



OpenAirInterface Core Network: Recent enhancements in OAI EPC

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Outline

- **EPC fundamentals**
- **OAI Core Network Overview**
- **Recent developments**
- **OAI Core Network detailed**
- **Future plans**

Outline

- **EPC fundamentals**

- 3GPP picture of network function and interfaces.
- Releases and features

- OAI Core Network Overview

- Recent developments

- OAI Core Network detailed

- Future plans

Core Network Fundamentals – Purpose of CN

■ Evolved Packet Core Network Purpose and history

- Evolved Packet Core (EPC) is a framework for providing converged voice and data on a 4G Long-Term Evolution (LTE) network.

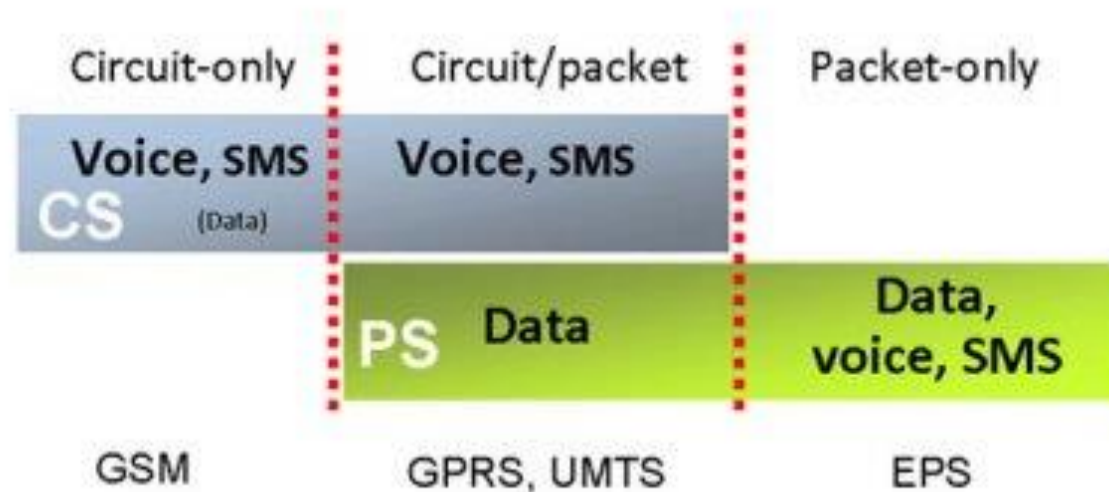


Figure 1: Circuit and packet domains

Source <http://www.3gpp.org/technologies/keywords-acronyms/100-the-evolved-packet-core>

Core Network Fundamentals

■ High level functions

- **Network Access Control Functions.**
 - Authentication and authorization, admission control, Policy and charging enforcement
- **Packet Routing and Transfer Functions:** IP header compression function, packet screening.
- **Mobility Management Functions.**
 - Reachability management for UE in ECM-IDLE state
- **Security Functions.**
- **Radio Resource Management Functions.**
- **Network Management Functions (O&M)**
 - GTP-C signaling based Load and Overload Control, Load balancing between MME, MME control of overload, PDN GW control of overload

