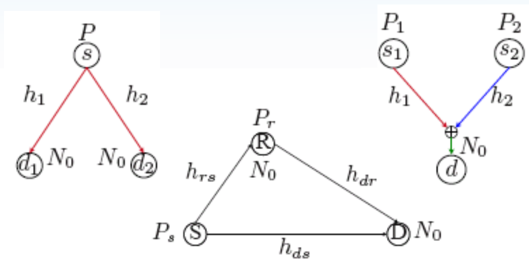
A comparative taxonomy of wireless networks in the wideband regime – *Fawaz, Thakur, Médard*

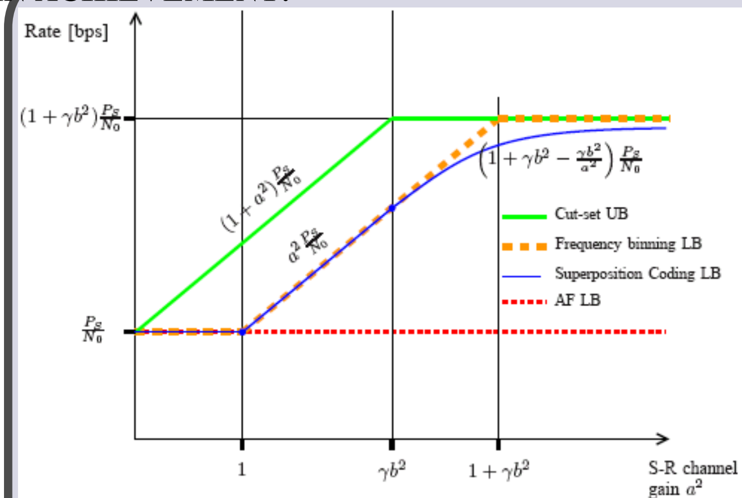
FLoWS ACHIEVEMENT

STATUS QUO



- *Capacity of wideband BC and MAC known*
- *Capacity of wideband relay channel unknown, but achievable rates + cut-set upper-bound*
- *Capacities linear in received SNR in wideband regime*

MAIN ACHIEVEMENT:



HOW IT WORKS:

Hypergraph models

- Model the broadcast nature of wireless transmission
- Clarify correlation between messages
- Correspondance with transmission schemes for wideband AWGN and fading models

MAC and BC: equivalent hypergraph model

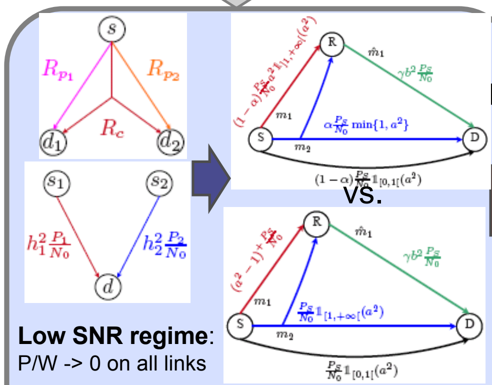
Relay channel: comparison of min-cuts of achievable hypergraphs

[Peaky binning hypergraph] **vs.** [Concatenation of BC and MAC equivalent hypergraph: superposition coding and FD] **vs.** [AF hypergraph]

ASSUMPTIONS AND LIMITATIONS:

- Wideband regime assumption
- Single source systems

NEW INSIGHTS



Low SNR regime:
P/W -> 0 on all links

Wideband point-to-point, BC, MAC and relay channels:

- Equivalent or achievable hypergraph models
- Transmission schemes achieving hypergraph min-cut for the AWGN and non-coherent multipath fading channels
- How does the optimal scheme for wideband BC and MAC perform in the relay channel?

IMPACT

1. **Hypergraph = *wired-like* error-free models** for error-prone wireless systems => apply network optimization tools

2. **Achievable hypegraphs of larger wideband networks** built from hypergraphs of small blocks (Point-to-Point, BC, MAC,Relay)

3. **Wideband relay channel > concatenation of wideband BC and MAC**
   - Highest rate achieved by block markov DF in AGWN/peaky binning DF in fading
   - Superposition coding is suboptimal in AWGN, yet close to optimal and easy to scale
   - AF equivalent to direct transmission

END-OF-PHASE GOALS

- Converse for relay channel
- Extension to optimization problem in larger networks in low SNR thanks to hypergaph model
- Optimal relay placement and geometry of wireless networks in wideband regime

Equivalent and achievable hyperpgrah models for building blocks of MANETs

Optimal relay location and power allocation for low SNR broadcast relay channels - *Thakur, Fawaz, Médard*

FLOWS ACHIEVEMENT

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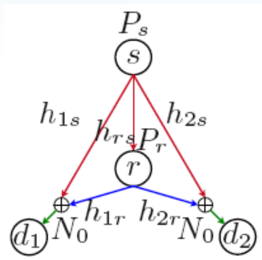
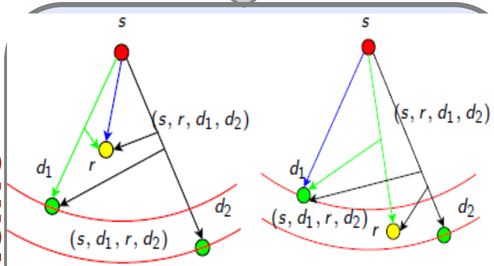


Wireless relay networks

- *optimization of relay location addressed in high SNR regime only*
- *optimization of power allocation alone addressed in low SNR regime*

