Kawaihiko and the Third-Quartile Day

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Abstract

The Kawaihiko network, linking the New Zealand Universities to the Internet, pioneered traffic measurement as a tool for network management and cost recovery. Its history and its use of the Realtime Traffic Flow Measurement (RTFM) architecture to measure its traffic are described.

The Kawaihiko members wanted a 'measured bandwidth' metric which would be a good indicator of the bandwidth required to carry each site's traffic. Kawaihiko developed such a metric - the Third-Quartile Day (3QD) - based on a daily usage profile or Third-Quartile Profile (3QP). 3QP and 3QD are described in detail, and illustrated with typical plots from several of the Kawaihiko sites.

The Kawaihiko members found 3QD to be an effective bandwidth measure, and 3QP a useful traffic management tool.

Introduction

History

Kawaihiko is a Maori word, derived from *kawai* (a branching structure, like tree roots) and *hiko* (electricity). The New Zealand Universities have been connected together via the Kawaihiko network, which began as a mesh of serial links, and changed to using Frame Relay in 1992. During this period Internet connectivity was provided via NZGate (New Zealand's only international Internet link) which was located at The University of Waikato. Traffic through NZGate was billed (by volume) directly to each Kawaihiko site and the Kawaihiko network developed a 'committed-rate' charging scheme to recover the costs of connectivity within New Zealand, as described in [NZ-PRICING].

Early in 1996 NZGate was scaled down and replaced by NZIX, New Zealand's first Internet Exchange, which provided a neutral interconnection point for many Internet Service Providers (ISPs) offering both international and New Zealand interconnectivity.

In March 1996 the Kawaihiko members decided to move to a new network structure using a star topology centred on a Cisco 7200 router ("the Kawaihiko router") located at The University of Waikato, and this router was installed early in 1997. Some of the Kawaihiko members chose to buy Internet connectivity directly from local ISPs, but most continued to use the Kawaihiko network as their ISP.

Figure 1 shows the network topology as it was in August 1997. The large box labelled 'R' is the Kawaihiko router, and the grey cloud to its right represents the NZ Internet Exchange. The Kawaihiko member sites are shown as heavy horizontal lines representing their 'gateway' networks. Each member's site had a gateway router (the small box labelled 'R'), which was connected to another router. Auckland, Massey, Canterbury and Otago connected via Frame Relay links to the Kawaihiko router; their committed rates (in kbps) are indicated on the diagram, and Lincoln connected to Canterbury via a 128 kbps Serial link. The Waikato gateway was attached to a 10 Mbps Ethernet port on the Kawaihiko router.

The small boxes labelled 'M' are traffic meters, their function will be explained below. The meters at each site's gateway measured traffic to and from that site. There were two meters at the Internet Exchange, one to measure the traffic from Kawaihiko to and from the Internet (labelled 'NZIX') the other to measure traffic to and from Kawaihiko's Web Cache.

With the Kawaihiko router installed and running, the Kawaihiko network arranged to buy Internet connectivity from three ISPs - Clear Communications, Telecom NZ and Telstra NZ. Each of these ISPs had a router connected directly to NZIX, allowing the Kawaihiko network to establish BGP (Border Gateway Protocol) peering with all three. There were at least two reasons for having multiple providers:

- Improved network reliability. If the connection to one ISP failed the other two would continue to carry Kawaihiko's traffic.
- Greater traffic management capability. BGP provides policy controlled routing which could be used to choose the best-performing routes, and also to balance the traffic between providers.

Cost recovery

Each Kawaihiko site was responsible for their access to the Kawaihiko router. For example Auckland paid Clear Communications directly for the Frame Relay link between the Universities of Auckland and Waikato. Since NZIX is located at Waikato, the University agreed to pay a fixed share of the access costs for each of the other Kawaihiko sites.

The Kawaihiko router was located at NZIX, which is a neutral Internet exchange, hence there were no costs incurred for 'New Zealand' traffic, i.e. between Kawaihiko and other sites within New Zealand. This left the Kawaihiko network management responsible for buying international Internet connectivity and for recovering the costs of that connectivity from its members.

The Kawaihiko sites agreed that charges for the new 'star' network would no longer be based on traffic volumes (total Megabytes per month), but would instead be based on network capacity (network 'bandwidth' in kilobits per second). Since the network didn't actually have any fixed-capacity links, the sites agreed to used 'measured bandwidth' instead.

The overall management strategy was:

a) Decide how much international bandwidth Kawaihiko should buy from each ISP. Manage the BGP routing configuration so as to keep the traffic within the contracted bandwidth for each ISP.

b) Pay the total monthly cost of the contracted bandwidth, and recover that cost from the Kawaihiko members. This required the Kawaihiko management to measure the bandwidth actually used by each site during the month, then divide the total monthly cost among the sites in proportion to their measured usage.

The cost recovery algorithm set out in (b) was seen by the Kawaihiko sites as both fair and easy to understand. It did, however, depend on establishing a suitable metric for 'measured bandwidth' for each month. Similarly, to achieve (a) the Kawaihiko management needed to agree with each ISP as to how the traffic they carried was measured and charged for.

The rest of this paper considers how Kawaihiko traffic was measured, and the metrics developed and used for Kawaihiko's Internet usage.

Making the Measurements

Since late 1992 Kawaihiko has measured its traffic using the Traffic Measurement architecture developed by the IETF's RTFM (Realtime Traffic Flow Measurement) Working Group (discussed in more detail below). In the early stages sites were billed by volume, and measurement data was collected every 15 minutes. With the change to billing for 'measured bandwidth,' data was collected every five minutes so as to provide average traffic rates for each five-minute interval. Shorter measurement intervals would have yielded finer time resolution at the expense of increased data collection and storage costs - five minutes was chosen as a practical compromise.

