Data Replication Technology

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Agenda

- Disaster Recovery/Business Continuance Background
- Application Based vs Storage Based Data Replication
- Data Replication Technology
  - Local Subsystem Replication
  - Remote Replication (Synchronous & Asynchronous)
  - Cross Site Connectivity
- The Current Marketplace
- Emerging Data Replication Technology
  - Host Based
  - Switch Based
  - SAN Replication Appliance within Data Path
  - SAN Replication Appliance outside Data Path
  - Storage Subsystem Peer
- Key Questions for Any Solution
- Discussion
7 Tiers of Business Recovery Options

Mission Critical Data

Key Customer Objectives:
RTO – Recovery Time Objective
RPO – Recovery Point Objective

Tier 1 – PTAM*
15 Min. 1-4 Hr. 4-8 Hr. 8-12 Hr. 12-16 Hr. 24 Hr. Days

Tier 2 – PTAM & Hot Site
Active Secondary Site
Point-in-time Backup to Tape
RPO: 4+ hrs
RTO: 4+ hrs

Tier 3 – Electronic Tape Vaulting
Tier 4 – Data Base Log Replication & Host Log Apply at Remote
Tier 5 – RPO > 15 min. RTO= Manual; PiT or SW Data Replication
Tier 6 - RPO=Near Zero, RTO= Manual - Disk or Tape Data Mirroring
Tier 7 - RPO=Near, RTO <1Hr.
Server/Workload/Network/Data Automatic Site Switch

Cost of Ownership
(Servers/Network Bandwidth/Storage)

1000
700
400
100
50
10
1

Time to Recover – How quickly is an application recovered after a disaster?

*PTAM – Pickup Truck Access Method

1000 700 400 100 50 10 1

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Time to Recover – How quickly is an application recovered after a disaster?

*PTAM – Pickup Truck Access Method
Lessons from 9/11

- Rolling disasters happen
- Distance is more important
- Redundancy may be smoke and mirrors
- Recovery needs a greater dependency upon automation and less on people

Recovery site:
- Capacity (MIP's and GBs) site needs to be sized for the production environment that will run there
- Disasters may cause multiple companies to recover and that puts stress on the commercial business recovery services
- D/R Plan after successful recovery from disaster

- Rethinking of synchronous versus asynchronous
Value of Data Replication

Operational Efficiency
- Data Mining
- Content Distribution
- Software Testing

Availability Improvements
- Backup Window
- Tape Backup
- Data Migration
- Archival

Disaster Recovery/Business Continuity
- Minimize data loss
- Minimize restart time
- Increase distance
- Enable automation

Data Replication Building Blocks

- Flash Copy
- PPRC
- File Flash
- Migration Copy
- Synch Asynch
- Tape Repl
Data Replication Building Blocks

- Data replication technologies provide non-disruptive ways to relocate, migrate and/or copy data.
- Replication can be performed by the host, in the SAN, in disk systems or tape systems.

### Replication Method

- **Point in Time**
  - App Specific
    - File System
    - AIX JFS2, GPFS, Stg Tank
    - Logical Volume Managers
      - AIX LVM
      - Veritas Application
    - Database Log Shipping
    - Disk System FlashCopy
    - Tape Volume Replication

- **Continuous**
  - **Synchronous**
    - Disk System
    - ESS PPRC
    - EMC SRDF
    - HDS HRC
    - FASTT
    - DB/Messaging Transaction Replication
    - LVM
      - AIX LVM, GeoRM, Veritas Volume Replicator
  - **Asynchronous**
    - LVM
    - GeoRM
    - Veritas Volume Replicator
    - Disk System
      - ESS PPRC-XD, XRC
    - EMC SRDF
    - HDS HRC
    - DB/Messaging Transaction Replication
    - Emerging New Players
Software Based vs Storage Based Data Replication

- Application/File/Transaction Based
  - Specific to application file system/DB
  - Generally less data is transferred -> lower Telco costs
  - No coordination across applications, FS, DBs, etc
  - Applications change - replication may need to change
  - May forget “other” related data necessary for recovery
  - With many transfers occurring in a corporation, it may be difficult to determine what is where in a disaster. RTO/RPO may not be repeatable, auditing may be difficult
  - Many targets possible (ex. millions of PDAs or cell phones)
  - Others
Software Based vs Storage Based Data Replication

