Chapter 1. Introduction

Chapter 1. Introduction Outline

- Definition
- Ideal Concept
- History, Benefits, Applications and Disadvantages
- Challenges
- Generic Architecture: Hardware and Software
- Evolution towards Cognitive Radio.

Definition

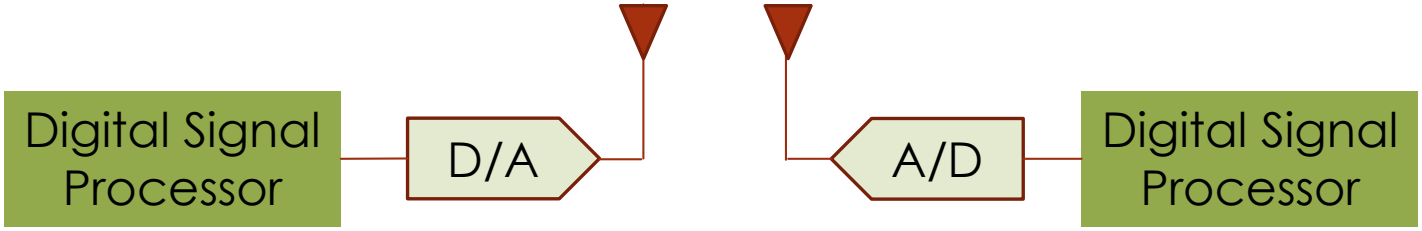
- No standard definition is available; some examples:
  - **ITU-R:** A radio transmitter and/or receiver employing a technology that allows the RF operating parameters including, but not limited to, frequency range, modulation type, or output power to be set or altered by software, excluding changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard.

Definition

- No standard definition is available; some examples:
  - **SDR Forum:** A software-defined radio is a radio in which some or all of the physical layer functions are software defined.
  - A software-defined radio is a radio transceiver for which the key radio parameters are software defined and the fundamental functional aspects can be reconfigured by upgrading a software image.

Ideal Concept

- Tx side: a DSP generates data that is D/A converted and is transmitted to the Tx antenna
- Rx side: the Rx antenna provides the data that is A/D converted and is transferred to a DSP



History

- The **Software Radio** term : 1984, E-Systems (Garland, Texas)
  - Was referring to a digital baseband receiver
- The **Software Defined Radio** term: 1995, Bell South Wireless
- Other used terms: **Software Controlled Radio**

History - Projects

- **SPEAKeasy projects** – Defence Advanced Research Projects Agency (DARPA) – US Air Force
  - **SPEAKeasy phase I**: 1990-1995, with the goal to implement a radio that could operate from 2 MHz to 2 GHz and interoperate with ground force radios
    - August 1994: first demonstration using HF band modems
  - **SPEAKeasy phase II**: extend the usage from a simple modem to a open, modular and reconfigurable architecture for the whole radio interface
    - Prototypes presented in 1997
    - Series production having frequency range 20 MHz – 400 MHz

History - Projects

- **JTRS – Joint Tactical Radio System** – US Department of Defence (DoD)
  - The initial program was structured in 3 phases, with the goal of defining, standardizing and implementing a common software architecture for SDR equipment
  - Three industrial consortiums were created, lead by Boeing, Motorola and Raytheon and including 30 companies
  - The architecture was named Software Communications Architecture (SCA)
  - Several prototypes were implemented by the industrial partners (Raytheon, Rockwell, ITT, Marconi)
  - The program was restructured starting from 2005 because of delays and exceeding of initial costs

Benefits

- **Interoperability**
- **Efficient use of resources under varying conditions**
- **Opportunistic frequency reuse (cognitive radio)**
- **Reduced obsolescence (future-proofing)**
- **Lower cost**
- **Research and develompment**

Applications

- **Military communications**
  - Configuring the radio depending on the communication conditions
  - Dynamically changing the bandwidth, modulation, rate, voice codec
  - Security offered by ad-hoc established codes for scrambling and encryption
- **Civil mobile communications**
  - Upgrade of the services
  - Transition to new generations of systems (ex: GSM->UMTS->LTE)
- **New technologies introduced in the bands of old systems**
  - Upgrade of the whole network can be done without service interruption
- **Emergency communications in case of disasters**

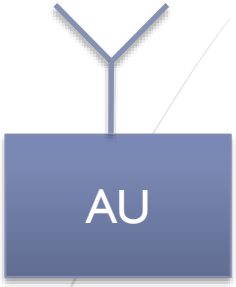
Disadvantages

- **Cost and Power**
  - The cost argument is particularly important simple devices produced in high-volumes;
  - Since an SDR is more complex than a single-function radio, the cost will also be higher;
  - Increased power consumption because of increased DSP complexity and higher mixed-signal/RF bandwidth.
- **Complexity**
  - Increased time and cost necessary to implement the radio
  - Longer and more costly specifications and requirements definition
  - Increased risk
- **Limited scope**
  - SDR only addresses the physical layer, as such the user cannot take advantage of link throughput improvements made possible by SDR without cooperation from upper layers.

Challenges

- **Wideband RF modules**
  - Multistandard, multiband systems
  - Wideband antennas
  - Several RF modules, one for each standard
- **Need for securing some SW components/modules from the image**
  - In case of a download, some modules that are protected by copyright contracts could be intercepted
- **Large traffic in case of the upgrade of all terminals from a network**
  - Can lead to network breakdown

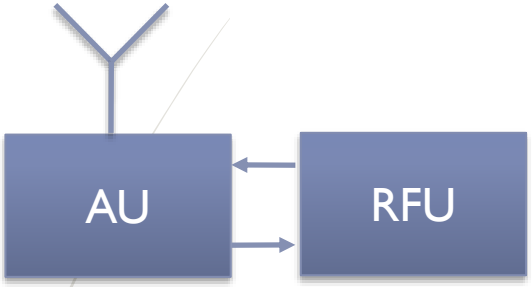
SDR Generic block diagram



AU – Antenna Unit

- Sectorial antenna/group of antennas
- Antenna system(SDMA, beamforming)
- Wideband antenna
- Omnidirectional antenna
- Set of multiple antennas for diversity

SDR Generic block diagram

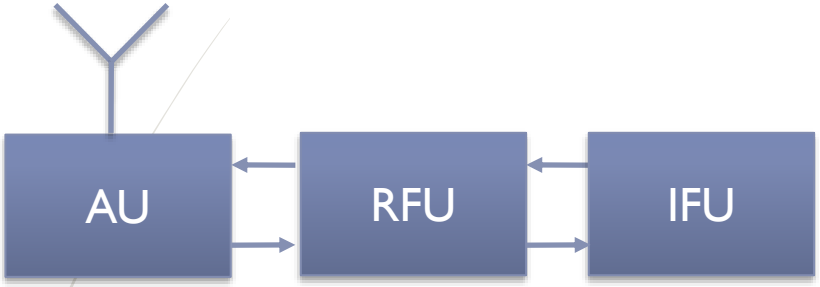


RFU – Radio Frequency Unit

Tx: Signals resulted from IFU/BBU are filtered, mixed on RF and amplified

Rx: Signals captured by the AU are amplified, pre-filtered and mixed towards IF or baseband

