FCJL8&5fJs9p=q

D6JBNs7W;;5!**JUMP-1**K*1k
J,;66&M-%a%b%j4IM}

;XF36541　IYEDbC<#65<x

5~ETBg3X9)3XIt>pJs9)3X2J

GiC+2m;K

J?@.#1#0G/#27n#1#3F|

D6JBNs7W;;5!**JUMP-1** K*1k
J,;66&M-%a%b%j4IM}

GiC+2m;K

FbMF9<35

CC-NUMA 7?$NJBNs7W;;5!$r<BAu9k>e$GJ,;66&M-%a%b%j(DSM:Distirbuted Shared Memory) $r4IM}$9$k%3%s%H%m!<%i$N<BAuJ}<0$,%7%9%F%`$N@_7W>e$N=EMW$J0LCV$N1$D$r@j$a$k!#$3$N%3%s%H%m!<%i$r40A4$K%O!<%I%o%$%d!<%I$G<B8=$9$l$P9bB.@-$OF@$i$l$k$b$N$N=@Fp@-$rB;$&62$l$,$"$k!#$=$3$G2f!9$,3+H/$7$F$$$kD6JBNs7W;;5!JUMP-1 $G$O$3$N%3%s%H%m!<%i$r%W%m%0%i%`%Y!<%9$G4IM}9k!#

3N%"%W%m!<%AKhlP DSM 4IM}$N=@Fp@-$OJ]$?$l$k!#$7$+$7!"C1$KHFMQ$N%W%m%;%C%5$rMQ$$$F<B8=7FbI,MWH5l$k=hM}G=NO$rF@k3HOFq$7$$!#J<Ji DSM 4IM}%W%m%;%C%5$O%i%$%s$NE>Aw5Z$S6&M->uBV$N99?7$J$IFC<l$J=hM}$r9T$oJ1PJiJ$$$+iG$"$k!#2f!9$O DSM 4IM}MQ$N@lMQ%W%m%;%C%5 MBP-light $r3+H/$7=@Fp@-$H9bB.@-$NN>N)$r?^$C$?!#

JUMP-1 $O%/%i%9%?9=@.$rHj!"%Q%1%C%H$N8r49$9k3HKhC$F%/%i%9%?%a%b%j%"%/%;%9$r9T$&!#%a%b%j%"%/%;%9$,%/%i%9%?FbKJD8$F$$$J$$>l9gKO MBP-light $O5/F0$5$l!"DSM 4IM}%W%m%0%i%`$,<B9T5l$k!#

MBP-light $N9T$&Y-=hM}$O%-%c%C%7%e%i%$%s$NE>Aw5Z$S%i%$%s$N>uBV$N99?7$G$"$k!#$=$3$GMBP-light $O%Q%1%C%H3JG<MQ$K@lMQ$N%P%C%U%!$H7FPBR(Packet Buffer Register) $rMQ0U$7$?!#MBP-light KOPBR A`:nMQ$N@lMQ$NL?Na%;%C%H$,MQ0U$5lF$*$j!"%Q%1%C%H$N%X%C%@It$N:n@.JI=@Fp$J=hM}$r9T$&$3H,G-$k!#

K\8&5fGOMBP-light >e$G<B9T$5lkDSM 4IM}%W%m%0%i%`$r<BAu$7$?!#K\9F$G$O!"$=$N<B9T@-G=B.EY$K4p$E$$$FDSM 4IM}%W%m%;%C%5MBP-light $NI>2A$r9TC?!#

<BAu7?MBP-light >e$G<B9T$5lkDSM 4IM}%W%m%0%i%`$O%i%$%s$NE>Aw$@1GJ/!"%/%i%9%?%a%b%j$N>uBV$N99?75Z$SMW5a$N9lA,$$5Z$SDI$$1[7,5/iLh&$K4IM}$7J/FOJi$J$$!#

%/%i%9%?%a%b%j$N>uBV$N99?7KODSM 4IM}%W%m%0%i%`KhCF99?7MQ$N%Q

%1%C%H$r:n@.$7%"%/%;%9$9$kI,MW$,$"$k!#

DI$$1[7,5/iJ$$$h$&:#2s$N%W%m%0%i%`GO%Z%s%G%#%s%0·%H%i%s%6%/%7%g%s·%F!<%V%k$H8F$Plk%F!<%V%k$rMQ0U$7!"MW5a$r%F!<%V%k$KEPO?9k3HKhCF4IM}$r9T$C$?!#MW5a$,MBP-light $KE~Ce$9kH%F!<%V%k$r8!:w$7!"Ev3:%"%I%l%9$K=hM}Cf$NMW5a$,$9GKB8:_7F$$$k>l9gKO%F!<%V%k$K%Z%s%G%#%s%0$5$l=hM}$OCfCG5l$k!#=hM}Cf$NMW5a$N1~Ez$,E~Ce9k$H!"CfCG$5lF$$$?MW5a$N=hM}$r3+;O9k3H$GDI$$1[7rKI;_7F$$$k!#

$^$?!"9lA,$$KI;_N?aK%W%m%0%i%`KhCF%m%C%/r+1kI,MW$,$"k,!"MBP-light $N%m%C%/$r$+$1$k5!G=$O$"$kK;$h!"$=lrB(:B$K9T$&3H$,$G$-$J$$!#7?$,$C$FAtomicity $N3NJ]$KLdBj$,$"kH8@$($k!#

5i$K:#2s$NDSM 4IM}%W%m%0%i%`$O%a%b%j$N99?7$b9T$oJ/FOJi$J$$!#%a%b%j$N99?7$O%a%b%j$+$i%G!<%?rFI_=P7?8e$K%G!<%?$r99?7$7!"%a%b%j$K=q$-La$9$H$$$C$?=hM}$r9T$&!#$3$N=hM}$Khj99?7MW5a$N=hM};~4V$N$&$A3 3d$,Hq$d5l$?!#

:#2s:n@.7?DSM 4IM}%W%m%0%i%`$rVHDL $GO@M}9g@.2DG=$Jh&$K5-=R$5l?@_7W%G!<%?$rMQ$$!"Mentor Graphics <R$NVHDL %7%_%e%l!<%?!<qhsim v8.5_4.6c $rMQ$$$FL5Ii2Y>uBVGN%7%_%e%l!<%7%g%s$r9T$C$?!#

=hM};~4VH7FOMBP-light $,3+H/$5l?Ev=iOFI_=P$7MW5a$O127 %5%$%/%k$G40N;9kH5lF$$$?$,!"<B:]$O>e5-Nh$&$J=hM}$r9T$&I,MW$,$"j=$NLs3.6 G\$N466 %5%$%/%k$b$N=hM};~4V$,$+$+CF7^$&7k2L$HJC$?!#

MBP-light $N=hM}G=NO$H7F$O!"99?7MW5a$K4X7F$O1 DN%/%i%9%?FbGN=hM}$,197 %5%$%/%kbN;~4V$,$+$+$k3H$,L@$+KJC?!#$^$?!"1 <!!"2 <!!"3 <!%-%&%C%7%e$N%R%C%HN($r$=$l$>$l95%!"97%!"99%H9kH!"FI$_=P$7J?6Q%l%$%F%s%7$O1.242 %5%$%/%k$G$"$C$?!#$^$?!"99?7MW5a$NMBP-light $N%P%s%II}$O8.1MByte/sec G"k3HbJ,$+$C$?!#

DSM 4IM}%W%m%;%C%5$O%-%&%C%7%e%i%$%s$NE>Aw$d>uBV$N99?7$H$$$&FC<l$J=hM}$r4IM}9k%W%m%;%C%5G"$k!#$7$?$,CF%/%i%9%?%b%a%b%j$N99?75Z$S%m%C%/JI$NFC<lL?Na$r%5%]!<%H9kCISC hj$N9=@.$G$"$kJ}$,$5iJ$k9bB.2=$,4|BTG-$k!#

Distibuted Shared Memory Management of a Massively Parallel Processor JUMP-1

Masashi Hakariya

Abstract

It is important to decide the distributed shared memory controller on CC-NUMA type multiprocessor. If the controller is completely composed of the hardware, performance is higher but it may lose flexibility. Therefore a massively parallel processor JUMP-1 we develop takes the program based control.

On this approach, the flexibility is kept. But it is difficult to get a needed performance when the processor of the controller is general one. Because distributed shared memory controller must manage special process, for example to transmit cache lines, to change state transition and so on. Therefore, we developed the special purpose processor MBP-light, which achieves both flexibility and performance.

JUMP-1 takes a cluster structure and cluster memory accesses are giving and taking of packets. Only inter-cluster access don't start the distributed shared memory management program.

If the program starts, it must transmit packets and change state transition. So MBP-light has special buffers called PBR(Packet Buffer Register) and has some instructions for PBR so as to make, for example, header of packet flexibly.

The distributed shared memory management program is implemented. On this paper, the performance of MBP-light is reported based on the performance of the program.

The program not only transmit packets but also control to change the state of cluster memory and prevent packets from cross-overing or overtaking other packet.

In order to change the state of cluster memory, the program need to make the header of write request packet and access it.

So as to prevent packets from cross-overing or overtaking, a table called pending transaction table(PTT) is used. When a request packet arrives at MBP-light, the program looks up PTT. If PTT has no entry, it is registered on PTT. But PTT has already an entry, the request packet is pended on the entry.

When a reply packet arrives at MBP-light, the entry is deleted and pended packet is executed. PTT makes all packets not to overtake others.

It is necessary to lock the cluster bus not to cross over others. MBP-light can't lock it immediately. So MBP-light has problem on the atomicity.

And MBP-light has to update the cluster memory, too. In order to update it, first, MBP-light read the data from it and update it. Then MBP-light writes back the data to it. This module cost 30% of all management for update request packet.

The program is simulated with no load condition on qhsim v8.5_4.6c Mentor Graphics corporation with the data described VHDL which can be logic composition.

When MBP-light was developed, we expected that it takes 127 cycles to manage read request packet. But actually it takes 466 cycles which is about 3.6 times longer than we expected.

The reason why the time is 3.6 times longer than we expected is that MBP-light must perform processes to write cluster memory with change of shared state. MBP-light should only transmit packets and change state transition and don't have to do memory access.

It takes 197 cycles to manage value update request packet in one cluster. When the first cache hit rate is 95%, the second is 97% and the third is 99%, an average read latency was measured and value update request packet band width in MBP-light was calculated. The result of average read latency is 1.242 cycle and band is 8.1MByte/sec.

The distributed shared memory controller manages special process. Therefore it should be developed based on CISC architecture and support special instruction for value update of cluster memory, to rock cluster bus and so on.

D6JBNs7W;;5!**JUMP-1** K*1k
J,;66&M-%a%b%j4IM}

L\<!

1 O8aK

CC-NUMA 7?$N%7%9%F%`$G$OJ,;66&M-%a%b%j(DSM:Distirbuted Shared Memory) $N4IM}$r9T$&%3%s%H%m!<%i$N<BAuJ}<0$,%7%9%F%`$r@_7W9k>e$G=EMW$J0LCV$N1 Dr@jak!#3N%3%s%H%m!<%i$r40A4$K%O!<%I%o%$%d!<%I$G<B8=9l$P9bB.@-$OF@ilkbNN!"@_7W%3%9%H$,Hs>o$KBg$-$/JC$?$j=@Fp@-$rB;$J$&2DG=@-$,$"$k!#

2f!9$,B>Bg3X$H6&F1$G3+H/$r?JaF$$$kCC-NUMA 7?D6JBNs7W;;5!**JUMP-1** GO3F%W%m%;%C%5$rBPEy$K@\B3$9$k%M%C%H%o!<%/GOJ/!"4 DN%W%m%;%C%5$H%a%b%j$r%3%R!<%l%s%H!&P%9@\B3$7$?bN$r1 DN%/%i%9%?H7!"%/%i%9%?F1;N$rBg5,LO$J@EE*LV$G@\B3$9k3HGA4BN$N%7%9%F%`$r9=@.9k%/%i%9%?9=@.$r:NMQ$7$F$$$k!#

3Nh&$J9=@.$rH?1G7FJUMP-1 GODSM 4IM}$N%3%R!<%l%s%9@)8f$r%/%i%9%?Fb$H%/%i%9%?4V$N2CJ3,$K3,AX2=$7!"%/%i%9%?Fb$N%3%R!<%l%s%9@)8f$O%9%L!<%WJ}<0$K4p$E$-%O!<%I%&%'%"$Khj9bB.$K9T$olk!#3lKBP7$F%/%i%9%?4V$G$O%G%#%l%/%H%jJ}<0$K4pE-%W%m%0%i%`%Y!<%9$G9T$&!#%/%i%9%?4VGO=hM}$N9bB.@-$b5k3HJ,$i!"%3%R!<%l%s%9@)8f$N=@Fp@-$d=hM}$NJ#;(5JIK$bBP1~$7J1lPJi$J$$$+iG$"$k!#

3N%"%W%m!<%AKhlPDSM 4IM}J}<0$N=@Fp@-$OJ]$?$l$k!#$7$+$7C1$KHFMQ$N%W%m%;%C%5$rMQ$$$F<B8=7FbI,MWH5l$k=hM}G=NO$rF@k3HOFq$7$$!#$=$3$GJUMP-1 GODSM 4IM}N?aN@lMQ$N%W%m%;%C%5**MBP-light** $r3+H/$7!"=@Fp@-$H9bB.@-$NN>N)$r?^$k!#

