The New Norm for Escalating PC Memory Demand

More DRAM and NVMe SSD

White Paper

SAMSUNG

More DRAM and NVMe SSD: Answers to today's escalating PC memory needs

Industry trends

The way PC is being used is changing, shifting many tasks away from the computer and onto smartphones. What remains on PC are those tasks with the most pressing and complex performance demands. As users go to their PCs for multi-tasking and 3D gaming, together with the improved resource utilization of new graphics APIs, the importance and benefits of putting high-performance memory and storage are greater than ever.

New complex applications are pushing memory limits

As users increasingly take advantage of fully-featured, cloud-based HTML5 applications, memory demands are growing swiftly. HTML5 websites can require more than three times as much memory as HTML4 sites[1]. On top of that, a recent survey[2] shows that 59% of PC users keep 6 or more websites open at a time. These trends together increase the minimum memory requirement for a typical PC to at least 4GB of DRAM, as illustrated in Figure 1.

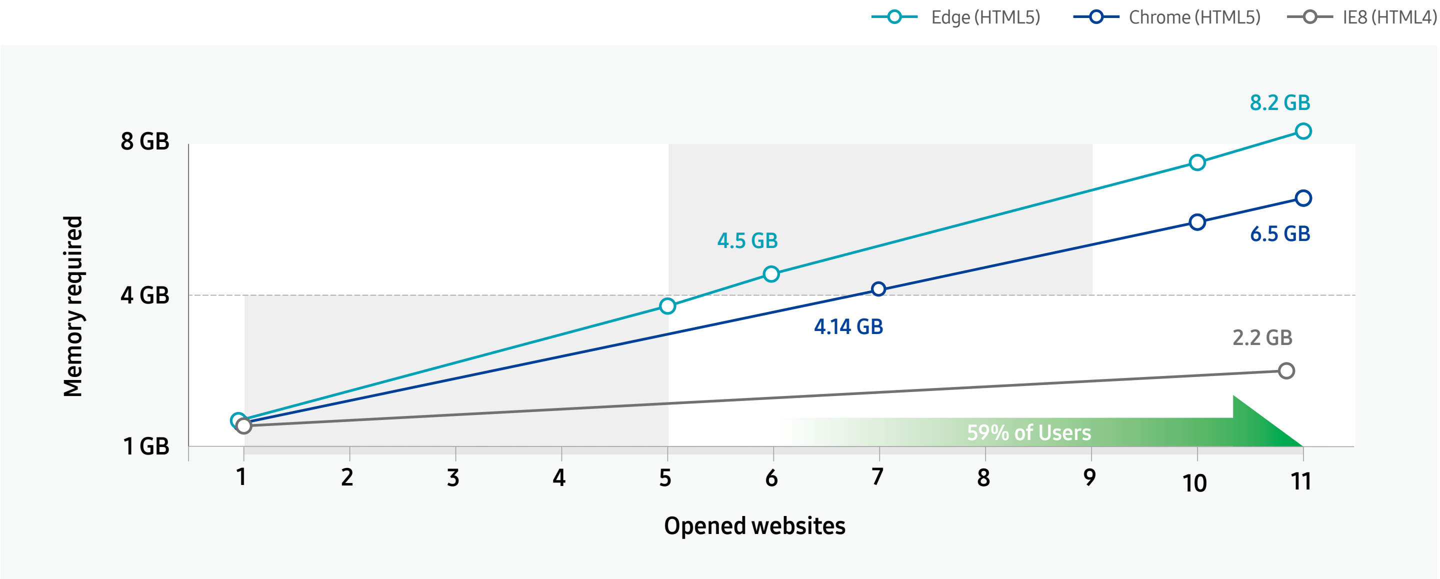

Figure 1. Memory requirements for web browsing[1]. 59% of users keep six or more websites open at a time, requiring more than 4 GB of DRAM for HTML5 applications.

