NFS/RDMA

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NetworkAppliance®

RDMA

- “Remote Direct Memory Access”
- Read and write of memory across network
  - Hardware assisted
  - OS bypass
  - Application control
  - Secure
- Examples:
  - Infiniband
  - iWARP/RDDP
  - (Proprietary cluster interconnects)
  - (Virtual Interface Architecture (VI))

Benefits of RDMA

- RDMA greatly reduces overhead via:
  1. Data copy avoidance
     - Especially in the receive path
     - Each data copy adds 2x line rate BW to memory bus
  2. Hardware offload
  3. OS bypass
     - Direct access to network from application
- If it hurts at 1Gb, it’s deadly at 10Gb
  - And Moore’s law won’t fix it
  - Memory busses aren’t scaling fast enough

Relative benefits of RDMA

- High client benefits:
  - Copy avoidance
  - Data alignment
  - Processing offload
  - OS bypass (kernel, trap and interrupt avoidance)
- Substantial Server benefits:
  - Data alignment
  - Processing offload
  - Interrupt avoidance

File protocol RDMA benefits

- Separation of header and data
- Zero-copy enables 0-touch directio, or removes one copy in cache path
- Operations map to wire ops 1-1
- RDMA is perfect for files
  - And pretty durn good for others too

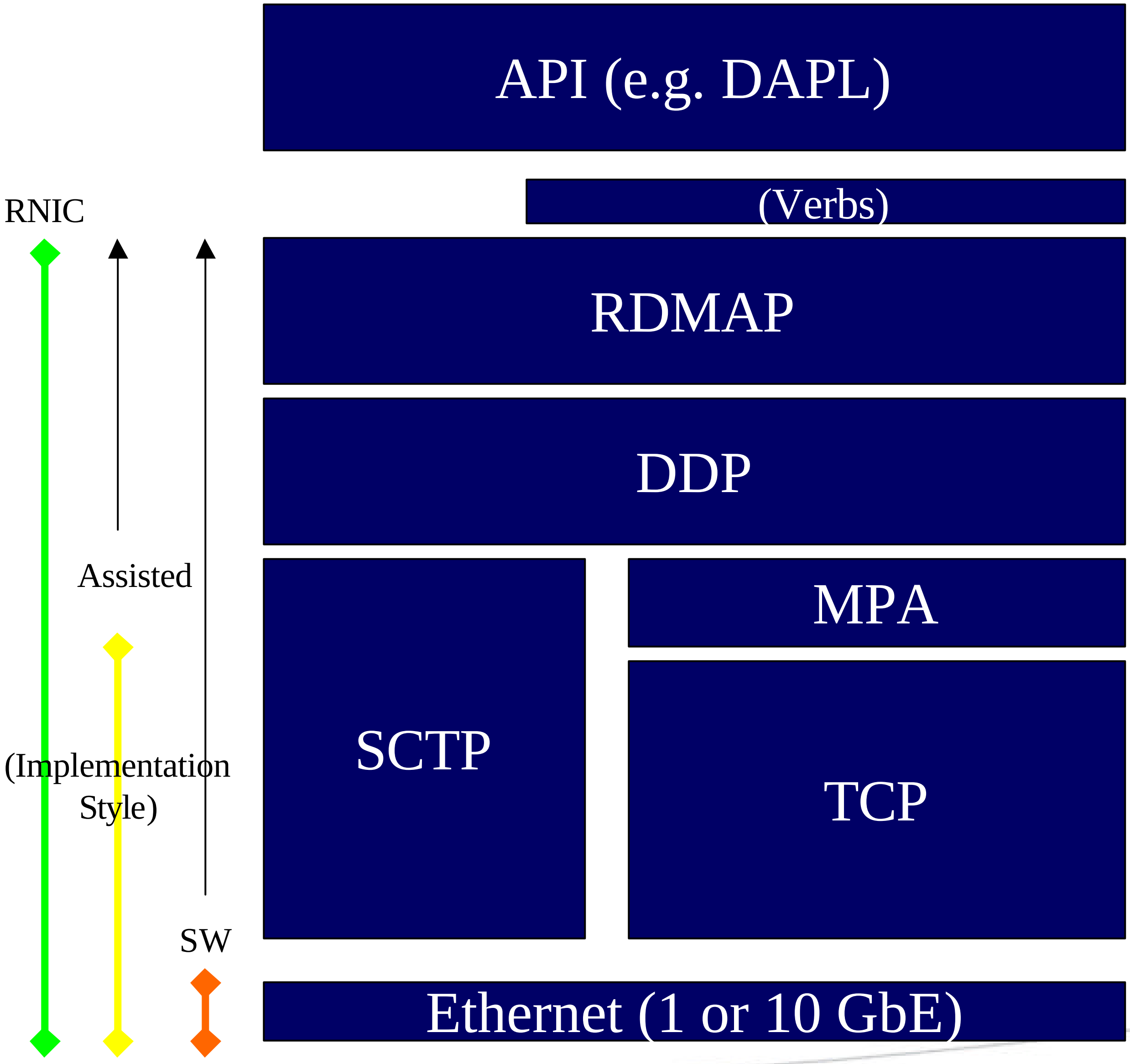
Why not just TOE?