- Block/Record Based
  - Independent of application, file systems, databases, etc
  - Common technique for corporation. (managed by operations)
  - Generally more data transferred -> higher Telco costs
  - Consistency groups yield cross volume/storage subsystem data integrity/consistency
  - Independent of application changes. Mirror all pools of storage
  - Consistent repeatable RPO. RTO depends on server/data/workload/network
  - Generally a handful of targets
  - Specific to data replication technique (tied to specific architecture & devices that support it)
  - Others
Data Consistency for Block Based Storage

- Only consider “power fail” consistency
- Typical Database transaction:
  - Journal entry indicating database update which is about to occur
  - Update database
  - Journal entry indicating database update has occurred
- Host is very careful to do each of the transactions in order
  - This provides power fail data consistency
- These transactions are likely done to different volumes on different control units
- Failure to be careful about transaction order results in loss of data consistency and data may become unusable
- In order to ensure data consistency at secondary site, dependent writes must be done in order
  - Writes that are done in parallel are not dependent
Placement of Data Replication Function

- **Application/File/Transaction Based**
  - Host Software Based
  - Application (ex. Mail systems)
  - LVM (Write/Write)
  - File system
  - Data Base

- **Block/Record Based**
  - Storage Subsystem Based
  - Host Based
  - Switch Based
  - SAN Appliance
  - In Data Path
  - Outside Data Path
  - Subsystem Peer
Local Subsystem Data Replication

**z-Series & Open Systems**
- **FlashCopy**

**z-Series Only**
- **Concurrent Copy**
  - Data Mover
  - Sidefile
FlashCopy – Internal to Storage Subsystem

When copy is complete, relationship between source and target ends

Normal Operations -> No Background Copy
- Dump -> Tape
- FlashCopy before Batch

Copy data command issued
Copy is immediately available

Read and write to both source and copy possible
# ESS PiT Consistent FlashCopy

- **FlashCopy S1 to T1**
  - Writes cannot proceed on S1
  - Any writes occurring on S2-S4 are not dependent writes
- **FlashCopy S2 to T2**
  - Writes cannot proceed on S1 or S2
  - Any writes occurring on S3-S4 are not dependent writes
- **FlashCopy S3 to T3 and S4 to T4**
- T1-T4 contain a consistent copy
- Issue Consistency Group Created
  - Writes may proceed to S1-S4.

- Hold off initiation / completion of write I/O to the source volumes until FlashCopy establish is completed
- Select source and target volumes with consistency option
- Enables creation of a consistent point-in-time copy across multiple volumes with minimum host impact and no operator intervention required
- Source and target volumes are within one ESS
- Consistency Groups Can Overlap Multiple ESSs
Synchronous & Asynchronous Data Replication

**Synchronous PPRC**

**Asynchronous Cascading PPRC**

**PPRC-XD**

**Asynchronous - XRC (zSeries Only)**

- **Performance Impact** - Related to Bandwidth
- Then "Go-to-sync'
  - Then Duplex
  - Then Suspended/Frozen

**FlashCopy**

**Hyperswap**

**Continuous Availability**

**Distance Disaster Recovery**

**Data Mover**
Consistency Groups

Cross Volume/Subsystem Data Consistency/Data Integrity
- Important for PiT Copy Solutions
- Important for D/R (DB Restart instead of DB Recovery)
- Important for Integrity of the Data (ex. DB Logs & Data Volumes)
- Scope can be Disk Storage Subsystem(s) BUT
  Generally requires Global Systems Level Monitoring

Three Approaches Used in Marketplace:
- Data Freeze Methodology
- Time Based Sequence (SYSPLEX Timer - Only Cross System Clock in Marketplace)
- Put all data requiring consistency on a single LUN
Peer to Peer Remote Copy - Synchronous

- Implemented by many storage vendors
- No data loss is goal (RPO= 0)
- Impact on application write I/Os - distance dependent
- Utilizes automation
  - To freeze secondary upon disaster
  - To provide cross-CU data consistency
- Integrated with DR solutions ex. GDPS (Server/Data/Workload/Network)
  - Freeze capability
  - Data consistency
  - Simplified and fast recovery
  - Automated reconfiguration
  - HyperSwap™ capable

PPRC Features:
- Distance to 400km
- zSeries & Open Systems Support.
- 1-8 paths per LSS/SSID pair. (ESS 800 - 2 paths w/FCP)
- Peer-to-Peer Link Optimizations
- Ability to FlashCopy PPRC Primary or Secondary.

