Diversity Backpressure Routing with Mutual Information Accumulation in Wireless Ad-hoc Networks

Hao Feng and Andreas F. Molisch
Wireless Devices and Systems (WiDeS) Group
Ming Hsieh Department of Electrical Engineering

Research Outline

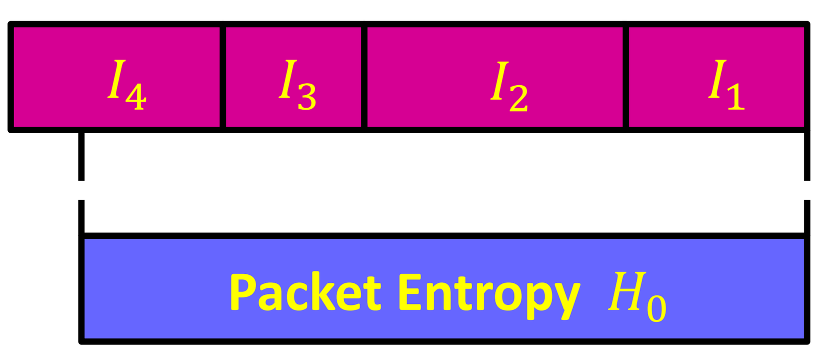
- **Goal**

  Design throughput maximizing algorithm for multi-hop, multiple packet streams (commodities) wireless ad-hoc networks with *Mutual Information Accumulation* (MIA) technique in the packet transmissions

- **Motivation**
  - ✓ **Repetition Transmission Scheme (REP)**: any packet not correctly received needs to be completely retransmitted in the future transmission attempts
  - ✓ **Mutual Information Accumulation (MIA)**: The efficiency of REP can be enhanced if the partially received information can be accumulated at the receiver and be used to facilitate the decoding of the packet in the future transmission attempts.
- **Main Idea**
  - ✓ Introduce MIA technique into the packet transmissions for the routing in the network
  - ✓ Combine *Lyapunov Drift Analysis* with MIA technique

