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By V.Sarasvathi , Dr.A.Santhakumaran

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# Towards Artificial Neural Network Model To Diagnose Thyroid Problems

V.Sarasvathi<sup>a</sup>, Dr.A.Santhakumaran<sup>Ω</sup>

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## I. INTRODUCTION

Medical decision making has become very essential nowadays because of the awareness of various health problems. It can be viewed as a pattern recognition problem whereby various patterns are recognized in order to arrive at a conclusion[1]. A group of causing factors of a particular disease or problem is given as inputs. Based on the given input values a decision will be arrived. The decision making can be done using an artificial neural network approach. In this paper thyroid hormonal problems are diagnosed using an artificial neural network approach. The back propagation learning algorithm is used to train the neural network. The efficiency of the network is analyzed. It is concluded to enhance the algorithm for still better results. This paper is organized as sections as follows: Section II discusses about medical decision making and it's advantages. Section III introduces about thyroid problems due to hormonal activities. Section IV gives brief explanation about neural networks. Section V gives the steps to construct a neural network for thyroid diseases diagnosis. Section VI analyses the given back propagation algorithm. Section VII concludes the article giving future directions.

## II. MEDICAL DECISION MAKING

Medical decision making includes diagnosis ,prognosis ,classification and treatment of various

diseases which can be acute or chronic. When the disease are diagnosed by the physician, sometimes there may be slight variations due to the inaccuracy of data or 'noise' in the data. when the data are fed through an information system, it can produce excellent results. Now a days, due to advance in information technology, computer based medical decision making systems have become essential in the health care industry. In most of the African countries like Rwanda, and Mozambique the physician people ratio is found to be 1 :25 000. Countries like these will be benefitted by implementing the computer based medical decision making.[4]. Medical decision making has the following advantages.(i) The data collection can be either fed through an operator or the patients themselves. (ii) images, X-rays also can be fed to the system (iii) Getting result is faster (iv) they are more accurate than done by physicians. It involves pattern recognition techniques. Decision making can be done through artificial intelligence techniques. Using these we can diagnose diseases like diabetes, thyroid, heart problems, hypertension, cancer ,HIV etc effectively. The advances in information technology has made every thing possible in today's medical field. [5]

## III. THYROID DISEASES

Thyroid is a butterfly shaped gland found just below the Adam's apple of our neck. It is responsible for the metabolism activities of our body. When it functions properly it produces two hormones called triiodothyronine (T3) and thyroxine(T4). A hormone called Thyroid Stimulating Hormone (TSH) which is secreted by pituitary gland is also responsible for T3 and T4 hormones. TSH,T3 and T4 decides the health of a person. Over activity of thyroid hormones results in hyperthyroidism where as the under activity of the same results in hypothyroidism. Thyroid disease can be diagnosed using the following tests (i) Radioimmunoassay test for TSH,T3 and T4. (ii) scanning for goiter or nodules etc. thyroid diseases are found in KERALA based people because the iodine content problem. More than 20% of the Americans are said to have thyroid problems [9]. People in the age group of 20 to 40 are mostly affected by thyroid disorders. Women are having more risk than men in developing thyroid disorders. They can develop thyroid disorders during their pregnancy also.[10]

*About<sup>a</sup> - Assistant Professor in Computer science, Cms college, Coimbatore, Tamilnadu, India.*

*E-mail- vsarasvathi@gmail.com*

*About<sup>Ω</sup> - Reader in Statistics, Salem Sowdeswari College, Salem, Tamilnadu India.*

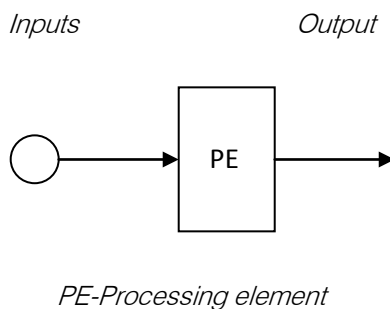
Thyroid disease is caused by the following factors which can be classified as controllable and contributing factors.

1. Age
2. Sex
3. T3
4. T4
5. TSH
6. Pregnancy
7. Iodine intake
8. Medication for thyroid problems.
9. thyroid cancer
10. Thyroid supplement

The T3,T4 and TSH tests are done using radio immuno chem. Assay test.[11]

#### IV. NEURAL NETWORKS

Neural networks called as Artificial Neural Networks, connectionist networks, neuroid, are massively parallel processors which get more number of inputs at a time and produces output based on some processing algorithms. They are constructed using neurons. Neurons are the processing elements consisting of a set of inputs, uses some activation functions and produce output(s). They resemble like biological neurons. A neuron can be represented by the following figure



When such neurons are connected together, the result is called neural network. Each layer is connected by the weights from previous layer neurons except for the input layer. The processing is done using special functions called activation functions. The one which is used in our research is multilayer feed forward network (MLF). It has one input layer, one output and one or more processing layers. A feed forward neural network is trained using back propagation, radial basis function, gradient descent method etc. the method selected in this paper is back propagation method. If the layer has got  $n$  neurons having index  $x_1$  to  $x_n$ , a hidden layer having  $m$  neurons, and an output layer having  $k$  neurons, the weight of each neuron in hidden layer is calculated using activation functions applied to the input layers.

The activation functions can be sigmoidal function, tanh function etc. the hidden layer and output layer are also mapped using some activation functions.

A neural network can be represented by the following diagram.

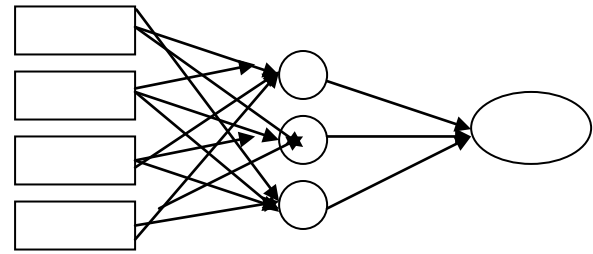


Figure 1 –structure of a back propagation neural network

In the above diagram, rectangles represent input layer neurons, circles represent hidden layer neurons and the oval represents the output layer neuron. The neurons in each layer don't have intra neuron associations where as inter layer association is there for any two consecutive layers.[6]

Neural networks learn by examples. Once they learn properly, they can be used to recognize any pattern.[12]

The neural networks have to be trained using training set for error convergence and tested for checking performance. They have to be validated also.

Neural network performance can be accessed using two factors called specificity and sensitivity. Sensitivity is the ratio of patients with disease whose test are positive. Specificity is the proportion of patients with out disease whose tests are negative. They are calculated as

$$\text{Sensitivity} = T / (T + a) \quad (1)$$

$$\text{Specificity} = F / (F + b) \quad (2)$$

where  $T$  = number of true positives

$F$  = number of true negatives

$a$  = number of true positives + number of false negatives where

$b$  = number of true negatives + number of false positives

where #true positives and #false negatives are the number of thyroid correctly classified and in correctly classified as normal case respectively. Likewise, #true negatives and #false positives are the number of correctly and incorrectly classified as thyroid problems respectively.[5]

Neural networks can be trained using various learning algorithms classified as supervised and unsupervised learning algorithms. Gradient descent, Radial Basis Function (RBF), Learning vector quantization, back propagation are some of the learning algorithms. Gradient descent is one of the supervised learning algorithms.[7][8]

Back propagation is one of the gradient descent learning algorithm applied in feed forward neural networks. The output may be a binary result or classification having multiple results. BPN assigns

weights to the input layer neurons, Calculates the weight of hidden layer neurons and from hidden layer neurons the output values are calculated[2][7]. The errors from the output are to be adjusted and again the process is repeated for another set of weights. Therefore BPN can otherwise be called as Error Back Propagation neural networks(EBP).

## V. NEURAL NETWORKS AND THYROID DIAGNOSIS

A neural network having 6 nodes in the input layer, 4 nodes in the hidden layer and one node in the output layer[13]. For the input layer, the controllable and contributing factors have been used. In order to have the hidden layer,  $1 < m \leq 2n$  number of neurons have been used where  $m$  is the number of neuron in hidden layer and  $n$  is the number of neurons in the input layer.

From the available data, training set, test set and validation set can be selected using some criterion. Data values have to be normalized between 0 and 1 or as discrete values -1 and 1. The normalization is done by the following formula

$$X = (X - X_{\min}) / (X_{\max} - X_{\min}) \quad (4)$$

The so constructed neural network has been trained and tested using 80 samples.

## VI. FUTURE WORK

When the network was trained using back propagation, error convergence takes a long time. When the number of samples become large, Back propagation algorithm is slow in performance. Therefore as the future research, a suitable modification has to be performed so as to improve the performance. The modification can be the structure network, selection of appropriate factors, increase in hidden nodes, number of hidden node neurons etc. Efficiency of the algorithm can be improved by providing various training sets and test sets.

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# IO Bound Property: A System Perspective Evaluation & Behavior Trace of File System

By Wasim Ahmad Bhat , S. M. K. Quadri

*Abstract* : File systems have been mostly benchmarked as per the application perspective. This approach hides all the underlying complexities of the system including the actual I/O being done with the secondary storage device like magnetic disk. The IO bound property of a file system is necessarily to be evaluated because the most dominant performance limiting factor of a file system is its I/O operation with secondary storage device. This IO bound property of file system dictates the quantity and frequency of IO that a file system does with secondary storage device. In this paper, we argue system perspective of file system benchmarks and develop a benchmark to evaluate some common disk file systems for IO bound property. The goal of this paper is to better understand the behavior of file systems and unveil the low level complexities faced by file systems.

