GNURadio Support for Real-time Video Streaming over a DSA Network

Debashri Roy

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Outline

- Challenges
- Objective
- Channel Model
- Adaptation Techniques
- Spectrum Sensing
- Experimental Setup
- Experimental Results
- Summary

Challenges

- Radio communication is fraught with uncertainties
  - Signal fading due to multi-path propagation
- Shadowing due to manmade and natural objects
- Interference
  - Natural and manmade noise
  - Other radio signals (adjacent band, intermodulation products, etc.)

Thus, ever-changing channel condition

- Channel Adaptive Video Streaming
- Intelligent Spectrum Allocation and Sharing

Adaptive Streaming

- Cisco's Visual Networking Index (VNI) Forecast:
  - Internet Video: 18,000 GB per second in 2016; 71,300 GB per second in 2021
  - Live Video: 5,400 GB per second in 2016; 9,300 GB per second in 2021

- Streaming Mechanisms:
  - Adobe HTTP Dynamic Streaming (HDS)
  - Apple HTTP Live Streaming (HLS)
  - Microsoft Smooth Streaming (MSS)

- Dynamic Adaptive Streaming over HTTP (DASH)
  - Stores multiple copies of same video of 2 - 10 seconds segments
  - Netflix, YouTube content based providers

Spectrum Sharing

- Spectrum allocation policy created spectrum scarcity
  - Disproportionate usage
  - Some do not use what has been allocated; some need more

- FCC is pushing for solutions.

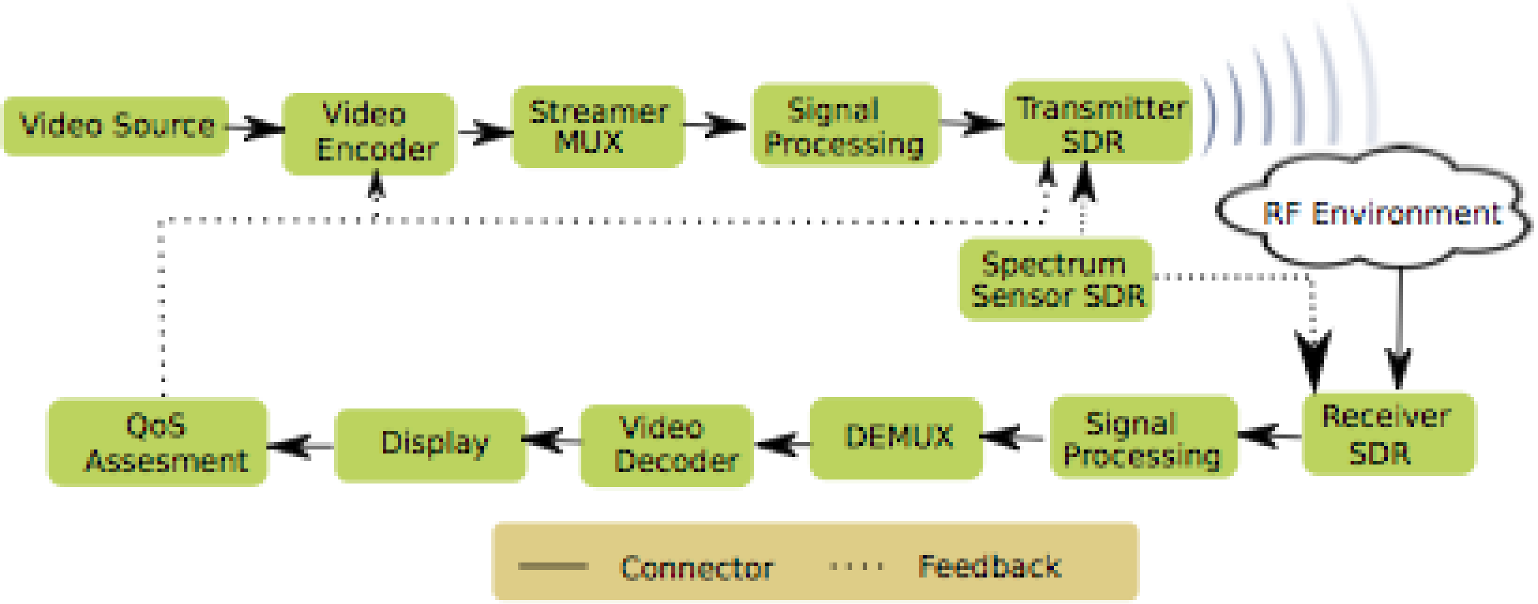
Spatial Reuse of Spectrum – Dynamic Spectrum Access (DSA)

Objective

- How to adapt to varying channel conditions for sustaining video QoS
  - How to adapt RF parameters based on feedback
  - How to adapt source coding parameters based on feedback

- To demonstrate the adaptation process for real time video transmission over SDR
  - How to identify PU presence using energy detection algorithm?
  - To identify usable channels for SUs
  - To implement DSA for SUs to use best channels

General Approach



Channel Models

- Pathloss Modeling: Simplified Pathloss

$$PL_{dB}(d) = 10\log_{10}\frac{P_r}{P_t} = 20\log(\frac{\lambda}{4\pi d_0}) + 10\gamma\log[\frac{d_0}{d}]$$

- Shadowing and Fading Model: Ricean with indoor LOS

$$\psi(x) = \frac{1}{\sqrt{2\pi\sigma_s^2}}\exp - \frac{(x-\mu_d)^2}{2\sigma_s^2}$$

- Channel to Source Coding:
  - Mean Power loss: $\mu_d = 20\log(\frac{\lambda}{4\pi d_0}) + 10\gamma\log[\frac{d_0}{d}]$
  - Deviation: $\sigma_s \sim [-2.6134 to 2.6134]$

Channel Adaptation Technique

- Objective: Maximize the video quality metrics based on source coding, and hardware capability constraints depending on channel condition.
- L: number of non-uniform divisions for mapping channel to source coding.

- Mathematical Formulation:

$$\underset{\forall i}{minimize}(L)$$

$$subjectto \int_{x_1=-\infty}^{x_2} \psi(x) = \int_{x_2}^{x_3} \psi(x) = \cdots = \int_{x_L}^{\infty} \psi(x) = \frac{1}{L}$$

$$\upsilon_i = \left(\frac{\varepsilon_{max}(d) - \varepsilon_{min}(d)}{L-2} \times \frac{x_i - \mu_d}{\sigma_s}\right), for 2 \le i \le (L-1)$$

$$\upsilon_{MIN} \le \upsilon_i \le \upsilon_{MAX}$$

Channel Adaptation Technique

- Channel to Source Coding:
  - Minimum and Maximum Bitrate:

$$\varepsilon_{min}(d) = \varepsilon_{MIN} for d \leq 1$$
$$\frac{\varepsilon_{MIN} \times \mu_{d=1}}{\zeta(\mu_d)} for d > 1$$

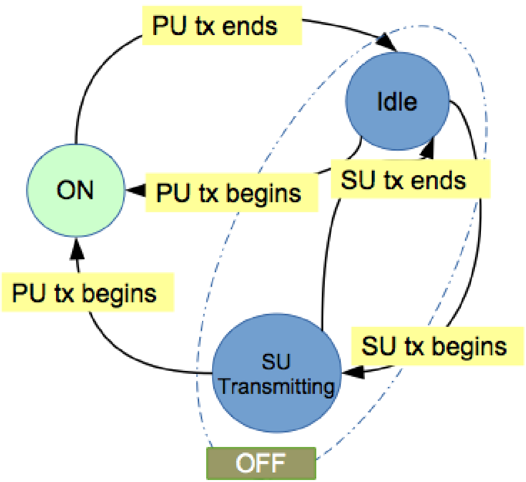
$$\varepsilon_{max}(d) = \varepsilon_{MAX} for d \leq 1$$
$$\frac{\varepsilon_{MAX} \times \mu_{d=1}}{\zeta(\mu_d)} for d > 1$$

  - Quantitive Encoding Rates: $\varepsilon_i = \varepsilon_{i-1} + \upsilon_i for 2 \leq i \leq (L-1)$

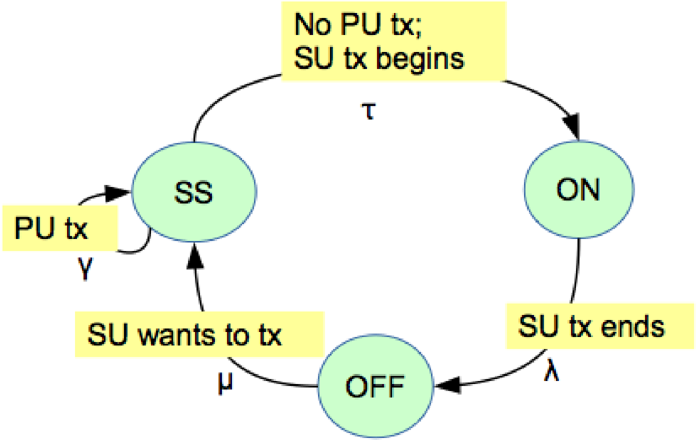
$$\varepsilon_1 = \varepsilon_{min}(d), and \varepsilon_L = \varepsilon_{max}(d)$$

