OmniPGW □□□□

runtime.exs □□□□□□□

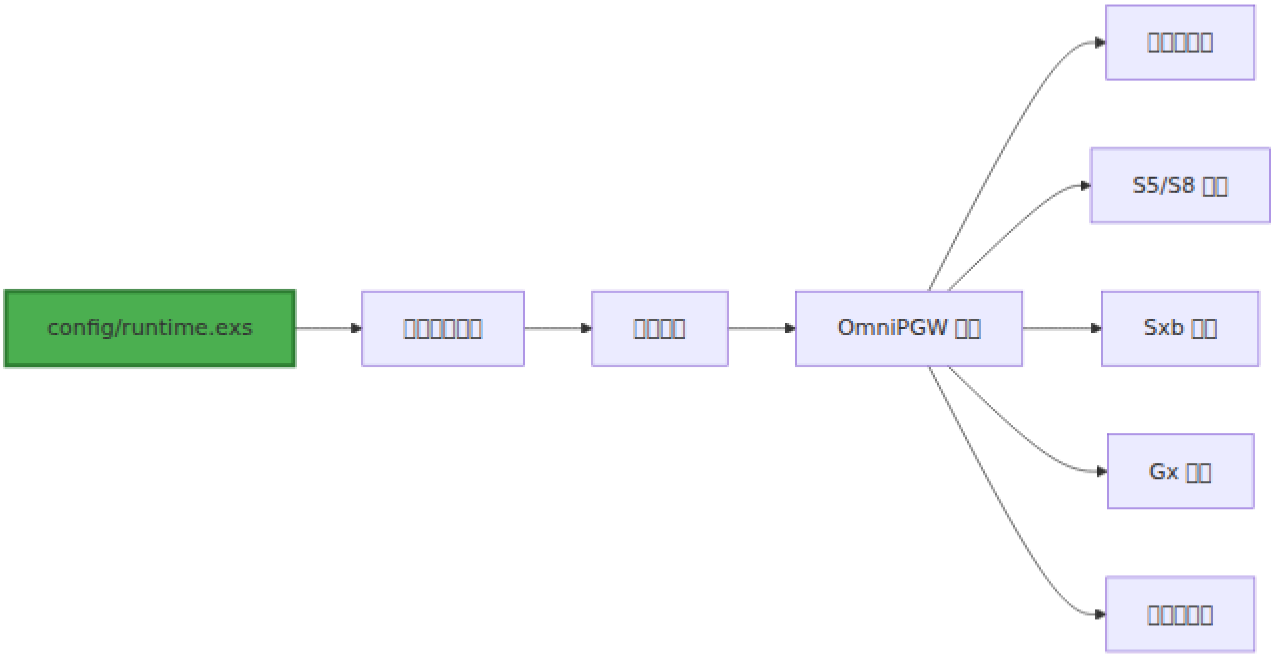
□ Omnitouch □□□□□□

□□

□□

OmniPGW □□□ `config/runtime.exs` □□□□□ □□□□□□□□□□□ □□□□□□□ □□□□□□□□□□□□□□□ □□□□□□□□□□□□

□□□□



□□□□□

- □□□□□□ - □□□□□□□□□□
- □□□□ - □□□□□□□
- □□□□□ - □□□□□□□□□□
- □□□□□□ - □□□□□□□□□□□□

□□□□

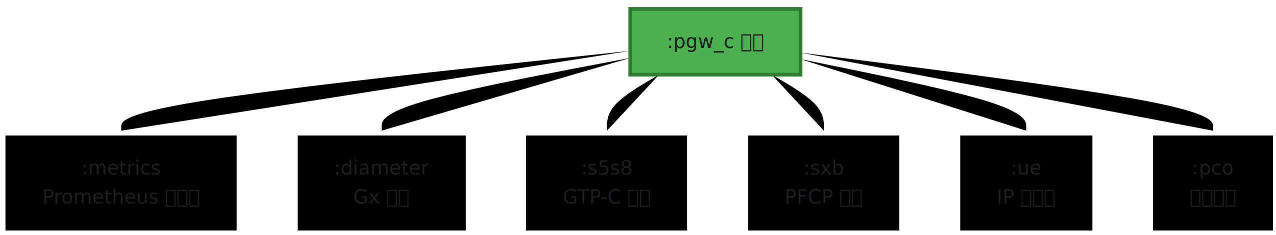
□□□□

```
pgw_c/
├── config/
│   ├── config.exs          # □□□□□□□ runtime.exs□
│   ├── dev.exs             # □□□□□□
│   ├── prod.exs            # □□□□□□
│   └── runtime.exs         # ← □□□□□□
```

□□□□

```
# config/runtime.exs
import Config

config :logger, level: :info

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

□□□□



□□□□

□□

□□ Prometheus □□□□□□□□ OmniPGW□

□□□

```
config :pgw_c,
  metrics: %{
    # □□/□□□□□□□
    enabled: true,

    # □□ HTTP □□□□ IP □□
    ip_address: "0.0.0.0",

    # □□□□□□□
    port: 9090,

    # □□□□□□□□□□□
    registry_poll_period_ms: 10_000
  }
```

□□

□□	□□	□□□	□□
`enabled`	□□□	`true`	□□□□□□□
`ip_address`	□□□ □IP□	`"0.0.0.0"`	□□□□□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
```

□□□ □□□□□□□ □□□□□□□□□□□

Diameter/Gx □□

□□

□□ Diameter □□□□□ Gx □□□PCRF □□□□

□□□

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

    # OmniPGW □ Diameter □□□Origin-Host□
    host: "omnipgw.epc.mnc001.mcc001.3gppnetwork.org",

    # OmniPGW □ Diameter □□Origin-Realm□
    realm: "epc.mnc001.mcc001.3gppnetwork.org",

    # PCRF □□□□□
    peer_list: [
      %{
        # PCRF Diameter □□
        host: "pcrf.epc.mnc001.mcc001.3gppnetwork.org",

        # PCRF □
        realm: "epc.mnc001.mcc001.3gppnetwork.org",

        # PCRF IP □□
        ip: "10.0.0.30",

        # □□□ PCRF □□□
        initiate_connection: true
      }
    ]
  }
```

□□

□□	□□	□□	□□
`listen_ip`	□□□□IP□	□	Diameter □□��□
`host`	□□□□FQDN□	□	OmniPGW □ Origin-Host□□□□ FQDN□
`realm`	□□□□□□	□	OmniPGW □ Origin-Realm
`peer_list`	□□	□	PCRF □□□□□

□□□□□□

□□	□□	□□	□□
`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 □□□2123□
    local_port: 2123,

    # GTP-C □□□□□□□□□□□□500□□□
    # □□ GTP-C □□□□□□□□□□
    request_timeout_ms: 500,

    # GTP-C □□□□□□□□□□□□□3□
    # □□□□□□□ = request_timeout_ms * request_attempts
    request_attempts: 3
  }
```

□□

□□	□□	□□□	□□
`local_ipv4_address`	□□□□IPv4□	□□	S5/S8 □□□ IPv4 □□
`local_ipv6_address`	□□□□IPv6□	`nil`	S5/S8 □□□ IPv6 □□□□□□
`local_port`	□□	`2123`	GTP-C □ UDP □□□□□□□ 2123□
`request_timeout_ms`	□□	`500`	□□□□□□□□□□□□□□
`request_attempts`	□□	`3`	□□□□□□□□□□□□

□□□□

- □□□ 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  # □□□□□
}
```

□□□□□□

```
s5s8: %{
  local_ipv4_address: "10.0.0.20",
  request_timeout_ms: 1500,  # □□□□ 1.5 □
  request_attempts: 3         # □□□□□ 4.5 □
}
```

□□□□

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

□□□□□□□□

```
□□□□□□□ = request_timeout_ms × request_attempts
□□□500□□ × 3 = 1.5 □
```

□□□□□

□□□□	□□□□	□□□□□
□□□□<50ms□	200-300□□	600-900□□
□□□50-150ms□	500□□□□□□	1.5□
□□□□>150ms□	1000-2000□□	3-6□
□□/□□□	2000-3000□□	6-9□

□□□□□

- □□□□ □□□□□□“□□□□□□□□□”□□□□ Wireshark □□□□□□
- □□□□ □□□□□□□□□□□□□□□□
- □□□□□□ □□□□□□□□□□□□□□□

□□□□□

- □□□□□□��□□`"□□□□□□□□"`
- □□□ PCRF □ Diameter □□□□□□□ 5012□□□□□□
- □ Charging-Rule-Remove □□□□□□□□□□□□□□□□□□□

□□□□

IP □□□□□

- □□□□□□/□□□□
- □□□□□ SGW-C □□□□
- □□□□□VRRP/HSRP□□□□□□□□

□□□□□□

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

Sxb/PFCP □□

□□

□□ 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_selection` □□□□□□□□□□□□ 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 □",
      priority: 10,
      match_field: :apn,
      match_regex: ~r/^ims$/,
      upf_pool: [
        %{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: [
    %{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` □□□□□□□□

□□□□

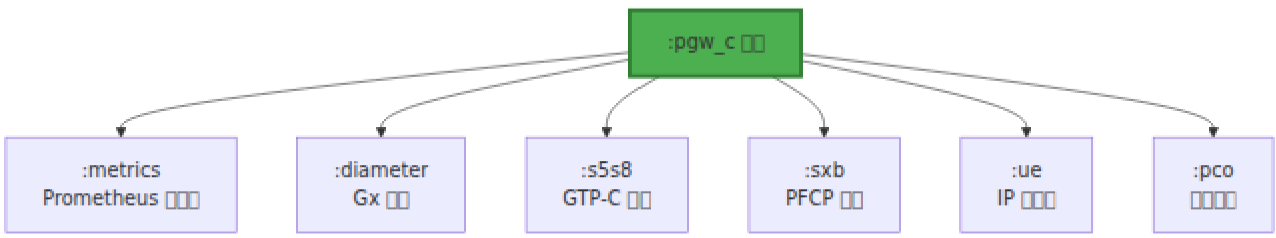
UPF □□□ **`upf_selection`** □□□□□□□□□□□□

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

□□□□□□□

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

UPF □□□□□□



□□□□□□

□□□□□□□□□□□□□□□□□

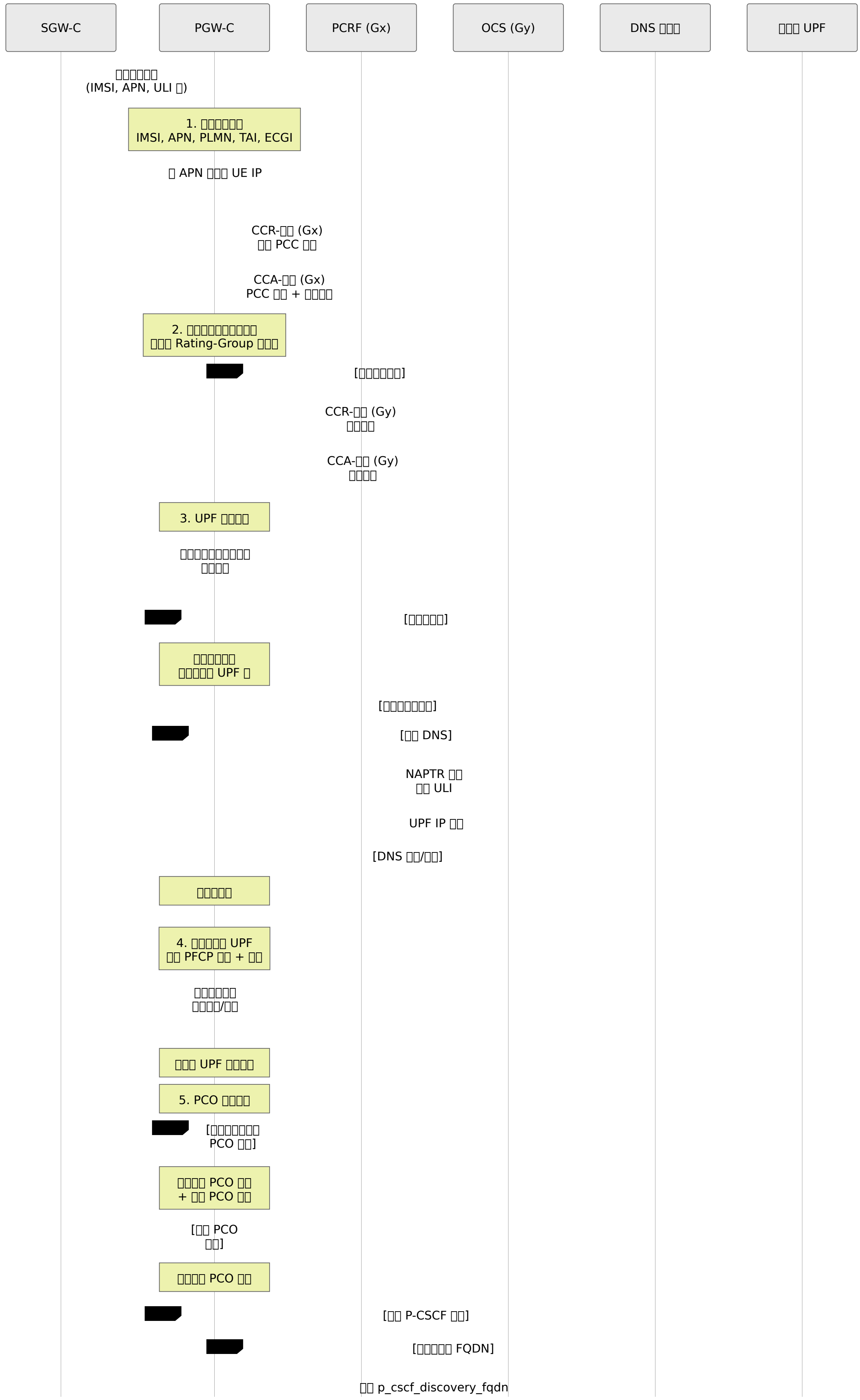
□□□□	□□	□□□□
`:imsi`	□□□□□□□□	`^313380.*`□□□□□□□
`:apn`	□□□□□ / DNN	`^internet\.` □ `^ims\.`
`:serving_network_plmn_id`	□□□□□□□	`^313380$`
`:sgw_ip_address`	SGW IP □□	`^10\.100\..*`
`:uli_tai_plmn_id`	□□□ PLMN ID	`^313.*`
`:uli_ecgi_plmn_id`	E-UTRAN □□ PLMN ID	`^313.*`

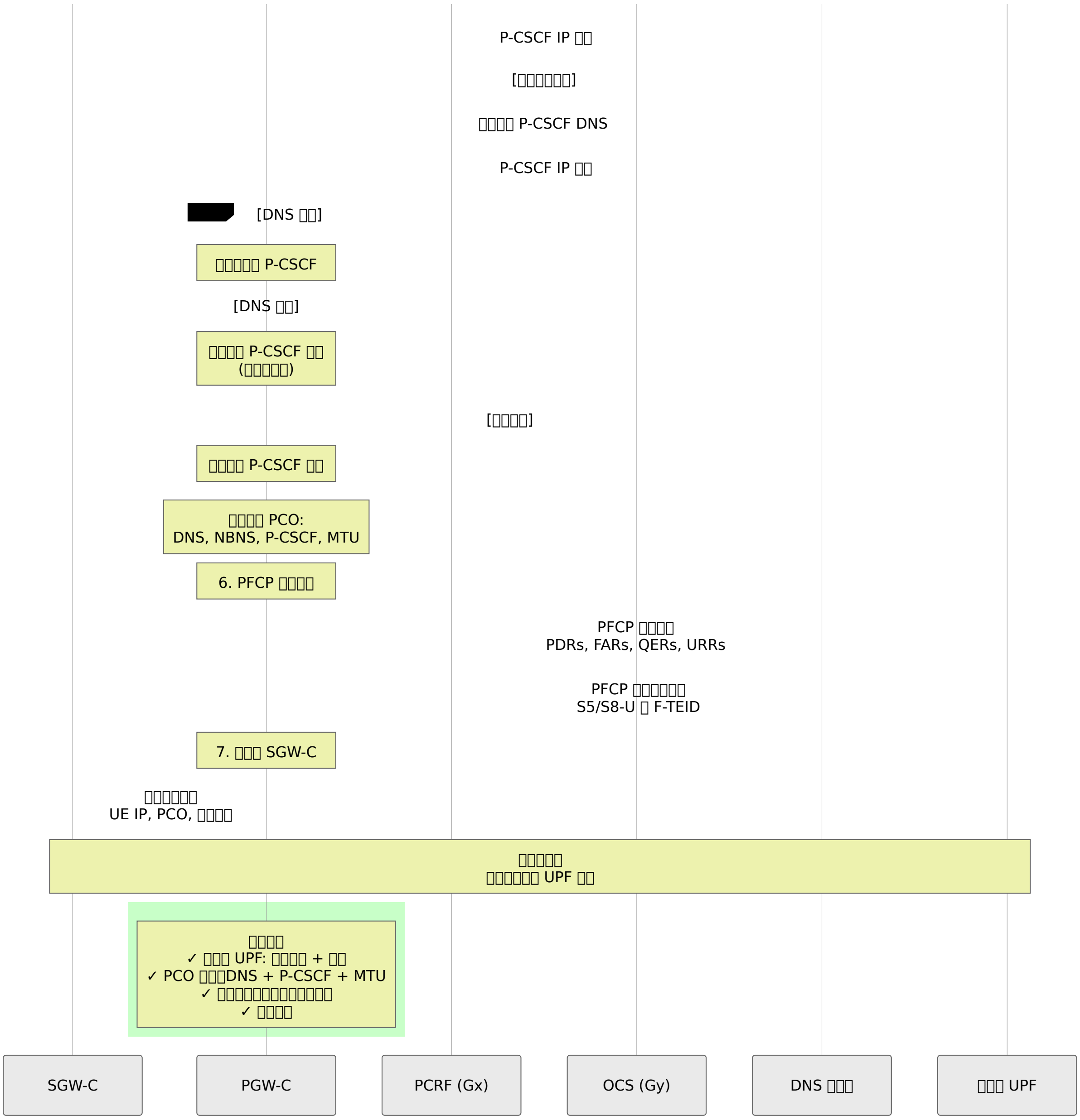
□□□□□□

□□	□□□□	□□	□□
UPF □	□□□□	□□□□□□□□□□□□□□	□□□□ UPF
□□ APN	□□□□	□□□□ IMS/□□□	□□□□
□□ IMSI	□□□□	□□□□	□□□□□□□□
□□ DNS	MEC/□□□□	□□□□□□□	□□ DNS □□□□
□□□	□□□	□□□□□ UPF	□□□□□□□□
□□□□□	□□□□	□□□□	□□□□□

□□□□□□□□

□□□□□□□□□□□□□□□□□□□ UPF □□□ PCO □□□


SGW-C
PGW-C
PCRF (Gx)
OCS (Gy)
DNS □□□
□□□ UPF
□□□□□□
(IMSI, APN, ULI □)
1. □□□□□□
IMSI, APN, PLMN, TAI, ECGI
□ APN □□□ UE IP
CCR-□□ (Gx)
□□ PCC □□
CCA-□□ (Gx)
PCC □□ + □□□□
2. □□□□□□□□□□
□□□ Rating-Group □□□
[□□□□□□]
CCR-□□ (Gy)
□□□□
CCA-□□ (Gy)
□□□□
3. UPF □□□□
□□□□□□□□□□
□□□□
[□□□□□]
□□□□□□
□□□□□ UPF □
[□□□□□□□]
[□□ DNS]
NAPTR □□
□□ ULI
UPF IP □□
[DNS □□/□□]
□□□□□
4. □□□□□ UPF
□□ PFCP □□ + □□
□□□□□□
□□□□/□□
□□□ UPF □□□□
5. PCO □□□□
[□□□□□□□
PCO □□]
□□□□ PCO □□
+ □□ PCO □□
[□□ PCO
□□]
□□□□ PCO □□
[□□ P-CSCF □□]
[□□□□□ FQDN]
□□ p_cscf_discovery_fqdn



□□□□□□

1. **UPF □□□□□□**

   - □□□□□□□□□□□ → DNS □□ → □□□
   - □□□���□□□□□□□
   - □□/□□□□□□□□□□□□
   - □□□ PFCP □□ □□□ UPF □□□□□□□

2. **PCO □□□□□□**

   - □□ PCO □□ → P-CSCF DNS □□ → □□ PCO □□
   - □□□□□□□□□□□□□□□□□□□□□□□□□

   - □□□ PCO □□ □□□□□□ PCO □□

3. **P-CSCF** □□□□□□

   - □□□ FQDN → □□ DNS □□ → □□□□ PCO → □□□□ PCO
   - □□□ P-CSCF □□ □□□□□□□□□□□□

4. □□□□□

   - PCRF □□□□□□□□□□□Rating-Group + Online=1□
   - OCS □□□□□□□□□□□
   - PGW-C □□□□□□□ CCR-Update □□□□
   - □□□ Diameter Gx □□ □ Diameter Gy □□ □□□□□□□□□

□□□□□□

□□□□□□□□□□□□□□ UPF □□□□□□□□□□□

```
config :pgw_c,
  # PFCP □□ - □□ UPF □ upf_selection □□□□
  sxb: %{
    local_ip_address: "127.0.0.20"
  },

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

    # □□□□□□□□□□□□□□□□
    rules: [
      # □□ 1□IMS □□ - □□□□□
      %{
        name: "IMS □□",
        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}
        ]
      },

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

      # □□ 3□□□□□□ - □□□□
```

```
      %{
        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}
    ]
  }
```

□□□□

□□□□□

- □ □□□□□□□□□ `upf_selection` □ UPF □□□□□□□□
- □ □□□□□□□ UPF □□□□□□□□□□□□□□
- □ □□□□□□□□□□ `upf_pool` □□□□□□□□ UPF□
- □ □□□□□□□□□ `fallback_pool` □□□□□□
- □ **DNS** □□□DNS □□□□□□□□□□□
- □ □□□□□DNS □□□ UPF □□□□□□□□□□
- □ □□□□□□□□□□ UPF □□□ 5 □□□□□□□

□□□□□□□□

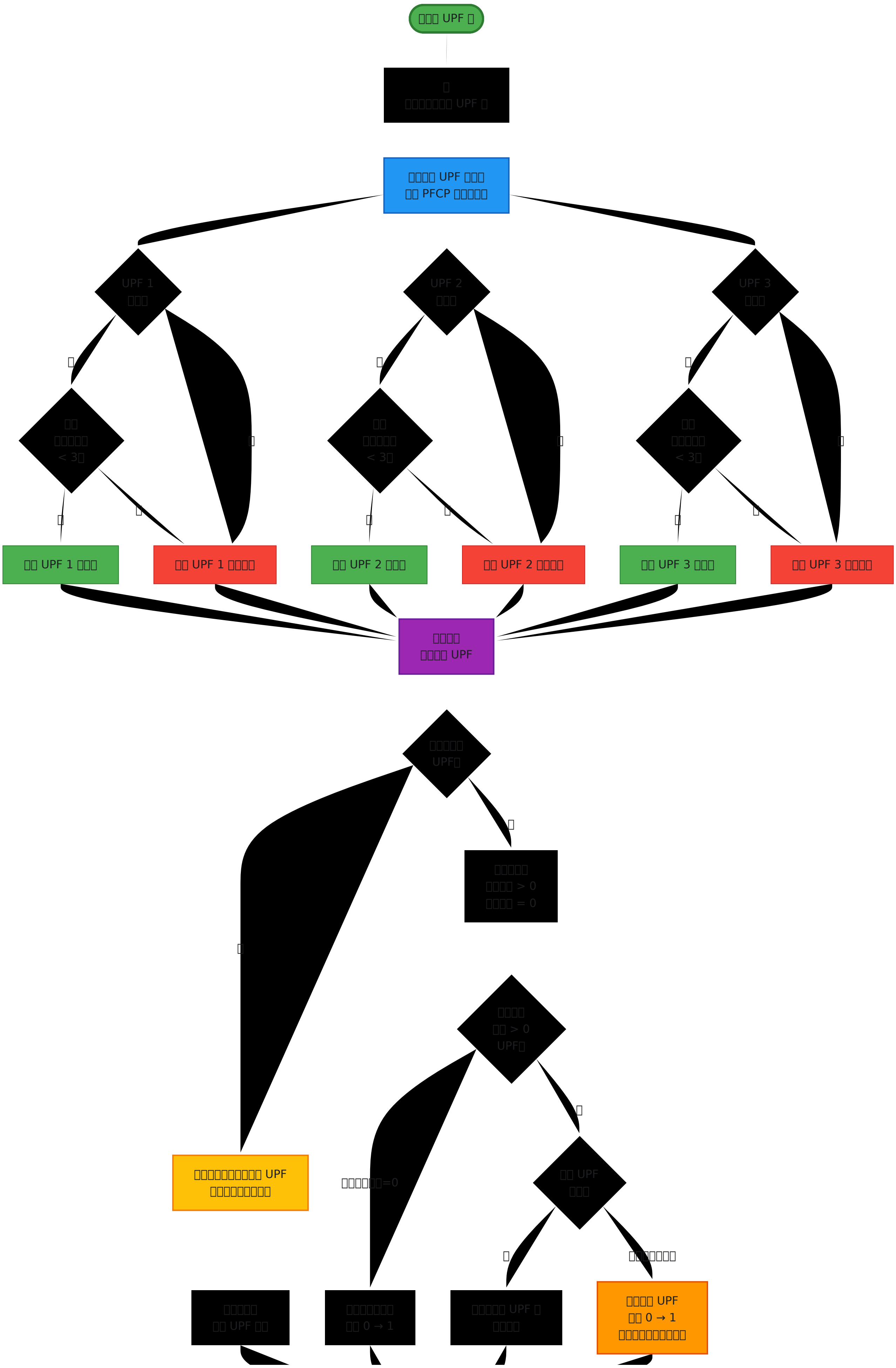
- □□□`sxb.peer_list` □□□□□□□□
- □□□□□□□□□□□□□ `selection_list`

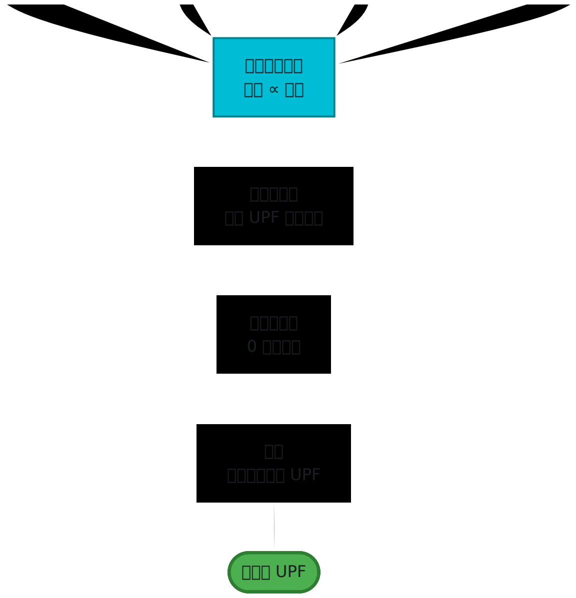
- □□ UPF □□□□□□ `upf_selection` □□□□□□□

UPF □□□□□□□

1. □□□□□□□□□□□ UPF □□□□
   - □□ = PFCP □□□□ + □□□□□□□ 3 □□□
   - □□□□ UPF □□□□□□
   - □□□□□□□ UPF□□□□□□□ UPF
2. □□/□□□□□□□ `weight: 0` □□□□ UPF
   - □□ **UPF**□□□ > 0□□□□□□□□□��
   - □□ **UPF**□□□ == 0□□□□□□□□ UPF □□□□□□□
   - □□□□□□□ UPF □□□ `weight: 1`
3. □□□□□□□□□□□□□□□□□□□□□□□ UPF
   - □□□□□□□70% □□□ .21□20% □□□ .22□10% □□□ .23
   - □□□□□□□□ UPF □□□□□□
   - □□□□ = □□□□
4. □□□□□□□□□□ UPF □□□□□□□□
   - □□□□□□□□`"UPF-<ip>:<port>"`
   - □□□□□□□ PFCP □□□5 □□□
   - □□□□□ UPF □□□□□□□□

□□□□□□□□□/□□


UPF 1
UPF 2
UPF 3
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

□□ 3: □□□□□□
→ □□□□□ UPF
→ □□□□□: [UPF-A: 100, UPF-B: 0]
→ □□□□□□□□□□□□□□□□□
→ □□□□□□□□□□ UPF□□□□□□□□□□
```

□□□□□□□

```
# □□□□□□□ 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}
]

# □/□□□□□□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}
]

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

# □□□□□□□□□□□□□□□□
upf_pool: [
  %{remote_ip_address: "10.0.1.1", remote_port: 8805, weight:
100},   # □□
  %{remote_ip_address: "10.0.1.2", remote_port: 8805, weight: 0},
# □□ 1
  %{remote_ip_address: "10.0.1.3", remote_port: 8805, weight: 0}
# □□ 2
]
# □□□□□□□ 100%□□□□□□□□□□□□ 50/50%□

# A/B □□□50% / 50%□
upf_pool: [
  %{remote_ip_address: "10.0.1.100", remote_port: 8805, weight:
50},  # □□□
  %{remote_ip_address: "10.0.1.200", remote_port: 8805, weight:
50}   # □□□
]
```

□□□

- □□/□□□□□□□□□ `weight: 0` □□□□ UPF□□□□ UPF □□□□□
- □□□□□□□□□□ UPF □□ PFCP □□□□□□���□□□□□□□
- □□□□□□□□□ UPF □□□□□□□□□
- □□□□□□□□□□□□□ UPF □□
- □□□□□□□□□□□□□□□□□□□□□95% □□5% □□
- □□□□□□□□□□□□□□□□□□ UPF
- □□□□□□□□ UPF □□□□□□

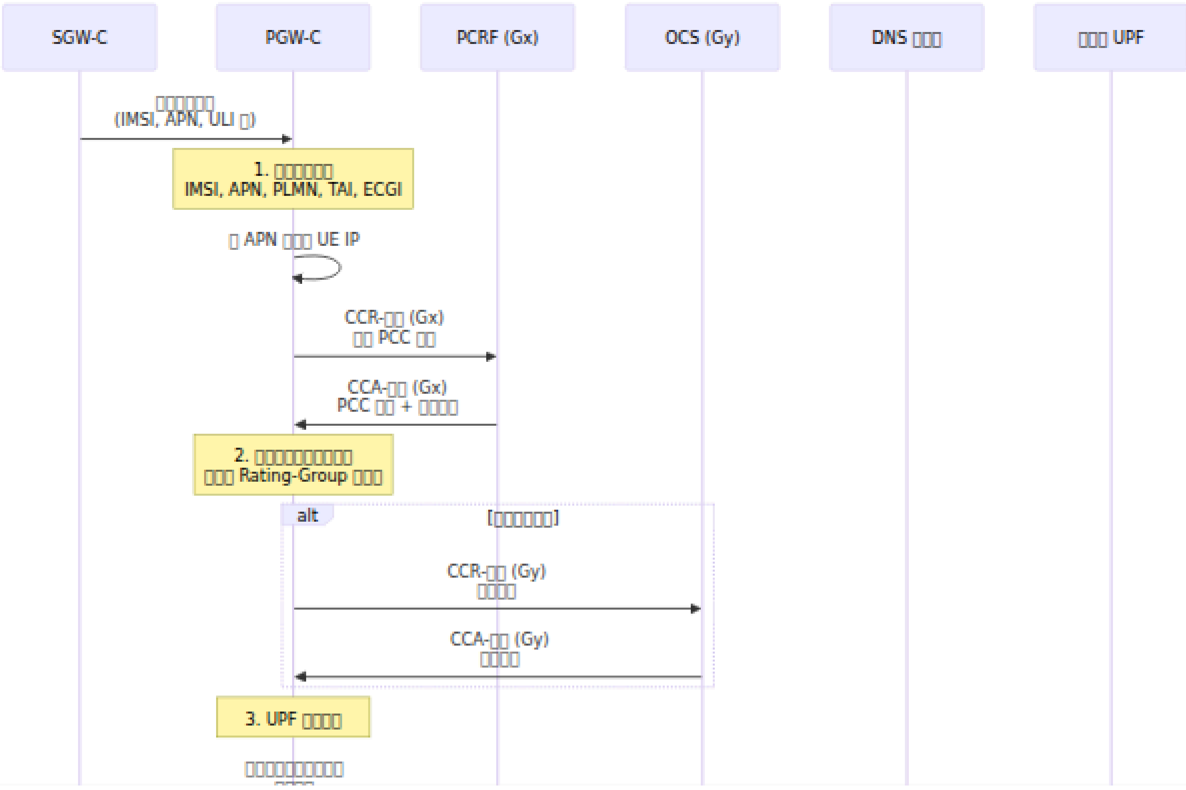
PCO□□□□□□□□□□□

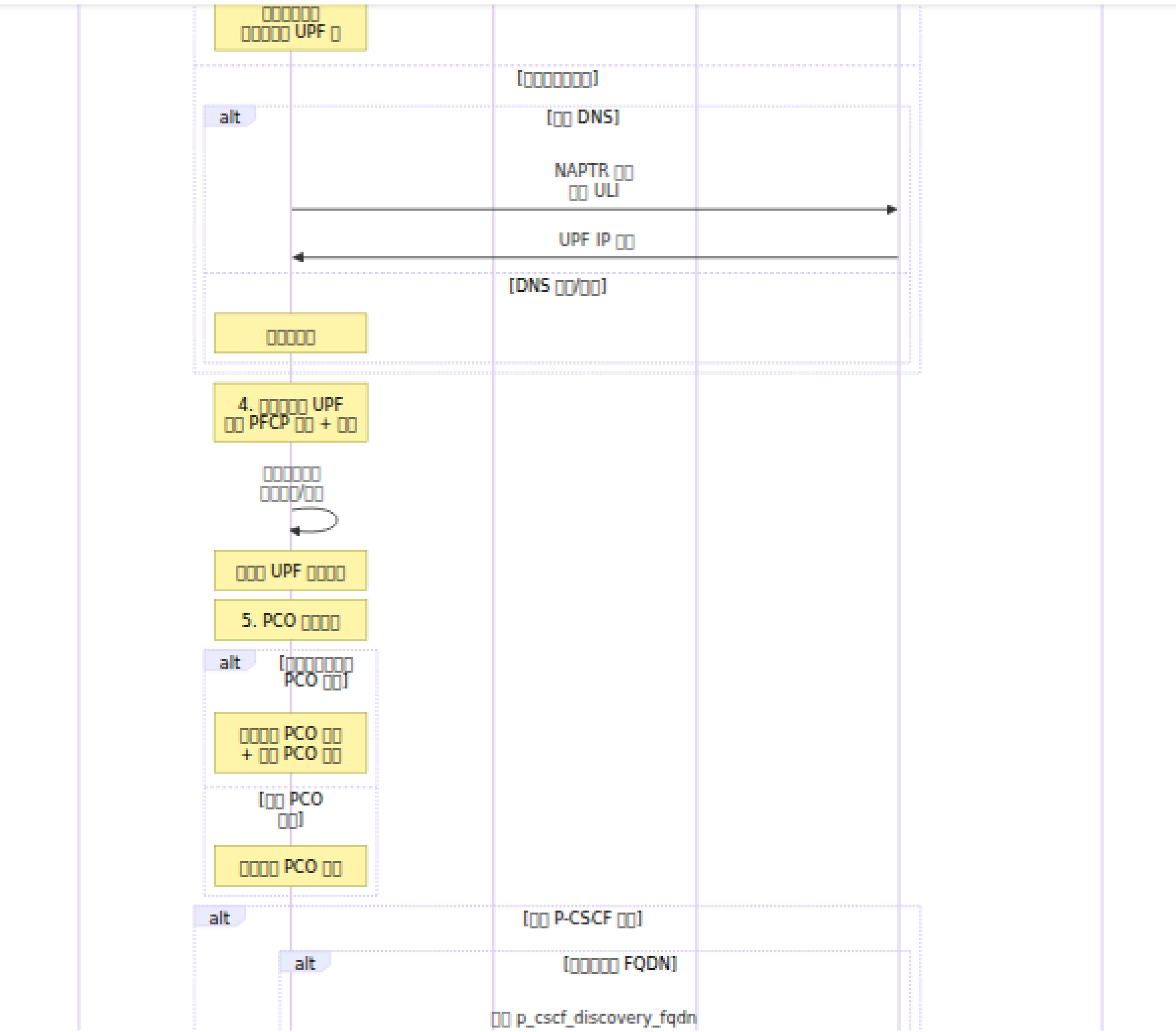
□□ UPF □□□□□□□□□□□□□□□ PCO □□□□□□□□□□□□□□ PCO □□□□□□□□□ APN □□□□□□□□□
□□□□□□

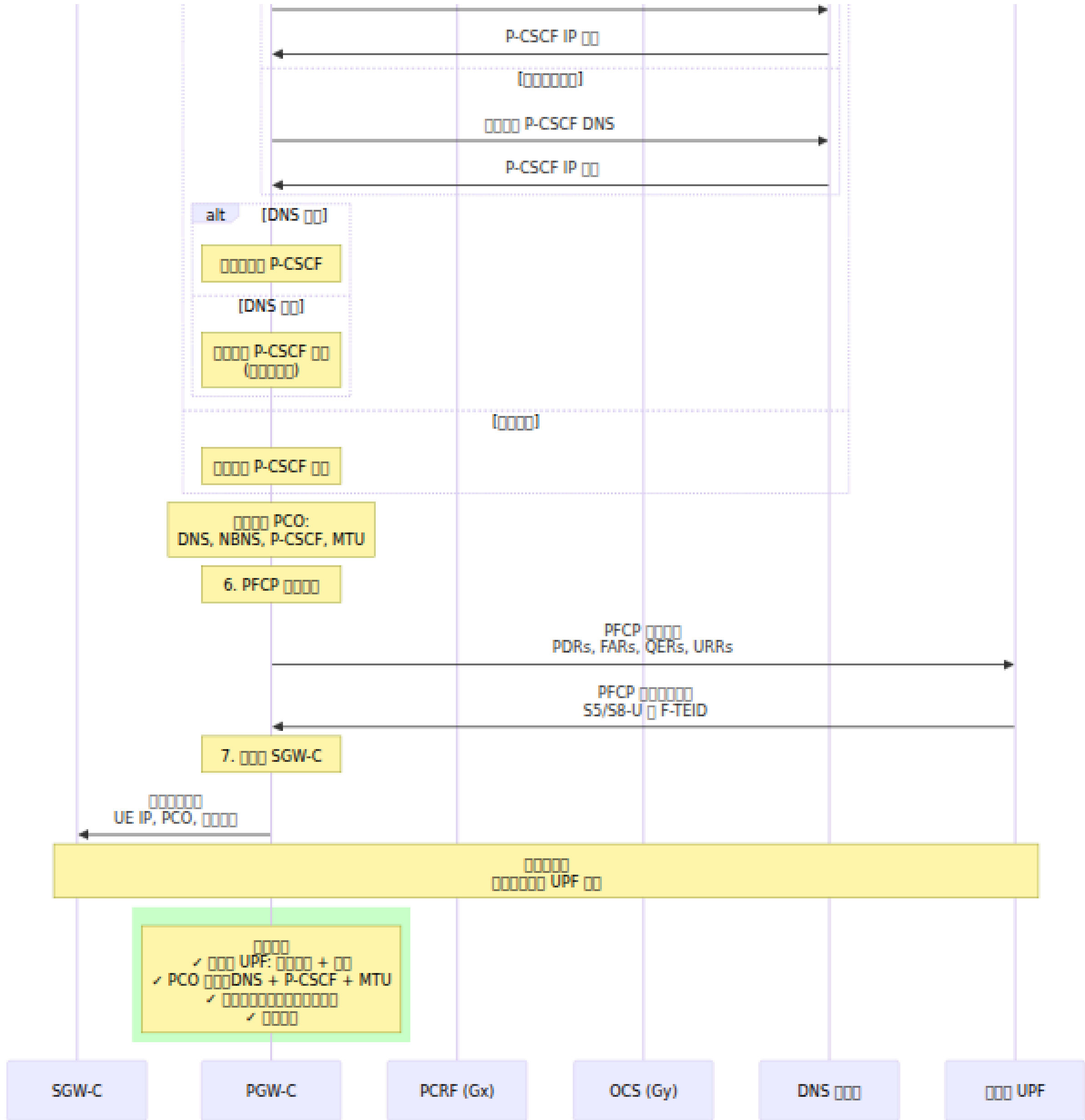
PCO □□□□□□□□

1. □□□□□□□□□□□□ PCO □□
2. □□□□□□□□□□□□□□□□ `pco` □□□□
3. □□□□□□□□□□□□□□□ PCO □□
4. □□□□□□□□ PCO □□□□□ PCO

PCO [illegible]


SGW-C
PGW-C
PCRF (Gx)
OCS (Gy)
(IMSI, APN, ULI
IMSI, APN, PLMN, TAI, ECGI
CCR- (Gx)
CCA- (Gx)
Rating-Group
alt
CCR- (Gy)
CCA- (Gy)
3. UPF


alt
NAPTR
ULI
UPF IP
4. UPF
PFCP
5. PCO
alt
PCO
alt
P-CSCF
alt
FQDN
p_cscf_discovery_fqdn



□□ PCO □□□□□□□□□

1. □□ **PCO □□□□□□□□□**
2. **P-CSCF DNS □□□□□□** P-CSCF □□□
3. □□ **PCO □□□□□□□□ / □□□**

□□□IMS □□□□ DNS□□□□□□□□□

```
IMS □□□□□“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"`□

□□□□□□□□

1. PGW-C □□□□□□□□□□□ FQDN □□ DNS □□
2. DNS □□□□□ P-CSCF IP □□□□
3. □□□ P-CSCF □□□□ PCO □□□ UE
4. □□ DNS □□□□□□□□□ PCO □□□□ `p_cscf_ipv4_address_list`□□□□□□□□□ PCO □□
5. □□□ P-CSCF □□ □□□□□□□□□/□□□

□□□□□□□□□□□□

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

□□□**IMS □□□□□□ P-CSCF**□

```
rules: [
  %{
    name: "IMS □□",
    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}
    ],
    # P-CSCF □□□□□□□ DNS □□□ P-CSCF □□
    # DNS □□□□□□□ FQDN □□□ P-CSCF IP
    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: [
      %{remote_ip_address: "10.100.3.21", remote_port: 8805,
weight: 100}
    ],
    # □□□□□□□□□ 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: [
      %{remote_ip_address: "10.100.5.21", remote_port: 8805,
weight: 100}
    ],
    # 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 □□□
- □□□□□□□□□□□□□□□□□□□□

□□ DNS □ UPF □□□

□□□□□□□□□□□ULI□□□□ UPF □□□□□ DNS NAPTR □□□DNS □□□□□ `upf_selection` □□□□□□

> □□□ □□□□□□□□□□□□ UPF □□□□□□ PFCP □□ □□□□□□□□ UPF □ PFCP □□□□□ □□□□ □□□□□□□□□□

```
upf_selection: %{
  # □□□□ DNS □□□
  dns_enabled: true,

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

  # 3GPP NAPTR □□□ DNS □□
  dns_suffix: "epc.3gppnetwork.org",

  # DNS □□□□□□□□
  dns_timeout_ms: 5000,

  # ... □□□□□□ ...
}
```

□□ DNS □□□□□□□□□□□

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

□□ **DNS** □□□□□□ DNS □□□□□□□□

```
; NAPTR □□□□ PLMN 313-380 □□ 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 □ A □□
upf-edge-1.example.com IN A 10.100.1.21
```

□□□

- □□□□□□□□**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 □□ UPF□1 □□□
[info] □□□□ UPF □□□□□□□ UPF□1 □□ 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: "□□□□□",
      priority: 10,
      match_field: :apn,
      match_regex: "^internet",
      upf_pool: [
        %{remote_ip_address: "10.100.1.21", remote_port: 8805,
weight: 100}
      ]
    }
  ],
  fallback_pool: [
    %{remote_ip_address: "10.100.2.21", remote_port: 8805,
weight: 100}
  ]
}
# □□ UPF □□□□□
# - 5 □□□
# - □□□□□□□
# - □□□□□□
```

2. □□□□ **UPF**□□□ `weight: 0` □□□□□ UPF □□□□□□□□□

```
upf_pool: [
  %{remote_ip_address: "10.1.1.1", remote_port: 8805, weight:
100},  # □□
  %{remote_ip_address: "10.1.1.2", remote_port: 8805, weight:
0}     # □□
]
```

3. □□ **Web UI** □□□□□□□□□□□□□ UPF □□□□

4. □□□□□□□□□ 3 □□□□□□□□□□□□□□□□□□□□□□□

□□ UPF □□

□□□PGW-C □□□□□□□□□ DNS □□□ UPF□□□□□□□ `upf_selection` □□□□

□□□□

□□□□□□□□□□□□□□□ DNS□□□□□□□□□□□ UPF □□□□□□□□

1. □□ **PFCP** □□□□□□□ UPF □□□□□□□□□
2. □□ **PFCP** □□□□□□ UPF □□ PFCP □□
3. □□□□□□□□□□□□ UPF □□□□□□□□□□□□
4. □□□□□□□□□□□□□□□□10 □□□□
5. □□□□□□□□□ UPF □□□□□□

□□ 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 □□□□□□□□□□□□□□

□□□□□□□□□□

□□	□□
□□□□ UPF	□ `upf_selection` □□□□□□□□□□□□□□□□
DNS □□□□□ UPF	□□□□□□□□□□□□□□□□□
□□/□□ UPF	□□□□□□□□□□□□□
□□□□ UPF	□ `upf_selection` □□□□□□□□□□□□□
□□/□□□□ UPF	□□□□□□□UPF □□□□□□□□

□□□□ UPF

□□ UPF □□□□□□□□□□□□□□□

```
[info] □□□ PFCP □□□□□□□□□ UPF {10, 200, 5, 99}□{10, 200, 5,
99}:8805□
[info] □□ UPF □□□ Dynamic-UPF-10-200-5-99 □□□□□PID #PID<0.1234.0>
```

[illegible]

```
# [illegible]
PGW_C.PFCP_Node.registered_peer_count()

# [illegible] UPF [illegible]
PGW_C.PFCP_Node.get_peer({10, 200, 5, 99})
# [illegible]{:ok, #PID<0.1234.0>} [illegible] :error
```

[illegible] UPF [illegible]

[illegible] UPF [illegible] PFCP [illegible]

```
# [illegible] UPF
PGW_C.PFCP_Node.register_dynamic_peer({10, 200, 5, 99}, 9999)
```

[illegible] DNS [illegible] 8805 [illegible] PFCP [illegible]

UPF [illegible]

[illegible]��� UPF [illegible]

□□□□□□□□ (CDR) □□

PGW-C □□□□□

OmniPGW □ Omnitouch □□□□□□

□□

□□

□□ **CDR**□□□□□□□□ □□□□□□□□□□□□□PGW-C□□□□□□□□□□CDR □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

□□□□□□ SGW-C CDR □□□□□ EPC □□□□□□□□□□□□□□

□□□□

- □□ **CSV** □□□ - □□□□□□□□□□□□□□□□
- □□□□□□□ - □□□□□□□□□□□□□□
- □□□□ - □□□□□□□□□□□□□

- □□□□ - □□□□□□□□□□□□□□
- □□ **3GPP ��**□ - □□ 3GPP TS 32.251□PS □□□□□ TS 32.298□CDR □□□

□□

□□	□□
□□□□	□□□□□□□□ CDR
□□	□□□□□□□□
□□□□	□□□□□□□□□□
□□□□	□□□□□□□□□
□□□□	□□□□□□□□□

CDR □□□□

□□□□□□

```
<epoch_timestamp>
```

□□□

```
1726598022
```

□□□□□□□□□□ Unix □□□□□□□□□□□□□

□□□□

□□□□□

- PGW-C: `/var/log/pgw_c/cdrs/`

□□□ `cdr_directory` □□□ config/runtime.exs □□□□

□□□

□□ CDR □□□□□□□□□□□□□□□

```
# □□ CDR □□□
# □□□□□□□HH:MM:SS (unix_timestamp)
# □□□□□□□HH:MM:SS (unix_timestamp)
# □□□□□<gateway_name>
#
epoch,imsi,event,charging_id,msisdn,ue_imei,timezone_raw,plmn,tac,eci
```

□□□□

- □□□□□□ - CDR □□□□□□□□□□□□□ Unix □□□□
- □□□□□□ - □□□□□□□□□□□□□□□□ Unix □□□
- □□□□ - PGW-C □□□□□□□□□ `pgw_name` □□□□□
- □□ - □□□□□ CSV □□□□

CDR □□

□□□□

□□	□□□□	□□	□□
0	epoch	□□	□□□□□□Unix □□□□
1	imsi	□□□	□□□□□□□□
2	event	□□□	CDR □□□□□□□□“default_bearer_start”□
3	charging_id	□□	□□□□□□□□□□
4	msisdn	□□□	□□□ ISDN □□□□□□□□
5	ue_imei	□□□	□□□□□□□□
6	timezone_raw	□□□	UE □□□□□□□□□□□
7	plmn	□□	□□□□□□□□□□□
8	tac	□□	□□□□□□
9	eci	□□	E-UTRAN □□□□□
10	sgw_ip	□□□	SGW-C S5/S8 □□□□ IP □□
11	ue_ip	□□□	UE IP □□□IPv4|IPv6 □□□
12	pgw_ip	□□□	PGW-C S5/S8 □□□□ IP □□
13	apn	□□□	□□□□□
14	qci	□□	QoS □□□□

□□	□□□□	□□	□□
15	octets_in	□□	□□□□□□□□□
16	octets_out	□□	□□□□□□□□□

CDR □□

□□□□

CDR □□□□□□□□□□□

□□□□	□□	□□	□□□□
□□□□	`<type>_bearer_start`	□□□□	□□□□□□□□
□□□□	`<type>_bearer_update`	□□□□□□□□□	□□□□□□□□□□□□□
□□□□	`<type>_bearer_end`	□□□□	□□□□□□/□□

□□□□□

- `default` - □□□□□□□ PDN □□□□□
- `dedicated` - □□□□□□□ PDN □□□□□□□□

□□□□

