



PS Data Off

3GPP Solution for Network Enabled Data Switch

White Paper

Introduction

One of the significant changes introduced in LTE compared to the previous cellular generations is that when the mobile device connects to the network it also implicitly gets an IP address. This is called EPS Default Radio Bearer (DRB) Activation. In 3G cellular generation, the mobile registers to the network first. Then based on downlink or uplink activities, the IP address allocation procedure starts as part of PDP context activation. This procedure is referred to in 3G systems as establishing Packet-Switch (PS) Data call. The procedure of PS data call setup follows the same of that in circuit switch. When the user initiates or receives a call, the CS or PS call is established and all resources are then allocated at the call setup stage.

With the default bearer activation in LTE, the packet call is established the same time when the UE attaches to the EPS network. This is the concept that makes the LTE's connectivity to be known as "always-on". This procedure, opposed to 3G, can provide a significant signaling reduction on the protocol layers and also improves the end-user experience in terms of data re-activation after a certain period of inactivity. In 3G system, when the user disconnects the data call and then re-initiates a new one, the PDP context activation may start all over again. However, in LTE, when the same procedure is done by the user, the call setup time for a data call is reduced because the default DRB has been already assigned to the user when first attached to the EPS system. Even though the default DRB is enough for the downlink and uplink data transfer in EPS networks, to exploit the services differentiation, LTE has also introduced another EPS bearer known as Dedicated EPS Data Bearer, which is initiated for an additional data radio bearer. The typical usage of dedicated DRB is to differentiate PS data calls from Voice over LTE (VoLTE) calls. In such case, the PS data can flow on the default DRB while the VoLTE call flows on a dedicated DRB with different Quality of Service Class Identifier (QCI).

Some Networks may not require to setup the dedicated DRB per user for the PS data services, especially when there is a single APN (Access Point Name) for the UE, for which the data can flow on the default DRB with the default QoS. However, with this implementation, some roaming issues may occur. As many operators have now signed LTE roaming agreements worldwide, the UE may be attached to LTE on the visiting network. In this case, if the user disables roaming or cellular data in the User Interface (UI), the UE will remain attached to LTE network (there is no detach nor APN disconnection as that done in 3G network with PDP deactivation procedure). For the voice calls, it will be maintained as CSFB from LTE, and upon returning to LTE after voice call is disconnected, the tracking area update procedure or a new service request will assign default DRB again in LTE. However, for the PS data services, since the UE is PDN (Packet Data Network) attached to the default DRB, the IP address may always be allocated and the incoming data from servers (downlink data, DL) may flow to the UE. In this case, the MME will page the UE and the UE will establish RRC connection to process the incoming DL data.

Meanwhile, the outgoing traffic (uplink data, UL) will be blocked by the UE upper layers and hence it will not send anything on the UL if the Cellular data/Roaming is turned OFF. But it is observed in some networks that data can flow on the DL and reach the UE Physical Layer. The LTE Protocol Stack processes the data after establishing the RRC connection with cause *mt-access*, but the upper layer does not respond since the data connection is turned off. In this particular scenario, it is observed that the PCRF still charges the roaming users for the incoming data as it is unknown to the PCRF, whether the user switched off data or not. To avoid such issues due to LTE "always-on" connectivity, several operators around the world have deployed a concept of "dummy APN". Dummy APN (known as No-Data APN) works as shown in figure 1. The initial attach is done to the PDN which is not connected to the internet. This helps to avoid the unsolicited data when roaming.