Spectrum Sensing and Selection

- 3 State Markov Chain Model

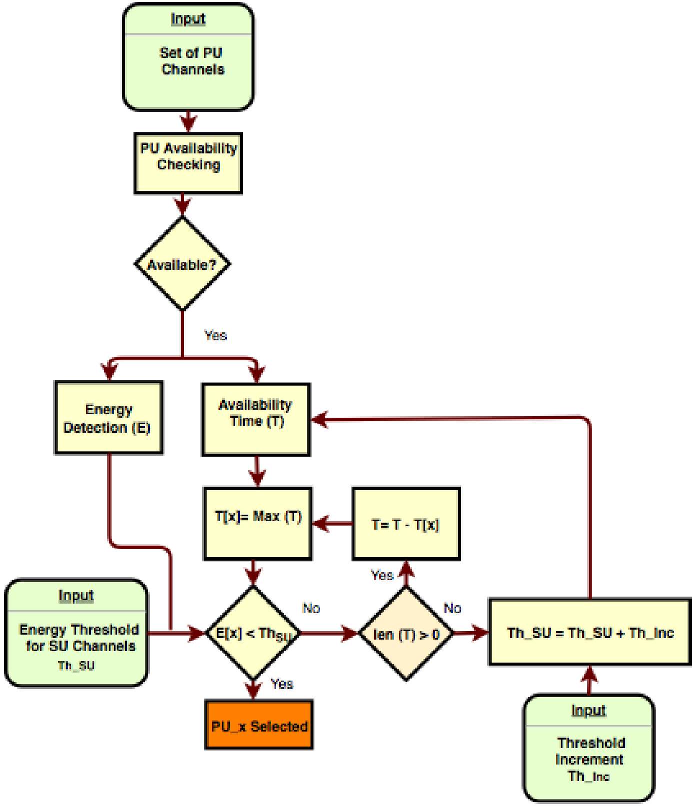


Primary User (PU) Activity Model



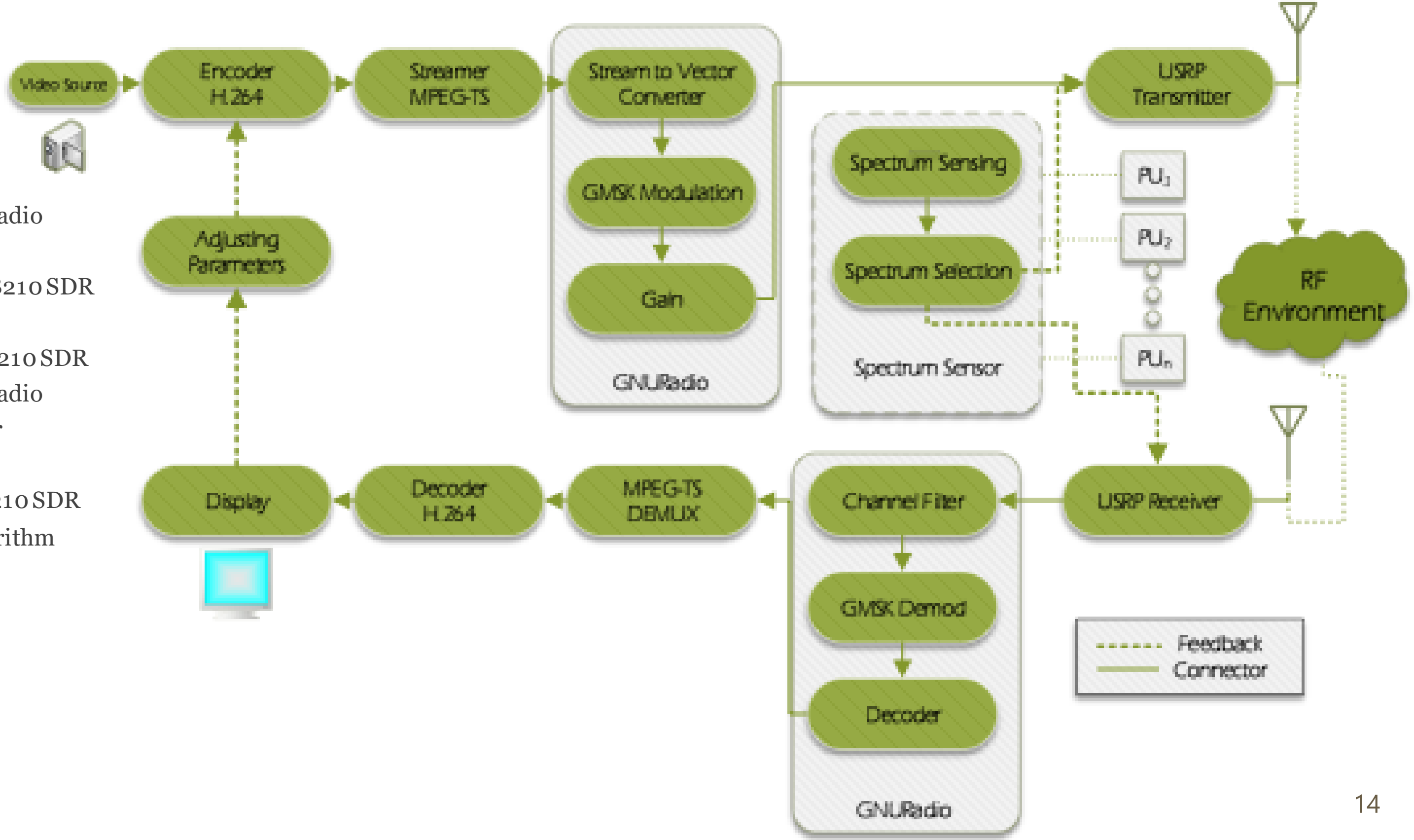
Secondary User (SU) Activity Model

Spectrum Sensing and Selection



Experimental Setup

- Video Source
  - Web Camera
- Encoder
  - H.264 codec
- Streamer
  - Gstreamer
- Transmitter
  - Signal Processing: GNURadio
  - Feedback Adaptation
  - Transmit through USRP B210 SDR
- Receiver
  - Receiver through USRP B210 SDR
  - Signal Processing: GNURadio
  - Channel Feedback Sender
- Spectrum Sensor
  - Sensing through USRP B210 SDR
  - Threshold based ED Algorithm
  - Send new Frequency to Transmitter and Receiver
- Decoder and Display
  - H.264 decoder
  - Mplayer display



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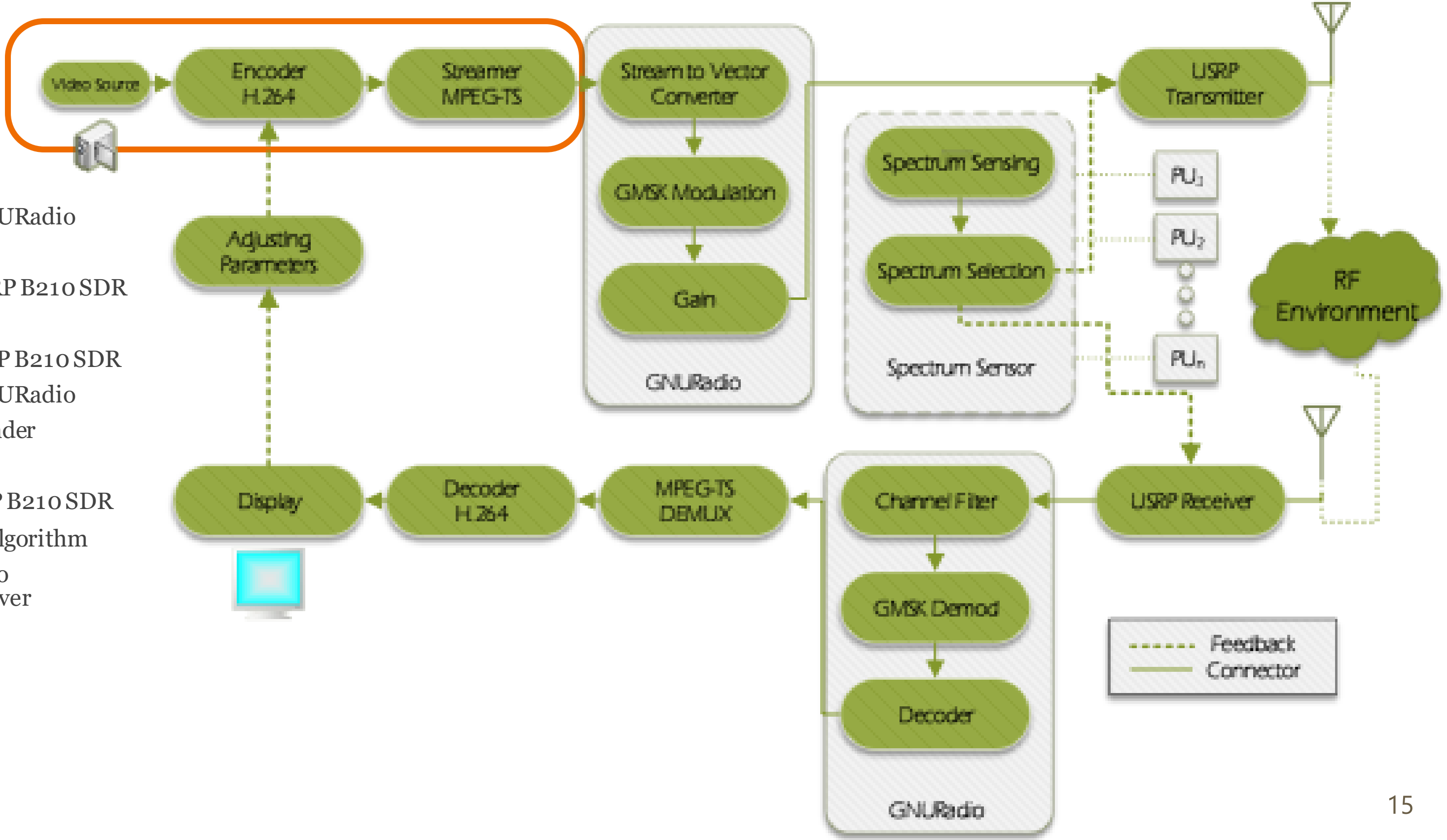

