Hardware/Software Co-Design

Performance Considerations – III

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Fall 2011

Outline

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Data Prefetching

- Global memory access is the biggest bottleneck in current GPU
  - Solution: move data from global memory to shared memory and then proceed from there

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    Load current tile to shared memory;
    __syncthreads()__;
    Compute current tile;
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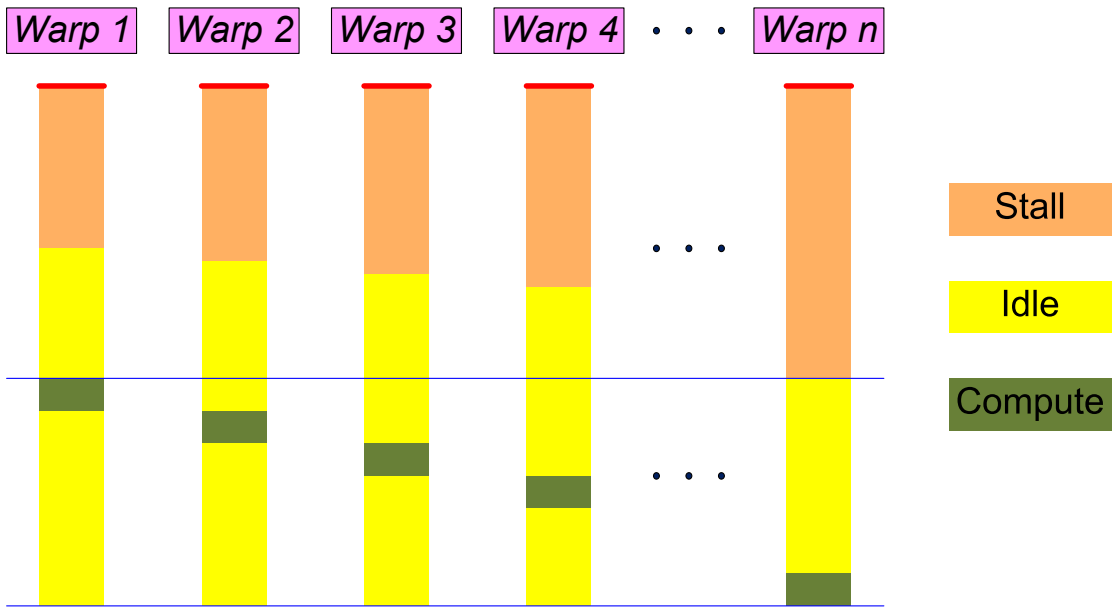
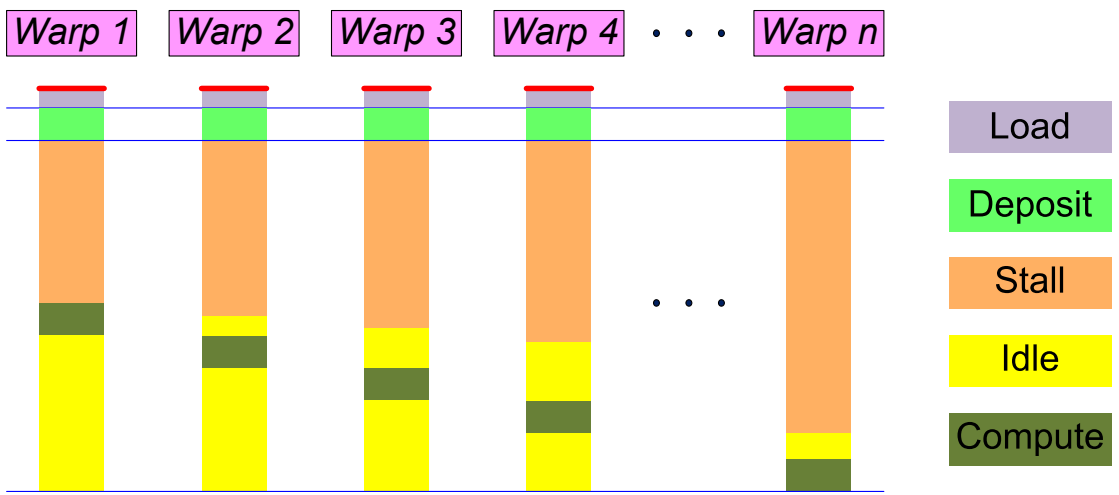


