Simplicity in Complex Networks

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COS 561
November 25, 2008

Six Viewpoints on Complex Networks

Simple Description:

- From Descriptive to Explanatory Models
- From Homogeneous to Heterogeneous Models

Simple Conceptual Framework:

- From Describing to Deriving Architectures
- Robustness to Network Dynamics

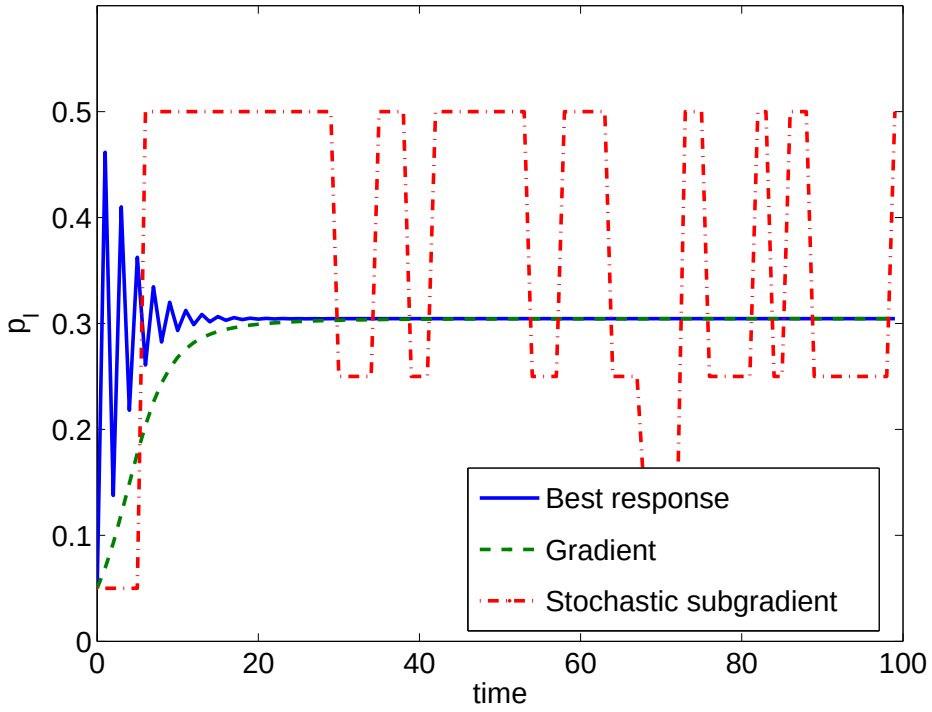
Simple Protocols:

- Tradeoff with Complexity
- Design for Optimizability

Making a difference in large-scale operational networks

1. From Descriptive to Explanatory

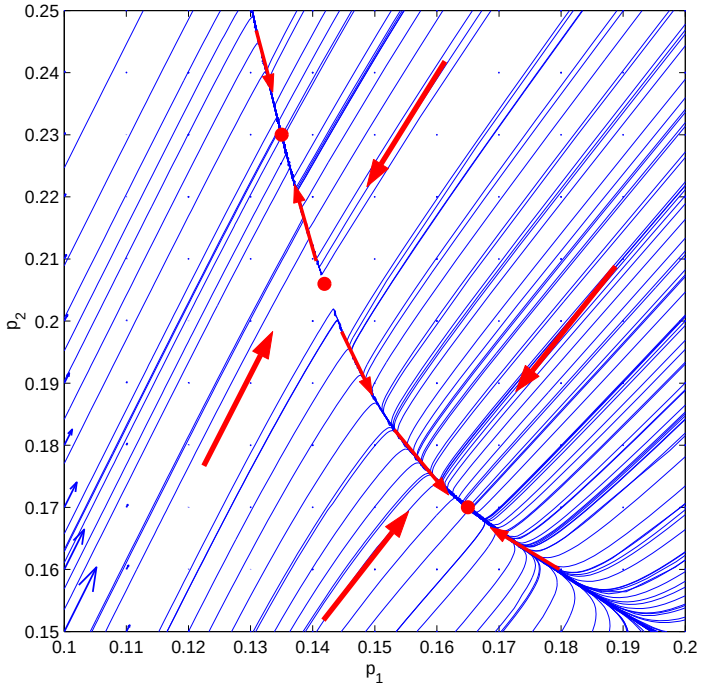
Reverse engineer backoff MAC as a non-cooperative game

