Implementing NB-IoT in Software - Experiences Using the srsLTE Library

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SRS
SOFTWARE RADIO SYSTEMS

WInnComm Europe 2017, Oulu, Finland

Outline

- Introduction
- Narrowband Internet of Things (NB-IoT)
  - Overview
  - srsLTE extension
  - Evaluation
  - Exploring commercial deployments
- Summary

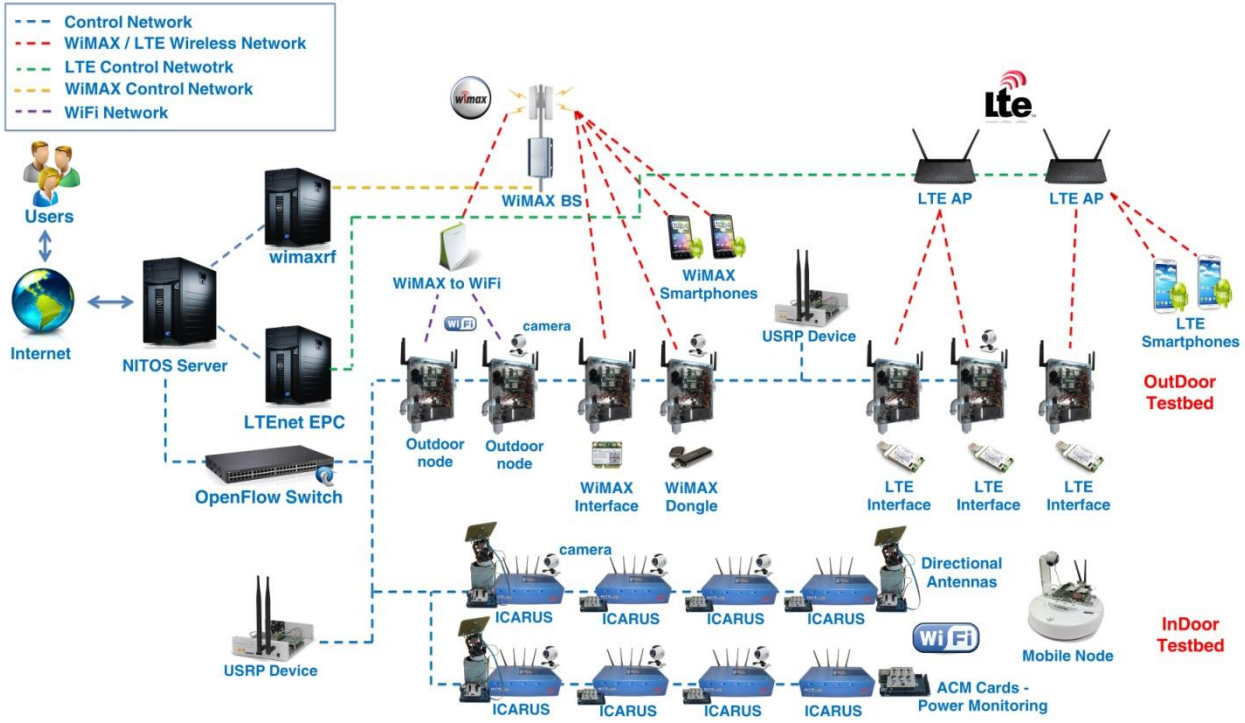
Company At a Glance

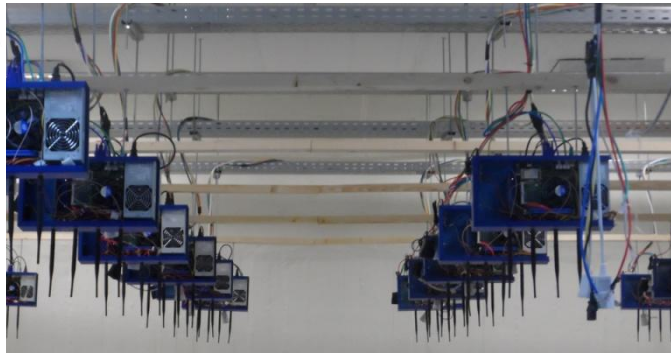
- Irish startup
- Founded at Trinity College Dublin in 2012
- Offices in Cork (Ireland) and Barcelona (Spain)
- High-performance software for wireless systems
  - Software Defined Radio
  - 3GPP LTE/LTE-Advanced
  - Satellite systems (DVB-S2/RCS2)
  - Internet of Things
- Commercial and research projects

