LTE UNI Aerial Profile

Version 1.0

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This is a Non-binding Permanent Reference Document of the GSMA

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1 Introduction

1.1 Overview

The LTE Aerial Profile identifies a minimum mandatory set of features defined in 3GPP specifications which an aerial User Equipment (UE) and network are required to implement in order to guarantee an interoperable LTE aerial service over Long Term Evolution (LTE) radio access. Although the primary use case considered for this profile is Unmanned Aircraft System (UAS), this does not exclude other commercial applications from using this profile in low altitude airspace.

Editor's Note: Contribution on what "low altitude" will be considered.

1.2 Relationship to Existing Standards

1.2.1 3GPP specifications

This profile is solely based on the open and published 3GPP specifications as listed in the Section 1.5. 3GPP Release 15, the first release supporting LTE UAV, is taken as a basis. It should be noted, however that not all the features mandatory in 3GPP Release 15 are required for compliance with this profile. Conversely, some features based on functionality defined in 3GPP Release 16 or higher releases may be required for compliance with this profile (as up to now, no Rel16 features are quoted). All such exceptions are explicitly mentioned in the following sections along with the relevant Release 15 or higher 3GPP release specifications, respectively. Unless otherwise stated, the latest version of the referenced specifications for the relevant 3GPP release applies.

1.3 Scope

This document defines a profile for LTE Aerial Service by listing a number of LTE, Evolved Packet Core, and UE features that are considered essential to launch interoperable services. The defined profile is compliant with 3GPP specifications. The scope of this profile is the interface between UE and network, where the UE is considered to be an aerial device, or aerial UE.

The profile does not limit anybody, by any means, to deploy other standardized features or optional features, in addition to the defined profile.

1.4 Definition of Acronyms and Terms

1.4.1 Acronyms

Acronym	Description
3GPP	3rd Generation Partnership Project
APN	Access Point Name
ATC	Air Traffic Control
BVLOS	Beyond Visual Line of Sight

Acronym	Description
DL	Downlink
eNB	eNodeB
EPC	Evolved Packet Core
Airspace Class F	IFR and VRF flights are permitted. ATC separation will be provided, so far as practical, to aircraft operating under IFR. Traffic Information may be given as far as is practical in respect of other flights. Airspace Classes F-G refer to Uncontrolled Airspace [7].
Airspace Class G	IFR and VFR flights are permitted. ATC has no authority but VFR minimums are to be known by pilots. Traffic Information may be given as far as is practical in respect of other flights. Airspace Classes F-G refer to Uncontrolled Airspace [7].
EPS	Evolved Packet System
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
GCS	Ground Control Station
IP	Internet Protocol
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
KPI	Key Performance Indicator
LOS	Line of Sight
MSS	Maximum Segment Size
PCRF	Policy and Charging Rules Function
PDB	Packet Delay Budget
PDN	Packet Data Network
PELR	Packet Error Loss Rate
P_GW	PDN Gateway
QCI	Quality of Service Class Identifier
RAN	Radio Access Network
RTT	Round Trip Time
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol
UE	User Equipment
UL	Uplink
USS	UAS Service Supplier
UTM	Unmanned Traffic Management

1.4.2 Terms

Term	Description
Downlink (Uplink)	For the scope of this document, downlink (DL) and uplink (UL) are used in their common meaning in the field of cellular communications, which usually adopts a convention opposite to the aviation world. Therefore, downlink is the part of the link initiated (transmitted) by the cellular tower and terminated (received) by the UE. Uplink represents return link from the UAV.
EPS	3GPP Evolved Packet System (EPS) is comprised of Evolved UTRAN (E-UTRAN) and Evolved Packet Core (EPC). E-UTRAN is commonly known as LTE (Long Term Evolution).
PDB	Packet Delay Budget (PDB) defines an upper bound for the time that a packet may be delayed between the UE and the PDN Gateway (also referred to as PCEF, or Policy and Charging Enforcement Function) [1].
PELR	Packet Error Loss Rate (PELR) defines an upper bound for a rate of non-congestion related packet losses [1].
Region	A part of a country, a country or a set of countries.
UAV	Unmanned Aerial Vehicle. For simplification when used in the context of wireless networks, this term expresses the idea of an aerial UE, embedded in a UAV. UAV is interchangeably used with “drone”.
UAV Connectivity	The service provided through a RAN that enables a UAV to connect to an application, a remote controller, the UTM or other entities.
Uncontrolled Airspace	Generally refers to the Class F or Class G airspace where any aircraft can fly without either notifying or getting permission from the National Aviation Authority [7].
USS	UAS Service Supplier. USSs provide services to support UAS and act as a communications bridge for the flow across the USS Network.

