ThingPark Wireless Evolved Packet Core (EPC) Connector Product Description

NOTICE

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VERSIONS

Version	Date	Author	Details
01	31/03/17	Rohit Gupta	Initial Version
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REFERENCE DOCUMENTS

	Documents	Author
01	ThingPark Product Description	Ramez SOSS
02	ThingPark Product Version Release Notes	Gilles LEFEVRE
03	ThingPark Wireless Device Manager User Guide	Gilles LEFEVRE
04	ThingPark Wireless logger User Guide	Marie-Laure ANCELLE
05	EPCCv2 Admin Guide	Jean-Philippe LONGERAY
06	EPCCv2 Configuration Guide	Jean-Philippe LONGERAY
07	ThingPark Usage Detail Records Description	Stephane DUFOUR
08	EPCCv2 Troubleshooting Guide	Jean-Philippe LONGERAY
09	EPCCv2 Monitoring Guide	Jean-Philippe LONGERAY
10	LRC AS Tunnel API	Gilles LEFEVRE
11	ThingPark OSS API Specification	Gilles LEFEVRE
12	How to build a multi-technology Scalable IoT connectivity Platform?	Rohit GUPTA
13	ThingPark Wireless Supplier User Guide	Gilles LEFEVRE
14	ThingPark Wireless Vendor User Guide	Gilles LEFEVRE
15	ThingPark X: IoT Flow	Bruno REGNIER

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Acronyms and Definitions

Acronyms	Definitions
ARPU	Average Revenue Per User
AS	Application Server
BSS	Billing Support Systems
CSP	Communication Service Provider
EPC	Evolved Packet Core
eSIM	Electronic Subscriber Identity Module
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber Identity
IoT	Internet of Things
ISM	Industrial Scientific Medical
GSCL	Gateway Service Capability Layer
LPWAN	Low Power Wide Area Network
LRC	Long Range Controller
M2M	Machine-2-Machine
MAC	Media Access Control
MCC	Mobile Country Code
MNC	Mobile Network Code
NIDD	Non-IP Data Delivery
NW	Network
OCS	Online Charging System
OFCS	Offline Charging System
OSS	Operations Support Systems
PCEF	Policy and Charging Enforcement Function
PCRF	Policy and Charging Rules Function
PGW	Packet Gateway
PKI	Public Key Infrastructure
POC	Proof Of Concept
REST	Representational State Transfer
SCEF	Service Capability Exposure Function
SLRC	Secured LRC (VPN Concentrator)
SMP	System Management Platform

Acronyms	Definitions
SMTP	Simple Mail Transfer Protocol
SNMP	Simple Network Management Protocol
SNR	Signal to Noise Ratio
SPR	Subscriber Profile Repository
TWA	ThingPark Wireless Application
UICC	Universal Integrated Circuit Card
USIM	Universal Subscriber Identity Module
VPN	Virtual Private Network

1 SCOPE

This document describes the ThingPark Wireless Evolved Packet Core (EPC) Connector solution which is a module within ThingPark Wireless to interface with 3GPP core network, and addresses the following topics:

- Architecture Description
- Solution Configuration
- Feature limitation and expected roadmap enhancements

2 THINGPARK WIRELESS: A CONVERGED SERVICE & DATA MANAGEMENT FRAMEWORK FOR LPWAN CONNECTIVITY

ThingPark Wireless offers a converged IoT platform seamlessly integrating LoRaWAN and Cellular IoT technologies. ThingPark Wireless presents a unified user interface and APIs to applications, and single layer of device and connectivity management for either both LoRaWAN and cellular technologies. It exhibits the following high-level features:

- Converged Platform agnostic to radio to seamlessly manage both LoRaWAN and Cellular IoT technologies
- Compliance with 3GPP Interfaces (S6/S5/S8) for inter-connection with operator's core network
- Support of message mode (NIDD) for low power devices and Direct IP mode
- Wireless logging and power saving features for low power devices using message mode
- OSS Solution with focus on IoT
- Data Mediation layer for building drivers, data analytics and interfacing with 3rd party cloud servers (for ex. Amazon AWS) using ThingPark X
- Pre-integrated interface with ThingPark Market enables acceleration of operator goto market through dynamic open ecosystem, and taping into the whole service value, not just connectivity
- Rating solution focused towards IoT
- Open and modular with OSS/BSS APIs allowing easy integration with operator's internal or 3rd party platforms/applications
- Multi-tenant architecture to share resources within different subscribers and operator instances
- Hardware based security using HSM to store the SIM Card secret keys
- Provision of eSIM/eUICC with multiple profiles
- Cellular device suspension at the subscriber level or the operator level

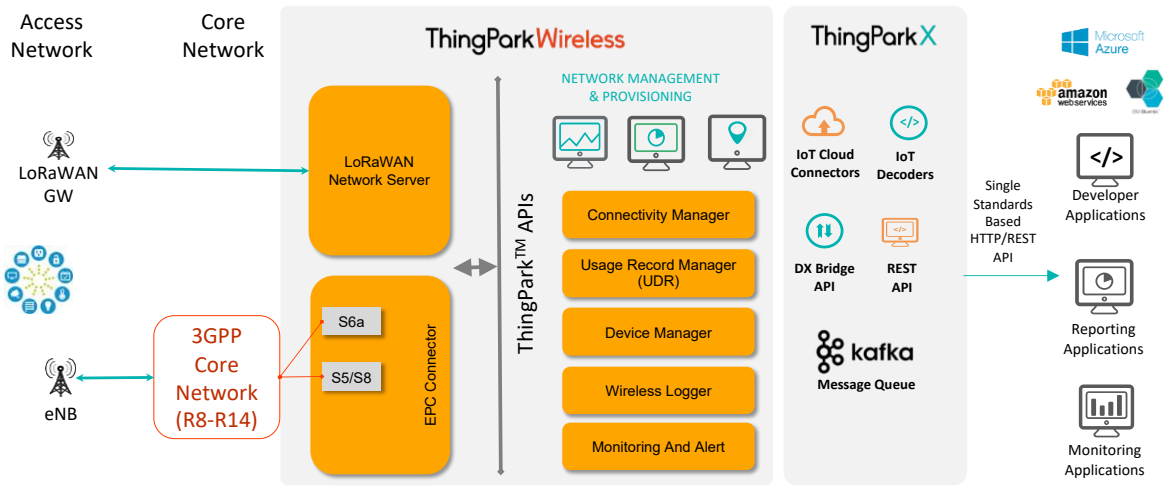


Figure 1 : ThingPark Wireless Architecture

ThingPark Wireless enables Operators to build value chain beyond connectivity

2.1 EPC Connector: Overview

EPC Connector is an add-on within ThingPark Wireless that provides insertion into existing 3GPP mobile operator core using standard-compliant interfaces (S6a, S5/S8) and provides unified device and connectivity management for IoT devices.

ThingPark wireless integrates both the EPC Connector and LoRaWAN network server and provides a unified interface to IoT subscribers which have both LoRaWAN and 3GPP (NB-IoT/Cat-M/LTE) based deployments. ThingPark wireless integrates seamlessly with ThingPark X, allowing a unified data management framework with connectivity towards apps and cloud platforms (for ex. Microsoft Azure, IBM Bluemix and Amazon AWS).
The key benefits are:

- Single layer of device provisioning
- Unique connectivity management layer related services
- Homogeneous interface to Application layers
- Unique & Consistent LPWAN Usage Record and Policy management layer
- Charging/rating capabilities specifically tailored for IoT
- Unique cost-effective licensing model to replace traditional HSS/PGW/PCRF/PCEF modules within 3GPP Core network which are too expensive for IoT use cases
- OSS/BSS APIs that can be used to pre-integrate 3rd party or legacy operator platforms

2.2 EPC Connector: High level features

This section describes the high-level features of EPC Connector:

- Support of S6a interface which includes HSS functionality compliant to Rel Rel 8 - 13 3GPP specs
- Support of S5/S8 interface which includes PGW functionality compliant to Rel 8 – Rel 13 3GPP specs
- Integration with ThingPark Wireless over APIs to manage cellular devices and connectivity plan
- Support for storing the HSS keys in hardware based secure module (HSM)
- Message mode and Direct IP mode support for the data plane of cellular devices
- Support for providing statistics to ThingPark Wireless for Usage Data Records (UDR generation
- Support for policy enforcement features managed by ThingPark Wireless connectivity Plan

2.3 EPC Connector: Multi-tenancy

Typically, service providers sell IoT connectivity to enterprise customers. This requires a multi-tenant platform that enables sharing of the same infrastructure for multiple enterprise customers.

Figure 2 shows the multi-tenancy concept in ThingPark wireless which can be used to host multiple enterprise clients within the same platform. Multi-tenancy is the key to providing horizontal IoT platform that can serve different IoT verticals, each representing markets with diverse requirements.

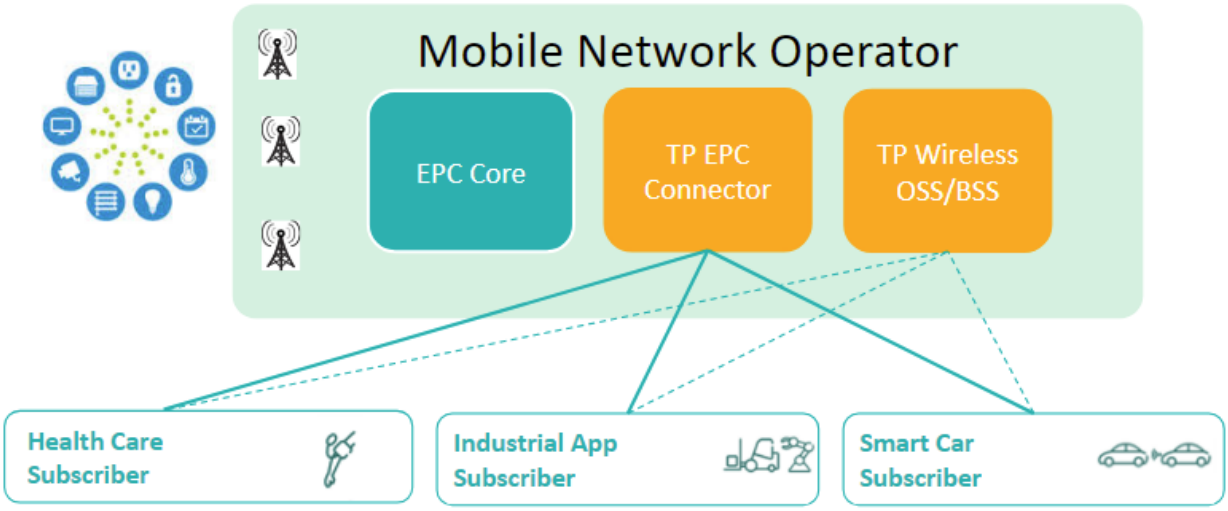


Figure 2 : Multi-tenancy support

Multi-tenancy is the key for operator scaling its B2B business with Enterprise customers

2.4 EPC Connector: Modes of Communication

LoRaWAN is a non-IP protocol purely based on exchanging small messages between LoRaWAN devices and application servers.

Cellular IoT is IP-based, but new proposals such as Non-IP Data Delivery (NIDD) in R13 3GPP standards enable efficient use in message mode. To optimize any Cellular IoT communication pattern, EPC Connection supports two modes of communication:

- **Message mode:** In this mode, devices exchange small messages (NIDD) or based on UDP payload (with specific source port) with the application server.
- **Direct IP mode:** In this mode, EPC Connector routes the traffic directly to Application Server Router (ASR) via Internet, which routes it further to Application servers sitting behind firewall for security reasons. However, it sends charging information in real-time to ThingPark wireless applications.

The modes of communication for different devices/IoT subscribers are configured within ThingPark Wireless using the routing profile and connectivity plan objects, which are also used for LoRaWAN. This unifies data records, traffic enforcement, traffic management seamlessly between LoRaWAN and Cellular devices to give a consistent experience for device and connectivity management to IoT subscribers.

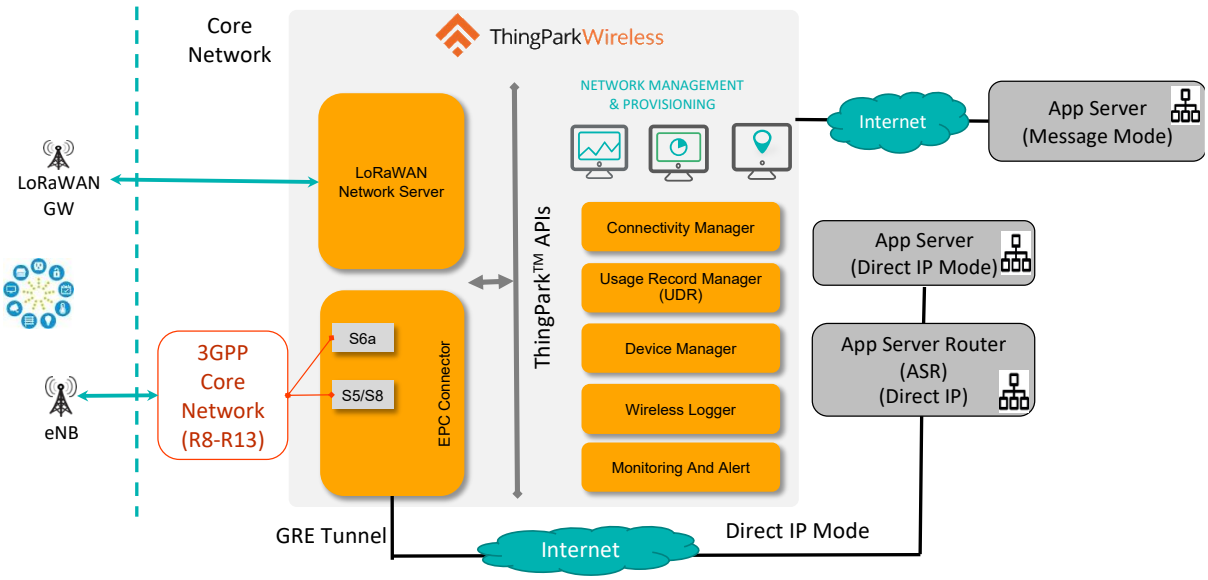


Figure 3 : Modes of Communication

2.5 EPC Connector: Key Enabler for billing features for Cellular IoT

Traditional billing systems within operator networks are designed for human-centric communications and do not meet the needs of IoT applications. However, upgrading the traditional billing systems is a costly exercise which can jeopardize the ROI on IoT investments for an operator. EPCC provides charging/rating features that facilitates integration with an optimized billing system allowing operators to monetize IoT connectivity easily from the ThingPark platform with minimal investment compared to traditional billing system upgrades, and with immediate time to market.

