Enabling LTE and Next Generation 5G Wireless Research with Software Defined Radio

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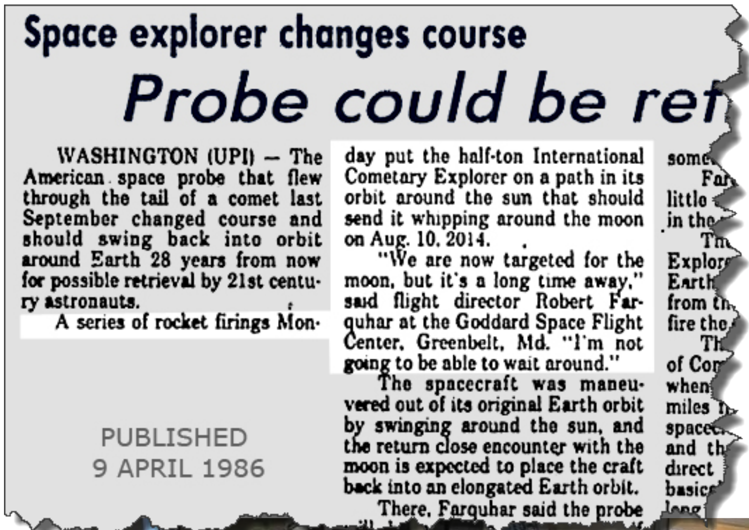
Ettus Research / National Instruments

Satellite Communication: ISEE-3 Rebooted After 36 Years

Launch: Aug 12, 1978
Contact: May 29, 2014



Space explorer changes course

Probe could be ret

WASHINGTON (UPI) — The American space probe that flew through the tail of a comet last September changed course and should swing back into orbit around Earth 28 years from now for possible retrieval by 21st century astronauts.

A series of rocket firings Monday put the half-ton International Cometary Explorer on a path in its orbit around the sun that should send it whipping around the moon on Aug. 10, 2014.

"We are now targeted for the moon, but it's a long time away," said flight director Robert Farquhar at the Goddard Space Flight Center, Greenbelt, Md. "I'm not going to be able to wait around."

The spacecraft was maneuvered out of its original Earth orbit by swinging around the sun, and the return close encounter with the moon is expected to place the craft back into an elongated Earth orbit.

There, Farquhar said the probe

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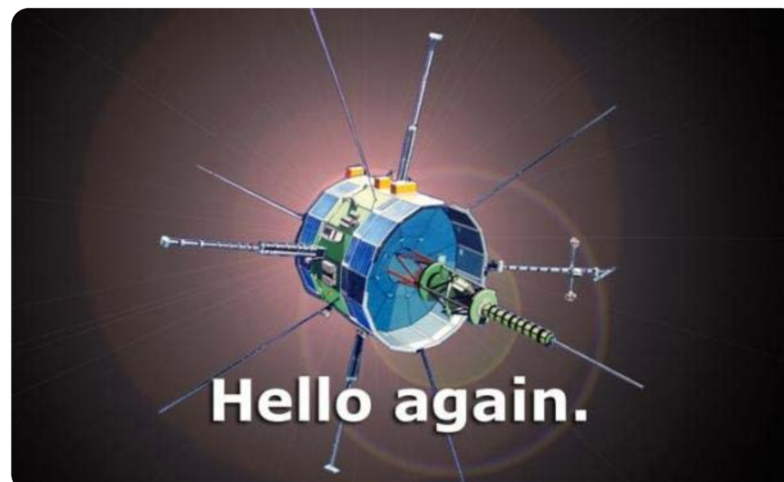
PUBLISHED
9 APRIL 1986

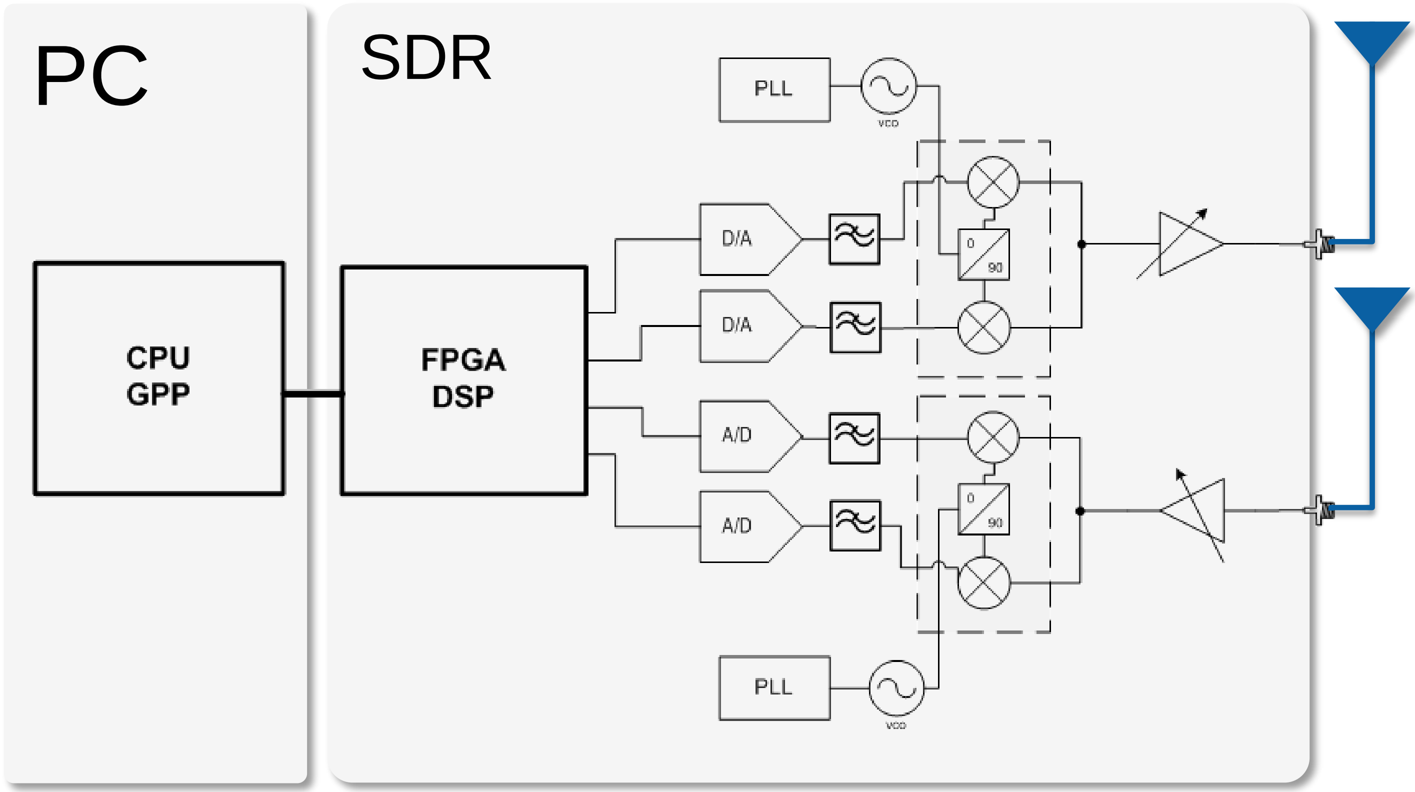


Source: spacecollege.org

NATIONAL INSTRUMENTS

COTS Software Defined Radio

Software Defined Radio (SDR) refers to the technology wherein software modules running on a generic hardware platform are used to implement radio functions…



Wireless Design & Prototyping Applications

NATIONAL INSTRUMENTS

Common Platform, Multiple Approaches

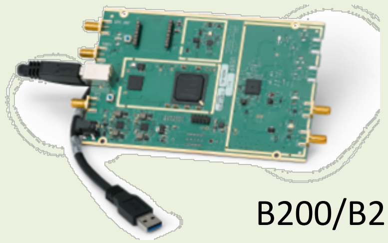
USRP Software Defined Radio Platform

LabVIEW / LabVIEW FPGA

C++/Python

Ettus Research USRP Family

Low Cost SDR



B200/B210

2x2 MIMO
70 MHz – 6 GHz
Up to 56 MHz Bandwidth
USB 3.0

High Performance SDR

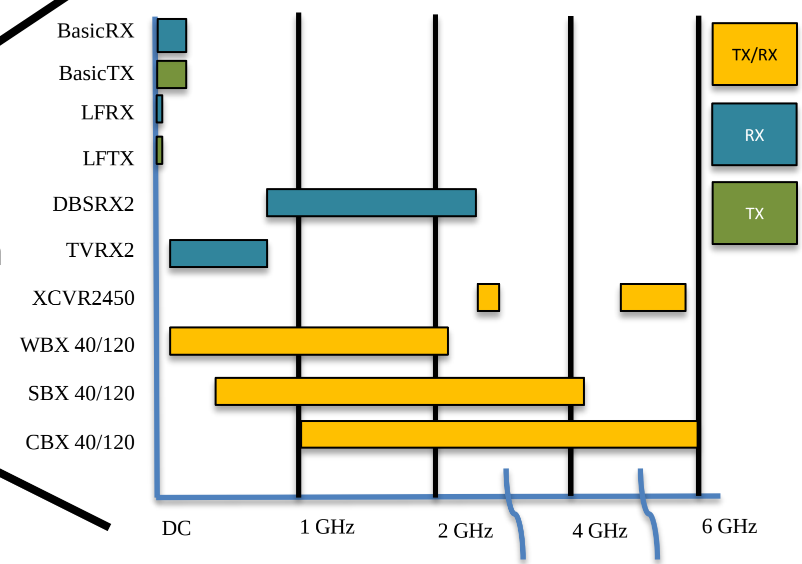
X300/X310

2x2 MIMO
DC – 6 GHz (options)
Up to 120 MHz Bandwidth
1GbE, 10 GbE, PCIe x4
Large K7 FPGA for DSP

Embedded SDR

E310

...



