High performance computing and Madagascar

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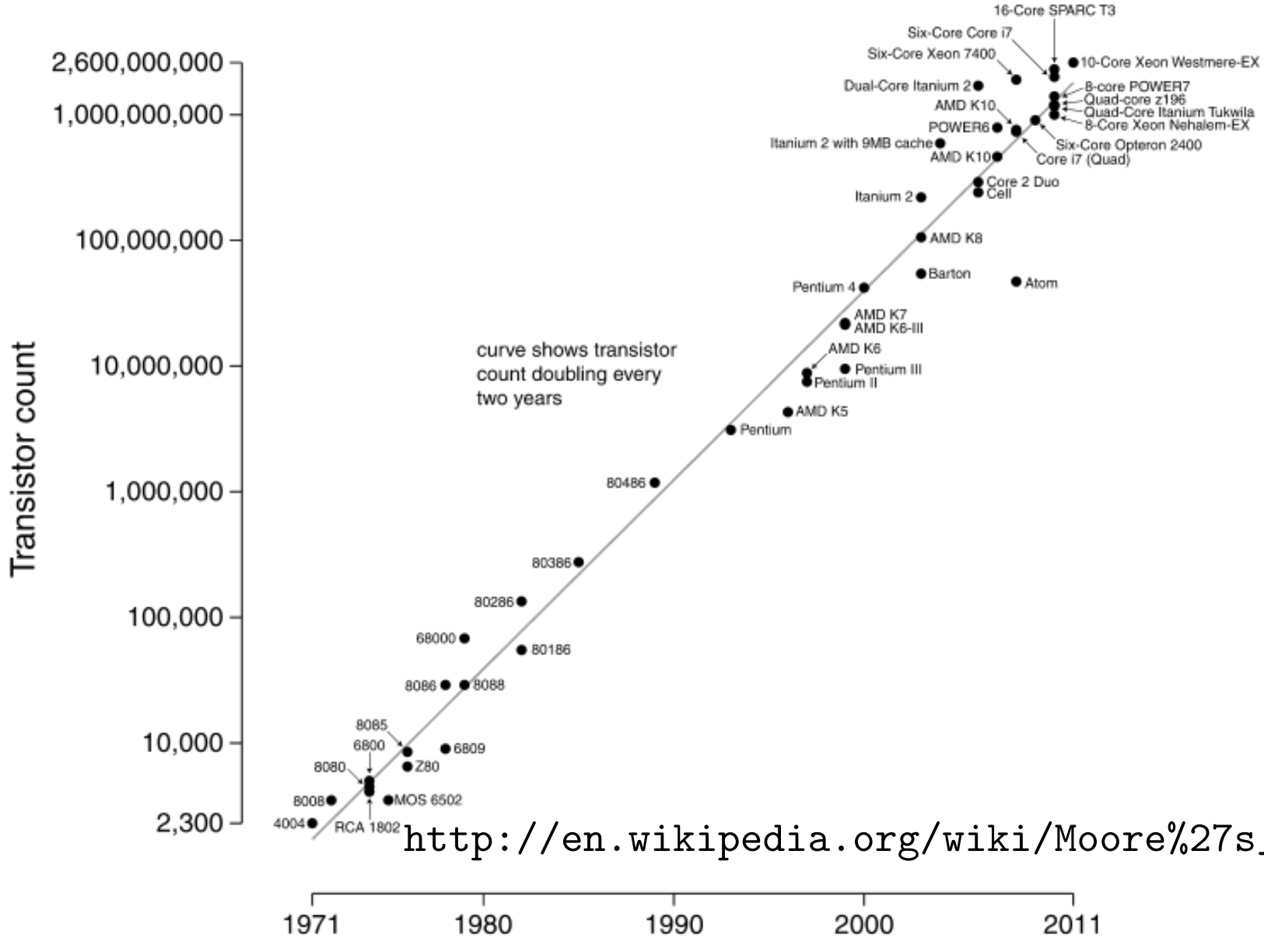
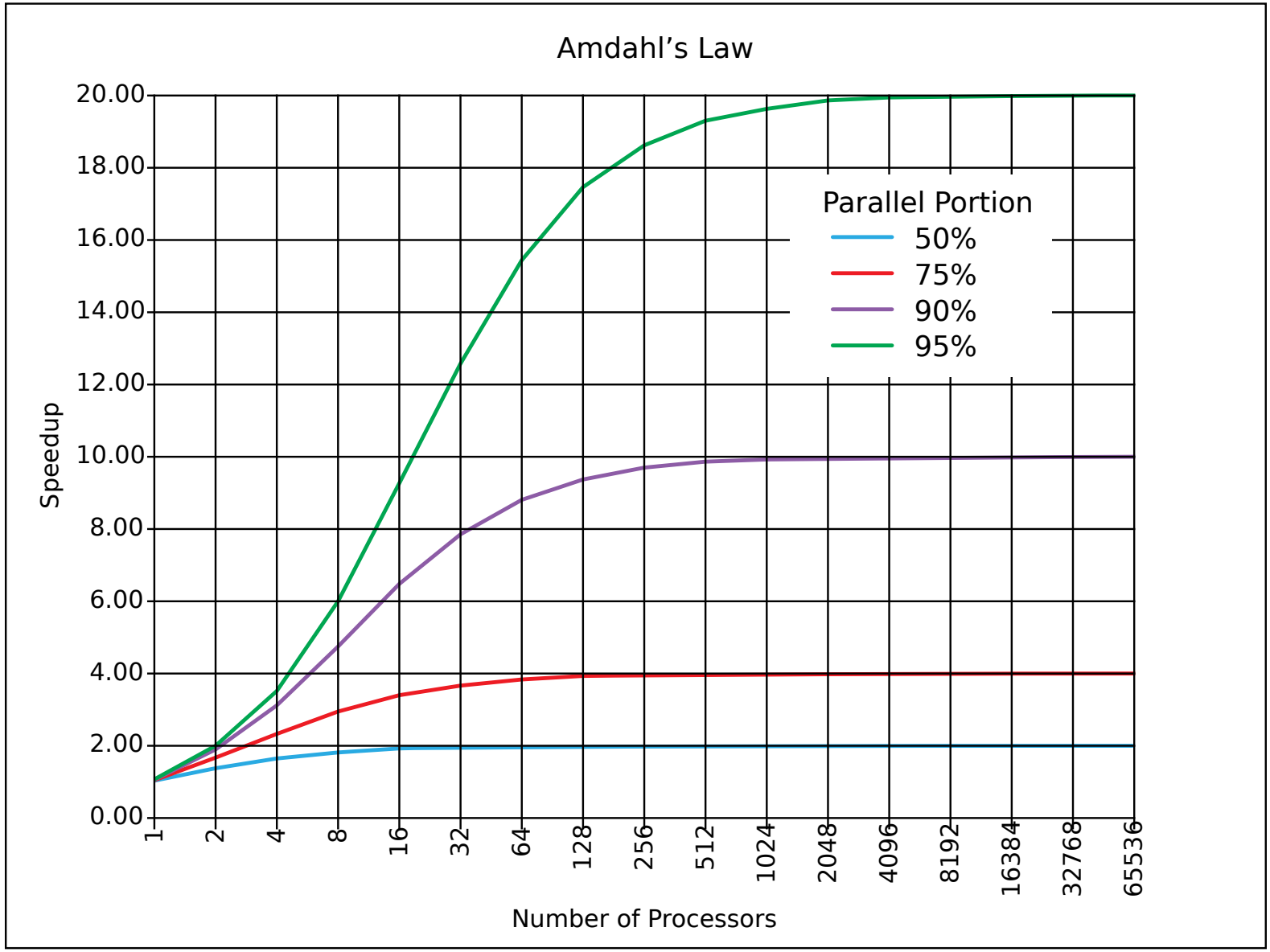
Why should we bother to go parallel?

