SMB remote file protocol (including SMB 3.x)

Jose Barreto
Microsoft

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Abstract and Learning Objectives

- Title: SMB remote file protocol (including SMB 3.x)
- Abstract

  - The SMB protocol evolved over time from CIFS to SMB1 to SMB2, with implementations by dozens of vendors including most major Operating Systems and NAS solutions. The SMB 3.0 protocol had its first commercial implementations by Microsoft, NetApp and EMC by the end of 2012, and many other implementations exist or are in-progress. The SMB3 protocol continues to advance. This SNIA Tutorial begins by describing the history and basic architecture of the SMB protocol and its operations. The second part of the tutorial covers the various versions of the SMB protocol, with details of improvements over time. The final part covers the latest changes in SMB3, including future work, and the resources available in support of its development by industry.

- Objectives
  - Understand the basic architecture of the SMB protocol family
  - Enumerate the main capabilities introduced with SMB 2.0/2.1
  - Describe the main capabilities introduced with SMB 3.0 and beyond

Summary

- History
  - Remote file protocol
  - A brief history of CIFS, SMB, SMB2 and SMB3
  - SMB implementers
- Basics
  - The basics of SMB
  - SMB 2.0
  - SMB 2.1
- SMB 3.0
  - SMB Transparent Failover
  - SMB Scale-Out
  - SMB Witness
  - SMB Multichannel
  - SMB Direct
  - SMB Directory Leasing
  - SMB Encryption
  - VSS for Remote File Shares
- SMB 3.0.2
- SMB 3.1.1

Remote file protocol

- Remote (not Local)
  - Access file across the wire (LAN, WAN)
- File (not Block)
  - Different semantics
- Protocol
  - Well-defined and documented
- Examples
  - NFSv4, SMB2, SMB3, WebDAV

A brief history of CIFS, SMB, SMB2, and SMB3

- SMB - 1980s
  - PC-DOS – 1984
  - LAN Manager – 1988
  - Implemented on Unix and other operating systems (part of the OS or as a suite like Samba)
- CIFS - 1996
  - Windows NT 4.0 – 1996
  - IETF draft – Common Internet File System – 1997
  - SNIA Technical Specification – 1999
- Back to SMB - 2000
  - Windows 2000 Extensions – 2000
  - Extensions for other implementations of SMB
- SMB 2.0 (or SMB2) - 2008
- SMB 2.1 (or SMB2.1) - 2010
- SMB 3.0 (or SMB3) – 2012
- SMB 3.0.2 (or SMB3.02) – 2013
- SMB 3.1.1 - 2015

CIFS as a generic term for SMB?

- CIFS means SMB as it existed in Windows NT 4 (mid-1990's!)
- However, the term "CIFS" is sometimes used *incorrectly* to refer to more recent versions of SMB, like SMB2 or SMB3
- 'CIFS' is sometimes used as a marketing term to identify specific products, independent of the SMB version
- Using the term 'CIFS' to refer to SMB 2.0 or SMB 3.0 is like...
  - Using POP to refer to IMAP (in e-mail protocols)
  - Using WEP to refer to WPA (in wireless security)
  - Using NFS to refer to NFSv4
- If it says 'CIFS' on the box, you don't know what you'll get.
  - Always look for the full protocol version!

SMB implementers (alphabetical order)

Apple

- MacOS X 10.2 Jaguar – CIFS/SMB 1.x (via Samba)
- MacOS X 10.7 Lion – SMB 1.x (via Apple's SMBX)
- MacOS X 10.9 Mavericks – SMB 2.1 (default file protocol)
- MacOS X 10.10 Yosemite – SMB 3.0 (default file protocol)

EMC

- Older versions – CIFS/SMB 1.x
- VNX – SMB 3.0
- Isilon OneFS 6.5 – SMB 2
- Isilon OneFS 7.0 – SMB 2.1
- Isilon OneFS 7.1.1 – SMB 3.0

Microsoft

- Microsoft LAN Manager – SMB
- Windows NT 4.0 – CIFS
- Windows 2000, Server 2003 or Windows XP – SMB 1.x
- Windows Server 2008 or Windows Vista – SMB 2
- Windows Server 2008 R2 or Windows 7 – SMB 2.1
- Windows Server 2012 or Windows 8 – SMB 3.0
- Windows Server 2012 R2 or Windows 8.1 – SMB 3.0.2
- Windows Server or Windows 10 Preview – SMB 3.1.1

NetApp

- Older versions – CIFS/SMB 1.x
- Data ONTAP 7.3.1 – SMB 2
- Data ONTAP 8.1 – SMB 2.1
- Data ONTAP 8.2 – SMB 3.0

Samba (Linux or others)

- Older versions – CIFS/SMB 1.x
- Samba 3.6 – SMB 2 (some SMB 2.1)
- Samba 4.1 and 4.2 – SMB 3.0

And many others…

- Most widely implemented remote file protocol in the world, available in nearly every NAS and File Server
- See the SDC participants on slide 30

Information on this slide gathered from publicly available information as of April 2015.