*Keywords*: File System, IO Bound, Evaluation, Trace.

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IO BOUND PROPERTY A SYSTEM PERSPECTIVE EVALUATION AND BEHAVIOR TRACE OF FILE SYSTEM

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# IO Bound Property: A System Perspective Evaluation & Behavior Trace of File System

Wasim Ahmad Bhat<sup>α</sup>, S. M. K. Quadri<sup>Ω</sup>

**Abstract-** File systems have been mostly benchmarked as per the application perspective. This approach hides all the underlying complexities of the system including the actual I/O being done with the secondary storage device like magnetic disk. The IO bound property of a file system is necessarily to be evaluated because the most dominant performance limiting factor of a file system is its I/O operation with secondary storage device. This IO bound property of file system dictates the quantity and frequency of IO that a file system does with secondary storage device. In this paper, we argue system perspective of file system benchmarks and develop a benchmark to evaluate some common disk file systems for IO bound property. The goal of this paper is to better understand the behavior of file systems and unveil the low level complexities faced by file systems.

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## I. INTRODUCTION

File system is an essential part of an operating system which dictates overall system performance and application specific performance. Thus, evaluating and analyzing file systems is necessary. There are many factors that affect the file system performance. Those factors include disk block organization, file name mapping, meta-data structure, reliability, concurrency control and data searching algorithms. Besides the above data storage related factors, the cache and memory buffer management scheme in the operating system plays a very important role in system I/O performance. Because the file system mitigates access to data on a mass storage subsystem, it has certain behavioral and functional characteristics that affect I/O performance from an application and/or system point of view. Measuring file system performance is significantly more complicated than that of the underlying disk subsystem because of the many types of higher-level operations that can be performed (allocations, deletions, directory searches, etc.)

*About<sup>α</sup> - Research scholar in P. G. Department of Computer Sciences, Kashmir University, India. He did his Bachelor's degree in Computer Applications from Islamia College of Science & Commerce and Master's degree in Computer Applications from Kashmir University.  
E-mail- wasim.ahmed.bhat@gmail.com*

*About<sup>Ω</sup> - Head, P. G. Department of Computer Sciences, Kashmir University, India. He did his M. Tech. in Computer Applications from Indian School of Mines and Ph. D. in Computer Sciences from Kashmir University.  
E-mail- quadrismk@hotmail.com*

Benchmarking file systems is a process of gathering some performance data by running a specific workload on a specific system. This technique clearly provides an accurate evaluation of performance of that system for that workload. Although file system design has advanced a lot, benchmarks for file system still lag far behind. The benchmarks used in file system research papers suffer from several problems. First, there is no standard benchmark. The closest to a standard is Andrew benchmark [1], but even then, some researchers use the original version while others use modified version [2][3]. Comparing results from different papers becomes difficult due to lack of standardization. Secondly, existing benchmarks are inadequate to measure file systems as they do not scale with technology [4], measure only part of file system [4][5][6] and do not yield results that would help a user to determine how a system might perform or would point designer towards possible areas for improvement. In addition to mentioned problems, file system benchmarks stress mainly on application perspective to evaluate and analyze the performance of a file system. Thus, this approach hides all the underlying complexities of system including the actual I/O being done with the secondary storage device like disk. This IO bound property of a file system dictates the quantity and frequency of I/O that a file system does with the secondary storage device to complete a particular operation. Hence, this property of file system is necessarily to be evaluated because the most dominant performance limiting factor of a file system is its I/O operation with secondary storage device. Although certain optimizations have been included in operating system like disk cache, read-ahead, delay-write, etc. to minimize the frequency of I/O being done by the file system, but the quantity of I/O is operation and design dependent. As such we need to evaluate and analyze file systems for the quantity of I/O being done with the secondary storage device for a set of different operations to look into the design efficiency of a file system. In other words, we need to analyze file system from system perspective and evaluate them for IO bound property.

In this paper, we evaluate and analyze 4 common file systems across WINDOWS and LINUX platforms for their IO bound property keeping all the system parameters for all operations constant across all the file systems under evaluation. The results so

obtained show that NTFS file system does lot of I/O with the disk. Also, LINUX file systems did least I/O with disk. Further, we observed 3 general patterns of disk accesses done by these file systems as far as our tests are concerned.

## II. BACKGROUND AND RELATED WORK

We now review the basics of benchmarking file systems and present the work that is somehow related or point towards our concept.

Lucas [7] stated three reasons to obtain performance data: to know which system is better, how to improve its performance and how well will it perform. Thus, benchmarking assists customers looking to buy a better system and system designers looking for possible areas for improvement. Benchmarks may be categorized in two ways. One way is to categorize a benchmark as being either a synthetic or an application benchmark; the other way is as a macro- or micro-benchmark.

Application benchmarks consist of programs and utilities that a user can actually use like SPECint92 [8].

Synthetic benchmarks, on the other hand, model a workload by executing various operations in a mix consistent with the target workload like Bonnie [5].

Macro-benchmarks measure the entire system, and usually model some workload; they can be either synthetic or application benchmarks like IOSTone [4].

Micro-benchmarks measure a specific part of a system. They can be thought of as a subset of synthetic benchmarks in that they are artificial; however, they do not try to model any real workload whatsoever. An example of a micro-benchmark is the create micro-benchmark from the original LFS paper: It timed how long the system took to create 10,000 files [9]. Micro-benchmarks are excellent for pointing out potential areas for improvement within the system as few operations are tested to isolate their specific overheads within the system. Thus, they measure specific part of file system. Generally, four parameters are the most common targets of file system micro-benchmarks:

1. The time to create a file,
2. The time to delete a file,
3. The throughput for reading files, and
4. The throughput for writing files.

Occasionally researchers use micro-benchmarks to measure other quantities, such as the time to create a symbolic link or read a directory. These quantities are measured less often, because the corresponding file system operations are perceived to occur less often in real file system workloads.

When an application makes a request to open, close, read, or write a file, the request is propagated through the operating system consisting of several levels of hierarchy before it reaches the actual storage

media. These levels of hierarchy add optimizations by implementing a disk cache to cache the recently accessed disk blocks for anticipated use, buffer management scheme, merger read and write. This hierarchy tries to minimize the frequency of disk I/O by reading and then caching more blocks of disk than requested to anticipate a sequential read. The delayed write and caching of disk blocks tries to minimize the frequency of disk I/O by anticipating future updation and read of a disk block respectively whose write was requested. This can have a significant impact on both the meta-data and user data performance. This performance is further increased if the design of file system takes this optimization into consideration to minimize the quantity of disk I/O done for a particular operation.

Seltzer et al. [10] suggested that most benchmarks do not provide useful information as they are not designed to describe performance of a particular application. They argued for an application-directed approach to benchmarking, using performance metrics that reflect the expected behavior of a particular application across a range of hardware or software platforms. They proposed three approaches to application specific benchmarking: vector-based, trace-driven, and hybrid. Each methodology addresses a different set of benchmarking requirements and constraints. The fundamental principle behind vector-based performance analysis is the observation that in a typical computer system, each different primitive operation, whether at the application, operating system, or hardware level, takes a different amount of time to complete. Traditional benchmarking techniques ignore this fact and attempt to represent the overall performance of a computer system or subsystem as a scalar quantity. Vector-based techniques address this problem by representing the performance of underlying system abstractions as a vector quantity. Each component of this system characterization vector represents the performance of one underlying primitive, and is obtained by running an appropriate micro-benchmark.

Chen [6] laid out criteria for evaluating I/O systems which can be adapted for file systems as well. Chen states that an I/O benchmark should be:

1. Prescriptive: It should point system designers towards possible areas for improvement.
2. I/O bound: The benchmark should measure the I/O system and not, for example, the CPU.
3. Scalable with advancing technology.
4. Comparable between different systems.
5. General: Applicable to a wide variety of workloads.
6. Tightly specified: No loopholes; clarity in what needs to be reported.



Tang [11] argued that these criteria should be applied to most benchmarking methodologies. He introduced a benchmark called *dtangbm*. This benchmark consisted of suite of micro-benchmarks called *fsbench* and a workload characterizer. The Phase I of *fsbench* measures disk performance so that it can be known whether improvements are due to disk or file system and can be compared to Phase III which measures file system block allocation policy to determine what overhead the file system imposes.

Traeger et al. [12] argued that some guidelines be followed while designing a micro benchmark. The two underlying themes of those guidelines are as follows:

1. *Explain What Was Done in as Much Detail as Possible.* This can help others understand and validate the results.
2. *In Addition to Saying What Was Done, Say Why It Was Done That Way?*

Ruwart [13] argued that not only are benchmarks ill-suited for testing but will fare even worse in future because of systems complexities. He presented the point of view from which the performance is measured. Three of the more generally accepted perspectives are:

1. Application
2. System
3. Storage Subsystem

The Application perspective is what most of the file system benchmarks represents. From this perspective all of the underlying system services and hardware functions are hidden. This perspective includes all the cumulative effects of other applications running at the same time as the benchmark run. This is also true for applications running on other machines that may be simultaneously accessing the storage subsystem under test. From this perspective the results of a benchmark can be skewed due to undesirable interactions from these other applications and other machines. The Application perspective can also divide I/O operations into the two distinct categories (Meta data and User data) based on the type of higher-level operation being performed. The Application interface to the file system is generally through high-level system calls such as open, close, read, write, and create. There are also higher level system calls that perform such operations as rename, create directory, remove, and lookup a name. It is the performance of these operations that ultimately determine the overall performance that the application sees for both metadata and user data operations.

