Towards an Object Store

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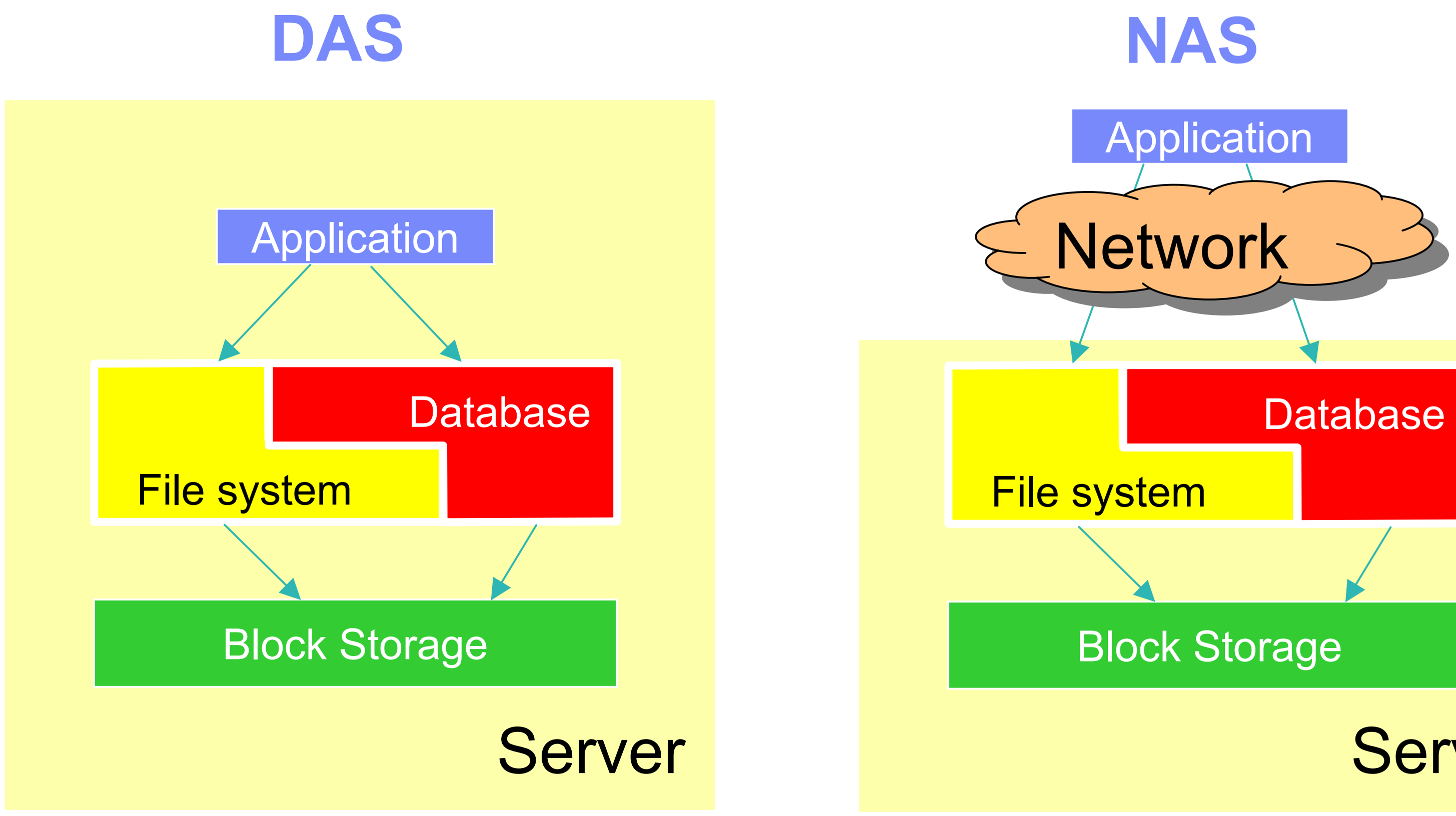
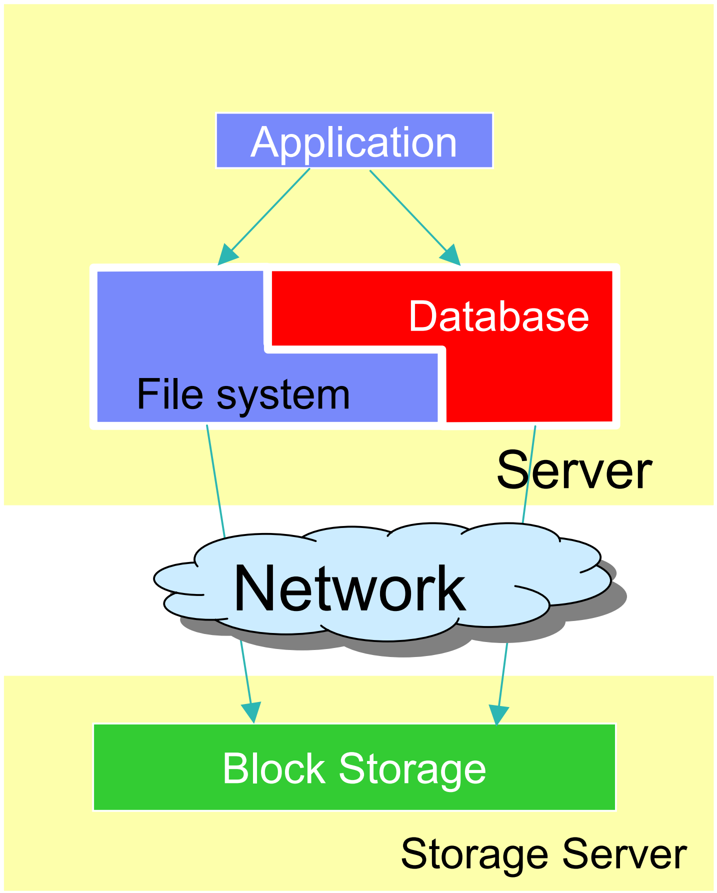
From Direct Attached Storage to Network Attached Storage…

