Performance Prediction and Optimization using Linux/cgroups

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Agenda

- Background
- Outline of Linux/Cgroups
- Performance prediction with RA
- Evaluation
- Conclusion

RA: Regression Analysis

Background

- Grow up server consolidation with the progress of the virtualization technology.
    - guarantee real time and performance at the same time and in the same server.
    - need stable operation.
- Important to optimize computing resources with performance prediction.
- Cgroups will be essential for process computing and cloud computing because of computing resources and access control.

Outline of Linux/Cgroups

(1) Bandwidth control

- Bandwidth control of CPU, Memory, Network and Disk.
- Account the CPU usage.

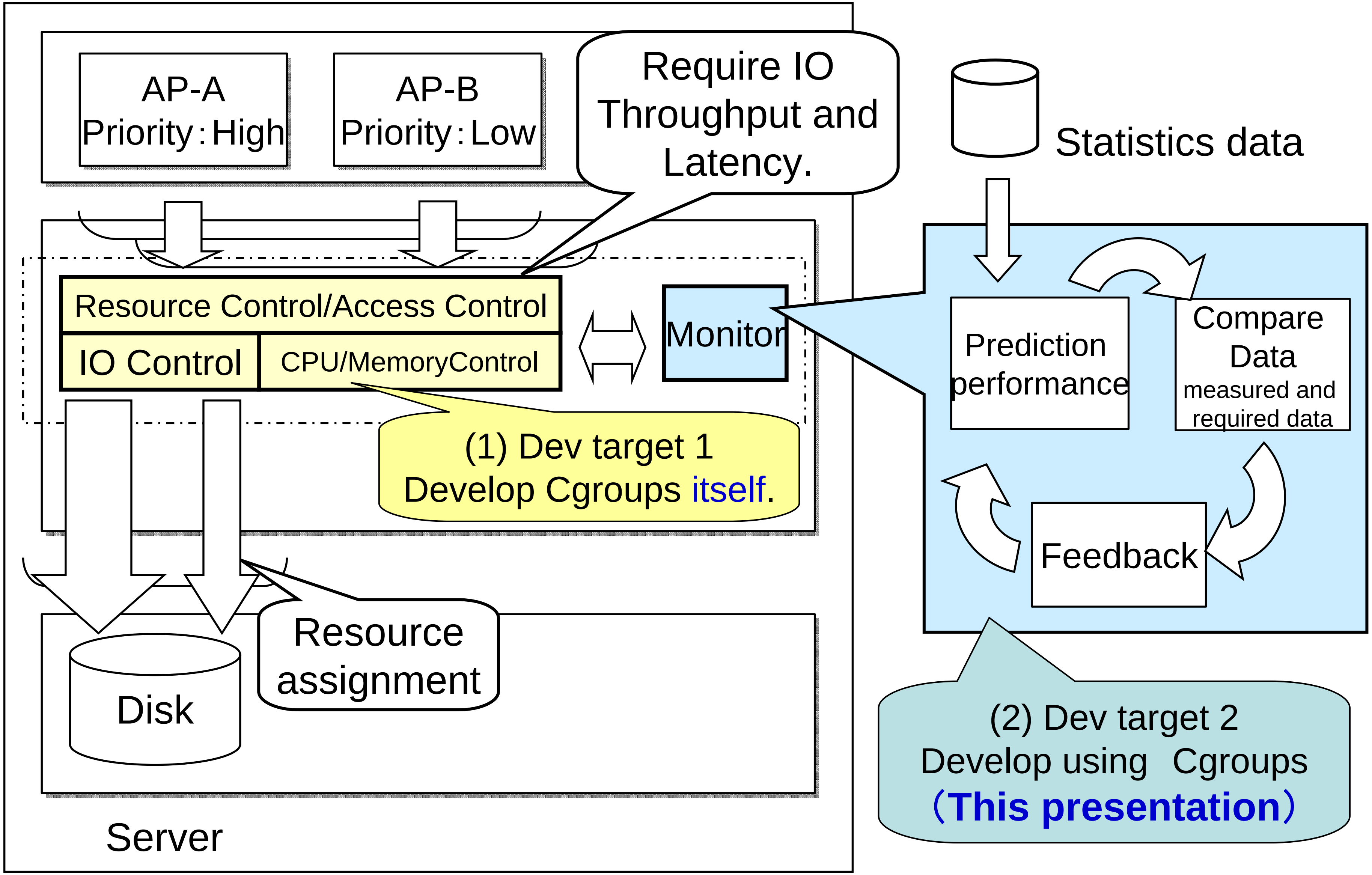
(2) Access control

- Access control of device.
- Constrain CPU and memory placement of tasks.
- name space control.

(3) Group control

- Freeze task.
- checkpoint and restart.

Target we research and develop on Linux/Cgroups



Outline of Block IO control

(1) About blkio.weight

bandwidth of IO.

range of weights is from 100 to 1000.

