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GROUP SPECIFICATION

Low Throughput Networks (LTN); Protocols and Interfaces

Disclaimer

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Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) Low Throughput Networks (LTN).

Modal verbs terminology

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Introduction

Low Throughput Network (LTN) is a technology of wide area wireless network with some specific characteristics compared to existing networks:

- LTN enables long-range data transmission (distances up to 40 km in open field) and/or communication with buried underground equipment.
- LTN operates with minimal power consumption in the device modems that allows operation on several years even with standard batteries.
- LTN implements low throughput along with advanced signal processing that provides effective protection against interferences.

As a consequence, LTN is particularly well suited for low throughput machine to machine (M2M) communication where data volume is limited and latency is not a strong requirement.

LTN could also cooperate with cellular networks to address use cases where redundancy, complementary or alternative connectivity is needed.

The objective of the present document is to provide a description of protocols and interfaces that are implemented in networks using LTN technology.

The elements provided in the document will contribute to standardize LTN protocols and interfaces in order to ensure interoperability of devices, modems, network elements and software solutions from various vendors, integrators and operators.

The present document defines the protocols and interfaces of LTN technology. It is organized as follows:

- Clause 4 gives an overview of the LTN architecture.
- Clause 5 describes the radio interface A.
- Clauses 6-10 describe LTN infrastructure interfaces.
- Clauses 11-13 briefly cover interfaces A', C' and F' that are out of scope of the present document.

1 Scope

The present document aims to define the protocols and interfaces of LTN systems. It goes along with the document GS LTN 002 [5] on LTN functional architecture.

The present document is intended for an audience with a technical perspective, whereas the use case document GS LTN 001 [i.2] addresses more business-oriented views on LTN.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents, which are not found to be publicly available in the expected location, might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document:

[1] FCC CFR 47 Part 15: "Telecommunication: Radio Frequency Devices".

[2] ETSI EN 300-220 (Parts 1 & 2): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW".

[3] GB/T 15629.15-2010: "Information technology - Telecommunications and information exchange between systems local and metropolitan area networks - Specific requirements - Part 15.4: Wireless medium access control and physical layer (PHY) specification for low rate wireless personal area networks".

NOTE: Available at http://www.sac.gov.cn/sac_en/.

[4] ARIB STD-T96 (2010.07.15) (H22.7.15) (Version 1.1): "950 MHz-Band Telemeter, Telecontrol and Data Transmission Radio Equipment for Specified Low Power Radio Station".

[5] ETSI GS LTN 002: "Low Throughput Networks (LTN); Functional Architecture".

[6] ETSI TS 102 690: "Machine-to-Machine communications (M2M); Functional architecture".

[7] ETSI TS 102 921: "Machine-to-Machine communications (M2M); mIa, dIa and mId interfaces".

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] IEEE 802.15.4-2011: "IEEE Standard for Local and metropolitan area networks - Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)".

[i.2] ETSI GS LTN 001: "Low Throughput Networks (LTN); Use Cases for Low Throughput Networks".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

AT commands: attention commands used when communicating with a modem

authentication: method to check the claimed identity of a communication partner

beacons: periodically transmitted frames

ciphering: cryptographic transformation of data

credentials: data attesting the truth of certain stated facts

fragmentation: process in which a packet is broken into smaller pieces to fit the requirements of a lower layer, which is used for the transmission of this packet

multi-bearer: association of multiple transmission channels or circuits, and switching, set up to provide a means for transfer of information between two or more points in a telecommunication network

piggy-backing: method of sending downlink data right after uplink transmission

registration: process by which a terminal informs the network of its presence and its willingness to use the network services

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Baud	(as a unit of modulation rate) one baud corresponds to one symbol (i.e. stable modulation state) per second on a transmission line

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AAA	Authentication, Authorization, Accounting
ADSL	Asymmetric Digital Subscriber Line
AFA	Adaptive Frequency Agility
API	Application Program Interface
AT	ATtention
bps	bits per second
BPSK	Binary Phase Shift Keying
BSS	Business Support System
CRA	Central Registration Authority
CRC	Cyclic Redundancy Check
CRC5	Cyclic Redundancy Check, 5 bit long
DSSS	Direct Sequence Spread Spectrum
FCS	Frame Check Sequence
GFSK	Gaussian-filtered Frequency Shift Keying
GPRS	General Packet Radio Service
I2C	Inter Integrated Circuit
ID	IDentifier
IS	Information System
kcps	kilo chip per second
LAP	LTN Access Point
LBT	Listen Before Talk
LEP	LTN End Point

LTN	Low Throughput Network
MAC	Medium Access Control
NID	UNB Node Identifier
OSS	Operation Support System
OSSS	Orthogonal Sequence Spread Spectrum
PAC	Porting Authorization Code
PHY	PHYsical layer
ppm	part per million
REST	REpresentational State Transfer
Rx	Reception
SEK	SEcret Key
SNMP	Simple Network Management Protocol
SPI	Serial Peripheral Interface
SRD	Short Range Devices
Tx	Transmission
UNB	Ultra Narrow Band
USA	United States of America
USB	Universal Serial Bus
WAN	Wide Area Network

4 Overall architecture

The detailed architecture of a LTN network is defined in architecture document GS LTN 002 [5]. Figure 1 highlights the various interfaces defined in the LTN architecture; each interface is described in the present document.

