



**A Tutorial on
Disk Defragmentation for Windows NT/2000/XP**

What You Don't Know Can Hurt You

April 2, 2002

Table Of Contents

Introduction.....	2
Fragmentation 101	2
Fragmentation and Performance	3
The Costs of Fragmentation.....	4
Productivity.....	4
Backup	4
System Administration/Help Desk	5
Hardware.....	5
Myths or Misperceptions	5
Myth 1-Our systems are new, we don't need defragmentation software.	5
Myth 2- We have lots of free space so fragmentation's not an issue.	5
Myth 3-Fragmentation isn't an issue for our workstations.....	6
Myth 4-We use RAID or striping, so we don't need defragmentation.....	6
Myth 5-We are going to use the built-in Windows defragmentation utility.....	6
Myth 6- A file is a file.....	7
Myth 7- All defragmentation software is the same.....	7
How Defragmentation Software Products Differ	7
Windows 2000 API's.....	7
Free Space Consolidation	8
Single Pass Defragmentation	8
Free Space Requirements.....	9
Optimization	9
Master File Table and System Files.....	9
Network Awareness	10
Schedule View/Cancel.....	10
Boot Time Defragmentation	10
NTFS and FAT Directory Consolidation.....	10
Page File Defragmentation	11
Auto Update	11
Command Line Interface	11
Exchange Data Store Defragmentation.....	11
Very Large, Very Fragmented Partitions.....	11
Windows XP and the MFT	12
Evaluating Defragmentation Software.....	12
Summary	13
Appendix 1.....	14
Appendix 2.....	17

Introduction

Over the past decade, businesses worldwide have experienced a tremendous expansion of decentralized, distributed, and networked information processing. Much of this expansion is based on enterprise versions of Windows-based operating systems like Windows NT or Windows 2000. A processing paradigm where end users have computing power on the desktop, and reliance on a network and central server to communicate with colleagues, suppliers, and customers, has substantially changed the role of the system administrator.

It is not uncommon now for system administrators to have responsibility for hundreds or thousands of machines, in geographically disparate locations, running all manner of applications and sharing information over the network. This model stresses the ability of organizations' system management resources to stay on top of system and application upgrades and service packs while performing routine system maintenance and sustaining adequate service levels. In this environment, system administrators need all of the proactive, enterprise-enabled system management assistance they can get.

Raxco Software has a 22-year history of developing system management software. Since 1997, Raxco has offered enterprise ready system management for Windows platforms with an emphasis on Windows NT, Windows 2000, and most recently Windows XP. Raxco, by virtue of its tenure and track record in this market segment, regards itself as expert in the area of file fragmentation on the FAT and NT file system (NTFS) that are part of these operating systems. This paper is provided as an educational instrument that will: explain how and why disk fragmentation happens, explain the costs of fragmentation, explode some myths about fragmentation, and examine the differences in disk defragmentation solutions.

Fragmentation 101

Fragmentation is a condition where a file on a disk is in more than one piece. Before we go much further with this we will address an area that is a little confusing. There are two kinds of fragmentation. There is logical fragmentation, which is how the file system "sees" the disk; and there is physical fragmentation, which is how the file actually resides on the disk itself.

Let's look at an example. You have a Windows 2000 Pro workstation with a 10GB hard drive. The file system knows the size of the drive and simply views it as a string of Logical Cluster Numbers (LCN's) starting at 000000000 and ending at NNNNNNNNNN. When an application creates a file, the file system looks for somewhere to put the file and makes a file entry in the Master File Table (MFT). The MFT contains pointers indicating the starting LCN for the file, and a length. If the file is fragmented, the MFT has a series of pointers with a starting LCN and a length for each fragment. The file is then physically written to the disk by the disk controller. In a simple example like this, the mapping between the file systems LCN and the Physical Cluster Number (PCN) is probably a one-to-one relationship. As a disk ages and develops bad sectors, the mapping between LCN and PCN will change. Alternative disk configurations like stripe sets and RAID are discussed in-depth a little later.

Fragmentation happens. It is a normal by product of everyday computer use and it begins the day you start using your machine, even with a new operating system. It is an unavoidable problem that affects every workstation and server using Windows operating systems. Fragmentation occurs under several different scenarios. The most obvious occurs when the file system cannot find sufficient contiguous free space for a file. One would think that with multi-gigabyte drives finding contiguous free space would not be a problem. The Microsoft file allocation algorithm is proprietary, but simple testing demonstrates that extreme file fragmentation can occur even when there is ample contiguous free space on the disk.