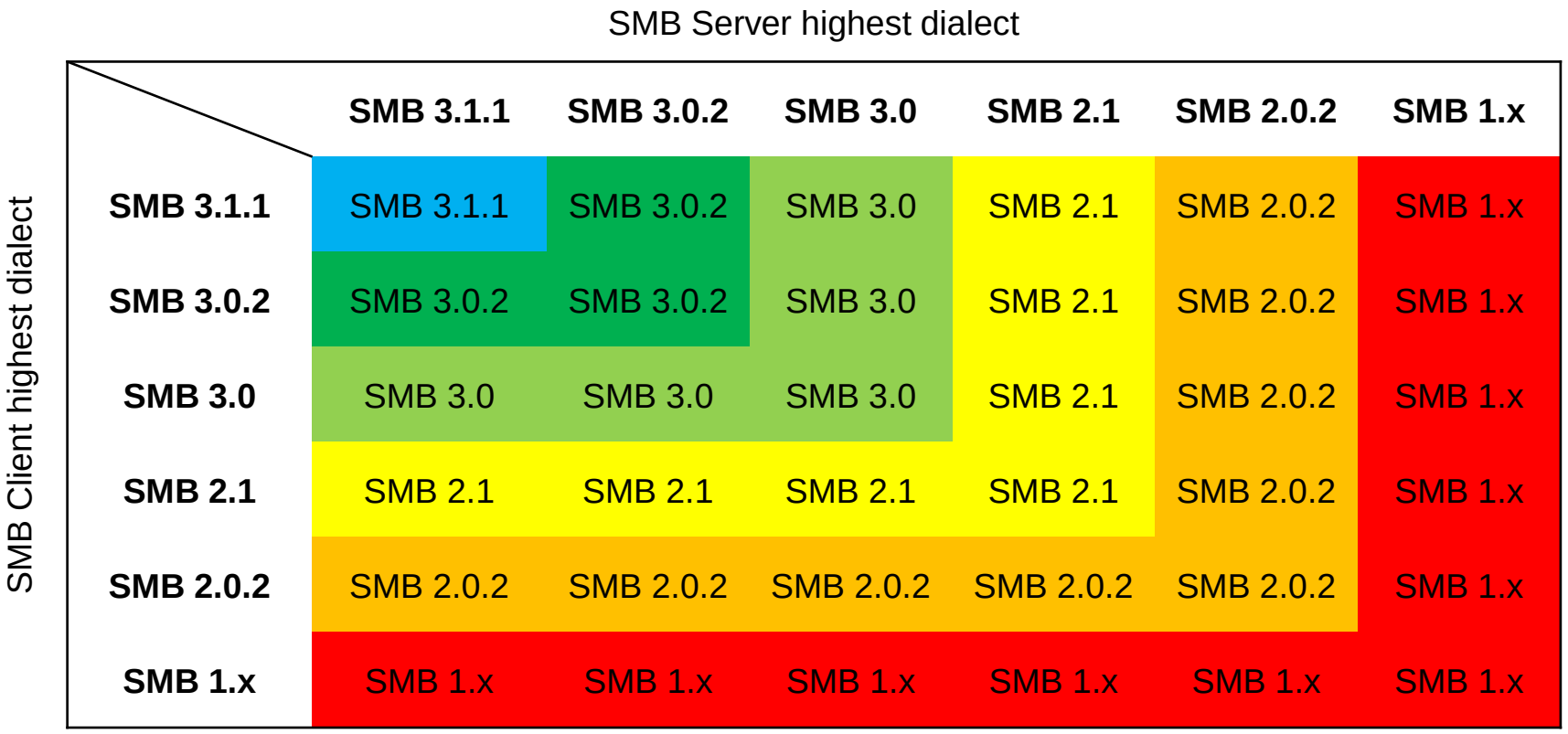
Please contact the implementers directly to obtain the accurate, up-to-date information on their SMB implementation.

The basics of SMB

- Negotiating a dialect
- Connecting to a share
- Executing operations
- Disconnecting from a share

Negotiating SMB dialects

The highest SMB dialect in common between peers is discovered and chosen.

