%m!<%+%k%a%b%j$r8zN(E*$K;HMQ9k$?$a$N!" %^%k%A%8%g%V EULASH %+!<%M%k$N<BAu!&I>2A

;38} 4n90　54F, 9(9,　;3K\ =_Fs　E7Ln 1Q@2

7DXf5A=NBg3XM}9)3XIt

EULASH $O!"%m!<%+%k%a%b%j$r;}$D6&M-%a%b%j7?JBNs7W;;5!$K$*$$$F!"3F%a%b%j$rM-8z$K;H$$J, 1k3H$G%"%W%j%1!<%7%g%s%W%m%0%i%`$N9bB.2=$r9TJ&$?$a$N%=%U%H%&%'%"4D6-$G$"$j!"%3%s%Q%
%i$*$h$S%+!<%M%k$+$i9=@.$5lk!#

EULASH %7%9%F%`$NCf$G!"%+!<%M%kIt$O3F%8%g%V$N9bB.<B9T$r$J$k$Y$/K8$2$:$KJ#?t$N%8%g%V$r 4IM}$9$kI,MW$,$"$k!#K\Js9p$G$O!"%P%C%A=hM}$*$h$S%.%c%s%0%9%1%8%e!<%j%s%0$N 2 <oN`$N%^%k%A%8% %V4IM}J}<0$rMQ$$$F!"%9%$%C%A7k9g7?%^%k%A%W%m%;%C%5 SNAIL >e$K EULASH %^%k%A%8%g%V%+!<%M %k$r<BAu$7I>2A7?!#

%P%C%A=hM}$GJ#?t$N%8%g%V$r<B9T$7$?7k2L!"%8%g%VC1BN$N<B9T;~4VNCYl$O 0.2%DxEY$G$"$C$?!#

%+!<%M%k, %^%k%A%W%m%;%C%5, %^%k%A%8%g%V4IM}, %m!<%+%k%a%b%j

Implementation and Evaluation of the Multi-job EULASH Kernel for Efficient use of Local memory

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Keio University

The EULASH is a software environment which improves the execution time of parallel application programs by making the best use of the memory structure of multiprocessors with local memory.

The multi-job management of the EULASH kernel is designed so as not to interfere the execution of single job. Here, two policies (batch processing and gang scheduling) are introduced and evaluated on a switch connected multiprocessor SNAIL.

When batch processing is used, the overhead of the execution time for running multiple jobs is only 0.2% compared to the cost of the single job.

Kernel, Multiprocessor, Multi-job management, Local memory

1 O8aK

8=:_!"7W;;5,LO$N3HBg$KH<$$JBNs7W;;5!$NI,MW@-$,9b$^$C$F$$$k!#JBNs7W;;5!$N9=@.$OB?<oB?MMG"k,!"CfGb!"A4FN%W%m%;%C%5$,%"%/%;%9$9k3HNG-$k6&M-%a%b%j$r;}$D9=@.$O!"9=B$$,4JC1G"$j!"C`<!7?$N1dD9H7$F%W%m%0%i%_%s%0$9k3H,G-k?$a>&MQ2=$7Ia5Z7F$$$kbN$bB?$$!#

7+$7!"$3Nh$&$J9=@.GO!"7W;;5!$,Bg5,LO$KJlPJk[$I!"3F%W%m%;%C%5$N6&M-%a%b%jXN%"%/%;%9;~4V$,Bg$-$/$JCF7^$&$H$$$&LdBj$,$"$k!#$=3G!"3F%W%m%;%C%58GM-$K%"%/%;%92DG=$J%m!<%+%k%a%b%j$r;}$D9=@.$,!"Bg5,LOJBNs7W;;5!$NM-NO$J8uJd$H7FCmL\$5lF$$$k!#

3Nh&$J9=@.$G$O!"%m!<%+%k%a%b%j$H6&M-%a%b%j$H$$$& 2 DN%a%b%j$r;H$$J,1k3H$,=EMW$HJk!#$=$3$G!"$3Nh$&$JJBNs7W;;5!K*$$$F!"2 DN%a%b%jr&$^$/;H$$J,$1!"%"%W%j%1!<%7%g%s$N=hM}B.EY$r9bB.2=$9k?aN%W%m%0%i%_%s%04D6- EULASH(Environment for Using Local And SHared memory)[1] $,Ds0F$5lF$$$k!#

EULASH %7%9%F%`$O!"%3%s%Q%$%i!&%i%$%V%i%j!&%Q!<%M%k$+$i9=@.$5$l$F$$$k!#EULASH %7%9%F%`$O%P%C%/%(%s%I$N4D6-K*$$$F%8%g%V$r9bB.$K=hM}9k3H$rL\E*$H7F$$$k$?$a!"%+!<%M%kItJ,$O%"%W%j%1!<%7%g%s$N<B9TrJkY$/K8$2$J$$$h$&$J9=@.rHkI,MW,$"$k!#$=$N$?$a!":#$^$G$N%+!<%M%k$O%7%s%0%k%8%g%V$r4IM}$9kbNG$"$C$?!#$7$+$7!"7W;;5!$,Bg5,LO2=$9kK=>$$!"%8%g%V$r<B9T$7$F$$$J$$%W%m%;%C%5$,B??tB8:_$9k3H,9M$($ilk!#$=$3$G!"K\Js9p$G$O EULASH $N4pK\J}?K$r0];}7?$^$^J#?t$N%8%g%V$r4IM}9kh&$J%+!<%M%k$N<BAuJ}K!H7$F!"%P%C%A=hM}!&%.%c%s%0%9%1%8%e!<%j%s%0$r:NMQ$7!"@-G=$K4X$9$kI>2A$r9TC?!#

