










































OmniPGW



















































































OmniPGW - (PGW-C)

 *OmniTouch*     





















































































































1.  
 2.  
 3.    
 4.    
 5.  
 6.  
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 8.     
 9.    
 10.    
 11.  
 12.  
-



OmniPGW                               (EPC)                               **OmniTouch**                      

-     -                
- **IP**     -             
-         -  **PCRF**           
-        -  **PGW-U** (   )      

PGW-C

-     **SGW-C**                 **S5/S8**   (GTP-C)
 -                     **UE IP**  
 -   **Gx**   (Diameter)   **PCRF**     
 -   **Sxb**   (PFCP)   **PGW-U**       
 -                     **QoS**     **QoS**  
 -                    
-

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????

PGW-C ?? Elixir/OTP ??????????????????????

- ????? - ?????????????????
- ????? - ?????????
- ????? - ????? PDN ????? GenServer
- ????? - ????????? (IP?TEID?SEID ?)
- **PFCP** ????? - ????? PGW-U ????? PFCP ??

??

????

PGW-C ????? 3GPP ???

S5/S8 ?? (GTP-C v2)

??? SGW-C ? PGW-C ?????????

??? UDP ? GTP-C ?? 2

????

- ?????/??
- ?????/??
- ?????/??
- ?????/??

??? [S5/S8 ??](#)

Sxb ?? (PFCP)

??? PGW-C ? PGW-U ?????????

??? UDP ? PFCP (????????)

????

- ?????/??
- ?????/??
- ?????/??

- 222222/22
- 2222/22

222 222 [PFCEP/Sxb 2222](#)

Gx 22 (Diameter)

222 2222222222 (PCRF) 22

222 Diameter (IETF RFC 6733)

22222

- 2222222222/22 (CCR-I/CCA-I)
- 2222 22222222/22 (CCR-T/CCA-T)

222 222 [Diameter Gx 2222](#)

2222

PDN 22

PDN (22222222) 2222 UE 22222 (2222) 2222222222222222

- **UE IP** 22 - 222222222222
- **APN** (222222) - 2222222
- 222222 - 22 QoS 22222222
- **ID** - 222222222222
- **TEID** (2222 ID) - S5/S8 22222222
- **SEID** (2222 ID) - Sxb 22222222

222222

2222222222 QoS 22222222

- 22222 - 22 PDN 2222
- 22222 - 22222 QoS 22222222
- **EBI** (EPS 22 ID) - 222222222222
- **QoS** 22 - QCI 2 ARP 2222 (MBR 2 GBR)

PFCEP 22

PGW-C 2 PGW-U 222222222222

- **PDR** (22222222) - 222222 (22/22)
- **FAR** (22222222) - 22222222

- **QER** (QoS `QoS`) - `QoS`
- **BAR** (`QoS`) - `QoS`

`PFCP`

IP

UE IP

- `APN` - `APN`
- `IP` - `IP`
- `UE IP` - `UE IP`
- `IP` - `IP`

`UE_IP`

`?`

`?`

- Elixir ~1.16
- Erlang/OTP 26+
- `SGW-C`/`PGW-U` `PCRF`
- `LTE EPC`

OmniPGW

1. `config/runtime.exs`
2. `?`

```
mix deps.get
mix compile
```

3. `?`

```
mix run --no-halt
```

`?`

`?`

```
[info] OmniPGW...
[info] 127.0.0.42:42069
[info] 127.0.0.10 S5/S8
[info] 127.0.0.20 Sxb
[info] Gx
```

[info] PFCP
[info] OmniPGW

http://127.0.0.42:42069/metrics

?

config/runtime.exs

?

?

metrics	Prometheus		
diameter	Gx PCRF	Diameter Gx	
s5s8	GTP-C SGW-C	S5/S8	
sxb	PFCP PGW-U	PFCP	
ue	UE IP	IP	
pc		PCO	

Web UI - ?

OmniPGW **Web UI**

Web UI

http://<omnipgw-ip>:<web-port>/

?

	URL		
PGW	/pgw_sessions	PDN	2
PFCP	/pfcpsessions	PGW-U PFCP	2
UPF	/upf_status	PFCP	2
Diameter	/diameter	PCRF	1
	/logs		

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◇◇◇◇◇

- ◇◇◇◇◇◇◇◇ (◇◇◇◇◇◇◇◇)
- ◇◇ OmniPGW ◇◇◇◇◇◇◇◇
- ◇◇◇◇◇◇◇◇◇◇ (◇◇/◇◇)

◇◇◇◇◇◇

- ◇ IMSI ◇ IP ◇ MSISDN ◇ APN ◇◇◇◇
- ◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇

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- ◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇
- ◇◇◇◇◇◇◇◇◇◇◇◇
- ◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇

◇◇◇◇◇◇◇ (◇◇◇◇)◇

- ◇◇◇◇◇◇◇◇◇◇◇◇
- ◇◇◇◇◇ NOC/◇◇◇◇◇◇◇◇
- ◇◇◇◇◇◇◇ IP ◇◇◇◇◇◇◇◇

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1. ◇◇◇◇◇◇◇◇◇◇
2. ◇◇ PGW ◇◇◇◇◇
3. ◇ IMSI ◇◇◇◇◇◇◇◇◇◇
4. ◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇
 - ◇◇◇◇ UE IP ◇◇
 - ◇◇ PCRF ◇ QoS ◇◇
 - ◇◇◇◇◇◇◇◇◇◇
5. ◇◇◇◇◇◇◇◇ → ◇◇ Diameter ◇◇◇◇◇◇◇◇ PCRF ◇◇◇◇

◇◇◇◇◇◇◇◇◇◇◇◇◇◇

1. ◇◇ UPF ◇◇◇◇◇ → ◇◇◇◇◇ PGW-U ◇◇◇◇◇ "◇◇"
2. ◇◇ Diameter ◇◇ → ◇◇◇◇◇ PCRF ◇◇◇◇◇◇◇ "◇◇◇◇"
3. ◇◇ PGW ◇◇ → ◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇◇

◇◇◇◇◇◇

- ◇◇ PGW ◇◇◇◇◇
- ◇◇◇◇◇/◇◇◇◇◇◇◇◇◇◇◇◇◇◇

- [?][?][?][?][?][?][?][?]
- [?][?][?] APN [?][?][?][?][?]

Web UI [?][?][?]

[?][?] Web UI [?][?][?]

- [?][?][?][?][?][?][?][?]
- [?][?][?][?][?][?][?]
- [?][?][?][?][?][?]
- [?][?][?][?][?][?][?][?][?]
- [?][?][?][?]

[?][?] Prometheus [?][?][?][?][?]

- [?][?][?][?]
- [?][?][?][?][?]
- [?][?][?][?][?]
- [?][?][?][?]
- [?][?][?][?]

[?][?][?][?][?] [?][?][?][?][?][?] - Web UI [?][?][?][?][?][?] Prometheus [?][?][?][?][?][?][?][?]

[?][?][?][?][?]

[?][?] Web UI [?] OmniPGW [?][?][?][?][?] Prometheus [?][?][?][?][?][?][?][?][?]

[?][?][?][?]

- [?][?][?][?]
 - teid_registry_count - [?][?] S5/S8 [?][?]
 - seid_registry_count - [?][?] PFCP [?][?]
 - session_id_registry_count - [?][?] Gx [?][?]
 - address_registry_count - [?][?][?] UE IP [?][?]
 - charging_id_registry_count - [?][?][?][?] ID
- [?][?][?][?]
 - s5s8_inbound_messages_total - [?][?][?][?] GTP-C [?][?]
 - sxb_inbound_messages_total - [?][?][?][?] PFCP [?][?]
 - gx_inbound_messages_total - [?][?][?][?] Diameter [?][?]
 - [?][?][?][?][?][?][?][?][?][?]
- [?][?][?][?]
 - s5s8_inbound_errors_total - S5/S8 [?][?][?][?]

- `sxb_inbound_errors_total` - PFCP
- `gx_inbound_errors_total` - Diameter

?

HTTP

```
curl http://127.0.0.42:42069/metrics
```

?

?

OmniPGW

?

OmniPGW

```

├── OPERATIONS.md ( )
├── docs/
│   ├── configuration.md           runtime.exs
│   ├── ue-ip-allocation.md       IP
│   └── pco-configuration.md      DNS-P-CSCF-MTU
│   ├── pfcpc-interface.md       Sxb/PFCP (PGW-U)
│   ├── diameter-gx.md           Gx (PCRF)
│   ├── diameter-gy.md           Gy/Ro (OCS)
│   └── s5s8-interface.md        S5/S8 (SGW-C)
│   ├── session-management.md    PDN
│   └── monitoring.md            Prometheus

```

?

?

?

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?

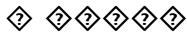
[OPERATIONS.md](#) ()



[configuration.md](#) runtime.exs 1,600+
[ue-ip-allocation.md](#) UE IP 943
[pco-configuration.md](#) (DNS P-CSCF MTU) 344



[pfcg-interface.md](#) PFCP/Sxb PGW-U 1,355
[diameter-gx.md](#) Diameter Gx PCRF () 941
[diameter-gy.md](#) Diameter Gy/Ro OCS () 1,100+
[s5s8-interface.md](#) GTP-C S5/S8 SGW-C 456



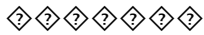
[session-management.md](#) PDN 435
[monitoring.md](#) Prometheus Grafana 807



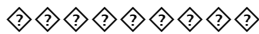
Mermaid

Mermaid

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- 2 2 2 2 3
- 2 2 2 2

2 2 2 2 2

2 2 2 2 2 2 2 2 2 2 2 2 2 2 2

2 2 2 2

2 2 2 2 2 2

1. [OPERATIONS.md](#) - 2 2 (2 2 2)
2. [configuration.md](#) - 2 2
3. [monitoring.md](#) - 2 2
4. [session-management.md](#) - 2 2 2 2

2 2 2 2 2 2

1. [OPERATIONS.md](#) - 2 2 2 2 (2 2 2)
2. [pfcf-interface.md](#) - 2 2 2 2 2 2
3. [diameter-gx.md](#) - 2 2 2 2
4. [diameter-gy.md](#) - 2 2 2 2
5. [s5s8-interface.md](#) - 2 2 2 2
6. [ue-ip-allocation.md](#) - IP 2 2

2 2 2 2 2 2

1. [configuration.md](#) - 2 2 2 2
2. [ue-ip-allocation.md](#) - IP 2
3. [pco-configuration.md](#) - 2 2 2 2
4. [monitoring.md](#) - 2 2 2 2

2 2 2 2

- 2 2 2 2 2 10
- 2 2 2 2 ~7,300+
- 2 2 2 2 ~180 KB
- **Mermaid** 2 2 2 65+
- 2 2 2 2 2 120+

2 2 2 2 2 2 2

2 2

- 2 2 2 / 2 2 2 2 2 2
- 2 OTP/Elixir 2 2

- 2 2 2 2 2
- 2 2 2 GenServer 2 2 2

2 2

- 2 PFCP (2 2 2 2 2 2 2 2)
- 2 GTP-C v2 (2 2 2 2 2 2 2 2 2 2 2 2)
- 2 Diameter (RFC 6733)

3GPP 2 2

- 2 Sxb (PGW-C ↔ PGW-U)
- 2 Gx (PGW-C ↔ PCRF)
- 2 Gy/Ro (PGW-C ↔ OCS)
- 2 S5/S8 (SGW-C ↔ PGW-C)

2 2

- 2 2 2 2 2
- 2 IP 2 2 2 2
- 2 QoS 2 2
- 2 2 2 2 2
- 2 2 2 2 2 2

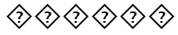
2 2 2 2

3GPP 2 2

- 2 2 TS 29.274 GTP-C v2 (S5/S8 2 2)
- 2 2 TS 29.244 PFCP (Sxb 2 2)
- 2 2 TS 29.212 Diameter Gx 2 2 (2 2 2 2)
- 2 2 TS 32.299 Diameter 2 2 2 2 (Gy/Ro)
- 2 2 TS 32.251 2 2 2 2 2 2
- 2 2 TS 23.401 EPC 2 2

2 2 2 2

- 2 2 2 2 2 2 2 [README.md](#)
- 2 2 2 2 2 [config/runtime.exs](#)



1. docs/ Markdown
2. Mermaid
- 3.
- 4.
5. OPERATIONS.md



- [GitHub](#)
- [Mermaid](#)
- [OPERATIONS](#)



OmniPGW

- ~~OmniPGW~~
- ~~OmniPGW~~
- ~~OmniPGW~~
- ~~OmniPGW~~

OmniPGW - LTE







OmniTouch

1.0 2025-10-29







































OmniPGW























runtime.exe      

 *OmniTouch*     





 

1. [!\[\]\(8c4dca64662d21542001ca0ed7eeb688_img.jpg\) !\[\]\(3de35c640e7147a3fb61ee393128d2ae_img.jpg\)](#)
2. [!\[\]\(d1438aeefda19c86ae7477bf1fb30796_img.jpg\) !\[\]\(dc4d2c544087998b6f093f485f5119d7_img.jpg\) !\[\]\(f26ab61dd00ea7e5f19553908ec3fa6b_img.jpg\) !\[\]\(ecf85e064bcd351a8999f71bf3f405e7_img.jpg\) !\[\]\(b7205a03f3dd3fe6f731085a326bb0d6_img.jpg\) !\[\]\(fea63d7e313047478d89177e38e2c72d_img.jpg\)](#)
3. [!\[\]\(3098c5e72378a1b0482fcc457c248f36_img.jpg\) !\[\]\(bdd076fceb1bd6f84cb17f8d6a04e32c_img.jpg\) !\[\]\(df648e0ad6c7cc181c595a3b5826b4ad_img.jpg\) !\[\]\(880be622b9312c3384b9a4cbb8f9cbc6_img.jpg\)](#)
4. [Diameter/Gx](#)  
5. [S5/S8](#)  
6. [Sxb/PFCP](#)  
 - [UPF](#)    
 -   [UPF](#)    
 -   [DNS](#)  
 -    
7. [UE IP](#)  
8. [PCO](#)  
9. [Web UI](#)  
10.   
11.   

OmniPGW    config/runtime.exe                   

-      -     
-    -   
-     -    
-     -    

◆◆◆◆◆

◆◆◆◆

```

pgw_c/
├── config/
│   ├── config.exs      # 2222222 runtime.exs
│   ├── dev.exs        # 22222
│   ├── prod.exs       # 22222
│   └── runtime.exs    # ← 22222

```

◆◆◆◆

```

# config/runtime.exs
import Config

config :logger, level: :info

config :pgw_c,
  metrics: %{...},
  diameter: %{...},
  s5s8: %{...},
  sxb: %{...},
  ue: %{...},
  pco: %{...}

```

◆◆◆◆

◆◆◆◆

◆◆

◆◆ Prometheus ◆◆◆◆◆◆◆◆ OmniPGW◆

◆◆◆

```

config :pgw_c,
  metrics: %{
    # 22/2222222
    enabled: true,

    # 22 HTTP 2222 IP 22
    ip_address: "0.0.0.0",

    # 2222222

```

```
port: 9090,  
  
# registry_poll_period_ms: 10_000  
}
```

◆◆

```
enabled          true  
ip_address       "0.0.0.0" =  
port             9090    /metrics HTTP  
registry_poll_period_ms 10_000
```

◆◆

◆◆ - ◆◆◆◆◆ IP◆

```
metrics: %  
  enabled: true,  
  ip_address: "10.0.0.20", #  
  port: 9090,  
  registry_poll_period_ms: 5_000 # 5  
}
```

◆◆ - ◆◆◆◆◆◆◆

```
metrics: %  
  enabled: true,  
  ip_address: "127.0.0.1",  
  port: 42069, #  
  registry_poll_period_ms: 10_000  
}
```

◆◆◆◆◆

```
metrics: %  
  enabled: false  
}
```

◆◆◆◆◆

```
#  
curl http://<ip_address>:<port>/metrics
```

```
#  
curl http://10.0.0.20:9090/metrics
```


◆◆◆◆◆

	◆◆		◆◆	◆◆	◆◆
host		◆◆◆◆	FQDN	◆◆	PCRF Diameter
realm		◆◆◆◆◆		◆	PCRF
ip		◆◆◆◆	IP	◆	PCRF IP
initiate_connection	◆◆			◆	OmniPGW
				◆◆◆◆◆	PCRF

FQDN ◆◆

Diameter ◆◆◆◆◆ FQDN◆

```
# ◆◆
host: "omnipgw.epc.mnc001.mcc001.3gppnetwork.org"
```

```
# ◆◆
host: "omnipgw" # ◆◆ FQDN
host: "10.0.0.20" # ◆◆◆◆ IP
```

3GPP ◆◆◆

```
<hostname>.epc.mnc<MNC>.mcc<MCC>.3gppnetwork.org
```

```
◆◆◆
- omnipgw.epc.mnc001.mcc001.3gppnetwork.org (MCC=001, MNC=001)
- pgw-c.epc.mnc260.mcc310.3gppnetwork.org (MCC=310, MNC=260 - ◆◆ T-Mobile)
```

◆◆

◆◆ PCRF◆

```
diameter: %{
  listen_ip: "0.0.0.0",
  host: "omnipgw.epc.mnc001.mcc001.3gppnetwork.org",
  realm: "epc.mnc001.mcc001.3gppnetwork.org",
  peer_list: [
    %{
      host: "pcrf.epc.mnc001.mcc001.3gppnetwork.org",
      realm: "epc.mnc001.mcc001.3gppnetwork.org",
      ip: "10.0.0.30",
      initiate_connection: true
    }
  ]
}
```

◆◆ PCRF◆◆◆◆◆

```
diameter: %{
  listen_ip: "0.0.0.0",
  host: "omnipgw.epc.mnc001.mcc001.3gppnetwork.org",
  realm: "epc.mnc001.mcc001.3gppnetwork.org",
  peer_list: [
    %{
      host: "pcrf-primary.epc.mnc001.mcc001.3gppnetwork.org",
      realm: "epc.mnc001.mcc001.3gppnetwork.org",
      ip: "10.0.1.30",
      initiate_connection: true
    },
    %{
      host: "pcrf-backup.epc.mnc001.mcc001.3gppnetwork.org",
      realm: "epc.mnc001.mcc001.3gppnetwork.org",
      ip: "10.0.2.30",
      initiate_connection: true
    }
  ]
}
```

PCRF ❖❖❖❖❖

```
diameter: %{
  listen_ip: "0.0.0.0",
  host: "omnipgw.epc.mnc001.mcc001.3gppnetwork.org",
  realm: "epc.mnc001.mcc001.3gppnetwork.org",
  peer_list: [
    %{
      host: "pcrf.epc.mnc001.mcc001.3gppnetwork.org",
      realm: "epc.mnc001.mcc001.3gppnetwork.org",
      ip: "10.0.0.30",
      initiate_connection: false # ❖❖ PCRF ❖❖
    }
  ]
}
```

❖❖ [Diameter Gx](#) ❖❖❖❖

S5/S8 ❖❖

❖❖

❖❖ GTP-C ❖❖❖❖ SGW-C ❖❖❖❖

❖❖❖

```
config :pgw_c,
```

```
s5s8: %{
  # S5/S8 IPv4
  local_ipv4_address: "10.0.0.20",

  # IPv6
  local_ipv6_address: nil,

  # GTP-C UDP 2123
  local_port: 2123
}
```

◆◆

```

      ◆◆          ◆◆          ◆◆          ◆◆
local_ipv4_address IPv4 S5/S8 IPv4
local_ipv6_address IPv6 nil S5/S8 IPv6
local_port          2123 GTP-C UDP 2123
```

◆◆◆◆

- GTP-C 2
- UDP
- 2123
- SGW-C

◆◆

◆ IPv4

```
s5s8: %{
  local_ipv4_address: "10.0.0.20"
}
```

IPv4 + IPv6

```
s5s8: %{
  local_ipv4_address: "10.0.0.20",
  local_ipv6_address: "2001:db8::20"
}
```

◆◆◆◆◆◆◆◆◆◆

```
s5s8: %{
  local_ipv4_address: "10.0.0.20",
  local_port: 2124 #
}
```

◆◆◆◆

IP ◆◆◆◆◆

- ◆◆◆◆◆/◆◆◆◆
- ◆◆◆◆ SGW-C ◆◆◆◆
- ◆◆◆◆ VRRP/HSRP ◆◆◆◆◆◆◆◆◆◆

◆◆◆◆◆

```
# ◆◆◆◆ SGW-C ◆ GTP-C
iptables -A INPUT -p udp --dport 2123 -s <sgw_c_network> -j ACCEPT
```

Sxb/PFCP ◆◆

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◆◆ PFCP ◆◆◆◆ PGW-U◆◆◆◆◆◆◆◆◆◆

◆◆◆

```
config :pgw_c,
  sxb: %{
    # PFCP ◆◆◆◆◆ IP ◆◆
    local_ip_address: "10.0.0.20",

    # ◆◆◆◆◆◆◆ PFCP ◆◆◆◆8805◆
    local_port: 8805
  }
```

◆◆

```
      ◆◆          ◆◆          ◆◆          ◆◆
local_ip_address◆◆◆◆IP◆◆ PFCP◆◆◆◆
local_port      ◆◆          8805 PFCP UDP◆◆
```

◆◆◆

- ◆◆ **UPF** ◆◆◆◆◆◆◆◆ **upf_selection** ◆◆◆◆◆ + ◆◆◆◆◆◆◆◆◆◆
- ◆◆◆◆◆ UPF ◆◆◆◆◆◆◆◆◆◆
 - ◆◆◆◆◆◆◆◆◆◆ "UPF-<ip>:<port>"
 - ◆◆ PFCP ◆◆◆◆◆◆ UPF ◆◆◆◆
 - 5 ◆◆◆◆◆◆◆◆
- UPF ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ [UPF ◆◆◆◆◆](#)
- ◆◆◆◆◆ UPF ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ DNS ◆◆◆◆ UPF

◆◆

◆◆◆◆◆

```
sxb: %{  
  local_ip_address: "10.0.0.20"  
}
```

```
# ◆◆◆ upf_selection ◆◆ UPF ◆◆◆◆◆◆◆◆  
# - ◆◆◆◆◆◆◆◆ "UPF-10.0.0.21:8805"  
# - ◆◆ PFCP ◆◆◆◆◆◆◆◆ UPF ◆◆◆  
# - 5 ◆◆◆◆◆◆◆◆
```

◆◆◆ **PFCP** ◆◆◆

```
sxb: %{  
  local_ip_address: "10.0.0.20",  
  local_port: 8806 # ◆◆◆ PFCP ◆◆  
}
```

◆ **UPF** ◆◆◆◆◆◆◆◆

```
sxb: %{  
  local_ip_address: "10.0.0.20"  
},  
upf_selection: %{  
  rules: [  
    %{  
      name: "IMS Pool",  
      priority: 10,  
      match_field: :apn,  
      match_regex: ~r/^ims$/,  
      upf_pool: [  
        100},  
        100} {remote_ip_address: "10.0.1.21", remote_port: 8805, weight:  
        100} {remote_ip_address: "10.0.1.22", remote_port: 8805, weight:  
        100}  
      ]  
    },  
    ],  
  fallback_pool: [  
    100} {remote_ip_address: "10.0.2.21", remote_port: 8805, weight: 100}  
  ]  
}  
# ◆◆ 3 ◆ UPF◆10.0.1.21, 10.0.1.22, 10.0.2.21◆◆◆◆◆◆◆◆
```

◆◆ **DNS** ◆◆◆◆◆◆◆◆◆◆

```
sxb: %{
```

```

local_ip_address: "10.0.0.20"
},
upf_selection: %{
  dns_enabled: true,
  dns_query_priority: [:ecgi, :tai],
  dns_suffix: "epc.3gppnetwork.org",
  fallback_pool: [
    %{remote_ip_address: "10.0.2.21", remote_port: 8805, weight: 100}
  ]
}
# DNS [?] UPF [?]