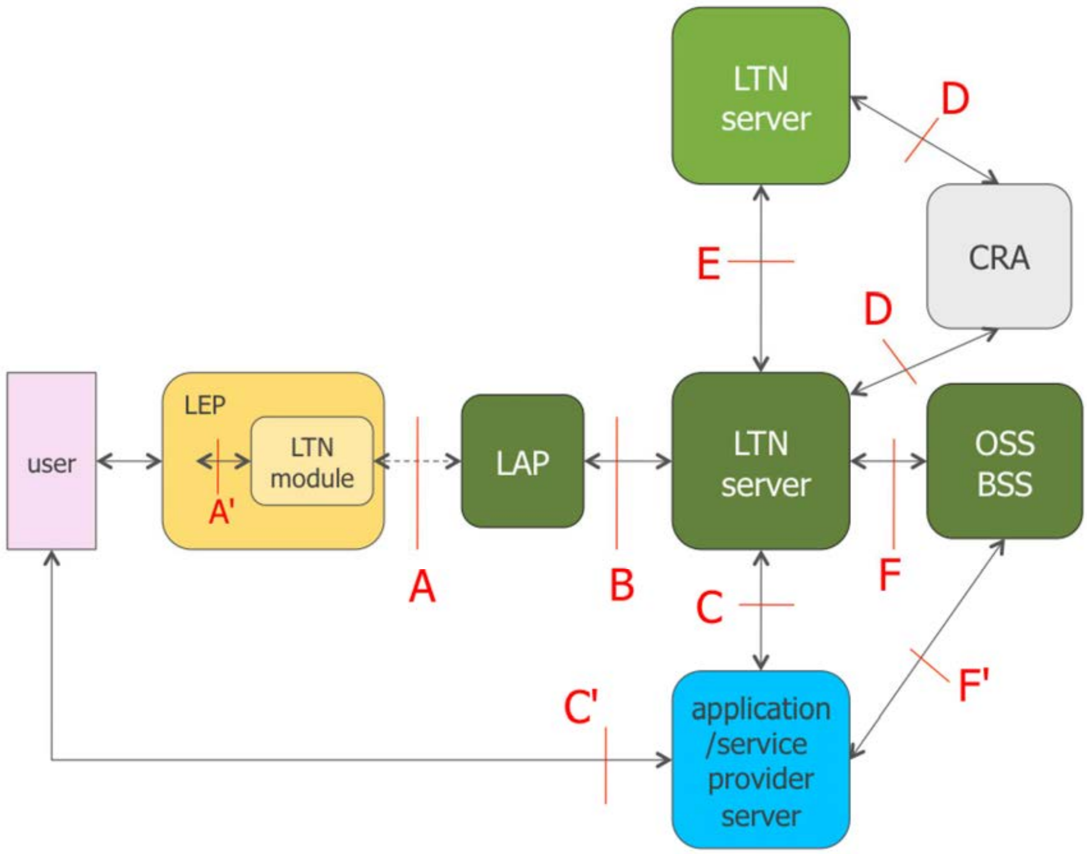

Figure 1: Overall LTN architecture and defined interfaces

In a LTN architecture, all bearers are standard WANs except for the A, A' and C' interfaces:

- A is the radio interface that makes the connection between LEPs and LAPs.
- A' is an internal interface between the LTN module and user-specific application within a LEP. A' interface is out of scope of the present document. It is given here as an indication only.
- C' is not a technical interface, but rather a multi-bearer communication link between the application provider and its customer. C' interface is out of scope of the present document. It is given here as an indication only.

5 Interface A

In the LTN architecture, A is the radio interface between LEPs and LAPs. Two implementations are foreseen to be included in the LTN architecture: UNB and OSSS. Both radio implementations use the same radio spectrum, but with different approach:

- UNB implementation uses ultra narrow band communication.
- OSSS implementation uses orthogonal sequence spread spectrum technologies.

5.1 Radio Spectrum

UNB and OSSS implementation of the A interface are compliant with:

- spectrum allocation in the USA [1],
- spectrum allocation in Europe [2],
- spectrum allocation in China [3],
- spectrum allocation in Japan [4].

5.2 UNB implementation of the radio interface

5.2.1 Interest of UNB implementation

The UNB radio interface gives an increased transmission range with a limited amount of energy spent by the end-point. Moreover the UNB allows large numbers of end-points in a given cell without having spectrum interference.

Uplinks (i.e. from the LEPs to the network) and downlinks (i.e. from the network towards the LEPs) are possible in the UNB solution. Spectrum optimization leads to slightly different uplink and downlink frames and time synchronization. Clause 5.2.2 details UNB uplink. Clause 5.2.3 details UNB downlink.

