JBNs7W;;5!%"!<%-%F%/%H$+$i$_$?7W;;5!%/%i%9%?

?9 bC0lO: IY ED bC <#

5~ETBg3XBg3X1!>pJs3X8&5f2JDL?.>pJs%7%9%F%'@196

1. O8aK

1980 G/Be8eH>$^$G$O, %9!<%Q!<%3%s%T%e!<%?$H$$$(
$P%Y%/%H%k%W%m%;%C%5$G$"$j, JBNs7W;;5!O^$@$^$@L$
=O$J5;=Q$H$$$C$?46$G$"$C$?$,, @$3&$NTOP500 Supercomputers[1y] $N:#G/6 7n$NE}7WGO, TOP10 $OA4$F512%W%m%;%C%50J>e$ND6JBNs7W;;5!(MPP), TOP30$^$G$, 100 %W%m%;%C%50J>e $NJBNs7W;;5!$+JBNs%Y%/%H%k5!G"$j, 10 %W%m%;%C%50J2<$N%^%7%s$O20 7o$KHI$^$C$F$$$k. JBNs=hM}$O8&5fBP>]$N;~Be$+$i<BMQ2=$N;~Be$X$H8~$+$$$DD"$k.

3N4V, 2f!9JBNs7W;;5!%"%-%F%/%H$O, ?t@i, ?tK|Bf5,LO$^$G%9%1!<%i%V%k$J%"!<%-%F%/%A%cOI$&$"kY$-$+, $^$?, JBNs=hM}%*!<%P%X%C%I$r7Z8:$7:¥N3E¥JBNs=hM}KBQ(F@$kDc%l%$F%s%7, 9b%9%k!<%W%C%H$N%a%b%j!?%M%C%H%o!<%/$$%s%?%U%'!<%9$rG!2?$K@_7W9Y$-$+JI$N8&5f2]Bj$K<hjAHsG-$?. 3Nh&$JJBNs=hM}5;=Q$NH/E8$H%^%$%/%m%W%m%;%C%59bB.2=$N287Cr&1F, :#F|, B?$/$NJBNs7W;;5!$,:G@hC<$N%9!<%Q!<%3%s%T%e!<%?$H7F3hLv7F$$$k.

0lJ}$G, 3Nh&$J%9%Q%3%sO)@~rAvkD6JBNs$"$k$$$O9bJBNs7W;;5!HO, 0l@~$r2h$7$F<EMQE*$JJBNsEY$NJBNs7W;;5!$N3hLv$bL\N)$CF-$F$$$k. 4k6H$NItLg%l%Y%k$dBg3X$N3X2J%/%i%9$NAH?%GbF~<j2DG=$J?t10Bf5,LO$N%W%m%;%C%5rbC?ItLg%5!<%PE*$J%_%C%I%l%s%8$NJBNs7W;;5!G"$k. $=$NCfGb, :G6aCmL\$r=8aF$$$kN, !VW;;5!%/%i%9%?!WG"$k.

