XMT-GPU

A PRAM Architecture for Graphics Computation

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Bifurcation Between CPU and GPU

- CPUs
  - General purpose, serial
- GPUs
  - Special purpose, parallel
- CPUs are becoming more parallel
  - Dual and quad cores, roadmaps predict many-cores
  - Unclear how to build or program these many-cores
- GPUs more general
  - Gaining momentum for more general apps

Is Unification Possible?

- Can a single general purpose, many-core processor replace a CPU + GPU?
- It must be
  - Standalone – no coprocessor needed
  - Easy and flexible to program
  - Competitive on anything with CPUs
  - Competitive on graphics with GPUs
- We choose a unification candidate (XMT) in part because it satisfies the first 3
- During the Q&A session we welcome your thoughts on what else could be used

Main Experiment and Results

- Can XMT satisfy the 4th?
- Simulate surface shading (a common graphics app) on GP and GPU representatives
- Mixed results
  - XMT slightly faster on some GPU tasks
  - GPUs significantly faster on others
- Unification unlikely, but momentum may shift towards GP

CPU History Overview

- Serial random access machine programming model
  - Great success story, dominant model for decades
  - Popular for both theory and practice
  - Relies on faster serial hardware for performance gains - no longer sufficient
- Multi-cores available (2-4 cores/chip)
- Many-cores on horizon (100’s or 1000’s); but how will they looks?

What Will Future CPUs Look Like?

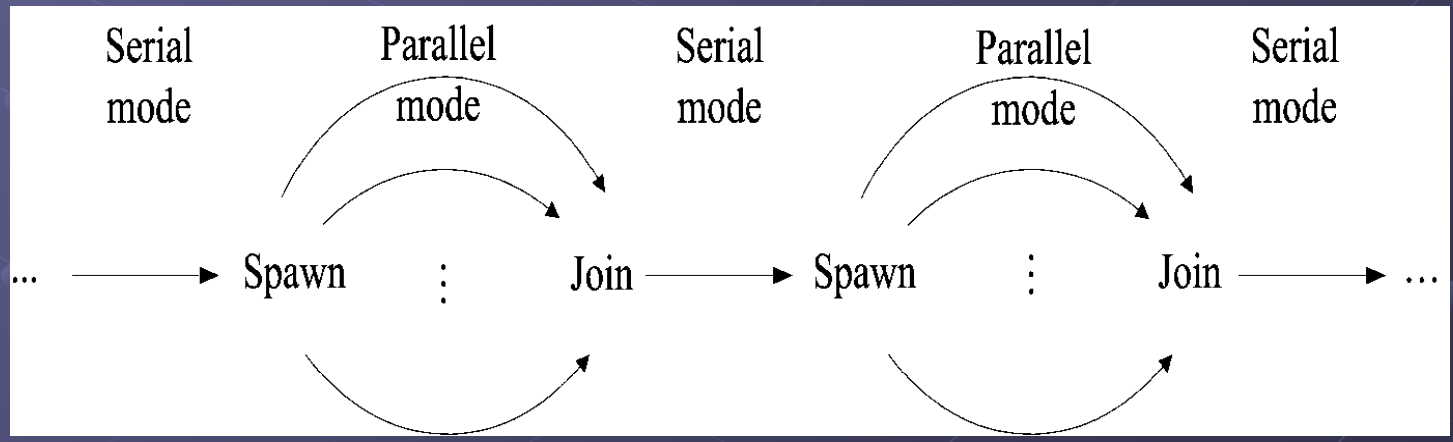
- Future from major vendors unclear
  - Proposals try to look like serial RAM to programmers
  - Long term software spiral broken
- PRAM (parallel random access machine)
  - Model preferred by programming community
    - natural extension of serial
    - scalable
    - included in major algorithm textbooks
  - Discounted because of difficulty building one
  - Recently building one has become feasible

XMT: eXplicit Multi-Threading

- PRAM-on-chip vision under development at the University of Maryland since 1997
  - Targeting ~1000 cores on chip
  - PRAM-like programmability
  - On chip shared L1 cache provides memory bandwidth necessary for PRAM
  - Previous work has established XMT's performance on a variety of applications
  - Simulator and FPGA implementations available
  - www.umiacs.umd.edu/users/vishkin/XMT