3N%W%m%;%C%5>e$G<B9T$5lk6&M-%a%b%j4IM}%W%m%0%i%`$O%-%c%C%7%e%i%$%s$NE>Aw5Z$S>uBV$N99?7$J$I$r9T$&$,!"3EMW5a!&~Ez5Z$S%G!<%?$N6&M->uBV$J$I$K$h$j$=$N=hM}$OMM!9$KJQ2=$9$k!#%7%9%F%`A4BN$N@-G=$N$?$aKO!"3NJ#;(B?MM$J=hM}$r$"$kDxEY9bB.$K9T$&I,MW$,$"$k!#

K\8&5fGOD6JBNs7W;;5!JUMP-1 K*1kDSM 4IM}%W%m%;%C%5>eGNDSM 4IM}%W%m%0%i%`$N%W%m%H%?%$%W$r<BAu$7$?!#K\9F$G$O!"$=$N<B9T@-G=B.EY$K4p$E$$$FDSM 4IM}%W%m%;%C%5$NI>2A$r9T$&!#

2>OGOBP>]HJ$k7W;;5!$G$"$kJUMP-1 $N35MW$H7F9=@.$H%3%R!<%l%s%9%W%m%H%3%k$K$D$$$F=R$Y!"3@a$G$OMBP-light $N9=@.$HFCD'$r=R$Y$k!#4>O$G$O:n@.$7$?%W%m%0%i%`$K$D$$$F=R$Y!":G8e$K5>O$G$O:n@.$7$?%W%m%0%i%`$Khk

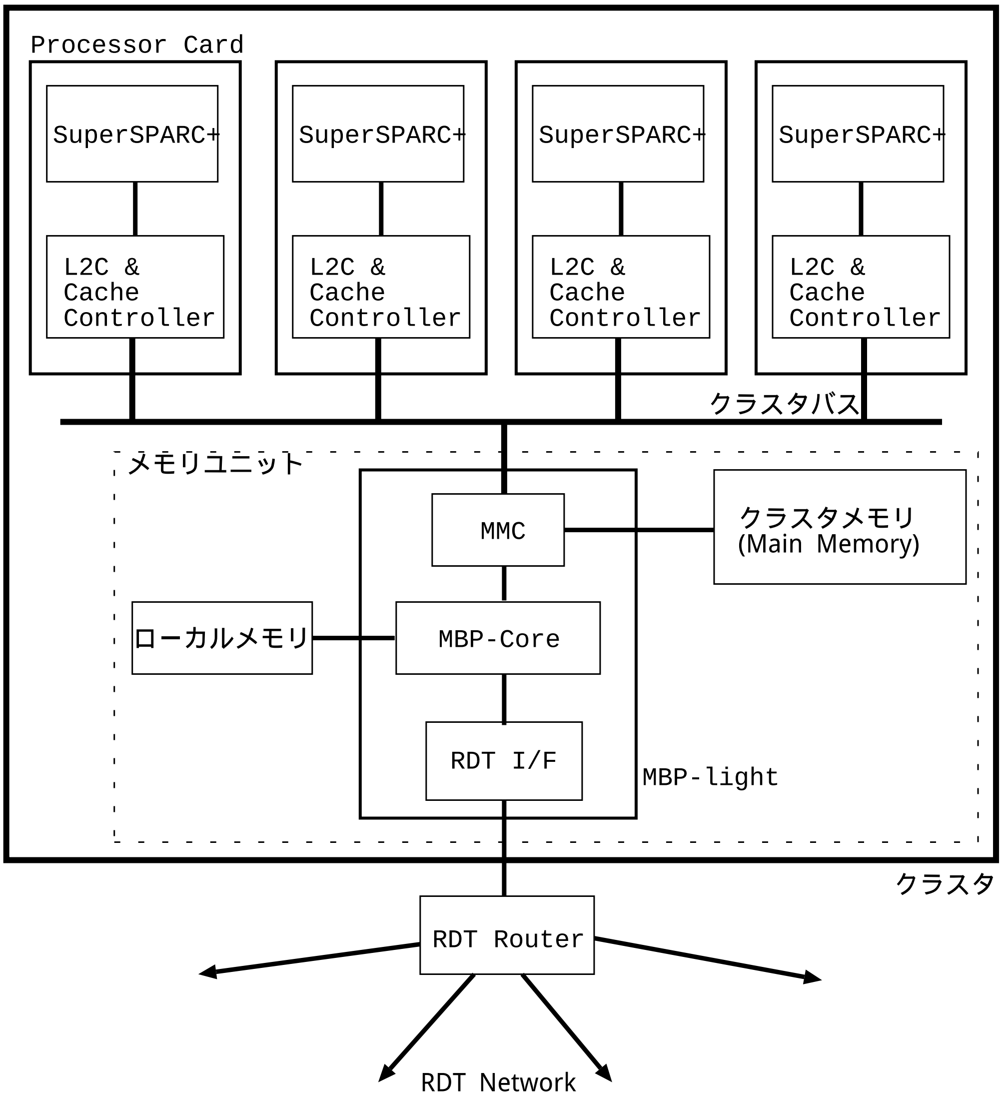
%7%_%e%l!<%7%g%s$N7k2L$+$i@-G=$NI>2A$H9M;!$r9T$&!#

2 D6JBNs7W;;5!JUMP-1 $N35MW

K\>OGOJUMP-1 $N9=@.5Z$SDSM 4IM}J}<0KD$$$F=RYk!#

2.1 JUMP-1 $N%/%i%9%?9=@.

D6JBNs7W;;5!JUMP-1 $N%/%i%9%?$N9=@.$r?^2.1$K<($9!#JUMP-1 $N%/%i%9%?$G$O4 DN**Processor Card** $H1 DN%a%b%j%f%K%C%H$,%/%i%9%?%P%9$G7k9g5l$F$$$k!#



?^2.1: JUMP-1 $N%/%i%9%?9=@.

- Processor Card !D1<!%-%&%C%7%e$rFbB"$9$kSuperSPARC+!"30It2<!%-%&%C%7%e(L2C) H=$N%-%&%C%7%e$r@)8f9kCache Controller(0J2<CC) $r<gBN$H9k!#
- %a%b%j%f%K%C%H!D%/%i%9%?%a%b%jH=$N@)8f$r9T$&**MBP-light** $KJ,3d$5lk!#%/%i%9%?%a%b%j$O%/%i%9%?$N<g5-21H7$F;HMQ$9k@1GJ/!"%/%i%9%?4VGN%a%b%j%"%/%;%9KBP9$k3<!%-%&%C%7%e$H7F$bMxMQ$9$k!#MBB-light KD$$$F$O3>O$G>\:Y$r@bL@$9$k!#

%/%i%9%?4V$O**RDT**(Recursive Diagonal Torus) Kh$jAj8_$K7k9g5l$F$$$k!#RDT $O2<!85%H!<%i%9$,Fat-tree >u$K3,AX2=$5l?9=B$$r;}$D[2]!#RDT 4V$NDL?.$O%/%i%9%?4V$N1BP1 $N%G!<%?E>Aw$H!"3,AX9=B$$r3h$+$7$?%^%k%A%-%c%9%H$,2DG=HJCF$$$k!#

2.2 JUMP-1 K*1k**DSM** 4IM}

K\@aGOJUMP-1 $N%3%R!<%l%s%9%W%m%H%3%k$H$=$N@)8fJ}K!KD$$$F=RYk!#

2.2.1 JUMP-1 $N%3%R!<%l%s%9%W%m%H%3%k

JUMP-1 GO%/%i%9%?Fb$KM-8z$J%G!<%?$r=jM-$9$k%/%i%9%?$r**Renter** %/%i%9%?$H8F$V!#

Renter %/%i%9%?$N%/%i%9%?%a%b%j$X$N%-%&%C%7%s%0$O**Home** %/%i%9%?$H8F$PlkFCJL$J%/%i%9%?$N%/%i%9%?%a%b%j$r<g5-21$H7F9T$&!#$9Jo$A!"Home %/%i%9%?$N%/%i%9%?%a%b%j$O3<!%-%&%C%7%e%3%T!<$KBP7F<g5-21$NLr3d$r2L$9!#Nc$($P!"$"$k%/%i%9%?%a%b%j$GFI$_=P$7MW5a$N%_%9%R%C%H$,5/C?>l9gKO!"Home %/%i%9%?$N%/%i%9%?%a%b%j$KBP7FFI$_=P$7MW5a$rAw?.$9$k!#

%-%&%C%7%s%0$NJ}K!$H7F$O%G!<%?$NFI$_=P$7$O%Z!<%8C10L$GOJ$/%V%m%C%/C10L$G9T$&!#$3NH$-!"%a%b%j$K$O%Z!<%8C10L$GNN0h$r3NJ]$7F10l%Z!<%8XNFI$_=P$7$,$5iK9Tol$k>l9g$K$O%V%m%C%/$N$_$N%3%T!<$r9T$&3HKJ$k!#

%Z!<%8%F!<%V%k$ODSM 4IM}%W%m%0%i%`$KhC$F4IM}$9$k!#

Home %/%i%9%?$OJ,;6G[CV$5lF$*$jDL?.$N=8Cf2=$rKI$$$G$$$k!#

%3%R!<%l%s%9%W%m%H%3%kH7$F JUMP-1 $O%i%$%H!&P%C%/J}<0$r:NMQ$7$F$$$k!#9JoA!"3<!%-%&%C%7%eG"$k%/%i%9%?%a%b%j$K=q$-9~$_$,$"CF$b!"Home %/%i%9%?$N%/%i%9%?%a%b%jXN=q$-9~$_$OB(:B$K9ToJ$$!#

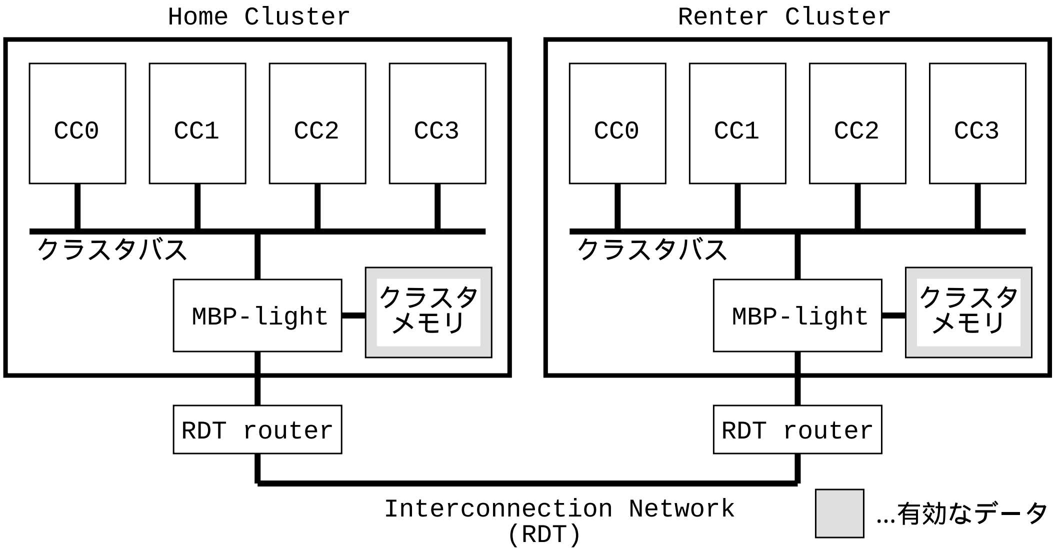
$^$?!"%f!<%6!<Kh$j99?75Z$SL58z2=%W%m%H%3%k$rA*Br$9k3H,2DG=HJCF$$$k!#

%*!<%J!<%7%C%W%W%m%H%3%k$r:NMQ$7F*$j!"M-8z$J%G!<%?$r=jM-$9$k%/%i%9%?$N$&$A!"%-%c%C%7%e$N%_%9%R%C%H;~$KEz$($k@UG$$r;}$D%/%i%9%?$r**Owner** %/%i%9%?$H8F$V!#JUMP-1 GO:G?7$N%G!<%?$r=jM-9k%/%i%9%?$rOwner %/%i%9%?$H9k!#Home %/%i%9%?$KM-8z$J%G!<%?$,B8:_$9$k>l9g$K$OHome %/%i%9%?$,!"M-8z$J%G!<%?$,B8:_7J$$>l9gKOL58z2=MW5a$rH/9T$7$?%/%i%9%?$,Owner %/%i%9%?HJ$k!#

- Home %/%i%9%?!D$"$k%"%I%l%9KD$$$F!"B>$N%/%i%9%?%a%b%j$N<g5-21H7$F5!G=$9$k%/%i%9%?%a%b%j$r=jM-9k%/%i%9%?!#M-8z$J%G!<%?$,B8:_9k%/%i%9%?$r<($9%G%#%l%/%H%j$r=jM-$9$k!#
- Owner %/%i%9%?!DFI$_=P$7MW5aKEz($k5AL3$r;}$D:G?7$N%G!<%?$r=jM-$9$k%/%i%9%?!#
- Renter %/%i%9%?!DM-8z$J%G!<%?$r;}$DHome %/%i%9%?0J30$N%/%i%9%?!#

JUMP-1 GO%G!<%?$,3F%/%i%9%?$KJ,;6G[CV5l$F$$$k!#%G!<%?$r%/%i%9%?4V$G6&M-9k>l9gKO3F%/%i%9%?$N%/%i%9%?%a%b%j$K$OI,$:M-8z$J%G!<%?$,B8:_9k;EMMH9$k(?^2.2<P@~It)!#

%/%i%9%?%a%b%jKO%a%b%j%G!<%?$NM-8z@-5Z$S6&M->uBV$r<($9%?%0$,B8:_$7F*$j!"MMC $O%?%0$NCMKh$j6&M->uBV$,%/%i%9%?FbGJD8$F$$$J1l$PMBP-Core $K=hM}$N0MMj$r9T$&!#



?^2.2: %/%i%9%?4VGN%G!<%?$N6&M-J}K!