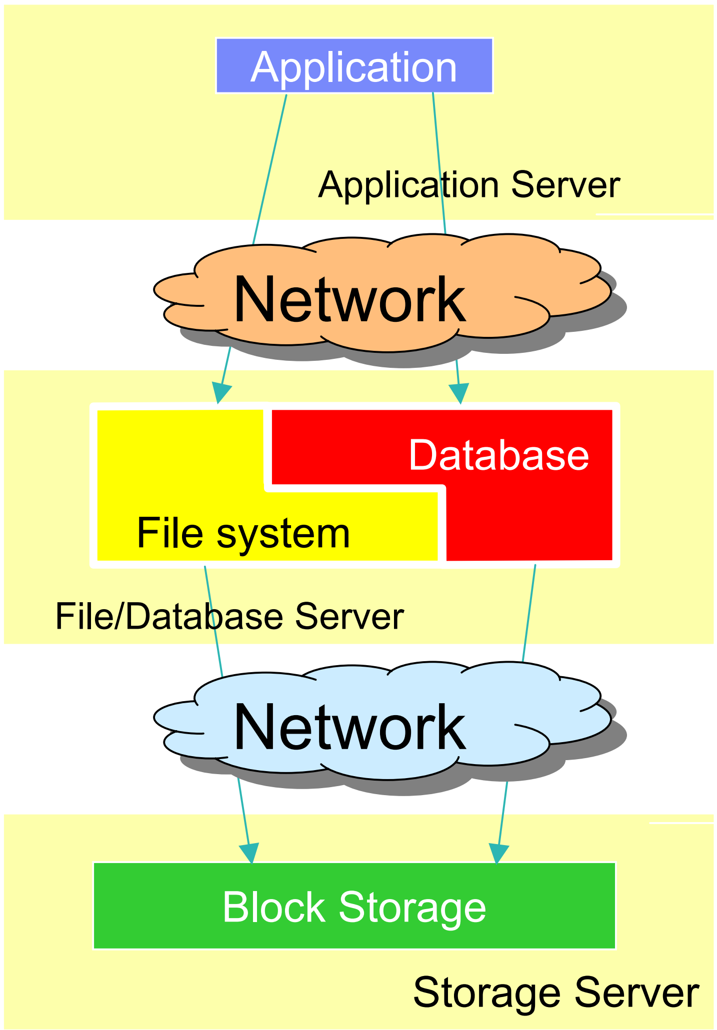


…to Storage Area Networks

SAN



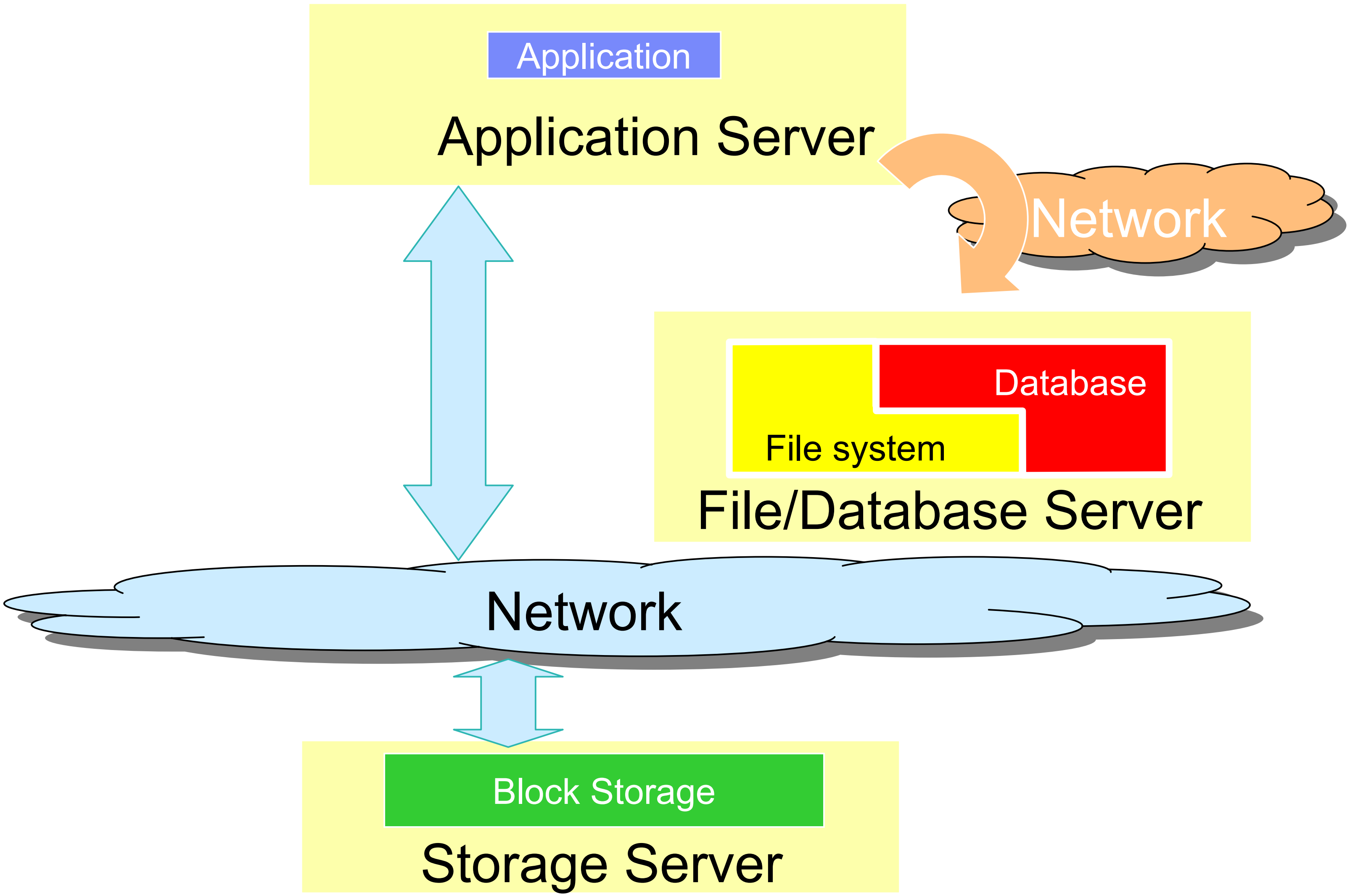
Combined Technologies



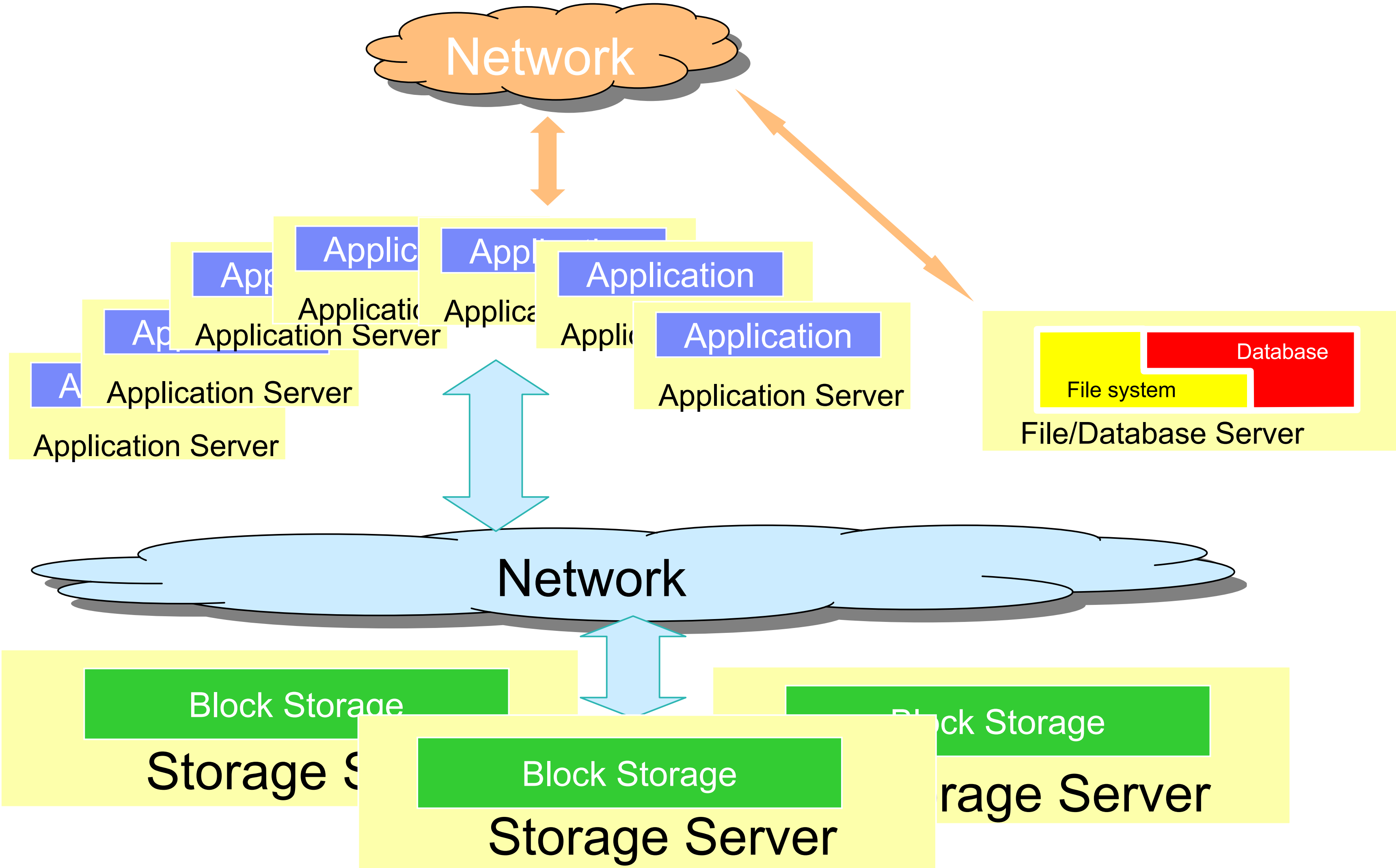
Network: IP
Protocol: CIFS NFS

Network – FibreChannel/IP
Protocol – FCP/iSCSI (SCSI)

SAN promise – Unmediated Access to Data

