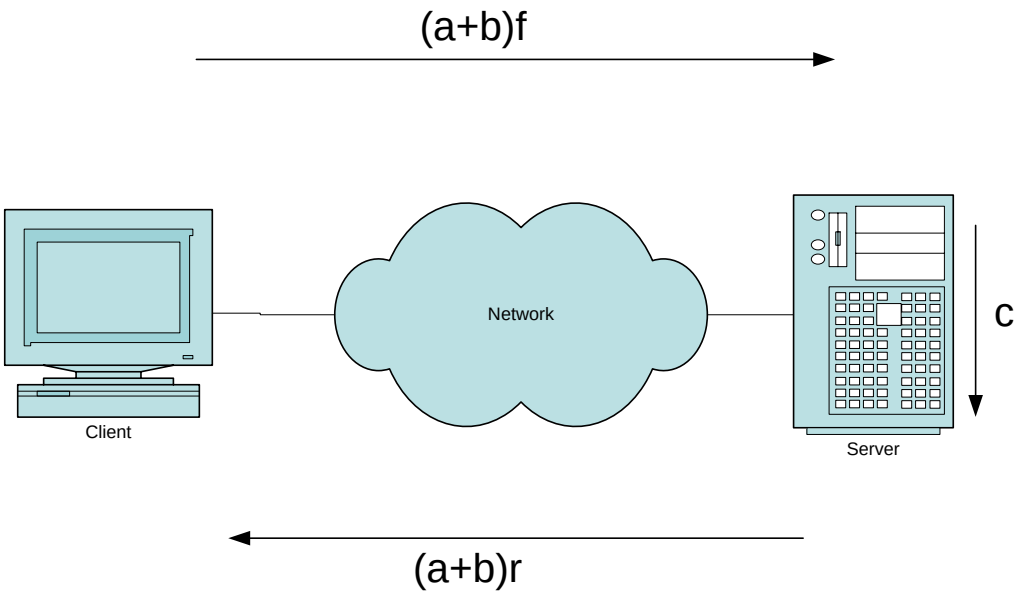
Performance Monitoring and Analysis

Weeks 30/31

Performance Monitoring

- Monitoring performance is a necessary part of **preventive maintenance** for your system.
- You obtain performance data that is useful in diagnosing system problems and in planning for the future (**Capacity Planning**)
- You can define a baseline — a range of measurements that represent acceptable performance under typical operating conditions and use it to determine operational problems and compare with future performance tests.

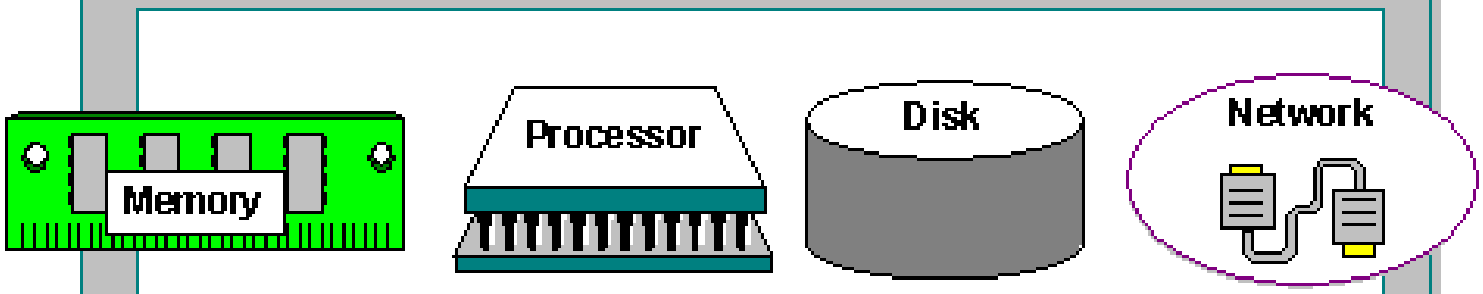
Basic Test System



We can use this simple network link to identify the resources which effect the performance of application running over the network.
The intention is to monitor both the computer systems and network Infrastructure in order to identify which subsystems may be causing poor (or less than optimal performance).

What to monitor?

