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A Coherence Control Scheme Based on a Memory Model Allowing Transitional Inconsistency

J!Eg D>?M(*FUKUSHIMA Naoto*)

J?@.9G/2 7n(*Feb. 1997*)

FbMF9<35

=>Mh!"%W%m%;%C%5$+$i$NF10l%V%m%C%/$KBP9k%a%b%j!&"%/%;%9KHbJ$&3F%-%c%C%7%e$N>uBVA+0\$dCM99?7$O%-%c%C%7%e4V$GF1$8=g=x$G9TolkbNH5lF-$?!#$7$+$7!">uBVA+0\$dCM99?7$N=g=x$r%-%c%C%7%e4V$G0lCW$5$;$kKOBg$-$J%*!<%P%X%C%IrMW9kN$G!"$3$N=g=x$,%-%c%C%7%e4V$G0lCW$7$J$$$3HrG'al$P7W;;5!$N9bB.2=$,4|BT$G$-$k!#

>uBVA+0\$dCM$N99?7=g=x$,%-%c%C%7%e4V$G0lCW$9$k>l9g$H7J$$>l9gHG$O!"7W;;5!$NMxMQ<T$+$i8+$?%a%b%j$NF0:n$O0[$JkN$G!"5,Dj$5lk%a%b%j!&b%G%k$b0[$J$k!#%a%b%j!&b%G%k$G5,Dj5l$k9`L\$H$7$F$O8D!9$N%W%m%;%C%5$+$iH/$;$i$l$k%a%b%j!&"%/%;%9$N%W%m%0%i%`$K<(5l$F$$$k=g=x$H<B9T;~$K$*$1$k=g=x$N4X78$d!"%W%m%;%C%54V$G$N%9%H%"$N4QB,=g=x$N4X78$H$$$C$?$bN,$"$k$,!">uBVA+0\$dCM99?7$N=g=x$,%-%c%C%7%e4V$G0lCW$9$k;~$H7J$$$H$-$HGO!"%W%m%;%C%54VGN%9%H%"$N4QB,$N=g=xNCfG$bF10l%"%I%l%9$KBP9k%9%H%"$N4QB,=g=x$N4X78$,0[$Jk3HKJk!#

F10l%V%m%C%/KBP9$k>uBVA+0\$dCM$N99?7=g=x$K4X9k@)LsH7FO!"(1)IN%-%c%C%7%eKBP7FbF1$8=g=x$G9Tol$k(ACS-CC)!"(2)=g=x$O%-%c%C%7%e4V$G0[$JkN$G0l;~E*$K$O%-%c%C%7%e4V$GL7=b$,@8$:k,!":G=*E*KOL7=b$,$J$/$J$k(TIS-CC)!"(3):G=*E*$K$bL7=b$O@8$:$k$,!%a%b%j!&"%/%;%9$KH<$&0l4S@-@)8f$O9ToJ$$!K"NA$KFC<l$JL?Na$rH/9T$9k3HKhjL7=b$,$J$/$J$k(NCC)!"$N3<oN`$,9M$(il$k!#$3N&$A!"ACS-CC$r:NMQ7?7W;;5!$O03$D$N@)Ls$N$&$A$G:G$bJ,$+$jd9$$F0:n$r9T$&%a%b%j$rMxMQ<T$KDs6!G-$k!#$=lKBP7F!"TIS-CC$r:NMQ$7$?7W;;5!$O<BAu%3%9%H$,$+$+$k0lJ}$G!"MxMQ<T$KBP7F$"$kDxEY<+A3$JF0:n$r9T$&%a%b%j$rDs6!G-kHHb$K:G$b@-G=8~>e$K9W8%$9k3H,4|BTG-!"NCC$r:NMQ$7$?7W;;5!$O:G$b<BAu$,MF0WG"$k!#

TIS-CCKh$k0l4S@-@)8fJ}<0$r<BAu9kKO!"(1)F10l%"%I%l%9XN%a%b%j!&"%/%;%94V$r%7%j%"%i%$%:9kCOE@!%7%j%"%i%$%:!&]%$%s%H!KrNc($P<g5-21$K@_$1!"(2)3F%W%m%;%C%5$+iN%9%H%"$KH<$&%-%c%C%7%eKBP9$k>uBVA+0\$dCM99?7$O%7%j%"%i%$%:5l$kA0$KEj5!E*$K9T$&!#$=$N8e!"(3):G=*E*KO%-%c%C%7%e4V$GL7=b$,@8$8$J$$$h$&$K!"%7%j%"%i%$%:$5l?8eKb$&0lEY%-%c%C%7%e$KBP7F>uBVA+0\$dCM$N99?7$r9T$&$,!"3N:](4)%7%j%"%i%$%:$5l?%a%b%j!&"%/%;%9$,3F%-%c%C%7%e$KE~C#9k=g=x$,%-%c%C%7%e4V$G0lCW9kh&$K!"%7%j%"%i%$%:!&]%$%s%H$K$*$$$F%H%i%s%6%/%7%g%s$N?J9T$rDd;_5;kJIN@)8f$r9T$&3HKh$j<B8=$G$-$k!#

8=:_3+H/Cf$ND6JBNs7W;;5!JUMP-1$oTIS-CCKh$k0l4S@-@)8fJ}<0$r<BAu7F$$$k!#JUMP-1GO!"hj@-G=8~>e$r?^$k$?$a$K0l4S@-@)8f$N:GE,2=$r9T$C$F$$$k!#$=$N0lDK%7%j%"%i%$%:$5lkCOE@$rJ#?t@_$1$F$$$k!#3lKh$j!"3F%V%m%C%/$r=jM-9k%-%c%C%7%e$,$"$k%/%i%9%?Fb$@1G$"$kH-JI$K!"%W%m%;%C%5$N0LCV$H%7%j%"%i%$%:5l$k0LCV$H$r6a$/9k3H$,$G$-$kNG!"0l4S@-@)8fK+$+$k;~4V$NC;=L$d%M%C%H%o!<%/K*1kIi2Y$rDc8:$9k3H,G-$k!#JUMP-1$K$*$1kb$&0l$D$N:GE,2=$H7F!"%7%j%"%i%$%:$5l?8e$N:G=*7k2L$N=q$-9~$_$r6KNO8:$i7F$$$k3H$,$"$k!#$3lO!"(1)%9%H%"KHbJ$$"$k%-%c%C%7%e$KBP7FEj5!E*$K=q$-9~$_$r9TC?8e!"$=$N%9%H%"$,4 0N;$9$kA0$KB>$N%9%H%"$Khj$=$N%-%c%C%7%e$NF10l%V%m%C%/$KBP7F=q$-9~$_$,9T$ol?3H$r8!=P$7$?;~$N$_:G=*7k2L$r=q$-9~$`!"(2)$"$k%-%c%C%7%e$KEj5!E*$K=q$-9~$_$r9T$C$?8e$=$N%9%H%"$,4 0N;9k$^$G$OEj5!E*$J=q$-9~$_$r9T$C$?%V%m%C%/$N>uBVdCM,JQ2=7J$$$h$&$KJ]8n9k!"$r>u67$Khj;H$$J,1F9TCF$$$k!#

Abstract

It is believed that state transitions and value updates for an identical memory block are performed in a consistent order among caches. But due to the large overhead to make the order consistent among caches, speed-up of a computer is expected if inconsistency of the order is allowed.

According to whether or not the inconsistency is allowed, the defined memory model differs because memory behaviors from the point of users differ. An item defined in a memory model is the relations between the order of memory accesses in a program and the order of them in execution. The other is the restrictions on the order of stores observed to processors. The order is consistent among processors in some memory models, and is inconsistent in others. If the order of state transitions and value updates among caches is inconsistent, the observation order of stores for an identical address is also inconsistent among processors. And if consistent, the observation order is also consistent. As such, a part of restrictions on the latter item differs according to whether or not the order of state transitions and value updates among caches is consistent.

Possible restrictions on the order of state transitions and value updates for an identical memory block are, (1) the order is consistent among caches (ACS-CC), (2) the order may be inconsistent, which leads the temporary incoherence of the states and values of the block among caches, but they will be coherent after all the memory accesses to the block will have completed (TIS-CC), and (3) states and values will not be coherent among caches even after all the memory accesses to the block will have completed (coherence control with processor's store is not performed), but they will be coherent if special instructions are issued (NCC). Among these three types of coherence control schemes, computers adopted ACS-CC can present the most comprehensible memories to users. On the other hand, computers adopted TIS-CC will require high implementation costs, but can present pretty comprehensible and high-speed memories. And computers adopted NCC can be easily implemented.

The implementation of TIS-CC coherence control scheme is possible by the following method. That is, (1)

set the serialize point which serializes memory accesses (in main memory, for example), (2) state transitions and value updates of caches by stores are speculatively performed before the stores are serialized. Then, (3) state transitions and value updates of caches are again performed so that states and values will be coherent among caches after all the memory accesses to the block will have completed. And during the above operations, (4) progress of memory accesses is suspended at the serialize point so that the order of state transition and value updates after serialized will be consistent.

The massively parallel computer JUMP-1 implements the TIS-CC coherence control scheme. Several optimizations of coherence control are adopted in JUMP-1 to pursue more speed-up. One of them is to set many serialize points. This method can reduce time taken for each transaction and load of network because the distance between a processor and a serialize point becomes short. Another optimization adopted in JUMP-1 is to reduce the overwrites performed after serialized. This optimization is achieved by introducing the following two mechanisms. Those are, (1) after a state and values are speculatively written to a cache block by a store, if a state and values are written to the cache block by another memory access before the store completes, detect that the cache block is written by another memory access, and overwrite is performed only when such a memory access is detected, (2) protect a state and values of the cache block where speculative write is performed until the access performed the speculative write will have completed.

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1 O8aK

6&M-%a%b%j7?JBNs7W;;5!K*1k0l4S@-@)8fKO%9%H%";~$KB>$N%-%c%C%7%e$rL58z2=$9k+99?7$9$k$+Ey$Khj!"MM!9$J%W%m%H%3%k$,9M$($i$l!"%W%m%H%3%k$,7W;;5!$N@-G=$KM?$($k1F6A$K4X$9$k8&5f$D$$$FO3l^GK$bB?$/9Tol$F$$$k!#7+$7!"7W;;5!$N@-G=$r8~>e$5$;$kKO!"INh&$J%W%m%H%3%k$r:NMQ9k$+$NB>Kb0l4S@-@)8f$N<BAuJ}K!$b=EMWG"k,!"@-G=8~>e$rL\;X$7$?<BAuJ}K!$K4X9k8&5fO[Hs$I0Y$5lF$$$J$$!#

3l$^$G0l4S@-@)8f$N<BAu$N:]$K!"F10l%V%m%C%/$X$N%a%b%j!&%"%/%;%9$KH<$&3F%-%c%C%7%e$KBP9k>uBVA+0\$dCM$N99?7$N=g=x!A+0\=g=x!K$K4X$7FO2?$b9M;!$5lF3il:!"A+0\=g=x$O%-%c%C%7%e4V$GF1$8$KJk$H0EL[$N$&$A$K7h$ailk3H,B?$+$C$?!#$7$+$7!"A+0\=g=x$,%-%c%C%7%e4V$GF1$8$KJkI,MWO[HsIJ$/!"$^$?!"A+0\=g=x$rF1$8$K9k$?$aKOBg$-$J%*!<%P%X%C%IrMW9$k!#$hCF!"A+0\=g=x$,F1$8KJ$kJ]>Z$r@_1J1l$P7W;;5!$N9bB.2=$,4|BT$G$-$k!#

$=$3$GK\8&5f$G$OA+0\=g=x$,%-%c%C%7%e4V$G0lCW$9kH$O8B$i$J$$0l4S@-@)8fJ}<0$r<($7!"$=$7F3$NJ}<0$N<BAuJ}K!$r=R$Y$k!#

K\8&5fK*$$$FO^$:!"A+0\=g=x$,0lCW9kJ}<0H7$J$$J}<0$N4V$N:9$rL@3N$K9k!#Hf3S$N9`L\$H7F!"%a%b%j!&%b%G%kK*1k:90[$*$h$S9M$(il$k<BAuJ}K!$r5s$2!"$=lKbH$E$$$F@-G=!"<BAu%3%9%H!"$*$h$S%W%m%0%i%^%S%j%F%#$K4X9kMx32F@<:$r9M;!$9$k!#

$=$N8e!"D6JBNs7W;;5!JUMP-1 K*1k0l4S@-@)8f$N<BAuNc$r<($9!#JUMP-1 K*$$$F$OA+0\=g=x$,%-%c%C%7%e4V$G0lCW$7$J$$0l4S@-@)8fJ}<0$r:NMQ$7$F@-G=8~>e$r?^kHHb$K!"%a%b%j!&%"%/%;%97PO)$NC;=L$d%M%C%H%o!<%/$K$*$1$kIi2Y$NDc8:$r?^$k:GE,2=Kh$j!"$h$j0lAX$N@-G=8~>e$rL\;X$7$F$$$k!#

0J2<!"$^$:2>OGOA0DsH7$FK\8&5f$NBP>]H9$k7W;;5!$N9=@.5Z$SF0:n$r=R$Y!"3>O$G$O%a%b%j!&%b%G%k$N35O@KD$$$F=RYFK\8&5f$N0LCV$E1r<($9!#$=$N8e!"4>O$GA+0\=g=x$,0lCW$7$J$$0l4S@-@)8fJ}<0rr<(9HHb$K=>Mh$N0lCW9kJ}<0$N4V$H$NMx32F@<:$r=R$Y!":G8e$K5>OG3$NJ}<0$r:NMQ7?7W;;5!H7$F!"8=:_3+H/Cf$ND6JBNs7W;;5!JUMP-1 K*1k<BAuNc$r<($9!#

2 BP>]H9$k7W;;5!

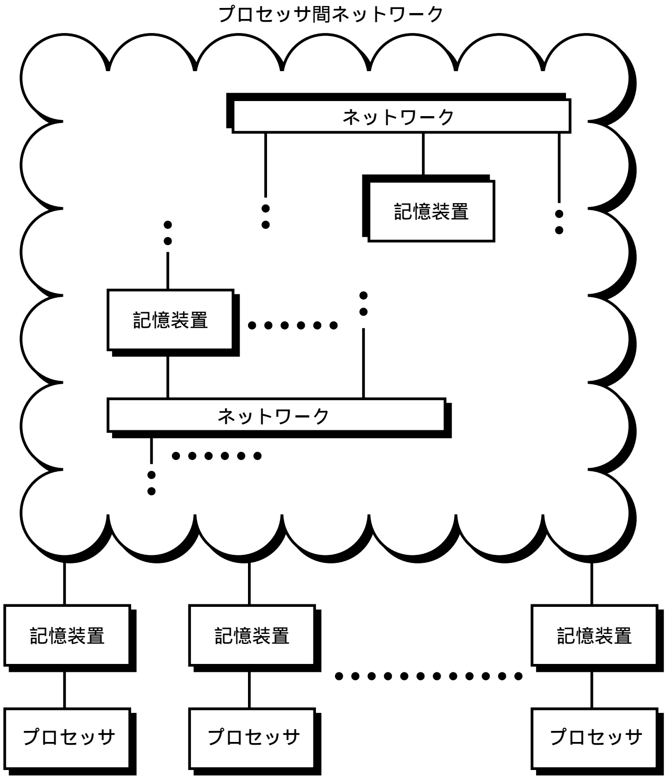
9=@. K\9F$NBP>]$H9k7W;;5!$r?^1$K<($9!#$9Jo$A!"3F%W%m%;%C%5Kh$K5-21AuCV$,<h$jD1ilF*$j!"$3$N5-21AuCV$O$"$k%"%I%l%9KBP9$k<g5-21$H7F!"$^$?B>$N5-21AuCV$KBP9k%-%c%C%7%eH7$F5!G=$9$k!#

$^$?!"%W%m%;%C%54V$N%M%C%H%o!<%/$OJ#?t$N7k9gLV$,Aj8_$K7k9g$5lkJ#9g%M%C%H%o!<%/$G9=@.$5lF$*$j!"5i$K!"%M%C%H%o!<%/$NCfKO%W%m%;%C%5KOD>@\7k9g5l$F$$$J$$5-21AuCV$,B8:_$7F@$k!#$3$N5-21AuCV$N5!G=$O%W%m%;%C%5$KD>@\7k9g5l$F$$$k5-21AuCV$HF1$8$/!"<g5-21$H7F$N5!G=$H%-%c%C%7%eH7FN5!G=$r;}$D!#

$?$@$7!"<g5-21$H%-%c%C%7%eOHbK>uBVHCMr;}DH8@$&B&LL$+$i8+$k$HF1$8bNG"$k!#0J8e!"K\9F$K$*$$$FOFCK

CGj,$J$$8B$j!"<g5-21$H%-%&%C%7%e$O6hJL$;$:!"?^1$K$*$1$k 5-21AuCV$rC1$K%-%&%C%7%e$H8FV3HK9k!#FC$K!"%W%m%;%C%5$KD>@\7k9g5l$?%-%&%C%7%e$OL1 %-%&%C%7%e$H8F$V!#

F0:n 014S@-@)8f$O!"$3N?aKI,MW$J>pJs!Nc$($P%a%b%j!&%"%/%;%9$N<oN`$d%G!<%?$J$I!K$,5-=R5l$F$$$k%Q%1%C%H$N0\F0$Khj?J9T9k!#9JoA!"%W%m%;%C%5$+$i$N%a%b%j!&%"%/%;%9$KHb$J$$%Q%1%C%H$,@8@.$5$l!"%Q%1%C%H$,%M%C%H%o!<%/$r7PM3$7$F3F%-%&%C%7%e$d%a%b%j$KE~C#$7!"I,MW$K1~$8$F>uBV$NA+0\$d%G!<%?$N=q$-9~$_$r9T$&!#$?$@$7!"3N%Q%1%C%H$O?^2$K<(9h$&$K!"0\F0ESCf$GJ#?t$KJ,4t7?$j!"$^$??^3$K<(9h$&$K0lEYDL2a7?%a%b%j$r:FEYDL2a$9k3H,$"$C$?$j!"5i$KF1$8%W%m%;%C%5$+$i@8@.5l$?%Q%1%C%H$G$b%a%b%j!&%"%/%;%9$N<oN`$d>u67$KhCF=$NDL2a7PO)$O0[Jk!#

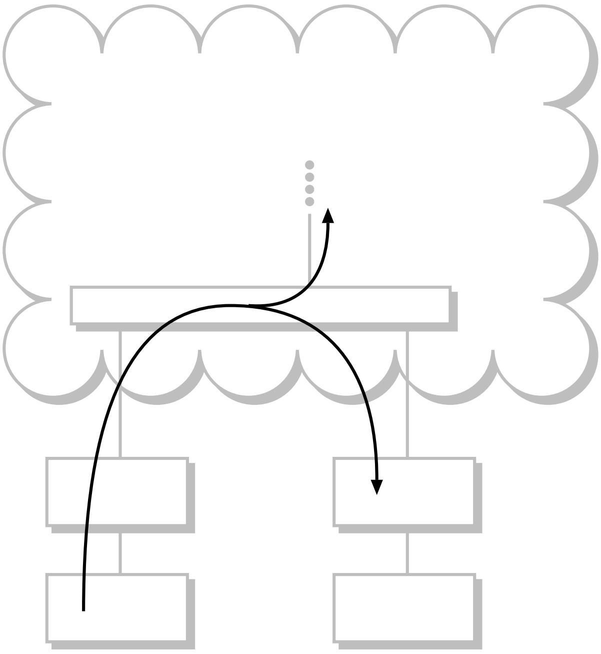


?^1: K\9F$NBP>]7W;;5!

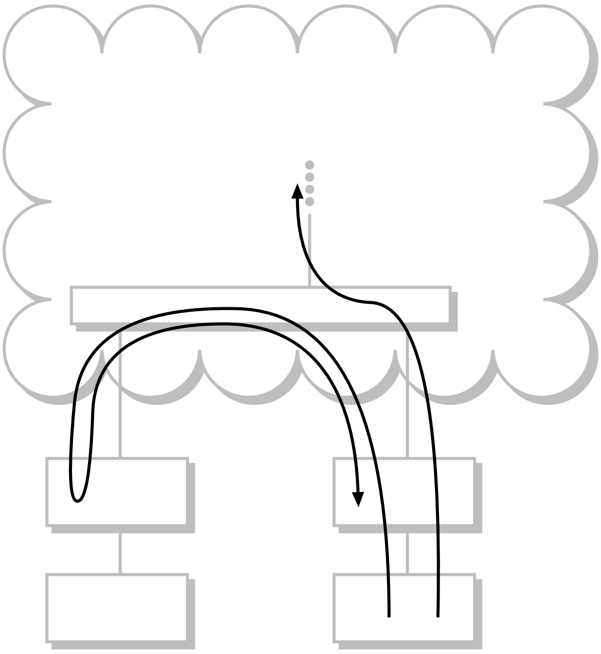
3 %a%b%j!&%b%G%k

%a%b%j!&%b%G%k$O6&M-%a%b%j7?JBNs7W;;5!$K$*$$$F!"3F%W%m%;%C%5$+$i$N%m!<%I!"%9%H%"L?Na$KBP9k%a%b%j$NF0:n$r5-=R9kbNG"$k!#%7%9%F%`$NMxMQ<T$H$7$F$O%a%b%j!&%b%G%k$K$h$j!"0lO"$N%a%b%j!&%"%/%;%9$KH<$&%a%b%j$NF0:n$r%$%a!<%8$9$k$3$H$,$G$-!"0lJ}3+H/<T$+$i8+$k$H!"%a%b%j!&%b%G%k$O5vMF$5$l$k%a%b%j$NF0:n$r5,Dj$9$k!#$9$J$o$A!"%a%b%j!&%b%G%k$O%7%9%F%`$N3+H/<T$HMxMQ<T$N4V$N%$%s%?%U%'!<%9H7FNLr3d$r;}$D!#

7W;;5!$N3+H/$N:]KO@-G=8~>eN?aK!"Nc$($P%9%H%"!&%P%C%U%!JI$NMM!9$J%a%b%j!&%"%/%;%9!&%l%$%F%s%7$NDc8:<jK!$,:NMQ$5lk!#%l%$%F%s%7Dc8:<jK!$r:NMQ9k3HKh$j!":NMQ$7$J$$>l9gHHfY$FMxMQ<T$+$i8+$?%a%b%j$NF0:n$O0[Jj



?^2: %Q%1%C%H$N0\F07PO)Nc(1)



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@h$K=R$Y$?$h$&$K!"K\8&5f$O>uBVA+0\$dCM99?7$N=g=x$,I,$:$7$b%-%&C%7%e4V$G0lCW7J$$0l4S@-@)8fJ}<0$N<BAu$Khj7W;;5!$NB.EY8~>e$rL\;X$9!#>uBV99?7$dCM99?7$N=g=x$,I,$:$7$b0lCW$7$J$$$3HKhj!"3N=g=x$,0lCW$9$k=>Mh$NJ}<0$r<BAu$7$?7W;;5!$HHf3S7F!"MxMQ<T$+$i8+$?%a%b%j$NF0:n$d3+H/<T$KHC$F5vMF$5lk%a%b%j$NF0:n$OJQok3HKJ$k!#

%a%b%j!&b%G%k$O4v$D$+$N%Q%i%a!<%?$NAH9g$o$;$KhjI=8=9k3H$,$G$-$k$,!"K\>O$G$O=>Mh$N0l4S@-@)8fJ}<0$HK\9F$G<($9J}<0$N4V$N:90[$rM}2r9k$?$a$N=`Hw$H$7$F!"%a%b%j!&%b%G%k$N350@$H3F%b%G%k$N:90[$rFCD'$E$1$k%Q%i%a!<%?$N<dN`$K$D$$$F=RYk!#

3.1 MQ8l$NDj5A

K\>O$G8=$l$kMQ8l$NDj5A$r9T$&!#

- %a%b%j!&"%/%;%9$N4 0N;
  $"$k%W%m%;%C%5$,9T$C$?%9%H%"$S$ NCMr%W%m%;%C%5$P_i$$,%m!<%IL?NaKh$jF@$k3H$,$G$-$kh&KJC?H-!"!V9%H%"S OP_i$ KBP7$F4 0N;$7$?!W$H$$$&

  $^$?!"%W%m%;%C%5$P_i$$,9TC?%m!<%IL $K4X$7$F!"%W%m%;%C%5$P_k$ Kh$kF10l%"%I%l%9$X$N%9%H%"$,!"P_i KJVkCM$K1F6A$rM?$($k3H$,$G$-$J$/$JC?;~E@$G!V$L$ OP_k$ KBP7$F4 0N;$7$?!W$H$$$&!#

