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Throughput Maximization by Time Switching in Multipoint WBAN With Fairness Consideration

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ABSTRACT In this paper, the average throughput maximization challenge with resources fairness consideration is proposed. In a multipoint wireless body area network (MP-WBAN), the time switching (TS) strategy and fairness algorithm are studied to improve system resources allocation performance. Under extreme circumstances, the sensors transfer command signals to the access point (AP) requesting the radio frequency (RF) energy from the source node. On the other hand, the sensors attached to the body surface transmit the perceived physiological information to the AP node. Owing to distance-dependent signal attenuation, the sensors near the AP node harvest more RF energy and time slots to achieve higher throughput. On the contrary, the sensors farther from the source node receive fewer RF energy and time slots to obtain lower throughput. Therefore, we design the common throughput maximization algorithm to allocate more time to farther sensors. At last, the effectiveness and accuracy of the studied fairness scheme are verified by simulation experimental data.

INDEX TERMS MP-WBAN, convex optimization technique, TS protocol, common throughput maximization.

I. INTRODUCTION

With the rapid development of ultra-high speed, low latency and high reliability 5th-generation (5G) technology, wireless body area networks (WBANs) with information sensing, processing, and transmission functions have once again caused a wave of research in the whole society [1]. As shown in Fig.1, above all, various types of sensors transmit the perceived physiological data to the access point (AP) node. Second, massive physiological data are transmitted to a personal digital assistant (PDA) in real time via wireless networks such as Bluetooth and wifi. Finally, 5G technology and minimalist base stations are used to transmit many human body data to the health monitoring center at high speed for analysis and storage. In the medical field, the application of WBAN can balance the shortage of medical resources and play the role of timely prevention and treatment. In addition to the medical field, WBAN technology can be extended to military, transportation, entertainment, industrial, social and public fields, and it has great commercial and social value. Sensors integrate human physiological information through real-time data sharing between the handheld terminal and residential areas (smart home), hospital (intelligent medical), automobile (intelligent travel) to provide quality service and industry efficiency.

Owing to sensors on the surface or inside of the body cannot change batteries frequently, WBANs face the major challenge of real-time work. It is well known that energy harvesting (EH) technology with extended network life is enough to solve this challenge. The sources of renewable energy include wind, solar, thermal, vibrational energy, radio frequency (RF) and so on. Compared with magnetic induction technology, RF technology has the advantages of large radiation distance, small device size, high energy conversion efficiency and strong work continuity. In addition, RF can carry simultaneously energy and information to improve

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the efficiency of information transmission [2]. Therefore, RF signal technology is the most effective mean of energy transmission for WBANs, and it helps the network to work reliably in real time [3], [4]. Therefore, WBANs with RF energy harvesting capabilities have been extensively studied to achieve energy sustainability. The authors propose two different helping relay strategies to achieve throughput gain for relay amplification and forwarding networks with EH [5]. In the bidirectional relay cooperative network, the authors design two different EH strategies including discrete and continuous time slots to optimize system energy efficiency [6]. In addition, the authors conduct a deep theoretical research of the entire system energy conversion rate. For an energy consumption performance problem, the original strategy is analyzed and studied in detail, and then the authors design the directed diffusion routing algorithm by introducing the gradient concept to achieve the goal of saving energy [7]. Because the heterogeneity of WBANs and the miniaturization of sensors, the contradiction between network sustainability and system fairness has been caused. In [8], the authors propose a scheduling strategy by allocating information rates to take into account the above-mentioned challenges to be solved. The authors jointly optimize the spectrum efficiency and EH, thereby obtaining the EH rate and maximizing the system throughput [9].

