The University of Kansas

Information and Telecommunication Technology Center

Technical Report

AAL2 Transmitter Simulation Study: Revised

Prema Sampath, Raghushankar R. Vatte, and
David W. Petr

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Contents

Abstract

Presently efforts are being to made to standardize the AAL type 2 layer specifications by the ATM forum and the ITU-T. This simulation study is performed to evaluate the performance of the AAL2 transmitter in terms of delay experienced inside the transmitter, percentage overhead incurred and the bandwidth gain achieved using AAL2. The simulations are performed for homogeneous sources only.

1 Overview

The objective of the simulation is to study the different performance metrics of the AAL2 transmitter. The key components of the simulation setup is an on-off source, a segmenter, and the transmitter. The AAL2 transmitter is modeled as a *finite state machine* based on the ITU-T draft specification I.362.3. The parameters associated with the simulation are CPS-Packet size, Number of Users, Voice Bit Rate(depends on the traffic model used), Peak VCC Rate, ATC (ATM Transfer Capability) type (DBR[1] or non-DBR) and Timer_CU setting. The primary characteristics that are measured are the total CPS_Packet delay, delay variation of the CPS_Packet (delay experienced inside the transmitter), AAL2 efficiency, overall Efficiency (AAL2 + ATM efficiency) and bandwidth gain. These measurements are determined for different parameter combinations associated with the voice sources and the transmitter.

2 Introduction

AAL type2 is proposed to be used for bandwidth-efficient transmission of low-rate, short and variable length packets in delay sensitive applications. According to the specifications, more than one AAL2 user stream can be supported on a single ATM connection. As illustrated in Figure 1., AAL type 2 is subdivided into two sub-layers, common part sub-layer (CPS) and service specific convergence sub-layer (SSCS). Different SSCS protocols may be defined to support specific AAL type2 user services, or groups of services. However it may be null, merely providing for the mapping of the equivalent AAL primitives to the AAL type 2 CPS primitives and vice versa. In the simulation performed it is assumed that the SSCS only performs the segmentation and re-assembly function. The packets from the higher layer are passed on to the AAL2 layer where they are segmented into CPS_SDUs of fixed length. This segmentation is done in the SSCS part of the AAL2 layer. Further a header is added to these CPS_SDU's to form the CPS_Packets, in the CPS part of the AAL2 layer. These CPS_Packets are packed into the CPS_PDU of length 47 and which has a 1 byte header (Start Field). The CPS_PDU forms the payload of the ATM Cell. ATM cells must obtain a permit before they can be sent by the AAL2 transmitter.

The rate of permit arrival, the Timer_CU and queuing are the fundamental factors in determining the delay inside the transmitter. In the model developed it is assumed that permit arrival is determined by the peak VCC rate. Simulation is performed for the DBR and Non_DBR type of connection. In this study, we assume that DBR

[1]The Deterministic Bit Rate transfer capability is used by connections that request a static amount of bandwidth that is continuously available during the connection lifetime. This amount of bandwidth is characterized by the peak cell rate value.

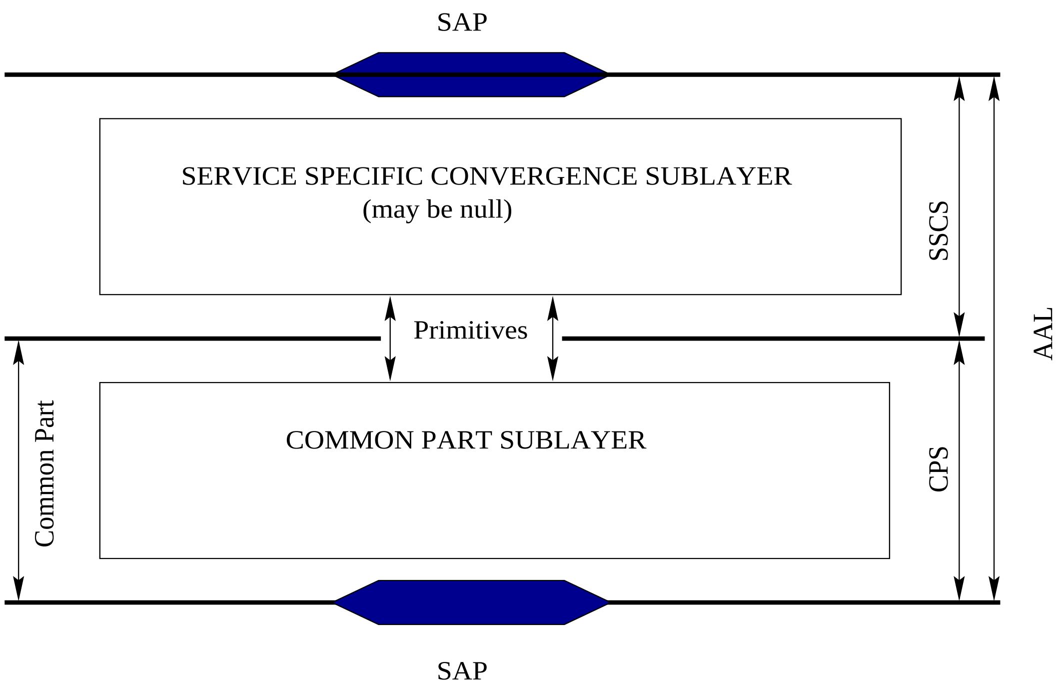

Figure 1: Structure of the AAL type 2 Layer

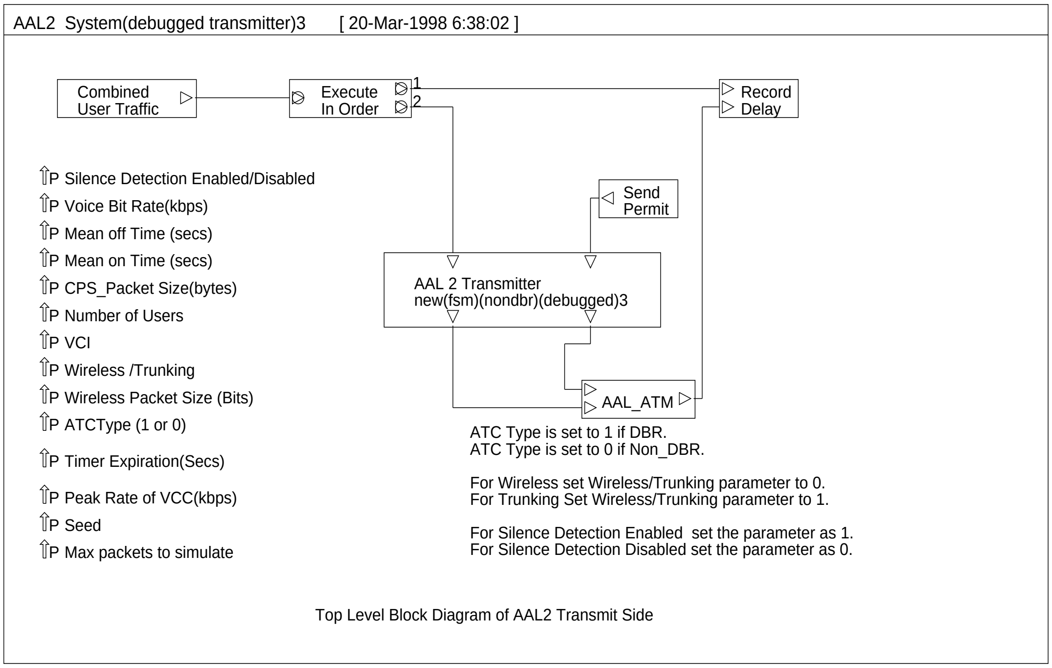

Figure 2: Block Diagram of the AAL2 Simulation Setup

connection generate a continuous cell stream at the peak VCC rate as long as there is any information to be sent (partially filled cells are sent on Permit arrival, but null cells are not sent). In contrast Non_DBR connections do not generate partially filled cells unless the Timer_CU has expired. In the Non_DBR case the delay inside the transmitter is influenced by the value of the Timer_CU setting in addition to the rate of permit arrival and queueing delay. Results obtained by simulating the AAL2 transmitter to evaluate the performance of AAL type 2 layer are presented in section 7.

3 Simulation Strategy

The model for simulating the transmitter side of the AAL2 layer is developed using the software BONeS (Block Oriented Network Simulator). The block diagram of the model is shown in Figure 2. The combined traffic source is associated with the parameter *Number of Users*, which allows one to select the number of users with a granularity of 1 and up to a maximum of 256 users , that are to be multiplexed over a single VC. Permit arrival as mentioned earlier is associated with the peak VCC rate

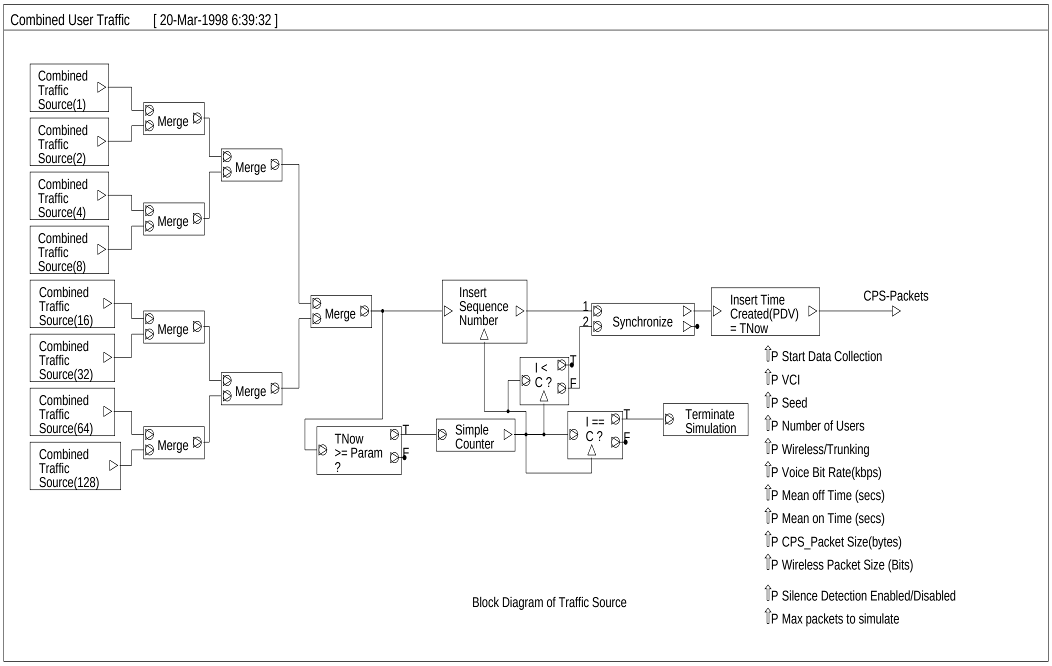

Figure 3: Block Diagram of the Traffic Source

and is independent of any other parameter in the simulation. The combined traffic source and On_Off Source are shown in Figure 3. and Figure 4. respectively. The AAL2 transmitter block is modeled as a finite state machine using the FSM editor utility provided by the software. The state machine is based on the model recommended in the ITU-T draft I.362.3 Feb 97[1]. There are some additional transitions incorporated in the state machine which are purely for ease of implementation. The sources are modeled as on_off sources and have exponential on and off times. If the speech activity factor is less than 100% then the mean on time is set to the speech activity factor (expressed as a proportion), and the mean off time is 1 second minus the mean on time[2]. The initial generation of packets by the sources is randomized as each source has a different seed. If the speech activity is 100% then the source generate a continuous stream of packets which are of the size of CPS_Packet size. In this case the step of segmentation is absent. For implementing the wireless traffic models which have a certain coding rate and packet size (for wireless segment) associated with them, an additional segmenter at the wireless end is incorporated. The packets from the source come out coded at the coding rate particular to the traffic model and are first segmented into the packets of length unique to the traffic model. These packets are now passed through the AAL2 segmenter to be segmented into the

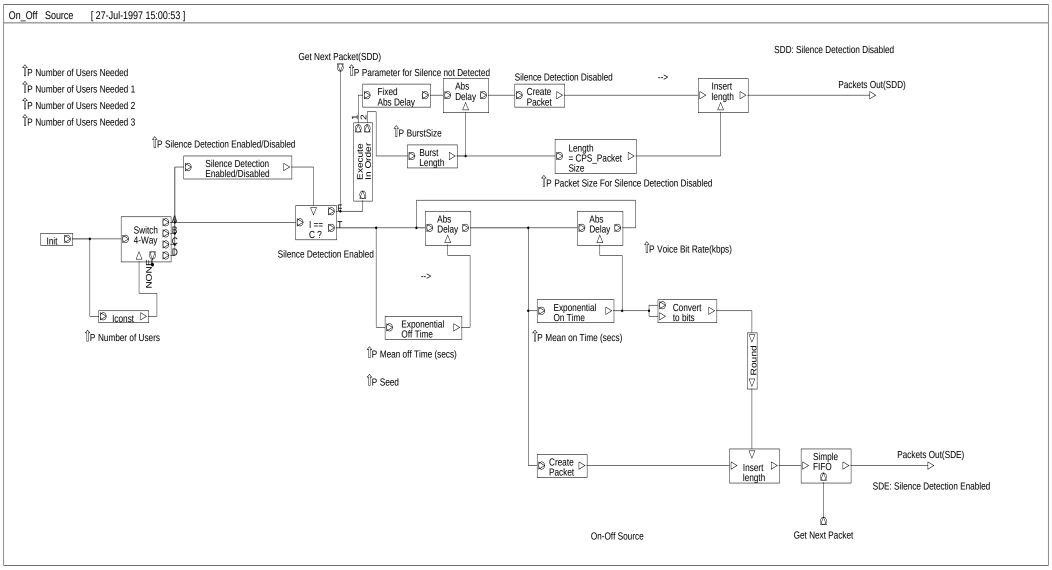

Figure 4: Block Diagram of the On-Off Source

CPS_Packet sizes. This process is illustrated in the block diagram in Figure. 5.

4 Parameters Used in the Simulation

Following is the list of parameters required to be set at the top level of simulation:

1. CPS_Packet Size in bytes
2. Number of Users
3. Voice Bit Rate in kbps
4. Timer Expiration in msecs (if ATC type is Non_DBR)
5. ATC Type (1 if DBR, 0 if Non_DBR)
6. Mean On Time in msecs
7. Mean Off Time in msecs
8. Peak Cell Rate of the VCC in kbps
9. Silence Detection (1 if Yes, 0 if No)

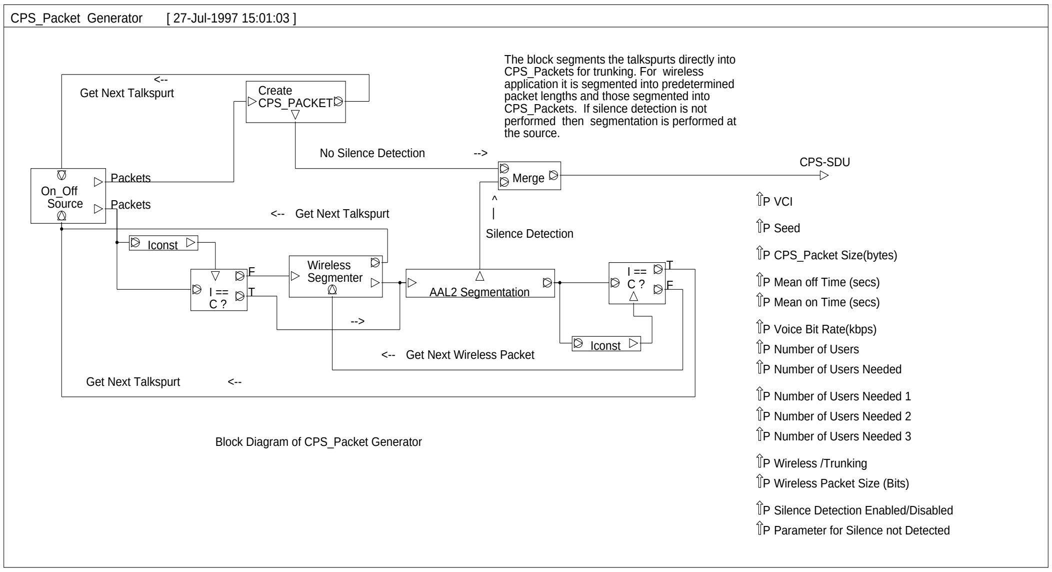

Figure 5: Block Diagram of CPS_Packet Generator

The simulation is performed considering only homogeneous sources. With homogeneous sources it is implied that all sources have the same set of values for the parameters associated with them. The simulation is performed for different combinations of the parameters. (parameter combination are given in section 6 and with the plots).

- CPS_Packet Size (in bytes)
  The CPS_Packet Size is varied according to the other parameters involved in the simulation(as explained in section 6),with a minimum achievable granularity of 1 byte.

- Number of users on the VCC

  - 0-256 (the granularity depends on the simulation, and the maximum granularity achivable is 1 user.)

- Traffic Models (Different bit rates in kbps [3])

  - Wireless Application

    * 4 kbps
    * GSM Full(Data)(9.6kbps)(packet size = 24 octets)
    * GSM full_rate (13kbps)(packet size = 260bits)

    * GSM half_rate (7kbps)(packet size = 140bits)
    * IS-54(VSELP) (7.95kbps) (packet size = 159bits)
    * IS-95(Q-CELP) (8.5kbps)(packet size = 171bits)

  Since for the above mentioned traffic models the packet sizes are fixed, the packets from the source will be initially segmented into the size particular to the traffic model. Then each packet is segmented into CPS_Packet Size set for that simulation run. In this case the additional segmenter is needed. It should be remembered that the maximum size of the CPS_Packet is 64 bytes.

  - Trunking
    * 8 kbps
    * 16 kbps
    * 24 kbps
    * 32 kbps

- Timer settings (in ms)

  The significance of this parameter depends on the ATC type. If the ATC type is of the type DBR then the timer is not significant, as the delay experienced inside the transmitter is not affected by the value of the timer setting. In that case the principal factor that governs the AAL2 transmitter delay is the permit arrival rate. If ATC type is Non_ DBR, then simulations are run for different values of timer setting. The timer value determines the approximate upper bound on the delay experienced by the CPS_Packets inside the transmitter. The timer values were determined based on some preliminary simulations. Following are the values of the timer settings usually used in the simulation(see section 6 for more details):

  - 125μ secs
  - 250μ secs
  - 500μ secs
  - 1 msecs
  - 2 msecs
  - 3 msecs
  - 4 msecs

  - 5 msecs
  - 6 msecs

- Peak Cell Rate

  Following are the values for which simulation was performed:

  - 384 kbps (H0 rate)
  - 768 kbps
  - 1.536 Mbps (T1 or H11 rate)
  - 1.92 Mbps (E1 or H12 rate)
  - 40.7 Mbps (DS-3 rate)

- With 42% speech activity and without silence removal

  The simulation is performed with 42% speech activity rate. The mean speech talk spurt and silence lengths for 42% speech activity is considered to be 420 ms and 580 ms respectively.

- Peak Cell Rate on VCC

  This parameter will directly determine at what rate the permit arrives. If the peak cell rate is p kbps, then the permit inter-arrival time is given by,

$$\frac{8 * 53}{p}\ ms \tag{1}$$

For example, when the peak rate of the VCC is assumed 1.536 Mbps, this results in generation of a permit every 0.276 ms. The load on the VCC is maintained below 100%. For example assuming 42% speech activity, R kbps coding, and accounting for ATM and AAL2 overhead, the number of users n must satisfy:

$$n * R * 0.42 * ((CPS\_Packetsize + 3)/CPS\_Packetsize) * (53/47) \ < p \tag{2}$$

Say given the above data, the peak VCC rate is 1536 kbps, the coding rate(bit rate) is 32 Kbps ,CPS_Packet size is 12 bytes then the maximum number of users that can be accomodated on a single VC after accounting for the ATM and AAL2 overhead is,

$$n * 32 * 0.42 * (15/12) * (53/47) \ = 1536 \tag{3}$$

This implies that parameter *Number of Users* can be varied only upto 81, when the value for coding rate is 32 kbps ,CPS_Packet size is 12 bytes and peak VCC rate is 1536 kbps.

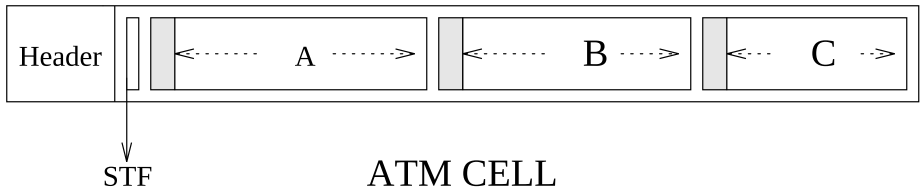

Figure 6: Illustration of an ATM Cell filled with CPS_Packets

5 Performance Measurements and Calculations

- AAL2 Efficiency

AAL2 efficiency [2] can be calculated as follows:

$$\%AAL2\ efficiency\ = (A + B + C)/48 \tag{4}$$

where A, B and C are the payload bytes of the CPS_Packets, i.e leaving out the overhead bytes. This is for the case when there are 3 CPS_Packets in the ATM cell. It should be noted that here A could be a piece of the CPS_Packet that has overflowed from the previous cell and C could be a piece that will overflow into the next cell. Figure 6. illustrates a typical ATM cell with payload bytes of A, B and C.
To calculate the utilization, in the simulation model a variable called *tot bytes* has been defined. It is set to the useful number of bytes in the payload. It is used to the calculate the AAL2 efficiency as below:

$$\%AAL2\ efficiency\ = \frac{Mean\ (tot\ bytes)}{48} * 100 \tag{5}$$

where, *tot bytes* refers to the total CPS_Packet bytes in the ATM Cell.
An upper bound (excluding STF overhead) for AAL2 efficiency is:

$$\%MaximumAAL2\ efficiency\ = \frac{CPS\_PacketSize}{CPS\_PacketSize + 3} * 100 \tag{6}$$

For a CPs_Packet size of 12 bytes, this upper bound is 80%.

- AAL2 + ATM Efficiency

[2]Referred in ATM-f/96-1134 pg 3 as Average Payload Rate

AAL2 + ATM efficiency[3] can be defined as the ratio of number of useful bits transmitted to the number of bits transmitted.

$$\%AAL2 \ + \ ATM \ efficiency \ = \ \frac{D}{D+H} \tag{7}$$

where the D is number of useful bits and H is number of overhead bits for both ATM and AAL2 layers.

In the simulation AAL 2 + ATM Efficiency (η) is calculated as below:

$$\%\eta \ = \ \frac{Mean\ (tot\ bytes)}{53} * 100 \tag{8}$$

The maximum possible AAL2 + ATM efficiency with CSP_Packet size of 12 Bytes is,

$$\%\eta \ = \ \frac{12}{15} * \frac{47}{53} * 100 \ = \ 70.9 \tag{9}$$

Alternatively bandwidth efficiency could also be expressed in terms of the overhead penalty per ATM cell basis as in one of the previous ATM Forum[4] documents.

- Total CPS_Packet Delay

  Total delay experienced by the CPS_Packet is sum of packetization(segmentation) delay and delay inside the transmitter. The simulation model takes into account the *AAL2 delay* while the previous contributions[4][5] have taken only packetization delay into account.

- Packet Delay Variation

  Packet delay variation is the delay experienced inside the transmitter. This is calculated by subtracting a reference delay from the delay measured at the probe at the output port of the transmitter. The reference delay in this case would be equal to zero, assuming the ATC type is DBR and the permit is available immediately. The delay variation is due to the time taken for the permit arrival, queueing delay, and in case the ATC type is Non_DBR, additional delay due to the presence of the timer.

[3] Also referred as bandwidth efficiency in ATM-f/96-1566
[4] ATM-f/96-1330

- Bandwidth Gain

  Bandwidth gain can be calculated relative to several different alternatives, including the following: 64 kbps TDM, 64 kbps AAL1, 64 kbps AAL5, AAL 1 with no rate conversion and AAL5 with no rate conversion. For AAL1 and AAL5 different packetization delays can be compared. For example, the gain relative to 64 kbps TDM is,

$$Bandwidth\ gain\ = \frac{K\ * 64kbps}{Measured\ bit\ rate\ for\ K\ Users\ with\ AAL2} \tag{10}$$

The above equation is equivalent to,

$$Bandwidth\ gain\ = \frac{(Coding\ gain\ ) *\ (AAL2\ +\ ATM\ Efficiency\ )}{Speech\ Activity\ Factor} \tag{11}$$

The above equation is used to verify the results obtained from simulations. For example, if the voice bit rate is 8 kbps, speech activity factor is 42% and the AAL2 + ATM efficiency is 50%, then the theoretical value for the bandwidth gain can be approximately calculated using the eqn.11 as below,

$$Bandwidth\ gain\ = \frac{64}{8}\ * 0.5 = 4 \tag{12}$$

For 64 kbps AAL1,

$$Bandwidth\ gain\ = \frac{K\ * 64kbps * (53/47)}{Measured\ bit\ rate\ for\ K\ Users\ with\ AAL2} \tag{13}$$

For 64 kbps AAL5,

$$Bandwidth\ gain\ = \frac{K\ * 64kbps * ((Packet\ Size\ + 8)/48) * (53/48)}{Measured\ bit\ rate\ for\ K\ Users\ with\ AAL2} \tag{14}$$

In the results section, bandwidth gain is shown relative to 64 kbps TDM (eqn. 10).

6 Parameter Combinations

A fixed value for each of the parameters is defined, and this set of values constitute the *baseline combination.* To start with, in any simulation run only one parameter is varied at a time, while fixing the other parameters to their baseline value.

Baseline values of each of the parameters[5] are given below:

[5]Unless and otherwise mentioned the values of parameters are set to be their baseline values.

- CPS_Packet Size = 12 octets
- Number of users = 64
- Bit Rate = 8 kbps
- Timer Setting = 3 ms
- Peak Cell Rate = 1536 kbps

Simulation is run for the following parameter variations:

1. *Different CPS_Packet sizes* and other parameters fixed at baseline values given above.
2. *Different Number of users* and other parameters fixed at baseline values given above.
3. *Different Bit Rates*[6] and other parameters fixed at baseline values given above.
4. *Different timer settings* (if non_DBR) and other parameters fixed at baseline values given above.
5. *Different Peak Cell Rates* and other parameters are fixed at baseline values given above.
6. Above is repeated for speech activity 42% and for the case of *no silence removal.*

For the above mentioned parameter combinations, measurements of total delay, packet delay variation, AAL2 efficiency, AAL2 + ATM efficiency, bandwidth gain is done. The above parameter combinations could be extended for the case when multiple parameters are changed. This would be the next phase of simulation.

7 Results and Discussion

The simulation duration is time taken to record data for 15,000 CPS_Packets. The results obtained from simulation are shown in Figures. 7 through 52. Each of plot contains 2 curves, one 42% speech activity and the other for 100% speech activity. There are two sets of plots one for the ATC type DBR and other for the Non_DBR.

