The Open-Source SDR LTE Platform for First Responders

Software Radio Systems
www.softwareradiosystems.com
www.github.com/srslte

SRS SOFTWARE RADIO SYSTEMS

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Outline

- SRS - Software Radio Systems
- NIST PSIAP and OpenFirst
- srsLTE – The Open-Source LTE Software Suite

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- srsLTE – The Open-Source LTE Software Suite

SRS

Paul Sutton
Director

Ismael Gomez
Director

Andre Puschmann
Senior Engineer

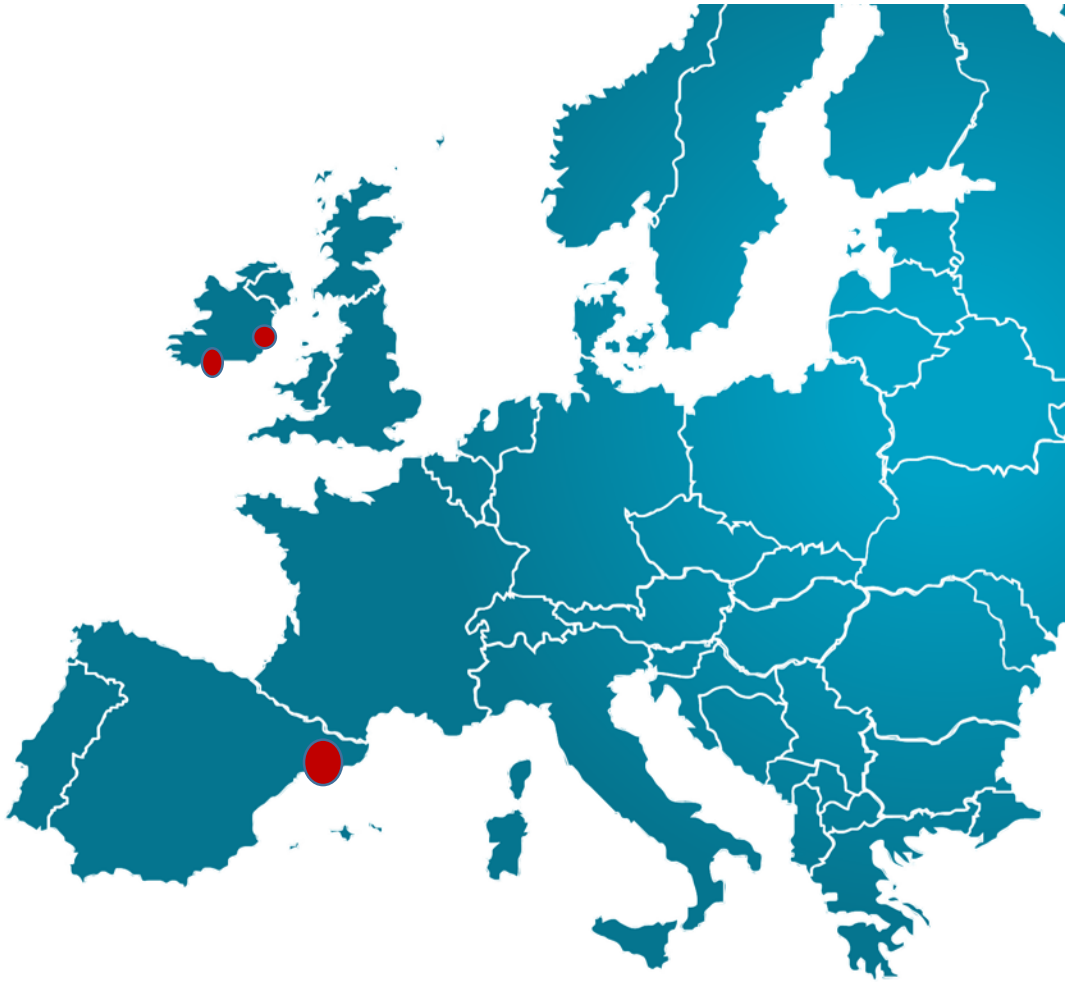
Linda Doyle
Director

Justin Tallon
Senior Engineer

Xavier Arteaga
Senior Engineer

Bastian Bloessl
Senior Engineer

Pedro Alvarez
Senior Engineer



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Software Radio

A software radio is a radio system where components such as modulators/demodulators, filters, detectors etc. which have historically been implemented in hardware, are instead implemented in software upon a general-purpose processing platform. Software Radio Systems (SRS) provides high-performance software radio solutions for a range of wireless technologies, leveraging the low-cost and availability of general-purpose hardware to rapidly deliver powerful, flexible systems.

LTE/ LTE-Advanced

SRS provides L1, L2 and L3 protocol stacks for UE and eNodeB. Our modular, portable srsLTE C library supports custom system design and development on a range of SDR platforms. Our tailored solutions include network test and diagnostic equipment and wide-band LTE scanners. We specialise in custom design and development for demanding applications and environments including machine to machine, airborne and high-speed deployments.

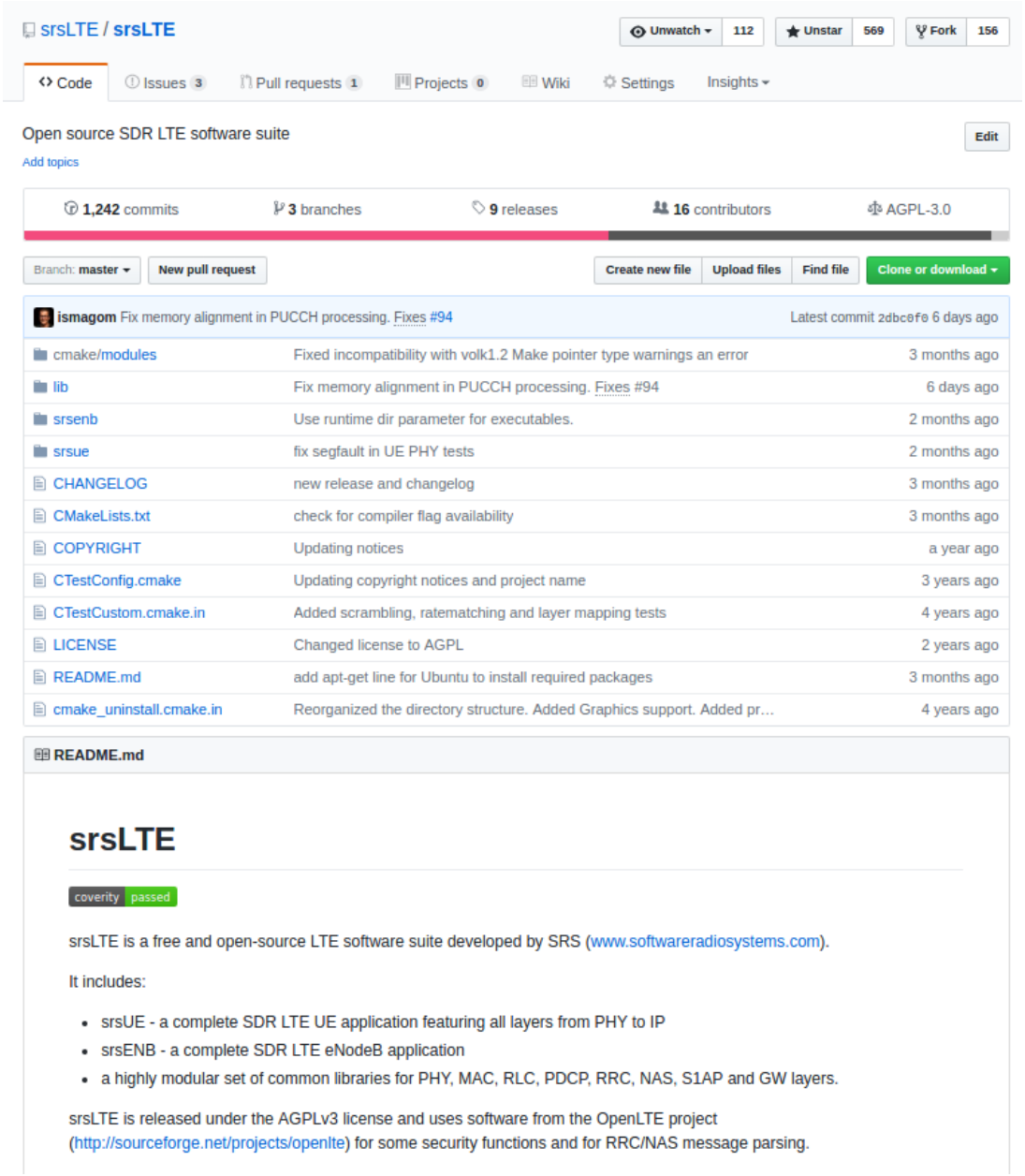
Satellite systems

SRS is developing solutions for a number of satellite communications projects in partnership with the European Space Agency and international collaborators. We provide high-performance software libraries for technologies including DVB-S2 and DVB-RCS2 and integration solutions for hybrid satellite/terrestrial networks.

Internet of Things

In the area of machine to machine communications, SRS develops custom low-cost, low-energy waveforms and network protocols. Our SDR basestation designs afford the flexibility to support a diverse range of application domains using a wide range of frequency bands. We specialise in cognitive radio and dynamic spectrum access solutions designed to benefit from evolving regulatory policies in this area.

SRS



srsLTE / srsLTE

Unwatch 112 | Unstar 569 | Fork 156

Code | Issues 3 | Pull requests 1 | Projects 0 | Wiki | Settings | Insights

Open source SDR LTE software suite

Edit

Add topics

1,242 commits | 3 branches | 9 releases | 16 contributors | AGPL-3.0

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

ismagom Fix memory alignment in PUCCH processing. Fixes #94 — Latest commit 2dbc0f0 6 days ago

cmake/modules	Fixed incompatibility with volk1.2 Make pointer type warnings an error	3 months ago
lib	Fix memory alignment in PUCCH processing. Fixes #94	6 days ago
srsenb	Use runtime dir parameter for executables.	2 months ago
srsue	fix segfault in UE PHY tests	2 months ago
CHANGELOG	new release and changelog	3 months ago
CMakeLists.txt	check for compiler flag availability	3 months ago
COPYRIGHT	Updating notices	a year ago
CTestConfig.cmake	Updating copyright notices and project name	3 years ago
CTestCustom.cmake.in	Added scrambling, ratematching and layer mapping tests	4 years ago
LICENSE	Changed license to AGPL	2 years ago
README.md	add apt-get line for Ubuntu to install required packages	3 months ago
cmake_uninstall.cmake.in	Reorganized the directory structure. Added Graphics support. Added pr…	4 years ago

README.md

srsLTE

coverity passed

srsLTE is a free and open-source LTE software suite developed by SRS (www.softwareradiosystems.com).

It includes:

- srsUE - a complete SDR LTE UE application featuring all layers from PHY to IP
- srsENB - a complete SDR LTE eNodeB application
- a highly modular set of common libraries for PHY, MAC, RLC, PDCP, RRC, NAS, S1AP and GW layers.

srsLTE is released under the AGPLv3 license and uses software from the OpenLTE project (http://sourceforge.net/projects/openlte) for some security functions and for RRC/NAS message parsing.

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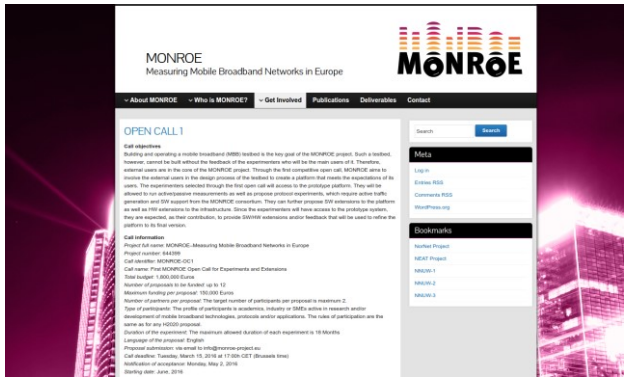
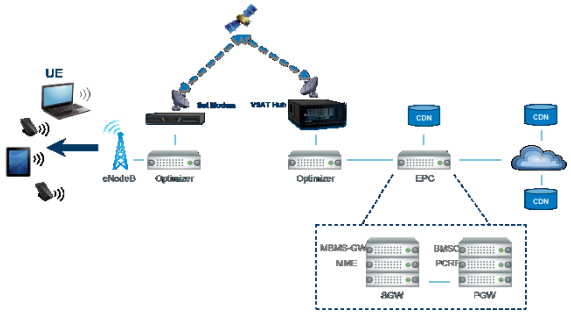
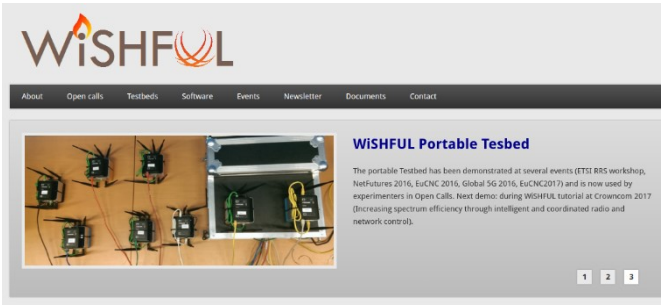


"OSMOSIS"

