



BSI Standards Publication

Space engineering — Communications

National foreword

This British Standard is the UK implementation of EN 16603-50:2022. It supersedes BS EN 16603-50:2014, which is withdrawn.

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A list of organizations represented on this committee can be obtained on request to its committee manager.

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European Foreword

This document (EN 16603-50:2022) has been prepared by Technical Committee CEN-CENELEC/TC 5 “Space”, the secretariat of which is held by DIN.

This standard (EN 16603-50:2022) originates from ECSS-E-ST-50C Rev.1 DIR1.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2023, and conflicting national standards shall be withdrawn at the latest by January 2023.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 16603-50:2014.

The main changes with respect to EN 16603-50:2014 are:

- Implementation of Change Requests
- Update w.r.t. of replacement of EN 16603-50-01:2014, EN 16603-50-03:2014 and EN 16603-50-04:2014 by EN 16603-50-21 to EN 16603-50-26
- Update of Terms, definitions and abbreviated terms in clause 3
- Term “space network” replaced by “on-board network”
- Update of Purpose and objective of Annex F “Communication system details design document (CSDDD) – DRD”
- Update of Purpose and objective of Annex F “Communication system profile document (CSPD) – DRD”
- Update of Annex I “Documentation summary”

This document has been prepared under a standardization request given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any EN covering the same scope but with a wider domain of applicability (e.g. : aerospace).

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This standard specifies requirements for the development of the end-to-end data communication system for spacecraft. Implementation aspects are defined in ECSS-E-ST-50 Level 3 standards, ECSS Adoption Notices, and CCSDS standards.

The complete set of standards to define a complete communication link is project dependent and cannot be specified here. ECSS-E-HB-50 provides some guidance on this aspect, and gives some practical examples.

1

Scope

This Standard specifies the requirements for the development of the end-to-end data communications system for spacecraft.

Specifically, this standard specifies:

- The terminology to be used for space communication systems engineering.
- The activities to be performed as part of the space communication system engineering process, in accordance with the ECSS-E-ST-10 standard.
- Specific requirements on space communication systems in respect of functionality and performance.

The communications links covered by this Standard are the space-ground (i.e. space-to-ground and ground-to-space) and space-to-space links used during spacecraft operations, and the communications links to the spacecraft used during the assembly, integration and test, and operational phases.

Spacecraft end-to-end communication systems comprise components in three distinct domains, namely the ground network, the space link, and the space network. This Standard covers the components of the space link and space network in detail. However, this Standard only covers those aspects of the ground network that are necessary for the provision of the end-to-end communication services.

NOTE Other aspects of the ground network are covered in ECSS-E-ST-70.

This Standard may be tailored for the specific characteristics and constraints of a space project in conformance with ECSS-S-ST-00.

2

Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revisions of any of these publications, do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system — Glossary of terms

Terms, definitions and abbreviated terms

3.1 Terms defined in other standards

- a. For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply, in particular for the following terms:
 - 1. function
 - 2. interface
- b. For the purpose of this Standard, the terms and definitions from ECSS-E-ST-20 apply, in particular for the following term:
 - 1. essential function
 - NOTE Synonym to the term “vital function” from ECSS-E-ST-70-11
- c. For the purpose of this Standard, the terms and definitions from ECSS-E-ST-70-11 apply, in particular for the following terms:
 - 1. commandable vital function
 - 2. high priority command
 - 3. high priority telemetry
 - 4. vital function
 - NOTE Synonym to the term “essential function” from ECSS-E-ST-20.
 - 5. vital telecommand

3.2 Terms specific to the present standard

3.2.1 channel

combination of protocol and medium that provides a physical layer service from end-to-end

NOTE This is the transfer of the unstructured bitstream from point-to-point.

3.2.2 communication service

service that provides the capability of moving data between users.

NOTE At least two users are involved when a communication service is used, one sending data and the other(s) receiving data.