File extension is another source of fragmentation. If a file is extended, and there is no room at the logical end to grow it contiguously, the file will have to be fragmented. File deletions are the third contributor to fragmentation. Deletions split the free space and this in itself can contribute to future fragmentation. We will discuss the significance of free space fragmentation later in this document.

Think of fragmentation as a computer virus. If a virus occurred that split all your files into hundreds of pieces, there would be an immediate system slowdown and everyone would want protection against this ever happening again. Yet, that is exactly what the file system is doing at a slower rate. Increasingly, file fragmentation erodes system performance, requires more resources to perform the same task, and increases the total cost of ownership for the organization. The good news is... it is preventable.

Fragmentation and Performance

As we described above, when an application requests a file, the file system must go and find it. The MFT is queried and the File ID is found along with the starting LCN and a length. If the file is in 2000 fragments, the starting LCN and length of 2000 fragments must be located and passed to the disk controller. In a server environment, the user has access to the processor for a brief slice of time (a quantum) to complete this task. If the file is so fragmented that all the information cannot be delivered during the time the user has the processor, he waits until it is his turn to use the processor again, and finishes reading the file. This wastes system resources and user productivity. If the file was contiguous, the file system would only have to pass the controller a single LCN and length and this would likely complete during the user's initial processor quantum.

Let's look at what this means in terms of system performance. Over the years, we have encountered systems with some very severe problems. One site had ten 10GB partitions each with about 100,000 files, and many of these had in excess of 11,000 fragments. Another site had a MFT in 25,000 pieces, while a third had a 339GB RAID partition with 5% free space. While these cases are extreme, we find that many sites routinely have files that are in several hundred to several thousand pieces. The improvement in the time it takes to read a file in several hundred pieces versus a contiguous file can range from 30-80%. When you consider the thousands of files being accessed every day on a busy server, an average 50% performance increase could come in handy.

A simple way to test this at your own site is done with backup. Perform a full disk backup before fragmentation and time it to completion. Then defragment the disk and time the backup again.

If a representative of Western Digital, EMC, or Winchester called and said there was a new disk drive that was 50% faster than what you were using today, you would probably be very interested. Defragmentation software delivers this performance increase on your current hardware and keeps delivering as the disk fills up, all at a fraction of the cost of new hardware.

The Costs of Fragmentation

International Data Corporation (IDC), in a white paper entitled “Disk Defragmentation for Windows NT/2000, Hidden Gold for the Enterprise,” estimated that the global cost of fragmentation is \$50 billion annually. There are many factors that contribute to this cost and some of them are not all that obvious. We will now examine the components of the costs of fragmentation and how they affect an organization.

Productivity

Defragmentation improves system performance, resulting in improved end user productivity. But how can this be measured and quantified? Most defragmentation software vendors provide tools that let you measure the time it takes to read a file before defragmentation and after. Testing has shown that defragmentation can improve I/O performance by 30-50%. The IDC report says 30-85%. If you can improve every I/O on a server by 30%, what is the savings in terms of productivity?

To answer this, let's look at an organization and make some assumptions. We will first assume defragmentation can improve I/O by 30%. The organization has 200 users with a loaded hourly cost of \$26. They spend 3 hours a day on their workstations and half that time is doing I/O to the disk. They work 5 days a week, 49 weeks a year. What is the organization saving in productivity?

$200 \text{ users} \times \$26/\text{hr.} \times 3\text{hrs.} \times .50 \text{ I/O time} \times 5 \text{ days} \times 49 \text{ weeks} \times .30 \text{ gain} = \$573,300$

Improving the access time to each file by 30% can improve server response so that over a half million dollars of payroll can be utilized more effectively.

Backup

Backup is one of the few operations that actually read an entire disk. As disks grow in size, the time it takes to perform a full backup will increase proportionally. Many organizations already face constraints on the time to perform routine system maintenance due to limits on system downtime.

Defragmentation can dramatically shorten backup times. Independent testing conducted by Syncsort Inc., the developers of Backup Express, showed that defragmentation could improve backup times by 30-50% ([Appendix 1](#)). Users are generally locked out of the system during backups. By cutting backup times by one-third to one-half, system availability can be improved.

If server availability is valued at \$100 per CPU hour and the organization saves 5 hours a week on backup due to defragmentation, the annual savings are \$26,000. (Make sure your tape system is not the I/O bottleneck).

System Administration/Help Desk

When users encounter application or system errors, they call the system administrator or the help desk. System and help desk personnel are generally highly trained and highly paid technical resources. These individuals then troubleshoot the problem and affect a solution.