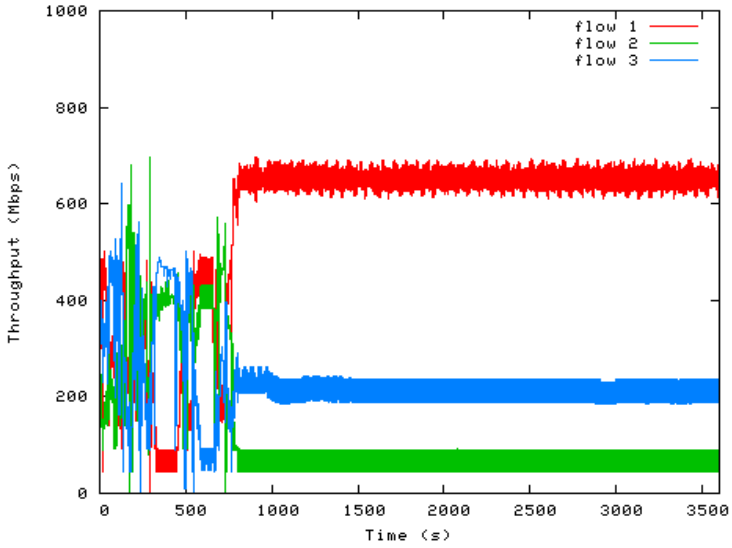


J. W. Lee, A. Tang, J. Huang, M. Chiang, and A. R. Calderbank, "Reverse engineering MAC: A game-theoretic model", *IEEE Journal of Selected Areas in Communication*, Jul. 2007

2. From Homogeneous to Heterogeneous

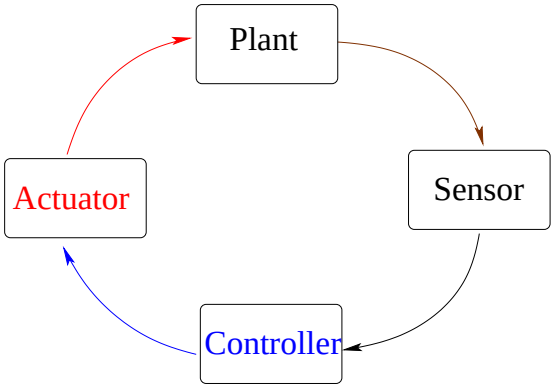
Steering heterogeneous congestion control to desirable equilibria

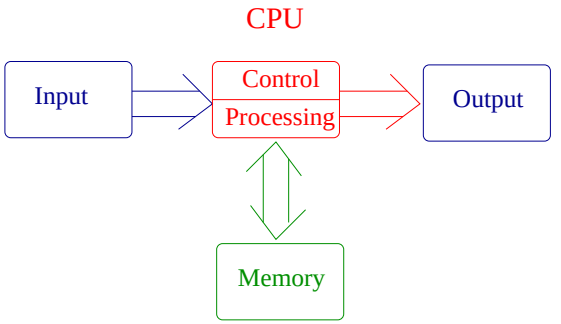




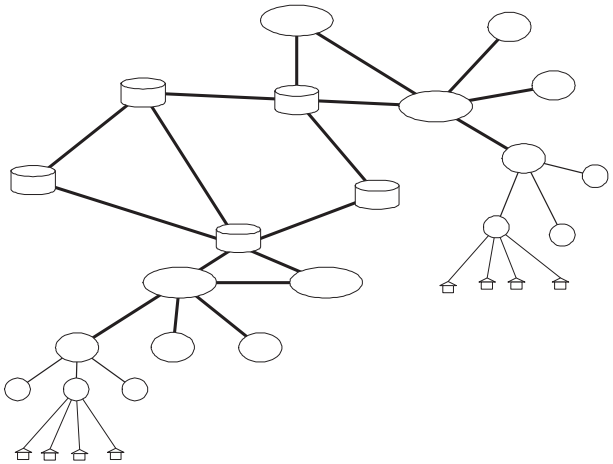
A. Tang, J. Wang, S. H. Low, and M. Chiang, "Equilibrium of heterogeneous congestion control protocols: Existence and Uniqueness", *IEEE/ACM Transactions on Networking*, Jul. 2007

