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Space data and information transfer systems — Licklider transmission protocol (LTP) for CCSDS

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Space data and information transfer systems — Licklider transmission protocol (LTP) for CCSDS

Données spatiales et systèmes de transfert d'information - Protocol de transmission Licklider (LTP) pour CCSDS

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DEDICATION

This book is dedicated to Adrian Hooke, whose end-to-end sensibilities and tireless advocacy for standardization of space data systems directly contributed to the formation of the Consultative Committee for Space Data Systems in 1982. His unique combination of technical skill, management abilities, and vision served CCSDS well for over 30 years. During that time CCSDS solidified the standardization of Physical and Data Link Layer protocols, and developed standards and technologies that had important and wide-ranging impacts in both the space and terrestrial communications industries. In the late 1990s, Adrian envisioned a new era for space communications leveraging a confluence of terrestrial internetworking and space-based data transport technologies. This led to the development of a concept that has come to be known as the Solar System Internetwork (SSI), of which the Licklider Transmission Protocol described here is a part.

Adrian will be missed, by CCSDS for the scope of his technical contributions and his leadership, and by his colleagues and friends for the greatness of his spirit and his wit. But his legacy to the space community remains. CCSDS will continue to provide useful and innovative solutions to space communication challenges so that Adrian's vision of an interoperable, standards-based communication system that reduces mission development time, cost, and risk will eventually be realized.

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1 INTRODUCTION

1.1 PURPOSE

This document defines a Recommended Standard for the CCSDS Licklider Transmission Protocol (LTP) and associated service for application in the space environment. LTP provides optional reliability mechanisms on top of an underlying (usually data link) communication service.

1.2 SCOPE

LTP is intended for use over the current and envisaged packet delivery services used in the space environment, including:

– CCSDS conventional packet telecommand;

– CCSDS conventional packet telemetry.

For space data links, LTP will typically be deployed over a CCSDS data link that supports CCSDS Encapsulation Packets so that one LTP segment can be encapsulated in a single Encapsulation Packet. LTP may also operate over a wide variety of ground-network services including those specified by the CCSDS for cross-support purposes.

1.3 ORGANIZATION OF THE DOCUMENT

This Recommended Standard is organized as follows:

a) Section 2 contains a descriptive overview of LTP operation as well as a brief history of the protocol's heritage. Users not already familiar with LTP may want to start with this section.

b) Section 3 contains a profile of RFC 5326 (reference [3]) for use by CCSDS.

c) Section 4 contains the abstract service specification for LTP.

d) Section 5 specifies the services that LTP requires from the underlying system.

e) Section 6 contains conformance requirements for the CCSDS profile of LTP.

f) Section 7 defines a client operations service that allows multiple layer-(N+1) SDUs to be aggregated into a single LTP block in order to improve efficiency.

g) Annex A contains the Protocol Implementation Conformance Statement (PICS) proforma.

h) Annex B specifies how to layer LTP over the CCSDS Space Packet Service or the CCSDS Encapsulation Service.

i) Annex C contains the Management Information Base (MIB) for the protocol.

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j) Annex D discusses security, SANA, and patent considerations related to the specification.

k) Annex E is a list of informative references.

l) Annex F is a list of abbreviations and acronyms that appear in the document.

1.4 CONVENTIONS AND DEFINITIONS

1.4.1 TERMS

1.4.1.1 Definitions from OSI Basic Reference Model

This Recommended Standard makes use of a number of terms defined in reference [1]. The use of those terms in this Recommended Standard is to be understood in a generic sense, i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are:

– entity;

– Protocol Data Unit (PDU);

– service;

– Service Access Point (SAP);

– Service Data Unit (SDU).

Figure 1-1 illustrates the relationship of the LTP protocol defined in this document and protocols at the layers above and below LTP. From the point of view of protocols above LTP (e.g., Bundle Protocol), the service LTP provides is optionally reliable delivery of layer-(N+1) PDUs across a link. For LTP, the interface to the data link is via either direct encapsulation in CCSDS Space Packets or via the CCSDS Encapsulation Service.