If we assume that our help desk technician has a loaded hourly cost of \$30 and it takes them four hours to diagnose a fragmentation related system or application error, the cost of that error is \$120. If our virtual organization has five such incidents a month, the annual cost is \$7,200. These assumptions are fairly conservative. Ohio Savings Bank, the nation's tenth largest mortgage banker, found that regular defragmentation eliminated intermittent application errors and shortened service calls by three hours ([Appendix 2](#)).

Hardware

The most common reaction system managers have to slow system performance is to change the hardware configuration. A bigger disk does not eliminate the fragmentation problem. The cost of upgrading hardware to address I/O related performance issues greatly exceeds the cost of defragmentation software. According to IDC, proactive fragmentation management can help lower the cost of ownership and help you protect your Windows NT/2000/XP hardware investment.

Myths or Misperceptions

System administrators face a host of challenges in keeping a networked Windows environment up and running. They are expected to know the operating system, the network protocols, dozens of applications, security, hardware configurations, and a myriad of other things associated with keeping the enterprise's IT resources going. It is therefore understandable that there could be some misunderstandings about how defragmentation software works and what it is doing to your system. The purpose of this section is to debunk some common myths and clear up misperceptions about defragmentation software.

Myth 1-Our systems are new, we don't need defragmentation software.

Fragmentation begins when you start using the system. If you take a brand new machine and install Windows 2000, Internet Explorer, Microsoft Office, and PerfectDisk 2000 (so you can analyze the disk) you will find over 300 fragmented files on the system and all you have done is install software. While fragmentation is not a problem at this time, it is a condition that will get worse with time and usage. Just like you go to the dentist to avoid serious tooth and gum problems, you should proactively manage fragmentation so it never becomes an issue.

Myth 2- We have lots of free space so fragmentation's not an issue.

The amount of free space on a disk has nothing to do with fragmentation. If you have 30GB of free space on a 40GB drive, but you have 10GB of frequently changing files that are in hundreds

or thousands of pieces, your machine performance can be adversely affected by fragmentation. In most cases, system administrators have no idea about the condition of the files on their system.

Myth 3-Fragmentation isn't an issue for our workstations.

There is a belief that defragmentation is not necessary on workstations. Windows NT/2000/XP workstations use the same file system as their counterpart servers, and fragmentation is a function of file system use. Many organizations have adopted policies requiring saving all data to the servers. While this ensures data integrity and protects data, it does not preclude users from saving files locally. Other file activity, like extension and deletion, also contribute to fragmentation on the desktop.

Windows XP possesses some unique features that also contribute to fragmentation. The growth of the layout.ini file can challenge the abilities of the built-in defragmenter. The built-in tool makes no attempt to clear out free space to ensure defragmentation of the applications referenced in layout.ini

The System Restore function fragments the free space on the disk. Since the built-in defragmenter does not consolidate free space, file fragmentation will occur at a faster rate on workstations with this feature enabled.

In a Windows XP white paper¹, Microsoft contends that fragmentation is a performance-robbing problem and frequent defragmentation is the only available solution.

Myth 4-We use RAID or striping, so we don't need defragmentation.

This is one of the most common misperceptions about defragmentation. As was noted in the Fragmentation 101 section of this document, there is "logical" fragmentation and "physical" fragmentation. In a RAID environment the file system has to locate the logical pieces of a file and pass them to the RAID controller. If the file is in 2000 logical fragments, the file system will have to pass 2000 separate I/O's to the controller. With defragmentation, that effort can be reduced to passing a single logical I/O to the controller. In testing using the ZD Server Bench and the Intel IOMeter benchmark suites, we have seen defragmentation double the transaction rate of both reads and writes to the disk in a RAID environment.

With RAID, a file that is logically contiguous will almost certainly be physically fragmented. The testing proves that a contiguous logical disk delivers twice the performance of a fragmented logical disk, regardless of the condition of the physical disk.

Myth 5-We are going to use the built-in Windows defragmentation utility.

If you are working at home on a single workstation, this is probably all you need. The built-in defragmentation utility is woefully inadequate for enterprise use. Some of the shortcomings of the built-in utility are:

¹Sechrest, S. and Fortin, M. "Windows XP Performance". URL: <http://www.microsoft.com/windowsxp/pro/techinfo/planning/performance/evalissues.asp> (June 2001).

It cannot be scheduled to run over the network

It can only defragment a single partition at a time

It cannot move certain file types so it never completely defragments the disk

It requires Admin privileges so you have to physically go to each machine to run

It may require multiple passes to defragment and does not consolidate the free space.

Busy administrators simply don't have the time to bother with a partial solution like the built-in defragmentation tool.

Myth 6- A file is a file.

