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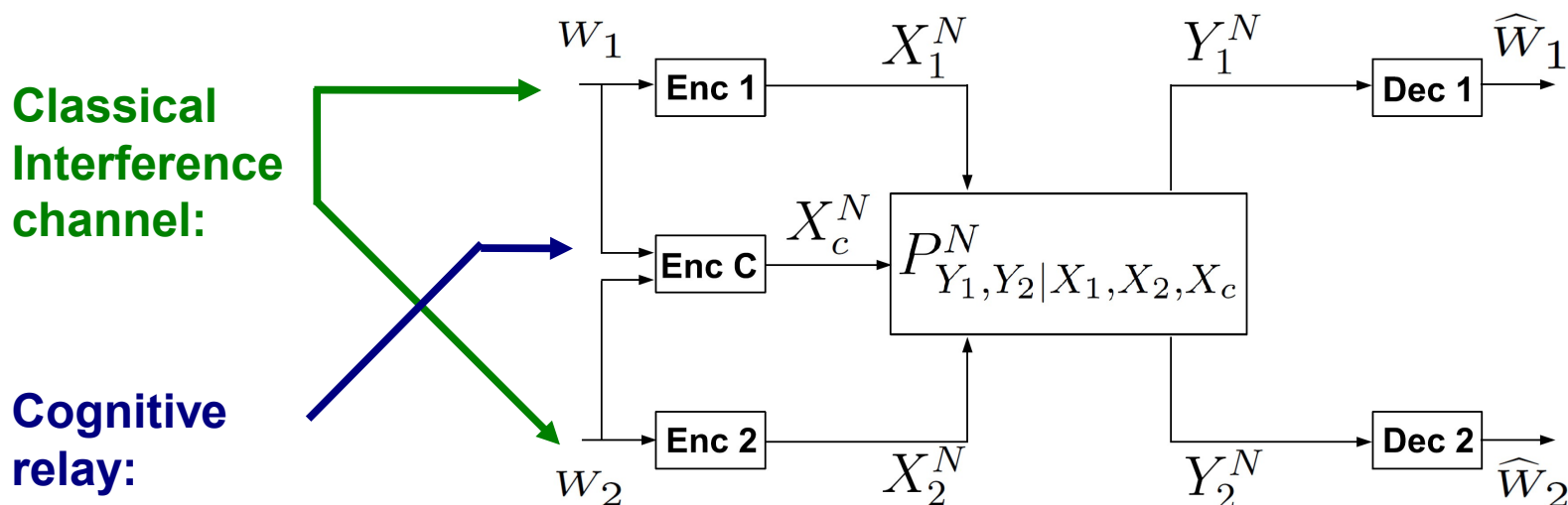


The Capacity of the Interference Channel with a Cognitive Relay in Very Strong Interference

Stefano Rini, Daniela Tuninetti, Natasha Devroye, Andrea Goldsmith

The interference channel with a cognitive relay IFC-CR

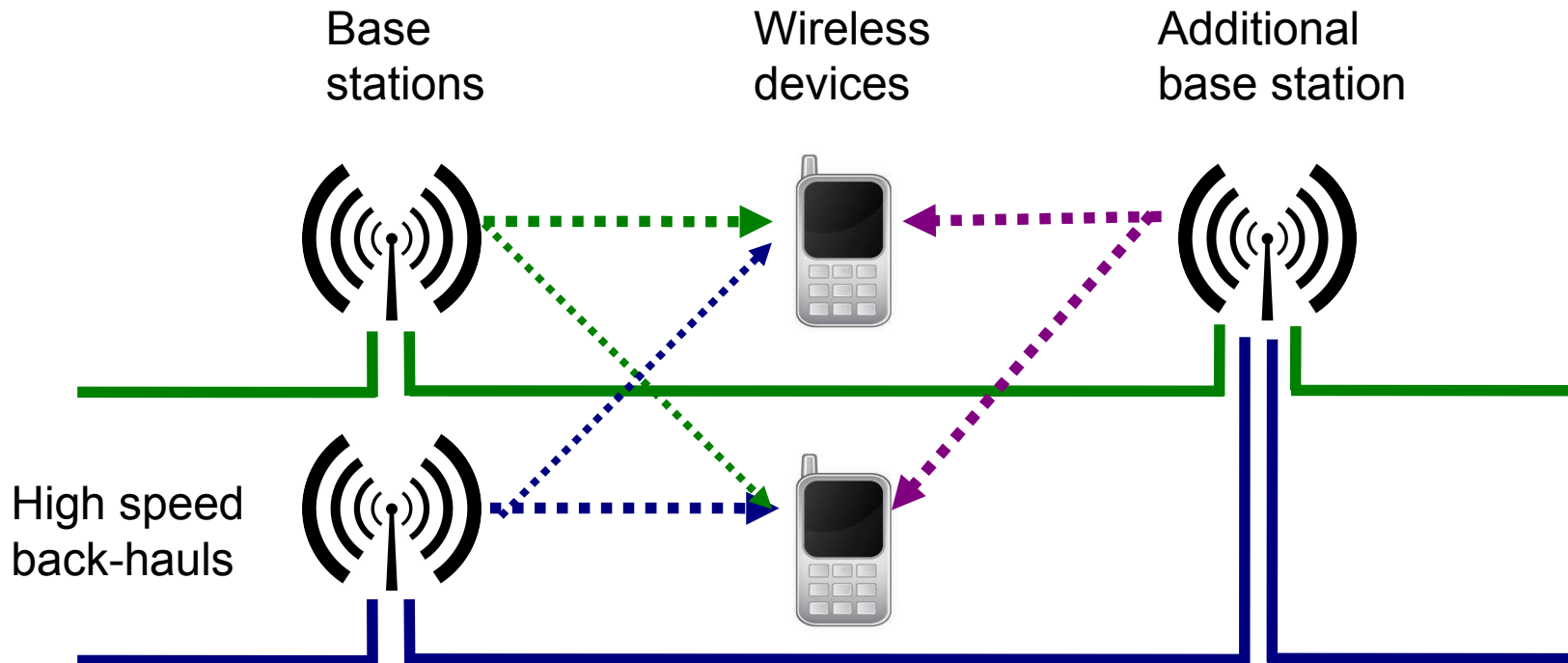
Channel Model:



