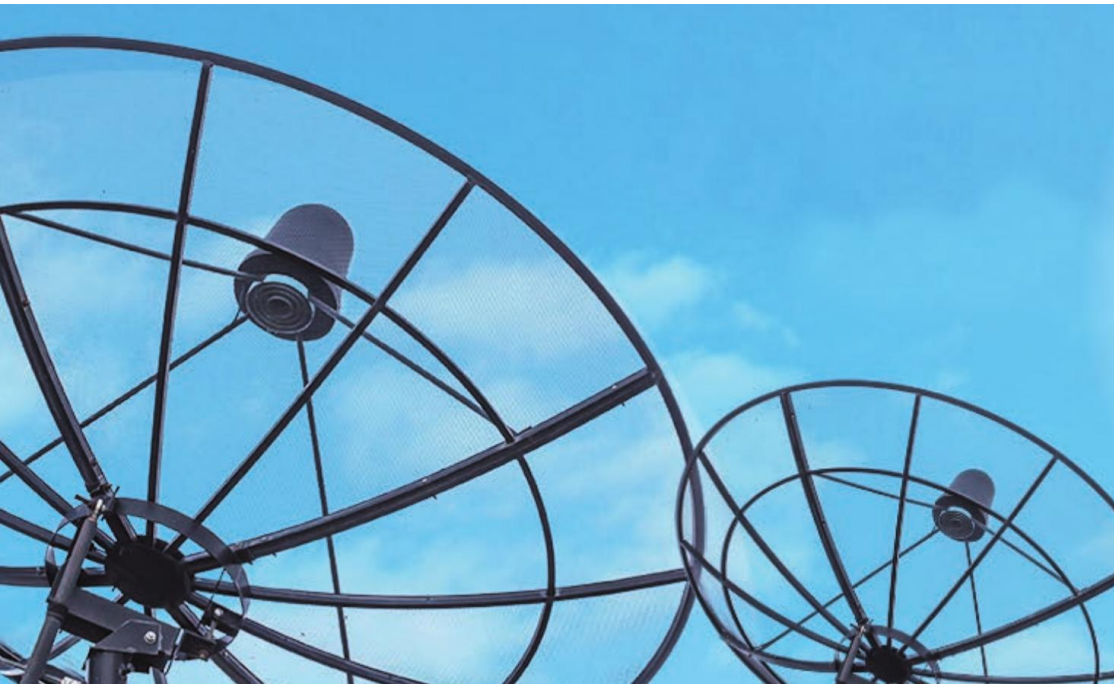


# A software-radio UE for NB-IoT - Experiences using the srsLTE suite

Andre Puschmann, Paul Sutton and Ismael Gomez



Cellular Internet of Things Workshop, VDE/ITG Section/Fachausschuss 5.2 “Communication Networks”  
December 1<sup>st</sup>, 2017, Munich

[www.softwareradiosystems.com](http://www.softwareradiosystems.com)

# Outline

- Introduction
- srsLTE Ecosystem Overview
- Narrowband Internet of Things (NB-IoT)
  - Overview
  - srsLTE extension
  - Exploring commercial deployments
  - Use-case examples