Traffic Flow Measurement

Since 1992 various Internet Engineering Task Force (IETF) Working Groups have been interested in measuring network traffic. In February 1996 the Realtime Traffic Flow Measurement (RTFM) Working Group was chartered to develop a traffic measurement architecture. The RTFM traffic measurement Architecture is described in [RTFM-ARC].

Central to the architecture is the notion of traffic *flows*. An RTFM traffic flow is a bi-directional stream of packets between two endpoints, each endpoint being defined by a set of *attribute* values. The most important flow attributes describe endpoint addresses, for example SourcePeerAddress is (for IPv4 flows) the 32-bit IP address of the flow's source. By choosing suitable combinations of attributes (or fields within them) one can specify the level of 'granularity' for a flow, from a single IP host and port ('fine' granularity) to a list of IP networks ('coarse' granularity).

The traffic measurement architecture defines three network entities: Meters, Meter Readers and Managers. Traffic measurements are made by a Meter, which is a network management agent attached to the network segment where the traffic is to be observed. The meter implements a standard Management Information Base (MIB) which is described in [RTFM-MIB]. The meter is configured by a user, who prepares a *ruleset* specifying which flows are to be measured. The measured flow data (which includes counts of packets and bytes in each direction for each flow) is collected from the meter by a Meter Reader.

Meters and Meter Readers are controlled by a Manager, which downloads rulesets to Meters and instructs Meter Readers as to which meters they should collect flow data from, and how often.

An RTFM ruleset is actually a program for a virtual machine contained within the meter, known as its Pattern Matching Engine (PME). Each packet observed by a Meter is passed to the PME, which runs the ruleset program using the packet to provide input data. The PME's instruction set has only 14 opcodes, but these are sufficient to determine whether a packet is to be counted by the meter (or simply ignored), and to specify which attributes are to be saved as attribute values in each counted traffic flow.

Writing rulesets directly requires a user to understand the PME and its opcodes so as to produce Assembler-language programs for it, which many users found to be a daunting task. The Working Group has developed a high-level language which makes it much easier to create rulesets; this is SRL, RTFM's Simple Ruleset Language [RTFM-SRL]. SRL provides statements for testing attributes against lists of values and for specifying which attribute values are to be saved when a flow is counted. Subroutines, compound statements and simple defines may be used to simplify the structure of an SRL program.

Collecting Kawaihiko's data

NeTraMet [NETRAMET], an open-source implementation of the RTFM traffic measurement architecture has been available since October 1992. This was produced at the University of Auckland as a tool for measuring traffic flows, providing data accurate enough to be used for cost recovery as well as for network management and development. The package includes NeTraMet (an RTFM meter running on Unix or DOS systems), NeMaC (a combined RTFM Manager and Meter Reader) and an SRL compiler.

The Kawaihiko network topology (Figure 1, see above) includes a NeTraMet traffic meter at the edge of each Kawaihiko site, and two at NZIX. An SRL program was written to collect the required data, this is described in detail below. All nine meters were controlled by a single copy of NeMaC running (within the Campus network) at Auckland. NeMaC was used to download the ruleset to the meters, to read the flow data from them at five-minute intervals and write it to data files. Daily, weekly and monthly processing of the flow data was performed by a collection of perl scripts so as to produce weekly plots.

The weekly plots included one for each site showing the traffic rates in and out during the week, and an NZIX plot showing the traffic rates for each of Kawaihiko's three ISPs.

SRL program for Kawaihiko measurements

The SRL program for Kawaihiko's ruleset is shown in Figures 2 and 3. Figure 2 is the program proper. It begins by defining `Private`, a list of the networks which are recommended for use inside end-user networks [PRIV-ADDR], but which should never be seen outside those networks. The addresses in the list are given in CIDR format [CIDR-ADDR]; note that they have different "widths," i.e. different numbers of significant leading bits.

The `Private` define is followed by the declaration of `classify`, a subroutine which receives `peer` as an input address parameter and returns `class` in an output variable parameter. `classify` begins by testing whether `peer` is a network belonging to one of the Kawaihiko sites, i.e. within the defines `Auckland` .. `Otago`. These defines are contained within "kawaihiko_nets," another SRL file, and are not shown here. If `peer` is a Kawaihiko network, `class` is set to indicate the Kawaihiko site it belongs to, i.e. `11` .. `17`.

If `peer` is not a Kawaihiko network `classify` tests whether it is one of the networks in the define `NZ_nets`, the structure of which is shown in Figure 3. `NZ_nets` is a list of networks arranged in three sections: 'old' Class B and Class C networks (allocated before CIDR addressing became common) and 'newer' networks within CIDR blocks allocated to New Zealand ISPs. Altogether there were about 650 networks in the list. The SRL compiler optimises these into at most 18 tests, one for each of the mask lengths /15 to /32.

If `peer` is a New Zealand network, `class` is set to 1. Failing that, `classify` tests whether it is a `Private` network; if so, `class` is set to 2. Kawaihiko's daily processing looks for these flows, which indicate the presence of a misconfigured router. If all the above tests fail, `class` is set to 3, indicating that the network is an 'international' network.

The ruleset's mainline begins by testing the flow's Peer Type. If it is not an IP (i.e. IPv4) flow it is ignored. Otherwise `classify` is called twice, to determine the class for the flow's source and destination Peer Addresses. After that the flow is counted - the meter makes an entry for the flow in it's flow table, and updates the flow's packet and byte counts.

When NeMaC collects the meter's flow data, it collects the source and destination class for each flow, together with the byte counts for each direction. Such flow data can be used to construct traffic matrices showing the number of bytes transferred in each direction between each class of network.

