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Information processing systems – Open Systems Interconnection – File Transfer, Access and Management –

Part 3 :
File Service Definition

AMENDMENT 2 : Overlapped access

*Systemes de traitement de l'information – Interconnexion de systemes
ouverts – Transfert, accès et gestion de fichiers –*

Partie 3: Définition du service de fichiers

AMENDEMENT 2 : Chevauchement d'accès



Reference number
ISO 8571-3:1988/Amd.2:1993 (E)

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Amendment 2 to International Standard ISO 8571-3:1988 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*.

ISO 8571 consists of the following parts, under the general title *Information processing systems – Open Systems Interconnection – File Transfer, Access and Management*:

- Part 1 : *General introduction*
- Part 2 : *Virtual Filestore Definition*
- Part 3 : *File Service Definition*
- Part 4 : *File Protocol Specification*
- Part 5 : *Protocol Implementation Conformance Statement Proforma*

Information processing systems – Open Systems Interconnection – File Transfer, Access and Management –

Part 3 :

File Service Definition

AMENDMENT 2 : Overlapped access

0 Introduction

Clause 0 provides an introduction to this amendment. The text in this clause is not intended for inclusion in ISO 8571 part 3.

0.1 General

ISO 8571 part 3 defines in an abstract way the externally visible file transfer, access and management service.

This amendment extends this service definition to incorporate the services offered by overlapped access.

0.2 Rationale

The objective in introducing overlapped access is to allow more efficient access to structured files when a single initiator has a need to perform many reading and updating operations; the serial nature of the current FTAM data transfer services introduces a significant control overhead if the FADUs are small. In this context, an FADU is small if its transmission time is comparable with the time to complete a confirmed service on the association (the association's round trip delay).

0.3 Summary

The current design envelope that there should be at most one file selection per association and one file open per file selection is maintained. If access to more than one file is to

be overlapped, more than one association is necessary. The overlapped access takes place within a constant set of presentation contexts established as at present when the file is opened, or previously.

Two different degrees of overlap have been identified. Firstly, requests for future accesses may be issued whilst a previously requested BDT action is in progress, allowing the creation of a queue of read and write requests. In general, PCI relating to a given BDT action may be overlapped with other BDT actions, subject to restrictions; this is called consecutive access. Secondly, read and write actions can be performed in parallel, so that both directions of data transfer are exploited at any one time. Requests are then taken from the queue whenever either direction of transfer becomes free; this is called concurrent access.

The transfer of a single FADU, specified in a single F-READ request has the same interpretation as in ISO 8571. The resultant effect on the virtual filestore of a set of overlapped requests using consecutive access shall be the same as that of the equivalent set of requests issued in series; the service provided is serializable. If concurrent access is used then the resultant effect of a set of write actions on the virtual filestore, is also serializable. However, due to the non-determinism introduced by the use of concurrent access, it is also possible that, in some uses of the service, the data transferred as a result of a read action is not consistent with the current state of the file.

1 Scope and field of application

This amendment makes no additions to clause 1.

2 References

This amendment makes no additions to clause 2.

3 Definitions

This amendment makes no additions to clause 3.

4 Abbreviations

This amendment makes no additions to clause 4.

5 Conventions

This amendment makes no additions to clause 5.

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Table 1 - Services and functional units of the External File Service

U15 Consecutive access	O				see note
U16 Concurrent access	O				see note

the role of sender), to the initiator (in the role of receiver);

d) the write bulk data service (see 24.2) is used by the initiator to initiate a bulk data transfer from the initiator (in the role of sender) to the responder (in the role of receiver);

e) the data unit transfer service (see 24.3) is used by the sender to transmit bulk data;

f) the end of data transfer service (see 24.4) is used by the sender to indicate completion of the data transfer;

g) the end of transfer service (see 24.5) is used by the initiator to confirm that the data transfer procedure is complete;

h) the cancel data transfer service (see 24.6) is used by either the sender or the receiver to cancel a data transfer procedure. When overlapped access is allowed either direction may be cancelled independently of the other.

7.10 Checkpointing and restarting

Add sentence to end of b):

If overlapped access is in use then either direction of transfer may be restarted.

8 Functional units and service classes

8.1 Functional units

Add the following clauses:

8.1.15 Consecutive access functional unit

The consecutive access functional unit allows the overlap of read and write data transfer procedures as defined in ISO 8571-1.

8.1.16 Concurrent access functional unit

The concurrent access functional unit allows the overlap of read and write data transfer procedures as defined in ISO 8571-1.

8.1.17 Service classes and functional units

Add entries to Table 1 and re-number entries accordingly:

Add note after Table 1:

Note - the consecutive access and concurrent access functional units allow the services provided by the read and write functional units to be overlapped. The description of the overlap allowed is contained within the definitions of individual services.

8.2 Service classes

8.2.2 File access class

Insert the following items and re-label accordingly:

d) optionally, the consecutive access functional unit;

e) optionally, the concurrent access functional unit;

9 Levels of file service

Replace Table 3 - Functional units in the file services

Insert note:

Note - Pending the specification of presentation symmetric synchronisation services, recovery mechanisms will not be available for use during overlapped access.

Table 3 - Functional units in the file service

External file service	Internal file service
Kernel	Kernel
Read	Read
Write	Write
File access	File access
Limited file management	Limited file management
Enhanced file management	Enhanced file management
Grouping	Grouping
FADU locking	FADU locking
	Recovery
	Restart data transfer
Consecutive access	Consecutive access
Concurrent access	Concurrent access

**10 Negotiation of service class, FTAM
QoS and functional units**

Amend third paragraph:

The availability of the functional units, read, write, consecutive access, concurrent access, file access, limited file management, enhanced file management, grouping and FADU locking is controlled by the service class negotiated (see Tables 1 and 2).

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Section two : Definition of file service primitives

11 File service primitives

Amend entries in Table 6.

12 Sequence of primitives

This amendment makes no additions to clause 12.

13 Common file service parameters

13.8 Concurrency Control

Replace fifth paragraph:

If FADU locking is negotiated the locks set at file open have the scope of the relevant bulk data transfer procedure. If overlapped access is not in use then this is equivalent to the bulk data transfer regime.

If overlapped access is in use then the scope of the FADU locking is that of the read and write action.

13.12 File Access Data Unit Identity

Add note.

Note: if concurrent access is in use then the FADU identifiers previous, current and next are dependent on whether the action is a read or a write.

Add the following clauses:

13.14 Bulk Transfer Number

The bulk transfer number parameter is only visible in the internal file service. The parameter is used to identify a particular bulk data transfer within an open regime. If the use of concurrent access is negotiated when the file open regime is established then the first read data transfer within an open regime is numbered 1, and subsequent read transfers are consecutively numbered. Similarly, the first write data transfer within the open regime is numbered 1, and subsequent write transfers are consecutively numbered. If overlapped access is not negotiated, or if consecutive access is negotiated, then read and write bulk transfers are numbered consecutively, starting from 1 for the first bulk data transfer procedure i.e. there is one

Table 6 - File service primitives

Primitive	Confirmed	Request by	Parameters
F-OPEN	Yes	Initiator	State result Action result Processing mode Contents type Concurrency control Shared ASE information Enable FADU locking Diagnostic Degree of overlap Transfer window [Activity identifier] [Recovery mode]
[F-RECOVER]	Yes	Initiator	[State result Action result Activity identifier Bulk transfer number Requested access Access passwords Contents type Recovery point Diagnostic Concurrent bulk transfer number Concurrent recovery point Last transfer end read request Last transfer end read response Last transfer end write request Last transfer end write response]

numbering sequence.

13.15 Transfer Number

The transfer number parameter is conditional on the use of overlapped access. The parameter is used by the initiator and responder to identify an uncompleted bulk data transfer. The value of the parameter is an integer. If overlapped access is not in use, or consecutive access is in use, then overlapping read and write transfers are consecutively numbered, starting from 1. The value is reset when all outstanding requests are completed.

Note - The transfer number of a bulk data transfer may exceed the value of the transfer window (17.1.2.10) as the latter parameter constrains the maximum number of transfers that are uncompleted at any one time.

13.16 Last transfer end read request

The last transfer end read request parameter is only visible in the internal file service, and is conditional on the use of overlapped access for the open regime. The value of the parameter is a transfer number (see 13.14). For the initiator it indicates the transfer number of the last read data transfer for which a F-TRANSFER-END request has been issued; for the responder it indicates the transfer number of the last read data transfer for which a F-TRANSFER-END indication has been received.

The default value 0 indicates that there are no outstanding F-TRANSFER-END requests or indications to be issued or received.

13.17 Last transfer end read response

The last transfer end read response parameter is only visible in the internal file service, and is conditional on the use of overlapped access for the open regime. The value of the parameter is a transfer number (see 13.13). For the initiator it indicates the transfer number of the last read data transfer for which a F-TRANSFER-END confirm has been received; for the responder it indicates the transfer number of the last read data transfer for which a F-TRANSFER-END response has been issued.

The default value 0 indicates that there are no outstanding F-TRANSFER-END responses or confirms to be issued or received.

13.18 Last transfer end write request

The last transfer end write request parameter is only visible in the internal file service, and is conditional on the use of overlapped access for the open regime. The value of the parameter is a transfer number (see 13.14). For the initiator it indicates the transfer number of the last write data transfer for which a F-TRANSFER-END request has been issued;

for the responder it indicates the transfer number of the last write data transfer for which a F-TRANSFER-END indication has been received.

The default value 0 indicates that there are no outstanding F-TRANSFER-END requests or indications to be issued or received.

13.19 Last transfer end write response

The last transfer end write response parameter is only visible in the internal file service, and is conditional on the use of concurrent access for the open regime. The value of the parameter is a transfer number (see 13.14). For the initiator it indicates the transfer number of the last write data transfer for which a F-TRANSFER-END confirm has been received; for the responder it indicates the transfer number of the last write data transfer for which a F-TRANSFER-END response has been issued.

The default value zero indicates that there are no outstanding F-TRANSFER-END responses or confirms to be issued or received.

14 FTAM regime control

This amendment makes no additions to clause 14.

15 File selection regime control

This amendment makes no additions to clause 15.

16 File management

This amendment makes no additions to clause 16.

17 File open regime control

Amend second sentence:

This regime establishes the degree of overlapped access, processing mode, presentation contexts, and concurrency control for the data transfer activity which is to be performed.

17.1 File open service

17.1.1 Function

Amend last sentence of first paragraph:

It also establishes concurrency control, the degree of overlapped access and possible processing modes.

17.1.2 Types of primitives and parameters

Replace entries in table 21.

Add the following sub clauses and re-number:

17.1.2.9 Degree Of Overlap

The degree of overlap parameter indicates the degree of overlapped access required during the file open regime: either no overlapped access (normal), consecutive access or concurrent access.

The degree of overlap available during the open regime is the lowest of the values offered by the initiator and responder. For the purposes of negotiation, the degrees of overlapped access are rated as: concurrent access (highest), consecutive access, no overlapped access (lowest). This value is used to set the current degree of overlap attribute.

17.1.2.10 Transfer Window

The transfer window parameter indicates the number of bulk data transfers that may be uncompleted at any time. There is an independent transfer window for reads and writes in concurrent access, although the value of the limit is the same, otherwise the transfer window is for both reads and writes.

The value of the transfer window is the lowest of the values offered by the initiator or responder.

18 Grouping control

This amendment makes no additions to Clause 18 of ISO 8571 part 3.

19 Recovery (Internal service only)

19.1 Regime recovery

19.1.2 Types of primitives and parameters

Replace table 24.

19.1.2.4 Bulk Transfer Number

The bulk transfer number is defined in 13.14. The parameter indicates the bulk transfer procedure that is to be recovered.

If concurrent access is in use then this parameter takes the value of the read transfer that is to be recovered (the write transfer is identified by the concurrent bulk transfer number parameter). The default value 0 indicates that there is no read bulk transfer to be recovered.

Add the following clauses.

19.1.2.9 Recovery Point

Add last paragraph.

If concurrent overlapped access is in use then the parameter is with respect to the read data transfer that is identified by the bulk data transfer number. If the bulk transfer number is zero then the recovery point parameter shall take the value zero.

19.1.2.10 Concurrent Bulk Transfer Number

The concurrent bulk transfer number parameter is conditional on the selection of the concurrent access functional unit and the degree of overlap (see 17.1.2.9) being set to concurrent access. The parameter takes the value of a bulk transfer number (defined in 13.14) and identifies the write transfer that is to be recovered (see 19.1.2.4).

The default value 0 indicates that there is no write bulk transfer to be recovered.

19.1.2.11 Concurrent Recovery Point

The concurrent recovery point parameter is conditional on the concurrent access functional unit and the degree of overlap (see 17.1.2.9) being set to concurrent access. The parameter indicates that recovery is to a point before the start of the write bulk data transfer (value zero), or to a checkpoint within the bulk data transfer, or to a point following its completion (see note). The recovery point is within the write bulk data transfer identified by the concurrent bulk transfer number (see 19.1.2.10); if the write bulk transfer number parameter is zero then the write recovery point parameter shall take the value zero. The recovery point is determined by the entity which was receiving data at the time of failure. Consequently the parameter is required to be present on the response primitive.

Table 21 - F-OPEN parameters

Degree of overlap	Conditional	Conditional (=)	Conditional	Conditional (=)
Transfer window	Conditional	Conditional (=)	Conditional	Conditional (=)

If the concurrent bulk transfer number is zero, the concurrent recovery point parameter shall take the value zero.

NOTE - Recovery to a point following a write bulk data transfer completion is defined for the case where the receiver has received an F-DATA-END indication but the F-TRANSFER-END exchange has not completed. In such a situation it would be unnecessary to go back to the last confirmed checkpoint. The only requirement is for both sender and receiver to have an agreed understanding of the completion of the transfer. A value one larger than the highest checkpoint number issued by the sender is used to indicate recovery after bulk data transfer.

19.1.2.12 Last Transfer End Read Request

The last transfer end read request parameter is defined in 13.16. It is only present on the response primitive, and therefore indicates the bulk transfer number of the last read data transfer for which a transfer end read indication primitive had been received by the responder. It is only present if recovery is to an open regime that had negotiated the use of concurrent access.

19.1.2.13 Last Transfer End Read Response

The last transfer end read response parameter is defined in 13.17. It is only present on the request primitive, and therefore indicates the bulk transfer number of the last read data transfer for which a transfer end read confirm primitive had been received by the initiator. It is only present if recovery is to an open regime that had negotiated the use of concurrent access.

19.1.2.14 Last Transfer End Write Request

The last transfer end write request parameter is defined in 13.18. It is only present on the response primitive, and therefore indicates the bulk transfer number of the last write data transfer for which a transfer end read indication primitive had been received by the responder. It is only present if recovery is to an open regime that had negotiated the use of concurrent access.

19.1.2.15 Last Transfer End Write Response

The last transfer end write response parameter is defined in 13.19. It is only present on the request primitive, and therefore indicates the bulk transfer number of the last write data transfer for which a transfer end read confirm primitive had been received by the initiator. It is only present if recovery is to an open regime that had negotiated the use of concurrent access.

Replace Table 24.

20 Access to file contents

20.1 Bulk data transfer

Replace second paragraph:

When overlapped access is not in use, these procedures start and finish in a single data transfer idle state, and so can be considered as a self-contained procedural unit, which is primitive in the definition of the remainder of the file service.

If overlapped access is in use then these procedures may be overlapped. It is therefore not necessarily true that read and write procedures start and finish in a data transfer idle state.

21 Bulk data transfer service primitives

Replace Table 30.

Add sentence to end of fourth paragraph:

If overlapped access is in use then the initiator and responder may each be acting as both sender and receiver, with respect to the read and write procedures, as previously described.

Table 24 - F-RECOVER parameters

Parameter	F-RECOVER request	F-RECOVER indication	F-RECOVER response	F-RECOVER confirm
State Result			Mandatory	Mandatory
Action Result			Mandatory	Mandatory
Activity Identifier	Mandatory	Mandatory (=)		
Bulk Transfer number	Mandatory	Mandatory (=)		
Requested Access	Mandatory	Mandatory (=)		
Access Passwords	Optional	Optional (=)		
Contents Type			Mandatory	Mandatory (=)
Recovery Point	Conditional	Conditional (=)	Conditional	Conditional (=)
Diagnostic			Optional	Optional
Concurrent Bulk Transfer Number	Conditional	Conditional (=)	Conditional	Conditional (=)
Concurrent Recovery Point	Conditional	Conditional (=)	Conditional	Conditional (=)
Last Transfer End Read Request			Conditional	Conditional (=)
Last Transfer End Read Response	Conditional	Conditional (=)		
Last Transfer End Write Request			Conditional	Conditional (=)
Last Transfer End Write Response	Conditional	Conditional (=)		

Section three: Definition of bulk data transfer primitives

22 Sequence of bulk data transfer primitives

22.1 Normal sequences

The normal progress of individual read and write bulk data transfer procedures is illustrated by the state transition diagram shown in Figure 8. Full state transition diagrams are contained in Annex E.

The sequences of primitives allowed as a result of the use

of the bulk data transfer service with overlapped access, is specified in Annex F.

Note - The use of a common Data Transfer Idle state for read and write bulk data transfer procedures in figure 8, serves to illustrate the progress of use of the bulk transfer service itself when overlapped access is not in use.

Re-label figure 8.

