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Workload Optimization with the IBM eX5 Family of Servers

Executive summary

With the number of interconnected devices increasing on a daily basis, the amount of data that is generated and collected is increasing dramatically. All of this data must be stored, and much of this data is used in processor-intensive workloads, such as online transaction processing (OLTP), business analytics, and to identify business trends. The data, storage needs, and processor workloads are placing unprecedented demands on information technology (IT) operations. Financial pressures are forcing many IT organizations to keep their budgets flat and, in some cases, to reduce them.

During this time, Intel Xeon processors have evolved, making technologies available to assist with workload optimization. These innovative technologies are maximized when implemented in the IBM® eX5 line of servers, the current generation of Enterprise IBM X-Architecture®. These powerful servers meet the need for efficient, cost-conscious business operations, and optimize OLTP and analytics workloads.

This IBM Redpaper™ publication describes some of the innovations that enable IBM eX5 servers to increase efficiency, lower operating costs, and therefore maximize workload optimization.

This publication is directed to IT professionals and decision-makers, such as CEOs, CIOs, CFOs, IBM clients, IBM Business Partners, information architects, business intelligence administrators, and database administrators.

Intel Xeon processors address the workload optimization challenge

The following innovations, among others, enable eX5 servers to optimize workloads:

- Increased chip density

  Chip densities are increasing in each generation of Intel Xeon processors. Increasing the density puts more processing cores in smaller packaging. Using more cores enables parallel execution of multiple software threads on a particular chip. Figure 1 illustrates these changes over time.

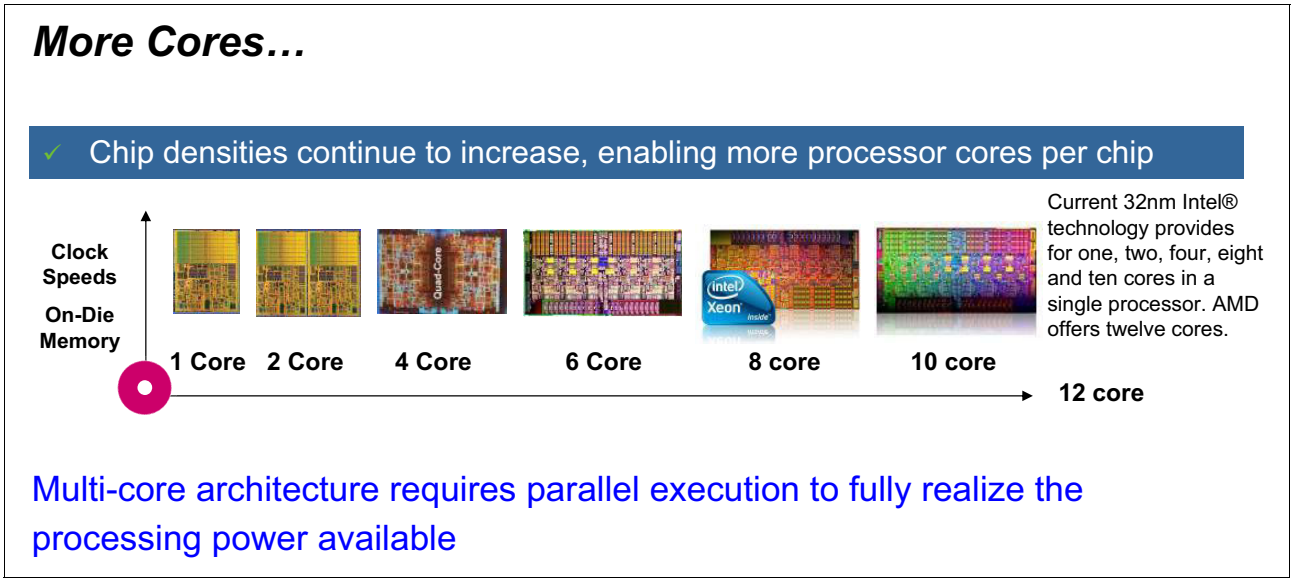

Figure 1 Chip densities are increasing with each generation of Intel x86 processors

- Hyper-Threading Technology

  In addition to core density, an innovation that is called *Intel Hyper-Threading Technology* allows a processor to handle more than one thread at a time. Also known as parallel processing, hyper-threading essentially doubles the number of threads that a processor core supports. The result is an efficiency gain, because the same amount of processor hardware is used to handle more workload by accommodating more process threads. Figure 2 illustrates the concept of hyper-threading.