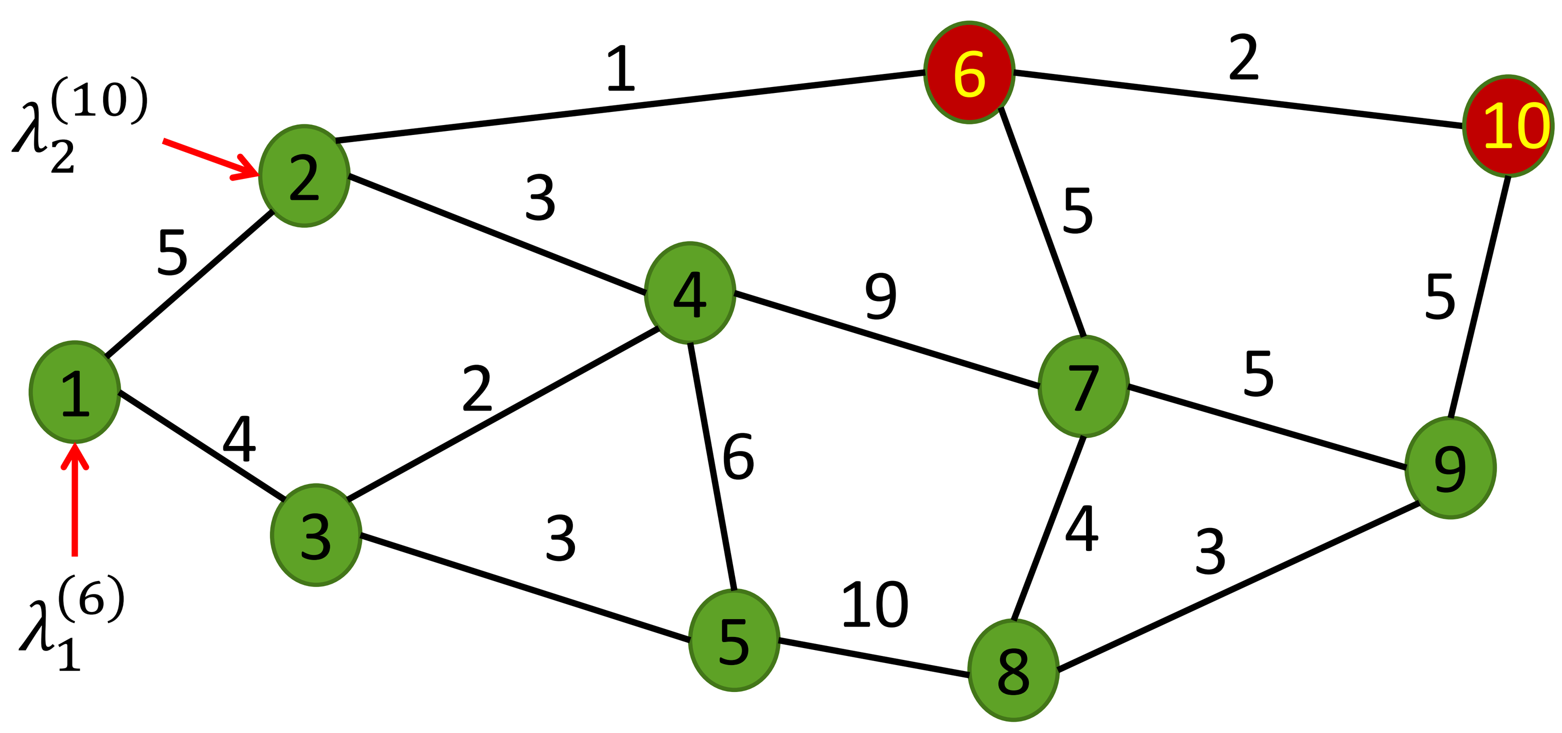
Mutual Information Accumulation

- **Fountain Codes (bitwise operation)**
  - ✓ Encode source information in an infinitely long code stream
  - ✓ Recover packet information once the total received information exceeds the source packet entropy