Note: It takes 20ms for light to travel 3000 km round trip
Data Freeze

• Notification of suspending event
• CU holds I/Os to suspended device until Global Systems Level Monitor can handle condition

During

• Global Systems Level Monitor issues freeze command to all CU's
• Suspends all PPRC pairs
• Holds I/O until told to continue
• Based on policy, Global systems Monitor will either allow host operation to resume or continue to hold them

After, depending on policy

• Both sites are suspended but in sync
• Sites are not in-sync, however data at secondary site is consistent
GDPS/PPRC - Hyperswap (Planned & Unplanned)

- GDPS/PPRC Hyperswap Planned & Unplanned Site Switches
- Procedure Step 1
  - Route exception condition (disk Subsystem I/O failure) to the active master system (must be a controlling system)
  - HyperSwap disk configuration (all disk subsystems)
- Procedure Step 2 - executed automatically via script on controlling system (C2)
  - Select secondary volumes (SYSRES, IODF)
  - Switch Coupled Data Set (switch to alternate CDS and spare in site-2)

*All production systems remain active throughout the procedure*
PPRC-XD (Extended Distance)

- Asynchronous transfer of updates over long distance through channel extenders
- Little performance impact on applications
- Creates a fuzzy secondary copy
- Can transition to Synchronous mode until full duplex to create PiT Consistency
  - FREEZE to get application level consistency
- FlashCopy onto tertiary to save consistent checkpoint
- Oracle Redo Logs/SAP Hot Standby/Quiesce DB->FlashCopy Resume
- Channel Extenders Compress & Batch PPRC-XD Updates yielding High Bandwidth Utilization
- Test- 256 PPRC XD Pairs, 6000 writes/second, 1200 miles, 2 OC30 lines caught up in 8 seconds
Asynchronous Cascading PPRC

• Three-site and two-site configuration options
  • Flexible configuration possibilities
    • Better application resiliency, at metro or long distances
    • Made simpler: no operational change between the two configurations
    • Match TCO (Total Cost of Ownership) to desired Tier of Recovery
Extended Remote Copy – Asynchronous (zSeries Only)

- XRC - open, non-proprietary implementation on several vendors
- Multiple reader offload support
- Dynamic balancing of application write bandwidth vs SDM read performance
- Minimal impact to primary application I/O
- Offload from utility device (different from application I/O)
- Unplanned outage support (Suspend/Resume)
- Host Mips required to form time based consistency groups
Time Based Consistency Groups (zSeries Only)

Primary Site

1. Application / Database Systems
2. primary CU
   - A
   - B
   - D
   - E

Recovery Site

1. Recovery System
2. secondary CU
3. SDM
4. DFSMS/MVS
5. Journal
   - A'
   - B'
   - D'
   - E'

Common Timestamps via SYSPLEX Timer

System Data Mover Software Consistency Group Logic
Time Based Consistency Groups

XRC SDM uses common Sysplex Timer timestamp to sort the incoming data, form consistency groups 10's of times per second across large numbers of volumes, disk frames, and z/OS® images.