As we all know, wireless sensor network (WSN) is an extension of WBAN. Radio signal signals are used to transmit energy through beamforming as an important energy harvesting method in WSN. For the situation of imperfect channel state information (CSI), the total transmission power is reduced by using the power splitting (PS) strategy and semidefinite relaxation algorithm (SDR) with the dual different constraints [10]. The authors jointly research the time slot ratio and information transfer to enhance the performance of the system through a typical time allocation protocol [11]. Moreover, the problem of unequal resources allocation is resolved in wireless powered communication networks (WPCNs). For WPCNs, in order to use energy efficiently, signal beamforming technology is introduced into the system. Through the detailed theoretical derivation, the nonconvex is transformed into a convex problem, and the uplink (UL) and downlink (DL) timeslots and DL beam vectors are jointly optimized [12]. For energy efficiency challenges, the transceiver power is studied by an algorithm of proportionally allocating resources for multiple-input-single-output (MISO) networks [13]. In [14], extensive multi-antenna EH communication schemes are investigated. The network architectures include broadcast, cognitive and relay radio networks. This article mainly studies the issues of communication security, energy transmission efficiency, etc. For multi-input multi-output (MIMO) systems, an energy beam generator is designed to increase node communication rate. Therefore, a reasonable power scheduling is performed to reduce the algorithm complexity [15]. In a three-node MIMO network with radio signal energy transmission, the authors study two kinds of information reception situations including

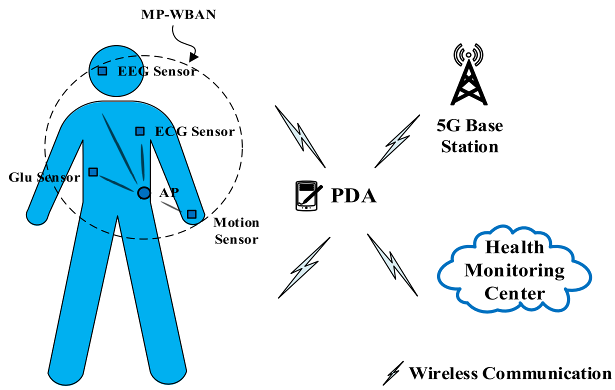

FIGURE 1. Architecture of multipoint WBAN.

EH and information decode (ID) separately or jointly [16]. Optimal transmission strategy is proposed to balance information rate and energy transmission.

Recently, scholars at home and abroad have developed great interest in WBAN. Based on the existing relay cooperation networks, the authors innovatively introduce direct links to adaptively improve system performance in simultaneous wireless information and power transfer (SWIPT) systems [17]. Similarly, the novel relay selection protocol and the optimized power splitting on maximum ratio combining (MRC) protocol are proposed to minimum outage and maximize sum-throughput with relay cooperative networks, respectively [18]. In [19], the authors are committed to optimizing the system utility function to improve network quality of service (QoS) and the fairness resource allocation through the theoretical method of marginal utility. Spectrum resources are an important performance indicator of WBANs. The authors design the fair distribution algorithm and relay selection algorithm to improve network performance [20], [21]. In [22], the authors use the mechanism of spectrum sharing and analyze the actual use cases in the medical field. In terms of system throughput analysis, single sensor network is designed to increase information rate with EH. Optimal closed expression for time slot and power ratio is obtained by employing Lambert W function [23]. The authors propose the dynamic time allocation and PS protocol. For the relay amplification and decoding two types, the nonlinear programming problems are solved to realize the location selection of relay nodes [24]. In the case of inter-network interference, the authors reduce the complexity of the scheme and improve energy efficiency by solving nonlinear programming problems. At the same time, the fairness between networks is effectively resolved [25].

The rest of this paper is organized as follows. Section II shows the main contribution of this paper. A system model is creatively proposed for MP-WBAN in Section III. Section IV analyzes and resolves the problem of unfair resource allocation in detail. Section V validates the effectiveness and accuracy of the proposed scheme through experimental simulations. Finally, Section VI gives the conclusion of this full paper.

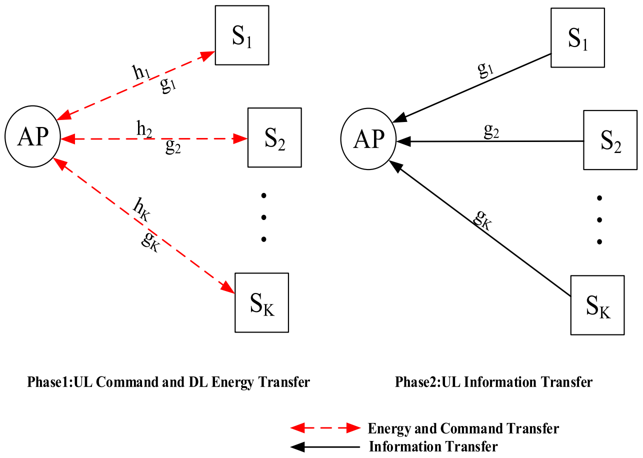

FIGURE 2. System model.