5.2.2 Preferred implementation of the UNB uplink

5.2.2.1 Radio band for uplink

The main radio specifications of the UNB uplink transmission are:

- channelization mask: 100 Hz (600 Hz in the USA)
- uplink baud rate: 100 baud (600 baud in the USA)
- modulation scheme: BPSK
- uplink transmission power: compliant with local regulation
- sensitivity: it is recommended to have high sensitivity receiver (i.e. better than -135 dBm)

- central frequency accuracy: not relevant, provided there is no significant frequency drift within an uplink packet

NOTE: In Europe, the UNB uplink frequency band is limited to 868,00 to 868,60 MHz, with a maximum output power of 25 mW and a maximum mean transmission time of 1 %. LBT (Listen Before Talk) and/or AFA (Adaptive Frequency Agility) are not implemented in UNB solution.

5.2.2.2 UNB MAC frame (up-link)

The format of the uplink UNB MAC frame is the following (see figure 2):

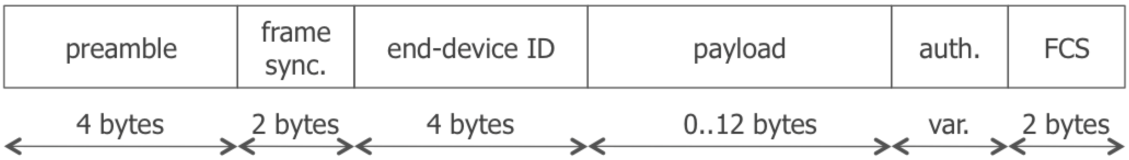

Figure 2: MAC frame in UNB up-link implementation

Fields of the UNB up-link MAC frames are:

- preamble size: 4 Bytes
- frame synchronization: 2 Bytes
- end-point ID: 4 Bytes
- payload: 0-12 Bytes
- authentication: variable length
- frame check sequence: 2 Bytes (CRC)

5.2.3 Preferred implementation of the UNB downlink

5.2.3.1 Radio band for UNB downlink

The main specifications of the UNB downlink transmission are:

- channelization mask: dynamic selection
- down link baud rate: 600 baud
- modulation scheme: GFSK
- downlink transmission power: 500 mW

NOTE: In Europe, the UNB downlink frequency band is 869,40 to 869,65 MHz (i.e. 500 mW band with 10 % duty cycle).

5.2.3.2 UNB MAC frame (downlink)

The format of the downlink UNB MAC frame is the following (see figure 3):

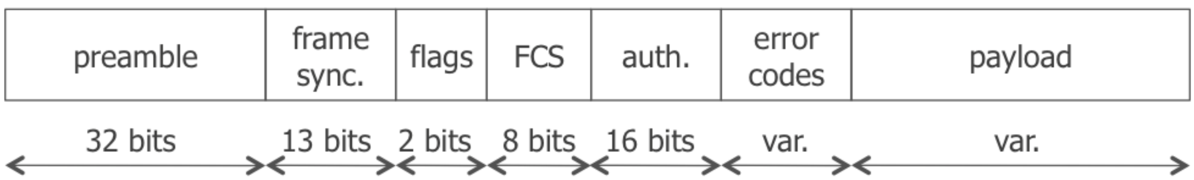

Figure 3: Downlink MAC frame in UNB implementation

Fields of the downlink MAC frame in UNB are:

- preamble: 32 bits
- frame sync: 13 bits
- flags: 2 bits
- FCS: 8 bits
- authentication: 16 bits
- error codes: variable
- payload: variable

5.2.4 Synchronization between uplink and downlink transmissions in UNB

The UNB solution is mainly dedicated to carry uplink messages. Nevertheless downlink transmission is available with two different implementations.

5.2.4.1 Piggy-backing in UNB downlink

In this implementation, a LEP willing to receive downlink messages opens a fixed window for reception after each uplink transmission. Delay and duration of this window have fixed values (see figure 4).

The LTN network transmits the downlink message for a given LEP in this LEP reception window. It is the duty of the network to define the best LAP for transmitting the downlink message.