The interference channel with a cognitive relay IFC-CR

Bluetooth is a short wireless range technology that has been widely used. Many reasons have been given for its success. It is a technology that is well suited to the needs of many applications. It is a technology that is well suited to the needs of many applications. It is a technology that is well suited to the needs of many applications.

When does it occur in practice?



The interference channel with a cognitive relay IFC-CR

Why do we study it?

There are many channel models out there,
but we want to answer the following questions:

- How do we **manage the interference** at the two decoders simultaneously?
- How do we **implement cooperation** with the two users simultaneously?
- Are there **novel coding strategies** to be learned from this model?

*R.T.D.: "Outer Bounds for the Interference Channel with a Cognitive Relay,"
ITW Dublin, 2010*

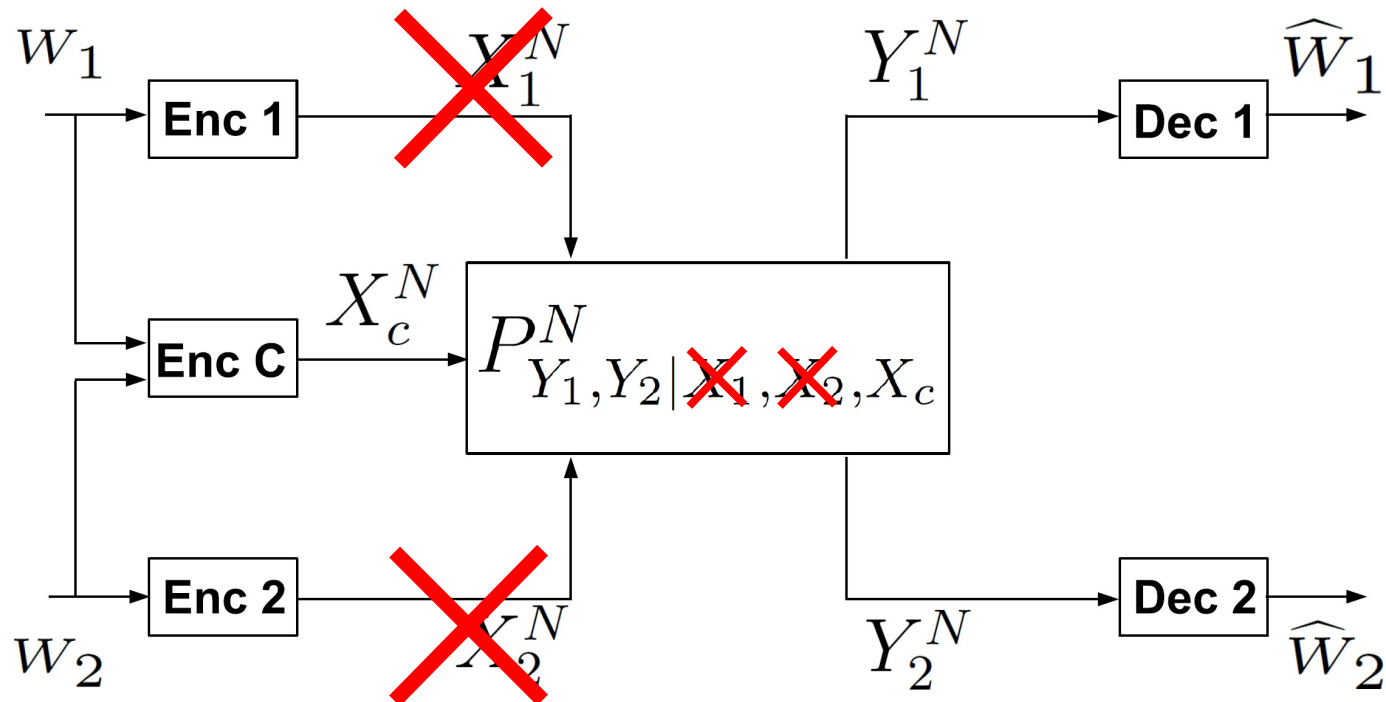
The interference channel with a cognitive relay IFC-CR

Some literature:

- Sahin & Erkip introduce the model
O. Sahin and E. Erkip,
“Achievable Rates for the Gaussian Interference Relay Channel,”
- Jiang et al. propose an achievable scheme
J. Jiang, I. Maric, A. Goldsmith, and S. Cui,
“Achievable Rate Regions for Broadcast Channels With Cognitive Relays,”
- Sridharan et al. propose outer bounds for the gaussian case
S. Sridharan, S. Vishwanath, S. Jafar, and S. Shamai,
“On the capacity of cognitive relay assisted Gaussian interference channel,”
- Rini et al. propose outer bounds for the general case
S. Rini, D. Tuninetti, and N. Devroye,
“Outer Bounds for the Interference Channel with a Cognitive Relay,”