The System perspective is viewed by running system-monitoring tools during a benchmark run. These tools provide coarse-grained real-time monitoring of the system I/O activity for such high-level operations as file reads and writes as well as the number of operations actually sent to the storage subsystem on a device-by-

device basis. From this perspective it is possible to see and measure the effect of other applications that are running concurrently with the benchmark program. Furthermore, with some of the more sophisticated system monitoring tools, it is possible to monitor the activity on other systems that may be sharing access to the storage subsystem under test. However, there is still a problem with getting a complete view of all the systems on a common reference clock in order to better understand the interaction of all the systems with the shared storage subsystem.

The Storage Subsystem perspective is the most difficult to monitor since there are not many tools available to collect performance data from the storage subsystem.

### III. IO BOUND PROPERTY

The smallest addressable read and write unit of secondary storage like disk is Sector. Typically sector size is 512 bytes. Although, disk drives allow random read and write of individual sectors, for performance reasons, file systems prefer to read and write a sequence of consecutive sectors called Cluster. Thus, the smallest addressable read and write unit of a file system is cluster. Cluster sizes vary from one sector to many in size. Clusters reduce the frequency of I/O operations by reading and writing more than one sector sequentially at a time which would have otherwise cost many individual reads and writes. File systems vary greatly in cluster sizes, allocation and layout policies, in addition to other parameters.

Linux operating system maintains an in-memory disk cache of recently accessed disk blocks in a hope that these blocks will be accessed again [14]. The blocks correspond to individual sectors of disk. When a process issues a file system syscall, the call passes through a hierarchy of layers within operating system and finally reaches the file system drives. The file system converts the call into appropriate disk blocks to be read or written as per the design of the file system mounted. Instead of directly reading and writing the disk block, it checks the disk cache for the block. If it is found, the block is accessed from cache and hence saving an I/O operation. If it is not found, the block is read from disk and cached. Linux further optimizes the I/O performance by asynchronously reading ahead few blocks in anticipation of sequential access whenever a block is to be read. It also delays write of updated blocks in anticipation of further updation of same block whenever a block is to be written or updated. All these optimizations by Linux operating system are done to reduce the number of I/O operations directly done with disk because an I/O operation with disk is costlier in time than with disk cache.

But due to design diversities in file systems, varying size of clusters, different allocation and layout

policies these optimizations are exploited by different file systems up to different levels. The file system benchmarks stress mainly on application perspective to evaluate and analyze a file system. This way they analyze the amount of data read and written by an application at higher level without being concerned about whether the data was read or written from cache only, disk only or partly from cache and partly from disk. Further, they ignore the data other than user data read or written by the application like when an application tries to open a file for reading they ignore the number of disk blocks that might have been read to locate the file on the mounted volume. Hence, this perspective does not give the actual measure of the IO bound property of a file system.

An IO bound property of a file system means the quantity and frequency of I/O operations that a file system does with the secondary storage device to complete a particular operation. Hence, this property of file system is necessarily to be evaluated because the most dominant performance limiting factor of a file system is its I/O operation with secondary storage device.

#### IV. PERFORMANCE MONITORING TOOLS

Two issues are to be considered when collecting performance data; the type of data to be collected and when to collect it. Concerning the first issue, there is essentially one type of data to collect: Number of disk block read and written from disk. The second issue of when to collect the data is obviously to be done after the completion of every individual workload generator.

Linux operating system provides many utilities to gather statistics about system resources used by the benchmark tests. Many utilities come along the default Linux package while others can be downloaded for free and recompiled for the distribution. We will review the most common, popular and useful utilities for system resource monitoring in Linux.

**VMSTAT** [15] reports information about processes, memory, paging, block I/O, traps, and cpu activity. The first report produced gives averages since the last reboot. Additional reports give information on a sampling period of length delay. The process and memory reports are instantaneous in either case. For Disk Mode, it reports total reads completed successfully, grouped reads (resulting in one I/O), sectors read successfully, milliseconds spent reading, total writes completed successfully, grouped writes (resulting in one I/O), sectors written successfully, milliseconds spent writing. For Disk Partition Mode it reports total number of reads issued to this partition, total read sectors for partition, total number of writes issued to this partition, total number of write requests made for partition.

**IOSTAT** [16] reports Central Processing Unit (CPU) statistics and input/output statistics for devices and partitions. The *iostat* command is used for monitoring system input/output device loading by observing the time the devices are active in relation to their average transfer rates. The *iostat* command generates reports that can be used to change system configuration to better balance the input/output load between physical disks. The first report generated by the *iostat* command provides statistics concerning the time since the system was booted. Each subsequent report covers the time since the previous report. All statistics are reported each time the *iostat* command is run. The report consists of a CPU header row followed by a row of CPU statistics. The second report generated by the *iostat* command is the Device Utilization Report. The device report provides statistics on a per physical device or partition basis. The device report generated constitutes of fields that indicate:

1. The number of transfers per second that were issued to the device. A transfer is an I/O request to the device. Multiple logical requests can be combined into a single I/O request to the device. A transfer is of indeterminate size.
2. The amount of data read from the device expressed in a number of blocks per second. Blocks are equivalent to sectors with 2.4 kernels and newer, and therefore have a size of 512 bytes. With older kernels, a block is of indeterminate size.
3. The amount of data written to the device expressed in a number of blocks per second.
4. The total number of blocks read.
5. The total number of blocks written.
6. The amount of data read from the device expressed in kilobytes per second.
7. The amount of data written to the device expressed in kilobytes per second.
8. The total number of kilobytes read.
9. The total number of kilobytes written.

**SAR** [17] is used to collect, report or save system activity information. The *sar* command writes to standard output the contents of selected cumulative activity counters in the operating system. The accounting system, based on the values in the count and interval parameters, writes information the specified number of times spaced at the specified intervals in seconds. The device report generated constitutes of fields that indicate:

1. The number of transfers per second that were issued to the device. Multiple logical requests can be combined into a single I/O request to the device. A transfer is of indeterminate size.
2. Number of sectors read from the device. The size of a sector is 512 bytes.

3. Number of sectors written to the device. The size of a sector is 512 bytes.

**IOTOP** [18] watches I/O usage information output by the Linux kernel (requires 2.6.20 or later) and displays a table of current I/O usage by processes or threads on the system. At least the `CONFIG_TASK_DELAY_ACCT` and `CONFIG_TASK_IO_ACCOUNTING` options need to be enabled in Linux kernel build configuration, these options depend on `CONFIG_TASKSTATS`. *iotop* displays columns for the I/O bandwidth read and written by each process/thread during the sampling period. It also displays the percentage of time the thread/process spent while swapping in and while waiting on I/O. For each process, its I/O priority (class/level) is shown. In addition, the total I/O bandwidth read and written during the sampling period is displayed at the top of the interface.

**PIDSTAT** [19] command is used for monitoring individual tasks currently being managed by the Linux kernel. It writes to standard output activities for every task selected with option `-p` or for every task managed by the Linux kernel if option `-p ALL` has been used. Not selecting any tasks is equivalent to specifying `-p ALL` but only active tasks (tasks with non-zero statistics values) will appear in the report. The *pidstat* command can also be used for monitoring the child processes of selected tasks. The interval parameter specifies the amount of time in seconds between each report. A value of 0 (or no parameters at all) indicates that tasks statistics are to be reported for the time since system startup. The count parameter can be specified in conjunction with the interval parameter if this one is not set to zero. The value of count determines the number of reports generated at interval seconds apart. If the interval parameter is specified without the count parameter, the *pidstat* command generates reports continuously.

**COLLECTL** [20] utility is a system monitoring tool that records or displays specific operating system data for one or more sets of subsystems. Any set of the subsystems, such as CPU, Disks, Memory or Sockets can be included in or excluded from data collection. Data can either be displayed back to the terminal, or stored in either a compressed or uncompressed data file. The data files themselves can either be in raw format or in a space separated plottable format such that it can be easily plotted using tools such as *gnuplot* [21] or *excel* [22]. Data files can be read and manipulated from the command line, or through use of command scripts.

**BLKTRACE** [23] is a block layer I/O tracing mechanism which provides detailed information about request queue operations up to user space. There are three major components: a kernel component, a utility to record the I/O trace information for the kernel to user space, and utilities to analyze and view the trace

information. *blktrace* receives data from the kernel in buffers passed up through the debug file system. Each device being traced has a file created in the mounted directory for the *debugfs* [24], which defaults to `/sys/kernel/debug`.

**PROC** [25] file system is a pseudo-file system which is used as an interface to kernel data structures. It is commonly mounted at `/proc`. Most of it is read-only, but some files allow kernel variables to be changed. `/proc/sys/vm/` directory facilitates the configuration of the Linux kernel's virtual memory (VM) subsystem. The kernel makes extensive and intelligent use of virtual memory, which is commonly referred to as swap space. The `/proc/sys/vm/block_dump` file configures block I/O debugging when enabled. All read/write and block dirtying operations done to files are logged accordingly. This can be useful if diagnosing disk spin up and spin downs for laptop battery conservation. All output, when `block_dump` is enabled, can be retrieved via *dmesg* [26]. The default value is 0 and can be enabled by setting its value to 1.