- TOE reduces stack overhead
  - But stack overhead is relatively small
- TOE does not avoid receive data copies
  - Unless TOE includes ULP processing such as NFS header cracking, SSL, etc.
- TOE requires substantial reassembly buffer space
- No defined TOE API
- Savings from TOE are not general to all platforms

IETF RDDP Working Group

- Specify RDMA over TCP, “iWARP”:
  - RDMAP (RDMA Protocol)
  - DDP (Direct Data Placement Protocol)
  - MPA (Markers with PDU Alignment – framing)
- Also consider RDMA over SCTP

iWARP Components



Portability

Interface semantics

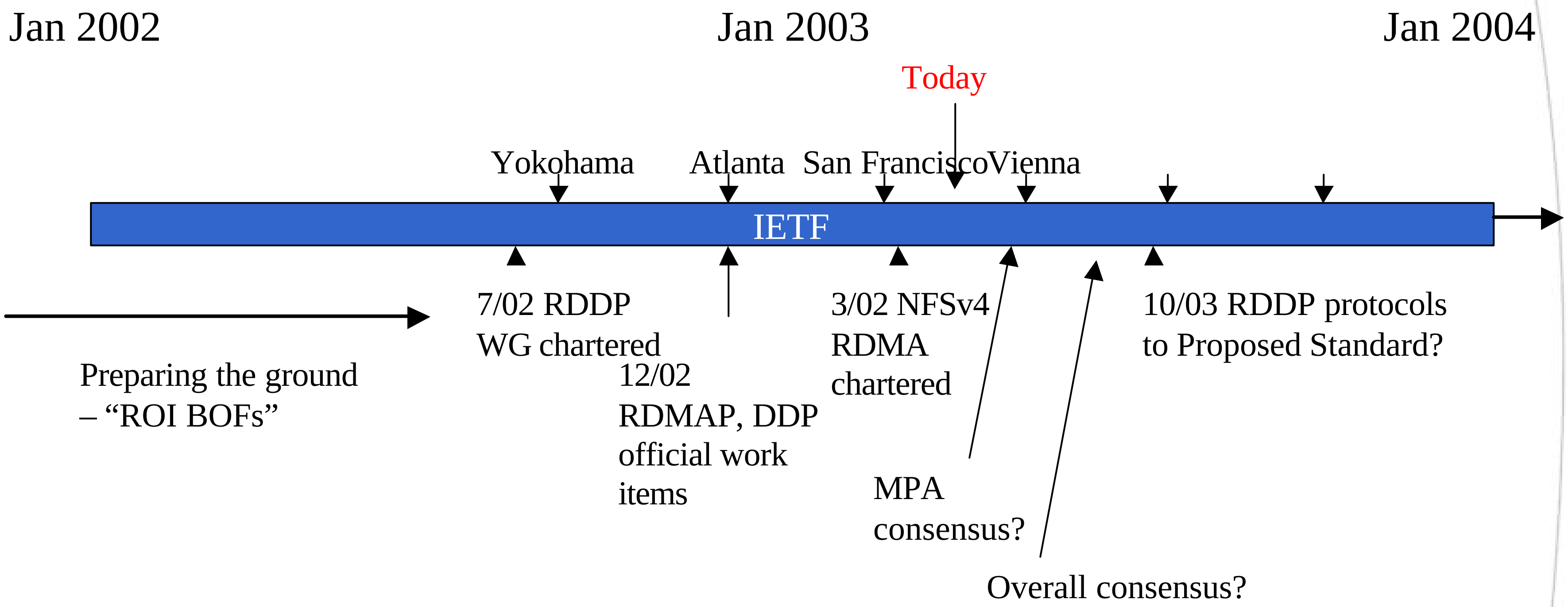
Read/Write/Send, protection

Placement, ordering

Framing, integrity (CRC)

Reliability, sequencing

IETF RDDP WG Timeline



Jan 2002

Jan 2003

Jan 2004

Today

Yokohama

Atlanta

San Francisco

Vienna

IETF

Preparing the ground – "ROI BOFs"

7/02 RDDP WG chartered

12/02 RDMAP, DDP official work items

3/02 NFSv4 RDMA chartered

MPA consensus?

Overall consensus?

10/03 RDDP protocols to Proposed Standard?

NFS/RDMA Internet-Drafts

- RDMA Transport for ONC RPC
  - Basic ONC RPC transport definition for RDMA
  - Transparent, or nearly so, for all ONC ULPs
- NFS Direct Data Placement
  - Maps NFS v2, v3 and v4 to RDMA
- NFSv4 RDMA and Session extensions
  - Transport-independent Session model
  - Enables exactly-once semantics
  - Sharpens v4 over RDMA

ONC RPC over RDMA

- Internet Draft, published May 16
  - draft-callaghan-rpcrdma-00
  - Brent Callaghan and Tom Talpey
- Defines RDMA RPC transport type
- Goal: Performance
  - Achieved through use of RDMA for copy avoidance
  - No semantic extensions

NFS Direct Data Placement

- Internet Draft, published May 16
  - draft-callaghan-nfsdirect-00
  - Brent Callaghan and Tom Talpey
- Defines NFSv2 and v3 operations mapped to RDMA
  - READ and READLINK
- Also defines NFSv4 COMPOUND
  - READ and READLINK