Microprocessor Transistor Counts 1971-2011 & Moore's Law



http://en.wikipedia.org/wiki/Moore%27s_law



http://en.wikipedia.org/wiki/Amdahl%27s_law

outline

concepts of parallel computing

approaches: OpenMP and MPI

do you need to code parallel? Let SCons do it for you!

demo example

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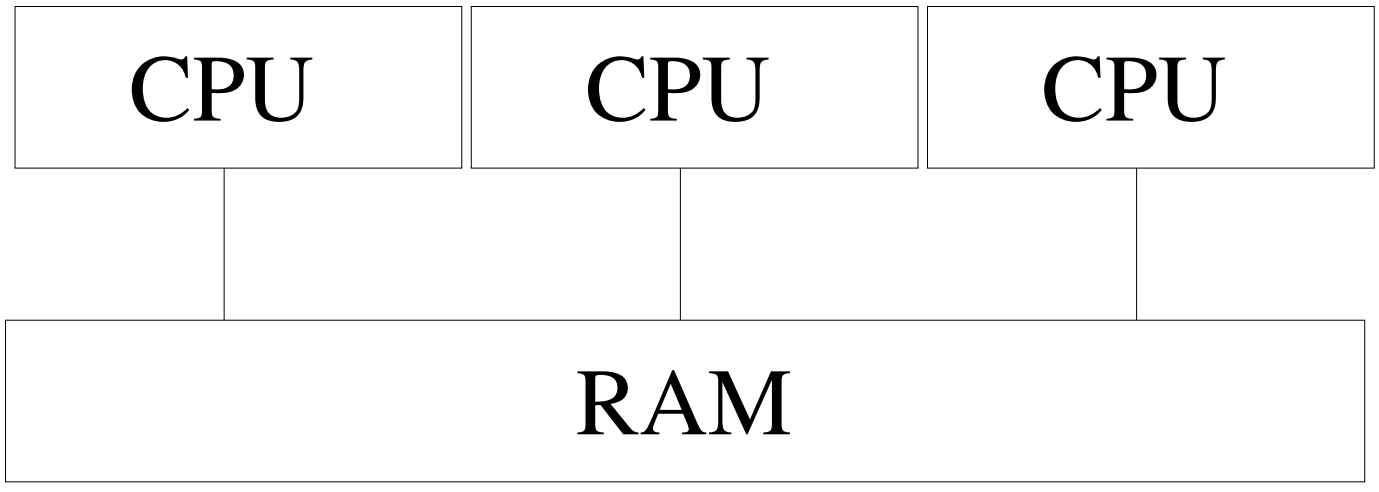
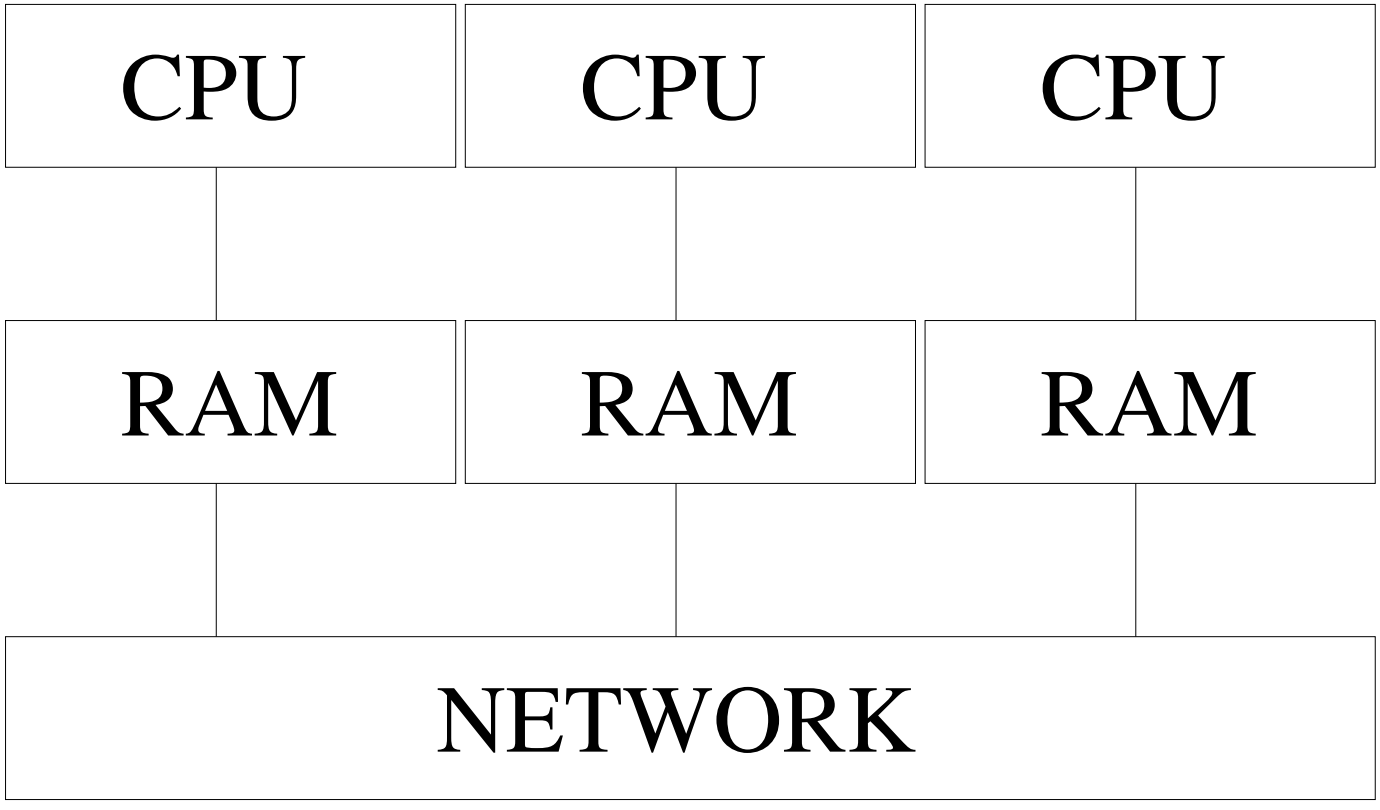
demo example