  $=$7$F!"%a%b%j!&"%/%;%9$M$$,9YFN%W%m%;%C%5KBP7$F4 0N;$7$?;~E@$G!VM $O4 0N;$7$?!W$H$$$&!#

3.2 Sequential Consistency

JBNs7W;;5!K*1kJBNs%W%m%0%i%`$KBP$9$k%a%b%j$NF0:n$r5-=R$9$k0l$D$NJ}K!$H$7$F!"MxMQ<T$K$H$C$F$O$"$?$+$b$"$kC10l%W%m%;%C%5>e$GJ#?t$N%W%m%;%9$,<B9T$5$l$F$$$k$h$&$K8+$;$k<jCJ$,5s$2$i$l$k!#$9$J$o$AMxMQ<T$K$O!"JBNs7W;;5!>e$NJBNs%W%m%0%i%`$O!"$"$kC10l%W%m%;%C%5$K$*$$$FJB9T%W%m%;%9$,%$%s%?%j!<%V<B9T5l$F$$$kNHF1$8F0:n$r9kh&$K8+$;$k!#$3lr7A<0E*KDja$?$N$,Sequential Consistency [4] G"$k!#$3lO!"Lamport Kh$j0J2<$Nh&KDjail$F$$$k!#

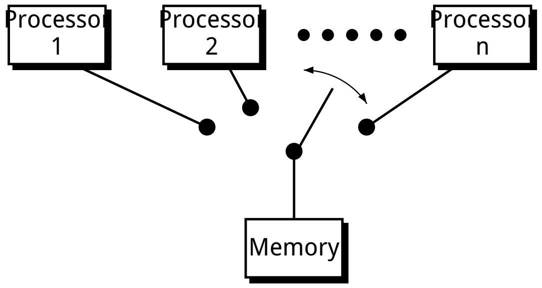
Dj5A1: Sequential Consistency

%W%m%;%C%5$N<B9T$9$kL?Na$rA4BNH7FO$"$kC`<!$N=g=x$G<B9T$7!"$+$D!"8D!9$N%W%m%;%C%5$NL?Na$,$3$N=g=x$K$*$$$F%W%m%0%i%`$G<($5lkNHF1$8=g=x$G$"$iol$F$$$kJi$P!"$=$N%^%k%A!&W%m%;%C%5$OSequential Consistent G"$k!#

Sequential Consistency $NF0:n$OMxMQ<TKHCF$O:G$b<+A3JbNG$"$k!#?^4$KSequential Concistency $NF0:n$N35G0?^$r<($9!#3F%W%m%;%C%5$O%W%m%0%i%`$K<(5l$?=g=x$NDLjK%a%b%j!&"%/%;%9$rH/9T$7!"3F%"%/%;%9$O%a%b%j$KhC$F!D>$A$K!W=hM}$5lk!#9JoA!"3F%"%/%;%9$OB>$N%a%b%j!&"%/%;%9KBP7$F%"%H%_%C/$K<B9T5l$k!#$^$?!"%a%b%j$,<!KI$N%W%m%;%C%5$+iN%a%b%j!&"%/%;%9$r=hM}$9k+$OHs7hDjE*$K7hDj5l$k!#

3.3 %a%b%j!&"%/%;%9!&l%$%F%s%71#JC5;=Q$NF3F~

%a%b%j!&"%/%;%9$NB.EY$O%W%m%;%C%5$NF0:nB.EY$KHfYFCx7/CY$$!#7?$,$C$F!"7W;;5!$N@-G=$r8~>e$5$;$k$?$aKO!"3N:9$rJd=~$9$k5;=Q$rF3F~9k3H$,=EMW$HJk!#Nc$($P!"%W%m%;%C%5N9$03OB&$K%9%H%"!&P%C%U%!$r@_$1$F!"%W%m%;%C%5$,%9%H%"$rH/9T$7$?8e!"$=l,4 0N;9k$^$G%W%m%;%C%5$r%9%H!<%k$5$;$F$*$/NGOJ$//!"%9%H%"!&P%C%U%!$KCM$r=q$-9~$`$@1G$=$N%W%m%;%C%5KHCF$O%9%H%"$,4 0N;7?3HK7!"<!$NL?Na$K?J$^$;k3HKhj!"%9%H%"$KH<$&%l%$%F%s%7$r:o8:9k!#7+$7!"$3Nh$&$J%a%b%j!&"%/%;%9$N%l%$%F%s%7$r1#JC$9$k5;=Q$NF3F~Kh$j7W;;5!$,Sequential Consistency $OK~$?5lJ/Jk!#



?^4: Sequential Consistency $K4p$E$/%a%b%j

Dj5A1$NSequential Consistency $rK~$?9H$O8@$$4 9$($l$P!"8D!9$N%W%m%;%C%5$+$i$N%a%b%j!&"%/%;%9$O%W%m%0%i%`$N=g=xDL$j$K<B9T$5$l!"$+$D$9$Y$F$N%a%b%j!&"%/%;%9$OB>$KBP$7$F86;RE*$K9T$o$l$F$$$k$h$&$K8+$($J$1$l$P$J$i$J$$$H$$$&$3$H$G$"$k!#$3$l$i$O$=$l$>$l%W%m%0%i%`'!&*!<%@$NMW5a(Program Order Requirement)!"%"%H%_%7%F%#$NMW5a(Atomicity Requirement)$H8F$Plk[5]!#0J2<$G!"%a%b%j!&"%/%;%9!&l%$%F%s%71#JC5;=Q$NF3F~$Khj!"INh&K3NFsD$N>r7o$,K~$?$5lJ$/$Jk+$r=R$Y$k!#

%W%m%0%i%`!&*!<%@$NMW5a %W%m%;%C%5$K$h$C$F$O%Q%$%W%i%$%s$K$*$$$F;q8;6%9g$,H/@8$7$?$H$-$J$I$K!"%a%b%j!&"%/%;%9$NH/9T=g=x$r%W%m%0%i%`$N=g=x$H$O5UE>$5$;$k>l9g$,$"$j!"$3lKhj%W%m%0%i%`!&*!<%@$NMW5a$,K~$?$5$l$J$$$2DG=@-$,@8$:$k!#$7$+$7!"%W%m%;%C%5$,%W%m%0%i%`$N=g=xDL$j$K%a%b%j!&%"%/%;%9$rH/9T7?H7Fb0J2<Nh$&$J5;=Q$rF3F~$9k3HKhj!"$=$N4 0N;=g=x$O%W%m%0%i%`!&*!<%@DL$jKO4 0N;7J$$$2DG=@-$,@8$:$k!#

$^$:$O%9%H%"!&P%C%U%!$r9M$($k!#7W;;5!$N@-G=$KBP7FBg$-$J1F6A$rM?$(kN$O%9%H%"$K$+$+$k;~4V$GOJ$/!"%m!<%I$K$+$+$k;~4V$G$"$k!#3N3H$+$i$"$k%9%H%"$N7k2L$,%9%H%"!&%P%C%U%!$K%P%C%U%!%j%s%0$5lF$$$k:]$K!"%W%m%;%C%5$,8eB3$N%m!<%IL?Na$rH/9T9k$H!"%m!<%IL?Na$r9bB.$K=hM}$9k?aK%9%H%"!&P%C%U%!$r%P%$%Q%9$9$k5;=Q$,:NMQ$5lk>l9g$,$"$k!#$3$N>l9g!"@h9T%9%H%"$H8eB3%m!<%I$O%W%m%0%i%`$N=g=xDLjK$O4 0N;$7$J$$!#

5i$K!"%M%C%H%o!<%/$KhCFb%a%b%j!&"%/%;%9$N=g=x$,F~lBXok2DG=@-$,$"$k!#Nc$($P!"%M%C%H%o!<%/$KhCFOIi2YJ,;6$r?^$k$?$a$KF1$8%W%m%;%C%5$+$iH/9T5l$?Fs$D$N%a%b%j!&"%/%;%9$G$b0[$J$k7PO)$rDL2a9k3H$,$"$k!#$3$N;~!"$"$k%W%m%;%C%5$,FsDN%9%H%"$(S_a, S_b : S_a$$,@h$KH/9T) $rO"B3E*$KH/9T7?H-!"b7FsDN%9%H%"$N4V$G%M%C%H%o!<%/K*1kDL2a7PO)$,0c$($P!"$"$k%W%m%;%C%5$KBP7FOS_b$$,@h$K4 0N;$9$k2DG=@-$,$"$k!#

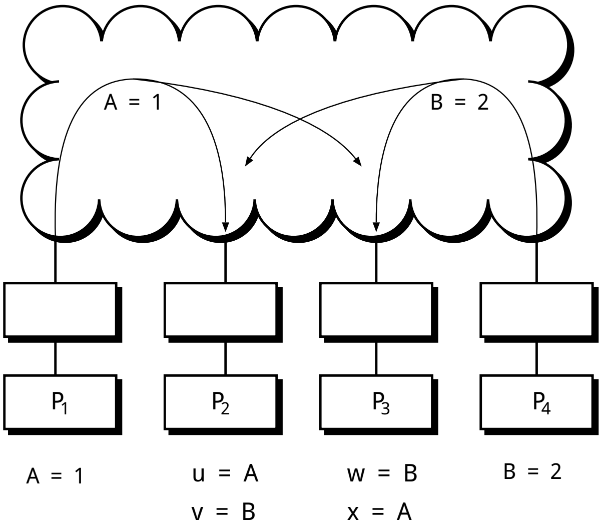
%"%H%_%7%F%#$NMW5a %-%&C%7%e!&a%b%j$NF3F~$O%a%b%j!&"%/%;%9$N%l%$%F%s%7Dc8:5;=Q$H7FHs>o$K=EMW$G$"$k!#7+$7!"%-%&C%7%e$NF3F~Kh$j!"3F6&M-%G!<%?$O7W;;5!Fb$KJ,;6$7$F

J#?tB8:_7F$$$k3HKJ$k!#3F%G!<%?$,J,;6$5$l$FB8:_$7$F$$$k$?$a!"%a%b%j!&"%/%;%9$,%"%H%_%C%/$K9Tolkh$&$K9kNO:FqHJk!#

%-%c%C%7%e$r:NMQ$9$k6&M-%a%b%j7?$NJBNs7W;;5!$O%9%H%"$NEYK3li$r:G?7$NCM$KJ]$D$?$a$N%-%c%C%7%e!&%3%R!<%l%s%9@)8f!"9JoA!"%9%H%"NEYKJ,;6$7$FB8:_7F$$$k%G!<%?$rL58z2=$7$?$j!"$=$liNCM$r?7$7$$CM$K99?7$9k3H,9Tol$k!#Nc$($P!"<!$N%W%m%0%i%`$r9M$($k!#

P_1	P_2	P_3	P_4
`A = 1;`	`u = A;`	`w = B;`	`B = 2;`
	`v = B;`	`x = A;`	

:G=i!"IN%W%m%;%C%5$NL1%-%c%C%7%e$K$bM-8z$J%G!<%?$N%3%T!<$,B8:_7F$*$j!"$=$NCM$O0$G$"$kH7!"%-%c%C%7%e!&%3%R!<%l%s%9@)8f$O99?77?$G9TolkH9k!#$3$3$G!" P_1 $H P_4 $,$[$\F1;~$K$=$l$>$lA,BKBP9$k%9%H%"$r9T$&$H9k!#3N;~!" P_1 $OJQ?tA$NB>$N%3%T!<$r1$K!" P_4 $OJQ?tB$N%3%T!<$r2$K99?7$9$k$?$a$N%3%R!<%l%s%9@)8f$r3+;O9k!#7+$7!"%W%m%;%C%54V$N5wN%$N:9$JINM}M3N?$a!" P_2 $H P_3 $N4V$G3liN99?7%Q%1%C%H$r<u$1<h$k=g=x$,5UKJ$k2DG=@-$,@8$8F@$k!#Nc$($P?^5$K<($9h&$K!" P_2 $O P_1 $+$i$N99?7%Q%1%C%H$r@h$K<u$1<h$j!"$=$N8e$G P_4 $+$i$N99?7%Q%1%C%H$r<u$1<h$k$,!" P_3 $O P_4 $+$i$N99?7%Q%1%C%H$r@h$K<u$1<h$k>u67$,5/3jF@$k!#$3$N7k2L!" $(u, v, w, x) = (1, 0, 2, 0)$ HJk3H,5/3jF@$F!"Sequntial Consistency $rK~$?5J$/$J$k!#$3lO!"6&M-%G!<%?A,B$,J,;6$7$FJ#?tB8:_$7F*$j!"N><T (P_2,P_3) KBP9$k99?7$r%"%H%_%C%/$K9TCF$$$J$$$?aK@8$:$k7k2LG"$k!#



?^5: %"%H%_%7%F%#$NMW5a$,K~$?$5lJ$$>u67

0J>e$K<($7$?$h$&$K!"7W;;5!$NB.EY8~>e$N$?$a$K%9%H%"!&%P%C%U%!$d%-%c%C%7%e!&%a%b%jJIMM!9$J%a%b%j!&"%/%;%9!&%l%$%F%s%7Dc8:5;=Q$,F3F~$5lk!#7+$7!"$3li$N5;=Q$NF3F~N?aKSequential Consistency $OK~$?5lJ/Jk!#

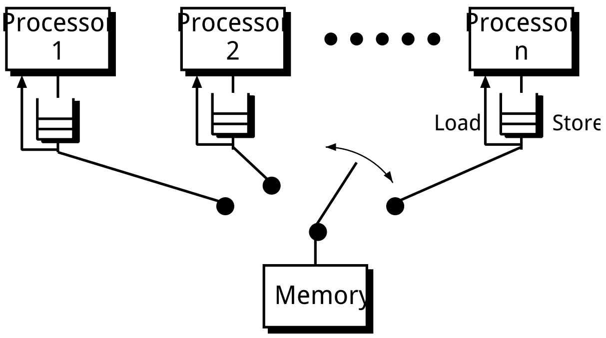
3.4 @)Ls$r4K$/7?%a%b%j!&%b%G%k

A0@a$G<($7$?$h$&$K!"%a%b%j!&"%/%;%9$N%l%$%F%s%7$rDc8:$9$k5;=Q$rF3F~9k3HKh$jSequential Consistency $rK~$?9?aN>r7oG"$k%W%m%0%i%`!&*!<%@$NMW5a$H%"%H%_%7%F%#$NMW5a$,$OK~$?$5lJ$$2DG=@-$,@8$:$k!#

3N3H$+$i!"%l%$%F%s%7Dc8:5;=Q$r:NMQ9k$?$a$K!"%a%b%j$NF0:nKBP7$F2]$5lk@)Ls$rSequential Consistency KBP7$F4K$/7?MM!9$J%a%b%j!&%b%G%k$,Ds0F5l$F$$$k!#8=:_$^$G$KDs0F$5lF$$$k<g$J%a%b%j!&%b%G%k$K$*$$$F$O@)Ls$r4Ka?7k2L!"%W%m%0%i%`!&*!<%@$H%"%H%_%7%F%#$NMW5a$O0J2<$Nh&$KK~$?5lJ/Jk!#

%W%m%0%i%`!&*!<%@$H<B9T;~$N4ON;=g=x$NITO1CW

IBM-370 %b%G%k[6] $O?^6$K<($935G0?^$Khj%a%b%j!&%b%G%k$,Dj$ail$k!#IBM-370 %b%G%k$K$*$$$F$O3F%W%m%;%C%5Kh$KFIFO $N%9%H%"!&%P%C%U%!$,@_1ilF$*$j!"%9%H%"$r9T$&H3$N%P%C%U%!$K=q$-9~$`$@$1$G<!$NL?Na$K?J$_!"$^$?!"%9%H%"!&%P%C%U%!KL4ON;$N%9%H%"$,B8:_7F$$$kH-$K%m!<%I$,9TolkH!J%9%H%"$HF10l%"%I%l%9$X$N%m!<%I$G$J$$$H$-$O!K%9%H%"hj$b%m!<%I$,@h$K=hM}$5lkH7$F$$$k!#3N7k2LIBM-370 %b%G%kGO@h9T$N%9%H%"$H8eB3$N%m!<%I$N4ON;=g=xO=li$,0[$J$k%"%I%l%9$KBP9kbNG"kJiP%W%m%0%i%`!&*!<%@DLjK4ON;9k3H$OJ]>Z$5lJ$$!#



?^6: IBM-370 %b%G%k$N35G0?^

$^$?!"Total Store Ordering(TSO)[7] K*$$$F$O!"?^6$HF1MM$N35G0?^$Khj%a%b%j!&%b%G%k$,Dj$ail$F$$$k!#$?$@$7!"8eB3%m!<%I$,@h9T%9%H%"$HF1$8%"%I%l%9$N>l9g$O%9%H%"!&%P%C%U%!$+$iD>@\%W%m%;%C%5KBP7FCM,JV5l$k%U%)%o!<%G%#%s%0$,9TolkbNH7F$$$k!#3N7k2L!"@h9T%9%H%"$H8eB3%m!<%I$N4V$N4ON;=g=x$OIBM-370 HO0[Jj!"F10l%"%I%l%9G"m&HJ$+$m$&$H%W%m%0%i%`!&*!<%@DLjK4ON;9k3H$OJ]>Z$5lJ$$!#

5i$K!"Partial Store Ordering(PSO)[7] K*$$$F$OTSO KHfY$F%9%H%"!&%P%C%U%!$OFIFO GO$J$$$H5l$F$$$kNG!"@h9T%9%H%"$H8eB3%9%H%"$N4V$N4ON;=g=x$b%W%m%0%i%`!&*!<%@DLjH$O8B$i$J$$!#

0lJ}!"Weak Ordering (WO) [3] $dRelease Consistency (RC) [8] $O%a%b%j!&%b%G%k$rDjakK"$?$C$F!"%W%m%0%i%`$NF14|E@$G$N$_@5$7$$CM$,8+$($l$PNI$$$H$$$&9M$($K4p$E$$$F$$$k!#$3$N$?$a$K%W%m%;%C%5$+$iH/$;$i$l$k%"%/%;%9$K$OF14|L?Na$HHsF14|L?Na$,$"$k$H$7$F!"F14|L?Na$r$O$5$^$J$$Fs$D$NHsF14|L?Na4V$N4ON;=g=x$K4X$9$k@)Ls$OB8:_$;$:!"@h9T/8eB3L?Na$N<oN`(%m!<%I/%9%H%")Khi:%W%m%0%i%`!&*!<%@DL$j$K4ON;$9$kJ]>Z$O$J$$!#WO $HRC $N4V$G$OF14|L?Na$N<oN`$,Bg$-$/0[$J$k!#WO GO!"0l<oN`$NF14|L?Na$,MQ0U$5$l$F$*$j!"%W%m%0%i%`Cf$KF14|L?Na$rA^F~9k3HG=$NA08e$N4ON;=g=x$O%W%m%0%i%`$N=g=x$,J]$?$l$k!#0lJ}!"RC $K$*$$$F$Oacquire,release $NFs<oN`$NF14|L?Na$,MQ0U$5lF$*$j!"acquire $H8eB3%"%/%;

%9$N4V!"5Z$S@h9T%"%/%;%9$Hrelease $N4V!"$=7FF14|L?Na4V$N40N;=g=x$OJ]$?$l$k[1] !#8@$$4 9$($l$P!"acquire $O6&M-JQ?t$KBP9k%"%/%;%98"$N3MF@$r!"release $O%"%/%;%98"$N2rJ|$r0UL#$7$F$$$k!#

%"%H%_%C%/<B9T$N4KOB %9%H%"$,%"%H%_%C%/$K<B9T$5lkJi$P!"8@$$4 9$($l$P%9%H%"$,D>AK40N;9kJi$P!"!0J[$J$k%W%m%;%C%5$+$iH/$;il$?$bNb4^aF!K9YFN%9%H%"OI$N%W%m%;%C%5$KBP7F$bF1$8=g=x$G4QB,$5lk!#7+$7!"%a%b%j!&%b%G%k$KhCFO%W%m%;%C%5$+$iH/$;$il?%9%H%"$OD>$AKO40N;7J$$$H5,Dj5lk?aK!"%9%H%"$N4QB,=g=x$,%W%m%;%C%54V$G0[$J$k2DG=@-$,@8$:$k!#

Nc$($P!"TSO $dPSO K*$$$F$O%9%H%"$O0lC6%9%H%"!&P%C%U%!$K3JG<$5lF$+$i%a%b%j$K=q$-9~$^$l!"5i$K%9%H%"!&P%C%U%!Fb$NCM$O<+%W%m%;%C%5$+iOD>AK4QB,2DG=G"kHDjailF$$$k!#3N$?$a!"%9%H%"$N7k2L$,%P%C%U%!$KB8:_$7$F$$$k4V$KB>$N%W%m%;%C%5$,%9%H%"$r9T$&$H%9%H%"$N4QB,=g=x$O%W%m%;%C%54V$G0lCW$7J/Jk!#

7+$7TSO $dPSO K*1k%9%H%"!&P%C%U%!$O!"K\Mh$O%a%b%j!&"%/%;%9$N%W%m%0%i%`K*1k=g=x$H<B9T;~$N40N;=g=x$r5,Dj9k3H$rL\E*$H7F$*$j!"3N%P%C%U%!Kh$j%"%H%_%C%/<B9T$N4KOB$,$J5lkH$$$&3H$OI{:nMQE*$KDj$^$k$K2a$.$J$$!#$^$?!"WO $dRC K*1kHsF14|L?NaNh$&$K%"%H%_%C%/$+H]$+$,L@5-$5lF$$$J$$%b%G%kb"$k[2] !#$3Nh$&$K!"%"%H%_%C%/<B9T$N4KOB$K$D$$$F$OL@5-$5lF$$$J$$%a%b%j!&b%G%k$,B?$$!#

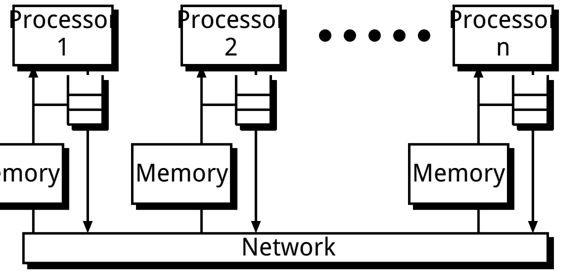
$=$NCfGb!"Processor Consistency[8] $O%"%H%_%C%/<B9T$N4KOB$,9MN8$5lF$$$k!#PC $O

1. %m!<%I$,B>$N3F%W%m%;%C%5KBP7$F40N;$9$kA0$K!"$=$l0JA0N9YF$N%m!<%I$O40N;7F$$$J1lPJiJ$$!#
2. %9%H%"$,B>$N3F%W%m%;%C%5KBP7$F40N;$9$kA0$K!"$=$l0JA0N9YF$N%"%/%;%9!&m!<%I!"%9%H%"!K$O40N;$7$F$$$J1lPJiJ$$!#

H@$1Dj$ail$F$$$k$,!"PC $O?^7$Nh&$J7W;;5!9=@.!"$9Jo$A3F%W%m%;%C%5Kh$K%U%)%o!<%G%#%s%05!G=rb$D%9%H%"!&P%C%U%!$H!"A4%"%I%l%9$NFbMF$rJ];}9k%a%b%j!&3%T!<$r=jM-$9k3HrA[Dj7F$*$j!"%a%b%j$N%3%T!<$,J#?tB8:_9k$?$a!"A4%a%b%j!&3%T!<$N99?7$r%"%H%_%C%/$K9T$&3H$O=PMh$J$$$3H,A0DsHJCF$$$k!#3N$?$a!"?^5Nh$&$K%9%H%"$N4QB,=g=x$,%W%m%;%C%54V$G0lCW$7$J$$2DG=@-$,$"kbNH5l$F$$$k!#$?$@$7!"3F%"%I%l%9$NFbMF$O%a%b%j4V$GL7=b$,@8$8$J$$$h$&$KF10l%"%I%l%9XN%9%H%"OI3+$G%7%j%"%i%$%:5l$F!"$=$N=g=xDL$j$K3F%3%T!<$K=q$-9~$^lkH7$F$$$k[9]!#