To adapt to the diversity of connectivity use cases, the EPC connector and ThingPark platform provide two options for usage records and policy enforcement:

- **Message mode:** this is the optimal mode for non-IP Cellular and LoRaWAN. Accounting is based on message count, and policy enforcement reports number of messages that did not comply to token bucket regulator, which therefore can be charged at a higher rate.
- **Direct IP mode:** this is the optimal mode for applications using traditional IP connectivity.

To provide accounting records for the flow mode (“Direct IP” mode), the EPC connector implements the concept of “microflow” to report the traffic statistics on a message queue. Each “Microflow” record characterizes the real-time traffic within a certain time and may be generated also based on volume triggers.

2.6 EPC Connector: Policy Enforcement

Policy enforcement for IoT devices is quite complex as there is need to manage enforcement for just not for each device individually, but also at IoT subscriber level, which represents a large group of devices. IoT device traffic patterns can be quite unpredictable at device level but become much smoother and consistent at aggregate level. Policy enforcement is the key to manage congestion in the cellular network and to maintain SLAs for human-centric, mission critical and premium IoT applications. There are many IoT applications which can result in

synchronized activity from many devices, hence enforcement needs to be done in real-time to avoid large overheads in the operator network.

2.7 OSS APIs for Integration with 3rd party platforms

IoT is synonymous with full automation, and therefore extensive support for APIs is an essential requirement for any IoT platform. APIs are also a way to introduce eSIM/eUICC features and build automated SIM lifecycle management, to scale IoT use cases to billions of devices.

ThingPark Wireless provides 100% API access to all platform features, and ThingPark X extends the scope of APIs to dataflow management, and semantics.

Once connectivity is in place, the value in IoT resides in extracting value from the data collected from end-devices, utilizing various data analytics tools. This often requires decoding and storing the data for later analysis. There is a very vast offering of cloud services and platforms available to process IOT data.

ThingPark Wireless OSS APIs provide the following benefits:

- Subscription & user management
- Offer subscription
- ThingPark Single-Sign-On
- Device management
- Gateway management
- Device data decoding

Open APIs and modular platform are the key to open innovation and industrialization of IoT landscape

2.8 ThingPark X: IoT Flow

Actility believes in a radically more efficient and sustainable world through ubiquitous digital-twin technology. Digital twins are software representation of physical devices. The software interface exposes the device properties (and their current values like battery level), along with callable method sending downlink messages.

We want to spark this transition and become the leading global mediation platform between cloud apps & physical world. ThingPark X is the cornerstone of Actility's vision to make digital twins common place. Positioned at the edge of the LoRaWAN/Cellular network, ThingPark X simplifies the interface between LPWAN-connected sensors and IoT application, transforming sensors raw data into application-friendly actionable information, that can be fed into digital twins object of various IoT Platforms.

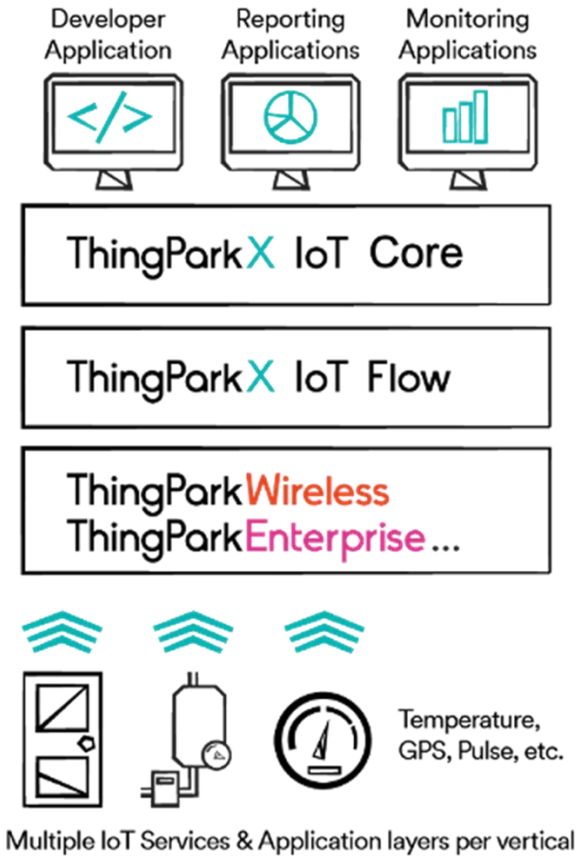


Figure 4 : Multiple IoT Services & Application layers per vertical

ThingPark X IoT-Flow acts as a mediation layer handling bi-directional communication between ThingPark powered networks and application servers or major cloud-based IoT Services to keep digital twins in sync. This ability to feed digital twins consistently whatever the LPWAN sensors connected relies on key capabilities delivered by TPX IoT-Flow:

- **Drivers:** Transforms the device specific payload into a generic JSON object. Based on ThingPark device profiles, our TPX Platform will be able to decode uplink messages collected through the LPWAN network, to transform raw data into actionable data points. ThingPark X Drivers Library supports already more that 100 sensor models and offers the possibility to upload custom drivers.

- **Connections:** Adapting transport protocol and forwarding to external application servers or cloud providers. Connectors ensure the proper delivery of the extracted sensor data (via the driver engine) to your selected IoT platform(TPX IoT Core, AWS IoT Core, Azure IoT hub, Thingworx, etc), ensuring that:

  a. Authentication is properly handled.

  b. Device / Thing provisioning is consistent. E.g., AWS IoT Core connector will create dedicated thing type on AWS IoT Core and instantiates things if it does not exist yet.

c. Data publication at the right place - E.g., in the device shadow, or in the alarm framework of the IoT platform if data extracted is an alarm.

- **Flows:** A data flow (Flow) processes payloads and sends commands to the list of devices associated to this Flow. The Flow is associated to one or more Connections to external application servers or IoT platform providers. As part of a given Flow instance you can also define the drivers to use for payload decoding/command encoding, add optional filtering, transformation and forwarding rules. Typically, a flow will first decode the devices' payload into the ThingPark X normalized ontology, then translate this payload into the format expected by the target IoT platform.

Note: This feature is only supported to message mode cellular traffic.

2.9 Summary

ThingPark wireless is carrier grade platform allowing operators to deploy converged IoT services. ThingPark offers:

- Scalability, multi-tenancy
- Choice of licensed cellular (NB-IoT, Cat-M, LTE) and unlicensed (LoRaWAN) technologies to optimize 100% of IoT use cases.
- Standard integration to any 3GPP core network (complaint to 3GPP Rel 8+)
- Flexible charging and policy enforcement models fully optimized for IoT
- Whole solution addressing dataflow, decoding, and popular cloud platform integration.
- Open ecosystem management via ThingPark market

2.10 EPCCv2 New features

In this section, we summarize the new features introduced in EPCCv2.

- Runs on Alma Linux 8.8 (but may run also on other OS)
- Both non-DPDK and DPDK versions available
- Installation based on docker images
- HSS / PGW can be combined or installed in separate containers
- A single configuration file in yaml format
- Unified CLI
- No proprietary UI (Replaced by Grafana)
- Multiple Prometheus counters for statistics
- Multiple Grafana Dashboards for statistics
- Log compatible with Loki
- PGW extensible services: Gx, Gy, Radius, etc.
- Automatic and rotating protocol captures
- All logs are rotating
- Up to 11 simultaneous radio bearers per IMSI
- Automatic Backup
- NIDD support
- Upto 4096 GRE Tunnels

3 IOT ENVIRONMENT

For the end-user to understand this product, this section provides a quick overview of the concepts related to LTE access for IOT traffic. It is an organized list of terms with their brief explanation which should allow the reader to get a quick understanding of the ecosystem and the role of EPC Connector within ThingPark Wireless.

IOT device
Mostly working with no user interaction, a simple device, generally designed for low power consumption with simple requirements for data.
Such a device is expected to require:

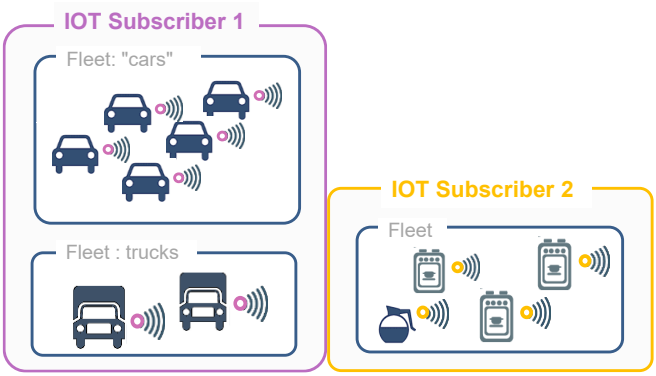
- Small data exchanges from time to time (for instance sending a temperature or measurement to a central system)
- Or bigger, sporadic exchanges of data (image upload, firmware download)

Devices range from low cost, low consumption, high battery life standalone devices to cards embedded in a system with sufficient power and higher networking demand.

AS/Application server
This is any server, hosted remotely, which needs to collect data from many devices, and to send them updates or triggers.

IOT subscriber
An IOT subscriber is an entity which owns devices and applications servers for a given purpose (locate and track objects/animals, provide alarms on a remote site, measure usage of objecs and so on).
IOT subscribers apply for a connectivity service to get an infrastructure allowing communication between their devices and AS.

Fleet
An IOT subscriber has a fleet of devices, all of them having the same communication and management needs.

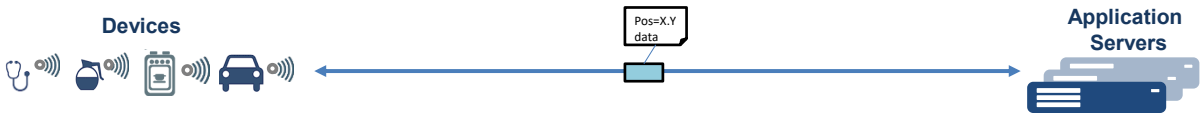


Message Mode

In this document and in the system, message is a small data packet exchanged between the device and the central system.

What makes the message special compared to a basic IP packet for instance is the fact that it is delivered to the AS with additional contextual information from the network. The typical information bundled with a message in uplink is the location of the device when the message was emitted. Note that downlink messages have no bundled information.

A second important feature for a message is that the delivery is handled by a system (such as ThingPark Wireless) which may store it, duplicate it, and forward it when convenient, with no hassle on the device and server to manage this asynchronous aspect. Recently, 3GPP has introduced the concept of Non-IP Data Delivery (NIDD) to send short messages from Rel13 IoT devices. We transport these short messages via message mode.



Direct IP Mode

By contrast with messages where relatively heavy processing is done, some types of exchanges require a direct connection to a remote AS, with plain IP.

For instance, a download of firmware is more efficiently managed using the TCP/IP layer. There would be no added value and a scalability issue if all packets were individually enriched, stored, and forwarded.

Note that some devices need only messages, some other need direct IP. “Mixed mode” is possible to have both simultaneously.

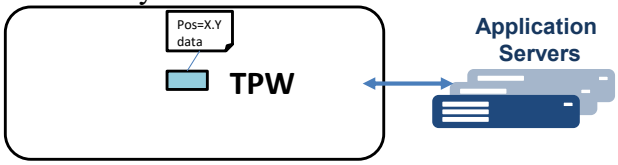
For instance, the device may wake up, receive a message from the application server which requests direct connection, and then start a download in direct IP.

ThingPark Wireless (TPW)

This is the OSS solution designed to store and forward, for each device, all messages and to bring the tools needed to manage, operate and charge IOT traffic.

ThingPark Wireless allows reaching LoRaWAN devices using LoRaWAN Network Server, as well as LTE devices though the “EPC connector” defined hereafter. It exposes the unified layer of device provisioning and handling of the data path to send/receive messages from both LoRaWAN and LTE devices.

ThingPark Wireless manages “message mode” completely and is also aware of direct IP communications but does not relay direct IP traffic.



EPC
As per 3GPP standard, it's the network part between the device and the Internet which provides IP connectivity with support for roaming. Only LTE access is considered, not 3G or 2G.

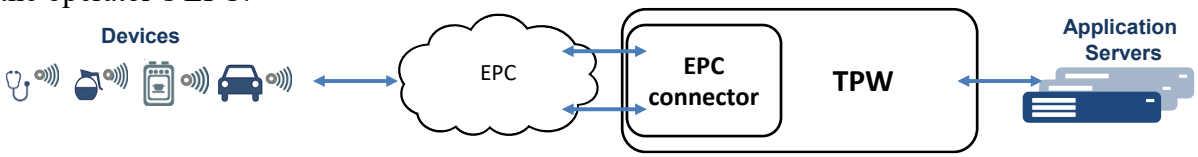
EPC comprises of **MME** (mobility and connection management, signalling stratum), **S-GW** (packet relay with mobility support, user stratum), **HSS** (Home Subscriber Server) and **P-GW** (Packet Gateway).

The goal of the EPC is to enable a network of roaming devices and connect it to a remote fixed network (which could be the Internet or a private network).

USIM, eUICC/eSIM, IMSI
The EPC identifies any connecting device not by its own hardware id (IMEI) but by a specific ID called IMSI.

The IMSI uniquely matches a secret key which is hidden in a piece of hardware (USIM card) or software (eUICC/eSIM). This is an extension of the network inside the device.

EPC connector
As stated in the introduction, it is part of TPW and supports the 3GPP compliant interfaces to the operator's EPC.



These interfaces are usually provided, in the standard 3GPP network architecture, by the following software modules:

- **MTC-LTE-GW** (access gateway for LTE for providing integrated functionality of PGW/PCEF/PCRF/OFCS/OCS)
- **HSS** (device/user database for authorization and authentication)

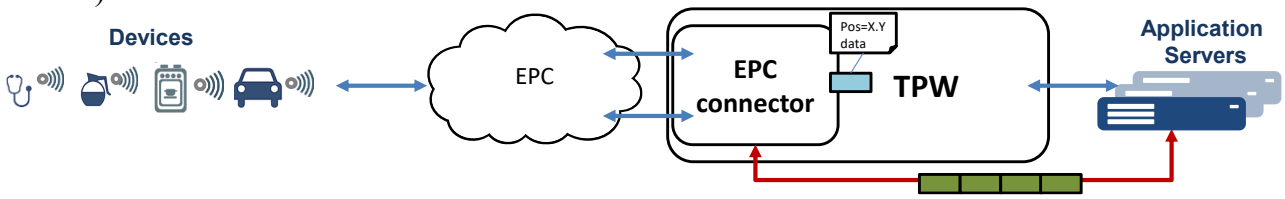
The EPC connector is therefore split into the MTC-LTE-GW function and HSS function. Moreover, a **SPR** (subscriber profile repository) function is co-located with the HSS. It contains the provisioned list of devices and the IOT subscriber and fleet they belong to. It is queried by the MTC-LTE-GW at device connection.

APN
In 3GPP, Access Point Name refers to a group of devices in the same network. They have a consistent IP range for devices, and their traffic needs to go to the same remote network and remain separated from the other APNs. This is the default usage of the EPCC, and a device in an APN can't reach anything but a local virtual private network.