Figure 8 - Simplified State Transition Diagram for Read and Write Bulk Data Transfer Procedures

22.2 Constraints on issue of primitives

Table 30 - Bulk data transfer service primitives

Primitive Name	Confirmed Service	Request by	Parameters	Failure Notification
F-READ	No	Initiator	Bulk data transfer specification Transfer number	F-DATA-END action result
F-WRITE	No	Initiator	Bulk data transfer specification Transfer number	F-CANCEL
F-DATA	No	Sender	Data value	F-CANCEL
F-DATA-END	No	Sender	Action result Diagnostic	F-CANCEL
F-TRANSFER-END	Yes	Initiator	Action result Shared ASE information Diagnostic Request type Transfer number [Last transfer end read response] [Last transfer end write response]	action result
F-CANCEL	Yes	Either	Action result Shared ASE information Diagnostic Request type Transfer number [Last transfer end read request] [Last transfer end read response] [Last transfer end write request] [Last transfer end write response]	none
[F-CHECK]	Yes	Either	[Checkpoint identifier Transfer number]	F-CANCEL
[F-RESTART]	Yes	Either	[Checkpoint identifier Request type Transfer number Last transfer end read request Last transfer end read response Last transfer end write request Last transfer end write response]	F-CANCEL

The primitives may be issued in any sequence consistent with the LOTOS specification in Annex F. In addition, for the non-overlapped case, the constraints are presented in tables 31 and 32. The sequences given with the individual primitive definitions apply.

22.3 Key to tables 31 and 32

This amendment makes no changes to sub-clause 22.3.

23 Common bulk data transfer parameters

23.2 Checkpoint identifier

Replace last sentence of first paragraph:

If the use of concurrent access has been negotiated for the open regime then there may be more than one checkpoint number sequence valid at any one time. The bulk transfer number is used to identify the correct sequence. For the F-RESTART primitive, the value is between 0 and 999998 for each direction of transfer.

23.43 Request type

The request type parameter identifies the type of transfer to which a primitive is related i.e. read or write.

24 Bulk data transfer

Replace the first paragraph:

This group of services performs the transfer of bulk data. Each procedure begins with the service initiator issuing either an F-READ request or an F-WRITE request as appropriate. This leads to the issue of a sequence of F-DATA requests followed by an F-DATA-END request by the sender of the data. A procedure is completed by the initiator issuing an F-TRANSFER-END request, as appropriate. If overlapped access has been negotiated, then the service primitives for read and write procedures may be interspersed, subject to the constraints defined for consecutive access and concurrent access. The primitives are defined in 24.1 to 24.6, and the valid sequences, with and without overlapped access, are defined in 24.7 and 24.8.

24.1 Read bulk data service

Replace sub-clause 24.1.1:

24.1.1 Function

The F-READ service specifies a data transfer from the service responder (that is the sender) to the service initiator (that is the receiver).

24.1.1.1 Service without overlapped access

Only one F-READ procedure may be in progress at any time on a single application association. The direction of data flow established continues until the exchange of F-TRANSFER-END primitives. Rejection of an F-READ indication is by issue of an F-DATA-END with an action result indicating unsuccessful.

These primitives signal a transfer of control from the initiator to the sender. They mark a reversal of the service asymmetry for the duration of the data transfer.

24.1.1.2 Service with consecutive access

F-READ procedures may be requested at any time during the open regime, up to the limit negotiated as the transfer window when the open regime was established. The requests for bulk transfer procedures are queued by the responder. If there are no outstanding bulk transfer requests then the F-DATA requests may be issued immediately, otherwise the F-DATA requests are issued subject to the following constraints:

- a) if the preceding bulk transfer procedure was a read procedure then the responder may issue F-DATA requests after issuing the F-DATA-END request for the preceding read procedure;
- b) if the preceding bulk transfer procedure was a write procedure then the responder may issue F-DATA requests after issuing the F-TRANSFER-END response for that write procedure.

A F-READ procedure concludes with the exchange of F-TRANSFER-END primitives.

Rejection of an F-READ indication is by issue of an F-DATA-END request with an action result indicating unsuccessful, although this may not be issued until the responder has issued a F-DATA-END indication or F-TRANSFER-END (write) response, as appropriate, for the preceding bulk transfer procedure.

24.1.1.3 Service with concurrent access

F-READ procedures may be requested at any time during the open regime, up to the limit negotiated as the transfer window when the open regime was established. The responder maintains two independent queues for the read and write bulk transfer requests. If there are no outstanding requests for read procedures then the responder may issue F-DATA requests immediately, otherwise the F-DATA requests are issued after the issue of an F-DATA-END

request for the preceding read procedure. A F-READ procedure concludes with the exchange of F-TRANSFER-END primitives.

Rejection of an F-READ indication is by issue of an F-DATA-END request with an action result indicating unsuccessful, although this may not be issued until the responder has issued a F-DATA-END indication for the preceding read procedure.

24.1.2 Types of primitives and parameters

Replace table 33.

Add sub-clause:

24.1.2.2 Transfer Number

The transfer number parameter is defined in 13.15.

24.2 Write bulk data service

Replace sub-clause 24.2.1:

24.2.1 Function

The F-WRITE service specifies a data transfer from the service initiator (that is the sender) to the service responder (that is the receiver).

24.2.1.1 Service without overlapped access

Only one F-WRITE procedure may be in progress at any time on a single application association. The direction of data flow established continues until the exchange of F-TRANSFER-END primitives. An F-WRITE indication can be rejected by issuing an F-CANCEL request (see 24.6). If the transfer is rejected, no further F-DATA indication primitives are received by the responder.

24.2.1.2 Service with consecutive overlapped access

F-WRITE procedures may be requested at any time during the open regime, up to the limit negotiated as the transfer window when the open regime was established. The requests for bulk transfer procedures are queued. If there are no outstanding bulk transfer requests then the F-DATA requests may be issued immediately, otherwise the F-DATA requests are issued subject to the following constraints:

Table 33 - F-READ parameters

Parameter	F-READ request	F-READ indication
Bulk data transfer specification	Mandator	Mandatory (=)
Transfer number	Conditional	Conditional (=)

a) if the preceding bulk transfer procedure was a read procedure then the initiator may issue F-DATA requests after issuing a F-TRANSFER-END request for the preceding read procedure;

b) if the preceding bulk transfer procedure was a write procedure then the initiator may issue F-DATA requests after issuing a F-TRANSFER-END request for the preceding write procedure.

An F-WRITE procedure concludes with the exchange of F-TRANSFER-END primitives.

A responder may reject an F-WRITE indication by issuing an F-CANCEL request, although this may not be issued until the responder has received an F-TRANSFER-END (read) indication or issued an F-TRANSFER-END (write) response, as appropriate, for the preceding bulk transfer procedure (see 24.7).

24.2.1.3 Service with concurrent access

F-WRITE procedures may be requested at any time during the open regime, up to the limit negotiated as the transfer window when the open regime was established. Two independent queues for the read and write bulk transfer requests. If there are no outstanding requests for write procedures then the initiator may issue F-DATA requests immediately, otherwise the F-DATA requests are issued after the issue of an F-TRANSFER-END request for the preceding write procedure. A F-WRITE procedure concludes with the exchange of F-TRANSFER-END primitives.

Rejection of an F-WRITE indication is by issue of an F-CANCEL request, although this may not be issued until the responder has issued a F-TRANSFER-END response, for the preceding write procedure (see 24.6).

24.2.2 Types of primitives and parameters

Replace table 34.

Add sub-clause:

24.2.2.2 Transfer Number

The transfer number parameter is defined in 13.15.

24.4 End of data transfer service

24.4.1 Function

Replace last sentence:

The sender may issue an F-DATA-END request with an unsuccessful action as a rejection of an F-READ indication, subject to the constraints defined in 24.1.

24.4.2 Types of primitives and parameters

Table 34 - F-WRITE parameters

Parameter	F-WRITE request	F-WRITE indication
Bulk Data Transfer Specification	Mandatory	Mandatory (=)
Transfer Number	Conditional	Conditional (=)

24.4.2.1 Action Result

Replace last sentence:

The initiator responds with an F-TRANSFER-END request as in the non error case.

24.5 End of transfer service

24.5.2 Types of primitives and parameters

Replace Table 37.

Add the following sub-clauses:

24.5.2.4 Request Type

The request type parameter is defined in 23.3.

24.5.2.5 Transfer Number

The transfer number parameter is defined in 13.15.

24.5.2.6 Last Transfer End Read Response

The last transfer end read response parameter is defined in 13.17.

24.5.2.7 Last Transfer End Write Response

The last transfer end write response parameter is defined in 13.18.

Replace sub-clause 24.6:

24.6 Cancel data transfer

24.6.1 Function

Either of the service users may cancel a data transfer activity by issuing an F-CANCEL request primitive. The conditions for use are described in the following clauses.

24.6.1.1 Service without overlapped access

The F-CANCEL primitive may be issued during data transfer after the issue or receipt of an F-READ or F-WRITE request or indication. At the end of data transfer, it may not be issued:

- a) by the initiator acting as sender after issue of an F-DATA-END request;
- b) by the responder acting as receiver after issue of an F-TRANSFER-END response;
- c) by the responder acting as sender after the issue of an F-DATA-END request;
- d) by the initiator acting as receiver after the issue of an F-TRANSFER-END request.

If either the cancel data transfer service or the end of data transfer service is used, the data transfer regime ceases.

Table 37 - F-TRANSFER-END parameters

Parameter	F-TRANSFER-END request	F-TRANSFER-END indication	F-TRANSFER-END response	F-TRANSFER-END confirm
Action result			Mandatory	Mandatory
Shared ASE Information	Optional	Optional (=)	Optional	Optional (=)
Diagnostic			Optional	Optional
Request Type	Conditional	Conditional (=)	Conditional	Conditional (=)
Transfer Number	Conditional	Conditional (=)	Conditional	Conditional (=)
[Last transfer end read response	Conditional	Conditional (=)		
Last transfer end write response	Conditional	Conditional (=)]		

Where use of these services collides, the cancel data transfer service takes precedence.

After an F-CANCEL procedure the two users may have different views of the state of the activity. The F-CANCEL primitives interrupt any activity in progress (including an F-RESTART sequence) and any undelivered indications or confirms may be discarded.

The file remains open after a sequence of F-CANCEL primitives, although the result of interrupted operations is not defined. Further F-READ or F-WRITE operations, not necessarily related to any previous read or write attempt, may be attempted after the completion of the sequence of F-CANCEL primitives has disposed of any previous activity.

24.6.1.2 Service with consecutive access

The cancel data transfer service may be used to cancel either a read transfer or a write transfer. If there are no uncompleted bulk transfer procedures then the constraints on the use of the service are as defined for the service without overlapped access. Otherwise, it may not be used:

a) by the initiator acting as sender before the issue of an F-TRANSFER-END request (as appropriate) for the preceding bulk transfer procedure, or after the issue of an F-DATA-END request for that write transfer;

b) by the responder acting as receiver before the receipt of an F-TRANSFER-END (read) indication or the issue of an F-TRANSFER-END (write) response (as appropriate) for the preceding bulk transfer procedure, or after the issue of an F-TRANSFER-END response for that write transfer;

c) by the responder acting as sender before the issue of an F-DATA-END request or F-TRANSFER-END (write) response (as appropriate) for the preceding bulk transfer, or after the issue of an F-DATA-END request for that read transfer;

d) by the initiator acting as receiver before the issue of an F-TRANSFER-END (read) request or receipt of an F-TRANSFER-END (write) confirm (as appropriate) for the preceding bulk transfer procedure, or after the issue of an F-TRANSFER-END request for that read transfer.

Outstanding F-TRANSFER-END primitives may not be exchanged until the F-CANCEL sequence has been completed. Also, the initiator may not issue further requests for bulk transfer procedures during the exchange of F-CANCEL primitives.

If the cancel data transfer service is used then all outstanding bulk transfer requests are cancelled and the data transfer regime ceases. Where uses of this service and the end of data transfer service collide, the cancel data transfer service takes precedence.

After an F-CANCEL procedure the two users may have

different views of the state of the activity. The F-CANCEL primitives interrupt any activity in progress (including an F-RESTART sequence) and any undelivered indications or confirms may be discarded.

The file remains open after a sequence of F-CANCEL primitives, although the result of interrupted operations is not defined. Further F-READ or F-WRITE operations, not necessarily related to any previous read or write attempt, may be attempted after the completion of the sequence of F-CANCEL primitives has disposed of any previous activity.

24.6.1.3 Service with concurrent access

The cancel data transfer may be used to cancel a read transfer or a write transfer. The constraints that apply to cancelling read and write transfers are independent of each other and the F-CANCEL service may only be used to cancel one type of transfer. To cancel both the current read transfer and the current write transfer, the file service user must issue two F-CANCEL requests.

24.6.1.3.1 Cancel write bulk transfer constraints

If there are no uncompleted write bulk transfer procedures the constraints on the use of the service are as defined for the service without overlapped access. Otherwise, the service may not be used to cancel a write transfer:

a) by the initiator before the receipt of an F-TRANSFER-END confirm for the preceding write transfer, or after the issue of an F-DATA-END request for that write transfer;

b) by the responder before the issue of an F-TRANSFER-END response for the preceding write transfer, or after the issue of an F-TRANSFER-END response for that write transfer.

Outstanding F-TRANSFER-END (write) primitives may not be exchanged until the F-CANCEL sequence has been completed. Also, the initiator may not issue further requests for write bulk transfer procedures during the exchange of F-CANCEL primitives.

If the cancel data transfer service is used then all outstanding write bulk transfer requests are cancelled and the data transfer regime ceases. Where uses of this service and the end of data transfer service collide, the cancel data transfer service takes precedence.

After an F-CANCEL procedure the two users may have different views of the state of the activity. The F-CANCEL primitives interrupt any activity in progress (including an F-RESTART sequence) and any undelivered indications or confirms may be discarded.

The file remains open after a sequence of F-CANCEL primitives, although the result of interrupted operations is not defined. Further F-WRITE operations, not necessarily

related to any previous write attempt, may be attempted after the completion of the sequence of F-CANCEL primitives has disposed of any previous activity.

24.6.1.3.2 Cancel read bulk transfer constraints

If there are no uncompleted read bulk transfer procedures then the constraints on the service user are as defined for the service without overlapped access. Otherwise, the service may not be used to cancel a read transfer:

a) by the initiator before the issue of an F-TRANSFER-END request for the preceding read bulk transfer procedure, or after the issue of an F-TRANSFER-END request for that procedure;

b) by the responder before the receipt of an F-TRANSFER-END indication for the preceding read bulk transfer procedure, or after the issue of an F-DATA-END request for that read transfer.

Outstanding F-TRANSFER-END (read) primitives may not be exchanged until the F-CANCEL sequence has been completed. Also, the initiator may not issue further requests for read bulk transfer procedures during the exchange of F-CANCEL primitives.

If the cancel data transfer service is used then all outstanding read bulk transfer requests are cancelled and the data transfer regime ceases. Where uses of this service and the end of data transfer service collide, the cancel data transfer service takes precedence.

After an F-CANCEL procedure the two users may have different views of the state of the activity. The F-CANCEL primitives interrupt any activity in progress (including an F-RESTART sequence) and any undelivered indications or confirms may be discarded.

The file remains open after a sequence of F-CANCEL primitives, although the result of interrupted operations is not defined. Further F-READ operations, not necessarily related to any previous read attempt, may be attempted after the completion of the sequence of F-CANCEL primitives has disposed of any previous activity.

24.6.2 Types of primitives and parameters

Replace table 38.

Add the following sub-clauses:

24.6.2.4 Request Type

The request type parameter is defined in 23.3.

24.6.2.5 Transfer Number

The transfer number parameter is defined in 13.15.

24.6.2.7 Last Transfer End Read Request

The last transfer end read request parameter is defined in 13.16.

24.6.2.8 Last Transfer End Read Response

The last transfer end read response parameter is defined in 13.17.

24.6.2.9 Last Transfer End Write Request

The last transfer end write request parameter is defined in

Table 38 - F-CANCEL parameters

Parameter	F-CANCEL request	F-CANCEL indication	F-CANCEL response	F-CANCEL confirm
Action result	Mandatory	Mandatory	Mandatory	Mandatory
Shared ASE information	Optional	Optional (=)	Optional	Optional (=)
Diagnostic	Optional	Optional	Optional	Optional
Request type	Conditional	Conditional (=)	Conditional	Conditional (=)
Transfer number	Conditional	Conditional (=)	Conditional	Conditional (=)
[Last transfer end read request	Conditional (Responder only)	Conditional (=)	Conditional (Initiator only)	Conditional (=)
Last transfer end read response	Conditional (Initiator only)	Conditional (=)	Conditional (Responder only)	Conditional (=)
Last transfer end write request	Conditional (Responder only)	Conditional (=)	Conditional (Initiator only)	Conditional (=)
Last transfer end write response	Conditional (Initiator only)	Conditional (=)	Conditional (Responder only)	Conditional (=)

13.18.

24.6.2.10 Last Transfer End Write Response

The last transfer end write response parameter is defined in 13.19.

24.7 Sequence of primitives on write

Add the following after first sentence:

If overlapped access is in use then the resultant sequence of primitives is the result of interleaving the two sequences for read and write operations. The rules for interleaving are defined for each individual primitive.

24.8 Sequence of primitives on Read

Add the following after first sentence:

If overlapped access is in use then the resultant sequence of primitives is the result of interleaving the two sequences for read and write operations. The rules for interleaving are defined for each individual primitive.

25 Checkpointing and restart (Internal BDT Service Only)

25.1 Checkpointing

Replace last sentence:

The checkpointing and restart primitives may be issued while a data transfer activity is in progress to control the progress of the data transfer.