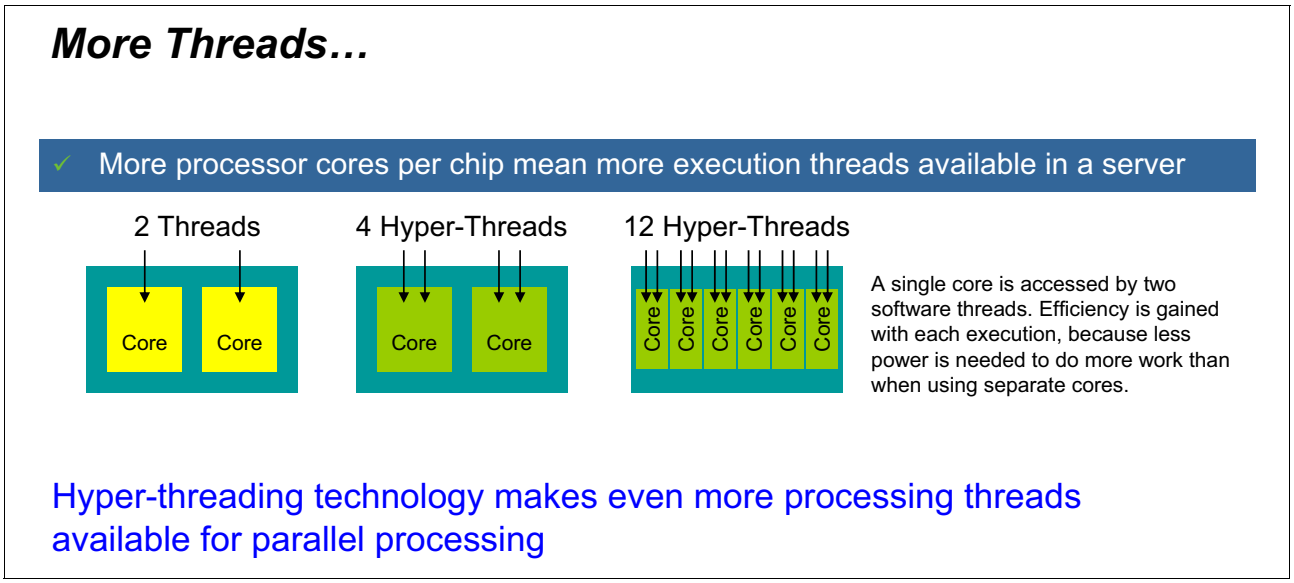

Figure 2 Hyper-threading (parallel processing)

With hyper-threading, a processor core can run multiple threads simultaneously. A physical processor has an architectural state on a single processor core. In Figure 2, each processor has two architectural states per core, making the physical processor appear as two logical processors to service threads.

- Turbo Boost Technology

  A similar technology, also from Intel, is Turbo Boost Technology. Turbo Boost is activated when the operating system requests the highest processor performance state. Headroom is dynamically assessed by continual measurement of temperature, current draw, and power consumption. The maximum frequency of Intel Turbo Boost Technology is dependent on the number of active cores.

  The amount of time the processor spends in the Turbo Boost Technology state depends on the workload and operating environment. Any of the following factors can set the upper limit of Intel Turbo Boost Technology on a workload:

  – Number of active cores
  – Estimated current consumption
  – Estimated power consumption
  – Processor temperature

- On-board cache

  Each processing thread typically must access data for its operations. Therefore, as the number of parallel running threads increases, more memory cache is needed to accommodate frequently accessed data. Figure 3 shows how on-board cache can help.

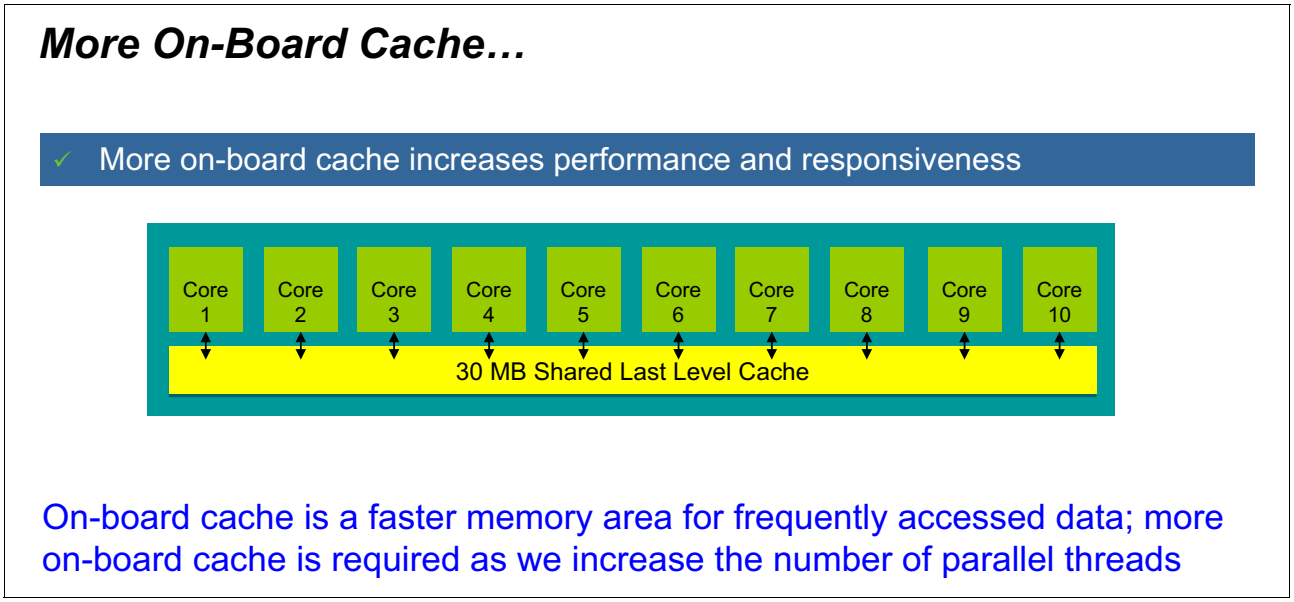

Figure 3 On-board cache is faster memory and helps with hyper-threading

On-board cache is a type of memory cache that is used by processor cores to reduce the average time to access the data in memory. The cache is a smaller, faster type of memory that stores copies of the most frequently used data that is pulled from main memory. If the most frequent memory accesses are cached memory locations, the average latency of those memory accesses is reduced, resulting in faster response time.