3. Architecture



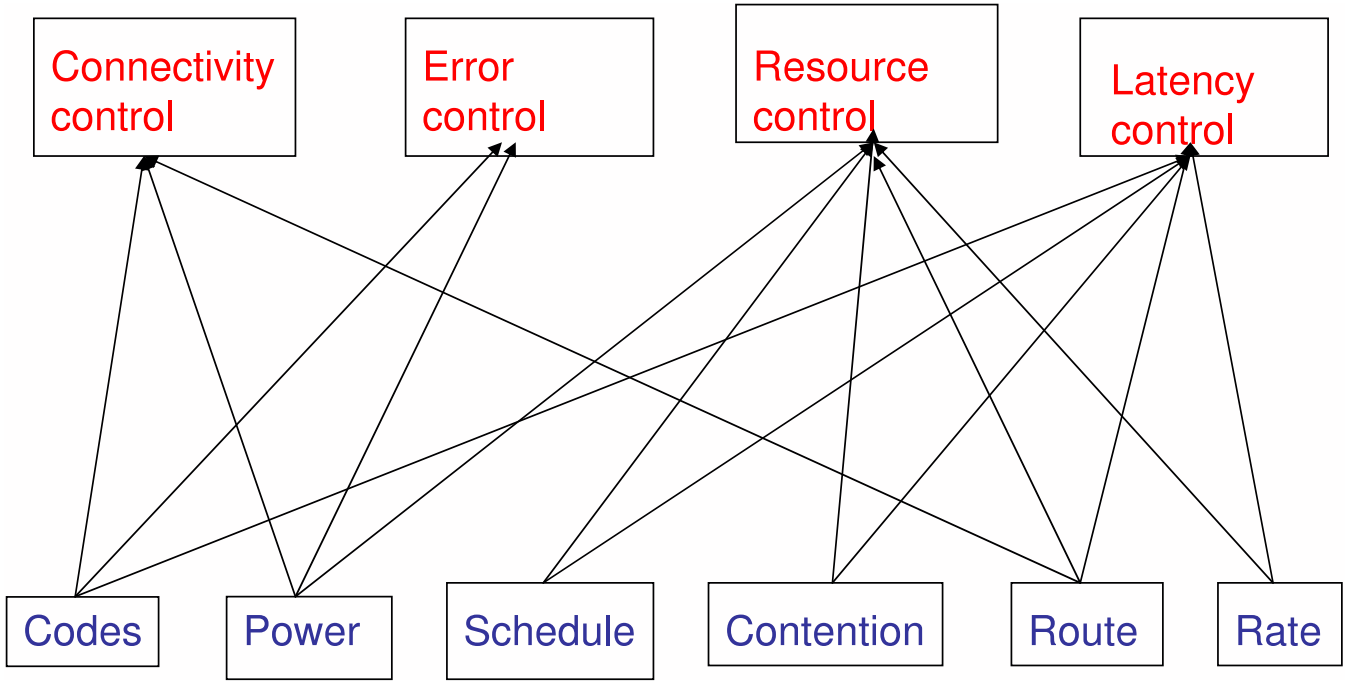


Application
Presentation
Session
Transport
Network
Link
Physical



3. Math Foundation for Network Architecture

Who should do what and how to connect them



M. Chiang, S. H. Low, A. R. Calderbank, and J. C. Doyle, "Layering as optimization decomposition: A mathematical theory of network architectures", Proceedings of the IEEE, Jan. 2007

3. Layering As Optimization Decomposition

Network: Generalized NUM

Layering architecture: Decomposition scheme

Layers: Decomposed subproblems

Interfaces: Functions of primal or dual variables

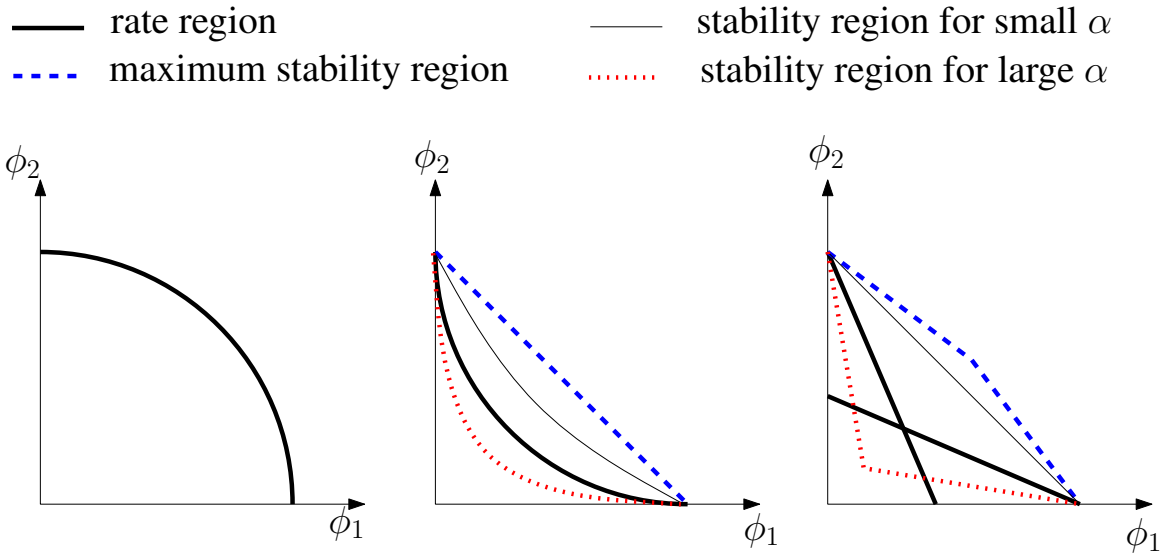
Horizontal and vertical decompositions through