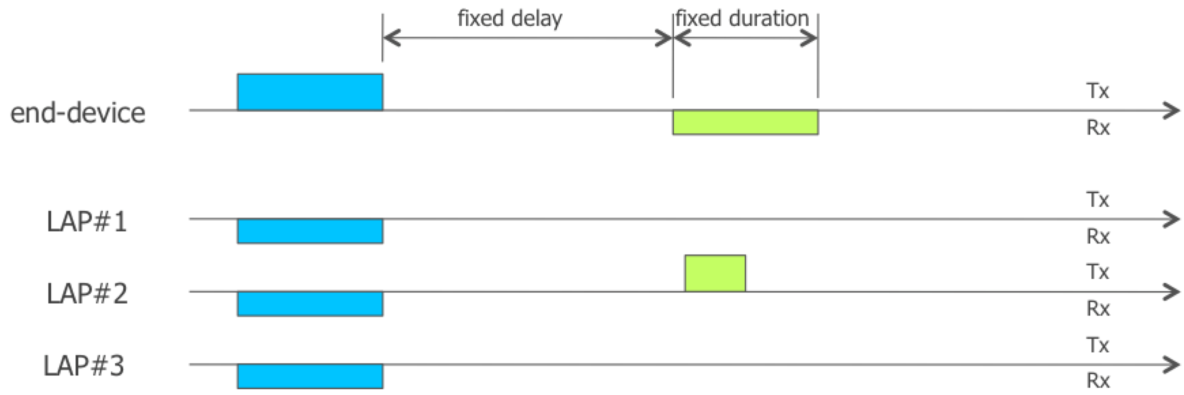

Figure 4: UNB downlink transmission with piggy-backing

5.2.4.2 Broadcasting in UNB downlink

Broadcast is possible in the UNB radio interface but not yet implemented.

5.3 OSSS implementation of the radio interface

This clause deals with the A interface when implemented with spread spectrum radio transmission.

5.3.1 Interests of OSSS implementation

The Orthogonal Sequence Spread Spectrum implements a specific spread spectrum transmission scheme, which is known to be effective in:

- giving increased reception sensitivity and therefore increased transmission range even in case of limited transmission power;
- allowing good spectrum efficiency mainly in case of high density of nodes.

5.3.2 Preferred implementation of OSSS transmission

5.3.2.1 Radio band

The main radio specifications of the OSSS link are:

- channelization mask: from 8 kHz to 500 kHz (depending on spreading factor)
- chip rate: 8 kcps up to 500 kcps
- data rate: 30-50 000 bps
- modulation scheme: equivalent to DSSS with orthogonal signaling
- sensitivity: it is recommended to have high sensitivity receiver (i.e. better than -135 dBm)
- center frequency accuracy: one quarter of the actual chip rate (e.g. 868 MHz center frequency and 125 kcps gives 35 ppm)
- intra-packet frequency drift: not relevant provided crystal quartz of the oscillator is properly defined

5.3.2.2 OSSS PHY frame

The OSSS Physical frame (see figure 5) is composed of:

- a preamble of 12 symbols (8 for signal detection and 4 for synchronization);
- a physical header: packet size, fragmentation flag, coding rate, CRC flag;
- a header CRC (CRC5) that checks physical header integrity;
- a payload that carries OSSS MAC frame, defined hereunder.

Field Size	**12 symbols**	**20 bits**		**variable**
Field Name	Preamble	Physical Header	Header CRC	Physical Payload

Figure 5: OSSS physical frame format

NOTE: Field sizes of the OSSS PHY frame are given in symbols or in bits, because their actual sizes depend on the OSSS spreading factor.

5.3.2.3 OSSS MAC frame

The OSSS MAC frame is depicted in figure 6. Its format is compliant with IEEE 802.15.4 recommendations [i.1].

Field Size (in Bytes)	2	0/2	0/2/8	0/2/8	0/2	variable	4
Field Name	Frame Control	Frame Counter	Destination Address	Source Address	Frame Control Extension	Frame Payload	Hash Crypto

Bit Position	0-2	3	4	5	6-7	8-9	10	11-12	13	14-15
Field Name	Frame Type	Security Enabled	AR	ADR Enabled	Dest. Addressing Mode	Source Addressing Mode	More Data	Transported Protocol	Frame Control Extension Enabled	Frame Version

Figure 6: Fields of the OSSS MAC frame

5.3.3 Synchronization between uplink and downlink in OSSS

Basically, the OSSS implementation is a two-way system. Nevertheless classes of end-points are defined depending on their receiving capability:

- Class A nodes open one (or several) receiving slot(s) after each transmission with a predefined timing.
- Class B nodes maintain a time synchronization derived from beacons transmitted by LAPs every 128 s. Downlink is slotted by the LAP. Class B nodes listen for receiving downlink messages in allocated time slots.

NOTE 1: Class of OSSS LEPs refers to the end-user point of view only. When looking at the radio interface, all OSSS LEPs are bidirectional because they have to exchange technical data with the network.

NOTE 2: Class A and class B nodes transmit user data asynchronously and open a receiving slot after each uplink transmission. Only class B nodes open extra reception slots synchronously with the LAPs.

5.4 LTN credentials

This clause gives a detailed list of LTN credentials used by LEPs for the purpose of authentication, registration and/or ciphering over the A interface.

5.4.1 Credentials in UNB networks

The A interface in UNB implementation uses credentials with two fields: an identifier and a secret key. These fields are detailed in hereunder sub-clauses. Clauses 8.1.1 and 8.1.2 show examples of sequence diagrams where UNB credentials are used in the LTN architecture.

5.4.1.1 UNB end-point identifier (NID)

A unique identifier, named NID, is given to each UNB end-point. The NID is 32 bit long.

The Central Registration Authority (CRA) allocates ranges of NIDs to LEP manufacturers and manages the list of NID ranges.

Every radio packet sent by a UNB end-point is tagged with the NID of the transmitting end-point.

5.4.1.2 UNB end-point secret key

Each UNB end-point has a secret key (SEK). This key is 128 bit long. It is used to authenticate each radio packet transmitted by an UNB end-point.

