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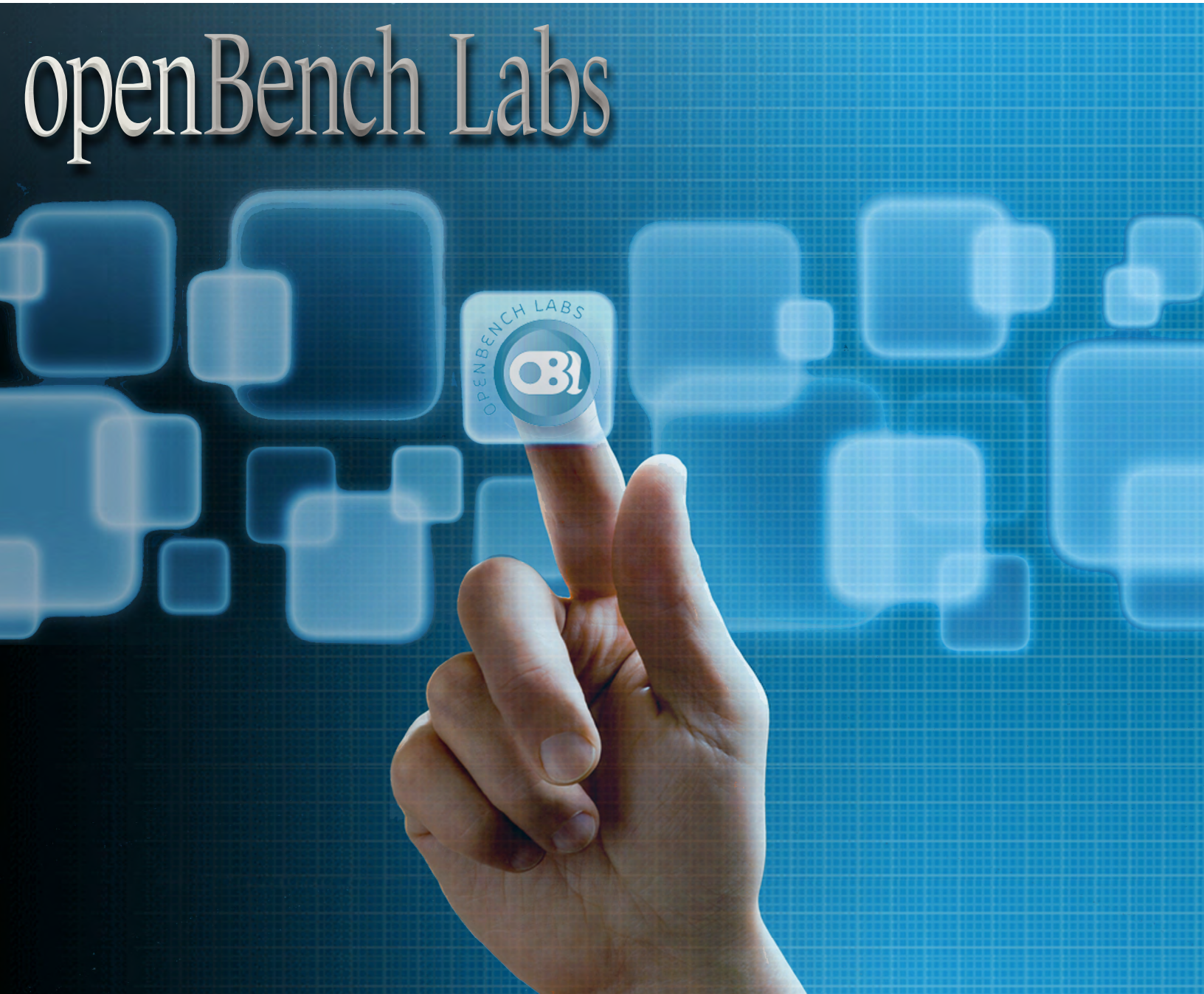
Benchmark Analysis

EMC Avamar: High Performance Backup and Recovery For a Software-Defined Data Center

New Technology Enablement for the Enterprise Cloud



EMC Avamar: High Performance Backup and Recovery For a Software-Defined Data Center

New Technology Enablement for the Enterprise Cloud

Protecting the Software-Defined Data Center

Data centers are becoming more difficult to manage and protect as more data and applications are moved into virtual software-defined environments. Adding fuel to the fire, CIOs must now deal with corporate mandates to build an IT infrastructure that scales to unknown demand levels and provides service assurance for fluctuating conditions that cannot be accurately projected. To gain an insight into how EMC Avamar builds high efficiency and high performance into a unified data protection solution for physical and virtual systems, a series of backup and restore tests were run in a VMware® vSphere 5.1 environment. Tests were performed on EMC systems and the Avamar 6.1 results were compared to CommVault Simpana 9, and Symantec NetBackup 7.5.0.4.

