Listing 1: AMF logged warning related to NF HTTP/2 server inaccessibility.

```
11/05 14:14:45.431: [sbi] WARNING: [7] Failed to connect to 127.0.0.4 port 7777: Connection
refused (../lib/sbi/client.c:585)
11/05 14:14:45.431: [amf] WARNING: client_cb() failed [-1] (../src/amf/sbi-path.c:56)
```

Listing 2: A SMF2 crash backtrace.

```
11/05 14:16:32.760: [smf] DEBUG: smf_state_operational(): OGS_EVENT_NAME_SBI_CLIENT
(../src/smf/smf-sm.c:83)
11/05 14:16:32.760: [smf] DEBUG: smf_gsm_state_wait_5gc_sm_policy_association():
OGS_EVENT_NAME_SBI_CLIENT (../src/smf/gsm-sm.c:480)
11/05 14:16:32.760: [pfcp] ERROR: CHECK CONFIGURATION: Cannot find subnet [family:2,
dnn:internet] (../lib/pfcp/context.c:1636)
11/05 14:16:32.760: [pfcp] ERROR: Please add FALLBACK subnet as below.
(../lib/pfcp/context.c:1638)
11/05 14:16:32.760: [pfcp] ERROR:     subnet: (../lib/pfcp/context.c:1639)
11/05 14:16:32.760: [pfcp] ERROR:      - addr: 10.50.0.1/16 (../lib/pfcp/context.c:1641)
```

Listing 3: An invalid PDU Session establishment request posted to SMF2.

```
11/05 14:16:32.754: [sbi] DEBUG: [POST] /nsmf-pdusession/v1/sm-contexts
(../lib/sbi/nghttp2-server.c:800)
11/05 14:16:32.754: [sbi] DEBUG: RECEIVED: 1142 (../lib/sbi/nghttp2-server.c:804)
11/05 14:16:32.755: [sbi] DEBUG: --=-KepEqNu8K4rVigBUOK4YlQ==
Content-Type: application/json

{
    "supi":    "imsi-666010000000001",
    "pei":     "imeisv-4370816125816151",
    "pduSessionId":    1,
    "dnn":     "internet",
    "sNssai":     {
        "sst":    1,
        "sd":     "000001"
    },
```

Listing 4: AMF failing to select an adequate SMF for a slice-aware PDU session establishment.

```
11/05 15:10:15.173: [gmm] INFO: UE SUPI[imsi-666010000000001] DNN[internet] S_NSSAI[SST:1
SD:0x1] (../src/amf/gmm-handler.c:1062)
11/05 15:10:15.173: [sbi] DEBUG: [POST]
http://127.0.0.24:7777/nsmf-pdusession/v1/sm-contexts (../lib/sbi/client.c:678)
11/05 15:10:15.173: [sbi] DEBUG: SENDING...[1142] (../lib/sbi/client.c:396)
11/05 15:10:15.173: [sbi] DEBUG: --=-edDbhslS4YBpe4hFtxQp8A==
Content-Type: application/json

{
    "supi":     "imsi-666010000000001",
    "pei":      "imeisv-4370816125816151",
    "pduSessionId":     1,
    "dnn":      "internet",
    "sNssai":       {
        "sst":      1,
        "sd":       "000001"
    },
```

Listing 5: Open5GS AMF source code: gmm_handle_ul_nas_transport.c.

```c
if (!SESSION_CONTEXT_IN_SMF(sess)) {
            ogs_sbi_nf_instance_t *nf_instance = NULL;
            ogs_sbi_service_type_e service_type =
                OGS_SBI_SERVICE_TYPE_NSMF_PDUSESSION;

            nf_instance = sess->sbi.
                service_type_array[service_type].nf_instance;
            if (!nf_instance) {
                OpenAPI_nf_type_e requester_nf_type =
                        NF_INSTANCE_TYPE(ogs_sbi_self()->nf_instance);
                ogs_assert(requester_nf_type);

                nf_instance = ogs_sbi_nf_instance_find_by_service_type(
                        service_type, requester_nf_type);
                if (nf_instance)
                    OGS_SBI_SETUP_NF_INSTANCE(
                            sess->sbi.service_type_array[service_type],
```
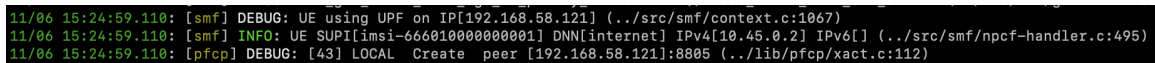
```
                    nf_instance);
            }


            if (nf_instance) {
                ogs_assert(true ==
                    amf_sess_sbi_discover_and_send(
                        OGS_SBI_SERVICE_TYPE_NSMF_PDUSESSION, NULL,
                        amf_nsmf_pdusession_build_create_sm_context,
                        sess, AMF_CREATE_SM_CONTEXT_NO_STATE, NULL));
            } else {
                ogs_assert(true ==
                    amf_sess_sbi_discover_and_send(
                        OGS_SBI_SERVICE_TYPE_NNSSF_NSSELECTION, NULL,
                        amf_nnssf_nsselection_build_get, sess, 0, NULL));
            }
```



```
11/06 15:24:59.110: [smf] DEBUG: UE using UPF on IP[192.168.58.121] (../src/smf/context.c:1067)
11/06 15:24:59.110: [smf] INFO: UE SUPI[imsi-666010000000001] DNN[internet] IPv4[10.45.0.2] IPv6[] (../src/smf/npcf-handler.c:495)
11/06 15:24:59.110: [pfcp] DEBUG: [43] LOCAL  Create  peer [192.168.58.121]:8805 (../lib/pfcp/xact.c:112)
```