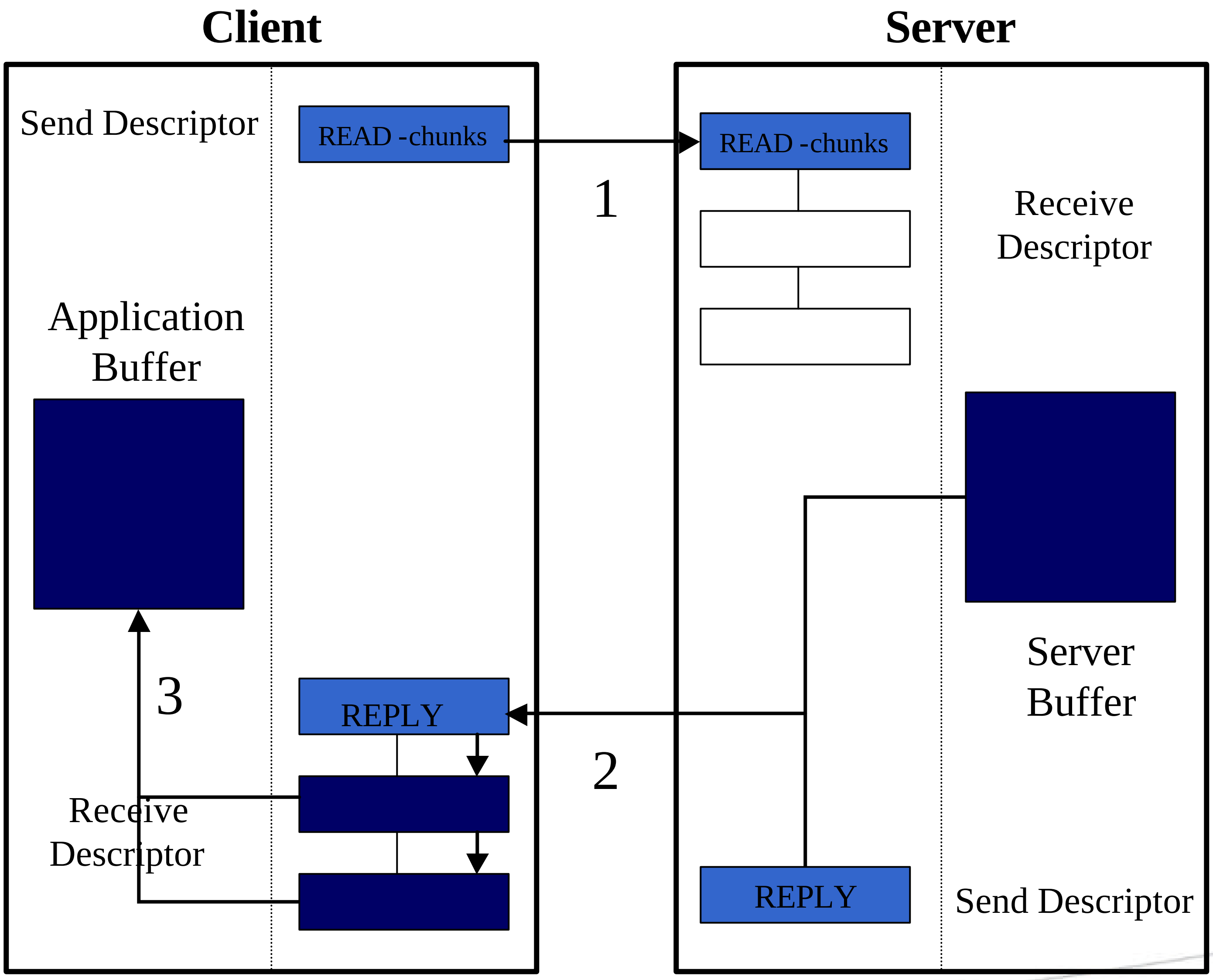
NFSv4 RDMA and Session extensions

- References ONC RPC RDMA document
- Internet Draft, published May 16
  - draft-talpey-nfsv4-rdma-sess-00
  - Tom Talpey and Spencer Shepler
- Goal: enable best use of Transport by NFSv4
  - Size negotiations
  - Channel management
  - Connection model (supports TCP, IB and iWARP)
- Also
  - Sessions
  - Exactly-once semantics