EMC Avamar Value Proposition	
1)	**Utilize VMware Change Block Tracking (CBT) for both backup and restore operations:** Avamar maintains a repository of virtual disk blocks with rich meta data rather than an archive of backup sets, which enables the Avamar VM proxy client and backup storage node to determine the minimum amount of data that must be changed for any saved recovery point.
2)	**Run CBT-based backups forever:** Avamar adds the blocks from a CBT-based backup into a global disk block repository that uses block meta data to map all of the blocks for a VM that correspond to the recovery point associated with CBT-based backup, which makes every CBT-based backup a full backup.
3)	**Run client-side global deduplication on every backup:** Avamar architecture sets up a communications link between a client and the Avamar Data Store—a purpose-built appliance—which enables Avamar to perform highly efficient variable-length client-side data deduplication within the context of full global data deduplication on the appliance.
4)	**Run CBT-based Recovery:** Avamar leverages the smart client architecture during a restore to analyze the current state of the CBT logs for the client with the CBT meta data stored for the selected recovery point to determine the minimum amount of data required to restore the client.
5)	**Synchronize RTO and RPO optimization:** Avamar's CBT-based Recovery is optimized when the time interval between the current operating state and the recovery point is minimized, which occurs when an optimal RPO strategy is employed.

For CIOs, the data protection equation is rapidly becoming further complicated by a growing trend among corporate departments to store "copy data" as an internal way to deal with their own needs for local data backup, and protection. Propelling the data copy problem is a toxic brew that is one part fear of government regulations and compliance mandates on how companies function and one part distrust of corporate IT to provide fast recovery services that never require the retrieval of tapes from an off-site location. As a result, there is a growing trend within Line of Business (LoB) groups to be over-protective with data by keeping multiple secondary copies.

Underscoring the seriousness of this problem, a recent IDC Insight Note on The Economics of Copy Data, found copy data was responsible for a major portion of enterprise data growth. Only 25% of added enterprise data was cited as being unique from a document perspective. From a block-data perspective, however, added data is likely to be less than 5% unique. What's more, while IDC found that several copies were maintained for most files, it was not unusual for some files to have upwards of 100 copies.

"For CIOs confronted with the VI data-protection conundrum, EMC's Avamar presents IT administrators with a smart unified solution that applies to physical and virtual machines in a way that is perfectly aligned with the explosive data copy issue."

For CIOs, the immediate challenge is to master this chaotic environment and deal with the explosive growth in the volume of data in an optimal manner. In the long run, they must also staunch the growth of copy data by providing centralized data protection procedures that LoB groups will accept and adopt as part of their own internal processes. CIOs are also expected to enter into highly visible Service Level Agreements (SLAs) with LoB executives with respect to maintaining business continuity. What's more, success in assuaging the business continuity fears of LoB executives can help forge successful partnerships between IT and LOB organizations in dealing with the data-copy iceberg.

A growing majority of CIOs, are finding a solution to these issues in a transition to a private cloud paradigm characterized by a software-defined, hypervisor-based, Virtual Infrastructure (VI). While a VI provides the technology to optimize physical server resources, it also introduces new data protection paradigms that can introduce greater complexity and make operations far less efficient when virtual and physical machines need separate backup methods and procedures. For CIOs confronted with the VI data-protection conundrum, EMC's Avamar presents IT administrators with a smart unified solution that applies to physical and virtual machines in a way that is perfectly aligned with the explosive data copy issue.

Application Specific Plug-ins

To provide IT administrators, with sophisticated backup and recovery options, EMC's Avamar leverages platform-specific agents for a wide array of business-critical applications across numerous operating systems running on client machines. The Avamar agents communicate with the Avamar Data Store and utilize multiple software plugins to provide specific features for file systems and business-critical applications.

Through this plugin-centric smart client architecture, data deduplication is enabled at any client to reduce both the amount of data transmitted to the Avamar Data Store and the amount of data stored. More importantly, this highly efficient client-side data deduplication procedure is performed globally across all virtual machines and physical machines.

During a backup, the Avamar agent breaks the client system's files into variable-length segments in order to identify redundant data and tag a single instance of the data with a unique ID. Next, the agent contacts the Avamar Data Store to determine if the single instance ID is already stored. If the unique ID is not present on the Avamar Data Store,

the agent compresses and sends the new segment to be cataloged with a the new segment ID. Otherwise, only a link to the existing ID is sent for every instance of the segment.

