Network Coded Cooperation Testbed: Implementation And Performance Results

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Outline

- Motivation
- System Model
- Testbed Details
  - NCC System
  - Image Transmission Structure
- Test Results

Motivation

Current status of Wireless Networks-5G

- Resource scarcity problems
- Increasing number of users
- Constant (or decreasing) radio resources
- Increasing data rate demands

System Model(1/2)

- Set-up includes three source nodes (M =3) , one destination node (P = 1) and one relay node (K = 1).

  -OFDMA uplink transmission is realized in the broadcast phase .

  -In the relaying phase, the relay node uses all N=1200 subcarriers.

  -X_i and X_k signals from source nodes and relay node are transmitted with 4-QAM modulation, respectively where ($i = 1,\ldots,M$ and $k = 1,\ldots,K$).

System Model(2/2)

- The global coding matrix of the total system in GF(4) is set as

$$\mathbf{Z} = \left(\begin{array}{ccc|ccc} 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 \end{array}\right)^{T}$$

- Although we use a single physical device as the relay node, we use the same subcarrier set for the relaying phase (i.e. 320 subcarriers).
- Three linear combinations of the received source symbols are generated at the relay node. Hence, the coding matrix becomes of dimension 3x6.
- In the end, a cooperative detection rule is used at the destination node.

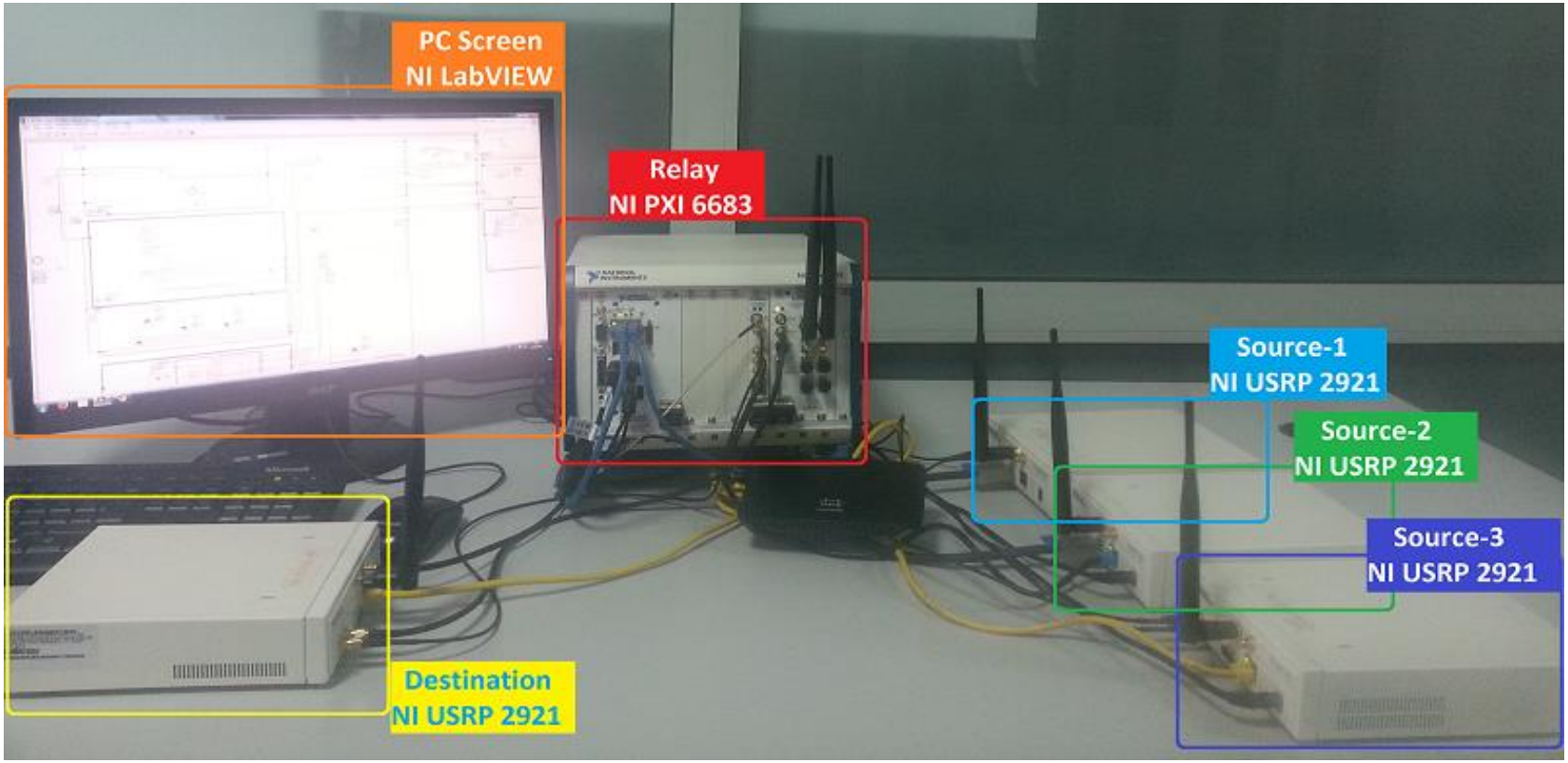
Testbed Details (1/14)

- Hardware Components:

  - NI USRP-2921: Source and Destination Nodes, Instantaneous bandwidth up to 20 MHz
  - NI PXIe-1082 Chassis:
    - NI PXIe-5644R VST: Relay Node, Instantaneous bandwidth up to 80 MHz
    - NI PXI-6683: Clock Signal Source

Testbed Details (2/14)

- Hardware Components:



Testbed Details (3/14)

