What’s happening in the world of USRPs?

NI: Sponsor Talk

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Let’s pick up where we left off…

ni.com

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Ettus USRP X410

Key RF Capabilities

- Frequency Range: 1 MHz - 7.2 GHz
- Signal Bandwidth: 400MHz
- Channels: 4 Rx - 4 Tx
- Max Power: Tx up to 22 dBm[1] - Rx 0 dBm

Digital Capabilities

- FPGA Technology: Zynq Ultrascale+ RFSoC
- Interface Options: Dual QSFP28 (100/10 GbE), PCIe Gen 3 x8 (LabVIEW), RJ45 (1 GbE)
- Onboard IP: SD-FEC, DDC, DUC
- Software Support: UHD, GNU Radio, LabVIEW, …
- Synchronization: Onboard GPSDO, External 10 MHz/PPS

Key Applications

- 5G / 6G Prototyping
- Signals Intelligence
- Wireless Communication
- Communications EW
- Software Defined Radio

[1] see specification for details

USRP Product Portfolio Overview

Ettus Research	Ettus Research USRP B2XX	Ettus Research USRP N310 / N32X	Ettus Research USRP X310	Ettus Research USRP E310/E320	NI Ettus USRP X410
Frequency	70 MHz – 6 GHz	3 MHz-6 GHz (N32X) 10 MHz-6 GHz (N310)	*10MHz – 6 GHz	70 MHz – 6 GHz	**1 MHz – 7.2 GHz**
Analog Bandwidth	56 MHz	200 MHz (N32X) 100 MHz (N310)	*160 MHz	56 MHz	**400 MHz**
Channels	2 Tx, 2 Rx	2 Tx, 2 Rx (N32X) 4 Tx, 4 Rx (N310)	2 Tx, 2 Rx *4 Rx (TwinRx)	2 Tx, 2 Rx	**4 Rx, 4 Tx**
RF Performance	Good	Best	Best	Good	**Better**
Architecture	Integrated	Integrated	*Configurable w/ Daughterboards	Integrated	**Integrated**
Communication	USB	10 GbE or PCIe	10 GbE or PCIe	1/10 GbE	**100/10/1 GbE or PCIe**
Synchronization	2x2 MIMO	Up to 128x128 (N32X) Full Phase Synchronization	*2x2 MIMO	2x2 MIMO	**4x4 MIMO**
SW Support	GNU Radio, C++, Python, MatLab, LabVIEW	GNU Radio, C++, Python, MatLab, RFNoC	GNU Radio, C++, Python, MatLab, RFNoC, LabVIEW, LabVIEW FPGA	GNU Radio, C++, Python, MatLab, RFNoC	**GNU Radio, C++, Python, RFNoC, LabVIEW**
Key Features	Low SWAP-C, Highly portable	Stand Alone, Wide bandwidth, Multi-Channel Sync Ready (N32X)	*Configurable RF Front End, Programmable FPGA	Low SWAP, Embedded Deployable, Standalone	**RFSOC Based, 5G Ready, Wide Band, Multi-Channel**

In the meantime,…

UHD Update Cycles

UHD 4.1.* Cycle

- X410 GPIO API
- X410 250 Msps MCR
- Support more hardware revisions
- B200 sync improvements, N320 IQ-balance/DC-offset improvements, …

UHD 4.2.* Cycle

- X410 Full 4x4 100 GbE streaming
- X410 DRAM Record/Replay Support
- X410 Full GPIO Support incl. timed commands

UHD 4.3.* Cycle

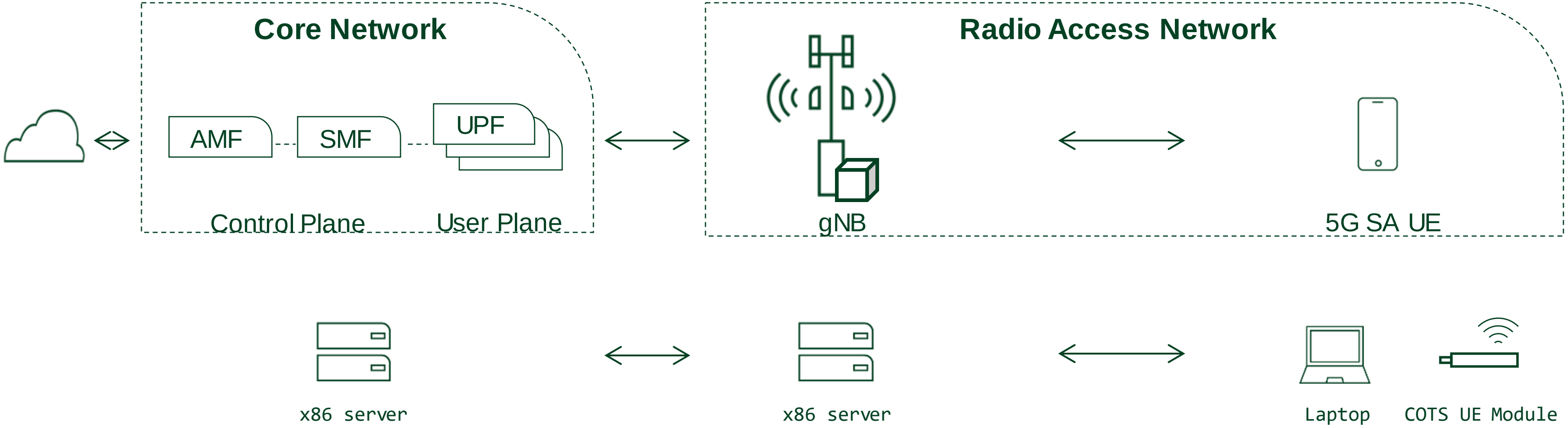
- Raw UDP streaming API
- Extension API
- Vivado 2021.1 Upgrade