In contrast, deduplication schemes that focus solely on local systems will transfer the same unique data segments on every full backup from every system that contains those segments. In the Avamar data deduplication process, a unique data segment is sent to the server only once, no matter how many clients contain that segment. Moreover, the Avamar server maintains all segment meta data to remain entirely independent of client systems.

"Backup scalability, through its relationship with VM density, plays a key supporting role in maximizing the Return on Investment (ROI) from a VI initiative."

In a VMware VI, Avamar provides two backup options for virtual machines (VMs) that can be utilized in tandem. The primary option for IT is to utilize Avamar for VMware image backup and restore, which employs a Linux-based appliance as a proxy VM client to leverage the VMware vStorage API for Data Protection (VADP). The alternative option is to install an Avamar agent directly on a VM guest operating system.

The proxy VM client follows the popular VMware OVF appliance model for image backup and restore operations by employing a SCSI hot-add operation to mount any datastore available to the ESX host and the Changed Block Tracking (CBT) mechanism to further leverage data transfer and capacity optimizations. For efficient centralized management of backup and restore jobs, the proxy VM client software interfaces directly with vCenter Server. In this way, Avamar provides IT administrators with the ability to restore a full VM, specific virtual disks of a VM, or individual folders and files of Microsoft Windows and Linux Guest VMs

Unlike many enterprise data protection packages, Avamar architecture provides the ability to run CBT-based backups in perpetuity. Every Avamar backup is a full backup. In contrast, both CommVault and Symantec require running either a synthetic full backup or a full VM backup without CBT every two weeks.

More importantly for CIOs, backup scalability, through its relationship with VM density, plays a key supporting role in maximizing the Return on Investment (ROI) from a VI initiative. Two essential elements for a high rate of return on a VI initiative are maximized resource utilization and minimized IT management costs. Both of these factors have a synergistic relationship with VM density on a host. In particular, driving up the number of VMs running on a host directly increases resource utilization. Furthermore, increasing the number of VMs without increasing the number of installed hypervisors, also limits the impact on VI management overhead for IT workloads. As a result, inefficient backup scaling has a direct negative impact on VM density by lowering resource utilization and raising IT management costs.

The Avamar client/server paradigm also provides significant advantages when dealing with Disaster Recovery (DR) and business continuity issues. For a business continuity SLA, ISO 22301 defines a Recovery Point Objective (RPO) and a Recovery Time Objective (RTO), which limit the acceptable amount of data lost and the length of time taken to recover from a downtime event, will be critical elements. The Avamar paradigm helps IT meet and support aggressive implementations of both objectives.

The proxy VM in Avamar for VMware utilizes the direct communications link established between the Avamar client and server to support CBT and data deduplication to efficiently minimize every backup window. Furthermore, communications between these two entities enables true global deduplication of data on the client. With the Avamar proxy VM client supporting CBT and global deduplication, the amount of data transferred in Avamar's backup is guaranteed to be a minimum amount, which minimizes the time performing a backup and is the key to providing a short RPO.

"Avamar's process of minimizing the amount of data transferred in a restore operation is most efficient when the elapsed time from the recovery point is minimized, ***which means that an IT strategy that provides an optimal RPO automatically provides an optimal RTO with Avamar."***