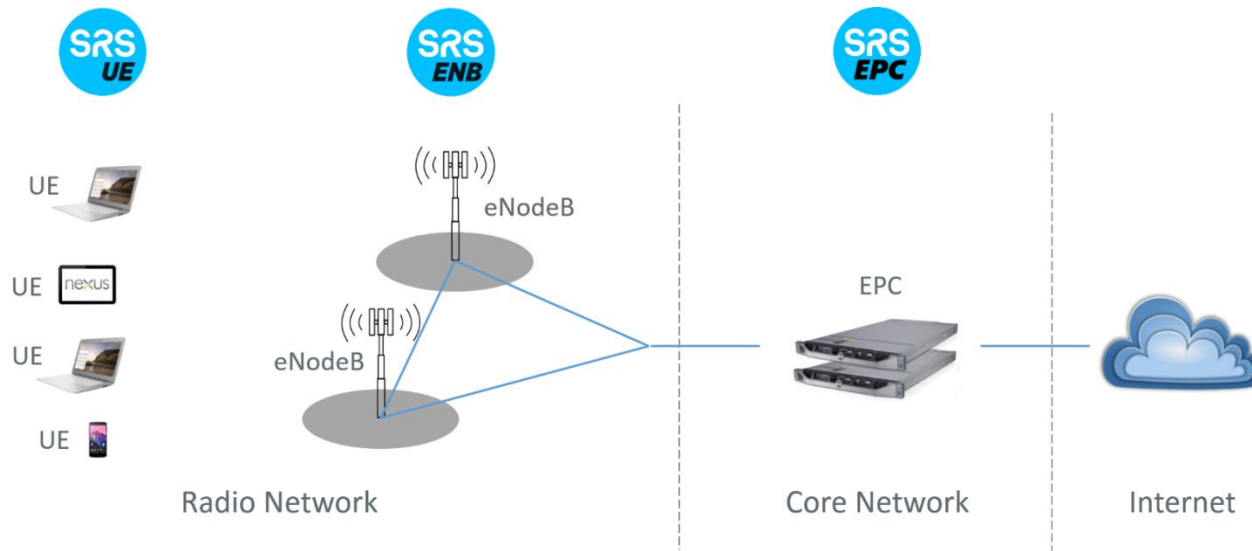
# Company At a Glance

- Irish startup
- Founded at Trinity College Dublin in 2012
- Cork and Dublin (Ireland) and Barcelona (Spain)
- High-performance software for wireless systems
  - Software Defined Radio
  - 3GPP LTE/LTE-Advanced toward 5G
  - Satellite systems (DVB-S2/RCS2)
- Commercial and research projects

# Recent Public-Funded Projects

## OPENFirst

- NIST Public Safety Innovation Accelerator Program
- Fully open-source end-to-end LTE network for public safety research & development (PTT, D2D, ..)



# Recent Commercial Projects

Feb  
15  
2017



## SRS partners with SmartSky Networks to deliver true 4G inflight connectivity

Software Radio Systems (SRS) today announced a strategic partnership with SmartSky Networks, a high-performance air-to-ground connectivity network operator, in which SRS will provide test and validation solutions for SmartSky's airborne products. Based on aviation-specific modifications to 4G wireless communications standards, SmartSky 4G delivers affordable and reliable office-like connectivity in the air. As a leading provider...

[Details >>](#)

15th February 2017 / Press / By Paul Sutton

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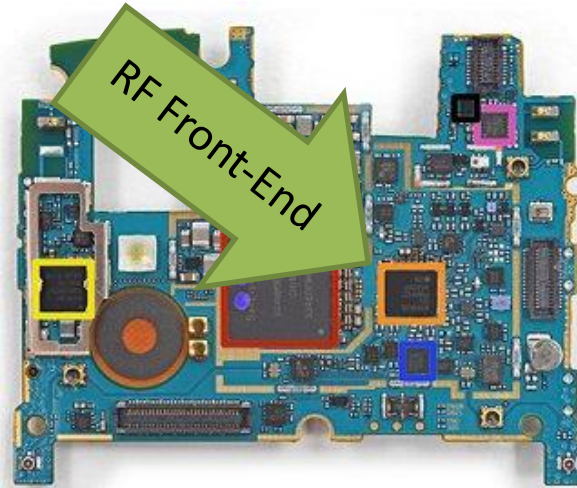
COMMS

## Cork tech company to deliver 4G in the sky at Mobile World Congress

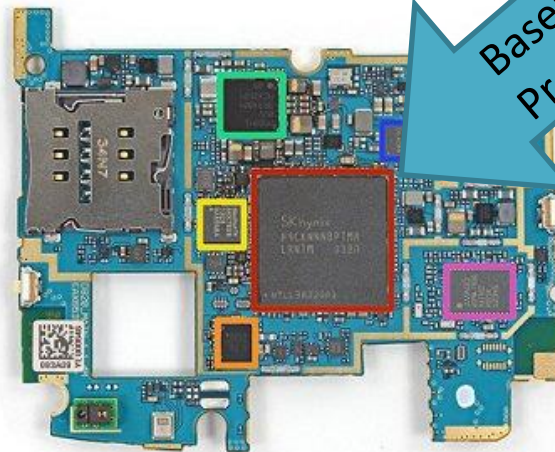
by [John Kennedy](#)