1.5 References

Ref	Doc Number	Title
[1]	3GPP TS 23.203	Policy and charging control architecture
[2]	IETF RFC 7805	TCP Maximum Segment Size
[3]	3GPP TS 36.331	Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol Specification.
[4]	GSMA PRD IR.88	LTE and EPC Roaming Guidelines
[5]	3GPP TS 23.401	General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access
[6]	3GPP TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 2
[7]	ICAO Annex 11	Air Traffic Services

2 Reference Architecture

The UE and network protocol stacks forming the scope of the LTE Aerial Profile are depicted in Figure 1 below:

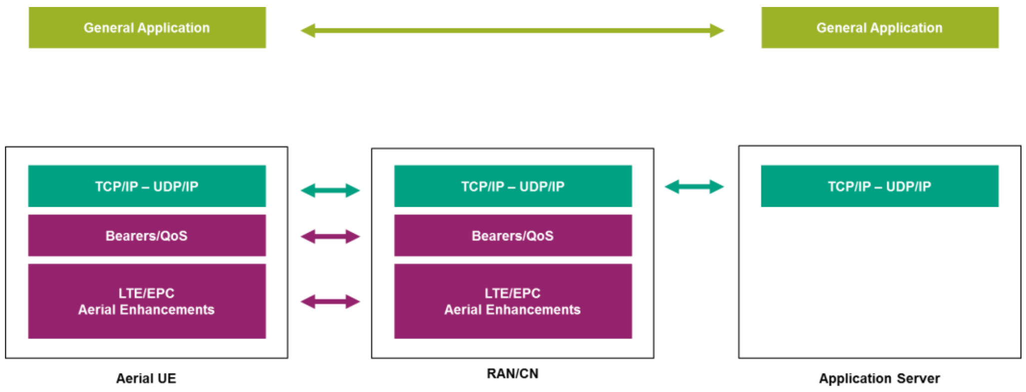

Figure 1: Depiction of UE and Network Protocol Stacks in LTE Aerial Profile

For the purposes of the User Network Interface (UNI) Aerial profile and the implementations to date, it is assumed that that all data sent is IP data and that TCP is primarily used protocol for Critical & non-Critical Communication, and UDP is the primary protocol for Video & Image Streaming. This assumption does not preclude the use of UDP for Critical & Non-Critical Communication.

The scope of the User to Network Interface as profiled is between the Aerial UE and the RAN/CN as shown in Figure 1."

The main body of this PRD is applicable for a scenario where LTE Aerial service is deployed over LTE in a standalone fashion without relying on any legacy infrastructure, packet or circuit switched.

In order to be compliant with LTE Aerial Profile, the UEs and networks must be compliant with all of the normative statements in the main body.

3 Unmanned Aerial Feature Set

3.1 Data Types

The LTE Aerial Data Types are categorized in consideration of the primary functions of UAV connectivity. The reference to UAV does not preclude the application of the LTE UNI Profile to other, similar use cases.

Non-Critical Communication

Non-critical communication may include the operational state of the UAV, including configuration of UAS elements. This data may also flow to a central management system or

USS to facilitate operational overview of fleet management and provide situational awareness.

Examples of non-critical communications in 4G LTE connected UAVs may include but is not limited to the following applications:

Aircraft System Telemetry

Routine measurements from aircraft subsystems. These are generally small messages sent at 1Hz at data rates approximately 30 kbps.

1. Battery Status
2. Speed
3. Heading
4. Location/GPS
5. Sensor Commands, Messages & Telemetry

UTM Messaging

Non-critical communications UTM messaging may include:

1. Airspace Access
2. Weather Alerts
3. Operational Volumes

Critical Communication

Critical communication may include commands issued for the purpose of facilitating control of the UAV. These data types occur at very low data rates. The rate at which these messages are emitted is system dependent.