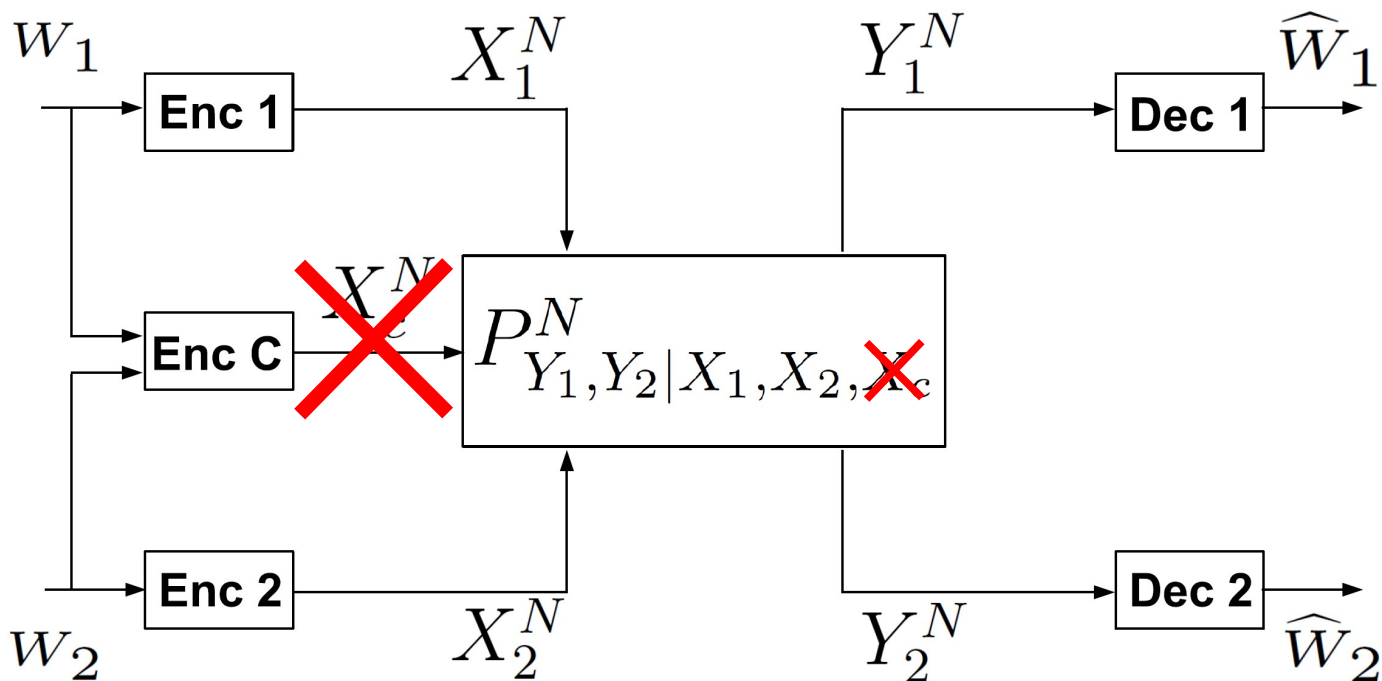
The interference channel with a cognitive relay IFC-CR

Broadcast channel:



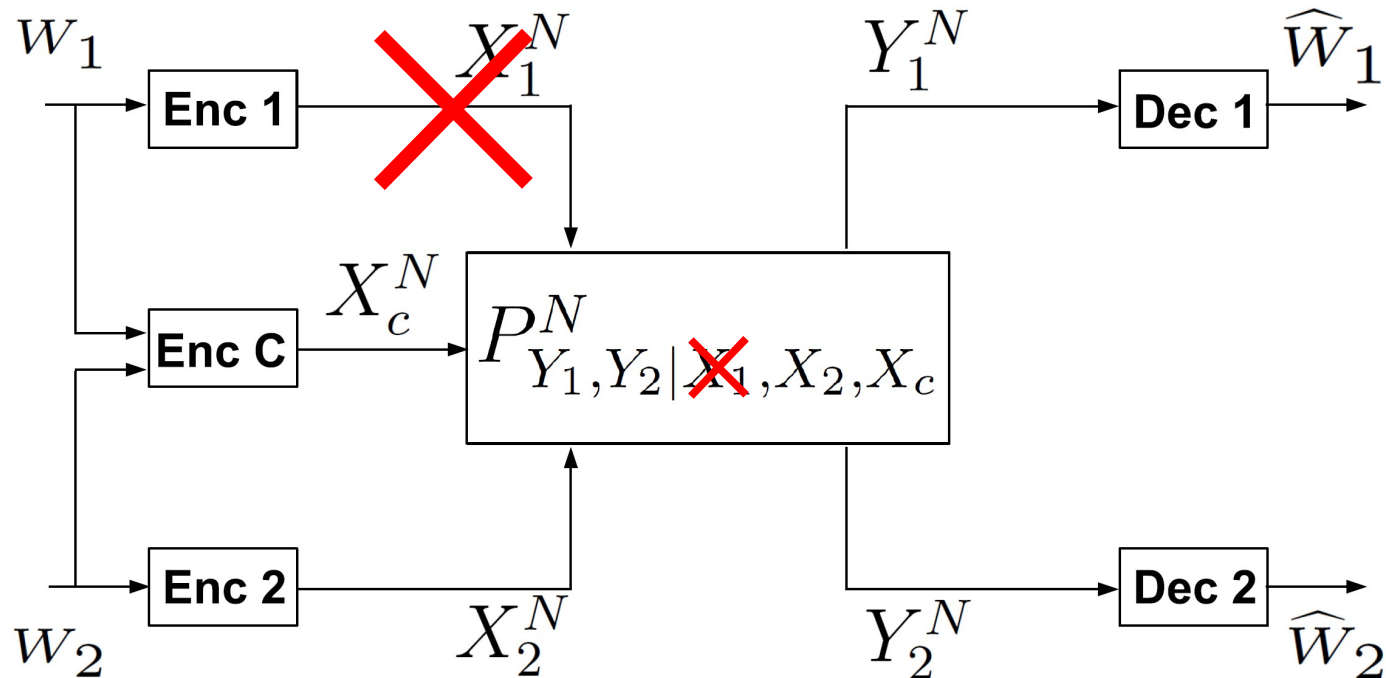
The interference channel with a cognitive relay IFC-CR