```
default_bearer_start      - □□□□□□□
default_bearer_update     - □□□□□□□□
default_bearer_end        - □□□□□□□
dedicated_bearer_start    - □□□□□□□
dedicated_bearer_update   - □□□□□□□□
dedicated_bearer_end      - □□□□□□□
```

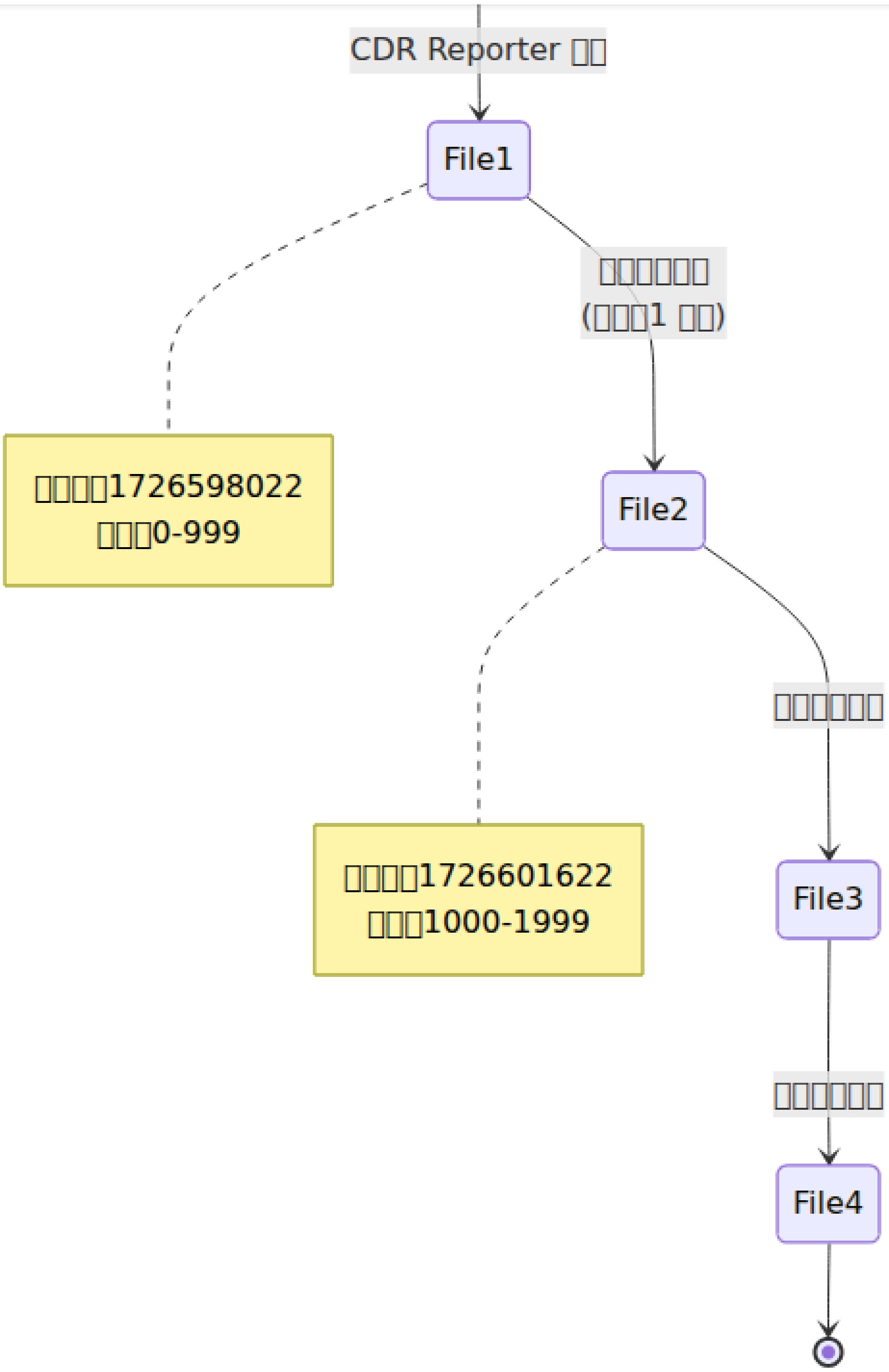
□□□□

□□ CDR □□

```
# □□ CDR □□□
# □□□□□□□18:53:42 (1726598022)
# □□□□□□□19:53:42 (1726601622)
# □□□□□sgw-c-prod-01
# epoch,imsi,event,charging_id,msisdn,ue_imei,timezone_raw,plmn,tac,e
1726598022,310260123456789,default_bearer_start,12345,15551234567,123
1726598322,310260123456789,default_bearer_update,12345,15551234567,12
1726598622,310260123456789,default_bearer_update,12345,15551234567,12
1726598922,310260123456789,default_bearer_end,12345,15551234567,12345
```

□□□□

CDR □□□□□□□□□□□□□□□□


CDR Reporter □□
File1
□□□□□□
(□□□1 □□)
□□□□1726598022
□□□0-999
File2
□□□□□□
□□□□1726601622
□□□1000-1999
File3
□□□□□□
File4

□□□□□

1. □□□□ CDR □□
2. □□□□□□□□□□□□□
3. □□□□□□□
4. □□□ CDR □□□□□□

□□

□□□□

PGW-C CDR □□□ `config/runtime.exs` □□□□

□□	□□	□□	□□□	□□□
`pgw_name`	□□□	PGW □□□□□□□□□ CDR □□□	"omni-pgw01"	���□□□□□□□ ID
`cdr_file_duration`	□□	□□□□□□□□□□	3600000	3600000□1 □□□
`cdr_directory`	□□□	CDR □□□□□□	"/tmp/pgw_c"	`/var/log/pgw_c/cdrs`
`usage_report_interval`	□□	URR □□□□□□□□ - PGW-U □□□□□□□□□	60000	60000□1 □□□

□□□□

□□□□ (config/runtime.exs):

```
config :pgw_c,
  # CDR □□□□
  pgw_name: "omni-pgw01",
  cdr_file_duration: 3_600_000,           # 1 □□
  cdr_directory: "/var/log/pgw_c/cdrs",

  # URR □□□□□ PGW-U □□□□□□
  usage_report_interval: 60_000           # 60 □
```

□□□□:

```
config :pgw_c,
  pgw_name: "pgw-c-prod-01",
  cdr_file_duration: 3_600_000,           # 1 □□□□
  cdr_directory: "/var/log/pgw_c/cdrs",
  usage_report_interval: 60_000           # 1 □□□□
```

□□□□:

```
config :pgw_c,
  pgw_name: "pgw-c-dev",
  cdr_file_duration: 300_000,             # □□□□ 5 □□□□
  cdr_directory: "/tmp/pgw_c_cdrs",
  usage_report_interval: 30_000           # □□□□□ 30 □□□
```

□□□:

```
config :pgw_c,
  pgw_name: "pgw-c-prod-heavy",
  cdr_file_duration: 1_800_000,           # 30 □□□□
  cdr_directory: "/mnt/fast-storage/cdrs",
  usage_report_interval: 300_000          # 5 □□□□□□□□□□
```

URR□□□□□□□□

PGW-C □□ **PFCP URRs**□□□□□□□□ □□□ PGW-U □□□□□□□□□ URR □□□□□□□□□□PGW-U □□□□□□□□□□□□□□□□□□□□ CDR □□□

URR □□□□□□□

1. `usage_report_interval`□□□□□□□□□□ PFCP □□□□□□
2. PGW-C □□□□□□□□□□□□□□ URR
3. PGW-U □□□□□□□□□□□□□
4. □□□□□□□□□ `bearer_update` CDR □□
5. □□□□□□□□□□□□□□ `bearer_end` CDR □□

□□□ `usage_report_interval: 60_000` □□□□

- PGW-U □ 60 □□□□□□□□
- □ 60 □□□ CDR □□□□
- □□□□□□□□□□□

URR □□□□□

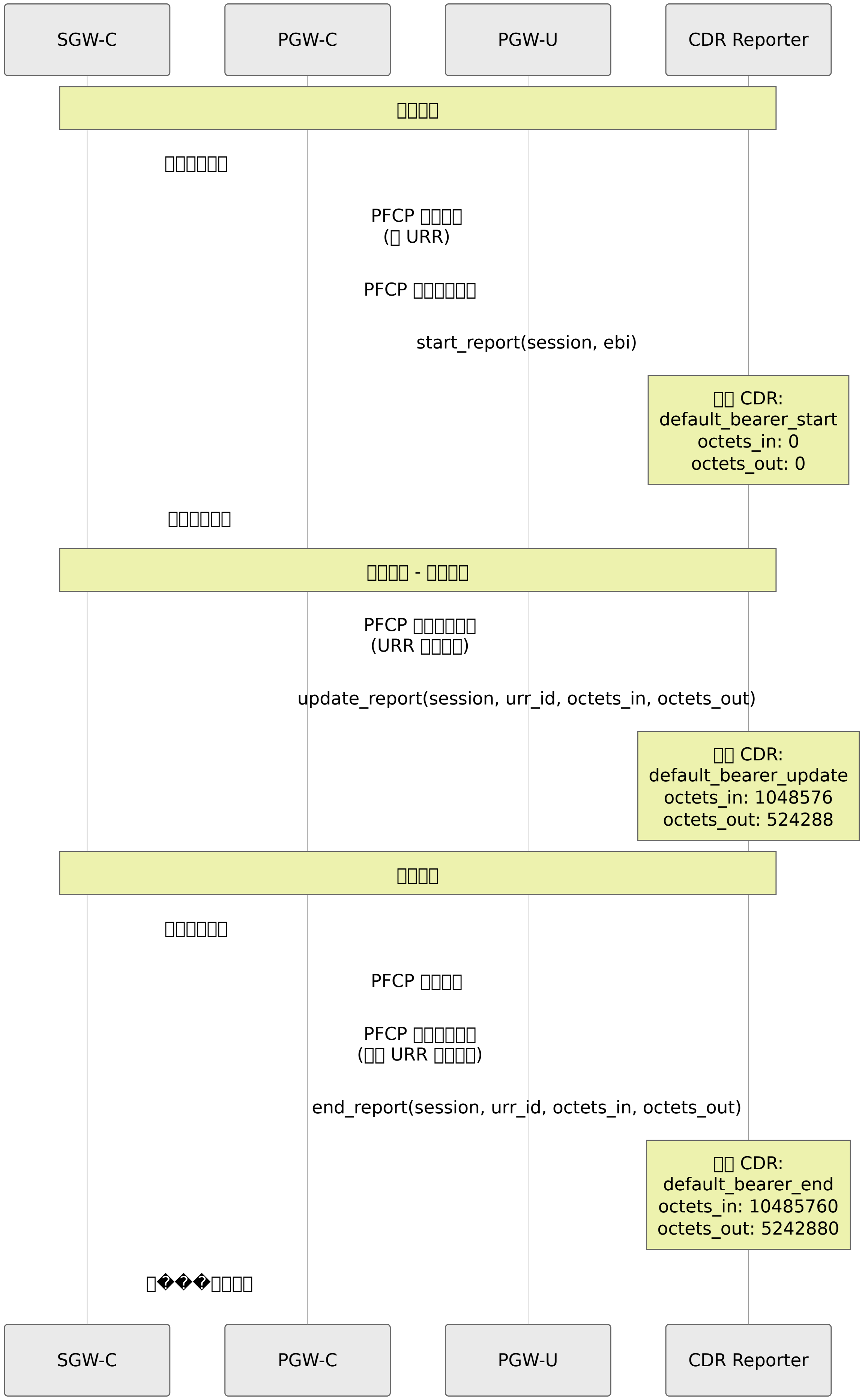
```
# lib/core/session/types.ex
defmodule PGW_C.Session.Types.URR do
  typedstruct do
    field :urr_id, non_neg_integer()
    field :measurement_method, :duration | nil
    field :reporting_triggers, :time_threshold | nil
    field :time_threshold, non_neg_integer() | nil  # □
  end
end
```

□□□ PFCP □□□□ □□□ URR PFCP □□□□□□ lib/core/session/impl/procedures.ex:468 □□□□□□□□ URR □□□

CDR □□□□

□□□□□□ CDR □□

PGW-C CDR □□□


SGW-C
PGW-C
PGW-U
CDR Reporter
PFCP
(URR)
PFCP
start_report(session, ebi)
CDR:
default_bearer_start
octets_in: 0
octets_out: 0
PFCP
(URR)
update_report(session, urr_id, octets_in, octets_out)
CDR:
default_bearer_update
octets_in: 1048576
octets_out: 524288
PFCP
PFCP
(URR)
end_report(session, urr_id, octets_in, octets_out)
CDR:
default_bearer_end
octets_in: 10485760
octets_out: 5242880
SGW-C
PGW-C
PGW-U
CDR Reporter

CDR □□□□

1. □□□□□

- □□□ □□□□□□□□□□
- □□□ □□□□□□□□□□□□
- **octets_in**□ 0
- **octets_out**□ 0

2. □□□□□

- □□□ □ PGW-U □□ PFCP □□□□□□□URR □□□□□
- □□□ □□□□□□□□
- **octets_in**□ □□□□□□□□□□□□□□
- **octets_out**□ □□□□□□□□□□□□□□
- □□□ URR □□□□□□□□□ `usage_report_interval` □□□

3. □□□□□

- □□□ □ PGW-U □□ PFCP □□□□□□□□□□□□□□□□□
- □□□ □□□□□□□□□□□□□□
- **octets_in**□ □□□□□□□
- **octets_out**□ □□□□□□□

□□□□□□

1. epoch□□□□□

□□□ Unix □□□□□□□□

□□□ CDR □□□□□□□

□□□

```
1726598022  → 2025-09-17 18:53:42 UTC
```

---

2. imsi□□□□□□

□□□ □□□□□□ 15 □□□□

□□□ MCCMNC + MSIN

□□□ □□□□□□□□□□□□□□

□□□

```
310260123456789
  └──┬─┘ └──┬─┘ └─────┬────┘
   MCC  MNC     MSIN
   (310)(260) (123456789)
```

□□□ UE □□□□□□□□□□□□□

---

3. event□CDR □□□□□

□□□ □□□

□□□ `<bearer_type>_bearer_<event>`

□□

- `default_bearer_start`
- `default_bearer_update`
- `default_bearer_end`
- `dedicated_bearer_start`
- `dedicated_bearer_update`
- `dedicated_bearer_end`

□□□

- □□ EBI□EPS □□ ID□□□ LBI□□□□□ ID□□`default`
- □□ EBI □□□ LBI□`dedicated`

□□□ □□□□□□EBI □ LBI □□□

---

4. charging_id□□□□□□□

□□□ □□□ 32 □□□

□□□ □□□□□□□□□□□□□□□□□

□□□

```
12345
```

□□□ □ PGW-C □□□□□□□□□□□□□

□□□

- □□ SGW □ PGW □□□□□□□
- □□□□ Gy/Gz □□□□
- □□□□□□

---

5. msisdn□□□□□□

□□□ □□□□E.164 □□□

□□□ □□□ ISDN □□□□□□□□□□□□

□□□ □□□□ + □□□□

□□□

```
15551234567
 └┬┘ └────┬────┘
  CC   □□
  (1) (5551234567)
```

□□□ UE □□□□□□□□ MME □ HSS □□

---

6. ue_imei□□□□□��

□□□ □□□□15 □□□□

□□□ TAC□8□+ SNR□6□+ Spare□1□

□□□ □□□□□□□□□□□□□□□

□□□

```
123456789012345
└───┬───┘ └─┬─┘ └┘
   TAC    SNR S
```

□□□ UE □□□□□ MME □□

---

7. timezone_raw□UE □□□

□□□ □□□□□□□□/□□□

□□□ □□□□□□□ UE □□□□

□□□□□ □□□□CSV □□□□□□

□□□□□ □□□□□□□□□□□□□□

□□□

```
,  (□□□)
```

---

8. plmn□□□□□□□

□□□ □□□□□□□□

□□□ □□□□□□□□□□□□□□□□□□□□□

□□□□□

```
MCC: 505, MNC: 57
    ↓
"50557"
    ↓
□□□□ "055570"
    ↓
□□□□□□□□□0x055570 = 349552
```

□□□

```
349552  → MCC: 505, MNC: 57
```

□□□ □ MME □□□ UE □□□□

□□□ □□□□□□□□□□□□□□□□□□

---

9. tac□□□□□□□□

□□□ □□□ 16 □□□

□□□ □□□□□□□□ UE □□□□□□□

□□□ 0 - 65535

□□□

```
1234
```

□□□ UE □□□□□□ MME □□□□□□□□□□

□□□

- □□□□□□□□
- □□□□□□□□□
- TAI□□□□□□□□□□□□

---

10. eci□E-UTRAN □□□□□

□□□ □□□ 28 □□□

□□□ E-UTRAN □□□□□□□□□□□ UE □□□

□□□ eNodeB ID□20 □□+ □□ ID□8 □□

□□□ 0 - 268,435,455

□□□

```
5678
```

□□□ □ MME □□□ UE □□□□

□□□

- □□□□□□□□□□□
- □□□□□□□□□
- □□□□□□□

---

11. sgw_ip□SGW □□□□ IP□

□□□ □□□□IPv4 □ IPv6 □□□

□□□ SGW-C □ S5/S8 □□□□ IP □□□F-TEID□

□□□ □□□□□□IPv4□□□□□□□□□IPv6□

□□□

```
10.0.0.15        (IPv4)
2001:db8::15     (IPv6)
```

□□□ □□□□□□□□□ S5/S8 □□

---

12. ue_ip□UE IP □□□

□□□ □□□□IPv4|IPv6 □□□

□□□ □□□ UE □ IP □□□□□ PDN □□

□□□ `<ipv4>|<ipv6>`

□□□

```
172.16.1.100|                      (□ IPv4)
|2001:db8::1                       (□ IPv6)
172.16.1.100|2001:db8::1          (□□)
```

□□��� □ PGW-C □□□ PDN □□□□□PAA□

□□□

- □ IPv4□□□□ IPv4 □□
- □ IPv6□□□□ IPv6 □□
- □□□□□□□□□ PDN □□

---

13. pgw_ip□PGW □□□□ IP□

□□□ □□□□IPv4 □ IPv6 □□□

□□□ PGW-C □ S5/S8 □□□□ IP □□□□□ F-TEID□

□□□ □□□□□□IPv4□□□□□□□□□IPv6□

□□□

```
10.0.0.20       (IPv4)
2001:db8::20    (IPv6)
```

□□□ □ PGW-C □□□□□□□□□□

---

14. apn□□□□□□□

□□□ □□□□□□ 100 □□□□

□□□ □□□□□□□PDN□□□□□□□

□□□ □□ DNS □□□□□

□□□

```
internet
ims
mms
enterprise.corporate
```

□□□ □ MME □□□□□□□□□□

□□□

- □□□□□□□□□□□
- □□□□□□□□□
- □□□□ IP □□□

---

15. qci□QoS □□□□□

□□□ □□□ 8 □□□

□□□ QoS □□□□□□□□□□□□

□□□ 1 - 9□□□□□□128-254□□□□□□□

□□□ **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	Non-GBR	1	100 ms	10^-6	IMS □□
6	Non-GBR	6	300 ms	10^-6	□□□□□□
7	Non-GBR	7	100 ms	10^-3	□□□□□□□□
8	Non-GBR	8	300 ms	10^-6	□□□□□□
9	Non-GBR	9	300 ms	10^-6	□□□□

□□□

```
9   →  □□□□□□□□□□
```

□□□ □ PGW-C □□□□□ QoS □□

16. octets_in□□□□□□

□□□ □□□ 64 □□□

□□□ □□□□□□□□ → UE□□□□□□□

□□□ □□

□□□

```
1048576  → 1 MB □□
```

□□□ □ PGW-U □□□ PFCP □□□□□□□ URR □□□□□

□□□

- □□ `update` □□□□□□
- □□ `end` □□□□□□□
- □□ `start` □□□□□ 0
- □□□ URR □□□□□□□□□ `usage_report_interval` □□□

---

17. octets_out□□□□□□

□□□ □□□ 64 □□□

□□□ □□□□□□UE → □□□□□□□□□

□□□ □□

□□□

```
524288  → 512 KB □□
```

□□□ □ PGW-U □□□ PFCP □□□□□□□ URR □□□□□

□□□

- □□ `update` □□□□□□
- □□ `end` □□□□□□□
- □□ `start` □□□□□ 0
- □□□ URR □□□□□□□□□ `usage_report_interval` □□□

□□

□□ 1□□□□□□□□□□

□□□□

1. □□□□
2. 5 □□□□□□□□□□□ 10 MB□□□ 5 MB□
3. □□□□

CDR □□□

```
# □□ CDR □□□
# □□□□□□□10:00:00 (1726570800)
# □□□□□□□11:00:00 (1726574400)
# □□□□□pgw-c-01
# epoch,imsi,event,charging_id,msisdn,ue_imei,timezone_raw,plmn,tac,e
1726570800,310260111111111,default_bearer_start,10001,15551111111,111
1726571100,310260111111111,default_bearer_update,10001,15551111111,11
1726571400,310260111111111,default_bearer_end,10001,15551111111,11111
```

□□ 2□□□□□□□□□□□□

□□□□

1. □□□□□□□IPv4 + IPv6□
2. □□□□□□
3. □□□□

CDR □□□

```
1726570800,310260222222222,default_bearer_start,10002,15552222222,222
1726571100,310260222222222,default_bearer_update,10002,15552222222,22
1726571400,310260222222222,default_bearer_update,10002,15552222222,22
1726571700,310260222222222,default_bearer_update,10002,15552222222,22
1726572000,310260222222222,default_bearer_end,10002,15552222222,22222
```

□□ 3□□□□□□□□□□

□□□□

1. □□□□□□□QCI 9□
2. □□□□□□□□□□QCI 6□
3. □□□□□□□□□
4. □□□□□□
5. □□□□□□

CDR □□□

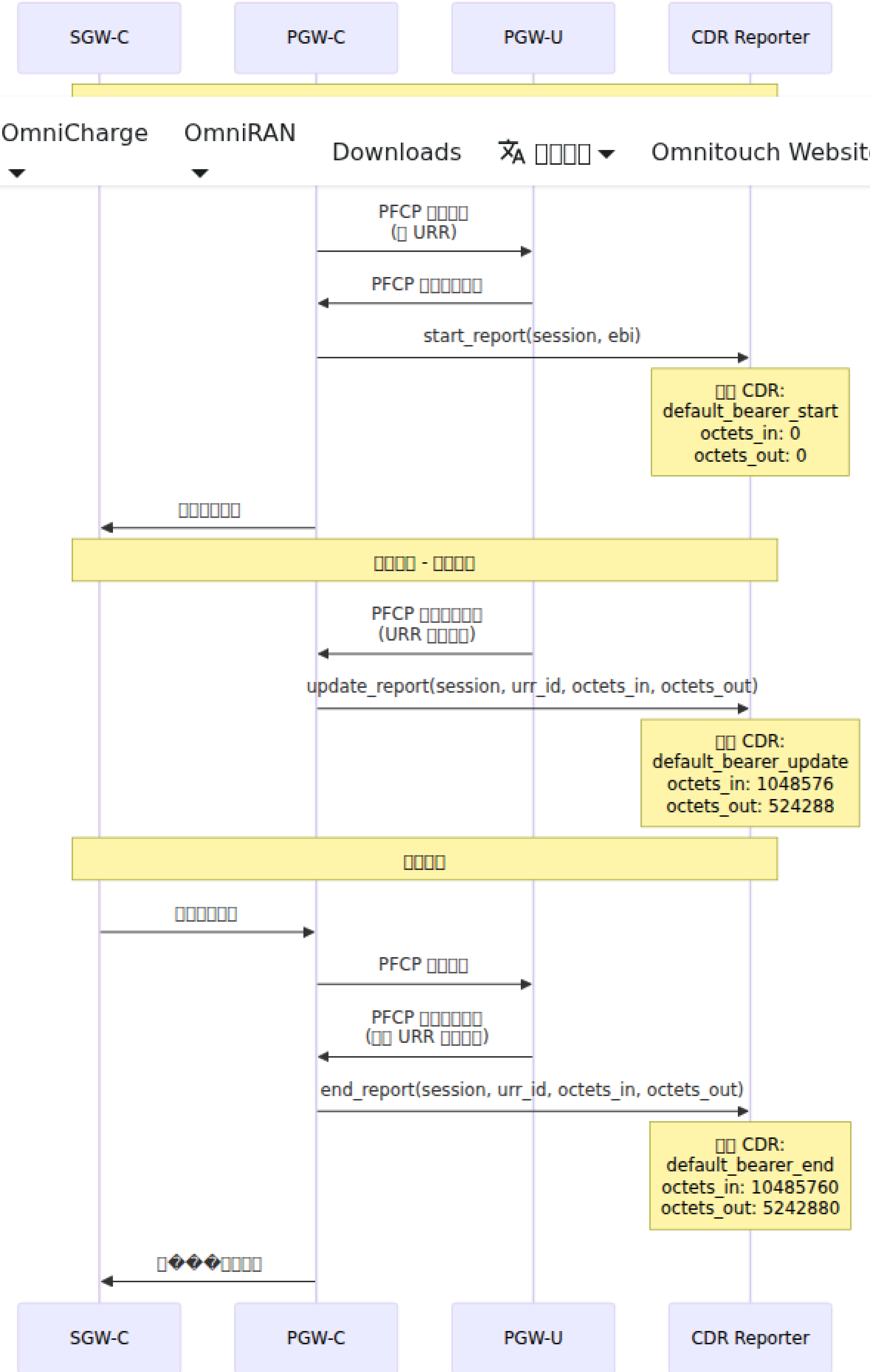
```
1726570800,310260333333333,default_bearer_start,10003,15553333333,333
1726571100,310260333333333,dedicated_bearer_start,10004,15553333333,3
1726571400,310260333333333,default_bearer_update,10003,15553333333,33
1726571400,310260333333333,dedicated_bearer_update,10004,15553333333,
1726571700,310260333333333,dedicated_bearer_end,10004,15553333333,333
1726572000,310260333333333,default_bearer_end,10003,15553333333,33333
```

□□□

- □□□□□10003□□□□□□□□□□ 10 MB□□□ 4 MB□
- □□□□□10004□□□□□□□□□□ 200 MB□□□ 2 MB□
- □□□ QCI □□9 □ 6□□□□□□ QoS □□

[illegible]

CDR [illegible]


SGW-C
PGW-C
PGW-U
CDR Reporter
PFCP □□□□
(□ URR)
PFCP □□□□□□
start_report(session, ebi)
□□ CDR:
default_bearer_start
octets_in: 0
octets_out: 0
□□□□□□
□□□□ - □□□□
PFCP □□□□□□
(URR □□□□)
update_report(session, urr_id, octets_in, octets_out)
□□ CDR:
default_bearer_update
octets_in: 1048576
octets_out: 524288
□□□□
□□□□□□
PFCP □□□□
PFCP □□□□□□
(□□ URR □□□□)
end_report(session, urr_id, octets_in, octets_out)
□□ CDR:
default_bearer_end
octets_in: 10485760
octets_out: 5242880
SGW-C
PGW-C
PGW-U
CDR Reporter

CDR □□□□

1. □□□□□□□□

```
# □□ CDR □□□PGW-C□
inotifywait -m /var/log/pgw_c/cdrs/ -e close_write | while read
path action file; do
    # □□□□□□□□□ CDR
    process_cdr "$path$file"
done
```

2. □□□□

```
# □□□□□□□□□□□□
tail -F /var/log/pgw_c/cdrs/* | process_cdr_stream
```

□□□□

- □□□□ - □□□□□□□ CDR □□
- PFCP □□ - □□ URRs □ PGW-U □□□□□□
- □□□□ - CDR □□□□□□□
- □□□□ - CDR □ URR □□□□
- □□ Gx □□ - CDR □ QCI □□□□□□
- □□ Gy □□ - □□□□□□

3GPP □□

- TS 32.251 - □□□□□□PS□□□□□
- TS 29.274 - 3GPP □□□□□□□□EPS□□GTP-C □□
- TS 29.244 - CP □ UP □□□□□□□□□PFCP□ - **URR □□**
- TS 32.298 - CDR □□

CDR □□ - *PGW-C □□□□□□□*

□ Omnitouch □□□□□□

□□□□□ 1.0 □□□□□ 2025-12-28

Diameter Gx □□□□

□□□□□□□□□ (PCRF) □□

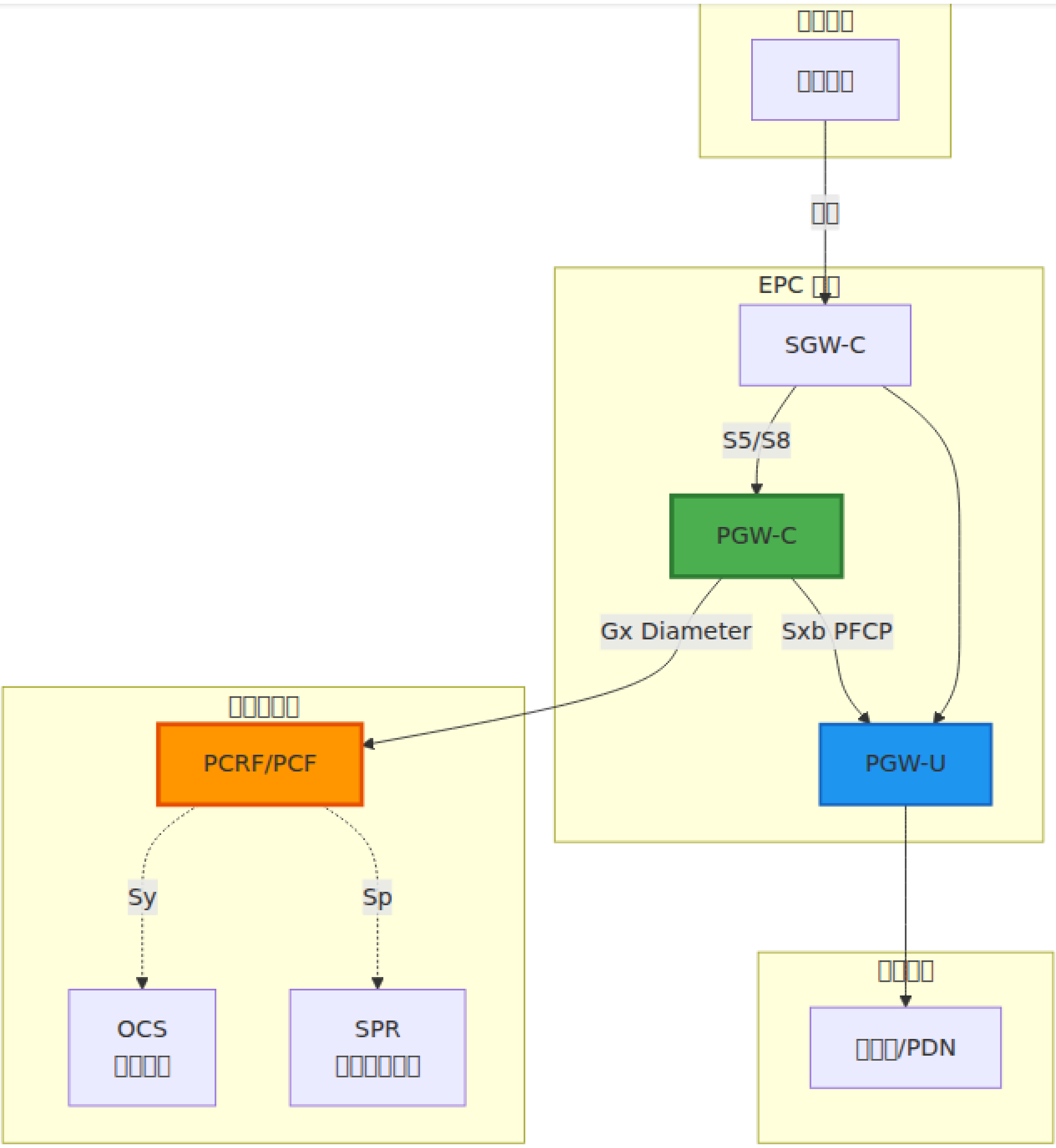
□□

□□

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

- □□□□□□ - □□ QoS □□□□□
- □□□□ - □□□□□□□□□
- □□□□ - □□□□□□□
- □□□□□□□□ - □□□□□□□

[illegible] Gx


EPC
SGW-C
S5/S8
PGW-C
Gx Diameter
Sxb PFCP
PCRF/PCF
PGW-U
Sy
Sp
OCS
SPR
/PDN

□□□□

□□	□□
□□□□	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: Proxiable
│   ├── 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 (□□-□□)
├── AVP Header
│   ├── AVP Code
│   ├── Flags (V, M, P)
│   ├── AVP Length
│   └── Vendor ID (optional)
└── AVP Data
```

□□ Diameter □□

AVP□□□-□□□□

- Diameter □□□□□□□□□
- □□□□□□□□□□
- □□□□□□□□ AVP□

□□□

- □□/□□□
- CCR□□□□□□□□□/ CCA□□□□□□□□□

□□□□□

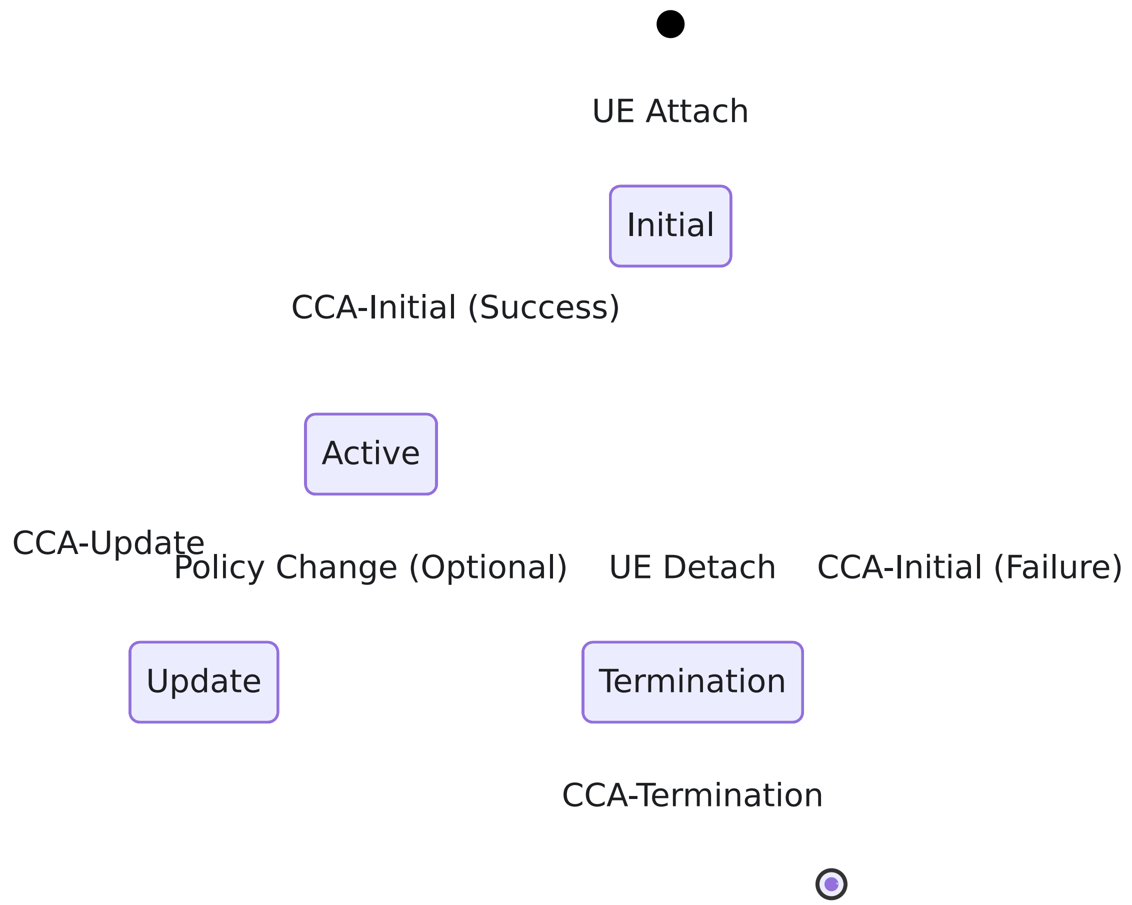
- `2001` - DIAMETER_SUCCESS
- `3xxx` - □□□□
- `4xxx` - □��□□

- `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 (Command Code: 272, Request)
├── 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 (Command Code: 272, Answer)
├── 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 - reduced)
│   └── APN-Aggregate-Max-Bitrate-DL: 100000000 (100 Mbps -
increased)
├── 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 (Command Code: 272, Request)
├── 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 □□□

□□□

- □□□□□□
- □□□□□□□

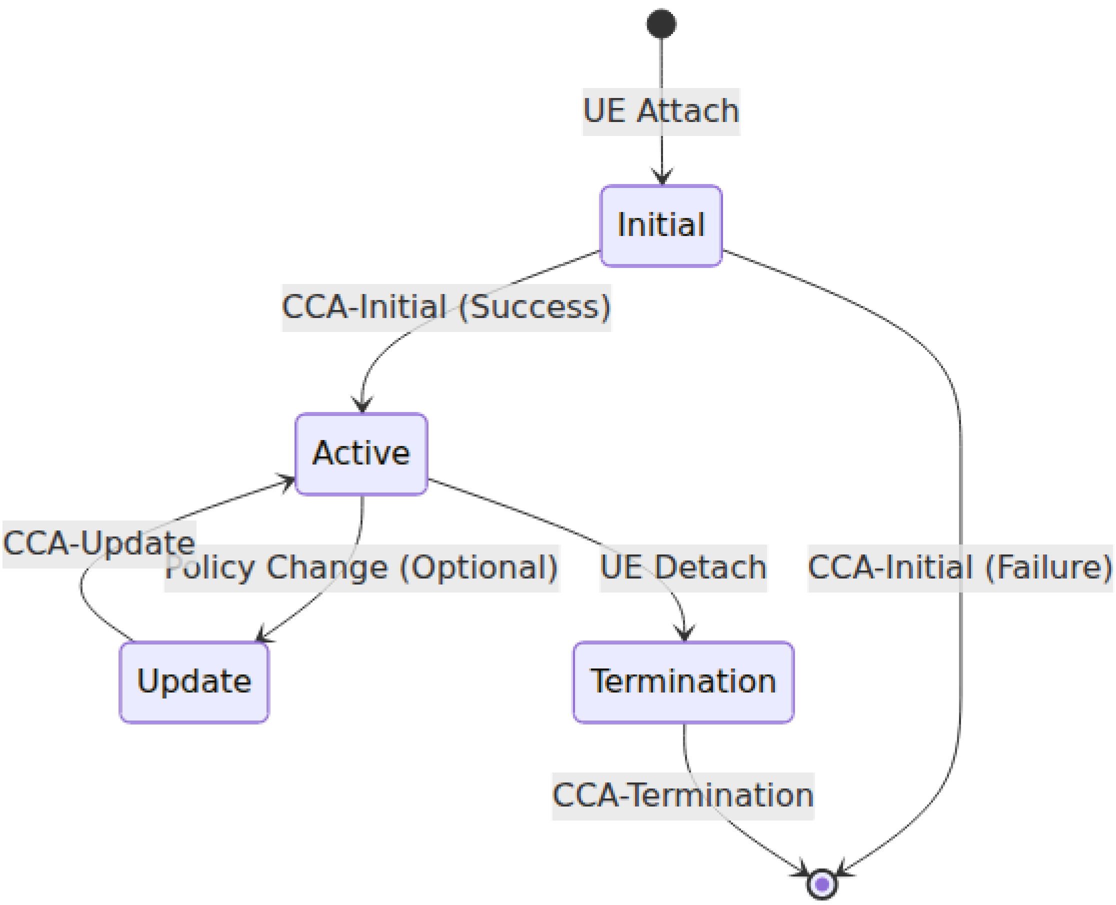
□□ **CCA-T□**

```
CCA (Command Code: 272, Answer)
├── 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. □□□□

- □□□□ = □□□□□
- □□□0-65535
- □□□□□□□□□□

3. □□□□□**TFT -** □□□□□□□

- □□□□□□□□□□□□
- □□□
  - IP 5 □□□□□□□/□□ IP□□/□□□□
  - `"permit out ip from any to 8.8.8.8 80"`

4. QoS □□□

- **QCI□QoS** □□□□□□ 1-9□□□□□□128-254□□□□□□□
  - QCI 1□□□□□
  - QCI 5□IMS □□
  - QCI 9□□□□□□
- **ARP**□□□□□□□□□□□ □□□□
- **MBR/GBR**□ □□/□□□□□

5. □□□□□

- □□□□ □□□□□□□□ OCS □□ - □ Diameter Gy □□□
- □□□□□ □□□□□□□□□□
- □□/□□□□□ OCS□□□ Diameter Gy □□□□□□□□ CDR□□□□ - □ □□ CDR □□□

6. □□□□□

- □□□ □□□□

- □□□ □□□□

□□□□□□

PCRF □□□□□□□□□□□□□

1. □□□□□□□□□□□

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

2. □□□□□□□□□□□

```
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□□□□□□□□□

□□□□ APN □□□□ GBR □□□

```
QoS-Information (Grouped)
├── APN-Aggregate-Max-Bitrate-UL: 100000000  # 100 Mbps
└── APN-Aggregate-Max-Bitrate-DL: 200000000  # 200 Mbps
```

PGW-C □□□

- □□□□ AMBR □□
- □ PGW-U □□□□□□□ QER □□□□□□□

□□

□□ 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□□□□□□□□□

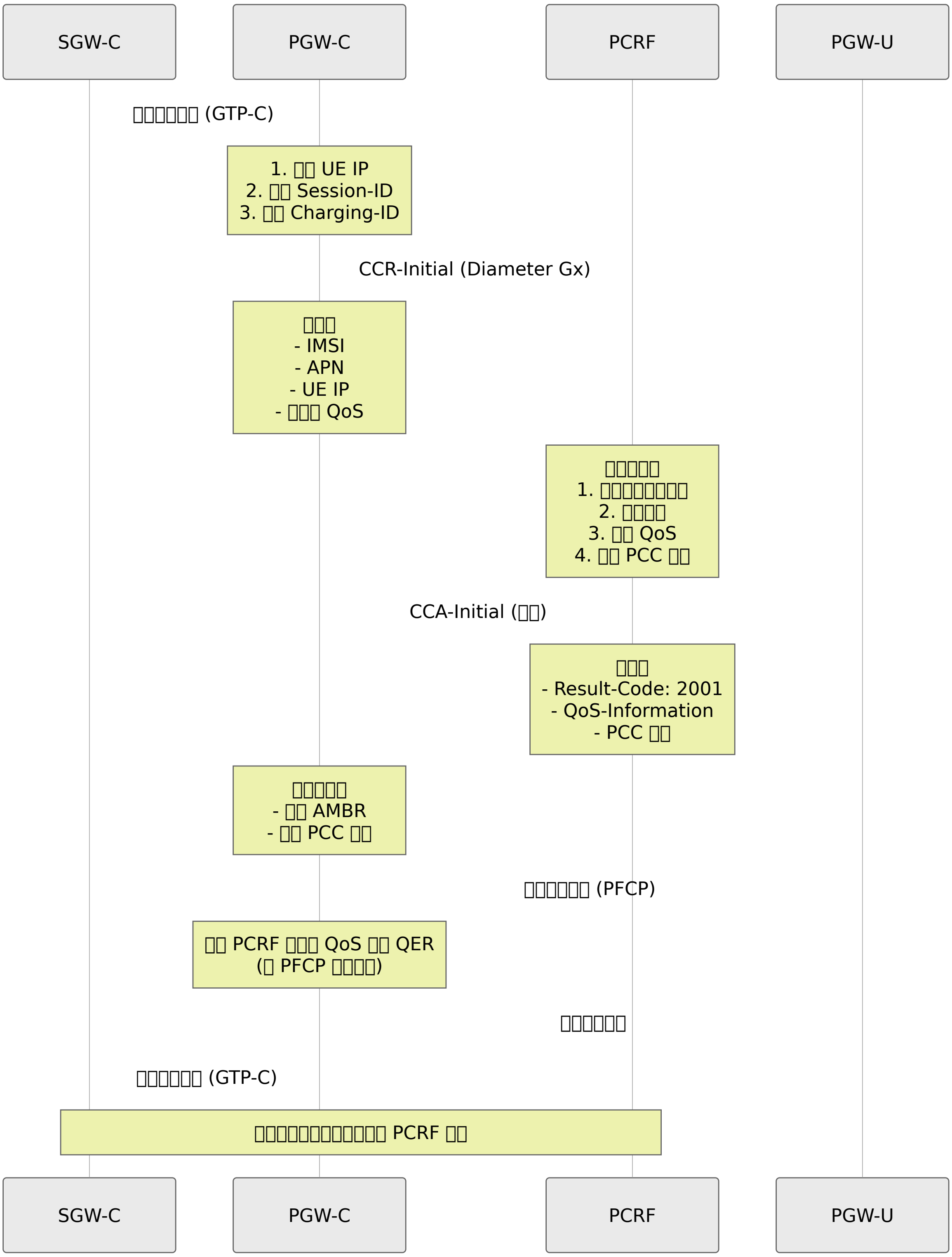
```
# □□ - FQDN □□
host: "pgw_c.epc.mnc999.mcc999.3gppnetwork.org"

# □□□ - □□□□□ Diameter □□
host: "pgw_c"
host: "10.0.0.20"  # □□□ IP □□
```

□□□□□

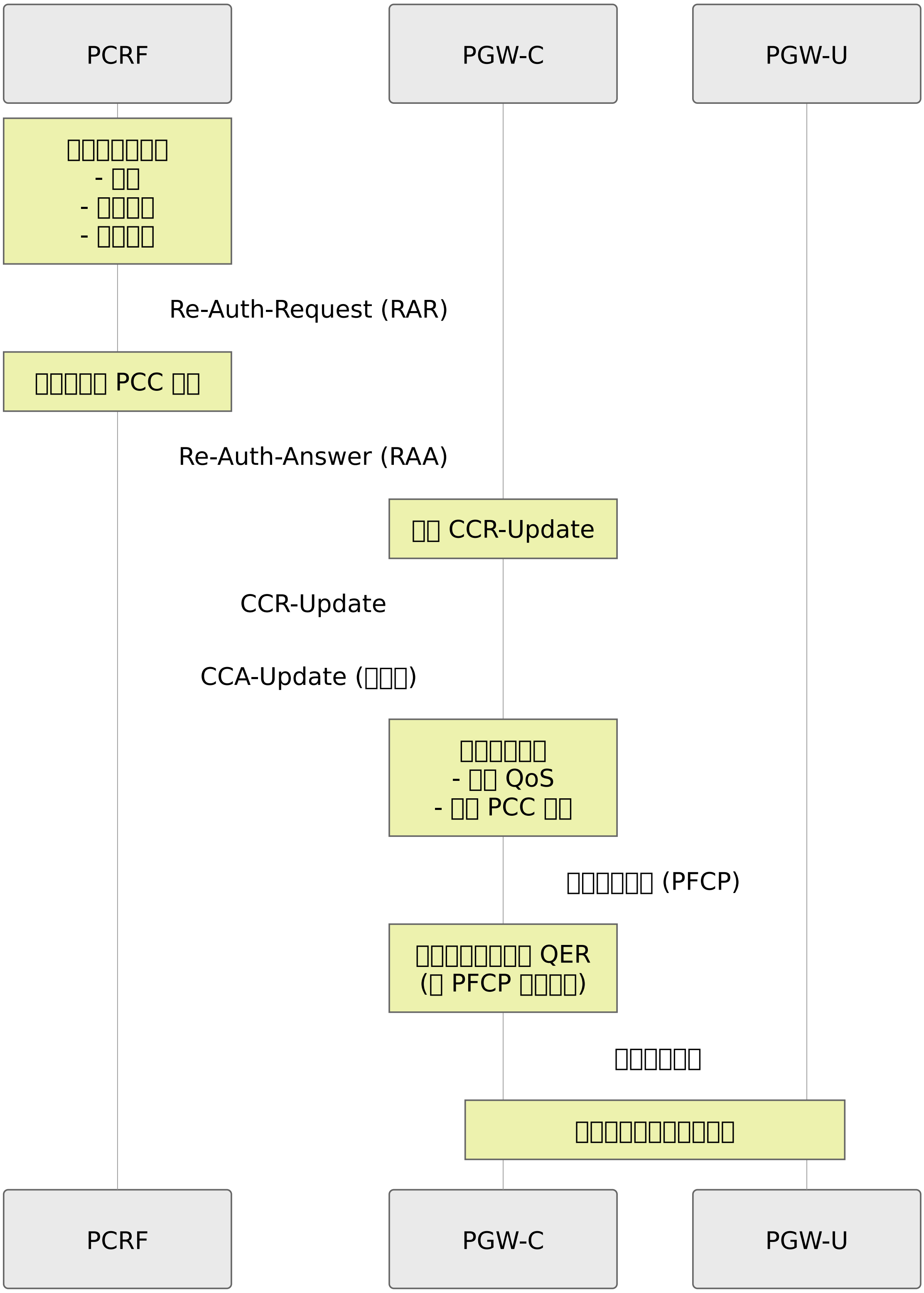
- □□□□□□□□
- □□□ 3GPP PLMN □□□□□`epc.mncXXX.mccYYY.3gppnetwork.org`

□□□

□□□□□□□

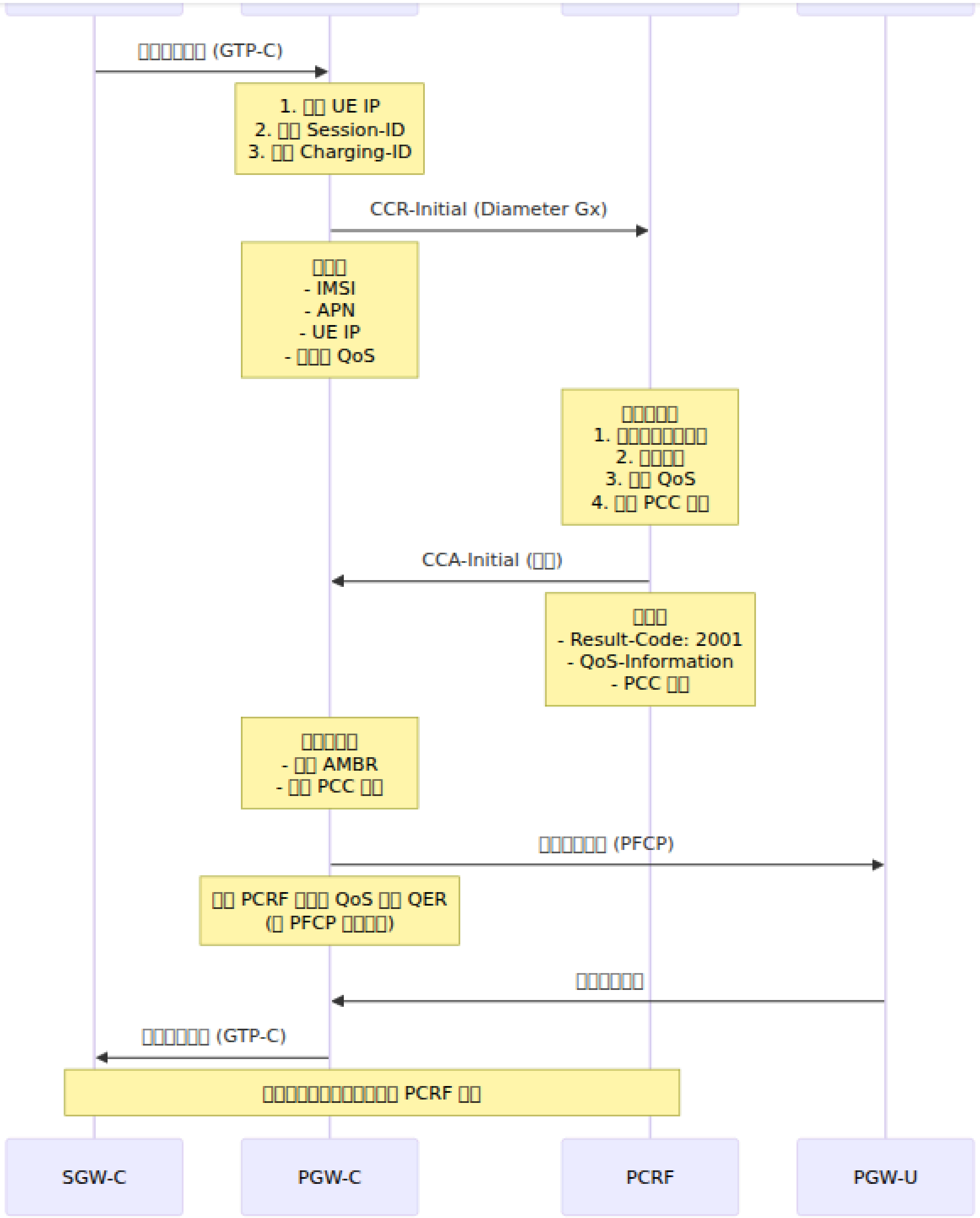


□□□ PCRF □ QoS □□□□□□ QER□QoS □□□□□□□□□□ PFCP □□□ PGW-U□□□ QER □□□□□□□□ □ PFCP □□□


PCRF
PGW-C
PGW-U
Re-Auth-Request (RAR)
Re-Auth-Answer (RAA)
CCR-Update
PCRF
PGW-C
PGW-U