SDR Generic block diagram

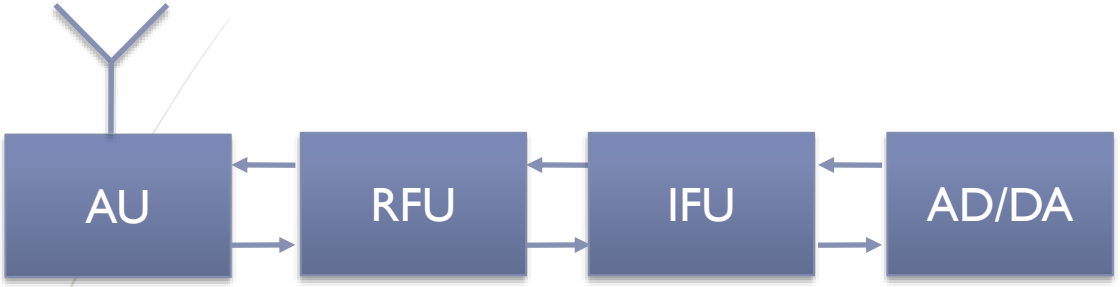


IFU – Intermediary Frequency Unit

Tx: Signals resulted from the D/A conversion are mixed on IF, amplified and transferred to the RFU

Rx: Signals resulted from the RFU are amplified, filtered for channel selection and then mixed towards baseband

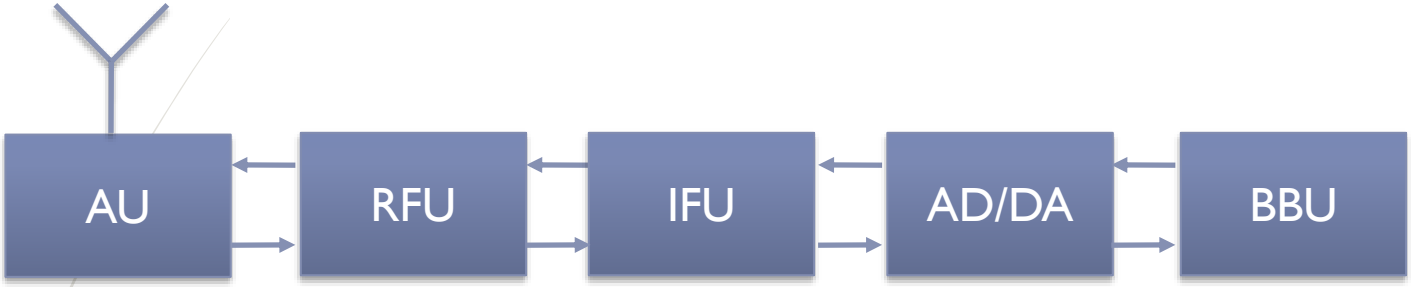
SDR Generic block diagram



AD/DA – Analog to Digital / Digital to Analog Unit

A/D and D/A Conversions

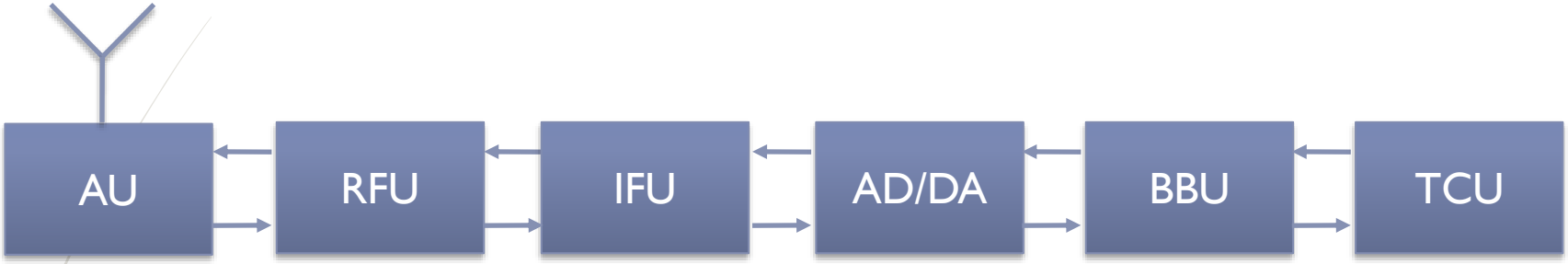
SDR Generic block diagram



BBU – Baseband Unit

Tx: Frame, coding, constellation mapping, pulse shaping filter
Rx: Sampling frequency conversion, timing alignment, carrier recovery, equalization, decoding

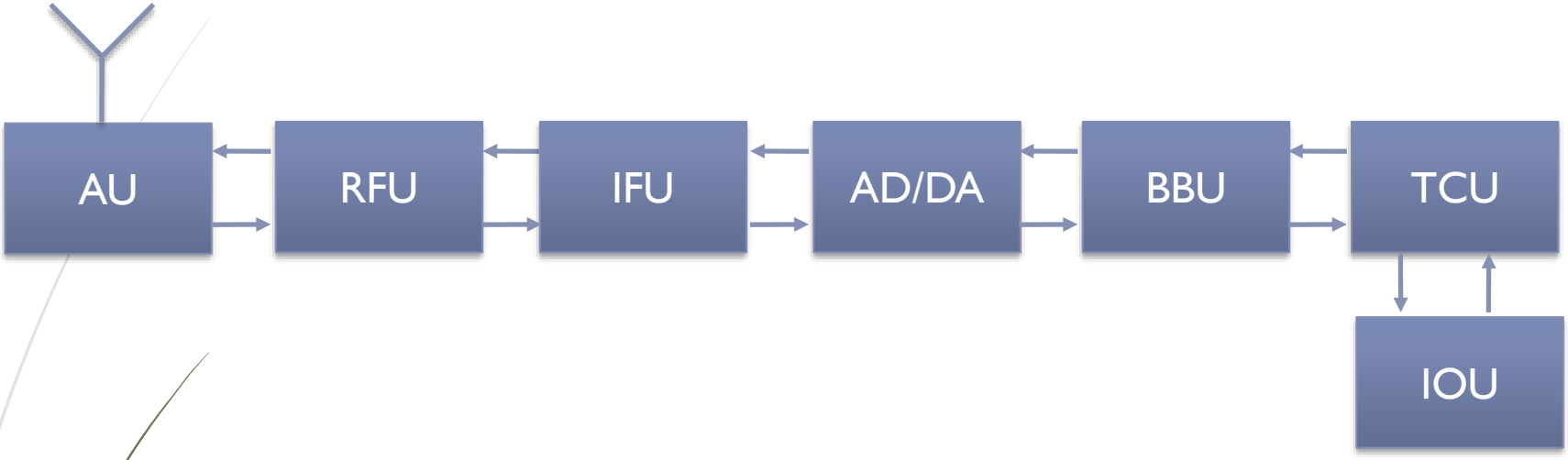
SDR Generic block diagram



TCU – Transmission Control Unit

- Cryptography
- Form data packets (Tx) according to the requirements of the superior level (MAC)
- Error control at packet level (Rx)