4 %-%&C%7%e4V$NA+0\E*L7=b$rH<$&014S@-@)8fJ}<0

8=:_$^$G$K3+H/$5lF$-$?6&M-%a%b%j7?JBNs7W;;5!$NB?$/$O!"F10l%V%m%C%/$KBP9k%a%b%j!&"%/%;%9Kh$kCM99?7$d>uBVA+0\$O%-%&C%7%e4V$GF1$8=g=x$G9T$olk!#3N$?$a$K!"3F%V%m%C%/$KBP9k%a%b%j!&"%/%;%9$r7W;;5!Fb$N$"$k0lE@$G=g=xIU$1$7$F!"3N=g=xNDLj$K3F%-%&C%7%e$N>uBVA+0\$dCM99?7$r9T$&@)8f$r9T$C$F$$$k!#7+$7!"=g=xIU$1K+$+$k%*!<%P%X%C%I$O>.$5$$$H$O8@$($J$$$N$G!"=g=xIU$1$r9T$&A0$K>uBVA+0\$dCM99?7$r9T$($P!"=g=xIU$1K+$+$k%*!<%P%X%C%I$r1#JC$9k3H,G-!"7W;;5!$N@-G=8~>e$K9W8%9k$H9M$(il$k!#



?^7: Processor Consistency $N35G0?^

K\>OGO$^$:!"%-%&C%7%e4V$NA+0\E*L7=b$rH<oJ$$014S@-@)8fJ}<0$HH<$&$=$l$NDj5A$r9T$$!"014S@-@)8f$NA+0\E*L7=b$r5vMF9k3H$G9bB.$J014S@-@)8f$N<BAu$r2DG=H9$kJ}<0$G$"$kTIS-CC $H!"TIS-CC HNHf3S$NBP>]$H7F014S@-@)8f$r9ToJ$$J}<0G"$kNCC $r<($9!#$=$N8e!"3F014S@-@)8fJ}<0$NE57?E*$J<BAuJ}K!$r=R$Y$?8e!"$3$N<BAuJ}K!$K4p$E$$$F3FJ}<0$NHf3S$r@-G=!"<BAu%3%9%H!"%W%m%0%i%^%S%j%F%#$N4QE@$+$i9T$&!#

4.1 MM!9$J014S@-@)8fJ}<0$NDj5A

4.1.1 ACS-CC

8=:_$^$G$K3+H/$5l?B?$/$N6&M-%a%b%j7?JBNs7W;;5!K*$$$F$OF10l%V%m%C%/$KBP9k014S@-@)8fKh$kCM99?7$d>uBVA+0\$O%-%&C%7%e4V$GF1$8=g=x$G9T$olk!#3N014S@-@)8fJ}<0$rACS-CC(Always Coherent Scheme of Cache Coherence) $H8F$V3HK7!"7A<0E*KO<!Nh$&$KDjak!#

Dj5A**2:**
Always Coherent Scheme of Cache Coherence
3F%"%I%l%9KBP7$F!"%m!<%IL?Na$Khj4QB,G-kCM,IN%W%m%;%C%5KBP7FbF1$8=g=x$GJQ2=7F$$/H-!"01
4S@-@)8f$OACS-CC Kh$j9TolkH$$$&!#

3l$OA0>O$G=RY?%a%b%j!&b%G%k$K>H$i9H!"%"%H%_%C%/<B9TNCfG$bF10l%"%I%l%9$KBP9k%9%H%"$N4QB,=g=x$O%W%m%;%C%54V$GF1$8KJk3H@1OJ]>Z$7!"0[$J$k%"%I%l%9$KBP9k%9%H%"$N4QB,=g=x$d%W%m%0%i%`!&*!<%@$H<B9T;~$N40N;=g=x$N0lCW$K4X7F$O2?$b8@5Z7F$$$J$$!#

ACS-CC $GJ]>Z$5lk3H$r6qBNE*$K5s2k$H!"Nc$(P"$k%"%I%l%9$NCM$,$I$N%W%m%;%C%5$+$i8+$F$b0 G"kH$-$K!"3N%"%I%l%9KBP7F[$\F1;~$K%W%m%;%C%5$P_1$$O1 $r!"$P_2$$O2 $r!"$P_3$$O3 $r%9%H%"$7$?$H9k$H!"

P_1 : 0 "*1 "*2 "*3 P_1 : 0 "*1 "*3 "*2
P_2 : 0 "*1 "*2 "*3 Kt$O P_2 : 0 "*1 "*3 "*2
P_3 : 0 "*1 "*2 "*3 P_3 : 0 "*1 "*3 "*2

EyNh$&$KIN%W%m%;%C%5KBP7FbF1$8=g=x$GCM$,JQ2=$7$F$$$/3H$rJ]>Z$7$F$$$k!#

4.1.2 TIS-CC

ACS-CC Kh$k014S@-@)8fJ}<0$Nh&$K!"F10l%V%m%C%/$KBP9k014S@-@)8fKh$kCM99?7$d>uBVA+0\$,%-%&C%7%e4V$GF1$8=g=x$G9T$olk$?$aKOBg$-$J%*!<%P%X%C%IrMW9$k!#0lJ}!"

---

[1] 87L)KORC KORC_{SC} $H RC_{PC} $NFs<oN`$"$j!"K\J8Cf$K<(7?NORC_{SC} G"$k!#$RC_{PC}$ K*$$$F$O@h9Trelease $H8eB3acquire $N4V$N=g=x$,J]$?lk3H$OJ]>Z$5lJ$$!#

[2] WO $dRC K*1kHsF14|L?Na$O%"%H%_%C%/$GOJ$$$3HO%a%b%j!&b%G%krDja$kGX7J$+$i?dB,$9k3HOG-$k!#

%U%)!<%k%9!&7%'%"%j%s%0$O%3%s%Q%$%iKh$jH/@8$,M^$($ilk$H2>Dj$7!"F10l%V%m%C%/Fb$N0[$J$k%"%I%l%9$KBP7F$[$\F1;~$K%a%b%j!&"%/%;%9$,9Tolk3HO$J$$$H9k$H!"F10l%V%m%C%/$KBP9k%"%/%;%9$,$[$\F1;~$K9Tolk3HO>/$J$$$H9M$($ilk!#J<Ji!"F10l%"%I%l%9XN%a%b%j!&"%/%;%9$O%/%j%F%#%+%k!&;%/%7%g%s$G$"$k3H$,B?$$$+iG$"$k!#3N$?$a!"F10l%V%m%C%/XN%a%b%j!&"%/%;%9$KH<$&%-%c%C%7%e$N>uBVA+0\$dCM99?7$N=g=x$,%-%c%C%7%e4V$G0lCW$9$kJ]>Z$r@_1J$/$F$b!":G=*E*$K$O%-%c%C%7%e4V$GL7=b$,@8$8$J$$$3H5$(J]>Z$5lF$$$l$P!"7W;;5!$NMxMQ<T$+$i8+$?<B<AE*$J%a%b%j$NF0:n$OACS-CC Kh$k0l4S@-@)8f$r9T$&$H$-$H$[$HsIJQoi$:!"$+$D>uBVA+0\$dCM99?7$N=g=x$,%-%c%C%7%e4V$G0lCW$9kNKI,MWG$"$C$?;~4V$r1#JC9k3H$,$G$-$k$H9M$(il$k!#

3lKbHE$/0l4S@-@)8fJ}<0$rTIS-CC(Transitionally Incoherent Scheme of Cache Coherence) $H8F$V3HK7!"7A<0E*KO<!Nh$&$KDjak!#

Dj5A **3: Transitionally Incoherent Scheme of Cache Coherence**
3F%"%I%l%9KBP7!"Ev3:%"%I%l%9KBP9kL40N;$N%9%H%"$,%7%9%F%`Fb$KB8:_$7J1lP!"IN%W%m%;%C%5$+$i8+FbF1$8CM$,4QB,G-kH$-!"0l4S@-@)8f$OTIS-CC Kh$j9T$olF$$$k$H$$$&!#

Dj5A3$O%a%b%j!&b%G%k$K>Hi9$H!"0[$J$k%"%I%l%9$KBP9k%9%H%"$N4QB,=g=x$d%W%m%0%i%`!&*!<%@$H<B9T;~$N40N;=g=x$N0lCW$K4X7F$O2?$b8@5Z7F$$$J$$$N$ODj5A2$HF1$8$G$"$k$,!"F10l%"%I%l%9$KBP9k%9%H%"$N4QB,=g=x$O%W%m%;%C%54V$G0lCW$9kH$O8B$i$J$$$?$a!"3F%"%I%l%9$NCM$O%W%m%;%C%54V$GL7=b$,@8$:$k2DG=@-$,$"$k!#7+$7!"$3Nh$&$JL7=b$OA+0\E*$JbNG"$j!"$[$\F1;~$K0[Jk%W%m%;%C%5$+$i%9%H%"$,9T$olF$b:G=*E*$K$OF1$8CM$r4QB,$G$-$k!#

ACS-CC K*1k%N%c$HF1MM$N6qBN%N%cKEvFOakH!"TIS-CC K*$$$F$O:G=*E*$K$OF1$8FbMFKJk,$=$NESCf7P2aOLdo$J$$$3H+$i

P_1 : 0 "*1 "*2 "*3 P_1 : 0 "*1 "*3 "*2
P_2 : 0 "*1 "*2 "*3 Kt$O P_2 : 0 "*3 "*1 "*2
P_3 : 0 "*2 "*1 "*3 P_3 : 0 "*1 "*3 "*2

Nh$&$KJQ2=$N=g=x$,%W%m%;%C%54V$G0[$JC?$j!"$^$?

P_1 : 0 "*1 "*2 "*3 P_1 : 0 "*1 "*3 "*2
P_2 : 0 "*1 "*2 "*3 Kt$O P_2 : 0 "*2
P_3 : 0 "*3 P_3 : 0 "*1 "*3 "*2

Nh$&$K4QB,5l$J$$%9%H%"$,$"C?$j!"$5iK

P_1 : 0 "*1 "*2 "*3
P_2 : 0 "*2 "*1 "*2 "*3
P_3 : 0 "*1 "*2 "*3

Kt$O

P_1 : 0 "*1 "*3 "*2
P_2 : 0 "*1 "*3 "*2
P_3 : 0 "*3 "*1 "*3 "*2

Nh$&$K$$$o$P0l$D$N%9%H%"$,$"$k%W%m%;%C%5$+$iFs2s4QB,5lFb!":G=*E*KOF1$8CM$,4QB,G-lP$h$$!#

TIS-CC Kh$k0l4S@-@)8fJ}<0$O!"Processor Consistency(PC) K*1k$=$l$HN`;w$7$F$$$k!#PC K*$$$F$O!"F10l%"%I%l%9$X$N%9%H%"$KH<$&3F%a%b%j!&3%T!<$NCM99?7$O%a%b%j!&3%T!<4V$GF1$8=g=x$G9TolkH7F$$$k$,!"?^7$K<(9h$&$K%U%)%o!<%G%#%s%05!G=$r;}$D%9%H%"!&P%C%U%!$r;}$DbNH7$F$$$kNG!"!V%W%m%;%C%5$+$i8+$?CM$NJQ2==g=x!W$O%W%m%;%C%54V$G0[JjF@$k!#

$?$@$7!"TIS-CC Kh$k0l4S@-@)8fJ}<0$OPC K*1k$=lH<!$NE@$G0[$JCF$$$k!#9JoA!"PC K*1k0l4S@-@)8fGOF10l%"%I%l%9XN%9%H%"$KH<$&3F%a%b%j!&3%T!<$NCM99?7$N=g=x$OF1$8KJkHDjailF$$$kNG!"3N7k2L!"Ev3:%"%I%l%9XN%9%H%"$r9T$o$J$$%W%m%;%C%54VGO%W%m%;%C%5$+$i8+$?CM$NJQ2==g=x$OF1$8KJ$k!#0lJ}TIS-CC GO!"Ev3:%"%I%l%9XN%9%H%"$r9T$o$J$$%W%m%;%C%54VGb!"%W%m%;%C%5$+$i8+$?CM$NJQ2==g=x$O0[$J$jF@$k!#

9JoA!"TIS-CC $OPC K*1k0l4S@-@)8f$K4X9k@)Ls$r5i$K4K$/7?bNHHi(k3H,G-$k!#

4.1.3 NCC

3F%V%m%C%/KBP7$F%9%H%"$,9TolFbB>%-%c%C%7%e$NL58z2=$d99?7$O9T$o$:$K!"NA$K%W%m%;%C%5$,2?i+$NFC<lL?Na!0J8e%3%R!<%l%s%9L?Na!K$rH/9T$9k3HKhj%W%m%;%C%54V$G4QB,$5lkCM$,F1$8CMKJk?aN@)8f$r9T$&J}K!$b9M$(il$k!#$3lrNCC(No Coherence Control) $H8F$V3HK7!"7A<0E*KO<!$K<($9h&KDja$k!#

Dj5A**4: No Coherence Control**
3F%W%m%;%C%5$,9T$C$?%9%H%"$NCM$rB>$N%W%m%;%C%5$+$i4QB,G-kh$&$K9k$?$aKO!"2?i+$NFC<lL?Na$r%W%m%;%C%5$,H/9T$9kI,MW,$"$kH-$O7W;;5!$ONCC G"kH$$$&!#

Dj5A4$r%a%b%j!&b%G%k$K>Hi9$H!"@h$NFsDHF1MM$K0[$J$k%"%I%l%9$KBP9k%9%H%"$N4QB,=g=x$d%W%m%0%i%`!&*!<%@$H<B9T;~$N40N;=g=x$N0lCW$K4X7F$O2?$b8@5Z7F$$$J$$!#$^$?!"F10l%"%I%l%9XN%9%H%"KD$$$F$O!"%9%H%"$r9TC?8e$K%3%R!<%l%s%9L?Na$rH/9T9k3HKh$jB>$N%W%m%;%C%5$K4QB,$5lk$,!"4QB,=g=x$b%W%m%;%C%54V$G0lCW$9kH$O8B$i$J$$!#

ACS-CC, TIS-CC $N9`$G5s2?NHF1$8%9%H%"7ONs$rNc$K5s$2kH!"NCC K*$$$F$O%9%H%"$r9TC?$@$1GOB>$N%W%m%;%C%5$NL58z2=5Z$S99?7$r9ToJ$$$3H+$i

P_1 : 0 "*1
P_2 : 0 "*2
P_3 : 0 "*3

HJ$k!#

%W%m%;%C%54V$G4QB,$G$-$kCM$r0lCW$5$;$k$?$a$NJ}K!$K$OMM!99M$(ilk,!"Nc$($P%-%c%C%7%e!&U%i%C%7%eKh$j%W%m%;%C%54V$GCM$,0lCW$9k3Hr?^kH9k$H!"$=$N8e$NCM$NJQ2=$O

P_1 : 1 "*2 "*3 P_1 : 1 "*1 "*1
P_2 : 2 "*2 "*3 Kt$O P_2 : 2 "*2 "*1
P_3 : 3 "*3 "*3 P_3 : 3 "*2 "*1

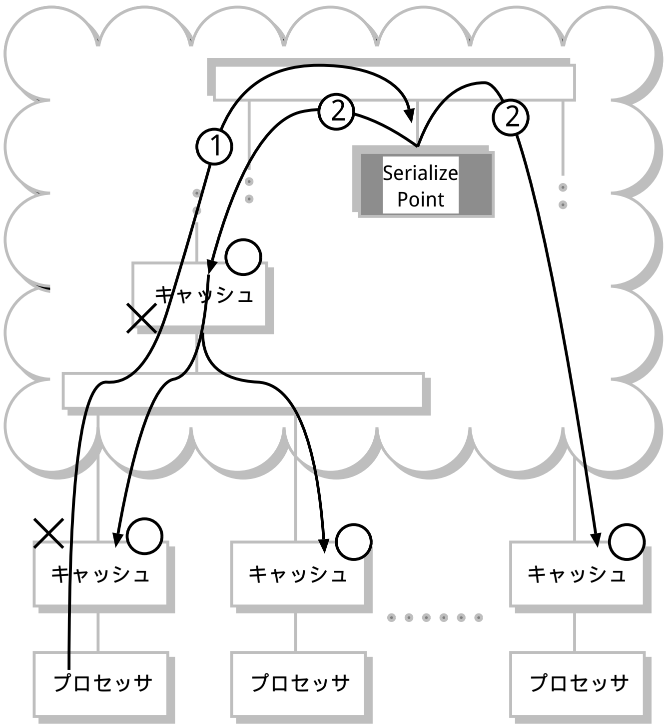
Nh$&$KJk!#:8NNcG$O!"$P_1$!"$P_2$!"$P_3$$N=g$G%-%c%C%7%e$,%U%i%C%7%e5l!"1&NNcGOP_3$!"$P_2$!"$P_1$$N=g$G%-%c%C%7%e$,%U%i%C%7%e5lkH7F$$$k!#

4.2 3F0l4S@-@)8fJ}<04V$NHf3S

K\@aGO$^$:ACS-CC, TIS-CC, NCC $NE57?E*$J<BAuJ}K!KD$$$F=R$Y!"$=$N8e!"$3$N<BAuJ}K!$K4p$E$$$F!"@-G=!"<BAu%3%9%H!"%W%m%0%i%^%S%j%F%#$N4QE@$+$i3F%b%G%k4V$NMx32F@<:$r9M;!$9$k!#

4.2.1 E57?E*$J<BAu<jK!

ACS-CC ACS-CC K*$$$F$OF10l%"%I%l%9$KBP9k%9%H%"$N4QB,=g=x$,%W%m%;%C%54V$G0lCW$9k3H,MxMQ<TKBP7$FJ]>Z$5lk!#3N$?$aKO3F%"%I%l%9Kh$K=g=xIU$1$r9T$&COE@(0J8e%7%j%"%i%$%:!&]%$%s%H)$r@_$1$kJ}K!$,9M$($ilk!#3N;~$N0l4S@-@)8f$N=hM}$NN.$l$r?^8$K<($9!#$9Jo$A!"%9%H%"$KH<$$@8@.5l$?%Q%1%C%H$O$^$:I,$:%7%j%"%i%$%:!&]%$%s%H$K8~$+$o$;$k!#$?$H$(%7%j%"%i%$%:!&]%$%s%H$K8~$+$&ESCfKI3+$N%-%c%C%7%e$rDL2a7F$b!">uBVA+0\$dCM$N99?7$JIO9ToJ$$!#$=$7$F%7%j%"%i%$%:!&]%$%s%H$KE~C#7?8e!"2~aF3F%-%c%C%7%e$K8~$1$FL58z2=$d99?7$N%Q%1%C%H$rAw$j!"$3l,3F%-%c%C%7%e$KE~C#$7$?;~E@$G>uBVA+0\$dCM$N99?7$r9T$&!#



① %9%H%"KHbJ$$@8@.5l$?%Q%1%C%H$O%7%j%"%i%$%:!&]%$%s%H$X8~$+$&!#$?$@$7!"3N:]DL2a9k%-%c%C%7%eKO=q$-9~$_$r9T$o$J$$(×0u)!#

② %7%j%"%i%$%:!&]%$%s%H$+$i:F$S%7%9%F%`3FIt$X%Q%1%C%H$rAw?.$9$k!#$3$N:]DL2a$9$k%-%c%C%7%e$K$O=q$-9~$_$r9T$&(◯0u)!#

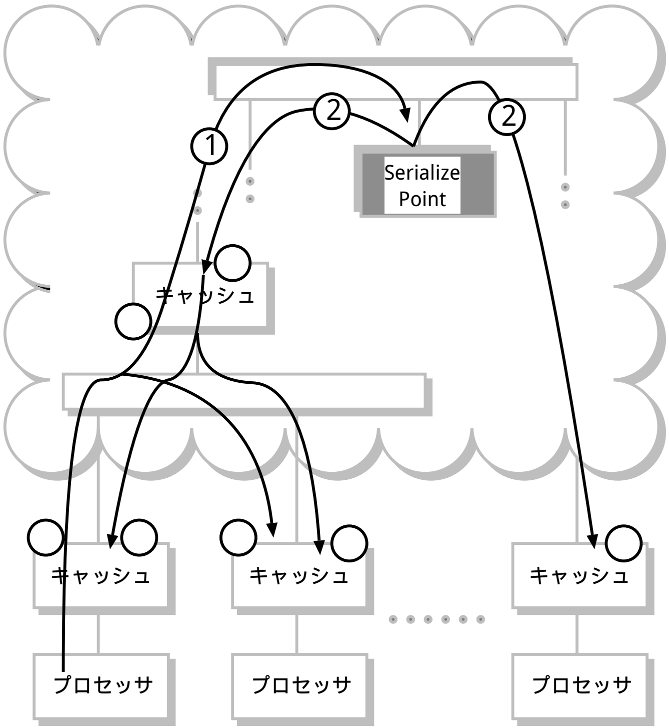
?^8: ACS-CC $NE57?E*$J<BAu<jK!

$?$@$7!"?^8$NN.lO%7%j%"%i%$%:!&]%$%s%H$rDL2a$7$?8e!"%Q%1%C%H$ND I$$1[7JIOH/@8$;$:!"3F%-%c%C%7%e$K%Q%1%C%H$,E~C#9k=g=x$O%7%j%"%i%$%:!&]%$%s%H$rDL2a7?=g=x$,J]B8$5lk3H$,A0Ds$G$"$k!#3NA0Ds$,@.N)$7$J$$$JiP!">uBVA+0\$dCM9 9?7$,9T$olk=g=x$,%-%c%C%7%e4V$G0lCW5;k?aK!"Nc$($P%7%j%"%i%$%:!&]%$%s%HK*$$$F0l4S@-@)8f$N?J9T$rDd;_5;kJIN@)8frJLK9T$&I,MW$,$"$k!#

3Nh&$K!"$"kFsD$N0l4S@-@)8f$KBP7F!">uBVA+0\$dCM9 9?7$N9T$olk=g=x$r%-%c%C%7%e4V$G0lCW5;k?aK0Y5l$k@)8f$r0J8e%7%j%"%i%$%:$H8F$V!#

TIS-CC TIS-CC K*$$$F$O!"ACS-CC HO0[Jj!"%9%H%"$N4QB,=g=x$O%W%m%;%C%54V$G0[JCFbNI$$!#7+$7!":G=*7k2L$K$D$$$F$O%W%m%;%C%54V$G0lCW9k3H$rJ]>Z$9$k!#

3N3H$+$iTIS-CC $N<BAu$O4pK\E*$K?^9$K<(9h$&$K7F9T$&$3H,G-$k!#$9Jo$A!"ACS-CC F1MM$K%7%j%"%i%$%:!&]%$%s%H$O@_$1k,!"%7%j%"%i%$%:!&]%$%s%H$rDL2a$9$kA0$G$b%-%c%C%7%e$N>uBV$r=q$-9~sG$bNI$$!#8e$K%7%j%"%i%$%:!&]%$%s%H$rDL2a7?%Q%1%C%HKhCF>uBVHCMr>e=q$-$9k3HKhj!"%W%m%;%C%54V$G4QB,$G$-$kCM$,0lCW$9k3HrJ]>Z9k!#



① %9%H%"KHbJ$$@8@.5l$?%Q%1%C%H$O%7%j%"%i%$%:!&]%$%s%H$X8~$+$&!#%7%j%"%i%$%:!&]%$%s%H$X8~$+$&ESCfK"$k%-%c%C%7%e$d$=$N6a$/$N%-%c%C%7%eKBP7$F=q$-9~$_$r9TCFNI$$!#

② %7%j%"%i%$%:!&]%$%s%H$+$i:F$S%7%9%F%`3FIt$X%Q%1%C%H$rAw?.$9$k!#$3$N:]DL2a$9$k%-%c%C%7%e$K$b=q$-9~$_$r9T$$!":G=*7k2L$,%W%m%;%C%54V$G0lCW9k3H$rJ]>Z$9$k!#

?^9: TIS-CC $NE57?E*$J<BAu<jK!

