%-%c%C%7%e@)8f5!9=FbB"7?B?CJ7k9gLV:MINC

0B@n 1Q<y =.66 7< @>B< 9n?. H9 IRGn E7Ln1Q@2

{yasukawa, funa, nisimura, hanawa, hunga}@aa.cs.keio.ac.jp

7DXf5A=NBg3X M}9)3XIt

35MW

MIN(Multistage Interconnection Network) $O, >.5,LO$J%9%$%C%A%s%0%(%l%a%s%H$rJ#?t%9%F!<%8@\B3$7$?7k9gLV$G, Hf3SE*>/NL$N%O!<%I%&%'%"$GBg5,LO%7%9%F%`$N<B8=$,2DG=$G$"$k. 0lJ}, :G6a$N VLSI 5;=Q$N?JJbKh$j, %9%$%C%A%s%0%(%l%a%s%HFb$K9b$$5!G=$rM?$($k;v$,2DG=HJC?$?$a, %-%c%C%7%e<+BN$d%-%c%C%7%e%G%#%l%/%H%j$rEk:\$7$? MIN $,Ds0F$5lF$$$k$,, 3liO$$$:lbBgNL$N%a%b%j$b7/$OCY1d$rI,MWH7F7$^$&. $=$3$GK\O@J8$G$O, =LLs$5l?3,AX%S%C%H%^%C%W$H>/NL$N;^4"$j%P%C%U%!$rMxMQ9k!"%-%c%C%7%e@)8f5!G=rHw($?B?CJ7k9gLV MINC(MINwith Cache control mechanism) $rDs0F$7, %=%U%H%&%'%"%7%_%e%l!<%7%g%sKh$kI>2A$r9TJC$?.

Multistage Interconnection Network with Cache control mechanism: MINC

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Abstract

Multistage Interconnection Network (MIN) has been used for connecting processors and memory modules in a large scale multiprocessor. While multiple memory modules can be accessed simultaneously with a reasonable amount of hardware in such a machine, coherent cache is difficult to be implemented. Some MINs including cache or cache directory in their switching elements have been proposed. However, conventional approaches require a large amount of memory and a latency for accessing the cache or directory inside switching elements. Here, a novel MIN with a cache coherent mechanism called MINC (MIN with cache control mechanism) is proposed. By introducing reduction schemes of the hierarchical bit map directory and the directory cache inside the MIN, the coherence is managed quickly with a small amount of memory.

1 O8aK

B?CJ7k9gLV (Multistage Interconnection Network: MIN) $O, 2×2 $+$i 8×8 DxEY$N>.5,LO$J%/%m%9%P%9%$%C%A$+$i@.$k%9%$%C%A%s%0%(%l%a%s%H$r#?t%9%F!<%8@\B3$7$?7k9gLV$G, Hf3SE*>/NL$N%O!<%I%&%'%"$GBg5,LO$J%7%9%F%`$r<B8=$G$-$k. %W%m%;%C%5-%a%b%j4V@\B3$K MIN $rMQ$$$?%^%k%A%W%m%;%C%5$O, T1;~$KB??t$N%a%b%j%b%8%e!<%k$r%"%/%;%9$9$k3H$,$G$-, %P%97k9g7?$KHfYFOk$+$KB?$/$N%W%m%;%C%5$r7k9g$9k3H,G-$k!#6aG/$NMWAG%W%m%;%C%5$N@-G=8~>e$N7k2L!"%P%9$G7k9g2DG=$J%W%m%;%C%5?t$O4 DxEY$K@)8B5lk3H+$i!"MIN 7k9g7?%^%k%A%W%m%;%C%5$O>-Mh$NCf5,LO!"Bg5,LO$JHFMQ%^%k%A%W%m%;%C%5$N7?%9%F%`H7$F9-$/MxMQ5l$k2DG=@-$r;}CF$$$k!#

7+$7!"MIN 7k9g7?%^%k%A%W%m%;%C%5O, FCK5,LO$,Bg$-$/$JkH, 6&M-%a%b%j$N%"%/%;%9;~4V$,Bg$-$/Jj, @-G=Dc2<$N860x$HJk. $3$3$G, <g5-21$KBP

9k%-%c%C%7%e$r%W%m%;%C%5-MIN 4V$K@_1k3F%H
G-lP%"%/%;%9;~4V$NDc8:$KBg$-$J8z2L$,D4BY
lk. H3m,, %W%m%;%C%5–MIN 4V$K%-%c%C%7%e$r
@_1k>l9g, $=$N0lCW@)8f$, LdBj$HJk.

MIN 7k9g7?$OF1;~$KJ#?t$N%W%m%;%C%5$, 6&M-%a
%b%j$r%"%/%;%9$9k?$a, 6&M-%P%9$K$*$1$k%9%D%
%W5!9=$rMQ$$$k3H$, G-$J$$. $^$?!"CC(Cache
Coherent)–NUMA $GMQ$$$ilF$$$k%G%#%l%/%H%j
<0$rMQ$$$k$?$aKO, %9%$%C%A%s%0%(%l%a%s%H$KBP
$7FC<l$J5!G=$r@_$1kI,MW,$"$k. 3N$?$a, =>Mh$N
MIN 7k9g7?%^%k%A%W%m%;%C%5$N%-%c%C%7%e@)8f$H
FO, %3%s%Q%$%iEy$Khk;vA02r@O$N7k2L$rMxMQ$9
$kJ}<0$,8!F$$5lF$-$?. :G$b4JC1$JNO, ;vA02r@O
Kh$j0l4S@-$rJ];}9kI,MW$,$J$$JQ?tN_$r%-%c
%7%e9k($"$k$$$O%m!<%+%k%a%b%j$K3d$jIU1k)J}
<0G"k,, 3lGO%-%c%C%7%e$N8z2L$,@)8B5l$k.
$=$3$G, JBNs DO J8$N6-3&Kh$K, L58z2=!&%-%c%C%7%e
3+;O/=*N;JI$N%-%c%C%7%e@)8fL?Na$r%3%s%Q%$%i$,
Kd$a9~$`J}K! [11], ;2>H%^!<%-%s%0K! [4], ItJ,E*
%O!<%I%&%'%"$N=u$1$r<Z$j$kJ}K! [3] EyMM!9$JJ}K!$,
Ds0F5l$F$$$k.

0lJ}, :G6a$N LSI =8@QEY$N8~>eKh$j MIN $N%9
%$%C%A%s%0%(%l%a%s%H$K9b$$5!G=$rM?$(k3H,
0WKJC?. 3N$?$a, %9%$%C%A%s%0%(%l%a%s%H$K
$K%-%c%C%7%e$rAH$_9~$s$@$j, %G%#%l%/%H%jrAH_9
$`J}K!$N8!F$$, 9TJolF$-$? [9][10]. 7+$7, =>Mh
$NJ}K!$O%9%$%C%A%s%0%(%l%a%s%HCf$K%-%c%C%7%e%a
$d%G%#%l%/%H%j$rAH$_9~$s$@$?$a, A4BN$N5-21NL$,Kd
BgKJ$j, %(%l%a%s%HKh$K30It%a%b%j$r%"%/%;%9$7$J
1lPJiJ$$%*!<%P%X%C%I$NE@$G$bITMx$G$"$C$?.