24 FEB 2017 133 SHARES

# What is a Software Radio?



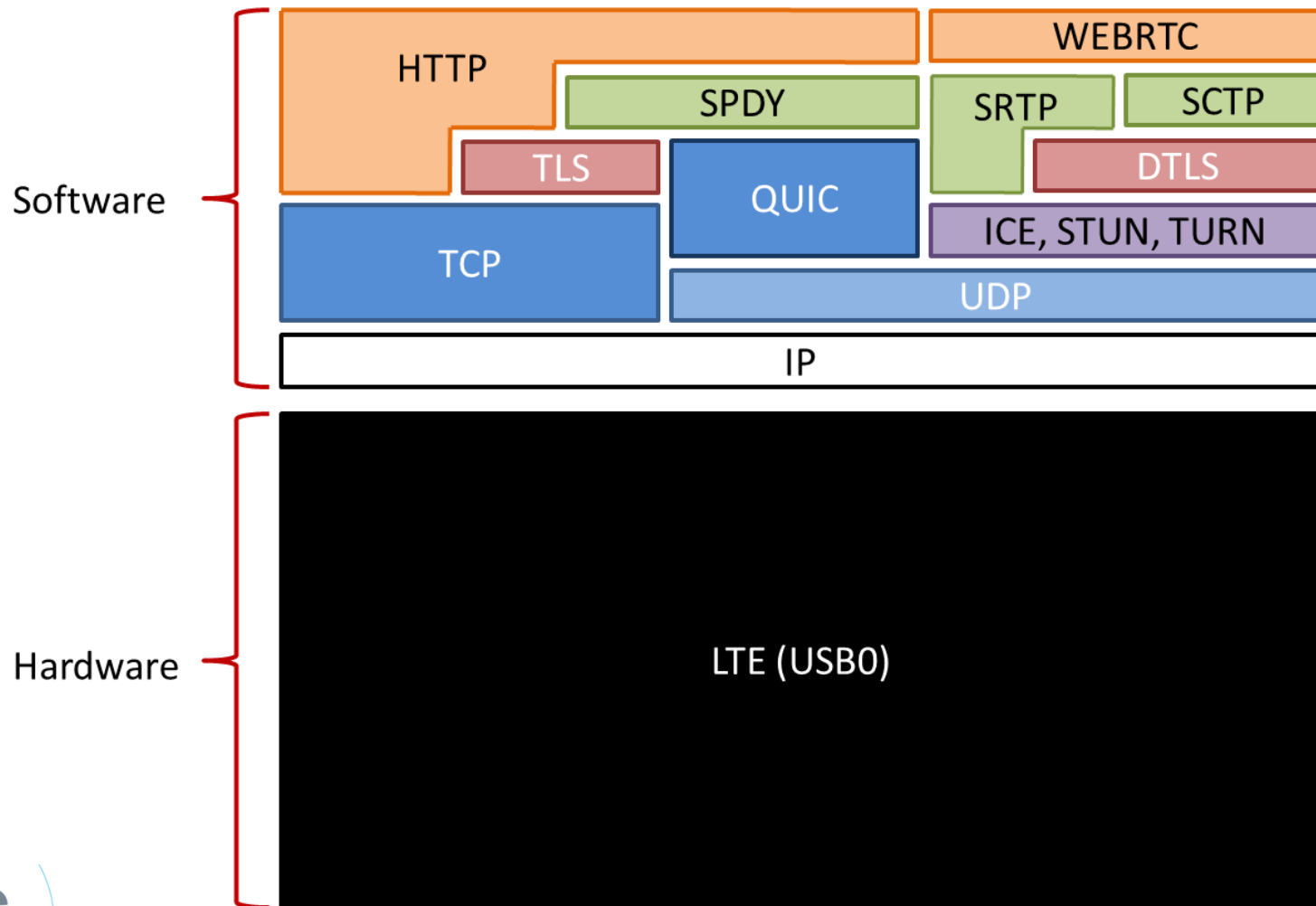
- Sandisk SDIN8DE4 16 GB NAND flash
- Qualcomm WTR1605L LTE/HSPA+/CDMA2K/TDSCDMA/EDGE/GPS transceiver
- Qualcomm PM8841 power management IC
- Broadcom BCM4339 5G Wi-Fi combo chip with integrated power and low-noise amplifiers (the updated version of the BCM4335).
- Avago RFI335
- InvenSense MPU-6515 six-axis (gyro + accelerometer) MEMS MotionTracking device.
- Asahi Kasei AK8963 3-axis electronic compass