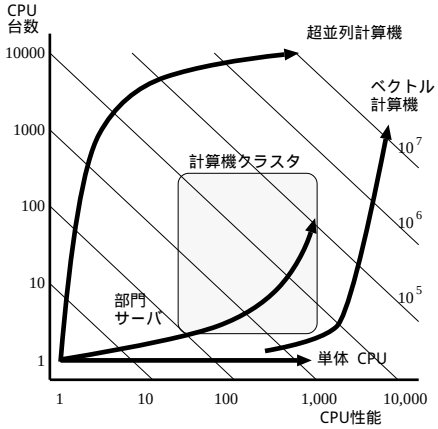
2. 7W;;5!%/%i%9%?BfF,$NGX7J

7W;;5!%/%i%9%?O, C1BN$N%Q!<%=%J%k%3%s%T%e!<%?(PC) $d%o!<%/%9%F!<%7%g%s(WS), >19gKhCF$OPC/WS %5!<%P$H$$$C$?>.5,LOJBNs7W;;5!$r, Hf3SE*MF0W$KF3F~2DG=$JHFMQ$N%M%C%H%o!<%/$G@\B3$7$?0l<o$NJBNs7W;;5!$H8+J9$3$H$,$G$-$k. %W%m%;%C%5JiSK%M%C%H%o!<%/@-G=$N5^B.$J?-Sr<u1F, %3%9%H%Q%U%)!<%^%s%9$KM%$l$?JBNs7W;;5!$H7F$NCO0L$rC[$-$DD"$k. JBNs7W;;5!$H7FOIAi$+$H$$$&$H%m!<%(%s%I%JJ,N'$KF~kN$G, Ev=i$OJBNs7W;;5!20O"$^$j$$K$+$1$F$$$J$+$C?$,, <!Bh$KCNiL?6jr7F$$$kLuKO$$$+J/JCF-$?$NG"$k.

$=$lGO, ?^2$r8+$J$,$i, JBNs7W;;5!$NEP>l$+$i7W;;5!%/%i%9%?$NBfF,$^$G$NF;Dx$r$*$CF_h&.

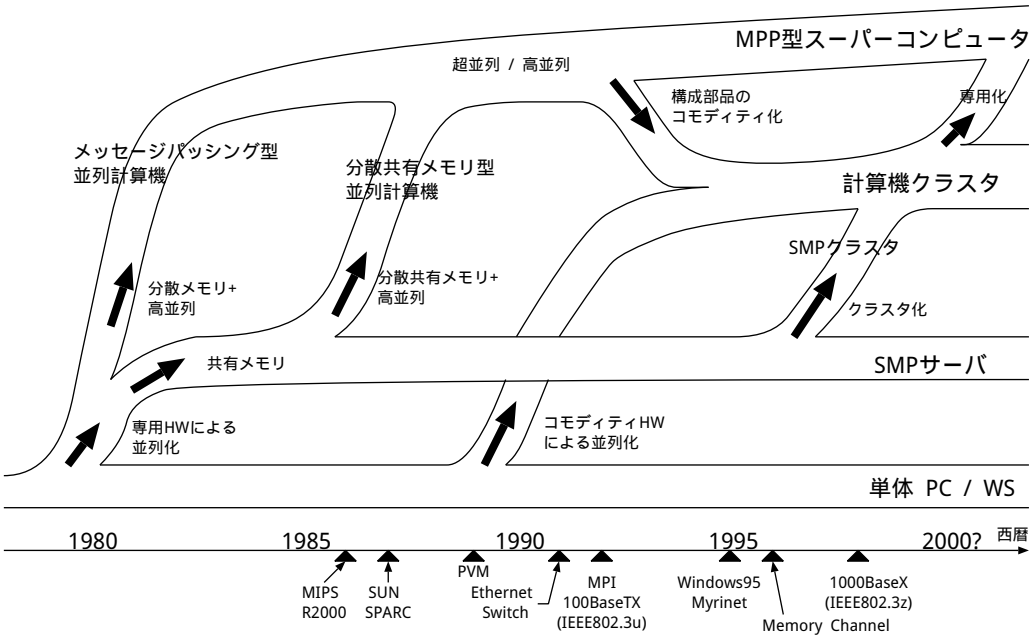
— JBNs7W;;5!$NEP>l —

1980 G/:"$O, HFMQ%W%m%;%C%5$NDc2A3J2=KHbJ$$, 3l$i%W%m%;%C%5$r@lMQ$N%O!<%I%&%'%"(HW) $r6n;H$7$FJBNs@\B3$9$kJBNs7W;;5!$,Aj<!$$GEP>l7?. %9!<%Q!<%3%s%T%e!<%?J_$N@-G=$rL\;X7F, 8D!9$N7W;;5!Kh$K:GE,2=5l$?%M%C%H%o!<%/7O$d%a%b%j7O$NHW $N8&5f!?3+H/$,9Tol$?. 3F%W%m%;%C%5Kh$K%a%b%j$rJ,;6G[CV$7%a%C;!<%8%Q%C7%s%0KhCF%W%m%;%C%54VDL?.$r9T$&%a%C;!<%8%Q%C7%s%07?JBNs7W;;5!$H, %W%m%;%C%5$H$OFHN)$K%a%b%j$r=8CfG[CV$7, 3N6&M-%a%b%j$r2p$7$F%W%m%;%C%54V$NDL?.$r9T$&!=8Cf!K6&M-%a%b%j7?JBNs7W;;5!(:G6a$O, Symmetric