```

UPF [?][?][?][?]

[?][?][?]UPF [?][?][?][?][?][?][?][?][?] UPF [?][?][?][?] upf_selection [?][?][?][?][?][?][?][?]

[?][?][?][?]

UPF [?][?][?] upf_selection [?][?][?][?][?][?][?][?]

1. [?][?][?][?] - [?][?][?][?][?][?][?][?][?][?][?][?][?][?][?]
2. **DNS** [?][?] - [?][?][?][?][?][?][?][?][?] UPF [?][?]
3. [?][?][?] - [?][?][?][?][?][?][?][?][?] DNS [?][?][?][?][?][?][?][?]

[?][?][?][?][?][?][?][?]

1. [?][?][?][?][?][?][?][?][?][?][?][?][?] - [?][?][?][?][?][?][?][?][?][?][?][?][?][?][?]
2. [?][?] **DNS** [?][?][?][?][?][?][?][?][?][?][?] - [?][?][?][?][?][?][?][?] UPF [?][?]
3. [?][?][?][?][?][?][?][?][?][?][?] - [?][?][?][?][?][?][?][?] DNS [?][?][?][?][?][?][?][?]

UPF [?][?][?][?][?][?]

[?][?][?][?][?][?][?][?]

[?]

	[?][?][?][?]	[?][?]	[?][?][?][?]
:imsi	[?][?][?][?][?][?][?][?]	[?][?]	^313380.*([?][?][?][?])
:apn	[?][?][?][?][?][?][?][?]	/ DNN	^internet\. [?] ^ims\.
:serving_network_plmn_id	[?][?][?][?][?][?][?][?]		^313380\$
:sgw_ip_address	SGW IP [?][?]		^10\.100\..*
:uli_tai_plmn_id	[?][?][?] PLMN ID		^313.*
:uli_ecgi_plmn_id	E-UTRAN [?][?] PLMN ID		^313.*


```

sxb: %{
  local_ip_address: "127.0.0.20"
},

# UPF 10.100.2.21 - 10.100.2.22 UPF 10.100.3.21
upf_selection: %{
  # 10.100.2.21 DNS 10.100.2.21
  dns_enabled: false,
  dns_query_priority: [:ecgi, :tai, :rai, :sai, :cgi],
  dns_suffix: "epc.3gppnetwork.org",
  dns_timeout_ms: 5000,

  # 10.100.2.21 10.100.2.22 10.100.3.21
  rules: [
    # 10.100.2.21 IMS 10.100.2.21 - 10.100.2.22
    %{
      name: "IMS 10.100.2.21",
      priority: 20,
      match_field: :apn,
      match_regex: "^ims",
      upf_pool: [
        weight: 80,
        %{remote_ip_address: "10.100.2.21", remote_port: 8805,
weight: 20}
        %{remote_ip_address: "10.100.2.22", remote_port: 8805,
weight: 20}
      ]
    },

    # 10.100.3.21 APN
    %{
      name: "10.100.3.21",
      priority: 15,
      match_field: :apn,
      match_regex: "^(enterprise|corporate)\.apn",
      upf_pool: [
weight: 100}
        %{remote_ip_address: "10.100.3.21", remote_port: 8805,
weight: 100}
      ]
    },

    # 10.100.3.21 10.100.1.21 - 10.100.1.21
    %{
      name: "10.100.3.21",
      priority: 5,
      match_field: :apn,
      match_regex: "^internet",
      upf_pool: [
weight: 33},
        %{remote_ip_address: "10.100.1.21", remote_port: 8805,
weight: 33},
      ]
    }
  ]
}

```



```

    %{remote_ip_address: "10.100.1.22", remote_port: 8805,
weight: 33},
    %{remote_ip_address: "10.100.1.23", remote_port: 8805,
weight: 34}
  ]
}
],

# 000 - 0000000000 DNS 00000
fallback_pool: [
  %{remote_ip_address: "127.0.0.21", remote_port: 8805, weight:
100}
]
}

```

0000

00000

- 0 000000000000 upf_selection 0 UPF 0000000000
- 0 0000000000 UPF 00000000000000000000
- 0 000000000000000 upf_pool 0000000000 UPF 0
- 0 000000000000000 fallback_pool 00000000
- 0 **DNS** 0000DNS 000000000000
- 0 0000000000DNS 000 UPF 000000000000
- 0 000000000000000 UPF 0 5 0000000000

0000000000

- 0000sxb.peer_list 0000000000
- 00000000000000000 selection_list
- 00 UPF 00000000 upf_selection 00000000

UPF 00000000

1. 000000000000000 UPF 00000
 - 00 = PFCP 0000 + 00 3 0000000000
 - 0000 UPF 0000000000
 - 0000000000 UPF0000000000 UPF0000000000
2. 00/0000000000 weight: 0 000000 UPF
 - 00 **UPF**0000 > 0000000000000000
 - 00 **UPF**0000 == 0000000000000000 UPF 0000000000
 - 0000000000 UPF 0000 weight: 1
3. 000 UPF

- 70% .21 20% .22 10% .23
- = UPF
- =

4. UPF

- "UPF-<ip>:<port>"
- PFCP 5
- UPF

/

```
[
  UPF-A: 50, ✓
  UPF-B: 30, ✓
  UPF-C: 20, ✓
]
```

50 + 30 + 20 = 100

```

UPF-A: 0-49    (50%)
UPF-B: 50-79  (30%)
UPF-C: 80-99  (20%)

```

```

63 → UPF-B
15 → UPF-A
91 → UPF-C

```

/

```
[
  UPF-A: 100, ✓ ( )
  UPF-B: 0, ✓ ( )
]
```

```

1 UPF-A
→ [UPF-A: 100]
→ UPF-A

```

```

2 UPF-A
→ UPF
→ [UPF-B: 1]
→ UPF-B
→ " UPF UPF"

```

3

```
→ [REDACTED] UPF
→ [REDACTED][UPF-A: 100, UPF-B: 0]
→ [REDACTED]
→ [REDACTED]“[REDACTED] UPF[REDACTED]”
```

```
[REDACTED]
```

```
# [REDACTED] 25%
```

```
upf_pool: [
  %{remote_ip_address: "10.0.1.1", remote_port: 8805, weight: 1},
  %{remote_ip_address: "10.0.1.2", remote_port: 8805, weight: 1},
  %{remote_ip_address: "10.0.1.3", remote_port: 8805, weight: 1},
  %{remote_ip_address: "10.0.1.4", remote_port: 8805, weight: 1}
]
```

```
# [REDACTED]90% / 10%
```

```
upf_pool: [
  %{remote_ip_address: "10.0.1.21", remote_port: 8805, weight: 90},
  %{remote_ip_address: "10.0.1.22", remote_port: 8805, weight: 10}
]
```

```
# [REDACTED]100% [REDACTED]0% [REDACTED]
```

```
upf_pool: [
  %{remote_ip_address: "10.0.1.21", remote_port: 8805, weight: 100},
  # [REDACTED]
  %{remote_ip_address: "10.0.1.22", remote_port: 8805, weight: 0}
# [REDACTED]
]
```

```
# [REDACTED] 100%[REDACTED] 50/50%
```

```
# A/B [REDACTED]50% / 50%
```

```
upf_pool: [
  %{remote_ip_address: "10.0.1.100", remote_port: 8805, weight: 50},
# [REDACTED]
  %{remote_ip_address: "10.0.1.200", remote_port: 8805, weight: 50}
# [REDACTED]
]
```

```
[REDACTED]
```

- [REDACTED] weight: 0 [REDACTED] UPF[REDACTED] UPF [REDACTED]
- [REDACTED] UPF [REDACTED] PFCP [REDACTED]
- [REDACTED] UPF [REDACTED]
- [REDACTED] UPF [REDACTED]
- [REDACTED]95% [REDACTED]5% [REDACTED]
- [REDACTED] UPF
- [REDACTED] UPF [REDACTED]

PCO

UPF PCO PCO
APN

PCO

1. PCO
2. pco
3. PCO
4. PCO PCO

PCO

PCO

1. PCO
2. P-CSCF DNS P-CSCF
3. PCO

IMS DNS

```

IMS
├── DNS
├── P-CSCF DNS p_cscf_discovery_fqdn
│   └── DNS
└── MTU

```

```

├── DNS 192.168.1.10, 192.168.1.11
├── P-CSCF
└── MTU 1500

```

```

├── DNS
├── P-CSCF DNS
└── MTU

```

PCO

- primary_dns_server_address - DNS IP
- secondary_dns_server_address - DNS IP
- primary_nbns_server_address - WINS IP
- secondary_nbns_server_address - WINS IP
- p_cscf_ipv4_address_list - P-CSCF IP IMS - [PCO](#)
- [P-CSCF](#) P-CSCF
- ipv4_link_mtu_size - MTU

P-CSCF

PCO UPF P-CSCF

- p_cscf_discovery_fqdn - DNS P-CSCF FQDN
"pcscf.mnc380.mcc313.3gppnetwork.org"

- PGW-C FQDN DNS
- DNS P-CSCF IP
- P-CSCF PCO UE
- DNS PCO p_cscf_ipv4_address_list PCO
- [P-CSCF](#) /

- IMS APN** - IMS P-CSCF
- P-CSCF
- DNS UE P-CSCF
- DNS P-CSCF

P-CSCF IMS

```
rules: [  
  %{  
    name: "IMS",  
    priority: 20,  
    match_field: :apn,  
    match_regex: "^ims",  
    upf_pool: [  
      80}{remote_ip_address: "10.100.2.21", remote_port: 8805, weight:  
      20}{remote_ip_address: "10.100.2.22", remote_port: 8805, weight:  
    ],  
    # P-CSCF DNS P-CSCF  
    # DNS P-CSCF IP FQDN  
    p_cscf_discovery_fqdn: "pcscf.mnc380.mcc313.3gppnetwork.org",  
    # IMS P-CSCF DNS  
    pco: %{  
      p_cscf_ipv4_address_list: ["10.101.2.100", "10.101.2.101"]  
      # DNS, NBNS, MTU pco  
    }  
  }  
]
```

DNS

```
rules: [  
  {
```

```

%{
  name: "????",
  priority: 15,
  match_field: :apn,
  match_regex: "^(enterprise|corporate)\.apn",
  upf_pool: [
    100}{
      %{remote_ip_address: "10.100.3.21", remote_port: 8805, weight:
    ],
    # ???? DNS ???? MTU
    pco: %{
      primary_dns_server_address: "192.168.1.10",
      secondary_dns_server_address: "192.168.1.11",
      ipv4_link_mtu_size: 1500
      # P-CSCF, NBNS ???? pco ????
    }
  }
}
]

```

????? **PCO** ????

```

rules: [
  %{
    name: "IoT APN - ????",
    priority: 10,
    match_field: :apn,
    match_regex: "^(iot\.m2m)",
    upf_pool: [
      100}{
        %{remote_ip_address: "10.100.5.21", remote_port: 8805, weight:
      ],
      # IoT ???? PCO
      pco: %{
        primary_dns_server_address: "8.8.8.8",
        secondary_dns_server_address: "8.8.4.4",
        primary_nbns_server_address: "10.0.0.100",
        secondary_nbns_server_address: "10.0.0.101",
        p_cscf_ipv4_address_list: [], # IoT ?? P-CSCF
        ipv4_link_mtu_size: 1280 # ???? MTU
      }
    }
  }
]

```

???

- **IMS/VoLTE** ???? P-CSCF ???
- **APN** ???? DNS ???? ???? ???
- **IoT/M2M** ???? DNS ???? MTU ???? ???
- ???? DNS ???

- [redacted]

[redacted] DNS [redacted] UPF [redacted]

[redacted] ULI [redacted] UPF [redacted] DNS NAPTR [redacted] DNS [redacted]
upf_selection [redacted]

[redacted] UPF [redacted] [PFPCP \[redacted\]](#) [redacted] UPF
[redacted] PFPCP [redacted] [redacted]

```
upf_selection: %{
# [redacted] DNS [redacted]
dns_enabled: true,

# [redacted]
dns_query_priority: [:ecgi, :tai, :rai, :sai, :cgi],

# 3GPP NAPTR [redacted] DNS [redacted]
dns_suffix: "epc.3gppnetwork.org",

# DNS [redacted]
dns_timeout_ms: 5000,

# ... [redacted] ...
}
```

[redacted] DNS [redacted]

1. [redacted] DNS [redacted]
2. [redacted] UE [redacted] DNS NAPTR [redacted]
 - ECGI [redacted]eci-
<hex>.ecgi.epc.mnc<MNC>.mcc<MCC>.epc.3gppnetwork.org
 - TAI [redacted]tac-lb<hex>.tac-
hb<hex>.tac.epc.mnc<MNC>.mcc<MCC>.epc.3gppnetwork.org
 - RAI [redacted]SAI [redacted]CGI [redacted] 3GPP TS 23.003 [redacted]
3. [redacted]
4. [redacted] DNS [redacted]
5. [redacted]

[redacted] DNS [redacted] DNS [redacted]

```
; NAPTR [redacted] PLMN 313-380 [redacted] TAC 100
tac-lb64.tac-hb00.tac.epc.mnc380.mcc313.epc.3gppnetwork.org IN NAPTR
10 50 "a" "x-3gpp-upf:x-sxb" "" upf-edge-1.example.com.
```

```
; UPF [redacted] A [redacted]
upf-edge-1.example.com IN A 10.100.1.21
```

[redacted]

- **MEC** UPF
- **UPF** PGW-C / UPF
- UPF
- UPF

UPF

PGW-C UPF UPF

UPF

1. **PFCP** UPF PFCP
2. 3
3. UPF GenServer

UPF

- PFCP associated: false
- 3
- UPF

UPF upf_selection

-
- PFCP
- 5
- missed_heartbeats_consecutive
- UPF

DNS UPF

-
-
-

/ weight: 0

1. UPF
2. > 0 == 0
3. UPF UPF
4. UPF UPF 1

5. `UPF`

`> 0`

1. `UPF`
2. `UPF`
3. `UPF`

```
[debug] UPF 2/3 UPF1  
[info] UPF UPF1 UPF 0 1  
[warning] UPF 3
```

UPF

```
# UPF  
iex> PGW_C.PFCP_Node.is_peer_healthy?({10, 100, 1, 21})  
true  
  
#  
iex> PGW_C.PFCP_Node.get_peer_health({10, 100, 1, 21})  
%{  
  associated: true,  
  missed_heartbeats: 0,  
  healthy: true,  
  registered: true  
}
```

Web UI

- `/upf_selection`
- `UPF`
- `-UP - -`
- `> 0 == 0 DNS`
- `UPF`

1. `upf_selection` `UPF` `UPF`

```
upf_selection: %{  
  rules: [  
    %{  
      name: "UPF",  
      priority: 10,  
    }  
  ]  
}
```

```

    match_field: :apn,
    match_regex: "^internet",
    upf_pool: [
      weight: 100}
    ]
  },
  fallback_pool: [
    weight: 100}
  ]
}
# 100 UPF 10.100.1.21
# - 5 10.100.2.21
# - 10.100.1.21
# - 10.100.2.21

```

2. 100 UPF 10.100.1.21 weight: 100 UPF 10.100.2.21 weight: 100

```

upf_pool: [
  weight: 100}, # 100
  weight: 0} # 0
]

```

3. Web UI 10.100.1.21 UPF 10.100.2.21

4. 10.100.1.21 < 3 10.100.2.21

- 10.100.1.21 lib/core/pfcp_node/impl/peer.ex 10.100.2.21 is_peer_healthy?/1
- 10.100.1.21 = 10.100.2.21
- 10.100.1.21 = 10.100.2.21

100 UPF 100

100 PGW-C 10.100.1.21 DNS 10.100.2.21 UPF 10.100.1.21 upf_selection 100

100

100 10.100.1.21 DNS 10.100.2.21 UPF 10.100.1.21

1. 100 PFCP 10.100.1.21 UPF 10.100.2.21
2. 100 PFCP 10.100.1.21 UPF 100 PFCP 100
3. 10.100.1.21 10.100.2.21 UPF 10.100.1.21 10.100.2.21
4. 10.100.1.21 10.100.2.21 10
5. 10.100.1.21 10.100.2.21 UPF 10.100.1.21

UPF

UPF

```
%{
  name: "Dynamic-UPF-<IP>",          # "Dynamic-
  UPF-10-100-1-21"
  remote_ip_address: <discovered_ip>, # DNS IP
  remote_port: 8805,                 # PFCP
  initiate_pfcp_association_setup: true, # PGW-C
  heartbeat_period_ms: 10_000        # 10
}
```

UPF upf_selection

DNS UPF

```
# DNS upf-edge-2.example.com -> 10.200.5.99
# UPF upf_selection
```

```
#
# 1. UPF 10.200.5.99
# 2. "UPF {10, 200, 5, 99} ..."
# 3. 10.200.5.99:8805 PFCP
# 4. UPF
# 5. UPF
```

```
 DNS UPF
 PGW-C UPF
 UPF
 UPF
```

UPF PFCP

```
[error] UPF {10, 200, 5, 99} PFCP:timeout
[error] UPF {10, 200, 5, 99}:timeout
      UPF upf_selection
```

PGW-C

3. assign_sxb_peer/1 { :error, :dry_run_mode }
- 4.
5. DNS

[warning] UPF -

[info]

 :apn

 ~r/^internet\.\/

 10

 UPF 10.0.1.21:8805

[warning] UPF

 IMSI 313380000000670

 APN internet.apn

 10.0.1.21:8805

LiveView UI

UPF LiveView /upf_selection

1. UPF
2. "UPF"
3.
 - IMSI 313380000000670
 - APN internet.apn
 - PLMN ID 313380
4. " " "
5.
 - DNS
 - UPF
 -
 -

LiveView

- **

13. pgw_ip (IP)

IP: IPv4 IPv6

S5/S8 IP F-TEID

- SGW-C CDR: PGW-C S5/S8 IP F-TEID
- PGW-C CDR: SGW-C S5/S8 IP F-TEID

IP: IPv4 IPv6

IP:

10.0.1.20 (IPv4)
2001:db8::20 (IPv6)

IP:

- SGW-C: PGW-C
- PGW-C: SGW-C

IP: "pgw_ip" IP

14. apn (APN)

IP: 100

IP: (PDN)

IP: DNS

IP:

internet
ims
mms
enterprise.corporate

IP: MME

IP:

-
-
- IP

15. qci (QoS)