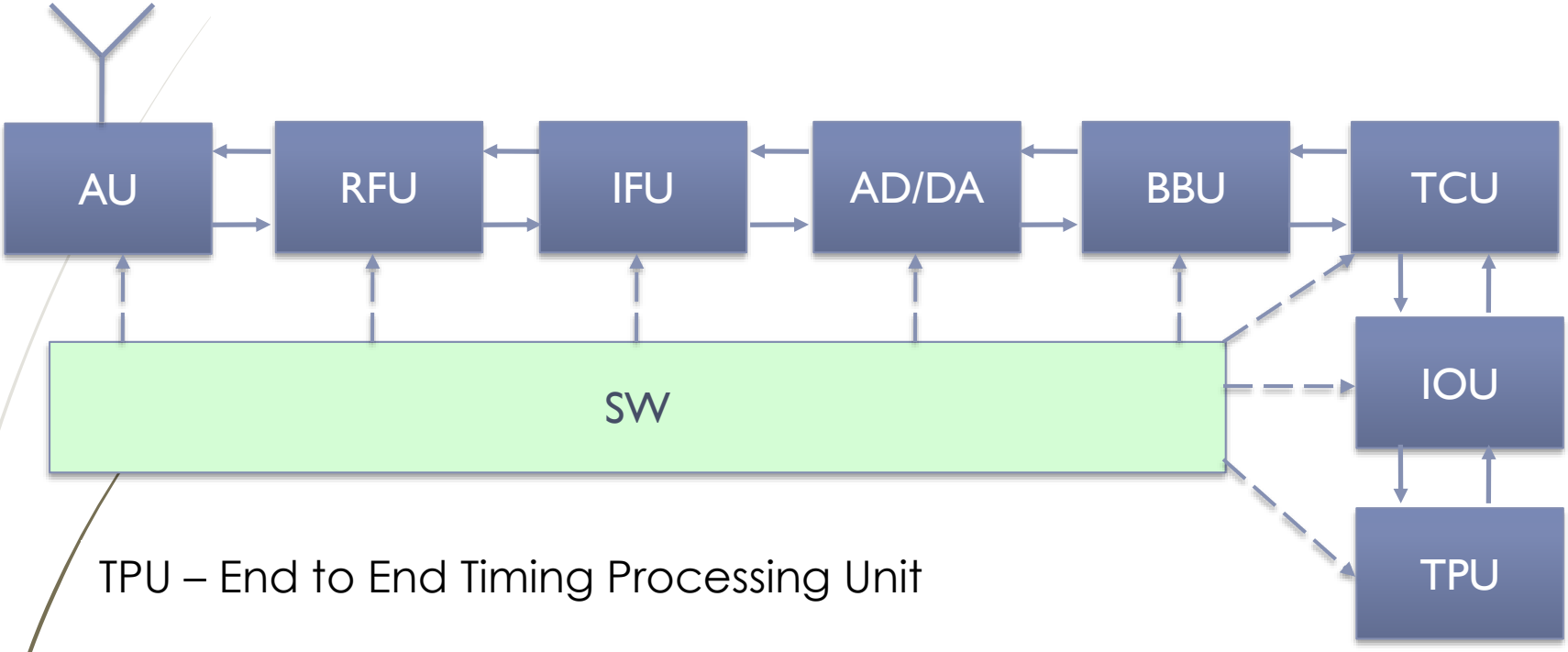
SDR Generic block diagram



IOU – Input/Output Processing Unit

Interface to the central processing unit

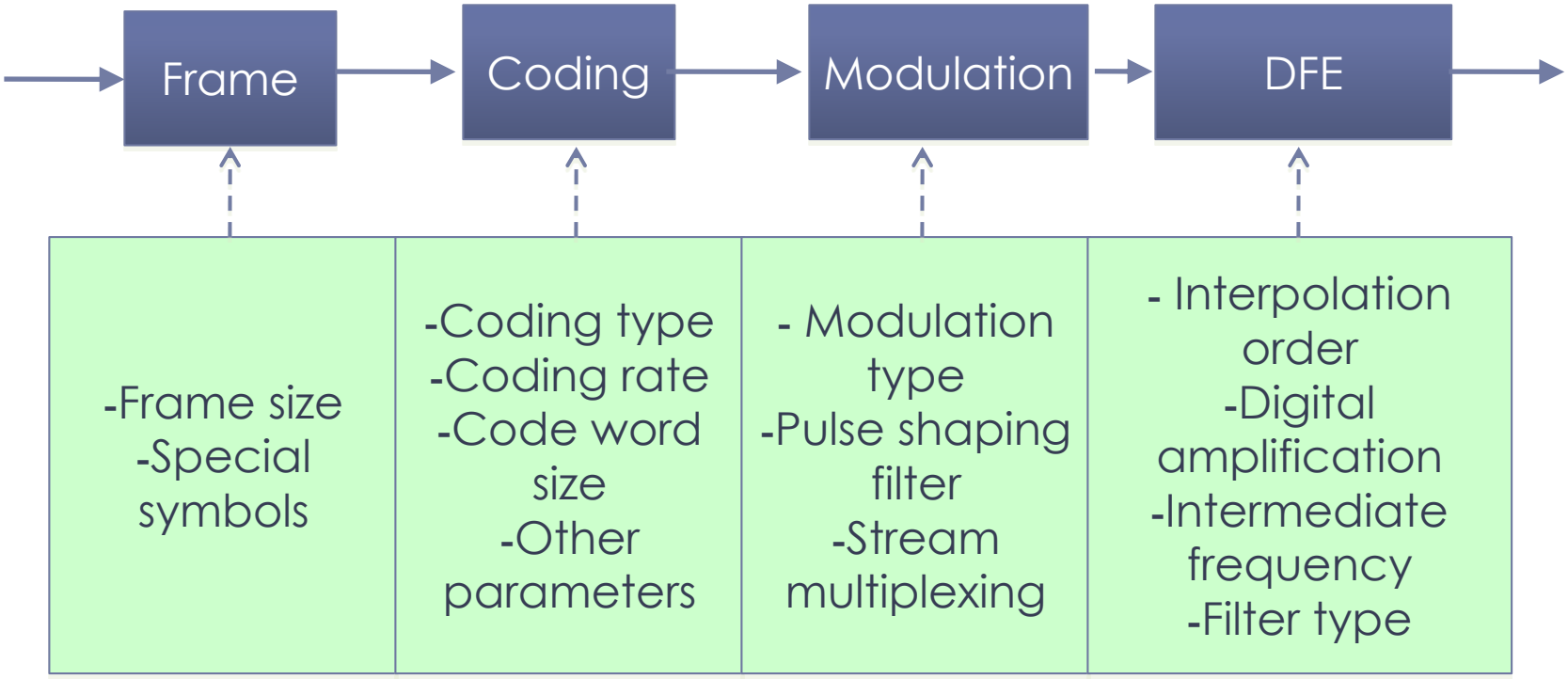
SDR Generic block diagram



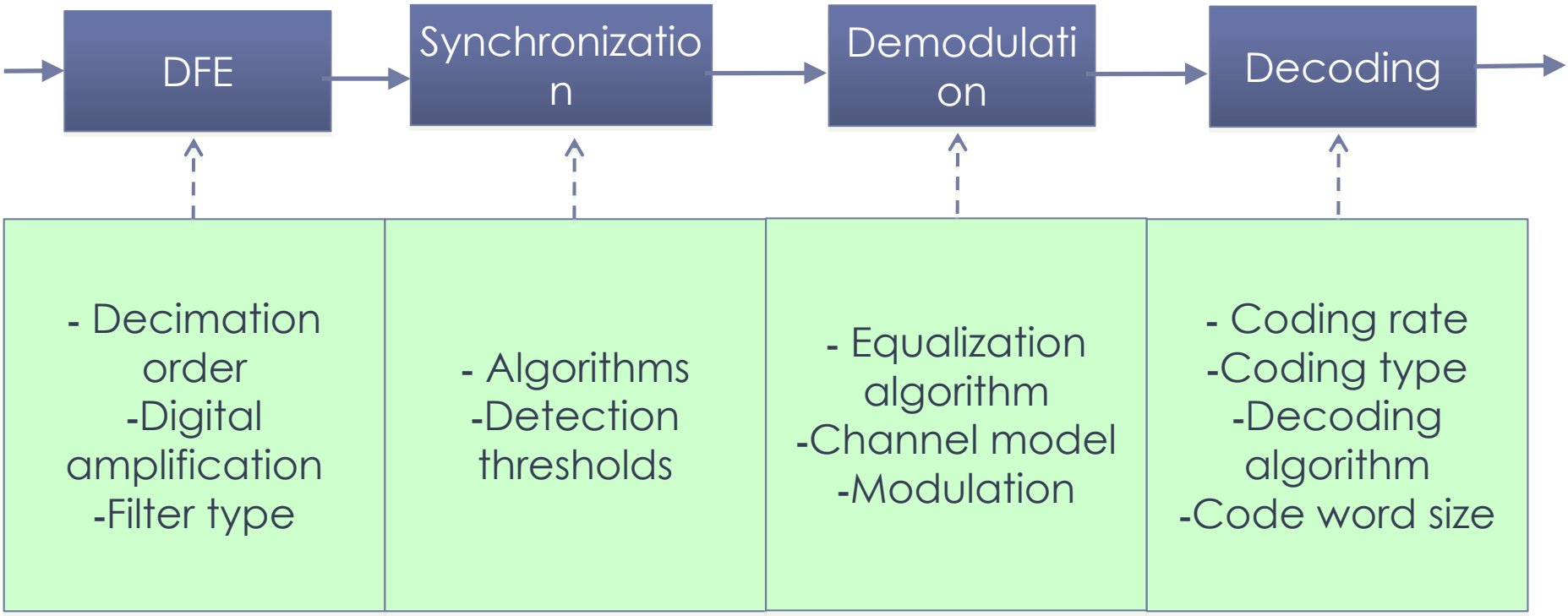
TPU – End to End Timing Processing Unit