3.2.3 cross support

use by one party of part of another party's data system resources to complement its own system

3.2.4 downlink

see "telemetry link"

3.2.5 duplex service

point-to-point system composed of two or more connected parties or devices that can communicate with one another in both directions

3.2.6 entity

active element within a system

3.2.7 essential telecommand

telecommand that controls essential or vital functions

NOTE This corresponds to "high priority telecommand" in ECSS-E-ST-70-11).

3.2.8 essential telemetry

telemetry that enables a reliable determination of the current status of vital on-board equipment available under all circumstances

NOTE This correspond to "high priority telemetry" in ECSS-E-ST-70-11.

3.2.9 frame

service data unit passed, at the sending end, from the protocol sublayer to the coding and synchronization sublayer

NOTE For definition of layers see Figure 4-2.

3.2.10 isochronous service

service providing for the transfer of data with a defined maximum deviation from a nominal delay from end to end

3.2.11 protocol

set of rules and formats (semantic and syntactic) that determine the communication behaviour of layer entities in the performance of communication functions

3.2.12 service

capability of a layer, and the layers beneath it (a service-provider), that is provided to service-users at the boundary between the service-provider and the service-users

NOTE The service defines the external behaviour of the service-provider, independent of the mechanisms used to provide that behaviour. Layers, layer entities, and application-service-elements are examples of components of a service-provider.

3.2.13 service data unit

amount of information whose identity is preserved when transferred between peer (N+1) entities and which is not interpreted by the supporting (N) entities

NOTE Also known as: (N) service data unit.

3.2.14 service-provider

abstract representation of the totality of those entities which provide a service to service-users

NOTE A service provider includes entities in the layer at which the service is provided, and in the layers beneath it.

3.2.15 service-user

entity in a single system that makes use of a service

NOTE The service-user makes use of the service through a collection of service primitives defined for the service.

3.2.16 simplex

communicating in one direction from data source to data sink

3.2.17 source

entity that sends service-data-units, using a service provider

3.2.18 sink

entity that receives service-data-units from a service provider

3.2.19 telecommand

command data transmitted to a spacecraft through a telecommand link

3.2.20 telecommand link

communication link from ground to space by which a spacecraft is commanded

NOTE The term “uplink” is synonymous.

3.2.21 telemetry

housekeeping data and payload data generated on-board the spacecraft and transmitted through a telemetry link

3.2.22 telemetry link

communication link from spacecraft to ground over which data generated on the spacecraft is provided to ground

NOTE The term “downlink” is synonymous.

3.2.23 uplink

see “telecommand link”

3.2.24 user

service-user

3.2.25 user application

application that makes use of data handling system services

NOTE An application can be a software entity or a non-software entity which is controlling an onboard system.

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-ST-00-01 and the following apply:

Abbreviation	Meaning
AIT	assembly, integration, and test
AR	acceptance review
ARQ	automatic repeat request
BER	bit error rate
CCITT	Consultative Committee for International Telegraph and Telephone
CCSDS	Consultative Committee for Space Data Systems
CDMU	central data management unit
CDR	critical design review
CSAD	communication system analysis document
CSADD	communication system architectural design document
CSBD	communication system baseline definition
CSDDD	communication system detailed design document
CSOM	communication system operations manual
CSPD	communication system profile document
CSRD	communication system requirements document
CSVP	communication system verification plan
DRD	document requirements definitions
EIRP	equivalent isotropically radiated power
EMC	electromagnetic compatibility
ISO	International Organization for Standardization
ITU	International Telecommunication Union
ITU/RR	ITU / Radio Regulations

LEOP	launch and early operations phase
MEC	mission experiment centre
OSI	open system interconnection
OCC	operational control centre
PDR	preliminary design review
PFD	power flux density
QR	qualification review
RF	radio frequency
SDLS	space data link security
SDU	service data unit
SRR	system requirements review
TT&C	telemetry, tracking and command

4

Space communications engineering principles

4.1 Context

Space communications engineering is concerned with the provision of end-to-end communication services to and from spacecraft. Communication links are generally between the spacecraft and ground. However, this Standard also addresses spacecraft-to-spacecraft links, e.g. in spacecraft constellations, and can be applied to links between spacecraft and landed elements such as orbiter-lander or orbiter-lander-rover configurations.

