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Proxy-Driven Server for Flexible Files Version 2
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Abstract

Parallel NFS (pNFS) with the Flexible Files Version 2 layout type supports client-side erasure coding and per-chunk repair between clients and data servers. This document extends that architecture with a proxy server (PS) role: a registered peer of the metadata server that polls the metadata server for work assignments and carries them out -- moving a file from one layout to another, reconstructing a whole file from surviving shards, or translating between codecs for clients that cannot participate in the file's native encoding (including NFSv3 clients). All PS-MDS coordination is fore-channel: the metadata server returns work assignments inline in the response to a PS-initiated PROXY_PROGRESS poll, and the PS reports completion via a fore-channel PROXY_DONE. No callback operations are required for the PS protocol.

Note to Readers

Discussion of this draft takes place on the NFSv4 working group mailing list (nfsv4@ietf.org), which is archived at https://mailarchive.ietf.org/arch/search/?email_list=nfsv4. Source code and issues list for this draft can be found at https://github.com/ietf-wg-nfsv4/flexfiles-v2-proxy-server.

Working Group information can be found at https://github.com/ietf-wg-nfsv4.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

The Flexible Files Version 2 layout type ([I-D.haynes-nfsv4-flexfiles-v2]) introduces client-side erasure coding for pNFS and a per-chunk repair protocol (CB_CHUNK_REPAIR) that lets the metadata server direct an active client to reconstruct individual damaged chunks. That mechanism is sufficient for repairs whose scope is a handful of chunks in a file that has at least one live client.

Three classes of work are outside the per-chunk repair model. The first is whole-file repair: the case in which enough data servers have failed that per-chunk reconstruction would require visiting every chunk, or in which no live client is available to drive the repair at all. The second is layout transitions: a file must move from one layout geometry to another for policy reasons (migrating to a new coding type, or re-mirroring), for maintenance reasons (evacuating a data server ahead of decommission), or for environmental reasons (moving between transport-security profiles or between filehandle backends). The third is codec translation: a client that cannot participate in the file’s native codec -- including every NFSv3 client, and any legacy or minimal NFSv4 client that does not implement the file’s encoding type -- still needs to read and write the file.

This document specifies a proxy server (PS) role to address those three cases with a single mechanism: the PS opens a session to the metadata server and registers its capabilities via PROXY_REGISTRATION; the PS then polls the MDS using PROXY_PROGRESS for work assignments (move, repair), which the MDS returns inline in the poll response; the PS carries out each assignment and signals completion via PROXY_DONE (or abort via PROXY_CANCEL). All of the PS-MDS coordination is fore-channel; the PS does not require a back-channel callback program. A client reaches a proxied file either by contacting the PS directly, as an ordinary NFS server, or through a pNFS layout whose data server is the PS. While a migration is in progress every client routes its I/O through the PS; for codec translation, only a client that cannot encode the file does.

Flex Files v1 provides no standardized mechanism for migrating a file's layout while the file remains in use. Without such primitives, migration is left to implementation-specific machinery and cannot be performed safely across implementations. This design codifies that mechanism, closing what is today the single biggest interop gap between pNFS and parallel-filesystem competitors that already expose migration primitives.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2.1. Relation to the Main Draft

[I-D.haynes-nfsv4-flexfiles-v2] defines CB_CHUNK_REPAIR and the per-chunk repair model. This document is the companion whole-file and per-client mechanism. Per-chunk and whole-file operations are mutually exclusive for a given file at a given time; coexistence rules are in Section 17.

3. Scope

This section draws the boundary between the wire-level mechanism defined here and the much larger space of useful behaviours a proxy implementation might support. Drawing the boundary tightly keeps the protocol small enough to specify and implement in a single revision; everything beyond the boundary is either future work or implementation latitude, and both categories are called out below so later readers know which is which.

3.1. In Scope

This document defines a new protocol role, a new session, and a small set of operations that flow on that session. Around that core it specifies the layout conventions a client observes while a proxy operation is active, the credential-forwarding rules a translating proxy must follow, and the recovery semantics for the three actor failures that matter during an operation (PS, MDS, DS).

The new role is the proxy server (PS), distinct from the MDS and DS roles defined in [I-D.haynes-nfsv4-flexfiles-v2]. A PS registers with an MDS and, on receipt of a directive from that MDS, performs a move, a repair, or an ongoing codec translation on behalf of a client. The PS is opaque to most clients and is visible to the MDS through a dedicated NFSv4.1+ session that the PS itself opens. All PS-MDS coordination is fore-channel: the PS issues ops to the MDS, and the MDS returns work assignments inline in its responses. No callback channel is required for the PS protocol.

The fore-channel surface is deliberately small. PROXY_REGISTRATION (Section 6.2) lets the PS declare the codec set it supports and its lease. PROXY_PROGRESS (Section 6.3) is the PS's poll-and-report op: the PS sends it as a heartbeat (with optional progress reports on in-flight migrations) and the MDS replies with zero or more new work assignments inline. PROXY_DONE (Section 7.1) commits or rolls back a migration when the PS finishes it; PROXY_CANCEL (Section 7.2) lets the PS abort early. All four ops are fore-channel PS-to-MDS.

Around the operation set, the document specifies the layout conventions a client sees during a proxy operation and how a client discovers the PS in the first place.

Codec translation for codec-ignorant clients, including NFSv3 clients, is in scope, and is the one case that stretches the move/repair vocabulary. The same proxy machinery that handles move and repair also provides the persistent per-client translation that lets a client incapable of participating in a file's native codec still read and write the file. Unlike move and repair, which are transient transitions on the file, codec translation is an ongoing routing arrangement that persists as long as the codec-ignorant client is active.

Credential-forwarding rules for a proxy that translates on behalf of a client are defined in the Security Considerations section. The proxy is a translator, not an authority: authorization decisions MUST remain with the MDS, using the client's forwarded credentials. Getting this boundary wrong turns the PS into a privilege-elevation vehicle, so the rules are stated normatively and enforced at the MDS rather than policed on the wire.

Finally, the document defines recovery semantics for the three actor failures that matter during a proxy operation -- PS failure, MDS failure, and DS failure -- each with its own fencing and re-registration rules so that a mid-operation crash does not leave a file in an unrecoverable state.

3.2. Out of Scope

The items below are deliberately deferred. They split into three groups: features whose absence was an explicit design decision (delta journaling, partial-range moves), orchestration that belongs to a layer above a single proxy (multi-proxy pipelines, automated load balancing), and proxy-internal behaviour that does not surface on the wire and therefore needs no standardisation. Nothing on this list is precluded by the current design; each is a reasonable future extension.

Journaling and partial moves: Move assignments in this revision are always whole-file. The PS performs a CSM-style write to all mirrors (source D, destination G, and any other mirrors in the file's mirror set) while reading source bytes from any mirror in the source set; the two-layout state on the MDS keeps client traffic on L1 throughout, with an atomic swap to L2 at PROXY_DONE time (Section 5.2.2). Delta-journaling mechanisms -- capturing writes against an otherwise-offline source, replaying them on completion, or maintaining reference integrity across detached clones -- are a future extension, as is a partial-range move that would move a byte range while the rest of the file stays on the source. The whole-file two-layout commit covers every motivating scenario the design currently has.

Orchestration beyond a single proxy: Multi-proxy pipelines (staged moves for very large files) and automated load balancing or predictive selection across registered proxies are out of scope. An MDS in this revision selects a single PS per operation; load distribution across many proxies, when it matters, is expected to be handled by the MDS's selection policy and does not surface as new wire protocol.

Server-side copy as an alternative path: Integration with server-

side copy ([RFC7862] Section 4) as an alternative to PS-driven moves for single-file moves within one namespace is adjacent work. The two mechanisms are complementary (server-side copy is a client-directed intra-server operation; the PS-driven move is an MDS-directed inter-server operation), and their intersection -- for example, using server-side copy under the hood of a PS move assignment -- is better specified in its own extension rather than bolted into this document.

Proxy-internal features that do not surface on the wire: A proxy MAY implement content-integrity and error-correction layers, encryption and compression pass-through, log-structured write staging, and sector-alignment normalisation. These are useful motivating scenarios for the move/repair vocabulary but do not require new protocol surface beyond what the PROXY_PROGRESS / PROXY_DONE / PROXY_CANCEL fore-channel set already provides, and so they are left to implementation rather than standardised here.

4. Use Cases

Seven motivating scenarios converge on the same mechanism. Six of them are transient transitions on the file itself: the file is changing state (being ingested, re-coded, evacuated, reconstructed, migrated between transport-security profiles, or migrated between filehandle backends), and the transition is what the PS drives to completion. The seventh is qualitatively different: the file is not changing, but specific clients -- those that cannot participate in the file's native codec -- are routed through a PS persistently, for as long as they are active.

The distinction matters for how the MDS schedules work. Transient transitions have a terminal state; the MDS expects each one to complete (via terminal PROXY_PROGRESS) and then to retire the associated layout. The persistent routing case has no terminal state for the file as a whole; the PS stays in the layouts of codec-ignorant clients as long as those clients are open.

In every case, a registered PS becomes the source of truth for a file's data during the operation, and clients are redirected to route I/O through that PS rather than directly to the original layout's data servers. The individual scenarios are described below.

4.1. Administrative Ingest

An administrator rsyncs a file from an external source into the cluster as a single-copy file. Server policy requires the file to be mirrored or erasure coded. The MDS queues a MOVE assignment for the file; the next PROXY_PROGRESS poll from a registered proxy whose codec set covers the destination layout returns the assignment in its response. The proxy populates the destination from the source, while any client that opens the file during the move sees a layout that routes I/O through the proxy.

The source "layout" may not even be a Flex Files layout; it could be a non-pNFS NFS mount that the proxy reads as an NFSv4.2 client. Throughout the move the proxy presents the file to pNFS clients as if the move had not started, while populating the destination in the background.

4.2. Policy-Driven Layout Transition

A server-objective or policy change ("files older than 30 days must be erasure coded", "high-access-rate files must have additional mirrors") requires transforming a file’s layout without user visibility. The transformation is purely a layout change; the file contents are unchanged except at the shard level. The MOVE assignment carries the new layout’s geometry and coding type via the destination deviceid in proxy_assignment4; the proxy reshapes the file’s shards to match. Because the transformation type (encode / decode / transcode) is entirely specified by the (source, destination) deviceid pair plus the file’s recorded layout type, the assignment does not need a separate transformation-class field.

4.3. DS Maintenance / Evacuation

A data server is scheduled for maintenance (hardware replacement, software upgrade, decommission). All files whose layouts reference that DS must be evacuated to replacement DSes before it is taken offline. The MDS queues a MOVE assignment per file (source = the outgoing DS, target = a replacement); registered proxies pick the assignments up via PROXY_PROGRESS polls. Evacuation can be large-scale (thousands or millions of files); running per-client per-chunk repair over every file would be prohibitively expensive, but a single registered proxy can drive many concurrent migrations subject to the per-PS in-flight cap (Section 8).

4.4. Whole-File Repair

Multiple DSes have failed such that per-chunk repair cannot reconstruct the file in place. The MDS constructs a new layout backed by replacement DSes and queues a REPAIR assignment. The next registered-PS PROXY_PROGRESS poll receives the assignment; the proxy drives reconstruction from whatever surviving shards remain. If fewer than k shards survive across the mirror set, the proxy reports terminal failure via PROXY_DONE with pd_status set to NFS4ERR_PAYLOAD_LOST, matching the per-chunk repair semantics in the Repair Client Selection section of [I-D.haynes-nfsv4-flexfiles-v2].

4.5. TLS Coverage Transition

A file whose layout currently points at non-TLS-capable DSes needs to be migrated to TLS-capable DSes, or vice versa (an inventory change, a policy change mandating transport security, onboarding a new storage class whose DSes are TLS-only). A PROXY_OP_MOVE assignment applies: the destination DSes have the required transport security profile, the source DSes are retired. A client that arrives mid-transition is routed through the proxy and does not directly see the heterogeneous DS set.

The proxy establishes its own RPC connections to source and destination DSes, potentially with different transport security profiles (non-TLS to source, mutual TLS [RFC9289] to destination, or any other combination). The proxy's per-DS security is independent of the client's security to the proxy.

4.6. Filehandle / Storage-Backend Transition

A DS changes the filehandles it issues for a file; this happens when the DS's underlying storage is migrated (e.g., from one backend object store to another) and the old filehandles become unresolvable on the new backend. Without a proxy, every client holding a layout has to be individually recalled and re-issued. With a proxy, the MDS points all clients at the proxy (keeping their existing stateids and FHs intact), the proxy reconciles old-to-new FHs internally, and clients are recalled only at the end.

This same mechanism covers several related situations: an NFSv3-to-NFSv4.2 DS protocol upgrade where the DS FHs change as a side effect of migrating from [RFC1813] to [RFC8881] semantics; a DS-side format change that invalidates existing FHs (for example, a transition from a local POSIX store to an object store); and backend-opaque FH migration where the DS's FH structure is internally versioned and old clients hold stale versions.