2 EULASH %7%9%F%`

%m!<%+%k%a%b%j$r;}$D6&M-%a%b%j7?JBNs7W;;5!K*$$$F$O!"%m!<%+%k%a%b%j$O6&M-%a%b%jKHfY9bB.$K%"%/%;%9$,2DG=G"$k!#

$=$3G3Nh$&$J7W;;5!K*$$$F$O!"3F%W%m%;%C%5$,FH<+$K;HMQ$9$k%G!<%?$r%m!<%+%k%a%b%j$K!"A4%W%m%;%C%5$,%"%/%;%9$9$k%G!<%?$r6&M-%a%b%j$KCV$/$3HG!"%"%W%j%1!<%7%g%s$r9bB.$K<B9T9k3H$,$G$-$k!#EULASH %7%9%F%`GO!"%G!<%?$N:GE,$JG[CVr9k3HG!"%"%W%j%1!<%7%g%s$N@-G=8~>e$rL\;X7F$$$k!#

2.1 9=@.C10L

EULASH %7%9%F%`$O0J2<$N 3 $D$+$i9=@.$5$l!"$=$l$>$l$,6(D4$7$F%7%9%F%`$r7A:n$C$F$$$k!#

- %3%s%Q%$%i

  %G!<%?$N6I=j@-(%W%m%;%94V$G$N6&M-4XO")$r2r@O$7!"3F%G!<%?$r%W%m%;%94V$G6&M-$5lk%0%m!<%P%k%G!<%?$H%W%m%;%98GM-$N%m!<%+%k%G!<%?$KJ,N`$7!"%G!<%?G[CV$N:GE,2=$r9T$&!#

- %i%$%V%i%j

  %7%9%F%`%3!<%k$NH/9T$O%*!<%P%X%C%I$,Bg$-$$$?$a!"F14|4X?t$dGSB>@)8fMQ4X?tEy$N%f!<%6%b!<%I$G$N<BAu(<B9T)$,2DG=$JJBNs=hM}5!G=$rDs6!9k!#

- %+!<%M%k

  %8%g%V4IM}!&%W%m%;%94IM}!&%a%b%j4IM}Ey$N:GDc8B$N=hM}$r9T$&!#

3Nh&$J4D6-$NCf$G!"%f!<%6%W%m%0%i%`$O:GE,$J%G!<%?G[CV$,9Tol!"9bB.$K<B9T$5lk!#

2.2 EULASH %+!<%M%k

2.2.1 =hM}C10L

%+!<%M%kNCfG0J2<$N 3 D,=hM}C10LH7$FDj5A$5lF$$$k!#

- %8%g%V

  %"%W%j%1!<%7%g%s%W%m%0%i%`$KAjEv$9$k=hM}C10L

- %W%m%;%9

  3F%W%m%;%C%5$K3d$jEvFilk=hM}C10L
  %W%m%;%94V$G%0%m!<%P%k%G!<%?$r6&M-9k

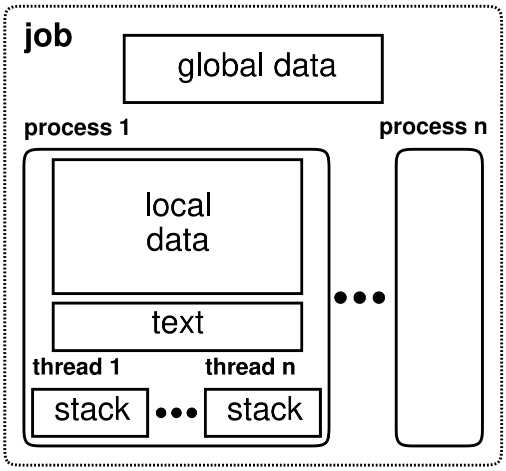
- %9%l%C%I

  %9%1%8%e!<%j%s%0$NBP>]$HJk<B9T<gBNF10l%W%m%;%9FbGOA4%a%b%j6u4V$r6&M-

3F=hM}C10L$N%G!<%?6&M-4X78$O?^ 1Nh$&$KI=$9$3H,G-$k!#

2.2.2 5!G=

EULASH %7%9%F%`$K$*$$$F!"%7%9%F%`%3!<%kJI$N=E$$=hM}rHr1k?af!<%6%l%Y%k$G%5%]!<%H2DG=$JbN$O6KNO%i%$%V%i%jKh$jDs6!$7!"%+!<%M%k$O:G>.8B$N5!G=N_$r;}$DbNH7$?!#<g$J!"%+!<%M%k$N5!G=$O0J2<NH$*$jG"$k!#



?^ 1: 3F=hM}C10L4V$N%G!<%?6&M-4X78

%8%g%V4IM}: J#?t$N%8%g%V$r:GBg8B$K<B9T$9k?aN4IM}$r9T$&!#

%W%m%;%94IM}: %W%m%;%9$r@8@.$7$?$j>CLG5;k?aN4IM}$r9T$&!#

%9%l%C%I4IM}: %9%l%C%I$r@8@.!&>CLG!&CfCG$9k?aN4IM}$^$?$O%9%1%8%e!<%j%s%0$r9T$&!#

%a%b%j4IM}: %m!<%+%k%a%b%j$r2>A[2=$9$k!#

3 %^%k%A%8%g%V$N4IM}J}K!