Recent Public-Funded Projects

FLEx
FIRE LTE TESTBEDS FOR OPEN EXPERIMENTATION

FIRE Future Internet Research and Experimentation





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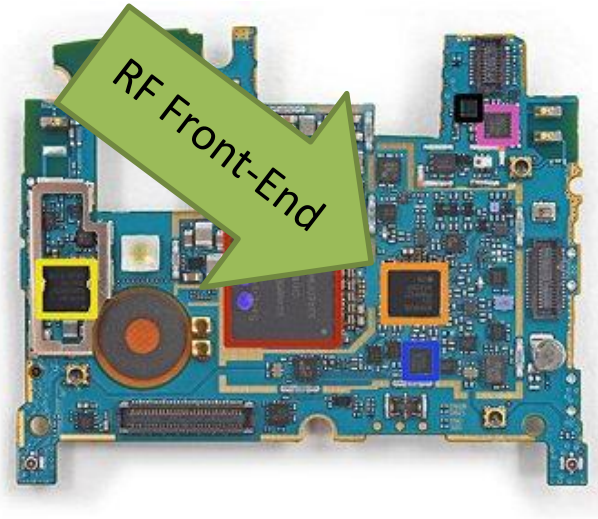
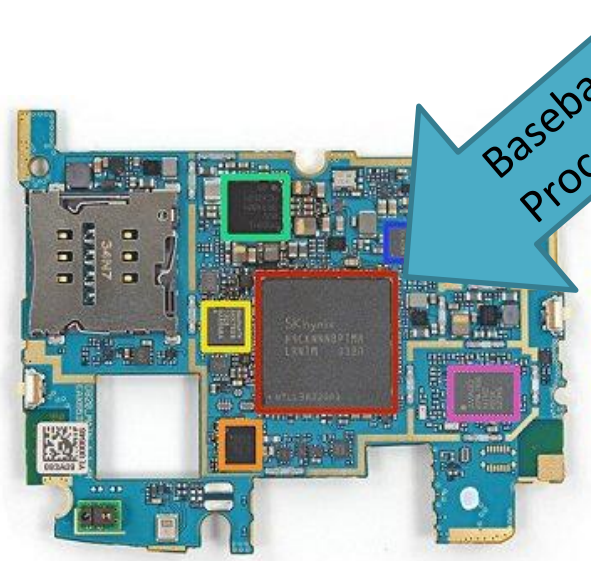
What is a Software Radio?



- 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



- SK Hynix H9CKNNNBPTMRLR-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/adapter charger
- Avago ACPM-7600