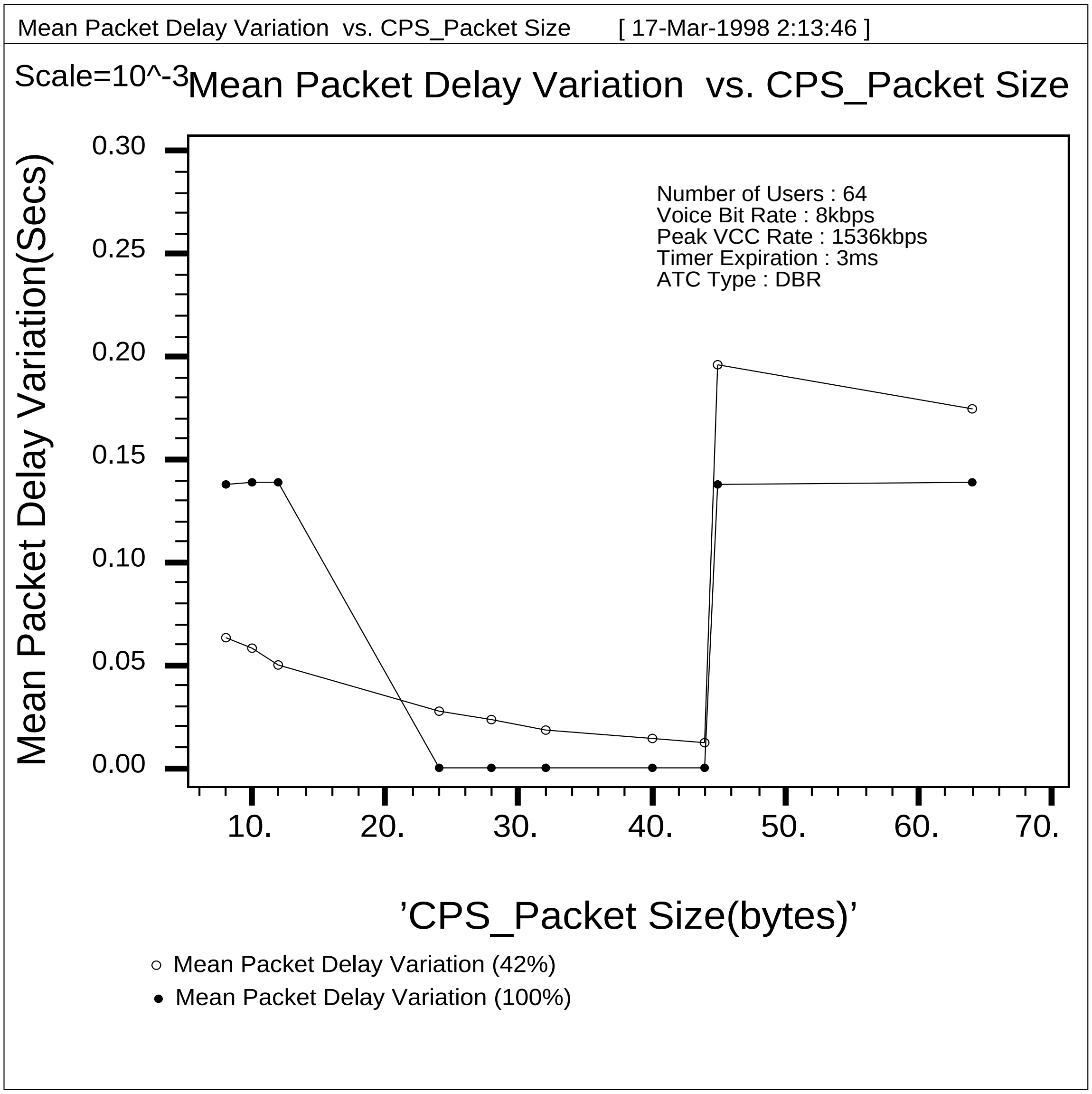

Figure 7: Mean Packet Delay Variation vs. CPS_Packet Size : DBR

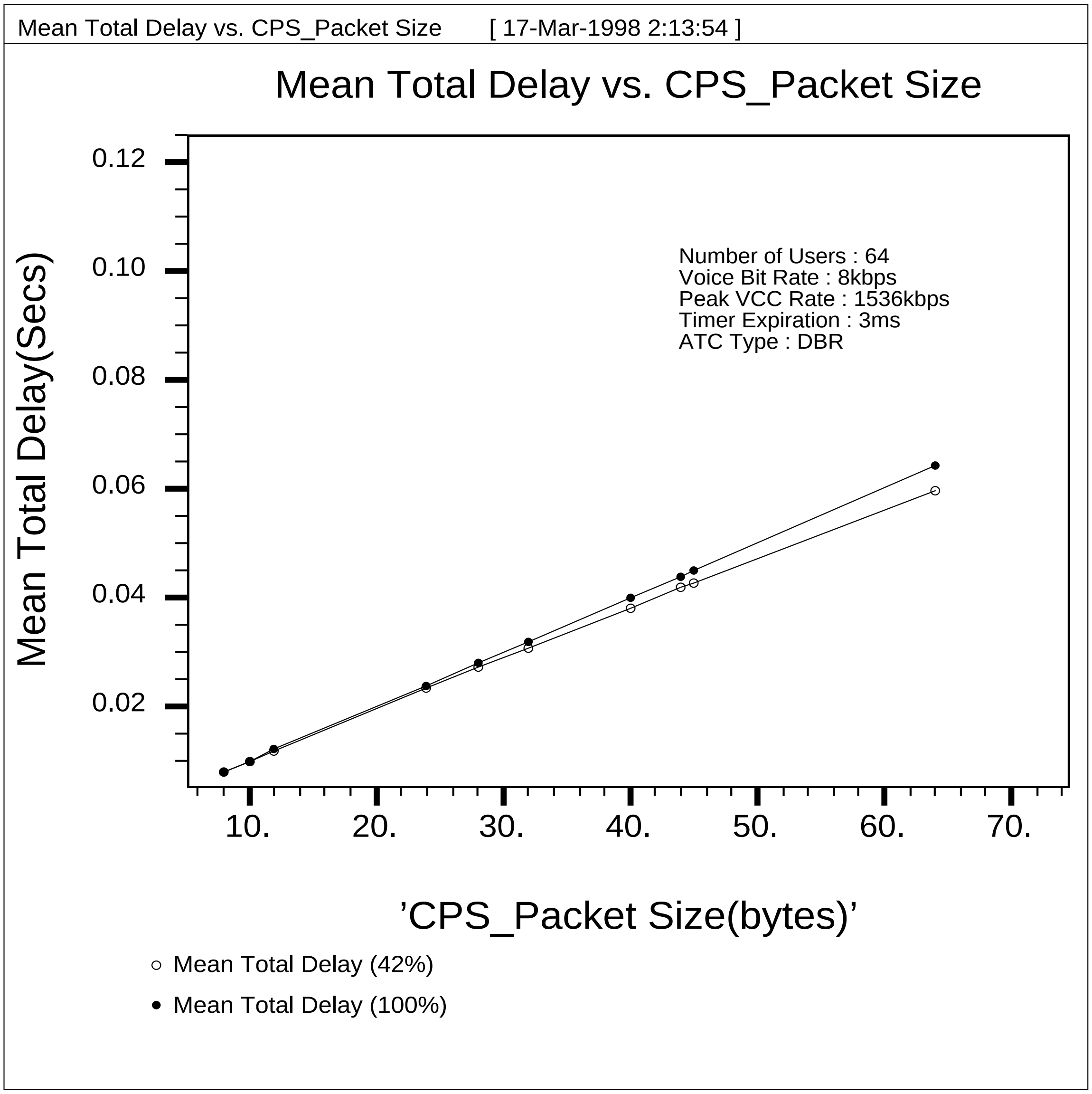

Figure 8: Mean Total Delay vs. CPS_Packet Size : DBR

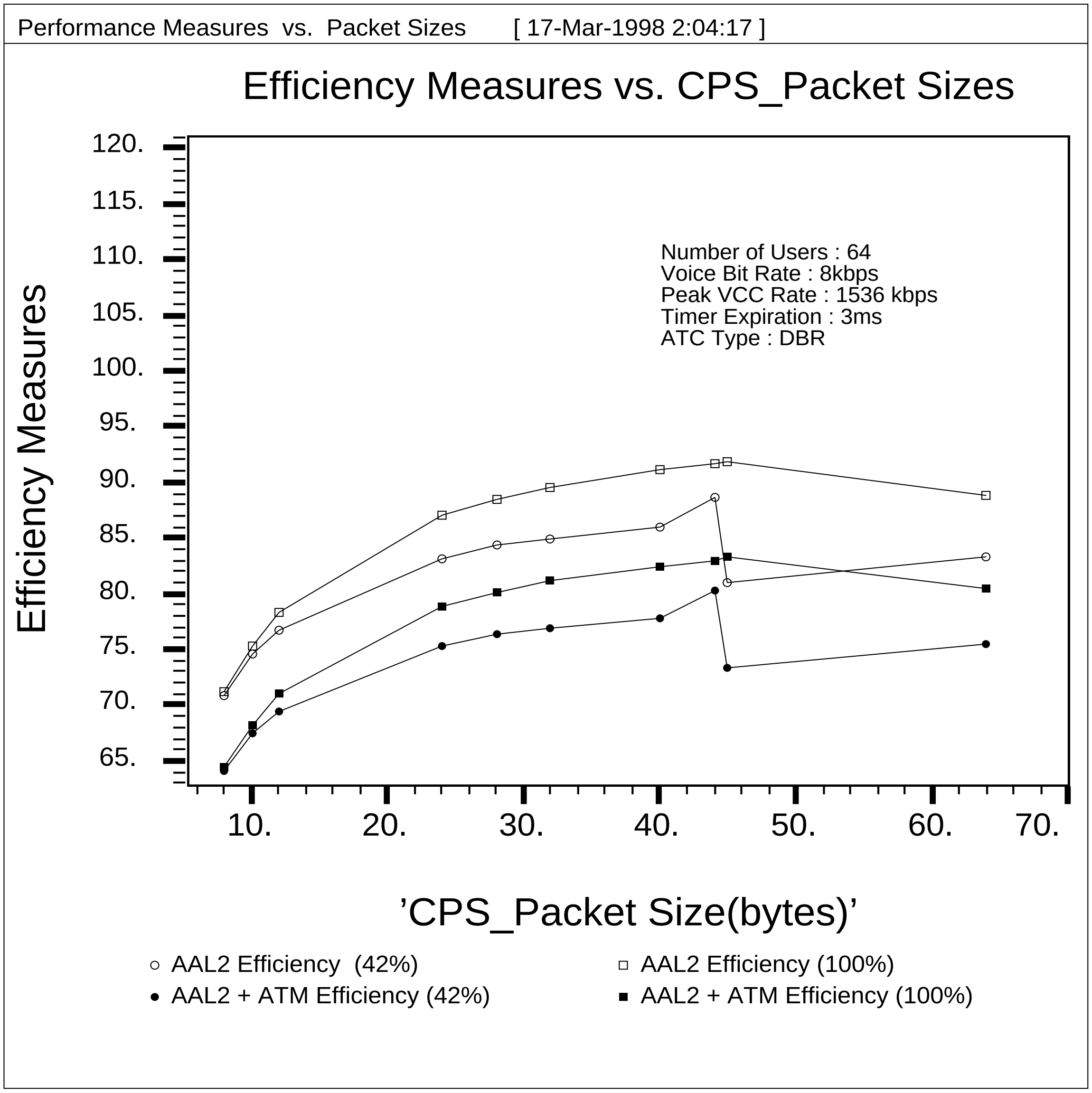

Figure 9: Efficiency Measures vs. CPS_Packet Size : DBR

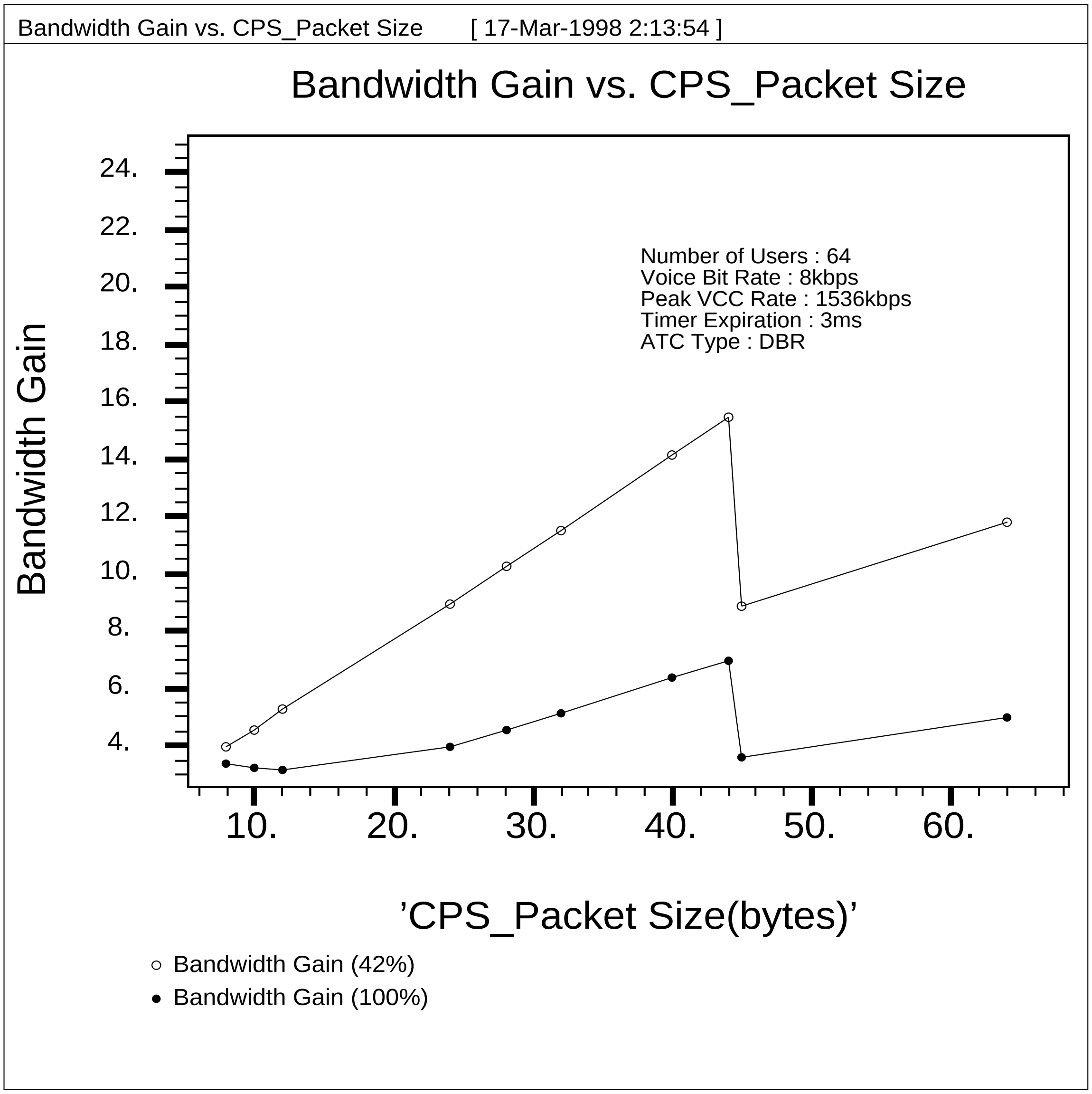

Figure 10: Bandwidth Gain vs. CPS_Packet Size : DBR

7.1 Plot for Different CPS_Packet Sizes

Figures. 7 through 14 show the performance characteristics obtained by varying the CPS_Packet sizes. Figures. 7 through 10 are for the ATC type DBR and 11 through 14 are for Non_DBR case.

In this section, the approximate VC load was 19.8% for 42% and 46.9% for 100% speech activity, so that queueing was not a significant factor. For the ATC type DBR, as the CPS_Packet size is increased, the mean total delay (Figure 8.) increases because the packetization delay increases while mean packet delay variation (PDV) (Figure 7.) decreases because the ATM cell is filled up faster when the packet sizes are larger. This trend continues until the CPS_Packet size reaches 44. For CPS_Packet sizes greater than 44 bytes, since the CPS_Packet overflows into the next ATM cell, the PDV goes up as 2 ATM cells have to be sent to send the CPS_Packet. The increase in the delay is approximately equal to the 1 permit inter-arrival time, which is approximately equal to 0.276 ms. As the CPS_Packet size is increased the AAL2 and AAL2 + ATM efficiencies go up and approach their upper bounds (80% and 71%) for the speech activity factor 100%. However the efficiency dips when the CPS_Packet overflows into the next ATM cell. The efficiency is the lowest for the CPS_Packet size of 45 since it would cause just 1 byte to spill into the next cell, thus resulting in the worst efficiency possible for the second cell. Efficiencies improve as the CPS_Packet sizes increase from 45 to 64, as the second ATM cell with the spilled-over CPS_Packet is increasingly more filled up. The bandwidth gain follows the same trend as that of the efficiency. The efficiency achieved with silence removal is around 20% lower than the case of no silence removal with smaller CPS_Packet sizes and around 10% with larger CPS_Packet sizes, since some CPS_Packets are smaller than the CPS_Packet size when silence removal is used.

For the Non_DBR case the mean total delay (Figure 12.) increases as the CPS_Packet size is increased because of the reason that the packetization delay dominates the value as compared to the PDV. PDV increases as the CPS_Packet size increases because of the result of frequent spill-overs into the next ATM Cell. AAL2 and AAL2 + ATM efficiency increase with the increase in the size of the CPS_Packet. Maximum possible efficiencies are nearly achieved in this case. For example, as mentioned earlier the maximum possible AAL2 + ATM efficiency with a 12 byte CPS_Packet is 70.9%, and it can be observed from the plot efficiency close to the theoretical value is achieved. Similarly maximum possible efficiency for other CPS_Packet sizes is calculated and verified. Bandwidth gain is relatively unaffected by the CPS_Packet size, since the efficiencies are all relatively large.

For speech activity factor of 100% the PDV values are slightly lower than the case of 42% speech activity factor because there are no large gaps (silence) between

[6] Only for traffic models which do not assume silence removal by default.

