JBNs%"%W%j%1!<%7%g%s$r;X8~$7$?J,;6%7%9%F%`
%3%s%T%e!<%?!&%3%m%K!<$N9=A[

;3 E: Gn ;K[†] ED Cf ?5 ;J[††] 0K C# ?7 :H[††]
8^ Eg @5 M5[†] ?9 bC 0l O:[†] IY ED bC <#[†]

K\8&5fGO!"JBNs%"%W%j%1!<%7%g%s$N<B9T$r;X8~7?J,;6%7%9%F%`$H$7$F"%3%s%T%e!<%?!&%3%m%K!<"$rDs0F$9$k!#%3%s%T%e!<%?!&%3%m%K!<$O!"%M%C%H%o!<%/$G7k9g$5$l$?MWAG%^%7%s72$H!"J,;64D6-$K$*$1$kJBNs=hM}$r;Y1g$9$k%*%Z%l!<%F%#%s%0%7%9%F%`"Colonia" $G9=@.$5$l!"6&M-%a%b%j$r%Y!<%9H7$?Dc%3%9%H$JDL?.5!9=$rDs6!$9$k!#

9bB.$J%a%b%j"%/%;%9$N$?$aKO!"%-%c%C%7%e$NMxMQ$,IT2D7gG"$k!#%j%b!<%H%a%b%j$NFbMF$r%m!<%+%k%a%b%j$"$k$$$O%W%m%;%C%5$KImB0$9$k%-%c%C%7%e$KCV$/$3HG!"9bB.$J%a%b%j"%/%;%9$,4|BTG-$k!#$hCF!"%3%s%T%e!<%?!&%3%m%K!<$,9bB.$+$DDcCY1d$J6&M-%a%b%j"%/%;%9$r<B8=$9kK$O!"%-%c%C%7%e%3%R!<%l%s%7%W%m%H%3%k$,@)8f2DG=$JDL?.%O!<%I%&%'%"$,MW5a$5lk!#

Computer Colony: A Distributed System for Efficient Execution of Parallel Applications

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Masahiro Goshima,[†] Shin-ichiro Mori[†] and Shinji Tomita[†]

We propose "computer colony", which is a distributed system oriented for the execution of parallel applications. Computer colony consists of machines connected with networks, and operating system "Colonia", it provides us a low-cost communication mechanism based on shared memory.

Effective use of cache is indispensable for fast memory access. Memory access is expected to become fast by bringing contents of remote memory on local memory or cache belong to processors. Therefore, to achieve fast and low-latency shared memory access, computer colony requires a communication hardware which can operate cache-coherency protocol.

1. O8aK

Hf3SE*Dc%3%9%H$GF3F~$d3HD%$,2DG=$JJ,;6%7%9%F%`$,!"$5$^$6$^$J>lLL$G3hMQ$5$l$F$$$k!#%G%#%9%/$d%W%j%s%?$J$I$N;q8;$,%M%C%H%o!<%/7k9g$5$l$F$$$F6&M-MxMQ$G$-!"DL>o$N6HL3$r9T$&$K$O==<J,$J4D6-$,@0$C$F$$$k!#$7$+$7!"$H$-$KBg5,LO$J%8%g%V$rEjF~$9$kI,MW$,$"$k$H!"J,;6%7%9%F%`$O1Bf$NMWAG%^%7%s$N@-G=0J>e$NbN$r=P$9$3$H$,$G$-$:!"<B9T$KHs>o$KD9$$;~4VrMW9$k!#$^$?!"$=$N1Bf$KHs>o$K=E$$I i2Y$,$+$+$k3HKJ$j!"B>$N%f!<%6O=$N%^%7%s$G$N6HL3$r9T$&$3H,$[$HsIG-$J$$!#

K\8&5fGO!"J,;6%7%9%F%`$K$OBg$-$JL%NO$,$"$k$,!"$=$NC1$J$k1dD9$N$_$G$O$3$l$i$NLdBjE@$r9nI~$G$-$J$$$H9M$(!"?7$7$$7W;;5!%7%9%F%`H7$F"%3%s%T%e!<%?!&%3%m%K!<" $rDs0F$7!"%O!<%I%&%'%"$H%=%U%H%&%'%"$r:F9=@.9k!#<!$K!"%3%s%T%e!<%?!&%3%m%K!<$NL\I8$r5s2k!#

Dc2A3J@- <B:]$NLdBj$H7FL5;kG-$J$$$N$,2A3J$NLdBjG"$k!#0lHL$N%f!<%6$K<j$,FO$+$J$$$2A3J$NBg7?JBNs7W;;5!$JIGOJ$/!"$bCH?H6a$KF3F~$d3HD%$,$G$-$k%7%9%F%`$,I,MW$G$"$k!#

7W;;5!;q8;$NM-8z3hMQ J#?t$"$k7W;;5!$N%W%m%;%C%5;q8;$rM-8z$KMxMQ9kKO!"JBNs=hM}$,M-8z$G$"$k!#SMP(BP>N7?%^%k%A%W%m%;%C%5) 5!$NIa5Z$KH<$$!">-Mh$OJBNs%"%W%j%1!<%7%g%s$NA}2C$,4|BT$5$l!"JBNs=hM}$r9T$&0U5A$,Bg$-$/Jk$H9M$(il$k!#

%^%k%A%f!<%64D6- %f!<%6$=$l$>$l$,MW5a$9$kQoS(Quality of Service) $rK~B-$7DD!"FCDj$N%f!<%6$N$_$,

---

[†] 5~ETBg3XBg3X1!9)3X8&5f2J>pJs9)3X@l96
Division of Information Science, Graduate School of Engineering, Kyoto University

[††] 5~ETBg3X9)3XIt>pJs9)3X2J
Department of Information Science, Faculty of Engineering, Kyoto University

7W;;5!;q8;$r@jM-$9k3HN$J$$$h$&!"%7%9%F%`

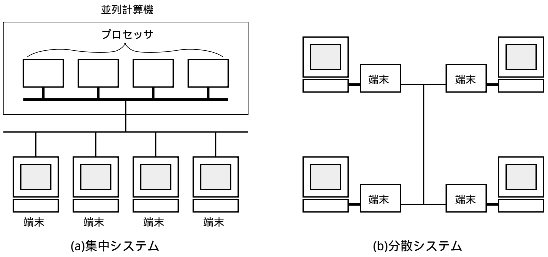
A4BNKOKk%9%1%8%e!<%j%s%0$,I,MW$G$"$k!#

0J2<!"2>O$G8=:_$N7W;;5!%7%9%F%`$NGX7J$K$D$$$F!"3>O$G%3%s%T%e!<%?!&%3%m%K!<$N35MWKD$$$F!"4>O$GK\8&5f<<$G$N<B834D6-$N<BAuKD$$$F=RYk!#