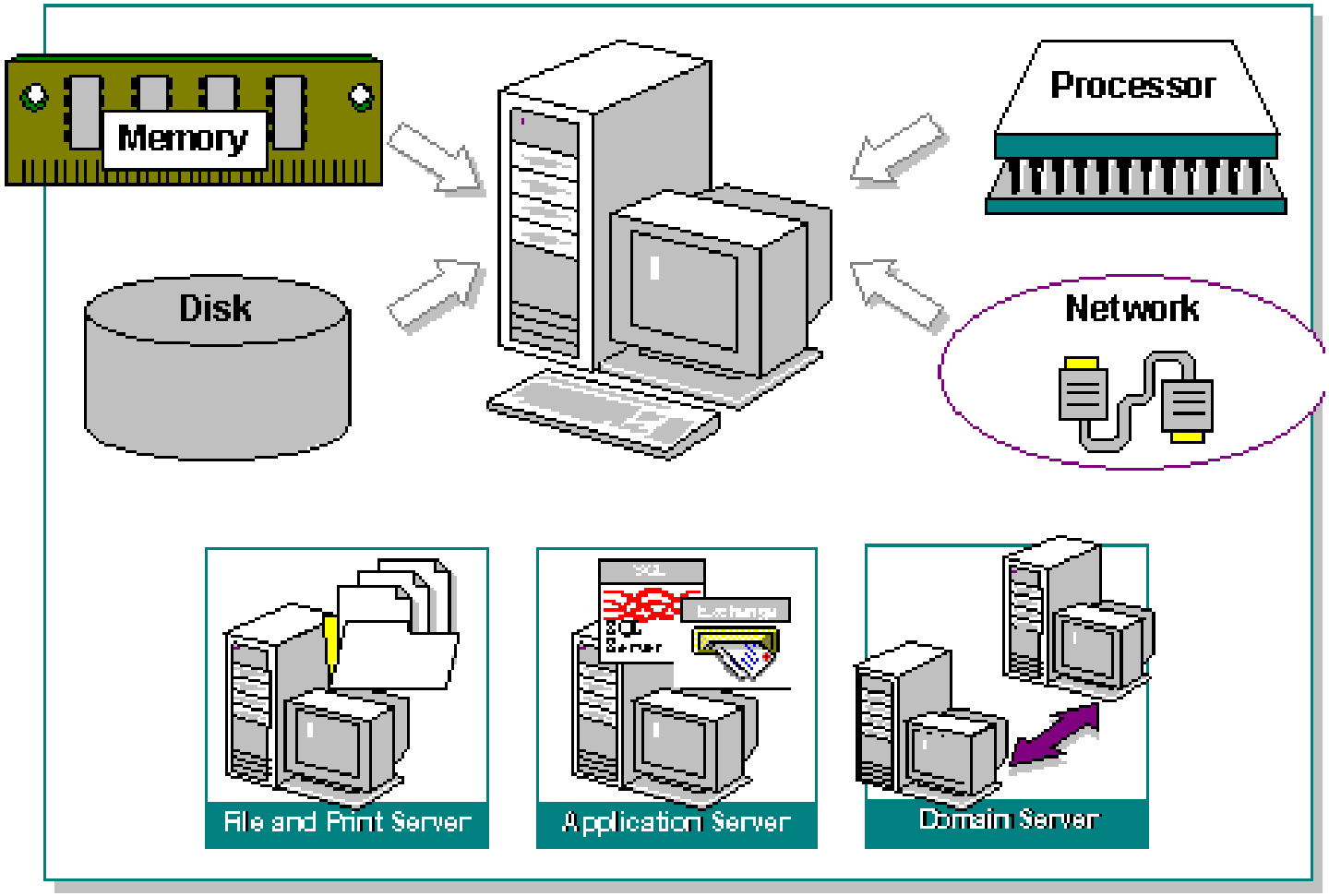
- Memory
- Processor
- Disk Subsystem
- Network Subsystem



Resource Implications

- The choice of components may have a great effect on overall system performance
- It depends on what the main function of the network is
- E.g. memory and processor have the greatest impact on file and print servers performance.
- The network (i.e. Bandwidth) should have the greatest effect on file download times, (the bottleneck) but all the other subsystems must be considered to achieve optimal performance.

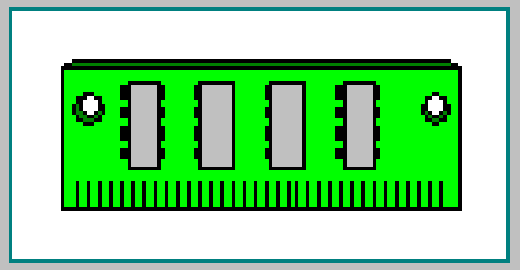
Components and Systems



Memory

When considering memory, take into account the following:

- The More Memory, the Better
- Size and Location of the System's Paging File



Memory Implications

- The current main memory technology for PCs is SDRAM (Synchronous Dynamic RAM). This is rated in MHz rather than the access time in ns to make it easier to correlate with system bus speed.

  E.g. 100MHz SDRAM (PC100) has an access time of 1/100M = 10ns and PC133 has a 7ns access time.

- Double Data Rate (DDR) which pumps 2x data by clocking on both edges of the system clock

  DDR2 gives 4x the speed

  DDR3 gives 8x the speed

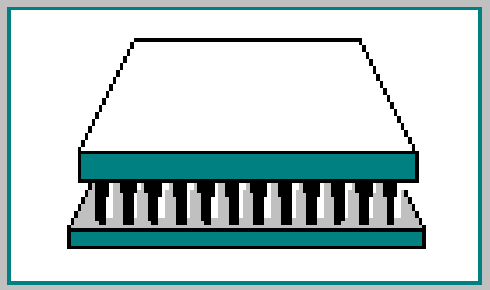
  DDR4 gives 16x the speed

- Care should be taken when using SDRAM since mixing different speed DIMMs may require BIOS changes to make it work and then at the speed of the slowest chips.

  When using multiple DDR DIMMS each channel should have the same capacity for the fastest (interleaved) mode of operation.

Processor

- Type of System Processor
- Number of Processors

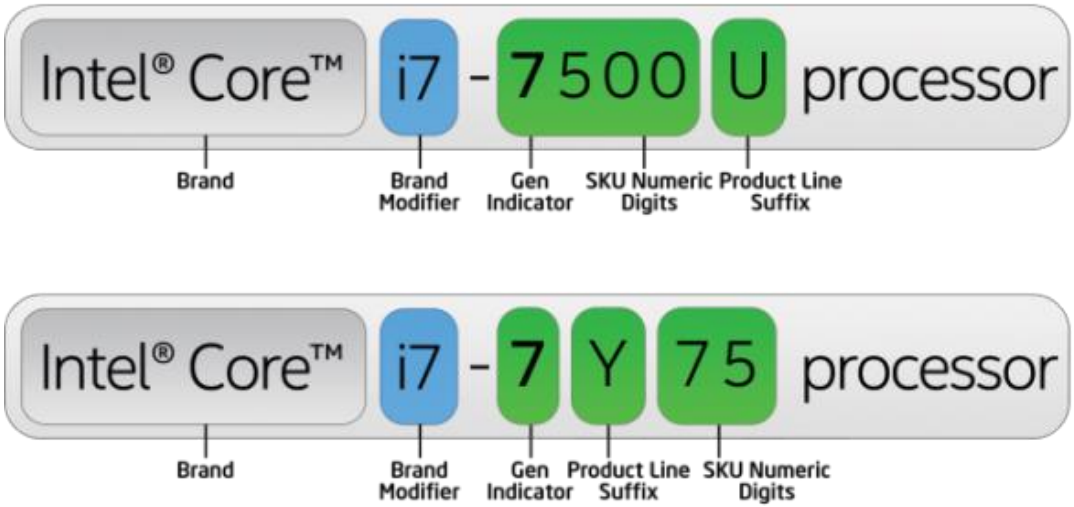


CPU Implications

- The type of system processor, as well as the number of processors, affects the overall performance of the system.
- For example, a Intel Core i7 will provide better performance than an old Intel P4.
- Intel Hyper-Threading P4s effectively provide two virtual processors to improve performance when executing two separate tasks in parallel e.g. Word processing while transferring files.
- Multiple processors are often used on servers so that if a system has multiple applications running concurrently, or applications that are multithreaded, the overall processor power is shared.
- The recently introduced quad, hexa and octa core processors give even better performance and don't need multiple socket motherboards.

