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ТАДҚИҚОТ ВА ИННОВАЦИЯЛАР ЖУРНАЛИ

ЖУРНАЛ ИССЛЕДОВАНИЯ И ИННОВАЦИИ | JOURNAL OF RESEARCH AND INNOVATIONS

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ADVANCEMENTS IN DATA STORAGE TECHNOLOGIES: A BREAKTHROUGH IN HARD DISK CAPACITY

ANNOTATION

In today's world, where data volumes are increasing daily, the importance of reliable storage technologies becomes critically important. Hard disk technologies, such as Perpendicular Magnetic Recording (PMR) and Shingled Magnetic Recording (SMR), provide a significant increase in capacity without expanding the physical size of devices. These achievements not only enhance data density but also open new possibilities for their use in data centers, cloud storage, and corporate servers, supporting technological progress. The development of these technologies helps to increase the efficiency of storing and processing large volumes of data, which is key to supporting modern business processes and research projects. Future innovations are expected to further increase storage capacity while simultaneously reducing energy consumption and equipment costs.

Keywords: hard disk, Perpendicular Magnetic Recording, PMR, SMR, data storage technology, capacity increase, data centers, cloud storage, innovations in data storage.

ДОСТИЖЕНИЯ В ОБЛАСТИ ТЕХНОЛОГИЙ ХРАНЕНИЯ ДАННЫХ: ПРОРЫВ В ОБЛАСТИ ЕМКОСТИ ЖЕСТКОГО ДИСКА

АННОТАЦИЯ

В современном мире, где объемы данных увеличиваются каждый день, важность надежных технологий хранения становится критически важной. Технологии жестких дисков, такие как перпендикулярная магнитная запись (PMR) и запись с наложением дорожек (SMR), обеспечивают значительное увеличение емкости без расширения физического размера устройств. Эти достижения не только повышают плотность данных, но и открывают новые возможности для их использования в центрах обработки данных, облачных хранилищах и корпоративных серверах, способствуя технологическому прогрессу. Развитие этих технологий способствует повышению эффективности хранения и обработки больших объемов данных, что является ключевым для поддержки современных бизнес-процессов и исследовательских проектов. Ожидается, что будущие инновации позволят ещё больше увеличить емкость хранения при одновременном уменьшении энергопотребления и стоимости оборудования.

Ключевые слова: жесткий диск, перпендикулярная магнитная запись, PMR, SMR, технология хранения данных, увеличение емкости, центры обработки данных, облачные хранилища, инновации в хранении данных.

MA'LUMOTLARNI SAQLASH TEXNOLOGIYASIDAGI YUTUQLAR: QATTIQ DISK SIG'IMIDAGI YUTUQ

ANNOTATSIYA

Zamonaviy dunyoda, har kuni ma'lumotlar hajmi ortib bormoqda, ishonchli saqlash texnologiyalarining ahamiyati tanqidiy darajada muhimdir. Qattiq disklar texnologiyalari, masalan, perpendicular magnit yozuvi (PMR) va yo'laklarni qoplash yozuvi (SMR), jismoniy hajmini kengaytirmasdan sig'imni sezilarli darajada oshirishni ta'minlaydi. Bu yutuqlar nafaqat ma'lumotlar zichligini oshiradi, balki ulardan ma'lumotlarni qayta ishlash markazlarida, bulutli saqlashlarda va korporativ serverlarda foydalanish uchun yangi imkoniyatlar ochadi, texnologik taraqqiyotni qo'llab-quvvatlaydi. Bu texnologiyalarning rivojlanishi katta hajmdagi ma'lumotlarni saqlash va qayta ishlash samaradorligini oshirishga yordam beradi, bu zamonaviy biznes jarayonlari va ilmiy loyihalarni qo'llab-quvvatlash uchun kalitdir. Kelajakdagi innovatsiyalar saqlash sig'imini yanada oshirish imkonini berishi kutilmoqda, bu bilan birga energiya iste'moli va uskunalar narxini kamaytiradi.

Kalit so'zlar. Qattiq disk, perpendicular magnit yozuvi, PMR, SMR, ma'lumotlarni saqlash texnologiyasi, sig'imni oshirish, ma'lumotlarni qayta ishlash markazlari, bulutli saqlashlar, ma'lumotlarni saqlashdagi innovatsiyalar.

Introduction: In the era of digitalization, the volume of data generated and processed in various sectors is growing exponentially. This not only increases the volume of data but also raises the demand for innovative storage technologies capable of handling this increase while ensuring their security and accessibility. The development of technologies such as Perpendicular Magnetic Recording (PMR) and Shingled Magnetic Recording (SMR) is a key element in responding to these challenges.

