optimal routing and power allocation for wireless networks with imperfect full-duplex nodes

David Ramírez D.
Behnaam Aazhang

Rice University

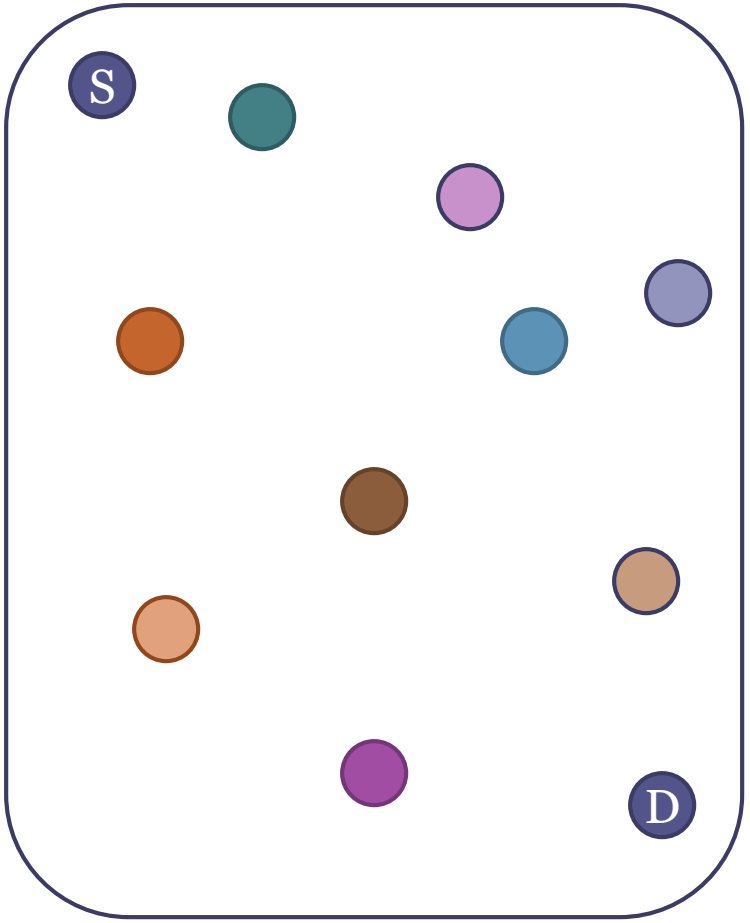
12 June 2013

Resource Allocation Challenge

- Wireless full-duplex network
- Self-interference
- Single source-destination pair
- Inter-node interference

To maximize the minimum rate,

- What power allocation?
- Which nodes should relay?



X. Fang, D. Yang, and G. Xue, “Distributed algorithms for multipath routing in full-duplex wireless networks,“

C. Weeraddana, M. Codreanu, M. Latva-aho, and A. Ephremides, “Resource allocation for cross-layer utility maximization in multi-hop wireless networks in the presence of self interference"

Our Approach

- Simplified Interference Model
- Focus on full-duplex
- Solve power allocation for fixed route
- Modify Dijkstra's Algorithm to find optimal solution

Interference Model

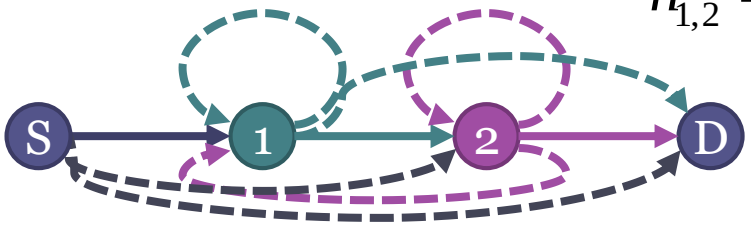
- Achievable rate as function of SINR
  - $P_i \leq P_{Max}$
- Simplified Interference Model
  - focus on full-duplex
- Imperfect self-interference cancellation