Core Network Fundamentals - Architecture

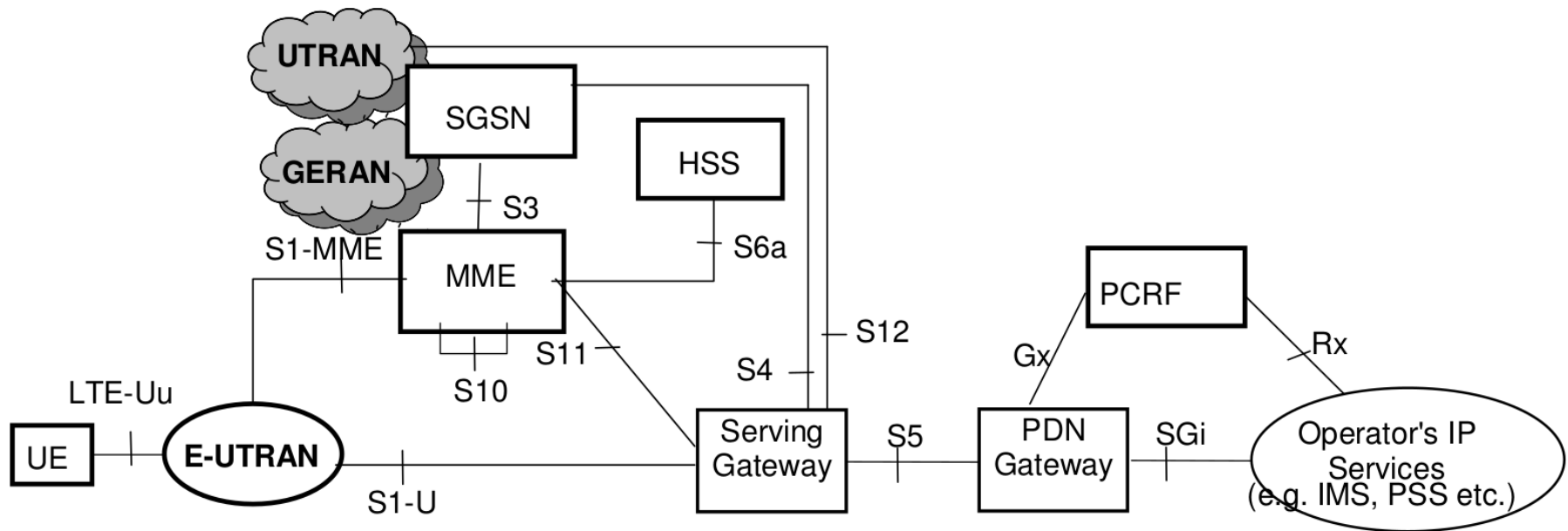


Figure 4.2.1-1: Non-roaming architecture for 3GPP accesses

Core Network Fundamentals – Access Networks

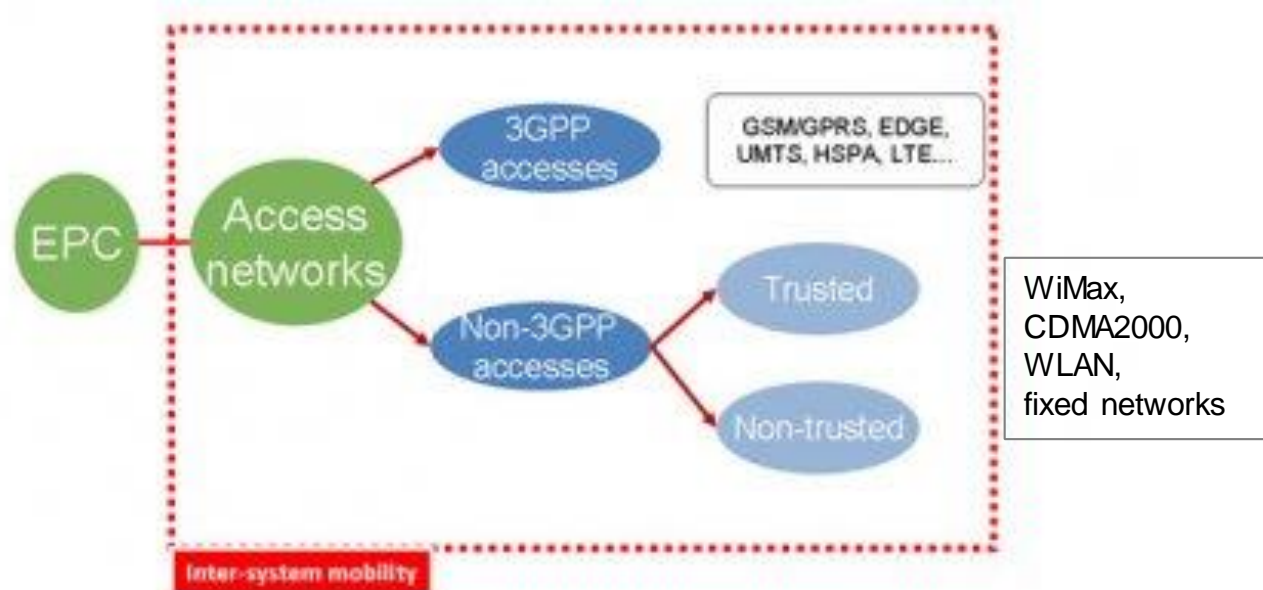
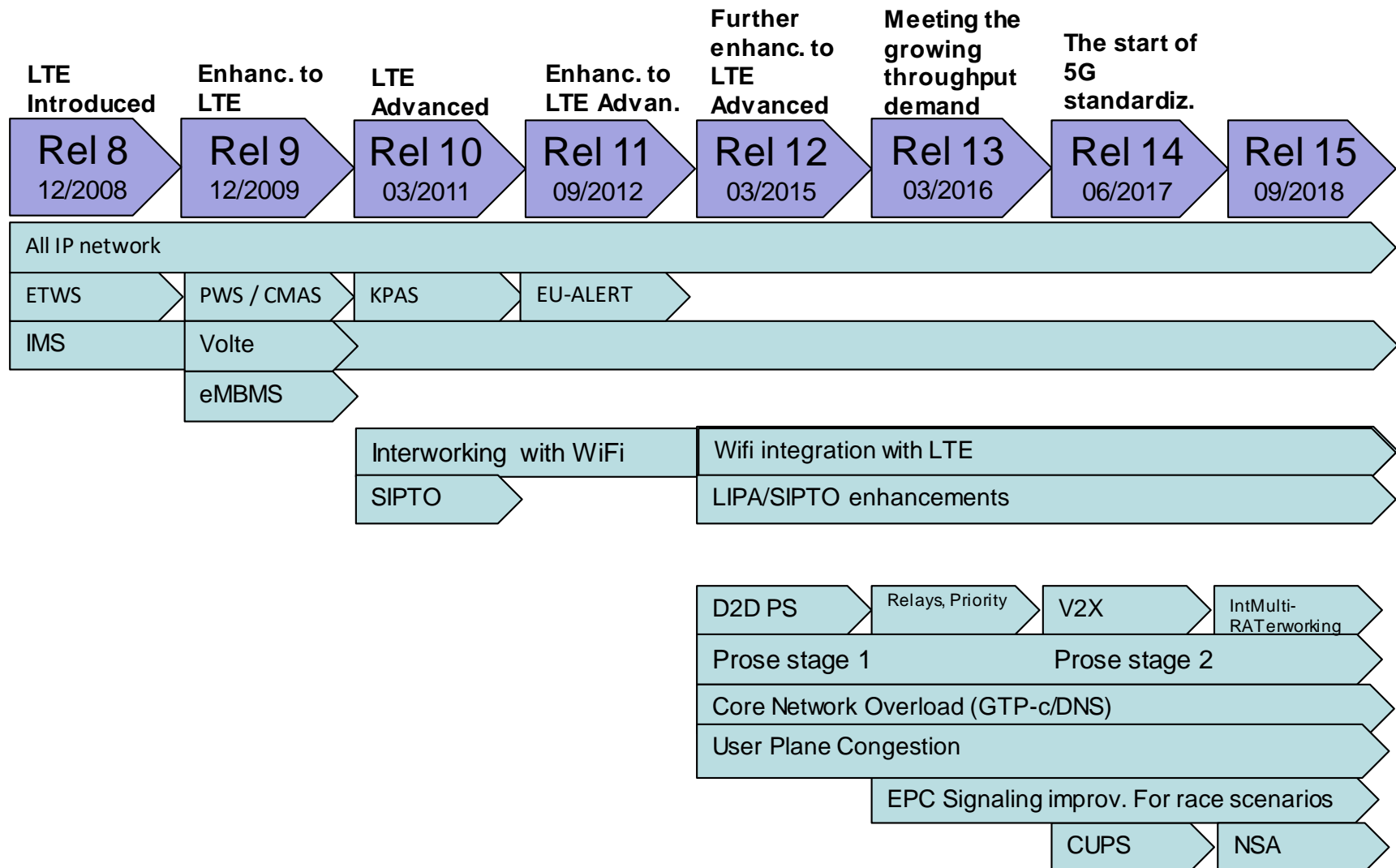


Figure 3: 3GPP and non-3GPP access networks

Core Network Fundamentals – schedule



Outline

- EPC fundamentals
- **OAI Core Network overview**
 - Architecture overview
 - Source Code
 - License
 - Deployment
- Recent developments
- OAI Core Network detailed
- Future plans