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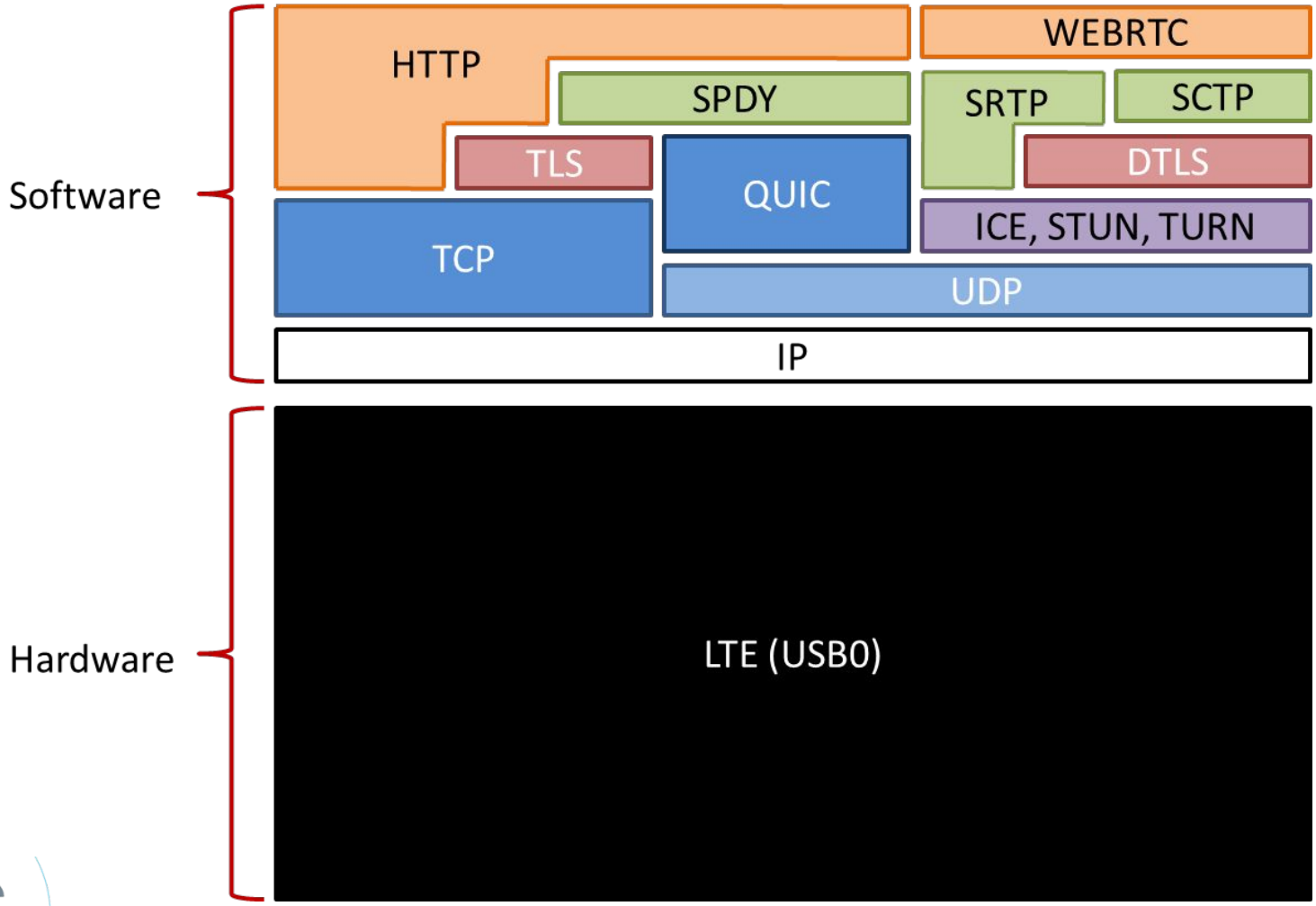
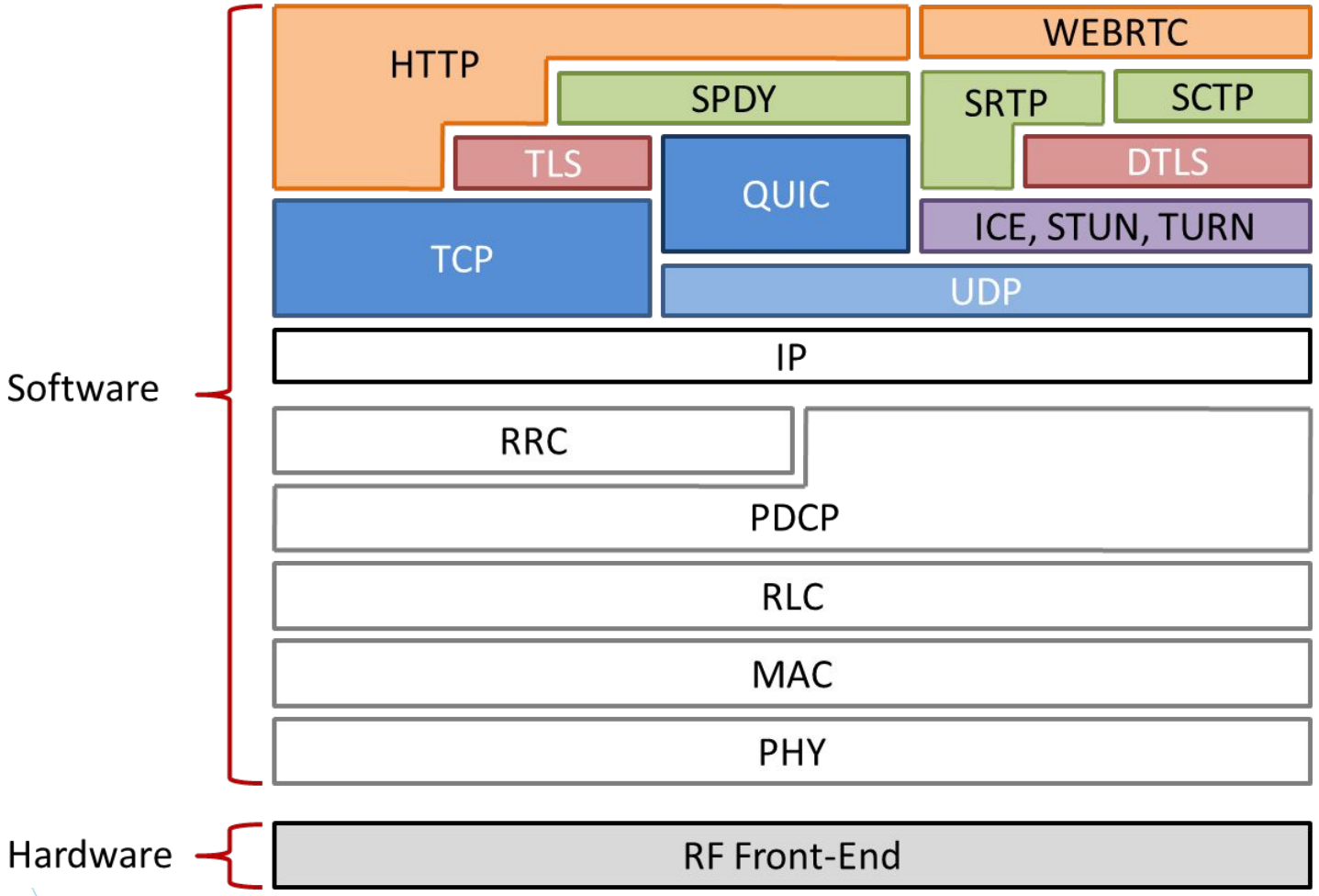


What is a Software Radio?