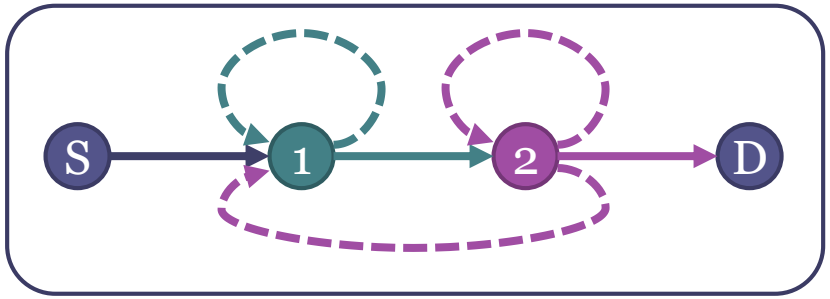
$$-20dB \leftrightarrow \gamma = 0.01$$

- One hop interference
  - hop defined by route

$$r_s = \log_2(1+SINR) = \log_2\left(\frac{P_s h_{s,1}}{1+\gamma_1 P_1 + P_2 h_{1,2}}\right)$$

$$h_{1,2} = d_{1,2}^{-\alpha}$$



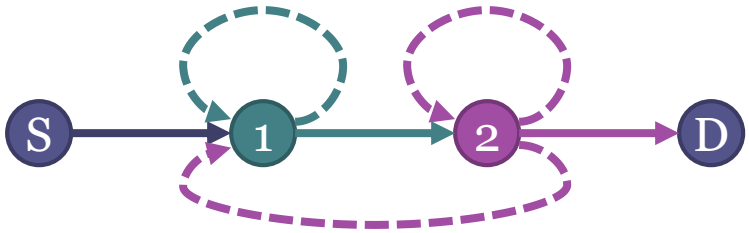


M. Duarte and A. Sabharwal, “Full-duplex wireless communications using off-the-shelf radios: Feasibility and first results“

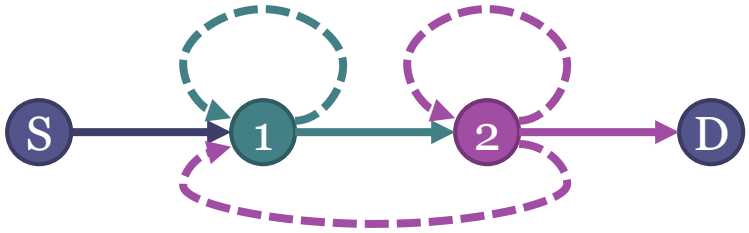
M. Jain, J. I. Choi, et. Al., “Practical, real-time, full duplex wireless”

Optimal Solution to Power Allocation

- Equal rates for all nodes in route
- At least one node at maximum transmit power
- Optimal power at each node
  - polynomial equation
  - parameter is SINR
  - degree equal to number of hops from D