shared memory system



modified from Vladimir Bashkardin, 2010

distributed memory system



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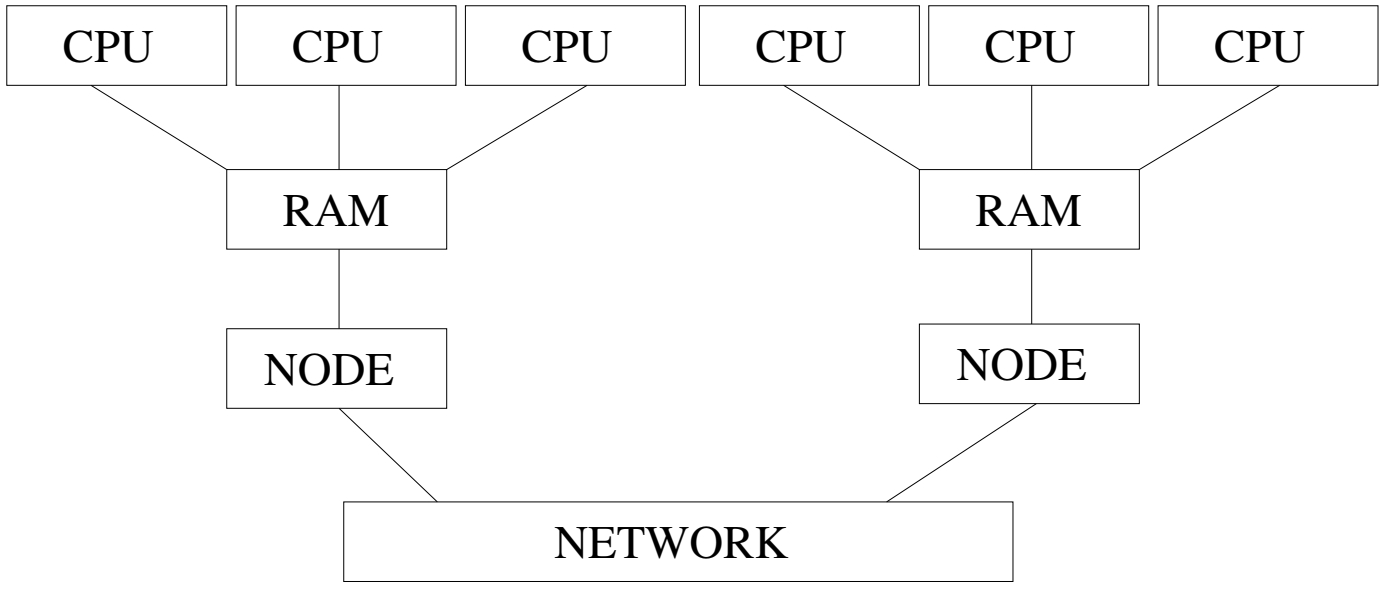