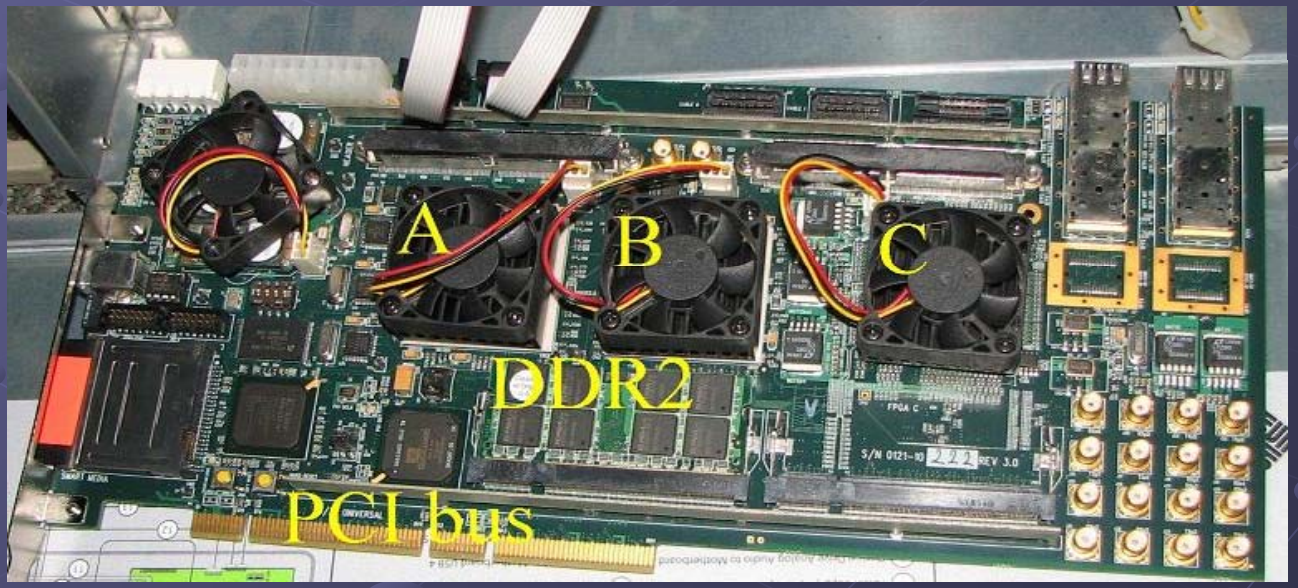
Programming XMT

- XMTC: Single-program multiple-data (SPMD) extension of standard C which resembles CRCW PRAM
- Spawning creates lightweight, asynchronous threads, serial execution resumes once all threads complete



XMT FPGA In Use

- 64 Processor, 75MHz prototype
- Used in undergrad theory class (also: non-major Freshmen and 35 high-school students)
  - 6 significant projects
  - No architecture discussion, minimal XMTC discussion

