# The Impact and Implications of the Growth in Residential User-to-User Traffic

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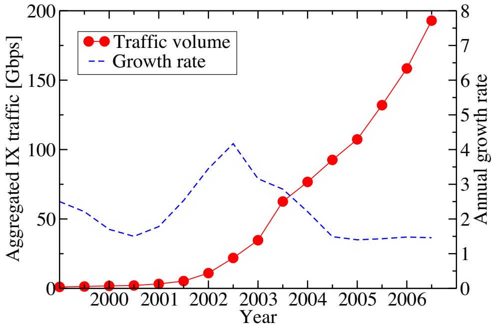
## about this talk

- extensive study on residentail broadband (RBB) traffic
  - comparison of heavy-hitters/other-users, fiber/DSL users
- results show impact of RBB to Internet usage/backbone traffic
  - research people should know
  - although each result may not be too surprising to experts

## unprecedented traffic increase in backbone

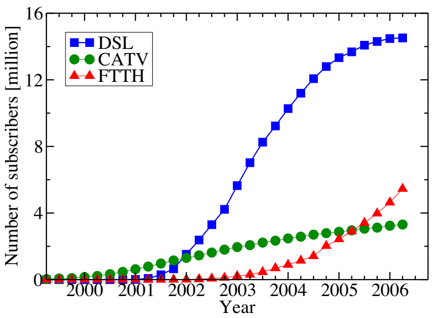
- rapidly growing residential broadband access
  - low-cost high-speed services, especially in Korea and Japan
  - Japan is by far the highest in Fiber-To-The-Home (FTTH)
- traffic growth of the peak rate at major Japanese IXes
  - still keeps growth of 50% per year
  - how much is contributed by residential broadband traffic?



Traffic growth at major Japanese IXes

## residential broadband subscribers in Japan

- 23.3 million broadband subscribers as of March 2006
  - 14.5 million for DSL, 3.3 million for CATV, 5.5 million for FTTH
- exponential increase of FTTH, expected to exceed DSL in 2007
  - 100Mbps bi-directional fiber access costs 40USD/month
  - significant impact to backbones



RBB subscribers in Japan

## motivation

- concerns about rapid growth of RBB traffic
  - backbone technologies will not keep up with RBB traffic
  - ISPs cannot invest in backbone simply for low-profit RBB
- ISPs and policy makers need to understand the effects of RBB
  - although most ISPs internally measure their traffic
    - data are seldom made available to others
    - measurement methods and policies differ from ISP to ISP

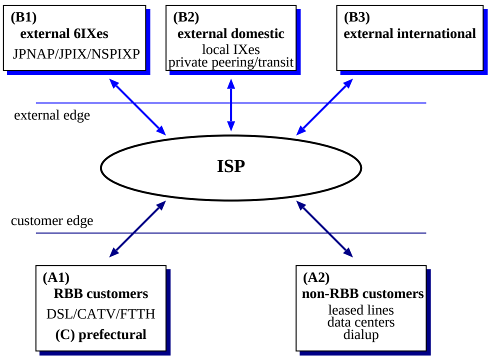
- to identify the macro-level impact of RBB traffic on ISP backbones
  - a study group with 7 major Japanese ISPs and government
- our approach consists of 2 analyses
  - aggregated traffic analysis
    - based on aggregated SNMP data from 7 major ISPs
  - per-customer traffic analysis
    - based on Sampled NetFlow data from one of the ISPs

## major findings in aggregated traffic data

- our data is considered to cover 42% of total Japanese traffic
  - total RBB traffic in Japan is estimated to be 468Gbps (2005/11)
- 70% of RBB traffic is constant, peak in the evening hours
- RBB traffic is much larger than office traffic, so backbone traffic is dominated by RBB traffic
- traffic volume exchanged via private peering is larger than volume exchanged via major IXes
- regional RBB traffic is roughly proportional to regional population

## data collection across major ISPs

- focus on traffic crossing ISP boundaries (customer and external)
  - tools were developed to aggregate MRTG/RRDtool traffic logs
- only aggregated results published not to disclose individual ISP share
- challenges: mostly political or social, not technical