Example



- Link to D
  - No interference

$$P_2 = \frac{1}{h_{2,D}}\omega_D$$

$$SINR = \omega$$

$$P_i \le P_{Max}$$

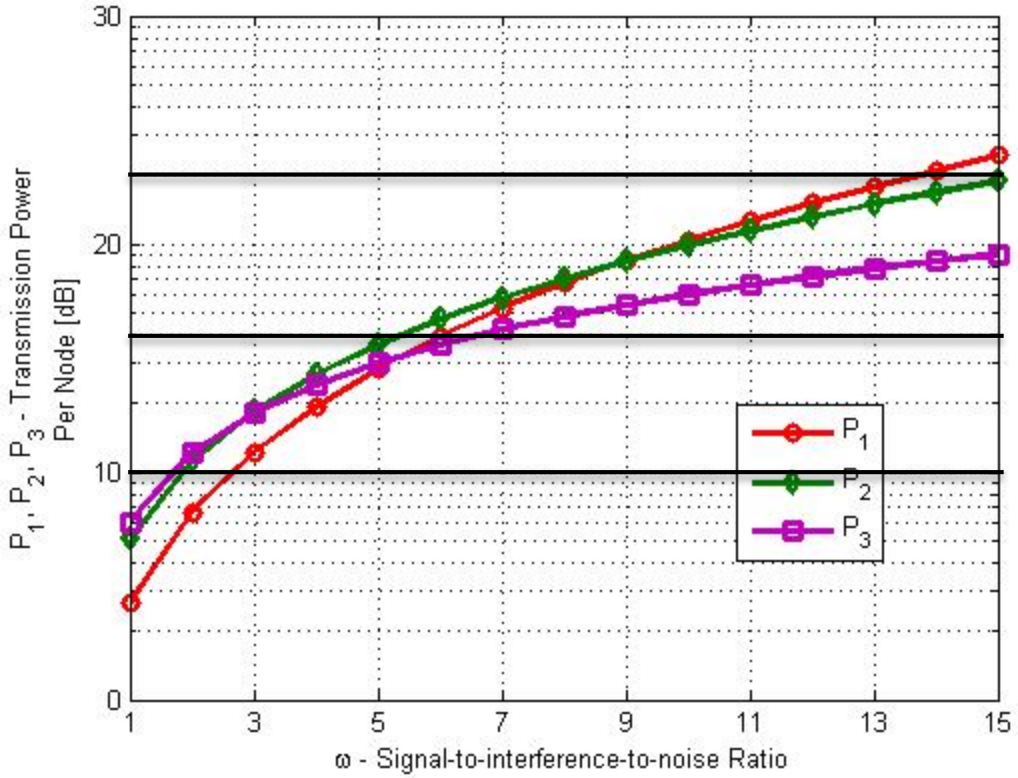
- Link to 2
  - Self-interference

$$P_1 = \frac{\gamma_2}{h_{1,2}h_{2,D}}\omega_2^2\omega_D + \frac{1}{h_{1,2}}\omega_2$$

- Link to 1
  - Self-interference and one hop interference

$$P_S = \frac{1}{h_{S,1}}\left(\frac{\gamma_1\gamma_2}{h_{1,2}h_{2,D}}\omega_1^3\omega_2\omega_D + \left[\frac{h_{1,2}}{h_{2,D}}\left[\frac{h_{1,2}\gamma_1}{h_{2,D}}\right] + \frac{\gamma_1}{h_{1,2}}\right]\omega_1\omega_2 + \omega_1\right)$$

Example



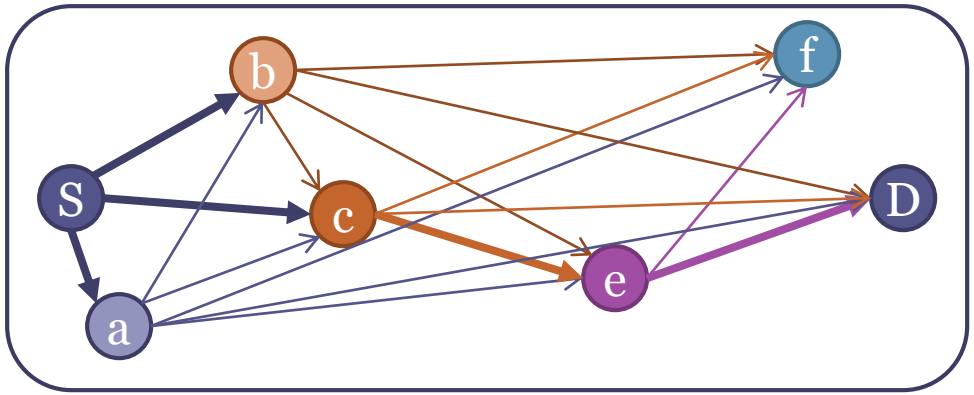
$$P_{Max} = 21dB$$

$$P_{Max} = 13dB$$

$$P_{Max} = 10dB$$

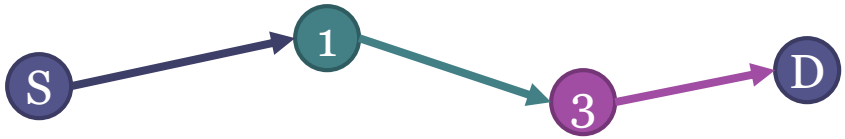
Optimal Route and Power Allocation

- Modify Dijkstra's Algorithm for max min rate
  - rates as edge weights
- Non decomposable objective function
  - monotonic decreasing
- Trade off between hop length and SINR