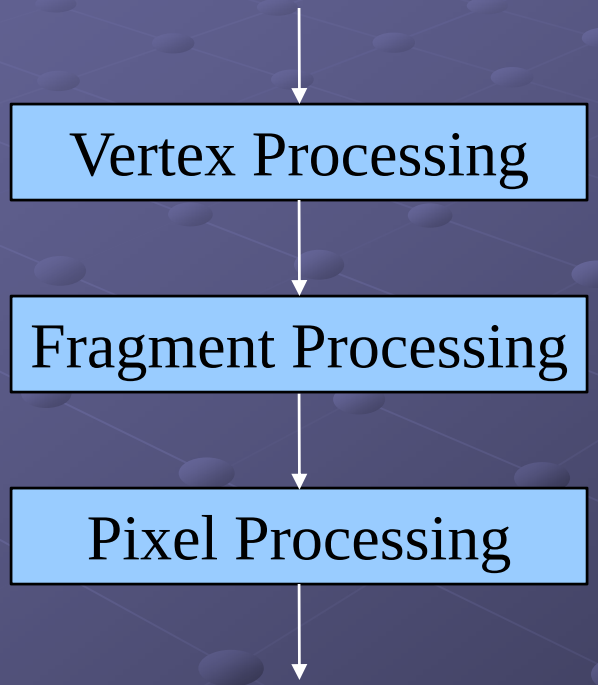


GPU History Overview

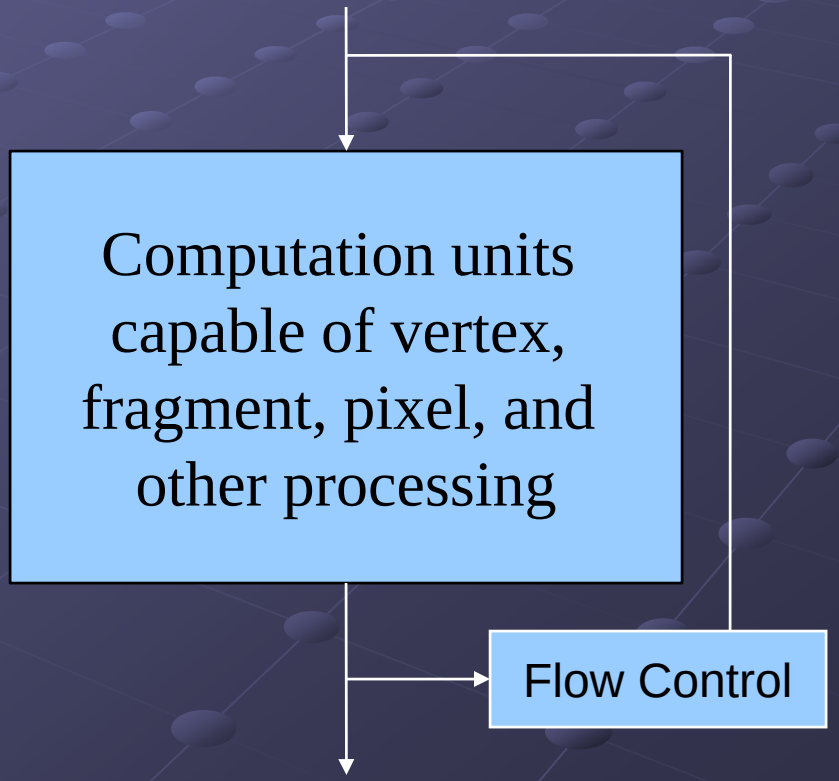
- Stream programming model
  - Streams and kernels: simple and easily exploits locality for some tasks
  - Handles irregular, fine-grained, and serial code poorly
- Originally very inflexible
  - “Programming” meant setting bits for Muxes
- Modern GPUs are much more flexible
  - C like languages
  - GPGPU
  - Still tied to stream model