Planning protocol, depending on the quality of service requirements

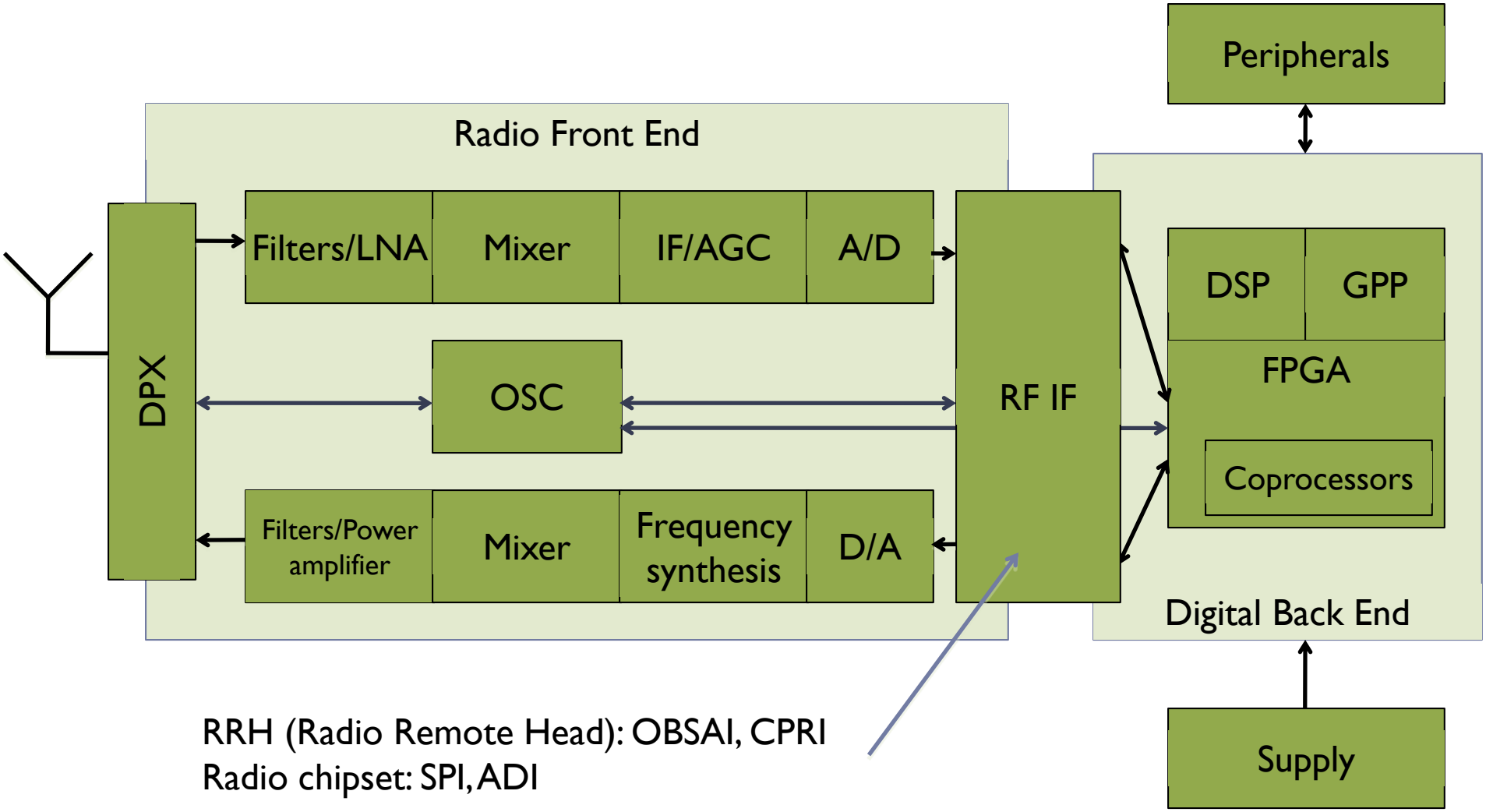
BBU - Tx


Frame
Coding
Modulation
DFE
-Frame size
-Special symbols
-Coding type
-Coding rate
-Code word size
-Other parameters
- Modulation type
-Pulse shaping filter
-Stream multiplexing
- Interpolation order
-Digital amplification