hybrid memory system (i.e. clusters)

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OpenMP:

addresses shared memory parallelization

supported by most of compilers

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resources:

`http://openmp.org/wp/`

`http://www.cOMPunity.org/`

MPI (Message Passing Interface):

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resources:

`http://www.open-mpi.org/software/`

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parallelization with SCons

instead of scons use **pscons**

it will automatically run in parallel independent Flows

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---

useful environmental variables to have:

```
$ export RSF_THREADS='8'
$ export RSF_CLUSTER='localhost 8'
$ export OMP_NUM_THREADS=$RSF_THREADS
```

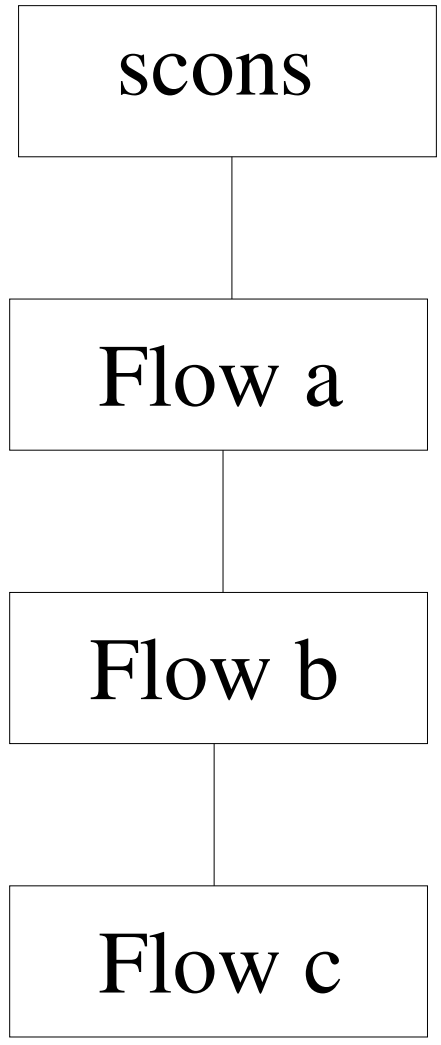
scons vs pscons

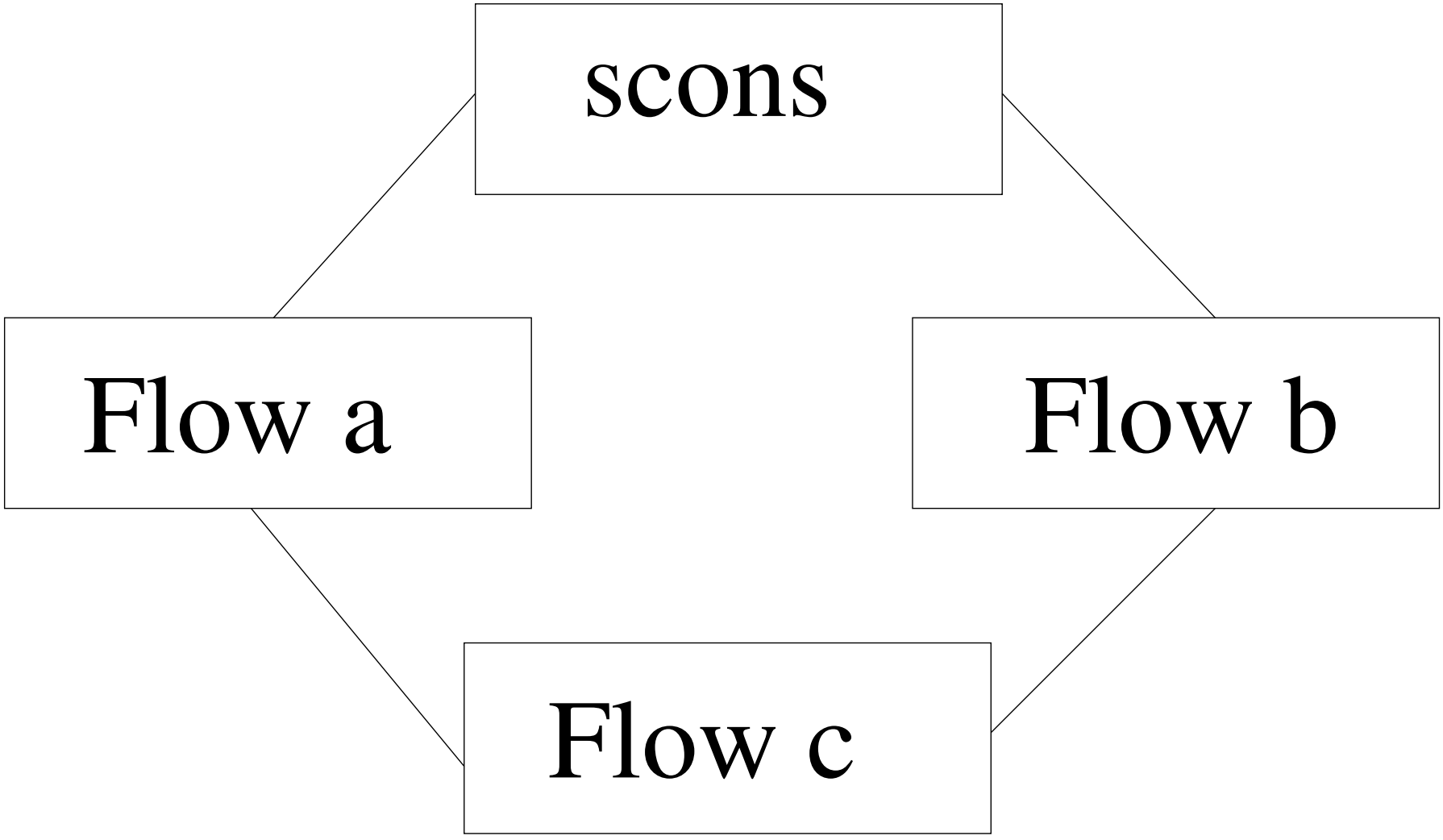
```
from rsf.proj import *


Flow('a','input','flow a')

Flow('b','input','flow b')

Flow('c','a b','flow c')
```


scons
Flow a
Flow b
Flow c


scons
Flow a
Flow b
Flow c

we can do better than the sequential flow:

```
Flow('Targets','Sources','flow')
```

... by setting up some parallel variables in Flow:

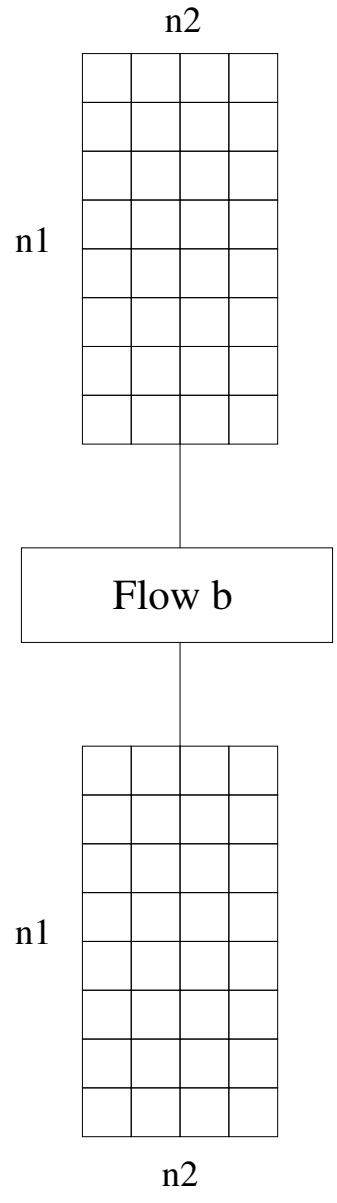
```
Flow('Targets','Sources','flow',
       split=[n,m],reduce='cat')
```

n = axis to split.

