STOCHASTIC MODELS FOR OPTIMIZATION OF SOFTWARE-DEFINED RADIO OPERATION

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ABSTRACT

Stochastic models can be used to capture uncertainty and variation in communication and computation systems as well as in communication channels. Our factored Markov decision process models capture characteristics of a communication system and its operating environment, allowing more robust optimization of its operation.

1. INTRODUCTION

Software-defined radios are complex systems that operate in complex environments. System operation must be optimized for communication parameters as well as operational parameters such as power consumption. We use factored Markov decision processes to efficiently represent both the communication channel and the characteristics of the communication system platform. Our approach allows us to more robustly optimize system operation compared to previous methods.

2. MARKOV DECISION PROCESSES

A Markov decision process (MDP) is an extension of a Markov model that provides for external input. In each state, the model accepts an input; the transitions out of each input are assigned probabilities. Each transition is associated with a reward.

Since the transitions out of a state depend on the input, the choice of inputs affects the possible rewards available as the model moves from one state to the next. A policy is a set of inputs to be applied to the machine. We can solve for an optimal policy that maximizes the reward on an infinite horizon; rewards are discounted over time using a discount factor. A number of algorithms have been developed to solve for optimal discounted rewards of an MDP.

Markov decision processes have been widely used to model communication channels [1]. They have also been used to optimize power management policies in embedded computing systems [2].

3. FACTORED MDP MODELS

We use factored Markov decision processes to model communication systems. Our models capture both the communication system as well as the channel and environment. Our approach exposes a larger design space because we consider the effects of the communication system as well as the channel. Our approach also allows us to optimize system operation for a wider range of objectives, including power consumption and thermal behavior.

The two major components of the system model are the channel state model and the control state machine. The channel state model is a hidden Markov model; it can be designed using simulation methods and updated using online training. The control state machine is a finite-state machine that describes the communication platform's behaviors; its states describe the performance and power consumption of the platform in various modes. The product of these two models produces a Markov decision process known as the configuration control machine (CCM). The CCM describes the channel, the communication platform, and their potential interactions.

We can solve the configuration control machine at design time to find a policy used to operate the machine. That policy allows the optimization framework to adapt to the environment in addition to the system being optimized.

We can also update and re-solve the model at run time. Dynamic updating of the model and policy allows the system to adapt to the environment.

4. COMMUNICATION SYSTEM MODELING

We have applied our factored MDP approach to the optimization of a channelization system [3]. The channelizer has three top-level processing states: an FIR downconverter with eight subconfigurations; a DFT filter bank; and a sleep mode. A two-frame delay was incurred to switch between algorithms. Our power cost estimates were based on measurements of an ARM Cortex-M3. We analyzed the system's behavior for two different use cases. Compared to the Highly Adaptive Reconfiguration Platform (HARP), our

MDP-based approach requires no a priori tuning and greater robustness.

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