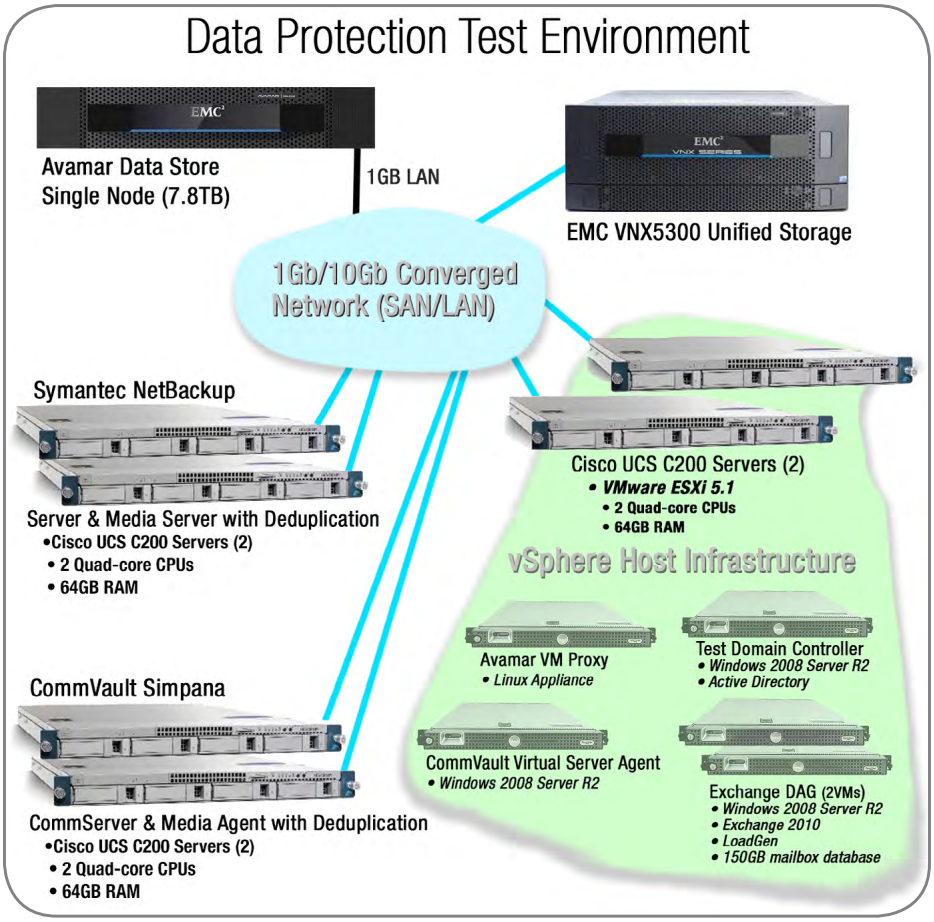
Every Avamar proxy VM client backup also includes CBT meta data, which the Avamar server stores and links to every recovery. By setting up a communications link between an Avamar client and server during a restore process, the client and backup server are able to analyze the current CBT data for the client in conjunction with the CBT data stored with a recovery point to explicitly determine which client data has changed since the recovery point was processed. In this way, Avamar is able to restore just the data that has changed since the recovery point was saved.

In what can be thought of as an "incremental restore," an Avamar CBT-based Recovery reduces the amount of data transferred in a recovery operation from potentially hundreds of gigabytes to hundreds—if not tens—of megabytes. More importantly, Avamar's process of minimizing the data transferred in a restore operation is most efficient when the elapsed time from the recovery point is minimized, which means that an IT strategy that provides an optimal RPO automatically provides an optimal RTO with Avamar.

Performance Test Validation

To test the efficiency and performance of Avamar in a VI, three VM servers running Windows Server 2008 R2 were set up. One VM server was configured as a primary domain controller running Active Directory. The remaining two servers were configured as an Exchange 2010 high availability group using the Database Availability Group (DAG) construct rather than server clustering.

To host the VMware VI for the data protection tests, two Cisco UCS C200 Servers were used running ESXi hypervisors. Each C200 Server was provisioned with two quad-core CPUs. All storage for the C200 servers was provisioned from an EMC VNX Series 5300 array in a single disk-processor enclosure. SAN fabric topology was configured as a 10GbE Fibre Channel over Ethernet (FCOE) converged SAN. More importantly, all backup tasks were conducted in a hardware neutral manner. No attempt was made to leverage any of the advanced hardware capabilities of the VNX array to bias backup performance.



Similar servers were used to test each of the data protection packages. To support the backup server and media server roles that are part of both the Symantec NetBackup and CommVault Simpana data protection configurations, two Cisco UCS C200 Servers were used with 10Gbit converged network connections. In the test configuration both the NetBackup and Simpana servers handling media also had a data deduplication option installed. The Avamar configuration, however, required only an Avamar Data Store Single Node with a 1Gbit LAN connection to the converged network. In addition, the Avamar and Simpana configurations included a proxy VM using VMware's SCSI hot-add to back up data, which was transferred over a LAN connection to the media server or data store.

The Avamar VM proxy client is packaged as a preconfigured OVF appliance with two virtual cores and 2GB RAM. The CommVault Virtual Server iDataAgent needs to be installed on a VM running a Windows server or desktop OS.

The Symantec NetBackup media server, on the other hand, implements backup directly over a SAN fabric. All backup tests for NetBackup utilized a LAN-free configuration and were run exclusively with direct SAN access to the VI disks. Nonetheless, significant network traffic was measured between the media and backup server during a VM backup.

Real World Business Continuity

A corporate email system is deeply embedded into IT infrastructure and the effectiveness of the EMAIL application portfolio dramatically impacts the productivity of the entire corporate staff. That's why the stability, reliability, and security of a corporate email system has far-reaching implications for IT and LoB organizations alike. As a result, multiple detailed backup and restore tests were run on the VMs hosting Exchange 2010 to

investigate the efficiency and performance of backup and restore operations needed to be performed in a business continuity plan for an email system.

