4. Find the current listing (64th) for the Top500 list for November 2024. Review the system architecture for each of the top 10 systems on this list. Provide a summary of trends that you find and discuss what kind of system you would design in the future so that it could be included in this impressive list. Make sure to provide a diagram of the architecture you would develop, and include details of the CPUs, memory and interconnect used.

Answer:

(a) The November 2024 TOP500 list features some of the latest supercomputers. Here's a clear overview of the top 10 supercomputers and some key trends:
(https://www.top500.org/lists/top500/2024/11/highs/)
(https://www.top500.org/lists/top500/list/2024/11/)

- **El Capitan** at Lawrence Livermore National Laboratory, USA, comes first with an HPL benchmark of 1,742 PFlop/s. It uses AMD's 4th Gen EPYC CPUs and Instinct MI300A accelerators, along with Cray's Slingshot-11 network for data sharing.
- **Frontier**, based at Oak Ridge National Laboratory, USA, is second with 1,353 PFlop/s. It uses 3rd Gen AMD EPYC CPUs, AMD Instinct 250X processors, and the Slingshot-11 interconnect.
- **Aurora** at the Argonne Leadership Computing Facility in the USA is in third place, with a speed of 1,012 PFlop/s. This system has Intel Xeon Max Series processors and Intel Data Center GPU Max Series accelerators connected by Slingshot-11.
- **Eagle**, a cloud server from Microsoft Azure in the USA, is in fourth place with a performance of 561.2 PFlop/s. It uses Xeon Platinum 8480C processors and NVIDIA H100 accelerators, which are linked together with NVIDIA Infiniband NDR connections.
- **HPC6** at Eni S.p.A. in Italy is ranked fifth, running at 477.9 PFlop/s. This supercomputer uses 3rd Gen AMD EPYC CPUs and AMD Instinct MI250X accelerators, connected through Slingshot-11.
- The supercomputer **Fugaku** in Japan is ranked sixth, with a speed of 442 PFlop/s. It uses Fujitsu's ARM-based A64FX CPUs and Tofu interface D.
- The **Alps** supercomputer at the Swiss National Supercomputing Centre is ranked seventh. It has NVIDIA Grace CPUs and GH200 Superchip accelerators, achieving a speed of 434.9 PFlop/s. It also uses Slingshot-11 for networking.
- **LUMI**, which is in Finland, is ranked eighth with a performance of 379.7 PFlop/s. It uses technology similar to HPC6, showing that Slingshot-11 is used in many leading systems.\
- **Leonardo**, located in Italy, uses Xeon Platinum CPUs and NVIDIA A100 accelerators. It is placed ninth and has Quad-rail NVIDIA HDR100 InfiniBand.
- **Tuolumne** at Lawrence Livermore National Lab in the USA, which is similar to El Capitan, also uses AMD technology and Slingshot-11. It is ranked tenth.

(b) The TOP500 list of supercomputers shows important trends and information about the designs of the highest-ranking systems. Here are the main traits and trends of the top 10 supercomputers:

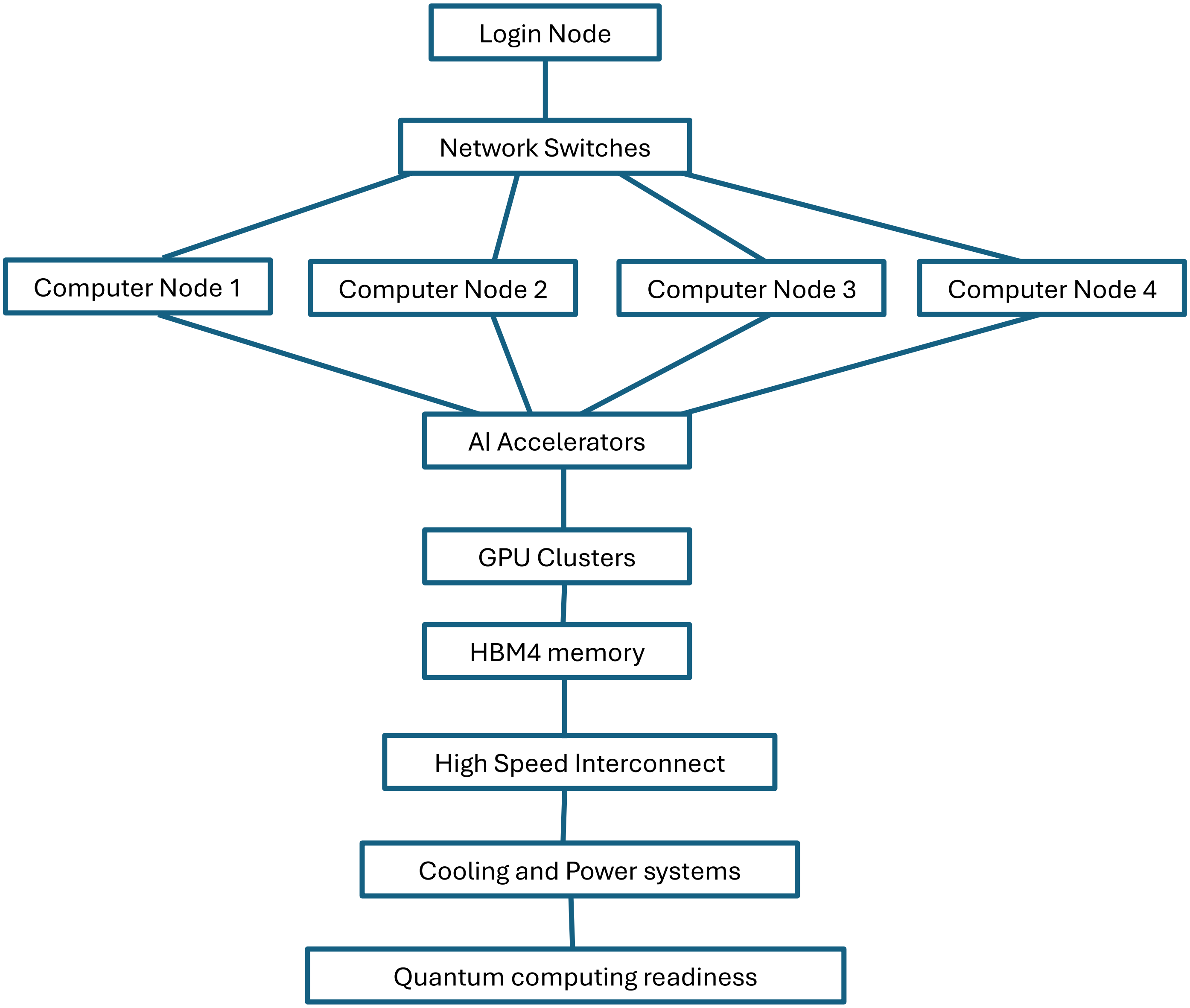
- **Increased use of hybrid architecture**: This architecture integrates high-core count CPUs with robust GPUs or dedicated accelerators. Almost all of the top 10 supercomputers currently adopt this methodology, utilizing GPUs like **AMD Instinct MI300A, Intel Data Center GPUs, and NVIDIA H100s** to enhance parallel processing tasks. These architectures enable CPUs to execute serial operations while GPUs perform extensive parallel computations, markedly enhancing performance and maximizing power economy.
- **Special emphasis on AI/ML Workloads**: Top systems like **Eagle, Leonardo**, and **Aurora** are made to help with deep learning as well as regular high-performance computing (HPC) jobs. The rise of big AI models has increased the need for powerful GPUs and AI-focused hardware, highlighting the importance of supercomputers in developing and using these advanced AI models. This trend shows that the lines between AI and supercomputing are becoming less clear, as supercomputers are now essential for improving AI technologies.
- **High-Speed Networking**: To connect everything and manage data flow effectively, we need to use advanced networking technology like Slingshot-11 and future versions.
- **Exascale Computing:** Three systems are now working at an exascale level, meaning they can do at least one exaflop or a billion billion calculations every second. El Capitan, Frontier, and Aurora are all located in the USA and are part of the Department of Energy.
- **Scalability and flexible system design**: It is now very important for making supercomputers last longer and work better. Many new systems, like Frontier and Aurora, have blade-based designs. This means you can update parts of the system without having to replace everything. This flexible method can also be seen in cloud supercomputing systems like Microsoft's Eagle, which lets users easily adjust their computing resources based on their needs. These new ideas make HPC systems easier to change, which helps lower the cost of upgrading big gear.