□□□□

OmniCharge OmniRAN Downloads □□□□ Omnitouch Website



□□□□

□□□□

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)□

□□	□□	**PGW-C □□**
4001	DIAMETER_AUTHENTICATION_REJECTED	□□□□□□□
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 □□□

□□ PCRF □□□□□□□ CCR-Initial□

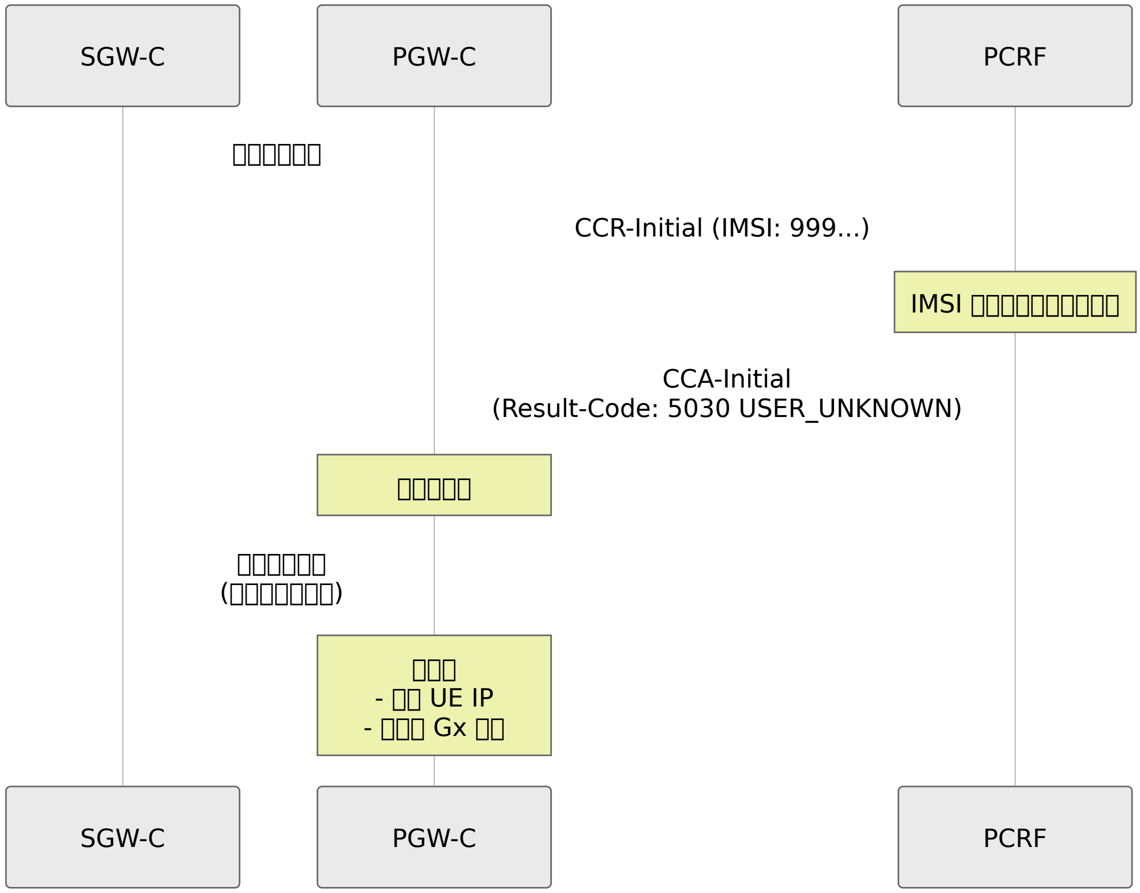
```
1. PGW-C □□□□□□□□□□□□5 □□
2. □□□□□ CCA□
   - □□□“Session-ID □ CCR-Initial □□□...”
   - □ SGW-C □□□□□□
   - □□□□□□□□
3. SGW-C □□□□□□□□□□□□□□□□□□□□□□□□
```

□ SGW-C □□□□□□

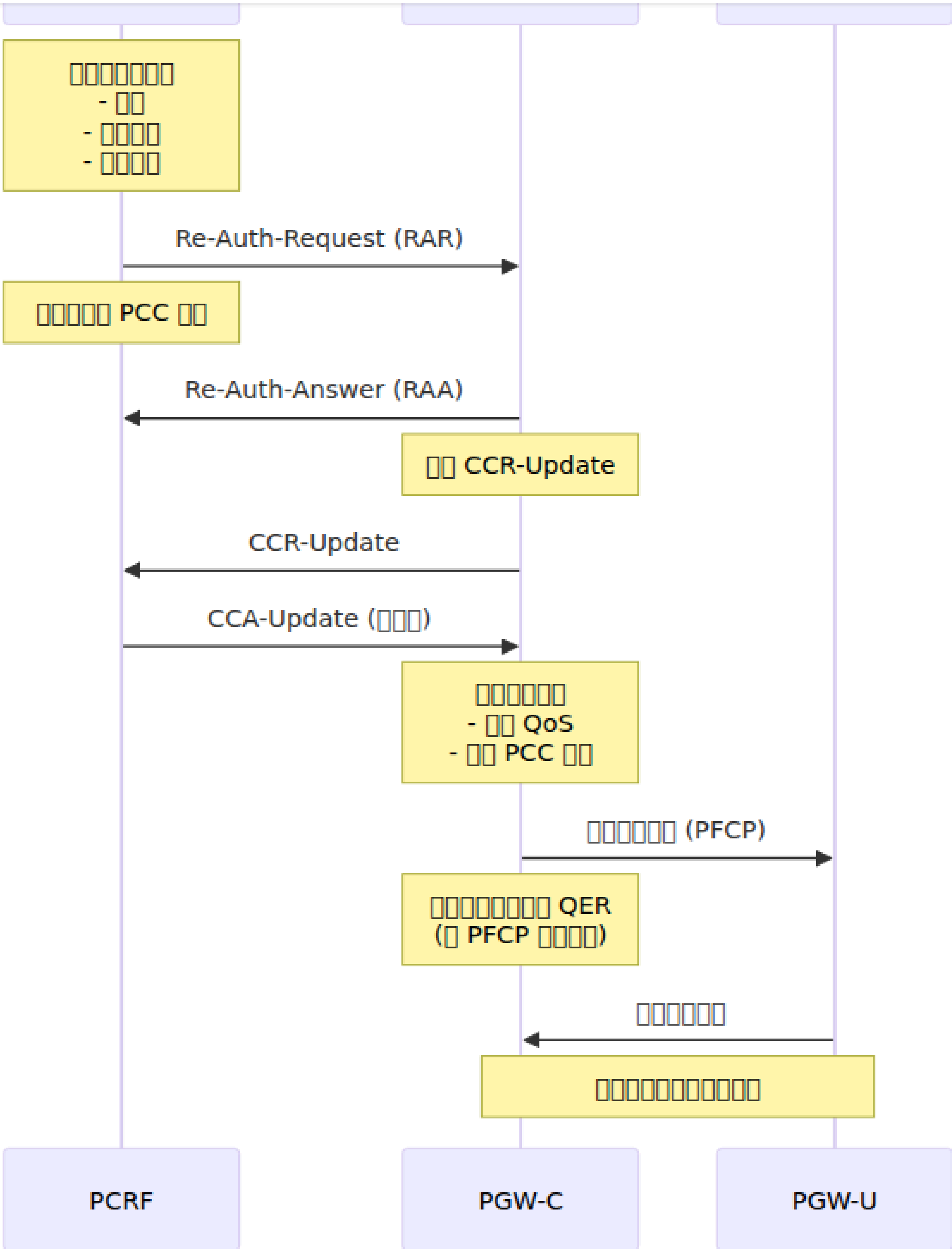
□ CCR-Initial □□□□PGW-C □ SGW-C □□□□□□□□□□□□□□□□ `:remote_peer_not_responding`□

□□□□

□□ 1□PCRF □□□□□□□□□□□


SGW-C
PGW-C
PCRF
□□□□□□
CCR-Initial (IMSI: 999...)
IMSI □□□□□□□□□□
CCA-Initial
(Result-Code: 5030 USER_UNKNOWN)
□□□□□
□□□□□□
(□□□□□□□)
□□□
- □□ UE IP
- □□□ Gx □□
SGW-C
PGW-C
PCRF

□□ 2□PCRF □□□□□


PCRF
PGW-C
PGW-U
Re-Auth-Request (RAR)
PCC
Re-Auth-Answer (RAA)
CCR-Update
CCR-Update
CCA-Update
- QoS
- PCC
(PFCP)
QER
(PFCP)

□□□□

□□□□

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

□□□□□

1. □□ PCRF □□□□□□□
2. □□ PCRF □□□□□□□□
3. □□□□□□□`ping <pcrf_ip>`
4. □□□□□□□□□□□□□

3. □□□ PCRF □□

□□□

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

□□□□□□□

□□□□	□□□□	□□□□
5030	IMSI □□□□□□□□	□ HSS/SPR □□□□□
5003	□□□□□	□□□□□□
4010	PCRF □□□□	□□□□□ PCRF □□

□□□□□

```
# PGW-C □□□□□
[error] Diameter Gx □□□□□□□ 5030 (DIAMETER_USER_UNKNOWN)
[error] IMSI 310260999999999 □ 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="gx_CCA"}[5m])
rate(gx_outbound_messages_total{message_type="gx_CCR"}[5m])

# Gx □□□□
rate(gx_inbound_errors_total[5m])

# Gx □□□□□□□□□□
sum(rate(gx_outbound_responses_total{result_code_class="2xxx"}
[5m])) /
sum(rate(gx_outbound_responses_total[5m])) * 100

# □ PCRF □□□ Gx □□□□
rate(gx_outbound_responses_total{result_code_class!="2xxx"}[5m])
by (diameter_host)

# Gx □□□□
session_id_registry_count

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

□□□□□□□□□□□□□□

`gx_outbound_responses_total` □��□□□□□□□ PCRF □□□□ Diameter □□□□□□□□□□□□□□□□□

- **`message_type`**□□□□□□□□`gx_RAA`□`gx_CCA`□
- **`result_code_class`**□□□□□□□□`2xxx`□`3xxx`□`4xxx`□`5xxx`□
- **`diameter_host`**□□□□□□ PCRF □□□

□□□□□□□

- **2001**□DIAMETER_SUCCESS□ - □□□□
- **3001**□DIAMETER_COMMAND_UNSUPPORTED□ - □□□□
- **5012**□DIAMETER_UNABLE_TO_COMPLY□ - □□□□□□
- **5030**□DIAMETER_USER_UNKNOWN□ - □□□□□

□□□□□

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

# □ Gx □□□□□□□
- alert: GxResponseFailureRate
  expr: |

sum(rate(gx_outbound_responses_total{result_code_class!="2xxx"}
[5m])) /
    sum(rate(gx_outbound_responses_total[5m])) > 0.1
  for: 5m
  annotations:
    summary: "□ Gx □□□□□"
    description: "□□ 10% □ Gx □□□□□"

# PCRF □□□□□□□
- alert: GxPCRFFailures
  expr:
rate(gx_outbound_responses_total{result_code_class=~"4xxx|5xxx"}
[5m]) by (diameter_host) > 0.05
  for: 3m
  annotations:
    summary: "PCRF {{ $labels.diameter_host }} □□□□□���"
    description: "PCRF □□□□□□□"

# □□□□□□□
- 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

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

□□□□□

- `[debug] □□ CCR-Initial□Session-ID: ...`
- `[debug] □□ CCA-Initial□Result-Code 2001`
- `[error] Diameter □□□...`

Web UI - Diameter □□□□□

OmniPGW □□□□□□ Web UI□□□□□ Diameter □□□□□□□□□

Diameter □□□□□

□□□ `http://<omnipgw-ip>:<web-port>/diameter`

□□□ □□□□ Diameter Gx □□□□ PCRF □□□

□□□

1. □□□□□□□

- □□□□ - □□□□□ PCRF □□□□□
- □□□□□ - □□□□□□□□□□□□
- □ 1 □□□□□□□□□□□□□□□□□

2. □□□□□□□□□ □□□□□□□ PCRF □□□□

- □□ - Diameter □□ (Origin-Host)
- **IP** □□ - PCRF IP
- □□ - Diameter □□□□□ 3868□
- □□ - □□□□□□/□□□□□□□
- □□ - TCP □ SCTP
- □□□□ - □□□□PGW □ PCRF□
- □□ - Diameter □□
- □□□□ - PCRF □□□□□□□□□□□□
- □□ **ID** - □□□ Diameter □□□□□□Gx = 16777238□

3. □□□□□□□□ □□□□□□□□□□□□

- □□□□□□□□
- □□□□□CER/CEA□□□□□
- □□□□□
- □□□□□□□

□□□□□□

□□ 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 □□□□□

- [illegible]“[illegible]”[illegible]
- [illegible] ID [illegible] Gx[illegible]16777238[illegible]
- [illegible] PCRF [illegible]

[illegible]

```
Web UI [illegible]
  [illegible]“[illegible]”
[illegible]
  initiate_connection: true

[illegible]
  - OmniPGW [illegible]
  - [illegible] PCRF [illegible]
  - [illegible]
```

[illegible]

- [illegible] - 1 [illegible]
- [illegible] - [illegible]/[illegible]
- [illegible] **Diameter** [illegible] - [illegible] Diameter CLI [illegible]
- [illegible] - [illegible]
- [illegible] - [illegible] Diameter [illegible]
- [illegible] - [illegible] Diameter [illegible]

[illegible]

[illegible] Web UI [illegible] Prometheus [illegible]

- [illegible] Gx [illegible]
- CCR/CCA [illegible]
- [illegible]

Web UI = “[illegible]” [illegible] = “[illegible]”

□□□□

□□□□□

- **□□□□** - Diameter □□□PCRF □□□□□
- **PFCP □□** - □□ PCC □□□ QER □□ QoS □□
- **□□□□** - □□□□□□□□□□□□
- **QoS □□□□□** - □□□ QoS □□□□□□□

□□□□

- **Diameter Gy □□** - □□ PCC □□□□□□□□□
- **□□ CDR □□** - □□□□□□□□□□□□□
- **PCO □□** - IMS □□□□□ P-CSCF □□

□□

- **□□□□** - Gx □□□□□□□□PCRF □□□□
- **S5/S8 □□** - □□□□□□□□□□

□□□□□□

Diameter □□□□ (Gy/Ro □□)

□□□□□□ (OCS) □□

□□

□□

Gy □□□□ IMS □□□□□□□ **Ro** □□□□ PGW-C □□□ □□□□□□ **(OCS)** □□□□□□□□□□□□□□

- □□□□□ - □□□□□□□□□
- □□□□□□ - □□□□□□□□□□
- □□□□□□□ - □□□□□□□□□□□□□□□□
- □□□□□□ - □□□□□□□□
- □□□□ - □□□□□□□□□□

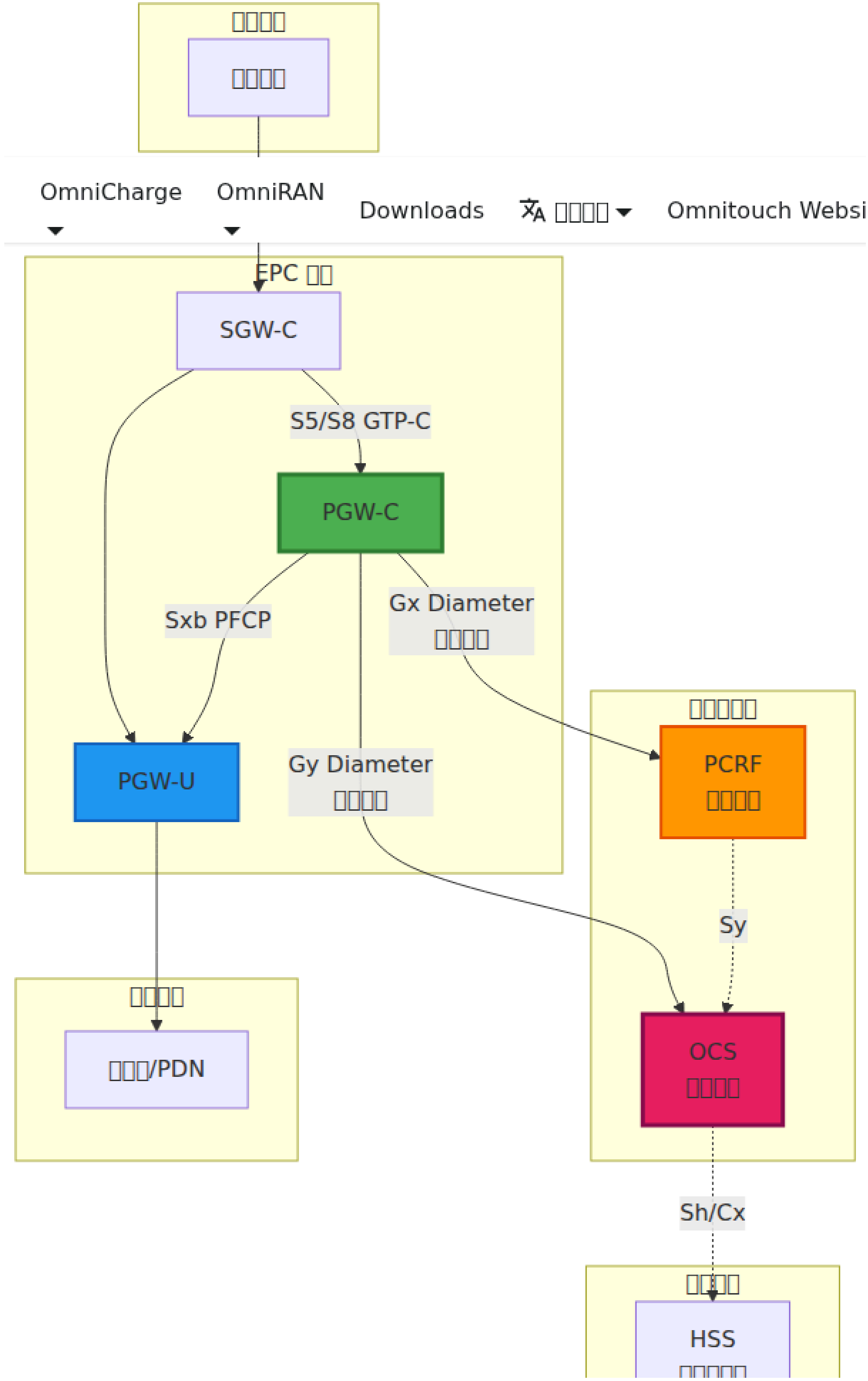
□□□□□□□

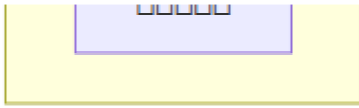
□□	□□□□ (Gy/Ro)	□□□□ (Gz/Rf)
□□	□□□□□□□□	□□□□□
□□	□□□□□	□□□□□
□□□□	□□□□□□□□□	□□□□□□□□
□□	OCS (□□□□□□)	CGF/CDF (□□□□□□)
□□	□□□□□	□□□□□□□□□
□□□	□□□□□□□	□□□□□□□
□□□□	□□□□□□□□□□□	□□□□□□

□□□ □□ CDR □□ □□□□□□□□□□□□□□□

□□□ □□□□ □□□□□□□□□ PDN □□□□□□

□□□□□□ Gy


EPC
SGW-C
S5/S8 GTP-C
PGW-C
Sxb PFCP
Gx Diameter
Gy Diameter
PGW-U
PCRF
Sy
OCS
/PDN
Sh/Cx
HSS

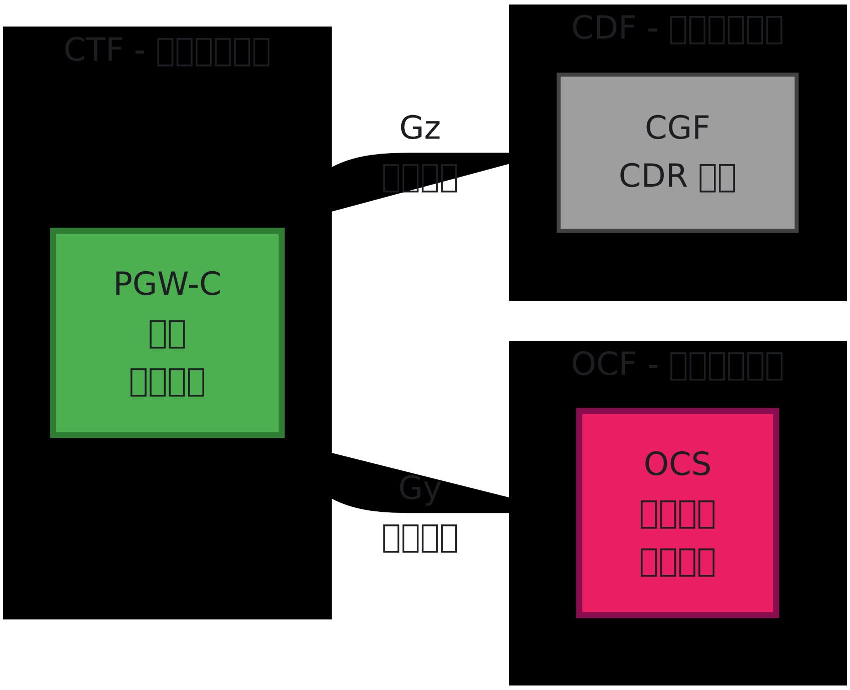


□□□□

□□	□□
□□□□	□□□□□□□□ OCS □□□□
□□□□	□□□□□□□□□□□□□□□□
□□□□□□	□□□□□□
□□□□	□□□□□□□□□□□□
□□□□	□□□□□□□□□□
□□□□	□□□□□□□□□□□□□

3GPP □□□□

□□□□□



□□□□□□ (CTF)

PGW-C □□ **CTF (□□□□□□)**□□□□

1. □□□□□□ - □□□□□□□□□□□□
2. □□□□□ - □□□□□□
3. □□□□□ - □□□□□□
4. □□□□□ - □□□□□
5. □□□□□ - □□□□□□□□

□□□□□□ (OCF)

OCS □□ **OCF (□□□□□)**□

1. □□□□□ - □□□□□
2. □□ - □□□□□□□□ MB□□□□
3. □□□□ - □□□□□□□□□

4. □□□□ - □□□□□□□□
5. □□□□ - □□□□□□□□□

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 □□

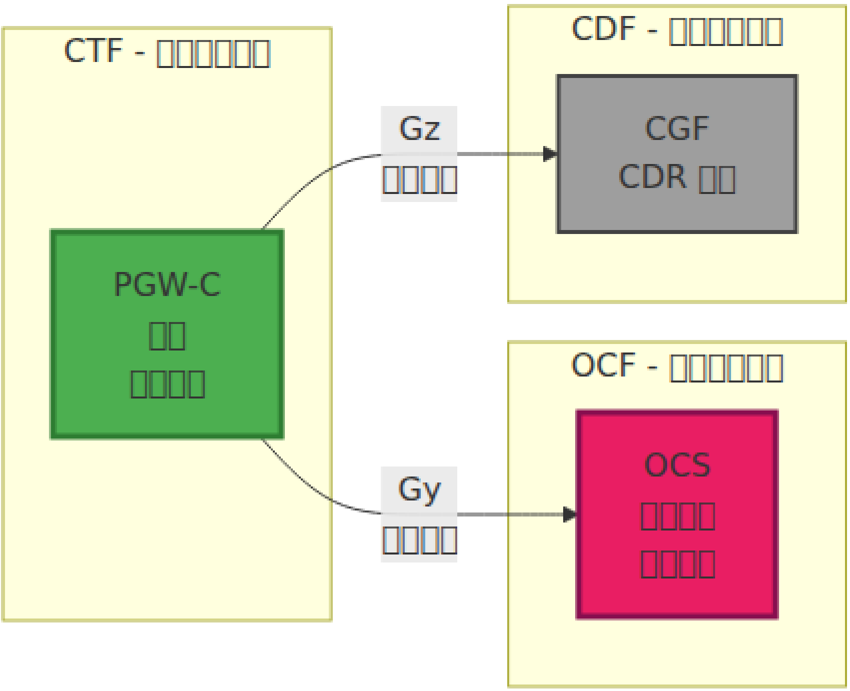
```
Session-ID: <Origin-Host>;<high32>;<low32>[;<optional>]
□□: omni-
pgw_c.epc.mnc999.mcc999.3gppnetwork.org;9876543210;12345;gy
```

□□□

- **Origin-Host:** PGW-C □ Diameter □□
- **high32:** □□□□□□ 32 □
- **low32:** □□□□□□ 32 □
- **optional:** □□□□□□□□“gy”□□□ Gx□

□□□□□□

□□□□



CCR-Initial (□□□□□□ - □□)

□□□ UE □□ PDN □□□□□□□□□□□□

□□□

- □ OCS □□□□□□□□
- □□□□□□□□□
- □□ Gy/Ro □□

PGW-C □□□□□ AVP□

AVP □□	**AVP □□**	□□	□□
Session-Id	263	UTF8String	□□□ Gy □□□□□
Auth-Application-Id	258	Unsigned32	4 (□□□□□)
Origin-Host	264	DiamIdent	PGW-C □ Diameter □□
Origin-Realm	296	DiamIdent	PGW-C □ Diameter □□
Destination-Realm	283	DiamIdent	OCS □□□
CC-Request-Type	416	Enumerated	1 = INITIAL_REQUEST
CC-Request-Number	415	Unsigned32	□□□□□ 0 □□□
Subscription-Id	443	Grouped	UE □□□ (IMSI/MSISDN)
Service-Context-Id	461	UTF8String	□□□□□□□□
Multiple-Services-Credit-Control	456	Grouped	□□□□□□□□□
Requested-Service-Unit	437	Grouped	□□□□□□□□□□□□□
Used-Service-Unit	446	Grouped	□□□□□□□□□ 0□
Service-Identifier	439	Unsigned32	□□□□□□□
Rating-Group	432	Unsigned32	□□□□□□□

□□ 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 (□□)
│   ├── Subscription-Id-Type: END_USER_IMSI (1)
│   └── Subscription-Id-Data: "310260123456789"
├── Subscription-Id (□□)
│   ├── Subscription-Id-Type: END_USER_E164 (0)
│   └── Subscription-Id-Data: "15551234567"
├── Service-Context-Id: "32251@3gpp.org"
├── Multiple-Services-Credit-Control (□□)
│   ├── Service-Identifier: 1
│   ├── Rating-Group: 100
│   └── Requested-Service-Unit (□□)
│       └── CC-Total-Octets: 10000000 (□□ 10 MB)
└── Used-Service-Unit (□□)
    └── CC-Total-Octets: 0 (□□□□)
```

CCA-Initial (□□□□□□ - □□)

□□□□ OCS □ CCR-I □□□

□□□

- □□□□□□□□□
- □□□□□□□□□
- □□□□□□□□□

PGW-C □□□□□ AVP□

AVP □□	AVP □□	□□
Result-Code	268	□□ (2001) □□□□□
Multiple-Services-Credit-Control	456	□□□□□□□□□
Granted-Service-Unit	431	□□□□□□□□□□□□□
Validity-Time	448	□□□□□□□□
Result-Code	268	□□□□□□□
Final-Unit-Indication	430	□□□□□□□□
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 (□□)
    ├── Result-Code: DIAMETER_SUCCESS (2001)
    ├── Service-Identifier: 1
    ├── Rating-Group: 100
    ├── Granted-Service-Unit (□□)
    │   └── 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 (□□)
    ├── Service-Identifier: 1
    ├── Rating-Group: 100
    ├── Used-Service-Unit (□□)
    │   └── CC-Total-Octets: 8000000 (□□□□□□□□ 8 MB)
    └── Requested-Service-Unit (□□)
        └── CC-Total-Octets: 10000000 (□□□□ 10 MB)
```

CCA-Update (□□□□□□ - □□)

□□□□ OCS □ CCR-U □□□

□□□

- □□□□□□□□□□□□□□□
- □□□□□□
- □□□□□□

□□□□□□

1. □□□□□□□

```
CCA (□□)
└── Multiple-Services-Credit-Control
    ├── Result-Code: DIAMETER_SUCCESS (2001)
    ├── Granted-Service-Unit
    │   └── CC-Total-Octets: 10000000 (□□□ 10 MB)
    └── Validity-Time: 3600
```

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: TERMINATE (0)
```

3. □□□□□□

```
CCA (□□)
├── Result-Code: DIAMETER_CREDIT_LIMIT_REACHED (4012)
└── Multiple-Services-Credit-Control
    ├── Result-Code: DIAMETER_CREDIT_LIMIT_REACHED (4012)
    └── Final-Unit-Indication
        └── Final-Unit-Action: TERMINATE (0)
```

CCR-Termination (□□□□□□ - □□)

□□□

- UE □□
- PDN □□□□□
- □□□□□□□□□

□□□

- □□□□□□
- □□ Gy/Ro □□
- □□□□

□□□□□

- `CC-Request-Type: TERMINATION_REQUEST (3)`
- `Used-Service-Unit` □□□□□□□□
- □ `Requested-Service-Unit`□□□□□□□□
- □□ `Termination-Cause`

□□ CCR-T □□□

```
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: TERMINATION_REQUEST (3)
├── CC-Request-Number: 5
├── Termination-Cause: DIAMETER_LOGOUT (1)
└── Multiple-Services-Credit-Control (□□)
    ├── Service-Identifier: 1
    ├── Rating-Group: 100
    └── Used-Service-Unit (□□)
        └── CC-Total-Octets: 18500000 (□□□ 18.5 MB)
```

CCA-Termination (□□□□□□ - □□)

□□□□ OCS □ CCR-T □□□

□□□

- □□□□□□
- □□□□
- □□□□□□□

□□ CCA-T□

```
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: TERMINATION_REQUEST (3)
└── CC-Request-Number: 5
```

□□□□□□

□□□□□□

OCS □□□□□□□□□□□□□

□□□□	**AVP**	□□	□□
□□	CC-Time	□	□□□□□□□□□□
□□	CC-Total-Octets	□□□□□□+□□□	□□□□
□□□□□□	CC-Input-Octets, CC-Output-Octets	□□□□□□	□□□□□
□□□□	CC-Service-Specific-Units	□□□□□	□□□□□□API □□
□□	-	□□□□	□□□□□□□

□□□□□□

□□□ PGW-C □□□□□□□□□□□□□

□□□□□ OCS □□ **Volume-Quota-Threshold** □ **Time-Quota-Threshold**□PGW-C □□ PGW-U □ PFCP □□□□□□□□□□□□ PFCP □□□□

□□□□□

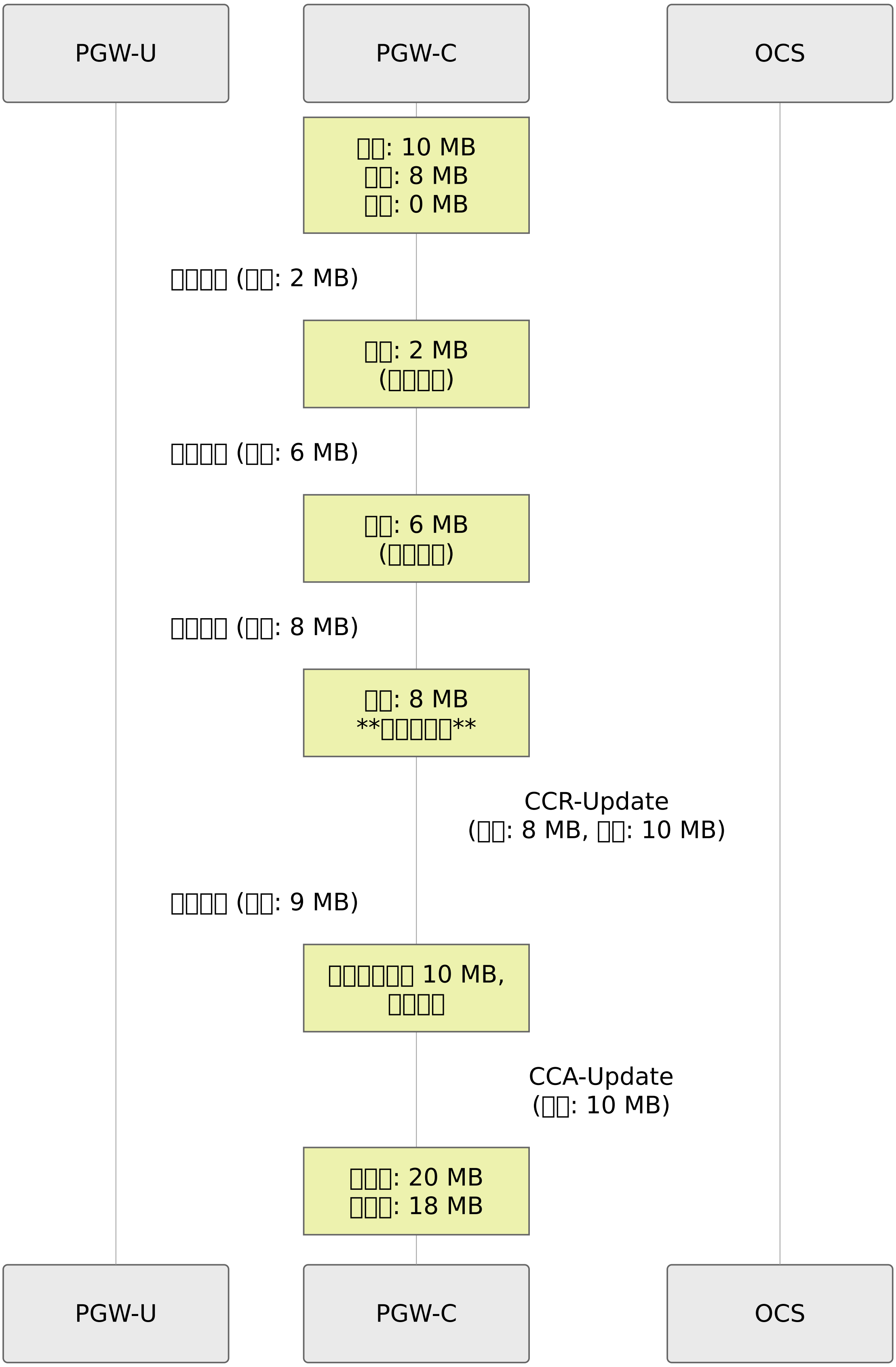
```
1. OCS [illegible] 10 MB [illegible] 80%[illegible]8 MB[illegible]
2. PGW-C [illegible] PGW-U [illegible]PFCP [illegible]
3. [illegible] 8 MB[illegible]
   → PGW-C [illegible] CCR-Update
   → [illegible]
4. OCS [illegible]
5. [illegible] CCR-Update [illegible]
   → PGW-C [illegible]
```

[illegible]

```
Granted-Service-Unit: 10000000 [illegible] (10 MB)
Volume-Quota-Threshold: 8000000 [illegible] (8 MB)

[illegible] 8 MB [illegible] → [illegible] CCR-Update
[illegible]2 MB[illegible] OCS [illegible]
```

PGW-C [illegible]

PGW-C [illegible] PGW-U [illegible] **PFCP** [illegible] [illegible]


PGW-U
PGW-C
OCS
CCR-Update
CCA-Update
PGW-U
PGW-C
OCS

[illegible]

[illegible]

OCS □ CCA □□□ **Final-Unit-Indication** AVP □□□□□

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:** □□ PFCP □□□□□□ HTTP □□□ URL
3. **RESTRICT_ACCESS:** □□ PFCP □□□□□□□□□ IP

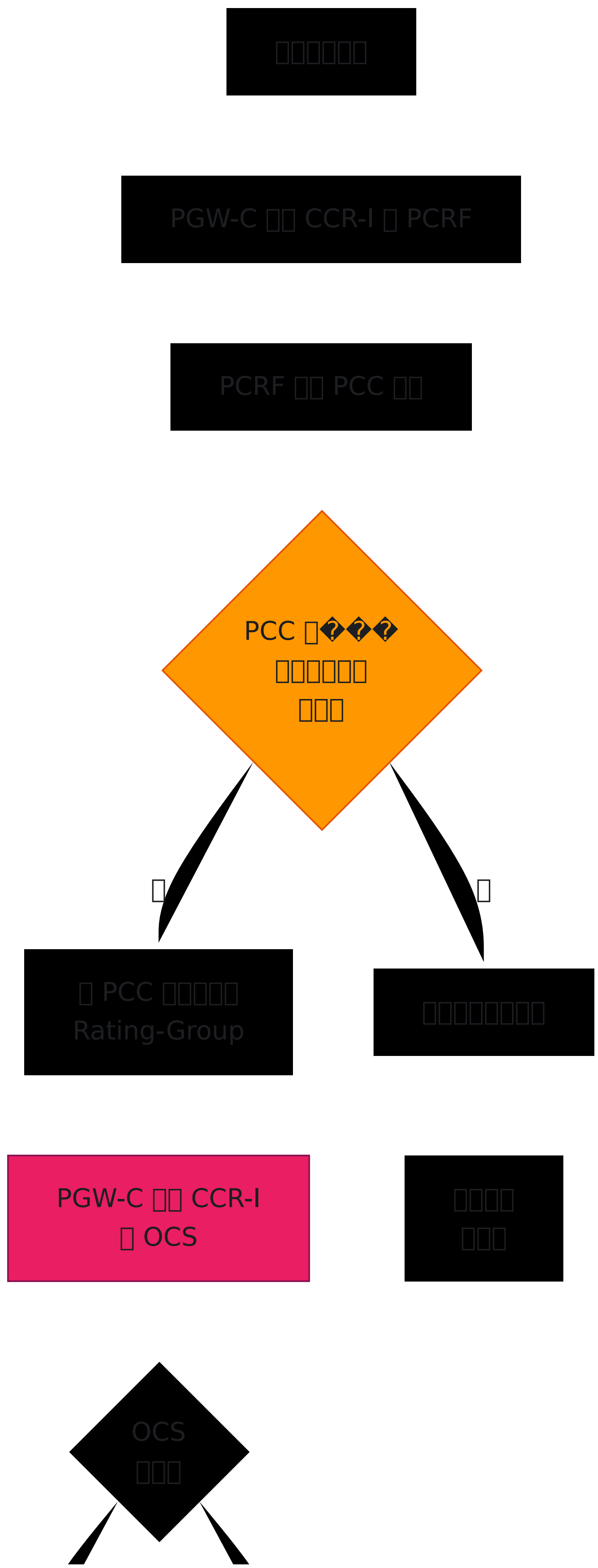
□□□□□□

□□□□□□□□□□

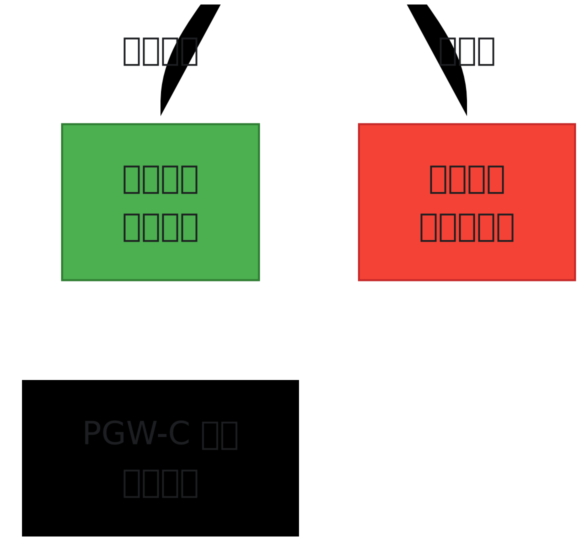
3GPP □□□ TS 23.203, TS 29.212, TS 32.251

□□□□□ PCRF □□ Gx □□□□□ **PCC** □□ □□□□□□ Diameter Gx □□ □□□□□□ PCC □□□□□

□□□□□□□



PCC
PGW-C CCR-I
OCS



□□□□□□ PCC □□

PCRF □□ (Gx □□ CCA-I)□

```
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=□□, 1=□□	□□□□□□ (Gy)
Offline	1008	0=□□, 1=□□	□□□□□□ (Gz)
Metering-Method	1007	0=□□□□, 1=□□, 2=□□	□□□□
Reporting-Level	1011	0=□□, 1=□□□	□□□□□□□

□□□□□□□□

□□	□□	Rating-Group	□□
1	0	□□	□□□□□□□□□□
0	1	□□	□□□□□□□□□□
1	1	□□	□□□□□□□□□
0	0	-	□□□□□□□□□

□□□□□

□□ PDN □□□□□ □□□□□□□□□□□□

□□□□□

```
□□□□□□□□□
├── Rating-Group: 100 (□□□□)
└── Online: 1

□□□□ 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 □□□

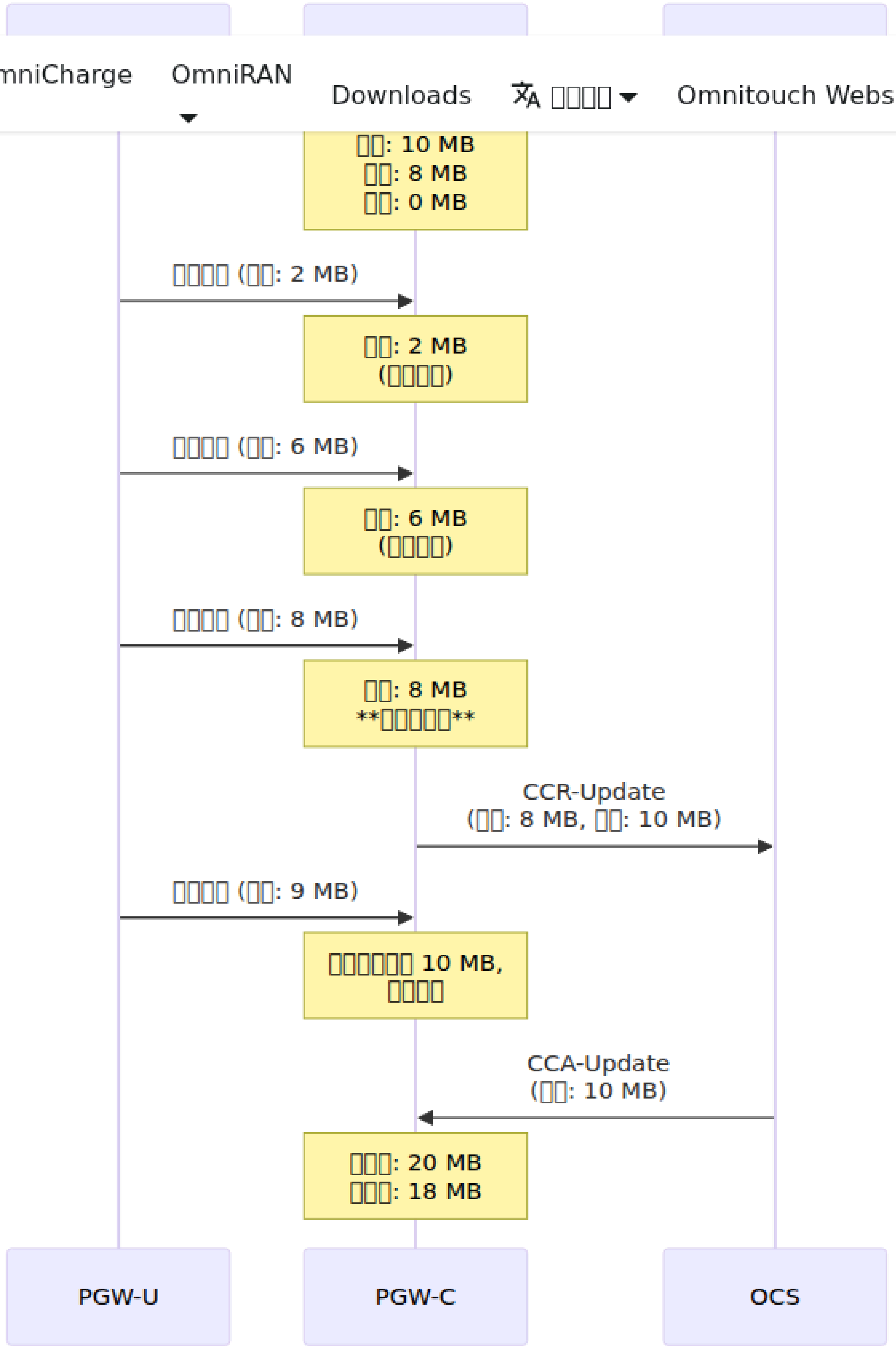
```
CCA-Initial
└── Multiple-Services-Credit-Control
    ├── [Rating-Group: 100] → □□: 10 MB
    ├── [Rating-Group: 200] → □□: 5 MB (□□□□)
    └── [Rating-Group: 300] → □□: 60 □
```

□□□□□□□

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}  # □□
}
```

□□□□□□□□□□


□□: 10 MB
□□: 8 MB
□□: 0 MB
□□□□ (□□: 2 MB)
□□: 2 MB
(□□□□)
□□□□ (□□: 6 MB)
□□: 6 MB
(□□□□)
□□□□ (□□: 8 MB)
□□: 8 MB
□□□□□
CCR-Update
(□□: 8 MB, □□: 10 MB)
□□□□ (□□: 9 MB)
□□□□□ 10 MB,
□□□□
CCA-Update
(□□: 10 MB)
□□□: 20 MB
□□□: 18 MB
PGW-U
PGW-C
OCS

□□□□□□□

MSCC (□□□□□□□) AVP

□□□ □□□□□/□□□□□□□□□

□□□

```
Multiple-Services-Credit-Control (□□, AVP 456)
├── 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)
├── Used-Service-Unit (□□, AVP 446)
│   └── [□ Requested-Service-Unit □□□□]
├── Granted-Service-Unit (□□, AVP 431)
│   └── [□ Requested-Service-Unit □□□□]
├── Validity-Time (Unsigned32, AVP 448)
├── Result-Code (Unsigned32, AVP 268)
└── Final-Unit-Indication (□□, AVP 430)
    └── Final-Unit-Action (Enumerated, AVP 449)
```

□□□□□□□□□

□□	□□□□□	□□□
□□	□□□□□□	□□□□□□
□□	1=□□, 2=□□, 3=□□	100=□□, 200=□□
□□	□□□□	□□□□
□□	□□	□□□□□□
□□	□□□��□□□ RG	OCS □□□□□□

□□□

```
Service-Identifier: 1 (□□□□)
├── Rating-Group: 100 (□□□□ - $0.01/MB)
└── Rating-Group: 200 (□□□□ - $0.05/MB)

Service-Identifier: 2 (□□)
└── Rating-Group: 300 (□□□□ - $0.10/□□)
```

□□

□□ Gy □□

□□ `config/runtime.exs`□

```
config :pgw_c,
  online_charging: %{
    # □□□□□□□□□□□
    enabled: true,

    # OCS □□□□□□□□
    timeout_ms: 5000,

    # □□□□□□□□□□□□□ PCRF □□□
    default_requested_quota: 10_000_000,  # 10 MB

    # □□□□□□□□□□
    # (0.8 = □□□ 80% □□□□□ CCR-Update)
    quota_threshold_percentage: 0.8,

    # OCS □□□□□□□□
    # □□□:block, :allow
    timeout_action: :block,

    # OCS □□□□□□□□□
    # □□□:terminate, :redirect
    no_credit_action: :terminate,

    # □□□□□□ URL□□ no_credit_action: :redirect □□□□
    topup_redirect_url: "http://topup.example.com"
  },
  diameter: %{
    listen_ip: "0.0.0.0",
    host: "omni-pgw_c.epc.mnc999.mcc999.3gppnetwork.org",
    realm: "epc.mnc999.mcc999.3gppnetwork.org",

    # OCS □□□□
    peer_list: [
      # PCRF □□□□□□ (Gx)
      %{
        host: "pcrf.epc.mnc999.mcc999.3gppnetwork.org",
        realm: "epc.mnc999.mcc999.3gppnetwork.org",
        ip: "10.0.0.30",
        initiate_connection: true
      },
      # OCS □□□□□□ (Gy)
      %{
        host: "ocs.epc.mnc999.mcc999.3gppnetwork.org",
```

```
        realm: "epc.mnc999.mcc999.3gppnetwork.org",
        ip: "10.0.0.40",
        initiate_connection: true
      }
    ]
  }
```

□□□□□□

`enabled`

- `true`: □□□□□□□CCR □□□□□ OCS
- `false`: □□□□□□□□□□□ Gy □□

`timeout_ms`

- □□ OCS □ CCA □□□□□
- □□□3000-5000 □□

`default_requested_quota`

- □□ PCRF □□□□□□□□□□□□□
- □□□□1-100 MB

`quota_threshold_percentage`

- □□□□ % □□□□□□□ CCR-Update
- □□□0.75-0.85 (75%-85%)
- □□ = □□□□□□□□□□□□□□□
- □□ = □□□□□□□□□□

`timeout_action`

- **`:block`** - □□ OCS □□□□□□□□□□□□□□□□□□□□□
- **`:allow`** - □□ OCS □□□□□□□□□□□□□□□□□□□□□□□

`no_credit_action`

- **`:terminate`** - □□□□□□□□□□□

- `:redirect` - □□□□□□□□□

□□□□□

□□□□□□□□□□□□□

```
config :pgw_c,
  online_charging: %{
    enabled: true,
    timeout_action: :block,
    no_credit_action: :terminate,
    quota_threshold_percentage: 0.8
  }
```

□□/□□□

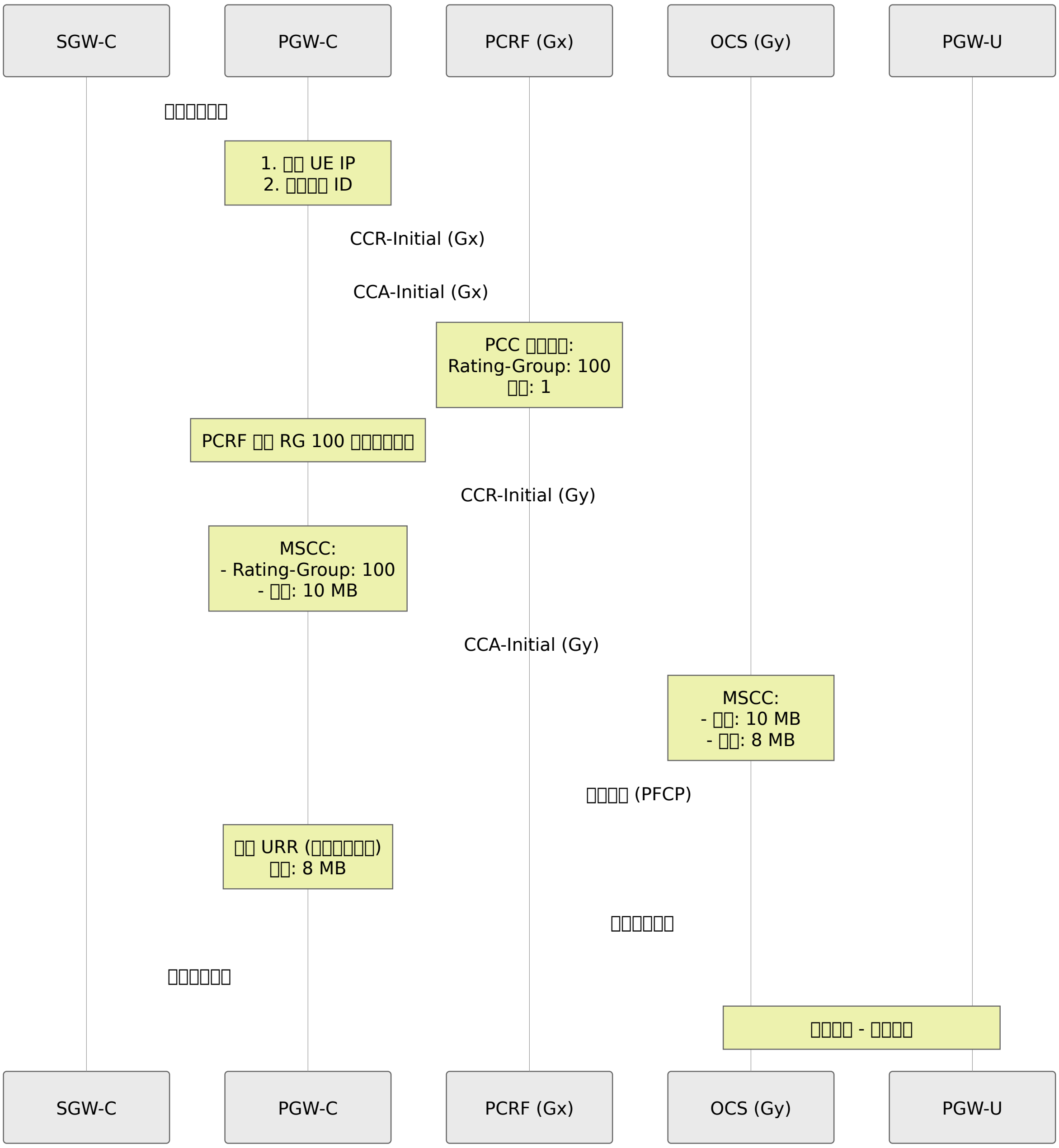
```
config :pgw_c,
  online_charging: %{
    enabled: false  # □□□□□
  }
```

□□□□□□□□□□□□□□□□

