UPGRADE OF THE SERVER ARCHITECTURE FOR THE ACCELERATOR CONTROL SYSTEM AT THE HEIDELBERG ION THERAPY CENTER

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Abstract

The Heidelberg Ion Therapy Center (HIT) is a heavy ion accelerator facility located at the Heidelberg university hospital and intended for cancer treatment with heavy ions and protons. It provides three treatment rooms for therapy of which two using horizontal beam nozzles are in clinical use and the unique gantry with a 360ï¿½ rotating beam port is currently under commissioning. The proprietary accelerator control system runs on several classical server machines, including a main control server, a database server running Oracle, a device settings modeling server (DSM) and several gateway servers for auxiliary system control. As the load on some of the main systems, especially the database and DSM servers, has become very high in terms of CPU and I/O load, a change to a more up to date blade server enclosure with four redundant blades and a 10Gbit internal network architecture has been decided. Due to budgetary reasons, this enclosure will at first only replace the main control, database and DSM servers and consolidate some of the services now running on auxiliary servers. The internal configurable network will improve the communication between servers and database. As all blades in the enclosure are configured identically, one dedicated spare blade is used to provide redundancy in case of hardware failure. Additionally we plan to use virtualization software to further improve redundancy and consolidate the services running on gateways and to make dynamic load balancing available to account for different performance needs e.g. in commissioning or therapy use of the accelerator.

THE HIT ACCELERATOR FACILITY

The Heidelberg Ion Therapy Centre (HIT) is a dedicated hadron accelerator facility for radio-therapeutical treatment of tumor patients [1, 2]. The two horizontally fixed treatment rooms as well as the gantry and experimental area (see Fig. 1) can be served in multiplexed operation with proton and carbon beams with qualified beam parameters (called MEFI, see Table 1), other ions like helium and oxygen have been tested.

The achieved energy range of 88-430 MeV/u for carbon ions and 48-221 MeV/u for protons is sufficient to reach a penetration depth of 20-300 mm in water. Patient treatment in the two horizontal treatment rooms is running at approximately 40 patients a day and the experimental area is used during night shifts. The gantry commissioning is ongoing and expected to finish in early 2012 [3, 4].

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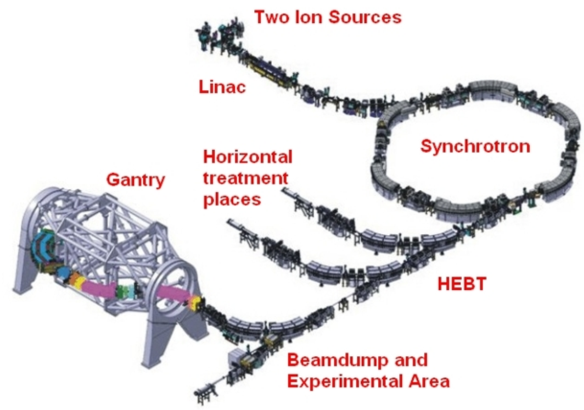

Figure 1: The HIT accelerator facility.

Table 1: MEFI Values

Parameter	Steps	Protons	Carbon
Energy	255	48–221 MeV/u	88–130 MeV/u
Focus	4(6)	8–20 mm	4–12 mm
Intensity	10(15)	$4 \cdot 10^8 - 1 \cdot 10^{10}$	$1 \cdot 10^7 - 4 \cdot 10^8$
Gantry Angle	36	365	365

SERVER ARCHITECTURE OF THE HIT ACCELERATOR CONTROL SYSTEM

The accelerator control system of the HIT facility (Fig. 2) was planned around several classical servers comprising the main ACS servers and the gateway and secondary servers [5, 6]. At the time of conception, this was the most practical way to limit negative influence of secondary systems and DSM calculations on the accelerator cycle.

Original ACS Servers

The original main ACS servers were housed inside two standard 19" racks together with secondary servers and gateways (see Fig. 3). A third 19" rack contains reserve servers and a network attached storage server (NAS) as well as a backup tape library. We used Fujitsu-Siemens TX100S2 and TX200S3 servers with dual core processors and 2 GB of memory running Windows Server 2003 and Oracle 9. This was deemed sufficient for the ACS and ran from 2005 through the commissioning of the facility until 2010 when gantry commissioning began in earnest. With the addition of the gantry angle as parameter for DSM calculations, the database tables for device data were filling rapidly. The addition of a second set of RAM data for de-