?^**1** 2a5n10G/4V$N7W;;5!@-G=$N?d0\7@~

[1y] J.Dongarra Ey$,H>G/Kh$K=P$7F$$$k@$3&$G3hLv$7F$$$k9b@-G=%3%s%T%e!<%?TOP500 $N%j%9%H(http://www.top500.org/). :G=i$NE}7W$G!<%?$O1993G/.



?^2 7W;;5!%/%i%9%?X$NF;Dx

MultiProcessor(SMP) $H8F$Plk3H$,B?$$.) $,EP>l$7$?.

1985 G/:"$+$i$O, =8CfG[CV$7$?6&M-%a%b%j%7%9%F%`$N%9%1!<%i%S%j%F%#$NLdBj$r2r7h9k<jK!H7$F, <g5-21$O3F%W%m%;%C%5$KJ,;6G[CV$9k,, %W%m%0%i%^KBP7FOHW $G6&M-%a%b%j%b%G%k$rDs6!9kJ,;66&M-%a%b%j7?JBNs7W;;5!$,EP>l$9$k. HFMQ7W;;5!$N;T>l$N0lIt$, RISC 7?$N%^%$%/%m%W%m%;%C%5$rEk:\$7$?%o!<%/%9%F!<%7%g%s$K0\$j;Oa?;~4|$G%b$"$j, JBNs7W;;5!$G;HMQ9k%W%m%;%C%5$N%3%9%H%Q%U%)!<%^%s%9$,8~>e7?.

— 7W;;5!%/%i%9%?$NKk3+$1 —

1990 G/A08eKO, B?$/$NJBNs7W;;5!%Y%s%@$,EP>l$7>&MQ$NJBNs7W;;5!$,?tB?$/3+H/$5l?. $^$?, ?t@i!A?tK|Bf$NCPU $rEk:\$9$kD6JBNs7W;;5!$N8&5f$,;O$^O?;~4|G"$k.

$=$NCf$G, TCP/IP %Y!<%9$N%M%C%H%o!<%/$G@\B3$5l?J#?t$N7W;;5!$N=89gBN$r, 2>A[E*$K#1BfNBg-$JJBNs7W;;5!$H7F8+$;$k$?$a$N%a+%K%:%`$G$"$kPVM(Parallel Virtual Machine) $, 1989 G/$K3+H/5l$?. PVM $O8D!9$N7W;;5!>e$NDL?.%G!<%b%s%W%m%;%9%r2p7F%a%C%;!<%88r49$r9T$&%a%C%;!<%8DL?.%i%$%V%i%j$G$"$j, FCJL$JHW $r0l@ZI,MW$H$;$:, 8x3+5l$?%=%U%H%&%'%"(SW) $r%$%s%9%H!<%k9k$@$1$G2>A[E*$JJBNs=hM}4D6-$,9=C[$G$-$?. $=$N$?$a, 7Z5;}$GJBNs=hM}$r3Z7_$?$%f!<%6$K;Y;}$5$l9-$/Ia5Z7?. 3l$,7W;;5!%/%i%9%?$NKk3+1G$"$k. [1]

$=$N?tG/8eKO, IBM $dIY;NDL$JIN%C%$%s(%s%I$NJBNs7W;;5!%a!<%+$,, <+<R@=$NUNIX %o!<%/%9%F!<%7%g%s$r@lMQ9bB.%M%C%H%o!<%/$G@\B3$7$?%a%C%;!<%8%Q%C%7%s%07?$NJBNs7W;;5!$r;T>l$KEjF~$7$?. 3N;~E@$G, !VW;;5!%/%i%9%?!W$H8FVY$-J*M}E*$J7W;;5!(72) $,EP>l$7$?Lu$G$"$k.