'Measured Bandwidth' Metrics

Most of the Kawaihiko sites used Frame Relay links to connect to the Kawaihiko router at Waikato. When ordering such a link one must specify two quantities:

- Committed Information Rate (CIR). The supplier guarantees that the link will always carry traffic at this rate.
- Access Rate. This is the maximum rate at which data can be carried by the link.

Frame Relay offers users the advantage of being able to pay for a link's committed rate, while maintaining the ability to send short bursts of traffic at rates up to the link's access rate. The Kawaihiko members wanted a bandwidth metric which would behave in the same way, i.e.

indicate the amount of traffic capacity normally available to a member's site, with the ability to carry short bursts at a higher rate. From this point of view, 'measured bandwidth' would indicate the CIR needed to carry a site's traffic via a Frame Relay link.

Since the bandwidth metric indicates the network's load carrying capacity, it must be determined by peaks in the load. Consider, for example, Auckland's link with an access speed of 512 kbps. Traffic flows through the link are normally limited by bottlenecks outside the Kawaihiko network, so that the five-minute average traffic rate is usually much less than 512 kbps. There will be times, however, when the traffic rate approaches 512 kbps, for example when an unusually large number of users happen to download large files at the same time. The bandwidth metric should not be sensitive to such transient peaks.

95th percentile

Some large ISPs are prepared to offer Internet capacity on the basis of the traffic's 95th percentile. To measure this one simply decides on a measurement interval (five minutes for Kawaihiko), collects traffic rate data throughout the billing period, and then computes the 95th percentile. The 95th percentile provides a bandwidth metric which is easy to understand and simple to measure.

The ISP provisions the service so that traffic at rates less than or equal to the 95th percentile are handled reliably, together with some additional capacity to carry the bursts above that rate. Over the course of time the traffic load will probably increase. Its 95th percentile will reflect this, and the supplier will use this information to increase the link capacity.

Traffic rate percentiles, however, are sensitive to 'unusual' peaks because these tend to skew the traffic rate distribution upwards. One example of such 'unusual' traffic is that caused by a bandwidth-based Denial-of-Service attack. Several Kawaihiko sites have suffered such attacks, some of which generated outbound traffic at the site's full access rate for several hours.

Third-Quartile Day (3QD)

The Third-Quartile Day (3QD) is a new metric developed by the Kawaihiko management group which attempts to measure the bandwidth necessary to carry a particular data stream. Development began by recognising several underlying assumptions:

- Traffic patterns have a strong diurnal component.
- Enough bandwidth must be provided to carry the expected daily peaks.
- These peaks occur at about the same time each day.

These assumptions suggested that one might attempt to characterise the traffic by producing a plot for a ‘typical’ day. To do this one would divide the day into small time intervals and plot the ‘typical’ traffic rate for each. The maximum value on such a plot should be an effective measure of the bandwidth actually needed. Clearly one must choose a suitable statistic to indicate the ‘typical’ rate for each interval. Since the underlying traffic distributions are not well understood it seemed sensible to choose a percentile. We call the resulting plot a ‘daily traffic profile,’ *DTP*.

In the above description no mention was made of the traffic direction. Kawaihiko's traffic rates were, however, always measured in both directions, inbound (from overseas to a Kawaihiko site) and outbound. Since Kawaihiko could only buy symmetric connectivity (same bandwidth in both directions), the maximum of the inbound and outbound rates was used to determine the traffic rate in each time interval.

A daily traffic profile is a member of a family of traffic profiles. Family members are determined by the values of three parameters $DTP(t, d, p)$:

a) The time interval, *t*, (in minutes) over which average traffic rates are measured. The shorter the interval, the more sensitive the metric will be to short bursts.

b) The number of days, *d*, over which the chosen percentile is calculated.

c) The percentile, *p*, plotted to produce the profile.

As explained above, Kawaihiko had already decided to use five-minute intervals, yielding 288 intervals in the day. A DTP was required at the end of each month so as to determine the month's measured bandwidth; 28 days was chosen so as to use the same number of days each month. The choice of a percentile is limited by the data available; the third quartile (75%) was arbitrarily selected.

To plot a daily traffic profile for Kawaihiko 288 distributions are produced, one for each interval of the day. These distributions have 28 points, one for each day contributing to the profile. The i-th value in the profile is the 75^{th} percentile of the i-th distribution. This process is illustrated in Figure 4.

Beginning early in 1997 the Kawaihiko management produced 'Third-Quartile Profiles' (3QP), and referred to the maxima of these profiles as 'Third-Quartile Day' (3QD) values.

Briefly *3QP = DTP(5, 28, 75)*

and *3QD = max(DTP(5, 28, 75))*

Experience with 3QD

Traffic was measured on the Kawaihiko network through most of 1997 and 1998. At weekly intervals the Kawaihiko Management circulated plots showing the previous week's traffic rates and the current 3QP and 3QD rate for each site. A representative sample of these plots are discussed below (Figures 5 - 10). Note that these plots were made at various times during 1998. Their vertical scales differ with site and time of year.

The 'traffic-rate' plots show inbound (upper trace) and outbound (lower trace) international traffic for the week beginning with their indicated dates. A horizontal line is plotted on each trace to indicate its 3QD value. The 3QP plots show the third-quartile traffic rate in each five-minute time slot for the 28 days. Vertical arrows on the 3QPs indicate the time slot when their maximum (i.e. 3QD) rates occurred.

Auckland

Figure 5 shows Auckland traffic in the summer holidays, just before the start of the first semester. The traffic-rate plot (Fig. 5a) shows a strong diurnal variation but this is hardly visible on the 3QP plot (Fig. 5b) – the 3QP brings together the daily variations, producing the effect of 'filling in' the day. This 'filling-in' effect is particularly noticeable from about 0400 to 0800, when the outbound traffic is higher then the inbound.