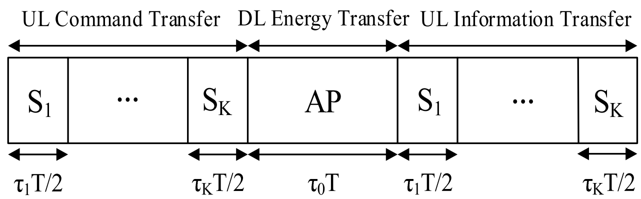

FIGURE 3. TS protocol of abnormal situations.

II. RELATED WORK

The related research content mentioned above is limited to point-to-point information and energy communication and relay cooperative communication in WBAN. At present, a multipoint SWIPT system is urgently needed to transmit key physiological data of the human body in real time. In pursuit of efficient information and energy transmission, the sum-throughput maximization algorithm is proposed. However, it ignores the fairness of network resources. Therefore we reveal a universal phenomenon. Sensors that are farther away from the AP node harvest less DL energy, but require more power to transmit UL information. The above situation is also named as the doubly near-far problem [11]. Next, we will solve this unfair resources allocation problem by adaptive DL-UL transmission scheduling algorithm in time division multiple access (TDMA). We maximize the minimum information rate by adaptively allocating DL energy transmission time and UL information transmission time to achieve fairness among all sensors. The specific method is divided into the following two steps: First, we fix DL energy transmission time and obtain UL command and information transmission time by bisection method; then, the common throughput is optimized through a one-dimensional search algorithm. In addition, abnormal situations refer to harsh environments that cause sensors to consume energy quickly [23]. Therefore, we propose a different protocol from the above literature. A sensor that is severely deficient in energy will generate a command signal to request energy supply instead of a harvest-then-transmit scheme.

III. SYSTEM MODEl

We research on a MP-WBAN, which contains a source node and K sensor nodes represented by S_i, $i = 1, 2, \ldots, K$, as described by fig.2. The AP and a set of network sensors are mounted with single antennas, which is beneficial to equipment miniaturization and cost control. It is assumed that the AP node has stable and sufficient energy sources. There is only initial power inside each node and all the required energy comes from the source node through EH technology. This results in the sensor's energy consumption is not greater than the energy harvesting. Meanwhile, all the receivers adopt TS structure. In addition, we assume communication channel status conforms perfect channel state information for UL and DL transmissions. The channel gains from the source to a set of nodes and from destination nodes to the source are set to h_i and g_i, respectively.

In this paper, according to multipoint WBAN model, we design the TS bidirectional communication protocol in the normalized time slot T. From fig.3, in the time slot $\tau_1 T/2$ to $\tau_K T/2$, a group of nodes attached to the body surface transmits command signals to the source in a certain order to request the supply of wireless RF signal. Next, during the $\tau_0 T$ period, the source transmits energy signals to the destination through the antenna. After obtaining energy with the RF harvesting technology, the target nodes sequentially transmit body index information to source in real time in the time period of $(1-\tau_0)\,T/2$. At the first stage of the normalized time T, the source node obtains the signal from the destination nodes as

$$y_{ci} = \sqrt{P_i} g_i x_{ci} + n_{ap} \tag{1}$$

where P_i represents information transmission power of all destination nodes. g_i represents the UL channel gain. x_{ci} is transmitted command signal. n_{ap} represents the process noise with zero mean and variance sigma σ_{ap}^2. The energy consumed by nodes to send information is in the first stage $t \in (0, (1-\tau_0)\,T/2)$ which is

$$\begin{aligned} E_{ci} &= E\left[|y_{ci}|^2\right]\left((\tau_i/2)\,T\right) \\ &= \left(P_i|g_i|^2 + \sigma_{ap}^2\right)\left((\tau_i/2)\,T\right) \end{aligned} \tag{2}$$