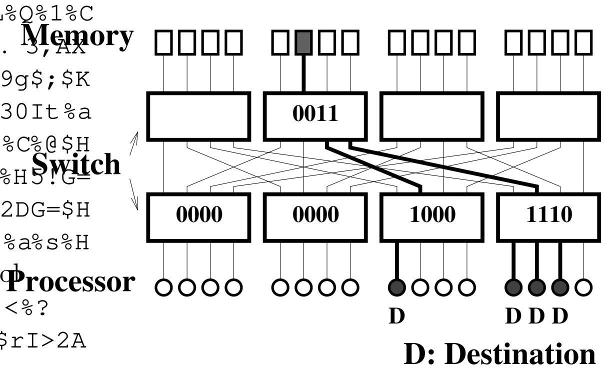
$=$3$G, 3liNLdBjE@$r2r7h$9k?aK, D0<TEy$O
%^%7%s JUMP-1[6] MQ$K3+H/$5l?3,AX%G%#%l%/%H%j
=LLsJ}<0 [13][8] $r MIN $KF3F~$7$?. 5i$K, MIN
$N@-<A$rMxMQ$7, =LLsJ}<0$NLdBjE@G"$kL5BL%Q%1%C
%H$r8:$i9?aN;^4"$j%P%C%U%!$rDs0F9k. 3,AX
%G%#%l%/%H%j=LLsJ}<0$H;^4"$j%P%C%U%!$NAH9g$;$K
hj!"$=$l$>$l$N%9%$%C%A%s%0%(%l%a%s%H$O30It%a
%b%j$r%"%/%;%9$9kI,MWOJ/, %Q%1%C%H$N%X%C%@$H
;^4"$j%P%C%U%!$NFbMF$K=>$C$?%^%k%A%-%c%9%H5!G=
N_$G, 9bB.$+$D8zN($NNI$$%-%c%C%7%e@)8f$,2DG=$H
Jk. K\O@J8GO3Nh&$J%9%$%C%A%s%0%(%l%a%s%H
$r;}$DB?CJ@\B3LV$r MINC(MIN with Cache control
mechanism)[12] $H8F$S, %=%U%H%&%'%"%7%_%e%l!<%?
$rMQ$$$F, L5BL%Q%1%C%H?t, 7k9gLV$N:.;(>uBV$rI>2A
7?.

$H$$$r;2>H7F%i%$%s$r6&M-9k%W%m%;%C%5HV9f$r
3liKBP$7L58z2=%a%C%;!<%8$"$k$$$O=q$-9~
$_%G!<%?$rAw$k.

%-%c%C%7%e%G%#%l%/%H%j$N4IM}J}<0$O9YFN%W
%m%;%C%5$KBP1~$9$k bit map $rJ];}$9$k%U%k^%C%W
J}<0rO8a, %j%_%F%C%I%G%#%l%/%H%jJ}<0 [1], %A%'
%$%s%I%G%#%l%/%H%jJ}<0 [7] JIMM!9$JJ}<0$,Ds0F$5
lFC$K CC-NUMA $GMQ$$$ilF$$$k.

3lKBP7$F, 7k9gLV$,3,AX9=B$$r;}$D>l9g$KM-
=LLsJ}<0$,3,AX%S%C%H%^%C%W%G%#%l%/%H%jJ}<0G"
$k. $3$3GO, LZ9=B$$N%M%C%H%o!<%/NMUN0LCV$K%W
%m%;%C%5$,B8:_$9kH>l9g$rA[Dj$9$k. LZ$N:,$+$i%Q
%1%C%H$r6!5k$7$F, F10l$N%Q%1%C%H$rJ#?t$N%W%m%;%C
%5$K%^%k%A%-%c%9%H$9$k>l9g$r9M$($k. LZ9=B$$N%M%C
%H%o!<%/G"k+$i, 3F@a$K$*$$$F08@hNMU,KvC<$K
$"$k$+$N$_%Q%1%C%H$rAwlP, I,MW$J%W%m%;%C%5$K
%7%e%Q%1%C%H$,FO$/3HKJ$k. J*, C1=c$JLZ9=B$
GO$,LZ$N:,IU6a$N%H%i%U%#%C%/$,Bg$-$/JC$Fp'O)$H
JCF7$^$&$?$a, 7k9gLV$O Fat-Tree $rFbJq$9k3$H
$,K>$^$7$$. Omega LV, Generalized-cube(G-Cube)
LV$rBeI=$H9kA4FN MIN Oa%b%j$r%k!<%H$H9k
Fat-Tree 9=B$$rFbB"7F$$$k$H9M$(k3H,G-$k.
3N$?$a, MIN $K%G%#%l%/%H%j4IM}J}<0$rAH$_9~$`
>l9g, 3,AX%S%C%H%^%C%W%G%#%l%/%H%jJ}<0$O:G$b<+A3
$JJ}K!$G$"$k.

?Mh$O, 3,AX%S%C%H%^%C%W%G%#%l%/%H%jJ}<0$r MIN
7k9gLV$K7%9%F%`$K1~MQ7?>l9g$r<($9. 6&M-%a%b%j
$N%Q%1%C%H<0L(%W%m%;%C%5B&) $N%9%F!<%8$,;}CF$$$l
$P, $=$&GJ1l$P 0 $H$$$& 4bit $N%S%C%H%^%C%W
rCf9%$%C%A$KM?$($k;v$G, Aw?.@h%W%m%;%C%5 D $r
40AAG$K;XDj$G$-$k$,, %U%k^%C%W$hjbB?$/$N%S%C%H
?trI,MWH7F7^$&.



?^ 1: 3,AX%S%C%H%^%C%W%G%#%l%/%H%jJ}<0

2 3,AX%G%#%l%/%H%jJ}<0

2.1 MIN $N9=B$$H3,AX%G%#%l%/%H%j

%9%L!<%W5!9=$rMQ$$$J$$$G%-%c%C%7%e$N0l4S@-$r
0];}9k$?$aKO, 6&M-4X78$r<($9%G%#%l%/%H%j$r;}
DI,MW,$"$k. DL>o, %G%#%l%/%H%jKO, %-%c%C%7%e
%i%$%s$rJ];}7F$$$k%W%m%;%C%5$,5-O?$5$l, %H%j$r
%7%e$K=q$-9~$_$,5/$-$?>l9gJIKO, 3N%G%#%l%/

2.2 =>Mh$N%-%c%C%7%e@)8f5!9=$rAH$_9~$s$@ MIN

7%L$K<($9h&$K, C1=c$K MIN >e$G3,AX%G%#%l%/
%H%j$r<B8=$9k?aK$OCf4V%N!<%I$KAjEv9k%9%$%C
%A%s%0%(%l%a%s%H$K%G%#%l%/%H%j$*hS>l9gKh$C

FO%-%c%C%7%eK\BN$rHw$(kI,MW,$"$k.