Very High Level GPU Pipeline

- Old pipelined architecture

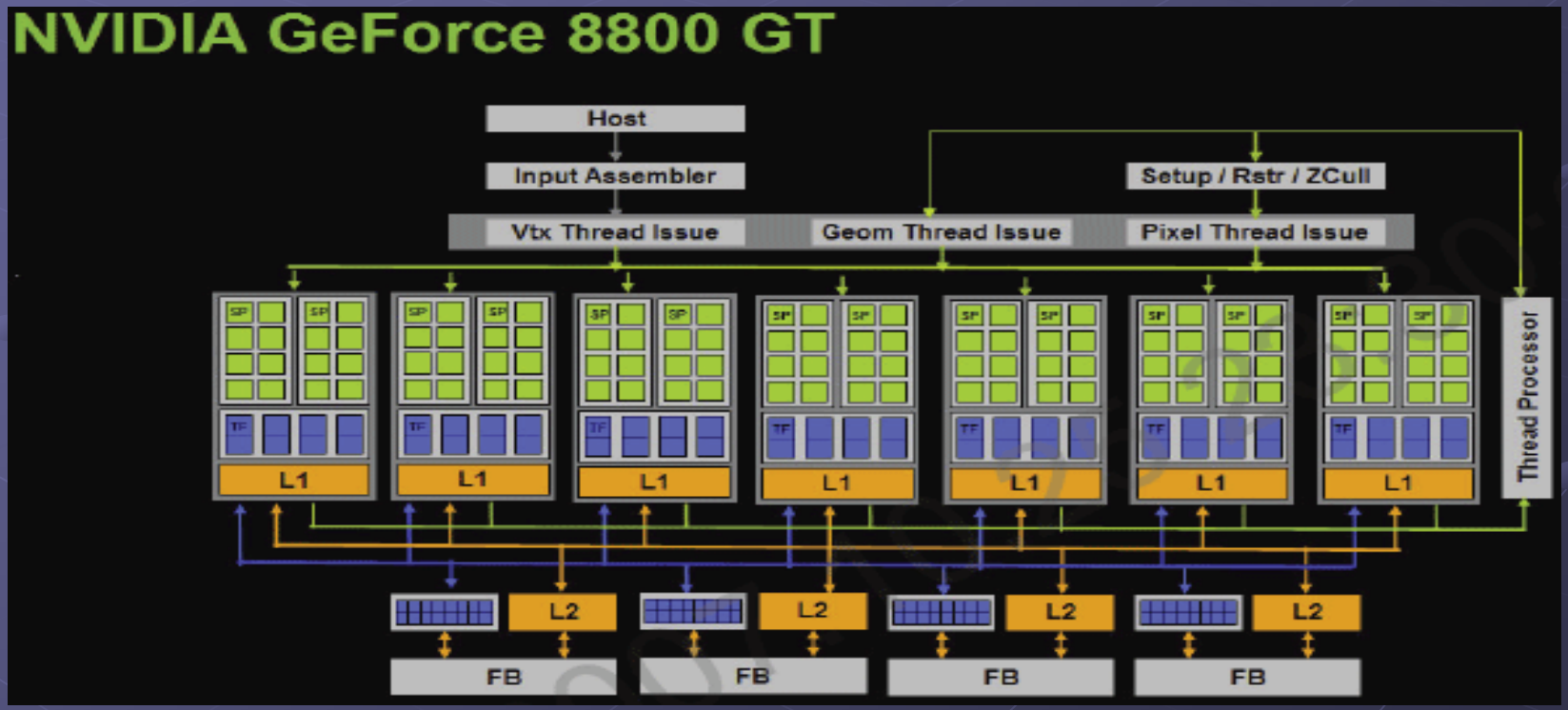


- New virtual pipeline architecture

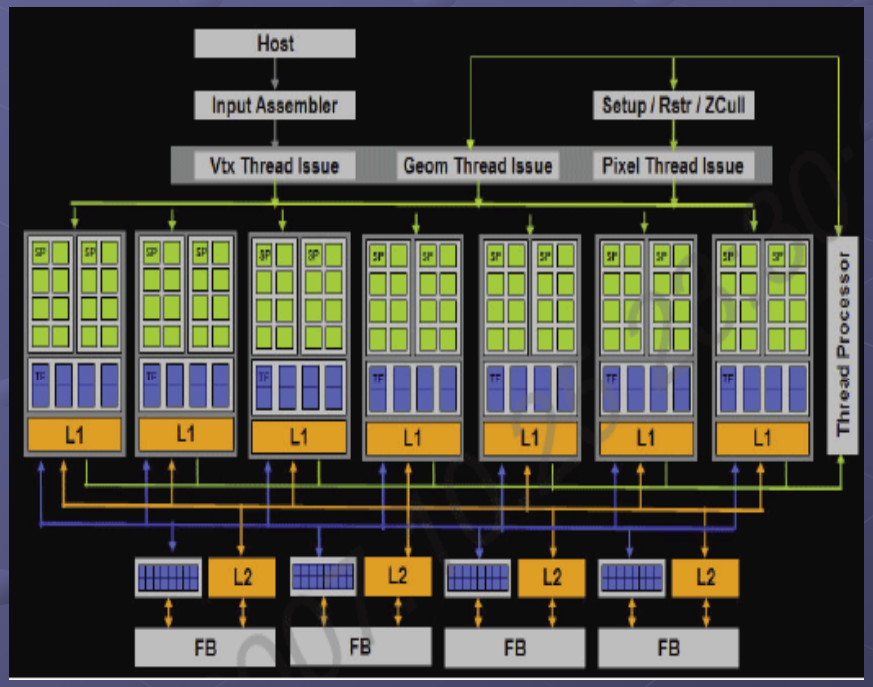