Next, the source node transmits wireless RF to the destination node in the second stage $t \in ((1-\tau_0)\,T/2, (1+\tau_0)\,T/2)$. The signal provided by the source node is

$$y_{si} = \sqrt{P_a} h_i x_a + n_i \tag{3}$$

where h_i represents the DL channel gain. P_a represents the source node energy transmission power. x_a and n_i are energy wave and process noise of the source, respectively. A linear energy harvesting model that can meet the basic energy requirements of the system is used to reduce the complexity of the objective function. The energy obtained by RF harvesting technology is

$$E_i = \eta_i E\left[|y_{si}|^2\right]\tau_0 T \approx \eta_i P_a |h_i|^2 \tau_0 T \tag{4}$$

where $\eta_i \in (0, 1)$ is energy conversion efficiency. Because P_a value is an order of magnitude higher than P_i value. In the last stage $t \in ((1+\tau_0)T/2, T)$, the information obtained by the source node is

$$y_{ai} = \sqrt{P_i} g_i x_{si} + n_{ap} \tag{5}$$

The energy required when the destination node sends key body index data to the source node is

$$\begin{aligned} E_{si} &= E\left[|y_{ai}|^2\right]((\tau_i/2)T) \\ &= \left(P_i|g_i|^2 + \sigma_{ap}^2\right)((\tau_i/2)T) \end{aligned} \tag{6}$$

According to the TS bidirectional transmission protocol and the system energy transmission mechanism, the energy required to transmit key information is almost the same as the collected energy. Through the UL-DL energy scheduling scheme, the system energy relationship is given by

$$\beta_i (E_{ci} + E_{si}) \le E_i \tag{7}$$

where β_i represents the relationship coefficient between energy demand and supply. By analyzing and deriving the above formulas, we have

$$\beta_i \le \frac{\eta_i P_a |h_i|^2 \tau_0}{\left(P_i|g_i|^2 + \sigma_{ap}^2\right)\tau_i} \tag{8}$$

During the final stage $t \in ((1+\tau_0)T/2, T)$, all destination nodes transfer key physical indicators to the source node. In a word, the destination node sends an amplified signal $\sqrt{\beta_i} y_{si}$ to the source node. In addition, the additional noise n_i' with zero mean and variance σ_i^2 can dominate n_i [5]. So n_i is cancelled during the derivation of the formula. The resulting signal is given by $y_{ai} = g_i\sqrt{\beta_i}\left(\sqrt{P_a} h_i x_a + n_i'\right) + n_{ap}$. The signal to noise ratio (SNR) as a function of τ_0 and τ_i is

$$\begin{aligned} \gamma_i(\tau_0, \tau_i) &= \frac{\beta_i P_a |h_i|^2 |g_i|^2}{|g_i|^2 \beta_i \sigma_i^2 + \sigma_{ap}^2} \\ &= \frac{\eta_i P_a^2 |h_i|^4 |g_i|^2 \frac{\tau_0}{\tau_i}}{\eta_i P_a |h_i|^2 |g_i|^2 \sigma_i^2 \frac{\tau_0}{\tau_i} + \left(P_i|g_i|^2 + \sigma_{ap}^2\right)\sigma_{ap}^2} \end{aligned} \tag{9}$$

Finally, the information throughput from sensors to the source node is

$$R_i = \frac{\tau_i}{2}\log_2(1+\gamma_i) = \frac{\tau_i}{2}\log_2\left(1 + \frac{X_i \frac{\tau_0}{\tau_i}}{Y_i \frac{\tau_0}{\tau_i} + Z_i}\right) \tag{10}$$

with

$$X_i = \eta_i P_a^2 |h_i|^4 |g_i|^2 \tag{11}$$
$$Y_i = \eta_i P_a |h_i|^2 |g_i|^2 \sigma_i^2 \tag{12}$$
$$Z_i = \left(P_i|g_i|^2 + \sigma_{ap}^2\right)\sigma_{ap}^2 \tag{13}$$

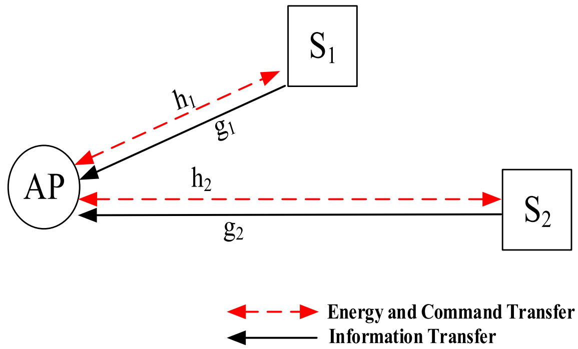

FIGURE 4. Two-sensor WBAN.