TIS-CC K*$$$F$b4QB,$5lk:G=*7k2L$O%W%m%;%C%54V$G0lCW9k$?$a$K0l4S@-@)8f$r%7%j%"%i%$%:$9$k!#

NCC NCC $O%9%H%"$KH<$&0l4S@-@)8f$O9ToJ$$!#8e$K%W%m%;%C%5$,%3%R!<%l%s%9L?Na$,H/9T$5l?H-$K%W%m%;%C%54V$GCM$r0lCW$5$;$k@)8f$r9T$&!#

%3%R!<%l%s%9L?Na$N<BAuJ}K!$K$OMM!9$JJ}K!$,$"$k!#$7$+$7!"NCC $OMF0W$K<BAu2DG=J3H,:GBg$N%a%j%C%H$H9M$($ilkNG!"%3%R!<%l%s%9L?Na$N<BAu$bMF0WG"kN$,K>$^$7$$!#

%3%R!<%l%s%9L?NaH7$F%-%c%C%7%e!&U%i%C%7%e$rMxMQ9kNOMF0W$K<BAu$G$-$k<jK!G"$k!#$9Jo$A!"%9%H%"$r9TC?8e$H%m!<%I$r9T$&A0$K%-%c%C%7%e!&U%i%C%7%e$r9T$($P3F%W%m

%;%C%5$+$i4QB,G-kCMOF1$8$KJk3H$,8@$($k!#

0J2<$G!"3F%b%G%k4V$NMx32F@<:$r9M;!$9k,!"NCC $O%3%R!<%1%s%9L?Na$H7F%-%&%C%7%e!&U%i%C%7%e$rMxMQ$9kH9k!#

4.2.2 Mx32F@<:$NHf3S

@-G= 7W;;5!$N@-G=$N8~>e$O!"$$$+$K3F%W%m%;%C%54V$NF0:nDd;_;~4V$r>/$J$/$9k,$,=EMW$HJk!#F0:nDd;_;~4V$r>/$J$/$9kK$O!"%m!<%I!"%9%H%"$N3FA`:n$K$+$+$k;~4V$rC;$/$9$k$3$H!"$=$7$F%W%m%;%C%54V$NDL?.;~4V$rC;$/$9$k$3$H$,=EMW$G$"$k!#0J2<$G3F9`L\$K4X9kHf3S$r9T$&!#

1. %9%H%"K+$+$k;~4V
   %9%H%"A`:n$K$+$+$k;~4V$O%9%H%"!&P%C%U%!$r:NMQ$9$k$3$H$GC;$/$9$k$3$H$,$G$-$k!#$9$J$o$A!"%9%H%"$r9T$C$?:]%W%m%;%C%5$N$9$0$=$P$K@_$1$i$l$?%9%H%"!&P%C%U%!$K=q$-9~$`$@$1$G%W%m%;%C%5$KHCFO%9%H%"$,4{N;$7$?$3HK$7!"%<!$NL?Na$K?J$`!#%9%H%"!&P%C%U%!$O0l4S@-@)8fJ}<0$K<dN`Khi::NMQ2DG=G"kN$G!"%9%H%"$K$+$+$k;~4V$K4X7F$OJ}<04V$G:9OJ$$!#

2. %m!<%IK+$+$k;~4V
   - L1 %-%&%C%7%e!&_%9
     L1 %-%&%C%7%e$K%_%9$7$?$H$-$OB>$N%-%&%C%7%e$+$i%G!<%?$rHCF/$k!#$3$N:]$K$+$+$k;~4V$O%M%C%H%o!<%/$N%H%i%U%#%C%/$,>/$J$$J}$,C;$/Jk$H9M$(il$k!#$3 DN%b%G%kN&$A!"NCC $O%9%H%"$KH<$&0l4S@-@)8f$r9ToJ$$$N$G:G$b%H%i%U%#%C%/$,>/$J$$$H;Wol$k!#$hCF!"L1 %-%&%C%7%e!&_%9K+$+$k;~4V$ONCC $,0lHVC;$$$H9M$($i$l!"B>$NFs$D(ACS-CC $HTIS-CC) $N4V$G$O:9$O@8$8$J$$$H9M$($ilk!#
   - L1 %-%&%C%7%e!&R%C%H
     L1 %-%&%C%7%e$K%R%C%H$7$?>l9g!"ACS-CC K*$$$FOCMNJQ2==g=x$r%W%m%;%C%54V$G0lCW5;k?aK!"%W%m%;%C%5KCMrJV9NrCYi$;$k3H$,I,MW$HJk>l9g$,$"$k!#$3lO$"$k%W%m%;%C%5$,%9%H%"$r9T$$!"$=$ND>8e$KF1$8%W%m%;%C%5$,F10l%"%I%l%9$KBP9k%m!<%I$r9T$C$?$H$-$KI,MWHJ$k!#$J$<$J$i!"?^8$K<(9h$&$K!"<+J,$,9T$C$?%9%H%"$N7k2L$O0lC6%7%j%"%i%$%:7F:F$S%Q%1%C%H$,<+%-%&%C%7%eKJVCF-$?8e$G$J$$$H;2>HG-$J$$$N$G!"%9%H%"$ND>8e$K%m!<%I$r9T$&$H%Q%1%C%H$,JV$CF/k^$G%W%m%;%C%5$KCMrJV9NrBT$?$5J1$1$PJi$J$$!#

     0lJ}TIS-CC $dNCC GO<+J,$,9TC?%9%H%"NCMOD>AKMxMQG-$k!#

     0lHL$K%W%m%0%i%`$K$O;2>H$N6I=j@-$,$"$k$3$H$,CN$i$l$F$*$j!"$"$k%W%m%;%C%5$K$h$C$F%9%H%"$5$l$?%"%I%l%9$O$=$ND>8e$KF10l%W%m%;%C%5$+$i;2>H$5$l$k$3$H$,B?$$$H$$$($k!#$h$C$F!"%9%H%"$ND>8e$N%m!<%I$N%l%$%F%s%7$O%W%m%0%i%`$KBg$-$J1F6Ar*h\$9$H9M$(il!"3N%l%$%F%s%7$rD{8:G-$kACS-CC $dTIS-CC O3NLLGACS-CC hj@-G=$KM-8z$G$"$k$H9M$(il$k!#$5iK!"3N@-G=:9$OEv3:JQ?t$r;2>H9k%W%m%;%C%5$,B?$$[IBg-$$$H9M$($ilk!#J<Ji!";2>H9k%W%m%;%C%5$,B?$$[$I!"%W%m%;%C%5$H%7%j%"%i%$%:!&]%$%sHN4V$N5wN%$OBg$-$$$H9M$($ilk3H$+$i!"%9%H%"$r9T$C$?8e:F$S%Q%1%C%H$,JV$CF/k^GN;~4V$bD9$/Jk$H9M$(ilk+iG$"$k!#

3. %W%m%;%C%54V$NDL?.;~4V
   $3$3$G8@$&DL?.;~4VHO!"$"$k%W%m%;%C%5$,%9%H%"$r9TCF$+$i!"B>$N%W%m%;%C%5$N%m!<%I$,$3$N%9%H%"$NCM$r%W%m%;%C%5$KJV9^GN;~4V$r0UL#$9$k!#

   %W%m%;%C%54V$NDL?.;~4V$rC;$/$9kNKOTIS-CC $,:G$b8~$$$F$$$k!#%9%H%"KHbJCFEv3:%"%I%l%9$N%3%T!<$r;}DB>%-%&%C%7%e9?7%Q%1%C%H$rD>@\Aw?.$9kN$,!"DL?.;~4V$r:G$bC;$/G-$kJ}K!$G$"$k$,!"$3$1$,2DG=JN$OTIS-CC N_$@$+iG$"$k!#ACS-CC K*$$$F$O!"Nc$(DL?.@h%W%m%;%C%5$,$9$06a$/G"CF$b!"0lC6%7%j%"%i%$%:7J$1$1PJiJ$$$?$a!"9?7$5$1$k$^$G$N;~4V$OD9$/$J$k!#$7$+$7!"TIS-CC K*$$$F$O%7%j%"%i%$%:9kA0$K9?7$7FbNI$$$N$G!":GC;7PO)$G9?7$9$k3H$,2DG=$G$"$k!#ACS-CC $HTIS-CC $N4V$NDL?.;~4V$N:9$O!"7W;;5!$N5,LO$,Bg$-$$$[$I82Cx$G$"$k$H9M$(il$k!#M}M3$O!"%7%9%F%`$N5,LO$,Bg$-$$$H%W%m%;%C%5$H%7%j%"%i%$%:!&]%$%s$H$N4V$N5wN%bBg-$/$JkH9M$($ilk$+$iG"$k!#0lJ}!"NCC K*$$$F$O!"B>%W%m%;%C%5$N%9%H%"$N7k2L$r4QB,9k$?$aKO!"%-%&%C%7%e$N%U%i%C%7%e$rMxMQ9kH9kH!">/J/HbI,$:%m!<%I;~$K%-%&%C%7%e!&_%9$,@8$:k3HKJkNG!"DL?.;~4V$OD9$/Jk!#3N:9$b7W;;5!$N5,LO$,Bg$-$$$[$I82Cx$G$"$k$H9M$(il$k!#$3$1$r2~A1$9$k$?$a$K!"%3%R!<%1%s%9L?Na$KhC$FB>%-%&%C%7%e$r99?7$9$kJ}K!$,9M$(ilk,!"3N$?$aKOACS-CC $dTIS-CC $HF1$8$/$i$$$N<BAu%3%9%H$,$+$+$k3H$,M=A[$5$l!"NCC $N:GBg$N%a%j%C%HG"$k!MF0W$J<BAu!W$O<:$olk!#

0J>eN^Ha$rI=1$K<($9!#I=1$+ibJ,$+$kh&$K!"TIS-CC $dNCC $OACS-CC hj$b@-G=8~>e$,8+9~$a!"$3$1$O7W;;5!5,LO$,Bg$-$$$[$I82Cx$J:9$,@8$:kH9M$($ilk!#$=$7$F!"%-%&%C%7%e!&_%9$N=hM}B.EYGONCC $,!"DL?.;~4V$NLLGOTIS-CC $,M-Mx$G$"$k$H9M$(il$k!#$7$+$7!"%-%&%C%7%e!&_%9;~$N=hM}B.EY$GNCC $,M-Mx$JM}M3$O%Q%1%C%H$N>WFM$,>/$J$$$H9M$($ilk$+$iJN$G!"TIS-CC Gb%M%C%H%o!<%/$r9bB.2=7F!"%Q%1%C%H$N>WFM$,$[Hs$I5/$3iJ$$$h$&$K$9$1$PNCC $r:NMQ$7$?>l9g$HF1Ey$N=hM}B.EY$rF@ilk3H,4|BTG-$k!#0lJ}!"DL?.;~4V$K4X7F$O!"%3%R!<%1%s%9L?Na$K%-%&%C%7%e!&U%i%C%7%e$rMxMQ$9$k8B$j!"NCC $OTIS-CC KO5ZPJ$$!#$?$H$(%M%C%H%o!<%/$r9bB.2=7FNCC $r:NMQ$7$?%7%9%F%`$,B.$/$J$C$F$b!"$=$l$HF1Ey$KTIS-CC $N%7%9%F%`$bB.$/$J$k!#$5iK!"@h$K=R$Y$?$h$&$KDL?.;~4V$N:9$OEv3:JQ?t$r;2>H$9$k%W%m%;%C%5$N?t$,B?$$$[$I82Cx$KJk$H9M$(il$k!#

: #8e!"5;=Q$N?JJb$KhC$FD6JBNs5,LO$N7W;;5!$OB?$/8=lk$H9M$(il$k!#0J>e$K<(7?3H$+$i!"TIS-CC $O%7%9%F%`5,LO$,Bg$-$$$[I=$N8z2L$,8=1k$H9M$(ilkN$G!">-MhE*$KHs>o$KM-K>$G$"$k$H9M$(il$k!#

I=1: 0l4S@-@)8fJ}<04V$N@-G=:9M=B,

	ACS-CC	TIS-CC	NCC
%9%H%"!&R%C%H			
%-%&%C%7%e!&_%9			!{
%-%&%C%7%e!&R%C%H		!{	!{
DL?.		!{	

!Om%9%H%"!&R%C%H$N:]$O:9OJ$$!K
!{0u$O!"L55-F~$N0l4S@-@)8fJ}<0KHfY$F@-G=LL$GM-MxG"k3Hr<($9!#$?$@$7!"NCC K*1k%3%R!<%1%s%9L?Na$O%-%&%C%7%e!&U%i%C%7%e$rMxMQ7?bNG"kH9k!#

<BAu$N%3%9%H 0l4S@-@)8f$r<BAu9k:]$K:G$bFq$7$$N$O!"F10l%V%m%C%/$X$N0l4S@-@)8f$,7W;;5!Fb$rF1;~$K?J9T9k>u67K*1k=hM}G"$k!#$3$N;~$O!"3F%"%I%l%9NCM,0l4S@-@)8fJ}<0$ND j5A$rK~$?$9h&$K%W%m%;%C%5$K4QB,5lkh$&$K@)8f7J1lPJiJ$$3HNB>$K!"%U%)!<%k%9!&7%'%"%j%s%0KbN10U7J1lPJiJ$$!#9JoA!"0l4S@-@)8f$NC10L$,%W%m%;%C%5$+$i$N%"%/%;%9C10L$hjBg-$$>l9g!"$"$kFsDNJQ?t$,$?$^$?$^F1$8%V%m%C%/KO$$$k3HKh$jK\Mh$J$i%W%m%;%C%54V$G6&M-7J$/$F$bNI$$JQ?t$r6&M-$7F7$^$&2DG=@-$,$"kN$G!"F10l%V%m%C%/Fb$N0[Jk%"%I%l%9XN%9%H%"$,Fs$D$N%W%m%;%C%5$+i[$\F1;~$K9Tol$?:]$K$b!"$IAi$N%9%H%"$NCM$b<:$olJ$$$h$&$K0l4S@-@)8f$r9T$&I,MW$,$"$k!#

%3%R!<%l%s%9L?Na$K%-%&%C%7%e!&U%i%C%7%e$r:NMQ9kNCC GO%U%)!<%k%9!&7%'%"%j%s%0K+$+$k<BAu%3%9%H$O>.$5$/$F:Q$`!#$J$<$J$i!"%-%&%C%7%e$r%U%i%C%7%e9k:]$K%V%m%C%/A4BN$r=q$-La$9NGOJ$/<+%W%m%;%C%5$,=q$-9~$s$@%"%I%l%9$@1rA*BrE*$K=q$-La$9$3HKhj%U%)!<%k%9!&7%'%"%j%s%0XOBP=hG-!"3lK+$+$k%3%9%H$O>.$5$$$+iG$"$k!#

0lJ}!"ACS-CC $dTIS-CC K*1k%U%)!<%k%9!&7%'%"%j%s%0XNBP=hJ}K!$O!"MM!9$"kH9M$($i$l!"0l4S@-@)8fJ}<04V$G0l35$KHf3S$9kN$O:$FqG"kN$G0lHIE*$J9M;!KD$$$F$OK\9F$NBP>]30H9$k!#$7$+$7!"%-%&%C%7%e!&U%i%C%7%e$r:NMQ$9$kNCC hj4JC1$K9T$&3H$O=PMh$J$$$H9M$($ilk!#

0J2<GO%H%%k!<!&7%'%"$J%V%m%C%/$,3F0l4S@-@)8fJ}<0$ND j5A$rK~$?$9$?$a$N%3%9%H$K4X7F9M;!9k!#

$^$:!"%-%&%C%7%e!&U%i%C%7%e$rMxMQ$9$kNCC K*$$$F$O0l4S@-@)8f$O9To:!"$^$?!"CM$r%W%m%;%C%54V$G0lCW5;k3HbC1=c$K%-%&%C%7%e$r%U%i%C%7%e7F<g5-2l0J30KOM-8z$J%3%T!<$OB8:_5;$J$$3HKhj<B8=2DG=G"kN$G!"<BAu$,MF0WG"k3HO<+L@G"$k!#

ACS-CC $HTIS-CC $N4V$N0c$$$O!"%9%H%"4V$N=g=x$,Dj$^$kA0K=$N%9%H%"$NCM$,$"$k%W%m%;%C%5$+$i4QB,$G$-$kh&KJCF$bNI$$$+I&$+$G$"$k!#ACS-CC GO=g=x$,Dj$^k^GO4QB,G-FOJi$J$$!#0lJ}TIS-CC GO=g=x$,Dj$^$k0JA0$K4QB,G-FbNI$$!#7+$7!"TIS-CC K*$$$F$b:G=*E*$J7k2LOI$N%W%m%;%C%5$+$i8+$F$b0lCW$5$;$J1lPJiJ$$N$G!"F10l%"%I%l%9$KBP9kJ#?t$N%9%H%"$,$[$\F1;~$KH/@8$7$?>l9g!"Ej5!E*$J=q$-9~$_$N<:GT$+iN2sI|$N@)8f$r9T$&I,MW$,$"$k!#4pK\E*KO3l$O?^9$K<(9h$&$K%7%j%"%i%$%:$5l?8e:F$S>e=q$-9k3H$G<B8=$G$-$k$,!"$3$N2sI|$N@)8fO5iK@-G=8~>e$r8+9~$a$k<jK!$,B8:_9k!#3N<jK!NNcO5>O$G=R$Yk,!"2sI|5!9=KhCF$O<BAu$OFq7/Jk!#

7+$7!"SPARC Ey$N%-%&%C%7%e$rFbB"$9$k%W%m%;%C%5$K$*$$$F$O%9%H%"$HF1;~$KFbB"%-%&%C%7%e$KBP9k=q$-9~$_$r9T$&bNb"kN$G!"ACS-CC $N>l9g$Gb=Nh$&$J%W%m%;%C%5$rMQ$$$kH-$O!"TIS-CC $HF1MM$JEj5!E*$J=q$-9~$_<:GT$+iN2sI|5!9=$r<BAu$9kI,MW,$"$k!#3l$OTIS-CC $HF1MM$K!"8e$K>e=q$-9k3H$G<B8=$G$-$k!#

3Nh&$K!"Ej5!E*=q$-9~$_$+iN2sI|$OTIS-CC ObAm$sACS-CC Gb9T$&I,MW@-$,@8$8F@$k!#7+$7!"TIS-CC K*$$$FO5iK@-G=8~>e$r5a$ak?aKMM!9$J<jK!$,B8:_$7!"$3$N<jK!$KhCFO<BAuOFq7$/$J$k!#

$^$?!"ACS-CC GOIN%W%m%;%C%5$+$i$bF1$8=g=x$G4QB,$G$-$J1lPJiJ$$3H+$i!"=g=xIU$1$,9T$olkA0$K%W%m%;%C%5$,%-%&%C%7%e$K%"%/%;%9$7$?>l9g$O!"CMrJV9Nr%7%j%"%i%$%:$,9Tolk^GCYi$;$k$?$a$N@)8f$,I,MWHJ$k!#$3N?$a!"ACS-CC $O%-%&%C%7%e!&R%C%H$7$?%m!<%I$rBT$?$;$k=hM}$r9T$&E@$GTIS-CC hj<BAu%3%9%H$,$+$+$k!#$?$@$7!"%m!<%I$N=hM}rBT?$;$k5!9=$N<BAu$O:FqJ3HGO$J$$!#

%W%m%0%i%^%S%j%F%# @)Ls$r4KOB$7$?%a%b%j!&b%G%k$r:NMQ9k7W;;5!K*1k%W%m%0%i%_%s%0$N:]$K$O!"I,MW$K1~8F%W%m%0%i%`!&*!<%@$rJ]B8$9$kEy$N$?$a$K%W%m%0%i%`Cf$KFCJL$JL?Na$rA^F~$9$k!#@5$7$$%W%m%0%i%`$r=q$/$3$H$@$1$,L\E*$G$"$l$P!"$3$NFC<lL?Na$r%W%m%0%i%`Cf$NE~$kH3mKKd$a9~$a$PC#@.$G$-$k$,!"$3lG$O4KOB$7$?%a%b%j!&b%G%k$r:NMQ9k3HKh$k287C$r<u1il:!"7W;;5!$N@-G=$r0z$-=P$9$3$HOG$-$J$$!#hC$F!"%W%m%0%i%_%s%0$N:]KO7W;;5!$N@-G=$r0z$-=P$9$?$a$KFC<lL?Na$O??KI,MWJH3mKN_Kd$a9~$^J1lPJi$J$$!#%W%m%0%i%`K*$$$FFC<lL?Na$,??$KI,MWJH3m$,$I3JN+$r8+6K$ak?aN<j4V$,%a%b%j!&b%G%k$KhC$F0[$J$j!"$3N?$a%W%m%0%i%^%S%j%F%#$b0[Jk!#

8=:_$^$G$KDs0F$5lF$$$k%a%b%j!&b%G%k$O!"%W%m%0%i%`!&%*!<%@$N@)Ls4KOB$K<g$J=EE@$,$*$+$l$F$*$j!"FC<lL?Na$b<g$K%W%m%0%i%`!&*!<%@$rJ]B8$9$k<jCJ$rDs6!$9kbNG$"$k!#7+$7!"K\8&5f$O3>O$G<($7$?%a%b%j!&b%G%k$K$*$1kb$&0l$D$N@)Ls4KOB$G$"$k%"%H%_%C%/<B9T$N4KOB$,BP>]G"$k!#0J2<$G!"3F0l4S@-@)8fJ}<0$r:NMQ$9$k:]$KINh&$J>u67$GINh&$JFC<lL?Na$rI,MWHJk+$r9M;!$9k,!"$=$liO9Y$F3F%"%I%l%9$NFbMF$r%W%m%;%C%54V$G0lCW5;k?aN<jCJ$r9M;!$9kbNG$"$k!#%W%m%0%i%`!&*!<%@$rJ]B8$9$kL?Na$rKd$a9~$`3HKD$$$FO3$3$G$OL5;k$9$k!#

$^$:!"ACS-CC K*$$$F$OF10l%V%m%C%/$X$N%9%H%"$N4QB,=g=x$O%W%m%;%C%54V$GEy$7$$$N$G!"3F%"%I%l%9$NFbMF$r%W%m%;%C%54V$G0lCW5;k?aNL?Na$OITMW$G$"$k!#

<!$K!"TIS-CC K*$$$F$O!"J#?t$N%W%m%;%C%5$,$[$\F1;~$K%9%H%"$r9T$C$?$H$-%9%H%"$N4QB,=g=x$,%W%m%;%C%54V$G0[Jk2DG=@-$,$"$k!#$3N?$a!"ACS-CC hj%W%m%0%i%^%S%j%F%#$,0-2=$9kh$&$K;W$($k$,!"8=<B$N%W%m%0%i%_%s%0$N:]$KO=l[IJQoiJ$$HM=A[5l$k!#

$=$NM}M3H7F^$:5s$2ilkN$O!"$"$k6&M-JQ?t$KBP7F%9%H%"$r9T$&%W%m%;%C%5$O0l$D$@$1G"k3H,B?$$$H9M$($ilk$+$iG"$k!#Nc$($P%W%m%;%C%54VDL?.$G:G$bE57?E*$JbNH7$F!"Producer-Consumer $,$"k,!"3N>l9g%9%H%"$r9T$&NOProducer B&$@$1G"$j!"Consumer B&$O%m!<%I7+9ToJ$$!#$^$?!"%"%W%j%1!<%7%g%sKhCF$O3FJQ?t$KBP9k1i;;$r9T$&%W%m%;%C%5$,7h$^CF$$$kowner-computes-rule $K=>$C$F$$$kbNb"kH9M$($ilk!#3N>l9g$b3FJQ?t$KBP7F%9%H%"$r9T$&NO$"$k0lDN%W%m%;%C%5$@$1G"kN$G!"%7%9%F%`$,3F%"%I%l%9NCMNJQ2==g=x$r%W%m%;%C%54V$GF1$8$K9k@)8f$r9T$oJ/Fb$h$$$3HO<+L@G"$k!#

$^$?!"$"$kJQ?tKBP7$FJ#?t$N%W%m%;%C%5$,%9%H%"$r9T$$F@kH$-$Gb=$NJQ?t$O%/%j%F%#%+%k!&%;%/%7%g%sKh$jJ]8n$5lk>l9g$,B?$$$H9M$($ilk!#3N>l9g!"F10l%"%I%l%9KBP9$k%a%b%j!&%"%/%;%9$,F1;~KO5/3i$J$$($"$k%9%H%"$,40N;$9$kA0$KB>$N%9%H%"$,3+;O5lk3HO$J$$) h&K9$kGSB>@)8f$OMxMQ<TKh$j9T$olk!#GSB>@)8f$,@5$7$/9T$olF$$$k8BjO!"TIS-CC $rMQ$$$?H7FbJQ2==g=x$,%W%m%;%C%54V$G0lCW9k3H$O<+A3$KK~$?$5lk!#

3liN3H$+$i!"$"$kJQ?t$,%W%m%;%C%54V$G6&M-5l!"$+$DEv3:JQ?tKBP9$k%9%H%"$,%W%m%;%C%54VG[$\F1;~$K5/3jF@$F!"$5iK$=$N%9%H%"$N4QB,=g=x$,%W%m%;%C%54V$GF1$8KJiJ1lPJiJ$$JQ?t$O>/$J$$$H9M$($ilk!#