OPTIMISATION OF STREAMED MEDIA OVER SATELLITE INFRASTRUCTURES





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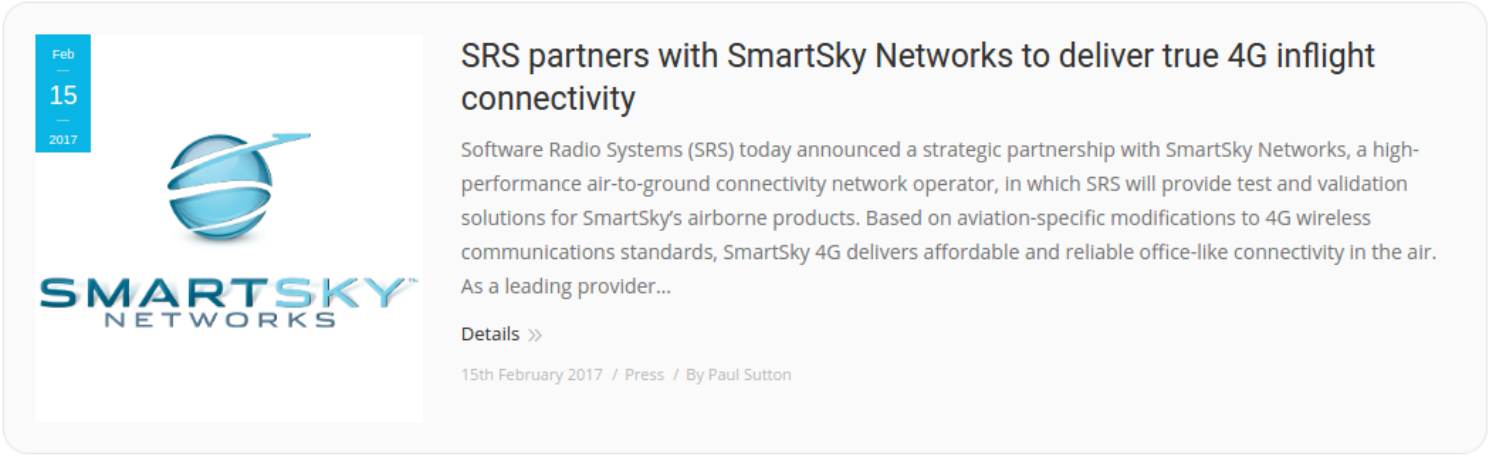

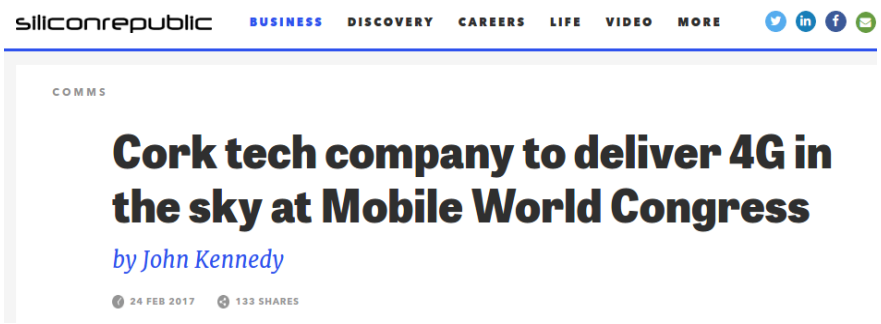

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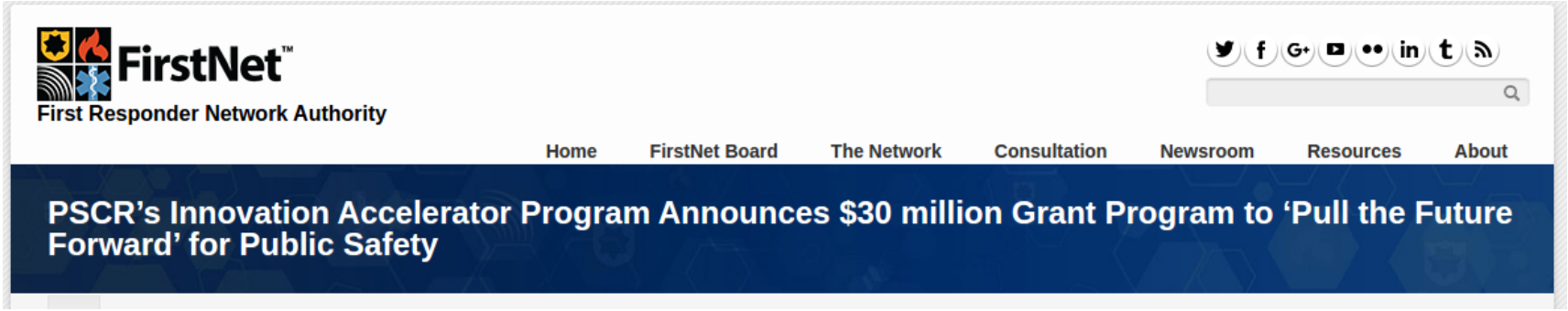
Public Safety Innovation Accelerator Program

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce



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Public Safety Innovation Accelerator Program

NIST

Search NIST | NIST MENU

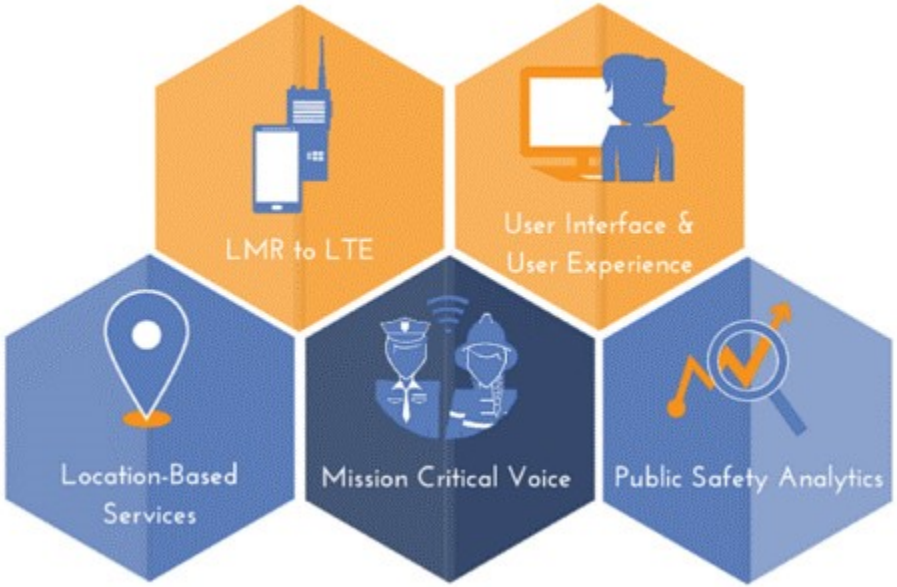
NEWS

NIST Awards $38.5 Million to Accelerate Public Safety Communications Technologies

June 13, 2017

BOULDER, Colo. – The U.S. Commerce Department's National Institute of Standards and Technology (NIST) has awarded $38.5 million to 33 research and development (R&D) projects aimed at advancing broadband communications technologies for first responders.

MEDIA CONTACT



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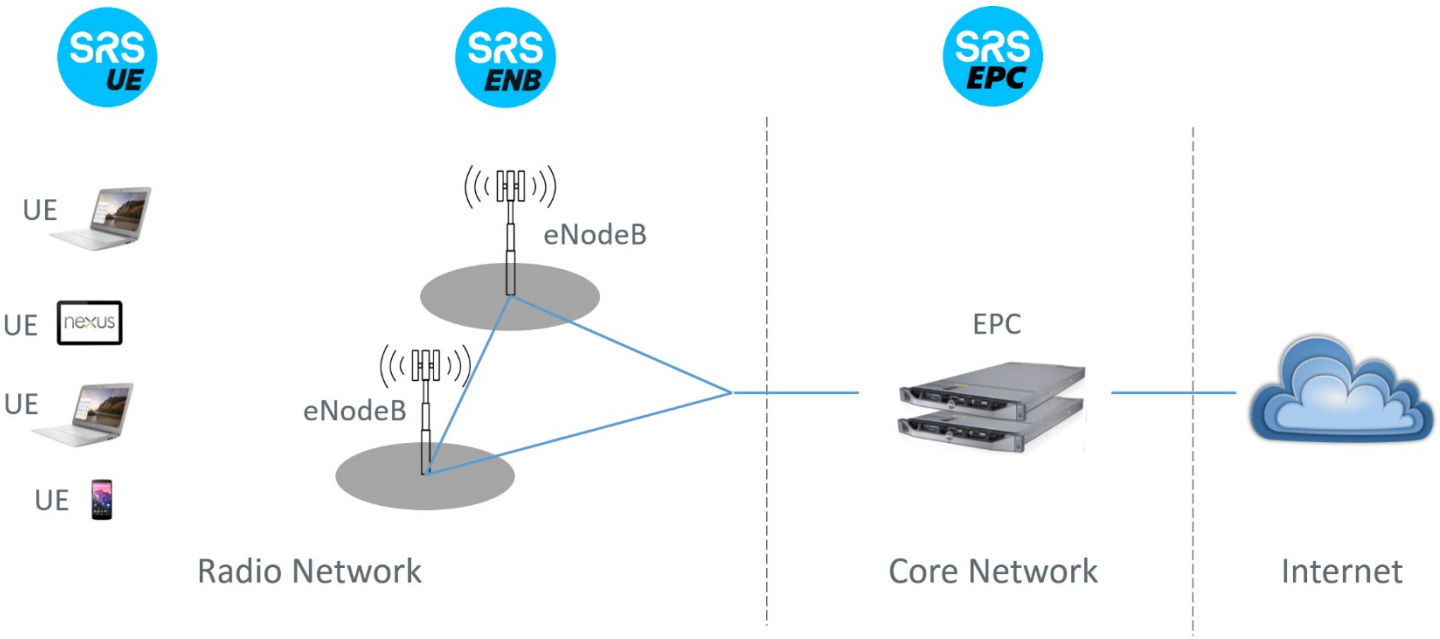
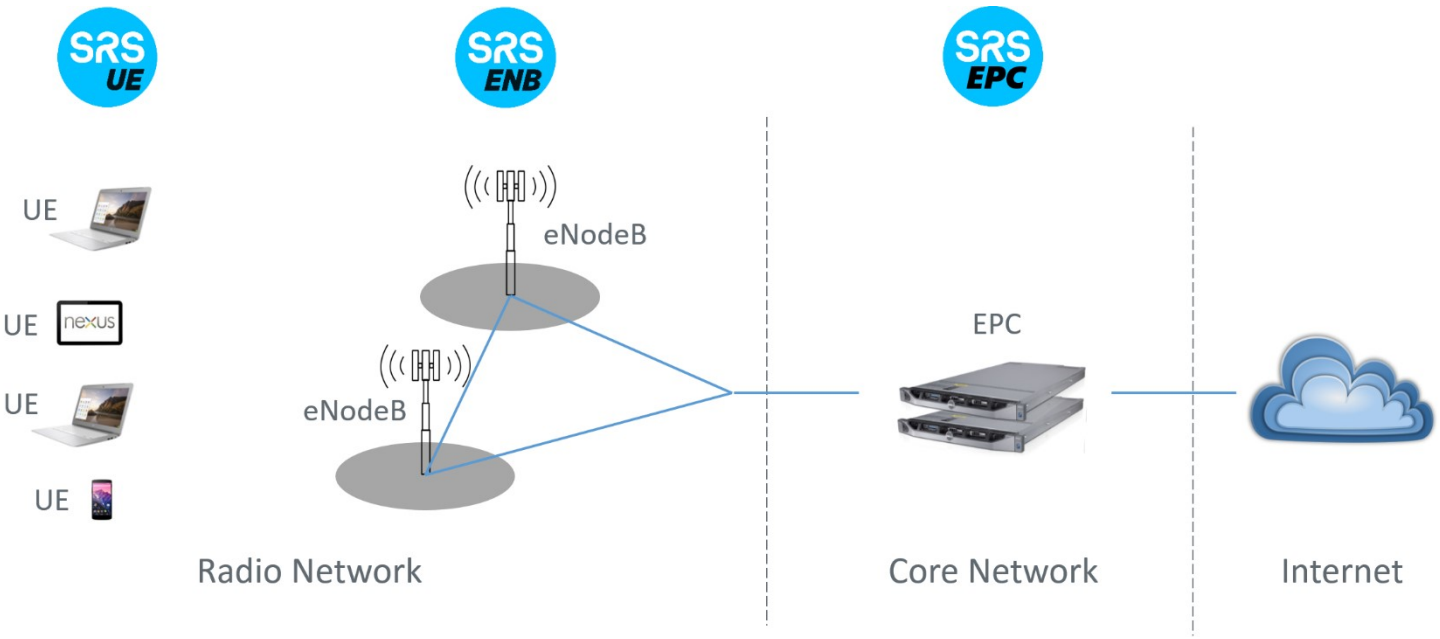
An open-source end-to-end LTE network for public safety research & development.



- A reference implementation of key LTE features for first responders.
- Enabling, supporting and growing the public safety broadband development ecosystem.
- Providing a commercialization path for public safety LTE using proven business models.
- Building upon the proven srsLTE suite of open-source libraries, tools and applications.

OPENFirst

An open-source end-to-end LTE network for public safety research & development.



