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Energy Efficient Packet scheduling with Timing Constraints in Wireless Networks

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Abstract - **Power efficiency is an important design issue in mobile devices with limited power supplies. Packet scheduling for wireless communication subsystem is one of the most important methods to achieve these issues. In this project, we identify the reward-based packet scheduling problem in wireless environments. A general scenario in which a transmitter communicates with multiple receivers periodically. To guarantee timely transmission of data, each packet is associated with a delay constraint. The periodic data streams have different importance levels, power functions, and levels of data sizes. The more data a transmitter delivers the more rewards it obtains. Objective is to develop schemes that selectively transmit data streams of different data sizes at different transmission rates so that the system reward can be maximized under given time and energy constraints..**

Index Terms - **Reward maximization, power-aware packet scheduling, wireless networks, embedded systems.**

I. INTRODUCTION

Energy is a critical resource of wireless devices powered by battery with limited capacity. Reliable content delivery over a wireless channel is a major source of energy expenditure. The increasing wireless transmission rate results in a rapid increase of the energy consumption of wireless devices. Studies show that energy expenditure for the transmission of a given amount of data can be reduced by reducing the transmission rate with proper wireless channel coding or modulation schemes [13], [29]. As applications are usually delay-sensitive, packet delivery delays should be allowed only if it is controllable. Different delay constraints were investigated in energy-efficient packet transmission, such as average delay [3], [6], [24], a common deadline to all packets [13], [31], [35], and individual deadlines [5], [18], [24], [29], [34], [37].

Most existing work focus on the minimization of the total energy consumption under the timing constraints. Meanwhile, more and more embedded systems are being built with renewable energy sources, such as solar power, wind power, and mechanical power, from the environment [19]. Wireless nodes powered by these energy sources are subjected to limited amount of energy which is collected in each period. Generally, a wireless node may generate a significant amount of data in a networked environment in periodic cycle. Due to the limitation in both delay and energy, it is often impossible for a wireless node to deliver all data in the transmission buffer at a time. Instead, the node tends to transmit data collected in the buffer selectively under time and energy constraints. The periodic data streams destined to different receivers may consume different amount of energy

These data streams may also have different importance. For example, in a wireless sensor network which is monitoring the fire outbreak of an area, the data related to some sensors might be more urgent and should transmitted with no delays. When a wireless node cannot send all of its data, it is more desirable to transmit more valuable data first. To quantify the level of importance of a packet, we associate a reward to each packet transmitted. Generally, the reward increases with more data transmitted, similar to the Increased Reward with Increased Service (IRIS) model [9].

The objective of this study is to maximize system rewards under given time and energy constraints. In this paper, we study the reward maximization problems for packets with individual energy and delay constraints. We consider a general scenario in which a wireless node communicates with multiple receivers periodically over an AWGN channel. As the receivers may have different distances to the sender, they may require different amount of power under the same data transmission rates. Each data stream has several discrete data size levels and can be transmitted at different transmission rate levels.We associate each data size with a reward that can be obtained by finishing the data transmission. A wireless transmitter may only work with a limited number of rate levels, as suggested by practical realization of multiple data rates [29], [8]. Practically, the IEEE 802.11a wireless LAN standard recommends MQAM with four rate levels at 1, 2, 4, 6 bits per symbol

II. SYSTEM MODEL AND PROBLEM FORMULATION

In this part, we first define data and energy consumption models for the reward maximization problem. Then, we present a formulation of the reward maximization problem under given time and energy constraints.

