Internet Measurement and Data Analysis (3)

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review of previous class

Class 2 Data and variability (10/02)

- Summary statistics
- Sampling
- How to make good graphs
- exercise: computing summary statistics by Ruby
- exercise: graph plotting by Gnuplot

today's topics

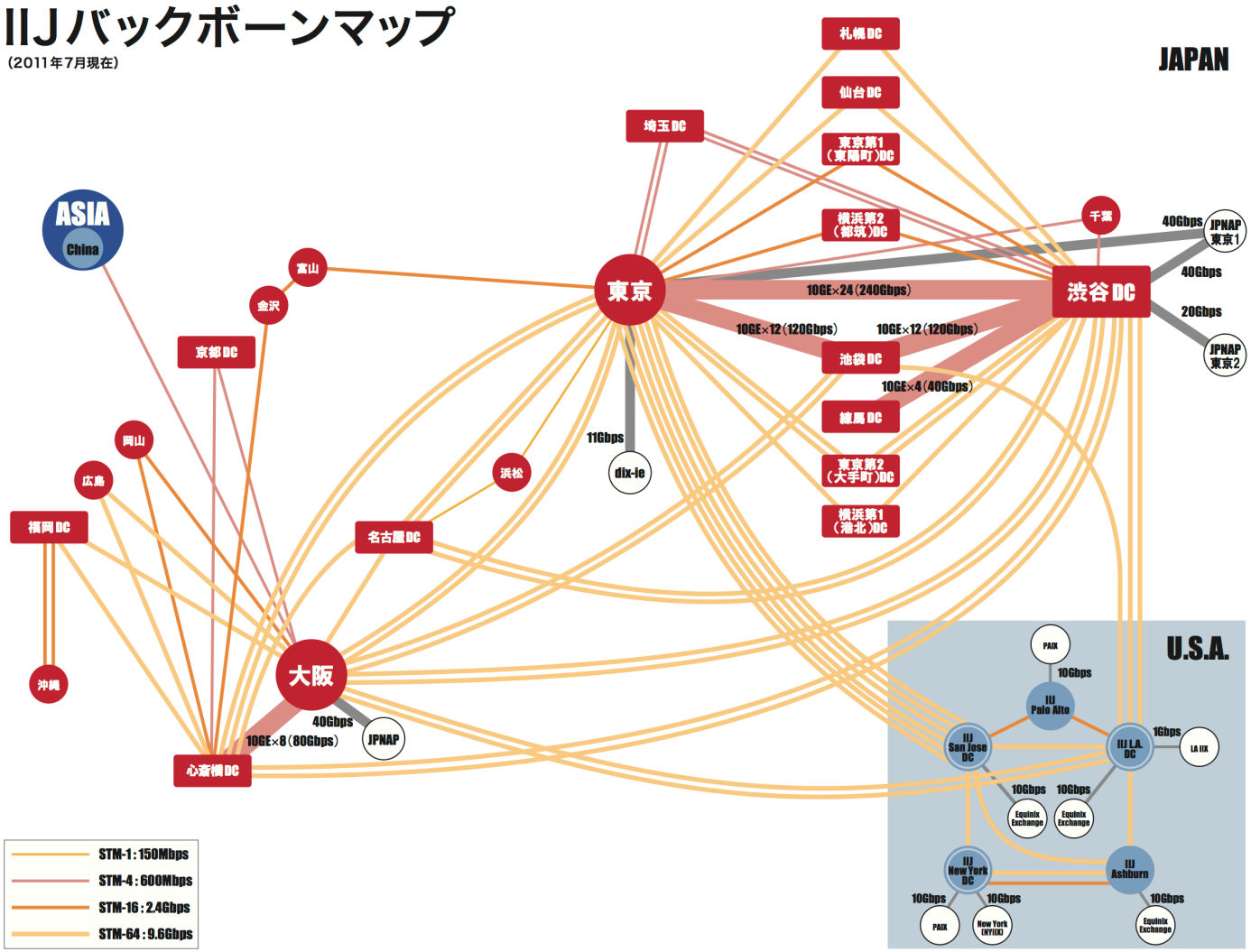
Class 3 Data recording and log analysis

- Network management tools
- Data format
- Log analysis methods
- exercise: log data and regular expression

network management tools

example network structure from a Japanese ISP

main facilities in Tokyo and Osaka, connecting regional POPs with redundant configuration



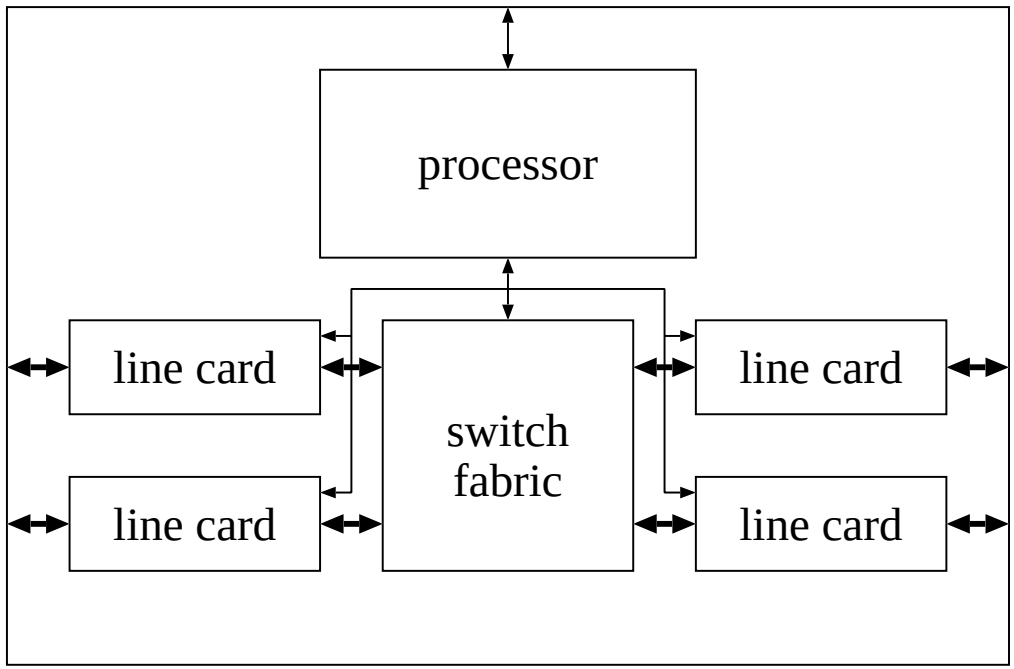
routers

router: equipment to connect networks

- functions
  - routing, packet-forwarding, management
- classes of routers
  - core-routers, edge-routers, broadband routers, etc.

router architecture

- fast path: hardware assisted processing
- slow path: software processing
  - ICMP packets are processed via slow path



commonly-used management tools

network management tools (originally not designed for measurement)