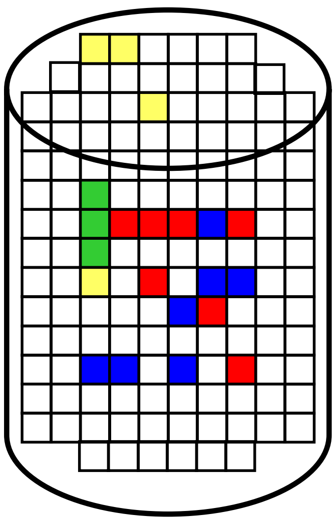


SAN promise – Disk Sharing



Object Storage

Today's Block Device

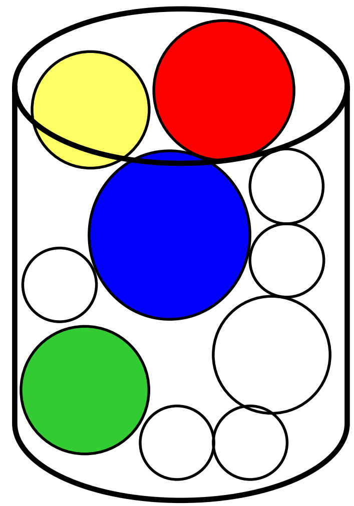


Operations
- read block
- write block

Security
- Weak
- Full disk

Allocation
- External

Object Store



Operations
- read object offset
- write object offset
- create object
- delete object