- implicit message passing (e.g., queuing delay, SIR)
- explicit message passing (local or global)

3 Steps: G.NUM $\Rightarrow$ A solution architecture $\Rightarrow$ Alternative architectures

4. Robustness: Stochastic NUM

Stochastic dynamics at session, packet, and constraint levels

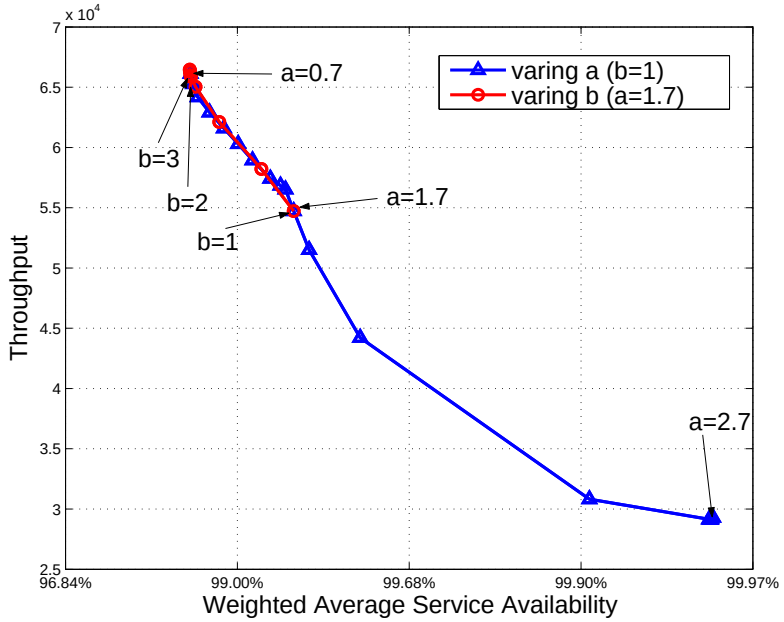


(a) convex rate region (b) nonconvex rate region (c) time-varying rate regions

Y. Yi and M. Chiang, "Stochastic network utility maximization: A tribute to Kelly's paper published in this journal a decade ago", *European Transactions on Telecommunications*, March 2008

4. Robustness: Availability Provisioning

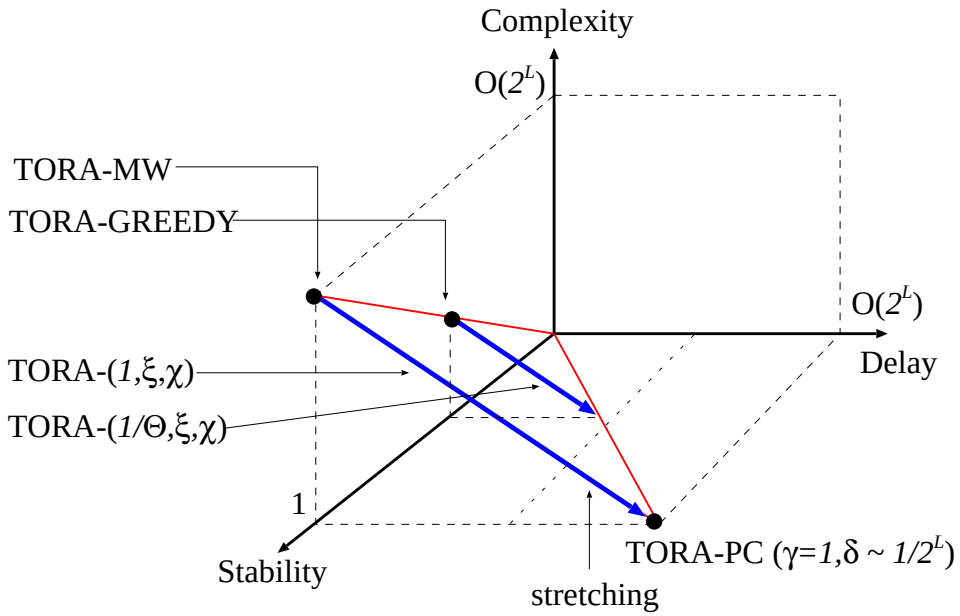
Quantify tradeoff: normal-time throughput and down-time availability