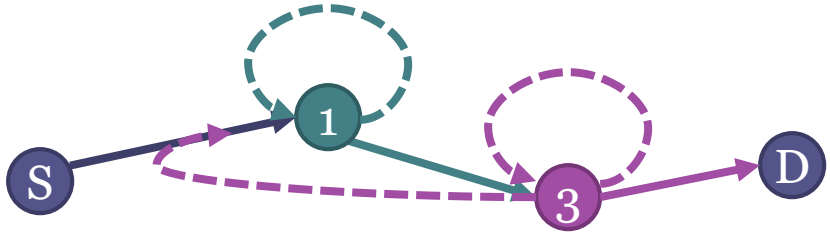


Effect of Interference

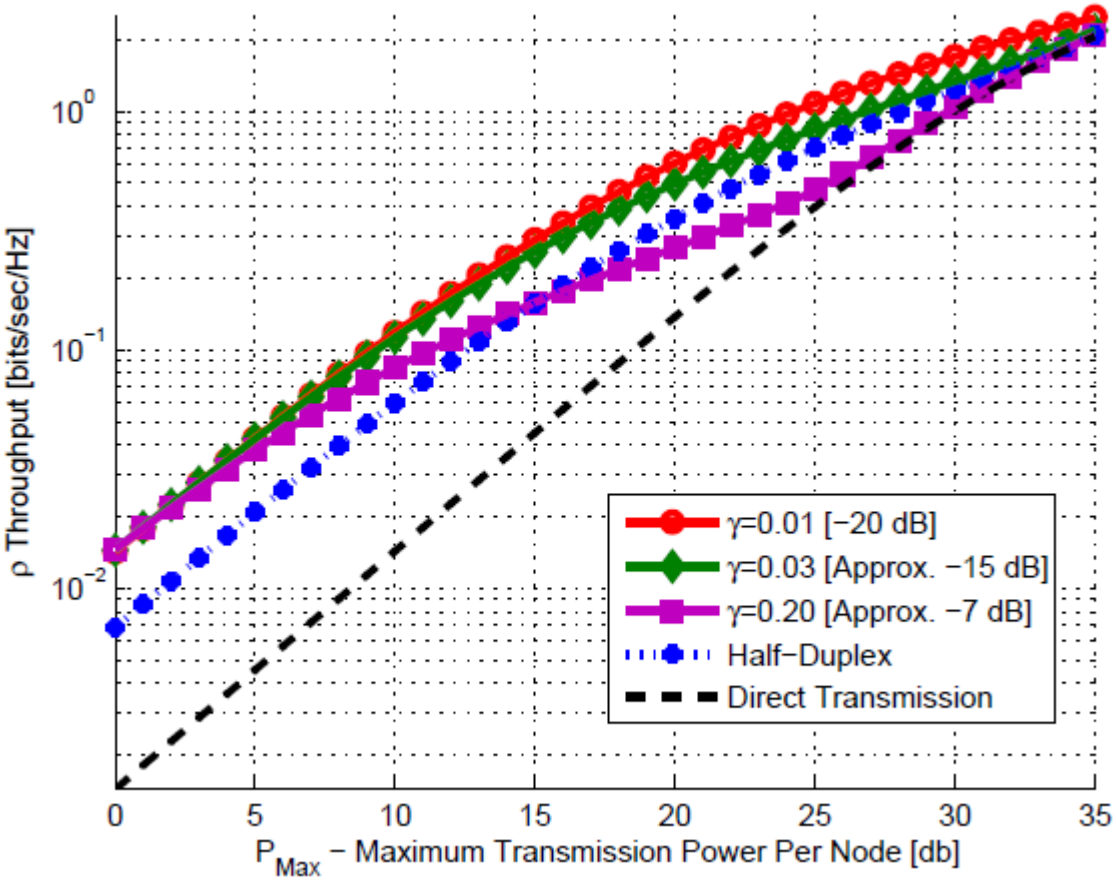
- without interference



- with interference

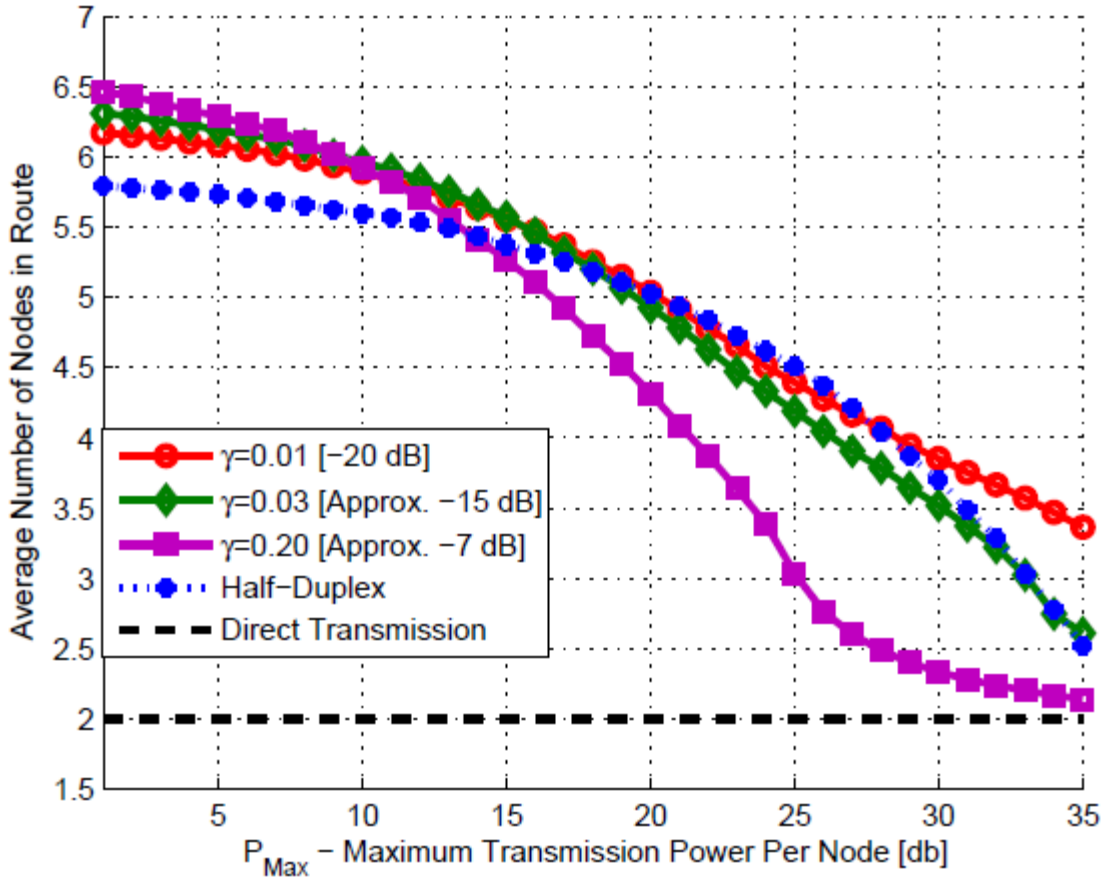


Results - Throughput



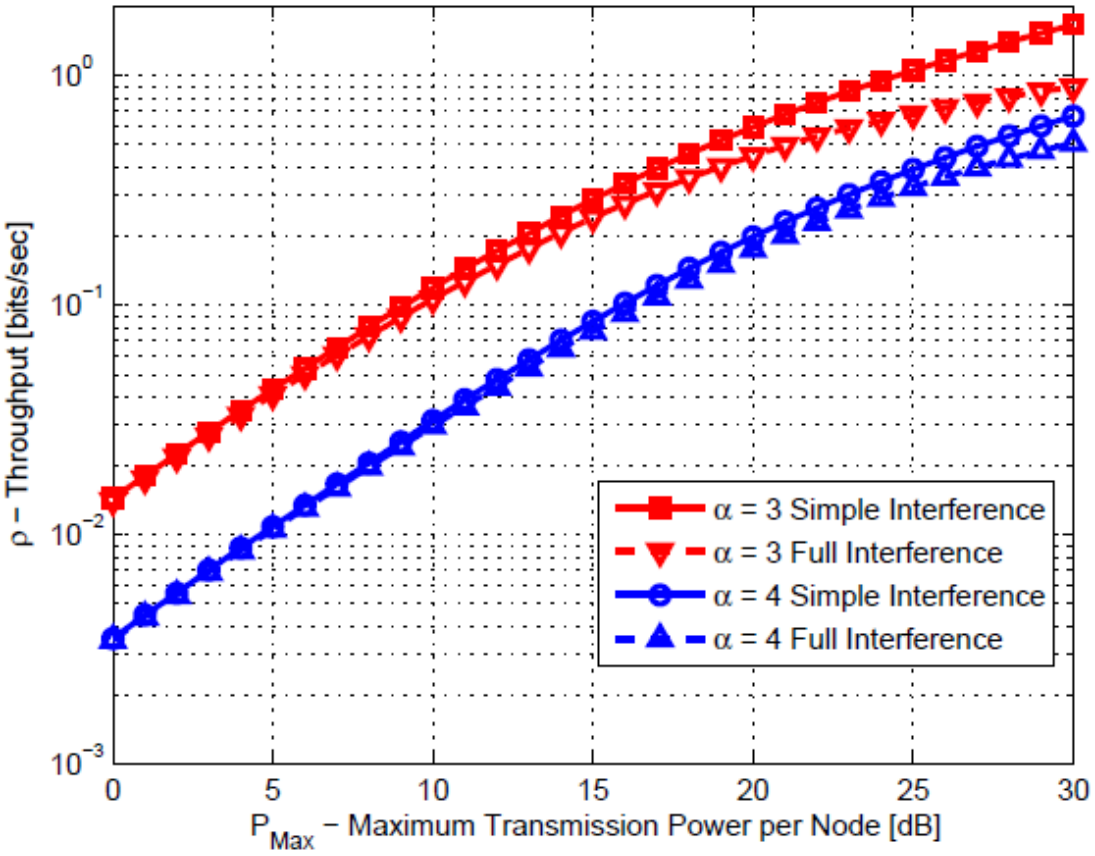
$\alpha = 3$ $N = 20$ $d_{S,D} = 20m$

Results – Optimal Route Length



$\alpha = 3$ $N = 20$ $d_{S,D} = 20m$

Results – Simplified vs. Full model



$N = 20$ $\quad d_{S,D} = 20m$ $\quad \gamma = 0.01 = 20dB$

Summary and Future Work

- Summary
  - simplified interference model
  - power allocation similar to polynomial root finding
  - algorithm for routing and power allocation
- Future Work