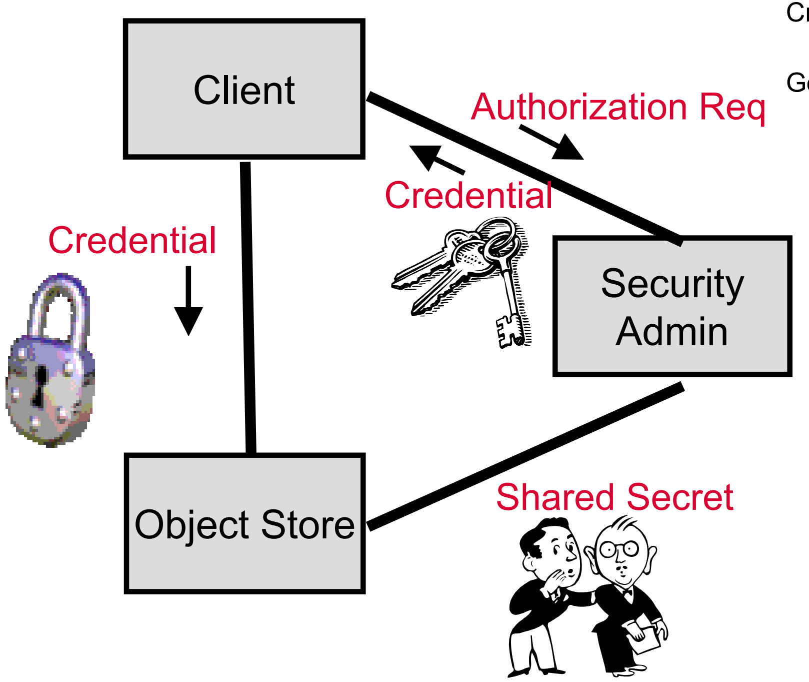
Security
- Strong
- Per Object

Allocation
- Local

Object Store Operations

- Basic Operations
  - Create Object
  - Delete Object
  - Write Offset in Object
  - Read Offset in Object
- Administrative Operations
- Basic abstract flow
  - Create an object, getting back an object ID
    - Clients responsibility to remember the ID
  - Send requests to read and write the object given the ID
  - Delete the object when done using

Object Store Security



All operations are secured by a credential

Security achieved by cooperation of:

- Admin - authenticates, authorizes and generates credentials.
- ObS - validates credential that a host presents.

Credential is cryptographically hardened

- ObS and admin share a secret

Goals of Object Store security are:

- Increased protection/security
  - At level of objects rather than whole LUs
  - Hosts do not access metadata directly
- Allow non-trusted clients to sit in the SAN
- Allow shared access to storage without giving clients access to all data on volume

Object Store Operations Read

- Read
  - Parameters: Object Store ID, Object ID, Offset, Length, Credentials
  - Basic steps an object store must provide
    - Receive request
    - Validate credentials
    - Find allocation data for indicated object
      - Map offset and length to a collection of LBAs in an underlying block storage
    - Stage the data if necessary
    - Gather the data and return to the host
  - Issues and Variants
    - Block alignment
    - Read of non-allocated data (sparse vs. past "end" of object)

Object Store Operations Write

Write

- Parameters: Object Store ID, Object ID, Offset, Length, Credentials, Data
- Basic steps an object store must provide
  - Receive request
  - <u>Validate credentials</u>
  - <u>Find allocation data</u> for indicated object
    - Determine if the indicated range is already bound to a collection of underlying LBAs
  - <u>If not already bound</u>
    - <u>Determine the mapping</u>
    - <u>Update the metadata</u>
  - Destage the data to the indicated LBAs
- Issues/Variants
  - Use of a non-volatile write cache
    - Late binding
  - Hardening the metadata updates
  - Ensuring metadata updates are only modified if data is hardened
  - Block alignment

Capability Structure

				Object Rights						ObS Rights			
Type	ObS ID	Object ID	R	W	A	T	C	D	I	F	C*	I*	Ver

Type

Does the credential apply to a specific object or entire object store

Object Rights

Read, **W**rite, **A**ppend, **T**runcate, **C**reate (given an ID), **D**elete, **I**nfo

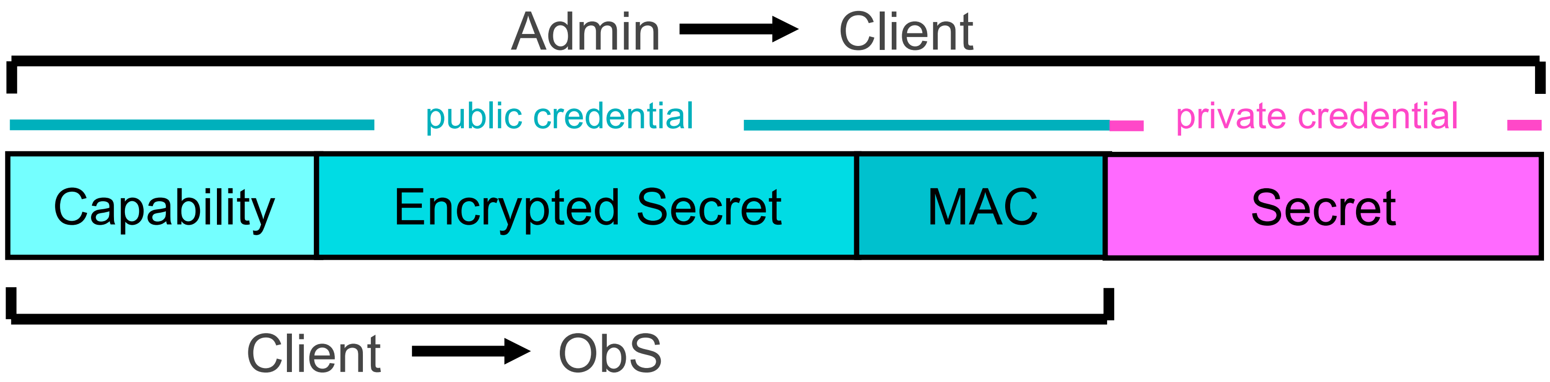
Object Store (ObS) Rights

Format, **C**reate (ObS generates ID), **I**nfo on Object Store

Ver(sion)