IP: 8

IP: QoS

IP: 1-9 128-254

IP: QCI:

QCI

- | | | | | |
|---|------|--------|------------------|------------------|
| 1 | GBR | 2 | 100 ms | 10 ⁻² |
| 2 | GBR | 4 | 150 ms | 10 ⁻³ |
| 3 | GBR | 3 | 50 ms | 10 ⁻³ |
| 4 | GBR | 5 | 300 ms | 10 ⁻⁶ |
| 5 | GBR1 | 100 ms | 10 ⁻⁶ | IMS |
| 6 | GBR6 | 300 ms | 10 ⁻⁶ | |
| 7 | GBR7 | 100 ms | 10 ⁻³ | |
| 8 | GBR8 | 300 ms | 10 ⁻⁶ | |
| 9 | GBR9 | 300 ms | 10 ⁻⁶ | |

IP:

9 →

IP: PGW-C QoS

16. octets_in (Octets In)

IP: 64

IP: → UE

IP:

IP:

1048576 → 1 MB

IP: PFCP PGW-U SGW-U

IP:

- update
- end
- start 0

17. octets_out (Octets Out)

IP: 64

IP: → UE

IP:

IP:

524288 → 512 KB











IP: PFCP PGW-U SGW-U

IP:

































- update
- end
- start 0










































Diameter Gx



















































        **(PCRF)**  

1.  
 2. **Gx**    
 3. **Diameter**  
 4.     
 5.      
 6.  
 7.   
 8.    
 9.    
-



 















Gx    **PGW-C**   **PCRF** (               **PCF** (               **5G**    












-       -   **QoS**    
-       -       
-      -     
-        -        
















     **Gx**













   
















 

    **PCRF**   **PCC**        

QoS          **QoS**  

     /          

      /      

Gx

3GPP

- 3GPP TS 29.212
- **Diameter ID:** 16777238 (Gx)
- Diameter (RFC 6733)

UE PDN Gx Session-ID

- UE (CCR-Initial)
- (CCR-Update) -
- UE (CCR-Termination)

ID

Session-ID: <Origin-Host>;<high32>;<low32>[;<optional>]

: omni-pgw_c.epc.mnc999.mcc999.3gppnetwork.org;1234567890;98765

- **Origin-Host:** PGW-C Diameter
- **high32:** 32
- **low32:** 32

Diameter

Diameter

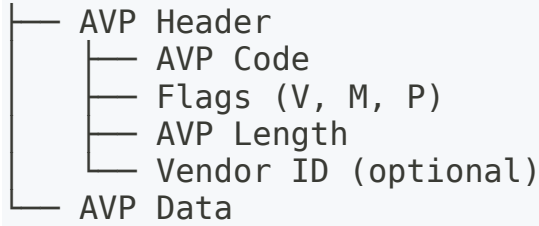
Diameter Header (20 bytes)

```

|— Version (1 byte) = 1
|— Message Length (3 bytes)
|— Flags (1 byte)
|   |— R: Request (1) / Answer (0)
|   |— P: Proxiabile
|   |— E: Error
|   |— T: Potentially retransmitted
|— Command Code (3 bytes)
|— Application ID (4 bytes) = 16777238 (Gx)
|— Hop-by-Hop ID (4 bytes)
|— End-to-End ID (4 bytes)

```

AVPs (Attribute-Value Pairs)



◆◆ Diameter ◆◆

AVP (◆◆-◆◆):

- Diameter ◆◆◆◆◆◆◆◆
- ◆◆◆◆◆◆◆◆
- ◆◆◆◆ (◆◆ AVP)

◆◆:

- ◆◆/◆◆◆
- CCR (◆◆◆◆◆◆) / CCA (◆◆◆◆◆◆)

◆◆◆◆:

- 2001 - DIAMETER_SUCCESS
- 3xxx - ◆◆◆◆
- 4xxx - ◆◆◆◆
- 5xxx - ◆◆◆◆

◆◆◆◆◆◆

PGW-C ◆◆ Diameter ◆◆◆◆◆◆◆◆ (RFC 4006) ◆◆ Gx◆

◆◆◆◆

CCR-Initial (◆◆◆◆◆◆ - ◆◆)

◆◆: UE ◆◆◆◆ PDN ◆◆

◆◆:

- ◆◆◆◆◆◆◆◆◆◆
- ◆ PCRF ◆◆ UE ◆◆◆◆◆◆
- ◆◆ QoS ◆◆◆◆◆◆

PGW-C ◆◆◆◆◆ AVP:

AVP	AVP	
Session-Id	263	UTF8String Gx
Auth-Application-Id	258	Unsigned32 16777238 (Gx)
Origin-Host	264	DiamIdent PGW-C Diameter
Origin-Realm	296	DiamIdent PGW-C Diameter
Destination-Realm	283	DiamIdent PCRF
CC-Request-Type	416	Enumerated 1 = INITIAL_REQUEST
CC-Request-Number	415	Unsigned32 (0)
Subscription-Id	443	Grouped UE (IMSI/MSISDN)
Called-Station-Id	30	UTF8String APN
Framed-IP-Address	8	OctetString UE IPv4
IP-CAN-Type	1027	Enumerated 5 = 3GPP-EPS
RAT-Type	1032	Enumerated 1004 = EUTRAN
QoS-Information	1016	Grouped QoS (AMBR)
Network-Request-Support	1024	Enumerated
Supported-Features	628	Grouped Gx

CCR-I:

```

CCR (272, )
├── Session-Id: "pgw_c.example.com;123;456"
├── Auth-Application-Id: 16777238
├── Origin-Host: "omni-pgw_c.epc.mnc999.mcc999.3gppnetwork.org"
├── Origin-Realm: "epc.mnc999.mcc999.3gppnetwork.org"
├── Destination-Realm: "epc.mnc999.mcc999.3gppnetwork.org"
├── CC-Request-Type: INITIAL_REQUEST (1)
├── CC-Request-Number: 0
├── Subscription-Id (Grouped)
│   ├── Subscription-Id-Type: END_USER_IMSI (1)
│   └── Subscription-Id-Data: "310260123456789"
├── Called-Station-Id: "internet"
├── Framed-IP-Address: 100.64.1.42
├── IP-CAN-Type: 3GPP-EPS (5)
├── RAT-Type: EUTRAN (1004)
├── QoS-Information (Grouped)
│   ├── APN-Aggregate-Max-Bitrate-UL: 100000000 (100 Mbps)
│   └── APN-Aggregate-Max-Bitrate-DL: 50000000 (50 Mbps)
├── Network-Request-Support: 1
└── Supported-Features: [...]

```

CCA-Initial (-)

: PCRF CCR-I

:

-

- PCC
- QoS

PGW-C AVP:

AVP	AVP	
Result-Code	268	(2001)
Experimental-Result	297	
QoS-Information	1016	QoS
Charging-Rule-Install	1001	PCC
Charging-Rule-Definition	1003	
Default-EPS-Bearer-QoS	1049	QoS

:

```

CCA ( : 272, )
├── Session-Id: "pgw_c.example.com;123;456"
├── Result-Code: DIAMETER_SUCCESS (2001)
├── Origin-Host: "pcrf.example.com"
├── Origin-Realm: "example.com"
├── Auth-Application-Id: 16777238
├── CC-Request-Type: INITIAL_REQUEST (1)
├── CC-Request-Number: 0
├── QoS-Information (Grouped)
│   ├── APN-Aggregate-Max-Bitrate-UL: 50000000 (50 Mbps - )
│   └── APN-Aggregate-Max-Bitrate-DL: 100000000 (100 Mbps - )
├── Charging-Rule-Install (Grouped)
│   ├── Charging-Rule-Name: "default_internet_rule"
│   └── Charging-Rule-Name: "video_streaming_rule"
├── Charging-Rule-Definition (Grouped)
│   ├── Charging-Rule-Name: "default_internet_rule"
│   ├── QoS-Information: {...}
│   └── Precedence: 1000

```

CCR-Termination (-)

: UE PDN

:

- PCRF
- /

CCR-I :

- CC-Request-Type: TERMINATION_REQUEST (3)
-
- AVP

◆◆ CCR-T:

```
CCR (◆◆◆◆: 272, ◆◆)
├── Session-Id: "pgw_c.example.com;123;456"
├── Auth-Application-Id: 16777238
├── Origin-Host: "omni-pgw_c.epc.mnc999.mcc999.3gppnetwork.org"
├── Origin-Realm: "epc.mnc999.mcc999.3gppnetwork.org"
├── Destination-Realm: "epc.mnc999.mcc999.3gppnetwork.org"
├── CC-Request-Type: TERMINATION_REQUEST (3)
├── CC-Request-Number: 1
└── Termination-Cause: DIAMETER_LOGOUT (1)
```

CCA-Termination

◆◆◆: PCRF ◆◆ CCR-T

◆◆:

- ◆◆◆◆◆◆
- ◆◆◆◆◆◆◆◆

◆◆ CCA-T:

```
CCA (◆◆◆◆: 272, ◆◆)
├── Session-Id: "pgw_c.example.com;123;456"
├── Result-Code: DIAMETER_SUCCESS (2001)
├── Origin-Host: "pcrf.example.com"
├── Origin-Realm: "example.com"
├── Auth-Application-Id: 16777238
├── CC-Request-Type: TERMINATION_REQUEST (3)
└── CC-Request-Number: 1
```

◆◆◆◆◆◆◆◆

PCC ◆◆◆◆

PCC (◆◆◆◆◆◆◆◆) ◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆

◆◆◆◆

1. ◆◆◆◆:

- ◆◆◆◆◆◆◆◆
- ◆◆: "video_streaming_rule"

2. ◆◆◆:

- 2222 = 22222
- 22: 0-65535
- 2222222222

3. 2222 (TFT - 22222):

- 222222222222
- 22:
 - IP 5-22: 22, 2/22 IP, 2/2222
 - "permit out ip from any to 8.8.8.8 80"

4. QoS 22:

- **QCI (QoS 2222):** 1-9 (222), 128-254 (22222)
 - QCI 1: 2222
 - QCI 5: IMS 22
 - QCI 9: 22222
- **ARP (2222222222):** 2222
- **MBR/GBR:** 22/222222

5. 2222:

- 222: 222222 (2 OCS 22 - 22 [Diameter Gy 22](#))
- 2222: 2222222222
- 22/2222: OCS (22222 [Diameter Gy](#)) 222 CDR (222 - 22 [22 CDR 2](#))

6. 222222:

- 22: 2222
- 22: 2222

222222

PCRF 222222222222:

1. 22222 (222):

```
Charging-Rule-Install (Grouped)
├─ Charging-Rule-Name: "gold_subscriber_internet"
└─ Charging-Rule-Name: "video_qos_boost"
```

2. 2222 (2222):

```
Charging-Rule-Definition (Grouped)
├─ Charging-Rule-Name: "dynamic_rule_123"
├─ Precedence: 100
├─ Flow-Information (Grouped)
│ └─ Flow-Description: "permit out ip from any to 192.0.2.0/24"
```

```
├── Flow-Direction: DOWNLINK
├── QoS-Information (Grouped)
│   ├── QoS-Class-Identifier: 5
│   ├── Max-Requested-Bandwidth-UL: 10000000
│   └── Max-Requested-Bandwidth-DL: 50000000
└── Rating-Group: 1000
```

QoS **AVP**

APN-AMBR (**AMBR**):

APN GBR

QoS-Information (Grouped)

```
├── APN-Aggregate-Max-Bitrate-UL: 100000000 # 100 Mbps
└── APN-Aggregate-Max-Bitrate-DL: 200000000 # 200 Mbps
```

PGW-C **PGW-C**:

- AMBR
- PGW-U QER

PGW-C

Gx

config/runtime.exs:

```
config :pgw_c,
  diameter: %{
    # Diameter IP
    listen_ip: "0.0.0.0",

    # PGW-C Diameter (Origin-Host)
    host: "omni-pgw_c.epc.mnc999.mcc999.3gppnetwork.org",

    # PGW-C Diameter (Origin-Realm)
    realm: "epc.mnc999.mcc999.3gppnetwork.org",

    # PCRF
    peer_list: [
      %{
        # PCRF Diameter
        host: "pcrf.epc.mnc999.mcc999.3gppnetwork.org",

        # PCRF (PGW-C)
        realm: "epc.mnc999.mcc999.3gppnetwork.org",
```

```

# PCRF IP
ip: "10.0.0.30",

# PGW-C PCRF
# true = PGW-C PCRF
# false = PCRF
initiate_connection: true
}
]
}

```

PCRF

```

config :pgw_c,
  diameter: %{
    listen_ip: "0.0.0.0",
    host: "omni-pgw_c.epc.mnc999.mcc999.3gppnetwork.org",
    realm: "epc.mnc999.mcc999.3gppnetwork.org",
    peer_list: [
      %{
        host: "pcrf-primary.example.com",
        realm: "epc.mnc999.mcc999.3gppnetwork.org",
        ip: "10.0.1.30",
        initiate_connection: true
      },
      %{
        host: "pcrf-backup.example.com",
        realm: "epc.mnc999.mcc999.3gppnetwork.org",
        ip: "10.0.2.30",
        initiate_connection: true
      }
    ]
  }
}

```

- Diameter
-
-

Diameter FQDN:

```

# - FQDN

```

host: "pgw_c.epc.mnc999.mcc999.3gppnetwork.org"

? - ? Diameter ?

host: "pgw_c"

host: "10.0.0.20" # ? IP ?

?:

- ? ? ? ? ? ? ? ?
- ? ? ? 3GPP PLMN ? ? ? ? : epc.mncXXX.mccYYY.3gppnetwork.org

???

??????

?: PCRF ? QoS ? ? ? ? ? ? QER ? QoS ? ? ? ? ? ? ? ? PFCP ? ? ? PGW-U ? ? ?
[PFCP](#) ? ? ? QER ? ? ? ? ?

???? (????)

????

????

????

PGW-C ? CCA ? ? ? ? ? ? ? Diameter ? ? ? ? ?

?:

?? ? ? ?
2001 DIAMETER_SUCCESS ? ? ? ? ? ? ?

???? (5xxx):

??	??	PGW-C ? ? ? ?
5002 DIAMETER_UNKNOWN_SESSION_ID		???? ? ? ? ?
5030 DIAMETER_USER_UNKNOWN		???? (????)
5140 DIAMETER_ERROR_INITIAL_PARAMETERS		???? ? ? ? ? ? ? ? ?
5003 DIAMETER_AUTHORIZATION_REJECTED		???? (???)

???? (4xxx):

4001 DIAMETER_AUTHENTICATION_REJECTED PGW-C
 4010 DIAMETER_TOO_BUSY
 4012 DIAMETER_UNABLE_TO_COMPLY

Experimental-Result (Grouped)

Vendor-Id: 10415 (3GPP)

Experimental-Result-Code: <vendor-specific code>

3GPP:

5065 IP_CAN_SESSION_NOT_AVAILABLE PCRF
 5143 INVALID_SERVICE_INFORMATION

CCR-I:

CCR-I:

PCRF CCR-Initial

- PGW-C (5)
- CCA:
 - CCR-Initial Session-ID: ...
 - SGW-C
 -
- SGW-C: (00:)

SGW-C:

/lib/session/impl/message_handlers.ex

```

{:error, :credit_control_initial_request_timeout} ->
  Procedures.do_gtp_c_error_response(
    from,
    :create_session_response,
    seq_num,
    :remote_peer_not_responding
  )

```

1: PCRF (1)

1: PCRF (1)

2: PCRF

1. Diameter

:

- : "Diameter"
- CCR-Initial

:

- PCRF
- PCRF IP
- Diameter (3868)
- Diameter (/)

:

```
#
```

```
ping <pcrf_ip>
```

```
# Diameter (TCP 3868)
```

```
telnet <pcrf_ip> 3868
```

```
# Diameter
```

```
# FQDN IP
```

:

```
config :pgw_c,  
  diameter: %  
    # FQDN IP  
    host: "pgw_c.epc.mnc999.mcc999.3gppnetwork.org",  
    realm: "epc.mnc999.mcc999.3gppnetwork.org",  
    peer_list: [  
      %  
        host: "pcrf.epc.mnc999.mcc999.3gppnetwork.org",  
        ip: "10.0.0.30"  
      ]  
    ]  
}
```


2. CCR-Initial

◆◆:

- ◆◆◆◆◆◆◆◆
- ◆◆: "CCR-Initial ◆◆"

◆◆◆◆:

- PCRF ◆◆
- ◆◆◆◆
- PCRF ◆◆◆◆ Session-ID

◆◆◆◆:

- ◆◆ PCRF ◆◆◆◆◆◆
- ◆◆ PCRF ◆◆◆◆◆◆◆◆
- ◆◆◆◆◆◆: ping <pcrf_ip>
- ◆◆◆◆◆◆◆◆◆◆◆◆◆◆

3. ◆◆◆ PCRF ◆◆

◆◆:

- CCA-Initial ◆ Result-Code != 2001
- ◆◆◆◆◆◆◆◆◆◆

◆◆◆◆◆◆:

```
◆◆◆◆      ◆◆◆◆      ◆◆◆◆
5030 IMSI ◆◆◆◆◆◆◆◆◆◆ HSS/SPR ◆◆◆◆◆
5003 ◆◆◆◆◆◆      ◆◆◆◆◆◆◆◆
4010 PCRF ◆◆◆◆◆      ◆◆◆◆◆◆ PCRF ◆◆
```

◆◆◆◆:

```
# PGW-C ◆◆◆◆:
[error] Diameter Gx ◆◆: Result-Code 5030 (DIAMETER_USER_UNKNOWN)
[error] IMSI 3102609999999999 ◆ PCRF ◆◆
```

4. QoS ◆◆◆

◆◆:

- ◆◆◆◆◆◆ QoS ◆◆
- ◆◆◆◆◆◆◆◆◆◆◆◆

◆◆◆◆:

1. CCA-Initial:

- QoS-Information AVP
- APN-Aggregate-Max-Bitrate-UL/DL

2. PFCP:

- QER MBR
- PGW-U QER

3. PCRF:

- PCRF
- QoS

5. Diameter

:

- Diameter PCRF
- :""

:

-

:

:

```
#
config :pgw_c,
  diameter: %{
    realm: "epc.mnc999.mcc999.3gppnetwork.org", # PGW-C
    peer_list: [
      %{
        realm: "epc.mnc999.mcc999.3gppnetwork.org" # PCRF (
      )
    }
  ]
}
```

CCR-Initial:

```
Origin-Realm: "epc.mnc999.mcc999.3gppnetwork.org"
Destination-Realm: "epc.mnc999.mcc999.3gppnetwork.org"
```

◆◆ Gx ◆◆

◆◆◆◆:

```
# Gx ◆◆◆◆  
rate(gx_inbound_messages_total{message_type="cca"}[5m])
```

```
# Gx ◆◆◆◆  
rate(gx_inbound_errors_total[5m])
```

```
# Gx ◆◆◆◆  
session_id_registry_count
```

```
# Gx ◆◆◆◆◆◆◆◆  
histogram_quantile(0.95,  
rate(gx_inbound_handling_duration_bucket[5m]))
```

◆◆◆◆:

```
# ◆ Gx ◆◆◆◆◆◆  
- alert: GxErrorRateHigh  
  expr: rate(gx_inbound_errors_total[5m]) > 0.1  
  for: 5m  
  annotations:  
    summary: "◆◆◆◆ Gx ◆◆◆◆"
```

```
# Gx ◆◆◆◆  
- alert: GxTimeout  
  expr: rate(gx_inbound_errors_total{error_type="timeout"}[5m]) >  
0.05  
  for: 2m  
  annotations:  
    summary: "◆◆ Gx ◆◆"
```

```
# ◆◆◆◆◆◆  
- alert: GxSessionRejection  
  expr: rate(gx_inbound_errors_total{result_code="5030"}[5m]) > 0.01  
  for: 5m  
  annotations:  
    summary: "PCRF ◆◆◆◆ (USER_UNKNOWN)"
```

◆◆◆◆

◆◆◆◆◆ Diameter ◆◆:

```
# config/runtime.exs  
config :logger, level: :debug
```

```
# 000000
iex> Logger.configure(level: :debug)
```

00:

- [debug] 00 CCR-Initial0Session-ID: ...
- [debug] 00 CCA-Initial: Result-Code 2001
- [error] Diameter 00: ...