However, APN management can also become a big constraint in some cases, as the right APN string must be configured both in the HSS (provisioning) and in each device (personalization) before it first connects. In such case, The MTC-LTE-GW has an option to fix an erroneous APN string. The MTC-LTE-GW will still provide the exact same network separation, using the IOT subscriber of the device (as provisioned centrally), instead of using the potentially erroneous or insecure APN string provided by the device.

Tunnelling
Tunnels allow extending a private network over remote places. They are used to connect devices in each fleet to a remote network. The Internet may be used as a transport while keeping the private network separated.

Tunnelling is used in the solution to enable direct IP for a fleet: the devices and AS are exchanging data as if in a local network. There is no packet "transformation" (NAT or Firewall for instance) needed, and the other networks are fully separated (Internet, other AS, other devices).



The AS may run some software to terminate the tunnel, or a separate server may be used if multiple AS need to share the connectivity with the fleet of devices.

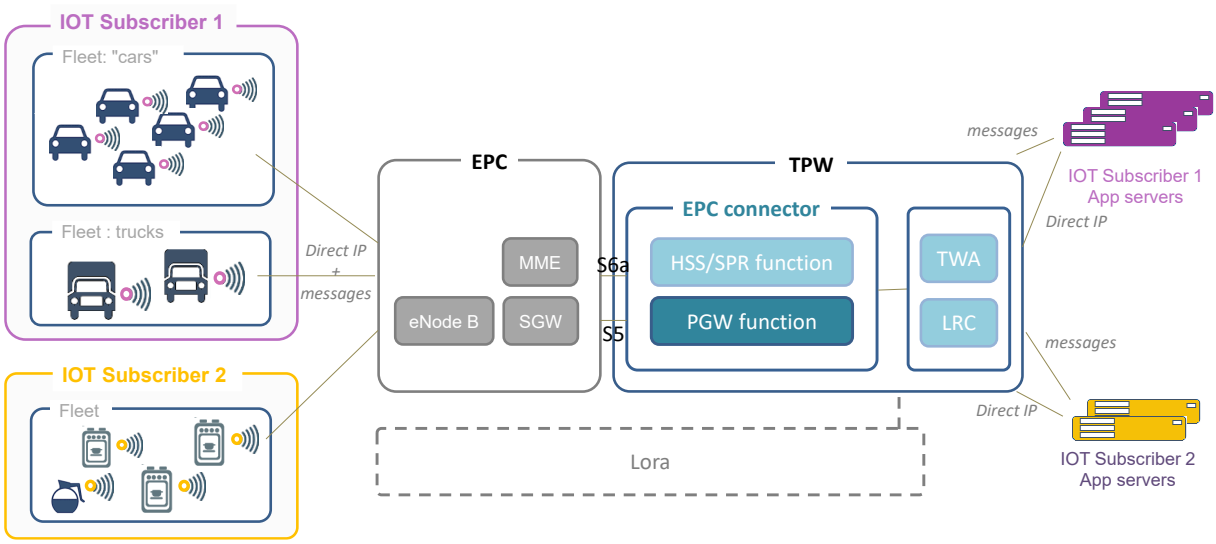
TP OSS API
OSS APIs provided by ThingPark Wireless to integrate third party OSS/BSS systems or applications.

Provisioning API
This API takes place between TPW (TWA) and the HSS/SPR to declare devices and tell their fleet.
The MTC-LTE-GW gets this information from the HSS/SPR when needed.

Activation / IoT Subscriber API
As the EPC connector is integrated into TPW, a specific API allows activating the fleets: TPW GUI shows the needed properties and accepts user input. In turn, this is translated into API calls to create the fleets inside the MTC-LTE-GW and give their characteristics that the MTC-LTE-GW needs for connectivity, enforcement, and charging. Most of the features of the MTC-LTE-GW are driven using "IoT subscriber API" which describes the following:

- The IOT subscriber the fleet belongs to
- The connectivity for the devices – AS direct IP, and for messages
- enforcement rules adapted to IOT traffic for all devices belonging to the fleet
- charging rules adapted to IOT traffic from all devices belonging to the fleet

Ecosystem overview


IOT Subscriber 1
Fleet: "cars"
Fleet : trucks
IOT Subscriber 2
Fleet
Direct IP
+
messages
EPC
MME
eNode B
SGW
S6a
S5
TPW
EPC connector
HSS/SPR function
PGW function
TWA
LRC
Lora
messages
Direct IP
IOT Subscriber 1
App servers
messages
Direct IP
IOT Subscriber 2
App servers

4 THINGPARK WIRELESS EPC CONNECTOR SOLUTION OVERVIEW

EPC Connector is an add-on within ThingPark Wireless that provides insertion into existing 3GPP mobile operator core using standard-compliant interfaces (S6a, S5/S8) and provides unified device and connectivity management for Cellular IoT devices. EPC Connector enables tighter integration of ThingPark Wireless with 3GPP Core networks. Figure 5 describes how EPC connector interacts with 3GPP network, ThingPark Wireless internal components (LRC, TWA) and Application servers.

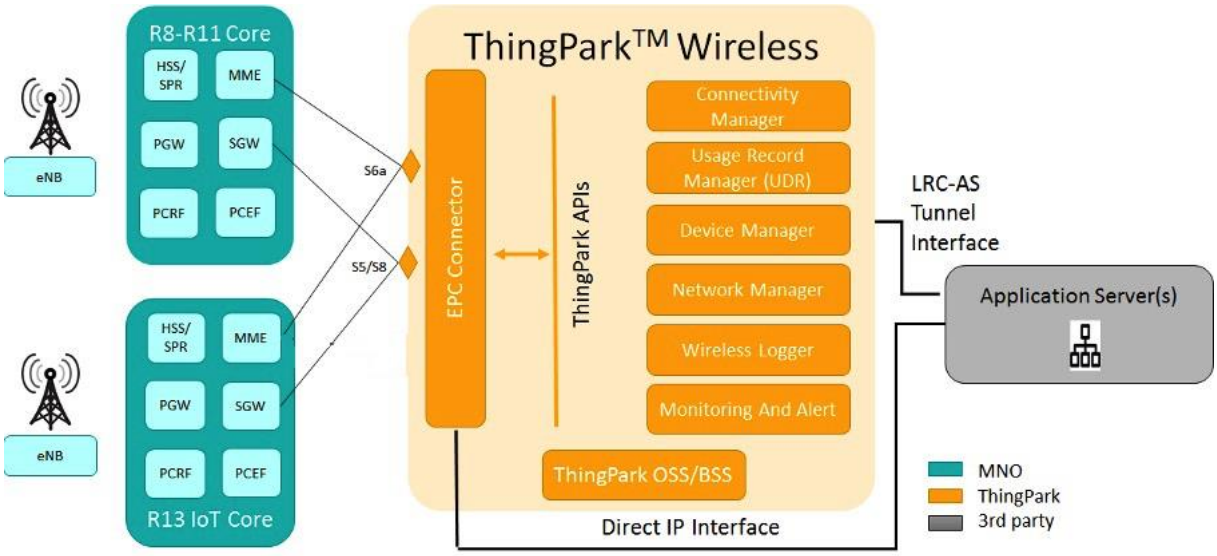


Figure 5 : ThingPark Wireless EPC Connector Overview

EPC Connector interacts with standard 3GPP core network elements using following interfaces:

- S6a: This interface implements the following functionalities of HSS/SPR to interact with MME
  - Unique provisioning layer for 3GPP devices which results in lower IT cost for provisioning and mass insertion of devices
  - IOT-oriented policy and charging provisioning
- S5/S8: EPC Connector implements integrated PGW, rating and policy enforcement module which has following functionalities:
  - Includes specific IoT policies and allows for message oriented communication leveraging unique ThingPark Wireless features and APIs
  - Support for direct IP through private and over the top network for efficient communication
  - Support for message mode traffic for delivering NIDD or UDP payloads (with a configurable UDP source port)
  - Support standard interfaces to the EPC (S5/S8) to enable LTE connectivity
  - Provide a means to distinguish the messages and forward them enriched to/from TPW
  - Provide end to end direct connectivity between devices and AS through a tunnel, in a private network
  - Provide metering features to enable TPW to do charging both for message mode and direct IP
  - Provide enforcement for direct IP (TPW may do so for messages)
  - Integrate with ThingPark through APIs
  - It provides integrated functionality of PGW/PCRF/OFCS/PCEF

5 THINGPARK WIRELESS EPC CONNECTOR ARCHITECTURE

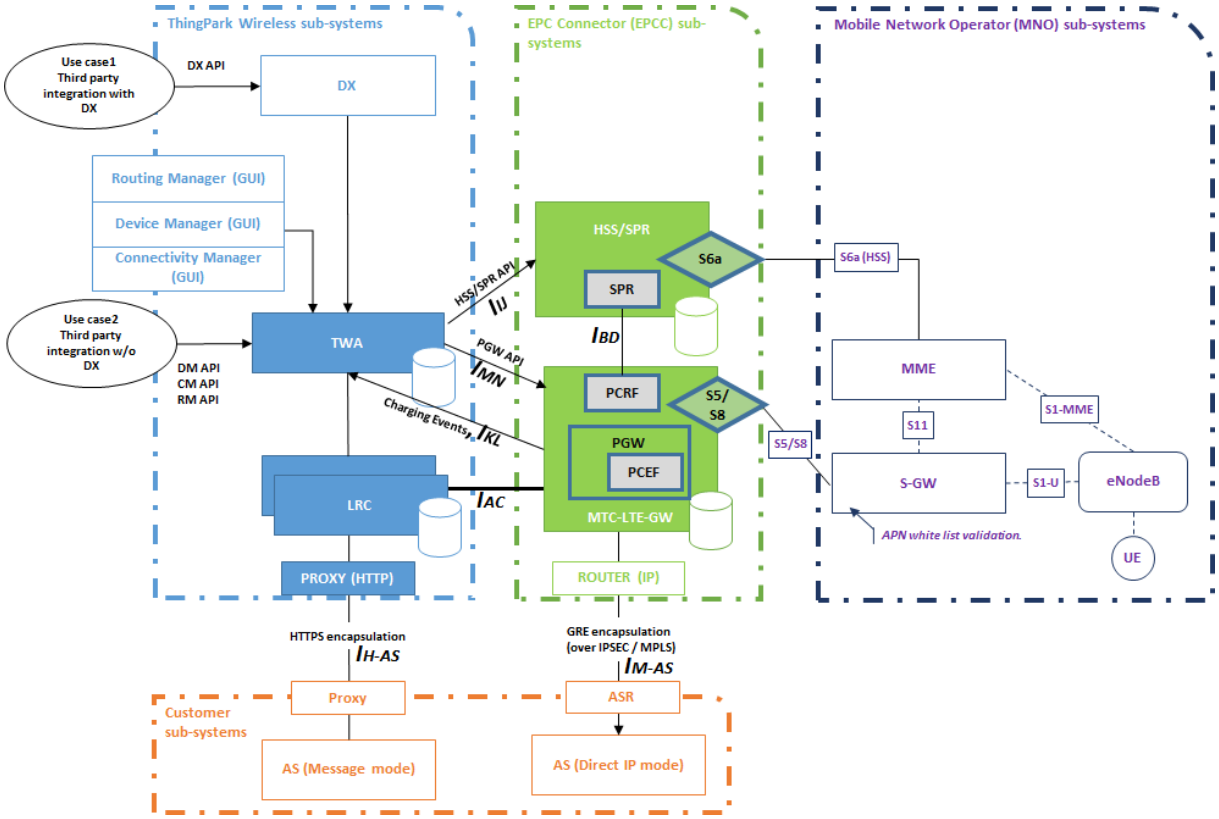


Figure 6 : ThingPark Wireless EPC Connector Interface Description

EPC connector consists of two fundamental modules as shown in Figure 6. One of them is HSS/SPR responsible for providing device provisioning functionality. The other module is MTC-LTE-GW which includes functionality for charging, traffic shaping and policy enforcement. MTC-LTE-GW implements integrated functionality for PGW, PCRF, OFCS, OCS and PCEF. It has the following high-level interfaces:

- **I_{IJ}:** This interface is used for provisioning devices between HSS/SPR and ThingPark. This interface is described in detail in section 5.1.1.
- **I_{BD}**: This interface is used by MTC-LTE-GW to fetch SPR values from HSS/SPR database. This interface is described in detail in section 5.2.
- **I_{AC}**: This interface is based on IEC104 and carries the user payload between MTC-LTE-GW and LRC in "message mode". The description of different modes of connectivity are described in section 6.
- **I_{MN}**: This interface is used to provision IoT subscriber from ThingPark to MTC-LTE-GW. Note, that this API is internal to ThingPark Wireless and EPC Connector and not relevant for customer.
- **I_{KL}**: This interface is used to generate CSV/Kafka based user traffic records. The charging mechanism is descried in detail in section **Error! Reference source not found.**.
- **$I_{M\text{-}AS}$**: This interface carries IP packets for IoT device for direct IP path between MTC-LTE-GW and AS.
- **$I_{H\text{-}AS}$**: This interface carries IP packets encapsulated in LRC-AS tunnel API. It is used for carrying "message mode" payloads between IoT device and AS. This interface is described in more detail in section 5.7.

- S6a: This interface is used by HSS/SPR to communicate with Mobility Management Entity (MME) of the operator network.
- S5/S8: This interface is used by MTC-LTE-GW to talk to Serving Gateway (S-GW) within the operator network. MTC-LTE-GW provides PGW functionality when talking to SGW within 3GPP core network of an operator.

We now describe all the interfaces in more detail.

5.1 IIJ: HSS-LRC Provisioning Interface

This interface is used for provisioning devices within HSS/SPR from ThingPark Wireless. It contains the fields specific to 3GPP security parameters and the SPR fields related to traffic management. We describe below the format of the data structure that is pushed from ThingPark Wireless to HSS/SPR when a new device is provisioned in ThingPark. This interface carries two types of provisioning data:

1. HSS Provisioning
2. SPR Provisioning

5.1.1 HSS Provisioning

A 3GPP standard compliant HSS is used to allow the devices to attach to the network (providing authentication features) and carry data updates during mobility events from one MME to the other. S6a interface is the sole point of integration, which is covered with the network, as only LTE access (3GPP Rel 13) is supported.

HSS complies with the following 3GPP TS (Release 13):

TS 29.272 - *Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol*	Includes most of the messages between the HSS and MME. A part of this specification is ignored (for ex. 3G access)
TS 23.401 - *General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access*	Includes some useful information related to the user's data to store and exchange between nodes of the network.
TS 23.008 – *Organization of subscriber data*	Includes details concerning information to be stored in home subscriber servers, visitor location registers, GPRS Support Nodes and Call Session Control Function (CSCF) concerning mobile subscriber.
TS 23.003 - *Numbering, addressing and identification*	defines the principal purpose and use of International Mobile station Equipment Identities (IMEI) within the digital cellular telecommunications system and the 3GPP system

This above list is non-limitative.