NEW INSIGHTS



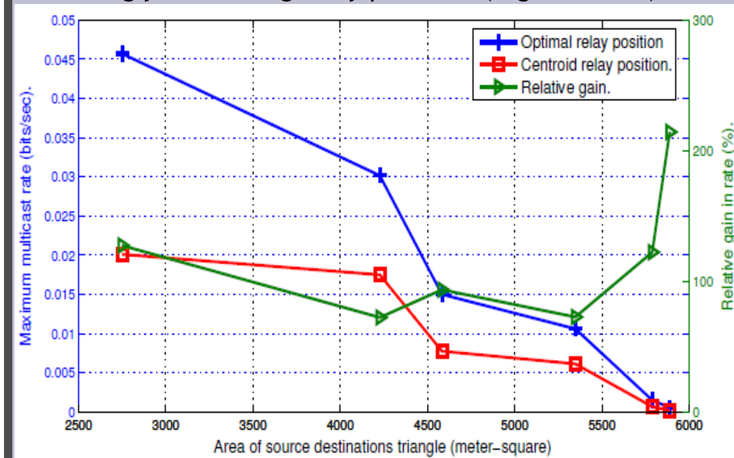
Problem: relay position and power allocation to maximize multicast rate in wideband broadcast relay channel

Hypergraph model =function of power allocation and relay location

Continuous switch functions to model varying hypergraph as relay position changes

MAIN RESULT:

Optimal relay positioning shows strong gains over seemingly interesting relay positions (e.g. centroid)



HOW IT WORKS:

Using superposition coding and frequency division – a wireline like model is created – Achievable hypergraph.

2-D plane is divided into disjoint regions for different relay positions with invariant network hypergraph (k-nearest neighbour problem).

Using switch functions, a combined network optimization problem is formulated.

ASSUMPTIONS AND LIMITATIONS:

Single source-multiple destination networks with a single relay as the only intermediate node.

Multicast rate maximization is considered.

Non-convex network optimization.

IMPACT

Optimal relay positioning shows gains compared to seemingly interesting positions

Achievable hypergraph approach (superposition coding and frequency division) for low-SNR networks offers a simple and easily scalable network model and transmission scheme

END-OF-PHASE GOALS

Exploring geometric properties of multicast in wireless networks to significantly reduce complexity.

Extension to multiple relay scenario

A comprehensive approach based on network optimization, computational geometry and information theory for optimal relay positioning is presented for low-SNR networks

A converse for the wideband relay channel – *Fawaz, Médard*

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FLoWS ACHIEVEMENT

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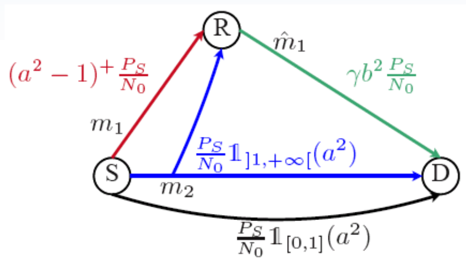
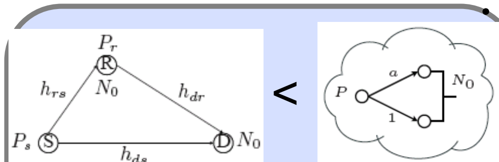


Capacity of general relay channel unknown

- *Bounds on general relay channel*
- *In wideband regime, cut-set upper-bound and lower bounds on AWGN/Fading relay channel*

NEW INSIGHTS

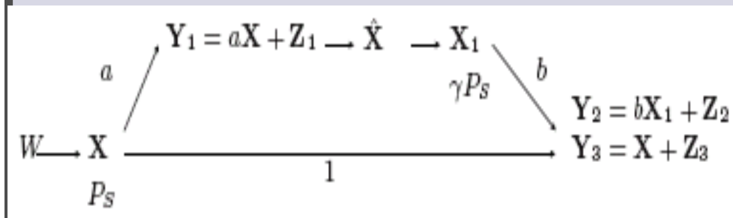


Relay channel in low SNR /wideband regime:

- At low SNR, cut-set upper-bound = virtual MIMO with perfect channel R-D, is not achievable

- Block Markov DF/ peaky binning hypergraph lower-bound is tight = capacity

MAIN ACHIEVEMENT:



HOW IT WORKS:

Assuming that the relay cannot decode:

- Split total mutual information into two parts
  - contribution from relay
  - remaining contribution from source after deducting contribution from relay
- Bound contributions using equivalence theory and rate distortion theory, in particular to justify
  - Gaussian input at source
  - Estimation with distortion at relay
  - Error-free R-D link with finite capacity
- Analyze the limit of these contributions in the low SNR regime and show that the total converges to the direct link capacity

Conclusion: the relay should decode in the low SNR

ASSUMPTIONS AND LIMITATIONS:

- Low SNR assumption

IMPACT

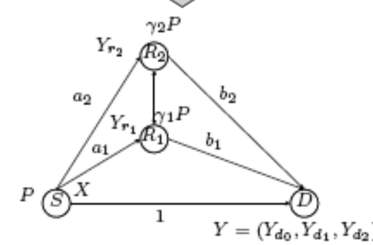
1. **Capacity of multipath fading /AGWN relay channel in low SNR regime**

   - Hypergraph min-cut
   - Achieved by block Markov DF in AWG relay channel and simple non-coherent peaky binning DFin the fading channel

2. **Network Coding in the digital domain at low SNR**

3. **New upper-bounding technique for capacity based on network equivalence theory**

END-OF-PHASE GOALS



-Scalability of optimal relaying scheme

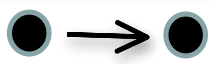
-Comparison with simpler and easy to scale linear schemes

Characterizing the capacity of the relay channel in the wideband regime

Positive Recurrent Medium Access

PI: *Shah*

STATUS QUO



Medium Access Control (MAC) is fundamental protocol of modern wireless communication

•Random backoff with CSMA provably works when demand is static (prior work of PI)

•In practice, demand could be dynamic

NEW INSIGHTS

Parameter $W(t)$

Observation $Y(t) \sim \text{Geom}(1/W(t))$

Learning Parameters of Time Varying Poisson Process based on Very Noisy Observations