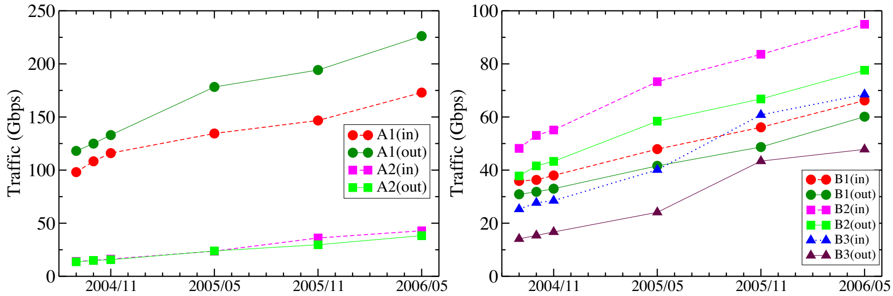

**5 traffic groups at ISP cusomer and external boundaries**

## methodology for aggregated traffic analysis

- month-long traffic logs for the 5 traffic groups with 2-hour resolution
  - MRTG's resolution for monthly log
- a script to read and aggregate a list of MRTG/RRDtool logs
  - each ISP creates log lists and makes aggreagated logs by themselves without disclosing details
- biggest workload for ISP
  - creating lists by classifying large number of per-interface logs
    - some ISPs have more than 100,000 logs!
  - maintaining the lists
    - frequent planned and unplanned configuration changes
- data sets
  - 2-hour resolution interface counter logs
    - from Sep/Oct/Nov 2004, May/Nov 2005, May 2006
    - by re-aggregating logs provided by 7 ISPs
- IN/OUT from ISPs' view

## traffic growth

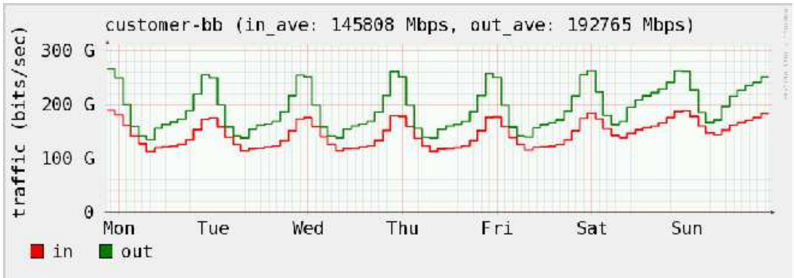
- 26-138% increase in 2005
  - RBB: 26% increase for inbound, 46% increase for outbound
- growth has slowed down from 100% in 2002 to 50% in 2005
  - observed worldwide




Growth of customer traffic    Growth of external traffic

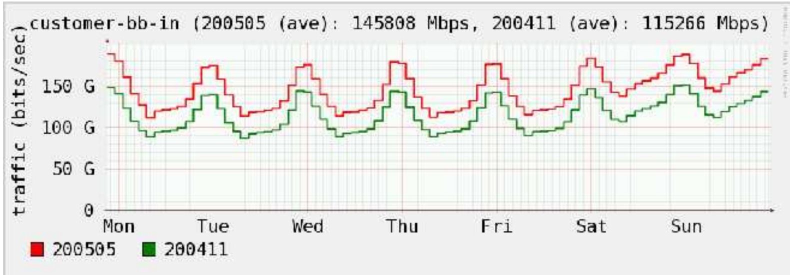
## RBB customer weekly traffic
### in November 2005

- DSL/CATV/FTTH customer traffic of the 7 ISPs
  - inbound and outbound are almost equal
  - almost 200Gbps on average!
  - 150Gbps is constant, probably due to automated p2p applications
  - daily fluctuations: peak from 21:00 to 23:00



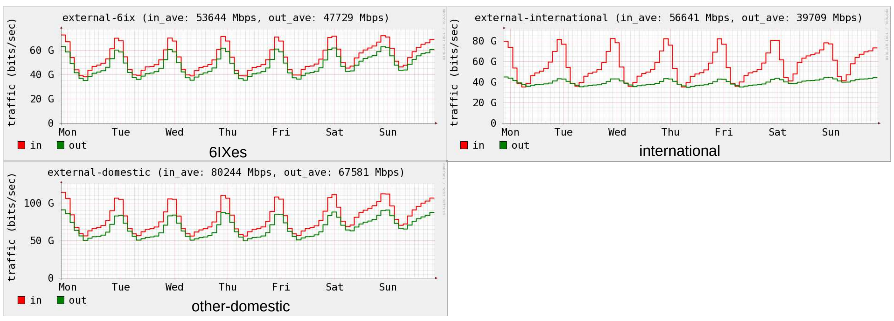
## comparing RBB in-volumes between 2004 and 2005

- the growth comes from the constant portion!