XRC is able to back out in-flight incomplete write sequences because in event of outage, the XRC SDM does not write out incomplete data, thus what is on the disk is the most recent complete Consistency Group.
Peer to Peer Virtual Tape Server

- Primary / secondary VTS
  - Primary performs host I/O
  - Secondary receives and stores copies

- Use for
  - Maintenance
  - Planned failover
  - Unplanned failover
Considerations for Cross-Site Connectivity

- How much bandwidth is required?
- What is available?
- What is supported for the required workloads?
- What does it cost?
- What is the distance?
Data Replication over OC3/OC30/OC48/ATM/IP

S/390 user

S/390 Server

S/390 SAN

UNIX/NT SAN

3494 Tape Library

UNIX NT user

AIX, UNIX, NT

IBM Enterprise Storage Server

Channel Extender
FCP->Telco
FCP to IP converters
or DWDM

IBM Enterprise Storage Server

S/390 Server

S/390 SAN

UNIX/NT SAN

3494 Tape Library

UNIX NT user

AIX, UNIX, NT

FCP links

Telco links

FCP links
Types of Connectivity – Cross-Site Connection

- Dark Fiber
- WDM/TDM
- Channel Extenders (non-optical transport)
Optical Cross-Site Connectivity

- **Distances driven primarily by optical considerations**
  - Host/device optical signals have limited distance
  - Switches/directors might have enhanced distance capability
  - WDM also provides multiplexing and may allow optical redrive

- **Other considerations**
  - Channel protocol runs end to end
  - Protocol may suffer from droop beyond a certain distance
  - Channel or switch/director provides buffering capability
  - Link throughput will reduce if distance exceed buffer limits
Types of Non-Optical Channel Extender

- **Frame buffering channel extender**
  - Channel protocol runs end to end
    - Protocol will suffer from droop beyond a certain distance
  - Channel extender may provide buffering/compression/retransmission

- **Emulation channel extender**
  - Channel protocol runs separately in each site
    - Channel extender emulates devices / host
  - Channel extender may provide buffering/compression/retransmission
Non-Optical Transports for Storage Protocols - Overheads

- Overheads exist in both Storage and Network protocols
  - 149Mb available on 155Mb SDH link
  - 135Mb available on 155Mb ATM link
  - 941.482 Mbps available for TCP on GigE without jumbo frames
  - FC-2 payload is maximum of 95% of frame size

- Some channel extenders may reduce storage protocol overheads
  - Emulation can strip data from the protocol and repackage at the other side
Types of Connectivity – Device Viewpoint

- **Direct Connection**

- **Via Switches/Directors**

- Connection via switches/directors
  - Switch/director capabilities may allow for longer unrepeated distances
  - Sharing of cross-site links or device ports may be possible
Non-Optical Transports for Storage Protocols – Network Characteristics

- **Latency**
  - Key issue with most storage extension is latency of network
  - Latency is not always advertised especially on backup routes

- **Resilience**
  - Resilience can mean different things to different people
  - Whether the storage service can run is the key item

- **Bandwidth**
  - Different protocol channel extenders can handle variance differently
  - Bandwidth and useable bandwidth are two different things
Business Continuity Problem

- Synchronous solutions do not work at distance
- Asynchronous solutions have data loss and potential problems managing consistency, particularly across different storage platforms
- Maximizing use of long distance link is critical for many customers
  - Smaller customers may want to purchase extended links which meet maximum transfer requirements for a shift, not their 15 second peak
- Being able to test, fail forward, and fail back is critical

Need to give customers new solutions!
Marketplace Objectives

- Reduce TCO for data replication
- Storage vendor interoperability for data replication
  - Any to any high-end, mid-range, low-end
- Reduce costs for producing data replication functions
Marketplace Observations

- Could Drive NEW Data Replication Scenarios & Management Flexibility
  - Low cost solution to move data from local or regional offices to main data center
  - Data migration/movement solution for distributed data consolidation efforts (simple install, simple day to day remote operation)
  - Inter-operability across storage vendors disks yields customer choice & preserves current investments
The SNIA Shared Storage Model

SNIA SMI-S Standards being extended for Copy Services
Marketplace Observations

- Market Opportunity - Switch, Channel Extender, Software, Storage Vendors
- Several new startup companies
- May be combined with emerging virtualization products
- Technology not yet "proven" in the marketplace
  - Cross volume/cross subsystem data integrity/data consistency issues can be a problem
- No interoperability with existing solutions
- Generally these companies do not participate in SNIA Copy Services Standards work
Emerging Data Replication Architectures