Figure 1-1 illustrates the general service user-service provider relationships among layers. For the specific case of LTP in the CCSDS stack, the LTP service sits between the Data Link Layer and the Network Layer.

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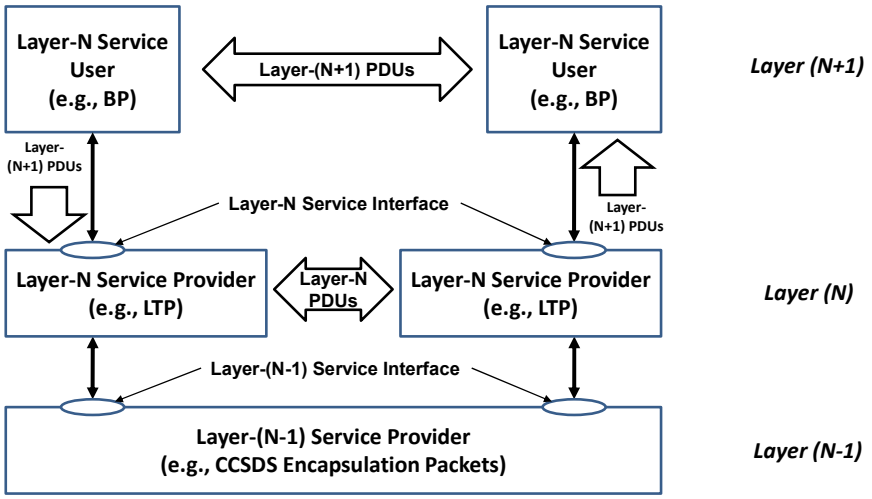

Figure 1-1: LTP's Relationship to Neighboring Protocols

1.4.1.2 Definitions from Open Systems Interconnection (OSI) Service Definition Conventions

This Recommended Standard makes use of a number of terms defined in reference [2]. The use of those terms in this Recommended Standard is to be understood in a generic sense, i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are:

- indication;
- primitive;
- request;
- response.

1.4.1.3 Definitions from RFC 5326

This Recommended Standard makes use of a number of terms defined in reference [3]. Some of the definitions needed for section 2 of this document are reproduced here for convenience.

engine ID: An integer that uniquely identifies a given LTP engine, within some closed set of communicating LTP engines.

NOTE – When LTP is operating underneath the Delay-Tolerant Networking (DTN) Bundle Protocol (BP), the convergence layer adapter mediating the two will be responsible for translating between DTN endpoint IDs and LTP engine IDs in an implementation-specific manner.

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block: An array of contiguous octets of application data handed down by the upper layer protocol (typically BP) to be transmitted from one LTP client service instance to another.

Any subset of a block comprising contiguous octets beginning at the start of the block is termed a 'block prefix', and any such subset of the block ending with the end of the block is termed a 'block suffix'.

red-part: The block prefix that is to be transmitted reliably, i.e., subject to acknowledgment and retransmission.

green-part: The block suffix that is to be transmitted unreliably, i.e., not subject to acknowledgments or retransmissions. If present, the green-part of a block begins at the octet following the end of the red-part.

session: A thread of LTP protocol activity conducted between two peer engines for the purpose of transmitting a block. Data flow in a session is unidirectional: data traffic flows from the sending peer to the receiving peer, while data-acknowledgment traffic flows from the receiving peer to the sending peer.

sender: The data-sending peer of a session.

receiver: The data-receiving peer of a session.

client service instance: A software entity, such as an application or a higher-layer protocol implementation, that is using LTP to transfer data.

segment: The unit of LTP data transmission activity. It is the data structure transmitted from one LTP engine to another in the course of a session. Each LTP segment is of one of the following types: data segment, report segment, report-acknowledgment segment, cancel segment, cancel-acknowledgment segment.

end of block, EOB: The last data segment transmitted as part of the original transmission of a block. This data segment also indicates that the segment's upper bound is the total length of the block (in octets).

end of red-part, EORP: The segment transmitted as part of the original transmission of a block containing the last octet of the block's red-part. This data segment also indicates that the segment's upper bound is the length of the block's red-part (in octets).

checkpoint: A data segment soliciting a reception report from the receiving LTP engine. The EORP segment must be flagged as a checkpoint, as must the last segment of any retransmission; these are 'mandatory checkpoints'. All other checkpoints are 'discretionary checkpoints'.

client service ID: Numeric identifier of the upper-level service to which the segment is to be delivered by the receiver. It is functionally analogous to a TCP port number. If multiple

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instances of the client service are present at the destination, multiplexing must be done by the client service itself on the basis of information encoded within the transmitted block.

self-delimiting numeric value, SDNV: A representation of integer values in binary format where the length of the representation is a function of the value being represented.