```
config :pgw_c,
  online_charging: %{
    enabled: true,  # □ PCRF □□□□□□
    timeout_action: :allow,  # OCS □□□□□□□□□
    no_credit_action: :terminate
  }
```

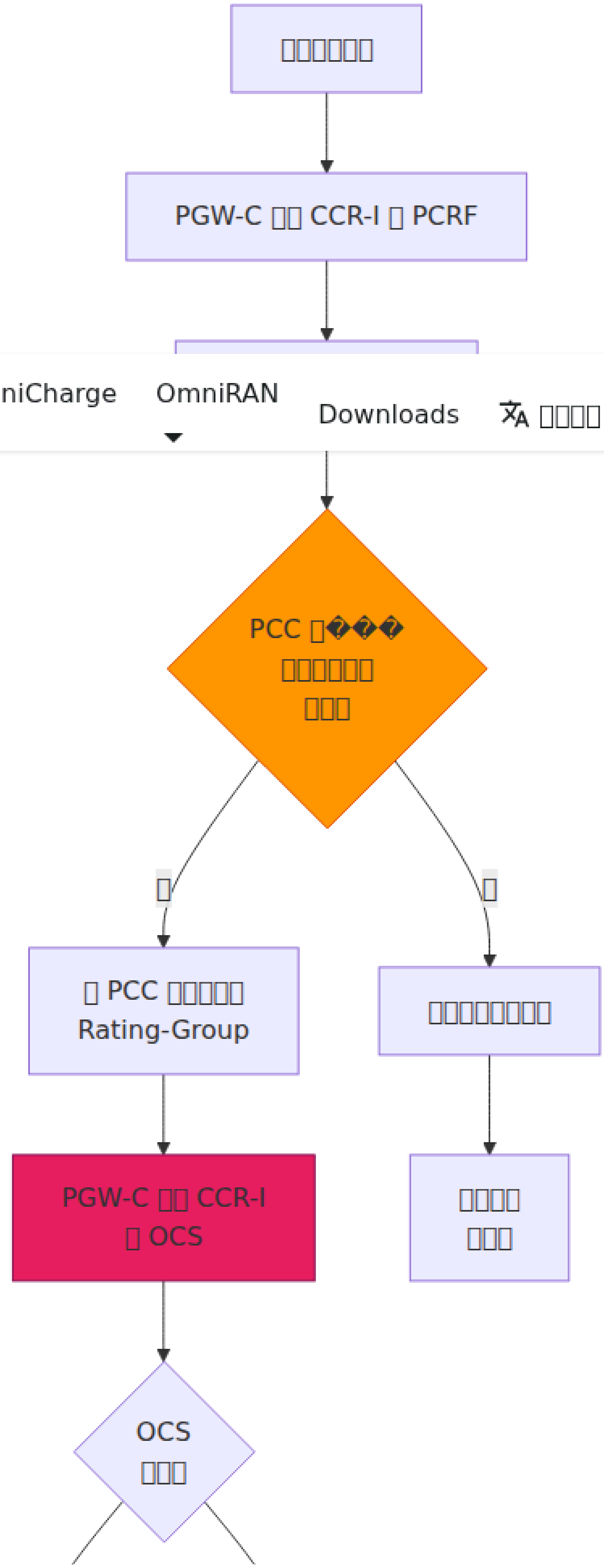
□□□□

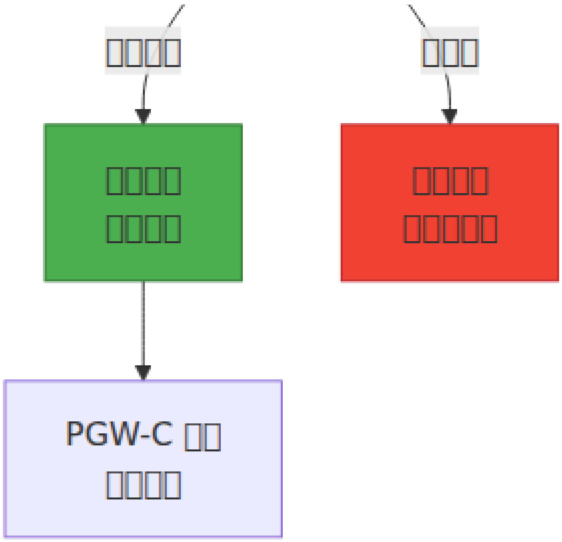
□□□□□□□□□

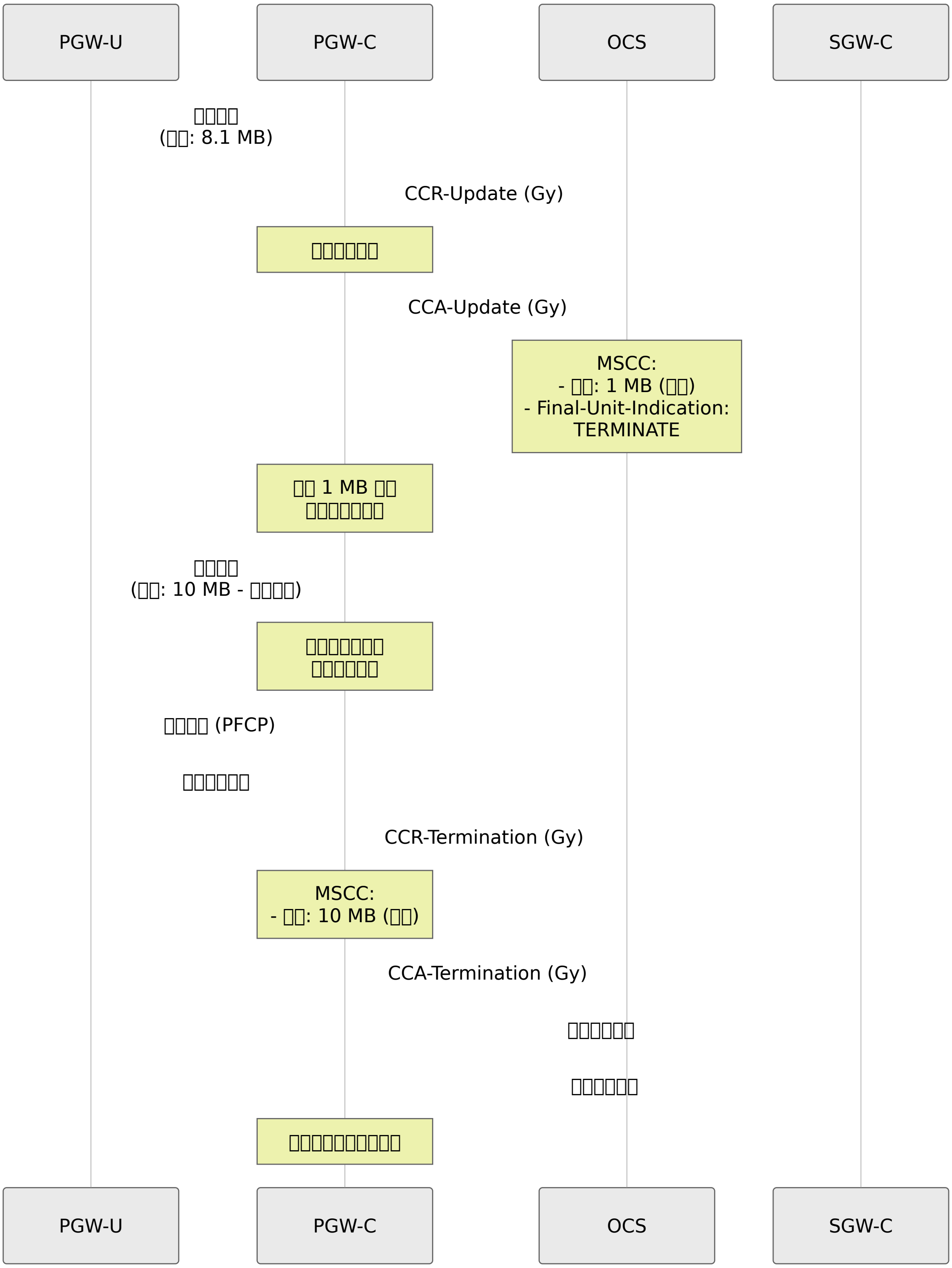


SGW-C
PGW-C
PCRF (Gx)
OCS (Gy)
PGW-U
□□□□□□
1. □□ UE IP
2. □□□□ ID
CCR-Initial (Gx)
CCA-Initial (Gx)
PCC □□□□:
Rating-Group: 100
□□: 1
PCRF □□ RG 100 □□□□□□
CCR-Initial (Gy)
MSCC:
- Rating-Group: 100
- □□: 10 MB
CCA-Initial (Gy)
MSCC:
- □□: 10 MB
- □□: 8 MB
□□□□ (PFCP)
□□ URR (□□□□□□)
□□: 8 MB
□□□□□□
□□□□□□
□□□□ - □□□□
SGW-C
PGW-C
PCRF (Gx)
OCS (Gy)
PGW-U

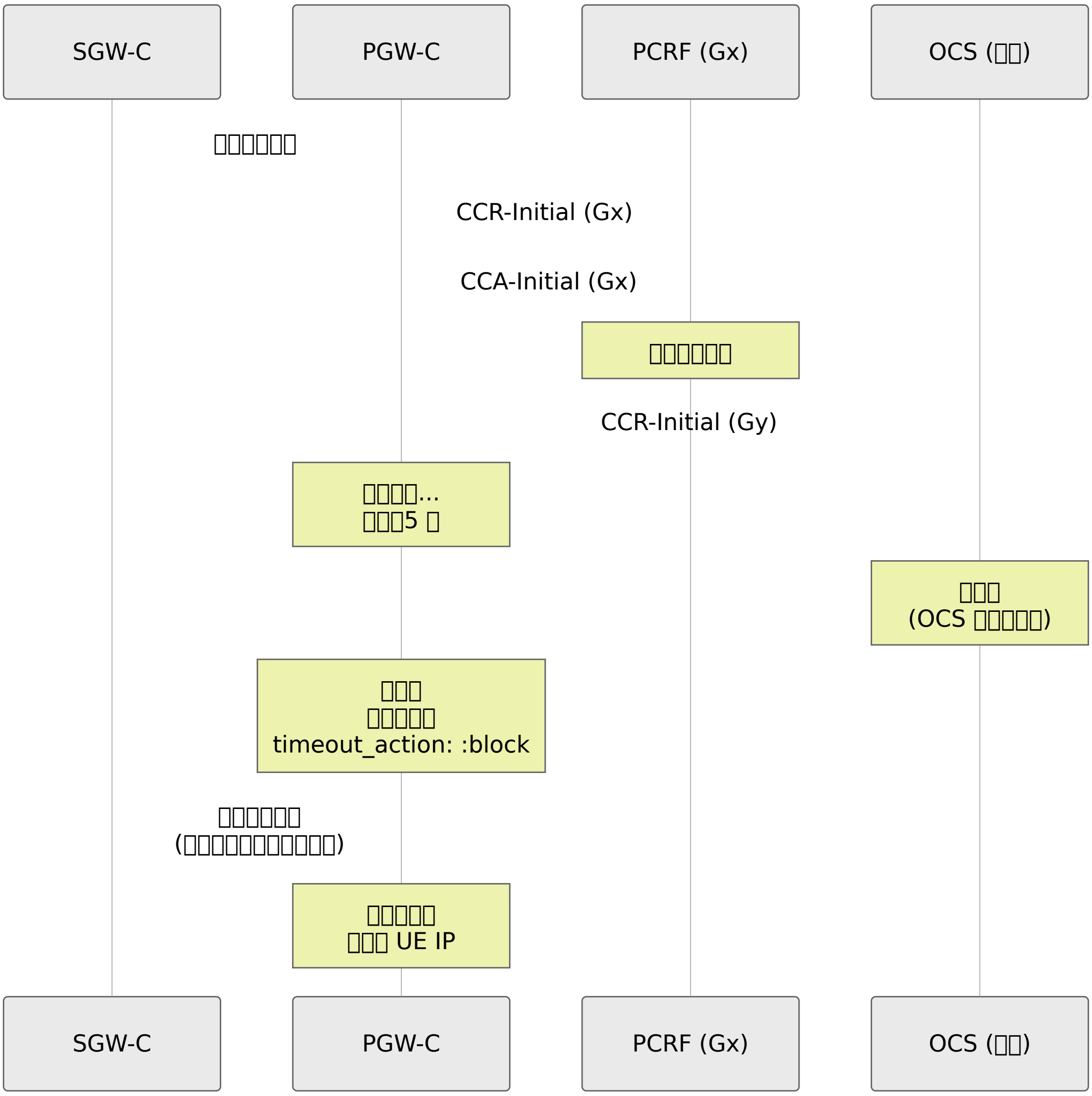
□□□□□□ (CCR-Update)


PGW-C CCR-I PCRF
PCC
PCC
Rating-Group
PGW-C CCR-I
OCS
OCS


PGW-C


PGW-U
PGW-C
OCS
SGW-C
MB)
CCR-Update (Gy)
CCA-Update (Gy)
MSCC:
- Final-Unit-Indication:
TERMINATE
1 MB
(PFCP)
CCR-Termination (Gy)
MSCC:
CCA-Termination (Gy)
PGW-U
PGW-C
OCS
SGW-C

OCS □□□□


SGW-C
PGW-C
PCRF (Gx)
OCS (□□)
□□□□□□
CCR-Initial (Gx)
CCA-Initial (Gx)
□□□□□□
CCR-Initial (Gy)
□□□□...
□□□5 □
□□□
(OCS □□□□□)
□□□
□□□□□
timeout_action: :block
□□□□□□
(□□□□□□□□□□□□)
□□□□□
□□□ UE IP
SGW-C
PGW-C
PCRF (Gx)
OCS (□□)

□□□□

□□□□

□□□□□

□□	□□	□□
2001	DIAMETER_SUCCESS	□□□□□□□

□□□□ (4xxx)□

□□	□□	**PGW-C □□**
4010	DIAMETER_TOO_BUSY	□□□□□
4011	DIAMETER_UNABLE_TO_COMPLY	□□□□□□□□□
4012	DIAMETER_CREDIT_LIMIT_REACHED	□□□□□□

□□□□ (5xxx)□

□□	□□	**PGW-C □□**
5003	DIAMETER_AUTHORIZATION_REJECTED	□□□□
5031	DIAMETER_USER_UNKNOWN	□□□□□□□□□□□

□□□□□□□

□□□ Result-Code □□□□□ □□□□□

1. □□□□ - □□□□
2. **MSCC □□** - □□□□□

□□□

```
CCA-Initial
├── Result-Code: DIAMETER_SUCCESS (2001)  ← □□□□□OK
└── Multiple-Services-Credit-Control
    ├── [Rating-Group: 100]
    │   └── Result-Code: DIAMETER_SUCCESS (2001)  ← RG 100: OK
    └── [Rating-Group: 200]
        └── Result-Code: DIAMETER_CREDIT_LIMIT_REACHED (4012)  ←
RG 200: □□□
```

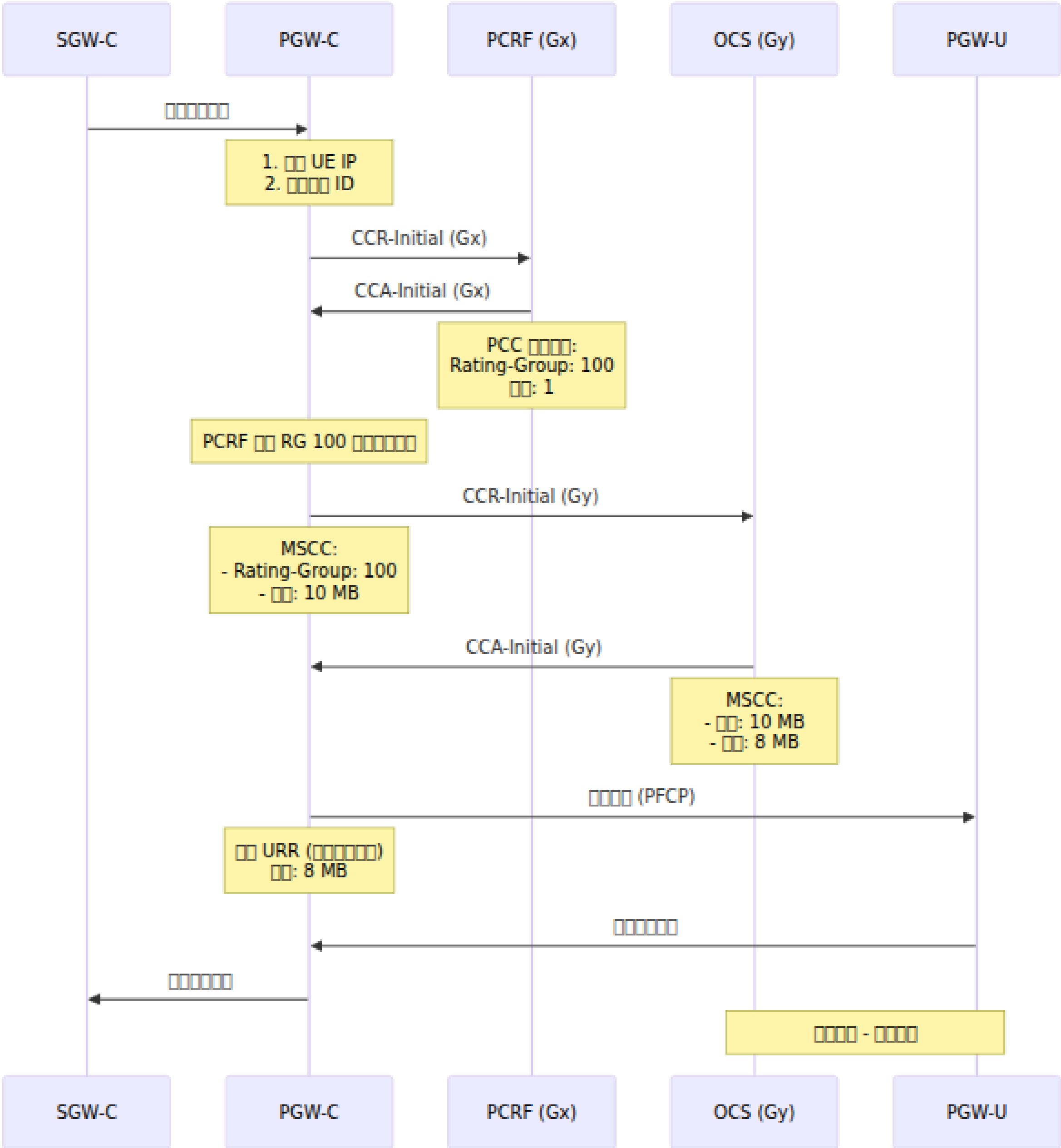
PGW-C □□□

- □□ Rating-Group 100 □□��
- □□ Rating-Group 200 □□□

□ Gx □□□

Gx □□□PCRF □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ Gy □□□ Rating-Group□□□□ Diameter Gx □□ □□□□□□□□□□□□□□□□□□

Gx □ Gy □□□


SGW-C
PGW-C
PCRF (Gx)
OCS (Gy)
PGW-U
□□□□□□
1. □□ UE IP
2. □□□□ ID
CCR-Initial (Gx)
CCA-Initial (Gx)
PCC □□□□:
Rating-Group: 100
□□: 1
PCRF □□ RG 100 □□□□□□
CCR-Initial (Gy)
MSCC:
- Rating-Group: 100
- □□: 10 MB
CCA-Initial (Gy)
MSCC:
- □□: 10 MB
- □□: 8 MB
□□□□ (PFCP)
□□ URR (□□□□□□□)
□□: 8 MB
□□□□□□
□□□□□□
□□□□ - □□□□

□□□□

1. □□□□□

```
PGW-C □□□□□□□□□
     ↓
□□ CCR-I □ PCRF (Gx)
     ↓
□□ CCA-I □ PCC □□
     ↓
□□ PCC □□□
     - □□□□□ Rating-Group□
     - □□ = 1 □□
     ↓
□□□□
     □□ CCR-I □ OCS (Gy) □ Rating-Group
     ↓
     □□ CCA-I □□□
     ↓
     □□□□□□□□□
     □□□□□□□□□□
□□□□
     □□□□□□□□□□
```

2. □□□□□□□PCRF □ RAR□□

```
PCRF □ Gx □□□ RAR□□□□□□□□
     ↓
□□ PCC □□□□□□□=1□Rating-Group=200
     ↓
PGW-C □□ CCR-U □ OCS (Gy)
     - □ Rating-Group 200 □□ MSCC
     ↓
OCS □□□□□□□□
     ↓
□□□□□□□□□□□□
```

□□□□

□□□□

1. CCR-Initial □ OCS □□

□□□

- □□□□□□□“OCS □□”
- □□□“CCR-Initial (Gy) □□”

□□□□□

- OCS □□□
- □□□□ OCS IP □□□
- □□□□□ Diameter □□□3868□
- OCS □□

□□□□□

```
# □□□□□□
ping <ocs_ip>

# □□ 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])

# □□□□□□
rate(gy_quota_exhausted_total[5m])

# OCS □□□
rate(gy_timeout_total[5m])

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

□□

```yaml
# □ 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 □□"

# □□□□□□□□
- 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`

□□□ □□□□□□□□□□□□□□□□□

□□□

1. □□□□

- **IMSI** - □□□□□□□□“310170123456789”□
- **MSISDN** - □□□□□□□□“14155551234”□
- □□□□ - □□□□□□□□□□□□□□
- □□ **ID** - □□□□□□□
- □□□ - □□□□

2. CCR-I □□

- □□ CCR-Initial□□□□□□□□□□
- □□□□□□□□□□□□□□□
- □□ OCS □□□□□□□□□

3. □□

- □□□□ - □□□□□□□ Gy □□
- **OCS □□** - □□ OCS □□□��□
- □□□□ - □□□□□□□□□

- □□□□ - □□□□□□
- □□ - □□□□□□□□□□□□

□□□□□

```
1. □□□□□□□□□IMSI□MSISDN□
2. □□□□□□□□□□1000000 □□ 1 MB□
3. □□□□ ID □□□□
4. □□“□□ CCR-I”
5. □□ OCS □□□□□□□□
```

□□□

- □□□□□□□□ OCS
- □□□□□□□□
- □□□□□□□
- □□□□□□□□

□□□□

□□□□□

- **Diameter Gx □□** - PCRF □□□□□□□□□□□□ PCC □□
- **□□ CDR □□** - □□□□□□□□□□□□□
- **□□□□** - □□□□□□□□□□□

□□□□

- **□□□□** - PDN □□□□□□□□□□□
- **PFCP □□** - □□ URR □ PGW-U □□□□□□
- **S5/S8 □□** - GTP-C □□□□□□□

□□

- **□□□□** - Gy □□□□□□□□OCS □□□□
- **UE IP □□** - □□□□□ IP □□□

□□□□□□

OmniPGW □□□□□□□

Prometheus □□□□□□□

□ Omnitouch □□□□□□

□□

□□

OmniPGW □□□□□□□□□□□□

1. □□ Web UI□□□□□□□□□□□□□□□□□□□□□□□

- □□□□□□□
- PFCP □□□□
- Diameter □□□□
- □□□□□□

2. Prometheus □□□□□□□□□□□□

- □□□□□□□
- □□□□□

- □□□□
- □□□□

□□□□□□□ **Prometheus** □□□□□ Web UI □□□□□□□□□□

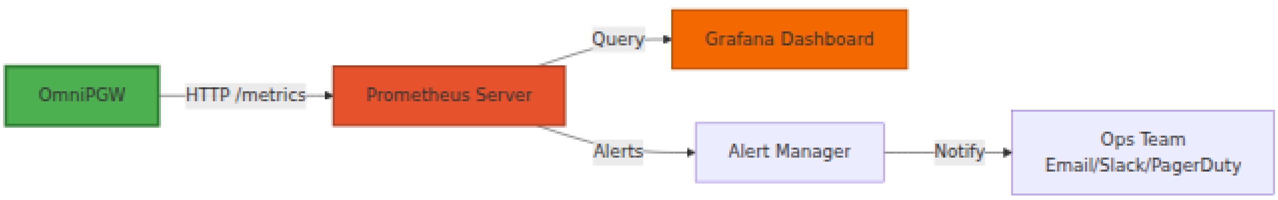
- □□□□ - Web UI
- PFCP □□ - Web UI
- Diameter Gx - Web UI

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	□□ PFCP □□□SEID □□□
`session_id_registry_count`	Gauge	□□ Gx □□□Diameter Session-ID □□□
`session_registry_count`	Gauge	□□□□□IMSI, EBI □□
`address_registry_count`	Gauge	□□□ UE IP □□
`charging_id_registry_count`	Gauge	□□□□ ID□□□□ □□ CDR □□ □□□ CDR □□□□□
`sxb_sequence_number_registry_count`	Gauge	□□□ PFCP □□□□□□□□
`s5s8_sequence_number_registry_count`	Gauge	□□□ S5/S8 □□□□□□□□
`sxb_peer_registry_count`	Gauge	□□□ PFCP □□□□□□

□□□

```
# □□□□□□
teid_registry_count

# □□□□□□□□□□
rate(teid_registry_count[5m])

# □□□□□□□□□□
max_over_time(teid_registry_count[1h])
```

□□□□□

S5/S8 (GTP-C) □□□

□□□□	□□	□□	□□
`s5s8_inbound_messages_total`	Counter	`message_type`	□□□ S5/S8 □□
`s5s8_outbound_messages_total`	Counter	`message_type`	□□□ S5/S8 □□
`s5s8_inbound_errors_total`	Counter	`message_type`	S5/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`	Counter	`message_type`	□□□ PFCP □□
`sxb_outbound_messages_total`	Counter	`message_type`	□□□ PFCP □□
`sxb_inbound_errors_total`	Counter	`message_type`	PFCP □□□□□□
`sxb_outbound_errors_total`	Counter	`message_type`	PFCP □□□□□□

□□□□□

- `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`	Counter	`message_type`	□□□ Diameter □□
`gx_outbound_messages_total`	Counter	`message_type`	□□□ Diameter □□
`gx_inbound_errors_total`	Counter	`message_type`	Diameter □□□□□□
`gx_outbound_errors_total`	Counter	`message_type`	Diameter □□□□□□
`gx_outbound_responses_total`	Counter	`message_type`, `result_code_class`, `diameter_host`	□□□□□□□□□□□□□□□ Diameter □□

□□□□□

- `gx_CCA` (Credit-Control-Answer)
- `gx_CCR` (Credit-Control-Request)
- `gx_RAA` (Re-Auth-Answer)
- `gx_RAR` (Re-Auth-Request)

□□□□□□□□□ `gx_outbound_responses_total`□□

- `2xxx` - □□□□□□□□2001 DIAMETER_SUCCESS□
- `3xxx` - □□□□□□□□3001 DIAMETER_COMMAND_UNSUPPORTED□
- `4xxx` - □□□□□□□□4001 DIAMETER_AUTHENTICATION_REJECTED□
- `5xxx` - □□□□□□□□5012 DIAMETER_UNABLE_TO_COMPLY□

□□□□□

```
# □□ Gx □□□□□
sum(rate(gx_outbound_responses_total{result_code_class="2xxx"}[5m]))
sum(rate(gx_outbound_responses_total[5m])) * 100

# □ PCRF □□□□□□
rate(gx_outbound_responses_total{result_code_class!="2xxx"}[5m]) by (

# □□□□□ Re-Auth-Answer □□□□
gx_outbound_responses_total{message_type="gx_RAA",result_code_class='

# □□□□ PCRF □□□□□□□□□
rate(gx_outbound_responses_total{result_code_class=~"4xxx|5xxx",diame
[5m]) > 0.1
```

□□□□□

□□□□	□□	□□	□□
`rescues_total`	Counter	`module`, `function`	□□□□□□□□□□□□

□□□□

□□□□□□□□□□□

[illegible]	[illegible]	[illegible]	
`s5s8_inbound_handling_duration`	Histogram	`request_message_type`	[illegible]
`sxb_inbound_handling_duration`	Histogram	`request_message_type`	[illegible]
`gx_inbound_handling_duration`	Histogram	`request_message_type`	[illegible]

[illegible]

[illegible]	[illegible]	[illegible]
`s5s8_outbound_transaction_duration`	Histogram	`request_message_type`
`sxb_outbound_transaction_duration`	Histogram	`request_message_type`
`gx_outbound_transaction_duration`	Histogram	`request_message_type`

[illegible]

- □□0.0001, 0.0005, 0.001, 0.005, 0.01, 0.05, 0.1, 0.5, 1.0, 5.0
- □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])
```

UPF □□□□

UPF □□□□□

□□□□	□□	□□	□□
`upf_peers_total`	Gauge	-	□□□ UPF □□□□
`upf_peers_healthy`	Gauge	-	□□□ UPF □□□□□□□ + □□□□□
`upf_peers_unhealthy`	Gauge	-	□□□□ UPF □□□□
`upf_peers_associated`	Gauge	-	□□□□ PFCP □□□ UPF □□□□
`upf_peers_unassociated`	Gauge	-	□□ PFCP □□□ UPF □□□□
`upf_peer_healthy`	Gauge	`peer_ip`	□□ UPF □□□□□□1=□□□ 0=□□□□
`upf_peer_missed_heartbeats`	Gauge	`peer_ip`	□□ UPF □□□□□□□□□□

□□□

```
# □□ UPF □□□
upf_peers_healthy / upf_peers_total

# □□□□□□ UPF □□□□
upf_peers_unhealthy > 0

# □□□□ UPF □□
upf_peer_healthy{peer_ip="10.98.0.20"}

# □□□□□□□ UPF
upf_peer_missed_heartbeats > 2
```

□□□□□

```yaml
# □ UPF □□□□□□□
- alert: UPF_Peer_Down
  expr: upf_peer_healthy == 0
  for: 1m
  labels:
    severity: critical
  annotations:
    summary: "UPF {{ $labels.peer_ip }} □□□"
    description: "UPF □□□□□ PFCP □□"

# □□□ UPF □□□□□□□
- alert: UPF_Pool_Degraded
  expr: (upf_peers_healthy / upf_peers_total) < 0.5
  for: 2m
  labels:
    severity: critical
  annotations:
    summary: "UPF □□□"
    description: "□□ {{ $value | humanizePercentage }} □ UPF □□□□"

# □□□□□□□□□
- alert: UPF_Heartbeat_Issues
  expr: upf_peer_missed_heartbeats > 2
  for: 30s
  labels:
    severity: warning
  annotations:
    summary: "UPF {{ $labels.peer_ip }} □□□□"
    description: "{{ $value }} □□□□□□□"
```

P-CSCF □□□□

P-CSCF □□□□□□

□□□□	□□	□□	□□
`pcscf_fqdns_total`	Gauge	-	□□□□□ P-CSCF FQDN □□
`pcscf_fqdns_resolved`	Gauge	-	□□□□ DNS □□□ P-CSCF FQDN
`pcscf_fqdns_failed`	Gauge	-	□□□□□ P-CSCF FQDN
`pcscf_servers_total`	Gauge	-	□□□ P-CSCF □□□□□
`pcscf_servers_healthy`	Gauge	`fqdn`	□□ FQDN □□□ P-CSCF □□□
`pcscf_servers_unhealthy`	Gauge	`fqdn`	□□ FQDN □□□□ P-CSCF □□□

□□□□ P-CSCF □□□□ □□□□□□ IMS □□□□□

□□□□□

□□□□□□

□□□□	□□	□□
`license_status`	Gauge	□□□□□□□□1 = □□□0 = □□□

□□□

```
# □□□□□□□□□□
license_status == 1

# □□□□□□□□□□□□
license_status == 0
```

□□□□□

```yaml
- alert: PGW_C_License_Invalid
  expr: license_status == 0
  for: 1m
  labels:
    severity: critical
  annotations:
    summary: "PGW-C □□□□□□□□"
    description: "□□□□□□□ - □□□□□□□□□"
```

□□□□□□□□□

□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□ GTP-C □□□□ **“□□□□□□” (73)**□□□□□□□□□□
□□□□□□□

Wireshark □□□□□□□□□□□□□□□□□□□□□“□□□□□□”

□□□

- □□□□□□□□□□□□□□□`omnipgwc`
- □□□□□ URL □ `config/runtime.exs` □□ `:license_client` □□□
- □□□□□□□□`license_status == 0`□□□□□□□□□□□□GTP-C □□□□ 73□□□□□□□□
- □□□□□□□□□□□□UI □□□□□□□□□
- Diameter□GTP-C □ PFCP □□□□□□□□
- □□□□□□□□ - □□□□□□□□□

□□□□

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`□

```yaml
# 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 □□

```yaml
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□

```yaml
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□
# □□□
#   □□□< 70%
#   □□□70-85%
#   □□□> 85%
```

□□ 4□□□□□□95th □□□□

```
# □□
histogram_quantile(0.95,

rate(s5s8_inbound_handling_duration_bucket{request_message_type="crea
[5m])
)

# □□□□□□□
# □□□□□
```

□□ 5□□□□

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

# □□□□□□□
# □□□□□/□
# □□□□□> 0.1
```

□□ 6□Gx □□□□□

```
# □□□□□□□ Gx □□□□□□
sum(rate(gx_outbound_responses_total{result_code_class="2xxx"}
[5m])) /
sum(rate(gx_outbound_responses_total[5m])) * 100

# □□□□□Gauge
# □□□□□□□0-100□
# □□□
#   □□□> 95%
#   □□□90-95%
#   □□□< 90%
```

□□ - □□□□□□□□□□□

```
# □□□□□□□□□□□□□□□□
sum(rate(gx_outbound_responses_total[5m])) by (result_code_class)

# □□□□□□□□□□□
# □□□{{ result_code_class }}
```

□□ - □ PCRF □□□□□

```
# □□□□ PCRF □□□□□□
sum(rate(gx_outbound_responses_total[5m])) by (diameter_host,
result_code_class)

# □□□□□□□□□□
# □□□{{ diameter_host }} - {{ result_code_class }}
```

□□ 7□UPF □□□□

```
# □□□□□□□□□□□
(upf_peers_healthy / upf_peers_total) * 100

# □□□□□Gauge
# □□□□□□□0-100□
# □□□
#   □□□100%
#   □□□50-99%
#   □□□< 50%
```

□□ - □□ UPF □□□

```
# □□□□□ UPF □□
upf_peer_healthy

# □□□□□Stat
# □□□
#   1 = "UP"□□□□
#   0 = "DOWN"□□□□
```

□□□□□□□

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

```yaml
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"

      # □□□□□
```

```yaml
      - 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 □□/□"

      # Gx □□□□
      - alert: OmniPGW_GxResponseFailureRate
        expr: |

sum(rate(gx_outbound_responses_total{result_code_class!="2xxx"}
[5m])) /
          sum(rate(gx_outbound_responses_total[5m])) > 0.1
        for: 5m
        labels:
          severity: warning
        annotations:
          summary: "OmniPGW □ Gx □□□□□"
          description: "{{ $value | humanizePercentage }} □ Gx □□□
□□□□ 2xxx □□□□□"

      - alert: OmniPGW_GxPCRFFailures
        expr:
rate(gx_outbound_responses_total{result_code_class=~"4xxx|5xxx"}
[5m]) by (diameter_host) > 0.05
        for: 3m
        labels:
          severity: warning
        annotations:
          summary: "PCRF {{ $labels.diameter_host }} □□□□□□"
          description: "{{ $value }} □ PCRF {{
$labels.diameter_host }} □□□□□/□"
```

```yaml
      # UPF □□□□
      - alert: OmniPGW_UPF_PeerDown
        expr: upf_peer_healthy == 0
        for: 1m
        labels:
          severity: critical
        annotations:
          summary: "UPF □□ {{ $labels.peer_ip }} □□□"
          description: "UPF □□□ PFCP □□"

      - alert: OmniPGW_UPF_PoolDegraded
        expr: (upf_peers_healthy / upf_peers_total) < 0.5
        for: 2m
        labels:
          severity: critical
        annotations:
          summary: "UPF □□□"
          description: "{{ $value | humanizePercentage }} □ UPF □□□□ (< 50%)"

      - alert: OmniPGW_UPF_HeartbeatFailures
        expr: upf_peer_missed_heartbeats > 2
        for: 30s
        labels:
          severity: warning
        annotations:
          summary: "UPF {{ $labels.peer_ip }} □□□□"
          description: "{{ $value }} □□□□□□□"

      - alert: OmniPGW_UPF_AllDown
        expr: upf_peers_healthy == 0 and upf_peers_total > 0
        for: 30s
        labels:
          severity: critical
        annotations:
          summary: "□□ UPF □□□□□"
          description: "□□□□□ UPF □□□□□□□"

      # □□□□
      - alert: OmniPGW_HighLatency
        expr: |
          histogram_quantile(0.95,
            rate(s5s8_inbound_handling_duration_bucket[5m])
```

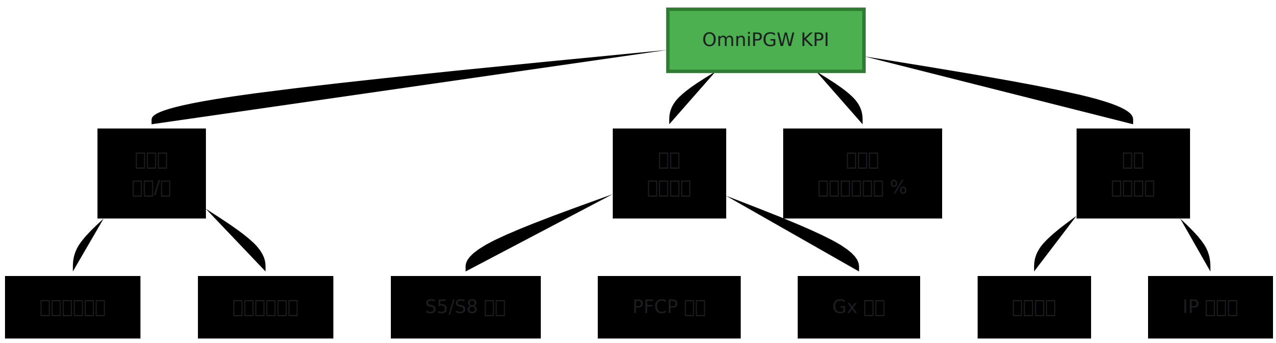
```yaml
        ) > 100000
      for: 5m
      labels:
        severity: warning
      annotations:
        summary: "OmniPGW □□□□□"
        description: "p95 □□ {{ $value }}μs (> 100ms)"

    # □□□□
    - 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 □□

```yaml
# 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)



□□□□□

□□□□□□□

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

□□□□□□□

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

□□□□□□

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

□□□□

□□□□□□□□□□□□□

```
# p50□□□□□
histogram_quantile(0.50,
  rate(s5s8_inbound_handling_duration_bucket[5m])
)

# p95
histogram_quantile(0.95,
  rate(s5s8_inbound_handling_duration_bucket[5m])
)

# p99
histogram_quantile(0.99,
  rate(s5s8_inbound_handling_duration_bucket[5m])
)
```

□□□□□□□□□□□

```
histogram_quantile(0.95,
  rate(s5s8_inbound_handling_duration_bucket[5m])
) by (request_message_type)
```

□□□□

□□□□□□□24□□□□

```
teid_registry_count -
teid_registry_count offset 24h
```

□□□□□

```
# □□□□□□ 10,000 □□
10000 - teid_registry_count
```

□□□□□□□□□□

```
# □□ 1 □□□□□□□□□□□□
(10000 - teid_registry_count) /
(rate(teid_registry_count[1h]) * 86400)
```

□□□��□□

□□□□

□□□□□□□□□

□□□

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

□□□

- □□□□□□
- □□ PCRF □□□Gx □□□
- □□ IP □□□

□□□□□□□□□

□□□

```
histogram_quantile(0.95,

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

□□□

- □□ Gx □□□PCRF □□□□□
- □□ PFCP □□□PGW-U □□□□□

- □□□□□□□□□□

□□□PCRF □□□□

□□□

```
# □□ Gx □□□□□
sum(rate(gx_outbound_responses_total{result_code_class!="2xxx"}
[5m])) /
sum(rate(gx_outbound_responses_total[5m])) * 100

# □ PCRF □□□□
sum(rate(gx_outbound_responses_total[5m])) by (diameter_host,
result_code_class)

# □□□□□□□□
rate(gx_outbound_responses_total{result_code_class="5xxx"}[5m]) by
(diameter_host)
```

□□□

- □□ PCRF □□□□□□□
- □□ PCRF □□□□□□□□□□5xxx □□□□□□□□□□□
- □□ Diameter □□□□
- □□ PCRF □□□□□□□□□
- □□ 5012□DIAMETER_UNABLE_TO_COMPLY□□□□ Re-Auth-Request □□

□□□□□□□□□

□□□

```
# □□□□□
rate(vm_memory_total[1h])

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

# □□□□□□
rate(vm_system_process_count[1h])
```

[illegible]

- [illegible]
- [illegible]
- [illegible]

[illegible]

[illegible]

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

[illegible]

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

[illegible]

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

[illegible]

[illegible]

1. [illegible] 15-30 [illegible]
2. [illegible] 15 [illegible]
3. [illegible] [illegible]

□□□□□

1. □□□□□ - NOC □□□ KPI
2. □□□□□ - □□□□□□□□□
3. □□□□□□□ - □□□□□□□

□□□□

1. □□□□□□ - □□□□□□□□□□□□
2. □□ - □□ → □□□□□□□□□□
3. □□□ - □□□□□□□□□□□□□□

□□□□

□□□□□

- □□□□ - Prometheus □□���□□Web UI □□
- □□□□□□ - □□□□□□□□

□□□□

- **PFCP □□** - PFCP □□□□□UPF □□□□
- **Diameter Gx □□** - Gx □□□□□PCRF □□□□
- **Diameter Gy □□** - Gy □□□□□□□□□□OCS □□
- **S5/S8 □□** - GTP-C □□□□□SGW-C □□

□□□□

- **P-CSCF □□** - P-CSCF □□□□□IMS □□
- □□□□ - □□□□□□□□□□□□□
- **UE IP □□** - IP □□□□□□

□□□□□□

OmniPGW □□□□ - *□ Omnitouch □□□□□□*

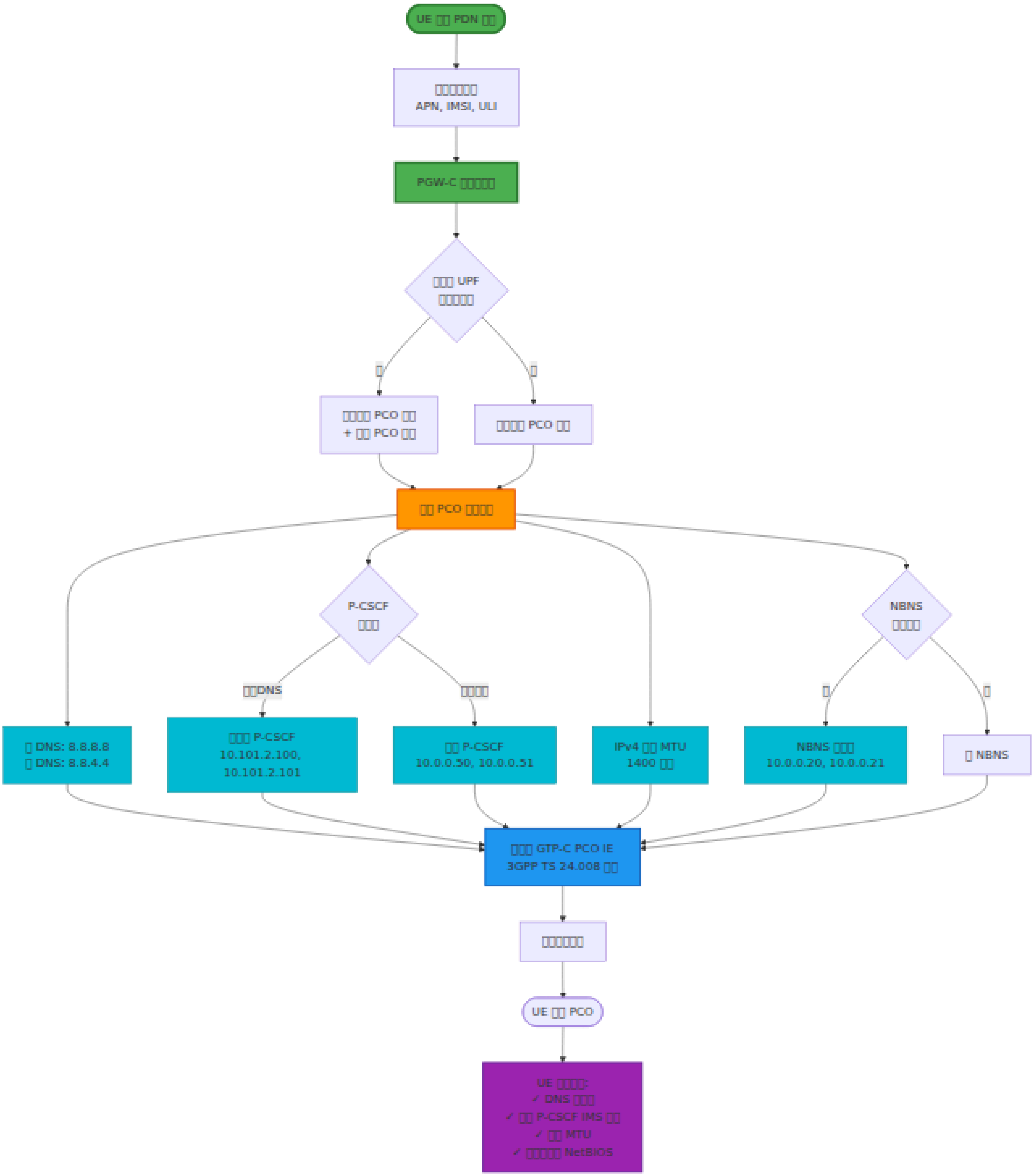
□□□□□□ (PCO)

□□□ UE □□□□□

OmniPGW □ Omnitouch □□□□□

□□

PCO (□□□□□□□) □□ PDN □□□□□□□□□□ UE (□□□□□) □□□□□□□□□□□□ UE □□□□□□□□□□□ DNS□ IMS□□□□□□□□□□


UE PDN
APN, IMSI, ULI
PGW-C
UPF
PCO
+ PCO
PCO
PCO
P-CSCF
DNS
NBNS
DNS: 8.8.8.8
DNS: 8.8.4.4
P-CSCF
10.101.2.100,
10.101.2.101
P-CSCF
10.0.0.50, 10.0.0.51
IPv4 MTU
1400
NBNS
10.0.0.20, 10.0.0.21
NBNS
GTP-C PCO IE
3GPP TS 24.008
UE PCO
UE
✓ DNS
✓ P-CSCF IMS
✓ MTU
✓ NetBIOS

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 □□□

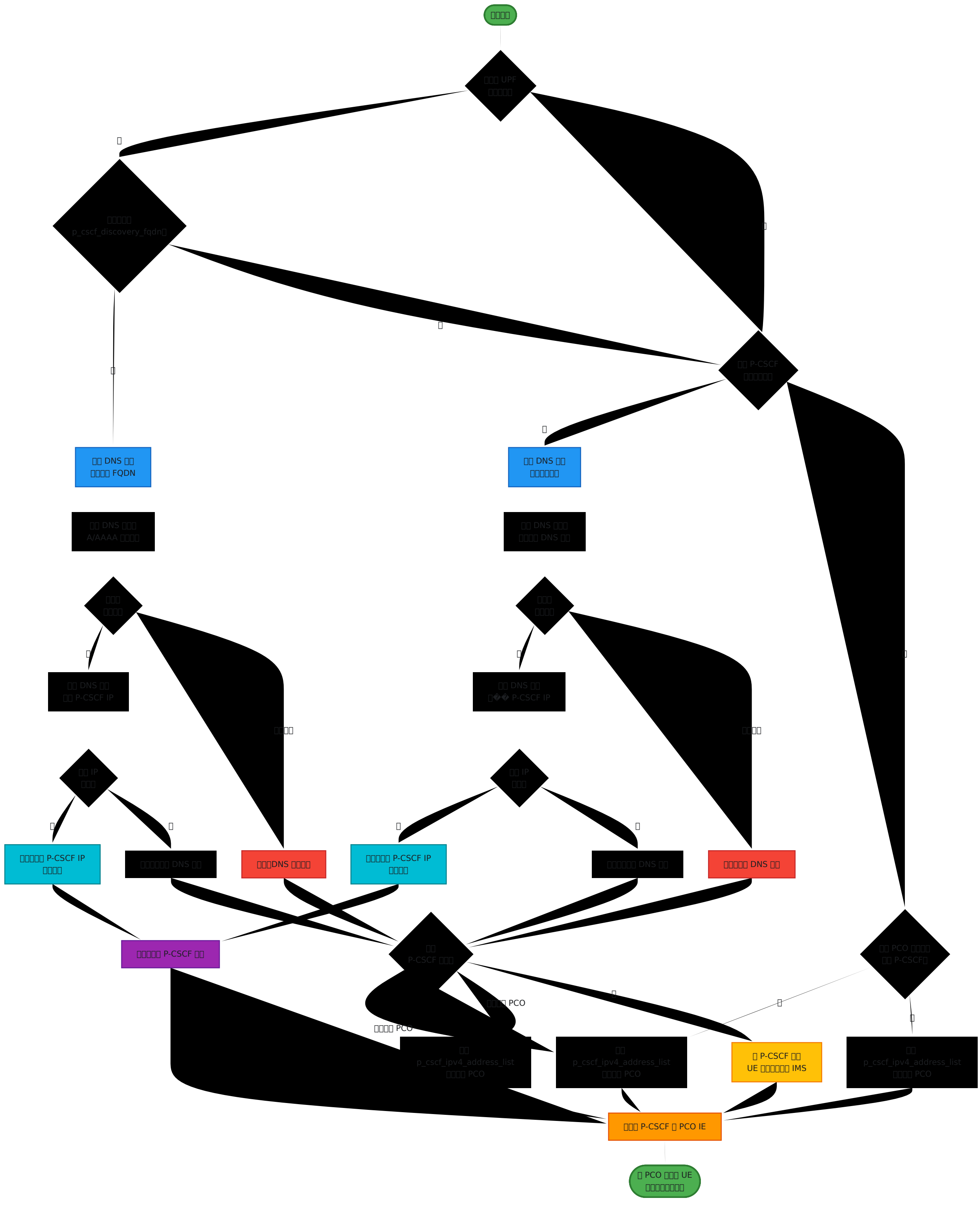
OmniPGW □□□□ DNS □□□□□□ P-CSCF □□□□□□□□ 3GPP TS 23.003 □ TS 24.229□□□□□□PGW-C □□□□ DNS □□ P-CSCF □□□□□□□□□□□□□

```
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` □□□ PCO □□□

3. □□ **PCO** □□□□ - `p_cscf_ipv4_address_list` □□□ PCO □□□
4. □□ **PCO** □□□□ (□□) - `p_cscf_ipv4_address_list` □□□ PCO □□□

□□□

□□ P-CSCF □□□□□□□□□□□□□□

- DNS □□□□/□□□
- □□□□
- □□□□□□
- □□□□□□□□□□

□□□□□□□□□□□□□□ P-CSCF □□□

□□□□□

□□	□□	□□□	□□
`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 □□□□□□□□□

□□□

- □□ **IMS** □□ - P-CSCF □□□□ DNS □□□□
- □□□□□□ - DNS □□□□□ P-CSCF □□□
- □□□□ - DNS □□□□□□□ P-CSCF □□□
- □□□□□ - □□□□□□□□□□□ P-CSCF □□□

□□□□□ DNS □□□□□ IMS