25.1.1 Function

Add following paragraphs:

If overlapped access is not in use then checkpoint primitives may be issued after an F-READ or F-WRITE and before an F-DATA-END, for the sender and F-TRANSFER-END (read) or F-TRANSFER-END (write) for the recipient.

If the use of overlapped access has been negotiated for the open regime then checkpoints for read and write data

transfers are independent of each other. A sender may only issue an F-CHECK request if all data has been sent for the preceding bulk data transfers; a responder may only issue an F-CHECK response if all data has been secured for the preceding bulk data transfer.

25.1.2 Types of primitives and parameters

Replace table 39.

Add the following sub-clause:

25.1.2.2 Transfer Number

The transfer number is defined in 13.15. The parameter identifies the data transfer to which the checkpoint is associated.

25.2 Restarting data transfer service

Replace sub-clause 25.2.1:

25.2.1 Function

The F-RESTART group of primitives interrupts any bulk data transfer activity in progress, with possible loss of any undelivered indications or confirms. It negotiates a point at which data transfer is to be restarted.

25.2.1.1 Service without overlapped access

At the end of data transfer, the service may not be used:

- a) by the initiator acting as sender after issue of an F-DATA-END request;
- b) by the responder acting as receiver after the issue of an F-TRANSFER-END response;
- c) by the responder acting as sender after the issue of an F-DATA-END request;
- d) by the initiator acting as receiver after the issue of an F-TRANSFER-END request.

If the receiver and the sender of data both issue an F-RESTART request, the service provider resolves the

Table 39 - F-CHECK parameters

Parameter	F-CHECK request	F-CHECK indication	F-CHECK response	F-CHECK confirm
Checkpoint identifier	Mandatory	Mandatory (=)	Mandatory	Mandatory (=)
Transfer number	Conditional	Conditional (=)	Conditional	Conditional (=)

collision and issues a confirmation to each user giving the point at which the transfer is to be restarted (see ISO 8571-4). An F-RESTART indication is rejected by using an F-CANCEL request primitive.

25.2.1.2 Service with consecutive access

The restarting data transfer service may be used to restart either a read transfer or a write transfer. If there are no uncompleted bulk transfer procedures then the constraints on the use of the service are as defined for the service without overlapped access. Otherwise, it may not be used:

a) by the initiator acting as sender before the issue of an F-TRANSFER-END request for the preceding bulk transfer procedure, or after the issue of an F-DATA-END request for that write transfer;

b) by the responder acting as receiver before the receipt of an F-TRANSFER-END (read) indication or the issue of an F-TRANSFER-END (write) response (as appropriate) for the preceding bulk transfer procedure, or after the issue of an F-TRANSFER-END response for that write transfer;

c) by the responder acting as sender before the issue of an F-DATA-END request (read) or F-TRANSFER-END (write) response, as appropriate, for the preceding bulk transfer, or after the issue of an F-DATA-END request for that read transfer;

d) by the initiator acting as receiver before the issue of an F-TRANSFER-END (read) request or receipt of an F-TRANSFER-END (write) confirm, as appropriate, for the preceding bulk transfer procedure, or after the issue of an F-TRANSFER-END request for that read transfer.

If the restarting data transfer service is used then all outstanding bulk transfer requests are cancelled and the initiator must reissue the bulk transfer requests. Where use of this service causes a collision, the service provider resolves the collision and issues a confirmation to each user giving the transfer, and the point at which the transfer is to be restarted (see ISO 8571-4). An F-RESTART indication is rejected by using an F-CANCEL request primitive.

25.2.1.3 Service with concurrent access

The restarting data transfer may be used to restart a read transfer or a write transfer. The constraints that apply to restarting read and write procedures are independent of each other. To issue an F-RESTART request for a read transfer and a write transfer, a service user must satisfy both sets of constraints.

25.2.1.3.1 Restart write bulk transfer constraints

If there are no uncompleted write bulk transfer procedures

then the constraints on the use of the service are as defined for the service without overlapped access. Otherwise, the service may not be used to restart a write transfer:

a) by the initiator before the issue of an F-TRANSFER-END request for the preceding write transfer, or after the issue of an F-DATA-END request for that write transfer;

b) by the responder before the issue of an F-TRANSFER-END response for the preceding write transfer, or after the issue of an F-TRANSFER-END response for that write transfer.

25.2.1.3.2 Restart read bulk transfer constraints

If there are no uncompleted read bulk transfer procedures then the constraints on the service user are as defined for the service without overlapped access. Otherwise, the service may not be used to restart a read transfer:

a) by the initiator before the issue of an F-TRANSFER-END request for the preceding read bulk transfer procedure, or after the issue of an F-TRANSFER-END request for that read procedure;

b) by the responder before the issue of an F-DATA-END request for the preceding read bulk transfer procedure, or after the issue of an F-DATA-END request for that read transfer.

Subject to the following, a bulk transfer procedure that is not in a direction to be restarted, may continue as normal:

i) outstanding F-TRANSFER-END primitives may not be exchanged until the F-RESTART sequence has been completed;

ii) the initiator may not issue further requests for bulk transfer procedures during the exchange of F-RESTART primitives.

If the receiver and the sender of data both issue an F-RESTART request for the same direction, the service provider resolves the collision and issues a confirmation to each user giving the transfer, and the point at which the transfer is to be restarted (see ISO 8571-4).

25.2.2 Types of primitives and parameters

Replace table 40.

Add the following clauses:

25.2.2.2 Request Type

The request type parameter is defined in 23.4.

25.2.2.3 Transfer Number

The transfer number is defined in 13.15.

The last transfer end read response parameter is defined in 13.17.

25.2.2.4 Last Transfer End Read Request

The last transfer end read request parameter is defined in 13.16.

25.2.2.6 Last Transfer End Write Request

The last transfer end write request parameter is defined in 13.18.

25.2.2.5 Last Transfer End Read Response

25.2.2.7 Last Transfer End Write Response

The last transfer end write response parameter is defined in 13.19.

Table 40 - F-RESTART parameters

Parameter	F-RESTART request	F-RESTART indication	F-RESTART response	F-RESTART confirm
Checkpoint identifier	Mandatory	Mandatory (=)	Mandatory	Mandatory (=)
Request type	Conditional	Conditional (=)	Conditional	Conditional (=)
Transfer number	Mandatory	Mandatory (=)	Mandatory	Mandatory (=)
Last transfer end read request	Conditional (Responder only)	Conditional (=)	Conditional (Initiator only)	Conditional (=)
Last transfer end read response	Conditional (Initiator only)	Conditional (=)	Conditional (Responder only)	Conditional (=)
Last transfer end write request	Conditional (Responder only)	Conditional (=)	Conditional (Initiator only)	Conditional (=)
Last transfer end write response	Conditional (Initiator only)	Conditional (=)	Conditional (Responder only)	Conditional (=)

Annex A Diagnostic parameter values

(This annex forms part of the standard.)

Amend table 48:

Table 48 - Access related diagnostics

Type	Identifier	Observer	Source	Reason
01	5nnn	5	5	Degree of overlap not available
0 2	5nnn	5	1	Transfer window - too large
0 2	5nnn	5	1	Transfer window - too small

Amend table 49:

Type	Identifier	Observer	Source	Reason
012	5nnn	5	5	Degree of overlap not available

The identifiers 5nnn are the next numbers in the sequence of identifiers for diagnostics.

Annex B

Relation of attributes to primitives

(This annex forms part of the standard.)

Amend table 51:

Table 51 - Activity attributes

Attribute Name	F-INITIALIZE	F-SELECT	F-CREATE	F-OPEN	F-READ & F-WRITE	F-LOCATE & F-ERASE	F-RECOVER
current degree of overlap				change			change

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Annex E State transition diagrams

(This annex forms part of the standard.)

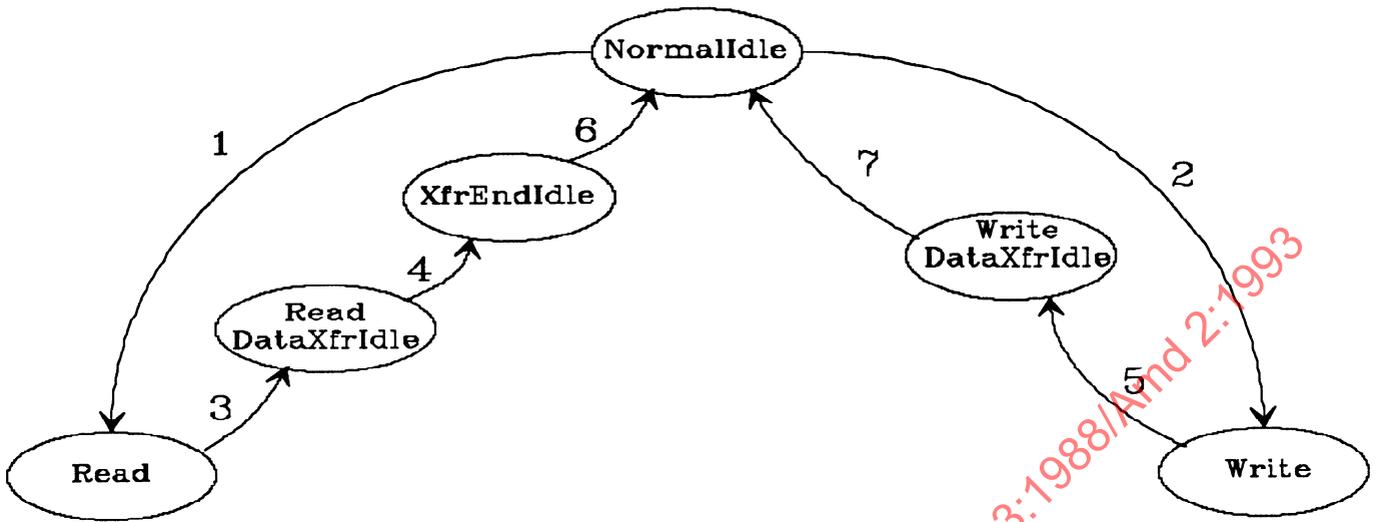
Replace first sentence.

This annex contains descriptions of the sequences of service primitives in the external file service. State transition diagrams are used to define all sequences of primitives except those in overlapped access. The sequences of bulk data transfer primitives in overlapped access are defined by the LOTOS specifications in Annex F. This annex contains diagrams that illustrate the structure of the specifications and identify those events that (may) result in a change in the

allowed behaviour i.e. the 'transition' between LOTOS processes (see note 1).

Note 1 - The notion of 'transition' between different processes is used in an informal manner for the purpose of this introduction. A transition relates to the situation in the LOTOS specifications where the use of a service primitive does not result in the same LOTOS process being instantiated.

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Initiator

- 1 - F-READ request
- 2 - F-WRITE request
- 3 - F-DATA-END indication
- 4 - F-TRANSFER-END request (Read)

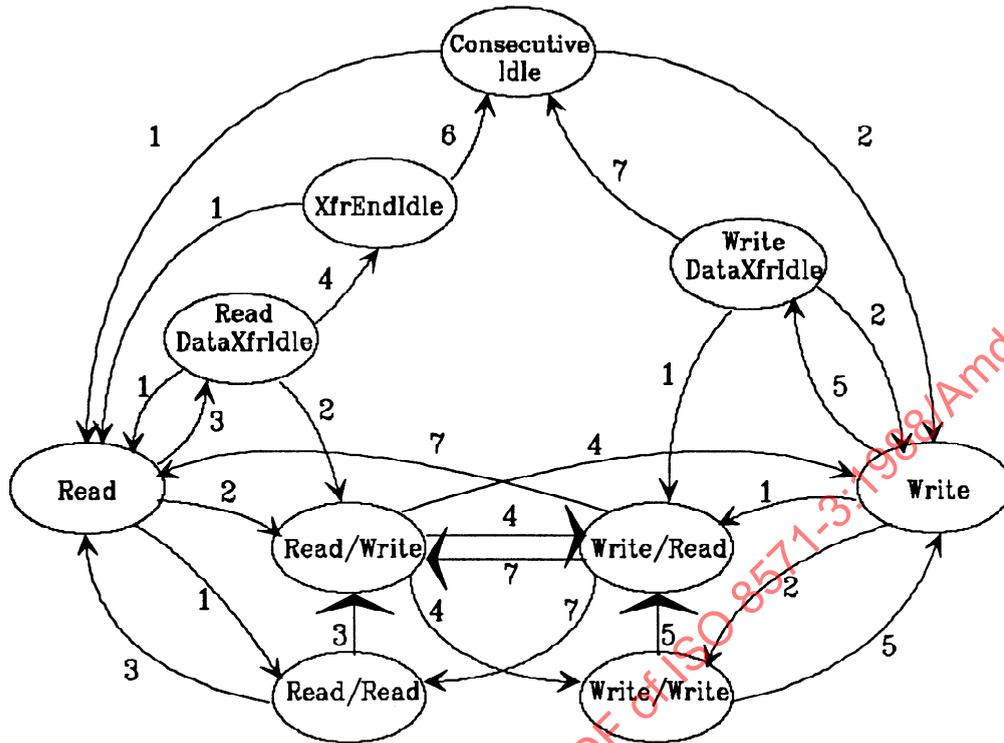
- 5 - F-TRANSFER-END request (Write)
- 6 - F-TRANSFER-END confirm (Read)
- 7 - F-TRANSFER-END confirm (Write)

Responder

- 1 - F-READ indication
- 2 - F-WRITE indication
- 3 - F-DATA-END request
- 4 - F-TRANSFER-END indication (Read)

- 5 - F-TRANSFER-END indication (Write)
- 6 - F-TRANSFER-END response (Read)
- 7 - F-TRANSFER-END response (Write)

Figure 19 - A LOTOS Process transition diagram for normal (non-overlapped) access



Initiator

- 1 - F-READ request
- 2 - F-WRITE request
- 3 - F-DATA-END indication
- 4 - F-TRANSFER-END request (Read)

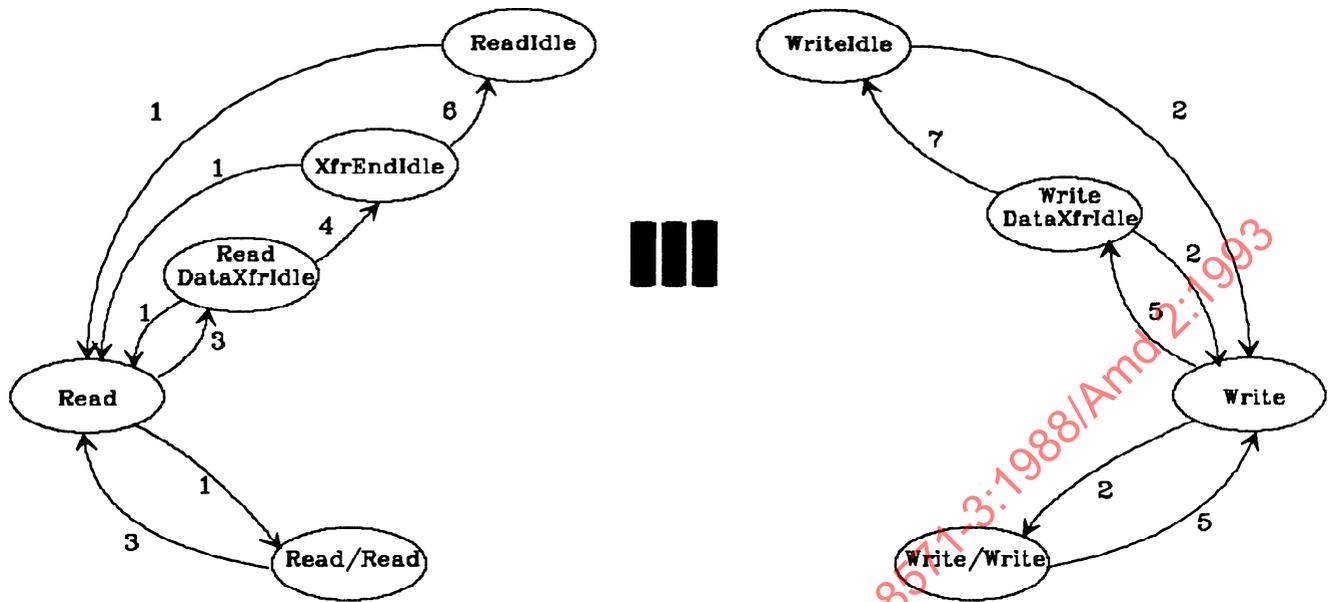
- 5 - F-TRANSFER-END request (Write)
- 6 - F-TRANSFER-END confirm (Read)
- 7 - F-TRANSFER-END confirm (Write)

Responder

- 1 - F-READ indication
- 2 - F-WRITE indication
- 3 - F-DATA-END request
- 4 - F-TRANSFER-END indication (Read)

- 5 - F-TRANSFER-END indication (Write)
- 6 - F-TRANSFER-END response (Read)
- 7 - F-TRANSFER-END response (Write)

Figure 20 - A LOTOS Process transition diagram for consecutive access



Initiator

- 1 - F-READ request
- 2 - F-WRITE request
- 3 - F-DATA-END indication
- 4 - F-TRANSFER-END request (Read)

- 5 - F-TRANSFER-END request (Write)
- 6 - F-TRANSFER-END confirm (Read)
- 7 - F-TRANSFER-END confirm (Write)

Responder

- 1 - F-READ indication
- 2 - F-WRITE indication
- 3 - F-DATA-END request
- 4 - F-TRANSFER-END indication (Read)

- 5 - F-TRANSFER-END indication (Write)
- 6 - F-TRANSFER-END response (Read)
- 7 - F-TRANSFER-END response (Write)

Figure 21 - LOTOS Process transition diagram for concurrent access

Note - Figure 21 uses the LOTOS operator "|||" to denote the concurrent execution of read and write operations.