According to (13), we solve the sum-throughput maximization problem in WBAN by using Lagrange dual function algorithm and Karush-Kuhn-Tucker (KKT) conditions [26], [27]. Then, as described by Fig.4, due to the unfair resources allocation, the throughput of S_2 is much lower than the throughput of S_1 for two-sensor MP-WBAN, i.e., $K = 2$. The throughput gap between the two sensors gradually increases with the AP transmit power becomes larger. For the abnormal UL-DL information and energy transmission, the farther sensor only harvests less energy compared to the closer sensor. Instead, it requires more energy to transmit key physiological information.

The phenomenon of unfair resource allocation can be solved by the sensors cooperative forwarding method. However, the relay forwarding method is not good for user experience (UE) and cost control, and increases the complexity of the system algorithm. Therefore, the adaptive UL-DL transmission scheduling algorithm is designed by TDMA. More energy transfer time and information transfer time are allocated to low-throughput sensors.

IV. COMMON THROUGHPUT MAXIMIZATION

In this section, adaptive DL-UL transmission scheduling algorithm is adopted to distribute more the system resources to the farther nodes. We adaptively allocate common throughput to each sensor to improve the fairness of system resources allocation by TDMA. From Section III, the common throughput maximization problem can be expressed as

$$(P1): \max_{\tilde{R}, \tau_i} \tilde{R}$$
$$s.t.\ R_i(\tau_i) \ge \tilde{R}, \tilde{R} \ge 0, \tag{14}$$
$$0 \le \sum_{i=0}^{K} \tau_i \le 1 \tag{15}$$
$$0 \le \tau_i \le 1, \quad i = 0, 1, \ldots, K \tag{16}$$

where $\tilde{R}$ represents the common information transmission rate. The UL throughput of each sensor is not less than the common throughput. The DL RF signal broadcast time and the UL key data transfer time are in a reasonable range.

Remark 1: Since the proposed protocol is within the normalized time slot T, only $\sum_{i=0}^{K} \tau_i \le 1$ is true. Therefore, we assume $\sum_{i=0}^{K} \tau_i < 1$ for constraints (15). Then,

$\tau_i\,(i = 0, 1, \ldots, K)$ is assumed to be the optimal energy and information transmission time-slot and the maximum value $R_i^*(\tau_i)$ can be obtained. From (10), $R_i(\tau_0, \tau_i)$ is an increasing function with τ_0 and τ_i for given $i = 1, \ldots, K$. We find that there exists $\tau_i + \Delta\tau > \tau_i$ such that $R_i'(\tau_i) > R_i^*(\tau_i)$. This contradicts $R_i^*(\tau_i)$ being the maximum value and thus $\sum_{i=0}^{K} \tau_i = 1$ is feasible. For constraints (14), we suppose $R_i(\tau_0, \tau_i) > \widetilde{R}$. The throughput of the sensor $S_i\left(i \neq j \bigcap 1 \leq i \leq K\right)$ is $R_i(\tau_0, \tau_i)$ and the sensor $S_j\left(i \neq j \bigcap 1 \leq j \leq K\right)$ has the smallest throughput $\widetilde{R}$ of all sensors. $R_i(\tau_0, \tau_i)$ will decrease and $\widetilde{R}$ will become larger with $\tau_i - \Delta\tau$ and $\tau_j + \Delta\tau'$, respectively. The above situation will cause the minimum throughput of the system to increase even $R_i(\tau_0, \tau_i) = \widetilde{R}$. Therefore, the assumption is not valid and $R_1(\tau_0, \tau_i) = R_2(\tau_0, \tau_i) = \cdots = R_K(\tau_0, \tau_i) = \widetilde{R}$ is feasible for (14).