```
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
}
```

□□□ 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"
  }
]
```

□□□□□ P-CSCF □□□□□□□□□□□□ UPF □□□□□

□□□ 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: %{
  primary_dns_server_address: "8.8.8.8",
  secondary_dns_server_address: "8.8.4.4",
  ipv4_link_mtu_size: 1400
}
```

IMS APN

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

□□ P-CSCF □□ □□□ IMS □□□□□□ P-CSCF □□□□

□□ APN

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

PCO □ GTP-C □□□□□□

□□□□□□

OmniPGW □ □□□□□□ □□□□□ PCO□

```
□□□□□□
├── □□: □□□□□
├── UE IP □□: 100.64.1.42
├── PCO (□□□□□□)
│   ├── DNS □□□ IPv4 □□: 8.8.8.8
│   ├── DNS □□□ IPv4 □□: 8.8.4.4
│   ├── P-CSCF IPv4 □□: 10.0.0.50
│   ├── P-CSCF IPv4 □□: 10.0.0.51
│   └── IPv4 □□ MTU: 1400
```

UE □□

UE □□ PCO □□

1. □□□□□□□□□□□ DNS □□□
2. □ P-CSCF □□ IMS □□
3. □□□ MTU □□□□□□

□□□□

□□□UE □□□□ DNS

□□□

- UE □ IP □□□□□□□□□□
- DNS □□□□

□□□□□

1. PCO □□□□ DNS □□□□□□□□
2. □ UE IP □□□□□ DNS □□□
3. □□□□□ DNS □□

□□□□□

```
# □□ DNS □□□□□□
ping 8.8.8.8

# □□ UE □□□□ DNS □□
nslookup google.com 8.8.8.8

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

□□□IMS □□□□

□□□

- VoLTE □□□□
- UE □□“□ IMS □□”

□□□□□

1. □□ P-CSCF □□
2. P-CSCF IP □□□□□
3. 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 □□

1. □□□□□ **DNS □□□**

   - □□□Google (8.8.8.8)□Cloudflare (1.1.1.1)
   - □□□□□□□ DNS

2. □□□□□□ **DNS**

   - □□□□
   - □□□□□

3. □□ **DNS** □□□

   - □□ DNSSEC □□□□
   - □□ DNS □□□□□□□□

IMS □□

1. □□□□ **P-CSCF**

   - □□ 2 □□□□□□
   - □□□□□□□□□□□

2. □□□□□

   - P-CSCF □□□□ UE IP □□□
   - □□ SIP □□□

MTU □□

1. □□□□

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

2. □□ **LTE MTU**

   - □□□**1400** □□
   - □□□□□□□□□

3. □□□□□□□

   - □□ MTU □□
   - □□□□□□□□□□

□□□□

□□□□

- **□□□□** - □□□ runtime.exs □□□UPF □□□ PCO □□
- **UE IP □□** - IP □□□□□□ APN □□□
- **P-CSCF □□** - P-CSCF □□□□□□□□□□□□□

□□□□□□□

- **□□□□** - PDN □��□□□□□□□□□
- **S5/S8 □□** - GTP-C □□□PCO □□□□□
- **PFCP □□** - □□□□□□□

IMS □ VoLTE

- **Diameter Gx □□** - IMS □□□□□□□
- **□□□□** - □ PCO □□□□□□□□□□

□□□□□□

OmniPGW PCO □□ - *□ Omnitouch □□□□□□*

P-CSCF [illegible]

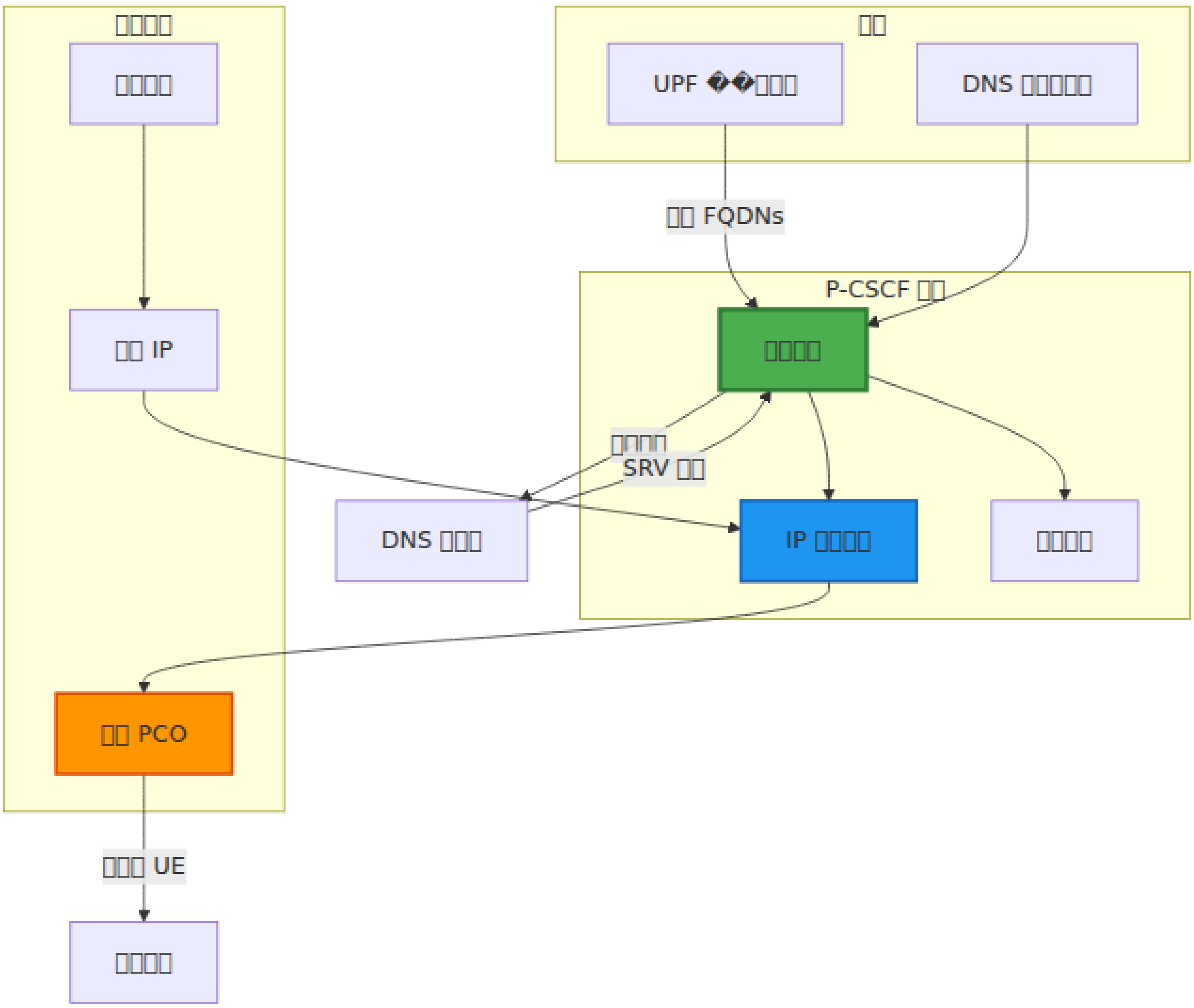
[illegible] **P-CSCF** [illegible]

OmniPGW [illegible] Omnitouch [illegible]

[illegible]

P-CSCF[illegible] DNS SRV [illegible] IMS P-CSCF [illegible] SIP OPTIONS [illegible]

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



□□

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 FQDNs

□□ UPF □□□□□□□□□□□□ P-CSCF □□ FQDN□

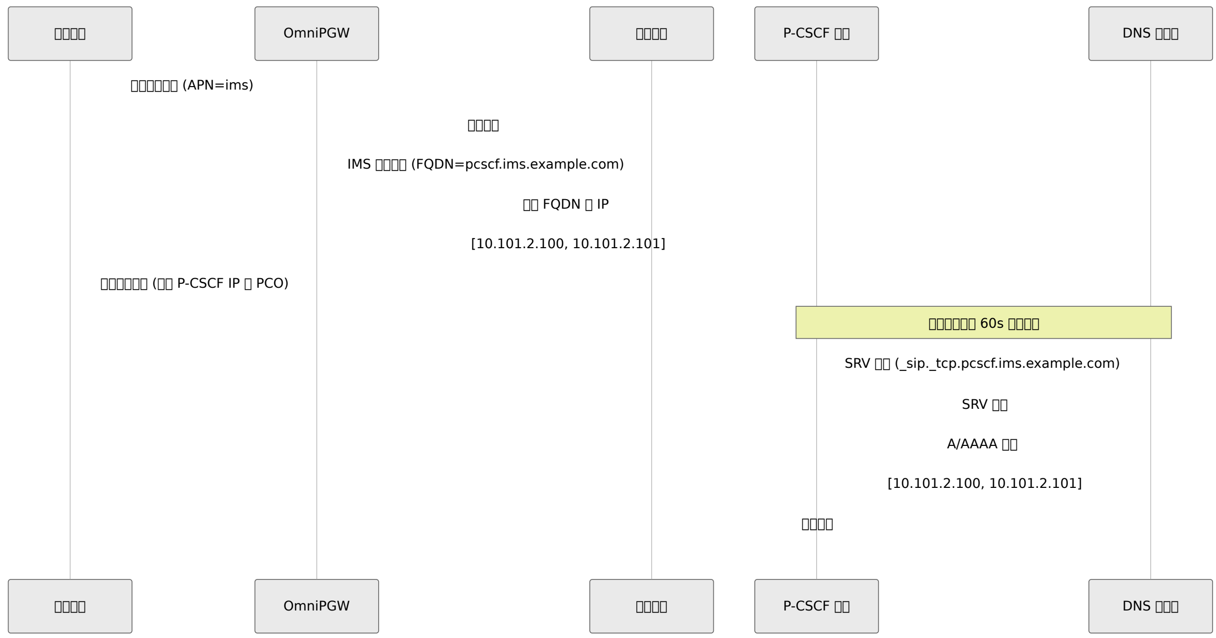
```
upf_selection: %{
  rules: [
    # IMS □□ - IMS □□□ P-CSCF
    %{
      name: "IMS □□",
      match_field: :apn,
      match_regex: "^ims",
      upf_pool: [...],
      p_cscf_discovery_fqdn:
"pcscf.ims.mnc380.mcc313.3gppnetwork.org",
      pco: %{
        p_cscf_ipv4_address_list: ["10.101.2.100"]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

    # □□ - □□□□□ 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: "□□□□□",
      match_field: :apn,
      match_regex: "^internet",
      upf_pool: [...]
      # □ p_cscf_discovery_fqdn - □□□□ PCO □□
    }
  ]
}
```

□□□□

□□□□

1. □□□□
   - P-CSCF □□ GenServer □□□
   - □□□□□□ UPF □□□□□□□□□□□□ P-CSCF FQDNs
2. **FQDN □□**
   - □□□□□ FQDN □□□□□□□□□
   - □□□□□□ FQDN □□□□ DNS SRV □□
   - **SIP OPTIONS** □□□□□□□□□□□□□□□□□□□□
     - □□□□ TCP□`SIP/2.0/TCP` □ 5060 □□□
     - □□ TCP □□□□□□□ UDP□`SIP/2.0/UDP` □ 5060 □□□
     - □□□□□□□□□ `:up`□□□□□□ `:down`□□□□/□□□
   - □□□IP□□□□□□□□□□□□□□□□□□
3. □□□□□□ 60 □□
   - □□□□□□□ FQDNs
   - DNS □□□□□□□□□□□□
   - □□□□□□□□□□□
     - □□ TCP □□ SIP OPTIONS□□□□5 □□
     - □□ TCP □□□□□□□ UDP□□□□5 □□
     - □□□□□□□□□□
   - □□□□□□□□ DNS □□□□□□□

□□□□□□



DNS □□□□

□□□□□ **DNS SRV** □□ □□□□ P-CSCF □□□

1. **SRV □□□□□** `_sip._tcp.{fqdn}` □ SRV □□
2. □□□□□□□□□□□□□□□
3. □□□□□□ SRV □□□□□□□□□□
4. □□□□□□□□□□□□□□□ IP □□□A/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"]   #
← □□
  }
}
```

□□□□□

□□	**P-CSCF □□**	**□□□ IP**	**□□□□**
FQDN □□□□	DNS □ □□□□□	□ DNS □□□ IP	`"□□□□ FQDN pcscf.example.com □ P-CSCF □□"`
FQDN □□□□	□□ PCO □ □	□□ `pco.p_cscf_ipv4_address_list` □□□ IP	`"□□□ FQDN □□ P-CSCF IPs..., □□□□□ □□"`
FQDN □□□□□	□□ PCO □ □	□□ `pco.p_cscf_ipv4_address_list` □□□ IP	□□□□
□□□□□	□□ PCO □ □	□□ `pco.p_cscf_ipv4_address_list` □□□ IP	□□□□□□
□□□ **FQDN**	□□ PCO □ □□□□	□□□□□□□□□□□□□ IP	□□□□□□□□

□□□□□

```
IMS □□□□□□□□□□
┌───────────────────────────────────────┐
│ 1. □□□□□□□ FQDN□        │
│    ✓ □: "pcscf.mnc380.mcc313..." │
└───────────────────────────────────────┘
               │
               │
               ▼
┌───────────────────────────────────────┐
│ 2. □□□□□□□□□□□ IP    │
│    Monitor.get_ips(fqdn)              │
└──────��───────────────────────────────────┘
               │
       ┌───────┴───────┐
       ▼               ▼
┌─────────────┐  ┌───────────────────┐
│ □□        │  │ □□/□          │
│ {:ok, ips}  │  │ {:error, reason} │
└─────────────┘  └───────────────────┘
       │                  │
       │                  │
       ▼                  ▼
┌─────────────┐  ┌───────────────────┐
│ □□ DNS IPs │  │ □□□□ PCO   │
│ [□□ DNS]  │  │ [□□□□]    │
└─────────────┘  └───────────────────┘
       │                  │
       └────────┬─────────┘
                ▼
      ┌───────────────────┐
      │ □ PCO □□□□□ │
      └───────────────────┘
```

□□□□□

□□ 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 □□: ERROR :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
□□: □□□ DNS □□
```

□□□□□□□□□□

1. □□□□□DNS □□□□□□□□□□□□□□□□□
2. □□□□□□□□□□□□□□□□□ DNS □□□□□
3. □□□□□□□□□□□□□□□□□□□□
4. □□□□□□□□□□□□□□

□□□□□□□□□□□□□ FQDN □□□ PCO□

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

# ⚠ □□: □□□□□□□□□ PCO□
%{
  p_cscf_discovery_fqdn: "pcscf.ims.example.com"
  # □□□□□□□□□
}

# ✓ □□: □□□□□ DNS □□□
%{
  pco: %{
    p_cscf_ipv4_address_list: ["192.168.1.50"]
  }
}
```

Web UI □□

P-CSCF □□□□

□□□□□□□ `https://localhost:8086/pcscf_monitor`

□□□

- □□□□
    - □□□□ FQDNs
    - □□□□□ FQDNs
    - □□□□□□□
    - □□□ P-CSCF IP □□
- **FQDN □**
    - □□□□□ FQDN
    - □□□□□✓ □□□ / ✗ □□ / □ □□□□
    - □□□ IP □□
    - □□□ IP □□□□□□□□□□□□□□□□□□
    - □□□□□□□
    - □□ FQDN □□□□□□□
    - □□□□□□□□□□□□□□□□
        - IP □□□□□
        - □□□□□□ DNS SRV □□□
        - □□□□□□□□✓ □□ / ✗ □□□□

- □□□□
    - □□□□ □□□□□□□□□□□ FQDNs
    - □ **FQDN** □□□□□□□□□ FQDN
    - □□□□□□□□ 5 □□□□□
- □□□□□□□
    - □ **FQDNs**□□□□□□□□□□ FQDN □□
    - □□□□□□□ DNS □□□□□ FQDNs
    - **DNS** □□□□□□□□□□ FQDNs
    - �� **P-CSCF** □□□□□□ FQDNs □□□□□□□□□
    - ✓ □□□**SIP OPTIONS** □□□□□□ SIP OPTIONS □□□□□□□□
    - ✗ □□□□**SIP OPTIONS** □□□□□□□□ SIP OPTIONS □□□□
    - **DNS** □□□□□□ DNS □□□□���□
    - □□□□□□□SIP OPTIONS □□□□□□□□60s□5s □□□

□□□□□□□□ DNS □□□□□ P-CSCF □□□□□□□□□□□□□□□ SIP OPTIONS□

UPF □□□□□□

UPF □□□□ (`/upf_selection`) □□□□□□□ P-CSCF □□□□□

```
□ IMS □□ (□□□ 20)
   □□: APN □□ ^ims
   □: UPF-IMS-Primary (10.100.2.21:8805)

   □ 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□□

Gauge □□

```
# FQDN □□□□
pcscf_fqdns_total                      # □□□ FQDN □□
pcscf_fqdns_resolved                   # □□□□□ FQDNs□DNS □□□
pcscf_fqdns_failed                     # □□□□□ FQDNs□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 □□□□□

```
# □□□□□□□ FQDNs
pcscf_fqdns_resolved

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

# □□□□□□□
pcscf_servers_total
```

SIP OPTIONS □□□□□

```
# □□ FQDNs □□□□□□□□□
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 □□□□□

```yaml
# □□□ 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 FQDNs □□□□: ["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_ipv4_address_list: ["10.101.2.100", "10.101.2.101"]
}
```

- □□ DNS □□□□□□□□□ IP□□□□
- □□□□□□□□□□□
- □□□□□□□□□□□□□□□□□□

□ 3 □□□□ PCO □□□□□□□□

```
# □□ PCO □□
pco: %{
  p_cscf_ipv4_address_list: ["10.101.2.146"]
}
```

- □□□□□□□□□□□□ DNS □□□□□□
- □□□□□ P-CSCF □□
- □□□□□□□□□□□□□□

□□□□□□

```
□□□□ "IMS □□" □□□

1. □□ DNS □□ "pcscf.ims.example.com"
   ├─ □□ → □□ [10.101.2.100, 10.101.2.101] ✓
   └─ □□ → □□□□□

2. □□□□□ PCO □□
   ├─ □□ → □□ [10.101.2.100, 10.101.2.101] ✓
   └─ □□□ → □□□□□

3. □□□□ PCO □□
   └─ □□ [10.101.2.146] ✓ (□□□□)
```

DNS □□

DNS □□□□□

□□ DNS □□□□□□ SRV □ A/AAAA □□□□ P-CSCF □□□

```
; P-CSCF □ SRV □□□_sip._tcp □□□□□□□□
_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 □□“□□”□□

□□□

- Web UI □□ ✗ □□□□
- □□□ `:nxdomain`□`:timeout` □ `:no_naptr_records`

□□□□□

1. DNS □□□□□□
2. FQDN □ DNS □□□□
3. □□□ NAPTR □□
4. 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 □ IP”
- □□□□□ ✓ □□□ □ ✗ □□

□□□□□

1. NAPTR □□□□□□□□ FQDN □□□□
2. □□□□□□□ IMS/SIP □□
3. □□ A/AAAA □□

□□□□□

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

# □□□□□□ "SIP" □ "IMS":
# □□: "SIP+D2U", "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: %{
  # □□□ P-CSCF □□□ DNS□□ 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 □□□ DNS□

```
# □ P-CSCF DNS
pcscf.mnc380.mcc313.3gppnetwork.org. IN NAPTR 10 50 "s" "SIP+D2U"
"" _sip._udp.pcscf1.example.com.

# □□ P-CSCF DNS
pcscf.mnc380.mcc313.3gppnetwork.org. IN NAPTR 20 50 "s" "SIP+D2U"
"" _sip._udp.pcscf2.example.com.
```

□□□□

- **PCO □□** - □□□□□□□DNS □ P-CSCF □□
- □□□□ - □□□ OmniPGW □□□□
- □□ - □□□□□□□□□□
- □□□□ - □□□□□□□ PCO □□
- **PFCP □□** - □□□□□□□□

□□□□□

OmniPGW P-CSCF □□ - *□ Omnitouch □□□□□□*

PFCP/Sxb □□□□

□□□□□□□□□ - PGW-C □ PGW-U □□

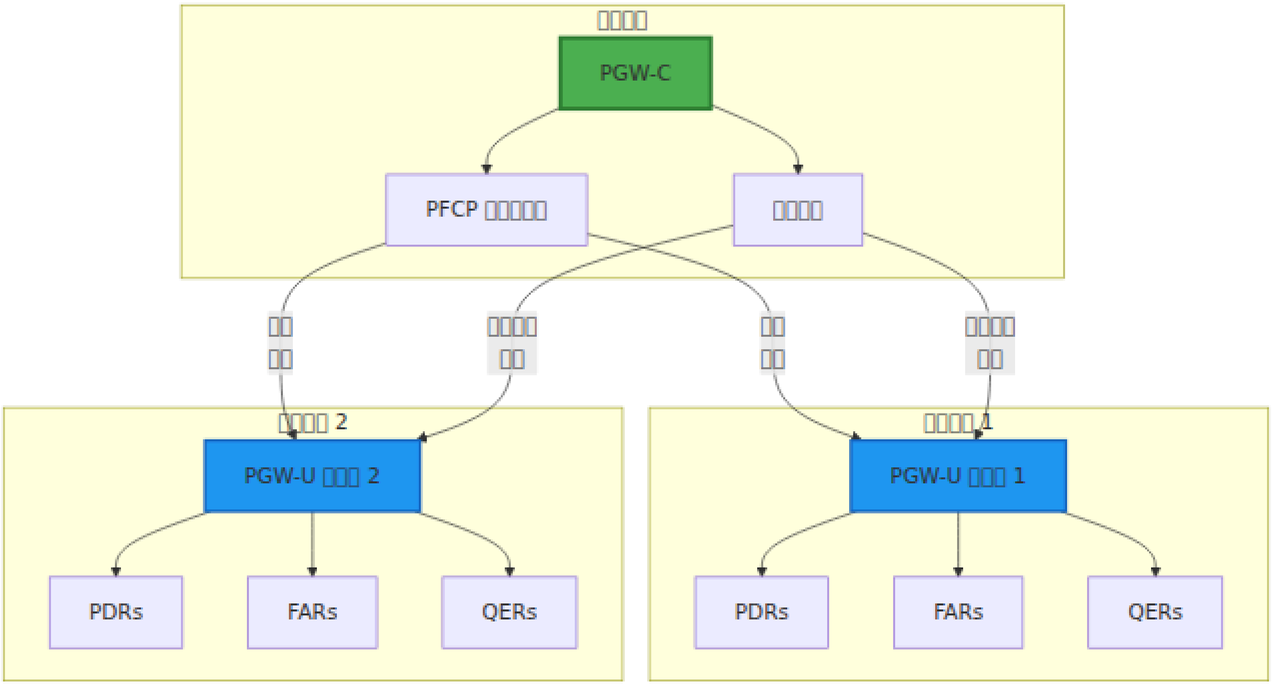
□□

□□

Sxb □□ □□ **PFCP (□□□□□□□□□□)** □□ PGW-C (□□□□) □ PGW-U (□□□□) □□□□□□□□□□□□□

- **□□□□ (PGW-C)** - □□□□□□□□□□□□□□□
- **□□□□ (PGW-U)** - □□□□□□□□□□□□□

PFCP □□



□□□□

PFCP □□

PGW-C □□ **PFCP □□ 1** (3GPP TS 29.244)□

□□

- □□□ UDP
- □□□□□ 8805
- □□□□□ □□ PFCP □□□□□□□□□

□□ ID □□

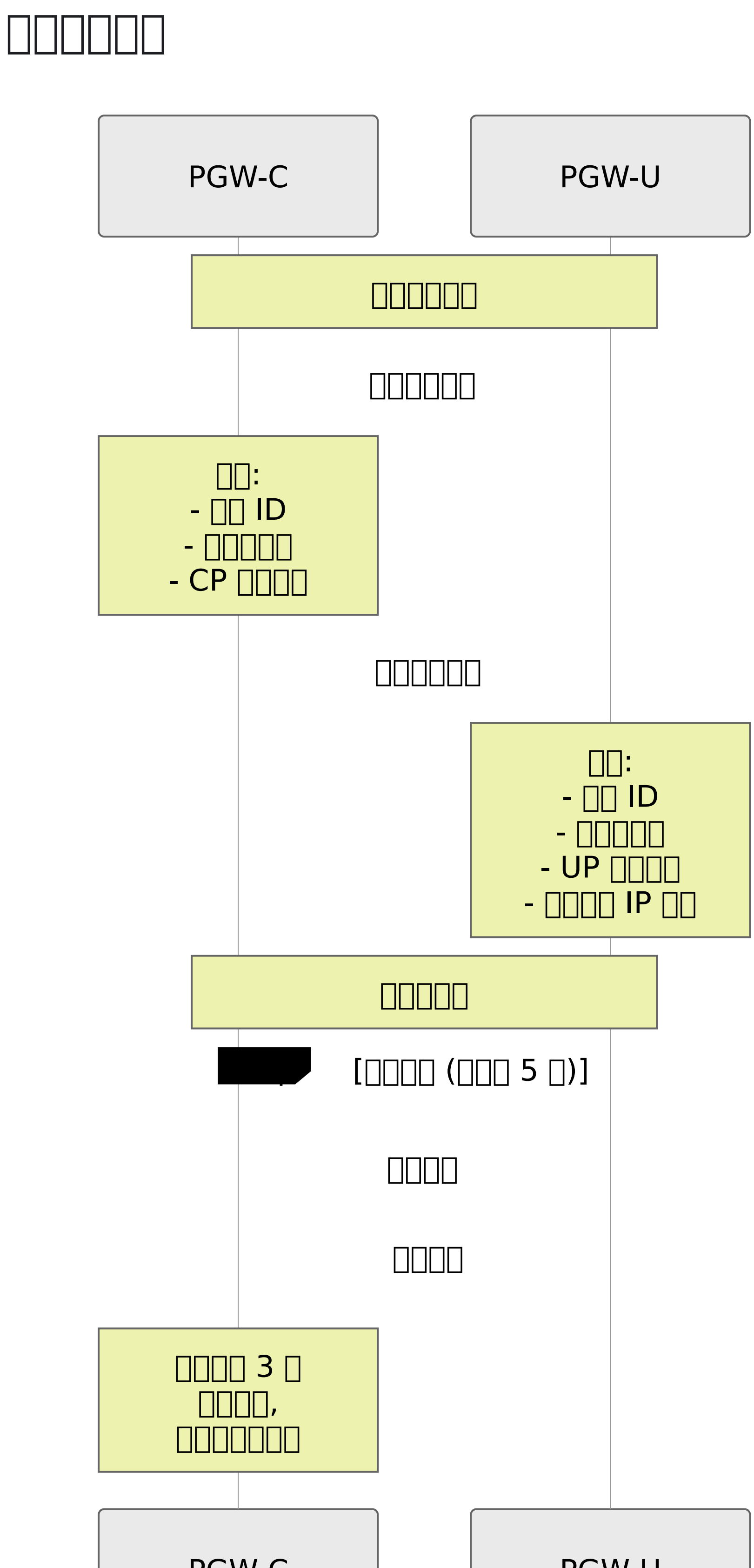
PFCP □□□□□□□ ID □□□□□□□□□

- **IPv4 □□** - □□□
- **IPv6 □□**

- **FQDN** ([illegible])

PFCP [illegible]

[illegible] PGW-C [illegible] PGW-U [illegible] PFCP [illegible]


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

□□□□□□□

□□ 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 □
```

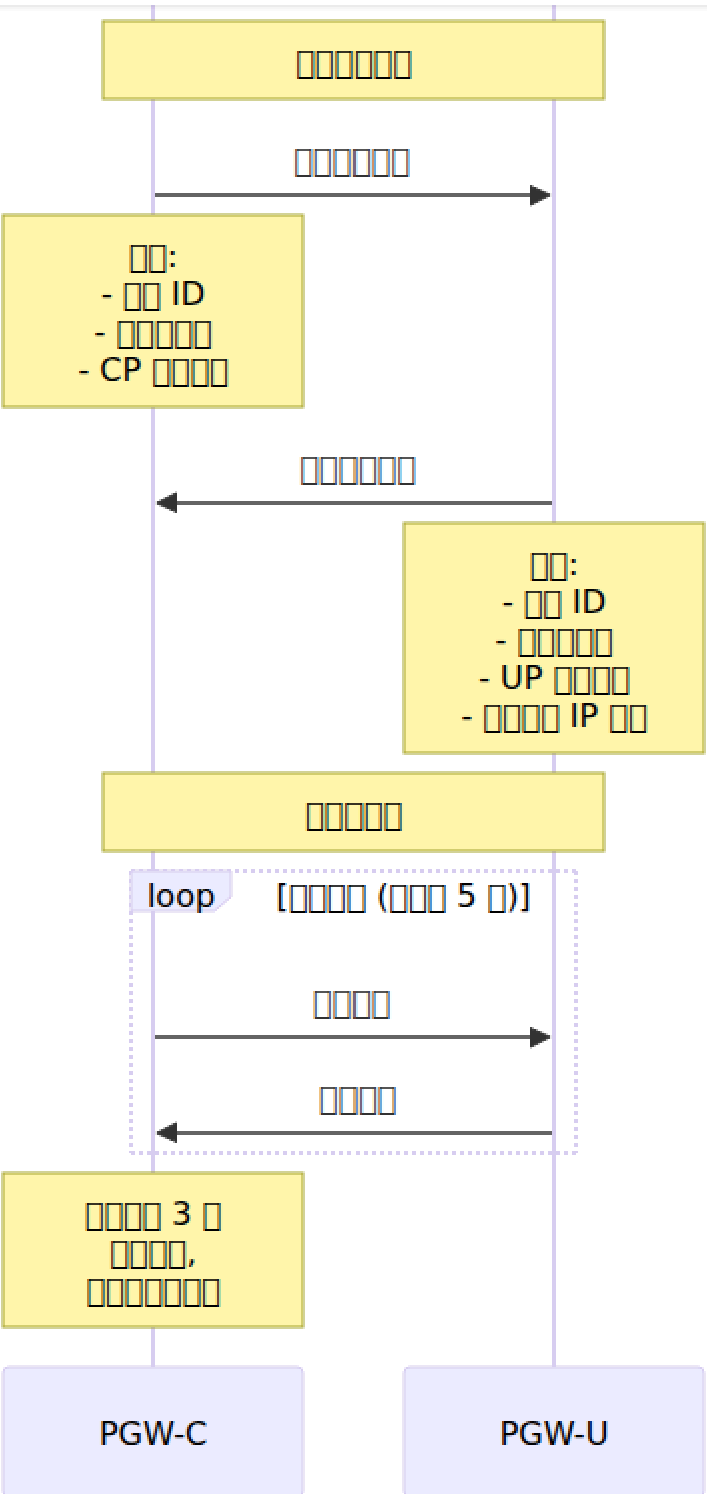
□□□□□

- □□□□□□□□□ `missed_heartbeats_consecutive`
- □□□□□□□□□ 3 □□□□
- □□□□□□□□□□□□□□□□□

PFCP □□□□

PFCP □□□□□ UE PDN □□□□□□□□□□□□□□□□□□

[illegible]


loop
PGW-C
PGW-U

□□□□

□□□ 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 □□□□□□□

F-TEID □□

F-TEID (□□□□□□□□□□) □□□□□□□□□□ GTP-U □□□□□□□ PFCP □□□□□□□ F-TEID□□□□ UPF □□□□□□□□□□□□□□□□□□□□

□□ F-TEID □□

□□□□□ F-TEID □□□□□

- **TEID** (□□□□□□□) - 32 □□□□□□□
- **IP □□** - □□ GTP-U □□□□□ (UPF □ IP □□)

□□□ □□□ TEID □□

□□ 1□UPF □□ (□□□□)

- PGW-C □“□□□□□ TEID”□CHOOSE □□□
- UPF □□□□□□□□□ TEID □□□□

□□ 2□PGW-C □□ (□□□□)

- PGW-C □□□□ TEID □□□ UPF“□□□□□□□ TEID”
- UPF □□□□□ TEID□□□□□□

UPF □□ (□□ - □□)

□□□

```
sxb: %{
  allocate_uplink_f_teid: false  # □□
}
```

□□□□□

1. PGW-C □□□□ F-TEID CHOOSE □□□ PFCP □□□□□□
2. UPF □□□□□□□□□□□□□ TEID
3. UPF □□□□□ F-TEID (TEID + IP □□)
4. PGW-C □□□□□□□□□□□□□ F-TEID

□□□□□□□□□

□ □□□□□

- UPF □□□□□□ = UPF □□□□□□□□□
- PGW-C □□□□ UPF □□□ TEID
- □□□□□□□□□□□□

□ □ **PGW-C** □□□□

- □□ PGW-C □□□□□□□ UPF □□□□□□□□
- □□ PGW-C □□□□□□ TEID □□□□□
- UPF □□□□□□□□□□□□□□□□□

□ □□ **3GPP** □□

- CHOOSE □□□ 3GPP TS 29.244 □□□
- □□ UPF □□□□□□□
- □□“□□□□□□□”□□

□ □□□□□□□□

- □□ PGW-C □□□UPF □□□□ TEID □□□□
- □□□□ TEID □□□□
- UPF □□□□□□□□ TEID

□□□□□

- □ □□ UPF □□□□□□□□
- □ □□ UPF □□□ PGW-C □□
- □ □□□□□□□□□□□
- □ □□□□□ 3GPP PFCP □□

□□□□□

- ⚠ □□□□□□□□ UPF □□□□□ CHOOSE □□
- ⚠ □□□□□□□□□□□“□□□□ IE”□□□□□□UPF □□□□□ CHOOSE

PGW-C □□ (□□□□□)

□□□

```
sxb: %{
  allocate_uplink_f_teid: true
}
```

□□□□□

1. PGW-C □□□□□□□□□□□□ TEID
2. PGW-C □□□□□ TEID □□ PFCP □□□□□
3. UPF □□□□□□□□□ TEID□□□□□□
4. PGW-C □ UPF □□□□□ TEID □

□□□□□□□□□

□ UPF □□□ CHOOSE

- □□ UPF □□□□□□□/□□□□□□□□□
- UPF □□ PFCP □□□□□□□□□ TEID
- □□□□□□□□□

□ □□□ TEID □□

- □□□□□ PGW-C □□□□□□□□ TEID
- □□□□□□□□□□□PGW-C □□□□□ TEID □□
- □□□□□□□□□ TEID □□□□□□

□ □□□□□

- □□□□□□□□□ TEID □□□□
- □□□□□□□□□□□□□ TEID □□

□□□

⚠ □ **PGW-C** □□□□

- □□ UPF □□□ PGW-C □□□□□□ TEID □□
- □□□
  - □□ PGW-C □□□ TEID □□□���□□□□
  - □□ TEID □□□□□□□□□□□□
  - □□□□□□□□□□□□□□□□

⚠ □□□□

- PGW-C □□□□□□□ TEID□□□□□□
- PGW-C □□□ TEID □□□□□□□□□□□□□□
- □□□□□□□□□□

⚠ □□□□□

- □□□□□ PFCP □□□□
- □□□□□□□ CHOOSE □ UPF □□□□□

□□□□□

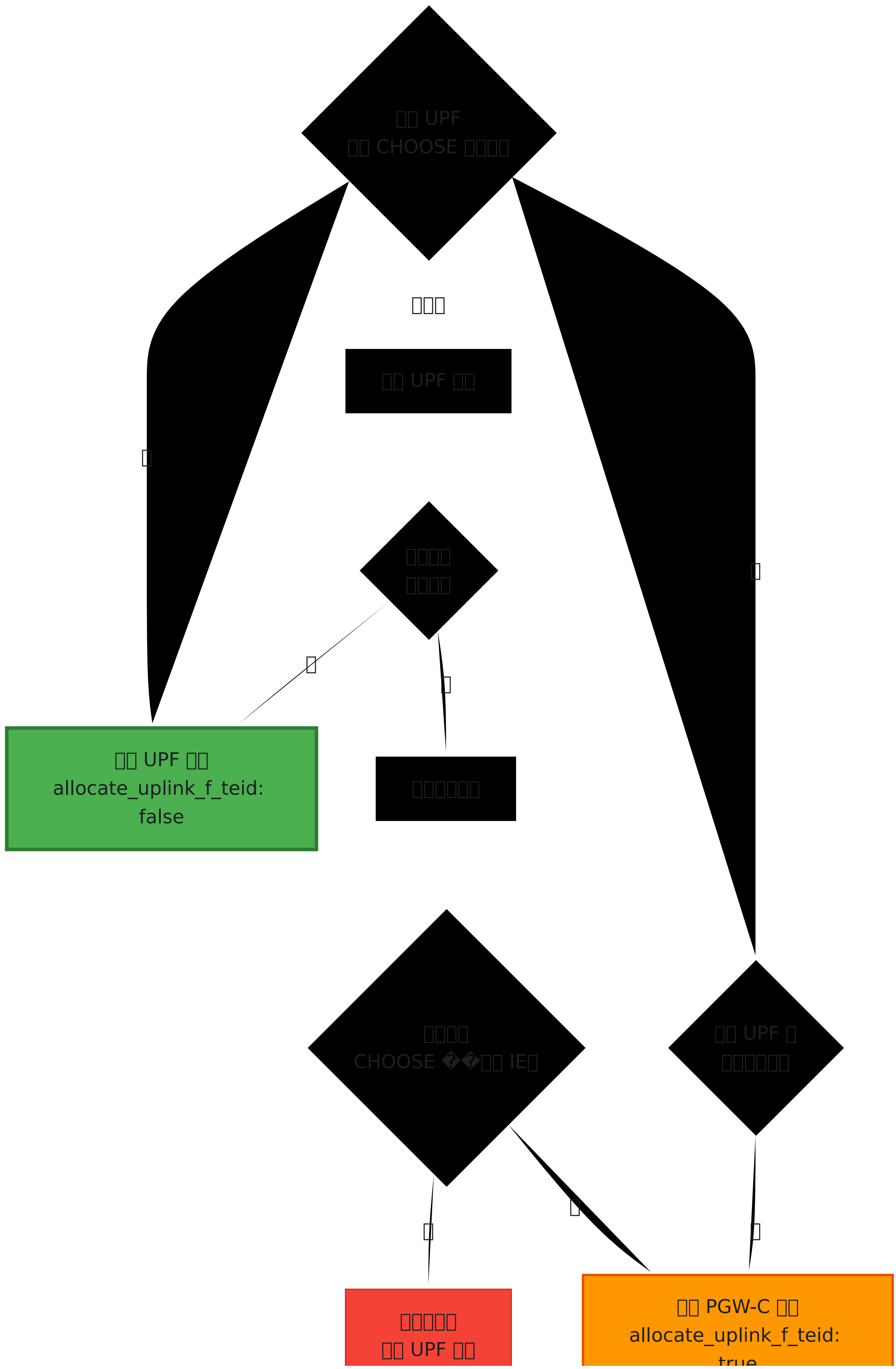
- ⚠ □□ **UPF** □□□ **CHOOSE** □□□
- ⚠ □□ UPF □□□□□□□□□□□□□
- ⚠ □□□□□□□□
- ⚠ □□ PGW-C TEID □□□□□□□□

TEID □□□□□ PGW-C □□□□□□□□□□□□

- TEID □□□1 □ 0xFFFFFFFF (42 □□□)
- □□□□□□ 100 □□□□□□□ 0.023%
- □□□□□□□□□□□□□□□

- □□□□□□□□□ TEID

□□□□


UPF
allocate_uplink_f_teid:
false
PGW-C
allocate_uplink_f_teid:
true
UPF

□□□□

□□□□□□□□□□□

□□ PFCP □□□

```
# □□□ CHOOSE □□□□□
grep -i "choose\|mandatory.*missing" /var/log/pgw_c.log

# □□ PFCP □□□□□□□□□□
grep "Session Establishment Response" /var/log/pgw_c.log
```

□□ UPF □□ CHOOSE □□□

- □□□□□□“□□□□ IE”□“□□ IE”
- UPF □□□□ F-TEID□□□□□ CHOOSE
- □□□□□ □□ `allocate_uplink_f_teid: true`

□□ PGW-C □□□□□□□

- □□□□ - TEID □□□□□□40 □□□□
- □□ TEID □□□□□□□□□□□□□□□□□□

```
# □□□□□□
grep "registered_teid_count" /var/log/pgw_c.log
```

□□□□□□□□

```
# □□ config/runtime.exs
sxb: %{
  local_ip_address: "10.0.0.20",
  allocate_uplink_f_teid: false  # □□ UPF □□□ CHOOSE□□□□□ true
}
```

□□□□ PGW-C□

```
systemctl restart pgw_c
```

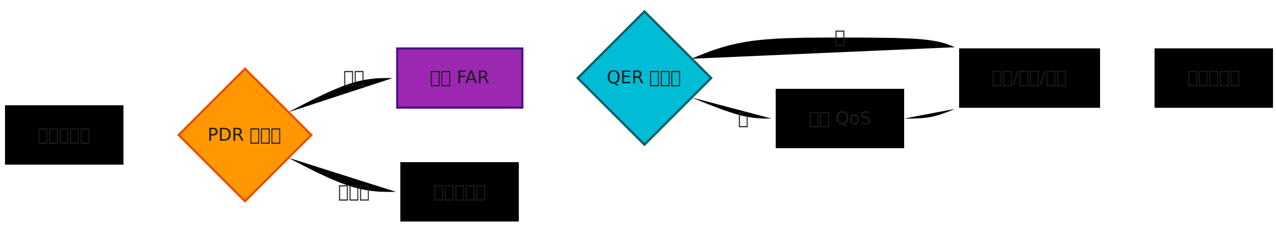
□□□□□□□□□□□□□□ □□ PFCP □□□□□□

```
# □□ PFCP □□
tcpdump -i any -n port 8805 -w pfcp.pcap

# □ Wireshark □□□□□□□□□□□□
# □□ F-TEID □□“CHOOSE”□□□UPF □□□□
# □□ F-TEID □□□□ TEID □□PGW-C □□□□
```

□□□□□□□

PFCP □□□□□□□□□□□□□□□□□□□□□□

□□□□



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,

    # □□□□□□□□□□ F-TEID □□
    # □□ false (□□)□UPF □□ F-TEID (CHOOSE □□)
    # □□ true□PGW-C □□□ F-TEID □□□□□□
    # □□□□□ UPF □□□□□ CHOOSE □□□□□□□□□
    allocate_uplink_f_teid: false
  },

  # 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 □□□

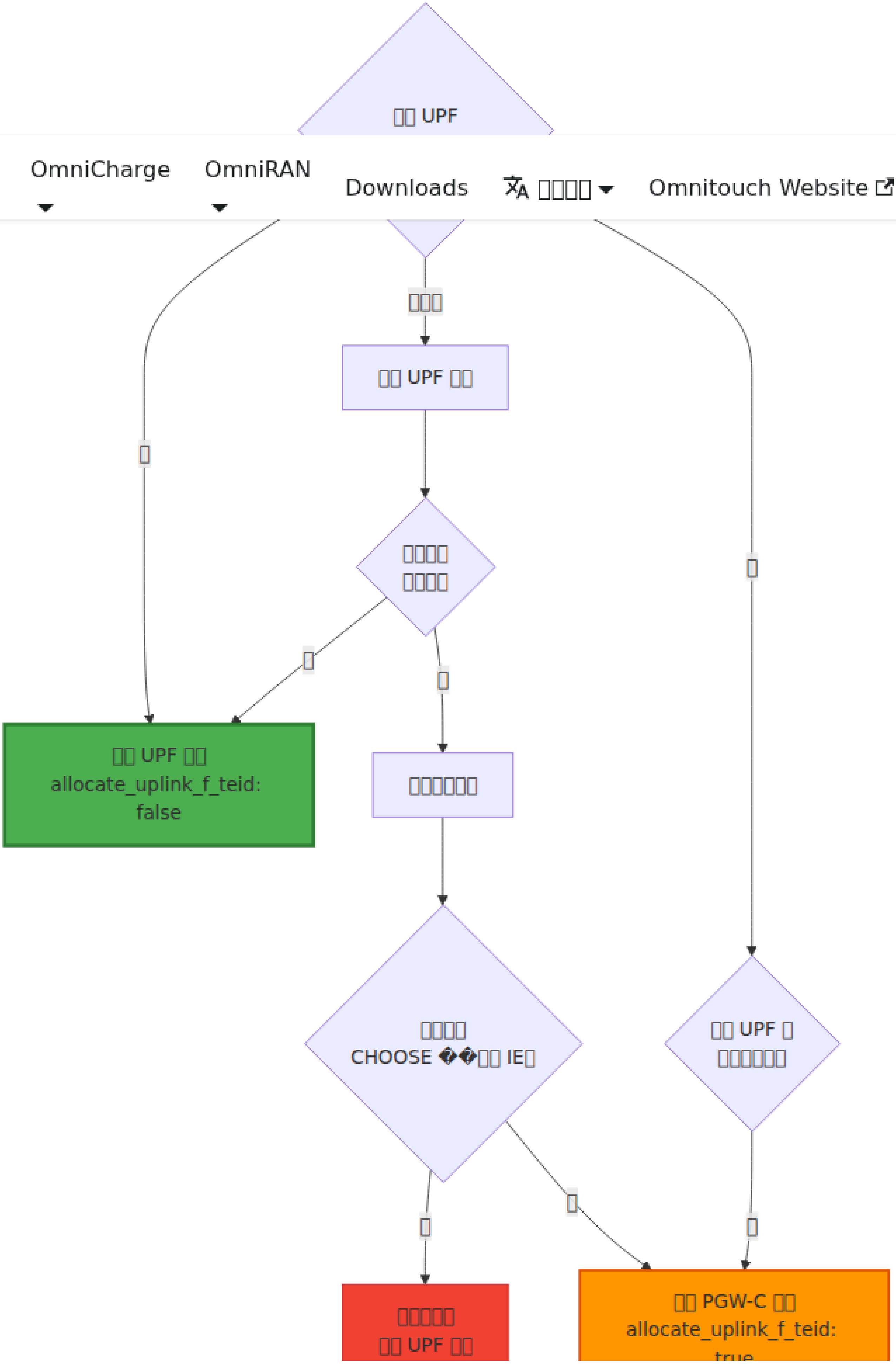
□□□□□□□□□□

```
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% □□
    ]
  }
# □□ UPF □□□□□□□□□ 5 □
```

UPF □□□□

PGW-C □□ □□ **UPF** □□□□□□□□□□□□□□

1. □□□□ (□□□□□) - □□□□□□□□
2. □□ **DNS** □□□ (□□□□□) - □□ DNS NAPTR □□□□□□□□□□
3. □□□ (□□□□□) - □□□□□□□□□□□ UPF □


UPF
UPF
UPF
allocate_uplink_f_teid:
false
CHOOSE IE
UPF
UPF
PGW-C
allocate_uplink_f_teid:

□□□ UPF □□□□

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

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

    #
==================================================================
    # □□□□□□ (□□□□□□)
    #
==================================================================
    # □□□□□□□□□□□□
    # □□□□□□□□□ UPF □
    rules: [
      # □□ 1□IMS □□ - □□□□□
      %{
        name: "IMS □□",
        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}
        ],
        # □□□□□□□ PCO □□
        pco: %{
          p_cscf_ipv4_address_list: ["10.101.2.100", "10.101.2.101"]
```

```
        }
      },

      # □□ 2□□□ APN - □□□□
      %{
        name: "□□□□",
        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
        }
      },

      # □□ 3□□□□□ - □□□□□
      %{
        name: "□□□□",
        priority: 10,
        match_field: :serving_network_plmn_id,
        match_regex: "^(310|311|312|313)",  # □□□□
        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% □□)
   - 80-100: UPF-3 (20% □□)

□□□

- □□□□□ □□□□□□ (33, 33, 34)
- □/□□ □□□□ (80)□□□□□ (20)
- □□□□□ □□□ UPF □□□□□

PCO □□

□□□□□�� PCO (□□□□□□) □□

```
%{
  name: "IMS □□",
  match_field: :apn,
  match_regex: "^ims",
  upf_pool: [...],
  pco: %{
    # □□□□□□□
    p_cscf_ipv4_address_list: ["10.101.2.100", "10.101.2.101"],
    # □□□□□□□ PCO □□□□□□
  }
}
```

□□□ PCO □□□□□

- `primary_dns_server_address`
- `secondary_dns_server_address`
- `primary_nbns_server_address`
- `secondary_nbns_server_address`
- `p_cscf_ipv4_address_list`
- `ipv4_link_mtu_size`

□□ DNS □□□

□□□□PGW-C □□□□□□□□□□ DNS NAPTR □□□

```
upf_selection: %{
  dns_enabled: true,
  dns_query_priority: [:ecgi, :tai, :rai, :sai, :cgi],
  dns_suffix: "epc.3gppnetwork.org",
  dns_timeout_ms: 5000
}
```

□□□□□□

1. **ECGI** (E-UTRAN □□□□□□□□) - □□□
2. **TAI** (□□□□□□) - □□□□
3. **RAI** (□□□□□□□) - 3G/2G □□
4. **SAI** (□□□□□□□) - 3G □□□□

5. **CGI** (□□□□□□□□) - 2G □□

□□ DNS □□□

```
# □□ ECGI □□□
eci-1a2b3c.ecgi.epc.mnc999.mcc999.epc.3gppnetwork.org

# □□ 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 □□□□ □□□□□□□□□□□□ UE □□□□□□□□□□□□ (ULI) □□ DNS NAPTR □□□

3GPP □□□ TS 23.003 - UPF □□□ DNS □□

□□□

- □□□□□□□□□□□ UPF
- □□□□□□□□□□□□□
- □□□□□□□□□□□
- □□□□□□□□□ UPF □□□□□□□

□□□□

Parse error on line 25: ... style PGWC fill:#4CAF50,stroke:#2E7 ---------------------^ Expecting 'SOLID_OPEN_ARROW', 'DOTTED_OPEN_ARROW', 'SOLID_ARROW', 'BIDIRECTIONAL_SOLID_ARROW', 'DOTTED_ARROW', 'BIDIRECTIONAL_DOTTED_ARROW', 'SOLID_CROSS', 'DOTTED_CROSS', 'SOLID_POINT', 'DOTTED_POINT', got 'TXT'

□□

□□