Annex F Lotos specifications

(This annex forms part of the standard.)

The LOTOS specifications in this annex specify the sequences of bulk data transfer service primitives in the external file service. The specifications of the initiator and responder are provided separately.

Each specification (figures 22 and 23) specifies the allowed sequence of bulk data transfer service primitives for normal (non-overlapped), consecutive and concurrent overlapped access (see note 1). Figures 19, 20 and 21 illustrate the structure of the specifications and identify those events that (may) result in a change in the allowed behaviour i.e. the 'transition' between LOTOS processes (see note 2).

Note 1 - The behaviour defined in the non-overlapped case is equivalent to that for consecutive access, where the number of transfers that may be uncompleted at any time is 1. Also, the behaviour for concurrent access is equivalent to the interleaving of consecutively overlapped read procedures with consecutively overlapped write procedures.

Note 2 - The notion of 'transition' between different processes is used in an informal manner for the purpose of this introduction. A transition relates to the situation in the LOTOS specifications where the use of a service primitive does not result in the same LOTOS process being instantiated.

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```

Specification

The specification Initiator_External_Service specifies the sequence of service primitives in the external file service of the
initiator, for the duration of the bulk data transfer regime, for normal, consecutive and concurrent overlapped access.*)

Specification      Initiator_External_Service[Iin,Iout,Local]      :exit

Data types

The specification imports the standard library definitions for the types Boolean and NaturalNumber, these are used to define
the following types:

ExtendedNaturalNumber - this extends the definition of NaturalNumber to include the operation pred, which decrements
a parameter of type Nat.

FileServicePrimitives - values are defined to represent the file service primitives. Boolean operations are defined that
identify a particular primitive e.g IsDataEndReq(transferEndReq)=false.

RequestQueue, QueueElement - a queue is defined with operations: empty (creates an empty queue), add (adds an
element to the queue), tail (removes the first element on the queue), head (returns the value of the first element on the queue),
last (returns the value of the last element on the queue), IsEmpty (determines whether the queue is empty), removeLast
(removes the last element on the queue), size (determines the number of elements on the queue), firstWriteReq (finds the
first write request on a queue), removeReqs (removes all elements from the end of a queue, up to and including the first write
request on the queue) and reverse (reverses the order of the elements on the queue). The elements of the queue are comprised
of a file service primitive and it's transfer number.

Note - the firstWriteReq and removeReqs operations are required to support the cancellation of a write data transfer after the
receipt of an F-TRANSFER-END indication by the responder. Equivalent operations are not required for read data transfer
operations.

DegreeOfOverlap - values are defined for normal, consecutive and concurrent; boolean operations are defined that
identify a given value.

FunctionalUnits - values are defined to represent the selection of the Read, Write and the combination of the Read &
Write functional units; boolean operations are defined that identify a given value.
*)

library
Boolean,NaturalNumber
endlib

type ExtendedNaturalNumber is NaturalNumber
  opna pred: Nat -> Nat
  opna forall x:Nat
    ofsort Nat
      pred(0)          - 0;
      pred(Succ(x))   - x;
endtype

```

Figure 22 - Initiator service definition

```

type FileServicePrimitives is Boolean
  sorts FSPrim
  ops
    null,
    readReq,
    writeReq,
    dataReq,
    dataInd,
    dataEndReq,
    dataEndInd,
    xfrEndReadReq,
    xfrEndReadConf,
    xfrEndWriteReq,
    xfrEndWriteConf,
    cancelReadReq,
    cancelReadInd,
    cancelReadResp,
    cancelReadConf,
    cancelWriteReq,
    cancelWriteInd,
    cancelWriteResp,
    cancelWriteConf:      -> FSPrim

  Mp:      FSPrim -> Nat

  isNull,
  isReadReq,
  isWriteReq,
  isDataReq,
  isDataInd,
  isDataEndReq,
  isDataEndInd,
  isXfrEndReadReq,
  isXfrEndReadConf,
  isXfrEndWriteReq,
  isXfrEndWriteConf,
  isCancelReadReq,
  isCancelReadInd,
  isCancelReadResp,
  isCancelReadConf,
  isCancelWriteReq,
  isCancelWriteInd,
  isCancelWriteResp,
  isCancelWriteConf: FSPrim -> Bool

  axms forall fsp:FSPrim

  ofsort Nat

  Mp(null)          = 0;
  Mp(readReq)       = Succ(0);
  Mp(writeReq)      = Succ(Mp(readReq));
  Mp(dataReq)       = Succ(Mp(writeReq));

```

Figure 22 (continued) - Initiator service definition

```

Mp(dataInd)           = Succ(Mp(dataReq));
Mp(dataEndReq)        = Succ(Mp(dataInd));
Mp(dataEndInd)        = Succ(Mp(dataEndReq));
Mp(xfrEndReadReq)     = Succ(Mp(dataEndInd));
Mp(xfrEndReadConf)   = Succ(Mp(xfrEndReadReq));
Mp(xfrEndWriteReq)    = Succ(Mp(xfrEndReadConf));
Mp(xfrEndWriteConf)   = Succ(Mp(xfrEndWriteReq));
Mp(cancelReadReq)     = Succ(Mp(xfrEndWriteConf));
Mp(cancelReadInd)     = Succ(Mp(cancelReadReq));
Mp(cancelReadResp)    = Succ(Mp(cancelReadInd));
Mp(cancelReadConf)    = Succ(Mp(cancelReadResp));
Mp(cancelWriteReq)    = Succ(Mp(cancelReadConf));
Mp(cancelWriteInd)    = Succ(Mp(cancelWriteReq));
Mp(cancelWriteResp)   = Succ(Mp(cancelWriteInd));
Mp(cancelWriteConf)   = Succ(Mp(cancelWriteResp));

```

ofsort Bool

```

isNull(fsp)           = Mp(fsp) eq Mp(null);
isReadReq(fsp)        = Mp(fsp) eq Mp(readReq);
isWriteReq(fsp)       = Mp(fsp) eq Mp(writeReq);
isDataInd(fsp)        = Mp(fsp) eq Mp(dataInd);
isDataReq(fsp)        = Mp(fsp) eq Mp(dataReq);
isDataEndInd(fsp)     = Mp(fsp) eq Mp(dataEndInd);
isDataEndReq(fsp)     = Mp(fsp) eq Mp(dataEndReq);
isXfrEndReadReq(fsp) = Mp(fsp) eq Mp(xfrEndReadReq);
isXfrEndWriteReq(fsp) = Mp(fsp) eq Mp(xfrEndWriteReq);
isXfrEndReadConf(fsp) = Mp(fsp) eq Mp(xfrEndReadConf);
isXfrEndWriteConf(fsp) = Mp(fsp) eq Mp(xfrEndWriteConf);
isCancelReadInd(fsp) = Mp(fsp) eq Mp(cancelReadInd);
isCancelReadReq(fsp) = Mp(fsp) eq Mp(cancelReadReq);
isCancelReadConf(fsp) = Mp(fsp) eq Mp(cancelReadConf);
isCancelReadResp(fsp) = Mp(fsp) eq Mp(cancelReadResp);
isCancelWriteInd(fsp) = Mp(fsp) eq Mp(cancelWriteInd);
isCancelWriteReq(fsp) = Mp(fsp) eq Mp(cancelWriteReq);
isCancelWriteConf(fsp) = Mp(fsp) eq Mp(cancelWriteConf);
isCancelWriteResp(fsp) = Mp(fsp) eq Mp(cancelWriteResp);

```

andtype

type QueueElement in FileServicePrimitives, Boolean, ExtendedNaturalNumber

sorts Element

```

opns nullEl:         -> Element
makeEl:   FSPrim, Nat -> Element
number:   Element    -> Nat
prim:     Element    -> FSPrim
isNullEl: Element    -> Bool

```

opns forall fsp:FSPrim,tn:Nat,q_el:Element

ofsort FSPrim

```

prim(makeEl(fsp,tn)) = fsp;
prim(nullEl)         = null;

```

ofsort Nat

```

number(nullEl)       = 0;
number(makeEl(fsp,tn)) = tn;

```

Figure 22 - (continued) Initiator service definition

```

ofsort Bool
  isNullEl (nullEl)      = true;
  isNullEl (q_el)       = isNull (prim (q_el));

ofsort Element
  makeEl (null,0)       = nullEl;

endtype

type RequestQueue is QueueElement, Boolean, ExtendedNaturalNumber

sorts Queue
ops empty:          -> Queue
  add:      Element, Queue -> Queue
  tailOf:   Queue         -> Queue
  head:     Queue         -> Element
  last:     Queue         -> Element
  isEmpty:  Queue         -> Bool
  removeLast: Queue       -> Queue
  size:     Queue         -> Nat
  firstWriteReq: Queue    -> Element
  removeReqs: Queue      -> Queue
  reverse:  Queue         -> Queue

axms forall x,y:Element,q:Queue
ofsort Element
  head (empty)          = nullEl;
  head (add (x, empty)) = x;
  head (add (x, add (y, q))) = head (add (y, q));
  last (empty)         = nullEl;
  last (add (x, empty)) = x;
  last (add (x, q))     = x;
  firstWriteReq (empty) = nullEl;
  isWriteReq (prim (head (q)))
    => firstWriteReq (q) = head (q);
  not (isWriteReq (prim (head (q))))
    => firstWriteReq (q) = firstWriteReq (tailOf (q))

ofsort Queue
  tailOf (empty) = empty;
  tailOf (add (x, empty)) = empty;
  tailOf (add (x, q)) = add (x, tailOf (q));
  add (nullEl, q) = q;
  removeLast (empty) = empty;
  removeLast (add (x, q)) = q;
  removeReqs (empty) = empty;
  isWriteReq (prim (head (q)))
    => removeReqs (q) = empty;
  not (isWriteReq (prim (head (q))))
    => removeReqs (q) = reverse (add (head (q), removeReqs (tailOf (q))));

ofsort Bool
  isEmpty (empty) = true;
  isEmpty (add (x, q)) = false;

ofsort Nat

```

Figure 22 (continued) - Initiator service definition

```

        size(empty) = 0;
        size(add(x,q)) = Succ(size(q));
endtype

type DegreeOfOverlap is Boolean
  sorts Overlap
  opns normal: -> Overlap
        consecutive: -> Overlap
        concurrent: -> Overlap
        isNormal: Overlap -> Bool
        isConsecutive: Overlap -> Bool
        isConcurrent: Overlap -> Bool

  eqns forall degree:Overlap
  ofsort Bool
    isNormal(normal) = true;
    isNormal(consecutive) = false;
    isNormal(concurrent) = false;

    isConsecutive(normal) = false;
    isConsecutive(consecutive) = true;
    isConsecutive(concurrent) = false;

    isConcurrent(normal) = false;
    isConcurrent(consecutive) = false;
    isConcurrent(concurrent) = true;
endtype

type FunctionalUnits is Boolean
  sorts FUnits
  opns setRead: -> FUnits
        setWrite: -> FUnits
        setReadWrite: -> FUnits
        isAvailableRead: FUnits -> Bool
        isAvailableWrite: FUnits -> Bool

  eqns forall x:FUnits
  ofsort Bool
    isAvailableRead(setRead) = true;
    isAvailableRead(setWrite) = false;
    isAvailableRead(setReadWrite) = true;

    isAvailableWrite(setRead) = false;
    isAvailableWrite(setWrite) = true;
    isAvailableWrite(setReadWrite) = true;
endtype

(*
Behaviour
All events occur at the gates lin, lout or Local. Events at the gate lin represent receipt of file service primitives by the file service provider; events at the gate lout represent file service primitives that are issued to the file service user by the file service provider. The events at the gate Local establish the bounds on the behaviour of the file service i.e. the degree of overlap.

```

Figure 22 - (continued) Initiator service definition

the functional units available and, if overlapped access is allowed, the maximum number of request that may be outstanding.

The sequence of primitives allowed in the external file service is specified by the behaviour the process **NormalIdle**, **ConsecutiveIdle** or **ConcurrentIdle** (chosen on the basis of the **degreeOfOverlap**, established by an event at the gate **Local**).

```

*)
behaviour

Local?degree:Overlap;
([isNormal(degree)]->
  Local?functionalUnits:FUnits;
  NormalIdle[Iin, Iout] (functionalUnits)

[]

[isConsecutive(degree)]->
Local?functionalUnits:FUnits?maxRequests:Nat;
  ConsecutiveIdle[Iin, Iout] (functionalUnits, maxRequests)

[]

[isConcurrent(degree)]->
Local?functionalUnits:FUnits?maxRequests:Nat;
  ConcurrentIdle[Iin, Iout] (functionalUnits, maxRequests)
)

```

where
 (*
 process **NormalIdle**

This process specifies the allowed behaviour when overlapped access is not in use. This point represents the completion of the exchange of F-OPEN primitives.

```

*)
process NormalIdle[Iin, Iout] (functionalUnits:FUnits) :exit:=

```

(* If the appropriate functional unit is available, the file service user may issue an F-READ request or an F-WRITE request. The request becomes the current data transfer. *)

```

( [isAvailableRead(functionalUnits)]->
  Iin?fsp:FSPrim[isReadReq(fsp)];
  Read[Iin, Iout]
  (normal, functionalUnits, Succ(0), Succ(0), makeEl(fsp, Succ(0)), Succ(0), empty, empty, empty)

[]

[isAvailableWrite(functionalUnits)]->
  Iin?fsp:FSPrim[isWriteReq(fsp)];
  Write[Iin, Iout]
  (normal, functionalUnits, Succ(0), Succ(0), makeEl(fsp, Succ(0)), Succ(0), empty, empty, empty)
)

```

>>

Figure 22 (continued) - Initiator service definition

(* Upon completion of the previous bulk data transfer the file service user may issue an F-READ or F-WRITE request (as specified by the process **NormalIdle**) or may **exit** the specification (i.e. initiate an exchange of F-CLOSE primitives). This point in the specification represents the data transfer idle state. *)

```
( NormalIdle[Iin, Iout] (functionalUnits)
```

```
[])
```

```
    exit
```

```
)
```

```
endproc (* NormalIdle*)
```

(*
process **ConsecutiveIdle**

This process specifies the allowed behaviour when consecutive overlapped access is in use. This point represents the completion of the exchange of F-OPEN primitives.

*)

```
process ConsecutiveIdle[Iin, Iout] (functionalUnits:FUnits, maxRequests:Nat) :exit:=
```

(* If the appropriate functional unit is available, the file service user may issue an F-READ request or an F-WRITE request. The request becomes the current data transfer. *)

```
( [isAvailableRead(functionalUnits)]->
```

```
Iin?fsp:FSPrim?tn:Nat[isReadReq(fsp) and (tn eq Succ(0))];
```

```
  Read[Iin, Iout]
```

```
    (consecutive, functionalUnits, maxRequests, tn, makeEl (fsp, tn), tn, empty, empty, empty)
```

```
[])
```

```
[isAvailableWrite(functionalUnits)]->
```

```
Iin?fsp:FSPrim?tn:Nat[isWriteReq(fsp) and (tn eq Succ(0))];
```

```
  Write[Iin, Iout]
```

```
    (consecutive, functionalUnits, maxRequests, tn, makeEl (fsp, tn), tn, empty, empty, empty)
```

```
)
```

```
>>
```

(* Upon completion of all outstanding data transfers the file service user may **exit** the specification (i.e. initiate an exchange of F-CLOSE primitives) or may issue an F-READ or F-WRITE request (as specified by the process **ConsecutiveIdle**). This point in the specification represents the data transfer idle state for consecutive access. *)

```
( ConsecutiveIdle[Iin, Iout] (functionalUnits, maxRequests)
```

```
[])
```

```
    exit
```

```
)
```

```
endproc (* ConsecutiveIdle*)
```

Figure 22 - (continued) Initiator service definition

```

(*
process ConcurrentIdle

This process specifies the allowed behaviour when concurrent overlapped access is in use. This point represents the
completion of the exchange of F-OPEN primitives.
*)

process ConcurrentIdle[Iin,Iout] (functionalUnits:FUnits,maxRequests:Nat) :exit:=

(* The file service user may issue an F-READ or F-WRITE request. *)

Iin?fsp:FSPrim?tn:Nat[ ((isAvailableRead(functionalUnits) and isReadReq(fsp)) or (isAvailableWrite(functionalUnits)
and isWriteReq(fsp))) and (tn eq Succ(0))];

(
(* The request for a data transfer becomes the current read or write data transfer as appropriate. Read data transfers will be performed concurrently
with any write data transfers that are subsequently requested. *)

( ( [isAvailableRead(functionalUnits) and isReadReq(fsp)]->
  Read[Iin,Iout] (concurrent,functionalUnits,maxRequests,tn,makeEl (fsp,tn),tn,empty,empty,empty)

  >>    ReadIdle[Iin,Iout] (functionalUnits,maxRequests)
)
[]

( [isAvailableWrite(functionalUnits) and isWriteReq(fsp)]->
  Write[Iin,Iout] (concurrent,functionalUnits,maxRequests,tn,makeEl (fsp,tn),tn,empty,empty,empty)

  >>    WriteIdle[Iin,Iout] (functionalUnits,maxRequests)
)
)
)

|||

(* The file service user may issue an F-READ or F-WRITE request depending on the type of the data transfer that was first requested. *)