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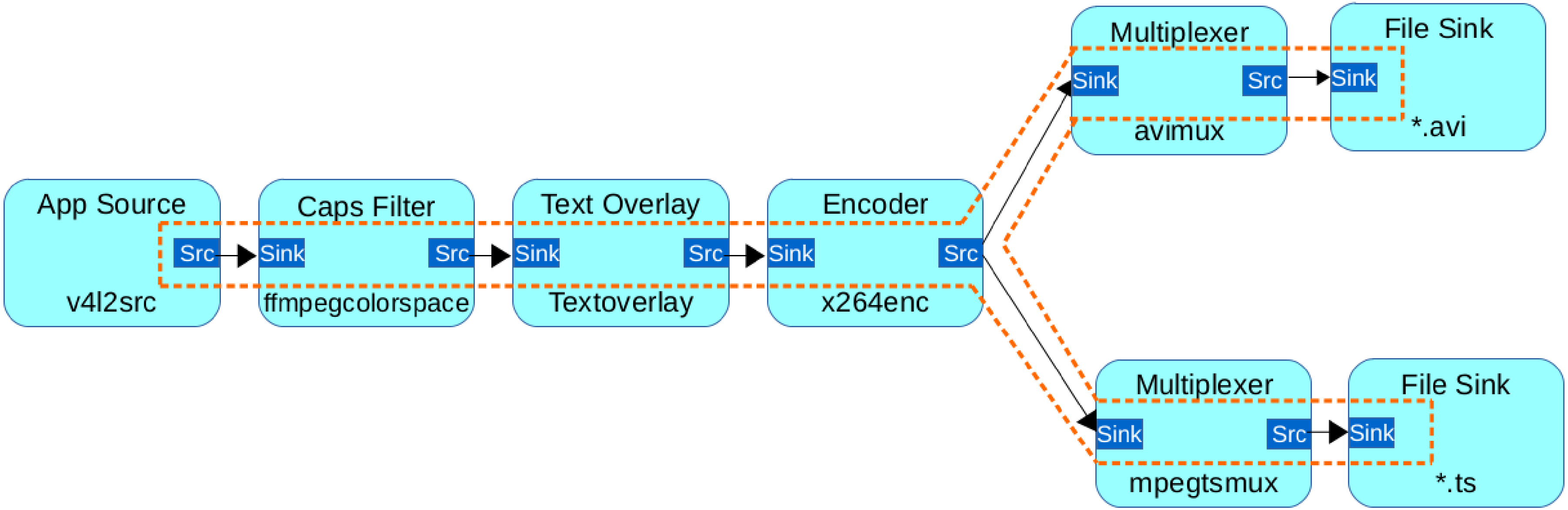

  - H.264 decoder
  - Mplayer display

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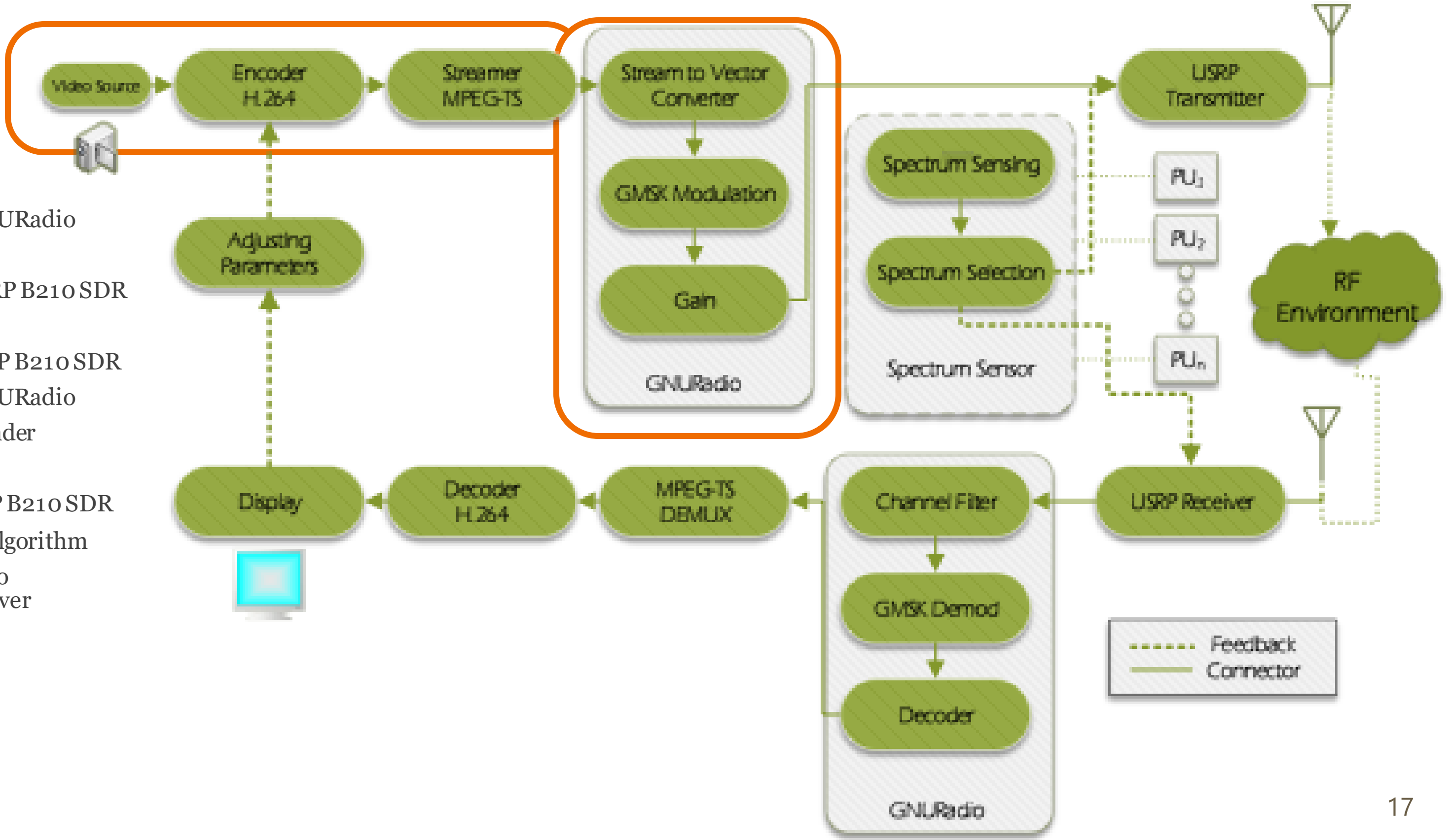