Pocket-sized, Stand-alone SDR

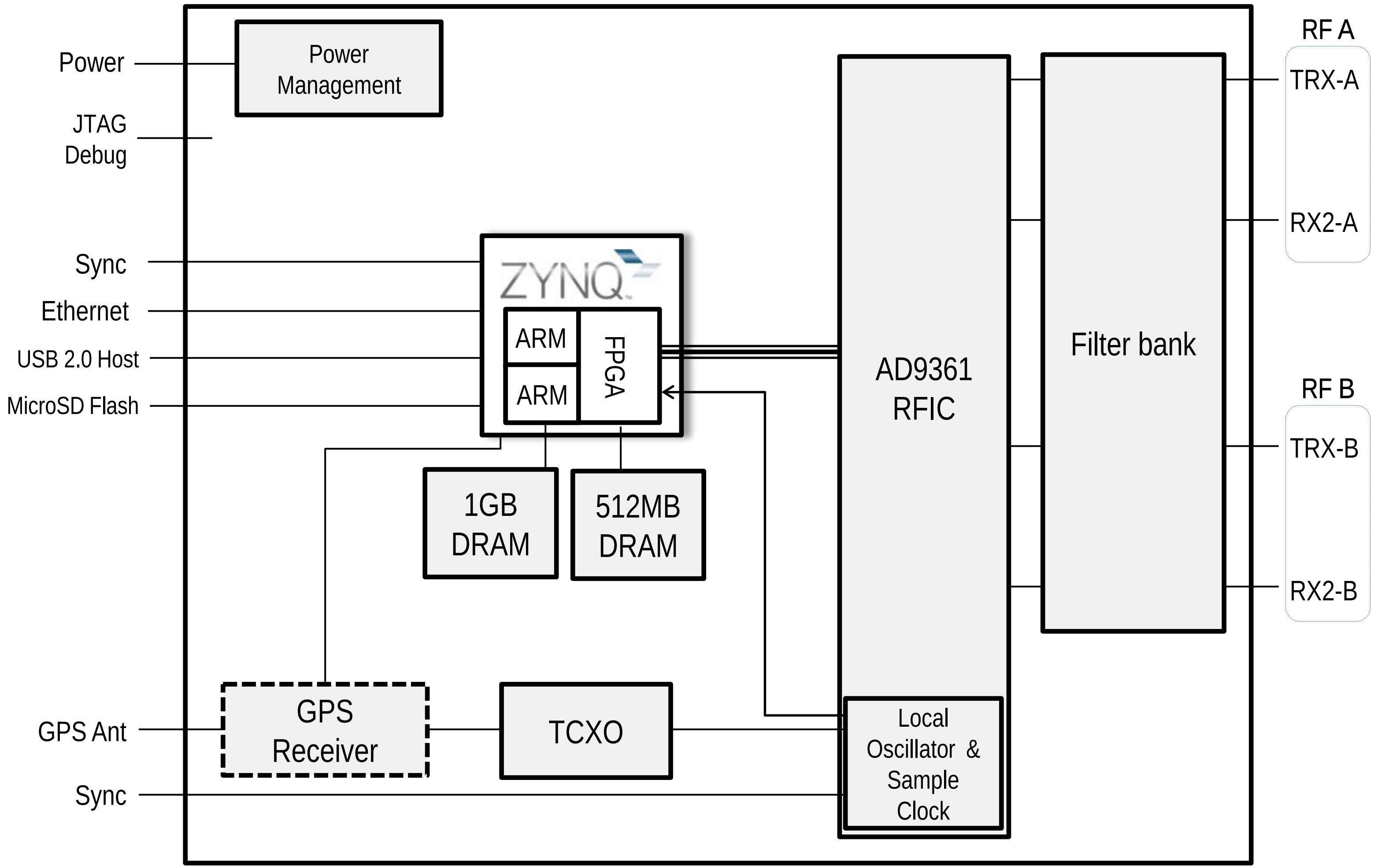
Mobile phone sized package

- 70 MHz - 6 GHz
- Filter banks for improved selectivity
- 56 MHz BW per channel
- Linux on Dual ARM A9
- 10/100/1000 Ethernet
- Internal GPS
- USB Host connectivity

Applications

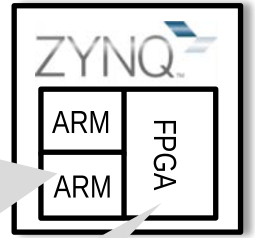
- Spectrum Sensing Solution
- Mobile Radio
- GSM Base Station

USRP E300 System Architecture

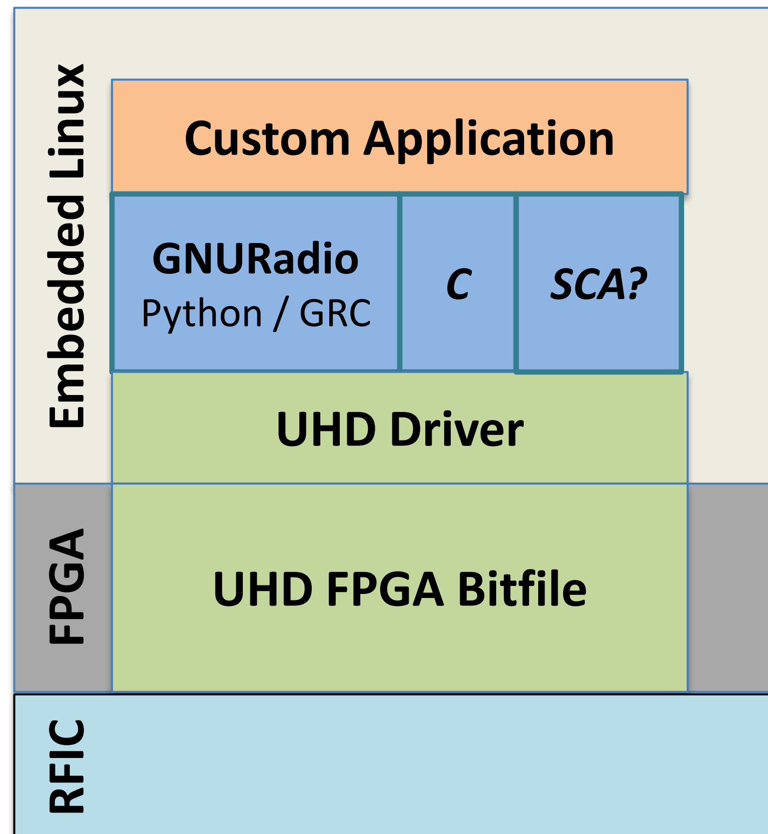


ZYNQ Hardware & Software Architecture

ARM Processor	Cortex A9
Processor cores	2
Clocking frequency	667 MHz
DMA Channels	8
External DRAM	1 GB

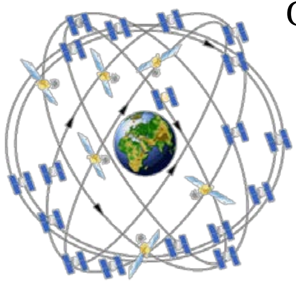


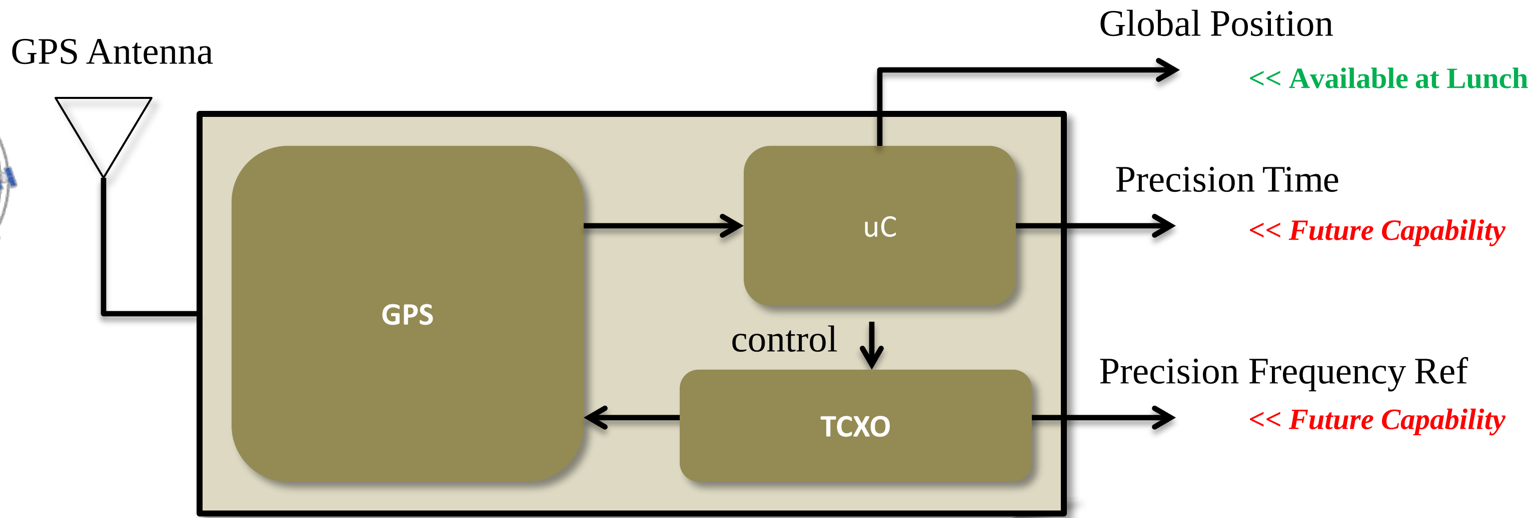
FPGA Resources	Artix-7 FPGA
Programmable Logic Cells	85k
LUTs	53,200
Flip-Flops	160,400
Block Ram	560kB
DSP Slices	220
Peak DSP Performance	276 GMACs