NOTE: The SEK authenticates the radio packet but it does not cipher the service payload. Payload ciphering is made at the application level.

5.4.2 Credentials in OSSS networks

5.4.2.1 Identifiers in OSSS networks

A LEP implementing in the OSSS radio interface has two identifiers:

- a long identifier (long ID) which is unique for each end-point. This identifier is 64 bit long and is allocated to a LEP at the end of production;
- a short identifier (short ID) which is network dependent. This identifier is 32 bit long and is down-loaded in the end-point during the join procedure.

Figure 7 depicts the overall joining procedure of an OSSS LEP.

5.4.2.2 OSSS end-point secret keys

Each OSSS end-point uses three different keys. All are 128 bit long:

- the activation key, which is used to authenticate the messages sent by the LEP during the join request procedure. It is also used for the derivation of the network session key and the application session key;
- the network session, which is used for the MAC frame header authentication;
- the application session key, which is used for the user's payload ciphering.

Figure 7 depicts when the various keys, which are used during the join procedure and during the transmission of application messages.

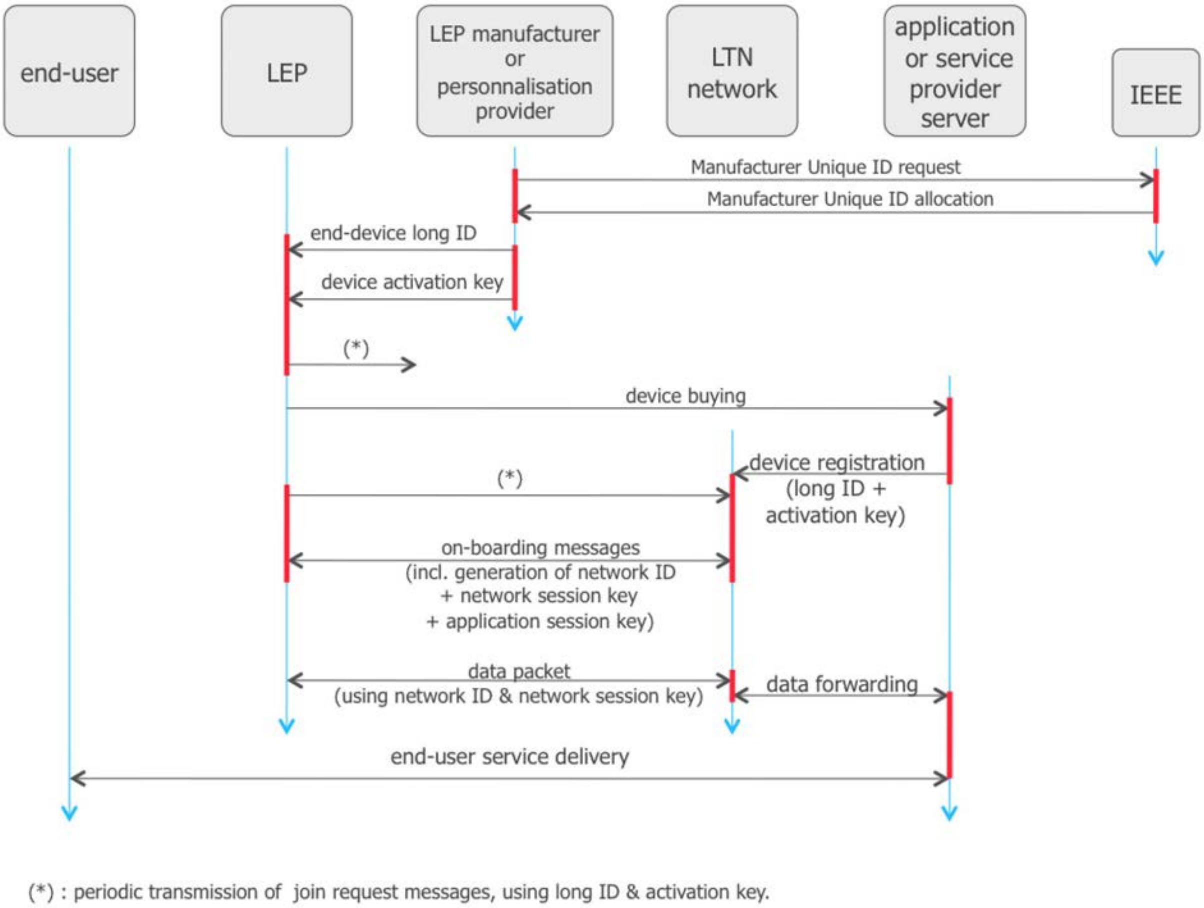

Figure 7: Use of credentials over the A interface in case of OSSS LEP

5.5 Interoperability at interface A

The three types of interoperability at interface A are:

- type A1: a LEP can embed two LTN modules (UNB and OSSS). This allows communicating with all available LTN networks;
- type A2: a LAP can embed two LTN radio front ends (UNB and OSSS). This allows reception and transmission of messages with the two radio technologies;
- type A3: UNB-based LAPs and OSSS-based LAPs are connected to the same LTN server.