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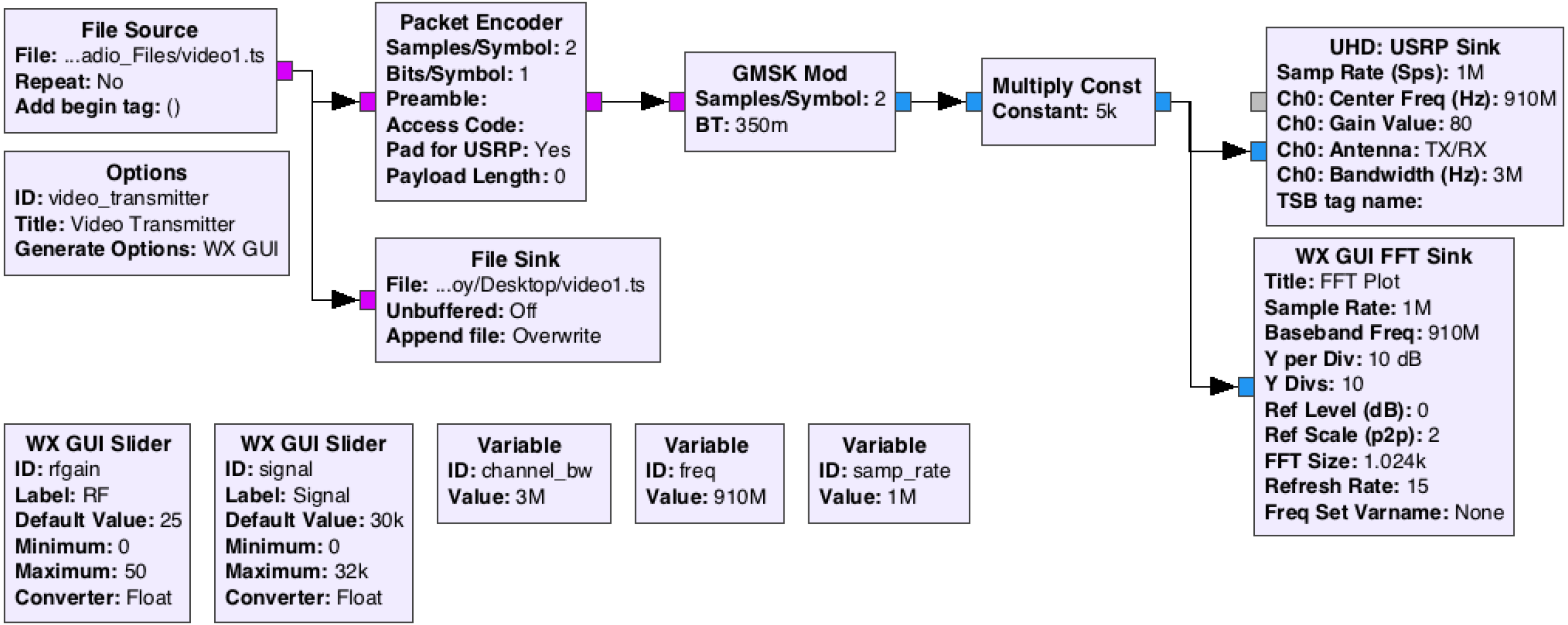

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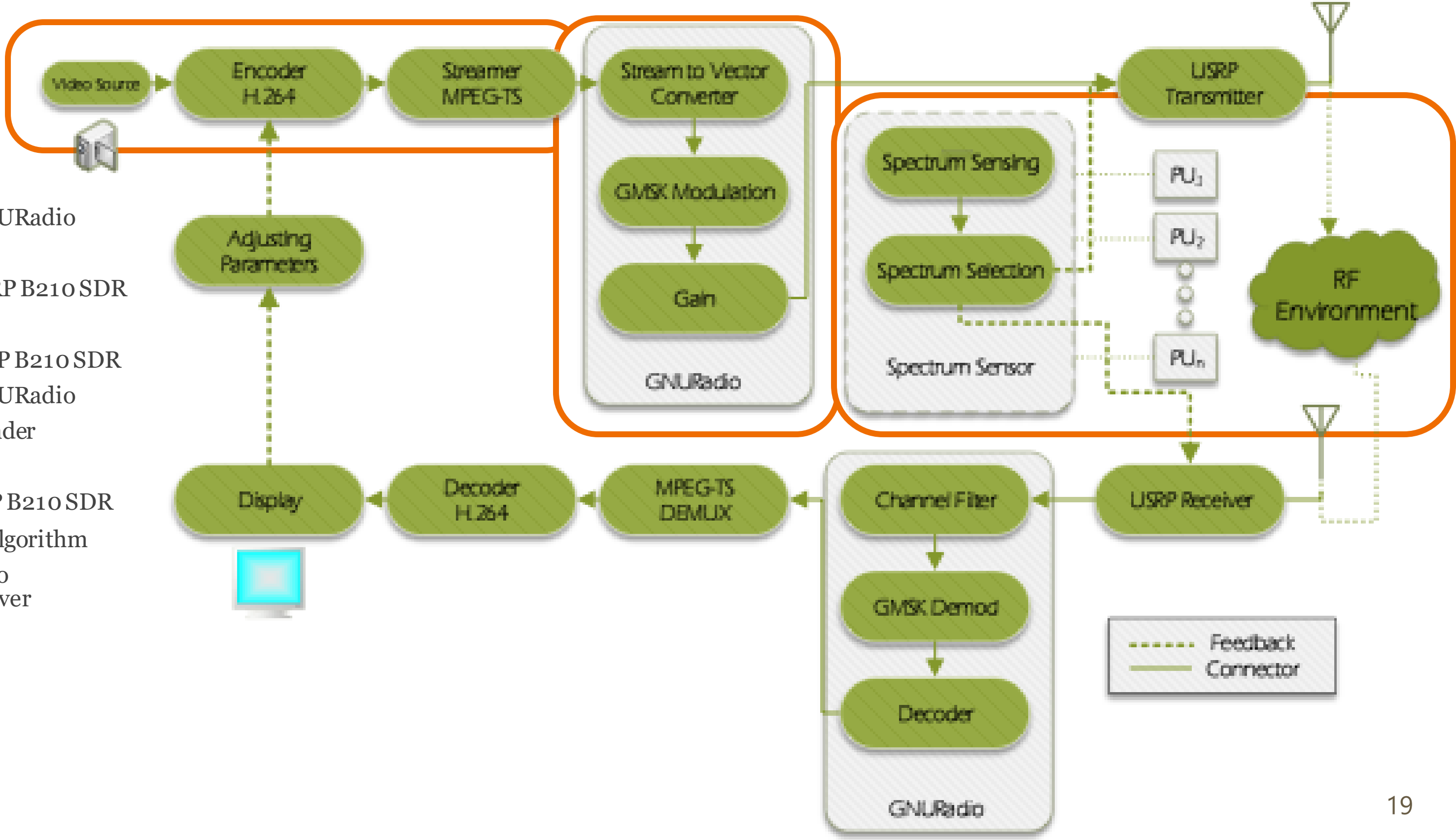

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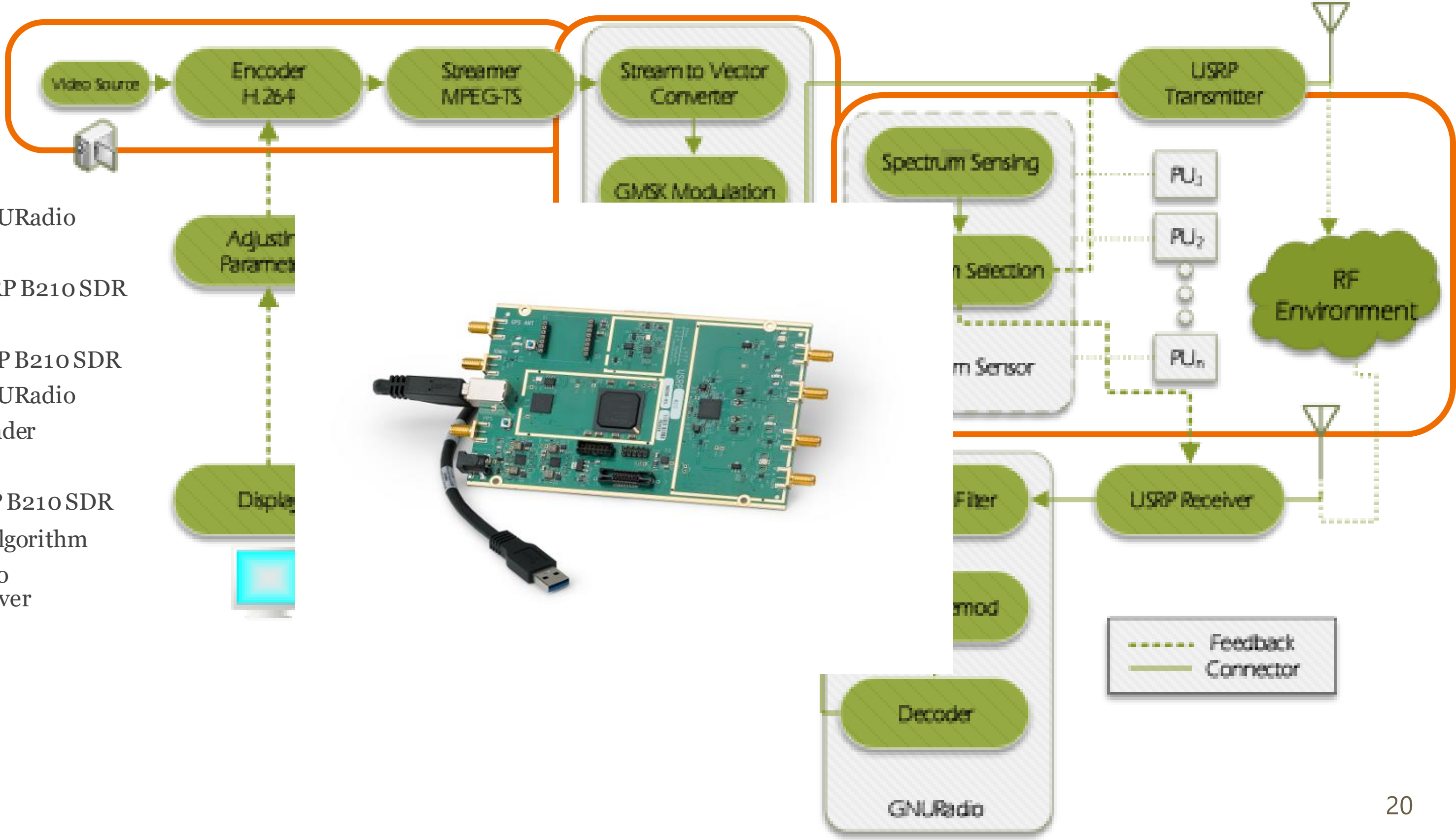