4.7. Codec Translation for Codec-Ignorant Clients

The coding-type registry defined in the IANA Considerations of [I-D.haynes-nfsv4-flexfiles-v2] is expected to grow. Not every client is required to implement every registered codec; a minimal client, a legacy client, or an NFSv3 client typically cannot participate in erasure-coded files at all. Per the codec-negotiation rules in [I-D.haynes-nfsv4-flexfiles-v2], such a client either retries with a different supported_types hint, falls back to MDS-terminated I/O, or (this case) is routed through a proxy that translates on its behalf.

Unlike the move / repair / evacuation / transition use cases above, codec translation is persistent per client. The file itself is not changing state. What changes is the layout the MDS hands to a codec-ignorant client: that client gets a single-DS layout naming a translating PS, with a coding_type the client does support (typically FFV2_ENCODING_MIRRORED, or for NFSv3 clients just a flat NFSv3 data surface). The proxy encodes and decodes on the fly against the real DSes; the client sees a flat file.

The same file may be accessed directly by codec-aware clients (with a normal layout naming the real DSes) and through the proxy by codec-ignorant clients (with a proxy layout) simultaneously. The MDS issues a different layout per request; only the codec-ignorant case routes through the PS.

4.7.1. Mechanism

A translating proxy runs two sides that meet internally. On its client-facing side it speaks the protocol the codec-ignorant client can speak: for an NFSv3 [RFC1813] client that is an NFSv3 server that re-exports the MDS's namespace; for a legacy NFSv4.2 client that understands only some codecs, it is an NFSv4.2 data-server surface presenting FFV2_ENCODING_MIRRORED (or an equivalent codec the client supports). On its MDS-facing side it is an NFSv4.2 client to the MDS plus whatever DS protocol the MDS's real DSes speak. The proxy translates each client-facing op into the corresponding MDS or DS op, applies the codec transformation between the two, and returns results.

For an NFSv3 client, a read flows:

* Client: NFSv3 READ against the proxy.

* Proxy: if it does not hold a layout for the file, issues LAYOUTGET on the MDS with the client's forwarded credentials (see Security Considerations).

* Proxy: issues CHUNK_READ (or v3 READ if the DS is NFSv3) against the real DSes, decodes the shards back to plaintext.

* Proxy: returns the plaintext bytes in the NFSv3 READ reply.

A write flows:

* Client: NFSv3 WRITE with stable_how and a byte range.

* Proxy: encodes the bytes per the file's codec, issues CHUNK_WRITE / CHUNK_FINALIZE / CHUNK_COMMIT against the real DSes.

* Proxy: returns NFSv3 WRITE ok with the stable_how it was able to honor (which may be downgraded based on the back-end DS's own stable_how behavior).

4.7.2. Why the same PROXY_REGISTRATION machinery

The registered-PS mechanism gives the MDS the information it needs for translation-proxy selection: prr_codecs enumerates the codecs the PS can translate between, the MDS <-> PS session carries the fore-channel control-plane traffic, and the lease bounds the relationship. No new op is required for the translation case -- the existing PROXY_REGISTRATION covers it. PROXY_OP_MOVE and PROXY_OP_REPAIR assignments are not used for pure translation (the file is not moving or being repaired); the PS simply serves the codec-ignorant client's I/O requests against the unchanged source layout.

5. Design Model

5.1. Roles

This document introduces a third role alongside the pNFS metadata server (MDS) and data server (DS):

Proxy server (PS): A persistent, registered peer of the MDS that carries out whole-file operations on the MDS's behalf -- moving file content between layouts, reconstructing files whose source layout has been damaged, and translating codecs on behalf of clients that cannot participate in the file's native encoding. A PS is a distinct role from a DS; a given server MAY implement both, and typically does, but the protocol does not require that. The MDS sees the PS through a dedicated session whose direction is defined in Section 5.3.

The existing roles are unchanged:

Metadata server (MDS): As defined in

[I-D.haynes-nfsv4-flexfiles-v2]: the coordinator for each file, and the authority that issues layouts, manages stateids, and selects repair participants.

Data server (DS): As defined in [I-D.haynes-nfsv4-flexfiles-v2]: serves the CHUNK data path to pNFS clients.

Only one of the three pairs carries new ops in this document. The MDS <-> PS pair gains the new PS-to-MDS regular ops for registration, progress, and terminal reporting (Section 6). No new callback ops are introduced; the MDS pulls work assignments to the PS in the PROXY_PROGRESS reply on the fore-channel, and the PS reports completion or cancellation back via PROXY_DONE / PROXY_CANCEL on the same session, so no callback program is required for this protocol. The Client <-> PS pair gains no new ops: clients reach a PS through the normal pNFS data path, seeing it as the DS named in a single-DS layout (Section 9). The MDS <-> DS pair is also unchanged; the tight-coupling control session in [I-D.haynes-nfsv4-flexfiles-v2] carries over as defined there.

5.2. Layout Model

5.2.1. Single-Layout Model

This design uses a single layout naming the PS as the sole DS rather than two linked layouts. Three considerations drive that choice. pNFS clients already handle single layouts cleanly, so no new layout-linkage mechanism needs to be invented or implemented on the client. The client’s view of the file -- "the file’s DS is the PS" -- is the truth during the operation, so exposing the source and destination DSes directly would invite confusion about which entry to address rather than clarify. And late-arriving clients see the proxy layout from the start, without any separate setup path to join an operation already in progress. The alternative -- a source layout plus a destination layout linked by a redirector record -- was considered and rejected on those three grounds.

Routing all client I/O through the PS has a cost deployments MUST weigh. For the duration of a migration the PS is a data-path single point of failure for the file: the client sees one data server, the PS, and the usual Flex Files mitigation -- client-side mirroring across several DSes -- is unavailable to it. A file under migration therefore has lower availability than a normally-mirrored file until PROXY_DONE. The PS is also a throughput funnel: all client read and write traffic for the file, plus the PS's own copy traffic, passes through one PS, adding a latency hop and a bandwidth bottleneck. These costs are inherent to the single-layout choice; they argue against migrating very large files in a single proxy operation, and motivate the multi-PS and partial-range extensions listed as out of scope (Section 3.2).

5.2.2. Two-Layout State on the MDS Side

For each file F whose mirror on a draining DS D is being migrated, the MDS keeps three logical layout records. Only L3 backs a client-facing layout; L1 and L2 are MDS-internal bookkeeping for the duration of the migration.

L1: the pre-migration mirror set, including D. This record is MDS-internal: it preserves what the file's layout was before the migration and is handed to no client while the migration is active.

L2: the post-migration mirror set: L1 with D replaced by the target G. Also MDS-internal; it becomes the file's layout after the PROXY_DONE swap.

L3: the composite the PS works from. It backs the layout every client is served during the migration: that client-facing layout names the PS as its data server, and the PS does the real I/O against L3's two mirror entries:

* M1 (read source): the L1 mirror set. The PS reads source bytes from any mirror in M1.

* M2 (write target): the L1 mirror set PLUS G. The PS writes via CSM to every mirror in M2.

During the migration every client of F -- whichever front door it used -- is served a layout naming the PS; the PS is the sole writer to M1 and M2. No client addresses D, E, or G directly. Because the PS is the sole writer, it MUST NOT acknowledge a client write until every mirror in M2 is durable: an acknowledged write has reached the whole target set, so a PS crash cannot leave a write acknowledged to the client but applied to only part of the mirror set.

D’s presence in M2 (alongside G) is intentional: the PS keeps D a current mirror until the PROXY_DONE swap, so a cancelled migration can fall back to L1 with no data loss. The PS writes both D and G, and because the PS is the only writer they converge to the same byte image with no inter-writer race.

A source mirror MAY be an NFSv3 DS. When it is, the PS reads from it using NFSv3 semantics and writes the NFSv4.2 destination using CHUNK semantics; the asymmetric-protocol bridging is the PS’s responsibility and is not visible to the client.

5.2.3. Pinned definitions

* L1.mirrors = the file’s pre-migration mirror set, includes D

* L2.mirrors = (L1.mirrors \ {D}) union {G}

* L3.M1 = L1.mirrors (PS’s read-source set)

* L3.M2 = L1.mirrors union {G} (PS’s CSM write-target set)

5.3. Session Between MDS and PS

The PS opens an NFSv4.1+ session to the MDS as a normal client. All PS-MDS coordination flows on the fore-channel of that session: PROXY_REGISTRATION establishes the relationship, PROXY_PROGRESS heartbeats and pulls work assignments, PROXY_DONE / PROXY_CANCEL report terminal state. No callback program is required for the PS protocol -- the session’s back-channel is unused by this draft (the PS may still establish one for unrelated NFSv4.1 callbacks if it wishes, but no PS-protocol op rides on it).

The session direction is intentionally opposite to the MDS -> DS tight-coupling control session in [I-D.haynes-nfsv4-flexfiles-v2]: that session is opened by the MDS to carry MDS-originated stateid management to a DS. The MDS <-> PS session is opened by the PS because registration is a PS-initiated act -- the PS is saying "here I am, with these capabilities." Without a PS-to-MDS direction the capability-advertisement would have to be inferred from session-setup flags alone, which is inadequate for the range of capabilities a PS can usefully advertise (codec set and -- as the DEVICEID_REGISTRATION open question anticipates -- fault-zone coordinates and other deployment attributes).

A consequence of this direction choice is that a server that implements both the DS and PS roles toward the same MDS runs two sessions between the same pair of hosts: the MDS opens the DS tight-coupling session toward the box, and the box’s PS opens the PS

session toward the MDS. That is two EXCHANGE_ID exchanges, two CREATE_SESSION exchanges, and two TCP connections. In deployments that use RPCSEC_GSS ([RFC7861]) or RPC-over-TLS ([RFC9289]) on the PS session -- which the credential-forwarding rules in Section 14 recommend for any PS that translates on behalf of clients -- reserved-port trust is not in use and the doubled connection has no security cost. In a strict AUTH_SYS-only deployment the second outbound reserved port is a real but typically negligible cost, because a storage box's outbound NFS traffic is usually limited to one connection per MDS it is registered with.

5.4. Flow Summary

The PS opens a session to the MDS and issues PROXY_REGISTRATION, declaring its supported codecs; the MDS records the registration and returns a registration id with a granted lease. The PS then polls the MDS via PROXY_PROGRESS at lease/2 cadence (or as the MDS's ppr_lease_remaining_sec hint directs). When the MDS decides to move or repair a file, it selects a registered PS whose capabilities match the operation and queues an assignment for that PS; the next PROXY_PROGRESS reply delivers the assignment in its ppr_assignments<> array. The PS picks the work up by issuing OPEN + LAYOUTGET on the assignment's pa_file_fh, drives the byte-shoveling phase to completion, and reports terminal status by issuing LAYOUTRETURN + PROXY_DONE in a single fore-channel compound on the same session. The MDS may at any time retract an assignment that the PS has not yet acknowledged via OPEN+LAYOUTGET by including a PROXY_OP_CANCEL_PRIOR assignment for the same (pa_file_fh, pa_target_deviceid) pair in a subsequent PROXY_PROGRESS reply; the PS may cancel work it has already started via the fore-channel PROXY_CANCEL (Section 7.2).

Clients interact with the PS through the normal layout path. During a proxy operation the MDS hands out a single-DS layout naming the PS; clients route CHUNK I/O to that DS. Clients that arrive mid-operation see the proxy layout from the start and need no additional signalling; clients that held an older (non-proxy) layout are recalled via CB_LAYOUTRECALL and reacquire.

5.5. Message Sequence: Policy-Driven Move

The simplest flow -- a quiesced whole-file move for a policy transition. Shown as a wire-level message sequence between the three protocol actors; clients are elided because in the quiesced case they are recalled before the PS work starts.