-Intermediate frequency
-Filter type

BBU - Rx

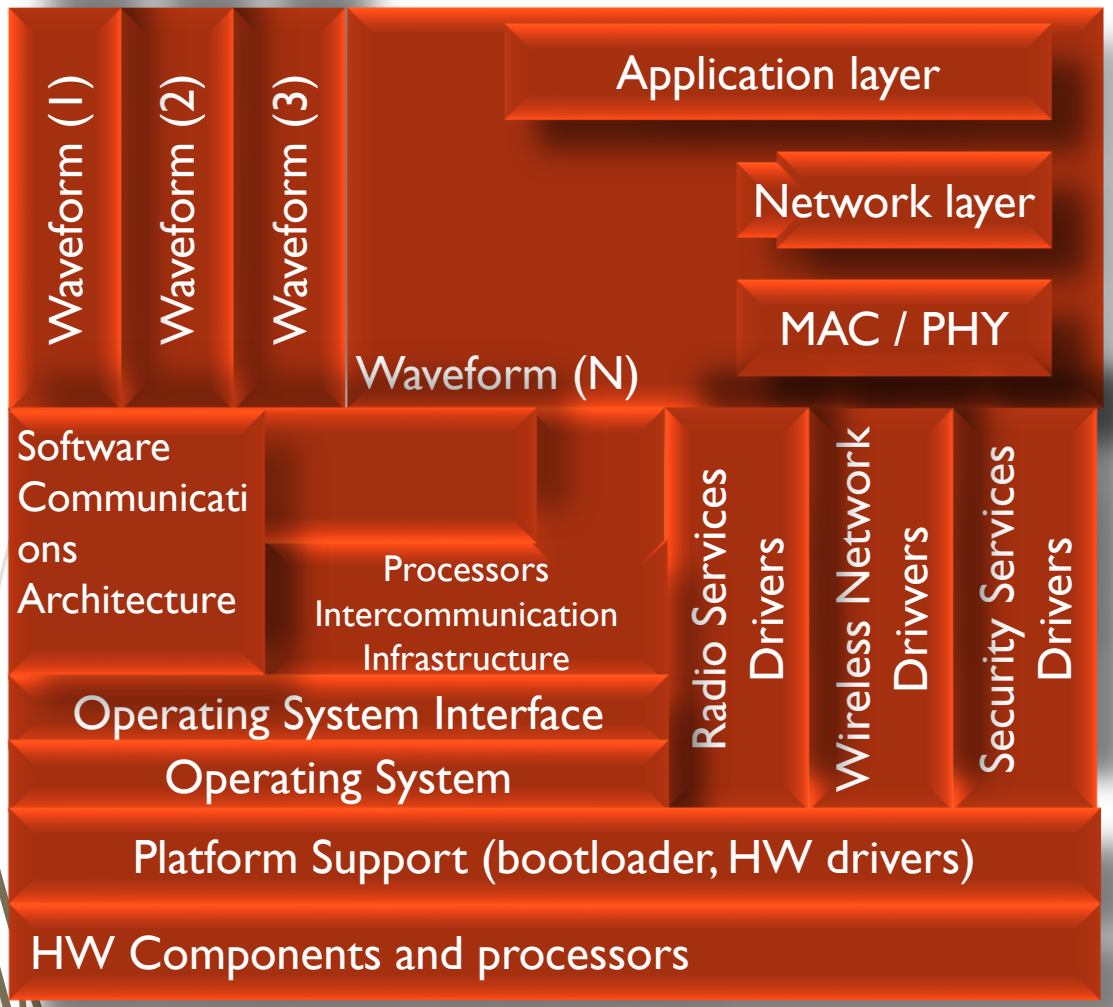

DFE
Synchronization
Demodulation
Decoding
- Decimation order
-Digital amplification
-Filter type
- Algorithms
-Detection thresholds
- Equalization algorithm
-Channel model
-Modulation
- Coding rate
-Coding type
-Decoding algorithm
-Code word size