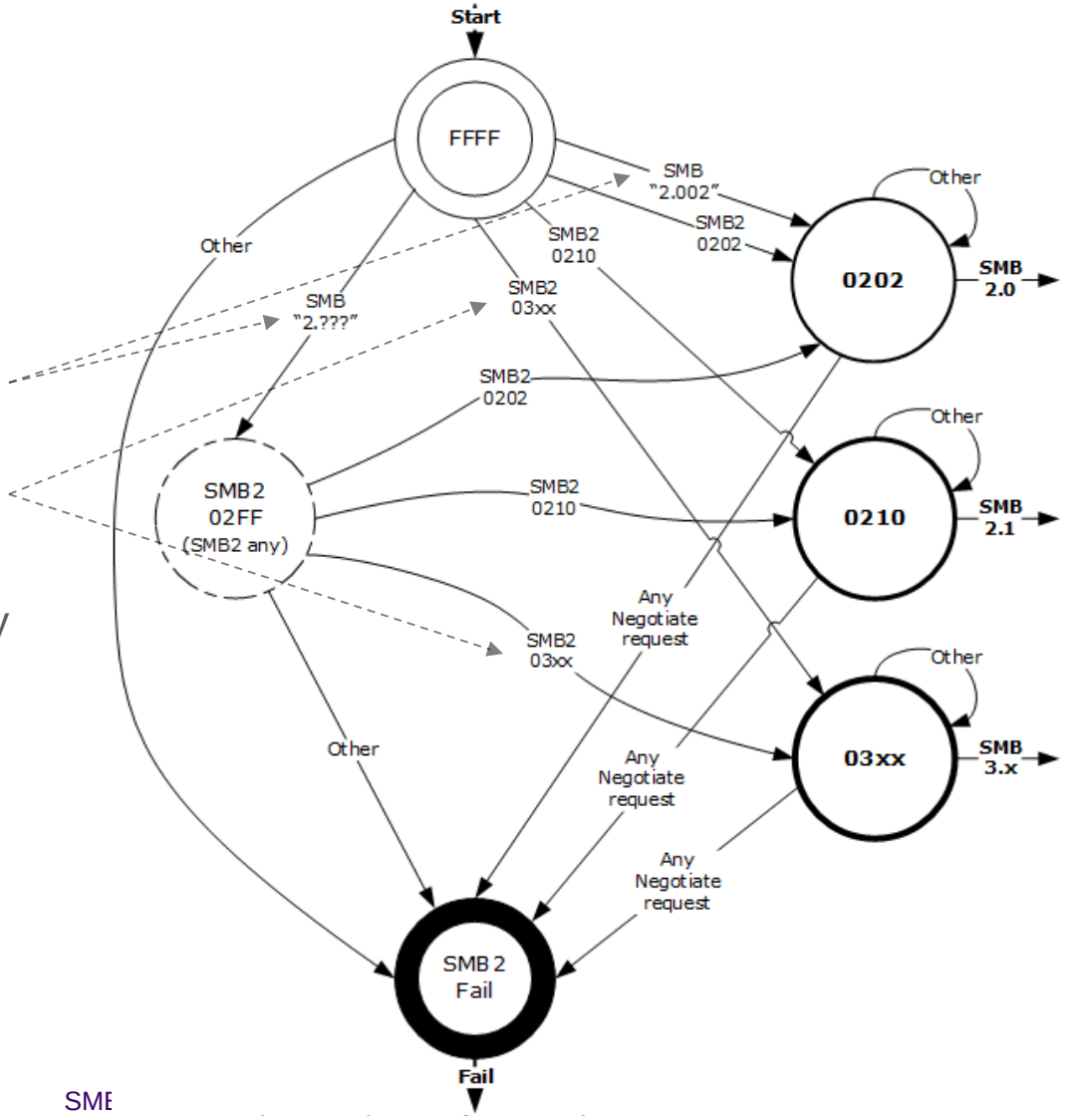


SMB Client highest dialect	SMB 3.1.1	SMB 3.0.2	SMB 3.0	SMB 2.1	SMB 2.0.2	SMB 1.x
SMB 3.1.1	SMB 3.1.1	SMB 3.0.2	SMB 3.0	SMB 2.1	SMB 2.0.2	SMB 1.x
SMB 3.0.2	SMB 3.0.2	SMB 3.0.2	SMB 3.0	SMB 2.1	SMB 2.0.2	SMB 1.x
SMB 3.0	SMB 3.0	SMB 3.0	SMB 3.0	SMB 2.1	SMB 2.0.2	SMB 1.x
SMB 2.1	SMB 2.1	SMB 2.1	SMB 2.1	SMB 2.1	SMB 2.0.2	SMB 1.x
SMB 2.0.2	SMB 2.0.2	SMB 2.0.2	SMB 2.0.2	SMB 2.0.2	SMB 2.0.2	SMB 1.x
SMB 1.x	SMB 1.x	SMB 1.x	SMB 1.x	SMB 1.x	SMB 1.x	SMB 1.x

(Any references to CIFS usually mean SMB 1.x, but could be other versions.)

Protocol negotiation

- Multi-protocol SMB1/SMB2/SMB3 negotiation
  - SMB1-style “string” dialect selection for SMB1 and SMB 2.0.2, or SMB2 “wildcard”
  - SMB2-style numeric dialect selection
  - Non-SMB1 clients may proceed directly to SMB2-style to save a round trip
- Figure is from the SMB2/SMB3 protocol doc (for full details, see link later in this deck)



DIR \\FS.EXAMPLE.COM\SHARE1

From	To	Packet
CL	FS	SMB:C NEGOTIATE, Dialect = (Dialect List)
FS	CL	SMB2:R NEGOTIATE (0x0), GUID={8E4F0109-0E04-FD9C-434A-05881428984C}, Mid = 0
CL	FS	SMB2:C SESSION SETUP (0x1), Mid = 1
FS	CL	SMB2:R SESSION SETUP (0x1) ,SessionFlags=0x0, Mid = 1
CL	FS	SMB2:C TREE CONNECT (0x3), Path=\\fs.example.com\IPC$, Mid = 2
FS	CL	SMB2:R TREE CONNECT (0x3), TID=0x1, Mid = 2
CL	FS	DFS:Get DFS Referral Request, FileName: \fs.example.com\share1, MaxReferralLevel: 4
FS	CL	SMB2:R , Mid = 3 - NT Status: System - Error, Code = (412) STATUS_FS_DRIVER_REQUIRED → Not a DFS Namespace, just a file share
CL	FS	SMB2:C TREE CONNECT (0x3), Path=\\fs.example.com\share1, Mid = 4
FS	CL	SMB2:R TREE CONNECT (0x3), TID=0x5, Mid = 4
CL	FS	SMB2:C CREATE (0x5), Context=DHnQ, Context=MxAc, Context=QFid, Mid = 5
FS	CL	SMB2:R CREATE (0x5), Context=MxAc, Context=QFid, FID=0xFFFFFFFF00000001, Mid = 5
CL	FS	SMB2:C QUERY INFO (0x10), FID=0xFFFFFFFF00000001, InformationClass=Query FS Volume Info, FID=0xFFFFFFFF00000001, Mid = 6
FS	CL	SMB2:R QUERY INFO (0x10), Mid = 6
CL	FS	SMB2:C CREATE (0x5), Context=DHnQ, Context=MxAc, Context=QFid, Mid = 8
FS	CL	SMB2:R CREATE (0x5), Context=MxAc, Context=QFid, FID=0xFFFFFFFF00000005, Mid = 8
CL	FS	SMB2:C CLOSE (0x6), FID=0xFFFFFFFF00000001, Mid = 11
FS	CL	SMB2:R CLOSE (0x6), Mid = 11
CL	FS	SMB2:C QUERY INFO (0x10), FID=0xFFFFFFFF00000005, InformationClass=Query FS Full Size Info, FID=0xFFFFFFFF00000005, Mid = 12
FS	CL	SMB2:R QUERY INFO (0x10), Mid = 12
CL	FS	SMB2:C TREE DISCONNECT (0x4), TID=0x1, Mid = 13
FS	CL	SMB2:R TREE DISCONNECT (0x4), Mid = 13
CL	FS	SMB2:C TREE DISCONNECT (0x4), TID=0x5, Mid = 14
FS	CL	SMB2:R TREE DISCONNECT (0x4), Mid = 14
CL	FS	SMB2:C LOGOFF (0x2), Mid = 15
FS	CL	SMB2:R LOGOFF (0x2), Mid = 15