D. Xu, Y. Li, M. Chiang, and A. R. Calderbank, "Elastic service availability: Utility framework and optimal provisioning", *IEEE INFOCOM*, 2007

5. Tradeoff with Complexity

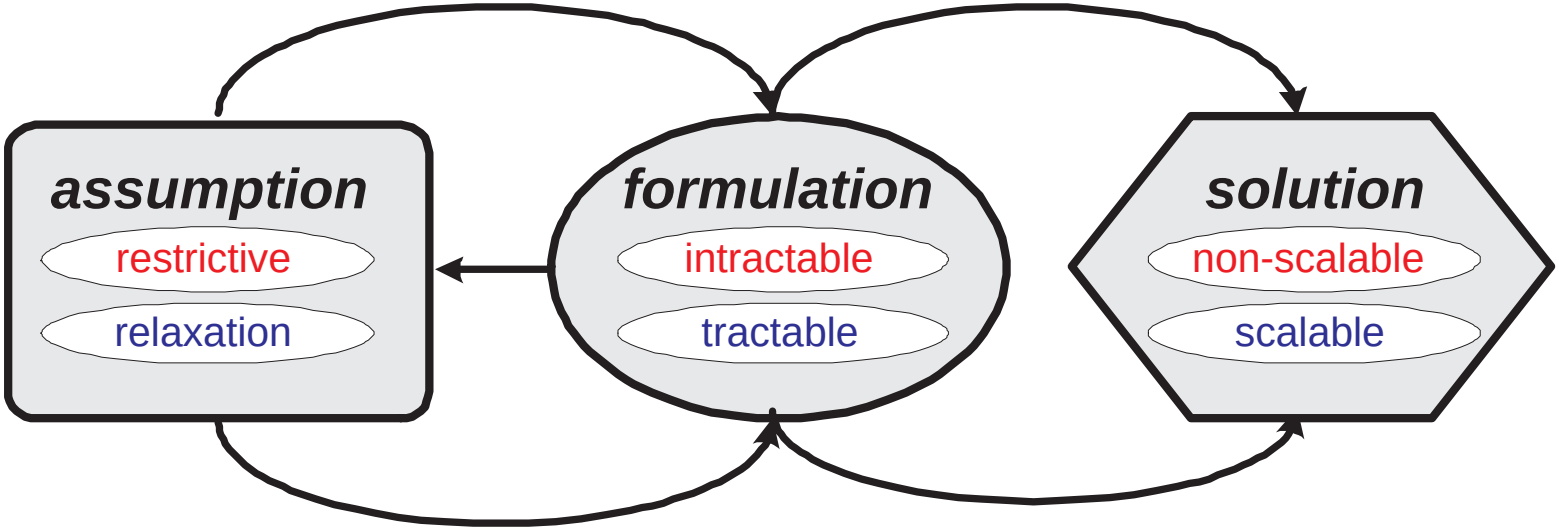
3D throughput-delay-complexity tradeoff in a parameterized framework



Y. Yi, A. Proutiere, and M. Chiang, "Complexity-stability-delay tradeoff in scheduling over wireless networks", *ACM Mobihoc*, May 2008