E310 – Integrated GPS-Disciplined Clock

Ettus Research™
A National Instruments Company





With GPS lock

- Improved frequency accuracy
- Global time & frequency sync
- GPS location information

NEW

Open Air Interface Supports USRP

Ettus Research™ A National Instruments Company

Applications

- Standards Coexistence
- Small Cells
- Cloud RAN
- 5G

Compatible Hardware

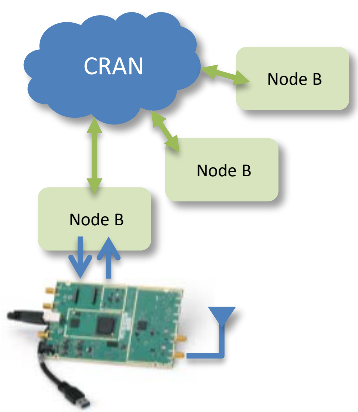
- USRP B200/B210
- USRP X300/X310

OPEN AIR INTERFACE

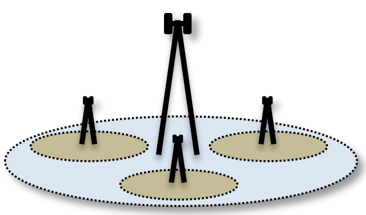
Open Air Interface Solution

- Subset of LTE Release 10
- LTE base station (eNb) and core network (EUTRAN) software stack
- Real-time on a desktop Ubuntu Linux PC
- Open, reconfigurable source code
- Integrated with Ettus Research UHD driver
    - supporting all USRP devices
    - *best on newer devices with adjustable clock*

Cloud RAN

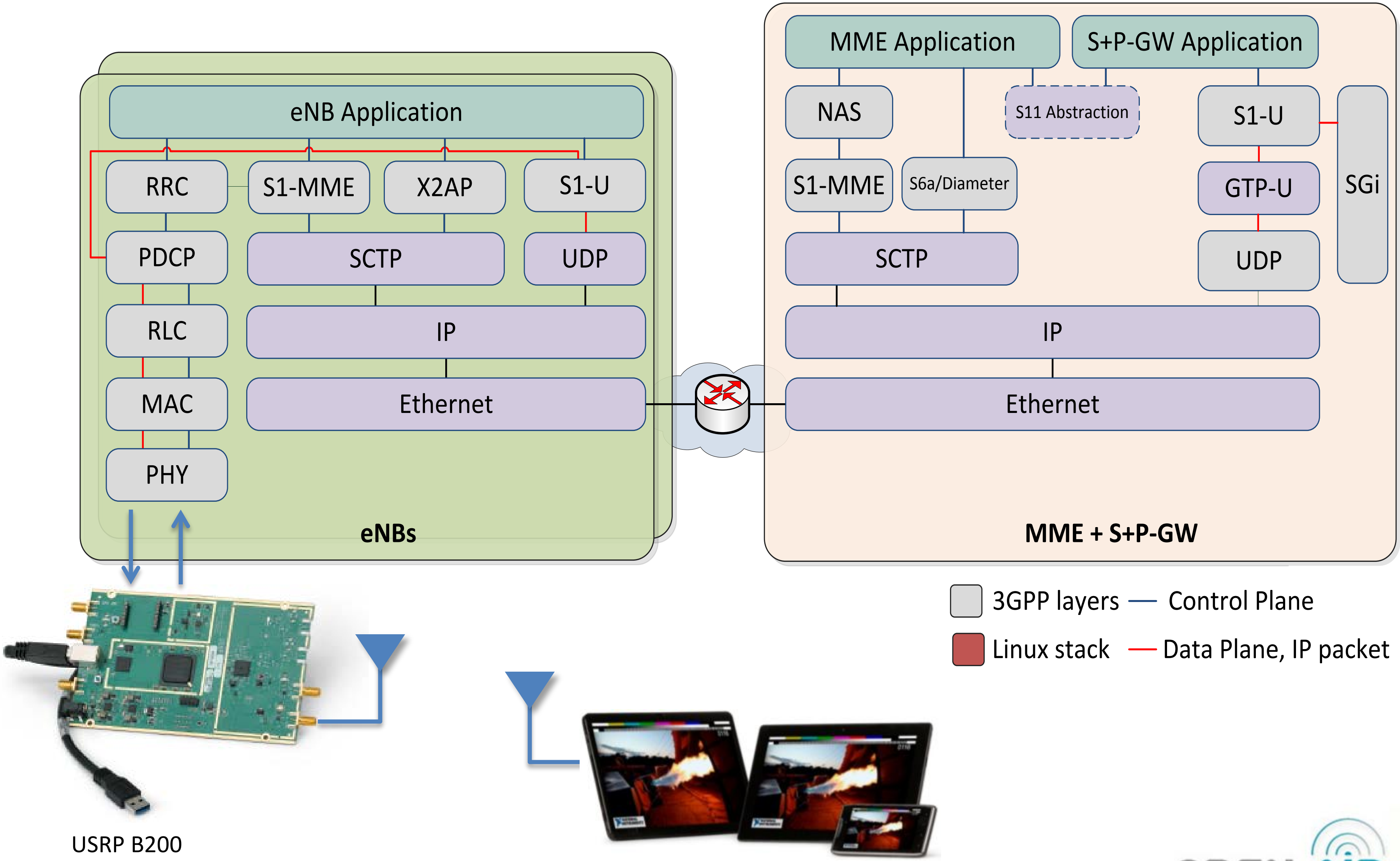


USRP B200



Small Cells

LTE Base Station with Open Air Interface



Download Open Air Interface Today

Requirements

- Desktop PC (typically i5 to i7)
- Supported USB3 adapter for USRP B210
- Ubuntu 14.04 (low latency install)
- LTE dongle with removable SIM card (and test SIM card)
- Strong understanding of building software from source

Steps for Getting Stated

0. Join the mailing list!

   Send an email to majordomo@eurecom.fr with content "subscribe openair4G-devel”

1. Download the Open Air Interface software

   http://svn.eurecom.fr/openair4G/trunk/

2. Build & Install eNB & EPC

   https://twiki.eurecom.fr/twiki/bin/view/OpenAirInterface/OpenAirSoftwareSupport

3. Install & Test with UHD
4. Install a test SIM card in a USB LTE dongle
5. Run the system

Ettus Research USRP Family

Ettus Research
A National Instruments Company

GNU Radio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

C \ C++

VIVADO

python

ISE
DESIGN SUITE

REDHAWK

OSSIE (SCA)

OPEN AIR INTERFACE

RF Studio™
for the USRP

openBTS

amarisoft
Amari LTE 100

navsys CORPORATION
GNSS Signal Architect®
GNSS Simulation and Testing Software

Accelerating 5G Research with Platform Based Design

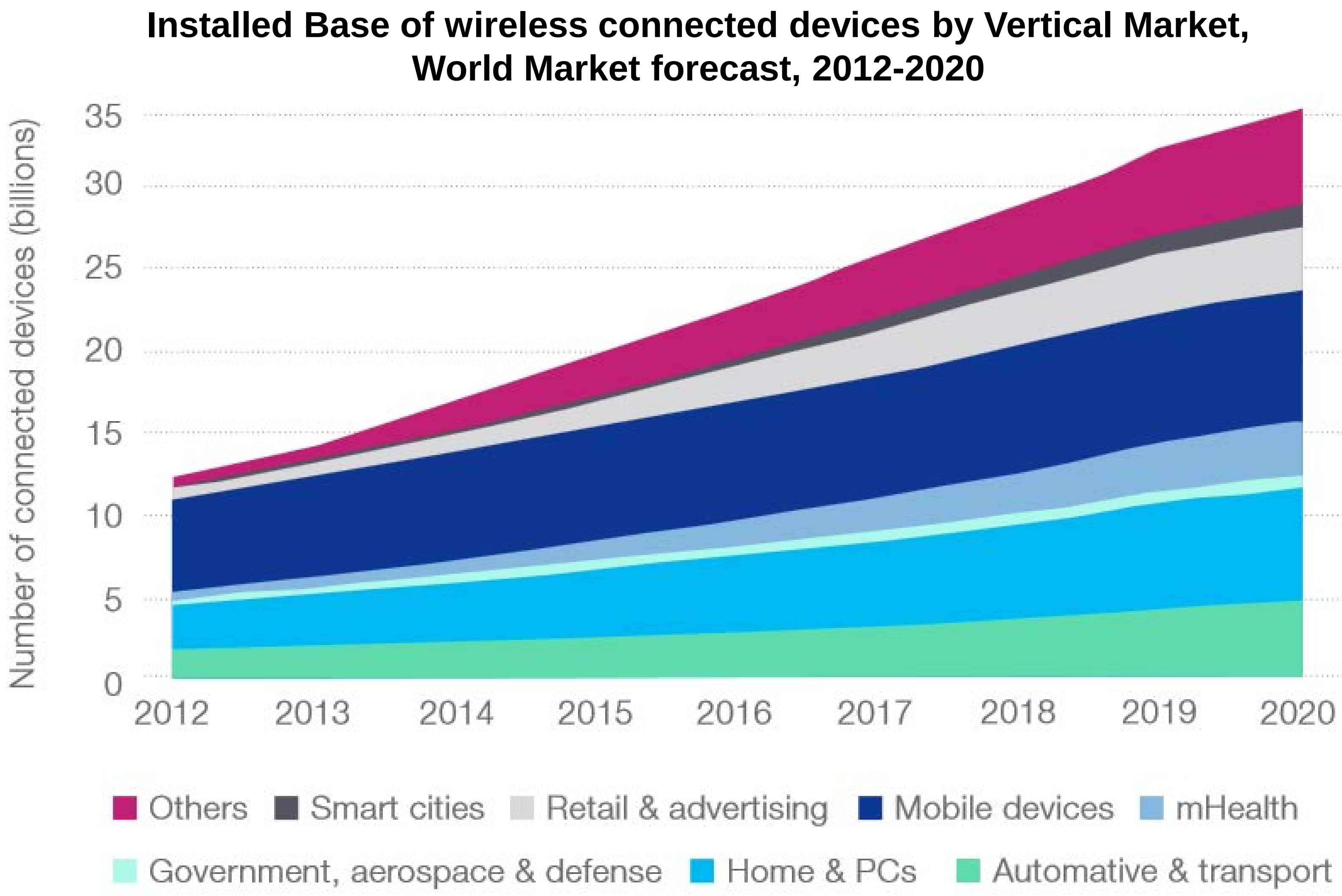
Wireless Research – Some Perspective

Papal election 2005

Papal election 2013

What a difference in just 8 years!