```
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: 0x1A2B3C (1,715,004 □□□)
# 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: 0x0064 (100 □□□)
# □□□: 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.rai.mnc<MNC>.mcc<MCC>.
<dns_suffix>
```

□□□

```
# RAC: 0x0A (10 □□□)
# LAC: 0x1234 (4660 □□□)
rac0a.lac-lb34.lac-hb12.lac.rai.mnc999.mcc999.epc.3gppnetwork.org
```

□□□□□ 3G/2G UMTS/GPRS □□

4. SAI (□□□□□□□)

3G □□□□

□□□

```
sac<SAC>.lac-lb<LB>.lac-hb<HB>.lac.sai.mnc<MNC>.mcc<MCC>.
<dns_suffix>
```

□□□

```
# SAC: 0x0001
# LAC: 0x1234
sac0001.lac-lb34.lac-
hb12.lac.sai.mnc999.mcc999.epc.3gppnetwork.org
```

□□□□□ 3G UMTS □□□□

5. CGI (□□□□□□□)

2G □□□

□□□

```
ci<CI>.lac-lb<LB>.lac-hb<HB>.lac.cgi.mnc<MNC>.mcc<MCC>.
<dns_suffix>
```

□□□

```
# CI: 0x5678
# LAC: 0x1234
ci5678.lac-lb34.lac-hb12.lac.cgi.mnc999.mcc999.epc.3gppnetwork.org
```

□□□□□ 2G GSM □□

DNS □□□□

NAPTR □□□□□

DNS □□ NAPTR □□□□□ UPF IP □□□

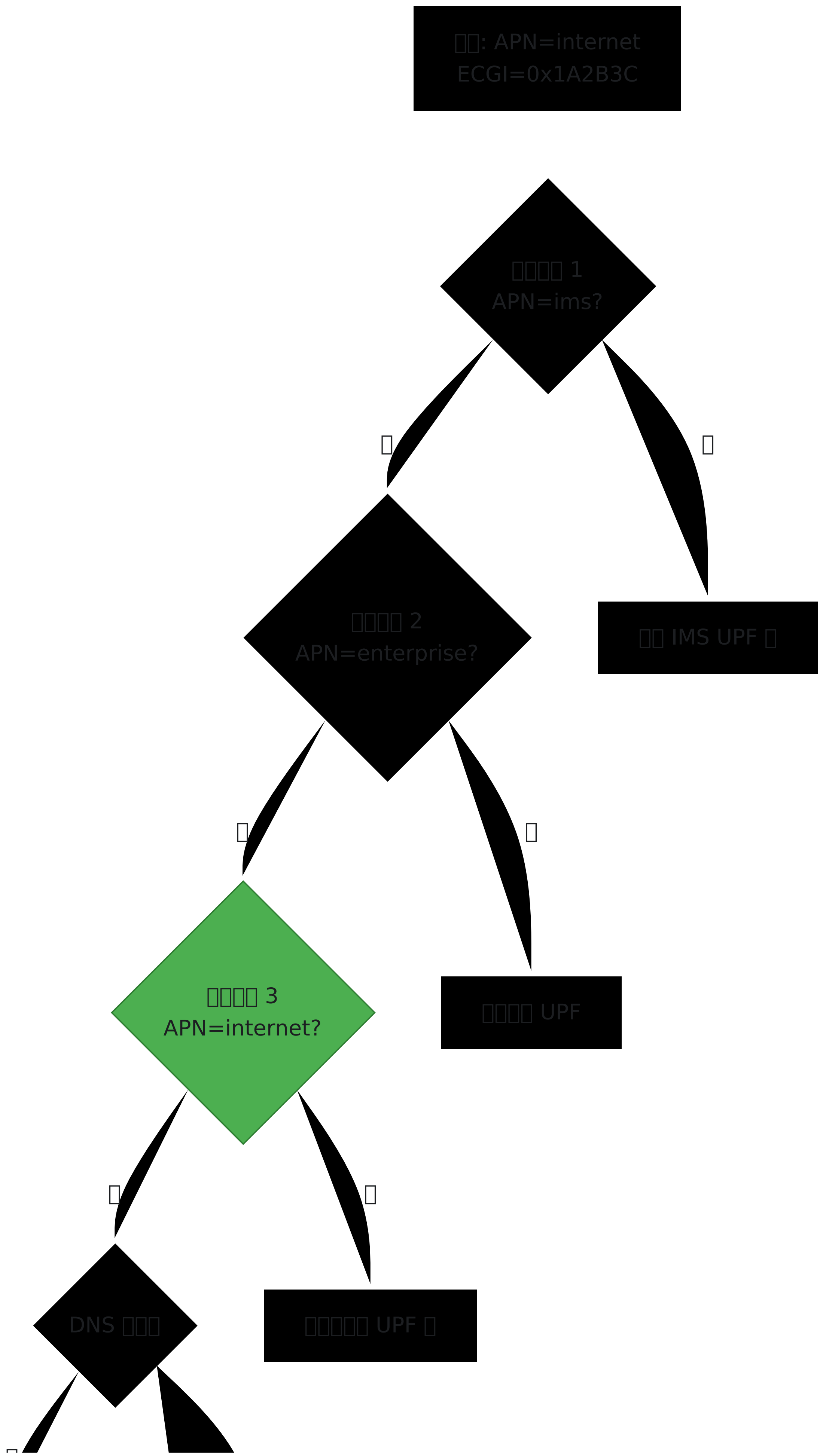
```
eci-1a2b3c.ecgi.epc.mnc999.mcc999.epc.3gppnetwork.org.
  IN NAPTR 10 50 "a" "x-3gpp-upf:x-s5-gtp:x-s8-gtp" ""
upf1.epc.mnc999.mcc999.3gppnetwork.org.

upf1.epc.mnc999.mcc999.3gppnetwork.org.
  IN A 10.100.1.21
```

PGW-C □□□

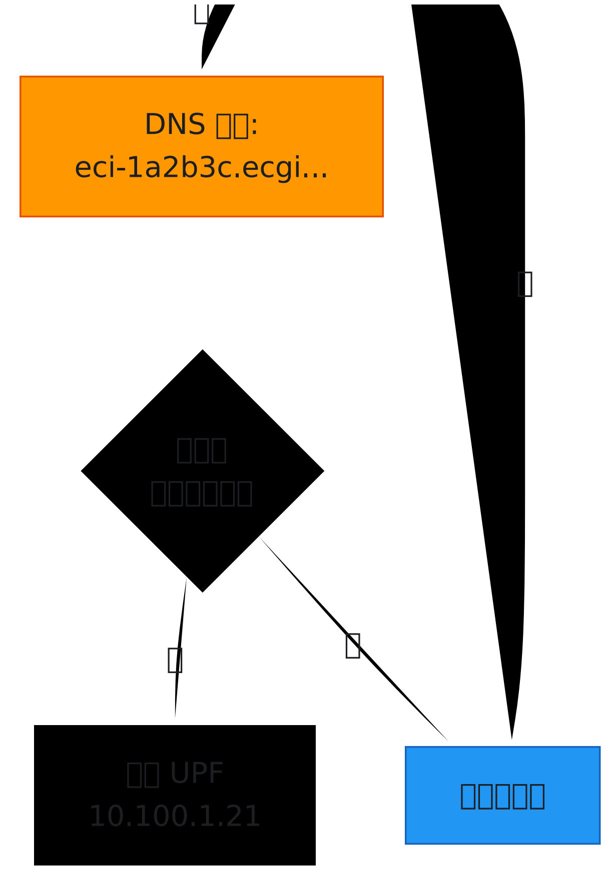
1. □□ NAPTR □□□□□ UPF IP □□
2. □ DNS □□□□□□□□□□□
3. □□□□□□□□□□□□ (□□□□□□□□□□)

□□□

```
DNS □□: [10.100.1.21, 10.100.5.99]

□□:    10.100.1.21 (□□□□□□)
□□:      □□□ upf_selection □□□□□□□□□
```



APN=internet?



□□

1. □□□□□□

□□□ □□□□□□□□□□□ UPF

DNS □□□

```
# □□□□□
eci-aaa.ecgi.epc.mnc999.mcc999.epc.3gppnetwork.org → UPF-□□□
(10.1.1.21)

# □□□□
eci-bbb.ecgi.epc.mnc999.mcc999.epc.3gppnetwork.org → UPF-□□
(10.2.1.21)

# □□□□□
eci-ccc.ecgi.epc.mnc999.mcc999.epc.3gppnetwork.org → UPF-□□□
(10.3.1.21)
```

□□□ □□□□□□□□□□□ UPF□□□□□□□□□□□

2. [illegible]

[illegible] [illegible] MEC ([illegible]) UPF

DNS [illegible]

```
# [illegible] UPF
eci-*.ecgi.epc.mnc999.mcc999.epc.3gppnetwork.org → [illegible] UPF
```

[illegible] [illegible]

3. [illegible]

[illegible] [illegible]UPF [illegible]

[illegible] [illegible] DNS [illegible] PGW-C [illegible]

[illegible] DNS [illegible]

DNS [illegible]

[illegible]

- [illegible]“DNS UPF [illegible]:nxdomain”
- ��[illegible]

[illegible]

1. DNS [illegible]
2. DNS [illegible] ID
3. GTP-C [illegible] ULI

[illegible]

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

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

# □□□□□□□ ULI
# □□□□□□□□ "uli" □□
```

DNS □□□□ UPF

□□□

- DNS □□□□□□ `upf_selection` □□□□ UPF
- □□□□□□□□□□
- □□ PFCP □□□□□□□□□□□□
- □□ 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 □□

□□□

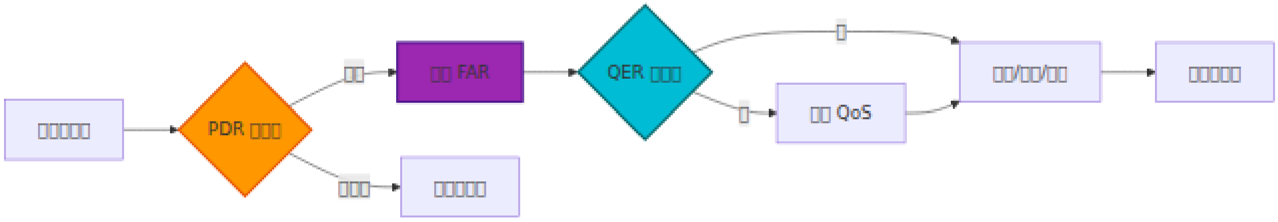
```
# DNS □□□□□
rate(upf_selection_dns_success_total[5m]) /
rate(upf_selection_dns_attempts_total[5m])

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

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

□□□

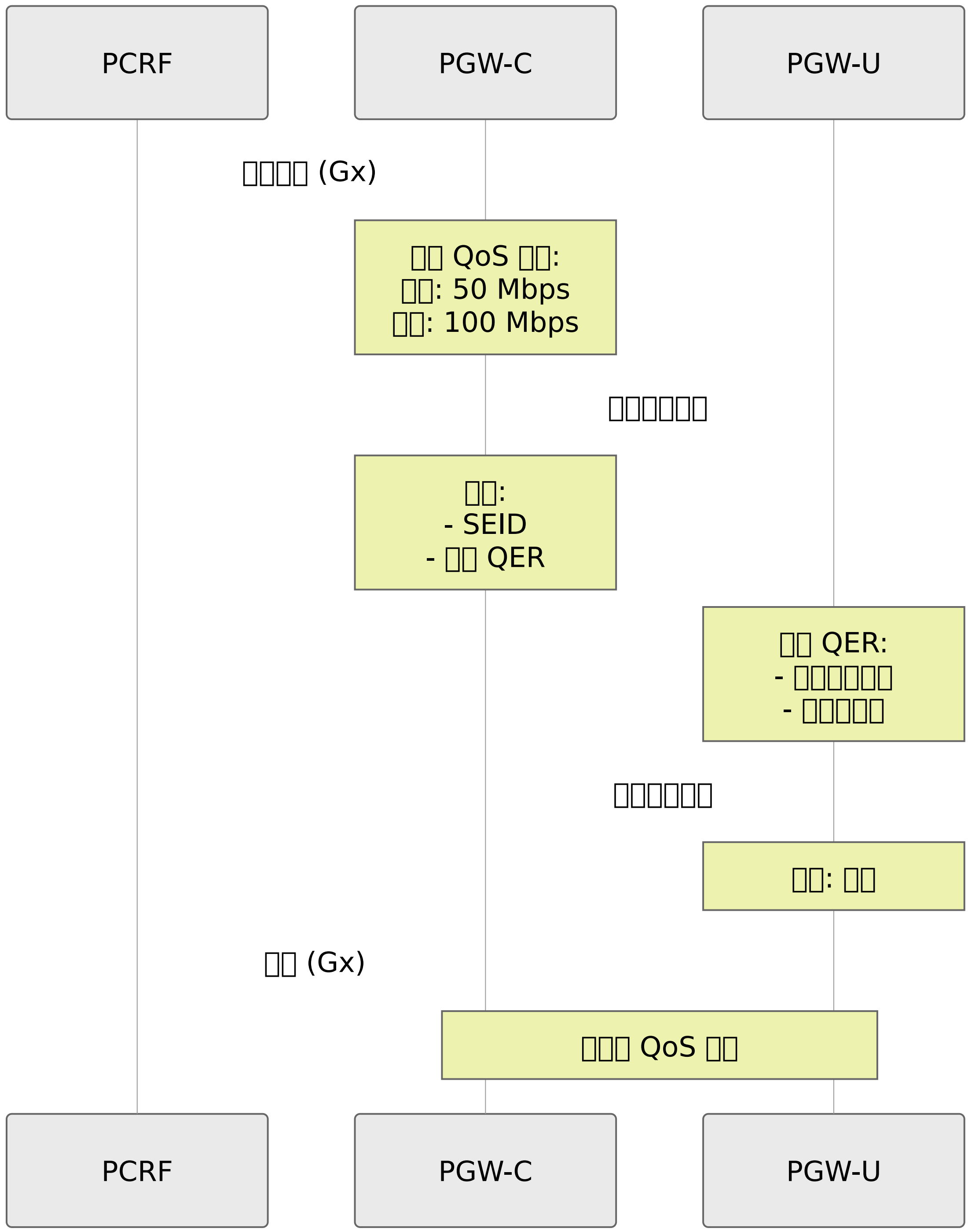
```
[debug] DNS UPF selection: querying eci-
1a2b3c.ecgi.epc.mnc999.mcc999.epc.3gppnetwork.org
[debug] DNS UPF selection: got 2 candidates from DNS
[info]  DNS UPF selection: selected 10.100.1.21
```

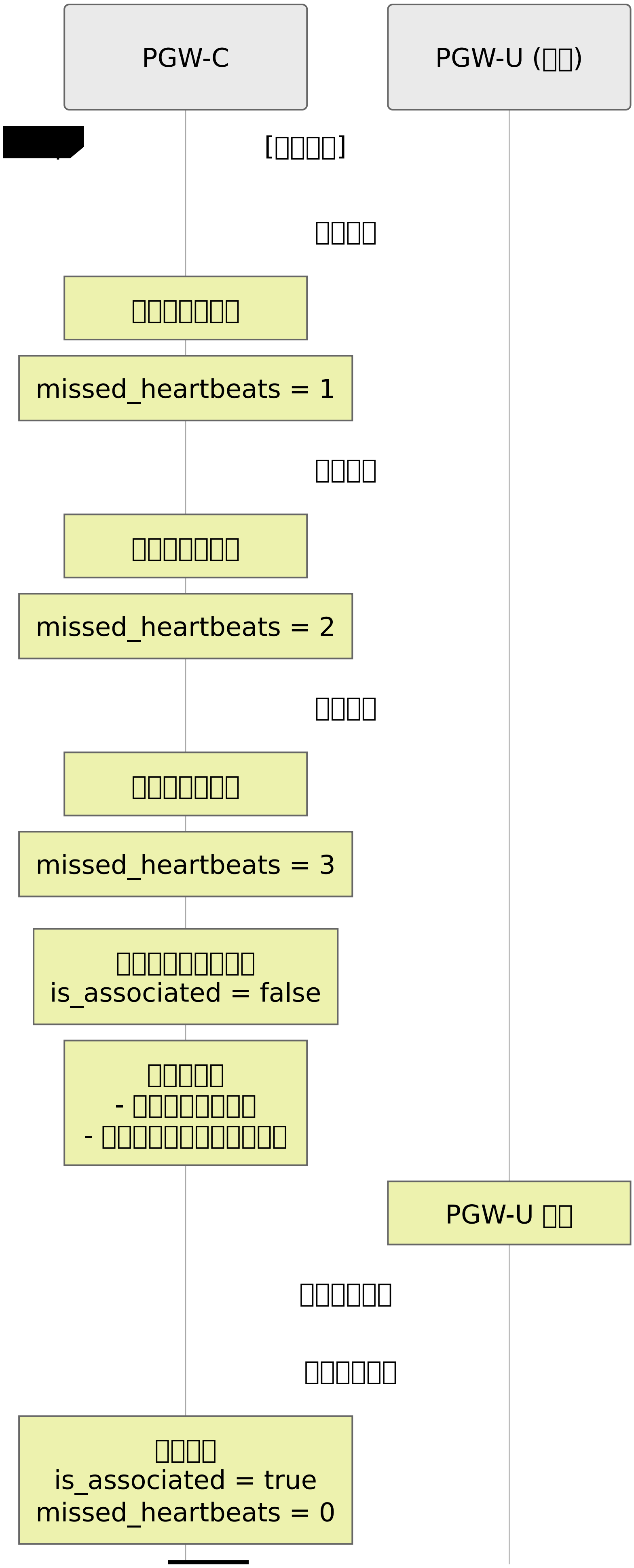
□□□

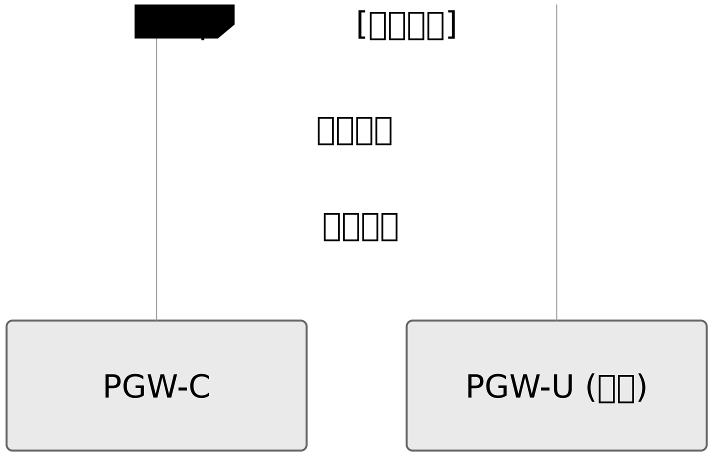
□□□□□□□□



PDR □□□
□□ FAR
QER □□□
□□ QoS
□□/□□/□□


PCRF
PGW-C
PGW-U
(Gx)
QoS :
: 50 Mbps
: 100 Mbps
:
- SEID
- QER
QER:
-
-
:
(Gx)
QoS
PCRF
PGW-C
PGW-U


PGW-C
PGW-U
missed_heartbeats = 1
missed_heartbeats = 2
missed_heartbeats = 3
is_associated = false
PGW-U
is_associated = true
missed_heartbeats = 0



[illegible]

[illegible]

1. [illegible]

[illegible]

- [illegible]“PFCP [illegible]”
- [illegible]

[illegible]

- PGW-U [illegible]
- PGW-U [illegible]
- [illegible] UDP [illegible] 8805
- [illegible] `remote_ip_address` [illegible]

[illegible]

```
# □□□□
ping <pgw_u_ip_address>

# □□ UDP □□
nc -u -v <pgw_u_ip_address> 8805

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

2. □□□□

□□□

- □□□“□□□□□□□3”
- □□□□□□□

□□□□□

- □□□□□□□□□□
- PGW-U □□
- □□□□□□□□

���□□□□

□□□□□□□ 5 □□□□□□□□□□□ 3 □□□□

3. □□□□□□

□□□

- □□□□□□□□□□□□
- □□□“PFCP □□□□□□”

□□□□□

- □□□□□ PGW-U □□□
- PGW-U □□□□
- □□□□□□□

□□□

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

4. □□ SEID □□

□□□

- □□□□□□□□□□“□□□□□□□□”

□□□

- SEID □□□□□□□□
- PGW-U □□□ PGW-C □□

□□□□□

- □□□□ PFCP □□□□□□□□□□□□□
- PGW-C □□□□ PGW-U □□□□□□□□

□□ PFCP □□

□□□□□□□

```
# PFCP □□□□□□□
pfcp_peer_associated{peer="PGW-U Primary"} 1

# □□ PFCP □□
seid_registry_count 150

# PFCP □□□□
rate(sxb_inbound_messages_total[5m])

# PFCP □□
rate(sxb_inbound_errors_total[5m])

# □□□□
pfcp_consecutive_heartbeat_failures{peer="PGW-U Primary"} 0
```

□□□□□

```yaml
# □□□□□□□
- alert: PFCPAssociationDown
  expr: pfcp_peer_associated == 0
  for: 1m
  annotations:
    summary: "PFCP □���□ {{ $labels.peer }} □□□"

# □□□□□□□□□□□
- alert: PFCPSessionEstablishmentFailureHigh
  expr:
rate(sxb_inbound_errors_total{message_type="session_establishment_res
[5m]) > 0.1
  for: 5m
  annotations:
    summary: "PFCP □□□□□□□□□"
```

Web UI - PFCP □□

OmniPGW □□□□ Web UI □□□□□□□□□ PFCP/Sxb □□□

UPF/PFCP □□□□□□□

□□□ `http://<omnipgw-ip>:<web-port>/upf_status`

□□□ □□□□□□□□ PGW-U □□□□ PFCP □□□□

□□□

1. □□□□□□□

- **□□□□** - □□ PFCP □□□□□□□□
- **□□□□□** - □□□□□□□□□□□□
- □ 2 □□□□□

2. □□□□□□□□ □□□□□□□ PGW-U □□□□

- **□□□□□** - □□□□□□□□□
- **IP □□** - □□ PGW-U IP
- **□□□□** - □□□□□□□□□□□□□□
- **□□ ID** - PFCP □□□□□
- **□□□□□** - □□□□□□□□□□
- **□□□□** - □□□□□□□

- [illegible] - [illegible]
- **UP [illegible]** - PGW-U [illegible]

3. [illegible] [illegible]

- ���[illegible]
- UP [illegible]
- [illegible]
- [illegible]

PFCP [illegible]

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

[illegible] [illegible] OmniPGW [illegible] PGW-U [illegible] PFCP [illegible]

[illegible]

1. [illegible]

- [illegible] PFCP [illegible]
- [illegible]

2. □□□□ □□□□ PFCP □□□

- □□□□ - □□□□□□
- □□ **ID** - □□□□□□□
- **IMSI** - □□□□□□□□□□□
- □□ - □□□□

3. □□□□□□□ □□□□□□□□

- □□□ PFCP □□□□□
- PDRs□FARs□QERs□BARs□□□□□□
- F-SEIDs□□□□□□□□□
- PGW-U □□□□□

□□□□

□□ PFCP □□□□□

```
1. □□ UPF □□□□
2. □□□□□□□□□“□□”
3. □□□□□□□□□ = 0
4. □□□□□□□“□□□”□
   - □□□□□ IP □□□
   - □□□□□□□□□
   - □□□□□ (UDP 8805)
```

□□□□□□□□□□□□

```
1. □□□□□□□□
2. □□ PGW □□□□ - □□□□□□
3. □□ PFCP □□□□ - PFCP □□□□□□
4. □□□□ PFCP □□□
   - □□ UPF □□ - □□□□□□□□□□□
   - □□□□□□ PFCP □□
5. □□ PFCP □□□□□
   - □□ PDRs/FARs □□□□□□□□□□
   - □□□□□□□□□□PGW-U □□□□
```

□□□□□□□□□□

```
1. □□□□ PGW-U □□□
2. □□ PFCP □□□□
3. □□□□□□□□□□□□□□
4. □□□□□□□□□□□□□□□□
```

□□□□□□□□

- □□□□ UPF □□□□
- □□“□□□”□□□□□□
- □□□□□□□□□□□□□
- □□ Web UI □□□□□□□□

□□□

- □□□□ - □□□□□□□ SSH
- □□□□ - □□□□□□□/□□□
- □□□□□□□ - □□□□□□□□□□□□□
- □□□□□ - □□□□□ PDRs/FARs/QERs □□
- □□□□ - □□□□□□□□□

□□□□

□□

- □□□□ - UPF □□□□□□□□PFCP □□
- □□□□ - PDN □□□□□□□□□□□

□□□□□

- **Diameter Gx □□** - □□ PFCP QoS □□□ PCC □□
- **Diameter Gy □□** - □□ URRs □□□□□□□□□□
- **□□ CDR □□** - □ PFCP □□□□□□ CDR

- [illegible] - PFCP [illegible]UPF [illegible]

[illegible]

- **S5/S8 [illegible]** - [illegible]
- **UE IP [illegible]** - [illegible] PFCP [illegible] UE [illegible]

[illegible]

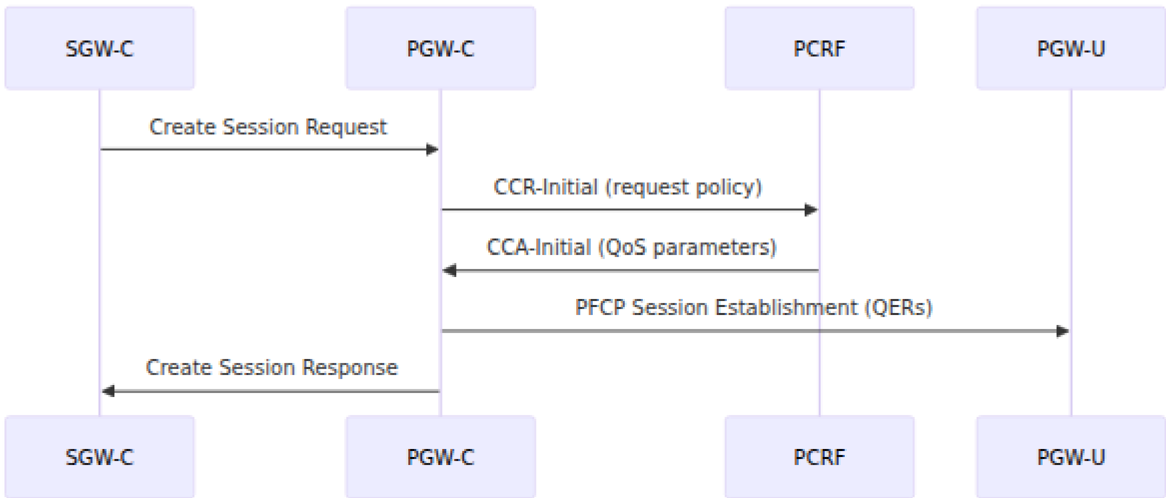
QoS □□□□□

□□

PGW-C □□□□□□□□□□□□□□ QoS □□□□□□□□□□□□□□□

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

□□□□



□□□□

- □□: □□ UE □□□□□□□□□PDR/FAR/QER/BAR □□□ AMBR
- □□□□□□: □ EBI (EPS □□ ID) □□□□□□□ PDR□FAR □ QER
- **QER (QoS □□□□)**: □□□□□□□□□□□ MBR/GBR □□□□□□
- □□□□: □□□ PDN □□□□□□□□□□□□□□
- □□□□: □□ PCRF □□□□□□���□□□□□ QoS □□

[illegible]

[illegible]: [illegible] QoS [illegible]

[illegible] QoS [illegible] Diameter Gx [illegible] PCRF[illegible] PCRF [illegible] OmniHSS[illegible]

[illegible] `config/runtime.exs` [illegible] **PCRF** [illegible]

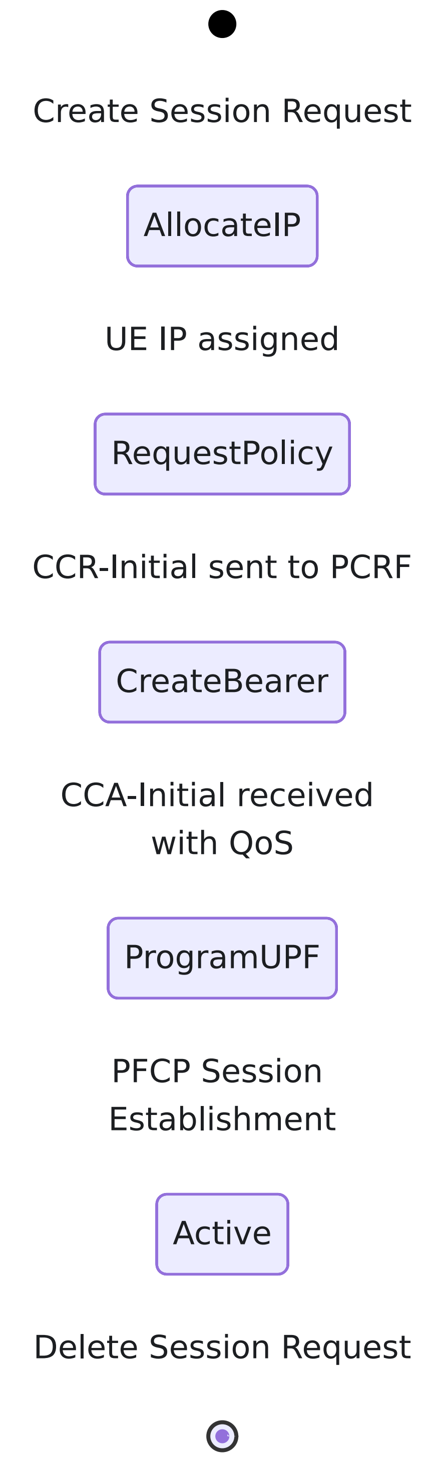
```
config :pgw_c,
  diameter: %{
    listen_ip: "0.0.0.0",
    host: "omni-pgw_c.epc.mnc999.mcc999.3gppnetwork.org",
    realm: "epc.mnc999.mcc999.3gppnetwork.org",
    peer_list: [
      %{
        host: "pcrf.epc.mnc999.mcc999.3gppnetwork.org",
        realm: "epc.mnc999.mcc999.3gppnetwork.org",
        ip: "192.168.1.100",
        initiate_connection: true
      }
    ]
  }
```

QoS [illegible] PCRF [illegible] PGW-C [illegible]

[illegible]

[illegible]

[illegible] PDN [illegible]



□□□□:

1. SGW-C □□ Create Session Request
2. PGW-C □□□□□□□ UE IP □□
3. PGW-C □□ CCR-Initial □ PCRF□□□ IMSI□APN□IP □□
4. PCRF □□ CCA-Initial□□□ QoS □□□
    - Default-EPS-Bearer-QoS (QCI, ARP)
    - QoS-Information (AMBR □□)

5. PGW-C □□□□□□□□□□
    - □□ ID: □□ PDR=1□□□ PDR=2□□□ FAR=1□□□ FAR=2□QER=1□BAR=1
    - QER □□□□□ QoS □□ MBR
6. PGW-C □ PGW-U □□ PFCP Session Establishment Request
7. PGW-C □ SGW-C □□ Create Session Response

□□□□□□:

- □ PDN □□□□□□□□□□□□□□
- □□□□ QCI 5 □ QCI 9□□ GBR□
- EBI □□□□□□□□
- □□□□□□□□□□□□□□□□

□□□□□□

□□□□□□ PCRF □□□□□□□

□□: □□ PCRF □ Re-Auth Request (RAR)□□□ Charging-Rule-Install

□□□□:

1. PCRF □□ RAR□□□ Charging-Rule-Definition□□□□□□
    - Charging-Rule-Name (□□□□□□□)
    - Flow-Information (□□□□□□)
    - QoS-Information (QCI, MBR, GBR, ARP)
    - Precedence (□□□□□□□)
2. PGW-C □□□□□□□□ PFCP □□□
    - □□ Flow-Information □□ → □□ PDR□□ SDF □□□
    - QoS-Information → □□ QER□□ MBR/GBR □□
    - Flow-Description → IP 5-□□□□□□
3. PGW-C □□ PFCP Session Modification Request□□□□ PDRs/FARs/QERs
4. PGW-C □ SGW-C □□ Create Bearer Request
5. SGW-C □□ Create Bearer Response□□□□□

□□ Charging-Rule-Definition:

```
Charging-Rule-Name: "video_streaming"
Flow-Information:
  - Flow-Description: "permit in ip from any to 10.0.0.1 5000-
6000"
    Flow-Direction: 1 (downlink)
QoS-Information:
  QoS-Class-Identifier: 7
  Max-Requested-Bandwidth-UL: 5000000 (5 Mbps)
  Max-Requested-Bandwidth-DL: 10000000 (10 Mbps)
  Guaranteed-Bitrate-UL: 1000000 (1 Mbps)
  Guaranteed-Bitrate-DL: 2000000 (2 Mbps)
Precedence: 100
Flow-Status: 2 (ENABLED)
```

□□□□

□□ QoS □□□□□□□□□□□□

- **Gx RAR**□□□□□ Charging-Rule-Definition
- **PFCP Session Modification**□□□□□□□□ QERs□□□□□□□□□FARs□□□□□□□□ PDRs□□□□□□□□□□□

□□□□

□□:

- **Delete Session Request**□SGW □□□ - □□□□□□□□□□□□
- **Re-Auth Request with Charging-Rule-Remove**□PCRF □□□ - □□□□□□

□□□□:

1. □□□□□□□□□□
2. □□□□□ PDRs/FARs/QERs
3. □ SGW-C □□ Delete Bearer Request□□□□ PCRF □□□
4. □□ PFCP Session Modification□□□□□□□ Session Deletion□□□□□□□□□

QoS □□

QCI (QoS □□□□)

□□: PCRF □□ Gx `QoS-Class-Identifier` AVP

□□□:

- **QCI 1**: □□□□ (GBR, 100ms □□□□)
- **QCI 2**: □□□□ (GBR, 150ms □□□□)
- **QCI 3**: □□□□ (GBR, 50ms □□□□)
- **QCI 4**: □□□□□ (GBR, 300ms □□□□)
- **QCI 5**: IMS □□ (□ GBR, 100ms □□□□) - □□□□□□□□
- **QCI 6**: □□ (□□ TCP)□□□□ (□ GBR, 300ms □□□□)
- **QCI 7**: □□□□□□□ (□ GBR, 100ms □□□□)
- **QCI 8**: □□ (□□ TCP)□□□ YouTube (□ GBR, 300ms □□□□)
- **QCI 9**: □□□□□ (□ GBR, 300ms □□□□)

□□□□□:

- QCI □ PCRF □□□□□□□□ QoS IE □□ SGW-C □□
- PGW-C □□□□□□□ QCI □□ - □□□□□□ QERs □□ MBR/GBR □□
- □□□ QCI □□□□□□□□□□□
- QCI □□□□□□□□□□□□□□□

ARP (□□□□□□□□□)

□□: PCRF □□ `Allocation-Retention-Priority` □□ AVP

□□:

- □□□□□: 1□□□□□□□□ 15□□□□□□□
- □□□□: □□□□□□□□□□□□□□□□□
  - 0 = □□□□□□□□□□
  - 1 = □□□□□□□□
- ���□□□□: □□□□□□□□□□□□□□□□□□

    - 0 = □□□□□□□□□□
    - 1 = □□□□□□□□□□

□□□:

- □□□□□: 1
- □□□□: □□ (0)
- □□□□□: □□ (1)

□□□□□:

- ARP □ SGW-C □□□□□□□□□ eNodeB
- **PGW-C** □□□□□□ - □□□□□□ eNodeB □□□□□□□□□□□
- □□□□□□□□□□□□□□□□□□□□□□
- □□□□□□□□□□□□□□ 1□□□□□□□□□□□□

MBR (□□□□□)

□□: PCRF □□ `Max-Requested-Bandwidth-UL` □ `Max-Requested-Bandwidth-DL` AVPs

□□: □□□□□□□□□□□ kbps: `bytes / 1000`□

□□□□: □□□□□□□□□□□□

□□□□:

- PGW-C □□ QER□□□ `mbr: %Bitrate{ul: kbps_ul, dl: kbps_dl}`
- QER □□ PFCP □□□ PGW-U
- **PGW-U** □□□□□□□□□□□□□□□□
- □□ MBR □□□□□□□□

□□:

```
Max-Requested-Bandwidth-UL: 5000000 (5 Mbps)
Max-Requested-Bandwidth-DL: 10000000 (10 Mbps)

→ QER □□□ mbr: {ul: 5000, dl: 10000} kbps
→ PGW-U □□□□ 5 Mbps □□□□□□
→ PGW-U □□□□ 10 Mbps □□□□□□
```

GBR (□□□□□)

□□: PCRF □□ `Guaranteed-Bitrate-UL` □ `Guaranteed-Bitrate-DL` AVPs

□□: □□□□□□□□ kbps□

□□□□: □□□□□□□□□□GBR □□□

□□□□:

- □□□ Charging-Rule-Definition □□□□ GBR□□□□□ **GBR** □□
- PGW-U □□ QER □□□□□□□□□□□□
- □□□ eNodeB □□□□□□□□□□□□□□
- GBR □□□□□□□ - □□□□□□□□□□□□□□

□□:

```
Guaranteed-Bitrate-UL: 1000000 (1 Mbps)
Guaranteed-Bitrate-DL: 2000000 (2 Mbps)

→ QER □□□ gbr: {ul: 1000, dl: 2000} kbps
→ □□□□□□ 1 Mbps □□□□ 2 Mbps □□□
→ □□ VoIP□□□□□□□□□
```

□□□□□:

- GBR □□□□□□□□□□□□
- □□□□ GBR □□□□□□□□□
- □□□□□□□□□□□□□□ GBR □□□□

AMBR (□□□□□□□)

□□: PCRF □□ `APN-Aggregate-Max-Bitrate-UL` □ `APN-Aggregate-Max-Bitrate-DL` AVPs

□□: □□□ □□□ **GBR** □□ □ APN□□□□□□□□□□

□□□□:

- AMBR □□□□□□□ GBR □□□□□□□
- □ Create Session Response □□□□ SGW-C
- □□□□□ eNodeB/SGW □□
- PGW-C □□□□□□□□ AMBR□□□□□□□□□ SGW-C

□□:

```
APN-Aggregate-Max-Bitrate-UL: 50000000 (50 Mbps)
APN-Aggregate-Max-Bitrate-DL: 100000000 (100 Mbps)

→ □□□ GBR □□□□□□□□□ 50 Mbps □□ / 100 Mbps □□
→ □□□□□□□□ MBR □□
→ AMBR □□□ UE/APN □□□□□□□□□
```

□□□□□:

- □□ HSS/PCRF □□□□□□□□□□□
- □□□□□□□□□□□□□□10 Mbps □□□ 100 Mbps □□□
- □□□ GBR □□

□□□□□□

□□□ (Gx) □□□□ (PFCP) □□

PCRF □□□ `Flow-Status` AVP □ Charging-Rule-Definition □□□□□□

Flow-Status (Gx)	Gate-Status (PFCP QER)	□□
0 = ENABLED-UPLINK	ul: OPEN, dl: CLOSED	□□□□□□□
1 = ENABLED-DOWNLINK	ul: CLOSED, dl: OPEN	□□□□□□□
2 = ENABLED	ul: OPEN, dl: OPEN	□□□□□□□
3 = DISABLED	ul: CLOSED, dl: CLOSED	□□□□□
4 = REMOVED	ul: CLOSED, dl: CLOSED	□□□□□□

□□:

- **DISABLED**: □□□□□□□□□□□□□□□□□□□□□
- **ENABLED-UPLINK**: □□□□□□□□□□□□□
- **ENABLED-DOWNLINK**: □□□□□□□□□□□□
- **ENABLED**: □□□□

□□□□□□□

Prometheus □□

���□□□□:

```
session_registry_count        # □□□□ (IMSI, EBI □)
address_registry_count        # □□□ UE IP
charging_id_registry_count    # □□□□□□
```

Gx □□□□:

```
gx_inbound_messages_total{message_type="gx_RAR"}     # □□ PCRF □□□□□
gx_outbound_messages_total{message_type="gx_CCR"}    # □ PCRF □□□□□
gx_outbound_transaction_duration_bucket              # □ PCRF □□□
```

PFCP □□□□:

```
sxb_outbound_messages_total{message_type="pfcp_session_establishment_
sxb_outbound_messages_total{message_type="pfcp_session_modification_r
sxb_outbound_transaction_duration_bucket
```

□□□□□□:

```
s5s8_inbound_messages_total{message_type="create_session_request"}
# □□□□
s5s8_outbound_messages_total{message_type="create_bearer_request"}
# □□□□
```

Web UI □□

PGW □□□□ (`/pgw_sessions`):

- □ IMSI□IP □□□MSISDN □ APN □□
- □□□□□□□□□□□
- □□□□ QoS □□ (QCI, MBR, GBR, AMBR)
- □□□□□□ (2 □)

Diameter □□ (`/diameter`):

- PCRF □□□□□□
- Gx □□□□
- □□□□□□□□/□□□□

□□□□ (`/logs`):

- □□□□□

- □□ "Credit Control" □□ CCR/CCA ���□
- □□ "Re-Auth" □□ RAR □□□□□□□□
- □□ "PFCP" □□□□□□□□□□

□□□□□□

```
[debug] Sending Credit Control Request: ...           # CCR □ PCRF
[debug] Handling Credit Control Answer: ...           # CCA □□ PCRF □□□ QoS□
[debug] Handling Re-Auth Request                      # RAR □□ PCRF □□□□□□
[debug] Sending Session Establishment Request         # PFCP □ PGW-U□□□ QERs□
[debug] Sending Session Modification Request          # PFCP □ PGW-U□□□ QERs□
```

□□□□

□□□□□□□□ QoS

1. □□ Web UI → **PGW** □□ □□
2. □□ IMSI□□□□`999000123456789`□
3. □□□□□□□□
4. □□ **qer_map** □□□

   ```
   qer_id: 1
   gate_status: {ul: OPEN, dl: OPEN}
   mbr: {ul: 50000, dl: 100000}  # kbps
   gbr: {ul: 10000, dl: 20000}   # kbps□□ nil □□□ GBR□
   ```

5. □□□□□□□ PCRF □□□□

□□□□□ QoS

□□: □□□□□□□□□ QoS

□□:

1. □□ **PCRF □□:**
    - □□ Web UI → **Diameter** □□
    - □□ PCRF □□□□ = "connected"
    - □□□□□□□□□□□□□□ Diameter □□
2. □□ **CCR/CCA □□:**
    - □□ Web UI → **Logs** □□
    - □□ "Credit Control Answer"
    - □□ CCA □□□□□ `QoS-Information` AVP
    - □□ CCA □□□□□Result-Code □□ 2001 = SUCCESS□
3. □□ **PFCP □□:**
    - □□□□□□ "PFCP Session Establishment Request"
    - □□□□□□□ QER
    - □□ PGW-U □□□□ PFCP □□□□
4. □□ **PCRF □□□□:**
    - □□ PCRF □□□□□□□□□
    - □□□□ APN □□□□□□□
    - □□ PCRF □□□□□□□□□□

□□□□□□□□

Prometheus □□:

```
# □□□□□□□□□□□/□□
rate(s5s8_inbound_messages_total{message_type="create_session_request
[5m])

# □□□□□□□□
rate(s5s8_outbound_messages_total{message_type="create_bearer_request
[5m])

# □□ PCRF □□□□□□□
rate(gx_inbound_messages_total{message_type="gx_RAR"}[5m])
```

□□□□

□□□□□□:

```
# UE IP □□□□□□□□□□
(address_registry_count / <configured_pool_size>) * 100

# □□□□□□
session_registry_count

# PCRF □□□□□P95□
histogram_quantile(0.95, gx_outbound_transaction_duration_bucket)
```

□□□□:

- □□□□□□□ `config/runtime.exs` □□□□□□ `ue.subnet_map` □
- TEID □□□32 □□40 □□□□□□□□□□□□□□
- □□□□□□□□□□□□□□□□□

□□□□:

- □□ IP □□□□□ - □□□ 80% □□□□□
- □□ PCRF □□ - □□□□□□□□□□□□
- □□□□□□□□□□ - □□□□□□□

[illegible]

- [illegible] - PDN [illegible]
- Diameter Gx [illegible] - PCRF [illegible]
- PFCP [illegible] - [illegible]
- [illegible] - [illegible]
- [illegible] - [illegible]

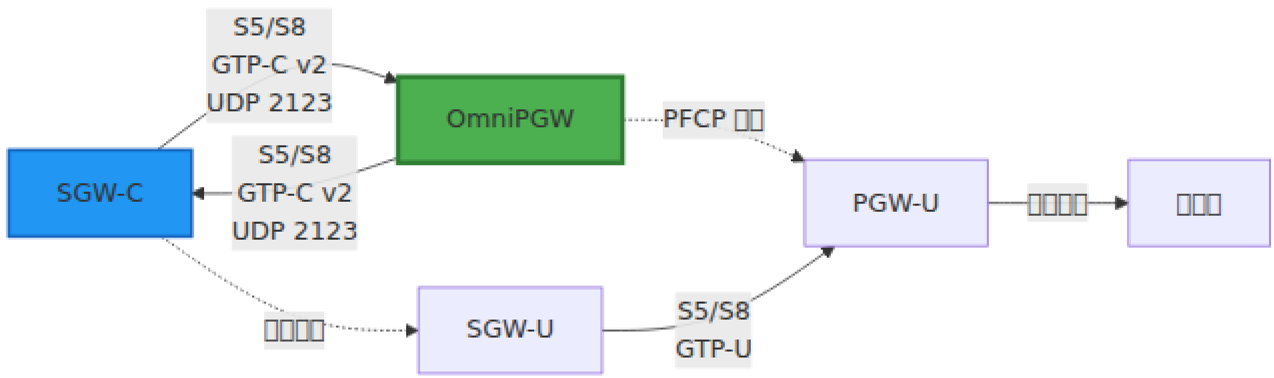
S5/S8 □□□□

□ 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,

    # GTP-C □□□□□□□□□□□□□□500ms□
    # □□ GTP-C □□□□□□□□□□□□□□□□□□□□□□□□
    request_timeout_ms: 500,

    # GTP-C □□□□□□□□□□□3□
    # □□□□□□□ = request_timeout_ms * request_attempts
    # □□500ms * 3 □□□ = 1500ms□1.5 □□□□
    request_attempts: 3
  }
```

□□□□

S5/S8 □□□□□□□□□□□□ GTP-C □□/□□□□□

□□□

- `request_timeout_ms` - □□□□□□□□□□□□□□□□□□□500ms□
- `request_attempts` - □□□□□□□□□□□□3□

□□□□□□ `request_timeout_ms × request_attempts`

□□□□□ 500ms × 3 □□□ = □□□□□ **1.5** □

□□□□□

□□□□	□□□ `request_timeout_ms`	□□□□□
□□□□<50ms□	200-300ms	600-900ms□3 □□□□
□□□50-150ms□	500ms□□□□	1.5s□3 □□□□
□□□□>150ms□	1000-2000ms	3-6s□3 □□□□
□□□/□□	2000-3000ms	6-9s□3 □□□□

□□ - □□□□□□

```
s5s8: %{
  local_ipv4_address: "10.0.0.20",
  request_timeout_ms: 1500,  # □□□□ 1.5 □
  request_attempts: 3         # □□□□□ 4.5 □
}
```

□□□□□□□

- OmniPGW □□□□□`"□□□□□□□□□"`
- □□□□□ PCRF□□□□□□□□5012 UNABLE_TO_COMPLY□
- □□□□□□□□□□□□□□ Charging-Rule-Remove □□

□□□□

□□□□□□

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

# □□□ SGW-C □□□ GTP-C
iptables -A OUTPUT -p udp --dport 2123 -d <sgw_network>/24 -j
ACCEPT
```

□□□

```
# □□□ SGW-C □□□□□
ip route add <sgw_network>/24 via <gateway_ip> dev eth0
```

□□□□

S5/S8 □□□□ PDN □□□□□ GTP-C □□□□□□□□□□□□□□□□□□□□□□ □□□□□□□

□□□□

□□□□□□

□□□ SGW-C → OmniPGW

□□□ □□□□ PDN □□

□□□□□□□**IEs**□□

IE □□	□□	□□
IMSI	□□	□□□□□□□□
MSISDN	□□	□□□□
APN	□□□	□□□□□□□□□"internet"□
RAT □□	□□	□□□□□□□EUTRAN□
□□□□□	□□	□□□□□□
UE □□	□□□	UE □□□
ULI	□□	□□□□□□□TAI□ECGI□
□□□□	PLMN	□□□□□ MCC/MNC

□□□

```
□□□□□□□
├── IMSI: 310260123456789
├── MSISDN: 14155551234
├── APN: internet
├── RAT □□: EUTRAN (6)
├── □□□□□
│   ├── EBI: 5
│   ├── □□ QoS (QCI 9, ARP, □□□)
│   └── S5/S8 F-TEID (SGW-U □□□□)
└── ULI
    ├── TAI: MCC 310, MNC 260, TAC 12345
    └── ECGI: MCC 310, MNC 260, ECI 67890
```

□□□□□□

□□□ OmniPGW → SGW-C

□□□ □□□□□□

□□ **IEs**□

IE □□	**□□**	**□□**
□□	□□	□□□□□□□
□□□��□	□□	□□□□
PDN □□□□	IP	□□□ UE IP □□□□□□ UE IP □□□
APN □□	□□	APN □□□□
PCO	□□	□□□□□□□□□□ PCO □□□