Used to allow the credential to time out

Credential Structure



Capability

Operations that the credential entitles

Encrypted Secret

A Secret generated by the Admin

A different secret for every credential

Encrypted with a key Admin shares with the ObS

MAC -- Message Authentication Code

Standard cryptographic hash on the capability and the encrypted secret

Ensures host cannot alter/forge a credential

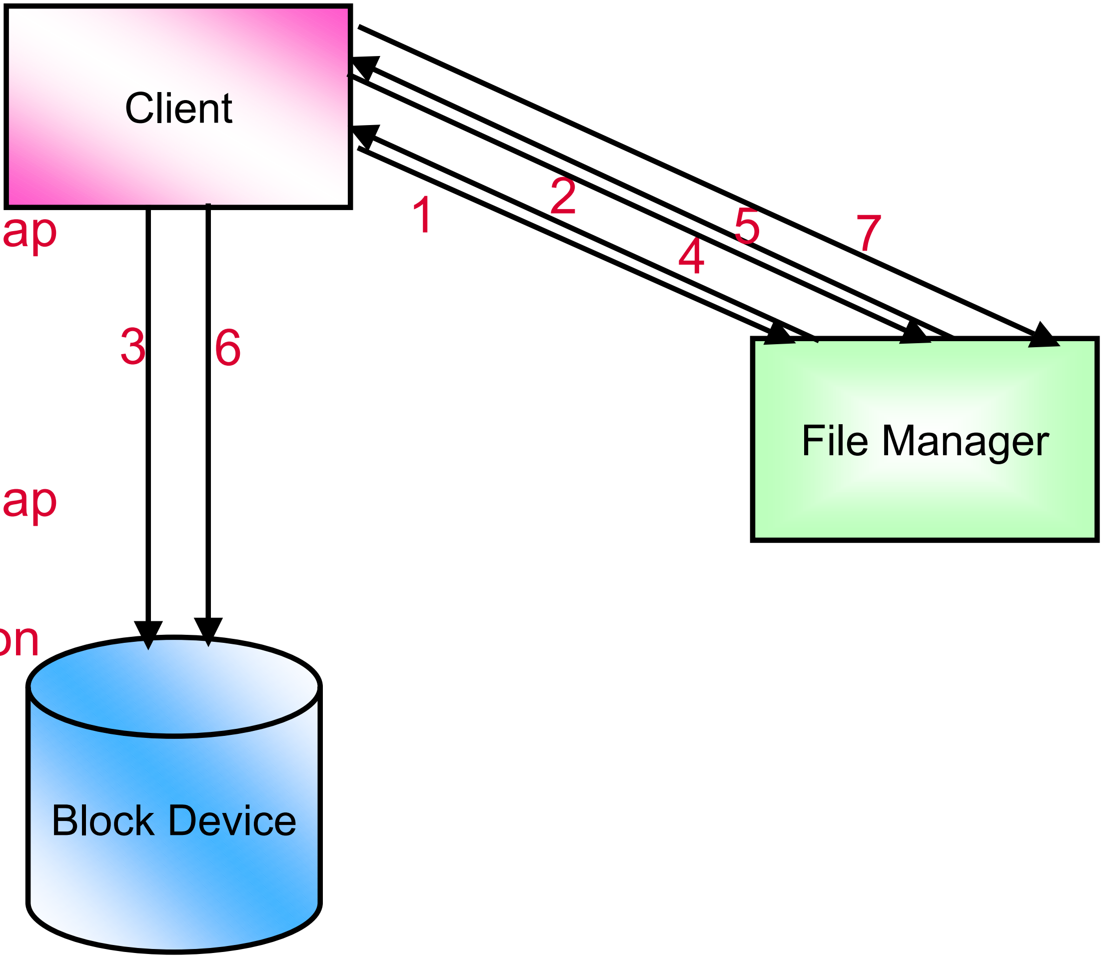
Secret

The (un-encrypted) secret

Used by the client to verify that it got the credential form the Admin

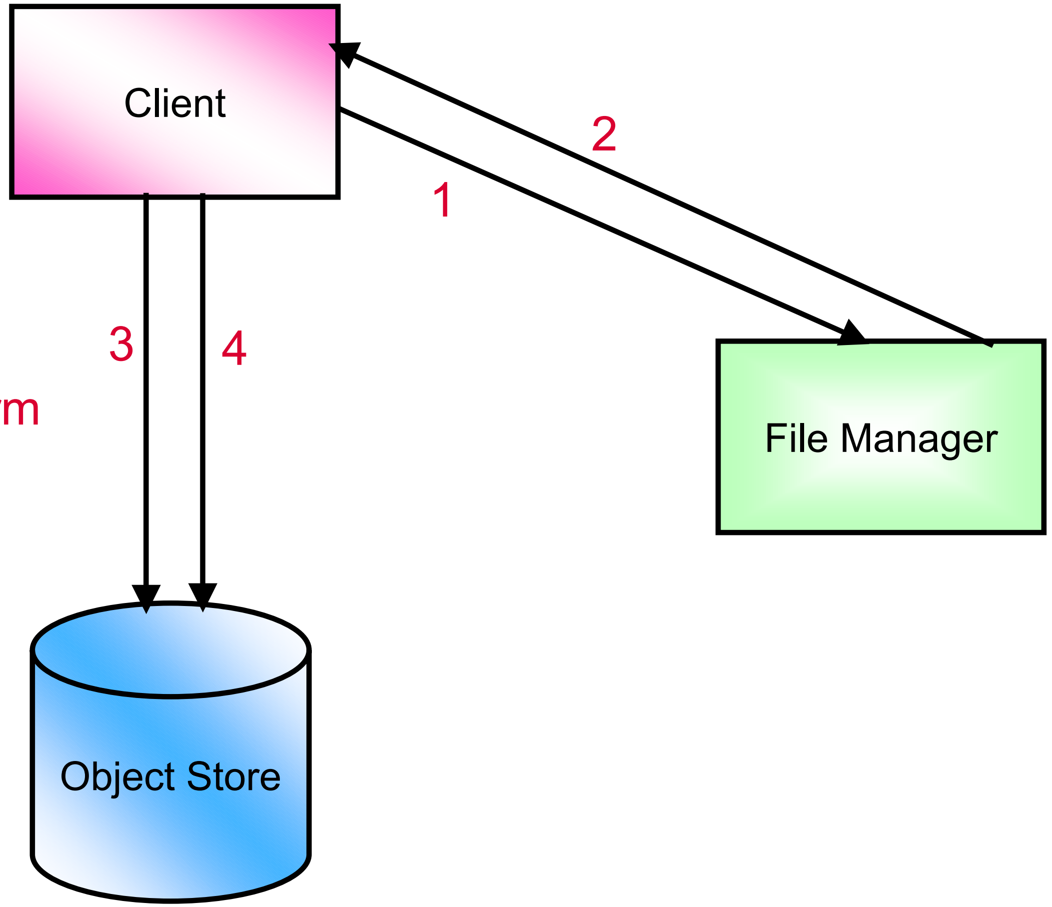
SAN File System without an Object Store

1. Create File
2. Return allocation bitmap
3. I/O (unsecured)
4. Request additional allocation bitmap
5. Return allocation bitmap
6. I/O (unsecured)
7. Return actual allocation data to File Manager