e.g. Intel i7 CPU

Intel® Core™ i7-900 Processor Series	
	INTEL® CORE™ i7-975 PROCESSOR EXTREME EDITION
Processor Frequency	3.33 GHz
Intel® Smart Cache	8 MB
Intel® Turbo Boost Technology[2]	Single-core performance up to 3.6 GHz
Number of Simultaneous Threads	8 (with Intel® HT Technology)
Processor Integrated Memory Controller	Yes
Number of Memory Channels	3 (DDR3 1066 MHz)
Intel® Express Chipset	X58
Socket	LGA1366
Microsoft® Windows® 7 Ready	Yes


Intel® Core™
i7
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7500
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processor
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Processor Bottlenecks

Are typically caused by:

- Excess demand put on the processor by CPU intensive applications

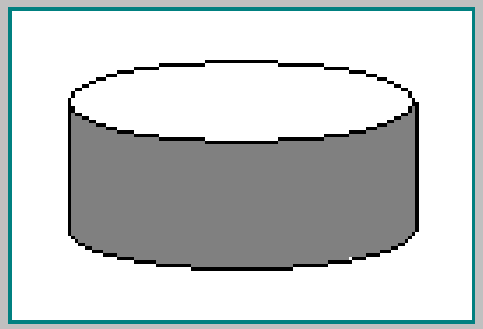
- Excess interrupts caused by device drivers, and network and disk components

Solutions

- Upgrade your existing processors to faster processors.
- Add any necessary additional processors.
- Spread programs effectively over your existing servers so that the workload is spread more efficiently

Disc Subsystem

- Type and Number of Controllers (IDE , SCSI....)
- Busmaster Controllers (DMA, ULTRA DMA...)
- Caching
- Controllers That Support RAID
- The Type of Work Being Performed
- The Type of Drives Implemented



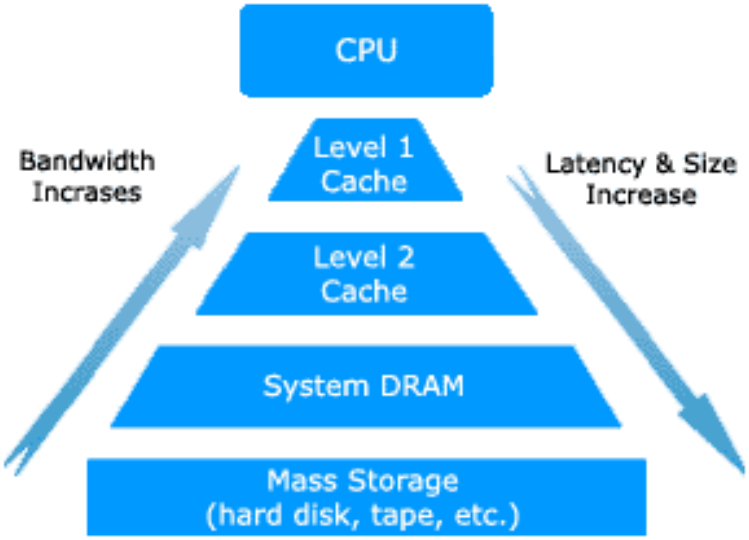
USB External Drive Connection

- USB 2.0 performance is limited to about 40 MB/s (480/8 = 60MB/s in theory) and now 400 MB/s (4800/8) for USB 3.0.
- Functionally, the drive appears to the user much like an internal drive.
- Other competing standards for external drive connectivity include eSATA, ExpressCard, and FireWire (IEEE 1394)

  Thunderbolt 10Gbps

  N.B.Windows 7 ReadyBoost feature allows flash drives (up to 4GB) to augment system memory and provide a performance boost

Cache



- Caching helps improve disk responsiveness as data is cached on the controller and does not require RAM or internal cache.

- Some drives have on board cache

RAID

- Controllers that support hardware-level RAID (Redundant Array of Independent Disks) can offer better performance than software implemented RAID.

- By implementing striping, disk performance may be improved dramatically - for example, writing a 200MB file to a stripe set is 20 percent faster than writing to a single hard disk drive.

RAID

- Use RAID to optimize disk performance.
- A number of different standard schemes called levels
- Mainly 5 levels, RAID 0, RAID 1, RAID 2, RAID 3, RAID 4, and RAID 5
- Main difference is in stripping, mirroring and parity e.g.
- RAID 0:
  - striping but no mirroring or parity
- RAID 5:
  - block level striping with distributing parity, Parity provides redundancy to guard against failure
  - Improved read performance due to parallel block transfers
  - Availability maintained if single disk fails, but at reduced performance

Disc Drive Performance

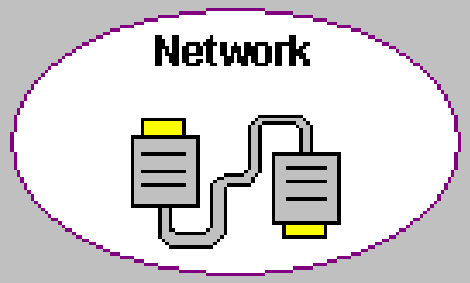
- Disc performance is generally measured in disc access time (ms) - typically 10ms, and
- Data Transfer Rate (Bytes/s) - the rate of transfer between the Disc and processor.
- Choose a manufacturer that supplies the fastest drive available.