3N$?$aTIS-CC K*$$$F$O!"$"$kJQ?t$,%W%m%;%C%54V$G6&M-$5$l!"$+$DEv3:JQ?t$KBP9k%9%H%"$,%W%m%;%C%54V$G$[$\F1;~$K5/$3$jF@$F!"5iK=$N%9%H%"$N4QB,=g=x$,%W%m%;%C%54V$GF1$8$KJiJ1lPJi$J$$H$-$O!"$=$NJQ?t$rNon-Cachable H7$F%"%/%;%9$9kJINJ}K!$,I,MW$HJk!#7+$7!"8=<B$N%W%m%0%i%_%s%0K*$$$FO3Nh$&$JJQ?t$OF14|JQ?t$JIK;HMQMQES$O8B$ilkNG!"TIS-CC K*1k%W%m%0%i%^%S%j%F%#$OACS-CC K*1k$=lHJQ2=$J$$$H8@$($k!#

0lJ}!"NCC K*$$$F$O3F%"%I%l%9$NFbMF$r%W%m%;%C%54V$G0lCW5;k?aK%-%c%C%7%e!&U%i%C%7%e$r9T$&!#C1=cKO%9%H%"$N8e$*hS%m!<%I$NA0$K%U%i%C%7%e9lPh$$!#7+$7!"6&M-JQ?t$KBP7F%9%H%"$r9T$CFb!"Nc$($P1i;;$NESCf7k2L$N%9%H%"JI!"I,$:$7$bB>%W%m%;%C%5$+$i4QB,$G$-$kI,MWOJ$$!#$^$?!"%m!<%I$NA0$N%U%i%C%7%e$b!"Ev3:%"%I%l%9$KBP7FB>%W%m%;%C%5$,%9%H%"$r9T$&$3H,$J$$$3H,J]>Z5l$F$$$l$PITMW$G$"$k!#7?$,$C$F!"%7%9%F%`$N@-G=$r0z$-=P9K$O%W%m%0%i%_%s%0$N:]K3Nh$&$J3H$r9MN8$9kI,MW,$"$k!#3N$?$a!"$[$HsI2?$b9MN8$7J/FbNI$$ACS-CC $dTIS-CC KHfYFFq7$/Jk!#

9M;!N^Ha　0J>e8+F-$?$h$&$K!"@-G=LLK*$$$F$OTIS-CC $,B>$KHfYFM-MxG"$k!#$5iK3l$O!"%7%9%F%`5,LO$,Bg$-$$$[$I82Cx$G$"$k$N$G!":#8eH/E8$,4|BT$G$-$kD6JBNs5,LO$N%7%9%F%`$X$N<BAu$K8~$$$F$$$k!#7+$b!"TIS-CC $O=>Mh$NJ}K!G"$kACS-CC KHfY$F%W%m%0%i%^%S%j%F%#b[$HsIJQoi$J$$!#

TIS-CC $,M#0l%M%C%/$HJjF@kN$O<BAu%3%9%H$G$"$k$,!"<BAu$,Fq7/JkNO!"hj@-G=$rDI5a$9$k>l9g$G$"$j!"C1=c$J<BAu$N:]KOACS-CC H[HsIJQoiJ$$!#@-G=$rDI5a$9$k:]$KI,MW$J5!9=$H@)8fKD$$$F$O<!>O$G=RYkD6JBNs7W;;5!JUMP-1 K*$$$F:NMQ5l$F$$$kJ}K!$,:#8e$N%7%9%F%`3+H/$N:]$NM-0U$J;29M:`NAKJkH9M$($i$l!"7P83$r@Q$_=E$Mk3HKhCF3$N5;=Q$O3NN)5lkbNH9M$($k!#

0J>eN3H+ib!";0DNJ}<0N&$ATIS-CC $,:G$b>-MhM-K>$J<jCJ$G$"$k$H9M$(il$k!#

5 D6JBNs7W;;5!**JUMP-1** K*1k<BAuNc

K\>OGO!"A0>O$G=R$Y$?TIS-CC Kh$k0l4S@-@)8f$r:NMQ7?7W;;5!NNcH7F!"D6JBNs7W;;5!JUMP-1[13] K*1k<BAuNc$r=R$Y$k!#

JUMP-1 GO!"4.2@a$G=R$Y$?TIS-CC $N<BAuJ}K!$r$?$@C1=c$K<B8=$9k@1GOJ$/!"$h$j@-G=$r8~>e5;k?aK$N:GE,2=$,J5lF$$$k!#0J2<!"$^$:JUMP-1 $N35N,$r=R$Y!"<!$K!"hj@-G=$r8~>e$5$;$k$?$a$KJUMP-1 $G:NMQ$7$F$$$k:GE,2=$N<jK!$r5s2k!#$=$N8e!":GE,2=$r?^$C$?0l4S@-@)8f$r<B8=9k$?$a$KJUMP-1 $GMQ0U$5lF$$$k5!9=$H9T$olF$$$k@)8fKD$$$F=RYk!#

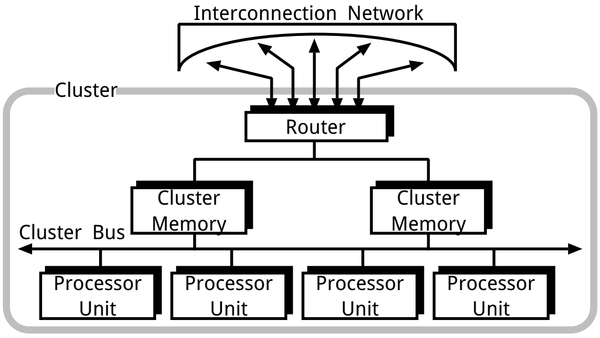
5.1 D6JBNs7W;;5!**JUMP-1** $N35N,

5.1.1 9=@.

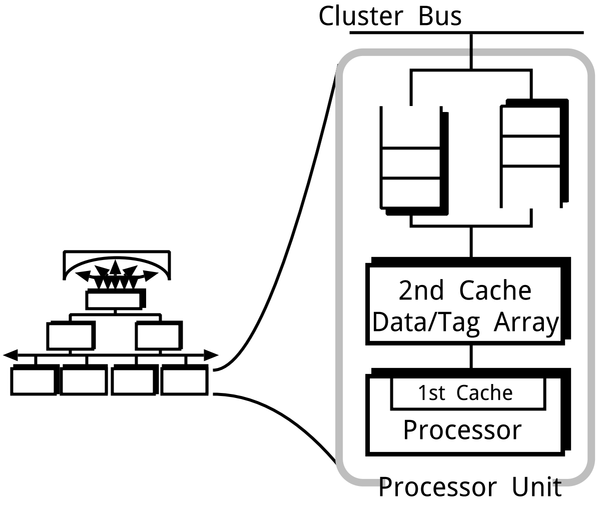
D6JBNs7W;;5!JUMP-1 $O!"%/%i%9%?9=B$$r:NMQ7?6&M-%a%b%j7?JBNs7W;;5!G"$k!#3F%/%i%9%?$O!"RDT[14] $H8F$Plk%M%C%H%o!<%/$G7k9g$5lF$$$k!#

%/%i%9%?$N9=@.$r?^10$K<($9!#9=@.MWAGH7FO!"4pK\E*$K4 DN%W%m%;%C%5!&%f%K%C%H!"2 DN%/%i%9%?!&%a%b%j!"5Z$SRDT HN%$%s%?%U%'!<%9$HJk%k!<%?$,$"2ilk!#%W%m%;%C%5!&%f%K%C%H$H%/%i%9%?!&%a%b%j$O%/%i%9%?!&%P%9$H8F$Plk%P%9$G@\B3$5lF$$$k!#JUMP-1 $OJ,;66&M-%a%b%j7?$NJBNs7W;;5!G"$j!"<g5-21$O3F%/%i%9%?$KJ,;6$7$FG[CV$5lF$$$k!#

3F%W%m%;%C%5!&%f%K%C%HFb$N9=@.$r?^11$K<($9!#%W%m%;%C%5!&%f%K%C%H$O0l<!%-%c%C%7%e$rFbB"9k;THN$N9b@-G=RISC%W%m%;%C%5(SuperSPARC+) $H30IU$1$N2<!%-%c%C%7%e$+iJ$k!#$^$?!"$3$N?^$K<(9h$&$K!"%P%9HN4V$G%Q%1%C%H$rAw<u?.9k$?$a$N%P%C%U%!$O2<!%-%c%C%7%ehj$b%P%9B&$K@_1ilF$*$j!"%W%m%;%C%5$+$i%9%H%"$,9T$olkH^$:2<!%-%c%C%7%e$X$NEj5!E*$J=q$-9~$_$r9T$$$!"$=$N8e!"%Q%1%C%H$r%P%9$XAw=P9k!#



?^10: %/%i%9%?$N9=B$



?^11: %W%m%;%C%5!&%f%K%C%H$N9=B$

5.1.2 %a%b%j!&%b%G%k

3>O$G=R$Y$?$h$&$K!"%a%b%j!&%b%G%k$G5,Dj$5lk9`L\$H$7$F$O8D!9$N%W%m%;%C%5$+$iH/$;$i$l$k%a%b%j!&"%/%;%9$N%W%m%0%i%`$K<($5lF$$$k=g=x$H<B9T;~$K$*$1$k=g=x$N4X78$d!"%W%m%;%C%54V$G$N%9%H%"$N4QB,=g=x$N4X78$H$$$C$?$bN,$"$k!#JUMP-1 K*$$$F3F9`L\$GDjailF$$$k@)Ls$r0J2<$K<($9!#

%W%m%0%i%`!&%*!<%@$N4KOB　JUMP-1 $GMQ$$$kMWAG%W%m%;%C%5SuperSPARC+$O%m!<%IL?Na$rH/9T$9$k$H$=$NCM$,JV$C$F$/$k$^$G$O8eB3L?Na$OH/9T$;$:$K%W%m%;%C%5$NF0:n$ODd;_$9$k!#$3$N$3$H$+$i!"@h9T$N%m!<%IL?Na$H8eB3$NL?Na$N4V$N4ON;=g=x$O%W%m%0%i%`!&%*!<%@$H0lCW$9k3HO<+A3$KJ]>Z$5lk!#

0lJ}!"%9%H%"L?NaO=$N4ON;$rBT$?$:$K8eB3$NL?Na$,H/9T$5lk!#3N$?$aSuperSPARC+KO@h9T$N%9%H%"L?Na$,9Y$F4ON;$9k^$G8eB3$NL?Na$NH/9T$rBT$?$;$k%9%H%"!&%P%j%"L?Na$,MQ0U5l$F$$$k!#9JoA!"MxMQ<T$,%W%m%0%i%`Cf$K%9%H

%"!&P%j%"L?Na$rA^F~$9k3HKhC$F@h9T%9%H%"$H8eB3L?Na$N4V$N4ON;=g=x$,%W%m%0%i%`!&*!<%@$H0lCW9k3H$,J]>Z$5lk!#

3Nh&$K!"JUMP-1 GO@h9T$N%9%H%"L?Na$H8eB3$NL?Na$N4V$N4ON;=g=x$O!"FsDNL?Na$N4V$K%9%H%"!&P%j%"L?Na$,A^F~$5lF$$$J1lP=$N4ON;=g=x$O%W%m%0%i%`!&*!<%@$H0lCW$7$J$$2DG=@-$,$"$k!#

%"%H%_%7%F%#$N@)Ls4KOB F10l%"%I%l%9$KBP9k0lO"$N%9%H%"$K4X7F$O4>O$G=RY?TIS-CC G"$j!"7W;;5!Fb$KL$4ON;$N%9%H%"$,B8:_$7$J$$$H$-$N$_4QB,$G$-$kCM$,%W%m%;%C%54V$G0lCW9k3H$rJ]>Z$9$k!#$^$?0[$J$k%"%I%l%9$KBP9k%9%H%"$N4V$K$OProcessor Consistency %b%G%k$HF1$8h&$KA4=g=x4X78$OB8:_$;$:!"%W%m%;%C%54VG=li$r4QB,$9$k=g=x$,0lCW9kJ]>ZOJ$$!#

5.1.3 0l4S@-@)8f%W%m%H%3%k

JUMP-1 K*1k%-%c%C%7%e4V$N0l4S@-@)8f$K$O!"3F%W%m%;%C%5!&f%K%C%HFb$N1 <!%-%c%C%7%e2 <!%-%c%C%7%e4V$N0l4S@-@)8f!"$=7F%W%m%;%C%5!&f%K%C%H4VK^$?$,$k2 <!%-%c%C%7%e4V$H%/%i%9%?!&a%b%j$N4V$N0l4S@-@)8f$,$"$k!#

$^$?!"JUMP-1 K*1k0l4S@-@)8f$O32 %P%$%HC10L$G9T$olk!#0J8e!"0l4S@-@)8f$,9T$olkC10L$r%V%m%C%/$H8F$V!#

2 <!%-%c%C%7%e4V-%/%i%9%?!&a%b%j$N0l4S@-@)8f $^$:!"%9%H%"$r9T$G$?$H$-!"B>%W%m%;%C%5$N2 <!%-%c%C%7%eNCMrL58z2=9k$+99?7$9k+$OMxMQ<T$,3F%"%/%;%9Kh$K;XDj$G$-$k!#$=$7$F%/%i%9%?!&a%b%j$N99?7OCMNE>Aw$,%/%i%9%?Fb$KJD8k>l9g$O9T$o$:!"%/%i%9%?4V$K$^$?$,$kH-N_9T$&!#

$^$?!"2 <!%-%c%C%7%e4V$N0l4S@-@)8f$O%/%i%9%?Fb$O%9%L!<%WJ}<0!"%/%i%9%?4VN=lO%G%#%l%/%H%jJ}<0$G9T$o$k!#%/%i%9%?4V$N0l4S@-@)8f$O%G%#%l%/%H%jJ}<0$Khj9Tolk?$a!"<g5-21$K$*$$$FM-8z$J%3%T!<$,B8:_9k%/%i%9%?$d%m!<%I$KBP7FCMrJV9@UG$$r;}$D%3%T!<$,B8:_9k%/%i%9%?$,4IM}$5lF$$$k!#D^$j!"%-%c%C%7%e$NL58z2=/99?7@)8f$dCMFI$_$@$7A`:n$,%/%i%9%?4V$K$^$?$,$k>l9g$O0lC6I,$:<g5-21$K%Q%1%C%H$,Awil$k!#$=$N8e<g5-21$+$i3F%/%i%9%?$KBP7F99?7/L58z2=@)8fdFI_9~$_MW5a$,Awil$k!#

JUMP-1 K*1k2 <!%-%c%C%7%e$N>uBV$rI=2$K<($9!#3F2 <!%-%c%C%7%e$O!"%-%c%C%7%e4V$N6&M->uBV$rDL>o$N !B7>$N%-%c%C%7%e$dK<g5-21KOM-8z$J%3%T!<$OB8:_7J$$!W(Exclusive)$d !B7>$N%-%c%C%7%e$dK<g5-21$K$bM-8z$J%3%T!<$,B8:_$7F@$k!W(Shared)$K2C$($F!"6&M->uBV$,%/%i%9%?Fb$KJD8F$$$k(Local)$+%/%i%9%?4V$K$^$?$,$C$F$$$k(Global)$+$H$$$&3H$b4IM}$9$k!#$3lKhjLocal G"lP!"L58z2=/99?7@)8f$N:]$K<g5-21$N%G%#%l%/%H%j$r0z$/<j4V$,>J$1!"8e$K=RYk%7%j%"%i$%:!&]%$%s%H$N:GE,2=$KDJ$,$k!#

$^$?!"%-%c%C%7%e$N>uBV$K$OGlobal Shared Dirty $OB8:_$7$J$$!#3l$O!"@h$K$b=R$Y$?$h$&$K%/%i%9%?!&a%b%jXO%/%i%9%?4VGCMNE>Aw$,9T$olkH-N_=q$-9~$_$,9T$olk$+$iG"$k!#$9Jo$A!"$"$k%V%m%C%/$N%3%T!<$,%/%i%9%?4V$K$^$?$,$C$FB8:_$9kH$-$KEv3:%V%m%C%/NCMr99?7$7$h$&$H7?H-!"$^$?%-%c%C%7%e!&_%9$KH<$C$FB>%/%i%9%?$+iCMr%U%'%C%A9kH-$K%/%i%9%?!&a%b%j$NCM$b99?7$5lkNG!"Global G"lPClean G"k3H,J]>Z5l$k!#

2 <!%-%c%C%7%e$N>uBVA+0\I=$rI=3$+$iI=5$K<($9!#

1 <!%-%c%C%7%e-2 <!%-%c%C%7%e4V$N0l4S@-@)8f SuperSPARC+$,FbB"9k1 <!%-%c%C%7%e$O!"JUMP-1 K*$$$F$O%i%$%H!&9%k!<$N%-%c%C%7%e$H7FF0:n9k!#

$^$?!"B>%W%m%;%C%5$+$i$N%9%H%"$KH<$&0l4S@-@)8f$O0l<!%-%c%C%7%e$NL58z2=$Khj9T$&!#$9Jo$A!"%/%i%9%?!&P%9$+$i99?7/L58z2=%Q%1%C%H$r<u$1<h$k$HSuperSPARC+$NFbB"%-%c%C%7%eKBP7$FEv3:%V%m%C%/$rL58z2=9k3H$rMW5a$9$k!#

I=2: #2<!%-%c%C%7%e$N>uBV

>uBV	@bL@
Invalid	Ev3:%V%m%C%/$OL58z2=$5lF$$$k!#
Exclusive Dirty	Ev3:%V%m%C%/$N:G?7%G!<%?$O!"%+%W%m%;%C%5!&f%K%C%H$N%-%c%C%7%e$K7+B8:_7J$$$3H,J]>Z5l$F$$$k!#
Local Shared Clean	Ev3:%V%m%C%/$O%/%i%9%?Fb$G6&M-5l$F$$$k2DG=@-$,$"$k!#
Local Shared Dirty	Ev3:%V%m%C%/$O%/%i%9%?Fb$G6&M-5l$F$$$k2DG=@-$,$"$k!#FbMF$O<g5-21HO0[Jj!"<g5-21XN=q$-La$7$N@UG$$r;}$D!#
Global Shared Clean	Ev3:%V%m%C%/$O%/%i%9%?4V$G6&M-5l$F$$$k2DG=@-$,$"$k!#FbMF$O<g5-21HEy7$$!#

I=3: 2 <!%-%c%C%7%e$N>uBVA+0\I= !J+%W%m%;%C%5$+$i$N%"%/%;%9$KhkA+0\!K

8=>uBV	%m!<%I	99?7%9%H%"	L58z2=%9%H%"
Invalid	(*1)	(*2)	Ex. Dirty
Ex. Dirty	—	—	—
Local Clean	—	Local Dirty	Ex. Dirty
Local Dirty	—	—	Ex. Dirty
Global	—	—	Ex. Dirty

*1 6&M->u67$K1~$8$FLocal Clean!"Local Dirty!"Global $N$$$El+KJ$k!#F10l%/%i%9%?Fb$NDirty %V%m%C%/$+$iCM$,JV$CF-$?>l9g$OLocal Dirty!#

*2 6&M->u67$K1~$8$FLocal Dirty $+Global NIAi$+$KJk

— >uBV$OJQ2=$7$J$$

I=4: 2 <!%-%c%C%7%e$N>uBVA+0\I= !J/%i%9%?Fb$N%W%m%;%C%5$+$i$N%"%/%;%9$KhkA+0\!K

8=>uBV	%m!<%I	99?7%9%H%"	L58z2=%9%H%"
Invalid	—	—	—
Ex. Dirty	Local Clean	Local Clean	Invalid
Local Clean	—	—	Invalid
Local Dirty	Local Clean	Local Clean	Invalid
Global	—	—	Invalid

I=5: 2<!%-%&%C%7%e$N>uBVA+0\I=!%J/%i%9%?30$N%W%m%;%C%5$+$i$N%"%/%;%9$KhkA+0\!K

8=>uBV	%m!<%I	99?7%9%H%"	L58z2=%9%H%"
Invalid	—	—	—
Ex. Dirty	Global	Global	Invalid
Local Clean	Global	Global	Invalid
Local Dirty	Global	Global	Invalid
Global	—	—	Invalid

5.1.4 %H%i%s%6%/%7%g%s

JUMP-1 K*$$$F$O%9%H%"$KH<$&B>%-%&%C%7%e$NL58z2=/99?7!"5Z$S%m!<%I!&_%9$KH<$&%G!<%?$NFI$_=P$7$O%Q%1%C%H$N0\F0Kh$j9T$olk!#0J8e!"%Q%1%C%H$N0\F0$Khj9Tol$k%-%&%C%7%e$N>uBVA+0\5Z$S%G!<%?$N99?7$r%H%i%s%6%/%7%g%s$H8F$V!#$^$?!"$"$k%H%i%s%6%/%7%g%s$Khj$"$k%-%&%C%7%e$N>uBVA+0\$dCM$N99?7$,9Tol$?$H$-!"$=$N%H%i%s%6%/%7%g%s$O$=$N%-%&%C%7%e$KE~C#$7$?$H$$$&3HK9$k!#F1MM$K!"Nc$($P<g5-21K*$$$F%G%#%l%/%H%j$r0z$/3HKh$j!"$"$k%-%&%C%7%e$KO"$k%H%i%s%6%/%7%g%s$Khk>uBVA+0\$JI,9Tol$J$$$3H,H=L@9l$P!"H=L@$7$?;~E@$G%H%i%s%6%/%7%g%sO=$N%-%&%C%7%e$KE~C#7?$H8@$&!#

%H%i%s%6%/%7%g%s$O!"%a%b%j!&%"%/%;%9$N<dN`!&%m!<%I/%9%H%"!K"Fs<!%-%&%C%7%e$N>uBV!"014S@-@)8f$NJ}?K!IL58z2=/99?7!K$N%Q%i%a!<%?$NAH9g$o$;$+$i$=$N<dN`$,7hDj$5lk!#$^$?!"%H%i%s%6%/%7%g%sKhCF$O!"B>$N%-%&%C%7%e$d%a%b%j$+iN1~Ez$,I,MW$HJkbN$bB8:_$9$k!#JUMP-1 K*1k<g$J%H%i%s%6%/%7%g%s$N<dN`$rI=6 $K<($9!#I=6$K<($90J30Kb%"%H%_%C%/!&%m!<%I!&%9%H%"$KH<$&%H%i%s%6%/%7%g%s$dJUMP-1 $K<BAu$5lF$$$k9b5!G=%a%b%j!&%"%/%;%9MQ$N%H%i%s%6%/%7%g%sEy$,$"$k!#

5.2 014S@-@)8f$N:GE,2=

TIS-CC $N<BAu$O?^9$K<($9h&$K!"4pK\E*$K$O3F%V%m%C%/$KBP7F7W;;5!Fb$K%7%j%"%i%$%:!&]%$%s%H$r0lE@@_$1!"%H%i%s%6%/%7%g%s$,I,$:%7%j%"%i%$%:!&]%$%s%H$rDL2a9kh&$K@)8f$9$k0lJ}$G!"%7%j%"%i%$%:!&]%$%s%H$rDL2a$9$kA0$K$bEj5!E*$K>uBVA+0\$dCM$N99?7$JIr9T$$!"5i$K%7%j%"%i%$%:!&]%$%s%H$rDL2a7?%Q%1%C%HKh$j:G=*7k2L$r>e=q$-$9k3HG<B8=G-$k!#

7+$7!"JUMP-1 GOTIS-CC $r<BAu$9kK$"$?$j!"$h$j@-G=8~>e$rDI5a9k$?$a$K0J2<$K<($9:GE,2=<jK!$,:NMQ5l$F$$$k!#

1. %7%j%"%i%$%:!&]%$%s%H$NJ#?tG[CV
   4pK\E*KO%7%j%"%i%$%:!&]%$%s%H$O7W;;5!Fb$N$"$k0lE@!"Nc$($P<g5-21KN$_B8:_$7$F$$$l$P014S@-@)8f$O<B8=G-$k!#$7$+$7!"JUMP-1 GO%7%j%"%i%$%:!&]%$%s%H$r7W;;5!Fb$N3F=j$K@_$1!"3F%V%m%C%/$,$"$k%/%i%9%?Fb%m!<%+%k$G$"$kH-Ey!"6I=jE*$JItJ,$K7+B8:_7J$$$3H,J]>Z5l$F$$$k>l9g$O<g5-21$r7PM3$;$:Hb%H%i%s%6%/%7%g%s$N4V$N%7%j%"%i%$%:$r2DG=H9k3HG!"%H%i%s%6%/%7%g%s$NDL2a7PO)$NC;=L!"$=$7$F%Q%1%C%H$NN.NL$NDc8:$r?^$k!#$J$*!"$3$N:GE,2=$OTIS-CC $N@-<A$H$OL54X78$G!"ACS-CC KbE,MQG-$k!#
2. :G=*7k2L>e=q$-$N:o8:
   4.2@a$G=R$Y$?$h$&$K%H%i%s%6%/%7%g%s$OI,$::G8e$K:G=*7k2L$r>e=q$-$9kh$&$K9l$P:G$bMF0W$K<B8=2DG=$G$"$k!#7+$7!"%U%)!<%k%9!&%7%"%j%s%0$O%3%s%Q%$%iKhCFM^$($k3H$,$G$-$k$H2>Dj$9kH!"F10l%"%I%l%9KBP9$k%"%/%;%9$O%/%j%F%#%+%k!&%;%/%7%g%sG"k3H,B?$$$H9M$($ilk3HEy$+$i!"U#?t$N%W%m%;%C%5$,$[$\F1;~$KF10l%V%m%C%/$KBP9k%9%H%"$r9T$&6ILL$O>/$J$$$H9M$($ilk!#D^$j!"K\Ev$K>e=q$-$7J1lPJi$J$$6ILL$O>/$J$$$N$G!">e=q$-$r9T$&NOJkY//:G>.8BKHIak3HG7W;;5!$NIi2Y$NDc8:$r?^$k!#