ACHIEVEMENT

MAIN ACHIEVEMENT:

Efficient, distributed MAC that can deal with dynamics in demand

- Formally, it is positive recurrent
- Random access probability :
  - function of queue-size, learnt info.
- Totally distributed, *no* message-passing

Learning $W(t)$

Short term $S(t)$

Long term $L(t)$

$$L(t+1) = L(t) \begin{cases} + \frac{1}{g(L(t))} & \text{if } S(t) > L(t) \\ - \frac{1}{g(L(t))} & \text{if } S(t) \leq L(t) \end{cases}$$

where $g(x) = \exp(\exp(\log^{\frac{1}{4}} x))$

HOW IT WORKS:

- Learning rates of time varying Poisson process
  - Appropriate *filter* design
  - Using a clever choice of function

ASSUMPTIONS AND LIMITATIONS:

- Collision based model of physical layer

IMPACT

$L(t)$ is near $W(t)$

$$|L(t) - W(t)| = o(W(t)) \quad \text{whp}$$

Resolution of a long-standing problem: fully distributed, efficient MAC that is positive recurrent (can deal with dynamic demand)

New theory for learning rates of time varying Poisson process using noisy observations

NEXT-PHASE GOALS

Beyond Inference=Noise

- Dealing with hidden terminals
- Improving delay through utilization of geometry

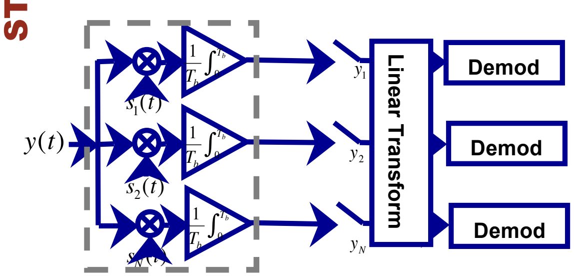
Resolution of a long standing challenge for network & information theory --- efficient, distributed wireless medium access

Reduced-Dimension Multiuser Detection

Y. Xie, Y. C. Eldar and A. Goldsmith

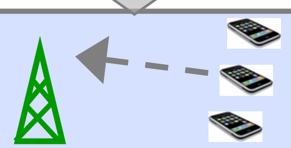
STATUS QUO

- Conventional multiuser detector employs a matched filter bank
- MF bank requires correlation with all possible signature waveforms
- High complexity with many users



The Conventional MUD (A. Duel-Hallen Et.al., Multiuser detection for CDMA systems, 1995)

NEW INSIGHTS



Base Station **Users**

- The number of active users K can be much smaller than N users – **user sparsity**
- Correlate with much fewer correlating waveforms can achieve similar detection BER to MF bank

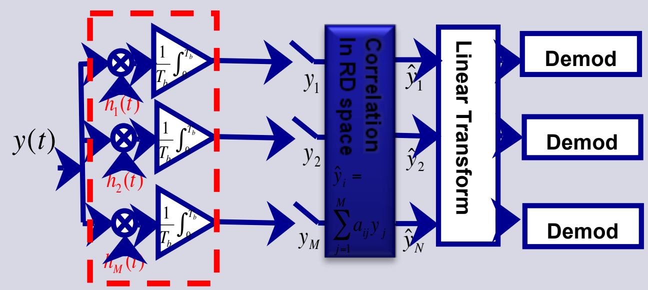
ACHIEVEMENT

MAIN RESULTS:

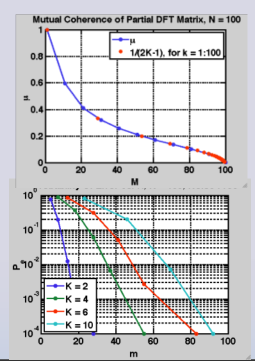
Compressive detection is done by first correlating with M sensing signals, then postprocessing to detect active users and their symbols. Sensing signals are constructed by linearly combining bi-orthogonal waveforms.

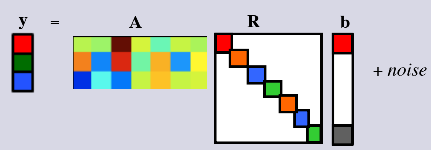
Performance guarantee of linear detector using worst coherence of combination partial DFT coefficient matrix

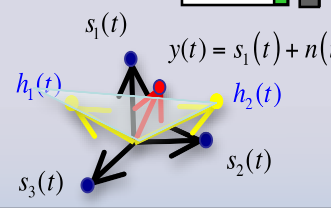
- Without noise, achieve correct detection:
  - K = 1, M = 2, BER = 0
  - K > 1, μ < 1/(D×(2K-1)), μ = max $a_i'a_j$
- With noise
  - μ < 1/(D×(2K-1)) f(SNR, N)



Intuition: project the original space consisting of N-dimensional waveforms onto an M-dimensional subspace.





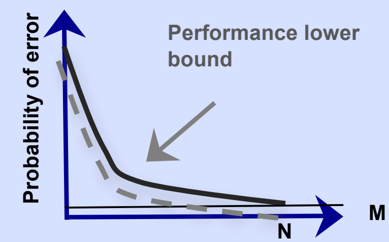


IMPACT

New detection framework: compressive detection allows for lower complexity front-end for all types of MUD detectors: linear detector, decorrelator, iterative detector, maximum likelihood detector.

Other applications: Compressive ARQ protocol, wideband white space detection, multi-sensor detection

Complexity-performance tradeoff



NEXT-PHASE GOALS

- Noise in RD-MUD is colored. How to optimally detect in colored noise
- Develop tighter performance guarantee based on restricted isometry constants (RIC)
- Performance guarantee based for other detectors: decorrelator, iterative detector based on OMP, maximum likelihood detector.