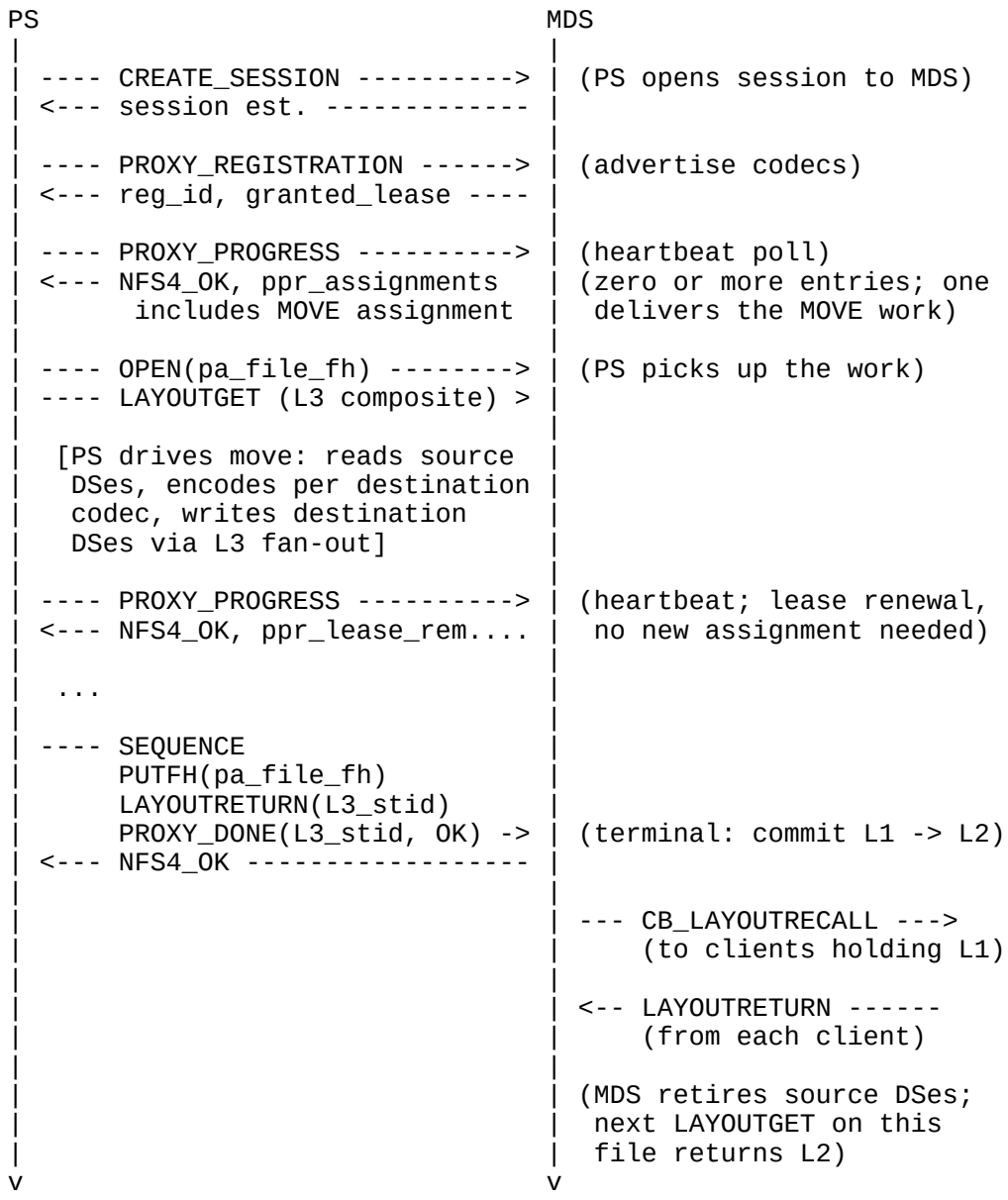


Figure 1: Message sequence for a policy-driven move

5.6. Message Sequence: Whole-File Repair

Same shape as a move, but the assignment in PROXY_PROGRESS carries pa_kind = PROXY_OP_REPAIR and the source layout is degraded. Terminal outcomes:

* NFS4_OK in pd_status: the PS reconstructed the file; the MDS proceeds as in Figure 1.

* NFS4ERR_PAYLOAD_LOST in pd_status: fewer than k shards survived across the mirror set; the MDS marks the affected byte ranges lost and rolls back to L1. No CB_LAYOUTRECALL is issued because there is no valid destination layout to issue.

5.7. Message Sequence: MDS-Initiated Cancellation

The MDS may decide to retract an assignment. Two cases:

Assignment not yet acknowledged by the PS: The MDS includes a PROXY_OP_CANCEL_PRIOR assignment in the next PROXY_PROGRESS reply, naming the same (pa_file_fh, pa_target_deviceid) pair as the prior MOVE / REPAIR assignment. The PS, which has not yet OPEN'd the file, simply drops the prior assignment from its in-flight queue.

Assignment acknowledged and in flight: The MDS internally aborts the migration and discards the in-flight record; the PS's eventual PROXY_DONE returns NFS4ERR_BAD_STATEID (the L3 layout stateid no longer resolves to a record), and the PS abandons the work and releases its OPEN. The MDS may also let the PS's registration lease expire as a coarser cancellation.

The PS-initiated cancellation case uses the fore-channel PROXY_CANCEL (Section 7.2).

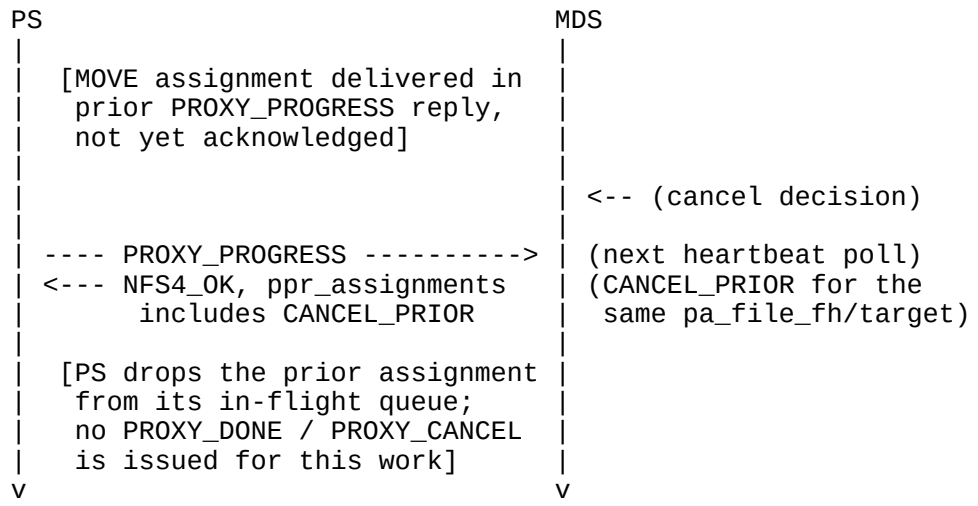


Figure 2: Message sequence for MDS-initiated cancellation (assignment not yet acknowledged)

6. New NFSv4.2 Operations

This document defines two new NFSv4.2 operations that a proxy server (PS) issues to the metadata server (MDS) on the fore-channel of the PS -> MDS session defined in Section 5.3. PROXY_REGISTRATION (93) is issued once at session setup and on renewal. PROXY_PROGRESS (94) is issued by the PS as a heartbeat-with-poll: the PS reports periodic and terminal progress for in-flight migrations and optionally requests new work; the MDS replies inline with zero or more new work assignments. PROXY_DONE (95) commits or rolls back an individual migration when the PS finishes it; PROXY_CANCEL (96) lets the PS abort early. None of these operations is sent by pNFS clients.

```
/// /* New operations for the proxy server (PS -> MDS) */
///
/// OP_PROXY_REGISTRATION   = 93;
/// OP_PROXY_PROGRESS       = 94;
/// OP_PROXY_DONE           = 95;
/// OP_PROXY_CANCEL         = 96;
```

Figure 3: Proxy server operation numbers

Opcodes 93 through 96 continue the MDS-to-DS control-plane range that [I-D.haynes-nfsv4-flexfiles-v2] opens at 88 (TRUST_STATEID through BULK_REVOKE_STATEID at 88-90).

The following amendment blocks extend the nfs_argop4 and nfs_resop4 dispatch unions from [RFC7863] with the new ops. A consumer that combines this document's extracted XDR with the [RFC7863] XDR applies the amendments at the unions' extension point.

```
/// /* nfs_argop4 amendment block */
///
/// case OP_PROXY_REGISTRATION:
///     PROXY_REGISTRATION4args opproxyregistration;
/// case OP_PROXY_PROGRESS:
///     PROXY_PROGRESS4args opproxyprogress;
/// case OP_PROXY_DONE:
///     PROXY_DONE4args opproxydone;
/// case OP_PROXY_CANCEL:
///     PROXY_CANCEL4args opproxycancel;
```

Figure 4: nfs_argop4 amendment block

```
/// /* nfs_resop4 amendment block */
///
/// case OP_PROXY_REGISTRATION:
///     PROXY_REGISTRATION4res opproxyregistration;
/// case OP_PROXY_PROGRESS:
///     PROXY_PROGRESS4res opproxyprogress;
/// case OP_PROXY_DONE:
///     PROXY_DONE4res opproxydone;
/// case OP_PROXY_CANCEL:
///     PROXY_CANCEL4res opproxycancel;
```

Figure 5: nfs_resop4 amendment block

6.1. proxy_stateid4: A New Stateid Type

This document introduces proxy_stateid4, a new server-issued stateid type used as the canonical handle for an in-flight proxy migration. The wire shape reuses the standard NFSv4 stateid4 from [RFC8881] S3.3.12; no new XDR type is added:

```
/// typedef stateid4  proxy_stateid4;
```

Figure 6: proxy_stateid4 wire shape

6.1.1. Value Space

The proxy_stateid value space is disjoint from the open, lock, layout, and delegation stateid value spaces defined in [RFC8881]. Disjointness is enforced by context, not by an in-band tag. A proxy_stateid4 appears in exactly four places: the PROXY_PROGRESS, PROXY_DONE, and PROXY_CANCEL arguments, and the open_claim_proxy4 operand of an OPEN(CLAIM_PROXY) (Section 9.3) -- where it is carried inside the open claim, not in a stateid argument slot. An implementation MUST NOT use an open, lock, layout, or delegation stateid lookup table to resolve a proxy_stateid. Conversely, a leaked proxy_stateid presented in the stateid argument of an ordinary operation (e.g., READ, WRITE, SETATTR, CLOSE) MUST be rejected with NFS4ERR_BAD_STATEID.

6.1.2. MDS Minting

The MDS mints a fresh proxy_stateid each time it accepts a work assignment for delivery to a PS, and includes it as the pa_stateid field of the proxy_assignment4 carried in the next PROXY_PROGRESS reply (Section 6.3).

The MDS guarantees that no two proxy_stateids in the same (server_state, boot_seq) are equal. An implementation MAY embed the MDS boot_seq in the high-order bytes of other[12] to enable cheap NFS4ERR_STALE_STATEID detection across reboots; this is informative implementation guidance, not a wire requirement. One known implementation uses the layout { uint16_t boot_seq | uint16_t reserved | uint64_t opaque } where the opaque tail is getrandom(2) output. The reserved field is zero in this revision; implementations MUST emit zero and MUST NOT reject non-zero on receipt (left as a forward-compat slot for widening boot_seq).

6.1.3. Lifetime

A proxy_stateid is valid from the instant the MDS mints it until either:

* The PS issues PROXY_DONE(proxy_stateid, ...) or PROXY_CANCEL(proxy_stateid) and the MDS acknowledges it. On acknowledgment the proxy_stateid is retired; subsequent references return NFS4ERR_BAD_STATEID.

* The PS's registration lease expires (Section 6.2), at which point all proxy_stateids minted for that PS are abandoned. Subsequent references return NFS4ERR_BAD_STATEID (or NFS4ERR_STALE_CLIENTID if the registration itself has been purged).

* The MDS reboots. Subsequent references to a proxy_stateid minted in a prior boot return NFS4ERR_STALE_STATEID.

6.1.4. Renewal Semantics

PROXY_PROGRESS may carry a proxy_stateid in its arguments to renew an in-flight assignment. The seqid field of proxy_stateid4 follows the standard NFSv4 stateid seqid semantics in [RFC8881] S8.2.4:

* The MDS bumps seqid on each issuance, including renewal acknowledgments.

* The PS sends the most recent seqid it has received.

* Out-of-order seqids are rejected with NFS4ERR_OLD_STATEID.

6.1.5. Authorization

Possession of a proxy_stateid is not sufficient to drive PROXY_DONE or PROXY_CANCEL on the corresponding migration. The MDS additionally validates that the calling session’s registered-PS identity owns that migration (see the "Authorization" subsection of Section 7.1 for the full normative rule). Without this check, a PS that learned another PS’s proxy_stateid (through a packet capture, a leaked log, or any other channel) could drive its PROXY_DONE / PROXY_CANCEL on a migration it does not own.

6.2. Operation 93: PROXY_REGISTRATION - Register as Proxy Server

6.2.1. ARGUMENTS

```
/// struct PROXY_REGISTRATION4args {
///     ffv2_coding_type4  prr_codecs<>;
///     uint32_t           prr_lease;
///     uint32_t           prr_flags;
/// };
```

Figure 7: XDR for PROXY_REGISTRATION4args

6.2.2. RESULTS

```
/// struct PROXY_REGISTRATION4resok {
///     uint64_t           prr_registration_id;
///     uint32_t           prr_granted_lease;
/// };
///
/// union PROXY_REGISTRATION4res switch (nfsstat4 prr_status) {
///     case NFS4_OK:
///         PROXY_REGISTRATION4resok  prr_resok4;
///     default:
///         void;
/// };
```

Figure 8: XDR for PROXY_REGISTRATION4res

6.2.3. DESCRIPTION

A proxy server (PS) calls PROXY_REGISTRATION on the fore-channel of its session to the MDS (Section 5.3) to declare its capabilities. The MDS records the registration and MAY select that PS for subsequent MOVE / REPAIR work assignments delivered inline in the response to PROXY_PROGRESS.

The prr_codecs field lists the ffv2_coding_type4 values the PS supports. The PS MUST be able to encode, decode, and transcode between any pair of values in this list. Because the transformation class of a PROXY_OP_MOVE assignment is inherent in the (source, destination) layout pair, this codec-set membership is all the capability information the MDS needs to match. An empty list results in NFS4ERR_INVAL in this revision.

The prr_lease field is the lease duration the PS requests in seconds. The MDS MAY grant a shorter one, returned in prr_granted_lease. The PS MUST renew before the granted lease expires; on expiry the MDS drops the registration and any in-flight migration record owned by this PS is abandoned (committed to L1 per Section 8).