— 7W;;5!%/%i%9%?$N5^@.D9 —

1995 G/A08eKO, %$!<%5%M%C%H%9%$%C%A$d100MBit Ethernet JI$N5;=Q$,0lHLKbIa5Z$7Hf3$E*0B2A$K9b@-G=$J%M%C%H%o!<%/$N9=C[$,2DG=KJC?. 5i$K, Myricom <R$NMyrinet[1] $dDEC <R$NMemory Channel Ey, 7W;;5!%/%i%9%?$r;X8~$7$?@lMQ$N9bB.%M%C%H%o!<%/$,EP>l$7$?. 3lKh$j, %M%C%H%o!<%/$N%9%k!<%W%C%HH7$F, @lMQ$NJBNs7W;;5!J_$N?tCM$rbD%M%C%H%o!<%/$N9=C[$b2DG=HJC?. 0lJ}$G, PC $N0lHL2HDm$X$NIa5Z$KH<$&NL;:8z2L$Khk2A3JDc2<$H, PC 8~$1%W%m%;%C%5$N5^B.$J@-G=8~>eKh$j, %3%9%H%Q%U%)!<%^%s%9%NM%l?7W;;5!%/%i%9%?$N<B8=$,, 2DG=HJC?. 3Nh&$JGX7J$+$i, 7W;;5!%/%i%9%?$r;HC?K\3JE*$JJBNs=hM}$X$ND)@o$,;O$^$C$?. 3N

[1] %M%C%H%o!<%/%/!&%s%?%U%'!<%9!&+!<%I(NIC) $N;EMM$r8x3+$7, %f!<%6$,$"$kDxEY%W%m%H%3%k$r%+%9%?%^%:%:2DG=$J$?$a, JBNs=hM}$rL\;X$98&5f<T$NCmL\$r=8$a, Myrinet $rA0Ds$H7?@vN}5l$?API(Application Programmer Interface) rbC?%I%i%$%P%=%U%H%&%'%"$,@$3&3FCO$G3+H/5l$?.

[1] PVM $O%=%U%H%&%'%"$,8x3+5l$?$?a$K, JBNs7W;;5!$r4^$`B?$/$N7W;;5!$K0\?"$5$l$?. $^$?, PVM $G$CDL?.%G!<%b%s$,8D!9$N7W;;5!$N%"!<%-%F%/%A%c$N:90[$r5[<}$9$k$?a, 0[5!<o7W;;5!$r4^$`7W;;5!%/%i%9%?$b<B8=2DG=G"$C?. J*, 3NEv;~$N!VW;;5!%/%i%9%?!W$C35GE*JbNG, !VW;;5!%/%i%9%?!W$H8F$VJ*M}E*$J7W;;5!$,B8:_7?c1GO$J$$.

;~4|$N7W;;5!%/%i%9%?$NFCD'$O, %/%i%9%?$r9=@.9k PC/WS 4V@\B3$N%M%C%H%o!<%/[!y$r%$%s%?!<%M%C%H@\B3$N$?$a$N%M%C%H%o!<%/$HOJLK@_1?%7%9%F%'$,3+H/$5l?E@G"$k.

0lJ}, SW $NJ}$G$O, %"%W%j%1!<%7%g%s%W%m%0%i%'%$%s%?%U%'!<%9(API) H7$F, B?$/$NJBNs7W;;5!%a!<%+$d8&5f<TiGAH?%5l$?MPI Forum $,:vDj$7$?Message Passing Interface(MPI) $,9-$/Ia5Z7?;~4|G"$k. 3lKh$jJBNs%W%m%0%i%'$N5-=R@-!?0\?"@-$,Cx7/2~A1$5$l, B?$/$N%W%m%0%i%^KHGFJBNs=hM}NI_5o,0lCJHDc/$JC?. $^$?, %W%m%;%C%54VDL?.$KH<$&%7%9%F%'%3!<%k$N%*!<%P%X%C%I$r7Z8:!?:o=|$9%k;n$_$,B?$/9Tol$?;~4|$G$"$k. %f!<%6%W%m%;%9$,D>@\%O!<%I%&%'%"$rA':n$9%k%f!<%6%l%Y%kDL?.$N<B8=$d%<%m%3%T!<DL?.$JI,$=$NNcG"$k. Linux $d FreeBSD JI$N%U%j!<$JOS $NIa5Z$,, 3liN;n$_$KGo<V$r2C$(, 0BDj$+$D9b@-G=$J7W;;5!%/%i%9%?8~$1$N%U%j!<$J%=%U%H%&%'%"$,F~<~j2DG=$KJC$?$NG"$k.