Low-complexity multiuser detection employs sparsity in the number of active users with analog processing

Mean Field Equilibria of Dynamic Auctions with Learning

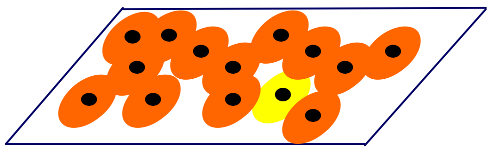
K. Iyer, R. Johari, and M. Sundararajan

DARPA

IPTO INFORMATION PROCESSING TECHNIQUES OFFICE

ACHIEVEMENT DESCRIPTION

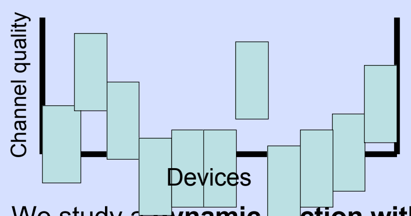
STATUS QUO



Many cognitive radio models do not account for **reaction** of other devices to a single device's action.

In prior work, we developed a general **stochastic game** model to tractably capture interactions of many devices via **mean field equilibrium**.

NEW INSIGHTS



We study a **dynamic auction with learning**.

Example: Multiple devices bid to share a channel; devices must learn their own channel quality.

We apply **mean field equilibrium** to obtain structural insights.

MAIN ACHIEVEMENT:

We show there exists a structurally simple MFE of a dynamic auction with learning, where at each time step a bidder participates in a Vickrey auction.

At each time step a bidder bids:

Conditional expected value of channel quality (given posterior) + Expected marginal value of one additional observation of channel quality

HOW IT WORKS:

Consider a limiting regime where # of bidders (N) and # of auctions (k) grows large, while holding # of bidders per auction (α) fixed.

$$\overbrace{\alpha \quad \alpha \quad \alpha \quad \cdots \quad \alpha}^{k}$$

An individual bidder's problem simplifies in this limit.

ASSUMPTIONS AND LIMITATIONS:

Our work provides existence of a simple equilibrium, but does not show how to converge to it.

We are applying a form of *model predictive control* to show that such equilibria can be easily found by bidders.

IMPACT

Dynamic auctions with learning have been widely studied across economics and engineering, but with little structural insight.

Our work provides a simple, intuitive description of how we expect bidders to play.

END-OF-PHASE GOALS

Provide a mechanism to converge to MFE.

- *Leverage methodology developed in earlier work on stochastic games with complementarities*
- *Also study how equilibria vary as parameters of the system are changed (i.e., # of bidders per auction)*

A sentence why it is important/useful

Instantaneous Efficiency of Communication

L. Zheng

STATUS QUO

•Information measured in rate and error exponent, lack of measure of soft information exchange

• Optimality in terms of long time average performance, not necessarily efficient at every time instance

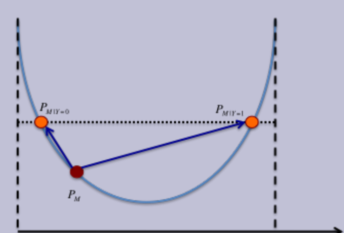
NEW INSIGHTS

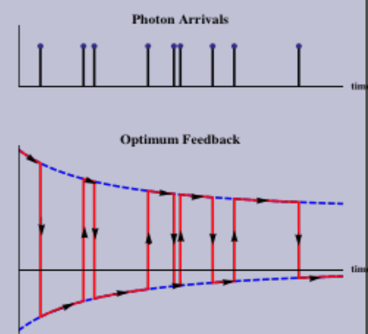
Information transmission with a single observation can be described as splitting of posterior distribution over messages, The measure of efficiency is however not unique, depends on how the information is combined with other observations

ACHIEVEMENT DESCRIPTION

MAIN RESULT:

- **Capacity and Error exponent optimal random coding schemes can be viewed as instantaneous optimization of certain metrics;**
- **Family of Renyi divergences measure information according to the urgency of decision making;**
- **Instantaneous efficiency particularly applicable for lossy processing.**





- **Two elements in designing of instantaneously efficient signaling**
  - **Choice of metrics**
  - **Progress balancing**

END-OF-PHASE GOAL

•Demonstrate the power of instantaneous designs in coded transmissions

• Apply to classical problems such as distributed hypothesis testing

COMMUNITY CHALLENGE

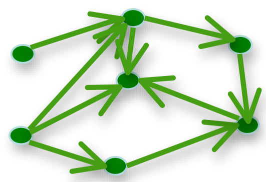
General design based on instantaneous efficiency should have broader applications in networked problems, utilizing all the temporal information

Different coding metrics at different time of a block

Separation of Source-Network Coding and Channel Coding in Wireline Networks: *Effros and Jalali*

FLOWS ACHIEVEMENT

STATUS QUO



Separation of source-network coding and channel coding in wireline networks with correlated sources and lossless reconstructions is not known.

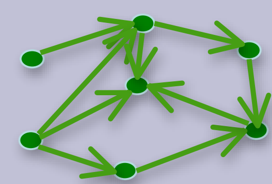
NEW INSIGHTS

$$E[d(U^L,\hat{U}^L)]<\varepsilon$$
$$\Updownarrow$$
$$P(U^L\neq\hat{U}^L)<\delta(\varepsilon)$$

Equivalence of zero-distortion reconstruction distortion reconstruction and lossless reconstruction in **general** memoryless (wireless or wireline) networks is shown.

MAIN RESULT:

Source-network coding and channel coding can be separated in wireline networks with correlated sources, and lossless or lossy reconstructions.



HOW IT WORKS:

–Given a code that achieves small distortion for some source-sink pair, by treating the reconstruction block generated by the code as side information, the extra rate required for lossless reconstruction of the source at the sink is negligible.

