5G FAPI: Network FAPI 1.0

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Key contributors
Small Cells and FAPI

• Small Cells
  • A small cell is a cellular base station that transmits and receives 3GPP-defined RF signals with small power and small form factor. In most cases, it services a small coverage area.
  • Find more at: https://www.smallcellforum.org/5g-product-definition-report

• FAPI:
  • The functional application platform interface (FAPI) is an initiative within the small cell industry to encourage competition and innovation among suppliers of platform hardware, platform software and application software by providing a common API around which suppliers of each component can compete.
5G FAPI Interfaces

Small cell internal architecture

L2/L3 – application software

- Control SON
- Cell Config
- MAC
- RF/DFE/ABF Config

L1 platform hardware

- PHY
- NMM
- FEU (RF/DFE/ABF)

SON (Self Organising Networks), MAC (Medium Access Control), NMM (Network Monitor Mode) FEU (Front End Unit) including DFE (Digital Front End) and ABF (Analog Beam Forming)
5G FAPI: PHY API

- Interface is abstracted from underlying architecture
- Control messages (P5) move PHY through a state machine to RUNNING state where a small cell becomes active
- Per Slot/TTI messages (P7) define what is transmitted and received over the air every subframe
5G Network FAPI (nFAPI)

nFAPI Motivation: Disaggregated RAN architecture

- System vendors
- Software vendors
- Hardware vendors

- Enable FAPI across non-ideal backhaul
- Converged approach to virtualization
- Scalable ecosystem
- Interoperability
- Centralization benefits
5G nFAPI 1.0 adds a network transport wrapper around the 5G FAPI PHY API to create the split option-6 interface between S-RU and S-DU network nodes.
SCF Option 6 (nFAPI) based solutions

S-CU: The central unit includes the SDAP, PDCP and RRC protocols.
S-DU: The distributed unit includes RLC and MAC.
S-RU: The radio unit includes PHY and Radio Front End Unit.
FAPI and nFAPI

- **gNB**
  - MAC
  - PHY API
    - P5 & P7
    - Vendor Ext
  - PHY

- **nFAPI messages**
  - S-DU
    - MAC
    - FAPI ↔ nFAPI
      - Vendor Ext
  - S-RU
    - PHY
    - nFAPI ↔ FAPI
      - Vendor Ext
    - P5 & P7
      - Vendor Ext
P5 procedures configure and control the PNFs and PHY instances within a PNF

New SCTP Payload Protocol Identifier (PPI) for 5G nFAPI (To be assigned by IANA)
P7 interface aligns slot, timing and jitter between VNF and PHY instance

P7 procedures provide PHY Sync, Delay management and DL/UL data transfer
5G nFAPI

- nFAPI framework evolved and optimized for 5G NR
- Based on 5G FAPI (SCF222.10.02) Mar 2020 release
- Support for 3GPP Rel 15
5G nFAPI message types

• **Dedicated nFAPI messages**: These are messages defined solely in the nFAPI protocol, e.g., PNF_XXX messages.

• **Transparent messages**: These are messages that are defined in the FAPI specification, and carried by the nFAPI protocol, as is. That is the nFAPI only provides a transport of these messages and does not modify these messages.

• **Combined messages**: These messages are defined by the FAPI specification, but the nFAPI specification adds new values and TLVs to these messages.
5G nFAPI header

**nFAPI Header**

- Segment Length
- More
- Segment Number
- Sequence Number
- Transmit Timestamp
- Reserved = 1
- Phy-id = 1
- Message Id
- Length = L1
- 5G nFAPI Message Body #1
Combined nFAPI message

**nFAPI Header**
- Segment Length = 8 + 6 + 2 + 8 + 6 + (4 + L1)
- Segment Number
- Sequence Number
- Transmit Timestamp
- Reserved
- PhyId = 1
- Message ID = PARAM.response
- Length = 2 + 8 + 6 + (4 + L1)
- Error Code = MSG_OK
- Num TLVs = 3
- TAG = 0x0103 (P7 PNF Address IPV4)
- Length = 4
- Value = 0xC0A80102
- TAG = 0x0105 (P7 PNF Port)
- Length = 2
- Value = 5000
- TAG = 0x0F00 (5G_FAPI_MSG_BODY)
- Length = L1
- 5G FAPI PARAM.response Body (as defined in SCF 222 5G FAPI spec)