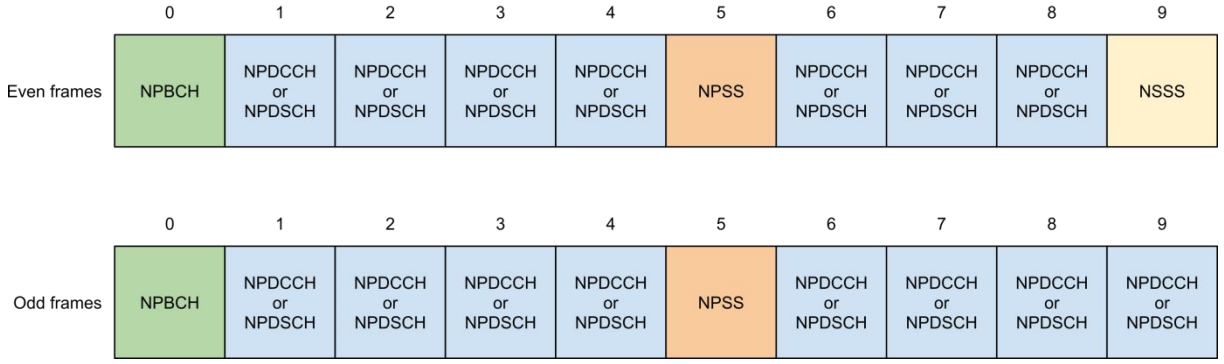


Narrowband Internet of Things

- 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

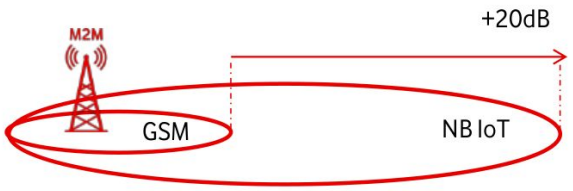
Technical Overview

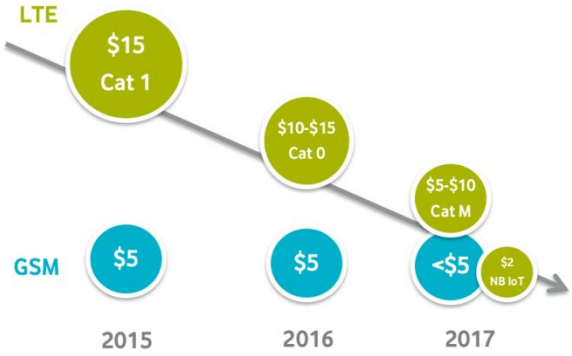
- Transmission scheme based on LTE, i.e., OFDM with 15kHz SC spacing
- System bandwidth reduced to 1 resource block (180kHz)
- LTE frame structure: 10ms frames, 1ms sub-frames, 500us slots
- In-band, guard-band and standalone deployment
- Narrowband alternatives for all LTE channels (multiplexed in time)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

