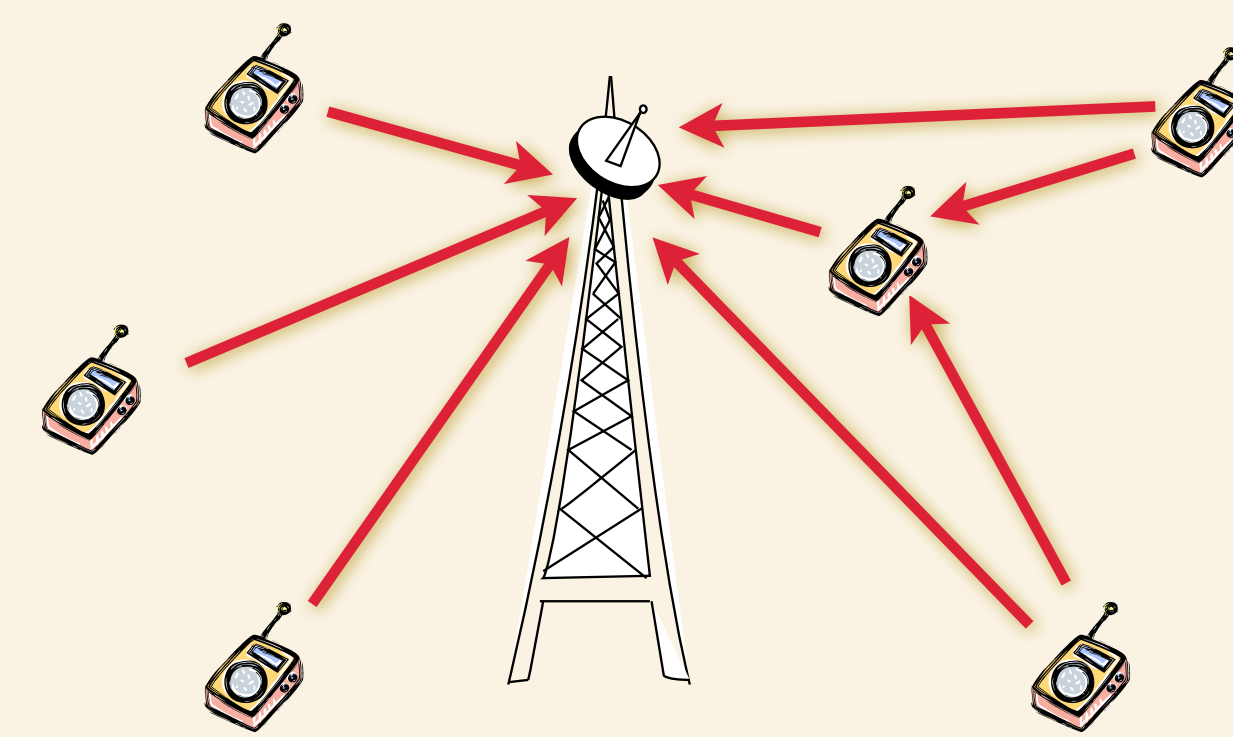


Motivation



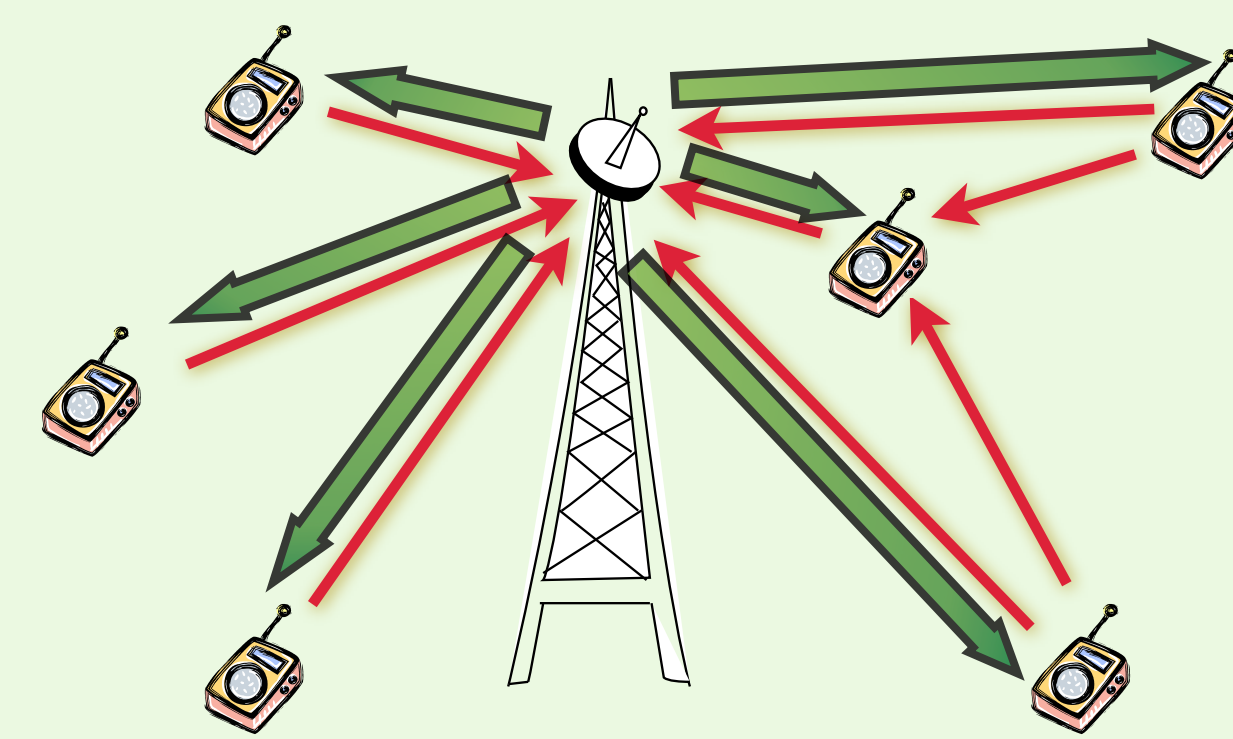
e.g. Sensor Network

Remote transmitters are limited by

- **Transmission power** - often rely on battery
- **Computation power** - limited processing and storage capability
- **Insufficient knowledge** of transmissions from other (possibly correlated) sources

The central unit is far less constrained!

Our Approach



Central unit sends useful information back to each transmitter

- The central unit has more power - assume infinite capacity on the feedback links

Main result: **feedback increases network capacity**

Feedback and Network Coding

Effros, Bakshi

STATUS QUO

In today's networks, bulk of transmission from sources to sinks

- Remote sources have often lesser power available than sinks
- Feedback is studied mostly in the context of channel knowledge, not source knowledge

ACHIEVEMENT DESCRIPTION