The prr_flags field is reserved for future use. In this revision the PS MUST set prr_flags to 0, and an MDS that receives a PROXY_REGISTRATION with any bit of prr_flags set MUST reject it with NFS4ERR_INVAL.

The "reject, don’t ignore" rule follows the NFSv4 extension model in [RFC8178]. Section 8 of [RFC8178] specifies that when a flag bit is used that is not known in the specified minor version, NFS4ERR_INVAL is returned; Section 4.4.3 of [RFC8178] then explains that this same error is how a requester determines whether the responder understands the bit. Silently ignoring an unknown bit would break that discovery contract: a PS that sets a future capability bit against an MDS that pre-dates the bit could not tell whether the MDS honored the capability or simply dropped it.

A future revision of this specification (or a successor document that updates it) MAY define new bit values in prr_flags, following the extension rules of Section 4.2 of [RFC8178]. A PS that understands a newly defined bit MAY set it when registering with an MDS that supports it; on NFS4ERR_INVAL the PS MAY retry with the bit cleared, treating the response as the [RFC8178] Section 4.4.3 signal that the MDS does not recognize the bit.

On success, the MDS returns a prr_registration_id that identifies this registration. The PS uses it to renew the registration before the granted lease expires (by re-issuing PROXY_REGISTRATION with the same prr_registration_id) and to identify itself across reconnects (see the squat-guard text below).

Registration conveys capabilities only; the PS’s network endpoint is conveyed through the same deviceinfo channel as any other DS’s address. When the MDS selects a PS for an operation, the layout issued to clients includes a ffv2_data_server4 entry pointing at the PS’s existing deviceinfo.

PROXY_REGISTRATION is issued on the fore-channel of the MDS <-> PS session. That session is opened by the PS, not by the MDS; it is distinct from the MDS -> DS tight-coupling control session defined by [I-D.haynes-nfsv4-flexfiles-v2] even when the same host acts as both DS and PS. The PS MUST present EXCHGID4_FLAG_USE_NON_PNFS on the session so that the MDS can distinguish it from a regular pNFS client. An MDS that receives PROXY_REGISTRATION on a session whose owning client did not present EXCHGID4_FLAG_USE_NON_PNFS MUST reject it with NFS4ERR_PERM.

Before recording the registration, the MDS MUST authorize the caller as a registered PS for this MDS. How that authorization is established -- a deployment allowlist, a per-MDS provisioning step, integration with a directory service, or any other mechanism -- is implementation. The MDS MUST reject an unauthorized PROXY_REGISTRATION with NFS4ERR_PERM.

The authorization MUST be applied to a cryptographically authenticated identity, per the MDS <-> PS transport- security requirements in Section 14.1. AUTH_SYS is never sufficient for PROXY_REGISTRATION; the MDS MUST reject it.

Because one PS proxies one MDS, a successful rogue registration displaces the legit PS and returns NFS4ERR_STALE to every client holding cached filehandles against the previous PS. To guard against registration squatting, the MDS MUST refuse a new PROXY_REGISTRATION from an authorized identity while an existing registration from that same identity still holds a valid lease; the MDS returns NFS4ERR_DELAY and SHOULD log the conflict. A renewal -- distinguished by the PS re-presenting the same prr_registration_id it received on the prior registration -- is not squatting and the MDS MUST accept it (refreshing the granted lease).

Registration revocation before lease expiry is not a dedicated operation in this revision. An MDS that needs to revoke a PS before its lease expires MUST cease delivering work assignments to that PS in PROXY_PROGRESS replies; MUST return NFS4ERR_STALE_CLIENTID on subsequent PROXY_PROGRESS or PROXY_REGISTRATION-renewal from the revoked PS; and MUST handle the PS’s in-flight migration records as if the lease had expired (see the lease-expiry paragraph above): the records are abandoned and the affected layouts revert to the pre-migration state. The revoked PS, on its next PROXY_PROGRESS, sees NFS4ERR_STALE_CLIENTID and may either re-register (if the deployment policy allows) or shut down. A future revision MAY define a dedicated PROXY_REVOKE operation if operational experience shows lease revocation through silence is insufficient.

6.3. Operation 94: PROXY_PROGRESS - Heartbeat and Receive Work Assignments

6.3.1. ARGUMENTS

```
/// struct PROXY_PROGRESS4args {
///     uint32_t  ppa_flags;
/// };
```

Figure 9: XDR for PROXY_PROGRESS4args

6.3.2. RESULTS

```
/// enum proxy_op_kind4 {
///     PROXY_OP_MOVE         = 0,
///     PROXY_OP_REPAIR       = 1,
///     PROXY_OP_CANCEL_PRIOR = 2
/// };
///
/// struct proxy_assignment4 {
///     proxy_op_kind4    pa_kind;
///     proxy_stateid4    pa_stateid;
///     nfs_fh4           pa_file_fh;
///     deviceid4         pa_source_deviceid;
///     deviceid4         pa_target_deviceid;
///     opaque            pa_descriptor<>;
/// };
///
/// struct PROXY_PROGRESS4resok {
///     uint32_t              ppr_lease_remaining_sec;
///     proxy_assignment4     ppr_assignments<>;
/// };
///
/// union PROXY_PROGRESS4res switch (nfsstat4 ppr_status) {
/// case NFS4_OK:
///     PROXY_PROGRESS4resok ppr_resok;
/// default:
///     void;
/// };
```

Figure 10: XDR for PROXY_PROGRESS4res

6.3.3. DESCRIPTION

A registered proxy server calls PROXY_PROGRESS on the fore-channel of its session to the MDS for two purposes:

1. *Heartbeat*: extend the PS’s registration lease. The MDS responds with ppr_lease_remaining_sec so the PS can size its next poll interval.

2. *Receive work assignments*: pick up zero or more units of work the MDS has queued for this PS. Each assignment is a proxy_assignment4 describing one migration or repair the MDS wants this PS to drive.

Per [RFC8178] S4.4.3, ppa_flags is a reserved-for-future-use flag word; the MDS MUST reject any non-zero bit with NFS4ERR_INVAL. The slot allows future revisions to add PS-side appetite signaling (e.g., "do not give me more assignments right now") without an XDR break.

The MDS returns work assignments inline in ppr_assignments<>. A PS that does not want new work simply ignores the assignments past its in-flight cap; the MDS does not retract assignments once delivered. Each assignment names a single file (pa_file_fh), the source and target DSes the migration moves data between (pa_source_deviceid / pa_target_deviceid), and a kind-specific opaque descriptor (pa_descriptor<>) for future extensions (for example, a precomputed source-layout descriptor so the PS can dial source DSes without a second LAYOUTGET). The pa_stateid field carries the proxy_stateid4 (Section 6.1) the MDS has minted for this migration; the PS presents it in the OPEN(CLAIM_PROXY) that binds it to the file (Section 9.3) and references it as the handle in the eventual PROXY_DONE / PROXY_CANCEL.

The pa_kind discriminates the work type:

PROXY_OP_MOVE: drain or migrate the file’s data between the named DSes. pa_stateid is the proxy_stateid the PS will reference in PROXY_DONE / PROXY_CANCEL.

PROXY_OP_REPAIR: reconstruct a missing or corrupt mirror on pa_target_deviceid from the surviving mirrors. pa_stateid is the proxy_stateid the PS will reference in PROXY_DONE / PROXY_CANCEL.

PROXY_OP_CANCEL_PRIOR: the MDS rescinds an assignment it delivered in a prior PROXY_PROGRESS reply, before the PS acknowledged it via OPEN+LAYOUTGET. pa_stateid is the proxy_stateid of the assignment being rescinded; the PS MUST drop any in-progress work tagged with this proxy_stateid and MUST NOT issue PROXY_DONE / PROXY_CANCEL for it (the MDS has already cleaned up the in-flight migration record on its side and retired the proxy_stateid).

For each MOVE / REPAIR assignment, the PS picks the work up by issuing a normal NFSv4 OPEN+LAYOUTGET against pa_file_fh (the L3 composite layout), shovels bytes per the kind-specific protocol, and reports terminal status via PROXY_DONE(pa_stateid, ...) (Section 7.1) or PROXY_CANCEL(pa_stateid) (Section 7.2).

pa_file_fh is an nfs_fh4 minted by the MDS and presented to the PS for use against the same MDS. Per [RFC8881] Section 4.2.3, NFSv4 filehandles are server-private opaque tokens; the receiving server treats the byte string as opaque, validates it only by attempting the lookup, and returns NFS4ERR_STALE or NFS4ERR_BADHANDLE if the bytes do not resolve. The PS MUST NOT inspect, mutate, or shape-check pa_file_fh; it forwards the filehandle verbatim in PUTFH on the same MDS that issued it, and the existing PUTFH semantics apply unchanged.

The ppr_lease_remaining_sec field is the MDS's acknowledgment of this PROXY_PROGRESS as a registration lease renewal. It is the number of seconds remaining until the PS's registration would expire absent further PROXY_PROGRESS. A well-behaved PS treats it as a lower bound on its next poll deadline; the MDS MAY return a smaller value than the standard NFSv4 lease period to drive a busy PS to poll more often or to encourage a quiet one to back off.

Polling cadence: lease/2 in steady state. Adaptive backoff to lease and then 2*lease after K consecutive empty replies; reset on any non-empty reply. The MDS may override the cadence via ppr_lease_remaining_sec.

The MDS-initiated cancellation case (the MDS abandons an in-flight assignment before the PS has driven it to terminal state) is signaled via the PROXY_OP_CANCEL_PRIOR assignment kind described above. There is no separate cancel callback; the PS-initiated cancel is handled by the fore-channel PROXY_CANCEL (Section 7.2).

7. New Fore-Channel Operations: PROXY_DONE and PROXY_CANCEL

The PS-to-MDS protocol uses two new fore-channel operations in addition to the extended PROXY_PROGRESS:

PROXY_DONE (op 95): PS reports terminal success or failure on a specific in-flight migration. The MDS uses the ppd_status to atomically commit (success: swap the file's active layout from L1 to L2) or roll back (failure: keep L1, drop L2/G).

PROXY_CANCEL (op 96): PS aborts a work item it was assigned but cannot complete (e.g., source DS becomes unreachable, PS resource exhaustion). The MDS treats this as PROXY_DONE with a fail-equivalent status: rolls back to L1, drops L2/G, frees the assignment for re-assignment by a later PROXY_PROGRESS poll.

Both operations identify the affected migration by layout stateid. The PS acquired this stateid earlier when it issued LAYOUTGET against the migration layout (L3) for this file; the MDS keys its in-flight migration record on the (clientid, pa_file_fh, layout_stid) triple. No new stateid type is required.

7.1. Operation 95: PROXY_DONE - Commit or Roll Back a Proxy Operation

7.1.1. ARGUMENTS

```
/// struct PROXY_DONE4args {
///     proxy_stateid4  pd_stateid;
///     nfsstat4        pd_status;
/// };
```

Figure 11: PROXY_DONE arguments

7.1.2. RESULTS

```
/// struct PROXY_DONE4res {
///     nfsstat4    pdr_status;
/// };
```

Figure 12: PROXY_DONE results

7.1.3. DESCRIPTION

PROXY_DONE signals the terminal outcome of a migration the PS was assigned via PROXY_PROGRESS. pd_stateid is the proxy_stateid the MDS minted when it delivered the corresponding proxy_assignment4 (Section 6.1). A pd_status of NFS4_OK directs the MDS to commit the migration (swap the file's active layout from the pre-migration shape L1 to the post-migration shape L2); any other value directs the MDS to roll back (keep L1, discard L2 and the PS-only composite L3).

The PS compounds PROXY_DONE after the byte-shoveling phase completes (or fails):

SEQUENCE PUTFH(pa_file_fh) LAYOUTRETURN(L3_stateid)
PROXY_DONE(pd_stateid, status)

LAYOUTRETURN runs FIRST per [RFC8881] S18.51, releasing the PS's reference to the L3 layout cleanly via the standard mechanism. PROXY_DONE then operates on the in-flight migration record keyed by the proxy_stateid; the record is the single source of truth for migration state, so PROXY_DONE remains valid even though L3 has just been returned. The PS MAY issue PROXY_DONE in a subsequent compound, but the single-compound shape is RECOMMENDED to keep the recovery window short.

7.1.3.1. Authorization

The MDS MUST validate, in this priority order, returning the first failure encountered:

1. The calling session belongs to a registered PS (i.e., the session's owning client has nc_is_registered_ps set). Otherwise: NFS4ERR_PERM.

2. pd_stateid.other was minted in the current (server_state, boot_seq) tuple. A proxy_stateid minted in a prior boot returns NFS4ERR_STALE_STATEID.

3. pd_stateid.other identifies a proxy operation currently in flight at the MDS. Otherwise: NFS4ERR_BAD_STATEID.

4. The proxy operation identified by pd_stateid is owned by the calling session's registered-PS identity. The identity captured at PROXY_REGISTRATION time -- the prr_registration_id if non-empty, or the matched GSS principal / mTLS fingerprint otherwise -- is the authorization principal, not the per-EXCHANGE_ID clientid4. This makes PROXY_DONE / PROXY_CANCEL tolerant of PS reconnect: a PS that drops its session and reconnects with a fresh EXCHANGE_ID but the same prr_registration_id retains authority over its in-flight migrations. Mismatch returns NFS4ERR_PERM.