2. GX 7J

2.1 =8Cf%7%9%F%`$HJ,;6%7%9%F%`

J#?t$N%W%m%;%C%5$r4^$`7W;;5!4D6-$H$7$F$O!"<g$K=8Cf%7%9%F%`$HJ,;6%7%9%F%`$N2$D$,5s$2$i$l$k!#=8Cf%7%9%F%`$O1$D$Nc~BN$KB??t$N%W%m%;%C%5$rEc:\$7$FJBNs7W;;5!$r9=@.$7!"%f!<%6$OC<KvrDL7$FMxMQ$9kH$$$&bNG"$j(?^1(a))!"J,;6%7%9%F%`$OC<KvH7Fb;H$($k!"FHN)7?7W;;5!$r%M%C%H%o!<%/7k9g$9kH$$$&bNG"$k(?^1(b))!#0J2<!"$$$/D+$N4QE@$+$iN><T$rHf3S9k!#



(a)集中システム

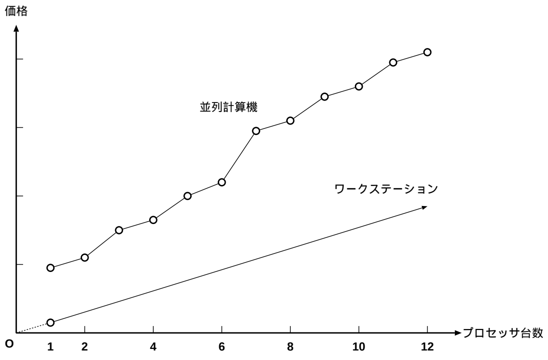
(b)分散システム

?^1 =8Cf%7%9%F%`$HJ,;6%7%9%F%`

2A3J@-G=Hf

7W;;5!$rF3F~$9kK$"$?CF!"$=$N2A3J$O=EMW$JH=CG:`NA$G$"$k!#$$$+$K9b@-G=$J%7%9%F%`G"CF$b!"M=;;$N8B3&$r1[$(F7$^$CFO8=<BE*$KF3F~$OIT2DG=G"$k!#

?^2$K!"F1<o$N%W%m%;%C%5$G9=@.$5lk!"$"$kJBNs7W;;5!$H%o!<%/%9%F!<%7%g%s$N%W%m%;%C%5Bf?t$H2A3J$N4X78$r<($9!#3l$@$1$GJBNs7W;;5!$H%o!<%/%9%F!<%7%g%s$N2A3J$K$OG\0J>e$N3+$-$,$"$k3H$,J,$+$k!#



?^2 JBNs7W;;5!$H%o!<%/%9%F!<%7%g%s$N2A3J

3l$O!"JBNs7W;;5!$OHNGdBf?t$,>/$J$/BgNL@8;:$,G-$J$$$,!"%o!<%/%9%F!<%7%g%sJIGOBgNLHNGd!"BgNL@8;:KhCFDc2A3J2=$,5/$3CF$$$k$?$a$H?dB,$5lk!#3N>u67$O5;=Q3W?7$JIKhCFOJQoi$:!"JBNs7W;;5!$NDc2A3J2=$O:#8e$b5/3i$J$$$H9M$($ilk!#

3HD%@-

=8Cf%7%9%F%`$G$O%W%m%;%C%5$,6aK5$KG[CV$5$l$k$?$a!"%W%m%;%C%54V$NJ*M}E*$JDL?.B.EY$N8~>e$OMF0W$G$"$k$,!"$3$l$O3HD%@-$r5>@7$K$7$?>e$G$N$3$H$G$"$k!#3N$+$K%W%m%;%C%5$r1$D$Nc~BNFb$K8GDj$7$FG[CV$9$l$PFbIt$G$N9bB.2=$O$7$d$9$$$,!"H?LL%W%m%;%C%5$N8r49$dDI2C$OJ,;6%7%9%F%`HHfY$F@)8B$,B?$$!#

8=;~E@$G:G$b9bB.$J7W;;5!$r9XF~7?H7Fb!"$=$lO9$0$K!CY$$!WItN`$N7W;;5!$KJCF7$^$&!#$=$Nh&JH$-$K3HD%@-$KK3$7$$JBNs7W;;5!$O!"$=$N;q8;$r:FMxMQ9k3H$,:$FqG"$j!"$$$:lO40A4$K<N$F@ZCF?7$7$$7W;;5!$KF~$l49$($kI,MW$,$"$k!#

3lKBP7J,;6%7%9%F%`$NBg$-$JFCD'$H$7$F$O!"=@Fp$J3HD%@-$,5s$2$i$l$k!#J,;6%7%9%F%`$r9=@.$9$kMWAG%^%7%s$O4pK\E*$KFHN)$7F*$j!"%"%C%W%0%l!<%I$dMWAG%^%7%sBf?t$NDI2C$N@)8B$OHf3SE*4K$d$+$G$"$k!#3N3HKhCF!"4{B8$N7W;;5!;q8;$r7QB3$7$FM-8z$K3hMQ$G$-$k!#

%^%k%A%a%G%#%"XNBP1~

J,;6%7%9%F%`$O=8Cf%7%9%F%`KHfY$F%^%k%A%a%G%#%"=hM}$K8~$$$F$$$k$H$$$&FCD'$,$"$k!#F02h$N:F@8JIKO9bB.$J2hA|=hM}$,I,MWG"k,!"$=$lKO%W%m%;%C%5$H%0%i%U%#%C%/%9!&"%/%;%i%l!<%?$,$h$j6a@\$7$F7k9g$5lF$$$kI,MW$,$"$k!#J,;6%7%9%F%`$r9=@.$9$kMWAG%^%7%s$,$3$N$h$&$J9=@.$r$H$k$3$H$OMF0W$@$,!"=8Cf%7%9%F%`$K$*$$$F$O%G%#%9%W%l%$$HJBNs7W;;5!K\BN$,N%$l$F$$$k$?$a3Nh&$J9=@.$rHk3H$O:$FqG"$k!#