IO-Weight is blkio.weight/100 (from 1 to 10) to simplify in only this presentation.

(2) Construct Measurement environment.

```
mount -t cgroup none /cgroup/ -o blkio
mkdir -p /cgroup/test1 /cgroup/test2
echo 900 > /cgroup/test1/bklio.weight
echo 100 > /cgroup/test2/bklio.weight
./fio-test.sh
```

Measurement Environment

【Measurement Machine】

#	Item	Content
1	Machine	Dell PowerEdge840
		CPU：Intel Xeon 3060 2.4GHz, Core(2), Memory：4 GB
2	OS	RHEL6.0 β 2 x86_64
3	Benchmark	FIO (Flexible IO) version1.41

【FIO condition】

#	Item	Content
1	Measurement item	IO Throughput (IO issue per second) & Latency (IO Complete clat)
2	Access type	Random read/write
3	Measure time	360 sec
4	IO type	Asynchronous I/O
5	I/O type	4kB, 64kB

Measurement item and result

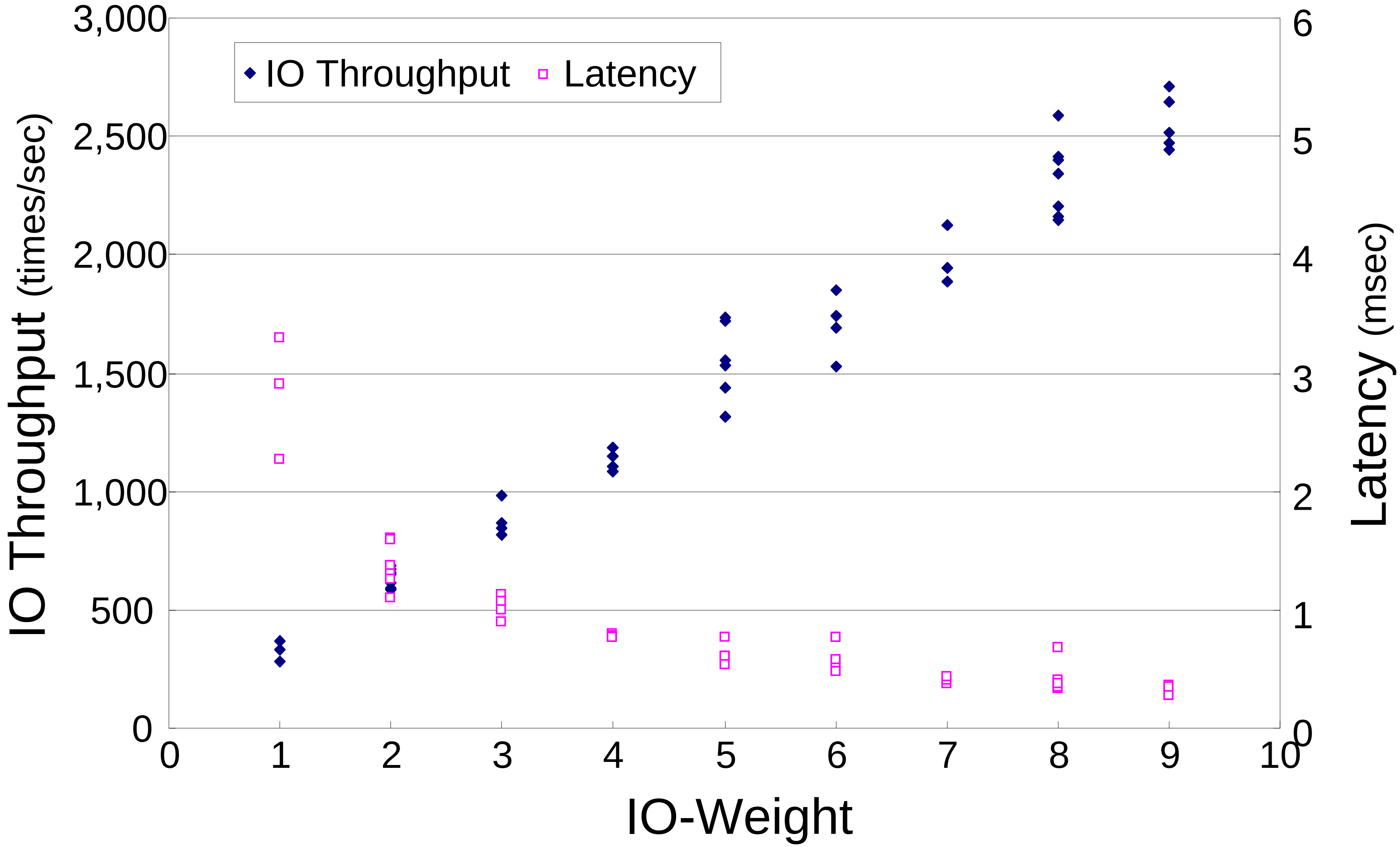
```
queryA: (g=0): rw=randrw, bs=32K-32K/32K-32K, ioengine=libaio, iodepth=50
Starting 1 process
queryA: (groupid=0, jobs=1): err= 0: pid=6562
  read : io=602MB, bw=1,710KB/s, iops=53, runt=360548msec
    slat (usec): min=6, max=331K, avg=260.46, stdev=6901.12
    clat (usec): min=21, max=2,183K, avg=474887.53, stdev=433054.37
    bw (KB/s) : min=    0, max= 4187, per=103.88%, avg=1776.39, stdev=847.50
  write: io=590MB, bw=1,677KB/s, iops=52, runt=360548msec
    slat (usec): min=6, max=1,192K, avg=459.21, stdev=12281.17