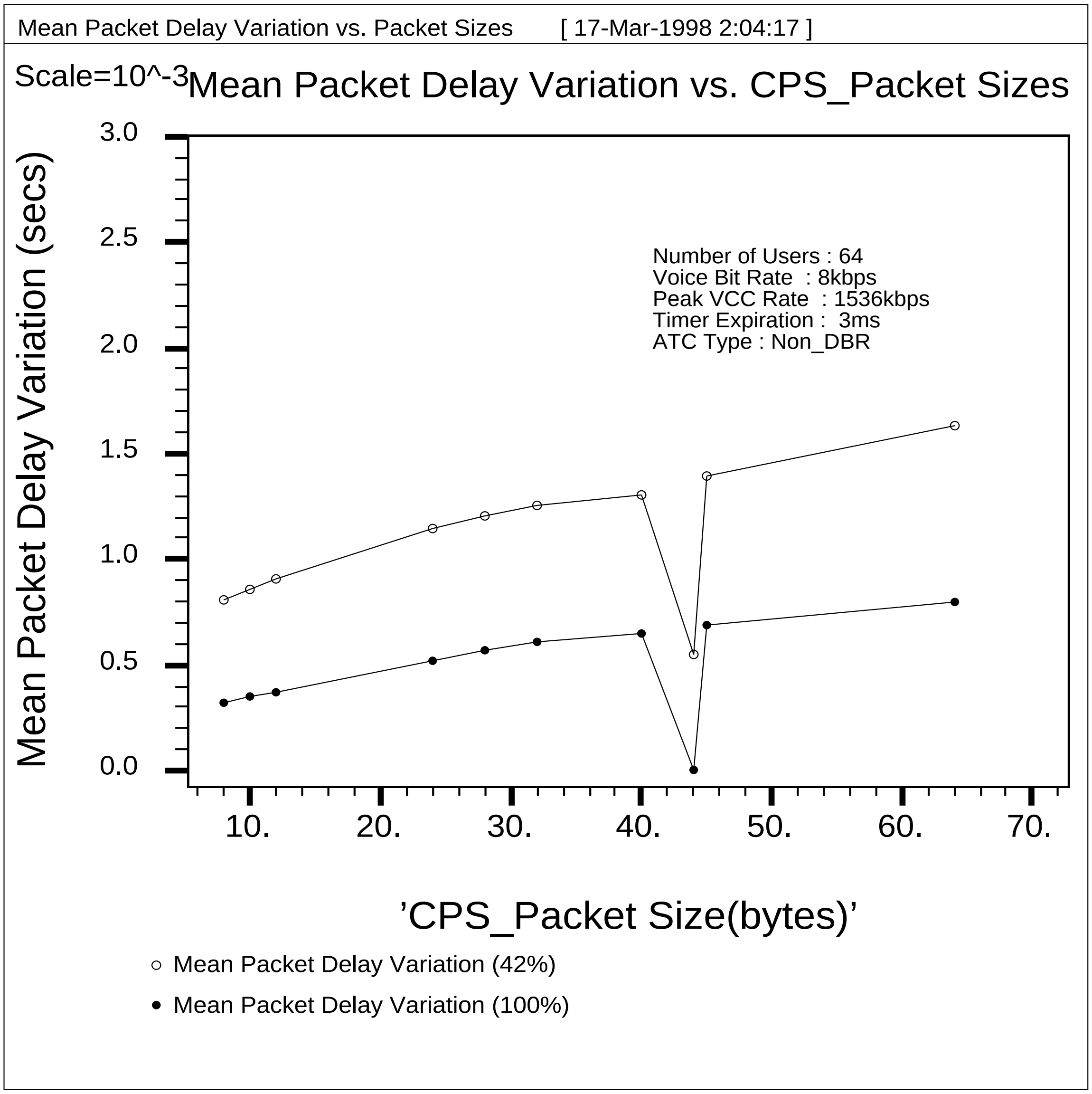

Figure 11: Mean Packet Delay Variation vs. CPS_Packet Size : Non_DBR

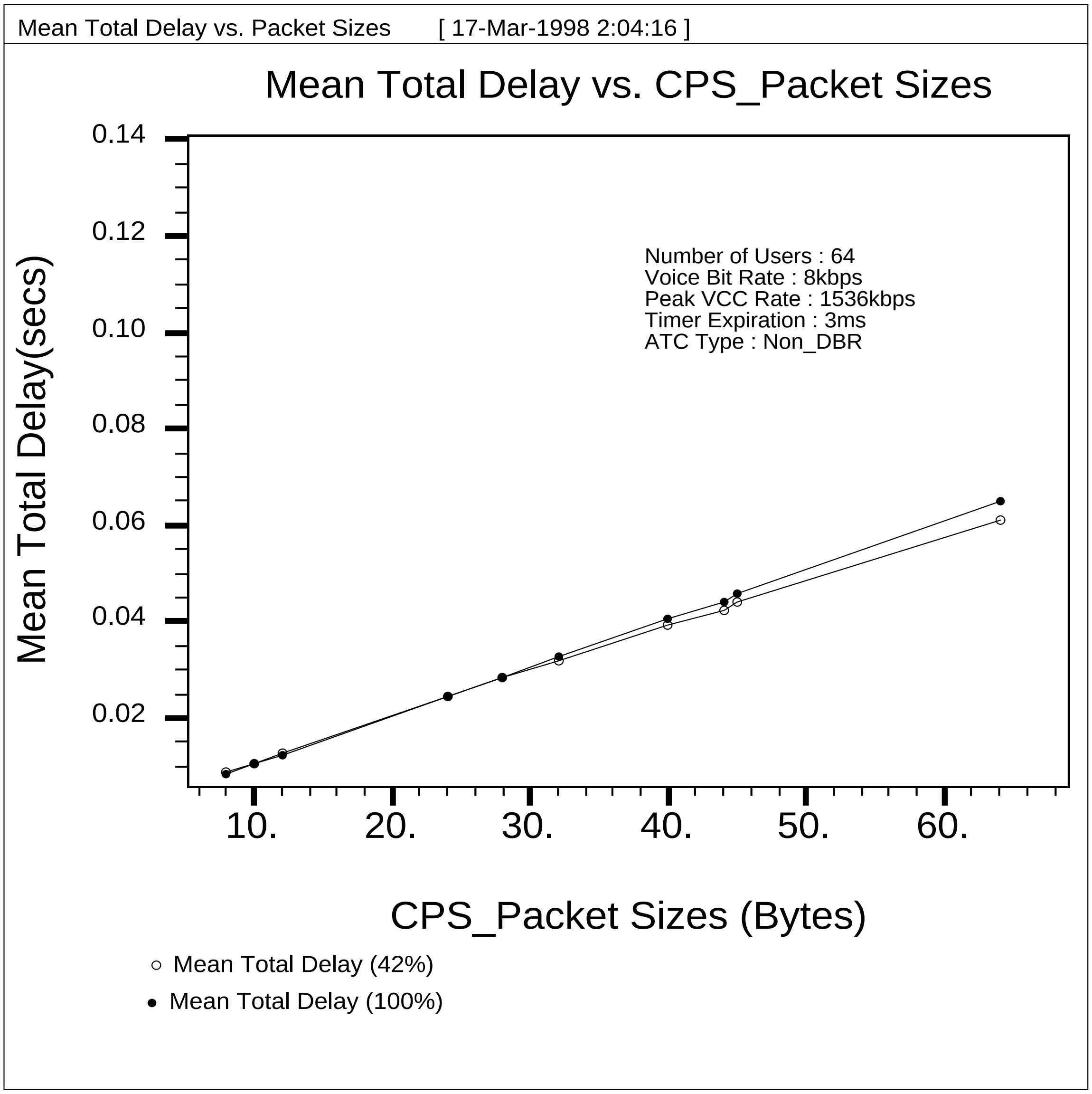

Figure 12: Mean Total Delay vs. CPS_Packet Size :Non_DBR

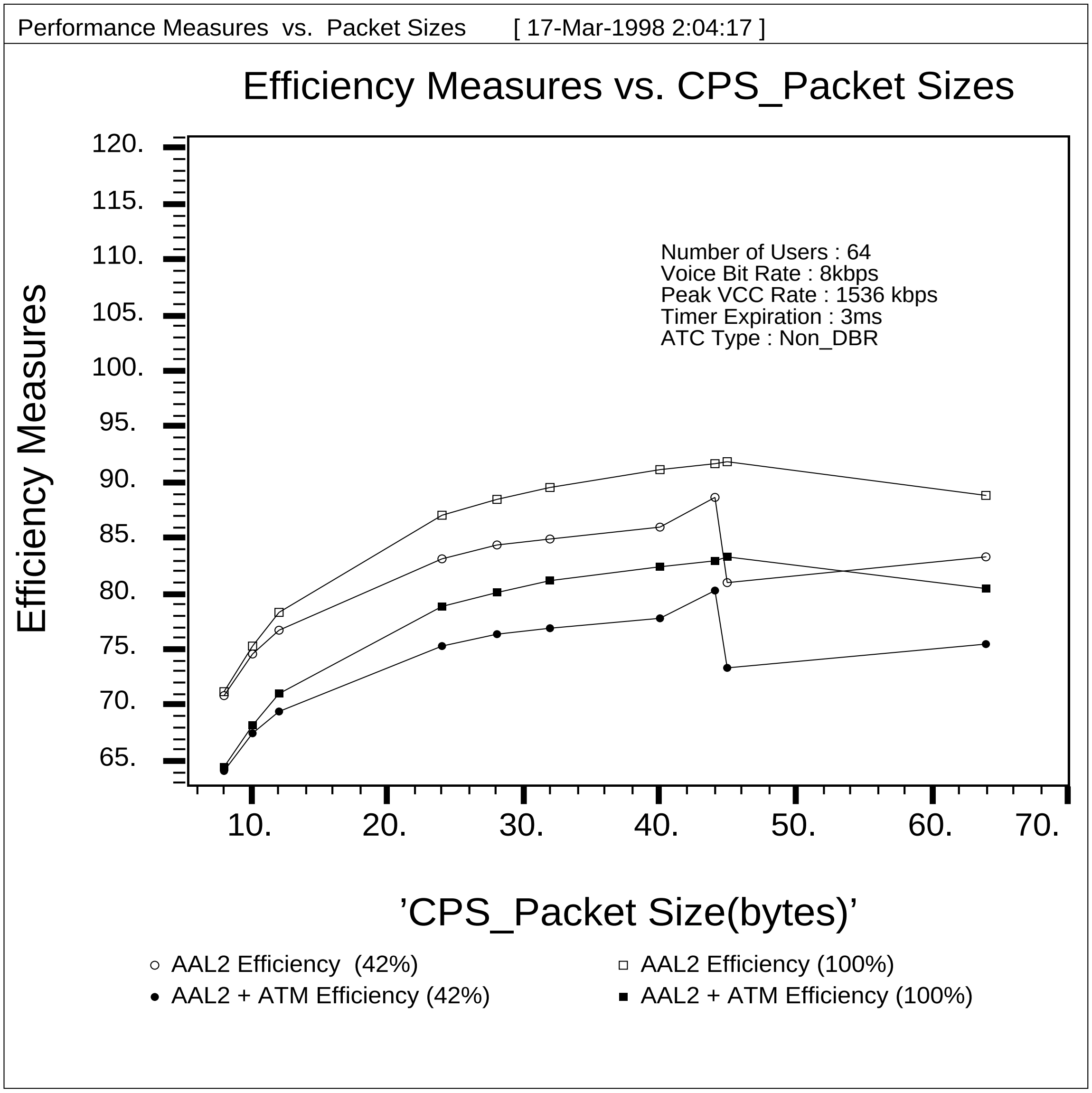

Figure 13: Efficiency Measures vs. CPS_Packet Size : Non_DBR

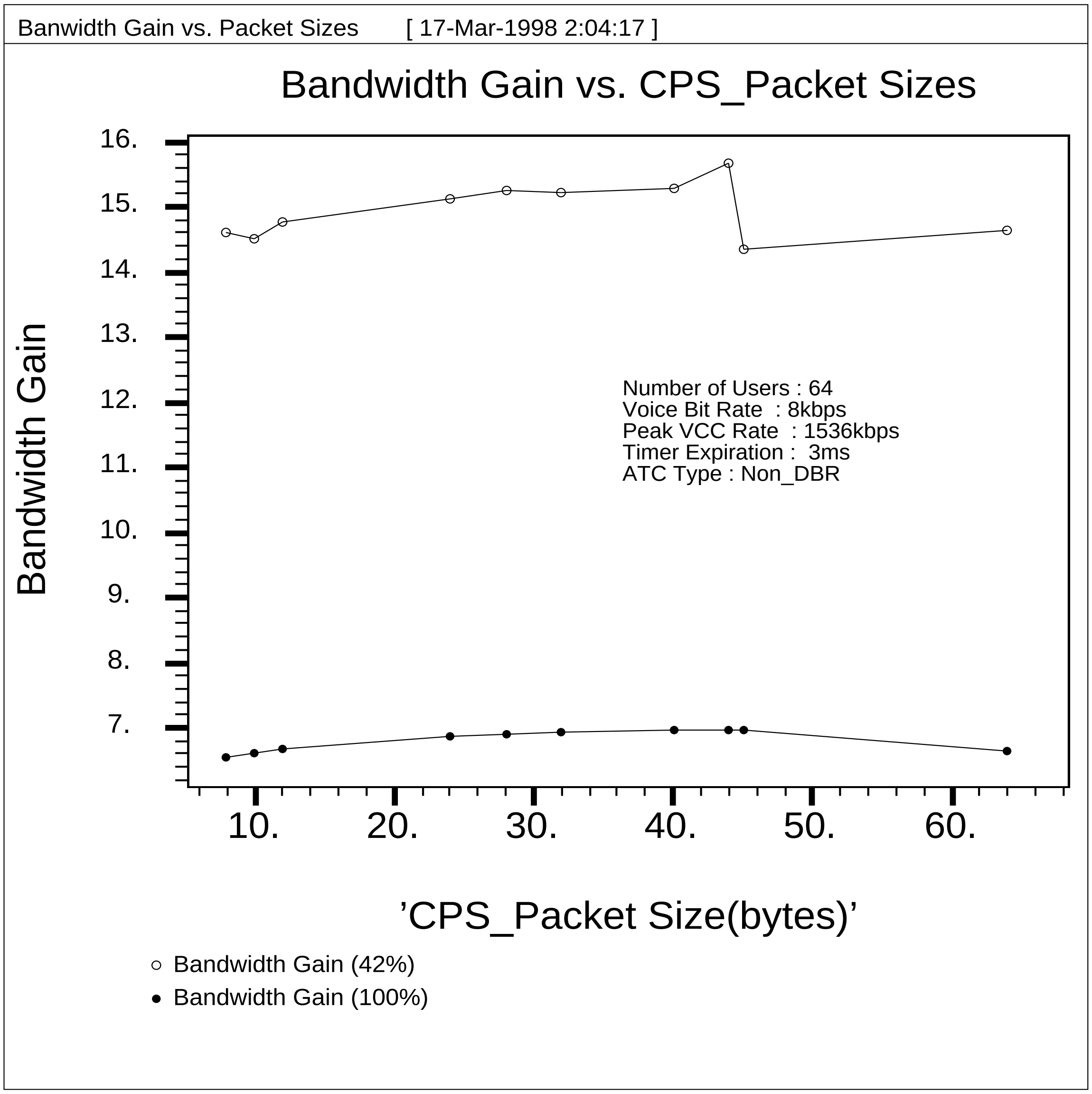

Figure 14: Bandwidth Gain vs. CPS_Packet Size : Non_DBR

packets, while the mean total delay values are almost the same. As one can expect, the bandwidth gain is higher for silence removal as compared to no silence removal case. As expected, ATC Type Non_DBR has higher delays relative to DBR, but also higher efficiencies and bandwidth gain.

7.2 Plots for Different Numbers of Users

Figures. 15 through 22 show the performance characteristics when the number of users on the AAL2 connection is varied. Figures. 15 through 18 illustrate the characteristics for ATC type DBR while Figures. 19 through 22 are for the Non_DBR case.
For the DBR case, as the number of users is increased the delay experienced inside the transmitter increases since queueing has a significant effect as the total load on the VC is increased (Figure 15.). PDV increases with silence removal, but only for the case larger number of users, while it is the same as the case of 42% speech activity for smaller number of users. The AAL2 and AAL2 + ATM efficiencies increase as the number of users increase as there are packets available more frequently to fill up the ATM cells. As expected it can be seen that efficiency values are higher when speech activity factor is 100% compared to 42%. AAL2 efficiency close to maximum possible efficiency (80% with 12 Byte CPS_Packets) is achieved for the case of silence removal. Bandwidth Gain increases with the increase in the number of users.

In the Non_DBR case, the PDV decreases initially and then increases with the increases in number of users (Figure 19.). The initial decrease is because CPS_packets arrive more frequently with more number of users, while the later increase is due to the effect of queuing which becomes significant with very larger number of users. The AAL2 and AAL2 + ATM efficiencies (Figure 21.) increase steeply with increase in number of users and reach the maximum value possible i.e 80% and 70.9% respectively. As the speech activity factor is increased fewer number of users are required to achieve the maximum efficiency attainable. As expected, bandwidth gain (Figures 18. and 22.) increases with increase in the number of users and is lower for 100% speech activity, irrespective of the ATC type.

Again all the corresponding values of delay, efficiency and bandwidth gain are higher for the Non_DBR as compared to that of DBR.

7.3 Plots for Different Voice Bit Rates (Trunking)

Figures. 23 through 30 show the performance characteristics when the voice bit rate is varied for trunking application. Figures. 23 through 26 are for the ATC type DBR and Figures. 27 through 30 are for Non_DBR case. As the voice bit rate is increased the packetization delay is decreased therefore mean total delay (Figures 24. and 28.) decreases as the voice bit rate increases irrespective of the ATC type. However, the