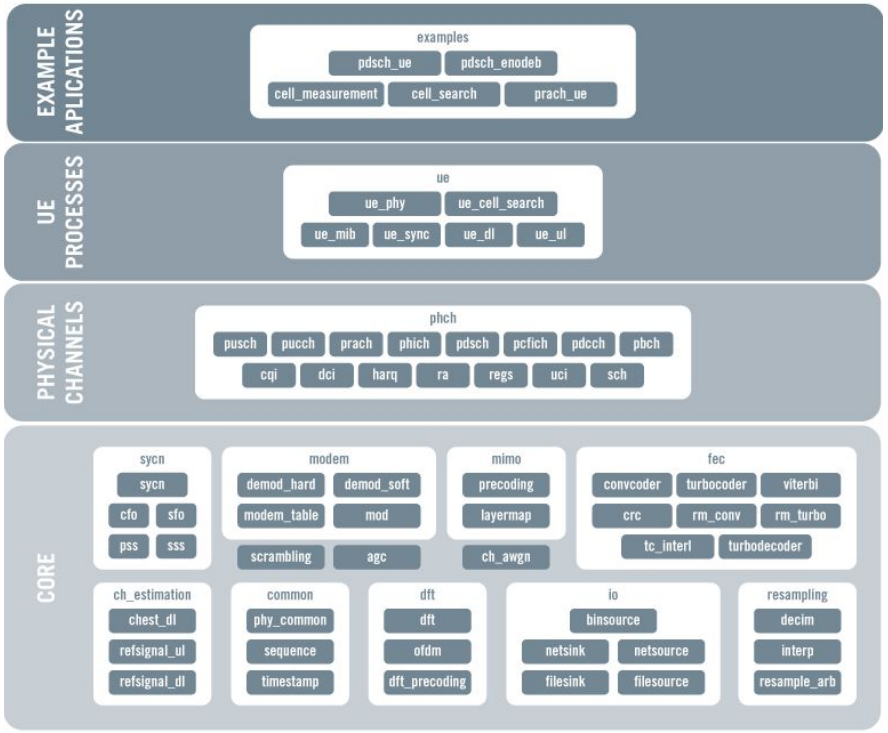




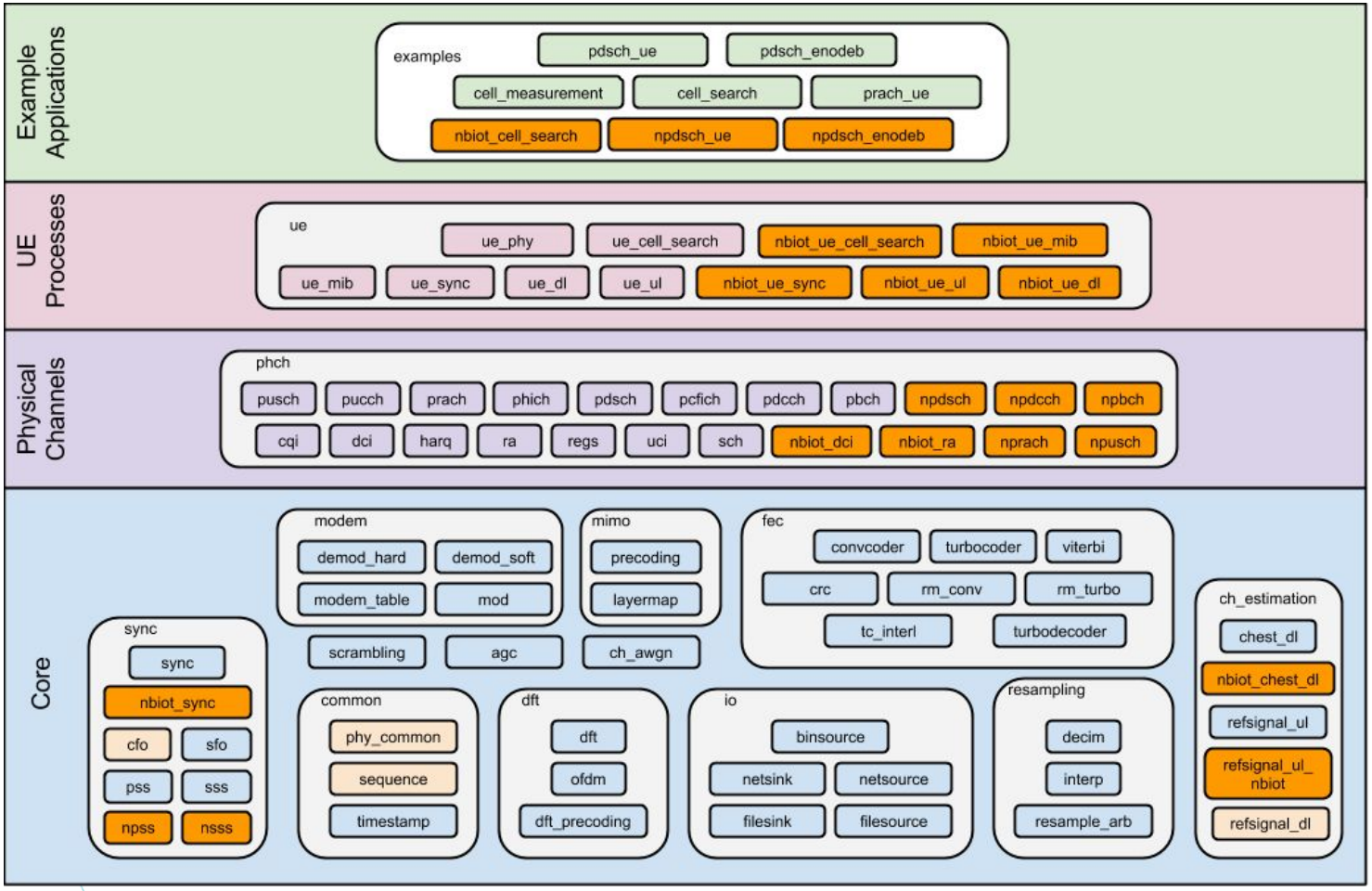
Sources: Ericsson, Vodafone

srsLTE: One Library for many Things

- Modular and portable, high-performance LTE library
- LTE Release 8 compliant
- All LTE bandwidths up to 20 MHz
- Transmission mode 1 (single antenna) and 2 (transmit diversity)
- All uplink and downlink channels
- Cell search and sync procedures
- Highly optimized Turbo decoder for Intel SSE4.1/AVX (+100Mbps)
- NB-IoT support (R13)

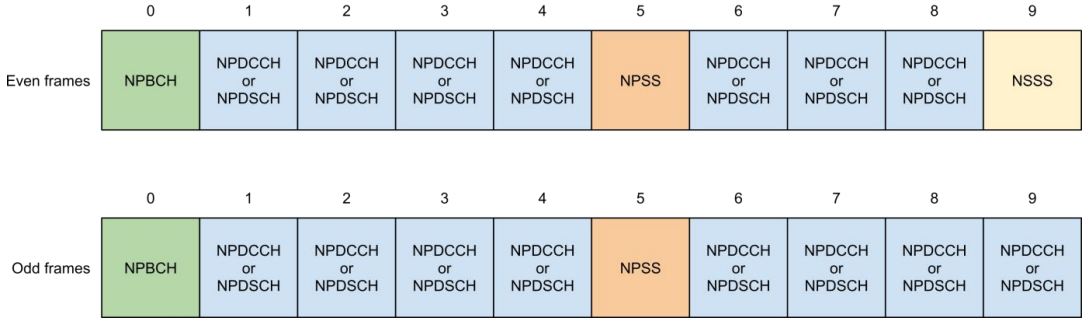


srsLTE: NB-IoT Extensions



Evaluation - Overview

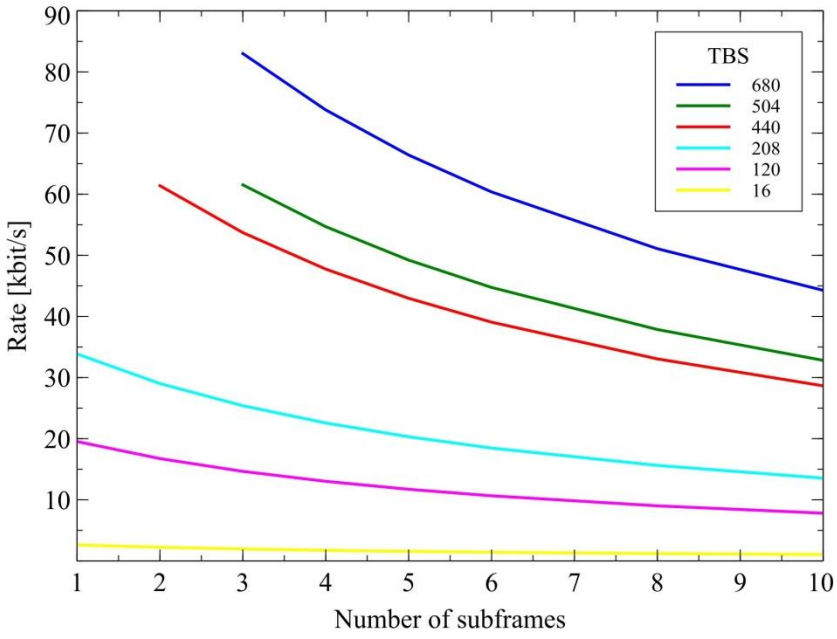
- Downlink acknowledged (AM) vs. unacknowledged (UM)
- Tx flow: Grant → Guard → Data (→ Guard → Ack)