NOTE – Definition (20) of RFC 5326 (reference [3]) or RFC 6256 (reference [E4]) can be consulted for additional explanation and examples.

1.4.1.4 Other Definitions

application process identifier, APID: Part of the path ID used to identify a logical data path for CCSDS Space Packets.

underlying communication protocols, UCP: The communication protocols used by LTP to transfer segments between LTP engines.

1.5 NOMENCLATURE

1.5.1 NORMATIVE TEXT

The following conventions apply for the normative specifications in this Recommended Standard:

a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;

b) the word ‘should’ implies an optional, but desirable, specification;

c) the word ‘may’ implies an optional specification;

d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

NOTE – These conventions do not imply constraints on diction in text that is clearly informative in nature.

1.5.2 INFORMATIVE TEXT

In the normative sections of this document, informative text is set off from the normative specifications either in notes or under one of the following subsection headings:

– Overview;

– Background;

– Rationale;

– Discussion.

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1.6 REFERENCES

The following publications contain provisions which, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid. All publications are subject to revision, and users of this document are encouraged to investigate the possibility of applying the most recent editions of the publications indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS publications.

[1] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. 2nd ed. International Standard, ISO/IEC 7498-1:1994. Geneva: ISO, 1994.

[2] *Information Technology—Open Systems Interconnection—Basic Reference Model—Conventions for the Definition of OSI Services*. International Standard, ISO/IEC 10731:1994. Geneva: ISO, 1994.

[3] M. Ramadas, S. Burleigh, and S. Farrell. *Licklider Transmission Protocol—Specification*. RFC 5326. Reston, Virginia: ISOC, September 2008.

[4] S. Farrell, M. Ramadas, and S. Burleigh. *Licklider Transmission Protocol—Security Extensions*. RFC 5327. Reston, Virginia: ISOC, September 2008.

[5] "Port Numbers." Internet Assigned Numbers Authority. Internet Corporation for Assigned Names and Numbers. http://www.iana.org/assignments/port-numbers.

[6] "Licklider Transmission Protocol Engine Identifiers." Space Assigned Numbers Authority. http://sanaregistry.org/r/ltp_engineid/.

[7] K. Scott and M. Blanchet. *Licklider Transmission Protocol (LTP), Compressed Bundle Header Encoding (CBHE), and Bundle Protocol IANA Registries*. RFC 7116. Reston, Virginia: ISOC, February 2014.

[8] "Licklider Transmission Protocol (LTP) Parameters." Internet Assigned Numbers Authority. Internet Corporation for Assigned Names and Numbers. http://www.iana.org/assignments/ltp-parameters/ltp-parameters.xhtml.

[9] *Encapsulation Service*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 133.1-B-2. Washington, D.C.: CCSDS, October 2009.

[10] "Protocol Identifier for Encapsulation Service." Space Assigned Numbers Authority. http://sanaregistry.org/r/protocol_id/.

[11] *Space Packet Protocol*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 133.0-B-1. Washington, D.C.: CCSDS, September 2003.

[12] "Space Packet Protocol Application Process Identifier (APID)." Space Assigned Numbers Authority. http://sanaregistry.org/r/space_packet_protocol_application_process_id/.

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2 OVERVIEW

2.1 GENERAL

CCSDS has identified requirements for a protocol to sit between an internetworking protocol such as the Bundle Protocol (reference [E1]) and the various CCSDS data links (see reference [E3]). The two requirements identified in reference [E3] for such a layer-N protocol are reliable delivery of layer-(N+1) PDUs and the ability to aggregate multiple layer (N+1) PDUs into a single layer-N PDU for the purposes of reliable delivery across the link.