Each member of the Exchange DAG configuration was provisioned with a 40GB system disk and a 150 GB maibox database volume. One member was designated as the active member for production. The second member maintained a passive copy of the mailbox database and was used in all of the backup and restore tests. The Microsoft Load Generator Tool (LoadGen) was used to generate consistent measurable amounts of email data in the mailbox database on the active server. With LoadGen, specific backup and restore test scenarios were readily created.

Exchange 2010 VM Backup

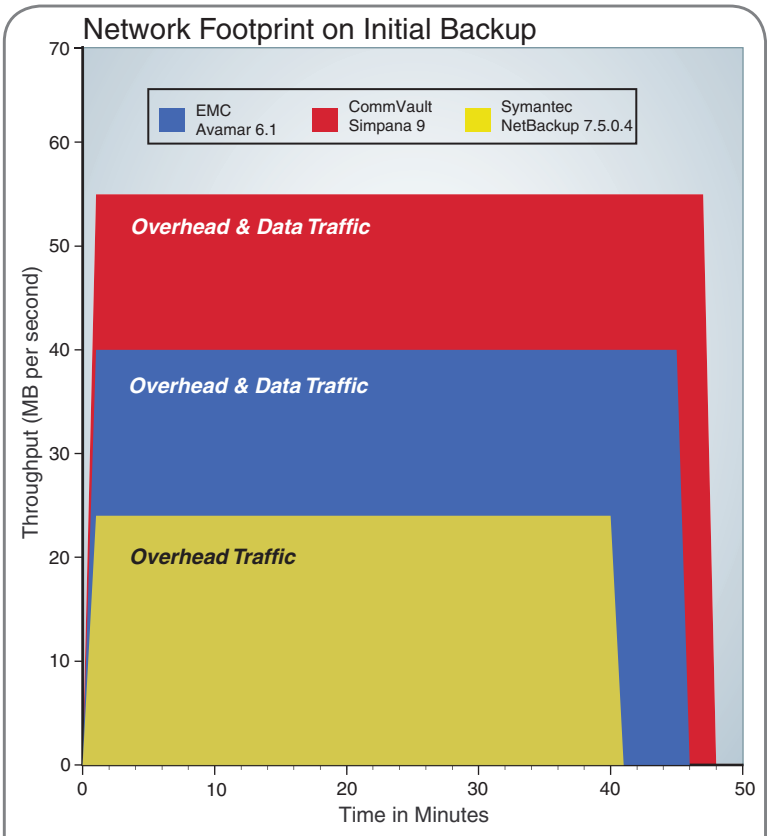
VM Configuration	Backup Software	Backup Time (mm:ss)	vs. Avamar Time
Initial Full Backup 40 GB system volume 150GB mailbox database	Avamar 6.1	45:00	1X
	CommVault Simpana 9	47:00	1.04X
	Symantec NetBackup 7.5.0.4	40:00	.89X
CBT-based Backup 2% mailbox database change 3GB mailbox database change	Avamar 6.1	02:30	1X
	CommVault Simpana 9	10:00	4X
	Symantec NetBackup 7.5.0.4	14:30	4.8X
Biweekly Backup 2% mailbox database change Recommended best practices CommVault & Symantec: full, no CBT Avamar: standard CBT-based backup	Avamar 6.1	02:30	1X
	CommVault Simpana 9	48:00	19.2X
	Symantec NetBackup 7.5.0.4	60:00	24X

Backup testing began with a baseline full backup, which initializes CBT for a VM. Running a full backup without CBT is a distinct one-time event for each VM with Avamar, as the 5.8XAvamar disk-block store always makes a CBT-based backup a full backup. With a traditional backup architecture with distinct full and incremental backup files, periodic backups with out CBT or synthetic full backup processes will be required.

In any backup with a large volume of data, such as an initial full backup, a SAN-based VM backup has a distinct advantage over an appliance, which relies on VMware's SCSI hot-add to access the logical disks belonging to the VM being backed up. In a SCSI hot-add scenario, backup data must traverse the appliance's SCSI and network protocol stacks, in addition to the hypervisor's SAN stack to get to the backup server. For a backup solution supporting both SAN- and appliance-based backups, a SAN-based backup of a VM with a large volume of data is typically twice as fast.

Nonetheless, even with an inherent advantage in topology for the initial backup of the VM hosting Exchange, Symantec NetBackup exhibited a remarkably small 11% advantage in backup time over Avamar. Moreover, In a CBT-based backup of the VM after a modest 2% data change in the mailbox database, Avamar was 4.8 times faster than NetBackup and 3 times faster than Simpana.