OAI EPC – Architecture overview

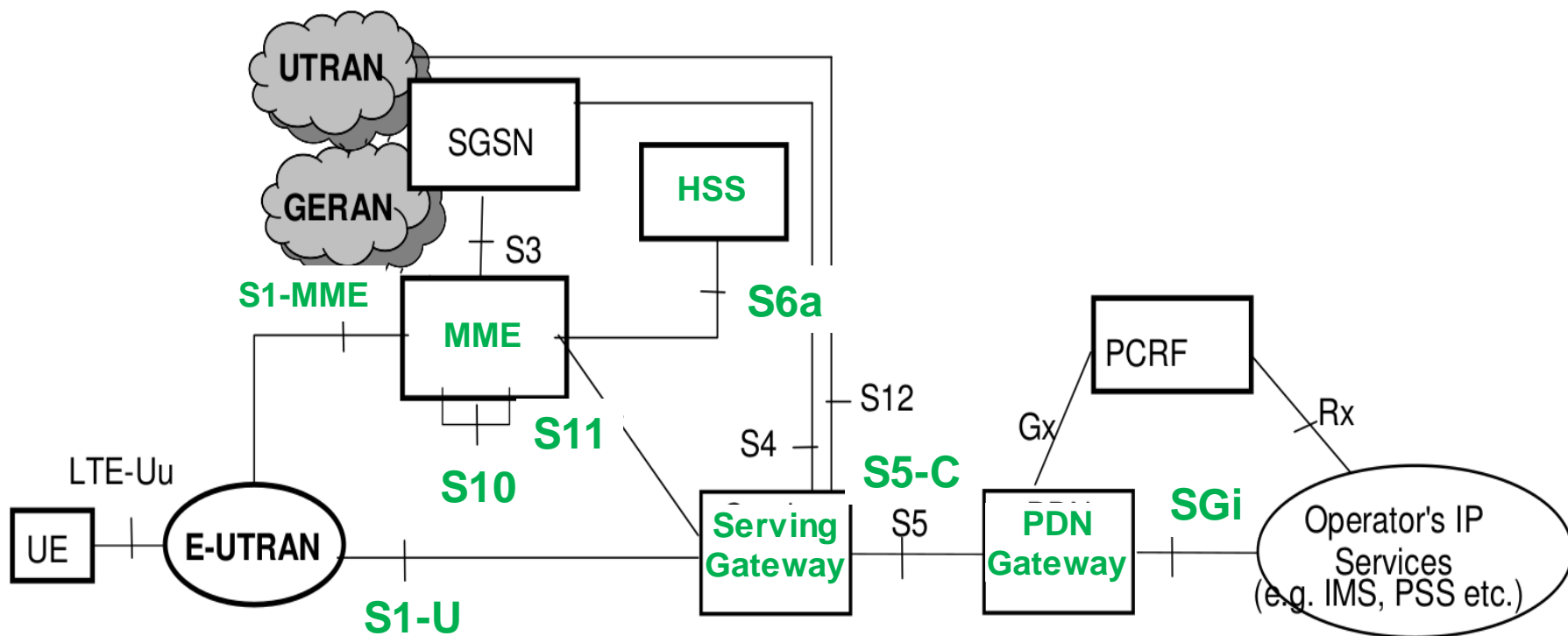


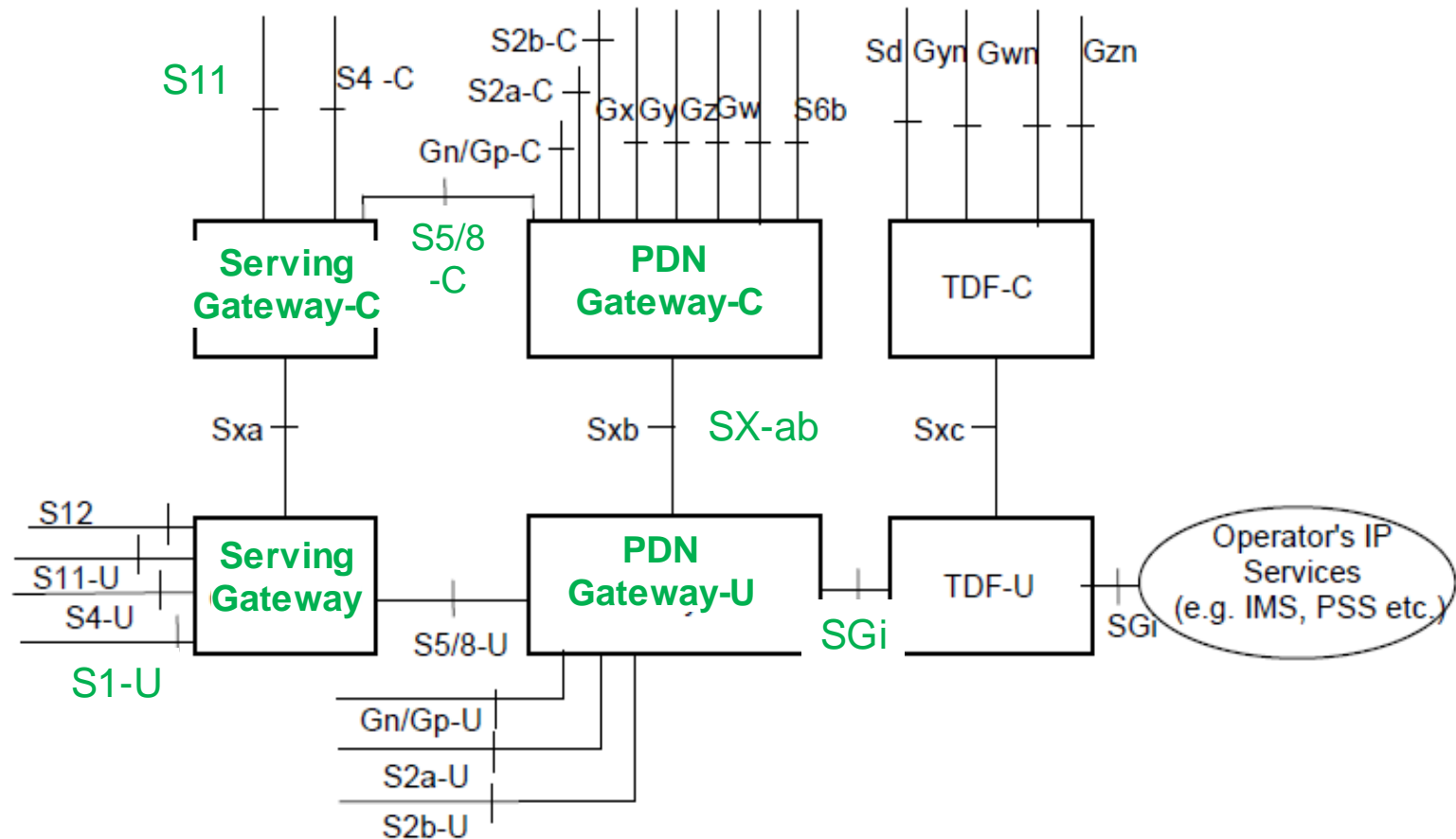
Figure 4.2.1-1: Non-roaming architecture for 3GPP accesses

OAI EPC – Architecture overview

23.214 version 15.4.0 Release 15

9

ETSI TS 123 214 V15.4.0



Architecture reference model with separation of user plane and control plane

OAI EPC – Architecture overview

3GPP TS 23.214 version 15.4.0 Release 15

10

ETSI TS 123 214 V15.4.0 (2018-09)

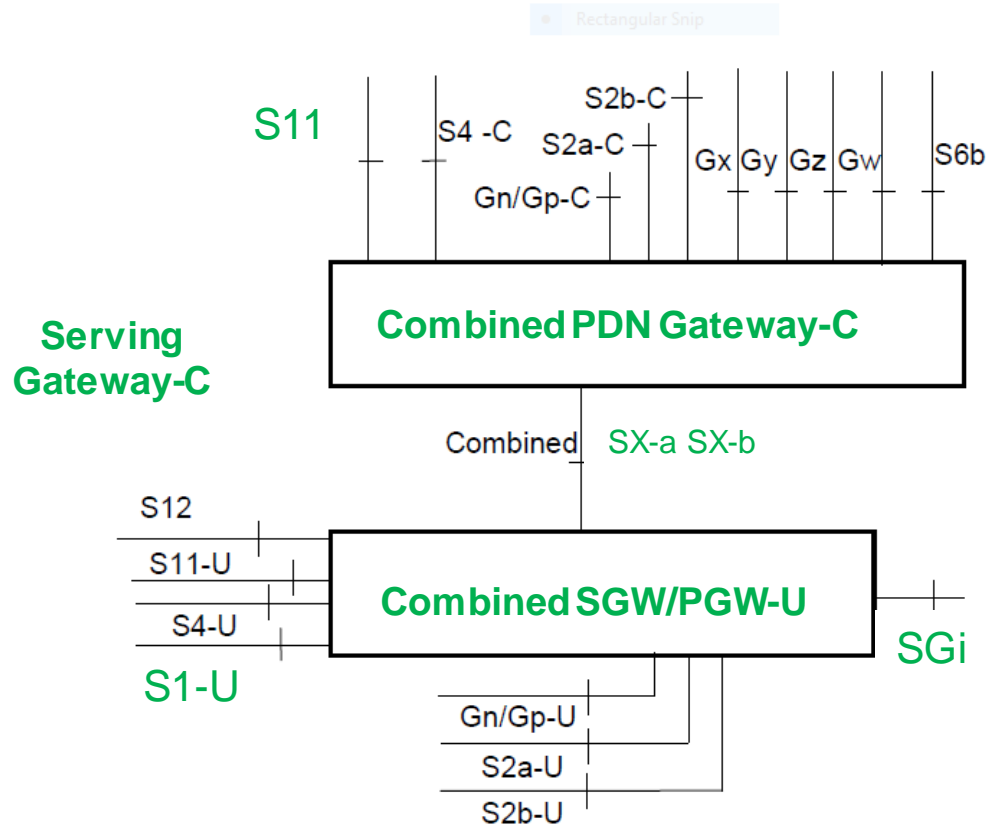


Figure 4.2.2-1: Architecture reference model with separation of user plane and control plane for a combined SGW/PGW

