Notes for Santander3, the third lecture of Stephen Wolbers and Heidi Schellman:

Overall:

This lecture is meant to have a look at some of the near-future experiments and which challenges they will face. In particular it seems useful to understand how large the computing issues will be and whether the developments in the world of computing (primarily hardware but also ideas such as GRID) will allow us to satisfy the requirements of these future experiments.

Slide 2:

The outline. First, the various trends in computing hardware and covered. Next, a sampling of future experiments is given. Data-taking rates, data-volumes, collaboration size, etc. are discussed. Finally, some possible technologies to address the problems of these future experiments is shown and described.

Slide 3:

Same as in lecture 1 just to reinforce.

Slide 4-5:

Rapid speed-up of computing hardware and rapid increase in density and decrease in cost are all part of the current world of computing. It is expected to continue for the foreseeable future – no limits are expected before 2010 or 2011 and possibly beyond. One concern, which is likely to be addressed, is the possible mismatch of some part of these computer systems with others. This produces bottlenecks, which then make it difficult to make full use of the power of these systems.

Slide 6-7:

These are definitions from a web page, reference given. They more or less describe the issues with respect to increases in computing technology.

Slide 8:

This is an older slide which has been floating around. All parts of computing systems are improving, in terms of price/performance. The two that are increasing the slowest are tape storage and trans-Atlantic networking. The tape storage is probably still the same. The trans-Atlantic networking may be much better than this. There are improvements recently which may be improving the situation, at least the bandwidth. It may not have improved the price performance, that I am not too certain about.

Slide 9:

This is the same information as slide 8 but it is a little more legible.

Slide 10:

More recent data and some predictions for the future for CPU price/performance. Don't have a reference for this plot.

Slide 11:

This slide show some recent disk performance data. The doubling time is 11 months, which is faster than the 1.4 years which was seen earlier. This is a good development, and argues for using more disk in systems in the future.

Slide 12:

The slide shows the recent memory price/performance increases. Even though it wanders around a bit there is a doubling time of 12 months.

Slide 13:

Given the previously shown increases in computing technology, it is still quite possible that there is much work to be done to build and operate big computing systems for future experiments. If experiments are growing faster than Moore's law (BaBar claims that they are) then it is not the case that a simple replacement of all equipment will automatically satisfy the needs of the future. More has to be done.

Slide 14:

The data volumes actually collected by experiments is plotted here. A rough fit is shown and gives a doubling time of 2.4 years. This is some kind of average, and does not look carefully at an experiment through its lifetime, for example. There are other caveats. This is the raw data only. There are interesting outliers – Fixed-target at Fermilab, LEP. The future is somewhat speculative and is likely to be even higher than listed (and maybe a little later). Nevertheless, it is an interesting plot and shows the expected direction.

Slide 16:

Run 2b at Fermilab is meant to be a big step in luminosity delivered to the experiments. Run 1 totaled 100 inverse picobarns, Run 2a is predicted to be 2000 inverse picobarns and Run 2a + Run 2b is predicted to be 15 inverse picobarns. All of these numbers are luminosity delivered per experiment. Because of the timescales involved the expectation is that the luminosity and hence data rates will increase by about a factor of 8.

Slide 17-18:

Because of the increase of luminosity one would expect some increase in the amount of data written to tape, processed through the farms and available for physics analysis. It may not be exactly a factor of 8 because the triggers could enrich the data which is being saved to tape, there may be limitations in the system that saves the data, etc. Nevertheless, it is prudent to prepare for data-taking rates of 100 MB/s to mass-storage (or potentially even more). This would be the case in 2005. The improvements in computing technology mentioned earlier in the lecture should make this sort of data-rate possible by simple replacement of Run 2a equipment. A more detailed analysis and plans will be developed in 2002.

Slide 19:

LHC computing is a very large and important part of the LHC experimental program. The 4 experiments are going to collect very large amounts of data. The experiments have very large, very distributed, international collaborations.

Slide 20:

CMS is one of the 4 LHC experiments. The detector is physically quite large (compare the size of the little man to the detector) and will collect quite a large amount of data.

Slide 21-22:

These slides give more feeling for the size and scope of the experimental collaboration CMS. The slides may be slightly out of date but give an indication of what the issues are. The experiment is being constructed and operated by collaborators from all over the world. Those collaborators want to make use of this scientific tool and to do so from wherever they are.

Slide 23:

The complexity of LHC events adds to the complexity of the computing problem. At full luminosity there are many collisions at each beam-crossing. This slide shows what such a crossing looks like.

Slide 24:

For LHC data will be first taken in 2005-2006. Full-sized computing systems will only be needed at that time. The extensive prototyping and software development needed to reach that point is represented here.

Slide 25:

There are other efforts in HEP and Nuclear Physics that deserve mention. They all need large data samples and their data rates are similar to Run 2 and LHC. There are many challenges ahead and work done in common to help solve them will be most useful.

Slide 27:

There are many technologies that will be available for use for future computing systems. The last section of the lectures is meant to touch on a few possible architectures. The first is a discussion of PCs for essentially all computing, not just desktops, L3 and reconstruction.

Slide 28-29:

A generic view of a future HEP computing system can be seen in these two diagrams. The data is stored on tapes and disk and is accessed over the network to a large number of computing systems. There is no reason why all the computing elements cannot be PCs.

Slide 30-31:

Some of the issues that need to be addressed in such future large computing systems are given here. These are taken from Les Robertson and represent thinking about LHC computing systems. This is clearly an interesting idea for future HEP computing.

Slide 32:

The next technology/idea for the future is GRID computing. GRID computing is being investigated throughout the world to allow scientists (and others) to take advantage of resources that are distributed all over the network and all over the world. Key questions include resource allocation, prioritizing, availability of resources, network reliability and stability, among others.

Slide 33-36:

Various diagrams of GRID-style computing ideas are shown, primarily based on LHC experiment computing models. Though more of a hierarchy than a GRID, it still makes good use of GRID software and ideas. The FNAL network diagram is there to show some details of connection of internal to external networks in a big laboratory.

Slide 37-38:

GRID computing can be described in many ways. My favorite is Les' description that sounds very nice and gives transparent access to data. It sounds very much like the mainframes and SMP systems that have been so successful up to now.

Slide 39:

One of the many GRID projects that are funded is the PPDG in DOE. This is a project specifically targeted at HEP computing and is moving into a phase that will try to produce real middleware for distributed HEP computing.

Slide 40:

Another US-based, NSF-funded GRID project is GRIPHYN. A group of HEP and Computer Science groups are working together to produce middleware for HEP and other scientific computing applications.

Slide 41:

Just another view of GRID computing.

Slide 42:

A toolkit for GRID called GLOBUS is being developed. There are many aspects of this project.

Slide 43-44:

There are many GRID projects all over the world. They are very common and relatively well-funded. These slides give a summary of many of the these projects to give a feeling for the size of the effort.

Slide 45:

A summary of GRID and its possibilities.

Slide 46:

Computing is not just hardware, software and integration. It involves a lot of effort that is provided by people. Very little in any of these lectures described the effort involved but it is clear that people need to be included in resource requirements.

Slide 47-55:

The final topic is an idea to use disk instead of tape for permanent storage. Tape technology is not improving in price performance as quickly as disk technology, meaning that it is possible to think about using disk to replace all of tape. This is ambitious given the problems of trying to keep that much disk connected and ready for use, spinning or spun-down.

Slide 56:

Summary