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Assignment 4, Question 3

Practical Issues in Supercomputing

Power Consumption

Typical modern home computers have power supplies of around 500 watts. While in the home environment this is simply an inconvenient cost, when we are talking about supercomputers made up of thousands of nodes (each using a certain amount of power, most likely less than our 500 watt home computer), our power consumption grows quickly. This is very costly for those responsible for maintaining supercomputers. Further, this amount of power may simply be unavailable.

This was the case with the TSUBAME supercomputer built at the Tokyo Institute of Technology. Japan's does not produce a lot of energy, so significant drains on the existing supply must be carefully regulated to ensure they are as energy efficient as possible. (Source: http://www.hpcwire.com/hpc/717825.html) TSUBAME manages to use less than one megawatt at peak-load, making it one of the most energy-efficient clusters in its class. (Source: http://pvmmpi07.lri.fr/satoshimatsuoka.html)

Heat Generation

Coupled with power consumption, thousands of circuits in confined spaces with electricity flowing through them very quickly produces a lot of heat. Most racks are built to allow air to circulate through them to cool the computers, but we also have to cool the rooms that house these supercomputers. We can consume a lot of power and money on air conditioning and maintenance of fans (which are prone to failure). Many researchers are investigating new ways to cool computing devices, including liquid cooling, conductive cooling, and phase-change cooling.

A cluster built at Virginia Tech faced a heat problem due to a relatively cramped housing facility. They created custom racks with cooling fans mounted on the top, to blow cold air into every second aisle; the racks would then take in that cool air through vents in the front, the air would pass through the rack and cool the computers, and hot air would be expelled out the back. A detailed description of their implementation can be found at http://www.datacentres.com/papers/papers/CaseStudyVirgtech.pdf.

Noise

A number of components in a facility housing a supercomputer produce a lot of noise. The elaborate air conditioning systems and computer fans can generate a surprising amount of noise. Moving parts such as hard drives and optical storage devices can also contribute to the noise produced. For this reason, the facilities that house supercomputers can rarely be used for other purposes.

There are some alternatives that can reduce the amount of noise created by a supercomputer, such as using alternative cooling methods like liquid cooling, or using solid state drives instead of traditional magnetic hard drives. However, for the time being, these alternatives are either too expensive or simply impractical.

Reliability

Electronic devices are not immune to failure. In particular, devices with moving parts such as hard drives are prone to failure. If we are looking at just one hard drive with a MTBF of 1000 hours, we are not terribly concerned. However, in a high-performance computing setting, we might have 1000 of the same hard drive, meaning that we will have 1 hard drive fail per hour on average.

Most supercomputers have some features that allow it to keep operating when a device fails. As discussed in question 4 of this assignment, the Blue Gene/L supercomputer has nodes dedicated to detecting and fixing failures. More generally, we can use RAID to ensure data reliability, or we could use solid state drives that are less prone to failure (due to a lack of moving parts such as a motor).

Physical Interconnections

Connecting together thousands of nodes is a non-trivial task. Most supercomputers use some form of mesh or toroidal network, which demands multiple connections incoming and outgoing. For close nodes, these connections may be possible in a circuit, but most connections will be done with physical copper or fiber cabling. A network must be designed carefully so that necessary connections can be made, and if required, more nodes can be added and connected. Further, cabling should not be so complex that it becomes difficult to swap out one

As we examined in assignment 3, wireless networking is not a viable solution to this problem due to bandwidth and latency issues. Most supercomputers are housed in custom made racks that provide easy access to the connection points. The Blue Gene/L, discussed in question 4, also houses nodes in cards that are designed such that a node can be swapped out with another node without having to move any cables.

Backups

Supercomputers must store immense amounts of data, especially when working on certain scientific problems. The issue of how one backs up a system's information is intractable in most cases, as not only are we dealing with such large amounts of data, that data is constantly being changed. It is difficult to obtain a 'snapshot' of the state of a supercomputer's data storage.

There is little we can do to combat this problem. In most cases, backups are simply not done and left up to the user. In other cases, we simply do not provide persistent storage to users at all, and instead drives are used as temporary storage areas.

Physical Limitations

Physics imposes one important limitation on supercomputers: the speed of light. Information cannot be passed between computers faster than the speed of light. If we're communicating between two nodes on separate sides of a facility, it will necessarily take a few microseconds.

Cray computers are built to use the shortest lengths of cable possible to combat this problem. This is the reason behind the cylindrical design of many of Cray's recently developed computers.

We may also see a remedy to this problem in the realm of quantum computing. If qubits (quantum bits) can pass information (electron spins) through other dimensions, we may be able to send information faster than the speed of light.

Space

Even though we are dealing with microcomputers, we are dealing with such a large number of them that we will eventually run into space limitations. Every rack of computers takes up a certain amount of floor space, and there's nothing that we can really do about that except organize the racks in a way that makes use of the space as well as possible keeping in mind that the closer together we put machines, the more heat they will produce.

Natural Disasters

Some parts of the world are more prone to natural disasters than others. Supercomputers must be aware of the risks associated with a certain geographic location, and design their facility to be able to withstand a variety of natural forces.

The Earth Simulator in Kanagawa, Japan was designed to have safeguards against the many natural disasters that can occur. The building housing the Earth Simulator has a wire nest over the building to protect from lightning. It is also built on a seismic isolation system to protect the building during earthquakes. (Source: http://en.wikipedia.org/wiki/Earth_Simulator)