Reducing the Massive Energy Appetite of Data Centers

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What is a Data Center?

-Basically a building what houses database servers

-database server: a computer that specializes in storing, retrieving, and computing with the information in its memory

-necessary functions:

    -serve multiple clients 24/7

    -must read/access data quickly

Energy Consumption

-limitations of data centers:

- -needs constant cooling
  - -prevent thermal noise, leakage currents in semiconductors, transistor failure, etc…
  - -40% of power goes toward cooling
- -needs constant power supply
  - -have the CPUs and memory active all the time

Energy Consumption

-2% of the United States’ total power goes toward powering data centers

-Total: 91 billion kWh (in 2015)

-all goes towards 3 million data centers (12 million computer servers)

-Costs:

    -Total: $9.48 billion (in 2015)

    -(per data center) at least $3000 annually

Solution 1: Improve Cooling System

-typically some implementation using air conditioning/cycling, heat sinks, and evaporator coils

-factors of consideration: location, local climate, building design, etc…

-deals with fluid dynamics and civil engineering

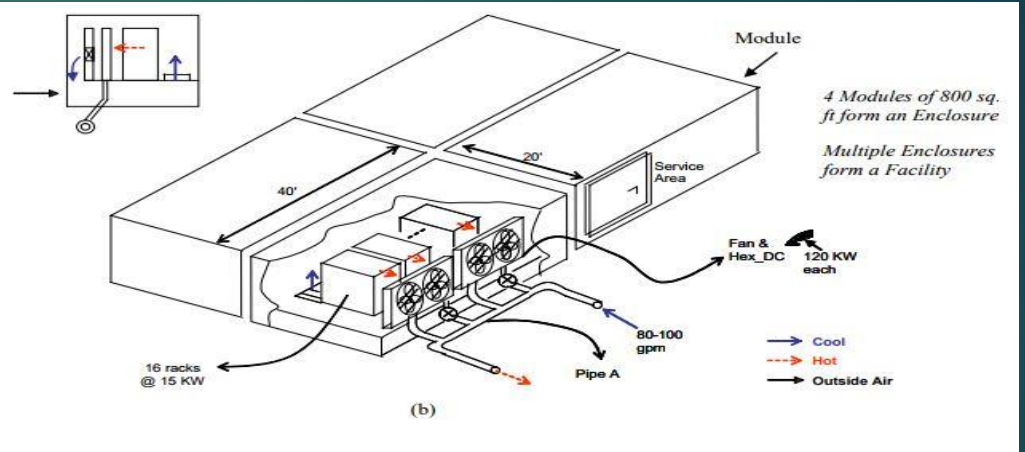
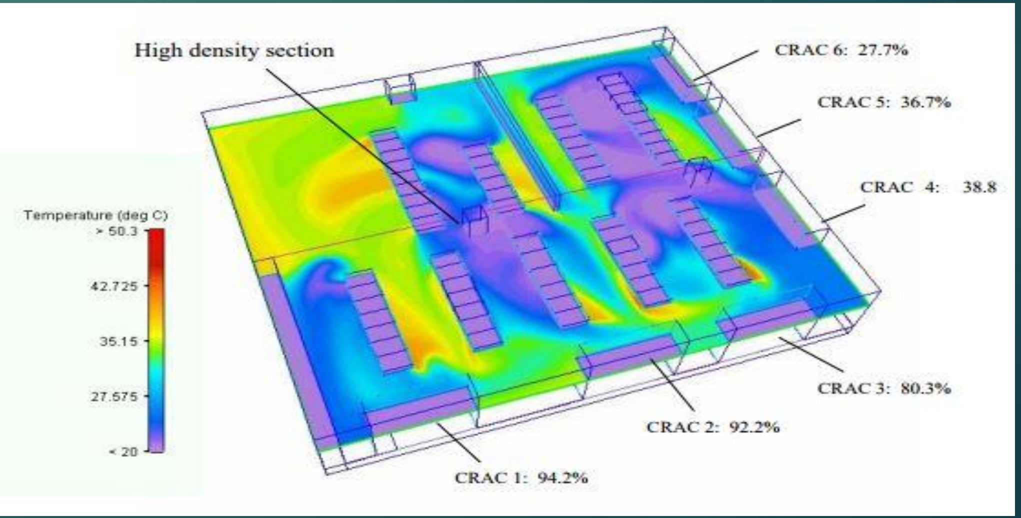
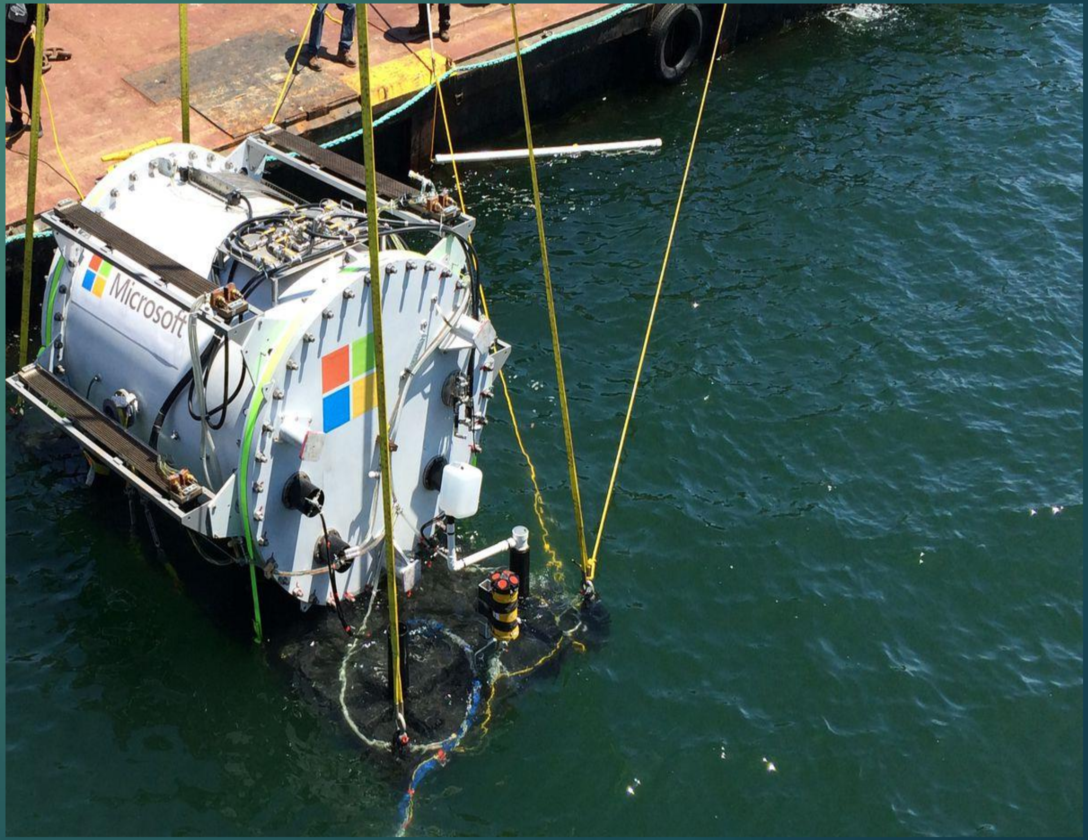