Interference channel:



Barbours is a plant which has always fascinated the human eye. Many believed that the reasons why Barbours is so attractive to man were due to the great number of ways it can be used for construction, for musical instruments, for pipes, for distillation, controlling soil erosion, food...

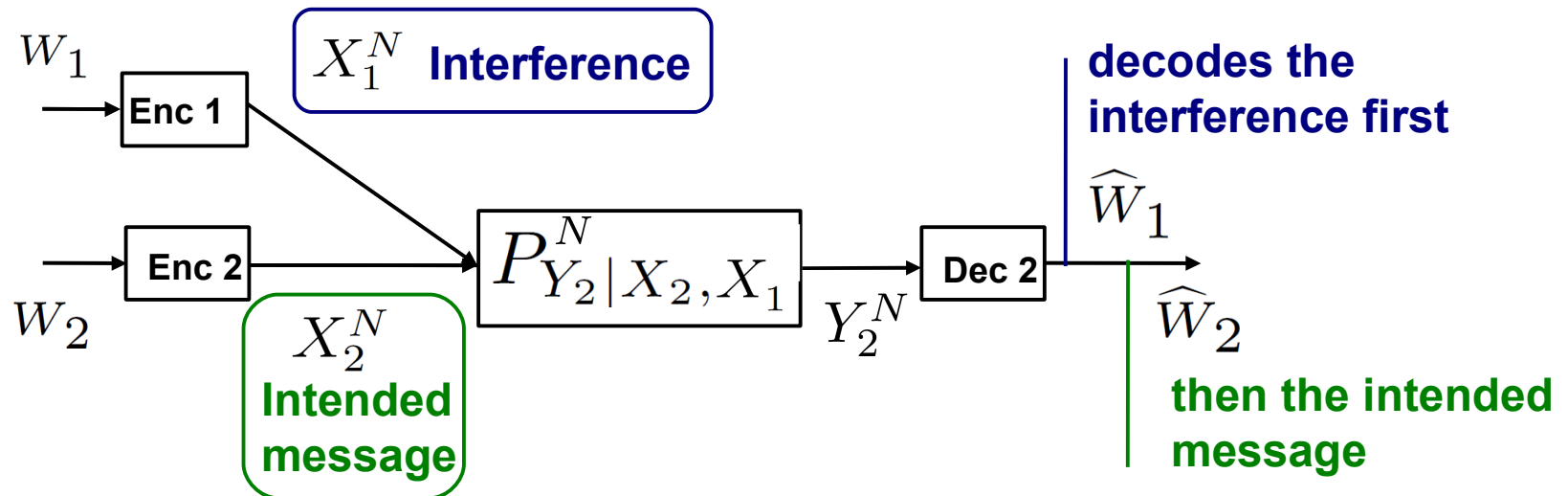
Cognitive interference channel:



Strong/very strong interference regime

Strong interference regime at Rx 2

For all these channel models, there is a regime where one decoder can decode the message of the other user from its channel output



This regime is usually referred to as “strong interference” regime

Strong/very strong interference regime

Bionics is a field which has always fascinated the human eye. Many theories about the reasons why bionics is so effective in our world have been put forward. It can be used for construction, for medical instruments, for agriculture, for controlling self-driving cars...

The transceiver clearly that bionics offers us, holds a number of solutions for many. From an economical to technical point of view.

Strong interference regime at RX 2

this condition is somewhat intuitive:

Assume that decoder 2 has decoded the intended message X_2

and assume that decoder 1 is provided with the interference X_2 ,

then decoder 2 can **still** decode X_1 more easily than decoder 1

$$I(X_1; Y_1 | X_2) \leq I(X_1; Y_2 | X_2)$$

Strong/very strong interference regime

Bartlett is a gift which has changed the human eye. Many believe that the reason why Bartlett is so effective is not only due to the great number of objects it can be used for construction, but also to its unique, innovative, controlling and elegant form. The translucent, clearly that Bartlett offers us, holds a number of solutions for many, from an emotional or technical point of view.