HSS is tightly integrated to ThingPark Wireless to provision the right data which is detailed further below.

HSS provisioned information, per IMSI
HSS requires a relatively small set of data to operate. These fields are automatically set by TPW using the provisioning interface.
Note: All this data is related to the USIM and is stored in ThingPark database.

IMSI
It is the Sim card unique identifier. Note that a physical card is not always present in the device, when using a software solution (based on eSIM/eUICC, Universal Integrated Circuit Card)

Ki
Sim card long term pre-shared key

APN
Whitelist of allowed access point names. This information must be set to allow access for the device

IMEI
Device unique identifier
This is a pointer to the SPR Table. Note that an internal binding is done between SPR and HSS using this information

OPid
As the HSS must prove its legitimacy to the device as the known operator, an operator key must be used. This is an index on this secret key

MSISDN
Subscription number for voice services. It is unused and not provisioned as voice is not an IOT service. It is referred here for future use only

AMBR (UL, DL)
This field is used to tell the network which maximum bitrate shall be enforced by the access (MNO) network. Note that the P-GW function does not use this field, which is replaced by shaping information found in the enforcement profile as described in Section 8.

Extra field (not usually used in the HSS itself):
Device static IP – IPv4 Optional and *not recommended*
Allows static assignment of the device's IP.
If not present, DHCP is used to provide an IP to the device when it connects, and ThingPark will have to learn it and keep track of its possible changes. As the IPv4 is valid only for a given APN, it is a per APN value.
Note that if an IPv4 is set this way, it must be unique (it means that it should not be part of the DHCP pool) and must belong to the APN subnet. Therefore, caution is needed if this feature is used.
We recommend setting the static IP by increasing the DHCP lease time in PGW globally in the product.

5.1.2 SPR Provisioning

SPR (subscriber profile repository) is an independent device database bundled with the HSS.
The MTC-LTE-GW function must know the device to tell how to manage its traffic, how to charge it, and identify some additional information (barring, and per device additional info), like a name for a group of devices (IOT subscriber and fleet) which is not related to the 4G access.
While the HSS may be left unused (if an external HSS is used), the SPR is core to the EPC connector and must be used for proper functioning of MTC-LTE-GW.

IMEI – *key*
Device Unique Identifier

Fleet – string(20) - mandatory
IOT Subscriber – string(20) - mandatory
Currently, in TP 5.0+ there is one to one mapping between IoT subscriber and Fleet objects. Hence, throughput the document, we use Fleet and IoT subscriber synonymously and ThingPark GUIs/APIs always refer to IoT Subscriber. However, in future releases of TP 5.x+, this restriction will be removed and one IoT subscriber could have several fleet objects. This would allow grouping of devices within same IoT subscriber with same routing profile/connectivity plan settings. But the distinct groups have slightly different settings for routing profile/connectivity plan. This would allow more automated provisioning of a group of IoT devices sharing similar characteristics using OSS/BSS APIs of ThingPark and significantly bring down device provisioning costs incurred by an IoT subscriber.

Barring int – string (2) - mandatory
It is used to tell if the user should be temporarily blocked. 0 (default) = no barring. 1 = full barring.
It may be extended in the future to selective barring, for instance prevent roaming access. (2 local only, 3 local and partners). However, such domains are not defined in the system yet.

Network context name override (string 20) - Optional
This is used to map the device to a specific network context (connectivity to the right remote AS)
The expected usual behavior is that the MTC-LTE-GW function evaluates the fleet field. The MTC-LTE-GW function contains a fleet object which tells the network context to use for devices belonging to this fleet. However, setting this field for a device within HSS provisioning will give the MTC-LTE-GW function the name of the network context to use directly.
Note: see references [6][8] on network contexts and their usage.

***Device Policy override*/profile** (string 20) - Optional
This is used to associate the device to an enforcement profile (per device limitations).
The expected usual behavior is that the MTC-LTE-GW function evaluates the fleet field. The MTC-LTE-GW function contains a fleet object which tells the enforcement profile to use for devices belonging to this fleet. However, setting this field for a device within HSS provisioning will give the MTC-LTE-GW function the name of enforcement profile to use directly.
Note: see references [6][8] on enforcement profiles and their usage.

FreeField – String(20) - optional
Free form field which is not used in the current release

5.2 I_{BD}: MTC-LTE-GW – HSS/SPR Interface

The interface, I_{BD} is used by MTC-LTE-GW to fetch SPR values from HSS/SPR database. This interface is internal to EPC connector and not exposed to other components of ThingPark Wireless or other 3GPP network elements. The details of the fields used in this interface are specified in section 5.1.2.

PGW functionality is compliant to Rel 13 of 3GPP standard and is included as part of MTC-LTE-GW. It is compliant to the following standards:

TS 23.002 - *Technical Specification Group Services and System Aspects; Network architecture*	It presents the possible architectures of the 3GPP System covering both UTRAN and GERAN radio access technologies
TS 29.274 - *Tunnelling Protocol for Control plane (GTPv2-C)*	It specifies the stage 3 of the control plane of the GPRS Tunnelling Protocol, Version 2 for Evolved Packet System interfaces (GTPv2-C).
TS 29.061 – *Interworking between the Public Land Mobile Network (PLMN) supporting packet based services and Packet Data Networks (PDN)*	The present document describes the network interworking for the Packet Domain. Interworking to various external networks is defined together with the interworking for data forwarding while subscribers roam within the 3GPP system.
TS 23.401 - *General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access*	It defines the Stage 2 service description for the Evolved 3GPP Packet Switched Domain - also known as the Evolved Packet System (EPS) in this document. The Evolved 3GPP Packet Switched Domain provides IP connectivity using the Evolved Universal Terrestrial Radio Access Network (E-UTRAN)

5.3 I_{AC}: IEC104 MTC-LTE-GW LRC Interface

This interface is based on IEC104 and carries the user payload between MTC-LTE-GW and LRC in “message mode”. The user payload in UL is enriched with 3GPP metadata shown below which is extracted when interacting with the operator network.

Field	**Size**	**Presence**	**Signification**	
Version	1 Byte	**M**	Current message format version (1=first version)	
Message Type	1 Byte	**M**	Type of event:	
			0	IP Data
			1	Session Creation
			2	Session Deletion
			3	Session Modification

Cause	1 Byte	**M**	Cause of session deletion, provided by MTC-LTE-GW only. Must be 0 in all messages from LRC
EBI	1 Byte	**M**	Extended bearer identification, provided by MTC-LTE-GW. Can be 0 in all LRC messages.
LRC Address	4 Bytes	**M**	LRC IPv4 Address. Must be filled in both directions.
UUID	8 Bytes	**M**	Sensor identification = IMSI BCD encoded (TS 29.274 / E.212) Must be filled in both directions.
Sensor Address	4 Bytes	**M**	Sensor IPv4 allocated address. Must be filled in both directions.
APN Id	4 Bytes	**M**	APN identifier declared in APN table and able to identify APN. Can be 0 in all LRC messages.
TAG Name	8 Bytes	O(*)	Name of the current Tag filled by zero if name size < 8 bytes
TAG Length	2 Bytes	O	Tag length in byte
TAG Value	N Bytes	O	Tag value of Tag length bytes (32 bits aligned)

Presence:
M **:** Mandatory in both directions
O **:** Optional.
(*) : When Message Type is IP Data, at least one tag named "IPDATA" is present.

From LRC to MTC-LTE-GW only IP Data type messages are allowed. These messages contain a unique IPDATA Tag. Tag allows transmitting LRC some PGW session information which is the metadata collected during interaction with operator's 3GPP network. Session related tags are presents in all messages, but only IP Data messages contain IPDATA Tag.
TAG list is dynamic. Number of tags is not fixed since it depends on variables present in MTC-LTE-GW USV Data base.
The following table shows current MTC-LTE-GW tags:

TAG Name	***Type***	***Usage***
IPDATA	Binary buffer	IP Data including IP Header and TCP/UDP Headers
MSISDN	String number	MISDN number E.164
IMEI	String number	International Mobile Equipment Identity
RAT	String	Radio Access Type
CELLID	String number	Cell identification
CMCCMNC	String number	Cell MCC/MNC
CELLTAC	String number	Cell Tracking Area number
SERVNET	String number	Serving Network MCC/MNC

5.4 I_{MN}: IoT Subscriber Interface

This interface is used to provision IoT subscriber from ThingPark to MTC-LTE-GW. The details of IoT Subscriber creation within ThingPark are internal to the product.

5.5 I_{KL}: Kafka UDR Interface

This interface is used to generate CSV/Kafka based user traffic records. The charging mechanism is descried in detail in section **Error! Reference source not found.**.

5.6 $I_{M\text{-}AS}$: Direct IP Interface

This interface carries IP packets for IoT device for direct IP path between MTC-LTE-GW and AS. It is also referred to as SGi interface in 3GPP terminology. However, unlike SGi interface which provides connectivity to Internet, this interface provides connectivity to Application Server Routers (ASRs) over IPSec/GRE tunnels for the device to connect with Application Servers.

5.7 $I_{H\text{-}AS}$: LRC-AS Tunnel Interface

This interface carries IP packets encapsulated in LRC-AS tunnel API. It carries "message mode" payloads between IoT device and AS. It carries the following metadata that is sent from MTC-LTE-GW:

- MSISDN: MISDN number E.164
- IMEI: International Mobile Equipment Identity
- RAT: Radio Access Type
- CELLID: Cell Identification
- CMCCMNC: Cell MCC/MNC Information
- CELLTAC: Cell Tracking Area number
- SERVNET: Serving network MCC/MNC

6 MODES OF CONNECTIVITY

EPC Connector interacts with Application servers (AS) in three modes which are configured in the connectivity plan (see Section 13.2):

1. **Mode 1: Message mode:** In this mode, infrequent UDP messages (on a specific UDP port) from the devices are forwarded to LRC within ThingPark which it forwards these to Application servers. In this mode, we leverage Thingpark Wireless' capabilities for charging, traffic shaping, wireless data logging and other features. 3GPP Non-IP Data Delivery (NIDD) is also implemented using this mode.
2. **Mode 2: Direct IP mode:** In this mode, IP traffic from EPC connector is directly routed to Application servers. However, the metadata regarding the traffic characteristics is still forwarded to ThingPark Wireless Application (TWA) Usage Data Record (UDR) for charging purposes. However, the microflow reports (which contains statistics of the Direct IP transfer) are still visible in wireless logger without the actual data.
3. **Mode 3: Mixed mode:** In this mode, both the message mode and direct IP mode are used for communication between devices and AS.

6.1 Mode 1: Message mode

In this mode, every packet arriving at MTC-LTE-GW is forwarded to LRC using I_{AC} interface (described in section 5.3), which then forwards it to Application Servers (AS) based on the AS configuration inside ThingPark Wireless. MTC-LTE-GW appends the following LTE metadata to each packet:

- MSISDN: MISDN number E.164
- IMEI: International Mobile Equipment Identity
- RAT: Radio Access Type
- CELLID: Cell Identification
- CMCCMNC: Cell MCC/MNC Information
- CELLTAC: Cell Tracking Area number
- SERVNET: Serving network MCC/MNC

This mode is currently applied only for NIDD or short-messages from end-devices which are contained within UDP packets. LRC and AS communicate with each other using LRC-AS tunnel API which has LTE metadata above appended to it. The details of LRC-AS tunnel API are provided in [10].

The charging and traffic shaping in message mode is done by TP Wireless and follows a model like that of LoRaWAN messages coming from LRR. MTC-LTE-GW identifies the traffic in "message mode" by using "source port" of UDP messages in uplink, whereas using the same "destination port" of UDP messages in downlink. The UDP port configuration is carried out in routing profile configuration which is described in section 13.5.

Figure 7 shows the message mode architecture and how packets are transported from the end-device to Application Server (AS).

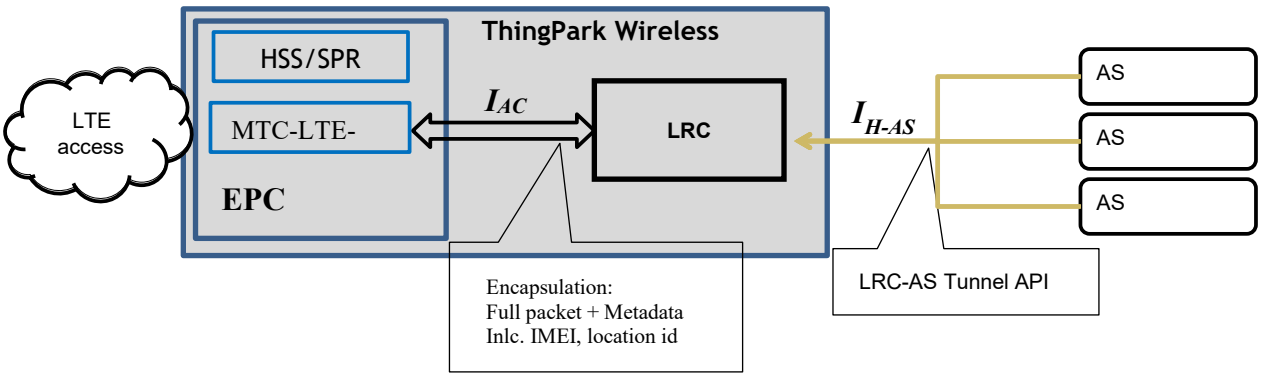


Figure 7 : Message mode

6.2 Mode 2: Direct IP

In this mode, MTC-LTE-GW forwards the IoT device traffic directly to AS, thus performing « over the top » routing. Direct IP mode is useful for sending large volumes of traffic (for example video feed from security camera or firmware upgrade) directly from MTC-LTE-GW to AS without going through ThingPark Wireless. However, MTC-LTE-GW in this case sends metadata related to charging events using interface, I_{KL} in terms of microflows. It receives configuration of traffic enforcement from ThingPark Wireless via IoT subscriber API, I_{MN}. Figure 8 shows the flow of traffic for « Direct IP » mode.

This mode is also useful to provide flat IP connectivity between the AS and devices. The communication between MTC-LTE-GW and AS happens with an intermediate entity, Application Serving Router (ASR), which talks to MTC-LTE-GW via GRE tunnel. This is a mandatory component which terminates the tunnel between the MTC-LTE-GW and the AS local network to enable over the top, private network and is also useful to protect ASs from Internet attacks.