    clat (usec): min=262, max=2,200K, avg=468998.71, stdev=431350.99
    bw (KB/s) : min=    0, max= 5396, per=96.80%, avg=1622.29, stdev=947.72
  cpu          : usr=0.04%, sys=0.23%, ctx=36654, majf=0, minf=41
  IO depths    : 1=0.1%, 2=0.1%, 4=0.1%, 8=0.1%, 16=0.2%, 32=99.6%, >=64=0.0%
     submit    : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.0%, >=64=0.0%
     complete  : 0=0.0%, 4=100.0%, 8=0.0%, 16=0.0%, 32=0.0%, 64=0.1%, >=64=0.0%
     issued r/w: total=19268/18893, short=0/0
     lat (usec): 50=0.01%, 100=0.01%, 250=0.02%, 500=0.65%, 750=0.09%
     lat (usec): 1000=0.12%
     lat (msec): 2=0.15%, 4=0.24%, 10=1.78%, 20=3.31%, 50=7.80%
     lat (msec): 100=8.29%, 250=16.79%, 500=22.52%, 750=15.86%, 1000=9.92%
     lat (msec): 2000=12.33%, >=2000=0.12%
Run status group 0 (all jobs):
   READ: io=602MB, aggrb=1,710KB/s, minb=1,751KB/s, maxb=1,751KB/s, mint=360548msec, maxt=360548msec
  WRITE: io=590MB, aggrb=1,676KB/s, minb=1,717KB/s, maxb=1,717KB/s, mint=360548msec, maxt=360548msec
Disk stats (read/write):
  dm-0: ios=31502/34760, merge=0/0, ticks=15140973/16651011, in_queue=31824277, util=100.00%, aggrios=0/0,
aggrmerge=0/0, aggrticks=0/0, aggrin_queue=0, aggrutil=0.00%
    sdb: ios=0/0, merge=0/0, ticks=0/0, in_queue=0, util=-nan%
```