Hardware Architecture



RRH (Radio Remote Head): OBSAI, CPRI
Radio chipset: SPI, ADI

Software Architecture



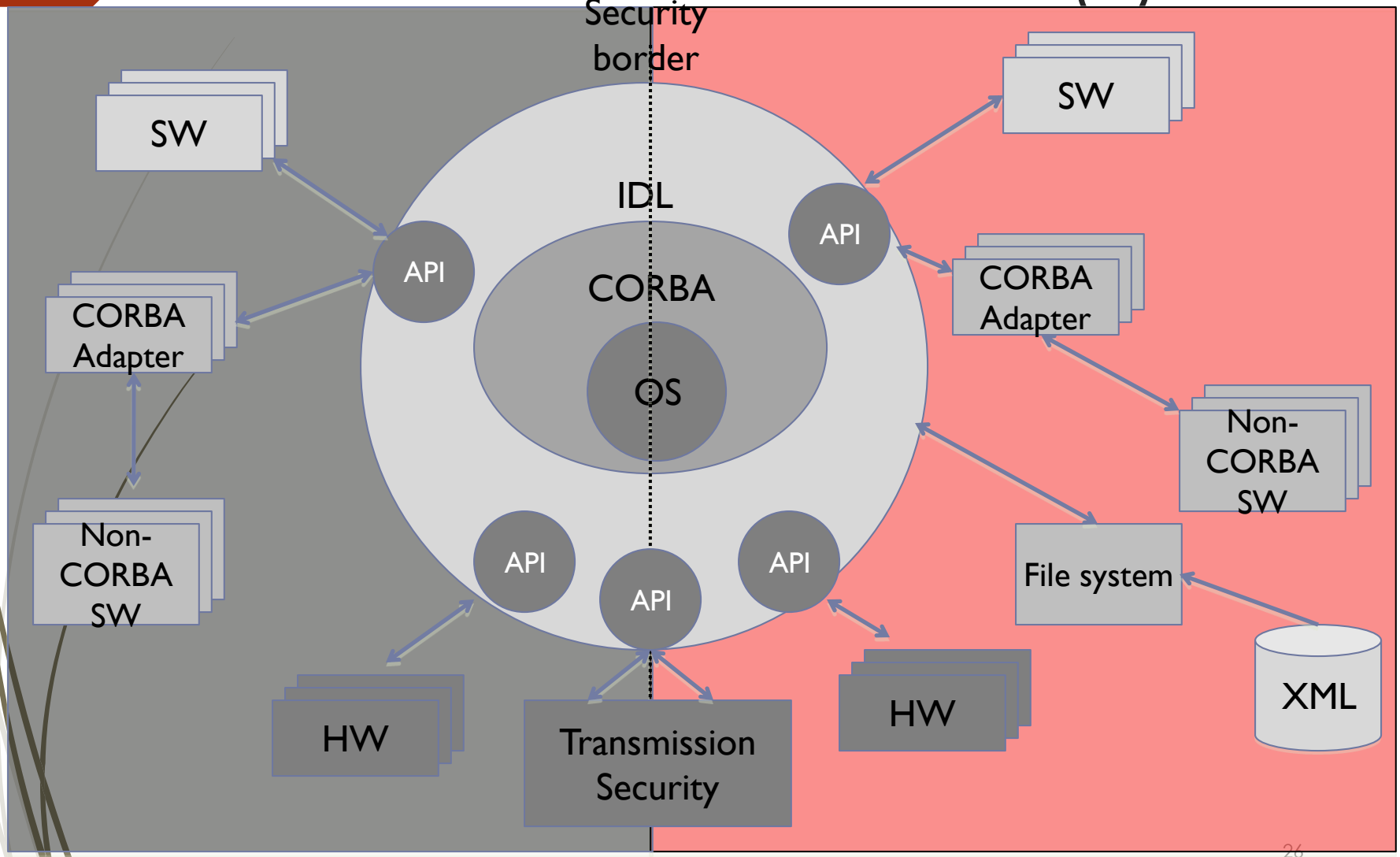
Waveforms and applications are installed, used and replaced

The hardware platform has standardized interfaces (API – Application Programming Interface)

Software Architecture (2)

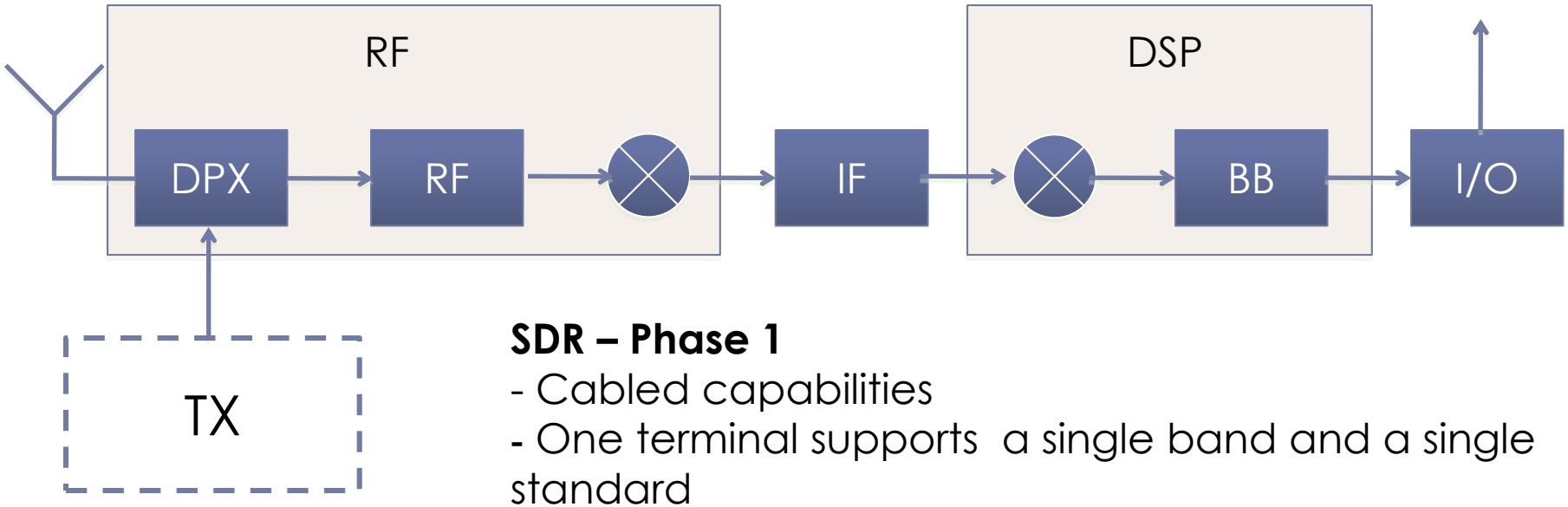
- SCA = Software Communication Architecture
  - Standardized open software architecture, proposed by U.S. Government
  - Built on a set of OS characteristics, which contains specialized API-s, POSIX (Portable Operating System Interface for UniX)
    - File management
    - Task and thread scheduling
  - Abstraction of SW + HW layers
  - Specifies a middleware CORBA (Common Object Request Broker Architecture) architecture
    - Standardized method of communicating between software objects, independent of the HW platform

Software Architecture (3)