Key Requirements:

Ease of use / Ease of programming new capabilities
Clarity and completeness of documentation
Long-term sustainability / Development ecosystem
Availability for follow-on research / Potential for commercialization

R&D Platform Requirements:

Sufficiently complete implementation / Interoperability
Sufficient set of components
Performance comparable to likely operational implementations
Network scale
Path towards operational implementation

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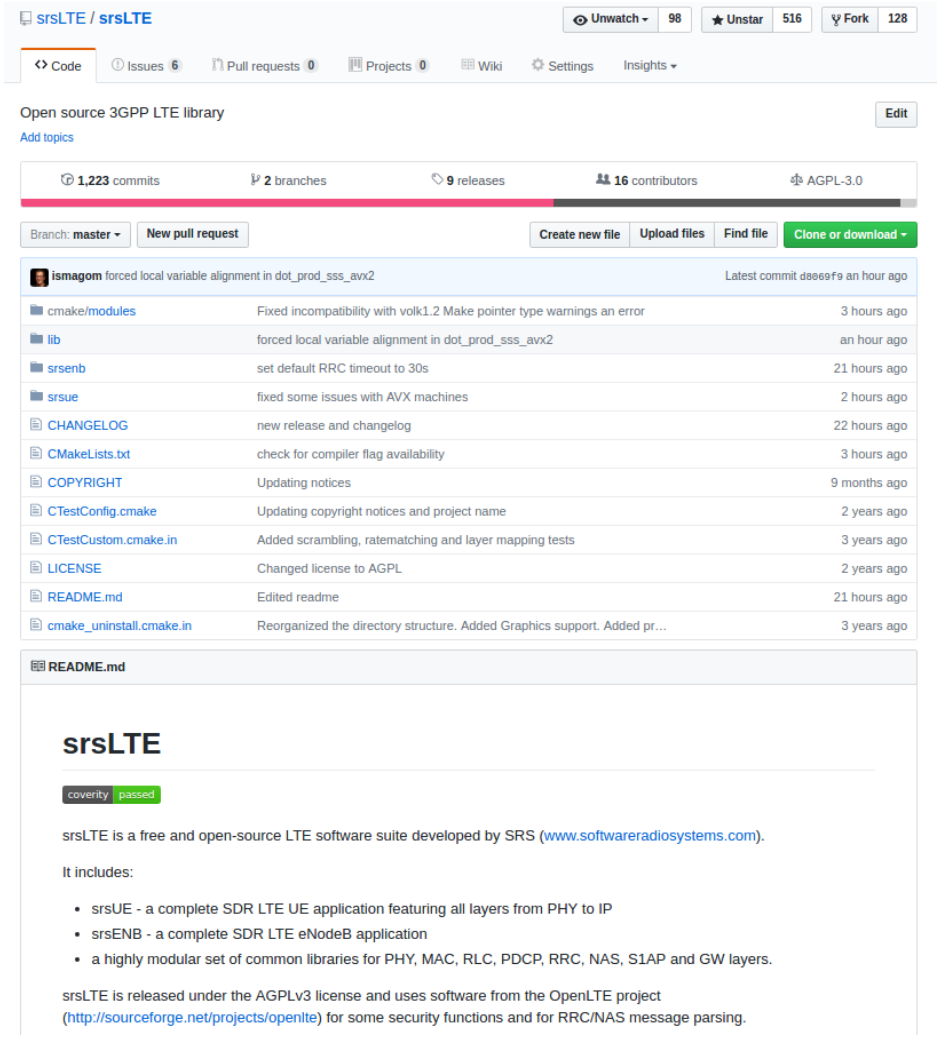

- GNU Affero General Public License (AGPLv3)
- Ensuring dissemination of the technology
- Maximizing usability
- Safeguarding availability
- Guaranteeing sustainability

www.github.com/srslte

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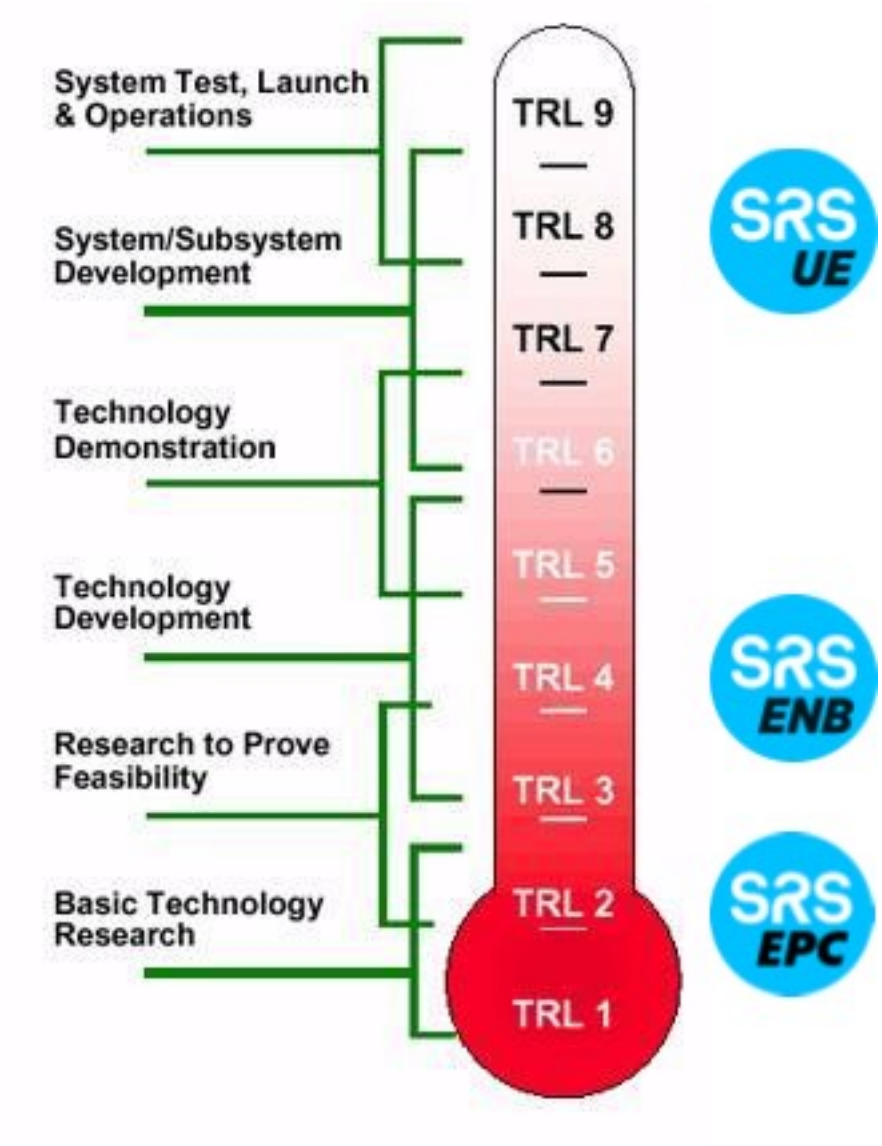
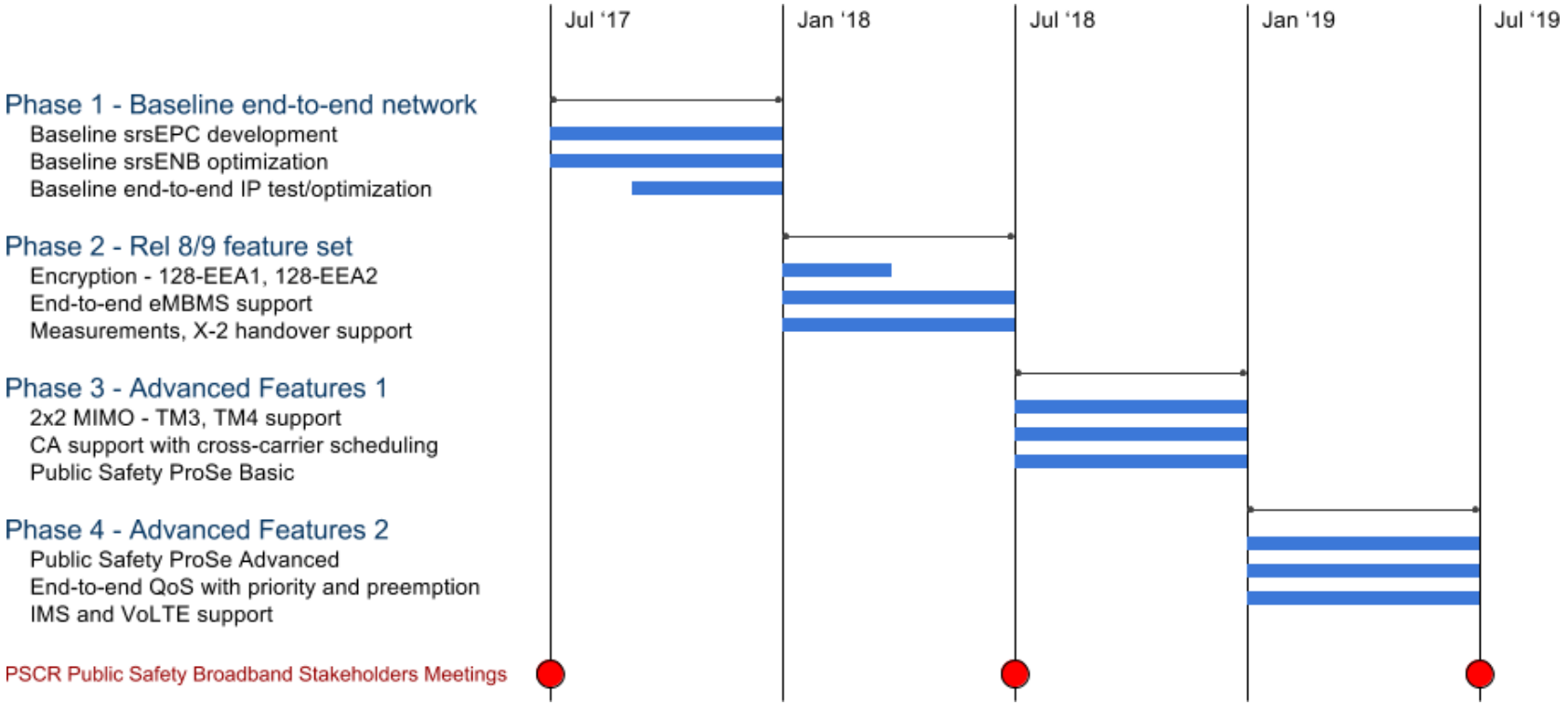

System Test, Launch & Operations
System/Subsystem Development
Technology Demonstration
Technology Development
Research to Prove Feasibility
Basic Technology Research
TRL 9
TRL 8
TRL 7
TRL 6
TRL 5
TRL 4
TRL 3
TRL 2
TRL 1
SRS UE
SRS ENB
SRS EPC



Complete end-to-end LTE network:

- Core network (EPC)
- Basestations (eNodeBs)
- Mobile terminals (UEs)

Key features for public safety:

- Priority, Pre-emption and Quality of Service (QPP).
- Proximity Services (ProSe)
- Evolved Multimedia Broadcast/Multicast Service (eMBMS)
- Multimedia broadcast single frequency networks (MBSFN)
- Single cell point-to-multipoint (SC-PTM).
- Carrier aggregation.
- IP Multimedia Subsystem (IMS) and Voice-over-LTE (VoLTE)

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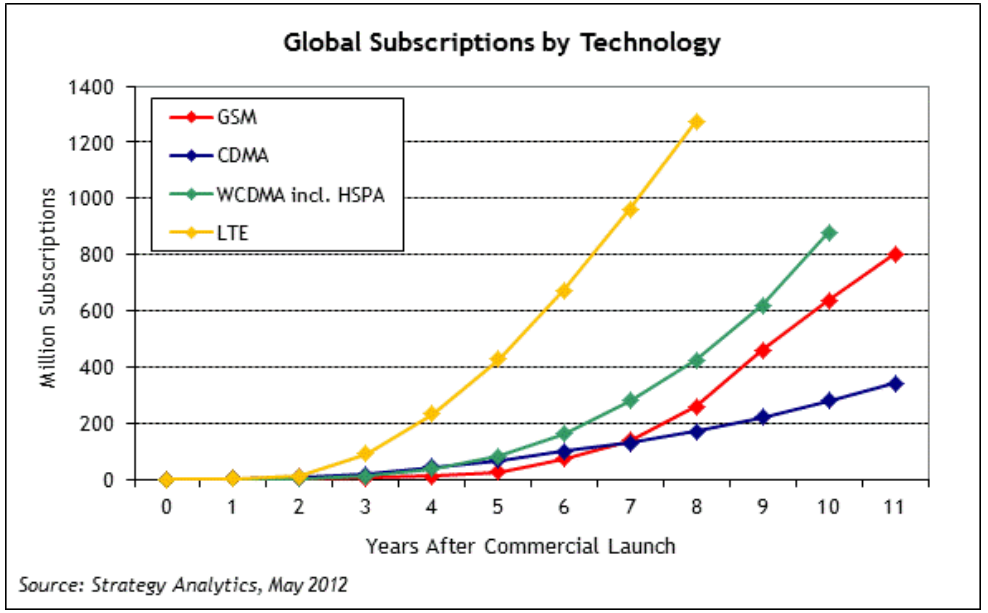
LTE FAST FACTS APRIL 2017 *

GSA

By the end of March 2017 GSA reports there were:

- **774** operators investing in LTE in **202** countries
- **591** commercially launched LTE or LTE-Advanced networks in **189** countries (GSA forecasts c. **646** commercial LTE networks by end-2017)
- **97** LTE-TDD (TD-LTE) networks launched in **56** countries
- **106** commercial VoLTE networks in **55** countries, and **167** operators investing in VoLTE in **74** countries
- **195** launched LTE-Advanced or LTE-Advanced Pro networks, in **95** countries
- **4** NB-IoT and **2** LTE-M networks commercially launched, with **40** NB-IoT and **12** LTE-M networks planned or being trialled
- **18** operators (at least) that have made public commitments to deploy pre-standards '5G' networks, in **13** countries