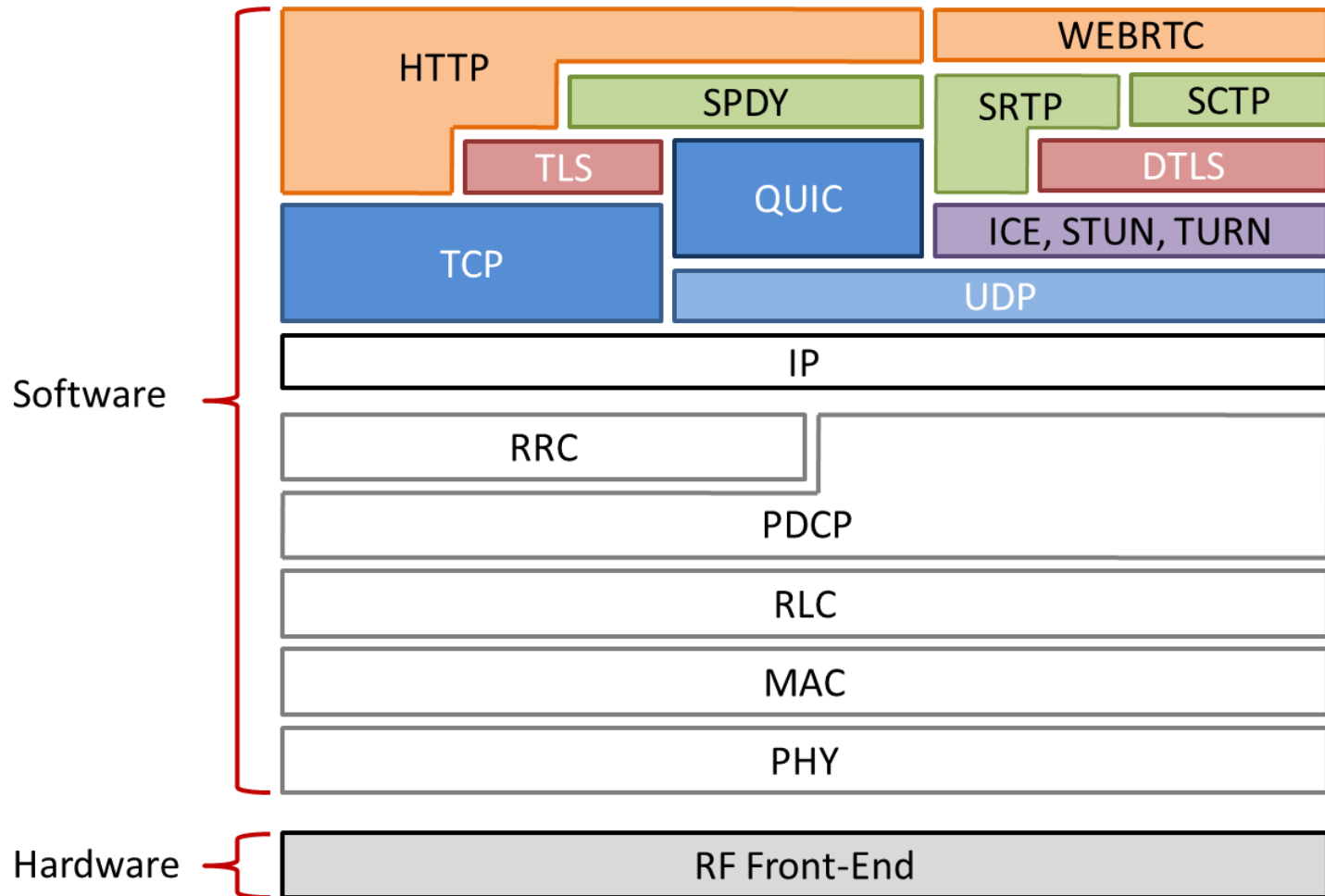
Baseband Processor

- SK Hynix H9CKNNN8PTMRLR-NTM 2 GB LPDDR3-1600 RAM
- The Quad-core, 2.26 GHz Snapdragon 800 SoC is layered beneath the RAM
- Qualcomm WCD9320 audio codec
- Analogix ANX7808 SlimPort transmitter
- Qualcomm PM8941 power management IC
- Texas Instruments BQ24192 I2C controlled 4.5 A USB/adaptor charger
- Avago ACPM-7600

# What is a Software Radio?



# What is a Software Radio?

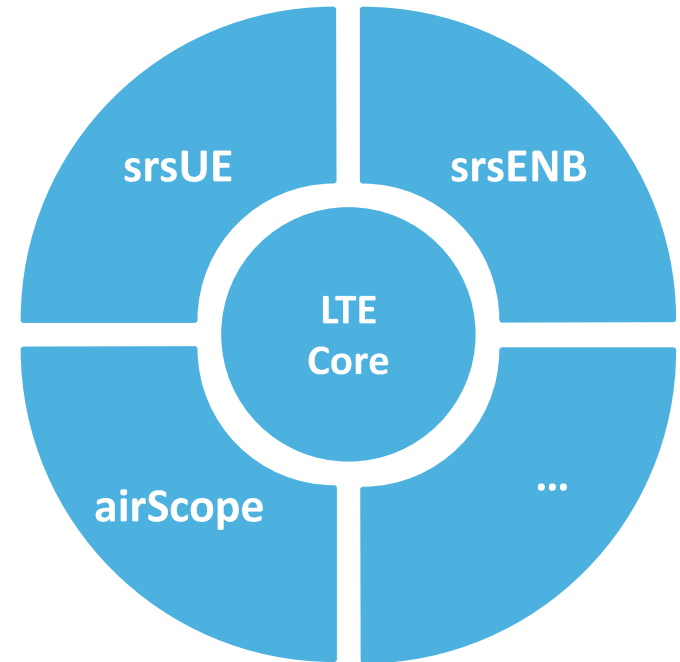






# The srsLTE Ecosystem

- Core LTE library
  - Modular and portable, high-performance library for LTE PHY, MAC, RLC, PDCP, RRC, NAS, S1AP and GW
  - All LTE bandwidths up to 20 MHz, TM1-4
  - Highly optimized Turbo decoder for Intel SSE4.1/AVX (+100Mbps)
- Applications
  - srsUE: First open-source SDR LTE UE (AGPLv3)
  - srsENB: A complete SDR LTE eNodeB application
  - srsEPC: A light-weight LTE core network
  - airScope: A passive LTE air-interface analyzer
  - ...