MAIN ACHIEVEMENT:

In several examples networks, the capacity with feedback is strictly bigger than that without feedback

- Butterfly network
- Source coding with coded side information
- Multiterminal source coding

HOW IT WORKS:

Receiver sends back everything it knows to the transmitter nodes.

e.g.

- Encoder 2 knows X after the feedback.

- Sum rate required is only H(X)

ASSUMPTIONS AND LIMITATIONS:

- Feedback links are assumed to have infinite capacity
- Sources nodes are assumed to have sufficient processing power

IMPACT

Increase in capacity is potentially unbounded.

Power consumption by remote sources can be decreased by employing feedback from the central receivers.

NEW INSIGHTS

Feedback increases the capacity region.

By knowing what the receiver already knows from other sources, source nodes can avoid unnecessary transmission.

NEXT-PHASE GOALS

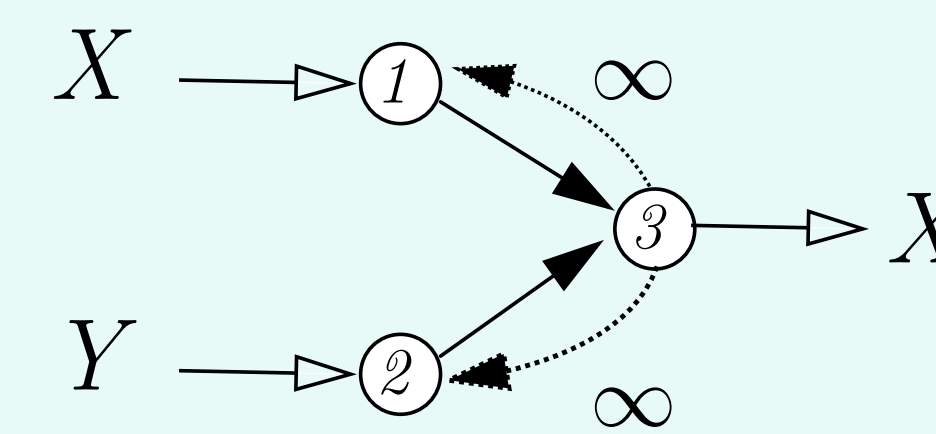
Cost of feedback?