A. Power Consumption Model

The power consumption of a wireless transmitter can be divided into two parts: circuit power and transmission power. The transmission power usually dominates since long-range communications (over 100 m) are common in wireless networks. In order to maintain the same transmission rate, the required transmission power needs to increase with the distance between the transmitter-receiver pair to offset the propagation loss. We take the AWGN channel model as an example, which explains how energy, rate, and data size are related. With optimal channel coding, the maximum transmission rate is [7]

$$S = B/2\log 2\ (1 + P0/N0B) \qquad (1)$$

where S is the transmission rate, P0 is the received signal power, N0 is the spectral density, and B is the channel bandwidth. From this equation, we can describe the relationship between the transmission rate S and the received power P0 by the following equation

$$P' = N0B.(2¶ -1) \qquad (2)$$

As we aforementioned, the power will increase with distance between transmitter and receiver in order to maintain the same transmission rate. Considering this power attenuation, we have

$$P = P'/A = N0B/A .(2¶-1) \qquad (3)$$

Where P is the transmission power and A is the attenuation

Factor for the transmitter- receiver pair. The attenuation factor A is generally inversely proportional to a function of the distance, denoted by l. For example, this function could be a square function, A ∞1/l, in [7]. In this paper, we do not assume any specific form of the relationship between attenuation factor and distance except that all transmitter receiver pairs have the same fading functions which are only affected by distance. It is easy to see that the required transmission power P is strictly increasing and strictly convex in the transmission rate S. This power function P(S) is continuous in S though we only consider the discrete cases for this function in this paper.

Let Pi denote the power consumption function for task Ti . Let Ci and Si represent the size and rate of data transmission for Ti, respectively. The transmission time to transmit data Ci equals to Ci/Si . Therefore, it consumes Pi(Si)Ci/Si units of energy. The energy consumed for _i for transmission in one period, denoted by Ei, with data size Ci at transmission rate Si becomes

$$Ei(Ci; Si) = Pi(Si)Ci/Si = N0B/Ai .(2¶-1) .Ci\text{-}Si \qquad (4)$$

where the coefficient Ai for each transmitter/receiver pair differs depending on the distance between them. Similar power models were defined in [35], [38], as well. As the channel states and receiving nodes are assumed to be static during the transmission period, the power attenuator factor Ai is also static. We fix the bandwidth B and assume it is the same for all the streams. To simplify the problem, we assume the overhead of switching among different transmission rates is tiny and can be ignored.

B. Problem Formulation

We consider the transmission in a hyper period T which is defined as the Least Common Multiple (LCM) of task periods T1; T2; . . . ; TN. The consideration of a hyper period ensures all tasks can finish their periodic transmissions at least once. Let Emax represent the units of energy budget allocated to the transmitter during this hyper period T. Our objective is to maximize the total reward while all tasks meet their deadlines and the total energy consumption does not exceed the budget

In general, we formulate the reward maximization problem as maximize

$$\Sigma\ Ni(T/Ti)\ .\ Ri(Ci) \qquad (5)$$

$$\text{subject to} \Sigma\ Ni=1T/Ti\ .Ci/Si \le T \qquad (6)$$

$$\Sigma\ Ni=1T/tiEi(Si; CiÞ) \le Emax \qquad (7)$$

$$Si \text{ € } \{s1; s2; . . . ; sM\};\ 1 \le i \le N \qquad (8)$$

$$Ci \text{ € } \{c1i; c2i; . . . ; cKi\};\ 1 \le i \le N \qquad (9)$$

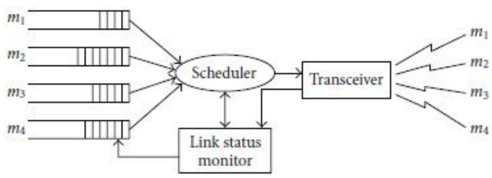
Packets in a hyper period are ready for transmission at time 0, (6) reduces to a discrete case as in [35]. If we enable continuous data size and transmission rate in (8) and (9), respectively, this problem is reduced to a continuous case, similar to that in [35]. In constraint (9), we enable multiple choices of data sizes; the problem is reduced to the one in [27] when we fix available data size of each task I in constraint (9) to be {c1i; c2i} g, with c1i= 0 and c2i6= 0, for all 1 ≤ i ≤ N.

III. PROPOSED WORK

We propose to maximize system rewards under given time and energy constraints. In this project we observe that the problem of packet scheduling in BWA networks could be described as a semi-Markov Decision Process (SMDP). There are two major advantages to solve the scheduling problem by the methodology of SMDP. We also propose new algorithm, called Reinforcement Learning Scheduling (RLS), and has in-built capability of self-training. It is able to adaptively and timely regulate its scheduling policy according to the instantaneous network conditions.