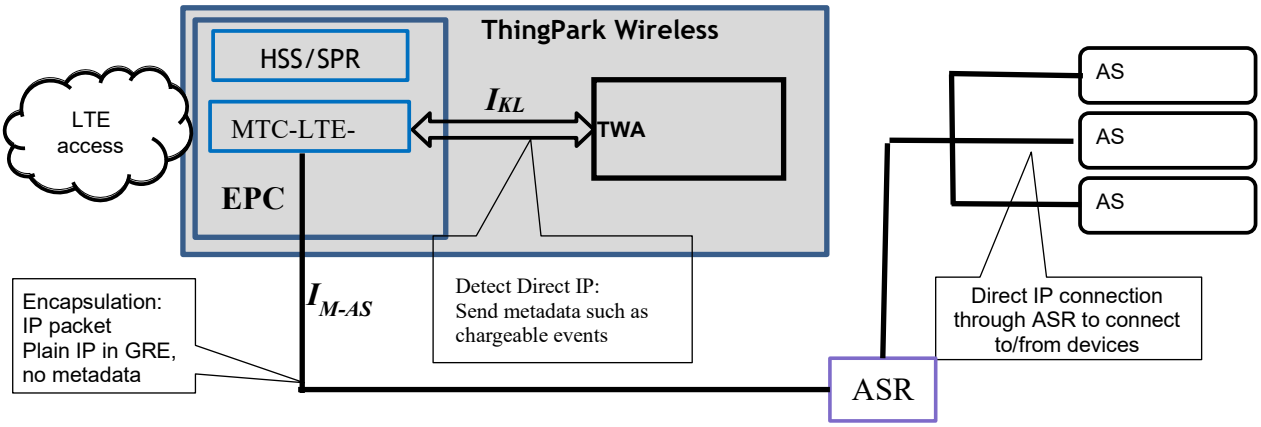


Figure 8 : Direct IP mode

6.3 Mode 3: Message mode + Direct IP

There are use cases when the device wants to do both “message mode” and “Direct IP” at the same time.

In mixed mode, the “message mode” traffic is filtered on MTC-LTE-GW using “specific” UDP port. The “specific” UDP port is configured using IoT subscriber interface, ***I*****MN**. This allows simultaneous support of both “message mode” and “Direct IP” mode. The UDP message below illustrates an example to identify a message towards a service on a given AS:

- IP:
  - device IP
  - AS IP
  - **UDP:**
    - Device port = Service reserved port -> 333
    - AS port = Service on the AS, as for direct IP.

This makes a standard UDP socket, easily created on the device which allows transporting any message as UDP payload.
This uses a “specific” UDP port on the device (as source port for outgoing packets and listening port for incoming packets). This “specific” UDP port can be configured by AS routing profile (see section 13.5), using IOT Subscriber API, ***I*****MN**.

7 RATING

ThingPark wireless platform elements (LRC in particular) have the capability to rate for IOT traffic in the form of messages as they are stored and forwarded there. For "message mode" traffic, rating is carried out directly by ThingPark Wireless (TPW) by treating all traffic in "message mode" like LoRaWAN messages. However, for "direct IP" traffic, as actual packets do not transit through TPW, MTC-LTE-GW sends rating information via Kafka UDR Interface, ***I_{KL}***. The product enables different charging strategies for IOT subscribers at distinct levels; however, all of them are optional tools to build rich offers.

The Usage detail records (UDRs) from ThingPark Wireless can then be used to generate invoices towards end customers.

Simple volume charging:
Based on number of messages and volume, this is the basis for messages (common approach for LTE or LoRaWAN access). This applies both to messages and direct IP traffic.

Event charging
An event is defined as IP activity within time and volume limits (a "microflow"). For direct IP, this mimics the simple charging where the event of some IP activity is charged for.
Instead of message per message, a certain amount of traffic volume is reported in the event and may be charged. For instance, a device with usually low traffic will cause generation of one microflow report per hour (if event time trigger is set to one hour), but if the device sends a large image, an event will be generated as soon as the traffic volume exceeds the value defined as event volume trigger.

Group charging:
IOT services use fleets of devices and not a single device. This very specific property in the service deserves a different charging mechanism:

- To come up with innovative billing plans
- To favor some good practices
- To characterize the traffic more easily than for individual devices (leveraging the smoothing effect of the law of big numbers)
- To better account for the effective cost to the network infrastructure: For instance, having all devices sending a message in the same minute is probably charged more than if the traffic is evenly spread over the entire day.

This impacts the sampling requirements. For direct IP, the MTC-LTE-GW must provide a "real time" measurement to accurately measure group usage. Note, that actual rating and billing can be done using higher level criteria, such as "flat rate" where a unique price is demanded per month, regardless of actual number of messages. This is out of scope of this document. However, EPC Connector provides all the necessary metrics for an operator to roll out group rating/billing for its IoT subscribers.

7.1 Flow-based events

7.1.1 Introduction
Direct IP mode allows the devices to start a communication directly with an application server via MTC-LTE-GW (thus bypassing the ThingPark Wireless IOT OSS/BSS/mediation).

IOT devices are not expected to generate substantial amounts of traffic for long periods of time, but it still happens from time to time for firmware downloads and data file uploads. Packet per packet reporting would not make much sense in this case.
The MTC-LTE-GW does a tailored reporting by detecting the real-time activity using volume triggers, and report near-real time aggregate reports ("microflow reports") to ThingPark Wireless Application (TWA).

7.1.2 Microflow event triggers

A "microflow" is defined in the MTC-LTE-GW as a chunk of traffic, defined by the following triggers:

Threshold

The typical volume granularity to report.
Typical value: 100KB

Example: If a device emits 150KB in a short timeframe, a first event is detected as soon as the first 100K are reached. The remaining 50K will be collected in a second event

Maximum inactivity time for last record

The time after which, if activity has been detected, no matter whether any threshold was reached, an event is reported.
Typical value: 120 sec.

Example: If a device emits 50KB in a short timeframe, and then stops, the flow will be emitted as soon as the 120 secs are reached from the beginning of the activity.

Minimum time between 2 records

A timer to avoid an overload of data records if a high data rate is sustained by a device for an extended period.
Typical value: 20 secs.

Example: If a device reaches 150 KB in less than 20 secs, the next data record will be issued right after 20 secs, reporting the whole volume exchanged during these 20 secs even though the threshold was exceeded. Figure 9 shows the different examples of microflows.

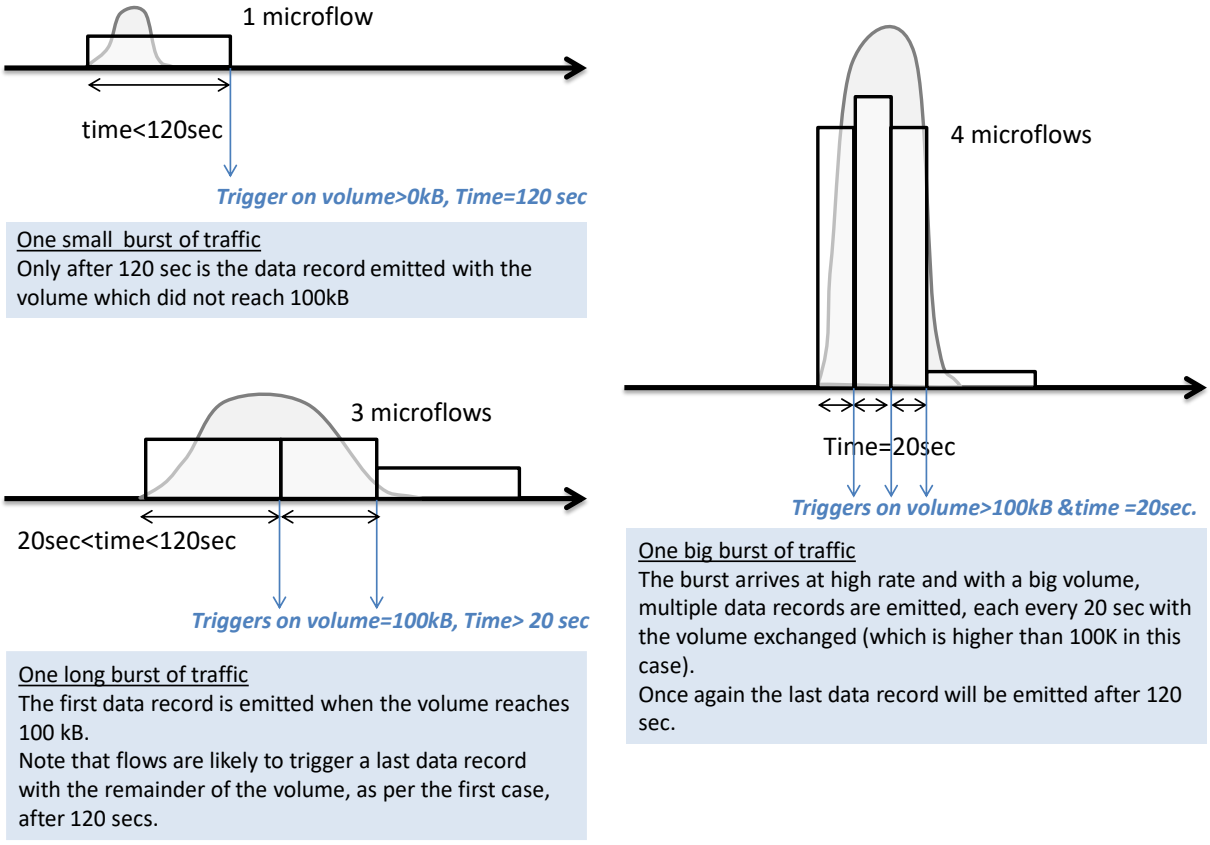


Figure 9 : Examples of different microflows

Values for flows triggers are provided through the IoT Subscriber API so they are the same for all devices of a given fleet.

7.1.3 Usage

One event is issued as soon as a flow is detected.

The event can be sent in real time with the device ID and timestamp, the flow event dimensions (the actual volume and duration). It is also enriched with metadata such as: IMSI, Cell ID and so on.

These events are sent to TWA UDR via Kafka and TWA aggregates these records when it generates UDRs.

Events are also aggregated and reported on a regular basis (not real time), with total volume and number of events. This is the default means to export charging records, which is described further in section below.

7.1.4 Subscriber data records

A device will send / receive messages as well as direct IP translated into flows events. Additionally, it will also incur signaling messages on the MTC-LTE-GW during its connection time. All of this is potentially chargeable information which is tracked on a regular basis. Internal counters are updated when:

- an event is seen online for a device
- a message is seen online for a device
- signaling messages are received or sent by the MTC-LTE-GW for a device

The following information is also gathered:

- Total volume / number of packets for packets in “message mode”, in each direction (uplink/downlink)
- Total volume / number of events for direct IP traffic, in each direction (uplink/downlink)
- Number of GTP-C signaling messages sent and received

ThingPark Wireless generates Usage detail records (UDRs) per subscriber every month. Here are the example fields of the generated UDR:

Column	Meaning
A	Record type (always `'nt'`).
B	Subscriber ID.
C	External subscriber ID.
D	Connectivity Plan ID.
E	**LoRaWAN™**: Total uplink packets. **Cellular**: Total, **Message Mode**, uplink packets. Total number of uplink packets sent by a device of this subscriber using this connectivity plan. Note: Packets are counted according to the definition given in section **Error! Reference source not found.**. Note: Packets were under connectivity plan limit or above connectivity plan limit.
F	**LoRaWAN™**: Total downlink packets. **Cellular**: Total, **Message Mode**, downlink packets. Total number of downlink packets received by a device of this subscriber using this connectivity plan. Note: Packets are counted according to the definition given in section **Error! Reference source not found.**. Note: Packets were under connectivity plan limit or above connectivity plan limit.
G	**LoRaWAN™**: Total out-of-profile uplink packets. **Cellular**: Total, **Message Mode**, out-of-profile uplink packets. Sub-total number of out-of-profile uplink packets sent by a device of this subscriber using this connectivity plan. Note: Packets are counted according to the definition given in section **Error! Reference source not found.**. Note: Packets were above connectivity plan limit.
H	**LoRaWAN™**: Total out-of-profile downlink packets. **Cellular**: Total, **Message Mode**, out-of-profile downlink packets. Sub-total number of out-of-profile downlink packets received by a device of this subscriber using this connectivity plan. Note: Packets are counted according to the definition given in section **Error! Reference source not found.**. Note: Packets were above connectivity plan limit.

Column	Meaning
I	**LoRaWAN™**: Total uplink payload (KB/1 digit precision). **Cellular**: Total, **Message Mode**, uplink payload (KB/1 digit precision). Cumulated payload size of uplink packets sent by a device of this subscriber using this connectivity plan. Note: Packets are counted according to the definition given in section **Error! R eference source not found.**. Note: Packets were under connectivity plan limit or above connectivity plan limit.
J	**LoRaWAN™**: Total downlink payload (KB/1 digit precision). **Cellular**: Total, **Message Mode**, downlink payload (KB/1 digit precision). Cumulated payload size of downlink packets received by a device of this subscriber using this connectivity plan. Note: Packets are counted according to the definition given in section **Error! R eference source not found.**. Note: Packets were under connectivity plan limit or above connectivity plan limit.
K	**LoRaWAN™**: Total out-of-profile uplink payload (KB/1 digit precision). **Cellular**: Total, **Message Mode**, out-of-profile uplink payload (KB/1 digit precision). Cumulated payload size of out-of-profile uplink packets sent by a device of this subscriber using this connectivity plan. Note: Packets are counted according to the definition given in section **Error! R eference source not found.**. Note: Packets were above connectivity plan limit.
L	**LoRaWAN™**: Total out-of-profile downlink payload (KB/1 digit precision). **Cellular**: Total, **Message Mode**, out-of-profile downlink payload (KB / 1 digit precision). Cumulated payload size of out-of-profile downlink packets received by a device of this subscriber using this connectivity plan. Note: Packets are counted according to the definition given in section **Error! R eference source not found.**. Note: Packets were above connectivity plan limit.
M	**LoRaWAN™**: Total network geolocation. **Cellular**: n/a Total number of valid network geolocation on an uplink packets received by a device of this subscriber using this connectivity plan.
N	**LoRaWAN™**: Managed Customer Network tag ID **Cellular**: n/a Filled if the network traffic is routed through a Managed Customer Network, otherwise empty. **The tag ID reported in the record is automatically generated by TWA when the tag is created. This ID is internal and not visible in TWA interfaces in the current release.**

Column	Meaning
O	**LoRaWAN™**: n/a **Cellular:** Total, **Direct IP Mode,** uplink/downlink microflows Total number of microflows reported for this subscriber using this connectivity plan.
P	**LoRaWAN™**: n/a **Cellular:** Total, **Direct IP Mode,** uplink IP packets size (KB / 1digit precession) Cumulated size of direct IP mode traffic sent by a device of this subscriber using this connectivity plan.
Q	**LoRaWAN™**: n/a **Cellular:** Total, **Direct IP Mode,** downlink IP packets size (KB / 1digit precession) Cumulated size of direct IP mode traffic received by a device of this subscriber using this connectivity plan.

For more information on ThingPark Wireless UDRs, please refer to [7] which provides details overview of UDRs that are generated for both Cellular and LoRaWAN traffic.

8 ENFORCEMENT

The enforcement for “message mode” traffic is carried out directly by ThingPark Wireless using the traditional connectivity plan settings. However, for the “Direct IP” mode, the MTC-LTE-GW enforces policies at two levels.