The traffic-rate plot has few 'spikes' above the 3QD line, which is typical for these traffic-rate plots. There is an unusual burst of traffic around midnight on Wednesday (11 Feb 99), and a smaller burst at midnight on Friday, but these do not appear on the 3QP.

Figure 6 shows Auckland traffic at a busier time of year, some weeks into the second semester. Higher traffic levels (Fig. 6a) with many peaks above the 3QD line, suggesting that network usage is increasing The 3QP (Fig. 6b) shows that the load has indeed increased during the day, rising during the morning, dipping a little during lunch hour (1300-1400) and slowly decreasing from about 1700 to midnight. Although there is a much higher total traffic volume, the 3QD figure has only increased from 330 to 370 kbps.

The gap in the traffic-rate plot from about 0830 to 1000 on Friday morning indicates that either Auckland’s meter or its Internet connection failed during that time; this is an ‘unusual’ event, and does not appear in the 3QP.

Lincoln

Figure 7 shows Lincoln traffic at the end of the summer holidays. The traffic rates are much lower than for Auckland, but there is a strong diurnal variation in traffic rate (Fig. 7a), also clearly visible in the 3QP (Fig. 7b). Although the total volume of traffic is low for the week - producing a very ‘spiky’ traffic-rate plot - the 3QP averages out variations over the month, producing a comparatively smooth daily usage profile.

One odd feature of Fig. 7a is the large outbound spike at midday on Thursday, when the measured rate reached 200 kbps for several time slots. Liincoln's connection to Kawaihiko is, however, a 128 kbps serial link. Such a spike may well have been caused by a network attack which generated very high volumes of outbound data. The Lincoln traffic meter observed traffic on Lincoln's gateway network; the actual outbound traffic rate would have been limited by their gateway router. Such spikes are unusual events, and do not appear in the 3QP.

Figure 8 shows Lincoln traffic some weeks into the second semester. Although the traffic volume has risen considerably, the traffic-rate plot (Fig. 8a) is still very ‘spikey.’ The 3QP (Fig. 8b) is, however, very similar to the earlier one. Traffic through the middle of the day is less variable, and some traffic continues in the evening through to about 0300. The 3QD rate has, however, remained unchanged at 88.5 kbps!

Waikato

Figure 9 shows Waikato traffic late in the second semester. The traffic-rate plot (Fig. 9a) shows a daily pattern, which is also visible in the 3QP. There are a few large spikes above the 3QD line; since Waikato had an Ethernet connection to the Kawaihiko router, they could sustain much higher burst rates than the other Kawaihiko sites. The 3QP (Fig 9b) shows interesting bursts of activity around 0240, 0300 and 0345, probably caused by scheduled data transfers. Had they all been scheduled at the same time their combined traffic rate would have been much more visible.

Figure 10 shows Waikato traffic just after the second semester. The traffic-rate plot (Fig. 10a) seems much more bursty, with many more large spikes visible. The 3QP (Fig. 10b) shows that although the total traffic volume has increased, it is well-distributed through the day. The nightly data transfer takes place from about 0240 to 0640, and the 3QD has only risen from 330 to 370 kbps.

Summary of the Kawaihiko traffic plots

The 3QP plots smooth out day-to-day variations, giving a good idea of the 'typical' traffic load. The 3QD lines on the traffic-rate plots show that most of the traffic can be carried without loss; short bursts above the 3QD line demand some burst capability from the link. In Kawaihiko's case all the traffic passes through a shared bottleneck - the Kawaihiko router. Burst capacity comes from the statistical sharing of that bottleneck as well as from similar bottlenecks in the ISP's networks (router queues, frame relay links, etc.).

3QD's sensitivity to short-term peaks which happen at the same time each day was demonstrated (Figure 9b). The 3QP provides a very useful tool for recognising such patterns, so that their traffic load can be smoothed out to utilise the capacity below the 3QD line.

Unfortunately Kawaihiko was unable to convince its three ISPs that 3QD was a good metric to use for monthly charging. This was partly because their management found it hard to understand, and partly because it requires a considerable data processing effort to collect the traffic data and generate the 3QPs and 3QD values. The ISPs were, however, happy to use the 95th percentile as a charging metric, thus providing Kawaihiko with 'measured bandwidth' bills.

Kawaihiko made careful comparisons of the 3QD and 95th percentile values for several months, and concluded that the 3QD traffic rates were generally higher than the 95th percentile making 3QD a more realistic indication of the bandwidth actually required to carry its traffic effectively.

Conclusion

The Kawaihiko network operated for two years - 1997 and 1998 - as a collective, buying Internet bandwidth from three suppliers on a 'measured volume' basis. Traffic data was measured using NeTraMet, i.e. the RTFM traffic measurement architecture, which provided an effective measurement system which was simple to configure and maintain.

The Third-Quartile Day proved to be an effective measure of the bandwidth needed for each of the Kawaihiko sites, and was well accepted when dividing up the monthly costs. In addition, the weekly 3QP plots proved to be a very useful management tool, making it possible for sites to spread the peaks in their daily traffic so as to minimise the bandwidth they needed. For Kawaihiko, 3QD's only real disadvantage was that it is difficult to explain!

By mid-1998 it had become obvious that the Kawaihiko Management effort was rather people-intensive, requiring considerable technical effort to maintain the traffic balance between the three providers and even more effort to maintain the data collection and cost recovery system. At the same time the Internet in New Zealand had developed to the point where individual ISPs could provide a sufficiently reliable service. These two factors made it clear that there was no longer a compelling need for Kawaihiko to maintain its own network.