- ping
  - reachability, round-trip time
- traceroute
  - path detection
- tcpdump
  - packet capturing
- SNMP
  - usage monitoring, network equipment status monitoring

ping

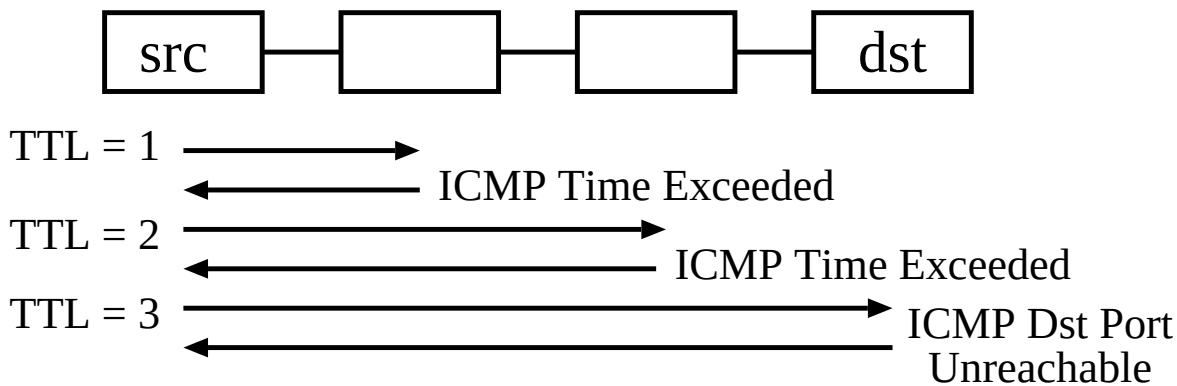
- a popular and widely-available tool to check connectivity
- ICMP-echo request/reply
- limitations
  - ping responses do not mean network is working correctly
  - ICMP is not representative of host/network performance

ping sample output

```
% ping -c 10 www.ait.ac.th
PING www.ait.ac.th (202.183.214.46): 56 data bytes
64 bytes from 202.183.214.46: icmp_seq=0 ttl=114 time=112.601 ms
64 bytes from 202.183.214.46: icmp_seq=1 ttl=114 time=106.730 ms
64 bytes from 202.183.214.46: icmp_seq=2 ttl=114 time=106.173 ms
64 bytes from 202.183.214.46: icmp_seq=3 ttl=114 time=111.704 ms
64 bytes from 202.183.214.46: icmp_seq=4 ttl=114 time=112.412 ms
64 bytes from 202.183.214.46: icmp_seq=5 ttl=114 time=114.603 ms
64 bytes from 202.183.214.46: icmp_seq=6 ttl=114 time=111.755 ms
64 bytes from 202.183.214.46: icmp_seq=7 ttl=114 time=115.273 ms
64 bytes from 202.183.214.46: icmp_seq=8 ttl=114 time=106.525 ms
64 bytes from 202.183.214.46: icmp_seq=9 ttl=114 time=111.562 ms

--- www.ait.ac.th ping statistics ---
10 packets transmitted, 10 packets received, 0% packet loss
round-trip min/avg/max/stddev = 106.173/110.934/115.273/3.142 ms
```

traceroute

- exploit TTL (time-to-live) of IP designed for loop prevention
  - TTL is decremented by each intermediate router
  - router returns ICMP TIME EXCEEDED to the sender when TTL becomes 0
- limitations
  - path may change over time
  - path may be asymmetric
    - can observe only out-going paths
  - report from one of the interfaces of the router
    - hard to identify interfaces belonging to same router



traceroute sample output

```
% traceroute www.ait.ac.th
traceroute to www.ait.ac.th (202.183.214.46), 64 hops max, 40 byte packets
 1  202.214.86.129 (202.214.86.129)  0.687 ms  0.668 ms  0.730 ms
 2  jc-gw0.IIJ.Net (202.232.0.237)  0.482 ms  0.390 ms  0.348 ms
 3  tky001ix07.IIJ.Net (210.130.143.233)  0.861 ms  0.872 ms  0.729 ms
 4  tky001bb00.IIJ.Net (210.130.130.76)  10.107 ms  1.026 ms  0.855 ms
 5  tky001ix04.IIJ.Net (210.130.143.53)  1.111 ms  1.012 ms  0.980 ms
 6  202.232.8.142 (202.232.8.142)  1.237 ms  1.214 ms  1.120 ms
 7  ge-1-1-0.toknf-cr2.ix.singtel.com (203.208.172.209)  1.338 ms  1.501 ms
 1.480 ms
 8  p6-13.sngtp-cr2.ix.singtel.com (203.208.173.93)  93.195 ms  203.208.172.
229 (203.208.172.229)  88.617 ms  87.929 ms
 9  203.208.182.238 (203.208.182.238)  90.294 ms  88.232 ms  203.208.182.234
(203.208.182.234)  91.660 ms
10  203.208.147.134 (203.208.147.134)  103.933 ms  104.249 ms  103.986 ms
11  210.1.45.241 (210.1.45.241)  103.847 ms  110.924 ms  110.163 ms
12  st1-6-bkk.csloxinfo.net (203.146.14.54)  131.134 ms  129.452 ms  111.408
 ms
13  st1-6-bkk.csloxinfo.net (203.146.14.54)  106.039 ms  105.078 ms  105.196
 ms
14  202.183.160.121 (202.183.160.121)  111.240 ms  123.606 ms  112.153 ms
15  * * *
16  * * *
17  * * *
```

tcpdump

- packet capturing tool
  - capture the first N bytes of packets
- flexible filtering
  - e.g., capture only TCP SYN from host X
- enables detailed analysis
- limitations
  - huge volume
  - difficult to capture on high-speed links