Owing to each sensor has the common throughput from Remark 1 and according to (10), we can have

$$\tau_0 = \frac{Z_i \tau_i}{\frac{X_i}{2^{\left(\frac{2\widetilde{R}}{\tau_i}\right)}} - Y_i} \tag{17}$$

Therefore, we propose a common throughput maximization algorithm to obtain optimal τ_0^*,τ_i^* and $\widetilde{R}^*$. And then we solve the problem of unfair resources allocation in MP-WBAN. To summarize, one algorithm for solving common throughput maximization problem (P1) is given as Algorithm 1. Through the common throughput maximization algorithm, we assign the equal throughput to each sensor and maximize the average throughput. This requires us to allocate more information and energy transmission time slots to "far" sensors, and less information and energy transmission time slots to "near" sensors. Furthermore, the key constraint variables are optimized by the algorithm to improve the network performance.

Algorithm 1 Algorithm to Slove (P1)

Stipulate the upper and lower limits of $\widetilde{R}$ as $\widetilde{R}^U$ and $\widetilde{R}^L$.
repeat
1. Update $\widetilde{R} = \frac{\left(\widetilde{R}^U + \widetilde{R}^L\right)}{2}$ and initialize $\tau_0 = 0$;
2. Solve τ_i with (17) by bisection method;
3. If $0 \leq 1 - \sum_{i=0}^{K} \tau_i \leq \alpha$, $\tau_i^* = \tau_i\,(i = 0, 1, \ldots, K)$; Else increase τ_0 and return 1;
4. If $0 \leq \sum_{i=0}^{K} \tau_i \leq 1$, $\widetilde{R}_{min} = \widetilde{R}$; Else $\widetilde{R}_{max} = \widetilde{R}$.

until
$\widetilde{R}_{max} - \widetilde{R}_{min} < \varepsilon$, where ε is a minimum value to guarantee the accuracy of the algorithm.

We note that the core of solving the optimal common throughput Algorithm 1 is the bisection method [27]. The feasible interval [0, 1] must contain the optimal time slot τ_i^*. We can know that $(1 - 0)$ is the length of the initial interval. Therefore, the length of the interval after the k_{th} iteration is $2^{-k}(1 - 0)$. In other words, the simulations show that the number of elements in the interval is

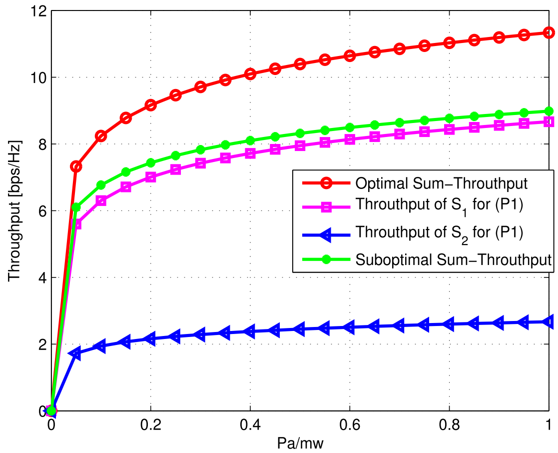

FIGURE 5. Sum-throughput performance comparison versus the AP transfer power P_a in STM and ETA algorithm.

$N\left(N \leq \left((1 - 0)/10^{-3}\right)\right)$. The computational complexity of the algorithm is $O\left(\log_2 N\right)$. Therefore, the algorithm is lower and meets the requirements of real-time processing.

Remark 2: The resource fair allocation algorithm in this paper is a special case of multi-antenna multi-sensor bidirectional information and energy transmission system in [28]. By using constraints (14), we can achieve equal throughput for different sensors. Therefore, after the introduction of beamforming, the algorithm can be extended to multi-antenna network. Given the energy efficiency of utilization $U = \left(\sum_{i=1}^{K} R_i\right) \big/ \left(E_i/T\right)$, the common energy efficiency of utilization is defined as $\widetilde{U} = K\widetilde{R}\big/\left(E_i/T\right)$. Therefore, $U \geq \widetilde{U}$ can be introduced into the rate-power ratio optimization problem as a fairness constraint. Due to the introduction of constraint (14) does not add new variables, the rate-power ratio optimization problem is still a convex optimization problem. Therefore, the interior point method and the bisection method can be used in combination to solve the problem perfectly.