Not exactly. With Windows NT/2000/XP, there are a number of different types of files, and different defragmentation software moves these files with varying degrees of completeness, depending on the operating system in use. Under Windows NT/2000, you need to do a boot time defragmentation to move the Master File Table (MFT), the related metadata files, and the page file. Windows NT can only move the directories at boot time. With Windows XP, the MFT can be moved online, but certain metadata files still need to be moved at boot time only. This is important because if the MFT, metadata files or other system files are not defragmented, it is very unlikely you will ever be able to completely defragment a disk. The unmovable fragments will cause data files to be split around them.

Myth 7- All defragmentation software is the same.

Different software vendors take different approaches to the defragmentation problem. Speed versus quality, multi-pass versus single pass, and interval versus event driven, all affect the final outcome. As a user, you need to determine which product best fits your needs and delivers the best results in your environment. The best way to determine this is to test solutions head to head, and compare their results and their utility. To help you understand the differences between defragmentation offerings, the next section compares and contrasts two products that approach defragmentation differently.

How Defragmentation Software Products Differ

All defragmentation software is not the same. How different products behave can have a significant effect on your systems. This section identifies some of the criteria you may want to consider when evaluating defragmentation software for your organization. It also describes how two different products address these criteria. The products compared are Raxco Software's PerfectDisk® 2000 and Executive Software's Diskeeper® 7.0.

Windows 2000 API's

Safety is a primary concern when you are moving files around a disk. Protection against data loss or corruption must be absolute. Microsoft offers a special Application Program Interface (API) that affords this protection to online defragmentation software vendors. The API's also guarantee

plug-and-play compatibility with version changes and service packs. The vendors, through the API's, implement defragmentation strategies/algorithms that determine where and when to move files or free space.

PerfectDisk 2000 uses the Microsoft developed API's to perform its online defragmentation.

Diskeeper also uses the API's for its online defragmentation.

Free Space Consolidation

The file system is more efficient if it can find contiguous free space from which it can allocate space to create files contiguously. Free space fragmentation causes file fragmentation and necessitates running defragmentation software more often.

PerfectDisk 2000's defragmentation algorithms favor consolidating all the free space into as large a piece as possible. This approach was taken because the Microsoft API's under Windows NT 4.0 and Windows 2000 offered different levels of granularity for a file move. By consolidating the free space, PerfectDisk can move larger files and get better file "packing". Free space consolidation also reduces the amount of free space required to completely defragment a disk in a single pass. The system performance benefit is that if the file system can find consolidated free space, new files will be created contiguously, and re-fragmentation will occur at a slower rate.

Diskeeper's algorithms appear to favor file defragmentation over free space consolidation. While this approach seems to provide a slight speed advantage, it fragments the free space. Depending on the version of the API's in use, many of these free space fragments are not usable by the API, so eventually Diskeeper runs out of usable free space and the only alternative is to quit and start over, or manually create additional free space by removing files. This is the idea behind the multi-pass defragmentation approach.

Single Pass Defragmentation

Many sites have a limited window of time for system maintenance. Running a defragmenter several times to get an acceptable result is not an option. The Microsoft API's support the ability to completely defragment a disk in a single pass.

PerfectDisk 2000 defragments 99-100% of the data files on a partition in a single pass, even in low free space conditions.

Diskeeper will defragment in a single pass provided the files or the free space are not too fragmented, and there is ample free space (>20%). If the files or free space are too fragmented, Diskeeper will employ a multi-pass approach. If the file or free space fragmentation are very severe, or the free space too limited, Diskeeper may never completely defragment the partition.

The time PerfectDisk 2000 requires to do a single pass defragmentation and consolidate the free space is less than the aggregate time Diskeeper requires to perform a similar quality job.

Free Space Requirements

All defragmentation software requires some free space to operate. With today's large partitions, a small percentage of free space can be a significant amount of storage. While it is not advisable to fill disks to capacity, defragmentation can be performed on very full partitions. In fact, these are likely to be the partitions that need defragmentation the most.

PerfectDisk 2000 will defragment a partition with as little as 5% free space outside the Master File Table reserved zone (prior to XP, defrag software could not use the MFT reserved space).

Diskeeper recommends a minimum 20% free space (outside the reserved zone) to run. If there is less than 20%, Diskeeper issues a message suggesting you remove files from the disk to free up space, and then run Diskeeper again.

Optimization

Where files are located on a disk can make a difference in performance. A Microsoft white paper addresses how performance is affected by where the Master File Table is on a partition. This is referenced later in this section.

PerfectDisk 2000 employs a patented disk optimization strategy that intelligently positions files according to their usage. The strategy suggests that if files that are not changing are defragmented and grouped together, they do not need to be moved on subsequent defragmentation runs. This means subsequent defragmentation passes take less time and resources. Free space consolidation is also part of the optimization scheme.