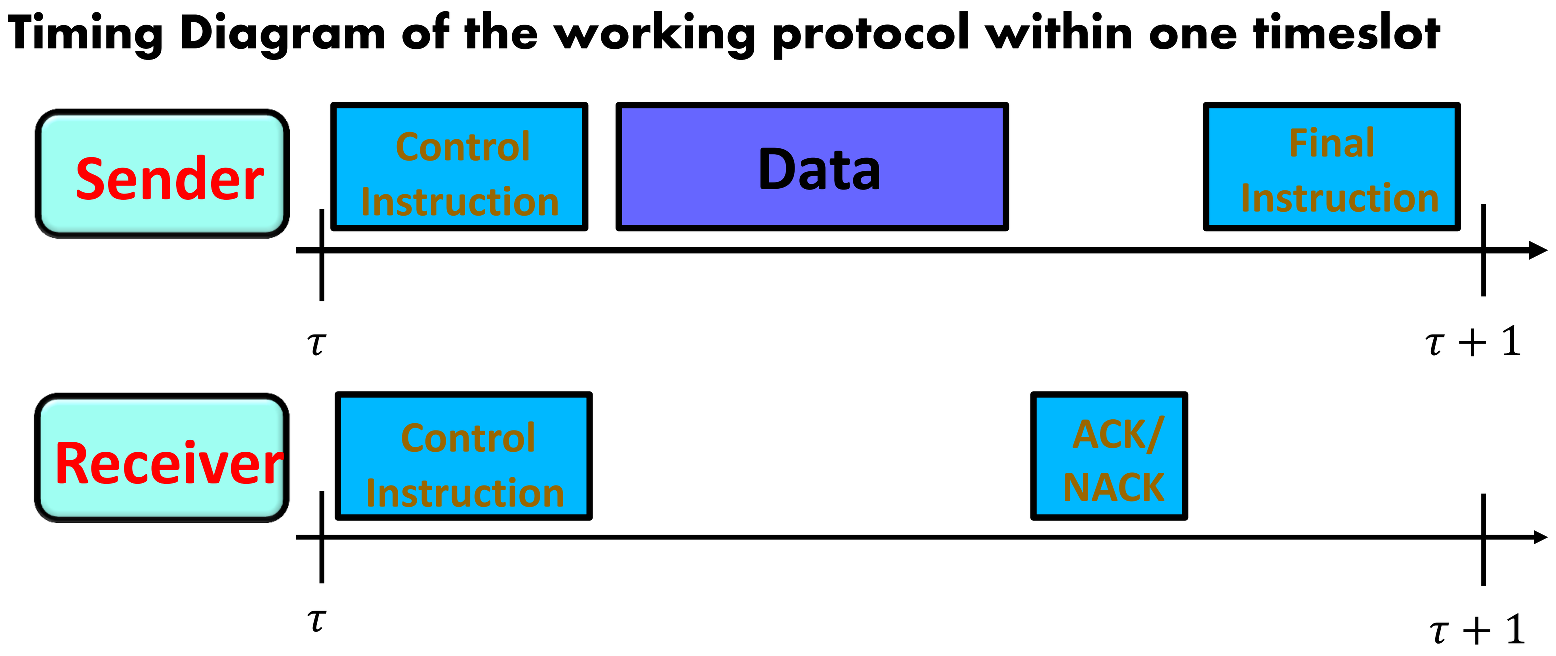


Network Model

- **Assumptions**:
  - ✓ Slotted Time
  - ✓ Multicast Effect
  - ✓ Capacity Achieving Transmission Rate
  - ✓ Fixed Transmission Power at Each Node
  - ✓ Perfect Decoding
  - ✓ Zero Packet Queue Length in Destination Nodes
  - ✓ Interference Free



- **Implementation of MIA technique in routing**
  - ✓ **Compact Packet Queue (CPQ)**: the queue that stores the complete packets
  - ✓ **Partial Packet Queue (PPQ)**: the queue that stores the partial packet information
  - ✓ Once the partial information of a packet in PPQ exceeds the entropy of the packet, the packet is decoded and will possibly be transferred to CPQ
- **Timing Diagram of the working protocol within one timeslot**