**nFAPI Specific TLVs** (defined in nFAPI spec)

**5G FAPI PARAM.response body**
Extraction of FAPI messages from nFAPI message

FAPI Msg 1

Number of PHY messages = 1
Phy-Id = 1
Message Id
Length = L1

FAPI Msg 2

Number of PHY messages = 1
Phy-Id = 2
Message Id
Length = L2

5G nFAPI Message Body #1

5G nFAPI Message Body #2
PNF Procedures

PNF Idle

PNF Configured

PNF Running

PNF PARAM.request

PNF CONFIG.request

PNF START.request

PNF STOP.request

PHY 1

Idle

Configured

Running

PARAM.request

CONFIG.request

START.request

STOP.request

DL Node Sync

PHY 2

PHY n
PHY Procedures – PNF initialization

sd Initialization

- VNF
  - ref
  - PNF PARAM
  - ref
  - PNF CONFIG
  - ref
  - PNF START

PNF
- State
  - IDLE
  - CONFIGURED
  - RUNNING
PHY Procedures – PHY initialization

sd Initialization

:VNF

PNF

PHY

PNF PARAM

PNF CONFIG

PNF START

NODE SYNC

(from nFAPI)
Delay management on P7

VNF derives PHY Time Reference & link latency

VNF drives the PHY Time 8 slots later

PHY

UL Node Sync (t1,t2,t3)

DL Node Sync (t1,+8)

DL_TTI (14/3)

DL_TTI (14/4)

DL_TTI (14/5)

DL_TTI (14/6)

Timing Info (14/4)

DL_TTI for SFN slot 14/4 arrived too late, it is lost and triggers Timing Info (e.g. configured to send after every late slot)

PHY updates the next slot to advance by 8
Planned for next releases

nFAPI enhancements
• nFAPI framework robustness enhancements
• P7 transport enhancements
• Support for FAPI P19 Front End Unit Control [SCF223]
• Support for FAPI P4 Network Monitor Mode [SCF224]

Ecosystem support
• Management models
• Transport Network Requirements
• Sync and timing design
• Test and Measurement support
For further information

Downloadable from our nFAPI page: https://www.smallcellforum.org/5g-network-fapi-specifications/
Annex: 5G FAPI
(Architecture & Sample Calls)
Multiple Architectures for Small Cells

- **Split 7-2x**
  - O-CU & O-DU
  - FAPI
  - O-RU
  - O-RAN FH

- **Split 6**
  - S-CU & S-DU
  - FAPI
  - S-RU
  - nFAPI

- **Split 2**
  - CU
  - FAPI
  - DU
  - F1

- **Distributed Small Cell**
  - FAPI
FAPI Location

- **AMF/UPF**
- **gNB**
- **CU**
  - **DU**
  - **F1**
- **Xn**
- **NG**

- **L1**: PHY + RF
- **L2/L3**: FAPI
- **Control (RRM/SON)**
  - **RRC**
  - **PDCP**
  - **RLC**
  - **MAC**
  - **Scheduler**

- **gNB**
- **Xn**
- **Ng**

- **DU**
- **F1**

- **FAPI**

- **AMF/UPF**

- **Xn**

- **Ng**
5G FAPI Synchronization:

- **SLOT.indication**
  - PHY → L2/L3
  - Indicating start of a slot.
  - Periodicity depends on numerology

- **Sync master determines slot #**
  - L2/L3 master
  - PHY Master

<table>
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<tr>
<th>Subframe</th>
<th>Radio Frame 10ms</th>
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<tr>
<td>N+0</td>
<td>N+1</td>
</tr>
<tr>
<td>N+2</td>
<td>N+3</td>
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<tr>
<td>N+4</td>
<td>N+5</td>
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<td>N+6</td>
<td>N+7</td>
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<tr>
<td>N+8</td>
<td>N+9</td>
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</table>

Subcarrier Spacing Numerology

- $u=0$
- $u=1$
- $u=2$
- $u=3$
P7: DL Transmission

- Prep & DL Tx for slot N:
  - PHY Ch in `DL_TTI.req`
  - MAC PDU in `Tx_Data.req`

- UL ARQ for unicast DL PDU in slot N:
  - ARQ arrives in slot N+K
  - PHY Ch in `UL_TTI.req`
  - ARQ from UE in `UL_UCI.ind`
P7: UL Transmission

- Prep for UL slot N:
  - PHY Ctrl Ch in **UL_DCI.req**
  - PHY Data Ch in **UL_TTI.req**

- UL Tx in slot N:
  - MAC PDU in **Rx_Data.req**
  - CRC outcome in **CRC.ind**
  - UL CSI in **UCI.ind**

- DL ARQ for unicast UL PDU:
  - 5G HARQ is asynchronous
  - NACK: Re-grant in later **UL_DCI.req**
  - ACK: No regrant needed
Annex: SCF FAPI: 2G to 5G
SCF FAPI support for different Radio Access Technologies (RAT)

<table>
<thead>
<tr>
<th>Brand name</th>
<th>3GPP RAT Type</th>
<th>PHY API</th>
<th>Network Monitor Mode</th>
<th>RF / Digital Front End</th>
<th>network FAPI PHY/MAC split</th>
<th>Small cell (PNF/RU) management model</th>
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SCF FAPI - A suite of APIs between small cell hardware and software from 2G to 5G

www.scf.io

*currently under development