- Synchronization Solution:

  - Three external 10 MHz signals are provided by NI PXI-6683 Timing and Synchronization Module

  - These signals are transmitted to two source nodes and destination node via cables

  - Remaining source node receives synchronization signal through MIMO cable

  - Synchronization configuration in code

Testbed Details (4/14)

- Software Components:

  -LabVIEW Software: Visual Programming Language, Programming with Virtual Instruments (VI)

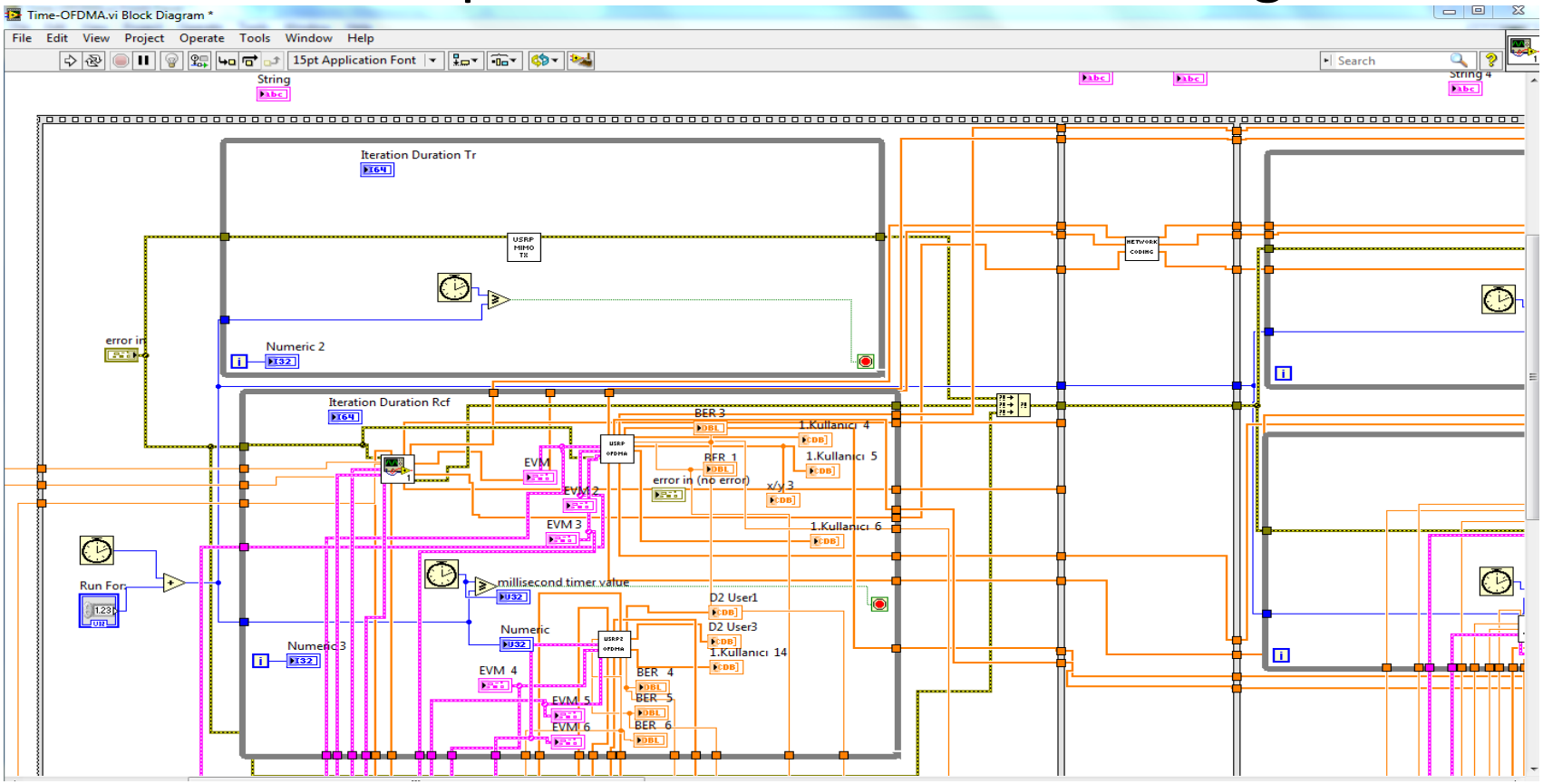
  -Timed Flat Sequence Structure: Main VI of the code, consists of:

    -Source, relay and destination node SubVI

    -Network coding and decoding SubVI

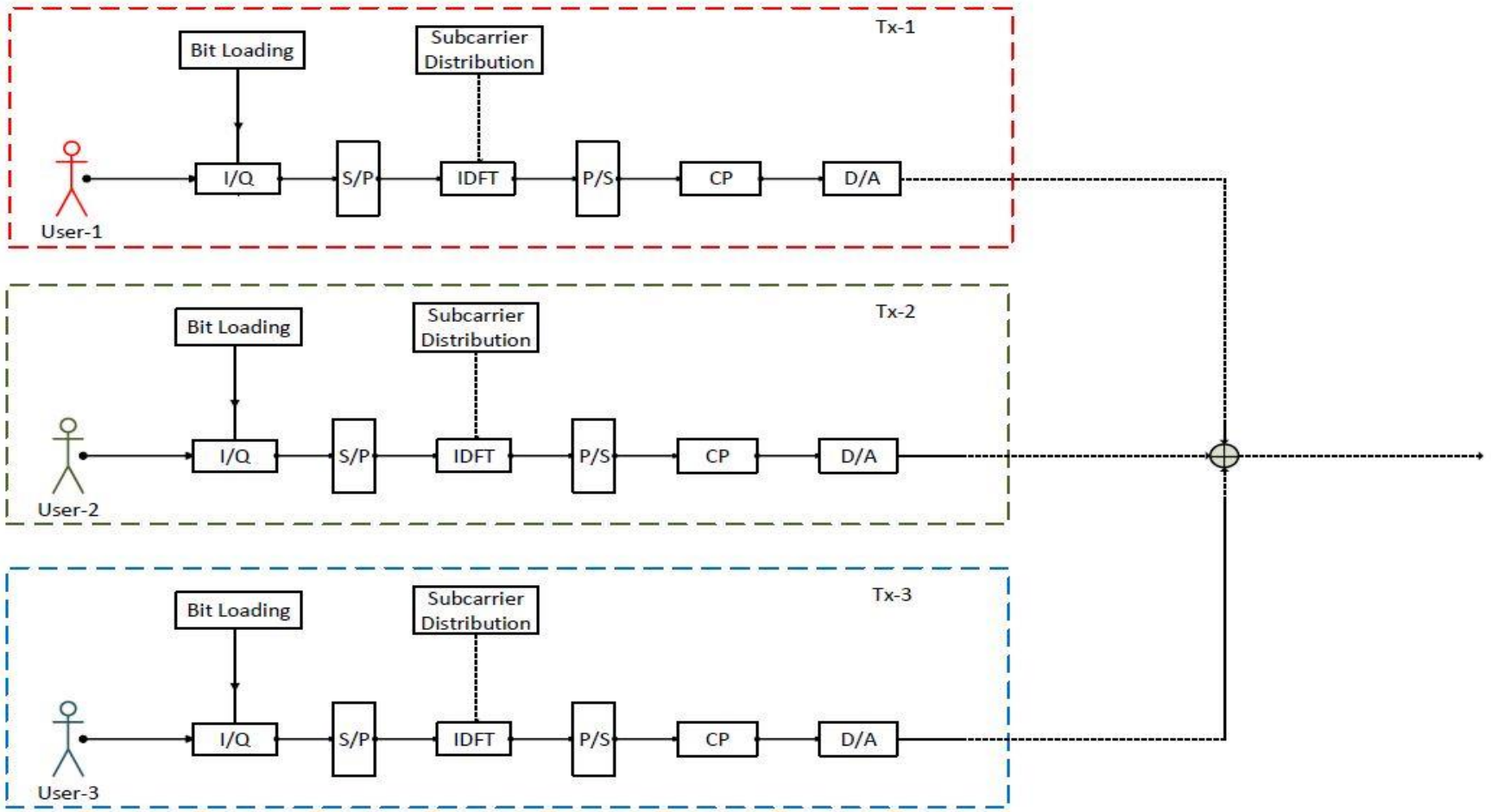
Testbed Details (5/14)

- Timed Flat Sequence Structure VI Block Diagram:



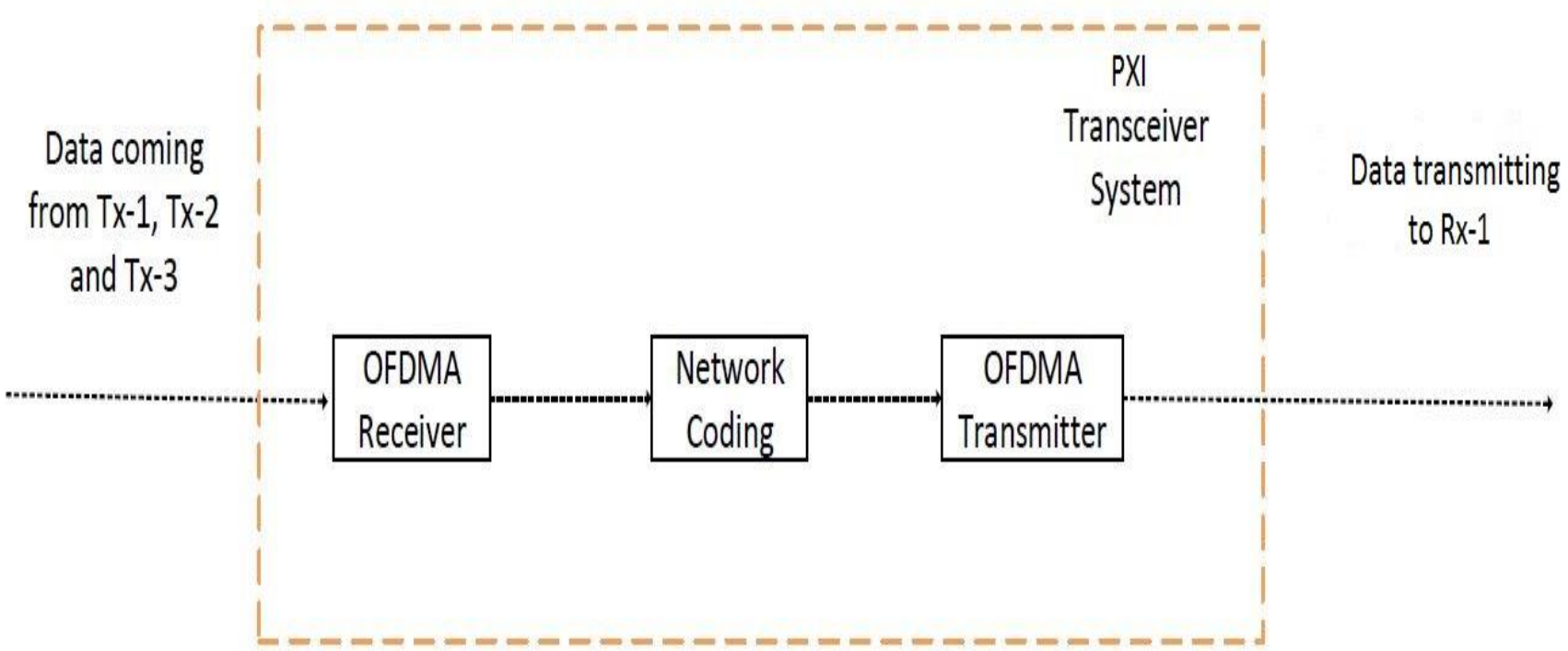
Testbed Details (6/14)