6. Optimizability

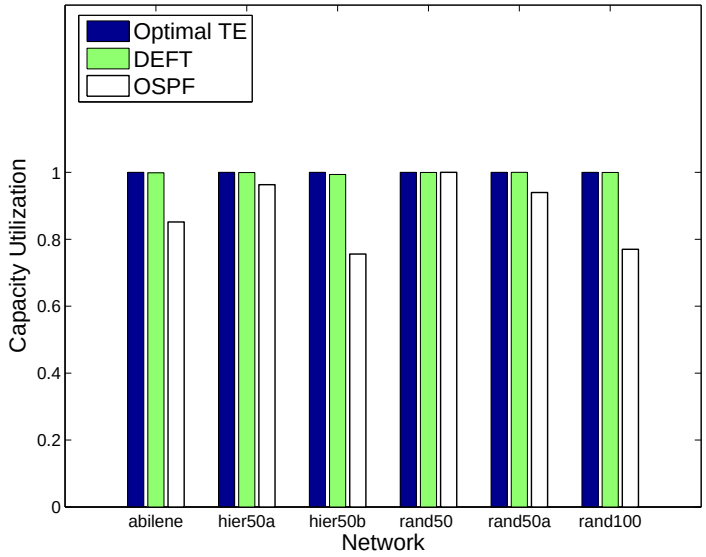
Design for optimizability

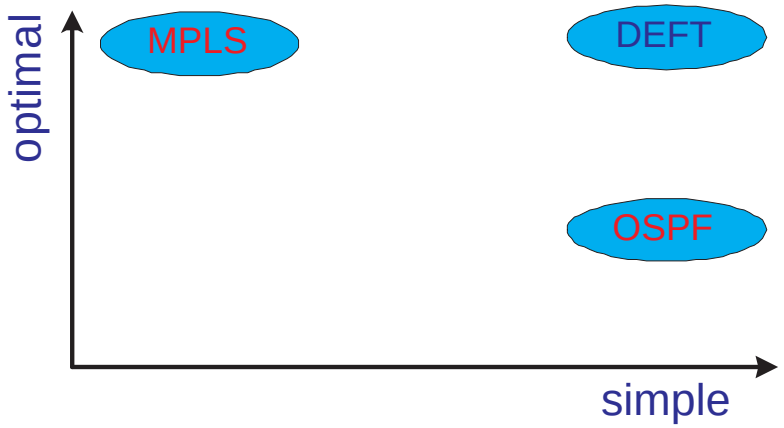


J. He, J. Rexford, and M. Chiang, "Don't optimize existing protocols, design optimizable protocols", *ACM Sigcomm Computer Communications Review*, Aug. 2007

6. DFO At Work

Simple distributed routing achieves optimal Internet traffic engineering

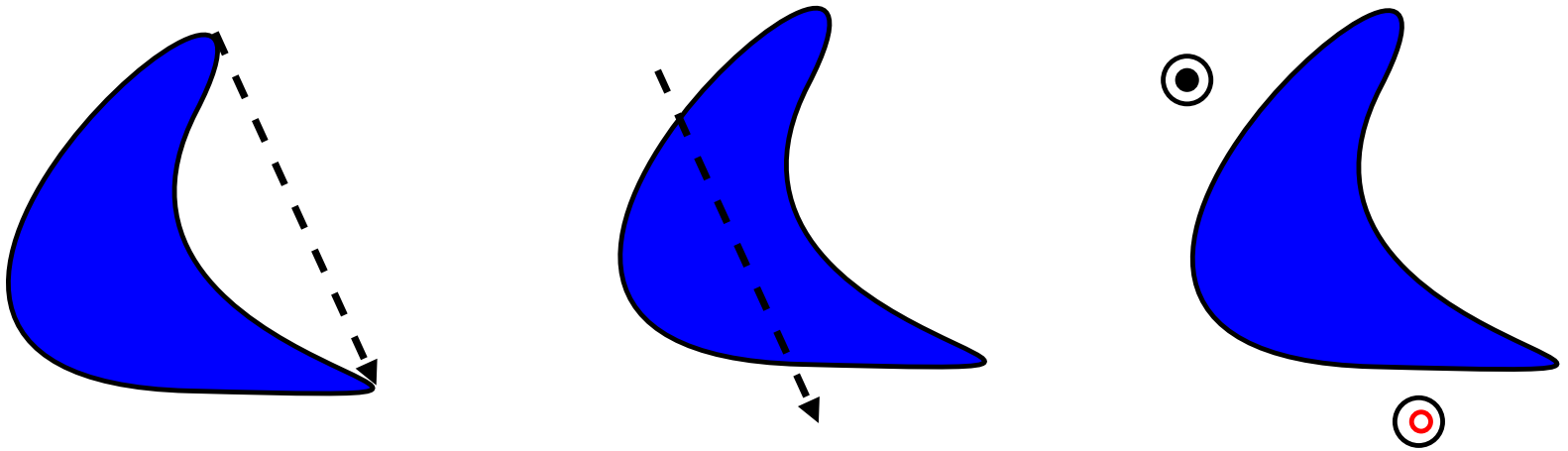




D. Xu, M. Chiang, and J. Rexford, "Link-state routing with hop-by-hop forwarding achieves optimal traffic engineering", *IEEE INFOCOM*, 2008

Geometry of Simplicity

Around, Through, or Above Nonconvexity



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M. Chiang, "Nonconvex optimization of communication systems", *Advances in Mechanics and Mathematics, Special Volumn on G. Strang's 70th Birthday*, Ed., D. Gao and H. Sherali, Springer, 2008.