The technology in the Intel Xeon family of processors continues to increase the amount of on-board cache available to each core to provide faster performance and responsiveness.

- QuickPath Interconnect

  Before a core can use the contents of its own cache, it must know whether another processor core has the same data that is stored in its cache. To determine this condition, a processor must communicate with the other processors. Formerly, a front-side bus carried all communications traffic. All of this traffic (processor-to-processor and processor-to-I/O) was carried over a single front-side bus. Checking the cache of another processor, which is known as *snooping*, is a task that puts much of the traffic on the front-side bus. In response to this condition, another innovative feature that is called *QuickPath Interconnect* (QPI) alleviates this effect.

In QPI Architecture, processor-to-processor communications are carried over coherent (shared-clock) QPI links, as traffic to the I/O controller is transported over non-coherent QPI links. Figure 4 illustrates this architecture.

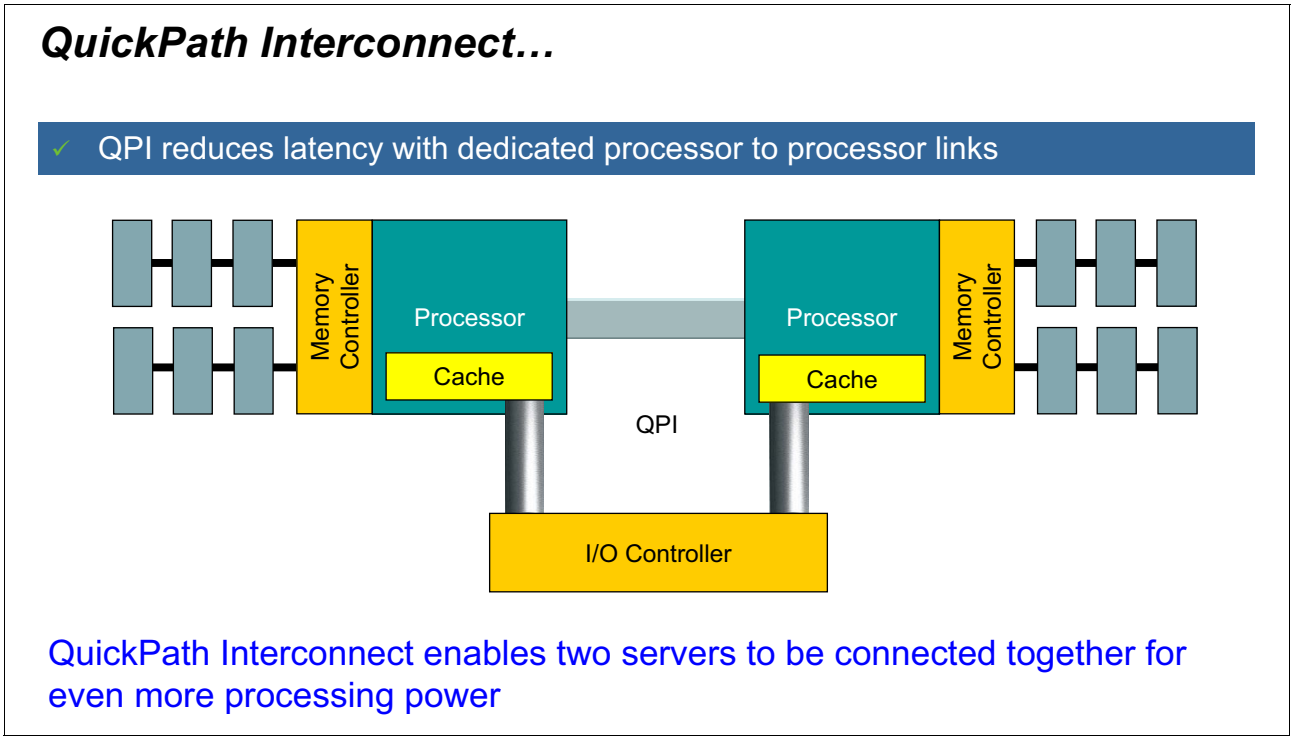

Figure 4 QPI provides for more processing power

The Intel Xeon 6500 and Xeon 7500 families of processors, which are implemented in eX5 servers, include a separate memory controller to each processor. The newly announced Intel Xeon E5-2600 family of processors includes this controller as well.[1] In previous designs that used a shared memory architecture, the entire range of memory on the computer was accessible by each processor. QPI design now creates a non-uniform memory access (NUMA) system. In this system, some of the memory is directly connected to a particular processor in which a specific thread is running. Any additional memory that is needed by that processor must be accessed over a QPI link to another processor. Similarly, I/O can be local to a processor, or remote through another processor.

