Feedback Strategies in Deterministic Interference Channels

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Motivation and Background

- Wireless systems are often interference limited.
- Feedback plays a pivotal role in communication system design. Understanding the effect of feedback is important.
- Gaussian models are difficult to solve. Easier approximate solutions are obtained by approximating it to a deterministic (noise free) model.

System Model

Forward Channel (fixed and known to all the transmitters and receivers)

- Two-user symmetric interference channel considered, i.e. both users observe the same Signal to Noise ratio (SNR) and Interference to Noise ratio (INR).
- The forward channel is deterministic (no noise).
- For each input X, its binary equivalent is considered such that the number of bits are limited to $\log(1 + \mathrm{SNR})$
- Interaction of signals is bitwise XOR operation.

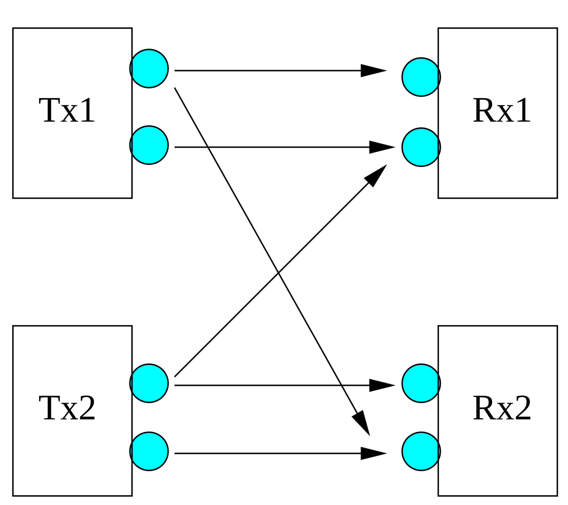

Figure 1: Example of Deterministic Interference Channel with $\mathrm{SNR} = \mathrm{INR}^2$. Interactions are at bit level. Bits below the noise floor are truncated.

Feedback Channel (channel output is fed-back, channel state information is fixed and known)

1. Feedback is broadcasted on error free orthogonal channels, i.e. both transmitters hear feedbacks from both receivers.
2. Only one tranmitter has feedback of its corresponding receiver's output.
3. Half-duplex model: Feedback channel is time-shared with the forward channel.

Define: $n = \log(\mathrm{SNR})$, $m = \log(\mathrm{INR})$
Let $\mathcal{C}_{sum}$ represent the sum-capacity of two user interference channel under various feedback schemes.

Noiseless Broadcast Feedback

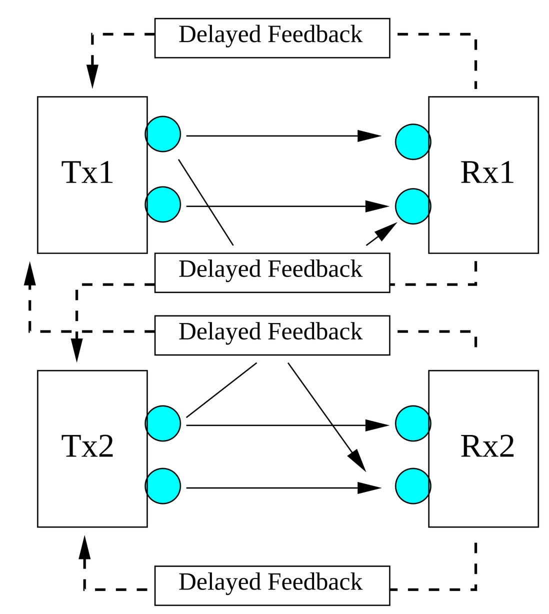

Figure 2: Feedback is broadcast. A total of four noiseless links carry channel output as feedback

$$\mathcal{C}_{sum} = n + (n-m)^+ \quad (1)$$

- Feedback capacity same as that with just two feedback links (receiver to its intended transmitter)
- Broadcast of feedback does not bring about more cooperation than required.

Idea of proof: Lower bounded by two-link feedback schemes. Tight upper bound was found.