* Taken from the GSA report *Evolution from LTE to 5G* April 2017. To download the full report, visit www.gsacom.com



Source: Strategy Analytics, May 2012

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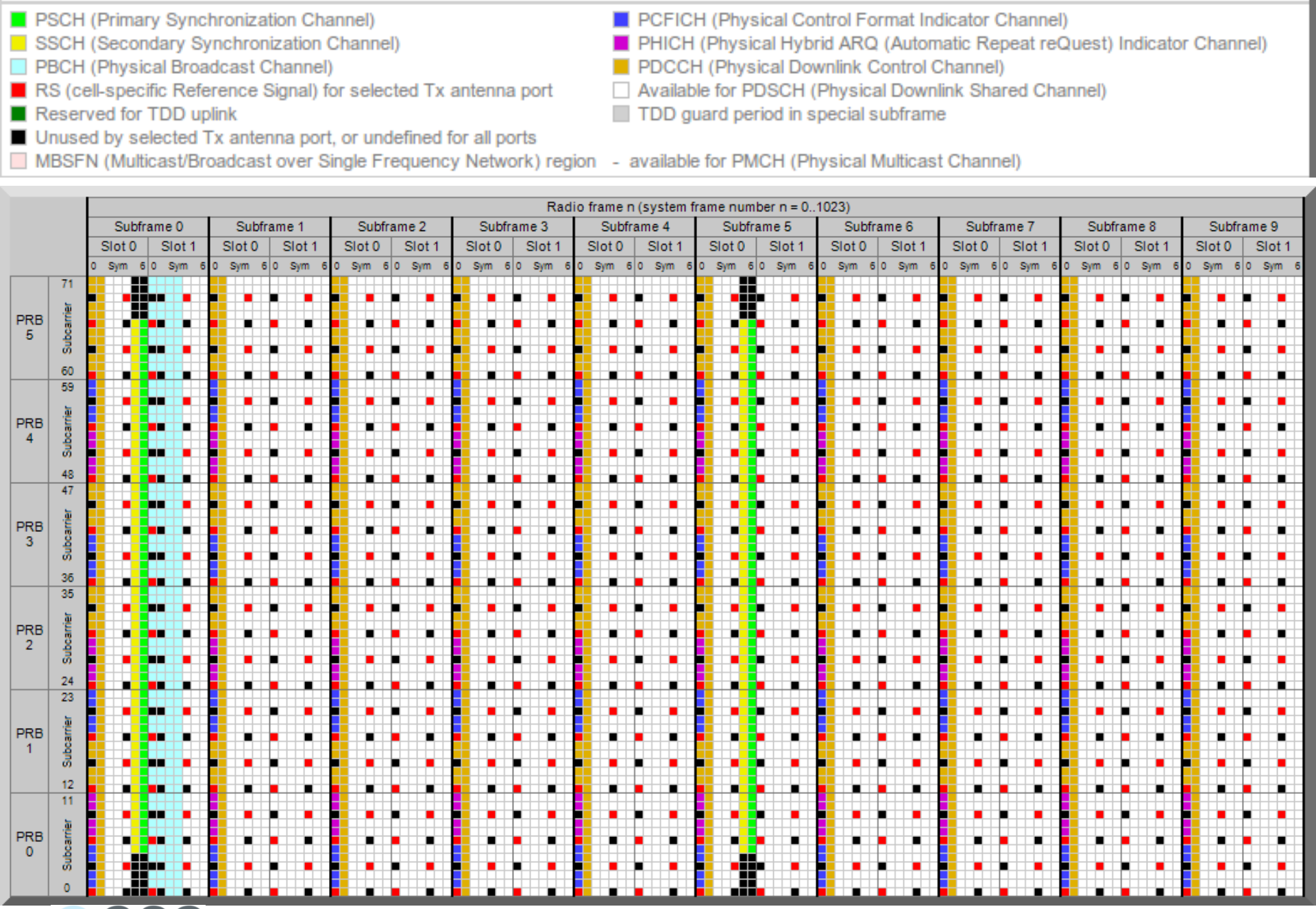

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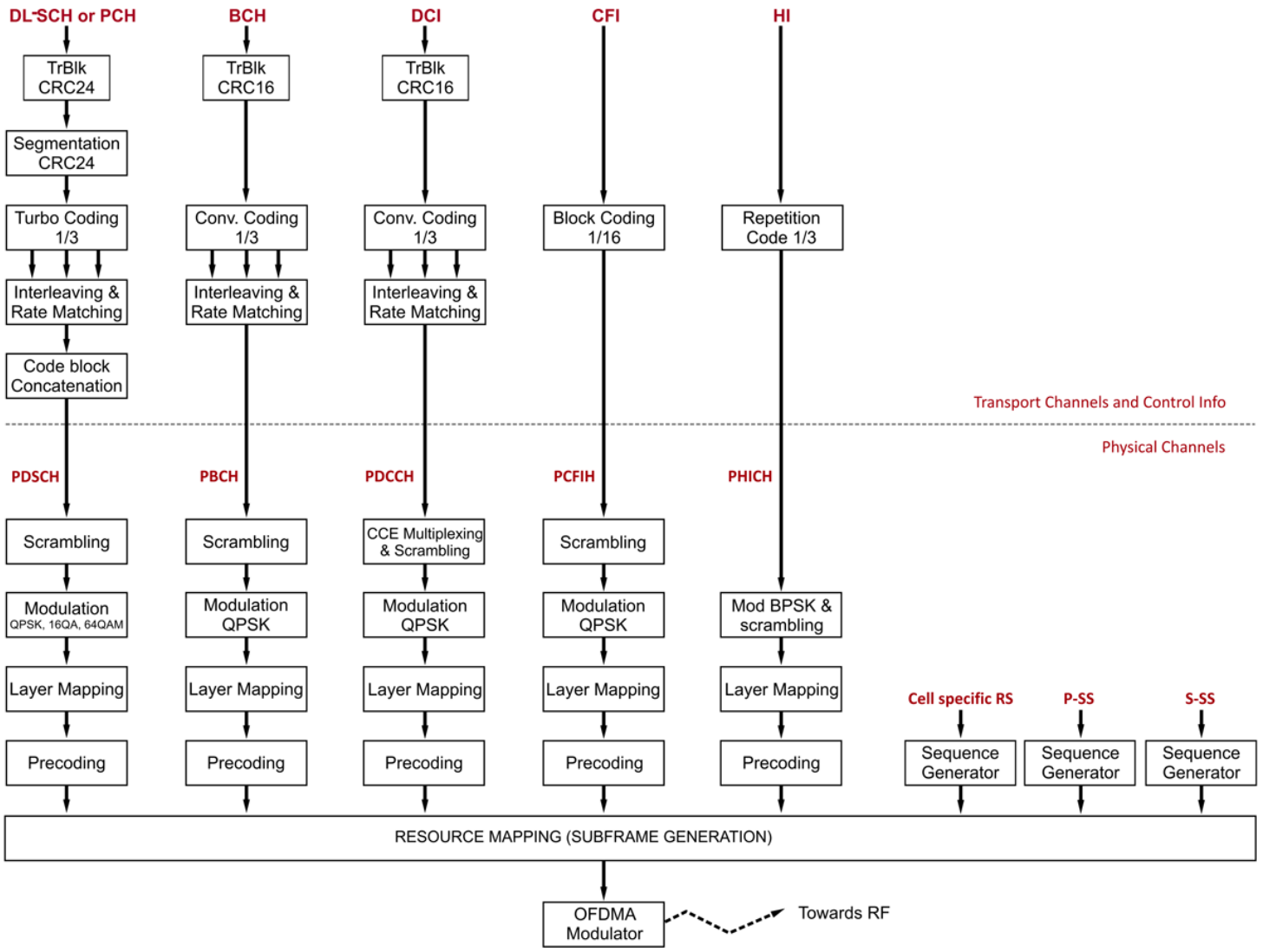
LTE Downlink Transmitter (eNodeB-side)



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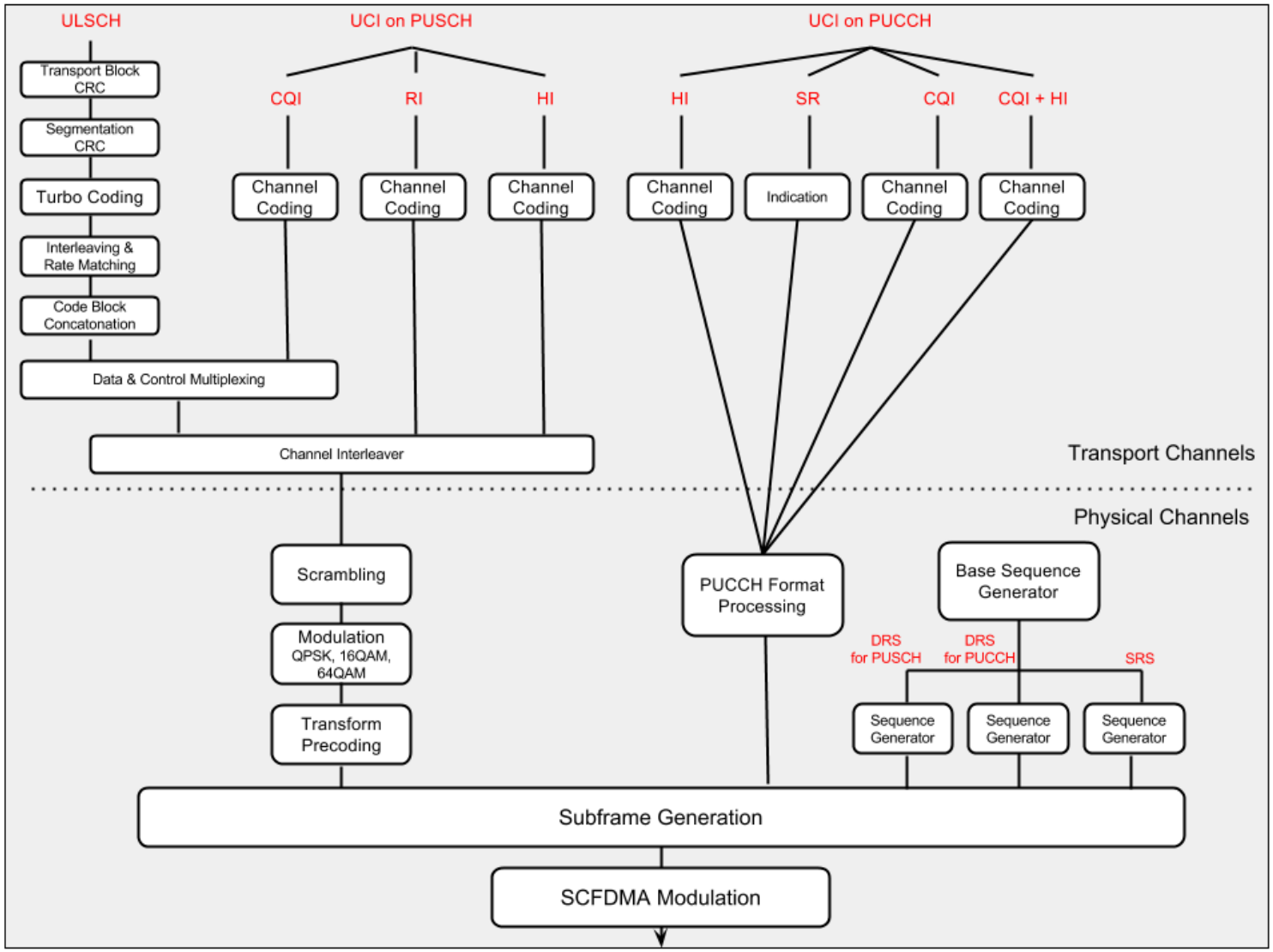
LTE Uplink Transmitter (UE-side)



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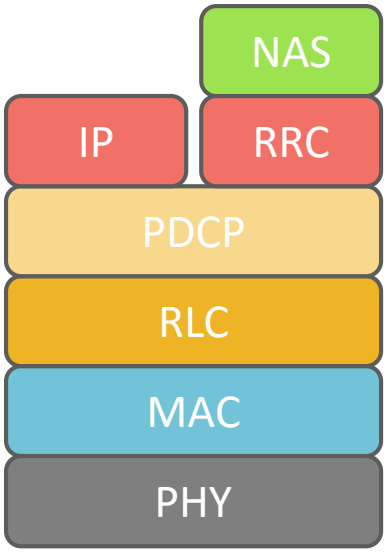
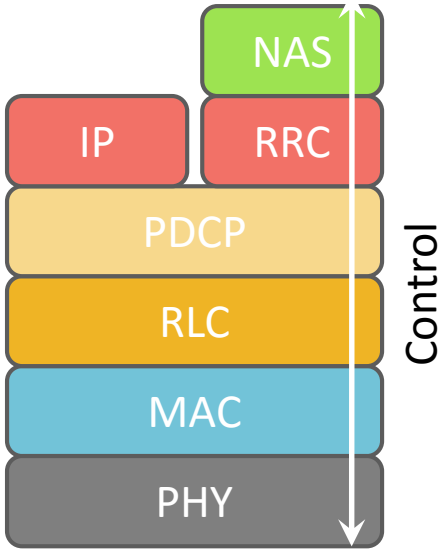
LTE Overview – protocol stacks