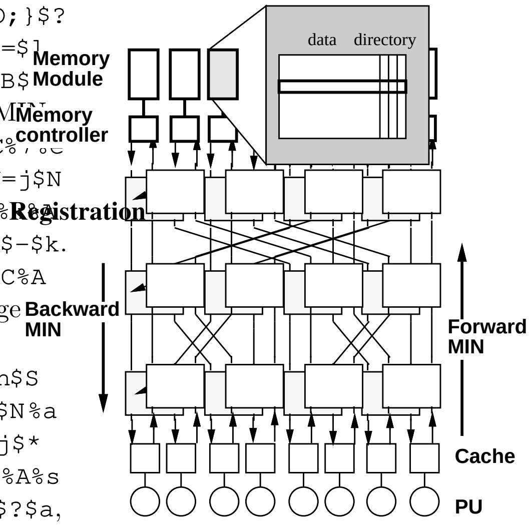
Memory Hierarchy Network(MHN)[9] $O, MIN $N 3,AX9=B$$rMxMQ$7, 3F%9%$%C%A%s%0%(%l%a%s%Hcf$K $=$N%(%l%a%s%H$r:,$H9k$D%j!<$NMUKEv?$k%W%m %;%C%5$N6&M-9k%G!<%?KBP9$k%-%c%C%7%e$rCV$/$J <0G"$k. L5BL$J%3%T!<$H%G!<%?0l4S@-$K4X9k%m %9rKI0$?$a, %-%c%C%7%e$N%3%T!<$ORHDK@)8B$5 lF$$$k. 6&M-9k%W%m%;%C%5?t$,>/$J$$%G!<%?$O MHN $N%W%m%;%C%5$K6a$$%9%F!<%8KCV+lk$?$a, %"%/%;%9CY1d$O>/$J$$. B?$/$N%W%m%;%C%5$,6&M-$9 $k%-%c%C%7%e$O MHN $N%a%b%jB&$N%9%F!<%8$K0\F0 7F$$$/.

3lKBP7 MIND(MIN with Directory)[10] $O, 3F %9%$%C%A%s%0%(%l%a%s%H>eKO%-%c%C%7%e<+BN$O;}$? $:, %G%#%l%/%H%j$N$_$rCV$/J}K!$G$"$k. MIN O=$l $>$l$N%a%b%j%b%8%e!]%k$rD:E@H9$k%D%j!<9=B$ 7F9M$($k3H$,$G$-$kNG, 3l$rMxMQ$7$F MIN A4BN$G3,AXE*$J%G%#%l%/%H%j$r<B8=9k. %-%c%C%7%e $NL58z2=%a%C%;!<%8$O%G%#%l%/%H%j$NFbMF$, 1 $N=j$N $_$KAwilk?a, I,MWJ%W%m%;%C%5KN$_, %^%k%A %-%c%9%H$N7A$GL58z2=%a%C%;!<%8$rAwk3H,G-$k. 3NJ}K!rh$j8zN(2=$9k?$a, MIN $N3F%9%$%C%A %s%0%(%l%a%s%H$r%P%9$G9=@.9k MBN(Multistage Bus Network)[2] $bDs0F$5lF$$$k.

7+$7, MHN $O3F%(%l%a%s%H$K%-%c%C%7%e$*$h$S %G%#%l%/%H%j$rCV$/$?$a, A4BN$H7FKDBgJNLN%a %b%jrI,MWH9k. 5i$K, MHN $N%G%#%l%/%H%j$* hS%-%c%C%7%e$OBgMFNL$N%a%b%jKJ$j, %9%$%C%A%s %0%(%l%a%s%HFb$KAuHw$9k3HOIT2DG=G"k?$a, %A%C%W30$KCV$/I,MW$,$"$k. %Q%1%C%H$NE>Aw$OA4$F %G%#%l%/%H%j$r%"%/%;%9$9$kI,MW$,$"kN$G,MHN GO%Q%1%C%HE>AwNEYK30It%a%b%j$N%"%/%;%9$rI, MWH7,E>AwCY1d$,Bg$-$/$J$k.

MIND $O%9%$%C%A%s%0%(%l%a%s%HFb$K%-%c%C%7%e $r;}$DI,MWOJ$$$,,%G%#%l%/%H%j$O;}$DI,MW$,$"$j, F1MM$K%A%C%W30%a%b%j$N%"%/%;%9$KI,MW$,@8$8$k. $3 N?$a, MHN F1MMA4BN$H7F$N5-21MFNL$,Bg$-$$>e, 3F%9%F!<%8GN30It%a%b%j$N%"%/%;%9$KhkCY1d$O, %-%c%C%7%e$,R%C%H7J$+$C$?>l9g$K%"%/%;%9;~4V$r Bg$-$/0z$-1dP92DG=@-$,$"$k.

- 3,AX%S%C%H%^%C%W$O3F%9%$%C%A%s%0%(%l%a%s%H KCV+$:, 6&M-%a%b%j$K=LLs5l$?%S%C%H%^%C%W $N7A$GCV$/. L58z2=$d99?7%G!<%?$NJ|Aw;~$K$O, 3N%S%C%H%^%C%W$r%Q%1%C%H$N%X%C%@$K3JG<$7, 3N%^%C%W$K=>CF Backward MIN >e$G%^%k%A %m%c%9%H9k.
- Backward MIN >e$K;^4"$j%P%C%U%!$r@_$1, %- %c%C%7%e%i%$%s$N%m!<%I;~$KEPO?$7,%S%C%H%^%C %W$r=LLs$9k3HKhjH/@8$9$kL5BL%Q%1%C%H rKI0.



?^ 2: %-%c%C%7%e@)8fIU$- MIN $N9=@.

0J2<, $^$:%G%#%l%/%H%j=LLsJ}<0$r>R2p$7, 3l$r MQ$$$? MINC $N4pK\A`:n$r=RY?8e, ;^4"$j%P%C%U%! KD$$$F2r@b9k. J*, Forward MIN, Backward MIN $N%H%]%m%8$K$D$$$FOFCK@)8B$,$J$$$,, $3$3 GO%W%m%;%C%5$N0LCV$Khk6I=j@-$rMxMQ$G$-$k$h $&$K, Baseline LV$rA[Dj$9$k. $^$?, ?^ 2GO 2×2 $N %9%$%C%A%s%0%(%l%a%s%H$r<($9$,, <B:]$O LSI %A%C%W GN<BAu$r9M$(, 8×8 DxEY$N%5%$%:$rA[Dj$7$F$$$k.

3 MINC(MIN with Cache control mechanism)

3.1 MINC $N4pK\9=@.

K\O@J8GO, =>Mh$N%-%c%C%7%e@)8f5!9=IU$-$N MIN $NLdBjE@$r2r7h9k?7$7$$5!9= MINC(MIN with Cache control mechanism) $rDs0F$9$k. MINC $O, DL>o$N%^%k%A%W%m%;%C%5K*1k MIN $HF1MM, ?^ 2 $K<($9h&$K, %W%m%;%C%5$+$i%a%b%j$KBP7F%Q%1%C %HrAwk Forward MIN $H, %a%b%j$+$i%W%m%;%C%5$K %Q%1%C%HrAwk Backward MIN $KJ,$+lF$$$k. => Mh$NJ}<0$H$NAj0c$O0J2<$NE@$G$"$k.