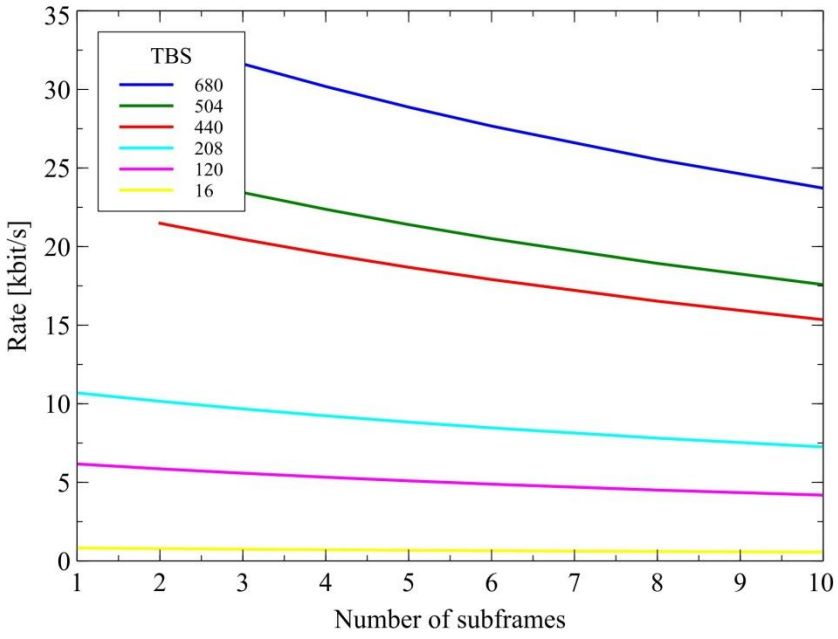
- "Peak rate"
  - 3 SF data, i.e. 680 bit / 3ms = 226 kbit/s
- UM peak rate:
  - 1 SF grant + 4 SF guards + 3 SF data = 8 SF
  - 680 bit / 8ms = 85 kbit/s
- AM peak rate:
  - 1 SF grant + 4 SF guards + 3 SF data +12 SF guard + 1 SF ACK
  - 680 bit / 21ms = 32.38 kbit/s