tcpdump sample output

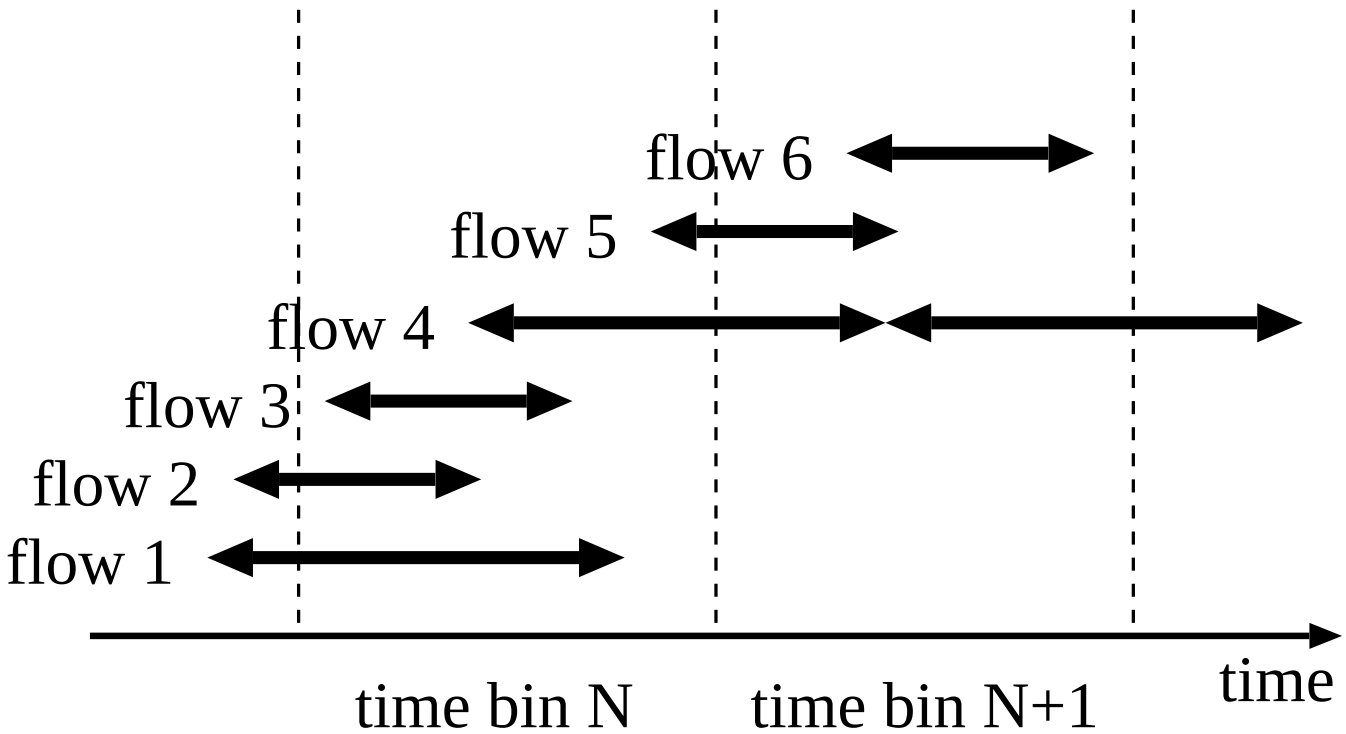
```
18:45:29.767497 IP 202.214.86.132.50052 > 202.210.220.18.80: \
  S 3304970307:3304970307(0) win 65535 <mss 1460,nop,nop,sackOK,nop, \
  wscale 1,nop,nop,timestamp 710778973 0>
18:45:29.770038 IP 202.210.220.18.80 > 202.214.86.132.50052: \
  S 3129218301:3129218301(0) ack 3304970308 win 65535 <mss 1460,nop, \
  ywscale 1,nop,nop,timestamp 2523776361 710778973,nop,nop,sackOK>
18:45:29.770090 IP 202.214.86.132.50052 > 202.210.220.18.80: \
  . ack 1 win 33304 <nop,nop,timestamp 710778973 2523776361>
18:45:29.787084 IP 202.214.86.132.50052 > 202.210.220.18.80: \
  P 1:521(520) ack 1 win 33304 <nop,nop,timestamp 710778975 2523776361>
18:45:29.791392 IP 202.210.220.18.80 > 202.214.86.132.50052: \
  P 1:222(221) ack 521 win 33304 <nop,nop,timestamp 2523776363 710778975>
18:45:29.887024 IP 202.214.86.132.50052 > 202.210.220.18.80: \
  . ack 222 win 33304 <nop,nop,timestamp 710778985 2523776363>
18:45:34.792726 IP 202.210.220.18.80 > 202.214.86.132.50052: \
  F 222:222(0) ack 521 win 33304 <nop,nop,timestamp 2523776864 710778985>
18:45:34.792763 IP 202.214.86.132.50052 > 202.210.220.18.80: \
  . ack 223 win 33304 <nop,nop,timestamp 710779475 2523776864>
18:45:42.528539 IP 202.214.86.132.50052 > 202.210.220.18.80: \
  F 521:521(0) ack 223 win 33304 <nop,nop,timestamp 710780249 2523776864>
18:45:42.531088 IP 202.210.220.18.80 > 202.214.86.132.50052: \
  . ack 522 win 33303 <nop,nop,timestamp 2523777637 710780249>
```

SNMP (Simple Network Management Protocol)

- SNMP allows a remote user to
  - query information, store information, set traps
  - by UDP (unreliable)
- standardized set of traffic statistics
  - supported by most of routers, switches, host OS
  - many management/monitoring products
- MIB (Management Information Base)
  - tree structured database of SNMP objects
    - e.g., interfaces.ifTable.ifEntry.ifOutOctets
    - standard MIBs and private MIBs
  - get, set, get-next to access MIB
- limitations
  - supported statistics are limited
    - most counter statistics are hard-coded, e.g.,interface counters
  - accessing to MIB objects is expensive

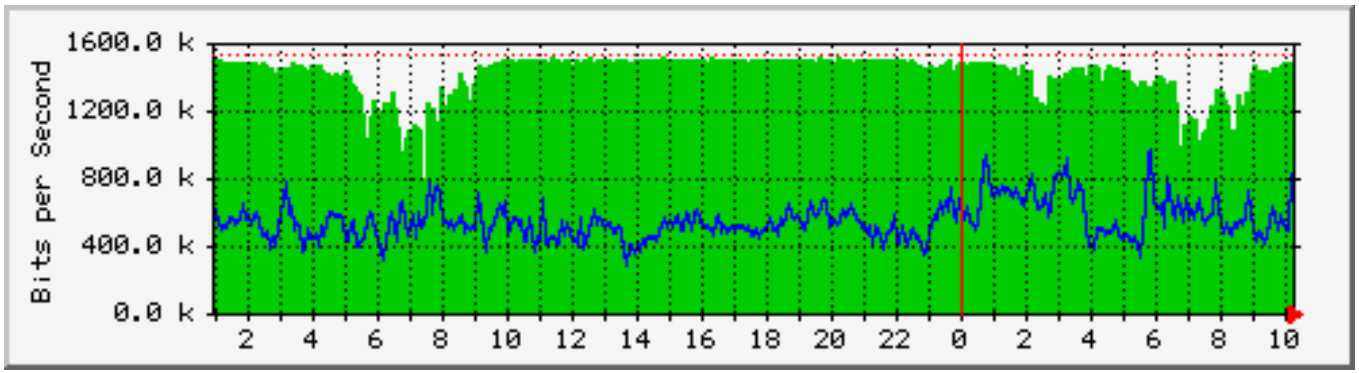
flow-based measurement

- SNMP: limited to counters (e.g., byte count)
  - only total amount
- flow-based measurement: router exports flow statistics by udp
  - 5 tupples (protocol, srcaddr, dstaddr, srcport, dstport), AS, etc
  - protocols: NetFlow, sFlow, IPFIX, etc.
- allows sampling to reduce exported data size



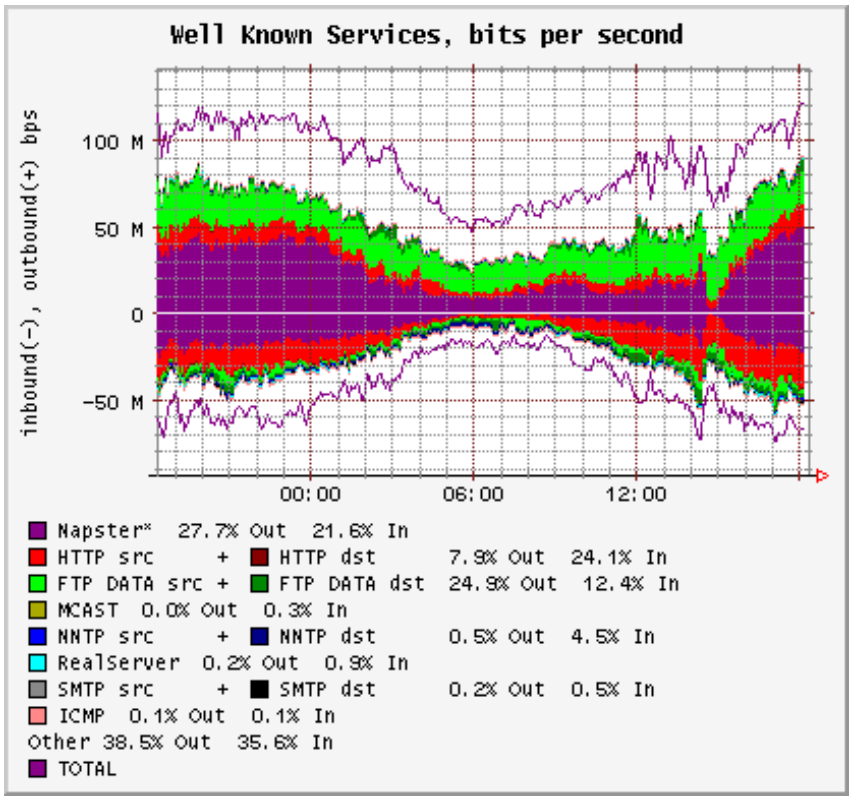
MRTG

- popular tool to show SNMP data
- time series data aggregated over time
  - daily, weekly, monthly to bound the storage size
- inbound/outbound traffic
  - can be used for other types of time series data



RRDtool

- RRDtool: successor of MRTG
  - flexible configuration, graphing
  - can be used for any time-series data
- flowscan: visualizes netflow data by rrdtool



from caida web site

summary of network management tools

- not originally designed for measurement
- still often used for measurement
- when using for measurement, need to understand the mechanisms and limitations

data format

log data

- web server accesslog
- mail log
- syslog
- firewall log
- IDS log
- other forms of event records

why do we analyze logs?