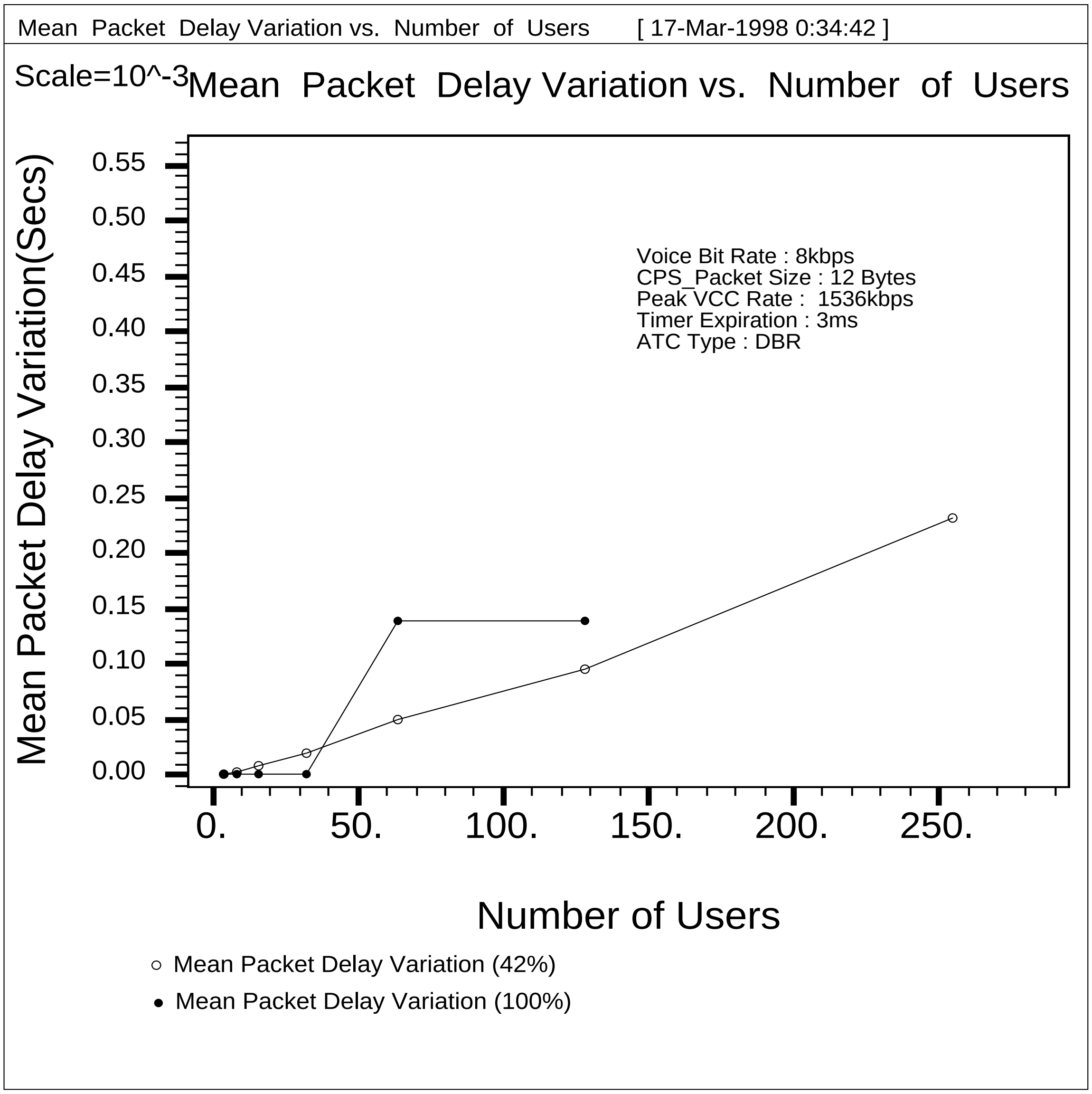

Figure 15: Mean Packet Delay Variation vs. Number of Users : DBR

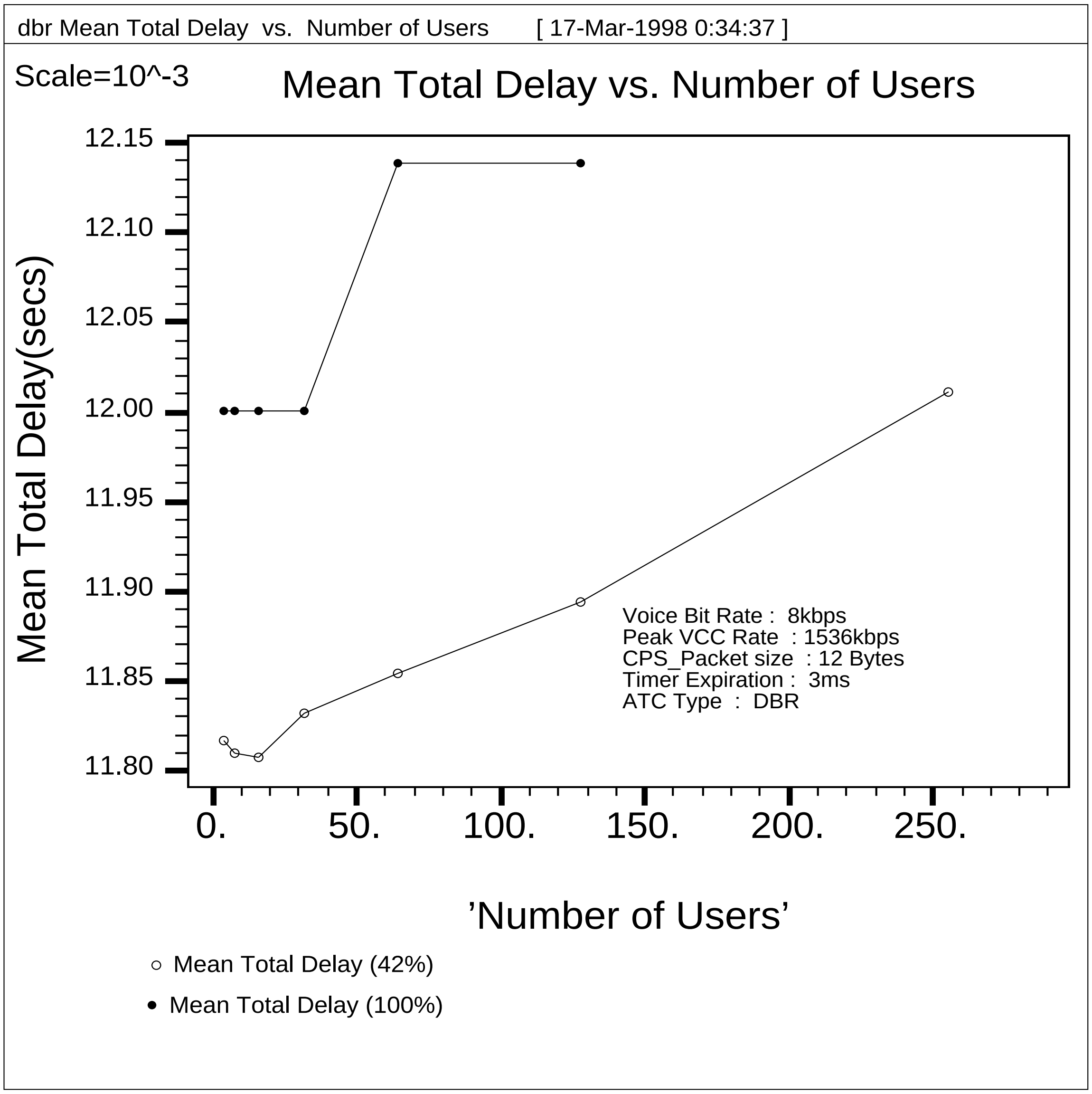

Figure 16: Mean Total Delay vs. Number of Users : DBR

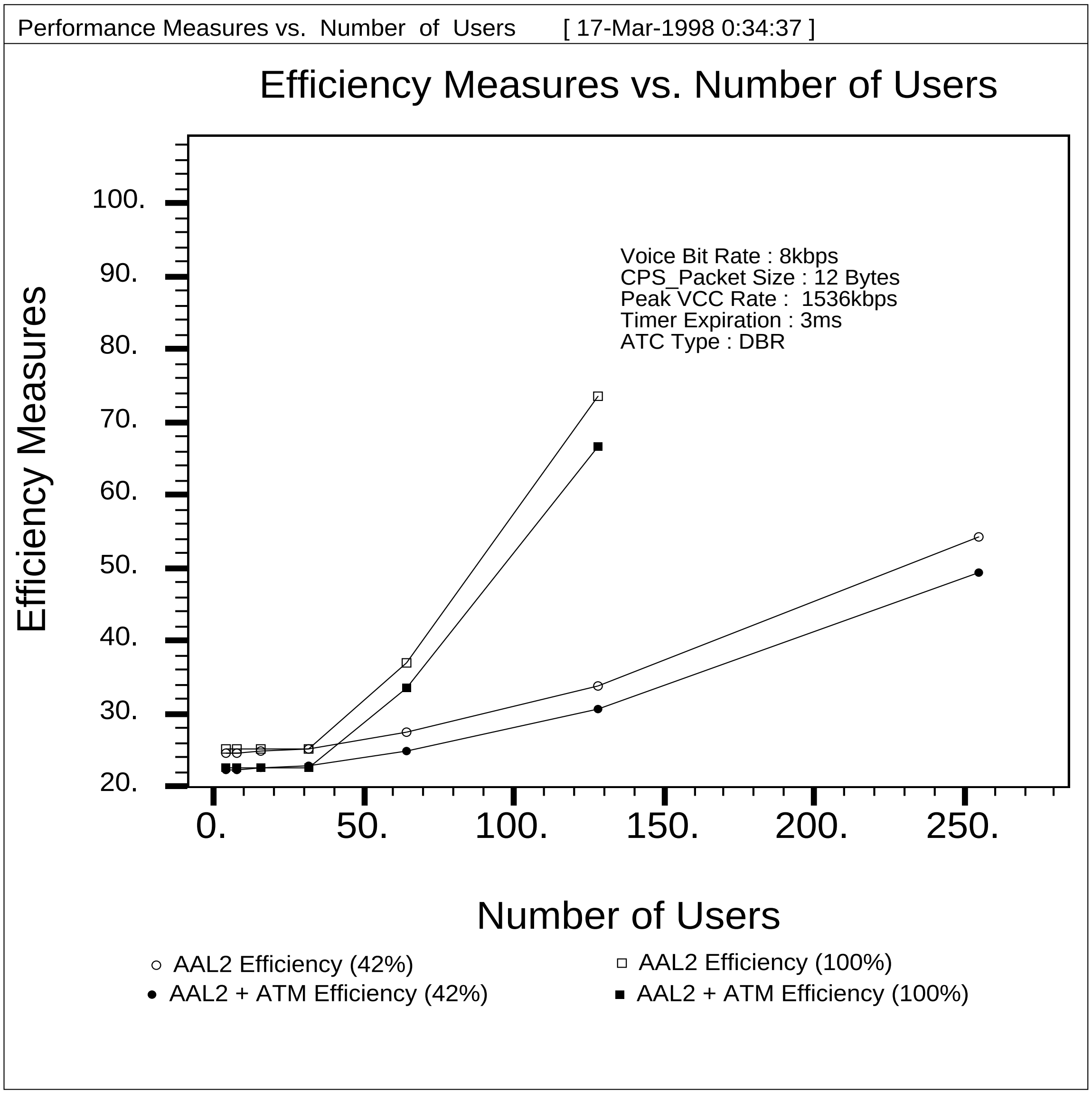

Figure 17: Efficiency Measures vs. Number of Users : DBR

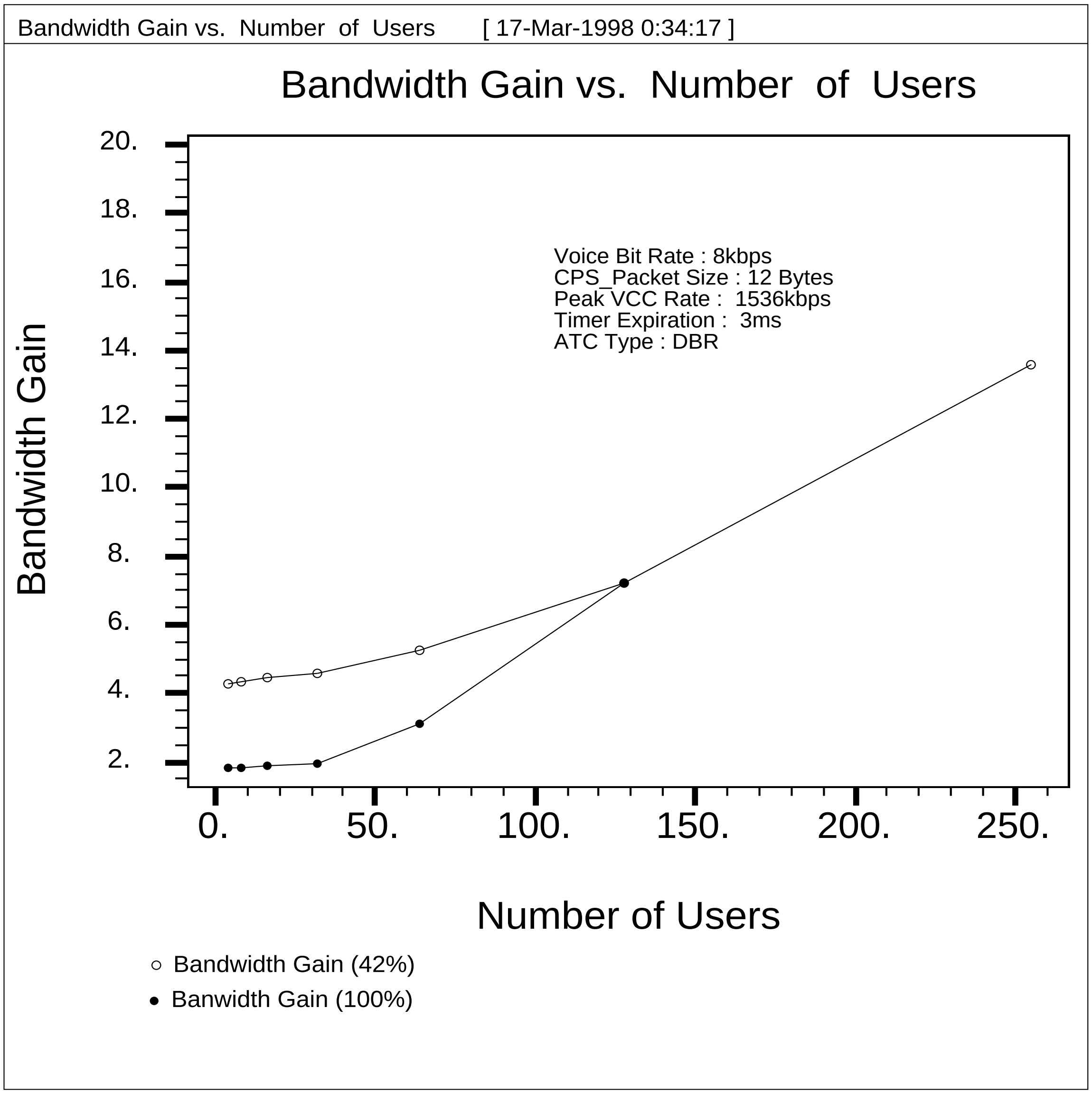

Figure 18: Bandwidth Gain vs. Number of Users : DBR

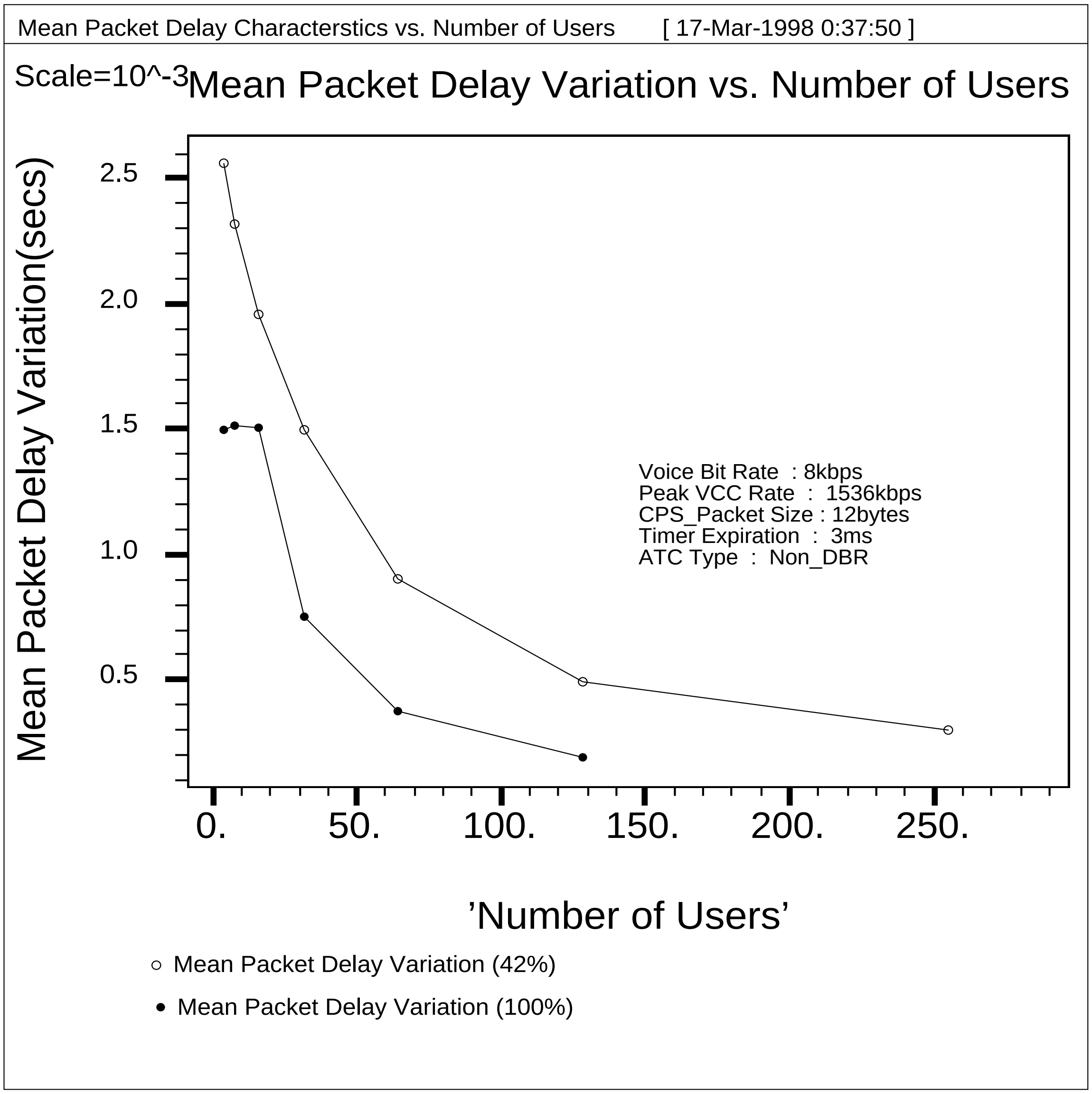

Figure 19: Mean Packet Delay Variation vs. Number of Users : Non_DBR

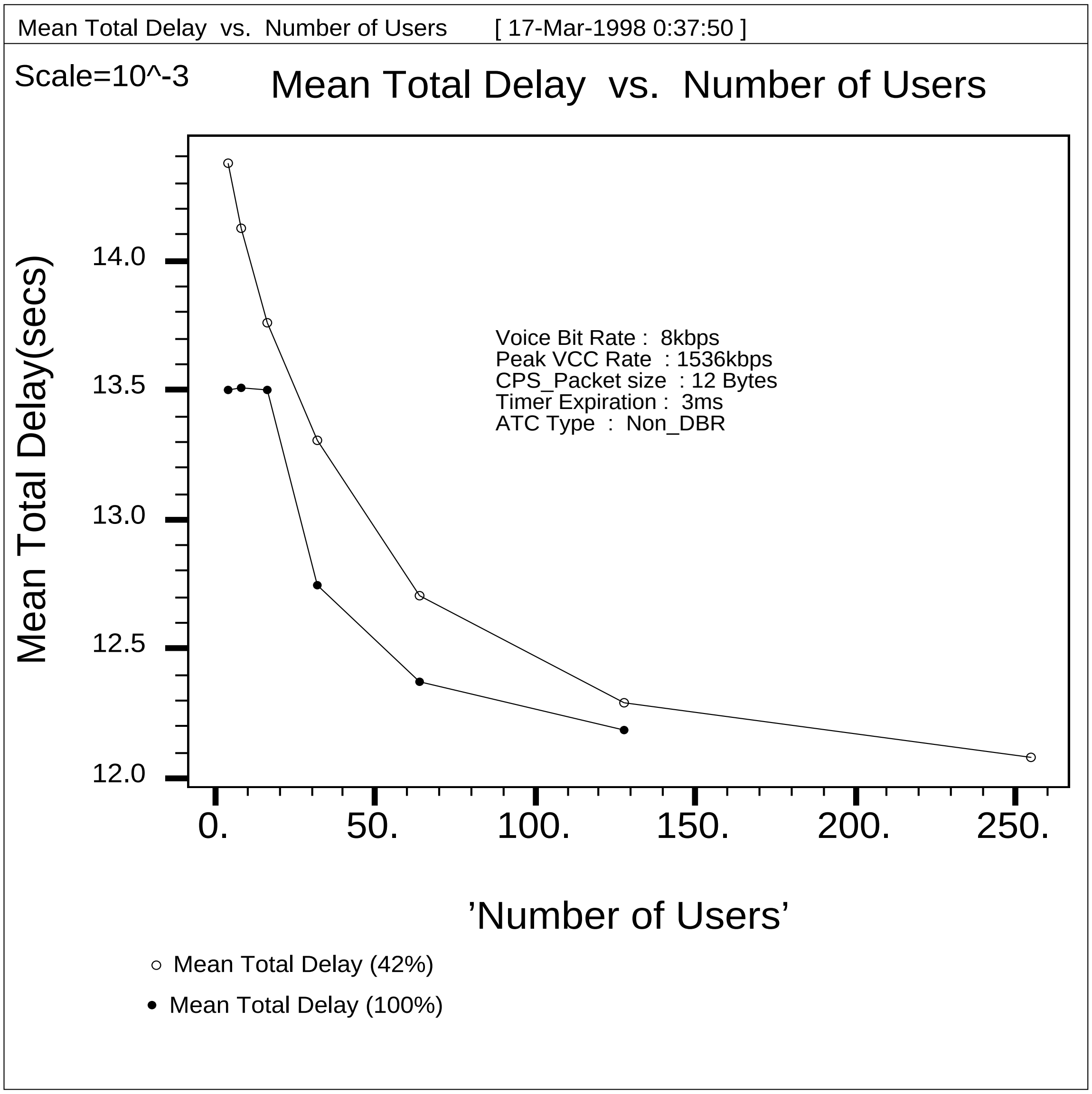

Figure 20: Mean Total Delay vs. Number of Users : Non_DBR

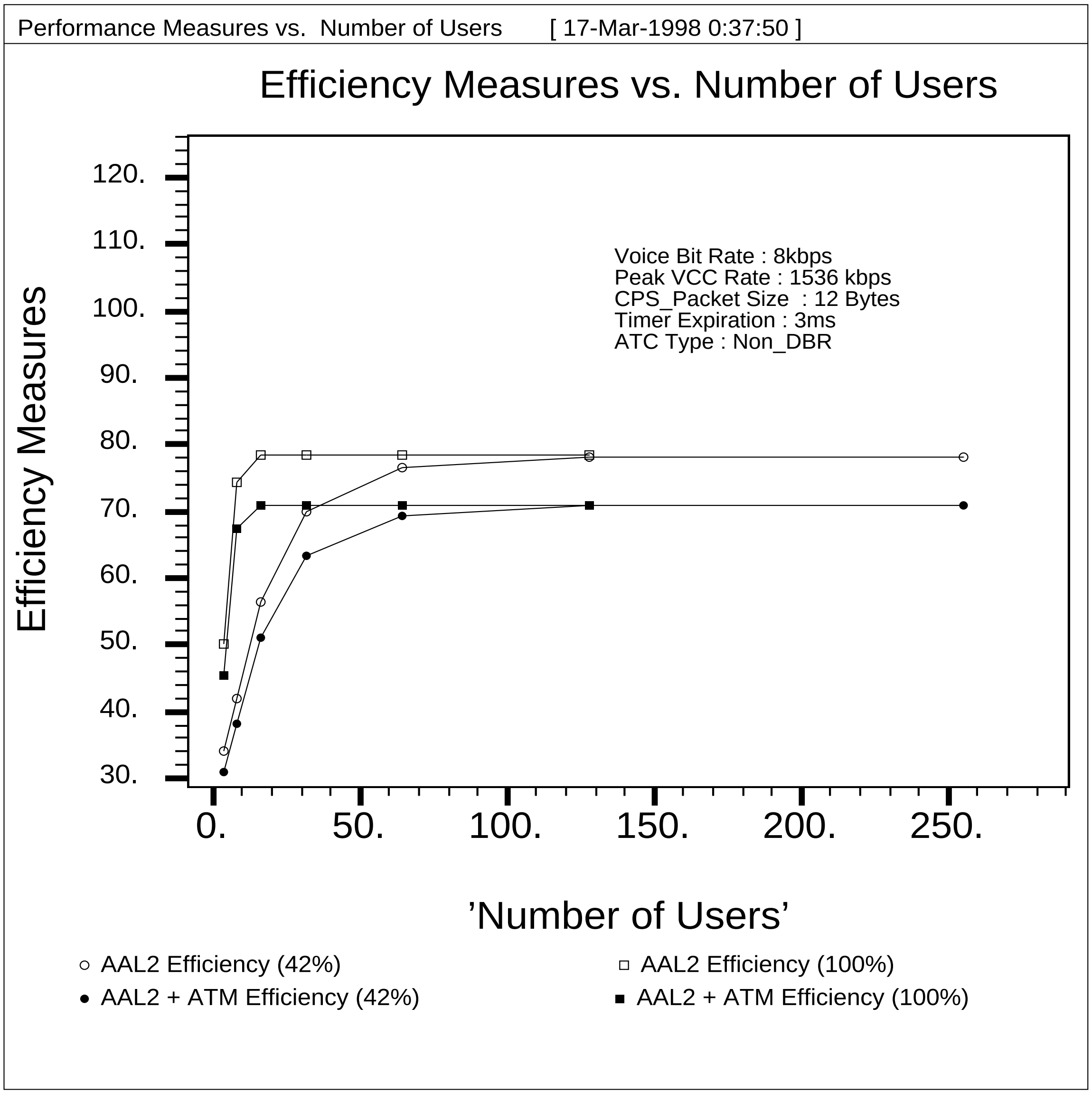

Figure 21: Efficiency Measures vs. Number of Users : Non_DBR

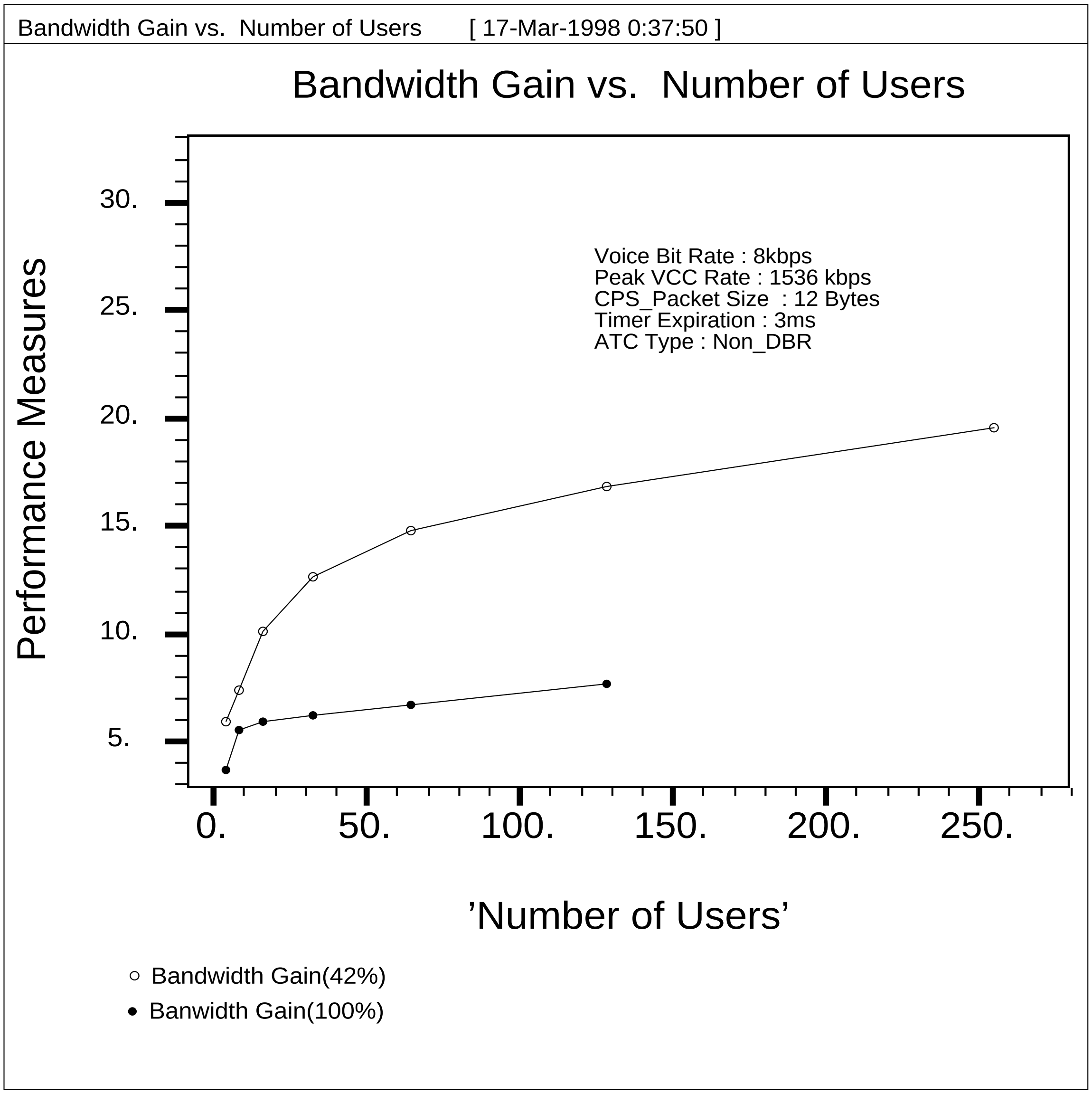

Figure 22: Bandwidth Gain vs. Number of Users : Non_DBR

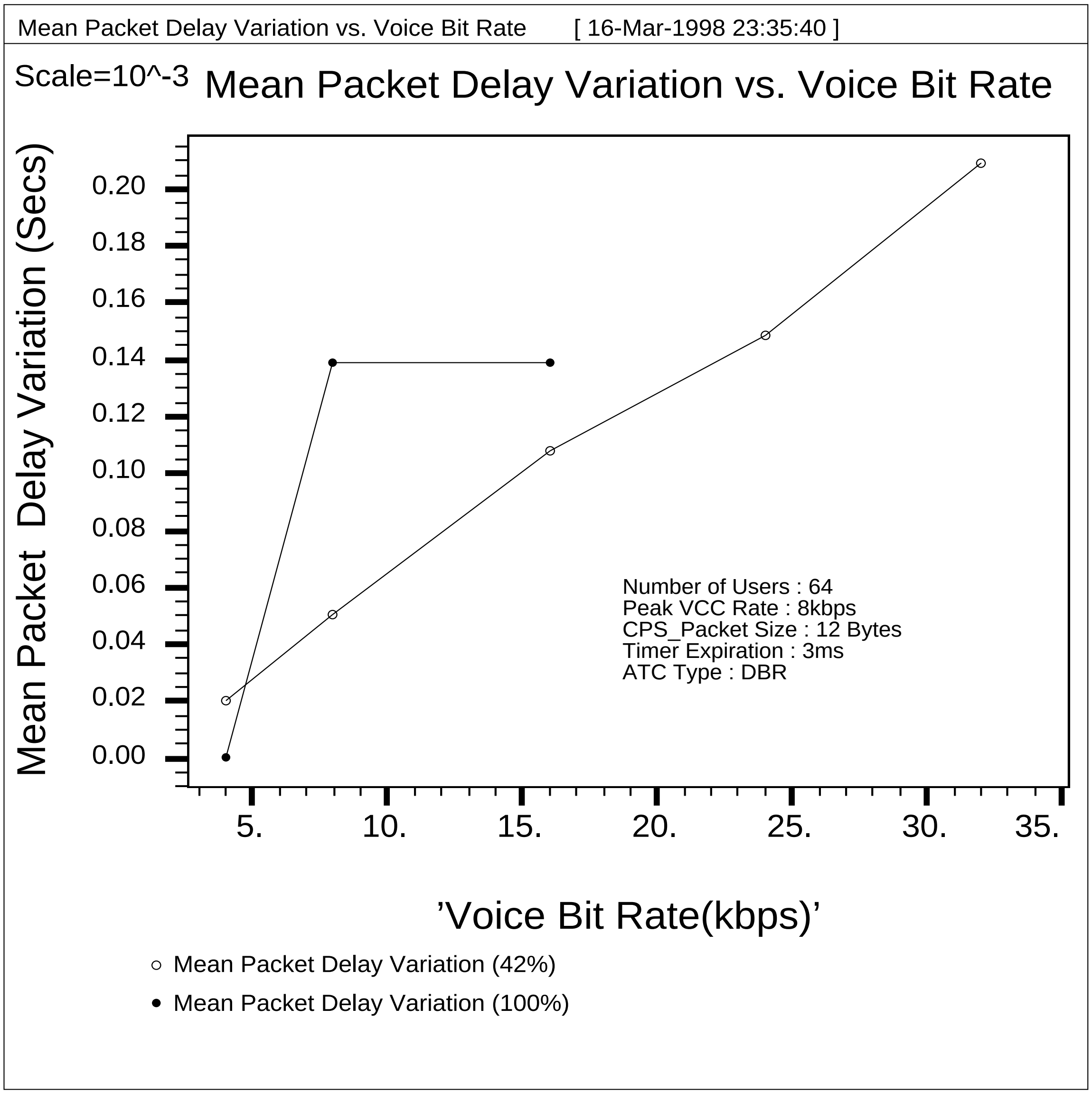

Figure 23: Mean Packet Delay Variation vs. Voice Bit Rates : DBR

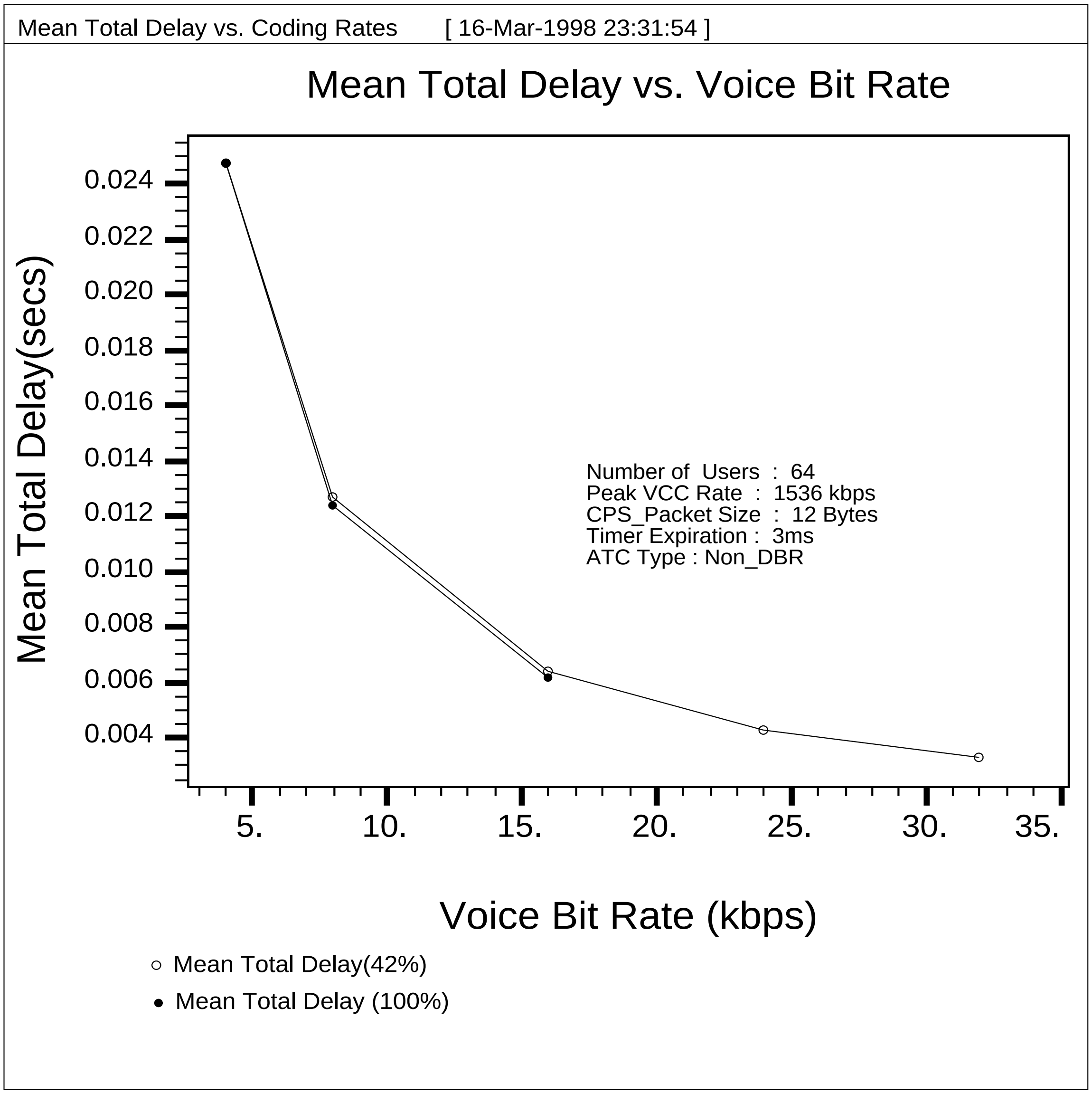

Figure 24: Mean Total Delay vs. Voice Bit Rates : DBR

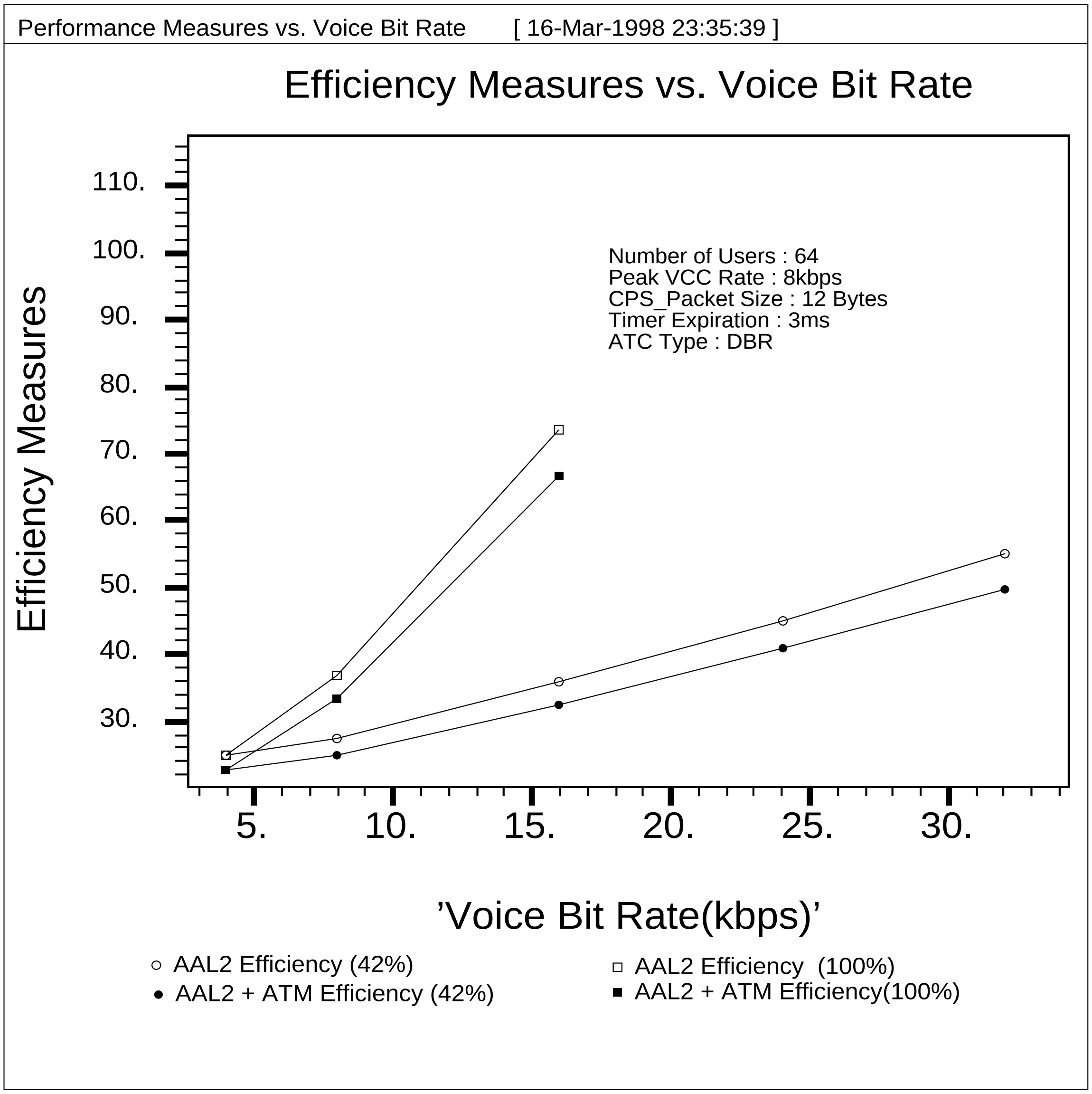

Figure 25: Efficiency Measures vs. Voice Bit Rates : DBR

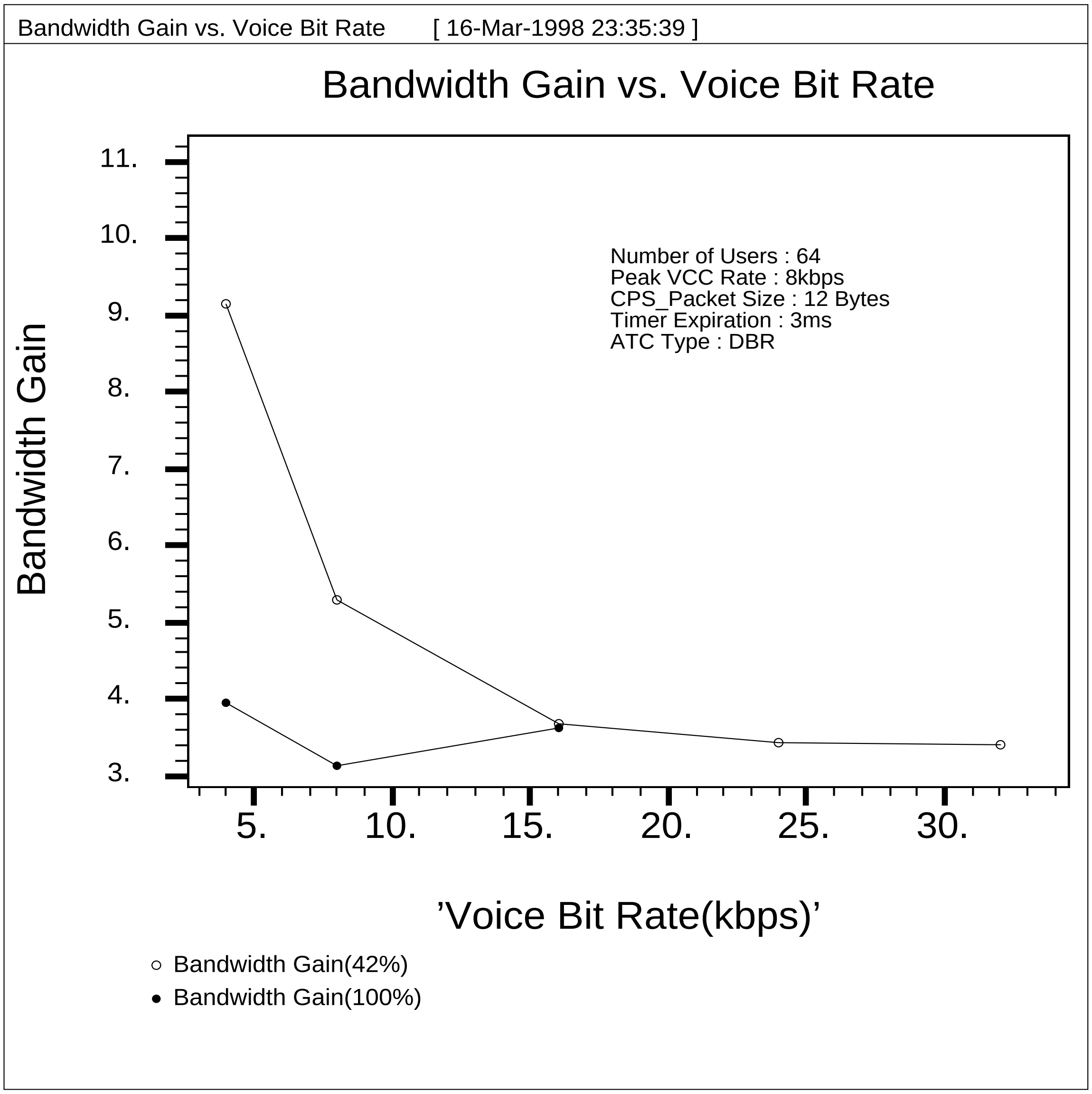

Figure 26: Bandwidth Gain vs. Voice Bit Rates : DBR

load increases for the higher bit rates, as the packetization time is smaller for the higher bit rates, therefore PDV (Figure 23.) increases due to queueing in the case of ATC type being DBR. AAL2 and AAL2 + ATM efficiencies (Figure 25.) increase as the voice bit rate increases and approach the maximum possible value with silence removal. Efficiencies with silence removal are worse (20%-30% less) as compared to that of no silence removal. Bandwidth gain decreases with the increase in voice bit rate because of the increase in utilization of the bandwidth. Also bandwidth gain is lower for the case of no silence removal as compared to the case of silence removal.