3.2 RHBD J}<0

3,AX%S%C%H%^%C%WJ}<0$O, %W%m%;%C%5?t$,B?$/$J$k $H%G%#%l%/%H%j$KI,MW$J%a%b%jNL$,KDBgKJ$j, <B8= $,:$FqKJ$k. $^$?, %G%#%l%/%H%jO+JjBgMFNLKJ k3H,M=A[5lkN$G, %9%$%C%A%s%0%(%l%a%s%H$r 9=@.$9$k%A%C%W$N30It$K@_$1kI,MW,$"$k. 3N>l9g, 3,AXKh$K%G%#%l%/%H%j$r;2>H9kKO, Bg$-$J;~4V$r MW$9$k. $=$3$G%S%C%H?t$r=LLs9k RHBD(Reduced Hierarchical Bit-map Directory) J}<0$rF3F~$9$k. $3 $NJ}K!$OD6JBNs%^%7%s JUMP-1 $N%G%#%l%/%H%j@)8f MQ$K9M0F5l$?J}<0 [13] [8] G"$k. 3NJ}K!$O,

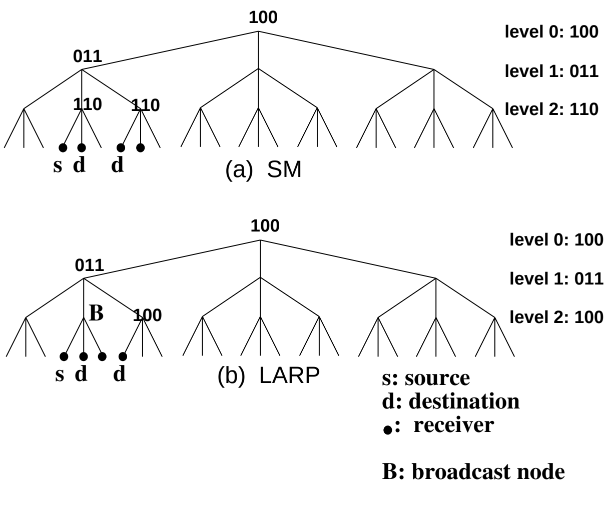
- $"$k@a0J2<$O%V%m!<%I%-%c%9%H$H9k.

• J#?t$N@a$GF10l$N%S%C%H%^%C%W$rMQ$$$k!% $N$$$:l+!$$b7/$$ON>J}NAH_9go;KhCF!$3,AXKh$K n bit(n ?JLZ$G) $N%S%C%H%^%C%W$r0lD@$1;}$D3HH9$k. 3Nh&K9kH, %G%#%l%/%H%j%(%s%H%jKhKI,MWJ bit ?t$O, m 3,AX$N n ?JLZK*$$$F $m \times n$ bit HJ$k. 5i$K, %S%C%H%^%C%W$O, %Q%1%C%H$N%X%C%@Cf$K;}D3H,G-kN$G, 40A4$K%(%l%a%s%HFbN_$G%^%k%A%-%c%9%H$,2DG=G"$j, 30It$N%G%#%l%/%H%j$r;2>H$9kI,MW,$J$$. >e5- 2 DNJ}K!$NAH9g$;Kh$j 3 DN%G%#%l%/%H%j=LLsJ}<0$,Ds0F$5lF$$$k [8] $,, $3$3GO, SM K!$H LARP K!$K$D$$$F8!F$$7$?.

• **SM(Single Map)** K!:
3F3,AXKh$K,$=$N3,AX$NA4FN@a$N=LLsA0$N%S%C%H%^%C%W$NO@M}OB$rHj,$=$N3,AX$NA4$F$N@a$GMQ$$$k.

• **LARP(Local Appropriate Remote Precise)** K!:
:,$+$iAw?.85$K;j$k%Q%9r=$NB>$N%Q%9$H6hJL$7$F07$$,$"$k@a$G (1) Aw?.85$r4^$`;^, (2) Aw?.85$r4^$^$J$$;^ $N$&$A$N$$:$l$+$KBP$7N>J}6&%Q%1%C%H$,Aw$i$l$k$H, Aw?.85$r4^$`;^$N2<$NItJ,A4BN$K%Q%1%C%H$,%V%m!<%I%-%c%9%H$5lk. $=$l0J30$N;^$G$O, F10l3,AX$NA4FN@a$G, $=$liN@a$N=LLsA0$N%S%C%H%^%C%W$NO@M}OB$rMQ$$$k.

?^ 3$K;0?JLZ$rMQ$$$?LN<0?^$r<($9. 3N?^Gs$,Aw?.85$N%/%i%9%?, **d** $,K\Mh$NAw$j@h, • $,7k2LE*$K%Q%1%C%H$,Aw$jIU1ilk%/%i%9%?G"$k. =>$C$F d $NL5$$ • $N?t$,>/$J$$$[$IL5BL$K%Q%1%C%H$r<u$1Hk%/%i%9%??t$,>/$J$$;vKJ$k. 3N=LLsJ}<0$r!N$JF~l?3,AX%S%C%H%^%C%W%G%#%l%/%H%jJ}<0$r=LLs3,AX%S%C%H%^%C%W%G%#%l%/%H%jJ}<0 (RHBD: Reduced Hierarchical Bit-map Directory) $H8F$V.



?^ 3: %G%#%l%/%H%j=LLsJ}<0

=LLsJ}<0$rMQ$$$?>l9g, MIN $N%(%l%a%s%HFb$K%G%#%l%/%H%j$r;}$DI,MWOJ$/$J$j, 6&M-%a%b%j>e$KN_, 3F%9%F!<%8 (3,AX) $GMQ$$$k%S%C%H%^%C%W$rJ];}$9lPNI$$. Backward MIN $rDL2a$9$k%Q%1%C%H$N%X%C%@K3$N3F%9%F!<%8$G;}$A$$$k%S%C%H%^%C%W$rF~$lF*$-, Backward MIN Fb$GO3$N%S%C%H%^%C%W$K=>CF%Q%1%C%H$r%^%k%A%-%c%9%H$9$k. 3NJ}<0GOL5BL$J%Q%1%C%H$,%W%m%;%C%5$KE~Ce$7F7$^$&$,, A4$/%9%$%C%A%s%0%(%l%a%s%HFb$N%G%#%l%/%H%j$r;%"%/%;%9$9kI,MW,J/Jj, 5-21MFNL$,@aLs$5lk$H6&$K, L58z2=$N<B9TB.EY$b8~>e9k.

3.3 MINC $N%-%c%C%7%e@)8f%W%m%H%3%k

$^$:,RHBD $rF3F~$7$?>l9g$N%-%c%C%7%e@)8f$N4pK\%W%m%H%3%k$K4X7F2r@b9k. MINC GO, %G%#%l%/%H%j$,6&M-%a%b%j$K=8Cf7F$$$kJ, MHN $d MIND KHfY$F%W%m%H%3%k$O4JC1G"$k. $?$@$7, %G%#%l%/%H%j$r=LLs7?$?$a, %i%$%s$N%3%T!<$rJ];}$7$F$$$k%W%m%;%C%5?t$r%+%&%s%?$r6&M-%a%b%j$N%G%#%l%/%H%j$K@_1kI,MW$,$"$k.

3F%W%m%;%C%5$K@\B3$5l?%-%c%C%7%eKO, $=$N%i%$%s$NM-8z/L58z (Valid:V / Invalid:I) $*$h$S, %3%T!<$,B>$KB8:_$9$k/B8:_$7$J$$ (Shared:S / Private:P) $N%?%0$,@_1ilF$$$k. Ds0F9k%W%m%H%3%k$O, 3liNAH9g$;$Khj I, P, S $N 3 >uBV$r;}$D%i%$%s$H%9%k!<7?$G$"$j, ?^ 4$K<($9>uBVA+0\$r9TJ&. MINC GOL58z2=7? (?^ 4a), 99?77? (?^ 4b) N>J}$N%W%m%H%3%k$NMxMQ$,2DG=$G$"$k.