Further conditions:

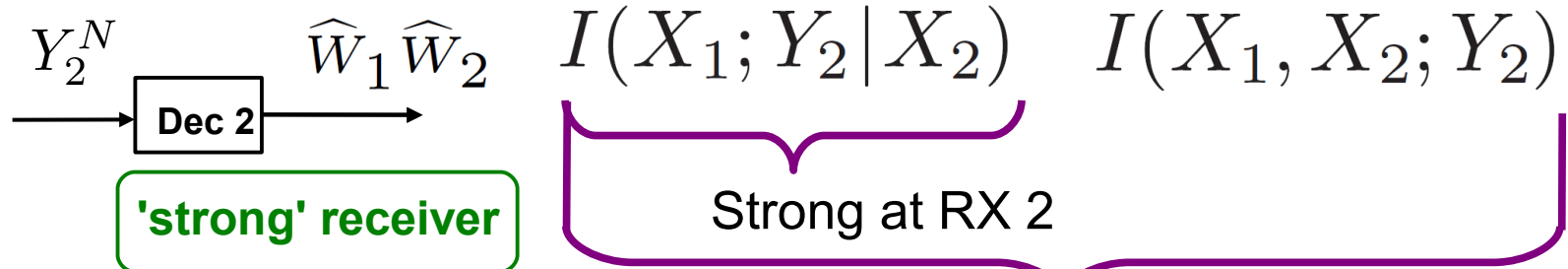
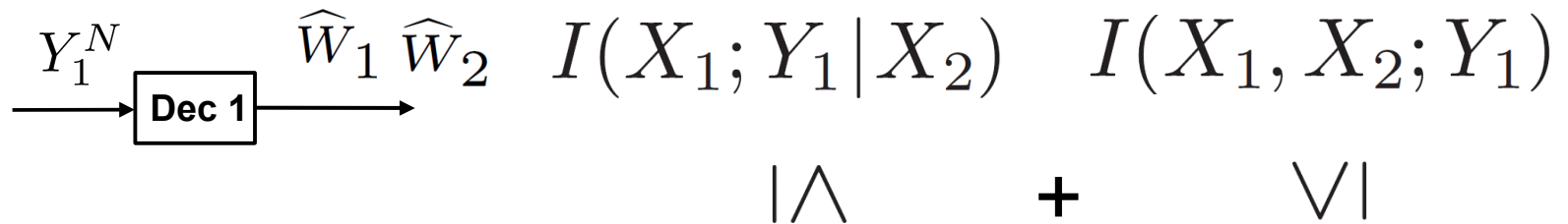
To achieve capacity in the strong interference at one decoder, one usually needs a further conditions:

- Strong interference regime at both decoders:
that is when both decoders are in strong interference
- Very strong interference at RX 2
or the 'weak' decoder can decode both messages better than what the 'strong' one does.

Baritone is a part which has always fascinated the human eye. Many believe that the reasons why baritone is so attractive to men are due to the great number of ways it can be used for construction of musical instruments, flutes, pipes, instruments, controlling well-known, hard...

Very strong interference regime at RX 2

'weak' receiver



very strong at RX 2

Strong/very strong interference regime

Bartlett is a gift which has changed the human eye. Many believe that the reason why Bartlett is so effective is not so much due to the great number of things it can do, but the combination of several instruments: telescope, microscope, controlling self-assembly, face.

The transition clearly that Bartlett offers us, holds a number of solutions for many. From an emotional or technical point of view.

Strong/very strong interference regime at RX 1/RX 2

In this regime it is usually possible to derive an outer bound using the condition above.

This holds for the:

- the more capable broadcast channel
- the interference channel in strong/very strong interference
- the cognitive interference channel in strong/very strong interference

In this paper

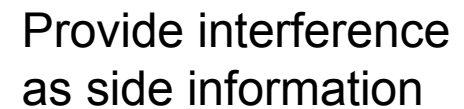
Bionics is a field which has changed the human eye. Many believe that the reason why bionics is an effective concept is due to the great number of applications it can be used for: construction, for medical instruments, prostheses, education, controlling self-driving, food...

The transmittal clearly that bionics offers us, holds a number of solutions for many. From an educational or technical point of view.

Our contribution:

- we obtain two new capacity results for the IFC-CR based on these ideas
- these are the first capacity results for this channel!
- look at the Gaussian case, where we can plot these results

Scatismo is a plot which has always fascinated the human eye. Many believe that the reason why catfish is so attractive is not even due to the great number of catfish it can be used for construction, for musical instruments, for pipes, for smoking, controlling soil erosion, food...

$$R_1 \leq I(Y_1; X_1, X_c | X_2, Q)$$


$$R_2 \leq I(Y_2; X_2, X_c | X_1, Q)$$

Strong interference at RX 1 outer bound

Sum rate bounds:

Use an genie and impose the strong interference condition

$$\begin{aligned} R_1 + R_2 &\leq I(Y_1; V, U_1, X_1) + I(Y_2; U_2, X_2, X_c | V, U_1, X_1) \\ &\leq I(Y_1; X_1, X_2, X_c) \end{aligned}$$

using the fact that

implies
$$I(Y_2; X_2, X_c | X_1) \leq I(Y_1; X_2, X_c | X_1)$$

$$I(Y_2; X_2, X_c | X_1, U) \leq I(Y_1; X_2, X_c | X_1, U)$$

as in the more capable broadcast channel.