Figure 1: Correct UPF selection for UE1 requested DN.

Listing 6: A SMF1 log exert showing registering PDU context for UE1 data session on PCF.

```
11/06 15:24:59.090: [sbi] DEBUG: [POST]
http://127.0.0.13:7777/npcf-smpolicycontrol/v1/sm-policies
11/06 15:24:59.091: [sbi] DEBUG: {
    "supi":     "imsi-666010000000001",
    "pduSessionId":    1,
    "pduSessionType":    "IPV4",
    "dnn":      "internet",
    "notificationUri":    "http://127.0.0.4:7777/nsmf-callback/v1/sm-policy-notify/1",
    "ipv4Address":    "10.45.0.2",
    "subsSessAmbr":    {
        "uplink":    "1048576 Kbps",
        "downlink":    "1048576 Kbps"
    },
    "subsDefQos":    {
        "5qi":    9,
        "arp":    {
```

```
            "priorityLevel":     8,
            "preemptCap":     "NOT_PREEMPT",
            "preemptVuln":     "NOT_PREEMPTABLE"
        },
        "priorityLevel":     8
    },
    "sliceInfo":     {
        "sst":     1,
        "sd":     "000001"
    },
    "suppFeat":     "4000000"}
[...]
11/06 15:24:59.110: [sbi] DEBUG: [201:POST]
http://127.0.0.13:7777/npcf-smpolicycontrol/v1/sm-policies
11/06 15:24:59.110: [sbi] DEBUG: {
    "sessRules":     {
        "1":     {
            "authSessAmbr":     {
                "uplink":     "1048576 Kbps",
                "downlink":     "1048576 Kbps"
            },
            "authDefQos":     {
                "5qi":     9,
                "arp":     {
                    "priorityLevel":     8,
                    "preemptCap":     "NOT_PREEMPT",
                    "preemptVuln":     "NOT_PREEMPTABLE"
                },
                "priorityLevel":     8
            },
            "sessRuleId":     "1"
        }
    },
    "suppFeat":     "4000000"
}
```

Figure 2: UE1 UERANSIM console with status for PDU session.

```
[2022-11-06 15:24:58.960] [rrc] [debug] UE[1] new signal detected
[2022-11-06 15:24:58.965] [rrc] [info] RRC Setup for UE[1]
[2022-11-06 15:24:58.966] [ngap] [debug] Initial NAS message received from UE[1]
[2022-11-06 15:24:59.043] [ngap] [debug] Initial Context Setup Request received
[2022-11-06 15:24:59.300] [ngap] [info] PDU session resource(s) setup for UE[1] count[1]
```

Figure 3: 5G-AN view of UE1 PDU service access.

```
vm5G-UERANSIM:~/UERANSIM/build# ./nr-cli  imsi-666010000000001
--------------------------------------------------------------
$ status
cm-state: CM-CONNECTED
rm-state: RM-REGISTERED
mm-state: MM-REGISTERED/NORMAL-SERVICE
5u-state: 5U1-UPDATED
sim-inserted: true
selected-plmn: 666/01
current-cell: 1
current-plmn: 666/01
current-tac: 1
last-tai: PLMN[666/01] TAC[1]
stored-suci: no-identity
stored-guti:
 plmn: 666/01
 amf-region-id: 0x02
 amf-set-id: 1
 amf-pointer: 0
 tmsi: 0xca0061a5
has-emergency: false
```

Figure 4: The connected status for UE1.

```
vm5G-UERANSIM:~/UERANSIM/build# ping -I uesimtun0 kt.agh.edu.pl
PING kt.agh.edu.pl (149.156.114.51) from 10.45.0.2 uesimtun0: 56(84) bytes of data.
64 bytes from mimas.tele.agh.edu.pl (149.156.114.51): icmp_seq=1 ttl=61 time=21.3 ms
64 bytes from mimas.tele.agh.edu.pl (149.156.114.51): icmp_seq=2 ttl=61 time=28.2 ms
64 bytes from mimas.tele.agh.edu.pl (149.156.114.51): icmp_seq=3 ttl=61 time=22.1 ms
64 bytes from mimas.tele.agh.edu.pl (149.156.114.51): icmp_seq=4 ttl=61 time=23.1 ms
64 bytes from mimas.tele.agh.edu.pl (149.156.114.51): icmp_seq=5 ttl=61 time=27.5 ms
64 bytes from mimas.tele.agh.edu.pl (149.156.114.51): icmp_seq=6 ttl=61 time=25.7 ms
64 bytes from mimas.tele.agh.edu.pl (149.156.114.51): icmp_seq=7 ttl=61 time=28.2 ms
```

Figure 5: PING to external network from UE1.