Growing Number of Wireless Devices

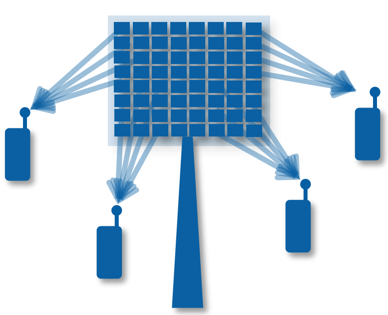


Source: ITU Report 2013

5G Applications

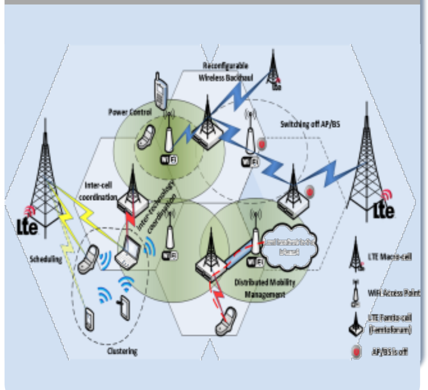
Massive MIMO

Dramatically increased number of antenna elements on base station.



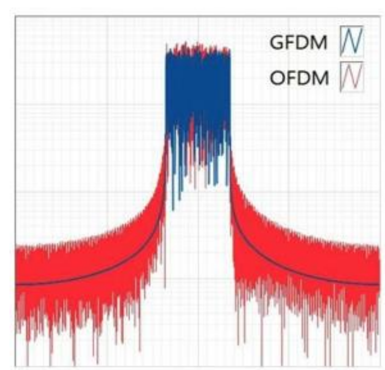
Dense Networks

Consistent connectivity meeting the 1000x traffic demand for 5G



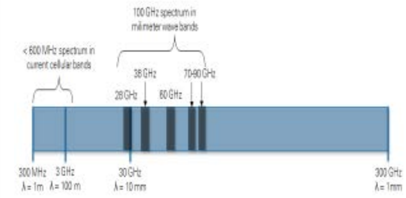
PHY Enhancements

Improve bandwidth utilization through signal structure improvements such as NOMA, GFDM, FBMC, & UFMC

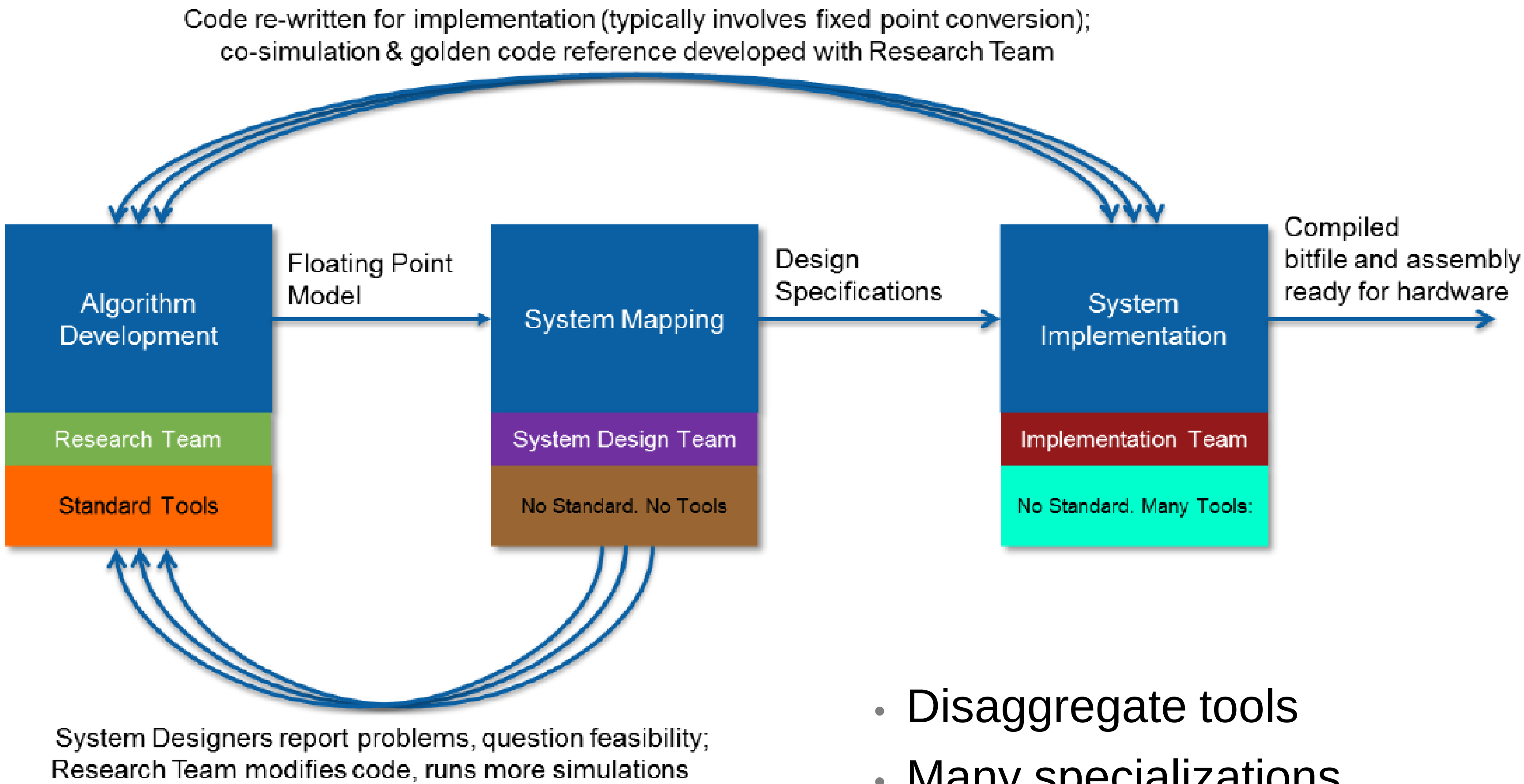


mmWave

Utilize potential of extremely wide bandwidths at frequency ranges ones thought impractical for commercial wireless.



Classic Tool Flow



- Disaggregate tools
- Many specializations
- Longer design cycles
- Increased time to result

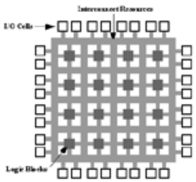
Today's Development Challenge

Tools

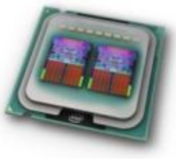
- Math (.m file script)
- Simulation (Hybrid)
- User Interface (HTML)
- FPGA (VHDL, Verilog)

- Host Control (C, C++, .NET)
- DSP (Fxd pt C, Assembly)
- H/W Driver (C, Assembly)
- System Debug

Targets



FPGAs



Multicore Processors

- SDR development requires multiple S/W tools
- Parallel processing increases system complexity
- S/W tools don't address system design

Long learning curves
Limited reuse
Need for "specialists"

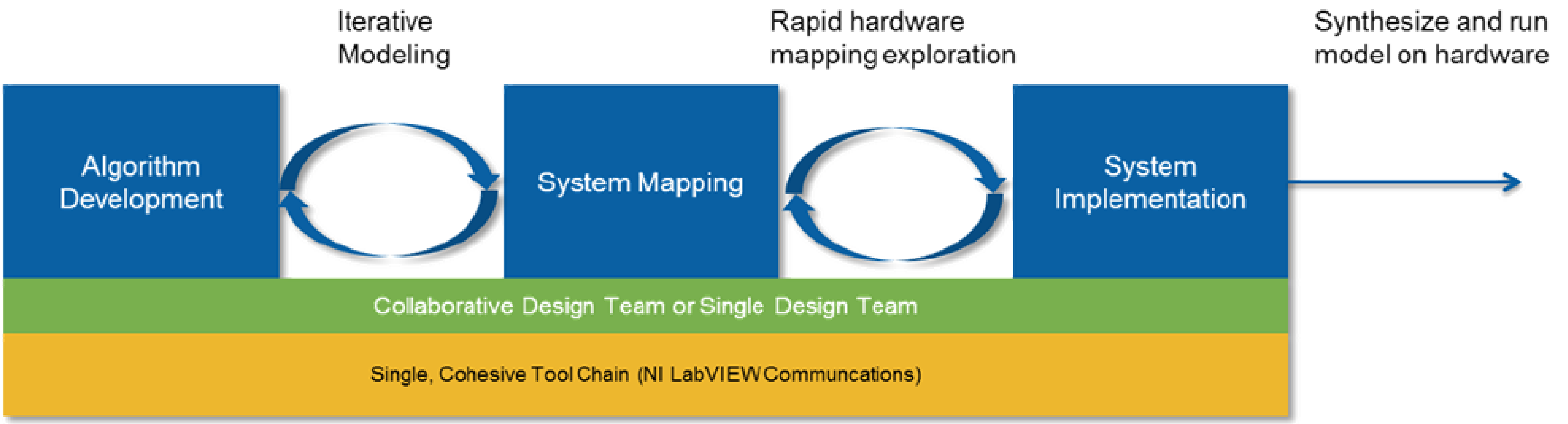
→

Increased costs
Increased time-to-result

“Processing capability has advanced at the rate of Moore’s Law but our ability to efficiently utilize that processing has not.”