- Source node SubVI implementation structure:



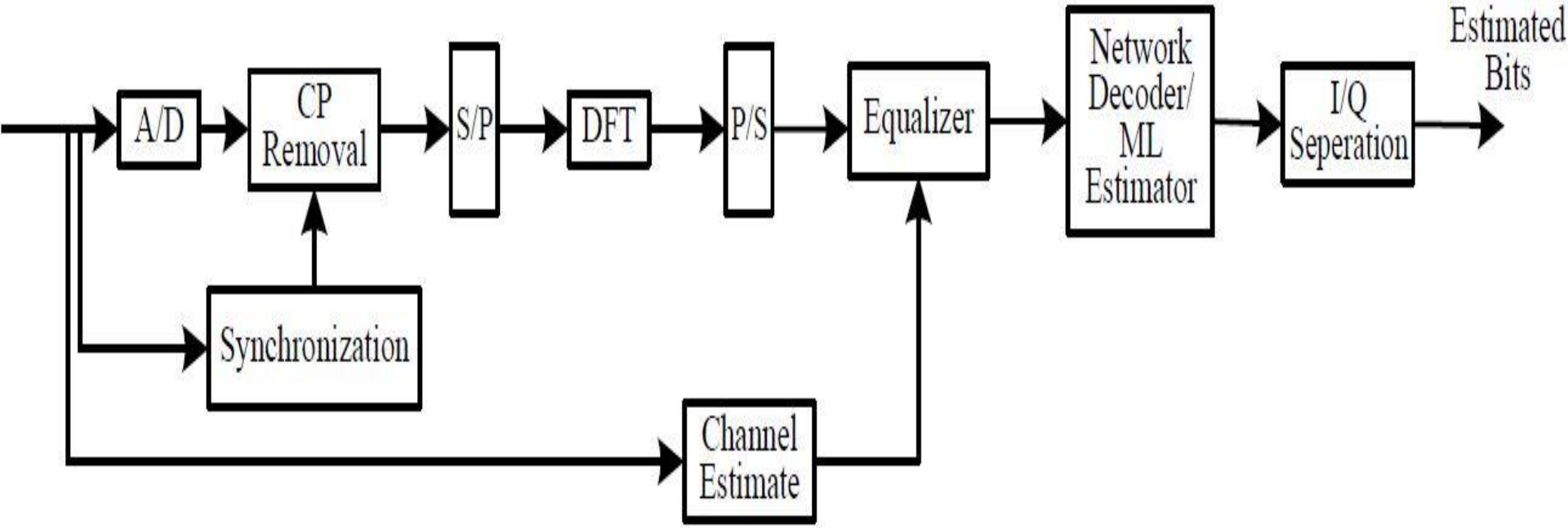
Testbed Details (7/14)

- Relay node SubVI implementation structure:



Testbed Details (8/14)

- Destination node SubVI implementation structure:



Testbed Details (9/14)

- Example of LabVIEW implementation:

  -Relay SubVI's transmitter code:

    -RFSG VI

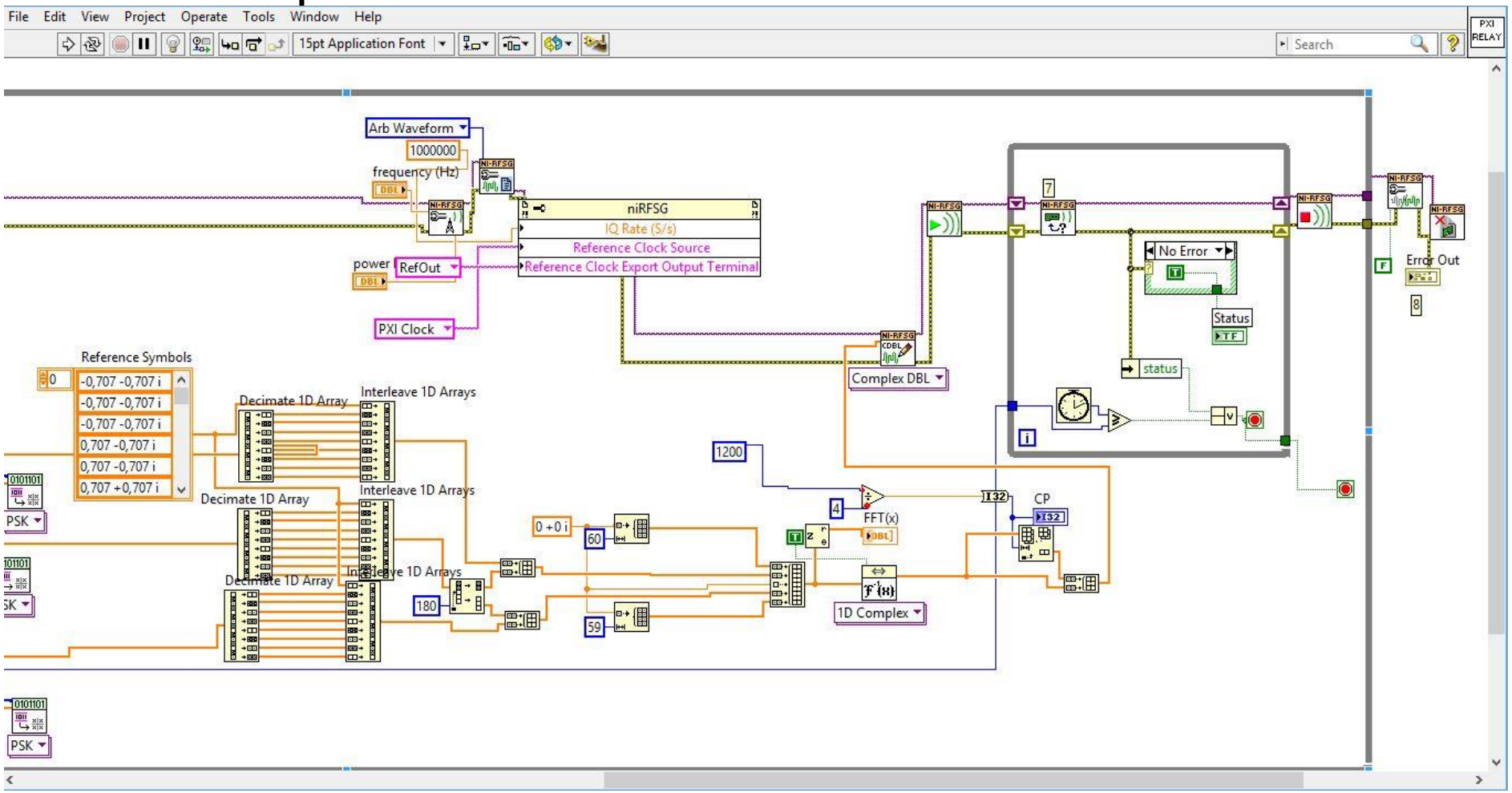
    -Modulation Toolkit VI

    -Signal Processing Library VI

    -Array functions

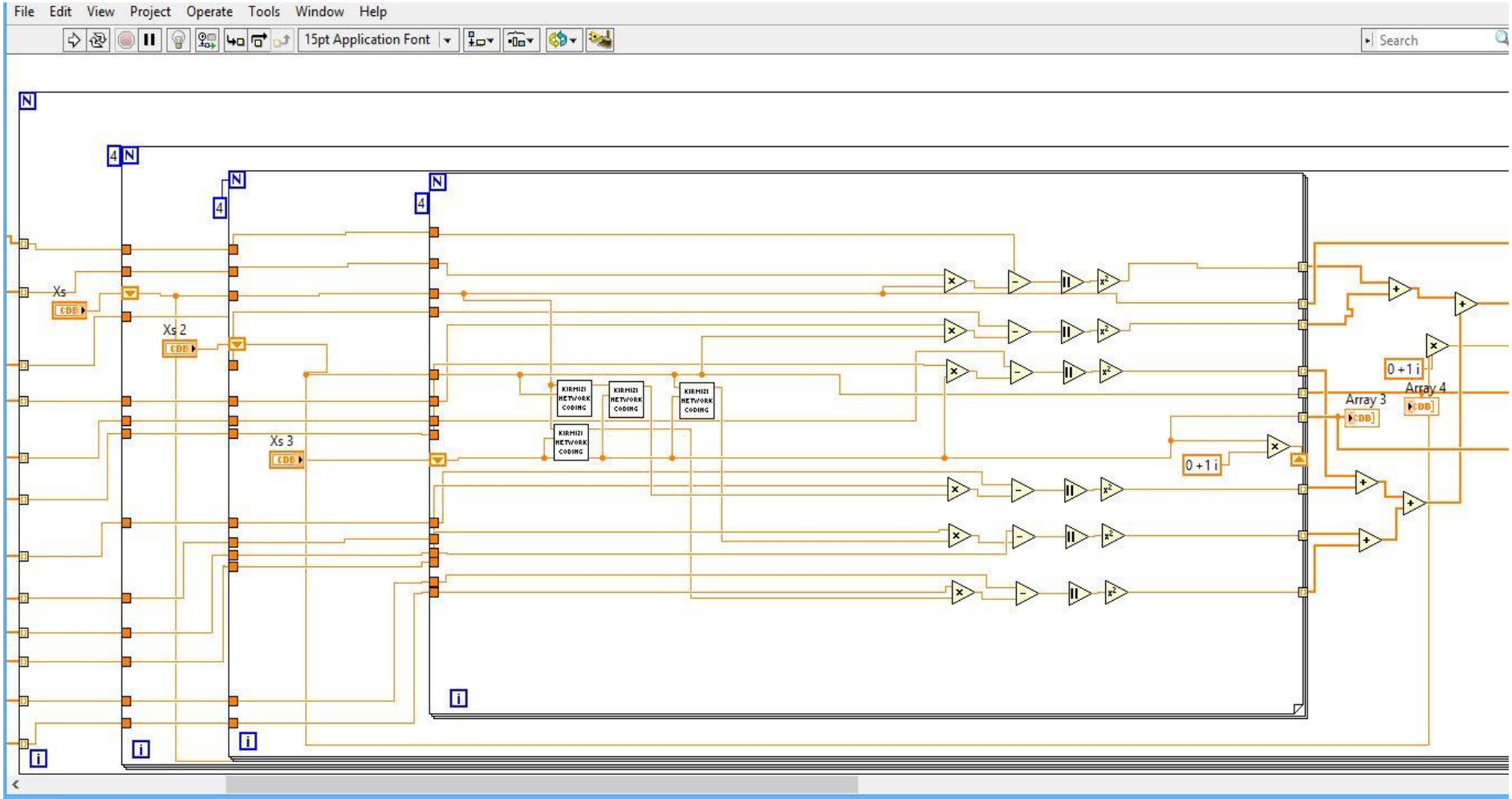
Testbed Details (10/14)

