Energy Efficient Collision Resolution in Wireless Ad-Hoc Networks

Yalin Evren Sagduyu / Anthony Ephremides

Objective, Motivation and Approach

- **Objective:** To prolong system lifetime and to decrease energy consumption of wireless ad-hoc networks consisting of limited energy nodes that have to involve in collision resolution process as a means for reliable communication
- **Motivation:** Scheduling of node transmissions according to available energy levels limits the contention, that low-energy nodes experience during the collision resolution process, and consequently reduces energy consumption due to unsuccessful retransmission of backlogged nodes.
- **Approach:** To resolve collisions, tree-splitting method is used, where contending packets are split into branches according to residual battery energy of corresponding nodes.

Details of the Algorithm

- At k^{th} time slot, the algorithm specifies the packets to be transmitted as the set of packets that arrived to nodes with residual energy of $(T(k) - \alpha(k)\,,\ T(k)]$.
- Algorithm determines parameters $T(k)$, $\alpha(k)$ and status $\sigma(k) = R$ or L (right or left branch on the tree) in terms of feedback, $T(k\text{-}1)$, $\alpha(k\text{-}1)$ and $\sigma(k\text{-}1)$.

Analysis of Algorithm in Mobile Networks

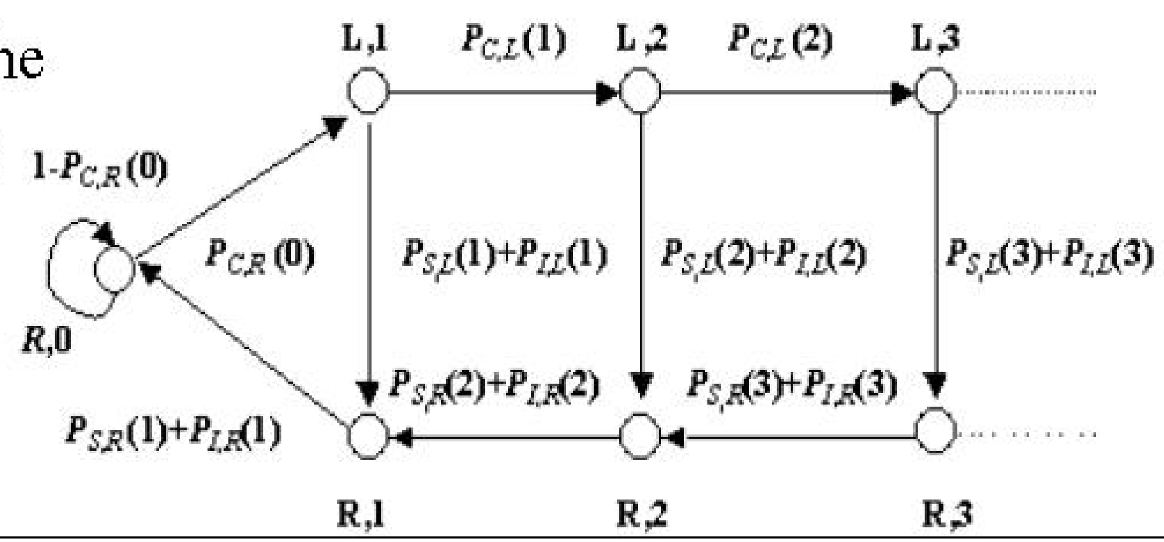
- Reflected Brownian Motion Model (Independent)
- Gauss-Markov Model (Correlated velocity vector)

$$P_{S,L}(k) = P_{S,R}(k) = \left(\sum_{m=1}^{\infty} \frac{G(k)^m e^{-G(k)}}{m!}\, m\, q(r)\big(1-q(r')\big)^{m-1} \right)$$

$$P_{I,L}(k) = P_{I,R}(k) = e^{-G(k)} + \left(\sum_{m=1}^{\infty} \frac{G(k)^m e^{-G(k)}}{m!} \big(1-q(r')\big)^{m} \right)$$

$$P_{C,L}(k) = P_{C,R}(k) = 1 - e^{-G(k)} - \left(\sum_{m=1}^{\infty} \frac{G(k)^m e^{-G(k)}}{m!} \big(1-q(r'),t)\big)^{m-1}\big(1-q(r'),t) + mq(r,t)\big) \right)$$

Markov chain for the algorithm operating in mobile ad-hoc network according to protocol model



Collision Resolution - Infinite Energy Case

- **Objective:** To reduce the total energy spent by individual nodes involving in collision resolution process under the infinite energy assumption
- **Approach:** The tree splitting algorithm developed specifies the packets to be transmitted in slot k as the set of all packets that arrived to nodes with transmission energy between $(E(k),\ E(k) + \alpha(k)]$ (or with a distance of $(r(k),\ r(k) + \beta(k)]$ to their intended receiver) required to achieve a given packet error rate.

