Roofline model

Serial machines

What is the maximum performance possible for a given algorithm?

- What is your bottleneck?
  - Disk?
  - Math ops?
  - Reading from cache?
  - Reading from main memory?

First a little on counting reads and ops

```
for(i2=0; i2 < n2; i2++){
   out[iloc[i2][1]]+=in[iloc[i2][0]] *val[i2]
}
```

First a little on counting reads and ops

Reads: 5

Writes: 1

```
for(i2=0; i2 < n2; i2++){
  out[iloc[i2][1]]+=in[iloc[i2][0]] *val[i2]
}
```

First a little on counting reads and ops

Reads: 5

Writes: 1

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for(i2=0; i2 < n2; i2++){
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}
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Multiply: 1

Add: 1

First a little on counting reads and ops

Reads: 5

Writes: 1

```
for(i2=0; i2 < n2; i2++){
   out[iloc[i2][1]]+=in[iloc[i2][0]] *val[i2]
}
```

Multiply: 1

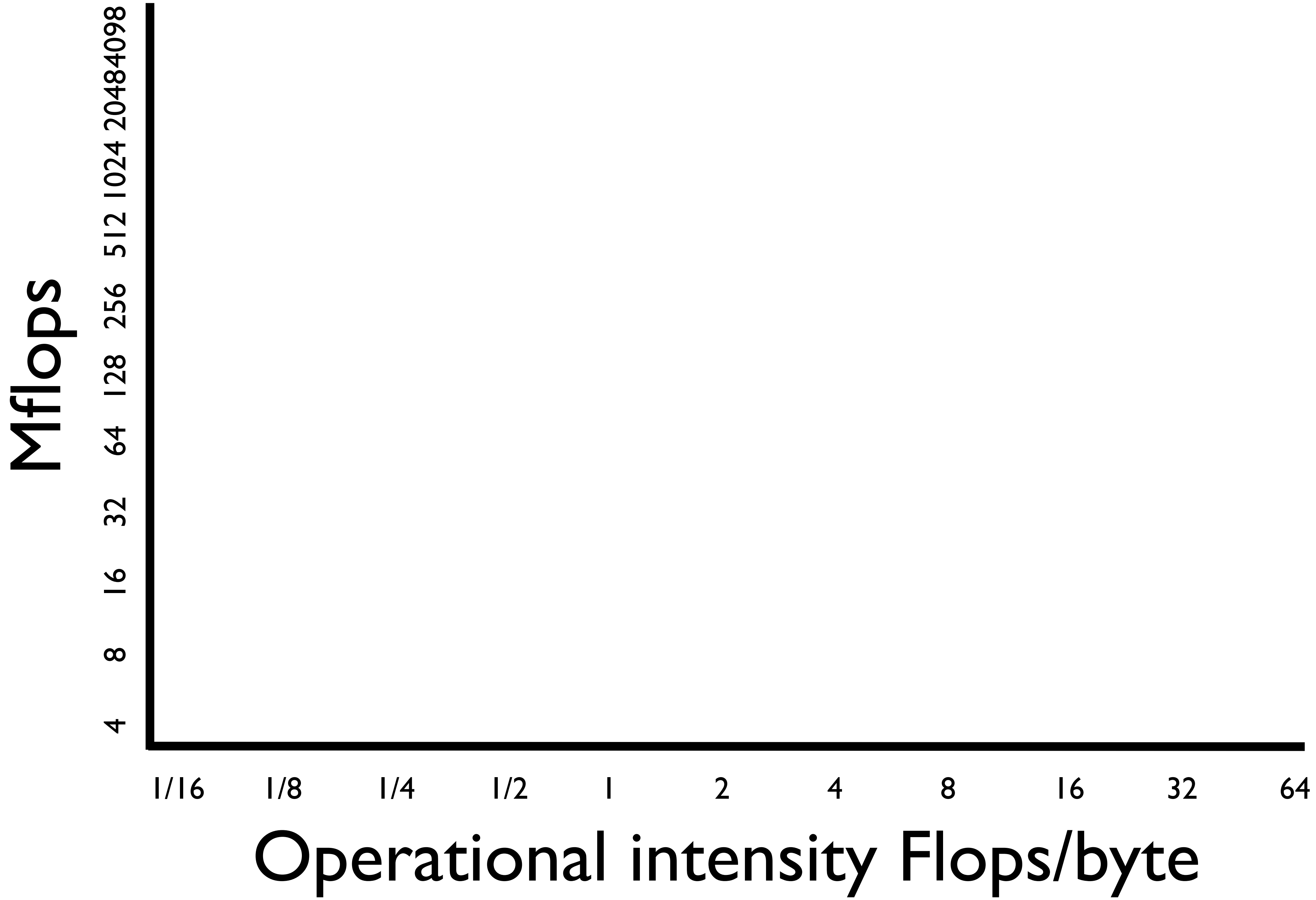
Add: 1

IO:24

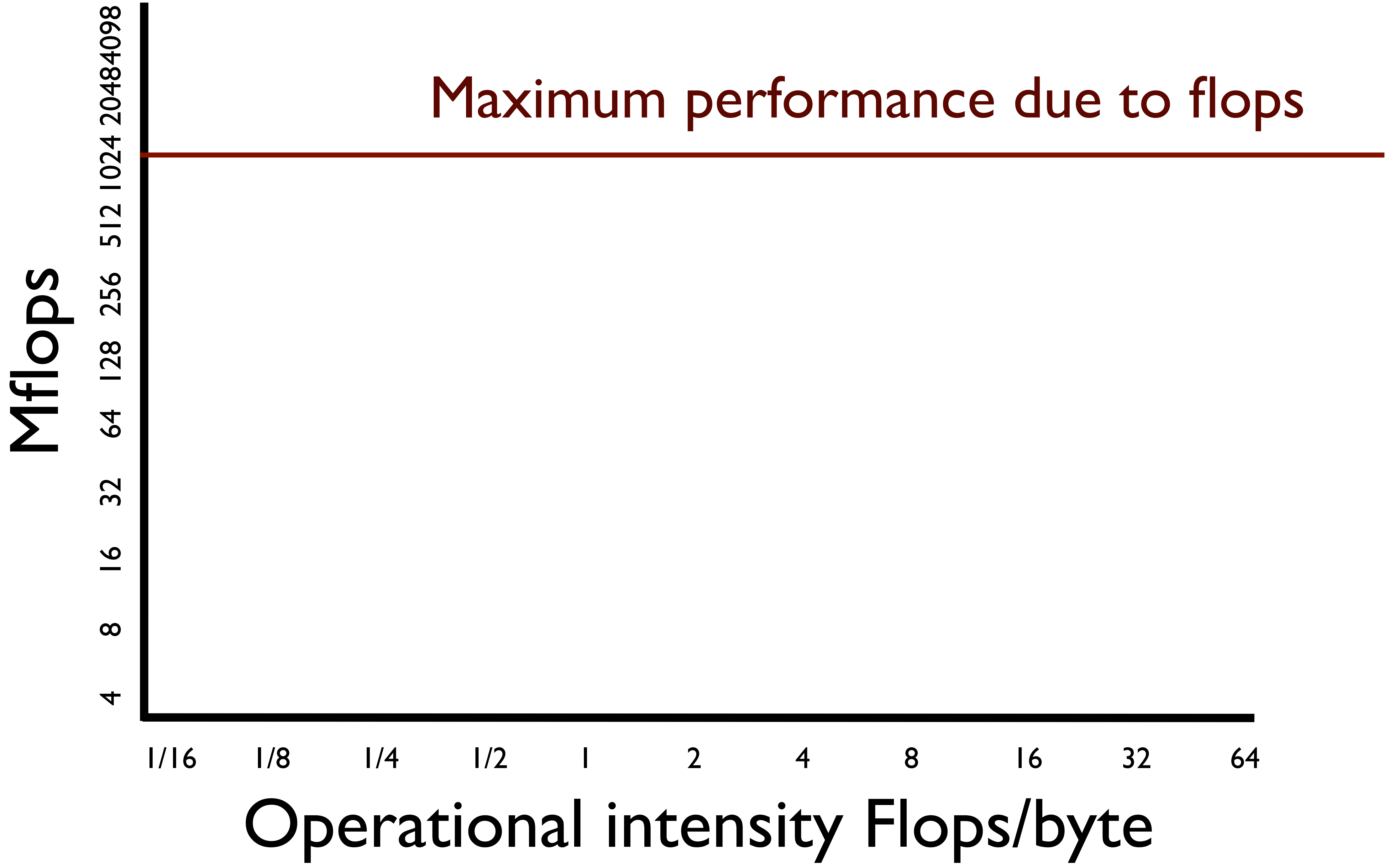
Flops:2

Ratio: 1/12

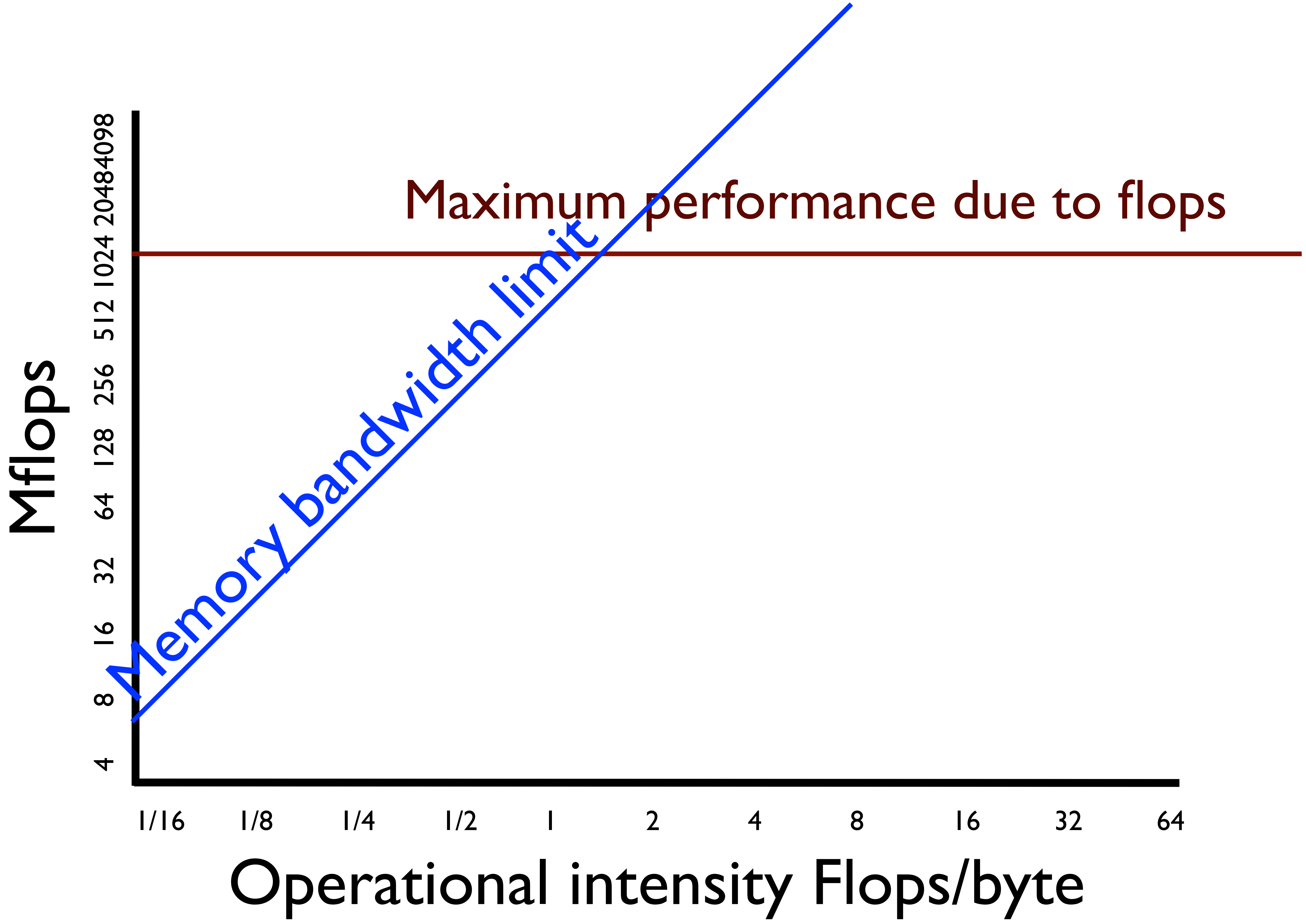
Roofline model



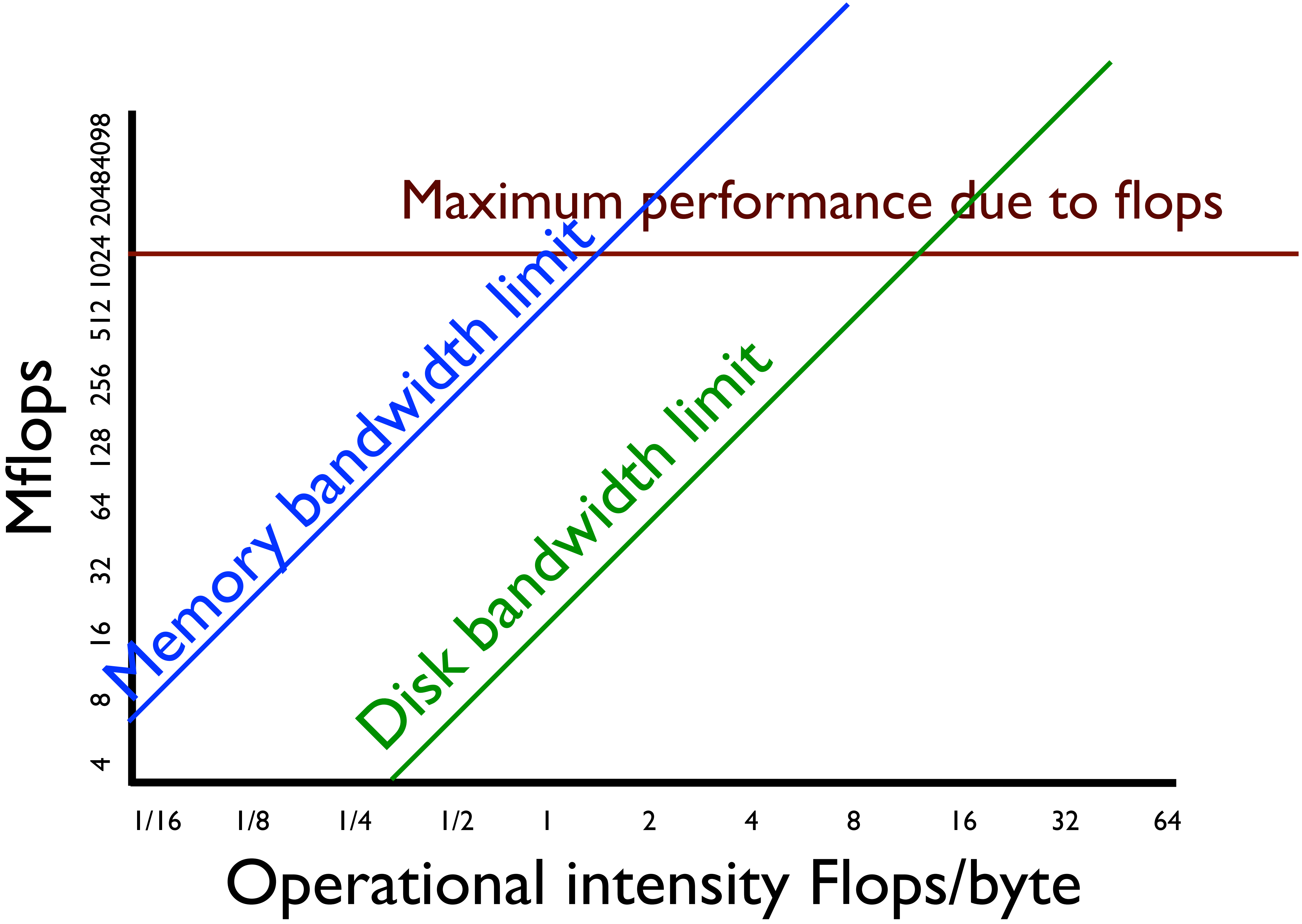