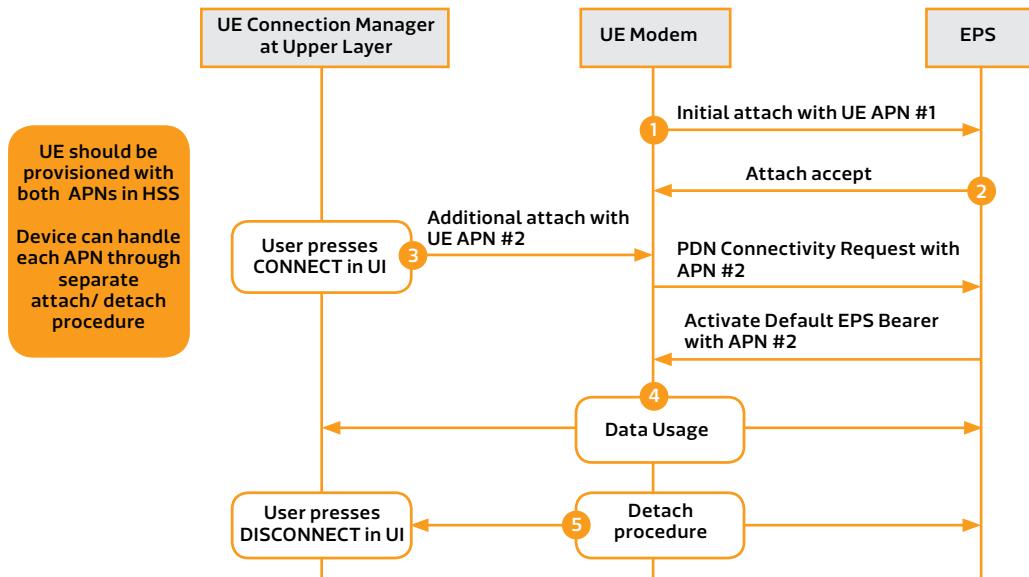


Figure 1: Multiple PDN Connectivity to Different APNs – with Dummy APN as a Default One

In the call flow in figure 1, the following steps are done at both UE and EPS:

1. At the time UE is switched on and connects to LTE, it sends *PDN Connectivity Request* with EPS Session Management (ESM) Information Transfer flag is set to 0, embedded in the *Attach Request* messages.
2. EPS sends *Attach Accept* message with first APN that can be set to “No-Data” APN. EPS activates default DRB bearer with the QCI associated with PS data by sending *Activate Default EPS Bearer Context Request* for which UE replies with *Activate Default EPS Bearer Context Accept* message.
3. As UE is configured in this network to use dual APNs (one with No-Data, APN #1, and one for internet usage, APN #2), the UE then sends another *PDN Connectivity Request* to EPS
 - a. UE indicates that the APN is the one valid for the PS data transfer associated with the one configured in UI for the home network.
 - b. EPS sends *Activate Default EPS Bearer Context Request* message to the UE indicating the same internet APN UE is requesting to activate, and the UE replies with *Activate Default EPS Bearer Context Accept* message.
4. PS Data can now flow on the default bearer assigned after the second *PDN Connectivity Request* sent with the internet APN configured for the home network.
5. When the user switches off the cellular data option in UI, EPS can deactivate the second default DRB associated with the UE. This way, if the roaming or cellular data options are switched off by the user in UI, the data will stop flowing because there is no default bearer from EPS side that data can flow on the downlink or uplink.

Based on this dual APNs configuration and call flow, in order to resolve possible roaming or end-user experience issues, the *ESM information request* procedure is used by the network to retrieve ESM information. This ESM information includes the Protocol Configuration Options (PCOs), and the APN, or both, from the device during the attach procedure. The purpose of this procedure is to provide a different UE-configured APN than the default one. Therefore, UE will initiate another default APN, and the UE will then register this APN and map the user data traffic to this another PDN connectivity.

As shown in the first step in figure 1, the user device can set either value of the EPS Session Management (ESM) Information Transfer flag in the PDN Connectivity Request message, which requires changes to the UE for each MNC/MNC configured for dual APNs, in order to control when to request additional APN connectivity for PS data services:

- If ESM Information Transfer flag is set to 0, the MME does not send an *ESM Information Request* message to the user device. This method helps to assign dual APN to the UE and one of them is used for PS data transfer. This bearer can be activated or deactivated based on the UI behavior for cellular/roaming options.

- If ESM Information Transfer flag is set to 1, the MME sends an *ESM Information Request* message to the user device to request ESM information and gets an *ESM Information Response* message including APN from the UE. As a result, the EPS and UE will not follow on with additional PDN connectivity and can use the default bearer for the data transfer.