□□□□□

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

□□□□□□

□□□ SGW-C → OmniPGW

□□□ □□ PDN □□

□□ IEs□

IE 名称	描述
EBI	要删除的 EPS 承载 ID
链接 EBI	用于删除整个会话

删除承载响应

方向： OmniPGW → SGW-C

目的： 确认承载删除

关键 IEs：

IE 名称	描述
原因	删除成功或失败

其他消息

更新承载请求

方向： OmniPGW → SGW-C

目的： 修改现有承载（例如 PCRF 策略更改）

发送时机：

- PCRF 发送新的 PCC 规则（重新授权）
- OmniPGW 需要 SGW-C 更新承载

回显请求／响应

方向： OmniPGW → SGW-C 和 SGW-C → OmniPGW

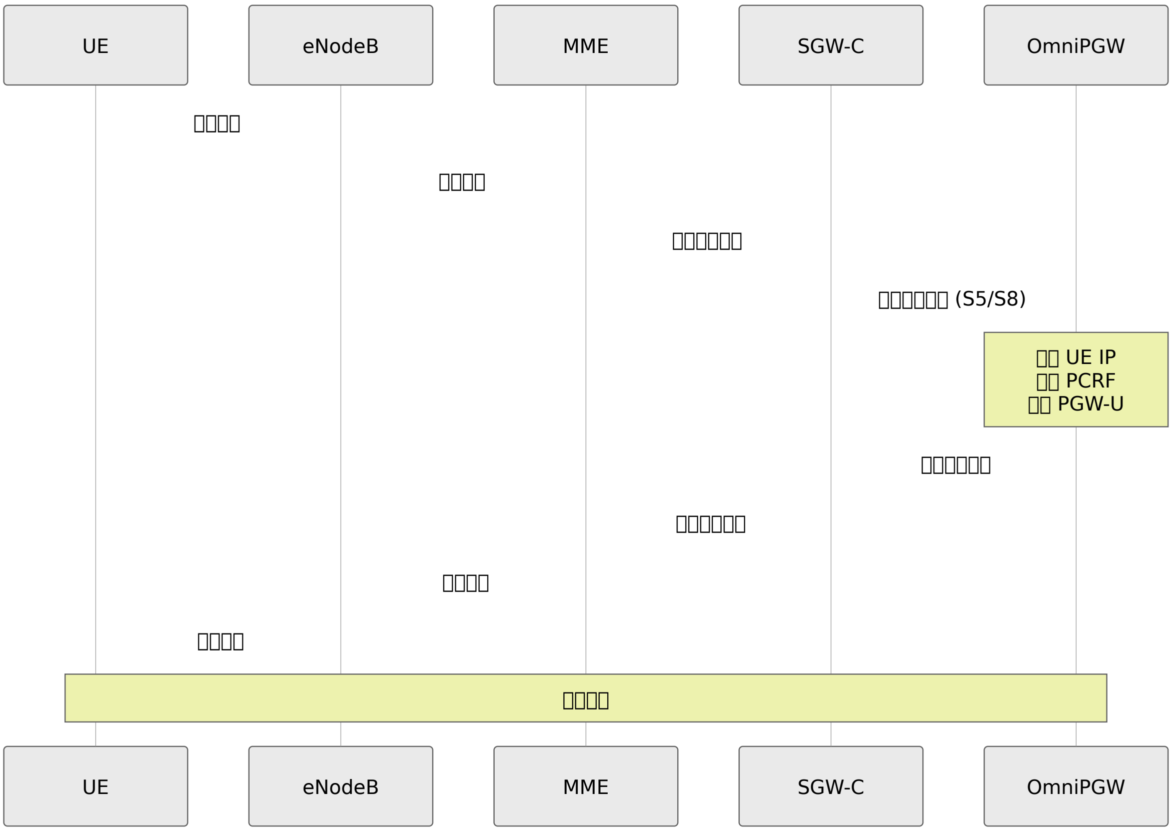
目的： 路径管理和保持

用途：

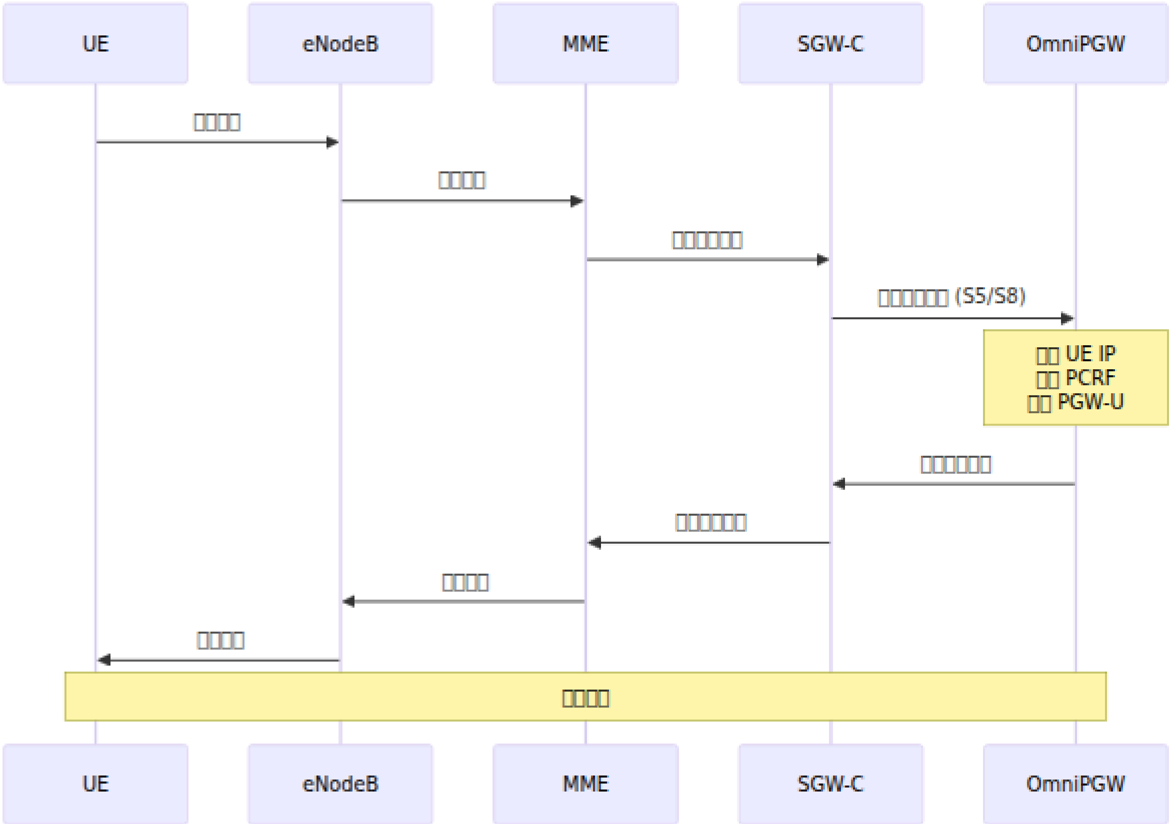
- **PGW** □□□ PCRF □□□□□□□□□□
- **SGW** □□□ □□□□□□

□□□

□□□□



[illegible]


UE
eNodeB
MME
SGW-C
OmniPGW
(S5/S8)
UE IP
PCRF
PGW-U
UE
eNodeB
MME
SGW-C
OmniPGW

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]

[illegible]

[illegible]	[illegible]	[illegible]
65	[illegible]	PCRF [illegible] IMSI[illegible]
66	[illegible]	IP [illegible]
93	[illegible]	[illegible] APN
94	TFT [illegible]	[illegible]

[illegible]

[illegible]	[illegible]	[illegible]
72	[illegible]	PCRF/PGW-U [illegible]
73	[illegible]	[illegible]

□□

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="crea
[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 □□□□□□□□□
- TEID □□□□□□□

□□□□□

- □□□□□ TEID □���
- □□ TEID □□□□□□□□□

□□□□

□□□□

1. □□□□□□
    - □ S5/S8 □□□□□ VLAN
    - □□□□□□□
2. **MTU** □□
    - □□ MTU □□ GTP □
    - □□ MTU□1500 □□□1464 □□□□ + 36 GTP□
3. □□
    - □□ OmniPGW □□
    - □ SGW-C □□ DNS □□□□□

□□

1. **UDP** □□□□□
    - □□□□□□□□□□□□
    - □□□□□□□□ 4-8 MB
2. □□□□
    - □□□□□□□□□
    - □□ TEID □□□□□

□□

1. **IP** □□
    - □□□□□□□ SGW-C IP □ GTP-C
    - □□ iptables □□□ ACL

2. □□□□

- OmniPGW □□□□□□□□
- □□□□□□□ GTP-C □□□

□□□□

□□□□

- □□□□ - S5/S8 □□□□□□□ IP □□
- □□□□ - PDN □□□□□□□□□□□
- **UE IP □□** - □□□□□□□□□□ IP □□
- **PCO □□** - GTP-C □□□□ PCO □□

□□□□

- **PFCP □□** - □ S5/S8 □□□□□□□□□□
- **□□ Gx □□** - □□□□���□□□□□
- **□□ Gy □□** - □□□□□□□□□□

□□

- □□□□ - S5/S8 GTP-C □□□□□□□
- **□□ CDR □□** - □ GTP-C □□□□ CDR

□□□□□□

OmniPGW S5/S8 □□ - *□ Omnitouch □□□□□□*

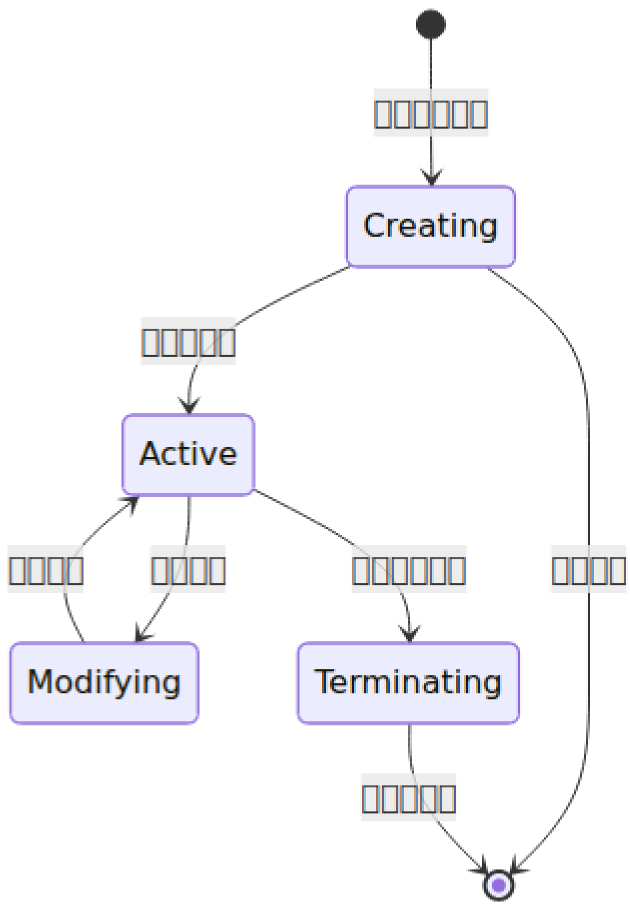
□□□□□□

PDN □□□□□□□□□

OmniPGW □ Omnitouch □□□□□□

□□

□□ **PDN (□□□□□□)** □□ □□□□□ OmniPGW □ UE □□□□□□□□□□□□□□□□□□□□□□□□□□



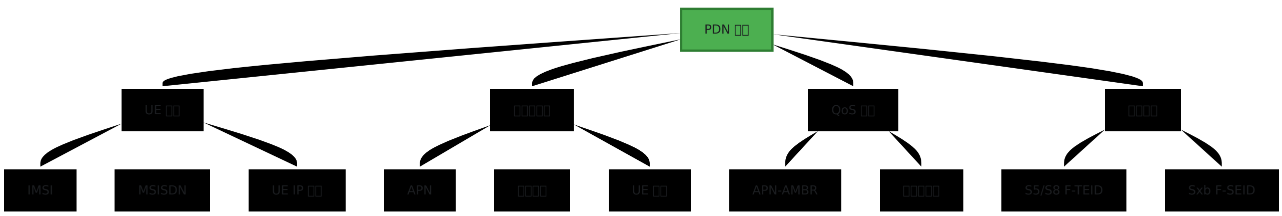
□□□□

□□□□□

□□□□□□□□□□□□□□□□□□□

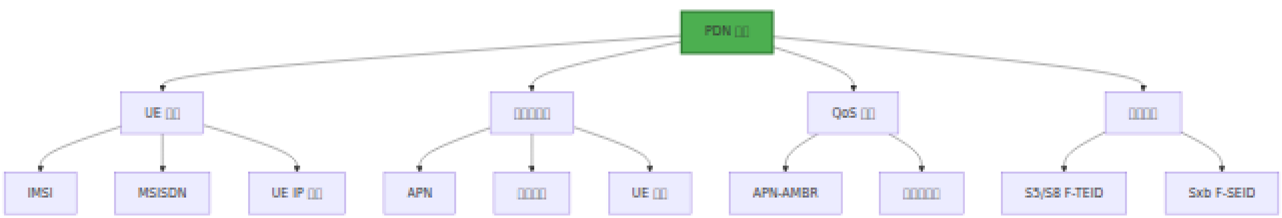
□□□	□□	□□
TEID	S5/S8 (GTP-C)	SGW-C □□□□□□□ ID
SEID	Sxb (PFCP)	PGW-U □□□□□□□ ID
Session-ID	Gx (Diameter)	PCRF □□□ Diameter □□
Charging-ID	□□	□□□□□/□□ ID

□□□□



□□□□

□□□□



□□

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)
- □□□□□

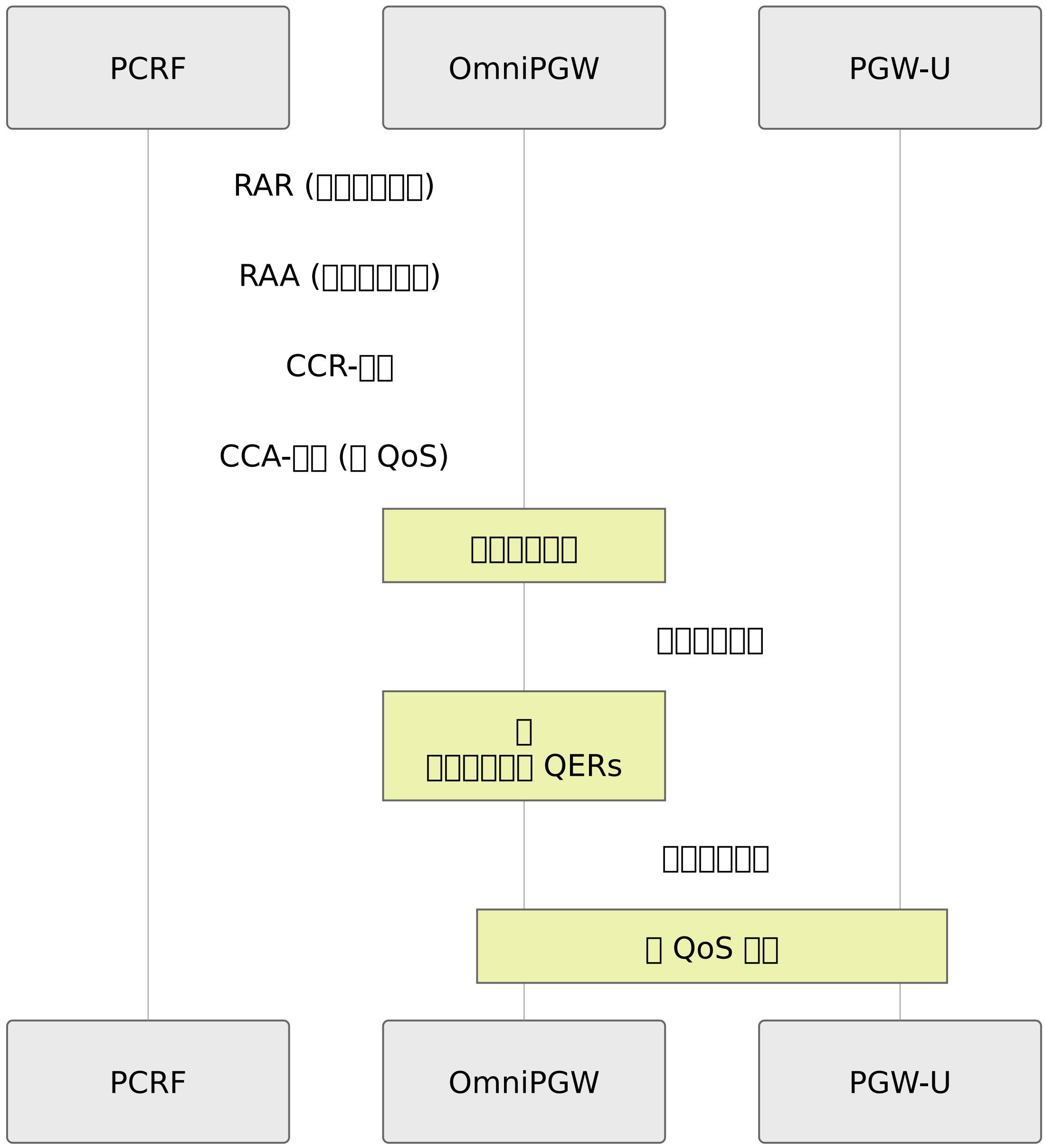
□□□□

□□□

□□□□□□□□□□□□□□

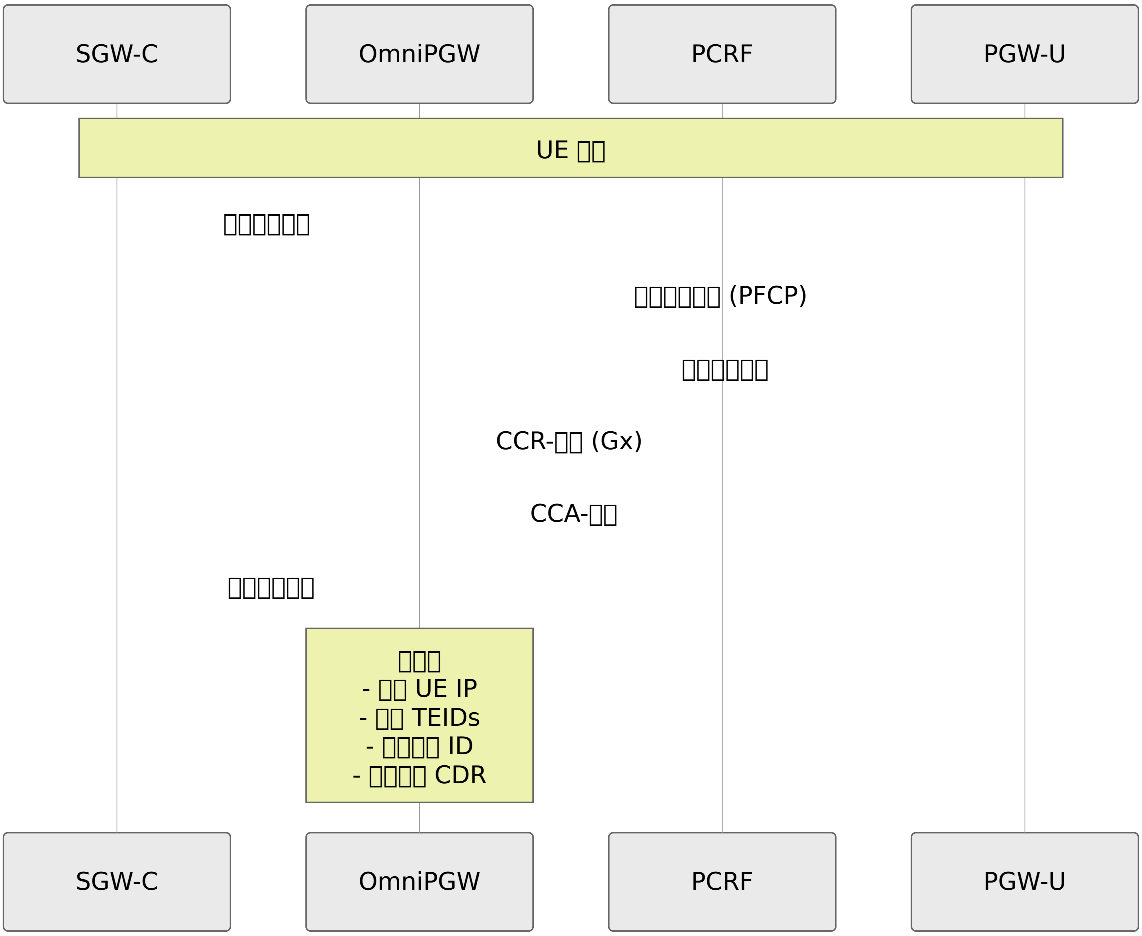
- **QoS** □□ - PCRF □□□□□
- □□□□ - □□/□□□□□□
- □□ - SGW □□
- □□□□ - □□ PCRF □□ PCC □□

QoS □□□□


PCRF
OmniPGW
PGW-U
RAR (□□□□□□□)
RAA (□□□□□□□)
CCR-□□
CCA-□□ (□ QoS)
□□□□□□
□□□□□□
□
□□□□□□ QERs
□□□□□□
□ QoS □□
PCRF
OmniPGW
PGW-U

□□□□

□□□□



□□□□

□□□□□□

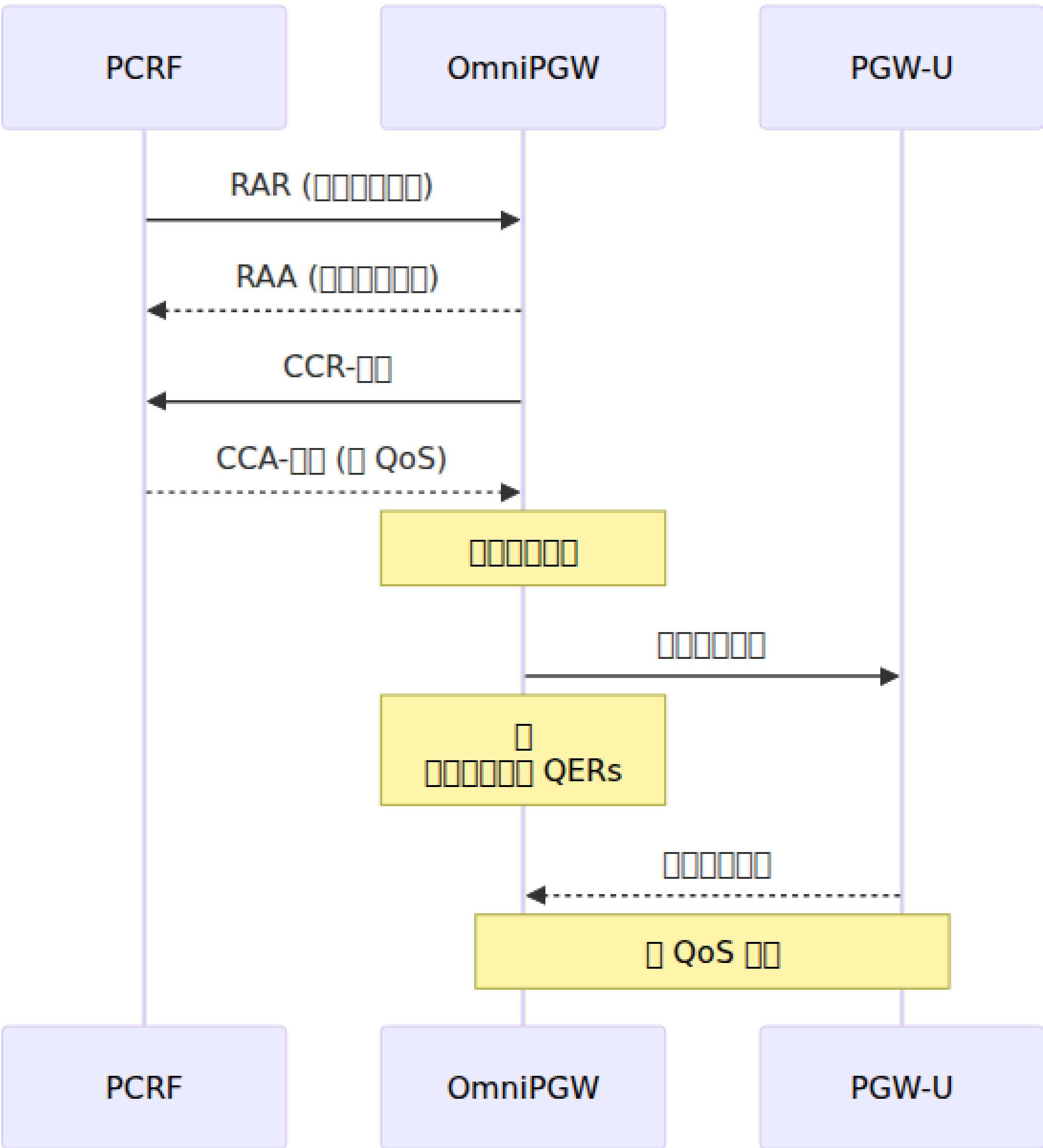
1. UE IP □□ → □□□□
2. TEID → □□□□□□□
3. SEID → □□□□□□□
4. □□-ID → □□□□□□□
5. □□-ID → □□
6. □□□□□□

□□□□□□□□

- □□□□□□□□□ CDR (□□□□□□) - □□□ □□ CDR □□

□□□□

□□□



PCRF
OmniPGW
PGW-U
RAR (□□□□□□□)
RAA (□□□□□□□)
CCR-□□
CCA-□□ (□ QoS)
□□□□□□
□□□□□□
□
□□□□□□ QERs
□□□□□□
□ QoS □□
PCRF
OmniPGW
PGW-U

□□□□

□□□□□□

```
□ TEID (S5/S8):
  TEID 0x12345678 → □□ PID

□ SEID (Sxb):
  SEID 0xABCDEF → □□ PID

□ □□-ID (Gx):
  "pgw.example.com;123;456" → □□ PID

□ UE IP:
  100.64.1.42 → □□ PID

□ IMSI + EBI:
  "310260123456789" + EBI 5 → □□ PID
```

□□□□

□□□□□

```
# □□□□□
teid_registry_count

# PFCP □□
seid_registry_count

# Gx □□
session_id_registry_count
```

□□□□

```
# □□□□□□
rate(s5s8_inbound_messages_total{message_type="create_session_request

# □□□□□□
rate(s5s8_inbound_messages_total{message_type="delete_session_request

# □□□□□□ (p95)
histogram_quantile(0.95,

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

□□□□

□□□□□□

□□□

1. **IP □□□** - □□□□□ IP
2. **PCRF □□���□** - Gx □□
3. **PGW-U □□** - □□ PFCP □□□□□
4. **PCRF □□** - □□□□□□□□

□□□

```
# □□ IP □
curl http://pgw:9090/metrics | grep address_registry_count

# □□ PCRF □□□
# □□□□□□ Gx □□

# □□ PGW-U □□
# □□ PFCP □□□□□
```

仪表板慢/冻结

症状：

- 仪表板页面卡顿
- 会话列表慢
- 浏览器标签页无响应或崩溃

解决：

1. 刷新浏览器标签页
2. 重启浏览器以清除内存
3. 检查网络

如有必要，

```
# 重启 OmniPGW (会中断会话)
# 仅在必要时使用
```

UE 无法获取服务

症状：

- UE 连接失败
- 会话创建失败并显示错误

检查可能的原因：

问题源	检查	修复
用户配置	PCRF 日志 (IMSI 未找到等错误)	添加用户配置
地址池已用尽	IP 池状态	扩充 IP 池
无法连接后端服务	PCRF/PGW-U 状态	检查连接性
不支持配置	无效 APN	添加 APN 等

□□□□

□□□□

□□□□□□□□

```
□□□□□□□10,000
□□□□□□□□□~10KB RAM
□□□ RAM□~100MB

Erlang VM □□□
  - □□□□□262,144 (□□)
  - □□□□□□□□□□□□
```

□□□□

□□□□□□□□

1. □□□□□□□□□□
2. □□□□□□□□□□□□□
3. □□□□□□□□□□□

□□□□

□□□□□

- □□□□□□□ (□□□□□□□)
- □□□□□□□□□□□□□□ (□□)
- DNS/□□□□□□□□□□□

□□□□□□

□□□□□□□□□□□

□□□□□ PDN □□□□□□□□□

UE □□□

- IMSI: "310260123456789" (□□□□)
- MSISDN: "14155551234" (□□□□)
- MEI/IMEI: □□□□□

PDN □□□□□

- APN: "internet" (□□□□)
- UE IP □□: 100.64.1.42 (□□□ IP)
- PDN □□: IPv4, IPv6 □ IPv4v6

□□□□□□

- □□ ID: □□□□□□□□
- □□□□ EBI: EPS □□□□□ (□□□ 5)

QoS □□□

- APN-AMBR: □□□□□□□
  - □□□100 Mbps
  - □□□50 Mbps

□□□□□

- PDRs (□□□□□□□): □□□□□
- FARs (□□□□□□): □□/□□□□
- QERs (QoS □□□□): □□□□
- BAR (□□□□□□): □□□□

□□□□□□

- S5/S8 □□: □□/□□ TEIDs, SGW-C □□
- Sxb □□: □□/□□ SEIDs, PGW-U □□
- Gx □��: Diameter □□-ID, □□□□□

Web UI - □□□□□□

OmniPGW □□□□□□ **Web UI** □□□□□□□□□□□□□□□□□□□

UE □□□□□□□

□□: `http://<omnipgw-ip>:<web-port>/ue_search`

□□: □□□□ UE □□□□□□□□□

□□□

1. □□□□ □□□□□□□□□□

- **IMSI** (□□□“310170123456789”)
- **MSISDN** (□□□□)

- **IP □□** (□□□“100.64.1.42”)

2. □□□□

- □□□□□□□□□□□
- □□□□□□□□□□□
- □□□□□□□□□□

3. □□□□□□ □□□□□□□□□□□□□□

a) □□□□

- □□□□□□□□□□
- IMSI, MSISDN, UE IP □□
- APN, RAT □□
- PGW TEID, SGW TEID

b) □□□□□□ □□□□□□□□□□□□

- **TAC** (□□□□□) - UE □□□□□□□
- □□ **ID (ECI)** - E-UTRAN □□□□□
- **ECGI** - E-UTRAN □□□□□□□ (PLMN + ECI)
- **MCC/MNC** - □□□□□□ / □□□□□□

□□□□□□□□ □□□□□ OpenCellID □□□□□□□□□□

- □□□□□□□ (□□/□□)
- □□□ Google □□□□□□□□□□□
- UE □□□□□□□□□□□□□□

□□□□□□ □□□□□□□ □□□□□□□□

c) □□□□ □□□□□□□□ QoS □□□

□□□□:

- EBI (EPS □□□□□)
- QCI (QoS □□□□)
- □□□□□□

- APN-AMBR (□□/□□)

□□□□ (□□□□□)□

- EBI, QCI, □□□□□□
- MBR UL/DL (□□□□□)
- GBR UL/DL (□□□□□)

d) □□□□ (Gy □□)

- Gy □□ ID
- □□□□, □□□□
- □□□□

e) □□□□ (Gx □□)

- Gx □□ ID
- PCRF □/□□□□
- CC □□□□
- □□□□□□□□ (□□□□□ PCC □□)

f) □□□□

- □□□□□□□□
- □□□□/□□/□□□□

[illegible]

- [illegible]
- [illegible]
- [illegible] IP [illegible]
- [illegible]

PGW [illegible]

[illegible]: `http://<omnipgw-ip>:<web-port>/pgw_sessions`

□□: □□□□□□□□ PDN □□

□□□

1. □□□□

- □□□□□□ (□ 2 □□□)
- □□□□□□□□□□□
- □□□□ - □□□□

2. □□□□□□ □□���□□□□

- **IMSI** - □□□□
- **UE IP** - □□□ IP □□
- **SGW TEID** - □□ SGW □ S5/S8 □□ ID
- **PGW TEID** - □□ OmniPGW □ S5/S8 □□ ID
- **APN** - □□□□□

3. □□□□ □□□□□□□□□□

- IMSI (□□□“310260”)
- UE IP □□ (□□□“100.64”)
- MSISDN / □□□□

- APN □□

4. □□□□□□□ □□□□□□□□□□□□□□□□□

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

□□□□□□

□□: `http://<omnipgw-ip>:<web-port>/topology`

□□: □□□□□□□□□□□□□□□

□□□

1. □□□□□

- □□□□□□□□□
- □□ PGW-C (□□□□) □□
- □□□ HSS (□□□□□□□) □□□
- □□□□□□□□

2. □□□□

- □□□□ (+/-)
- □□□□□□
- □□□□□□□□□□
- □□□□□□ (□□ = □□, □□ = □□)

3. □□□□

- □□□□□□□□□
- □□□□
- □□□□□□□□

□□□

- □□□□□□□□□□□
- □□□□□□
- □□□□□□
- □□□□□□□□

□□□□□□□□□

□□: `http://<omnipgw-ip>:<web-port>/session_history`

□□: □□□□□□□□□□□□□

□□□

1. □□□□

- □□□□□□□ (□□□□, □□□□, □□□□, □)
- □□□□□□ (□□□□ / □□□□)
- □ IMSI, MSISDN, IP □□□ TEID □□

2. □□□□

- □□□ CSV □□□□
- □□□□□□□□
- □□□□□□□□

3. □□□□□□□

- □□□□□□
- □□□□□□
- □□□□
- □□□□

□□□

- □□□□□□
- □□□□□□
- □□□□□□□
- □□□□□□
- □□□□□□□□□□□

□□□□

□□□□□

```
1. □□□□□□□□
2. □ IMSI □□□□□□ Web UI □□□
3. □□□□□□□ UE □ IP □□
4. □□ QoS □□□□□□□□□□
5. □□□□□□□□□□□
```

□□□□□

- □□□□□□□□□□□□□
- □□□□□□□□□
- □ APN □□□□□□

□□□□□

- □□□□□□□□□□□□
- □□□□□□□□□□□□ SSH/IEx
- □□ SGW □ PGW TEIDs □□□□□□□□□
- □□ PCRF □□□ AMBR □

□□□□□□□□□

- □□□□□□□□□□ (□□□□□□)
- □□□□□□□
- □□□□□□ (□□□ Mbps □□□□□□ bps)
- □□□□□□
- □□□□□□□

□□□□□□□

OmniPGW □□□ OpenCellID □□□□□□□□ UE □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

□□

□□□□UE □□□□□□

- □□□□□□ (□□/□□)
- □□□□□□□□□ Google □□□□
- □□□□□□□□□□□□
- □□□□□□□□□□□□□

□□

□□□□□□ `http://<omnipgw-ip>:<web-port>/cell_towers` □□□ **“□□□□□□□”** □□□□□□□□□□□□□□□□□□□□

□□□

- □ OpenCellID.org □□□□□□

- [illegible] SQLite
- [illegible] ([illegible] 10-15 [illegible])
- [illegible] Web [illegible]
- [illegible]

[illegible] [illegible]“[illegible]���[illegible]”[illegible]

[illegible]

[illegible]

- SQLite DB: `priv/cell_towers.db`
- CSV [illegible] ([illegible]): `priv/data/cell_towers.csv.gz`
- [illegible] MCC, MNC, LAC, CellID [illegible]

[illegible]

- [illegible] OpenCellID.org [illegible] 107 MB
- [illegible] 10-15 [illegible]

[illegible]

- [illegible] (<1ms)
- [illegible]
- [illegible] UE [illegible]

[illegible]

[illegible]

UE [illegible]

- [illegible]
- [illegible] Google [illegible]
- [illegible]

[illegible] **Web UI**[illegible]

- □□□□□□□□□ (□□□□, □□□□□, □□□□)
- □□□□□□□□□ - □□□□□□□□ OpenCellID □□
- □□□□□□□
- □ MCC, MNC, LAC, Cell ID □□
- □□□□□□□□□
- □□□□□□□□□□□□□□□□

□□□□□

- □□□□□□□□□□□
- □□□□□□
- □□□□□□□□□
- □□□□□□□□□□

□□□□□

OpenCellID □□□□□□□□□□□□□□

□□□□□□□□□

1. □□□ `http://<omnipgw-ip>:<web-port>/cell_towers`
2. □□ **“□□□□□□□”** □□
3. □□□□□□□□□□□
4. □□ 10-15 □□□□□□□□□/□□
5. □□□□□□□□□□□□□□

□□□□□□□ □□□□□□

□□□ OpenCellID □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

□□□□

□□□□□□□

- □□□ OpenCellID.org □□□□□□
- □□□□□□□ HTTPS □□
- □□□□□□ (□□ ~200 MB □□□□□)

- □□□□□□□□□□□□□□□□□
- OpenCellID □□□□□□□□ - □□□□□□□□□
- □□ Web UI □□□□□□□□□□□□□

□□□□□□□□

- □□ `priv/` □□□□□□□□□□□
- □□□□□□□□□□□□ (~150 MB □□□□□)
- □□□□□□□□□□□□ `priv/` □□□/□□□□

□□□□□□

- □□□□□□□□□□□□
- OpenCellID □□□□□□□□□□□□□
- □□□□□□□□□□□□□□□

□□□□□□

- □□□□□□ JavaScript □□□□□□□
- □□ Google □□□□□□
- □□□□□□□□□□

□□��□

□□□□□□

- **PFCP □□** - □□□□□□□□, PDRs, FARs, QERs, URRs
- **UE IP □□** - IP □□□□, APN □□□
- **PCO □□** - □□□ UE □ DNS, P-CSCF, MTU □□
- **□□□□** - UPF □□, □□□□□□

□□□□□

- **Diameter Gx □□** - PCRF □□□□, PCC □□, QoS □□
- **Diameter Gy □□** - OCS □□□□, □□□□

- **[illegible] CDR [illegible]** - [illegible]

[illegible]

- **S5/S8 [illegible]** - GTP-C [illegible], SGW-C [illegible]
- **QoS [illegible]** - [illegible] QoS [illegible]

[illegible]

- [illegible] - [illegible], [illegible], [illegible]
- **P-CSCF [illegible]** - IMS [illegible]

[illegible]

OmniPGW [illegible] - *[illegible] Omnitouch [illegible]*

OmniPGW [illegible]

[illegible]

[illegible] Omnitouch [illegible]

[illegible]

[illegible]

[illegible] OmniPGW [illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]

- [illegible] - Prometheus [illegible]

- □□□□ - □□□□□□

□□□□□□

Web UI

□□□ `http://<omnipgw_ip>:4000`

□□□□□

- **/pgw_sessions** - □□□□□□□□□□ IMSI□IP□MSISDN□APN □□□
- **/diameter** - Diameter □□□□□Gx PCRF□Gy OCS□
- **/pfcp_peers** - PFCP □□□□□PGW-U □□□□
- **/logs** - □□□□□□□□□□□

Prometheus □□

□□□ `http://<omnipgw_ip>:9090/metrics`

□□□□□

- `teid_registry_count` - □□□□
- `address_registry_count` - □□□ UE IP
- `sxb_inbound_errors_total` - PFCP □□
- `gx_inbound_errors_total` - Diameter Gx □□
- `gy_inbound_errors_total` - Diameter Gy □□

□□□ □□□□ □□□□□□□□□□

□□□□

Web UI□ □□ /logs □□□□□□□□□□

□□□□□□□□

- "create_session_request" - □□□□
- "Credit Control" - Gx/Gy □□
- "PFCP Session" - □□□□□□
- "error" □ "ERROR" - □□□□
- "timeout" - □□□□

□□□□□□

□□□□□□□□□□□□□□□□ "□□□□□□"

□□□

- SGW-C □□□□□□□□□□□□ "□□□□□□" (73)
- □□□□□□□□□□
- □□□□□□□□
- □□□`[PGW-C] □□□□□□□□□□ - □□□□□`

Wireshark □□□□□□□□□□□□□□□□ "□□□□□□"

□□□□□

- □□□□□□ OmniPGW □□□

- □□□□□□□□□□

□□□

1. □□□□□□□□

   ```
   license_status
   ```

   - □□ 0 □□□□□□□

2. □□□□□□□□□□□□

   - □□ "license" □ "License"
   - □□ "□□□□□□□□□□" □□

3. □□□□□□□□□□□□

   - □□ `config/runtime.exs` □ `:license_client` □□□□ URL
   - □□□`https://localhost:10443/api`

□□□□□

1. □□□□□□□□□□□□□□

   ```
   curl -k https://<license_server_ip>:10443/api/status
   ```

2. □□ **`config/runtime.exs`** □□□□□□□□

   ```
   config :license_client,
     license_server_api_urls:
   ["https://<license_server_ip>:10443/api"],
     licensee: "□□□□□□"
   ```

3. □□□□□□□□□□□□□

   - □□□□□`omnipgwc`
   - □□ Omnitouch □□□□□□□

4. □□□□□□□□ **OmniPGW**

□□□

- □□ `license_status` □□□□□□□□□
- □□□□□□□□□□□□□
- □□□□□□□□□□□□□

□���□□□□□□□□□□□□□□□□

□□□

- SGW-C □□□□□□□□□□□□□□□
- □□□□□□ PDN □□
- □□□`s5s8_inbound_errors_total` □□

□□□□□

1. IP □□□
2. PCRF (Gx) □□□□□□□□□
3. PGW-U (PFCP) □□□
4. □□□ APN □□

□□□

1. □□ **IP** □□□□□

   ```
   address_registry_count
   ```

   - □□□□□□□□□□□□□□□□

2. □□ **PCRF** □□□□

   - Web UI → **/diameter** □□
   - □□ PCRF □□□□ = "disconnected"
   - □□□□□ "Credit Control Answer" □□□□□

3. □□ **PFCP** □□□□

   - Web UI → **/pfcp_peers** □□
   - □□ "Association: DOWN"
   - □□□`pfcp_peer_associated` = 0

4. □□ **APN** □□□

   - □□ `config/runtime.exs` □□ `ue.apn_map`
   - □□□□ APN □□□□□□□

□□□□

□□ IP □□□

1. □□□□□□Web UI → **/pgw_sessions**□□□□□
2. □ `config/runtime.exs` □□□ IP □□

```
config :pgw_c,
  ue: %{
    subnet_map: %{
      "internet" => "10.0.0.0/23"  # □ /24 □□□ /23□□□□□
    }
  }
```

3. □□ OmniPGW
4. □□□`curl http://<ip>:9090/metrics | grep address_registry_count`

□□ PCRF □□□□

1. □□□□□□`ping <pcrf_ip>`
2. □□ PCRF Diameter □□□`telnet <pcrf_ip> 3868`
3. □□ `config/runtime.exs` □□ Diameter □□□
4. □□□□□□□□ OmniPGW
5. □□ Web UI → **/diameter** □□□□□□□ "connected"□

□□ PFCP □□□

- □□□ PFCP / □□□□□ □□

[illegible]

- [illegible] IP [illegible] 80% [illegible]
- [illegible] PCRF [illegible] Diameter [illegible]
- [illegible]

[illegible]

[illegible]

- [illegible] Web UI [illegible]
- [illegible]
- [illegible]

[illegible]

1. PFCP [illegible] S5/S8 [illegible]
2. PCRF CCR-Initial [illegible]
3. [illegible]
4. [illegible]

[illegible]

1. [illegible] **Web UI** [illegible]
   - **/pgw_sessions** → [illegible] IMSI [illegible]
   - [illegible] `pfcp_seid` [illegible] PFCP [illegible]
   - [illegible] `gx_session_id` [illegible] Gx [illegible]
2. [illegible] **IMSI**[illegible]
   - [illegible] IMSI [illegible]
   - [illegible] "Session Establishment Request"[illegible]PFCP[illegible]
   - [illegible] "Credit Control Request"[illegible]Gx[illegible]
   - [illegible]
3. [illegible]

```
# □ TEID □□□ PFCP □□□□□
teid_registry_count - seid_registry_count

# □ TEID □□□ Gx □□□□□
teid_registry_count - session_id_registry_count
```

□□□□□

1. □□ **PFCP □□□□□**

    - □□ PGW-U □□□□□□□□
    - □□ PFCP □□□Web UI → **/pfcp_peers**
    - □ SGW-C □□□□□□□□□□□

2. □□ **Gx □□□□□**

    - □□ PCRF □□□`histogram_quantile(0.95, rate(gx_outbound_transaction_duration_bucket[5m]))`
    - □□□□□□ `config/runtime.exs` □□□ Gx □□
    - □□□□□□□□□□□

3. □□□□□□□□□□□

    - □□□□□□ OmniPGW □□□□□□□□
    - □□□□□□□ `teid_registry_count` □□□□□

□□□

- □□ PFCP □ Gx □□□□
- □□□□/□□□□□□□□□□□□□
- □□□□□□□□□□□□

PFCP / □□□□□□

□□□PFCP □□□□

□□□

- Web UI → **/pfcp_peers** □□ "Association: DOWN"
- □□□□□□□□□□□
- □□□`pfcp_peer_associated` = 0
- □□□"PFCP □□□□" ��� "□□□□□□"

□□□□□

1. PGW-U □□□□□□□□□□
2. PGW-U □□□□□
3. PFCP □□□□□□IP□□□□
4. □□□□□ UDP 8805

□□□

1. □□□□□□□

   ```
   ping <pgw_u_ip>
   nc -u -v <pgw_u_ip> 8805
   ```

2. □□ **PFCP** □□□

   - □□ `config/runtime.exs` □□ `upf.peer_list`
   - □□ IP □□□□□ ID □□□ PGW-U □□□□

3. □□ **PGW-U** □□□

   - □□ PGW-U □□
   - □□ PGW-U □□□□□□□`systemctl status omnipgw_u`□□□□□□□

4. □□□□□

```
# □□□□
pfcp_consecutive_heartbeat_failures

# PFCP □□□
rate(sxb_inbound_errors_total[5m])
```

□□□□□

1. □□□□□□□
   - □□□□□`traceroute <pgw_u_ip>`
   - □□□□□□□□□□ UDP 8805 □□□
   - □□□□□□□□□□□□□
2. □□ **PGW-U □□□**
   - □□ PGW-U □□
   - □□ 30 □□□□□□□□
   - □□ Web UI → **/pfcp_peers** □□□□□□ "Association: UP"□
3. □□□□□□□
   - □□ `config/runtime.exs` □□ PFCP □□□□
   - □□ OmniPGW
   - □□□□□□□□

□□□

- □□ `pfcp_peer_associated` □□□□□���□□□
- □□ `pfcp_consecutive_heartbeat_failures`□□□□□ > 2□
- □□□□ PGW-U □□
- □□ PFCP □□□□/□□□□□□□□□□

□□□PFCP □□□□□□

□□□

- □□□□□□□□
- QoS □□□□□□□ PCRF RAR□□□
- □□□"□□□□□□□□"
- □□□ `sxb_inbound_errors_total{message_type="session_modification_response"}` □□

□□□□□

1. □□□ PFCP □□□PDR/FAR/QER □□□
2. PGW-U □□□□
3. □□ ID □□
4. PGW-U □□□□

□□□

1. □□□□□
   - □□ "□□□□" □ SEID
   - □□ PFCP □□□□□□□□□□
   - □□□□□"□□ ID □□□"□"□□□□"
2. □□ **PGW-U** □□□
   - □□ PFCP □□□□
   - □□□□□□□□CPU□□□□
3. □ **Web UI** □□□□□□□□
   - **/pgw_sessions** → □ IMSI □□□□
   - □□ `pdr_map`□`far_map`□`qer_map` □□□□□□
   - □□□□ ID

□□□□□

1. □□□□□□□
   - □□□□□□□□□□□
   - □□□□□□□□□□□□□ UE □□□□

2. □□ **PGW-U □□□□□**

   - □□ PGW-U □□□□□□PDR□□□□□
   - □□□□□□□ PGW-U
   - □���□□□ PGW-U □□□□□□□□

3. □□□□□□□

   - □□□□□□□□□□Web UI □□□□□□□
   - □□ PFCP □□□□
   - □□□□□□□□□□□□□

□□□

- □□ PGW-U □□□□□
- □□□□□□□□□□□□□□□
- □□ `sxb_inbound_errors_total` □□□□□

Diameter (Gx/Gy) □□

□□□PCRF □□□□□□□Gx□

□□□

- Web UI → **/diameter** □□ PCRF □□ "disconnected"
- □□□□□□□ QoS □□□□□□□ QCI=5□
- □□□"Diameter □□□□□□" □ "CER/CEA □□"

□□□□□

1. PCRF □□□□□□□□□□
2. PCRF □□□□
3. Diameter □□□□□□Origin-Host□Realm□
4. □□□□□ TCP 3868

□□□

1. □□□□□□□

   ```
   ping <pcrf_ip>
   telnet <pcrf_ip> 3868
   ```

2. □□ **Diameter** □□□

   - □□ `config/runtime.exs` □□ `diameter.peer_list`
   - □□ `host`□`realm`□`ip` □□□ PCRF □□□□
   - □□ `origin_host` □□□ PCRF □□□□□

3. □□ **PCRF** □□□

   - □□□□ PGW-C □ CER□□□□□□□□
   - □□□□□□

4. □□□□□

   ```
   # Diameter □□□□
   diameter_peer_connected{peer="<pcrf_host>"}
   ```

□□□□□

1. □□□□□□□

   - □□□ PCRF □□□
   - □□□□□□□□□□ TCP 3868 □□□
   - □□□□□□`nc -v <pcrf_ip> 3868`

2. □□ **PCRF** □□□□□

   - □□ PCRF □□
   - □□□□□□□□□□30 □□□□□□
   - □□ Web UI → **/diameter** □□

3. □□□□□□□□

   - □□ `config/runtime.exs` □□ Diameter □□□

```
config :pgw_c,
  diameter: %{
    host: "pgw-c.epc.mnc999.mcc999.3gppnetwork.org",  # □□□
PCRF □□□□
    realm: "epc.mnc999.mcc999.3gppnetwork.org",
    peer_list: [
      %{
        host: "pcrf.epc.mnc999.mcc999.3gppnetwork.org",
        realm: "epc.mnc999.mcc999.3gppnetwork.org",
        ip: "192.168.1.100",
        initiate_connection: true
      }
    ]
  }
```

  - □□ OmniPGW
  - □□□□□□□□

□□□

- □□ Diameter □□□□□□□□□□□□
- □□□□ PCRF □□□□□□□□
- □□□□□□□□□ Diameter □□

□□□CCR/CCA □□□Gx □□□□□

□□□

- □□□□□□□> 5 □□
- □□□"□□□□□□□□"
- □□□`gx_outbound_transaction_duration` □□□□> 5s□
- □□□□□□□□□□ QoS□□□□□□

□□□□□

1. PCRF □□
2. PCRF □□□□□
3. □□□□

4. PCRF □□□□

□□□

1. □□ **Gx □□□**

```
# P95 □□
histogram_quantile(0.95,
rate(gx_outbound_transaction_duration_bucket[5m]))

# P99 □□□□□□□
histogram_quantile(0.99,
rate(gx_outbound_transaction_duration_bucket[5m]))
```

2. □□ **PCRF □□□□□**

   - □□ PCRF □□□□□
   - □□ CPU□□□□□□□□□
   - □□ PCRF □□□□□□□□

3. □□□□□□□

```
ping -c 100 <pcrf_ip> | tail -1  # □□□□□□
```

4. □□□□□

   - □□ CCR/CCA □□□□□□□ "□□□□"
   - □□ "□□ CCR" □ "□□ CCA" □□□□□

□□□□□

1. □□ **PCRF □□□**

   - □□ PCRF□□□□□□
   - □□□□□□□ CCR □□□□
   - □□ PCRF □□□/□□□

2. □□□□□□□

- □□□□□□□□□□□□□□□
- □□□ PGW-C □ PCRF □□□□□□□

3. □□□□□□□□□□□□□

- □□ `config/runtime.exs`□

```
config :pgw_c,
  diameter: %{
    transaction_timeout_ms: 10000  # □□□□ 5000 □□
  }
```

- □□ OmniPGW
- □□□ □□□□□□□□□□□□□□

□□□

- □□ Gx □□□□□□□□□□ > 1s□□□ > 5s□
- □□□□□□□□□□□ PCRF □□□□
- □□□□□□ PCRF □□

□□□OCS □□□□□□□Gy□

□□□

- Web UI → **/diameter** □□ OCS □□ "disconnected"
- □□□□□□□□□□□□□□
- □□□"Gy □□□□□□"

□□□□□□□□

□□□ PCRF □□□□□□□□□□ Gy □□□

□□□□□

- □□□□□□ TCP 3868□□ Gx □□□
- □□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□
- □□□□□ `diameter.peer_list` □□ OCS □□

□□□ Diameter Gy □□ □□□ Gy □□□□□□□

IP □□□□

□□□IP □□□

□□□

- □□□□□□□□□□□□□ "□□□□□□"
- □□□`address_registry_count` □□□□□□□□
- Web UI → **/pgw_sessions** □□□□□□□□
- □□□"IP □□□□□□□□"

□□□□□

1. □□□□□□□□□
2. □□□□□ IP□□□□□□□□
3. □□□□□□□□□
4. IP □□□□

□□□

1. □□□□□□□

```
# □□ /24 □□□254 □ IP□
(address_registry_count / 254) * 100
```

2. □□□□□□□□□
   - □□ `config/runtime.exs` □□ `ue.subnet_map`
   - □□□"10.0.0.0/24" = 254 □□□ IP

3. □□□□□□□ **IP** □□□

```
# □□□□□
teid_registry_count
address_registry_count
```

4. □□□□□□□

   ◦ Web UI → **/pgw_sessions**
   ◦ □□□□□□□□□
   ◦ □□□□□□□□□□□□□□

□□□□□

□□□□□□□□

1. □□ `config/runtime.exs`□