7W;;5!5,LO$,Bg$-$/$JlPJk$[$I!"0lDN%8%g%V$,;HMQ$9$k%W%m%;%9?t$OA4BN$N%W%m%;%C%5?t$KBP7F>.5/Jk!#$=$3$G!"6u$-%W%m%;%C%5$KB>$N%8%g%V$r3d$jIU1k3H$G%W%m%;%C%5$N;HMQ8zN(r"2k3H$,$G$-$k!#7+$7!"$=N?aK$OJ#?t$N%8%g%V$r4IM}$9kI,MW,$"$k!#

3.1 4IM}J}K!

J#?t$N%8%g%V$r4IM}9kK"$?$j!"%+!<%M%k$,$JkY$/%8%g%V$N<B9T$rK8$2k3H,$J$$$h$&$K9kKO!"TSS(%?%$%`%7%'%"%j%s%0%7%9%F%`)$Nh&$JIQHK$K%+!<%M%k$,2pF~$9$k%8%g%V4IM}J}K!$OE,5J$$!#$=$3$G!"%P%C%/%(%s%I$N4D6-K*1k=>Mh$N<g$J%8%g%V4IM}J}K!G"$k0J2<$N2DNJ}K!$r:NMQ$9$k!#

- %P%C%A=hM}
  EjF~5l$?%8%g%V$r%-%e!<$KJ]B8$7!"6u$-%W%m%;%C%5$,G-$?$H3m$G%W%m%;%C%5$K3djEvF$kJ}<0
- %.%c%s%0%9%1%8%e!<%j%s%0 [3]
  TSSKHfY%?%$%`%9%i%$%9rBg-$/$9k3HG!"%+!<%M%k$N%*!<%P%X%C%I$r:G>.8BK9$k

3.2 %P%C%A=hM}Kh$k%^%k%A%8%g%V4IM}

%P%C%A=hM}$r:NMQ$7$?>l9g!"OS$N2pF~9k;~4V$,>/$J$/$F:Q$`$?$a!"%8%g%VC1BN$N<B9TB.EYXN1F6A$,>/$J$$$H$$$&MxE@$,$"$k!#$7$+$7!"%8%g%V$rEjF~$5l?=g$K<B9T$7$F$$$/NG!"M%@hEY$r@_Dj$9k3H,G-$J$$$JIN7gE@$,$"$k!#

3.2.1 %8%g%V$N3d$jIU$1

%8%g%V$,EjF~$5lk$H!"%+!<%M%k$Khj0J2<Nh$&$K=hM}$,$5lk!#

1. 0J2<$N2$D$N?t$rD4$Y!"Hf3S$9$k
   - $=$N%8%g%V$,@8@.$9$k%W%m%;%9?t (%f!<%6!&%3%s%Q%$%i$Khj;X<()
   - %"%$%I%k%W%m%;%C%5?t

   (1-a) (@8@.%W%m%;%9?t)!c(%"%$%I%k%W%m%;%C%5?t) %8%g%V$O<B9T$r3+;O$9$k

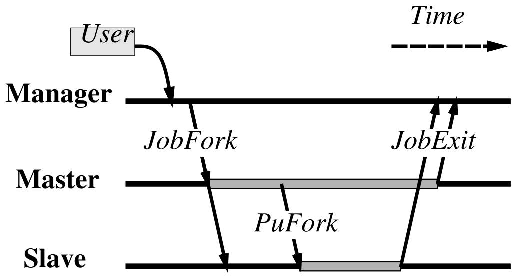
   (1-b) (@8@.%W%m%;%9?t)!d(%"%$%I%k%W%m%;%C%5?t) %8%g%V$N>pJs$r%8%g%V%-%e!<$KEPO?$7!"%8%g%VK\BN$r6&M-%a%b%j$KJ]B8$9$k
2. %8%g%V$N<B9T$,=*N;9k$H!"%8%g%V%-%e!<$rD4$Y!"%8%g%V%-%e!<$KEPO?5l$F$$$k%8%g%V$,<B9T2DG=$JiP<B9TrO8a$k

3.2.2 %8%g%V$N<B9TJ}K!

%8%g%V$r<B9T$9kK$"$?$j!"%W%m%;%C%5$r0J2<$N3$D$KJ,N`$9$k!#

- Manager
  %8%g%V$N4IM}!"$^$?$OB>$N%W%m%;%C%5$NF~=PNO$N4IM}$r9T$&%W%m%;%C%5!#
- Master
  %8%g%V$r<B9T$9$k%W%m%;%C%5!#Slave$r5/F0$9$k!#
- Slave
  Master$K$h$j5/F0$5lk%W%m%;%C%5!#

<B:]$N%8%g%V$N<B9TJ}K!$r?^2$K<($9!#$3$N?^$Nh&$K!"0l$D$N%8%g%V$,Manager$H Slave$Khj<B9T5l$k!#$^$?!"Manager$O%W%m%;%C%54V3d$j9~$_$r;H$$=hM}$NEAC#$r9k!#



?^ 2: %P%C%A=hM}Kh$k%8%g%V$N<B9TJ}K!