m = length of dimension **n**

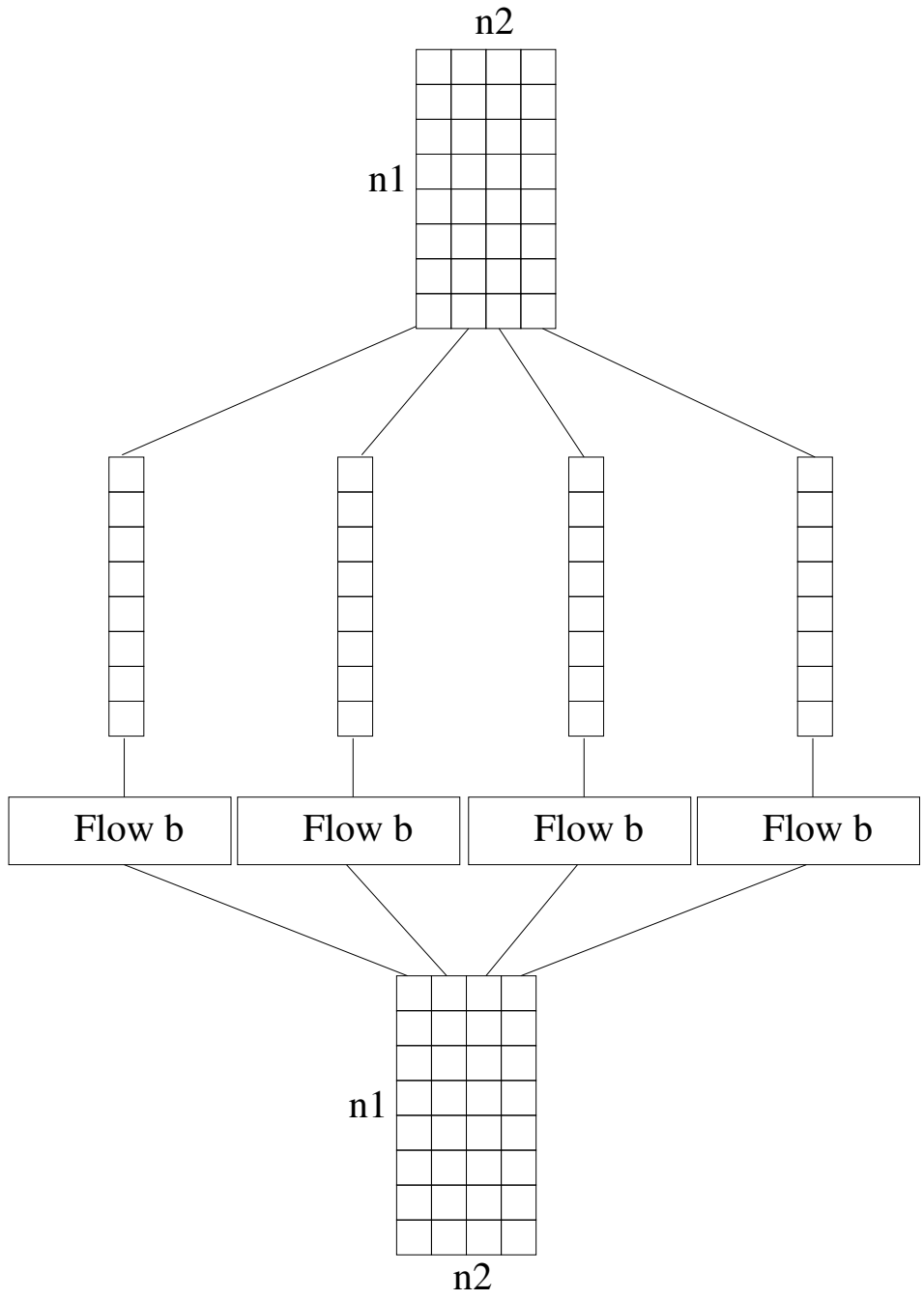
Let's consider a sequential example:

```
Flow('a',None,'spike n1=8 n2=4 ')
Flow('b','a','noise rep=y')
```