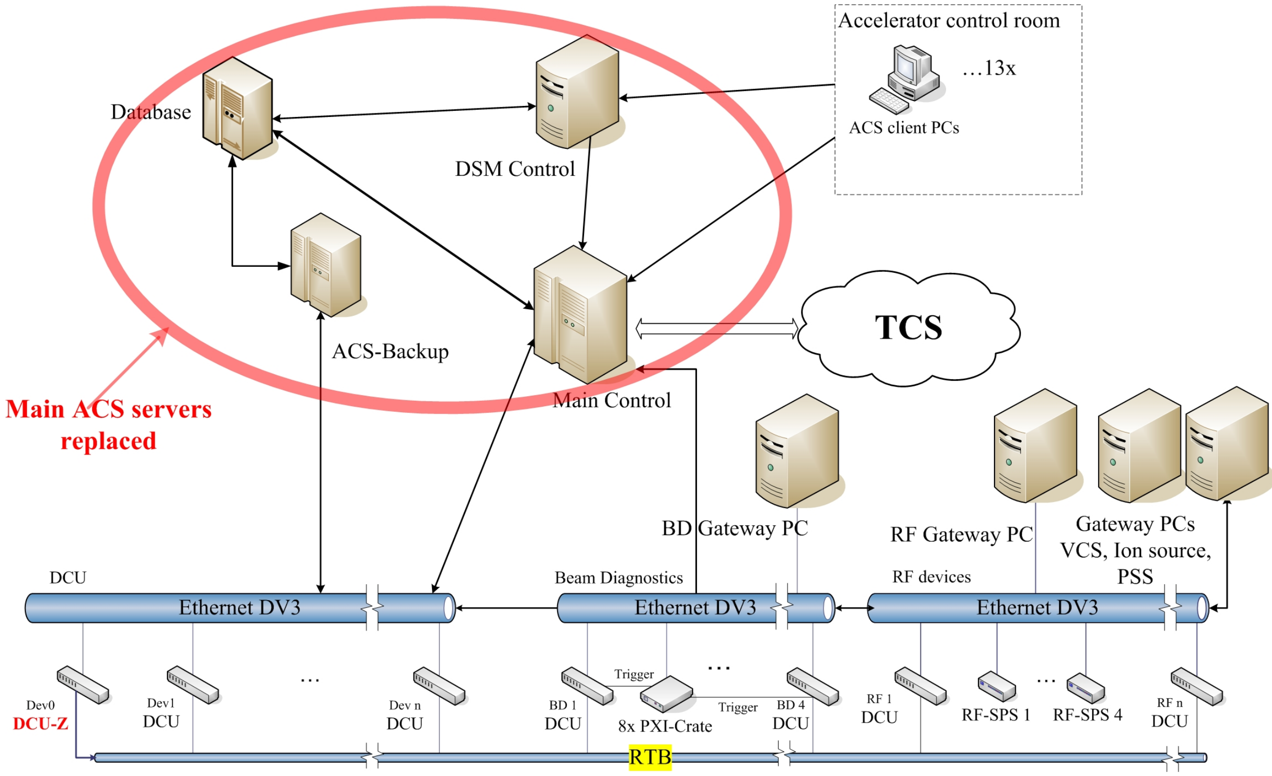

Figure 2: Server architecture and devices of the HIT accelerator control system with replaced servers shown.

vice control units to help in commissioning also strained the database. Underlying flaws in database design and configuration as well as limitations in CPU power, RAM and I/O speed reduced performance of operations and calculations of device settings. Regular statistic optimization and manual pruning were necessary to keep the database from choking.

Figure 3: One of the ACS 19” racks.

One complete interpolation of all gantry devices took between 4 and 6 hours per ion type. Downloading to the device control units (DCU) took more than 38 minutes and flashing took another 30 minutes. Cycle overhead (time between end of one beam cycle and start of a new one) was on average 1000 ms with a high spread. This proved to be an impediment mainly for commissioning of the gantry, but cycle performance was also an important consideration because of its influence on patient throughput. A performance analysis of the database system in cooperation with the industrial supplier of the control system (Eckelmann AG) and the GSI Helmholtzzentrum für Schwerionenforschung revealed issues in the database design as well as installation and configuration problems of the oracle server [7].

New Blade Servers

A part of the solution to these performance problems was a plan to replace the aging server structure with a new, state of the art blade center. Blade centers have several advantages over classical servers.

- High density - more processing power in less space
- Flexibility, modularity, and ease of upgrading - take out and add in server blades while the system is up and running
- Power consumption and power management - consolidation of power supplies and reduction of overall power consumption

- Network and other cabling - simplified cabling requirements and reduced wiring
- Load balancing and failover - blades have simpler and slimmer infrastructure and are designed for this task from the manufacturer

The disadvantages of blade centers are mainly high initial costs for the enclosure and vendor lock-in. To spread the costs over several budgets, it was decided to first replace only the main ACS servers more or less directly with blade servers and also procure the necessary infrastructure for further expansion. We started with one 16-space enclosure with redundant power supplies, management modules and dual Flex-10 10Gb/s Ethernet connections. Four identical blade servers with two 8-core CPUs, 24 GB of RAM and two internal HDDs and one storage blade with four HDDs in a RAID configuration are integrated into the enclosure (Fig. 4. The new database server, running Oracle 11 on Windows Server 2008, is connected to the storage blade and has a completely new configuration according to the tests and recommendations by GSI. All blades are inter-