5. The current filehandle (set by the preceding PUTFH) is the pa_file_fh of the proxy operation identified by pd_stateid. Otherwise: NFS4ERR_BAD_STATEID.

6. pd_stateid.seqid matches the most recently issued seqid for this proxy_stateid (per [RFC8881] S8.2.4 stateid sequence semantics). Otherwise: NFS4ERR_OLD_STATEID.

If all validations succeed, the MDS atomically:

* For a pd_status of NFS4_OK: commits the migration -- promotes L2 to be the file's layout (D dropped, G promoted), drops L1 and L3, issues CB_LAYOUTRECALL on the prior layout to external clients still holding cached L1 references, and defers final removal of the decommissioned mirror D until all L1 holders return their layouts. See Section 9.1 for the full mechanics.

* For any other pd_status: leaves the file's layout unchanged -- L1 stays in force; L2 and L3 are discarded. No CB_LAYOUTRECALL is needed (external clients never saw the post-image). The PS owns cleanup of any half-written data it placed on the target G.

In both cases the MDS retires the proxy operation; pd_stateid is thereafter invalid.

Atomicity is critical: external client traffic must transition cleanly across this op; either the per-instance deltas commit fully or they do not commit at all.

7.2. Operation 96: PROXY_CANCEL - Abort a Proxy Operation

7.2.1. ARGUMENTS

```
/// struct PROXY_CANCEL4args {
///     proxy_stateid4  pc_stateid;
/// };
```

Figure 13: PROXY_CANCEL arguments

7.2.2. RESULTS

```
/// struct PROXY_CANCEL4res {
///     nfsstat4    pcr_status;
/// };
```

Figure 14: PROXY_CANCEL results

7.2.3. DESCRIPTION

PROXY_CANCEL discards an assigned-but-unfinished migration. The PS uses it when it knows it cannot complete the assignment (the PS is being shut down gracefully, the source DS is unreachable, the destination DS rejected the writes, etc.) and wants to release the work item back to the MDS without computing a specific failure status.

pc_stateid is the proxy_stateid the MDS minted when it delivered the corresponding proxy_assignment4.

Compound shape:

SEQUENCE PUTFH(pa_file_fh) LAYOUTRETURN(L3_stateid) PROXY_CANCEL(pc_stateid)

LAYOUTRETURN runs first (standard [RFC8881] S18.51 release of the L3 layout); PROXY_CANCEL then operates on the in-flight migration record only.

7.2.3.1. Authorization

The same priority-ordered validation as PROXY_DONE (Section 7.1) applies, with pc_stateid substituted for pd_stateid. In particular, the registered-PS identity that owns the proxy operation identified by pc_stateid MUST match the caller’s, or the MDS returns NFS4ERR_PERM; a PS cannot cancel another PS’s migration.

7.2.3.2. Side effects

If validation succeeds, layout-side effects mirror PROXY_DONE with a failing pd_status -- L1 stays in force; L2 and L3 are discarded; the half-filled target G is the PS's to clean up. The MDS retires the proxy operation, invalidates pc_stateid, and (informatively) updates its operator-facing telemetry to record the cancellation. No CB_LAYOUTRECALL is needed.

The distinction between PROXY_DONE(FAIL) and PROXY_CANCEL is purely intent / accounting: PROXY_DONE(FAIL) records that the PS attempted the migration and ran into a recoverable error; PROXY_CANCEL records that the PS abandoned the assignment without attempting it (or while attempting, decided not to report a specific failure cause). An MDS implementation MAY surface the distinction in operator telemetry but MUST NOT make any behavioral distinction on the wire.

8. Multi-PS Assignment Fan-out

When multiple PSes are registered against the same MDS, the MDS coordinates assignment fan-out under one hard invariant: at any time, at most one migration MUST be in flight for a given (pa_file_fh, pa_target_deviceid) pair. The MDS MUST NOT assign a migration whose (pa_file_fh, pa_target_deviceid) matches that of an in-flight migration.

How the MDS chooses among eligible PSes -- by load, locality, fault domain, capability match, or any combination -- is an implementation matter. The protocol constrains only the outcome: the PS that receives the assignment is registered at delivery time, and the (pa_file_fh, pa_target_deviceid) invariant holds.

When a registered PS loses its session -- its lease expires, or a competing PS takes its registration slot in a squat -- the MDS MUST treat each migration the PS had in flight as if PROXY_DONE(FAIL) had been issued: L1 stays in force, L2 and L3 are discarded. The MDS MAY then reassign the work to another eligible PS; the (pa_file_fh, pa_target_deviceid) invariant continues to hold across reassignment.

A PS that reconnects with the same client_owner4, and so recovers the same clientid via EXCHANGE_ID, retains ownership of its in-flight migrations; no reassignment is needed. The PS reclaims its layouts via the MDS-recovery path in Section 13.

A host that does not implement the proxy server role simply does not call PROXY_REGISTRATION and is never selected for a MOVE or REPAIR assignment. A deployment with no registered PS falls back to per-chunk CB_CHUNK_REPAIR for single-shard repair, to admin-coordinated

offline procedures for policy transitions and DS evacuation, and to blocking DS maintenance -- the DS cannot drain through a PS, so it must remain reachable to clients throughout its service life.

Deployments SHOULD ensure at least one registered PS exists per failure domain to avoid a single point of failure on move operations.

9. Layout Shape During a Proxy Operation

The layout the MDS hands out to clients while a proxy operation is active is the mechanism's sole client-facing surface. Everything else in this document -- the session, the ops, the credential-forwarding rules -- is between the MDS and the PS. The layout shape is therefore what a client implementer needs to read to know how its code interacts with a proxied file.

On a LAYOUTGET, the MDS chooses one of three outcomes:

* A direct-DS layout, when no proxy operation is in flight for the file and the client's coding-type support set includes the file's coding. This is the unchanged FFv2 path.

* A single-DS layout naming the PS, when a MOVE or REPAIR migration is in flight for the file, or when the client's coding-type support set does not include the file's coding and a registered PS can translate. The client uses this layout as it would any FFv2 layout, sending CHUNK ops to the named DS; the PS internally dispatches reads and writes to the source and destination DSes.

* NFS4ERR_CODING_NOT_SUPPORTED (see [I-D.haynes-nfsv4-flexfiles-v2]), when the client's coding-type support set does not include the file's coding and no registered PS can translate.

A client that supports FFv2 -- which is the precondition for any of this -- needs no proxy-specific code: the proxy case arrives as a single-DS layout, indistinguishable from any other FFv2 layout.

9.1. Atomic commit on PROXY_DONE

When the PS issues PROXY_DONE(pd_stateid, pd_status=NFS4_OK), the MDS atomically (in one transaction):

1. Promotes L2 to be the file's layout (D dropped, G promoted)

2. Drops L1 and L3 from the file's layout records

3. Retires the in-flight migration record

4. Issues CB_LAYOUTRECALL for the file's outstanding client-facing (PS-naming) layouts

5. Defers REMOVE_MIRROR(D) until those layouts are returned

On its next LAYOUTGET each client receives the post-migration layout (L2): the real DSes, with no PS.

When PROXY_DONE indicates failure (or PROXY_CANCEL is issued):

1. L1 is promoted unchanged -- the file falls back to its pre-migration mirror set

2. L2 is dropped; the half-filled G instance is internally unlinked

3. L3 is dropped and the migration record retired

4. CB_LAYOUTRECALL is issued for the PS-naming layouts; on the next LAYOUTGET clients receive L1

9.2. The swap window

Because every client wrote through the PS, no client ever addressed D directly, and there are no client writes in flight to D when the swap occurs. The deferred REMOVE_MIRROR(D) covers only the PS's own trailing writes: by the time it issues PROXY_DONE the PS, as the sole writer, has quiesced its M2 fan-out, so the deferral window is short and contains no client-visible activity.

A client holding a PS-naming layout when CB_LAYOUTRECALL arrives returns it and re-LAYOUTGETs in the usual way. In-flight client I/O to the PS across that boundary is handled by the in-flight-I/O rules for a PS change (see "In-Flight I/O When the PS Changes").

9.3. The CLAIM_PROXY open claim

The PS opens the file with a new OPEN claim, CLAIM_PROXY. A bare OPEN(CLAIM_NULL) cannot serve here: it would be indistinguishable from an ordinary or racing OPEN on the registered-PS session, leaving the MDS to infer proxy intent from session state -- which it cannot do reliably. CLAIM_PROXY makes the proxy OPEN explicit and carries, in one step, what the MDS needs to bind the PS to the file.

open_claim_type4 gains one enumerant and open_claim4 one union arm:

```
/// /* New OPEN claim for a proxy server; extends the
///    open_claim_type4 enumeration of [RFC8881]. */
///
/// const CLAIM_PROXY = 7;
///
/// struct open_claim_proxy4 {
///         proxy_stateid4  ocp_proxy_stateid;
///         nfs_fh4         ocp_ps_fh;
/// };
///
/// /* open_claim4 gains the arm:
///         case CLAIM_PROXY:
///                 open_claim_proxy4       ocp_proxy;
///  */
```

Figure 15: The CLAIM_PROXY open claim

CLAIM_PROXY is filehandle-based and opens an existing file: the PS issues PUTFH of the assignment's pa_file_fh followed by OPEN(CLAIM_PROXY), with no directory filehandle and no component name, in the manner of CLAIM_FH. CLAIM_PROXY MUST NOT be combined with OPEN4_CREATE.

The operand carries two values:

ocp_proxy_stateid: the proxy_stateid4 the MDS minted for this assignment and returned in the PROXY_PROGRESS work assignment (Section 6.3). It is the correlator that identifies this OPEN as the proxy OPEN for a specific assignment; the MDS does not infer proxy intent from the session.

ocp_ps_fh: the filehandle under which the PS will serve the file to clients: the data-server filehandle that appears in the layout the MDS hands a codec-incapable client, and the filehandle a non-pNFS client obtains by LOOKUP against the PS. Only the PS can mint this filehandle; it is opaque to the MDS, which records it and copies it verbatim into the layouts it issues. Carrying it in the OPEN binds it atomically with the proxy OPEN.

The MDS MUST verify that ocp_proxy_stateid is valid, that it names an outstanding assignment, that the assignment was made to the calling clientid, and that the current filehandle is that assignment's file. An invalid or stale stateid draws NFS4ERR_BAD_STATEID.

A PS MUST NOT issue OPEN(CLAIM_PROXY) unless it holds a successful PROXY_REGISTRATION (Section 6.2); successful registration is what establishes that the MDS implements this extension.

OPEN(CLAIM_PROXY) returns the ordinary OPEN result: an open stateid, and an open_delegation4 which the MDS MUST set to OPEN_DELEGATE_NONE -- a delegation to the PS would conflict with the migration the PS is itself driving. The PS opens with OPEN4_SHARE_ACCESS_BOTH and OPEN4_SHARE_DENY_NONE. A retransmitted or re-issued OPEN(CLAIM_PROXY) is handled exactly as for any other claim: the session replay cache absorbs retransmits, and a genuine repeated OPEN by the same open-owner is an ordinary share-state operation.

The PS then obtains the L3 composite layout with an ordinary LAYOUTGET; the MDS serves L3 because the calling clientid holds an in-flight migration record for the file. The L3 layout stateid is a normal NFSv4 layout stateid, used for CHUNK / WRITE / READ I/O against the source and target DSes in the standard way. It is distinct from proxy_stateid4 (Section 6.1), which is a control-plane handle for the migration as a whole and is never presented to LAYOUTGET; the MDS keys its in-flight migration record on the proxy_stateid. Separating the two -- one for I/O on a layout, one for the migration -- keeps the migration record's lifetime independent of any LAYOUTGET / LAYOUTRETURN cycle the PS performs during the byte-shoveling phase.

9.4. Drain interaction

The DRAINING state on D is observable to external clients only through the absence of new layouts naming D: while D is DRAINING, the MDS does not place D in any new mirror set. Before the migration becomes active for an existing file whose layout names D, the MDS issues CB_LAYOUTRECALL on every outstanding layout for the file whose mirror set includes D. Once those layouts have been returned -- or administratively revoked when a client's CB back-channel fails to ack within the recall window -- the migration is in flight.

From that point until the assigned PS completes its OPEN(CLAIM_PROXY) (Section 9.3) and registers the filehandle under which it will serve the file, the MDS cannot yet build a client-facing layout, and answers every LAYOUTGET for the file with NFS4ERR_DELAY; clients retry. This window MUST be bounded: if the assigned PS does not complete its OPEN(CLAIM_PROXY) within a deadline tied to its registration lease, the MDS reassigns or abandons the assignment and stops returning NFS4ERR_DELAY. Once the PS has opened, subsequent LAYOUTGETs for the file return a layout naming the PS.

This omit-and-replace ordering guarantees that no client write hits D after the migration has started. The alternative -- keep-and-shadow, in which the layout view continues to include D and the PS shadows client writes from D to G as they happen -- requires the PS to expose itself as a flex-files data server (an INTERPOSED instance taking the

place of D in the visible layout, with the PS funneling writes to both D and G). This shape is defined in the per-instance delta model below (informative) but is not exercised by the wire ops in this revision.