End-to-end communication is used both to control the operation of the spacecraft, and to transfer data, such as payload data. However, the requirements on the communications system for controlling the spacecraft differ from those for payload data transfer. For control operations, the communication system objective is to provide guaranteed delivery of commands in the order of transmission. Commands can be repeated, but not lost. By contrast, the requirement for payload data transfers is to transfer as much data as possible. Some loss of data may be acceptable, and delivery order is generally unimportant, provided the data can be reconstituted.

In addition to the end-to-end transfer of commands and data, some additional services are provided across space communication links, such as time correlation and orbit determination (via e.g. ranging and/or Doppler measurements). Time correlation is used to accurately relate the local time maintained at each end of the communication link in order to determine the absolute time relationship between events. Ranging and/or Doppler measurements are used to determine the distance and/or the velocity between a ground station antenna and the spacecraft for orbit determination.

The goals of standardization for space communication systems are:

- to ensure efficient use of the RF spectrum allocated to the space infrastructure in a non-interfering manner;
- to ensure that the RF links to and from the spacecraft can be used for orbit determination (via e.g. ranging and/or Doppler measurements);
- to ensure reliable and error free end-to-end communication between ground stations and the spacecraft or between a spacecraft and a landed element;
- to enable the use of the same ground segment infrastructure by different spacecraft;

- to ensure that standard communication interfaces are provided to the spacecraft payloads and experiments in order to simplify the spacecraft development process;
- to enable cross support between agencies.

Cross support can be beneficial for many reasons, including:

- Technical: to attain additional network coverage or to conduct some programmatic endeavour, such as very long baseline interferometry measurements.
- Economic: to avoid the expense of duplicate implementation, especially to meet some short term requirement.
- Emergency: to increase mission support over that normally planned.
- Research: to avoid the cost and time delay of repeating investigations or re-flying an experiment and to obtain unique data acquired in the past and held by another agency.

These arguments were apparent as long ago as the early 1970s. For this reason, the Consultative Committee for Space Data Systems (CCSDS) was established to standardize space link protocols. Where appropriate, this ECSS Standard calls up CCSDS recommendations directly.

4.2 Overall space communication

Figure 4-1 shows an example of a configuration for a space communication system.

NOTE This configuration includes a space-to-space link between two flight elements.

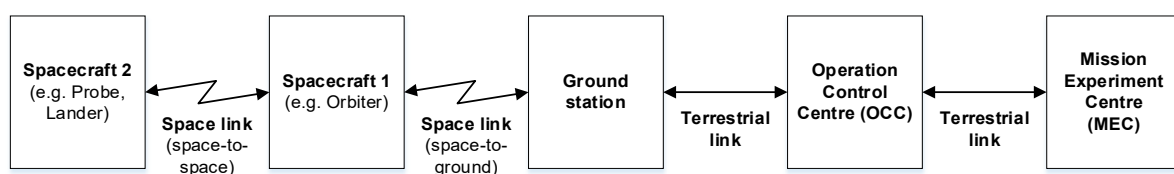


Figure 4-1: Example configuration of a space communication system

The overall data communication requirement is to transfer data to and from any element of the space system in accordance with the mission requirements.

The elements of a space communication system are described in the following paragraphs. In a real space communication system, the number and type of elements actually present can vary. For example, in complex missions, there can be several spacecraft, and multiple ground stations. In other missions, a single spacecraft can be controlled from a single operation control centre, without a mission experiment centre.