0B2A$JHW $H%U%j!<$JSW $r;H$C$?%Q!<%=%J%kJBNs7W;;5!$H7F$N7W;;5!%/%i%9%?$,EP>l7?;~4|$H$$$CFb$h$$.

— 7W;;5!%/%i%9%?$NH/E8 —

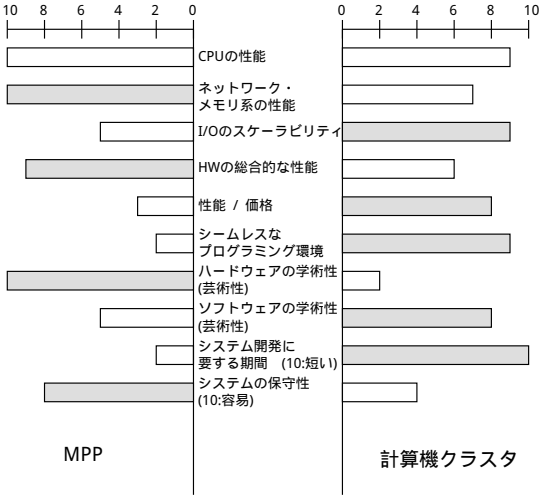
8=:_$O, J#?t$N%W%m%;%C%5$rEk:\$7$?SMP 7?$NWS $dPC $,Hf3SE*MF0W$KF~<~j2DG=KJCF$*$j, 3lir%Y!<%9K7$?SMP %/%i%9%?$,EP>l7F$$$k. %O%$%(%s%I$NSMP %5!<%P$rDs6!$9$k7W;;5!%a!<%+$b, 99Jk%9%1!<%i%S%j%F%#$rD15f$7$F, SMP %5!<%P$rHEMQ$N9bB.%M%C%H%o!<%/$G@\B3$9$kSMP %/%i%9%?$rH/I=$7;OaF$$$k. 7W;;5!%/%i%9%?$N@-G=$O9G$K, %O%$%(%s%I$J%9!<%Q!<%3%s%T%e!<%?$NNN0h$KE~C#$7DD$"$k$H$$$CFb$h$$.%=%U%H%&%'%"4D6-$kK\3JE*$J%^%k%A%f!<%6BP1~NbN,@0$$;OaF$$$k.

:#8e$O, 99$J$kHW $N9b@-G=2=$H%W%m%0%i%'$N5-=R@-8~>e$rL\;X7F, J,;66&M-%a%b%j$rDs6!$9$k7W;;5!%/%i%9%?$,Ia5Z7F$/$kbN$H9M$(Jilk. J,;66&M-%a%b%j$rDs6!$9$k7W;;5!%/%i%9%?$O, 8=:_3hH/$J8&5f$,9Tol$F$$$k$,, SW N_$G2>A[E*$J6&M-%a%b%j$r%a!<%8$rDs6!9kJ}K!$H, HW $G<B:]$K6&M-%a%b%j$r<B8=$9$k%"%W%m!<%A$,$"$k[5). 8e<T$O, =>Mh$NU,;66&M-%a%b%j7?JBNs7W;;5!$GG]$ol?5;=Q$r1~MQ$9kbNG, %O!<%I%&%'%";q8;$N2>A[2=$dDL?.%l%$%F%s%7$N7Z8:!?1#JCN?aK%M%C%H%o!<%/$d%a%b%j2s$j$K6/NO$JHW %5%]!<%H$,$"kN$,FCD'$G$"$k[y].

3N%/%i%9KJCF$/$k$H=>Mh$NJBNs7W;;5!HN%"!<%-%F%/%A%<e$N:9UL$,$[$HsIJ/JCF/$k.

