



Vector triad code

```
double wcs,wce,ct;
int repeat=1,...;
double runtime=0.0;

for(; runtime<.1; repeat*=2) {
    timing(&wcs, &ct);
    for(int r=0; r<repeat; r++){
        for(int i=0; i<SIZE; i++){
            a[i]=b[i]+c[i]*d[i];
        }
        if(a[SIZE>>1]<0){
            dummy(a,b,c,d);
        }
    }
    timing(&wce, &ct);
    runtime = wce-wcs;
}
repeat /= 2;
```

Ensure proper time measurement

Actual benchmark loop

Prevent compiler from optimizing the r loop (or just everything) away

Do not forget to initialize your arrays with valid FP numbers!



Matrix-vector multiply

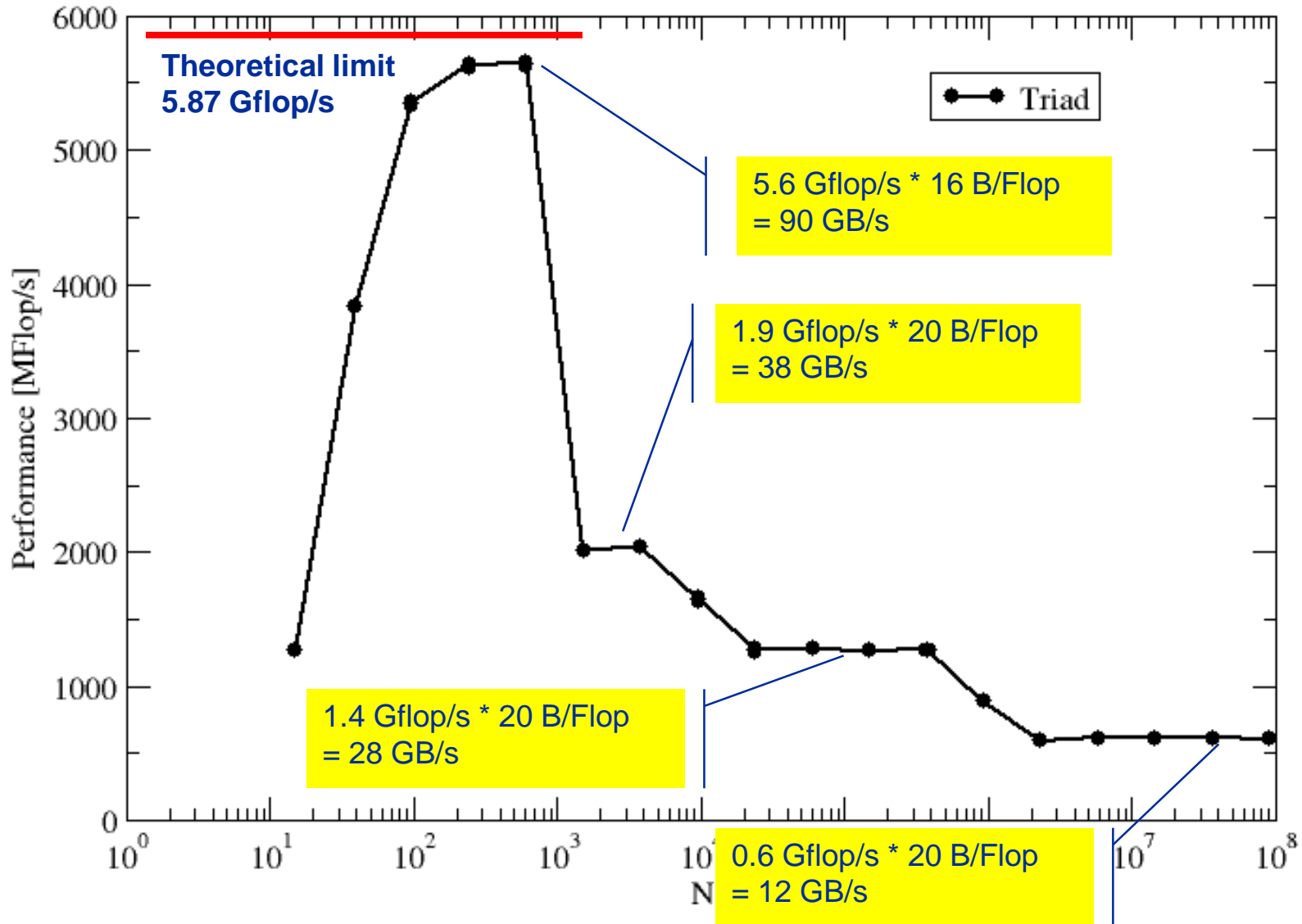
```
// C with 1D arrays
for(int r=0; r<repeat; r++){
    for(int m=0; m<SIZE; m++){
        for(int n=0; n<SIZE; n++)
            y[m] += a[m*SIZE+n] * x[n];
    }
    <DUMMY>
}
```