Note: CL= SMB Client, FS= SMB File Server

SMB Past, Present and Future

- SMB 1.0
- SMB 2.0
  - SMB 2 Protocol simplification
- SMB 2.1
- SMB 3.0
  - Detailed SMB3 feature elements
- SMB 3.0.2
- SMB 3.1.1 (Future)

SMB 1.0

- CIFS as in the 1997 IETF draft
- Windows improvements (over time)
  - Kerberos authentication
  - Shadow copy
  - Server to server copy
  - Signing – MD5
- Non-Windows improvements (over time)
  - Improvements proposed and/or implemented by communities using CIFS/SMB on other operating systems including Unix and MacOS. Not part of any official standard.

SMB 2.0

- First major redesign of SMB
- Increased file sharing scalability
- Improved performance
  - Improved request compounding (reduced round trips)
  - Asynchronous operations (multiple packets in flight)
  - Larger reads/writes (more data in each packet)
- Security-related changes
  - Much smaller command set (from 75 to just 19)
  - SMB Durability provides limited network fault tolerance
  - Signing – Uses HMAC SHA-256 instead of old MD5

SMB 2.0 reduced command set

- Protocol negotiation, user authentication and share access
  - NEGOTIATE, SESSION_SETUP, LOGOFF, TREE_CONNECT, TREE_DISCONNECT
- File, directory and volume access
  - CANCEL, CHANGE_NOTIFY, CLOSE, CREATE, FLUSH, IOCTL, LOCK, QUERY_DIRECTORY, QUERY_INFO, READ, SET_INFO, WRITE
- Other
  - ECHO, OPLOCK_BREAK

SMB 2.1

- File leasing improvements
  - File Leasing replaces Opportunistic Locking (oplocks)
  - Improves performance when frequently updating metadata
  - Uses local metadata caching, some forms of shared leases
- Large MTU support
  - Large message support increases throughput
  - Specially relevant for high bandwidth networks like 10GbE
- Peer Content Caching and Retrieval
  - Implemented as BranchCache in Windows
  - Open source implementation in Prequel from Red Hat

SMB 3.0

- Availability
  - SMB Transparent Failover
  - SMB Witness
  - SMB Multichannel
- Performance
  - SMB Scale-Out
  - SMB Direct (RDMA)
  - SMB Multichannel
  - Directory Leasing
  - BranchCache™ V2
  - Server Copy Offload
- Backup
  - Volume Shadow Copy (VSS) for SMB File Shares
- Security
  - SMB Encryption – AES-CCM
  - Signing - AES-CMAC
- Management
  - PowerShell™ over WS-Man
  - SMI-S File

SMB Transparent Failover

Failover transparent to application

- SMB Client and Server handle failover gracefully
- Zero downtime – small IO delay during failover

Planned and unplanned failovers

- Hardware or Software Maintenance
- Hardware or Software Failures
- Load Rebalancing

Resilient for both file and directory operations

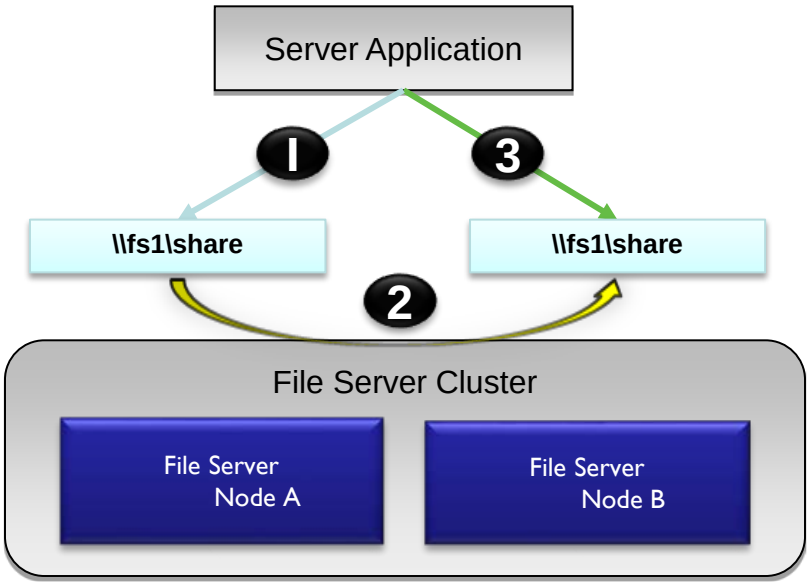
Requires:

- SMB Server in a Failover Cluster
- SMB Client and Server must implement SMB 3.0
- Shares enabled for 'Continuous Availability'

Impact to SMB before 3.0

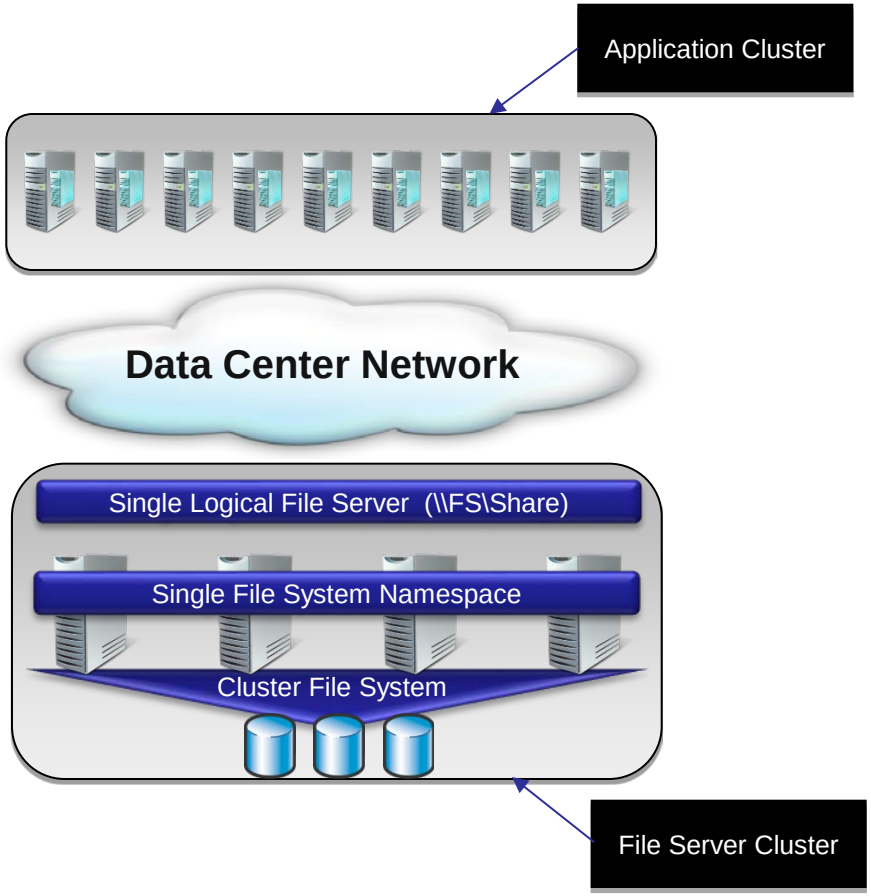
- Older clients can connect,
  but without the Transparent Failover capability

1. **Normal operation**
2. **Failover share - connections and handles lost, temporary stall of IO**
3. **Connections and handles auto-recovered Application IO continues with no errors**



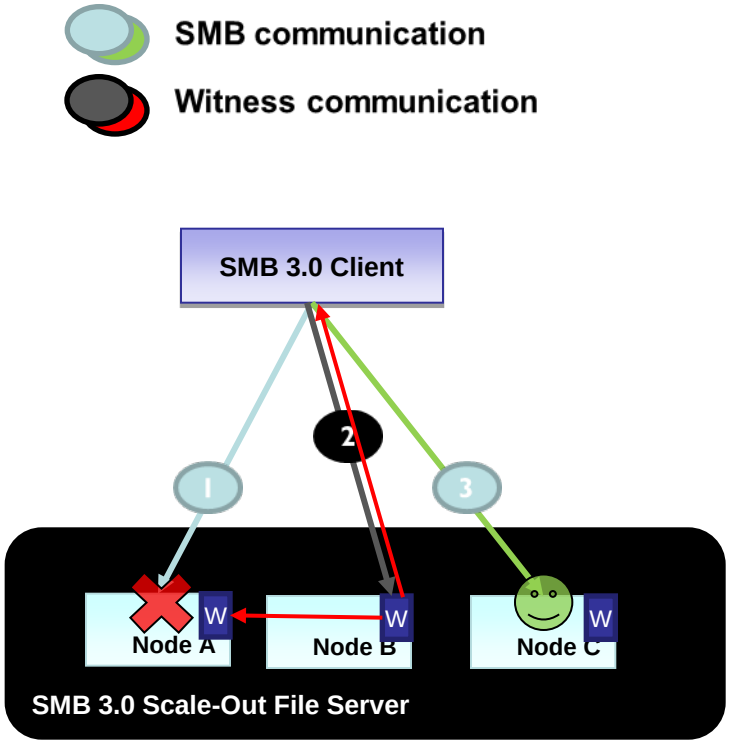
SMB Scale-Out

- Targeted for server application storage
  - Example: Virtualization and Databases
  - Increase available bandwidth by adding cluster nodes
- Key capabilities:
  - Active/Active file shares
  - Fault tolerance with zero downtime
  - Fast failure recovery
- Impact to SMB before 3.0
  - SMB 2.x clients can connect, but without the failover capability
  - SMB 1.x clients not supported