Roofline model



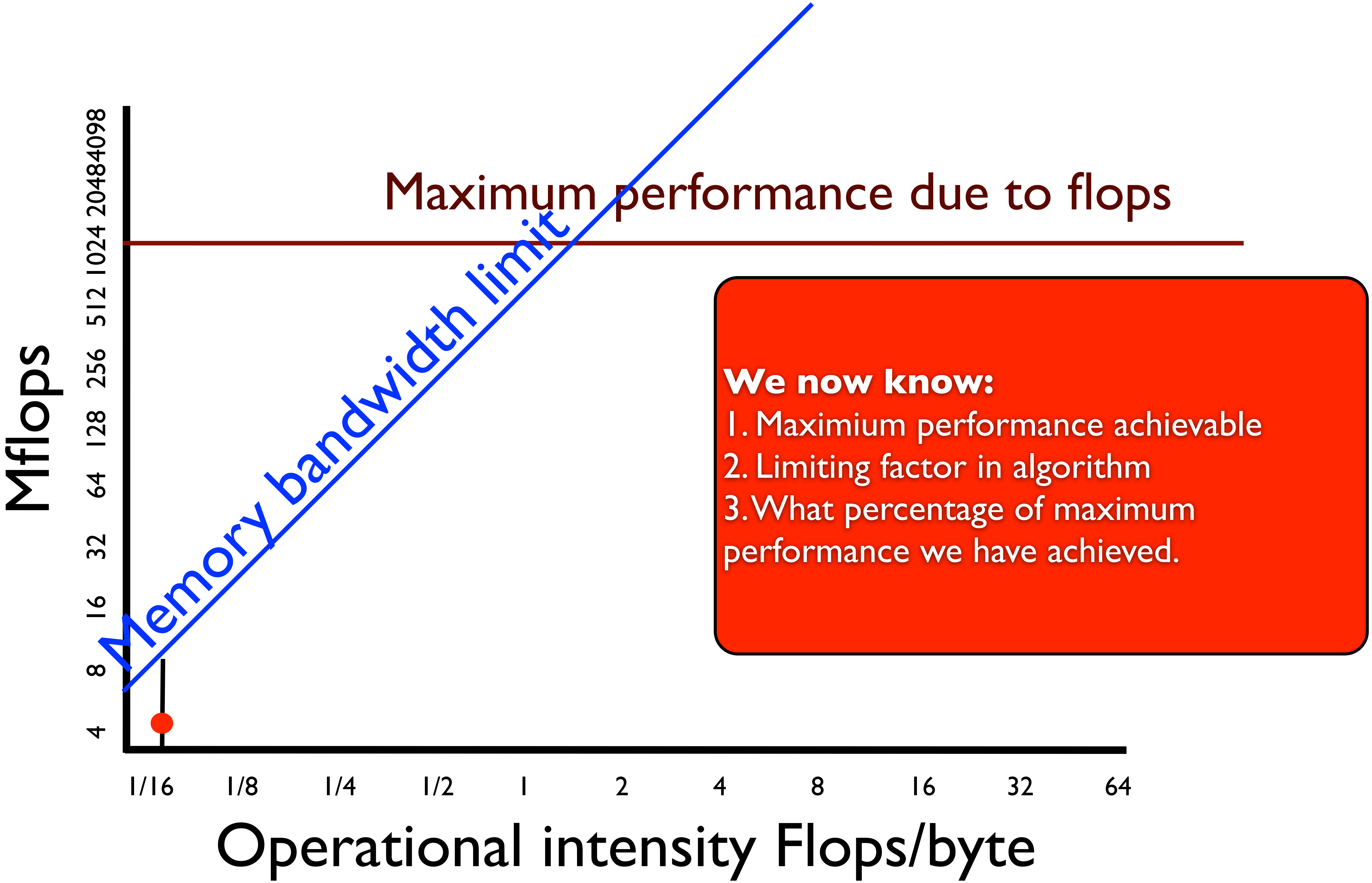
Roofline model



Roofline model



Roofline model



We now know:

1. Maximium performance achievable
2. Limiting factor in algorithm
3. What percentage of maximum performance we have achieved.

Causes for not achieving maximum performance

1. Indirection (iloc needs to be looked up before knowing what to grab from in, out)
2. Poor use of cache line for in,out
3. Inability to use prefect on in,out

```
for(i2=0; i2 < n2; i2++){
   out[iloc[i2][1]]+=in[iloc[i2][0]] *val[i2]
}
```

What if the relative filter locations where always the same?

```
i=0;
for(i2=3; i2 < n2-3; i2++){
   ib=i2-3;
   for(i1=0; i1 < 7; i1++){
      out[i2]+=in[ib++]*val[i++];
}
```