LTE Overview – protocol stacks



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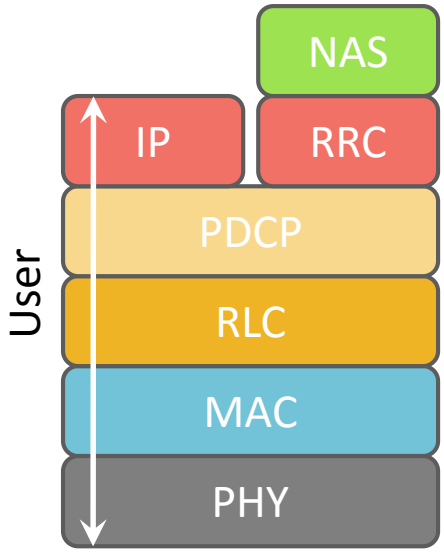
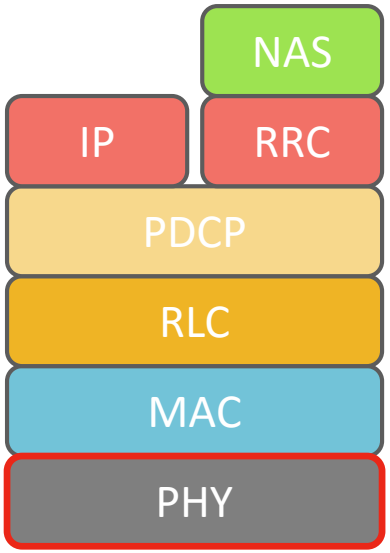
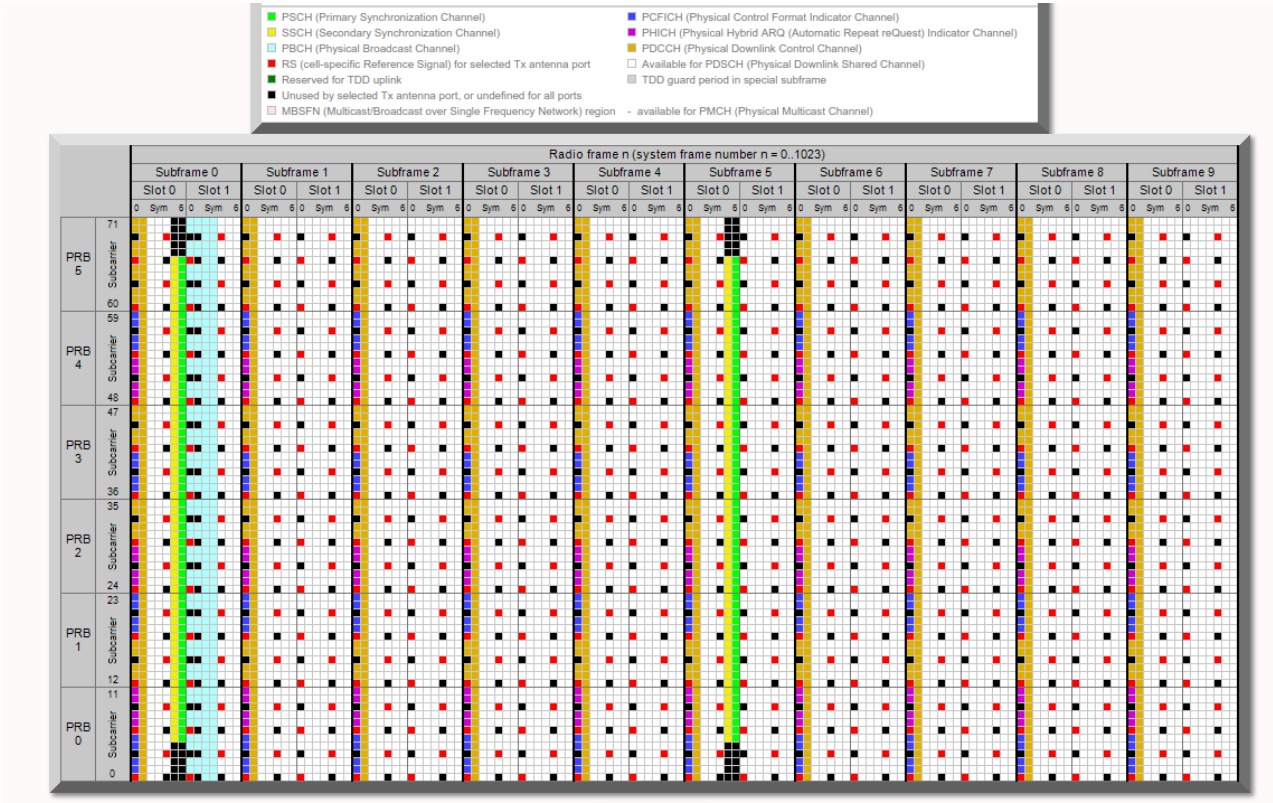


LTE Overview – protocol stacks



Physical Layer

- Tx/Rx across air interface
- Very flexible, many multiplexed signals
- OFDM / SC-FDMA



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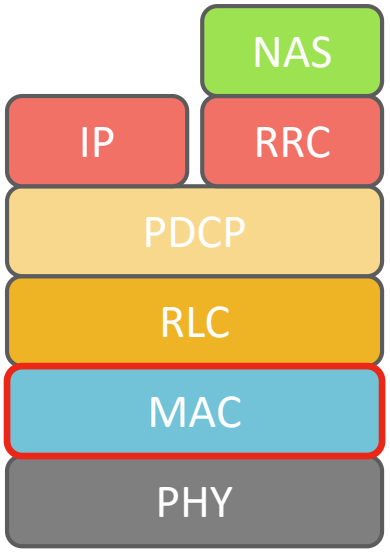
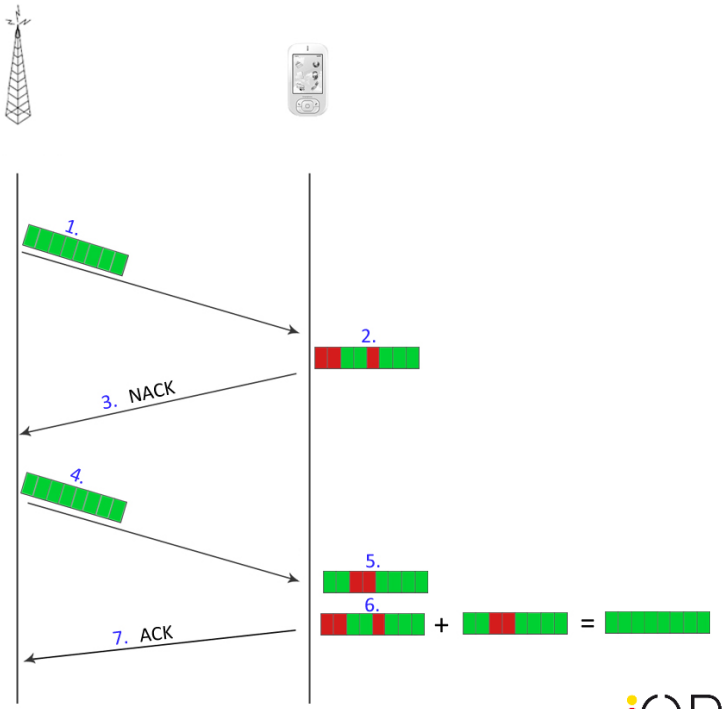


Medium Access Control Layer

- Prioritize and multiplex logical channel data
- Scheduling
- Link adaptation
  - modulation scheme and coding rate
  - transport block size

Hybrid Automatic Repeat reQuest (HARQ)



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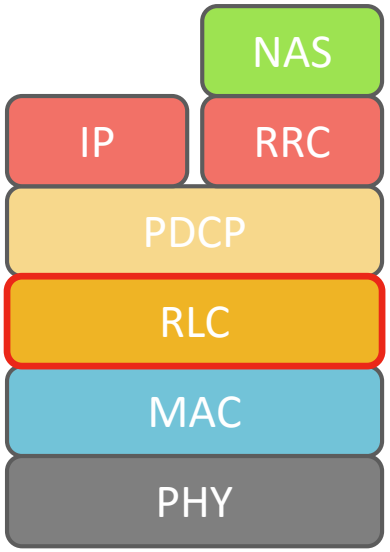
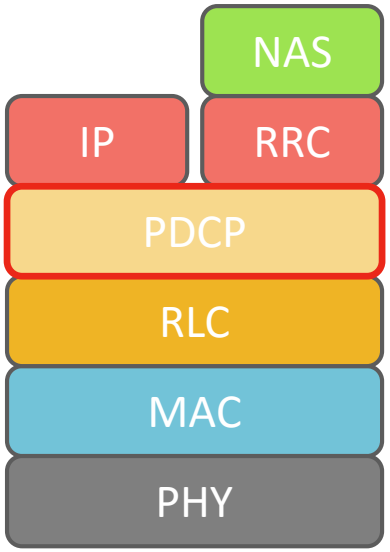
LTE Overview – protocol stacks



Radio Link Control Layer

- Segment and concatenate packets
- Error correction through ARQ
- In-sequence packet delivery
- Three modes:
  - Transparent (TM)
  - Unacknowledged (UM)
  - Acknowledged (AM)

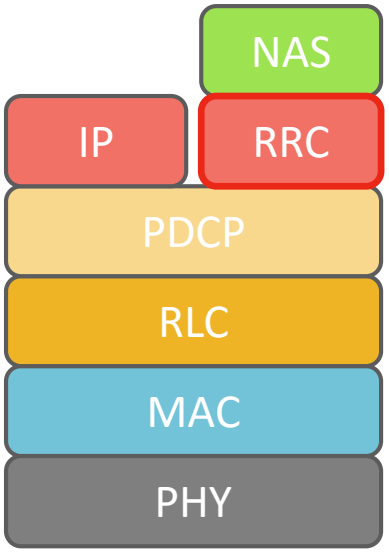
LTE Overview – protocol stacks



Packet Data Convergence Protocol Layer

- IP packet header compression (RoHC)
- Ciphering of control and data plane traffic
- Integrity protection of control plane traffic

LTE Overview – protocol stacks

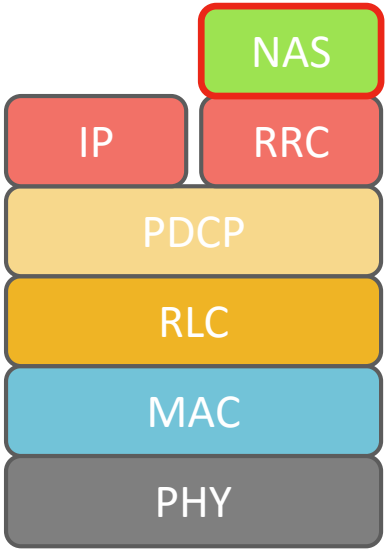


Radio Resource Control Layer

- Control plane functions:

- Paging
- Management of RRC connection with eNodeB
- Mobility management
- QoS management

LTE Overview – protocol stacks

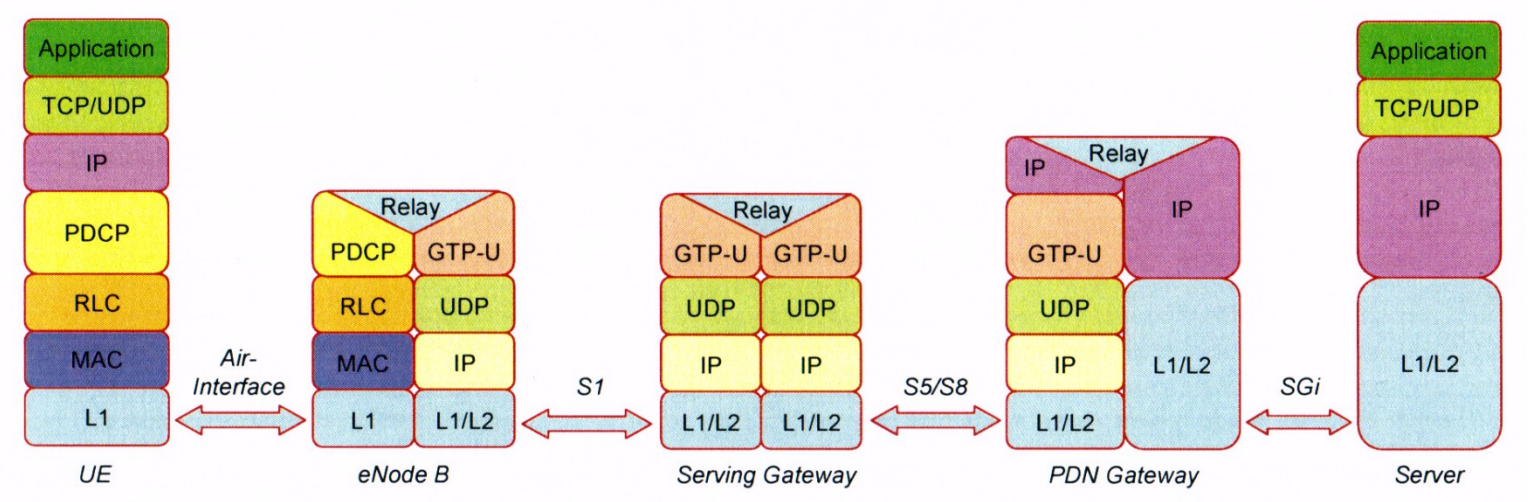


Non-Access Stratum Layer

- Control plane connection UE <-> MME:

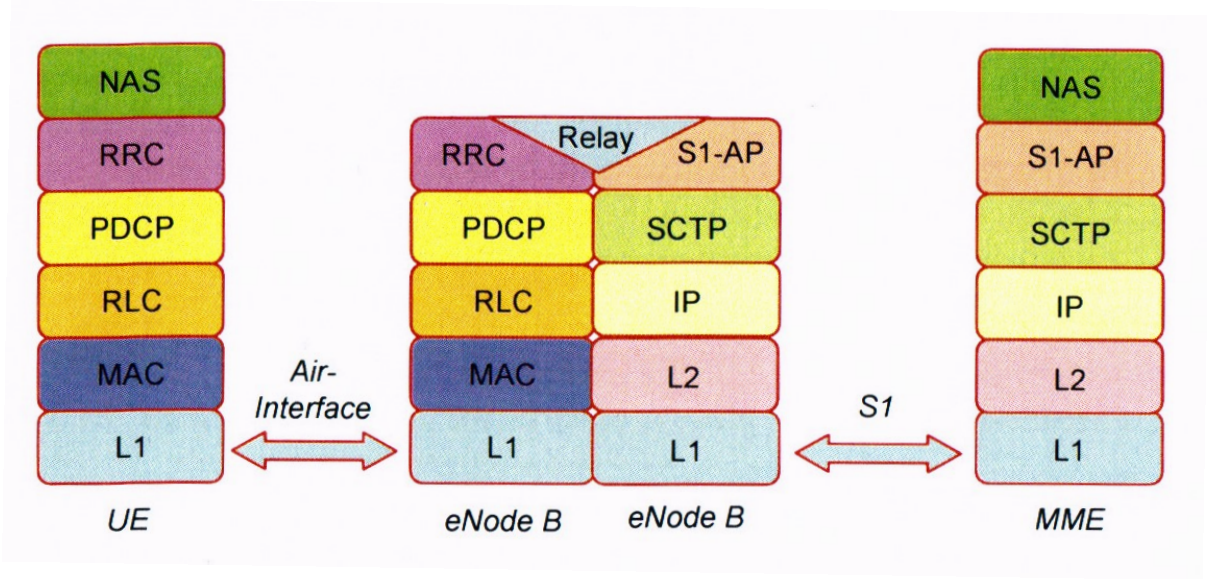
- Network attach/detach
- Authentication
- Security mode management
- Identity management
- Tracking area updates
- Bearer management
- PDN connectivity management

LTE Overview – protocol stacks



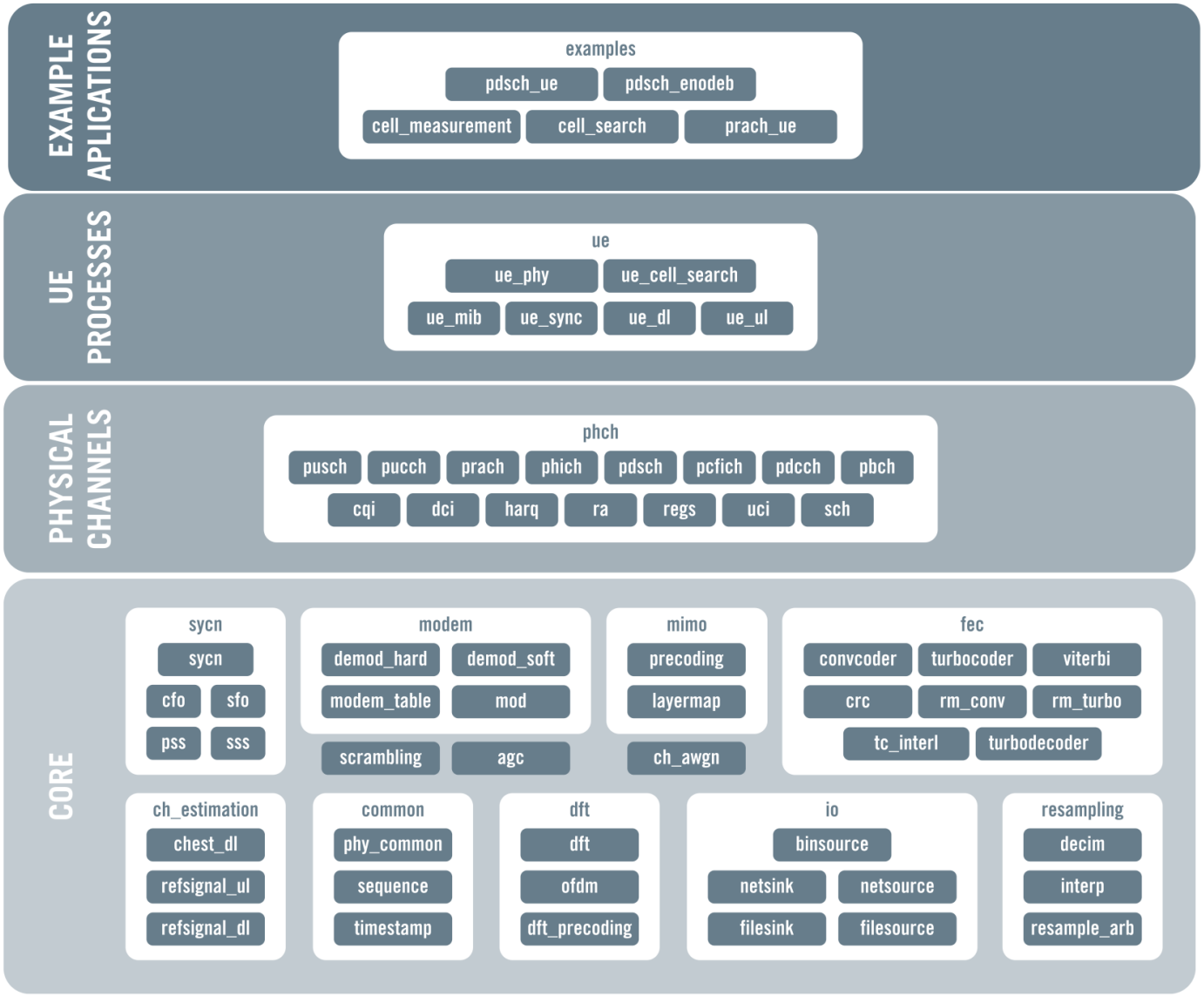
User plane protocol stacks

LTE Overview – protocol stacks



Control plane protocol stacks

PHY-layer DSP library - srsLTE



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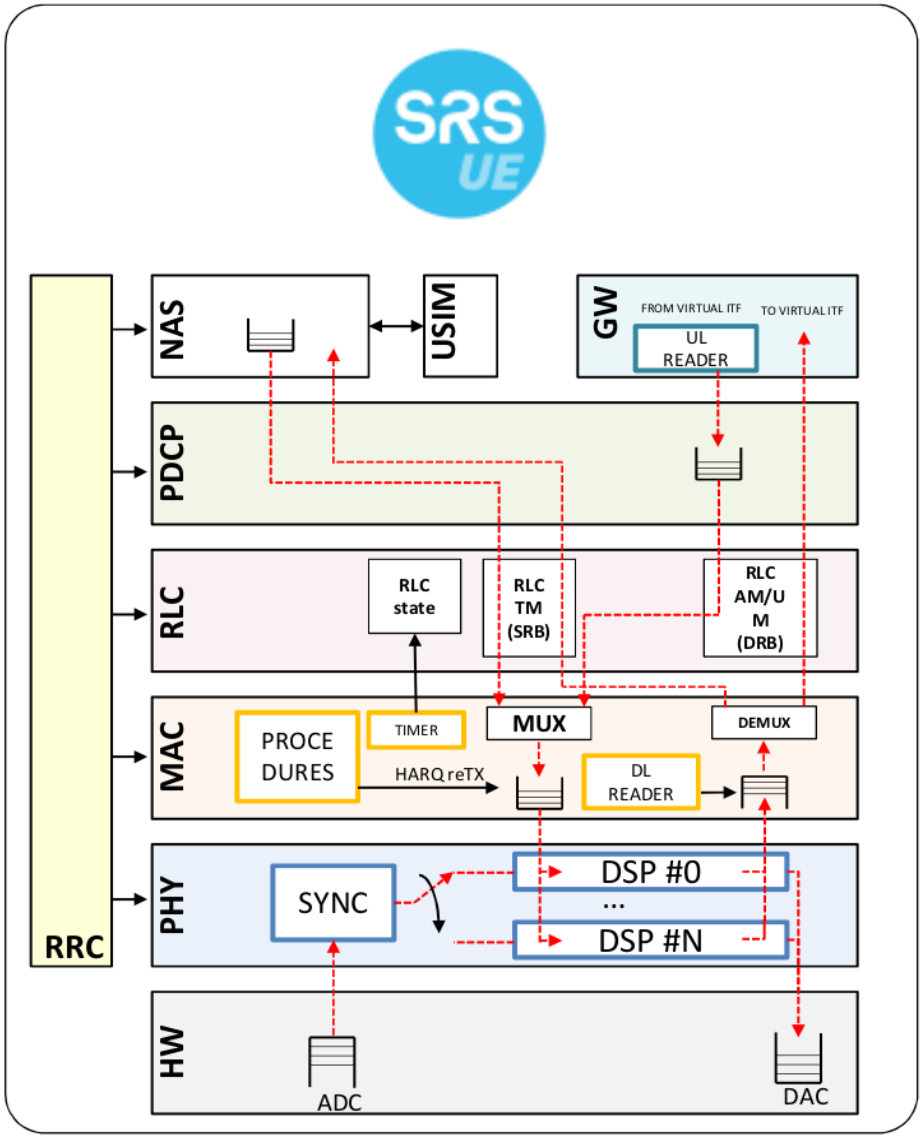
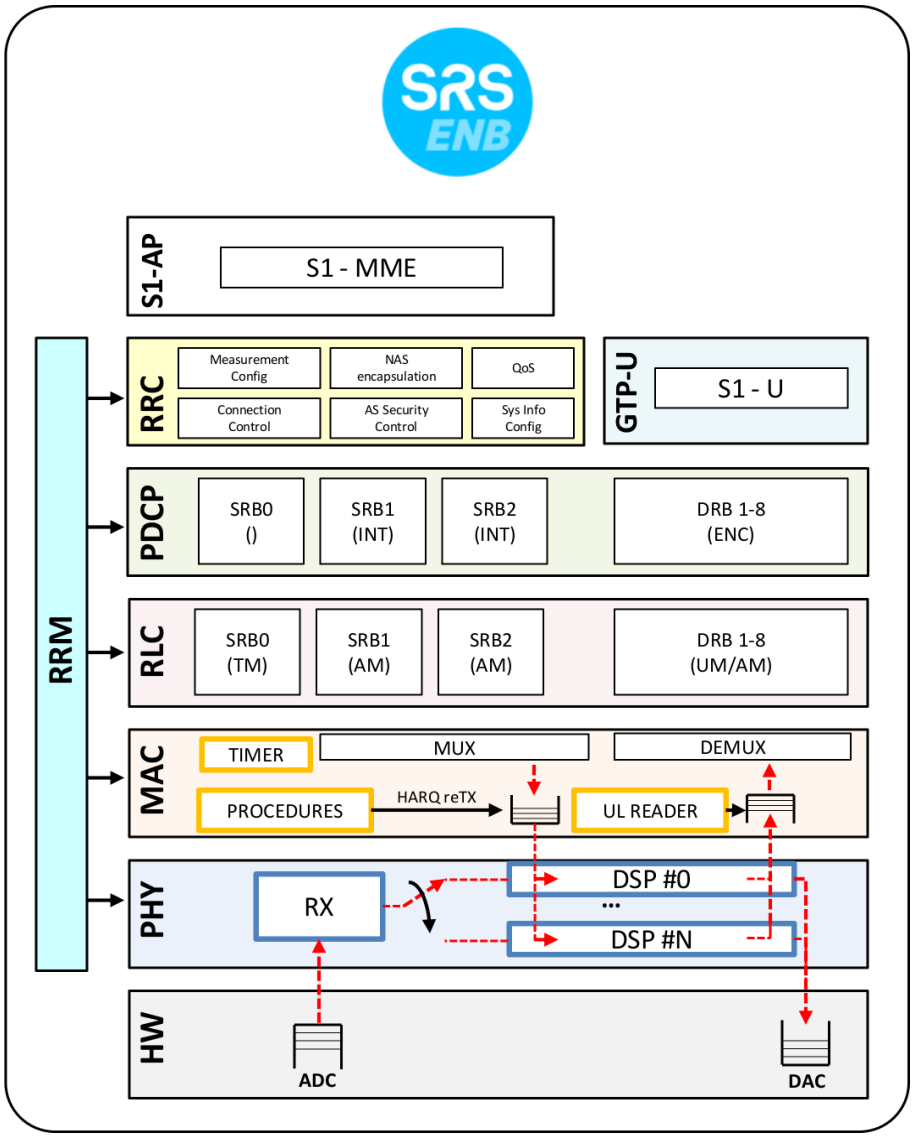
UE application - srsUE



eNodeB application - srsENB



Class/Layer Design

- srsUE/srsENB written in C++, srsLTE in C
- Each layer (PHY, MAC, RLC, PDCP, GW) is implemented in a single class
  - Some complex layers use auxiliary sub-classes
- Each layer provides a separate clean C++ pure virtual interface to any other class that make use of it (e.g. passing messages/data between layers)
- Threads only for performance or priority management reasons

Processing Latency Constraint in LTE

In LTE the basic time unit is 1 ms = 1 subframe

The processing latency constraint or *critical time* is 4 ms, given by:

N	***N+1***	***N+2***	***N+3***	***N+4***

a) **N: Reception of DL grant through PDCCH**
N: Decoding of PDSCH
N+4: Transmission of ACK/NACK HARQ through PUCCH

Processing Latency Constraint in LTE

In LTE the basic time unit is 1 ms = 1 subframe

The processing latency constraint or *critical time* is 4 ms, given by:

N	***N+1***	***N+2***	***N+3***	***N+4***

b) **N:** **Reception of UL grant or NACK HARQ**
N+4: **(re)-Transmission of PUSCH**

Processing Latency Constraint in LTE

BUT worse case happens in case of a union of a) and b), then:

N	***N+1***	***N+2***	***N+3***	***N+4***

a+b) **N:** **Reception of DL grant + UL grant or NACK HARQ**
N: **Decoding of PDSCH**
N+4: **(re)-Transmission of PUSCH + ACK/NACK HARQ**

In this case, we have 4 ms to receive samples from ADC, decode PDSCH, encode PUSCH and transmit samples to ADC in time.