Applications to Operational Networks

- Wireline Broadband Access

FAST Copper Project: With AT&T and Marvell

- Wireless Broadband Access

Load-spillage power control: With Qualcomm and Siemens-Nokia

- Internet Management and Virtualization

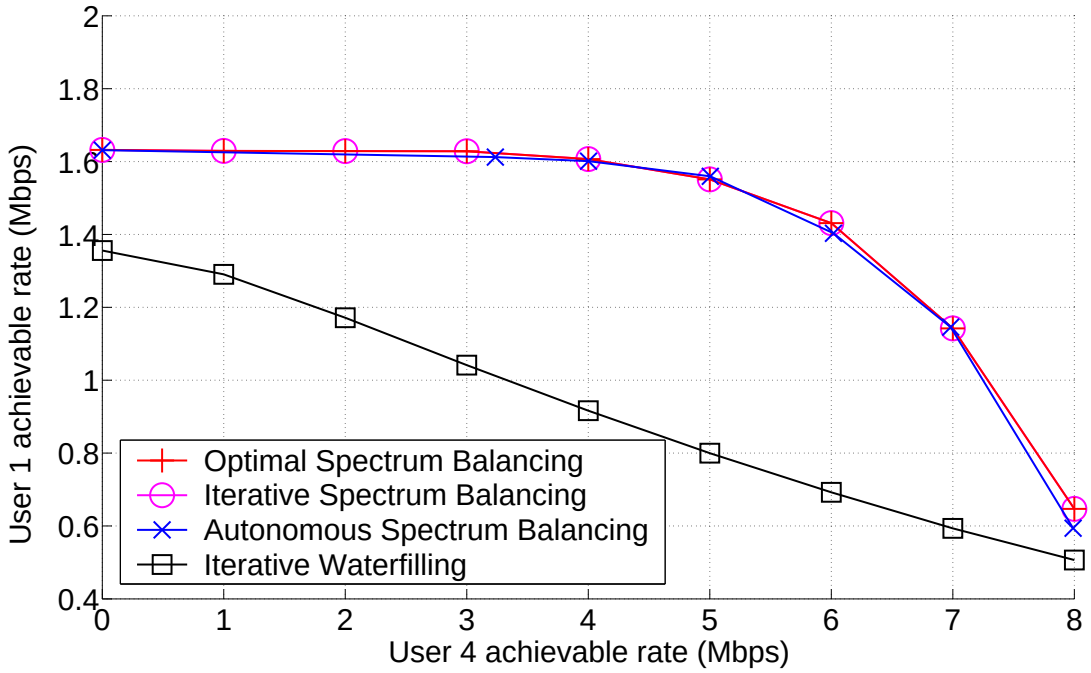
DEFT and Adaptive Virtualization: With AT&T and Cisco

- Content Distribution and P2P

Achieving streaming capacity of P2P: With Microsoft and Motorola

Application: Wireline Broadband Access

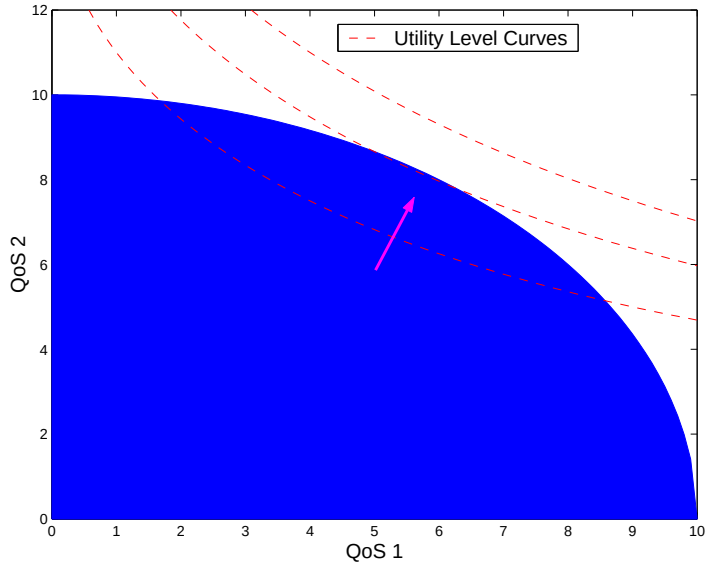
Power allocation over multi-carrier interference channel of DSL



R. Cendrillon, J. Huang, M. Chiang, and M. Moonen, "Autonomous Spectrum Balancing for Digital Subscriber Lines", *IEEE Transactions on Signal Processing*, Aug. 2007