- Matt Ettus, Ettus Research

Platform Based Design Flow

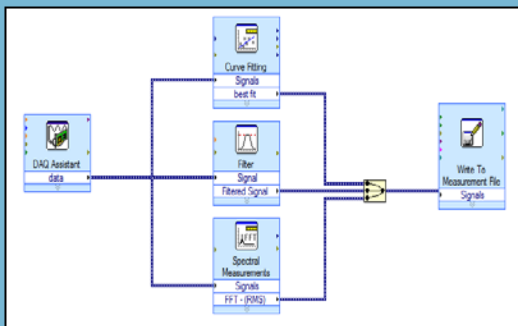


Accelerating productivity by enabling:

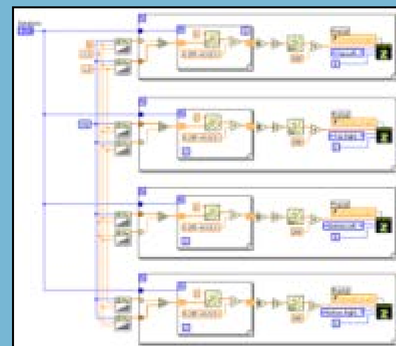
- Mapping algorithms across processors
- Context aware float-to-fixed conversion
- Integration of custom IP such as .m, C, HDL
- Code sharing across traditional hardware boundaries

Faster time to prototype "rapid prototyping"

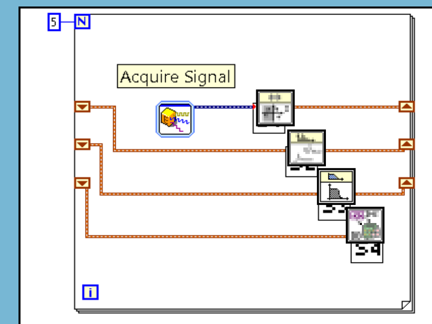
Integrated Tool Flow – Processor & FPGA



Task Parallelism

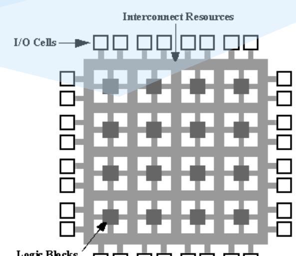


Data Parallelism



Pipelining

Multicore Processors

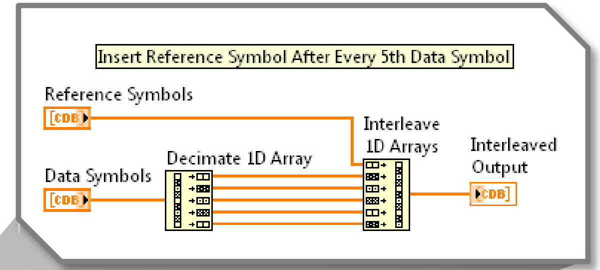


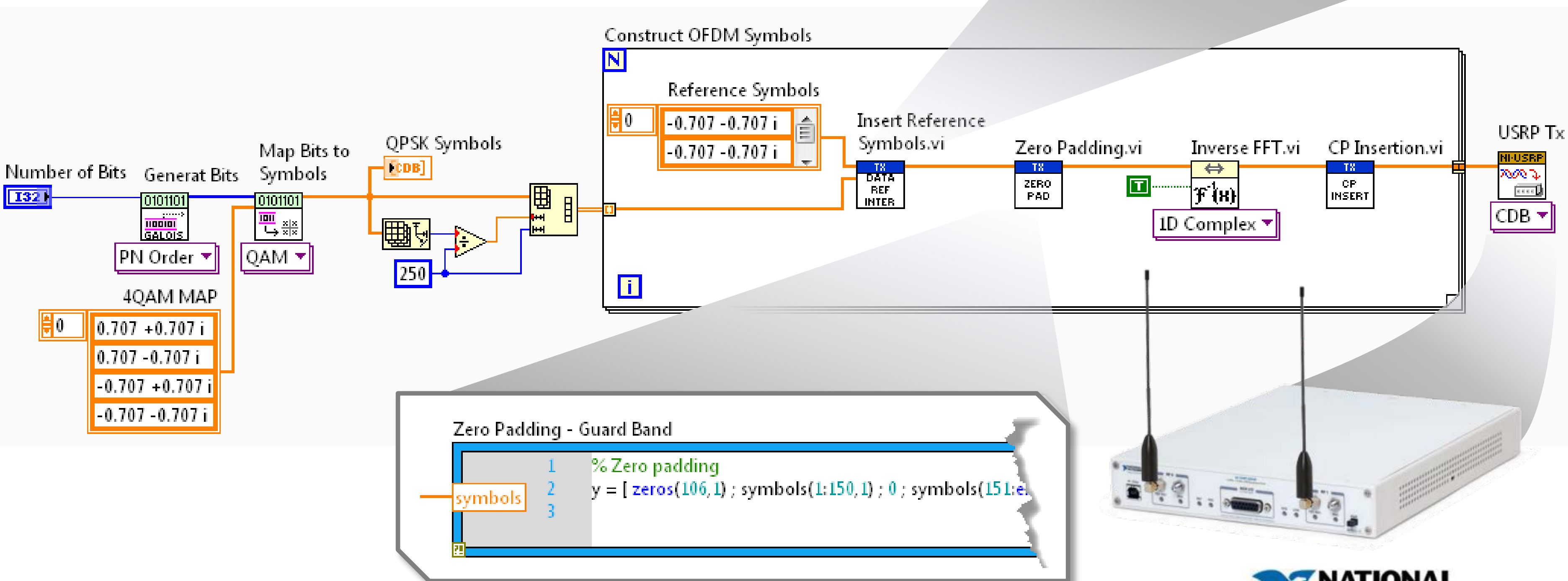
FPGAs

Common Development Environment for Host & FPGA

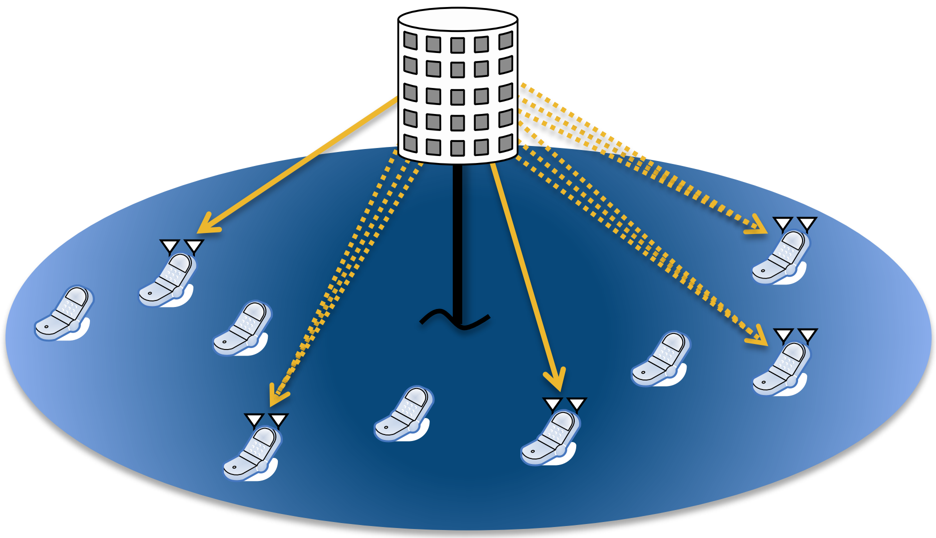
Example: Host Based OFDM Transmitter

- Describe the algorithm graphically
- Combine models of computation
- Seamlessly integrate I/O