SDR Evolution

- **Goal:** bring the digital part as close to the antenna as possible

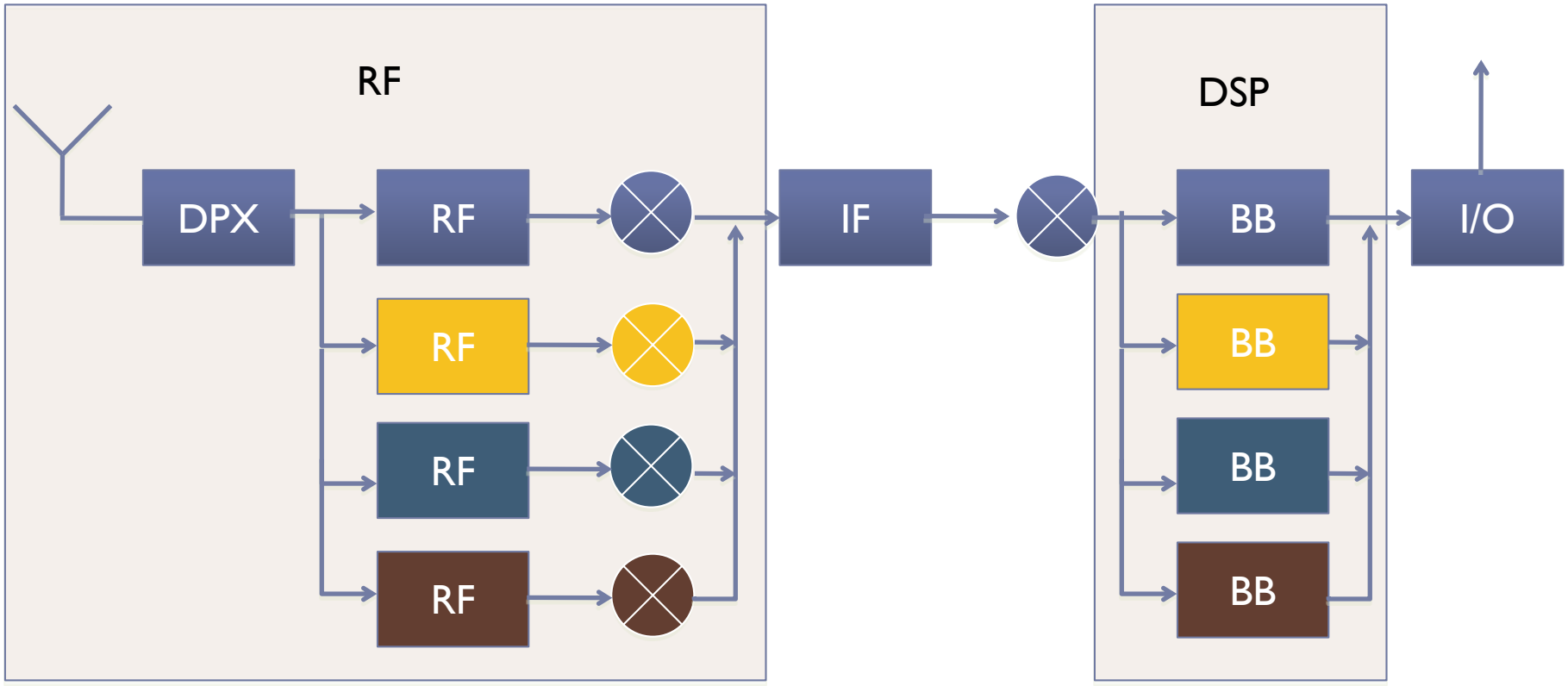


SDR – Phase 1

- Cabled capabilities
- One terminal supports a single band and a single standard
- For multi-band/multi-standard, additional modules are added

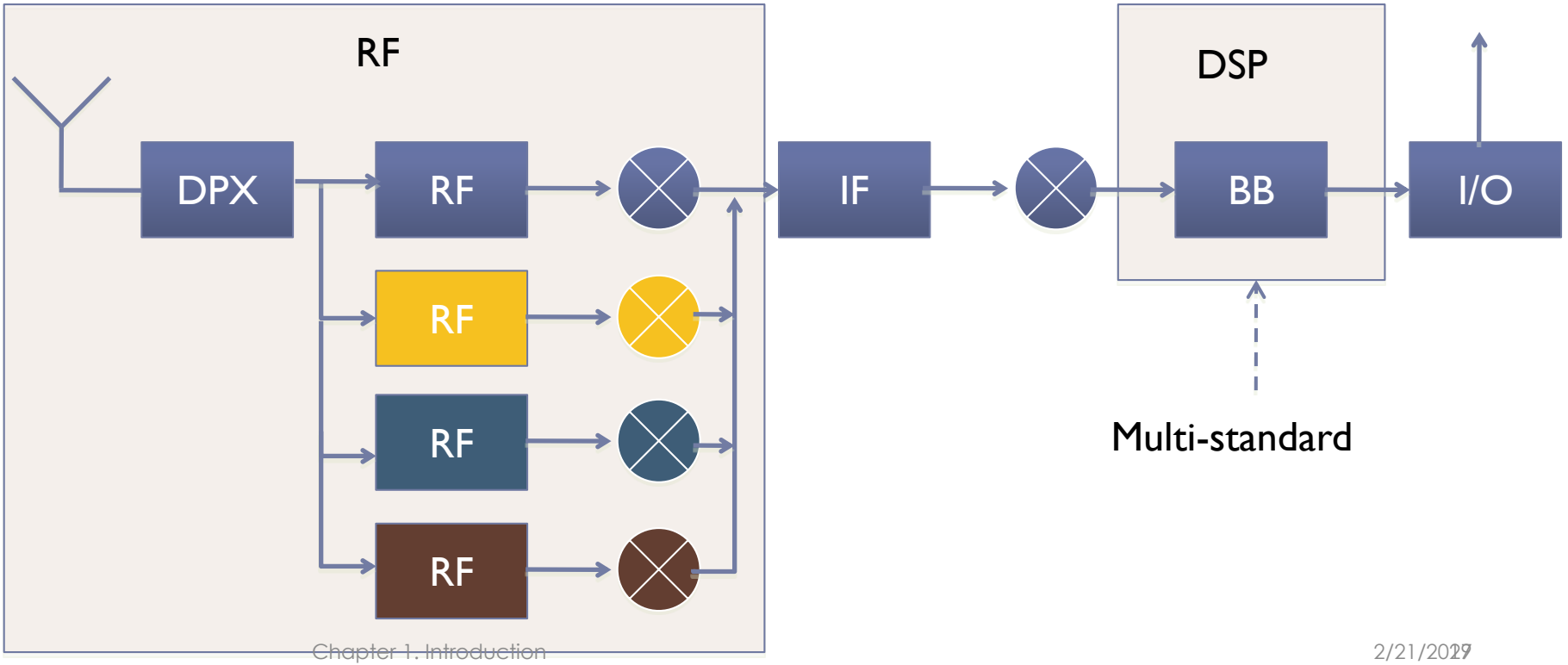
SDR Evolution(2)