3Nh&$KJ,;6%7%9%F%`$O!"<g$K=hM}$N9bB.2=$K=EE@$rCV$/=8Cf%7%9%F%`$HO[Jj!"2A3J@-G=Hfd=lrJd$&3HD%@-$JI+$i!"0lHL%f!<%6$KHCFh$j?H6a$G$"$k!#3N$?$a!"9b2A$JJBNs7W;;5!$rCf?4H9$k=8Cf%7%9%F%`$hjbIa5Z7F$*$j!"MxMQ7d$9$$4D6-HJCF$$$k!#

2.2 =>Mh$NJ,;6%7%9%F%`$NLdBjE@

J,;6%7%9%F%`$O!"Dc2A3J$GMxMQ$G$-$k$?$a0lHL$N%f!<%6$K$H$C$F?H6a$G$"$j!"$^$?3HD%@-$d%^%k%A%a%G%#%"$X$NE,@-$r9MN8$9$k$H!">-MhE*$K2DG=@-$N9b$$%7%9%F%`G"$k!#$7$+$7!"=>Mh$NJ,;6%7%9%F%`$G$O!"%M%C%H%o!<%/7k9g$5l?7W;;5!;q8;$N@-G=$r:GBg8B$KH/4x$5$;$k3HOG$-$J$$!#3l$O!"<!$K5s2k;vJA$,M}M3

H7$F9M$(il$k!#

- DL?.%3%9%H$,9b$$
- M-8z$JIi2YJ,;6$,?^il$F$$$J$$
- %^%k%A%f!<%6XNBP1~$,IT==J,

JBNs2=5l$?%"%W%j%1!<%7%g%s$r<B9T5;h&H7Fb!"DL?.%3%9%H$,9b$1lPE~DlJBNs2=$N8z2L$O4|BTG-$J$$!#$^$?b7!"DL?.%3%9%H$r=<J,Dc$/G-$?$H7F$b!"Ii2YJ,;6$d%^%k%A%f!<%6XNBP1~JI!"5^6^$J0UL#$G$NF)2a@-$K7g1F$$$k!#0J2<!">e$NM}M3$N$=$l$>$lKD$$$F=RYk!#

DL?.%3%9%H$,9b$$

J,;6%7%9%F%`$K$*$1$k%M%C%H%o!<%/$r7PM3$7$?DL?.$O!"=8Cf%7%9%F%`K*1kJBNs7W;;5!Fb$N%W%m%;%C%54V$NDL?.KHfY!"=>Mh$NJ}K!$G$O%3%9%H$,9b$$!#h/8+il$kDL?.J}K!$O!"%7%9%F%`%3!<%k$r2p$7$F I/O $K%"%/%;%9$9$k$3$H$GDL?.$r3NN)$7!"%i%$%V%i%j$rMQ$$$F%a%C%;!<%8DL?.$d6&M-%a%b%j$r<B8=$9$k$H$$$&$b$N$G$"$k!#$3$N$h$&$JJ}<0$G$O$$$/$i%M%C%H%o!<%/$,9bB.$G$b!"$=$3$K;j$k$^$G$N2aDx$K$*$$$F%i%$%V%i%j$d%7%9%F%`%3!<%kJI!"%=%U%H%&%'%"Kh$k%*!<%P!<%X%C%I$,Bg$-$$!#3lGO:YN3EY$NJBNs=hM}$r9T$&$H!"$+$(CF=hM}@-G=$,Mn$A$k2DG=@-$5$($"$k!#

M-8z$JIi2YJ,;6$,?^il$F$$$J$$

JBNs=hM}$rM-8z$K<B9T9kKO!"9bB.$JDL?.$r<B8=9kHHbK!":GE,$JIi2YJ,;6$r9T$&$3H,=EMWG"$k!#Ii2Y>u67$O9o!9$HJQ2=$9kN$G!"%7%9%F%`A4BN$,>o$K8=;~E@$G$NIi2Y>u67$rGD0.$7!"E,@Z$JIi2Y$NG[CV$r9ToJ1lPJiJ$$!#

=>Mh$NJ,;6%7%9%F%`$K$*$$$F$O!"7W;;5!$N=hM}G=NO$dIi2Y>u67$r%f!<%6$,GD0.$7!"L@<(E*$KIi2Y$NG[CV$r;XDj$7J1lPJi$J$$!#3lGOIi2Y>u67$NJQ2=$K$OBP1~$G$-$:!":GE,$JIi2YJ,;6$O9Tol$J$$!#

%f!<%6$OJ,;6%7%9%F%`$rC10l$N9b@-G=7W;;5!$H$7$F$H$i$($F=hM}$rEjF~$7!"%7%9%F%`$,<+F0E*$KIi2Y$r4IM}7F6Q<A2=9k$H$$$&3H$,I,MW$G$"$k!#

%^%k%A%f!<%6XNBP1~$,IT==J,

F02h$d2;@<$N:F@8JI!"%j%"%k%?%$%`@-$N9b$$%"%W%j%1!<%7%g%s$N<B9T$K$O!"0lDj;~4V$4$H$K0lDj$N=hM}G=NO$N3d$jEv$F$,I,MW$G$"$k!#$3$N$h$&$K!"%f!<%6$,<B9T$9$k%"%W%j%1!<%7%g%s$K$h$C$FMW5a$9$k QoS $O0[$J$j!"$=$l$K1~$8$?%9%1%8%e!<%j%s%0$,I,MW$H$J$k$,!"%^%k%A%f!<%6$K7W;;5!;q8;$rDs6!$9$kJ,;6%7%9%F%`$H7F$O!"C10l$N%f!<%6N_$K=8Cf$7$?=hM}G=NO$r3djEvFFOJi$J$$!#$"$k%^%7%sK*$$$FM%@h=g0L$,9b$/JC$F$$$k%f!<%6KBP7FO!"B>$N%^%7%s$G$OM%@h=g0L$r2<2kJI7F!"%7%9%F%`A4BNH7FN4QE@$+$i7W;;5!;q8;$N@jM-$rHr1kI,MW$,$"$k!#

=>Mh$NJ,;6%7%9%F%`$GO3Nh$&$J!"%f!<%6$NMW5a$K1~8?%8%g%V$N%9%1%8%e!<%j%s%0$,I,MWHJk,!"%^%k%A%f!<%6$K7W;;5!$N;q8;$r9MN8$7$?%9%1%8%e!<%j%s%0$O9Tol$F$$$J$$!#

