Energy Harvesting in Wireless Communications

Wireless networking with energy harvesting nodes:
- Green, self-sufficient nodes,
- Extended network lifetime,
- Smaller nodes with smaller batteries,
- Very limited and varying energy.

Fujitsu's hybrid device utilizing heat or light.

Nanogenerators built at Georgia Tech, utilizing strain

System Model and Energy Feasibility

Unifying model for any network topology with arbitrary utility function.

\[ f(p_1, p_2, \ldots, p_n, \alpha) \]

Energy Causality:
\[ \sum_{i=0}^{n} E_{r,i} - \int_0^t p_i(t) dt \geq 0 \quad n \leq t \leq (n+1) \tau \]

Battery Capacity:
\[ \sum_{i=0}^{n} E_{r,i} - \int_0^t p_i(t) dt \leq E_{r,\text{max}} \quad n \leq t \leq (n+1) \tau \]

Average utility maximization problem
\[ \max_{p(t)} \frac{1}{T} \int_0^T f(p(t), \alpha) dt, \quad \text{s.t.} \quad p(t) \in 2^T \]

Simplifying the problem
\[ U(e_i, \alpha) = \max_{p(t)} \frac{1}{T} \int_0^T f(p(t), \alpha) dt \]
\[ \text{s.t.} \quad e_i = \sum_{j=1}^n p_j(t) dt, \quad \forall j \]

Concavity of \( U(e, \alpha) \)

Simulations
- EH Transmitter w/ adaptive modulation
- EH Receiver w/ linear storage cost

Both nodes with 50mW base power
- Harvests iid, ~U[0,100mW]

Optimal Transmission Policy

Concavity for EH Tx-Rx pair

Generalized Water-Filling

Water-filling with generalized water levels:
\[ v_{ij} = \frac{d}{dx_j} U(x_i, \alpha) \bigg|_{x_j = \lambda_j - \mu_j - \eta_j} = \sum_{j=1}^n (\lambda_j - \mu_j - \eta_j) \]

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