Even though Symantec NetBackup was moving all backup data over the SAN, it was also generating a very significant amount of overhead traffic over the LAN network. As a result, LAN Network efficiency was a distinct gating factor for NetBackup.



To understand the impact of backup operations on a network, we used the volume of network traffic as a measure of efficiency. Using this metric, Avamar, which moved all data—backup and overhead—over the LAN, moved in total just 1.88X times the overhead data moved over the LAN by Symantec NetBackup. Moreover, compared to CommVault Simpana, which also moved all data over the LAN, Avamar moved .7X the amount of data.

Network efficiency of a backup operation, can be represented by the average network throughput over the time taken by the backup process. In particular, the area under the graph for average throughput rate over backup process time gives a measure of the work performed, which also equates to the volume of data transferred during the process.

Using this measure of network efficiency, CommVault Simpana moved 1.44X more data than Avamar over the LAN. More importantly, just Symantec NetBackup's overhead traffic equaled .53X of the total backup and overhead traffic sent by Avamar.

With CBT meta data established for the VM, 2% more data—3GB—was added to the Exchange mailbox database. A CBT-based backup, which will be the dominant form of backup for most sites, was then run with each backup solution.

Avamar's efficiency advantage came to the forefront, as the VM client proxy performed full global data deduplication guided by the Avamar Data Store. In particular, Avamar reduced the total amount of data acquired using VMware's CBT to less than 500MB for transfer to the Avamar Data Store. In contrast, a CBT-based backup using Simpana took 10 minutes and 14 and a half minutes with NetBackup.

Far more important for IT operations, VMware's CBT makes it relatively easy to create a fast block-based incremental backup regime that is far more efficient than traditional file-based incremental backups. By storing backup files containing the data generated in a full backup without CBT along with backup files associated with CBT-based backups in an ordered set creates a traditional forward incremental backup chain.

This approach creates a sequential series of recovery points corresponding to the full backup and subsequent incremental backups. Recovery of a VM to any recovery point requires that the full backup is restored as the starting point followed by the ordered restoration of the CBT-based incremental backups to roll up to the desired recovery point. Advanced data protection solutions run this rollup process automatically.

Breaking Incremental Chains

For IT operations, there is the distinct reliability issue associated with storing a forward incremental backup chain: Any corrupted or deleted file in the chain will invalidate all follow-on backup files in the chain. It is therefore imperative to keep any series of forward-chained incremental backups short.

> *"For every restore operation with Avamar, a full system image can always be navigated within the virtual block space for every CBT-based recovery point of every protected system."*

To resolve the dependency issues of incremental backups while maintaining minimum backup windows, mid-range backup packages often implement a loosely dubbed "incremental forever" backup scheme that relies on a periodic synthetic full backup processes, which is a consolidation process and not a true backup. Without reading data from the client, a synthetic backup takes the last full backup—also probably synthetic—and all subsequent incremental backups to synthesize an ersatz full backup file on which to build a new forward chain.

The new synthesized backup is complete and independent of previous backup files; however, it is susceptible to perpetuating a corrupt or missing file, which is why synthetic backups are considered problematic at large enterprise-class IT sites. Given the reliability questions for synthetic backups, both Symantec NetBackup and CommVault Simpana recommend running a full backup without CBT every two weeks to initialize a new backup chain. While this strategy lessens the likelihood of losing a series of recovery points, it is very inefficient at processing each biweekly backup.

In tests with a 200GB VM Server running Exchange, full backups without CBT averaged about 45 minutes. Scheduling 26 full backups of that VM will add about 19 hours to backup processing over a year. Worse yet, this scenario needs to be repeated for every VM. Assuming perfect distribution of full backups, a site running 42 VMs that require 20 minutes each for a full backup—which is typical of a VM running a database-driven application with about 75-to-100GB data—will add about an hour to each daily backup schedule to handle the recommended full backups. As a result, the mandate on IT operations to run periodic full backups adversely impacts backup scalability, which is tied to factors driving ROI for virtualization.

Avamar avoids this problem by never creating incremental backup files from CBT-based backups. Instead of creating a collection of discrete backup files, Avamar creates a virtual block space for the universe of protected systems. In any backup, with or without CBT support, blocks with rich meta data links are saved in Avamar's global virtual space.

Every Avamar backup functions as a full backup. For every restore operation with Avamar, a full system image can always be navigated within the virtual block space for every CBT-based recovery point of every protected system. There are no incremental backup chains to close. There are no synthetic backup processes that need to run on the server. There are no requirements to run periodic full backups.