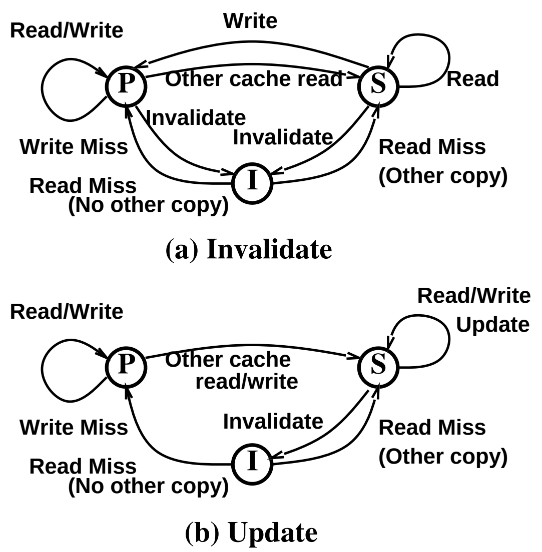
$^$:,M-8z$J%-%c%C%7%e$KBP7FNFI_=P$7%"%/%;%9$,%R%C%H9l$P, LdBj$J$/%-%c%C%7%e$+$i%G!<%?$rFI$_9~$`. $=$NB>$N%"%/%;%9$O0J2<Nh$&$K=hM}5l$k.

1. L58z=q$-9~$_%_%9!?%R%C%H: Forward MIN $rMQ$$$F6&M-%a%b%j$K%G!<%?$rAw$j, 6&M-%a%b%j>e$N%G%#%l%/%H%j$K=>$C$F Backward MIN $rMQ$$$F, L58z2=%Q%1%C%H$^$?$O99?7MQ$N%G!<%?$r%^%k%A%-%c%9%H$9$k.

2. FI$_=P$7%_%9: %_%9$7$?%i%$%s$KBP1~9k%;%C%H$K I >uBV$,B8:_7J1l$P, 3. $K=>$C$FEPO?>C5n$r9T$J$$$FI$_9~$_NN0h$r3NJ]$9$k. <!$K Forward MIN $rMQ$$$F%i%$%sMW5a%Q%1%C%H$r6&M-%a%b%jKAwk. $3$3$G, 6&M-%a%b%j%3%s%H%m!<%i$O, 6&M-%a%b%j>e$N%S%C%H%^%C%WNI,MWJ>l=j$K 1 $r%;%C%H$7, %+%&%s%?$r%$%s%/%j%a%s%H9k. $=$7$F,Backward MIN $rMQ$$$FMW5a85$N%W%m%;%C%5$N%-%c%C%7%eKFI_=P7?%i%$%s$rAw$k. 3N;~, %G%#%l%/%H%j>e$N%+%&%s%?$, 0, 9JoAB>$KF10l%i%$%s$r6&M-9k%W%m%;%C%5$,B8:_7J$$>l9g, 6&M-%a%b%jOFI_=P7?%i%$%s$rAw$k%Q%1%C%H$N%X%C%@Cf$N Private bit $r%;%C%H$7FAwj=P$9. %Q%1%C%H$rAw$j=P$7$?8e, 6&M-%a%b%j%3%s%H%m!<%i$O%+%&%s%?$r%$%s%/%j%a%s%H$9$k. MW5a$r=P7?%W%m%;%C%5$O, %Q%1%C%H$r<u$1<h$j%X%C%@Cf$N Private bit $,%;%C%H$5lF$$$l$P P >uBV, $=$&GJ1l$P S >uBV$KJk.

5F, 6&M-%a%b%j%3%s%H%m!<%i$O, %+%&%s%?$N6&M-4X78$N6I=j@-$,>.$5$$$HM-8z%Q%1C%H$N?t$N%i%$%s$KBP9k%i%$%sMW5a%Q%1C%H$r<L$G\$NL5BL%Q%1C%H$,H/@8$9$k2DG=@-$,$"$k [8]. kH, 6&M-2=%Q%1C%H$r Backward MIN $rMQ$$3N?$a, Backward MIN >e$NFCDj$N%9%F!<%8$N$F%^%k%A%-%c%9%H$7, 3N%i%$%s$r6&M-7F$$$k%a%s%HN_$K, %A%C%WFbIt$K<BAuG-$kDxEY$N4Jb&01DN%-%c%C%7e%i%$%s$N>uBV$r S KJ$9%U%k%"%=%7%"%F%#%V$J;^4"$j%P%C%U%!$r@_1k. 9k. ?^ 5$O, LARP 7? MINC $K;^4"$j%P%C%U%!$rE,1~$5$;$?bNG"$k. ;^4"$j%P%C%U%!$OOJ2<$Nh&$KF0:n$9$k.

3. EPO?>C5n: %G%#%l%/%H%j$r=LLs$7$?>l9g, %S%C%H%^%C%WCf$N 1 $OJ#?t$N%-%c%C%7e$N%3%T!<$r8=7F$$$k>l9g$,$"$k. 7?$,CF, 4JC1$K3N%S%C%H$r%j%;%C%H$9k3HOG-$J$$. %i%$%s$r<NFk>l9g$O, Forward MIN $rMQ$$$FEPO?>C5n%a%C%;!<%8$r6&M-%a%b%j$KAw$j, %G%#%l%/%H%j$Cf$N%+%&%s%?$r%G%/%j%a%s%H9k. 6&M-%a%b%j%3%s%H%m!<%i$O, %G%/%j%a%s%H$N7k2L, %+%&%s%?$, 0 KJC?;~KN$_%S%C%H%^%C%WCf$NA4FN bit $r>C5n$9$k.



?^ 4: %-%c%C%7e$N>uBVA+0\

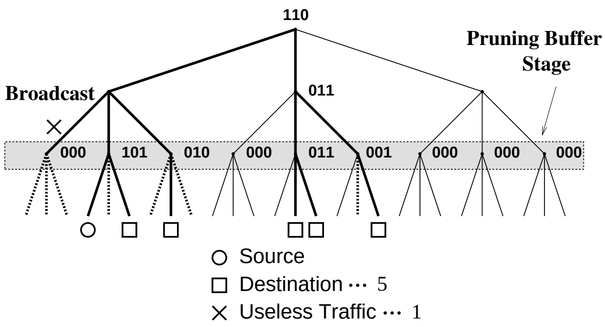
MINC $OL58z2=7?$H99?77?$NN>J}$rMQ$$$k3H$,$G$-$k$,, 99?77?$rMQ$$$k$H6&M-%G!<%?$N%^%k%A%-%c%9%H$d%V%m!<%I%-%c%9%H$r8zN(NI$/9T$J$&$3H,G-$k. 3N>l9g, %-%c%C%7e$N%R%C%HN($,>e$,iJ$$>l9gGb,1 BP 1 E>AwN_$K5!G=$, 8BDj5l$k=>Mh$N MIN KHfYkH9b$$@-G=$rF@$k3H$, 4|BT$G$-$k.

3.4 ;^4"$j%P%C%U%!$NF3F~

=LLsJ}<0OBg-$JMxE@$r;}$D01J}, L58z2=%Q%1C%H$,I,MW0J30$N%W%m%;%C%5$K$bFO$$$F7^$&LdBj$,$"$k. 3N%a%C%;!<%8$OFO$$$?%W%m%;%C%5$N%-%c%C%7e%3%s%H%m!<%i$G<NFF7^$($P$h$$$N$G%W%m%H%3%k>e$N<B32OJ$$$,, %i%$%s$r6&M-9k%W%m%;%C%5?t$,A}$(kH, L5BL$J%Q%1C%H$,A}$(Backward MIN $N:.;($,7c7/Jk. %7%9%F%`$N%5%$%:$,Bg$-$/$J$k.

?$N6&M-4X78$N6I=j@-$,>.$5$$$HM-8z%Q%1C%H$N?t$N%i%$%s$KBP9k%i%$%sMW5a%Q%1C%H$r<L$G\$NL5BL%Q%1C%H$,H/@8$9$k2DG=@-$,$"$k [8].