- This asymptotically negligible rate can be conveyed using the channel induced by the code between the source and sink nodes.
- For using this channel, we need to fix the other inputs to appropriate blocks.

ASSUMPTIONS AND LIMITATIONS:

-Channels are single-input single-output

-Channels are memoryless

IMPACT

This result shows that in wireline networks, with lossy or lossless reconstructions, even when the sources are correlated, source-network codes and channel codes can be designed separately without any loss in the performance.

For computing the distortion region of such a network, this result shows that it suffices to study the distortion region of an equivalent network of bit-pipes.

END-OF-PHASE GOALS

- Channels with memory: Does separation still hold for *acyclic* networks where channels have memory?
- Multi-user channels: Can we use the techniques used for deriving these results to general wireless networks and derive bounds?

Source-network coding and channel coding separate in a wireline network.

Optimal Control of ARQ Interference Networks

Levorato, Firouzabadi, Goldsmith

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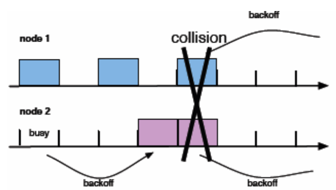
FLOWS ACHIEVEMENT

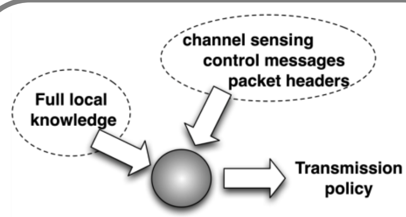
STATUS QUO

Collision-based approach :



❑ Binary idle/busy model of the state of the network
❑ Specifically designed to avoid interference (collision assumption)

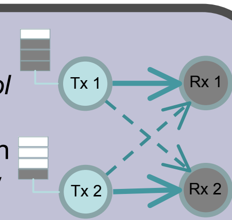
NEW INSIGHTS



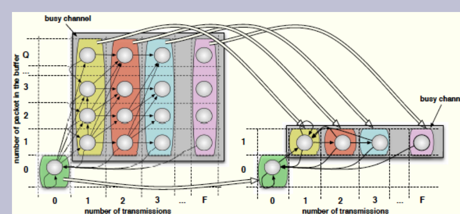
❑ Channel sensing can be extended to manage advanced communication techniques
❑ Nodes can sense the Channel, and possibly use information collected by decoding control messages, headers, etc

Cognitive network Problem

❑ primary source: *dumb ARQ protocol with random arrivals*
❑ secondary source: optimizes its own throughput with constraints on primary source's throughput

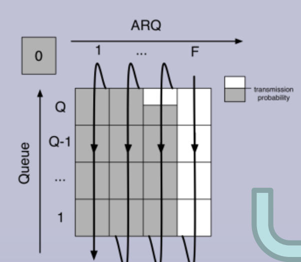


Compact representation of the state space :

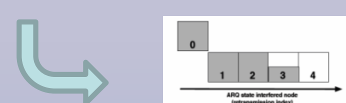


Reinforcement learning based on the aggregated state space (coarse empty/non empty primary users' queue representation and retransmission state):

- ❑ No a priori knowledge of Statistics
- ❑ Iteratively learns from experience
- ❑ Automatically adapts to variations

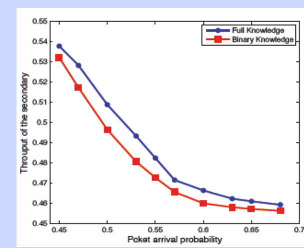


❑ Having a single constraint on degradation of the primary user's performance, the global optimum solution can be found.



IMPACT

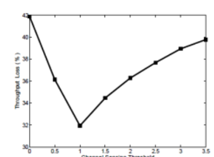
We proposed an on line learning algorithm for optimizing the channel access strategy of the cognitive network under some constraints on the performance degradation of primary users' performance and showed that the performance of the learning algorithm is close to the case where we have full-knowledge of the network statistics



END-OF-PHASE GOALS

❑ How can we generalize it to a network of primary/secondary users

❑ What is the effect of noise in observing the state of the system?



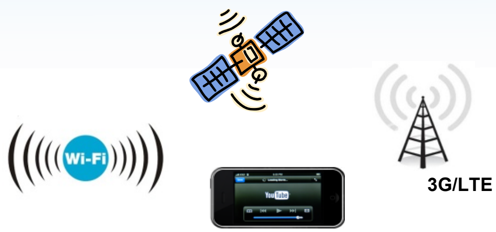
(Noisy packet decoding/loss of the header/ Channel sensing error, etc.)

Optimal Control of ARQ Interference Networks

Metrics and Control Algorithms for Media Streaming in Heterogeneous Environments: *Medard and Ozdaglar*

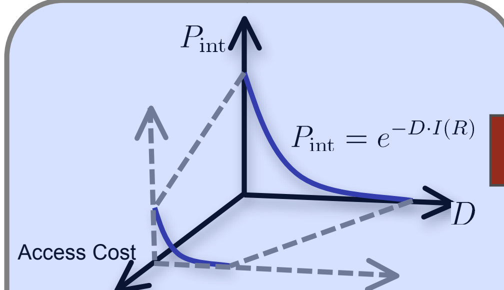
FLoWS ACHIEVEMENT

STATUS QUO



- Quality of user Experience (QoE) for streaming applications is captured by initial waiting time and interruptions in media playback.
- Use random linear network coding to combine streams and avoid duplicate packet reception at the receiver