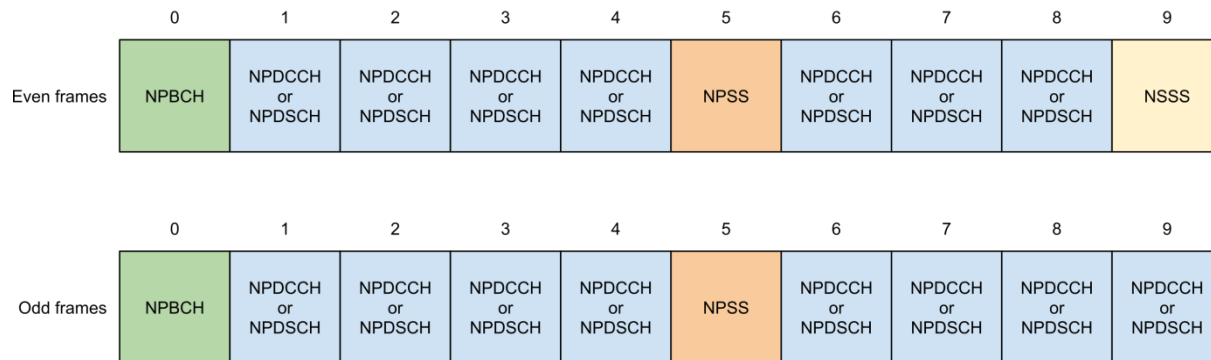


# Narrowband Internet of Things

- Low-Power Wide Area (LPWA)
  - Internet of Things (IoT) / Machine to Machine (M2M)
  - Characterization:
    - Low device costs and energy consumption
    - Better coverage and lower bandwidth requirements
  - Market currently dominated by technology in unlicensed spectrum (e.g., sigfox, LoRa, etc.)
- Make LTE ready for the Internet of Things (IoT)
  - Provide LPWA solution based on cellular technology
  - First final version available with 3GPP Release 13 (June 2016)
- SRS with compliant implementation after <6m

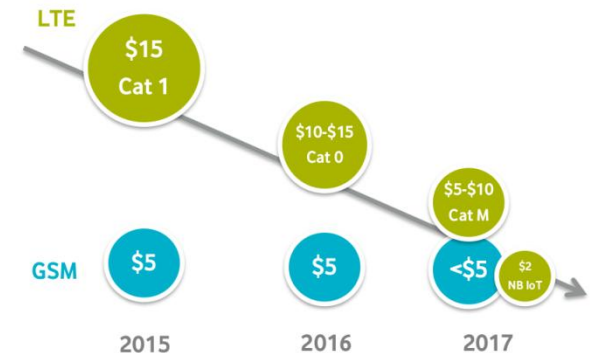
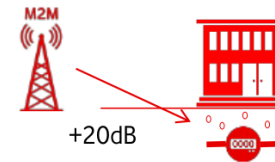
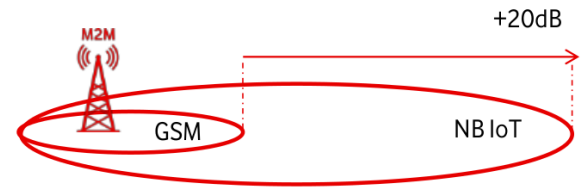
# Technical Overview

- Transmission scheme based on LTE, i.e., OFDM with 15kHz SC spacing
- System bandwidth reduced to 1 resource block (12x15kHz=180kHz)
- LTE frame structure: 10ms frames, 1ms sub-frames, 500us slots
- In-band, guard-band and standalone deployment
- Narrowband alternatives for (almost) all LTE channels (multiplexed in time)
  - E.g., Narrowband Physical Broadcast Channel (NPBCH)