The ability to access memory through a QPI link gave IBM the avenue to design the Memory Access for eX5 (MAX5) module for IBM System x servers. It also provided a way for IBM to develop the ability to do QPI scaling of two systems into one logical system. For more information about QPI, see “IBM eX5 servers maximize Intel technology” on page 6.

[1] The Intel Xeon E5-2600 family of processors is featured in the following newly announced IBM System x® servers: IBM HS23 BladeCenter®, IBM iDataPlex® dx360 M4, IBM System x3500 M4, System x3550 and System x3650 M4.

IBM eX5 servers maximize Intel technology

IBM is recognized by its clients for its strong product lines, hardware quality and reliability, and service excellence[2]. IBM wanted to help its clients to receive the maximum benefit from advancements in technology. So, in a relatively short time, IBM System x technology used the innovative advancements of Intel to accommodate processing threads on a system.

Figure 5 shows the family of IBM System x, 4-socket servers and how processing thread capacity increased 20 times, from 4 threads in 2001, to 80 threads in 2011. But, the size of the processor decreased by more than 64 percent, from 90 nm in 2001 to 32 nm in 2011.

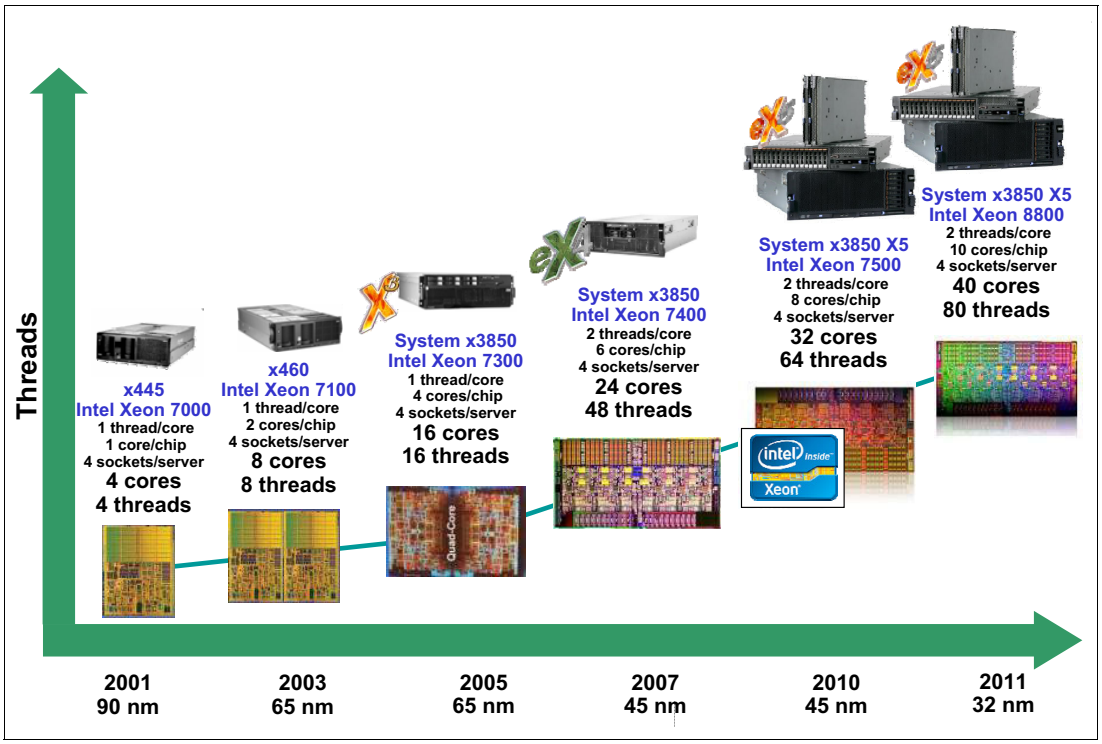

Figure 5 Progression of thread capacity from 2001 to 2011

IBM designed a family of enterprise class eX5 servers that draw upon Intel innovative QPI architecture. This design provides scalability that is unprecedented in x86-based systems. The System x3690 X5, for example, is a 2-socket, rack-mounted system, and the IBM BladeCenter HX5 is a 2-socket blade system. Using QPI technology, IBM designed the HX5 so that a single-image, 4-socket server can be created by scaling a pair of 2-socket BladeCenter HX5 servers. The System x3850 X5 is a 4-socket, rack-mounted system. Similarly, using QPI technology, it is possible to create a single-image, 8-socket, 80-core, 160-thread system by scaling two System x3850 X5 servers.

With the world getting smarter and the demands on IT increasing, eX5 enterprise class servers are able to provide form factors and scalability characteristics that give businesses the flexibility and growth capabilities they need.

[2] *Server reliability has come to the forefront of customer preferences as budgets remain tight*, published by TECHNOLOGY BUSINESS RESEARCH, INC. at: http://public.dhe.ibm.com/common/ssi/ecm/en/xsl03032usen/XSL03032USEN.PDF

Further enhancements that are offered by IBM eX5 servers

Tremendous processing power is required from today's systems. However, processing power alone is insufficient for many current IT workloads.