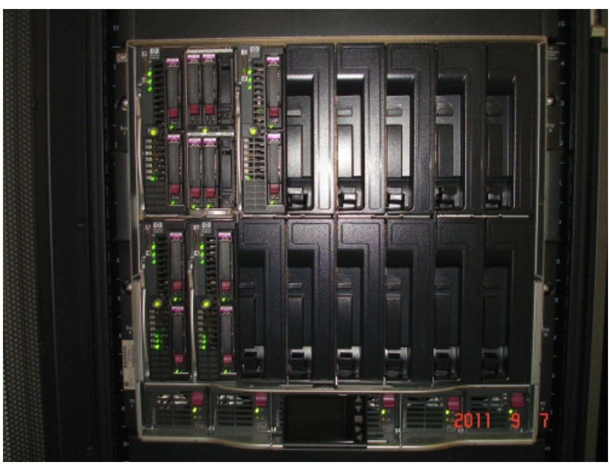

Figure 4: The blade enclosure.

connected and share the same power supply, management modules and network connection. After installation and configuration of the blade enclosure and the blade servers, the newest version of oracle 11g was installed on the designated database blade (blade 1 and storage blade) and the HIT ACS on the other servers. As planned, the second blade replaced the maincontrol server, the third blade the DSM and the fourth blade the ACS backup server. The third and fourth blade also double as backup blades in case of hardware failure.

PERFORMANCE IMPROVEMENTS

Following the take-over of the new blade system for the old ACS servers, several measuring shifts were used to determine the performance gains. We compared pre-blade data of cycle times to several testing plans run in patient mode. These testing plans showed an average cycle overhead of 740 ms as opposed to ∼1000 ms. Scatter plots of cycle times before and after the server upgrade are shown in Figures 5 and 6. Red data points show cycles collected with the old servers, while green data points show cycles running with the new blade center. These points show a mix of different accelerator modes and so the decrease in average cycle overhead is not as pronounced.

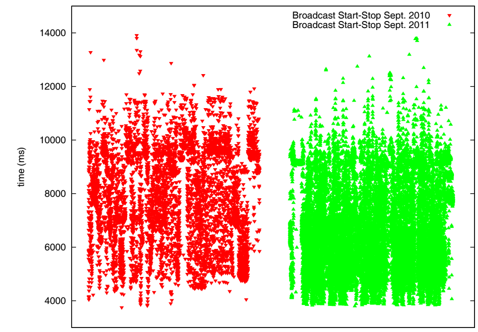

Figure 5: Scatter plot of cycle time.

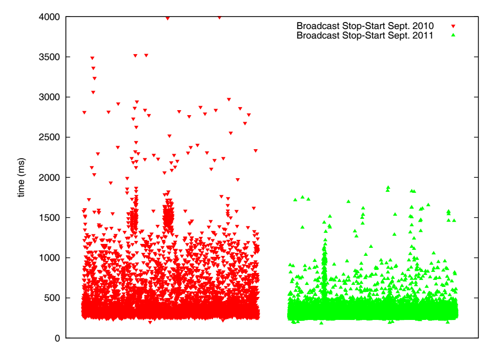

Figure 6: Scatter of cycle overhead.

The spread of the data points is smaller, especially in the cycle overhead graph. The better database performance results in less waiting time during cycle overhead and so reduces average overhead by approximately 30% in test plans. The average overall length of the cycle has been reduced also, while beam time is identical. The improvements in DSM calculation is very significant. As Table 2 shows, the interpolations and download have improved significantly.

Also very noticeable are the improvements in GUI performance. All GUI functions using database queries have been sped up by an appreciable amount. Most responses that took several seconds before, are now instantaneous. Only some functions, like reading and filtering longer log histories or loading data for therapy protocols, still take several seconds.

Table 2: Approximate Improvements with New Blade System

	Original	Blade	Gains
Interpolation (incl. gantry devices)	∼4–6 hrs.	∼1.5 hrs.	>200%
Download (per ion type)	∼40 mins.	∼10 mins.	∼400%
Flash (per ion type)	∼30 mins.	∼8 mins.	>250%
Avg. cycle overhead (with test plans)	∼1000 ms	∼740 ms	∼35%

CONCLUSIONS AND OUTLOOK

The performance gains with the new blade servers are substantial. The Table 2 shows great improvements in DSM computations and gains in operating are also significant. GUI performance is significantly improved and waiting times for database queries are vastly reduced. Even cycle overhead has shortened by a factor of ∼30% and is expected to improve more with new database enhancements. Redundancy is enhanced by the hot spare blade servers which are pre-configured to run all ACS services and by the dual Ethernet connection.

The next step in our upgrade will be to procure more blade servers and incorporate the auxiliary and gateway servers into the blade center. Also planned is a Storage Area Network (SAN) blade that will be connected to all blade servers via internal 10 Gb/s Ethernet and allows saving of server images and fast failover capabilities. More and dedicated hot spare blades will also bring more redundancy. We also plan on using virtualization software to run some of our servers with resource sharing and load balancing to better utilize our server resources to the fullest.

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