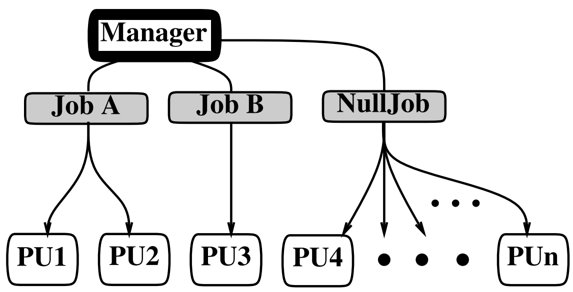
3.3 %.%c%s%0%9%1%8%e!<%j%s%0Kh$k%^%k%A %8%g%V4IM}

%.%c%s%0%9%1%8%e!<%j%s%0Kh$k4IM}K!$O!"%8%g%V$K M%@hEY$r@_DjG-!"5i$K%9%1%8%e!<%j%s%0J}K!$KhC FO:GE,$J%8%g%V$N3djIU1$,$G$-$k$H$$$&MxE@$,$" $k!#$7$+$7!"OS $N2pF~$9$k3d9g$,B?$/$Jk?$a!"%8%g %V$N<B9T;~4V$,A}2C$9k3H,9M$($ilk!#

3.3.1 %8%g%V$N3d$jIU$1

Manager $,%8%g%V$N4IM}r7!"time slice Kh$K3F%W%m %;%C%5$KIN%8%g%V$r3d$jEvFk$+7hDj$9$k!#3d$jEv Fk%8%g%VNJ$$%W%m%;%C%5KO “2?b7$J$$%8%g%V” (null job) $r3d$jEvFk!#

%8%g%V$N3d$jIU1r?^ 3$K<($9!#



?^ 3: %.%c%s%0%9%1%8%e!<%j%s%0Kh$k%8%g%V$N3djIU1

3.3.2 %8%g%V$N<B9TJ}K!

%8%g%V$,EjF~$5lk$H!"%8%g%V$N>pJs$O%8%g%V%-%e!< $KEPO?$5lk!#time slice Kh$KK,$l$k%9%1%8%e!<%j%s%0 Kh$j7hDj$5l?%W%m%;%C%5$O!"<!$N%8%g%V$,8=:_<B9T 7F$$$k%8%g%V$HF1$8G"lP$=$N$^$^<B9T$rB3$1!"0c $&$bNG$"$l$P<B9TCf$N%8%g%V$H>pJs$rB`Hr$7!"<!$N %8%g%V!&>pJs$r%m!<%I$7<B9T$r3+;O$9$k!#

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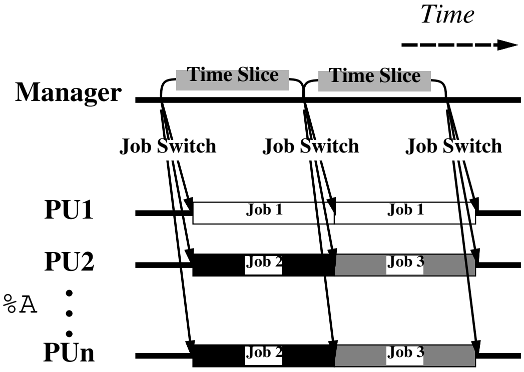


?^ 4: %.%c%s%0%9%1%8%e!<%j%s%0Kh$k%8%g%V$N<B9TJ}K!

3.3.3 %8%g%V$N@ZBX$(

%+!<%M%kO"$k time slice Kh$K%8%g%V$N@ZBX$($rDLC# 9k$,!"@ZBX$($rDLC#$5l?%W%m%;%C%5$O!"$=$N%8%g%V HV9f$H8=:_<B9T5l$F$$$k%8%g%V$N%8%g%VHV9f$rHf3S $7!"0[$J$k>l9g$K$O%8%g%V$N@ZBX$($r9T$&!#

B`Hr9k%8%g%V$N>pJs$r0J2<$K<($9!#

!& HFMQ%l%8%9%?
!& %W%m%0%i%`%+%&%s%?!"%9%?%C%/%]%$%s%?
!& FC<l%l%8%9%?
!& %+!<%M%k$G;HMQ$9$k>pJs
!& %9%?%C%/%U%l!<%`
!& %f!<%6$K3d$jEvF?%a%b%jNN0h
!& %8%g%V$N%G!<%?NN0h

5i$KI|85$9$k%8%g%V$N>pJs$r0J2<$K<($9!#

!& B`Hr7?>pJs
!& %8%g%V$N%F%-%9%HNN0h

3.3.4 %9%1%8%e!<%j%s%0

<!$N%8%g%V$rA*Br9k$?$a$N%9%1%8%e!<%j%s%0J}K!$H 7F0J2<$NJ}K!$r$"$2$k!#

- %i%&%s%I%m%S%s
  %8%g%V%-%e!<$N@hF,$+$i=g$K%W%m%;%C%5$K3d jEvF$F$$$/J}K!!#@8@.%W%m%;%9?t$,6u$-%W %m%;%C%5?t$r1[$($?$i=*N;!#

— 6u$-%W%m%;%C%5$,B?$/$J$k798~$,$"$k!#

- %U%!!<%9%H%U%#%C%H
  - %8%g%V%-%e!<$N@hF,$+$i=g$K:G8e$N%8%g%V$^$GD4$Y$F3d$jEvFkJ}K!!#
  - @8@.%W%m%;%9?t$N>/$J$$$bN,M%@hE*$K3d$jEvFilk!#
- M%@hEYIU$-%U%!!<%9%H%U%#%C%H
  - %U%!!<%9%H%U%#%C%H$KM%@hEY$rIU1k3H$G!6QEy$J%8%g%V$N3dEv$r9T$&J}K!!#