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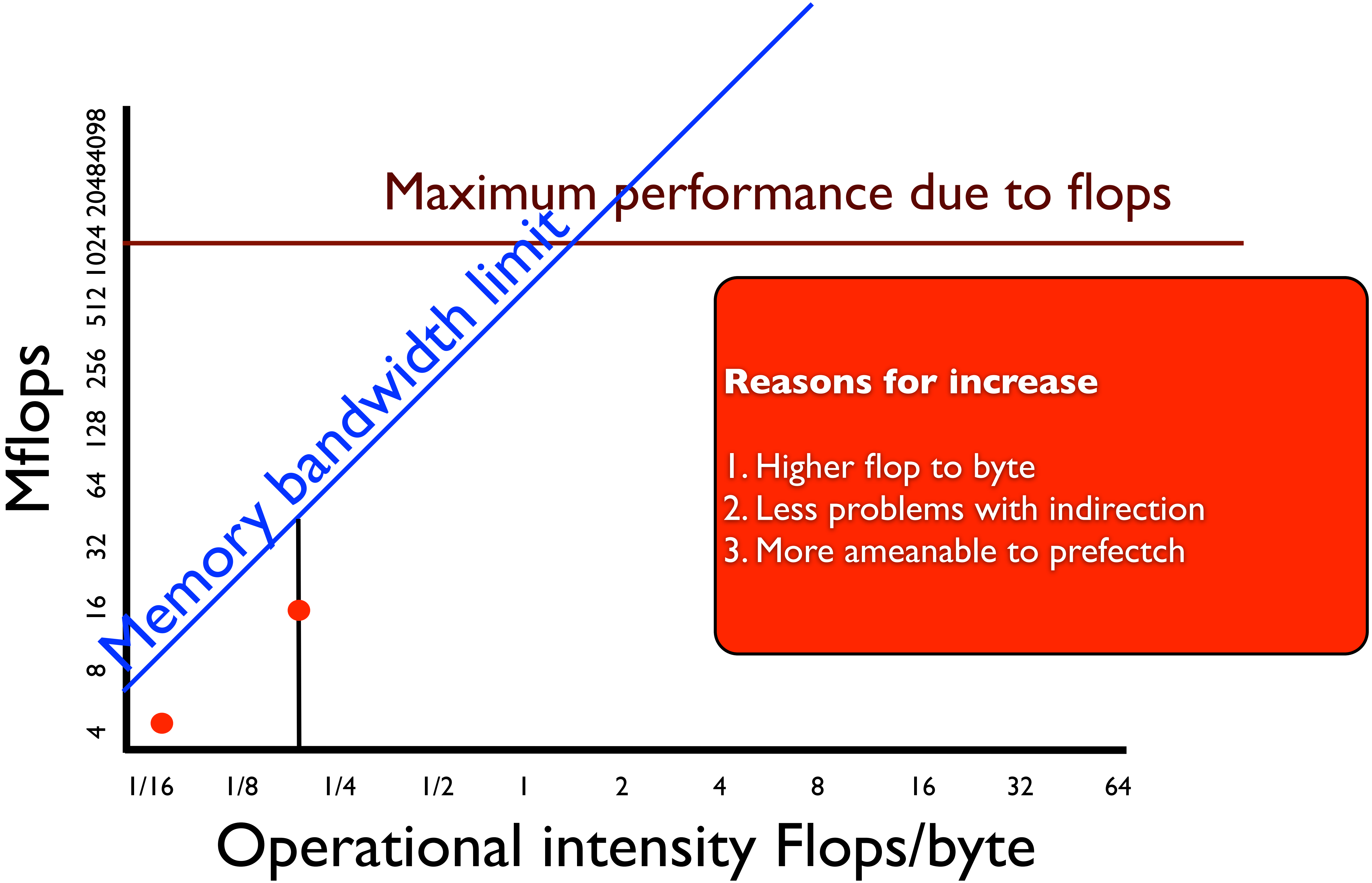
i=0;
for(i2=3; i2 < n2-3; i2++){
   ib=i2-3;
   for(i1=0; i1 < 7; i1++){
      out[i2]+=in[ib++]*val[i++];
}
```

Reads: 3
Writes: 1

Multiply: 1
Add: 1

IO:12
Flops:2
Ratio: 1/6

Roofline model



Reasons for increase

1. Higher flop to byte
2. Less problems with indirection
3. More ameanable to prefectch

But we aren’t dealing with a Von Neumann machine, we have cache

