Optimal Simultaneous Wireless Information and Power Transfer with Low-Complexity Receivers

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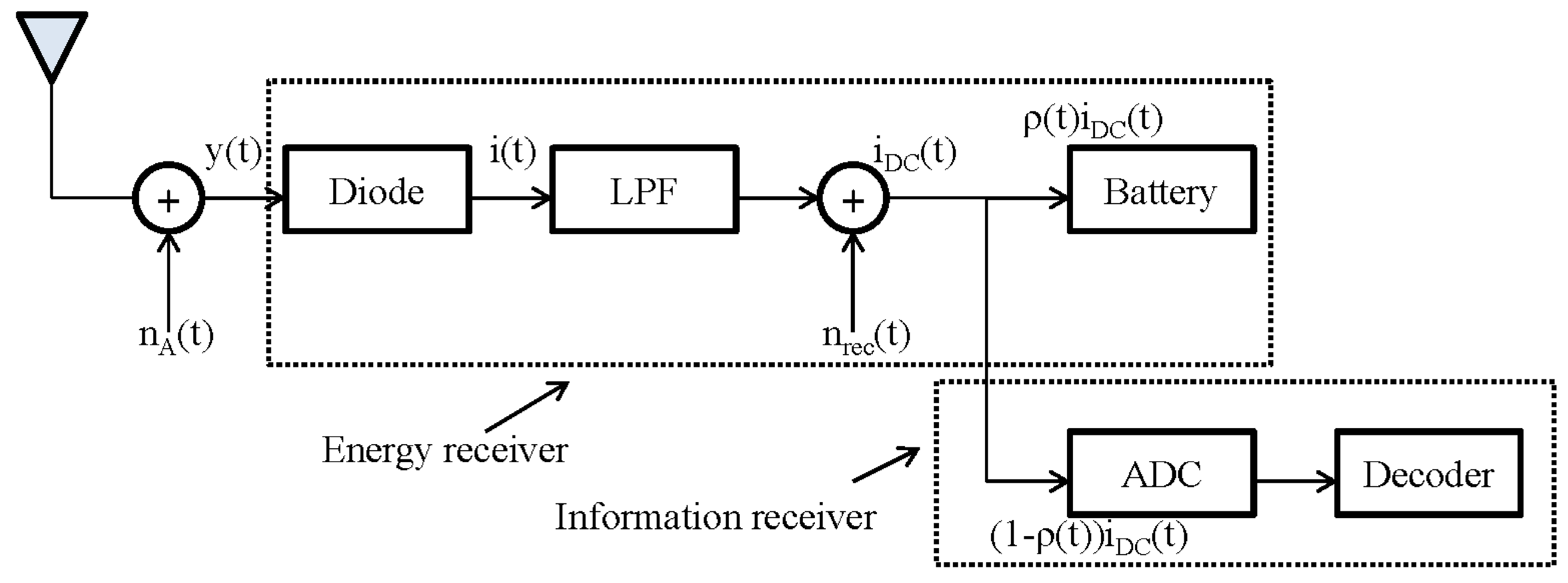
Motivation

- ✓ In today's widely used devices and internet-of-things (IoT) applications, such as wearables, and sensor networks, energy harvesting (EH) can be seen as the final challenge to true mobility.
- ✓ Harvesting energy from sources using radio frequency signals in communication applications, termed as wireless power transfer (WPT), has received much attention during the last years.
- ✓ Simultaneous wireless information and power transfer (SWIPT) system with an integrated energy and information receiver, with the advantage of low complexity and energy cost.

Contribution

- ➢ A tractable expression of the achievable rate of the integrated receiver.
- ➢ Definition of the joint harvested energy-rate outage probability, which is calculated for a point-to-point and multicasting system.
- ➢ Minimization of the joint harvested energy-rate outage probability, by optimizing the power-splitting (PS) ratio.

System Model



The equivalent discrete-time memoryless **channel** is modeled as

$$Y = l|h|^2 PX + Z,$$

or (channel output) = (path loss) × (channel gain) × (average transmit power) × (channel input) + (equivalent processing noise)

➢ channel input:

$$X \geq 0 \in \mathbb{R} \text{ and } \mathbb{E}[X] \leq 1$$

➢equivalent processing noise caused by the rectifier and the analog-to-digital converter (ADC):

$$Z \sim \mathcal{N}\left(0, \sigma_{\text{rec}}^2 + \frac{\sigma_{\text{ADC}}^2}{(1-\rho)^2}\right)$$

PS factor

Two systems:

point-to-point communication

downlink multicasting, the base station transmits the same information to N users, simultaneously.