Strong interference at RX 1 outer bound

Strong interference at Rx 1 outer bound:

The capacity region is contained in

$$R_1 \leq I(Y_1; X_1, X_c | X_2, Q),$$

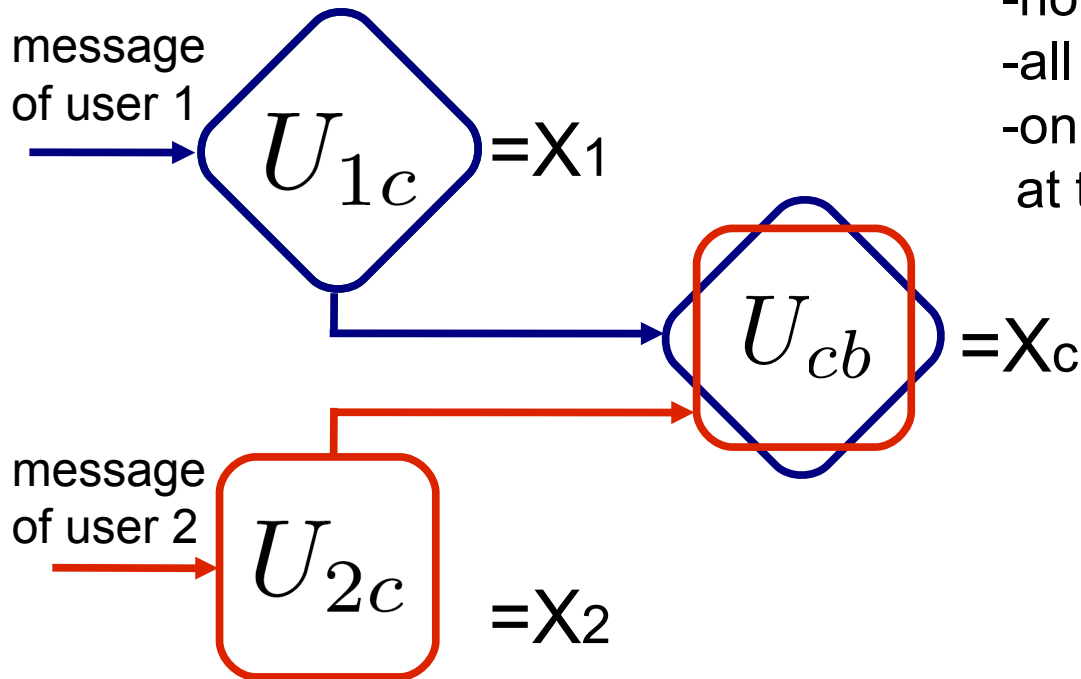
$$R_2 \leq I(Y_2; X_2, X_c | X_1, Q),$$

$$R_1 + R_2 \leq I(Y_1; X_1, X_2, X_c | Q),$$

when

$$I(Y_2; X_2, X_c | X_1) \leq I(Y_1; X_2, X_c | X_1)$$

Achievability of the outer bound



- no rate split
- all common messages
- only superposition coding at the cognitive relay

Achievability of the outer bound

Achievable region

$$R_1 \leq I(Y_1; X_1, X_c | X_2, Q),$$

$$R_2 \leq I(Y_2; X_2, X_c | X_1, Q),$$

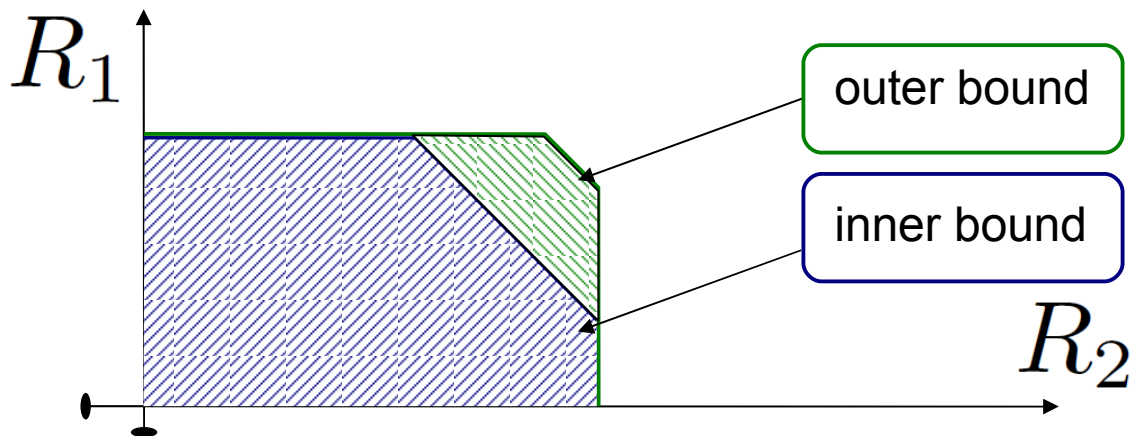
$$R_1 + R_2 \leq I(Y_1; X_1, X_2, X_c | Q),$$

$$R_1 + R_2 \leq I(Y_2; X_1, X_2, X_c | Q),$$

Achievability of the outer bound

The inner and outer bound differ only in one sum rate outer bound.
The two region coincide if:

- we can drop one sum rate from the inner bound
 - very strong interference condition
- we can add one sum rate at the outer bound
 - strong interference at both RXs



Capacity in very strong interference at RX 1

When:

$$I(Y_2; X_2, X_c | X_1) \leq I(Y_1; X_2, X_c | X_1)$$

the channel is in strong interference at RX1, and when

$$I(Y_1; X_1, X_2, X_c) \leq I(Y_2; X_1, X_2, X_c)$$

we can drop the sum rate

$$R_1 + R_2 \leq I(Y_2; X_1, X_2, X_c | Q),$$

In the inner bound

CAPACITY !