```
i=0;
for(i2=3; i2 < n2-3; i2++){
   ib=i2-3;
   for(i1=0; i1 < 7; i1++){
      out[i2]+=in[ib++]*val[i++];
}
```

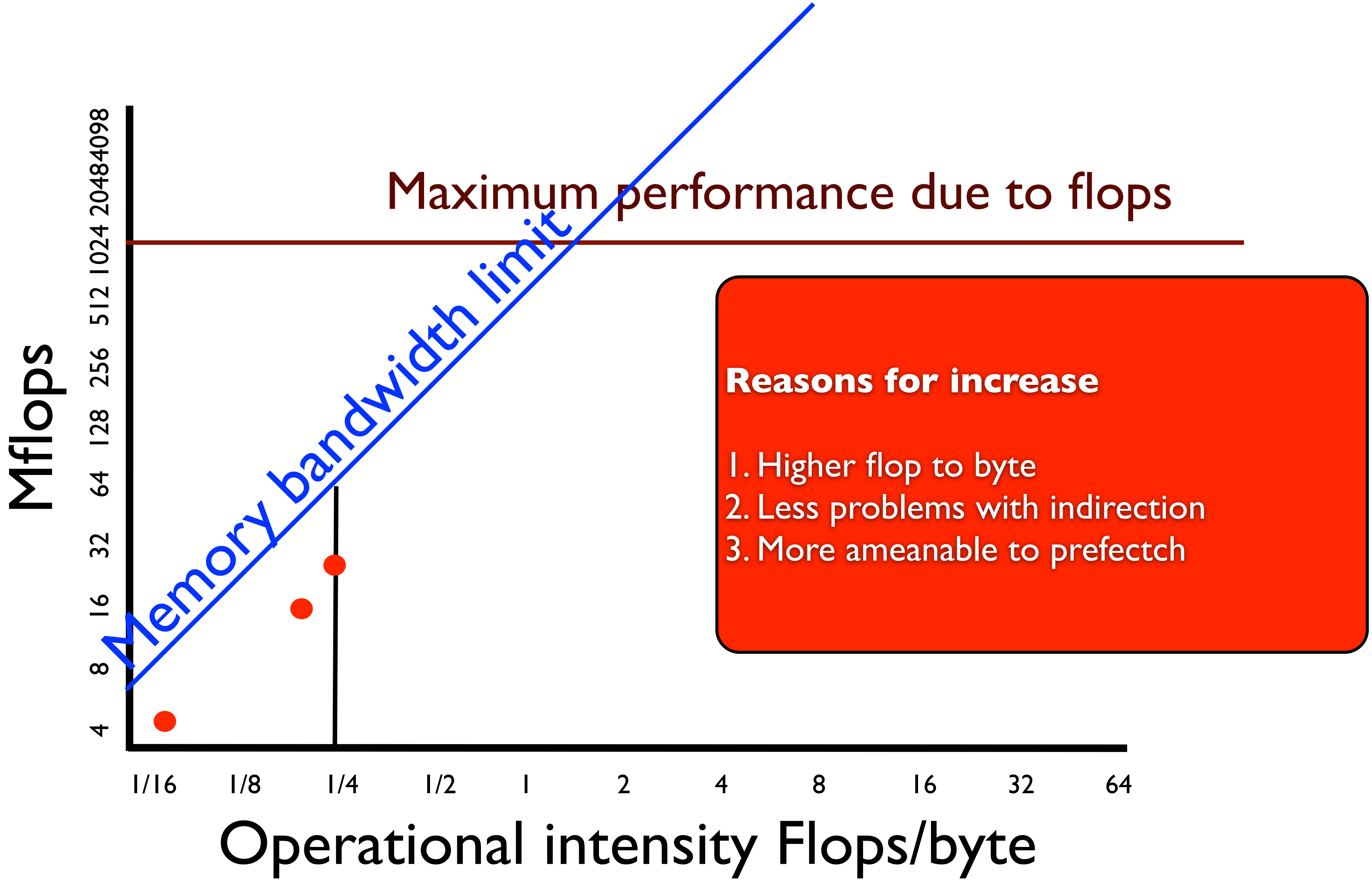
In
Has a reuse rate of 7. Only when i1=6 does a new value need to be read in from memory

out
Has a reuse rate of 1/7. Only when i1=0 does a new value need to be read. Only when i1=6 does a new value need to be written.

IO: 9.1
Flops:2
Ratio: 1/4.5

Reads: 11/7
Writes: 1/7

Roofline model



Reasons for increase

1. Higher flop to byte
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What if val is only a function of i1?