JUMP-1 GO4KOB5l$?(relaxed) %a%b%j%b%G%k$r:NMQ7F$*$j!"%a%b%j%G!<%?$OHome %/%i%9%?$KMW5a$,E~Ce$7$?=g$KH?1G5l$k!#

2.2.2 JUMP-1 $N%3%R!<%l%s%9@)8f

%/%i%9%?FbGN%3%R!<%l%s%9@)8f$O6&M-%P%9%Y!<%9$N%9%L!<%WJ}<0$r:NMQ$7$F$$$k!#IQHK$K@)8fMW5a$,5/kN$G!"9bB.=hM}$,2DG=$J%O!<%I%&%'%"9=@.$G$"$k!#%/%i%9%?Fb$N%-%c%C%7%e%3%R!<%l%s%9$OMBP-Core $+$iIT2D;kG"kN$G0J2<$=N3HK$D$$$F$N@bL@$O9ToJ$$!#

0J2<%/%i%9%?4VGN%3%R!<%l%s%9@)8fKD$$$F=RYk!#

%/%i%9%?4VGN%-%c%C%7%e%3%R!<%l%s%9$O%G%#%l%/%H%jJ}<0$r:NMQ7F$$$k!#%G%#%l%/%H%j$OHome %/%i%9%?$KCV$+$lRenter %/%i%9%?$r4IM}$7$F$$$k!#

%G%#%l%/%H%j$O=LLs3,AX%S%C%H%^%C%W[2] $r%Z!<%8(4KByte) C10L$G;}$A4IM}$9$k!#$3$NJ}K!$Khj!"=>Mh$NJ}K!$G$O:$FqG"C?%7%9%F%`%5%$%:$NA}2C$KH<$J$&%G%#%l%/%H%j$NA}2C$r8:>/$5$;!"9bB.$J%a%b%j$K3JG<$9k3H,MF0WHJCF$$$k!#

6&M-5l$?%G!<%?$r%^%k%A%-%c%9%H9k:]KO!"=LLs3,AX%S%C%H%^%C%W%G%#%l%/%H%j$rRDT $KAw?.$9$k%X%C%@It$J,KKda9~$`$3HKhj3,AXE*$K%^%k%A%-%c%9%H$9$k!#

JUMP-1 GO%Q%1%C%H$r8r49$9k3HKhC$F%/%i%9%?%a%b%j%"%/%;%9$r9TJ&!#1 DN%Q%1%C%H$O64b $r1 DN%U%j%C%HH7!"1 DN%X%C%@It$H1 %V%m%C%/$KBP1~7?4 DN%G!<%?ItHN9g7W5 %U%j%C%H$+$i9=@.5l$F$$$k!#%Q%1%C%H$ND9$5$O2DJQD9$G$"$j%U%j%C%H$KIU?o$9$k2b $N%?%0$NItJ,$r@_Dj$9k3HG%X%C%@ItN_!"$^$?$O%X%C%@It$H%G!<%?It$,$=l>$l1 %U%j%C%H$G$"$k%Q%1%C%H$bB8:_$9$k!#%G!<%?It$N%?%0$O%G!<%?$NM-8z@-$r<($9NK;HMQ5l$k!#

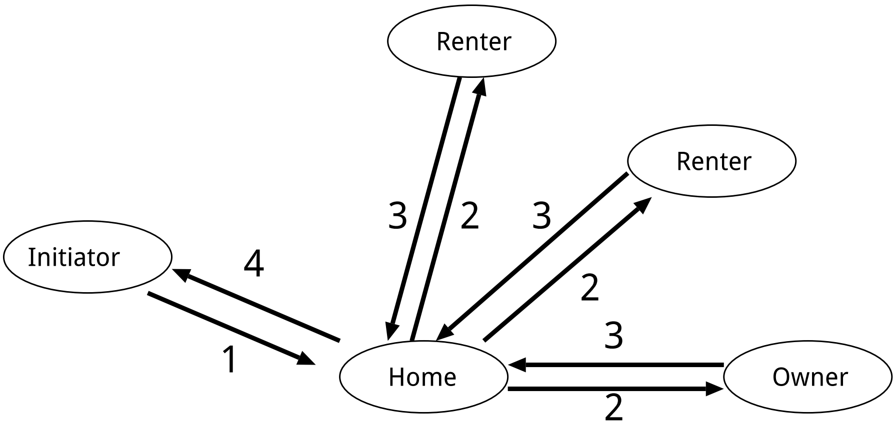
$"$k6&M-5l$?%G!<%?$KBP9k%/%i%9%?4V$N%Q%1%C%H$NE>Aw5Z$S0lO"$N>uBVA+0\$r%H%i%s%6%/%7%g%s$H$$$&!#%H%i%s%6%/%7%g%s$r3+;O$9$k%/%i%9%?$r**Initiator** %/%i%9%?$H8F$V!#

- Initiator %/%i%9%?!DMW5a%Q%1%C%H$rAw?.$7!"%H%i%s%6%/%7%g%s$r3+;O$7$?%/%i%9%?!#

E57?E*$J%H%i%s%6%/%7%g%s$NNN.lr<($9!#

FI$_=P$7MW5a$N>l9g(?^2.3)

1. FI$_=P$7MW5a$,H/9T$5l?Initiator %/%i%9%?$OHome %/%i%9%?$KBP7FMW5a%Q%1%C%H$rAw?.$9$k!#



?^2.3: %/%i%9%?4VGN%Q%1%C%H$NN.$l

2. Home %/%i%9%?O=$NMW5a$KBP7FOwner %/%i%9%?$KMW5a$rAw?.9k!#
3. Owner %/%i%9%?$O1~Ez%Q%1%C%H$rHome %/%i%9%?$KAw?.$9$k!#
4. Home %/%i%9%?O=$N1~Ez%Q%1%C%H$rInitiator %/%i%9%?$KAw?.$9$k!#

3Nh&K7$F1$D$N%H%i%s%6%/%7%g%s$O=*N;9k!#3NH-1~Ez%Q%1%C%H$OI,$:Home %/%i%9%?$r7PM3$9kh$&$K7F03$QDL?.$O9ToJ$$!#

99?7MW5a$N>l9g$K$OInitiator %/%i%9%?$+$iHome %/%i%9%?$KMW5a%Q%1%C%H$,E~Ce$9kH!"Home %/%i%9%?$OOwner %/%i%9%?$@1GJ/!"Renter %/%i%9%?Kb%Q%1%C%H$,Aw?.$5$l%G!<%?$,99?7$5$l$k!#

3 MBP-light $N9=@.

K\>OGOMBP-light $N%O!<%I%&%'%"9=@.$H$=$NFCD'KD$$$F=RYk!#

3.1 MBP-light $N%O!<%I%&%'%"9=@.

DSM 4IM}%W%m%5%C%;$N9T$&Y-=hM}$O%Q%1%C%H$N<oJL$NH=JL$r9T$$!"%-%c%C%7%e%i%$%s$NE>Aw$d%i%$%s$N>uBV$NJQ99JI$N%/%i%9%?4V$G$N%3%R!<%l%s%9@)8f$G$"$k!#7?$,$C$F%Q%1%C%HA`:n$NFC<l$JL?Na$rI,MW$7!"HFMQ$N%W%m%;%C%5GO==J,$J@-G=$,F@il$J$$!#$=$3$GJUMP-1 GODSM 4IM}$r9T$&$?aN@lMQ%W%m%;%C%5**MBP-light** $r3+H/$7$?!#

MBP-light $O%/%i%9%?%a%b%j$N%3%s%H%m!<%i (MMC)!"%3%"%W%m%;%C%5G"$k**MBP-Core** $H30It%/%i%9%?$H$N%$%s%?!<%U%'!<%9(RDT I/F) $+$i9=@.5l$k!#(?^2.1;2>H)

MBP-Core $OL?NaD921b %G!<%?D916b $NRISC %W%m%;%C%5$G0J2<NbN+$i

9=@.5l$k!#

- HFMQ%l%8%9%?(GPR:Genenal Purpose Register)
- 16b×256 $NFbIt%a%b%j
- %Q%1%C%H3JG<MQ%l%8%9%?(PBR:Packet Buffer Register)

GPR $O16b I}$NbN$,16 K\MQ0U$5lF$*$jGPR 4V$N1i;;$@1GJ/PBR XN%]%$%s%?5Z$SPBR-GPR 4V$N1i;;$r9T$&$3H,G-$k!#

FbIt%a%b%j$O%F!<%V%k%8%c%s%W$K;HMQ9k%MQE%S$N%B>$K!"%/%i%9%?%P%9XNAw<u?.%P%C%U%!$N>uBV$J$I MMC $N>uBV$r<($9%l%8%9%?5Z$SRDT-router $N@)8f$r9T$&3F%l%8%9%?$,%^%C%T%s%0$5$l$F$$$k[3]!#3liN%l%8%9%?$r;HMQ$9k3HKhj%/%i%9%?%P%9XN%m%C%/$rMBP-Core $+$i@)8f9k!#%m%C%/%l%8%9%?$O%"%I%l%9$r3JG<9k$?$a$K64b I}$N%l%8%9%?$,4 AHMQ0U$5lF$*$j!"%m%C%/$r9T$&%"%I%l%9!"%V%m%C%/$d%Z!<%8$JIN%m%C%/$N%^%9%/5Z$SValid $N3 K\$r1 AHH7$F$$$k!#FbIt%a%b%j$O1 %/%m%C%/$G%"%/%;%9$9$k3H$,$G$-$k!#

PBR KD$$$F$O<!@a$G>\$7$/@bL@$r9T$&!#

$^$?30It$K21b×64K $H64Kb $N%"%I%l%96u4V$r;}$D%m!<%+%k%a%b%j(?^2.1 ;2>H) rHw($F$$$k[5]!#%m!<%+%k%a%b%j$ODSM 4IM}%W%m%0%i%`$d3F<o%F!<%V%k$r3JG<$9kN$KMQ$$!"L?Na%a%b%j$H%G!<%?%a%b%j$NJ,N%$O9T$C$F$$$J$$!#%-%c%C%7%e$bFbB"$5lF$$$J$$$?aK%a%b%j%"%/%;%9KO1 %/%m%C%/$N%9%H!<%k$rH<J&!#

3.2 %Q%1%C%H3JG<MQ$N<h$j07$$

MBP-light Kh$k=hM}$O!"4pK\E*$K%Q%1%C%H$NE~CeKh$k3d9~$_$G5/F0$5$l!"3FMW5a%Q%1%C%H$N<oJL$rH=JL$7=hM}$r9T$&!#A0=RNh$&$KMBP-light $N9T$&Y-=hM}$O%-%e%C%7%e%i%$%s$NE>Aw5Z$S>uBV$N99?7$JIG$"$k!#7?$,$C$F%Q%1%C%H$NH=JL5Z$SA`:n$r=@FpK+$D9bB.$K9ToJ$/$FOJiJ$$!#$=$3$GMBP-light KO%Q%1%C%H3JG<MQ$N@lMQ$N%l%8%9%?$,MQ0U$5lF$$$k!#3N%Q%1%C%H3JG<MQ$N%l%8%9%?$rPBR(Packet Buffer Register) $H8F$S!"3N9=@.$rBuffer-Register Architecture $H8F$V[2, 3]!#