n2
n1
Flow b
n1
n2

now let's run it in parallel:

```
Flow('a',None,'spike n1=8 n2=4 ')
Flow('b','a','noise rep=y',split=[2,4],reduce='cat')
```


n2
n1
Flow b
Flow b
Flow b
Flow b
n1
n2

The variable ‘split‘ in Flow can take several options:

```
Flow('Targets','Sources','flow',
     split=[n,m],reduce='cat')
```

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Flow('Targets','Sources','flow',
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```

```
Flow('Targets','Sources','flow',
     split=[n,'omp'],reduce='cat')
```

The variable ‘split‘ in Flow can take several options:

```
Flow('Targets','Sources','flow',
     split=[n,m],reduce='cat')
```

```
Flow('Targets','Sources','flow',
     split=[n,'omp'],reduce='cat')
```

```
Flow('Targets','Sources','flow',
     split=[n,'mpi'],np=m,reduce='cat')
```

other reduce commands: sfrcat, sfadd, sfinterleave ...

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demo example

```
from rsf.proj import *

# Input data to use in example:
# produces random numbers with uniform
# distribution [-1000,1000]

Flow('random',None,
     '''spike n1=1024 n2=1024 n3=128|
        noise rep=y range=2000  type=n
       |math output="input-1000"''')

Flow('clip_seq','random','clip clip=500')
```

Let's see the timing:

```
time pscons clip_seq.rsf
```

```
# 1: In this case scons will split the input,
#    process separately, and cat all the
#    individual outputs into one target.
Flow('clip_scons','random',' clip clip=500',
      split=[3,128],reduce='cat')
```

```
time pscons clip_scons.rsf
```

```
# 2: Now, I am specifying the type of parallelization
#    using OpenMP, it is parallelizing over the
#    slower axis (the third one)
Flow('clip_omp_scons','random',' clip clip=500',
    split=[3,'omp'],reduce='cat')
```

```
time pscons clip_omp_scons.rsf
```

```
# 3: In this case I use explicit parallelization
#    with MPI [n,'mpi'] in this case m is the
#    number of CPU's to use, n is the axis to split

Flow('clip_mpi_scons','random',' clip clip=500',
    split=[3,'mpi'],np=8,reduce='cat')
```

```
time pscons clip_mpi_scons.rsf
```

```
# 4: OMP parallelization in the code. It uses the
#    number of maximum number of cores available if
#    $OMP_NUM_THREADS doesn't exist.
Program('clip_omp','Mclip.c')
Flow('clip_omp_incore','random clip_omp.exe',
     './${SOURCES[1]} clip=500')
```

```
time pscons clip_omp_incore.rsf
```

```
# 5: Hybrid case, OMP parallelization in the code, and
#    extra parallelization with MPI. In a single
#    computer doesn't make too much sense but with
#    a cluster it does.
Flow('clip_hybrid','random clip_omp.exe',
    './${SOURCES[1]} clip=500',split=[3,'mpi'],np=4,
                                    reduce='cat')
```

```
time pscons clip_hybrid.rsf
```

Issues that affect scalability:

- I/O (read and write data to disk)

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- network

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- I/O (read and write data to disk)
- network
- combination of both

conclusions

- parallelize as much as you can (Amdahl's law)
- use pscons instead of scons
- avoid I/O and network as much as possible
- do code parallelization if needed

resources

http://ahay.org/wiki/Parallel_Computing

Vladimir Bashkardin's, Houston 2010 school:

http://ahay.org/wikilocal/docs/Houston2010_HPC.pdf

Dave Hale's, Houston 2011 workshop:

http://www.beg.utexas.edu/pttc/2011/2011_pres_01_03_hale.pdf

Thank you!

check at the Yang Liu's 2010 school for a real data example with parallelization:
$RSFSRC/book/rsf/usp/data/