```
for(i2=3; i2 < n2-3; i2++){
   ib=i2-3;i=0;
   for(i1=0; i1  < 7; i1++){
      out[i2]+=in[ib++]*val[i++];
}
```

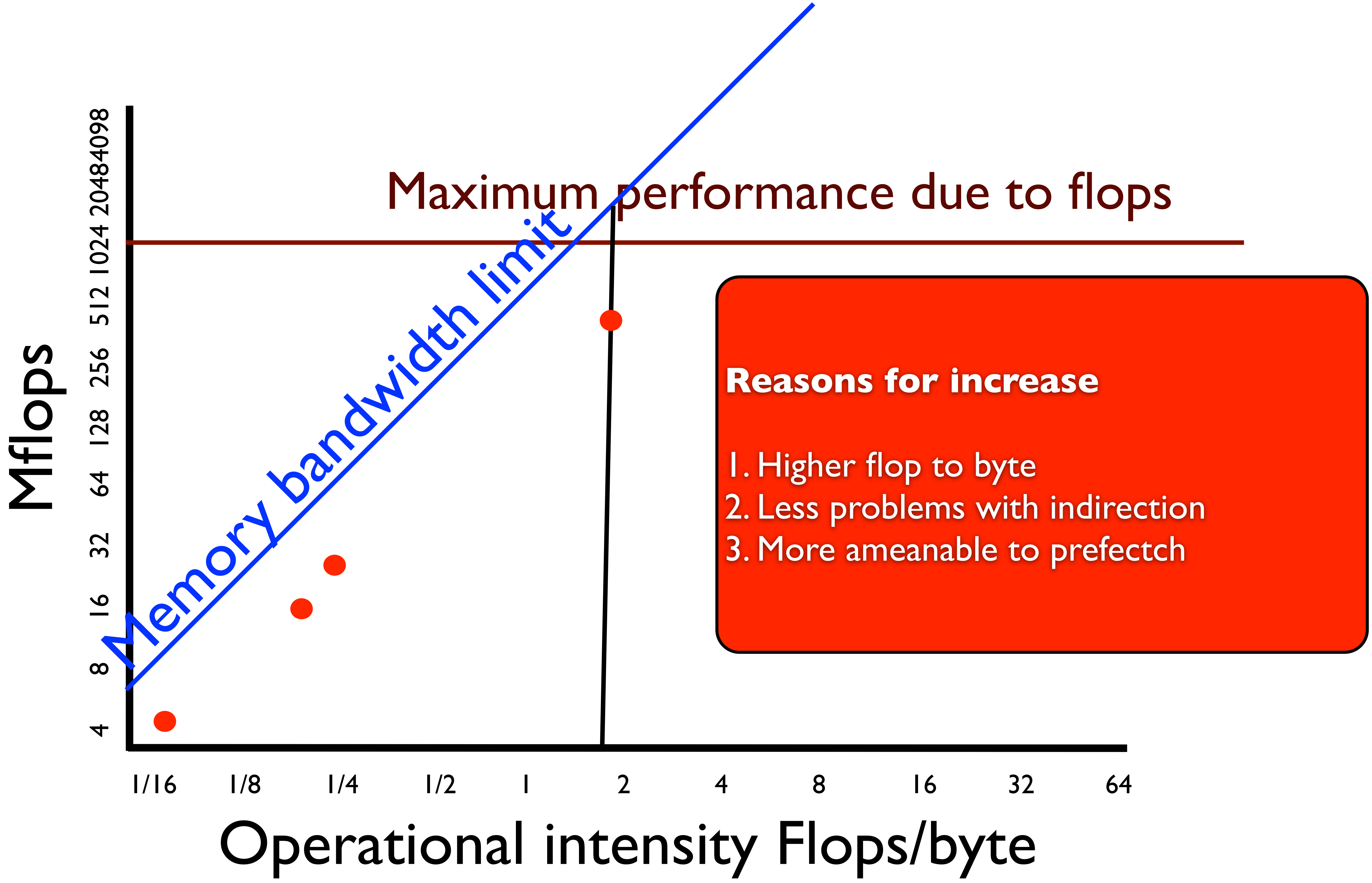
What if val is only a function of i1?

```
for(i2=3; i2 < n2-3; i2++){
  ib=i2-3;i=0;
  for(i1=0; i1 < 7; i1++){
    out[i2]+=in[ib++]*val[i++];
}
```

IO: 1.12
Flops:2
Ratio: 1/4.5

Reads: 1/7
Writes: 1/7

Roofline model



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