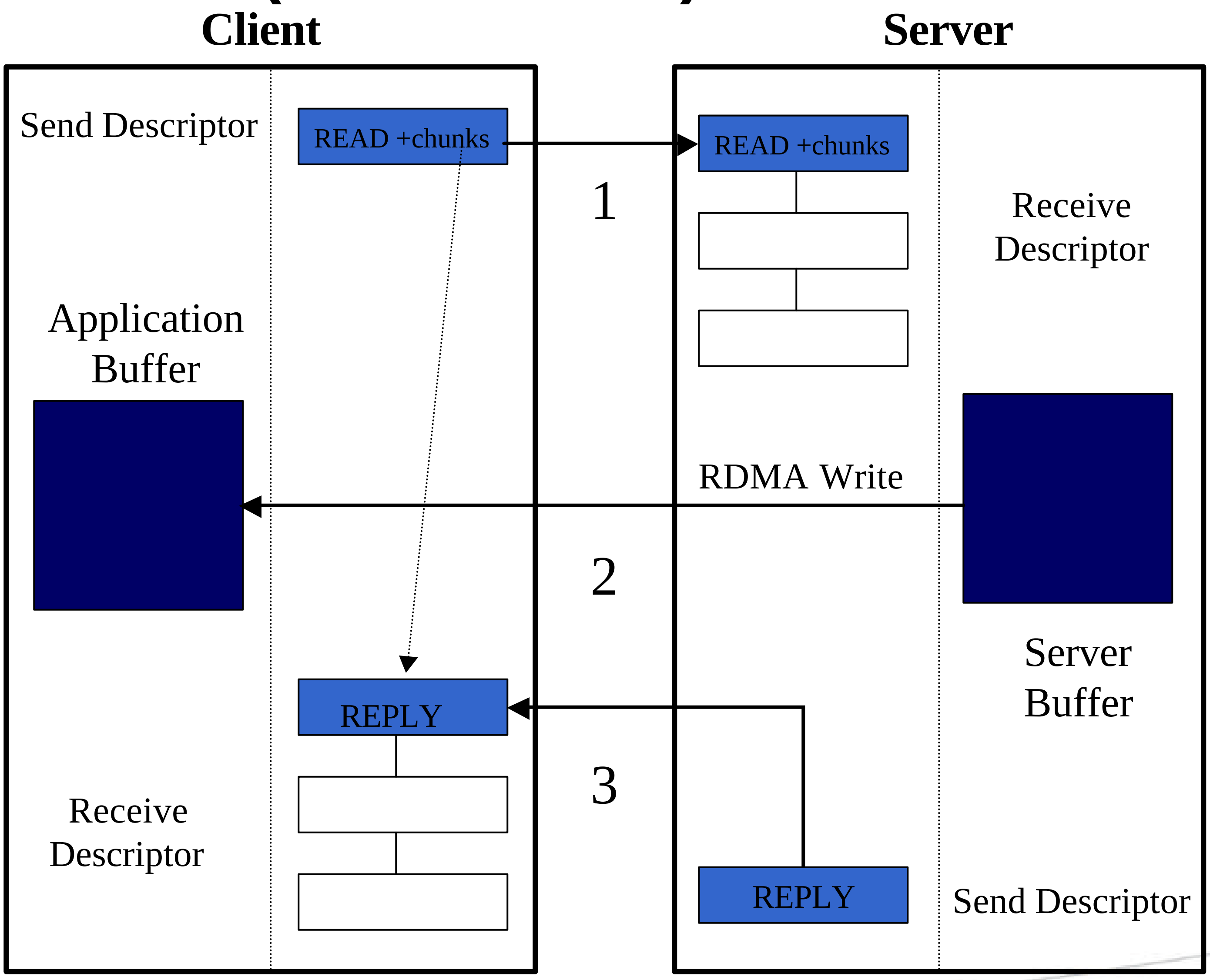
DAT – Direct Access Transport

- Common requirements and an abstraction of services for RDMA - Remote Direct Memory Access
  - Portable, high-performance transport underpinning for DAFS and applications
  - Defines communications endpoints, transfer semantics, memory description, signalling, etc.
- Transfer models:
  - Send (like traditional network flow)
  - RDMA Write (write directly to advertised peer memory)
  - RDMA Read (read from advertised peer memory)
- Transport independent
  - 1 Gb/s VI/IP, 10 Gb/s InfiniBand, future RDMA over IP
- http://www.datcollaborative.org

Inline Read


Client
Server
Send Descriptor
READ -chunks
READ -chunks
1
Receive Descriptor
Application Buffer
3
REPLY
2
Server Buffer
Receive Descriptor
REPLY
Send Descriptor

Direct Read (write chunks)