Moreover, the introduction of Microsoft's latest DirectX12 graphics APIs means that 3D gaming and other 3D graphics applications are able to make better use of DRAM resources than before. Benchmarks[3], as shown in Figure 2, indicate that DirectX 12 could improve the system's 3DMark score by as much as 10 times the performance of the same system under DirectX 10, but requires nearly double the DRAM to do so. For users hoping to use their PCs for 3D gaming or other graphics-intensive applications, 8 GB of DRAM is effectively now the minimum.

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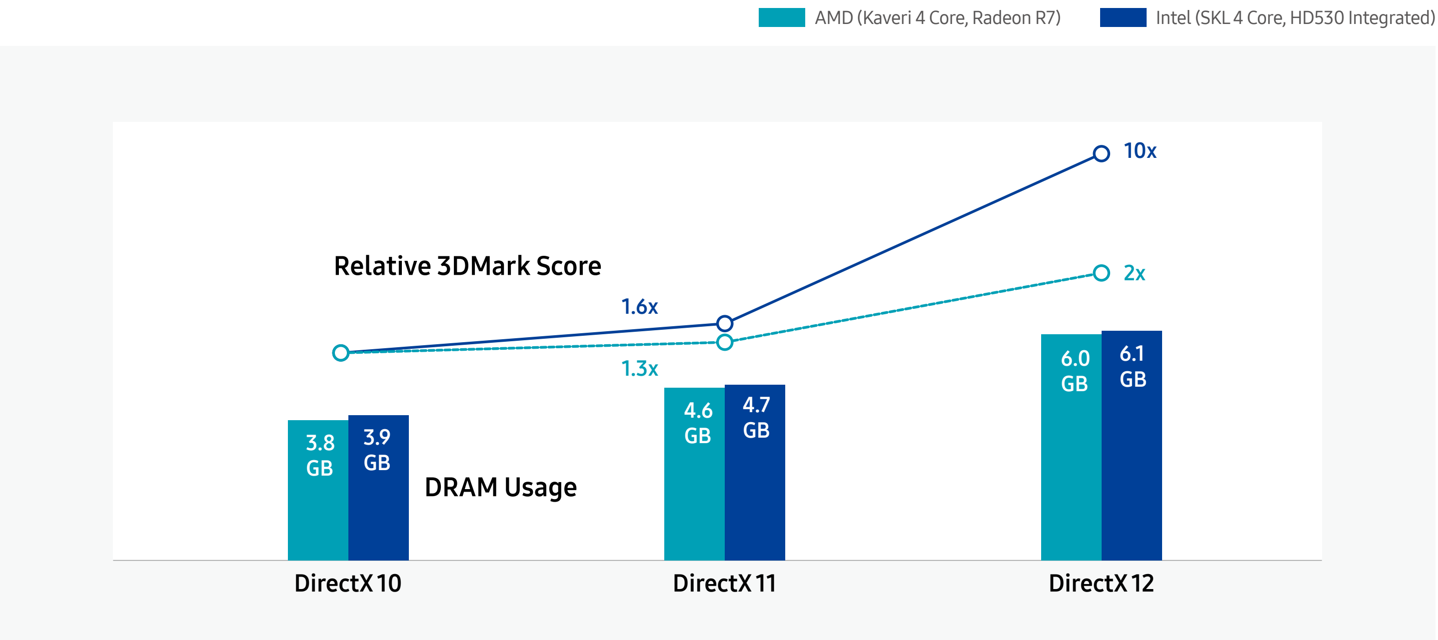

Figure 2. Illustrates 3D graphics DRAM usage and performance[3]. The performance gain of DirectX 12 depends largely on additional DRAM.

In addition to DRAM, storage device speed greatly affects the user's experience in loading and saving video games, watching downloaded movies, and opening new programs. For many years, the main storage available for PCs was in the form of spinning magnetic HDDs (hard disk drives). Because these HDDs were highly limited by their mechanical nature, legacy storage interfaces like SATA were designed without much focus on high speeds.

The introduction of NAND-based SSDs has greatly improved the latency and performance of storage, but they are highly limited by legacy storage interfaces. To overcome this limitation, the industry introduced the NVMe standard to better realize the potential of SSD storage. PCMark Vantage test results[4] show that the performance of NVMe SSDs is more than 20 times higher than HDDs, providing a significant improvement in the user experience.

