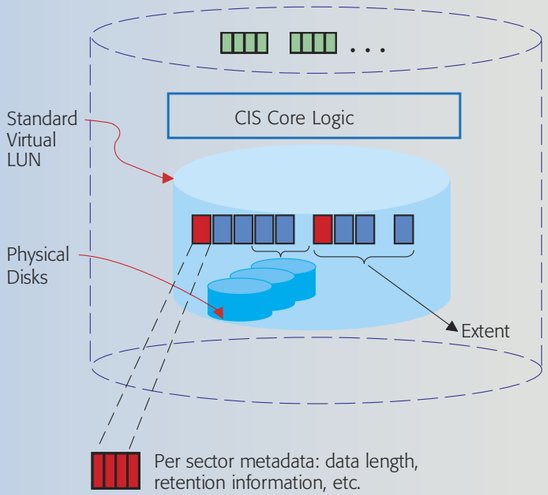
OPERATING SYSTEMS AND STORAGE SYSTEMS

IBM Research's long list of innovations in operating systems and storage includes seminal work on virtual machines, magnetic disk storage, transaction memory, journaling file systems, Redundant Array of Independent Disks (RAID), parallel file systems, and enterprise backup and restore. The advanced technologies developed at Research have contributed to many major IBM products. Early examples include RAMAC®, the first hard disk computer that was introduced nearly 50 years ago, and the Virtual Machine/370 (VM/370), a time-sharing operating system announced in 1972 that provided users with independent virtual computers. AIX®, the IBM Blue Gene® Solution supercomputer, IBM 9337 RAID subsystem, Tivoli® Storage Manager, General Parallel File System (GPFS), and the IBM TotalStorage® family of products are among the notable later examples. In addition, Research has been a key contributor to the open source movement and to Linux™, in particular.

OPERATING SYSTEMS

IBM's research on operating systems addresses the challenges of reconciling both ever-changing program requirements and rapidly advancing hardware technologies, and also investigates improvements in system performance through a number of approaches. For example, research groups are working on a new software architecture for high-performance network servers; on power management schemes that can significantly improve the battery life of mobile devices; and on new operating system designs that allow for online reconfiguration of services, providing a way to extend and replace active operating system components. Hypervisor technology is also being explored to validate features developed for new processors, such as the Cell Broadband Engine™, to study future architecture ideas and functions for the high-performance computing community, and to provide security, resource control, and integrity guarantees for server platforms. In addition, researchers are working on enabling Linux to efficiently support enterprise-level applications, reducing lock contention within the kernel, and developing schedulers that improve scalability under heavy load. AIX efforts center on enhancing the performance, reliability, availability, and system manageability of high-end virtual and flexible servers.

CONTENT IMMUTABLE STORAGE (CIS™) PROTOTYPE OVERVIEW

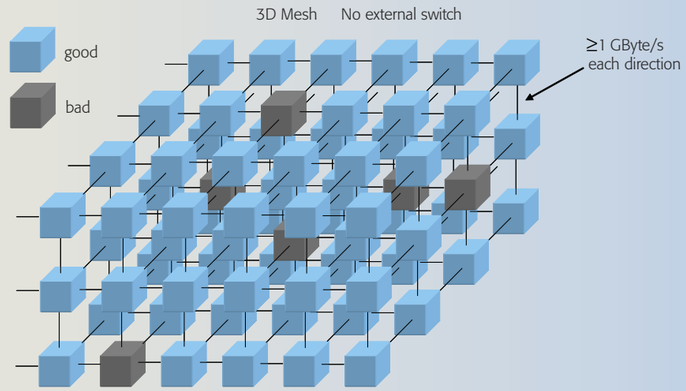


- Virtual Logical Unit Number (LUN) with Write Once Read Many property
- Physical space divided into extents
- Per extent metadata enables data retention functions: term-retention shredding, event trigger, deletion hold
- Small write capability to efficiently support index mechanisms

- CIS Sector
- Data Sector
- Metadata Sector

CIS for Proper and Regulatory Compliance Record Retention (Fossilization™ Project).

3x3x3 'Intelligent Brick' Storage Server (IceCube Project).



STORAGE SYSTEMS

In storage systems, IBM Research's objective is to continue to build innovative systems that use high-speed network protocols, centralize storage management, provide enhanced policy-based storage management functions, and dramatically reduce storage management costs. Another focus is the development of systems that make data sharing across heterogeneous platforms easier to perform, provide incremental scalability that can handle exabytes of data, and ensure high system availability and reliability.

Research in advanced storage functions is being extended into such areas as storage services and solutions, performance and power management, and large storage system deployment. Some of the key challenges include creating holistic and coherent solutions for information lifecycle management, including record retention solutions for regulatory compliance. The Contents Immutable Storage is part of an end-to-end approach called fossilization™ that we are developing to insure that electronic records are trustworty. Innovative solutions are being developed to enhance the reliability, scalability, security, performance, manageability, and cost effectiveness of storage systems. The Intelligent Bricks storage server pictured above is an example of such a solution. With the advent of new, non-volatile "storage-class" memory technologies, which offer the promise of DRAM-like performance at disk-like costs, IBM researchers are exploring the impact of such technologies on the design of computer systems. Key focus areas in storage resource management are availability, utilization, performance, and increased quality of storage service levels that reduce the total cost of ownership.