These solutions on UE and network sides can come with limitations such as the ESM flag should be set to specific operator network because not all operators have implemented No-Data APN. In addition, in networks or devices implemented without such ESM signaling level solutions, the current form of 3GPP does not involve procedures that allow UE to notify the network if the cellular data or roaming is activated from UI side. Therefore, when a UE is allocated an IP address for a PDN connection, Internet application servers may go on sending downlink IP packets to the UE for a while. As a consequence the user will be charged for downlink IP packets even though cellular data switch on UE is turned off, leading to customer complaints.

Moreover, the current 3GPP protocol stack, prior to Release 14, does not allow network operators to differentiate services that are allowed to be running when the data is turned off. For example, IMS calling (VoLTE or VoWiFi) may not be clearly set in relations to cellular data being turned on per the current form of 3GPP protocol policies. This means if the operator wants to differentiate these services to run with or without cellular data turned on, then extra requirements must be added to the UE IMS stack in order to make such differentiation. This leads to additional interoperability constraints, especially if the operator requirements change in the future or post service commercialization, which increases the complexity in making design changes for service differentiation for the operators. Some other services may be transparent to cellular data conditions such as USSD (Unstructured Supplementary Service Data), video calling, XCAP (XML Configuration Access Protocol used for IMS supplemental services), BIP (Bearer Independent Protocol), SMS over IP, etc... Network operators may choose to enable the end-to-end communication of these features even when the data is turned off, in order to improve end user experience or to retrieve/push new/updated information into SIM card.

As a result of these issues, 3GPP identified the need to handle a unified solution with new procedures that allow the user device and EPS to be fully aware of the data connectivity option settings in the UI (roaming or cellular data). Based on this information exchange between the device and network, there can be additional service differentiators to control data connections when in roaming or when cellular data is turned On/Off. The mechanism was initially described in GSMA IR.88 – LTE and EPC Roaming Guidelines – 6.3.3.5 Data Off related functionality. 3GPP PS Data Off and 3GPP PS Data off Exempt Services have been defined in GSMA RPD IR.92. The home network supporting 3GPP PS Data Off, as defined in 3GPP Release 14 TS 23.401, must only send IP packets for services that are configured as 3GPP PS Data off Exempt Services.

PS Data Off Requirements

By introducing the always on IP connectivity in LTE network, it became difficult for the subscriber to have explicit control of the traffic sent or received by its UE, which could lead to unexpected charging. Therefore, the main purpose of 3GPP PS Data Off feature is to inform the network that the user has deactivated the data services, in order to avoid excessive roaming charges or for other exemptions to any form of services the operator can offer to the end user in such conditions. When 3GPP PS Data Off is activated, the UE and the network must not send any IP packet via any PDN connection of any service other than 3GPP PS Data off Exempt Services. 3GPP PS Data Off Exempt Services are set of operator services (i.e. the exempt services enumerated as explained in later sections, including the signaling used to enable such services) that are allowed even if the 3GPP PS Data Off status set to active in the UE by the user. This applies both to non-IMS based services and SIP-based IMS services.

The general idea of this feature, as illustrated in figure 2, is that the UEs are configured with a default list of 3GPP PS Data Off Exempted Services in USIM or MO (Management Object). The UE discovers whether a PDN Gateway (PGW) supports 3GPP PS Data Off feature at initial attach and during the establishment of a PDN connection via the presence of the 3GPP PS Data Off Support Indication in the Create Session response message. Meanwhile, when the UE requests a new PDN Connectivity, the UE shall include the indication in the PCO within the PDN Connectivity Request message. When the user changes its PS Data Off status, the UE shall report a change of its 3GPP PS Data Off status in PCO by using Bearer Resource Modification procedure. For the IMS services, the UE shall inform the IMS domain in the initial REGISTER request and subsequent to that via a re-REGISTER request, when updating its IMS registration status with the IMS server.

