely used in study

Classic Automatic Control Methods		Root Locus Method, PID control, Frequency Response Method
Modern Automatic Control Methods	Intelligence Algorithm	Machine Learning, Fuzzy Logic, Dynamic Programming, Artificial Neural Network, Genetic Programming, Collective Intelligence, Ant Colony Algorithm, Agent, Cellular Automata, Evolutionary Strategies, Expert Control System
	Others	Nonlinear Control, Robust Control, Adaptive Control, Distributed Control, Predictive Control

Figure 1: Classification of Automatic Control Methods

today in wireless communication, so we did not focus on them. In the second category of Modern Automatic Control Methods, the methods such as adaptive control are too widely used, that in the study today they are seldom used as a core technique but used as a manner, so we did not focus on them. The methods in the Intelligence Algorithm are quite widely used and perform well in wireless domain, so we focus on studying them.

3 APPLICATIONS OF AUTOMATIC CONTROL METHODS

3.1 Machine Learning

3.1.1 Definition

Machine learning is a scientific discipline that allows computers to evolve behaviors based on empirical data, such as from sensor data or databases. A learner can take advantage of examples (data) to capture characteristics of interest of their unknown underlying probability distribution. Data can be seen as examples that illustrate relations between observed variables. A major focus of machine learning research is to automatically learn to recognize complex patterns and make intelligent decisions based on data; the difficulty lies in the fact that the set of all possible behaviors given all possible inputs is too large to be covered by the set of observed examples (training data). Hence the learner must generalize from the given examples, so as to be able to produce a useful output in new cases.

3.1.2 Cases Studied

Machine learning has been utilized to solve problems in wireless communication for a relatively long time. In [3], Machine learning is applied to solve a network selection problem in a heterogeneous environment. Traditionally, network selection is based on signal strength received at the mobile terminal, however there are some drawbacks of the strategy, firstly signal strength does not mean better service, if the cell is congested, then QoS may be low. Secondly, because of the mobility of the terminals, maybe the signal is strong when you enter, but may not last for the whole calling session. In this sense, Q-LEARNING is applied to select the one with higher QoS and meanwhile, control the handover frequency.

In[5], an autonomous load balancing strategy is given by using cooperative learning. In traditional hop by hop delivery, they suffer from a low efficiency because they always select a short but sometimes congested path instead of a longer by ideal path. So a cooperative learning methods is used to determine whether the path is crowded, and to exchange results with learning agents in adjacent cells to implement load-balancing among the cells involved.

In [6], an interference mitigation problem in self-organized femtocell is studied by using reinforcement learning. Femtocell is a popular indoor service cellular network, it brings a lot of advantages such as coverage indoor, but also faces some drawbacks such as interference. In order to solve the interference problem, a better resource schedule and power control scheme is expected. So a algorithm which can automatically adjust the parameters corresponding to some change in traffic load is designed by using Reinforcement Learning. This algorithm mitigate the interference by controlling power and scheduling to qualify the QoS.

In [7], an application in m-health is discussed. Since mobile health care service need low delay and higher QoS, a design of cross-layer ultrasound video streaming in WiMAX and HSDPA networks is provided. Machine learning is applied here to optimize the delay and QoS of the cross-layer manner. Another case about m-health using Machine learning is studied in [8]

In[10], an intra-cell interference mitigation problem in LTE network is studied. In [11], An access control problem in heterogeneous networks is studied

with Q-learning.