- Countless cleanups, Boost compatibility patches, Fedora/Windows/Ubuntu compatibility patches, bugfixes, CMake patches, documentation improvements, stale code cleanup, RFNoC improvements, …

NI SDR System Support

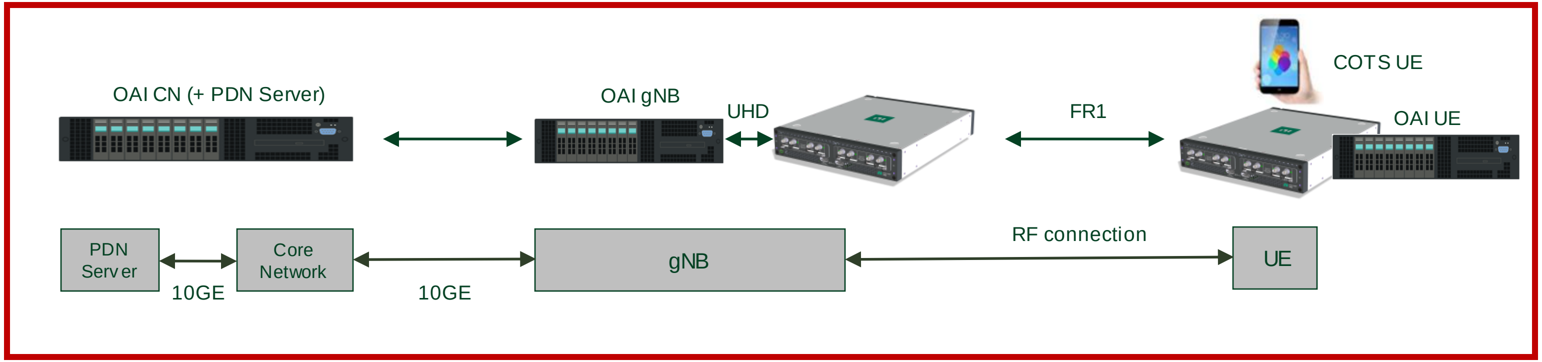
OAI Reference Design for 5G System Prototyping with USRP