- Backward MIN KhjFI_=P7?%i%$%s$rMW5a5N%W%m%;%C%5$KE>Aw$9$k:]$K, DL2a9k%(%l%a%s%H>e$N;^4"$j%P%C%U%!>e$K%i%$%s%"%I%l%9$rEPO?$7, BP1~9kF~NO$N bit $r%;%C%H$9$k. 4{$K%-%c%C%7e>e$K%(%s%H%j$,B8:_9k>l9g$O, %Q%1C%H$N9T$-@h$KAjEv9k bit $r%;%C%H$9$k.
- Backward MIN $r2p$7$F99?7%G!<%?$"$k$$$OL58z2=%Q%1C%HrAwk;~, %9%$%C%A%s%0%(%l%a%s%HFb$N;^4"$j%P%C%U%!$r;2>H$7, %"%I%l%9$,01CW$9$1P=$N%G%#%l%/%H%j$N%S%C%H%^%C%W$rMxMQ$7$F, 1 $KBP1~$9$k=PNO$KBP7FN_%Q%1C%HrAwk. L58z2=7?%W%m%H%3%k$rMQ$$$?>l9g$O, ;^4"$j%P%C%U%!>e$N%(%s%H%j$O, L58z2=%Q%1C%HrAwC$?;~E@$G:o=|9k.



?^ 5: ;^4"$j%P%C%U%!

L58z2=7?%W%m%H%3%k$G;^4"$j%P%C%U%!$O, %9%$%C%A%s%0%(%l%a%s%HFb$K<BAu$9k3H, I,MW$G, J*$+$D9bB.$J%"%/%;%9$, MW5a5l$k. 3Nh&$KMFNL$N@)8B$, 87$7$$$?$a, L58z2=%W%m%H%3%k$GIQHK$KL58z2=$, 9TJolk>l9g$r=|$$$F, %G%#%l%/%H%j%-%c%C%7e$NEPO?$GKO%P%C%U%!$NNN0h$,J/Jk>l9g$, IQHK$K5/$-$k$H9M$(il$k. ;^4"$j%P%C%U%!$NL\E*$OL5BL%Q%1C%H$N:o8:$K$"$kNG, 3Nh&$J>l9g$O, C1=cKI3+$N%i%$%s$rA*$s$G<N$FF7$^$C$FNN0h$r3NJ]9k. 3N>l9g, IN%i%$%s$rA*V+$O, 0J2<$N%"%k%4%j%:%`$, 9M$(il$k.

- :G$b 1 $N?t$NB?$$%S%C%H%^%C%W$r;}$DbN$r<N$F$k. 3l$O 1 $N?t$,>/$J$$$bNNJ}$,, L5BL%Q%1C%H:o8:$N8z2L$,Bg$-$$$+iG$"$k.
- C1=c$J FIFO $G@h$KEPO?5l$?$bN+$i=gHV$K<NFF$$$/.
- DL>o$N%-%c%C%7eF1MM LRU $rMQ$$$k.

$3$1iNA*Br$O, <B:]$N%"%/%;%9$K4p$E$/I>2A$, I,MWG"$k.

4 I>2A

4.1 %7%_%e%l!<%7%g%s%b%G%k

<B:]$K MINC $r@_7W$9$kA0$K3NN(%b%G%k$K4p$E$/ 4JC1$JI>2A$r9T$J$$, $=$NM-8z@-$r3NG'$7$?. I>2A $KMQ$$$?%7%_%e%l!<%?GO, 3NN(%b%G%kKh$j3F%W %m%;%C%5$, 6&M-%a%b%j%"%/%;%9%Q%1%C%H$r@8@.$9$k. 3F!9$N%Q%1%C%H$N%"%I%l%9$N7hDjJ}K!$O0J2<$N 2 DL jG$"$k.

- **Nonlocal** %b!<%I 0lMMMp?t$rMQ$$$?7hDjK!$G, IN%a%b%j%b%8%e!<%kKbEy3NN($G%"%/%;%9$r9$k.
- **Local** %b!<%I %G!<%?$N6I=j@-$r5?;wE*$K<B8=$9$k7hDjK!$G$"$k. 9JoA, $"$k%i%$%s$r6&M-9k%W%m%;%C%5$, , FCDj$N%W%m%;%C%5HV9f$r%T!<%/$H7?@55,J,I[$K4p$E$$$F J,I[7F$$$k$H2>Dj$9$k. 9JoA, $"$k%W%m%;%C%5HV9f$, 6a$$%W%m%;%C%54VGb$/$J$k lk3NN($, 9b$/, $"$k%W%m%;%C%5$O, FCDj$N%a%b%j%b%8%e!<%k$K6a$$HV9f$N%a%b%j%b%8%e!<%k%"%/%;%9$9$k3NN($, 9b$/Jk.

MINC $O, SSS 7? MIN[5] Kh$j@)8f$9k3HrA[Dj7?. 9JoA, A4FN%"%/%;%9$O6&DL$N%U%l!<%`?.9f$KF14|$7$F?t bit %7%j%"%k$N%Q%1%C%H$N7A$GF~NO$5$l, %M%C%H%o!<%/DL2aCf$K>WFM$7$FL\E*CO%a%b%j%b%8%e!<%k$KE~C#$G$-$J$+$C$?%Q%1%C%H$O<!$N%U%l!<%`$G:FAw$5lk. %-%c%C%7%e%3%R!<%l%s%9$r0];}$9k?aKH/9T5l$k%^%k%A%-%c%9%H%Q%1%C%H$K$D$$$F$bF1MM$G$"$k$,, $"$k%-%c%C%7%e%i%$%s$KBP9k%^%k%A%-%c%9%H%Q%1%C%H$N0lItJ,$,>WFM7?>l9g$O, >WFM$r5/$3$7$?%Q%1%C%H$K$D$$$FN_:FAw9k.

MINC $O, 3F%9%$%C%A%s%0%(%l%a%s%H$K%P%C%U%!$r@_1FFHN)$KE>Aw$9$k=>Mh7?$N MIN KbMQ$$$k3H$,$G$-$k$,, SSS 7? MIN GO%Q%1%C%H$NF~NO$,%U%l!<%`$KF14|$5$l$k$?$a, 6&M-%a%b%j$G$N%G%#%l%/%H%j$NEPO?A`:n$d%^%k%A%-%c%9%H;~$N;^4"$j%P%C%U%!$N@)8f$,MF0W$G9bB.$JF0:n$,4|BTG-$k.