```
config :pgw_c,
  ue: %{
    subnet_map: %{
      "internet" => "10.0.0.0/22"  # 1022 □ IP□□□□ /24 = 254 □
IP□
    }
  }
```

2. □□ OmniPGW
3. □□□□□□□□□□□

□□□□□□□

1. □ Web UI □□□□□□□
2. □ SGW-C □□□□□□□□□□
3. □ PCRF/SGW □□□□□□□□□
4. □□ `address_registry_count` □□□□□□□□□□□

□□□

- □□ IP □□□□□□□□□□
  ◦ □□□> 70%
  ◦ □□□> 85%

- □□□□□□□□□
- □□���□□□□□
- □□□□□□

□□□□□□□□ IP □□

□□□

- UE □□ IP □□□□
- □□□□□ "IP □□□"
- Web UI □□□□□□□□□□□ IP □□

□□□□□

1. □□□□□□□□
2. □□□□□□□□□□
3. □□□□□□

□□□

1. □ **Web UI □□□ IP**□
    - **/pgw_sessions** → □ IP □□□□
    - □□□□□□□ IMSI □□□□□ IP
2. □□□□□
    - □□ IP □□
    - □□ "IP □□" □□

□□□□□

1. □□□□□□□□□
    - □□□□□□ IP □□ IMSI
2. □□□□□□□
    - □ SGW-C □□□□□□□□□□□□□□□ IMSI

- [illegible]

3. **UE [illegible]**
    - UE [illegible]
    - [illegible] IP

4. [illegible]
    - [illegible] OmniPGW [illegible] IP [illegible]
    - [illegible]

[illegible]

- [illegible]
- [illegible]

□□□□

□□ Prometheus □□

```
# □□□□
teid_registry_count

# □□□□□□□□□□
rate(s5s8_inbound_messages_total{message_type="create_session_request

# IP □□□□□□□ /24 □□□
(address_registry_count / 254) * 100

# P95 □□□□□□
histogram_quantile(0.95,
rate(s5s8_inbound_handling_duration_bucket{request_message_type="crea
[5m]))

# □□□
rate(s5s8_inbound_errors_total[5m])

# PCRF □□
histogram_quantile(0.95, rate(gx_outbound_transaction_duration_bucket

# PFCP □□□□
pfcp_peer_associated
```

□□□□□□□□Web UI□

□□□	□□
IMSI	□□□□□□□□□□□
"create_session"	□□□□□□
"delete_session"	□□□□□□
"Credit Control"	Gx PCRF □□
"PFCP Session"	□□□□□□
"error"	□□□□□□
"timeout"	□□□□
"Association"	PFCP □□□□

□□□□□□

```
# □□□□□□
systemctl status omnipgw_c

# □□ Web UI
curl http://<omnipgw_ip>:4000

# □□□□□□
curl http://<omnipgw_ip>:9090/metrics

# □□□□□□
curl http://<omnipgw_ip>:9090/metrics | grep teid_registry_count

# □□ PFCP □□
curl http://<omnipgw_ip>:9090/metrics | grep pfcp_peer_associated

# □□ IP □□□□□
curl http://<omnipgw_ip>:9090/metrics | grep
address_registry_count
```

□□□□

- □□□□ - Prometheus □□□Grafana □□□□□□
- □□□□ - □□□□□□
- □□□□ - □□□□□□□□□□
- **PFCP □□** - PFCP □□□□□□□□
- **Diameter Gx □□** - Gx □□□□□□
- **Diameter Gy □□** - Gy □□□□□□
- **QoS □□□□□** - QoS □□□□

□□□□□□

OmniPGW □□□□□□ - *□ Omnitouch □□□□□□*

UE IP □□□□□

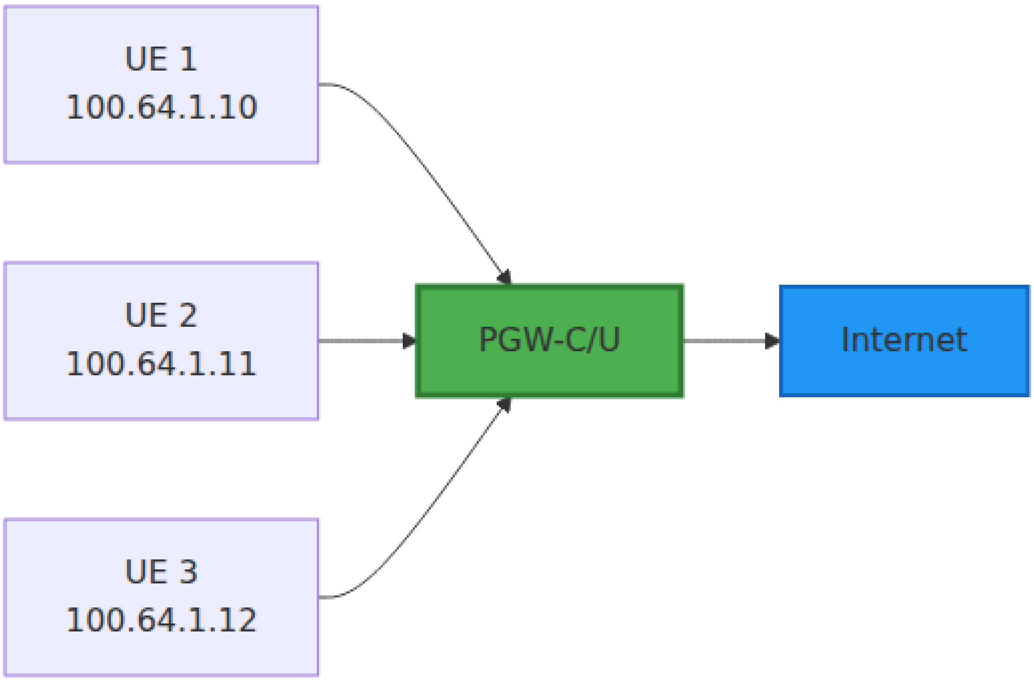
□□□□□ IP □□□□

□□

□□

PGW-C □ UE□□□□□□□□ PDN□□□□□□□□□□□□□ IP □□□□□□□□□□□□□□□□□□□□□□□□□□□□□

□□□ IP □□□□□



□□ UE □ PGW-C □□□□ □□□ **IP** □□□□□□□

- □□□□□□□□
- □□□□□□□
- □□□□□□□□□
- □ PDN □□□□□□□□

□□□ IP □□

IP □□	**���□**	**□□**
IPv4	□ □□	□□ IPv4 □□
IPv6	□ □□	IPv6 □□□□□
IPv4v6	□ □□	□□□IPv4 □ IPv6□

IP □□□□

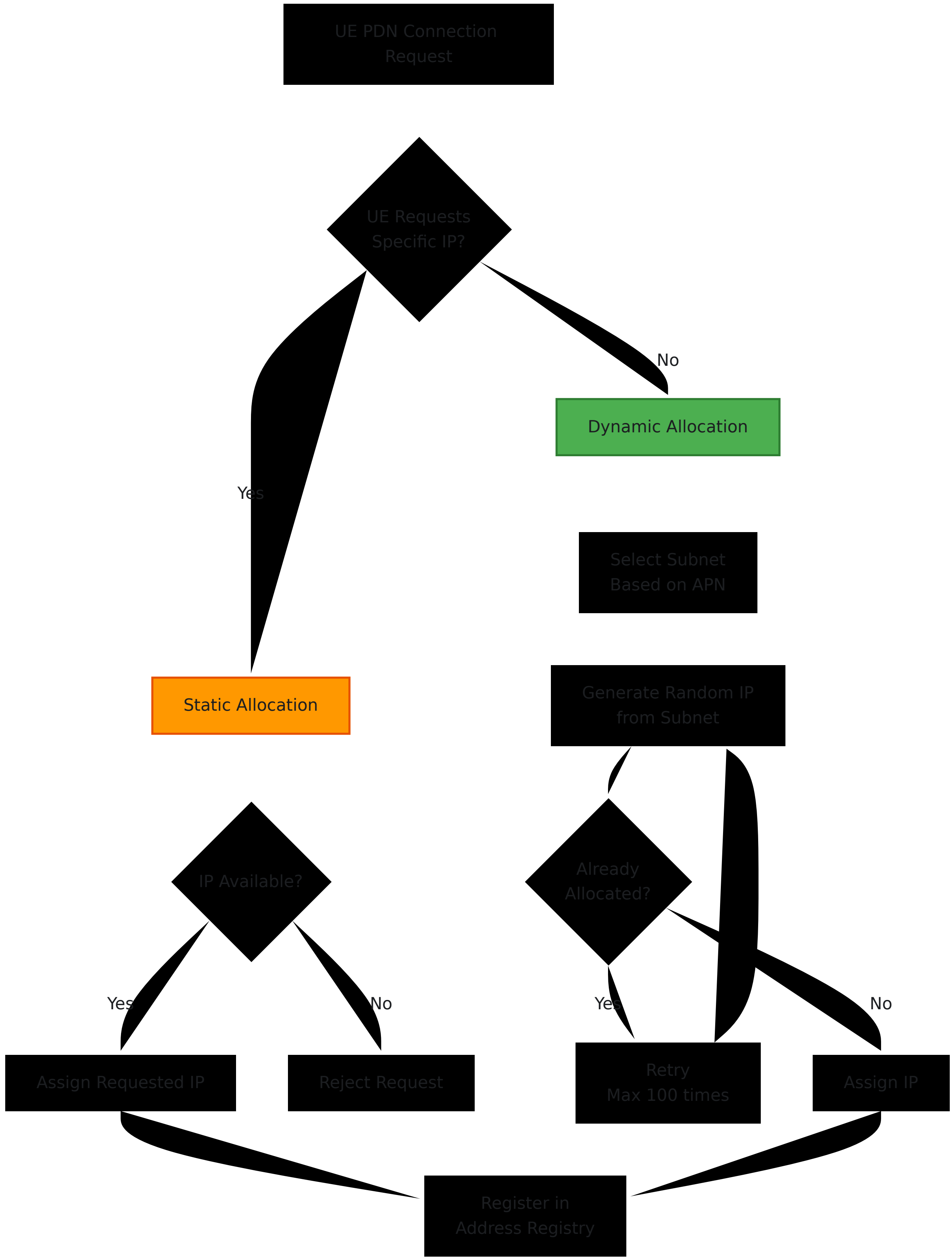
PDN □□

□ UE □□ PDN □□□□□□□□□ **PDN □□□**

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

□□□□

PGW-C □□□□ IP □□□□□



1. □□□□□□□□□□□

- PGW-C □□□□□□□□□ IP
- □□□□□□□□□□□□

- [illegible]

2. [illegible]

- UE [illegible] GTP-C [illegible] IP
- PGW-C [illegible]
- [illegible] IP [illegible]

[illegible] APN [illegible]

[illegible] **APN**[illegible] [illegible] IP [illegible]


UE Requests
Specific IP?
Yes
No
Dynamic Allocation
Select Subnet
Based on APN
Static Allocation
Generate Random IP
from Subnet
IP Available?
Already
Allocated?
Yes
No
Yes
No
Assign Requested IP
Reject Request
Retry
Max 100 times
Assign IP
Register in
Address Registry

□□□

- □□□□ - □□ APN □□□□□□□
- □□□□□ - □□ APN □□□□□□

- □□□□ - □□□□□□□□□□□□□
- □□ - □□□□□□□□□□□

□□□□□

□□□□□ □□□□□□ IP□

□□	□□
□□	□□ UE IP → □□□□ PID
□□	□□ UE 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` □□□□

□□ APN □□□□

□□□□□□□□

```
config :pgw_c,
  ue: %{
    subnet_map: %{
      "internet" => [
        "100.64.1.0/24",
        "100.64.2.0/24",
        "100.64.3.0/24",
        "100.64.4.0/24"
      ]
    }
  }
```

□□□□□

- PGW-C □□□□□□□□□□□□
- □□□□□□□□□
- □□□□□□□□□□□□

□□□

- □□□□□□□□□□□
- □□□□□□□□□□□□□□
- □□□□□□□

□□□□□□

```
config :pgw_c,
  ue: %{
    subnet_map: %{
      # □□□□□□□
      "internet" => [
        "100.64.0.0/20"     # 4094 □□□□□□□□ IP
      ],

      # IMS□□□ LTE □□□□
      "ims" => [
        "100.64.16.0/22"    # 1022 □□□ IMS □ IP
      ],

      # □□ APN
      "enterprise.corp" => [
        "10.100.0.0/16"     # 65534 □□□□□□ IP
      ],

      # IoT □□□□□□□□
      "iot.m2m" => [
        "100.64.20.0/22"    # 1022 □□□ IoT □ IP
      ],

      # □□□□
      default: [
        "42.42.42.0/24"     # 254 □□□□□ APN □ IP
      ]
    }
  }
```

IPv6 □□

```
config :pgw_c,
  ue: %{
    subnet_map: %{
      "internet" => [
        # IPv4 □
        "100.64.1.0/24"
      ],
      "internet.ipv6" => [
        # IPv6 □□□□□□□
        "2001:db8:1::/48"
      ],
      default: [
        "42.42.42.0/24"
      ]
    }
  }
```

IPv6 □□□□□

- UE □□□□□□ /64 □□
- □□ UE □□□□ IP□□□□□□□□□□□
- □□□UE □□ `2001:db8:1:a::/64`

□□□IPv4v6□□□

```
config :pgw_c,
  ue: %{
    subnet_map: %{
      "internet" => [
        "100.64.1.0/24",        # IPv4 □
        "2001:db8:1::/48"       # IPv6 □□□□□ IPv6 □□□
      ]
    }
  }
```

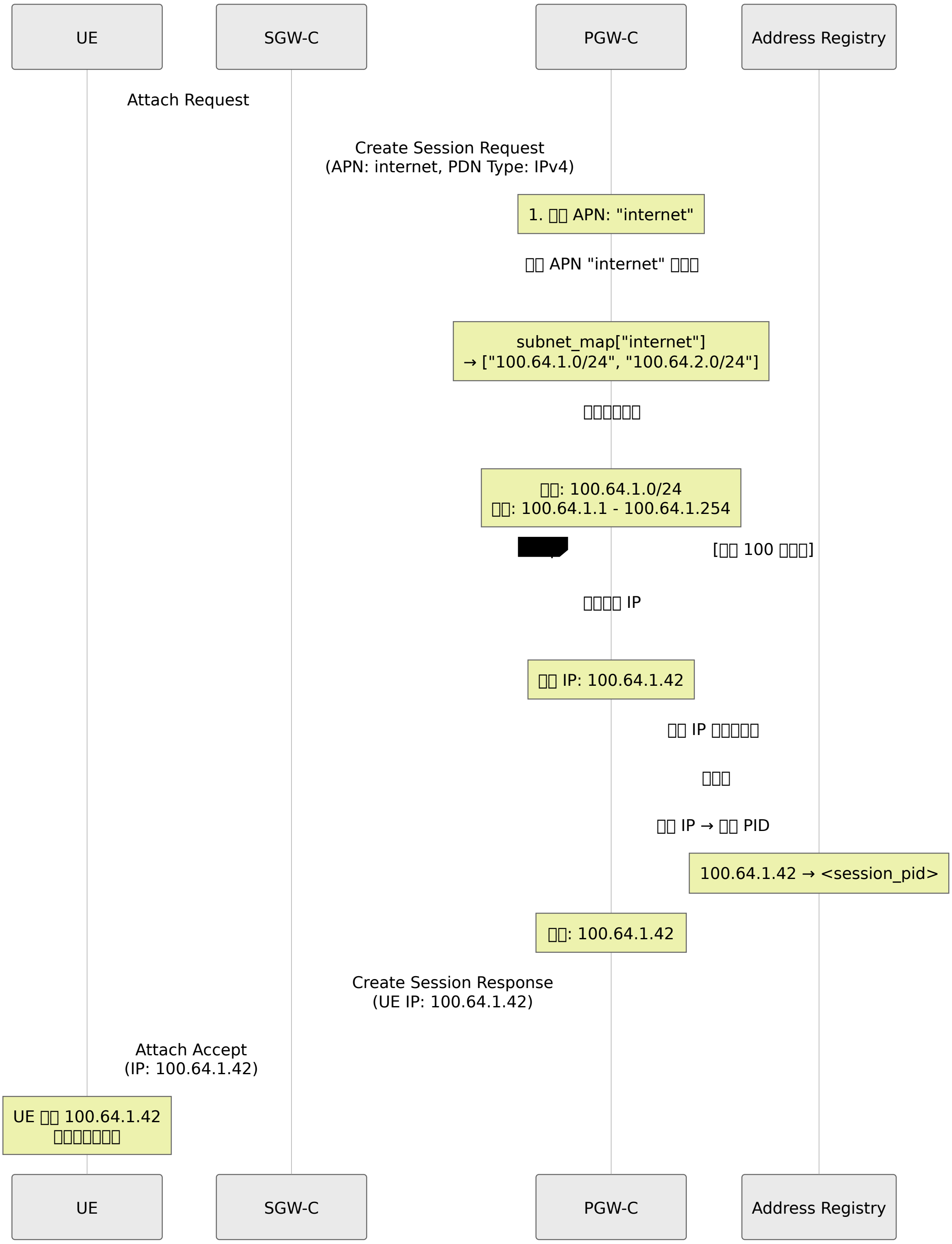
□□□□□

- UE [illegible] PDN [illegible]IPv4v6
- PGW-C [illegible] IPv4 [illegible] IPv6 [illegible]
- [illegible]

[illegible]

IP [illegible] PGW-C [illegible] S5/S8 [illegible] GTP-C [illegible] S5/S8 [illegible] [illegible] [illegible] [illegible]

□□□□□ IPv4 □□



UE
SGW-C
PGW-C
Address Registry
Attach Request
Create Session Request
(APN: internet, PDN Type: IPv4)
1. □□ APN: "internet"
□□ APN "internet" □□□
subnet_map["internet"]
→ ["100.64.1.0/24", "100.64.2.0/24"]
□□□□□□
□□: 100.64.1.0/24
□□: 100.64.1.1 - 100.64.1.254
[□□ 100 □□□]
□□□□ IP
□□ IP: 100.64.1.42
□□ IP □□□□□
□□□
□□ IP → □□ PID
100.64.1.42 → <session_pid>
□□: 100.64.1.42
Create Session Response
(UE IP: 100.64.1.42)
Attach Accept
(IP: 100.64.1.42)
UE □□ 100.64.1.42
□□□□□□□
UE
SGW-C
PGW-C
Address Registry

□□□□

□□□□□□□

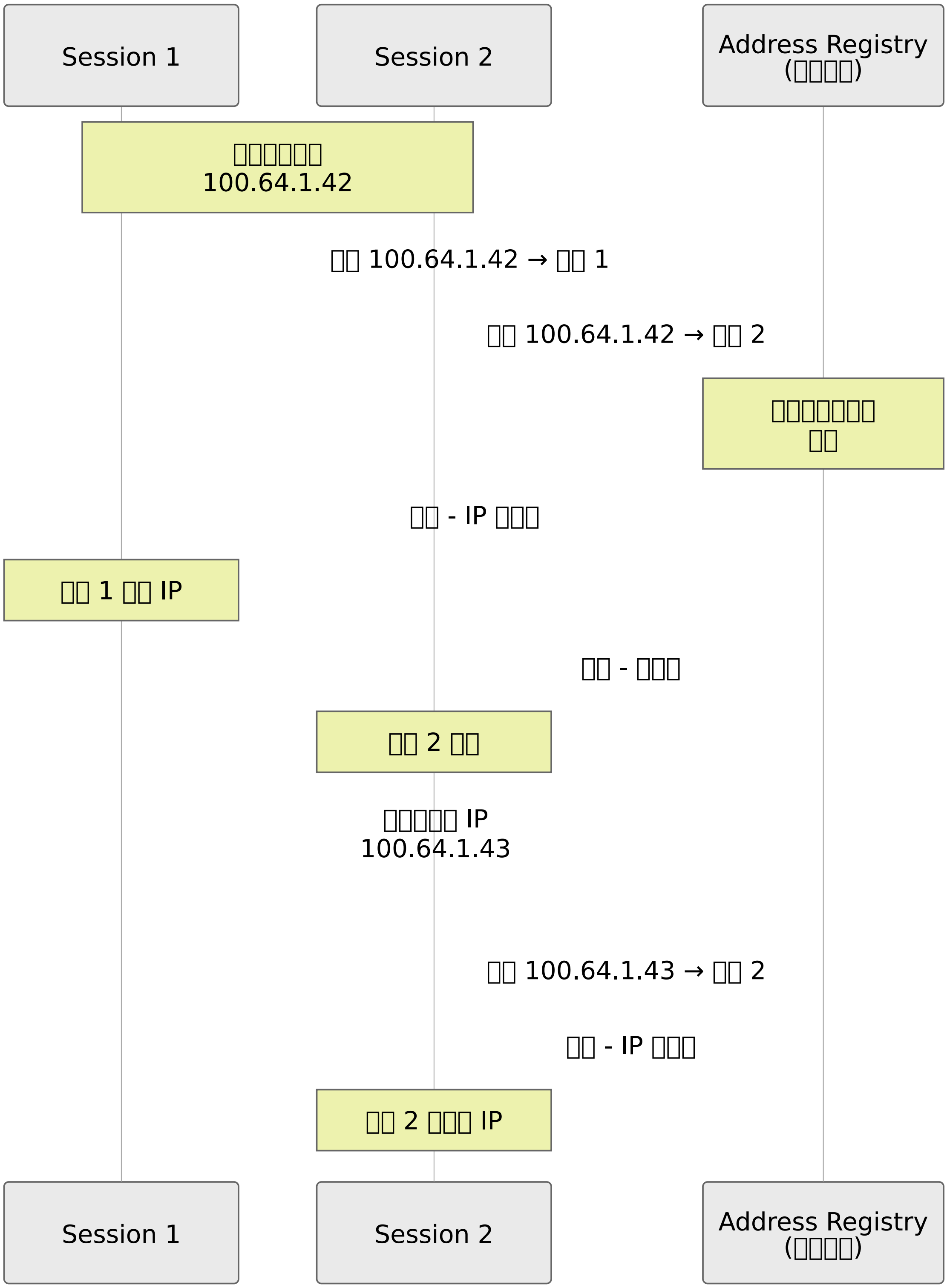
1. [illegible] [illegible] APN [illegible]
2. [illegible] [illegible]
3. **IP [illegible]** [illegible]��[illegible] IP
4. [illegible] [illegible] IP [illegible]
5. [illegible] [illegible] 100 [illegible] IP
6. [illegible] [illegible] IP[illegible]

[illegible]

- [illegible] **100 [illegible]** [illegible]
- [illegible] [illegible] IP [illegible]
- [illegible] [illegible]
- [illegible] [illegible] APN[illegible]

[illegible]

[illegible] [illegible] IP


Session 1
Session 2
Address Registry
100.64.1.42
100.64.1.42 → 1
100.64.1.42 → 2
- IP
1 IP
-
2
IP
100.64.1.43
100.64.1.43 → 2
- IP
2 IP
Session 1
Session 2
Address Registry

[illegible]

- [illegible]
- [illegible]
- [illegible] IP [illegible]
- [illegible] IP [illegible]
- [illegible] IP

□□□□□□

□□□ UE □□□□ APN

□□□□□

```
# □□
subnet_map: %{
  "internet" => ["100.64.1.0/24"],
  default: ["42.42.42.0/24"]
}
```

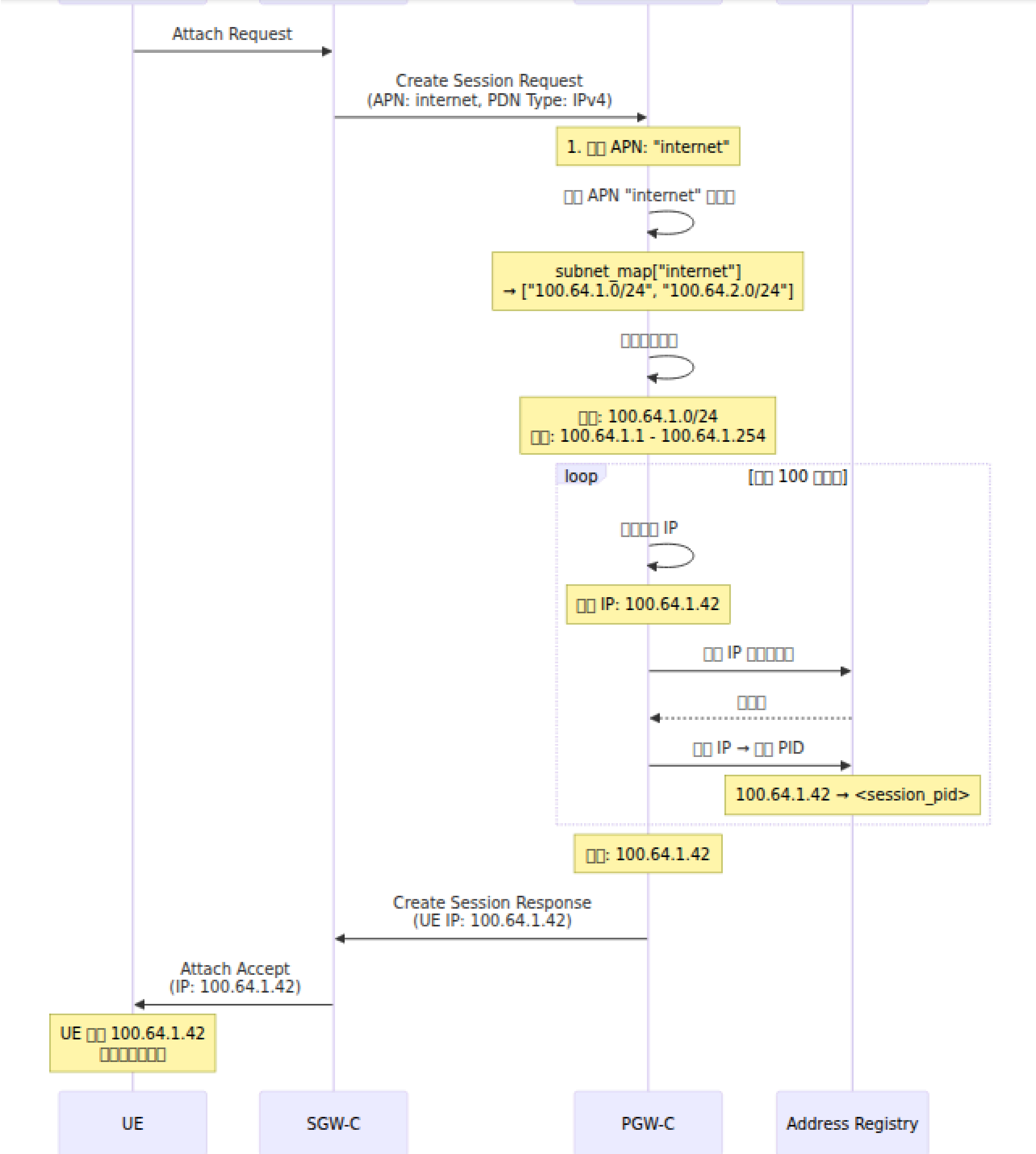
□□□

- UE □□ APN: "unknown.apn"
- □□□ subnet_map □□□ "unknown.apn"
- □□□□□□□□□□□□
- □ 42.42.42.0/24 □□□ IP

□□□□□

1. □□□□□□□□□□ APN □□□
2. □□□□□□□□□ `default` □
3. □□□□□□□□□□□□□□

□□□□□□□□□


Attach Request
Create Session Request
(APN: internet, PDN Type: IPv4)
1. □□ APN: "internet"
□□ APN "internet" □□□
subnet_map["internet"]
→ ["100.64.1.0/24", "100.64.2.0/24"]
□□□□□□
□□: 100.64.1.0/24
□□: 100.64.1.1 - 100.64.1.254
loop
[□□ 100 □□□]
□□□□ IP
□□ IP: 100.64.1.42
□□ IP □□□□□
□□□
□□ IP → □□ PID
100.64.1.42 → <session_pid>
□□: 100.64.1.42
Create Session Response
(UE IP: 100.64.1.42)
Attach Accept
(IP: 100.64.1.42)
UE □□ 100.64.1.42
□□□□□□□
UE
SGW-C
PGW-C
Address Registry

□□□□□

- □□□□□□□□□□□□□□□□
- IP □□□□□□□□
- □□□□□□

□□□□

□□□

□□□ □□□□□ IP □□□□

```
□: 100.64.1.0/24 (254 □□□ IP)
□□□: 254 □ IP
□□□□□ → □□
```

□□□□□□

1. PGW-C □□ 100 □□□□□
2. □□□□□□ IP □□□
3. □□: `{:error, :ue_ip_address_allocation_failed}`
4. □□□□□□
5. SGW-C □□□□□□

□□□□□

```
# □□□□□□
address_registry_count / total_pool_size > 0.8  # □ 80% □□□□□

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

□□ IP □□

□□□ □□□□□□□□ IP

GTP-C □□□□□

```
Create Session Request
├── IMSI: 310260123456789
├── APN: enterprise.corp
├── PDN □□□□ (IE)
│   └── PDN □□: IPv4
│   └── IPv4 □□: 10.100.0.50  ← UE □□□□ IP
```

OmniPGW □□□

1. □□□□□ **IP**□ □□□□□□ PDN □□□□ IE
2. □□ **IP**□ □□□□□ IP □□□□ APN □□□□□
3. □□□□□□ □□ IP □□□□□□□□□□
4. □□□□□□
   - ��□□□□□□□□ IP □□□□□□
   - □□□□□□□□□□□□□□□□□□

□□□□□□

- □□□ UE □□□□□□□□ IP □□
- □□□**IP** □□□□□ □□□□□ - IP □□□
- □□□**IP** □□□□□□ □□□□□ - IP □□□□□□□

IPv6 □□□□

UE □□ IPv6□

```
Create Session Request
├── PDN □□: IPv6
```

PGW-C □□ /64 □□□

```
□□□□□: 2001:db8:1:a::/64

UE □□□□□
- 2001:db8:1:a::1
- 2001:db8:1:a::2
- ... (18 □ quintillion □□)
```

□□□

- UE □□□□□□ IP□□□□□□□□□
- □□ SLAAC□□□□□□□□□□□
- □□ NAT □□

□□□□

UE □□ IPv4v6□

```
Create Session Request
├── PDN □□: IPv4v6
```

PGW-C □□□□□□□

```
IPv4: 100.64.1.42
IPv6: 2001:db8:1:a::/64
```

□□□□□

- IPv4 □□□□ IPv4 □□
- IPv6 □□□□ IPv6 □□
- □□□□□□□□□□
- □□□ GTP □□□□□□□□□

□□□□□ 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%
```

□□

```yaml
# □□□□□□□
- 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: ["42.42.42.0/24"]
}
```

□□□□□

- □□□□ □□□□□□
- □□□□□□□ □□ PGW-C □□□□□□ IP
- □□□□□ □□ `runtime.exs` □□□□□□

□□ 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 □
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 - □□□□□□□□□
      "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 □□
- **PFCP □□** - □□ PFCP □□ UE □□□ UPF

□□□□

- **S5/S8 □□** - □□ GTP-C □□ IP □□
- **Diameter Gx □□** - IP □□□□□□□

□□

- **□□□□** - IP □□□□□□□□□□□
- **□□ CDR □□** - CDR □□ UE IP □□□□□□□□

□□□□□□

OmniPGW □□□□

OmniPGW - □□□□□□□□□ (PGW-C)

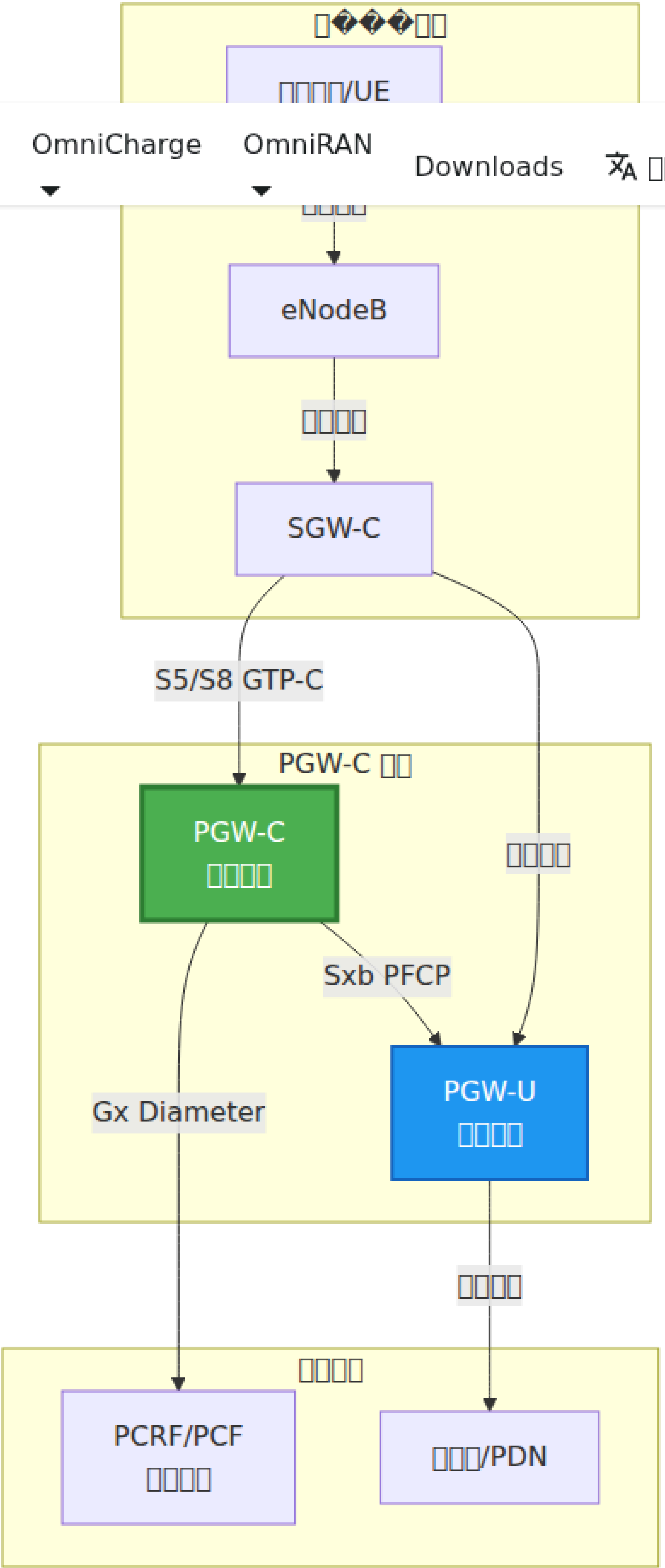
□ Omnitouch □□□□□□

□□

□□

OmniPGW □□□□□□□□□□□□□□□□ (PGW-C) □□□□□□ 3GPP LTE □□□□□□ (EPC) □□□□ Omnitouch □□□□□□□□□□□□□□□□□□□□□□□□□

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

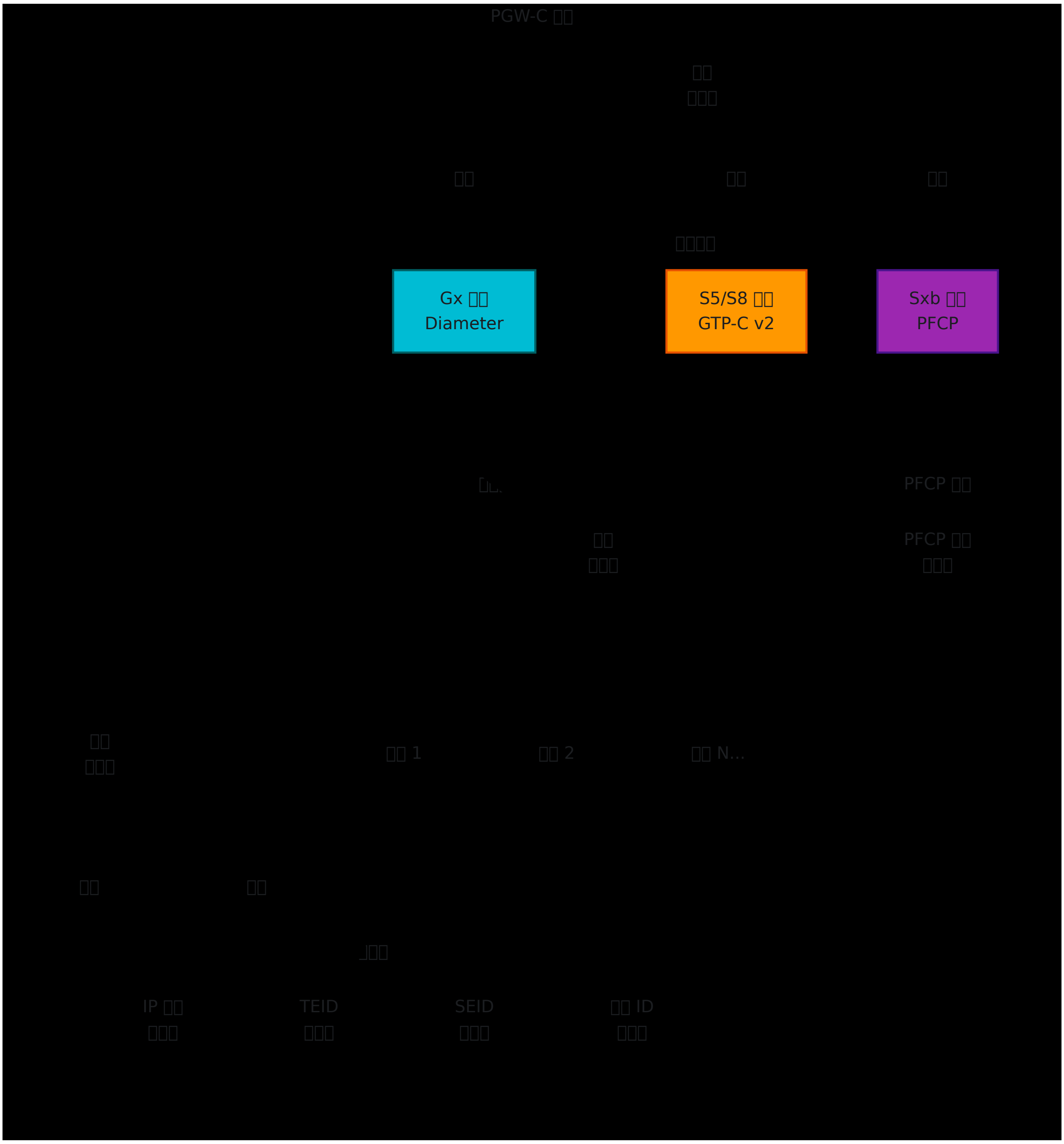

eNodeB
SGW-C
S5/S8 GTP-C
PGW-C
Sxb PFCP
Gx Diameter
PGW-U
PCRF/PCF

PGW-C □□□

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

□□

□□□□



□□□□

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 (□□□□□□□□□)

□□□□□

- □□□□□□/□□
- □□□□□□/□□

- □□□□□□/□□
- □□□□□□/□□
- □□□□/□□

□□□ □□□ PFCP/Sxb □□□□

Gx □□ (Diameter)

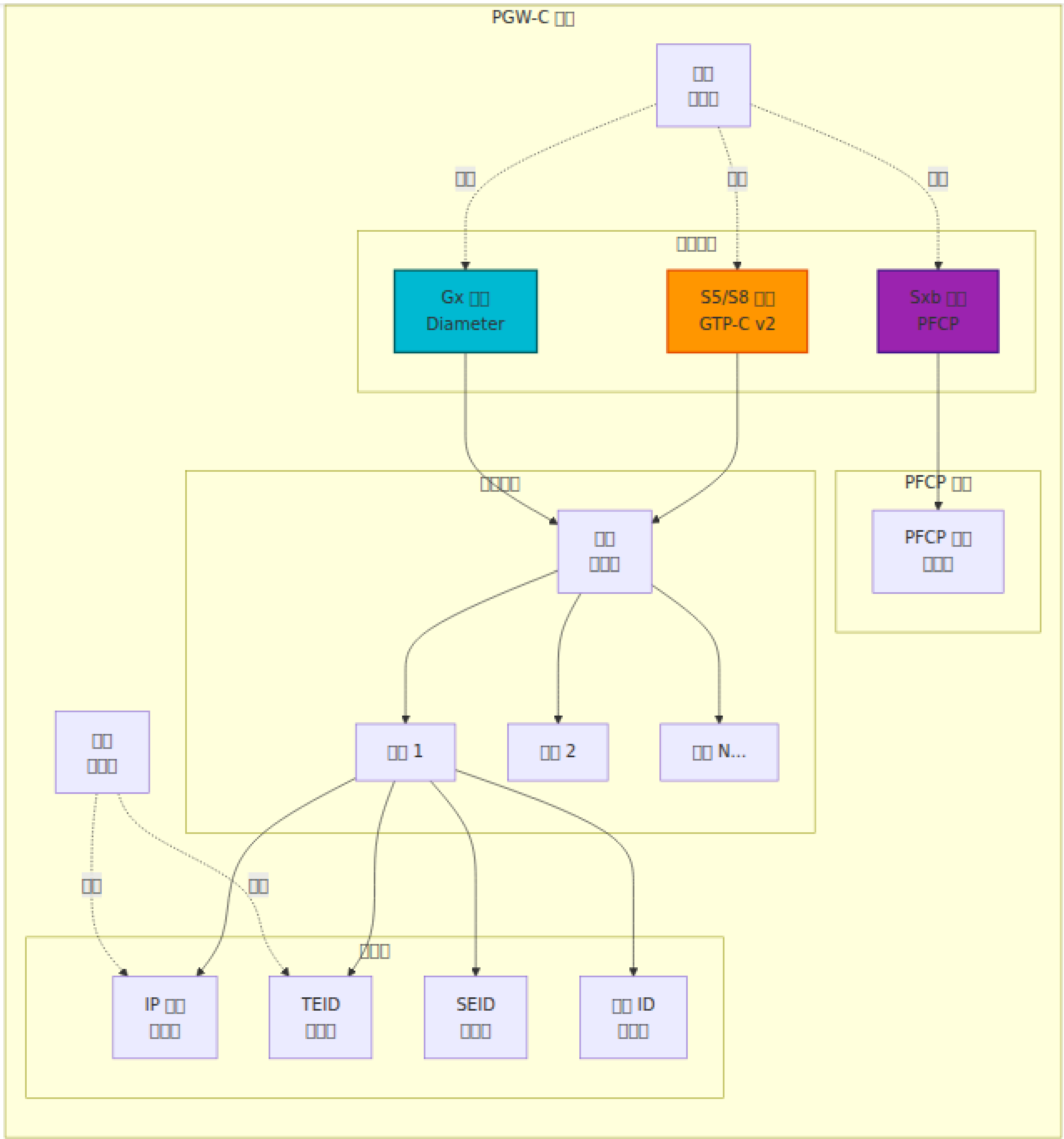
□□□ □□□□□□□□□ (PCRF) □□

□□□ Diameter (IETF RFC 6733)

□□□□□

- □□□□□□□□/□□ (CCR-I/CCA-I)
- □□□□□□□□/��□ (CCR-T/CCA-T)

□□□ □□□ Diameter Gx □□□□



□□□□

PDN □□

PDN (□□□□□□□) □□□□ UE □□□□□ (□□□□) □□□□□□□□□□□□

- **UE IP □□** - □□□□□□□□□□

- **APN** (□□□□□) - □□□□□□
- □□��□□ - □□ QoS □□□□□□□
- □□ **ID** - □□□□□□□□□□
- **TEID** (□□□□ ID) - S5/S8 □□□□□□□
- **SEID** (□□□□ ID) - Sxb □□□□□□□

□□□□□

□□□□□□□□ QoS □□□□□□□

- □□□□ - □□ PDN □□□□
- □□□□ - □□□□ QoS □□□□□□□
- **EBI** (EPS □□ ID) - □□□□□□□□□□
- **QoS** □□ - QCI□ARP□□□□ (MBR□GBR)

PFCP □□

PGW-C □ PGW-U □□□□□□□□□□

- **PDR** (□□□□□□□) - □□□□□ (□□/□□)
- **FAR** (□□□□□□) - □□□□□□
- **QER** (QoS □□□□) - □□□□□□□
- **BAR** (□□□□□□) - □□□□□□□

□□□□□□□□□□ PFCP □□□□□

IP □□□□

UE IP □□□□□□□□□□□□□

- □□ **APN** □□□ - □□ APN □□□□□□□□□
- □□□□ - □□□□□□□□□□ IP
- □□□□ - □□ UE □□□ 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
```

□□□□

□□□□□□□□□□□□□

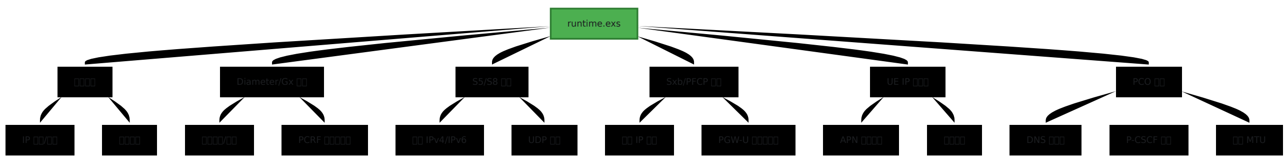
```
[info] □□ OmniPGW...
[info] □ 127.0.0.42:42069 □□□□□□□
[info] □ 127.0.0.10 □□ S5/S8 □□
[info] □ 127.0.0.20 □□ Sxb □□
[info] □□ Gx □□
[info] □□ PFCP □□□□□
[info] OmniPGW □□□□
```

□□□□□ `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 □□□
pco	□□□□□□	PCO □□
CDR	□□□□□□□□□	CDR □□

□□□□□□□□□□ □□□□□□□

Web UI - □□□□□□□□

OmniPGW □□□□□□□ **Web UI**□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

□□ Web UI

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

□□□□□

□□	URL	□□	□□□
UE □□	`/ue_search`	□□□□□□□□□	□□
PGW □□	`/pgw_sessions`	□□□□□□ PDN □□	2 □
□□□□	`/session_history`	□□□□□□□□□	5 □
□□□□	`/topology`	□□□□□□□□□	5 □
IP □	`/ip_pools`	UE IP □□□□□□	2 □
PFCP □□	`/pfcp_sessions`	□□□ PGW-U □ PFCP □□	2 □
UPF □□	`/upf_status`	□□ PFCP □□□□□	2 □
UPF □□	`/upf_selection`	□□ UPF □□□□□ P-CSCF □□	□□
Diameter □□□	`/diameter`	□□ PCRF □□	1 □
P-CSCF □□	`/pcscf_monitor`	P-CSCF DNS □□□□	5 □
Gy □□□	`/gy_simulator`	□□ Gy/Ro □□□□	□□
□□	`/cell_towers`	□□ OpenCellID □□□	□□
□□	`/logs`	□□□□□	□□

□□□□

□□□□□

- □□□□□□□□□ (□□□□□□□□□)
- □□ OmniPGW □□□□□□□□
- □□□□□□□□□□ (□□/□□)

□□□□□□

- □ IMSI□IP□MSISDN □ APN □□□□
- □□□□□□□□□□□□□

□□□□□□□□

- □□□□□□□□□□□□□□
- □□□□□□□□
- □□□□□□□□□□

□□□□□□ (□□□□)□

- □□□□□□□□□
- □□□□ NOC/□□□□□□
- □□□□□□ IP □□□□□

□□□□□□

□□□□□□ (□□□□)□

```
1. □□□□□□□□
2. □□ UE □□□□ (/ue_search)
3. □ IMSI□MSISDN □ IP □□□□
4. □□□□□□□□□□□□
   a) □□□□ - □□□□□□□□□□□□□
   b) □□□□□□ - □□ TAC□□□ ID□□□□□
   c) □□□□ - □□□□□□□□□
      - QCI□MBR/GBR□□□□□□□
      - APN-AMBR □□
   d) □□□□ - Gy □□ ID□□□□□
   e) □□□□ - Gx □□□□□□□ PCC □□
   f) □□□□ - □□□□□□□□□
5. □□□□□□□ → □□ Diameter □□□□□ PCRF □□
6. □□□□□□□□ → □□□□□□□□□□□□□□□
```

□□□□□□□

```
1. □□□□□□
2. □□ PGW □□□□ (/pgw_sessions)
3. □ IMSI □□□□□□□
4. □□□□□□□□□□□□□□□□□□
   - □□□ UE IP □□
   - QoS □□
   - □□□□□□□
5. □□□□□□ → □□□□□□□□□□ UE □□
```

□□□□□□□

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

□□□□□

- □□□□ PGW □□□□
- □□□/□□□□□□□□
- □□□□□□□□
- □□ APN □□□□□

Web UI □□□

□□ Web UI□

- □□□□□□□□□□□ (UE □□)
- □□□□□□□□□□□□□
- □□□□□□□ (PFCP□Diameter)
- □□□□□□□□□□□□
- □ IMSI/MSISDN/IP □□□□□□□□
- □□□□□□ (□□□□)
- □□ QoS □□ (MBR□GBR□QCI)
- □□□□□□□□□
- □□□□□□□□□
- IP □□□□□
- □□□□□□□

□□ 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://127.0.0.1:42069/metrics
```

□□□ □□□□□□□ □□□□□□□□□□□□

□□□□

□□□□□ OmniPGW □□□□□□□□□□□□□□□□□□□

□□□□

```
OmniPGW □□
├── OPERATIONS.md (□□□)
│
└── docs/
    ├── □□□□□
    │   ├── configuration.md          □□□ runtime.exs □□
    │   ├── ue-ip-allocation.md       IP □□□
    │   └── pco-configuration.md      DNS□P-CSCF□MTU □□
    │
    ├── □□□□
    │   ├── pfcp-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 □□□□□
```

□□□□□□□□

□ □□

□□	□□	□□
OPERATIONS.md	□□□□□□ (□□□)	□□□□□□□

⚙ □□

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

□ □□□□

□□	□□	□□
pfcp-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
data-cdr-format.md	CDR □□□□□URR □□□□□□□	847
qos-bearers.md	QoS □□□□□□□□□□	448
troubleshooting.md	□□□□□□□□□□□	687

□ □□□□

□□	□□	□□
pcscf-monitoring.md	P-CSCF □□□□□□□	894

□□□□

□ Mermaid □□

□□□□□□□ **Mermaid □□** □□□□□□□□□

- □□□
- □□□ (□□□)
- □□□
- □□□□

□ □□□□

□□□□□□□□

- □□□□□□□
- □□□□□□□□□□
- □□□□

□ □□□□

□□□□□□□□□□

- □□□□□□□□□
- □□□□
- □□□□

□ □□□□

□□□□□□□□□□□□□□□□□□□

□□□□

□□□□□□□

1. OPERATIONS.md - □□ (□□□)
2. configuration.md - □□
3. monitoring.md - □□
4. session-management.md - □□□□

□□□□□□□

1. OPERATIONS.md - □□□□ (□□□)
2. pfcp-interface.md - □□□□□□
3. diameter-gx.md - □□□□
4. diameter-gy.md - □□□□
5. s5s8-interface.md - □□□□
6. ue-ip-allocation.md - IP □□

□□□□□□□

1. configuration.md - □□□□
2. ue-ip-allocation.md - IP □
3. pco-configuration.md - □□□□
4. monitoring.md - □□□□

□□□□

- □□□□□ 14
- □□□□ ~10,900+
- □□□□ ~265 KB
- **Mermaid** □□□ 75+
- □□□□□ 150+

□□□□□□□

□□

- □ □□/□□□□□□
- □ OTP/Elixir □□
- □ □□□□
- □ □□ GenServer □□□

□□

- □ PFCP (□□□□□□□□□)
- □ GTP-C v2 (GPRS □□□□)
- □ Diameter (RFC 6733)

3GPP □□

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

□□

- □ □□□□
- □ IP □□□□
- □ QoS □□
- □ □□□□
- □ □□□□□

□□□□

3GPP □□

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

□□□□

- □□□□□ config/runtime.exs