## weekly external traffic

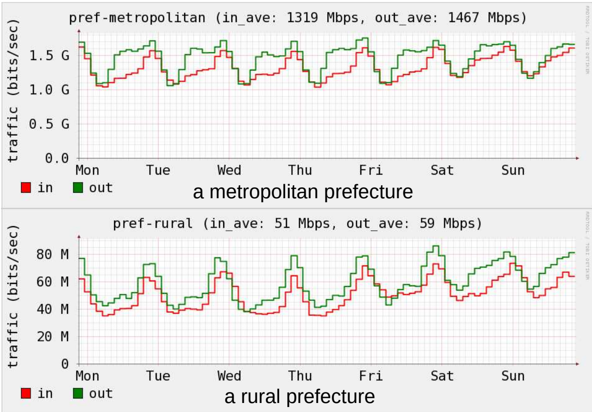
- external traffic is also strongly affected by RBB traffic
  - other-domestic: mainly private peering (also transit, regional IXes)
    - larger than traffic via majior IXes
  - international: inbound much larger than outbound
    - traditional content downloading seems still non-negligible




External weekly traffic in November 2005

## prefectural differences in RBB traffic

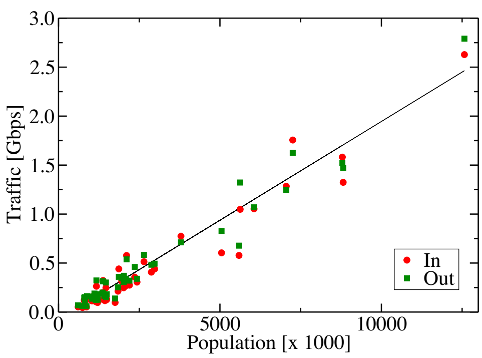
- similar temporal traffic pattern across different prefectures
  - e.g., peak in evening, 70% is constant, regardless the volume
  - metropolitan prefectures with larger office hour traffic




Example prefectural traffic

## prefectural population and traffic

- traffic is roughly linear to population!
  - from a scatter plot of population and traffic volume
  - similar result with the number of Internet users
- no clear difference in usage or heavy-hitter ratio




Prefectural traffic volumes are roughly linear to populations

## analysis of per-customer traffic in one ISP

- one ISP provided per-customer traffic data for Feb and Jul 2005

- data sets
  - Sampled NetFlow data
    - from edge routers accommodating fiber/DSL RBB customers
  - week-long logs from Feb and Jul 2005

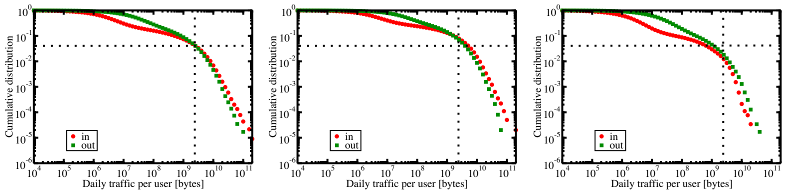
- heavy-hitters: denote users who upload more than 2.5GB/day
  - larger in fiber users

## major findings in per-customer traffic data

- 4% of heavy-hitters account for 75% of the total inbound volume
- the fiber users account for 86% of the inbound volume
  - DSL is only 14%
  - even though the number of DSL active users is larger than fiber
- the distribution of heavy-hitters is heavy-tailed
  - no clear boundary between heavy-hitters and normal users
- dominant applications have poor locality and communicate with a wide range and number of peers

# CCDF of daily traffic per user

- heavy-hitters are statistically distributed
  - over a wide range of traffic volume (heavy-tailed)
    - even up to 200GB/day (19Mbps)!
  - no clear boundary between heavy-hitters and normal users
- lines at 2.5GB/day (230kbps) and the top 4% heavy-hitters
  - knee of the total users's slope
- heavy-hitter population: 4% in total users, 10% in fiber, 2% in DSL