Measurement item

- IO Throughput (IO issue per sec)
- Latency (clat)
  clat：complete latency

Measurement Data

IO Size: 4kB



IO-Weight: blkio.weight/100

What is Regression Analysis (RA)?

Why the straight line?

To reduce computational complexity to be able to set the moderate value in online in the future.

(1) Regression Analysis?

To be approximated by the straight line that is the nearest to data.

$$y = a + b \cdot x \qquad \begin{cases} b = S_{xy} / S_x \\ a = \tilde{y} - b \cdot \tilde{x} \end{cases}$$

$S_{xy} = \sum(x_i - \tilde{x}) \cdot \sum(y_i - \tilde{y})$

$S_x = \sum(x_i - \tilde{x})$

~ : average

(2) Least Squares Method

To minimize the distance between each point and the straight line.

Adapt Regression analysis (1)

【Purpose】

Predict performance with Regression analysis

【Procedure】

(1) Regression analysis with all range of IO-Weight

- IO-Weight : from 1 to 9

【Result】

- IO throughput

  May be good（easy to predict）.

- Latency

  Not so good（hard to predict）.

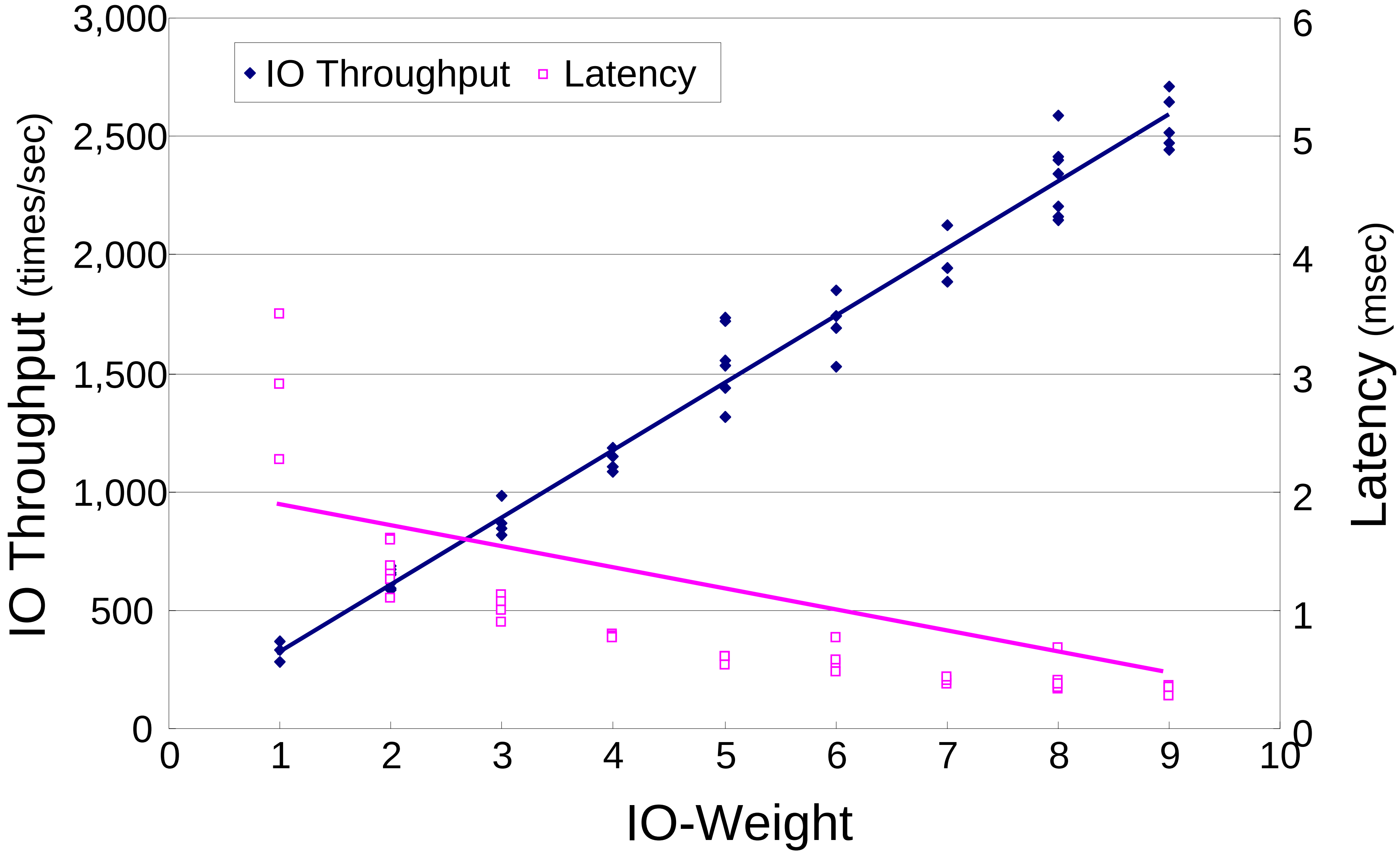
  point to rise suddenly when I make IO-Weight small(1-3).

IO-Weight is an evaluation to 1-9, and the predictive range of the regression analysis is wide, and a prediction is difficult.

An evaluation to considering a characteristic of IO throughput the latency is necessary.

【Regression Analysis (1)】

IO Size: 4kB



IO-Weight: blkio.weight/100

Adapt Regression Analysis (2)

【Purpose】

Extract characteristic of IO Throughput and Latency by limited IO-Weight range.