In the Non_DBR case PDV initially decreases as the voice bit rate goes up since the timer expiry would be infrequent with the faster arrival of CPS_Packets (Figure 27.). Efficiencies achieved are much higher compared to the DBR case. For voice bit rates of 16 kbps for 42% speech activity maximum possible efficiency is achieved, while for 100% speech activity maximum efficiency is achieved at 4 kbps.

All the corresponding values of delay, efficiency and bandwidth gain are higher for the Non_DBR as compared to that of DBR.

7.4 Plots for Different Voice Bit Rates (Wireless)

Figures 31 through 40 show the results obtained for different wireless coding rate. Figures 31. through 35 are for DBR and Figures. 36 through 40 are for Non_DBR case. Simulations have been performed with voice bit rates used for wireless applications. The coding rates used are already mentioned in the previous section. It can be observed that the trend for the delay, efficiencies and bandwidth gain remain the same as that of the coding rates used for wireless applications. However it can be seen that there is significant increase in the mean total delay, which is due to that fact that particular packet sizes are associated with wireless coding rates. These packet sizes being larger, packetization delay experienced is greater than that experienced in the trunking applications.

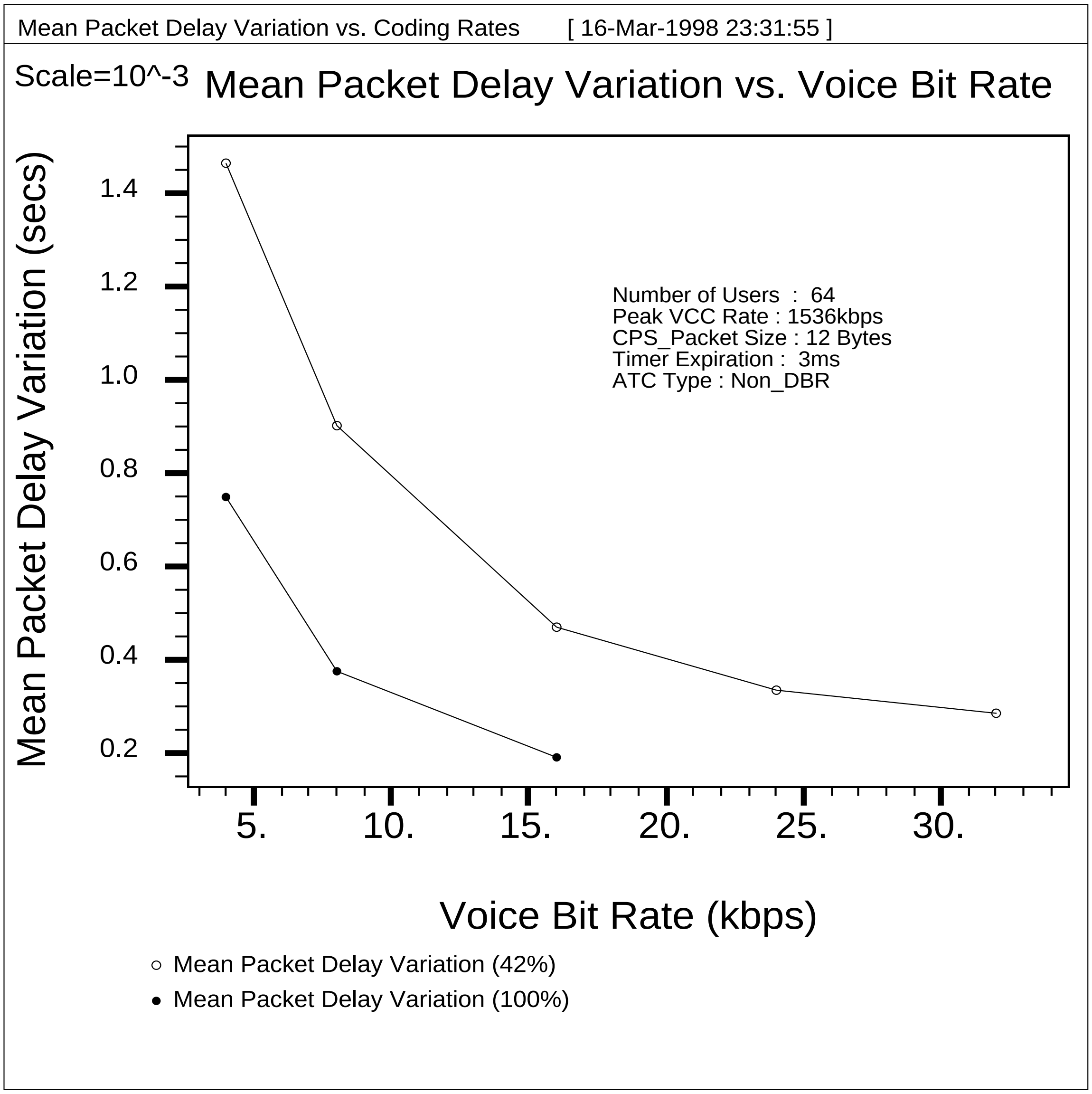

Figure 27: Mean Packet Delay Variation vs. Voice Bit Rates : Non_DBR

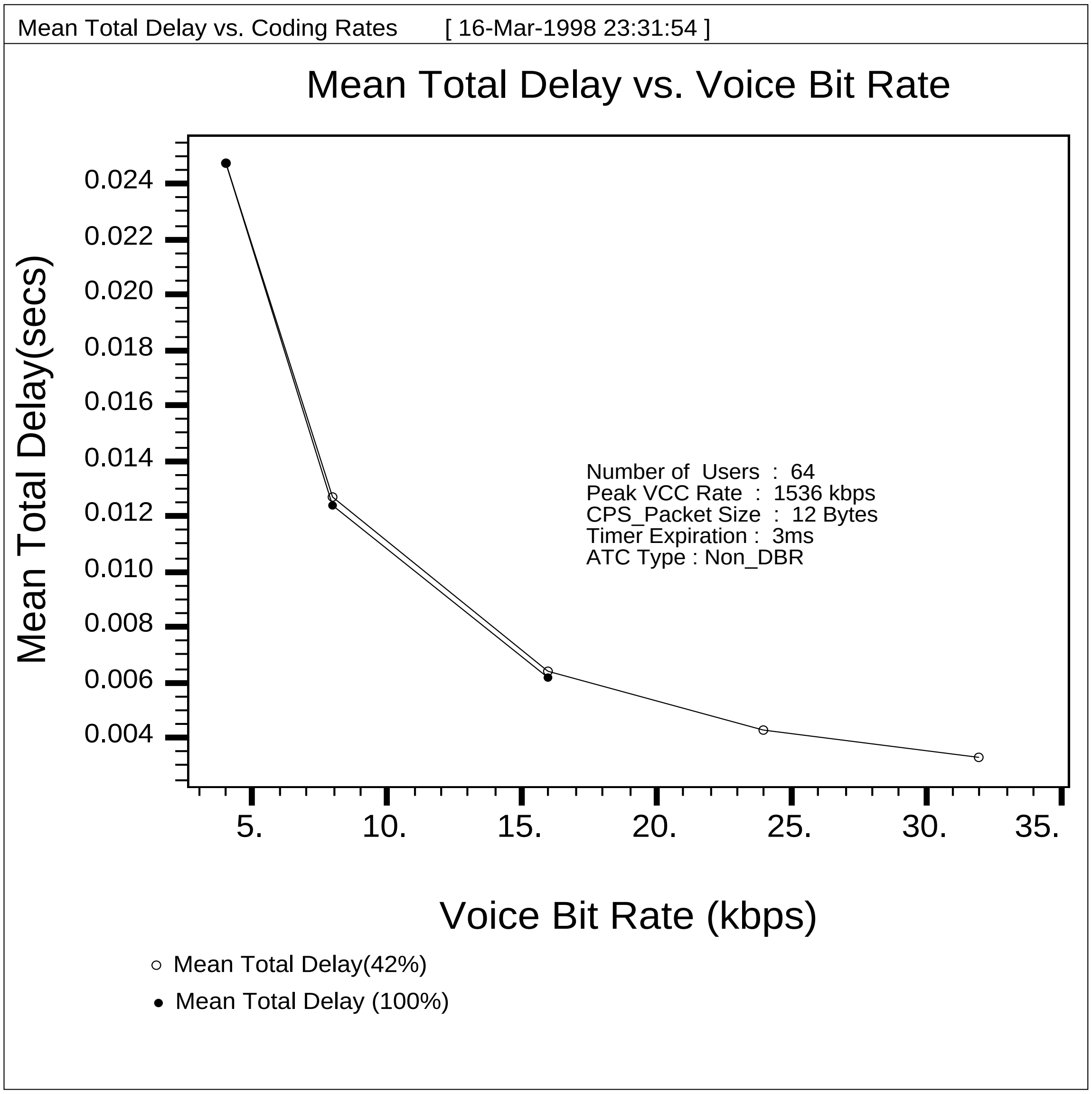

Figure 28: Mean Total Delay vs. Voice Bit Rates : Non_DBR

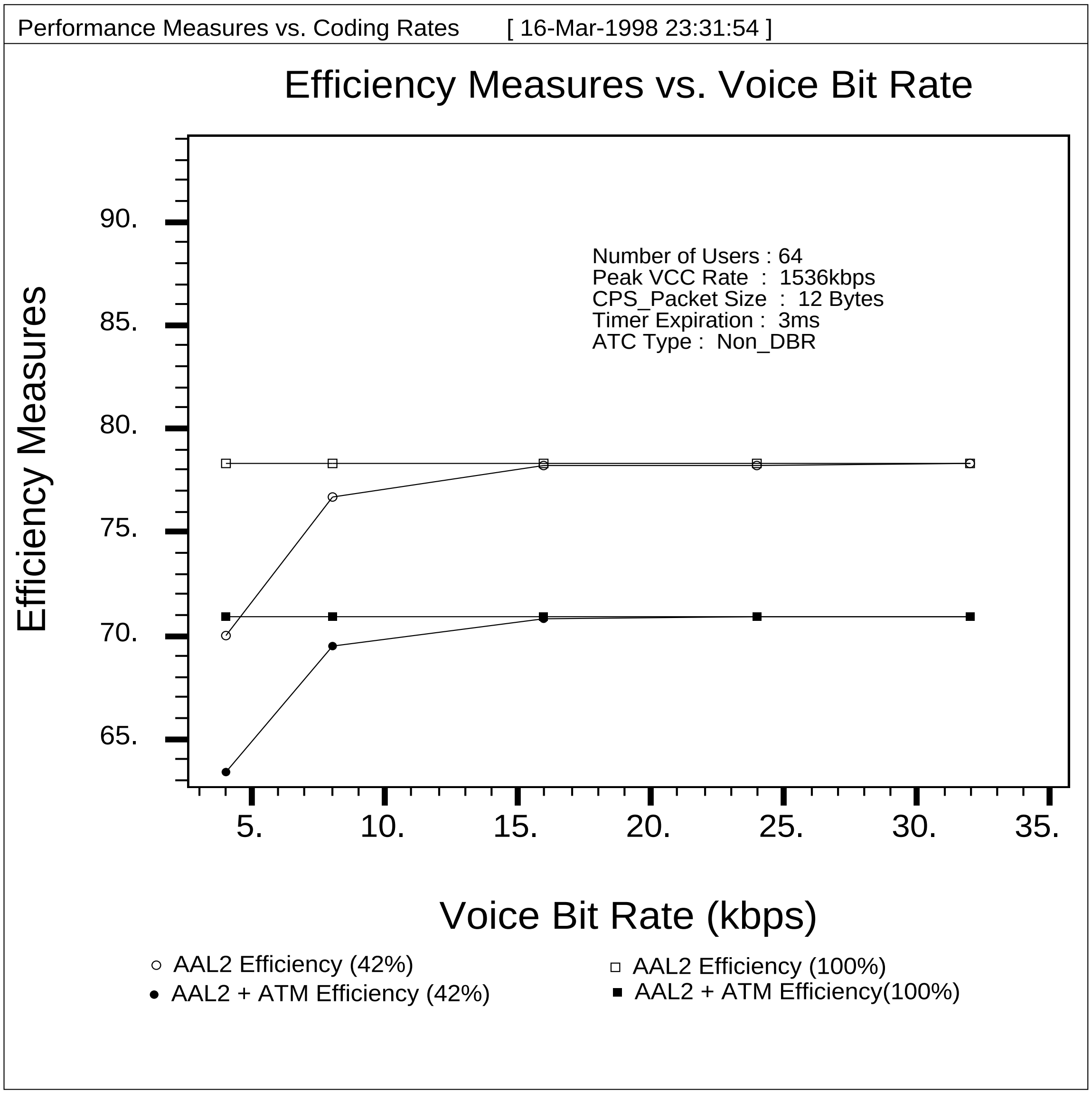

Figure 29: Efficiency Measures vs. Voice Bit Rates : Non_DBR

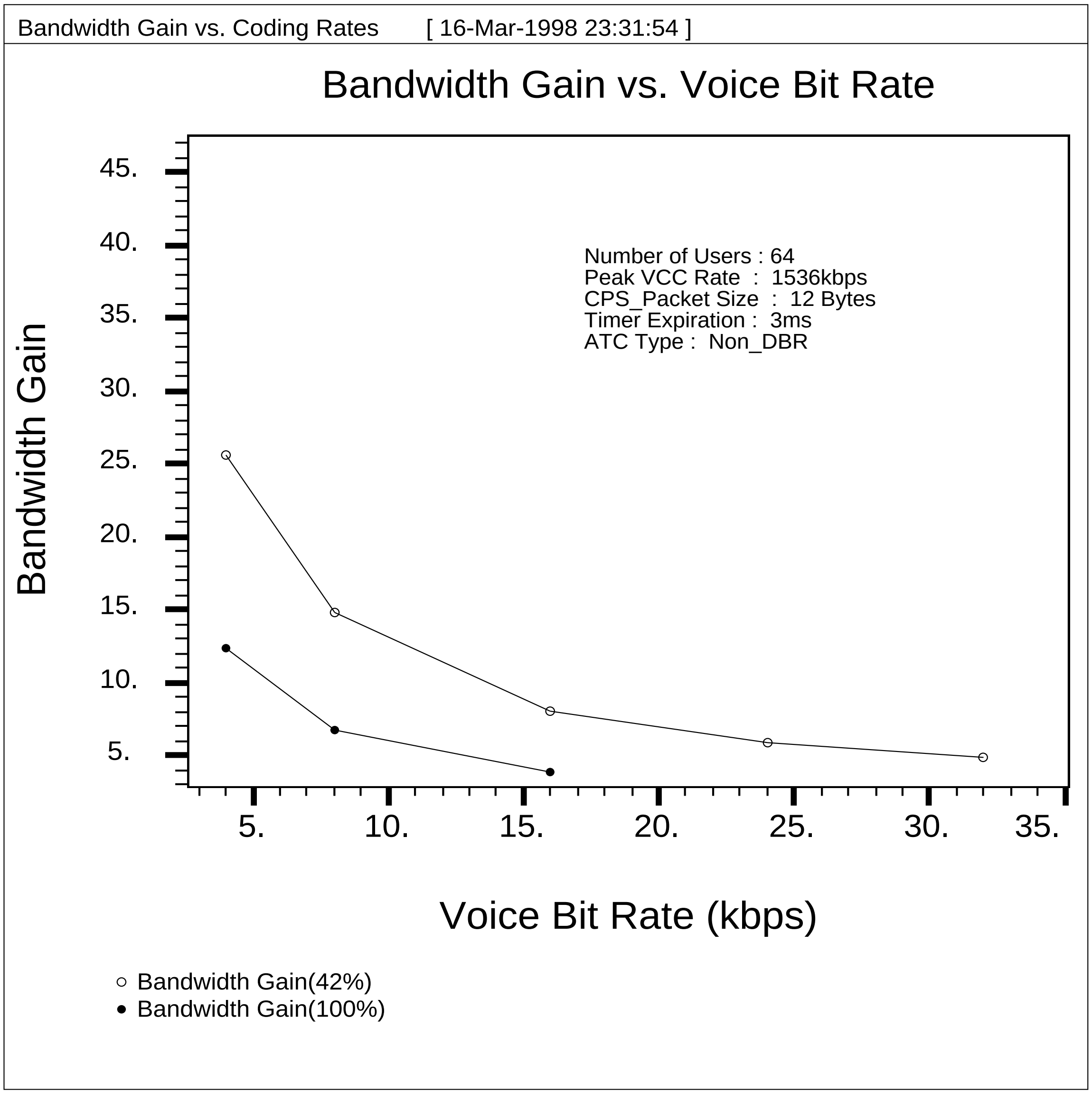

Figure 30: Bandwidth Gain vs. Voice Bit Rates : Non_DBR

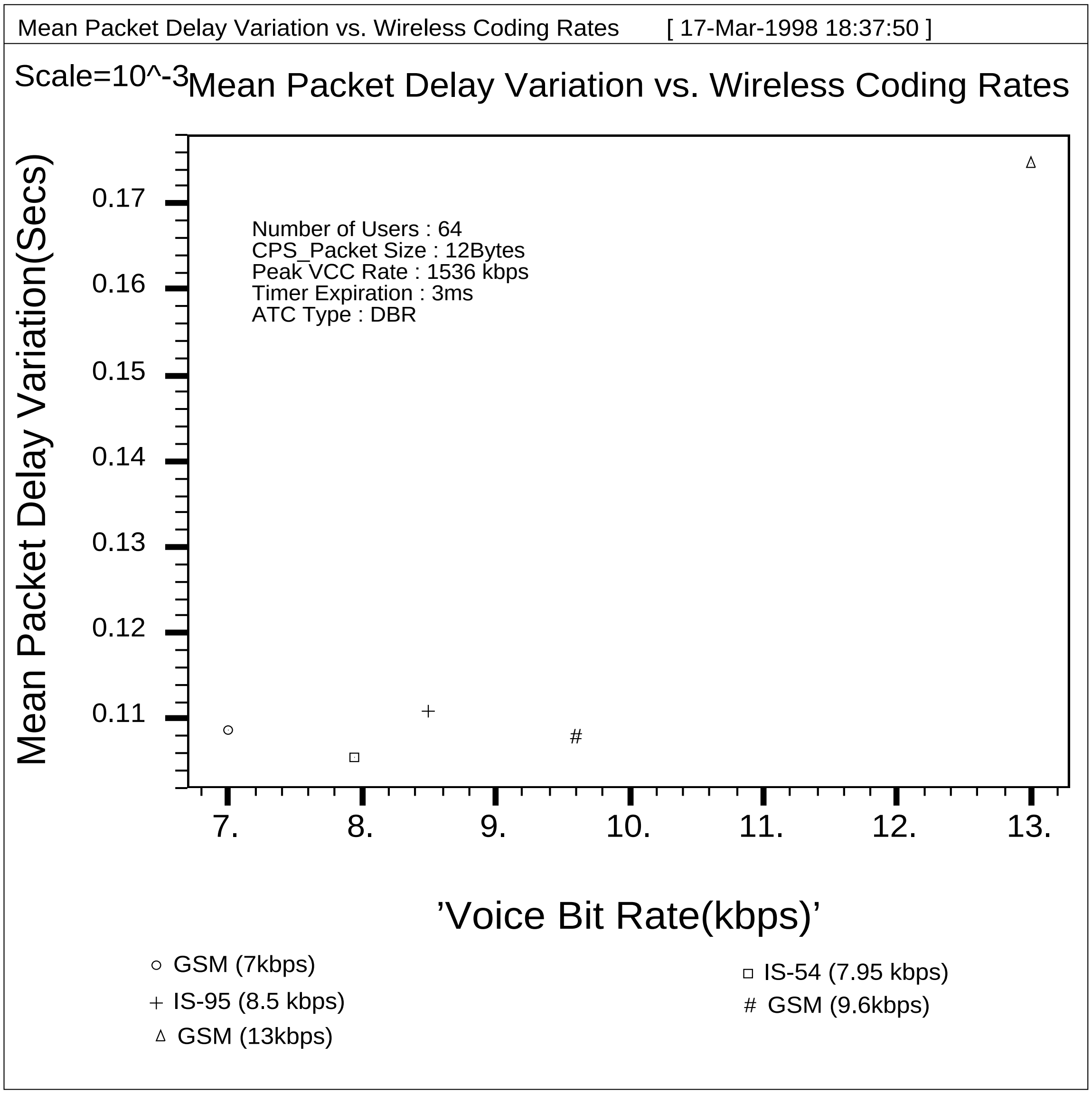

Figure 31: Mean Packet Delay Variation vs. Voice Bit Rates : DBR

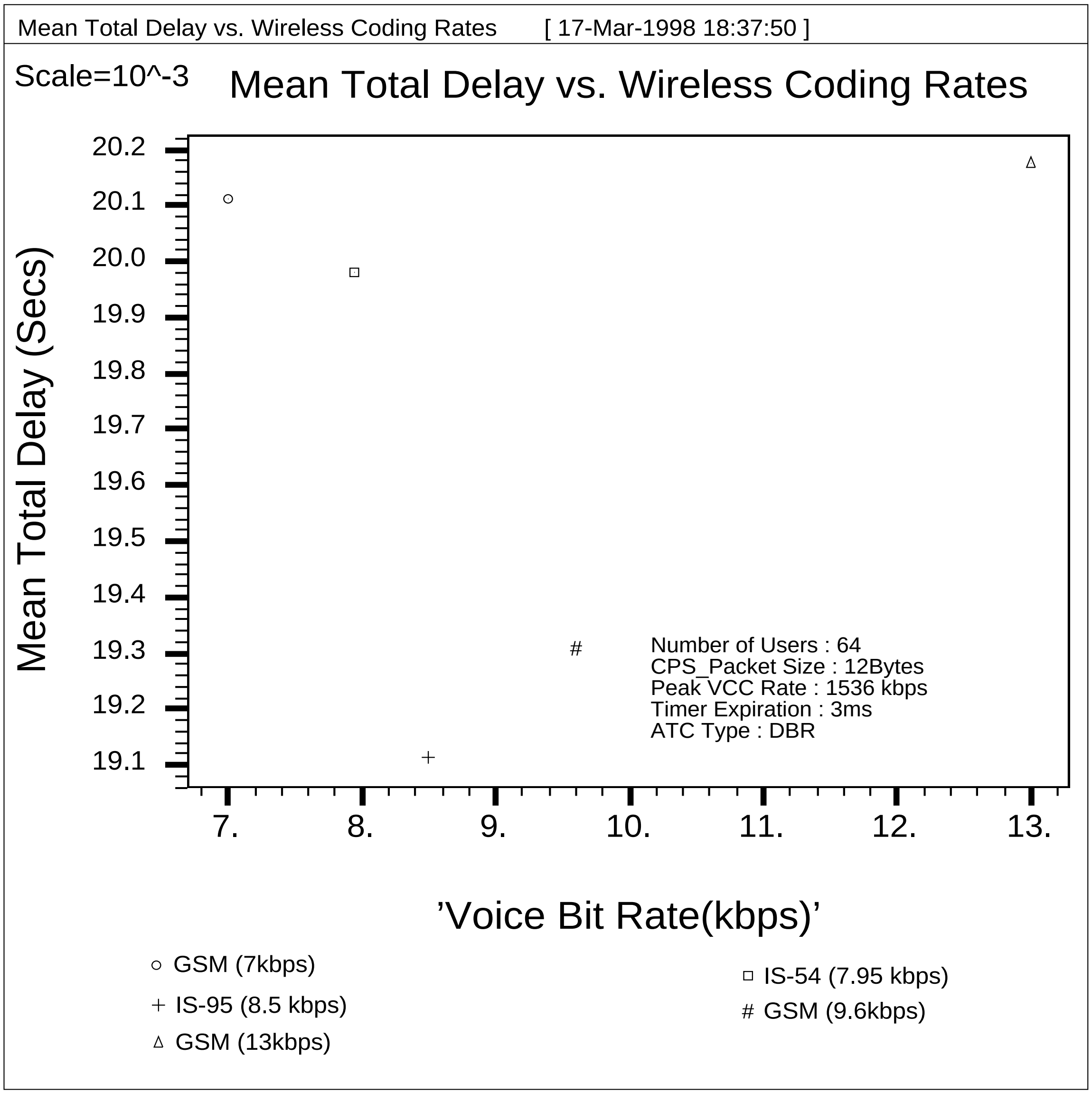

Figure 32: Mean Total Delay vs. Voice Bit Rates : DBR

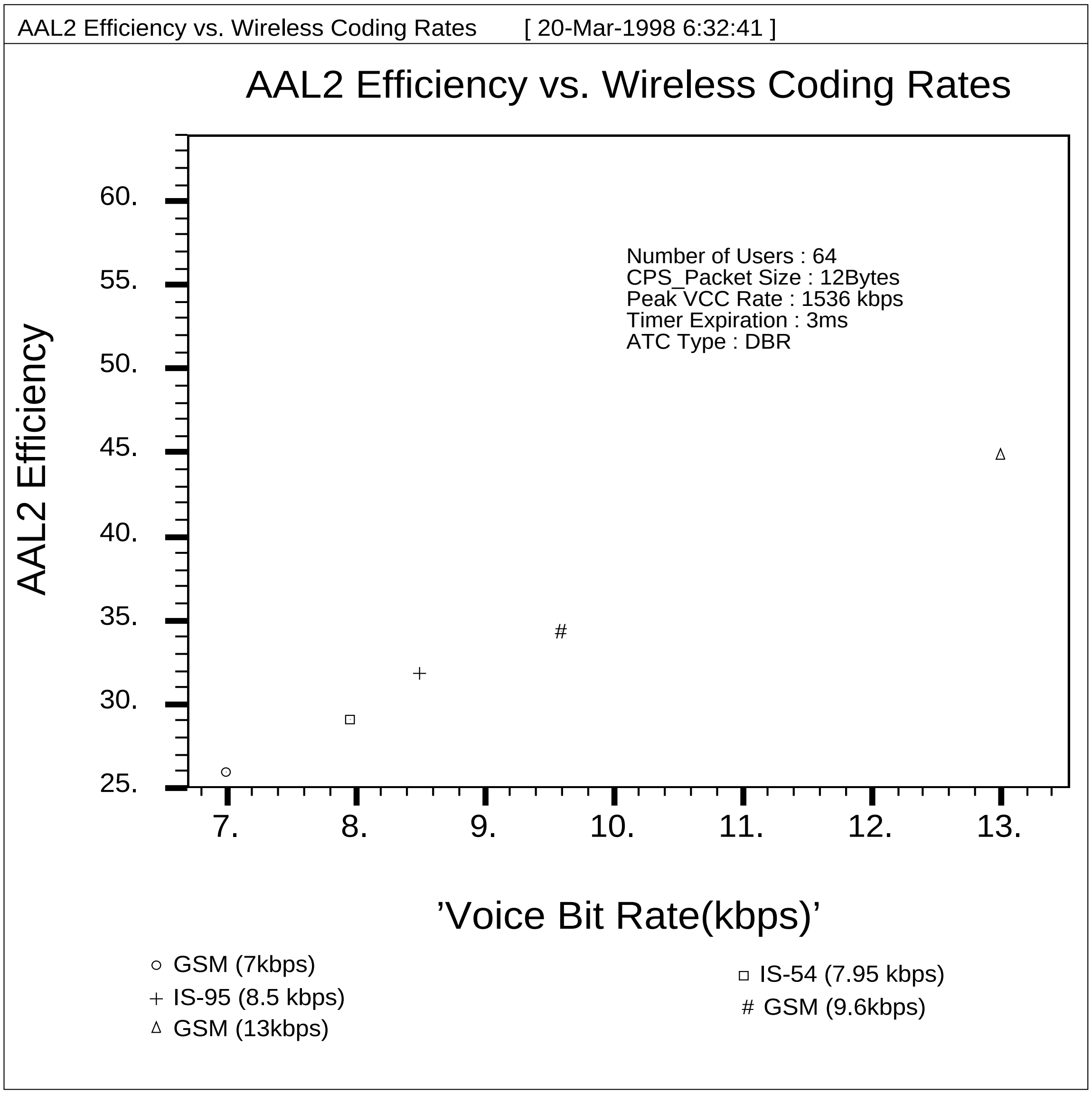

Figure 33: AAL2 Efficiency vs. Voice Bit Rates : DBR

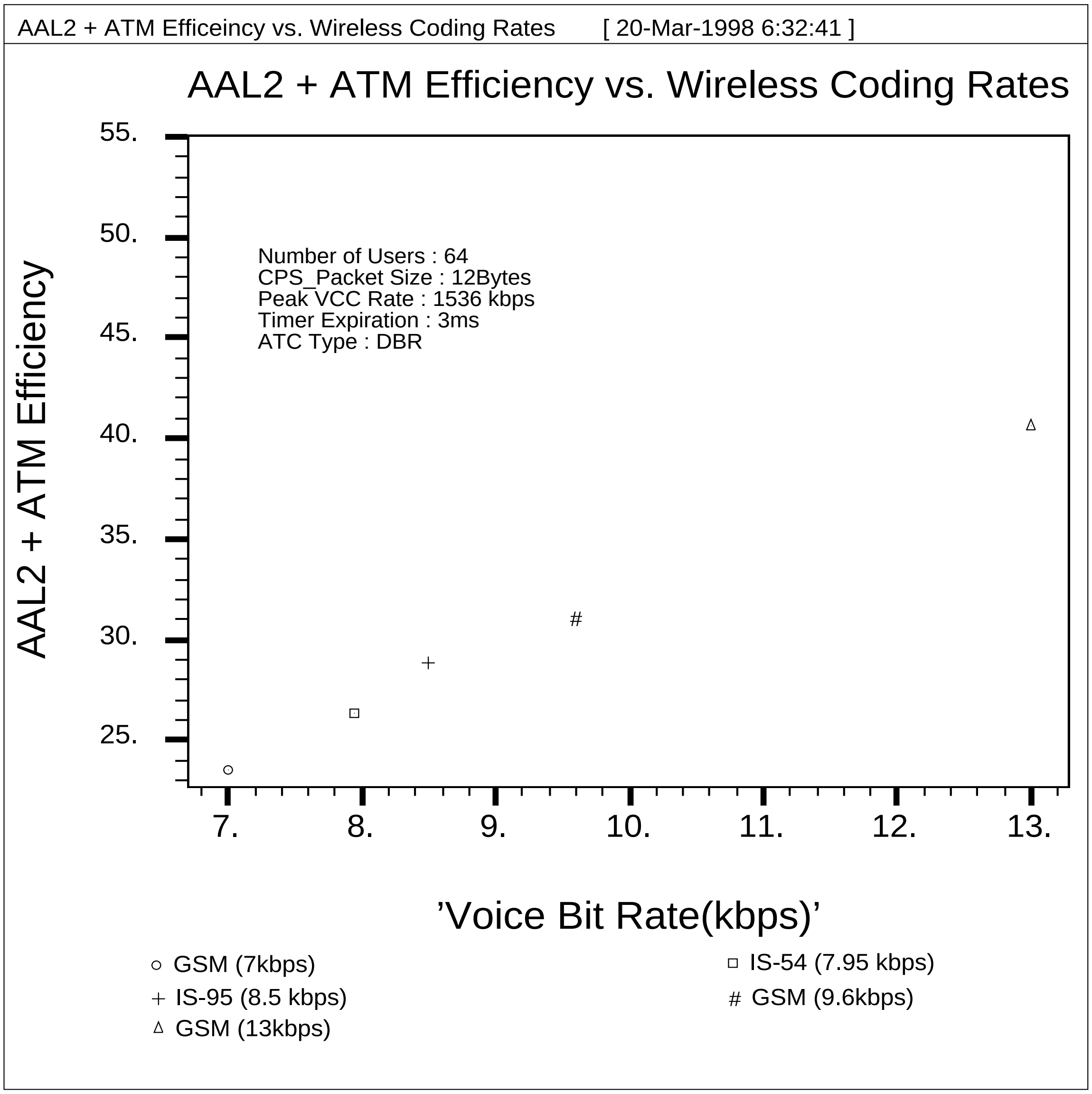

Figure 34: AAL2 + ATM Efficiency vs. Voice Bit Rates : DBR

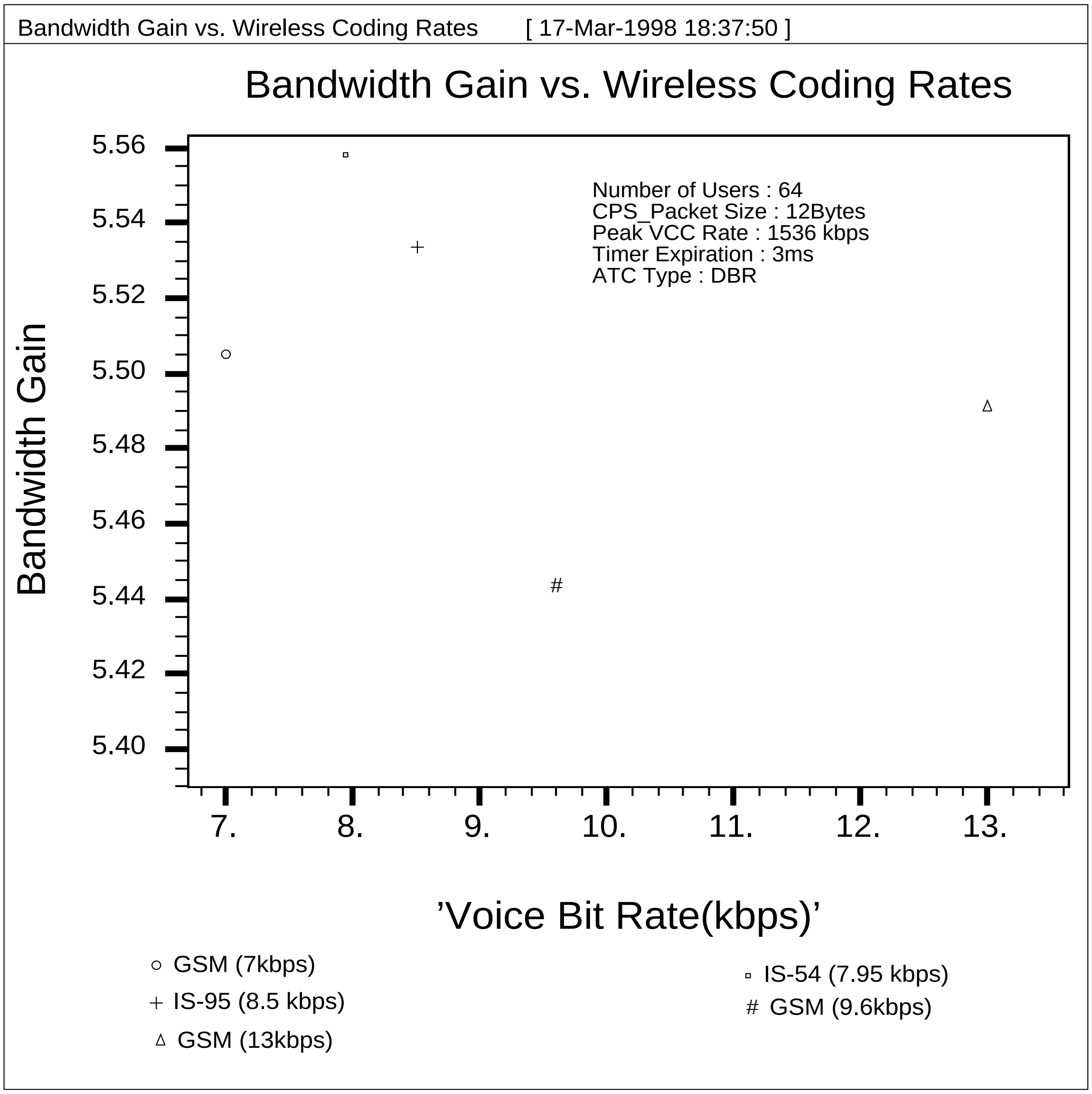

Figure 35: Bandwidth Gain vs. Voice Bit Rates : DBR

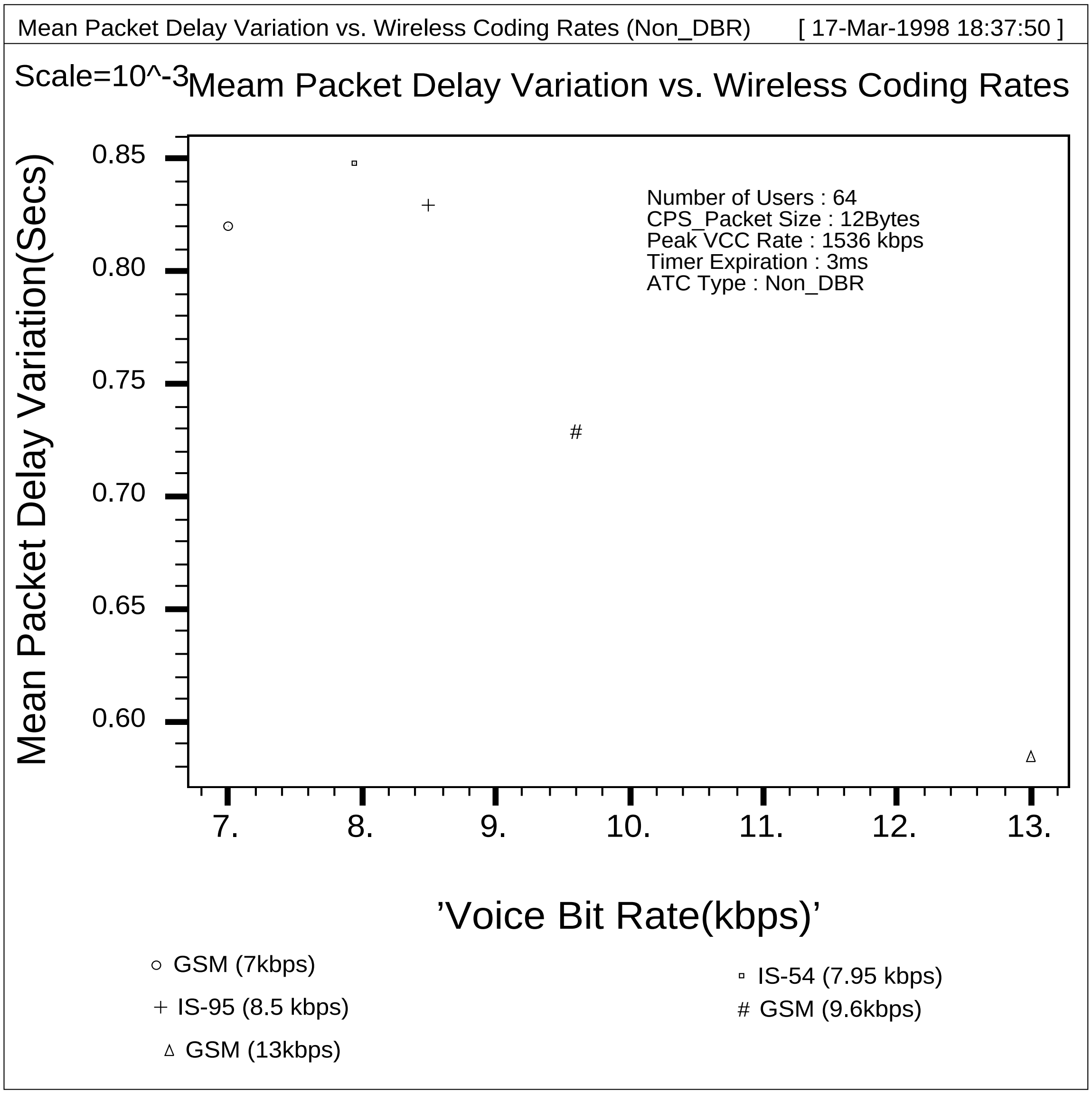

Figure 36: Mean Packet Delay Variation vs. Voice Bit Rates : Non_DBR

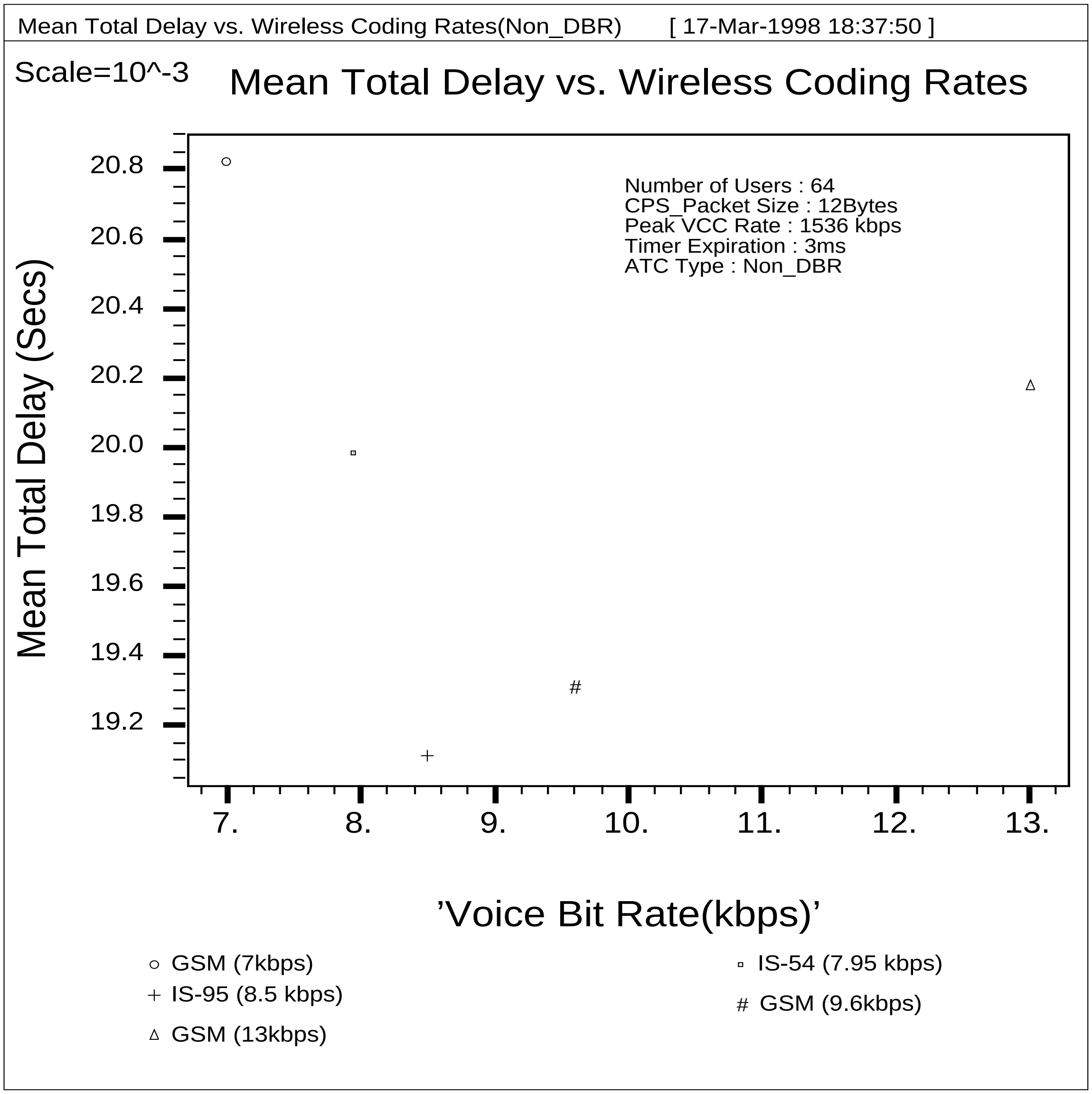

Figure 37: Mean Total Delay vs. Voice Bit Rates : Non_DBR

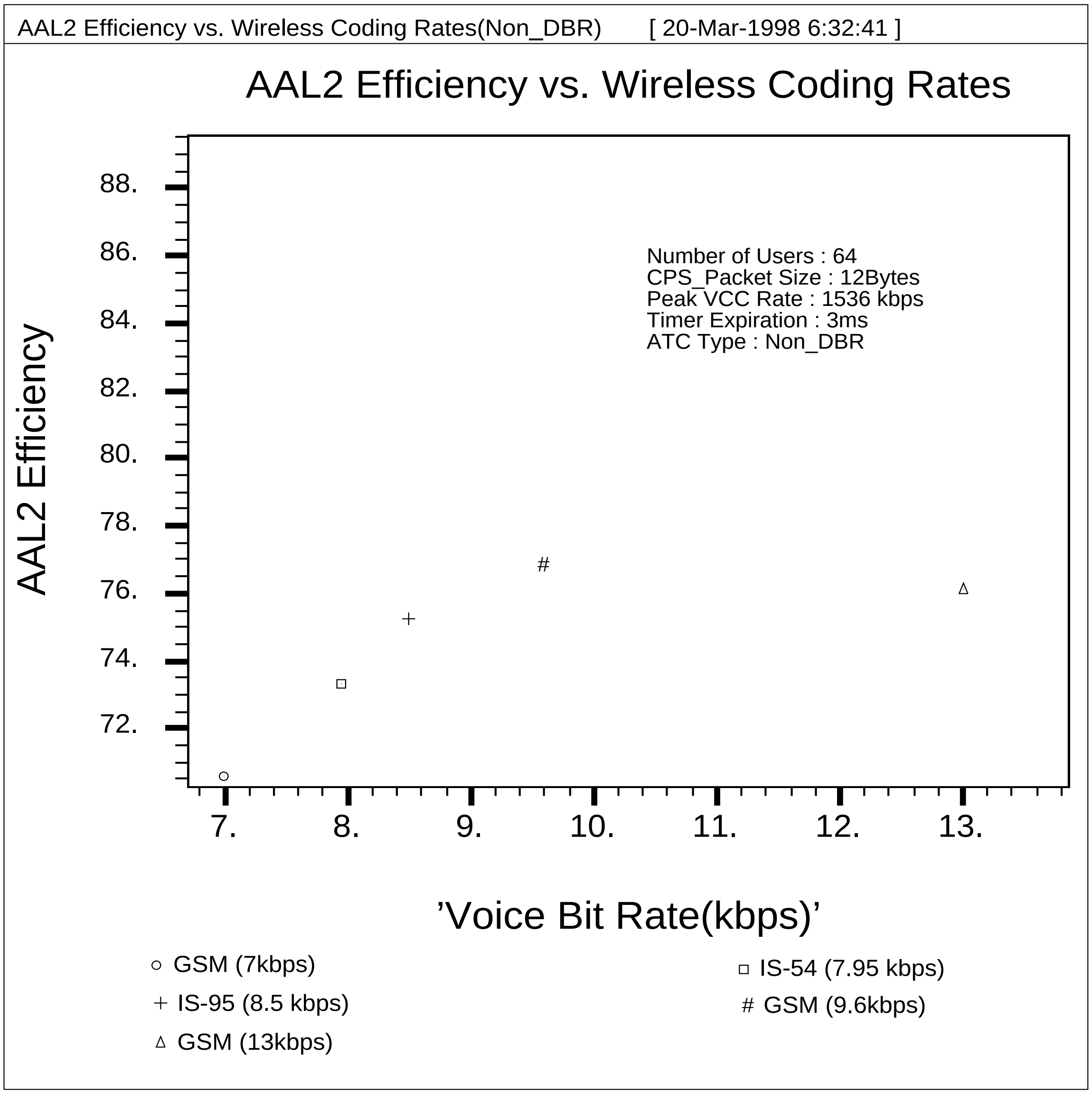

Figure 38: AAL2 Efficiency vs. Voice Bit Rates : Non_DBR

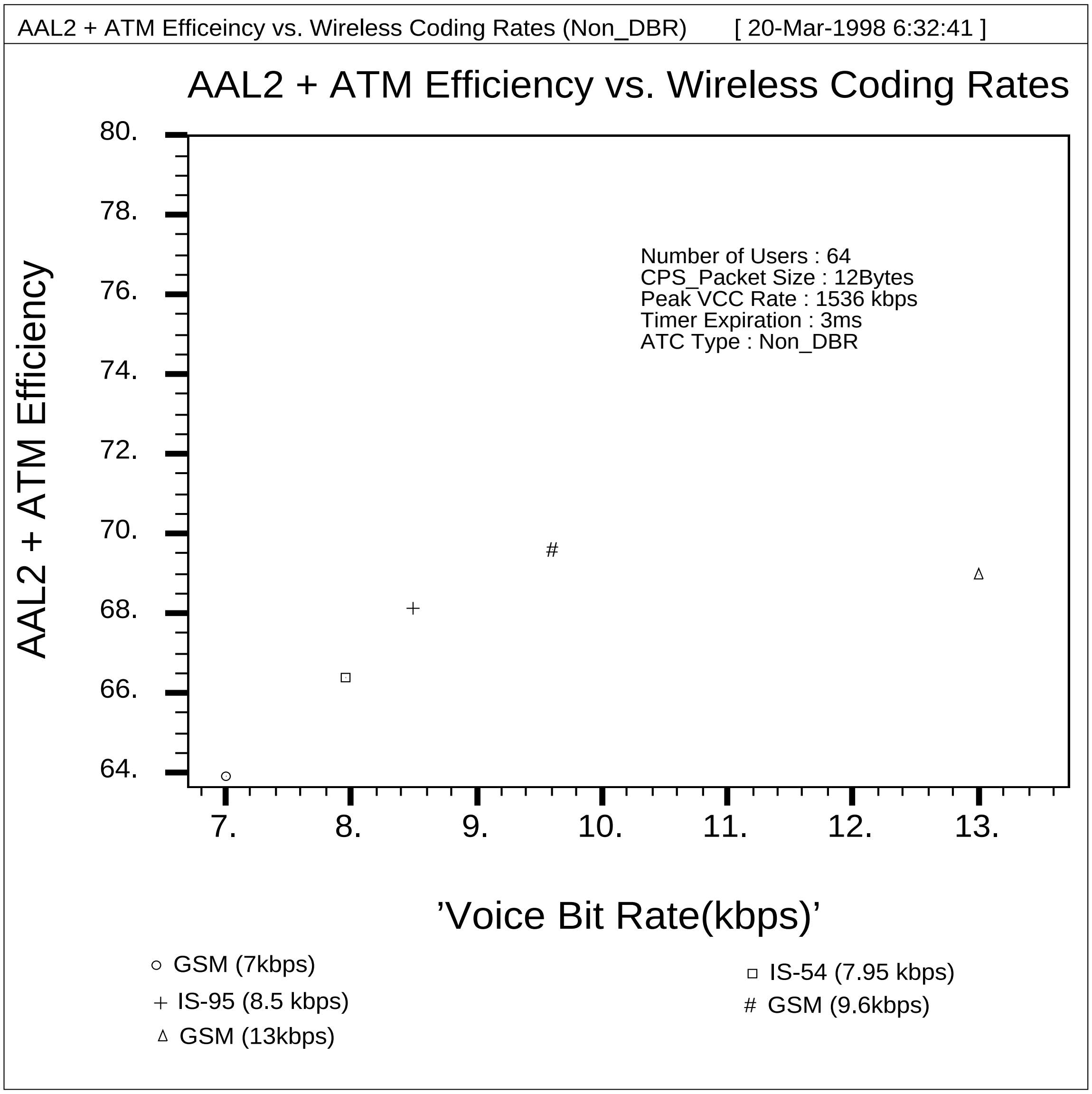

Figure 39: AAL2 + ATM Efficiency vs. Voice Bit Rates : Non_DBR