(c) **Proposal for the future computer for the top500**:

To build a future TOP500 supercomputer, it must offer very fast performance, have high-speed connections, be able to grow and change easily, use both CPUs and GPUs (or other accelerators), and be suited for artificial intelligence and machine learning tasks.

- The supercomputer incorporates a hybrid computing model that integrates high-performance CPUs, GPUs, and AI accelerators. The system leverages AMD EPYC 6th Gen CPUs, featuring 256 cores per socket, optimized for multi-threading and high-memory bandwidth to handle complex parallel workloads efficiently.
- NVIDIA GH300 Tensor Superchip GPUs and AMD Instinct MI400X accelerators provide huge parallel processing power, making the system ideal for deep learning, AI inference, and scientific simulations. Custom AI processors like Tensor Processing Units (TPUs) or Graphcore's AI chips are used for specific machine learning tasks. These tools lower the amount of computing power needed and use energy more efficiently.
- This supercomputer is equipped with HBM4 (High Bandwidth Memory 4) for ultra-fast memory access, ensuring terabytes per second of bandwidth. A CXL 3.0 (Compute Express Link) interconnect is implemented, allowing memory pooling between CPUs, GPUs, and AI accelerators.
- This supercomputer employs cutting-edge high-speed networking technologies to ensure low-latency communication between compute nodes. The system utilizes Slingshot-12 interconnects, designed for exascale-level scalability, along with NVIDIA Quantum-2 InfiniBand NDR 800G, which offers extreme bandwidth for rapid data exchange.
- This supercomputer uses cryogenic cooling to dissipate heat directly from the processors significantly reducing power consumption and ensure stable operation for superconducting quibs.

(d) The **diagrammatic block diagram** of the future supercomputer which contains Login Node, Network Switches, Compute Nodes, AI Accelerators, GPU Cluster, HBM4 Memory, High-Speed Interconnects, Cooling & Power Systems, and Quantum Computing Readiness


Login Node
Network Switches
Computer Node 1
Computer Node 2
Computer Node 3
Computer Node 4
AI Accelerators
GPU Clusters
HBM4 memory
High Speed Interconnect
Cooling and Power systems
Quantum computing readiness

5. Find the current listing (18th) for the Green500 list for November 2024. Review the system architecture for each of the top 10 systems on this list. Discuss the differences that you see from this list and the list for the Top500 you found in question 4. Also compare it to the 1st Green500 list for June 2013

Answer:

(a) The Green500 list showcases the most energy-efficient supercomputers in the world, with a particular focus on gigaflops per watt performance. The Top 10 systems of the Green500 list is:

- **JEDI**, the top system on the Green500 list, is known for its excellent energy economy. The BullSequana XH3000 uses NVIDIA's Grace Hopper Superchip and GH200 Superchip to provide an impressive energy efficiency of 72.733 GFlops per watt. This efficiency comes from its powerful GPUs and the advanced Quad-Rail NVIDIA InfiniBand NDR200 connection. Its architecture, focused on maximizing efficiency per watt, marks it as a pinnacle of energy-efficient design.
- **ROMEO-2025:** It's similar to the JEDI system in technology but has more than double the number of cores. This growth in size lowers energy efficiency to 70.912 GFlops/W, showing that it's hard to keep efficiency when things get bigger. Still, it demonstrates impressive energy control using the same advanced technology.
- **Adastra 2:** It uses AMD's 4th Gen EPYC CPUs and Instinct MI300A GPUs and is very energy efficient, reaching 69.098 GFlops per watt. This system shows how AMD's technology can be improved to save a lot of energy, making it a great choice for eco-friendly work.
- **Isambard-AI phase 1:** It uses NVIDIA's new Grace and GH200 chips to enhance AI and deep learning, getting energy efficiency of 68.835 GFlops per watt. Its design shows how specialized AI supercomputers can work well under heavy workloads.
- **Capella:** It has strong computing power that is great for complex scientific jobs, thanks to AMD EPYC CPUs and NVIDIA H100 GPUs. It has an energy efficiency of 68.053 GFlops per watt, showing how modern parts can be adjusted for great performance while using less energy**.**
- **JETI**: It is one of the biggest systems available, known for its great performance and high energy economy. This balance is reached by using NVIDIA's Grace Hopper and GH200 superchips, along with a fast InfiniBand connection, showing that big systems can be energy efficient.
- **Helios GPU**: It focuses on computations that require a lot of processing power from GPUs, which is especially useful in scientific study. With an energy efficiency of 66.948 GFlops per watt, this shows how GPUs can deliver good performance while using less power.
- **Henri:** It combines Intel Xeon CPUs with Nvidia H100 GPUs, leveraging the high-speed InfiniBand HDR interconnect to enhance data transfer efficiency. Despite its smaller size