Web UI - Diameter 000000

OmniPGW 000000 Web UI000000 Diameter 0000000000

Diameter 000000

00: http://<omnipgw-ip>:<web-port>/diameter

00: 0000 Diameter Gx 0000 PCRF 0000

00:

1. 00000000

- 0000 - 00000000 PCRF 000000
- 0000 - 0000000000000000
- 1 000000 (000000000000)

2. 00000000000000000000 PCRF 0000:

- 00 - Diameter 00 (Origin-Host)
- **IP** 00 - PCRF IP
- 00 - Diameter 00 (00 3868)
- 00 - 00 (00) / 00 (00)
- 00 - TCP 0 SCTP
- 0000 - 0000 (PGW 0 PCRF)
- 00 - Diameter 00
- 00000 - PCRF 000000 (000000)
- 00 **ID** - 0000 Diameter 00 (0000Gx = 16777238)

3. 00000000000000000000:

- 0000000000
- 00000 (CER/CEA) 00000
- 000000
- 000000000000

◆◆◆◆

◆◆ PCRF ◆◆◆:

1. ◆◆◆◆◆ Diameter ◆◆
2. ◆◆◆◆ PCRF ◆◆◆◆◆ "◆◆"
3. ◆◆◆◆◆◆◆◆◆◆◆◆
4. ◆◆◆◆ ID ◆◆ Gx (16777238)

◆◆◆◆◆◆◆◆◆◆ (Gx ◆◆):

1. ◆◆◆◆◆◆◆◆◆◆ "PCRF ◆◆" ◆◆
2. ◆◆ Diameter ◆◆
3. ◆◆◆◆◆◆◆◆:
 - ◆◆◆?
 - ◆◆◆◆◆◆◆◆
 - ◆◆ PCRF ◆◆◆◆◆◆◆◆
 - ◆◆◆◆◆◆◆◆◆◆◆◆◆◆ TCP 3868 ◆◆
 - ◆◆◆◆◆◆◆◆◆?
 - ◆◆◆◆◆◆◆◆◆ (◆◆◆◆◆)
 - PCRF ◆◆◆◆◆◆◆◆

◆◆ Diameter ◆◆◆:

1. ◆◆◆◆ PCRF ◆◆◆◆◆
2. ◆◆ Diameter ◆◆
3. ◆◆◆◆◆◆◆◆◆◆◆◆◆◆
4. ◆◆◆◆◆◆◆◆◆◆ "◆◆"
5. ◆◆◆◆◆◆◆◆◆◆:
 - ◆◆◆◆◆◆◆◆◆◆
 - ◆◆ ID ◆◆ Gx
 - ◆◆◆◆◆◆◆◆ PCRF ◆◆◆◆

◆◆◆◆◆◆◆:

- ◆◆: ◆ PCRF ◆◆
1. Diameter ◆◆◆◆◆◆◆◆◆◆◆◆◆◆ "◆◆"
 2. ◆◆◆◆◆ PCRF ◆◆◆ "◆◆"
 3. ◆◆◆◆◆◆◆◆◆◆◆◆
 4. ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ "◆◆"

◆◆ Diameter ◆◆◆◆◆:

- ◆◆◆◆◆◆◆ "◆◆" ◆◆◆◆◆◆◆
- ◆◆ ID ◆◆◆ Gx (16777238)
- ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ PCRF ◆◆◆◆

◆◆◆◆◆◆◆◆◆◆:

Web UI `??`:
`?????: "?????"`
`?????:`
`initiate_connection: true`

- `???:`
 - OmniPGW `????`
 - `?` PCRF `????`
 - `????????????`

- `??:`
 - `?????? - 1 ??`
 - `?????? - ??/?`
 - **Diameter** `??` - `??` Diameter CLI `??`
 - `???????? - ??????????`
 - `?????? - ????? Diameter ??`
 - `???? - ?? Diameter ??`

`?????`

`??` Web UI `?????????????` Prometheus `??`:

- `?? Gx ??`
- CCR/CCA `????`
- `????`

Web UI = "`????????????`" `??` = "`????????????????????`"

`????`

`?????`

- [????](#) - Diameter `????` PCRF `????`
- [PF](#) `??` - `??` PCC `??` QER `??`
- [????](#) - `????????`
- [QoS](#) `????` - `???` QoS `????`

`????`

- [Diameter Gy](#) `??` - `?` PCC `????????`
- [CDR](#) `????` - `????????`
- [PCO](#) `??` - IMS `????` P-CSCF `??`

◇◇

- [◇◇◇◇](#) - Gx ◇◇◇◇◇◇◇◇◇◇ PCRF ◇◇◇◇
- **S5/S8** [◇◇](#) - ◇◇◇◇◇◇◇◇◇◇

[◇◇◇◇◇◇](#)



Diameter (Gy/Ro)

(OCS)

1. [Gy](#)
2. [3GPP](#)
3. [Gy/Ro](#)
4. [Gz/RD](#)
5. [OCS](#)
6. [CGF/CDF](#)
7. [CDR](#)
8. [PDN](#)
9. [Gy](#)
10. [Gz/RD](#)
11. [Gx](#)
12. [Gx](#)

Gy IMS Ro PGW-C (OCS)

- Gy - IMS
- Ro - PGW-C
- OCS

Gy (Gy/Ro) Gz/RD

OCS (CGF/CDF)

CDR

PDN

Gy

OCS

Gz/RD

3GPP

(CTF)

PGW-C CTF

1. Gy - IMS
2. Ro - PGW-C
3. OCS
4. CGF/CDF
5. CDR

(OCF)

OCS OCF

1. Gy - IMS
2. Ro - PGW-C
3. OCS
4. CGF/CDF
5. CDR

Gy/Ro

3GPP

- 3GPP TS 32.299
- 3GPP TS 32.251 (PS)
- Diameter ID 4 (Gy/Ro)
- RFC 4006 (Diameter)

UE PDN Session-ID Gy/Ro

- CCR-Initial
- CCR-Update
- CCR-Termination

ID

Session-ID: <Origin-Host>;<high32>;<low32>;<optional>

omni-pgw_c.epc.mnc999.mcc999.3gppnetwork.org;9876543210;12345;gy

- Origin-Host: PGW-C Diameter
- high32: 32
- low32: 32
- optional: "gy" Gx

CCR-Initial (-)

UE PDN

- OCS
- Gy/Ro

PGW-C AVP

Table with 3 columns: AVP, AVP, AVP. Rows include Session-Id, Auth-Application-Id, Origin-Host, Origin-Realm, Destination-Realm, CC-Request-Type, CC-Request-Number, Subscription-Id, Service-Context-Id, Multiple-Services-Credit-Control, Requested-Service-Unit, Used-Service-Unit, Service-Identifier, Rating-Group.

CCR-I

CCR (272)
- Session-Id: "pgw_c.example.com;123;456;gy"
- Auth-Application-Id: 4
- Origin-Host: "omni-pgw_c.epc.mnc999.mcc999.3gppnetwork.org"
- Origin-Realm: "epc.mnc999.mcc999.3gppnetwork.org"
- Destination-Realm: "epc.mnc999.mcc999.3gppnetwork.org"
- CC-Request-Type: INITIAL_REQUEST (1)
- CC-Request-Number: 0
- Subscription-Id (0)
- Subscription-Id-Type: END_USER_IMSI (1)
- Subscription-Id-Data: "310260123456789"
- Subscription-Id (0)
- Subscription-Id-Type: END_USER_E164 (0)
- Subscription-Id-Data: "15551234567"
- Service-Context-Id: "3225103gpp.org"
- Multiple-Services-Credit-Control (0)
- Service-Identifier: 1
- Rating-Group: 100
- Requested-Service-Unit (0)
- CC-Total-Octets: 10000000 (10 MB)
- Used-Service-Unit (0)
- CC-Total-Octets: 0

CCA-Initial

OCS CCR-I

- •
•

PGW-C AVP

Table with 3 columns: AVP, AVP, AVP. Rows include Result-Code, Multiple-Services-Credit-Control, Granted-Service-Unit, Validity-Time, Result-Code, Final-Unit-Indication, Volume-Quota-Threshold.

CCA (272)
- Session-Id: "pgw_c.example.com;123;456;gy"
- Result-Code: DIAMETER_SUCCESS (2001)
- Origin-Host: "ocs.example.com"
- Origin-Realm: "example.com"
- Auth-Application-Id: 4
- CC-Request-Type: INITIAL_REQUEST (1)
- CC-Request-Number: 0
- Multiple-Services-Credit-Control (0)
- Result-Code: DIAMETER_SUCCESS (2001)
- Service-Identifier: 1
- Rating-Group: 100
- Granted-Service-Unit (0)
- CC-Total-Octets: 10000000 (10 MB)
- Validity-Time: 3600 (1)
- Volume-Quota-Threshold: 8000000 (8 MB 80%)

CCR-Update

- 80%
•
•
•

- •
•

CCR-I

- CC-Request-Type: UPDATE_REQUEST (2)
• CC-Request-Number
• Used-Service-Unit
• Requested-Service-Unit

CCR-U

CCR (272)
- Session-Id: "pgw_c.example.com;123;456;gy"
- Auth-Application-Id: 4
- Origin-Host: "omni-pgw_c.epc.mnc999.mcc999.3gppnetwork.org"
- Origin-Realm: "epc.mnc999.mcc999.3gppnetwork.org"
- Destination-Realm: "epc.mnc999.mcc999.3gppnetwork.org"
- CC-Request-Type: UPDATE_REQUEST (2)
- CC-Request-Number: 1
- Multiple-Services-Credit-Control (0)
- Service-Identifier: 1
- Rating-Group: 100
- Used-Service-Unit (0)
- CC-Total-Octets: 8000000 (8 MB)
- Requested-Service-Unit (0)
- CC-Total-Octets: 10000000 (10 MB)

CCA-Update

OCS CCR-U

- •
•


```

Final-Unit-Action   PGW-C
TERMINATE           0
REDIRECT            1
RESTRICT_ACCESS    2

```

```

CCA
├─ Multiple-Services-Credit-Control
│   └─ Result-Code: DIAMETER_SUCCESS (2001)
│       └─ Granted-Service-Unit
│           └─ CC-Total-Octets: 1000000 (1 MB)
│               └─ Final-Unit-Indication
│                   └─ Final-Unit-Action: REDIRECT (1)
│                       └─ Redirect-Server
│                           └─ Redirect-Address-Type: URL (2)
│                               └─ Redirect-Server-Address: "http://topup.example.com"

```

```

PGW-C
1. TERMINATE: CCR-T
2. REDIRECT: PCFP HTTP URL
3. RESTRICT_ACCESS: PCFP IP

```

```


```

```

3GPP TS 23.203, TS 29.212, TS 32.251

```

```

PCRF Gx PCC PCC Diameter Gx

```

```

PCC

```

```

PCRF (CCA-I Gx)

```

```

CCA (Gx)
├─ Charging-Rule-Definition
│   └─ Charging-Rule-Name: "prepaid_data_rule"
│       └─ Rating-Group: 100
│           └─ Online: 1
│               └─ Offline: 0
│                   └─ Metering-Method: VOLUME (1)
│                       └─ Precedence: 100
│                           └─ Flow-Information: [...]
│                               └─ QoS-Information: [...]

```

```

PCC AVP

```

```

AVP AVP
Rating-Group 432 Unsigned32 OCS
Online 1009 0=0,1=0 (Gy)
Offline 1008 0=0,1=0 (Gz)
Metering-Method 1007 0=0,1=0,2=0
Reporting-Level 1011 0=0,1=0

```

```


```

```

Rating-Group
1 0
0 1
1 1
0 0

```

```


```

```

PDN

```

```


```

```

Rating-Group: 100
Online: 1

```

```

Rating-Group: 200
Online: 1

```

```

2 IMS
Rating-Group: 300
Online: 1

```

```

PGW-C Gy

```

```

• CCR-I MSCC

```

```

CCR-Initial
├─ Session-Id: "...
├─ Multiple-Services-Credit-Control
│   └─ [Rating-Group: 100]
│       └─ [Rating-Group: 200]
│           └─ [Rating-Group: 300]

```

```

OCS

```

```

CCA-Initial
├─ Multiple-Services-Credit-Control
│   └─ [Rating-Group: 100]
│       └─ [Rating-Group: 200]
│           └─ [Rating-Group: 300]

```

```


```

```

PGW-C Rating-Group

```

```

state:charging_quotas = %{
  100 => {granted: 10_000_000, used: 0, threshold: 8_000_000},
  200 => {granted: 5_000_000, used: 0, threshold: 4_000_000},
  300 => {granted: 60_000, used: 0, threshold: 48_000} #
}

```

```


```

```


```

```

MSCC AVP

```

```


```

```


```

```

Multiple-Services-Credit-Control
├─ Service-Identifier (Unsigned32, AVP 439)
├─ Rating-Group (Unsigned32, AVP 432)
├─ Requested-Service-Unit (AVP 437)
│   └─ CC-Time (Unsigned32, AVP 420)
│       └─ CC-Total-Octets (Unsigned64, AVP 421)
│           └─ CC-Input-Octets (Unsigned64, AVP 412)
│               └─ CC-Output-Octets (Unsigned64, AVP 414)

```



```
# Diameter (TCP 3868)
telnet <ocs_ip> 3868

# peer_list OCS
```

2. OCS

```
• CCA-I Result-Code != 2001
•

4012
5003
5031 OCS

1. OCS
2. OCS
3. CCR-I IMSI/MSISDN
```

3.

```
• CCR-Update
•

• PGW-U URR
•
• PFCP
```

```
1. PFCP URR
  URR
  | URR-ID: 1
  | Measurement-Method: VOLUME
  | Volume-Threshold: 8000000 (8 MB)
  | Reporting-Triggers: VOLUME_THRESHOLD
2. PGW-U
3. quota_threshold_percentage
```

4. Rating-Group

```
• OCS "Rating-Group"
•

• CCR-I Rating-Group OCS
• PCRF Rating-Group

1. PCRF PCC Rating-Group
2. OCS Rating-Group
3. PCC OCS
```

```

# Gy
rate(gy_inbound_messages_total{message_type="cca"}[5m])
rate(gy_outbound_messages_total{message_type="ccr"}[5m])

# Gy
rate(gy_inbound_errors_total[5m])

# Gy
rate(gy_quota_exhausted_total[5m])

# OCS
rate(gy_timeout_total[5m])

# Gy
histogram_quantile(0.95, rate(gy_inbound_handling_duration_bucket[5m]))

# Gy
- alert: GyErrorRateHigh
  expr: rate(gy_inbound_errors_total[5m]) > 0.1
  for: 5m
  annotations:
    summary: "Gy"

# OCS
- alert: OcsTimeout
  expr: rate(gy_timeout_total[5m]) > 0.05
  for: 2m
  annotations:
    summary: "OCS"

# Gy
- alert: CreditExhaustionSpike
  expr: rate(gy_quota_exhausted_total[5m]) > 10
  for: 5m
  annotations:
    summary: ""
```






Web UI - Gy

```
OmniPGW Gy/Ro OCS
http://<omnipgw-ip>:<web-port>/gy_simulator
```































OmniPGW

Prometheus

 *OmniTouch*    




1.  
 2.    
 3.    
 4. [Prometheus](#)  
 5. [Grafana](#)   
 6.  
 7.    
 8.      
-














OmniPGW

1. **Web UI**

-    
- PFCP  
- Diameter  
-   

2. **Prometheus**

























-    
-   
-  
-  

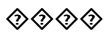
Prometheus **Web UI**

- [Prometheus - Web UI](#)
- [PFCP - Web UI](#)
- [Diameter Gx - Web UI](#)

Prometheus

OmniPGW **Prometheus**

-       
-     
-      
-   
-     



◆◆◆◆

◆◆

◆ config/runtime.exs ◆◆◆◆◆

```
config :pgw_c,
  metrics: %{
    enabled: true,
    ip_address: "0.0.0.0", # ◆◆◆◆◆
    port: 9090, # HTTP ◆◆
    registry_poll_period_ms: 5_000 # ◆◆◆◆
  }
```

◆◆◆◆

HTTP ◆◆◆

http://<omnipgw_ip>:<port>/metrics

◆◆◆

curl http://10.0.0.20:9090/metrics

◆◆◆◆

◆◆◆ Prometheus ◆◆◆◆ ◆◆◆

```
# HELP teid_registry_count The number of TEID registered to sessions
# TYPE teid_registry_count gauge
teid_registry_count 150

# HELP address_registry_count The number of addresses registered to sessions
# TYPE address_registry_count gauge
address_registry_count 150

# HELP s5s8_inbound_messages_total The total number of messages received from S5/S8 peers
# TYPE s5s8_inbound_messages_total counter
s5s8_inbound_messages_total{message_type="create_session_request"} 1523
s5s8_inbound_messages_total{message_type="delete_session_request"} 1487
```

◆◆◆◆

OmniPGW ◆◆◆◆◆◆◆◆

◆◆◆◆

◆◆◆◆◆◆

◆◆◆◆	◆◆	◆◆
teid_registry_count	Gauge◆◆	S5/S8 ◆◆◆◆TEID ◆◆◆
seid_registry_count	Gauge◆◆	PCFP ◆◆◆◆SEID ◆◆◆
session_id_registry_count	Gauge◆◆	Gx ◆◆◆◆Diameter Session-ID ◆◆◆
address_registry_count	Gauge◆◆◆◆	UE IP ◆◆
charging_id_registry_count	Gauge◆◆◆◆	ID◆◆◆◆◆ ◆◆ CDR ◆◆◆ ◆◆◆ CDR ◆◆◆◆◆

◆◆◆

```
# ◆◆◆◆◆◆
teid_registry_count
```

◆◆◆◆◆◆◆◆◆◆◆

```
rate(teid_registry_count[5m])
#
max_over_time(teid_registry_count[1h])
```

◆◆◆◆

S5/S8 (GTP-C) ◆◆◆

```

      ◆◆◆◆          ◆◆          ◆◆          ◆◆
s5s8_inbound_messages_total Countermessage_type◆◆◆ S5/S8 ◆◆
s5s8_outbound_messages_total Countermessage_type◆◆◆ S5/S8 ◆◆
s5s8_inbound_errors_total Countermessage_typeS5/S8 ◆◆◆◆
```

◆◆◆◆

- create_session_request
- create_session_response
- delete_session_request
- delete_session_response
- create_bearer_request
- delete_bearer_request

Sxb (PFCP) ◆◆◆

```

      ◆◆◆◆          ◆◆          ◆◆          ◆◆
sxb_inbound_messages_total Countermessage_type◆◆◆ PFCP ◆◆
sxb_outbound_messages_total Countermessage_type◆◆◆ PFCP ◆◆
sxb_inbound_errors_total Countermessage_typePFCP ◆◆◆◆
```

◆◆◆◆

- association_setup_request
- association_setup_response
- heartbeat_request
- heartbeat_response
- session_establishment_request
- session_establishment_response
- session_modification_request
- session_deletion_request

Gx (Diameter) ◆◆◆

```

      ◆◆◆◆          ◆◆          ◆◆          ◆◆
gx_inbound_messages_total Countermessage_type◆◆◆ Diameter ◆◆
gx_outbound_messages_total Countermessage_type◆◆◆ Diameter ◆◆
gx_inbound_errors_total Countermessage_typeDiameter ◆◆◆◆
```

◆◆◆◆

- cca (Credit-Control-Answer)
- ccr_initial
- ccr_termination

◆◆◆◆

◆◆◆◆◆◆

```

      ◆◆◆◆          ◆◆          ◆◆          ◆◆
s5s8_inbound_handling_duration Histogram request_message_typeS5/S8 ◆◆◆◆◆◆
sxb_inbound_handling_duration Histogram request_message_typePFCP ◆◆◆◆◆◆
gx_inbound_handling_duration Histogram request_message_typeDiameter ◆◆◆◆◆◆
```

◆◆◆◆◆

- ◆◆◆◆100μs, 500μs, 1ms, 5ms, 10ms, 50ms, 100ms, 500ms, 1s, 5s

◆◆◆

```
# 95th ◆◆◆ S5/S8 ◆◆  
histogram_quantile(0.95,  
  rate(s5s8_inbound_handling_duration_bucket[5m])  
)
```

```
# ◆◆ PFCP ◆◆  
rate(sxb_inbound_handling_duration_sum[5m]) /  
rate(sxb_inbound_handling_duration_count[5m])
```

◆◆◆◆

Erlang VM ◆◆◆◆

```
◆◆◆◆           ◆◆           ◆◆  
vm_memory_total      Gauge ◆ VM ◆◆◆◆◆◆◆◆  
vm_memory_processes  Gauge ◆◆◆◆◆◆◆◆◆  
vm_memory_system     Gauge ◆◆◆◆◆◆◆◆◆  
vm_system_process_count Gauge ◆ Erlang ◆◆  
vm_system_port_count Gauge ◆◆◆◆◆◆◆
```

Prometheus ◆◆

◆◆◆◆

◆ OmniPGW ◆◆◆ Prometheus ◆ prometheus.yml ◆

```
# prometheus.yml  
global:  
  scrape_interval: 15s  
  evaluation_interval: 15s  
  
scrape_configs:  
  - job_name: 'omnipgw'  
    static_configs:  
      - targets: ['10.0.0.20:9090']  
        labels:  
          instance: 'omnipgw-01'  
          environment: 'production'  
          site: 'datacenter-1'
```

◆◆ OmniPGW ◆◆

```
scrape_configs:  
  - job_name: 'omnipgw'  
    static_configs:  
      - targets:  
          - '10.0.0.20:9090'  
          - '10.0.0.21:9090'  
          - '10.0.0.22:9090'  
        labels:  
          environment: 'production'
```

◆◆◆◆

Kubernetes◆

```
scrape_configs:
```

```
- job_name: 'omnipgw'
  kubernetes_sd_configs:
  - role: pod
  relabel_configs:
  - source_labels: [__meta_kubernetes_pod_label_app]
    action: keep
    regex: omnipgw
  - source_labels: [__meta_kubernetes_pod_ip]
    target_label: __address__
    replacement: '${1}:9090'
```