7.5 Plot for Different Peak VCC Rates

Figures. 41 through 48 show the performance characteristics when the peak VCC rates are varied. Figures. 41 through 44 are for the ATC type DBR and 45 through 48 are for Non_DBR case.

If the ATC type is DBR, the rate of arrival of permit is the principal factor in determining the delay inside the transmitter. Thus the delay experienced inside the transmitter decreases as the permit arrival rate increases, as illustrated in the Figure 41. The mean packet delay values are approximately equal to the inter-arrival time between the permits. For the peak VCC rate of 1.536 Mbps the inter-arrival time between the permit is 0.276 ms, and it can be observed from the Figure 41. that the value of the mean PDV is approximately equal to the theoretical value. The mean total delay follows the same trend, with the packetization delay of 12ms added. As expected the delay values are slightly larger for 100% speech activity at lower permit rates, while the difference dies down with the increase in the permit rate. However as the ATM cell is sent out after the receipt of the permit irrespective of it being partially filled, AAL2 efficiency is affected to an large extent. It can be seen from the plots that AAL2 and AAL2 + ATM efficiency decreases from a near maximum value (77% and 72%) to lows of 27% and 23%, as peak VCC rate increases. Efficiency is higher with the 100% speech activity at lower peak VCC rates, while as the peak VCC rate increases the efficiencies for both the speech activity factors approach the same value. This implies that as the peak VCC rate increases the delay is reduced to the minimum but would result in poor utilization of the bandwidth, irrespective of the speech activity. Bandwidth gain (Fig. 44) decreases steeply with the increases in the peak VCC rate. For 100% speech activity and 45 Mbps peak VCC rate, the bandwidth gain is slightly less than 2 (coding gain of $64/8 = 8$ and AAL2 + ATM efficiency of 23% as expected from eqn. 11).

For the ATC type Non_DBR delay values (Figs. 45, 46) are marginally increased in the case of lower speech activity factor, due to the delay caused by the timer, while for higher speech activity factor there is almost no effect as the there is continuous stream of packets and the need for timer expiration to send to the ATM cell does not always arise. As expected the efficiencies are higher in the case of Non_DBR and 100% speech activity factors. AAL2 and AAL2 + ATM efficiencies attained are close to the maximum possible value for all values of the peak VCC rates. Similarly, bandwidth gain is not significantly affected by the peak VCC rate.