Consider OLTP and virtualization, for example. In addition to processing power, OLTP and virtualization also require increased memory and storage capacity. In a well-balanced design, a system with tremendous processing capabilities must not be constrained by a bottleneck in either the memory or disk subsystems. The design of System x includes further enhancements to allow for the creation of a balanced design that is well-suited for the workload. Figure 6 shows these enhancements. The following sections provide details about each enhancement.

Figure 6 System x hardware enhancements

IBM System x memory, with and without MAX5

Increases in server real memory often provide dramatic performance improvement. Access to main memory is much faster than access to disk. The more real memory a system has available, the less often data needs to be fetched from the slower disk subsystem. The System x3850 X5, for example, can have up to 2 TB of RAM.

Because of the need to maximize the efficiency of IT utilization and reduce idle time, virtualization is one of the highest-impact trends in IT, with server virtualization one of the fastest-growing IT initiatives for mid-size and large businesses. It is estimated that nearly 50 percent of business applications are hosted by virtualized servers[3]. The MAX5 product addresses this trend. It provides more memory, up to 1 TB, without adding processors. If you combine a System x3850 X5, for example, with MAX5, the design allows for up to 3 TB of memory. MAX5 has the following additional features:

- MAX5 offers the following capabilities:
  - Can be added to any of the eX5 family of servers
  - Provides the additional memory that you need for OLTP and virtualization
  - Provides higher memory capacity with less expensive DIMMs
- By using the MAX5 design, you can benefit from the following advantages:
  - Expand memory capacity (up to 1 TB of additional memory).
  - Partition MAX5 memory to CPUs or pool.
  - Add memory without adding processor cores, reducing hardware and software costs.

Virtualization, however, requires considerable amounts of memory to run effectively. In many cases, the amount of memory that is required by the number of virtualized workloads the

[3] *IBM Virtualization Services*
http://www-935.ibm.com/services/us/its/pdf/idc_white_paper_for_ibm_on_virtualization_srvcs-v2.pdf

processor cores can manage exceeds the amount of memory the system board can accommodate. In this situation, the typical approach was to add another server for the additional memory.

IBM designed eX5 so that you no longer need to add another under-utilized and expensive processor or processors. In fact, if your applications or your need for virtualization require large quantities of memory (more than the system board can accommodate), eX5 servers are designed so you can expand memory with the external MAX5 memory module.

MAX5 works well for some workloads, such as Business Intelligence[4]. As of this writing, it provides the most memory in the industry in 2-socket and 4-socket servers. The ability to add memory without adding processor cores keeps the licensing cost of the software flat, and increases the performance capabilities of the system.

IBM eXFlash storage

IBM eXFlash is a solid-state disk (SSD) storage subsystem[5]. An SSD stores data by using flash memory (solid-state NAND) technology, instead of using spinning disks, such as hard disk drives (HDDs). The NAND-based memory retains its memory even when the power is lost. This feature gives NAND-based memory much faster access time, faster throughput, and less latency. They also use the same interfaces that HDDs use so they can be easily replaced. eXFlash storage has the following primary benefits:

- SSD option for eX5 rack mount servers
- Combination backplane shuttle and disks, compatible controller, which supports RAID 5 and 6 configurations for greater data availability
- 1.8” Form factor, 50/200 GB capacities
- Improved performance for some I/O-intensive workloads

Compared to a regular hard disk drive, SSDs have a lower write endurance, but that gap is narrowing as the technology continues to improve. SSDs also are more expensive than HDDs; therefore, they tend to be used when performance is the gating factor rather than size, although SSDs are closing that gap. From 2000 to 2009, HDD capacity grew five times, from 180 GB to 2 TB. In that same time frame, SSD capacity grew 71 times, from 14 GB to 1 TB.[6]

System x eXFlash is a unique, next-generation flash memory technology. System x eXFlash does more than provide an SSD. It combines SSD technology with a special, optimized controller that delivers maximum I/O. Additionally, by design, eXFlash offers considerable storage density, reliability, energy savings, and throughput. Because of this design, it is ideal for a broad set of applications from database and data warehousing, to video automation and editing, imaging, and more.

Many features of the eXFlash design assist with your storage needs:

- A backplane, RAID controller, and choice of SSD
- High random read/write performance (with I/O that is 100-1000 times better than 10K RPM HDDs)
- Low-power consumption (2.3 W, maximum)

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[4] *Add Memory, Improve Performance, and Lower Costs with IBM MAX5 Technolo*gy at: http://www.redbooks.ibm.com/abstracts/redp4846.html

[5] *Solid State Drives for OLTP Database Optimization: What Difference Can an SSD Make?*, 2012, at: http://www.redbooks.ibm.com/abstracts/redp4849.html

[6] *SSDs and HDDs - how things changed in 10 years* (inset) at: http://www.storagesearch.com/bitmicro-art3.html

- High data integrity and reliability
- A 200-GB drive that offers a maximum IOPS of 240 K
- Eight 1.8-inch drives that fit in the same space as four 2.5-inch drives
- Deploys eight drives per eXFlash:
  - The System x3850 X5 supports up to 16 SSDs, and the System x3690 X5 supports up to 24 SSDs
  - The System x3690 X5 supports three eXFlash packs

IBM Storwize V7000 Unified Storage

As storage needs increase and IT budgets remain flat, what is needed from storage systems is efficiency, intelligence, and automation for more flexibility and less complexity.