Figure 5.4. (b) Schematic of a single 800 sq ft module, which contains the computer racks and air-conditioning units.



Google’s use of seawater from the Gulf of Mexico to cool one of its data centers.

Microsoft’s project of building underwater data centers.



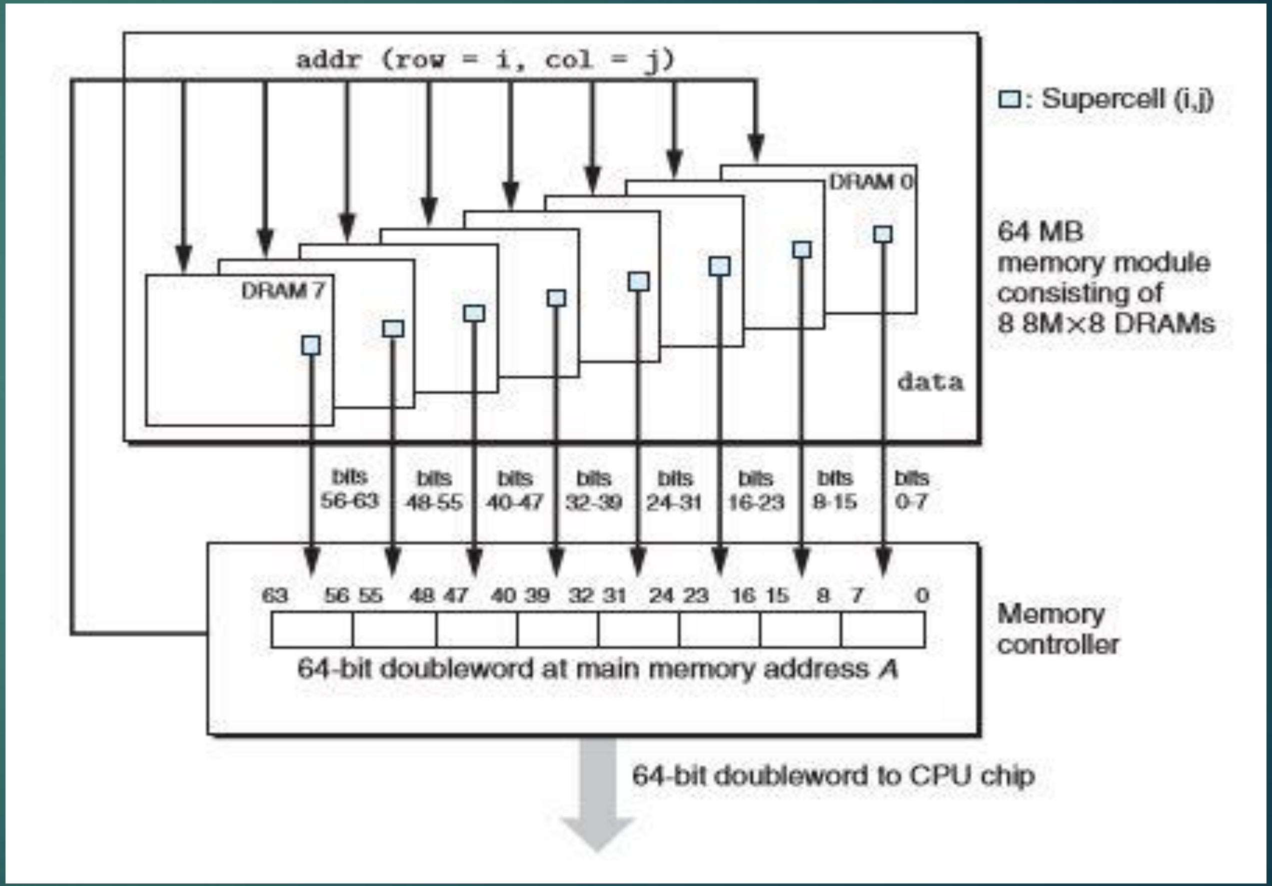
Solution 2: Solid-State Drives

-for good performance, effective caching is needed

-sometimes, all the data is stored in main memory (“in-memory database”)

-DRAM: dynamic random-access memory (typically for main memory)

-generally, avoid cache misses, otherwise penalty towards performance



	Nanoseconds (ns)	Microseconds (µs)	Milliseconds (ms)	If L1 Access is 1 second
L1 Cache Reference	0.5			1 sec
L2 Cache Reference	7			14 secs
DRAM Access	200			6 mins, 40 secs
Intel Octane 3D XPoint	7,000	7		3 hours, 53 mins, 20 secs
Micron 9100 NVMe PCIe SSD Write	30,000	30		16 hours, 40 mins
Mangstor NX NVMeF Array Write	30,000	30		16 hours, 40 mins
DSSD D5 NVMeF Array	100,000	100		2 days, 7 hours, 33 mins, 20 secs
Mangstor NX NVMeF Array Read	110,000	110		2 days, 13 hours, 6 mins, 40 secs
NVMe PCIe SSD Read	110,000	110		2 days, 13 hours, 6 mins, 40 secs
Micron 9100 NVMe PCIe SSD Read	120,000	120		2 days, 18 hours,m40 mins
Disk Seek	10,000,000	10,000	10	7 months, 10 days, 11 hours, 33 mins, 20 secs
DAS Disk Access	100,000,000	100,000	100	6 years, 4 months, 19 hours, 33 mins, 20 secs
SAN Array Access	200,000,000	200,000	200	9 years, 6 months, 2 days, 17 hours, 20 mins