( [isAvailableWrite(functionalUnits) and isReadReq(fsp)]->
  WriteIdle[Iin,Iout] (functionalUnits,maxRequests)

[]

[isAvailableRead(functionalUnits) and isWriteReq(fsp)]->
  ReadIdle[Iin,Iout] (functionalUnits,maxRequests)
)
)

>>

(* The file service user has the opportunity to exit the specification. Alternatively, further data transfers may be requested, as specified by process
ConcurrentIdle. This represents the data transfer idle state. *)

( ConcurrentIdle[Iin,Iout] (functionalUnits,maxRequests)

[]

```

Figure 22 (continued) - Initiator service definition

```

        exit
    )
where
(*
process ReadIdle
This process specifies the behaviour for the progress of read data transfers.
*)
process ReadIdle[Iin, Iout] (functionalUnits:FUnits, maxRequests:Nat) :exit:=
(* The file service user may issue an F-READ request, this request will become the current read data transfer. *)
( Iin?fsp:FSPrim?tn:Nat[isReadReq(fsp) and (tn eq Succ(0))];
  Read[Iin, Iout]
  (concurrent, functionalUnits, maxRequests, tn, makeEl(fsp, tn), tn, empty, empty, empty)

>> ReadIdle[Iin, Iout] (functionalUnits, maxRequests)
)

[]

exit

andproc (*ReadIdle*)
(*
process WriteIdle
The process specifies the behaviour for the progress of write data transfers.
*)
process WriteIdle[Iin, Iout] (functionalUnits:FUnits, maxRequests:Nat) :exit:=
(* The file service user may issue an F-WRITE request, this request will become the current write data transfer. *)
( Iin?fsp:FSPrim?tn:Nat[isWriteReq(fsp) and (tn eq Succ(0))];
  Write[Iin, Iout] (concurrent, functionalUnits, maxRequests, tn, makeEl(fsp, tn), tn, empty, empty, empty)

>> WriteIdle[Iin, Iout] (functionalUnits, maxRequests)
)

[]

exit

andproc (*WriteIdle*)

andproc (*ConcurrentIdle*)
*)

```

Figure 22 - (continued) Initiator service definition

process Read

This process specifies the behaviour for the current read data transfer in the case where there are no outstanding requests on the requestQ.

*)

```
process Read[Iin, Iout]
    (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
     current:Element, reqOutstanding:Nat, reqQ, dataEndQ, xfrEndQ:Queue) :exit:=
```

(* An F-DATA indication may be issued to the file service user. *)

```
Iout?fsp:FSPrim[isDataInd(fsp)];
Read[Iin, Iout]
    (degree, functionalUnits, maxRequests, tnCounter, current, reqOutstanding, reqQ, dataEndQ, xfrEndQ)
```

[]

(* An F-DATA-END indication may be issued to the file service user. The type and transfer number of the current read data transfer is added to the dataEndQ. *)

```
Iout?fsp:FSPrim[isDataEndInd(fsp)];
ReadDataXfrIdle[Iin, Iout]
    (degree, functionalUnits, maxRequests, tnCounter,
     nullEl, reqOutstanding, reqQ, add(current, dataEndQ), xfrEndQ)
```

[]

(* If overlapped access is in use and the number of outstanding requests has not exceeded the maximum, then the file service user may issue an F-READ request. If consecutive access is in use and the Write functional unit has been negotiated then the file service user may issue an F-WRITE request. The type and transfer number of the request is added to the requestQ and the number of outstanding requests is incremented. The subsequent behaviour is dependant on the type of the request. *)

```
[not(isNormal(degree)) and (reqOutstanding lt maxRequests)]->
( Iin?fsp:FSPrim?tn:Nat[isReadReq(fsp) and (tn eq (tnCounter+Succ(0)))]);
ReadRead[Iin, Iout]
    (degree, functionalUnits, maxRequests, tn,
     current, Succ(reqOutstanding), add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)
```

[]

```
[isAvailableWrite(functionalUnits) and isConsecutive(degree)]->
Iin?fsp:FSPrim?tn:Nat[isWriteReq(fsp) and (tn eq (tnCounter+Succ(0)))]);
ReadWrite[Iin, Iout]
    (degree, functionalUnits, maxRequests, tn,
     current, Succ(reqOutstanding), add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)
```

)

[]

(* The file service user may issue an F-TRANSFER-END request for the data transfer at the head of the dataEndQ. The data transfer is removed from the dataEndQ and added to the xfrEndQ. *)

```
[not(isEmpty(dataEndQ))]->
Iin?fsp:FSPrim?tn:Nat[isXfrEndReadReq(fsp) and (tn eq number(head(dataEndQ)))]);
Read[Iin, Iout]
```

Figure 22 (continued) - Initiator service definition

```

(degree, functionalUnits, maxRequests, tnCounter,
current, reqOutstanding, reqQ, tailOf (dataEndQ), add (head (dataEndQ), xfrEndQ))

[]

(* An F-TRANSFER-END confirm may be issued to the file service user for the data transfer at the head of the xfrEndQ. The data transfer is removed
from the xfrEndQ. *)

[not (isEmpty (xfrEndQ)) ]->
Iout?fsp:FSPrim?tn:Nat [isXfrEndReadConf (fsp) and (tn eq number (head (xfrEndQ)))];
Read [Iin, Iout]
(degree, functionalUnits, maxRequests, tnCounter,
current, pred (reqOutstanding), reqQ, dataEndQ, tailOf (xfrEndQ))

[]

(* The initiating file service user may issue an F-CANCEL request for the data transfer at the head of the dataEndQ. If this is empty then the file
service user may issue an F-CANCEL request for the current data transfer. If the dataEndQ is empty then an F-CANCEL indication may be issued
to the file service user for the current data transfer. *)

Interrupt [Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

endproc (* Read *)

(*
process ReadRead

This process specifies the behaviour in the case where the current transfer is a read and the next requested data transfer
is also a read. The behaviour is only allowed if consecutive or concurrent access is in use. *)

process ReadRead [Iin, Iout] (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
current:Element, reqOutstanding:Nat, reqQ, dataEndQ, xfrEndQ:Queue) :exit:=

(* An F-DATA indication may be issued to the file service user for the current data transfer. *)

Iout?fsp:FSPrim [isDataInd (fsp)];
ReadRead [Iin, Iout]
(degree, functionalUnits, maxRequests, tnCounter, current, reqOutstanding, reqQ, dataEndQ, xfrEndQ)

[]

(* An F-DATA-END indication may be issued to the file service user for the current data transfer. The current data transfer is added to the
dataEndQ; the request at the head of the dataEndQ becomes the current data transfer. The subsequent behaviour is determined on the basis
of the request that will now be at the head of the requestQ. *)

Iout?fsp:FSPrim [isDataEndInd (fsp)];
([isWriteReq (prim (head (tailOf (reqQ)))))]->
ReadWrite [Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
head (reqQ), reqOutstanding, tailOf (reqQ), add (current, dataEndQ), xfrEndQ)

[]

[isReadReq (prim (head (tailOf (reqQ))))]->
ReadRead [Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
head (reqQ), reqOutstanding, tailOf (reqQ), add (current, dataEndQ), xfrEndQ)

```

Figure 22 - (continued) Initiator service definition

```

[]

[isEmpty(tailOf(reqQ))]->
Read[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
  head(reqQ), reqOutstanding, tailOf(reqQ), add(current, dataEndQ), xfrEndQ)
)

[]

(* Further requests for read data transfers may be requested if the number of requests outstanding does not exceed the maximum. Write requests may
also be requested only if consecutive access is in use and the write functional unit is available. The type and transfer number of the request is added
to the requestQ*)

[reqOutstanding lt maxRequests] ->
(Iin?fsp:FSPrim?tn:Nat[isReadReq(fsp) and (tn eq (tnCounter+ Succ(0))]);
  ReadRead[Iin, Iout]
  (degree, functionalUnits, maxRequests, tn,
  current, Succ(reqOutstanding), add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)

[]

[isAvailableWrite(functionalUnits) and isConsecutive(degree)]->
Iin?fsp:FSPrim?tn:Nat[isWriteReq(fsp) and (tn eq (tnCounter+ Succ(0))]);
  ReadRead[Iin, Iout]
  (degree, functionalUnits, maxRequests, tn,
  current, Succ(reqOutstanding), add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)
)

[]

(* The file service user may issue an F-TRANSFER-END request for the data transfer at the head of the dataEndQ. The head of the dataEndQ
is removed and added to the xfrEndQ. *)

[not(isEmpty(dataEndQ))]->
Iin?fsp:FSPrim?tn:Nat[isXfrEndReadReq(fsp) and (tn eq number(head(dataEndQ))]);
  ReadRead[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
  current, reqOutstanding, reqQ, tailOf(dataEndQ), add(head(dataEndQ), xfrEndQ))

[]

(* An F-TRANSFER-END confirm may be issued to the file service user for the data transfer at the head of the xfrEndQ. The head of the xfrEndQ
is removed. *)

[not(isEmpty(xfrEndQ))]->
Iout?fsp:FSPrim?tn:Nat[isXfrEndReadConf(fsp) and (tn eq number(head(xfrEndQ))]);
  ReadRead[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
  current, pred(reqOutstanding), reqQ, dataEndQ, tailOf(xfrEndQ))

[]

(* The initiating file service user may issue an F-CANCEL for the data transfer at the head of the dataEndQ. If this is empty then the file service user
may issue an F-CANCEL request for the current read data transfer. If the dataEndQ is empty then an F-CANCEL indication may be issued to the
file service user for the current read data transfer. *)

```

Figure 22 (continued) - Initiator service definition

```

Interrupt[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

endproc (* ReadRead *)

(*
process ReadWrite

This process specifies the behaviour in the case where the current transfer is a read and the next requested data transfer
is a write. The behaviour is only allowed if consecutive access is in use. *)

process ReadWrite[Iin, Iout] (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
    current:Element, reqOutstanding:Nat, reqQ, dataEndQ, xfrEndQ:Queue) :exit:=

[not(isNullEl(current))]->

(* An F-DATA indication may issued to the file service user for the current data transfer. *)

( Iout?fsp:FSPrim[isDataInd(fsp)];
  ReadWrite[Iin, Iout]
  (degree, functionalUnits, maxRequests, tnCounter, current, reqOutstanding, reqQ, dataEndQ, xfrEndQ)

[]

(* An F-DATA-END indication may be issued to the file service user for the current read data transfer. The current read data transfer is added to
the dataEndQ and the current data transfer becomes null. *)

Iout?fsp:FSPrim[isDataEndInd(fsp)];
ReadWrite[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
  nullEl, reqOutstanding, reqQ, add(current, dataEndQ), xfrEndQ)
)

[]

(* The file service user may issue an F-TRANSFER-END request for the (read) data transfer that is at the head of the dataEndQ. The head of the
dataEndQ is removed and added to the xfrEndQ.

If the dataEndQ is empty and there is no current data transfer, then the head of the requestQ becomes the current data transfer. The
subsequent behaviour is determined on the basis of the type of the request that is now at the head of the requestQ. If however, there is a current
data transfer, or the dataEndQ is not empty, then the behaviour is specified by process ReadWrite.)

[not(isEmpty(dataEndQ))]->
Iin?fsp:FSPrim?tn:Nat[isXfrEndReadReq(fsp) and (tn eq number(head(dataEndQ)))];
( [isEmpty(tailOf(dataEndQ)) and isNullEl(current)]->
  ([isReadReq(prim(head(tailOf(reqQ))))]->
    WriteRead[Iin, Iout]
    (degree, functionalUnits, maxRequests, tnCounter,
      head(reqQ), reqOutstanding, tailOf(reqQ), tailOf(dataEndQ), add(head(dataEndQ), xfrEndQ))

    []

    [isWriteReq(prim(head(tailOf(reqQ))))]->
      WriteWrite[Iin, Iout]
      (degree, functionalUnits, maxRequests, tnCounter,
        head(reqQ), reqOutstanding, tailOf(reqQ), tailOf(dataEndQ), add(head(dataEndQ), xfrEndQ))

```

Figure 22 - (continued) Initiator service definition

```

[]

[isEmpty(tailOf(reqQ))]->
  Write[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
    head(reqQ), reqOutstanding, tailOf(reqQ), tailOf(dataEndQ), add(head(dataEndQ), xfrEndQ))
)

[]

[not(isEmpty(tailOf(dataEndQ))) or not(isNullEl(current))]->
  ReadWrite[Iin, Iout]
  (degree, functionalUnits, maxRequests, tnCounter,
  current, reqOutstanding, reqQ, tailOf(dataEndQ), add(head(dataEndQ), xfrEndQ))
)

[]

(* The file service user may issue an F-WRITE or F-READ request. The type and transfer number of the request is added to the requestQ *)

[reqOutstanding lt maxRequests]->
  Iin?fsp:FSPrim?tn:Nat[(isReadReq(fsp) or isWriteReq(fsp)) and (tn eq (tnCounter+Succ(0)))];
  ReadWrite[Iin, Iout]
  (degree, functionalUnits, maxRequests, tn,
  current, Succ(reqOutstanding), add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)

[]

(* An F-TRANSFER-END confirm may be issued to the file service user for the data transfer at the head of the xfrEndQ. The head of the xfrEndQ is
then removed. *)

[not(isEmpty(xfrEndQ))]->
  Iout?fsp:FSPrim?tn:Nat[isXfrEndReadConf(fsp) and (tn eq number(head(xfrEndQ)))];
  ReadWrite[Iin, Iout]
  (degree, functionalUnits, maxRequests, tnCounter,
  current, pred(reqOutstanding), reqQ, dataEndQ, tailOf(xfrEndQ))

[]

(* If the dataEndQ is empty then the file service user may issue an F-CANCEL request for the current read data transfer and an F-CANCEL
indication may be issued to the file service user for the current read data transfer. If the dataEndQ is not empty then the file service user may issue
an F-CANCEL request for the read data transfer at the head of the dataEndQ. *)

Interrupt[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

endproc (* ReadWrite *)

(*
process ReadDataXfrIdle

The process specifies the behaviour where there are no data transfer requests on the requestQ and there is no current data
transfer in progress. *)

process ReadDataXfrIdle[Iin, Iout] (degree:Overlap, functionalUnits:FUnits,
  maxRequests, tnCounter:Nat, current:Element, reqOutstanding:Nat, reqQ, dataEndQ,

```

Figure 22 (continued) - Initiator service definition

```

xfrEndQ:Queue) :exit:=

(* The file service user may issue an F-TRANSFER-END request for the (read) data transfer at the head of the dataEndQ. The head of the
dataEndQ is removed and added to the xfrEndQ. The subsequent behaviour is dependant on whether the dataEndQ is empty. *)

Iin?fsp:FSPrim?tn:Nat[isXfrEndReadReq(fsp) and (tn eq number(head(dataEndQ)))]);
( [isEmpty(tailOf(dataEndQ))] )->
  ReadXfrEndIdle[Iin, Iout]
  (degree, functionalUnits, maxRequests, tnCounter,
  current, reqOutstanding, reqQ, tailOf(dataEndQ), add(head(dataEndQ), xfrEndQ))

[]

[not(isEmpty(tailOf(dataEndQ)))]->
  ReadDataXfrIdle[Iin, Iout]
  (degree, functionalUnits, maxRequests, tnCounter,
  current, reqOutstanding, reqQ, tailOf(dataEndQ), add(head(dataEndQ), xfrEndQ))
)
[]

(* If overlapped access is in use then the file service user may issue an F-READ request. If consecutive access is in use then the user may issue an
F-WRITE request. A request for a read data transfer will become the current data transfer with subsequent behaviour specified in process Read
a request for a write data transfer is added to the requestQ and subsequent behaviour is specified by process ReadWrite. *)

[not(isNormal(degree)) and (reqOutstanding lt maxRequests)]->
( Iin?fsp:FSPrim?tn:Nat[isReadReq(fsp) and (tn eq (tnCounter+Succ(0)))]);
  Read[Iin, Iout]
  (degree, functionalUnits, maxRequests, tn,
  makeEl(fsp, tn), Succ(reqOutstanding), reqQ, dataEndQ, xfrEndQ)

[]

[isAvailableWrite(functionalUnits) and isConsecutive(degree)]->
Iin?fsp:FSPrim?tn:Nat[isWriteReq(fsp) and (tn eq (tnCounter+Succ(0)))]);
  ReadWrite[Iin, Iout]
  (degree, functionalUnits, maxRequests, tn,
  current, reqOutstanding, add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)
)
[]

(* An F-TRANSFER-END confirm may be issued to the file service user for the data transfer at the head of the xfrEndQ. The data transfer is removed
from the head of the xfrEndQ. *)

[not(isEmpty(xfrEndQ))]->
Iout?fsp:FSPrim?tn:Nat[isXfrEndReadConf(fsp) and (tn eq number(head(xfrEndQ)))]);
  ReadDataXfrIdle[Iin, Iout]
  (degree, functionalUnits, maxRequests, tnCounter,
  current, pred(reqOutstanding), reqQ, dataEndQ, tailOf(xfrEndQ))

[]

(* The file service user may issue an F-CANCEL request for the read data transfer at the head of the dataEndQ. *)

```

Figure 22 - (continued) Initiator service definition

```

Interrupt [Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

andproc (* ReadDataXfrIdle *)

(*
process ReadXfrEndIdle

The process specifies the behaviour when there is no current data transfer and the dataEndQ is empty. *)

process ReadXfrEndIdle [Iin, Iout]
    (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
    current:Element, reqOutstanding:Nat, reqQ, dataEndQ, xfrEndQ:Queue) :exit:=

(* An F-TRANSFER-END confirm may be issued to the file service user for the data transfer at the head of the xfrEndQ. The data transfer is removed
from the xfrEndQ. If the xfrEndQ is empty then the process may exit. *)

Iout?fsp:FSPrim?tn:Nat [isXfrEndReadConf (fsp) and (tn eq number(head(xfrEndQ)))];
([isEmpty(tailOf(xfrEndQ))]->
    exit

[]

[not(isEmpty(tailOf(xfrEndQ)))]->
    ReadXfrEndIdle [Iin, Iout]
    (degree, functionalUnits, maxRequests, tnCounter,
    nullEl, pred(reqOutstanding), empty, empty, tailOf(xfrEndQ))
)

[]

(* If overlapped access is in use then the file service user may issue an F-READ request. If consecutive access is in use then the user may issue an
F-WRITE request. A request for a read or write data transfer will become the current data transfer. The subsequent behaviour is dependant on the
type of the request. *)

[not(isNormal(degree)) and (reqOutstanding lt maxRequests)]->
(Iin?fsp:FSPrim?tn:Nat [isReadReq(fsp) and (tn eq (tnCounter+Succ(0))]);
    Read [Iin, Iout]
    (degree, functionalUnits, maxRequests, tn,
    makeEl (fsp, tn), Succ(reqOutstanding), reqQ, dataEndQ, xfrEndQ)

[]

[isAvailableWrite(functionalUnits) and isConsecutive(degree)]->
Iin?fsp:FSPrim?tn:Nat [isWriteReq(fsp) and (tn eq (tnCounter+Succ(0))]);
    Write [Iin, Iout]
    (degree, functionalUnits, maxRequests, tn,
    makeEl (fsp, tn), Succ(reqOutstanding), reqQ, dataEndQ, xfrEndQ)
)

andproc (* ReadXfrEndIdle *)

(*
process Write

```

Figure 22 (continued) - Initiator service definition

This process specifies the behaviour for the current write data transfer in the case where there are no outstanding requests on the requestQ.