## V. THE BENCHMARK

The most crucial part for evaluating and analyzing file systems for their IO bound property is to choose the set of tests that are to be executed which will give us some insight of the IO bound property. To make the choice simple and logical, we tried to find out the types of file system operations that vary in the quantity of I/O being done with the disk for different file systems due to their design variations. The ruled out option is, thus, a large file where the user data dominates the disk I/O and this dominance is constant throughout the file systems under evaluation. This makes one criterion clear; we are going to test large number of empty or small sized files.

We identified following file systems operations in which the quantity of disk I/O varies greatly for different file systems due to their design.

Test Number	Description	Corresponding Figure Set
Test 1	Create 10,000 files with 'touch' utility	Figure 1
Test 2	Run 'find' utility on that directory	Figure 2
Test 3	Remove these 10,000 files using 'rm' utility	Figure 3
Test 4	Create 10,000 directories with 'mkdir' utility	Figure 4
Test 5	Run 'find' utility on that directory	Figure 5
Test 6	Remove these 10,000 directories using 'rm' utility	Figure 6

The tests to be performed are listed as per the sequence they are executed along necessary Linux utility used and figure set that depicts their sector traces. The test code is organized as a shell script. All file systems are to be created using default options and each file system is tested on a cleanly made file system. All tests are to be run 3 times and the average is to be taken. Between every test; cache is flushed. The test measures quantity of I/O in terms of sectors read or written from the disk for every individual test ignoring the requests fulfilled by the cache and the time consumed to complete the operation.

Before the file system under evaluation is mounted we enable block dumping in kernel by setting `/proc/sys/vm/block_dump` to 1. After this, if any read or write request has to do disk I/O and as such is not fulfilled by cache, the corresponding operation, device file and block is dumped. The interested data can be collected by using `'dmesg -c'` which gets the dumped operations and clears the log. The collection can be further refined by piping the output of `'dmesg -c'` to `'grep sda1'` (say) to get all the operations pertaining to some mounted file system corresponding to device file `sda1`.

## VI. FILE SYSTEMS TO BE EVALUATED

We evaluate the performance of four file systems, two viz. FAT32 and NTFS being Windows native and two viz. Ext2, and Ext3 being Linux native. We test them under Fedora Core Release 7 (Moonshine) Kernel 2.6.21. To make the paper self-contained, we briefly describe the tested file systems as follows:

### a) *FAT32*

The FAT (File Allocation Table) file system was developed in the late 1970s and early 1980s and was the file system supported by the Microsoft® MS-DOS® operating system [27]. FAT was originally developed for floppy disk drives less than 500K in size. As storage capacity increased, FAT was enhanced to support large storage media. As such we have three fully documented FAT file system types: FAT12, FAT16 and FAT32. FAT32, which can address large storage media and is supported by all major desktop operating systems, is still the most widely used file system in portable digital devices [28]. As compared to other file systems, the performance of FAT is poor as it uses simple data structures, making file operations time-consuming and inefficient disk space utilization in situations where many small files are present. But for same simple design and legacy it is supported by almost all existing operating systems for personal computers. This makes it a useful format for solid-state memory cards and a convenient way to share data between different operating systems.

exFAT [29] is the recent compilation of Microsoft® while KFAT [30], TFAT [31] and FATTY [32] are the reliability enhancements to the actual design by the same and other researchers.

### b) *NTFS*

The New Technology File System [33] was originally developed for Windows NT and now is used in Windows NT, 2000, XP, Vista and 7. NTFS provides performance, reliability, and functionality not found in FAT design. NTFS includes security and access controls, encryption support, and has reliability control built in, in the form of a journaling file system. In NTFS, all file data—file name, creation date, access permissions, and contents—are stored as metadata in the Master File Table. NTFS allows any sequence of 16-bit values for name encoding (file names, stream names, index names, etc.). NTFS contains several files which define and organize the file system. In all respects, most of these files are structured like any other user file (\$Volume being the most peculiar), but are not of direct interest to file system clients. These metafiles define files, back up critical file system data, buffer file system changes, manage free space allocation, satisfy BIOS expectations, track bad allocation units, and store security and disk space usage information. NTFS includes several new features over its predecessors: sparse file support, disk usage quotas, reparse points, distributed link tracking, and file-level encryption, also known as the Encrypting File System (EFS).

### c) *Ext2*

The Second Extended File System was designed and implemented to fix some problems present in the first Extended File System. The goal was to provide a powerful file system, which implements UNIX file semantics and offers advanced features. The Second Extended file system is the default file system in most Linux distributions [34] and is the most popular file system for Linux. In addition to the standard UNIX features, Ext2fs supports some extensions which are not usually present in UNIX file systems. File attributes allow the users to modify the kernel behavior when acting on a set of files. One can set attributes on a file or on a directory. In the latter case, new files created in the directory inherit these attributes. Ext2fs implements fast symbolic links. A fast symbolic link does not use any data block on the file system. The target name is not stored in a data block but in the I-node itself. This policy can save some disk space (no data block needs to be allocated) and speeds up link operations (there is no need to read a data block when accessing such a link). Ext2 borrows ideas from previous UNIX file systems using I-nodes to represent files and objects. It was designed to be extensible to make it possible to add features like journaling on at a later time.



d) *Ext3*

The Third Extended file system is a journaling file system developed by Stephen Tweedie [35] as an extension to Ext2. It is mount compatible to Ext2 file system, but includes a journaling file to provide recovery capability. Ext3 can use all of the existing applications that have already been developed to manipulate the Ext2 file system. Journaling increases the file system reliability, and reduces recovery time by eliminating the need for some consistency checks. The ext3 file system adds, over its predecessor: A Journaling file system, Online file system growth, Htree [36] indexing for larger directories (An HTree is a specialized version of a B-tree). Without these, any ext3 file system is also a valid ext2 file system. This has allowed well-tested and mature file system maintenance utilities for maintaining and repairing ext2 file systems to also be used with ext3 without major changes. Since ext3 aims to be backward compatible with the earlier ext2, many of the on-disk structures are similar to those of ext2. Because of that, ext3 lacks a number of features of more recent designs, such as extents, dynamic allocation of I-nodes, and block sub-allocation. There is no support of deleted file recovery in file system design. Ext3 driver actively deletes files by wiping file I-nodes [37] for crash safety reasons. That is why an accidental `'rm -rf *'` may cause permanent data loss. An enhanced version of the file system was announced by Theodore Ts'o [38] on June 28, 2006 under the name of ext4.

## VII. EXPERIMENT

The tests are performed on a clean 5GB file system containing nothing. The same partition is formatted to support all the file systems under evaluation in order to approximate disk latency. The computer used for testing is a PC with Intel Pentium 4 2.4 GHz CPU and 512MB DDR2 333MHz RAM. The hard drive is a 5400RPM 80GB ATA Device. The hard drive is partitioned into a 5GB partition to house the file system under evaluation and a 10GB partition for Fedora Core Release 7 (Moonshine) Kernel 2.6.21 [39] on an i386.

## VIII. RESULT & DISCUSSION

Table 1 lists the result of all tests conducted and the quantity of I/O in terms of sectors read from disk by each individual test for each file system under evaluation. It can be observed from the table that NTFS file system did lot of I/O with disk by reading lot of sectors in total for all tests while ext3 did least I/O with disk reading least sectors in total for all tests. Also, there is comparatively a consistency in NTFS regarding the number of sectors read for each individual test.

*Table1. Result of tests (Sectors Read)*

File System	FAT32	NTFS	Ext2	Ext3
Test 1	19	1541	319	10
Test 2	643	1566	35	9
Test 3	643	4522	359	375
Test 4	721	4128	559	214
Test 5	643	1566	35	9
Test 6	160721	4522	10569	10592

Table 2 lists the result of all tests conducted and the quantity of I/O in terms of sectors written to disk by each individual test for each file system under evaluation. It can be observed from the table that in tests where files were created and deleted, NTFS file system did lot of I/O with disk by writing lot of sectors while ext2 did least; whereas in test where directories were created FAT32 file system did lot of I/O with disk by writing a lot of sectors while NTFS file system did least I/O. In contrast in test where directories were deleted ext3 file system did lot of I/O with disk by writing lot of sectors while FAT32 did least I/O with disk. Again, it can be clearly observed that there is comparatively a consistency in NTFS file system regarding the number of sectors written for each individual test.

*Table2. Result of tests (Sectors Written)*

File System	FAT32	NTFS	Ext2	Ext3
Test 1	1210	2982	356	1171
Test 2	0	0	2	2
Test 3	627	3218	341	1403
Test 4	34707	2980	11574	24980
Test 5	0	0	2	2
Test 6	790	2964	1244	9507

Further, the trace of all file systems under evaluation depicting the order in which the sectors on a track are accessed is shown in figure 1 to figure 6. The figures only show the position/location of sector on track that is being accessed (read/written) and thus can be used to interpret only rotational delay incurred in the tests and as such ignores the seek time.