3FMWAG%^%7%s$OC10l%W%m%;%C%5$r4pK\$H9k%O!<%I%&%'%"$H!"C1FH$G2TF/9k%*%Z%l!<%F%#%s%0%7%9%F%`$,$bHKJCF*$j!"I/O 5!G=$N1DH7FDL?.%O!<%I%&%'%"$H%=%U%H%&%'%"$rIU2C7?bN$,B?$$!#3lGO!"DL?.$ODI2C5!G=$G$"$j!"3F7W;;5!$OFHN)$7$F2TF/$9kH$$$&7/$_$,:,K\$+$iH4$1$-$CF*i:!"JBNs=hM}$r9bB.2=$9k?aNB-[HHJCF$$$k!#

3. %3%s%T%e!<%?!&3%m%K!<

3.1 @_7WL\I8

2>O$G8+$F$-$?h&$K!"J,;6%7%9%F%`$O=8Cf%7%9%F%`$h$jDc2A3J$GF3F~!"0];}$,2DG=$G$"$j!"DL>o$N6HL3$K4X7F$O=<J,$J@-G=$r<($9$,!"7W;;5!;q8;$NM-8zMxMQ$,?^$ilF$$$J$$!#3NE@$r9nI~$9kK$O!"C1$J$kDI2C5!G=$GOJ$/!"IT2D7g$J4pK\5!G=H7$F%M%C%H%o!<%/$r9=@.9k$?$a$N%O!<%I%&%'%"5Z$S%=%U%H%&%'%"$r:F9=@.$9kI,MW,$"$k!#

K\8&5fGO!"J,;6%7%9%F%`$NMxE@$r:N$j!"$5$i$K%7%9%F%`A4BN$r0U<1$7F=$N7W;;5!;q8;$r:GBg8B$K3hMQ$G$-$k7W;;5!%7%9%F%`$H$7$F!"“%3%s%T%e!<%?!&3%m%K!<” $r3+H/$7$F$$$k!#%3%m%K!<$H$O@8J*$G$$$&“72BN” $G$"$j!"J#?t$N8DBN$,L)Ce$7$F6&F1@83h$r9T$$!"A4BN$H$7$F1$D$N8DBN$G$"$k$+$N$h$&$K?6Iq$&$b$N$r$$$&!#%3%s%T%e!<%?!&3%m%K!<$O!"72BN$N$h$&$KJ#?t$NMWAG%^%7%s(0J2<!"%N!<%I$H8F$V) $,8_$$$KL)$KO"Mm$7$FJBNs=hM}$dIi2YJ,;6!"%7%9%F%`A4BNKOKk%9%1%8%e!<%j%s%0JI$r9T$$!"1DN9b5!G=$J7W;;5!$G$"$k$+$Nh&$K?6Iq$&3H$rL\I8$H7?%7%9%F%`G"$k!#

%3%s%T%e!<%?!&3%m%K!<$N@_7WL\I8$O!"<!Nh$&$JbNG"$k!#

- Dc2A3J@-
- 7W;;5!;q8;$NM-8z3hMQ
- %^%k%A%f!<%64D6-

0J2<K3li$N@_7WL\I8$K$D$$$F=RYk!#

Dc2A3J@-

=>Mh$NJ,;6%7%9%F%`$HF1$8$/!"3F%N!<%I$ODc2A3J$N7W;;5!$G$"$j!"%7%9%F%`A4BN$bDc2A3J$GF3F~!"0];}$G$-$J1lPJiJ$$!#0lHL$N%f!<%6$KHC$FM=;;$O@Z<B$JLdBj$G$"$j!"$=$NHO0OFb$G:GBg8B$N@-G=$rF@$k3H$,I,MW$G$"$k!#3lKO!"3F%N!<%I$N%b%8%e!<%i%j%F%#$,IT2D7gG"$k!#$D$^$j!"8E$/$JC?%W%m%;%C%5$r8r49$7$?$j!"?7$7$/%W%m%;%C%5Bf?t$rDI2C$7$?$j$H$$$&3H$,MF0W$KG-k3HG!"$=$l$^$G$N7W;;5!;q8;$r7QB3$7$FMxMQ$7!"Dc2A3J$GBgI}$J@-G=8~>e$r?^k3H,G-$k!#

7W;;5!;q8;$NM-8z3hMQ

J#?t$N%W%m%;%C%5;q8;$rM-8z$K3hMQ$7!"JBNs=hM}$r<B9T$5$;$k3H$G!"%7%9%F%`$N@-G=$rBg$-$/0z$-=P$9$3$H$,$G$-$k!#=>Mh$NJ,;6%7%9%F%`$G$O:YN3EY$NJBNs=hM}$OIT2DG=$JNG!"$3$1$r=8Cf%7%9%F%`$K6aE1kh$&$JDL?.5!9=$rDs6!$9$k%O!<%I%&%'%"$,I,MWHJ$k!#2f!9$OC1$K%P%s%II}$N9b$$%M%C%H%o!<%/%G%P%$%9$rMQ$$$k$@$1GOJ/!"%=%U%H%&%'%"Kh$k%*!<%P!<%X%C%I$r6KNO>J$/$3HGBgI}$JB.EY8~>e$r?^$k!#

%^%k%A%f!<%64D6-

%j%"%k%?%$%`@-$,MW5a$5$l$kF02h$d2;@<$N:F@8$J$I$r<B9T$9$k$?$a$K$O!"C1$K6QEy$K%f!<%6$K=hM}G=NO$rDs6!$9$k$N$G$O$J$/!"QoS $K1~$8$?Ds6!$,I,MW$G$"$k!#$7$+$7!"$3$l$rK~B-$9$k$HF1;~$K!"FCDj$N%f!<%6$N$_$,7W;;5!;q8;$r@jM-$9$k$3$H$O$"$C$F$O$J$i$J$$!#$3$N$?$a%3%s%T%e!<%?!&%3%m%K!<$O%7%9%F%`A4BN$r8+EO$7!"=E$$%8%g%V$OIi2Y$N>/$J$$%N!<%IK*$$$F<B9T9kJI7F!"B>$N%f!<%6$KDs6!9k=hM}G=NO$rB;$Jo&3HNJ$$$h$&%9%1%8%e!<%j%s%0$r9T$&I,MW$,$"$k!#

%3%s%T%e!<%?!&%3%m%K!<K*$$$F$O!"JBNs=hM}$r9T$&$?aN9bB.$+$DDcCY1d$JDL?.5!9=$rDs6!9k%O!<%I%&%'%"$H!"%^%k%A%f!<%6$K;q8;A4BN$r1 DN9b@-G=7W;;5!$K8+$;$k%*%Z%l!<%F%#%s%0%7%9%F%`“Colonia”$,!"8_$$$K6[L)7F2TF/9k3H$,I,MW$HJk!#

3.2 6&M-%a%b%j%Y!<%9$NDL?.