SAN File System with an Object Store

1. Create File
2. Return Locks and Credentials
3. Create Object and perform I/O with Credentials
4. I/O with Credentials



Blocks vs. Objects vs. Files

Block Storage

- Fastest
- Small set of operation
- No connection to user's abstraction
- Dumb device
- No access security

Object Storage

- Fast
- Small set of operations
- Object usually maps to user abstraction
- Local space management
- Enable end-to-end management
- Access is Secure

File Storage

- Slow
- Rich set of operations (sometimes more than what the application requires)
    - Locking
    - Hierarchical name service
    - …
- File usually maps to user abstraction
- Access is Secure (strength depending on the protocol)

How Real Are Object Stores?

Object Stores

- First big push
  - Garth Gibson, et al., NASD -- CMU, Panasas
- DSF Storage Manager
- Antara – a prototype Object Store
- Lustre and Object Store Target (LLNL)
- CAS (EMC Centera – A Write-Once ObS)
- . . .

Drivers

- iSCSI
  - IP access to storage exacerbates SAN security problems
- Data Sharing Facility (DSF)
  - A highly scalable research file system which incorporated an object-store like component to ensure local space allocation
- Storage Tank and other SAN file systems
  - Shared access requires SAN security (or trusted clients!)

What is Antara*?

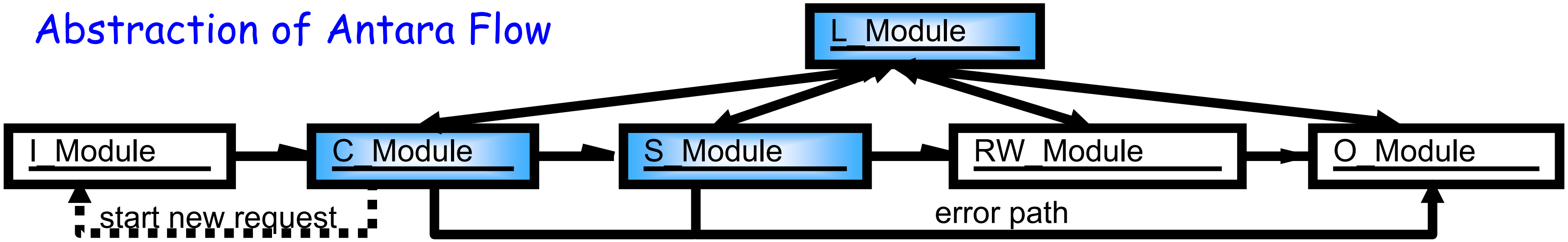
- **A prototype implementation of an object store as a standalone control unit**
  - First generation ObS prototype
    - Generation zero: DSF Storage Manager
    - Generation two…
  - Initial focus on integrity and recoverability of metadata and scalable design
    - Current focus on demonstrating "reasonable" performance
  - Multiple versions have been developed
- **Features**
  - IP connectivity (but design is fairly transport independent)
  - Supports the Antara ObS protocol
    - Similar in functionality to T10 draft but not SCSI
    - Commands currently supported:
      - Open/Close Session, Create/Delete Object, Read/Write/Append, Truncate, . . .
  - Export a single object store
  - Current version assumes a non-volatile store
    - Prior versions did not have this assumption

* "interior" in Sanskrit

General Design

- **A conceptual pipeline**
  - Uses completion ports to avoid context switches
  - In most cases same operating system thread handles multiple stages
- **The modules are:**
  - I-Module (communication **i**nput, connection management)
  - S_Module (**s**ecurity)
  - C_Module (**c**ontrol and dispatching)
  - L_Module (**l**ookup, metadata tables and locking mechanisms)
  - RW_Module (**r**ead-**w**rite of data and log of metadata)
  - O_Module (communication **o**utput)
- **The C, L, and S modules are mostly object store unique**
  - I, RW, and O provide functions that are in most control units