OAI Core Network – Source code

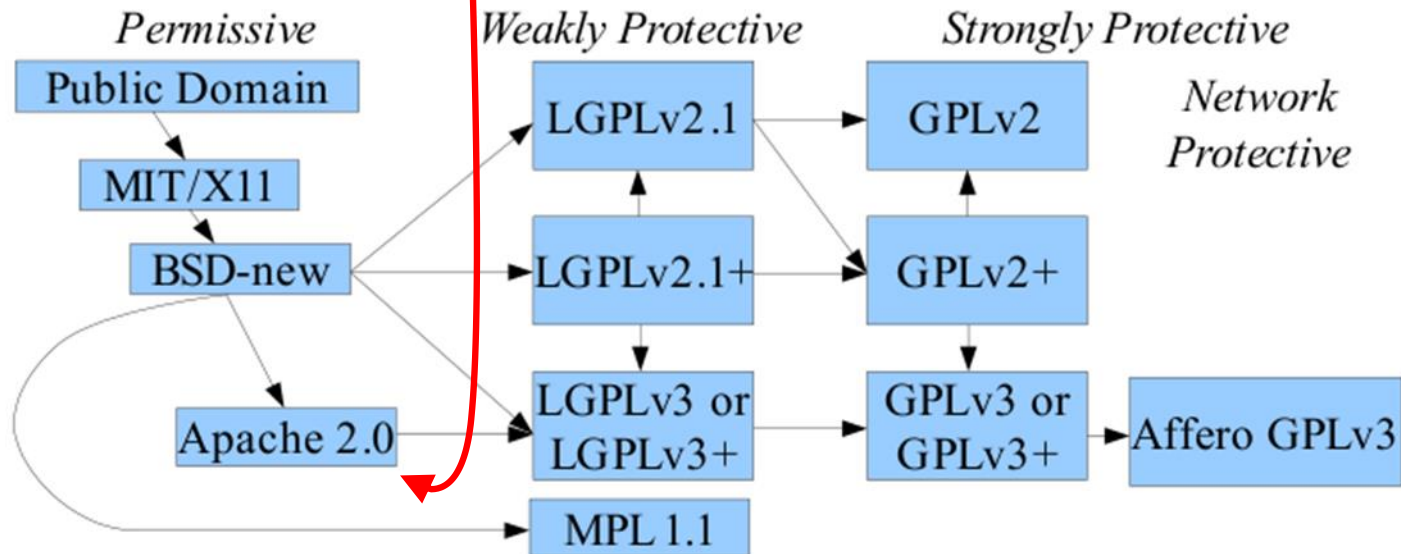
■ OAI Core network source code

- **Download** is free, no registration required.
 - GitHub main page
 - <https://github.com/OPENAIRINTERFACE/openair-cn>
<https://github.com/OPENAIRINTERFACE/openair-cn-cups>
- **Is open source**
 - all binaries can be generated from what is in the git repository, and on internet, for 3rd party software.
 - If there is generated source code in the repository, you will find the code generator in it.
- **Contribution is opened** to any people who signs the license agreement.

OAI Core Network – License

- **License is Apache v2 (differ from RAN)**

- Compatibility chart



Source: https://en.wikipedia.org/wiki/License_compatibility

OAI Core Network – License

■ License Apache v2

Cannot

- ▶ Hold Liable
- ▶ Use Trademark



Must

- ▶ Include Copyright
- ▶ Include License
- ▶ State Changes
- ▶ Include Notice



Can

- ▶ Commercial Use
- ▶ Modify
- ▶ Distribute
- ▶ Sublicense
- ▶ Private Use
- ▶ Use Patent Claims
- ▶ Place Warranty



Source: [https://tldrlegal.com/license/apache-license-2.0-\(apache-2.0\)](https://tldrlegal.com/license/apache-license-2.0-(apache-2.0))

OAI Core Network – License

- **Openair-cn-cups repository license is OAI Public License v1.1**
 - This repo contains code that can be reused as it is in 5G Core network (PFCP for example).
 - 5G Core network license is OAI Public License v1.1

OAI Core Network – Deployment

■ Target OS

- Linux, interest is no proprietary stacks, open-source.
- The OS target is Ubuntu 18.04 (Bionic).
- May be a plan for Centos in 2019.

■ Hardware requirements

- CPU:
 - Target is X86-64 (Intel, AMD).
 - No plans for ARM, we cannot guarantee the endianness-proof.
- RAM
 - Some work is needed there.
- Network interfaces
 - 1 network device may be a minimalistic solution.

■ Linux Kernel

- Any kernel that comes along the OS for all NFs is fine.
- (No more Kernel 4.9.x dependency for the SPGW data plane).

■ Practically

- You can deploy any Network Function on a PC, server, container or VM.

Outline

- EPC fundamentals
- OAI Core Network overview
- **Recent developments**
 - MME
 - SPGW
 - HSS (none)
- OAI Core Network detailed
- Future plans

Recent developments – MME (Blackned)

■ Actualizing the code:

- Merging different branches for most actual version (develop branch).
- Thereby rework on the whole code, reviewing the layers, contexts and procedures.
 - Clear separation between **EMM** and rest of the layers.

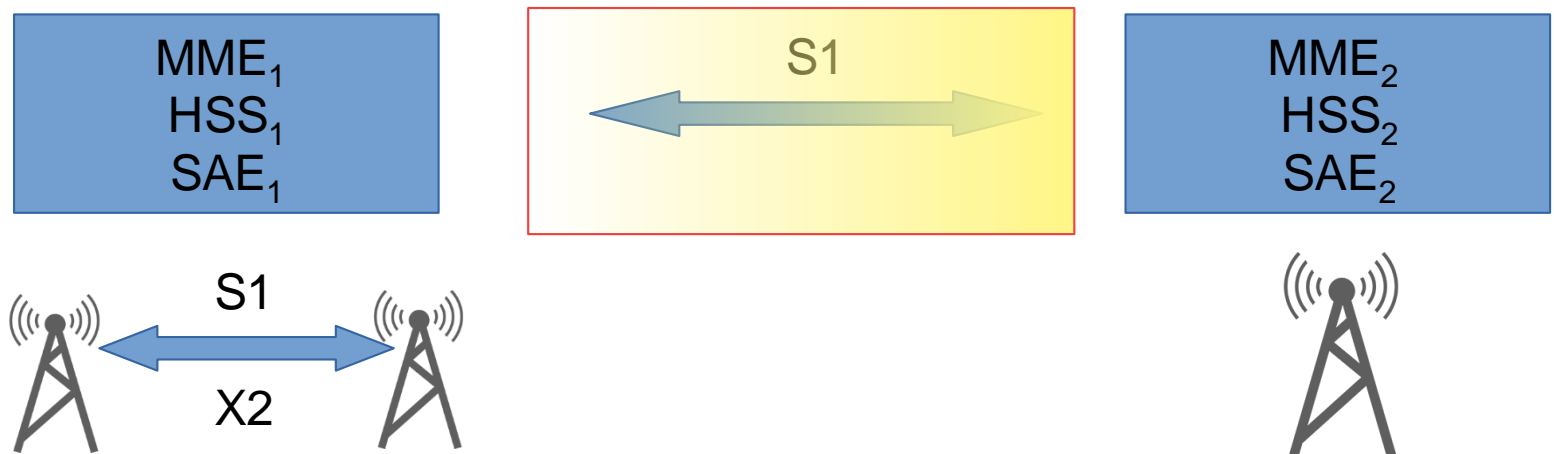
■ Stabilisation

- Burst attaches with NG4T, Out of coverage scenarios with real eNBs.