The solution is the IBM Storwize® V7000, which provides high performance and high availability, and includes large cache memory as a base feature. The Storwize V7000 control enclosure has eight 8-Gbps Fibre Channel host ports and four 1-Gbps Internet Small Computer System Interface (iSCSI) host ports for connectivity to the storage area network-(SAN)-fabric or host servers. You can have both Fibre Channel and iSCSI host connectivity to an IBM Storwize V7000. The following are the primary intended benefits of the Storwize V7000:

- Enterprise class storage at a midrange price
- Up to twelve 3.5-inch or twenty-four 2.5-inch drives or mix sizes, HDD and SSD (RAID 0, RAID 1, RAID 5, RAID 6, and RAID 10)
- Virtualization and thin provisioning to improve storage utilization
- Block and file storage in a single system
- Cache and SSD option for improved performance
- IBM System Storage® Easy Tier® software automatically allocates SSDs for optimum performance
- Intuitive icons and graphics for point-and-click system management capability
- The ability to move data as necessary and maintain access

The Storwize V7000 comes equipped with four 1-Gbps iSCSI host ports with an RJ-45 connector for each port. The Storwize V7000 can accommodate serial-attached SCSI (SAS) disk drives, Nearline SAS disk drives, and SSDs. Intermixing these drive types in the Storwize V7000 control and expansion enclosures is also supported, adding versatility to these models.

Developed by IBM Research, the IBM Storwize V7000 Easy Tier software automatically scans files for high I/O usage and moves them to higher-performing SSD drives for quick access. IBM provides ProtecTIER®, which is a technology that eliminates duplicate files. Real-time compression software further reduces the storage footprint. IBM also designed non-disruptive migrations, meaning that you can move around data, but you and your clients can still access it, thus reducing one of the main causes of planned downtime.

Quality-of-service features of eX5 servers

Figure 7 illustrates some of the value-added, industry-unique, quality-of-service (QoS) features of eX5 servers.

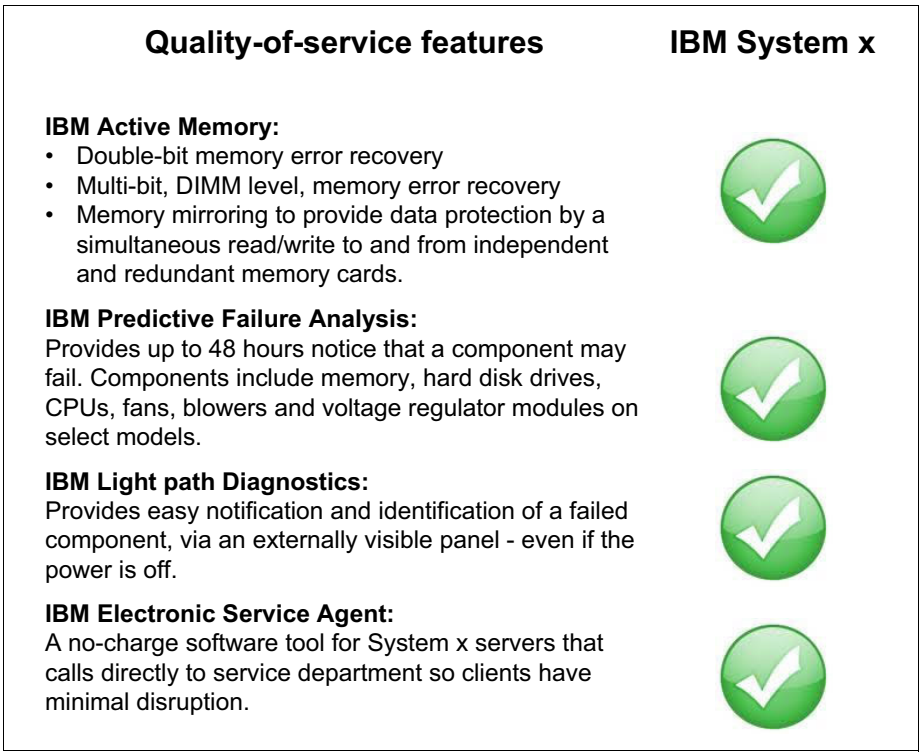

Figure 7 Unique features of System x

Integrating IBM Software with IBM System x

More cores on a system run more workloads on a system, thus reducing the cost per workload. However, the software must be able to use the additional cores that are provided by the hardware platform.

The IBM Software suite of products takes better advantage of the available hardware computing capacity, as shown in Figure 8. Together with the System x hardware and the features that IBM provides, IBM Software takes advantage of the additional cores and threads. IBM Software increases application utilization and efficiency, and delivers better price performance.

