Senior Project Proposal
Department of Computer Science
Calvin College

Title: Crayowulf
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Date: 10/11/2017
Mentor: Joel Adams
Honors Project: For Peter Oostema, yes. For Benjamin, Noah, and Phillip, no.

Vision and General Overview of Proposal

Background and Problem

This project is about building a small-scale supercomputer that can be taken to conferences and local high schools. This will determine the limits of how much computing power can be packed into a small space. This will also provide insight into the cooling system and enclosure design necessary to provide adequate cooling capacity for a custom-built system that is tightly packed. The finished product will provide an important outreach mechanism and serve as a public relations piece for Calvin College and the Department of Computer Science.

Brief Description of Solution Being Provided

We will build a computer using NVIDIA Jetson TX2 developer kits[1] (scroll down after clicking the link to find the developer kits) and place it in an enclosure that resembles a Cray-1 supercomputer. This will be a self-contained unit, only requiring power (1 cable to the wall), network, display, and keyboard/mouse connectivity. The Cray-1 design will generate visual interest when on display, due to its aesthetics and the excellent reputation of the Cray-1.

Your Interest and Qualifications

I (Benjamin) am interested in networking and system administration. Building a Beowulf cluster requires system administration work to configure the nodes and get them to share a file system, and some networking to support communication. I've been interested in building supercomputers, especially at the small-scale, personal level – I read the Calvin documentation on Dahl and Beowulf clusters even before I came to Calvin and found it interesting, especially Microwulf.

I (Peter) am interested in high performance computing and parallel algorithms. Writing software to best use the hardware it runs on can be more important than

[1] We will use the full developer kit, not just the compute module. The developer kit includes the compute module but also provides I/O ports (e.g. Ethernet).

buying better software. I have done similar work at Carnegie Mellon University where I worked to speed up finite field matrix multiplication on CPUs.

I (Noah) am interested in designing the mechanical enclosure for the computer cluster system, as I have ventured into the area of designing computer cases for desktop PCs. I also am quite interested in thermodynamics and in cooling systems, especially liquid cooling. Thermal design and thermodynamics courses, as well as mechanical design courses have provided me with the capability to perform such tasks.

I (Philip) am interested in thermal systems and mechanical design. I have very much enjoyed my thermodynamics courses and look forward to applying what I have learned to the cooling system we will integrate into the case. My courses in mechanical design will also allow me to design a structurally integral and aesthetically pleasing case.

Mentor Selection, Expert User and Collaboration

Professor Joel Adams is our mentor. He has built several supercomputers at Calvin and is recognized as the department expert on high-performance computing. We are also collaborating with Professor Mark Michmerhuizen from Electrical Engineering. We may also consult with Professor Ned Nielsen (Mechanical Engineering) as needed for the case and heat flow studies.

Research Question

We have three research questions:

1. We will work to find out the maximum performance achievable from a cluster built from system-on-a-board computers (NVIDIA Jetsons), given our budget.
2. We will determine how to design and manufacture a practical case that exhausts the heat and resembles a Cray-1 supercomputer. This case must protect the components as well as provide space for a power supply, shared disk, network switch, and cabling, provide adequate cooling capacity, and ideally be easy for others to reproduce.
3. We will work to develop a parallel version of a post-quantum cryptography scheme called supersingular elliptic curve isogeny . (Honors component for Peter Oostema)

Development Approach

We plan to take a phased approach. In the fall semester, we will complete preliminary design studies, perform initial software configuration, and perhaps an initial prototype. In the spring semester, we will implement a final system, tune it, and benchmark it using a standard supercomputing benchmark.

We plan to perform some tasks in parallel. For example, basic software configuration can be done while the case is being designed and fabricated. It should also be possible to perform some electrical design and implementation before the case is completely fabricated. We envision using as many 3D-printed parts as practical to facilitate reproduction. This will involve creating CAD files of those designs, which will be publicly available on the project website.

Quality Assurance

Critical Delivery Dates

October 15: Project approval in CS.
November 1:

- Equipment ordered

November 15: Completed:

- Equipment has arrived
- Draft proposal for Engineering
- Preliminary CAD designs for case and cooling system.
- Initial system configuration for head node (can do test configuration using existing CS department Jetson TK1 boards but can't work on the "production" Jetson TX2 boards until the first one arrives).
- Initial electrical design.