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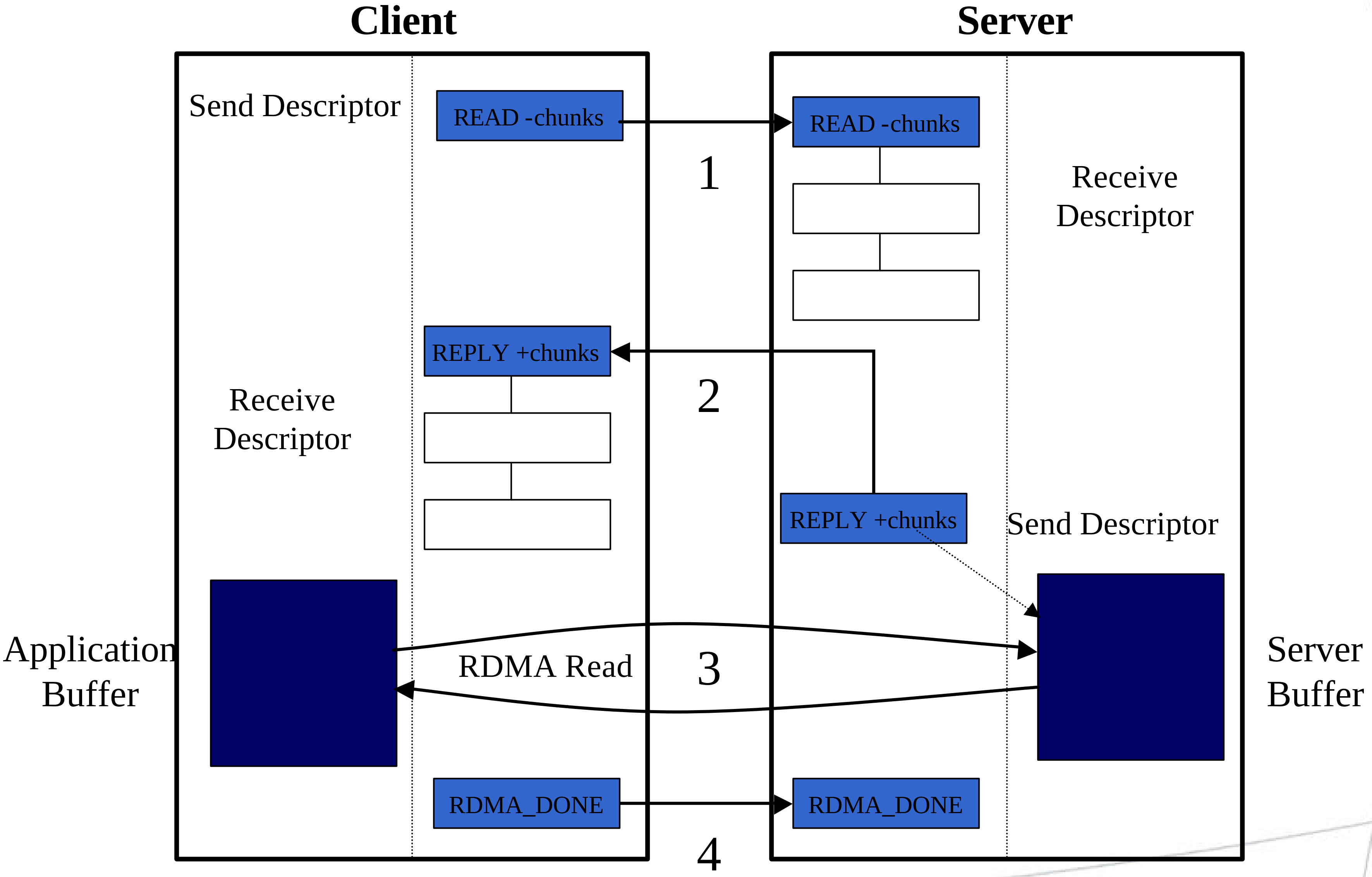
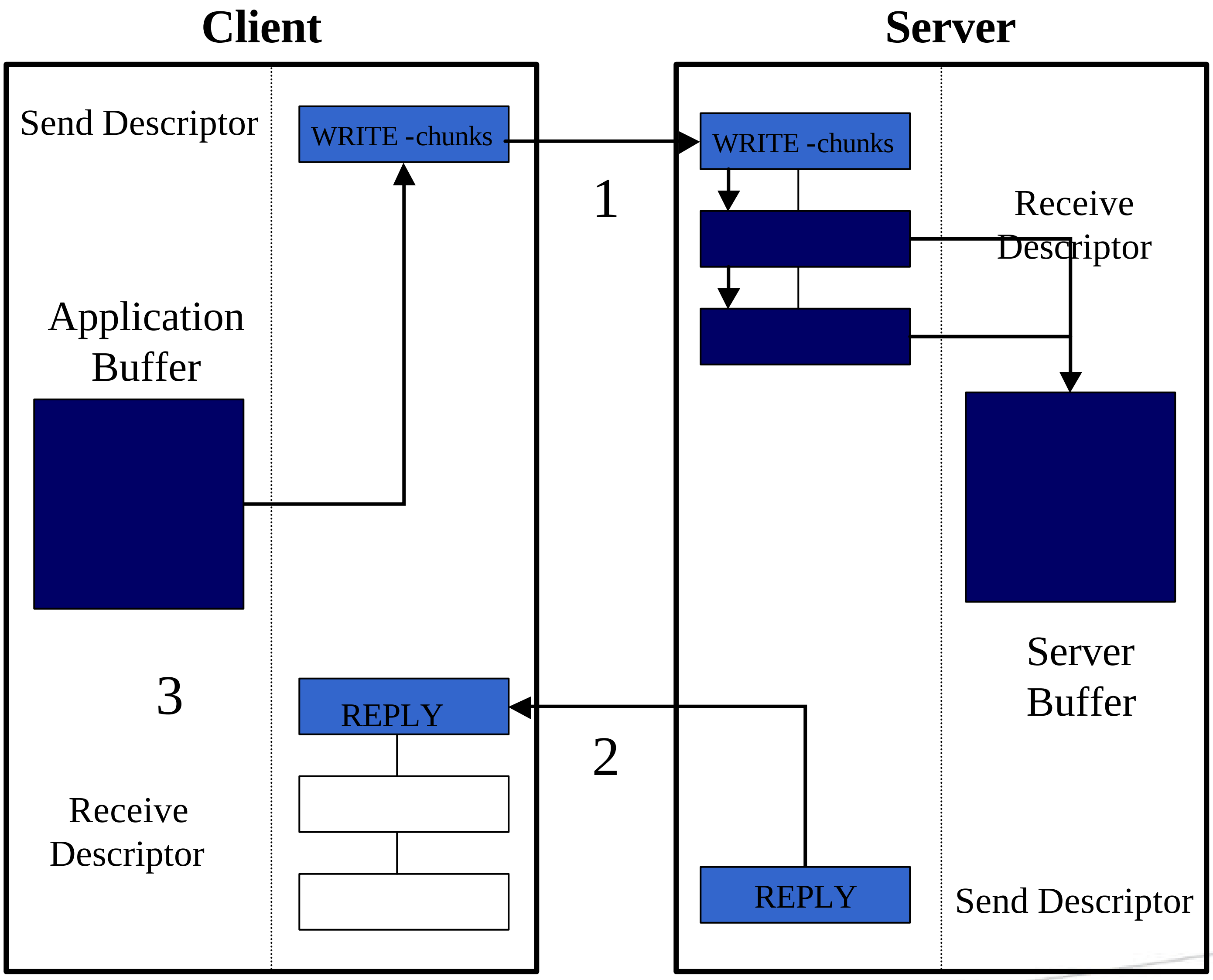
Direct Read (read chunks) – Rarely used