◆◆

◆◆◆◆

◆◆ Prometheus ◆◆

```
curl http://prometheus:9090/api/v1/targets
```

◆◆◆◆◆◆

```
curl 'http://prometheus:9090/api/v1/query?query=teid_registry_count'
```

Grafana ◆◆◆

◆◆◆◆◆

1. ◆◆ Prometheus ◆◆◆◆

◆◆ → ◆◆◆ → ◆◆◆◆◆ → Prometheus

URL: http://prometheus:9090

2. ◆◆◆◆◆◆

◆◆◆◆◆◆◆◆◆◆ JSON ◆◆◆

◆◆◆◆

◆◆ 1◆◆◆◆◆

◆◆

```
teid_registry_count
```

◆◆◆◆◆Gauge

◆◆◆

◆◆◆ < 5000

◆◆◆ 5000-8000

◆◆◆ > 8000

◆◆ 2◆◆◆◆◆

◆◆

```
rate(s5s8_inbound_messages_total{message_type="create_session_request"}[5m])
```

◆◆◆◆◆◆◆◆

◆◆◆◆◆◆/◆

◆◆ 3◆◆IP ◆◆◆◆

◆◆◆◆◆ /24 ◆◆◆◆254 ◆ IP◆

```
(address_registry_count / 254) * 100
```

◆◆◆◆◆Gauge

◆◆◆◆◆◆ (0-100)

```
# 4
# < 70%
# 70-85%
# > 85%
```

4 95th

```
#
rate(s5s8_inbound_handling_duration_bucket{request_message_type="create_session_request"}[5m])
)
# 00
#
```

5

```
#
rate(s5s8_inbound_errors_total[5m])
#
# /
# > 0.1
```

6 PFCP

```
#
pfcp_peer_associated
#
#
# 1 = "UP" ( )
# 0 = "DOWN" ( )
```



```
{
  "dashboard": {
    "title": "OmniPGW - 4",
    "panels": [
      {
        "title": "4",
        "targets": [
          {
            "expr": "teid_registry_count",
            "legendFormat": "4"
          }
        ],
        "type": "graph"
      },
      {
        "title": "5",
        "targets": [
          {
            "expr": "rate(s5s8_inbound_messages_total{message_type=\"create_session_request\"}[5m])",
            "legendFormat": "/"
          }
        ],
        "type": "graph"
      },
      {
        "title": "IP 4",
```

```

    "targets": [
      {
        "expr": "(address_registry_count / 254) * 100",
        "legendFormat": "◆◆◆◆ %"
      }
    ],
    "type": "gauge"
  },
  {
    "title": "◆◆◆◆ (p95)",
    "targets": [
      {
        "expr": "histogram_quantile(0.95,
rate(s5s8_inbound_handling_duration_bucket[5m]))",
        "legendFormat": "S5/S8 p95"
      },
      {
        "expr": "histogram_quantile(0.95,
rate(sxb_inbound_handling_duration_bucket[5m]))",
        "legendFormat": "PFCP p95"
      }
    ],
    "type": "graph"
  }
]
}
}
}

```

◆◆

◆◆◆◆

◆◆ omnipgw_alerts.yml◆

```

groups:
- name: omnipgw
  interval: 30s
  rules:
  # ◆◆◆◆◆◆
  - alert: OmniPGW_HighSessionCount
    expr: teid_registry_count > 8000
    for: 5m
    labels:
      severity: warning
    annotations:
      summary: "OmniPGW ◆◆◆◆◆◆"
      description: "{{ $value }} ◆◆◆◆◆◆◆◆8000◆◆"

  - alert: OmniPGW_SessionCountCritical
    expr: teid_registry_count > 9500
    for: 2m
    labels:
      severity: critical
    annotations:
      summary: "OmniPGW ◆◆◆◆◆◆◆◆"
      description: "{{ $value }} ◆◆◆◆◆◆◆◆◆◆"

  # IP ◆◆◆◆
  - alert: OmniPGW_IPPoolUtilizationHigh
    expr: (address_registry_count / 254) * 100 > 80
    for: 10m
    labels:
      severity: warning
    annotations:

```

```

summary: "OmniPGW IP 🎯🎯🎯🎯"
description: "IP 🎯 {{ $value }}% 🎯🎯🎯"

- alert: OmniPGW_IPPoolExhausted
  expr: address_registry_count >= 254
  for: 1m
  labels:
    severity: critical
  annotations:
    summary: "OmniPGW IP 🎯🎯🎯"
    description: "🎯🎯🎯🎯 IP"

# 🎯🎯🎯🎯
- alert: OmniPGW_HighErrorRate
  expr: rate(s5s8_inbound_errors_total[5m]) > 0.1
  for: 5m
  labels:
    severity: warning
  annotations:
    summary: "OmniPGW 🎯🎯🎯🎯"
    description: "{{ $value }} 🎯/🎯 S5/S8 🎯🎯"

- alert: OmniPGW_GxErrorRate
  expr: rate(gx_inbound_errors_total[5m]) > 0.05
  for: 5m
  labels:
    severity: warning
  annotations:
    summary: "OmniPGW Gx 🎯🎯"
    description: "{{ $value }} Diameter 🎯/🎯"

# PFCP 🎯🎯
- alert: OmniPGW_PFCPAssociationDown
  expr: pfcpeer_associated == 0
  for: 1m
  labels:
    severity: critical
  annotations:
    summary: "PFCP 🎯🎯 {{ $labels.peer }} 🎯🎯🎯"
    description: "PFCP 🎯🎯🎯🎯"

- alert: OmniPGW_PFCPHeartbeatFailures
  expr: pfcpeer_consecutive_heartbeat_failures > 2
  for: 30s
  labels:
    severity: warning
  annotations:
    summary: "PFCP 🎯🎯🎯🎯"
    description: "{{ $value }} 🎯🎯🎯🎯 {{ $labels.peer }}"

# 🎯🎯🎯🎯
- alert: OmniPGW_HighLatency
  expr: |
    histogram_quantile(0.95,
      rate(s5s8_inbound_handling_duration_bucket[5m])
    ) > 100000
  for: 5m
  labels:
    severity: warning
  annotations:
    summary: "OmniPGW 🎯🎯🎯🎯"
    description: "p95 🎯🎯 {{ $value }}µs (> 100ms)"

# 🎯🎯🎯🎯
- alert: OmniPGW_HighMemoryUsage

```

```

expr: vm_memory_total > 2000000000
for: 10m
labels:
  severity: warning
annotations:
  summary: "OmniPGW 📦📦📦📦"
  description: "VM 📦📦 {{ $value | humanize }}B 📦📦"
- alert: OmniPGW_HighProcessCount
expr: vm_system_process_count > 100000
for: 10m
labels:
  severity: warning
annotations:
  summary: "OmniPGW 📦📦📦📦"
  description: "{{ $value }} Erlang 📦📦📦📦📦📦"

```

AlertManager 📦📦

```

# alertmanager.yml
global:
  resolve_timeout: 5m

route:
  receiver: 'ops-team'
  group_by: ['alertname', 'instance']
  group_wait: 10s
  group_interval: 10s
  repeat_interval: 12h

routes:
- match:
  severity: critical
  receiver: 'pagerduty'

- match:
  severity: warning
  receiver: 'slack'

receivers:
- name: 'ops-team'
  email_configs:
  - to: 'ops@example.com'

- name: 'slack'
  slack_configs:
  - api_url: 'https://hooks.slack.com/services/YOUR/SLACK/WEBHOOK'
    channel: '#omnipgw-alerts'
    title: 'OmniPGW 📦📦{{ .GroupLabels.alertname }}'
    text: '{{ range .Alerts }}{{ .Annotations.description }}{{ end }}'

- name: 'pagerduty'
  pagerduty_configs:
  - service_key: 'YOUR_PAGERDUTY_KEY'

```

📦📦📦📦

📦📦📦📦📦 (KPI)

📦📦📦📦

📦📦📦📦📦

◆◆◆

- ◆◆◆◆◆◆
- ◆◆ PCRF ◆◆◆◆Gx ◆◆◆
- ◆◆ IP ◆◆◆

◆◆◆◆◆◆◆◆◆◆

◆◆◆

```

histogram_quantile(0.95,
rate(s5s8_inbound_handling_duration_bucket{request_message_type="create_session_request"}[5m])
)

```

◆◆◆

- ◆◆ Gx ◆◆◆◆PCRF ◆◆◆◆◆◆
- ◆◆ PFCP ◆◆◆◆PGW-U ◆◆◆◆◆◆
- ◆◆◆◆◆◆◆◆◆◆◆◆

◆◆◆◆◆◆◆◆◆◆

◆◆◆

```

# ◆◆◆◆◆◆
rate(vm_memory_total[1h])

# ◆◆◆◆◆◆
rate(vm_memory_processes[1h])

# ◆◆◆◆◆◆
rate(vm_system_process_count[1h])

```

◆◆◆

- ◆◆◆◆◆◆
- ◆◆◆◆◆◆
- ◆◆◆◆◆◆◆◆◆◆◆◆

◆◆◆◆

◆◆◆◆◆◆◆◆◆◆

```
max_over_time(teid_registry_count[24h])
```

◆◆◆◆◆◆◆◆◆◆

```
teid_registry_count /
avg_over_time(teid_registry_count[7d])
```

◆◆◆◆◆◆

```
abs(
  teid_registry_count -
  avg_over_time(teid_registry_count[1h])
) > 100
```

◆◆◆◆◆◆

◆◆◆◆◆◆

1. ◆◆◆◆◆◆ 15-30 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆

2. [15](#)
3. [15](#)

[15](#)

1. [NOC](#) [KPI](#)
2. [15](#) - [15](#)
3. [15](#) - [15](#)

[15](#)

1. [15](#) - [15](#)
2. [15](#) - [15](#) → [15](#)
3. [15](#) - [15](#)

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- [Prometheus](#) [Web UI](#)
- [15](#) - [15](#)

[15](#)

- [PCFP](#) - [PCFP](#) [UPF](#)
- [Diameter Gx](#) - [Gx](#) [PCRF](#)
- [Diameter Gy](#) - [Gy](#) [OCS](#)
- [S5/S8](#) - [GTP-C](#) [SGW-C](#)

[15](#)

- [P-CSCF](#) - [P-CSCF](#) [IMS](#)
- [15](#) - [15](#)
- [UE IP](#) - [IP](#)

[15](#)

OmniPGW - *OmniTouch*



◆◆◆◆◆ (PCO)

◆◆◆ UE ◆◆◆◆◆

OmniPGW by Omnitouch Network Services



PCO (◆◆◆◆◆) ◆◆ PDN ◆◆◆◆◆◆◆◆◆ UE (◆◆◆◆) ◆◆◆◆◆◆◆◆◆◆ UE ◆◆◆◆◆◆◆◆◆◆ DNS◆IMS◆◆◆◆◆◆◆◆◆

PCO ◆◆◆◆◆

IE ◆◆	◆◆ ID	◆◆	◆◆
DNS ◆◆◆ IPv4 ◆◆	0x000D◆	DNS	◆
DNS ◆◆◆ IPv4 ◆◆	0x000D◆	DNS	◆◆
P-CSCF IPv4 ◆◆	0x000C IMS ◆	P-CSCF	◆◆ (IMS)
IPv4 ◆◆ MTU	0x0010 ◆◆◆◆◆◆		◆◆
NBNS ◆◆◆ IPv4 ◆◆	0x0011 NetBIOS ◆◆◆◆◆◆◆◆		



```
# config/runtime.exs
config :pgw_c,
  pco: %{
    # DNS ◆◆◆ (◆◆)
    primary_dns_server_address: "8.8.8.8",
    secondary_dns_server_address: "8.8.4.4",

    # NBNS ◆◆◆ (◆◆◆◆◆◆ Windows ◆◆)
    primary_nbns_server_address: nil,
    secondary_nbns_server_address: nil,

    # IMS/VoLTE ◆ P-CSCF ◆◆ (◆◆)
    p_cscf_ipv4_address_list: [],

    # P-CSCF ◆◆◆◆ (◆◆)
    p_cscf_discovery_enabled: false,
    p_cscf_discovery_dns_server: nil,
```

```
p_cscf_discovery_timeout_ms: 5000,  
# IPv4 MTU ( )  
  ipv4_link_mtu_size: 1400  
}
```

PCO ()

DNS ()

() DNS () DNS ()

```
pco: %  
  primary_dns_server_address: "8.8.8.8",  
  secondary_dns_server_address: "8.8.4.4"  
}
```

() DNS () () ()

() ()	() DNS	() DNS
Google	8.8.8.8	8.8.4.4
Cloudflare	1.1.1.1	1.0.0.1
Quad9	9.9.9.9	149.112.112.112
OpenDNS	208.67.222.222	208.67.220.220

() DNS ()

```
pco: %  
  primary_dns_server_address: "10.0.0.10",  
  secondary_dns_server_address: "10.0.0.11"  
}
```

P-CSCF () (IMS)

() IMS/VoLTE () ()

```
pco: %  
  p_cscf_ipv4_address_list: [  
    "10.0.0.50", # ( ) P-CSCF  
    "10.0.0.51" # ( ) P-CSCF  
  ]  
}
```

P-CSCF () () () () () () () () ()

- IMS () () () () ()

- VoLTE ◊ VoWiFi ◊ RCS ◊ ◊ ◊
- UE ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ SIP

P-CSCF ◊ ◊ ◊ ◊

◊ ◊ DNS ◊ P-CSCF ◊ ◊ ◊

OmniPGW ◊ ◊ ◊ ◊ DNS ◊ ◊ ◊ ◊ ◊ ◊ P-CSCF ◊ ◊ ◊ ◊ 3GPP TS 23.003 ◊ TS 24.229
 ◊

```
pco: %{
  # ◊ ◊ ◊ ◊ P-CSCF ◊ ◊
  p_cscf_discovery_enabled: true,

  # ◊ ◊ P-CSCF ◊ ◊ ◊ DNS ◊ ◊ ◊ (◊ ◊ ◊ ◊)
  p_cscf_discovery_dns_server: {10, 179, 2, 177},

  # DNS ◊ ◊ ◊ ◊ ◊ (◊ ◊)
  p_cscf_discovery_timeout_ms: 5000,

  # ◊ ◊ P-CSCF ◊ ◊ (◊ ◊ DNS ◊ ◊ ◊ ◊ ◊ ◊)
  p_cscf_ipv4_address_list: ["10.0.0.50"]
}
```

◊ ◊ ◊ ◊ ◊

1. ◊ p_cscf_discovery_enabled: true ◊ ◊ PGW-C ◊ ◊ DNS ◊ ◊ ◊ ◊ ◊ ◊ P-CSCF ◊ ◊
2. DNS ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ p_cscf_discovery_dns_server
3. ◊ ◊ DNS ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ P-CSCF ◊ ◊ ◊ ◊ ◊ ◊ PCO ◊ ◊ ◊ ◊ UE
4. ◊ ◊ DNS ◊ p_cscf_ipv4_address_list
5. ◊ ◊ P-CSCF ◊

P-CSCF ◊ ◊ ◊ ◊

◊ ◊ ◊ ◊ ◊ ◊

1. ◊ ◊ ◊ ◊ **FQDN** ◊ ◊ (◊ ◊ ◊ ◊ ◊ ◊) - p_cscf_discovery_fqdn ◊ UPF ◊ ◊ ◊ ◊ ◊ ◊
2. ◊ ◊ **DNS** ◊ ◊ - p_cscf_discovery_enabled: true ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊
3. ◊ ◊ **PCO** ◊ ◊ ◊ ◊ ◊ ◊ - p_cscf_ipv4_address_list ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊
4. ◊ ◊ **PCO** ◊ ◊ ◊ ◊ ◊ ◊ (◊ ◊) - p_cscf_ipv4_address_list ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊

◊ ◊ ◊

◊ ◊ P-CSCF ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊ ◊

- DNS ◊ ◊ ◊ ◊ ◊ ◊ / ◊ ◊ ◊ ◊
- ◊ ◊ ◊ ◊ ◊

- `dns`
- `dns`

`dns` `P-CSCF`

`dns`

```

p_cscf_discovery_enabled false DNS P-CSCF
p_cscf_discovery_dns_server (IP) nil DNS IP 4 ({10, 179, 2, 177})
p_cscf_discovery_timeout_ms 5000 DNS

```

`dns`

- `IMS` - `P-CSCF` DNS
- `dns` - `DNS` `P-CSCF`
- `dns` - `DNS` `P-CSCF`
- `dns` - `P-CSCF`

`ims` `DNS`

```

pco: %{
  primary_dns_server_address: "10.0.0.10",
  secondary_dns_server_address: "10.0.0.11",

  # P-CSCF
  p_cscf_discovery_enabled: true,
  p_cscf_discovery_dns_server: {10, 179, 2, 177}, # IMS DNS
  p_cscf_discovery_timeout_ms: 3000,

  # P-CSCF (DNS)
  p_cscf_ipv4_address_list: [
    "10.0.0.50", #
    "10.0.0.51" #
  ],

  ipv4_link_mtu_size: 1400
}

```

`upf` `P-CSCF`

`P-CSCF` `UPF` `APN` `DNS` `P-CSCF`

```

# upf_selection
rules: [
  %{

```

```

name: "IMS",
priority: 20,
match_field: :apn,
match_regex: "^ims",
upf_pool: [...],

# P-CSCF
p_cscf_discovery_fqdn: "pcscf.mnc380.mcc313.3gppnetwork.org"
}
]

```

UPF P-CSCF

P-CSCF P-CSCF

NBNS (NetBIOS)

Windows

```

pco: %{
  primary_nbns_server_address: "10.0.0.20",
  secondary_nbns_server_address: "10.0.0.21"
}

```

- Windows
-
- NetBIOS

MTU

```

pco: %{
  ipv4_link_mtu_size: 1400 #
}

```

MTU

MTU
1500
1400 GTP
1420
1280 IPv6 MTU
1360 VPN/

LTE **1400** GTP-U



Internet APN

```
pco: %{\n  primary_dns_server_address: "8.8.8.8",\n  secondary_dns_server_address: "8.8.4.4",\n  ipv4_link_mtu_size: 1400\n}
```

IMS APN

```
pco: %{\n  primary_dns_server_address: "10.0.0.10",\n  secondary_dns_server_address: "10.0.0.11",\n  p_cscf_ipv4_address_list: [\n    "10.0.0.50",\n    "10.0.0.51"\n  ],\n  ipv4_link_mtu_size: 1400\n}
```

[P-CSCF](#) IMS P-CSCF

APN

```
pco: %{\n  primary_dns_server_address: "10.100.0.10",\n  secondary_dns_server_address: "10.100.0.11",\n  primary_nbns_server_address: "10.100.0.20",\n  secondary_nbns_server_address: "10.100.0.21",\n  ipv4_link_mtu_size: 1400\n}
```

PCO GTP-C



OmniPGW PCO



```
|  :   
| UE IP  : 100.64.1.42  
| PCO (  )
```

```
— DNS 111 IPv4 11: 8.8.8.8
— DNS 111 IPv4 11: 8.8.4.4
— P-CSCF IPv4 11: 10.0.0.50
— P-CSCF IPv4 11: 10.0.0.51
— IPv4 11 MTU: 1400
```

UE 11

UE 11 PCO 11

1. 1111111111111111 DNS 1111
2. 11 P-CSCF 11 IMS 11
3. 1111 MTU 11111111

111111

111111 UE 111111 DNS

1111

- UE 11 IP 1111111111111111
- DNS 111111

11111111

1. PCO 111111 DNS 1111111111111111
2. 11 UE IP 11111111 DNS 111111
3. 11111111 DNS 1111

11111111

```
# 11 DNS 111111111111
ping 8.8.8.8
```

```
# 11 UE 111111 DNS 11
nslookup google.com 8.8.8.8
```

```
# 11 PCO 11
grep "primary_dns_server_address" config/runtime.exs
```

111111 IMS 111111

1111

- VoLTE 111111
- UE 11 "11 IMS 1111"

❖❖❖❖

- ❖❖ P-CSCF ❖❖
- P-CSCF IP ❖❖❖❖❖
- P-CSCF ❖❖❖❖

❖❖❖❖

```
# ❖❖ P-CSCF ❖❖
pco: %{
  p_cscf_ipv4_address_list: ["10.0.0.50"] # ❖❖❖❖❖
}
```

❖❖❖MTU ❖❖

❖❖❖

- ❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖
- ❖❖❖❖❖❖❖
- ❖❖❖❖

❖❖❖❖

- MTU ❖❖❖❖❖❖❖❖❖
- MTU ❖❖❖❖❖❖❖❖❖

❖❖❖❖

```
# ❖❖❖GTP ❖❖❖❖ 1400
pco: %{
  ipv4_link_mtu_size: 1400
}
```

```
# ❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖❖
pco: %{
  ipv4_link_mtu_size: 1360
}
```

❖❖❖❖

DNS ❖❖

- ❖❖❖❖❖ **DNS** ❖❖❖
 - ❖❖❖Google (8.8.8.8), Cloudflare (1.1.1.1)
 - ❖❖❖❖❖❖❖❖ DNS

2. DNS

- o
- o

3. DNS

- o DNSSEC
- o DNS

IMS

1. P-CSCF

- o 2
- o

2.