# Approach

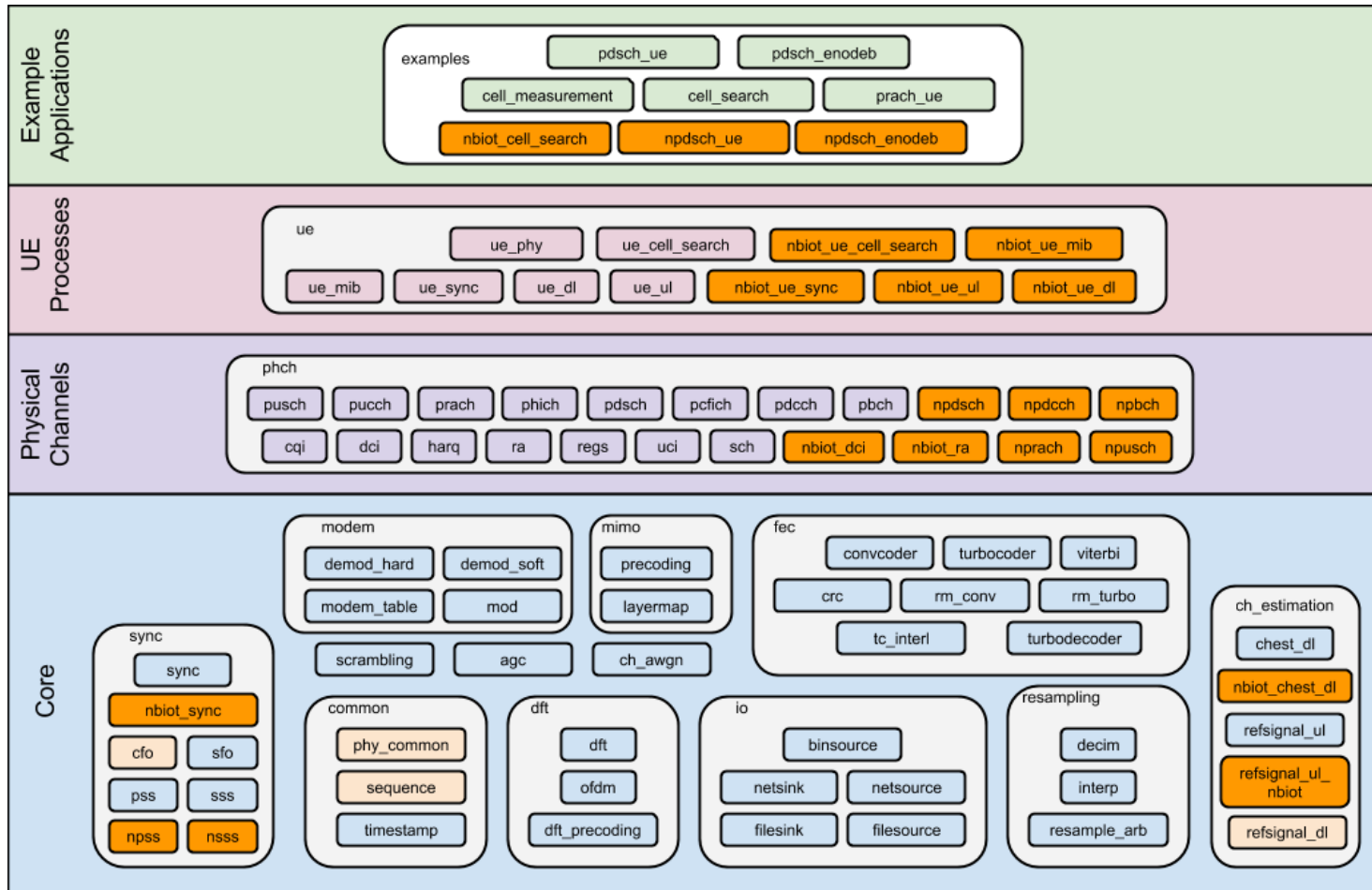
- 10x Years Battery Life
  - Better Power Saving Mode (PSM) & sleep cycles (eDRX)
  - Avoid unnecessary receiver wakeups
- Extended Coverage
  - Up to +20dB compared to GSM
  - Repetitive transmissions and new control channels
- Module Cost Reduction
  - Reduced complexity, functionality and capability
  - E.g., half-duplex operation, single antenna, reduced memory requirements