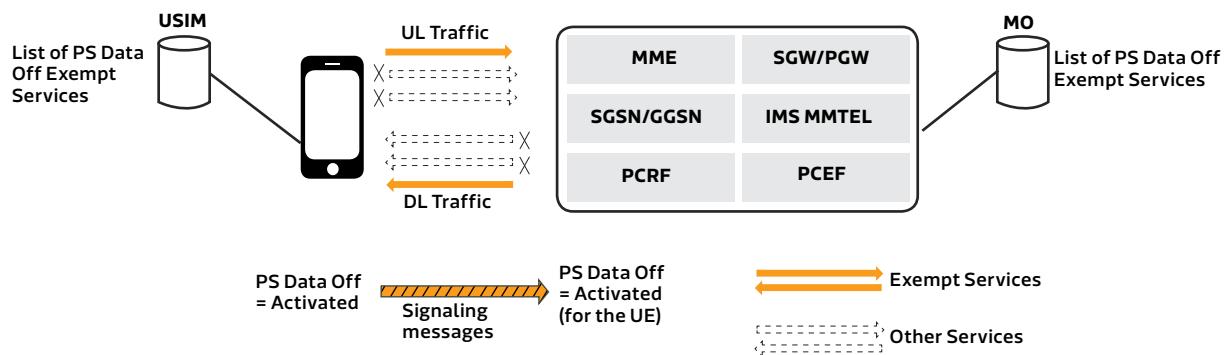


Figure 2: 3GPP PS Data Off general Concept

The following requirements were formed and described in GSMA IR.92:

- The UE must support to be provisioned with the list of SIP-based 3GPP PS Data Off Exempt Services,
- The UE must support be provisioned with the list of non-IMS 3GPP PS Data Off Exempt Services,
- A UE must report its 3GPP PS data off status, and each change in its 3GPP PS data off status,
- If the 3GPP PS data off status changes from "inactive" to "active" the UE must release all IMS sessions/dialogs except those in the Exempt Services,
- The UE must be able to perform supplementary service settings management regardless of whether 3GPP PS Data Off is active,
- The UE must be able to initiate and receive Voice Calls and SMS over IMS regardless whether Data Off is active. For this reason, the operator must configure "MMTel Voice" and "SMS over IMS" as 3GPP PS Data Off Exempt Services.

Architecture requirements also include minimization of the impact on both UE and network infrastructure. The feature is designed to address four key issues:

- **Key Issue #1. UE informing the network about the UE's status.** This key issue relates to the core network becoming aware immediately of the UE's status of the 3GPP PS Data Off feature (i.e. activated or deactivated) upon UE initial attach and when UE's changes the status of 3GPP PS Data Off feature. Activation/deactivation of the 3GPP PS Data Off feature triggered by the end user applies to all existing PDNs and newly established PDNs for the UE.
- **Key Issue #2. Making the UE aware of 3GPP PS Data Off Exempt Services.** This key issue relates to the UE being aware of the list of services configured to be part of the 3GPP PS Data Off Exempt Services defined in TS 22.011
- **Key Issue #3 Support for controlling non-SIP based services which are not 3GPP PS Data Off Exempt Services in roaming (LBO and roaming with no IMS roaming interfaces) and non-roaming cases.** This key issue addresses the control of non-SIP based services which are not part of the 3GPP PS Data Off Exempt Services. This will cover following scenarios:
 - a) PCRF is deployed;
 - b) PCRF is not deployed.

The non-SIP based 3GPP PS Data Off Exempt Services can be used over a PDN connection to an APN other than the IMS well known APN only.

- Key Issue #4 Support for per service control of SIP messages (and associated media traffic) for SIP based services which are not 3GPP PS Data Off Exempt Services in roaming (LBO and roaming with no IMS roaming interfaces) and non-roaming cases.** This key issue addresses per service control of SIP messages and associated media traffic for SIP based services which are not part of the 3GPP PS Data Off Exempt Services. The SIP based 3GPP PS Data Off Exempt Services can be used over a PDN connection to IMS well known APN (when used as part of carrier grade services of GSMA IR.92, GSMA IR.94, GSMA NG.101), or over any PDN connection (when used as part of GSMA RCS).

This feature requires additional changes to several nodes in LTE network. Each node is responsible of maintaining or applying the feature based on the state PS data switch in UI, and the services that are under the operator control. The implementation logic, addresses the key issues described in the requirements highlighted above, is listed in Table 1.