The Kawaihiko network closed down in December 1998, and the Kawaihiko sites moved to dealing directly with their chosen ISPs.

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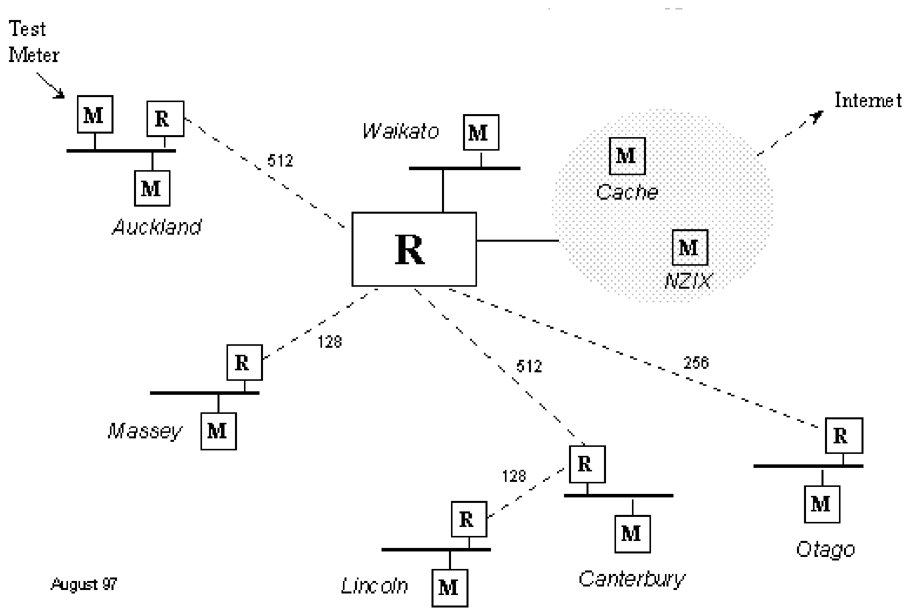

Figure 1. Kawaihiko Network Topology, August 1997

```
#
# Rule file for Kawaihiko meters
#

define Private =  # RFC 1918 addresses
   10.0/8, 172.16/12, 192.168/16;
define IP = 1;  # IPv4 Address Family (from RFC 1700)

# include kawaihiko_nets.srl;  # defines for Kawaihiko members' networks
# include nz_nets.srl;         # define for NZ_nets (see figure 3)


subroutine classify(ADDRESS peer, VARIABLE class)

   if peer == (Auckland)     store class := 11;
   # ... other Kawaihiko sites
   else if peer == (Otago)   store class := 17;

   else if peer == (NZ_nets) store class := 1;

   else if peer == (Private) store class := 2;

   else store class := 3;  # Not a New Zealand network

   endsub;

if SourcePeerType == IP save;
else ignore;  # Not an IP packet

call classify(SourcePeerAddress, SourceClass)
   endcall;
call classify(DestPeerAddress, DestClass)
   endcall;

count;
```

Figure 2. Program (in SRL) for the Kawaihiko traffic meters

```
define NZ_nets =
    130.123.0.0/16   # Old class B networks
   ,130.195.0.0/16
   ,130.216.0.0/16
   ,140.200.0.0/16
#  . . .

   ,192.54.130.0/24  # Old Class C networks
   ,192.58.229.0/24
   ,192.67.168.0/24
   ,192.73.21.0/24
#  . . .

   ,202.27.0.0/20     # New Zealand CIDR blocks
   ,202.27.32.0/19
   ,202.27.64.0/18
   ,202.27.128.0/17
   ,202.36.0.0/15
   ,202.49.0.0/16
   ,202.50.0.0/16
#  . . .

  ;
```

Figure 3. NZ_nets define (in SRL) for the Kawaihiko traffic meters

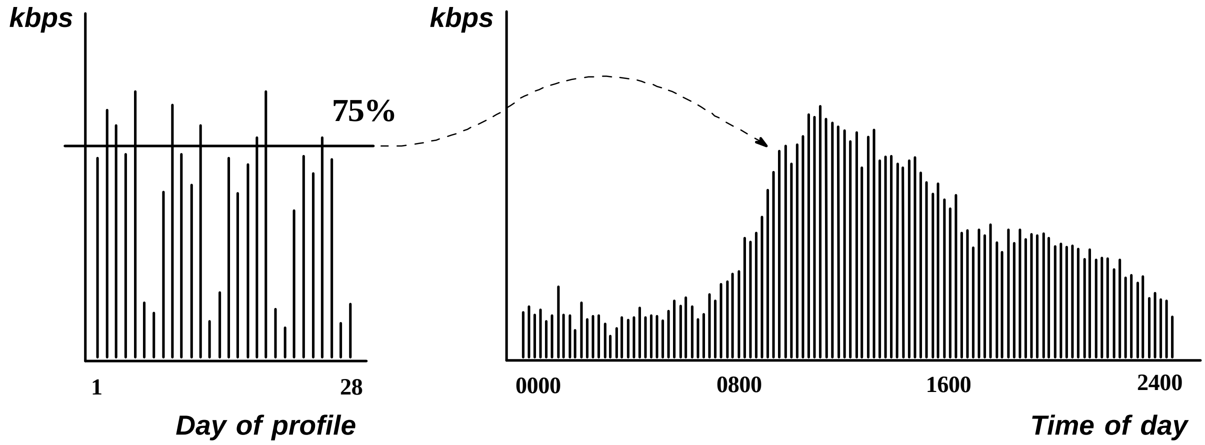

Figure 4. Distribution for one interval (left) producing one point in a 3QP plot (right)