Examples of critical communications in 4G LTE connected UAVs may include but is not limited to the following applications:

Vehicle and Mission Commands, Messaging & Telemetry

GCS to UAV commands may include flight plan changes for navigation/movement, speed changes, or conditional commands

1. UAV to GCS messaging may include mission requests, acknowledgement of mission completion, messaging when a new waypoint is reached, and other mission status messages

2. UAV may also download a mission in response to these messages, and provide an acknowledgement message containing the final result of the operation

Autopilot messages may be configured for guaranteed delivery, requiring corresponding acknowledgement. In the absence of this acknowledgement, the commands may automatically be re-transmitted until acknowledgement is received. This mechanism is used to ensure transmission over a loss link.

Heartbeat

A heartbeat is a broadcasted message from the UAV which is used to confirm the aircraft has connectivity. An example of use may be an LTE connected BVLOS mission requiring a heartbeat confirmation to ensure the UAV has cellular connectivity before entering the BVLOS stage of flight.

UTM Messaging

Critical communications UTM messaging may include:

1. Remote ID
2. Geofencing
3. Flight Authorization

Video and Image Streaming (and other services)

The video and image streaming datatype (which can also be extended to other application payloads) are considered a best effort service. The parameter optimization for this data type is left as implementation decision.

Use of low bandwidth payload transfer on UAVs may include but is not limited to the following applications:

Video Streaming

Video streaming is primary for the purpose of payload support. Payload is the business function of the UAV. This can be used for linear inspection, where the video is being streamed over the network for analytics and real time processing.

Image Transfer

Image transfer may also be used to support the business function of the UAV via reconnaissance. Multiple images may be captured by the UAV and used for the purpose of mapping, event detection, or real time assessment of an asset or geography.

3.2 Key Performance Indicator

Parameter	Direction	Protocol	Bandwidth (kbps)	RTT (ms)	MSS (bytes) (Note 1)	Reliability (PLER)	Priority
Non-Critical Communication	UL/DL	TCP	35	500	500	10-3	System Design (Note 2)
Critical Communication	UL/DL	TCP	35	500	100	10-5 (Note 3)	Very High
Video and Image Streaming	UL	UDP	4096	500	N/A	10-3	System Design (Note 2)

Table 1 Traffic Requirements[1] for UAV applications

Note 1: MSS is TCP Maximum Segment Size [15]

Note 2 The priority level is met in the system design of the aircraft which is based on the system requirements and hardware specifications.

Note 3: Reliability of 10^{-5} for Critical Communication is in reference to ARP4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment is an Aerospace Recommended Practice from SAE International. ARP4761 provides a framework to assess safety critical data for aircraft. This framework, which is written into FAA regulations, prescribes higher reliability requirements for safety critical functions and data.

3.3 Data Traffic Prioritization

No regulation exists today which places determination on priority of data for a UAS using a 3GPP system as the primary or singular data link. The purpose of exploring prioritization is to understand the role this feature plays in meeting the needs of 3GPP systems as part of a UAS.

4 Radio and Packet Core Feature Set

4.1 LTE Radio Capabilities

4.1.1 Power Control

Aerial UEs, such as UAVs, differ from the classical LTE scenarios with terrestrial UEs. They are more likely to experience LOS to their respective serving cells than a terrestrial UE, in special in urban areas. Consequently, they can cause unobstructed interference in several cells for dozens of kilometres. Therefore, they require different power control settings compared to terrestrial UEs.

In order to accommodate for the different scenarios defined in 3GPP, in 3GPP Release 15 TS 36.331 [3], the UE specific P0 offset parameter (*UplinkPowerControlDedicated-v1530*) is set to a wider range (from -16 dB to 15 dB) in comparison to legacy versions (-8 dB and 7 dB) whereas the UE specific alpha factor choices remains unchanged.

Reasons for using P0 compared to alpha is that it controls the received power at the serving cell and as the serving cell and interfered cells level related to each other, it also controls the interference indirectly.

4.1.2 Height Reporting

New RRC measurement events have been introduced in 3GPP Release 15 TS 36.331 [3], specific to aerial UEs. Whereas most legacy events are conditioned to radio condition, such as signal strength and load, the new events are addressing the influence of UE flight pattern in radio conditions. The two new events introduced, H1 and H2, state respectively:

1. Event H1: Aerial UE height becomes higher than a threshold
2. Event H2: Aerial UE height becomes lower than a threshold

Additionally, when the event is triggered at the UE, the measurement report sent by the UE may contain information related to the flight pattern: the UE 3D location and speed (both vertical and horizontal). The reception of such reports by the network may be used to adjust the UE’s mobility related parameters, such as the thresholds and Time-to-Trigger (TTT) or the power control settings.