```

*)
process Write[Iin, Iout]
    (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
     current:Element, reqOutstanding:Nat, reqQ, dataEndQ, xfrEndQ:Queue) :exit:=

[not(isNullEl(current))]->

(* The file service user may issue an F-DATA request. *)

(Iin?fsp:FSPrim[isDataReq(fsp)]);
  Write[Iin, Iout]
  (degree, functionalUnits, maxRequests, tnCounter, current, reqOutstanding, reqQ, dataEndQ, xfrEndQ)

[]

(* The file service user may issue an F-DATA-END request. The current data transfer is added to the dataEndQ and the current data transfer becomes null. *)

Iin?fsp:FSPrim[isDataEndReq(fsp)];
  Write[Iin, Iout]
  (degree, functionalUnits, maxRequests, tnCounter,
   nullEl, reqOutstanding, reqQ, add(current, dataEndQ), xfrEndQ)
)

[]

(* The file service user may issue an F-TRANSFER-END request for the (write) data transfer at the head of the dataEndQ. The data transfer is removed from the dataEndQ and added to the xfrEndQ. *)

[not(isEmpty(dataEndQ))]->
Iin?fsp:FSPrim?tn:Nat[isXfrEndWriteReq(fsp) and (tn eq number(head(dataEndQ)))]);
  WriteDataXfrIdle[Iin, Iout]
  (degree, functionalUnits, maxRequests, tnCounter,
   current, reqOutstanding, reqQ, tailOf(dataEndQ), add(head(dataEndQ), xfrEndQ))

[]

(* If overlapped access is in use and the number of outstanding requests has not exceeded the maximum, then the file service user may issue an F-Write request. If consecutive access is in use and the Write functional unit has been negotiated then the file service user may issue an F-READ request. The type and transfer number of the request is added to the requestQ, and the number of outstanding requests is incremented. The subsequent behaviour is dependant on the type of the request. *)

[not(isNormal(degree)) and (reqOutstanding lt maxRequests)]->
([isAvailableRead(functionalUnits) and isConsecutive(degree)]->
Iin?fsp:FSPrim?tn:Nat[isReadReq(fsp) and (tn eq (tnCounter+Succ(0)))]);
  WriteRead[Iin, Iout]
  (degree, functionalUnits, maxRequests, tn,
   current, Succ(reqOutstanding), add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)

[]

Iin?fsp:FSPrim?tn:Nat[isWriteReq(fsp) and (tn eq (tnCounter+Succ(0)))]);
  WriteWrite[Iin, Iout]

```

Figure 22 - (continued) Initiator service definition

```

(degree, functionalUnits, maxRequests, tn,
current, Succ(reqOutstanding), add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)
)
[]

(* An F-TRANSFER-END confirm may be issued to the file service user for the data transfer at the head of the xfrEndQ. The data transfer is removed
from the xfrEndQ. *)

[not(isEmpty(xfrEndQ))]->
Iout?fsp:FSPrim?tn:Nat[((isXfrEndReadConf(fsp) and isReadReq(prim(head(xfrEndQ))))
or (isXfrEndWriteConf(fsp) and isWriteReq(prim(head(xfrEndQ))))
and (tn eq number(head(xfrEndQ))))];
Write[Iin, Iout]
(degree, functionalUnits, maxRequests, tnCounter,
current, pred(reqOutstanding), reqQ, dataEndQ, tailOf(xfrEndQ))
[]

(* The file service user may issue an F-CANCEL request for the current write data transfer. An F-CANCEL request may be issued to the file service
user for the first write data transfer on the xfrEndQ. If there is no write data transfer on the xfrEndQ then an F-CANCEL request may be issued to
the file service user for the data transfer at the head of the dataEndQ, or if this is empty, the current data transfer. *)

Interrupt[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

endproc (* Write *)

(*
process WriteWrite

This process specifies the behaviour in the case where the current data transfer is a write and the next requested data transfer
is also a write. The behaviour is only allowed if consecutive or concurrent access is in use. *)

process WriteWrite[Iin, Iout]
(degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
current:Element, reqOutstanding:Nat, reqQ, dataEndQ, xfrEndQ:Queue) :exit:=

[not(isNullEl(current))]->
(
(* The file service user may issue an F-DATA request for the current data transfer. *)

Iin?fsp:FSPrim[isDataReq(fsp)];
WriteWrite[Iin, Iout]
(degree, functionalUnits, maxRequests, tnCounter, current, reqOutstanding, reqQ, dataEndQ, xfrEndQ)

[]

(* The file service user may issue an F-DATA-END request for the current data transfer. The current data transfer is added to the dataEndQ and
the current data transfer becomes null. *)

Iin?fsp:FSPrim[isDataEndReq(fsp)];
WriteWrite[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
nullEl, reqOutstanding, reqQ, add(current, dataEndQ), xfrEndQ)
)

```

Figure 22 (continued) - Initiator service definition

[]

(* The file service user may issue an F-TRANSFER-END request for the data transfer at the head of the dataEndQ. The head of the dataEndQ is removed and added to the xfrEndQ. The subsequent behaviour is dependant on the request at the head of the requestQ; the current data transfer remains null. *)

```
[not (isEmpty (dataEndQ)) ]->
Iin?fsp:FSPrim?tn:Nat [isXfrEndWriteReq (fsp) and (tn eq number (head (dataEndQ)) )];
( [isEmpty (tailOf (reqQ)) ]->
  Write [Iin, Iout]
    (degree, functionalUnits, maxRequests, tnCounter,
     head (reqQ), reqOutstanding, tailOf (reqQ), tailOf (dataEndQ), add (head (dataEndQ), xfrEndQ))
  )
)
```

[]

```
[isReadReq (prim (head (tailOf (reqQ)) ) ) ]->
  WriteRead [Iin, Iout]
    (degree, functionalUnits, maxRequests, tnCounter,
     head (reqQ), reqOutstanding, tailOf (reqQ), tailOf (dataEndQ), add (head (dataEndQ), xfrEndQ))
  )
)
```

[]

```
[isWriteReq (prim (head (tailOf (reqQ)) ) ) ]->
  WriteWrite [Iin, Iout]
    (degree, functionalUnits, maxRequests, tnCounter,
     head (reqQ), reqOutstanding, tailOf (reqQ), tailOf (dataEndQ), add (head (dataEndQ), xfrEndQ))
  )
)
```

[]

(* Further requests for write data transfers may be requested if the number of requests outstanding does not exceed the maximum. Read requests may be requested only if consecutive access is in use and the read functional unit is available. The type and transfer number of the request is added to the requestQ *)

```
[reqOutstanding lt maxRequests ]->
( [isAvailableRead (functionalUnits) and isConsecutive (degree) ]->
  Iin?fsp:FSPrim?tn:Nat [isReadReq (fsp) and (tn eq (tnCounter+Succ (0)) )];
  WriteWrite [Iin, Iout]
    (degree, functionalUnits, maxRequests, tn,
     current, Succ (reqOutstanding), add (makeEl (fsp, tn), reqQ), dataEndQ, xfrEndQ)
  )
)
```

[]

```
Iin?fsp:FSPrim?tn:Nat [isWriteReq (fsp) and (tn eq (tnCounter+Succ (0)) )];
  WriteWrite [Iin, Iout]
    (degree, functionalUnits, maxRequests, tn,
     current, Succ (reqOutstanding), add (makeEl (fsp, tn), reqQ), dataEndQ, xfrEndQ)
  )
)
```

[]

(* An F-TRANSFER-END confirm may be issued to the file service user for the data transfer at the head of the xfrEndQ. The data transfer is removed

Figure 22 - (continued) Initiator service definition

```

from the xfrEndQ. *)

[not(isEmpty(xfrEndQ))]->
Iout?fsp:FSPrim?tn:Nat[ ((isXfrEndReadConf(fsp) and isReadReq(prim(head(xfrEndQ))))
or (isXfrEndWriteConf(fsp) and isWriteReq(prim(head(xfrEndQ))))
and (tn eq number(head(xfrEndQ))))];
WriteWrite[Iin, Iout]
(degree, functionalUnits, maxRequests, tnCounter,
current, pred(reqOutstanding), reqQ, dataEndQ, tailOf(xfrEndQ))

[]

(* The file service user may issue an F-CANCEL request for the current write data transfer. An F-CANCEL request may be issued to the file service
user for the first write data transfer on the xfrEndQ. If there is no write data transfer on the xfrEndQ then an F-CANCEL request may be issued to
the file service user for the data transfer at the head of the dataEndQ, or if this is empty, the current data transfer. *)

Interrupt[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

andproc (* WriteWrite *)

(*
process WriteRead

This process specifies the behaviour in the case where the current data transfer is a write and the next requested data transfer
on the requestQ is a read. *)

process WriteRead[Iin, Iout]
(degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
current:Element, reqOutstanding:Nat, reqQ, dataEndQ, xfrEndQ:Queue) :exit:=

[not(isNullEl(current))]->
(
(* The file service user may issue an F-DATA request. *)

Iin?fsp:FSPrim[isDataReq(fsp)];
WriteRead[Iin, Iout]
(degree, functionalUnits, maxRequests, tnCounter, current, reqOutstanding, reqQ, dataEndQ, xfrEndQ)

[]

(* The file service user may issue an F-DATA-END request for the current data transfer. The data transfer is added to the dataEndQ and the
current data transfer becomes null. *)

Iin?fsp:FSPrim[isDataEndReq(fsp)];
WriteRead[Iin, Iout]
(degree, functionalUnits, maxRequests, tnCounter,
nullEl, reqOutstanding, reqQ, add(current, dataEndQ), xfrEndQ)
)

[]

(* The file service user may issue an F-TRANSFER-END request for the data transfer at the head of the dataEndQ. The data transfer is removed
from the dataEndQ and added to the xfrEndQ. *)

```

Figure 22 (continued) - Initiator service definition

```

[not (isEmpty (dataEndQ))] ->
In?fsp:FSPrim?tn:Nat [isXfrEndWriteReq(fsp) and (tn eq number(head(dataEndQ)))]);
  WriteRead[Iin, Iout]
    (degree, functionalUnits, maxRequests, tnCounter,
     current, reqOutstanding, reqQ, tailOf (dataEndQ), add (head (dataEndQ), xfrEndQ))
[]

(* An F-TRANSFER-END confirm may be issued to the file service user for the data transfer at the head of the xfrEndQ. The data transfer is removed
from the xfrEndQ. If the xfrEndQ and the dataEndQ are empty, and the current data transfer is null, then the data transfer at the head of the
requestQ becomes the current data transfer and is removed from the requestQ; the subsequent behaviour is dependant on the type of the data
transfer that is now at the head of the requestQ. *)

[not (isEmpty (xfrEndQ))] ->
Iout?fsp:FSPrim?tn:Nat [(isXfrEndReadConf (fsp) and isReadReq (prim (head (xfrEndQ))))
or (isXfrEndWriteConf (fsp) and isWriteReq (prim (head (xfrEndQ))))
and (tn eq number (head (xfrEndQ)))]);
( [isEmpty (tailOf (xfrEndQ)) and isEmpty (dataEndQ) and isNullEl (current)] ->
  ( [isEmpty (tailOf (reqQ))] ->
    Read[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
      head (reqQ), pred (reqOutstanding), tailOf (reqQ), dataEndQ, tailOf (xfrEndQ))

    []

    [isReadReq (prim (head (tailOf (reqQ))))] ->
      ReadRead[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
        head (reqQ), pred (reqOutstanding), tailOf (reqQ), dataEndQ, tailOf (xfrEndQ))

      []

      [isWriteReq (prim (head (tailOf (reqQ))))] ->
        ReadWrite[Iin, Iout]
          (degree, functionalUnits, maxRequests, tnCounter,
           head (reqQ), pred (reqOutstanding), tailOf (reqQ), dataEndQ, tailOf (xfrEndQ))

        )

      []

      [not (isEmpty (tailOf (xfrEndQ))) or not (isEmpty (dataEndQ)) or not (isNullEl (current))] ->
        WriteRead[Iin, Iout]
          (degree, functionalUnits, maxRequests, tnCounter,
           current, pred (reqOutstanding), reqQ, dataEndQ, tailOf (xfrEndQ))

        )

      []

```

(* The file service user may issue an F-WRITE or F-READ request. The type and transfer number of the request is added to the requestQ. *)

```

[reqOutstanding lt maxRequests] ->
In?fsp:FSPrim?tn:Nat [(isReadReq (fsp) or isWriteReq (fsp)) and (tn eq (tnCounter+ Succ (0)))]);
  WriteRead[Iin, Iout]
    (degree, functionalUnits, maxRequests, tn,
     current, Succ (reqOutstanding), add (makeEl (fsp, tn), reqQ), dataEndQ, xfrEndQ)

```

Figure 22 - (continued) Initiator service definition

```

[]

(* The file service user may issue an F-CANCEL request for the current write data transfer. An F-CANCEL request may be issued to the file service
user for the first write data transfer on the xfrEndQ. If there is no write data transfer on the xfrEndQ then an F-CANCEL request may be issued to
the file service user for the data transfer at the head of the dataEndQ, or if this is empty, the current data transfer. *)

Interrupt[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

endproc (* WriteRead *)

(*
process WriteDataXfrIdle

This process specifies the behaviour when the current data transfer is null, the dataEndQ is empty and the xfrEndQ is not empty.
*)

process WriteDataXfrIdle[Iin, Iout]
  (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
   current:Element, reqOutstanding:Nat, reqQ, dataEndQ, xfrEndQ:Queue) :exit:-

(* An F-TRANSFER-END confirm may be issued to the file service user for the data transfer at the head of the xfrEndQ. The data transfer is removed
from the xfrEndQ. The subsequent behaviour is dependant on whether or not the xfrEndQ is now empty. *)

(( [isReadReq(prim(head(xfrEndQ)))]->
  Iout?fsp:FSPrim?tn:Nat[isXfrEndReadConf(fsp) and (tn eq number(head(xfrEndQ)))]);
  exit

[]

[isWriteReq(prim(head(xfrEndQ)))]->
  Iout?fsp:FSPrim?tn:Nat[isXfrEndWriteConf(fsp) and (tn eq number(head(xfrEndQ)))]);
  exit
)

>>

([isEmpty(tailOf(xfrEndQ))]->
  exit

[]

[not(isEmpty(tailOf(xfrEndQ)))]->
  WriteDataXfrIdle[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter,
  current, pred(reqOutstanding), reqQ, dataEndQ, tailOf(xfrEndQ))
)
)

[]

(* Further requests for write data transfers may be requested if consecutive or concurrent access is in use and the number of requests outstanding
does not exceed the maximum. Read requests may be requested only if consecutive access is in use and the read functional unit is available. The
subsequent behaviour is dependant on the type of the request. *)

[not(isNormal(degree)) and (reqOutstanding lt maxRequests)]->
([isAvailableRead(functionalUnits) and isConsecutive(degree)]->

```

Figure 22 (continued) - Initiator service definition

```

Iin?fsp:FSPrim?tn:Nat[isReadReq(fsp) and (tn eq (tnCounter+ Succ(0)))];
  WriteRead[Iin, Iout]
    (degree, functionalUnits, maxRequests, tn,
     current, Succ(reqOutstanding), add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)

[]

Iin?fsp:FSPrim?tn:Nat[isWriteReq(fsp) and (tn eq (tnCounter+ Succ(0)))];
  Write[Iin, Iout]
    (degree, functionalUnits, maxRequests, tn,
     makeEl(fsp, tn), Succ(reqOutstanding), reqQ, dataEndQ, xfrEndQ)
)