Reliable data delivery is accomplished by the red-part delivery service of the LTP protocol described in section 3 of this document. Aggregation of multiple layer-(N+1) SDUs into a single layer-N PDU (LTP block) is achieved by the implementation of the standardized 'Service Data Aggregation' client operation described in section 7. Such an adaptor is envisaged by figure 2-4 of reference [E3], which lists an 'LTP/ENCAP Convergence Layer Adaptor' as a work item. The rationale for aggregating multiple layer-(N+1) PDUs into a single layer-N PDU for the purposes of reliable delivery is that it may allow the system to reduce the acknowledgement-channel bandwidth in the case that the layer-(N+1) (and higher) protocols transmit many small PDUs, each of which might otherwise require independent acknowledgement.

The Licklider Transmission Protocol (LTP) sits between the Data Link and the Network Layers of the ISO stack and provides optionally reliable communications over a single data link hop. While LTP can be deployed over multi-hop services (e.g., UDP) on the ground, this document recommends that LTP be terminated at the ends of each long-delay, error-prone, or disruption-prone link (such as a space link) in what might be a multi-hop path. Thus when considering LTP's suitability for use on space links, it is enough to consider its functionality, its scalability to multiple 1-hop peers, and its interaction with other protocols on a single space link. The main restriction on LTP's scalability to multiple peers is the storage required to maintain data for retransmission between contacts to a particular peer. Because of the sparseness of space communications, it is not envisioned that this scalability with the number of peers will be an issue.

LTP was originally developed for space communication and is largely derived from the Acknowledged-mode procedures of the CCSDS File Delivery Protocol (CFDP). The protocol specification below is a reproduction of the Internet Engineering Task Force (IETF) Request for Comments (RFC) 5326, Licklider Protocol Specification. A separate motivational RFC (reference [E2]) provides the motivation behind the IETF specification of the protocol and may be informative in this context.

The IETF's classification of the Licklider Transmission Protocol RFC as 'experimental' should be considered in the context of LTP's deployment on the global Internet, where millions of end systems are exchanging millions of data flows at any given instant, and where protocols such as LTP are typically thought of as 'transport' or 'end-to-end' protocols operating across multiple data links. In the Internet context, issues such as scalability to millions of nodes, congestion control, and non-destructive coexistence with other established protocols (in particular the Transmission Control Protocol [TCP]), are of extreme

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importance. The specification's status as 'experimental' for use in the Internet is independent of and orthogonal to its applicability for space use. As stated above, because this document recommends LTP for use over individual space links, the scalability concerns associated with LTP deployment in the Internet do not pertain to CCSDS.

While LTP could be used as a bearer mechanism for cross-support between CCSDS Agencies across the Internet, it is more likely that Internet protocols such as TCP mentioned above would be used for that purpose, in part because of the issues that cause LTP to be marked as 'experimental' for use in the Internet.

2.2 ARCHITECTURAL ELEMENTS

The architectural elements of LTP are depicted in figure 2-1.

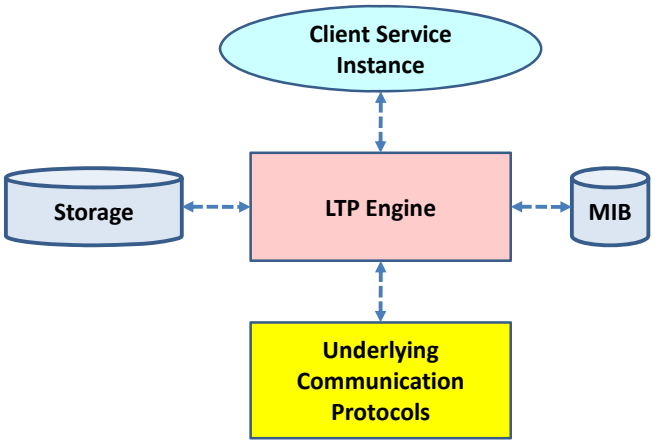

Figure 2-1: Protocol Stack View of LTP Architectural Elements

2.3 SERVICE PROVIDED BY LTP

2.3.1 GENERAL

LTP provides a data transmission service to move blocks of data from one LTP engine to another, where in general the two engines are resident in separate data systems, often with a single connecting space link.