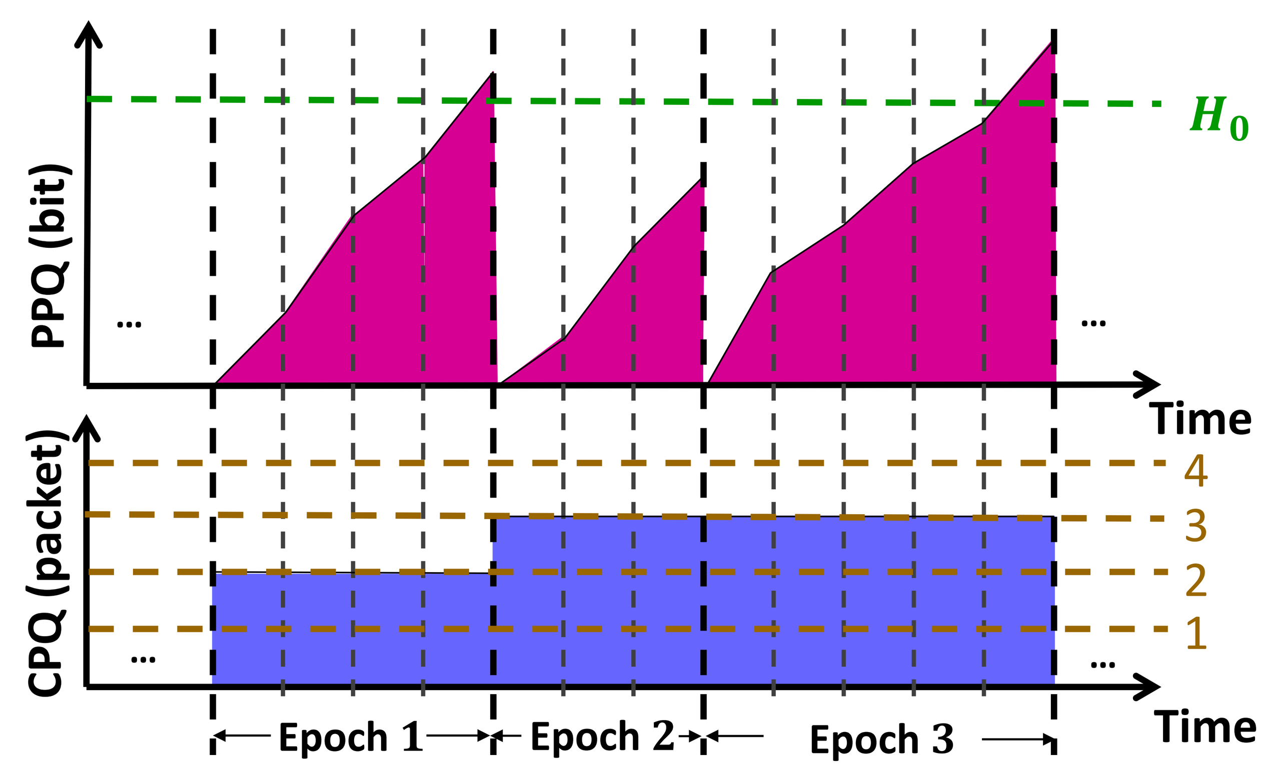


Diversity Backpressure Algorithm

- **Distributed routing algorithm for wireless ad-hoc network**
- **Each node chooses packet of the commodity, which maximizes the Max-weight-matching metric, to transmit in each timeslot**
- **Each node routes the packet in the direction of the maximum differential backlog (the queue length difference between the sender and receiver)**
- **Throughput-optimum among the policies with REP**

Two Proposed Algorithms

- **DIVBAR-RMIA Algorithm**
  - ✓ **Renewal Mutual Information Accumulation (RMIA)**: all the receivers clear the partial information of the packet being transmitted once there is at least one receiver that firstly decodes the packet
  - ✓ **DIVBAR-RMIA**: modify DIVBAR algorithm and combine it with RMIA



- **DIVBAR-MIA Algorithm**
  - ✓ Retain the partial information accumulated at the receivers until the corresponding packet is delivered to the destination
  - ✓ The retained partial information can facilitate the decoding in the future transmission attempts
  - ✓ Have synchronized epochs with DIVBAR-RMIA

Network Capacity Region (Stability Region)

- **Network Capacity Region with RMIA**
  - ✓ **Definition**: The set of all possible exogenous input rate matrix $\left(\lambda_n^{(c)}\right)$ that can be supported by policies with RMIA
  - ✓ **The network capacity region can be reached by a *stationary randomized policy***
- **Theorem**

  If $0 < F_{R_{nk}}(x) < 1$, where $F_{R_{nk}}(x)$ is the cdf function of the amount of information transmitted over link (n,k) in one timeslot, for $x > 0$, the network capacity region with RMIA is strictly larger than the network capacity region with REP

Throughput Performance Analysis

- ***D* Timeslots Average Lyapunov Drift**:

$$\Delta_D(\boldsymbol{Q}(t)) = \frac{1}{D}\sum_{n,c}\mathbb{E}\left\{\left(Q_n^{(c)}(t+D)\right)^2 - \left(Q_n^{(c)}(t)\right)^2 \middle| \boldsymbol{Q}(t)\right\}$$

- **Theorem**

  DIVBAR-RMIA is throughput-optimum among all policies with RMIA

- **Theorem**

  DIVBAR-MIA's throughput performance is at least as good as DIVBAR-RMIA

Simulation Results