Current State of Data Storage Technologies: Current data storage solutions range from traditional hard disks to the latest SSDs and cloud technologies. Each of these solutions has its advantages and disadvantages, for example, in terms of data access speed, cost, and reliability. Hard disks remain an important part of this spectrum due to their high capacity and relatively low cost, especially in the context of PMR and SMR technologies, which significantly increase data density.

Breakthrough Technologies in Data Storage: Perpendicular Magnetic Recording (PMR) and Shingled Magnetic Recording (SMR) are significant innovations that increase the amount of data that can be stored per unit area. These technologies not only enhance the overall capacity of devices but also contribute to the development of archival data storage, where the speed of writing is not a critical factor. The integration of modern technologies with cloud solutions also begins to play a key role in optimizing data management and ensuring their reliability and availability on a global scale [1].

Impact on Industry and Business: Innovations in data storage led to significant changes in the business landscape, allowing companies to reduce operational costs and increase the efficiency of data processing. Enhanced big data analytics directly impacts strategic decision-making and can significantly improve the operational activities of companies in various sectors.

Future Directions and Growth Potential: The integration of artificial intelligence and machine learning with data storage systems is expected to open new opportunities for automating and optimizing data management. These technologies provide the ability to create self-learning systems that can adapt to changes in data and optimize processes without direct human intervention, supporting the development of smart cities, advanced healthcare systems, and personalized marketing.

TRIM Technology: An In-depth Analysis of Its Impact on SSDs.

Introduction to TRIM Technology: TRIM technology is a key mechanism for optimizing the performance of solid-state drives (SSDs), aiding in their performance enhancement and lifespan extension. Introduced as an ATA standard under the DATA SET MANAGEMENT command, TRIM plays a crucial role in managing the data deletion process on SSDs. This technology allows the operating system to inform SSDs about data blocks that are no longer considered necessary and can be erased.

What a TRIM Works: At a low level, TRIM modifies the data usage map of the storage device, allowing the SSD controller to efficiently redistribute the writing of new data to "fresh" blocks, minimizing wear and enhancing writing speed. In traditional HDDs, unused data is simply overwritten, but in SSDs, each data block must be erased before being overwritten, which can significantly slow down the writing operation if TRIM is not used.

Thermodynamics and Kinetics of Erasure Processes in SSDs: The erasure process in solid-state drives involves changing the state of electrical charges in memory cells. Each memory cell consists of a transistor with a floating gate, which can store electrons. When data is written, electron charges accumulate, modifying the threshold voltage of the transistor, which determines whether the cell will represent a bit 0 or 1. Erasing data involves removing electrons, which requires the application of reverse voltage, causing electron tunneling through the oxide film. This process can lead to the degradation of the oxide layer and a reduction in data storage reliability.

TRIM's Role in Maintaining SSD Performance: By using TRIM, SSDs can effectively "clean up" old data at the physical level, avoiding the need to erase data blocks at the moment of writing new ones. This not only provides a higher writing speed but also reduces the load on the controller, thereby extending its service life. Additionally, TRIM technology improves wear leveling, distributing write and erase operations evenly across all memory blocks, preventing the premature failure of individual cells [2].

End-to-End and Hardware Encryption: Key Technologies for Data Confidentiality Protection

End-to-End Encryption: End-to-End Encryption (E2EE) is one of the most effective methods for protecting data transmitted and stored in network and cloud services. This method ensures that data is encrypted on the sender's side and remains encrypted throughout its entire journey and storage, being decrypted only on the receiver's side. This prevents the possibility of interception and reading by third parties, including cloud service providers and Internet providers.

Hardware Encryption: Hardware encryption provides data protection at the physical device level, using encryption mechanisms typically implemented on storage device controllers, such as SSDs and HDDs. This method of encryption is independent of the operating system software and offers high data processing speed while maintaining a high level of security. Hardware encryption is particularly effective for protecting data in case of unauthorized physical access to the device [3].

Conclusion: TRIM technology is an integral part of modern solid-state drive architectures, aiding in optimizing their operation and enhancing the overall efficiency of data storage systems. As SSD technologies develop, the role of TRIM will only strengthen, as the importance of fast and reliable data processing continues to grow in the field of information technologies. The incorporation of end-to-end and hardware encryption into modern storage architectures enhances the importance of technologies such as TRIM and other contemporary data management methods. These encryption technologies play a crucial role in ensuring data confidentiality and security, which becomes increasingly important in conditions of growing digital information volumes and cybersecurity threats. The development of data storage technologies, including innovations in the field of encryption, remains at the forefront of technological progress, essential for ensuring not only efficiency but also the reliability of future information systems. Thus, continuing innovations in this area will support the stability, speed, and confidentiality of data in an increasingly information-saturated global environment.

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