9.5. Per-instance migration deltas (informative)

The L1/L2/L3 framing above describes one valid implementation approach -- whole-layout swap -- that captures the simplest case (single mirror replacement under a Client Side Mirroring codec). An MDS implementation that supports more general migrations (e.g., a single shard add to an erasure-coded file, or a partial mirror-set rotation under FFv2 RS) MAY record migration state as per-instance deltas on the file's existing layout records, rather than as a complete L2/L3 pair.

In this informative model, each migration record carries an array of per-instance deltas, each delta describing a transformation on one position within one segment of layout_segments. Four instance states are useful:

STABLE: unchanged; client writes go here directly.

DRAINING: a slot being decommissioned; under omit-and-replace, the LAYOUTGET view-build path omits this slot and replaces it with the matching INCOMING.

INCOMING: a new slot the PS is filling; under omit-and-replace, the LAYOUTGET view-build path emits this slot in place of the matching DRAINING.

INTERPOSED: a slot whose visible endpoint is the PS, with the PS internally fanning writes out to one or more target DSes. Used by keep-and-shadow (forward-compat; not produced by the wire ops in this revision).

The current published layout (layout_segments) is built through the deltas: when LAYOUTGET runs while a migration is active, the layout-build path consults the migration record and emits the during-migration view by applying the deltas to the base segments. layout_segments itself is never mutated until PROXY_DONE(NFS4_OK) collapses the deltas into the base records permanently.

This per-instance model and the L1/L2/L3 swap model agree on the wire-visible behavior in the simplest case (single mirror replacement, omit-and-replace). The wire ops in this draft do not require either implementation; an MDS chooses whichever matches its layout-record machinery.

The wire ops in this draft do not constrain the choice; the per-instance delta model is one known implementation strategy that has been used to track the four record-builder invariants and a lease-aware reaper for the migration record / proxy_stateid tables across the lifecycle described above.

10. Client Behavior

During a proxy operation the layout the MDS hands a client is a single-DS FFv2 layout naming the PS. The client treats it as any other FFv2 layout, sending CHUNK ops to the named DS under its existing layout stateid. Nothing in the client's path distinguishes "the DS is a PS" from "the DS is a real data server"; that distinction lives entirely on the MDS side.

The PS accepts those CHUNK ops under the client's existing layout stateid because the MDS has registered the stateid via TRUST_STATEID on the PS, per the tight-coupling semantics in [I-D.haynes-nfsv4-flexfiles-v2].

The client handles PS-side errors (NFS4ERR_DELAY, connection loss, NFS4ERR_BAD_STATEID) exactly as it would any other DS error: report LAYOUTERROR to the MDS and expect either a new layout or a PS reassignment in return.

10.1. When the Layout Is Recalled

If the MDS recalls the layout mid-operation (the PS failed and is being replaced, or the operation completed and normal DS layouts are being reissued), the client LAYOUTRETURNs as usual and reacquires via LAYOUTGET. The new layout may name a different PS, a different mirror set, or -- if the proxy operation has completed -- the real DSes directly.

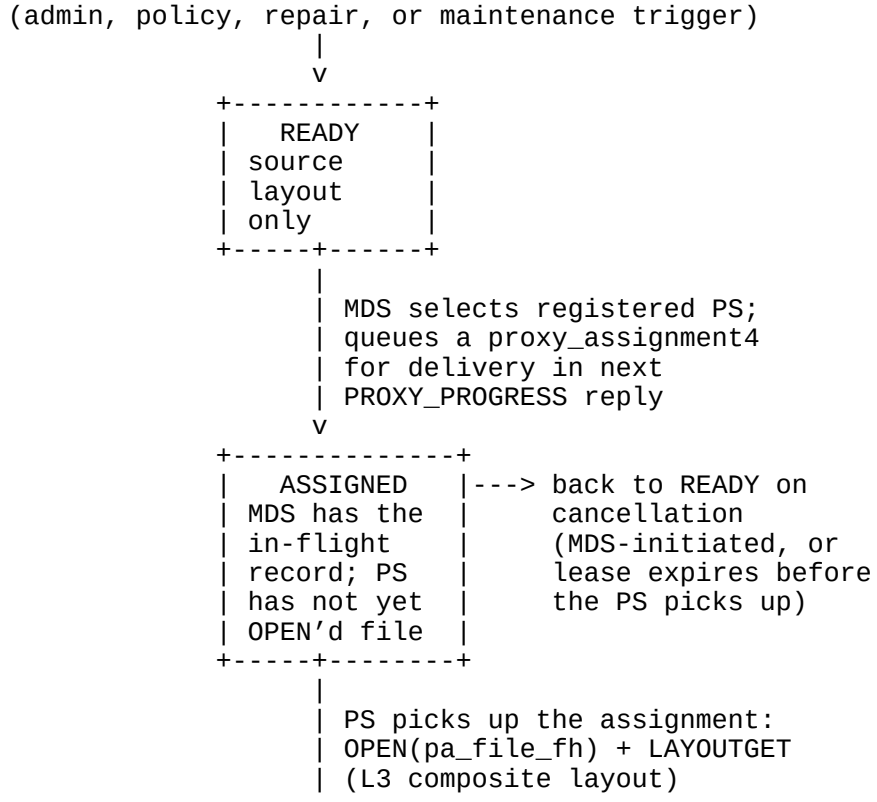
10.2. In-Flight I/O When the PS Changes

In-flight I/O to the old PS when the MDS recalls the layout MAY complete at the old PS; results remain valid under the old PS's authority. New I/O issued after LAYOUTRETURN MUST go through the DS(es) the new layout names: a replacement PS, or the real DSes if the proxy operation has completed.

11. State Machine

A file's participation in a proxy operation passes through five states: READY (no operation in flight), ASSIGNED (the MDS has queued an assignment for a PS but the PS has not acknowledged it via OPEN+LAYOUTGET), PROXY_ACTIVE (the PS is driving a move or repair), COMMITTING (the PS has issued PROXY_DONE(OK) and the MDS is recalling the old layout from external clients), and DONE (clients are on the post-move layout, source DSes retired). The state is MDS-local: clients never observe these state names directly, but a client's behaviour is shaped by which layout the MDS is currently handing out. A given file spends most of its lifetime in READY; a proxy operation is a relatively short excursion through the other four states, after which the file returns to READY with a new layout in place (or, on cancellation or failure, with the old layout preserved).

The diagram below shows the states and the principal transitions, including the failure exits from ASSIGNED and PROXY_ACTIVE back to READY. The Transitions table that follows enumerates each transition with its trigger and effect.



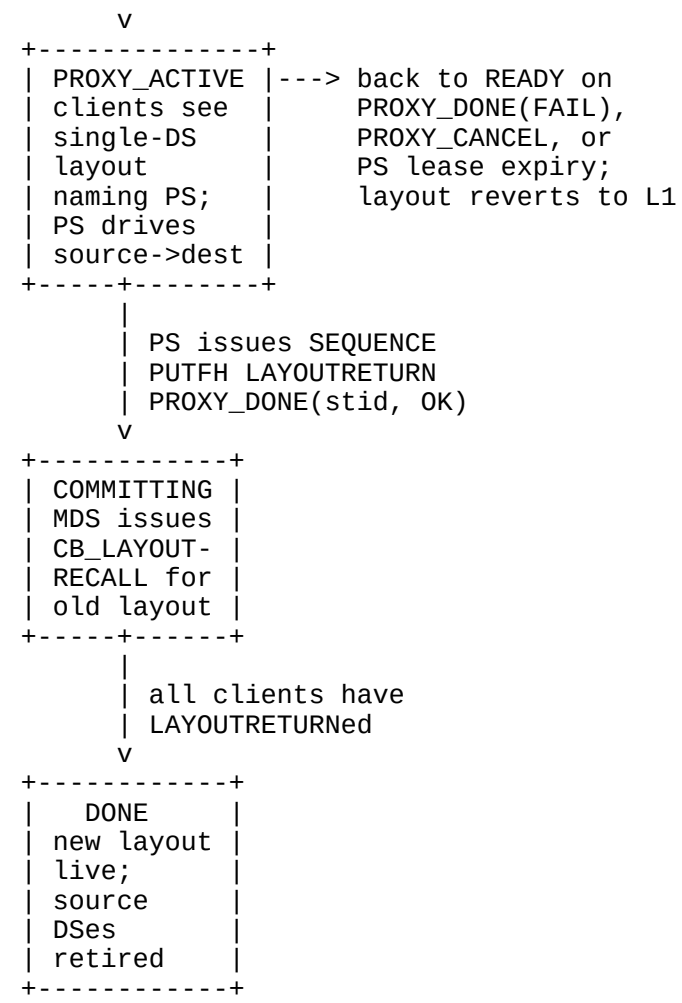


Figure 16: File state during a proxy operation

11.1. Transitions

From	To	Trigger	Actions
READY	ASSIGNED	MDS decides to move or repair	MDS queues a proxy_assignment4 (kind=MOVE or REPAIR) for delivery in the next

			PROXY_PROGRESS reply to the selected PS; creates the in-flight migration record
ASSIGNED	PROXY_ACTIVE	PS picks up the assignment	PS issues OPEN(CLAIM_PROXY) + LAYOUTGET against pa_file_fh; MDS begins serving clients a layout naming the PS
PROXY_ACTIVE	COMMITTING	PS issues PROXY_DONE with pd_status=NFS4_OK	MDS begins CB_LAYOUTRECALL fan-out to clients still on the old layout
COMMITTING	DONE	All clients have LAYOUTRETURNed	MDS issues post-move layouts (L2); source DSes retired
ASSIGNED	READY	MDS-initiated cancellation: MDS includes a PROXY_OP_CANCEL_PRIOR assignment in the next PROXY_PROGRESS reply	MDS drops the in-flight record; PS drops the assignment from its in-flight queue
PROXY_ACTIVE	READY	PS failed and no replacement available; or PS-initiated cancellation via PROXY_CANCEL; or PROXY_DONE with a failing pd_status	MDS reverts layouts to pre-move source set (L1)

Table 1

12. PS Failure and Recovery

12.1. PS Crash During PROXY_ACTIVE

When a PS crashes mid-operation, client I/O routed through it receives NFS4ERR_DELAY (if the PS is reachable but unhealthy) or connection errors (if unreachable), and the affected clients report LAYOUTERROR to the MDS. The MDS MAY select a replacement PS from the registered pool and queue a fresh proxy_assignment4 (kind MOVE or REPAIR) for that PS in its next PROXY_PROGRESS reply, with the source layout updated to reflect current reality -- destination DSes that the failed PS populated are now part of the source set -- and the destination layout unchanged; the replacement PS resumes from wherever the failed PS left off.

Before the replacement PS's layout becomes live, the MDS MUST fence the failed PS: it revokes the failed PS's L3 layout stateid (REVOKE_STATEID) and, where the DS protocol supports it, fences the failed PS at the source and target DSes. Fencing closes the window in which a delayed write from a failed-but-not-dead PS could land after the replacement PS has taken over -- a two-PS instance of the write race the single-writer model otherwise prevents. The MDS then issues CB_LAYOUTRECALL on the old layout and the replacement PS's layout becomes live for new LAYOUTGETs.

If the MDS cannot find a replacement within a policy timeout, it MUST cancel the operation: revert to the pre-move source layout, do not issue a destination layout, and mark the destination DSes for cleanup or retry.

12.2. Cascading PS Failure

A second PS failure on the same operation SHOULD escalate to deployment management rather than trigger another automatic replacement. Recurring failures across multiple PSes indicate an environmental issue no PS can work around -- an unreachable source DS, a misconfiguration, or a starved replacement pool -- that operator attention will resolve sooner than another retry.

12.3. Source DS Crash During PROXY_ACTIVE

A source DS crash reduces the PS's read parallelism but does not block forward progress as long as the erasure code can still reconstruct the file from the surviving source DSes. If the source set degrades past reconstructibility, the operation transitions to whole-file repair semantics automatically: ranges that can still be reconstructed succeed; ranges that cannot terminate the operation with NFS4ERR_PAYLOAD_LOST.

12.4. Destination DS Crash During PROXY_ACTIVE

A destination DS crash is handled as a normal DS failure on the destination side. The PS, acting as a client to the destination DSes, reports LAYOUTERROR to the MDS, which MAY substitute a spare or mark the destination FFV2_DS_FLAGS_REPAIR. The PS continues pushing to the remaining destinations, and clients are unaffected.

13. MDS Crash Recovery

Clients and the PS detect MDS session loss and enter RECLAIM per [RFC8881] S8.4 / S10.2.1. The PS's recovery extends the standard NFSv4.1 client-recovery sequence with one proxy-specific step -- re-registration -- and one explicit safety rule: if the PS cannot reclaim a layout for a migration it had in flight, the PS drops that migration rather than continuing with stale state.

13.1. PS Recovery Sequence

The PS, after detecting MDS session loss, performs the following steps in order:

1. *EXCHANGE_ID + CREATE_SESSION* with the PS's prior client_owner4. Standard NFSv4.1 client recovery; the PS's clientid4 is restored when the MDS recognizes the prior client_owner4.