New solutions are emerging but still immature

Due to these new memory demand dynamics, new memory media are emerging, aiming to bridge the cost and performance gap between DRAM and NAND. Ideally, these solutions can provide the speed of DRAM with the capacity, cost and non-volatility of NAND. PRAM (Phase-change RAM) is the farthest along in the development cycle among the emerging technologies. Vendors are using it as a storage cache to accelerate HDD performance. However, current PRAM technology is still immature and not yet optimized for mainstream commercial use. Four main shortfalls are identified, which may take years to resolve.

- **Low endurance:** Further material science and cell structure research are needed.
- **High power consumption:** Further material and end-device development are needed.
- **High cost:** The manufacturing process is not yet optimized.
- **Underdeveloped ecosystem:** Standardization is not established. Current solutions are mostly based on proprietary interfaces and software, restricting market exposure and adoption.

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DRAM cannot be substituted

While the current PRAM solution can be used as storage cache to reduce loading times for some applications, it doesn't improve performance and responsiveness for graphics-intensive applications. Under the 3DMark benchmark test, there's virtually no performance impact when adding a small amount of PRAM to HDD, whereas, the score increases by 20 to 25% when the amount of DRAM is doubled from 4 GB to 8 GB[5], as shown in Figure 3.

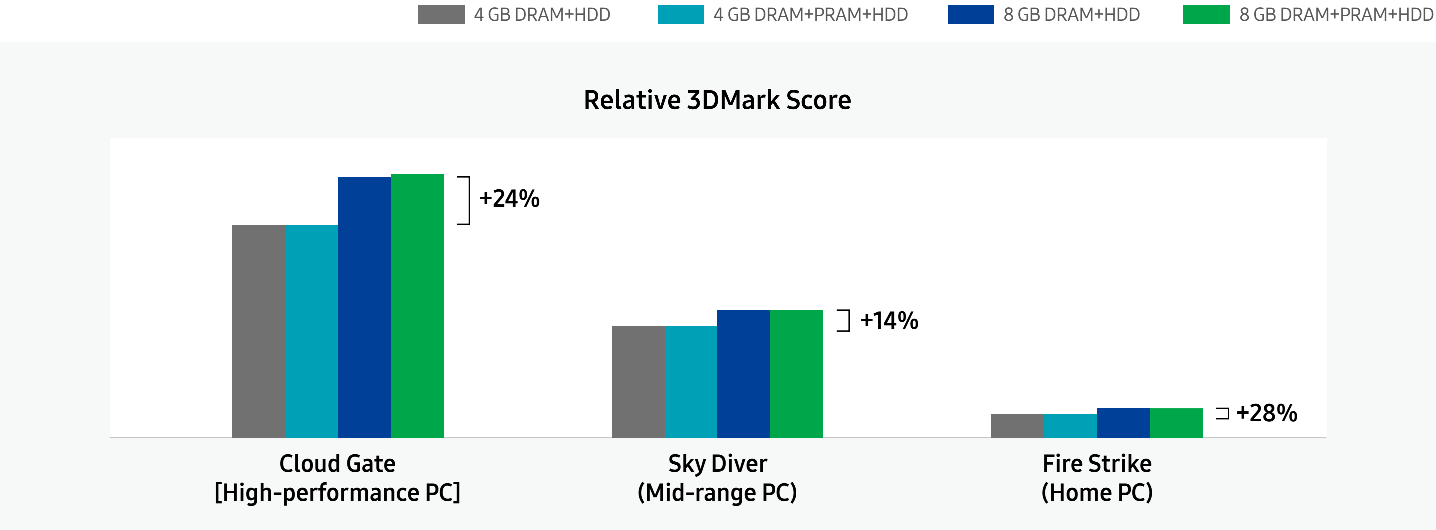

Figure 3. Effects on 3D performance of PRAM and DRAM[5]. 3D performance depends solely on DRAM.