- Feedback links may not always be "free"

Feedback increases the capacity of networks

Results

Source Coding with Coded Side Information



- Node 1 sends codeword to Node 3 assuming no feedback
- Node 3 sends the X codeword to Node 2
- Node 2 decodes X and sends the remaining part of X to Node 3

Feedback increases the capacity region

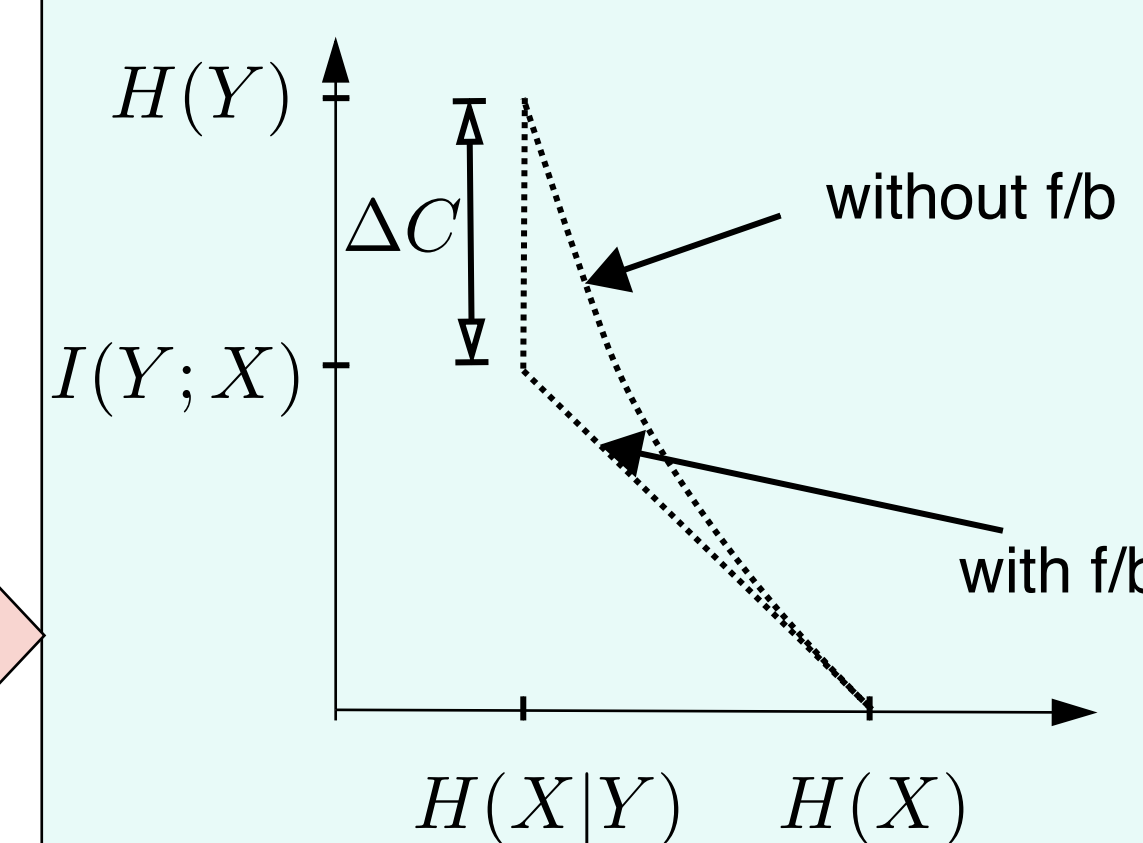
Without feedback

$$\begin{aligned} R_{13} &\geq H(X|U) \\ R_{23} &\geq I(Y;U) \end{aligned}$$

for some U s.t. $U \rightarrow Y \rightarrow X$

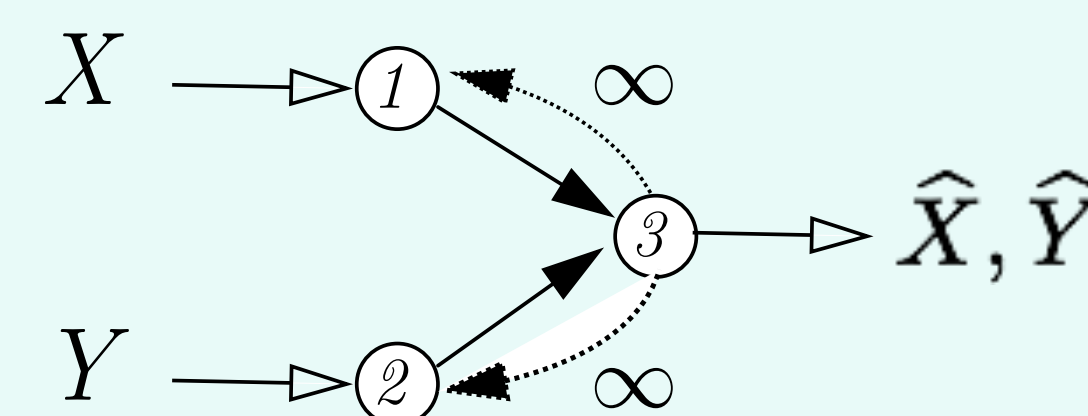
With feedback

$$\begin{aligned} R_{13} &\geq H(X|Y) \\ R_{13} + R_{23} &\geq H(X) \end{aligned}$$