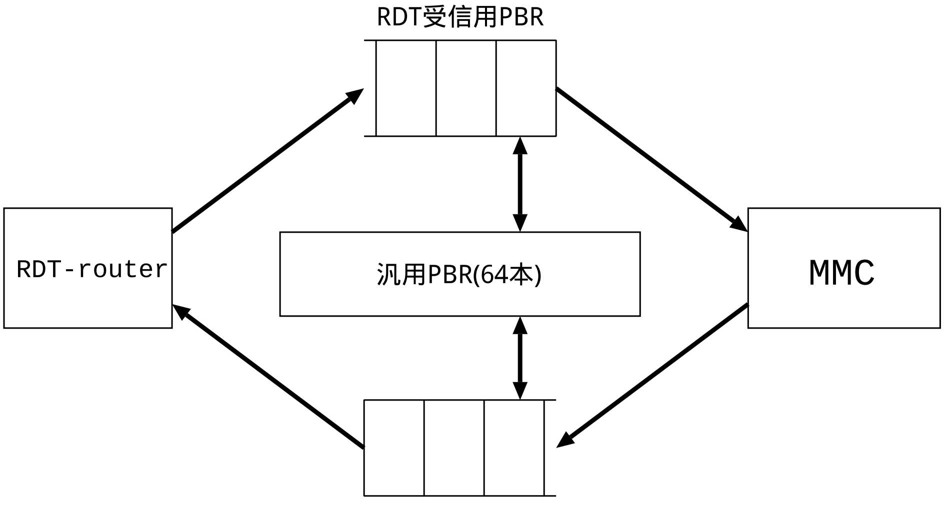
DSM 4IM}%W%m%;%C%5$NLr3d$,%Q%1%C%H$N<oJL$JIrH=CG$7E>Aw$9k@1G$"$l$P!"%Q%1%C%H$N%X%C%@It$@$1$r<h$jF~$l%G!<%?It$OJ,N%7F$*$/Y-G"$k!#$7$+$7!"JUMP-1 $N%Q%1%C%H$O%G!<%?It$K4^$^lk%?%0$b%W%m%H%3%k$K4X78$7$F$*$j!"%G!<%?$r4^$a$?%Q%1%C%HA4BN$r%l%8%9%?H7$FMBP-light $+$i07

$ (kh$&$K7J1lPJiJ$$! #$=$3$GMBP-light $O%G!<%?It$b%X%C%@ItF1MM $KPBR $K3JG<$7! "D>@\<h$j0 7$&3H$,2DG=$HJC$F$$$k! #5i$KMBP-light $O%Q%1%C%H$N%X%C%@It$H%G!<%?It$rJ,N%7FPBR $K3JG<$9k3H,G-! "=@ Fp@-$N9b$$%Q%1%C%HA`:n$,$G$-$k! #

$^$?! "MBP-light KOPBR A`:n$N@lMQ$NL?Na%;%C%H$,MQ0U$5$l$F$*$j! "GPR $r%]%$%s%?$H$7$FPBR-GPR 5Z$SPBR-PBR 4V$Nl i; ;$d%G!<%?E>Aw$,2DG=$G$" $j! "%Q%1%C%H$N%X%C%@:n@.$J$I$,MF0W$K$G$-$k! #$7$+$7! "PBR-PBR 4V$N%3%T!<$O1 K\$:$D$7$+$G$-$:! "%G!<%?It$N%3%T!<$r9T$&>l9g$K$OC`<!E*$K%3%T!<$r9T oJ1lPJiJ$$! #

PBR $O64b+2b $G%Q%1%C%H1 %U%j%C%H$K1 K\3djEvFil$F$$$k! #PBR $O HFMQ$,64 K\$HRDT $NAw<u?.MQ$K$=$1$>$18 K\×3 AH$:$DMQ0U5l$F$$$k! #

RDT Aw<u?.MQPBR $OFIFO 9=B$$rHj! "MMC 5Z$SMBP-Core $+$i$OAw?. MQPBR $NKvHx$H<u?.MQPBR $N@hF,$N$_$,2D;kHJCF$$$k! #(?^3.1)



?^3.1: PBR

%W%m%0%i%`KhCFFIFO $,%G%-%e!<5Z$S% (%s%-%e!<5l<u?.BT$A>uBV5Z$S Aw?.>uBVHJ$k! #

PBR $OMBP $+$iMMC rDL7$F%/%i%9%?%a%b%j$KD>@\FI$_=q$-$r9T$&:]! " %X%C%@It$N:n@.5Z$S%G!<%?It$N3JG<$dMCC $+$i$Nl~Ez$r3JG<9k%P%C%U%!$H 7FMxMQ5l$k! #

$^$?!"3.1@a$G=R$Y$?%/%i%9%?%P%9$N%m%C%/%l%8%9%?XN%"%/%;%9Kb;HMQ9k!#

4 DSM 4IM}%W%m%0%i%`

JUMP-1 GO%/%i%9%?4V$G6&M-$5lk%G!<%?$N4IM}$OA4$FMBP-light $,9T$&!#K\>OGOMBP-light $K<BAu$7$?DSM 4IM}%W%m%0%i%`$K$D$$$F=RYk!#

4.1 DSM 4IM}%W%m%0%i%`$N4pK\9=B$

DSM 4IM}%W%m%0%i%`$O%-%c%C%7%e%i%$%s$NE>Aw$d>uBV$N99?7$r9T$&!#

%W%m%0%i%`$OMBP-Core $K3d9~$_$,$+$+$C$?>l9g$K<B9T$5$l!":#2s:n@.$7$?MBP-light >e$N%W%m%0%i%`$O<!$Nh&$JF0:n$r9T$&!#

- %Q%1%C%H$rPBR $K%m!<%I$7!"%X%C%@It$J,$+$i%Q%1%C%H$NH=JL$r9T$&!#
- MW5a%Q%1%C%H5Z$S1~Ez%Q%1%C%H$r%/%i%9%?%P%95Z$SRDT $KE>Aw$9$k!#
- 6&M->uBV$N99?7$,9Tol$?>l9g$K$O%/%i%9%?%a%b%j$N%?%0$NJQ99$r9T$&!#
- 99?7MW5a5Z$S%/%i%9%?4V$G$N%G!<%?6&M-$r9T$&FI$_=P$7MW5a$O%/%i%9%?%a%b%jXN=q$-9~$_5Z$S99?7$r9T$&!#
- %/%i%9%?4V$N%3%R!<%l%s%9@)8f%G%#%l%/%H%j5Z$S%Z!<%8%F!<%V%k$N4IM}$r9T$&!#

4pK\E*$K%/%i%9%?%P%9$+iN%Q%1%C%H$ORDT $KAw?.$9$k2DG=@-$,9b$$$?aKRDT Aw?.MQPBR $K3JG<$7!"RDT $+$i$N%Q%1%C%H$O<u?.MQPBR $+$i%/%i%9%?%P%9$KAw=P$9$k!#

$=$3$G:#2s$N%W%m%0%i%`$OHFMQPBR $r0J2<$Nh&$K;HMQ$7$?!#

- %"%I%l%9%U%j%C%HMQ$N%F%s%W%l!<%H$rHFMQPBR >eK"i+8a:n@.7F$*$/3HKh$j%X%C%@It$J,:n@.$N9bB.2=$r?^$k!#
- BT$A%Q%1%C%H$NJ]B8>l=jH7FbMxMQ9k!#
- %/%i%9%?%a%b%j$^$?$O%?%0$NFI$_=P$75Z$S99?7$r9T$&:]$N%Q%1%C%H$N%X%C%@It$N:n@.5Z$S%G!<%?It$N:n@.!"3JG<$KMxMQ$9$k!#

BT$A%Q%1%C%H$K$D$$$F$O8e=R$N4.2@a$G@bL@$r9T$&!#

$^$?!"DSM 4IM}%W%m%0%i%`GO:G=*E*$J%-%c%C%7%e%G!<%?$NCM$,3F%-%c%C%7%e4V$G0[Ji$J$$$h$&<B9T=g=x$K4X7F0J2<Nh$&$J3H$r9MN8$9kI,MW,$"$k!#

- F10l%"%I%l%9KBP9$kMW5a%Q%1%C%H$NDI$$1[7,$*$3CFOJiJ$$!#
- MBP-light Kh$k%/%i%9%?Fb$G$N=hM}$OAtomic $K9T$oJ1lPJi$J$$!#

4.2@aGOMW5a$ND I$$1 [7rK I0?aKMQ0U7?%Z%s%G%#%s%0·%H%i%s%6%/%7%g%s·%F!<%V%kKD$$$F=RYk!#$=$N8e!"4.3@aGO%F!<%V%k$rMxMQ$9k3HKhj Atomic $J=hM}$r9T$&J}K!$H$=$NNc3 0KD$$$F=RYk!#

4.2 %Z%s%G%#%s%0·%H%i%s%6%/%7%g%s·%F!<%V%k(PTT)

MW5a%Q%1%C%H$NAw?.$r9T$$!"1~Ez%Q%1%C%H$N<u?.$rBT$D4V$KEv3:%"%I%l%9KBP9$kB>$NMW5a%Q%1%C%H$,E~Ce$9$k>l9g$,$"$k!#$=$N:]$N6%9g$rHr1k$?$a$K MBP GO0J2<Nh$&$J%Z%s%G%#%s%0·%H%i%s%6%/%7%g%s·%F!<%V%k$rMQ0U$9$k!#$3$N%F!<%V%k$O%"%I%l%9$r%-!<$H9kO"A[%F!<%V%kG"$k!#0J2<!"%Z%s%G%#%s%0·%H%i%s%6%/%7%g%s·%F!<%V%k$r PTT $H5-=R$9$k!#

MW5a%Q%1%C%H$, MBP $KE~Ce$7$?>l9g$K$O PTT $r8!:w$9$k!#Ev3:%"%I%l%9$KBP7F=hM}$,$J5l$F$$$J1l$P!"PTT $KEPO?$r9T$$%Q%1%C%HKBP9$k=hM}$r<B9T9k!#3NH-9G$KEPO?$,$"$lPBTA%Q%1%C%H(CfCGCf%Q%1%C%H) H7$F%j%9%H$KDI2C9k(?^4.1)!# BT$A%Q%1%C%H$O9G$KEPO?$5lF$$$?MW5a%Q%1%C%H$N1~Ez%Q%1%C%H$,E~Ce9k$HD>$A$K<B9T>uBV$KO\$5lk!#3lKhCF MBP $KF10l$N%"%I%l%9KBP9$kMW5a$,E~Ce7?>l9gKb=hM}$N=g=x$OJQok3HOJ$$!#

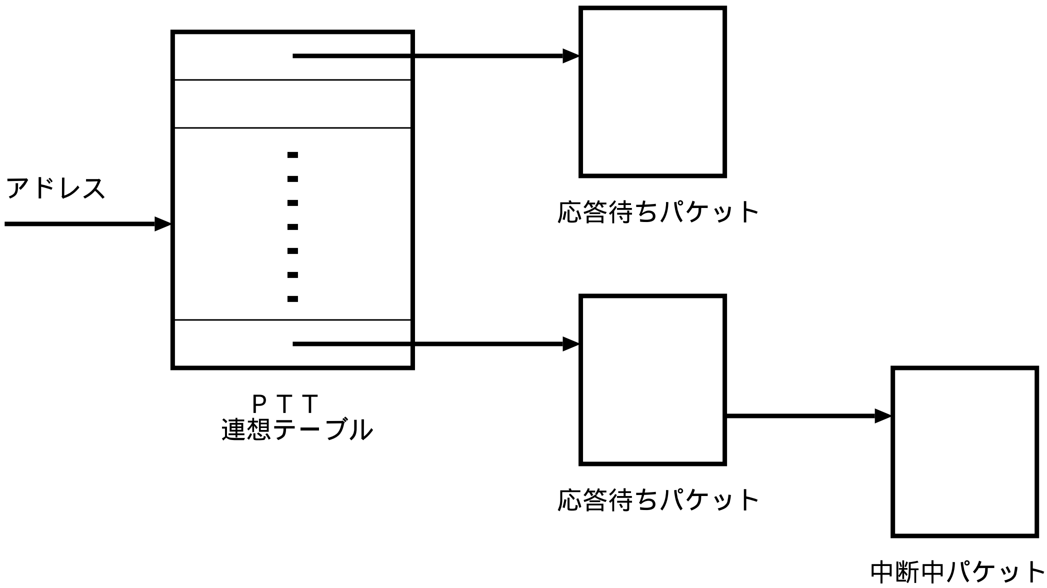
MW5aE~Ce;~K9GKBT$A%Q%1%C%H$NEPO?$,$"$k>l9g$KOBTA%Q%1%C%H$NEPO?$r:F5"E*$K9T$(Ph$$!#

PTT KOMW5a$rH/9T$7$?%G%P%$%9ID!"MW5a$N<oJL5Z$SBT$A%Q%1%C%H$H7FEPO?9k>l9gKO%Q%1%C%H$r3JG<$7$F$$$k PBR XN%]%$%s%?$JIrEPO?9k!#

4.3 %Q%1%C%HN9lA$,$$5Z$SD I$$1 [7NK I;_

4.2@a$G=R$Y$?PTT XNEPO?$r9T$&3HKh$jMW5a%Q%1%C%H$ND I$$1 [7rK I$0$3H,2DG=G"k3HO<(5l$?!#$7$+$7!"PTT $O1~Ez%Q%1%C%H$,E~Ce9k$H%(%s%H%j$r:o=|9k$?$a$K!"99?7MW5a$JIN1~Ez%Q%1%C%HrI,MWH7J$$MW5a%Q%1%C%H$OEPO?$5lJ$$!#3Nh&$JMW5a$N>l9gKO%Q%1%C%H$N=hM}$r9T$&A0$K PTT $r8!:w$7!"Ev3:%"%I%l%9$K=hM}Cf$N%Q%1%C%H$NM-L5$r3NG'7F$+$i=hM}$r3+;O$9$k!#=hM}Cf$N%Q%1%C%H$,B8:_$7$F$$$k>l9gKO PTT $K%Z%s%G%#%s%0$7F*$-!"=hM}Cf$NMW5a$N1~Ez%Q%1%C%H$,E~Ce$7=hM}$,=*N;7?8e$K PTT $+$i:o=|$7<B9T$5lk!#