The figure 1 depicts the trace of test 1 conducted on all file systems which creates 10,000 empty files. It is clear from the figure 1.1 that NTFS does a consistent sequential read while ext2 read every 8<sup>th</sup> sector of the track. Also, a consistent sequential write as depicted by figure 1.2 is done by FAT32 while NTFS, ext2 & ext3 did write every 8<sup>th</sup> sector of the track. From this figure, it can be comprehended that the trace of the file system in which every 8<sup>th</sup> sector of track is read or

written may efficiently utilizing the cache as LINUX does a sequential block read/write of 8 sectors [34].

The figure 2 depicts the trace of test 2 conducted on all file systems which finds a fugitive filename among the files created after flushing the cache. It is clear from the figure that both FAT32 & NTFS did a consistent sequential read.

The figure 3 depicts the trace of test 3 conducted on all file systems which deletes the 10,000 files created in test 1 after flushing the cache. It is clear from the figure 3.1 that both FAT32 & NTFS does a consistent sequential read while ext2 & ext3 read every 8<sup>th</sup> sector of track. Also, this pattern is repeated by FAT32 while writing sector whereas NTFS, ext2 and ext3 read every 8<sup>th</sup> sector of the track as shown in figure 3.2.

The figure 4 depicts the trace of test 4 conducted on all file systems which creates 10,000 empty directories after flushing the cache. It is clear from the figure 4.1 that both FAT32 & NTFS did a sequential read while ext2 & ext3 did a random read. Also, FAT32 repeated its pattern of sequential write and ext2 repeated its random write while writing sectors whereas NTFS & ext3 wrote every 8<sup>th</sup> sector of track as depicted by figure 4.2.

The figure 5 depicts the trace of test 5 conducted on all file systems which finds a fugitive directory name among the directories created after flushing the cache. It is clear from the figure that a sequential read is done by FAT32 & NTFS.

The figure 6 depicts the trace of test 6 conducted on all file systems which deletes the 10,000 directories created in test 4. It is clear from the figure 6.1 that both FAT32 & NTFS did a consistent sequential read while ext3 did a random read. Also, ext2 did a sequential read in different bands. Further, it is clear from figure 6.2 that FAT32 did a consistent sequential write while ext2 did a random write whereas both NTFS & ext3 did wrote every 8<sup>th</sup> sector of track.

From the discussion, we can conclude that NTFS is highly I/O bound so far as these tests are concerned. Also, LINUX file systems are less I/O bound. One important thing worth noting is the pattern in which the sectors are accessed on a track because this pattern will dictate the rotational delay incurred by these file systems to complete these operations. Generally, we observed only 3 types of patterns; Sequential, Random & every 8<sup>th</sup> sector. Among the observed patterns, LINUX file systems mostly exhibit a pattern in which every 8<sup>th</sup> sector is read or written and occasionally exhibited random and sequential behavior. Also, WINDOWS file systems exhibited both sequential and every 8<sup>th</sup> sector behavior with NTFS being highly I/O bound.

## IX. CONCLUSION

In this paper, we argued that current file system benchmarks mostly concentrate on application perspective and generally ignore the system perspective of benchmarking. We stressed on system perspective in addition to application perspective and presented IO bound property of file system. Then, we developed certain tests that will evaluate file systems for IO bound property and discussed various mechanisms to monitor the performance. Finally, we evaluated some common disk file systems across WINDOWS and LINUX platforms for this IO bound property. From the results we gathered, it can be summed up that NTFS does lot of I/O with disk and thus is highly IO Bound. At the same time, "LINUX file systems did least I/O with the and thus are least IO Bound Further, we observed 3 general disk access patterns; Random, Sequential and every 8<sup>th</sup> sector read/write. Among these patterns, we found that random pattern is occasionally exhibited by any file system while LINUX file systems mostly exhibit every 8<sup>th</sup> sector read/write while WINDOWS file systems either exhibit sequential or every 8<sup>th</sup> sector read/write behavior.

## X. FUTURE WORK

The traces gathered from the tests conducted are interesting. The traces although take into consideration only the rotational delay incurred, can tell us lot about the design efficiency of the file system. Thus, more investigations need to be done to understand the traces and correlate them with the design evaluation of file system. Further, the tests conducted here need to be broadened both in terms of number of tests and types of tests in addition to the platform on which the tests are conducted.

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Figure 1. Sector Read/Write Trace for Test 1.

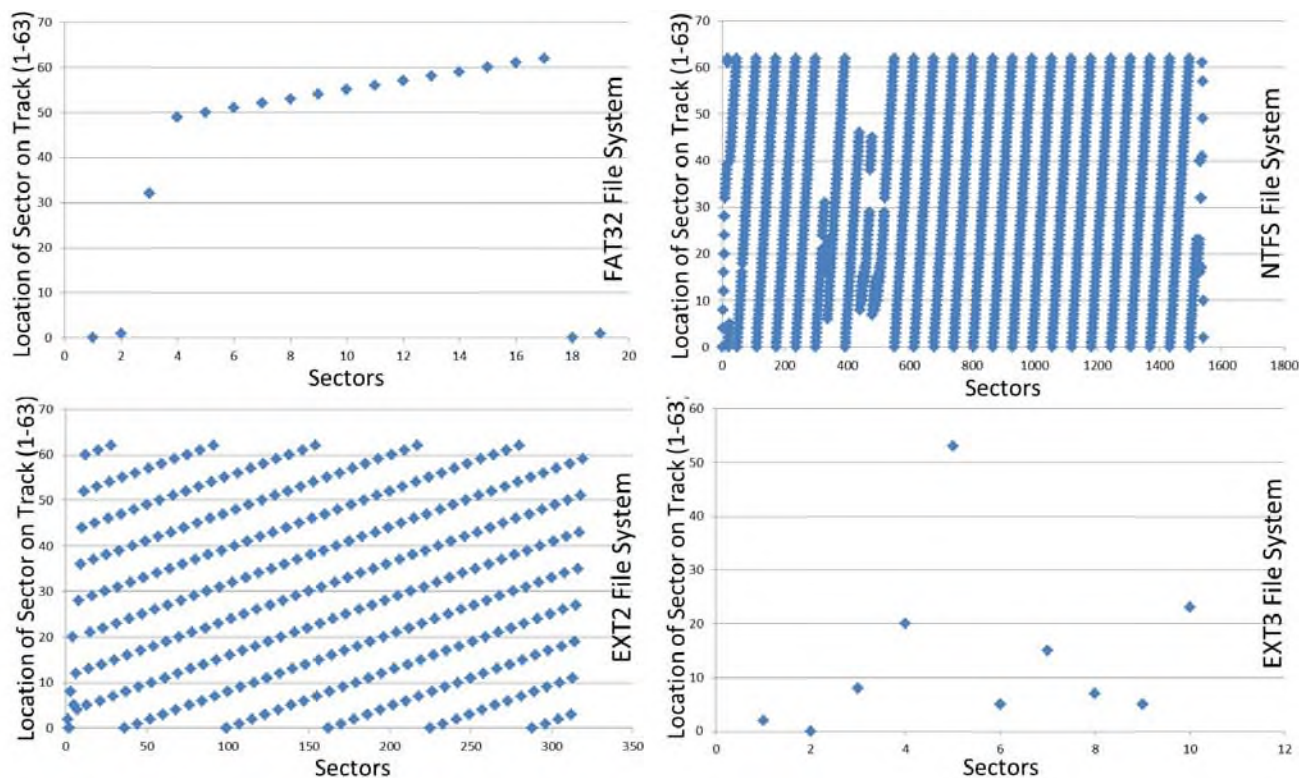


Figure 1.1 Read Trace for Test 1.

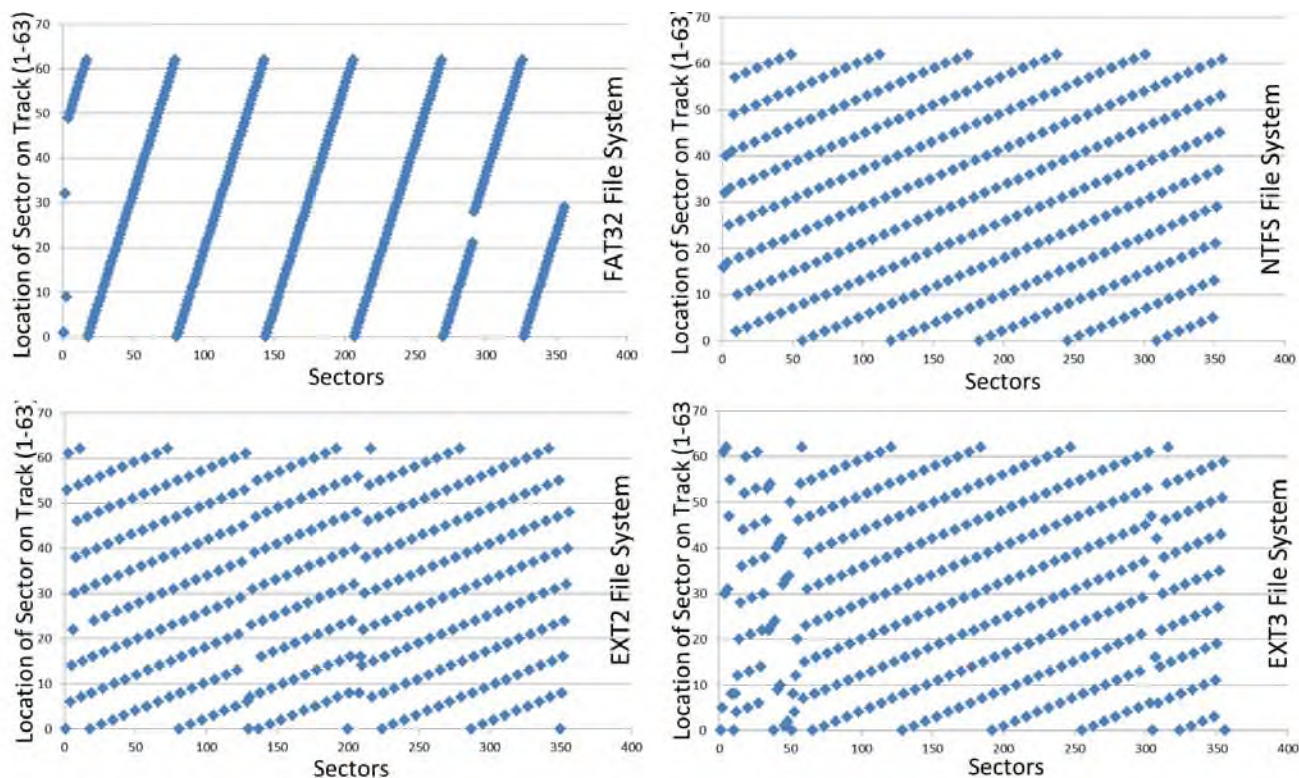


Figure 1.2 Write Trace for Test 1.