JBNs=hM}$r9bB.2=$9kK$"$?CF!":GM%@h$G2r7h$9Y-LdBj$O!"DL?.$N%3%9%HG"$k!#DL?.$r9bB.2=9kKO!"J*M}E*$K%P%s%II}$N9b$$%O!<%I%&%'%"$rMQ$$$k3H$b=EMW$@$,!"$=lr@8$+$9KO!"CY1d$,>.$5$$DL?.5!9=$r@_7W$7J1lPJi$J$$!#

CY1d$N<g$J860xH7$F!"%=%U%H%&%'%"$Khk%*!<%P%X%C%I$,5s$2il$k!#DL>o!"%f!<%6$,I/O $rA`:n$9$k$K$O!"%7%9%F%`%3!<%k$rH/9T9kI,MW$,$"$k!#$hCF!"DL?.$NCY1d$r:o8:9kKO!"G-k@$1%7%9%F%`%3!<%k$rHr1k!"D^$j%f!<%6$K2rJ|G-$kDL?.J}<0$r:NMQ9k3H$,I,MW$G$"$k!#

%3%s%T%e!<%?!&%3%m%K!<GO!"DL?.%W%j%_%F%#%VH7$F6&M-%a%b%j$rMQ$$$k3H$G!"9bB.$+$DDcCY1d$JDL?.5!9=$r%f!<%6$K2rJ|9k!#6&M-%a%b%jJ}<0K*$$$F$O!"%f!<%6$O%7%9%F%`$+$iM?$($i$l2>A[%a%b%j6u4V$KBP$7$F%"%/%;%9$9$k$3$H$K$h$C$FDL?.$r9T$&!#$3$N;~E@$G$9$G$KB>$N%f!<%6$N%"%/%;%9$+$i$OJ]8n$5$l$F$*$j!"%*%Z%l!<%F%#%s%0%7%9%F%`Kh$k%a%b%jJ]8n5!9=$OI,MW$J$$!#DL?.5!9=$O%f!<%6$K2rJ|5l!"%7%9%F%`%3!<%kKh$k%*!<%P!<%X%C%I$O:o8:G-$k!#

3.3 DL?.%O!<%I%&%'%"$NMW7o

A0=R7?h&$J6&M-%a%b%j$r<B8=9kKO!"DL>o$N%a%b%j%"%/%;%9$KBP1~7F%j%b!<%H%a%b%j%"%/%;%9$r9T$&%O!<%I%&%'%"$,I,MW$KJk!#7+$7!"C1$K%7%9%F%`%3!<%k$r>J$$$?$@$1GO!"dO$j<g5-21$X$N%"%/%;%9B.EY$K6aE/3HOG$-$J$$!#3F%N!<%IK*$$$F$"$?$+$b<g5-21$,A}@_$5l?$+$Nh&$K%j%b!<%H%"%/%;%9$9k?aK$O!"DL?.%O!<%I%&%'%"$O<!Nh$&$JMW7o$rK~$?5J$/$FOJiJ$$!#

6&M-%G!<%?$N%-%c%C%7%s%0 %j%b!<%H%"%/%;%9K*$$$F$b!";2>H$N6I=j@-$rMxMQ$7!"%W%m%;%C%5$+$iG-k@$119bB.$K%"%/%;%9G-$k5-21AuCV$K%G!<%?rCV/3H$G!"BgI}$J9bB.2=$,4|BT$G$-$k!#6qBNE*KO!"%m!<%+%k$J%-%c%C%7%e$d<g5-21$K%j%b!<%H%a%b%j$NFbMF$r%-%c%C%7%s%0$9$k!#

<g5-21$r6&M-%a%b%j$H7FMxMQ ?7$?$K6&M-%G!<%?MQ%a%b%j$rA}@_$9kNGOJ/!"8=:_$"$k<g5-21$r6&M-%G!<%?$rCV$/>l=j$H7F;HMQ9k3H$G!"7W;;5!;q8;$NM-8z3hMQ!"JiSKBgMFNL$N6&M-%a%b%j$,2DG=G"$k!#

8=:_B?$/Ds0F$5lF$$$k6&M-%a%b%jMQ$NDL?.%O!<%I%&%'%"(Memory Channel $dSHRIMP JI) $O!"9bB.%M%C%H%o!<%/$rI/O %P%9$K@\B3$9kH$$$&bNG"$j!"2>A[%a%b%j6u4V$K%^%C%T%s%0$9$k3HKh$j!"%f!<%6$,%*%Z%l!<%F%#%s%0%7%9%F%`$N2p:_$J7K%"%/%;%9$9$k3HOG$-$k!#

7+$7!"$$$/$i%M%C%H%o!<%/%G%P%$%9$dI/O %P%9$N%P%s%II}$,9b$/!"2>$K1 2s$N%j%b!<%H%"%/%;%9K+$+$k;~4V$,<g5-21$X$N%"%/%;%9$HF1$8$@H7Fb!"3N@\B3J}K!GO<g5-21XN%"%/%;%9KHfY$F%j%b!<%H%"%/%;%9$NB.EY$OAm9gE*$K$O1s$/5ZPJ$$!#

3l$O!"<g5-21$X$N%"%/%;%9;~$K$O%W%m%;%C%5$O6aK5K"$k9bB.$J%-%c%C%7%e%a%b%j$K%G!<%?$r%-%c%C%7%s%0G-k,!"I/O %P%9rDL7$F@\B3$5lk%j%b!<%H%a%b%jKD$$$FO=lO<B:]>eIT2DG=G"k3HKhk!#%W%m%;%C%5KHfY<g5-21%"%/%;%9NCY5$O1W!9L\N)$CF-F*$j!"%-%c%C%7%s%0$rH4$-$K7?9bB.$J%a%b%j%"%/%;%9$O9M$($ilJ$$!#