In addition, current PRAM endurance is insufficient for compute memory functionality, where data is being re-written frequently. With an endurance that is only 10 times better than NAND-based SSD, it is still far from reaching the typical compute memory usage. The needs for additional DRAM cannot be fulfilled by current PRAM solution. Users still have to rely solely on DRAM to improve their graphics needs.

NVMe SSD is still the fastest and the most reliable storage solution

To cost-effectively speed up storage operations, vendors developed caching systems that use PRAM as a memory cache to accelerate traditional HDD. While the performance of any caching system depends greatly on the workload, the current PRAM/HDD solution does not come close in matching the performance of an NVMe SSD. The PCMark Vantage score of the NVMe SSD is more than 20 times higher than PRAM/HDD on the first run. Even after caching sets in, the NVMe SSD is still approximately 1.6 times higher than PRAM/HDD[4], depicted in Figure 4. Additionally, storage-caching solutions have some unavoidable limitations, such as cold caches, cache evictions and increased complexity. These will ultimately restrict utilization by consumers that rely on performance consistency and large datasets.

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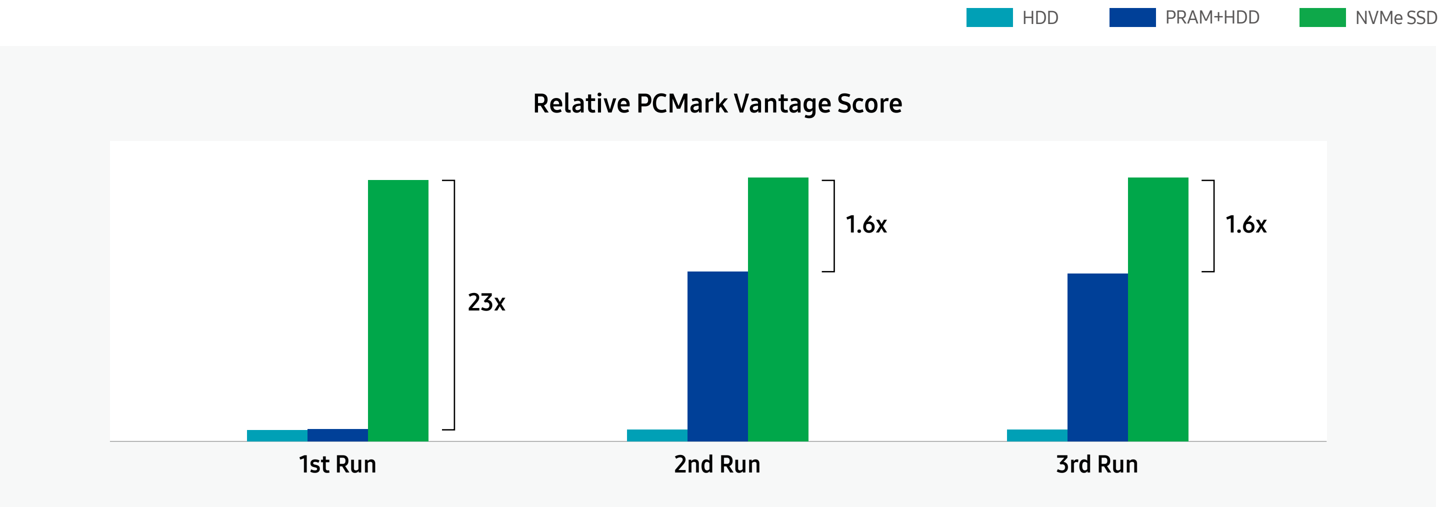

Figure 4. PCMark Vantage scores for PRAM and NVMe SSD[4]. The NVMe SSD has the best performance; 1.6 times better than the PRAM/HDD solution.

Current PRAM products also lack a proper power-saving mode, resulting in very high idle power consumption, which can be more than 10 times that of an NVMe SSD. Using PRAM as a cache will likely only increase the already high energy demands of the HDD. Under the SYSmark 2014 SE energy consumption overall benchmark, the NVMe SSD consumes 13% less energy compared to PRAM/HDD[6]. This difference will be a huge concern to notebook and mobile users, since battery life will take a significant hit.