Recent developments – MME (Blackned)

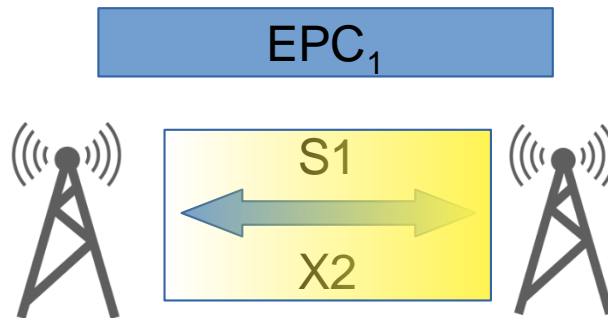
■ Inter-MME S1 Handover & S1-TAU:

- Fallback methods and validations: **VERY fault tolerant.**
 - Rejects, Missing Messages (TAC after HO, HO-Notify)
 - Failed Authorizations → Fallback to local security.
 - Return to local cell during handover.
 - Burst tests with NG4T.
- Multi-APN is supported, Multi-Bearer in works.



Recent developments – MME (Blackned)

- **Intra-MME S1 Handover & S1-TAU & X2:**
 - Up to 50 eNBs on a single node, same or different TAC.
 - X2 : No SP-GW relocation considered.



Recent developments – MME (Blackned)

Aktivitäten Chromium Mo, 10. Dez, 09:19

System - mup4 x System - mup-fr3 x ng40-bnd - ci_bne x (5) blackned GmbH x

Nicht sicher bned-ng40:8080/ng40gui/

Current: ng40-bnd Current: /home/ng40/ci_bned_mme

Test cases Counters Rates table Rates graph Configuration

Live Freeze Reset

☐ as
☒ bridge
☒ nas
☐ nasdcnr
☐ pkt
☐ pktas
☐ rate
☒ slap
☐ slgtpv1
☐ slscpt
☐ slscptpkt

> nas:

Attach Req. (r) (tx)	0 Serv. Req. (tx)	0 Intra MME Handin Req. (rx)	398
Attach Req. (tx)	201 Serv. Req. (rx)	0 Intra MME Handin Acc. (tx)	398
Attach Acc. (rx)	201 CSW (tx/rx)	0 Intra MME Handout Acc. (rx)	398
Attach Cmp. (tx)	201 EMM Status (tx/rx)	0 Inter MME Handout Req. (tx)	0
Attach Req. (rx)	0 PDN Conn. Req. (r) (tx)	0 Inter MME Handin Req. (rx)	0
Detach Req. (r) (tx)	0 PDN Conn. Req. (tx)	201 Inter MME Handin Acc. (tx)	0
Detach Req. (tx/rx)	200: 0 PDN Conn. Req. (rx)	0 Inter MME Handout Acc. (rx)	0
Detach Acc. (tx/rx)	0: 200 PDN Disc. Req. (r) (tx)	0 IRAT 3G Handout Req. (tx)	0
Auth. Req. (rx)	201 PDN Disc. Req. (tx)	0 IRAT 3G Handout Acc. (rx)	0
Auth. Res. (tx)	201 PDN Disc. Req. (rx)	0 IRAT 3G Handin Req. (rx)	0
Auth. Fail. (tx)	0 ESM Inf. Req. (tx)	201 IRAT 3G Handin Acc. (tx)	0
Auth. Req. (rx)	0 ESM Inf. Res. (tx)	201 IRAT 2G Handout Req. (tx)	0
Sec. Mode Cmd. (rx)	201 Act. Def. Bear. Req. (rx)	201 IRAT 2G Handout Acc. (rx)	0
Sec. Mode Cmp. (tx)	201 Act. Def. Bear. Acc. (tx)	201 IRAT 2G Handin Req. (rx)	0
Sec. Mode Rej. (tx)	0 Act. Def. Bear. Rej. (tx)	0 IRAT 2G Handin Acc. (tx)	0
Id. Req. (rx)	101 Act. Ded. Bear. Req. (rx)	0 Pathswitch X2 Req. (tx)	0
Id. Res. (tx)	101 Act. Ded. Bear. Acc. (tx)	0 Pathswitch X2 Acc. (rx)	0
Tau Req. (r) (tx)	0 Act. Ded. Bear. Rej. (tx)	0 Pathswitch X2 Fail. (rx)	0
Tau Req. (tx)	0 Modify Bear. Req. (rx)	0 SMS (4G) RP Ack (tx/rx)	0
Tau Req. Per. (tx)	0 Modify Bear. Acc. (tx)	0 SMS (4G) RP Data (tx/rx)	0
Tau Acc. (rx)	0 Modify Bear. Rej. (tx)	0 SMS (4G) RP Error (tx/rx)	0
Tau Cmp. (tx)	0 Deact. Bear. Req. (rx)	0 SMS (4G) Submit (tx)	0
Tau Rej. (rx)	0 Deact. Bear. Acc. (tx)	0 SMS (4G) Deliver (rx)	0
Intra MME TAU Idle (tx)	0 Bear. Res. All. Req. (r) (tx)	0 NB IoT CP Serv. Req. (tx)	0
Intra MME TAU Conn (tx)	0 Bear. Res. All. Req. (tx)	0 NB IoT Serv. Acc. (rx)	0
Inter MME TAU Idle (tx)	0 Bear. Res. All. Rej. (rx)	0 NB IoT ESM Data Transp. (tx/rx)	0
Inter MME TAU Conn (tx)	0 Bear. Res. Mod. Req. (r) (tx)	0 Attached Users	0
Inter RAT TAU Idle (tx)	0 Bear. Res. Mod. Req. (tx)	0 Active Users	0
Inter RAT TAU Conn (tx)	0 Bear. Res. Mod. Rej. (rx)	0 Active Default Contexts	0
Ext. Serv. Req. (tx)	0 Intra MME Handout Req. (tx)	398 Active Dedicated Contexts	0

> slap:

Total (tx/rx)	3617/2817	E-RAB Modify Failure (tx)	0
NAS Transport (tx/rx)	1093/ 904	E-RAB Modify Indication (tx)	0
Initial UE Message (tx)	213	E-RAB Modify Confirm (rx)	0
Initial Context Setup Request (rx)	201	E-RAB Release Command (rx)	0
Initial Context Setup Request CSFB EM (rx)	0	E-RAB Release Response (tx)	0
Initial Context Setup Response (tx)	201	E-RAB Release Failure (tx)	0
Initial Context Setup Failure (tx)	0	E-RAB Release Indication (tx)	0
UE Context Modif. Request (rx)	0	Path Switch Request (tx)	0
UE Context Modif. Request CSFB EM (rx)	0	Path Switch Request Ack (rx)	0
UE Context Modif. Response (tx)	0	Path Switch Request Failure (rx)	0
UE Context Modif. Failure (tx)	0	Handover Required (tx)	398
UE Context Modif. Indication (tx)	0	Handover Command (rx)	398
UE Context Modif. Confirm (rx)	0	Handover Prep. Failure (rx)	0
UE Context Release Request (tx)	0	Handover Request (tx)	398
UE Context Release Command (rx)	518	Handover Request Ack (tx)	398
UE Context Release Complete (tx)	518	Handover Request Ack Failure (tx)	0
E-RAB Setup Request (rx)	0	Handover Notify (tx)	398
E-RAB Setup Response (tx)	0	Handover Cancel (tx)	398
E-RAB Setup Failure (tx)	0	Handover Cancel Ack (rx)	0
E-RAB Modify Request (rx)	0	eNB Status Transfer (tx)	398
E-RAB Modify Response (tx)	0	MME Status Transfer (rx)	398

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Recent developments – MME (Blackned)

■ Dynamic QoS:

- Multiple Dedicated Bearer Establishment, Modification and Removal.
- Default Bearer QoS update based on PCRF authorized values.
- All TFT operations supported.
 - Fault Detection: Verifying Packet Filters and Precedences.
 - Update of TFT & filter rules, precedence, QoS, IP-Filter supported.
- Bearer QoS Update supported.
- Transaction based: Update of contexts only if success in access network.
- Congestion support.
 - Implicit Indicators : Handover/Service Request failures.
 - Explicit Indicator: Bearer Resource Command, Delete Bearer Command.