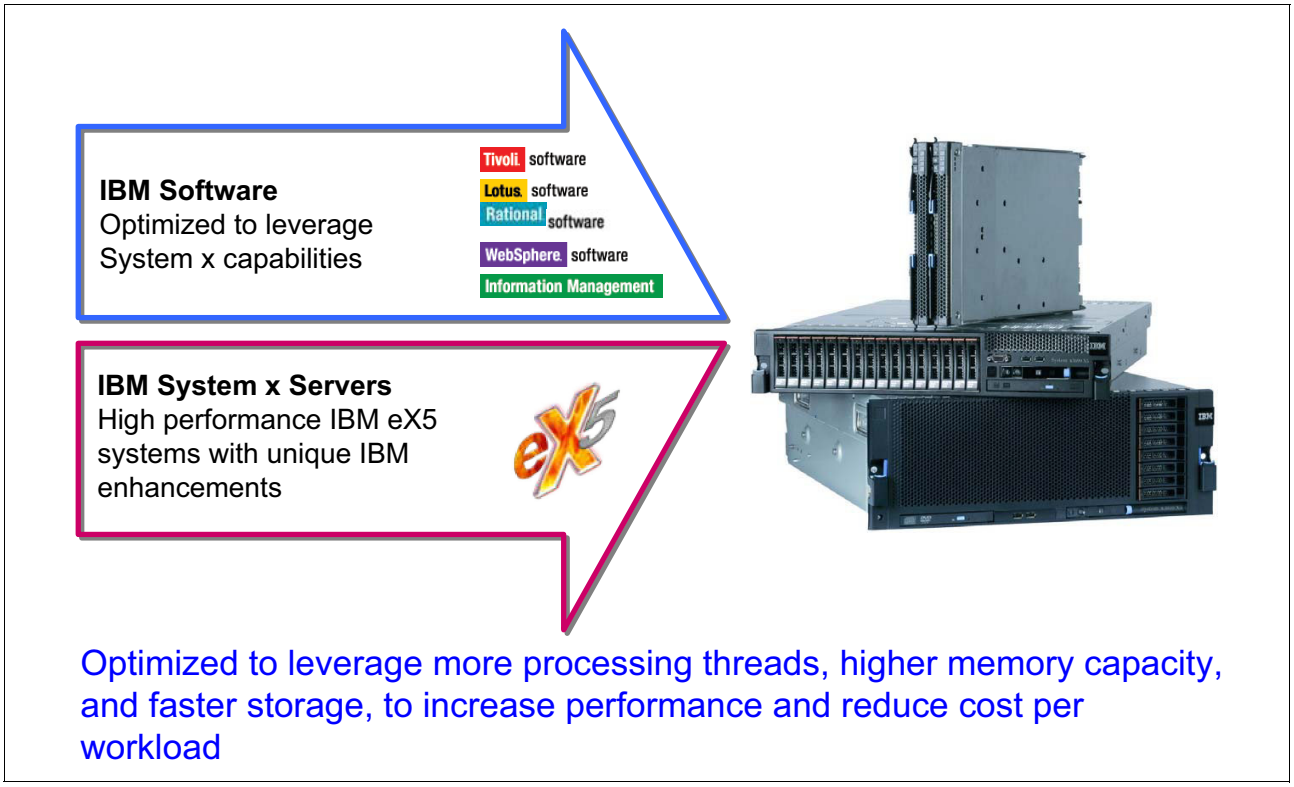

Figure 8 IBM Software, together with System x servers, optimize your workloads

For your most arduous processing workloads, IBM System x provides benefits and features that enable your business to function efficiently and at a lower operating cost.

Web-facing workloads

Web-facing workloads are supported by the multi-threaded processing power and scalability of IBM System x. The IBM Strategy and Technology Lab (STL) conducted in-house testing by using an OLTP application to determine whether MAX5 improved system performance. The System x3690 X5 server was used, and testing was carried out with and without the additional memory that is afforded by MAX5.

Results with MAX5 were significant. Throughput was 2.4 to 4.9 times that of the system without MAX5, and response times were 60 - 80 percent less than the times of the base system. Results also showed that, for one MAX5 system configuration, it can cost 49 percent more for a system without MAX5 to match the performance of a system with MAX5.

For more information about this study, see *Add Memory, Improve Performance, and Lower Costs with IBM MAX5 Technology*, REDP-4846.

Database workloads

Database workloads use System x accelerators to improve performance and reduce cost. STL conducted in-house testing to determine the effect of MAX5 on performance that follows a serial execution test in which successive reports were generated. The cost and performance of the additional memory that is created by MAX5 also was determined. These tests used the System x3690 X5 server and the IBM DB2® to determine the effect, with and without MAX5, on a 1.3-TB data warehouse in a business-analytics environment.

The tests demonstrated the ability to cache up to twice as much information in memory with MAX5, compared with a system without MAX5. This result reduced disk I/O considerably and increased performance and productivity. Having available extra memory for a business-analytics and data warehouse workload is valuable. By caching the data in memory rather than continually reading from disk I/O, response time was improved. Further, with MAX5 for business intelligence workloads, twice as many reports were produced, as demonstrated in a test over a one-week period. Over a three-year period, the cost per report can potentially be 31 - 64 percent lower with the addition of MAX5.