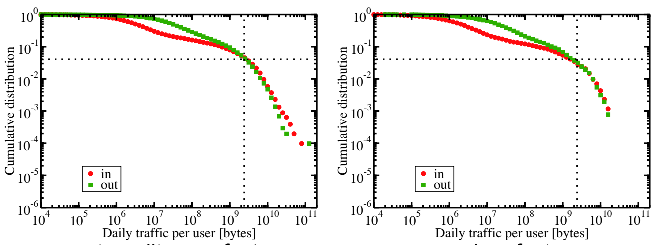



total fiber DSL

CCDF of daily traffic volume per user

# prefectural comparison

- distribution similar in all prefectures
  - differences in tail length (population size)
    - probably due to universal broadband access in Japan

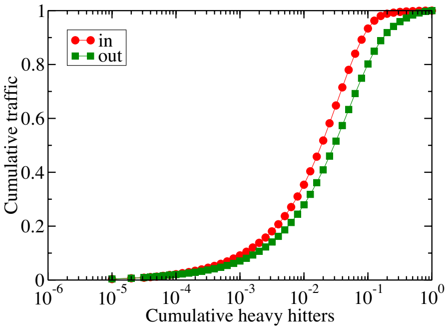



a metropolitan prefecture a rural prefecture

CCDF of daily traffic volume per user

## CDF of traffic volume of heavy-hitters

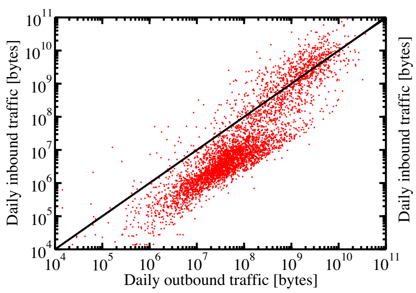
- graph: the top N% of heavy-hitters use X% of the total traffic
- highly skewed distribution in traffic usage
  - the top 4% use 75% of the total inbound traffic
  - the top 4% use 60% of the total outbound traffic



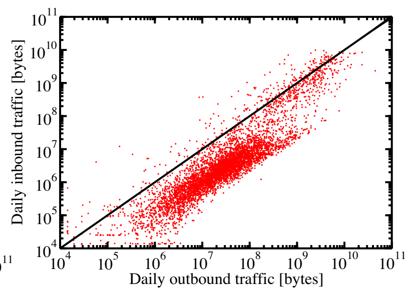

Cumulative Traffic of heavyhitters

## correlation of inbound/outbound volumes per user

- 2 clusters: one below the unity line, another in high volume region
  - more heavy-hitters in fiber, more lightweight users in DSL
- no qualitative difference between fiber users and DSL users
  - except the percentage of heavy-hitters
- again, no clear boundary between heavy-hitters and normal users