Figure 2. Sector Read Trace for Test 2.

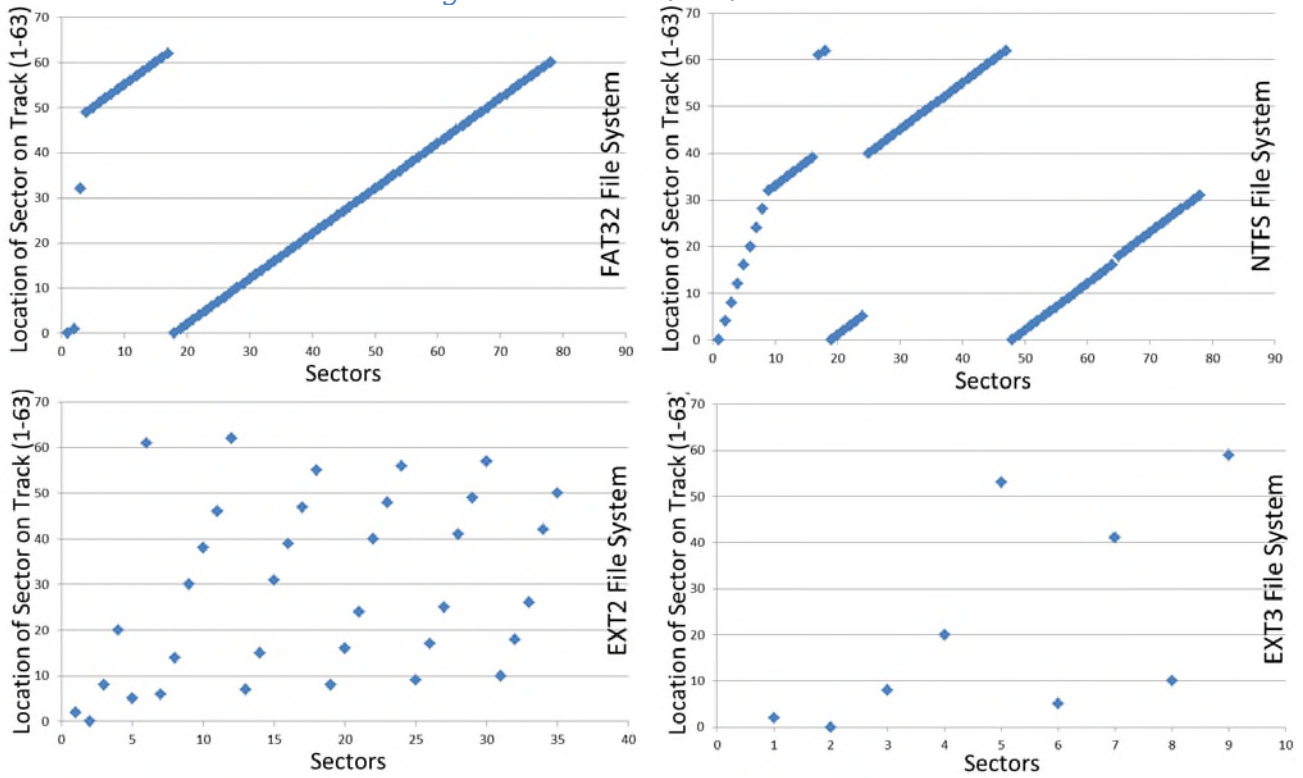


Figure 5. Sector Read Trace for Test 5.

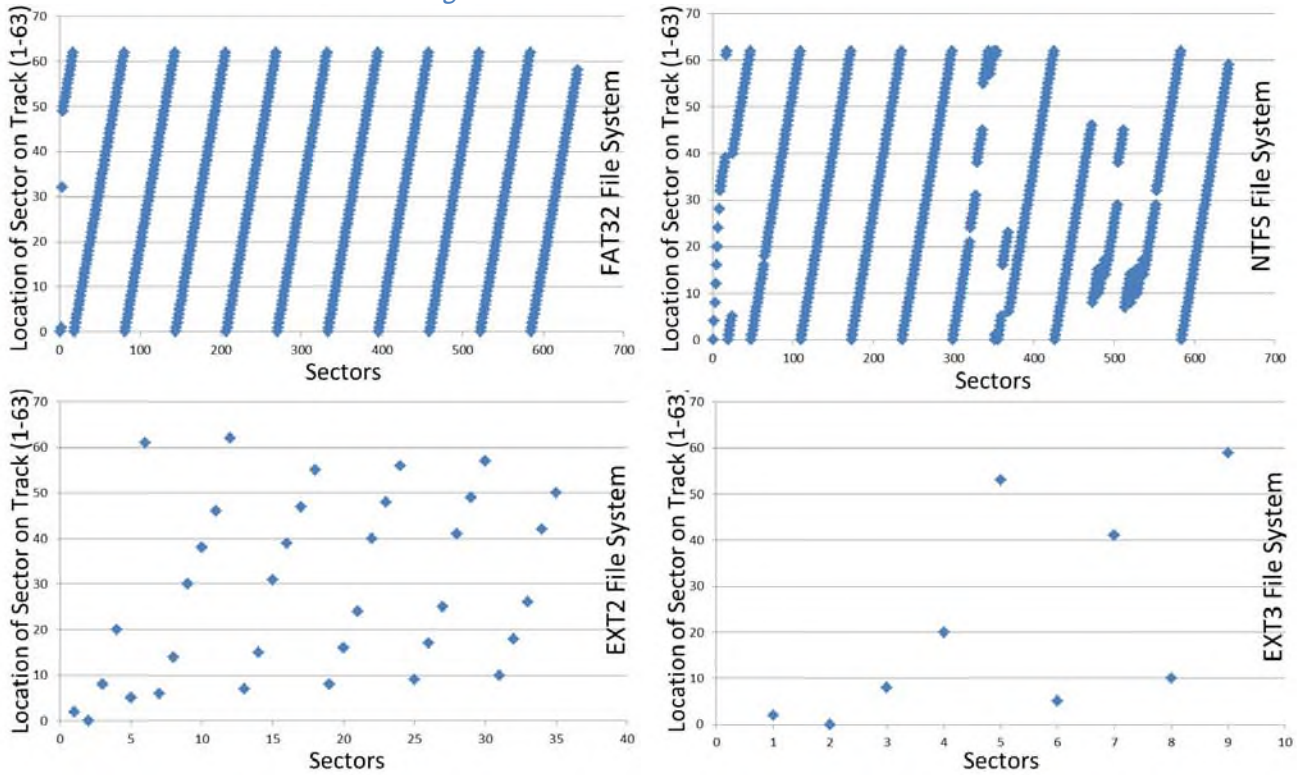


Figure 3. Sector Read/Write Trace for Test 3.



