Journal Watch
IEEE Transactions on Wireless Communications
December 1, 2016

Prabhasa K

Signal Processing for Communications Lab
Department of ECE
Indian Institute of Science

December 31, 2016

Stochastic Online Control for Energy-Harvesting Wireless Networks With Battery Imperfections

Authors: Xin Wang, Tianhui Ma, Rongsheng Zhang, and Xiaolin Zhou

- Goal - Dynamic resource allocation for EH wireless networks, taking into account imperfect finite-capacity energy storage devices.
- **System Model**
  - For ideal battery, there is connection between the energy queue dynamics and the Lagrange multiplier updates for the intended optimization problem
  - For imperfect batteries, they propose a degenerated energy-queue based power allocation scheme

$$Q_n^c(t+1) \leq \left[Q_n^c(t) - \sum_{m \in \mathcal{N}_n^o} \mu_{[n,m]}^c(t) \right]^+ + \sum_{m \in \mathcal{N}_n^i} \mu_{[m,n]}^c(t) + R_n^c(t), \quad \forall n, c$$

  - Updating the data backlog vector -

$$\bar{Q} := \lim_{T \to \infty} \sup \frac{1}{T} \sum_{t=0}^{T-1} \sum_{n,c} \mathbb{E}\{Q_n^c(t)\} < \infty.$$

  - Network stability -

$$\sum_{m \in \mathcal{N}_n^o} P_{[n,m]}(t) \leq \xi \eta E_n(t), \quad \forall n \qquad E_n(t+1) = \eta E_n(t) - \frac{\sum_{m \in \mathcal{N}_n^o} P_{[n,m]}(t)}{\xi} + \xi e_n(t), \qquad E_n(t+1) = \min\{E_n(t+1), E_{\max}\} \qquad \bar{r}_n^c = \lim_{T \to \infty} \frac{1}{T} \sum_{t=0}^{T-1} \mathbb{E}\{R_n^c(t)\}$$

  - $$U^{opt} := \max_{\mathcal{X}} \sum_{n,c} U_n^c(\bar{r}_n^c)$$

- **Algorithm**
  - This is a stochastic optimization problem, which requires DP, hence significant knowledge of network statistics.
  - An alternative is to use the Lyapunov optimization techniques to develop a low-complexity online control algorithm, which can be proven to yield a feasible near-optimal solution. The algorithm depends on two parameters - queue perturbation parameter and a weight parameter

$$0 < V < V^{\max}, \quad \Gamma^{\min} \leq \Gamma \leq \Gamma^{\max}$$

$$V^{\max} := \frac{E_{\max} - \xi e_{\max} - \frac{P_{\max}}{\xi}}{\xi(\delta_1 + \delta_2) g_{\max}};$$
$$\Gamma^{\min} := \frac{P_{\max}}{\xi\eta} + \frac{\xi}{\eta}\delta_1 g_{\max} V;$$
$$\Gamma^{\max} := \frac{E_{\max} - \xi e_{\max}}{\eta} - \frac{\xi}{\eta}\delta_2 g_{\max} V.$$

  - Data admission and Power allocation

$$\max_{R_n^c(t)} \; [V U_n^c(R_n^c(t)) - Q_n^c(t) R_n^c(t)]$$
$$\text{s. t. } 0 \leq R_n^c(t) \leq R_{\max}$$

$$\max_{\boldsymbol{P}(t)} \sum_n \Big[\sum_{m \in \mathcal{N}_n^o} [W_{[n,m]}(t) \mu_{[n,m]}(t)] + \frac{\eta}{\xi}(E_n(t) - \Gamma) \sum_{m \in \mathcal{N}_n^o} P_{[n,m]}(t) \Big]$$
$$\text{s. t. } 0 \leq \sum_{m \in \mathcal{N}_n^o} P_{[n,m]}(t) \leq P_{\max}, \quad \forall n$$

- **Contributions**
  - A stochastic optimization was formulated to maximize the long-term utility subject to the energy availability constraints. The optimality gap vanishes as V^{max} approaches infinity.
  - An online control algorithm was proposed to make data admission, power allocation and routing decisions, without any statistical knowledge of channel, data-traffic, and EH processes.

Delay-Aware Energy Optimization for Flooding in Duty-Cycled Wireless Sensor Networks

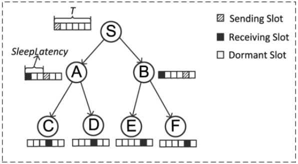
Authors: Shaobo Wu, Jianwei Niu, Wusheng Chou, and Mohsen Guizani

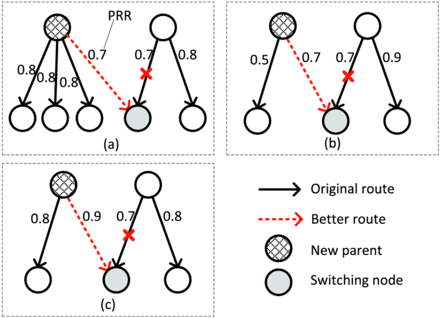
- Goal - Delay-aware energy-optimized flooding algorithm (DEF) tailored for synchronous duty-cycled WSNs.
- **System Model**
  - Synchronous - nodes having the same parent wake up simultaneously to receive broadcast packets.