5G cellular architecture



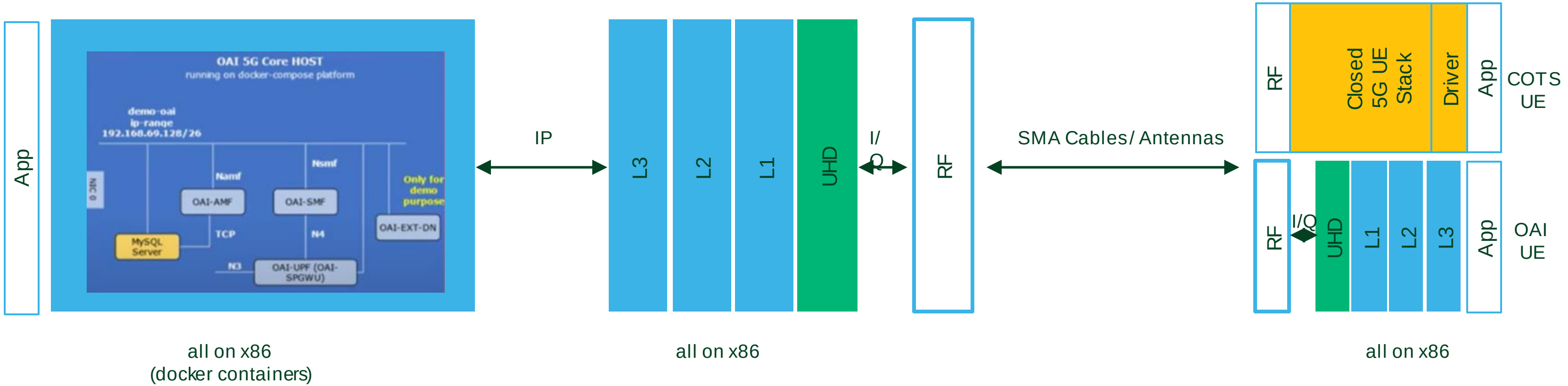
Using OAI + USRP for your 5G research

Hardware



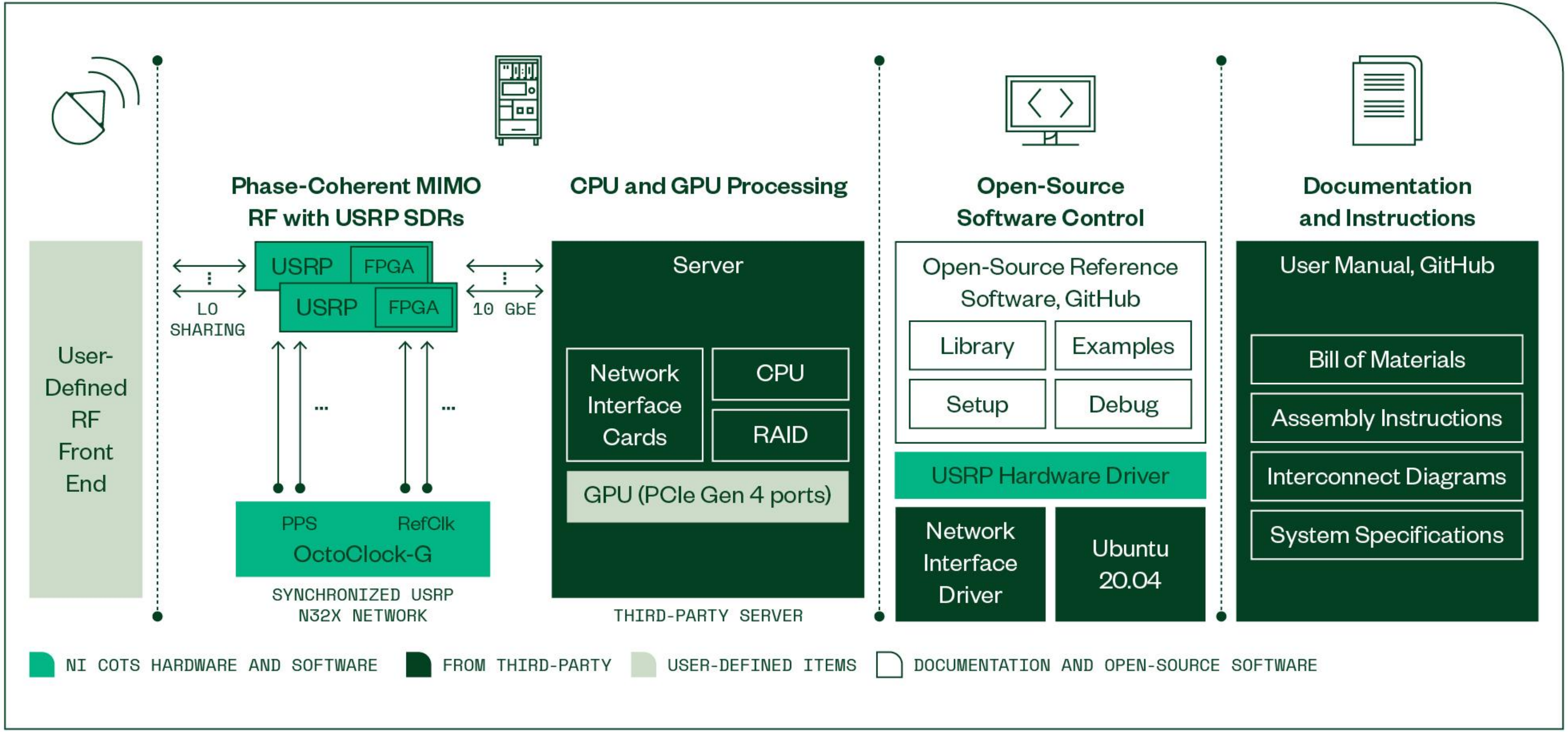
Software

OAI
NI
Closed



Open Architecture for Radar/EW/Comms Research

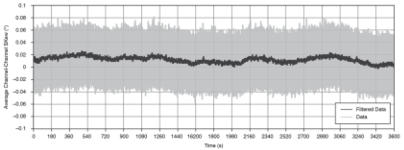
Validated design pattern enables researchers struggling to rapidly prototype new concepts to move **quickly** from software simulation to hardware demonstration, ultimately turning novel concepts into fielded capability faster



Open Architecture for Radar/EW/Comms Research

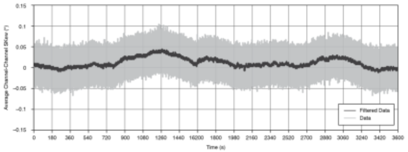
- Higher system-level support
- More documentation, reference designs, recommended hardware, assembly best practices, …
- Get results faster by avoiding all the pitfalls!