Vector update

```
#define OFFSET ...
for(int r=0; r<repeat; r++){
    for(int m=OFFSET; m<SIZE; m++){
        a[m] = s * a[m-OFFSET];
    }
    <DUMMY>
}
```

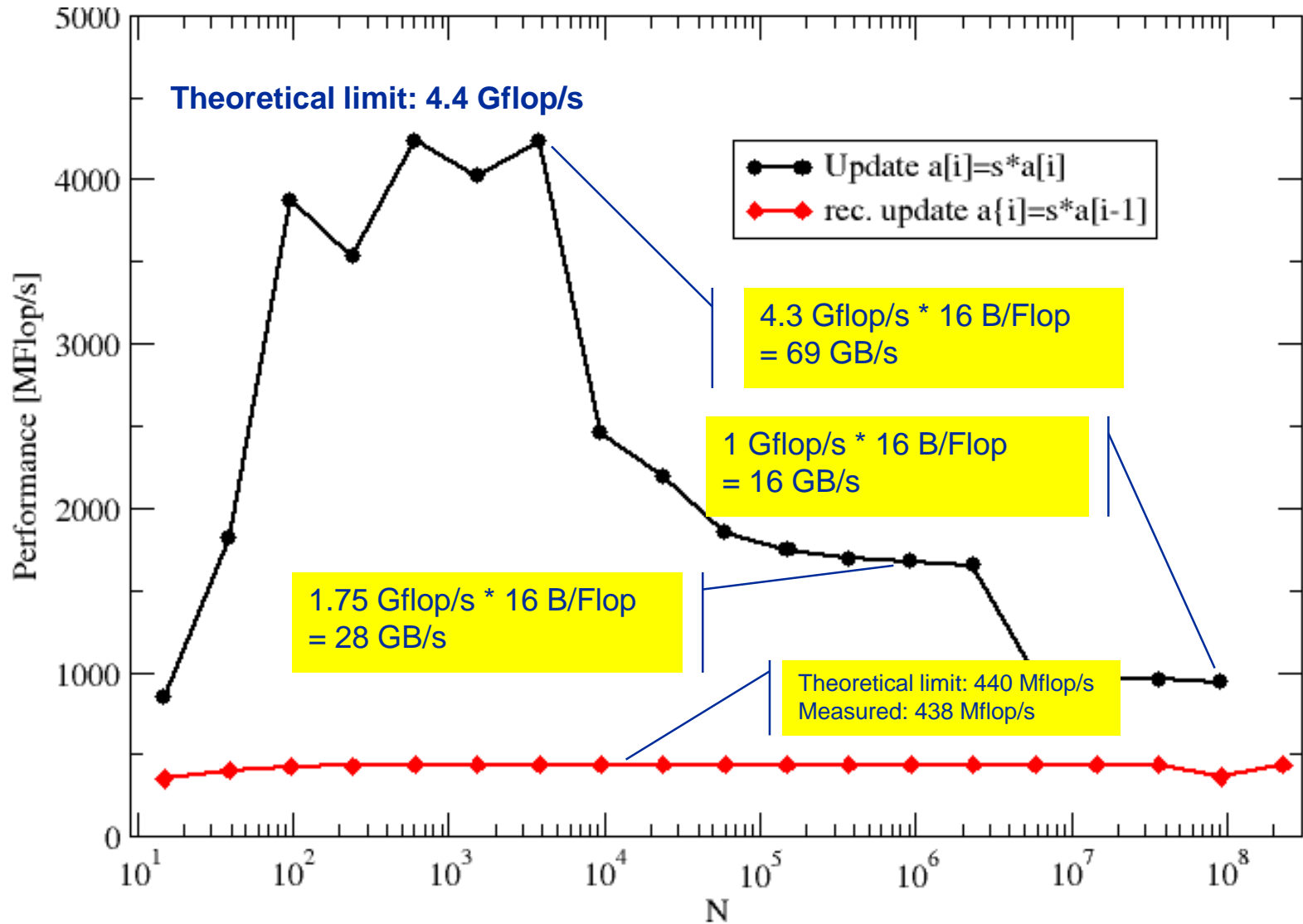
Vector Triad on Emmy @ 2.2 GHz

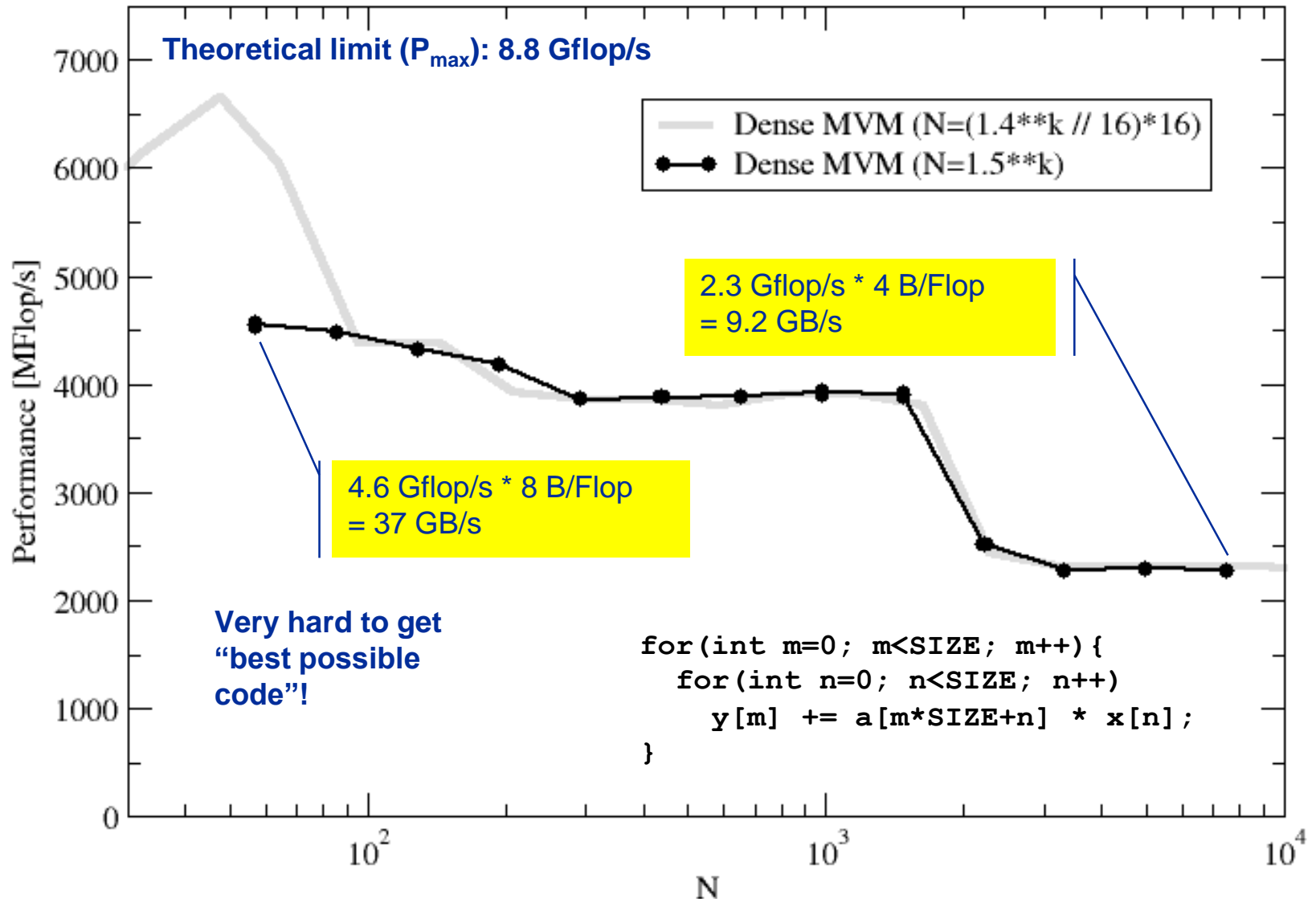
$$A(:) = B(:) + C(:) * D(:)$$



Vector update on Emmy @ 2.2 GHz

```
for(int m=OFFSET; m<SIZE; m++) {
    a[m] = s * a[m-OFFSET];
}
```





Dense MVM assembly code



Inner loop (scalar product) – remainder loop omitted

```
vmovupd ymm6, [rdx]
vmovupd ymm8, [rdx+0x20]
vmovupd ymm10, [rdx+0x40]
vmovupd ymm12, [rdx+0x60]
vmulpd ymm7, ymm6, [r13+rcx*8+0x0]
vmulpd ymm9, ymm8, [r13+rcx*8+0x20]
vmulpd ymm11, ymm10, [r13+rcx*8+0x40]
vmulpd ymm13, ymm12, [r13+rcx*8+0x60]
vaddpd ymm5, ymm5, ymm7
vaddpd ymm4, ymm9, ymm4
vaddpd ymm3, ymm11, ymm3
vaddpd ymm2, ymm13, ymm2
add rcx, 0x10
add rdx, 0x80
cmp rcx, r15
jb 4035f0 <do_it_+0xf0>
vaddpd ymm4, ymm5, ymm4
vaddpd ymm2, ymm3, ymm2
vaddpd ymm3, ymm4, ymm2
vextractf128 xmm5, ymm3, 0x1
vaddpd xmm6, xmm3, xmm5
vunpckhpd xmm7, xmm6, xmm6
vaddsd xmm2, xmm6, xmm7
```

“bulk” code
16-way unrolled (4x4)

tree reduction:
16 partial results
→ final result

Final result in
scalar slot of
xmm2

Assignment 1 – Task 2: Vector Triad C vs. C++, Intel (Emmy @ 2.2 GHz)



```
icpc -Ofast -xHost -fno-alias ...
```