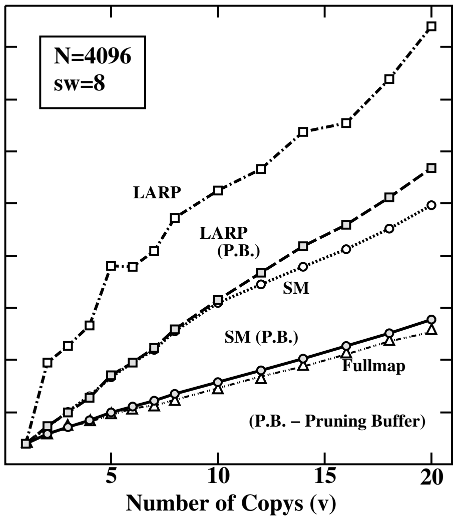
4.2 %H%i%U%#%C%/NL$NI>2A

$^$:,Backward MIN >e$rN.$l$kAm%Q%1%C%H?t$r3F=LLsK!KD$$$FD4Yk$H6&$K;^4"$j%P%C%U%!$N8z2L$rI>2A$7$?. $3$3$G, @-G=Hf3S$N4p=`H7$F%H%i%U%#%C%/NL$rDj5A9k. %H%i%U%#%C%/NLHO, %-%c%C%7%e%3%R!<%l%s%9$r<h$k$?$a$NL58z2= (99?7) %Q%1%C%H$, Backward MIN $rDL2a$9$kAm%j%s%/?t$r%+%&%s%H7?bNG"$k. =>$C$F, %H%i%U%#%C%/NL$,Bg$-$$$[$I%M%C%H%o!<%/$N:.;(EY$r<($9;XI8G"k3$3$G$N%7%_%e%l!<%7%g%s$GMQ$$$?%Q%i%a!<%?$r %G!<%?$N6&M-$, 6I=j@-$r;}$D Local %b!<%I$Khj SM K!,LARP K!N=l>$l;^4"$j%P%C%U%!(Pruning Buffer: P.B.) $rEk:\$7$?>l9g$H$=$&GJ$$>l9g7F$$$k. Hf3SN?$a%^%k%A%-%c%9%H$r9TJo$:,1 BP 1 E>Aw$r9TJ&>l9g$N%H%i%U%#%C%/NL (Fullmap) $bJ;$;$F<($9.

2A7?7k2L$r?^ 6$K<($9. $3$3GO, ;^4"$j%P%C%U%!$O:G$b%W%m%;%C%5$K6a$$$9%F!<%8$K0lCJ$N$_Ek:\$7$F$$$k.

?^ 6$O,%W%m%;%C%5$N%-%c%C%7%e$K%3%T!<$5lk%i%$%s?t (v), 9JoA, $"$k%i%$%s$r6&M-9k%W%m%;%C%5?tKBP9$k%H%i%U%#%C%/NL$rD4YF$$$k. %7%9%F%`Cf$N%W%m%;%C%5?t N $O 4096, MIN $O 8 × 8(sw) $N%9%$%C%A%s%0%(%l%a%s%H$r 4 %9%F!<%8@\B3$7$F, 4096 F~=PNO$H7F$$$k.

%-%c%C%7%e$K%3%T!<$5lk%i%$%s?t$,A}Bg9k$H,$=lKDl$F%H%i%U%#%C%/NL$bA}$($k. 8r?.$N6I=j@-$r9MN8$7$F$$$kKb$+$+oi$:,LARP K!$G$O%H%i%U%#%C%/NL$,A}Bg$7,;^4"$j%P%C%U%!(P.B.) $rEk:\$7$?>l9g$G$b" Ek:\$7$F$$$J$$ SM K!KHfY$F%H%i%U%#%C%/NL$,Bg$-$/JCF7$^$&. 0lJ},SM K!$O,;^4"$j%P%C%U%!$rEk:\$9kH,%H%i%U%#%C%/NL$O8:>/$7,1 BP 1 E>AwH[Hs$I:9$,$J$$$/$i$$$KM^$($k3H$,$G$-$F$$$k.50J>e$N%7%_%e%l!<%7%g%s7k2L$Khj,MINC K*1k=LLsK!$O SM K!$,M-Mx$G,;^4"$j%P%C%U%!$NEk:\$O%H%i%U%#%C%/NL$NM^@)$KBg$-$J8z2L$,$"k3H,o+$k.



?^ 6: %G%#%l%/%H%j=LLsK!$NI>2A

4.3 7k9gLV$N:.;(>u67$NI>2A

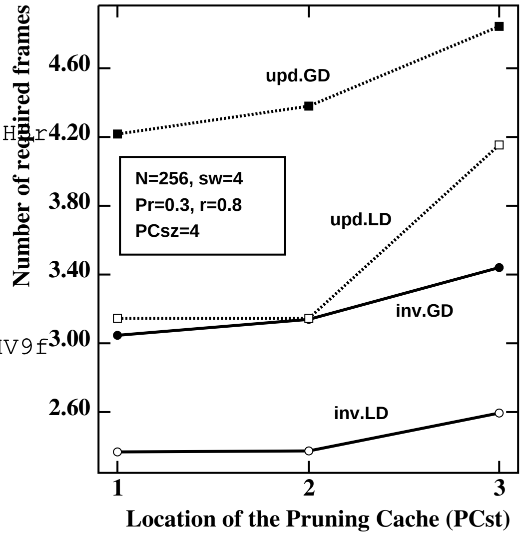
<?$K, A0=R$N%7%_%e%l!<%7%g%s%b%G%k$K4p$E$-, MIN >e$N%Q%1%C%H$N>WFM, $=$lKh$k:FAwEy$N MIN $NF0$-$r@%$$J%_%C%/$J>u67$r%7%_%e%l!<%7%g%s7?7k2L$r<($9.

I>2A$K<($9.

$3$3$G<($97k2L$O, %W%m%;%C%5?t (N) $r 256 H7, 4 × 4 $N%9%$%C%A%s%0%(%l%a%s%H (sw=4) 3 %9%F!<

I= 1: %7%_%e%l!<%?%Q%i%a!<%?

%Q%1%C%H@8@.%Q%i%a!<%?	
Pr	3F%W%m%;%C%5$,$"$k%U%l!<%`$G%Q%1%C%H@8@.9k3NN(
r	read %Q%1%C%HN(
%7%9%F%`%Q%i%a!<%?	
N	%7%9%F%`$N%N!<%I?t (256)
sw	%9%$%C%A%5%$%: (4x4)
PBst	;^4"$j%P%C%U%!$rEk:\$9$k%9%F!<%8$NHV9f
PBsz	;^4"$j%P%C%U%!$N%5%$%: (4)
%a%b%j%Q%i%a!<%?	
GM	6&M-%a%b%j%5%$%: [bytes](64M)
BS	%-%c%C%7%e%i%$%s%5%$%: [bytes](16)



?^ 7: ;^4"$j%P%C%U%!$NEk:\CJ?t BP %Q%1%C%HJ?6Q:FAw2s?t

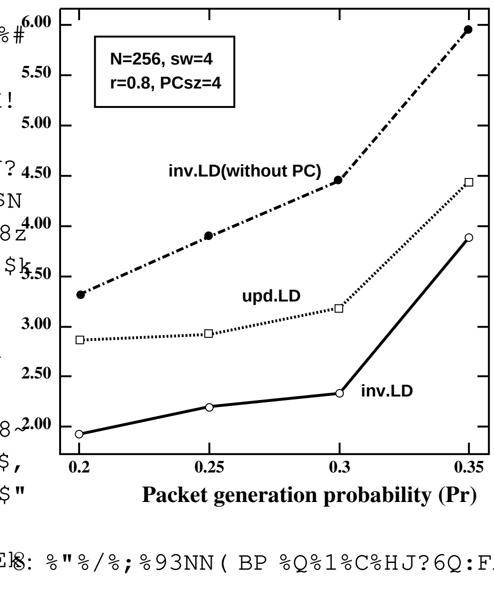
%8$+$iJk MIN $rA[Dj$7$F$$$k. ;^4"$j%P%C%U%!$N%5%$%: (LTsz) $O<BAu$r9MN8$7$F>.5a$N 4 $K@_Dj$7$?. B>$N%Q%i%a!<%?$O, Pr=0.3, GM=64Mbyte, BS=16byte H7$F8GDj$7$?. 3N>r7o$G, ;^4"$j%P%C%U%!$rF~lk%9%F!<%8 (PBst) rJQ($F, %Q%1%C%H$NJ?6Q:FAw2s?t$rD4$Y$?7k2L$r?^ 7$K<($9. J*, %9%F!<%8?t$O%W%m%;%C%5 (%-%c%C%7%e) $K6a$$B&$+$i 1,2,3 $H=gHV$KHV9frIU1$F$$$k. I>2A$KMQ$$$?%G!<%?$O, $=$l$>$l$N>r7o$G%7%_%e%l!<%?$r 10,000 %U%l!<%`$@$1F0:n$5$;$?bNG"$k. ?^Cf$N **prob**, **local** O=l>$l,