Table 1: Nodes Impacted by PS Data Off Implementation

Node	Impact
UE	UE needs to report the UE's 3GPP PS Data Off status to MME in Attach Request and TAU Request messages. UE needs to report the UE's 3GPP PS Data Off status to SGSN in Attach Request and RAU Request messages.
MME	MME needs to report the UE's 3GPP PS Data Off status to all SGWs serving the UE's PDN connections in Create Session Request and Modify Bearer Request messages for the Attach and TAU procedure respectively. MME needs to store the 3GPP PS Data Off status.
SGW	In Attach procedure, SGW needs to forward the UE's 3GPP PS Data Off status to all PGWs serving the UE's PDN connections in Create Session Request message. In TAU procedure, when SGW knows the UE's 3GPP PS Data Off status is included, it will further forward this information to all PGWs serving the UE's PDN connections in the Modify Bearer Request message.
PGW	PGW stores the latest 3GPP PS Data Off status in the UE's context.
S4-SGSN	S4-SGSN needs to report the UE's 3GPP PS Data Off status to all SGWs serving the UE's PDN connections in Create Session Request and Modify Bearer Request messages for the PDP Context Activation procedure and RAU procedure respectively. S4-SGSN needs to store the 3GPP PS Data Off status.
SGSN	SGSN needs to report the UE's 3GPP PS Data Off status to all GGSNs serving the UE's PDN connections in Create PDP Context Request message and Update PDP Context Request message for the PDP Context Activation procedure and RAU procedure respectively. SGSN needs to store the 3GPP PS Data Off status.
GGSN	GGSN needs to store the 3GPP PS Data Off status.
PCRF	When the PCRF is informed about the activation of 3GPP PS Data Off, it shall update the PCC rules in such a way that only downlink packets for services belonging to the list of 3GPP PS Data Off Exempt Services are forwarded while all other downlink packets are discarded.
PCEF	When the PCEF is informed about activation of 3GPP PS Data Off, only downlink packets for services belonging to the list of 3GPP PS Data Off Exempt Services are forwarded while all other downlink packets are discarded. When PCEF is informed about deactivation of 3GPP PS Data Off, downlink packets are forwarded according to the operator policy for the subscriber.

The standardization work for PS Data off is discussed in both 3GPP and GSMA documents, with the following highlights.

- The main work items were covered by 3GPP TR 23.702 “Study on 3GPP PS Data off (Release 14)”. The final version was completed in November 2016. This Study also contains the full list of impacted 3GPP specifications.
- Release 14 version of 3GPP TS23.401 describes the PS Data off feature from the UE-Network interworking point of view.
- Release 14 version of 3GPP TS23.203 describes the PS Data off feature in PCC (Policy Control and Charging) architecture.
- The full support of all services requirements defined in TS 22.011 requires additional work in Release 15, and this can be considered phase 2 for this feature.
- The latest versions of GSMA IR.92 and IR.88 contain the description of the feature with references to

Feature Implementation Details

PS Data Off feature can be considered ready for implementation from standardization point of view. It is expected that both UE and network infrastructure vendors will enable the support until the end of 2018. This section reviews some of the functionality changes at different layers associated with the feature from both UE and network sides.

Handling PS Data Off in NAS Layer

If the UE supports 3GPP PS data off, the UE provides the 3GPP PS data off UE status in the PCO (Protocol Configuration Options) IE during attach procedure, UE-requested PDN connectivity, or UE-requested bearer modification procedure. The UE discovers whether a PDN GW supports 3GPP PS Data Off feature at initial attach and during the establishment of a PDN connection via the presence of the 3GPP PS Data Off Support Indication in the Create Session response message.

For those PDN GWs (PGW) that indicated support for the 3GPP PS Data Off feature during PDN connection setup and at Initial Attach, the UE shall report immediately a change of its 3GPP PS Data Off status in PCO by using Bearer Resource Modification procedure, this also applies to the scenario of inter-RAT mobility procedure to E-UTRAN. If the UE has not received any 3GPP PS Data Off Support Indication during the establishment of the PDN connection, it shall not report any change of its 3GPP PS Data Off Status for this PDN connection. The solution to control PS Data off status via Bearer Resource Modification Procedure is shown in figure 3.