- At device level:
  - A profile is applied, which is preconfigured in the MTC-LTE-GW.
  - It tells limits to enforce to the device’s traffic (rates, blocking).
- At IOT subscriber or fleet level:
  - If associated to a VLine, rate limiting can be applied globally.

Note: ThingPark Wireless connectivity plan configuration (see 13.2) is performing enforcement only at the device level.

Once the cellular traffic exceeds the connectivity plan settings, its dropped.

8.1 Device enforcement profile

An enforcement profile is a preset, which is created through the fleet management API, to do the following:

- Block messages or not
- Block direct IP or not
- Rate limit per device direct IP: uplink limit. This limit is sent to the operator’s core network of operator as part of APN configuration and the limit is applied by the eNodeB/S-GW of the operator’s core network.

Rate limit per device direct IP: downlink limit. This limit is sent to the operator’s core network of operator as part of APN configuration and the limit is applied by the eNodeB/S-GW of the operator’s core network.

9 SECURITY

Security in the EPC connector is ensured through different means:

- Access control based on usual Linux best practices, using different accounts, and limiting access to authorized personal only. This mitigates most of the risks of misuse or unauthorized modification.

- Location of the components behind a firewall to restrict protocols to only the required one.
  - By network design, the HSS function is accessible only from the core network and ThingPark Wireless, and never exposed to any untrusted network.
  - The PGW is recipient of all the traffic to / from customers and devices which is carried over the internet. A firewall is required for protection from direct attacks coming from the internet.

- Cryptography for all secrets. HSS must use and manage several secret keys (per operator and per device). None of these keys are accessible from anyone as they are stored encrypted, the master key for their protection being deeply hidden in memory and accessible to no one. No option is given to read any key, and transport of any key to the HSS is done remotely, through an encrypted API. HSM can be offered as an add-on solution which is hardware-based security and encryption of HSS keys.

- Protection of the Internet from the IOT devices: IOT devices are often low-end products, some of them showed strong vulnerabilities in the past, being turned into botnets. The EPC connector provides two ways to cope with such threats:

  - The traffic of all devices is tunneled up to the end-customer Application Server, which means that a corrupted device cannot reach any other target than its customer's legitimate network.
  - All incoming and outgoing traffic is monitored by the EPC connector which may be used to detect and block any malfunctioning device, at device level and at group level. Rate limiters can also be used as a means of protection.

- Confidentiality for the data going from/to the devices, to the application server is not in the scope of the EPC connector. However, for such requirement, having an end-to-end protection is most often required and already put in place. It is advisable for customers to implement such mechanism this way (note that anyway GTP does not encrypt the traffic either). Future versions of the EPC connector may provide additional means for very low-end devices which cannot perform any encryption. IPSec can also be used as one of the options to connect Application servers (ASs) from customer premises to PGW.

10 SCALABILITY

A single system in a virtual machine can easily scale to several Gbps and multimillion of devices (depending on the hardware it is running on and the availability of state-of-the-art virtual acceleration techniques like SR-IOV). A key point is that the number of connections per second is not the limiting factor, nor is the number of concurrent connection as it has been with legacy systems.

If more capability is required on the MTC-LTE-GW function, adding servers is done easily. The provisioning is centralized, each server gets its data from a centralized database, and load balancing is achieved on a per device basis. A DNS is usually used to spread the load. HSS nodes can also be added, which requires a Diameter Routing Agent doing the load sharing.

11 HIGH AVAILABILITY

All components of the EPC connector are highly available and switch over is transparent to the access network, which means that devices do not have to reconnect if ever the HSS function or PGW function fails. This is critical to avoid a rush of connections which may overload the 3GPP Core Network.

High availability is provided in the form of cluster working in active/standby mode, also called '1+1' redundancy. The EPC Connector components work in an active/standby cluster; the standby server is synchronized in real time with the active server. Only one node of the cluster is active at a time. At cluster startup, the node starting first will usually claim the Master role.

When a failed server recovers (for instance upon a reboot), it is unavailable until the resynchronization process has finished, and it has all the states of all devices in memory. This is done automatically and has no noticeable impact on the active node (as states are exchanged with lower priority, this does not block new connections or mobility events). The global cluster is up during the entire process.

The cluster management is performed by 2 components:

- The component 'heartbeat' maintains a status for each node of a cluster (called local status) and a state for the whole cluster (called cluster status)
- The component 'health manager' monitor the critical resources of a node (processes, interfaces, CPU, memory). When a monitored resource reaches a critical state, it takes some defined actions.

For more information on High availability configuration, please refer to [5][6].

12 DISASTER RECOVERY

If for any reason, a full cluster fails and is completely lost, then recovery procedures are run:

- The system is first restored/reinstalled from a saved image; this allows setting up a new empty cluster very fast.
- All data is safely stored within ThingPark Wireless and loaded again. A manual procedure allows loading the required data in bulk (data is duplicated in the 2 nodes along the way)

The second step is manually triggered, and no device can reconnect before it is loaded in the system again.

The cluster starting fresh again announces this event to the network so that all previous contexts prior to the failover are flushed immediately.

13 CELLULAR DEVICE MANAGEMENT/PROVISIONING

This section gives an overview of the provisioning and management of Cellular devices within ThingPark Wireless.

13.1 Operator Manager / Device Profile

The first step to provisioning a Cellular LTE device is to create a "Cellular" profile in operator manager. The cellular profile contains generic information on cellular device capabilities.

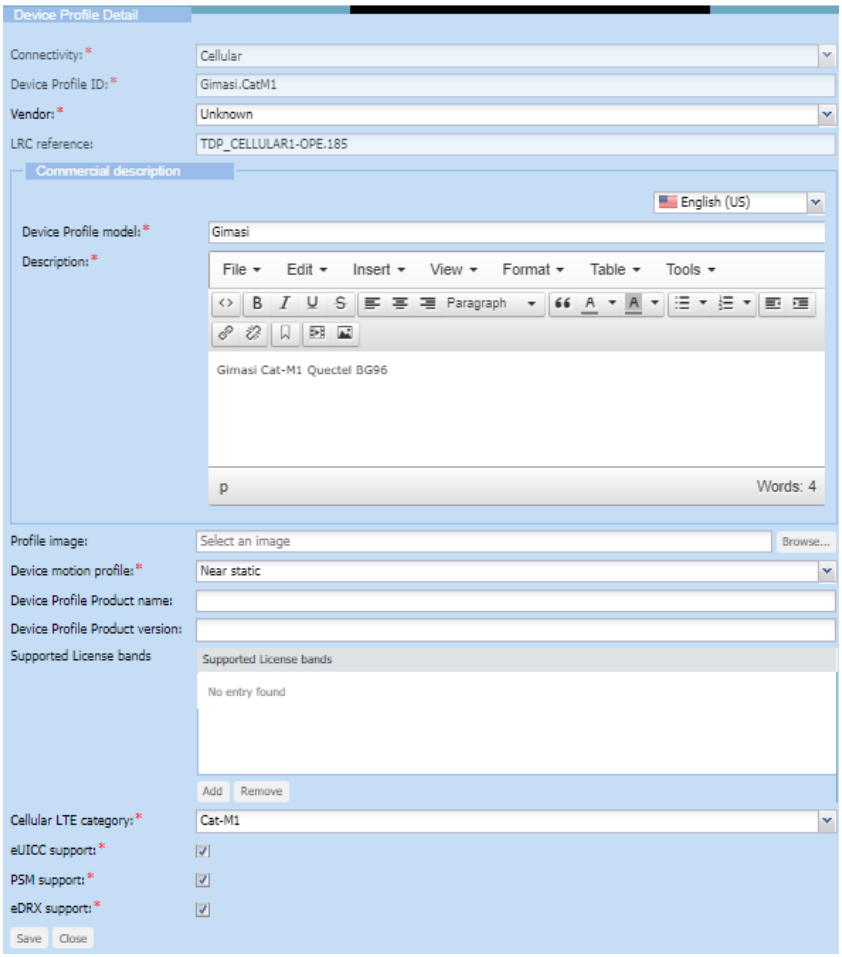


Figure 10 : Device Profile Creation

13.2 Operator Manager / Connectivity Supplier / Connectivity Plan

The figure below shows an example connectivity plan that applies to "message mode" and "Direct IP" traffic. It can only be created by connectivity supplier account that exists within operator manager. For more details on connectivity plan configuration, please refer to [13].

Cellular Connectivity plan is divided into two parts:

1. **Message mode**: The connectivity plan parameters of this mode control all the message mode traffic.

2. **Direct IP mode**: The connectivity plan parameters of this mode control all the Direct IP traffic. These parameters are applicable to traffic that is routed directly from MTC-LTE-GW to Application servers bypassing ThingPark Wireless

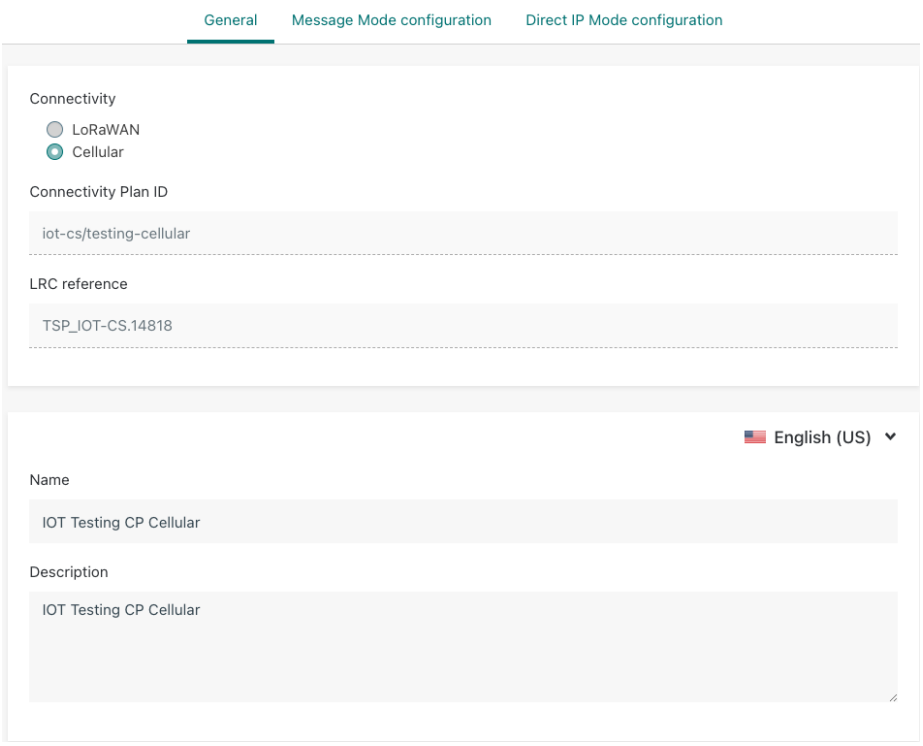


Figure 11 : Connectivity Plan Creation (General settings)

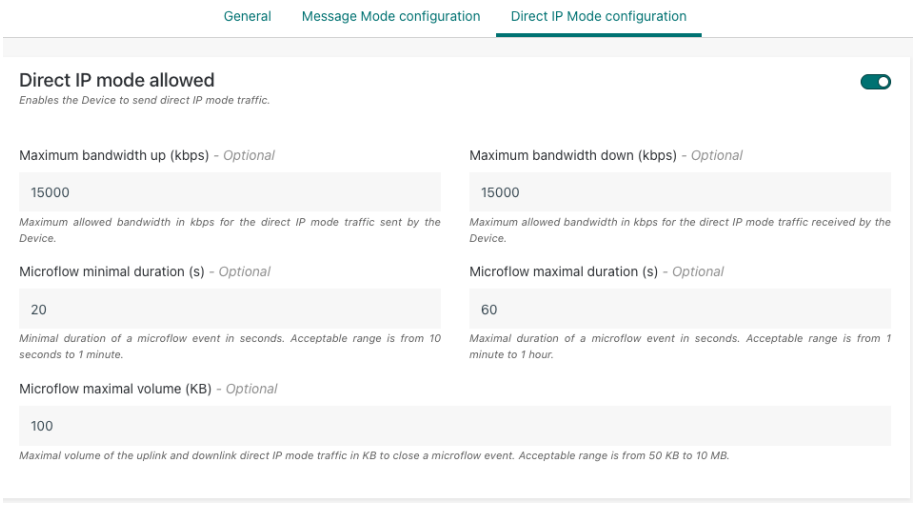


Figure 12 : Connectivity Plan Creation (Direct IP settings)

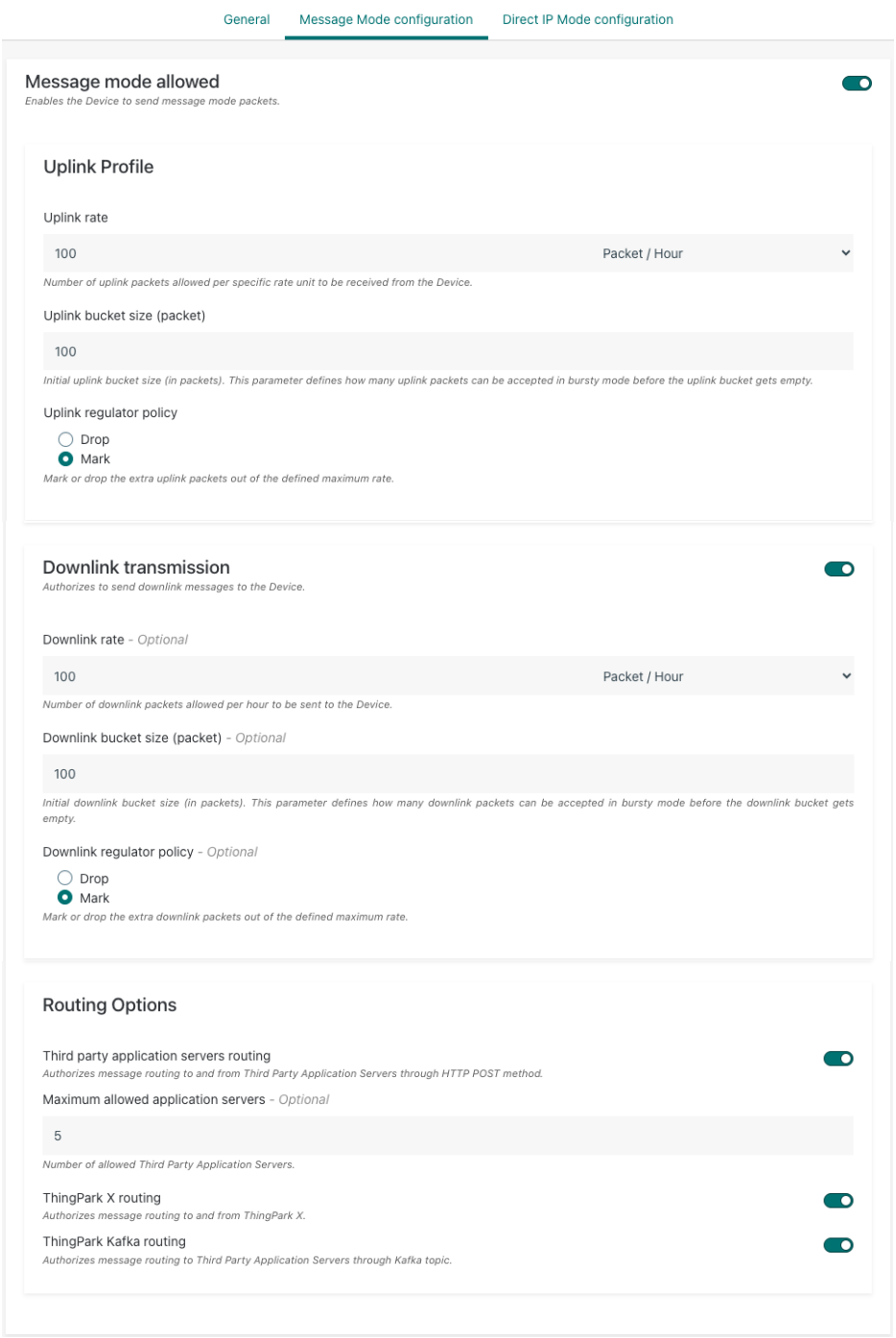


Figure 13 : Connectivity Plan Creation (Message mode settings)

13.3 Operator Manager / Connectivity Supplier / Connectivity Plan / SIM Cards

The next step is to pre-provision the SIM Card keys in connectivity supplier. The figure below illustrates the UI below. The SIM Card secret keys can be mass imported with a simple comma

separated text file. Once the SIM Card keys are uploaded successfully, they are shown in the Connectivity supplier UI with the status of their allocation.