4.1.3 DL Interference Measurements

Airborne UEs, such as UAV, flying above the clutter, are likely to experience LOS with multiple base stations in a wide radius, which can lead to an increase in the number of significant interfering cells. Consequently, the amount of radio measurement reports, triggered by events such as A3, A4 and A5 [3GPP TS 36.331] may also increase significantly causing an excessive load over the physical resources.

In Release 15 3GPP added a new parameter *numberOfTriggeringCells* to the trigger configuration, in order to minimize the amount of trigger events. When this is parameter is set, a report is only sent if the number of neighbouring cells triggering the event condition is at least equal to the value indicated in *numberOfTriggeringCells* and no additional subsequent reports are sent if the number of triggering cells further increases.

Another configuration introduced to minimize the number of reports is the optional of the "*report on leave"* configuration*,* which triggers the transmission of a measurement report once one of the cells leave the event condition. Simulations have demonstrated that the "*report on leave"* can be used to perform frequent updates on the "interfering cell set" reported by the UE.

The network operator must observe the configuration used for the measurement report in order to minimize the load over the physical resources while maintaining good mobility and interference management procedures.

4.1.4 Connected Mode DRX

A UE in connected mode must listen the network signals to be able to decode DL initiated procedures or message exchanges (ex: paging, UL or DL scheduling info). In order to minimize the power consumption at the UE side, LTE specifications provide discontinuous reception (DRX) modes allowing the UE to go to sleep mode when there is no traffic between network and UE – after an inactivity timer. A connected mode UE must listen the network only during its active time (see Figure 2).

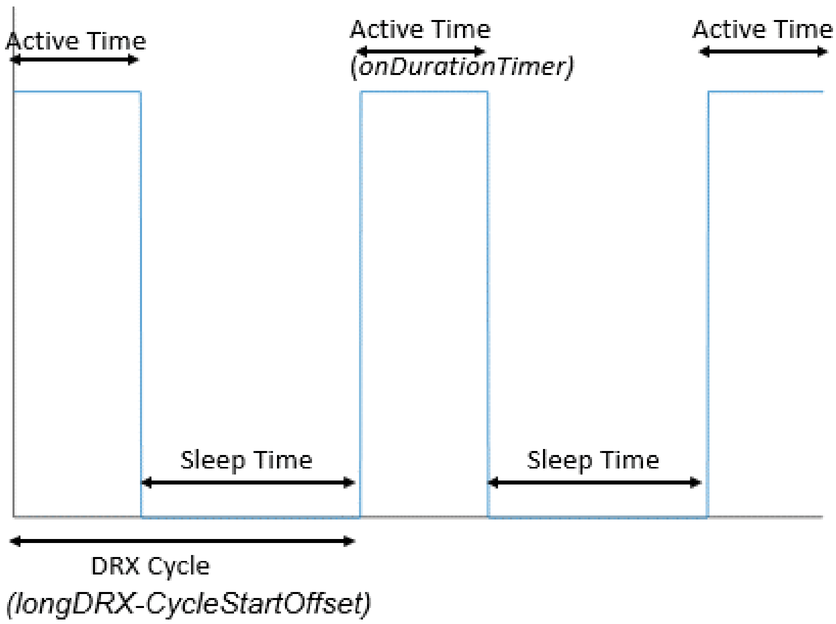

Figure 2 : Example of DRX Cycle showing Active and Sleep Time and the standard parameters that define them.

The downside of DRX is that increases the latency, as the UE is not available at all times. This happens as the eNB with data to be transmitted for a particular UE has to wait until the next active cycle of this UE before sending a PDCCH (physical downlink control channel) message with scheduling the downlink data reception. This effect is of particular interest for the critical communication traffic type.

In Section 3.5, the requirements for the critical communication propose a delay budget at 500 ms with a reliability of $10^{-5.}$ The delay in this case is a round-trip measurement between the UAV and the GCS or the UTM. It includes not only the radio part of the full link, but additional delays on core network, routing, internet relaying, fiber connections and others elements dependent on scenario deployments. Eventually, DRX introduced delays may be added up on top of these. For example, if the “off-cycle” (sleep mode) between active time periods is 250 ms or more, there is a risk the awaiting time spent by the eNB for the next UE active cycle exceeds the RTT delay budget.