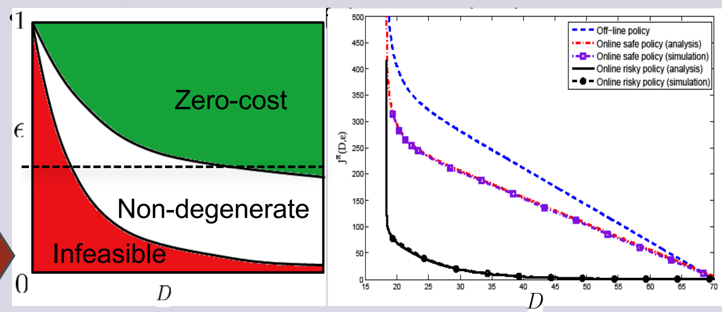
NEW INSIGHTS



- Some resources are more costly or limited compared to the others
- Consider the *initial buffer size* and the *interruption probability* as Quality of user Experience metrics
- **Goal:** Design resource allocation policies that minimize the access cost given QoE requirements

MAIN ACHIEVEMENT:

- Designed several access control policies for a system with two classes of servers (costly and free)
  1. Off-line policy: Queue-length not observable
  2. On-line Safe policy: Use the costly server until the *safety* threshold is crossed
  3. On-line Risky policy: Use the costly server only when the queue crosses the *low-buffer* threshold
- Explicit performance characterization of these policies



HOW IT WORKS:

- Using random linear network coding allows us to model the receiver's buffer as an M/D/1 queue
- Problem formulated as an MDP with a *probabilistic* constraint: optimal policy not necessarily Markov
- Dynamic programming equation for the problem is achieved by state-space expansion

ASSUMPTIONS AND LIMITATIONS:

Packet arrivals are assumed to be a Poisson process

IMPACT

- We take into account more realistic user experience metrics for media streaming applications to capture their transient behavior
- Using proper dynamic control algorithms, we may decrease the usage cost of expensive equipments
- Less usage of costly back-up servers also results in larger capacity of such servers, hence fewer servers need to installed to achieve a reasonable quality of service

End-of-PHASE GOALS

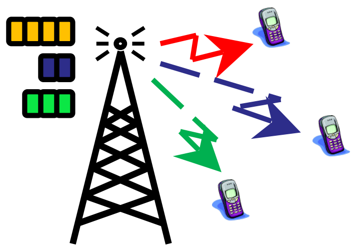
- Design optimal resource allocation policies for multiple users with heterogeneous interruption probability and initial waiting time targets
- Design resource allocation algorithms when broadcasting delay-sensitive content to multiple cooperative users

The availability of the helper server significantly improves the user experience, not its usage!

Scheduling for Small Delay in Wireless Downlink Networks: Shreeshankar Bodas

ACHIEVEMENT DESCRIPTION

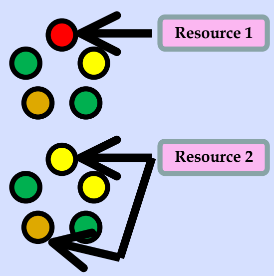
STATUS QUO



Multi-channel (OFDM-based) networks: 4G Standard

- *Many users, large bandwidth*
- *Need: resource allocation schemes with good (low) per-user delay*

NEW INSIGHTS



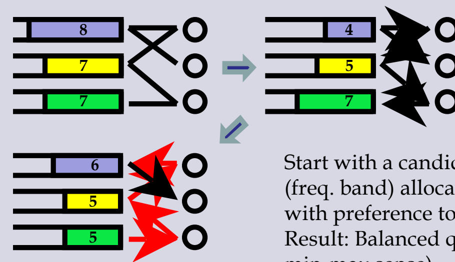
Throughput and delay are not conflicting requirements.

Iterative resource allocation algorithms yield good throughput *and* small per-user delay.

MAIN ACHIEVEMENT:

Polynomial-time resource allocation algorithm (K-MTLB) that is **throughput-optimal,** and yields provably good per-user **delay performance.**

MTLB: Max Throughput, Load-Balancing



Start with a candidate resource (freq. band) allocation, modify with preference to longer queues. Result: Balanced queues (in a min-max sense)

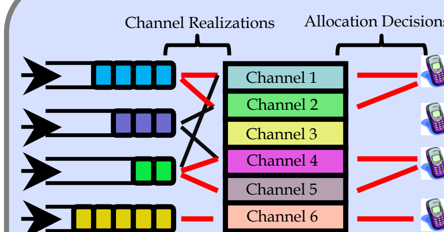
HOW IT WORKS:

- OFDM-based system: one freq. band can serve only one mobile user.
- Channels are "ON-OFF" type (the only interesting case).
- In each timeslot, allocate freq. bands to users with preference to longer backlogs (user-queues at the base-station).

ASSUMPTIONS AND LIMITATIONS:

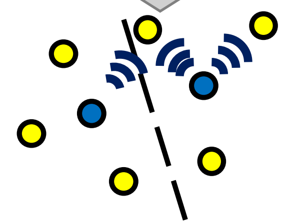
- Equal priority for all users
- Poly-time complexity, but somewhat higher exponent: $O(n^3)$ computations per time-slot

IMPACT



- A poly-time scheduling algorithm for the multi-user, multi-channel system with a provably good worst-case delay performance.
- Brings the new intuition of *iterative resource allocation,* that may be applicable to a wider class of problems.