Data Prefetching – using double buffers

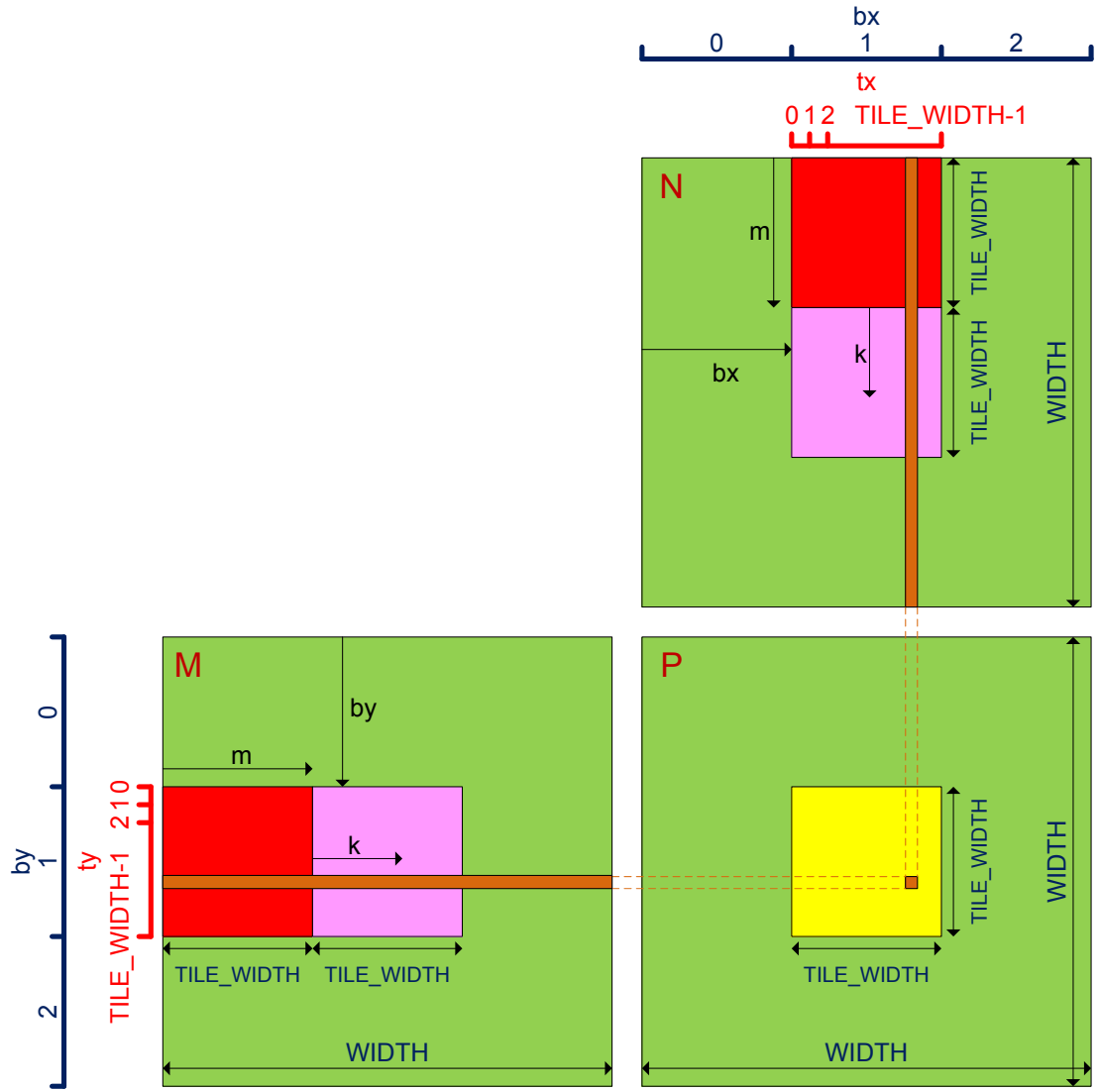
- One could double buffer the computation, getting better instruction mix within each thread

```
Load the first tile from global memory into registers;
__syncthreads()__;
Loop {
    Deposit tile from registers to shared memory;
    __syncthreads()__;
    Load next tile from global memory into registers
    Compute current tile on shared memory;
    __synthreads()__;
}
```



Matrix Multiplication Using Multiple Blocks with Tile

- .....
- Deposit Red tile from register into shared memory
- Syncthreads
- Load Pink tile into register
- Compute Red tile
- Syncthreads
- Deposit Pink tile into shared memory
- .....



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Limited Processing Bandwidth of An SM

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for (int k = 0; k < BLOCK_SIZE; ++K) {
    Pvalue += Ms[ty][k] * Ns[k][tx];
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- How many instructions are required to be carried out in each iteration?

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- How many instructions are required to be carried out in each iteration?
  - Two floating-point arithmetic instructions
  - One loop branch instruction
  - Two address arithmetic instruction
  - One loop counter increment instruction
  - Only $\frac{1}{3}$ of the instructions executed are for real computation!!!

Loop Unrolling

```
// Assume BLOCK_SIZE = 16
Pvalue = Ms[ty][0] * Ns[0][tx] + Ms[ty][1] * Ns[1][tx] + ...
         + Ms[ty][15] * Ns[15][tx];
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- Loop branch instructions $\longrightarrow$ gone
- Loop counter increment instructions $\longrightarrow$ gone
- Address arithmetic instructions $\longrightarrow$ gone
  - Indices are constants
  - Compiler is able to eliminate address arithmetic instructions
- Only floating-point arithmetic instructions are still there

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- Only floating-point arithmetic instructions are still there
  - Close to peak performance!!!

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Kernel Launch Overhead

- Kernel launches are not free
  - A null kernel launch will take non-trivial time
  - Actual number changes with HW generations and driver software
  - If you are launching lots of small grids you will lose substantial performance due to this effect
- Independent kernel launches are cheaper than dependent kernel launches
  - Dependent launch: Some readback to the cpu
- If you are reading back data to the cpu for control decisions, consider doing it on the GPU
  - Even though the GPU is slow at serial tasks, can do surprising amounts of work before you used up kernel launch overhead