Each block consists logically of two parts, either of which may be of length zero. The first part, termed the 'red-part', is transmitted reliably between LTP entities, using acknowledgements and retransmissions to ensure that the entire red-part is received reliably at the receiver; this provides a reliable transmission service. The second part of the block, termed the 'green-part', consists of data to be transmitted unreliably. Data in the green-part is not subject to acknowledgements and retransmissions and therefore provides an unreliable service. The LTP Client Service Instance controls what data in a block is 'red' and what is

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'green'. A Client Service Instance that desires completely reliable data transfer must therefore specify that all of the data be sent as 'red' (reliable) data. In this specification, the ability to send/receive green-part data is optional. However, if green-part capability is supported, then both transmission and reception must be supported. Block transmission may span periods of disconnection. During these periods, retransmission timers maintained by LTP are suspended.

As depicted in figure 2-2, below, the data transmission procedures constitute the interaction between two LTP engines. LTP uses an underlying communication service as described in 5.2 to transmit and receive LTP segments.

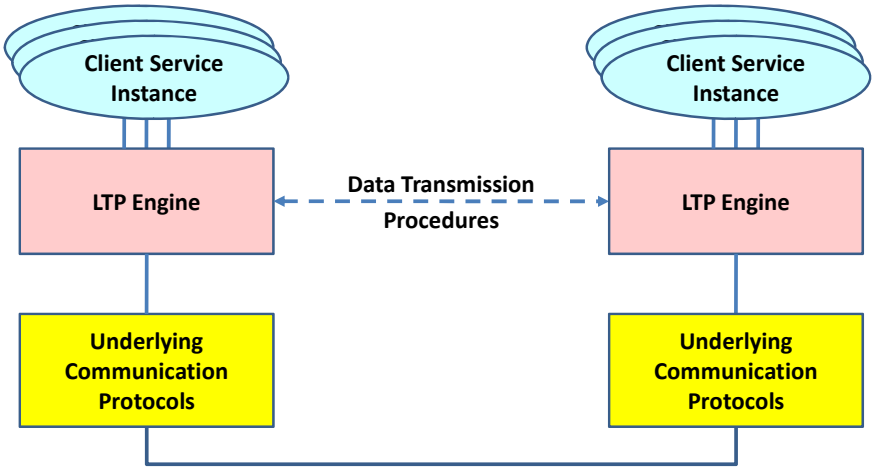

Figure 2-2: Communications View of LTP

Figure 2-3 illustrates an LTP block transmission operation involving both red (reliable) and green (unreliable) parts. In the figure, the sender generates an asynchronous checkpoint (third red segment) to which the receiver responds with a report segment. The segment containing the EORP is lost, as well as the second green-part segment. The EORP segment is retransmitted; the lost green segment is not.

Section 7 of this document describes LTP Service Data Aggregation (SDA). SDA reduces the acknowledgement overhead associated with multiple small red LTP blocks by aggregating them together for the purposes of transmission and reporting. Figure 2-4 illustrates the operation of LTP when using Service Data Aggregation.