0J2<$G!"$3liFsDN<jK!$N>\:Y$r=RYk!#

5.2.1 %7%j%"%i%$%:!&]%$%s%H$NJ#?tG[CV

%7%j%"%i%$%:!&]%$%s%H$O7W;;5!Fb$N$"$k0lE@!Nc$($P<g5-21!KKN$_B8:_$9lP!"%H%i%s%6%/%7%g%s$N%7%j%"%i%$%:$O2DG=$G$"$k!#7+$7!"$"$k%V%m%C%/$N6&M->uBV$,0l$D$N%/%i%9%?Fb$KJD8F$$$k>l9g$O!"%H%i%s%6%/%7%g%s$N%7%j%"%i%$%:$r<g5-21GOJ/$=$N%/%i%9%?Fb$G9T$&3H$,$G$-$kNJ$i!"%H%i%s%6%/%7%g%s$NDL2a7PO)C;=L$d%Q%1%C%H$NN.NL$NDc8:$,?^lkNG!"7W;;5!$N@-G=8~>e$KLrN)DH9M$($ilk!#

3N$?$a$K!"JUMP-1 GO%7%j%"%i%$%:!&]%$%s%H$r7W;;5!Fb$NE~kH3m$K@_$1!"3F%V%m%C%/$N6&M->u67$K1~8F<B:]$K%7%j%"%i%$%:$,9T$olkCOE@$,JQ2=9k<jK!$r:NMQ7F$$$k!#6qBNE*KO!"3F2<!%-%&%C%7%e!"3F%/%i%9%?$N%/%i%9%?!&P%9!"$=7F<g5-21$r%7%j%"%i%$%:!&]%$%s%H$HDj$a!"86B'E*$K3F%H%i%s%6%/%7%g%s$,DL2a$9k9YF$N%7%j%"%i%$%:!&]%$%s%H$K$*$$$FB>$N%H%i%s%6%/%7%g%s$H%7%j%"%i%$%:$9$k!#$3$N<jK!$Khj!"7W;;5!Fb$rF1;~$K?J9T9kG$0U$NFsDN%H%i%s%6%/%7%g%s$N4V$G%7%j%"%i%$%:$r9T$&$3H,G-!"$+$D%H%i%s%6%/%7%g%s$NDL2a7PO)$NC;=L$r?^$k3H$,$G$-$k!#

Nc$($P!"$"$k%V%m%C%/$r=jM-$9kN$,0l$D$N%/%i%9%?$NFb$NJ#?t$N2<!%-%&%C%7%e!%J/%i%9%?Fb%m!<%+%k!KG"kH$-$O!"Ev3:%/%i%9%?Fb$N%W%m%;%C%5$+$iH/$;il$?%H%i%s%6%/%7%g%s$O!"%/%i%9%?!&P%9rDLC$F!"%/%i%9%?!&P%9$+$iB>%W%m%;%C%5!&f%K%C%H$KFO1ilkN,:GC;7PO)G"$k!#$=7F!"Ev3:%/%i%9%?Fb$+$iH/$;$il?%H%i%s%6%/%7%g%s$OI,$:%/%i%9%?!&%P%9$rDL2a$9$k!#=>$C$F!"6&M->uBV$,%/%i%9%?Fb%m!<%+%kG"kH$-$O!"%/%i%9%?!&P%9$r%7%j%"%i%$%:!&]%$%s%H$H9k3H$G!"I IMW$J7PO)$rDL2a$5$;$:$K:GC;7PO)$NDL2a$@$1$G!"Ev3:%/%i%9%?Fb$N%W%m%;%C%5$+$iH/$;$il?G$0U$NFsDN%H%i%s%6%/%7%g%s$r%7%j%"%i%$%:9k3H$,2DG=$G$"$k!#

5i$K!"%H%i%s%6%/%7%g%s$,DL2a9k9YFN%7%j%"%i%$%:!&]%$%s%H$G%7%j%"%i%$%:$r9T$&3HKh$j!"6&M->u67$rJQ2=5;$k%H%i%s%6%/%7%g%s$,?J9T7F$$$kH-KbG$0U$NFsDN%H%i%s%6%/%7%g%s$r%7%j%"%i%$%:G-$k!#Nc$($P?^12$K<(9h$&$K!"$"$k%V%m%C%/$,$"$k0l$D$N%/%i%9%?(Cluster 4) KN$_B8:_7F$$$kH-$K!"JL$N%/%i%9%?(Cluster 2) $+$i%m!<%I$,9T$olk$H!"$3$N%H%i%s%6%/%7%g%s$O<g5-21(Cluster 1) $r7PM3$7$FCluster 4 KFO1il$k!#3N:]!"Cluster 2 $HCluster 4 $N%/%i%9%?!&P%9$d<g5-21K*$$$F$bB>%H%i%s%6%/%7%g%s$H%7%j%"%i%$%:$9k3HG!"Cluster 4 $+$iH/$;$il?%H%i%s%6%/%7%g%sHOCluster 4 $N%/%i%9%?!&P%9$G!"Cluster 2 $+$iH/$;$il?%H%i%s%6%/%7%g%sHOCluster 2 $N%/%i%9%?!&P%9$G!"$=$7$FB>$N%/%i%9%?(Cluster 3) $+$iH/$;$il?%H%i%s%6%/%7%g%sHO<g5-21K*$$$F%7%j%"%i%$%:$5$l!"$I$N%H%i%s%6%/%7%g%s$H$b%7%j%"%i%$%:9k3H$,$G$-$k!#

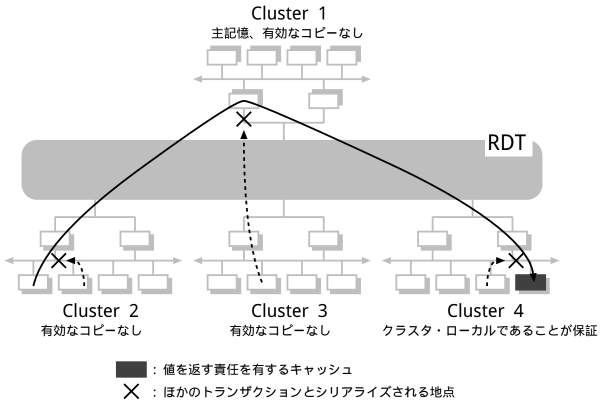
5.2.2 >e=q$-$N:o8:

>e=q$-:o8:$N$?$a$N%"%W%m!<%A I,$:7b:G=*7k2L$r>e=q$-7J$$$?aN%"%W%m!<%AH7$F!"<!$NFsD,9M$($ilk!#

I=6: %H%i%s%6%/%7%g%s$N<oN`

%m!<%I/%9%H%"	CCP	>uBV	%H%i%s%6%/%7%g%s	1~Ez
%m!<%I	—	Invaild	CMFI$_$@$7	M-
		Otherwise	(H/@8$7$J$$)	
%9%H%"	L58z2=	Invalid	L58z2=7sCMFI$_=P$7^{*1}	M-
		Global	L58z2=7sCMFI$_$@$7^{*1}	M-
		Ex. Dirty	(H/@8$7$J$$)	
		Otherwise	L58z2=	L5
	99?7	Invalid	CMFI$_=P$7 + 99?7^{*2}	M-
		Ex. Dirty	(H/@8$7$J$$)	
		Otherwise	99?7	L5

CCP	014S@-@)8fJ}?K
>uBV	2<!%-%&%C%7%e$N>uBV
1~Ez	1~Ez$NM-L5
*1	CMFI$_$@7HL58z2=$rF1;~$K9T$&
*2	CMFI$_$@7r9T$$!"40N;7?8e99?7



?^12: J#?t$NCOE@$GB>$N%H%i%s%6%/%7%g%s$H%7%j%"%i%$%:$5lk>u67

- Ej5!E*$K=q$-9~$_$r9TC?8e!"$=$N%H%i%s%6%/%7%g%s$,40N;$9$kA0$KJL$N%H%i%s%6%/%7%g%s$KhC$FF1$8%V%m%C%/KBP7$F=q$-9~$_$,9Tol$?$3Hr8!=P7F!"3N>l9g$@$1>e=q$-$r9T$&!#

- Ej5!E*$K=q$-9~$_$r9TC?8e!"$=$N%H%i%s%6%/%7%g%s$,40N;$9k^GO=q$-9~$_$r9T$C$?%V%m%C%/$NCM$d>uBV$,JQ2=7J$$$h$&$KJ]8n9k!#

A0<T$NJ}K!$r:NMQ9k:]KO!"2?i+$NJ}K!$KhCFJLN%H%i%s%6%/%7%g%sKhCF=q$-9~$_$,$J5l$?$3Hr8!=P9k$?$a$N5!9=$H!"3l$r8!=P$7$?:]$K%H%i%s%6%/%7%g%s$N<oN`$dDL2a7PO)JI$rJQ99$9k?aN5!9=$rMQ0U$9k3HKhj<B8=9k3H$,$G$-$k!#3liFsD$N5!9=$N<B8=$OI,$:7bMF0W$K9T$(kH$O8B$i$:!"<BAu$N$?$a$N%3%9%H$,A}Bg9k2DG=@-b"k,!"3NJ}K!$O%Q%1%C%H$NN.NL$r8:$i9?aK$OM-8z$J<jK!G"$k!#

0lJ}!"8e<T$NJ}K!$N<BAuO=l[$I:$FqGO$J$$$,!"3N<jK!$O7k6I:G8e$K=q$-9~$_6X;_$r2r=|$9kI,MW,$"$kNG!":NMQ9k>u67KhCF$O!":G=*7k2L$r>e=q$-$9kNH[$\F1$8=hM}$,I,MW$HJjF@$F!"Ii2Y$NDc8:KDJ,iJ$$2DG=@-N"k3HK$OCm0U$9kI,MW,$"$k!#

JUMP-1 K*1kJ}K! JUMP-1 K*$$$F$O7W;;5!$NIi2Y$NDc8:$r?^k?aK>eNFsD$N<jK!$r:NMQ7F$$$k!#0lJ}$G!"I,$:>e=q$-$r9TCFbBg-$J@-G=Dc2<$KODJ,iJ$$H9M$($ilk>u67GO!"7W;;5!$N@)8f$rMF0WK9k?aKI,$:>e=q$-$r9T$&!#

JUMP-1 >e$G<B9T$5lk%"%W%j%1!<%7%g%sGO!"JQ?t$N6&M->uBV$,%/%i%9%?FbKJD8kbNbB?$$$H9M$($ilk!#3N$?$a!"%/%i%9%?4VK^$?$,$k%H%i%s%6%/%7%g%s$O$=$l$[$IB?$/$OH/@8$7$J$$$,!"%/%i%9%?FbKJD8$k%H%i%s%6%/%7%g%s$OIQH/9k$H9M$(il$k!#$hCF!"6&M->u67$,%/%i%9%?Fb$KJD8F$$$k>l9g$O:G=*7k2L$N>e=q$-$r:G>.8BKHIak3HG!"%7%9%F%`K+$+$kIi2Y$r:o8:$9k3H,2DG=G"kHM=A[5l$k!#$9Jo$A!"JUMP-1 GO6&M->u67$,%/%i%9%?4VK^$?$,CF$$$k>l9g$OI,$:>e=q$-$r9T$&$,!"%/%i%9%?FbKJD8$F$$$k>l9gKD$$$F$O>e=q$-$r9T$&Nr:G>.8BKHIa$k!#

>e=q$-$r:G>.8BKHIak?$a!"6&M->u67$,%/%i%9%?FbKJD8$F$$$k:]$K!"%9%H%"$KHb$J$$Ej5!E*$K%-%&%C%7%e$N>uBV$rJQ2=$5$;$?jCM$r=q$-9~s@>l9g$O!"%H%i%s%6%/%7%g%s$,40N;9kA0$K

1. F101%V%m%C%/KBP7$FL58z2=MW5a$,J5l?>l9g$O!"L58z2=$5l?3H$r8!=P$7$F!"8e$K>e=q$-$r9T$&!#

2. $=$10J30$NMW5a$,J5l?>l9g$O!"$=$NMW5a$KhkEv3:%V%m%C%/$N>uBVA+0\$*hS%9%H%"$r9T$C$?%"%I%l%9$NCM$,JQ2=$7$J$$$h$&$KJ]8n9k!#

J}K!$r:NMQ$7$F$$$k!#

L58z2=5l$?>l9g$@$107$$$,JLJN$O!"F101%V%m%C%/$X$N0[$J$k%"%I%l%9$KBP7F$[$\F1;~$KJ#?t$N%W%m%;%C%5$,%9%H%"$r9T$$!"$=$lKHbJ$$$N>J}$,$*8_$$$rL58z2=7h$&$H9k>u67$KBP1~$9k?aG$"$k!#>\:Y$O5.4@a$G=RYk!#

$^$?!"@h$K>uBV$dCM$rJ]8n$9$k<jK!$OIi2Y$NDc8:$K9W8%7J$$2DG=@-$,$"kH=RY?$,!"6&M->uBV$,%/%i%9%?FbKJD8$F$$$k>l9g$O!">uBV$dCM$NJ]8n$OIi2Y$NDc8:$K==J,9W8%9k!#J<Ji!"JUMP-1 K*$$$F$OJ]8n5!9=$O%W%m%;%C%5!&f%K%C%H$NAw?.%P%C%U%!$N3F%(%s%H%j$K@_$1il$F$$$k$+$iG"$k!#%W%m%;%C%5$,%9%H%"$r9T$&$H!"Ej5!E*$K2<!%-%&%C%7%e$K=q$-9~$_$r9T$&$HF1;~$KAw?.%P%C%U%!$K%(%s%H%j$r3dIU$1$FB>%-%&%C%7%e$r99?7b7$/$OL58z2=9k$?$a$N%Q%1%C%H$r=q$-9~$`!#$3

$N:]!">uBV$dCM$rJ]8n$9k?aKI,MW$J>pJs$bF1$8%(%s%H%j$K=q$-9~$`!#$=$N8e!"Aw?.%P%C%U%!$KB8:_$7$F$$$?%Q%1%C%H$,%/%i%9%?!&%P%9$rDL2a9k$H!"6&M->uBV$,%/%i%9%?FbKJD8$F$$$kNG!"3N;~E@$G%H%i%s%6%/%7%g%s$,40N;7?$H8@$($k!#$^$?!"%Q%1%C%H$N%/%i%9%?!&%P%9$NDL2a$HF1;~$KAw?.%P%C%U%!$K3dIU1ilF$$$?%(%s%H%j$O2rJ|$5$l!"F1;~$K>uBVdCMNJ]8n$b2r=|$5lk!#%(%s%H%j$N2rJ|$O2<!%-%&%C%7%e$KIi2Y$rM?$($:$K2DG=$G$"$k$+$i!"%H%i%s%6%/%7%g%s$N40N;$rbC$FJ]8n$N2r=|$b<+A3$K9Tol!"$+$D2<!%-%&%C%7%e$KIi2Y$rM?$($:$K9T$olk!#=>CF!"%9%H%"$KH<$&2<!%-%&%C%7%eXN%"%/%;%9$O:G=i$KEj5!E*$K=q$-9~$`$H$-$@$19T$olkNG!"8e$K>e=q$-$r9T$&J}K!hj$b2<!%-%&%C%7%e$K$+$+$kIi2Y$O>.5/9k3H$,$G$-$k!#

5.3 TIS-CC $N<B8=$N$?$a$N5!9=$H@)8f

4.2@a$G=R$Y$?TIS-CC $N<B8=$KI,MW$J4pK\E*$J=hM}!"9JoA!"%H%i%s%6%/%7%g%s$N%7%j%"%i%$%:$d:G=*7k2L$N>e=q$-$r<B8=9k$?$a!"$=$7$F5.2@a$G=RY?:GE,2=!"9JoA!"%7%j%"%i%$%:!&%]%$%s%H$NJ#?tG[CV$d:G=*7k2L$N>e=q$-$r:o8:$9k?aN=hM}$r<B8=$9k?$a!"JUMP-1 K*$$$F$O%W%m%;%C%5!&%f%K%C%HFb$NAw<u?.%P%C%U%!$=$7$F<g5-21$K$*$$$FMM!9$J5!9=$,@_1ilF$$$k!#

%W%m%;%C%5!&%f%K%C%HFb$NAw<u?.%P%C%U%!$GMQ0U5l$F$$$k5!9=$r?^13$K<($9!#?^13$K$*$$$F!"%"%I%l%9$d%G!<%?0J30$N5!9=$NLr3d$O<!NDLjG"$k!#

- MDFD
  %b%G%#%U%!%$%I!&%S%C%H!#%V%m%C%/$N%P%$%H?t$HF1$8$@1N%S%C%H?tG"$k32 %S%C%HMQ0U$5lF$$$k!#Aw?.%P%C%U%!$K=q$-9~$^$l$?%Q%1%C%H$,<+%W%m%;%C%5$+$i$N%9%H%"$KH<$&%Q%1%C%H$N;~N_0UL#$r;}$D!#Ev3:%V%m%C%/NCfN%9%H%"$r9T$C$?%"%I%l%9$K$O%S%C%H$,$?$C$F$$$k!#
- >uBV
  Ev3:%"%I%l%9$N2<!%-%&%C%7%e$N>uBV$rI=$9!#3l$H%W%m%;%C%5$+iN%"%/%;%9$N<oN`$J$I$+$i%/%i%9%?!&%P%9$KN.$9%Q%1%C%H$N<oN`$r7hDj9k!#
- OTST
  %"%&%H!&%9%?%s%G%#%s%0!&%S%C%H!#1~Ez$,I,MW$J%H%i%s%6%/%7%g%s$r%/%i%9%?!&%P%9$KAw=P7?8e!"1~Ez$,JV$CF/k^$G%S%C%H$,N)CF$$$k!#
- RPLY
  Aw?.%P%C%U%!K*$$$F$O!"Ev3:%(%s%H%j$KF~CF$$$k%Q%1%C%H$,B>$N%W%m%;%C%5XN1~Ez%Q%1%C%HG"k3Hr!"<u?.%P%C%U%!K*$$$F$OB>$N%W%m%;%C%5XN1~Ez$,I,MW$J%Q%1%C%H$r<u$1<hC?3H$r0UL#$7$F$$$k!#
- SBHE
  Aw?.%P%C%U%!$KF10l%V%m%C%/$X$N%Q%1%C%H$,B8:_7F$$$k3H$r<($9!#

$^$?!"%/%i%9%?!&%a%b%jK*1k5!9=$r?^14$K<($9!#%/%i%9%?!&%a%b%j$K$*$$$F$O%G%#%l%/%H%j$NB>$K!"0J2<$N5!9=$,MQ0U$5lk!#

- %W%m%;%9!&F!<%V%k
  8=:_?J9TCf$N%H%i%s%6%/%7%g%s$N%F!<%V%k!#8eB3%H%i%s%6%/%7%g%s$N?J9T$r%/%i%9%?!&%a%b%j$GDd;_$5$;$kI,MW$,$"$k>l9g!"%W%m%;%9!&F!<%V%k$K$=$N%"%I%l%9$dDd;_$5$;$k%H%i%s%6%/%7%g%s$N<oN`$r5-O?9k!#
- %5%9%Z%s%I!&%P%C%U%!
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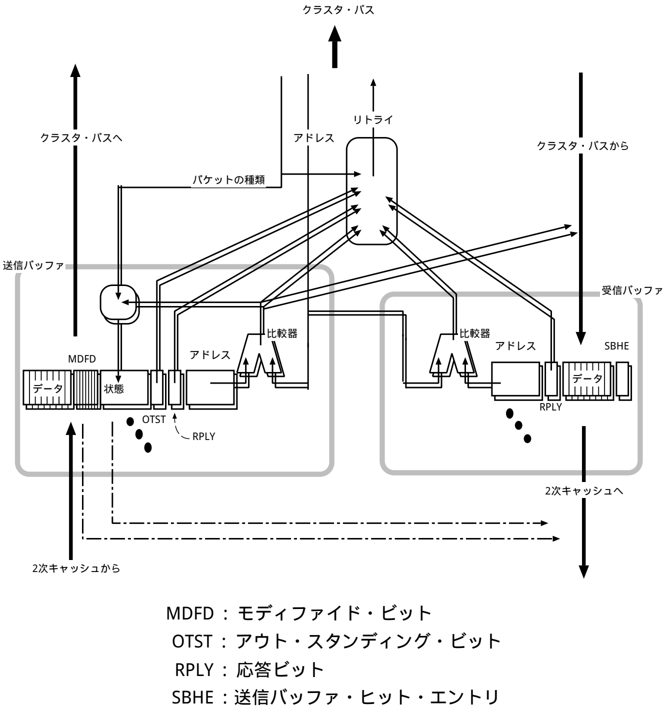

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- %l%G%#!<!&%-%e!<
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3liN5!9=$rMQ$$$F!"4.2 @a$G5s$2$?4pK\E*$JTIS-CC $N<B8=J}K!$K2C$($F!"5.2@a$G5s$2$?:GE,2=<jK!$r<B8=9k$?$a$N@)8f$r9T$&!#0J2<$G!"TIS-CC $r<B8=$9k?aK9Tol$k@)8f$K$D$$$F=RYk!#

5.3.1 %H%i%s%6%/%7%g%s$N?J9TDd;_

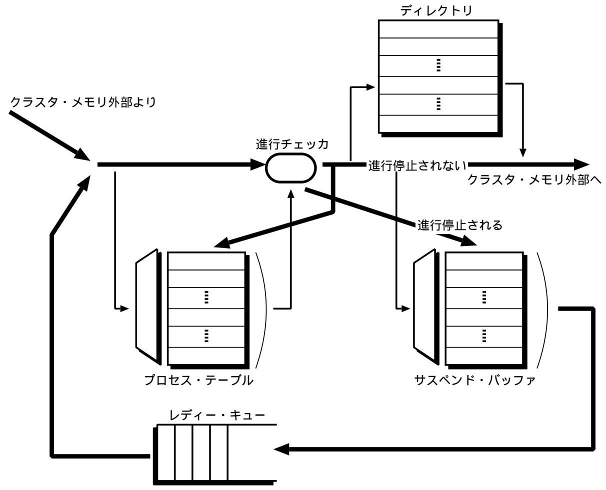
4.2@a$G=R$Y$?$h$&$K!"3F%W%m%;%C%5$+$i4QB,G-kCM,:G=*E*$KF1$8KJk?aK!"%7%j%"%i%$%:$5l?%H%i%s%6%/%7%g%s$,3F%-%c%C%7%e$d%a%b%j$KE~C#$9$k=g=x$O%7%j%"%i%$%:$5l?=g=x$rJ]$Dh&$K@)8f$r9T$&!#$3lO!"8eB3%H%i%s%6%/%7%g%s$,%7%j%"%i%$%:!&%]%$%s%H$rDL2a9k$H!"@h9T%H%i%s%6%/%7%g%s$hjb@h$K!"$"$k%-%c%C%7%e$d%a%b%j$KE~C#$9$k2DG=@-$,$"$k>l9g$O!"8eB3%H%i%s%6%/%7%g%s$NDL2arBT?$;$k3HKh$j<B8=$9$k!#

8eB3%H%i%s%6%/%7%g%s$,@h$KE~C#$7F@$k>l9gH7$F0J2<$NFsD,9M$($ilk!#

- %M%C%H%o!<%/K*$$$F%Q%1%C%H$NDI$$1[7,H/@8$9$k
- %7%j%"%i%$%:!&%]%$%s%H$rDL2a8e$N7PO)$,@h9T%H%i%s%6%/%7%g%s$H8eB3%H%i%s%6%/%7%g%s$N4V$G0[Jk

JUMP-1 K*$$$F!"3liO0J2<$N;~$K5/3jF@$k!#

1. %Q%1%C%H$NDI$$1[$7
   JUMP-1 K*$$$F%Q%1%C%H$NDI$$1[7O!"RDT K*$$$FH/@8$7F@$k!#RDT KOPoint-to-Point DL?.$N7PO)$H%^%k%A%-%c%9%H$N7PO)$,JL$K@_$1ilF*$j!"@h9T$H8eB3$N%H%i%s%6%/%7%g%s$N0lJ}$,Point-to-Point DL?.$G9Tol!"