Inline Write



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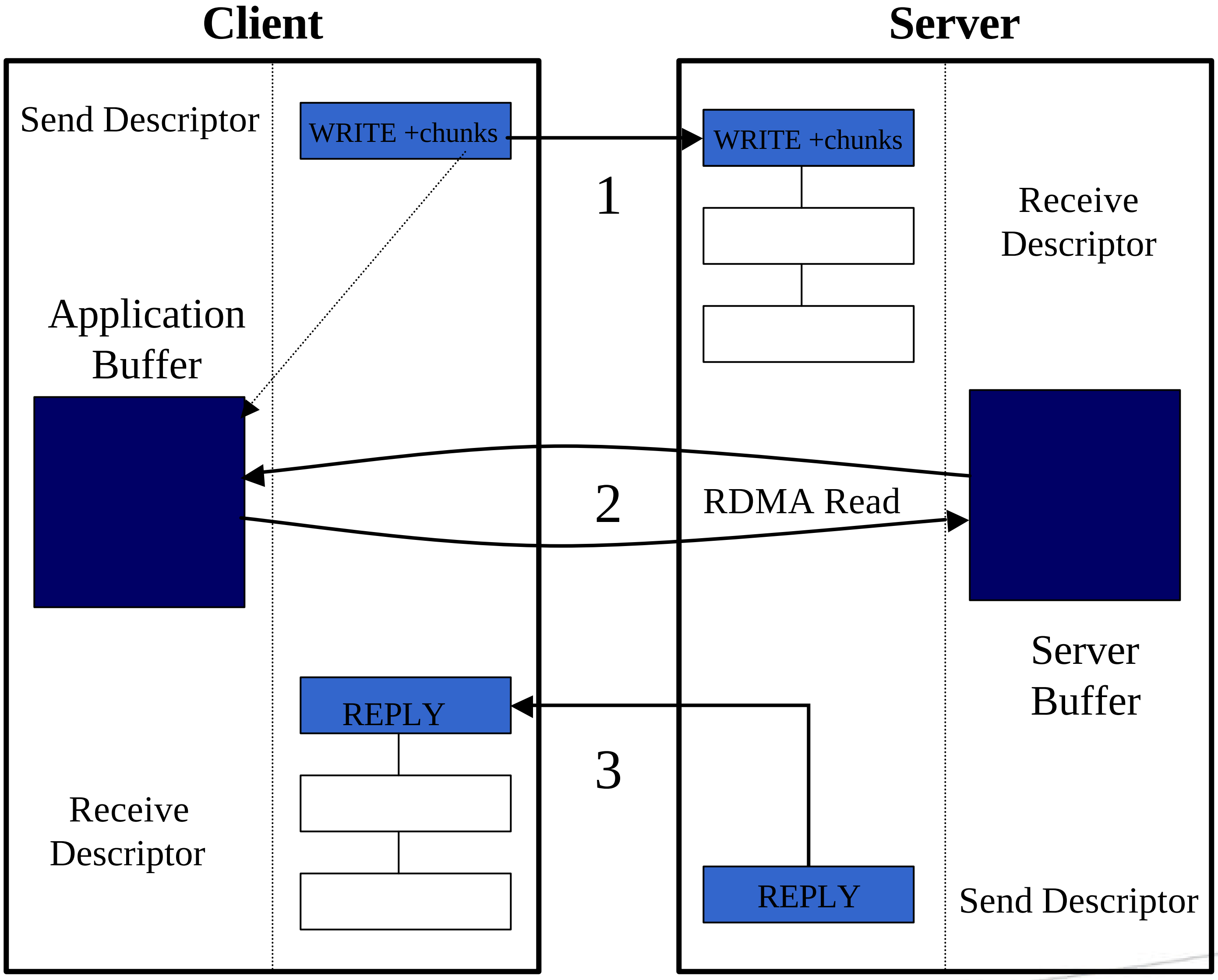
Direct Write (read chunks)