SSDs and Hybrids

- Solid State Drives have no moving parts
- Expensive, but eliminate some of the performance issues HDDs
- Hybrids combine the features of SSDs and HDDs in the same unit, containing a large hard disk drive and an SSD cache to improve performance of frequently accessed data.

Network Subsystem

- Network Adapter Type
- Multiple Network Adapters
- Number of Users
- Routers, Bridges, and Other Physical Network Components
- Protocols in Use
- Additional Network Services in Use
- Applications in Use
- Directory Services (Domain Model and Structure)



Adapter Types

- High bandwidth cards are best.
- Avoid programmed input/output (PIO) adapters, as they use the CPU to move data from the network adapter to RAM.
- Example transfer speeds of the 10BaseT adapters:
  - 8-bit network adapters transfer up to 400 KBps.
  - 16-bit adapters transfer up to 800 KBps.
  - 32-bit adapters transfer up to 1.2 MBps.

Gigabit Adapters

- The latest Gigabit Ethernet (1000BaseT) cards also support 10 and 100Mbps operation and auto-speed sensing functions.
- They may have other features to improve system performance such as teaming, FDX operation and off-loading some TCP/IP functions
- Some can use jumbo size frames to increase wire efficiency at 1000Mbps (e.g. 9014 Bytes)

Multiple Adapters

- Installing multiple network adapters is beneficial in a server environment because doing so allows the server to process network requests over multiple adapters simultaneously.
- Teaming allows several adaptors to work as one
- If your network uses multiple protocols, consider placing each protocol on a different adapter.

Network Devices

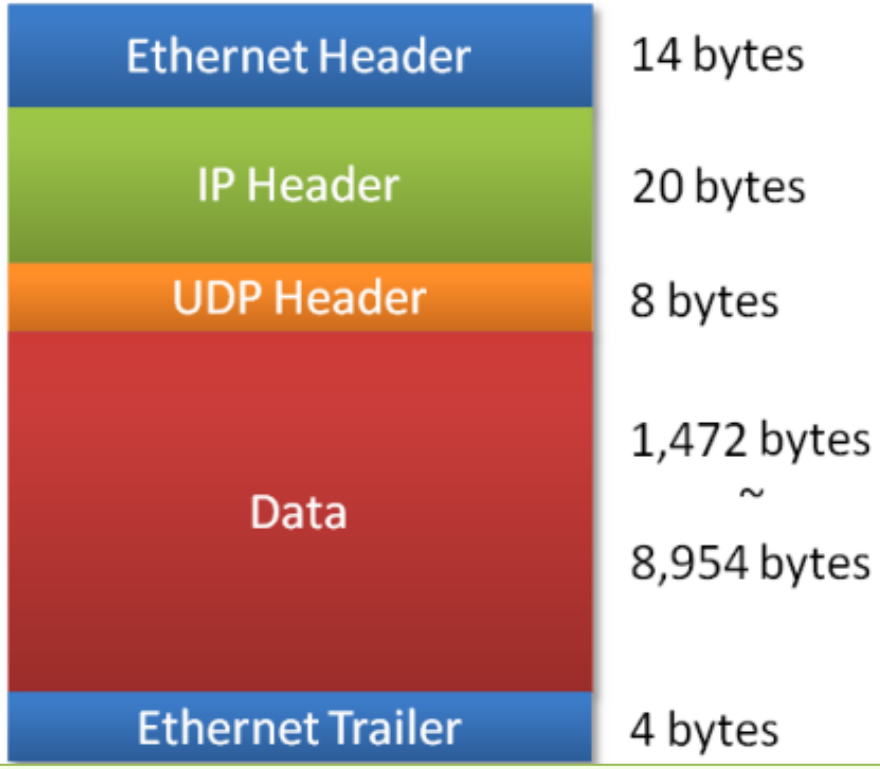
- Routers, bridges, switches and other physical network components affect performance of the network.

- Other devices and technology will also impact on performance:
  WAN interface adapters, VPN, Firewall, IPS, etc.

Protocols in use

- Reducing the number of protocols installed can increase performance.
- Setting the TCP MTU (maximum transfer unit) and RWIN (receive window size) to the optimum size can have remarked effects on network throughput.
- *Most Gigabit network cards do TCP error checking on board to increase throughput and can use Jumbo frames*

Jumbo Frames



The original 1,518-byte MTU for Ethernet was chosen because of the high error rates and low speed of communications. If a corrupted packet is sent, only 1,518 bytes must be re-sent to correct the error. However, each frame requires that the network hardware and software process it. If the frame size is increased, the same amount of data can be transferred with less effort. This reduces CPU utilization (mostly due to interrupt reduction) and increases throughput by allowing the system to concentrate on the data in the frames, instead of the frames around the data. (Jumbo frames up to 9000 bytes)

Network Services

- Each service adds memory and processor overhead on the system e.g. for a server:
  - DNS
  - RAS
  - DHCP
  - WINS
- Disable unnecessary services

Security Services

- Encryption of data packets has performance overheads -more on delay than bandwidth, since there must be processing on each end of the transfer.
- Intrusion Prevention Systems (IPS) inspect/analyse packets for potential threats before blocking or allowing them through potentially creating a bottleneck on a gigabit network, reducing the actual throughput to fast Ethernet speeds.

Solving Network Performance Issues

- Unbind unnecessary and infrequently used network adapters.
- Upgrade your network adapters.
- You can increase file sharing throughput by deploying multiple network adapters.

Performance Data

- Performance monitoring concentrates on how the operating system and any applications/ services use the resources of the system, such as the disks, memory, processors, and network components.
- *Throughput*, *queue*, and *response time* are terms that describe resource usage.