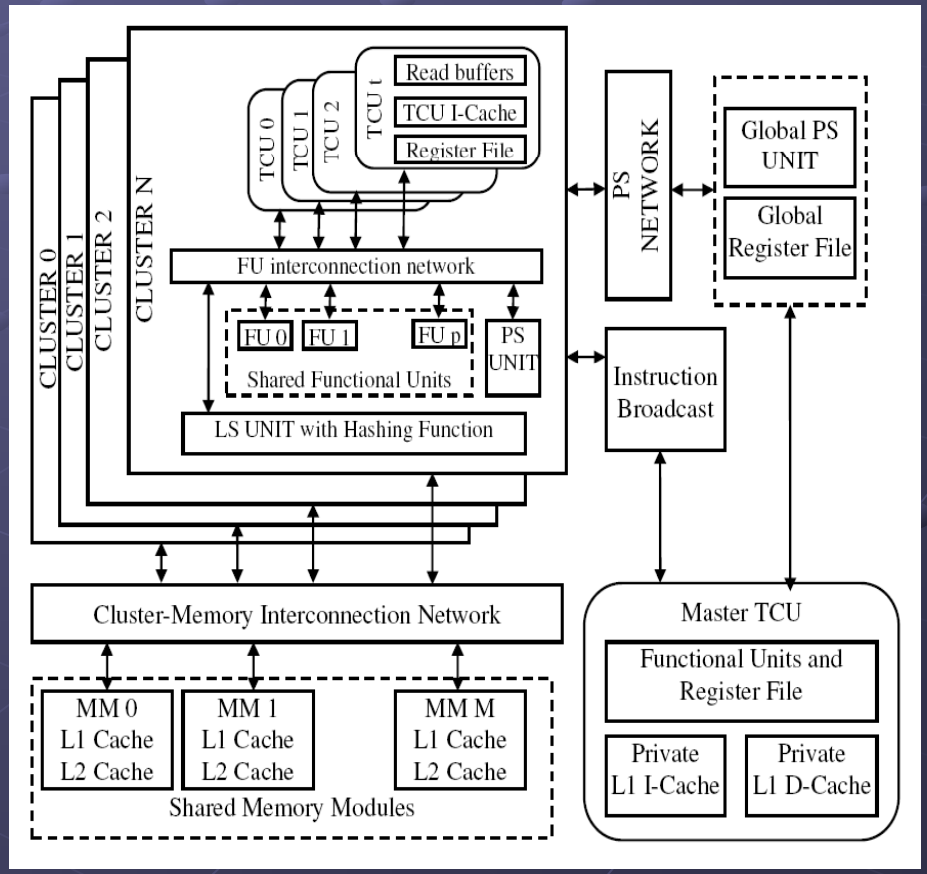
More Detailed Modern GPU

- From NVIDIA GeForce 8800 GPU Architecture Overview
  - Virtual pipelined



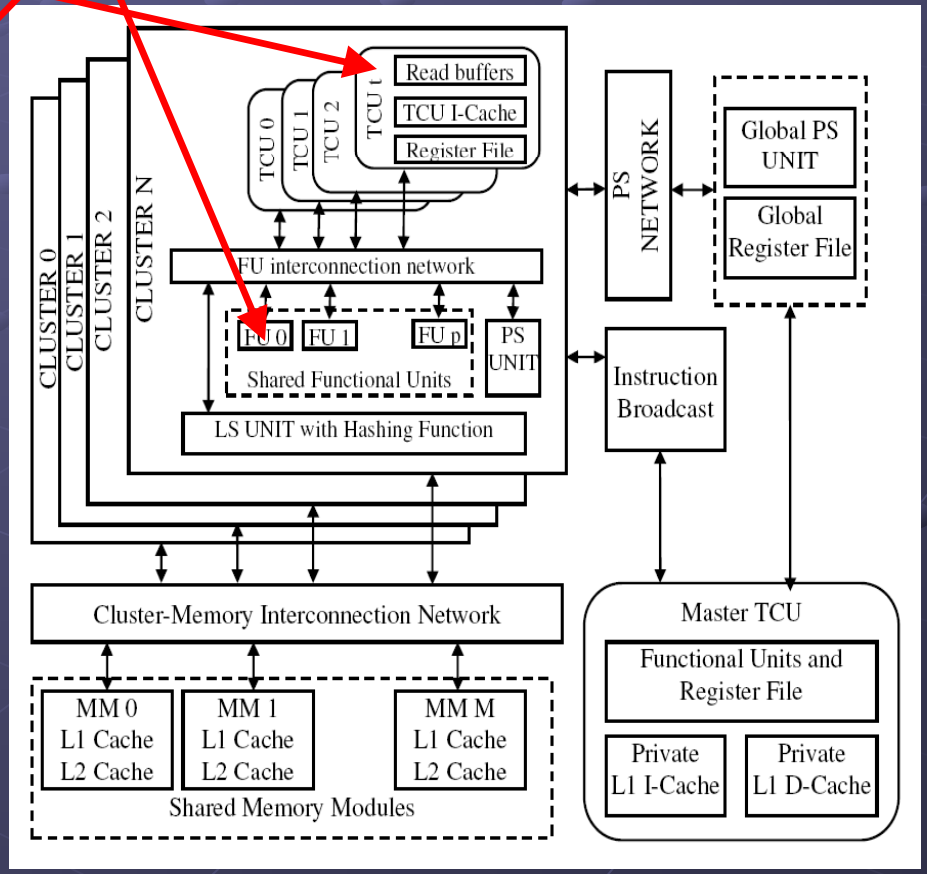