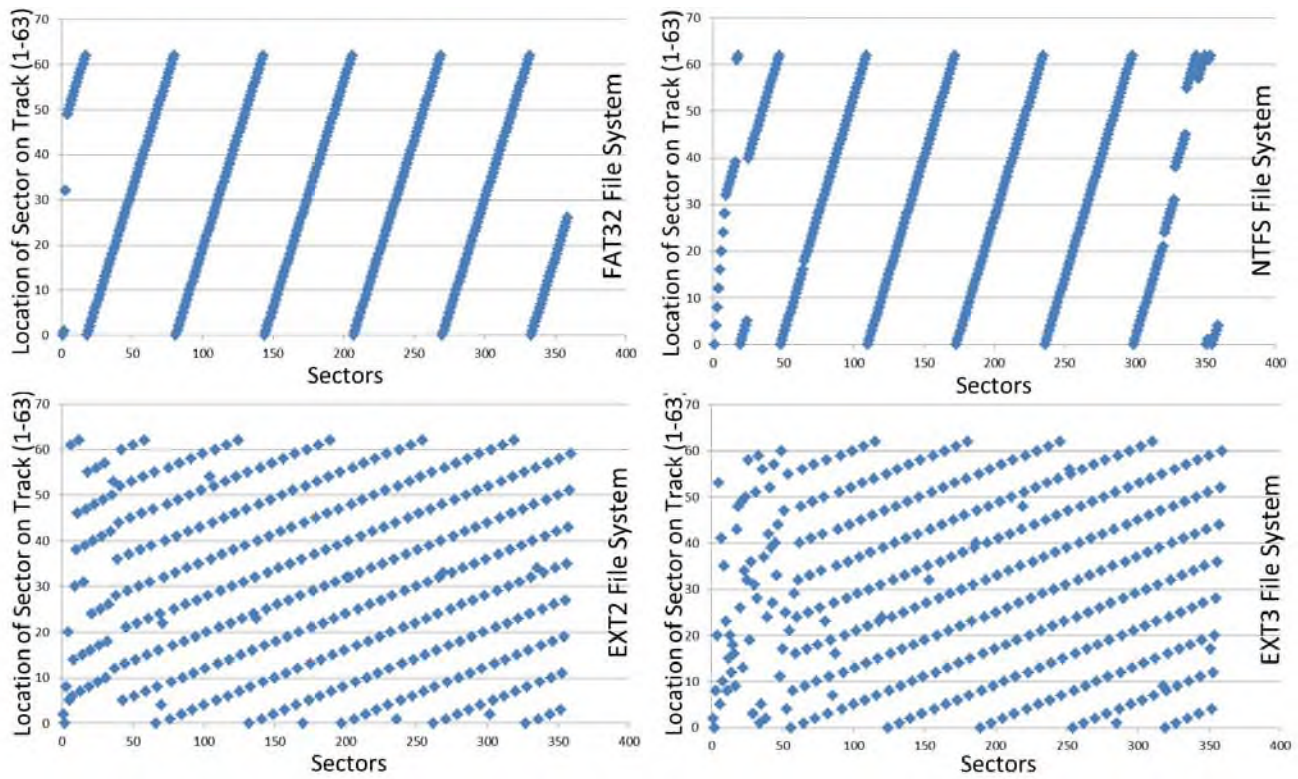


Figure 3.1 Read Trace for Test 3.

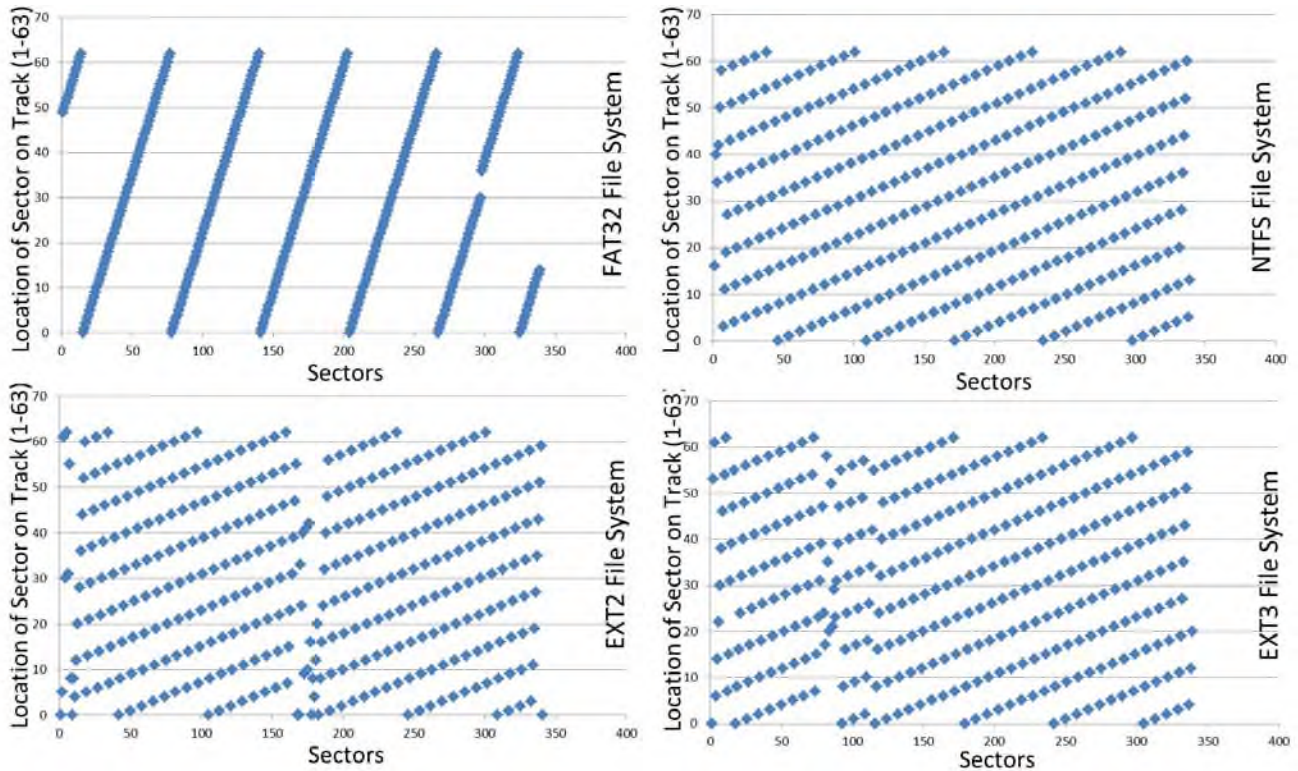


Figure 3.2 Write Trace for Test 3.



Figure 4. Sector Read/Write Trace for Test 4.

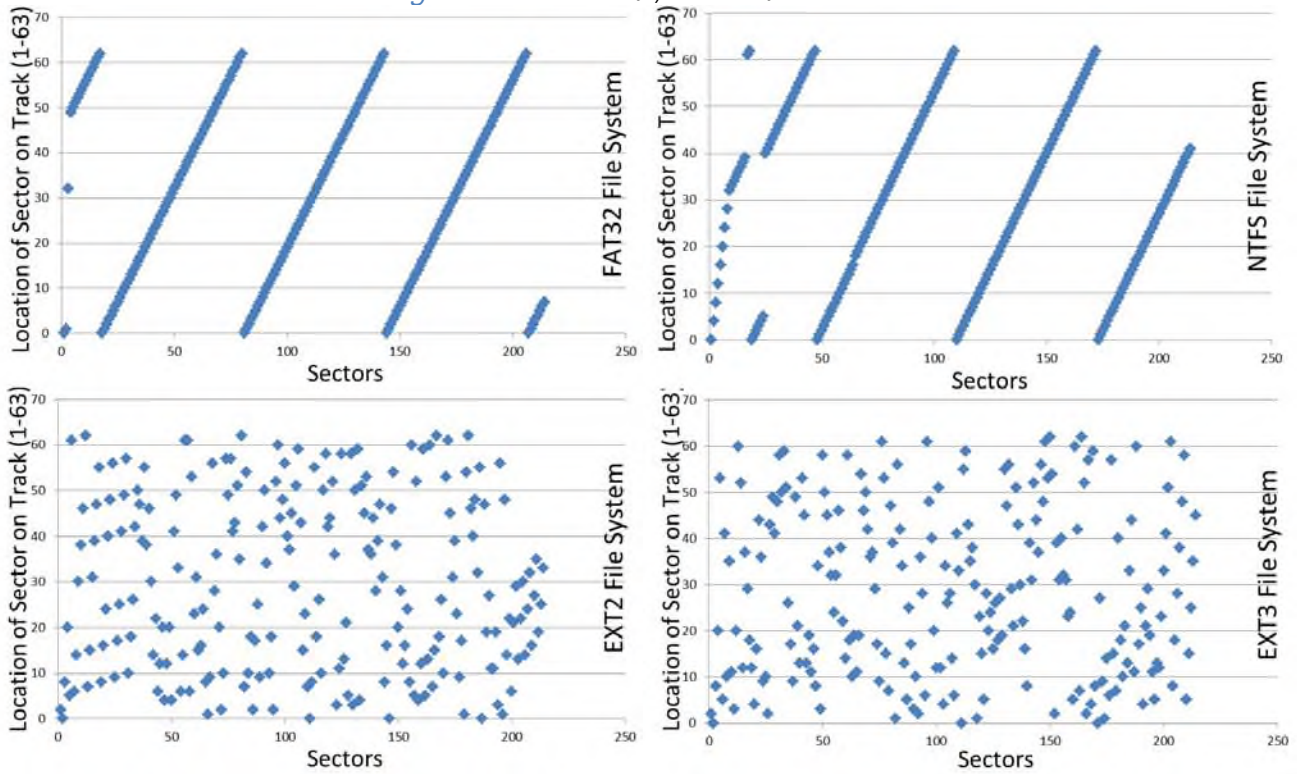


Figure 4.1 Read Trace for Test 4.