SMB Witness

- Faster client failover
  - Client is quickly notified of cluster events
  - Avoids lengthy TCP timeout
  - RPC protocol not in-band with SMB
- Example
  - (1) Client connects via SMB to cluster Node A
  - (2) Client connects via Witness to cluster Node B
  - Node A fails, client is waiting on requests
  - Node B tells client that Node A failed
  - Node B tells client to connect to cluster Node C
  - (3) Client reconnects via SMB to Node C
- Can also be used for Scale-Out moves
  - Administrator can move a client to a specific node using the Witness protocol (for instance, to rebalance load in a Scale-Out cluster)
- Impact to SMB before 3.0
  - Older clients won't connect to Witness service



SMB Multichannel

Full Throughput

- Bandwidth aggregation with multiple NICs
- Multiple CPUs cores engaged when NIC offers Receive Side Scaling (RSS) or Remote Direct Memory Access (RDMA)

Automatic Failover

- SMB Multichannel implements end-to-end failure detection
- Leverages NIC teaming if present, but does not require it

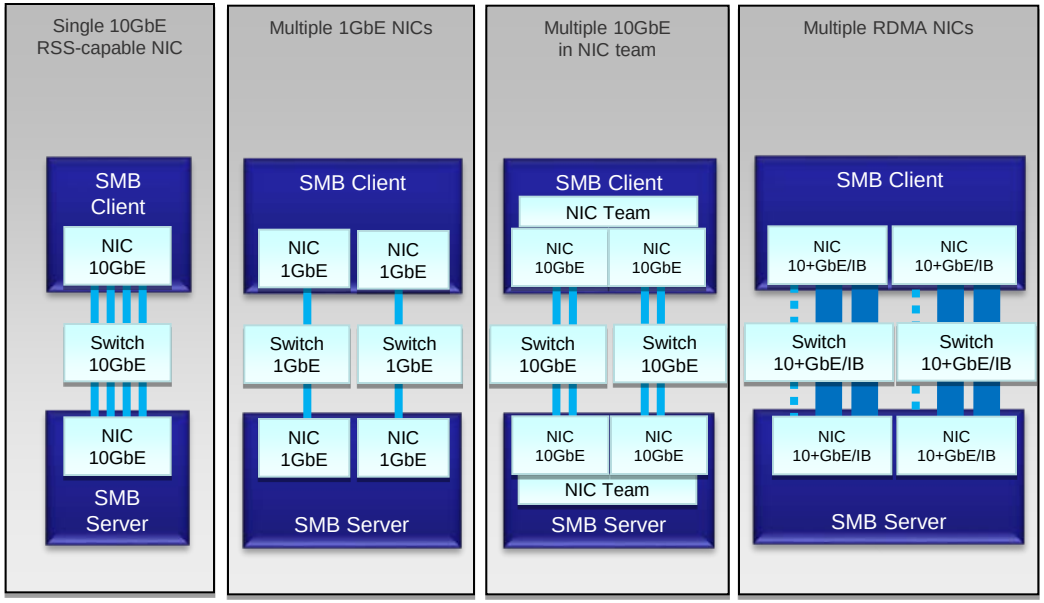
Automatic Configuration

- SMB detects and uses multiple paths

Impact to SMB before 3.0

- Older clients can connect, but without Multichannel capability

Sample Configurations



SMB Direct (SMB over RDMA)

Advantages

- Scalable, fast and efficient storage access
- High throughput with low latency
- Minimal CPU utilization for I/O processing
- Load balancing, automatic failover and bandwidth aggregation via SMB Multichannel

Scenario

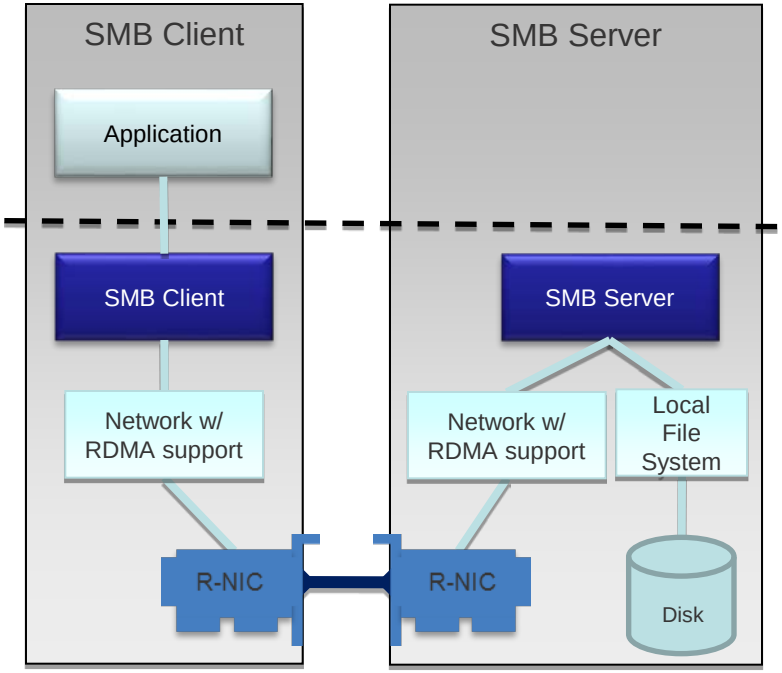
- High performance remote file access for application servers like Virtualization and Databases

Required hardware

- RDMA-capable network interface (R-NIC)
- Three types: iWARP, RoCE and InfiniBand

