RATE-ENERGY TRADE-OFF IN MULTIUSER SCHEDULING NETWORKS UNDER LONG RANGE COMMUNICATION SCENARIO

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Abstract

With the evolution of wireless communication technologies, the need for green communication and energy saving become more critical than ever. The lifetime of a battery-powered network usually depends on the battery capacity. RF energy harvesting is a promising technique to prolong the battery lifetime effectively. The performance of multiuser scheduling schemes for a time-slotted system with simultaneous wireless information and power transfer under Rayleigh fading channel is studied in this paper. In each time slot, one user is scheduled to receive information while the remaining users opportunistically harvest the energy. We study the tradeoff between information rate and total harvested energy for different scheduling schemes. The MATLAB simulation results show that rate-energy performance of order-based SNR scheduling is better than that of the order-based N-SNR scheduling which is better than that of the order-based Equal Throughput scheduling under long range power transfer conditions. Also the result shows that the consumed power in Nakagami sub-channels is less than consumed power in Rayleigh sub-channels.

Keywords: RF energy harvesting, multi-user scheduling, Wireless information and power transfer.

1. Introduction

Energy Harvesting(EH) holds a promising future for generating a small amount of electrical power to drive circuits in electronics especially in wirelessly communicating electronic devices. A major challenge in wireless sensor networks is to reduce power consumption. It is a vital factor for energy constrained wireless networks, such as sensor networks. Replacing the device batteries in such circuits may cost high and is inconvenient in difficult-toaccess environments or even infeasible for sensors that are used for biological purpose i.e. embedded inside the human body. This point out the need to utilize renewable energy sources. Energy harvesting from dedicated radio frequency (RF) signals is a feasible solution for supplying energy wirelessly to low-power devices[1,2]. With an antenna integrated rectifier, we can convert the RF signal to a direct current (DC) signal for RF Energy Harvesting. This can then be used to power battery-free devices such as to trickle charge low-power devices or passive RFidentification (RFID) tags.

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Fading is an important factor which affects the transmission power and energy consumption. Fading means the rapid fluctuations of the amplitudes, phases of a radio frequency signal over a short period or short transmitted distance. Fading may cause distortion to the radio signal and causes problems like phase distortion and intersymbol interference when signals are transmitted. Therefore the effect of this has to be minimized. When a signal is transmitted to the receiver it will reach the destination not only via the direct path, but also take a different path as a result of reflections from objects such as buildings, hills, ground etc. Multipath fading can affect radio communications channels in mainly two ways; flat fading -fading frequencies across a given channel is affected equally[3]. In this signal may just change in amplitude, rising and falling over a period of time. Selective fading affects different frequencies across the channel to different degrees in this phase and amplitudes of the signal will vary across the channel. To minimize the effect of fading in multiuser system, scheduling schemes can be incorporated. A better scheduling scheme improves the efficiency of the system, i.e. which balances the trade-off between the rate and energy.

Multi-user scheduling schemes that exploit the independent and time-varying multipath fading for information-only transfer systems is studied in [4,5]. For maximum-throughput achieving the user with most favorable channel conditions is scheduled to transmit/receive over the time slot there by achieving maximum signal-to-noise ratio (SNR). Sometimes users with high path loss may be deprived from gaining access to the channel. For avoiding this disadvantage, maximum normalized SNR (N-SNR) is used. In this paper, the performance of multiuser scheduling schemes for a time-slotted system with simultaneous wireless information and power transfer under Rayleigh fading channel is analyzed . In each time slot, one user is scheduled to receive information while the remaining users opportunistically harvest the energy. We studied the tradeoff between information rate and total harvested energy for different scheduling schemes. In this paper we analyzed the performance of different scheduling schemes under Rayleigh fading conditions. Rayleigh fading is a well-known special case of Nakagami-m fading with m=1, m is the shaping parameter. It may be considered as one of the most realistic channel models for long range wireless power transfer, as it has no line of sight path. The results show that the consumed power in Nakagami sub-channels is less than consumed power in Rayleigh sub channels.