2. *PROXY_REGISTRATION* with the PS's prior prr_registration_id. Re-registration is idempotent: the PS sends the same fields it would for a first-time registration and the MDS accepts them as re-establishing the PS role on this session. The MDS does not assume that it retained any record of this PS being registered previously; PROXY_REGISTRATION is the PS's explicit assertion of PS-ness for this session. Until this step completes, the MDS treats the client as an ordinary NFSv4 client and MUST NOT deliver proxy assignments to it.

3. *PROXY_PROGRESS* to pull the assignment queue. If the MDS has retained any in-flight migrations owned by this PS, it delivers them in the reply -- each as a fresh proxy_assignment4 carrying a fresh proxy_stateid (the prior proxy_stateid is from a prior boot and is permanently stale; see Section 6.1). For each re-delivered assignment, the PS attempts to match it to a retained sidecar entry by (pa_file_fh, pa_target_deviceid). Matched assignments proceed to step 4; unmatched assignments are handled as fresh assignments.

4. *Per-file layout reclaim*, for each matched assignment: OPEN_RECLAIM(CLAIM_PREVIOUS, pa_file_fh) per [RFC8881] S9.11.1, followed by LAYOUTGET(reclaim=true) per [RFC8881] S18.43.3 with the PS's retained layout stateid as the reclaim key. On success the MDS returns a fresh layout stateid for the resumed migration and the PS continues from where it left off. On NFS4ERR_NO_GRACE, NFS4ERR_RECLAIM_BAD, or any other reclaim failure, the PS MUST drop the migration: it issues PROXY_CANCEL with the fresh proxy_stateid delivered in step 3 to signal the MDS that the migration cannot be resumed, discards the retained sidecar entry, and halts any pending I/O for the file.

5. *Sidecar entries the MDS did not re-deliver.* For any migration the PS retained in its sidecar but the MDS did not include in step 3, the PS MUST drop that migration: discard the sidecar entry and halt any pending I/O for the file. No signal to the MDS is needed -- the MDS already has no record of this migration.

6. *RECLAIM_COMPLETE* when all per-file reclaims and drops are done.

Dropped migrations rejoin the MDS's normal assignment path: a DS still DRAINING when recovery settles will, in due course, attract a fresh proxy_assignment4 -- to this PS or another -- under the (pa_file_fh, pa_target_deviceid) invariant of Section 8.

The sidecar match in step 3 is best-effort across an MDS reboot. deviceid4 is server-scoped and MAY change across a restart per [RFC8881] S3.3.7; a target deviceid the MDS reassigns on restart will not match the PS's retained sidecar entry, the PS will not recognize the re-delivery as the same migration, and the affected sidecar entries are dropped per step 5. The autopilot re-drives the work as a fresh assignment. Implementations that preserve target deviceids across restart will resume mid-flight; those that do not will re-drive from scratch -- both are conformant.

13.1.1. Retention Requirement

A PS MUST be able to supply each in-flight migration's layout stateid as the reclaim key after a PS-process restart. The natural implementation retains it in PS-local storage (e.g., a small sidecar file or DB table keyed by pa_file_fh) when the MDS grants the L3 layout; how it is retained is an implementation matter. A PS that cannot supply the prior stateid cannot reclaim its layouts after a restart, and the affected migrations are dropped per step 5 above.

13.2. PS Identity Continuity

A PS implementation SHOULD retain its client_owner4 across PS-process restart so that post-restart EXCHANGE_ID recovers the same clientid and the in-flight migration records remain valid.

If the PS's client_owner4 rotates (e.g., because PS process state was lost), the new EXCHANGE_ID gets a fresh clientid4. The PS's prr_registration_id (if matching the prior registration) identifies it as the same operator-meaningful PS instance via the squat-guard, but the in-flight migration records keyed on the OLD clientid cannot be claimed by the NEW clientid. Those migrations are dropped per the safety rules in Section 13.1; the autopilot re-issues fresh assignments at its discretion.

13.3. Lost Migration Records

The drop rules in Section 13.1 cover the lost-state case end-to-end: a migration the MDS did not retain is dropped by the PS -- either because the MDS does not re-deliver it in PROXY_PROGRESS, or because the per-file reclaim returns NFS4ERR_NO_GRACE / NFS4ERR_RECLAIM_BAD -- and the autopilot is free to re-drive the work as a fresh assignment. No proxy-specific signalling beyond standard NFSv4 reclaim errors and PROXY_CANCEL is needed.

14. Security Considerations

The security surface added by this document sits in two places: the session the PS establishes with the MDS, and the data path clients take through the PS during a proxy operation. The session is narrower than the data path -- only the MDS talks to the PS over it, and the MDS has long been a trusted coordinator in the pNFS model -- but it carries operations that affect every client whose layouts reach a PS. The data path is broader, because it exposes the PS to every client whose layout names it; a compromised PS on that path has the same observational and modification reach as a compromised DS, and in the translating-PS case a larger reach because of the elevated identity the PS typically runs with.

Each threat the design addresses or explicitly leaves out of scope is named below. Credential forwarding, the most consequential and the most easily implemented incorrectly, is expanded in Section 14.1.

PS authority: A PS in PROXY_ACTIVE sees all client I/O for the

proxied file. A compromised PS can observe or modify file data. Deployments MUST treat PS-capable hosts as at least as trusted as the DSes they proxy for. PROXY_REGISTRATION SHOULD be gated by deployment-level authorization; arbitrary hosts that present the op without prior provisioning SHOULD be rejected.

Transport security across the operation: The PS's connections to source and destination DSes are independent of the client's connection to the PS. A PS MAY read from an AUTH_SYS source and write to a TLS destination (or any other combination). The PS is responsible for enforcing the effective security policy (e.g., do not downgrade encrypted data to a plaintext DS).

Principal binding during a proxy operation: For PS-to-DS traffic (the PS reading source DSes and writing destination DSes to carry out a MOVE or REPAIR assignment), the PS presents a principal to those DSes that they will accept; this is the PS's own service identity unless constrained delegation or equivalent is arranged. Forwarding the client's identity to the peer DSes for PS-driven data movement is NOT required and is typically NOT practical (the client is not in the conversation at that point). See Section 14.1 for the case of client-initiated file I/O through a translating PS, where the credential-forwarding rule is different and stricter.

PS impersonation: A malicious MDS could register a hostile entity as a PS. The existing MDS trust model already grants the MDS this capability via CB_LAYOUTRECALL and the ability to issue any layout it chooses; PROXY_REGISTRATION does not weaken it. Clients that require stronger PS identity verification SHOULD apply deployment-level authorization to the PS's transport-security credentials.

Registration lease expiry: If a PS's lease expires mid-operation, the MDS MUST abandon the operation: discard the in-flight migration record, revert the affected layouts to the pre-operation state, and arrange cleanup of any half-populated destination DSes. The MDS MUST NOT continue to route client I/O to a PS whose registration has lapsed.

14.1. Credential Forwarding and the Privilege Boundary

A translating PS (see Section 4.7) has structurally elevated privilege by design. To perform its management tasks -- moves, repairs, evacuations, cross-tenant re-exports -- the deployment grants the PS's service identity broad access: typically not-root-squashed, often read/write to every file in the namespace, and session authority to every DS. That privilege is intentional.

A codec-ignorant client that reaches the PS, however, arrives with its own RPC credentials that the PS does not itself need in order to function. An NFSv3 client's uid/gid, an AUTH_SYS-squashed identity, an RPCSEC_GSS principal -- none of these are the PS's own. If the PS ignores the client's credentials and issues MDS or DS operations under its own service identity when translating client I/O, every client that reaches the PS silently inherits the PS's privilege. This is a protocol-level privilege-escalation vector, and this document calls it out rather than hiding it.

The normative requirements below apply whenever a PS is translating client-initiated file I/O (as distinct from PS-driven move / repair work, which runs under the PS's own authority on directives from the MDS). They form a cohesive set: credential pass-through is the core requirement; no-squash-inversion closes the most common way pass-through can be implemented incorrectly; authorization-remains-with-MDS names the responsibility on the MDS side of the same contract; service-identity-is-for-the-control-plane draws the line between the op paths where the PS uses its own credentials and the op paths where it does not; and the failure-mode rule specifies the correct refusal behaviour rather than letting a silent fall-through become the escape hatch.

Credential pass-through: The PS MUST present the client's credentials (RPC auth flavor and principal) on every MDS or DS operation it issues as a consequence of a client-initiated request. Specifically, a client READ that the PS expands into LAYOUTGET + CHUNK_READ MUST carry the client's credentials on both the LAYOUTGET against the MDS and the CHUNK_READ against the DSes. The PS MUST NOT substitute its own service identity for client-initiated operations.

No squash inversion: If the client arrives with a root-squashed identity (for example, uid 0 mapped to nobody by the NFSv3 export configuration on the client-facing side of the PS), the PS MUST preserve the squashed identity when forwarding. The PS MUST NOT translate a client's squashed credentials back into unsquashed root, even though the PS's own identity is typically unsquashed.

Authorization remains with the MDS: When a client-initiated operation reaches the MDS over a PS <-> MDS session, the MDS MUST use the RPC credentials carried on that compound for authorization and MUST NOT substitute the PS's session-level identity. Equivalently: the MDS performs access-control checks against the forwarded client credentials, not against the PS's service identity, for any client-initiated file operation. The PS is a translator, not an authority. This is what prevents PS deployment from becoming a blanket ACL override.

PS service identity is for the control plane only: The PS MAY, and typically MUST, use its own service identity for:

* The MDS <-> PS session (the session the PS opens to the MDS, on which PROXY_REGISTRATION, PROXY_PROGRESS, PROXY_DONE, and PROXY_CANCEL all flow on the fore-channel; the session's back-channel is not used by this draft).

* Peer-DS session setup for PS-driven data movement (reading source DSes, writing destination DSes under a MOVE assignment the MDS has delivered via PROXY_PROGRESS).

* PS housekeeping.

The PS's service identity MUST NOT be used for client-initiated file data operations.

Failure mode on missing credentials: If the PS cannot forward a client's credentials for some reason (e.g., the client presented AUTH_NONE, or the client-facing side used a security flavor the PS cannot propagate), the PS MUST reject the client operation with the equivalent of NFS4ERR_ACCESS (or NFS3ERR_ACCES for NFSv3 clients). The PS MUST NOT fall back to serving the operation under its own identity.

Deployment-level requirements:

* PROXY_REGISTRATION MUST be deployment-authorized. An unknown host presenting PROXY_REGISTRATION MUST be rejected. This is the only wire-level defense against a hostile entity registering as a PS and then receiving client-forwarded credentials.

* The MDS <-> PS session MUST use RPCSEC_GSS [RFC7861] or RPC-over-TLS [RFC9289] with mutual authentication. AUTH_SYS on the MDS <-> PS session is forbidden.

* Deployments SHOULD audit both the PS's credential-forwarding behavior (the PS logs what it forwards) and the MDS's authorization checks (the MDS logs what principal authorized each operation). Divergence between the two indicates a credential-forwarding bug or compromise.

What the protocol cannot defend against:

* A compromised PS has direct access to whatever credentials pass through it. Credential confidentiality collapses the moment the PS is under adversary control. Mitigation is operational: restrict which hosts can register as a PS, audit PROXY_REGISTRATION events, rotate deployment-level keys.

* A deployment that configures a PS to run as root while the client is root-squashed has already violated rule 2 above; no wire mechanism detects a PS deliberately mis-implementing credential forwarding. Deployments SHOULD verify their PS implementation's credential-forwarding behavior through conformance testing before production use.

Future work (noted as an Open Question below): RPCSEC_GSSv3 structured privilege assertion per [RFC7861] Section 2.5.2 is the natural strong-authentication mechanism for PS-forwarded credentials. This revision does not require GSSv3 because the broader NFSv4 deployment base does not yet support it; deployments that can use GSSv3 SHOULD prefer it over AUTH_SYS passthrough for the credential-forwarding channel.

14.2. Namespace Traversal Privilege

A PS that translates client I/O has to know how the MDS's namespace is shaped: which paths are exported, what filehandle each path resolves to, how the exports mount within one another. The PS acquires this information by traversing the MDS's namespace -- LOOKUP, LOOKUPP, PUTFH, PUTROOTFH, GETFH on the PS <-> MDS session.

This traversal cannot always run under forwarded client credentials: at the point the PS needs to discover a new export (a client has not yet asked for it, or the PS has just restarted and has no FH cache) there is no client whose credentials the PS could forward. Deployments have two choices for how the PS acquires namespace shape:

Grant a narrow traversal privilege: The MDS MAY treat a registered PS's service identity as authorized for LOOKUP, LOOKUPP, PUTFH, PUTROOTFH, GETFH, and SEQUENCE on the PS <-> MDS session without applying the MDS's export-rule filtering that would normally gate those names. This is strictly a structural privilege: it permits the PS to see that paths exist and to obtain their filehandles, but grants no data access. All operations that carry or require data authorization (OPEN, READ, WRITE, LAYOUTGET, GETATTR of privileged attributes, etc.) MUST still run under the rules of Section 14.1: forwarded client credentials for client-initiated operations, and PS service identity only for control-plane operations.