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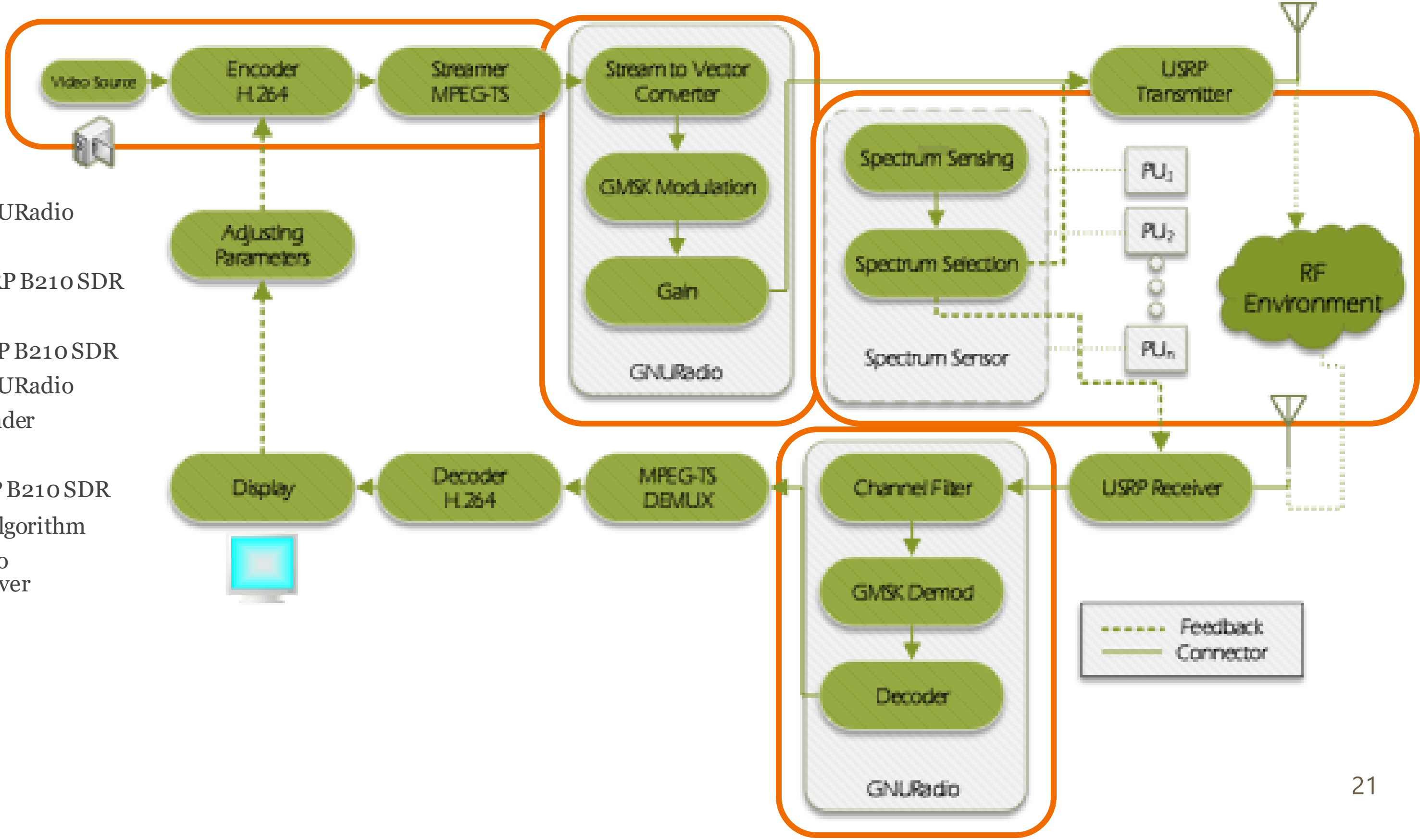

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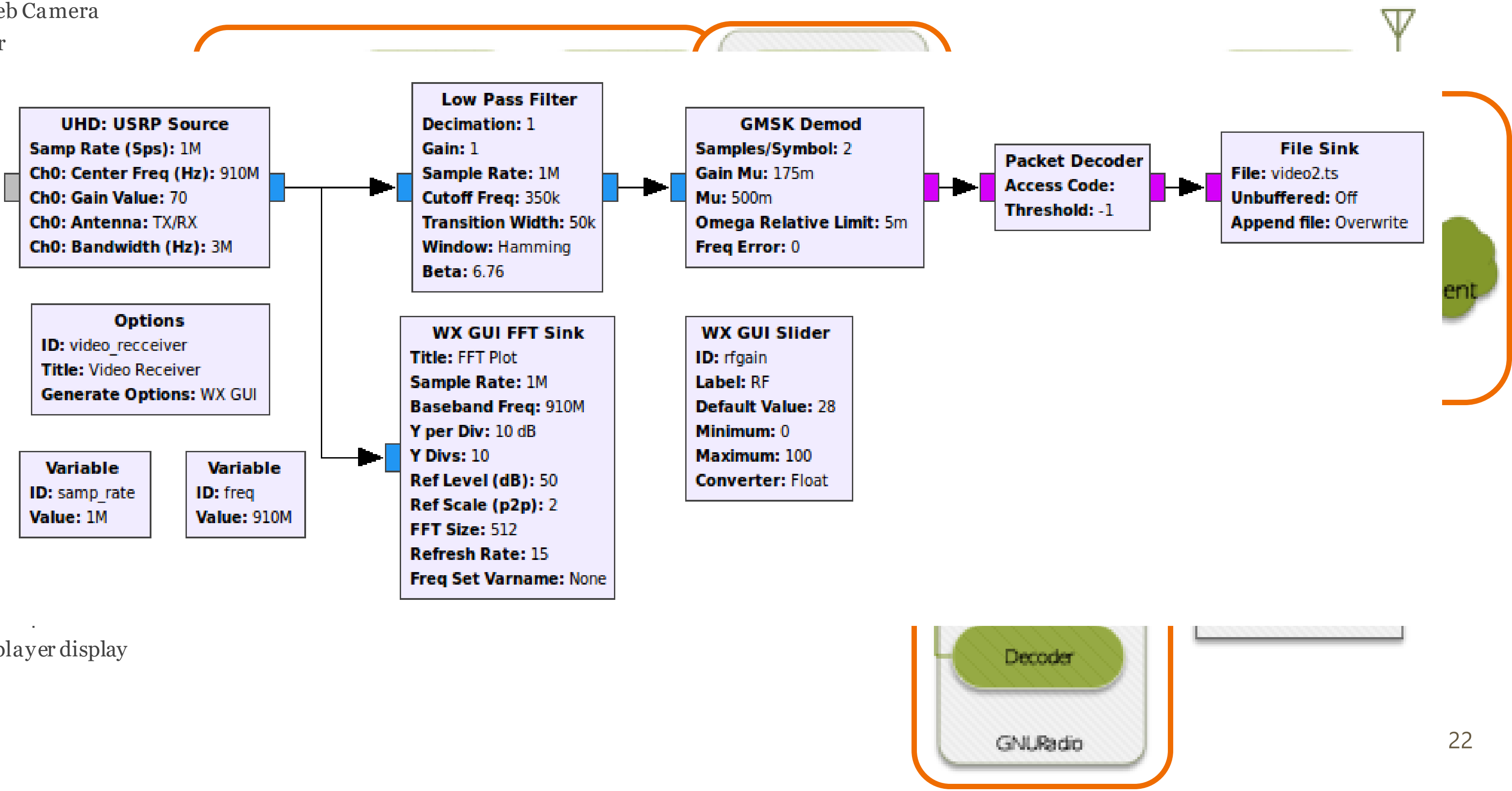