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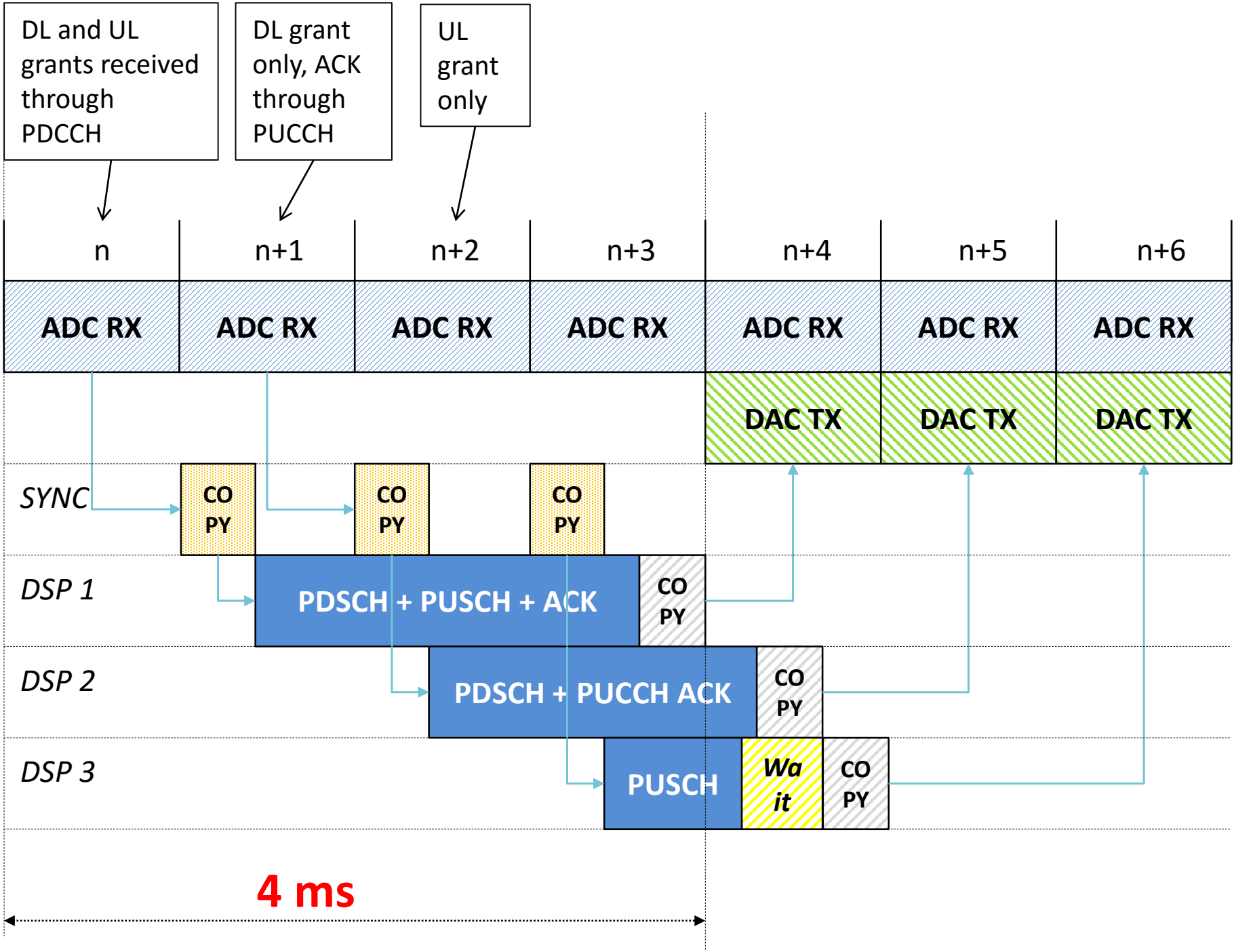
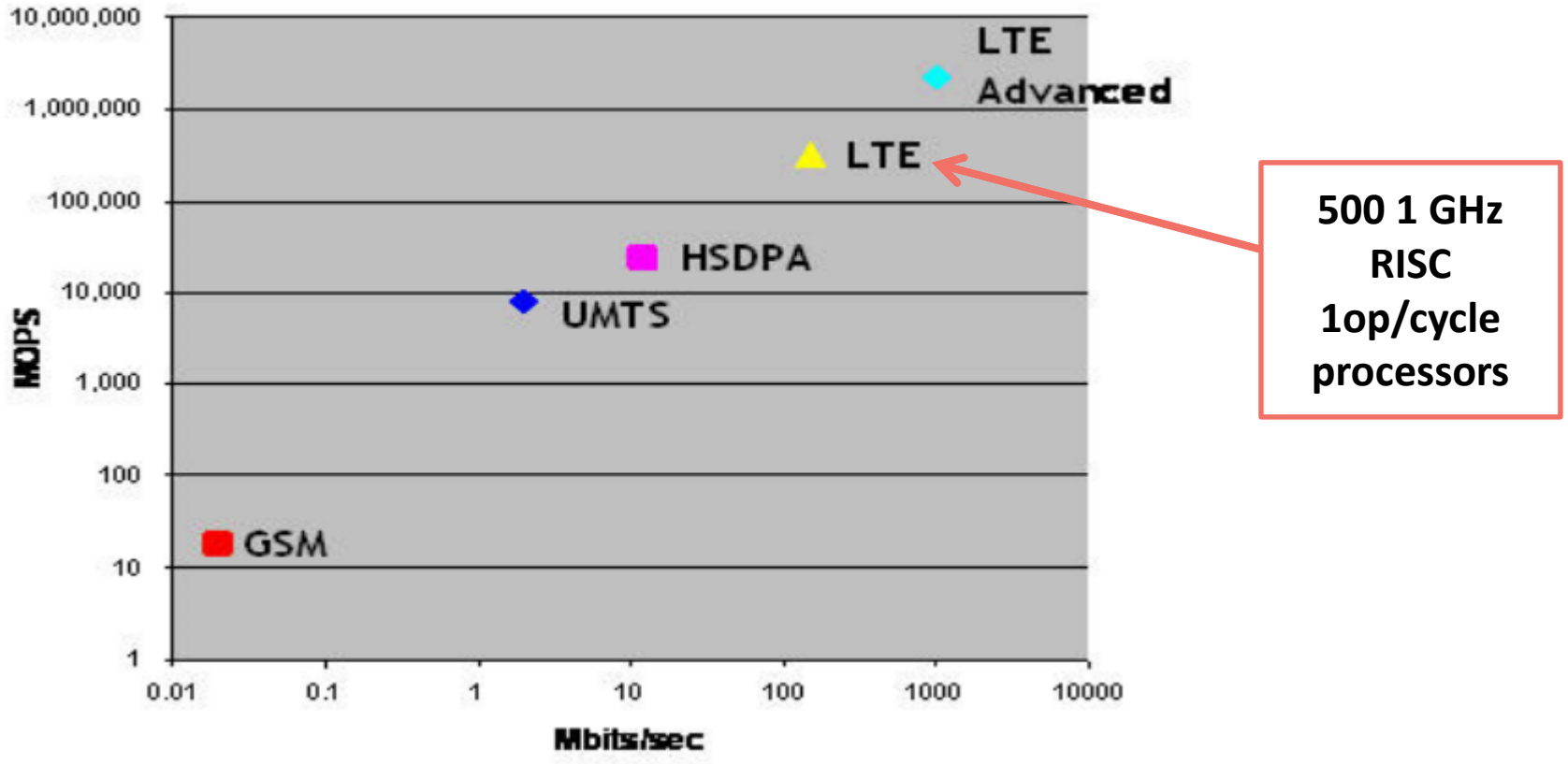

DL and UL grants received through PDCCH
DL grant only, ACK through PUCCH
UL grant only
n
n+1
n+2
n+3
n+4
n+5
n+6
ADC RX
ADC RX
ADC RX
ADC RX
ADC RX
ADC RX
ADC RX
DAC TX
DAC TX
DAC TX
SYNC
CO PY
CO PY
CO PY
DSP 1
PDSCH + PUSCH + ACK
CO PY
DSP 2
PDSCH + PUCCH ACK
CO PY
DSP 3
PUSCH
Wa it
CO PY
4 ms

Some Considerations on Threading

- The maximum useful pipeline depth is 3 stages (3 threads).
- Dividing uplink and downlink in two threads is also inefficient because uplink thread has to wait for downlink thread (i.e. there is no parallelization gain!)
- If more cores are available, we may divide each DSP thread and process multiple streams or codeblocks in parallel.

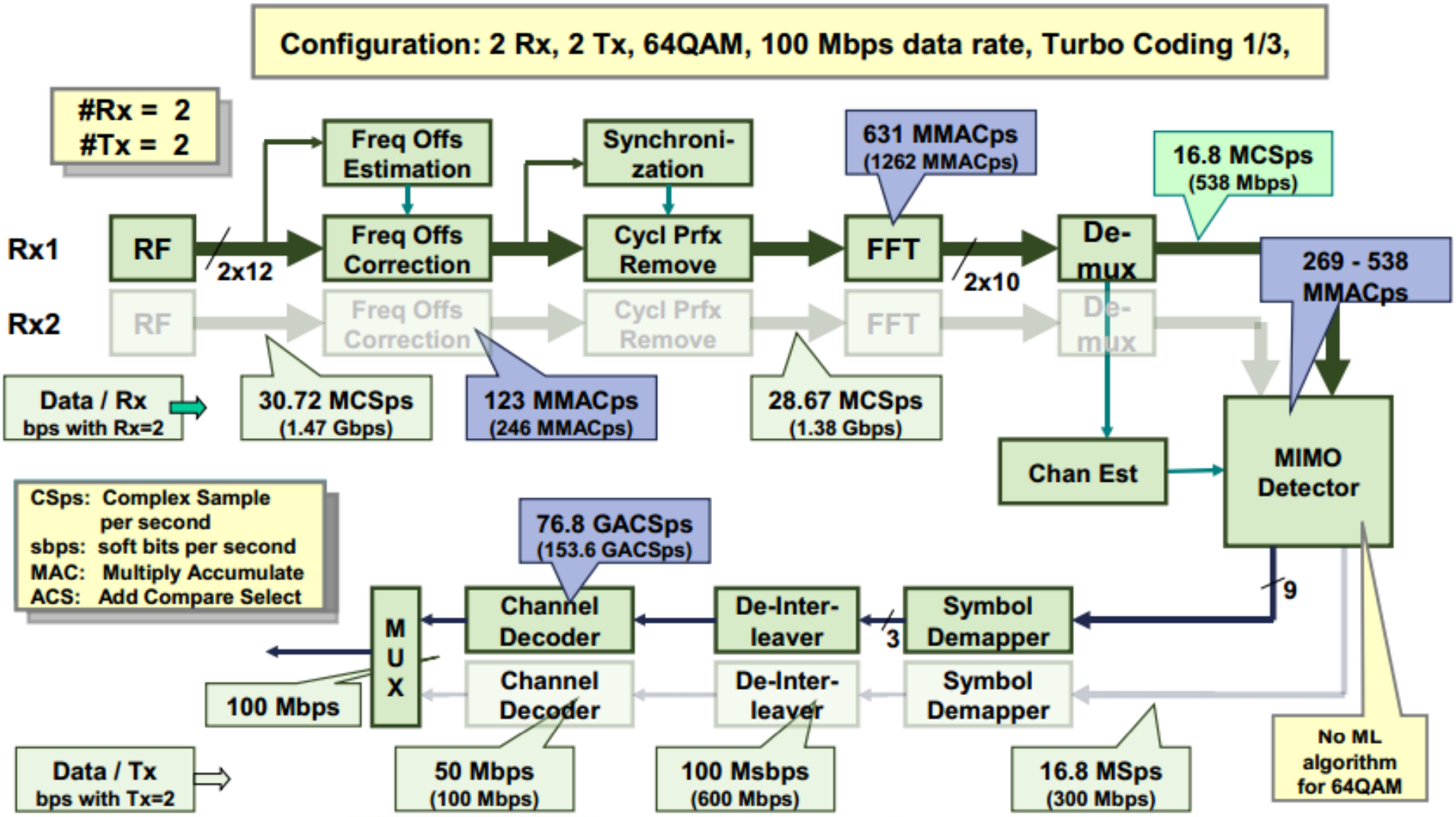
- Breakdown of the 4 ms deadline:
  - 1.0 ms for RX buffering
  - 0.5 ms for USRP -> Host transport
  - 2.0 ms left for processing
  - 0.5 ms for Host -> USRP transport

Processing Requirements



Abhijit Shah, “A MultiCore Design Approach for LTE PHY,” Tensilica, Inc.

