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Disseminating For Concurrent Wireless Data And Power Transfer Using MIMO

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Abstract-**The Electromagnetic (EM) Radio signal enabled Wireless power transfer(WPT)Radio signal can carry energy as well as information at the same time, the unified study on Simultaneous Wireless Information and Power Transfer(SWIPT) is pursued. This paper studies a multiple input multiple output(MIMO) wireless broadcast system consisting of three nodes, where one receiver harvests and another receiver decodes information separately from signals sent by a common transmitter, all transmitter and receiver may be multiple antenna.**

General Term: broadcast channel, energy harvesting, MIMO system, rate-energy trade off, wireless power,

I.INTRODICTION

Energy-Constrained wireless networks, are typically powered by batteries. Although replacing or recharging the batteries can prolong the lifetime of the network to a certain extent, hazardous (say, in toxic environments), or even impossible (e.g., for sensors embedded in building structures or inside human bodies).A more convenient, safer, as well as "greener" alternative is thus to harvest energy from the environment. In addition, ambient radio-frequency (RF) signals can be a viable new source for energy scavenging.

It is worth noting that RF-based energy harvesting is typically suitable for low-power applications (e.g., sensor networks), but also can be applied for scenarios with more substantial power consumptions if dedicated wireless power transmission is implemented. Since RF signals that carry energy can at the same time be used as a vehicle for transporting information, simultaneous wireless information and power transfer (SWIPT) becomes an interesting new area of research that attracts increasing attention.

For the single-antenna or SISO (single-input single-output) AWGN (additive white Gaussian noise) channel with amplitude-constrained inputs, there exist nontrivial tradeoffs in maximizing information rate versus (vs.) power transfer by optimizing the input distribution.

However, if the average transmit-power constraint is considered instead, the above two goals can be shown to be aligned for the SISO AWGN channel with Gaussian input signals, and thus there is no nontrivial tradeoff. As a matter of fact, wireless power transfer (WPT) or in short wireless power, which generally refers to the transmissions of electrical energy from a power source to one or more electrical loads without any interconnecting wires, has been investigated and implemented.

WPT is carried out using either the "near-field" electromagnetic (EM) induction (e.g., inductive coupling, capacitive coupling) for short-distance (say, less than a meter) applications such as passive radio-frequency identification (RFID) , or the "far-field" EM radiation in the form of microwaves or lasers for long-range (up to a few Kilometers) applications such as the transmissions of energy.

Assume a multi-antenna or MIMO (multiple-input multiple-output) system, in which the AP is equipped with multiple antennas, and each UT is equipped with one or more antennas, for enabling both the high-performance wireless energy and information transmissions (as it is well known that for WIT only, MIMO systems can achieve folded array/capacity gains over SISO systems by spatial beamforming/multiplexing).

In this paper, we focus our study on the downlink case with simultaneous WIT and WPT from the AP to UTs. Wireless information and energy receivers are typically designed to operate separately with very different power sensitivities.

The simplified scenarios with only one or two active UTs in the network at any given time. Some further assumptions are made Firstly, this paper considers a quasi-static fading environment where the wireless channel between the AP and each UT is assumed to be constant over a sufficiently long period of time during which the number of transmitted symbols can be approximately regarded as being infinitely large.

Secondly, we assume that the system under our study typically operates at the high signal-to-noise ratio (SNR) regime for the ID receiver in the case of co-located receivers. This is to be compatible with the high-power operating requirement for the EH receiver of practical interest as previously mentioned. Thirdly, without loss of generality, we assume a multi-antenna or MIMO (multiple-input multiple-output) system, in which the AP is equipped with multiple antennas.

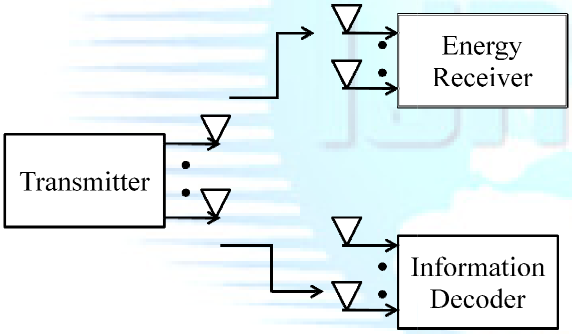


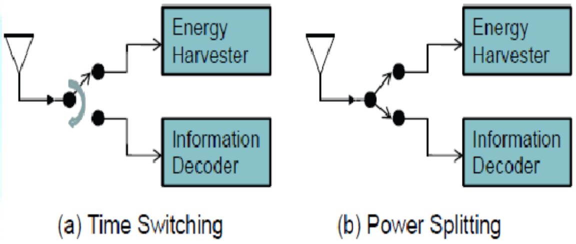
Figure 1 A MIMO broadcast system for simultaneous wireless information and power transfer.