- o P-CSCF UE IP
- o SIP

MTU

1.

- o GTP-U: 36 (IPv4)
- o IPsec: (50-100)

2. LTE MTU

- o 1400
- o

3.

- o MTU
- o

- [runtime.exe](#) UPF PCO
- [UE IP](#) - IP APN
- [P-CSCF](#) - P-CSCF

◆◆◆◆◆◆◆◆

- [◆◆◆◆◆](#) - PDN ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
- [S5/S8](#) ◆◆ - GTP-C ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
- [PFCP](#) ◆◆ - ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆

IMS ◆ VoLTE

- [Diameter Gx](#) ◆◆ - IMS ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
- [◆◆◆◆◆](#) - ◆◆ PCO ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆

[◆◆◆◆◆◆◆◆](#)

OmniPGW PCO ◆◆ - ◆ *OmniTouch Network Services* ◆◆

P-CSCF

P-CSCF

OmniPGW Omnitouch

P-CSCF (DNS SRV IMS P-CSCF SIP OPTIONS

- P-CSCF
- DNS 60
- SIP OPTIONS SIP OPTIONS ping P-CSCF
 - TCP SIP OPTIONS
 - UDP TCP UDP
 - :up :down
- Web UI IP
- Prometheus Prometheus

- 1.
- 2.
- 3.
4. Web UI
- 5.
- 6.
7. DNS
- 8.
- 9.

config/runtime.exs

PCO P-CSCF DNS

config :pgw_c,

```
pco: %{  
  p_cscf_discovery_dns_server: "10.179.2.177",  
  p_cscf_discovery_enabled: true,  
  p_cscf_discovery_timeout_ms: 5000  
},
```

upf_selection: %{

```
  rules: [  
    # IMS - P-CSCF  
    %{  
      name: "IMS",  
      priority: 20,  
      match_field: :apn,  
      match_regex: "~ims",  
      upf_pool: [  
        %{remote_ip_address: "10.100.2.21", remote_port: 8805, weight: 80}  
      ],  
      # P-CSCF FQDN UPF  
      p_cscf_discovery_fqdn: "pcscf.mnc380.mcc313.3gppnetwork.org",  
      # PCO  
      pco: %{  
        p_cscf_ipv4_address_list: ["10.101.2.100", "10.101.2.101"]  
      }  
    }  
  ]  
}
```

UPF PCO P-CSCF

1. OmniPGW
2. Web UI - P-CSCF (https://localhost:8086/pcscf_monitor)
3. IP

P-CSCF

PCO P-CSCF DNS

```
pco: %{  
  # P-CSCF DNS UE DNS  
  p_cscf_discovery_dns_server: "10.179.2.177",  
  
  # P-CSCF DNS  
  p_cscf_discovery_enabled: true,  
  
  # DNS SRV  
  p_cscf_discovery_timeout_ms: 5000,  
  
  # P-CSCF  
  p_cscf_ipv4_address_list: ["10.101.2.146"]  
}
```

P-CSCF FQDN

UPF P-CSCF FQDN

upf_selection: %{

```
  rules: [  
    # IMS - P-CSCF  
    %{  
      name: "IMS",  
      match_field: :apn,  
      match_regex: "~ims",  
      upf_pool: [...],  
      p_cscf_discovery_fqdn: "pcscf.ims.mnc380.mcc313.3gppnetwork.org",  
      pco: %{  
        p_cscf_ipv4_address_list: ["10.101.2.100"] #  
      }  
    },  
  
    # - P-CSCF  
    %{  
      name: "",  
      match_field: :apn,  
      match_regex: "~enterprise",  
      upf_pool: [...],  
      p_cscf_discovery_fqdn: "pcscf.enterprise.example.com",  
      pco: %{  
        p_cscf_ipv4_address_list: ["192.168.1.50"] #  
      }  
    }  
  ],  
  
  # - P-CSCF
```

```

%{
  name: "P-CSCF",
  match_field: :apn,
  match_regex: ".*internet",
  upf_pool: [...]
  # p_cscf_discovery_fqdn - PCO
}
}

```

1. P-CSCF

1.1 P-CSCF

- P-CSCF GenServer
- UPF P-CSCF FQDN

2. FQDN

- FQDN
- DNS SRV
- SIP OPTIONS
 - TCP/SIP/2.0/TCP 5060
 - TCP/SIP/2.0/UDP 5060
 - :up :down
- IP

3. 60

- FQDN
- DNS
- TCP/SIP OPTIONS
 - TCP/UDP 5060
- DNS

DNS

DNS SRV

P-CSCF

1. SRV _sip._tcp.{fqdn} SRV
2. SRV _sip._tcp.{fqdn} SRV
3. SRV _sip._tcp.{fqdn} SRV
4. IP AAAA
5. IP

P-CSCF

FQDN PCO FQDN

```

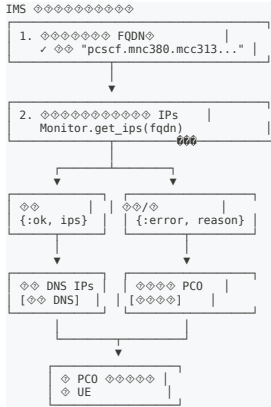
%{
  name: "IMS",
  p_cscf_discovery_fqdn: "pcscf.mnc380.mcc313.3gppnetwork.org", # -
  pco: %{
    p_cscf_ipv4_address_list: ["10.101.2.100", "10.101.2.101"] # -
  }
}

```

IP

P-CSCF IP
 FQDN DNS IP "FQDN pcscf.example.com P-CSCF"
 FQDN PCO pco.p_cscf_ipv4_address_list IP FQDN P-CSCF IP
 FQDN PCO pco.p_cscf_ipv4_address_list IP
 FQDN PCO pco.p_cscf_ipv4_address_list IP
 FQDN PCO pco.p_cscf_ipv4_address_list IP

IMS



1 DNS

```

p_cscf_discovery_fqdn: "pcscf.ims.example.com"
pco.p_cscf_ipv4_address_list: ["10.101.2.100"]

DNS [10.101.2.150, 10.101.2.151]
UE [10.101.2.150, 10.101.2.151] - DNS
DNS PCO

```

2 DNS

```

p_cscf_discovery_fqdn: "pcscf.ims.example.com"
pco.p_cscf_ipv4_address_list: ["10.101.2.100"]

DNS :no_naptr_records
UE [10.101.2.100] - PCO
DNS

```

3 FQDN

```

# p_cscf_discovery_fqdn
pco.p_cscf_ipv4_address_list: ["192.168.1.50"]

UE [192.168.1.50] - PCO

```



```

  ◇ P-CSCF ◇
  FQDN: pcscf.mnc380.mcc313.3gppnetwork.org
  ◇ : / ◇ (2 ◇ IP)
  ◇ IPs: 10.101.2.100, 10.101.2.101

  ◇ PCO ◇
  ◇ DNS: 10.103.2.195
  P-CSCF ◇ ◇ ◇ ◇ ◇ ◇ ◇ ◇ ◇ ◇ ◇ ◇ 10.101.2.100, 10.101.2.101

```

◆◆◆◆◆◆◆◆

Prometheus ◆◆

P-CSCF ◆◆◆◆◆◆ Prometheus ◆◆◆◆◆◆◆◆◆◆ 42069◆◆

◆◆◆◆

```

# FQDN ◆◆◆◆◆
pcscf_fqdns_total # ◆◆◆ FQDN ◆◆
pcscf_fqdns_resolved # ◆◆◆◆ FQDN◆DNS ◆◆◆
pcscf_fqdns_failed # ◆◆◆ FQDN ◆◆◆DNS ◆◆◆

# ◆◆◆◆◆◆◆◆◆◆◆◆◆
pcscf_servers_total # ◆◆ DNS SRV ◆◆◆ P-CSCF ◆◆◆◆◆
pcscf_servers_healthy # ◆◆ SIP OPTIONS ◆◆◆◆◆◆◆◆◆
pcscf_servers_unhealthy # ◆◆◆ SIP OPTIONS ◆◆◆◆◆◆◆◆◆

# ◆◆◆◆◆◆◆◆◆◆◆◆ FQDN ◆◆◆◆◆
pcscf_servers_healthy{fqdn="..."} # ◆◆ FQDN ◆◆◆◆◆◆◆◆
pcscf_servers_unhealthy{fqdn="..."} # ◆◆ FQDN ◆◆◆◆◆◆◆◆

```

```

◆◆◆◆◆◆◆◆
  • healthy: ◆◆◆◆◆ SIP OPTIONS ping◆TCP ◆ UDP◆
  • unhealthy: ◆◆◆◆◆◆◆◆ SIP OPTIONS◆◆◆◆◆ 5s ◆◆◆◆◆

```

◆◆◆◆

DNS ◆◆◆◆◆

```

# ◆◆◆◆◆◆◆◆ FQDN
pcscf_fqdns_resolved

# ◆◆◆ DNS ◆◆◆◆◆
(pcscf_fqdns_resolved / pcscf_fqdns_total) * 100

# ◆◆◆◆◆◆◆◆
pcscf_servers_total

```

SIP OPTIONS ◆◆◆◆◆

```

# ◆◆ FQDN ◆◆◆◆◆◆◆◆◆◆◆◆
pcscf_servers_healthy

# ◆◆◆◆◆◆◆◆◆◆◆
pcscf_servers_unhealthy

# ◆◆◆◆◆◆◆◆◆◆◆
(pcscf_servers_healthy / pcscf_servers_total) * 100

# ◆◆◆ FQDN ◆◆◆◆◆◆◆◆
pcscf_servers_healthy{fqdn="pcscf.mnc380.mcc313.3gppnetwork.org"}

# ◆◆◆◆◆◆◆◆◆◆◆◆
pcscf_servers_healthy == 0 AND pcscf_servers_total > 0

```

◆◆◆ **Prometheus** ◆◆◆

```

# ◆◆◆ P-CSCF ◆◆◆◆◆◆◆◆◆◆◆◆
- alert: AllPCSCFServersDown
  expr: pcscf_servers_healthy == 0 AND pcscf_servers_total > 0
  for: 5m
  labels:
    severity: critical
  annotations:
    summary: "◆◆◆ P-CSCF ◆◆◆◆◆◆◆◆"
    description: "{{ $value }} ◆◆◆◆◆ (0) - ◆◆◆ SIP OPTIONS ◆◆◆◆◆"

# ◆◆◆ 50% ◆◆◆◆◆◆◆◆◆◆◆◆
- alert: MajorityPCSCFServersDown
  expr: (pcscf_servers_healthy / pcscf_servers_total) < 0.5
  for: 5m
  labels:
    severity: warning
  annotations:
    summary: "◆◆◆◆◆ P-CSCF ◆◆◆◆◆◆◆◆"
    description: "◆◆◆ {{ $value }}% ◆◆◆◆◆◆◆◆ SIP OPTIONS◆"

# DNS ◆◆◆◆◆◆◆◆◆◆◆
- alert: PCSCFDNSResolutionFailed
  expr: pcscf_fqdns_failed > 0
  for: 5m
  labels:
    severity: warning
  annotations:
    summary: "P-CSCF DNS ◆◆◆◆◆"
    description: "{{ $value }} ◆◆◆ FQDN ◆◆◆◆◆"

```

◆◆◆◆◆

```

[info] P-CSCF ◆◆◆◆◆
[info] ◆◆◆ 2 ◆◆◆◆◆ P-CSCF FQDN ◆◆◆◆◆: ["pcscf.ims.example.com", "pcscf.enterprise.example.com"]
[info] P-CSCF ◆◆◆◆◆◆◆ FQDN pcscf.ims.example.com
[debug] P-CSCF ◆◆◆◆◆◆◆ pcscf.ims.example.com ◆◆◆◆◆ 2 ◆◆ IP
[warning] P-CSCF ◆◆◆◆◆◆◆ pcscf.enterprise.example.com: :nxdomain
[debug] ◆◆◆◆◆ FQDN pcscf.ims.example.com ◆◆ P-CSCF ◆◆: [{10, 101, 2, 100}, {10, 101, 2, 101}]

```

◆◆◆◆◆

◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆

◆◆◆ 1 ◆◆◆◆◆ DNS ◆◆◆◆◆◆◆◆◆◆◆

p_cscf_discovery_fqdn: "pcscf.ims.example.com"

- ◆◆◆◆◆ DNS ◆◆◆◆◆◆◆◆◆◆ IP
- ◆◆◆◆◆◆◆◆◆◆ IP
- ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆

◆◆◆ 2 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ PCO◆◆◆◆◆

```

pco: %[
  p_cscf_ip4_address_list: ["10.101.2.100", "10.101.2.101"]
]

```

- ◆◆◆ DNS ◆◆◆◆◆◆◆◆◆◆ IP◆◆◆◆◆
- ◆◆◆◆◆◆◆◆◆◆◆
- ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆

3 PCO

```
# PCO
pcscf: {
  p_cscf_ipv4_address_list: ["10.101.2.146"]
}
```

- DNS
- P-CSCF
-

IMS

"IMS"

- DNS "pcscf.ims.example.com"
└─ [10.101.2.100, 10.101.2.101] ✓
- PCO
└─ [10.101.2.100, 10.101.2.101] ✓
- PCO
└─ [10.101.2.146] ✓

DNS

DNS

DNS SRV A/AAAA P-CSCF

```
; P-CSCF SRV sip._tcp.pcscf.mnc380.mcc313.3gppnetwork.org. IN SRV 10 50 5060 pcscf1.example.com.
_sip._tcp.pcscf.mnc380.mcc313.3gppnetwork.org. IN SRV 20 50 5060 pcscf2.example.com.
```

```
; A
pcscf1.example.com. IN A 10.101.2.100
pcscf2.example.com. IN A 10.101.2.101
```

OmnipGW FQDN _sip._tcp.p_cscf_discovery_fqdn: "pcscf.mnc380.mcc313.3gppnetwork.org" _sip._tcp.pcscf.mnc380.mcc313.3gppnetwork.org

SRV

SRV

_service._proto.domain. IN SRV priority weight port target.

- 10 20
- =
- SIP TCP 5060 UDP 5060
- IP

DNS

```
# SRV _sip._tcp
dig SRV _sip._tcp.pcscf.mnc380.mcc313.3gppnetwork.org @10.179.2.177
```

```
# _sip._tcp.pcscf.mnc380.mcc313.3gppnetwork.org. 300 IN SRV 10 50 5060 pcscf1.example.com.
```

```
# P-CSCF IP
dig A pcscf1.example.com @10.179.2.177
```

```
# pcscf1.example.com. 300 IN A 10.101.2.100
```

FQDN

FQDN

- Web UI X
- nxdomain:timeout :no_naptr_records

- DNS
- FQDN DNS
- NAPTR
- DNS

```
# 1. DNS
ping 10.179.2.177
```

```
# 2. NAPTR
dig NAPTR pcscf.mnc380.mcc313.3gppnetwork.org @10.179.2.177
```

```
# 3. OmnipGW
grep "P-CSCF" /var/log/pgw_c.log
```

```
# 4.
grep "p_cscf_discovery_dns_server" config/runtime.exs
```

```
# 5. Web UI
# FQDN
```

IP

- Web UI "0 IPs"
- / X

- NAPTR FQDN
- IMS/SIP
- A/AAAA

```
# NAPTR
dig NAPTR pcscf.example.com @10.179.2.177
```

```
# "SIP" "IMS":
# "SIP+DZU", "x-3gpp-ims:sip"
# "HTTP", "FTP"
```

```
# A/AAAA
dig pcscf1.example.com A @10.179.2.177
```

P-CSCF

- UE P-CSCF
- IP

1. DNS
- 2.
3. FQDN

```
# 1. P-CSCF
# FQDN
```

```
# 2.
grep " FQDN P-CSCF" /var/log/pgw_c.log
```

```
# 3. UPF
# FQDN
```

```
# 4. APN
```

DNS

-
- pcscf_discovery_query_duration_seconds

1. DNS
2. DNS
- 3.

```
#
```

```
pco: {
  p_cscf_discovery_timeout_ms: 2000 # 5000ms
}
```

```
# DNS
```

```
pco: {
  p_cscf_discovery_dns_server: "10.0.0.10" # DNS
}
```

1. DNS

DNS

```
pco: {
  # DNS P-CSCF UE DNS
  p_cscf_discovery_dns_server: "10.179.2.177",

  # UE DNS
  primary_dns_server_address: "8.8.8.8",
  secondary_dns_server_address: "8.8.4.4"
}
```

- UE DNS IMS DNS
-
-

2.

```
{
  p_cscf_discovery_fqdn: "pcscf.ims.example.com", #
  pco: {
    p_cscf_ipv4_address_list: ["10.101.2.100"] #
  }
}
```

- DNS
-
- SLA

3. FQDN

```
rules: [
  # IMS
  {
    name: "IMS",
    match_regex: "~ims",
    p_cscf_discovery_fqdn: "pcscf.ims.mnc380.mcc313.3gppnetwork.org"
  },
  #
  {
    name: "",
    match_regex: "~enterprise",
    p_cscf_discovery_fqdn: "pcscf.enterprise.example.com"
  }
]
```

- P-CSCF
-
-

4. DNS

```
# P-CSCF
alert: HighPCSCFQueryLatency
expr: histogram_quantile(0.95, pcscf_discovery_query_duration_seconds_bucket) > 2
for: 5m
labels:
  severity: warning
annotations:
  summary: "P-CSCF DNS (p95 > 2s)"
```

5. DNS

- Web UI P-CSCF
- pcscf_monitor_fqdns_failed
- DNS
- DNS

6.

```
#
pco: {
  p_cscf_discovery_timeout_ms: 5000 # 5
}
```

```
#
```

```
pco: {
  p_cscf_discovery_timeout_ms: 2000 # 2
}
```

7. DNS

DNS

```
# P-CSCF DNS
pcscf.mnc380.mcc313.3gppnetwork.org. IN NAPTR 10 50 "s" "SIP+D2U" "" _sip._udp.pcsf1.example.com.

# P-CSCF DNS
pcscf.mnc380.mcc313.3gppnetwork.org. IN NAPTR 20 50 "s" "SIP+D2U" "" _sip._udp.pcsf2.example.com.
```

- PCO - DNS P-CSCF
- OmniPGW
- PCO
- PECP

















OmniPGW P-CSCF - Omnitouch



PFCP/Sxb































         - PGW-C  PGW-U 

1.  
 2.    
 3. [PFCP !\[\]\(25cd75bfe2d7f399ad762823735fb2c3_img.jpg\) !\[\]\(e8284b9a92aac1a1f37ca62524734a5e_img.jpg\) !\[\]\(f225a792c387c5a21a86689ea9ec5413_img.jpg\) !\[\]\(6153994a24b6c5700aeadfb5e14c9888_img.jpg\)](#)
 4. [PFCP !\[\]\(a4f01b8782e7ecc47e2d2e12923a93af_img.jpg\) !\[\]\(0d5062aec49305a3df9dc6e9b6c1ef24_img.jpg\) !\[\]\(2f9e511daccc2141dbdf0f1329ef7f0b_img.jpg\) !\[\]\(95200cc5827a28a224651c3e69f8035b_img.jpg\)](#)
 5. [PFCP !\[\]\(5d8175e9181940f43d67b8d7d81ef24f_img.jpg\) !\[\]\(00bf6bba0ae22e77a12237f17ebcd9af_img.jpg\) !\[\]\(2fe43b604388af364b4547c1f9148369_img.jpg\) !\[\]\(fba4e04e4d1303c9d44ad0d63d57efde_img.jpg\) !\[\]\(a16c4afde424ce676d91ff9e5bd2ed2c_img.jpg\)](#)
 6.  
 7. [DNS !\[\]\(b2f1b773b7848037be403c879daa048e_img.jpg\) UPF !\[\]\(a0517be77a18de4b9e0c148d21d82276_img.jpg\)](#)
 8.  
 9.   
 10. [Web UI - PFCP !\[\]\(9f9c101623d4be49e0877e1d46b5b0ef_img.jpg\) !\[\]\(99c645604d71c49cab177d2ea3373a3c_img.jpg\)](#)
 11.   
-








Sxb     ****PFCP**            ******  PGW-C     PGW-U                   

-     **PGW-C**  -          
-     **PGW-U**  -          



















PFCP

PFCP


PGW-C   **PFCP**   **1**  3GPP TS 29.244  

-    UDP
-     8805
-      PFCP      

  **ID**  

PFCP      ID    

- **IPv4**   -  
- **IPv6**  

- FQDN

PFCP

PGW-C PGW-U PFCP

PFCP

is_associated	
remote_node_id	ID IP FQDN
remote_ip_address	IP
remote_port	UDP 8805
heartbeat_period_ms	
missed_heartbeats_consecutive	
up_function_features	
up_recovery_time_stamp	

```
# config/runtime.exs
sxb: %{
  local_ip_address: "10.0.0.20"
},
upf_selection: %{
  fallback_pool: [
    %{remote_ip_address: "10.0.0.21", remote_port: 8805, weight: 100}
  ]
}
# UPF 5
```