The space communication system elements are:

- a spacecraft linked to the ground via a space link (space-ground). This spacecraft can also be linked to other spacecraft, landers, and probes via space-to-space (proximity) links;
- other spacecraft, landers, and probes linked only with the main spacecraft via proximity links;
- other spacecraft, landers, and probes linked together forming an inter-spacecraft network (see clause 4.3.2.3) not shown in Figure 4-1;
- a ground station that forms the terrestrial end of the space-ground space link, and is connected to the operational control centre via a terrestrial link;
- an operational control centre (OCC), connected to the ground station via a terrestrial link. The OCC is used to control the spacecraft;
- a dedicated mission experiment centre (MEC) connected to the operations control centre. Mission payloads and experiments are operated from the MEC.

Each element includes a data handling system, which provides three main communication functions:

- managing data communication interfaces internal to the element (internal links);
- managing data communication interfaces with external links (i.e. space links and terrestrial links to other elements);
- performing data processing for the transfer between internal and external links.

The processing for transferring data from a sending element to a receiving element of the space communication system via an external link consists of:

- For the downlink data stream:
 - At the sending element
 - Acquisition of data from subsystems or next element (e.g. probe or lander).
 - Processing and formatting of the data stream.
 - Transmission of the data stream to the ground via the external (space) link as telemetry.
 - At the receiving element
 - Acquisition of the data stream from the sender via the external link.
 - De-formatting and processing for delivery to receiver internal elements (e.g. space system user when ground station and OCC are in the same system) and for transfer to the next element via an external link (e.g. transfer from ground station to OCC).
 - Delivery of data to receiver internal elements .

- Transmission of data to the next element via external (terrestrial) link.
- For the uplink data stream:
 - At the sending element
 - Acquisition of data from space system user.
 - Processing and formatting of the data stream.
 - Transmission of the data stream to the spacecraft via the external (space) link as telecommand.
 - At the receiving element
 - Acquisition of the data stream from the sender via the external link.
 - De-formatting and processing for delivery to receiver internal elements (e.g. commands to spacecraft subsystems for a link between ground station and spacecraft) and for transfer to the next element (e.g. probe or lander) via an external link.
 - Delivery of data to receiver internal elements.
 - Transmission of data to the next element via external (space-to-space) link.

In the case of space-to-space links, the processing for transferring data from a sending element to a receiving element of the space communication system via return and forward link is similar to the one described for downlink and uplink.