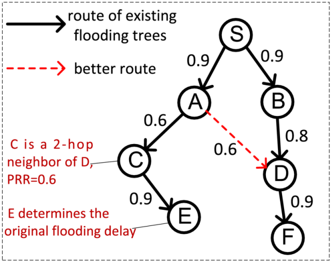
$$\begin{aligned} &\min EnergyCost \\ &FloodingDelay \leq \Delta \end{aligned} \tag{1}$$

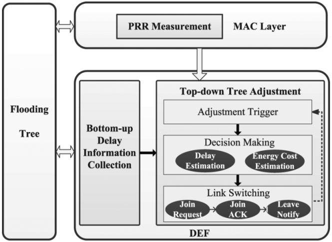
$$d(e) = (ETX(e) - 1)T + \sigma \tag{2}$$

  - DEF globally adjusts a constructed flooding tree, to maximize the energy efficiency improvement while following the delay constraint.
  - Flooding delay due to waiting time and transmission failure
  - Theorem 1: In synchronous duty-cycled networks with unreliable links, a node costs less ETX to send a packet to its child nodes through broadcast than through unicasts.
  - Theorem 2: A node saves more energy if it chooses the node having more child nodes, or having poorly linked child nodes, or with a better PRR as the parent, when the other conditions are the same.
  - Assumptions - Despite duty-cycled setting, all nodes are always awake.

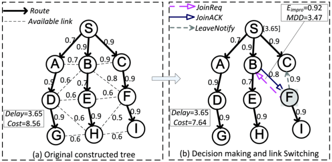

T
S
SleepLatency
A
B
C
D
E
F
Sending Slot
Receiving Slot
Dormant Slot


PRR
0.8
0.8
0.8
0.7
0.7
0.8
(a)
0.5
0.7
0.7
0.9
(b)
0.8
0.9
0.7
0.8
(c)
Original route
Better route
New parent
Switching node


route of existing flooding trees
better route
S
0.9
0.9
A
B
0.6
0.8
0.6
C
D
C is a 2-hop neighbor of D, PRR=0.6
0.9
0.9
E
F
E determines the original flooding delay



- **Algorithm**
  - DEF can decrease a constructed trees flooding cost, while not increasing its flooding delay
  - 3 stages - Delay Information Collection, Tree Adjustment, Decision making and link switching



- **Contributions**
  - Address the fundamental flooding tree construction problem in this new environment concerning both the energy optimality and delay requirement, by globally optimizing the structure of a constructed tree.

On the Effects of LOS Path and Opportunistic Scheduling in Energy Harvesting Relay Systems

Authors: Haiyang Ding et al

- Goal - Analyzed the impacts of the LOS path component and opportunistic scheduling on the outage performance of an EH-based dual-hop AF relay system.
- **System Model**
  - After the PS operation, the information signal at the EH relay

$$y_R(k) = \sqrt{(1-\rho)P_S}h_1 s(k) + n_R(k), \tag{3}$$

  - The EH relay amplifies $y_R(k)$ and the transmitted signal from R

$$x_R(k) = \frac{\sqrt{P_R}y_R(k)}{\sqrt{(1-\rho)P_S|h_1|^2 + N_0}}, \tag{4}$$

  - Received signal at the destination D

$$\begin{aligned} y_D(k) =& h_2 x_R(k) + n_D(k) \\ =& \frac{\sqrt{(1-\rho)P_S P_R}h_1 h_2 s(k)}{\sqrt{(1-\rho)P_S|h_1|^2 + N_0}} \\ &+ \frac{\sqrt{P_R}h_2}{\sqrt{(1-\rho)P_S|h_1|^2 + N_0}} n_R(k) + n_D(k), \end{aligned} \tag{5}$$

Contributions

- Showed that a strong LOS path component between source and EH relay (in the form of a large Rician K factor) can improve the end-to-end transmission robustness and the outage curves scale as 1/SNR in the high SNR regions.
- Opportunistic scheduling of the second-hop links can also enhance the end-to-end performance and the outage curves decay as 1/SNR, provided that the number of destinations is greater than one.
- When the LOS path component between source and EH relay is strong and opportunistic scheduling in the form of BCS or NCS is deployed to schedule the second-hop links, the system diversity order can be increased to the number of destinations.

Other Interesting Papers

- Accurate and Effective Localization of an Object in Large Equal Radius Scenario.
- Generalized Precoder Designs Based on Weighted MMSE Criterion for Energy Harvesting Constrained MIMO and Multi-User MIMO Channels.
- Energy-Efficient Joint Sensing Duration, Detection Threshold, and Power Allocation Optimization in Cognitive OFDM Systems.
- Simultaneous State Estimation of Cluster-Based Wireless Sensor Networks.
- Enhanced Dynamic Spectrum Access in Multiband Cognitive Radio Networks via Optimized Resource Allocation.