In a comparison test of a CBT-based Avamar backup with a biweekly full backup without CBT, which is recommended as a best practice by CommVault and Symantec, differences in backup times were quite dramatic. In the biweekly cycle, the Avamar

continuous CBT-based backup process was 18.2 times faster than CommVault Simpana and 23 times faster than Symantec NetBackup.

Synchronizing RTO with RPO

A key benefit CIOs cite for implementing a Virtual Infrastructure is the ability to leverage VI capabilities, such as rapid VM restart, non-disruptive VM moves, and VM cloning, to assuage the down-time fears of corporate executives. That makes a highly flexible VI a necessary component of any IT arsenal; however, a VI alone is not sufficient to resolve all of the knotty IT issues related to the most critical component of business continuity: data recovery. In a business continuity context, backup is simply a means to an end. For any CIO the main concern is recovery.

Exchange 2010 VM Restore

VM Configuration	Backup Software	RestoreTime (hh:mm:ss)	vs. Avamar Time
2% Data Change* 153GB mailbox database	Avamar 6.1	02:00	1X
	CommVault Simpana 9	4:43:00	141.5X
	Symantec NetBackup 7.5.0.4	55:00	27.5X
5% Data Change* 158GB mailbox database	Avamar 6.1	16:00	1X
	CommVault Simpana 9	5:16:00	19.75X
	Symantec NetBackup 7.5.0.4	65:00	4.06X

*Initial mailbox database 150 GB

VM backup solutions now universally leverage CBT-based backups, which minimize backup time and support shorter RPO targets to minimize the amount of processed data that will likely be lost when recovering from a computer outage. Nonetheless, the work to provide an aggressive RPO can be quickly negated by a prolonged recovery process. Fast backup must be complemented with reliable accelerated recovery technologies to support an aggressive RTO, which must be measured in minutes for critical business applications.

Avamar uniquely addresses the process of restoring any VM to any recovery point by leveraging the CBT meta data saved with each VM backup to implement a CBT-based Recovery. **Using the CBT meta data maintained in the Avamar Data Store and the current CBT data on the target VM, the Avamar VM Proxy Client and Data Store coordinate the minimum set of blocks needed to restore a VM to a desired recovery point. In sharp contrast, the other solutions needed to transfer all of the data present at the time of the recovery point. What's more, all of the data involved in these restore operations must be processed using the hypervisor, which forces all data transfers to occur over an Ethernet connection.**

For supporting an aggressive RTO, the Avamar CBT-driven restore operation was unparalleled. Restore tests of the Exchange VM began with a series of 2% and 5% changes to the Exchange mailbox database using LoadGen that were followed by a CBT-based backup in order to create a set of recovery points. To test restore capabilities, two recovery points were chosen. The first recovery point was associated with the most recent backup, which represented a 2% change in the maibox database. In addition, an older 5% change point was also chosen for recovery.

In each case, Avamar CBT-based recovery was dramatically faster than either CommVault Simpana or Symantec NetBackup. Not surprisingly, the differential in recovery time was greatest for more recent backups, as less data needs to be transferred and calculation of a minimal set of data is less complicated. In particular, the advantage that CBT-based recovery brings to IT is maximized when both the rate of change and the time elapsed since the recovery point are minimized. As a result, IT ensures an optimal RTO with Avamar simply by using backup operations that provide an optimal RPO.

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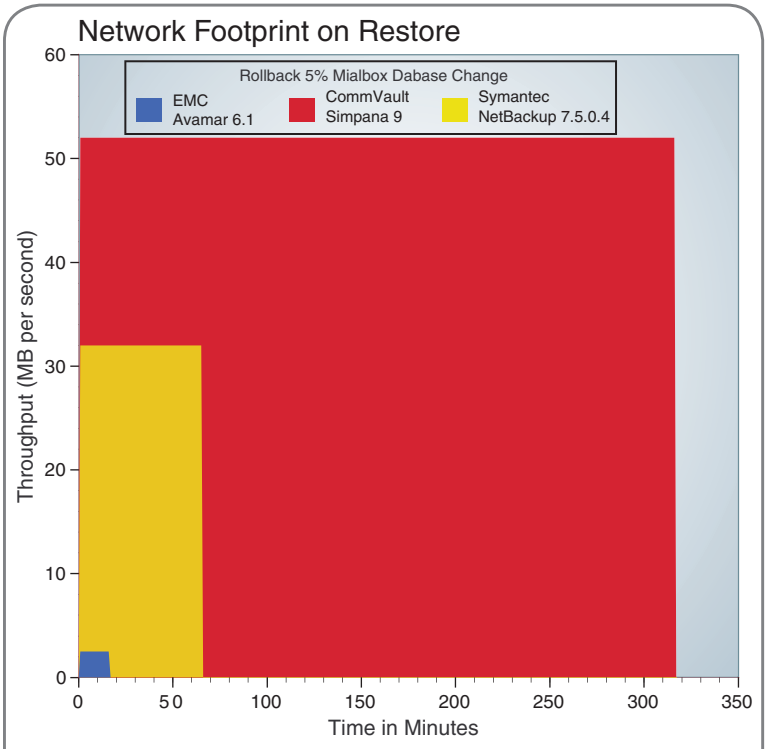