Recent developments – MME (Blackned)

■ Dynamic QoS (Handover):

- X2, S1 and S10 Handover, as well as idle TAU support dedicated bearers completely (session initiation on target side with dedicated bearers and bearer modification on the target side immediately after handover).
- Complete support for IPv6 filter rules and messaging.

Recent developments – MME (Blackned)

■ EMM/ESM separation

- Independent processing to reduce dependency errors.
- Towards an AMF/SMF like structure in the MME.
- No ESM context, only transactions.

■ IPv6 Testing

- S1, S11 and S10 interfaces are now IPv4 and IPv6 capable.
- Further bugfixes in UE IPv6 handling.

■ Valgrind Testing

- Fixed all known memory leaks.

■ Further Achievement

- Multi-APN
- Paging

Recent developments - SPGW

■ New SPGW and CUPS : Why ?

- Some RAN users had difficulties for installing and using the tagged v0.7.0 release of SPGW:
 - No NAT, Specific kernel version 4.9 that do not come with installed OS, need of at least 2 physical network devices.
- We had also some requirements from some members to maintain a separation between control and user plane.
- We had also to contribute to the dev of 5G blocks (PFCP)
- So the obvious option was to develop a CUPS SPGW in order to also have the benefit of starting to develop for 5G-CN (UPF).
- This v1.0.x release has no ambition for performance (handle big amount of users, data).
- The main objective is to be an easy to use SPGW.

Recent developments - SPGW

■ SPGW CUPS

- So SPGW is composed of almost 2 network functions:
 - 1 SPGW-C, 1 SPGW-U.
- Written entirely in C++ (-std=c++17).
 - Internal design still asynchronous (ITTI based API).
 - Use spdlog, libfolly (nolock collections).
- Difference with tag v0.7.0
 - Should handle GTP fragmentation (+)
 - NAT (based on iptables) (+)
 - Easy to install, no kernel dependency (+)
 - Switch talking natively PFCP. (+)
 - Data is copied/handled in user space (no zero copy) (--)
 - This enables us to do easily whatever we want to do with it. (+)

Outline

- EPC fundamentals
- OAI Core Network overview
- Recent developments
- **OAI Core Network detailed**
 - MME conformance functions
 - SPGW conformance functions
 - PFCP procedures
 - SPGW internals
- Future plans

OAI EPC – MME Available features

#	interfaces	Status	Comments	Protocols
1	S1-MME	V	Still rel 10 should be upgraded to rel 15 soon.	S1AP/SCTP
2	S11	V	should be upgraded to rel 15 soon	GTPv2-C/UDP
3	S3	X	To interface SGSN, not planned.	GTPv2-C/UDP
4	S6a	V	Still rel 14 should be upgraded to rel 15.	freeDiameter/TCP-SCTP
5	S10	V		GTPv2-C/UDP

OAI EPC – MME conformance functions 1/4

(3GPP TS 23.401 V15.5.0 §4.4.2)

#	Classification	Status	Comment
1	NAS signalling	V	
2	NAS signalling security	V	
3	Inter CN node signalling for mobility between 3GPP access networks (terminating S3)	X	Intra LTE HO only
4	UE Reachability in ECM-IDLE state (including control, execution of paging retransmission and optionally Paging Policy Differentiation)	V	We are working on this
5	Tracking Area list management	V	

OAI EPC – MME conformance functions 2/4

(3GPP TS 23.401 V15.5.0 §4.4.2)

#	Classification	Status	Comment
6	Mapping from UE location (e.g. TAI) to time zone, and signalling a UE time zone change associated with mobility	X	
7	PDN GW and Serving GW selection	V	spgw selection & neighboring MME selection via WRR
8	MME selection for handovers with MME change	V	S1 (inter (S10) and intra MME S1AP handover), X2 HO supported
9	SGSN selection for handovers to 2G or 3G 3GPP access networks	X	
10	Roaming (S6a towards home HSS)	X	
11	Authentication	V	Also NAS messages inside the S10 at mobility
12	Authorization	V	HSS (UE-AMBR + defaults), PCRF (APN/Bearer Level QoS)

OAI EPC – MME conformance functions 3/4

(3GPP TS 23.401 V15.5.0 §4.4.2)

#	Classification	Status	Comment
13	Bearer management functions including dedicated bearer establishment	V	Dedicated bearers are supported
14	Lawful Interception of signalling traffic	X	
15	Warning message transfer function (including selection of appropriate eNodeB)	X	
16	UE Reachability procedures	V	
17	Support Relaying function (RN Attach/Detach)	X	

OAI EPC – MME conformance functions 4/4 (3GPP TS 23.401 V15.5.0 §4.4.2)

#	Classification	Status	Comment
18	Change of UE presence in Presence Reporting Area reporting upon PCC request in the case of Change of UE presence in Presence Reporting Area reporting, management of Core Network pre-configured Presence Reporting Areas.	X	
19	For the Control Plane CloT EPS Optimisation a) transport of user data (IP and Non-IP); b) local Mobility Anchor point; c) header compression (for IP user data); d) ciphering and integrity protection of user data; e) Lawful Interception of user traffic not transported via the Serving GW (e.g. traffic using T6a).	X	Future : NB-IoT, SMS

OAI EPC – SGW conformance Interfaces

#	Interface	Status	Comment	Protocol
1	S5/S8	V/X	«Split in control plane only, missing split in User plane»	GTP-C/U
2	S1-U	V		GTP-U/UDP
3	S11	V	S11-C only actually	GTP-C/UDP
4	S4	X	No interconnection with SGSN	GTP-C/UDP
5	S12	X	No interconnexion with UTRAN	GTP-U/UDP

OAI EPC – SGW conformance functions 1/2

(3GPP TS 23.401 V15.5.0 §4.4.3.2)

#	Classification	Status	Comments
1	the local Mobility Anchor point for inter-eNodeB handover (except when user data is transported using the Control Plane CIoT EPS optimisation)	?	Should be, X2HO have to be tested.
2	sending of one or more "end marker" to the source eNodeB, source SGSN or source RNC immediately after the Serving GW switches the path during inter-eNodeB and inter-RAT handover, especially to assist the reordering function in eNodeB	X	Could be if requested.
3	Mobility anchoring for inter-3GPP mobility (terminating S4 and relaying the traffic between 2G/3G system and PDN GW)	X	No support of 2G and 3G systems.
4	ECM-IDLE mode downlink packet buffering and initiation of network triggered service request procedure and optionally Paging Policy Differentiation	X	buffering is not supported for paging in idle mode yet.
5	Lawful Interception	X	

OAI EPC – SGW conformance functions 2/2

(3GPP TS 23.401 V15.5.0 §4.4.3.2)