- Phase 2: Multi-band, multi-standard



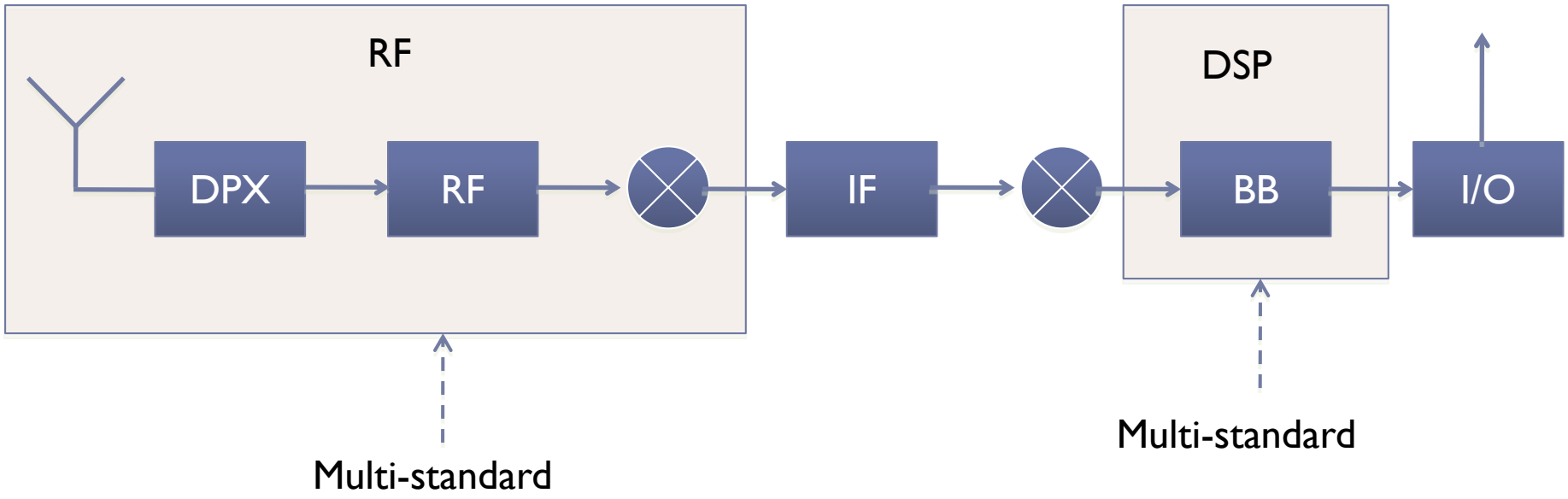
SDR Evolution(3)

- Phase 3: BBU is programmable to support different standards



SDR Evolution(4)

- Phase 4: RFU is programmable to support different standards

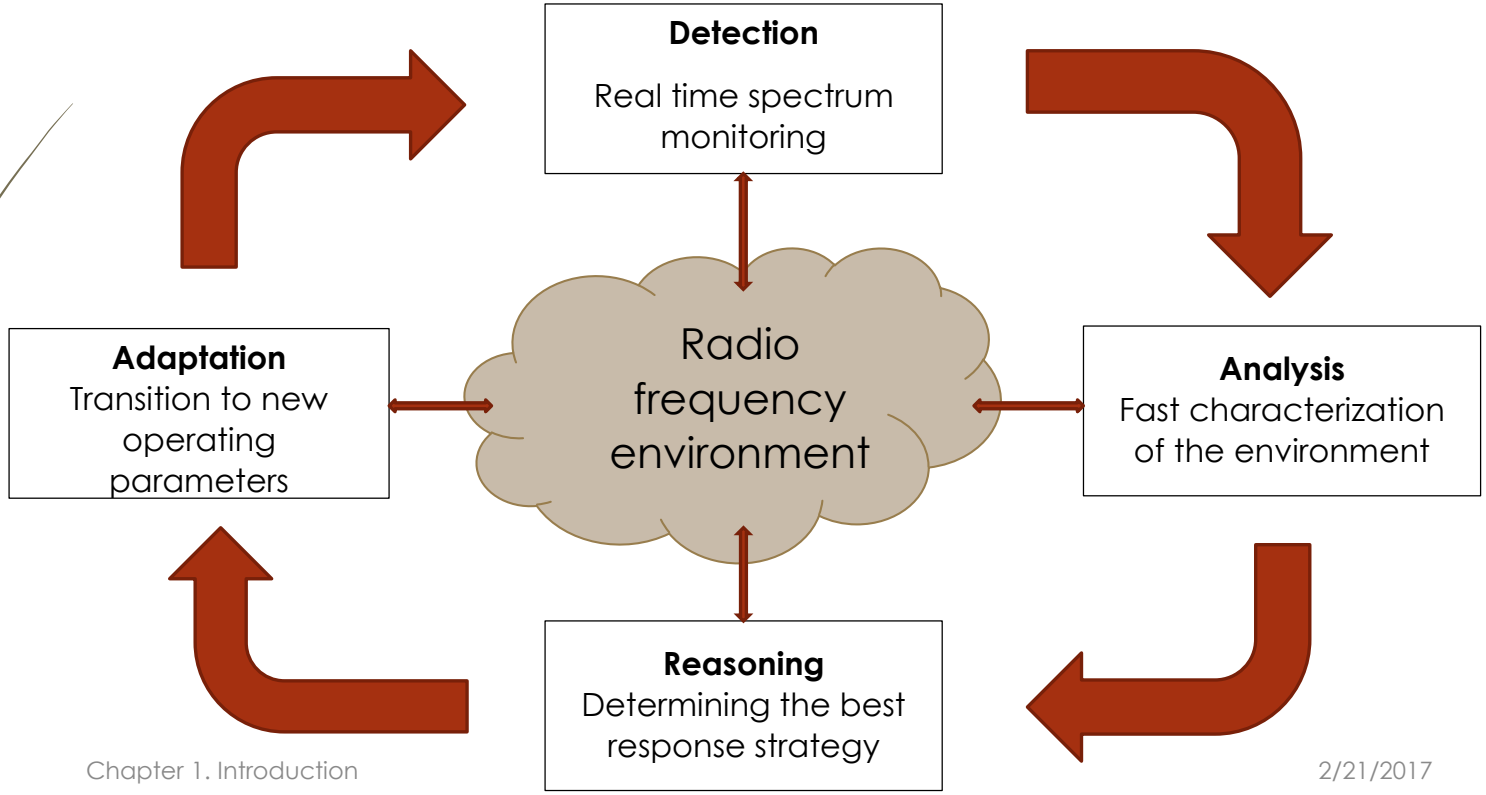


SDR Evolution towards Cognitive Radio

- Cognitive Radio term coined in 1998 by J. Mitola
- Possible Cognitive Radio (CR) definitions:
  - **H. Arslan**: An SDR that is aware of its environment, internal state, and location, and autonomously adjusts its operations to achieve designated objectives.
  - **S. Haykin**: A radio capable of being aware of its surroundings, learning, and adaptively changing its operating parameters in real-time with the objective of providing reliable anytime, anywhere, and spectrally efficient communication.
  - **FCC (Federal Communications Comission)**: A radio that can change its transmitter parameters based on the environment in which it operates.

SDR Evolution towards Cognitive Radio

- Cognitive Cycle:



SDR Evolution towards Cognitive Radio