Performance Analysis 1

- Determine the bandwidth efficiency (%utilization) and frame transfer rate for standard (shared) Ethernet for min and max frame sizes.
- What is the most efficient frame size?
- What is the inter-frame gap for?
- Why does a switch usually improve performance over a hub?

Ethernet Bandwidth Efficiency

- Frame rate depends on frame size
- Small packets achieve higher frame rates, but small packets have greater overhead (overhead is extra time needed for transmission)

- Efficiency = framesize/(framesize+overhead) =64/(64+20) x100 =76% for min frame size
- =1518/(1518+20)x100 =98.6% for max frame size

- **Therefore better link utilization with larger frame sizes (assuming no collisions and re-transmissions)**

- ***N.B. the latest NICs and switches support JUMBO frames (typ 9Kbytes)- much larger than the standard size which should improve throughput in some cases***

Gigabit Ethernet Performance

- In theory Gigabit Ethernet (1000Mbps) is:
- 100x faster than standard Ethernet -10Mbps
- 10x faster than fast Ethernet -100Mbps
- But is this true in practice?

The following results are from tests done to show advantages using gigabit compared with the older Ethernet technologies when performing a 1GByte back up

1GByte file transfer

Type	Raw Speed (Mbps)	calc time (mins)	actual time (mins)	Throughput (Mbps)	Utilization %
10	10	13	17	8	saturated
100	100	1.3	3.5	38	50
1000	1000	0.13	2	72	10

EXPLAIN these results

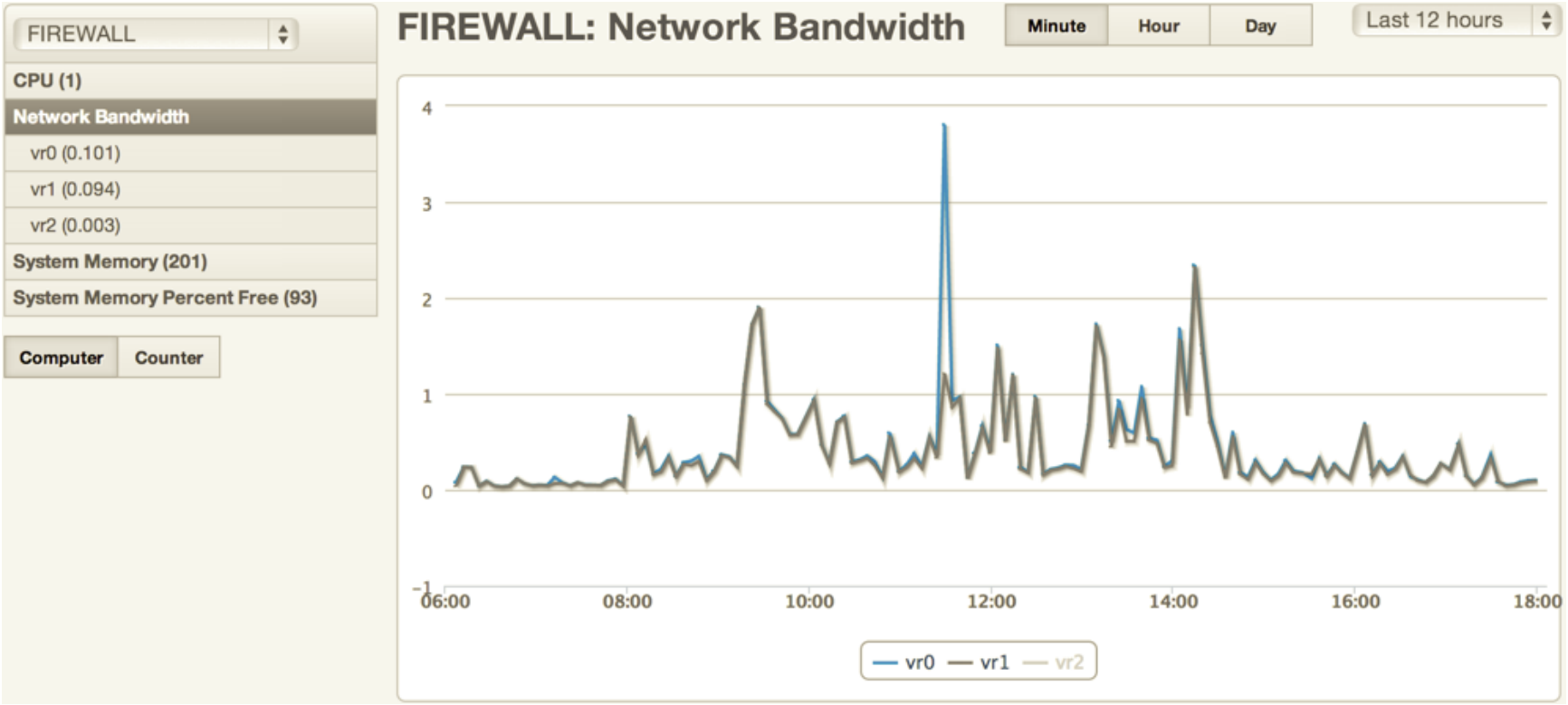
Performance Investigation 2

- Memory subsystem or PCI interface is often the limiting factor NOT the network adaptor.
- Older PCs and notebooks unable to use the full potential of a Gigabit network card.
- The advertised performance spec of the memory subsystem may not be true