【Procedure】

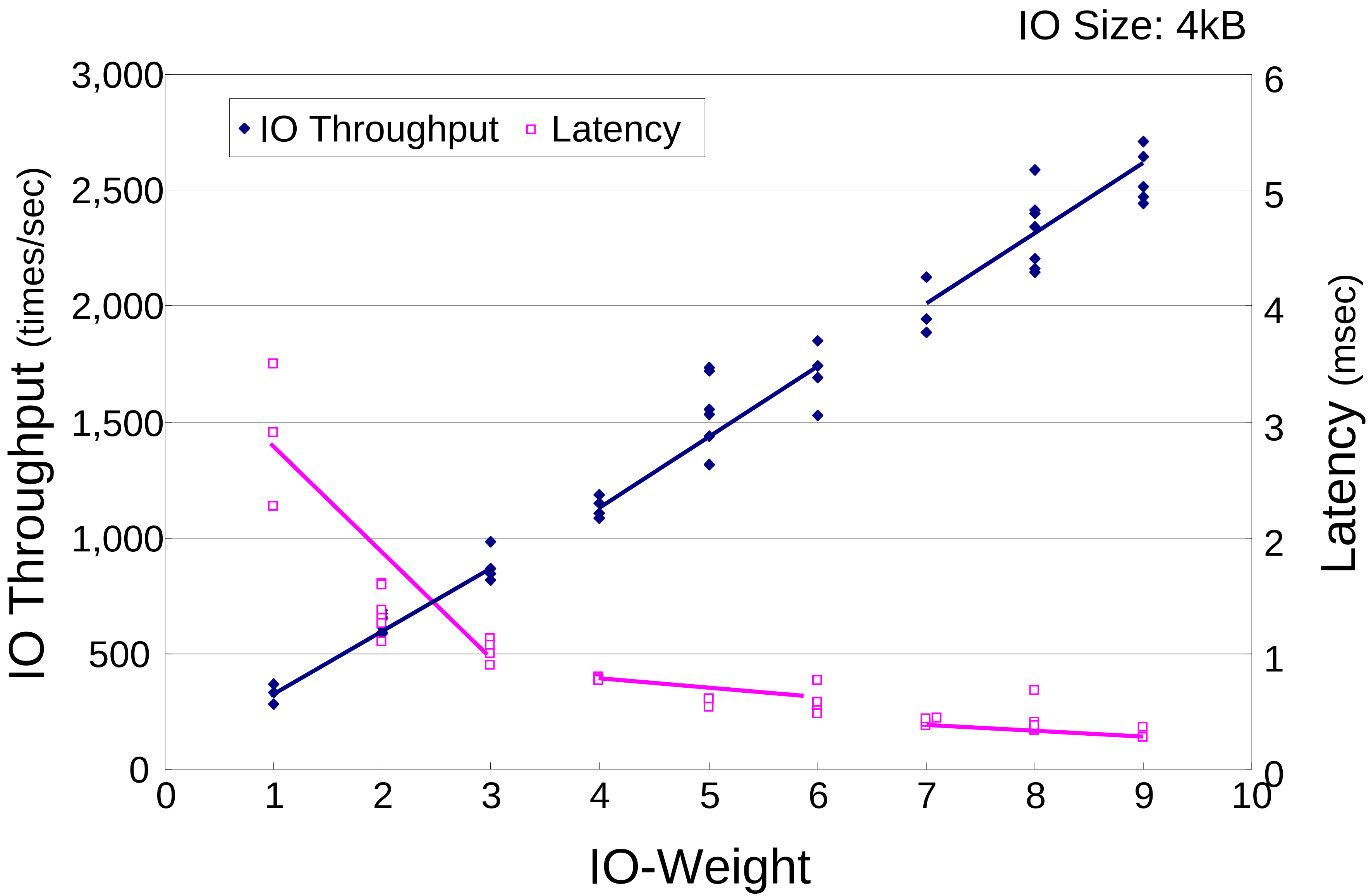
(1) Regression analysis with partitioned range of IO-Weight

- Divide IO-Weight as limited range as1-3, 4-6, 7-9 etc.
- Do Regression analysis.

(2) Characteristic of IO Throughput and Latency

- IO throughput
  Improve linearly according to the mount of resources.
- Latency
  Be constant (cannot shorten) even if resources is increased.

【Regression Analysis (2)】



IO-Weight: blkio.weight/100

Optimized procedure

【Optimized procedure】

(1) Collect statistics data

・Normalize data. (Sum of IO-Weight is 10 and decide performance of each IO-Weight (1 to 9).)

(2) Predict performance

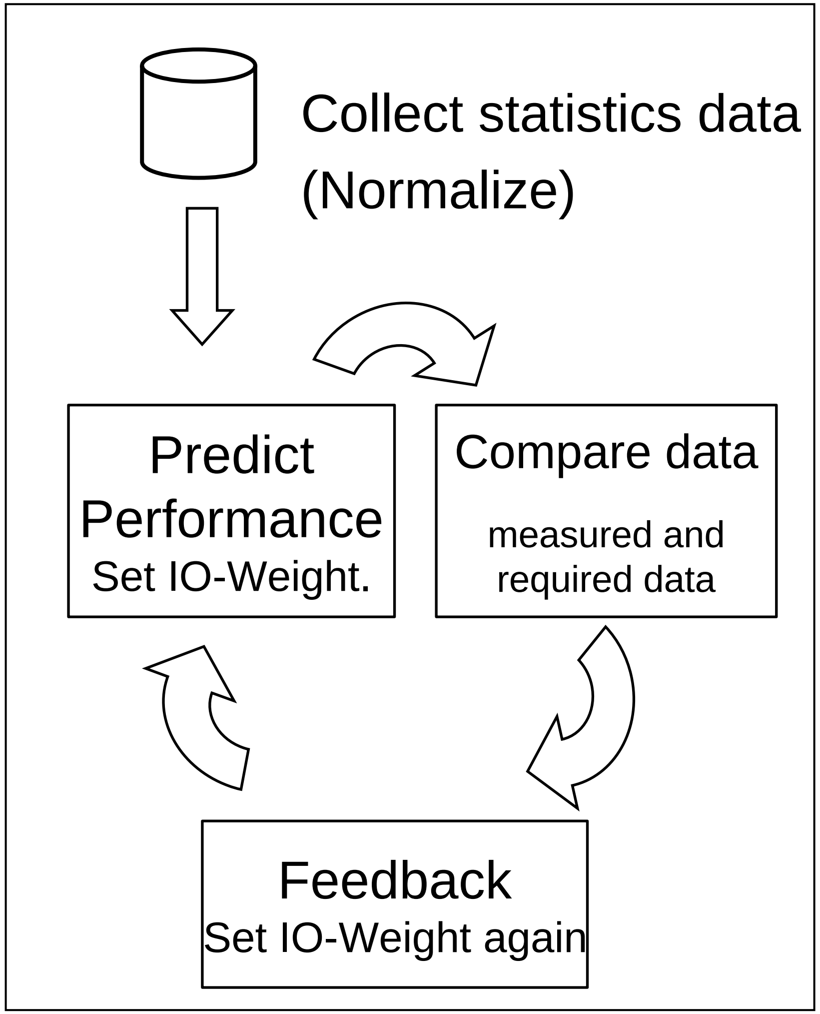
・Predict performance by statistics data.