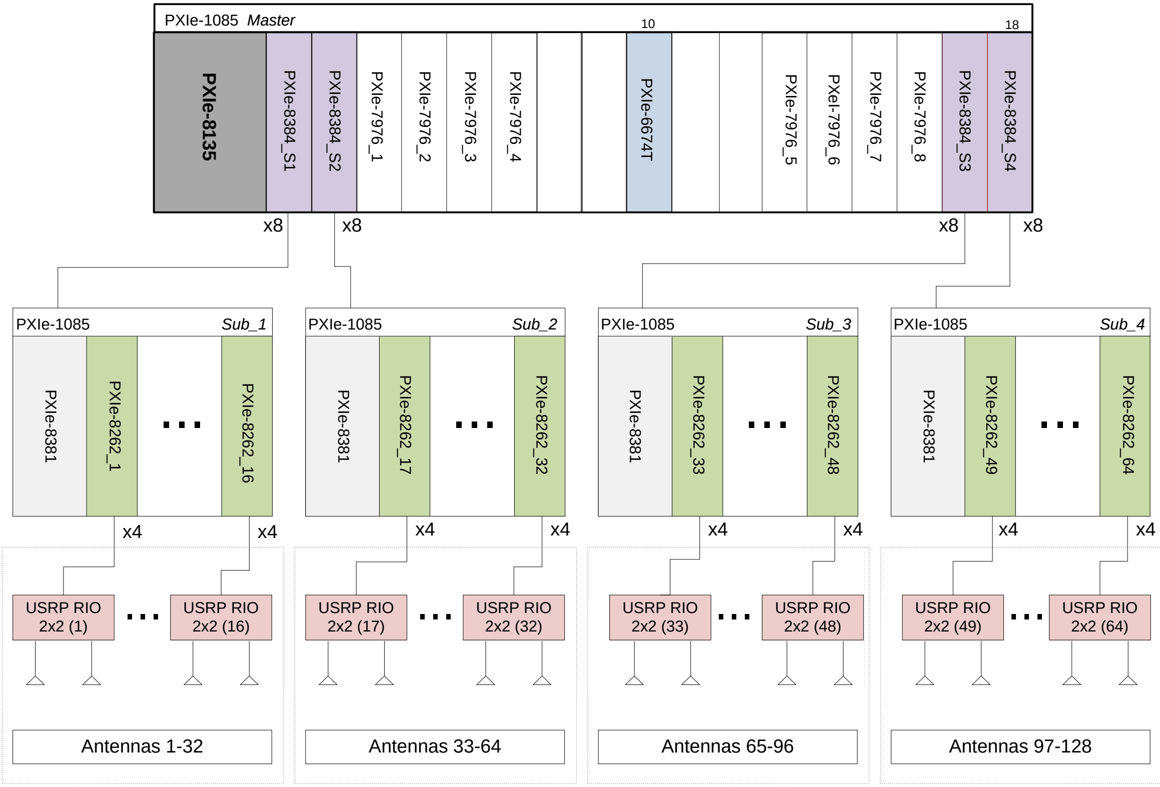
Massive MIMO Testbed



Lund University is prototyping a massive MIMO with a 100 antennas at the Base Station and 10 User Terminals

LUND UNIVERSITY

100-Antenna Massive MIMO Block Diagram



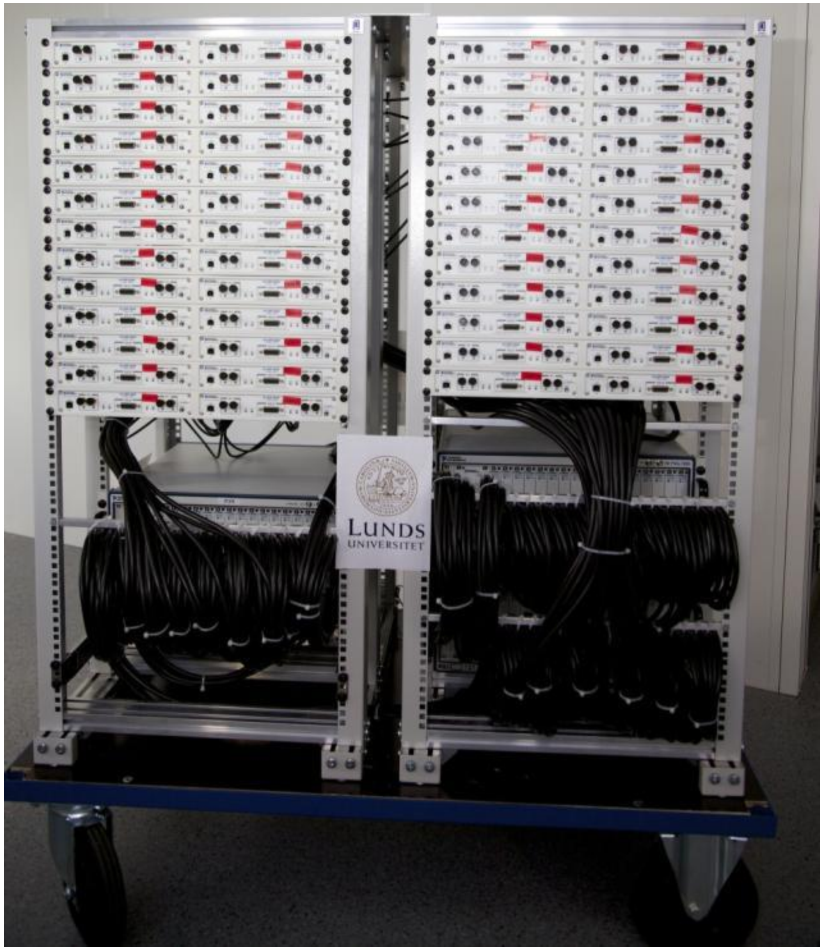
Massive MIMO System Design Challenges

- Programming
- Synchronization
- Data aggregation
- Signal Processing
- Bandwidth

LTE-like System Parameters

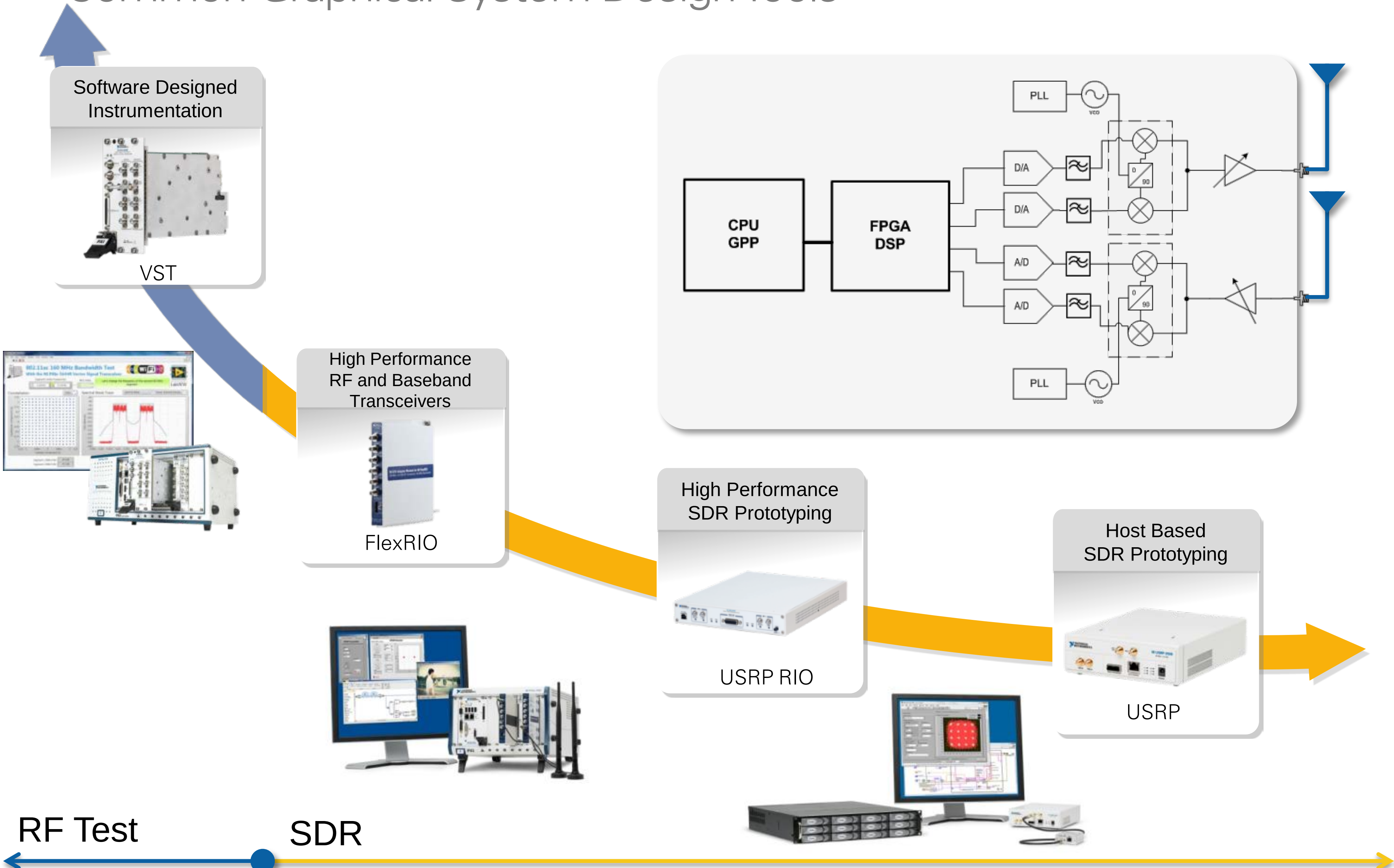
Parameter	Values
No. of base station antennas	64 - 128
RF Center Frequency	1.2 GHz – 6 GHz
Bandwidth per Channel)	20 MHz
Sampling Rate	30.72 MS/s
FFT Size	2048
No. of used subcarriers	1200
Slot time	0.5 ms
Users sharing time/freq slot	10