A deployment that grants this privilege discloses the MDS's namespace shape to the PS's service identity -- specifically, names that the PS's source address would not be able to see through the MDS's normal export filtering. Deployments SHOULD audit traversal compounds on registered-PS sessions so the disclosure is reviewable; the MDS SHOULD log each LOOKUP / GETFH that benefits from the bypass.

Do not grant the privilege: The PS is required to translate every client-originated LOOKUP into a separate LOOKUP against the MDS under the forwarding client's credentials, caching only what the client's credentials authorized the MDS to return. This eliminates the namespace-shape disclosure but costs an extra MDS round-trip per client LOOKUP-miss and leaves the PS unable to pre-discover exports.

This document does not normatively prefer one approach over the other. Implementations SHOULD document which they use; deployment guidance for the common combined DS+PS case is that granting the privilege is the expected choice, acceptable given the PS is already a trusted control-plane peer of the MDS.

The traversal privilege is distinct from and narrower than root_squash bypass. A forwarded-uid-0 client operation (OPEN, READ, etc.), even when the privilege is granted, is still subject to normal root_squash handling on the PS's source-address rule at the MDS; the privilege applies only to the six ops enumerated above.

14.3. PS-Side Policy Enforcement (informative)

A PS implementation MAY perform per-client export-rule enforcement locally, rejecting operations the MDS would also reject before forwarding them. This is a performance optimization: it keeps bad requests off the PS <-> MDS wire and lets the PS return NFS4ERR_WRONGSEC / NFS4ERR_ACCESS without paying a round-trip.

Local enforcement is not a security boundary. Rule 3 of Section 14.1 names the MDS as the authority for every client-initiated file operation. A PS that performs local enforcement is checking its own cached copy of the MDS's per-client rules; if the copy is stale, wrong, or absent, the PS MUST forward the operation and let the MDS decide. A PS implementation that declines to perform local enforcement is conformant with this specification.

Deployments that want local enforcement need a mechanism for the PS to acquire the MDS's per-export client-rule list. This document does not standardise such a mechanism; implementation-specific options include a control-plane probe-protocol extension, out-of-band admin

distribution, or a future revision of this specification. Any such mechanism MUST limit distribution to PSes that the deployment has authorized (the rules are sensitive deployment policy) and MUST support a refresh path so PSes see rule changes within a bounded time.

15. Implementations

This section is to be removed before publishing as an RFC.

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [RFC7942]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

15.1. reffs

reffs is an open-source NFSv4.2 server, MDS, and erasure-coding client. The reffs source ships an MDS, a Proxy Server, and a multi-codec client harness used as the working implementation for this draft. reffs is licensed AGPL-3.0-or-later.

The PS surface implemented in reffs covers, at the time of writing:

* The proxy listener model (one process serving its native NFS port and a per-[[proxy_mds]] PS port from independent SB namespaces, see Section 5.3).

* PROXY_REGISTRATION over RPCSEC_GSS-class auth, presently exercised via mutually-authenticated RPC-over-TLS ([RFC9289]) with a client-cert SHA-256 fingerprint allowlist. AUTH_SYS over plain TCP is rejected with NFS4ERR_PERM per Section 14.

* PROXY_PROGRESS lease renewal and the empty-assignment idle path used by every steady-state PS poll.

* Forwarding of LOOKUP, OPEN, READ, WRITE, GETATTR, CLOSE, LAYOUTGET, GETDEVICEINFO, LAYOUTRETURN, LAYOUTERROR through the PS to the upstream MDS using the end-client’s credentials.

Forward-channel ops not yet exercised end-to-end in the public implementation include PROXY_DONE / PROXY_CANCEL, which are issued only after a PROXY_PROGRESS reply that delivers a proxy_assignment4. The MDS-driven assignment model (move, repair) is wire-implemented but the only assignment kind exercised by the published demo is the implicit no-assignment heartbeat that every PROXY_PROGRESS produces.

15.2. Demonstration

A reproducible demonstration of cross-PS proxying, exercising the layout-passthrough data path through PS-A and PS-B against a shared MDS + 6 DSes, lives in the reffs source under deploy/sanity/. The demo does not exercise migration, repair, or any proxy_assignment4; its purpose is to show that a client's codec-encoded write through one PS is recoverable byte-for-byte through a peer PS that shares the same MDS.

The matrix:

Path	Layout	Codec	Result
/ffv1-csm	FF v1	plain mirror	PASS
/ffv1-stripes	FF v1	stripe k=6, m=0	PASS
/ffv2-csm	FF v2	plain mirror, CHUNK	PASS
/ffv2-rs	FF v2	RS(4,2), CHUNK	PASS
/ffv2-mj	FF v2	Mojette systematic (4,2)	PASS

Table 2

For each row the client opens <path>/codec_<label>.bin through the PS-A proxy listener, performs a codec-encoded write of a 96 KiB random payload, then opens the same filehandle through the PS-B proxy listener and reads it back. The client's cmp(1) of the original payload and the PS-B-served payload returns no differences in all four rows.

The demo is published with the reffs source; the matrix above is the empirical record from the most recent published run on the editors' infrastructure.

16. IANA Considerations

This document has no IANA actions.

17. Interaction with the Main Draft

The mechanism this document specifies is built on top of four constructs that [I-D.haynes-nfsv4-flexfiles-v2] defines: the chunk_guard4 compare-and-swap primitive, the CHUNK_LOCK mechanism, the CB_CHUNK_REPAIR per-chunk repair callback, and the TRUST_STATEID / REVOKE_STATEID control plane. None of these are modified or extended here; this section states how each is used (or explicitly excluded) when a PS is active on a file. Two of the four (chunk_guard4, CHUNK_LOCK) describe what the PS does on the DS side of the mechanism; the other two (CB_CHUNK_REPAIR, TRUST_STATEID) describe how MDS-side bookkeeping composes with a live proxy operation.

17.1. chunk_guard4

The PS enforces chunk_guard4 CAS on the destination mirror set on behalf of clients. The PS MAY use the same guard values client writes carry through it, or generate fresh guard values on the destination side, provided uniqueness on the destination is preserved.

17.2. CHUNK_LOCK

If a client holds a chunk lock on a file when a proxy operation activates, the lock follows the file: the PS takes ownership of the lock on the destination mirror set, and the MDS-escrow semantics (the Reserved cg_client_id Value subsection of [I-D.haynes-nfsv4-flexfiles-v2]) apply if the original holder becomes unreachable during the operation.

17.3. CB_CHUNK_REPAIR

Per-chunk CB_CHUNK_REPAIR and an in-flight proxy MOVE or REPAIR migration on the same file are mutually exclusive at any given time. The MDS MUST NOT issue CB_CHUNK_REPAIR for a file currently in PROXY_ACTIVE; the PS handles any mid-move repair internally. If the MDS decides a proxied file also needs per-chunk repair after the proxy operation completes, it issues CB_CHUNK_REPAIR against the post-move layout.

17.4. TRUST_STATEID / REVOKE_STATEID

When the MDS selects a PS for a proxy operation, it issues TRUST_STATEID on the PS for every client layout stateid that will route through the PS during PROXY_ACTIVE. On PS retirement the MDS issues REVOKE_STATEID on the retired PS. This is the same mechanism [I-D.haynes-nfsv4-flexfiles-v2] defines for any DS in a tightly coupled deployment.

18. Open Questions

This section is to be removed before publishing as an RFC.

The design is substantially complete but still has open points that need Working Group input or internal agreement before the first submission. They fall into three rough categories: wire-level details that need to be nailed down (richer capability advertising), architectural choices that affect the mechanism's shape (multiple concurrent proxies per file, transitive proxy, capability-scoped EXCHGID flag), and policy questions whose answers bind deployment choices more than wire behaviour (MDS operation-state persistence, RPCSEC_GSSv3 requirement level, DEVICEID_REGISTRATION generalization). Each item below briefly states the question and the candidate resolutions; none of them block this document's core mechanism but each may reshape a detail of it.

Multiple concurrent proxies per file: The design assumes one proxy per file per operation. Should two proxies be allowed to pipeline a large file (proxy A drives the first 1 TB, proxy B drives the next)? The motivating case is a multi-terabyte move where a single proxy's bandwidth is the bottleneck; parallelizing across proxies would shorten the operation proportionally. The cost is state-machine complexity (two operation ids to track, partial-completion bookkeeping, range ownership between proxies) and layout complexity (the client sees two PS entries in ffs_data_servers and needs routing rules between them). One-proxy-per-file keeps the mechanism simple; if the bandwidth case turns out to dominate in practice, a follow-on extension can add parallelism later without invalidating the single-proxy path.

Transitive proxy: If a file in PROXY_ACTIVE needs a second move (e.g., a DS maintenance window opens while a repair is already running), what happens? Queueing the second move postpones the maintenance, which may not be acceptable if the maintenance window is hard. Aborting the first move wastes the repair work already done and puts the file back into a degraded state. Allowing a proxy to act as the source for another proxy (a "chained" proxy setup) preserves the repair progress but doubles the state-machine

work and introduces failure-mode compounds that the current design does not cover. The right answer probably depends on operator priorities and may need to be a configurable MDS policy rather than a protocol rule.

Migration-state retention across restart: The recovery model leaves retention of in-flight migration state across an MDS restart to the implementation; an MDS that retains nothing is conformant. Should the document nonetheless add a SHOULD recommending retention, so that a reboot does not discard the progress of a large move? Production deployments would likely want it; it is a quality-of-implementation recommendation only, with no effect on interoperability.

Registration as a capability-scoped authority: Should PROXY_REGISTRATION require a separate EXCHGID4 flag (e.g., EXCHGID4_FLAG_USE_PROXY_DS) to distinguish proxy-capable DSes from generic DSes, or is the registration itself the capability declaration?

Richer capability advertising: prr_codecs covers the transformation classes that matter for move / repair. Features that are implementation-internal (encryption, compression, alignment normalization) do not need to be advertised because they do not affect the wire contract. Features that DO affect the wire (e.g., support for some future sparse-read or TRIM op) would warrant a richer capability descriptor. Worth revisiting when those ops are defined.

RPCSEC_GSSv3 for translating-proxy credential forwarding: Credential forwarding under AUTH_SYS is weak (uid spoofable, no integrity protection). RPCSEC_GSSv3 structured privilege assertion ([RFC7861] Section 2.5.2) is the natural strong-authentication mechanism, but its deployment base in the NFSv4 community is narrow. Should the draft REQUIRE GSSv3 for translating proxies, RECOMMEND it, or leave it as implementation-optional? The answer likely depends on how aggressively the WG wants to push GSSv3 adoption as a side effect of standardizing this mechanism.

DEVICEID_REGISTRATION generalization: PROXY_REGISTRATION in this document is a proxy-specific capability-advertisement op: a DS opens a session to the MDS and declares that it is proxy-capable, along with codec-set membership and a lease.

The same mechanism has broader applicability as a generic DS -> MDS capability advertisement -- a DEVICEID_REGISTRATION op whose payload can carry:

* Fault-zone coordinates (building, floor, room, rack, power domain, network domain, cooling domain). An admin who needs to power down a rack can drive the MDS to recall all layouts referencing DSes in that zone and evacuate files via PROXY_OP_MOVE assignments before the outage.

* Storage media type (SSD / HDD / tape / cloud tier), for layout-policy decisions.

* Geographic location, for data-locality policy.

* Transport security profile (TLS-capable, required mutual-TLS cert fingerprint).

* Performance tier labels, for admin-assigned QoS.

* Encryption-at-rest and compression-at-rest flags.

* Scheduled maintenance windows, so the MDS can preemptively drain a DS before a planned outage.

Under this framing, PROXY_REGISTRATION is one arm of a generic DEVICEID_REGISTRATION op: the proxy-capability arm. If the WG prefers the generalization, the op in this document re-homes as a specialization of DEVICEID_REGISTRATION, keeping its wire shape for the proxy arm and adding typed entries for the other capability classes. The broader op may land in the main draft, in a dedicated draft, or as an extension of this document; settlement of that scoping question is the open item.

The op direction (DS -> MDS) is the same for both specialized PROXY_REGISTRATION and generalized DEVICEID_REGISTRATION; that direction does not today exist as a session in the main draft's tight-coupling control plane (which runs MDS -> DS). A resolution of this item also settles whether the proxy-server draft introduces a new DS-initiated session or whether the generalized version does.

19. Deferred

This section is to be removed before publishing as an RFC.

The items below are explicit protocol extensions identified during design that this revision does not specify. They overlap with Out of Scope in Section 3.2; where Out of Scope frames a deferral in the context of what the mechanism does do, this list reads as a standalone punch list of candidate follow-on work items, useful to a future revision's planner. A future editorial pass MAY merge this list into Out of Scope before submission.

* Partial-range PROXY_OP_MOVE assignments.

* Multi-proxy pipelines for very large files.

* Automated proxy selection with load balancing.

* Proxy-failure predicate (when should the MDS pre-emptively replace a slow proxy?).

* Integration with server-side copy ([RFC7862] Section 4) as an alternative for single-file moves within one namespace.

* Delta-journaling during a move for online moves without dual-writes.

20. References

20.1. Normative References

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