END-OF-PHASE GOALS



Extensions to multi-source networks

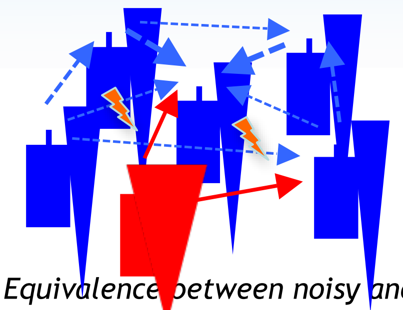
- *Femto/Pico-cell networks*
- *Minimal coordination*

Iterative resource allocation schemes ➔ Low per-user delay, in addition to network stability

Network Equivalence in the Presence of Adversary - *Effros*

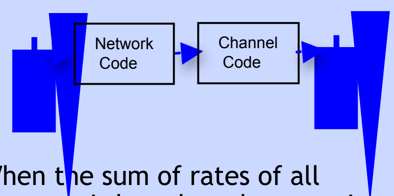
FLOWS ACHIEVEMENT

STATUS QUO



- *Equivalence between noisy and noiseless known in networks of independent point-to-point channels - relies on the random nature of errors*
- *Adversary can introduce errors that are not independent of each other*

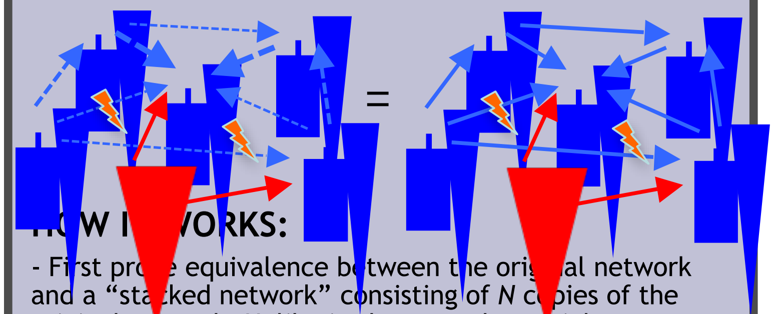
NEW INSIGHTS



-When the sum of rates of all messages is less than the capacity of a noisy link, the noisy link is equivalent to noiseless link

-Noise is emulated on the noisy link by source coding and randomly choosing a codebook from a set of possibilities

MAIN ACHIEVEMENT:



HOW IT WORKS:

- First prove equivalence between the original network and a "stacked network" consisting of *N* copies of the original network. Unlike in the non-adversarial case, errors for different layers are dependent. Upper bound the error probability by considering the worst case adversarial strategy and using an error correcting code with a hamming distance based decoding

- A code $C_{noiseless}$ for the noiseless networks can be used on the noisy network by adding a channel code at each link

- A code C_{noisy} for noisy network can be modified to a code $C_{noiseless}$ for noiseless network:
  - Randomly design a source code for the noiseless link
  - Remove those outputs from the source code for which the error probability for any message exceeds a threshold.

ASSUMPTIONS AND LIMITATIONS:

-Memoryless, point-to-point channels, acyclic network

-Sum of rates of messages is less than capacity of the noisy link under consideration

-Adversary can see links in a causal order

IMPACT

- Simplifies capacity calculations - noiseless networks with adversaries are better understood than noisy networks with adveraries
- Simplifies code design for the class of adversarial networks where this applies by enabling a two step design - network code followed by channel code
- By removing the assumption of independence of noise on links, this result opens the door to extending equivalence to more general cases

END-OF-PHASE GOALS

- *Remove the sum rate Constraint on messages*
- *Extend beyond the point-to-point case – MAC, Broadcast etc*
- *Other transmission models?*

Network Equivalence extends to networks with Adversaries

Shannon meets Nyquist --- Capacity Limits of Sampled Analog Channels

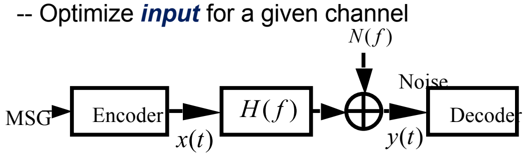
Yuxin Chen, Andrea J. Goldsmith and Yonina C. Eldar

STATUS QUO

- **Information Theory**

-- Traditional Shannon framework deals with ***continuous*** domain.

-- Optimize ***input*** for a given channel

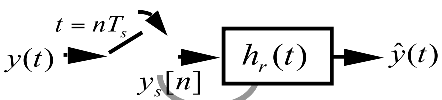


- **Sampling Theory**

-- analog signals → ***digital*** sequences

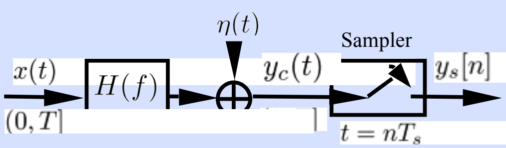
(***Nyquist rate*** sampling)

-- Optimize ***sampling mechanisms*** for given input



NEW INSIGHTS

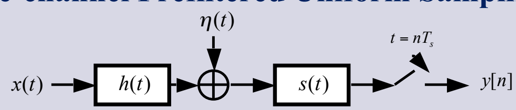
- ***Info Theory*** meets ***Sampling Theory***



- What is the ***capacity limit*** of the sampled analog channel
- What is the ***tradeoff*** between capacity and sampling rate
- How to ***jointly optimize*** input and sampling methods

ACHIEVEMENT

Single-channel Prefiltered Uniform Sampling



Theorem 1: The sampled channel capacity is

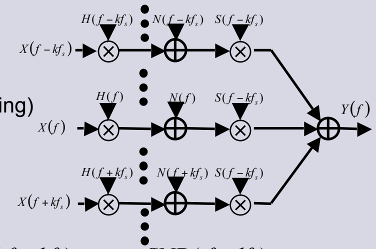
$$C(f_s) = \frac{1}{2}\int_{f\in\mathcal{F}(B)} \log\left(B\frac{\sum_{i=-\infty}^{\infty}|H_c(f-if_s)S_c(f-if_s)|^2}{\sum_{i=-\infty}^{\infty}|S_c(f-if_s)|^2}\right)df \qquad (1)$$

MISO Interpretations:

-- Filtered channel, colored noise

-- Combining (due to uniform sampling)

-- Maximum Ratio Combining



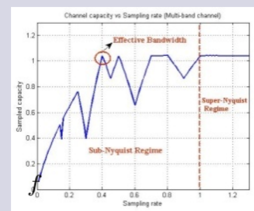
Optimal Prefilter:

$$S_{\text{opt}}(f-kf_s) = \begin{cases} 1 & \text{if } \mathrm{SNR}(f-kf_s) = \max_l \mathrm{SNR}(f-lf_s) \\ 0 & \text{otherwise} \end{cases}$$