Application: Wireless Broadband Access

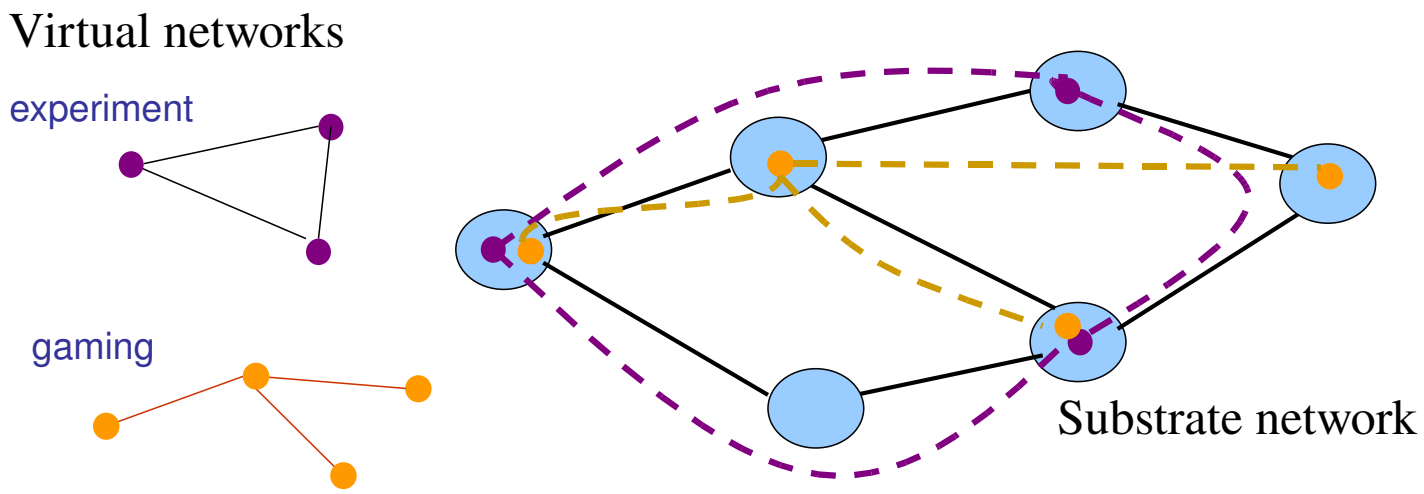
Maximize: utility function of powers and SIR assignments
Subject to: SIR assignments feasible
Variables: transmit powers and SIR assignments



P. Hande, S. Rangan, M. Chiang, and X. Wu, "Distributed uplink power control for optimal SIR assignment in cellular data networks", *IEEE/ACM Transactions on Networking*, 2008

Application: Virtual Network Embedding

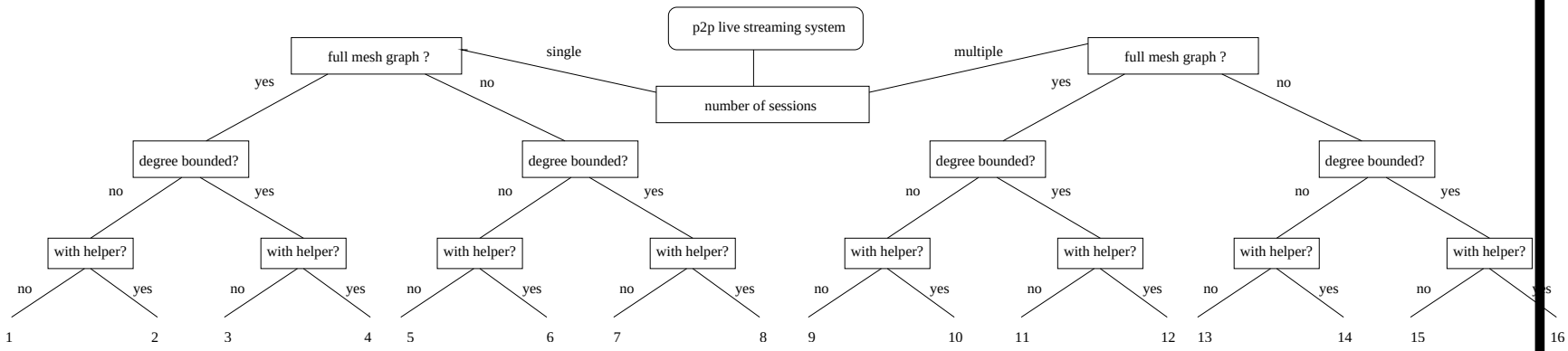
Multipath support in substrate to enable more efficient virtualization



M. Yu, Y. Yi, J. Rexford, and M. Chiang, "Rethinking virtual network embedding: Support of path splitting and migration", *ACM Computer Communication Review*, April 2008

Application: P2P Content Sharing

Fundamental bounds on how much can P2P help in streaming



S. Liu, R. Zhang-Shen, W. Jiang, J. Rexford, and M. Chiang, "Performance bounds for peer-assisted live streaming", *ACM Sigmetrics*, 2008

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