- Correspondent SubVI:



Testbed Details (11/14)

- Network Decoding and ML Estimator SubVI:



Testbed Details (12/14)

- Image Transmission Implementation:

  -Packet Transmission Algorithm:

  -Dividing 100x100 pixel images to packets

  -Index Portion: Shows packet's index number, %5 of the frame length

  -At Rx, by using index portion, packets are determined and put in right order to form image

Testbed Details (13/14)

- OFDMA Frame Structure:

	Subcarrier Index						
	0-59	60-419	420-599	600	601-780	781-1140	1141-1199
	ZP Sequence	Info+Reference	Info+Reference	DC	Info+Reference	Info+Reference	ZP Sequence
S_1	60 Samples 0 Sequence	360 Samples	0 Sequence 180 Samples	1 Sample	0 Sequence 180 Samples	0 Sequence 360 Samples	59 Samples 0 Sequence
S_2	60 Samples 0 Sequence	0 Sequence 360 Samples	180 Samples	1 Sample	180 Samples	0 Sequence 360 samples	59 Samples 0 Sequence
S_3	60 Samples 0 Sequence	0 Sequence 360 Samples	0 Sequence 180 Samples	1 Sample	0 Sequence 180 Samples	360 Samples	59 Samples 0 Sequence

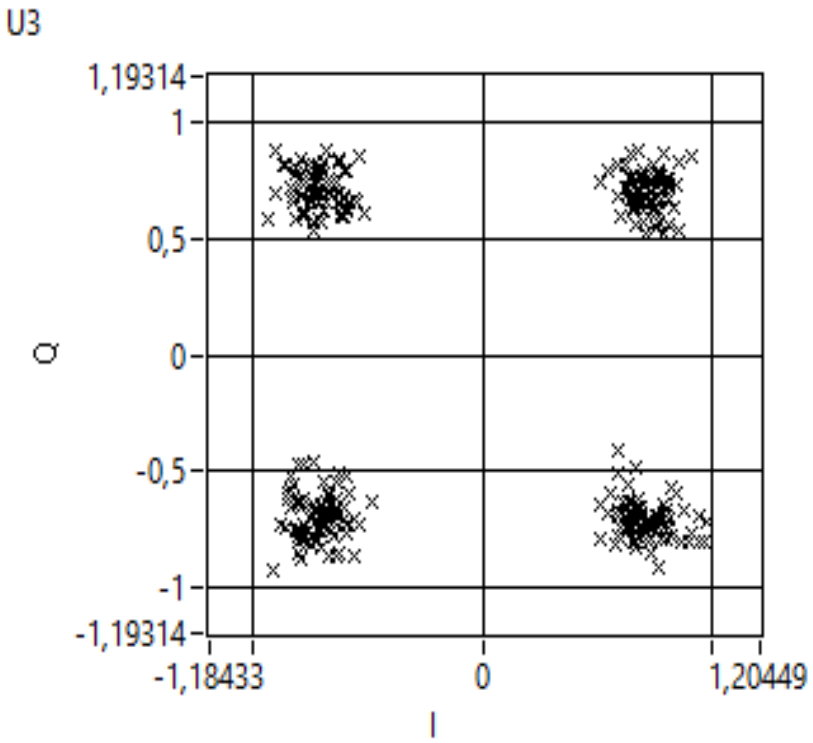
Testbed Details (14/14)

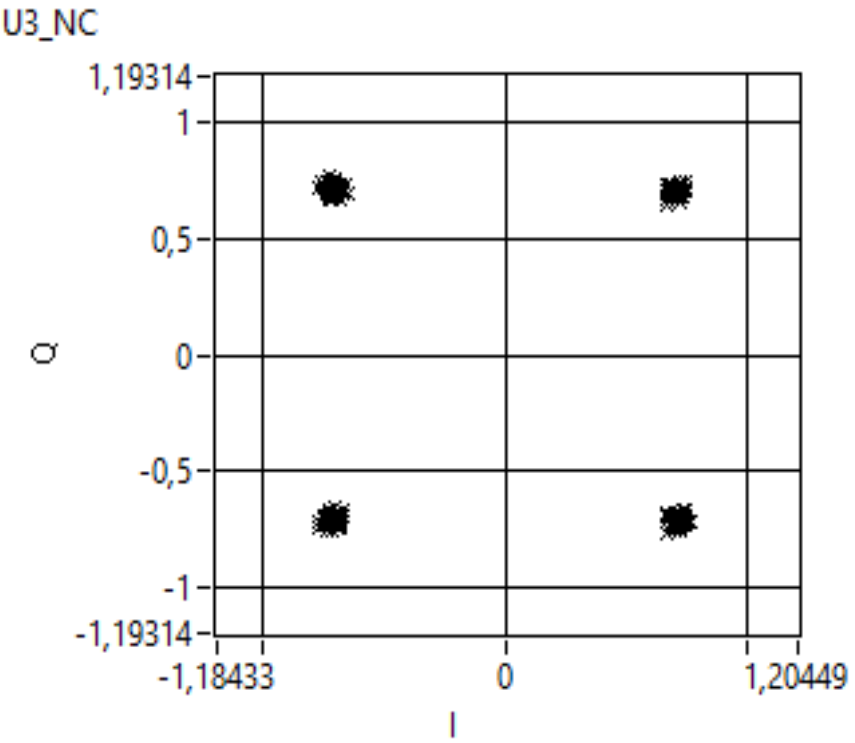
- Set-up Parameters:

Carrier frequency	2.45 GHz
I/Q data rate	1 MS/sec
Bandwidth	1 MHz
Number of bits used in one frame	2080 bits
Number of 4-QAM symbols	1040 samples
Total number of subcarriers of the one user data portion	320 samples
Number of reference subcarriers	40 samples
Number of source nodes	3
Number of relay nodes	1
Number of destination nodes	2
Zero padding length	120 samples
DFT length (N)	1200 samples
CP length	300 samples
Distances of nodes	75 cm/ 90 cm

Test Results (1/5)

- Received 4-QAM Constellation Diagrams:





Test Results (2/5)

- NCC System Test Results:

Broadcast Phase

Destination	Source Gain	Source	75 cm BER	75 cm EVM	90 cm BER	90 cm EVM
D_1	1 dB	S_1	6×10^{-3}	37.23	1.99×10^{-2}	44.78
		S_2	2×10^{-2}	42	3.7×10^{-2}	51.18
		S_3	2.9×10^{-2}	45.04	4.5×10^{-2}	55.26
D_2		S_1	2.4×10^{-2}	51.6	2.5×10^{-2}	52.28
		S_2	2×10^{-2}	50.38	3.7×10^{-2}	55.73
		S_3	3×10^{-2}	52.69	3.9×10^{-2}	56.33
R		S_1	0	8.49	0	8.63
		S_2	3.1×10^{-5}	14.5	2.4×10^{-5}	13.26
		S_3	0	18.21	3×10^{-5}	19

Relaying Phase

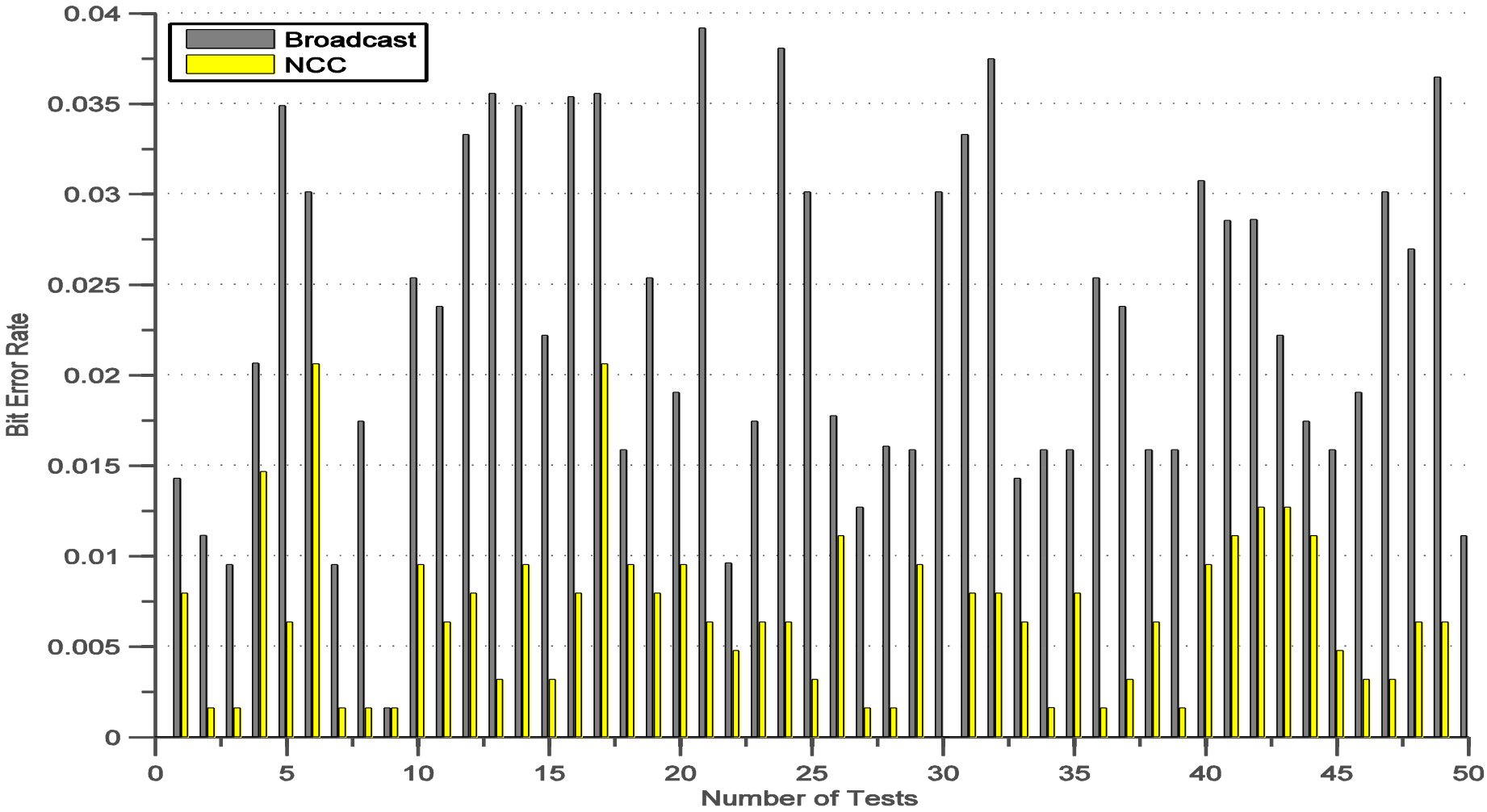
Destination	Gain: Source	Gain: Relay	Source	75 cm BER	75 cm EVM	90 cm BER	90 cm EVM
D_1		-23 dBm	S_1	2.8×10^{-4}	29.62	1.3×10^{-3}	36.05
			S_2	3×10^{-4}	30.32	1.3×10^{-3}	35.96
			S_3	2.1×10^{-4}	29.99	1.7×10^{-3}	36.76

Network Decoder

Destination	Gain: Source	Gain: Relay	Source	75 cm-BER	90 cm-BER
D_1		-23 dBm	S_1	8×10^{-4}	6×10^{-3}
			S_2	2.5×10^{-3}	3.24×10^{-2}
			S_3	3×10^{-3}	3.7×10^{-2}

Test Results (3/5)

- Link performance comparison for S3 data at 4 dB gain. The relay gain is -23 dBm.