-- Selection Combining + Noise Suppression

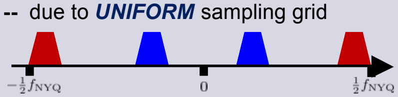
-- Suppress Aliasing

-- Minimize MMSE reconstruction error



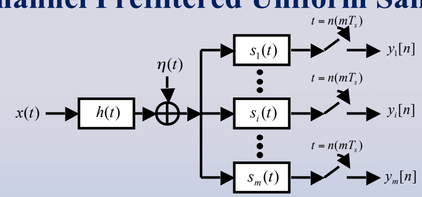
Non-monotonicity:

-- due to ***UNIFORM*** sampling grid



IFORM sampling

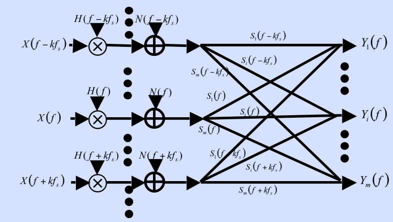
Multi-channel Prefiltered Uniform Sampling



Theorem 2: The sampled capacity with multi-channel sampling is:

$$C(f_s) = \frac{1}{2}\max_{\mathbf{Q}(f)\in\mathcal{Q}}\int_{-\frac{f_s}{2}}^{\frac{f_s}{2}}\frac{1}{m}\log\left(\det\left(\mathbf{I}_m + f_s^{-\frac{1}{2}}f_h^{\frac{1}{2}}\mathbf{Q}f_h^{\frac{1}{2}}f_s^{-\frac{1}{2}}\right)\right)df$$

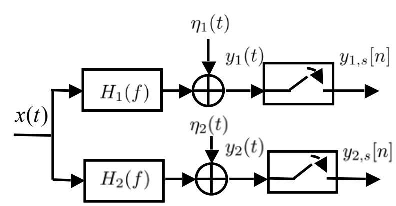
MIMO Interpretation:



NEXT-PHASE GOALS

- Extension to **Network Info. Theory**

-- Example: (Broadcast Channel)



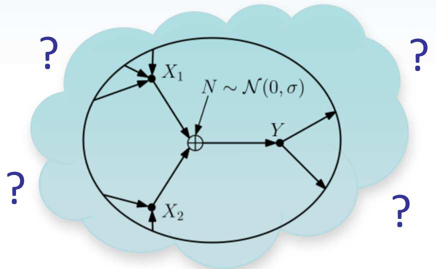
-- *Gaussian MIMO Broadcast Channel*

- **Connection** between IT and Sampling theory
- **Sufficient Statistics** (that favors the channel structure)

A first attempt to study the tradeoff between data rate and hardware complexity

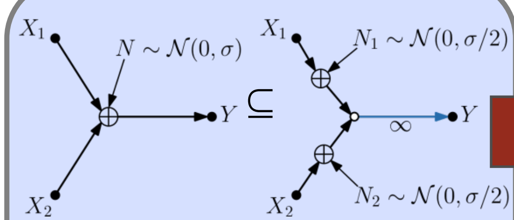
A Network Equivalence-Based Analysis of the Multiple Access and Broadcast Channels: *Calmon and Médard*

STATUS QUO



- Analyzing the capacity region of an intricate network is intractable with current techniques.
- Recent Network Equivalence results have provided a new approach for the problem.

NEW INSIGHTS

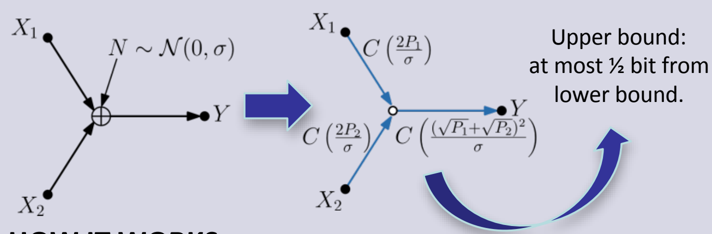


- If one network can "emulate" on its border nodes any coding scheme of the multiterminal channel, it also bounds the capacity region of the channel (and vice-versa).
- **Goal:** try to find simple yet effective point-to-point upper bounding networks for multiterminal channels that can provide relevant results.

FLoWS ACHIEVEMENT

MAIN ACHIEVEMENT:

- An effective approach for finding capacity region bounds for discrete and memoryless multiterminal channels as components of larger networks.
- This method also provides valuable insights when applied to channels in isolation.
- Precise bounds for the multiple access AWGN channel within a larger network.
- Alternative look at the MAC with correlated sources and at the broadcast channel.



HOW IT WORKS:

- If a network can reproduce the same input-output relation of a given channel, it represents an upper bound model for the capacity region of the channel.
- Furthermore, if this upper bound consists of independent, point-to-point links, we can determine the upper bounding capacity region.
- By taking the intersection of different bounds we can find better results.

ASSUMPTIONS AND LIMITATIONS:

- Only useful for discrete memoryless channels.
- Difficult to determine tightness of bounds.

IMPACT

- A new approach for difficult and open problems in network information theory.
- Motivates the idea of analyzing a complicated network with heterogeneous links by appropriately modeling it as another equivalent network composed by point-to-point bit pipes.
- Provides relevant results without the need of intricate mathematical formulations, as well as key insights for understanding complicated networks

End-of-PHASE GOALS

- Extend this method for finding bounds for more general multiterminal channels.
- Compare results with existing bounds in literature and investigate if new upper bounds can be proved using this technique.

Bounding multiterminal channels by point-to-point models can be an effective approach!