Thesis Title: Novel Approaches to Performance Evaluation and Benchmarking for Energy-Efficient Multicast: Empirical Study of Coded Packet Wireless Networks
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Abstract
With the advancement of communication networks, a great number of multicast applications such as multimedia, video and audio communications have emerged. As a result, energy efficient multicast in wireless networks is becoming increasingly important in the field of Information and Communications Technology (ICT). According to the study by Gartner and Environmental Protection Agency (EPA) report presented to United State Congress in 2007, energy consumption of ICT nodes accounts for 3% of the worldwide energy supply and is responsible for 2% of the global Carbon dioxide (CO2) emission. However, several initiatives are being put in place to reduce the energy consumption of the ICT sector in general. A review of related literature reveals that existing approaches to energy efficient multicast are largely evaluated using a single metric and while the single metric is appropriate for effective performance, it is unsuitable for measuring efficiency adequately. This thesis studied existing coded packet methods for energy efficiency in ad hoc wireless networks and investigates efficiency frontier, which is the expected minimum energy within the minimum energy multicast framework. The energy efficiency performance was based on effective evaluation and there was no way an inefficient network could reach a level of being an efficiency frontier. Hence, this work looked at the position of how true efficiency evaluation is obtained when the entire network under examination attains their efficiency frontiers using ratios of weighted outputs to weighted inputs with multiple variables.

To address these challenges and assist network operators when formulating their network policies and performing network administrations, this thesis proposed novel approaches that are based on Data Envelopment Analysis (DEA) methodology to appropriately evaluate the efficiency of multicast energy and further minimizes energy transmission in ad hoc wireless networks without affecting the overall network performance. The DEA, which was used to study the relative efficiency and productivity of systems in Economic and Operational Research disciplines, is a non-parametric method that relies on linear programming technique for optimization of discrete units of observation called the decision making units (DMUs). Thus, the main goal of this work was to design an empirical DEA architecture that incorporates Technical Efficiency (TE), Scale Efficiency (SE) and Energy Gap (EG) and Benchmarking models to extend the minimum energy multicast system. The first novel contribution of this thesis is the adaptation of the Charnes, Cooper and Rhodes (CCR) and Banker, Charnes and Cooper (BCC) models to develop Envelopment models that are based on input-orientation approach, and assuming constant returns to scale (CRS) and variable returns to scale (VRS) in comparison with the existing techniques in literature for the implementation of TE in ad hoc wireless networks. Subsequently, the Slack models were formulated to improve the performance of the Envelopment models. Hence, the Envelopment models were only able to evaluate the TE scores (ratings) of ad hoc wireless networks thereby classifying them into efficient or inefficient networks. More so, the Slack models were able to identify the inefficient, the weak efficient and the full efficient ad hoc wireless networks and project the inefficient, the weak efficient unto their efficiency frontiers so that they also become full efficient. The SE was obtained by comparing the TE measures, and derivative parameters assumptions of CRS and VRS.

In addition, a novel Benchmarking model was proposed to establish standard of excellence among the ad hoc wireless networks. Similar to Envelopment models, the CCR and BCC models were adapted to develop variable-benchmarking models that are based on input-orientation approach, and assuming CRS and VRS are compared with existing techniques in literature for the implementation of benchmark in ad hoc wireless networks. This architecture ensures that all the weak efficient and inefficient ad hoc wireless networks that were identified by the Envelopment and Slack models performed efficiently according to the best practice meaning they are on efficiency frontier. To achieve this, the architecture considered an Efficiency Reference Set (ERS) to create peers for the weak efficient and inefficient ad hoc wireless networks. In addition to this, it considered the Lambdas to calculate the extent to which weak efficient and inefficient ad hoc wireless networks would observe or catch up with their peer networks.

Furthermore, in order to estimate the amount of energy reduction in ad hoc wireless networks and address the concerns of the ICT environmentalist, a novel energy gap (EG) model was formulated to analyse and compare energy reduction using empirical DEA architecture for minimum energy multicast and the existing architecture that was designed based on network coding technique. This is important because if the entire ad hoc wireless networks operated efficiently, then, the excess energy that could be very hazardous for environmental sustainability and global warming can be conserved.

The Envelopment, the Slack, EG and the Benchmarking models developed are implemented using the DEA tool, which technically consists of DEA Solver and Linear Programing (LP) Solver libraries available over the Internet as open source or propriety package. The data set used for the implementation of these models is obtained from the simulation results of the minimum energy multicast framework. Thus the primary basis used to validate the claims is done through simulation, and then the DEA analysis of the data produced from simulated scenarios are reported. Empirical results using DEA tool show an improvement in term of frontier performance and energy reduction when ad hoc wireless networks operated efficiently compare to the existing solutions that are implemented using simulation tool for the same data set.