Under the above assumptions, a three-node MIMO broadcast system is considered, as shown in Fig. 2, wherein the EH and ID receivers harvest energy and decode information separately from the signal sent by a common transmitter.

Assuming this model, the main the case of separated EH and ID receivers, we design the optimal transmission strategy to achieve different tradeoffs between maximal information rate and energy transfer, which are characterized by the boundary of a so-called rate-energy (R-E) region.

For the case of co-located EH and ID receivers, we show that the proposed solution for the case of separated receivers is also applicable with the identical MIMO channel from the transmitter to both ID and EH receivers.

Furthermore, we consider a potential practical constraint that EH receiver circuits cannot directly decode the information (i.e., any information embedded in received signals sent to the EH receiver is lost during the EH process). Under this constraint, we show that the R-E region with the optimal transmit covariance (obtained without such a constraint) in general only serves as a performance outer bound for the co-located receiver case.



(a) Time Switching (b) Power Splitting

Figure 2 Two practical designs for the co-located energy and information receivers, which are applied for each receiving antenna.

Here investigate two practical receiver designs, namely time switching and power splitting, for the case of co-located receivers. As shown in Fig. 2, for time switching, each receiving antenna periodically switches between the Energy Harvester receiver and Information Decoder receiver, whereas for power splitting, the received signal at each antenna is split into two separate signal streams with different power levels..

II. SYSTEM MODEL AND PROBLEM FORMULATION

As shown in Fig. 2, considers a wireless broadcast system consisting of one transmitter, one EH receiver, and one ID receiver.

$$Q = \zeta \mathbb{E}[\|\boldsymbol{G}\boldsymbol{x}(n)\|^2] \qquad (1)$$

Where ζ is a constant that accounts for the loss in the energy transducer for converting the harvested energy to electrical energy to be stored; In addition, it is assumed that the transmitter and both receivers operate over the same frequency band. Assuming a narrow-band transmission over quasi-static fading channels, the baseband equivalent channels from the transmitter to the Energy Harvester receiver and Information Decoder receiver can be modeled by matrices $G \in \mathbb{C}^{NEH\times M}$ and $H \in \mathbb{C}^{NID\times M,}$

respectively. Analysis, it is assumed that $\zeta = 1$ in this paper unless stated otherwise. On the other hand, the baseband transmission from the transmitter to the ID receiver can be modeled by

$$y(n) = Hx(n) + z(n) \qquad (2)$$

where $y(n) \in C^{NID\times 1}$ denotes the received signal at the nth symbol interval, and $z(n) \in C^{NID\times 1}$ denotes the receiver noise vector. Under the assumption that $x(n)$ is random over n, we use $S = E[x(n)x^H(n)]$ to denote the covariance matrix of $x(n)$. Consider first the MIMO link from the transmitter to the EH receiver when the ID receiver is not present. In this case, the design objective for S is to maximize the power received at the EH receiver. Since from (1) it follows that $Q = tr(GSG^H)$.

$$(P1) \max_{S} Q := tr(GSG^H)$$
$$s.t\ tr(S) \leq P, S \geq 0.$$

Let $T_1 = \min(M, N_{EH})$ and the (reduced) singular value decomposition (SVD) of G be denoted by $G = U_G\Gamma_G^{1/2}V_G^H$,where $U_G \in C^{M\times T1}$ and $V_G \in C^{M\times T1}$, each of which consists of orthogonal columns with unit norm, and $\Gamma_G = diag(g_1, \ldots, g_{T1})$ with $g_1 \geq g_2 \geq \ldots \geq g_{T1} \geq 0$. Furthermore, let v_1 denote the first column of V_G.

