Introduction to OpenACC

Objective

- **To Understand the OpenACC programming model**
  - basic concepts and pragma types
  - Simple examples to illustrate basic concepts and functionalities

OpenACC

- **The OpenACC Application Programming Interface provides a set of**
  - compiler directives (pragmas)
  - library routines and
  - environment variables

  that can be used to write data parallel FORTRAN, C and C++ programs that run on accelerator devices including GPUs and CPUs

OpenACC Pragmas

- In C and C++, the #pragma directive is the method to provide, to the compiler, information that is not specified in the standard language.

Simple Matrix-Matrix Multiplication in OpenACC

```
1  void computeAcc(float *P, const float *M, const float *N, int Mh, int Mw, int Nw)
2  {
3
4   #pragma acc parallel loop copyin(M[0:Mh*Mw]) copyin(N[0:Nw*Mw])
copyout(P[0:Mh*Nw])
5   for (int i=0; i<Mh; i++) {
6       #pragma acc loop
7       for (int j=0; j<Nw; j++) {
8           float sum = 0;
9           for (int k=0; k<Mw; k++) {
10              float a = M[i*Mw+k];
11              float b = N[k*Nw+j];
12              sum += a*b;
13          }
14          P[i*Nw+j] = sum;
15      }
16  }
17 }
```

Some Observations

- **The code is almost identical to the sequential version, except for the two lines with #pragma at line 4 and line 6.**
- **OpenACC uses the compiler directive mechanism to extend the base language.**
  - #pragma at line 4 tells the compiler to generate code for the ‘i’ loop at line 5 through 16 so that the loop iterations are executed in parallel on the accelerator.
  - The copyin clause and the copyout clause specify how the matrix data should be transferred between the host and the accelerator. The #pragma at line 6 instructs the compiler to map the inner ‘j’ loop to the second level of parallelism on the accelerator.