3. 7W;;5!%/%i%9%?$NOlCV$E$1

3Nh&$K, 7W;;5!%/%i%9%?$OJBNs7W;;5!$N9=@.<jK!$N#1DH7FCC0L$r3NN)$7F-$?. GO, =>Mh$NJBNs7W;;5!HO2?$,0c$&$NG"m&$+. 0J2<GO, FH<+$K3+H/5l$?@lMQHW/SW KhCF9=@.5l$k !W8?h$NJBNs7W;;5!!W$NBeI=$H7F$ND6JBNs7W;;5!(MPP) $H, 4pK\E*$K%3%b%G%#$F%#HW/SW KhCF9=@.5l$k !W7W;;5!%/%i%9%?!W$rHf3S9k3H$G7W;;5!%/%i%9%?$NOlCVE1$r9T$&[y] (?^3;2>H).



?^3 MPP $H7W;;5!%/%i%9%?$NHf3S

CPU @-G=

4pK\E*KO, MPP $b7W;;5!%/%i%9%?$b;THN$N%W%m%;%C%5$r;HMQ9k$H$$$&E@$GF101$G$"$k$,, :G6a$N%W%m%;%C%5$O>&6HE*$J@dN,$+$i, %O%$%(%s%I8~$1$H%m!<%(%s%I8~$1$G<o43$N:9$r=P$9@=IJ$,$"kNG3$N:9$,=P$k2DG=@-$,$"$k. $?$@$7, %7%9%F%'$N3+H/4|4V$NLdBj$,Mm$'$H, 8e=R9kDL$j7W;;5!%/%i%9%?$NJ}$,M-Mx$KJk>19gb"$k.

%M%C%H%o!<%/!?%a%b%j7O$N@-G=

MPP O=$N@=IJ8~$1$K@lMQLIS $N3+H/$r9T$&$JI, JBNs=hM}N?aK:GE,2=7?%a%b%j7O$d%M%C%H%o!<%/?7O$N%O!<%I%&%'%"$,Hw$(kNKBP7$F, 7W;;5!%/%i%9%?$G$O%3%b%G%#$F%#JPC/WS $r;HMQ$9k?a, HW $N%l%$%F%s%7$K4X$7$FMPP hjNt$k798~$,$"$k. HW %9%k!<%W%C%H$K4X$7FO, 7W;;5!%/%i%9%?$bMPP $K6a$$$@-G=$r=P$7;O

[!y] $"$/^G$b%3%b%G%#$F%#tIJrD$+$G?%M%C%H%o!<%/$G"$k

[!y!y] IEEE1596 $G5,Dj$5l?Scalable Coherence Interface =`5rNbNr=|1P, B?$/$N>19g@lMQ$NHW $r;H$&I,MW$"$k$?$a$K, 87L)$K$O7W;;5!%/%i%9%?$H$O8@$($J$$2DG=@-$,$"$k. 7+$7, Myrinet $bEv=i$O%3%b%G%#$F%#$H$O8@$$,$?$F$C<l$JHW G"C?NG, J,;66&M-%a%b%j8~1N@lMQHW $,%3%b%G%#$F%#ItIJKJk+H]$+$O;T>l<!BhG"$k.

[!y!y!y] 8=:_$O, $3$3$G$$$&!W7W;;5!%/%i%9%?!WH7FN>r7o$rK~B-$9$kMPP $bB8:_$9k,,OC$r4JC1$K9k?%a$KN><T$CFHN)G"kH7FOC$r?J$a$k.

aF$$k[y].

I/O $N%9%1!<%i%S%j%F%#

7W;;5!%/%i%9%?$O8D!9$N PC/WS $,FH<+$K I/O AuCV$r;}$CF*$j,%W%m%;%C%5Bf?t$KHfNc7F I/O G=NO$,%9%1!<%k%"%C%W$9$k.$3lKBP7F MPP GO,%7%9%F%'A4BN$K18D,$"$k$$$O,$"$kDxEY$N %W%m%;%C%5Bf?tKh$K18D$N I/O AuCV$r;}$D9=@.$,B?$$.1Bf$N I/O AuCV$N@-G=$rHf3S$9kH,01HL$K MPP 8~$1$NU}$,@-G=$,$h$$$bN,B?$$![ØA3Jb=lJjK9b$$!K$,,I/O $N%9%k!<%W%C%H$K4X7F$O?t$G>!Ii$N7W;;5!%/%i%9%?$KIi1k798~$,$"$k.