Capacity in strong Interference at both RXs

When

$$I(Y_2; X_2, X_c | X_1) \leq I(Y_1; X_2, X_c | X_1)$$

the channel is in strong interference at RX1, and when

$$I(Y_1; X_1, X_c | X_2) \leq I(Y_2; X_1, X_c | X_2)$$

the channel is in strong interference at RX2, so we add the bound

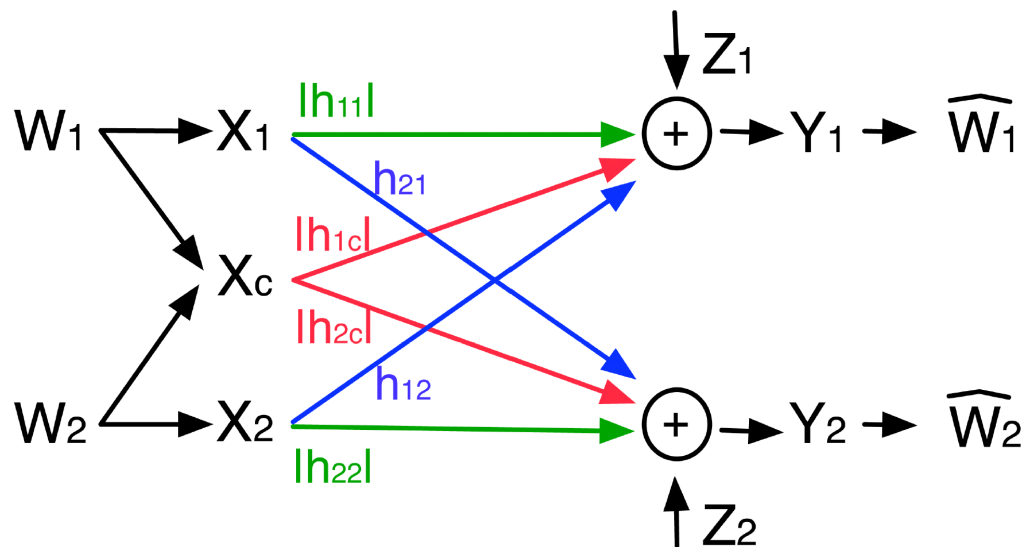
$$R_1 + R_2 \leq I(Y_2; X_1, X_2, X_c | Q),$$

In the outer bound.

CAPACITY !

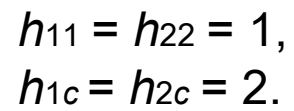
The Gaussian IFC-CR

Let's visualize these results for the Gaussian case:



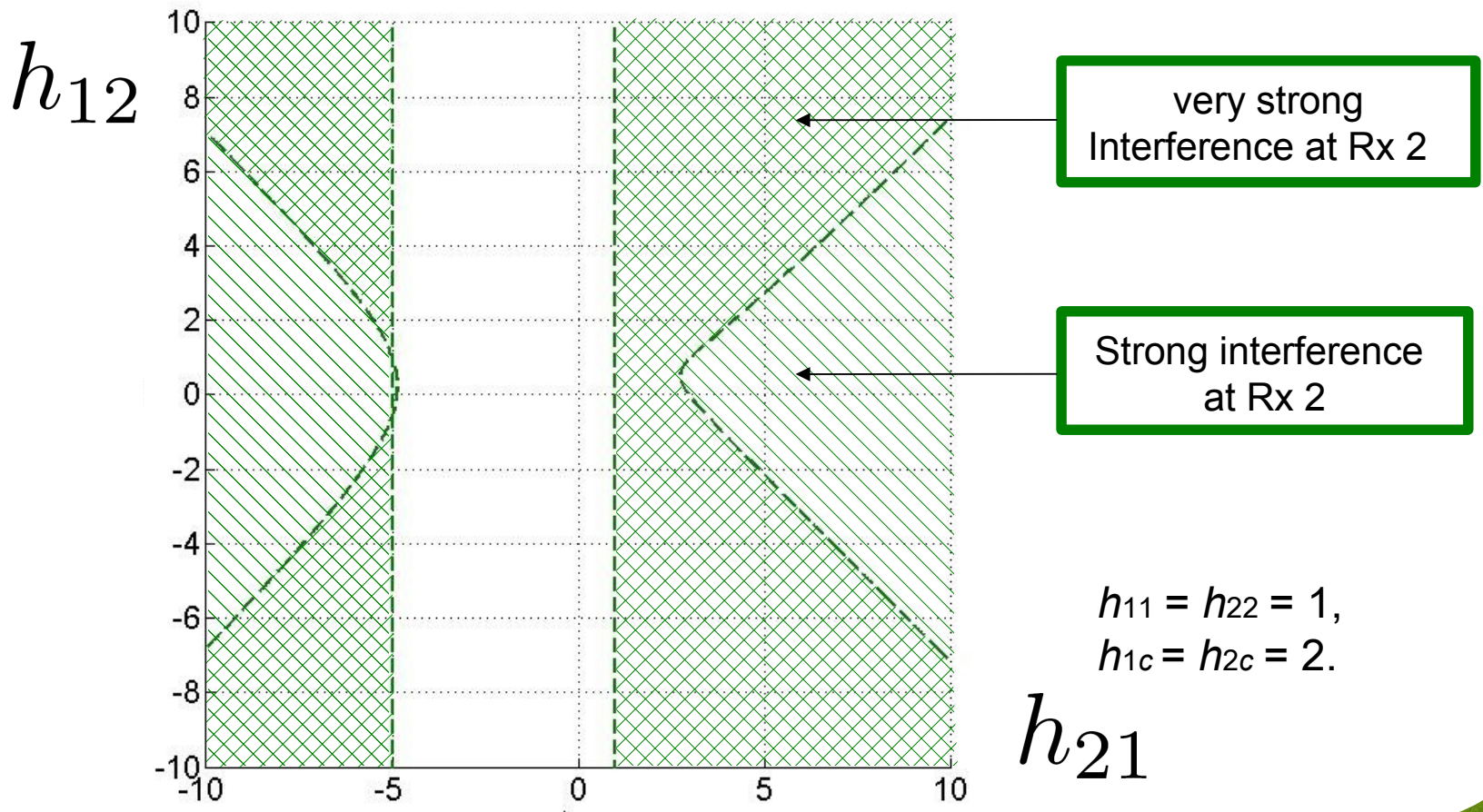
So we can see how the strong-very strong interference regimes play out.