Solution 2: Solid-State Drives

-solution: use combination of flash memory and DRAM

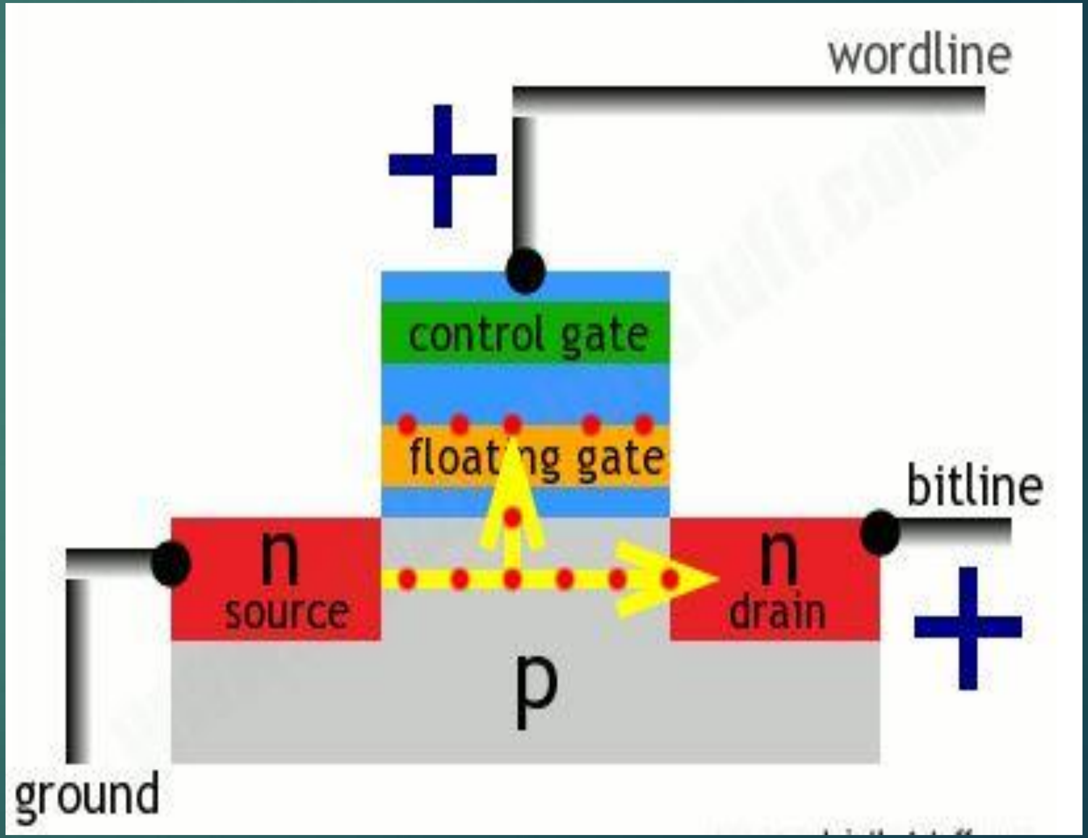
-known as BlueCache

-brought up by MIT researchers in 2015

-claimed to be viably competitive with DRAM

-flash memory advantages:

- -uses on 5% the power of DRAM
- -cost about 1/10
- -100 times storage density



Solution 2: Solid-State Drives

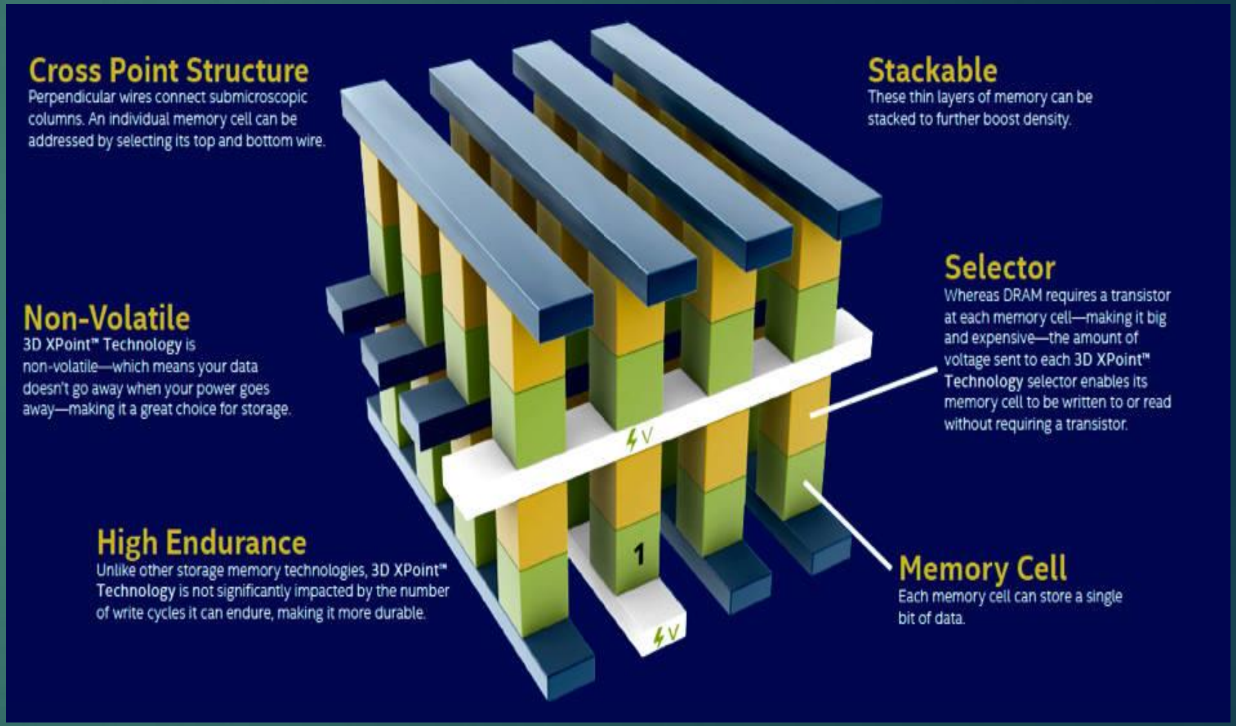
-another solution: Micron’s 3D XPoint

-faster alternative to HDD

-Phase Change Memory material

-slower than DRAM, but faster than flash memory

-basically, a new form of SSD



Solution 3: Efficient CPUs

-individually, the CPUs for each server in the data center is responsible for most of the power consumption

-example: Piton microchip

- -25-core processor developed by Princeton researchers
- -executes multiple instances of the same command in parallel
- -20% more energy efficient

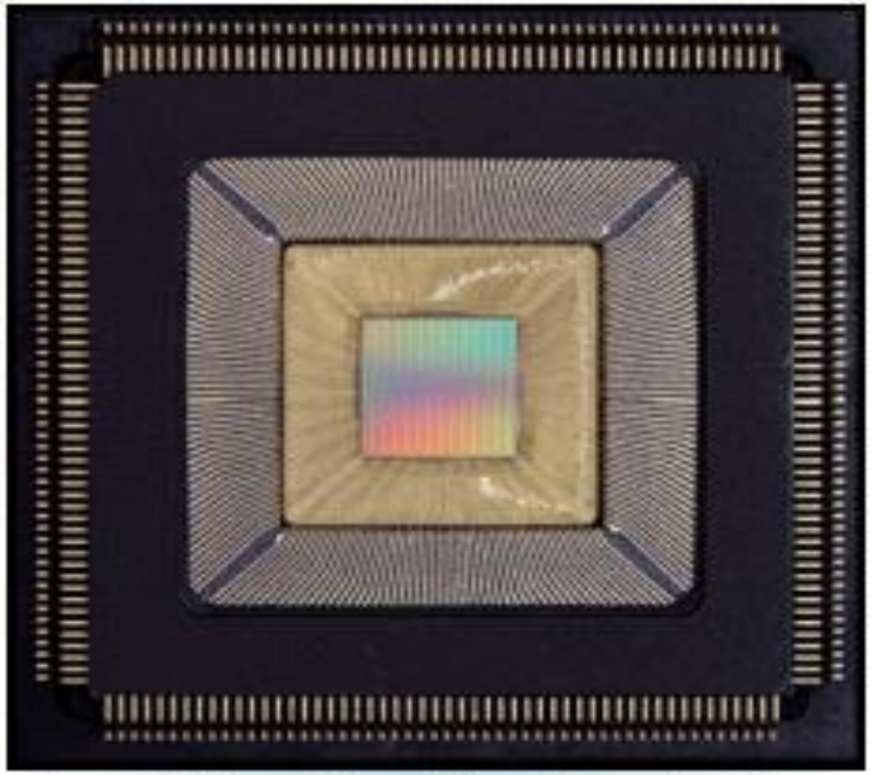


Figure 1. Piton die, wirebonds, and package without epoxy encapsulation.

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