December 11: Completed:

- Final proposal for Engineering
- Theoretical heat flow study
- Initial system configuration for worker nodes.
- Mid-project progress report for CS.
- Prototype implementation of algorithm for cryptography scheme.
- Project website.

February 15: Completed:

- Final CAD design

March 15: Completed:

- Components fabricated

March 20: Completed:

- System assembled

April 1: Completed:

- System tuned and benchmarked.

April 15: Completed:

- First draft of final report
- Power and temperature studies

May 1:

- Project completed and ready to present in both CS and Engineering

Reviews

Preliminary designs reviewed by respective experts by December 15:

Professor Adams: - code and configuration
Professor Nielsen - case design and heat flow
Professor Michmerhuizen - electrical

We will meet weekly with Professor Adams to check on progress.

Testing

1. The cluster will run the HP Linpack benchmark after it is assembled to see how it compares to other supercomputers.
2. The encryption program will be tested for performance of encrypting and decrypting files.
3. The case will be tested for temperature both at idle and under load.

Resources

We present two budget scenarios below. The first involves 5 Jetson TX2 boards but goes over the $1500 recommended by Pofessor Adams. The second scales down to 4 Jetson TX2 boards, staying under $1500 but also making Crayowulf less of a "cluster" – it would have one head node and three worker nodes.

NVIDIA will provide one TX2 for free and give us the educational price ($299 per unit) on the others. We do not list the price of the extra TX2 in the tables since it is free. We do, however, list the extra network card for it since we must still purchase that (we are adding an extra network card to each node).

Note that using 5 nodes requires a bigger network switch than using 4 nodes. Also note that prices do not include shipping or tax.

The engineering department will cover the costs of the case ($100) and cooling system ($200) so those costs are not included in the tables. The engineering department also has material available that can be used with no charge to our budget.

Using 5 Nodes

Item	Source	Qty	Cost per unit	Cost for all units	Notes
Jetson TX2 boards	NVIDIA	4	$299.00	$1,196.00	not including fifth node since it is free
Extra network adapters (PCIe)	https://www.newegg.com/Product/Product.aspx?Item=N82E16833114095	5	$27.15	$135.75	need to purchase 5 adapters for 5 nodes
Extra network adapter (USB-to-Ethernet) and USB hub combo	https://www.newegg.com/Product/Product.aspx?Item=N82E16833114145&cm_re=usb_to_ethernet_adapter-_-33-114-145-_-Product	1	$33.99	$33.99	
Molex to barrow	https://smile.amazon.com/gp/product/B0121QHR2E/ref=s9u_simh_gw_i1?ie=UTF8&fpl=fresh&pd_rd_i=B0121QHR2E&pd_rd_r=35QB0AYHEQ6BJD2ZBMY1&pd_rd_w=5UaYm&pd_rd_wg=W9Gzk&pf_rd_m=ATVPDKIKX0DER&pf_rd_s=&pf_rd_r=RY6A0PNZDNP3MPKK5YNB&pf_rd_t=36701&pf_rd_p=1cf9d009-399c-49e1-901a-7b8786e59436&pf_rd_i=desktop	6	$7.99	$47.94	
6pin to molex x2	https://www.newegg.com/Product/Product.aspx?Item=N82E16812423173&cm_re=6_pin_to_molex-_-12-423-173-_-Product	3	$1.99	$5.97	
hard drive	https://www.newegg.com/Product/Product.aspx?Item=9SIA98C63H3047	1	$65.99	$65.99	
Power Supply	https://www.newegg.com/Product/Product.aspx?item=N82E16817151095	1	$59.99	$59.99	
switch	https://www.newegg.com/Product/Product.aspx?Item=N82E16833122822	1	$59.99	$59.99	bigger (16 port) switch necessary for 5 nodes (2 network ports per node)
PRICES DO NOT INCLUDE SHIPPING OR TAX					
Total				**1,605.62**	