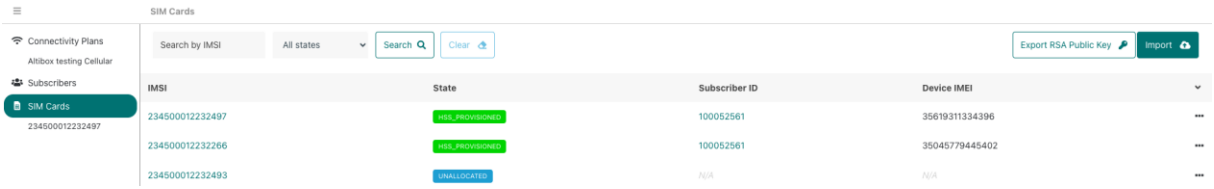


Figure 14 : SIM Cards Pre-provisioning

The details status of the SIM card which is already allocated to the subscriber can be seen by further clicking the SIM Card.

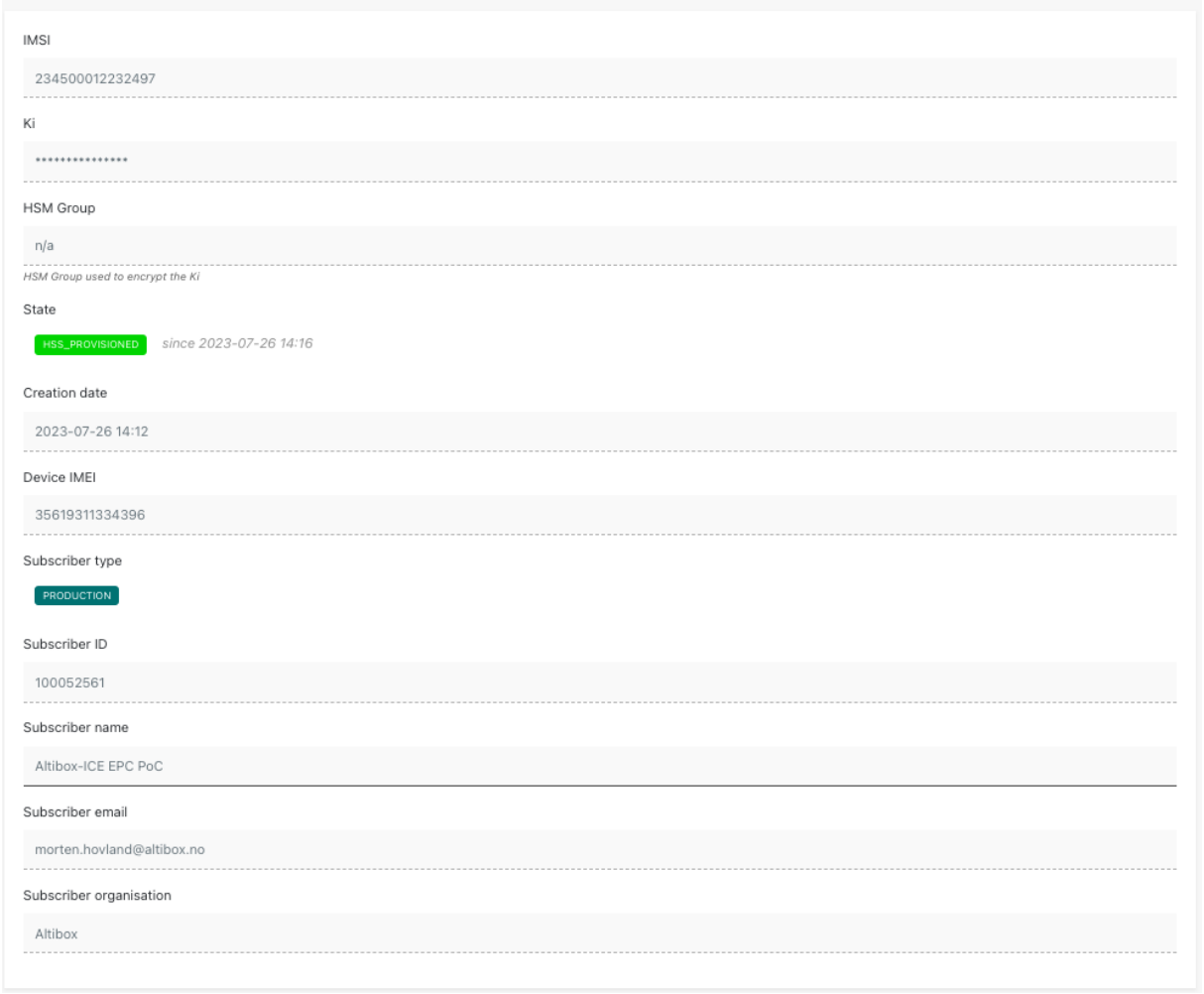


Figure 15 : SIM Cards Allocation

13.4 Device Manager: Create Application Server

The next step is to create application server from device manager user interface [03]. In the example shown in figure below, the Application server IP address is listed in the destination field. Note, that this application server is only for handling “message mode” traffic.

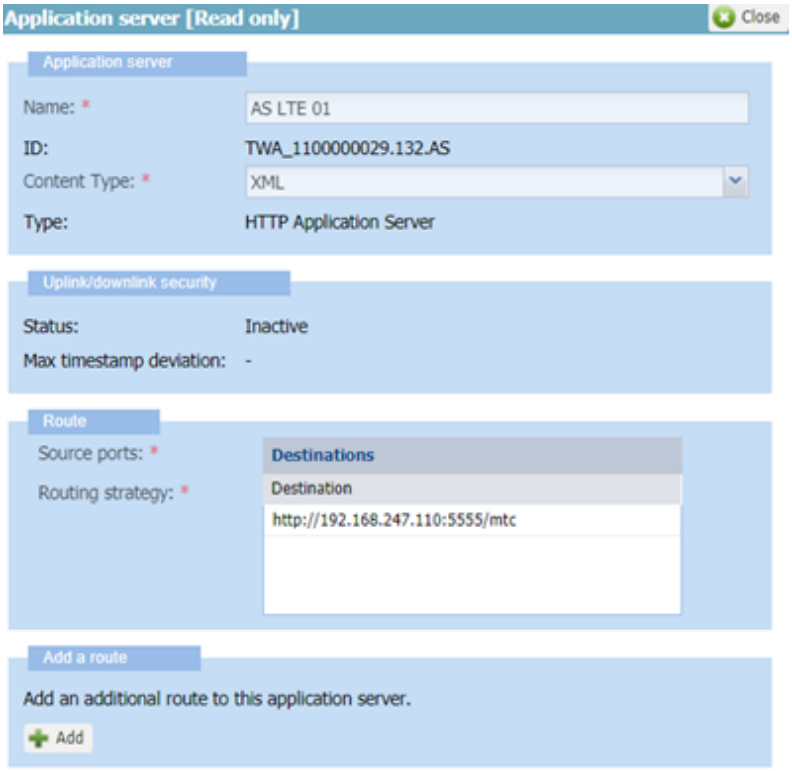


Figure 16 : Application Server Configuration

13.5 Device Manager: Create AS Routing Profile

After that, Application Server (AS) Routing profile is created to link the Application server to it. This will allow LRC to route “message mode” or “Direct IP” traffic for the devices that belong to a particular IoT subscriber to the Application Server (AS) listed in earlier section. AS Routing profile also has configuration for UDP source port (for ex. 7777) which is used to identify message mode packets.

Figure 17 : Routing Profile Configuration

13.6 Device manager: Creation of devices

Once the device profile is created in operator manager, IoT subscriber account can add devices from the device manager [03]. Here are the following fields that must be carefully entered in device manager for cellular device to connect successfully to the cellular network, EPC Connector and ThingPark Wireless.

- **IMEI**: This is the identity of the module and is printed on the module. The IMEI on the module must match to that provisioned in ThingPark Wireless
- **IMSI**: This is the identifier that is present inside the SIM card and must match to that provisioned in ThingPark Wireless
- **Ki**: This is set to automatic (because it was pre-provisioned in earlier step).

The new device created should be mapped to the connectivity plan and routing profile that were created in earlier sections.

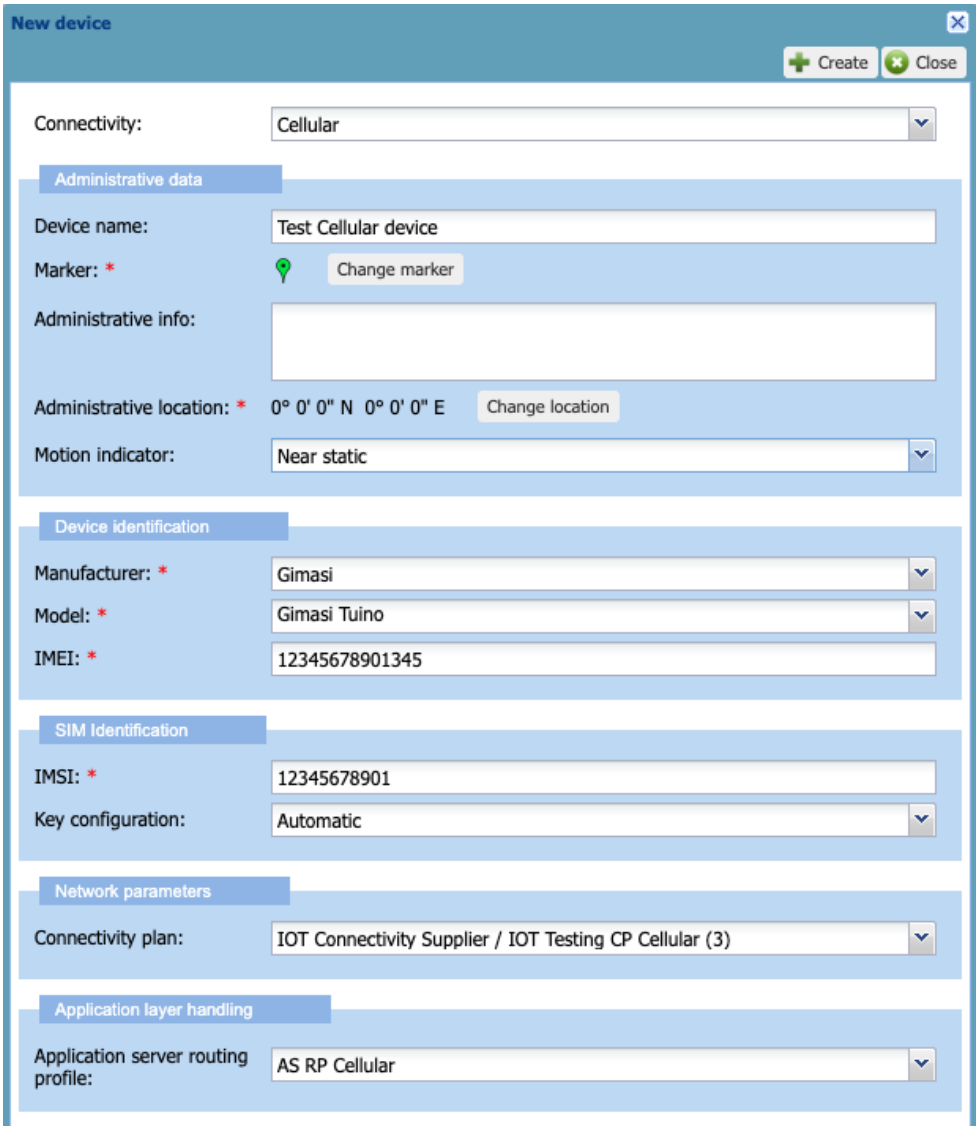


Figure 18 : New Device Creation

13.7 Device Manager: Statistics

The figure below shows the device manager statistics once the device is registered on the cellular network. Here are the important parameters that are shown in the statistics:

- **IMEI**: It is the IMEI that was provided during device creation
- **IP Address**: It is the IP Address of the device that is provided from the core network. It is listed here for information purposes
- **Serving network MCC/MNC**: It is the MCC/MNC that is provided from SGW to the EPC Connector
- **Uplink/Downlink packets**: This is the statistics of message mode traffic that goes through LRC for this device
- **Direct IP mode bytes**: This is the statistics of the direct IP based microflow reports