H3m,!"0J2<Nh$&$J>l9gKO99?7MW5aN9lA$,$$$,5/$j!"%/%i%9%?Fb



?^4.1: %Z%s%G%#%s%0%H%i%s%6%/%7%g%s%F!<%V%k(PTT)

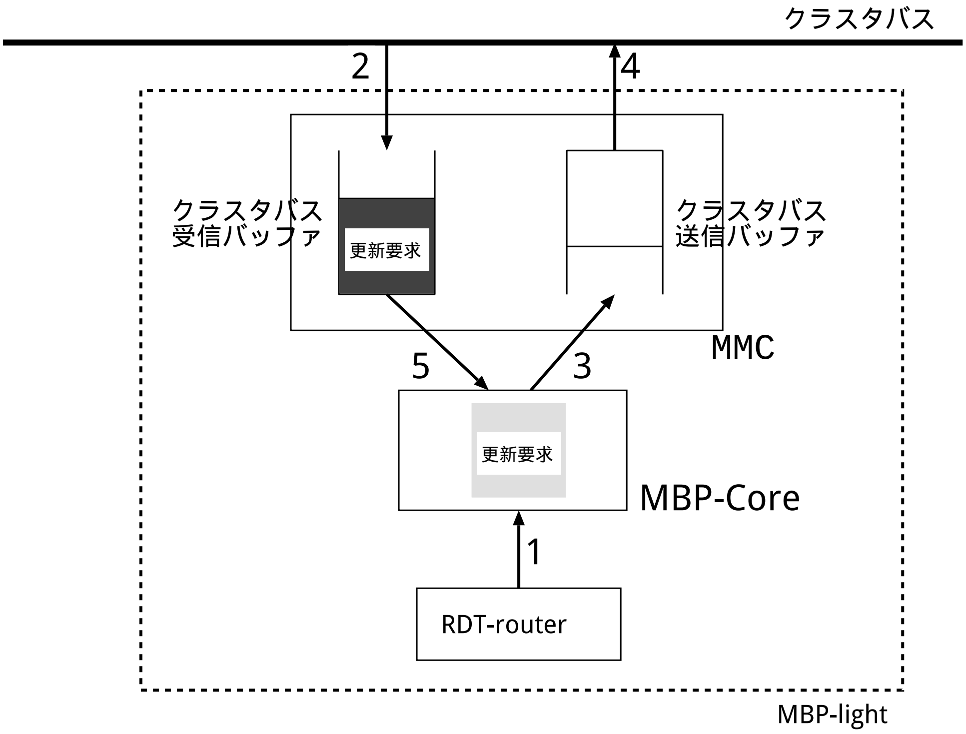
$N%-%&%C%7%e$H%/%i%9%?%a%b%j$NFbMF$,0[JCF7$^$&!#

?^4.2K9lA$,$&>l9g$N>uBV$r<($9!#?^$ORDT $+$i$N<u?.$7$?9 9?7MW5a%Q%1%C%H$r=hM}7F$$$k4V$K%/%i%9%?%P%9$K9 9?7MW5a$,N.$l!"MMC $N%P%C%U%!$K3JG<5l$F$$$k>uBVG"$k!#

1. B>$N%/%i%9%?$+iN9 9?7MW5a$,E~Ce$7DSM 4IM}%W%m%0%i%`$O%Q%1%C%H$N=hM}$r3+;O$9$k!#
2. %/%i%9%?Fb$NCC $+$i9 9?7MW5a$,H/9T$5$lMMC $N%/%i%9%?%P%9<u?.%P%C%U%!$KMW5a$,3JG<5l$k!#
3. DSM 4IM}%W%m%0%i%`KhCF%/%i%9%?%a%b%j$,9 9?7$5$l!"%/%i%9%?%P%9$KMW5a$rAw?.$9k?aKMMC $NAw?.%P%C%U%!$KMW5a$r3JG<$9$k!#
4. B>$N%/%i%9%?$GH/9T5l$?9 9?7MW5a$,%/%i%9%?%P%9$KN.$l$k!#
5. DSM 4IM}%W%m%0%i%`$O%/%i%9%?%P%9<u?.%P%C%U%!$+$i%Q%1%C%H$r<h$j=P$7=hM}$r3+;O$9$k!#%W%m%0%i%`KhCF%/%i%9%?%a%b%jNCMO9 9?7$5$l$k!#

CC $N9 9?7$O%/%i%9%?%P%9$KN.$l$?=g$K9 9?7$5$l$k!#$H3m$,>e5-$NNc$N>l9g$G$"$k$H%/%i%9%?%a%b%j$N9 9?7=g=x$H0[$Jk3H,J,$+$k!#

$=$3$GDSM %W%m%0%i%`$G$ORDT-router $+$i$N9 9?7MW5a$r=hM}9k>l9gKO%/%i%9%?%P%9$K%m%C%/$r$+$1F+$i=hM}$9kI,MW,$"$k!#



?^4.2: 99?7MW5aN9$1$A$,$$

4.4 MBP-light Kh$k%Q%1%C%H$N=hM}

K\@aGODSM 4IM}%W%m%0%i%`Kh$k%Q%1%C%H$N=hM}rNcr5s2k!#

Nc$O1~Ez%Q%1%C%H$,I,MW$JMW5a$OInitiator %/%i%9%?Fb$GMW5a$,H/9T5l!"1~Ez$,JV$CF/k^GNMBP-light Kh$k=hM}$G$"$k!#1~Ez%Q%1%C%HrI,MWH7J$$MW5a$O3F%/%i%9%?$G$N=hM}$G$"$k!#

=hM}NNcH7F<!$N3 DK$D$$$F@bL@$r9T$&!#

- FI$_=P$7MW5a(Read Request)
- 99?7MW5a(Update Request)
- FI$_=P$75Z$SL58z2=MW5a(Read Invalidate Request)

0J2<$K3F%Q%1%C%H$N=hM}$N>\:Y$K$D$$$F=RYk!#

FI$_=P$7MW5a(Read Request) MBP-light $,=hM}$r9T$&FI$_=P$7MW5a$O%/%i%9%?Fb$KM-8z$J%G!<%?$,B8:_$;$:!"Home %/%i%9%?$KMW5a%Q%1%C%H$rAw?.$9$k>l9g$G$"$k!#

FI$_=P$7MW5a$NMBP-light Kh$k=hM}$NO1Nc$rI=4.1$K<($9!#Nc$ORenter %/%i%9%?G"$kInitiator %/%i%9%?$,Owner %/%i%9%?G"$kHome %/%i%9%?$KMW5a$rAw?.9k>l9gG"$k!#%/%i%9%?4VGN%G!<%?$N6&M-$OJ5lF$*i:!"Home

%/%i%9%?Fb$N2 <!%-%&%C%7%e$,M-8z$J%G!<%?$rJ]; }7F$$$kH7$?!#

I=4.1: Read Request KBP9$k=hM}

%/%i%9%?	=hM}
Initiator %/%i%9%?GN=hM}1	%Q%1%C%H$NH=JL
	PTT XNEPO?
	RDT Aw?.MQ$N%X%C%@$N:n@.5Z$SAw?.
Home %/%i%9%?GN=hM}1	%Q%1%C%H$NH=JL
	PTT XNEPO?
	%/%i%9%?%P%9$XMW5a%Q%1%C%H$rN.$9
Home %/%i%9%?GN=hM}2	%Q%1%C%H$NH=JL
	%/%i%9%?%a%b%jXN=q$-9~$_
	PTT $N:o=|
	6&M->uBV4IM}%G%#%l%/%H%jXNEPO?
	RDT Aw?.MQ$N%X%C%@$N:n@.5Z$SAw?.
Initiator %/%i%9%?GN=hM}2	%Q%1%C%H$NH=JL
	%/%i%9%?%a%b%jXN=q$-9~$_
	%Z!<%8%F!<%V%kXNEPO?
	PTT $N:o=|
	%/%i%9%?%P%9$X1~Ez%Q%1%C%H$rN.$9

I=Cf$N%/%i%9%?%a%b%j$X$N=q$-9~$_$H$O2.2.1@a$G=RY?$,!"%/%i%9%?4V$G%G!<%?$N6&M-$r9T$&>l9g$K$O%/%i%9%?%a%b%j$r3 <!%-%&%C%7%eH7$FMxMQ$9k?aKMBP-light $,%/%i%9%?%a%b%j=q$-9~$'I,MW$,$"$j!"$=$N=hM}$r;X$9!#

99?7MW5a **(Update Request)** 99?7L?Na$,H/9T$5lk$HInitiator %/%i%9%?$OEv%/%i%9%?%a%b%j$r99?7$7!"Home %/%i%9%?$X%Q%1%C%H$,Aw?.9k!#Home %/%i%9%?$+$iEvMW5a%Q%1%C%H$rRenter %/%i%9%?$X$HAw?.$9$k!#

MW5a%Q%1%C%H$,E~Ce$7$?%/%i%9%?$G$O%/%i%9%?%a%b%j$N99?7$H%/%i%9%?%P%9$X$NAw?.$,9Tol$k!#=LLs3,AX%S%C%H%^%C%W$r;HMQ7F%^%k%A%-%c%9%H5lk?$a!"Renter %/%i%9%?$G$OE~Ce$7$?%G!<%?$,Ev%/%i%9%?Fb$G6&M-$5lF$$$k$+$N3NG'$r9T$oJ1lPJi$J$$!#

I=4.2$KMBP-light Kh$k99?7MW5a$N=hM}$r<($9!#

FI$_=P$75Z$SL58z2=MW5a **(Read Invalidate Request)** FI$_=P$75Z$SL58z2=MW5a$H$OGSB>E*FI$_=P$7MW5a$H$b8F$P$l!"MW5a$rH/9T7?%/%i%9%?KOM-8z$J%G!<%?$N1~Ez$,!"$=$NB>$N%G!<%?$r6&M-$7$F$$$?%/%i%9%?KOL58z2=MW5a$,Aw?.$5lk!#

I=4.2: Update Request KBP9$k=hM}

%/%i%9%?	=hM}
Initiator %/%i%9%?GN=hM}	%Q%1%C%H$NH=JL
	%/%i%9%?%a%b%j$N99?7
	RDT Aw?.MQ$N%X%C%@$N:n@.5Z$SAw?.
Home %/%i%9%?GN=hM}	%Q%1%C%H$NH=JL
	%/%i%9%?%P%9XN%m%C%/
	%Z!<%8%F!<%V%k$N8!:w
	%/%i%9%?%a%b%j$N99?7
	%/%i%9%?%P%9$XMW5a%Q%1%C%H$rN.$9
	%/%i%9%?%P%9XN%m%C%/$N2r=|
	Renter %/%i%9%?XNRDT Aw?.MQ$N%X%C%@$N:n@.5Z$SAw?.
Renter %/%i%9%?GN=hM}	%Q%1%C%H$NH=JL
	%/%i%9%?%P%9XN%m%C%/
	%Z!<%8%F!<%V%k$N8!:w
	%/%i%9%?%a%b%j$N99?7
	%/%i%9%?%P%9$XMW5a%Q%1%C%H$rN.$9!#
	%/%i%9%?%P%9XN%m%C%/$N2r=|

MW5a$rH/9T$9$k Initiator %/%i%9%?$, Renter %/%i%9%?G"$k>l9g$N=hM}$rI=4.3$K<($9!#

%"%/%;%9$9$k%G!<%?$,$9GK%/%i%9%?4V$G6&M-$5lF$*$j!"Home %/%i%9%?$N%/%i%9%?%a%b%j$KM-8z$J%G!<%?$,$"$k>l9g$N=hM}$H9k!#

5 @-G=I>2A5Z$S9M;!