Diskeeper file placement is purely random and the free space is fragmented all over the disk. The random placement means a lot of files must be moved to defragment the files that changed since the last defragmentation pass.

PerfectDisk 2000 defragments files, consolidates free space, and optimizes the disk in less time than Diskeeper only defragments.

Master File Table and System Files

Under Windows NT/2000, the MFT, its associated metadata files, and certain system files need to be defragmented offline by a boot time defragmentation. If these files are not defragmented, data files may need to be "split" around them making a complete online defragmentation impossible. With Windows XP, a boot time defragmentation is only needed to handle the page file, hibernate file, non-MFT metadata files, and directories on FATxx partitions.

PerfectDisk completely defragments the MFT, all the metadata files, and the system files. It also reports accurate status of these files in its statistics.

Diskeeper does not defragment all the metadata files and it does not report on their status. If metadata files are fragmented, Diskeeper does not report it. In some cases, Diskeeper does not completely defragment the MFT.

Network Awareness

Enterprise defragmentation is the ability to schedule and run defragmentation events anywhere in the network from anywhere in the network.

PerfectDisk 2000 can be scheduled over the network from both the workstation and server licenses.

Diskeeper supports network scheduling only from a server license.

Schedule View/Cancel

An administrator will want to view and possibly modify defragmentation schedules in consideration of other system tasks. The ability to quickly access this information gives the administrator a quick response mechanism to changing system requirements and the ability to balance resources.

PerfectDisk 2000 supports a Scheduling Wizard that lets an administrator view or cancel schedules on any machine in the network, from any machine in the network. With the most recent release, schedules can also be modified.

Diskeeper requires that network schedules be viewed/cancelled only from the machine on which the original schedule was set.

Boot Time Defragmentation

As we noted above, a boot time defragmentation is required under Windows NT/2000 to defragment the MFT, metadata, and system files. Enterprise defragmentation should support the ability to perform boot time defragmentation on remote machines from one or more schedules.

PerfectDisk 2000 can schedule a boot time defragmentation pass on multiple systems at the same time. Under Windows NT/2000/XP, PerfectDisk 2000 uses the boot time option to explicitly position the MFT according to Microsoft's recommendation. On data partitions, PerfectDisk 2000 does not require a reboot if it can get an exclusive lock on the partition. System partitions always require a reboot.

Diskeeper's boot time defragmentation can only be scheduled on a single system at a time. Diskeeper requires a boot time defragmentation on both system and data partitions.

NTFS and FAT Directory Consolidation

Directory defragmentation and consolidation moves these files and their fragments out of the way so the online defragmentation engine can do the best possible job of defragmenting the partition and avoid splitting data files.

PerfectDisk 2000 defragments and consolidates directories on NTFS and FAT partitions.

Diskeeper does not consolidate directories on NTFS.

Page File Defragmentation

PerfectDisk 2000 can defragment the page file regardless of the amount of free space on the partition.

Diskeeper requires free space equal to the size of the page file.

Auto Update

Auto Update has no impact on system performance. It is an automated mechanism that ensures you have a product's most recent version.

PerfectDisk 2000 has an Auto Update feature whereby updates can be automatically downloaded from our web site, or redirected to an internal site prior to distribution.

Diskeeper has no Auto Update capability.

Command Line Interface

A Command Line Interface (CLI) eases the integration of the defragmentation process and scheduling with other system maintenance job streams like backup.

PerfectDisk 2000 has a full-featured Command Line Interface supporting the integration of both local and network defragmentation commands in your own scripts. PerfectDisk 2000 can run the CLI and the GUI at the same time.

Diskeeper provides a limited CLI with only local defragmentation support. If you are running the Diskeeper CLI, you cannot run the GUI, and vice versa.

Exchange Data Store Defragmentation

Microsoft recommends the periodic offline compaction/defragmentation of Exchange data stores. This activity improves Exchange performance by re-indexing the data stores and reclaiming disk space. Exchange defragmentation is generally a manual, time-consuming, and cumbersome task.

PerfectDisk 2000 has an additional module that automates the offline compaction/defragmentation of Exchange data stores.

Diskeeper has no Exchange compaction/defragmentation support.

Very Large, Very Fragmented Partitions

Defragmenting very large, very fragmented partitions is a special problem and one particularly related to enterprise RAID configurations. The primary issue is performing the task with a minimal impact on resources and within an acceptable timeframe. The number of files, number of fragments, and the amount of free space can all impact the time it takes to defragment a large partition.

