Energy Constrained Real Time Wireless Multicasting

Nof Abuzainab and Anthony Ephremides

Motivation

• Multicasting in wireless medium is challenging due to the time varying nature of the wireless channel.
• Also, transmission of real time applications in wireless medium is difficult since:
  - Real time applications have strict delay requirements.
  - Wireless devices operate on batteries and hence are energy limited.

System Model

• A transmitter multicasting T packets to M receivers over a wireless single hop network.
• T packets to be delivered in N time slots and up to a maximum value of E units of energy.
• Erasure channel model between the transmitter and each receiver.
• The probability of successful reception for receiver i in time slot k is given by \( p_{ik} \).
• Two cases for \( p_{ik} \):
  - \( p_{ik} \) is time varying and is modeled by a two state Markov chain.
  - \( p_{ik} \) is constant in time.
• Binary energy expenditure in every time slot.
• Transmission schemes:
  - Simple Automatic Repeat Request (ARQ)
  - Random Network Coding (RNC).

Objective

• Finding the optimal energy allocation that maximizes the number of packets successfully received by every receiver.
• Solving the original problem is intractable.
• A suboptimal approach is provided in which the global constraints are distributed among all individual packets for ARQ (or groups of \( L \) packets for RNC).

Proposed Approach

- Translate the energy and delay constraints for the T packets into constraints for every batch of \( L \) coded packets
- The case of ARQ corresponds to \( L=1 \).
- For the \( t \)th group of \( L \) coded packets, the problem is:

\[
\max_{\mathbf{x}, \mathbf{n}} \sum_{t=1}^{M} \left( \sum_{i=1}^{N} x_{iti} \right)
\]

Subject to:

\[
\sum_{i=1}^{N} u_i \leq E_t
\]

where:
- \( E_t \) is the maximum allowable energy to spend per \( t \)th batch of \( L \) coded packets.
- \( N_t \) is the maximum number of time slots to deliver \( t \)th batch of \( L \) coded packets.
- \( u_i \) is the value of energy expenditure in time slot i.
- \( \sum_{i=1}^{N} x_{iti} \) is the number of receivers who receive the packet successfully up to time \( N_t \).

This problem can be solved using dynamic programming.

Numerical Evaluation

- For the evaluation, the parameters values are \( T=8 \) packets, \( E=16 \) units, \( N=24 \) time slots and \( M=2 \) receivers.
- Receiver 1 has good channel quality; receiver 2 has poor channel quality.

Conclusion and Future Directions

• We have used dynamic programming to maximize the multicast throughput in a finite delay constraint and within an energy budget over a time varying channel under two transmission schemes: ARQ and RNC.
• The solution can be used for extending the problem to multiple sources and more general multihop topologies.

Applications

Efficient multicast for real time applications especially in military applications, multimedia streaming, distant learning, gaming, …