2. Literature survey

In this era green communication has much more importance. RF energy harvesters are a promising solution for charging small wireless devices[1]. RF energy harvesting techniques are different for different networks[2]. But in wireless sensor networks multipath fading is a severe problem, both in case of energy harvesting and information transfer. Daniele et.al. [3] presented a study about the multipath fading in wireless network. Network topology and interference has large influence in the consensus of network[5]. There is a trade-off between energy and rate existed in wireless network. So to balance this, effective scheduling schemes are necessary. A number of methods proposed and implemented to achieve reliable throughput in communication[4]. Gam et.al.[7] developed algorithm for optimization of transmission schedules in capture based wireless network. Channel modeling can be done on the basis of markov chain[8]. Success and failure of transmission can related with good and bad channel respectively. Quing et.al. [9] developed delay constrained optimal link scheduling scheme. They implemented this algorithm in wireless sensor network. In [10], Steven et.al discuss about the effect of fading, scheduling threshold and channel inversion in adhoc networks. They developed a threshold based scheduling scheme and effectively reduced the influence of fading on transmission.

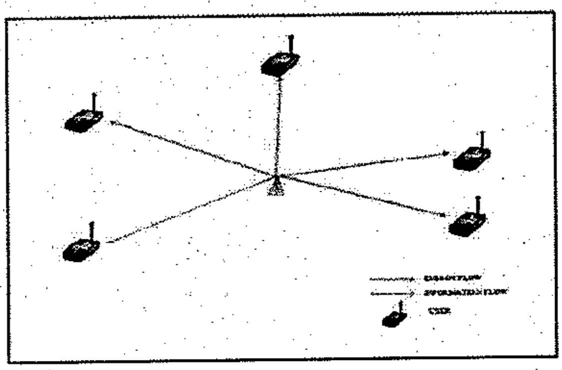

Figure 1. Multi user system with time scheduled users

In current generation systems, cognitive networks has important role[11]. Many researchers are concentrated over the interference reduction in the cognitive radio communication. The sensor devices are low power devices. The quality of radio communication in the sensor network varies significantly with time and geometrical features. To achieve an optimal transmission power consumption for specified link qualities, an adaptive transmission power control algorithm for wireless sensor networks is presented by Shan et.al. in [12]. By the use of adaptive transmission power control algorithm, each node knows power required to transmit to its neighbor, and every node maintains good link qualities with its neighbors by dynamically adjusting the transmission power by using ondemand feedback packets. Rania et.al. proposed new scheduling schemes which can be used in multiuser environment, which allows simultaneous information and power transfer under fading conditions[6]. The author simulated these schemes under nakagami fading condition. In this paper we used rayleigh fading channel model which is well suited for long range power transfer simulation. Martin et. al.done a deep study about the interference in large wireless networks[13].

3. System model

Consider a time-slotted system with one access point (AP) power supply and N user terminals which are energized by the energy harvested from the access point downlink RF signal. Both the AP and the user terminals(UTs) are equipped with a single antenna. The system is studied for downlink transmission, where it is assumed that the AP always has a dedicated packet to transmit for each user. In each time slot, the AP schedules one user for information transmission, while the remaining idle users opportunistically harvest energy from the received signal.

The system model is depicted in Fig. 1.We assume that the receivers of the UTs employ time-switching i.e., each user terminal may use the received signal for either information transfer or EH. To this end, the AP broadcasts at the beginning of each time slot the index of the UT which is scheduled for ID, which is determined using the scheduling described in section 6.

The channels from the AP to the users are block fading, i.e., the channel characteristics changes independently from one slot to the next. The channel coefficients of the different user links are assumed to be independent and have identical small-scale fading distributions but different path losses. This is a realistic assumption since the users may have different distances from the AP but they are in the same physical environment. In this paper we consider rayliegh fading for channel modeling.

4. Importance of slot allocation in a communication network

The slot allocation scheme, actually allocates the transmission slots to each users. This slot allocation is to maximize the throughput. In a communication network, two users are communicating after the base station has allocated a channel. This channel allocation is based on different accessing methods like TDMA, FDMA etc. A scheduler aim is one of many goals, for example, maximizing throughput ,minimizing response time, or minimizing latency (the time between work becoming enabled and its subsequent completion),maximizing fairness (generally appropriate times according to the priority and workload of each process). In practice, these goals often conflict (e.g. throughput versus latency), then a scheduler is implementing a suitable compromise. Link scheduler determines which link active at what time and what power level. In this paper, the access point schedules one user for information transmission in each time slot, while the other users except information receiving user opportunistically harvest energy from the received signal.