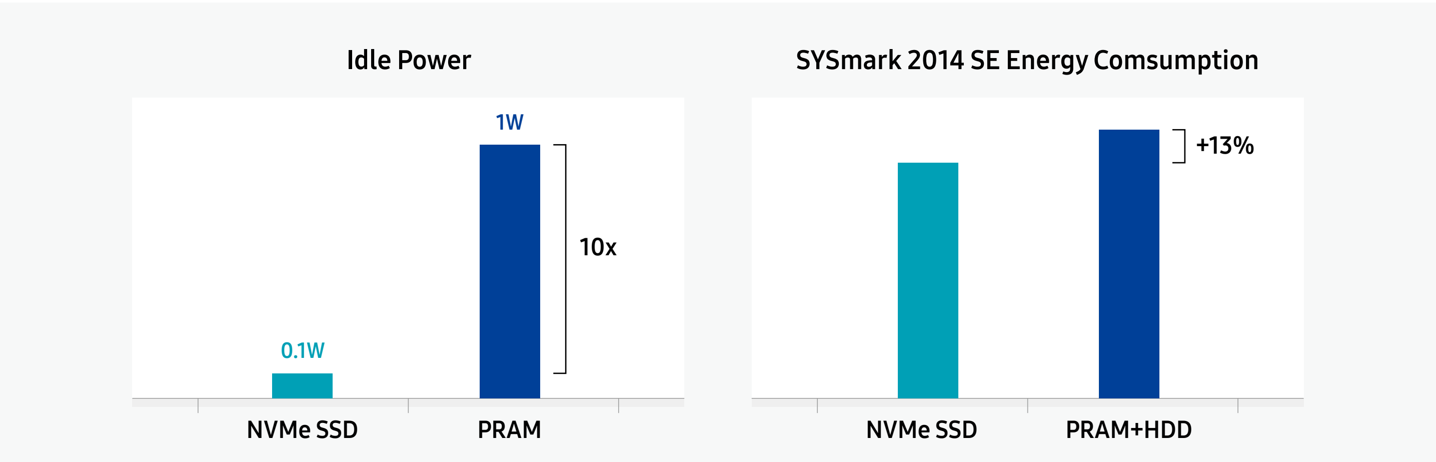

Figure 5. Power consumption comparison between the NVMe SSD and PRAM[6]. NVMe SSD consumes significantly less power.

Conclusion

Utilizing PRAM as a cache solution is just a bandage on slow, legacy spinning storage, while adding a great deal of complication for only a tiny performance benefit. Any caching or hybrid solution will always depend on the workload, but for most users' everyday tasks, the lag from storage access will be very apparent. No caching can take the place of consistent performance from a faster media.

In place of adopting new and complicated technologies, the user's best choice is to invest in standard memory solution, and the interfaces designed to support them. Adding additional DRAM or substituting HDD with NVMe SSD to the system is the most cost-effective way for a PC user to get the best and most reliable performance from their machines.

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Footnote :

1. HTML benchmark system: Intel Haswell i5 5200m, 2*4 GB DDR3, Windows10 x64
2. Notebookreview.com, June 2013
3. Intel test system: Intel 4-core Skylake-S CPU, 2*4 GB DDR4; AMD test system: 4-core Kaveri CPU with a Radeon R7 GPU, 2*4 GB DDR3.
4. SSD test system: Intel Core i7-7700K, ASUS Prime 270-A, 2*4 GB DDR4, HDD (HGST)/SATA (850 PRO)/NVMe (960 PRO), Windows 10 x64
5. DRAM test system: Intel Core i7-7700K, ASUS Prime 270-A, 4 GB DDR4/2*4 GB DDR4, Windows 10 x64
6. Power test system: Intel Core i5-7400, ASUS B250-PLUS, 2*8 GB DDR4, NVMe (960 EVO), Windows 10 x64. Anandtech.com, April 2017

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