All the corresponding values of delay, efficiency and bandwidth gain are higher for Non_DBR as compared to DBR.

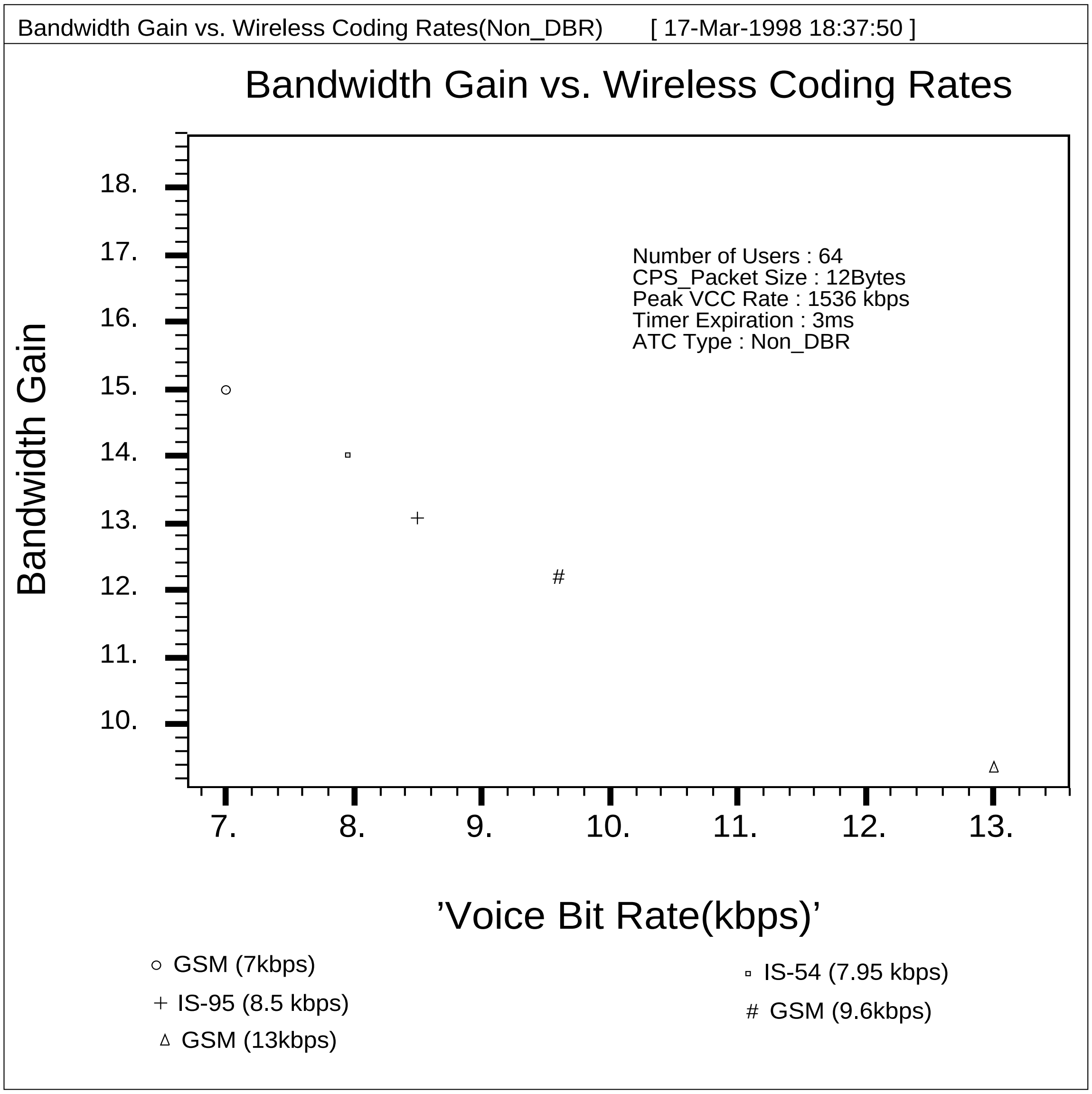

Figure 40: Bandwidth Gain vs. Voice Bit Rates : Non_DBR

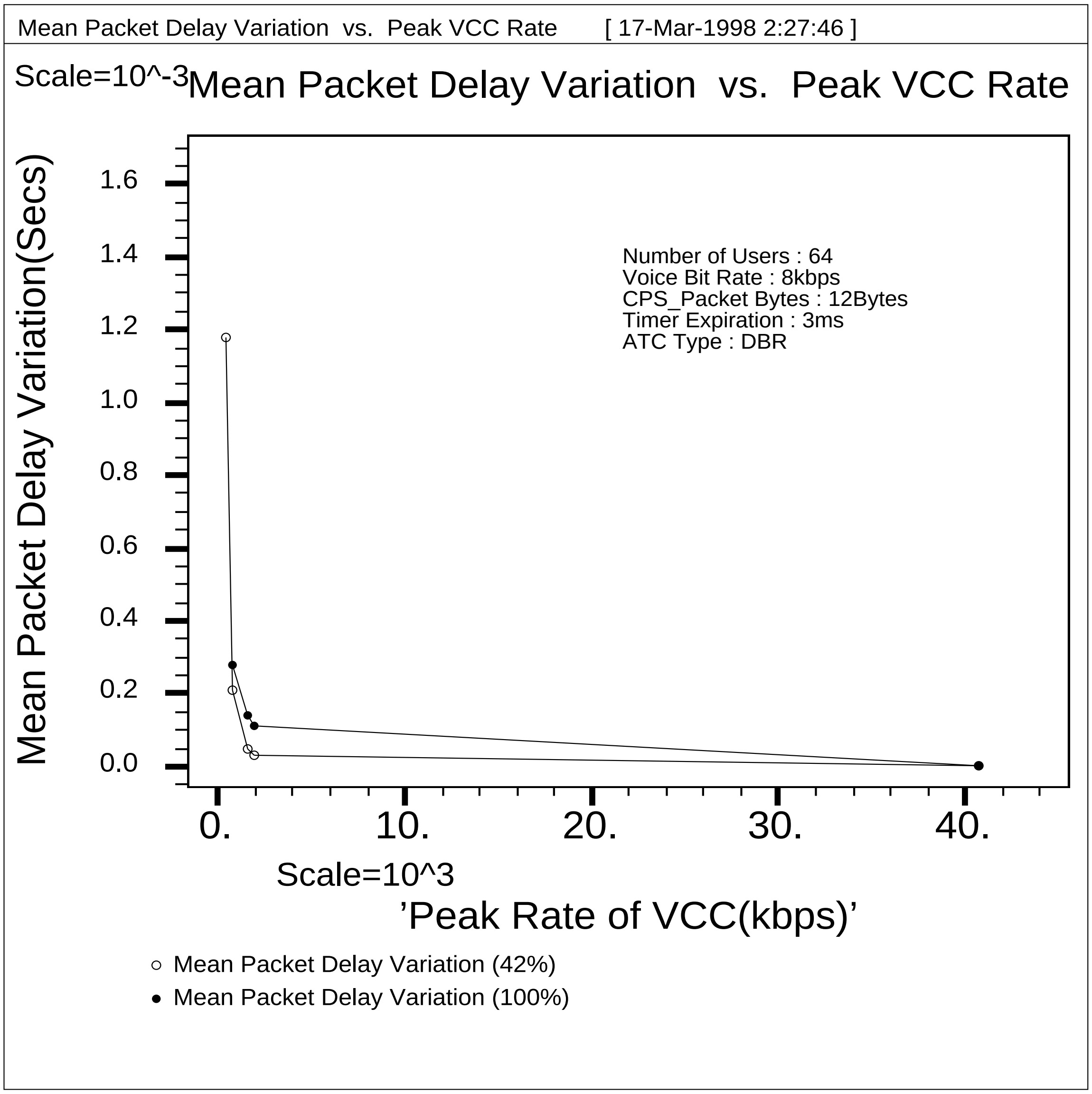

Figure 41: Mean Packet Delay Variation vs. Peak VCC Rates : DBR

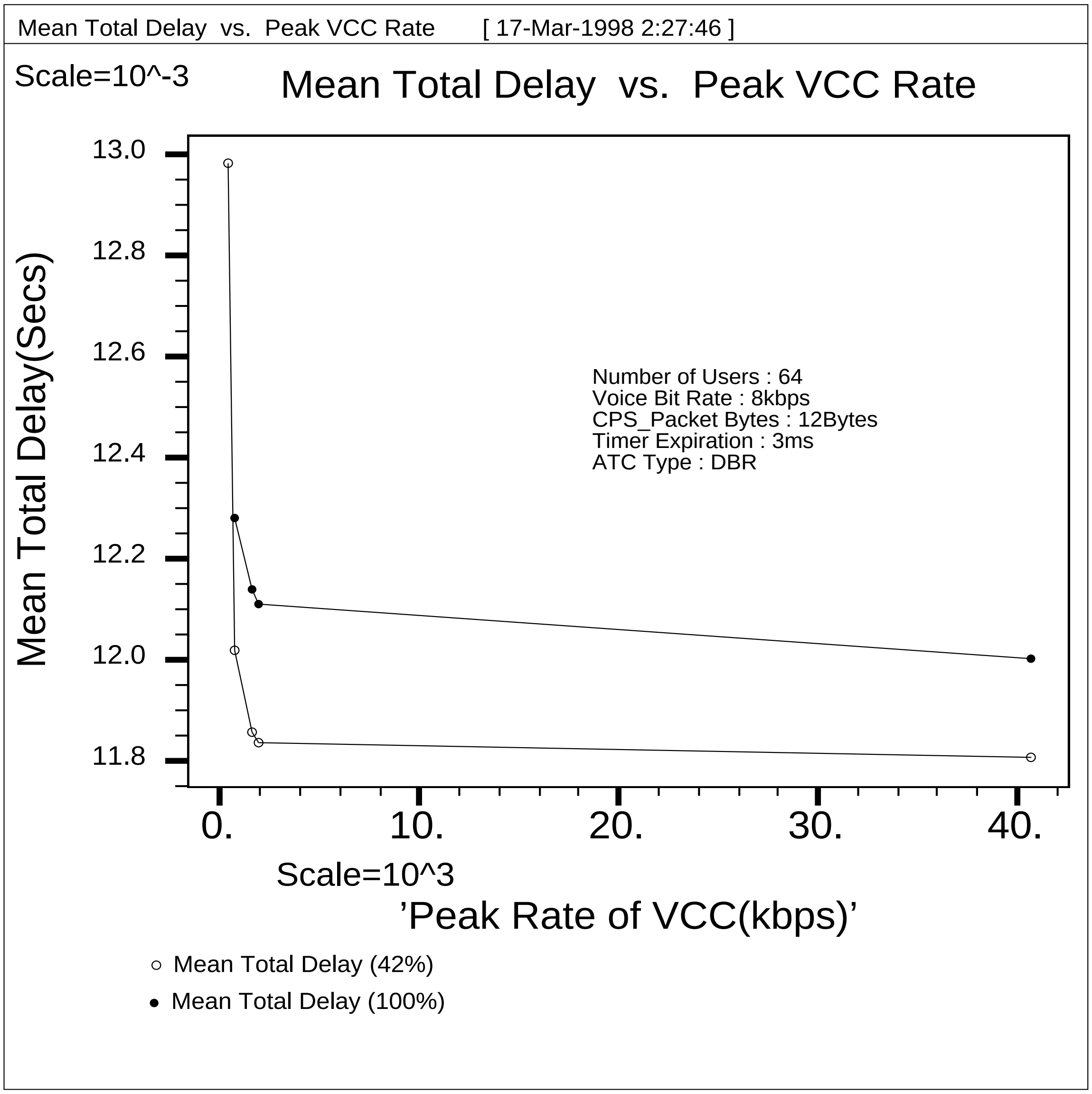

Figure 42: Mean Total Delay vs. Peak VCC Rates :DBR

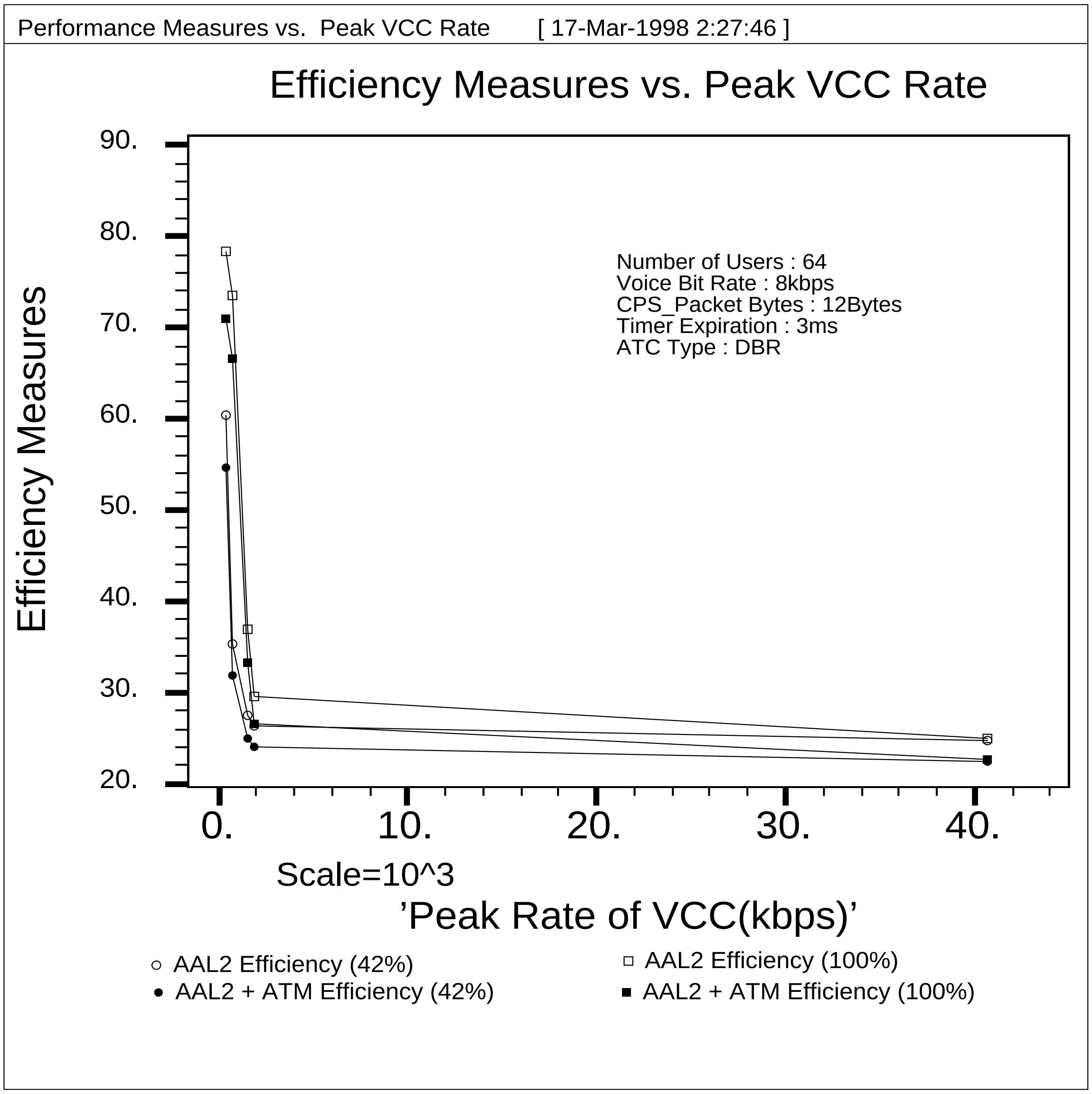

Figure 43: Performance Measures vs. Peak VCC Rates : DBR

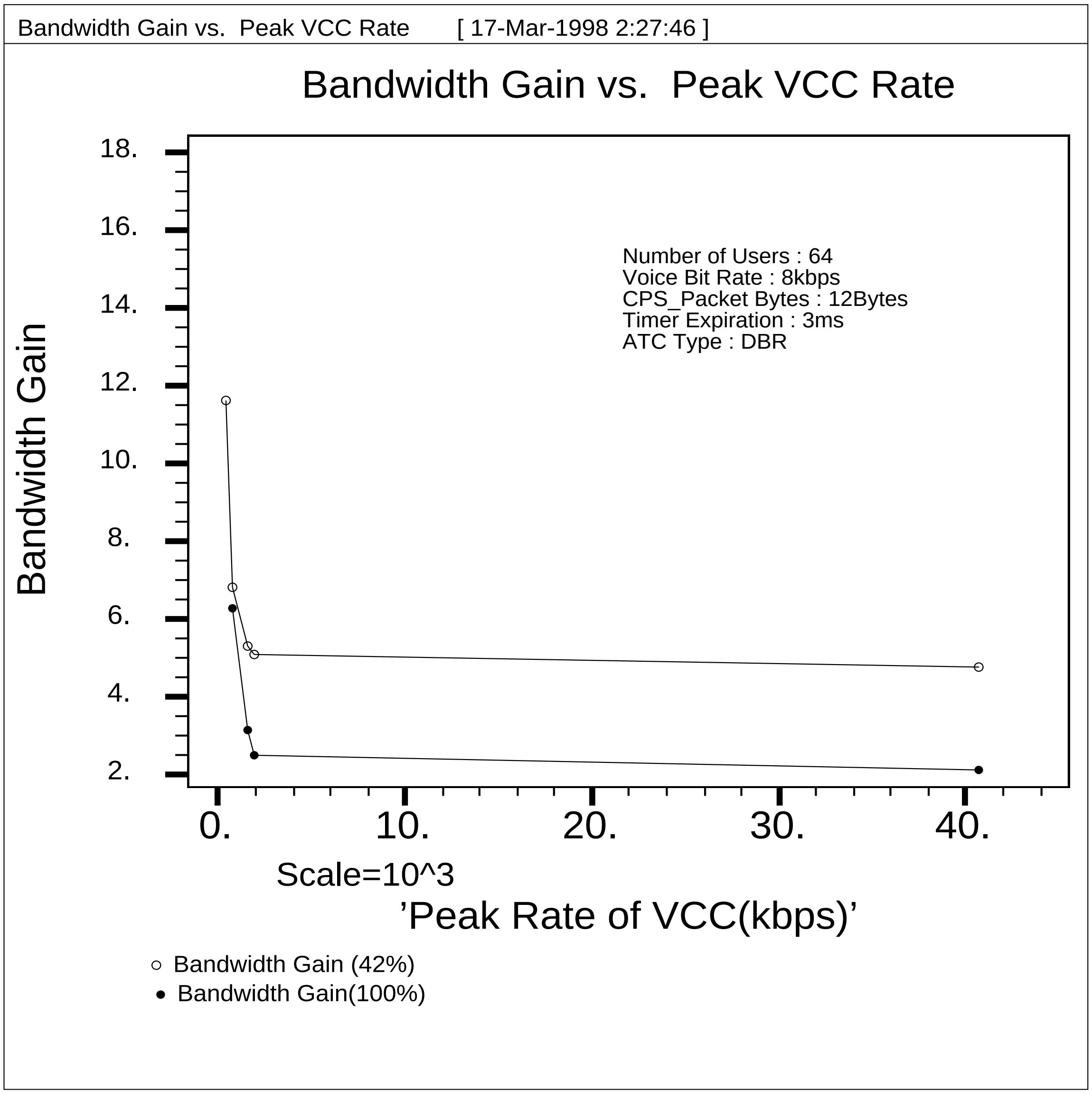

Figure 44: Bandwidth Gain vs. Peak VCC Rates : DBR

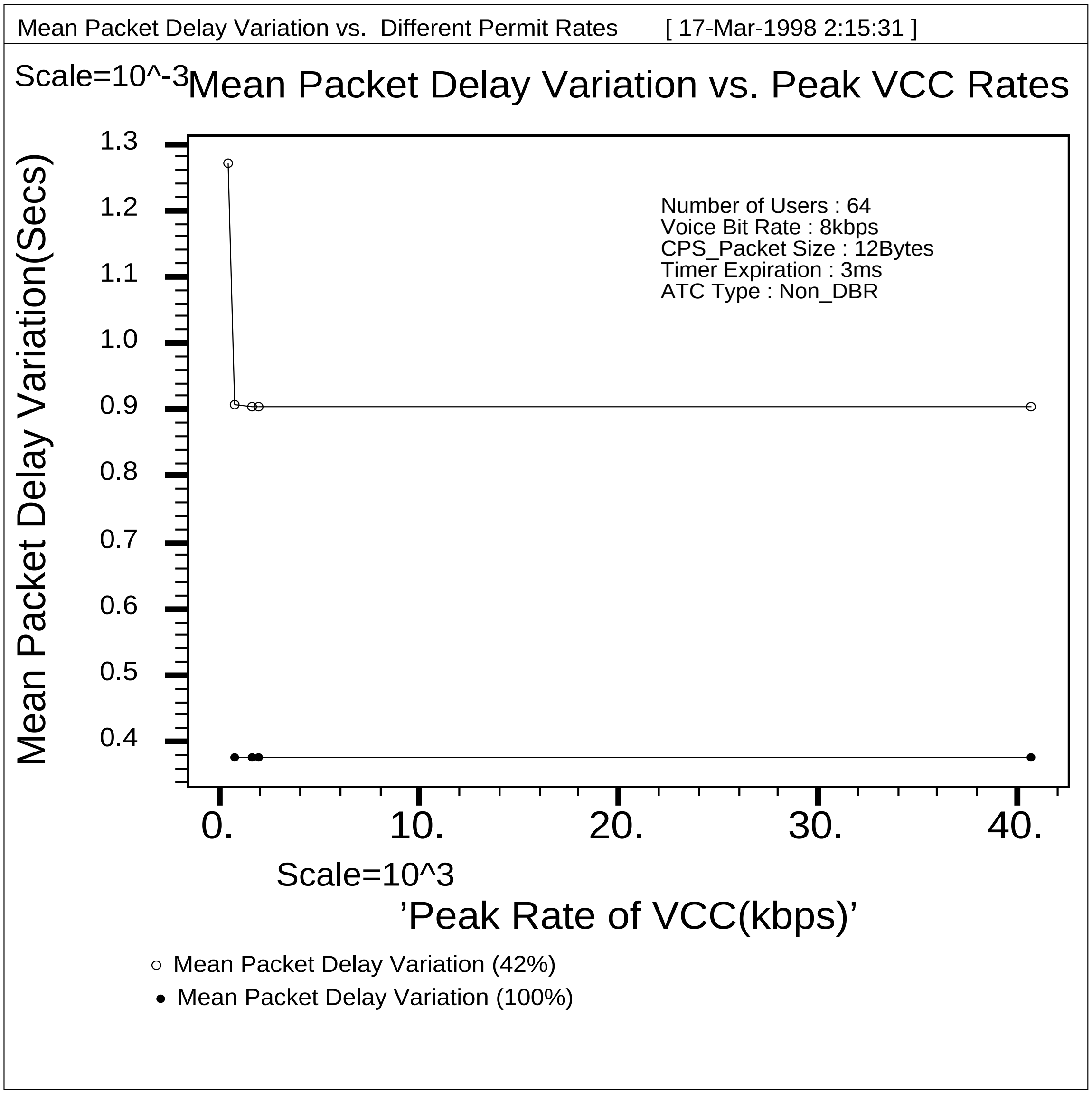

Figure 45: Mean Packet Delay Variation vs. Peak VCC Rates : Non_DBR

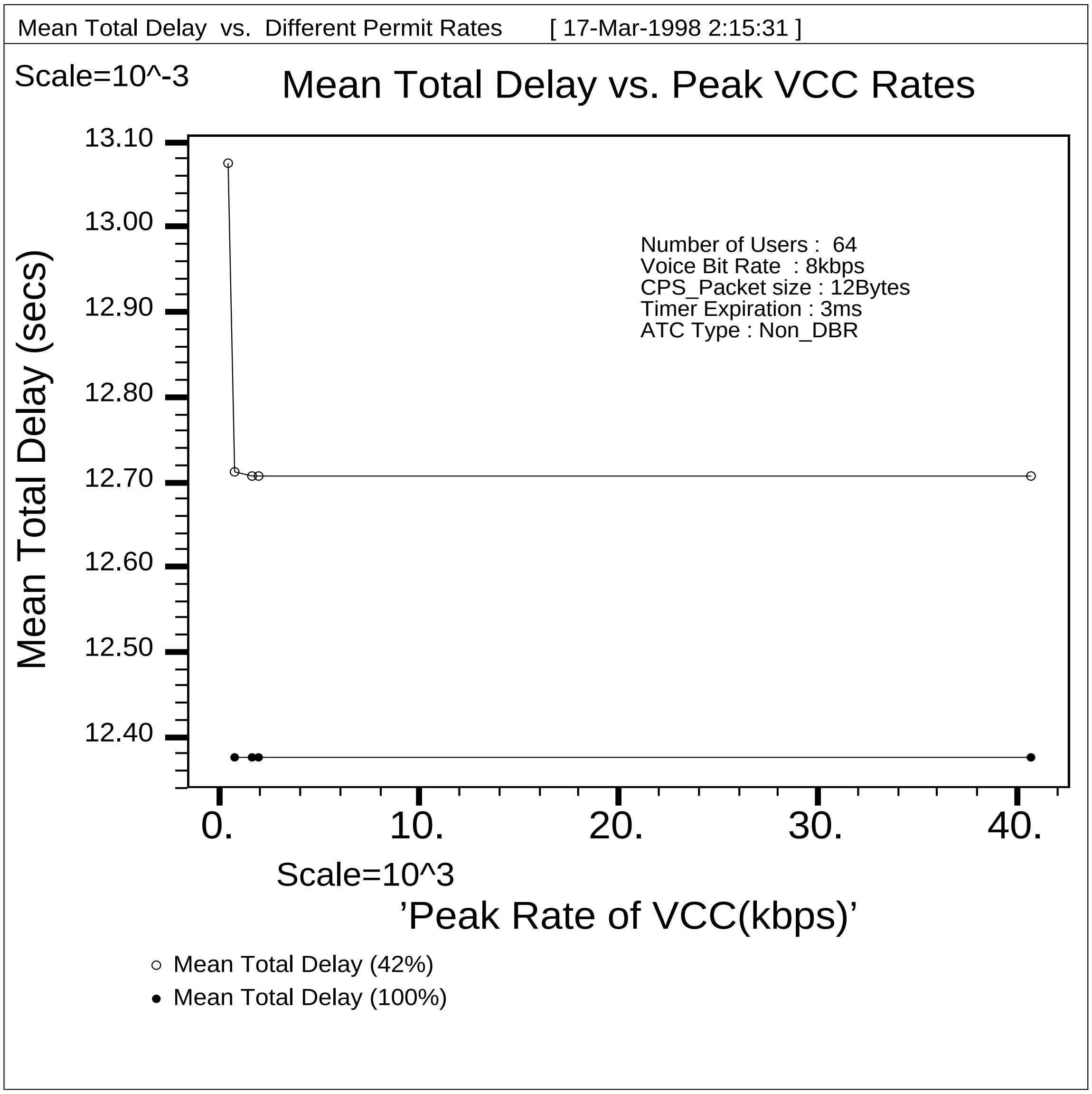

Figure 46: Mean Total Delay vs. Peak VCC Rates :Non_DBR

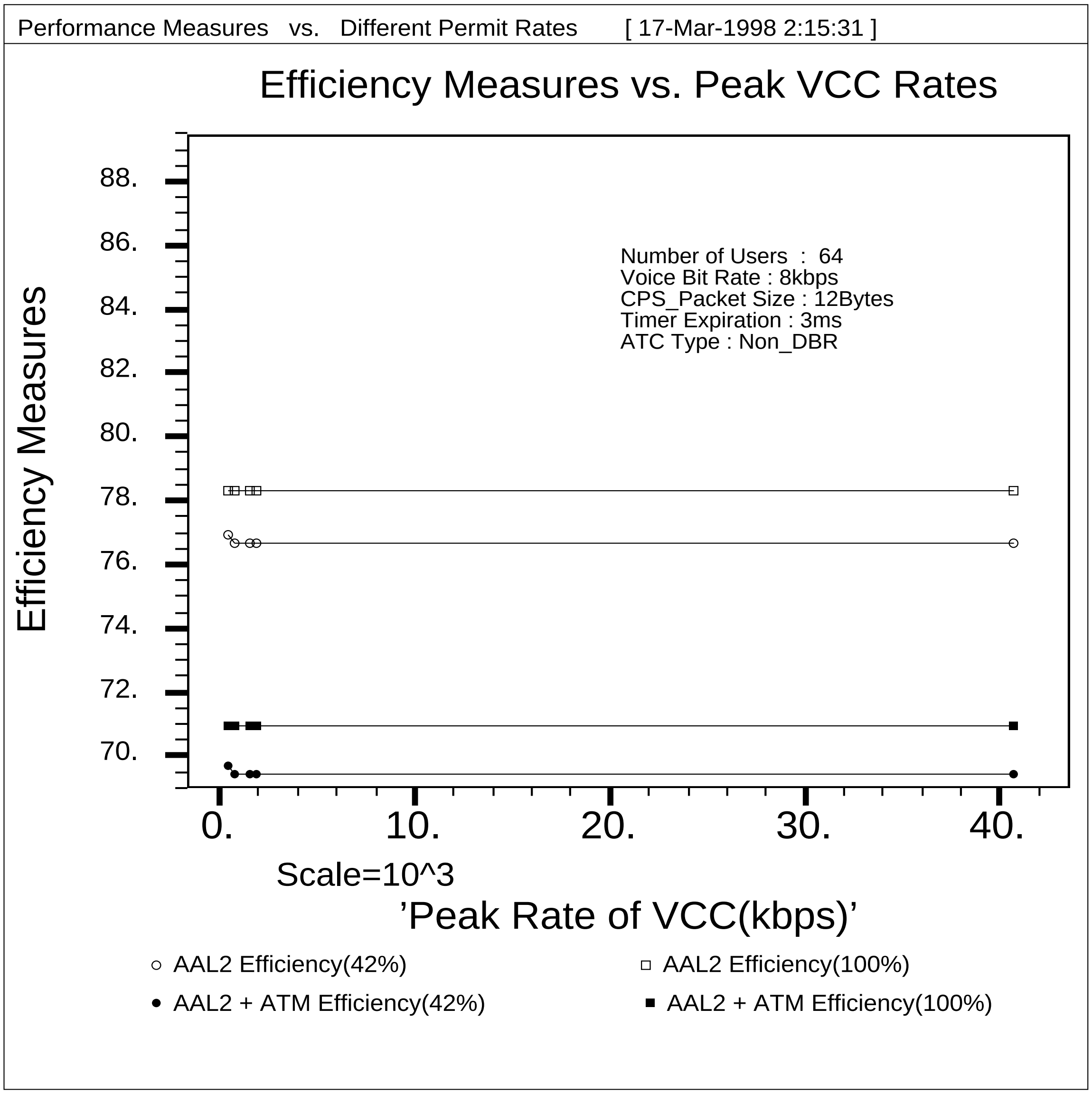

Figure 47: Performance Measures vs. Peak VCC Rates : Non_DBR

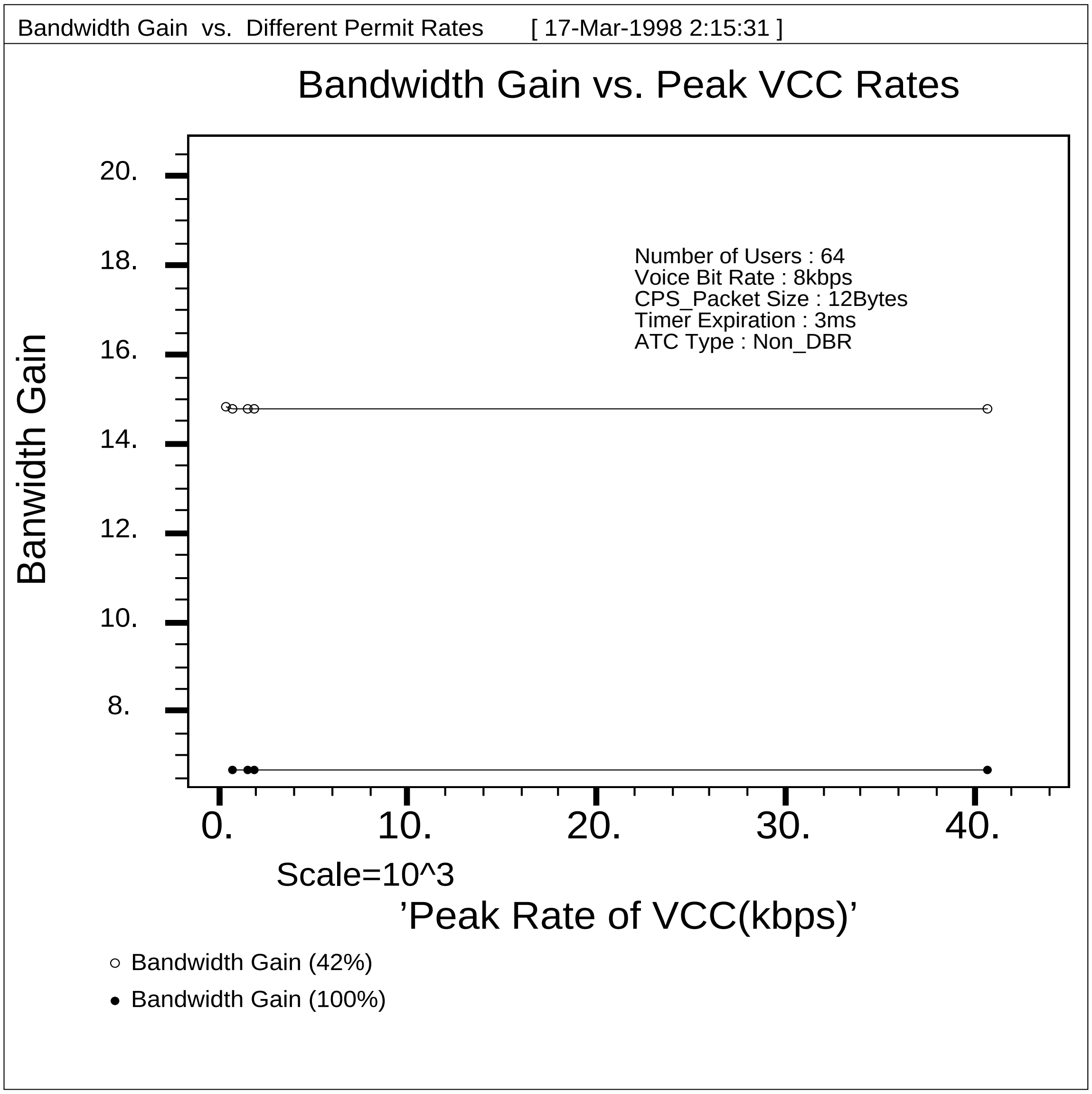

Figure 48: Bandwidth Gain vs. Peak VCC Rates : Non_DBR

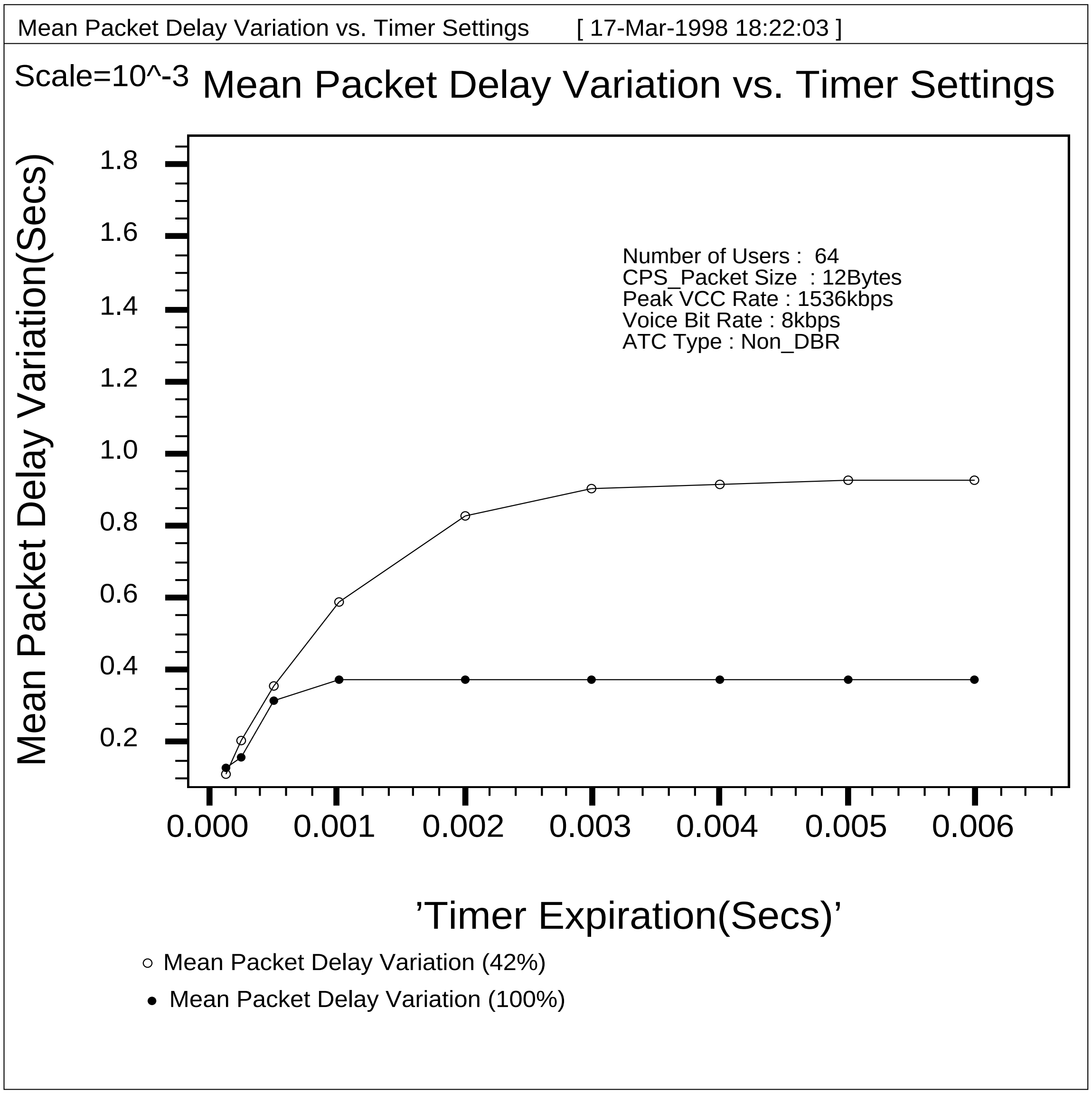

Figure 49: Mean Packet Delay Variation vs. Timer_CU Values : Non_DBR

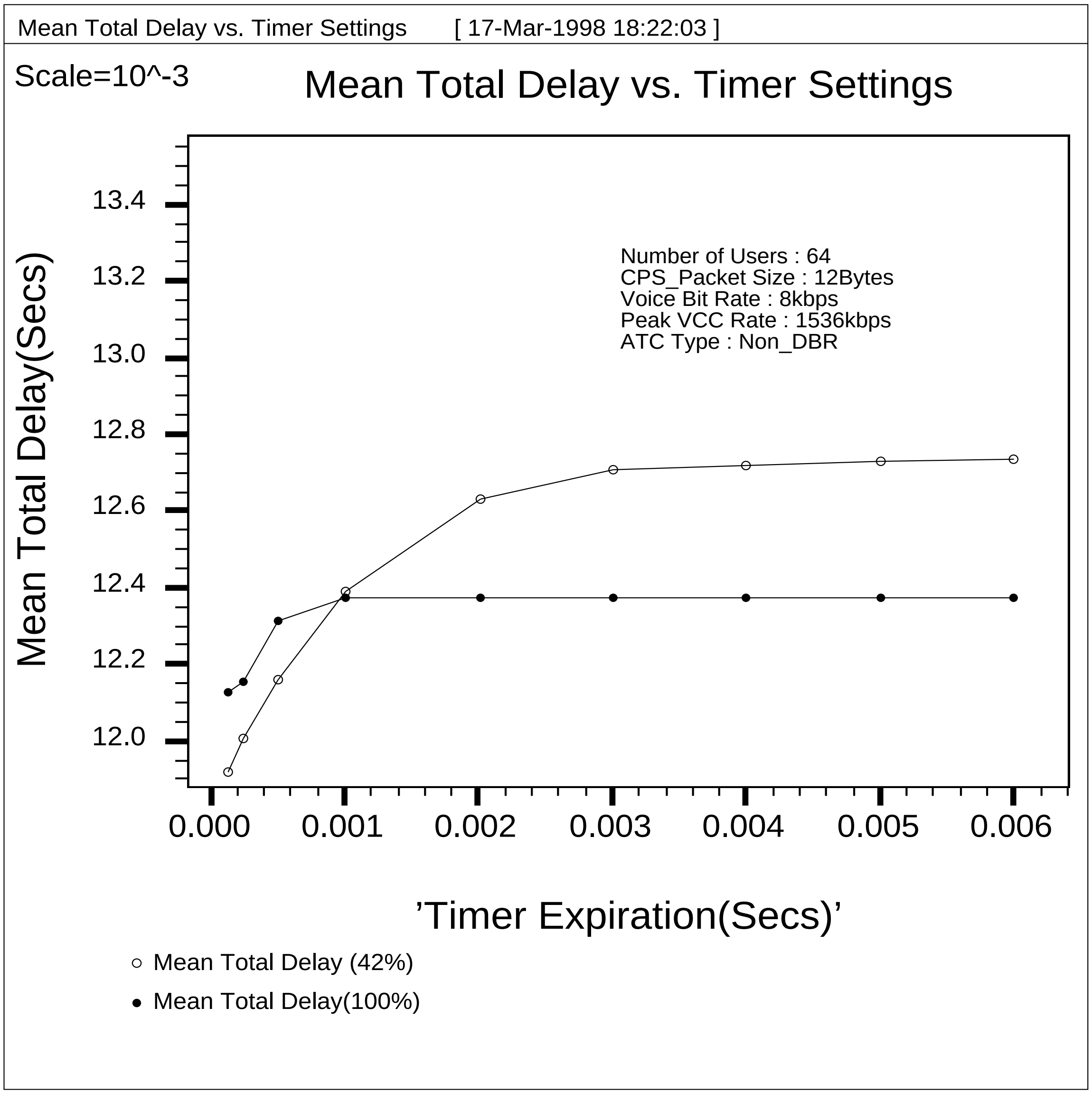

Figure 50: Mean Total Delay vs. Timer_CU Values : Non_DBR

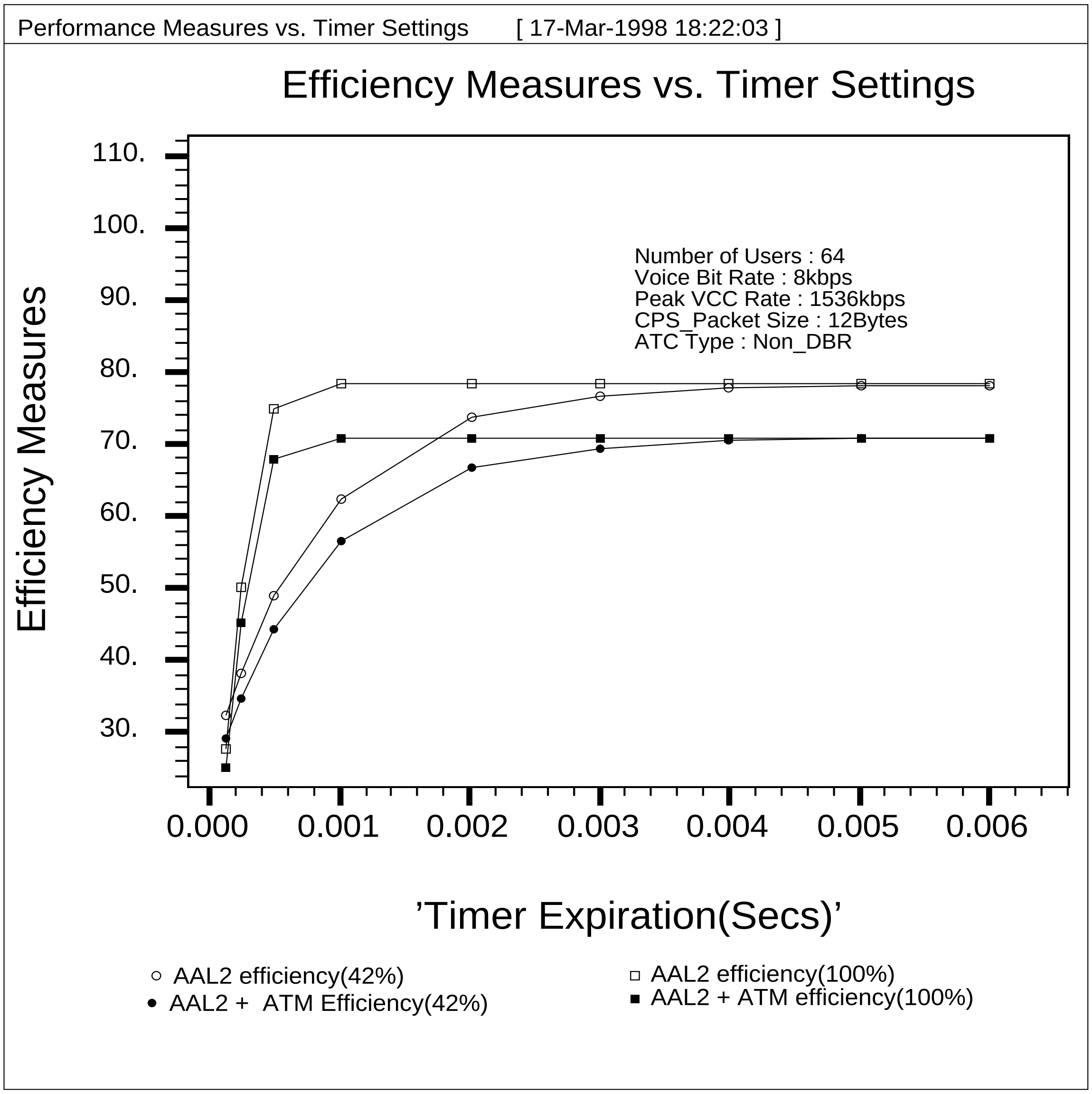

Figure 51: Efficiency Measures vs. Timer_CU Values : Non_DBR

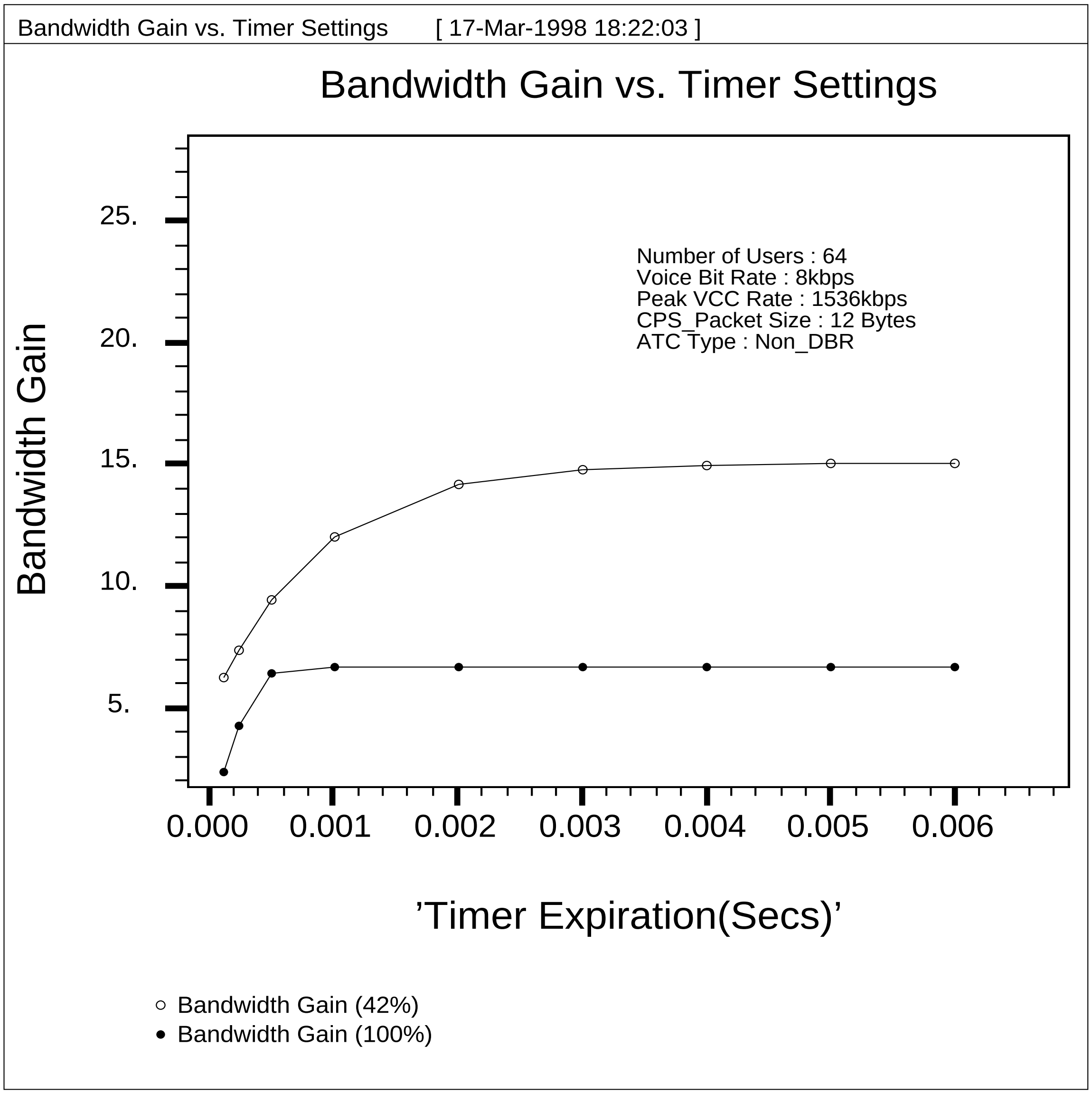

Figure 52: Bandwidth Gain vs. Timer_CU Values : Non_DBR

7.6 Plots for Different Timer_CU Values

Figures. 49 through 52 show the performance characteristics when the timer values are varied. All plots are for the Non_DBR case, since the timer value does not affect performance in the DBR case (which has been verified via simulation). Since the timer limits the maximum delay inside the transmitter, the mean packet delay variation in each case is less than the timer expiration value. The permit arrival would have a greater impact on the packet delay variation when the timer value is smaller than the inter-arrival time between the permits. The same can be observed Figure 49. (PDV), where PDV is larger than the timer value only when the timer value (0.1ms) is less than the permit inter-arrival time (0.276 ms). For speech activity factor of 100%, the delay experienced inside the transmitter asymptotes to a value determined as follows for approximately 100% speech activity. There are 3 CPS_Packets per ATM cell. One must wait for 1 CPS_Packet arrival (12/64 ms), one must wait twice this time and the third must wait three times this time. The mean CPS_Packet delay is thus approximately,

$$\frac{1}{3} * \frac{12}{64}(1+2+3) = 0.38ms \tag{15}$$

For 42% speech activity, the CPS_Packet delay asymptotes to approximately $\frac{0.38}{0.42} = 0.9ms$. The mean total delay (Fig.50) follows the same pattern as that of the mean packet delay variation since it is the sum of the packet delay variation and the packetization delay, which depends only on the voice bit rate. It can seen from Fig 51, as the timer values are increased the AAL2 and AAL2 + ATM efficiencies increase and reach their maximum possible values (80% and 70/9% respectively) for all the timer values greater than 5ms for 42% speech activity and 0.5ms for 100% speech activity.