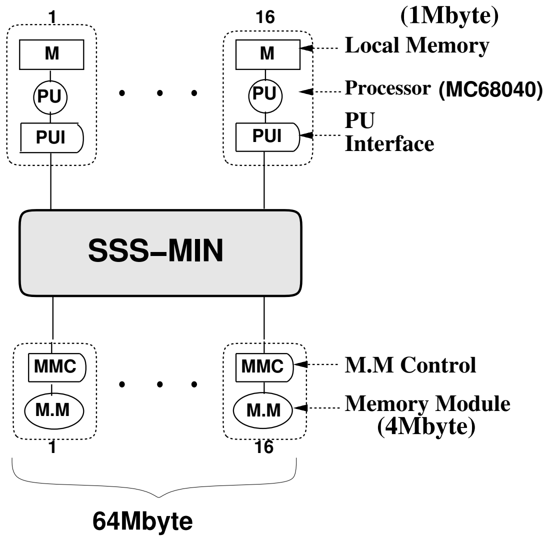
4 I>2A

%P%C%A=hM}!"%.%c%s%0%9%1%8%e!<%j%s%0Kh$k%^%k%A%8%g%V%+!<%M%k$r<BAu$7!"I>2A$r9TC?!#

4.1 %?!<%2%C%H%^%7%s

%9%$%C%A7k9g7?%^%k%A%W%m%;%C%5 SNAIL[8] >e$K%+!<%M%k$r<BAu7?!#$^$?B,DjKO%/%m%C%/<~GH?t 1MHz $N%?%$%^$r;HMQ$7$?!#

SNAIL(SSS Network Architecture ImpLementation) $N9=B$$O?^ 5Nh$&$KJC$F$$$k!#



?^ 5: SNAIL $N9=B$?^

%m!<%+%k%a%b%j$r;}$D 16 8D$N%W%m%;%C%5$H 16 8D$N6&M-%a%b%j%b%8%e!<%k$,SSS-MIN rDL7$F@\B3$5lF$*$j!"A4FN%7%9%F%`%b%8%e!<%k$O%7%9%F%`%/%m%C%/ (12MHz) $H!"F14|A`:n$N$?$a$N%U%l!<%`%/%m%C%/(12/16=0.75MHz) $r6&M-$7$F$$$k!#

3F%f%K%C%H$O0J2<$Nh&KJCF$$$k!#

%W%m%;%C%5It: Motorola <R$N MC68040 $r;HMQ$7!"SSS-MIN $G;HMQ$5lk%/%m%C%/ (12MHz) $rA4%W%m%;%C%5$N%7%9%F%`%/%m%C%/H7$F;H$C$F$$$k!#3F%W%m%;%C%5$O1Mbyte $N%m!<%+%k%a%b%j$r;}CF$$$k!#

%a%b%j%b%8%e!<%k: 16 8D$N 4Mbyte $N DRAM Kh$j!"64Mbyte $N6&M-%a%b%j6u4V$r7A@.7F$$$k!#%a%b%jXNF14|A`:nH7$F!"Test&Set!&Fetch&Dec $,MQ0U$5lF$$$k!#

- **Read:** %W%m%;%C%5$O%G!<%?$,%a%b%j$+$iFI$_$@5lk^$GBT5!$7J1lPJi$J$$!#

- **Write:** %W%m%;%C%5$O packet buffer(2 packet) $,6u$$$F$$$kJi!"$9$0$K<!$NL?Na$r<B9T$9k3H,G-$k!#

- **Prefetch:** %W%m%;%C%5$O<!$NL?Na$r<B9T$9k3H,G-$k!#%G!<%?$O prefetch buffer(2 word) $KE>Aw$5lk!#

- **Synchronization:** Test&Set!&Fetch&Dec A`:n$,S-NAIL GO%5%]!<%H5l$F$$$k!#Test&Set $O MIN $NFbIt$G%3%s%P%$%s$5lk!#

SNAIL $N%"%/%;%9=jMW;~4V$rI=1$K<($9!#

%m!<%+%k%a%b%j	333nsec
6&M-%a%b%j$N 32bit data FI$_=P$7	2667nsec

I=1: SNAIL $N%"%/%;%9=jMW;~4V

4.2 =hM}B.EY$NB,Dj

0J2<$N%+!<%M%k$N=hM}B.EY$NB,Dj$r9TC?!#

- %8%g%V$N5/F0;~4V
- %W%m%;%9$N@8@.;~4V
- %9%l%C%I$N@8@.!&%3%s%F%-%9%H%9%$%C%A
- %.%c%s%0%9%1%8%e!<%j%s%0K*1k%8%g%V$N@ZBX$(;~4V

4.2.1 %8%g%V$N5/F0;~4V

%8%g%V$N5/F0$K$O "%"!<%.%e%a%s%H$NE>Aw", "%U%!%$%k>pJs$NJ]B8", "%8%g%V%F!<%V%k$N:n@." JI$r9T$$!"5i$K%P%C%A=hM}$GO=$N8e$K "<B9T%W%m%;%C%5$N7hDj!&DLC#" $r9T$&!#$=$liN;~4Vr^Ha$F%8%g%V$N5/F0;~4VH7!"$=$N;~4VrB,Dj7$?!#

	Batch	Gang
%8%g%V$N5/F0	84.9 msec	64.1 msec

%8%g%V$N5/F0$K$+$+$k;~4V$O!"$[$HsI$,%"!<%.%3%s %s%H$d%U%!%$%k>pJs!"%8%g%V$N>pJs$r6&M-%a%b%j$K=q$- 9~$`;~4VG"$k!#$=N?aK!"msec %*!<%@!<$N=hM}$K Jk$H9M$(il$k!#