%-%c%C%7%e$NMxMQ$,;v<B>eIT2DG=JN$O!"I/O %P%9$K@\B3$5$l$?DL?.%O!<%I%&%'%"$+iO!"%7%9%F%`%P%9B&$N%W%m%;%C%5$d%a%b%j$KBP$7$F!"%-%c%C%7%e%3%R!<%l%s%7@)8f$K4X$9$kA`:n$,$G$-$J$$$+iG$"$k!#0lHL$K%-%c%C%7%e%3%R!<%l%s%7@)8f$O%7%9%F%`%P%9$K@\B3$5$l$kJ#?t$N%W%m%;%C%5$H%a%b%j4V$G9T$o$l!"I/O $O$=$l$K4X$o$i$J$$!#$h$C$F!"%7%9%F%`%P%9$HI/O %P%9$N%$%s%?!<%U%'%$%9$O!"%-%c%C%7%e%3%R!<%l%s%7@)8f$K4X$9$k5!G=$rI/O %P%9B&$KDs6!$7F*i:!"I/O %P%9$KDL?.%O!<%I%&%'%"$r@\B3$7$F$b<g5-21$d%-%c%C%7%e$OMxMQ$G$-$J$$$NG"$k!#

b7I/O %P%9B&$NDL?.%O!<%I%&%'%"$,%N!<%IFb$N

5-21AuCV$K%-%&C%7%s%0$r9T$&$NG"lP!"6&M-%G!<%?d=$N%-%&C%7%e$O!"%3%R!<%l%s%7@)8f$,2DG=$JHO0OKJ1lPJiJ$$?$a!"DL?.%O!<%I%&%'%"$,J];}9k3HKJ$k!#

7+$7$3$N>l9g$O!"<g5-21$r6&M-%a%b%j$H7FMxMQG-$:!"7W;;5!;q8;$rM-8z3hMQ7F$$$kHO8@$($J$$!#3lGO7W;;5!$r7k9g$7$F6&M-%a%b%j$r<B8=9k$H$$$&hj$b!"6&M-%a%b%j$K%W%m%;%C%5$r@\B3$9kH$$$&h&$J7ABV$KJCF7$^$&!#$^$?!"6&M-%G!<%?$r%-%&C%7%s%0$7Fb%W%m%;%C%5$,%"%/%;%9$9kK$OI/O rDL5MPJi$J$$?$a!"%W%m%;%C%5$N6aK5$KG[CV$5lk%-%&C%7%eXN%"%/%;%9B.EYKOE~D15ZPJ$$!#

$$$:lK7F$b!"I/O %P%9$K@\B3$9$k7ABV$N!"=>Mh$N6&M-%a%b%j%b%8%e!<%kGO!"9G$KB8:_$9$kBgMFNL$N<g5-21$r6&M-%a%b%j$H7F07$$!"$=$l$r%-%&C%7%s%0$9k3H,IT2DG=J?$a!"9bB.$J6&M-%a%b%j%"%/%;%9$O<B8=$G$-$J$$$NG"$k!#

3.4 DL?.%W%m%H%3%k

%3%s%T%e!<%?!&%3%m%K!<$,I,MW$H9k%M%C%H%o!<%/$O!"6&M-%a%b%j$KFC2=7?@lMQ%M%C%H%o!<%/G"k?$a!"TCP/IP Nh$&$JHK;($JHFMQ%W%m%H%3%kOI,MWJ$$!#hC$FC1=c$J%W%m%H%3%k$r:NMQ$7!"%W%m%H%3%k=hM}K+$+$k%*!<%P%X%C%I$r:o8:$9$k!#

%M%C%H%o!<%/$N6qBNE*$J%G%P%$%9$O!"9b$$%P%s%II}$r;}$DbNG"kI,MW,$"$k$,!"%W%m%H%3%kEy$K4X7F$O%3%s%T%e!<%?!&%3%m%K!<$H7F$NMW5a$OFCKJ$$!#hC$F%3%s%T%e!<%?!&%3%m%K!<$r9=@.9k%M%C%H%o!<%/%G%P%$%9$O$[$\G$0U$G$"$j!"hj9bB.JbNK8r49$7$F$b9=$o$J$$!#

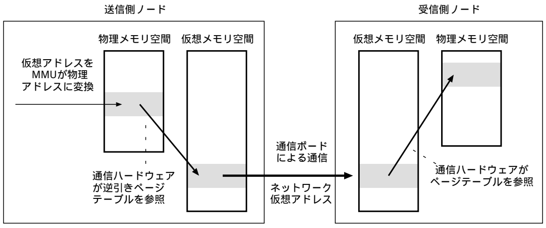
2<0L%W%m%H%3%k$O%M%C%H%o!<%/%G%P%$%9$K0MB8$9k,!">e0L%W%m%H%3%k$O%M%C%H%o!<%/F)2a$J6&M-%a%b%j$r<B8=$9k?aK%3%s%T%e!<%?!&%3%m%K!<K*$$$FDj5A5l$k!#

%3%s%T%e!<%?!&%3%m%K!<$NDL?.%O!<%I%&%'%"$O!"FCDj$NJ*M}%"%I%l%9$KBP9k%"%/%;%9$r8!=P$7$F%j%b!<%H%"%/%;%9$r9T$&!#$3NH$-!"J*M}E*$J%N!<%IHV9f$dJ*M}%"%I%l%9$G%j%b!<%H%a%b%j$r;XDj$9kH!"=@Fp@-$K7g$1$k!#

%a%b%j$NJ*M}E*$J%"%I%l%9$O!"%9%o%C%W%"%&%H$KhC$F>o$KJQ2=9k!#hC$F%f!<%6$,MQ$$$k2>A[%"%I%l%9$rJ*M}E*$J0LCV$KJQ49$9$k5!9=$,I,MWKJk,!"%j%b!<%H%a%b%j%"%/%;%9MW5a$rAw?.$9$k%N!<%I$,3NJQ49$r9T$&3HK9kH!"J*M}E*$J0LCV$NJQ99N?SKA4%N!<%I$NJQ49%F!<%V%k$NJQ99$,I,MW$KJk!#