3.2 Fuzzy Logic

3.2.1 Definition

Fuzzy logic is a form of many-valued logic or probabilistic logic; it deals with reasoningthat is approximate rather than fixed and exact. In contrast with traditional logic theory, where binary sets have two-valued logic: true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false.[11]

3.2.2 Cases Studied

The channels in a cell is limited, when the number of busy channels is over some threshold, it will reject the calls. If the threshold is static, ping-pong effect will happen and the resources are wasted. In[14], Fuzzy logic is used to determine whether a cell is "hot" or "cold", it is not only determined by the load but also determined by the number of available channels in the neighbour cell. Thus a dynamic channel borrowing scheme is designed.
In [15] ,[16] and [17], vertical handover problem is proposed, and fuzzy logic is used to solve this problem, however, there are some differences in these two papers. In [15], a vertical handover happens between macrocells and microcells, since the micro cell is smaller but with higher speed and higher QoS, and it can spare the load from macro cells, so it is good to hand over to such cells. However, if the terminal is in high speed, or it moves along the border region, frequent handover will happen a lot which takes so many resources. So fuzzy logic is used, to take the mobility parameter into account, and gives a improved strategy. In [16], handover is done between WLAN and LTE. In [17], when some big events like football match or global conference is held, the regional load will be extremely high, in order to solve the problem, the operator will adjust the handover parameter to decrease the area of the congested region, and guide the load to the idle ones. The adjustment of the parameters is done by fuzzy logic. In [18], adjustment of the antenna is done by fuzzy logic, to optimize the coverage and capacity of the cells.

3.3 Dynamic Programming

3.3.1 Definition

Dynamic programming is a method for solving complex problems by breaking them down into simpler subproblems. It is applicable to problems exhibiting the properties of overlapping subproblems which are only slightly smaller[12] andoptimal substructure .

3.3.2 Cases Studied

Spectrum Action has been a hot spot recently. The users can be classified as Primary Users and Secondary Users, so there is a price to buy the spectrum of the resources. In [20], a way to determine the prices of secondary users is given, using random dynamic programming.
The services are classified into different service types, which demands different constrains. So this scheme determines that the packet scheduling is more complicated than before, [21]gives a dynamic programming method to determine a schedule that is fair and with high efficiency.
Routing problem in Wireless Mesh Network is puzzling, traditional way is to find the shortest path. But it will lead to some drawbacks, such as congested paths or else. [22]gives a dynamic method to find the best path, considering the channel quality, link quality and delay.

3.4 Neural Network

3.4.1 Definition

The term neural network was traditionally used to refer to a network or circuit of biological neurons. Artificial neural networks are composed of interconnecting artificial neurons (programming constructs that mimic the properties of biological neurons). Artificial neural networks may either be used to gain an understanding of biological neural networks, or for solving artificial intelligence problems without necessarily creating a model of a real biological system. The real, biological nervous system is highly complex: artificial neural network algorithms attempt to abstract this complexity and focus on what may hypothetically matter most from an information processing point of view. Good performance (e.g. as measured by good predictive abil-

Automatic Control Methods	Correspond Problems
Machine Learning	Network selection, load balancing, interference mitigation, coding, cross-layer design, interference balancing
Fuzzy Logic	Handover problem, channel borrowing, load balancing, coverage and capacity balancing
Neural Network	Resource allocation
Dynamic Programming	Pricing, data simplification, packet scheduling, path selection

Figure 2: Summary of Methods and Problems

ity, low generalization error), or performance mimicking animal or human error patterns, can then be used as one source of evidence towards supporting the hypothesis that the abstraction really captured something important from the point of view of information processing in the brain. Another incentive for these abstractions is to reduce the amount of computation required to simulate artificial neural networks, so as to allow one to experiment with larger networks and train them on larger data sets.[13]

3.4.2 Cases Studied

Artificial Neural Networks have the advantages that it deploys a parallel manner, so the calculation speed is quite high, and its coverage is quite high, so In [19], in the situation when there are some WLANs, some UMTSs and GSMs. Neural network is used to determine which of the base stations should be selected to be the optimized group, and provided the best RAT (Radio Access Technology) to the users.

3.5 Other Methods

Other methods such as genetic programming, expert control system and so on also have applications in wireless communication domain. In the work after this project, the work will be carried on.

4 Summary

After studying the methods and relative papers with applications of them, we can find out what problems can be solve by applying a specific method. Summary is in figure 2.

At last, the detailed reports about each problem and method is in the project report of ¡Applications of Automatic Control Methods in Wireless Networks¿ with Hua Wei Corporation.

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