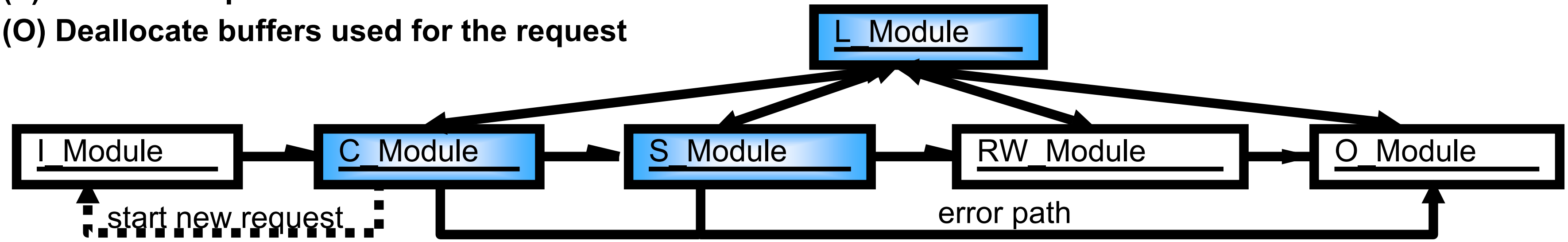
Abstraction of Antara Flow



Flow for Read and Write in Antara

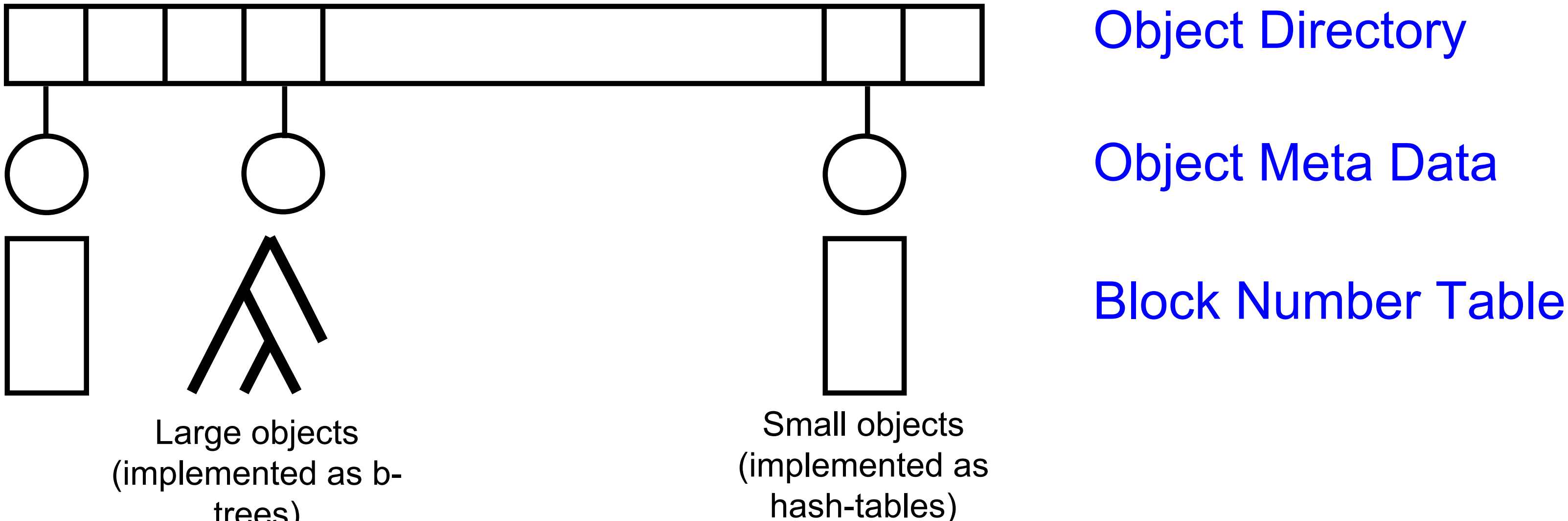
1 **(I) Receive CB, determine needed buffers, allocate and receive data into buffers**
2 **(C) Mark the request as running; Delay this request if clashes with other operation**
3 **(C,I) Notify OS ready to receive the next request from the client**
   Additional requests handled in parallel
4 **(S) Check Security (e.g., proper session, credentials, etc.)**
5 **(L) Perform necessary lookups (and/or allocations in case of writes)**
   Put allocation information in the request
6 **(RW) Read/write the data from the cache**
7 **(L) Mark the request as done**
   1Allows delayed requests to start, e.g., read-write conflict although read response may need to wait for log complete
8 **(L) Log the request (this is a no-op in the case of read)**
   Ensures hardening of the allocation information
9 **(L) Mark the request as logged (this is a no-op in the case of read)**
   Allows delayed requests to complete

- **(O) Send the reply**
- **(L) Mark the request as sent**
- **(O) Deallocate buffers used for the request**



Metadata

- **Significant effort invested in designing efficient, scalable data structures**
  - Minimize contention for concurrent clients and multiple processors
- **Object Directory maps from OID to object's metadata via a sparse hashtable**
- **Object metadata includes object size and a block number table**
- **Block number table maps from offset in block to extents**
  - Small objects use a dynamic, linear-probe, hash table.
  - Large objects use a b-tree.
- **Freespace managed via a buddy list bitmap**