Harvested Energy-Rate Trade-off

❖**Harvested energy:**

conversion efficiency

$$Q = \rho\zeta l|h|^2 P$$

❖**Achievable rate:**

$$R = \frac{1}{2}\log_2\left(1 + \frac{e(l|h|^2P)^2}{2\pi\sigma^2}\right)$$

$$\sigma = \sigma_{\text{rec}}^2 + \frac{\sigma_{\text{ADC}}^2}{(1-\rho)^2}\ .$$

There is no exact expression for the capacity, the proposed one is a lower bound.

Harvested Energy-Rate Region

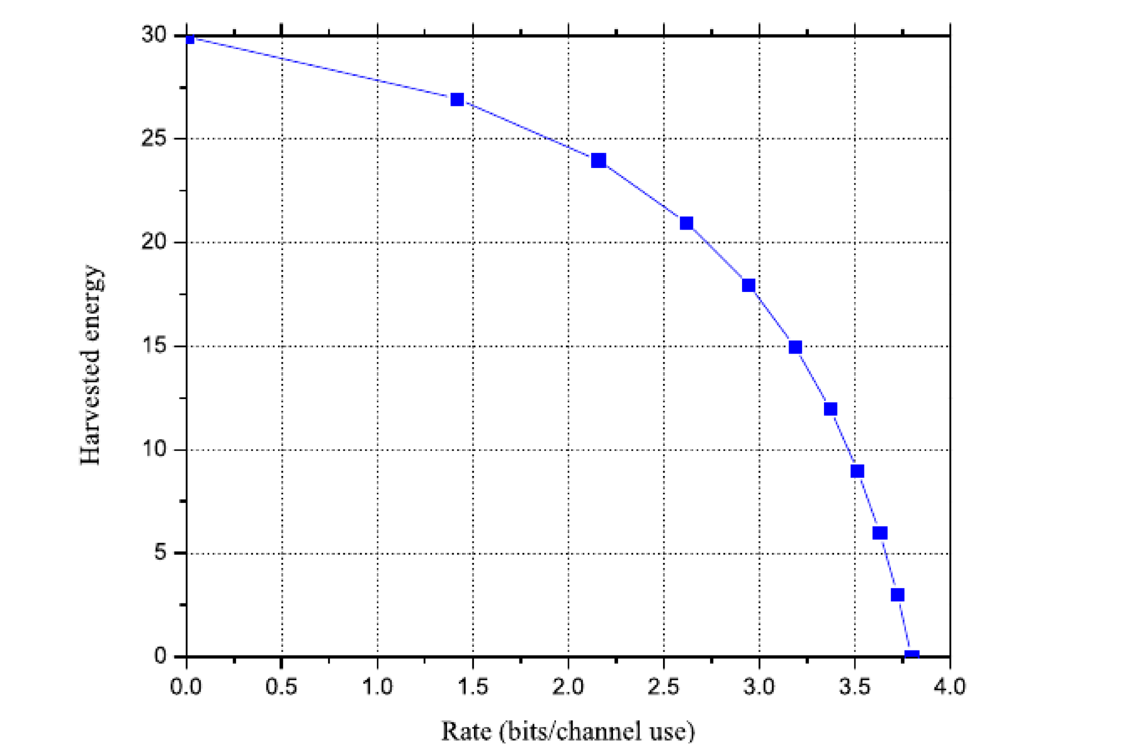


Fig. 1. Harvested energy-rate region with $P = 100$, $h \sim \mathcal{CN}(0,1)$, $\zeta = 0.6$, $l = \frac{1}{2}$, $\sigma_{\text{ADC}}^2 = 1$.

Joint Harvested Energy-Rate Outage Probability

Definition: $P_o = \Pr\left(Q \leq q_{\text{th}} \cup R \leq r_{\text{th}}\right)$,

energy threshold   rate threshold.

It is proved that the joint harvested energy-rate outage probability for the point-to-point system is given by

$$P_o = 1 - e^{-\max\left\{\frac{q_{\text{th}}}{\rho\zeta lP},\ \frac{1}{lP}\sqrt{\frac{2\pi\sigma^2}{e}\left(2^{2r_{\text{th}}}-1\right)}\right\}}.$$

The optimal value of $\rho \in [0,1]$ is given by the solution of

$$\rho^4 - 2\rho^3 + \left(1 + \frac{\sigma_{\text{ADC}}^2}{\sigma_{\text{rec}}^2} - \frac{A^2}{2\pi e\sigma_{\text{rec}}^2 B^2}\right)\rho^2 + \frac{2A^2}{\sigma_{\text{rec}}^2 B^2}\rho - \frac{A^2}{\sigma_{\text{rec}}^2 B^2} = 0,$$

where $A = \frac{q_{\text{th}}}{\zeta lP}$ and $B = \frac{1}{lP}\sqrt{\frac{2\pi}{e}}\sqrt{2^{2r_{\text{th}}} - 1}.$