While defragmenting large partitions is a challenge, defragmenting large files also poses a challenge. With an increase in multi-media presentations, animation, and the built-in digital video editing capabilities in Windows XP, files over 1GB will not be uncommon. The viewing of

digital video or multi-media presentations can be adversely affected if fragmentation interrupts the streaming of the file to the processor.

PerfectDisk 2000 Version 5.0 has been specifically designed to efficiently defragment partitions of 100GB to greater than 1TB. The new design delivers quick file movement, low memory footprint, and less CPU usage than other products. While single pass defragmentation is still the preferred approach, some sites may have specific situations where a large partition cannot be defragmented in the time allotted. PerfectDisk 2000 Version 5.0 provides better stop/restart capability that lets defragmentation benefits accrue, even when the defragmentation task is interrupted.

During the development of PerfectDisk 2000 5.0, we ran a stress test on an IDE controlled 300GB partition with 1,000,000 files, 4,500,000 fragments, and 12% available free space. The machine had a 1 Ghz processor with 512MB of RAM. The disk had no MFT or system file fragmentation. This is not your average partition. PerfectDisk 2000 defragmented this partition in 42 hours elapsed time and used 4 hours of CPU.

Our only experience with Diskeeper 7.0 was on this same partition. Diskeeper 7.0 defragmented the partition in 108 hours elapsed and used 50 hours of CPU. The Microsoft newsgroups are a good alternative source of information for other user experiences with large, fragmented environments.

Windows XP and the MFT

With the advent of Windows XP, Microsoft documented a finding that states that locating the Master File Table approximately one-third of the way down a volume delivers a 5-10% performance increase.

Only PerfectDisk 2000 explicitly positions the MFT in this location on Windows NT/2000/XP platforms.

Evaluating Defragmentation Software

The best way to determine which defragmentation solution is the best for your environment is to evaluate them on your systems. The first thing you need to do is ensure that you run both products against exactly the same disk. To do this, you will need a disk-imaging tool like Norton's *Ghost*[®] or PowerQuest's *Disk Image*[™]. These tools ensure that you have at least two disks that are sector-by-sector copies.

Install the defragmentation software you want to evaluate. Run the Analysis phase of one of the products against the disk you want to defragment and note the total number of files and the number of fragmented files. Identify the "Most Fragmented Files" and note how badly fragmented are the worst files. Also note the condition of the free space on the disk. Is it fragmented or contiguous? Disk defragmentation software is only as good as your worst disk. Choose a disk that has badly fragmented files and/or limited free space. You want to make sure the product you select can defragment just about anything.

Once you understand how bad the problem is on your target disk, run one of the defragmentation products and time it to completion. Vendors make suggestions on the running order of the boot time and online defragmentation. Follow the suggestion of the product vendor. Run the second product on the cloned disk and do the same. When the products are finished, review the reported statistics by looking at the same information you evaluated before the defragmentation. Things you will want to look for are:

Did the boot time defragmentation completely defragment the MFT, metadata, and system files?

Did the online defragmentation completely defragment the data files?

Is the free space fragmented or consolidated?

Was the time to complete acceptable?

An interesting exercise to validate your results is to cross check the statistics with both products. For example: if you defragment a disk with product A, view the results with both product A and product B interfaces. There may be some disparity in file counts due to how each vendor counts directories and subdirectories, but between the two sets of statistics you will get a very good idea of the quality of the job done.

Summary

While enterprise disk defragmentation sounds relatively simple, it is clear that one's choice of technology can have a profound impact on user productivity and system performance, as well as ongoing system administration and support costs. The right product is the one that reliably and consistently delivers the best results under the worst conditions. Proactive defragmentation protects the user's investment in the platform, lowers the total cost of ownership, and delivers customer satisfaction.

Copyright 2002, Raxco Software, Inc. All rights reserved.

PerfectDisk is a registered trademark of Raxco Software, Inc. Executive Software and Diskeeper are trademarks or registered trademarks of Executive Software International. Microsoft, Windows, NT, and XP are trademarks or registered trademarks of Microsoft Corporation. All other trademarks or trade names are the property of their respective owners.

Appendix 1

Syncsort's Backup Express Partners with Raxco Software to Speed Backup with PerfectDisk 2000

Combination of Leading Disk Defragmentation and Optimization Utility and Backup Solution Improves Backup 30% - 50%

GAITHERSBURG, MD, October 23, 2001 – Syncsort Incorporated, the respected developer of high-performance backup and data warehousing software, and Raxco Software, Inc., a leading provider of systems management utilities, have entered a joint partnership offering two of their products in tandem. Recent benchmarks have shown that using the combination of Raxco's PerfectDisk 2000 and Syncsort's Backup Express can speed backup up to 50% over baseline.