GeForce and XMT Similarities





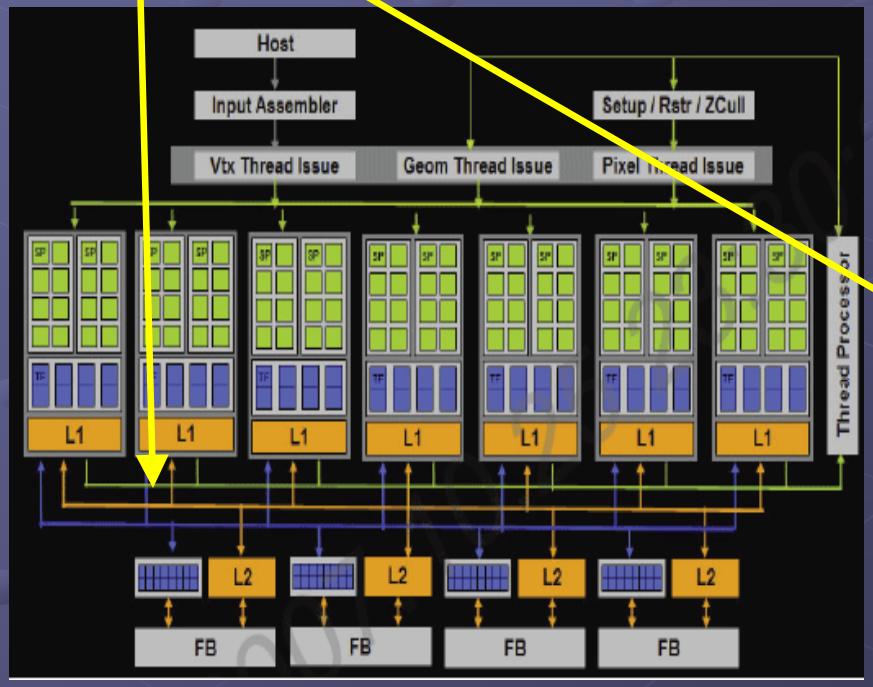
GeForce and XMT Similarities

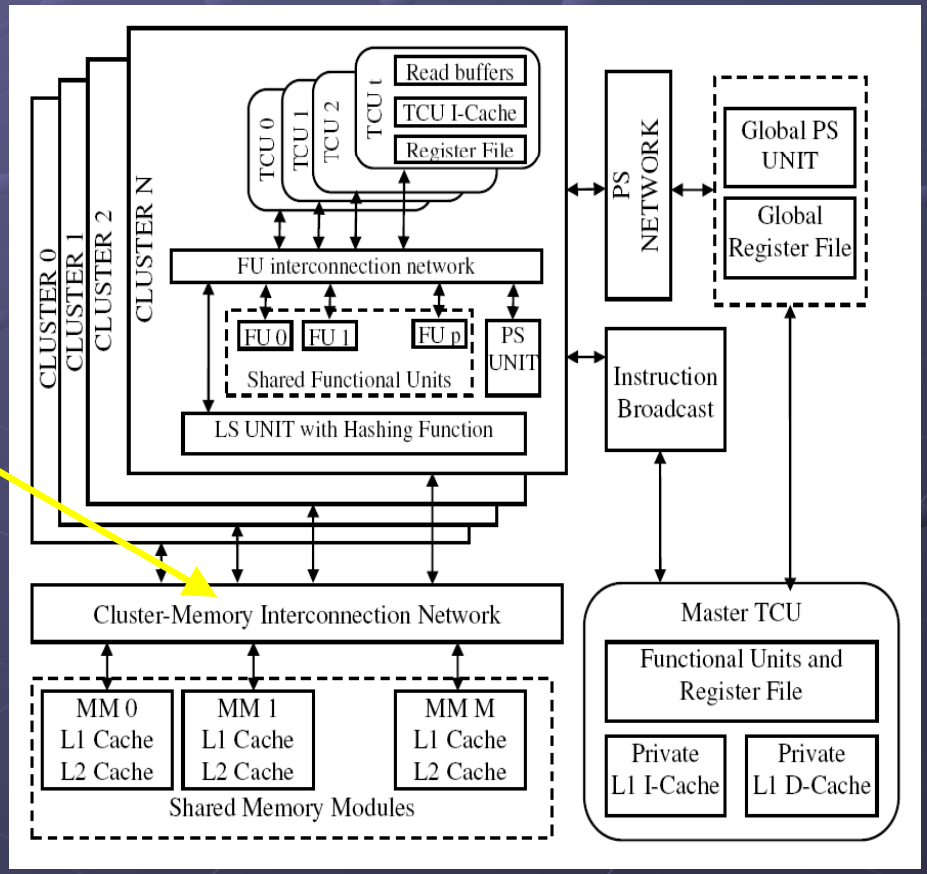
Clusters of processors, functional units