・Set IO-Weight.

(3) Compare with measured and required data

・Within allowable range, do nothing to modify IO-Weight.

・Without allowable range, do feedback and set IO-Weight again.



Evaluation

【Procedure】

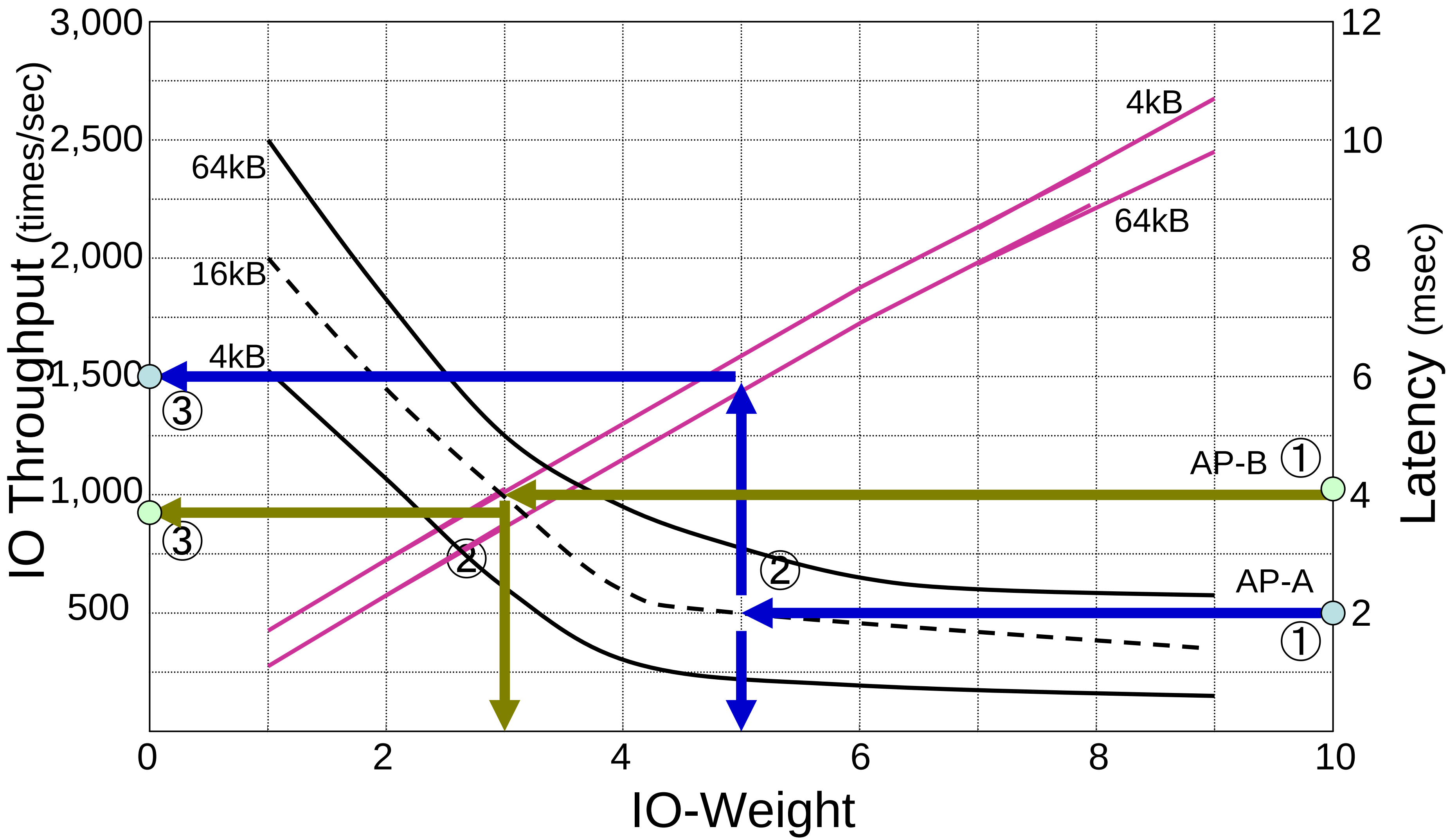
(1) Predict Latency and IO Throughput of 16kB by data of 4kB and 64kB.