K\>OGO:n@.7?6&M-%a%b%j4IM}%W%m%0%i%`$r<B9T$7!"MBP-light $N@-G=I>2A$H9M;!$r9T$&!#

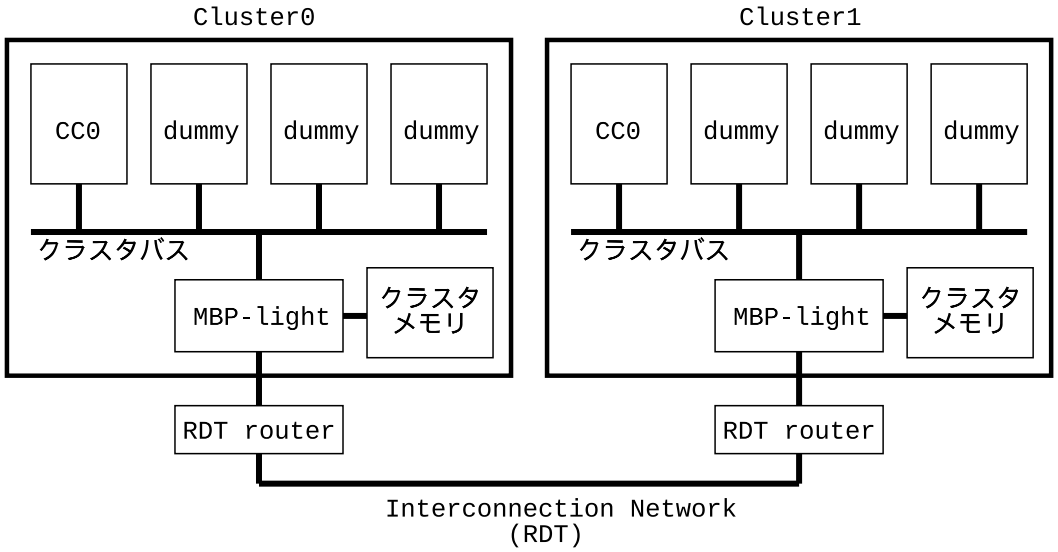
5.1 I>2A4D6-

VHDL $GO@M}9g@.2DG=$Jh&$K5-=R$5l?@_7W%G!<%?$rMQ$$!"Mentor Graphics <R$N VHDL %7%_%e%l!<%?!<qhsim v8.5_4.6c $rMQ$$$F%7%_%e%l!<%7%g%s$r9T$C$?!#$7$?$,CF%5%$%/%k?t$O<B:]NbNHF1$8$G$"$k!#L5I i2Y>uBV$G%/%i%9%??t$O2!"3F%/%i%9%?KO%W%m%5%C%5$r1 DH7?(?^5.1)!#JUMP-1 $O50MHz $GF0:n$9kN$G1 %5%$%/%k$O20ns G"$k!#

:#2s$N PTT NBTA%Q%1%C%H$O!"%/%i%9%?FbItGOMW5a%Q%1%C%H$,Aw?.5lkH$=$N%"%I%l%9KBP7$F CC $+$i$N<!$NMW5a$,H/9T$5lJ$$$?aKB?$/$H$b

I=4.3: Read Invalidate Request KBP9$k=hM}

%/%i%9%?	=hM}
Initiator %/%i%9%?GN=hM}1	%Q%1%C%H$NH=JL
	PTT XNEPO?
	RDT Aw?.MQ$N%X%C%@$N:n@.5Z$SAw?.
Home %/%i%9%?GN=hM}	%Q%1%C%H$NH=JL
	%/%i%9%?%a%b%jXNFI$_9~$_
	%/%i%9%?%P%9$XL58z2=MW5a$rN.$9
	%/%i%9%?%a%b%j$NL58z2=
	Renter %/%i%9%?XNL58z2=MW5aMQRDT Aw?.MQ$N%X%C%@$N:n@.5Z$SAw?.
	6&M->uBV%G%#%l%/%H%jXNEPO?
	Initiator %/%i%9%?XN1~EzMQRDT Aw?.MQ$N%X%C%@$N:n@.5Z$SAw?.
Initiator %/%i%9%?GN=hM}2	%Q%1%C%H$NH=JL
	PTT $N:o=|
	%/%i%9%?%P%9$X1~Ez%Q%1%C%H$rN.$9
Renter %/%i%9%?GN=hM}	%Q%1%C%H$NH=JL
	%/%i%9%?%a%b%j$NL58z2=
	%/%i%9%?%P%9$X(L58z2=) %Q%1%C%H$rN.$9



?^5.1: I>2A4D6-

1 D@1G$"$k!#

Home %/%i%9%?KO6&M->uBV$r<($9%G%#%l%/%H%j$O:n@.$;$:!"%Z!<%8%F!<%V%k$b=jM-7F$$$J$$!#7?$,$C$F<B:]$NJUMP-1 GO5i$K=hM};~4V$,A}Bg$9

k3Hr9MN8$5$l$?$$!#:#2s$N%W%m%0%i%`$G$O6&M->uBV$NH=CG$O%/%i%9%?%a%b%j$N%?%0$rMBP-light $,FI$_=P$9$3HGH=CG7F$$$k!#

5.2 3FMW5a%Q%1%C%H$N=hM};~4V

4.4@aGNcH7F5s2?MW5a%Q%1%C%H$N=hM};~4V$rI=5.1$K<($9!#

=hM};~4V$O1~Ez%Q%1%C%H$rI,MWH9$kMW5a$O$=$NMW5a$,Initiator %/%i%9%?$N%/%i%9%?%P%9$KMW5a$,N.lF$+$i!"$=$N1~Ez%Q%1%C%H$,%/%i%9%?%P%9$KN.lk$^$G$N;~4V$G$"$k!#

$^$?!"1~Ez%Q%1%C%HrI,MWH7J$$9?7MW5a$OInitiaor %/%i%9%?$G$N=hM};~4V$HHome %/%i%9%?GNMBP-light $N=hM};~4V$G$"$k!#

%W%m%0%i%`$OE83+$5lF$*$j%b%8%e!<%k$N8F=P$7$O9T$C$F$$$J$$!#

I=5.1: 3F%Q%1%C%H$N=hM};~4V

MW5a	;~4V(%5%$%/%k)
FI$_=P$7MW5a	466
FI$_=P$75Z$SL58z2=MW5a	354
9 9?7MW5a(Initiator)	135
9 9?7MW5a(Home)	197

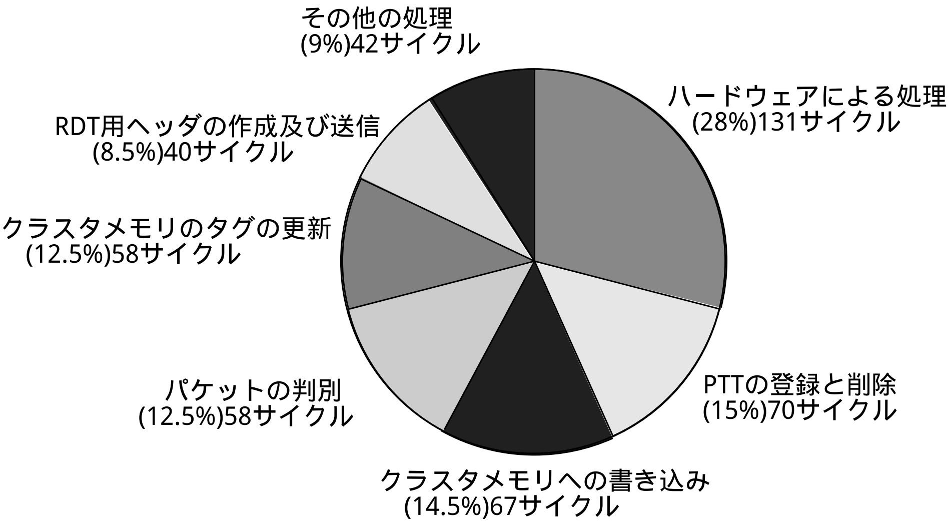
MBP-light $,3+H/$5l?Ev=iOFI_=P$7MW5a$O127 %5%$%/%k$G4 0N;9kH5lF$$$?[2] $,!"<B:]$O$=$NLs3.6 G\$N466 %5%$%/%k$b$N=hM};~4V$,$+$+CF7^$&7k2L$HJC$?!#

5.3 MW5a%Q%1%C%H$N=hM}$K$*$1$k=jMW%5%$%/%k?t

K\@aGO4.4@aNNcN$&$A!"FI$_=P$7MW5a5Z$S9 9?7MW5a$N2 DK$D$$$F$N>\:Y$J=jMW%5%$%/%k?t$r$^$Ha?!#

FI$_=P$7MW5a ?^5.2OFI_=P$7MW5a$N3F=hM}KI,MWJ=jMW%5%$%/%k?t$NFbLu$r%0%i%U$K7?bNG"$k!#

3F=hM}$O2 DN%/%i%9%?GN=hM}$N9g7WG"$j, %Q%1%C%H$NH=JL$OMBP-light $,5/F0$5lk4H$K=hM}$5lkNG4 2sJ,$N9g7W$G$"$k!#>\$7$$=hM}$N2s?t$OI=4.1$r;2>H$K5l$?$$!#



?^5.2: FI$_=P$7MW5a$N=hM}$KI,MW$J=jMW%5%$%/%k?t

J*!"MBP-Core KO%a%b%j%"%/%;%9$d%/%i%9%?%P%9$X$N%Q%1%C%H$NAw=P$r9T$CFb%9%H!<%k$r5/$5$:$K=hM}$r?J$ak3H,G-$k5!G=$rHw$($F$$$k$,!"4JC1$N$?$a:#2s$N%W%m%0%i%`$G$O%"%/%;%9$,40A4$K=*N;$9k^$G%9%H!<%k$5$;$F$$$k!#

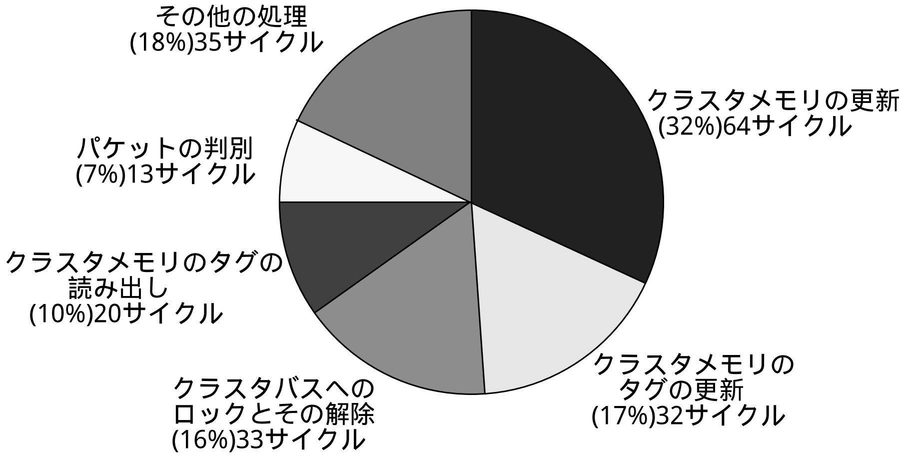
I=Cf$N3F=hM};~4V5Z$SFbMFKD$$$F@bL@$r9T$&!#

- %O!<%I%&%'%"Kh$k=hM}!DMW5a$,%/%i%9%?%P%9$KN.$lF+$i MBP-light $,5/F0$5lk$^$G$N;~4V!"RDT 4V$NE>Aw;~4V5Z$S Home %/%i%9%?$N%/%i%9%?%P%9$KMW5a$rN.7F$+$i$=$N1~Ez%Q%1%C%HKh$k MBP-light $,5/F0$5lk$^$G$N;~4V$N9g7WG"$k!#
- PTT $NEPO?$H:o=|!DEvMW5aGO Initiator %/%i%9%?5Z$S Home %/%i%9%?$GH<$K PTT $NEPO?$r9T$&!#$7$?$,CFI=Cf$N%5%$%/%k?t$ON>%/%i%9%?$G$N9g7W;~4V$G$"$k!#
- %/%i%9%?%a%b%j$N=q$-9~$_!D2.2.1@a$G=RY?$,%/%i%9%?4V$G%G!<%?$N6&M-$9$k>l9g$K$O%/%i%9%?%a%b%j$K$OM-8z$J%G!<%?$r=jM-$7J1lPJi$J$$!#%/%i%9%?%a%b%j$N=q$-9~$_$O DSM 4IM}%W%m%0%i%`KhCF9ToJ1lPJiJ$/!"I=Cf$N=hM};~4V$O%X%C%@It$N:n@.$H%a%b%j$X$N=q$-9~$_$G$"$k!#
- %Q%1%C%H$NH=JL!DMBP-light $,5/F0$5$l%X%C%@It$+$i%Q%1%C%H$N<oJL$rH=Dj$7!"$=$l$>$l$N=hM}%k!<%A%s$X%F!<%V%k%8%c%s%W9k$^$G$N;~4V$G$"$k!#
- %/%i%9%?%a%b%j$N%?%0$N99?7!D2.2.1@a$G=R$Y$?$,%/%i%9%?%a%b%jKO6&M->uBV$r<($9%?%0$,B8:_$7$F$$$k!#DSM 4IM}%W%m%0%i%`$O%?%0$N99?7$r9T

oJ1lPJiJ$/!"I=Cf$N=hM};~4V$O%/%i%9%?%a%b%j$X$N=q$-9~$_F1MM%X%C%@It$N:n@.$H%"%/%;%9$N;~4VG"$k!#

- RDT MQ%X%C%@$N:n@.5Z$SAw?.!DRDT Aw?.MQ$N%X%C%@It$N:n@.$HAw?.$G$"$k!#1 2s$N=hM}$K$O20 %5%$%/%k$N;~4V$rMW9k!#
- $=$NB>$N=hM}!D%/%i%9%?%P%9$X$NAw?.$N:]$N%X%C%@It$NJQ99!"Aw=P5ZS=$NB>$N?t%5%$%/%k$G=*N;9k=hM}G"$k!#%/%i%9%?%P%9$X$NAw=P$K$O14 %5%$%/%kMW9k!#

99?7MW5a ?^5.3$O99?7MW5a$N Home %/%i%9%?K*1k3F=hM}KI,MWJ=jMW%5%$%/%k?t$NFbLu$r%0%i%U$K7?bNG"$k!#



