

Rate Selection Heuristics for Network Coding in Wireless Networks

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Motivation

Energy Efficient Broadcasting

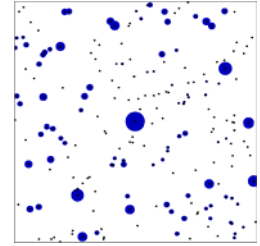
- Energy Efficient Broadcasting:
 - Broadcast packets from one source to all nodes with the minimum number of transmissions

Network Coding

- Allows encoding data at intermediate nodes
- Linear coding
 - Packets are vectors of a Galois Field (ex: $GF(2^8)$)
 - Linear Combination : $P_{send} = \sum \alpha_i P_i$
 - Decoding from a set of vectors : linear algebra
- Random linear coding
 - Collect received packets
 - Wait some delay – then send one linear combination with random coefficients : Delay defines a **rate**

Network Coding Solution for Broadcasting in Wireless Networks

- Finding an optimal solution: “subgraph selection”:
 - Selecting nodes which inject encoded packets
 - Selecting their rates
- Can be formulated as a Linear Program
 - Can be solved in polynomial time [Lun et al '06] [Wu et al '05]



- But, We intend to find: **simpler and intuitive heuristics based only on local topology information**

Key Contribution

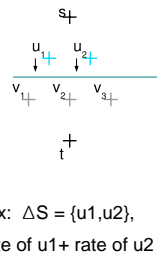
- Propose simple heuristics for rate selection for efficient broadcasting in wireless networks
 - Can outperform broadcasting without network coding
 - Starts from simple rate selection in our previous work [WITS '07]
 - Improve the heuristic for smaller networks, inspired by [Fragouli et al '06]
- Study the performance of heuristics on various graphs
 - Investigate and analyze cases where the performance becomes low
 - By experimental simulations

Metrics for Performance

- Evaluating the cost: E-cost, ratio between:
 - The number of transmissions from all nodes per unit time (= sum of selected rates of each node)
 - The number of packets successfully broadcast from the source to every node per unit time (= achievable broadcast rate)
 - **Achievable broadcast rate with network coding = mincut from the source to all nodes in hypergraph [Deb et al '05]**
- Relative Efficiency
 - The ratio of the cost from an optimal solution to the cost from the heuristic : E-rel-efficiency = E-optimal/E-cost
 - E-optimal obtained by solving linear problem [Lun et al '06]
 - E-cost computed for the heuristic IRMS

Achievable Broadcast rate = Min-cut

- Definition of a cut
 - s: source, t: one of the destinations
 - Partition of the network $s \in S, t \in T$
 - Capacity of the cut : amount of information from $S \rightarrow T$
 - For an hypergraph (wireless) : if ΔS nodes within range of nodes of T
 - Capacity = sum of the rates of nodes in ΔS
 - Cut with the minimum capacity : min-cut



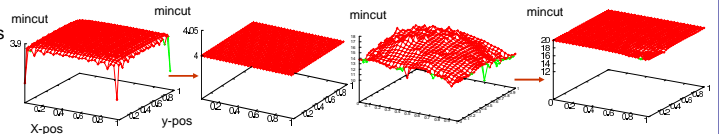
Heuristics and experiments

Heuristics

- IRON only (Identical Rate for other nodes): every node retransmits with rate 1, except for the source, with rate M
- Why is the source rate M, average # of neighbours?
 - Proved that achievable broadcasting rate is asymptotically M [WITS '07]
 - Intuitively
 - Assume every transmission bring an innovative packet to every receivers
 - Assume every node, which has M neighbours, has rate 1
 - Every node would receive M packets per second
 - The source should inject M packets per second

IR-MS (Increased Rate for Most Starving Node)

- Set the rate of a node v to $C_v = \frac{M}{\min H_u \text{ for } u \in H_v}$
- H_u : set of neighbours of node v
- M : the source rate and the average number of neighbours



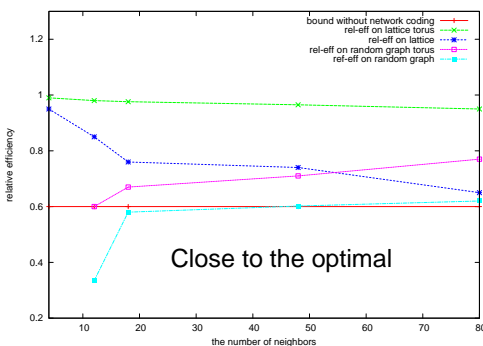
(a) IRON in a lattice graph (20x20 lattice, M=4) (b) IRMS in a lattice graph (c) IRON in a random graph (d) IRMS in a random graph (N = 200, M = 20)

– The min-cut is improved by the heuristic IRMS

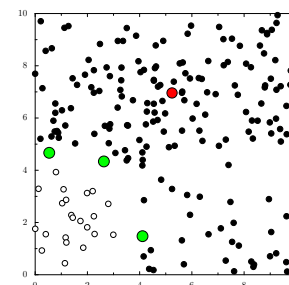
Simulation : Relative Efficiency

- Efficiency without Coding

$$E_{bound-rel-eff}^{no-coding} \approx 0.609$$



Difficulty to achieve the min-cut, M, only with local topology information



– In sparse networks, the local topology information is not enough

- Source
 - Nodes receiving M source packets per second
 - Starving nodes, receiving less than M source packets per second
 - Nodes receiving M source packets per second, but that do not provide enough retransmissions to starving nodes
- Total number of nodes = 200
the average number of nodes, M = 10