Figure 23. Average Channel-to-Channel Phase Skew between Two Rx Channels on the Same Device over One Hour, Relative to t_0



Range, single device	0.139°

Figure 24. Average Channel-to-Channel Phase Skew between Two Rx Channels on Separate Devices over One Hour, Relative to t_0



Range, system	0.167°

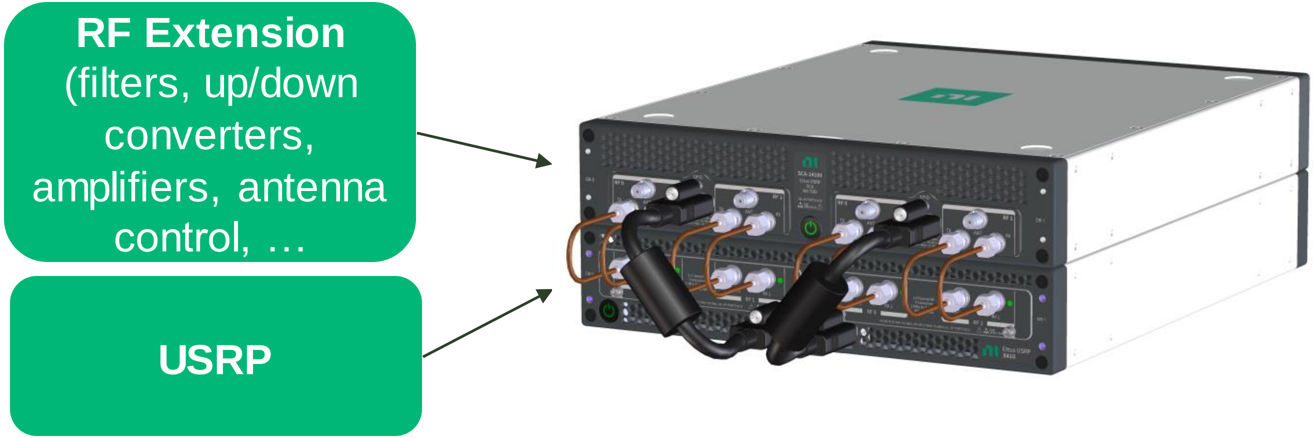
Multichannel RF Reference Architecture

Contents [hide]

New UHD Features

UHD Extension API

- More RF conditioning is moving outside the box
- RF Extensions: Bespoke modules for specific RF applications
- What if the extension requires its own software control?
  => Enter the UHD Extension API!
- Many internal APIs were moved public to allow easy integration into UHD-based applications



Overview

The SC2430 NR Signal Conditioning Module (SCM) is a front-end solution that provides signal conditioning and amplification for Software Define Radio (SDR) systems.

It was designed specifically for use in conjunction with the NI Ettus-USRP X410. In this configuration, its input and output radio characteristics are compliant with select 3GPP 5G/NR standards for 5G NR User Equipment (UE) and gNodeB (gNB) implementations.

Ettus UHD Driver

The SC2430 Signal Conditioning Module (SCM) can be tightly integrated with the NI Ettus X410 USRP (4 Tx/Rx Channels w/ 400 MHz BW).

An SCM extension for the Ettus USRP Hardware Driver (UHD) has been created and is available on SCT's Github repository.

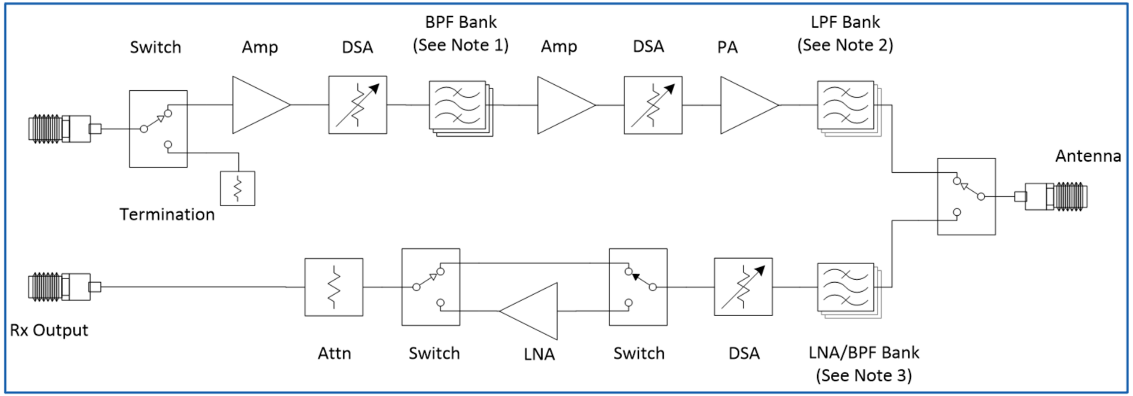
When enabled, the driver extension provides users with seamless control of the SCM via the X410. For example, when setting X410 gain, the driver will recognize presence of the SCM and distribute the desired system gain between both units to optimize performance. Likewise, when setting operating frequency, the relevant Band Pass Filters (BPF) will be selected in the SCM.