- missed_heartbeats_consecutive 1
- 3
-

PFCP

PFCP UE PDN

□□□□□□

□□□□

□□□ UE □□□□□ PDN □□

PGW-C □□□ PGW-U□

□□□□□□□ □□□

- **SEID**□□□□□ ID□ - □□□□□□□□
- □□ ID - PGW-C □□□ ID
- **F-SEID** - □□□□□ SEID□□□ IP + SEID□
- **PDRs** - □□□□□□□□□□ 2□□□ + □□□
- **FARs** - □□□□□□□□□□ 2□□□ + □□□
- **QERs** - QoS □□□□□□□□□□□□
- **BAR** - □□□□□□□□□□□□□□

PGW-U □□□

□□□□□□□ □□□

- □□ - □□□□□□□□
- **F-SEID** - PGW-U □□□□□
- □□□ **PDRs** - □□□□□□□□
- **F-TEID** - S5/S8 □□□□□□□□ TEID

□□□□

□□□ QoS □□□□□□□□□□□□□□

□□□□□□□

- □□□□ PDRs□FARs□QERs
- □□□□□□
- □□□□□□

□□□□

□□□ UE □□□ PDN □□□□□

□□□

1. PGW-C □□□□□□□□□□ SEID
2. PGW-U □□□□□□□□□□
3. PGW-U □□□□□□□□

□□□□□□□□

PFPCP □□□□□□□□□□□□□□□□□□

□□□□

PDR □□□□□□□□

□□□ □□□□□□□□□□□□

□□ PGW-C □□□

PDR #1 - □□□

PDR ID: 1
□□□: 100
PDI □□□□□□□□□□
- □□□: CORE □□□□□□
- UE IP □□: 100.64.1.42/32
FAR ID: 1 □□□□□□□□

PDR #2 - □□□

PDR ID: 2
□□□: 100
PDI □□□□□□□□□□
- □□□: ACCESS □ SGW □□
- F-TEID: <S5/S8 □□□□>
FAR ID: 2 □□□□□□□□
QER ID: 1 □ QoS □□□

□□ PDR □□□

- PDR ID - □□□□□□□□□□
- □□□ - □□□□□□□□□□
- PDI - □□□□□□□□ IP □ TEID □□
- □□□□□□ - □□□□□□ GTP-U □□
- FAR ID - □□□□□□□
- QER ID - □□□ QoS □□□□□□

FAR □□□□□□□□

□□□ □□□□□□□□□□□□

FAR #1 - □□□□□□ → UE □□

FAR ID: 1
□□□□: □□
□□□□□
- □□□□: ACCESS □□ SGW □
- □□□□□□: GTP-U/UDP/IPv4
- □□ F-TEID: <SGW S5/S8 □□□□>

FAR #2 - □□□ UE → □□□□□

FAR ID: 2
□□□□: □□
□□□□□
- □□□□: CORE □□□□□□
- □□□□□□ - □ IP □□□

FAR

- **FAR ID** -
- -
- - ACCESS/CORE
 - GTP-U
 - VRF/

QER QoS

QoS QER Diameter Gy

QER

```

QER ID: 1
:
:
- : 100 Mbps
- : 50 Mbps
: : GBR
- : 10 Mbps
- : 10 Mbps
  
```

QER

- **QER ID** -
- -
- **MBR** - /
- **GBR** -
- **QCI** - QoS

BAR

UE

BAR

```

BAR ID: 1
: : 100ms
: : 10
  
```

DRX

Sxb

config/runtime.exs

```

config :pgw_c,
  sxb: %{
    # PFCP IP
  }
  
```

```

    local_ip_address: "10.0.0.20",

    # 8805
    local_port: 8805
  },

  # UPF - UPF
  upf_selection: %{
    fallback_pool: [
      %{
        # PGW-U IP
        remote_ip_address: "10.0.0.21",

        # PFCP 8805
        remote_port: 8805,

        # 100 = 0 =
        weight: 100
      }
    ]
  }
}

```

PGW-U

```


```

```

config :pgw_c,
  sxb: %{
    local_ip_address: "10.0.0.20"
  },
  upf_selection: %{
    fallback_pool: [
      %{remote_ip_address: "10.0.1.21", remote_port: 8805, weight: 50}, # 50%
      %{remote_ip_address: "10.0.2.21", remote_port: 8805, weight: 50} # 50%
    ]
  }
# 5 UPF

```

UPF

PGW-C UPF

1. -
2. **DNS** - DNS NAPTR
3. - UPF

UPF

```

config :pgw_c,
  # PFCP
  sxb: %{
    local_ip_address: "10.0.0.20"
  },

```

```

# UPF 10.100.2.21 UPF 10.100.2.22
upf_selection: %{
# =====
# 10.100.2.21 DNS 10.100.2.22
# =====
# 10.100.2.21 ULI 10.100.2.22 DNS
# 10.100.2.21 UPF 10.100.2.22
dns_enabled: false,
dns_query_priority: [:ecgi, :tai, :rai, :sai, :cgi],
dns_suffix: "epc.3gppnetwork.org",
dns_timeout_ms: 5000,

# =====
# 10.100.2.21
# =====
# 10.100.2.21
# 10.100.2.21 UPF 10.100.2.22
rules: [
# 10.100.2.21 IMS 10.100.2.22 - 10.100.2.21
%{
name: "IMS 10.100.2.21",
priority: 20,
match_field: :apn,
match_regex: "^ims",
upf_pool: [
%{remote_ip_address: "10.100.2.21", remote_port: 8805, weight: 80},
%{remote_ip_address: "10.100.2.22", remote_port: 8805, weight: 20}
],
# 10.100.2.21 PCO 10.100.2.22
pco: %{
p_cscf_ipv4_address_list: ["10.101.2.100", "10.101.2.101"]
}
},

# 10.100.2.21 APN - 10.100.2.22
%{
name: "10.100.2.21",
priority: 15,
match_field: :apn,
match_regex: "^(enterprise|corporate)\.apn",
upf_pool: [
%{remote_ip_address: "10.100.3.21", remote_port: 8805, weight: 100}
],
pco: %{
primary_dns_server_address: "192.168.1.10",
secondary_dns_server_address: "192.168.1.11",
ipv4_link_mtu_size: 1500
}
},

# 10.100.2.21 30.100.2.21 - 10.100.2.22
%{
name: "30.100.2.21",
priority: 10,
match_field: :serving_network_plmn_id,
match_regex: "^(310|311|312|313)", # 10.100.2.22

```

```

    upf_pool: [
      %{remote_ip_address: "10.100.4.21", remote_port: 8805, weight: 100}
    ]
  },

# 4 - 
%{
  name: "",
  priority: 5,
  match_field: :apn,
  match_regex: "^internet",
  upf_pool: [
    %{remote_ip_address: "10.100.1.21", remote_port: 8805, weight: 33},
    %{remote_ip_address: "10.100.1.22", remote_port: 8805, weight: 33},
    %{remote_ip_address: "10.100.1.23", remote_port: 8805, weight: 34}
  ]
}
],

# =====
# 
# =====
# DNS 
fallback_pool: [
  %{remote_ip_address: "127.0.0.21", remote_port: 8805, weight: 100}
]
}

```

◆◆◆◆◆

	◆◆◆◆	◆◆	◆◆◆
:imsi	◆◆◆◆◆◆◆◆		"310260123456789"
:apn	◆◆◆◆◆		"internet"◆"ims"
:serving_network_plmn_id	◆◆◆◆ PLMN	◆MCC+MNC	"310260"◆◆◆◆◆◆◆◆
:sgw_ip_address	SGW IP	◆◆◆◆◆◆◆◆◆◆	"10.0.1.50"
:uli_tai_plmn_id	◆◆◆◆ PLMN ID		"310260"
:uli_ecgi_plmn_id	E-UTRAN	◆◆ PLMN ID	"310260"

UPF ◆◆◆◆◆

◆◆◆◆◆◆◆◆◆◆ **UPF** ◆◆◆◆◆◆◆◆◆◆

```

upf_pool: [
  %{remote_ip_address: "10.100.1.21", remote_port: 8805, weight: 50},
  %{remote_ip_address: "10.100.1.22", remote_port: 8805, weight: 30},
  %{remote_ip_address: "10.100.1.23", remote_port: 8805, weight: 20}
]

```

◆◆◆◆◆◆◆◆◆◆

1. ◆◆◆◆◆50 + 30 + 20 = 100
2. ◆◆◆◆◆0.0 ◆ 100.0
3. ◆◆◆◆◆◆◆◆◆◆ UPF◆
 - 0-50◆UPF-1◆50% ◆◆◆
 - 50-80◆UPF-2◆30% ◆◆◆


```
# TAI
tac-lb64.tac-hb00.tac.epc.mnc999.mcc999.epc.3gppnetwork.org
```

DNS

1. ECGI TAI
2. DNS
3. UPF
4. DNS DNS

[DNS UPF](#)

DNS UPF

DNS UPF DNS NAPTR UE ULI

3GPP TS 23.003 - UPF DNS

- UPF
-
-
- UPF

```
config :pgw_c,
  upf_selection: %{
    # DNS
    dns_enabled: true,

    # ECGI TAI RAI
    dns_query_priority: [:ecgi, :tai, :rai, :sai, :cgi],

    # DNS
    dns_suffix: "epc.3gppnetwork.org",

    # DNS
    dns_timeout_ms: 5000,

    # DNS
    rules: [...],

    # DNS
    fallback_pool: [...]
  }
```

DNS

DNS GTP-C ULI

1. ECGI-E-UTRAN

- LTE

```
eci-<HEX-ECI>.ecgi.epc.mnc<MNC>.mcc<MCC>.<dns_suffix>
```

```
# ID: 0x1A2B3C1,715,004  
# PLMN: MCC=999, MNC=999  
eci-1a2b3c.ecgi.epc.mnc999.mcc999.epc.3gppnetwork.org
```

LTE 4G

2. TAI

-

```
tac-lb<LB>.tac-hb<HB>.tac.epc.mnc<MNC>.mcc<MCC>.<dns_suffix>
```

```
# TAC: 0x0064100  
# : 0x64, : 0x00  
tac-lb64.tac-hb00.tac.epc.mnc999.mcc999.epc.3gppnetwork.org
```

LTE 4G

3. RAI

3G/2G

```
rac<RAC>.lac-lb<LB>.lac-hb<HB>.lac.raimnc<MNC>.mcc<MCC>.<dns_suffix>
```

```
# RAC: 0x0A10  
# LAC: 0x12344660  
rac0a.lac-lb34.lac-hb12.lac.raimnc999.mcc999.epc.3gppnetwork.org
```

3G/2G UMTS/GPRS

4. SAI

3G


```
# DNS
dig eci-1a2b3c.ecgi.epc.mnc999.mcc999.epc.3gppnetwork.org NAPTR

# PGW-C DNS
grep "DNS UPF: " /var/log/pgw_c.log

# ULI
# "uli"
```

DNS UPF

- DNS upf_selection UPF
-
- PFCP UPF
- PFCP

```
DNS: [10.99.1.50]
upf_selection: [10.100.1.21, 10.100.1.22]
```

```
: 10.99.1.50
- PFCP
-
-
```

1. upf_selection

```
upf_selection: %{
  fallback_pool: [
    %{remote_ip_address: "10.99.1.50", remote_port: 8805, weight: 100}
  ]
}
```

2. DNS UPF IP
3. MEC/

- "DNS UPF"
-

```
upf_selection: %{
  dns_timeout_ms: 10000 # 10
```

◆◆ DNS ◆◆

◆◆◆

```
# DNS ◆◆◆◆◆
rate(upf_selection_dns_success_total[5m]) /
rate(upf_selection_dns_attempts_total[5m])

# DNS ◆◆◆◆
histogram_quantile(0.95, rate(upf_selection_dns_duration_seconds_bucket[5m]))

# ◆◆◆◆◆◆◆◆◆ DNS ◆◆◆
rate(upf_selection_fallback_used_total[5m])
```

◆◆◆

```
[debug] DNS UPF ◆◆: ◆◆ eci-1a2b3c.ecgi.epc.mnc999.mcc999.epc.3gppnetwork.org
[debug] DNS UPF ◆◆: ◆ DNS ◆◆ 2 ◆◆◆
[info] DNS UPF ◆◆: ◆◆ 10.100.1.21
```

◆◆◆

◆◆◆◆◆◆◆◆◆

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◆◆◆◆◆

◆◆◆◆◆

1. ◆◆◆◆◆◆◆

◆◆◆

- ◆◆◆◆◆◆◆◆◆◆“PFCP ◆◆◆◆◆◆◆◆◆◆”
- ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆

◆◆◆◆◆◆

- PGW-U ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
- PGW-U ◆◆◆◆
- ◆◆◆◆◆◆◆ UDP ◆◆ 8805
- ◆◆◆◆◆ remote_ip_address ◆◆◆◆

◆◆◆◆◆◆

```
# ◆◆◆◆◆◆◆
ping <pgw_u_ip_address>

# ◆◆ UDP ◆◆
```

```
nc -u -v <pgw_u_ip_address> 8805
```

```
# iptables -L -n | grep 8805
```

2.

•

- "3"
-

•

- PGW-U
-

•

```
# 5  
#  
# lib/core/pfcp_node/impl/peer.ex - function is_peer_healthy?/1  
# state.missed_heartbeats_consecutive < 3  
# state.missed_heartbeats_consecutive < 5
```

3.

•

-
- "PFCP"

•

- PGW-U
- PGW-U
-

•

1. is_associated = true
2. PGW-U
3. SEID

4. SEID

•

-

•

- SEID
- PGW-U PGW-C

1. [?][?][?][?][?][?]

- [?][?][?][?] - [?] PFCP [?][?][?][?][?][?]
- [?][?][?][?] - [?][?][?][?][?][?][?][?][?][?]
- [?] 2 [?][?][?][?]

2. [?][?][?][?][?][?][?] [?][?][?][?][?] PGW-U [?][?][?]

- [?][?][?][?] - [?][?][?][?][?][?][?]
- **IP** [?][?] - [?] PGW-U IP
- [?][?][?] - [?][?][?][?][?][?][?][?][?][?]
- [?] **ID** - PFCP [?][?][?][?]
- [?][?][?][?] - [?][?][?][?][?][?][?][?][?]
- [?][?][?] - [?][?][?][?][?]
- [?][?][?][?] - [?][?][?][?]
- **UP** [?][?][?] - PGW-U [?][?][?][?]

3. [?][?][?][?][?][?][?] [?][?][?][?][?][?][?][?]

- [?][?][?][?][?][?]
- UP [?][?][?][?][?]
- [?][?][?][?]
- [?][?][?][?][?][?]

PFCP [?][?][?][?]

[?][?][?] http://<omnipgw-ip>:<web-port>/pfcp_sessions

[?][?][?] [?] OmniPGW [?] PGW-U [?][?][?][?] PFCP [?][?]

[?][?][?]

1. [?][?][?][?][?]

- [?] PFCP [?][?][?][?]
- [?][?][?]

2. [?][?][?] [?][?][?] PFCP [?][?][?]

- [?][?][?] - [?][?][?][?]
- [?] **ID** - [?][?][?][?][?]
- **IMSI** - [?][?][?][?][?][?][?][?][?]
- [?][?] - [?][?][?]

3. [?][?][?][?][?][?] [?][?][?][?][?][?][?]

- [?][?][?] PFCP [?][?][?][?]
- PDRs [?] FARs [?] QERs [?] BARs [?][?][?][?][?]
- F-SEIDs [?][?][?][?][?][?][?][?]
- PGW-U [?][?][?][?]

[?][?][?][?]

[?][?] **PFCP** [?][?][?][?]

1. [?][?] UPF [?][?][?][?]

- [S-MIP](#) - PFCP - UPF

S-MIP

- [S5/S8](#) -
- [UE IP](#) - PFCP UE

S-MIP



S5/S8

SGW-C GTP-C

OmniPGW Omnitouch



S5/S8 GTP-C v2 GPRS - OmniPGW SGW-C



GTP-C 2

- GTP-C v2 (3GPP TS 29.274)
- UDP
- 2123
-

TEID

TEID

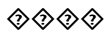
- TEID - OmniPGW
- TEID - SGW-C



```

SGW-C → OmniPGW: TEID = OmniPGW TEID
OmniPGW → SGW-C: TEID = SGW-C TEID

```



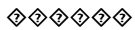
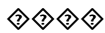
```

# config/runtime.exs
config :pgw_c,
  s5s8: %{
    # S5/S8 IPv4
    local_ipv4_address: "10.0.0.20",

    # IPv6
    local_ipv6_address: nil,

    #
    local_port: 2123
  }

```



```

# SGW-C GTP-C
iptables -A INPUT -p udp --dport 2123 -s <sgw_network>/24 -j ACCEPT

# SGW-C GTP-C

```


◆◆◆◆

```

◆◆◆◆
├── 000: ◆◆◆ (16)
├── PDN ◆◆◆
│   ├── IPv4: 100.64.1.42
│   └── ◆◆◆
│       ├── EBI: 5
│       ├── ◆◆: ◆◆◆
│       └── S5/S8 F-TEID (PGW-U ◆◆◆◆◆ PFCP)
├── APN ◆◆: Public-1 (1)
└── PCO
    ├── DNS ◆◆◆: 8.8.8.8
    ├── DNS ◆◆◆: 8.8.4.4
    └── ◆◆ MTU: 1400

```

◆◆◆◆◆

◆◆ SGW-C → OmniPGW

◆◆◆ ◆◆ PDN ◆◆

◆◆ IEs◆

IE ◆◆ ◆◆

EBI ◆◆◆◆ EPS ◆◆ ID

◆◆ EBI◆◆◆◆◆◆◆◆

◆◆◆◆◆

◆◆◆ OmniPGW → SGW-C

◆◆◆ ◆◆◆◆◆◆◆

◆◆ IEs◆

IE ◆◆ ◆◆

◆◆ ◆◆◆◆◆◆◆◆

◆◆◆◆

◆◆◆◆◆

◆◆◆ OmniPGW → SGW-C

◆◆◆ ◆◆◆◆◆◆◆◆◆ PCRF ◆◆◆◆◆

◆◆◆◆◆

- PCRF ◆◆◆◆ PCC ◆◆◆◆◆◆◆◆◆◆
- OmniPGW ◆◆ SGW-C ◆◆◆◆◆

◆◆◆◆◆

◆◆◆ OmniPGW → SGW-C ◆ SGW-C → OmniPGW

◆◆◆ ◆◆◆◆◆◆◆

◆◆◆

- **PGW** ◆◆◆ PCRF ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
- **SGW** ◆◆◆◆◆◆◆◆◆◆◆◆



???

???

???

????

??

?? ?? ??
16 ?????

??????

?? ?? ????
65 ????? PCRF ????IMSI ????
66 ????? IP ????
93 ????? APN
94 TFT ?????

??????

?? ?? ????
72 ????? PCRF/PGW-U ??
73 ?????

??

S5/S8 ??

```
# ?????
s5s8_inbound_messages_total{message_type="create_session_request"}
s5s8_inbound_messages_total{message_type="delete_session_request"}
```

```
# ?????
s5s8_inbound_errors_total
```

```
# ?????
s5s8_inbound_handling_duration_bucket
```

```
# ?? TEID
teid_registry_count
```

????