Assuming the optimal Gaussian codebook at the transmitter, i.e., $x(n) \sim CN(0, S)$, the transmit covariance S to maximize the transmission rate over this MIMO channel can be obtained by solving the following problem

$$(P2) \max_{S} R := \log\left|I + HSH^H\right|$$
$$s.t.\ tr(S) \leq P, S \geq 0.$$

The optimal solution to the above problem is known to have the following form $S_{ID} = V_H$, where $V_H \in C^{M\times T2}$ is obtained from the (reduced)SVD, of expressed by $H = U_H\Gamma_H^{1/2}V_H$ with $T_2 = \min(M, N_{ID})$, $U_H \in C^{NID\times T}{}_2$, with the diagonal elements obtained from the standard "water-filling (WF)" power allocation.Now, consider the case where both the EH and ID receivers are present.

It thus motivates our investigation of the fol-lowing question: What is the optimal broadcasting strategy for simultaneous wireless power and information transfer? To answer this question, we propose to use the *Rate-Energy* (R-E) region (defined below) to characterize all the achievable rate (in bits/sec/Hz or bps for information transfer) and energy (in joule/sec or watt for power transfer) pairs under a given transmit power constraint.

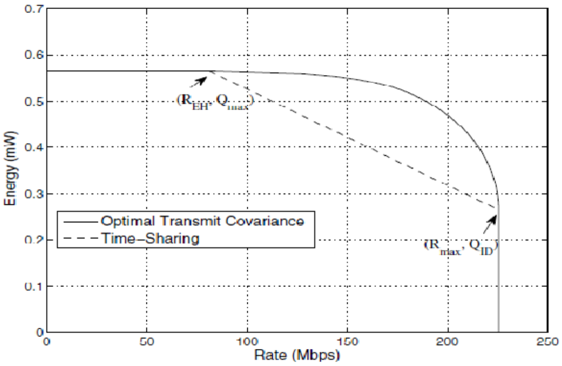
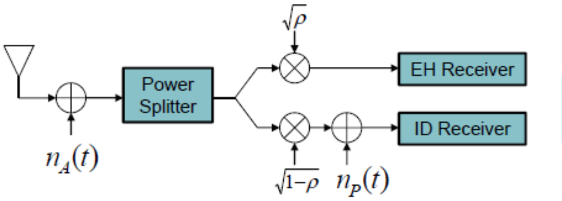


Fig. 3. Rate-energy tradeoff for a MIMO broadcast system with separated EH and ID receivers, and $M = NEH = NID = 4$.

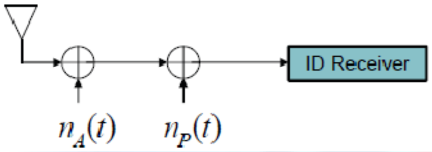
Without loss of generality, assuming that the transmitter sends Gaussian signals continuously (cf. Remark 2.1), the R-E region is defined as

In Fig. 3, an example of the above defined R-E region (see Section III for the algorithm to compute the boundary of this region) is shown for a practical MIMO broadcast system with separated EH and ID receivers (i.e., G _= H). It is assumed that $M = N_{EH} = N_{ID} = 4$. The transmitter power is assumed to be $P = 1$ watt(W) or 30dBm. The distances from the transmitter to the EH and ID receivers are assumed to be 1 meter and 10 meters, respectively; thus, we can exploit the near-far based energy and information transmission scheduling, which may correspond to, e.g., a dedicated energy transfer system (to "near" users) with opportunistic information transmission (to "far" users), or vice versa. Assuming a carrier frequency of $f_c = 900$MHz and the power path loss exponent to be 4, the distance-dependent signal attenuation from the AP to EH/ID receiver can be estimated as 40dB and 80dB, respectively. Accordingly, the average signal power at the EH/ID receiver is thus 30dBm−40dB= −10dBm and 30dBm−80dB= −50dBm, respectively.

It is further assumed that in addition to signal pathloss, Rayleigh fading is present, as such each element of channel matrices G and H is independently drawn from the CSCG distribution with zero mean and variance −10dBm (for EH receiver) and −50dBm for (for ID receiver), respectively. The bandwidth of the transmitted signal is assumed to be 10MHz, while the receiver noise is assumed to be white Gaussian with power spectral density −140dBm/Hz (which is dominated by the receiver processing noise rather than the background thermal noise) .As a result, considering all of transmit power, signal attenuation, fading and receiver noise. Which corresponds to P = 100 in the equivalent.



(a) Co-located receivers with a power splitter



(b) ID receiver without a power splitter

Figure 4 Receiver operations with/without a power splitter (the energy harvested due to the receiver noise is ignored for EH receiver).