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B>J}$,%^%k%A%-%c%9%H$rH<$&%H%i%s%6%/%7%g%s$G$"$l$P%Q%1%C%H$NDI$$1[7,H/@8$9$k!#3l$O:G$bC1=cKO!"3F%/%i%9%?$OPoint-to-Point $N%Q%1%C%H$rRDT $KN.$7$?$H$-$O!"$=$l$,Aj<j$KFO$/$^$G%^%k%A%-%c%9%H!&%Q%1%C%H$rN.$5$:!"$=7F!"$=$N5U$b9T$&3HKh$j=g=x$rJ]>Z9k3H$,2DG=$G$"$k!#

2. DL2a7PO)$N0[$J$j

DL2a7PO)$N0[$JjO!"@h9T%H%i%s%6%/%7%g%s$,1~Ez%Q%1%C%H$rH<$&>l9g$KH/@8$7F@$k!#@h9T%H%i%s%6%/%7%g%s$,1~Ez%Q%1%C%H$rH<$&>l9g!"0lC6JL$N%-%c%C%7%e$d%a%b%j$r7PM3$7$F$+$i!"$=$N%H%i%s%6%/%7%g%s$r3+;O$7$?%W%m%;%C%5$KJVk?$a!"8eB3$N%H%i%s%6%/%7%g%sHN$"$$$@$G7PO)$,0[Jk!#

3N>u67$r?^15$K<($9!#$^$:!"$P_1$$,1~EzrI,MWH9k%H%i%s%6%/%7%g%s$rH/$7!"$=$l$,%7%j%"%i%$%:!&]%$%s%H$rDL2a9k!#$=$l$,1~Ez$rJV$9%W%m%;%C%5($P_3$)$KFO$-!"$P_3$$O<+%-%c%C%7%e$N>uBV$rJQ2=5;!"$=$lHHbK1~Ez%Q%1%C%H$r@8@.$7FP_1$$K$`$1$FAw?.$9$k!#$7$+$7!"$3$N4V$KB>$N%W%m%;%C%5($P_2$)$NH/$7$?%H%i%s%6%/%7%g%s$,%7%j%"%i%$%:!&]%$%s%H$KE~C#$7!"$=$N;~D>$A$K$P_1$$K$`$1$F%Q%1%C%H$rAw?.9l$P!"$P_2$$+iN%Q%1%C%H$NJ}$,$P_3$$+iN1~Ez%Q%1%C%Hhj@hKP_1$$KE~C#$7F@$k!#3N$?$a$K!"1~Ez$rH<$&%H%i%s%6%/%7%g%s$,%7%j%"%i%$%:!&]%$%s%H$rDL2a$9kH8eB3$N%H%i%s%6%/%7%g%s$O$=$N%7%j%"%i%$%:!&]%$%s%H$KE~C#$7$?;~E@$G?J9T$,Dd;_$5lk!#

$?$@$7!"@h9T%H%i%s%6%/%7%g%s$,1~Ez%Q%1%C%HrI,MWH9k>l9gGb<!$K<($9>l9g$O8eB3%H%i%s%6%/%7%g%s$NDd;_OJ5l$J$$

(a) %7%j%"%i%$%:$,9TolkN$,2<!%-%c%C%7%e$N;~3N;~O?H(1~Ez$,I,MW$G$"$CFb1~Ez%Q%1%C%H$OD>$A$K%7%j%"%i%$%:!&]%$%s%H$rDL2a9k3H$+$i;v<B>e8eB3%H%i%s%6%/%7%g%s$N?J9T$,Dd;_5lk3HO$J$$!#

(b) %/%i%9%?!&P%9K*1kNc30

%/%i%9%?!&P%9K*$$$F!"?^16$K<($9h&$KRDT$rDLCF%/%i%9%?!&a%b%j$+$iH/$;$il?%H%i%s%6%/%7%g%s(A)KD$$$F$O!"$?H(!"$=$N%/%i%9%?Fb$K1~Ez$,I,MWJL40N;%H%i%s%6%/%7%g%s(B)$,B8:_$7$F$$$F$b!"%V%m%C%/$N6&M->uBV$,%/%i%9%?4V$K$^$?$,$C$F$$$kH-$O?J9T$rDd;_7J$$!#

J<Ji!"6&M->uBV$,%/%i%9%?4V$K$^$?$,$C$F$$$kH-$O!"%H%i%s%6%/%7%g%sA Kh$j<g5-21K*$$$F%H%i%s%6%/%7%g%sB $N?J9T$,Dd;_5l$F$$$k2DG=@-$,$"kN$G!"%/%i%9%?!&P%9$K$*$$$F%H%i%s%6%/%7%g%sB Kh$jA $N?J9T$,Dd;_5lkH%G%C%I%m%C%/$K4Y$k!#6&M->uBV$,%/%i%9%?4V$K$^$?$,$C$F$$$kH-$O<g5-21$K$*$$$F%7%j%"%i%$%:$5lk$H$$$&9M$($+$i!"%/%i%9%?!&P%9$K$*$$$F$O?J9T$rDd;_5;$J$$!#

J*!"@h9T%H%i%s%6%/%7%g%s$,%/%i%9%?Fb$KJD8k;~$O!"%/%i%9%?!&a%b%j$+$iH/$;il$?%H%i%s%6%/%7%g%s$b?J9TDd;_5l$k!#

>e5-$r<B8=$9k?aN%H%i%s%6%/%7%g%s$N?J9TDd;_@)8f$O?^13$*$h$S?^14 $K<($95!9=$rMQ$$$F<!Nh$&$K9Tol$k!#

1. %/%i%9%?!&P%9K*1k?J9TDd;_

%/%i%9%?!&P%9K*1k?J9TDd;_$O!"%P%9$KN.l?%Q%1%C%H$NL58z2=$H:FAw$rMW5a$9$k%j%H%i%$5!9=$rMQ$$$F<B8=5l$k!#

%/%i%9%?!&P%9K*1k%j%H%i%$5!9=$r?^17$K<($9!#?^17 $O!"?^13$N$&$A$N%j%H%i%$$K4X78$9$kItJ,$N_$r<B@~$GI=$7$?$bNG$"$k!#

%/%i%9%?!&P%9$K%Q%1%C%H$,N.lk$H!"F10l%V%m%C%/$X$N%Q%1%C%H$,<+J,$NAw<u?.%P%C%U%!$KB8:_9k$+$I$&$+$r3F%(%s%H%j$K@_1il?Hf3S4o$rMQ$$$F8!:w9k!#$=$N7k2L%R%C%H7?%(%s%H%j$,$"lP!"Aw?.%P%C%U%!$+$iO=$N%(%s%H%j$,1~EzBTA+I&$+$r<($9OTST %S%C%H$H!"B>KBP9$k1~Ez%Q%1%C%H$+I&$+$r<($9RPLY %S%C%H$,!"<u?.%P%C%U%!$+$iO=$N%(%s%H%j$,1~EzrI,MWH9kMW5aG"k3Hr<($9RPLY %S%C%H$,!"%j%H%i%$MW5a5!9=$KEA$($ilk!#

$=$7$F!"0J2<$N>r7o$,@.N)$7$?$H$-$K%j%H%i%$$rMW5a9k!#

- OTST $,N)$C$F$$$kAw?.%P%C%U%!$K%R%C%H$7!"$+$D%P%9$K%Q%1%C%H$rN.7?N,%/%i%9%?!&a%b%jGO$J$$!#
- RPLY $,N)$C$F$$$kAw?.%P%C%U%!$"$k$$$O<u?.%P%C%U%!$K%R%C%H$7$?!#

A0<T$N>r7o$Khj!"1~EzBTAN;~$KB>$N%W%m%;%C%5!&f%K%C%H$,%P%9$K%H%i%s%6%/%7%g%s$rN.$9Nr6X;_9k!#$=$7$F!"%H%i%s%6%/%7%g%s$,%/%i%9%?FbKJD8kH$-$O!"$?$H$(%/%i%9%?!&a%b%j$+$iH/$;il$?%H%i%s%6%/%7%g%s$G$"$CFb?J9T$rDd;_$9k?aK8e<T$N>r7o$r2C$($k!#JUMP-1GO!"%H%i%s%6%/%7%g%s$,%/%i%9%?Fb$KJD8k$H$$$&Nr!V~Ez$r9T$&N,%/%i%9%?Fb$N%W%m%;%C%5!&f%K%C%H$G$"$k!W$H$$$&3HKh$j8!=P$9$k!#

2. <g5-21K*1k?J9TDd;_

<g5-21K*1k?J9TDd;_@)8f$NN.$l$r?^18 $K<($9!#

$^$:!"1~Ez$,I,MW$J%H%i%s%6%/%7%g%s$O<g5-21$rDL2a9k:]$K!"8eB3$N%H%i%s%6%/%7%g%s$rDd;_$5$;$k$?$a$K!"%W%m%;%9!&F!<%V%k$KBP7FEPO?$r9T$&!#

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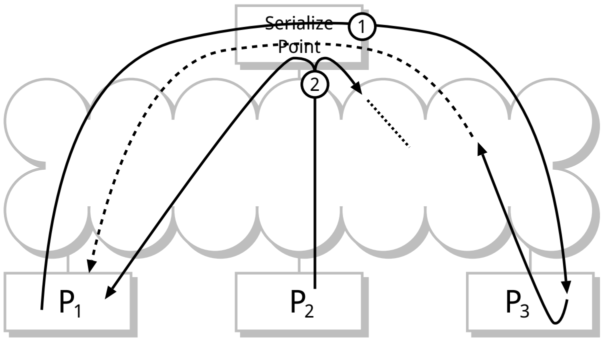

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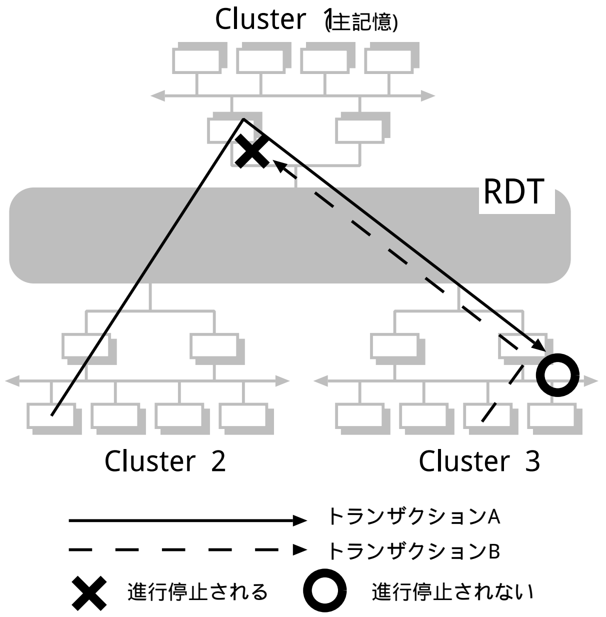

- %V%m%C/$N6&M->uBV$O%/%i%9%?4VK^$?$,CF$$$k
- %H%i%s%6%/%7%g%s A,B Hb$K1~Ez$rI,MWH9$k

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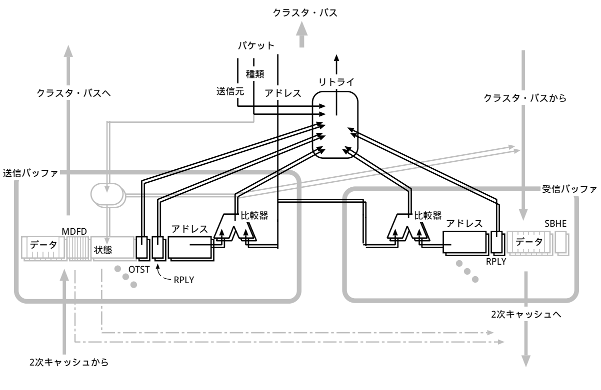

?^17: %/%i%9%?!&P%9K*1k%j%H%i%$5!9=

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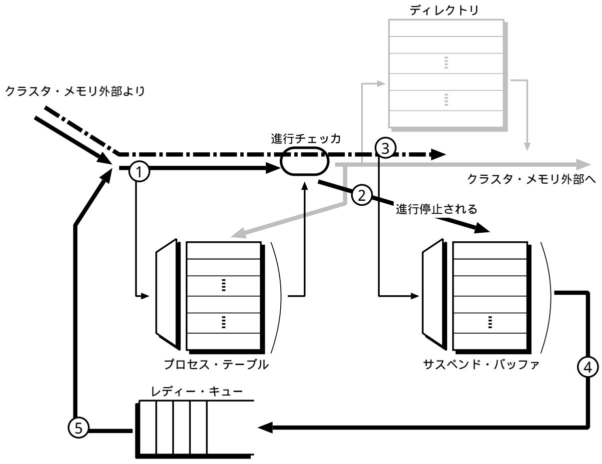

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5.3.2 :G=*7k2L$N>e=q$-

5.2@a$G=R$Y$?$h$&$K!":G=*7k2L$N>e=q$-$OL58z2=$^$?$O99?7%H%i%s%6%/%7%g%s$,%/%i%9%?4V$K$^$?$,$k>l9g$H!"%/%i%9%?Fb$KJD8kH-GbEj5!E*$K%9%H%"$N7k2L$r=q$-9~s@2<!%-%c%C%7%e$,L58z2=$5l?H-$K9T$&!#

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   %/%i%9%?4VK^$?$,$k99?7%H%i%s%6%/%7%g%s$Khk>e=q$-$O!"%7%j%"%i%$%:$5l?8e$KEj5!E*$K=q$-9~$_$r9T$C$?%-%c%C%7%e$K%Q%1%C%H$,:F$SE~C#9k$H!">uBV$rA+0\$5$;$kHHbK!"%V%m%C/FbN&$A%9%H%"$,9Tol$?%"%I%l%9$NCM$r%-%c%C%7%e$K=q$-9~$`3H$G9T$&!#
2. %/%i%9%?4VK^$?$,$kL58z2=%H%i%s%6%/%7%g%s$Khk>e=q$-
   0lJ}!"%/%i%9%?4VK^$?$,$kL58z2=%H%i%s%6%/%7%g%s$N;~$O!"CM$rJV$9@UG$$r;}$D%-%c%C%7%e$^$?$O%a%b%j!J%*!<%J!K$+$i%V%m%C/A4BNNCMrFI$_=P$7$?8e!"%H%i%s%6%/%7%g%s$r3+;O7?%W%m%;%C%5!&f%K%C%H$K1~Ez$rJV7F!"$=$N1~Ez%Q%1%C%HKh$j>uBVA+0\$HCM$N99?7$r9T$&!#%*!<%J$+iCMrFI$_=P$9NO!"F10l%V%m%C/Fb$N0[$J$k%"%I%l%9$KJ#?t$N%W%m%;%C%5$,$[$\F1;~$K%9%H%"$r9TCF!"$=$lKHbJ$$L58z2=%H%i%s%6%/%7%g%s$,$[$\F1;~$K3+;O5lk3

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3. Ej5!E*=q$-9~$_$r9T$C$?%-%c%C%7%e$,L58z2=5l$?$H$-$3$N;~$O!"L58z2=5l$?%W%m%;%C%5!&f%K%C%H$Khj3+;O5l$?%H%i%s%6%/%7%g%s$O%*!<%J$+$iCMrFI_=P$7!"$=7FL58z2=5l$?%-%c%C%7%e$N>uBVA+0\$HCM$N99?7$r9T$&!#$?$@$7!"L58z2=5l$?%-%c%C%7%e$NCM99?7$N;~$K$O!"<+%W%m%;%C%5$,%9%H%"$r9T$C$?%"%I%l%9$K$O=q$-9~$_$r9ToJ$$!J5.4@a;2>H!K#

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5.3.3 %H%i%s%6%/%7%g%s$N<dN`JQ99@)8f

5.2@a$G=R$Y$?$h$&$K!"%H%i%s%6%/%7%g%s$,%/%i%9%?Fb$KJD8kH-$O!"2<!%-%c%C%7%e$KEj5!E*$K=q$-9~$^$l$?8e!"%H%i%s%6%/%7%g%s$,4{N;9kA0$KEv3:%V%m%C%/$,L58z2=5lkH!"$=$l$r8!=P$7$F!"8e$K:G=*7k2L$r>e=q$-9kh&$K@)8f$9$k!#

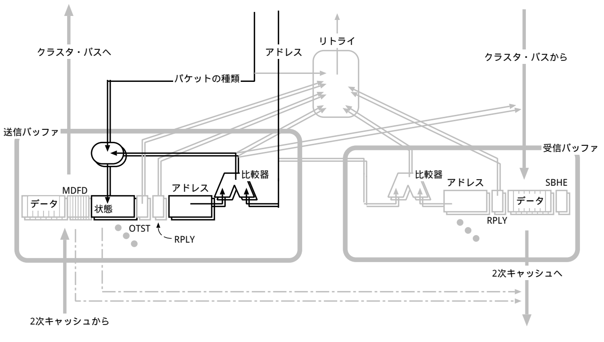
%H%i%s%6%/%7%g%s$,%/%i%9%?Fb$KJD8k>l9g!"%P%9$K%Q%1%C%H$rN.$9$3H,G-lP!"l~EzrI,MWH7J$$%H%i%s%6%/%7%g%s$O4{N;$7$?$H$$$&3H$,$G$-$k!#=>CF!"L58z2=5l$?$3HN8!=P$O%W%m%;%C%5!&f%K%C%H$NAw?.%P%C%U%!K*$$$F9T$&!#

L58z2=5l$?$3HN8!=P$H!"$=lKHb$J$$8e$K>e=q$-5;k?aN@)8f$r?^19$K<($9!#%Q%1%C%H$,Aw?.%P%C%U%!$KB8:_$9kH$-$K%P%9$r%Q%1%C%H$,N.lk$H!"Hf3S4o$rMQ$$$FAw?.%P%C%U%!$KB8:_$9$k%Q%1%C%H$H%"%I%l%9$,0lCW$9k+I&$+8!=P$9$k!#$b$7!"%"%I%l%9$,0lCW$7!"$+$D%P%9$rN.l?%Q%1%C%H$N<oN`$,%-%c%C%7%e$rL58z2=$9$k%Q%1%C%H$G$"$l$P!"Aw?.%P%C%U%!$K5-O?5l$F$$$k%-%c%C%7%e$N>uBV$rInvalid H9$k!#$3lKhj!"Aw?.%P%C%U%!$KB8:_$9k3$N%Q%1%C%H$,%P%9$KAw=P$5lk:]KO%9%H%"!&_%9$KH<$&%H%i%s%6%/%7%g%sH7$FH/$;ilk3HKJk!#hC$F!"8e$KB>$N%-%c%C%7%e$^$?$O%a%b%j$+$il~Ez$,JV$j!"l~Ez%Q%1%C%H$r%-%c%C%7%e$K=q$-9~$`3H$G>e=q$-$,9T$olk!#

$^$?!"3N5!9=$O2<!%-%c%C%7%e$K=q$-9~$s$@$H$-$O%/%i%9%?Fb%m!<%+%kG"C?%H%i%s%6%/%7%g%s$r%/%i%9%?4V$K$^$?$,$k%H%i%s%6%/%7%g%s$KJQ99$5$;$k$?$aKbMQ$$$k!#9JoA!"2<!%-%c%C%7%e$K=q$-9~s@H-$Olocal shared {clean/dirty} G"C?NK!"%/%i%9%?!&P%9$KAw=P$5lkA0$Kglobal shared clean KJC?H-!"3N5!9=$rMQ$$$F>uBV$rglobal H7$F!"%P%9$KAw=P9k:]KO%/%i%9%?4V%H%i%s%6%/%7%g%sHJkh$&$K@)8f7F$$$k!#

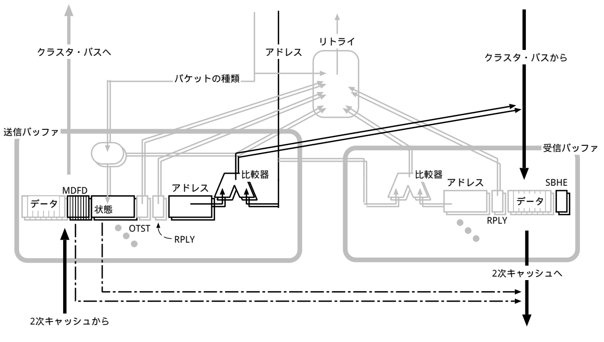
5.3.4 =q$-9~$_J]8n5!9=

5.2@a$G=R$Y$?$h$&$K!"6&M->uBV$,%/%i%9%?Fb$KJD8F$$$kH-$K!"2<!%-%c%C%7%e$KEj5!E*$K=q$-9~$_$r9TC?8e!"$=$N%H%i%s%6%/%7%g%s$,4{N;$9k^GO!IL58z2=5l$k>l9g$r=|$-!KEv3:%V%m%C%/$N>uBVA+0\5Z$S%9%H%"$r9TC?%"%I%l%9$,JQ2=$7$J$$$h$&$KJ]8n9k!#@h$K=R$Y$?$h$&$K%9%H%"!&R%C%H$N%H%i%s%6%/%7%g%s$O%P%9$K%Q%1%C%H$rN.$9$3H,G-$?;~E@$G4{N;7?$H$$$&3H$,$G$-$kNG!"%9%H%"$KH<$&%Q%1%C%H$,Aw?.%P%C%U%!$KB8:_7F$$$k4V$@$1>uBVA+0\$dCM$NJ]8n$r9l$PNI$$!#



?^19: %H%i%s%6%/%7%g%s$N<dN`JQ99@)8f

=q$-9~$_J]8n$N@)8f$NN.lr?^20$K<($9!#$^$:!"%9%H%"KHbJ$$2<!%-%c%C%7%e$K=q$-9~$_$r9T$&$HAw?.%P%C%U%!$K%Q%1%C%H$r=q$-9~$`$,!"$=$N:]Ev3:%V%m%C%/$N$&$A$N$I$N%"%I%l%9$K%9%H%"$r9T$C$?$+$r%b%G%#%U%!%$%I!&S%C%H$K5-O?$9$k!#%Q%1%C%H$,Aw?.%P%C%U%!$KB8:_$7$F$$$k;~$K!"JL%W%m%;%C%5$+$i$N%Q%1%C%H$,%P%9$rN.$l$F!"$=$N%Q%1%C%H$r<u$1<h$k$J$i$P!"<u?.%P%C%U%!$K=q$-9~$`H-$KAw?.%P%C%U%!$KB8:_9k%Q%1%C%H$H%"%I%l%9$rHf3S7F!"F10l%V%m%C%/XN%Q%1%C%H$,B8:_$9kJiPAw?.%P%C%U%!NI$N%(%s%H%j$H0lCW7?$+$rSBHE $K=q$-9~$`!#<u?.%P%C%U%!$+$i2<!%-%c%C%7%e$K=q$-9~$`$H$-$K!"$^$@Aw?.%P%C%U%!$K%Q%1%C%H$,B8:_9l$P%b%G%#%U%!%$%I!&S%C%H$H>uBV$rAw?.%P%C%U%!$+$iFI$_=P$9!#Aw?.%P%C%U%!$+$iFI$_=P$7$?2<!%-%c%C%7%e$N>uBV$+$i!"Aw?.%P%C%U%!$KB8:_$9kN$,%9%H%"!&R%C%H$KH<$&%Q%1%C%H$G$"$l$P!">uBVA+0\$O!IL58z2=9k>l9g$r=|$$$F$O!K9T$o$:!"$^$?!"%b%G%#%U%!%$%I!&S%C%H$,$?CF$$$k%"%I%l%9KO=q$-9~$_$r9T$o$J$$!#



?^20: =q$-9~$_J]8n@)8f

$^$?!"%b%G%#%U%!%$%I!&S%C%H$OF10l%V%m%C%/Fb$NO[$J$k%"%I%l%9$KFsDN%W%m%;%C%5$,$[$\F1;~$K%9%H%"$r9T$C$F!"$=lKHb$J$$L58z2=%H%i%s%6%/%7%g%s$r9T$&>l9g$K!"$IAi$+$N%-%c%C%7%e$KN>J}$N%9%H%"$N7k2L$r;D9?aK$bMQ$$$ilk!#5.4@aG3$N;~$NF0:n$N>\:Y$r=RYk!#