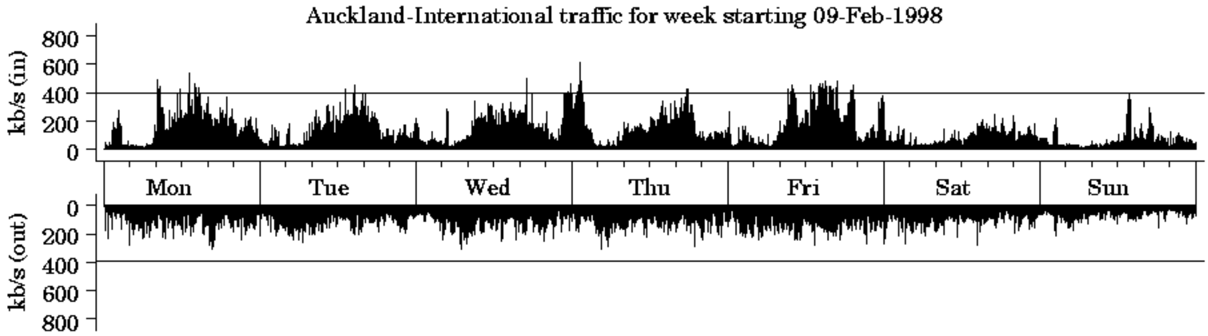

Figure 5a. Inbound traffic rate for Auckland, week starting 9 Feb 98

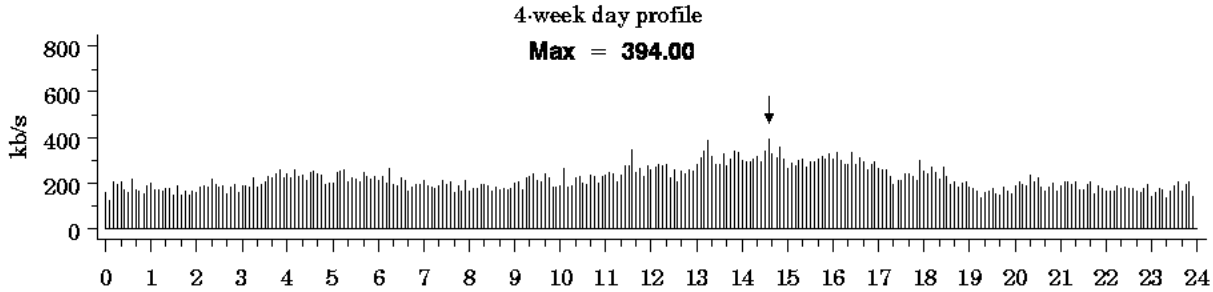

Figure 5b. 3QP for Auckland, after week starting 9 Feb 98. Maximum (3QD) was at 1435

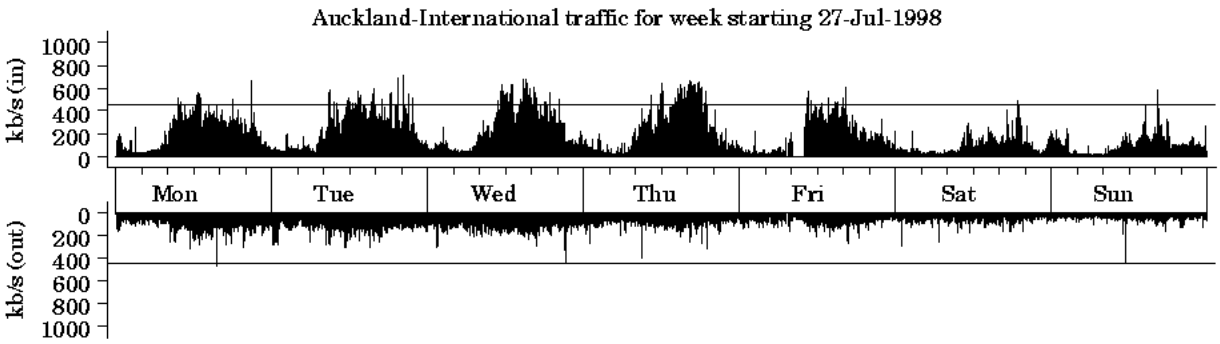

Figure 6a. Inbound traffic rate for Auckland, week starting 27 Jul 98

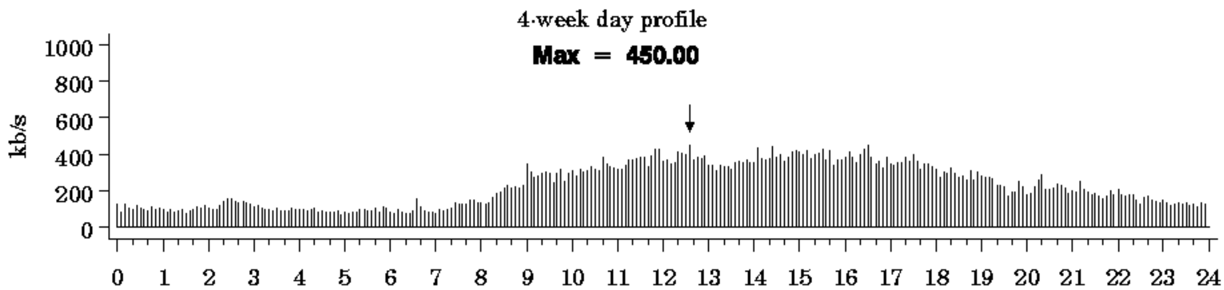

Figure 6b. 3QP for Auckland, after week starting 27 Jul 98. Maximum (3QD) was at 1235