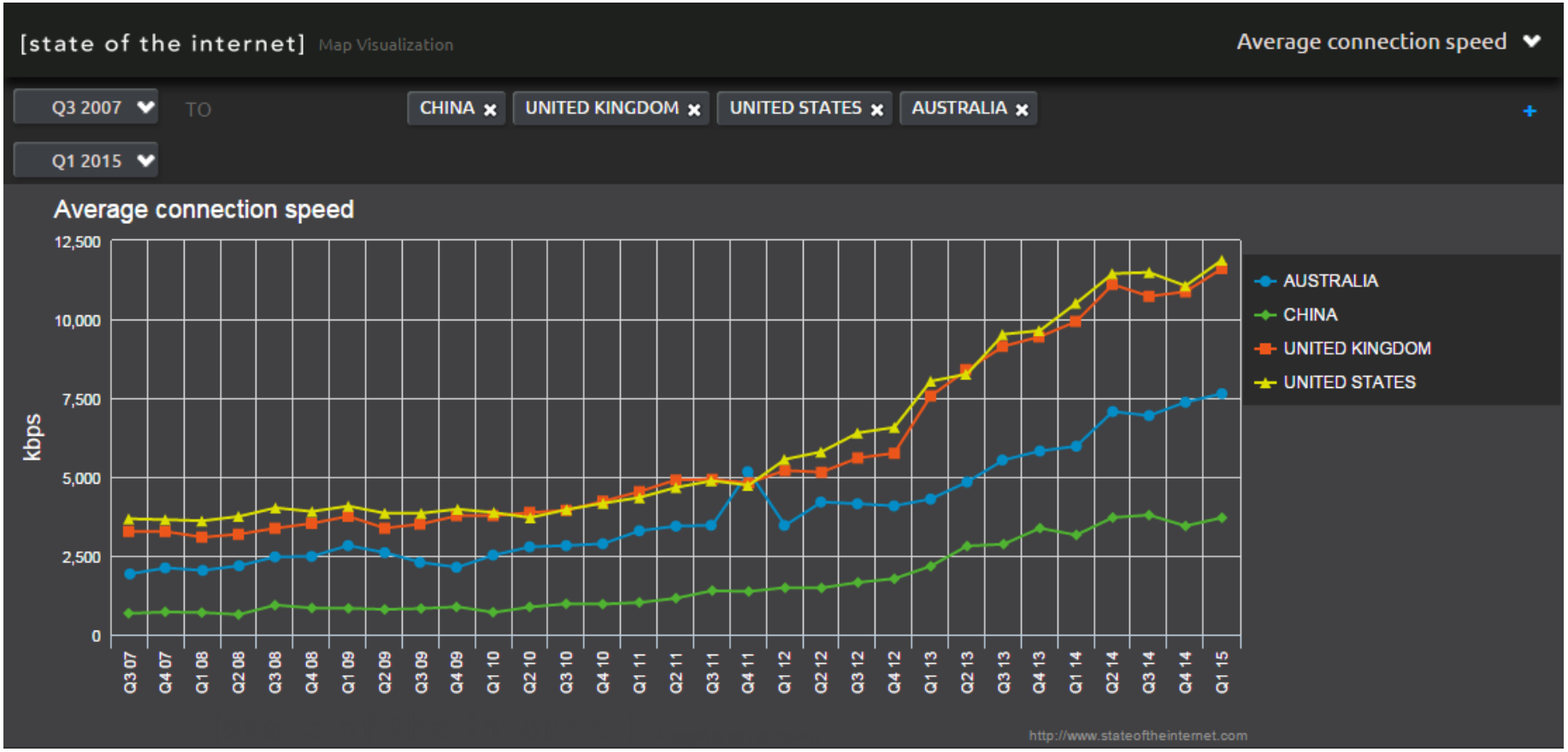
Baseline

- A measurement derived from the collection of data over an extended period.
- Varying but typical types of workloads and user connections.
- The baseline is an indicator of how system resources are used during periods of normal activity.
- **Trend analysis** describe the analysis of long term data to reveal problems which occur over time due to changing network usage