Sources: Ericsson, Vodafone

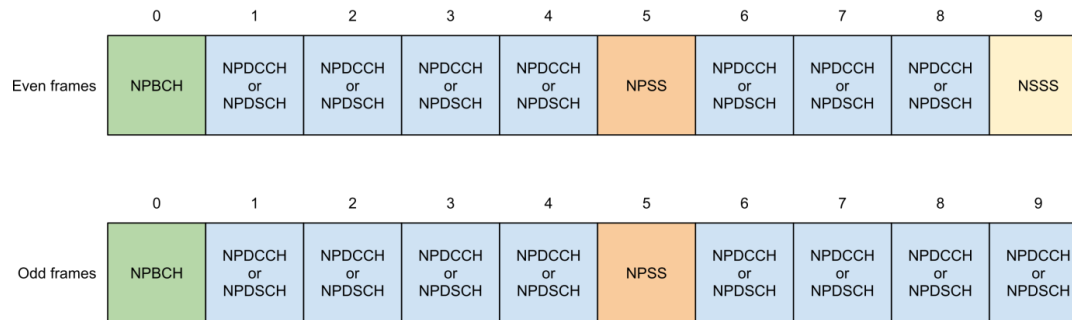


# srsLTE: NB-IoT Extensions



# Brief Performance Evaluation

- Tx flow: Grant → Guard → Data → Guard → Ack



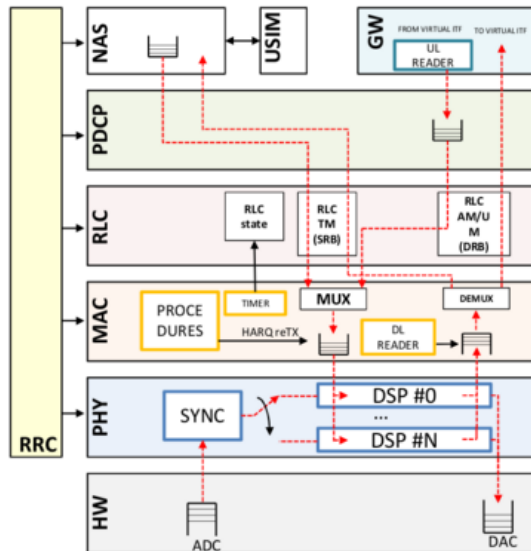
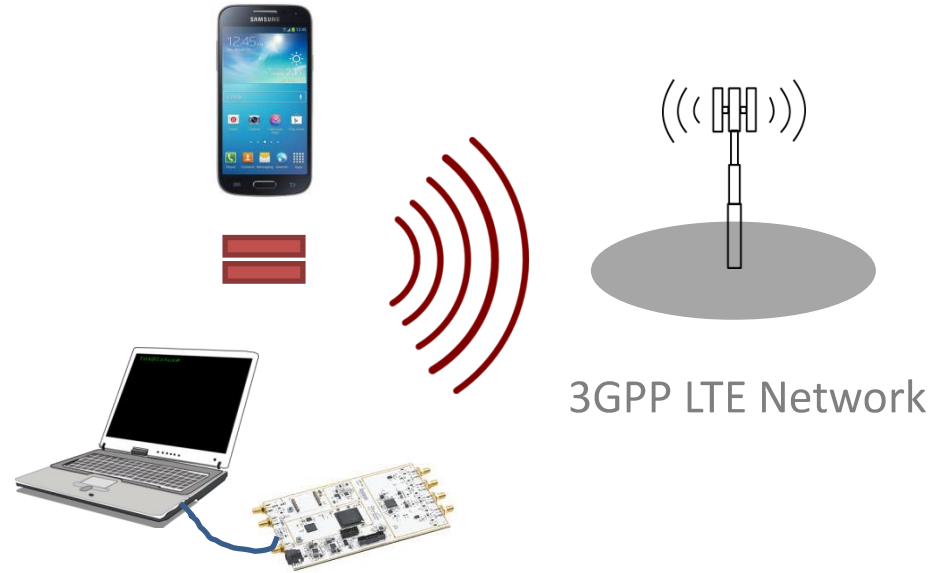
	Downlink	Uplink (single carrier)	Uplink (multi carrier)
Peak rate	680b/3ms=226kbit/s	1kb/4ms=250kbit/s	
Real rate	680b/24ms=30.9kbit/s	1kb/61ms=16.39kbit/s	1kb/17ms=58.82kbit/s

- Example:
  - DL: 1 SF grant + 4 SF guards + 3 SF data + 12 SF guard + 2 SF ACK (NPUSCH format 2) == 680 bit / 23ms = 30.90 kbit/s
  - UL MC: 1 SF grant + 8 SF guards + 4 SF data + 3 SF guard + 1 SF ACK (new DCI from eNB)



# srsUE: Open-source LTE UE

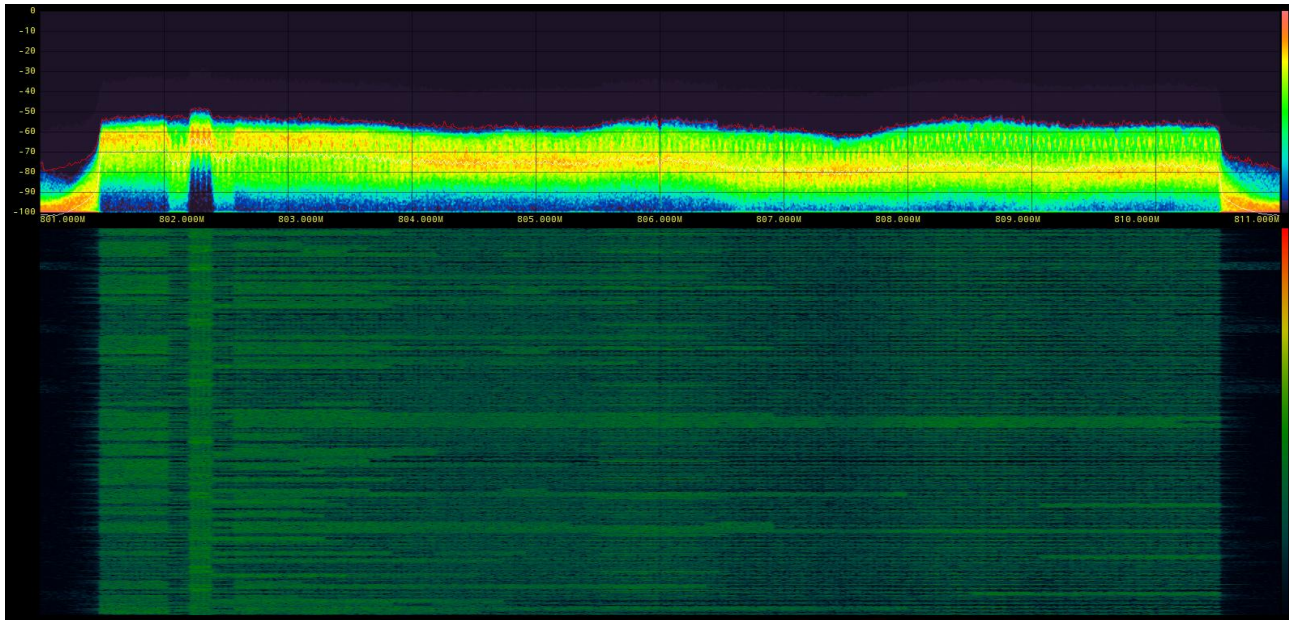
- Builds upon srsLTE
- First open-source LTE UE (AGPLv3)
- Full-speed UL and DL (75 Mbps) and >110 Mbps in TM3/4
- Commercial NB-IoT extensions