Test Results (4/5)

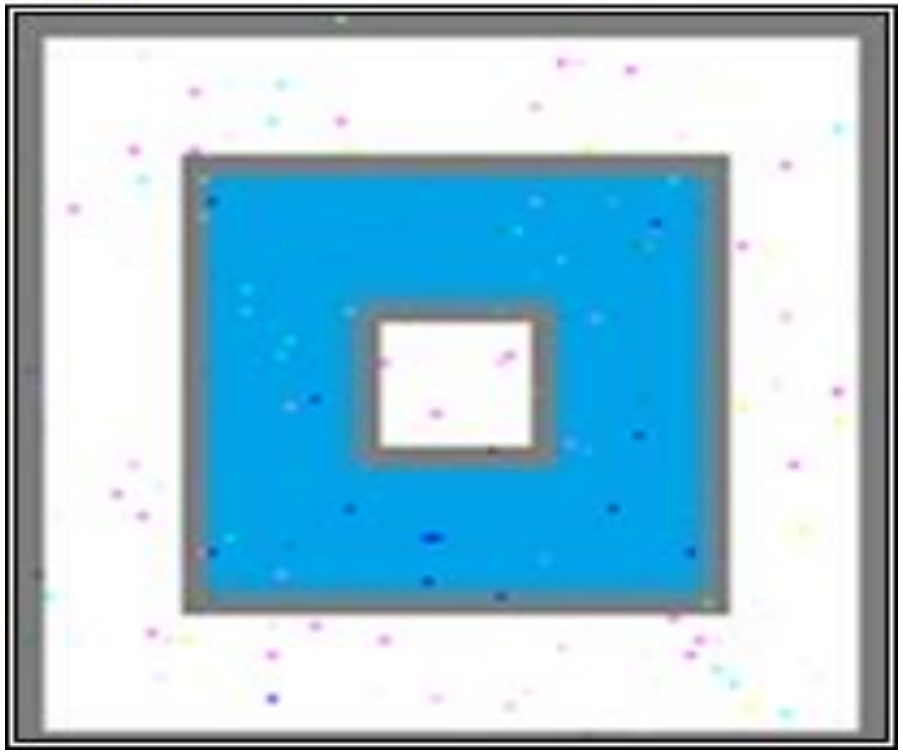
- BER performance comparison of the links in the image tranmission implementation

	S_1	S_2	S_3
Direct Link	5.39×10^{-5}	6.49×10^{-4}	4.42×10^{-4}
S-R Link	2×10^{-6}	4.1×10^{-6}	6.96×10^{-5}
Network Decoder	1.95×10^{-6}	1.14×10^{-5}	1.2×10^{-4}

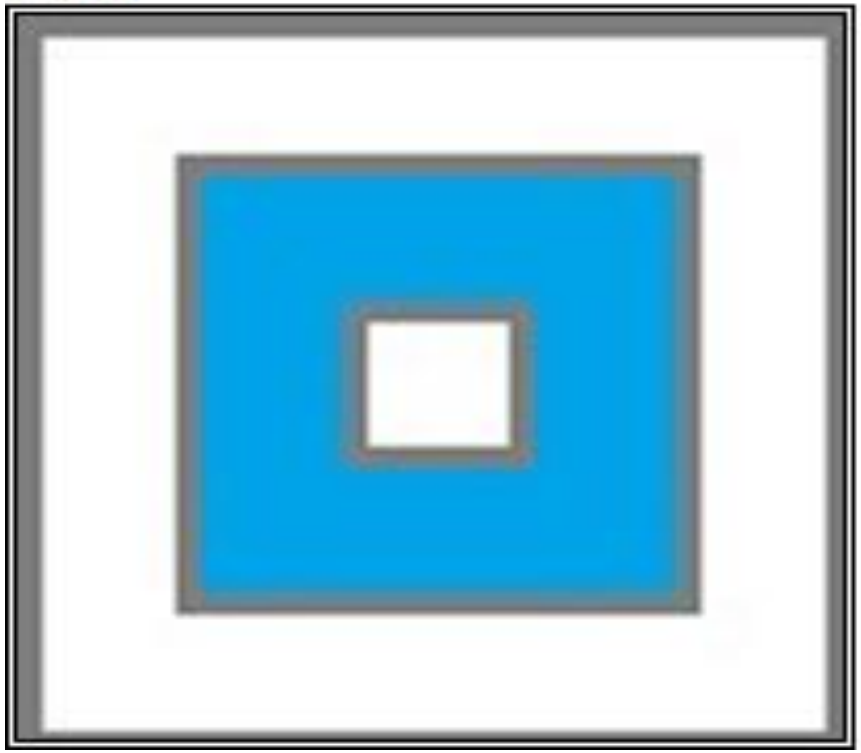
Test Results (5/5)

- Received image at direct link and network decoder:

S2-D



NCC2



Conclusions

- Provide efficient usage of limited resources
- NCC is very effective on improvement of transmission quality of OFDMA based transmission
- Reliable communications against imperfect effects of wireless fading channel
- Suitable for applications such as multimedia transmission

Thank you!

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