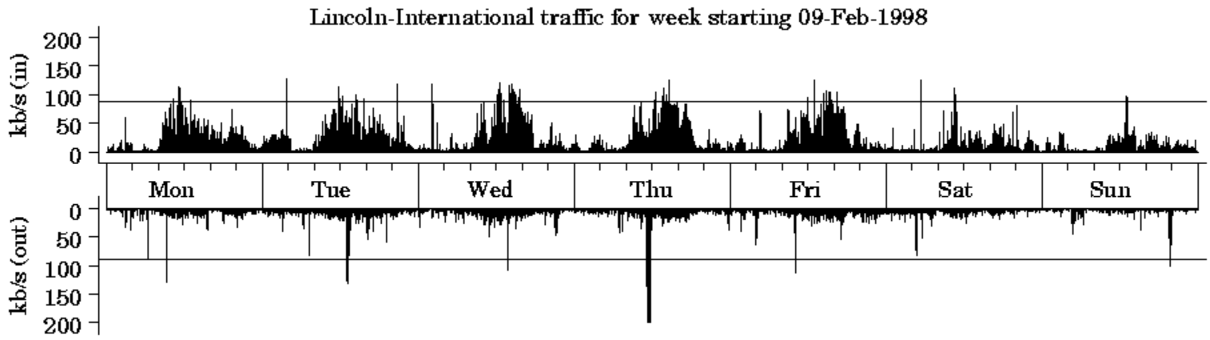

Figure 7a. Inbound traffic rate for Lincoln, week starting 9 Feb 98

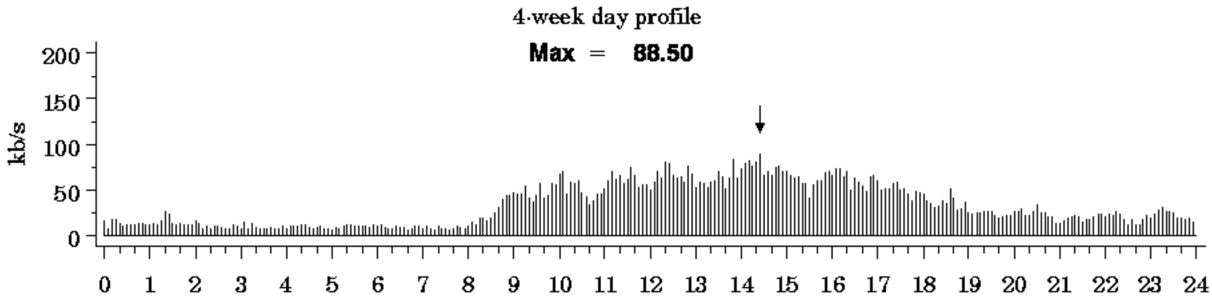

Figure 7b. 3QP for Lincoln, after week starting 9 Feb 98. Maximum (3QD) was at 1425

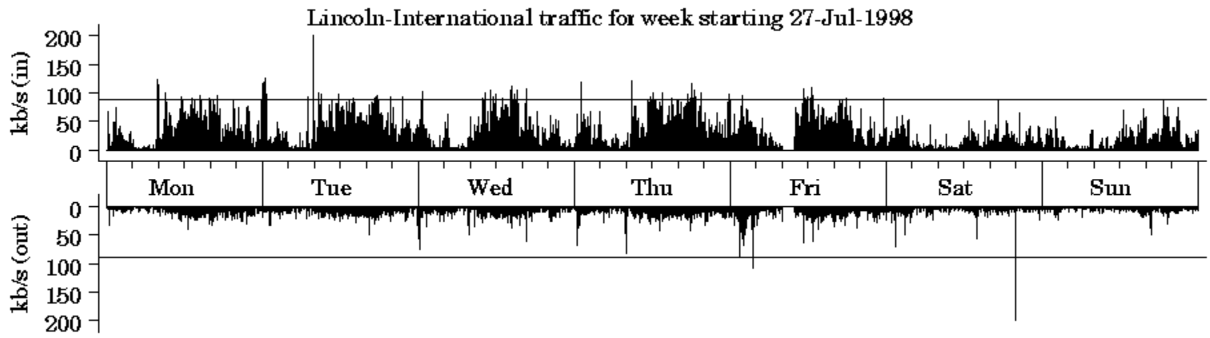

Figure 8a Inbound traffic rate for Lincoln, week starting 27 Jul 98

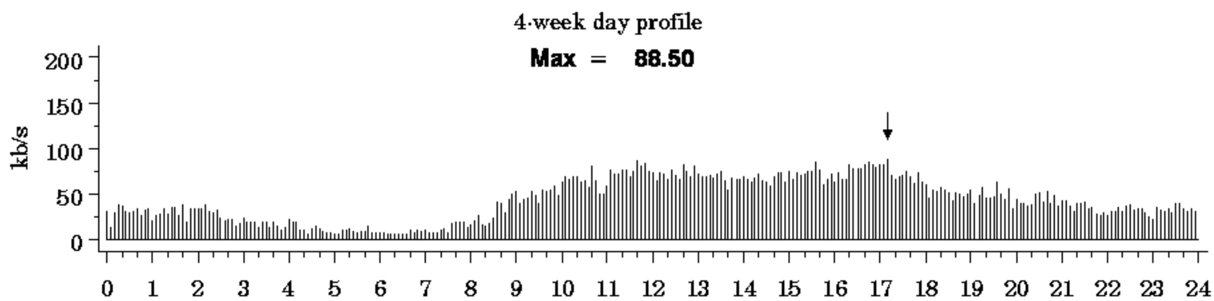

Figure 8b. 3QP for Lincoln, after week starting 27 Jul 98. Maximum (3QD) was at 1710