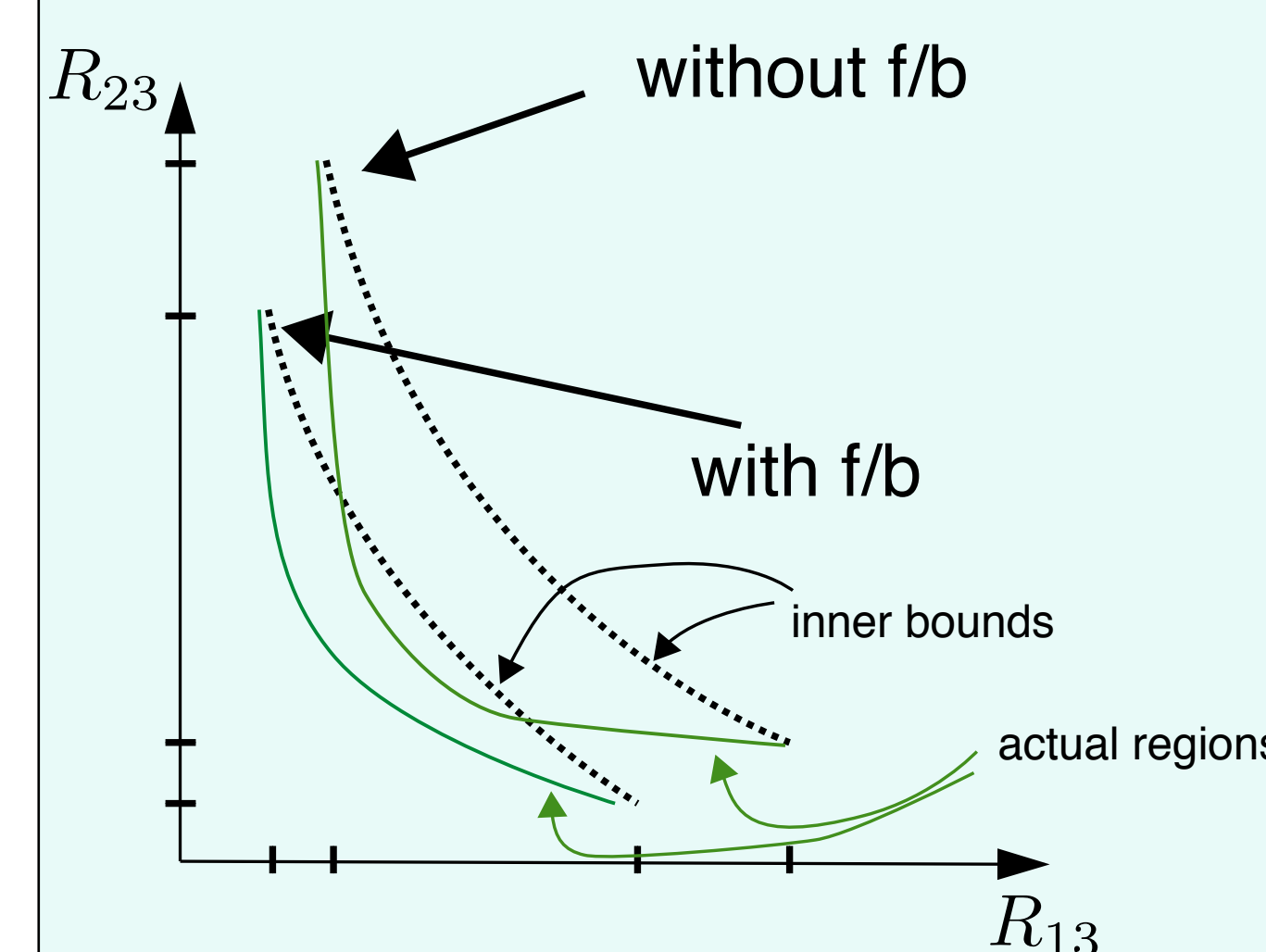


The improvement is potentially unbounded!