Joint Operation of Collision Resolution Trees

- Interdependent Simultaneous Collision Resolution Processes
- Partial Decoupling of Collision Resolution Processes
- **Algorithm:**

If $\max(T_1(k), T_2(k)) - \min(T_1(k), T_2(k)) > \phi$

partially decouple collision resolution trees, where nodes in transmission range of both receivers perform nonlinear mapping operation from $(T_1(k), T_2(k), \alpha_1(k), \alpha_2(k))$ to $(T_3(k), \alpha_3(k))$ based on the dual feedback.

If $\exists k$ s.t. $\min(T_1(k), T_2(k)) < \gamma < \max(T_1(k), T_2(k))$

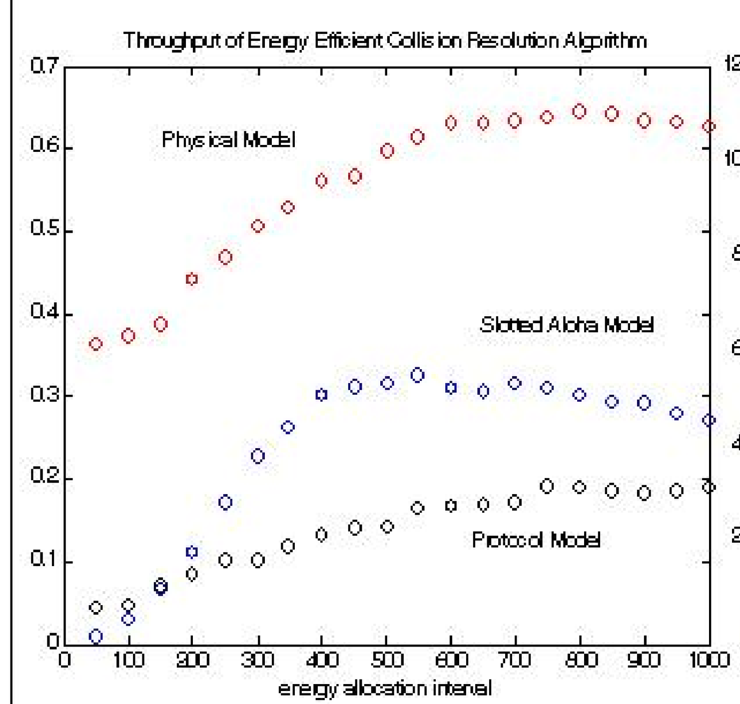
couple collision resolution processes on both trees to avoid further delays and to slow down the decrease in $\min(T_1, T_2)$.

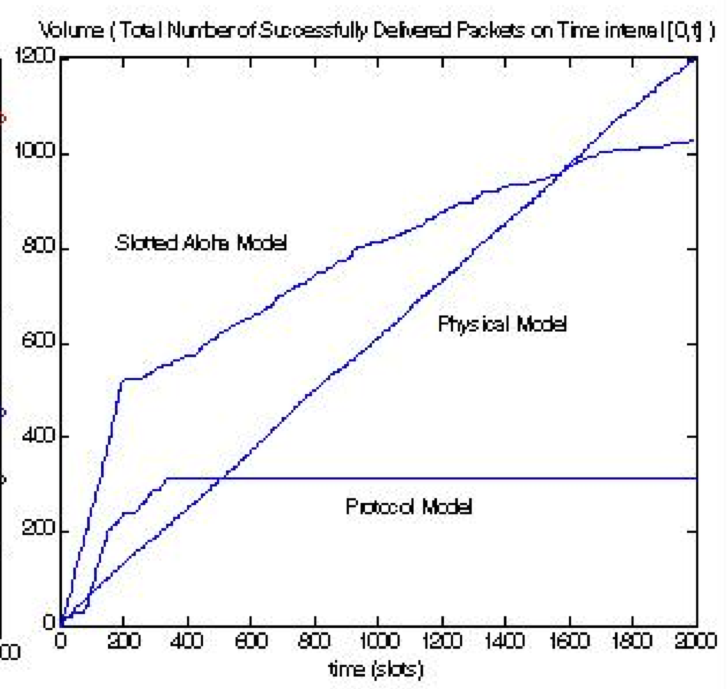
- $\forall\, \eta>0,\ \exists\, k_o$ s.t. $|\max(T_1(k), T_2(k)) - \min(T_1(k), T_2(k))| < \eta,\ \forall k \ge k_o$

Simulation Results

- Mobile Multi-hop Ad-hoc Network
- Poisson Packet Arrivals
- Slotted Aloha with Perfect Feedback
- Protocol Model with Guard Zones
- Physical Model with Capturing Effect

	Energy Efficient Algorithm			FCFS Algorithm		
	Aloha	Protocol	Physical	Aloha	Protocol	Physical
Throughput	0.3296	0.1788	0.6607	0.3306	0.1381	0.5856
CRP length	8.2837	2.3898	1.1114	8.2778	3.4267	1.3491
Dead node ratio	0.1836	0.1154	0.0113	0.2561	0.1308	0.0131





Conclusion and Future Work

- **Conclusion:** Energy efficient collision resolution approach increases throughput and throughput per unit energy as well as system lifetime and decreases CRP length and average number of dead nodes over time.
- **Future Work:** Distributed and joint optimization of simultaneous interdependent collision resolution processes at multiple receivers under limited and infinite energy assumptions