#	Classification	Status	Comments
6	Packet routing and forwarding	V	
7	Transport level packet marking in the uplink and the downlink, e.g. setting the DiffServ Code Point, based on the QCI, and optionally the ARP priority level, of the associated EPS bearer	X	could be supported quickly
8	Accounting for inter-operator charging. For GTP-based S5/S8, the Serving GW generates accounting data per UE and bearer	X	
9	Interfacing OFCS according to charging principles and through reference points specified in TS 32.240	X	
10	Forwarding of "end marker" to the source eNodeB, source SGSN or source RNC when the "end marker" is received from PDN GW and the Serving GW has downlink user plane established. Upon reception of "end marker", the Serving GW shall not send Downlink Data Notification.	X	

OAI EPC – PGW conformance interfaces

#	Interface	Status	Comment
1	GTP-based S5/S8	V	Available on control plane only.
2	Gx	X	Policy.
3	Gy interface	X	Charging.
4	SGi	V	

OAI EPC – PGW conformance functions 1/4

(3GPP TS 23.401 V15.5.0 §4.4.3.3)

#	Classification	Status	
1	Per-user based packet filtering (by e.g. deep packet inspection)	V	
2	Lawful Interception	X	
3	UE IP address allocation	V	Pools of IP addresses
4	Transport level packet marking in the uplink and downlink, e.g. setting the DiffServ Code Point, based on the QCI, and optionally the ARP priority level, of the associated EPS bearer	X	Could be done
5	Accounting for inter-operator charging: for home routed roaming, the P-GW shall collect and report the uplink and downlink data volume (per EPS bearer) as received from and sent to the serving node	X	

OAI EPC – PGW conformance functions 2/4

(3GPP TS 23.401 V15.5.0 §4.4.3.3)

#	Classification	Status	
6	UL and DL service level charging as defined in TS 23.203 (e.g. based on SDFs defined by the PCRF, or based on deep packet inspection defined by local policy)	X	
7	Interfacing OFCS through according to charging principles and through reference points specified in TS 32.240	X	
8	UL and DL service level gating control as defined in TS 23.203	X	Gating control shall be applied by the PCEF on a per service data flow basis
9	UL and DL service level rate enforcement as defined in TS 23.203 (e.g. by rate policing/shaping per SDF);	X	Could be implemented
10	UL and DL rate enforcement based on APN-AMBR (e.g. by rate policing/shaping per aggregate of traffic of all SDFs of the same APN that are associated with Non-GBR QCI);	X	Could be implemented
11	DL rate enforcement based on the accumulated MBRs of the aggregate of SDFs with the same GBR QCI (e.g. by rate policing/shaping);	X	
12	DHCPv4 (server and client) and DHCPv6 (client and server) functions	X	Contributions welcome for server.

OAI EPC – PGW conformance functions 3/4

(3GPP TS 23.401 V15.5.0 §4.4.3.3)

#	Classification	Status	
13	The network does not support PPP bearer type in this version of the specification. Pre-Release 8 PPP functionality of a GGSN may be implemented in the PDN GW	X	
14	The PDN GW may support Non-IP data transfer (e.g. with Clot EPS Optimizations)	X	
15	Packet screening	X	
16	sending of one or more "end marker" to the source SGW immediately after switching the path during SGW change;	X	No SPGW-U split
17	PCC related features (e.g. involving PCRF and OCS) as described in TS 23.203	X	

OAI Core Network – PGW conformance functions

4/4 (3GPP TS 23.401 V15.5.0 §4.4.3.3)

#	Classification	Status	
	Additionally the PDN GW includes the following functions for the GTP-based S5/S8:		
18	UL and DL bearer binding as defined in TS 23.203	X	
19	UL bearer binding verification as defined in TS 23.203	X	
20	Functionality as defined in RFC 4861	X	
21	Accounting per UE and bearer	X	

OAI Core Network – PFCP implementation

Node related procedures 1/2 (TS 3GPP 29.244v150300)

#	Classification	Status	
2	Heartbeat Procedure	V	
3	Load Control Procedure (optional)	X	
4	Overload Control Procedure (optional)	X	
5	PFCP PFD Management Procedure (optional)	X	
6.2	PFCP Association Setup Procedure Initiated by the CP Function	X	
6.3	PFCP Association Setup Initiated by the UP Function	V	

OAI Core Network – PFCP implementation

Node related procedures 2/2 (TS 3GPP 29.244v150300)

#	Classification	Status	
7	PFCP Association Update Procedure	?	
8	PFCP Association Release Procedure	?	
9	PFCP Node Report Procedure	X	

OAI Core Network – PFCP implementation

Session related procedures 1/2 (TS 3GPP 29.244v150300)

#	Classification	Status	
2	PFCP Session Establishment Procedure	V	
3	PFCP Session Modification Procedure	V	
4	PFCP Session Deletion Procedure	V	
5	PFCP Session Report Procedure	V	Paging only

OAI Core Network – PFCP implementation

■ PFCP main grouped IE family for controlling UE flows

➤ Packet Detection Rule

- containing information required to classify a packet arriving at the UP function

➤ Usage Reporting Rule (optional)

- defines how a packet shall be accounted as well as when and how to report the measurements.

➤ Forwarding Action Rule

- defines how a packet shall be forwarded, including packet encapsulation/decapsulation and forwarding destination.

➤ QoS Enforcement Rule

- defines how a packet shall be treated in terms of bit rate limitation and packet marking for QoS purposes.

➤ Usage Report generated by UP function (optional)

- inform the CP function about the measurement of an active URR or about the detection of application traffic of an active Packet Detection Rule

OAI Core Network – Existing functionality of SGW, PGW 1/6 (3GPP TS 23.214 V15.4.0 §4.3)

# A	Session Management Sub-functionality	SGW-C	SGW-U	PGW-C	PGW-U	
1	Resource management for bearer resources	X	X	X	X	
2	IP address and TEID assignment for GTP-U	X	V	X	V	
3	Packet forwarding	-	V	-	V	
4	Transport level packet marking	-	X	-	X	

OAI Core Network – Existing functionality of PGW 2/6 (3GPP TS 23.214 V15.4.0 §4.3)

# B	UE IP address management Sub-functionality	PGW-C	PGW-U	
1	IP address allocation from local pool	V	-	
2	DHCPv4 / DHCPv6 client	X	-	
3	DHCPv4 / DHCPv6 server	X	-	
4	Router advertisement, router solicitation, neighbour advertisement, neighbour solicitation (as in RFC 4861)	X	-	

OAI Core Network – Existing functionality of SGW, PGW

3/6 (3GPP TS 23.214 V15.4.0 §4.3)

# C	Support for UE Mobility Sub-functionality	SGW- C	SGW- U	PGW- C	PGW- U	
1	Forwarding of "end marker" (as long as user plane to source eNB exists)	-	X	-	-	
2	Sending of "end marker" after switching the path to target node	X	X	X	X	
3	Forwarding of buffered packet	X	X	-	-	
4	Change of target GTP-U endpoint within 3GPP accesses and non-3GPP access	V	-	X	-	X because no SPGW-U split

OAI Core Network – Existing functionality of SGW, PGW

4/6 (3GPP TS 23.214 V15.4.0 §4.3)

# D	S1-Release / Buffering / Downlink Data Notification Sub-functionality	SGW -C	SGW- U	PGW- C	PGW- U	
1	ECM-IDLE mode DL packet buffering; Triggering of Downlink Data Notification message generation per bearer (multiple, if DL packet received on higher ARP than previous DDN); Inclusion of DSCP of packet in DDN message for Paging Policy Differentiation	X	X	-	-	
2	Delay Downlink Data Notification Request (if terminating side replies to uplink data after UE service request before SGW gets updated)	X	-	-	-	Downlink Data Notification Request is implemented
3	Extended buffering of downlink data when the UE is in a power saving state and not reachable (high latency communication); dropping of downlink data (if MME has requested SGW to throttle downlink low priority traffic and if the downlink data packet is received on such a bearer (see clause 4.3.7.4.1a).	X	X	-	-	
4	PGW pause of charging procedure based on operator policy/configuration the SGW (failed paging, abnormal radio link release, number/fraction of packets/bytes dropped at SGW)	X	-	X	-	No Charging.