$=$3$G!"%j%b!<%H%a%b%j%"%/%;%9$N:]$K$O!"%M%C%H%o!<%/2>A[%"%I%l%9$rMQ$$$F%"%/%;%9@h$r;XDj$9$k!#%"%/%;%9MW5a$r<u?.7?%N!<%I$O!"JQ49%F!<%V%k$rMQ$$$F%N!<%IFb$NJ*M}%"%I%l%9$KJQ49$7!"<B:]$N%"%/%;%9$r9T$&!#J*M}%"%I%l%9$NJQ99$O!"<u?.%N!<%I$NJQ49%F!<%V%k$rJQ49$9$k$@$1$G9T$($k!#

1DN<B8=NcH7$F!"%M%C%H%o!<%/$GM#0lG"$k%"%/%F%#%S%F%#$N<1JL;R$H!"$=$N%"%/%F%#%S%F%#$N;}$D2>A[%"%I%l%9$G!"%M%C%H%o!<%/2>A[%"%I%l%9$rI=8=$9kH$$$&J}K!$,9M$(il$k!#$hCF!"J*M}%"%I%l%9rbHKDL?.$r3+;O$9$kAw?.B&%N!<%I$G$O5U0z$-%Z!<8%F!<%V%k$r;2>H$9k3HG2>A[%"%I%l%9$r<hF@$7!"<u?.B&%N!<%IGO%Z!<8%F!<%V%k$r;2>H$9k3HG$=$N2>A[%"%I%l%9$KBP1~$9$kJ*M}%"%I%l%9$r<hF@9k3HKJ$k!#$3Nh$&$9$r?^3$K<($9!#



?^**3** %M%C%H%o!<%/2>A[%"%I%l%9$rMQ$$$?%j%b!<%H%"%/%;%9

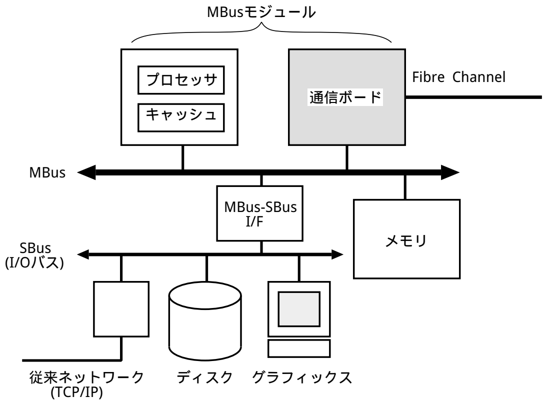
4. <B834D6-

4.1 DL?.%\!<%I$N<BAu

A0=R7?h&$K!"DL?.%O!<%I%&%'%"$rI/O %P%9B&$K@\B3$9kNO5$^$6$^$J@)8B$,B?$/!"8zN($h$$JBNs=hM}$r<B8=$9k?aN6&M-%a%b%jDL?.5!9=$rDs6!$G$-$J$$!#%3%s%T%e!<%?!&%3%m%K!<GO!"%-%&C%7%e$K4X$7$F40A4$JA`:n$,$G$-$k(%^%k%A%W%m%;%C%5$r<BAu$G$-$k)%7%9%F%`%P%9$K!"@lMQDL?.%\!<%I$r@\B3$9$k$H$$$&J}?K$r:N$k!#

%^%k%A%W%m%;%C%7%s%02DG=$J%7%9%F%`%P%9$K%\!<%I$r@\B3$9kH!"$=$l$O%-%&C%7%e$r;}$D%W%m%;%C%5$HF1MM$K?6Iq$&3H$,$G$-$k!#%W%m%;%C%5$N%-%&C%7%e$OJ*M}%"%I%l%9$r%9%L!<%W$9k3HG!"<+?H$N;}$D%-%&C%7%e$N>uBV$rJQ99$7$?$j!"%a%b%j$NH?1~$rDd;_$7$F<+?H$N;}$D%G!<%?$rAw?.7?j9$k!#$3NBeojKDL?.%\!<%I$r@\B3$9k3HG!"J*M}%"%I%l%9$r%9%L!<%W$7F=$N%"%/%;%9$KBP7F%"%/%;%9$NDd;_$d<+J,$,;}$D%G!<%?$NL58z2=$JI,9T$($kNG$"$k!#D^$j!"%7%9%F%`%P%9$K@\B3$5$l$?DL?.%\!<%I$O!"$"$?$+$b%j%b!<%H%a%b%j9YFr07$&%-%&C%7%e%a%b%j$G$"$k$+$Nh&$K?6Iq$&!#

K\8&5fGO!"%3%s%T%e!<%?!&%3%m%K!<$N<B8=Nc$H7F!"8=:_8&5f<<K"$k%o!<%/%9%F!<%7%g%sSPARCstation 20 $r7k9g$7$F%3%s%T%e!<%?!&%3%m%K!<$r9=@.9k!#L\E*$N9bB.!"DcCY1d$JDL?.$r<B8=$9k?aK!"2f!9$O@lMQDL?.%\!<%I$r%7%9%F%`%P%9G"$kMBus $K@\B3$9$k!#%M%C%H%o!<%/%G%P%$%9$OA0=R$Nh&KFCKMW5a$O87$7$/$J$/!"K\8&5f<<$K$*$1$k<B834D6-$G$OFibre Channel $rMQ$$$k!#3NH-$N%O!<%I%&%'%"9=@.$r?^4$K<($9!#



?^**4** MBus $K@\B3$7$?DL?.%\!<%I

4.2 **MBus** $N;EMM

SPARCstation 20 $O%^%6!<%\!<%I>e$KJ#?t$NMBus %9%m%C%H$r;}$D!#$3$3$KI8=`$G%W%m%;%C%5$rEc:\$7$?MBus %b%8%e!<%k$,AuCe5l$F$$$k!#MBus %b%8%e!<%k$r8r49$9k3HG8E$$%W%m%;%C%5$r?7$7$$%W%m%;%C%5$K8r49$7$?$j!"$"$k$$$O30It%-%c%C%7%eIU$-$N%W%m%;%C%5$K8r49$9k3H,G-$k!#$^$?!"B>$NMBus %9%m%C%HKJLN%W%m%;%C%5$r;}$D%b%8%e!<%k$rDI2C$9k3HG!"SMP(BP>N7?%^%k%A%W%m%;%C%5) $K3HD%$9k3H,G-$k!#

SPARCstation 20 $NMBus $O!"%-%c%C%7%e%3%R!<%l%s%7@)8fN?aN?.9f$r%5%]!<%H$7F*$j!"J#?t$N%-%c%C%7%e$,%9%L!<%W$9k3HG0l4S@-$rJ]$D3H$,$G$-$k!#3N?.9fKO!"<!$N2$D$,$"$k!#