After extensive testing of Raxco's PerfectDisk 2000, Syncsort determined that backup speeds can be improved by 30% - 50% by first defragmenting drives with PerfectDisk 2000. "With PerfectDisk 2000, we're assured that data files and all metadata files are defragmented in a single pass, which no other defragmenter can do," said Winston Hait, senior product manager for Syncsort. "In addition, PerfectDisk 2000 optimizes the disk, resulting in consolidated free space and a reduced rate of refragmentation that saves even more time and resources. PerfectDisk 2000 for Exchange helps further by compacting and defragging Exchange data stores."

"As the leader in defragmentation and optimization, Raxco Software is delighted to be partnering with a company with the stature of Syncsort," said Jim Williams, Windows® product manager for Raxco Software. "The addition of Syncsort as a Raxco partner solidifies our position as the leader in this field and provides another channel for PerfectDisk 2000. The advanced capabilities of PerfectDisk and Backup Express will provide a powerful disk and backup management solution for customers demanding high performance and superior quality in their enterprises."

Fragmentation and Backup Speed

File fragmentation is a normal by-product of using a computer, occurring when files cannot be created contiguously or when file deletions or truncations cause “holes” of free space.

Fragmented files take longer to read, and so slow data streaming, and therefore the backup process. For read-intensive applications like backup to realize their optimum performance, the files should be as contiguous as possible.

About Backup Express

Syncsort’s Backup Express is an advanced, enterprise-wide backup and restore solution that supports NAS, NDMP, Storage Area Networks (SANs) and other network configurations. Its distributed architecture allows it to back up to any device in the network whether it is running UNIX, Windows, or NetWare, while maintaining a single central catalog for the entire enterprise. Backup Express can cluster tape drives, including large automated libraries, at any server on the enterprise; dynamically allocate drives within a SAN; provide three different backup options for NDMP-based systems; keep sensitive data off the network; and allow on-line backups of large database servers such as Oracle, SAP, MS Exchange, and SQL Server.

About PerfectDisk 2000

Raxco Software’s PerfectDisk 2000 is a complete enterprise disk defragmentation solution. PerfectDisk 2000 was engineered as an industrial-strength defragmentation solution for today’s distributed Windows networks. PerfectDisk 2000 is fast, thorough, scalable, flexible and safe.

Among its features are:

- Completely defragments files in a single pass
- Defragments all 16 Metadata files, including the Master File Table
- Consolidates free space and organizes disk according to usage patterns to slow future re-fragmentation
- Automates the defragmentation of Exchange data stores
- Provides threshold management to prevent unnecessary defragmentation runs
- Offers a Network Scheduling Wizard to let users set, view and cancel schedules
- Provides offline defragmentation of the MFT and system files that is fully automated and requires no human intervention.

About Syncsort

Syncsort Incorporated is a leading developer of high-performance data warehousing software for mainframe, UNIX, and Windows environments. For more than 30 years, Syncsort has built a reputation for superior product performance and reliable technical support. An independent market research firm has named Syncsort as one of the top Data Warehouse 100 Vendors for three years in a row. Over 95 percent of the Fortune 100 companies are Syncsort customers, and Syncsort's products are used in more than 50 countries to back up and protect data in distributed environments, speed data warehouse processing, improve database loads and speed query processing. For more information, visit the Syncsort web site at www.syncsort.com.

About Raxco Software

Raxco Software is a leading software engineering company that has been offering system utilities for more than 20 years. Its PerfectDisk 2000 is Windows 2000-certified and designed for Windows XP, and works on Microsoft Windows 95/98/Me/NT/2000/XP systems. Raxco also makes other products for Windows operating systems and suites of utilities for Compaq Computer's OpenVMS operating system. Raxco Software can be found on the Web at www.raxco.com.

###

Editorial Contacts:

Joe Abusamra
Raxco Software, Inc.
(301) 519-7835
jabusamra@raxco.com.

All brands or products are trademarks or registered trademarks of their respective holders.

Appendix 2

Ohio Savings Bank Increases Licenses Of Raxco's PerfectDisk[®] 2000 Defragmenter By 19%, Bringing Total to 2,210 Copies

Ability to Schedule Automatic Defragmentation Runs and Flexible Options Called Key to Selection; Weekly Defragmentation Achieves an Average 30% Performance Increase and Three Hour Reduction in Trouble Ticket Response

GAITHERSBURG, MD, July 10, 2001 – Raxco Software Inc. today announced a follow-on order from Ohio Savings Bank that has increased to 2,210 the number of copies of Raxco's PerfectDisk[®] 2000 defragmenter that the bank uses. Regular defragmentation with PerfectDisk 2000 has helped the bank increase the performance of its workstations by 30 percent, and has reduced the time it takes to answer support calls by three hours per call.