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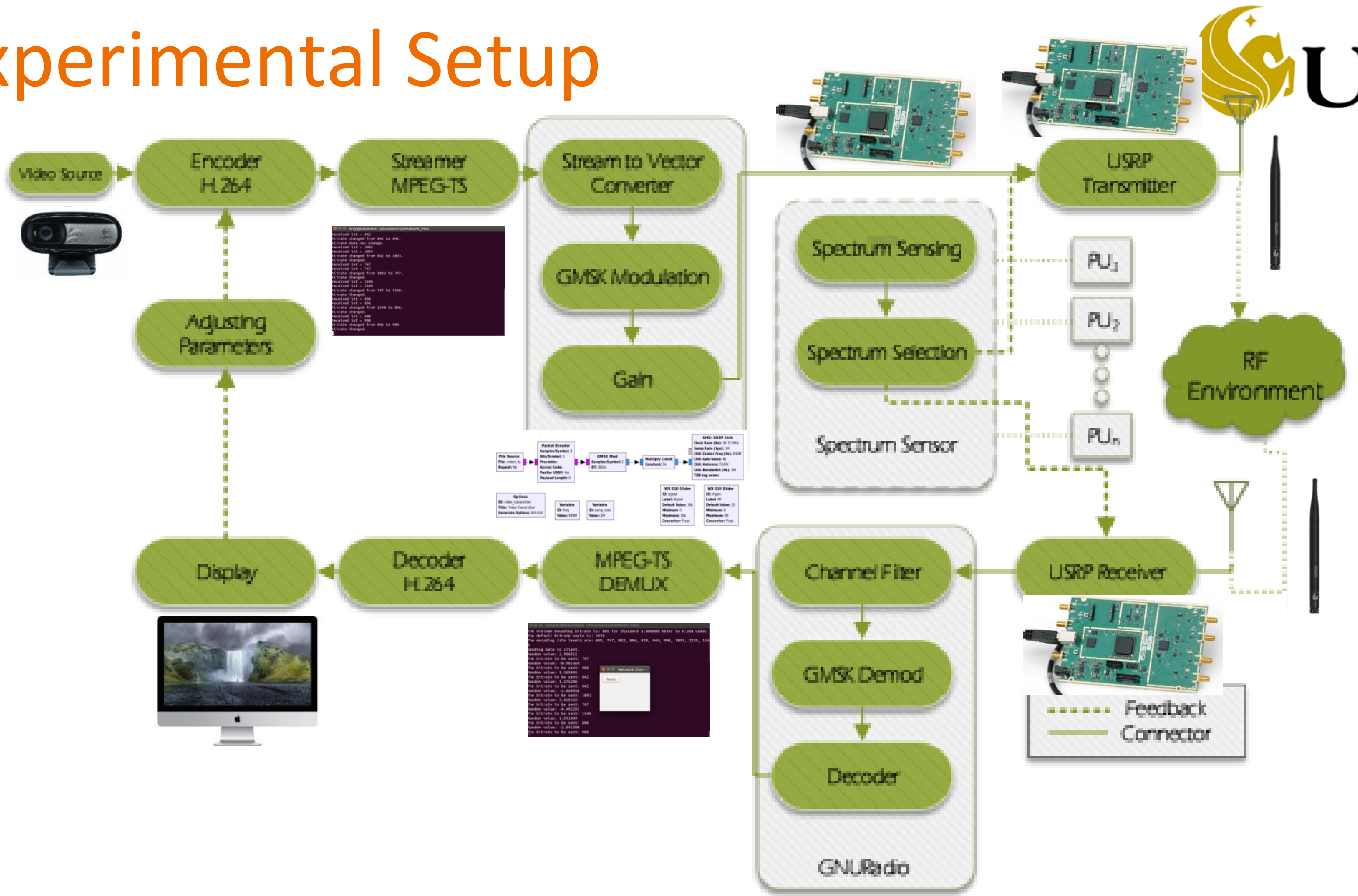

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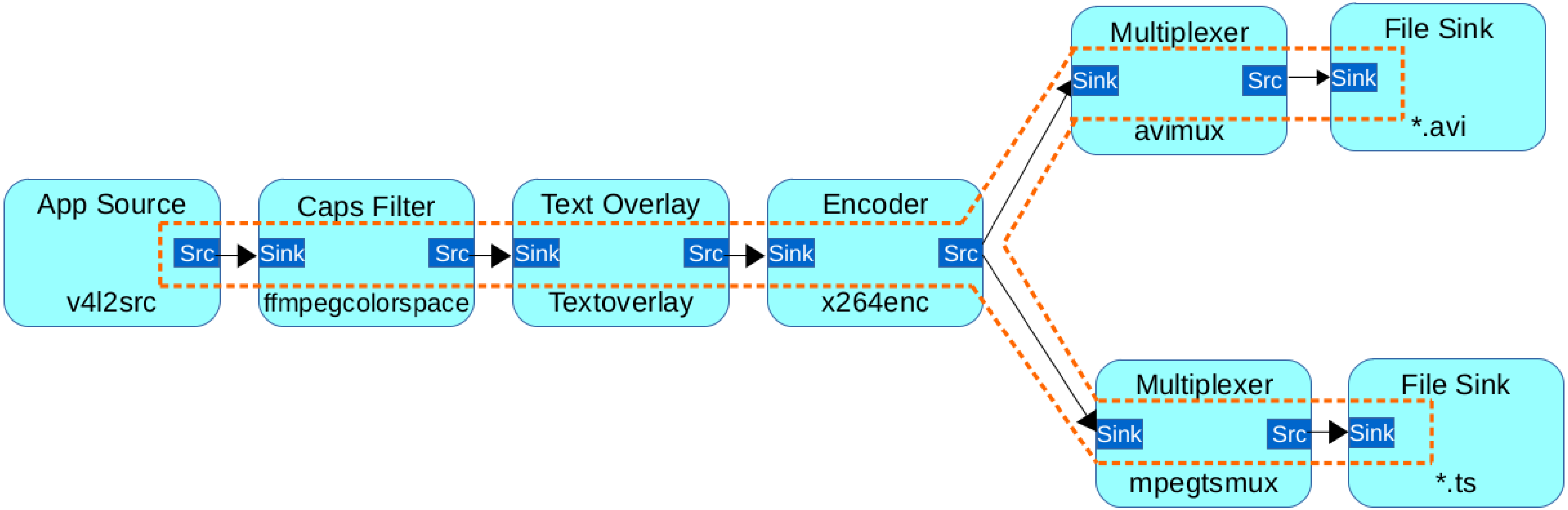
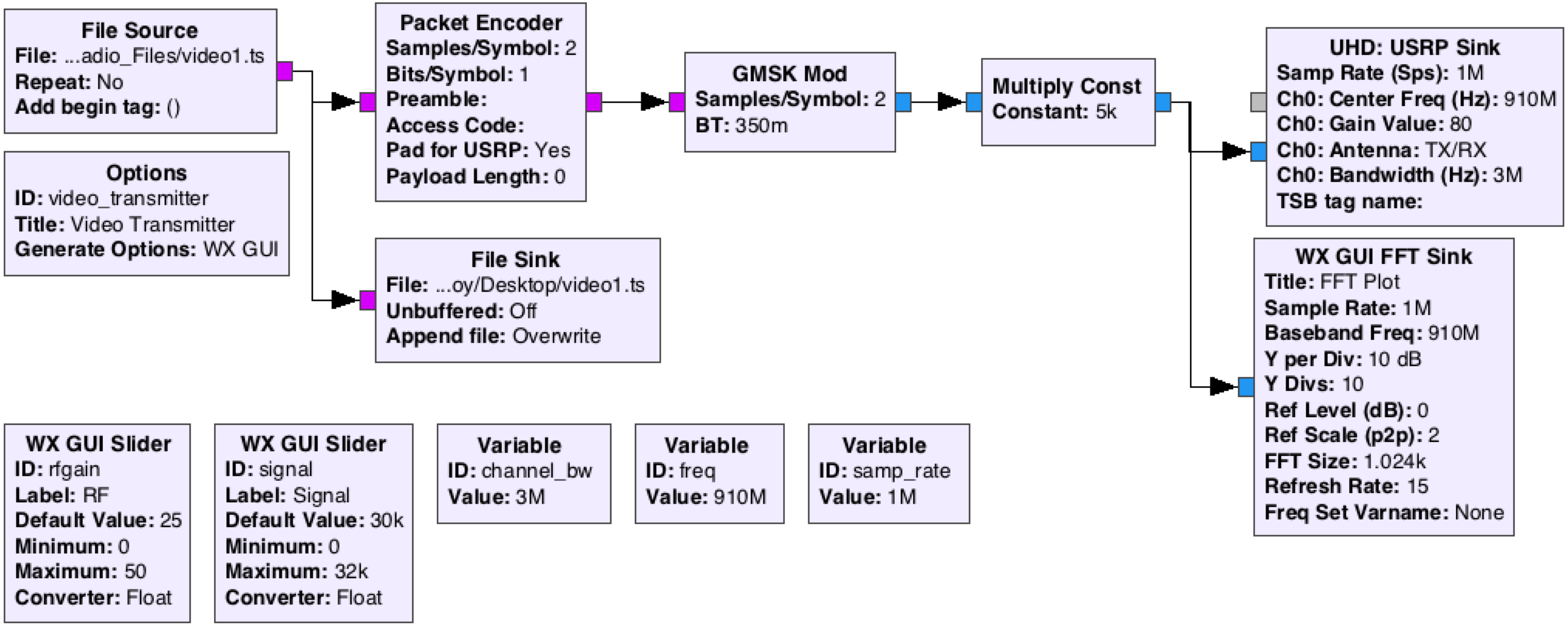