An optional override function exists to provide users with SCM specific control. For example, users may prefer to bypass the internal 5G band-specific filters for other applications.

Mechanically, bracket options exist to support bench top (shown below) or rack mount configurations.

SIGNAL CRAFT TECHNOLOGIES

RF Channel Block Diagram



Note 1
On the transmit site, wider BPF that lump several adjacent NR Bands are implemented.

BPF Bypass	300 MHz to 7125 MHz
BPF Band A	1880 MHz to 2690 MHz (n39, n34, n40, n41, n53, n38)
BPF Band B	3300 MHz to 4200 MHz (n78, n77, n48)
BPF Band C	4400 MHz to 5000 MHz (n79)
BPF Band D	5150 MHz to 5925 MHz (n46, n47)
BPF Band E	5925 MHz to 7125 MHz (n96)

Note 2
On the transmit site, wider BPF that lump several adjacent NR Bands are implemented.

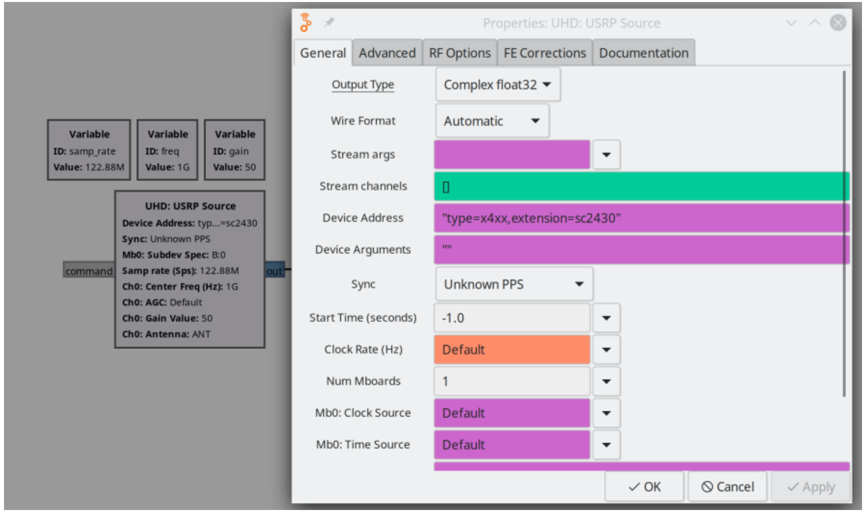
LPF Bypass	300 MHz to 7125 MHz
LPF Band 1	1880 MHz to 2690 MHz (n39, n34, n40, n41, n53, n38)
LPF Band 2	3300 MHz to 5000 MHz (n78, n77, n48, n79)
LPF Band 3	5150 MHz to 7125 MHz (n46, n47, n96)

Note 3
Each path of this bank contains an LNA combined with the following NR Band channel filters:

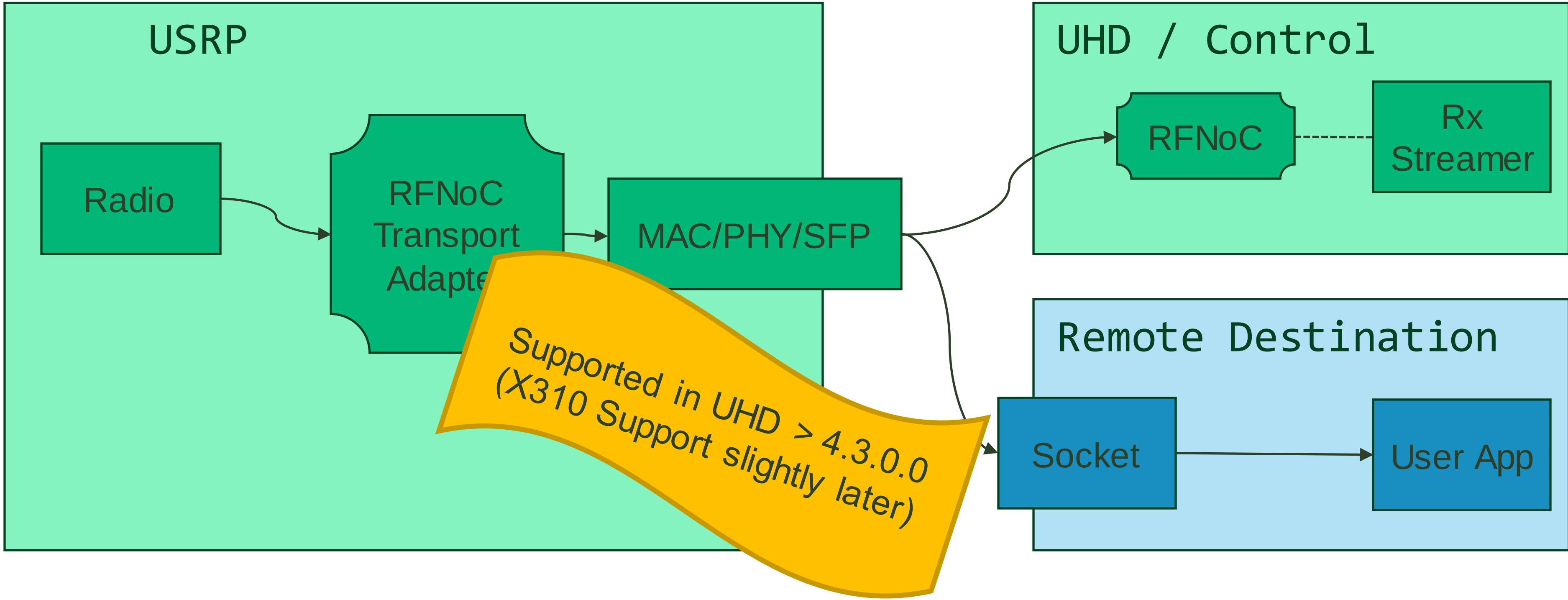
NR Band	Frequency
n34	2010 MHz – 2025 MHz
n38	2570 MHz – 2620 MHz
n39	1880 MHz – 1920 MHz
n40	2300 MHz – 2400 MHz
n41	2496 MHz – 2690 MHz
n46	5150 MHz – 5925 MHz
n47	5855 MHz – 5925 MHz
n48	3550 MHz – 3700 MHz
n77	3300 MHz – 4200 MHz
n78	3300 MHz – 3800 MHz
n79	4400 MHz – 5000 MHz
n90	2496 MHz – 2690 MHz
n96	5925 MHz – 7125 MHz

Seamless integration into SDR Applications at UHD level

- RF Extensions that use the UHD Extension API can be used in existing UHD Applications without recompiling
- Dynamic DLL loading
- Transparent forwarding of RF commands to extension driver

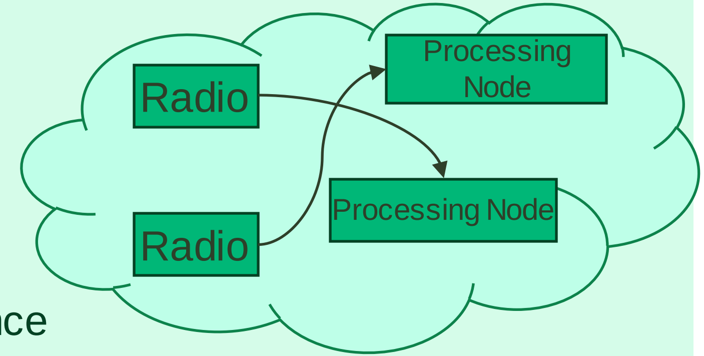


Raw UDP Traffic to Remote Destination



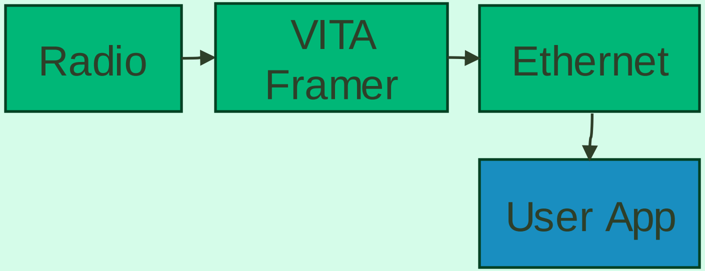
Raw UDP Traffic to Remote Destination

- More **streaming flexibility**:
  - Stream to any network destination
  - Stream data with or without CHDR metadata
  - Seamless integration into RFNoC
  - Hand-optimize streaming endpoint for higher performance