[]

(* An F-CANCEL indication may be issued to the file service user for the first write request on the xfrEndQ. *)

Interrupt[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

endproc (* WriteDataXfrIdle *)

(*
process Interrupt

This process specifies the behaviour when a data transfer request is cancelled. *)

process Interrupt[Iin, Iout]
  (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
   current:Element, dataEndQ, xfrEndQ:Queue) :exit:-

  InitiatorCancel[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

[]

  ResponderCancel[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

where

(*
process InitiatorCancel

This process specifies the predicates and behaviour for the cancellation of a data transfer by the initiating file service user. *)

process InitiatorCancel[Iin, Iout]
  (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
   current:Element, dataEndQ, xfrEndQ:Queue) :exit:-

[isAvailableRead(functionalUnits)]->
  ReadCancel[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

[]

[isAvailableWrite(functionalUnits)]->

```

Figure 22 - (continued) Initiator service definition

```

WriteCancel[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

where

(*
process ReadCancel

This process specifies the predicates and the behaviour for the cancellation of a read data transfer by the file service user.
*)

process ReadCancel [Iin, Iout] (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
    current:Element, dataEndQ, xfrEndQ:Queue) :exit:=

(* The file service user may issue an F-CANCEL request for the read data transfer at the head of the dataEndQ. *)

[isReadReq(prim(head(dataEndQ)))]->
Iin?fsp:FSPrim?tn:Nat[isCancelReadReq(fsp) and (tn eq number(head(dataEndQ)))];
CancelPending[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, makeEl (fsp, tn), xfrEndQ)

[]

(* The file service user may issue an F-CANCEL request for the current data transfer if the dataEndQ is empty. *)

[isEmpty(dataEndQ) and isReadReq(prim(current))]->
Iin?fsp:FSPrim?tn:Nat[isCancelReadReq(fsp) and (tn eq number(current))];
CancelPending[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, makeEl (fsp, tn), xfrEndQ)

endproc (* ReadCancel *)

(*
process WriteCancel

This process specifies the predicates and the behaviour for the cancellation of a write data transfer by the file service user.
*)

process WriteCancel [Iin, Iout]
    (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
    current:Element, dataEndQ, xfrEndQ:Queue) :exit:=

(* The file service user may issue an F-CANCEL request for the current write data transfer if the xfrEndQ is empty. *)

[isEmpty(xfrEndQ) and isWriteReq(prim(current))]->
Iin?fsp:FSPrim?tn:Nat[isCancelWriteReq(fsp) and (tn eq number(current))];
CancelPending[Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, makeEl (fsp, tn), xfrEndQ)

endproc (* WriteCancel *)

(*
process CancelPending

This process specifies the completion of a data transfer cancellation.
*)

process CancelPending [Iin, Iout]

```

Figure 22 (continued) - Initiator service definition

```

        (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
        cancelData:Element, xfrEndQ:Queue) :exit:=

(* An F-CANCEL confirm may be issued for the data transfer that is being cancelled. *)

( [isCancelReadReq(prim(cancelData))]->
  Iout?fsp:FSPrim?tn:Nat[isCancelReadConf(fsp) and (tn eq number(cancelData))];
  exit

  []

  [isCancelWriteReq(prim(cancelData))]->
  Iout?fsp:FSPrim?tn:Nat[isCancelWriteConf(fsp) and (tn eq number(cancelData))];
  exit
)

>>

(* If there are any data transfers on the xfrEndQ then these will be read data transfers, subsequent behaviour is therefore as specified in process
ReadXfrEndIdle, otherwise the file service user may exit the specification. *)

( [isEmpty(xfrEndQ)]->
  exit

  []

  [not(isEmpty(xfrEndQ))]->
    ReadXfrEndIdle[Iin, Iout]
    (degree, functionalUnits, maxRequests, tnCounter, nullEl, 0, empty, empty, xfrEndQ)
  )

andproc (* CancelPending *)

andproc (* InitiatorCancel *)

(*
process ResponderCancel

This process specifies the predicates and behaviour for the cancellation of a data transfer by the responding file service user.
*)

process ResponderCancel [Iin, Iout]
  (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
  current:Element, dataEndQ, xfrEndQ:Queue) :exit:=

[isAvailableRead(functionalUnits)]->
ReadCancel [Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

[]

[isAvailableWrite(functionalUnits)]->
WriteCancel [Iin, Iout] (degree, functionalUnits, maxRequests, tnCounter, current, dataEndQ, xfrEndQ)

where

```

Figure 22 - (continued) Initiator service definition

```

(*
process ReadCancel

This process specifies the predicates and the behaviour for the cancellation of a read data transfer by the responding file
service user. *)

process ReadCancel[Iin,Iout]
  (degree:Overlap,functionalUnits:FUnits,maxRequests,tnCounter:Nat,
   current:Element,dataEndQ,xfrEndQ:Queue) :exit:=

(* An F-CANCEL indication may be issued to the file service user for the current data transfer if the dataEndQ is empty. *)

[isEmpty(dataEndQ) and isReadReq(prim(current))]->
Iout?fsp:FSPrim?tn:Nat[isCancelReadInd(fsp) and (tn eq number(current))];
CancelPending[Iin,Iout](degree,functionalUnits,maxRequests,tnCounter,makeEl(fsp,tn),xfrEndQ)

andproc (* ReadCancel *)

(*
process WriteCancel

This process specifies the predicates and the behaviour for the cancellation of a write data transfer by the responding file
service user. *)

process WriteCancel[Iin,Iout](degree:Overlap,functionalUnits:FUnits,maxRequests:Nat,
  tnCounter:Nat,current:Element,dataEndQ,xfrEndQ:Queue) :exit:=

(* If there are no write data transfers on the xfrEndQ then an F-CANCEL indication may be issued to the file service user for the current write data
transfer, if the dataEndQ is empty, or the write data transfer at the head of the dataEndQ. *)

[isNull(prim(firstWriteReq(xfrEndQ)))]->
( [isEmpty(dataEndQ) and isWriteReq(prim(current))]->
  Iout?fsp:FSPrim?tn:Nat[isCancelWriteInd(fsp) and (tn eq number(current))];
  CancelPending[Iin,Iout](degree,functionalUnits,maxRequests,tnCounter,makeEl(fsp,tn),xfrEndQ)

  []

  [isNullEl(current) and isWriteReq(prim(head(dataEndQ)))]->
  Iout?fsp:FSPrim?tn:Nat[isCancelWriteInd(fsp) and (tn eq number(head(dataEndQ)))]);
  CancelPending[Iin,Iout](degree,functionalUnits,maxRequests,tnCounter,makeEl(fsp,tn),xfrEndQ)
)

[]

(* An F-CANCEL indication may be issued to the file service user for the first write data transfer on the xfrEndQ. *)

[not(isNullEl(firstWriteReq(xfrEndQ)))]->
Iout?fsp:FSPrim?tn:Nat[isCancelWriteInd(fsp) and (tn eq number(firstWriteReq(xfrEndQ)))]);
CancelPending[Iin,Iout](degree,functionalUnits,maxRequests,tnCounter,makeEl(fsp,tn),removeReqs(xfrEndQ))

andproc (* WriteCancel *)

```

Figure 22 (continued) - Initiator service definition

```

process CancelPending

This process specifies the completion of a data transfer cancellation.
*)

process CancelPending[Iin, Iout]
    (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
     cancelData:Element, xfrEndQ:Queue) :exit:=

(* An F-CANCEL confirm may be issued for the data transfer that is being cancelled. *)

( [isCancelReadInd(prim(cancelData))] ->
  Iin?fsp:FSPrim?tn:Nat[isCancelReadResp(fsp) and (tn eq number(cancelData))];
  exit

[]

[isCancelWriteInd(prim(cancelData))] ->
  Iin?fsp:FSPrim?tn:Nat[isCancelWriteResp(fsp) and (tn eq number(cancelData))];
  exit
)

>>

(* If there are any data transfers on the xfrEndQ then these will be read data transfers, subsequent behaviour is therefore as specified in process
ReadXfrEndIdle, otherwise the file service user may exit the specification. *)

( [isEmpty(xfrEndQ)] ->
  exit

[]

[not(isEmpty(xfrEndQ))] ->
  ReadXfrEndIdle[Iin, Iout]
  (degree, functionalUnits, maxRequests, tnCounter,
   nullEl, size(xfrEndQ), empty, empty, removeLast(xfrEndQ))
)

endproc (* CancelPending *)

endproc (* ResponderCancel *)

endproc (* Interrupt *)

endproc (* Initiator_External_Service *)

```

Figure 22 - (continued) Initiator service definition

Specification

The specification Responder_External_Service specifies the sequence of service primitives in the external file service of the responder, for the duration of the bulk data transfer regime, for normal, consecutive and concurrent overlapped access.*)

```
Specification Responder_External_Service [Rout, Rin, Local] :exit
```

Data types

The specification imports the standard library definitions for the types Boolean and NaturalNumber, these are used to define the following types:

ExtendedNaturalNumber - this extends the definition of NaturalNumber to include the operation **pred**, which decrements a parameter of type Nat.

FileServicePrimitives - values are defined to represent the file service primitives. Boolean operations are defined that identify a particular primitive e.g. **IsDataEndInd**(transferEndInd)=false.

RequestQueue, QueueElement - a queue is defined with operations: **empty** (creates an empty queue), **add** (adds an element to the queue), **tail** (removes the first element on the queue), **head** (returns the value of the first element on the queue), **last** (returns the value of the last element on the queue), **isEmpty** (determines whether the queue is empty), **removeLast** (removes the last element on the queue), **size** (determines the number of elements on the queue), **firstWriteInd** (finds the first write request on a queue), **removeReqs** (removes all elements from the end of a queue, up to and including the first write request on the queue) and **reverse** (reverses the order of the elements on the queue). The elements of the queue are comprised of a file service primitive and it's transfer number.

Note - the firstWriteInd and removeReqs operations are required to support the cancellation of a write data transfer after the receipt of an F-TRANSFER-END indication by the responder. Equivalent operations are not required for read data transfer operations.

DegreeOfOverlap - values are defined for **normal**, **consecutive** and **concurrent**; boolean operations are defined that identify a given value.

FunctionalUnits - values are defined to represent the selection of the **Read**, **Write** and the combination of the **Read & Write** functional units; boolean operations are defined that identify a given value.

*)

Library

```
Boolean, NaturalNumber

andlib

type ExtendedNaturalNumber is NaturalNumber
  opns pred: Nat -> Nat
  opns forall x:Nat
  ofsort Nat
    pred(0) = 0;
    pred(Succ(x)) = x;
endtype

type FileServicePrimitives is Boolean
  sorts FSPrim
  opns null,
```

Figure 23 - Responder service definition

```

readInd,
writeInd,
dataInd,
dataReq,
dataEndInd,
dataEndReq,
xfrEndReadInd,
xfrEndReadResp,
xfrEndWriteInd,
xfrEndWriteResp,
cancelReadInd,
cancelReadReq,
cancelReadConf,
cancelReadResp,
cancelWriteInd,
cancelWriteReq,
cancelWriteConf,
cancelWriteResp: -> FSPrim

Mp:          FSPrim -> Nat

isNull,
isReadInd,
isWriteInd,
isDataInd,
isDataReq,
isDataEndInd,
isDataEndReq,
isXfrEndReadInd,
isXfrEndReadResp,
isXfrEndWriteInd,
isXfrEndWriteResp,
isCancelReadInd,
isCancelReadReq,
isCancelReadConf,
isCancelReadResp,
isCancelWriteInd,
isCancelWriteReq,
isCancelWriteConf,
isCancelWriteResp: FSPrim -> Bool

acqs forall x,y,fsp:FSPrim

of sort Nat

Mp(readInd)          = 0;
Mp(writeInd)         = Succ(Mp(readInd));
Mp(dataInd)          = Succ(Mp(writeInd));
Mp(dataReq)          = Succ(Mp(dataInd));
Mp(dataEndInd)       = Succ(Mp(dataReq));
Mp(dataEndReq)       = Succ(Mp(dataEndInd));
Mp(xfrEndReadInd)    = Succ(Mp(dataEndReq));
Mp(xfrEndReadResp)   = Succ(Mp(xfrEndReadInd));
Mp(xfrEndWriteInd)   = Succ(Mp(xfrEndReadResp));
Mp(xfrEndWriteResp)  = Succ(Mp(xfrEndWriteInd));

```

Figure 23 (continued) - Responder service definition

```

Mp(cancelReadInd)      = Succ(Mp(xfrEndWriteResp));
Mp(cancelReadReq)     = Succ(Mp(cancelReadInd));
Mp(cancelReadConf)   = Succ(Mp(cancelReadReq));
Mp(cancelReadResp)   = Succ(Mp(cancelReadConf));
Mp(cancelWriteInd)   = Succ(Mp(cancelReadResp));
Mp(cancelWriteReq)   = Succ(Mp(cancelWriteInd));
Mp(cancelWriteConf)  = Succ(Mp(cancelWriteReq));
Mp(cancelWriteResp)  = Succ(Mp(cancelWriteConf));

```

ofsort Bool

```

isNull(fsp)           = Mp(fsp) eq Mp(null);
isReadInd(fsp)       = Mp(fsp) eq Mp(readInd);
isWriteInd(fsp)      = Mp(fsp) eq Mp(writeInd);
isDataInd(fsp)       = Mp(fsp) eq Mp(dataInd);
isDataReq(fsp)       = Mp(fsp) eq Mp(dataReq);
isDataEndInd(fsp)    = Mp(fsp) eq Mp(dataEndInd);
isDataEndReq(fsp)    = Mp(fsp) eq Mp(dataEndReq);
isXfrEndReadInd(fsp) = Mp(fsp) eq Mp(xfrEndReadInd);
isXfrEndWriteInd(fsp) = Mp(fsp) eq Mp(xfrEndWriteInd);
isXfrEndReadResp(fsp) = Mp(fsp) eq Mp(xfrEndReadResp);
isXfrEndWriteResp(fsp) = Mp(fsp) eq Mp(xfrEndWriteResp);
isCancelReadInd(fsp) = Mp(fsp) eq Mp(cancelReadInd);
isCancelReadReq(fsp) = Mp(fsp) eq Mp(cancelReadReq);
isCancelReadConf(fsp) = Mp(fsp) eq Mp(cancelReadConf);
isCancelReadResp(fsp) = Mp(fsp) eq Mp(cancelReadResp);
isCancelWriteInd(fsp) = Mp(fsp) eq Mp(cancelWriteInd);
isCancelWriteReq(fsp) = Mp(fsp) eq Mp(cancelWriteReq);
isCancelWriteConf(fsp) = Mp(fsp) eq Mp(cancelWriteConf);
isCancelWriteResp(fsp) = Mp(fsp) eq Mp(cancelWriteResp);

```

andtype

type QueueElement **is** FileServicePrimitives, Boolean, ExtendedNaturalNumber

sorts Element

```

opns nullEl: -> Element
      makeEl: FSPrim, Nat -> Element
      number: Element -> Nat
      prim: Element -> FSPrim
      isNullEl: Element -> Bool

```

eqns forall fsp:FSPrim, tn:Nat, q_el:Element

ofsort FSPrim

```

prim(makeEl(fsp, tn)) = fsp;
prim(nullEl) = null;

```

ofsort Nat

```

number(nullEl) = 0;
number(makeEl(fsp, tn)) = tn;

```

ofsort Bool

```

isNullEl(nullEl) = true;
isNullEl(q_el) = isNull(prim(q_el));

```

ofsort Element

```

makeEl(null, 0) = nullEl;

```

andtype

Figure 23 (continued) - Responder service definition

```

type RequestQueue is QueueElement, Boolean, ExtendedNaturalNumber

  sorts Queue
  ops empty:    -> Queue
      add: Element, Queue -> Queue
      tailOf: Queue -> Queue
      head: Queue -> Element
      last: Queue -> Element
      isEmpty: Queue -> Bool
      removeLast: Queue -> Queue
      size: Queue -> Nat
      firstWriteInd: Queue -> Element
      removeReqs: Queue -> Queue
      reverse: Queue -> Queue

  axms forall x, y: Element, q: Queue
  ofsort Element
    head(empty) = nullEl;
    head(add(x, empty)) = x;
    head(add(x, add(y, q))) = head(add(y, q));
    last(empty) = nullEl;
    last(add(x, empty)) = x;
    last(add(x, q)) = x;
    firstWriteInd(empty) = nullEl;
    isWriteInd(prim(head(q)))
      => firstWriteInd(q) = head(q);
    not(isWriteInd(prim(head(q))))
      => firstWriteInd(q) = firstWriteInd(tailOf(q))

  ofsort Queue
    tailOf(empty) = empty;
    tailOf(add(x, empty)) = empty;
    tailOf(add(x, q)) = add(x, tailOf(q));
    add(nullEl, q) = q;
    removeLast(empty) = empty;
    removeLast(add(x, q)) = q;
    removeReqs(empty) = empty;
    isWriteInd(prim(head(q)))
      => removeReqs(q) = empty;
    not(isWriteInd(prim(head(q))))
      => removeReqs(q) = reverse(add(head(q), removeReqs(tailOf(q))));

  ofsort Bool
    isEmpty(empty) = true;
    isEmpty(add(x, q)) = false;

  ofsort Nat
    size(empty) = 0;
    size(add(x, q)) = Succ(size(q));

endtype

type DegreeOfOverlap is Boolean

```

Figure 23 (continued) - Responder service definition

```

sorts Overlap
opns normal: -> Overlap
      consecutive: -> Overlap
      concurrent: -> Overlap
      isNormal: Overlap -> Bool
      isConsecutive: Overlap -> Bool
      isConcurrent: Overlap -> Bool

acns forall degree:Overlap
ofsort Bool
      isNormal(normal) = true;
      isNormal(consecutive) = false;
      isNormal(concurrent) = false;

      isConsecutive(normal) = false;
      isConsecutive(consecutive) = true;
      isConsecutive(concurrent) = false;

      isConcurrent(normal) = false;
      isConcurrent(consecutive) = false;
      isConcurrent(concurrent) = true;

andtype

type FunctionalUnits is Boolean
sorts FUnits
opns setRead: -> FUnits
      setWrite: -> FUnits
      setReadWrite: -> FUnits
      isAvailableRead: FUnits -> Bool
      isAvailableWrite: FUnits -> Bool

acns forall x:FUnits
ofsort Bool
      isAvailableRead(setRead) = true;
      isAvailableRead(setWrite) = false;
      isAvailableRead(setReadWrite) = true;

      isAvailableWrite(setRead) = false;
      isAvailableWrite(setWrite) = true;
      isAvailableWrite(setReadWrite) = true;

andtype

(*)
Behaviour

All events occur at the gates Rout, Rin or Local. Events at the gate Rin represent receipt of file service primitives by the file service provider; events at the gate Rout represent file service primitives that are issued by the file service user by the file service provider. The events at the gate Local establish the bounds on the behaviour of the file service i.e. the degree of overlap, the functional units available and, if overlapped access is allowed, the maximum number of request that may be outstanding.