The QoS class identifiers provided in specification define maximum packet delay budgets for the air interface, as presented in Section 4.4. This values must also be considered in combination with the maximum sleep cycle of the DRX settings when specifying both. The “sleep period” on LTE is configured by two parameters: the *onDurationTimer*, which defines the active part of the cycle and the *longDRX-CycleStartOffset* (see Figure 2).

To avoid impacts on flight safety, DRX should be disabled or, if enabled, its off cycle in combination with the configured QCI budget should not exceed 150-200 ms, whenever the critical or non-critical communication traffic types are set up at the UAV.

The impact on “battery saving” may be not so significant, as a UE battery is expected to outlast the UAV flight duration.

4.2 Bearer Management

4.2.1 EPS Bearer Considerations for Critical Communication

For UAS Critical and non-Critical Communications, the UAS application in the UE must use the UAS well-known APN as defined in GSMA PRD IR.88 [4]. The use of a dedicated, well-known APN ensures that the UE implementations provide separate path for UAS Critical and non-Critical Communications data traffic ; thus, changes to other APNs for other services will not affect the path and availability of UAS Communications services.

Note 1 : The network has to be prepared to receive any APN, including the UAS well-known APN, during the E-UTRAN initial attach procedure, as per 3GPP TS 23.401 [5] and 3GPP TS 24.301 [6]

Note 2 : When preconfiguring the UE to provide the UAS well-known APN during initial attach, the home operator needs to ensure that the UAS well-known APN is part of the subscription of the user of the UE in order to avoid attach failure.

If the PDN connection established during the initial attach is to an APN other than the UAS well known APN, then prior to registering with USS/UTM the UE must establish another PDN connection to the UAS well-known APN.

For Non-Critical Video and Image streaming, and by extension for other application payloads, the UE creates a PDN connection to a different APN (for example, Internet APN), as defined in 3GPP specifications.

4.2.2 EPS Bearer Considerations for Critical Communication

A default bearer must be created for a Critical Communications when the UE creates the PDN connection to the UAS well-known APN, as defined in 3GPP specifications. As stated in Section 4.X (QoS Class Identifier), no hard recommendation is made regarding the QCI choice for UAS critical communications. There are 4 standard QCIs in current 3GPP spefication designed to reach the requested data constraints, (5, 69, 70, and 71). The choice of the QCI within this subset of suitable candidates is left as a deployment decision.

4.2.3 EPS Bearer Considerations for Non-Critical Communication

For a UAS session request for a Non-Critical Communications, a dedicated bearer for UAS Critical Communications must be created utilizing interaction with dynamic PCC as specified in TS 203.203 [1] clause 6.1.1.   The network must initiate the creation of a dedicated bearer to transport the UAS Non-Critical Communication data. The dedicated bearer must utilize the standardised non-GBR QCI value and have the associated characteristics as specified in 3GPP TS 23.203 [1]

4.2.4 EPS Bearer Considerations for Video and Image Streaming

The default bearer for the APN used (e.g. Internet APN) must utilize non-GBR QCI value and have the associated characteristics as specified in 3GPP TS 23.203 [1]. If Video and Image streaming are used to facilitate control of the UAV, the bearers are as defined in Section 4.3.2. The recommendations in this document do not preclude commercial considerations regarding the type of application used by the UAV and the network design.

4.3 QoS Class Identifier

The QoS Class Identifiers (QCIs) chosen to support a UAV application, must have performance parameters in accordance to those described in Section 3.x [Key Performance Indicators] of this document. The traffic requirements for UAV applications defined in Section 3.x [Key Performance Indicators] presents a round-trip delay budget, whereas the QCI tables provide the performance in terms of one-way delay between UE and Core Network. Accounting for a round-trip (two-way) flow of the data, and to additional delays external to the RAN (internet relays, application layer processing, etc.), the QCI delay budget parameter may not reach or exceed 50% of the values described previously in Section 3.x [Key Performance Indicators].

There are 4 QCIs that fulfil the performance requirements for Critical Communications: 5, 69, 70 and 71 (see Table 2). However, their Packet Error Rate is more conservative than the requirements for Non-Critical Communication & Video and Imaging by a wide margin ($10^{-6}\ vs\ 10^{-3}$), which will represent a conservative approach by the RAN, possibly resulting in inefficient use of resources.