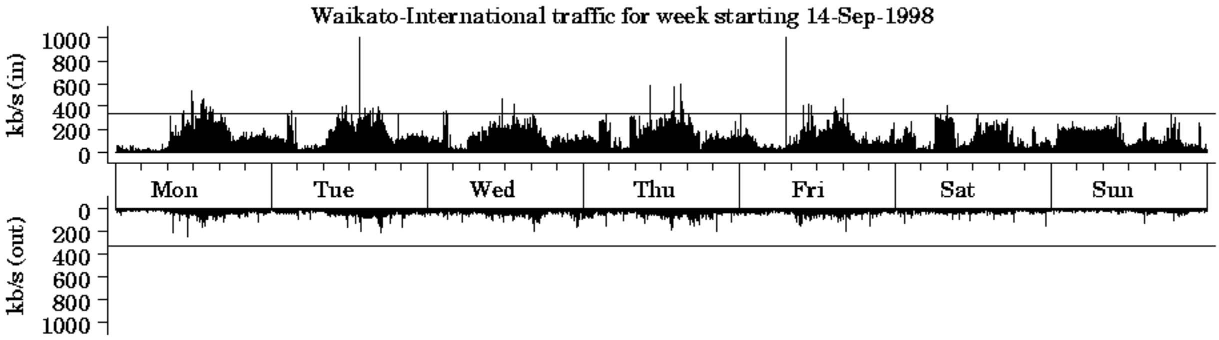

Figure 9a. Inbound traffic rate for Waikato, week starting 14 Sep 98

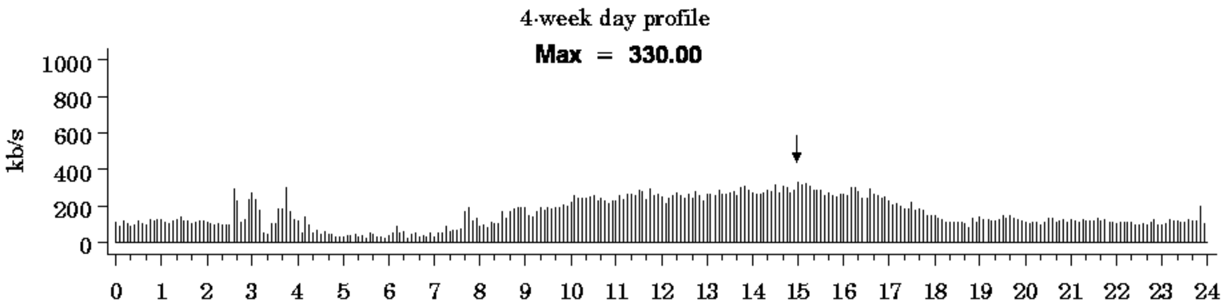

Figure 9b. 3QP for Waikato, after week starting 14 Sep 98. Maximum (3QD) was at 1500

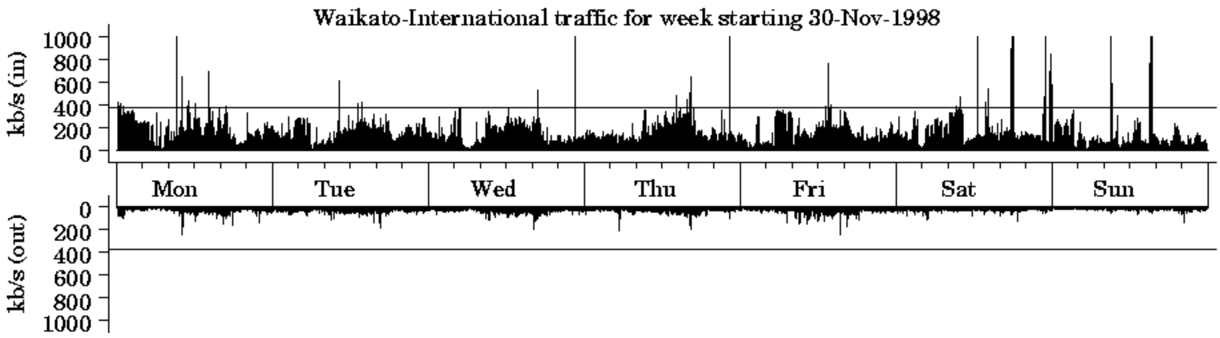

Figure 10a. Inbound traffic rate for Waikato, week starting 30 Nov 98

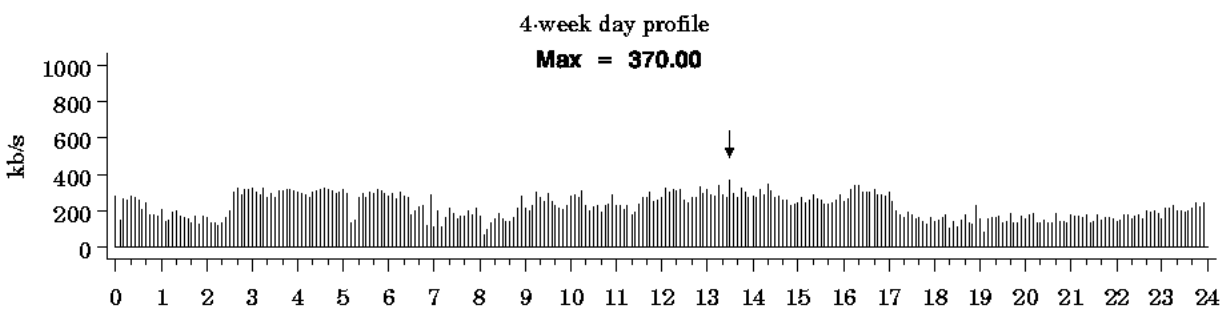

Figure 10b. 3QP for Waikato, after week starting 30 Nov 98. Maximum (3QD) was at 1330