5. Effect of fading on transmission power in a scheduled network

Fading means that, the rapid fluctuations of the amplitudes, phases of a radio frequency signal over a short period or short transmitted distance. This might be so severe. In wireless networks, fading is a change in the attenuation coefficient affecting a signal over certain propagation media which may vary with time, location of node or radio frequency, and is often modeled as a random process. A communication channel referred as a fading channel is one that experiences fading. In wireless communication, different types of fading may occur. Fading due to multipath propagation is referred as multipath induced fading and fading due to shadowing from obstacles referred as shadow fading.

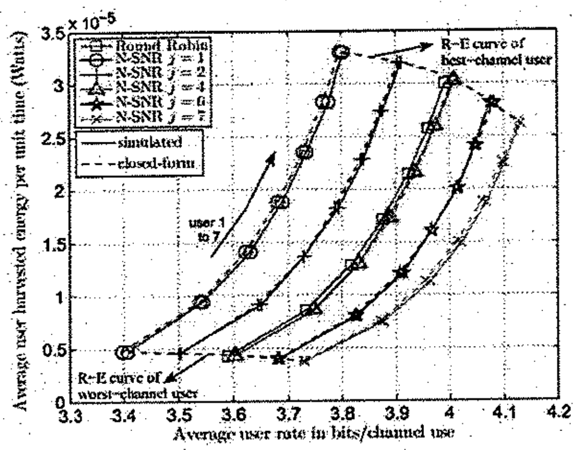

Figure 2. Performance of different scheduling schemes under Nakagami fading [ref:6]

Actually highly connected wireless networks may have lower throughput because of increased interference due to

fading. In the consensus algorithm[7] the transmit power at each node determines its neighbors. Fading model is suitable for modeling wireless power transfer in a different environment [8]. In particular, Nakagami-m fading is a suitable model for indoor environments Weibull fading can effectively characterize the radio channel of narrowband wireless body area network, which may solely depend on wireless power transfer when implanted inside human

bodies. Rayleigh fading is a well-known special case of Nakagami-m fading with m=1 and Weibull fading with k =1, Rician fading may be considered as one of the most realistic channel models for short range wireless power transfer, as it includes a line of sight path. Rania et.al. studied the performance of different scheduling schemes in nakagami fading[6]. Fig.2 shows the tradeoff between energy and rate in a multiuser system under Nakagami fading environment, with different scheduling schemes. In this paper we consider Rayleigh fading model, which is well suited for performance analysis of the multiuser system in long range communication scenario. To improve the network performance we can use network information such as scheduling, topology, and channel conditions. In many cases, the network performance is improved significantly if the nodes operate according to an optimized schedule[9]. Scheduling is an appropriate method to increase performance of network under fading conditions. Scheduling is an interesting area of research. The important characteristics of wireless communication networks such as, time varying channel conditions and multiple subscriber diversity reveals that new scheduling solutions need to be developed that are specifically suitable for this environment. A wireless channel can be modeled by a two-state Markov chain, a user experiences error-free transmission when it observes a good performance channel, and unsuccessful transmission in a bad channel. Using such a channel model, wireless fair scheduling policies have been anlysed. Transmission power varies under different fading conditions[10].

An optimal link scheduling problem in wireless networks is subjected to schedule time slots and possibly transmit powers for multiple users. For that certain criteria, such as throughput and spectral efficiency is optimized. The key issue in the design of link scheduling is how to model and reduce interference due to fading. Though simultaneous transmissions in each matched pairs can increase the frequency reuse of the network, the fixed power allocation may cause heavy interference for the other on-going transmissions in the neighborhood. Therefore, again to reduce the interference and increase the frequency spatial reuse, we can introduce a power control scheme into the original optimal scheduling process [11]. Randomized transmissions perform poorly in the presence of either fading or variable channel distances[12]. Variability strictly reduces capacity in transmitters. A scheduled network has capacity which is about three times higher than that with no scheduling. We note that scheduling users whose interference is below a threshold is analogous to a more conventional downlink problem. Specifically, in a fading downlink channel, it is known that only scheduling the user with the strongest channel gain maximizes throughput. So a secondary network to be useful if at least one node could transmit while maintaining its interference below a given threshold.

6. Multiuser scheduling schemes

Scheduling algorithms play a major role in the process of resource management in mobile communication networks.