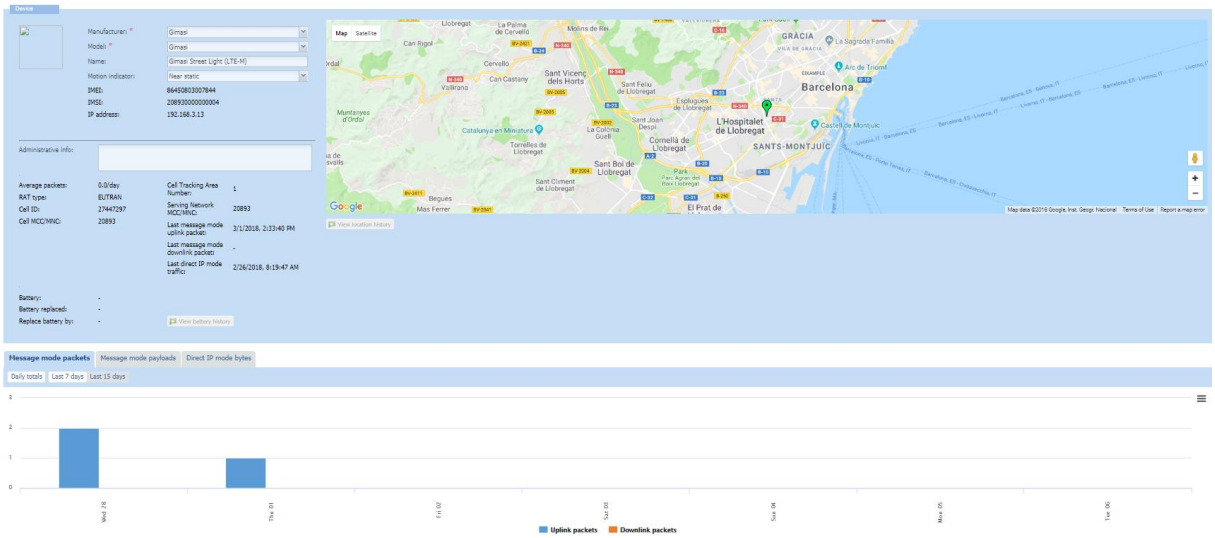


Figure 19 : Device Manager Statistics

13.8 Device Manager: Listing of devices

The figure below shows different LoRaWAN and 3GPP based IoT devices within the same IoT subscriber. The columns of the list give you the following information on the displayed devices:

- **Name/Type**: name and device profile
- **Identifier**:
  - **For LoRaWAN™ devices**: **DevEUI** and **DevAddr** of the device: similar to a MAC address and a Network address
  - **For cellular devices**: **IMEI** and **IP** address are used for identification.
- **Connectivity**: Connectivity plan and AS routing profile
- **Average packets**: number of packets/day (not applicable to cellular devices)
- **Mean PER**: mean Packet Error Rate (not applicable to cellular devices)
- **Average SNR**: based on the last five packets received (Not applicable to cellular devices)
- **Battery** (not applicable to cellular devices)
- **Alarm**: number of alarms not acknowledged
- **Locate**: opens the Device location window displaying the device on a map

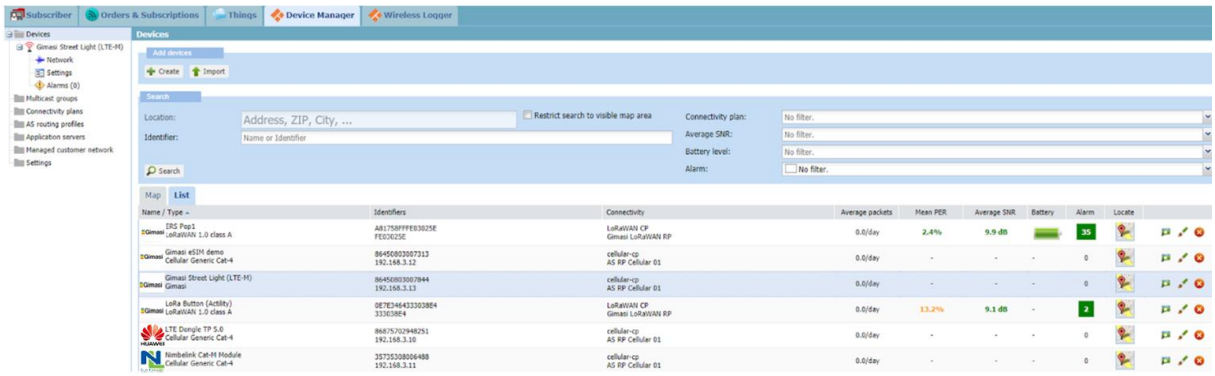


Figure 20 : Device Manager listing of devices

13.9 Wireless logger

Wireless logger [04] is very useful tool within ThingPark Wireless information to track the "message mode" traffic that goes through LRC between the device and Application server (AS). It also shows the microflow reports that represent "Direct IP" traffic passing through MTC-LTE-GW directly to Application Servers. Once the device is provisioned in ThingPark Wireless, it has five distinct types of packets in wireless logger specific to LTE:

1. **Session Creation**: This is an uplink message in wireless logger when the device successfully connects to the eNodeB/Core network and is successfully registered to the network. It is created in the last step of LTE Attach procedure when SGW of the operator's core network sends session creation request to the MTC-LTE-GW within EPC Connector, which then forwards this to LRC within ThingPark Wireless. The snapshot of session creation packet is shown below.

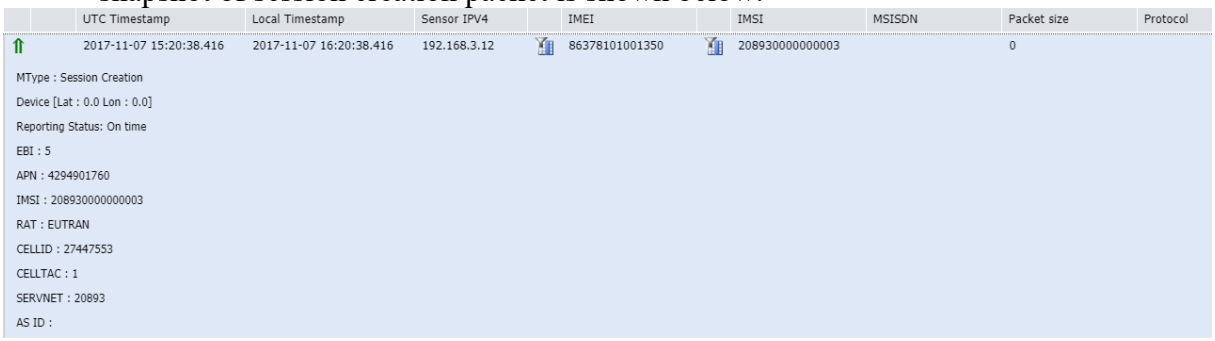


Figure 21 : Wireless logger (session creation)

2. **Uplink Payload**: This is the typical uplink UDP payload that is captured by LRC when the device is doing uplink "message mode" traffic between itself and the Application Server (AS). Note, that the UDP source port is 7777 which classifies uplink UDP packet received by MTC-LTE-GW as a "message mode" packet. This port is configurable in the AS Routing profile.

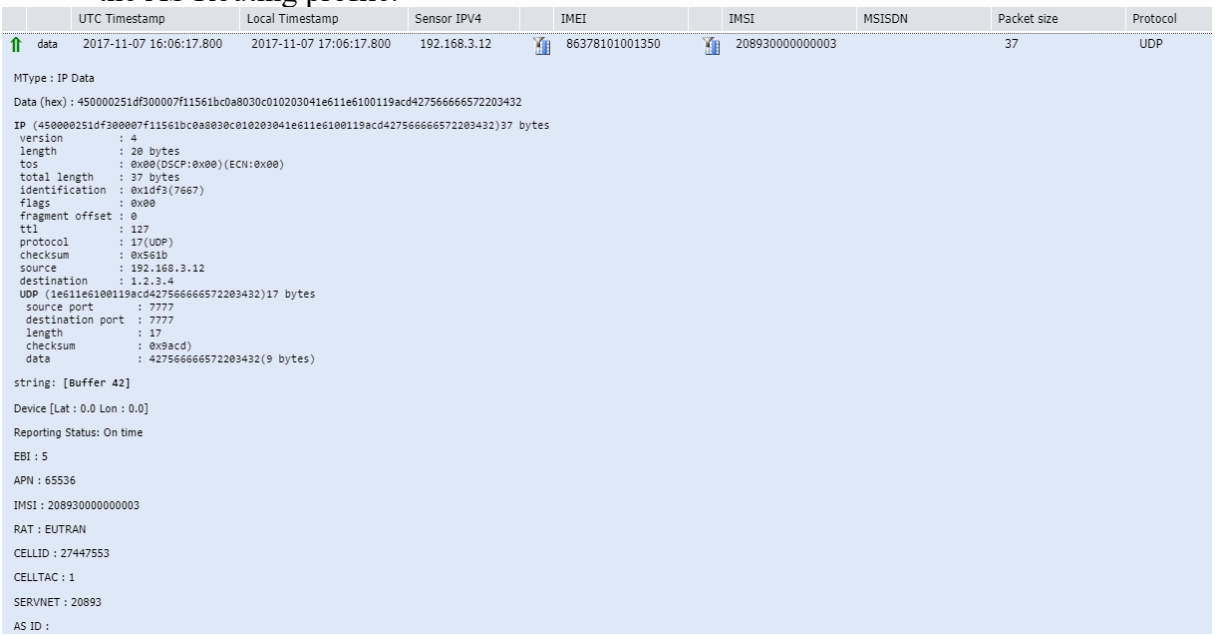


Figure 22 : Wireless logger (uplink payload)

3. **Downlink Payload**: This is the typical downlink payload that is captured by LRC when the AS is doing downlink "message mode" traffic between itself and the device. However, the device needs to always initiate uplink traffic first with the AS before AS can start any downlink traffic.

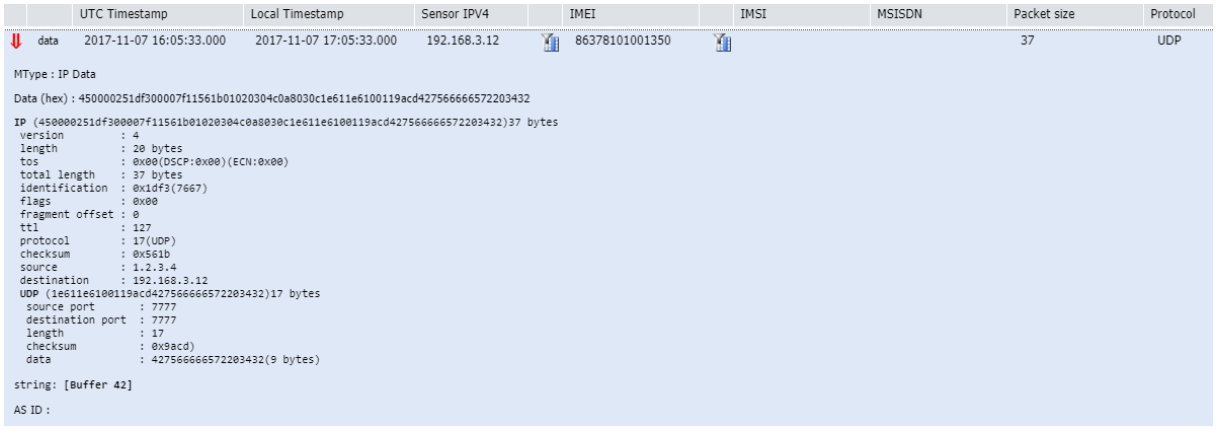


Figure 23 : Wireless logger (downlink payload)

4. **Session Deletion**: This message is received when the device detaches from the network for some reason (for example, when it loses connectivity or is switched off). This message is sent from MTC-LTE-GW to LRC upon receiving of session deletion request from SGW.

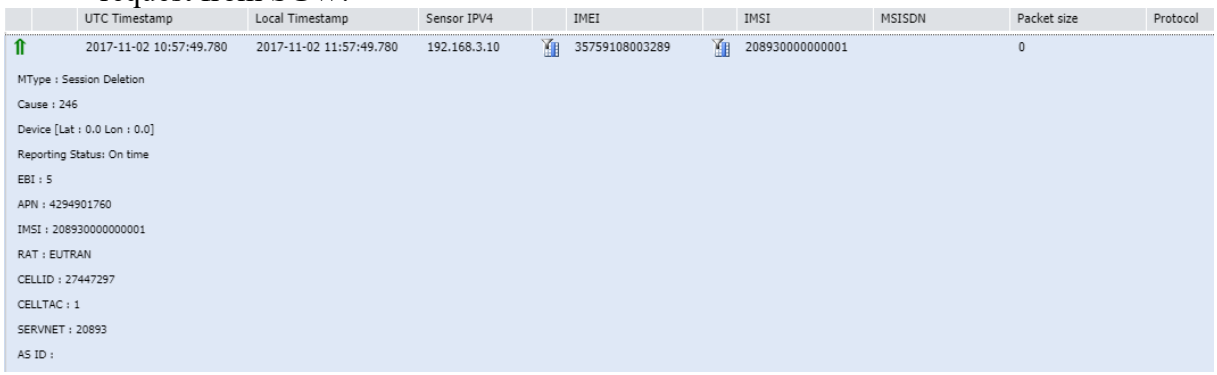


Figure 24 : Wireless logger (session deletion)

5. **Microflow Report**: This message is sent from MTC-LTE-GW to LRC whenever there is Direct IP traffic. It is not the actual payload but only the statistics of the traffic that passes though MTC-LTE-GW.

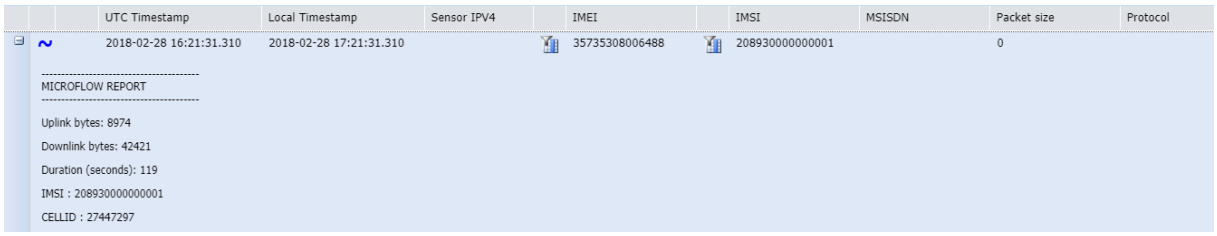


Figure 25 : Wireless logger (Microflow Reports)

14 UNSUPPORTED FEATURES

Following features are not supported in EPC Connector:

- 2G/3G device connections (in HSS are not supported). PGW supports GTPv1 protocol to handle the data traffic from 2G/3G devices.
- Circuit-switched voice call

ABOUT ACTILITY

Actility is an industry leader in LPWAN (Low Power Wide Area) large scale infrastructure with ThingPark™, the new generation standard-based IoT/M2M communication platform. Actility's ThingPark Wireless™ network provides long-range coverage for low-power sensors used in SmartCity, SmartBuilding and SmartFactory applications. Actility also provides the ThingPark X which provides big data storage for sensor data and exposes sensor function through an open API allowing developers to provide vertical applications on top of rolled out sensors. To help vendors transform their sensors, Actility provides the ThingPark IoT platform which include embedded software solutions and cloud solutions to help devices connect to innovative applications. Via the ThingPark Market, an online marketplace engine dedicated to the IoT sensors, applications and network solutions, Actility enables the roll-out of new innovative IoT services for sensor vendors and network solution vendors. Actility is a founding member of the LoRa Alliance™: the largest, most powerful standards-based effort to enable the Internet of Things (IoT). Visit www.actility.com.