Hourly Trend Example

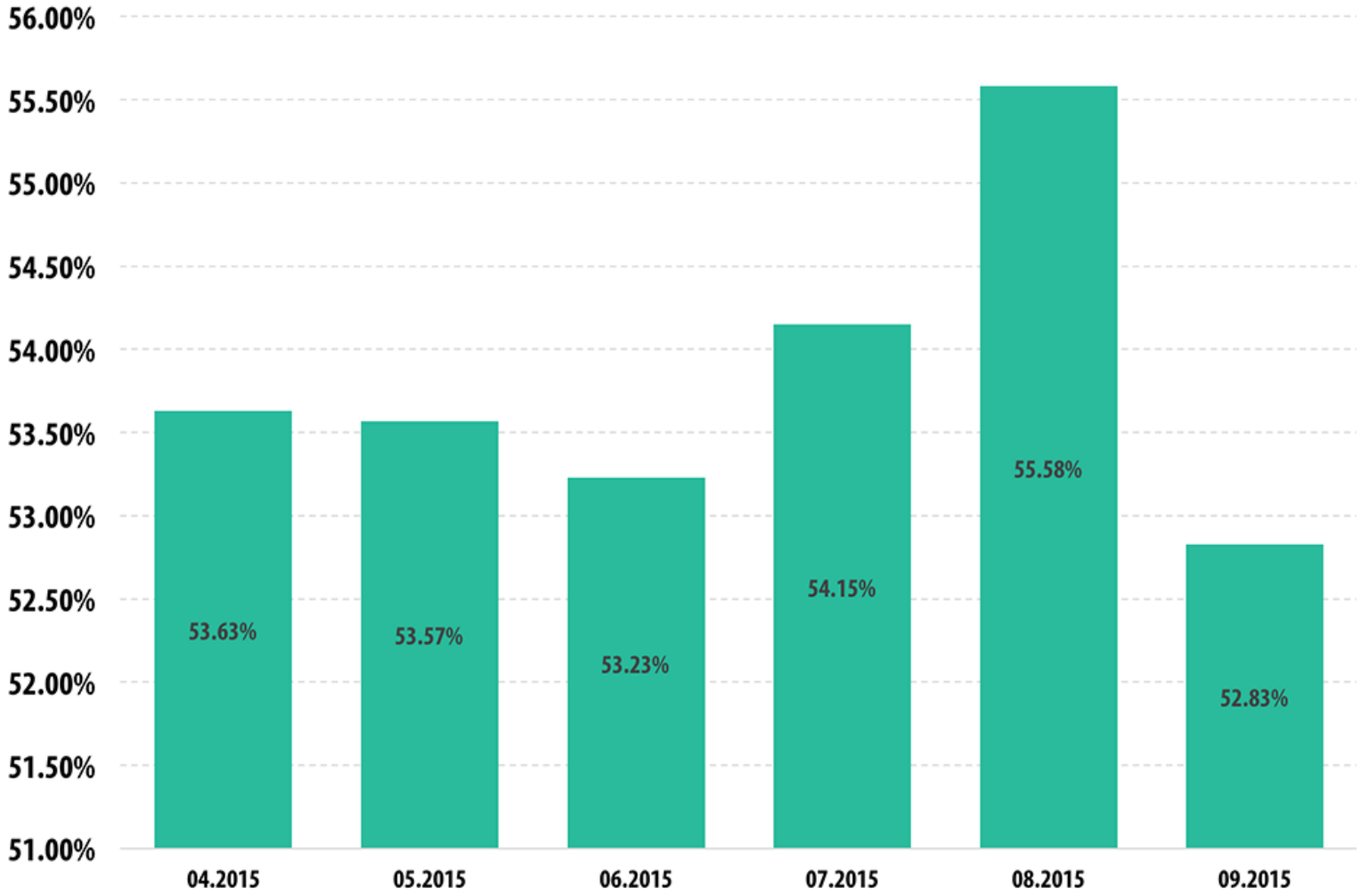


Yearly Trend Example



Trend Report Example 2

Percentage of spam in email traffic, April-September 2015



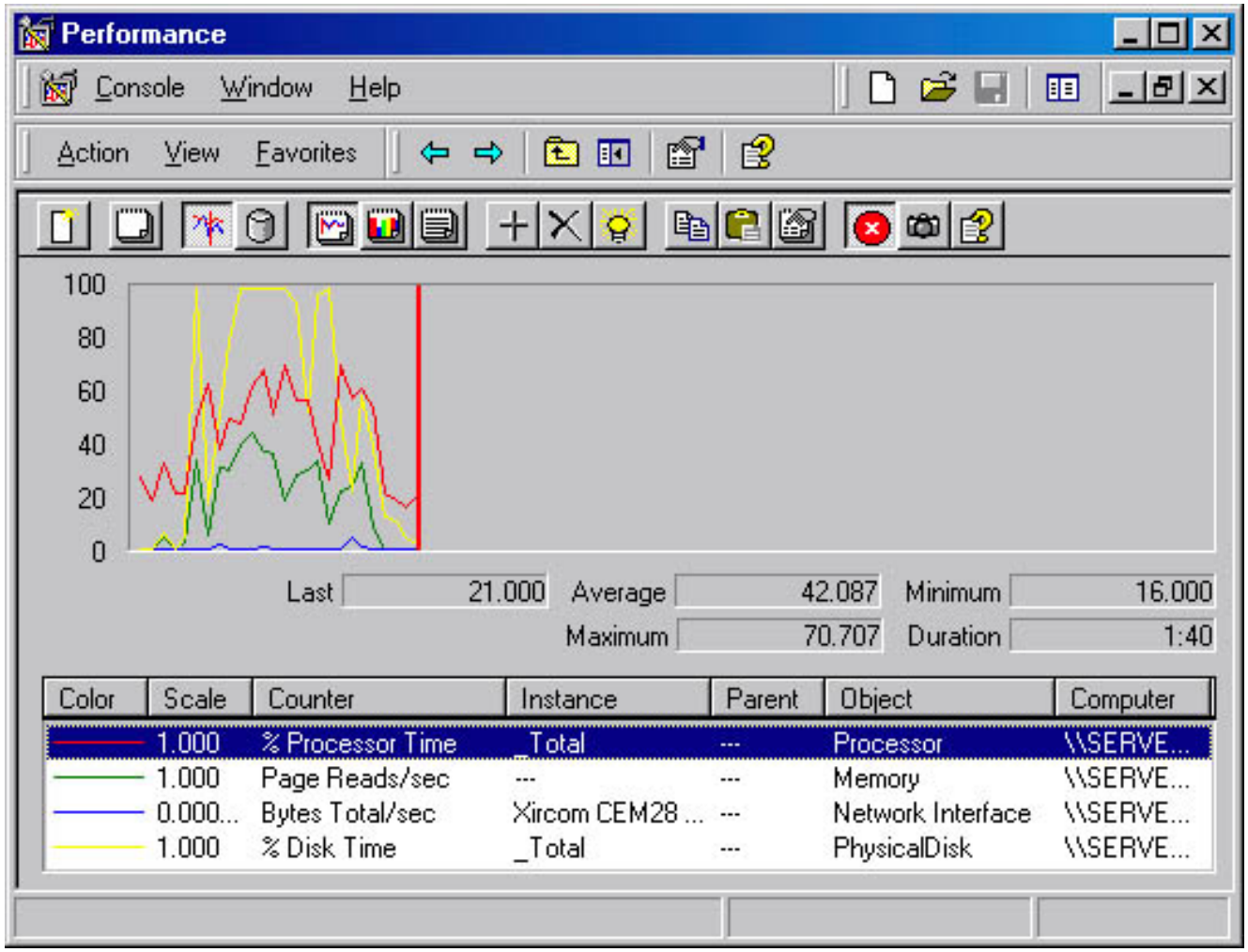
Performance Counters

- Counters are performance metrics
- Tell us how well the operating system or an application, service is performing.
- The counter data can help determine system bottlenecks and fine-tune system and application performance.
- The operating system, network, and devices provide counter data that an application can consume to provide users with a graphical view of how well the system is performing.