The sequence of primitives allowed in the external file service is specified by the behaviour the process NormalIdle, ConsecutiveIdle or ConcurrentIdle (chosen on the basis of the degreeOfOverlap, established by an event at the gate Local).

```

Figure 23 (continued) - Responder service definition

```

)
behaviour

Local?degree:Overlap;
([isNormal(degree)]->
  Local?functionalUnits:FUnits;
  NormalIdle[Rout,Rin](functionalUnits)

[])

[isConsecutive(degree)]->
Local?functionalUnits:FUnits?maxRequests:Nat;
  ConsecutiveIdle[Rout,Rin](functionalUnits,maxRequests)

[])

[isConcurrent(degree)]->
Local?functionalUnits:FUnits?maxRequests:Nat;
  ConcurrentIdle[Rout,Rin](functionalUnits,maxRequests)
)

where

(*
process NormalIdle

This process specifies the allowed behaviour when overlapped access is not in use. This point represents the completion of
the exchange of F-OPEN primitives.
*)

process NormalIdle[Rout,Rin](functionalUnits:FUnits) :exit:=

(* If the appropriate functional unit is available, the file service user may receive an F-READ indication or an F-WRITE indication. The request
becomes the current data transfer. *)

([isAvailableRead(functionalUnits)]->
  Rout?fsp:FSPrim[isReadInd(fsp)];
  Read[Rout,Rin]
    (normal,functionalUnits,Succ(0),Succ(0),makeEl(fsp,Succ(0)),Succ(0),empty,empty,empty)

[])

[isAvailableWrite(functionalUnits)]->
  Rout?fsp:FSPrim[isWriteInd(fsp)];
  Write[Rout,Rin]
    (normal,functionalUnits,Succ(0),Succ(0),makeEl(fsp,Succ(0)),Succ(0),empty,empty,empty)
)
>>

(* Upon completion of the previous bulk data transfer the file service user may receive an F-READ or F-WRITE indication (as specified by the process
NormalIdle) or may exit the specification (i.e. initiate an exchange of F-CLOSE primitives). This point in the specification represents the data transfer
idle state. *)

```

Figure 23 (continued) - Responder service definition

```

    ( NormalIdle[Rout,Rin] (functionalUnits)

    []

    exit
    )

endproc (* NormalIdle*)

(*
process ConsecutiveIdle

This process specifies the allowed behaviour when consecutive overlapped access is in use. This point represents the
completion of the exchange of F-OPEN primitives.
*)

process ConsecutiveIdle[Rout,Rin] (functionalUnits:FUnits,maxRequests:Nat) :exit:=

(* If the appropriate functional unit is available, the file service user may receive an F-READ indication or an F-WRITE indication. The request
becomes the current data transfer. *)

( [isAvailableRead(functionalUnits)]->
  Rout?fsp:FSPrim?tn:Nat[isReadInd(fsp)];
  Read[Rout,Rin]
  (consecutive,functionalUnits,maxRequests,tn,makeEl(fsp,tn),tn,empty,empty,empty)

  []

  [isAvailableWrite(functionalUnits)]->
  Rout?fsp:FSPrim?tn:Nat[isWriteInd(fsp)];
  Write[Rout,Rin]
  (consecutive,functionalUnits,maxRequests,tn,makeEl(fsp,tn),tn,empty,empty,empty)
)
>>

(* Upon completion of all outstanding data transfers the file service user may exit the specification (i.e. initiate an exchange of F-CLOSE primitives)
or may receive an F-READ or F-WRITE indication (as specified by the process ConsecutiveIdle). This point in the specification represents the
data transfer idle state for consecutive access. *)

( ConsecutiveIdle[Rout,Rin] (functionalUnits,maxRequests)

  []

  exit

endproc (* ConsecutiveIdle*)

(*
process ConcurrentIdle

This process specifies the allowed behaviour when concurrent overlapped access is in use. This point represents the
completion of the exchange of F-OPEN primitives.

```

Figure 23 (continued) - Responder service definition

```

*)
process ConcurrentIdle[Rout,Rin] (functionalUnits:FUnits,maxRequests:Nat) :exit:=

(* The file service user may receive an F-READ or F-WRITE indication. *)

    Rout?fsp:FSPrim?tn:Nat[ ((isAvailableRead(functionalUnits) and isReadInd(fsp)) or
(isAvailableWrite(functionalUnits) and isWriteInd(fsp)))and (tn eq Succ(0))];

(

(* The request for a data transfer becomes the current read or write data transfer as appropriate. Read data transfers will be performed concurrently
with any write data transfers that are subsequently requested. *)

( ( [isAvailableRead(functionalUnits) and isReadInd(fsp)]->
    Read[Rout,Rin] (concurrent,functionalUnits,maxRequests,tn,makeEl (fsp,tn),tn,empty,empty,empty)

    >>    ReadIdle[Rout,Rin] (functionalUnits,maxRequests)
    )

    []

( [isAvailableWrite(functionalUnits) and isWriteInd(fsp)]->
    Write[Rout,Rin] (concurrent,functionalUnits,maxRequests,tn,makeEl (fsp,tn),tn,empty,empty,empty)

    >>    WriteIdle[Rout,Rin] (functionalUnits,maxRequests)
    )
)
)

|||

(* The file service user may receive an F-READ or F-WRITE indication depending on the type of the data transfer that was first requested. *)

( [isAvailableWrite(functionalUnits) and isReadInd(fsp)]->
    WriteIdle[Rout,Rin] (functionalUnits,maxRequests)

    []

    [isAvailableRead(functionalUnits) and isWriteInd(fsp)]->
    ReadIdle[Rout,Rin] (functionalUnits,maxRequests)
    )
)
)
>>

(* The file service user has the opportunity to exit the specification. Alternatively, further data transfers may be requested, as specified by process
ConcurrentIdle. This represents the data transfer idle state. *)

    ( ConcurrentIdle[Rout,Rin] (functionalUnits,maxRequests)

    []

    exit
    )

```

Figure 23 (continued) - Responder service definition

```

where

(*
process ReadIdle

This process specifies the behaviour for the progress of read data transfers.
*)

process ReadIdle[Rout,Rin] (functionalUnits:FUnits,maxRequests:Nat) :exit:=

(* The file service user may receive an F-READ indication, this request will become the current read data transfer. *)

( Rout?fsp:FSPrim?tn:Nat[isReadInd(fsp)] ;
  Read[Rout,Rin]
  (concurrent,functionalUnits,maxRequests,tn,makeEl(fsp,tn),tn,empty,empty,empty)

>> ReadIdle[Rout,Rin] (functionalUnits,maxRequests)
)

[]

exit

endproc (*ReadIdle*)

(*
process WriteIdle

The process specifies the behaviour for the progress of write data transfers.
*)

process WriteIdle[Rout,Rin] (functionalUnits:FUnits,maxRequests:Nat) :exit:=

(* The file service user may receive an F-WRITE indication, this request will become the current write data transfer. *)

( Rout?fsp:FSPrim?tn:Nat[isWriteInd(fsp)] ;
  Write[Rout,Rin] (concurrent,functionalUnits,maxRequests,tn,makeEl(fsp,tn),tn,empty,empty,empty)

>> WriteIdle[Rout,Rin] (functionalUnits,maxRequests)
)

[]

exit

endproc (*WriteIdle*)

endproc (*ConcurrentIdle*)

(*
process Read

This process specifies the behaviour for the current read data transfer in the case where there are no outstanding requests
on the requestQ.
*)

```

Figure 23 (continued) - Responder service definition

```

process Read[Rout,Rin]
    (degree:Overlap, functionalUnits:FUnits, maxRequests, tnCounter:Nat,
     current:Element, reqOutstanding:Nat, reqQ, dataEndQ, xfrEndQ:Queue) :exit:-

(* An F-DATA request may be issued by the file service user. *)

Rin?fsp:FSPrim[isDataReq(fsp)];
  Read[Rout,Rin]
    (degree, functionalUnits, maxRequests, tnCounter, current, reqOutstanding, reqQ, dataEndQ, xfrEndQ)

[]

(* An F-DATA-END request may be issued by the file service user. The type and transfer number of the current read data transfer is added to the
dataEndQ. *)

Rin?fsp:FSPrim[isDataEndReq(fsp)];
  ReadDataXfrIdle[Rout,Rin]
    (degree, functionalUnits, maxRequests, tnCounter,
     nullEl, reqOutstanding, reqQ, add(current, dataEndQ), xfrEndQ)

[]

(* If overlapped access is in use and the number of outstanding requests has not exceeded the maximum, then the file service user may receive an
F-READ indication. If consecutive access is in use and the Write functional unit has been negotiated then the file service user may receive an F-
WRITE indication. The type and transfer number of the request is added to the requestQ and the number of outstanding requests is incremented. The
subsequent behaviour is dependant on the type of the request. *)

[not(isNormal(degree)) and (reqOutstanding lt maxRequests)]->
( Rout?fsp:FSPrim?tn:Nat[isReadInd(fsp) and (tn eq (tnCounter+Succ(0)))];
  ReadRead[Rout,Rin]
    (degree, functionalUnits, maxRequests, tn,
     current, Succ(reqOutstanding), add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)

[]

[isAvailableWrite(functionalUnits) and isConsecutive(degree)]->
Rout?fsp:FSPrim?tn:Nat[isWriteInd(fsp) and (tn eq (tnCounter+Succ(0)))];
  ReadWrite[Rout,Rin]
    (degree, functionalUnits, maxRequests, tn,
     current, Succ(reqOutstanding), add(makeEl(fsp, tn), reqQ), dataEndQ, xfrEndQ)
)

[]

(* The file service user may receive an F-TRANSFER-END indication for the data transfer at the head of the dataEndQ. The data transfer is
removed from the dataEndQ and added to the xfrEndQ. *)

[not(isEmpty(dataEndQ))]->
Rout?fsp:FSPrim?tn:Nat[isXfrEndReadInd(fsp) and (tn eq number(head(dataEndQ)))];
  Read[Rout,Rin]
    (degree, functionalUnits, maxRequests, tnCounter,
     current, reqOutstanding, reqQ, tailOf(dataEndQ), add(head(dataEndQ), xfrEndQ))

[]

```

Figure 23 (continued) - Responder service definition

(* An F-TRANSFER-END response may be issued by the file service user for the data transfer at the head of the **xfrEndQ**. The data transfer is removed from the **xfrEndQ**.)

```
[not (isEmpty(xfrEndQ))]->
Rin?fsp:FSPrim?tn:Nat[isXfrEndReadResp(fsp) and (tn eq number(head(xfrEndQ)))]);
Read[Rout,Rin]
(degree,functionalUnits,maxRequests,tnCounter,
current,pred(reqOutstanding),reqQ,dataEndQ,tailOf(xfrEndQ))
```

[]

(* The initiating file service user may receive an F-CANCEL indication for the data transfer at the head of the **dataEndQ**. If this is empty then the file service user may receive an F-CANCEL indication for the **current** data transfer. If the **dataEndQ** is empty then an F-CANCEL request may be issued by the file service user for the **current** data transfer. *)

```
Interrupt[Rout,Rin] (degree,functionalUnits,maxRequests,tnCounter,current,dataEndQ,xfrEndQ)
```

```
andproc (* Read *)
```

(*
process ReadRead

This process specifies the behaviour in the case where the **current** transfer is a read and the next requested data transfer is also a read. The behaviour is only allowed if consecutive or concurrent access is in use. *)

```
process ReadRead[Rout,Rin] (degree:Overlap,functionalUnits,FUnits,maxRequests,tnCounter:Nat,
current:Element,reqOutstanding:Nat,reqQ,dataEndQ,xfrEndQ:Queue) :exit:-
```

(* An F-DATA request may be issued by the file service user for the **current** data transfer. *)

```
Rin?fsp:FSPrim[isDataReq(fsp)];
ReadRead[Rout,Rin]
(degree,functionalUnits,maxRequests,tnCounter,current,reqOutstanding,reqQ,dataEndQ,xfrEndQ)
```

[]

(* An F-DATA-END request may be issued by the file service user for the **current** data transfer. The **current** data transfer is added to the **dataEndQ**; the request at the head of the **dataEndQ** becomes the **current** data transfer. The subsequent behaviour is determined on the basis of the request that will now be at the head of the **requestQ**.)

```
Rin?fsp:FSPrim[isDataEndReq(fsp)];
([isWriteInd(prim(head(tailOf(reqQ))))]->
ReadWrite[Rout,Rin] (degree,functionalUnits,maxRequests,tnCounter,
head(reqQ),reqOutstanding,tailOf(reqQ),add(current,dataEndQ),xfrEndQ)
```

[]

```
[isReadInd(prim(head(tailOf(reqQ))))]->
ReadRead[Rout,Rin] (degree,functionalUnits,maxRequests,tnCounter,
head(reqQ),reqOutstanding,tailOf(reqQ),add(current,dataEndQ),xfrEndQ)
```

[]

```
[isEmpty(tailOf(reqQ))]->
```

Figure 23 (continued) - Responder service definition

```

Read[Rout,Rin] (degree,functionalUnits,maxRequests,tnCounter,
  head(reqQ),reqOutstanding,tailOf(reqQ),add(current,dataEndQ),xfrEndQ)
)
[]

(* Further requests for read data transfers may be requested if the number of requests outstanding does not exceed the maximum. Write requests may
also be requested only if consecutive access is in use and the write functional unit is available. The type and transfer number of the request is added
to the requestQ*)

[reqOutstanding lt maxRequests] ->
(Rout?fsp:FSPrim?tn:Nat[isReadInd(fsp) and (tn eq (tnCounter+Succ(0)))]);
  ReadRead[Rout,Rin]
  (degree,functionalUnits,maxRequests,tn,
  current,Succ(reqOutstanding),add(makeEl(fsp,tn),reqQ),dataEndQ,xfrEndQ)

[]

[isAvailableWrite(functionalUnits) and isConsecutive(degree)]->
Rout?fsp:FSPrim?tn:Nat[isWriteInd(fsp) and (tn eq (tnCounter+Succ(0)))];
  ReadRead[Rout,Rin]
  (degree,functionalUnits,maxRequests,tn,
  current,Succ(reqOutstanding),add(makeEl(fsp,tn),reqQ),dataEndQ,xfrEndQ)
)
[]

(* The file service user may receive an F-TRANSFER-END request for the data transfer at the head of the dataEndQ. The head of the dataEndQ
is removed and added to the xfrEndQ. *)

[not(isEmpty(dataEndQ))]->
Rout?fsp:FSPrim?tn:Nat[isXfrEndReadInd(fsp) and (tn eq number(head(dataEndQ)))];
  ReadRead[Rout,Rin] (degree,functionalUnits,maxRequests,tnCounter,
  current,reqOutstanding,reqQ,tailOf(dataEndQ),add(head(dataEndQ),xfrEndQ))

[]

(* An F-TRANSFER-END response may be issued by the file service user for the data transfer at the head of the xfrEndQ. The head of the xfrEndQ
is removed. *)

[not(isEmpty(xfrEndQ))]->
Rin?fsp:FSPrim?tn:Nat[isXfrEndReadResp(fsp) and (tn eq number(head(xfrEndQ)))];
  ReadRead[Rout,Rin] (degree,functionalUnits,maxRequests,tnCounter,
  current,pred(reqOutstanding),reqQ,dataEndQ,tailOf(xfrEndQ))

[]

(* The initiating file service user may receive an F-CANCEL for the data transfer at the head of the dataEndQ. If this is empty then the file service
user may receive an F-CANCEL indication for the current read data transfer. If the dataEndQ is empty then an F-CANCEL request may be issued
by the file service user for the current read data transfer. *)

Interrupt[Rout,Rin] (degree,functionalUnits,maxRequests,tnCounter,current,dataEndQ,xfrEndQ)

andproc (* ReadRead *)

```

Figure 23 (continued) - Responder service definition