Evaluation – Theoretical Analysis

Unacknowledged Mode

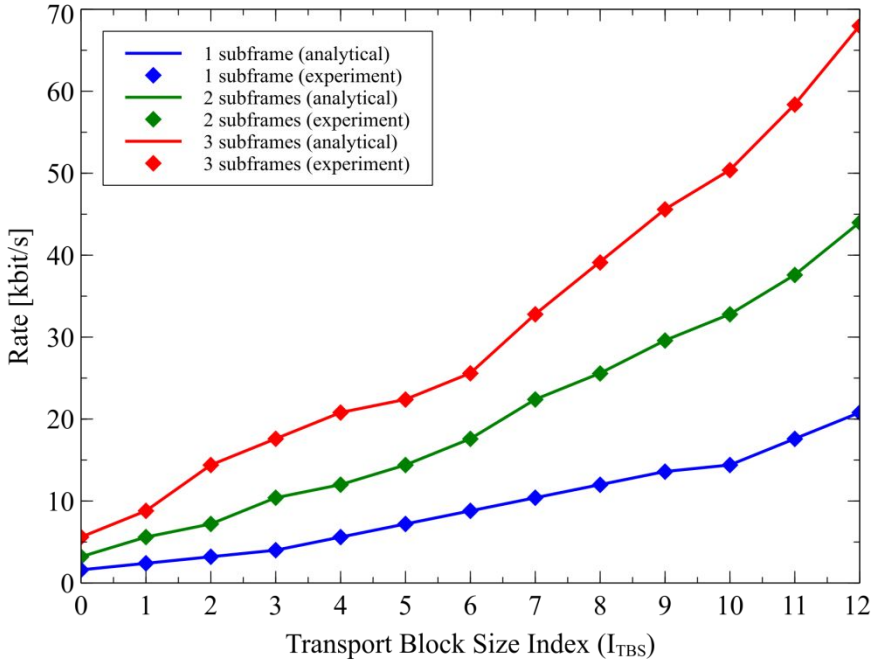


Acknowledged Mode



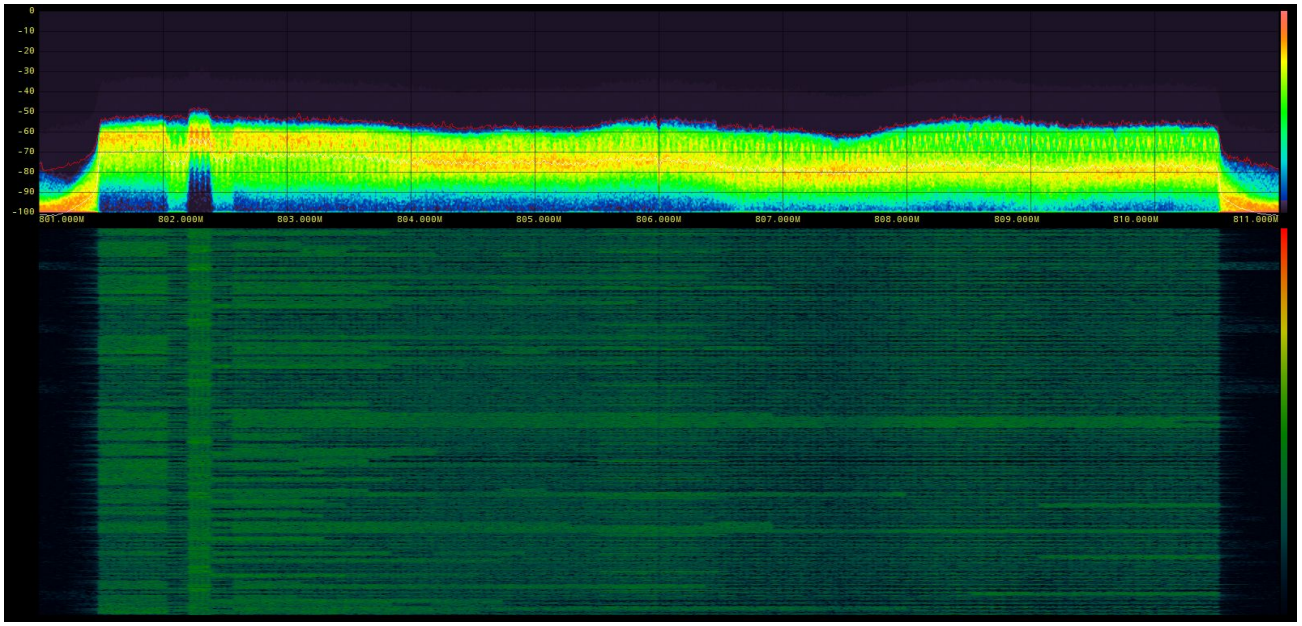
Evaluation – Experiments

- Practical considerations:
  - Anchor vs. non-anchor carrier transmissions
  - Multi-user scheduling constraints
  - …
- Example allocation:
  - In every DL frame:
    - Grant in SF 1
    - Data in SF 6-8
  - Rate: 680 bit / 10ms = 68 kbit/s