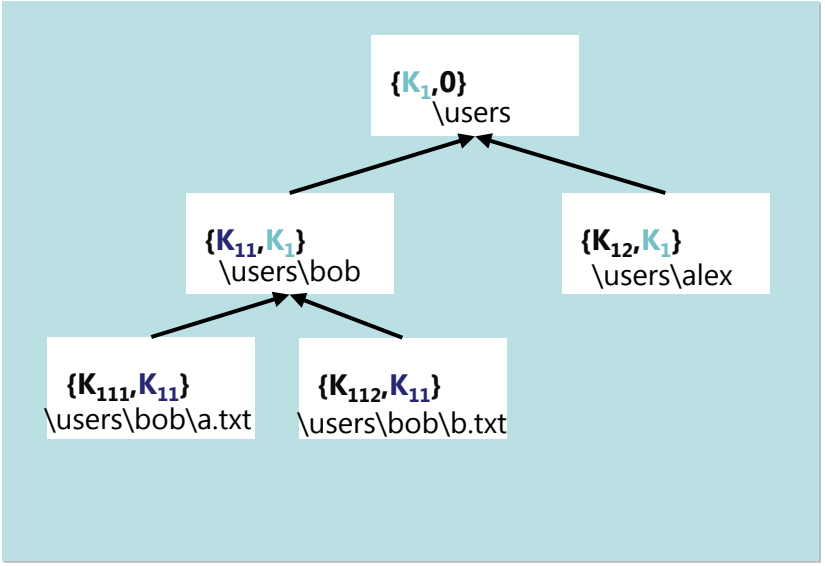
Impact to SMB before 3.0

- Older clients can connect, but without the RDMA capability



SMB Directory Leasing

- Reduces roundtrips from client to server
  - Metadata is retrieved from longer lived directory cache
  - Directory cache coherency is maintained due to the implementation of directory leases
  - Client gets notified if directory information on server changes
- Targeted at
  - HomeFolder (read/write with no sharing)
  - Publication (read-only with sharing)
- Metadata cache
  - Directory handles
  - Directory metadata
- Impact to SMB before 3.0
  - Older clients connect, but without the Directory Leasing capability



- Lease breaks when directory metadata is updated
  - Creation of new children
  - Rename of immediate child file/directory
  - Deletion/Modification of immediate children (manifests when handle is closed)
- Lease breaks when directory handle itself gets a sharing conflict
  - Another conflicting open to directory
  - Rename/deletion of a parent directory

SMB Encryption

End-to-end encryption of data in flight

- Protects data from eavesdropping/snooping attacks on untrusted networks
- Configured per share or for the entire server

Used in scenarios where data traverses untrusted networks

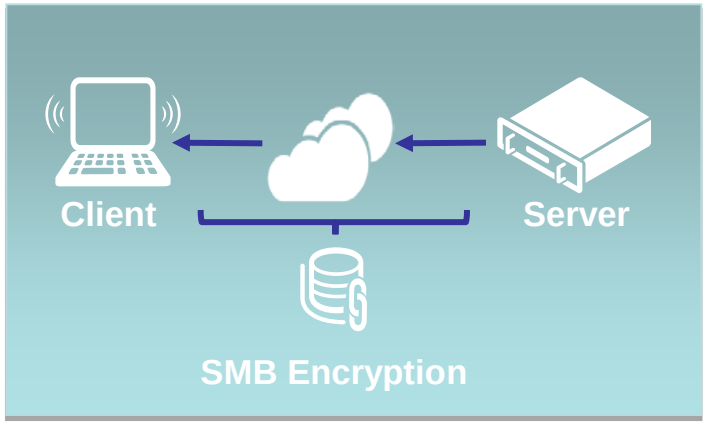
- Application workload over unsecured networks
- Branch Offices over WAN networks

Low deployment costs

- No IPsec required
- No Public Key Infrastructure (PKI) required
- No specialized hardware required

Impact to SMB versions before 3.0

- If encryption is turned on, older clients get "Access Denied" errors

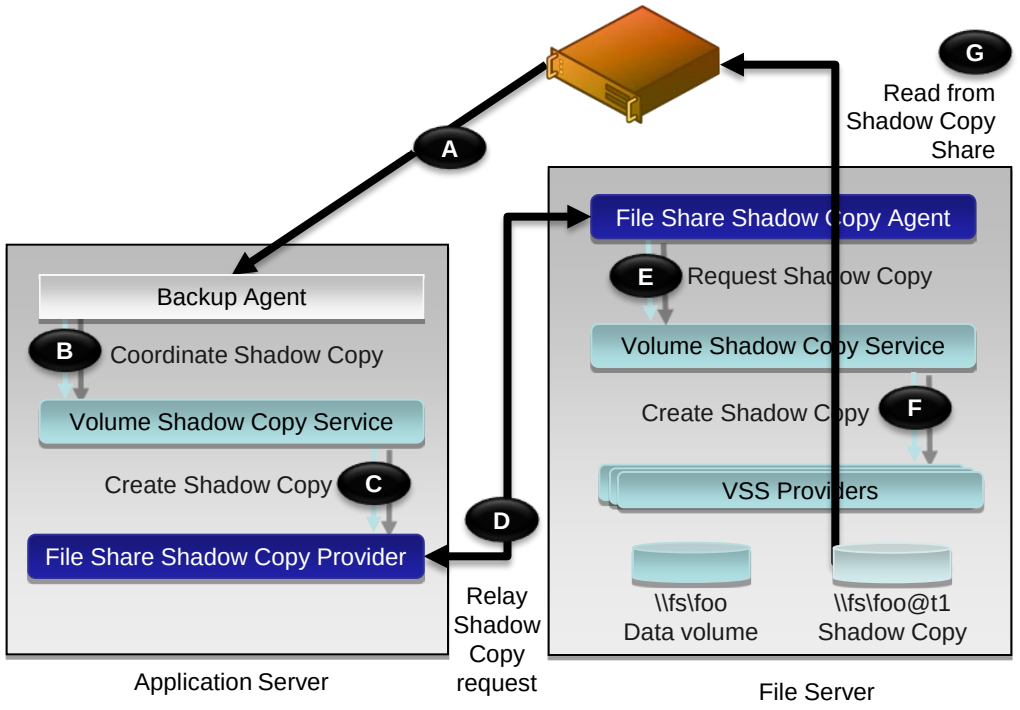


Algorithm

- AES-CCM-128 bit (more in SMB 3.1.1)
- Will sign AND encrypt in the same step (independent of SMB Signing setting)
- AES acceleration provided by most new processors aids in performance
- Some CPUs provide AES hardware acceleration.