- understand current situations
  - new findings: technical advances, changes in usage
  - then, predict the future
- identify security problems and equipment failures, and their symptoms
- improve techniques for analysis
  - automation
- report outages, and responses to problems
- record events
  - for legal and other reasons

if not analyzed, logs have no value
(do not be satisfied only with collecting logs)

problems in log analysis

- huge data volume
- lack of necessary information and precision, credibility of timestamps and content
- missing records (due to failures of data collection systems)
- many different formats
- data analysis requires time and efforts
- many people think data analysis is difficult

log management

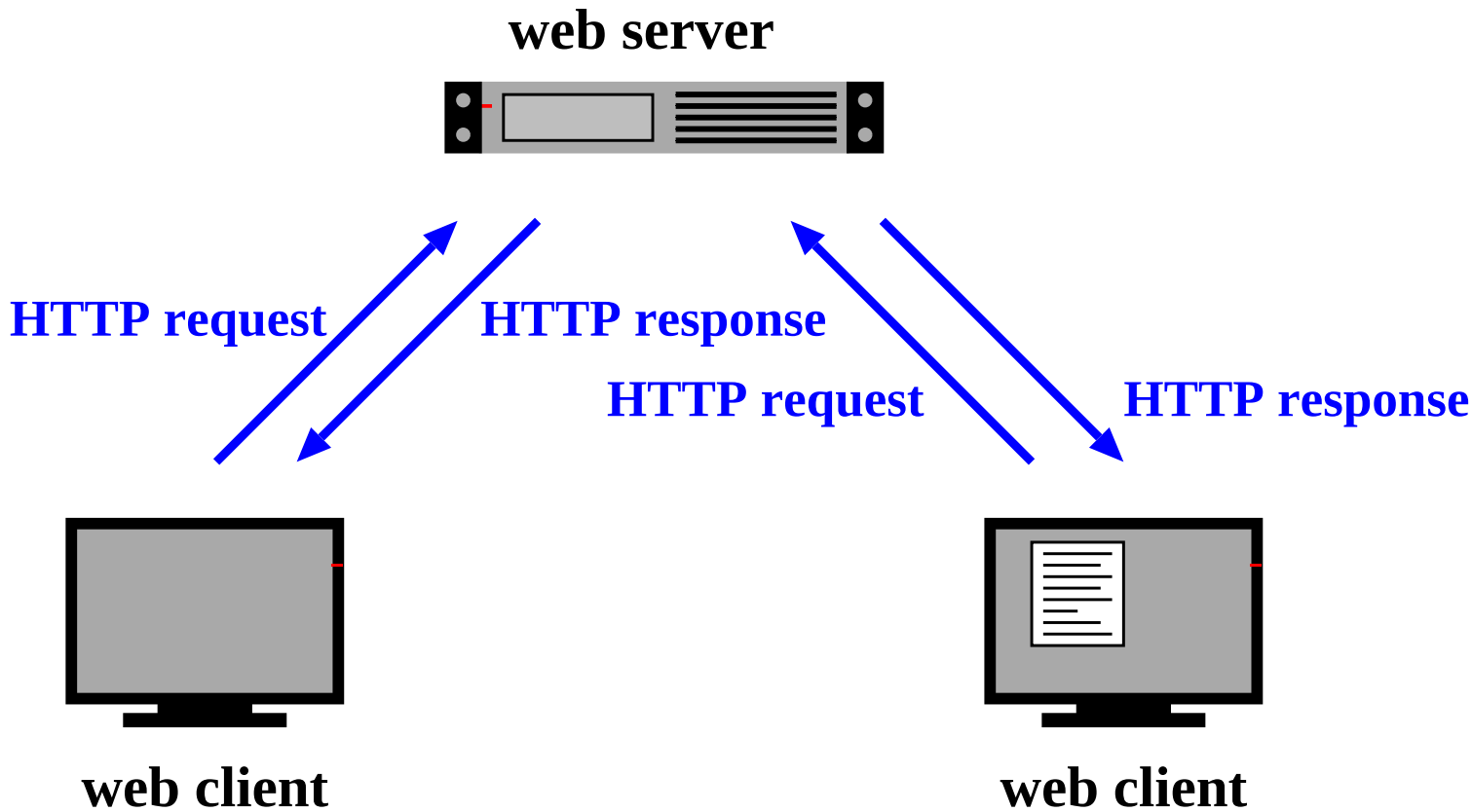
- log collection
  - programming (e.g., use of the syslog API)
  - building a data collection system
- log rotation
  - remove old data after a certain period
  - according to log size, time order, ages of data
  - should not lose data at log rotation
- RRD (Round Robin Database)
  - keep the data size by aggregating old logs
  - examples: 5 min data for 1 week, 2 hour data for a month, 1 day data for a year
- visualization
  - make it easier to grasp situation

log formats

- web server access log
- mail log
- DHCP server log
- syslog

access to a web server

- HTTP protocol
- request/response



web server access log

- Apache Common Log Format
  - client_IP client_ID user_ID time request status_code size
- Apache Combined Log Format
  - Common Log Format plus “referer” and “User-agent”
  - client_IP client_ID user_ID time request status_code size referer user-agent
- other customizations are possible

```
client_IP: IP address of the client
client_ID: identity of the client (when the client is authenticated)
user_ID: authenticated user name
time: the time that the request was received
request: the first line of the request
status_code: HTTP response status
size: the size of the object returned (not including the deader), "-" means
referer: the site that the client referred from (source of the link)
user-agent: client's browser type
```

Example Combined Log Format:

```
127.0.0.1 - frank [10/Oct/2000:13:55:36 -0700] \
  "GET /apache_pb.gif HTTP/1.0" 200 2326 \
  "http://www.example.com/start.html" \
  "Mozilla/4.08 [en] (Win98; I ;Nav)"
```

mail log

logging when email is processed (receiving, sending, etc)
example:

```
Oct 27 13:32:54 server3 sm-mta[24510]: m9R4WsBe024510:\
 from=<client@example.com>, size=2403, class=0, nrcpts=1 \
 msgid=<201012121547.oBCFlPX6032787@example.com>, \
 proto=ESMTP, daemon=MTA, relay=mail.example.co.jp [192.0.2.1] \
Oct 27 14:43:04 server3 sm-mta[24511]: m9R4WsBe024510: \
 to=<user@example.co.jp>, delay=01:10:10 xdelay=00:00:00, \
 mailer=local, pri=32599, dsn=2.0.0, stat=Sent
```