Figure 6: GTP-U data related to ICMP Ping to kt.agh.edu.pl, issued by UE1.

Figure 7: PDU session release reported by SMF1 to AMF.

Listing 7: N2 message presenting an accepted PDU session request and resource reservation in 5G-AN for UE2.

```
11/06 16:20:07.405: [amf] DEBUG: PDUSessionResourceSetupRequest(Session)
(../src/amf/ngap-build.c:1329)
11/06 16:20:07.405: [amf] DEBUG:    RAN_UE_NGAP_ID[3] AMF_UE_NGAP_ID[3]
(../src/amf/ngap-build.c:1374)
11/06 16:20:07.405: [amf] DEBUG:    IP[192.168.58.130] RAN_ID[1]
(../src/amf/ngap-path.c:70)
11/06 16:20:07.405: [sbi] DEBUG: STATUS [200] (../lib/sbi/nghttp2-server.c:357)
11/06 16:20:07.405: [sbi] DEBUG: SENDING...: 40 (../lib/sbi/nghttp2-server.c:365)
11/06 16:20:07.405: [sbi] DEBUG: {
    "cause":    "N1_N2_TRANSFER_INITIATED"}
11/06 16:20:07.408: [amf] DEBUG: amf_state_operational(): AMF_EVENT_NGAP_MESSAGE
(../src/amf/amf-sm.c:78)
```

```
11/06 16:20:07.408: [amf] DEBUG: ngap_state_operational(): AMF_EVENT_NGAP_MESSAGE
(../src/amf/ngap-sm.c:53)
11/06 16:20:07.408: [amf] DEBUG: PDUSessionResourceSetupResponse
(../src/amf/ngap-handler.c:1515)
11/06 16:20:07.408: [amf] DEBUG:     IP[192.168.58.130] RAN_ID[1]
(../src/amf/ngap-handler.c:1540)
11/06 16:20:07.408: [amf] DEBUG:     RAN_UE_NGAP_ID[3] AMF_UE_NGAP_ID[3]
(../src/amf/ngap-handler.c:1572)
11/06 16:20:07.408: [sbi] DEBUG: [POST]
http://127.0.0.24:7777/nsmf-pdusession/v1/sm-contexts/1/modify (../lib/sbi/client.c:678)
11/06 16:20:07.408: [sbi] DEBUG: SENDING...[291] (../lib/sbi/client.c:396)


Content-Type: application/json


{
    "n2SmInfo":    {
        "contentId":    "ngap-sm"
    },
    "n2SmInfoType":    "PDU_RES_SETUP_RSP"
}


11/06 16:20:07.413: [sbi] DEBUG: [204:POST]
http://127.0.0.24:7777/nsmf-pdusession/v1/sm-contexts/1/modify (../lib/sbi/client.c:562)
```


Figure 8: An overview of 5G-AN data related to UE2 PDU service establishment for IP data.

Figure 9: UE2 access to a remote network through 5G user plane.

Figure 10: AMF logs regarding a SMF1 profile update (IP address of 127.0.0.4), together with UL NAS message containing UE1 request to establish data service.

Listing 8: A slice summary for S-NSSAI: [SST:1, SD:0x000001].

```
{'S_NSSAI[SST:1 SD:000001]': {
    'ALL_SUPPORTING_IMSIS': ['666010000000001',
     '666011',
     '666012',
     '666013'],

    'PER_DNN_AGGREGATED_BITRATE': {'ims': {'TOTAL_AMBR_DL': '260096Kbps',
    'TOTAL_AMBR_UL': '260096Kbps'},
    'internet': {'TOTAL_AMBR_DL': '1506304Kbps',

    'TOTAL_AMBR_UL': '1506304Kbps'}},
    'PER_DNN_COMMON_SUPPORTED_SSC': {'ims': ['SSC_MODE_3',
                                             'SSC_MODE_1',
                                             'SSC_MODE_2'],
                                     'internet': ['SSC_MODE_3',
                                                  'SSC_MODE_1',
                                                  'SSC_MODE_2']},
                    'PER_DNN_DEFAULT_REQUIRED_SSC': {'ims': {'SSC_MODE_1'},
                    'internet': {'SSC_MODE_1'}},
                    'TOTAL_AMBR_DL': '1766400Kbps',
                    'TOTAL_AMBR_UL': '1766400Kbps',
                    'TOTAL_IMSIS': 4}}
```