8 Conclusions

- The CPS_Packet mean total delay and mean packet delay variation (PDV) for the ATC type Non_DBR is greater than that experienced in the case of DBR type. This delay penalty is balanced by larger values of efficiency and bandwidth gain for Non_DBR. This is the fundamental trade off associated with the Timer_CU.

- The packet delay variation i.e the delay experienced inside the transmitter is limited by the value of the Timer_CU value, as should be. This enables restricting the delay inside the transmitter to an acceptable value and also improving the packing efficiency.

- Smaller CPS_Packet sizes will result in lower end-to-end delay as compared to that of the larger CPS_Packets, but would result in poor AAL2 and AAL2 + ATM efficiencies, given the ATC type is Non_DBR. Hence smaller CPS_Packets may be used where delay is the primary consideration and not the bandwidth utilization. In the cases where bandwidth efficiency is very important, larger CPS_Packets can be used.

- Delay experienced inside the transmitter (PDV) is usually very small in the case of DBR. For lightly loaded VCCs, PDV is primarily determined by permit inter-arrival time.

- With the increase in Timer_CU value the AAL2 and AAL2 + ATM efficiencies steeply increase and reach a maximum after a certain threshold value. This threshold value depends on a number of factors for example the % load on the VCC, inter-arrival time between the permits.

- The effectiveness of the timer to bound the delay experienced inside the transmitter is limited by the inter-arrival time between the permits.

- AAL2 and AAL2 + ATM efficiency decrease steeply with the increase in the peak VCC rates, for ATC type DBR while for Non_DBR the efficiencies are close to maximum. This is due to the presence of Timer_CU. Thus for higher efficiency the introduction of Timer_CU is essential.

- With increase in voice bit rate, and Non_DBR operation mean total delay decreases because the packetization delay decreases. However PDV increases slightly for DBR due to the arrival of CPS_Packets at a faster rate. For Non_DBR, PDV also decreases with increasing voice bit rate.

- With the increase in VCC load (e.g., increase in number of users), efficiencies and bandwidth gain close to maximum can be achieved.

- In the case of inter-working with wireless systems, the mean total delay will depend on the packet size particular to the wireless coding scheme.

- For the ATC type DBR with the increase in number of users better bandwidth utilization can be achieved. However this would also mean there would be a slight increase in the end-to-end delay experienced by the CPS_Packets.

- For Non_DBR operation and a given Timer_CU value, an optimal number of users can be found in the sense of minimizing delay and maximizing efficiency.

9 References

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4. ATM forum Contribution ATM-f/96-1134

5. ATM forum contribution ATM-f/96-1330

6. ATM Forum Contribution ATM-f/97-0575

7. ATM Forum contribution ATM-f/97-0513

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