- time
- host name
- process owner [process id]
- Queue ID: internal id for the email
- ...
- nrcpts: number of recipients
- relay: next mail server to send the message
- dsn: Delivery Status Notification, RFC3463
  - 2.X.X:Success, 4.X.X:Persistent Transient Failure, 5.X.X:Permanent Failure
- stat: Message Status
  - Sent, Deferred, Bounced, etc

DHCP server log

```
SYSLOG messages:

Oct 28 15:04:32 server33 dhcpd: DHCPDISCOVER from 00:23:df:ff:a8:a7 via eth0
Oct 28 15:04:32 server33 dhcpd: DHCPOFFER on 192.168.2.101 \
  to 00:23:df:ff:a8:a7 via eth0
Oct 28 15:04:32 server33 dhcpd: DHCPREQUEST for 192.168.2.101 \
  from 00:23:df:ff:a8:a7 via eth0
Oct 28 15:04:32 server33 dhcpd: DHCPACK on 192.168.2.101 \
  to 00:23:df:ff:a8:a7 via eth0
Oct 28 15:09:32 server33 dhcpd: DHCPREQUEST for 192.168.2.101 \
  from 00:23:df:ff:a8:a7 via eth0
Oct 28 15:09:32 server33 dhcpd: DHCPACK on 192.168.2.101 \
  to 00:23:df:ff:a8:a7 via eth0

dhcpd.leases: records of status of each assigned IP

lease 192.168.100.161 {
  starts 4 2010/12/09 23:13:39;
  ends 5 2010/12/10 00:13:39;
  tstp 5 2010/12/10 00:13:39;
  binding state free;
  hardware ethernet 5c:26:0a:17:06:00;
}
```

syslog

- a framework to send and store arbitrary messages on UNIX-like systems
  - originally designed for mail server logs
  - widely used for other purposes
  - supports sending messages to other servers
  - log rotation support
- Windows Event Log

web crawlers

data collection by crawlers

- crawler: programs to automatically collect data from many places
- web crawlers: automatically visit web pages and collect data
  - to create database and indices for search engines
  - move to next page by following links in the visiting page
- many existing tools
  - note: rapid crawling is often considered as attacks

log analysis techniques

- try out ideas by plotting graphs
  - new ideas often come up when working on data
- scripts and command line tools (grep, sort, uniq, sed, awk, etc)
- consider how to process huge data sets efficiently
- automate processes which you will repeat
  - do not rely too much on automated processes

how to handle huge data sets

- naive algorithms often consume too much memory
  - it helps to study data structures and algorithms
- how to handle huge data sets
  - remove unnecessary information
  - aggregate data temporally and spatially
  - divide and conquer
  - distributed and/or parallel processing
- convert to an intermediate file
- estimate required memory
  - use of efficient data structures
  - limit the size and/or dimensions to process at a time
- estimate processing time
  - a test run with a smaller data set
  - use scalable algorithms
- trade-off between memory size and processing time

regular expressions

regular expressions

- expressions of patterns of characters, used for search and replace of strings
- originally designed to specify formal language in formal language theory
- later widely used for text pattern matching
  - grep, expr, awk, vi, lex, perl, ruby, ...

Ruby's regular expression

```
Regexp class
regular expression literal: /regexp/opt
=~ operator: subject =~ /regexp/
match() method:  /regexp/.match(subject)
string class: string.match(/regexp/)
```

Ruby regular expressions: quick reference

```
[abc]  A single character: a, b or c
[^abc]  Any single character but a, b, or c
[a-z]  Any single character in the range a-z
[a-zA-Z]  Any single character in the range a-z or A-Z
^  Start of line
$  End of line
\A  Start of string
\z  End of string
.  Any single character
\s  Any whitespace character
\S  Any non-whitespace character
\d  Any digit
\D  Any non-digit
\w  Any word character (letter, number, underscore)
\W  Any non-word character
\b  Any word boundary character
(...)  Capture everything enclosed
(a|b)  a or b
a?  Zero or one of a
a*  Zero or more of a
a+  One or more of a
a{3}  Exactly 3 of a
a{3,}  3 or more of a
a{3,6}  Between 3 and 6 of a
```

Ruby regular expressions: quick reference (cont'd)

```
options:
i case insensitive
m make dot match newlines
x ignore whitespace in regex
o perform #{...} substitutions only once
```

longest match and shortest match (shortest match is faster)

```
"*" and "+" are longest match, "*?" and "+?" are shortest match
/<.*>/.match("<a><b><c>")  # => "<a><b><c>"
/<.*?>/.match("<a><b><c>") # => "<a>"
```

previous exercise: computing summary statistics

- mean
- standard deviation
- median

- finish-time data of a city marathon: from P. K. Janert "Gnuplot in Action"

`http://web.sfc.keio.ac.jp/~kjc/classes/sfc2012f-measurement/marathon.txt`

```
% head marathon.txt
# Minutes Count
133 1
134 7
135 1
136 4
137 3
138 3
141 7
142 24
143 13
```

previous exercise: computing mean

- read finish-time(in minutes) and the number of finishers from each line, sum up the product, and finally divide it by the total number of finishers

```
# regular expression to read minutes and count
re = /^(\d+)\s+(\d+)/

sum = 0 # sum of data
n = 0 # the number of data
ARGF.each_line do |line|
    if re.match(line)
      min = $1.to_i
      cnt = $2.to_i
      sum += min * cnt
      n += cnt
    end
end

mean = Float(sum) / n

printf "n:%d mean:%.1f\n", n, mean
```

```
% ruby mean.rb marathon.txt
n:2355 mean:171.3
```

previous exercise: computing standard deviation

- algorithm: $\sigma^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2$

```
# regular expression to read minutes and count
re = /^(\d+)\s+(\d+)/

data = Array.new
sum = 0 # sum of data
n = 0 # the number of data
ARGF.each_line do |line|
    if re.match(line)
      min = $1.to_i
      cnt = $2.to_i
      sum += min * cnt
      n += cnt
      for i in 1 .. cnt
        data.push min
      end
    end
end
mean = Float(sum) / n
sqsum = 0.0
data.each do |i|
  sqsum += (i - mean)**2
end
var = sqsum / n
stddev = Math.sqrt(var)
printf "n:%d mean:%.1f variance:%.1f stddev:%.1f\n", n, mean, var, stddev
```

```
% ruby stddev.rb marathon.txt
n:2355 mean:171.3 variance:199.9 stddev:14.1
```

previous exercise: computing standard deviation in one-pass

- one-pass algorithm: $\sigma^2 = \frac{1}{n}\sum_{i=1}^{n} x_i^2 - \bar{x}^2$

```
# regular expression to read minutes and count
re = /^(\d+)\s+(\d+)/

sum = 0 # sum of data
n = 0 # the number of data
sqsum = 0 # su of squares
ARGF.each_line do |line|
    if re.match(line)
      min = $1.to_i
      cnt = $2.to_i
      sum += min * cnt
      n += cnt
      sqsum += min**2 * cnt
    end
end

mean = Float(sum) / n
var = Float(sqsum) / n - mean**2
stddev = Math.sqrt(var)

printf "n:%d mean:%.1f variance:%.1f stddev:%.1f\n", n, mean, var, stddev
```

```
% ruby stddev2.rb marathon.txt
n:2355 mean:171.3 variance:199.9 stddev:14.1
```

previous exercise: computing median

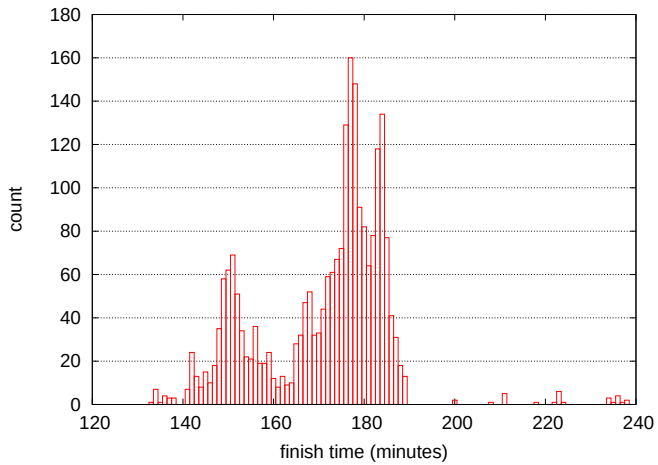
- create an array of each finish time, sort the array by value, and extract the central value