5.4 F0:nNc

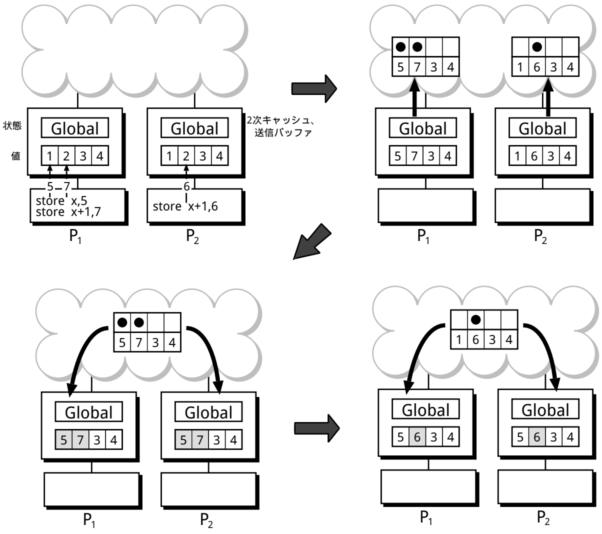
5.3@a$G=R$Y$?5!9=5Z$S@)8fKh$j!"F101%"%I%l%9$KBP7FJ#?t$N%W%m%;%C%5$+$i%a%b%j!&"%/%;%9$,J5l?H-Kb!"$=$7$FF10U%V%m%C/Fb$NO[Jk%"%I%l%9KBP7$FJ#?t$N%W%m%;%C%5$+$i%a%b%j!&"%/%;%9$,$J5l$?$H$-$K$b!VG=*E*$K$O%-%&%C%7%e4V$GL7=b$,@8$8$J$$!W3H$,K~$?5l$F$$$k!#

K\@aGO4vD+$N>u67$K$*$1$kF0:n$KBP7F:G=*E*KOL7=b$,@8$8$J$$$3H,K~$?$5lk3H$r<($9!#K\@a$G5s$2$k0J30$N>u67K*$$$F$b!"0J2<$G5s2kF0:nNc$HF1MM$J=hM}$,9T$olk3HKh$j:G=*E*$K$OL7=b$,@8$8$J$$$3H,K~$?$5lF$$$k!#

6&M->uBV$,%/%i%9%?4V$K$^$?$,$kH-$N99?7%9%H%"$N6%9g

$^$:!"%V%m%C/$N6&M->uBV$,%/%i%9%?4VK^$?$,CF$$$k>u67$G!"Fs$D$N%W%m%;%C%5$,$[$\F1;~$K99?7%9%H%"$r9TC?;~$N=hM}$NN.lr<($9!#

JUMP-1 GO!"99?7%9%H%"KHbJ$$$B>$N%-%&%C%7%e$NCM$r99?7$9kH$-$O!"%V%m%C/FbA4ItNCMr99?7$9$kNGOJ$/!"%9%H%"$,9Tol$?%"%I%l%9$NCM$@$1$r99?7$9kh$&$KJC$F$$$k!#3N;~$N=hM}$NN.lr?^21$K<($9!#



?^21: %0%m!<%P%k$N>u67$G$N99?7%9%H%"$N6%9g

$^$:!"$P_1$$,%"%I%l%9x $*$hSx + 1$ KBP7$FO"B3E*$K99?7%9%H%"$r9T$$!"$P_2$$,%"%I%l%9$x + 1$ KBP7$F99?7%9%H%"$r9TC?H9$k!#$3$N:]!"$P_1$$+iNFsDN%9%H%"$O%^!<%8$5lF!"0lDN%H%i%s%6%/%7%g%s$GB>%-%&%C%7%e$N99?7=hM}$,9T$olkH9$k!#

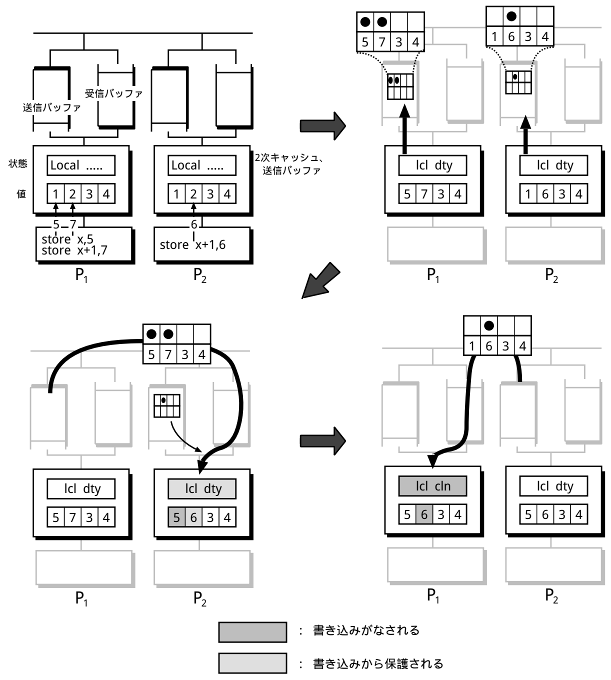
3N%9%H%"KHbJ$$!"3F%W%m%;%C%5!&f%K%C%H$NFs<!%-%&%C%7%e$OCM$,Ej5!E*$K=q-49(il!"B>%-%&%C%7%e$r99?7$9k?aN%Q%1%C%H$,Aw=P$5lk!J?^21 0lCJL\1&!K#3N%Q%1%C%HKO!"%V%m%C/FbNI$N%"%I%l%9$KBP7F%9%H%"$,9T$ol?$+$,5-O?5l$F$$$k!J●J0u!K#

$=$N8e!"FsDN%H%i%s%6%/%7%g%s$,%7%j%"%i%$%:5l$k!#$IAi$N%H%i%s%6%/%7%g%s$b6&M->uBV$,%/%i%9%?4V$K$^$?$,$C$F$$$k;~$N%9%H%"$KH<$&%H%i%s%6%/%7%g%s$G$"$k$+$i!"5.2@a$G=R$Y$?$h$&$K%7%j%"%i%$%:$5l?8eI,$:A4It$N%-%&%C%7%e$r>e=q$-9k!#3N;~$P_1$$+iN%H%i%s%6%/%7%g%s$,!@h!W$KJC$?$H9k$H!"N>J}$N%-%&%C%7%eKP_1$$+iN%9%H%"$KH<$&99?7%Q%1%C%H$,E~C#$9$k!#$=7F!"%Q%1%C%HNCfK5-O?5l$F$$$k!V%H%"$,9T$ol?%"%I%l%9!W$rMxMQ$7$F%-%&%C%7%e$NCM$r99?7$9$k!J?^21FsCJL\:8!K#$=$N8e!"$P_2$$+iN99?7%Q%1%C%H$bE~C#$9$k!#$3$N%Q%1%C%H$,E~C#7?H-$bF1MM$J=hM}Kh$j=q$-9~$_$,9Tol$k!J?^21FsCJL\1&!K#

0J>e$N=hM}$NN.lKhj!"?^21$K<($9h&$K:G=*E*$K$ON>J}$N%-%&%C%7%e4V$KL7=b$O@8$8$J$$!#

6&M->uBV$,%/%i%9%?Fb$KJD8kH-$N99?7%9%H%"$N6%9g >e$G=R$Y$?$h$&$K!"99?7%9%H%"$KH<$C$FB>%-%&%C%7%e$r99?7$9$kH-$O%V%m%C/A4It$NCM$r=q$-49$($kNGOJ$/!"%V%m%C/Fb$N%9%H%"$r9T$C$?%"%I%l%9$@$1=q$-49$($k!#3l$O6&M->uBV$,%/%i%9%?4VK^$?$,CF$$$h$&$H$$"$k%/%i%9%?Fb$KJD8F$$$h$&$,F1$8$G$"$k!#

6&M->uBV$,%/%i%9%?4V$K$^$?$,$C$F$$$kH-$H%/%i%9%?Fb$KJD8F$$$kH-HG0[JkNO!"Ej5!E*=q$-9~$_$r9T$C$?%-%&%C%7%e$KBP9k>e=q$-$r9k$+$7$J$$$+G"$k!#$9Jo$A!"%/%i%9%?4V$K$^$?$,$C$F$$$kH-$O>e$G=RY?h&$K%7%j%"%i%$%:5l$?8eI,$:A4It$N%-%&%C%7%e$KBP7F>e=q$-$r9T$&$,!"0lJ}!"%/%i%9%?FbKJD8$F$$$kH-$O5.2@a$G=RY?h&$K!"Ej5!E*$K=q$-9~$_$,9T$ol?%-%&%C%7%e!&V%m%C/$N>uBVA+0\$*hS$=$N%V%m%C/Fb$N%9%H%"$,9Tol$?%"%I%l%9$NCM$N99?7$,J]8n5l$k!#



?^22: %m!<%+%k$N>u67$G$N99?7%9%H%"$N6%9g

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$^$:!"$=$l$>$l$N%9%H%"$KHb$J$$!"3F%W%m%;%C%5!&f%K%C%H$NFs<!%-%&%C%7%e$KBP7FEj5!E*$JCM99?7$H>uBVA+0\$,9Tol$k!#$=lHF1;~$KAw?.%P%C%U%!$KB>%-%&%C%7%e$r99?7$9k?

\$a\$N%Q%1%C%H\$,=q\$-9~\$^\$l\$k!#\$3\$N;~Aw?.%P%C%U%!\$N MDFD %U%#!<%k%I!J?^13;2>H!K\$K%V%m%C%/Fb\$N\$I\$N%"%I%l%9\$K%9%H%"\$,9T\$o\$l\$?\$+\$bF1;~\$K5-O?\$5\$l\$k!J?^220lCJL\1&!K#

\$3\$N8e!"\$I\$A\$i\$+\$N%W%m%;%C%5!&f%K%C%H\$+\$i%Q%1%C%H\$,%P%9\$KBP\$7\$FAw=P\$5\$l\$k!#:#!"P_1\$+\$i\$N%Q%1%C%H\$,@h\$KAw=P\$5\$l\$?\$H\$9\$k!#\$3\$N%Q%1%C%H\$,P_2\$N<u?.%P%C%U%!\$KFO\$\$\$?\$H\$-!"?^20\$N5!9=\$rMQ\$\$\$FP_2\$NAw?.%P%C%U%!\$r8!:w\$9\$k\$HF10l%V%m%C%/\$X\$N99?7%Q%1%C%H\$,B8:_\$7\$F\$\$\$k\$3\$H\$,J,\$+\$k!#\$3\$N\$?\$a!"P_1\$+\$i\$N99?7>pJs\$r2<!%-%&%C%7%e\$K=q\$-9~\$`:]\$K%-%&%C%7%e!&%V%m%C%/\$N>uBVA+0\$H%"%I%l%9 $x+1$ \$NCM99?7\$O9T\$o\$J\$\$!\$J?\$@\$7!"%"%I%l%9 x \$NCM99?7\$O9T\$&!#!K#

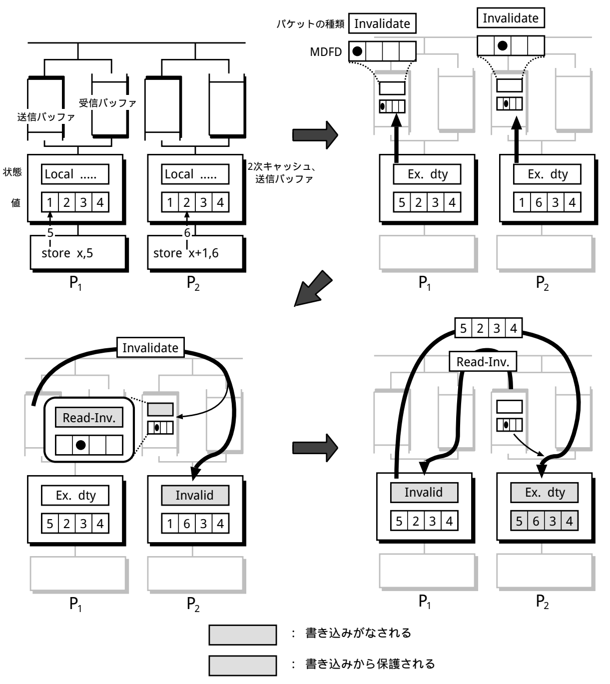
\$=\$N8e!"P_2\$+\$i%Q%1%C%H\$,Aw=P\$5\$l\$k!#\$3\$N%Q%1%C%H\$,P_1\$KFO\$\$\$?\$H\$-\$K\$O!"P_1\$NAw?.%P%C%U%!\$K\$O4{\$K99?7%Q%1%C%H\$OB8:_\$7\$F\$\$\$J\$\$\$N\$GP_1\$N2<!%-%&%C%7%e\$KBP\$7\$F\$ODL>o\$N99?7=hM}!"\$9\$J\$o\$Alocal clean \$X\$N>uBVA+0\$H%"%I%l%9 $x+1$ \$NCM99?7\$,9T\$o\$l\$k!#

0J>e\$K<(\$9N.\$l\$K\$h\$j!":G=*E*\$K%-%&%C%7%e4V\$GL7=b\$,@8\$8\$F\$\$\$J\$\$\$3\$H\$,J,\$+\$k!#

6&M->uBV\$,%/%i%9%?Fb\$KJD\$8\$k\$H\$-\$NL58z2=%9%H%"\$N6%9g

Fs\$D\$N%W%m%;%C%5\$+\$i\$[\$\F1;~\$KF10l%V%m%C%/Fb\$N0[\$J\$k%"%I%l%9\$XL58z2=%9%H%"\$,9T\$o\$l\$?\$H\$-\$K\$O!"\$I\$A\$i\$+\$N%W%m%;%C%5!&f%K%C%H\$N2<!%-%&%C%7%e\$KN>J}\$N%9%H%"\$N7k2L\$r;D\$9\$?\$a\$N=hM}\$,\$J\$5\$l\$k!#

\$3\$N\$?\$a\$K JUMP-1 \$K\$*\$\$\$F\$O!"5.3.29`\$N:G=*7k2L\$N>e=q\$-@)8f\$d5.3.39`\$N%H%i%s%6%/%7%g%s\$N<oN`JQ99@)8f!"\$=\$7\$F5.3.49`\$N=q\$-9~\$_J]8n5!9=\$r%U%k3hMQ\$7\$F\$\$\$k!#=hM}\$NN.\$l\$r?^23\$K<(\$9!#



?^23: %m!<%+%k\$N>u67\$G\$NL58z2=%9%H%"\$N6%9g

P_1\$,%"%I%l%9 x \$KBP\$7\$FL58z2=%9%H%"\$r!"P_2\$,%"%I%l%9 $x+1$ \$KBP\$7\$FL58z2=%9%H%"\$r\$=\$l\$>\$l9T\$C\$?\$H\$9\$k!#\$^\$:!"\$=\$l\$>\$l\$N%9%H%"\$K\$H\$b\$J\$\$!"3F%W%m%;%C%5!&f%K%C%H\$NFs<!%-%&%C%7%e\$KBP\$7\$FEj5!E*\$JCM99?7\$H>uBVA+0\$,9T\$o\$l\$k!#\$=\$l\$HF1;~\$KAw?.%P%C%U%!\$KB>%-%&%C%7%e\$rL58z2=\$9\$k\$?\$a\$N%Q%1%C%H\$,=q\$-9~\$^\$l\$k!#\$3\$N;~Aw?.%P%C%U%!\$N MDFD %U%#!<%k%I!J?^13;2>H!K\$K%V%m%C%/Fb\$N\$I\$N%"%I%l%9\$K%9%H%"\$,9T\$o\$l\$?\$+\$bF1;~\$K5-O?\$5\$l\$k!J?^230lCJL\1&!K#\$3\$3\$^\$G\$O!"%V%m%C%/\$N6&M->uBV\$,%/%i%9%?Fb\$KJD\$8\$F\$\$\$k\$H\$-\$KFs\$D\$N%W%m%;%C%5\$+\$i99?7%9%H%"\$,9T\$o\$l\$?\$H\$-\$H\$[\$\F1\$8N.\$l\$G=hM}\$5\$l\$k!#

\$3\$N8e!"P_1\$+\$i%Q%1%C%H\$,%P%9\$KN.\$l\$FP_2\$KFO\$\$\$?\$H\$-!"2<!%-%&%C%7%e\$rL58z2=\$9\$k\$,!"\$3\$N:]\$K?^19\$N5!9=\$rMQ\$\$\$F!"P_2\$NAw?.%P%C%U%!\$+\$iH/\$;\$i\$l\$k%Q%1%C%H\$N<oN`\$rJQ99\$9\$k@)8f\$,9T\$o\$l\$k!#\$3\$N%Q%1%C%HJQ99@)8f\$K\$h\$j!"P_2\$+\$iH/\$;\$i\$l\$k%Q%1%C%H\$OL58z2=%9%H%"\$,%-%&%C%7%e!&_%9\$7\$?:]\$KH/\$;\$i\$l\$k%Q%1%C%H!"\$9\$J\$o\$AI=6\$K<(\$9\$h\$&\$KL58z2=7sFI\$_\$@\$7%H%i%s%6%/%7%g%s\$N\$?\$a\$N%Q%1%C%H\$H\$J\$k!J?^23FsCJL\:8!K#

\$=\$N8e!"P_2\$+\$i%Q%1%C%H\$,H/\$;\$i\$l\$k!#\$?\$@\$7!"\$3\$N%H%i%s%6%/%7%g%s\$O1~Ez\$rMW\$9\$k\$?\$a%Q%1%C%H\$rAw=P\$7\$F\$bAw?.%P%C%U%!\$N%(%s%H%j\$r2rJ|\$7\$J\$\$!#P_2\$+\$i\$N%Q%1%C%H\$,P_1\$KE~C#\$9\$k\$H!"P_1\$N%-%&%C%7%e\$OL58z2=\$5\$l\$k\$HF1;~\$KP_2\$KBP\$7\$F1~Ez\$rJV\$9!#\$=\$7\$F!"1~Ez\$,P_2\$KFO\$/\$3\$H\$K\$h\$j:G=*7k2L\$N>e=q\$-\$,9T\$o\$l\$k!J5.3.29`;2>H!K#\$?\$@\$7\$3\$N:]$P_2$\$N%9%H%"\$N7k2L\$b%-%&%C%7%e\$K;D\$9\$?\$a\$K!"5.3.49`\$G=R\$Y\$?\$h\$&\$KAw?.%P%C%U%!\$KB8:_\$9\$k%b%G%#%U%!%\$%I!&S%C%H\$rMxMQ\$9\$k!#\$9\$J\$o\$A!"1~Ez\$,P_2\$KJV\$C\$F\$-\$?\$H\$-%V%m%C%/A4BN\$NCM\$r=q\$-49\$(\$k\$N\$G\$O\$J\$/!"%b%G%#%U%!%\$%I!&S%C%H\$,N)\$C\$F\$\$\$k%"%I%l%9\$NCM\$O=q\$-49\$(\$J\$\$!J?^23FsCJL\1&!K#

0J>e\$K<(\$9=hM}\$NN.\$l\$K\$h\$j!"P_1,P_2\$NN>J}\$N%9%H%"\$N7k2L\$,P_2\$N%-%&%C%7%e\$KB8:_\$9\$k\$3\$H\$,J,\$+\$k!#

6&M->uBV\$,%/%i%9%?4V\$K\$^\$?\$,\$k\$H\$-\$NL58z2=%9%H%"\$N6%9g

\$3\$N;~\$O6&M->uBV\$,%m!<%+%k\$N;~\$H\$[\$\F1\$8N.\$l\$G9T\$o\$l\$k!#0[\$J\$k\$N\$O!"%H%i%s%6%/%7%g%s\$NJQ99@)8f\$,9T\$o\$l\$J\$\$\$3\$H\$G\$"\$k!#\$D\$^\$j!"6&M->uBV\$,%m!<%+%k\$N;~\$OEj5!E*=q\$-9~\$_\$r9T\$C\$?%-%&%C%7%e\$,L58z2=\$5\$l\$?\$H\$-\$N\$_:G=*7k2L\$r>e=q\$-\$9\$k\$h\$&\$K!"?^23FsCJL\1&\$K<(\$9\$h\$&\$KL58z2=\$5\$l\$?\$3\$H\$r8!=P\$7\$F%H%i%s%6%/%7%g%s\$N<oN`\$rJQ99\$9\$k@)8f\$,9T\$o\$l\$k!#0lJ}!"6&M->uBV\$,%0%m!<%P%k\$N;~\$O!"Ej5!E*=q\$-9~\$_\$r9T\$C\$?%-%&%C%7%e\$,L58z2=\$5\$l\$h\$&\$,\$5\$l\$^\$\$\$,!">o\$K:G=*7k2L\$r>e=q\$-\$9\$k\$?\$a\$K%H%i%s%6%/%7%g%s\$N<oN`JQ99@)8f\$O9T\$o\$l\$J\$\$!#

6 \$*\$o\$j\$K

K\9F\$G\$O!"A+0\E*L7=b\$rH<\$&0l4S@-@)8fJ}<0\$G\$"\$k TIS-CC \$r<(\$7!"\$3\$NJ}<0\$ND6JBNs7W;;5!JUMP-1 \$KBP\$9\$k<BAuNc\$r=R\$Y\$?!#

4.2@a\$G=R\$Y\$?\$h\$&\$K!"TIS-CC \$O=>MhJ}<0\$KBP\$7\$F!"%W%m%0%i%^%S%j%F%#\$rFq\$7\$/\$9\$k\$3\$H\$J\$/@-G=8~>e\$,4|BT\$G\$-!"\$5\$i\$K4|BT\$G\$-\$k@-G=8~>e\$O:#8e5;=Q\$N?JJb\$K\$h\$jH/E8\$,8+9~\$^\$l\$k!"5,LO\$,Bg\$-\$JJBNs7W;;5!\$[\$I82Cx\$G\$"\$k\$3\$H\$,M=A[\$5\$l\$k!#

0lJ}\$G!"TIS-CC \$O\$h\$j@-G=8~>e\$rL\;X\$9\$H<BAu%3%9%H\$,9b\$/\$J\$k\$?\$a!"8=:_\$^\$G\$3\$NJ}<0\$r<BAu\$7\$?7W;;5!\$O\$[\$H\$s\$I\$J\$\$!#\$7\$+\$7!"JUMP-1 \$K\$*\$1\$k<BAuNc\$G<(\$7\$?\$h\$&\$K!"<BAu%3%9%H\$O7h\$7\$FHs8=<BE*\$J\$b\$N\$G\$O\$J\$\$!#JUMP-1 \$K\$*\$1\$k<BAuNc\$r:#8e\$N7W;;5!3+H/\$N:]\$N;29M\$H\$7!"?tB?\$/\$N7W;;5!\$KBP\$7\$F<BAu\$9\$k\$3\$H\$G!"<BAu5;=Q\$N3NN)\$O\$J\$5\$l\$k\$b\$N\$H9M\$(\$k!#

:#8e\$N2]Bj\$H\$7\$F\$O!"TIS-CC \$N<BAu5;=Q\$r3NN)\$9\$k\$3\$H\$H!"TIS-CC \$N87L)\$J@-G=I>2A\$r9T\$&\$3\$H\$,5s\$2\$i\$l\$k!#

<UK-

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

$^$?!"5.=EJ4=u8@$r$$$?$@$$$?CfEg9@=u65<x!"?9bC0lO:=u65<x!"8^Eg@5M5=u<j$K?<$/46<UCW7^$9!#

5i$K!$6&F18&5f<TG"$k=.K\015W;a!";3K\9M?-;a$rO8aH7F!$F|:"$+$i8fJ\Z%2<$5C?5~ETBg3XBg3X1!9)3X8&5f2J>pJs9)3X65<<IYED8&5f<<$N=t7;$K46<UCW7^$9!#

;29MJ88%

[1] John L.Hennessy,David A.Patterson !JJYED bC<#!"B<>e OB>4!"?7Ui<#CKLu!K !V3%s%T%e!<%?!&"!<%-%F%/%A%c!W F|7PBP<R 1992 G/12 7n

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[14] Aj8_7k9gLV$H%k!<%?. J8It>J=EE@NN0h8&5f. D6JBNs86M}$K4p$E$/>pJs=hM}4pK\BN7O. Bh#32s%7%s%]%8%&%`M=9F=8.pp.257-279. 1993 G/9 7n