(2) Predict most suitable IO-Weight and perform performance measurement and check whether AP requirement is satisfied.

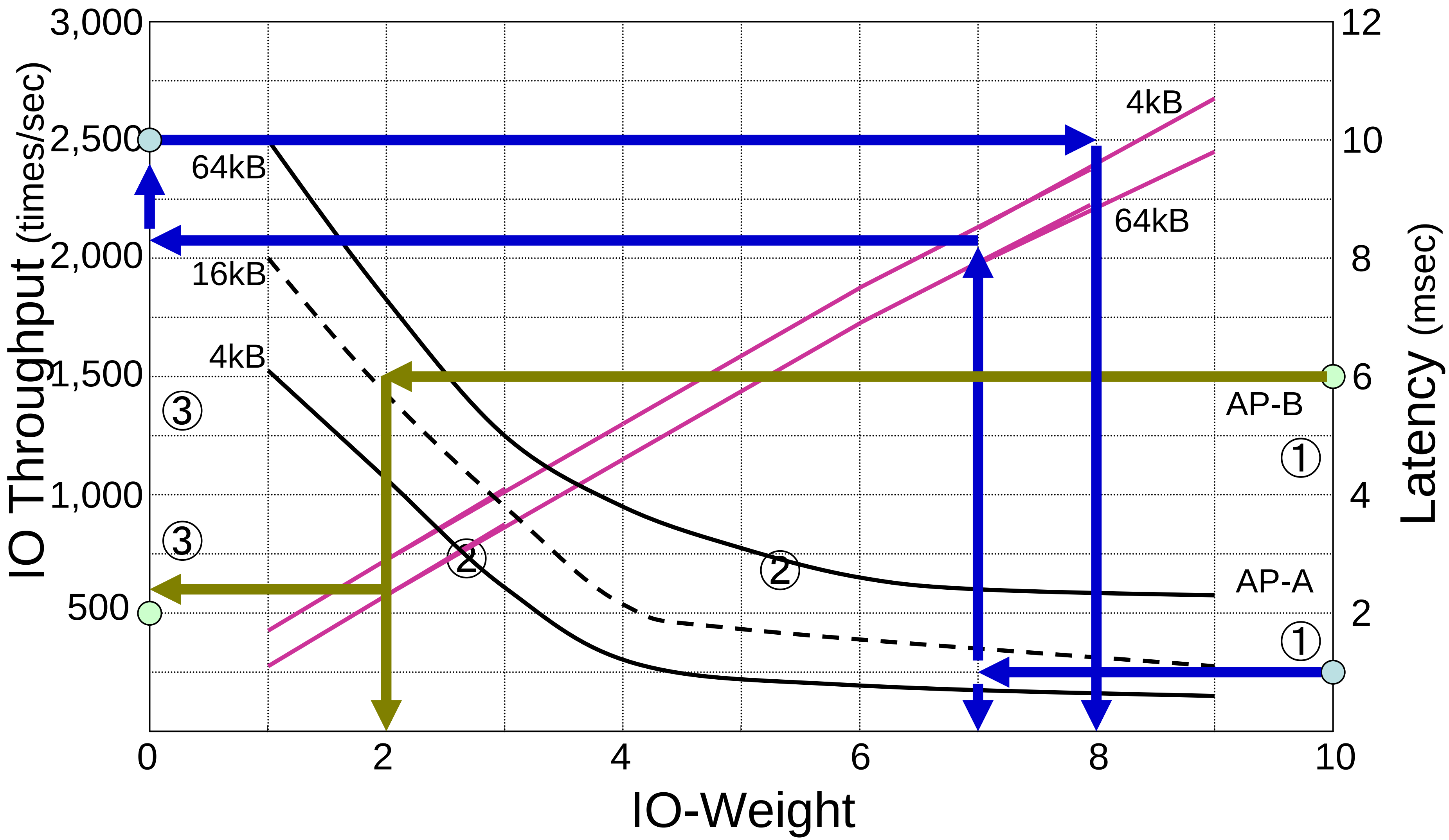
(3) Feed back again if I do not meet it.

Case	AP	Required value	
		Latency	IO Throughput
1	AP-A	2.0	1,500
	AP-B	4.0	750
2	AP-A	1.0	2,500
	AP-B	6.0	500
3	AP-A	1.0	2,500
	AP-B	1.5	1,750