Interoperability is not described in the present LTN specification, but it is expected for the next release.

5.6 Coexistence at interface A

Coexistence of UNB and OSSS networks is "de facto" available because UNB and OSSS radio interfaces are fully compatible with SRD regulations [2]. Moreover, UNB and OSSS radio technologies cope with mutual interference because one is ultra narrow band and the other one is spread spectrum.

6 Interface B

Interface B is implemented between the LAPs and the LTN servers. Bearers of interface B can be any Internet Protocols Standard WAN such as GPRS, ADSL, satellites, microwave links, etc. The system is designed to work with permanently available links, but it can manage short unavailability of the WAN access (store and forward).

This interface carries traffic for both user plane and control plane and should use secure links. User plane is encapsulated in specific LTN messages. The control plane is mapped on the SNMP-like messages.

6.1 Interoperability at interface B

Interoperability at interface B is the capability to connect UNB-LAPs or OSSS-LAPs to the same LTN servers. This type of interoperability is expected for the next release.

7 Interface C

The C interface is between the LTN server and one or many application server(s). It is based on the REST principles. The LTN servers expose the following main methods on the C interface:

- application/service APIs, such as retrieve, push, delete methods
- operation support APIs, needed for end-point and/or account management

Stream of information between the LTN servers and the application/service provider servers is either in push or pull mode.

Implementation should be compatible with the ETSI SmartM2M recommendations [6] and [7].

8 Interface D

The D interface is between the CRA and one or many LTN servers. Data available at this interface are forwarded to various functional blocks within a LTN server, such as: AAA, IS and/or network management.

This interface is mainly used during personalization of LEP and/or joining procedure of LEPs onto a LTN network. Main parameters that cross this interface are:

- end-point identifiers;
- end-point secret keys;
- porting authorization code.

8.1 Interface D in the case of UNB implementation

This clause gives an overview of the way interface D is used during manufacturing, personalization and joining procedure of a LEP. When considered all together, these three processes are called the "beginning of life" of an UNB LEP. Their description, given hereafter, is for information only.

8.1.1 Beginning of life of an UNB LEP

LEP manufacturing, personalization and joining procedure (i.e. beginning of live) involve the following parties:

- LEP or LTN module manufacturer;
- personalization provider (if it is a separate entity from the LEP or LTN module manufacturer);
- CRA;
- service or application provider;
- LTN network;
- end-user.

Figure 8 depictures mainstream interactions between the manufacturing, personalization and joining process of a LTN end-point.