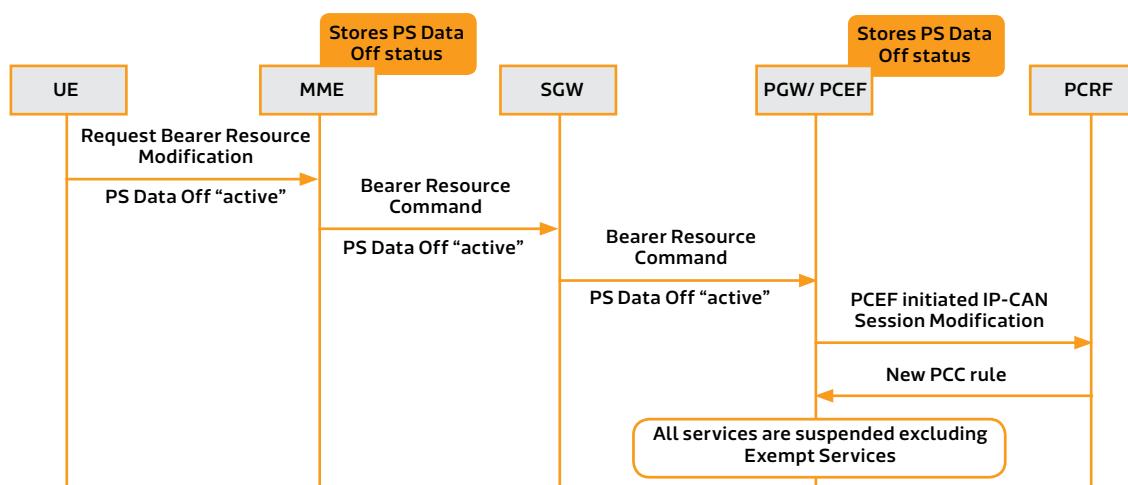


Figure 3: Activating PS Data Off via Bearer Resource Modification

Handling PS Data Off in IMS Layers

There is a separate procedure to handle PS Data Off feature in IMS since there are several SIP services that fall into Exempt category and only IMS entity can correctly detect the exact service type. An IMS Application Server (AS) that supports 3GPP PS data off determines if the UE supports the feature from the third party REGISTER SIP message. If this REGISTER request contains a "+g.3gpp.ps-data-off" Contact header field parameter, PS data off is supported, and the value of the parameter indicates the PS data off status.

When the AS receives an initial request for a dialog or a standalone transaction destined to the served user, if:

- the latest "+g.3gpp.ps-data-off" Contact header field parameter, that was received in a third party REGISTER request, as mentioned above, was set to "active" in the UE; and
- the service the AS supports is not configured as a 3GPP PS data off exempt service;

The AS shall not send the request to the UE via GPRS IP-CAN or EPS IP-CAN. This logic is shown in figure 4.