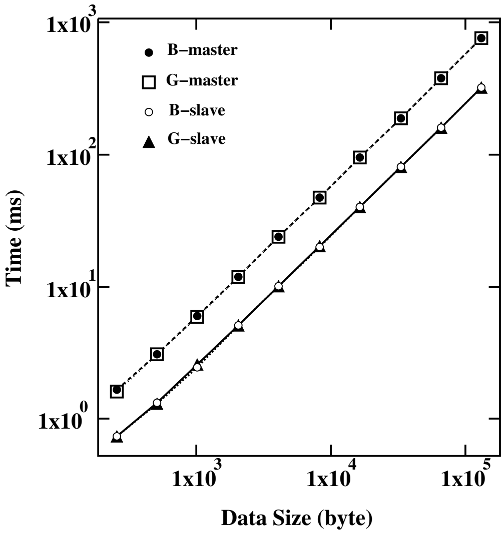
5i$K%P%C%A=hM}$G$O!"“<B9T%W%m%;%C%5$N7hDj!&D% C#” $NCJ3,$G$b5/F0$9k?aN>pJs$r!"6&M-%a%b%j$rDL 7F<B9T%W%m%;%C%5$KEAC#$9kI,MW,$"$k$?$a!"%.%c%s %0%9%1%8%e!<%j%s%0KHfY$F;~4V$,$+$+CF7^CF$$$b NH9M$($ilk!#

4.2.2 %W%m%;%9$N@8@.;~4V

%W%m%;%9$N@8@.$9$k;~4V$rB,Dj7?!#%W%m%;%9$N@8 @.$O%G!<%?NN0h$r Master $+$i Slave $KEAC#$9kI,MW, $"$k$?$a!"6&M-%a%b%j$r2p$7$F%G!<%?NN0h$N%3%T!<$r 9T$&!#

7k2L$r?^ 6$K<($9!#3F%0%i%U$O$=$l$>$l0J2<$rI=$7$F $$$k!#

- **B-Master:** %P%C%A=hM}Kh$k%W%m%;%9@8@.;~4V (Master $N=*N;;~4V)
- **B-Slave:** %P%C%A=hM}Kh$k%W%m%;%9@8@.;~4V (Slave $N=*N;;~4V)
- **G-Master:** %.%c%s%0%9%1%8%e!<%j%s%0Kh$k%W %m%;%9@8@.;~4V (Master $N=*N;;~4V)
- **G-Slave:** %.%c%s%0%9%1%8%e!<%j%s%0Kh$k%W%m %;%9@8@.;~4V (Slave $N=*N;;~4V)



?^ 6: %W%m%;%9$N@8@.;~4V

3Na]!"Master(%G!<%?rAwkB&)$O6&M-%a%b%j$K%G!< %?$r=q$-!"$=$N8e$G Slave $,$=$N%G!<%?$rFI$`$H$$$C$? =hM}$r9T$&$?$a!"Slave B&$G$O Master $N@8@.;~4V$K$5 $i$K%G!<%?$rFI$`;~4VJ,$,2C;;5l$k!#

!"DL$i%W%m%;%9$N@8@.;~4V$OE>Aw$9$k%G!<%?$N%5%$%: $KHfNc$9k3H,o+$k!#

4.2.3 %9%l%C%I$N@8@.!&%3%s%F%-%9%H%9%$%C%A

%9%l%C%I$N@8@.$H%3%s%F%-%9%H%9%$%C%A$K$D$$$FB,Dj $r9T$C$?!#B,Dj$O%9%l%C%I$N@8@.!&%3%s%F%-%9%H%9%$%C %Ar=l>$l 100000 2s9T$$!"$=$NJ?6QrHC?!#

	Batch	Gang
%9%l%C%I$N@8@.	134.4 &L sec	141.5 &L sec
%3%s%F%-%9%H%9%$%C%A	66.2 &L sec	70.7 &L sec

%9%l%C%IKBP9$k=hM}NL$ON><T$GA4$/F1$8$G$"$kKb $+$+oi$:!"%9%l%C%I$N@8@.!"%3%s%F%-%9%H%9%$%C%A$H bK!"%.%c%s%0%9%1%8%e!<%j%s%0$NJ}$,!"B?>/;~4V$,$+ $+$C$F$$$k!#3l$O!"%.%c%s%0%9%1%8%e!<%j%s%0GO<B 9TCf$K%8%g%V$N@ZBX$($N$?$a$N3d$j9~$_$,$+$+CF7^ $&$?$a!"$=$N;~4VJ,$@$1=hM}$KCYl,=PF7$^$C$?$b$N $H9M$(il$k!#

4.2.4 %.%c%s%0%9%1%8%e!<%j%s%0%+!<%M%k>eGN%8%g %V@ZBX$(;~4V

%.%c%s%0%9%1%8%e!<%j%s%0K*$$$F%8%g%V$r@ZBX$($k :]$N;~4VrB,Dj7$?!#@ZBX$($k;~4V$O!"%G!<%?NN0h$d%9 %?%C%/NN0h$JINBg$-$5JIKh$jJQ2=$9kH;Wol$k NG!"A4FN%a%b%jE>Aw$N%G!<%?$r0l3gK7$F!"$=$N%5 %$%:KBP9$k@ZBX$(;~4V$r?^ 7$KI=7?!#