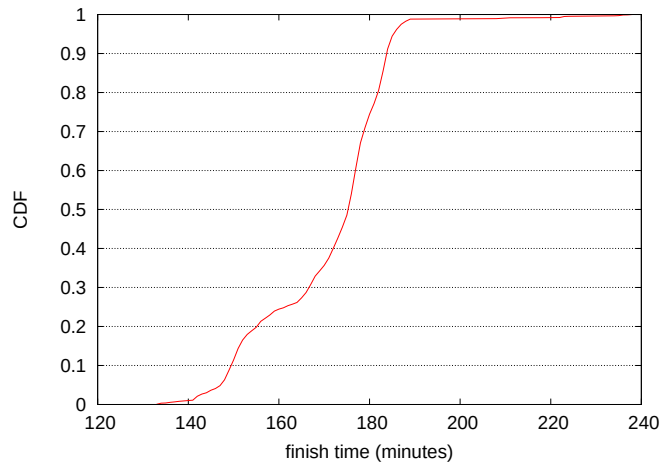
```
# regular expression to read minutes and count
re = /^(\d+)\s+(\d+)/

data = Array.new

ARGF.each_line do |line|
    if re.match(line)
      min = $1.to_i
      cnt = $2.to_i
      for i in 1 .. cnt
        data.push min
      end
    end
end

data.sort! # just in case data is not sorted

n = data.length # number of array elements
r = n / 2 # when n is odd, n/2 is rounded down
if n % 2 != 0
  median = data[r]
else
  median = (data[r - 1] + data[r])/2
end

printf "r:%d median:%d\n", r, median
```

```
% ruby median.rb marathon.txt
r:1177 median:176
```

previous exercise: gnuplot

- plotting simple graphs using gnuplot
  - to intuitively understand the data





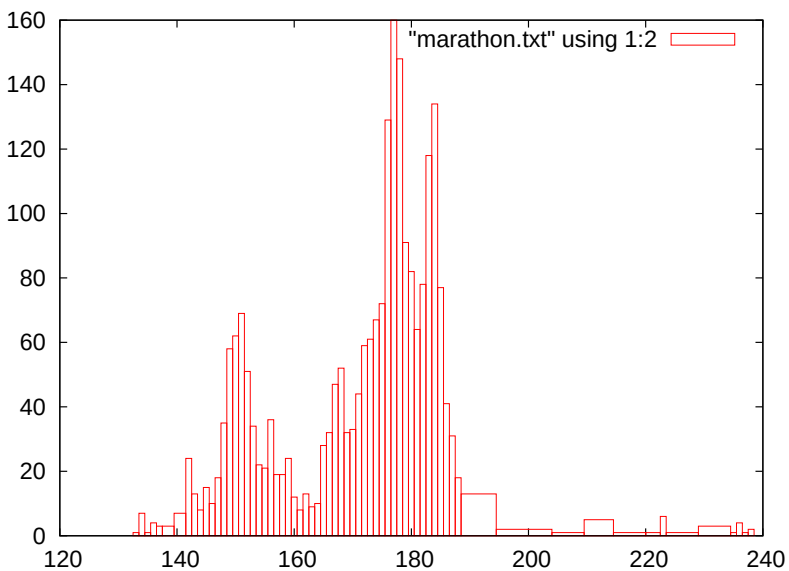
previous exercise: histogram

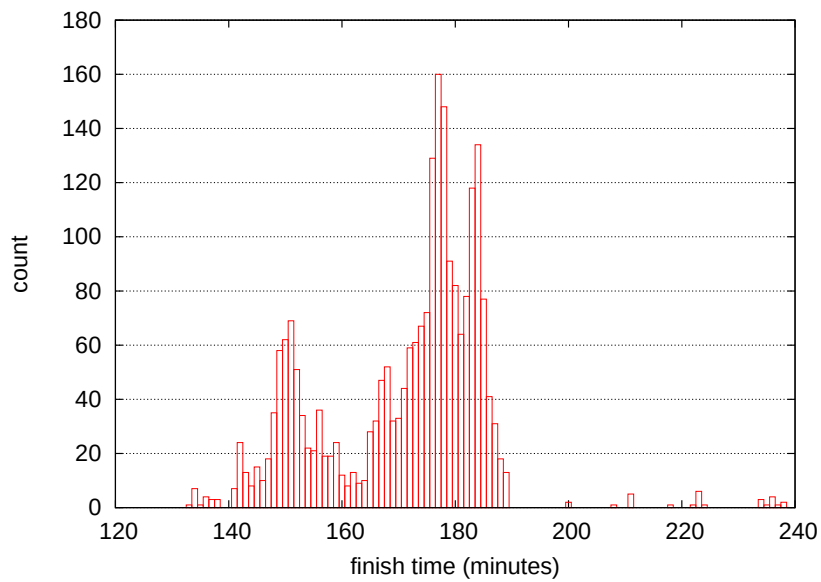
- distribution of finish time of a city marathon

```
plot "marathon.txt" using 1:2 with boxes
```

make the plot look better (right)

```
set boxwidth 1
set xlabel "finish time (minutes)"
set ylabel "count"
set yrange [0:180]
set grid y
plot "marathon.txt" using 1:2 with boxes notitle
```





previous exercise: plotting CDF of finish-time

original data:

```
# Minutes Count
133 1
134 7
135 1
136 4
137 3
138 3
141 7
142 24
...
```

add cumulative count:

```
# Minutes Count CumulativeCount
133 1 1
134 7 8
135 1 9
136 4 13
137 3 16
138 3 19
141 7 26
142 24 50
...
```

previous exercise: CDF (2)