  - difference from optimal full interference solution
  - multiple source-destination pairs

References

- X. Fang, D. Yang, and G. Xue, “Distributed algorithms for multipath routing in full-duplex wireless networks,” in *Mobile Adhoc and Sensor Systems (MASS), 2011 IEEE 8th International Conference on*, Oct. 2011.
- C. Weeraddana, M. Codreanu, M. Latva-aho, and A. Ephremides, “Resource allocation for cross-layer utility maximization in multi-hop wireless networks in the presence of self interference,” in *Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt), 2010 Proceedings of the 8th International Symposium on*, June 2010
- M. Duarte and A. Sabharwal, “Full-duplex wireless communications using off-the-shelf radios: Feasibility and first results,” in *Signals, Systems and Computers (ASILOMAR), 2010 Conference Record of the Forty Fourth Asilomar Conference on*, Nov. 2010, pp. 1558 –1562
- M. Jain, J. I. Choi, T. Kim, D. Bharadia, S. Seth, K. Srinivasan, P. Levis, S. Katti, and P. Sinha, “Practical, real-time, full duplex wireless,” in *Proceedings of the 17th annual international conference on Mobile computing and networking*, ser. MobiCom ’11. ACM, 2011.
- Ramirez, David, and Behnaam Aazhang. “Optimal Routing and Power Allocation for Wireless Networks with Imperfect Full-Duplex Nodes.” *Wireless Communications, IEEE Transactions on* 12.9 (2013) 4692-4704