To visualize the impact of restore operations on a network, we used the volume of network traffic generated by a restore as a measure of efficiency. Using this metric, the footprint of an optimized CBT-based Avamar restore was 52 times as efficient as NetBackup and 410.8 times as efficient as Simpana.

Specifically, restoring the most recent recovery point with Avamar took just two minutes. CommVault Simpana took 141.5X the time taken by Avamar and Symantec NetBackup took 27.5X the time taken by Avamar. For an older recovery point, which at the time represented a 5% change in the mailbox database, Avamar took 16 minutes—8X the running time of the most recent change. Nonetheless, ComVault Simpana took 19.75X the Avamar run time and Symantec NetBackup took 4.06X the Avamar run time.

In addition to the time to run a restore operation, the network efficiency of a restore operation, represented by average network throughput over the time taken by the restore process, was also examined. In particular, the area under the graph of throughput over time gives a measure of the work performed during the backup process and equates to the amount of data transferred in the process. Using this measure of network efficiency, Symantec NetBackup transferred 52X the amount of data over the LAN as Avamar and CommVault Simpana transferred 410.8X the data transferred by Avamar.

Customer Value

For CIOs, the top-of-mind issue is how to reduce the cost of IT operations. With storage volume the biggest cost driver for IT, all storage management functions are directly in the spotlight. Furthermore, the concerns of Line of Business (LoB) executives over business continuity are helping to drive the next wave of IT projects. In a competitive 24x7x365 environment, computer downtime represents more than lost revenue to sales and marketing executives. These executives equate computer outages with potential losses

in customer confidence and market share and expect IT to meet an RTO that is measured in minutes and an RPO measured in hours rather than in days.

Avamar Feature Benefits	
1)	**Avamar Data Store Maintains a Virtual Disk Block Space:** Avamar maintains a repository of virtual disk blocks rather than an archive of backup sets which radically improves the dynamics of backup and restore operations.
2)	**Virtual Disk Block Space Enables a Shorter RPO:** A virtual disk block repository, provides a way to map a full restore using any CBT-based backup, which enables IT to execute a fast continuous CBT-based backup strategy.
3)	**Smart Client Architecture Enables Client-side Global Deduplication:** A communications link between a client and the Avamar storage node, enables highly efficient variable-length, client-side, global data deduplication.
4)	**Stored CBT Meta Data Minimizes Data Transfer on Recovery:** Avamar architecture leverages smart clients during recovery to analyze the current state of VMware CBT for the client with the CBT meta data stored for the recovery point to determine the minimum amount of data needed.
5)	**CBT-based Backup and Recovery Synchronizes RTO and RPO optimization:** The amount of data that must be transferred in a restore is minimized when the time interval between the current operating state and the recovery point is minimized, which occurs when an optimal RPO strategy is employed,

Avamar never creates incremental backup files from CBT-based backups. Instead of storing a discrete set of backup files, Avamar creates a global block space for the universe of protected systems. As a result, a full system image can always be navigated within the virtual block space for every recovery point of every protected system

What's more, Avamar collects CBT meta data on each backup, which provides a means to minimize the amount of data transferred in a restore operation of a logical volume. Rather than simply restore all of the data associated with a volume at the selected recovery point, Avamar compares the current CBT data from the VM virtual proxy with the meta data associated with the recovery point to determine the explicit data that needs to be changed in order return the VM to its state at the recovery point. .

With Avamar, IT can double down on the advantages garnered in CBT-based backup processing to implement frequent automated backups to provide minimally spaced recovery points for mission critical systems. This strategy in turn minimizes the amount of data needed to be transferred in a restore operation, As a result, an IT strategy that optimizes RPO also optimizes RTO with Avamar.

Jack Fegreus is Managing Director of openBench Labs; consults through Ridgetop Research; and contributes to InfoStor and Open Magazine. Previously he was Editor in Chief of Open Magazine, Data Storage, BackOffice CTO, Client/Server Today, and Digital Review. Jack also served as CTO of Strategic Communications, a consultant to Demax Software, and IT Director at Riley Stoker Corp. Jack holds a Ph.D. in Mathematics and worked on Lie Algebras the application of computers to symbolic logic.