Some of the several scheduling schemes are discussed below:

1) Round-robin (RR) Scheduling scheme: Round-robin is one of the algorithms employed by network schedulers. As the name suggests, in RR Scheduling time slots are allocated to each user in equal portions and in circular order, handling all users without priority. In RR Scheduling, the order of the users within each round is arbitrary. Therefore, a user receives information with x probability, and harvests energy with probability (1 " x). The Access Point only has to know the instantaneous channel of the scheduled user. In a centralized wireless packet radio network, a scheduling algorithm in a central base station (AP) may reserve time slots for the mobile stations in a round-robin fashion and provide fairness. However, if link adaptation is used, transmission of pilot symbols to the different users yields channel state information and allocates most resources to the users having the best channels. Hence the total system capacity could be increased but such allocation of resources favors the users closest to the transmitting node, resulting in reduced fairness between the different users. As a solution to this, Proportional fair scheduling algorithm exploits multiuser diversity and schedules each user approximately an equal amount of time so that the throughput for each user will in most cases be slightly higher than the throughput using round-robin.

2) Conventional Equal Throughput (ET) Scheduling: In this scheme, the user having the minimum average throughput is scheduled for information decoding and others for energy harvesting. Hence, the long-term average

throughput of all users can be made identical. Inorder to control the rate-energy tradeoff for each user, the other scheduling schemes we considered for simulation are:

1) Order-Based SNR Scheduling scheme: In this SNR is first ascendingly ordered. For maximum-SNR scheduling, the user having maximum SNR is scheduled for information decoding.

2) Order-Based Normalized-SNR (N-SNR) Scheduling scheme: If the users have different average channel conditions, order-based SNR scheduling may deprive some of the users from receiving information. So in Order - Based Normalized - SNR (N-SNR) Scheduling, SNR is first normalized and then ascendingly ordered and selected for information retrieval.

3) Order-Based Equal Throughput Scheduling: For both Order- Based SNR and Order-Based N-SNR Scheduling, the user having minimum SNR may not get a chance to decode information. To avoid this, in the proposed orderbased ET scheduling scheme, a user is selected only if the order of its N-SNR falls into a specific set of allowed orders. Also, the selected user is the one which has the smallest throughput.

7. Simulation Results and Analysis

7.1 Simulation Environment

The scheduling schemes have been simulated for Rayleigh fading channel. We assume an AP transmit power of P = 1 W and an RF-to-DC conversion efficiency of = 0.5. We consider a system with number of users equal to 7.

7.2 Simulation results and performance evaluation

Figure. 3 shows the information rate vs. the total harvested energy for various scheduling schemes. The result shows that the Rate-Energy tradeoff of order-based SNR scheduling is better than that of the order-based N-SNR scheduling which is better than that of the order-based Equal Throughput scheduling. This is because of the proportional fairness and the equal throughput constraints of the order-based N-SNR and the order-based Equal Throughput schedulers, respectively. While comparing the results with those obtained for scheduling schemes in nakagami fading environment, it is clear that the consumed power in Nakagami sub-channels is less

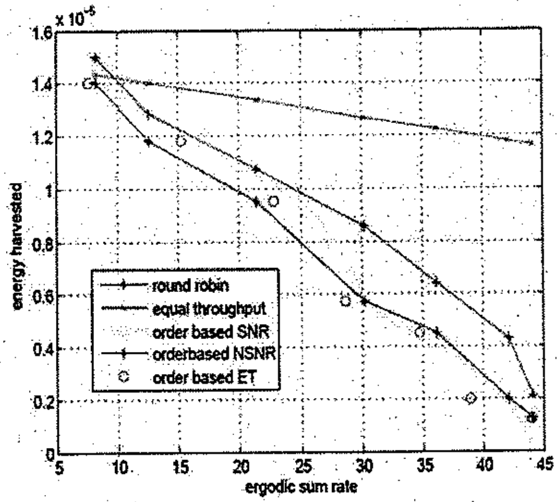

Figure 3. Performance of scheduling schemes under Rayleigh fading Environment

8. Conclusion

Optimal link scheduling is a problem in wireless multiuser scheduling networks because rate- energy trade off is an important factor to be balanced. The scope of this paper is to check the performance of different scheduling schemes under long range communication scenario. In this paper we used rayleigh fading channel model for simulation and analyzed the performance of different scheduling schemes. From the simulation results it can be concluded that that the consumed power in Nakagami sub-channels is less than consumed power in Rayleigh subchannels and the scheduling schemes explained in section 6 is well suited for multiuser scheduling in indoor environment.

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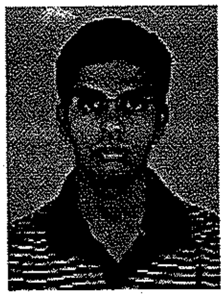

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