fiber

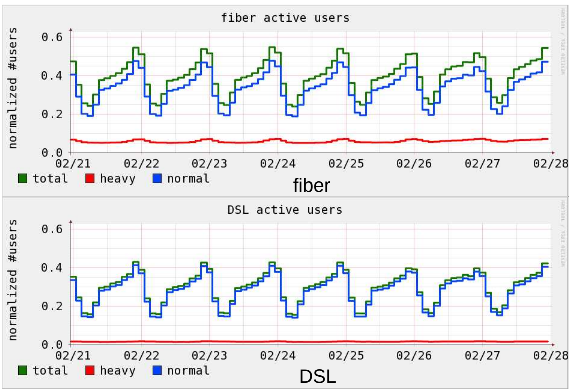



DSL

daily per-user inbound/outbound volumes

## number of active users

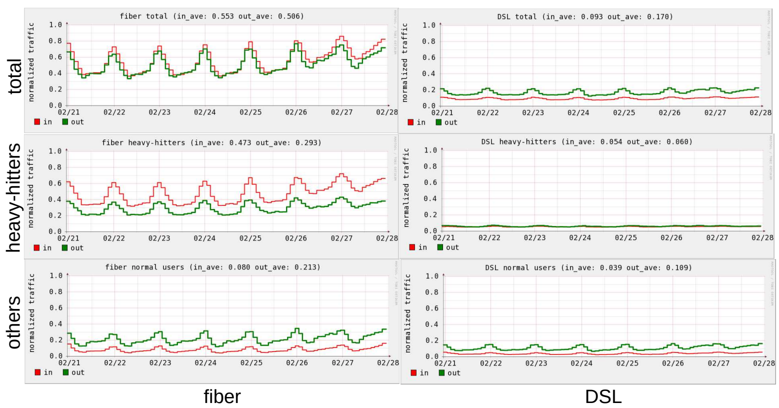
- numbers are normalized to the fiber/DSL combined peak
- total numbers are similar between fiber and DSL
- heavy-hitters are fairly constant, especially in DSL




Normalized number of active users

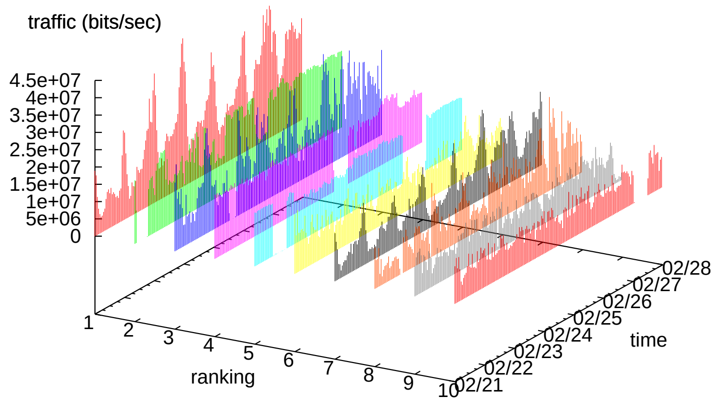
## comparison of fiber/DSL traffic

- again, normalized to the combined peak
- inbound: 86% is from fiber users, DSL is only 14%
- total traffic is heavily influenced by fiber heavy-hitters



## uploading behavior of top 10 heavy-hitters

- one hour average traffic over a week
  - considerable variations, suggesting differences in usage




## protocols/ports ranking

- port 80 (http) is only 9%
- 83% is TCP dynamic ports!
  - each port usage is small except port 80

| protocol | port | name | (%) | port | name | (%) |
|---|---|---|---|---|---|---|
| **TCP** | * | | **97.43** | | | |
| | (< 1024 | | 13.99) | 81 | - | 0.15 |
| | 80 | http | 9.32 | 25 | smtp | 0.14 |
| | 20 | ftp-data | 0.93 | 119 | nntp | 0.13 |
| | 554 | rtsp | 0.38 | 21 | ftp | 0.11 |
| | 443 | https | 0.30 | 22 | ssh | 0.09 |
| | 110 | pop3 | 0.17 | | others | 2.27 |
| | (>= 1024 | | 83.44) | 1935 | macromedia-fsc | 0.20 |
| | 6699 | winmx | 1.40 | 1755 | ms-streaming | 0.20 |
| | 6346 | gnutella | 0.92 | 2265 | - | 0.13 |
| | 7743 | winny | 0.48 | 1234 | - | 0.12 |
| | 6881 | bittorrent | 0.25 | 4662 | edonkey | 0.12 |
| | 6348 | gnutella | 0.21 | | others | 79.41 |
| **UDP** | * | | **1.38** | 6257 | winmx- | 0.06 |
| | 6346 | gnutella | 0.39 | | others | 0.93 |
| **ESP** | | | **1.09** | | | |
| **GRE** | | | **0.07** | | | |
| **ICMP** | | | **0.01** | | | |
| **others** | | | **0.02** | | | |