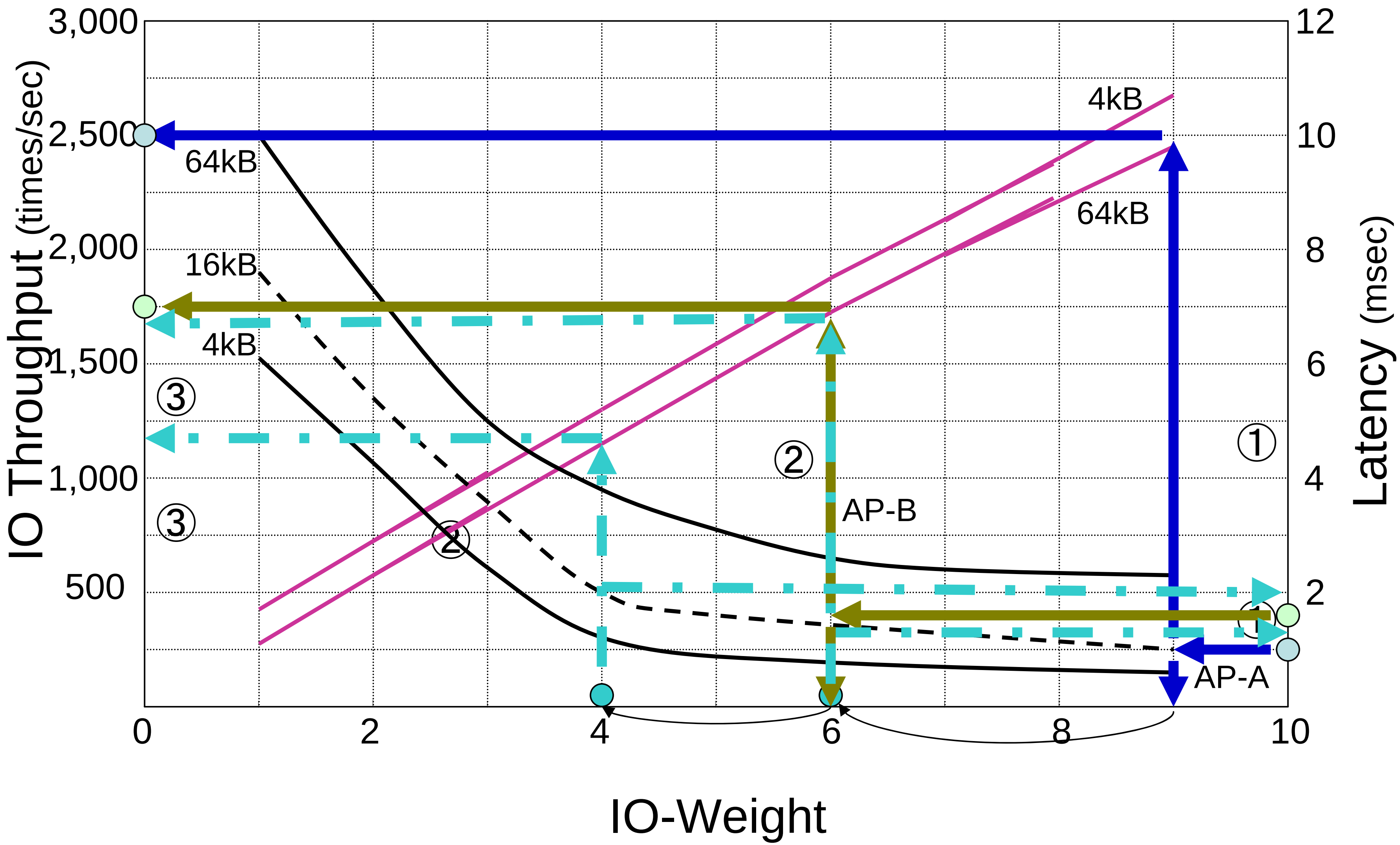
Example of case1(OK without feedback)



Example of case2 (OK with feedback)



Example of case3 (NG: shortage of resource)



Evaluation result

Case	AP	Before feedback			After feedback			Evaluation
		IO-Weight	Latency	IO Throughput	IO-Weight	Latency	IO Throughput	
1	AP-A	5	2.01 (2.0)	1,789 (1,500)	–	–	–	○
	AP-B	3	3.93 (4.0)	985 (900)	–	–	–	
	Reserved	2	5.25	736	–	–	–	
2	AP-A	7	1.51 (1.0)	2,224 (2,500)	8	1.02 (1.0)	2,538 (2,500)	△
	AP-B	2	5.84 (6.0)	670 (500)	2	4.66 (2.0)	751 (500)	
	Reserved	1	10.6	371	0	–	–	
3	AP-A	9 -> 6	2.01 (1.0)	1,879 (2,500)				×
	AP-B	6 -> 4	2.89 (1.5)	1,333 (1,500)				
	Reserved	-5 -> 0	–	–				

Resource shortage by reserved value after performance prediction.

Upper : Measured value, (Lower) : Required value

Conclusion

1. Summary

(1) Normalize throughput and latency with fio.

- Evaluate Linux/Cgroups

(2) Adapt Regression Analysis

- RA1: Adapt RA in all field (from 1 to 9).
- RA2: Divide 3 parts and adapt RA.

(3) Propose Feedback function

- to enable to be within an allowable error.

2. Future Works

(1) Predict performance in online and set.

(2) Cooperate other resource assignment

- CPU and memory

(3) and cooperate access control.

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