?^5.3: 99?7MW5a$N=hM}$KI,MW$J=jMW%5%$%/%k?t

FI$_=P$7MW5aF1MM$KI=Cf$N3F=hM};~4V5Z$SFbMF$K$D$$$F@bL@$r9T$&!#

- %/%i%9%?%a%b%j$N99?7!D%/%i%9%?%a%b%j$N99?7$O%/%i%9%?%a%b%j$+$i%G!<%?$rFI$_=P$7!"%G!<%?$r99?7$7$?8e$K%/%i%9%?%a%b%j$K=q$-La$9!#>\$7$$=hM}FbMFKD$$$F$O8e=R$9$k!#
- %/%i%9%?%a%b%j$N%?%0$N99?7!DFI$_=P$7MW5a$N>l9g$HF1MM$N=hM}$G$"$k!#
- %/%i%9%?%P%9XN%m%C%/H=$N2r=|!D4.3@a=R$Y$?$h$&$K99?7MW5a$,%/%i%9%?Fb$NCC $+$iH/9T5lkH%/%i%9%?%a%b%j$H2<!%-%&%C%7%e$N%G!<%?$NFbMF$,0[CF7^$&!#$=3GRDT $+$iE~Ce7?99?7MW5a$r=hM}$9$k>l9g$K$O%/%i%9%?%P%9$K%m%C%/r+$1!"=hM}$,=*N;$9$1$P%m%C%/$r2r=|9k!#%m%C%/$K22 %5%$%/%k!"2r=|$K11 %5%$%/%k$[$I;~4VrMW9$k!#
- %/%i%9%?%a%b%j$N%?%0$NFI$_=P$7!D99?7MW5a$,Initiator %/%i%9%?$GH/9T$5

1F$+$i Home %/%i%9%?$KE~Ce$9k^GK!"6&M->uBV$,B>$NMW5a%Q%1%C%HKhCFJQ99$5$1$F$$$k>19g$,$"$k!#$7$?$,CF9G$K99?7$9kY$-%G!<%?$,%/%i%9%?%a%b%j$KB8:_$;$:L58z2=$5$1$F$$$k2DG=@-$,$"$j!":#2s$N%W%m%0%i%`GO%/%i%9%?%a%b%j$N%?%0$rF I$_=P$9$3$HKhCFH=CG$r9T$C$F$$$k!#%5%$%/%k?t$O99?7$HF1MM$K%X%C%@It$N:n@.$H%"%/%;%9;~4V$N9g7W$G$"$k!#

- %Q%1%C%H$NH=JL!D MBP-light $,5/F0$5$1$F$+$i99?7MW5a=hM}%k!<%A%s$X%F!<%V%k%8%c%s%W$9k^GN;~4VG"$k!#
- $=$NB>$N=hM}!D%/%i%9%?%P%9$X$N99?7MW5a$NAw=PJI$N=hM}$G$"$k!#%/%i%9%?%a%b%j$N%?%0$NF I$_=P$7$G=R$Y$?$,9G$K99?7$9Y-%G!<%?$,$J$$>l9gHN>r7oJ,4t$N=hM}$JIb4^$^$l$k!#

0J>e$N2 DNNcKD$$$FFC$K;~4V$,$+$+CF$$$k=hM}

1. %/%i%9%?%a%b%j$N99?7
2. %/%i%9%?%a%b%j$N%?%0$N99?7
3. %/%i%9%?%P%9XN%m%C%/H=$N2r=|
4. PTT $NEPO?$H:o=|

$N4 DK$D$$$F$O0J2<$K$=$NM}M3KD$$$F@bL@9k!#

%/%i%9%?%a%b%j$N99?7 JUMP-1 $N%Q%1%C%H$K$O2.2.2@a$G=RY?$,64b $NK\BN$NB>$K2b $NJd=u%U%#!<%k%I$,B8:_9k!#3N%U%#!<%k%I$O%X%C%@It$G$O%Q%1%C%HD9$r<($7!"%G!<%?It$G$O%G!<%?$NM-8z@-JI$r<($9!#

%a%b%j$N99?7$O%G!<%?It$NJd=u%U%#!<%k%I$Khj32b $:$D;XDj7F99?7$9$k3H$,$G$-$k!#

7?$,$C$F<B:]$K$O%a%b%j$+$i%G!<%?$rFI$_9~$s$@8e$KJd=u%U%#!<%k%INCMKhj99?7$9$k$+$I$&$+$rH=Dj$7!"5i$K99?7$7$?%G!<%?$r%a%b%j$K=q$-La5J1lPJiJ$$!#%/%i%9%?%a%b%j$+$iNFI_=P7K14 %5%$%/%k!"=q$-9~$_$K$O13 %5%$%/%k$+$+$k!#

99?7ItJ,$N%W%m%0%i%`$r?^5.4$K<($9!#WWE HO2b $NJd=u%U%#!<%k%I$r;X$9!#MVBPG L?Na$OPBR NCMr%1%8%9%?$K%m!<%I$9$kL?Na!"MVPP $OPBR 4V$N%3%T!<$r9T$&L?NaG"$k!#

%G!<%?It$O4 K\$NPBR $K3JG<$5$1$F$*$j!"?^5.4$N=hM}$r4 K\J,KBP7$F9T$oJ1lPJi$J$$!#$3$1i,=hM};~4V$,A}Bg$7F7$^$C$F$$$k860xG"$k!#

```
update: MVBPG   R8, P(R6+8)       ;WWE %U%#!<%k%I$r<h$j=P$9!#
        ANDGI   R9, R8, 00000001b        ;R9 $KWWE $N2<0L%S%C%H
        ANDGI   R8, R8, 00000010b        ;R8 $KWWE $N>e0L%S%C%H
        SRLGI   R8, R8, 1
        SUBGI   R8, R8, 0
        BOZ     nonwrite_low      ; 2<0L32bit $O99?7$7$J$$>l9g
        NOP
        MVPP    P(R7+0), P(R6+0)
        MVPP    P(R7+2), P(R6+2)
nonwrite_low:   SUBGI   R9, R9, 0
        BOZ     nonwrite_high     ; >e0L32bit $O99?7$7$J$$>l9g
        NOP
        MVPP    P(R7+4), P(R6+4)
        MVPP    P(R7+6), P(R6+6)
nonwrite_high:          BR      R15
        ADDGI R1, R0, 1
```

?^5.4: 99?7ItJ,$N%W%m%0%i%'

%/%i%9%?%a%b%j$N%?%0$N99?7 %/%i%9%?%a%b%j$N%?%0$rJQ99$9$kKO%/%i%9%? %a%b%j%"%/%;%9$HF1MM$K%X%C%@It$N:n@.$r9T$&I,MW$,$"$k!#%X%C%@ItO"i+ 8aHFMQPBR $K%F%s%W%l!<%H$r:n@.7F$$$k$,!"%X%C%@MQ$NPBR $r;XDj$7%3 %T!<7F;HMQ7F$$$k!#5i$K%"%I%l%9It$N%3%T!<$b9T$oJ1lPJi$J$$!#

$^$?!"%?%0$K=q$-9~$`CM$b%G!<%?ItH7$FPBR $K@_Dj$7J/FOJi$:!" PBR $O64b G"kNKBP7$FMBP-light $NHFMQ%l%8%9%?$O16b G"kN$G!" PBR KCMr%;%C%H9kNK4 %5%$%/%kI,MW$HJk!#

%/%i%9%?%P%9XN%m%C%/H=$N2r=| %/%i%9%?%P%9$X$N%m%C%/$OEv3:%"%I%l%9 KBP7$Fatomic $J=hM}$r9T$&>l9g$KI,MWG"$k!#3.2@a$G=RY?$,%m%C%/$r9T $&$K$OPBR KCMr%;%C%H7FMMC $NFbIt%l%8%9%?$K=q$-9~$^J/FOJi $J$$!#

2r=|9k:]Kb%m%C%/9k>l9g$HF1MM$KPBR $rMQ$$$F%"%/%;%9$7$J$/$F$O Ji$J$$!#

%m%C%/%l%8%9%?$O%m%C%/$9$kBP>]$HJk%"%I%l%9!"%m%C%/9kHO0O$r;XDj$9 $kMask 5Z$SlValid $N3 K\$+iJ$j3 2s$N%"%/%;%9$,I,MW$HJk!#%"%I%l%9It $O%Q%l%C%H$N%X%C%@It$r;HMQ$9k@1G$h$$$,!"B>$N%l%8%9%?$OCM$rPBR $K %;%C%H$7F+iN%9%H%"7J1lPJiJ$$!#

%/%i%9%?%a%b%j$N%?%0$N99?7$HF1MM$K1 K\$NPBR NCMN%;%C%H$K4 %5%$%/ %k$+$+$k!#

PTT $NEPO?$H:o=| PTT $OEPO?$K23 %5%$%/%k!":o=|$K12 %5%$%/%k$+$+$k!#

:#2s$NPTT GOBT$A%Q%l%C%H$,9b!9 1 DG$"$kNG!"$"i+8aA4FN%V%m%C

%/KBP7$F PTT KBTA%Q%1%C%HMQ$NNN0h$r3NJ]7F$"$k!#7?$,$CFBTA%Q%1%C%HXN%]%$%s%?$N:9$7BX$(5Z$SNN0h$N2rJ|JI$O9TCF$$$J$$!#PTT $O%m!<%+%k%a%b%j>e$K3NJ]7F$"$j!"%"%/%;%9$K1 %/%m%C%/$N%9%H!<%k$rH<$&$?$a!">e5-$N%5%$%/%k?t$OBEEv$JCMG"kH9M$($ilk!#

:#2s$OL5Ii2Y$G$N%7%_%e%l!<%7%g%s$G$"$kNGBT$A%Q%1%C%H$KJC$?>l9g$N%5%$%/%k?t$O9MN8$7$F$$$J$$$,!"BT$A%Q%1%C%H$HJk>l9gGO5i$K=hM};~4V$,I,MWHJ$k!#BT$A%Q%1%C%H$NEPO?$N=hM}$O0J2<$N4 DN=hM}$+$iJk!#

1. 4{$KEPO?$5lF$$$k%Q%1%C%H$NB8:_$r3NG'
2. %"%I%l%9%U%j%C%H$H%G!<%?%U%j%C%H$N3JG<>l=j$N3NJ]
3. %"%I%l%9%U%j%C%H$H%G!<%?%U%j%C%H$NO\F0
4. PTT XNBT$A%Q%1%C%H3JG<>l=j$NEPO?

RDT $NAw<u?.MQ$N PBR $O%5%$%/%j%C%/%P%C%U%!KJCF$*$j!"MBP-Core $H@\B3$5lF$$$J$$ PBR $,B8:_$9$k(?^3.1;2>H)!#$7$+$7!"MBP-Core $O%Q%1%C%H$,E~Ce9k$H

1. MBP-Core $O%/%i%9%?%P%9$+iN3d9~$_$,$+$+kH%G!<%?$,%/%i%9%?4V$G6&M-5l$F$$$kNG$+$JjN3NN($GRDT XNAw?.$H9T$&!#$=3G%/%i%9%?%P%9$+iN%Q%1%C%H$O RDT Aw?.MQ$N PBR $K3JG<$9$k!#
2. RDT $+$i$N3d9~$_$N>l9g$K$O RDT <u?.MQ$N PBR $K%Q%1%C%H$,3JG<5l$F$$$k!#

$H$$$&;EMMHJCF$$$k!#7?$,$CFBTA%Q%1%C%HHJ$k>l9g$KOIAi$N>l9g$b%Q%1%C%H$rHFMQ$N PBR $N3NJ]$H0\F0$,I,MW$HJk!#H3m,!"PBR 4V$N%Q%1%C%H$N%3%T!<$O1 %U%j%C%H$:D7$+9T$&3H$,$G$-$:!"?^5.5Nh$&$JA`:n$r9T$oJ1lPJi$J$$!#

MVLPP L?Na$O%Q%1%C%H$N PBR 4VGN%3%T!<L?NaG"$k!#0z?t$N%l%8%9%?$O PBR $r:9$9%]%$%s%?$G$"$k!#%G!<%?%U%j%C%H$N%3%T!<$r9T$&0Y$K$O PBR $r;X$7<($9%l%8%9%?$NCM$r3 2s%$%s%/%j%a%s%H7J1lPJiJ$$!#BT$A%Q%1%C%H$NEPO?$r9T$&>l9gKOLs63 %5%$%/%kDx$+$+$k!#

BT$A%Q%1%C%H$N=hM}$r3+;O$9$k>l9g$K$OK\Mh$N%Q%1%C%H$N=hM}$NB>$K3JG<>l=j$N2rJ|$r9T$oJ1lPJi$:!"BT$A%Q%1%C%H$r RDT $KAw?.$9$k>l9g$K$OAw?.MQ$N PBR $N0\F0$r9T$&I,MW$,$"$k!#3N0\F0OBTA%Q%1%C%H$NEPO?;~$N0\F0$HF1MM$G1 %U%j%C%H$:$D9ToJ$/$FOJiJ$$!#

```
;R2, R3:source $NPBR
;R8, R9:destination $NPBR

        MVLPP R2, R8          ; %"%I%l%9%U%j%C%H$r0\F0
        MVLPP R3, R9          ; %G!<%?%U%j%C%H$r0\F0(4 2s)
        ADDGI R3, R3, NEXT_FLIT
        ADDGI R9, R9, NEXT_FLIT
        MVLPP R3, R9
        ADDGI R3, R3, NEXT_FLIT
        ADDGI R9, R9, NEXT_FLIT
        MVLPP R3, R9
        ADDGI R3, R3, NEXT_FLIT
        ADDGI R9, R9, NEXT_FLIT
        MVLPP R3, R9
```

?^5.5: %U%j%C%H$N%3%T!<

5.4 9M;!