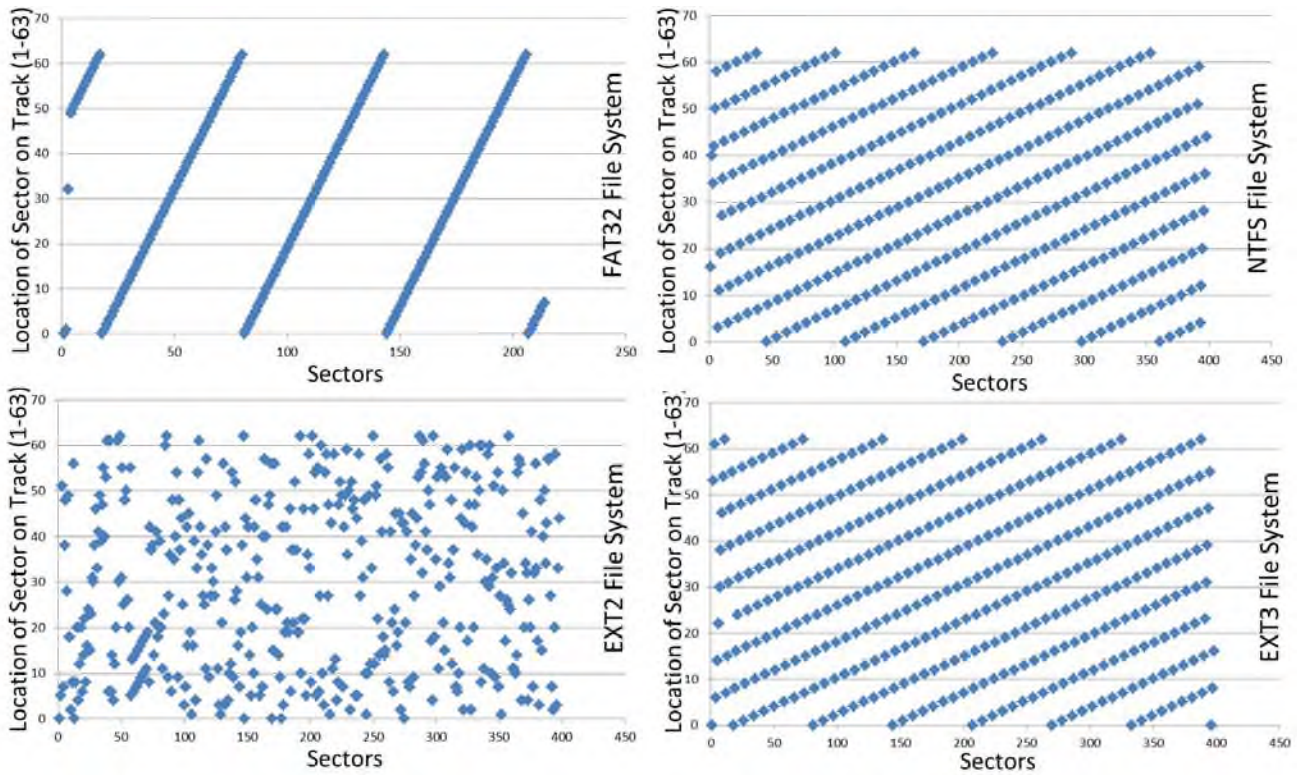


Figure 4.2 Write Trace for Test 4.



Figure 6. Sector Read/Write Trace for Test 6.

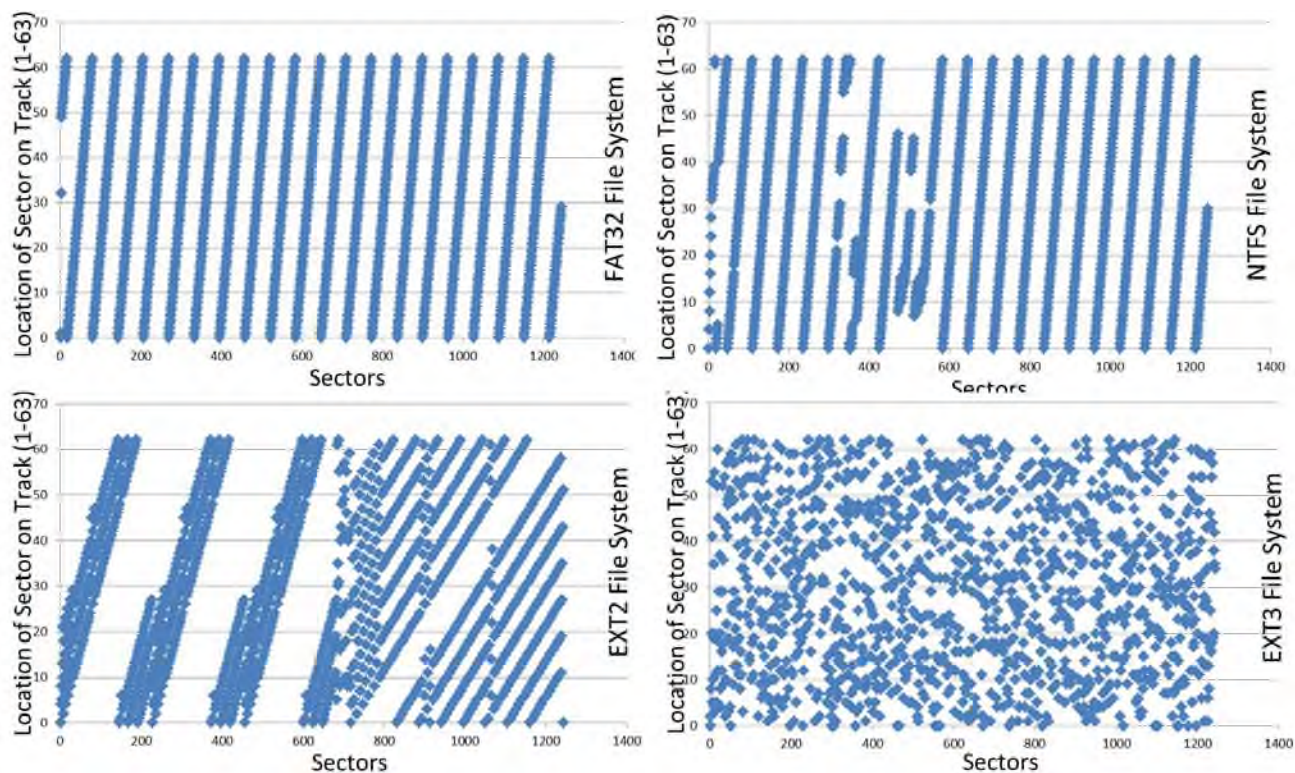


Figure 6.1 Read Trace for Test 6.

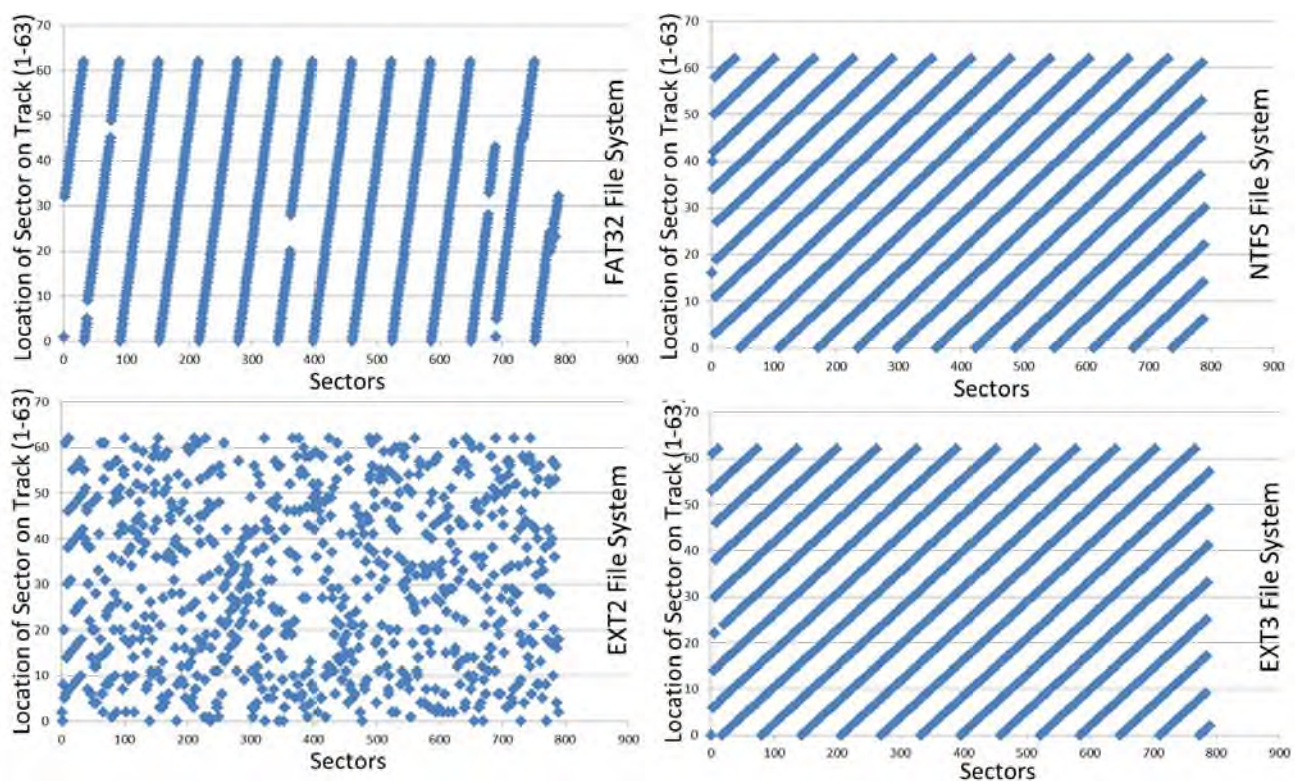


Figure 6.2 Write Trace for Test 6.