- Host Based
- Switch Based
- SAN Replication Appliance within Data Path
- SAN Replication Appliance outside Data Path
- Storage Subsystem Peer
Host Based Data Replication

- Server Dependent
- Host Mips - typically 3-5%
- In Data Path
- Interoperability Between Disk Subsystems

- File/DB Subsystem Based
- Application Based
- DR Client Above LVM
- DR Client in Device Driver
Topio

- Topio agents installed in all primary hosts
- All writes are also transferred to a single Topio appliance at secondary site
- The Topio appliance applies the data to the proper location
Switch Based Data Replication

- In Data Path
- Multi-Switch Function Management
- Within Existing Enterprise Box
- Interoperability across Disk Subsystems
SAN Storage Appliance (Within Data Path)

- In Data Path
- New Box to Manage in Enterprise
- Interoperability across Disk Subsystems
IBM’s Virtualization Engine

Redundant, modular, scalable, complete solution

The pool of managed disks is controlled by a cluster of paired nodes (up to 4 pairs initially, scaling higher in future)

Virtual volumes are shared between a pair of nodes

Copy Services
- PPRC
- FlashCopy

Managed Disks

Virtual LUNs
Node Node

Virtual LUNs
Node Node

Virtual LUNs
Node Node

Virtual LUNs
Node Node
SAN Storage Appliance (Outside Data Path)

- Outside Data Path
- New Box to Manage in Enterprise
- Host Client Code Required
- Interoperability across Disk Solutions

![SAN Storage Appliance Diagram]
Forming Point-In-Time Consistency

Appliance optimizes, compresses, and encrypts all of the transactions associated with a color. The color is then transferred to the secondary appliance. The color is then applied to the secondary by reading the blocks to be updated, writing them to a side file, then applying the updates.
Point-in-Time Consistency Groups

- A consistency group is a group of I/Os which represent a consistent "point-in-time" view of the data

- Appliance Optimizations:
  - Optimize transactions in a consistency group
    - Eliminate blocks which have been multiply written
    - Form large blocks for efficient transmission over extended link
  - Compress/Encrypt data between appliances
  - Apply consistency groups without the use of flash technology (keep multiple versions)
    - Includes things such as: Beginning of Day, Beginning of Hour, last 10 consistency groups, etc
Kashya

- Device driver installed in all hosts
- Each write to a replicated LUN is first sent to the appliance
- After successfully received by the appliance, write is sent to CU
- Consistent sets of data applied to secondary site
- Ability to roll state of secondary site backwards and forwards
Storage Appliance (Peer to Storage Controller)

- Outside of Data Path
- No Host Client Code Required
- Requires Storage Subsystem Support

- Appliance located
  - Within the Storage Controller
  - Within Primary Site
  - In a Campus Bunker

![Diagram showing the storage appliance setup with logical components and site 1 and site 2 connections.](attachment:image)
IBM’s SAN File System

Metadata Server Cluster

IP Network for Client/Metadata Cluster Communications

Metadata Store

AIX
Solaris
HP-UX
Linux
Win2K/XP

VFS w/Cache
VFS w/Cache
VFS w/Cache
VFS w/Cache
IFS w/Cache

NFS
CIFS

External Clients
Admin Client

Storage Network

Multiple Storage pools
Data Store

Shared Storage Devices
Key Questions for Any Solution

- How does the solution provide cross volume/cross subsystem data integrity/data consistency?
- What is the impact to the primary application I/O?
- What happens if data replication fails or slows down?
- Interoperability with other data replication solutions?
- Cost of installing & maintaining solution?
- Do solutions within data path provide “concurrent maintenance”?
- What flexibility does the solution provide?
- If I failover, how do I failback?
- If I use different “types" of disk subsystems, in a failover can I maintain my QoS to my users?
- Others ...
Discussion

- How has 9/11 affected your DR plans, if at all?
- In your businesses, what do you feel is more important
  - Long distance separation of data sites?
  - Ensuring RPO of 0?
  - Has this changed at all in the past few years?
- How difficult is it to manage your storage infrastructure?
- Do you have resources (hardware, people, time) to practice your DR plans?
  - Do you actually practice?
  - Would you like to?
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