Multiterminal Source Coding

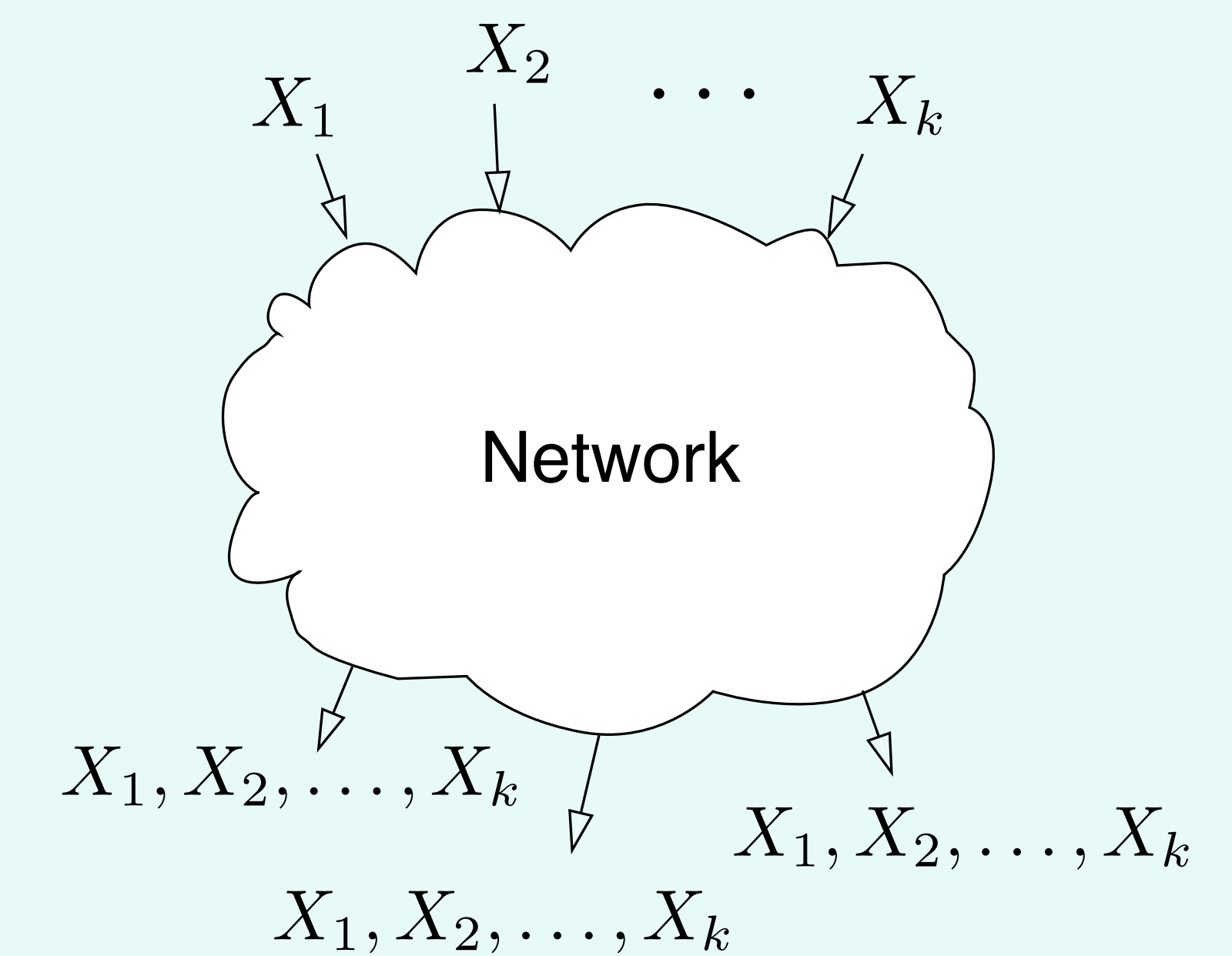


- Reconstructions are desired subject to distortion levels (D_X, D_Y)
- We obtain an inner bound by performing a conditional rate distortion coding based on the received codewords from the other source, which is not possible without feedback



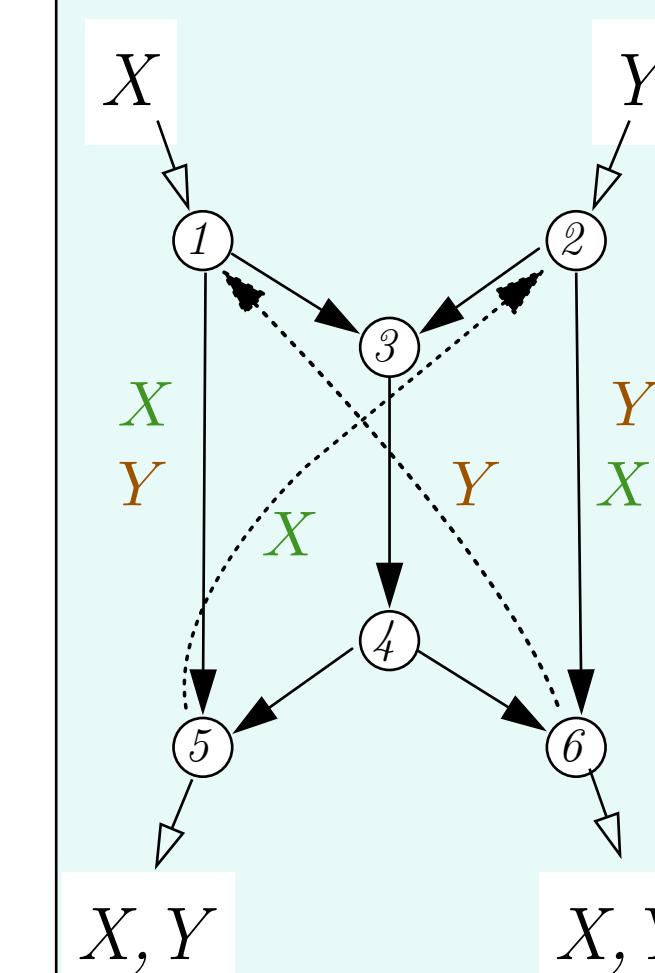
There are rate points in the region with feedback that are not achievable without feedback

Multicast with multiple sources



- cutset region is modified by adding feedback links
- without feedback the mincut between each source and sink pair has to be at least equal to the source entropy
- with feedback, the min-cut between each source and just one of the sinks needs to be at least equal to the source entropy.

e.g. Butterfly Network



With feedback, the rate vector $\mathbf{R} = (R_e : e \in E)$ given by $R_{15} = R_{26} = H(X, Y), R_e = 0 \forall e \notin \{(1, 5), (2, 6)\}$ is feasible. This is not possible without feedback

Future directions

- We assumed infinite capacity for the feedback links. How do results change when these links have capacity constraints?
- Extend the result to more general networks and identify general principles involved in networks with feedback.