GeForce and XMT Similarities

On chip memory and access network





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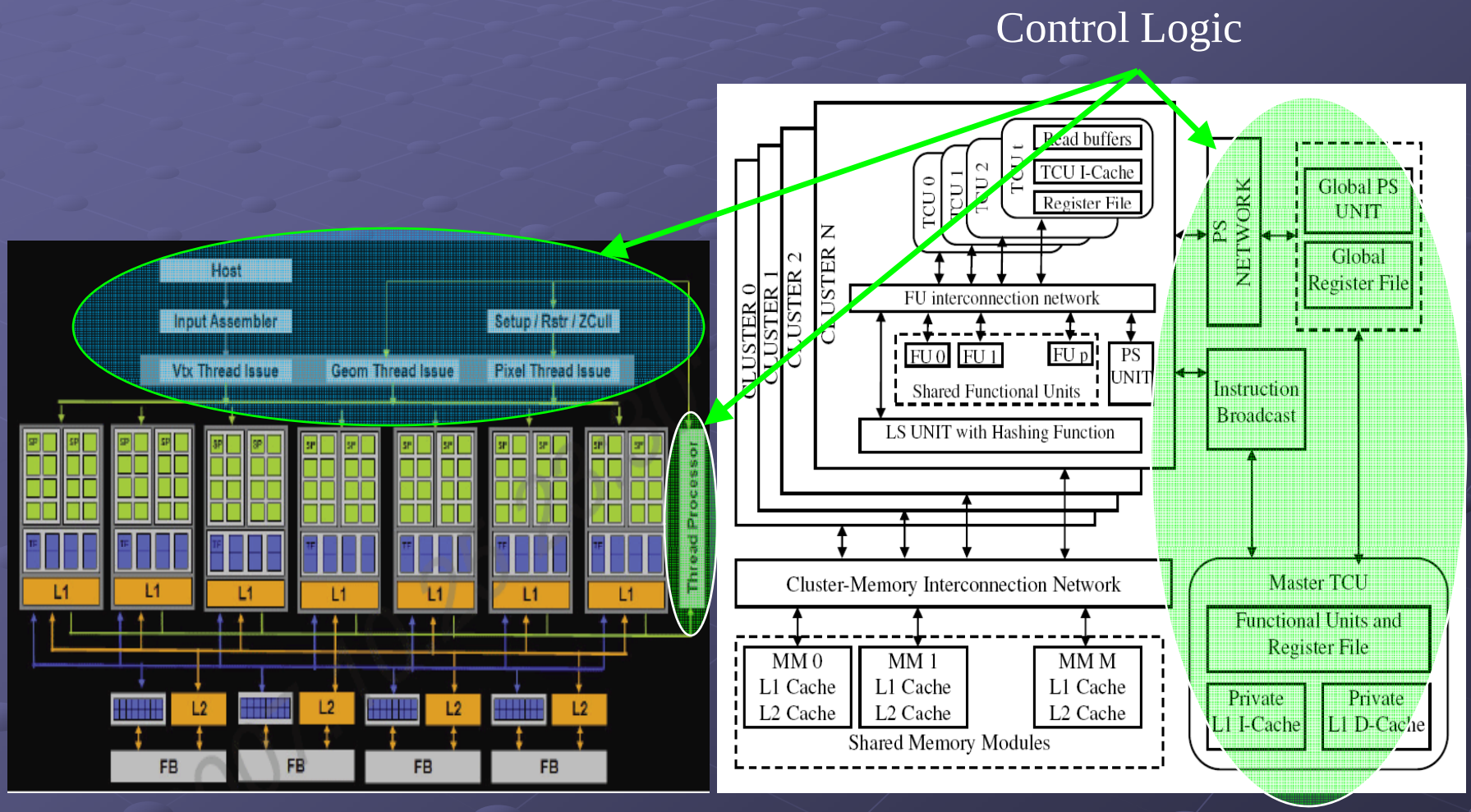


Does XMT Meet Unification Requirements?