- Detailed logging interface with per layer output and hex dumps
- Command line trace interface
- Wireshark support

# Exploring Commercial Deployments

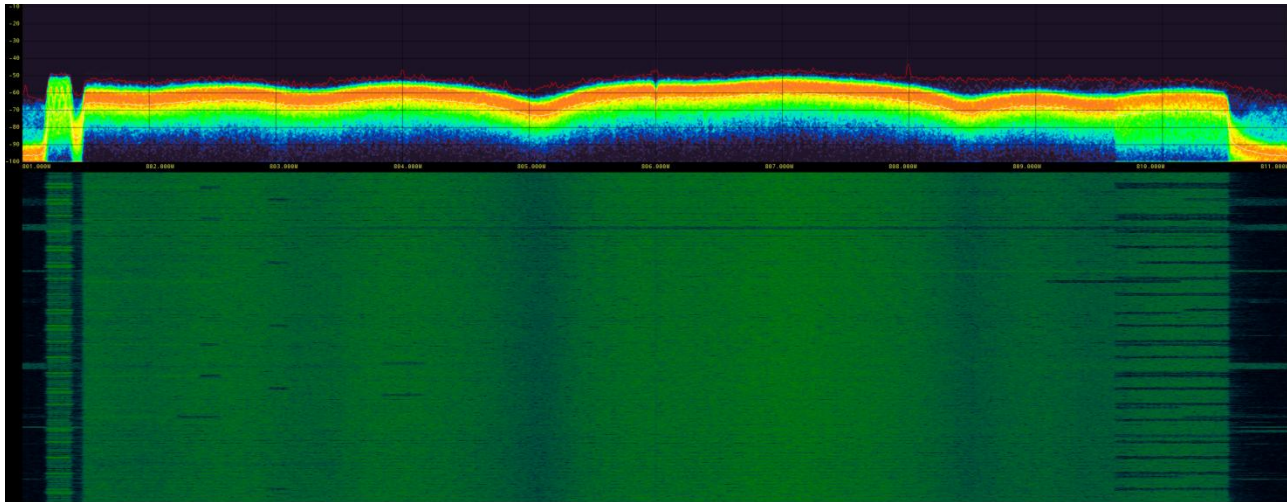
- Vodafone Spain started roll-out in Q1/2017
- Inband deployment in 800 MHz band
- Single PRB with guard PRB mostly





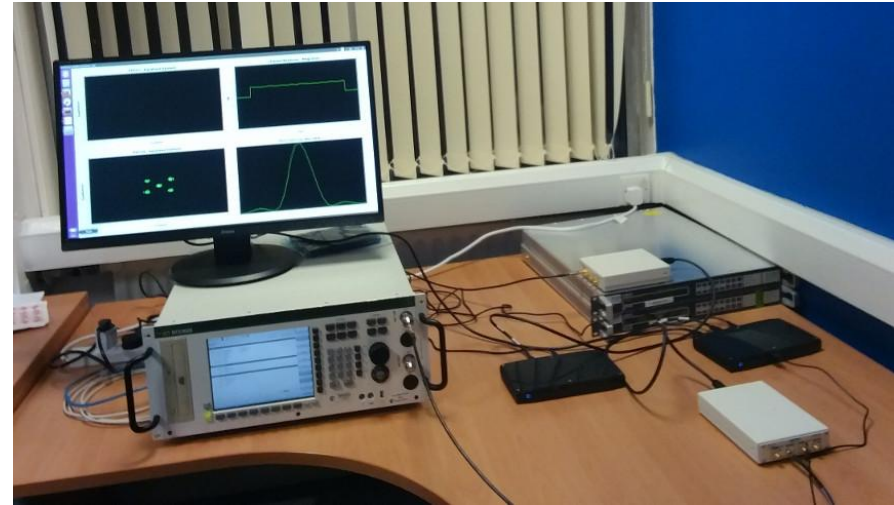
# Vodafone Configuration Changes

- Switched to Release 14 in May 2017
- Switched to guard-band operation in Q3/2017



# (Un-?) Usual NB-IoT Use-Cases

- As satellite waveform
  - Project with ESA M2M IoT Makerspace (ARTES)
- Public safety comms
- For connectivity in rural areas



Thanks!

SRS

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