Lund University Prototype

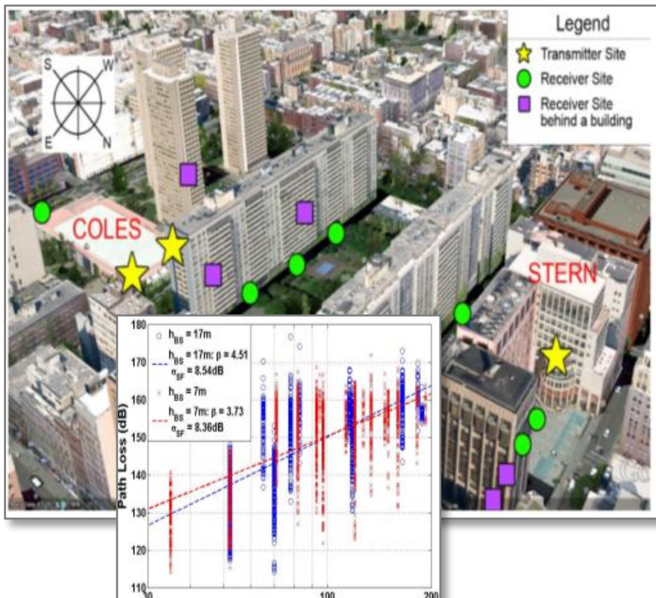


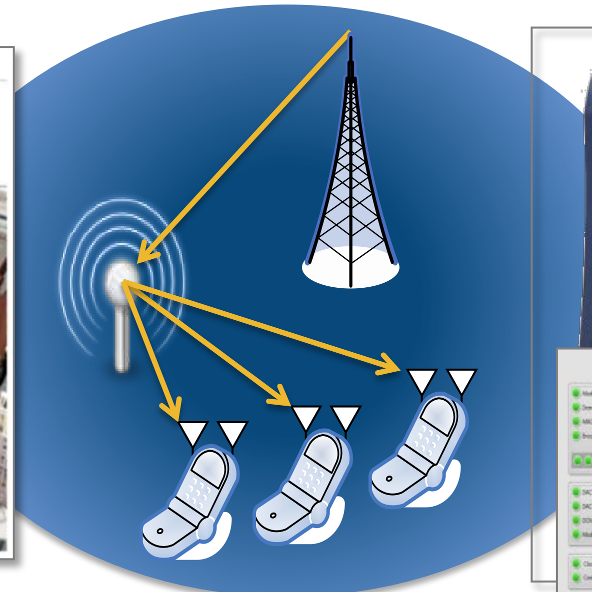
Software Defined Radio Platform

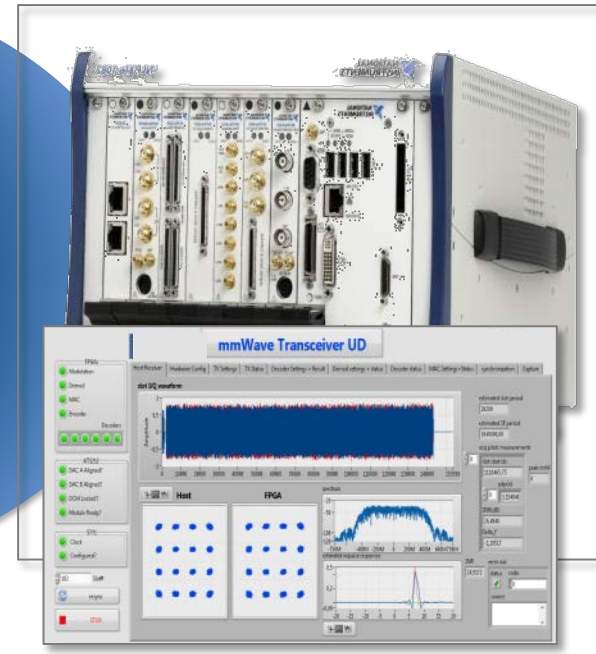
Common Graphical System Design Tools



mmWave Channel Sounding







Channel sounding at 28, 38, and 72 GHz

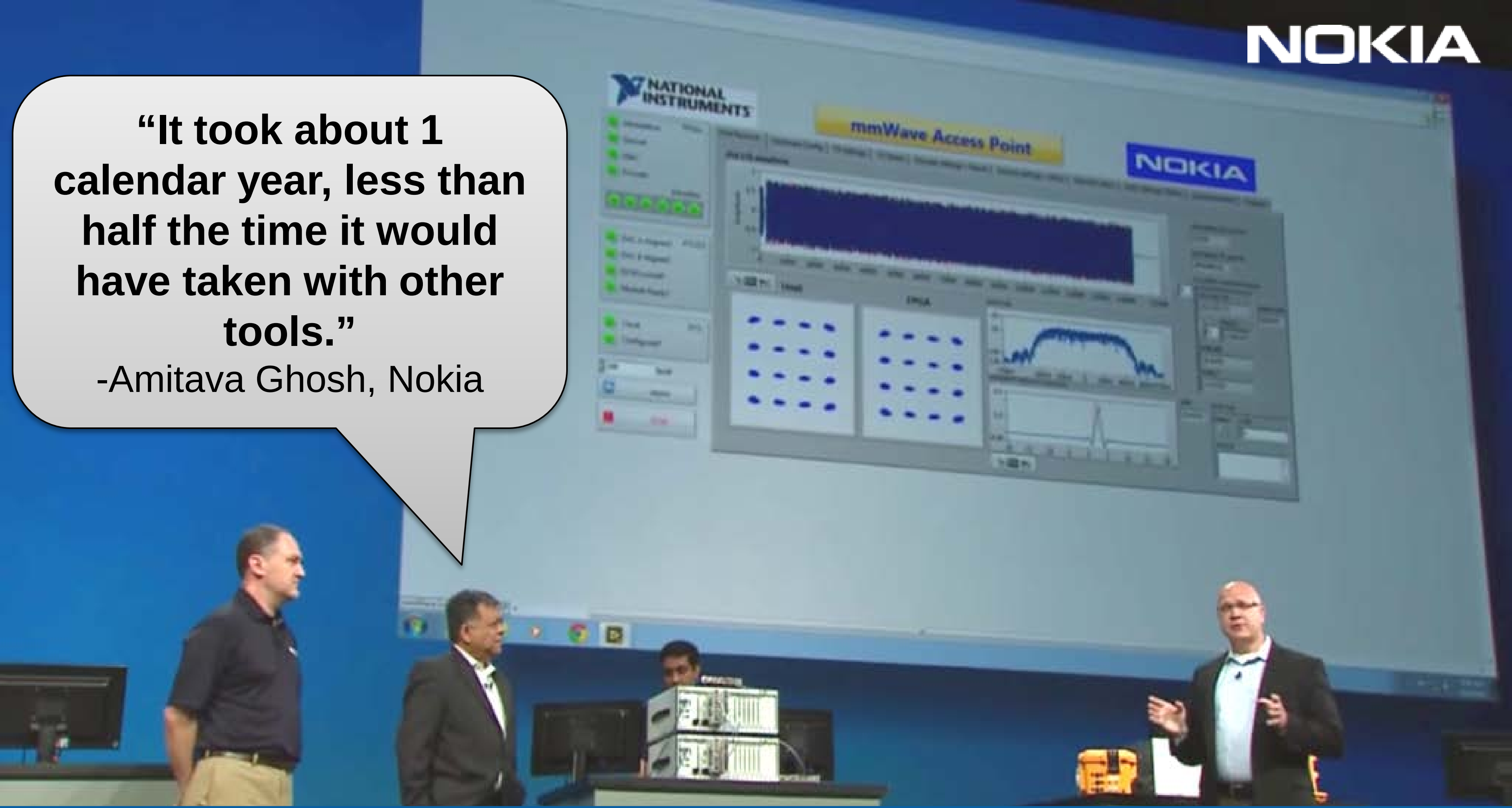
Multi-GB/s Backhaul and Access Link Prototype Using NI FlexRIO and NI LabVIEW

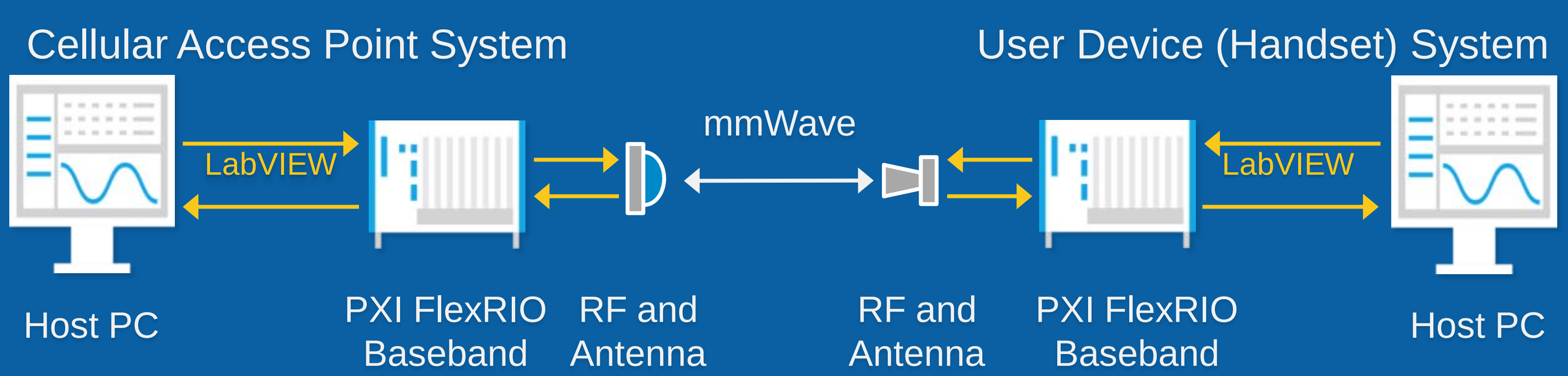
FCC Considering mmWave Spectrum

"Acting on a recommendation of the Commission's Technological Advisory Council, I am circulating to my fellow commissioners a **Notice of Inquiry** that seeks to broaden the Commission's understanding of the state of the art in technological developments that will enable the **use of millimeter wave spectrum above 24 GHz** for mobile wireless services."