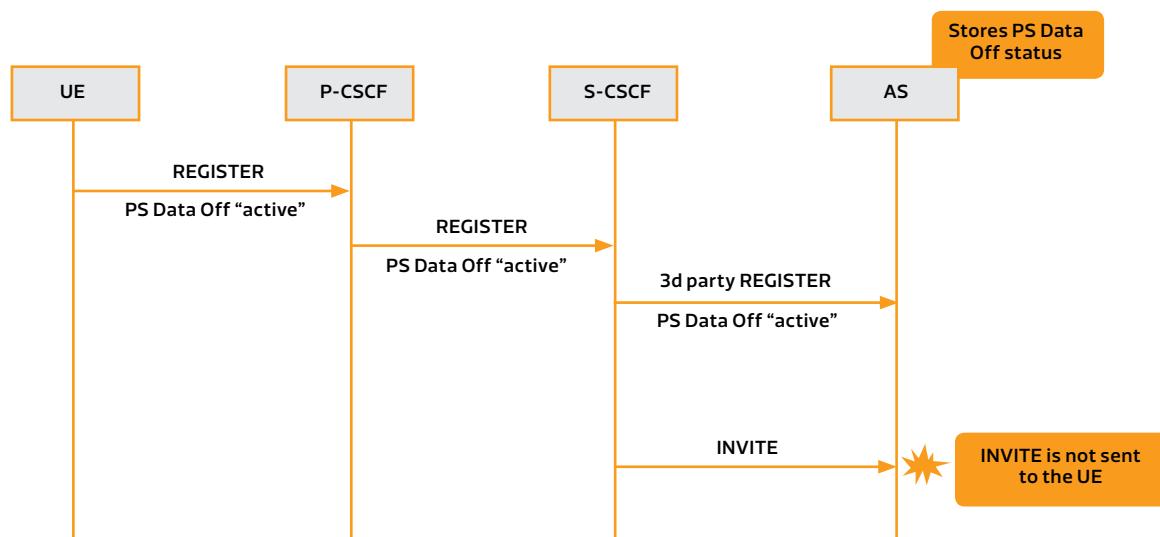


Figure 4: PS Data Off Handling in IMS

Exempt Services

As already mentioned in this document, there are some Exempt services to the PS Data off feature. The task to handle those Exempt services effectively falls into two subtasks – controlling them in the network side for DL traffic and in the UE side for UL. Also different approach is taken for non-SIP and SIP services. Current list of 3GPP PS Data off Exempt services configurable by HPLMN operator is defined in 3GPP TS 22.011:

- MMTel Voice;
- SMS over IMS;
- USSD over IMS (USSI);
- MMTel Video;
- Particular IMS services not defined by 3GPP, where each such IMS service is identified by an IMS communication service identifier;
- Device Management over PS
- Management of USIM files over PS (e.g. via Bearer Independent Protocol);
- IMS Supplementary Service configuration via the Ut interface using XCAP.

Making UE Aware of the Exempt Services

For Release 14 solution, the UE is pre-configured with the list of PS Data Off exempted non-SIP and SIP services and exempted APNs, either using Device Management or UICC provisioning. The list of exempted services is the same for all VPLMNs the home operator has roaming agreements with. For Release 15 this solution will be enhanced with an option to control Exempt services on per-VPLMN basis.

For the Device Management the HPLMN configures the UE with the 3GPP PS Data Off Exempt Services using a management object in the ME.

The non-SIP based 3GPP PS Data Off Exempt Services are identified in the UE by an APN and an uplink filter to be enforced by the UE for originating non-SIP requests.

The SIP based 3GPP PS Data Off Exempt Services are identified in the UE by enumeration (MMTel Voice, SMS over IMS, USSD over IMS, MMTel Video) or by IMS communication service identifier. The UE enforces originating SIP based requests based on these. The new management object is described in 3GPP TS 24.368 for Device management over PS and Bearer Independent Protocol. The UICC file containing Exempt services is described in 3GPP TS 31.102 as **EF3GPPPSDATAOFF** (3GPP PS Data Off). The current coding of the file uses one byte to control the state of each Exempt service as listed earlier in this document while 3 more bytes are reserved for future use.

Non-SIP Exempt Services

When dynamic PCC is deployed, PCRF is configured to know the list of 3GPP PS Data Off Services, PCC rule needs to be enhanced to indicate whether it is for 3GPP PS Data Off Exempt Services, thus when PGW/PCEF receives the notification of status of 3GPP PS Data Off, it can take according action (e.g. the packet flows related to 3GPP PS Data Off exempt service are allowed to be transmitted, while the other packet flows are prevented) according to the PCC rule received from PCRF. If there is no indication of 3GPP PS Data Off Exempt Service in a PCC rule, it should be regarded as a rule for non 3GPP PS Data Off Exempt Service.

When receiving the UE's latest 3GPP PS Data Off status, PGW/PCEF will act as following:

- If the received UE's 3GPP PS Data Off status is activated, PGW will set Gate status to "closed" in all PCC rules for non 3GPP PS Data Off Exempt Services and not change the Gate status in PCC rules for the 3GPP PS Data Off Exempt Services. If the Gate status is set to "closed" for a PCC rule, the related downlink service data flow belonging to the packet filters in such PCC rule shall be prevented at the PGW.
- If the received UE's 3GPP PS Data Off status is deactivated, PGW will set Gate status in the PCC rules to "open", in which the Gate status was set to "Closed" when the 3GPP PS Data Off status of "activated" was received previously.