Processing Requirements



Source: "MIMO-LTE A relevant step towards 4G", Thomas Kaiser, MobiMedia, August 27-29, 2007

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DSP optimizations

2 essential tools: **SIMD** and **Precompute**

- SIMD intrinsics wherever possible
  - e.g. integer arithmetic DSP, turbo decoder, soft demodulator, etc.
  - At compile time, choose generic/SSE4/AVX

- Initially target GPPs, so assume memory is almost free
- Use LUTs or pregenerate signals extensively:
  - Scrambling sequences for each subframe
  - PUCCH signals for each subframe
  - DL/UL reference signals for each subrame
  - CRC
  - Rate matching interleaver
  - …

DSP optimizations

- We use libfftw, which is fast enough even with non power of 2 sizes. This allows ¾ sampling rates:
  - 10 MHz BW: FFT 768 samples, 11.52 Msamples/s
  - 20 MHz BW: FFT 1536 samples, 23.04 Msamples/s

- This constrains us to use 32-bit complex float for transport and FFT processing.

- Yet to find a good open source integer FFT library…

Turbo Decoder

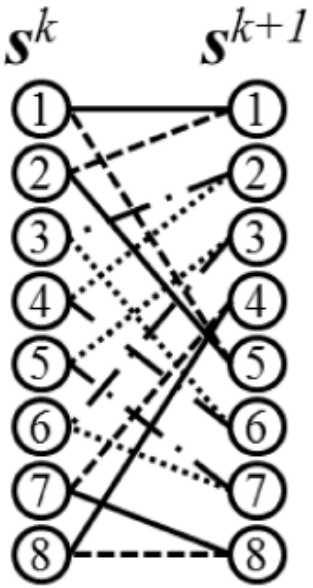
- The Turbo Decoder is the most demanding component:

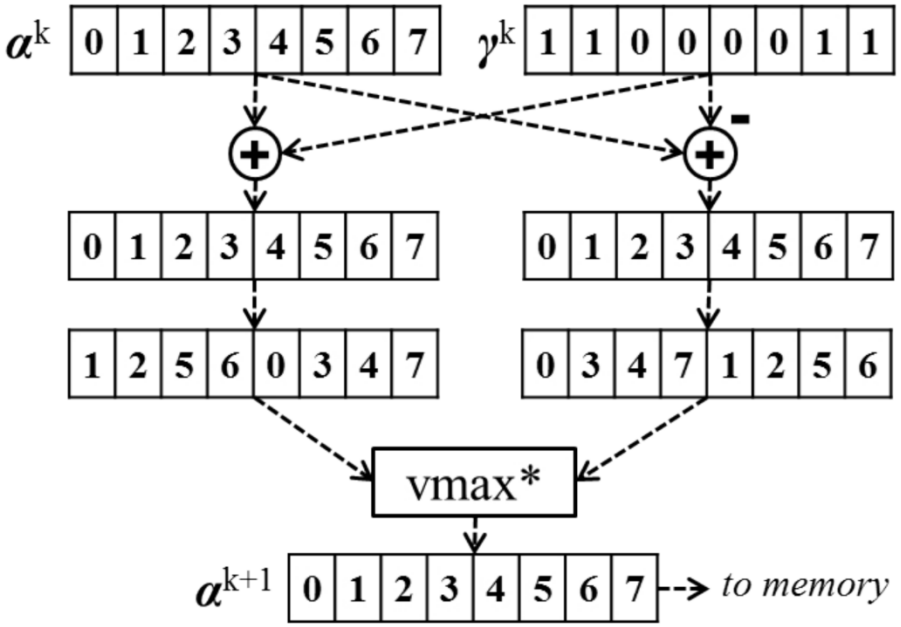
TABLE I
TOTAL PDSCH RECEIVER PROCESSING TIME AND BREAK-DOWN OF THE CPU UTILIZATION FOR 20 MHZ BANDWIDTH CONFIGURATION.

Module Name	Percentage of CPU		
	75 Mbps 64QAM	30 Mbps 16QAM	3.62 Mbps QPSK
Turbo decoder (1 iteration)	78.14 %	64.21 %	20.89 %
OFDM receive processing	6.08 %	11.70 %	33.33 %
Resource Element de-mapping	4.92 %	9.31 %	25.26 %
Rate recovery	4.49 %	5.64 %	8.34 %
CRC checksum	2.92 %	2.23 %	0.72 %
Soft demodulation	1.76 %	2.11 %	3.38 %
Equalization	0.16 %	1.84 %	4.98 %
Others	1.53 %	2.96 %	55.12 %
Total Execution Time	954 μs	488 μs	170 μs

Turbo Decoder

- We used 16-bit integer arithmetic and 128-bit SSE4 instructions to compute all the trellis (8 states) in parallel
- With 8-bit arithmetic could do 2 codeblocks in parallel
- With AVX2 could do 2 or 4 codeblocks in parallel





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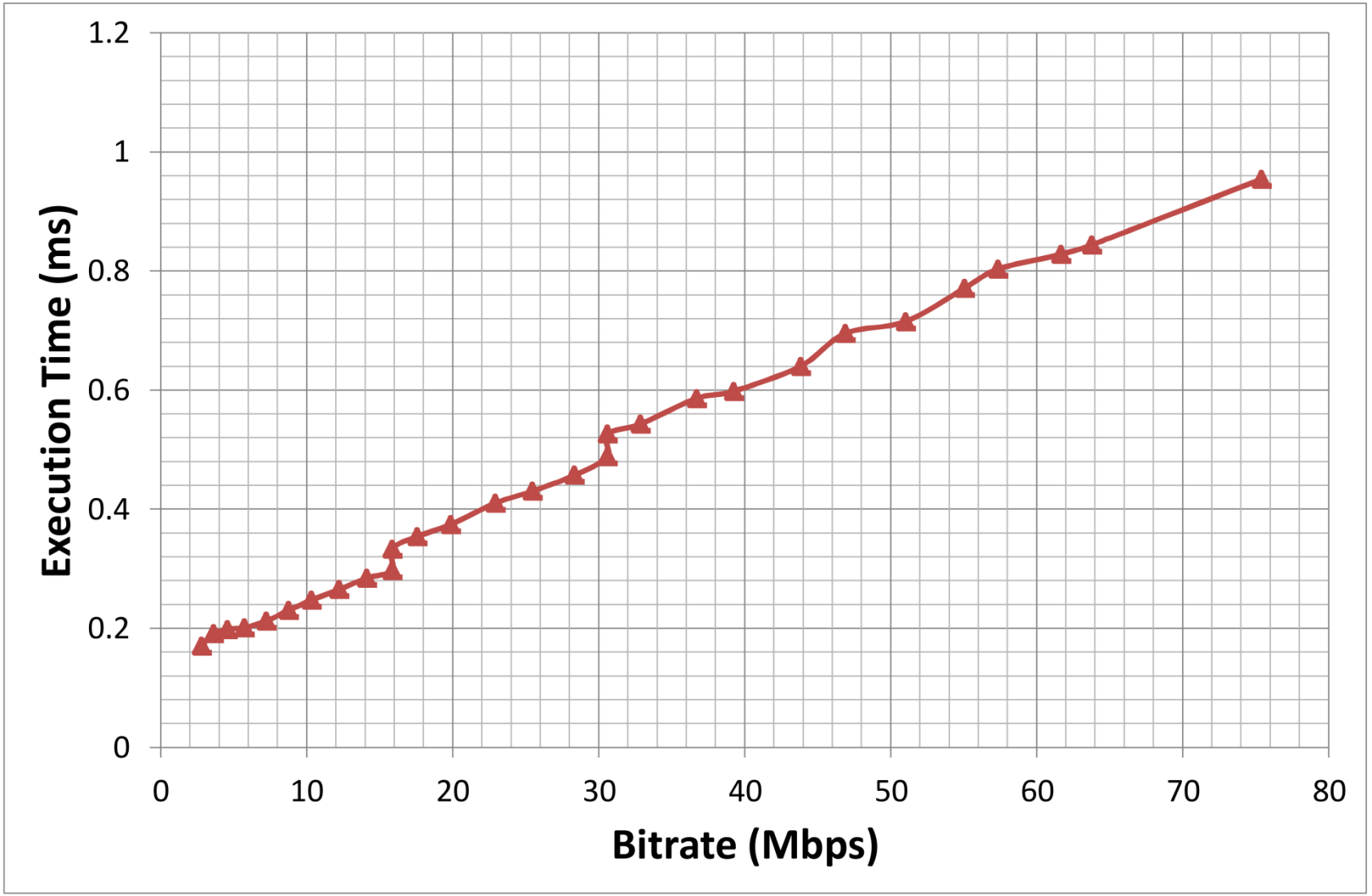
Execution time of PDSCH only @ 20 MHz



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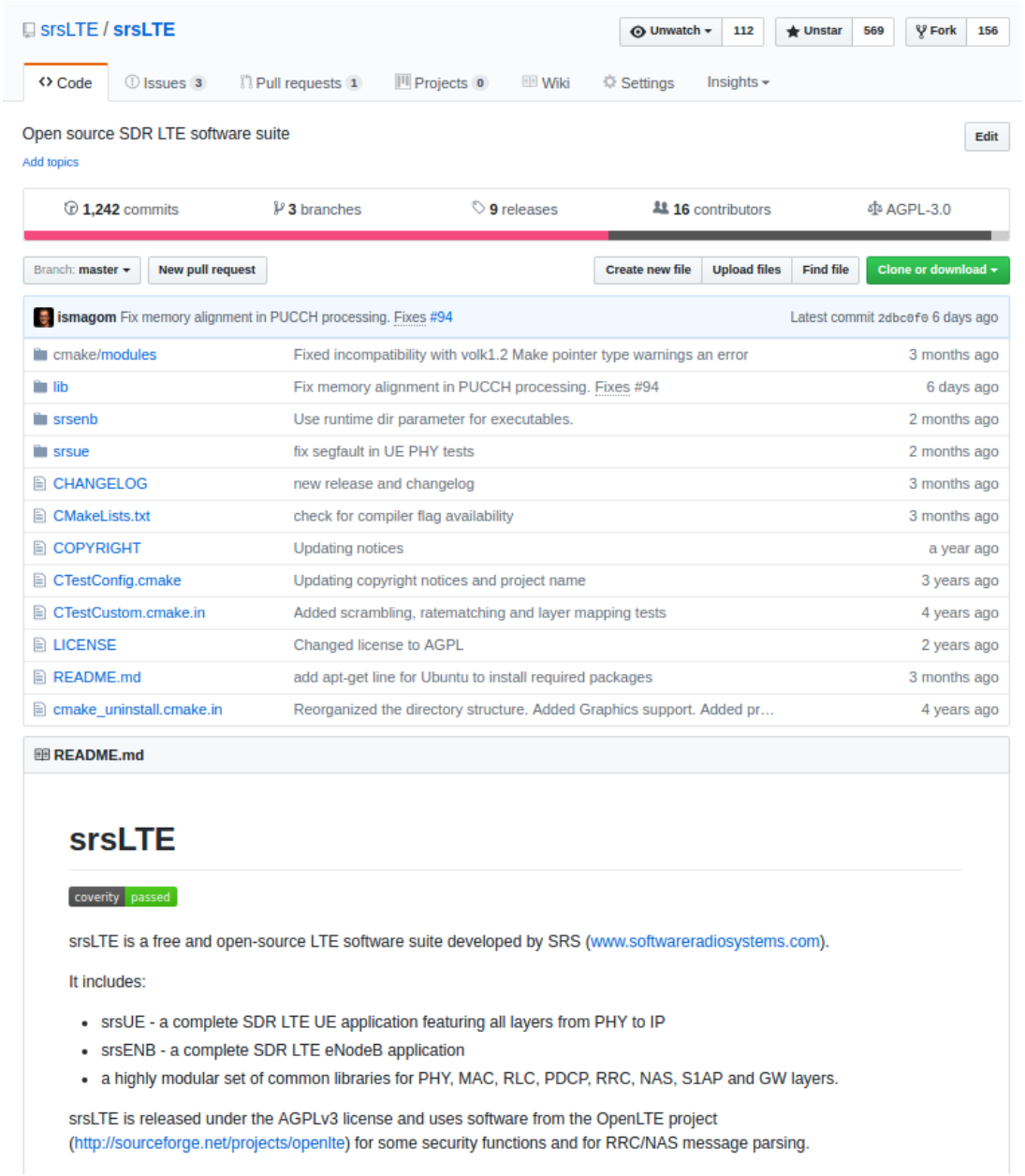

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Open source SDR LTE software suite

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ismagom Fix memory alignment in PUCCH processing. Fixes #94 — Latest commit 2dbc0f0 6 days ago

cmake/modules	Fixed incompatibility with volk1.2 Make pointer type warnings an error	3 months ago
lib	Fix memory alignment in PUCCH processing. Fixes #94	6 days ago
srsenb	Use runtime dir parameter for executables.	2 months ago
srsue	fix segfault in UE PHY tests	2 months ago
CHANGELOG	new release and changelog	3 months ago
CMakeLists.txt	check for compiler flag availability	3 months ago
COPYRIGHT	Updating notices	a year ago
CTestConfig.cmake	Updating copyright notices and project name	3 years ago
CTestCustom.cmake.in	Added scrambling, ratematching and layer mapping tests	4 years ago
LICENSE	Changed license to AGPL	2 years ago
README.md	add apt-get line for Ubuntu to install required packages	3 months ago
cmake_uninstall.cmake.in	Reorganized the directory structure. Added Graphics support. Added pr…	4 years ago

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srsLTE

coverity passed

srsLTE is a free and open-source LTE software suite developed by SRS (www.softwareradiosystems.com).

It includes:

- srsUE - a complete SDR LTE UE application featuring all layers from PHY to IP
- srsENB - a complete SDR LTE eNodeB application
- a highly modular set of common libraries for PHY, MAC, RLC, PDCP, RRC, NAS, S1AP and GW layers.

srsLTE is released under the AGPLv3 license and uses software from the OpenLTE project (http://sourceforge.net/projects/openlte) for some security functions and for RRC/NAS message parsing.


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