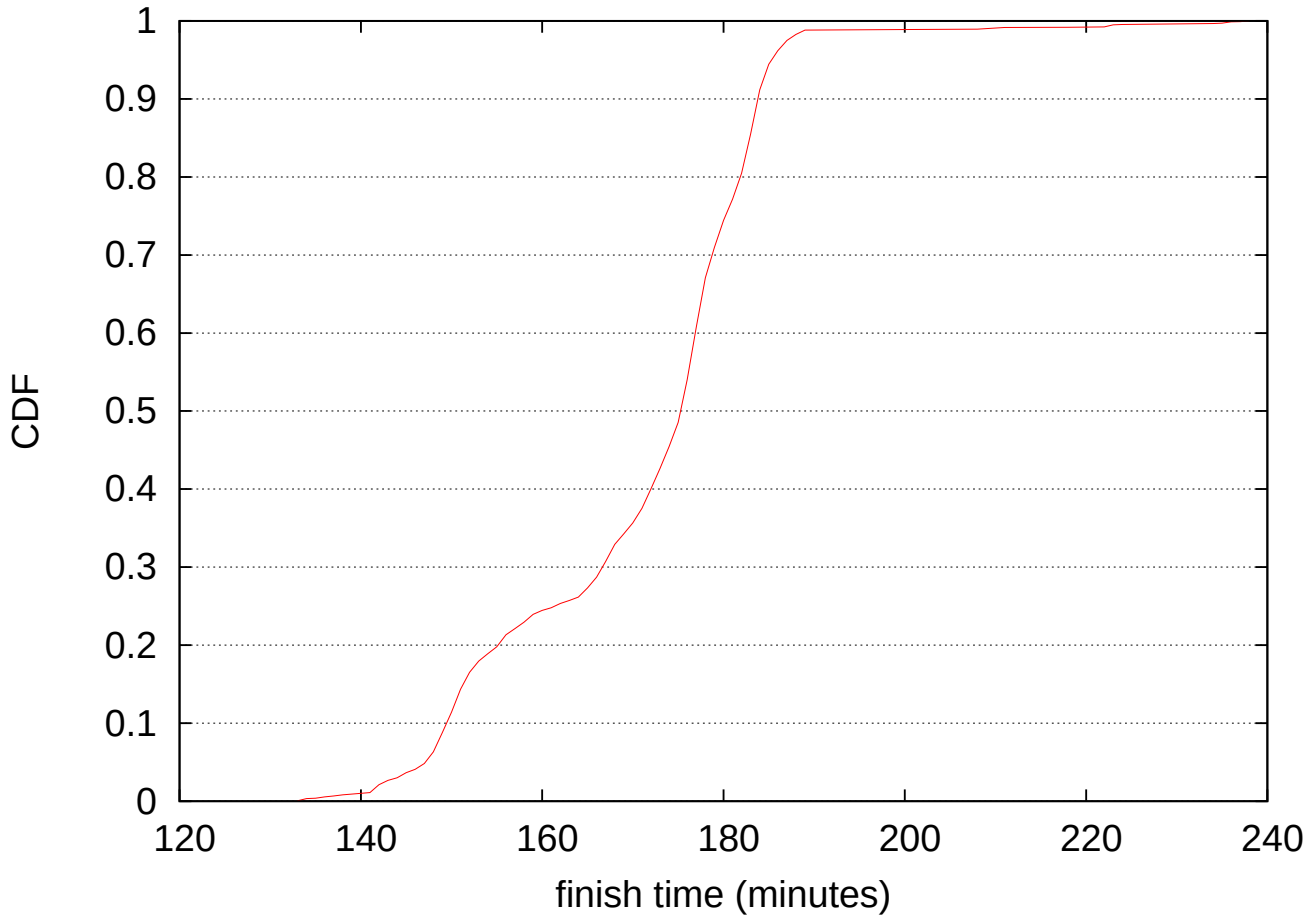
ruby code:

```
re = /^(\d+)\s+(\d+)/
cum = 0
ARGF.each_line do |line|
  begin
    if re.match(line)
      # matched
      time, cnt = $~.captures
      cum += cnt.to_i
      puts "#{time}\t#{cnt}\t#{cum}"
    end
  end
end
```

gnuplot command:

```
set xlabel "finish time (minutes)"
set ylabel "CDF"
set grid y
plot "marathon-cdf.txt" using 1:($3 / 2355) with lines notitle
```

previous exercise: CDF plot of finish-time of city marathon



today's exercise: web access log sample data

- apache log (combined log format)
- from a JAIST server, access log for 24 hours
- about 20MB (zip compressed), about 162MB after unzip
- 1/10 sampling
- client IP addresses are anonymized for privacy
  - using "ipv6loganon –anonymize-careful"

```
access log for 24 hours:
 http://www.iijlab.net/~kjc/classes/sfc2013f-measurement/sample_access_log.zip
```

sample data

```
117.136.16.0 - - [01/Oct/2013:23:59:58 +0900] "GET /project/morefont/liangqiushengshufaziti.apk \
  HTTP/1.1" 200 524600 "-" "-" jaist.dl.sourceforge.net
218.234.160.0 - - [01/Oct/2013:23:59:59 +0900] "GET /pub/Linux/linuxmint/packages/dists/olivia/\
  upstream/i18n/Translation-ko.xz HTTP/1.1" 404 564 "-" "Debian APT-HTTP/1.3 (0.9.7.7ubuntu4)" \
  ftp.jaist.ac.jp
119.80.32.0 - - [01/Oct/2013:23:59:59 +0900] "GET /project/morefont/xiongtuti.apk HTTP/1.1" 304 \
  132 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; Foxy/1; InfoPath.1)" \
  jaist.dl.sourceforge.net
218.234.160.0 - - [02/Oct/2013:00:00:00 +0900] "GET /pub/Linux/linuxmint/packages/dists/olivia/\
  import/i18n/Translation-en.gz HTTP/1.1" 404 562 "-" "Debian APT-HTTP/1.3 (0.9.7.7ubuntu4)" \
  ftp.jaist.ac.jp
117.136.0.0 - - [02/Oct/2013:00:00:00 +0900] "GET /project/morefont/xiaoqingwaziti.apk HTTP/1.1"\
  200 590136 "-" "-" jaist.dl.sourceforge.net
123.224.224.0 - - [02/Oct/2013:00:00:00 +0900] "GET /pub/Linux/ubuntu/dists/raring/main/i18n/\
  Translation-en.bz2 HTTP/1.1" 304 187 "-" "Debian APT-HTTP/1.3 (0.9.7.7ubuntu4)" ftp.jaist.ac.jp
123.224.224.0 - - [02/Oct/2013:00:00:00 +0900] "GET /pub/Linux/ubuntu/dists/raring/multiverse/\
  i18n/Translation-en.bz2 HTTP/1.1" 304 186 "-" "Debian APT-HTTP/1.3 (0.9.7.7ubuntu4)" \
  ftp.jaist.ac.jp
124.41.64.0 - - [01/Oct/2013:23:59:58 +0900] "GET /ubuntu/pool/universe/s/shorewall6/\
  shorewall6_4.4.26.1-1_all.deb HTTP/1.1" 200 435975 "-" "Wget/1.14 (linux-gnu)" ftp.jaist.ac.jp
...
240b:10:c140:a909:a949:4291:c02d:5d13 - - [02/Oct/2013:00:00:01 +0900] "GET /ubuntu/pool/main/m/\
  manpages/manpages_3.52-1ubuntu1_all.deb HTTP/1.1" 200 626951 "-" \
  "Debian APT-HTTP/1.3 (0.9.7.7ubuntu4)" ftp.jaist.ac.jp
...
```