Volume Shadow Copy for SMB File Shares

- Supports backup and restore scenarios for application servers such as Virtualization and Databases
- Application-consistent shadow copies for server application data stored on SMB 3.0 file shares
- Full integration with Microsoft's Volume Shadow Copy Services (VSS) infrastructure
- Implemented by at least one vendor besides Microsoft



SMB Management

WMI objects introduced (accessible via WS-Management)

- Manages SMB shares, file server sessions and settings, client connections and settings
- Aimed at both System Administrator and Developers
- Covers both standalone and clustered file server and shares

Main objects and associated methods

- SMB Share: Get, New, Set and Remove
- SMB Share Access: Get, Grant, Revoke, Block and Unblock
- SMB Session: Get and Close
- SMB Open File: Get and Close
- SMB Configuration: Get and Set for Server and Client
- SMB Network Interfaces: Get for Server and Client
- SMB Connection: Get for Connection and Multichannel Connection
- SMB Mappings: Get, New and Remove
- SMB Multichannel Constraints: Get, New and Remove

WMI = Windows Management Instrumentation, implementation of DMTF standards (WBEM, CIM) on the Windows Platform.

WS-Management = Web Services Management, DMTF open standard SOAP-based protocol for server management.

SMI-S = Storage Management Initiative – Specification, SNIA Storage Management Standard.

SMI-S File

- Main WMI objects mapped to SMI-File object model
- Initial support by Microsoft, NetApp, and EMC

SMB 3.0.2

- Asymmetric Scale-Out File Server Clusters
  - SMB share ownership which can move within the File Server Cluster
  - Witness protocol enhanced to allow moving client per SMB share
  - In Windows, SMB clients automatically rebalance
- SMB Direct Remote Invalidation
  - Avoids specific invalidation operations, improving RDMA performance
  - Especially important for workloads with high rate of small IOs
- Unbuffered read/write operations
  - Per-request flags for read/write operations
- Remote Shared Virtual Disk Protocol
  - New protocol defines block semantics for shared virtual disk files
  - Implements SCSI over SMB (SMB protocol used as a transport)

SMB 3.1.1 (future)

- Under Development as of this presentation
  - More details in SNIA SDC 2014 talks, and Microsoft protocol document previews
- Features include:
  - Extensible Negotiation
  - Preauthentication Integrity
    - Increased Man-in-the-Middle protection
  - Encryption improvements
    - Negotiated cryptographic algorithm
    - New default is the faster AES-128-GCM
  - Cluster improvements
    - Dialect rolling upgrade
    - Cluster Client Failover v2

- Related new and enhanced protocols in preview:
  - Storage Quality of Service (MS-SQOS)
  - Shared VHDX v2 (supporting virtual disk snapshots) (MS-RSVD)

SMB Protocol Resources

- Documentation
- Interoperability Events

Links to protocol documentation

- [MS-CIFS] Common Internet File System (CIFS) Protocol Specification
- [MS-SMB] Server Message Block (SMB) Protocol Specification
- [MS-SMB2] Server Message Block (SMB) Protocol Versions 2 and 3 Specification
- [MS-SMBD] SMB Remote Direct Memory Access (RDMA) Transport Protocol Specification
- [MS-SWN] Service Witness Protocol Specification
- [MS-FSRVP] File Server Remote VSS Provider Protocol Specification
- [MS-RSVD] Remote Shared Virtual Disk Protocol
- [MS-SQOS] Storage Quality of Service Protocol (Preview)

Note: Protocols published by Microsoft, and available to anyone to implement in non-Windows platforms. For details, see https://msdn.microsoft.com/en-us/library/cc216517.aspx

SNIA SMB2/SMB3 Plugfest

- SMB/SMB2/SMB3 Plugfest happens every year side-by-side with the Storage Developer Conference (SNIA SDC) in September
- Intense week of interaction across operating systems and SMB implementations.

Agenda, Calendar and past content at:
http://www.snia.org/events/storage-developer

Participants in the 2014 edition of the
SNIA SMB2 / SMB3 Plugfest
Santa Clara, CA – September 2014

Review

Objectives

- Understand the basic architecture of the SMB protocol family
- Enumerate the main capabilities introduced with SMB 2.0/2.1
- Describe the main capabilities introduced with SMB 3.0 and beyond

Attribution & Feedback

The SNIA Education Committee thanks the following individuals for their contributions to this Tutorial.

Authorship History

Jose Barreto / September 2012

Updates:

- **Jose Barreto / October 2012**
- **Jose Barreto / January 2014**
- **John Reed / April 2014**
- **Tom Talpey / February 2015**
- **Jose Barreto / April 2015**

Additional Contributors

SW Worth
Christopher Hertel
John Reed

Please send any questions or comments regarding this SNIA Tutorial to ***tracktutorials@snia.org***

Thank you!