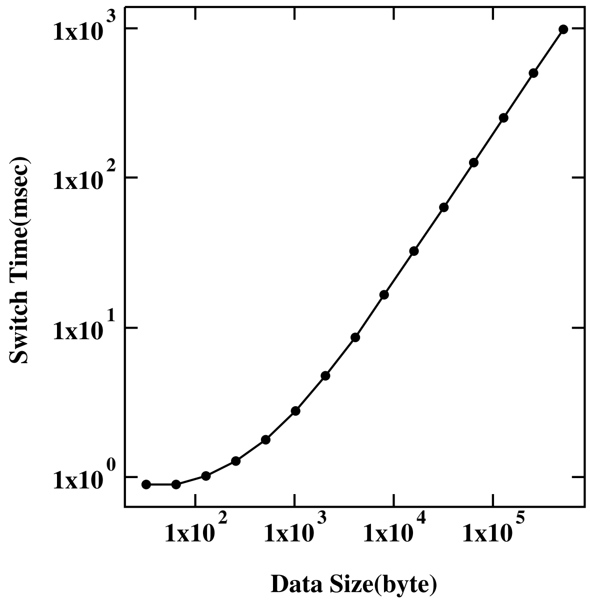
<B9T7k2L$+$iE>Aw9k%G!<%?$,>/$J$$$F$b!"@ZBX$(k?aK01Dj$N;~4V$,I,MW$@$H$$$&3H$,$o$+$k!#$^ $?!"1Kbyte 0J>e$N%G!<%?$,B8:_$9$k>l9g$K$O!"$[$\$= $N%G!<%?NL$KHfNc7F@ZBX$(;~4V$,$+$+kH$$$&3H$, o+$k!#

4.3 %"%W%j%1!<%7%g%sKh$kB,Dj

4.3.1 C10l%8%g%V$N<B9T7k2L

N-Queen LdBj$N2r$r5aak%"%W%j%1!<%7%g%s$r<B9T 7?>l9g$N<B9T;~4V$rB,Dj7?!#Queen ?t$O 16 $G<B9T r7$?!#

3N%"%W%j%1!<%7%g%s$r0J2<$N 5 DN>l9gKD$$$FB, Dj7?!#

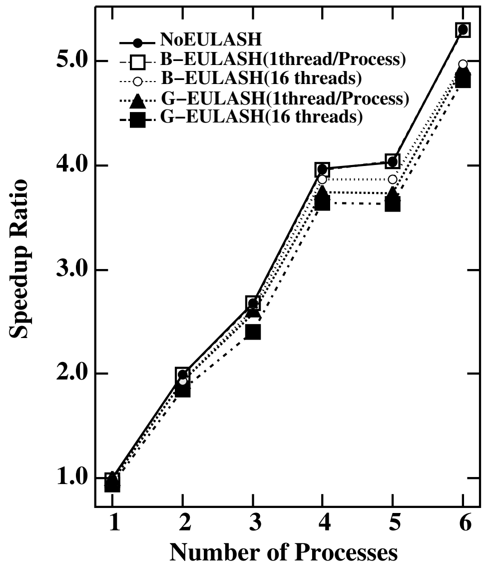


?^ 7: %8%g%V$N@ZBX$(;~4V

- **NoEULASH**
  %+!<%M%k$r;HMQ$7$J$$
- **B-EULASH(1 Thread/PU)**
  %P%C%A=hM}
  1 %W%m%;%C%5$K 1 %9%l%C%I$G<B9T
- **G-EULASH(1 Thread/PU)**
  %.%c%s%0%9%1%8%e!<%j%s%0
  1 %W%m%;%C%5$K 1 %9%l%C%I$G<B9T
- **B-EULASH(some Threads)**
  %P%C%A=hM}
  A4%W%m%;%C%5$K 16 %9%l%C%I;HMQ
- **G-EULASH(some Threads)**
  %.%c%s%0%9%1%8%e!<%j%s%0
  A4%W%m%;%C%5$K 16 %9%l%C%I;HMQ

7k2L$r?^ 8$K<($9!#$3$N?^$O NoEULASH $N 1PU $G $N<B9T;~4V$r4p=`H7$F!"3F<B9T;~4V$+$i%9%T!<%I%"%C %WN($r;;=P7F$$$k!#

%9%l%C%I$r@8@.$7$J$$$H$- (1 thread/PU) KO!"4p=` (NoEULASH) KBP7$F!"%P%C%A=hM}$N%0%i%UO[$\F1 $8%9%T!<%I%"%C%WN($rF@$F$$$k!#3l$O OS $,$[Hs$I %"%W%j%1!<%7%g%s$N<B9T$rK8$2$F$$$J$$$3Hr<(7F$$ $k!#$7$+$7!"%.%c%s%0%9%1%8%e!<%j%s%0$NJ}$G$O!"%+!< %M%k$r;HMQ7J$$$H$-$KHfYk$H%9%T!<%I%"%C%W$NA}2C



?^ 8: NQueen LdBjKh$k%9%T!<%I%"%C%WN(

$,>/$J$$!#3l$O!"Dj4|E* (time slice) $K@8$8$k%8%g%V $NF~$l49$($N=hM}$,1F6A$rM?$($F$$$k$H9M$(il$k!#

$^$?%9%l%C%I$r@8@.$7$?$H$- (some threads/PU) $K $O!"%9%l%C%I$r@8@.7J$$$H$-$KHf$Y!"%9%T!<%I%"%C%W N($,>.$5$$$3H,o+$k!#$3lOF14|A`:n$N;~$KH<$&!" %9%l%C%I$N%3%s%F%-%9%H%9%$%C%A$Khk1F6A$@$H9M$($i lk!#