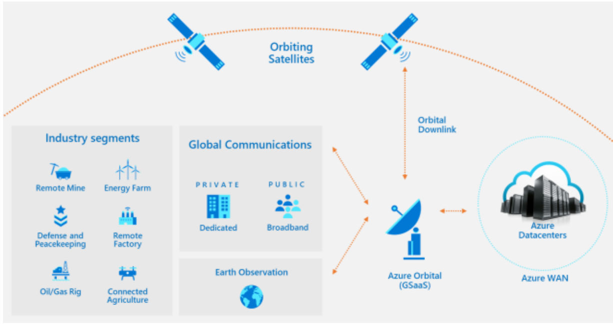
- Raw-UDP-to-USRP streaming on the roadmap ("Tx")
  - (Slightly more difficult on the user end)

- Use custom RFNoC blocks to **format output data**
  - For example, enable VITA 49.2 frames



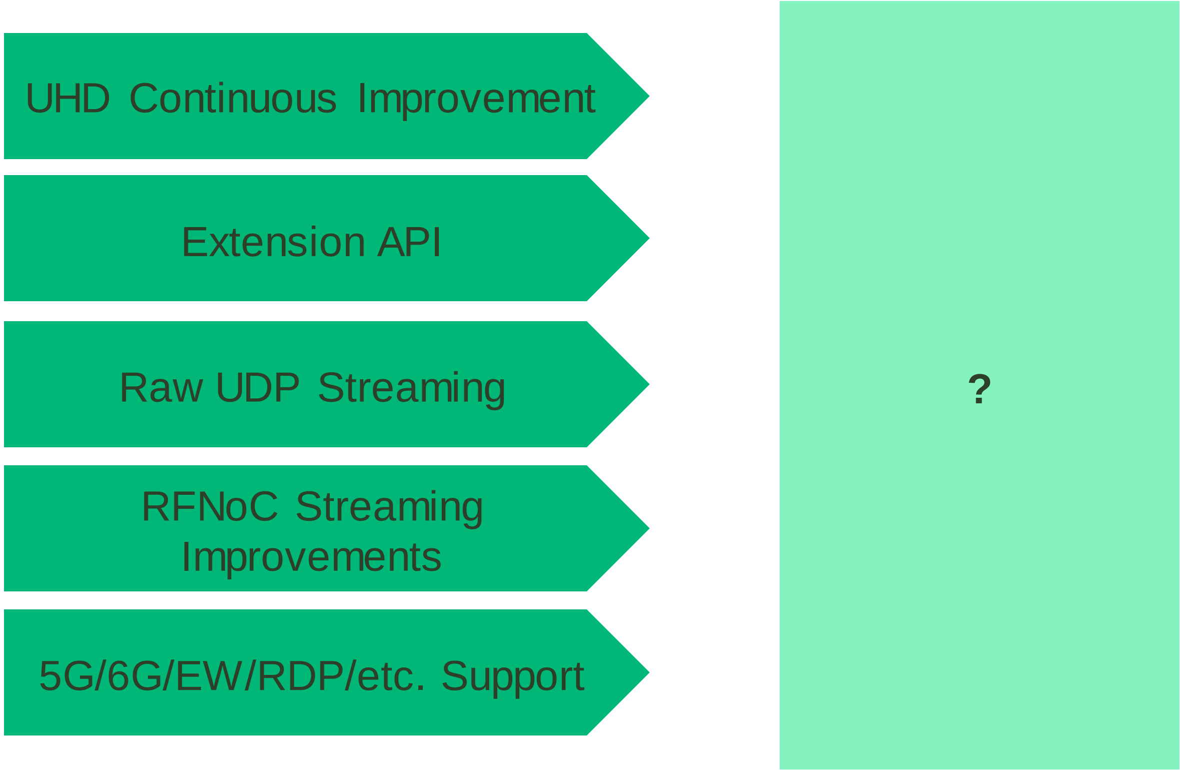
Azure Orbital Use-Case

- We want to be able to use general purpose SDRs like the X410 for satellite ground stations, due to their flexibility, open source nature, and popularity
- We currently use DIFI (a specific form of VITA 49.2) to pipe IQ samples between transceivers and software modems within each ground station
- To use an X410 as a ground station digitizer, it must be able to output DIFI, and allow for control on a separate interface or onboard
- By using NIs recent untangling of UHD's data and control plane, combined with a new RFNoC block we created, we can now use the X410 as a ground station digitizer
- The RFNoC block can be found here https://github.com/DIFI-Consortium/rfnoc-difi
  - Currently supports standard DIFI data packets
  - More DIFI functionality (e.g., context packets, timestamps) coming soon
- On Thursday there will be a talk on DIFI and gr-difi at GRCon
  - https://github.com/DIFI-Consortium/gr-difi includes a CPU-based DIFI Source/Sink
- For more information on DIFI see https://dificonsortium.org/



What’s Next?