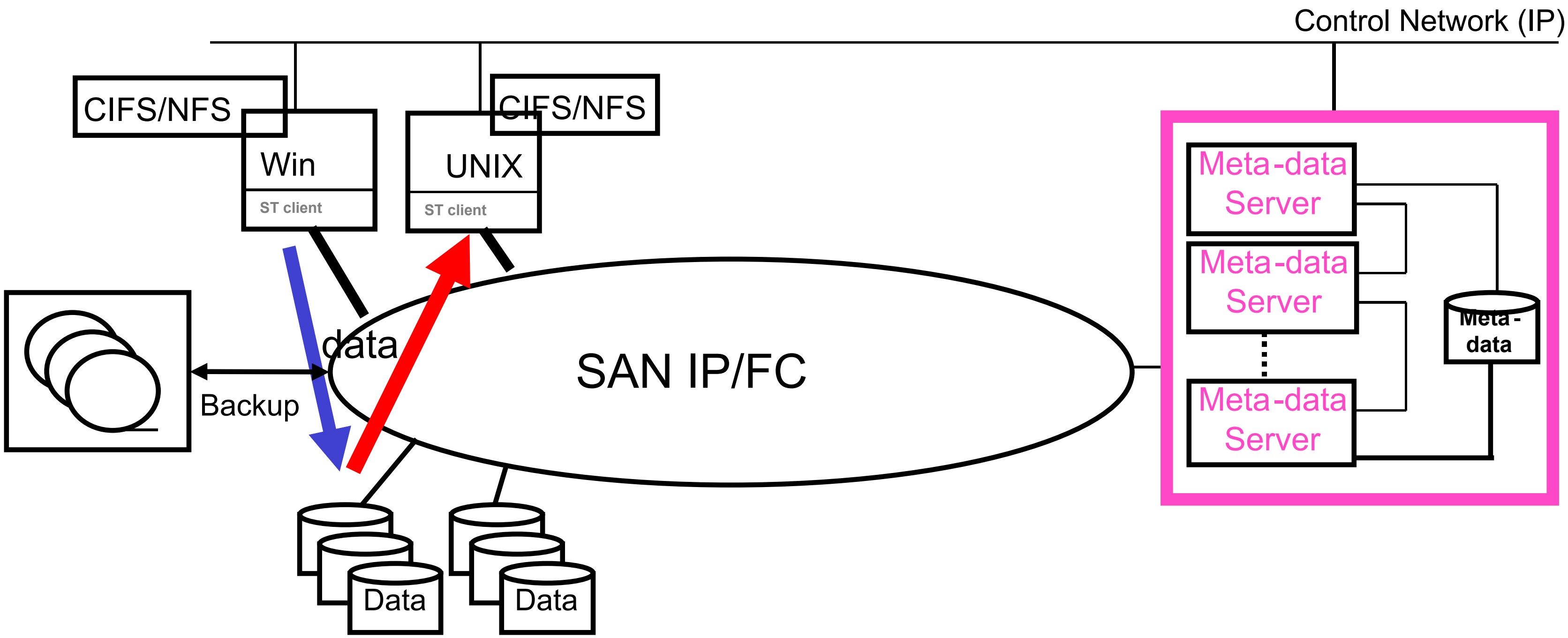
Metadata *(cont)*

- **The linear-probe hash table used for mapping OIDs to OMDs was chosen for parallelism**
  - Not all of the metadata can fit into main memory.
  - Some metadata accesses will require disk accesses
  - Shared/exclusive locks, created on-the-fly, allow locking only specific entries of the hash table.
- **The block-number table implementations were chosen for minimizing page-faults**
  - For large objects, b-trees were chosen based on similar choices in databases.
  - For small objects, an entire b-tree page is inefficient in terms of space and time.
- **Entries in block number table represent extents**
  - Extents range from one block up to the maximum amount of data transferred in a write request

Antara Space Allocation

- **Goals**
  - Logically consecutive blocks of an object will map to consecutive LBAs
  - Avoid fragmentation
  - Quick allocation decisions
- **Approach**
  - Maintain a MRU cache of objects receiving allocating writes
  - Non-persistently associate with each object a large extent of consecutive LBAs
  - For an allocating write, take space from large extent at appropriate offset
    - Persistently update free space bitmap

Storage Tank Background (IBM Research Almaden)



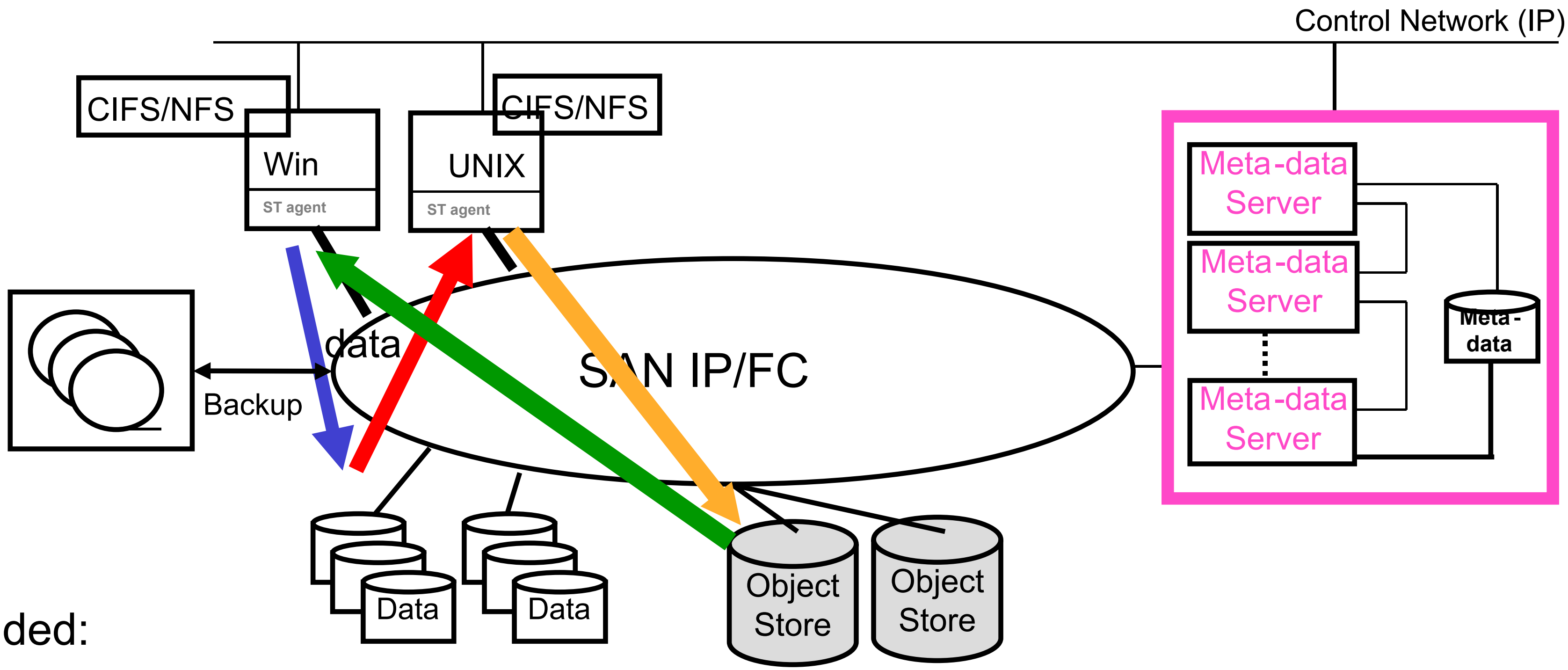
Capabilities:

- Performance and semantics similar to local file system
- Sharing like NAS
- Policy-based, centralized storage management

Object Store and Storage Tank

- **Storage Tank was designed with an Object Store in mind**
- **Object Store will be at same level as control units**
- **To integrate an Object Store into Storage Tank requires changes to**
  - Meta Data Server
  - Storage Tank Client
- **Main customer benefit will be security and protection**
  - Other benefits will follow
- **ObS initiator is the callable module that interacts with the ObS Target**
  - Initiator integrated into both Storage Tank client and Meta Data Server
  - Current Initiator comes in several flavors
    - Synchronous and Asynchronous
    - User-mode and Kernel-mode

Object Store added to Storage Tank



added:

- SAN security
- Scalability
- Manageability