MIH(Inhibit) L58z$J%a%b%j$KBP9k%"%/%;%9$,$"C?>l9g!"M-8z$J%G!<%?$r;}$D%-%c%C%7%e$,%"%5!<%H9k!#

MSH(Shared) M-8z$J%a%b%j$KBP9kFI$_9~$_$,$"C?>l9g!"$=$N%G!<%?$r6&M-$9$k%-%c%C%7%e$,%"%5!<%H9k!#

MIH $,%"%5!<%H$5lk$H!"%a%b%j$OMW5a5l$F$$$k%"%I%l%9XN%"%/%;%9$rDd;_$9$k!#$3lKhC$F!"L58z$J%G!<%?XN%"%/%;%9rKI0$3$H$,$G$-$k!#Nc$($P!"$"$k%-%c%C%7%e$KJQ99$5l?%G!<%?$,$"$j!"%a%b%j>e$N%G!<%?$,L58z$KJC$F$$$kH-$O!"B>$N%W%m%;%C%5Khk=$N%"%I%l%9$X$N%"%/%;%9$K$O!"%a%b%j$GOJ$/M-8z$J%G!<%?$r;}$D%-%c%C%7%e$,BP1~$7J1lPJi$J$$!#hC$F!"$=$N%-%c%C%7%e$,MIH $r%"%5!<%H$7$F%a%b%j$,%G!<%?$rE>Aw$9kN$rDd;_$7!"<+J,$N;}$DM-8z$J%G!<%?$rMW5a85$N%W%m%;%C%5$KE>Aw9k!#

$^$?!"$"$k%W%m%;%C%5$,M-8z$J%a%b%jrFI_9~$`MW5a$r=P9H!"$=$NH-K9GK$=$N%G!<%?$r6&M-$7$F$$$k%-%c%C%7%e$,MSH $r%"%5!<%H$7!"3N%W%m%;%C%5$,FI$_9~s@%G!<%?$O6&M->uBV$HJk!#hC$F!"$3$N%W%m%;%C%5$O<+J,$N%-%c%C%7%e$,B>$K6&M-$5lF$$$k3HrCNj!"=q$-9~$_$,$"C?H-$KB>$N%-%c%C%7%eKBP7$FL58z2=$N?.9frAwk!#

5. $^ $H $a

K\9FGO!"JBNs=hM}$r<B9T$5$;$k$?$a$N?7$7$$%7%9%F%`H7FN%3%s%T%e!<%?!&%3%m%K!<H=$N%O!<%I%&%'%"9=@.$K$D$$$F=RY?!#%W%m%;%C%5;q8;$r:GBg8B$KMxMQ$7JBNs=hM}$r9T$&%^%k%A%f!<%64D6-$rDc2A3J$G<B8=$9k3HO!"JBNs%"%W%j%1!<%7%g%s$NA}2C$KH<CF!">-Mh$N7W;;5!2J3X$,Hr1FDLlJ$$F;G"kH9M$($k!#%-%c%C%7%e%3%R!<%l%s%7@)8f?.9f$r;}$D%^%k%A%W%m%;%C%5BP1~$N%7%9%F%`%P%9$KDL?.%O!<%I%&%'%"$r@\B3$9k3HG!"40A4$J%-%c%C%7%s%0$r<B8=$7!"$3l^GK$J$$9bB.$J6&M-%a%b%j%"%/%;%9$r9T$&$3H,G-$k!#

:#8e$O!"%3%s%T%e!<%?!&%3%m%K!<K*1kJBNs=hM}$N<B9TC10L$N;EMM$d!"Fibre Channel $rMQ$$$?DL?.%W%m%H%3%k$N@_7W$*hS<B:]$N%O!<%I%&%'%"3+H/!"$5iKColonia $N<BAu$JIr?JaF$$$/!#

<U <-

%a%s%?!<!&0%i%U%#%C%/%9!&8%c%Q%s!3t!KKO!"Higher Education Program $N0l4D$H7F@=IJ$H%5!<%S%9$r$4Ds6!$$$?$@$-$^$7$?!#$3$3$K46<U$$$?7^$9!#

J*K\8&5f$N0lIt$O!"J8It>J2J3X8&5fHqJd=u6b!4Jp HW8&5f(C) 2]BjHV9f09680334 JiSK>)Ne8&5f(A) 2]BjHV9f09780268!KKh$k!#

;2 9M J8 8%

1) A. S. %?%M%s%P%&%`(0zCO?.9T, 0zCOH~7C;RLu): OS $N4pAC$H1~MQ — @_7W$+$i<BAu, DOS $+$iJ,;6OS Amoeba $^$G, %H%C%Q%s(1995)

2) J. %Y!<%3%s(F#ED><J?, <DEDM[0l, :#@t5.;KLu): JB9TJ,;6%7%9%F%` — %*%Z%l!<%F%#%s%0%7%9%F%`, %G!<%?%Y!<%9, J,;6%^%k%A%a%G%#%"%7%9%F%`XNE}9gE*%"%W%m!<%A, %H%C%Q%s(1996)

3) A0@n<i, =j?ZM}M:, @6?e8,B@O/: J,;6%*%Z%l!<%F%#%s%0%7%9%F%` — UNIX $N<!$K$/$kbN, 6&N)=PHG(1991)

4) Gk869(, DEED9'IW, Bg5WJ]1Q;L: 8=Be%*%Z%l!<%F%#%s%0%7%9%F%`$N4pAC, %*!<%`<R(1988)

5) A0@n<i: %*%Z%l!<%F%#%s%0%7%9%F%`, 4dGH9V:B%=%U%H%&%'%"2J3X6, 4dGH=qE9(1988)

6) SPARC International, INC. (Aj1[9n5W, EDCfD98wLu/B?ED9%9n4FLu): SPARC %"!<%-%F%/%A%c!&%^%K%e%"%k %P!<%8%g%s8, %H%C%Q%s(1992)

7) F|K\%5%s!&%^%$%/%m%7%9%F%`%:3t<02q<R: SPARCstation 20 %7%9%F%`!&%"!<%-%F%/%A%c, Sun Expert, No. 16, Sun Expert 16(1994)

8) SPARC Technology Business: SuperSPARC & MultiCache Controller User's Manual, Sun Microsystems(1996)