compared to other top-ranked systems, Henri achieves an impressive energy efficiency of 65.396 GFlops/W. This configuration makes it particularly effective for a range of tasks requiring both high compute capabilities and energy efficiency.

- **HoreKa-Teal**: It uses AMD EPYC 9354 processors and Nvidia H100 GPUs, which are linked by Infiniband NDR200. This system can manage different types of tasks effectively, balancing how well it works with how much energy it uses, reaching a rate of 62.964 GFlops per watt. Its design is made to deliver strong performance while using less energy, making it ideal for various uses, from scientific study to handling large amounts of data.
- **rzAdams**: It uses AMD's 4th Generation EPYC CPUs and Instinct MI300A GPUs, connected by the Slingshot-11 system. This method works very well, achieving 24.38 PFlop/s and using energy efficiently at 62.803 GFlops per watt. rzAdams shows how AMD technologies can create powerful supercomputers that use energy efficiently, making it important for environmentally aware computing setups.

(b) Difference between the top 10 systems in the Green500 and Top500 list are:

Feature	Top 500	Green 500
Technological Adoption	Promotes the use of energy-saving tools.	Emphasizes improving processing power, often valuing strength more than speed.
Economic Implications	Lowers operating costs by saving energy, which is good for the long-term sustainability of computer centers.	Higher operational costs from energy needs, which come with more funds and recognition.
Policy and Regulatory Impact	Helps achieve world energy efficiency goals and may affect policies for using sustainable technology.	Shows the country's technology skills, affecting science and tech rules and financial support.
Innovation Drivers	Works on new ways to make processing, cooling, and power control more efficient.	Promotes faster and more powerful computer systems, resulting in important improvements in processing technology.

Scalability Concerns	It's harder to stay efficient as things get bigger; it's usually easier to be efficient in smaller systems.	It focuses on being able to manage large amounts of work, which often results in new ideas for system design and growth.

(c) Comparison of Green500 list of 2024 with Green500 list of 2013:

The comparison of the Green500 lists from 2024 and 2013 shows that supercomputing energy efficiency has greatly improved over the past ten years. The difference and trends from 2013 to 2024 is as follows:

- **Integration of renewable energy**: In the past ten years, there has been more focus on not just making things work better with less energy, but also on using renewable energy to power them. This trend is part of a bigger effort in the tech industry to lower the carbon emissions from large data centers.

- **Technological evolution**:
  - **Cooling Technologies**: New advancements in cooling technologies have been very important. In 2013, the best systems, like Eurora, used water cooling. By 2024, systems probably use even better cooling methods, such as liquid or immersion cooling, which are more efficient and better for the environment.

  - **Processor and GPU Development**: The move from older GPU models, such as the NVIDIA Tesla K20, to newer ones like the NVIDIA GH200 Superchip shows major improvements in processing power and energy economy.

- **Energy Efficiency improvements**: In 2013, Eurora (the best supercomputer) had energy efficiency of 3.208 GFlops per watt. Each node had two Intel Xeon E5 CPUs and two NVIDIA Tesla K20 GPUs, and it used water cooling to save energy.

  In 2024, JEDI - BullSequana XH3000, has improved energy efficiency to 72.733 GFlops per watt, which is a big rise. This system uses NVIDIA's Grace Hopper Superchip and GH200 Superchip, showing how much GPU and system design have improved to use power more efficiently.

- **Market and Manufacturer Reaction**: Manufacturers have reacted to the need for better performance and energy-saving products. In 2024, there will probably be more companies focused on creating energy-efficient solutions than there were in 2013.

Source:

1. (https://www.top500.org/lists/top500/2024/11/highs/)
2. (https://www.top500.org/lists/top500/list/2024/11/)
3. (https://top500.org/lists/green500/list/2024/11/)
4. (https://www.top500.org/lists/green500/list/2013/06/)