Assymetric Single Link Feedback

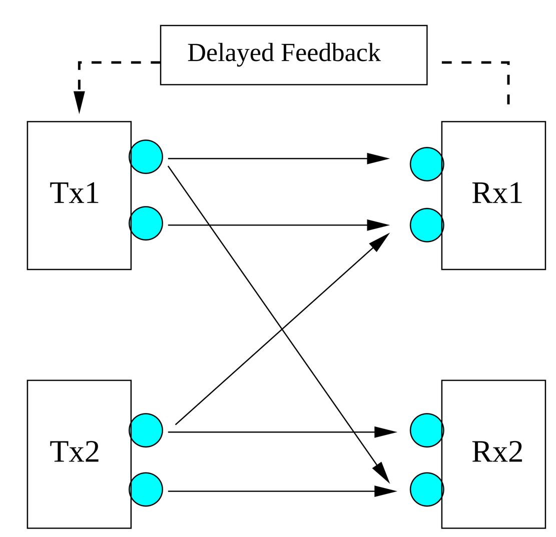

Figure 3: Only one user has feedback. Models the asymmetry in the system

$$\mathcal{C}_{sum} = n + (n-m)^+ \quad (2)$$

- Maximum achievable sum capacity is same as that of broadcast feedback case.
- When interference is much stronger than direct link ($\mathrm{INR} \geq \mathrm{SNR}^2$), use the feedback link alongwith its receiver and transmitter as a virtual relay (Fig. 4).
- Weak interference: Set common message of user 1 same as common message of user 2 (feedback link aids this communication).
- Key observation: The user (transmitter-receiver pair) without the feedback link obtains all the gains.

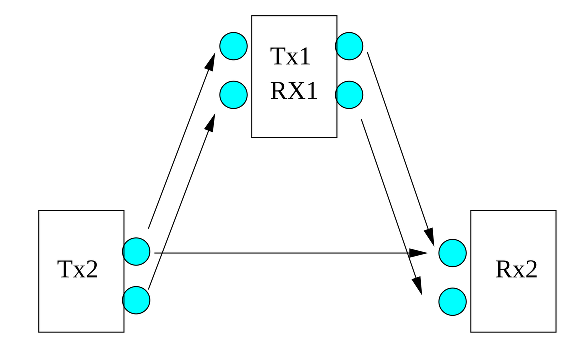

Figure 4: Feedback along with transmitter-receiver used as relay

Half-Duplex : Time-Shared Feedback

- Forward channel and Feedback channel are time-shared (resource is accounted).
- Observation: All gains are lost in the very strong interference regime.
- Reason: No infinite capacity link (feedback itself is a bottleneck).

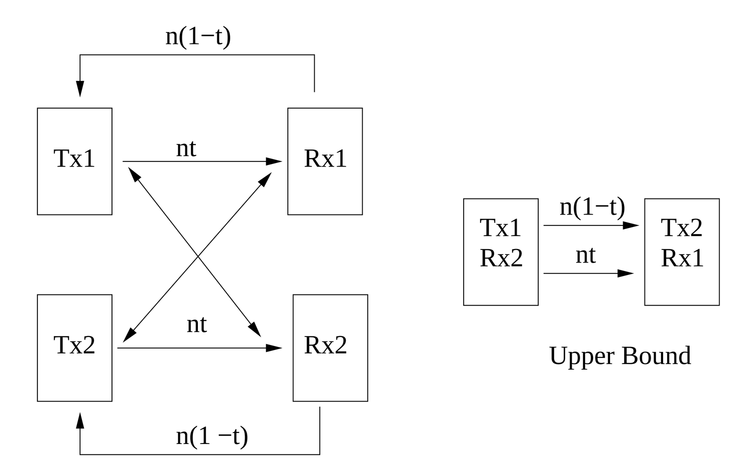

Figure 5: Half-Duplex deterministic model. The fraction $t \in [0, 1]$. Double arrow-heads on the cross links indicate that they are used in either direction. Cross links are assumed to be of infinite capacity and upper bound on the right is formed. Feedback links also present in upper bound, but feedback does not improve capacity in point to point channel

Idea of proof: Upper-bound it by making the cross links noiseless (infinite capacity) and then observe the total sum-rate across the cut.

Results on a Plot

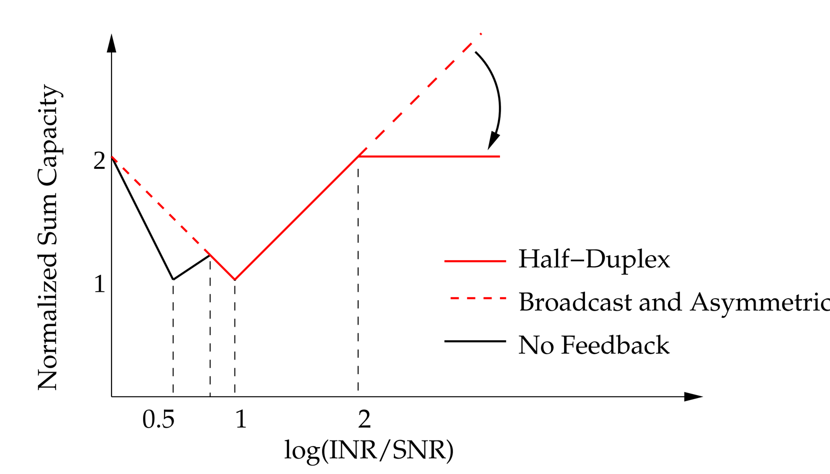

Figure 6: Normalized Sum-Capacity versus $\log\left(\frac{\mathrm{INR}}{\mathrm{SNR}}\right)$. Assumption of high SNR and INR are made.