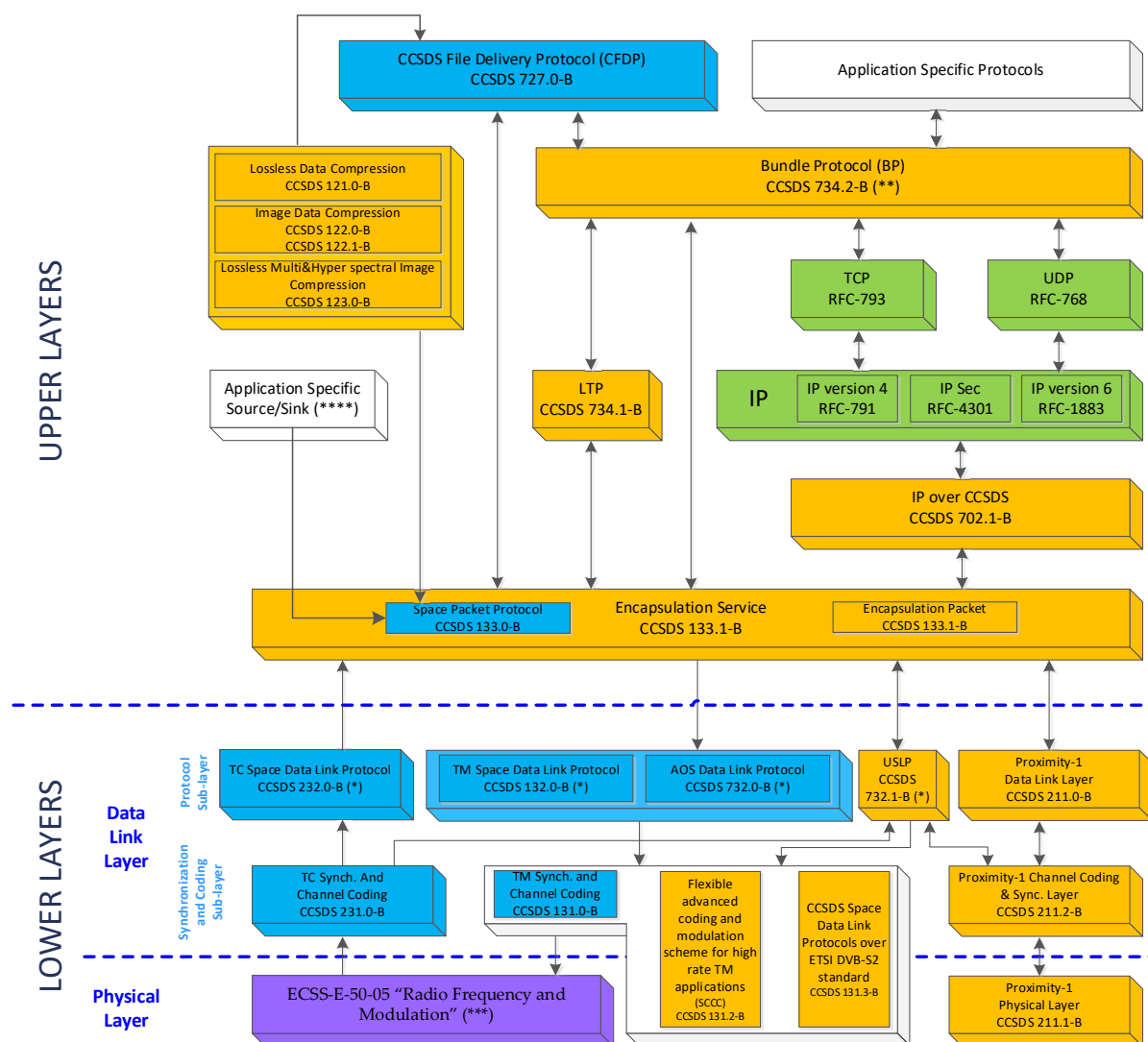
The type of data to be transmitted can be telemetry, files, video, and digital voice for the downlink, and telecommands, files, video, and digital voice for the uplink. The same type of data can be transmitted for return and forward links in space-to-space transmission.

For each type of data transmission, protocols defined by CCSDS or other standardization bodies can be used. Figure 4-2 shows some of the CCSDS and internet protocols that can be used over the space links (i.e. space-ground and space-to-space). Connections among standards are marked with arrow highlighting the most usual data flow direction as seen on-board (e.g. the TC data flow enters the spacecraft from the bottom while the TM data flow exits the spacecraft towards the bottom; i.e. RF standards). However, not all the possible connections among boxes are shown to avoid making the picture too complex; e.g. the fact that CFDP can run directly on top of either TCP or UDP is not shown. This figure illustrates some relationship to the seven ISO reference model layers defined in ISO 7498. Data Link Layer (including the two Protocol and Coding & Synchronization sublayers) and Physical Layer are shown in detail while the other layers are grouped as Upper Layers.

It is also important that some of the CCSDS Standards are formally adopted by ECSS via Adoptions Notices, namely:

ECSS Adoption Notice	Based on CCSDS	Superseded ECSS	Part of ECSS Standard superseded
ECSS-E-AS-50-21	CCSDS 131.0-B-3 (Sept. 2017) - TM Synchronization and Channel Coding	ECSS-E-ST-50-01C 31 July 2008	Whole ECSS Standard
ECSS-E-AS-50-22	CCSDS 132.0-B-2 (Sept. 2015) - TM Space Data Link Protocol	ECSS-E-ST-50-03C 31 July 2008	Clause 5 "TM Transfer Frame"
ECSS-E-AS-50-23	CCSDS 732.0-B-3 (Aug. 2016) - AOS Space Data Link Protocol		ECSS-E-ST-50-03 was limited to the TM Transfer Frame. It did not include the AOS Transfer Frame
ECSS-E-AS-50-24	CCSDS 231.0-B-3 (Sept. 2017) - TC Synchronization and Channel Coding	ECSS-E-ST-50-04C 31 July 2008	Clause 8 (Synchronization and channel coding sublayer) Clause 9 (Physical layer)
ECSS-E-AS-50-25	CCSDS 232.0-B-3 (Sept. 2015) - TC Space Data Link Protocol		Clause 5 (Segmentation sublayer) Clause 6 (Transfer sublayer)
ECSS-E-AS-50-26	CCSDS 232.1-B-2 (Sept. 2010) - Communications Operation Procedure-1		Clause 7 (COP-1)

Figure 4-2 references the Proximity-1 suite of standards, that is however just one possible choice for communications over proximity links.



NOTES:

- CCSDS standard formally adopted by ECSS
- Internet TCP/IP standard
- CCSDS standard not formally adopted by ECSS
- ECSS standard
- (*) including Space Data Link Security Protocol (optional) CCSDS 355.0-B
- (**) including the Bundle Security Protocol (BSP) CCSDS 734.5-B (under development).
- (***) CCSDS has its own Physical Layer standard (401.0-B) which includes additional options with respect to ECSS-E-50-05 "Radio Frequency and Modulation"
- (****) An example of «Application Specific Source/Sink» is the ECSS-E-ST-70-41C «Telemetry and telecommand packet utilization»
- Future Optical Communication Standards: CCSDS 141.0-B «Optical Communications Physical Layer» and CCSDS 142.0-B «Optical Communications Coding and Synchronization» are not shown in figure
- Uni-directional arrows are applicable to the On-Board segment, they are reversed in the Ground segment

Figure 4-2: CCSDS and Internet space link protocols

Each layer provides services and protocols defined either in ECSS standards, or by other explicitly referenced standards such as CCSDS recommended standards. Depending on their profile, users access services provided by any of the on-board or ground layers. Communications internal to the on-board and ground segments are performed via the local transfer protocols and sub-networks, which are not covered by this Standard. End-to-end communications between space and ground segments are via the spacelink upper layers protocols and Data Link and Physical layers (i.e. the lower layers), which do form part of this Standard.

The space link Data Link and Physical layers enable access to the space link medium and provide basic services for the transmission of delimited or undelimited data across the link. The space link upper and lower layers can be resident in a single data system or can be partitioned between data systems in space and on the ground. In general the space link layers reside within the on-board TT&C and Data Handling subsystems. On the ground they can reside completely in the ground station, or can be partitioned between ground station and control centre or customer facility.

The ground and on-board upper layers provide common services between the space and ground segment. They operate in a peer-to-peer interaction with their equivalent layers in the space and ground segments. The on-board and ground upper layers make use of the services provided by the space link upper and lower layers to transfer data from data system to data system.

The ground and on-board layers (upper and lower) implement the services and protocols used for the independent operation of the on-board and ground systems.

4.3 Space communication domains

4.3.1 Overview

A space communication system comprises three distinct domains that each have markedly different characteristics. The three domains are

- the space network,
- the space link, and
- the ground network.

4.3.2 Space network

4.3.2.1 Overview

The space network comprises all of the nodes in the flight segment of a spacecraft mission. These nodes can all be on a single spacecraft, or can be distributed among several spacecraft, for example in a constellation. The space network therefore includes both intra-spacecraft and inter-spacecraft links.

4.3.2.2 On-board network

On-board network is limited to intra-spacecraft links within a given spacecraft. The type of network medium and topologies of the on-board network are highly varied, often being based on proprietary protocols. The emphasis of this Standard in this case is on the definition of appropriate upper layers services that maintain freedom of choice in the on-board Data Link and Physical layers, while also moving towards harmonization and better definition of the on-board Data Link and Physical layers.