Windows Performance Counters

Resource	Object\Counter	Comments
Disk	PhysicalDisk\% DiskTime	Amount of disc activity
Disc	PhysicalDisk\Bytes/s	Data Throughput
Disc	Physical Disk\Avg Disc Queue Length	Read/write requests queued
Memory	Memory\ Available Bytes	Memory usage
Memory	Memory\ Pages/sec	Rate of paging from disc
Network	Network Segment\% Net Utilization	Network bandwidth in use
Network	NetworkSegment\Bytes Total/s	Data Throughput
Processor	Processor\% Processor Time	Processor activity
Processor	Processor\ Interrupts/sec	Average rate of interrupts
Paging	PagingFile\%Usage	Amount of page file in use

System Monitor



Results Analysis

- The baseline establishes the typical counter values you should expect to see when your system is performing satisfactorily.

- When you are collecting and evaluating data to establish a valid performance baseline, consider the following guidelines:

Bottlenecks

- A bottleneck exists if a particular component's limitation is keeping the entire system from performing better.

- Performance monitoring tells you where bottlenecks occur in your system.

Investigating Bottlenecks

- Investigating performance problems should always start with monitoring the whole system before looking at individual components.

- The device with the smallest throughput ratio is probably the primary source of the bottleneck.

Typical Bottlenecks

- Poor response time on a workstation is most likely to result from memory and processor problems.
- Servers are more susceptible to disk and network problems.
- Problems in one component might be the result of problems in another component, not the cause.
- When memory is scarce, the system begins moving pages of code and data between disks and physical memory. The memory shortage becomes evident from increased disk and processor use, but the problem is memory, not the processor or disk.

Threshold Values

- Deviations from the baseline provide the best indicator of performance problems.
- However, as a secondary reference monitor thresholds for some common object counters.
- Table 2 identify when a performance problem is developing on a system. If the values listed are consistently reported then there may be a problem.

Counter Thresholds

Resource	Object\Counter	Suggested Threshold	Comments
Disk	LogicalDisk\% Free Space	15 percent	None
Disk	LogicalDisk\% Disk Time	90 percent	None
Memory	Memory\ Available Bytes	< 4 MB	Research memory usage and add memory if needed.
Memory	Memory\ Pages/ sec	20	Research paging activity.
Network	Network Segment\% Net utilization	Depends on type of network	Depends on type of network - e.g. for Ethernet 30 percent is the recommended threshold.
Paging File	Paging File\% Usage	>70 percent	Review this value in conjunction with Available Bytes and Pages/sec to understand paging activity on your computer.
Processor	Processor\% Processor Time	85 percent	Find the process that is using a high percentage of processor time. Upgrade to a faster processor or install an additional processor.
Processor	Processor\ Interrupts/sec	Current CPUs, use a threshold of 1500	A dramatic increase in this counter value without a corresponding increase in system activity indicates a hardware problem. Identify the network adapter or disk controller card causing the problem.
Server	Server\Bytes Total/sec		If the sum of Bytes Total/sec for all servers is roughly equal to the maximum transfer rates of your network, you might need to segment the network.
Server	Server Work Queues\Queue Length	4	If the value reaches this threshold, there might be a processor bottleneck. This is an instantaneous counter; observe its value over several intervals.
Multiple Processors	System\Processor Queue Length	2	This is an instantaneous counter; observe its value over several intervals.

Benchmarks

- Programmes are available to stress test systems by generating typical traffic
- Veritest provide benchmark programmes to help test network servers.
- NetBench is used to test file servers
- WebBench is used to test web servers

Calculating Frame Rate (10BaseT)

Raw bandwidth (transmission speed) = 10M/8 = 1.25MBps

Minimum frame size = 64 Bytes

Maximum frame size = ……. Bytes

interframe gap =9.6µs (equiv to 12 byte times @10Mbps)

preamble =8 bytes

total bytes per min frame = 64+12+8 =84 bytes

maximum frame rate =1.25M/84 =14880 frames/sec

Min frame rate =1.25M/? = ? frames/sec

10BaseTx

- **Raw bandwidth (transmission speed) =10M/8 =1.25MBps**

- **minimum frame size = 64 Bytes**
- **maximum frame size = 1518 Bytes**

- **Interframe gap =9.6µs (equiv to 12 byte times @10Mbps)**
- **preamble =8 bytes**

- **total bytes per min frame = 64+12+8 =84 bytes**
- **maximum frame rate =1.25M/84 =14880 frames/sec**
- **Min frame rate =1.25M/? = ? frames/sec**

100BaseTx

- **Raw bandwidth (transmission speed) = …..Bps**
- **minimum frame size = ……..Bytes**
- **maximum frame size =……Bytes**
- **interframe gap =…….µs (equiv to 12 byte times @100Mbps)**
- **preamble =……bytes**
- **total bytes per min frame = …….bytes**
- **maximum frame rate = ……..frames/sec**
- **Min frame rate =…… frames/sec**

1000BaseT

- **Raw bandwidth (transmission speed) = …..Bps**
- **minimum frame size = ……..Bytes - careful**
- **interframe gap =…….µs**
- **preamble =……..bytes**
- **total bytes per min frame = …….bytes**
- **maximum frame rate = frames/sec**
- **Min frame rate =…… frames/sec**

Study Resources?

- 3 Monitoring Windows Server 2012 https://www.youtube.com/watch?v=koDFirQuvjI
- Introduction to CPUs https://www.youtube.com/watch?v=iaui8sPWEx4
- What is RAID? https://www.youtube.com/watch?v=U-OCdTeZLac
- Network Monitoring https://www.youtube.com/watch?v=2M3bq22iIaQ
- Network Performance Optimization https://www.youtube.com/watch?v=nNBZM2Pd9sY
- Understanding CPU Characteristics https://www.youtube.com/watch?v=0PliMca_kVQ
- Understanding PC Memory https://www.youtube.com/watch?v=bmRMRlDXph0
- An Overview of Storage Devices https://www.youtube.com/watch?v=NgVm2kUmrYo
- An Overview of RAID https://www.youtube.com/watch?v=NqozAmsUsWI
- Computer Interface Speeds and Distances https://www.youtube.com/watch?v=VkcKtTU61ZM