V. SIMULATION RESULTS

This paper proposes an adaptive UL-DL scheduling algorithm to solve the problem of resource fairness. In this part, we perform simulation experiments on the proposed algorithm to verify its accuracy and effectiveness. We employ sensors placed on the surface of the human torso and assume the reciprocity of the uplink and downlink channels. The channel attenuation model is $10^{-P_L(d_0) - n\log_{10}(d_i/10)}$ [29]. We set the relative path loss $P_L(d_0)$ and exponent n as 41.2 and 3.23, respectively. The normalized energy conversion rate η_i is usually set to 0.6 to be more representative via RF energy harvesting technology. Because the magnitude of the node's transmit power and noise power is small in MP-WBAN, it avoids radiation causing harm to human tissues. Therefore, we set $\sigma_{ap}^2 = \sigma_i^2 = -144dBm/Hz, \forall i \in \{1, \ldots, K\}$ and $P_i = 10dBm$.

The relationship between sum-throughput and source transmission power P_a is studied in Fig. 5. The

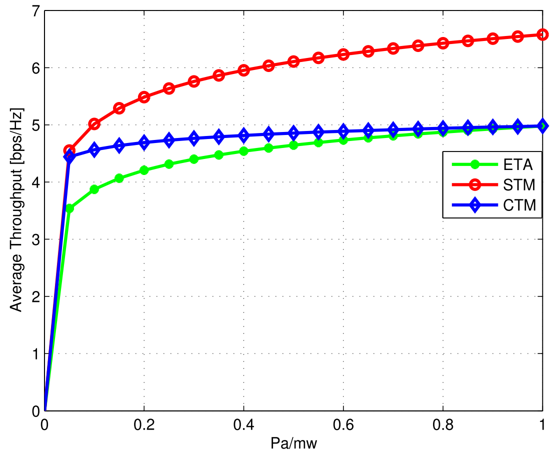

FIGURE 6. Average throughput performance comparison versus the AP transfer power P_a in STM, ETA and CTM algorithm.

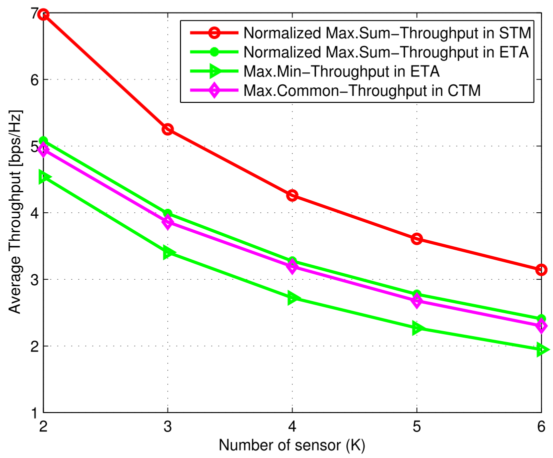

FIGURE 7. Average throughput performance comparison versus number of sensors.

sum-throughput maximization (STM) algorithm is proposed based on the bidirectional TS transmission protocol to maximize the information transmission rate of the entire network. However, the STM algorithm pursues maximum throughput while sacrificing the network resource of the farther sensors. As a low complexity equal time allocation (ETA) algorithm, the system performance is improved by assigning the same information and energy transmission time slots to each sensor, i.e., $\tau_i = 1/(K+1), i = 0, 1, \ldots, K$. Obviously, the STM algorithm is superior to the ETA algorithm in terms of information rate. In Fig. 4, we take two nodes as an example. d_i represents the distance from the source node to the i_{th} sensor. We set the distance of d_1 and the distance of d_2 to $0.25m$ and $0.3m$, respectively. We find that throughput of S_1 is much larger than the throughput of S_2 due to different transmission distance. This is because sensors farther away from the AP harvest less wireless RF energy. On the other hand, sensors closer to the AP have more information transmission time. This phenomenon not only achieves the efficient transmission of information, but also causes an unfair allocation of system resources. For this reason, the common throughput maximization (CTM) algorithm is designed to improve the fairness of the network.