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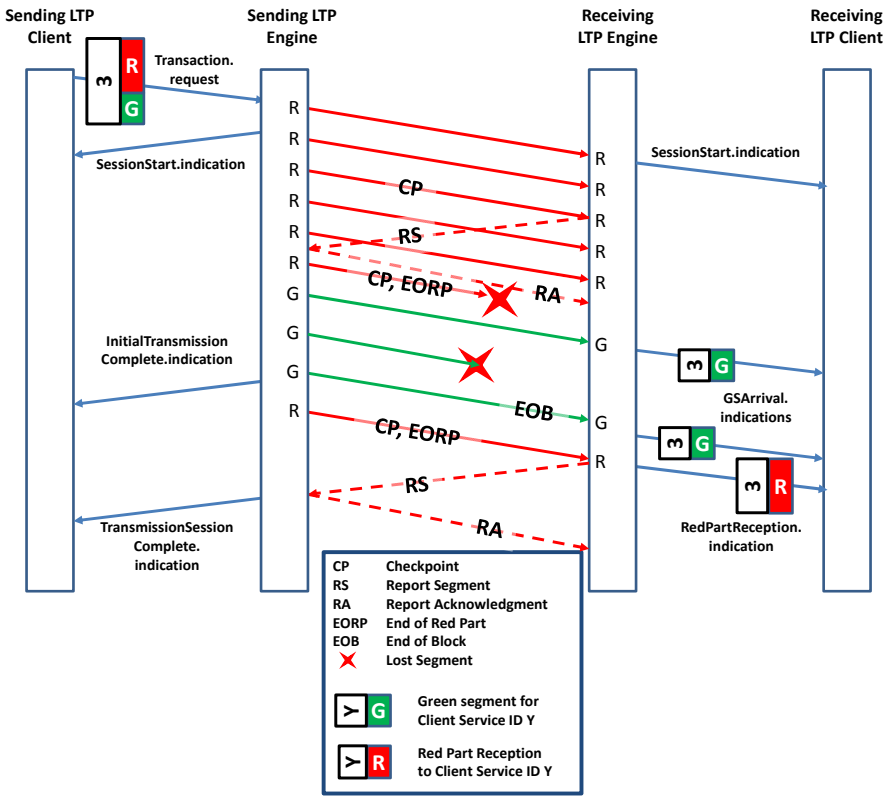

Figure 2-3: Overview of LTP Interactions

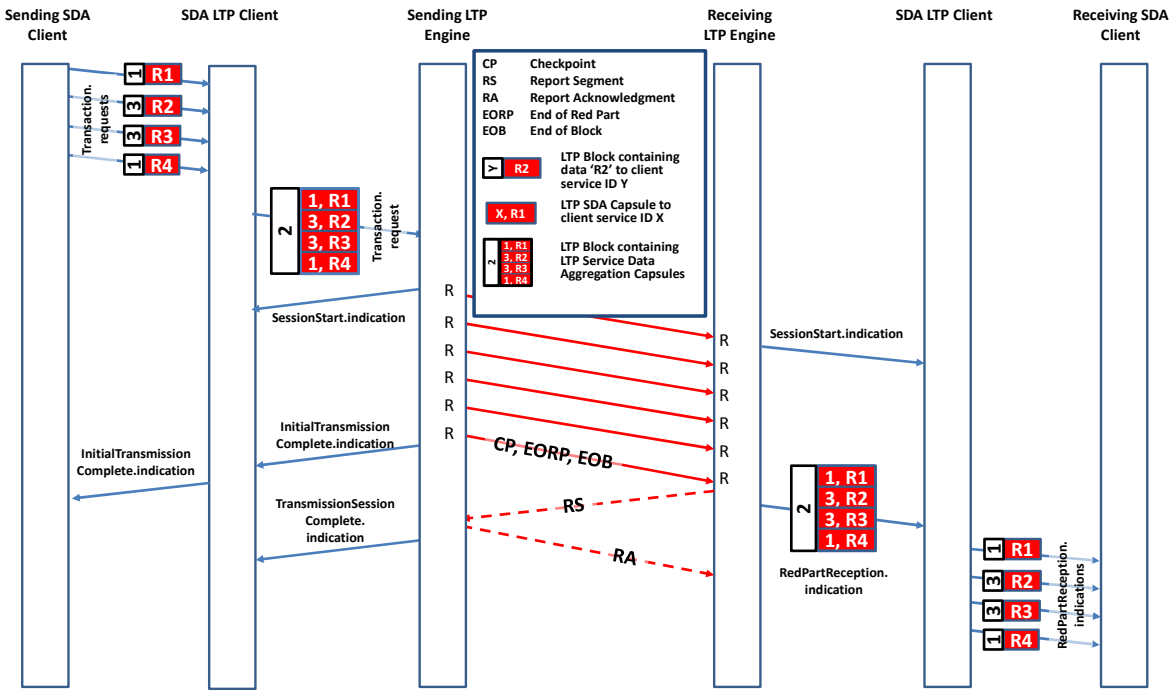

Figure 2-4: Transmission Using Service Data Aggregation

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