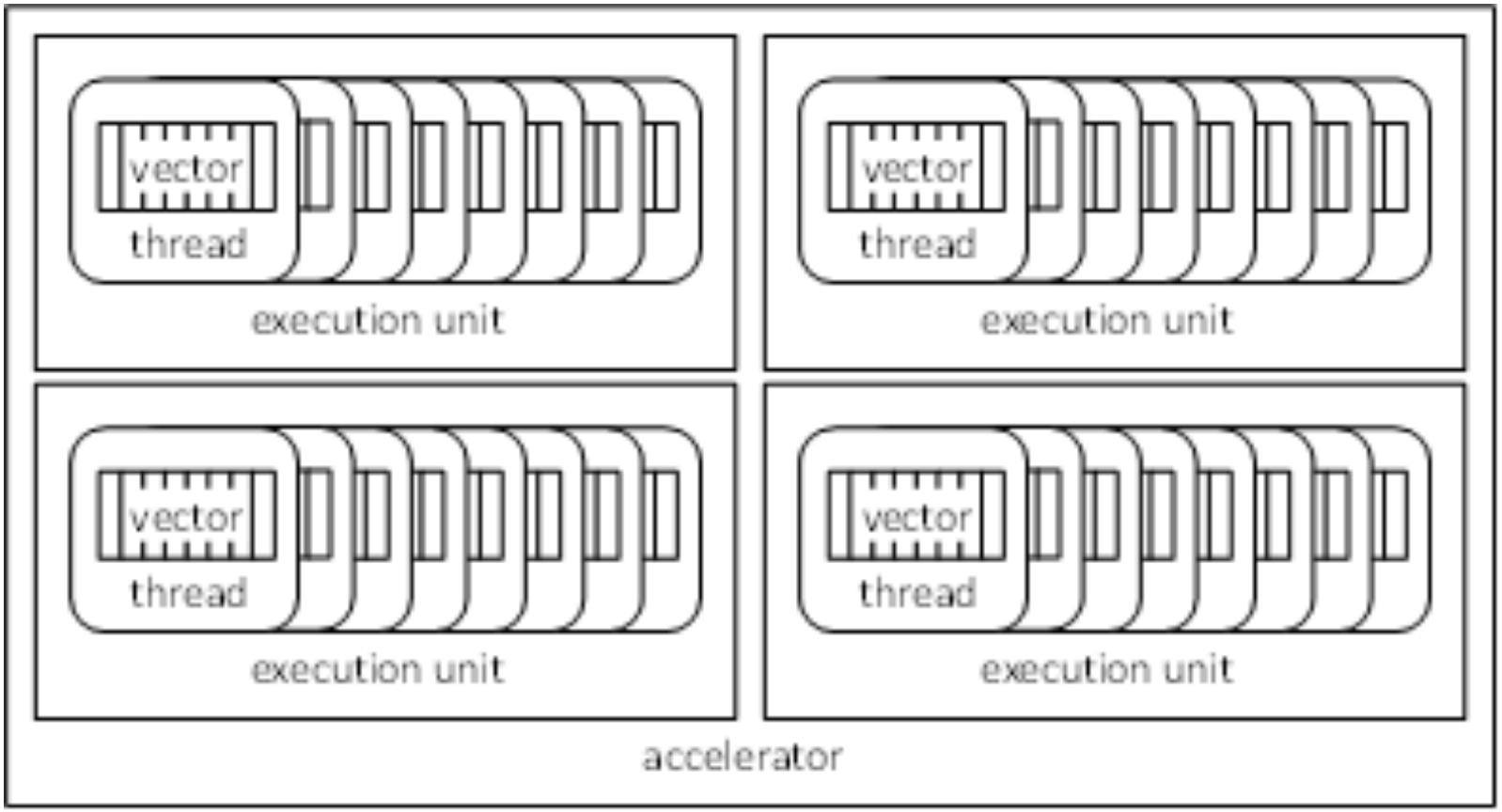
Motivation

- **OpenACC programmers can often start with writing a sequential version and then annotate their sequential program with OpenACC directives.**
  - leave most of the details in generating a kernel and data transfers to the OpenACC compiler.
- **OpenACC code can be compiled by non-OpenACC compilers by ignoring the pragmas.**

Frequently Encountered Issues

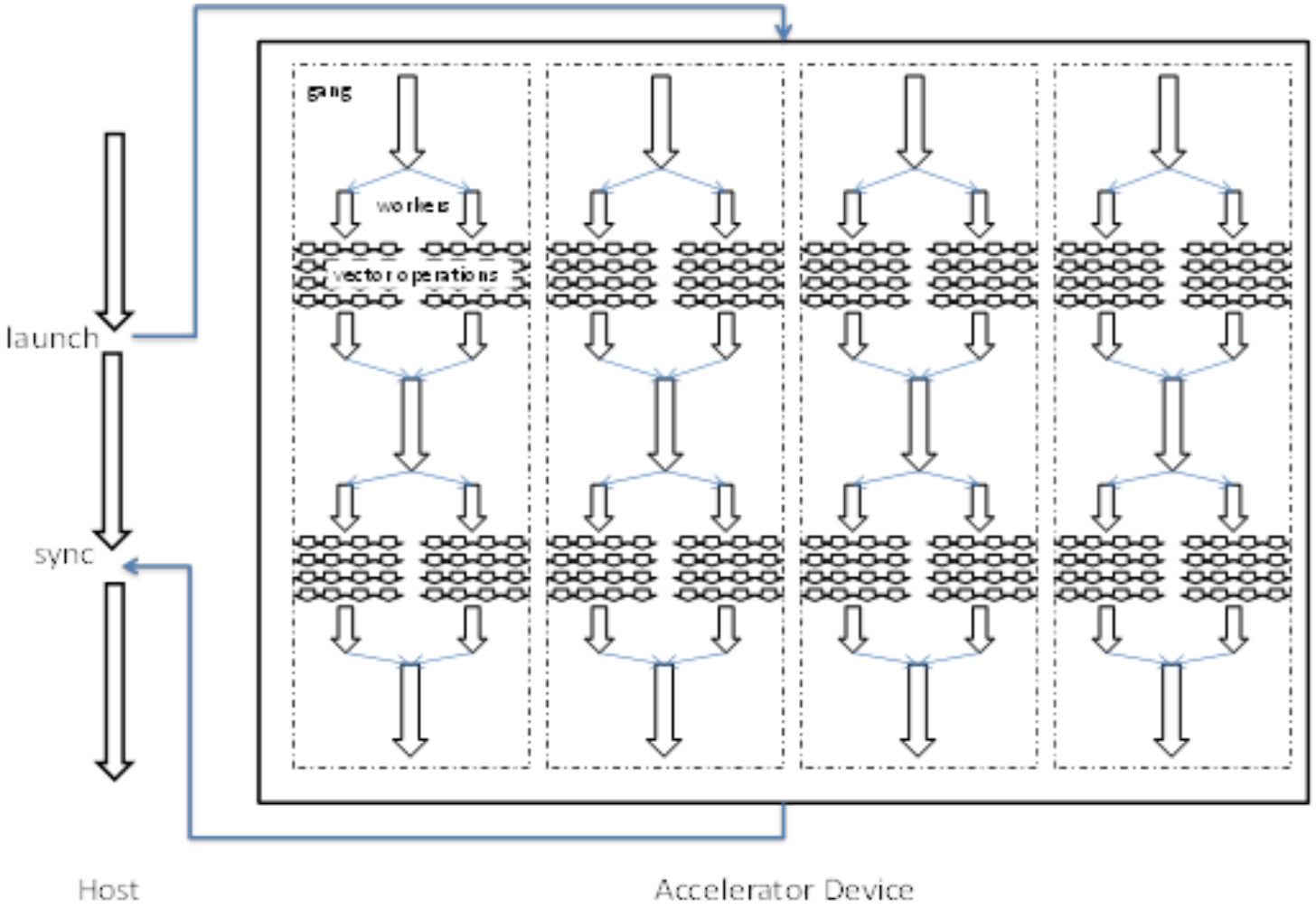
- **Some OpenACC pragmas are hints to the OpenACC compiler, which may or may not be able to act accordingly**
  - The performance of an OpenACC depends heavily on the quality of the compiler.
  - Much less so in CUDA or OpenCL
- **Some OpenACC programs may behave differently or even incorrectly if pragmas are ignored**