????

```
rate(s5s8_inbound_messages_total{message_type="create_session_request"}[5m])
```

????

```
rate(s5s8_inbound_errors_total[5m])
```

??p95??

```
histogram_quantile(0.95,
```

```
rate(s5s8_inbound_handling_duration_bucket{request_message_type="create_session_request"}[5m])
)
```

◆◆◆◆

◆◆◆◆◆◆◆◆ OmniPGW ◆◆◆

◆◆◆

- SGW-C ◆◆◆◆◆◆◆◆
- ◆◆◆◆◆◆◆
- SGW-C ◆◆

◆◆◆

1. ◆◆◆◆◆◆
2. OmniPGW ◆◆◆◆◆◆◆ IP ◆◆◆
3. ◆◆◆◆◆◆ UDP 2123
4. ◆◆◆◆◆ TEID ◆◆

◆◆◆

```
# ◆◆ OmniPGW ◆◆◆◆◆◆
netstat -ulnp | grep 2123

# ◆◆◆◆◆◆◆◆
tcpdump -i any -n port 2123

# ◆◆◆◆◆
grep "local_ipv4_address" config/runtime.exs

# ◆◆◆◆◆◆
iptables -L -n | grep 2123
```

◆◆◆◆◆◆◆◆◆◆

◆◆◆

- ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
- ◆◆◆◆◆◆

◆◆◆◆◆◆

```
◆◆ 65◆◆◆◆◆◆◆◆◆◆
→ PCRF ◆◆◆◆◆
→ ◆◆ HSS/SPR ◆◆ IMSI

◆◆ 66◆◆◆◆◆◆◆◆◆◆
→ IP ◆◆◆◆
→ ◆◆: curl http://pgw:9090/metrics | grep address_registry_count
→ ◆◆ IP ◆

◆◆ 72◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
→ PCRF ◆◆◆◆◆ PGW-U ◆◆◆◆◆
→ ◆◆ Gx ◆◆
→ ◆◆ PFCP ◆◆
```

◆◆◆◆ TEID ◆◆◆

◆◆◆

- ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
- ◆◆◆◆◆◆

◆◆◆

- TEID 11111111
- TEID 22222222

1111

- 11 TEID 2222
- 11 TEID 33333333

1111

1111

1. 111111

- 11 S5/S8 111111 VLAN
- 11111111

2. MTU 11

- 11 MTU 11 GTP 11
- 11 MTU 1500 11111464 111111 + 36 GTP 11

3. 11

- 11 OmniPGW 11
- 1111 SGW-C 111111 DNS 111111

11

1. UDP 111111

- 1111111111111111
- 111111111111 4-8 MB

2. 111111

- 111111111111
- 11 TEID 111111

11

1. IP 11

- 1111111111 SGW-C IP 11 GTP-C
- 11 iptables 1111 ACL

2. 111111

- OmniPGW 1111111111
- 1111111111 GTP-C 1111

1111

1111

- [111111](#) - S5/S8 1111111111 IP 11
- [111111](#) - PDN 1111111111111111
- [UE IP 11](#) - 1111111111111111 IP 11
- [PCO 11](#) - GTP-C 111111 PCO 11

◆◆◆◆

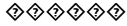
- [PCFP](#) ◆◆ - ◆ S5/S8 ◆◆◆◆◆◆◆◆◆◆◆◆
- [Diameter Gx](#) ◆◆ - ◆◆◆◆◆◆◆◆◆◆◆◆
- [Diameter Gy](#) ◆◆ - ◆◆◆◆◆◆◆◆◆◆◆◆

◆◆

- ◆◆◆◆◆ - S5/S8 GTP-C ◆◆◆◆◆◆◆◆
- ◆◆ [CDR](#) ◆◆ - ◆ GTP-C ◆◆◆◆ CDR

◆◆◆◆◆◆◆◆

OmniPGW S5/S8 ◆◆ - ◆ *Omni*touch ◆◆◆◆◆◆◆◆



PDN

OmniPGW by Omnitouch Network Services



PDN () UE OmniPGW



TEID S5/S8 (GTP-C) SGW-C ID
SEID Sxb (PFCP) PGW-U ID
Session-ID Gx (Diameter) PCRF Diameter
Charging-ID ID



1. (S5/S8)

S5/S8 GTP-C GTP-C S5/S8

:

- IMSI, MSISDN, IMEI
• APN ("internet")
• RAT (EUTRAN)
• UE (TAI, ECGI)
• (QoS, F-TEID)

2.

- APN UE IP
- ID
- Gx ID
- S5/S8 TEID
- PGW-U

3. (Gx)

PCRF

- CCR
• QoS PCC CCA

4. (PFCP)

PGW-U

- • PDRs, FARs, QERs, BAR
• S5/S8 F-TEID

5. SGW-C

- UE IP
• S5/S8 F-TEID (PGW-U)
• PCO (DNS, P-CSCF, MTU)



- QoS - PCRF
• - /
• - SGW
• - PCRF PCC

QoS



:

1. UE IP -
2. TEID -
3. SEID -
4. ID -
5. ID -
6. -

:

- CDR () - CDR



:

TEID (S5/S8):
TEID 0x12345678 - PID
SEID (Sxb):
SEID 0xABCDEF - PID
ID (Gx):

- MEI/IMEI: $\diamond\diamond\diamond\diamond$

PDN $\diamond\diamond\diamond$:

- APN: "internet" ($\diamond\diamond\diamond$)
- UE IP \diamond : 100.64.1.42 ($\diamond\diamond$ IP)
- PDN \diamond : IPv4, IPv6, \diamond IPv4v6

$\diamond\diamond\diamond$:

- $\diamond\diamond$ ID: $\diamond\diamond\diamond\diamond\diamond$
- $\diamond\diamond\diamond$ EBI: EPS $\diamond\diamond\diamond$ ($\diamond\diamond$ 5)

QoS \diamond :

- APN-AMBR: $\diamond\diamond\diamond\diamond$
 - \diamond : 100 Mbps
 - \diamond : 50 Mbps

$\diamond\diamond\diamond$:

- PDRs ($\diamond\diamond\diamond\diamond$): $\diamond\diamond\diamond$
- FARs ($\diamond\diamond\diamond$): $\diamond/\diamond\diamond$
- QERS (QoS $\diamond\diamond$): $\diamond\diamond$
- BAR ($\diamond\diamond\diamond$): $\diamond\diamond$

$\diamond\diamond\diamond$:

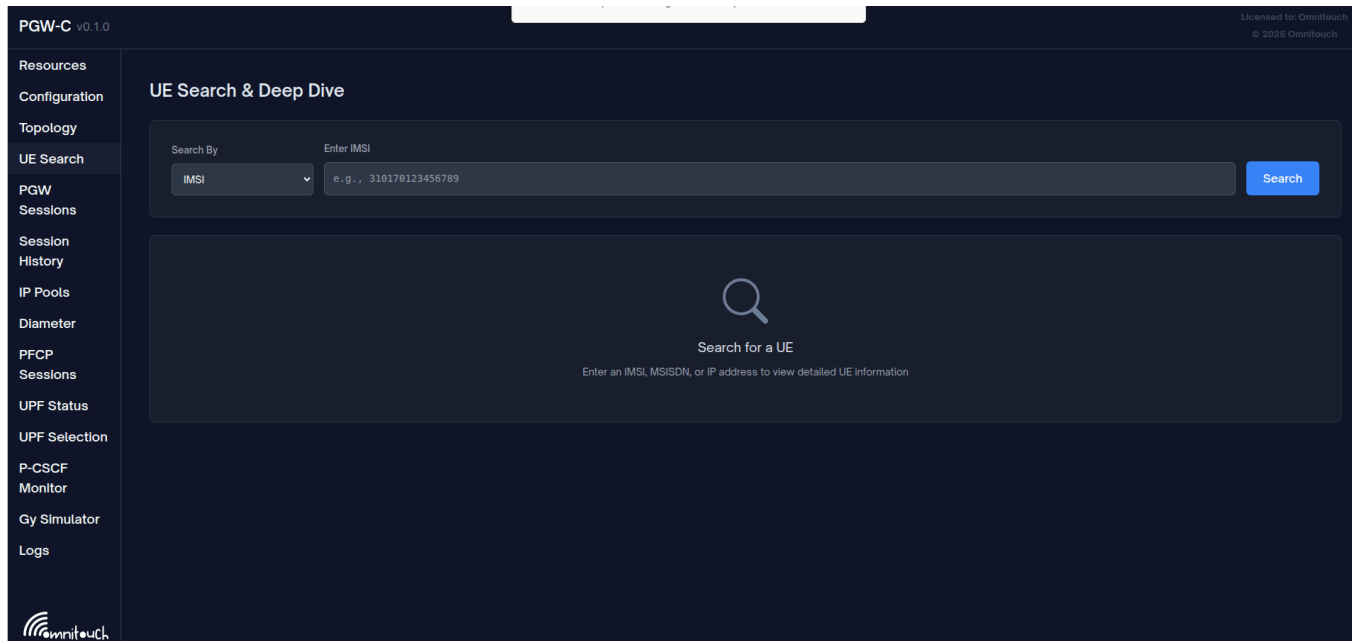
- S5/S8 \diamond : \diamond/\diamond TEIDs, SGW-C \diamond
- Sxb \diamond : \diamond/\diamond SEIDs, PGW-U \diamond
- Gx \diamond : Diameter \diamond ID, $\diamond\diamond\diamond$

Web UI - $\diamond\diamond\diamond\diamond$

OmniPGW $\diamond\diamond\diamond$ **Web UI** $\diamond\diamond\diamond\diamond\diamond\diamond\diamond\diamond\diamond\diamond$

UE $\diamond\diamond\diamond\diamond$

\diamond : http://<omnipgw-ip>:<web-port>/ue_search



\diamond : $\diamond\diamond\diamond$ UE $\diamond\diamond\diamond\diamond$

\diamond :

1. $\diamond\diamond\diamond$ $\diamond\diamond\diamond\diamond$

- **IMSI** ($\diamond\diamond$ "310170123456789")
- **MSISDN** ($\diamond\diamond$)
- **IP** \diamond ($\diamond\diamond$ "100.64.1.42")

2. $\diamond\diamond$

- $\diamond\diamond\diamond\diamond\diamond$
- $\diamond\diamond\diamond\diamond$
- $\diamond\diamond\diamond$

3. $\diamond\diamond\diamond$ $\diamond\diamond\diamond\diamond\diamond\diamond\diamond$

- $\diamond\diamond\diamond\diamond$
- $\diamond\diamond\diamond\diamond\diamond$
- QoS $\diamond\diamond$
- $\diamond\diamond\diamond$

\diamond :

- $\diamond\diamond\diamond\diamond$
- $\diamond\diamond\diamond$
- $\diamond\diamond\diamond$ IP \diamond
- $\diamond\diamond\diamond$

PGW $\diamond\diamond$

\diamond : http://<omnipgw-ip>:<web-port>/pgw_sessions

\diamond : $\diamond\diamond\diamond\diamond$ PDN \diamond

\diamond :

1. $\diamond\diamond$

- $\diamond\diamond\diamond$ (\diamond 2 $\diamond\diamond$)
- $\diamond\diamond\diamond\diamond\diamond$
- $\diamond\diamond$ - $\diamond\diamond$

2. $\diamond\diamond\diamond$ $\diamond\diamond\diamond$

- **IMSI** - $\diamond\diamond$

- UE IP - IP
- SGW TEID - SGW S5/S8 ID
- PGW TEID - $OmniPGW$ S5/S8 ID
- APN -

3. $IMSI$

- $IMSI$ ("310260")
- UE IP (100.64)
- MSISDN /
- APN

4. RAT

- $IMSI, MSISDN, IMEI$
- $RAT, MCC/MNC$
- QoS (AMBR/)
- TEIDs
- ID
- ($TEIDs$)

URL

URL: http://ip:$port$/topology

PGW-C v0.1.0
Licensed for: Omnitouch
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Resources

Configuration

Topology

UE Search

PGW

Sessions

Session

History

IP Pools

Diameter

PFCP

Sessions

UPF Status

UPF Selection

P-CSCF

Monitor

Gy Simulator

Logs

Network Topology

0 Active Sessions

+
-
⊙

Legend:

- $GTP-C (S5/S8)$
- Diameter (Gy/Gr/S6a)
- PFCP (S6c)

+

Select a Node

Click on any network element to view details

URL: URL

URL:

1. $IMSI$

- $IMSI$
- $PGW-C$
- HSS
- APN

2. RAT

- $IMSI (+/-)$
- RAT
- MCC/MNC
- <math>TEIDs (TEID = IP, <math>TEID = IP)</math>

3. $IMSI$

- $IMSI$
- $IMSI$
- $IMSI$

URL:

- $IMSI$
- $IMSI$
- $IMSI$
- $IMSI$

URL: URL

URL: http://ip:$port$/session_history



OmniPGW ♦♦♦♦ - *by Omnitouch Network Services*



UE IP

IP

◆◆

1. IP
2. IP
3. IP
4. IP
5. IP
6. IP
7. IP

◆◆

PGW-C UE PDN IP

IP

UE PGW-C IP

- IP
- IP
- IP
- PDN

◆◆ IP

IP
 IPv4 IPv4
 IPv6 IPv6
 IPv4v6 IPv4 IPv6

IP

PDN

UE PDN PDN

PDN
 IPv4 IPv4 IPv4
 IPv6 IPv6 IPv6/64
 IPv4v6 IPv4 IPv6

◆◆◆

PGW-C IP

1. ◆◆◆◆◆

- PGW-C IP
- IP
- IP

2. ◆◆◆◆◆

- UE GTP-C IP
- PGW-C IP
- IP

◆◆ APN

APN IP

◆◆◆

- APN
- APN
- APN
- APN

◆◆◆◆

IP

◆◆ UE IP → PID
 ◆◆ UE IP
 ◆◆ IP
 ◆◆ IP

◆◆

◆◆◆◆

config/runtime.exs

```
config :pgw_c,
  ue: %{
    subnet_map: %{
      # APN "internet"
      "internet" => [
        "100.64.1.0/24", # 254 IP
        "100.64.2.0/24" # 254 IP
      ],

      # APN "ims"
      "ims" => [
        "100.64.10.0/24"
      ],

      # APN
      default: [
        "42.42.42.0/24"
      ]
    }
  }
}
```

◆◆◆◆

CIDR <network>/<prefix_length>

CIDR IP
 /24 254 100.64.1.1 - 100.64.1.254
 /23 510 100.64.0.1 - 100.64.1.254
 /22 1022 100.64.0.1 - 100.64.3.254
 /20 4094 100.64.0.1 - 100.64.15.254
 /16 65534 100.64.0.1 - 100.64.255.254

◆◆◆

- 100.64.1.0
- 100.64.1.255
- PGW-C <network> + 1 <broadcast> - 1

◆◆◆◆ IP ◆◆

◆◆ IP ◆◆RFC 1918◆◆

```
# ◆◆◆◆◆◆◆◆◆◆
subnet_map: %{
  "internet" => [
    "10.0.0.0/8",
    "172.16.0.0/12",
    "192.168.0.0/16"
  ]
}
```

◆◆◆ PGW-U ◆◆ NAT ◆◆◆◆◆◆

◆◆ IP ◆◆

```
# ◆◆◆◆◆◆ IP◆◆◆◆◆◆
subnet_map: %{
  "internet" => [
    "203.0.113.0/24" # ◆◆ IP ◆◆
  ]
}
```

◆◆◆◆ NAT - ◆◆◆◆◆◆

◆◆◆

- ◆◆◆ IP◆RFC 6598◆100.64.0.0/10◆◆◆◆◆ NAT◆
- ◆◆◆◆◆◆◆◆◆ IP

◆◆

Web UI - IP ◆◆◆

OmniPGW ◆◆◆◆ Web ◆◆◆◆◆◆◆◆ IP ◆◆◆◆◆◆◆◆◆◆

◆◆◆◆ http://<omnipgw-ip>:<web-port>/ip_pools

◆◆◆

1. ◆◆◆

- ◆◆◆◆◆ IP ◆◆
- ◆◆◆◆◆◆◆◆◆
- ◆◆◆◆ IP
- ◆◆◆◆◆◆◆◆◆

2. ◆◆ APN ◆◆◆◆◆◆◆◆◆◆

- ◆◆◆ - APN ◆◆◆◆◆◆◆◆◆ "default"◆◆"ims.something.else"◆◆"Internet"◆
- ◆ APN ◆◆ - ◆◆◆ APN ◆◆◆◆◆
- ◆ IP ◆◆ - ◆◆◆◆◆◆◆◆ CIDR ◆◆◆
- ◆◆◆ - ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
- ◆◆◆◆◆◆◆◆◆
 - ◆◆◆◆◆◆◆ IP ◆◆
 - ◆◆◆◆◆◆◆◆◆ IP
 - ◆◆◆◆◆◆◆◆◆ IP

3. ◆◆◆◆

- ◆ 2 ◆◆◆◆◆
- ◆◆◆◆◆◆◆◆◆
- ◆◆◆◆◆◆◆◆◆

◆◆◆

- ◆◆◆◆◆◆◆◆◆
- ◆◆◆◆◆◆◆◆◆
- ◆◆◆◆◆
- ◆ APN ◆◆◆◆◆◆◆◆◆

◆◆◆◆◆

◆◆◆◆◆◆◆◆◆

```
# ◆◆◆◆◆ IP
address_registry_count
```

```
# ◆◆◆◆◆◆◆◆◆◆
address_registry_count / <total_pool_size> * 100
```

◆◆◆

◆: 100.64.1.0/24 (254 ◆ IP)

◆◆: 150 ◆ IP

🔗🔗: 150 / 254 = 59%

🔗🔗

🔗🔗🔗🔗🔗🔗

```
- alert: UEIPPoolUtilizationHigh
  expr: address_registry_count > 200 # 🔗🔗 /24 🔗
  for: 10m
  annotations:
    summary: "UE IP 🔗🔗🔗🔗 80%"
    description: "🔗🔗: {{ $value }} / 254 🔗 IP 🔗🔗"
```

🔗🔗🔗🔗🔗

```
- alert: UEIPPoolExhausted
  expr: address_registry_count >= 254 # 🔗🔗 /24 🔗
  for: 1m
  annotations:
    summary: "UE IP 🔗🔗 - 🔗🔗 IP"
```

🔗🔗🔗🔗🔗🔗

```
- alert: UEIPAllocationFailures
  expr: rate(ue_ip_allocation_failures_total[5m]) > 0
  for: 5m
  annotations:
    summary: "UE IP 🔗🔗🔗🔗🔗"
```

Grafana 🔗🔗🔗

🔗🔗 1🔗IP 🔗🔗🔗

🔗🔗🔗🔗🔗🔗

```
(address_registry_count / 254) * 100
```

🔗🔗 2🔗🔗🔗🔗🔗🔗 IP

🔗🔗🔗

```
address_registry_count
```

🔗🔗 3🔗🔗🔗

🔗🔗🔗

```
rate(address_registry_count[5m])
```

🔗🔗 4🔗🔗🔗🔗

🔗🔗🔗🔗🔗🔗🔗🔗

```
(254 - address_registry_count) / rate(address_registry_count[1h])
```

🔗🔗🔗🔗

🔗🔗 1🔗🔗🔗🔗🔗🔗🔗 IP🔗

🔗🔗

- 🔗🔗🔗🔗🔗🔗🔗🔗
- 🔗🔗🔗 UE IP 🔗🔗🔗🔗

🔗🔗🔗🔗

1. 🔗🔗

🔗🔗🔗🔗

```
curl http://<pgw_c_ip>:42069/metrics | grep address_registry_count
```

2. 🔗🔗🔗

🔗🔗🔗🔗

```
config: pgw_c,
  ue: %{
    subnet_map: %{
      "internet" => [
        "100.64.1.0/24" # 🔗🔗🔗 CIDR
      ]
    }
  }
```

3. APN 🔗🔗🔗

🔗🔗🔗 APN🔗🔗🔗

```
# 🔗🔗🔗🔗
subnet_map: %{
  default: ["42.42.0/24"]
}
```

🔗🔗🔗

- 🔗🔗🔗 🔗🔗🔗
- 🔗🔗🔗🔗🔗 PGW-C 🔗🔗🔗 IP
- 🔗🔗🔗🔗 runtime.exe 🔗🔗🔗

🔗🔗 2🔗IP 🔗🔗🔗

🔗🔗

- 🔗 UE 🔗🔗🔗 IP🔗🔗🔗
- 🔗🔗

🔗🔗

- 🔗🔗🔗🔗🔗🔗

🔗🔗

```
# 🔗🔗🔗🔗 IP
grep "already_registered" /var/log/pgw_c.log
```

🔗🔗🔗

- 🔗🔗🔗🔗🔗🔗
- 🔗🔗🔗🔗🔗

🔗🔗🔗 3🔗🔗🔗 IP 🔗

🔗🔗

- UE 🔗🔗🔗 IP
- APN "internet" 🔗 "ims" 🔗🔗 IP

🔗🔗

- 🔗🔗🔗🔗

🔗🔗

🔗🔗🔗 APN 🔗🔗🔗

```
subnet_map: %{
  "internet" => [...], # 🔗🔗🔗
  "Internet" => [...], # 🔗🔗 APN!
}
```

🔗🔗🔗

- 🔗 APN 🔗🔗🔗🔗🔗
- 🔗🔗🔗🔗🔗

4 IPv6

- UE IPv6

1. IPv6

```
# IPv6
subnet_map: %{
  "internet" => [
    "100.64.1.0/24" # IPv4
  ]
}
```

2. IPv6

```
# /48
"internet" => [
  "2001:db8::/128" # -
]
```

IPv6

```
# IPv6
subnet_map: %{
  "internet" => [
    "100.64.1.0/24",
    "2001:db8:1::/48" # IPv6
  ]
}
```

5

- address_registry_count

1.

```
"internet" => [
  "100.64.1.0/24", #
  "100.64.2.0/24", # 254 IP
  "100.64.3.0/24" # 254 IP
]
```

2.

```
# /24 /22
"internet" => [
  "100.64.0.0/22" # 1022 IP
]
```

3.

-
-


```
10,000
30% 3,000
50%
IP 3,000 * 1.5 = 4,500 IP
```

```
/20 4,094 IP -
/19 8,190 IP -
```


- 100.64.0.0/10 RFC 6598 - NAT
- 400 IP
- NAT

- IP
- VPN


```
config :pgw_c,
  ue: %{
    subnet_map: %{
      # APN
      "internet" => [
        "100.64.0.0/18" # 16,382 IP
      ],
      # IMS
      "ims" => [
        "100.64.64.0/22" # 1,022 IP
      ],
      #
      "enterprise.corp" => [
        "100.64.68.0/22" # 1,022 IP
      ],
      #
      "iot.m2m" => [
        "100.64.72.0/20" # 4,094 IP
      ],
      #
      default: [
        "100.64.127.0/24" # 254 IP
      ]
    }
  }
}
```


- UE IP APN
- PCO - IP DNS P-CSCF MTU
- - PDN IP
- PECP - PCFP UPF UE