What do we do with our development?



NI Ettus USRP X440 Product Overview

IF Capabilities

Front-End Conn:	Balun coupled, MMPX
IF Range:	30MHz – 4GHz (direct sampling)
Bandwidth:	1GHz / channel, 4GHz / total
Direct Sampling:	Up to 4GSps
	~1.8 GHz (1st Nyquist)
	~3.6 GHz (2nd Nyquist)
Number Channels:	8 (TX/RX or TRX)
Phase Coherency:	Yes (sample based)
TX output level:	< 0dBm full scale
RX input level:	10dBm full scale

Integration with Custom Front-Ends for Radar and Comms/EW research and prototyping

Digital Capabilities

Xilinx Zynq Ultrascale+ RFSOC ZU28DR-2

Built-in quad core ARM processor

Streaming Interface: Dual 100GEth

Synchronization: 10 MHz / PPS, GPSDO, IF

Software: Open source (GNU Radio, RFNoC, UHD)

GPIO for Front-End control via UHD API or FPGA

2x 12 lanes via HDMI with SPI protocol support

subject to change

Expected Use Cases

Direct Sampling:

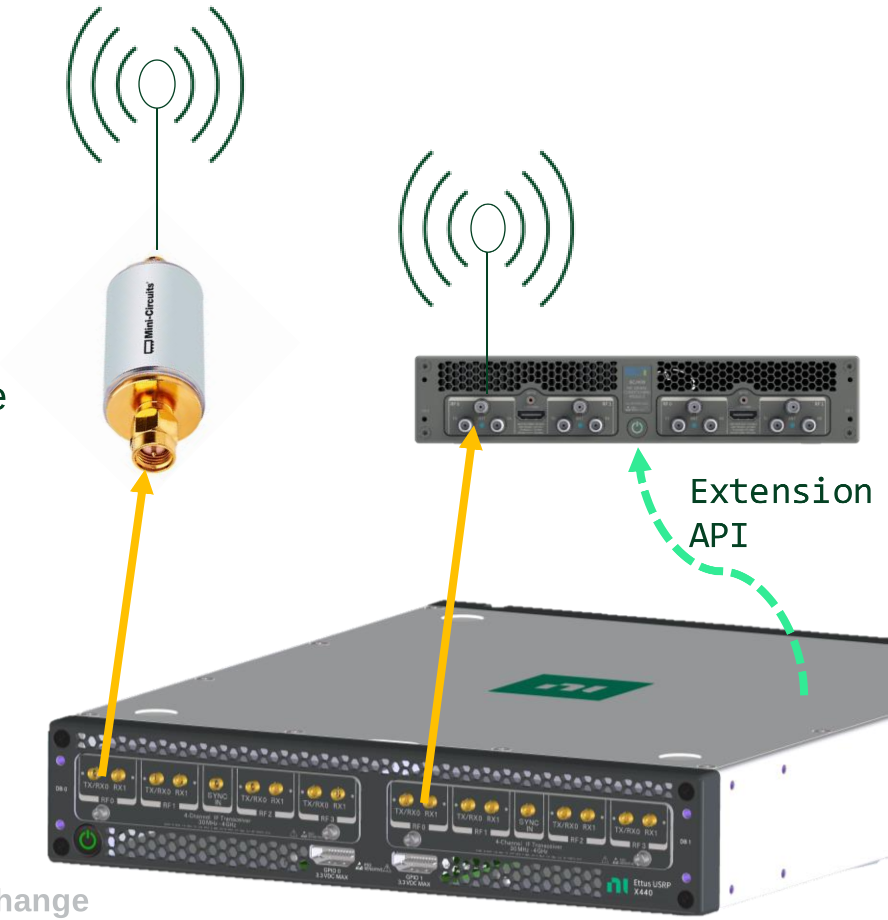
- Configure ADC/DACs for your specific need
  - You will need to provide your own filtering
  - Supporting for frequencies up to 3.6 GHz*

IF Stage:

- Utilizing an Up/Down Converter this product become the transceiver stage.
- Using the extension API, UHD can manage your RF settings for you in a familiar way

Applications:

- Satellite ground stations
- Radar/Comms/EW Research with specific RF requirements
- …anything that requires many channels, high bandwidth



*subject to change

Summary

Past, Present, and Future of USRP at NI

High-Performance and low-cost USRP

Extension API, Raw UDP, UHD Enhancements, …

USRP X440

- Existing portfolio of USRPs covers a large spectrum of applications
  - Different SW workflows
  - Research/Prototyping, Deployment, System Integration, Defense, Security, ….
- UHD/RFNoC/USRP are being continuously improved
- New Products are being released