OpenACC Device Model



Currently OpenACC does not allow synchronization across threads.

OpenACC Execution Model



Parallel vs. Loop Constructs

```
#pragma acc parallel loop copyin(M[0:Mh*Mw]) copyin(N[0:Nw*Mw]) copyout(P[0:Mh*Nw])
for (int i=0; i<Mh; i++) {
…
}
```

is equivalent to:

```
#pragma acc parallel copyin(M[0:Mh*Mw]) copyin(N[0:Nw*Mw]) copyout(P[0:Mh*Nw])
{
    #pragma acc loop
    for (int i=0; i<Mh; i++) {
        …
    }
}
```

(a parallel region that consists of just a loop)

Parallel Construct

- A parallel construct is executed on an accelerator
- One can specify the number of gangs and number of works in each gang

```
#pragma acc parallel copyout(a) num_gangs(1024) num_workers(32)
{
        a = 23;
}
```

1024*32 workers will be created. a=23 will be executed redundantly by all 1024 gang leads

What does each "Gang Loop" do?

```
#pragma acc parallel
num_gangs(1024)
{
    for (int i=0; i<2048; i++) {
        …
    }
}
```

```
#pragma acc parallel
num_gangs(1024)
{
#pragma acc loop gang
    for (int i=0; i<2048; i++) {
        …
    }
}
```

Worker Loop

```
#pragma acc parallel num_gangs(1024) num_workers(32)
{
    #pragma acc loop gang
    for (int i=0; i<2048; i++) {
        #pragma acc loop worker
        for (int j=0; j<512; j++) {
            foo(i,j);
        }
    }
}
```

1024*32=32K workers will be created, each executing 1M/32K = 32 instance of foo()

```
#pragma acc parallel num_gangs(32)
{
    Statement 1; Statement 2;
    #pragma acc loop gang
    for (int i=0; i<n; i++) {
        Statement 3; Statement 4;
    }
    Statement 5;  Statement 6;
    #pragma acc loop gang
    for (int i=0; i<m; i++) {
        Statement 7;  Statement 8;
    }
    Statement 9;
    if (condition)
      Statement 10;
}
```

- Statements 1 and 2 are redundantly executed by 32 gangs
- The n for-loop iterations are distributed to 32 gangs

Kernel Regions

```
#pragma acc kernels
{
    #pragma acc loop num_gangs(1024)
    for (int i=0; i<2048; i++) {
        a[i] = b[i];
    }
    #pragma acc loop num_gangs(512)
    for (int j=0; j<2048; j++) {
        c[j] = a[j]*2;
    }
    for (int k=0; k<2048; k++) {
        d[k] = c[k];
    }
}
```

- Kernel constructs are descriptive of programmer intentions