The enhanced PCC rule can be provisioned to PGW/PCEF during IP-CAN Session Establishment procedure and IP-CAN Session Modification procedure initiated by either PCEF or PCRF. When dynamic PCC is not deployed, the list of 3GPP PS Data Off Services and the related PCC rules can be pre-configured in PGW.

SIP Exempt Services

In Release 14, SIP-AS is configured with a list of IMS services that can be PS Data Off exempted when the 3GPP PS Data Off feature is activated for a UE. This list applies to any VPLMN the UE is in. The IMS PS Data Off services exempt list is realized using IMS Service Communication Identifier values (ICSI) where possible. SIP AS is required to ensure that non exempted services are blocked over 3GPP PS accesses (2G/3G/LTE) when PS Data Off feature is activated. T-ADS (as SIP AS) should take this information into account (i.e. determine the IP-CAN selection via WLAN or to select CS Domain at the first attempt, etc...).

In Release 15, the list of IMS services that can be PS Data Off exempted is conveyed from HSS. It is still to be decided how this information is to be provided to SIP AS (e.g. via Sh, or ISC/Cx). S-CSCF provides the PS Data Off UE status indication to SIP AS via ISC. SIP AS may use this information instead of the local static list from Rel-14 for terminating domain selection.

Conclusion

One of the significant changes introduced in LTE compared to the previous cellular generations is to establish default bearer at the same time when the UE attaches to the EPS network. This is the concept that makes the LTE's connectivity to be known as "always-on". This procedure, opposed to 3G, can provide a significant signaling reduction on the protocol layers and also improves the end-user experience in terms of data reactivation after a certain period of inactivity. However, with this implementation, some roaming issues may occur. When a UE is allocated an IP address for a PDN connection, Internet application servers may go on sending downlink IP packets to the UE for a while. As a consequence the user will be charged for downlink IP packets even though Data Off feature is activated, leading to customer complaints. In addition, the current 3GPP protocol stack, prior to Release 14, does not allow network operators to differentiate services that can still be running when the data is turned off, including IMS MMTEL voice and video services, USSD, XCAP, BIP, or SMS over IP.

As a result of these limitations, 3GPP identified the need to handle a unified solution with new procedures that allow the user device and EPS to be fully aware of the data connectivity option settings in the UI (roaming or cellular data). The main purpose of 3GPP PS Data Off feature is to inform the network that the user has deactivated the data services, in order to avoid excessive roaming charges or for other exemptions to any form of services the operator can offer to the end user in such conditions. When 3GPP PS Data Off is activated, the UE and the network must not send any IP packet via any PDN connection of any service other than 3GPP PS Data off Exempt Services. 3GPP PS Data Off Exempt Services are set of operator services that are allowed even if the 3GPP PS Data Off status set to active in the UE by the user. This applies both to non-IMS and SIP-based IMS services.

By introducing this feature in 3GPP, it is expected that the network operators will unlock new areas of service differentiators and enhance the end-user experience in the home and visiting networks. This whitepaper reviewed the impact to the protocol layers as well as the changes required in different network nodes including the signaling and call flows.

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Abbreviations

AS	Application Server
DL	Downlink
DRB	Data Radio Bearer carrying user plane data
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
eNB	E-UTRAN Node B
EPS	Evolved Packet System
IE	Information Element
HPLMN	Home Public Land Mobile Network
IMS	IP Multimedia Subsystem
MME	Mobility Management Entity
P-CSCF	Proxy Call Session Control Function
PCC	Policy Control and Charging
PCEF	Policy and Charging Enforcement Function
PCO	Protocol Configuration Options
PCRF	Policy and Charging Rules Function
PGW	PDN Gateway
PDN	Packet Data Network
PS	Packet Switched
S-CSCF	Serving Call Session Control Function
SIP	Session Initiation Protocol
UE	User Equipment
UL	Uplink
VPLMN	Visiting Public Land Mobile Network

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