Using 4 nodes

Item	Source	Qty	Cost per unit	Cost for all units	Notes
Jetson TX2 boards	NVIDIA	3	$299.00	$897.00	not including fourth node since it is free
Extra network adapters (PCIe)	https://www.newegg.com/Product/Product.aspx?Item=N82E16833114095	4	$27.15	$108.60	need to buy 4 network cards because we get an extra TX2 for free
Extra network adapter (USB-to-Ethernet) and hub combo	https://www.newegg.com/Product/Product.aspx?Item=N82E16833114145&cm_re=usb_to_ethernet_adapter-_-33-114-145-_-Product	1	$33.99	$33.99	
Molex to barrow cable	https://smile.amazon.com/gp/product/B0121QHR2E/ref=s9u_simh_gw_i1?ie=UTF8&fpl=fresh&pd_rd_i=B0121QHR2E&pd_rd_r=35QB0AYHEQ6BJD2ZBMY1&pd_rd_w=5UaYm&pd_rd_wg=W9Gzk&pf_rd_m=ATVPDKIKX0DER&pf_rd_s=&pf_rd_r=RY6A0PNZDNP3MPKK5YNB&pf_rd_t=36701&pf_rd_p=1cf9d009-399c-49e1-901a-7b8786e59436&pf_rd_i=desktop	5	$7.99	$39.95	
6pin to molex x2	https://www.newegg.com/Product/Product.aspx?Item=N82E16812423173&cm_re=6_pin_to_molex-_-12-423-173-_-Product	3	$1.99	$5.97	
hard drive	https://www.newegg.com/Product/Product.aspx?Item=9SIA98C63H3047	1	$65.99	$65.99	
Power Supply	https://www.newegg.com/Product/Product.aspx?item=N82E16817151095	1	$59.99	$59.99	
switch	https://www.newegg.com/Product/Product.aspx?Item=N82E16833122610	1	$25.82	$25.82	8 port switch for four nodes (2 ports per node)
	PRICES DO NOT INCLUDE SHIPPING OR TAX				
Total				**1,237.31**	

Risk Analysis

Risk	Exposure Analysis	Mitigation Strategy
Do you have a dependency on others completing work for your project to be a success?	We all depend on each other in this team. Philip and Noah will conduct heat-flow studies and design the case. I (Benjamin) will handle software configuration and Peter will perform cryptography research.	Weekly meetings to check on progress.
Is there any doubt about the availability of financial resources?	We hope the CS department will fund this project out of its research budget	Professor Adams may be able to find other sources of funding
Do you have a dependency on an expert user to provide advice and who may not always be available at critical times?	If Professor Adams, Professor Nielsen, or Professor Michmerhuizen are not available for an extended period of time, this could be detrimental. This does not appear likely, however.	N/A
If success depends on testing by an outside source, are there any barriers to completing testing?	N/A	N/A
Will this project involve new skills for you?	Benjamin: I have not configured a Linux-based system (or any system) to this extent. Philip: Metalworking, 3D printing, liquid cooling Peter: Different mathematics involved in cryptography scheme	Research will be necessary. Professor Adams, Professor Nielsen, Professor Michmerhuizen, and perhaps Chris Wierenga and Phil Jaspers will hopefully be able to assist.

	and parallelization for high performance. Noah: Metalworking, liquid cooling	
Will there be anything preventing you from investing at least twenty hours a week on this at a minimum?	Full course loads	Time management and prioritization.
Is there any potential of physical resources you have listed of not being available?	We may have to share the 3D printer with other users.	May need to coordinate with the Engineering department on 3D printer time slots.

Appendix A
Test Plan

Unit Testing

General Approach

Test the necessary components, key generations, key communication, and the encrypting j-invariant function.

Equipment/Resources

Crayowulf

Testers/Volunteers

Peter and Benjamin

Function Testing

General Approach

Run key generation and encrypted message passing at one time.

Equipment/Resources

Crayowulf

Testers/Volunteers

Peter and Benjamin

System Testing

General Approach

Running the HP Linpack benchmark.

Equipment/Resources

Crayowulf and HP Linpack benchmark software.

Testers/Volunteers

Crayowulf team.

Acceptance Testing

General Approach

Ask professor Adams if the system will suit his and the department's needs.

Equipment/Resources

Crayowulf

Testers/Volunteers

Professor Joel Adams