NFSv4 RDMA and Session Extensions

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The Proposal

- **Add a session to NFSv4**
- **Enable operation on single connection**
  - **Firewall-friendly**
- **Enable multiple connections for trunking, multipathing**
- **Enable RDMA accounting (credits, etc)**
- ***Provide Exactly-Once semantics***
- **Transport-independent**

5 new ops

- SESSION_CREATE
- SESSION_BIND
- SESSION_DISCONNECT
- OPERATION_CONTROL
- CB_CREDITRECALL

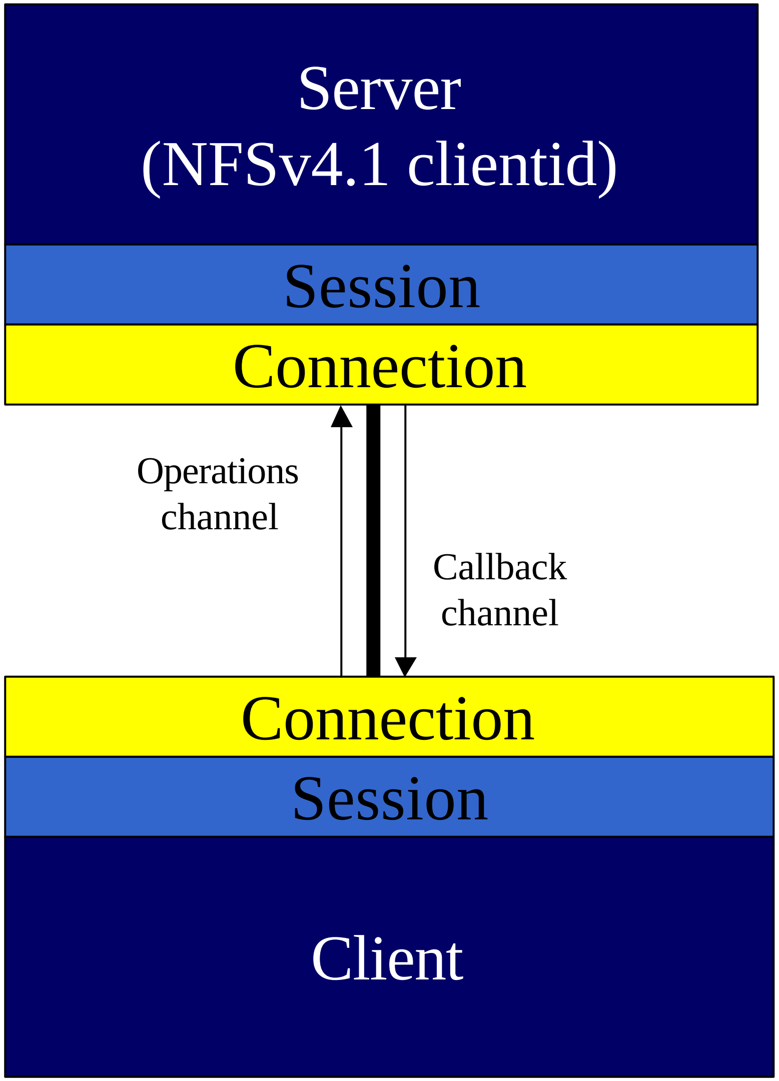
Channels versus Connections

- Channel: a connection bound to a specific purpose:
  - Operations (1 or more connections)
  - Callbacks (typically 1 connection)
- Multiple connections per client, multiple channels per connection
  - Many-to-many relationship
- All operations require a channelid
  - Encoded into COMPOUND