- **prob** – Nonlocal %b!<%I 90%, Local %b!<%I 10% $N3d9g$G%Q%1%C%H$r@8@.$7$?>l9g
- **local** – Local %b!<%I 90%, Nonlocal %b!<%I 10% $N3d9g$G%Q%1%C%H$r@8@.$7$?>l9g

$r, invalid/valid O=l>$l, %-%c%C%7%e%W%m%H%3%k$NL58z2=7?/99?77?$rI=7F$$$k. @h$NI>2A$G$O%#%l%/%H%j=LLsK!$K$D$$$F$O, LARP K!$h$j SM K!$NJ}$,NI$$@-G=$r<($9;v$,J,$+C?NG, :#2s$O SM K!$K4X7F99$K>\:Y$JI>2A$r9T$JCF$$$k.

?^ 7KhkH, 6I=j@-NJ$$>l9gGb:FAw2s?t$OJ?6Q 4 2sDxEY$G:QsG$*$j, %^%k%A%-%c%9%H$r9T$J$&$NKMW9$k;~4V$, 8=<BE*G"k3H,o+$k. $^$?, L58z2=7?!&99?77?$$$:lN>l9g$b%Q%1%C%H$K6I=j@-N"kJ}$,$h$jNI$$@-G=$r<($7$F$$$k. 0lJ}, update.local KD$$$F, LTst $r 3 K9kH LTst=2,1 $N;~$KHf$Y, 5^7c$KE>Aw2s?t$,A}2C$7$F$$$k. 3l$O, MINC $N%H%]%m%8$, Baseline LVG"kN$G, %"%/%;%9$K6I=j@-$,$"$k>l9g$O2<0L%9%F!<%8$NJ}$G=iaFJ#?tJ}8~$K%^%k%A%-%c%9%H%Q%1%C%H$,;^JLl7$F$$$/>l9g$,B?$/, >e0L%9%F!<%8$NJ}$G$O;^4"$jG-$J$$$?aG$"$k. $=$NB>,IN>r7oGb, LTst=1 $N>l9g$,:G$bDc$$CM$r<($7F*$j,;^4"$j%P%C%U%!$O%9%F!<%8 1 $K@_Dj$9kN$,:G$b8z2LE*G"k3H,o+$k.

<!$K;^4"$j%P%C%U%!$r 1 %9%F!<%8L\$KF~lk>l9g$K4X$7$F, ;^4"$j%P%C%U%!$N8z2L$K$D$$$FD4Y?. ?^ 8 $O, invalid.local $H update.local KD$$$F$O PBst=1 8GDj$H$7, ;^4"$j%P%C%U%!HsEk:\7? (invalid) HNHf3S$r<($7$F$$$k. %W%m%;%C%5$N%"%/%;%9H/@83NN($, Pr=0.3 $N;~, %P%C%U%!HsEk:\7?$,J?6QLs 3.5 2s$N:FE>Aw$rI,MWH9kNKBP7$F, ;^4"$j%P%C%U%!IU$-$NJ}$OLs 1.5 2s$G:QsG$$$k. 3N3H$+$i, ;^4"$j%P%C%U%!$N8z2L$OL@$i$+$G$"$k. $^$?, Pr=0.35 KJkHIN>l9g$b:FAw2s?t$,>e>:9k$,, 3l$O MIN KBP9$k%"%/%;%9$,A}2C$7, A4BN$NK0OB$,;O$^CF$$$k3H$r<($7$F$$$k.



?^ 8: %"%/%;%93NN(BP %Q%1%C%HJ?6Q:FAw2s?t

:G8e$K, ;^4"$j%P%C%U%!$r 1 %9%F!<%8L\$KEklH$?>l9g$N;^4"$j%P%C%U%!$N%R%C%HN($rD4$Y$? (I= 2). invalid.prob $NJ}$, 48.52%G"kNKBP7$F, update.local %R%C%HN($NJ}$, 54.20%$H9b$$$NKb4Xoi$:, invalid.prob $NJ}$,, %^%k%A%-%c%9%Hro$:$+G"k,%9%`!<%:$K9T$JCF$$$k. 3l$O, L58z2=7?$O$$$:l+$N%W%m%;%C%5$, write $r5/$3$9$H%G%#%l%/%H%j$r:n$jD>9NKBP7$F, 99?77?$O%G%#%l%/%H%j>e$N%S%C%H%^%C%W$,J]B8$5$l$kE@$K5/0x9k. 9JoA, 99?77?$N>l9g$O4{$KITMW$KJC$?%-%c%C%7%e$H%$%s$N99?7N?aN%H%i%U%#%C%/$, MIN $N:.;($r$-5/$3$92DG=@-$,$"$k.

I= 2: ;^4"$j%P%C%U%!%R%C%HN(

invalid local	invalid prob	update local	update prob
77.87%	48.52%	54.20%	34.22%

5 7kO@

RHBD $*$h$S;^4"$j%P%C%U%!$rF3F~$9$k;v$G9bB.$J%-%c%C%7%e%3%R!<%l%s%9@)8f2DG=$JB?CJ7k9gLV MINC $r9=C[$7$?. 99$K%=%U%H%&%'%"%7%_%e%l!<%?GNI>2A$r9T$$, 0J2<$N7kO@$,F@il$?.

1. 6&M-%a%b%jKBP7FN%"%/%;%9$K6I=j@-$,$"$k>l9g, hj8z2LE*$K%3%R!<%l%s%9@)8f$r9TJ&3H$,$G$-$k.
2. %9%F!<%8 1 $K;^4"$j%P%C%U%!$rEk:\$9kH:G$b8zN(NI$/%^%k%A%-%c%9%H$r9T$J$&$3H,G-$k.
3. %G%#%l%/%H%j=LLs$K4X$7FO SM K!$,M-8z$G$"$k. %-%c%C%7%e%W%m%H%3%k$K4X$7FO, 99?77?$O%^%k%A%-%c%9%H$NM-8z@-$rMxMQ$9k3H,G-$k0lJ}, ITI,MW$J%-%c%C%7%e%i%$%s$,B8:_9k$H8r?.NL$,A}Bg9k$?$a, ITMWHJC?%i%$%s$rH=JL$7,L58z2=$9$k5!9=$,K>$^$l$k.

:#2s$N%7%_%e%l!<%7%g%s$O3NN(%b%G%k$K4p$E$$$?$?$a, $=$N7k2L$OL\0B$K2a$.$J$$. :#8e$O MINC $N%9%$%C%A%s%0%(%l%a%s%H$N@_7W$r?Jak0lJ}, Hl$<%9%I%j%V%s%7%_%e%l!<%?$rMQ$$$F5i$K8=<BE*$J@-2A$r9T$J$&M=Dj$G$"$k.

;29MJ88%

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