- **Tom Wheeler, FCC Chairman**

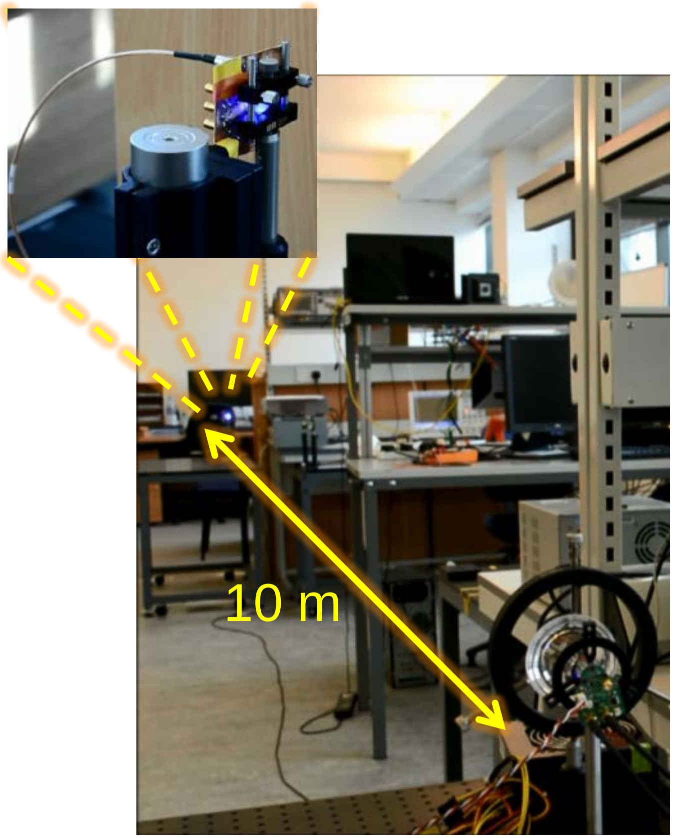
http://www.fcc.gov/blog/meeting-mobile-moment


NOKIA
“It took about 1 calendar year, less than half the time it would have taken with other tools.”
-Amitava Ghosh, Nokia
NATIONAL INSTRUMENTS
mmWave Access Point
NOKIA


Cellular Access Point System
User Device (Handset) System
LabVIEW
mmWave
LabVIEW
Host PC
PXI FlexRIO Baseband
RF and Antenna
RF and Antenna
PXI FlexRIO Baseband
Host PC

Visible Light Communication Link

- 1.1 Gb/s link using OFDM for HD video transmission over a distance of 10 m
- Single GaN LED with a diameter of 50 µm at the transmitter
- An avalanche photodetector at the receiver
- NI 5781 Baseband transceiver used at both transmitter and receiver



Courtesy: Harald Haas, University of Edinburgh

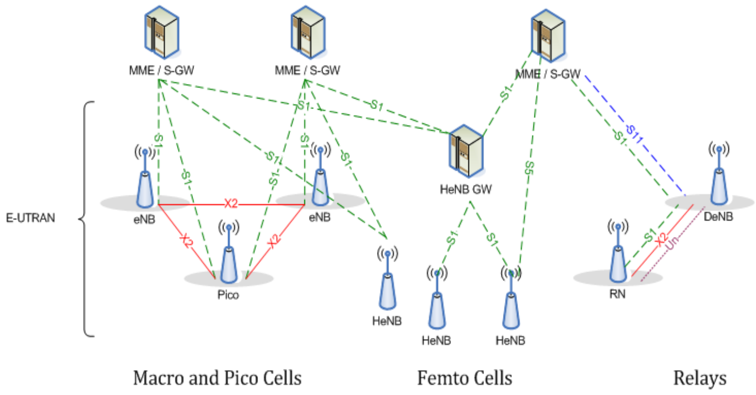
Protocol Stack Design: Initial Use Cases

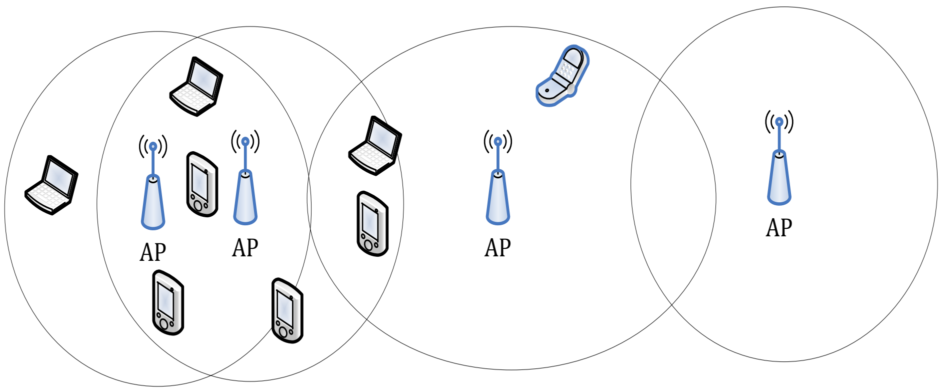
Cellular systems

- Licensed band deployment
- Centralized/carefully managed
- Heavy stack
- Moderate round trip latencies
- LTE, LTE-A and evolution to 5G

WLAN Systems

- Unlicensed band
- Ad-hoc networks
- Light stack
- Tighter round trip latencies
- 802.11ac and evolution to 802.11ax





Architecture for Protocol Stack Explorations

802.11 | LTE | MTC | IoT

Open Source Upper Layer Stack (e.g. ns-3)

↕

802.11 Ref Design | LTE Ref Design

PHY/MAC Stack in LabVIEW

↕

NI Hardware

PXI Systems

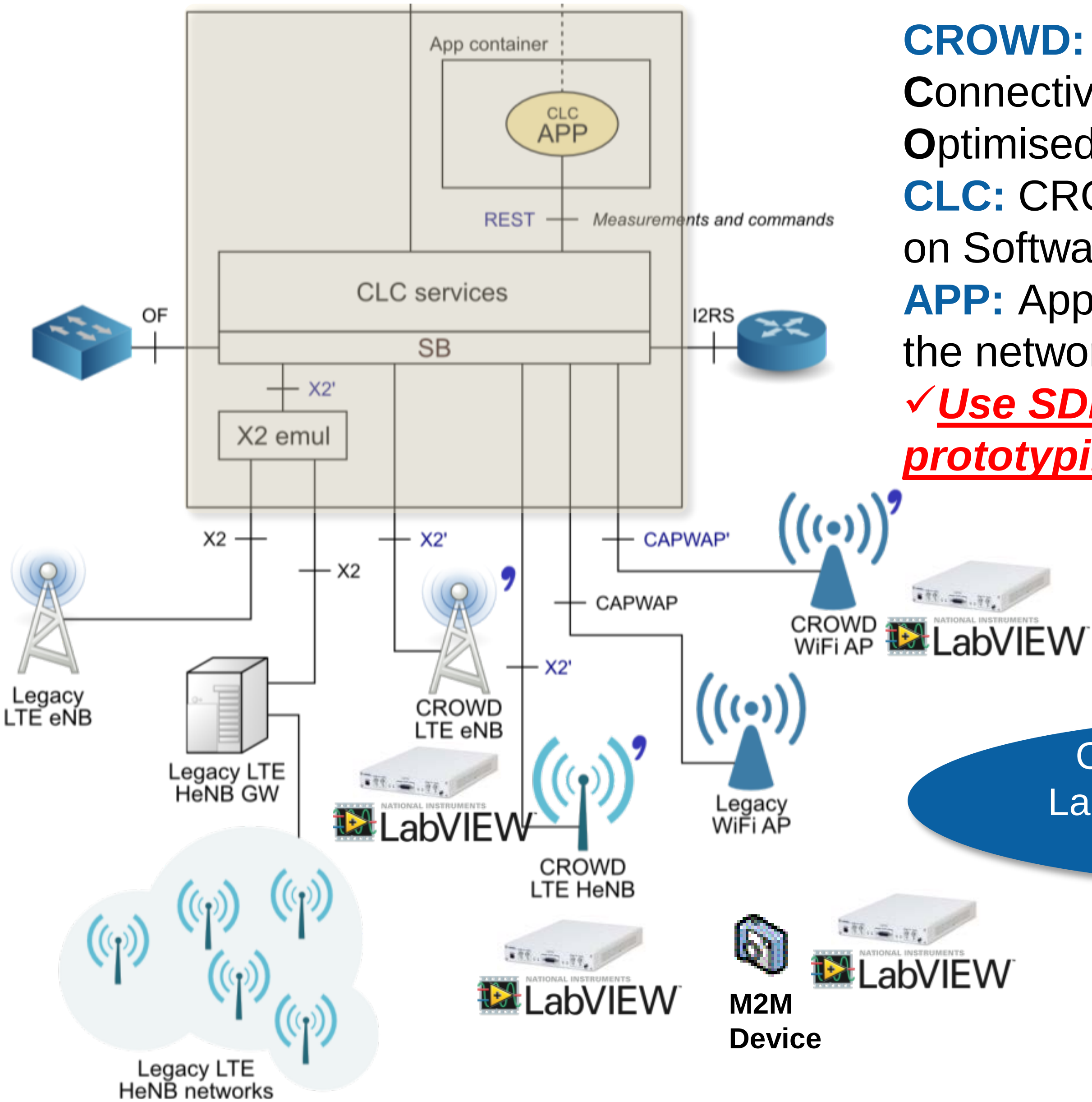
USRP RIO

ns-3

NATIONAL INSTRUMENTS LabVIEW

NATIONAL INSTRUMENTS

EU FP7 CROWD Project Overview



CROWD: An EU FP7 Project - Connectivity management for eneRgy Optimised Wireless Dense Networks

CLC: CROWD Local Controller based on Software Defined Networking (SDN)

APP: Application like ABSF to optimize the network

✓***Use SDN as a paradigm for prototyping heterogenous systems***

Open Architecture based on LabVIEW to integrate 3rd Party IP

Source: EU FP7 CROWD project

Summary

Ettus Research™
A National Instruments Company

ettus.com

- Exciting new SDR hardware platforms
- Continued investment in end-to-end open source SDR solutions

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ni.com/sdr

- Refined tool flow for more productive SDR prototyping
- Proving 5G technologies for next generation wireless systems

innovate**FASTER**

NATIONAL INSTRUMENTS™