Gstreamer Pipeline: Source → Encoding → Streaming

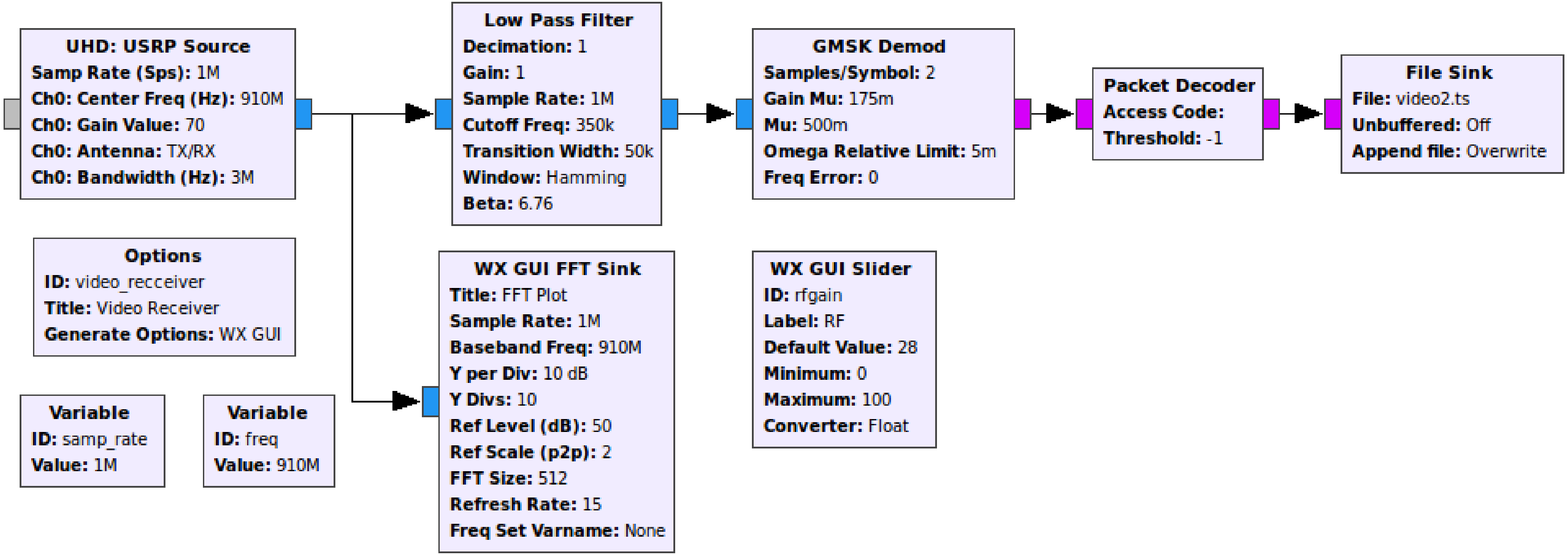
Experimental Setup

Video Transmitter Modeled using GNURadio Flowgraph



Experimental Setup

Video Receiver Modeled using GNURadio Flowgraph



Software Defined Radios

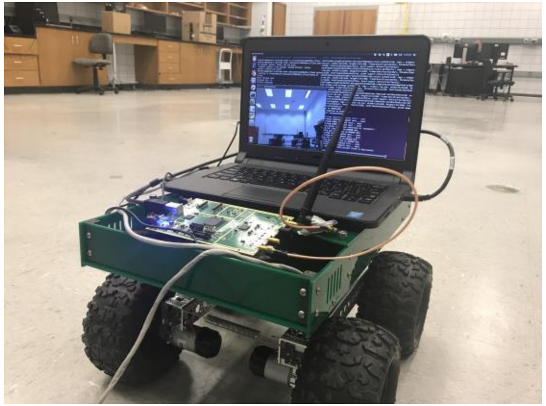
- Hardware components of the past
  - Modulators, demodulators, amplifiers, etc
- Today's Software components
  - Modulators, demodulators, amplifiers, etc
- Advantages
  - Low-cost
  - Commercially available
  - Easy signal processing
  - Easy configuration/re-configuration

USRP B210 SDR by Ettus Research

Configuration Parameters

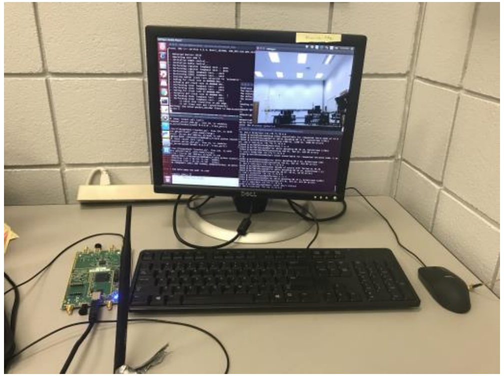
Parameters	Values
Experimental Scenario	Indoor
Pathloss Model	Simplified Pathloss
Channel Fading Model	Ricean
Starting Frequency	910 MHz (ISM band)
Channel Bandwidth	3 MHz
Modulation Scheme	Gaussian Minimum Shift Keying (GMSK)
Error Control Mechanism	None
Transmitter Channel Gain	80 dB
Receiver Channel Gain	70 dB
Antenna Gain	3 dBi
Min Encoding Bitrate	512 Kbps
Max Encoding Bitrate	2048 Kbps
Encoder Frame Rate	25 fps
Spectrum Sensing Method	Energy Detection (ED)
Video Codec	H.264
Streaming Encapsulation	MPEG-TS
Video QoS	Peak Signal to Noise Ratio (PSNR) Structural SIMilarity (**SSIM**)
Each Experiment Time	5 minute

Experimental Scenario



(a) Live Video Capture and Transmit

(b) RF Environment



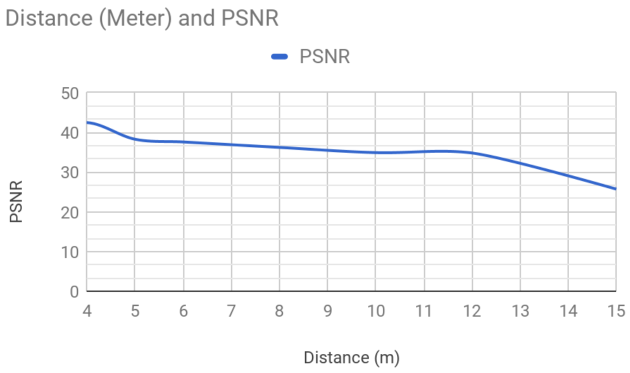
(c) Video Receiver

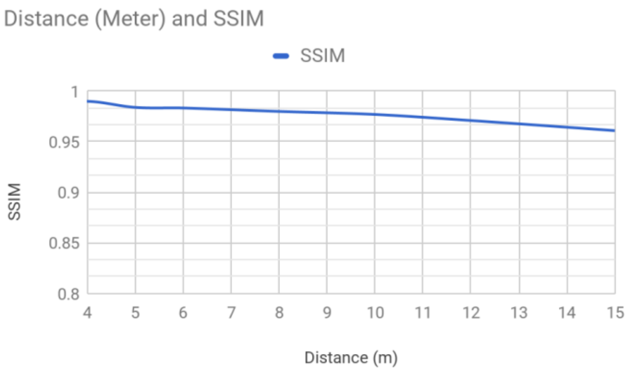
Experimental Results

- **Video Quality of Ideal Channel with Distance**
- **Video Quality for Continuous Changing Channel Implementing Channel Adaption Algorithm**
- **Video Quality for Fixed Channel Implementing Dynamic Spectrum Access**
- **Video Quality for Continuous Changing Channel Implementing Dynamic Spectrum Access**