exercise: plotting request counts over time

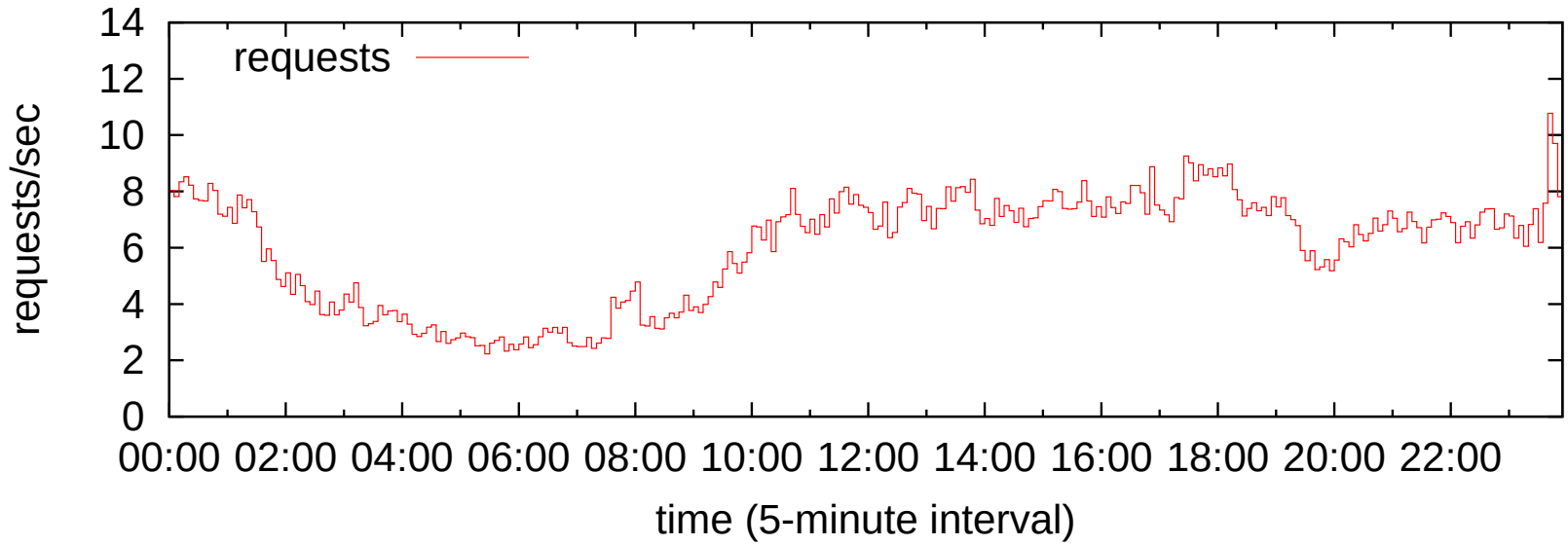
- use the sample data
- extract request counts and transferred bytes with 5 minutes bins
- plot the results

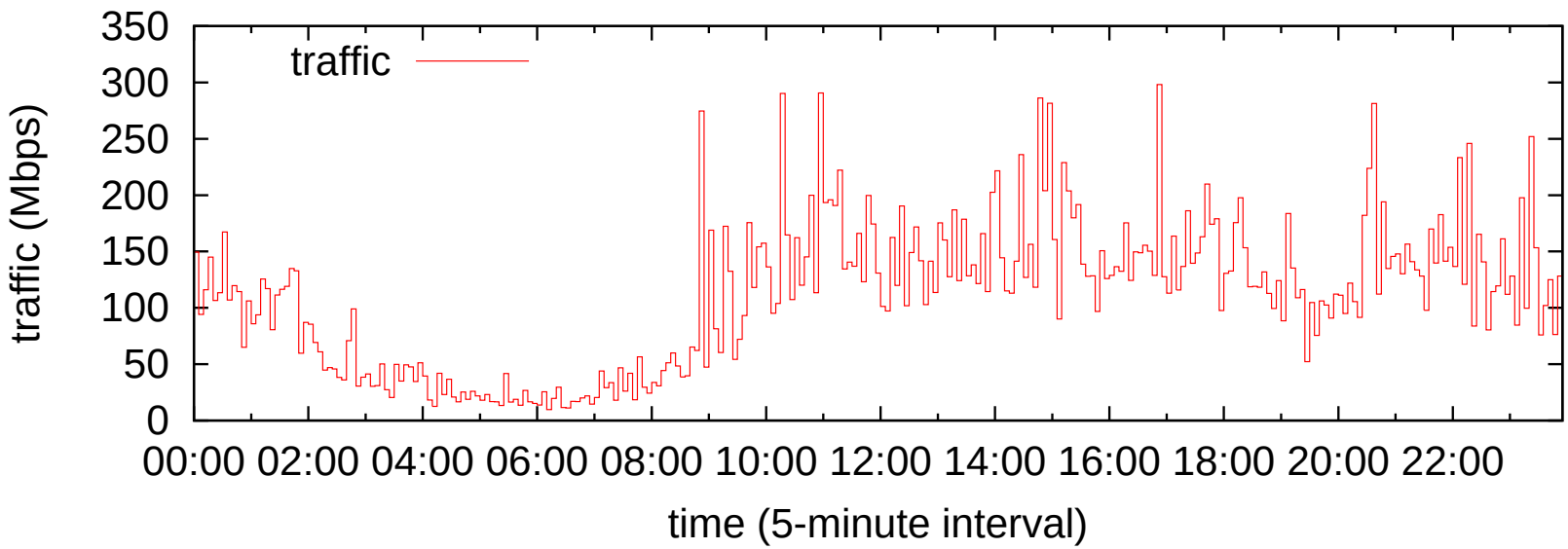
```
% ruby parse_accesslog.rb sample_access_log > access-5min.txt
% more access-5min.txt
2013-10-01T20:00 1 1444348221
...
2013-10-01T23:55 215 1204698404
2013-10-02T00:00 2410 5607857319
2013-10-02T00:05 2344 3528532804
2013-10-02T00:10 2502 4354264670
2013-10-02T00:15 2555 5441105487
...
% gnuplot
gnuplot> load 'access.plt'
```

extract request counts and transferred bytes with 5 minutes bins

```
#!/usr/bin/env ruby
require 'date'

# regular expression for apache common log format
#   host ident user time request status bytes
re = /^(\S+) (\S+) (\S+) \[(.*?)\] "(.*?)" (\d+) (\d+|-)/
timebins = Hash.new([0, 0])
count = parsed = 0
ARGF.each_line do |line|
  count += 1
  if re.match(line)
    host, ident, user, time, request, status, bytes = $~.captures

    next unless request.match(/GET\s.*/) # ignore if the request is not "GET"
    next unless status.match(/2\d{2}/) # ignore if the status is not success (2xx)
    parsed += 1
    # parse timestamp
    ts = DateTime.strptime(time, '%d/%b/%Y:%H:%M:%S')
    # create the corresponding key for 5-minutes timebins
    rounded = sprintf("%02d", ts.min.to_i / 5 * 5)
    key = ts.strftime("%Y-%m-%dT%H:#{rounded}")
    # count by request and byte
    timebins[key] = [timebins[key][0] + 1, timebins[key][1] + bytes.to_i]
  else
    # match failed
    $stderr.puts("match failed at line #{count}: #{line.dump}")
  end
end
timebins.sort.each do |key, value|
  puts "#{key} #{value[0]} #{value[1]}"
end
$stderr.puts "parsed:#{parsed} ignored:#{count - parsed}"
```

plot graphs of request counts and transferred bytes





gnuplot script

- put 2 graphs together using multiplot

```
set xlabel "time (5-minute interval)"
set xdata time
set format x "%H:%M"
set timefmt "%Y-%m-%dT%H:%M"
set xrange ['2013-10-02T00:00':'2013-10-02T23:55']
set key left top

set multiplot layout 2,1

set yrange [0:14]
set ylabel "requests/sec"
plot "access-5min.txt" using 1:($2/300) title 'requests' with steps

set yrange [0:350]
set ylabel "traffic (Mbps)"
plot "access-5min.txt" using 1:($3*8/300/1000000) title 'traffic' with steps

unset multiplot
```

summary

Class 3 Data recording and log analysis

- Network management tools
- Data format
- Log analysis methods
- exercise: log data and regular expression

next class

Class 4 Distribution and confidence intervals (10/16)

- Normal distribution
- Confidence intervals and statistical tests
- Distribution generation
- exercise: confidence intervals
- **assignment 1**