Results

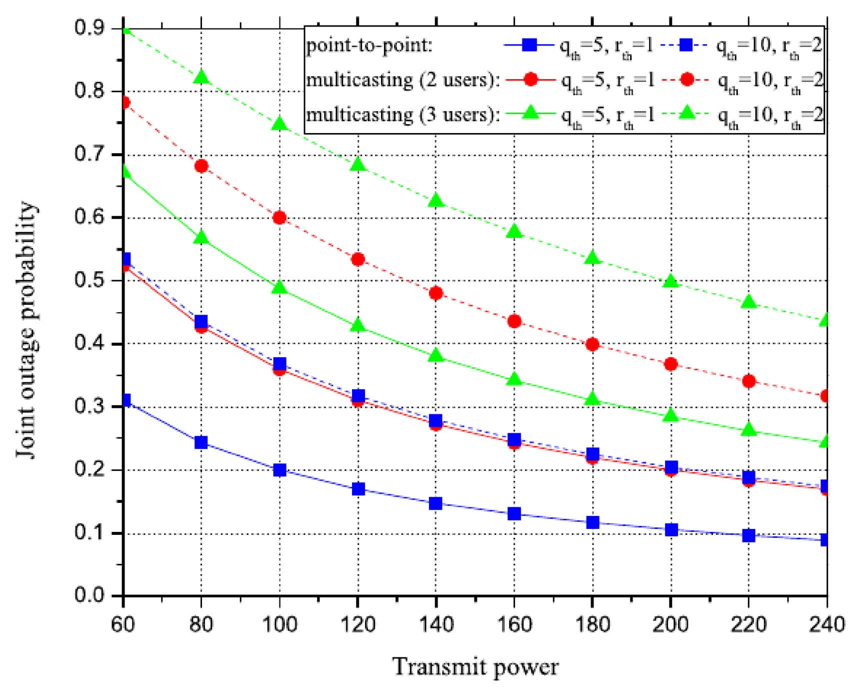


Fig. 2. Outage probability versus transmit power.

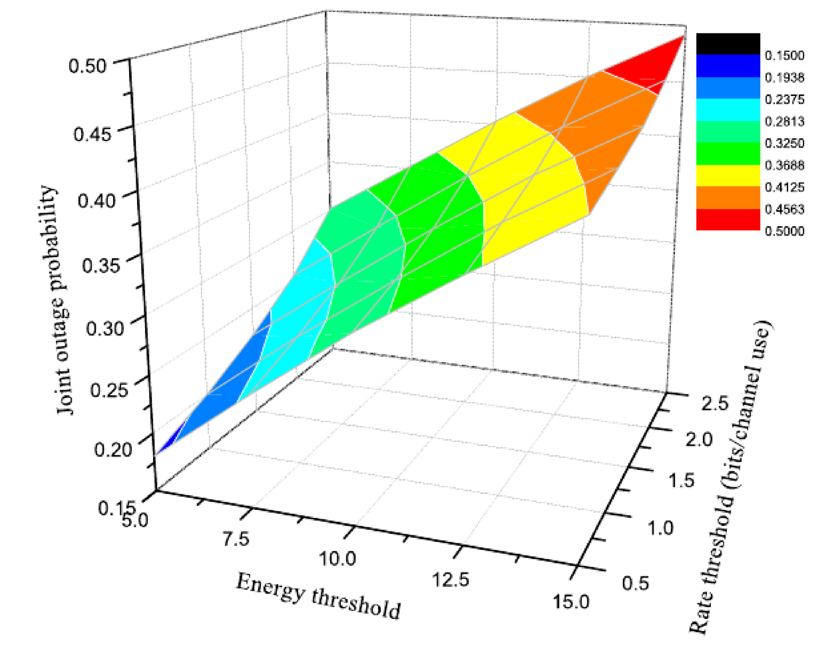


Fig. 3. Outage probability versus energy and rate thresholds in a point system.

Conclusions

•A tractable expression for the achievable rate is provided.

•The joint harvested energy-rate outage probability is defined, calculated in closed-form expressions for a point-to-point and a multicasting system and minimized by optimizing the PS factor.

•The proposed theoretical framework facilitates the investigation of performance of the integrated receiver and opens the road for future research on this topic.