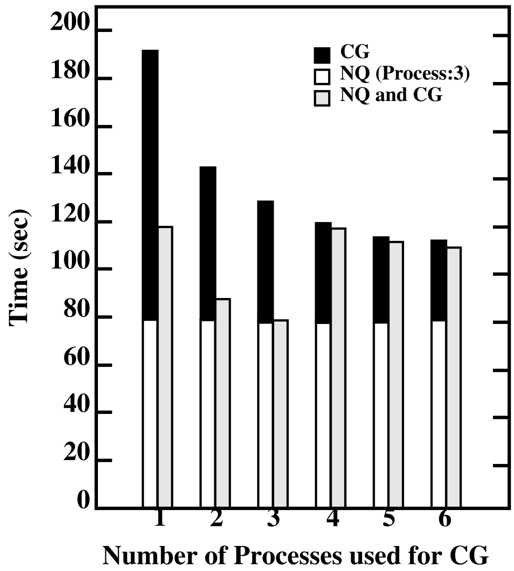
4.3.2 %P%C%A=hM}%+!<%M%k>e$GJ#?t$N%8%g%V$r<B9T$7$?>l9g$NB,Dj

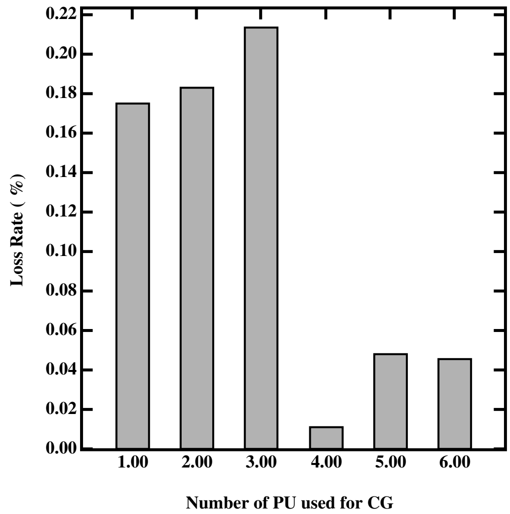
NQueen LdBj$N2r$r5aak%"%W%j%1!<%7%g%s$H!"CG K!$Khj9TNs<0$N2r$r5aak%"%W%j%1!<%7%g%s$rF1;~$K EjF~7?>l9g$N%P%C%A=hM}%+!<%M%k$G$N<B9T;~4V$rB,Dj 7?!#NQueen LdBj$OC10l%8%g%V$G<B9T7?>l9g$HF1MM $N>r7o$GB,Dj$7!"CG K!$O9TNsNBg-5, 96 GB,Djr 9TC?!#

:GBg%W%m%;%C%5?t$r 6 H7!"NQueen $O>o$K 3 8D$N%W %m%;%9$r!"CG K!$O 1!A6 %W%m%;%9@8@.$9kbNH9k!# ?^ 9$N%0%i%U$N:8B&$O!"$=l>lr=g$K<B9T$7$?>l9g $N<B9T;~4V$rC1=c$K9g7W$7$?$bNG$"$k!#

NQueen $, 3 %W%m%;%9@8@.$7!"CG K!$, 1!A3 %W%m%; %9@8@.$9kH$-$K$O 2 DN%"%W%j%1!<%7%g%s$OF1;~$K <B9T5lk,!"CG K!$, 4 %W%m%;%90J>e@8@.9k>l9g$K $O1,MW$J%W%m%;%9$NAm?t$,A4%W%m%;%C%5$r>e2s$k$?$a!" NQueen $,=*N;$7F+$i CG K!$N<B9T$,;O$^$k!#

3Nh&$JM}M3$+$i!"F1;~$K<B9T$,9T$ol?>l9g (CG K!$, 1!A3 %W%m%;%9) KO!"A4<B9T;~4VOBg-$/8:>/$7





?^ 10: <B9T;~4VHfN(

?^ 9: J#?t%8%g%V$N<B9T

$F$$$k$,!"F1;~$K<B9T$,9T$olJ$$>l9g (CG K!$N 4!Y 6 %W%m%;%9) KOA4<B9T;~4VK"$^$j:9$,$J$$$H9M$($i lk!#

4.3.3 %P%C%A=hM}%+!<%M%k>e$GJ#?t%8%g%V<B9T;~$NB> %8%g%VXN1F6A

?^ 10$O NQueen $N8e$K CG K!$r<B9T$7$?>l9g$N!"N-Queen C1BN$N<B9T;~4V$NCYlrI=7F$$$k!#$3$3GO NQueen N_$r<B9T$7$?>l9g$r4p=`K7$F!"CG K!$r$= $N8e$GEjF~7?>l9g$N NQueen $N<B9T;~4V$NCYlr<(7F$$$k!#

%P%C%A=hM}Kh$k%+!<%M%k>e$G$OJ#?t$N%8%g%V$r<B9T 7F$bC1O1$N%8%g%V$N<B9T;~4V$KO"$^$j1F6A$,$J$$$3 H,o+$k!#

5 $^$H$a

:#2s!"%P%C%A=hM}$H%.%c%s%0%9%1%8%e!<%j%s%0Kh$k %^%k%A%8%g%V%+!<%M%k$r<BAu7?!#

%P%C%A=hM}GOJ#?t$N%8%g%V$r8zN(NI$/=hM}$7$?!#$? $?!"01$D$N%8%g%V$r<B9T7?>l9gHHfY!"J#?t$N%8%g%V $r<B9T$7$?>l9g$OC1O1$N%8%g%V$N<B9T;~4V$KLs 0.2% DxEY NCYl$,=P$?DxEYJN$G!"C1O1$N%8%g%V$N<B9T;~4VK" $^$j1F6A$rM?$($J$$$3H,o+C?!#

8=:_$N;~E@$G$O%.%c%s%0%9%1%8%e!<%j%s%0$GJ#?t$N %8%g%V$r<B9T$9k3HOG-J+C?$,!"$*$=$i$/%P%C %A=hM}$KHfYF$+$JjN<B9T;~4VrMW9kHM=A[5l$k!#

;29MJ88%

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