The proposed scheduling algorithm RLS simultaneously considers three performance issues in BWA networks

- QoS differentiation and guarantee
- Bandwidth utilization
- Fair service.



First, we propose the optimal solution to the time and energy constrained reward maximization problem. We show that the reward optimization problem for periodic data streams with discrete data sizes and transmission rate levels is NP-hard. We develop a dynamic programming algorithm to solve the problem optimally in pseudo polynomial running time. Second, we propose a heuristic approach, named Clustering, to closely approximate the optimal solution with a polynomial-time complexity. Simulation results show the effectiveness of the algorithms. Furthermore, the Clustering approach can effectively approximate the optimal solution at a small cost of space and execution time.

IV. ARCHITECTURE

In this part, we first define data and energy consumption models for the reward maximization problem. Then, we present a formulation of the reward maximization problem under given time and energy constraints. 2.1 Data Model Early studies of energy-efficient problem in wireless networks were largely targeted at communication channels over a single-transmitter-single-receiver model; see [6], [3], [31], [12] for examples. A single-transmitter-single-receiver model is also known as point-to-point communication where there is only one transmitter which will communicate with a single receiver. In recent years, we have seen the extension of the studies to a more general single transmitter- multiple-receiver model [13], [35], [23], [38] in which a wireless transmitter communicates with multiple receivers periodically, as shown in Fig. 4.1.In this model, the transmitter can only communicate with one receiver at a time and has an energy budget in each transmit cycle.

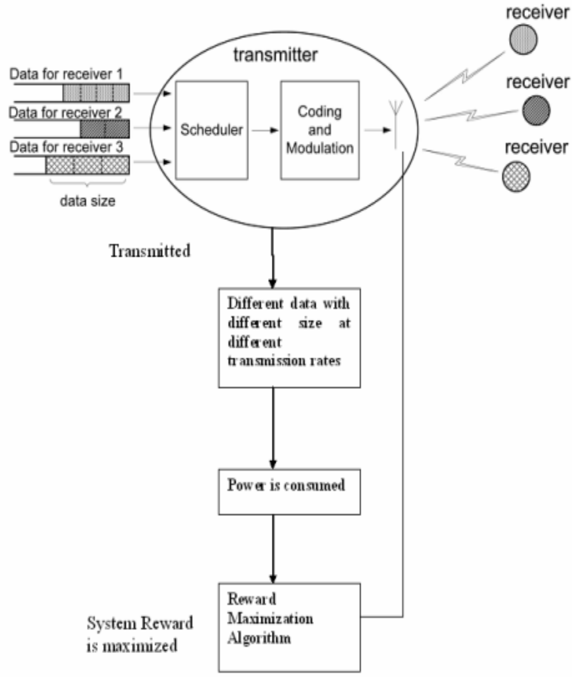


Fig :4.1

Each receiver will receive data from the transmitter periodically. Every transmitter-receiver pair has a maximal amount of data to be transmitted in each time period. The receivers are located with different distances from the transmitter. The data to different receivers can be transmitted at different transmission rates. We regard the transmission between each transmitter receiver pair as a periodic data stream and refer this as a task. It is a sequence of packet transmissions with the same characteristics that occurs at a regular interval

V. CONCLUSION

We study reward maximization problem under time and energy constraints in wireless networks in this paper. Transmitting different periodic data streams to different receivers will consume different energy and produce different reward values. Each data stream has several levels of data sizes while the transmitter can deliver them at several levels of transmission rate. Our objective is to maximize system reward under time and energy constraints by selecting a certain data size and a certain transmission rate for each data stream. The exact optimal solution is obtained by the dynamic programming algorithm presented in this paper. Instead of searching the optimal solution with tremendous costs, we propose time-efficient approximated approaches, including a polynomial-time heuristic approach and two greedy algorithms, to approximate the optimal solution closely at much lower cost.

In Future we have to develop this project more robust and intelligent system which includes further analysis of the simulation results with richer semantic information.

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