Baritone is a sport which has always fascinated the human eye. Many believe that the reasons why baritone is so attractive to men have to do with the great number of ways it can be used for construction, for musical instruments, for pipes, for decoration, controlling self-esteem, for...



The Gaussian IFC-CR

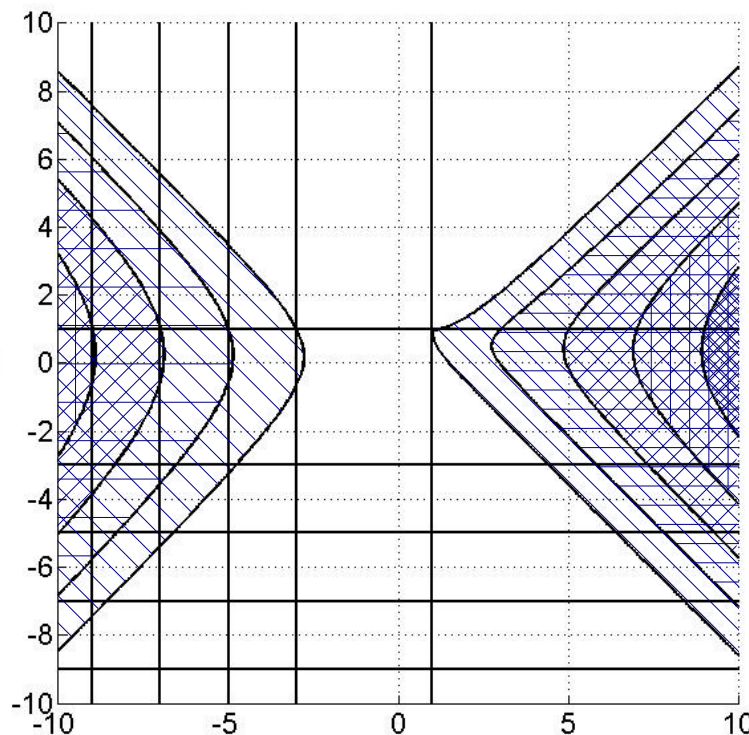
Blindness is a gift which has changed the human eye. Many learned that the reason why blindness is a disadvantage is not only due to the great number of things it can be used for, but also for the great number of things it can be used for. The blindness, clearly that blindness offers us, holds a number of advantages for many, both as described in technical point of view.



The Gaussian IFC-CR

Statistics is a field which has always fascinated the human eye. Many centuries ago the reason why statistics is an effective tool was due to the great number of things it can be used for: conducting the census, measuring the population, predicting the weather, etc. The transition clearly that statistics offers us, today, a number of solutions for many, from an economical to technical point of view.

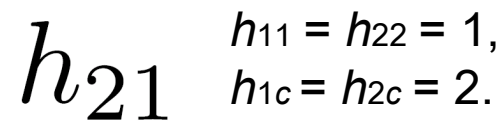
h_{12}



$$I(Y_1; X_1, X_2, X_c) = I(Y_2; X_1, X_2, X_c)$$

h_{21}

Scissors is a sport which has always fascinated the human eye. Many believe that the reason why Scissors is so addictive is not just due to the great number of ways it can be used for construction, for several instruments like pipes, demolition, controlling soil erosion, etc...



Conclusion

Bartlett is a gift which has changed the human eye.
Many believe that the reason why Bartlett is so effective is not
only due to the great number of people who have used
the construction for several instruments, but also, it is
containing all the best of the world.
The translation clearly that Bartlett offers us, is a number of
translations for many, from an abstract to a concrete point of view.

What did we do:

derive two new capacity results for the interference channel with a cognitive relay:

- very strong interference channel an RX 1/RX 2
- strong interference at both decoders



Thank you!

Binocular is a gift that has always fascinated the human eye. Many theories about the reasons why binocular is an effective device have been put forward, but the most common one is that it can be used for construction, for example, in architecture, engineering, and other fields.

The binocular is a device that offers us a wide range of options for viewing. From an architectural or technical point of view,

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Any question ?

Look for the journal version online!

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