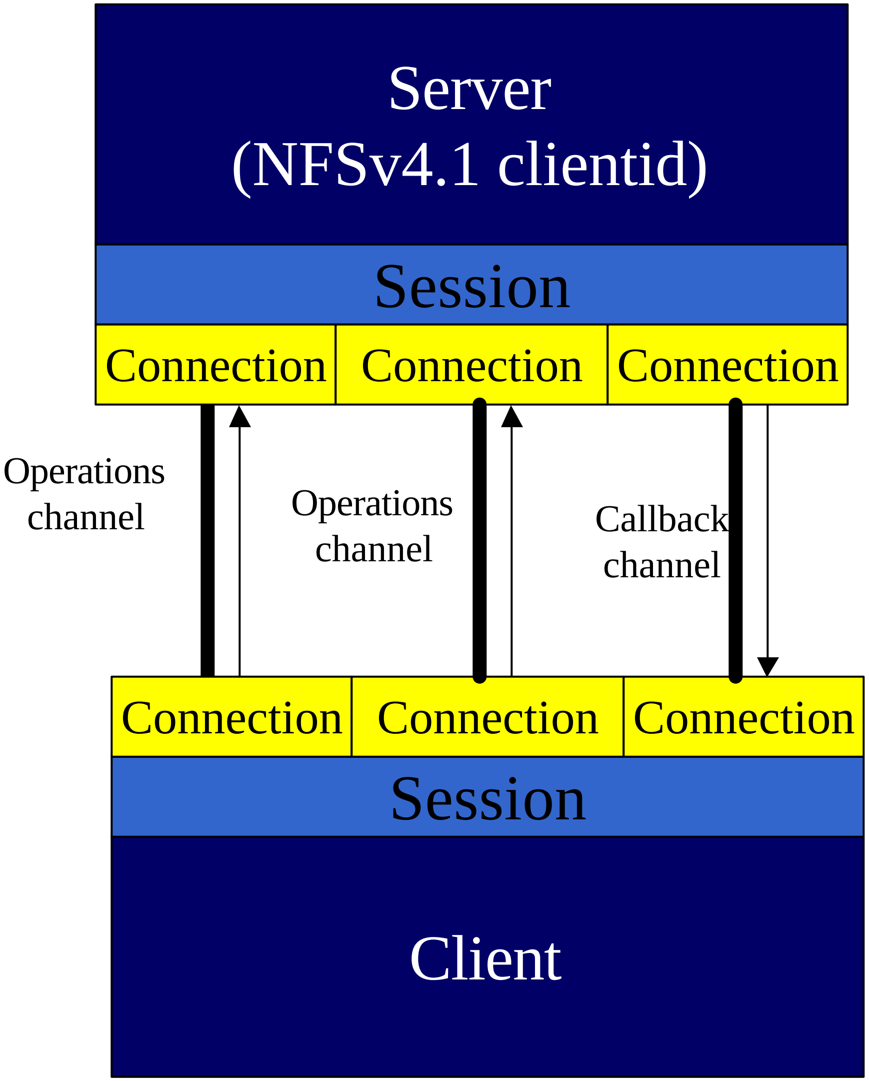
Session Connection Model

- Client connects to server
- First time only:
  - New session via SESSION_CREATE
- Initialize channel:
  - Bind “channel” via SESSION_BIND
  - May bind operations, callback to same connection
  - May connect additional times
    - Trunking, multipathing, failover, etc.
- CCM fits perfectly here
- If connection lost, may reconnect to existing session
- When done:
  - Destroy session context via SESSION_DISCONNECT

Example Session – single connection



Example Session – multiple connections



Example Session – single connection

- Resource-friendly
- Firewall-friendly
- No performance impact
- Isn’t this the way callbacks should have been spec’ed?

Exactly-Once Semantics

- Highly desirable, but never achievable
- Need flow control (N) , operation sizing (M) in order to support RDMA
- Flow control provides an “ack window”
  - Use this to retire response cache entries
- N * M = response cache size
- Session provides accounting and storage
- Done!

Streamid

- A per-operation identifier in the range 0..N-1 of server’s current flow control
  - In effect, an index into an array of legal in-progress ops
- Highly efficient processing – no lookup
- Used in conjunction with RPC transaction id to maintain duplicate request cache

Chaining

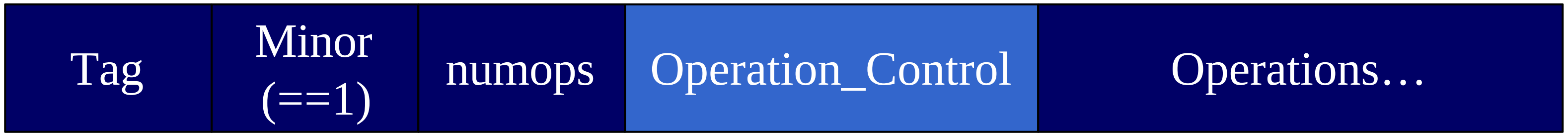
- Problem: COMPOUND restricted in length at session negotiation
- Chaining provides strict sequencing of requests
- Start, middle, end flags (and none)
- Maintains current and saved filehandles like COMPOUND

Connection model and negotiation

- Simplest form – no session at all
- Session creation enables use of RDMA
  - Per-channel (connection) RDMA mode too
  - Mix TCP and RDMA channels per-client!
- TCP mode if either RDMA mode is off
- Dynamic enabling of RDMA at session binding
  - After RDMA mode, sizes, credits, etc exchanged
- Statically enabled RDMA (e.g. Infiniband) also supported
  - Requires preposted buffer

V4 Protocol integration

- Piggyback on existing COMPOUND
- New OPERATION_CONTROL first in each session COMPOUND request and reply
- Conveys channelid, streamid, and chaining



Tag | Minor (==1) | numops | Operation_Control | Operations…

V4 efficiencies

- No need for sequenceid
  - Field will stay, but ignored under a session
- No need for clientid per-op
  - Clientid may be provided as zero
- Each request within session renews leases
- OPEN_CONFIRM not needed
- CCM is enabled

Summary

- This is a v4 proposal, not just RDMA
- Sessions are a substantial simplification
  - Clients associated with connections
  - Recoverable
  - Firewall-friendly
- Exactly-once semantics are enabled

RDMA Requirements

- Can make simple statement:
  - RDMA concepts map well to RPC and file protocols
  - These concepts benefit all transports and server implementations
  - The “RDMA changes” are in fact a fundamental, beneficial alignment

☞ **These are transport requirements, general to RDMA and TCP.**

- Much text exists already in the documents