Except in very rare circumstances, the on-board network cannot be maintained or upgraded during a mission. Usually, the technology used to implement the on-board network is conservative, and reflects the state-of-the-art years before launch. This severely constrains the performance available when compared with the ground network.

4.3.2.3 Inter-spacecraft network

An inter-spacecraft network is a set of spacecraft connected by inter-spacecraft links. An increasing number of missions involve a space segment consisting of multiple elements possibly from different organizations, e.g. constellations of spacecraft, or planetary missions consisting of an orbiter and lander, or orbiter-lander-rover. These type of missions impact the nature of the space network by including spacecraft-to-spacecraft unreliable/intermittent wireless links (e.g. spacecraft constellations, and links between spacecraft and landed elements such as orbiter-lander or orbiter-lander-rover configurations) and introducing the potential for a variable network topology.

NOTE CCSDS 734.2-B-1 provides a Bundle Protocol (BP) which defines end-to-end protocol, block formats, and abstract service descriptions for the exchange of messages (bundles) that support Delay Tolerant Networking (DTN). For DTN, CCSDS-734.1-B-1 also provides a Licklider Transmission Protocol (LTP) that provides optional reliability mechanisms on top of an underlying (usually data link) communication service.

4.3.3 Space link

The space link is essentially a point-to-point wireless link between a ground station and a spacecraft or between two spacecraft as shown in Figure 4-1. This link is inherently unreliable, and the emphasis of this Standard here is on the achievement of reliable data transfer services. Users concerned only with the exchange of data, either on-board or on ground, do not generally use the space link services directly, accessing these services instead through their local ground or on-board sub-networks, which are not covered by this Standard. However, users concerned with the operation and control of the spacecraft can access space link services for a number of reasons, including routine operations such as orbital position determination, and emergency operations such as low level commanding.

Equipment at the terrestrial end of the space link is essentially unconstrained in terms of power, mass, and volume requirements. By contrast, equipment at the on-board end of the space link is severely constrained in these respects. This limits the bandwidth that can be achieved, especially in the return (space-to-ground) direction.

The medium through which the space link signal propagates can interfere with or distort the signal, and the very high relative velocity of some spacecraft introduces severe Doppler effects. The movement of the spacecraft relative to its ground station makes the signal propagation path characteristics highly variable. The combination of these factors imposes on the space link to be capable of operating reliably over a very wide range of conditions, and to tolerate very high bit error rates (BER).

For bi-directional communications, the space link comprises at least two physical channels, one for forward (e.g. ground-to-space) and one for return (e.g. space-to-ground) communication links. However, it is assumed that emergency control of the spacecraft can be achieved with only a uni-directional link, e.g. with only the forward link operational. Emergency and degraded scenarios are further elaborated in clause 4.7.

In a space-ground link the forward link corresponds to the uplink, i.e. the telecommand link.

In a space-to-space link the forward link corresponds to the portion of a proximity space link in which the caller transmits and the responder receives (typically a command link).

4.3.4 Ground network

The ground network comprises ground-based equipment and terrestrial links that are used to support the mission operations. The ground segment is largely described by ECSS-E-ST-70.

The ground network comprises the ground data processing equipment, usually connected by a combination of local and wide area networks. Communication between nodes is achieved using a variety of reliable terrestrial links with well-defined protocols. The emphasis of this Standard in the ground network is on the services and protocols used to transfer spacecraft data between nodes in the ground network and nodes in the space network.

This Standard is not concerned with ground based services and protocols used to transfer data between communication end points on the ground, or with services related to archiving and retrieval of spacecraft data.

An important aspect of the ground network is that it can be maintained and upgraded to take advantage of technological developments occurring during the lifetime of a mission. Furthermore, the performance of the ground network can be enhanced by improving the terminal equipment and by increasing the number or performance of the links in the subnet.