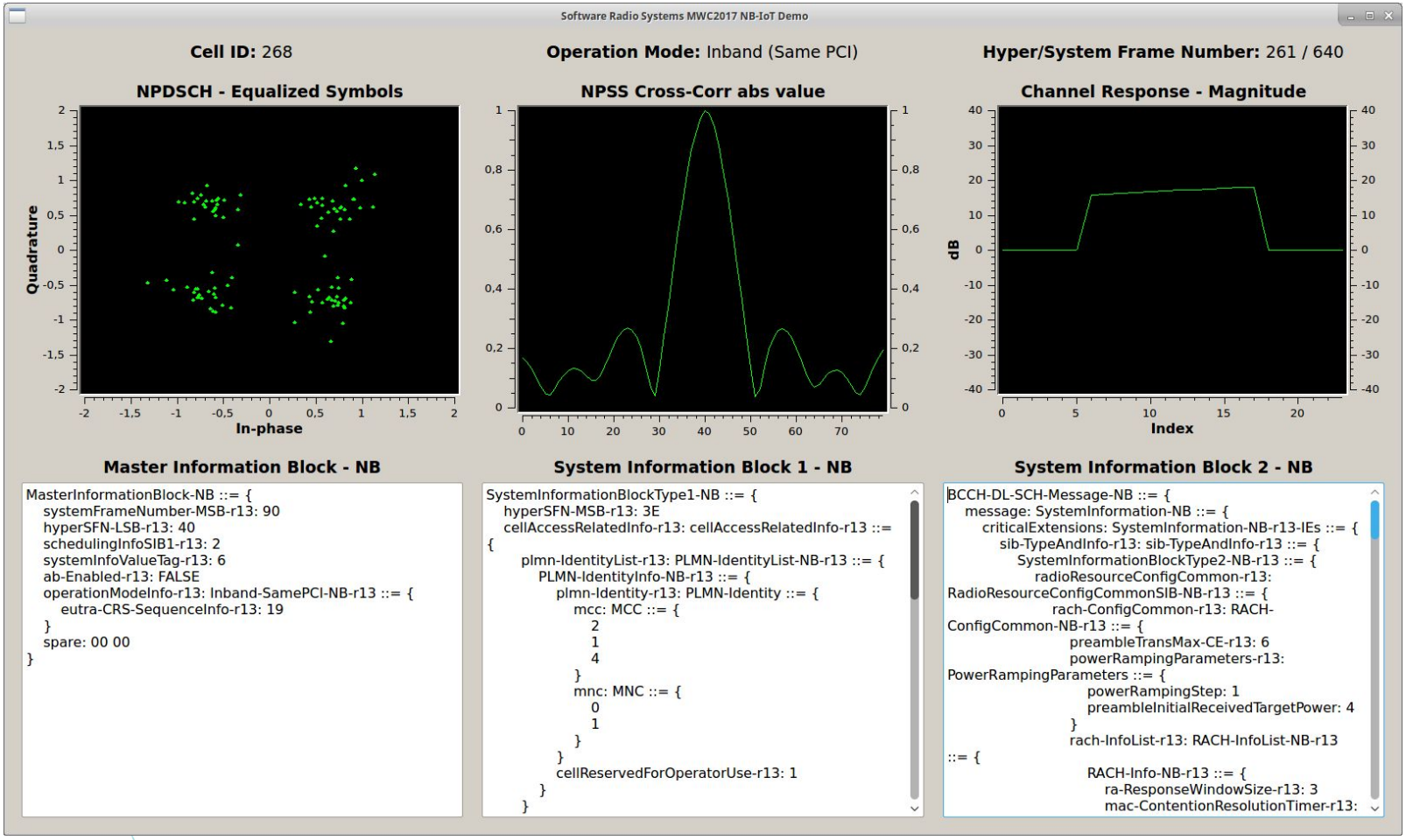


Exploring Commercial Deployments

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



Live demonstration at MWC'17



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Summary and Outlook

- NB-IoT as new cellular standard for mMTC
- srsLTE extension with PHY layer
  - All DL and UL channels and signals
- Analysis and experiments show max. DL rate between 33-85 kbit/s
- srsUE extension for NB-IoT with upper layers

Thanks!

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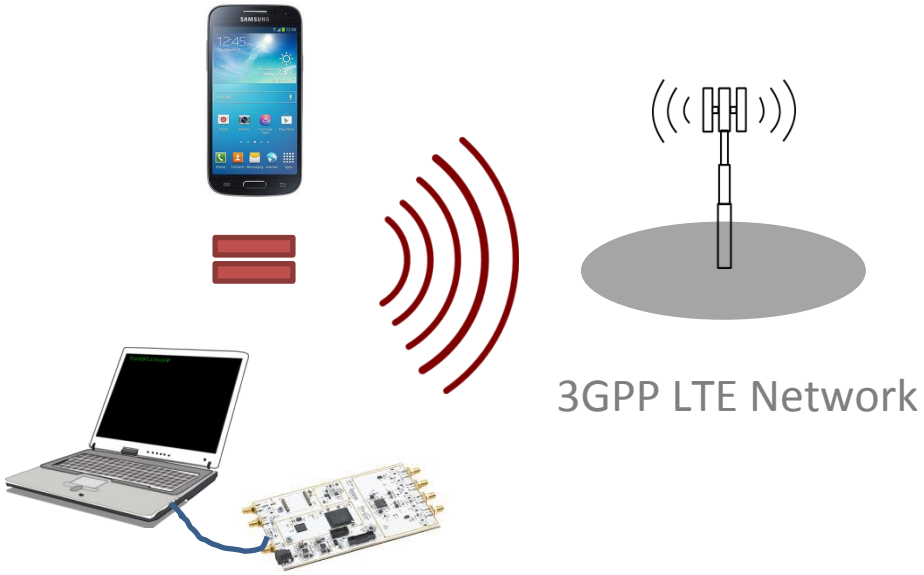
Backup

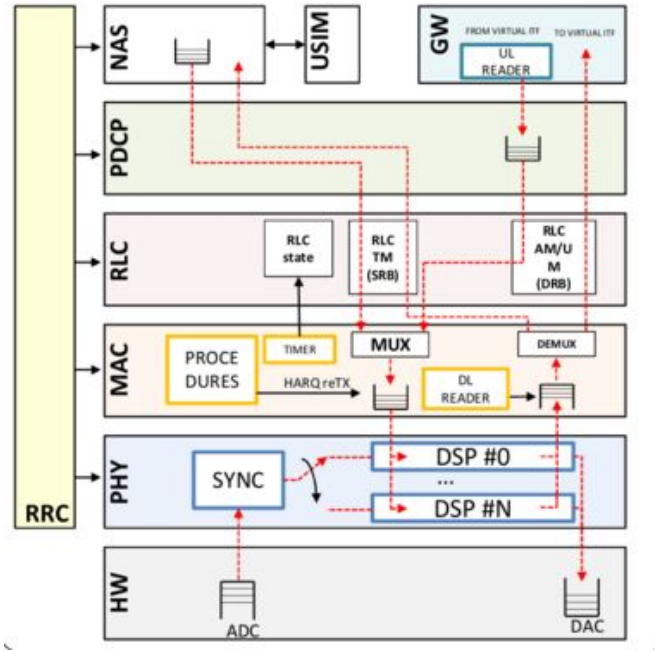
airScope: The LTE Analyzer

- LTE air interface analyzer
- Capture and decode entire downlink control traffic of arbitrary LTE cells in real-time
- Per-user and cell-wide measurements, e.g.,
  - Active users, UL and DL traffic
  - Channel quality
  - Congestion patterns
  - Scheduling performance
- Web-based graphical interface
- Standalone or distributed deployment

srsUE: Open-source LTE UE

- Builds upon srsLTE
- First open-source LTE UE (AGPLv3)
- Full-speed UL and DL (75 Mbps)





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