The Cleveland-based bank, with nearly \$10 billion in assets, is one of the largest financial institutions in Ohio, Florida, and Arizona, and the tenth largest wholesale mortgage lender in the United States.

The bank began using PerfectDisk two years ago, when it began migrating from the Windows[®] 95 operating system to Windows NT. Today, although the majority of its workstations use Windows NT, PerfectDisk 2000 also supports computers running Windows 98 and Windows 2000.

Ohio Savings Bank selected Raxco's PerfectDisk 2000 because of its flexible scheduling options said Jody Graff, Desktop Planning Manager. "We like its ability to defragment disks on a scheduled basis. PerfectDisk allows us to choose the automatic scheduler, let the user schedule the disk defragmentation, or have a technician complete it while visiting the site. This flexibility allowed us to change our approach to meet new business requirements," she added.

The bank has hundreds of applications running on approximately 1,500 workstations that are locally connected. Remote installations consist of laptop units using dial-up lines and units

connected through a virtual private network. The workstations are scattered throughout the several states in which Ohio Savings Bank does business.

Graff initially used PerfectDisk as a way to address user complaints about decreased performance. “Many of our Bank applications are file intensive, requiring large data downloads. This results in a lot of file movement, and this type of file manipulation often leads to file fragmentation,” she said. “We found that if we ran PerfectDisk once a week it would improve performance by an average of 30 percent.” Another benefit was that defragmenting disks often eliminated intermittent application errors on individual machines. “The errors disappeared after we ran PerfectDisk,” Graff said.

Graff pointed out that PerfectDisk’s flexibility enables the bank to set up a defragmentation scheme that matches the schedules of individual users. “Users who dial in disconnect or shut down their laptops at night, so we can’t defragment their systems automatically,” she said. “PerfectDisk allows us to run in a mixed environment, where locally attached systems can be defragmented automatically overnight, and remote systems are defragmented by the users when it’s convenient for them.”

File fragmentation is a normal by-product of using a computer. It occurs when the computer’s file system cannot find enough free space on the disk to create a file or extend an existing file in one piece. If there are files on the system that are changing on a regular basis, it is possible these files can be in hundreds or thousands of pieces all over the disk. Fragmentation can cause a computer to use excessive resources to complete tasks related to reading and writing files. This unnecessarily increases the work the computer must do to support the applications being run.

PerfectDisk 2000

Raxco Software’s PerfectDisk 2000 is a complete enterprise disk defragmentation solution. PerfectDisk 2000 was engineered as an industrial-strength defragmentation solution for today’s distributed Windows networks. PerfectDisk 2000 is fast, thorough, scalable, flexible and safe. Among its features are:

- Defragments all data files in a single pass
- Defragments all 16 Metadata files, including the Master File Table

- Consolidates free space and organizes disk according to usage patterns to slow future re-fragmentation
- Automates the defragmentation of Exchange data stores
- Threshold management prevents unnecessary defragmentation runs
- Network Scheduling Wizard lets users set, view and cancel schedules
- Offline defragmentation of the MFT and system files is fully automated and requires no human intervention

About Ohio Savings Bank

Ohio Savings Bank was founded in Cleveland, Ohio in 1889. Since then, the bank has grown to nearly \$10 billion in assets, and is one of the largest financial institutions in Ohio, Florida and Arizona, and the 10th largest wholesale mortgage lender in the United States. Expansion into Florida began more than 10 years ago with the inception of its AmTrust Bank division. Today, there are 15 AmTrust Bank branches located throughout southeast Florida. In 2000, the first AmTrust Bank branch opened in Phoenix, Arizona, with two more opening in the first half of 2001 and a fourth planned for later this year.

About Raxco Software

Raxco Software is a leading software engineering company that has been offering system utilities for more than 20 years. Its PerfectDisk 2000 is the only Windows 2000-certified optimized defragmenter that works on Microsoft Windows 2000, Windows NT, Windows Millennium Edition, and Windows 98/95 operating systems. Raxco also makes other products for Windows operating systems and suites of utilities for Compaq Computer's OpenVMS operating system.

###

Editorial Contacts:

Joe Abusamra
Raxco Software, Inc.
(301) 519-7835
jabusamra@raxco.com.

Edgar E. Geithner
g.m marketing communications
(508) 875-3821
edgar@gdotm.com

All brands or products are trademarks or registered trademarks of their respective holders.