TWENTY FIVE YEARS OF WIRELESS NETWORKS

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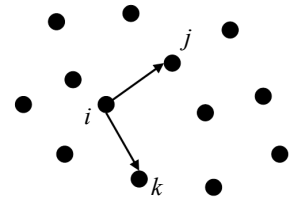
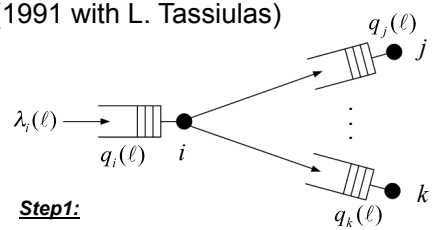
Back-Pressure Algorithm (BPA)

(1991 with L. Tassiulas)



-arbitrary wireless network

-L "commodities" (i.e. S-D pairs)



Claim

Def: The set of all arrival rates $\lambda_i(\ell)$ that can be served without any of the queue sizes growing to infinity is called: *Stable Throughput Region*.

Result: If $\bar{\lambda}$ is in the Stable Throughput Region, then the BPA achieves stable behaviour.

Step1:

$$\beta_{ij} = \max_{\ell \in L}[q_i(\ell) - q_j(\ell)]$$

"Choose the commodity over link (i,j) that has the maximum differential backlog"

Step2:

Select the set (S) of links that can be activated simultaneously so that $\sum_{(i,j)\in S} \beta_{ij}$ is maximum.

**** This work started a new direction of research that continues to date ****

"Rate" Regions

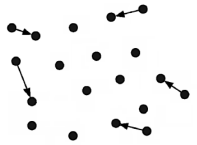
(2005 with Jie (Rockey) Luo)

C: (Saturated) Capacity Region = Maximal set of achievable rates (bits/s) when sources are backlogged.

T: (Saturated) Throughput Region = Maximal set of achievable rates (packets/slot) when sources are backlogged.

S: Stable Throughput Region = Maximal set of achievable rates (packets/slot) so that queue sizes do not grow to infinity (Bursty sources).

C': Stable Capacity Region = Maximal set of achievable rates (bits/s) so that queue sizes do not grow to infinity (Bursty Sources) -Timing Channels-



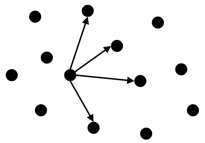
-arbitrary wireless network

1. We show that S can be greater than T
2. We show that C' can be greater than C.
3. For "Packet erasure Channels" and simple multiple access T=C. Also, S=T under the hypothesis of *sensitivity monotonicity*.

****A major contribution towards bridging the gap between Information Theory and Networking****

Wireless Network Coding

(2005 with Y. Sagduyu) (2007 with B. Shrader)



-arbitrary wireless network

-Multicasting (each stream has multiple destinations).

Random Network Coding for Wireless

1. The RNC theory can be generalized to wireless networks if the *"capacity"* of each node is redefined as *"one"* instead of as the degree of the node.
2. Performance of RNC (i.e. achievement of *"capacity"*) depends on the Media Access Control Layer.
3. Delay Performance of Content Distribution with RNC was fully characterized.

Random Network Coding (RNC)

- In wireline networks, it was established that merging traffic streams that are destined for multiple destinations in the manner of:

$$a_1P_1 \oplus a_2P_2 \oplus \ldots\ldots \oplus a_nP_n$$

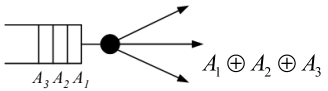
Where $a_i \in$ symbol alphabet and P_i is the corresponding packet of the ith stream.

Can achieve the max-flow/min-cut rate bound.

- It was shown by R. Koetter et al (2003) that the a_i 's can be chosen randomly

Content Distribution

Performing RNC over the content of a file improves multicast throughput.

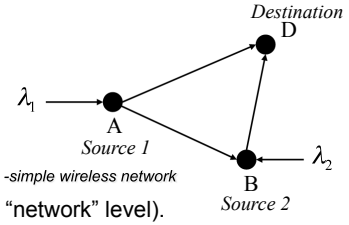


**** Extended the Power of Network Coding to Wireless ****

Cooperative Networking

(2010 with B. Rong)

- Cooperative techniques have been developed mostly at the physical layer (Amplify and Forward, Decode and Forward, etc).
- Result of *MIMO* Technology.
- Main mechanism: *RELAY*.



-simple wireless network

- Proposed simple Relaying Function (at "packet" or "network" level).
- Channels A→D, B→D, and A→B: Packet erasure.
- Criterion: Stable Throughput
- Assume channel B→D is superior to channel A→D.

Claim: If B relays A's packets to D (that fail direct transmission) then ***both*** A and B benefit (Stable Throughput Region increases).

**** Has started a new form of cooperative techniques ****