Efficient Resource Allocation and Interference Management for Streaming Multiflow Wireless Networks

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Ad-Hoc Network Challenge

Moving Information through Decentralized Networks

- Slotted packet-based system
- Simultaneous transmissions interfere
- Multiple streaming flows
- Half duplex terminals

Challenges

- Routing and scheduling are NP-Hard in general
- Non-convex problem
- Interference management
Our Approach

- Rate Control: *enable interference management—no collisions*
- Decomposition Technique: *tear apart the problem*
- Complexity-managing data structure: *represent the network in space and time*
- Efficient Algorithms: *compute the allocation*

Demonstrate improved network throughout
Randomly placed terminals

System Model:
- Half-duplex system, limited transmission power
- Distance-based pathloss model
- Only sources have traffic, all other terminals have infinite buffers

Goals
- Determine routes, schedules, and power allocations
- Maximize the minimum throughput
- Manage interference among packets
- Do all this in polynomial time
Information-Theoretic Rate Control

Key to Our Approach

Collisions: all is lost
Interference: some information is received

Fundamental Approach

Characterize link capacities in relation to each other:

Information Theory

For a point-to-point link:

$$\log_2(1 + \text{SINR})$$

SINR-based rate control: interference management
- Change one packet, affect all others
Decomposition by Flows and Packets

Tear the problem apart

- Sequence flows from longest to shortest: 1, 2, 3
- Rotate through flows, allocating one packet to each

Resulting problem sequence:

1
2
3
4
5
6
NFIC: Network-Flow Interaction Chart
Spatial and Temporal Network Representation

- Represent terminals as nodes
- Expose temporal dimension on $x$ axis
- Edges represent transmissions, weighted with capacity of a link

$log_2(1 + \text{SINR})$
NFIC: Network-Flow Interaction Chart
Allocation using Dynamic Programming (1 Flow A → B, 2 packets)

- Weight source node with $\infty$, infinite data
- Update edges with $\min$ of nodes and edges
- Update nodes with $\max$ of incoming edges
- Compute throughput at destination nodes

Complexity: $O(N^3)$

Monotone Semiring
Optimal Subproblem Property

min{edge, node}      max{edges}
Interference Management

Rate Control
Packet X-B was allocated first:
\[ R_{XB} = \log_2(1 + \text{SINR}(B)) \]

Allow fractional loss \( \gamma \in (0, 1] \):
\[ \hat{R}_{XB} \geq \gamma R_{XB} \]

Limit \( P_A \) ⇒ limit interference at B

- \( P_A = f(D_{A,B}, N_0, \hat{R}_{XB}) \)
- Calculate rates between and all other terminals in time 2 with \( P_A \).
- Update NFIC edges in slot 2
Multiflow, Multipacket Allocation
Route Multiplicity in Action

Larger scale example:
- Two flows
- Two packets
- Sequence: 

NFIC Allocation
- Memory used to help manage interference
- Half-duplexing penalty mitigated, higher throughput results
Simulation result: 3 flows

- Interference management: more routes, good performance
- Curve will flatten as number of routes reaches a max

Result
Simultaneous interfering transmissions aid performance!
Conclusion and Future Work

Contributions

- Polynomial-time resource allocation algorithm
- Clear performance gains using NFIC allocation: route multiplicity, interference management
- Rethink “collisions” as interference?

Future Work

- Study advanced multiterminal PHY techniques: cooperation, etc
- Distributed implementations

Thanks!