Energy-Efficient Joint Power and Rate Control via Pricing in a Multi-Cell Wireless Data Network
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RESEARCH BACKGROUND

Next Generation Wireless Systems is expected to support heterogeneous services for mobile users with different transmission rates that include real-time multimedia transmission (e.g. voice and video teleconferencing) as well as non-real-time data transmission (e.g. web browsing and file downloading) [1,2]. In order to provide these heterogeneous services, efficient use of system resources, i.e. bandwidth and energy, are required to control of both transmission data rate and power [3-7]. Meanwhile, since most of the mobile terminals in wireless networks are battery powered, to use energy efficiently, each terminals need to transmit just enough power to achieve the desired transmission rate without causing excessive interference in the network [8-11]. Game-theoretic approaches to radio resource allocation have recently attracted much attention [7]. Game theory is a mathematical tool for analysing the interaction of two of more decision makers so it can be used as a unifying framework to study radio resource management in a variety of wireless networks with different service criteria and also in practical scenarios, the distributed algorithms are preferred over centralized ones. Power and rate control in cellular and ad hoc networks helps with several functionalities [10, 12]:

- Interference management: due to the broadcast nature of wireless communication, signals interfere with each other. Power control helps ensure efficient spectral reuse and desirable user experience.
- Energy management: due to limited battery power in mobile stations, handheld devices, or any “nodes” operating on small energy budget, energy conservation is important for the lifetime of the nodes and even the network. Power control helps minimize a key component of the overall energy expenditure.
- Connectivity management: due to uncertainty and time variation of wireless channels, even when there is neither signal interference nor energy limitation, the receiver needs to be able to maintain a minimum level of received signal so that it can stay connected with the transmitter and estimate the channel state. Power control helps maintain logical connectivity for a given signal processing scheme.
- Bandwidth management: due to the different services provided by wireless data networks (real time and non-real time services) with different transmission rates. Rate control helps to provide flexible transmission rates to each terminal in the system.

In this project, the problem of joint power and rate control in a multi-cell 3G wireless data networks by using non-cooperative game theory will be considered. First, the problem of joint power and rate control problem will be studied and then a novel utility function for the proposed a multi-cell non-cooperative power and rate control game will be investigated. The utility function will measure the number of reliable bits transmitted per joule energy which is especially suitable for energy efficiency wireless communication. In a multi-cell environment each user experiences interference from terminals outside its cell in addition to the ones within the same cell [4]. In this work, K cells serving N users which randomly spread throughout the service area will be considered and the
terminals are assumed stationary to obtain fix path gains; each terminal is received at each base station with different rate level and different power level and therefore resulting in a different quality of service (QoS) level at each base station. Another assumption is that there is no base station diversity, i.e., each terminal is connected to a single base station at any given time, although all terminals interfere at all base stations in the systems. The most basic form of non-cooperative games are players in which each player has a set of strategies with associated payoff values [10]; each player makes an independent decision on a strategy so as to get the most out of the game on the basis that the other player is not cooperating. In the proposed system the users terminals represent the players in the game and rate and power levels represent the strategies of the game and the utility is the outcome of the game (payoff) so each user make an independent decision to choose its rate and power strategy to maximize its utility output.

RESEARCH METHODOLOGY

In this project, the solution of joint power and rate control in wireless data networks will be presented within a game theoretic framework. The equivalent quality of service (E-QoS) that a wireless terminal receive is referred to as the utility, and distributed power and rate control is a non-cooperative power and rate game where users maximize their utility. In addition to the conventional QoS parameter, like BER, the EQoS incorporate requirements that a given BER=$P_e$ is obtained with minimum power, which preserves the energy and minimize the interference inflicted on other users. The outcome of the game results in a Nash equilibrium that is inefficient. By introducing the linear pricing function, Pareto improvement of the noncooperative power and rate control game is obtained. The project has been divided into 5 phases, with each phase emphasizing a different activity.

Phase 1: Literature review (3 months)

In phase 1, the emphasis is on the following activities:

- Literature review on game theory concepts and its application in telecommunication networks.
- Literature review on energy-efficient power and rate control game theoretic approaches.
- Formulate suitable utility function that measure the number of bits that can be transmitted per joule of energy consumed.
- Design an algorithm for a single cell wireless data networks with one base station (BS) that serve several users (mobile stations) located in the uniform distance from base station.

Phase 2: Simulation of single cell (5 months)

In this phase a single cell power and rate control system will be simulated by using OPNET and MATLAB simulation tools. The performance parameter tested are the transmission rate, transmission power, SIR and the utility versus the distance of each user from the base station (BS). Introduce the rate and power pricing to the utility function to measure the net utility (utility minus pricing) and compare the result with an algorithm without pricing.

Phase 3: Simulation of multi-cell (5 months)

This phase emphasises on designing an algorithm for multi-cell power and rate control wireless data network. A multiple cells wireless data which contain 4 base stations serve 28 mobile stations (terminals) distributed randomly in (2km x 2 km) coverage area will be tested. Other layout can be considered as well. Each user is assigned to its base station depend on the distance. Similar to phase 2, OPNET and MATLAB will be used for simulation and the expected results are the transmission rate, transmission power, SIR and utility for each user in each cell with the distance between the user and its home base station. 1 conference and 1 journal paper to be sent for potential publication at this phase.

Phase 4: Embedding Linear Pricing functions (7 months)

Linear pricing functions best equal-SIR function, rate pricing function and power pricing function will be investigated simulated and the results will be compared with the previous an algorithm without pricing in this
phase. Again, both MATLAB and OPNET will be used. Fine tuning of algorithm will also be conducted in this phase in the case of not satisfactory results are obtained. 1 conference and 1 journal paper to be sent for potential publication at this phase

Phase 5: Documentation (4 months)

This phase is the final report and thesis writing.

ACHIEVEMENT

Name of Articles/Manuscripts/Books Published

ISI-Indexed Journal:

iv. A. W. Reza, M. S. Sarker and K. Dimyati “A Novel Integrated mathematical Approach of Ray Tracing and Genetic Algorithm for Optimizing Indoor Wireless Coverage” Accepted in PIER.

Conference Paper:


Human Capital Development

One (1) PhD Students
Two (2) Masters Students

REFERENCES