OAI Core Network – Existing functionality of SGW, PGW 5/6 (3GPP TS 23.214 V15.4.0 §4.3)

# E	Bearer/APN Policing Sub-functionality	SGW -C	SGW-U	PGW-C	PGW-U	
1	UL/DL APN-AMBR enforcement	-	-	-	X	Can be done
2	UL/DL bearer MBR enforcement (for GBR bearer).	-	-	-	X	When dedicated bearers
4	UL/DL bearer MBR enforcement (for nonGBR bearer on Gn/Gp interface)	-	-	-	X	Irrelevant

OAI Core Network – Existing functionality of SGW, PGW

6/6 (3GPP TS 23.214 V15.4.0 §4.3)

#	Functionality	SGW-C	SGW-U	PGW-C	PGW-U	
F	PCC related functions	-	-	X	X	
G	NBIFOM	X	-	X	-	(Network-Based IP Flow Mobility)
H	Inter-operator accounting (counting of volume and time)	X	X	X	X	
I	Load/overload control functions	-	-	-	-	See 29.244
J	Lawful interception	X	X	X	X	No Charging.
K	Packet screening function	-	-	-	X	
L	Restoration and recovery					See 29.244
M	RADIUS / Diameter on SGi	-	-	X	X	
N	OAM interfaces					See SA WG5 TS xx.xxx
O	GTP bearer and path management					As defined in CT WG4 TS 29.244

SPGW Detailed

- **SPGW tuning**

- Thread Scheduling Policy
 - Basic spgw-c/u configuration files have thread scheduling policies commented by default.
 - If you expect better responsiveness on control plane and less jitter and more speed on the data plane, uncomment them.
- Networking
 - You have to set the egress routing for user traffic.
 - You may have to create your custom routing table
 - For example

```
sudoer@spgwu# echo '200 lte1' | sudo tee --append /etc/iproute2/rt_tables
```

```
# Here the gateway is at 192.168.78.245
```

```
sudoer@spgwu# sudo ip r add default via 192.168.78.245 dev ens10 table lte1
```

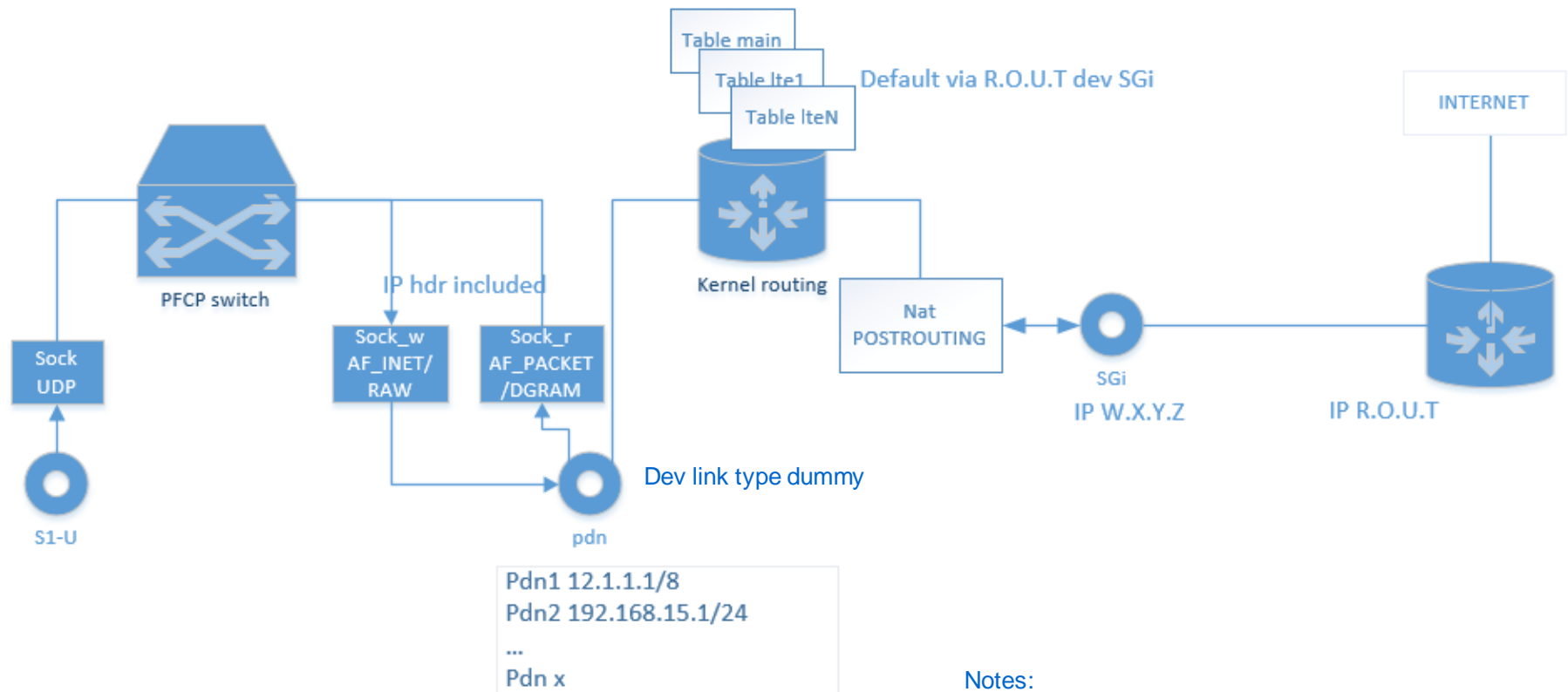
```
# you will have to repeat the following line for each PDN network set in your SPGW-U config file
```

```
sudoer@spgwu# sudo ip rule add from 12.0.0.0/8 table lte1
```

- User ingress routing is done seamless, due to internal 'pdn interface'.

Extra – SPGW-U internals

■ SPGW networking internals



Notes:

- S1-U and SGi network devices can be the same.
- SGi network device must be seen as a physical nw device.

Extra – MME testing pcap captures

- **PCAP Captures while testing MME**

- Temporary share:
 - <https://www.dropbox.com/sh/f3i8pl57qsvq6hi/AADcZ28jFubXZMEmMiT1aoffa?dl=0>
 - S10 HO with dedicated bearers
 - status_transfer_multi_bearer.pcapng (X2HO)
 - 50 eNBs multi handovers (S1, X2)
 - Cups 4G M2AS TCP

Outline

- OAI Core Network Overview
- Recent developments
- OAI Core Network detailed
- Future plans
- **Future plans**

CN Future Plans

☐ Multicast (eMBMS) Support for MME

- MCE (Multicast/Multicell Coordination Entity) implementation & integration with M3AP interfaces towards the MME and the eNBs.

☐ NSA mode (option 3) ASAP.

☐ ProSe ASAP.

☐ SPGW-U Zero-Copy solution (DPDK)

☐ LTE-M, SCEF ~mid 2020.

☐ Dedicated bearers (TO be confirmed).

QUESTIONS ?