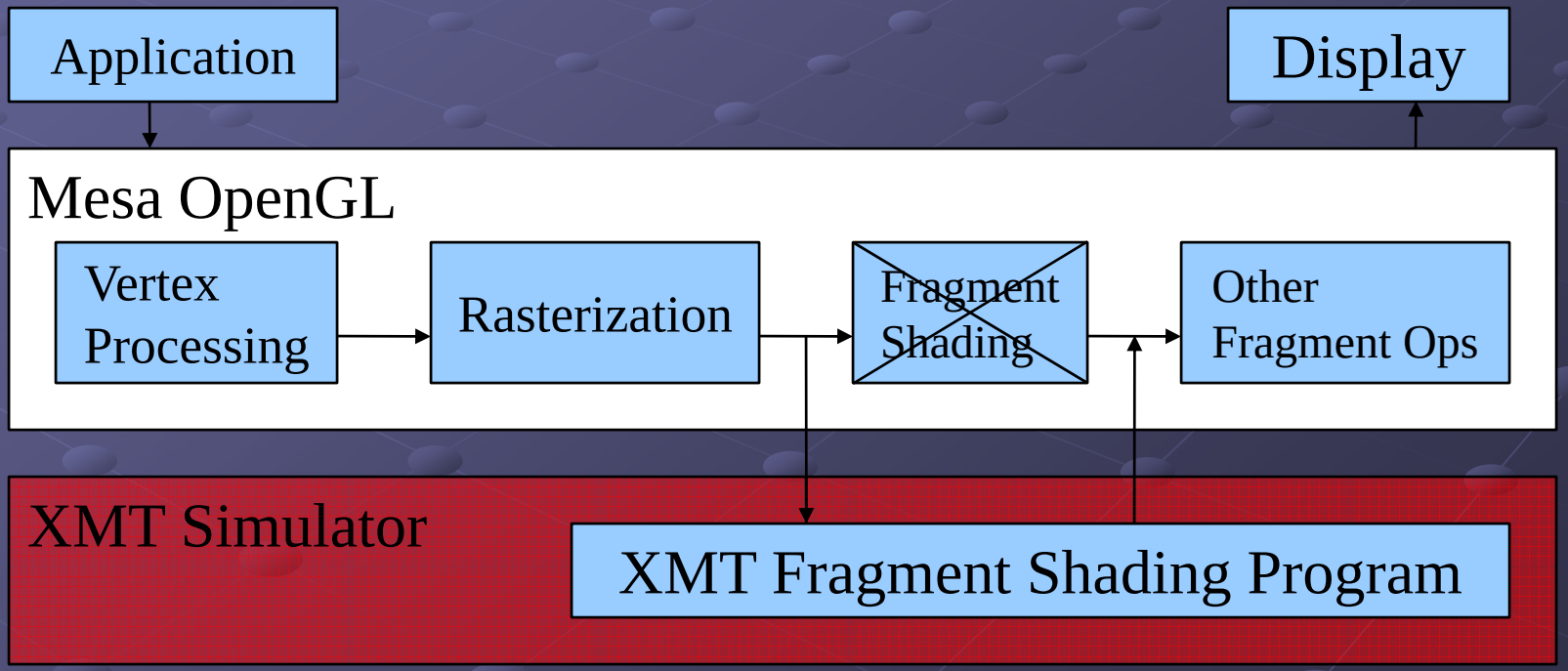
- Unification requirements
  - Ability to stand alone
  - Easy and flexible to program
  - Must perform GP tasks well
  - Competitive with modern GPUs
- Graphics performance only unknown
- GPUs are a unique competitor
  - Successful, commodity, parallel hardware

Our Experiment

- Simulated XMT system vs. several real GPUs on fragment shading
  - Compute shading – memory light, general
  - Texture shading – memory heavy, specialized
- Only fragment shading stage compared

Simulating Fragment Shading

- Simulated XMT used in place of the fragment shading step in software



The Competitors

Simulated XMT*	
ATI x700	Released mid 2004
NVidia GeForce 7900	Released mid 2006
NVidia GeForce 8800	Released late 2006

*Scaled for the same FLOPS level as GeForce 8800

XMT Variants

- We used 3 variants of XMT
  - Version 1 - unmodified
  - Version 2 - with graphics ISA
    - Floor, Fraction, Linear Interpolation
  - Version 3 – graphics ISA and 4-way vector computations on 8-bit arithmetic

Compute Shader Results

x700	354 FPS
GeForce 7900	1917 FPS
GeForce 8800	**2760 FPS**
XMT version 1	1423 FPS
XMT version 2	**3222 FPS**

Texture Shader Results

x700	1846 FPS
GeForce 7900	**8632 FPS**
GeForce 8800	**3179 FPS**
XMT version 1	197 FPS
XMT version 2	275 FPS
XMT version 3	**487 FPS**

Analysis

- XMT compute shades faster
- XMT texture shades much slower
  - Acceptable for some apps, not all
- The GeForce GPUs follow the same trend
  - Sacrificing speed on most used apps for greater flexibility on others

Summary

- Divide between CPU/GPU is blurring
- A unified system gives
  - Ease of programming
  - Good GP performance
  - Good graphics performance
- Combination systems needed for truly high performance apps
  - An XMT + GPU system could provide the best of both worlds
  - How to partition between them? Can they cooperate?
- www.umiacs.umd.edu/users/vishkin/XMT