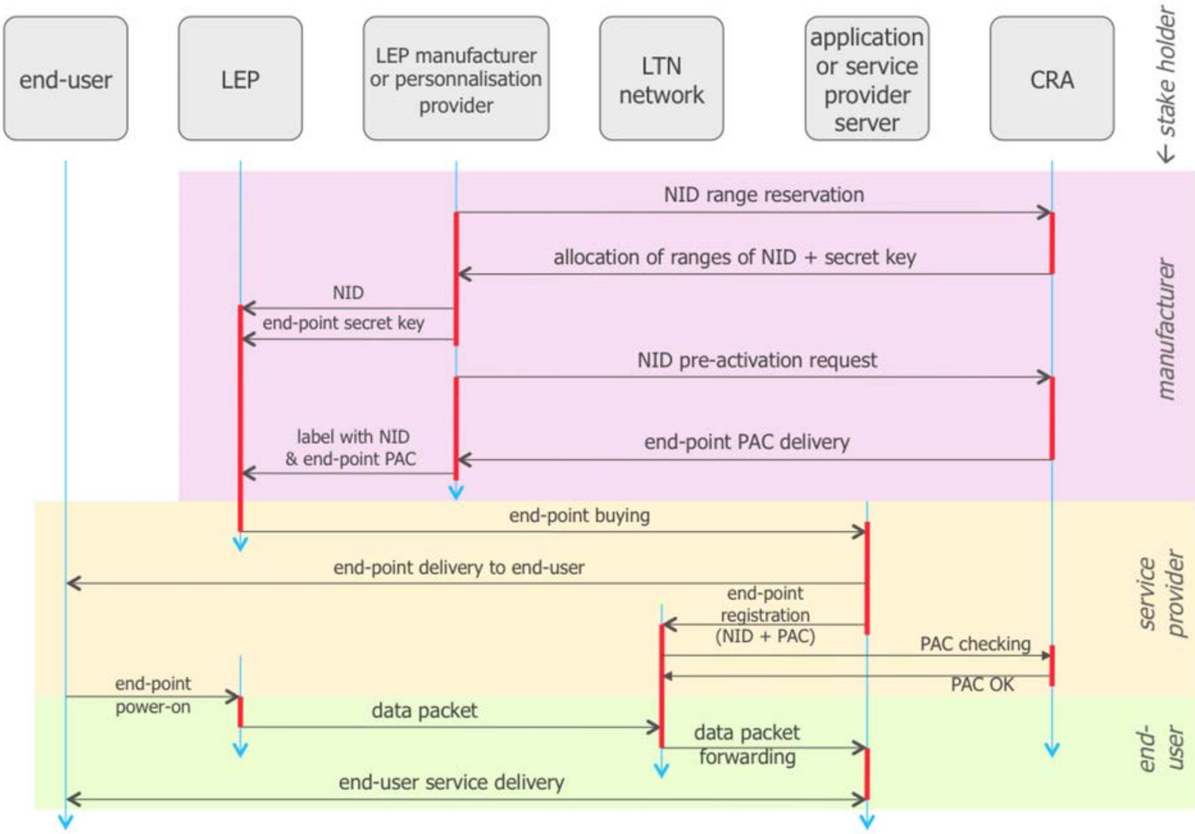

Figure 8: Beginning of live of an UNB LEP

8.1.2 Portability of an UNB LEP

When a LEP is acquired by an end-user, portability between service providers is possible. The end-user triggers the procedure by getting a new PAC from the CRA. Then, the new service provider uses this code to register the LEP onto a LTN network. A sequence diagram of the portability procedure is given in figure 9.

NOTE: Portability of an UNB LEP has not impact on the LEP itself. Its NID and end-point secret key remain the same. Portability is managed by the LTN network.

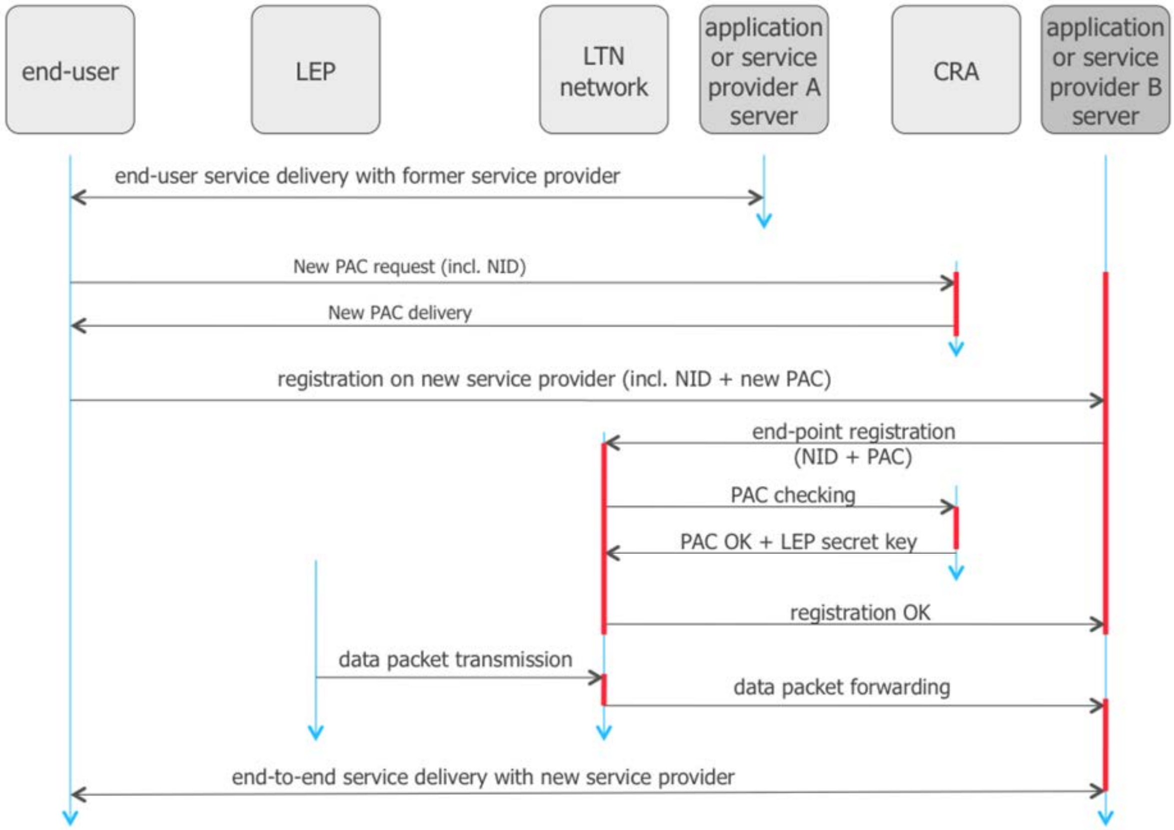

Figure 9: Sequence diagram of portability in the UNB implementation

8.1.3 Porting authorization code (PAC)

The porting authorization code (PAC) is used by an application/service provider to authenticate its registration request of a new LEP. PAC is one-time usable. It is 16 hexadecimal digits long and is managed by the CRA.

The legitimate owner of a LEP can ask the CRA for a PAC and give it to its new application/service provider. The application/service provider uses this PAC to authenticate the registration of the LEP onto the LTN network.

NOTE: The PAC is never carried over the radio interface at anytime during the LEP life.