Experimental Results

Video Quality of Ideal Channel with Distance

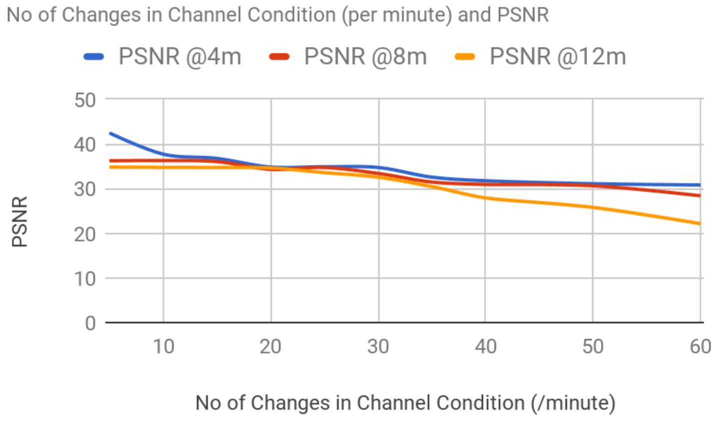


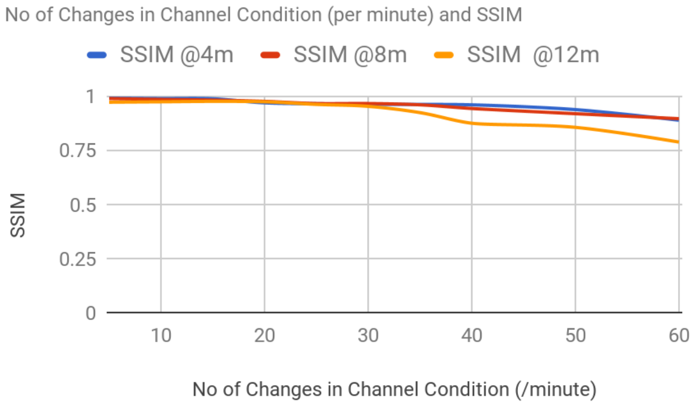


- ➔ Video Quality degrades with increasing distance.
- ➔ Good Quality video is achieved until 12 meter distance indoor.

Experimental Results

Video Quality for Continuous Changing Channel Implementing Channel Adaption Algorithm

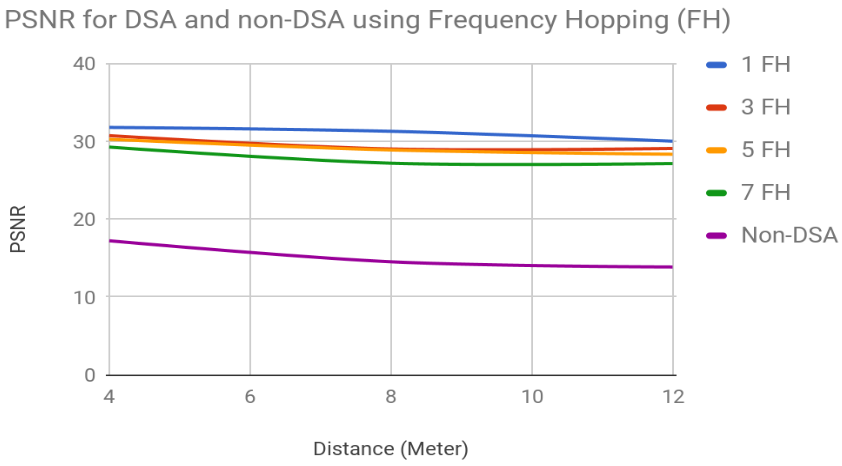


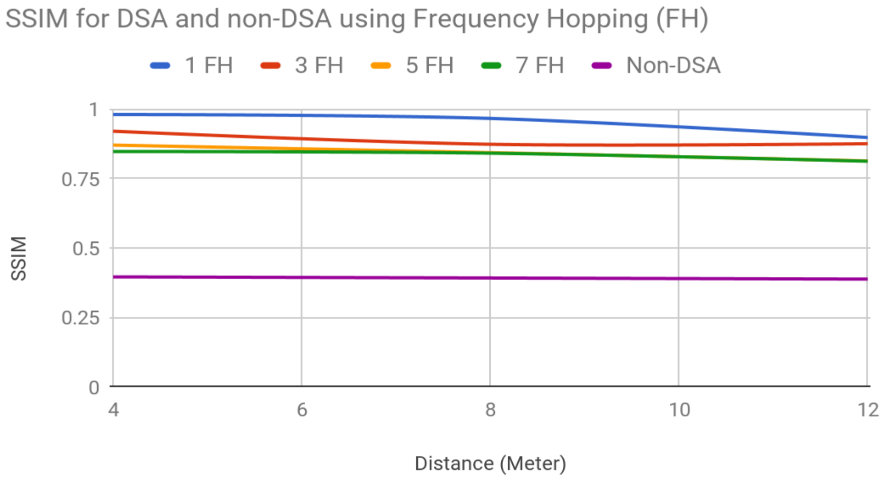


- ➔ Video Quality degrades with more unstable channels.
- ➔ Good Quality video is achieved until 40 changes per minute until 8 meters distance.
- ➔ Good Quality video is achieved until 30 changes per minute until 12 meters distance.

Experimental Results

Video Quality for Fixed Channel Implementing Dynamic Spectrum Access

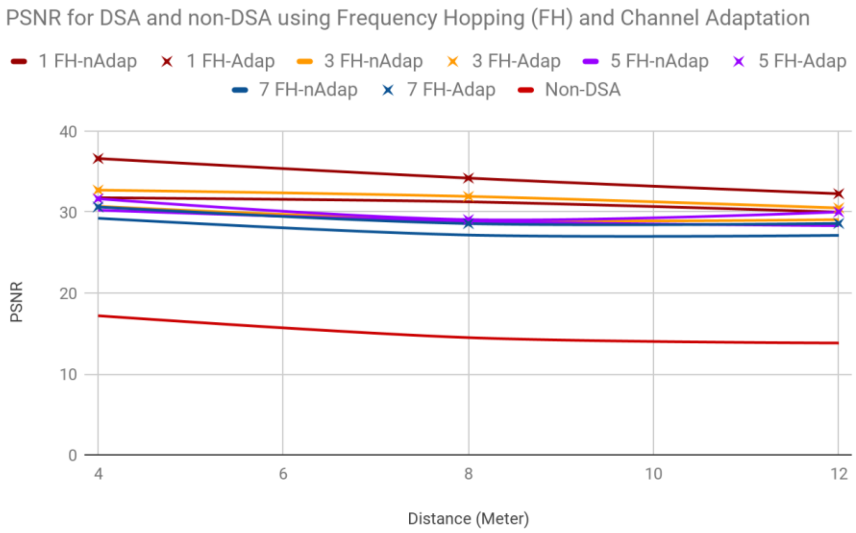


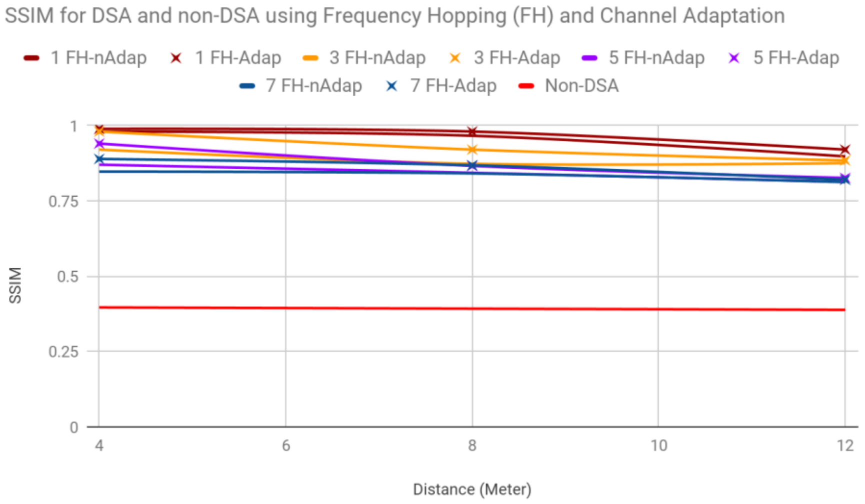


- ➔ DSA implementation provides better video quality than Non-DSA ones.
- ➔ Video Quality degrades with increasing number of frequency hopping.
- ➔ Good Quality video is achieved until 3-5 hoppings per minute for indoor situation.

Experimental Results

Video Quality for Continuous Changing Channel Implementing Dynamic Spectrum Access





➔ DSA implementation for adaptive channel provides better video quality than non-adaptive one.

Summary

- Implemented feedback-controlled adaptive mechanism of video transmission for unstable channel implementing Dynamic Spectrum Access.
- Better video quality implementing DSA as opposed to non-DSA based methods.
- A solution for real-time adaptive video streaming with GNURadio and SDRs for contested wireless environment.
- Code available: *https://github.com/debashriroy/video-over-dsa*

Thank You