QCI	Priority	PDB	PELR	Notes
5	1	100 ms	10^{-6}	
69	0.5	60 ms	10^{-6}	Delay budget too much lower than the requirements
70	5.5	200 ms	10^{-6}	
71	5.6	150 ms	10^{-6}	

Table 2: List of standard QCIs fulfilling the Critical Communications Performance requirements

This document has identified different default QCIs whose operating settings fulfil the criteria established for UAV applications. As all of them are, in principle, able to cope with the requirements, no recommendation for a specific QCI is given. The choice of any of the fulfilling QCIs can be left at implementation's discretion.

In most cases, the QCIs that fulfil the requirements present a much lower delay budget than the expected by UAV applications. Choosing one of such QCIs may result in a highly conservative approach that may trigger excessive robustness for the RAN, leading to unnecessary consumption of physical resources.

The standardized characteristics associated with standardized QCI values are specified in clause 6.1.7.2 in TS 23.203 [1].

The mapping of these to radio parameters is described in the next sections.

5 Common Functionalities

5.1 IP Version

The UE and the network must support both IPv4 and IPv6 for all protocols that are used for the Aerial application. At PS attach, the UE must request the PDN type: IPv4v6, as specified in section 5.3.1.1 in 3GPP TS 23.401 [5]. If both IPv4 and IPv6 addresses are assigned for the UE, the use of the IPv6 address type must be preferred.

Note: There are certain situations where interworking between IP versions is required. These include, for instance, roaming and interconnect between networks using different IP versions. In those cases, the network needs to provide the interworking in a transparent manner to the UE.

5.2 Roaming

Further work is needed in GSMA on the roaming model(s) that would be needed to support LTE Aerial Roaming.

Annex A Informative

A.1 Waypoint Reporting

In LTE, there is a feature that allows the eNB to request the UAV information about location and planned flight route. The network can send a ***UEInformationRequest*** message including parameter ***flightPathInformationReq*** and the UE should reply with a flight path information included in ***UEInformationResponse*** message consisting of up to 20 waypoints. Each waypoint is composed of a 3D location information, optionally combined with a time stamp to provide the expected time of arrival of the UE at that location with a maximum of one second granularity.

This information can be used to provide early resource reservation in cells suitable for a handover and by doing so, ensure a higher QoS for instance, and optimization of other radio related parameters. However, the reporting is to a large extent left for UE implementation. There is no specification in the standards for the distance between waypoints nor how accurate the waypoints must be from the actual flight path.

The waypoint reporting is left as an optional feature for UAV and eNB implementations.

Annex B Document Management

B.1 Document History

Version	Date	Brief Description of Change	Approval Authority	Editor / Company
0.1	08/03/2021	New PRD (RILTE Doc nn/nnn).	LAPTF#1	Jignesh Patel, Verizon
0.2	08/03/2021	LAPTF02_001, LAPTF02_002, LAPTF02_003	LAPTF#2	Jignesh Patel, Verizon
0.3	22/03/2021	LAPTF04_001, LAPTF04_002, LAPTF04_003, LAPTF04_004, LAPTF04_005	LAPTF#4	Jignesh Patel, Verizon
0.4	31/03/2021	LAPTF04_006, LAPTF004_07, LAPTF005_001, LAPTF005_002	LAPTF#5	Jignesh Patel, Verizon
0.5	09/04/2021	LAPTF06_001, LAPTF06_002	LAPTF#6	Jignesh Patel, Verizon
0.6	09/05/2021	LAPTF07_001, LAPTF08_001, LAPTF08_002	LAPTF#7, LAPTF#8	Jignesh Patel, Verizon
0.7	28/05/2021	LAPTF08_003	LAPTF#9	Jignesh Patel, Verizon
0.8	14/06/2021	LAPTF10_001, LAPTF10_002, LAPTF10_003	LAPTF#10	Jignesh Patel, Verizon
0.9	15/06/2021	LAPTF11_001	LAPTF#11	Jignesh Patel, Verizon
1.0	11/11/2021	PRD First version	TG	Jignesh Patel, Verizon

B.2 Other Information

Type	Description
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Editor / Company	Jignesh Patel, Verizon

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Your comments or suggestions & questions are always welcome.