8.2 Interface D in the case of OSSS implementation

The present release of the LTN solution does not use the CRA in the OSSS implementation.

Activation uses long ID and the activation key stored in the LEP. Roaming cases are straightforward because the network session key holds the home LTN of a LEP. Therefore no reference to a central authority is needed when rerouting application data frames towards the home LTN.

9 Interface E

The interface E is a direct interface between LTN servers from different LTN operators. It is used to exchange data between LTN operators when end-points are roaming or when registration of an end-point is ported between two LTN operators. There are two types of roaming data:

- data forwarding where only user plane continuity is in place between visited LTN and home LTN;
- network service cooperation where value added services such as geo-localization are implemented. In this case, the interface E exchanges technical data as well as user data.

Figure 10 illustrates how data are conveyed between visited LTN and home LTN when a LEP is roaming.

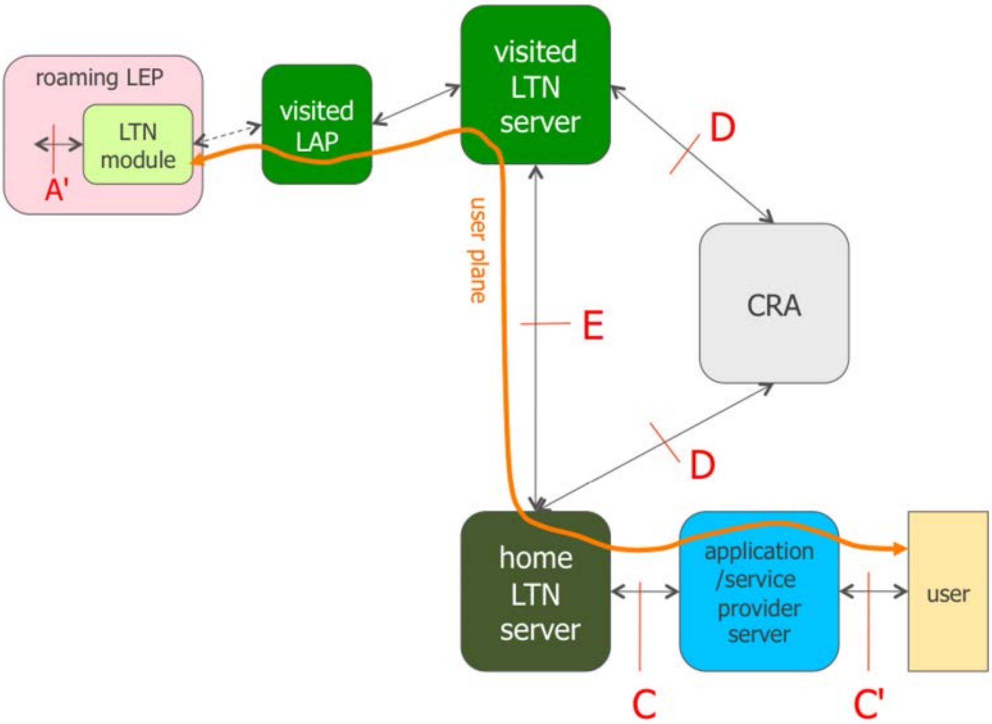

Figure 10: Use of the E interface in case of a roaming LEP

NOTE: Basically, interface E carries application data regardless the technology deployed in the A interface. Therefore interface E can be seen as a convenient way to implement interoperability with LTN between different radio interfaces.

10 Interface F

The F interface is between the LTN server and the OSS/BSS systems. It is used by OSS/BSS system to:

- activate registration of a LEP onto a LTN network;
- collect charging data of LEPs;
- retrieve network status.

This interface is at the application level and is carried over the Internet Protocol Standards WANs.

Detailed description of the F interface is out of scope of the present document.

11 Interface A'

The A' interface is used to send and receive information to/from the LTN module within the LTN end-point.

It should be based on AT commands (generic and specific) and should be implemented over a standardized serial communication bus.

Further details on the A' interface is out of scope of the present document.

12 Interface C'

The C' interface is the end-user interface towards the application provider. This interface is out of scope of the present document.

13 Interface F'

The F' interface is between the application/service provider servers and OSS/BSS. It is used by the application/service providers to:

- manage LEP registration;
- retrieve billing data on its LEPs.

This interface is at the application level and is carried over the Internet Protocol Standard WANs.

A detailed description of the F' interface is out of scope of the present document.

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Annex B (informative): Change history

Date	Version	Information about changes
2013-10	0.0.1	document creation and review in ISG LTN meeting #9
2013-12	0.0.2	document reviewed in meeting LTN#10
2014-01	0.0.3	document reviewed in meeting LTN#11
2014-03	0.0.4	updated after LTN#12 meeting
2014-03	0.0.5	updated during and after meeting LTN#13 in Sophia Antipolis
2014-06	0.0.6	updated during and after meeting LTN#14 in Sophia Antipolis
2014-06	0.0.7	updated with inputs from ETSI Secretariat, before LTN#15
2014-06	0.0.8	updated and finalized during LTN#15
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