For more information about this study, see *Add Memory, Improve Performance, and Lower Costs with IBM MAX5 Technology*, REDP-4846

Big Data

Big Data refers to huge amounts of data and new processing algorithms that efficiently extract business value from that data. Big Data processing runs well on low-cost System x processing nodes.

New processing techniques enable new, cost-effective solutions for solving the problem of volume, velocity, and variety of data. These new capabilities drive business innovation, but require low-cost processing nodes to be effective. IBM InfoSphere® BigInsights™ and InfoSphere Streams take advantage of IBM System x low-cost distributed computing nodes.

Enterprise service bus

Enterprise service bus operations are optimized by efficient IBM Software and the multi-threaded processing power of IBM System x.

IBM WebSphere® Message Broker and System x deliver significant enterprise service bus performance. Efficient processing with a messaging hub requires the following characteristics:

- Reliability. High-speed, asynchronous messaging backbone, and broad support for connections and protocols
- High performance. Can achieve high throughput (messages per second)
- Scalability. Maximizes cores and threads for optimal performance
- Networking flexibility. Can adapt to changes by reconfiguring rather than reprogramming

Summary

The design of the eX5 line of servers incorporates the innovations of x86-based processors to have a significant positive effect on workload optimization. In doing so, this feature enables a level of scalability that is unprecedented in x86-based systems.

In a well-balanced design, a system with extensive processing capabilities must not be constrained by bottlenecks in either the memory or disk subsystems.

The eX5 servers are intended to provide the enhancements that allow for this balanced design:

- MAX5

  With MAX5, you can take control of virtualization, one of the highest impact trends in IT for mid-size and large businesses. MAX5 provides more memory, up to 1 TB, without the addition of processors.

- eXFlash

  eXFlash is a next-generation flash-storage technology that combines SSD technology with a special, optimized controller that delivers maximum I/O. IBM eXFlash offers significant storage density, reliability, energy savings, and throughput. Because of this design, it is ideal for a broad set of applications, including database and data warehousing.

- Storwize V7000

  The design of the Storwize V7000 provides high performance, high availability, and includes a large cache memory as a base feature. It automatically scans files for high I/O usage and moves them to higher-performing SSD drives for quick access. Both Fibre Channel and iSCSI host connectivity are available to the IBM Storwize V7000.

Combined with the QoS features that IBM incorporated, the eX5 design is the solution of choice. Additionally, the IBM Software suite of products takes advantage of the computing capacity of eX5 servers. Together, the design of the IBM Software, the eX5 hardware, and the enhancements described in this Redpaper, provide increased application utilization and efficiency.

IBM Software and the eX5 line of servers can be the key to improving your OLTP and virtualized environments, optimizing your most arduous workloads and maximizing your IT dollars.

For more information

For more information about the products that are highlighted in this publication, see the following websites:

- The IBM Sales team

  http://ibm.com/systems/x/

- IBM System x home page

  http://ibm.com/systems/x/

- IBM eX5 Enterprise Servers overview

  http://www.ibm.com/systems/info/x86servers/ex5/

- IBM System x3690 X5 server:
  - *Ground-breaking two-socket server delivers outstanding performance, memory, and storage*

    http://www.ibm.com/systems/x/hardware/enterprise/x3690x5/
  - *IBM eX5 Portfolio Overview: IBM System x3850 X5, x3950 X5, x3690 X5, and BladeCenter HX5*, REDP-4650

    http://www.redbooks.ibm.com/abstracts/redp4650.html
- IBM System x3850 X5

  http://www.ibm.com/systems/x/hardware/enterprise/x3850x5/
- IBM BladeCenter HX5

  http://www.ibm.com/systems/info/x86servers/ex5/blade/
- IBM System Storage Easy Tier:
  - IBM Storwize V7000 and Storwize V7000 Unified Disk Systems

    http://www.ibm.com/systems/storage/disk/storwize_v7000/features.html
  - "Easy Tier function" topic in the IBM Storwize V7000 Version 6.4 Information Center

    .ibm.com/infocenter/storwize/ic/index.jsp?topic=%2Fcom.ibm.storwize.v7000.doc%2Fsvc_easy_tier.html
- IBM eXFlash storage

  http://www.ibm.com/systems/info/x86servers/optimized/database/index.html
- IBM MAX5:
  - *Add Memory, Improve Performance, and Lower Costs with IBM MAX5 Technology*, REDP-4846

    http://www.redbooks.ibm.com/abstracts/redp4846.html
  - *The MAX5 Advantage: How IBM System x MAX5 Benefits Microsoft SQL Server Data Warehouse Workloads*, REDP-4751

    http://www.redbooks.ibm.com/abstracts/redp4751.html
  - *IBM Unveils Industry's First Systems that Rewrite Economics of 'Industry-Standard' Computing,* 2010

    http://www.ibm.com/press/us/en/pressrelease/29570.wss
- IBM ProtecTIER:

  http://.ibm.com/systems/storage/tape/ts7650g/
- IBM Systems home page:

  http://www.ibm.com/systems/

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