An alternative receiver design called power splitting (PS), whereby the power and information transfer to the co-located EH and ID receivers are simultaneously achieved via a set of power splitting devices. The received signal from the antenna is first corrupted by a Gaussian noise denoted by $n_A(t)$ at the RF-band, which is assumed to have zero mean and equivalent baseband power $\sigma_A^{\,2}$.

The RF-band signal is then fed into a power splitter, which is assumed to be perfect without any noise induced. The power splitter, the portion of signal power split to the EH receiver is denoted by ρ, and that to the ID receiver by 1 − ρ.The achievable R-E region for the PS scheme (in the worst case) is thus given by

$$\mathcal{C}^{\mathrm{PS}}_{\mathrm{R-E}}(P) \triangleq \bigcup_{0\le\rho_i\le 1,\forall i} \Big\{(R,Q): Q \le \mathtt{tr}(\boldsymbol{\Lambda}_\rho \boldsymbol{H} \boldsymbol{S} \boldsymbol{H}^H),$$
$$R \le \log|\boldsymbol{I} + \bar{\boldsymbol{\Lambda}}_\rho^{1/2} \boldsymbol{H} \boldsymbol{S} \boldsymbol{H}^H \bar{\boldsymbol{\Lambda}}_\rho^{1/2}|, \mathtt{tr}(\boldsymbol{S}) \le P, \boldsymbol{S} \succeq 0\Big\}$$

where $\boldsymbol{\Lambda}\rho$ = diag(ρ1, . . . , ρN), and $\bar{\boldsymbol{\Lambda}}\rho = \boldsymbol{I} - \boldsymbol{\Lambda}\rho$.

III. SIMULATION VERIFICATION

Based on the analyzed results X-graphs are plotted. In the Node Creation Enter the source node to the destination node and Given the input message in Fig5 (a) In this Message Passing, transfer the data from source node to destination node shown Fig 5(b). Form the comparison result, finally multicast nodes are created.

Figure 5(a) Node Creation

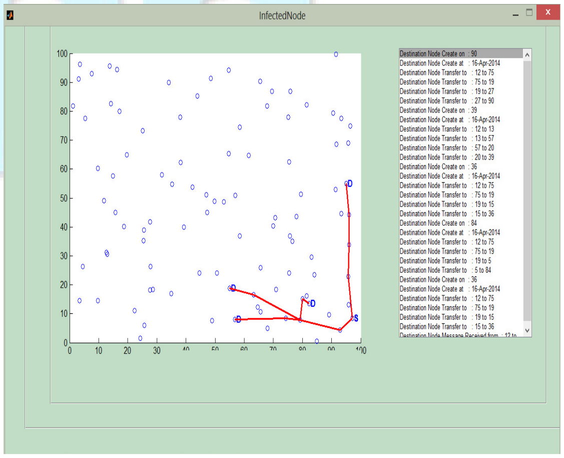


Figure 5(b) Transfer Data

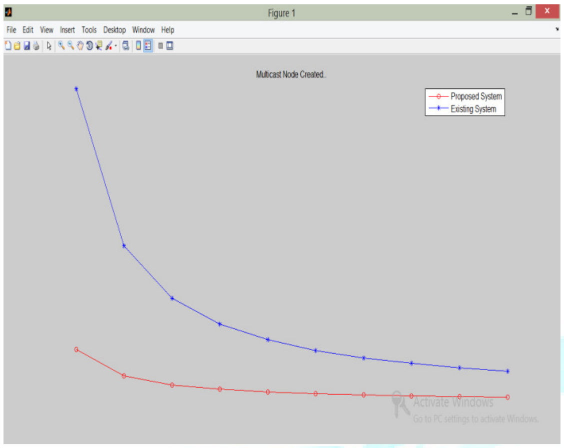


Figure 5(C) Multicast Node Created

IV CONCLUSION

This paper investigated the performance limits of emerging "wireless-powered" communication networks by means of opportunistic energy harvesting from ambient radio signals or dedicated wireless power transfer. Under a simplified three node Set up, our study revealed some fundamental tradeoffs in designing wireless MIMO systems for maximizing the efficiency of simultaneous information and energy transmission.

It will be interesting to extend the rate-energy region characterization to more general MIMO broadcast systems with more than two receivers. Depending on whether the energy and information receivers are separated or co-located, and the broadcast information is for unicasting or multicasting, various new problems can be formulated for which the optimal solutions are challenging to obtain.

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