## geographic traffic matrix of RBB traffic

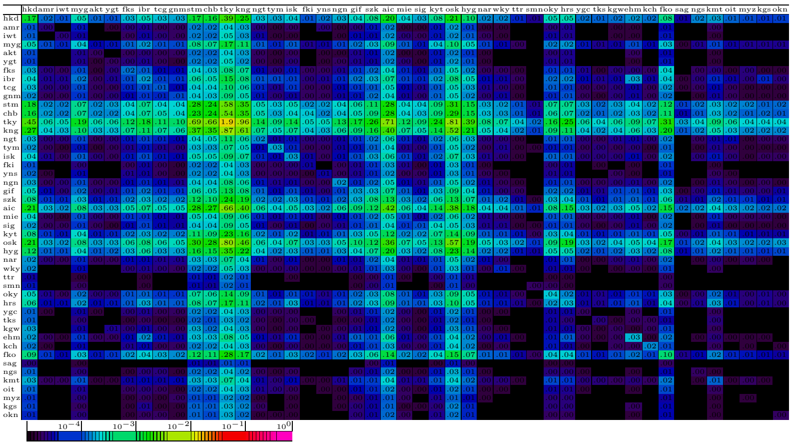
- RBB (home users), DOM (other domestic), INTL (international)
  - both ends are classified by commercial geo-IP databases
- 62% of residential traffic is user-to-user
- 90% is inside Japan (among RBB and DOM)
  - possible reasons are:
    - language and cultural barriers
    - p2p super-nodes among bandwidth-rich domestic fiber users

| $src \backslash dst$ | ALL | RBB | DOM | INTL |
|---|---|---|---|---|
| ALL | 100.0 | 84.8 | 11.1 | 4.1 |
| RBB | 77.0 | 62.2 | 9.8 | 3.9 |
| DOM | 18.0 | 16.7 | 1.1 | 0.2 |
| INTL | 5.0 | 4.8 | 0.2 | 0.0 |

## prefectural traffic matrix

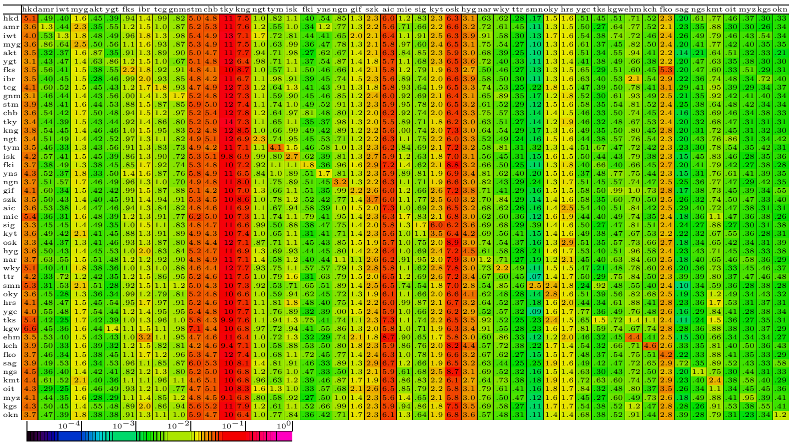
### (src on Y-axis, dst on X-axis)

- looking into 47 prefectures
  - traffic volumes are roughly linear to prefectural populations



## prefectural traffic matrix normalized to src

- the sum of columns is 100% for each row
- no clear difference among prefectures
  - similar distribution, only small locality (1-3%) is found
  - similar result when normalized to dst



## implications

- we tend to attribute the skews in usage to the divide between a handful of heavy-hitters and the rest of the users
  - but there are diverse and widespread heavy-hitters
- heavy-hitters are no longer exceptional extremes
  - too many of them, statistically distributed over a wide range
    - casual users start playing with p2p applications, become heavy-hitters, and eventually shift from DSL to fiber
    - or, sometimes users subscribe to fiber first, and then, look for applications to use the abundant bandwidth
  - these users' behavior would be easily affected by social, economic or political factors (they don't care about underlying technologies)
  - but surely users as a whole are shifting towards high-volume usage
- is this specific to Japan?
  - a model of widespread symmetric residential broadband access
    - with language/cultural barriers, geographic concentration

## conclusion

- we need to prepare for the future to accommodate innovations brought by empowered end-users
- our study to understand residential broadband traffic
  - cooperation with major ISPs and government
  - detailed analysis of traffic data from one ISP
- RBB traffic accounts for 2/3 of ISP backbone traffic
  - a significant impact on pricing and cost structures of ISP business
- future work
  - we will continue collecting aggregated traffic logs from ISPs
  - plans to compare results with other Japanese ISPs, other countries


- acknowledgments
  - IIJ, Japan Telecom, K-Opticom, KDDI, NTT Communications, POWEREDCOM, SOFTBANK BB for data collection support
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