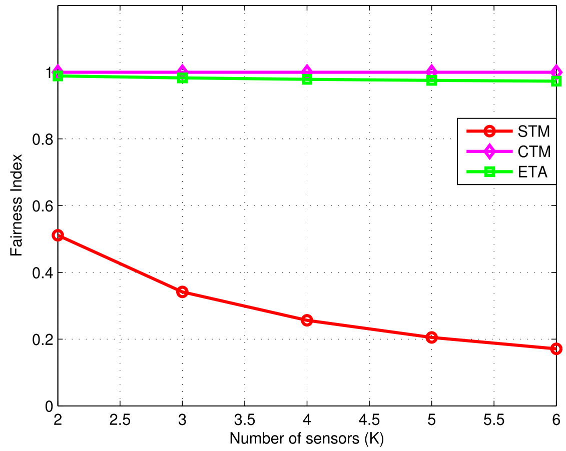

FIGURE 8. Fairness index versus number of sensors.

In Fig. 6, the relationship between AP transfer power and average throughput of the entire system is studied. In general, for the three algorithms, with the AP node's transmit power becomes larger, the average throughput of the system increases gradually. There are obvious results that the STM method maximizing the normalized throughput of the two destination nodes ($\sum_{i=1}^{K} R_i(\tau)/K, K = 2$) is higher than the CTM algorithm maximizing the common throughput in the MP-WBAN. This is because the CTM algorithm solves the unfair allocation problem of system resources at the cost of achieving fair allocation of information rate. However, the STM algorithm sacrifices the resources of S_2 to increase the overall information rate. Both the STM and CTM algorithms yield better throughput than the ETA scheme. Based on analysis of information transmission performance, with the source transfer power becomes larger, the performance gap between the CTM and the ETA scheme gradually becomes smaller.

Fig. 7 proves the influence of number of nodes on the average information rate. We set the source node transmit power P_a is $0.4mw$. The distance between K $(2 \leq K \leq 6)$ nodes and the source in a MP-WBAN is equally divided. In addition, distance between the source and nodes is set to be $d_i = (0.2m/K) \times i, i = 1, 2, \ldots, K$. Obviously, average information rate drops with the number of nodes increasing. This is because as new nodes join the network, the energy broadcast time slot drops, which in turn reduces the information rate of each node. It can be clearly observed that the STM algorithm is superior to the low-complexity sub-optimal ETA algorithm in pursuit of information rate maximization. In the pursuit of system fairness, the CTM algorithm is superior to the ETA algorithm in terms of minimum throughput.

From Fig. 8, we show the effect of number of nodes on the fairness index in MP-WBAN. According to fairness index formula [30], we have $f(R) = \left(\sum_{i=1}^{K} R_i\right)^2 / \left(K \sum_{i=1}^{K} (R_i)^2\right)$. On the one hand, with new sensors joining the network, fairness index of optimal time allocation algorithm is gradually decreasing. On the other hand, fairness index value of the CTM scheme is always

1 and remains unchanged. For the ETA algorithm, since the protocol allocates the same information and energy transmission time slots to each sensor, as the number of sensors becomes larger, the fairness index decreases slightly. Therefore, in terms of resource fairness, the CTM algorithm and ETA algorithm are superior to the STM algorithm.

VI. CONCLUSION

In this paper, we investigate the system resource allocation problem in a multipoint WBAN. In order to ensure that each node harvests enough energy, the common throughput maximization algorithm is proposed to optimize the average throughput. In the network model and UL-DL time scheduling protocol, we perform detailed formula derivation and theoretical analysis to improve the network fairness index. Next, the adaptive allocation method is proved to be efficient and accurate by a series of experiments verification. We compare the designed strategy with the sum-throughput maximization and the low-complexity equal-time allocation strategy in terms of transmit power, number of nodes, fairness index, etc. At last, it is obvious that employing optimized allocation scheme is more efficient than the two algorithms mentioned above.

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