K\@aGO: #2s$N%W%m%0%i%`$rMQ$$$$?>l9g$NMW5a$N=hM}G=NOKD$$$F9M;!7F$_$?!#

5.4.1 MBP-light $N=hM}G=NO

%7%_%e%l!<%7%g%sKhCFF@il$?7k2L$+iFI_=P7N%l%$%F%s%7$HCPI KBP9$k0-2=N(5Z$S9 9?7$N:]$N%9%k!<%W%C%H$r5a$aF_$?!#

1 <!%-%&%C%7%eXNFI$_=P$7$O1 %5%$%/%k!"2 <!%-%&%C%7%eXO5 %5%$%/%k!"%/%i%9%?%a%b%j$X$O29 %5%$%/%k$+$+$k!#$=3G1 <!!"2 <!5Z$S3 <!%-%&%C%7%e$N%R%C%HN(r\alpha_1$%!"$\alpha_2$%!"$\alpha_3$%$H2>Dj9k$HJ?6Q%l%$%F%s%7L $O

$$L = 1\times\alpha_1+5\times(1-\alpha_1)\alpha_2+29\times(1-\alpha_1)(1-\alpha_2)\alpha_3+472\times(1-\alpha_1)(1-\alpha_2)(1-\alpha_3)$$

$GM?$(il$k!#3F%R%C%HN($KhkJ?6Q%l%$%F%s%7$rI=5.2$K<($9!#L' HO2>$KMBP-light $N=hM}B.EY$,2 G\$KJC$?>l9g$NbNG"$k!#

I=5.2: FI$_=P$7J?6Q%l%$%F%s%7

α_1 (%)	α_2 (%)	α_3 (%)	L(%5%$%/%k)	L'(%5%$%/%k)
95	97	99	1.242	1.238
90	93	95	1.732	1.640
75	0	0	118.8	59.75

:G2<CJ$N%R%C%HN($O%a%b%jNCMrA4FFI_=P$9>l9g$G$"$k!#SupurSPARC+

$oDoubleWord GNFI$_=P7r9T$&$,!"%-%&%C%7%eKO%V%m%C%/(32Byte) C10L $G%-%&%C%7%s%0$9kN$G!"1 <!%-%&%C%7%e$N$_%R%C%HN($,75%HJ$k!#

JUMP-1 $KEc:\$5lkSuperSPARC+$O3 L?NaF1;~H/9T$N%9!<%Q!<%9%+%i$G $"$j!"CPI $r1.5 G"kH2>Dj9k$H1 %5%$%/%kK_{\frac{2}{3}}$L?NaH/9T$5lk!#%W%m%0%i %`N_{\frac{1}{4}}$$,%m!<%I!&%9%H%"L?NaG"kH9k$H0-2=N($r<!NMMKDj5A9k!#

$$\frac{1}{4}(\frac{L}{\frac{2}{3}} - 1)$$

I=5.2NCMrMQ$$$F0-2=N($r5a$a$?7k2L$rI=5.3$K<($9!#2<CJNCMOMBP-light $N=hM}B.EY$,2 G\$KJC$?>l9g$NbNG"$k!#

I=5.3: 0-2=N(

L(%5%$%/%k)	0-2=N((%)
1.242	21.6
1.732	40.0
1.238	21.4
1.640	36.5

%-%&%C%7%e%R%C%HN($,$"$kDxEY9b$/Jkh&$J%"%W%j%1!<%7%g%s$G$"$lP= $lAj1~$N@-G=$O3NJ]$G$-$h$&!#%-%&%C%7%eN($,Dc2<9k$HMBP-light $N=hM}G= NO$N8~>e$,5a$alk!#

<!$K9 9?7MW5a$N%P%s%II}KD$$$F9M;!7F$_$k$H%/%i%9%?%P%9$N%P%s%II}$O M}O@:GBgCM$G$O320MByte/sec G"$k!#RDT $O76.2MByte/sec G"$k!#

9 9?7=hM}$OInitiator %/%i%9%?$h$jHome %/%i%9%?Fb$G$N=hM}$KB?$/$N;~4V$r MW$9$k!#Home %/%i%9%?Fb$N=hM}$O197 %5%$%/%kG"kN$GMBP-light $N%P%s %II}$O8.1MByte/sec G"$k!#

%P%s%II}$N%M%C%/$HJkItJ,$,MBP-light G"$j!"A4BNGN9 9?7MW5a$N%P%s %II}$O8.1MByte/sec G"$k!#L@$+$K%/%i%9%?%a%b%j$N9 9?7$r9T$&I,MW$,$"$k $?$a$KMBP-light Kh$k=hM}G=NO$NDc2<$,8 60xG"$k!#

5.4.2 DSM 4IM}%W%m%;%C%5H7FN<eE@

K\@aGODSM 4IM}%W%m%;%C%5H7FNMBP-light $N<eE@$K$D$$$F9M;!7F $_$?!#

%/%i%9%?%a%b%j$N9 9?7　%/%i%9%?%a%b%j$N9 9?7$O5.3@a$G=RY?h&$KMBP-light $N9 9?7MW5a=hM}$N$&$ABgItJ,$r@j$a$k! #DSM 4IM}%W%m%0%i%`$,%-%c%C%7%e %i%$%s$NE>Aw5Z$S>uBV$NJQ99G"1P%=%U%H%&%'%"$G9T$&Y-GO$J$$=hM}$G $"$k! #

%/%i%9%?%P%9$N%m%C%/　DSM 4IM}$G$OAtomic $J=hM}$r9T$&$3HOI,MWIT2D7g G"$k! #$7$+$7! "%P%9$K%m%C%/$r$+$1k3HO2DG=G"kK$;$hB(:BK=1r 9T$&$3HOG-$:! "Atomicity $N3NJ]$,==J,KG$-$J$$$H$$$&E@GO5!G=E*<e E@G"kH8@$($k! #

%m!<%+%k%a%b%j%"%/%;%9　PTT $O%m!<%+%k%a%b%j>e$KNN0h$r3NJ]$7F"k,! " %"%/%;%9$K1 %5%$%/%k$N%9%H!<%k$rH<J&! #%/%i%9%??t$,A}Bg$9kHHome %/ %i%9%?GNPTT %"%/%;%9$O:#2s$N%W%m%0%i%`$KHf$YHtLvE*$KA}$($k! #$^$?%b %8%e!<%k8F$S=P$7$r9T$J$&$K$O%m!<%+%k%a%b%j>e$K%1%8%9%?$NB`HrJI$r9T$o J1lPJi$J$$! #L?Na%-%c%C%7%e$N<BAu$JIN%"%/%;%9;~4V$NC;=L$+! "DSM 4IM}%W%m%;%C%5H7$FPTT $N4IM}$r9T$&@lMQ$N%O!<%I%&%'%"$rMQ0U$9Y-$G $"$k! #

6　$*$ojK

K\9FGOCC-NUMA 7?$ND6JBNs7W;;5!JUMP-1 $KEc:\$5lkMBP-light $N DSM 4IM}%W%m%;%C%5$H7F$NI>2A$r9TC?! #

JUMP-1 GO%/%i%9%?Fb$H%/%i%9%?4V$G%3%R!<%l%s%9@)8f$,2 3,AX2=$5lF $$$k! #K\9FGO%/%i%9%?4VGN%3%R!<%l%s%9@)8f$r@lMQ$N%W%m%;%C%5$H%=%U%H %&%'%"$rMQ$$$k3HKh$k@)8fJ}<0$K$D$$$F=RYF$-$?! #

MBP-light $ODSM 4IM}$r9T$&@lMQ$N%W%m%;%C%5$GPBR $H$$$&FC<l%l%8%9%? $r;}$A%Q%1%C%H$N2r@O! ":n@.$r4JC1$K9T$($k! #$7$+$7! "0lJ}GO%/%i%9%?%a%b %j$N9 9?7$J$I;~4V$,$+$+$j! "=hM};~4V$NA}BgKBg-$/1F6A$9k3H,J,$+$C$?! #

$^$?DSM 4IM}%W%m%;%C%5H7$F%P%9$X$N%m%C%/$H$$$&Atomicity $N3NJ]$K BP7F$N<eE@$,$"$k3H$bJ,$+C?! #

:#2s$N%W%m%0%i%`$G$O6&M->uBV$r4IM}9k%G%#%l%/%H%j$r:n@.$7$F$$$J$$$N $G! "MBP-light $N=hM}$KO5iK;~4VrMW9k3H,M=A[G-$k! #$7$+$7! "MBP-light $O=@Fp$J%Q%1%C%H$N=hM}$,2DG=G"k,%a%b%j%"%/%;%9JI$K%X%C%@$N:n @.$r9T$&I,MW$,$"$j! "MM!9$J=hM}$K;~4V$rMW9k3H$,J,$+C?! #

<B:_9k%"%W%j%1!<%7%g%s$rF0$+$9$3H,G-lP5i$K@5$7$$I>2A$,$G$-

kG$"$m$&$,JUMP-1 $,$^$@4 0@.$7$?$$$J$$$?aKK\9FGOL5Ii2Y>uBVGNI>2A$r9T$C$?!#$3$NI>2A$KhjF I$_=P$7MW5a%Q%1%C%H$,H/9T$5$1$F$+$i1~Ez%Q%1%C%H$,E~Ce$9k^GK$+$+$k;~4V$,Ev=i$NM=A[$hjb3.6 G\$b$N;~4V$,$+$+CF7^$&7k2L$HJC$?!#

:#2s$NJs9p$GL5Ii2Y>uBVGN%1%$%F%s%7$H%P%s%II}KD$$$F$bL@$+K9k3H,G-$?!#9 9?7MW5a$N%P%s%II}KD$$$F$OMBP-light $N=hM}$,%M%C%/HJCF$*$j!"$=$N8 60x$O%/%i%9%?%a%b%j$N99?7G"k3HbJ,$+$C$?!#

0J>er^HakH!"DSM 4 IM}%W%m%;%C%5$O%-%&%C%7%e%i%$%s$NE>Aw$d>uBV$N9 9?7$H$$$&F C<1$J=hM}$r4 IM}9k%W%m%;%C%5G"$k!#$7$?$,CF%Q%1%C%H$N%3%T!<!"%/%i%9%?%P%9$X$N%m%C%/!"%/%i%9%?%a%b%j$NFI$_=P$75Z$S=q$-9~$_$JINFC<1L?Na$r%5%]!<%H$9$kCISC hj$N9=@.G"$kJ}$,$5iJ$k9bB.2=$,4 |BTG-$k!#

<UK-

K\8&5f$N5!2q$rM?$($F$/$@5j!"E,@Z$J8f;XF3$r;roC$?IYEDbC<#65<x$K?<?S$J<U0U$rI=7^$9!#

$^$?!"5.=EJ4=u8@$r$$$?$@$$$??9bCO1O:=u65<x!"8^Eg@5M5=u<j$K?<$/46<UCW7^$9!#

5i$K!$6&F18&5f<TG"$k=.K\015W;a!";3K\9M?-;a!"DEED7r;arO8aH7$F!$F|:"$+$i8fJ\Z%2<5G$?5~ETBg3XBg3X1!9)3X8&5f2J>pJs9)3X65<<IYED8&5f<<$N=t7;$K46<UCW7^$9!#

$^$?!"F|:"$+$i5.=E$J8f0U8+$rD:$$$F$$$kJ8It>J=EE@NN0h8&5f6&F18&5f<T3F0L$K46<UCW$7$^$9!#

;29MJ88%

[1] ;3K\9M?-B>!'1N6JBNs7W;;5!JUMP-0.5 K*1kJ,;66&M-%a%b%j4IM}<jK!!W>p=h8&Js97-ARC-125, pp. 85-90!%

[2] :4F#=<B>!'!N6JBNs%^%7%sJUMP-1 N?aNJ,;66&M-%a%b%j4IM}%W%m%;%C%5!W"JBNs=hM}%7%s%]%8%&%`JSPP '97, pp. 265-272.

[3] 0f>e9@L@!'MBP Core $+$i8+$kMMC $NFbIt Register(1997 9/5)

[4] J!Eg D>?M!'1A+0\E*L7=b$r5vMF$9$k%a%b%j!&b%G%k$K4p$:$/0l4S@-@)8fJ}<0!W"=$;NO@J8, 5~ETBg3X(1996)

[5] JUMP-1 @_7W%0%k!<%W!'MBP-light %^%K%e%"%k(1997 12/5)

[6] JUMP-1 @_7W%0%k!<%W!'JUMP-1 %k!<%?30It;EMM(1995 1/27)

[7] JUMP-1 @_7W%0%k!<%W!'JUMP-1 %a%b%j%3%^%s%I;EMM(ver.2.1)(1997 9/10)

[8] JUMP-1 @_7W%0%k!<%W!'JUMP-1 6&DL%P%9;EMM=q(1994 7/29)

[9] JUMP-1 @_7W%0%k!<%W!'JUMP-1 %a%b%j!<%3%s%H%m!<%i!<;EMM@bL@=q(1995 10/8)