HW $NAm9gE*$J@-G=

N><T$N HW @_7W$N4pK\J}?K$r4:$($F6hJL$9kJiP,MPP $,!ÑBf$N CPU $r;H$C$F,1CPU NH$-$N7W;;~4V$N1/N $N;~4V$G7W;;G-k3$H!W$KBP7F,7W;;5!%/%i%9%?$O!ÑBf$N7W;;5!$r;H$C$F1Bf$NH-$K8=<BE*$J;~4V$G=hM}$G$-$k$G!<%?%5%$:$N N G\$N%5%$:$N%G!<%?$r07$&3H!WG"$k.01HL$K.A0<T$NMW5a$rK~B-9kKO,:YItKEOC$F@-G=$KM>M5rb$?$;$?HW @_7W$,I,MWG"$k.$7$?$,CF,%T!<%/@-G=$,F101$G$"$CFbAm9gE*$J@-G=$O MPP $NU}$,M%lF$$k.

%3%9%H%Q%U%)!<%^%s%9

%T!<%/@-G=$K6a$$@-G=$r0z$-=P$;$J$$%W%j%1!<%7%g%sKBP7$F,7W;;5!%/%i%9%?$O MPP KHfY$F@-G=$NDc2<798~$,82Cx$G$"$k.7?$,$CF,G0U$N%"%W%j%1!<%7%g%s$KBP9k%3%9%H%Q%U%)!<%^%s%9$r5DO@$9k3HOG-$J$$.7+$7,%T!<%/@-G=$r0z$-=P$;$k%"%W%j%1!<%7%g%s$KBP7F$O,0J2<$N5DO@$,@.N)$9$k.

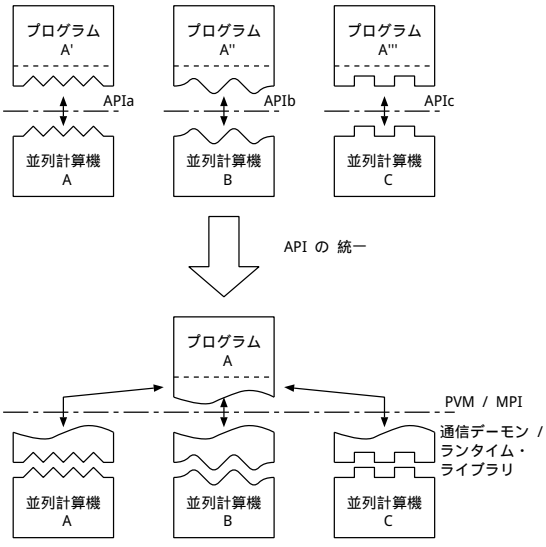
%W%m%;%C%5100 Bf5,LO$N%7%9%F%'$GHf3S9k$H,MPP $H7W;;5!%/%i%9%?$N=V4V:GBg@-G=$OHf8*$7$F$$$kNG,NL;:8z2L$N9b$$7W;;5!%/%i%9%?$,C12AEv$j$N%T!<%/@-G=$,9b$/%3%9%H%Q%U%)!<%^%s%9$KM%lk$H$$($k.$7$+$7,MPP $O4pK\%3%9%H$O9b$$$,,Bf?t$KHfNc$9$k%W%m%;%C%5#1BfEv$j$N2A3J$O7W;;5!%/%i%9%?KHfY$F01HL$KDc$$N$G,2>$K%W%m%;%C%51000 Bf5,LO$N7W;;5!%/%i%9%?$r<B8=7?>19gKO,%3%9%H%Q%U%)!<%^%s%9$N5UE>$$,5/$k2DG=@-$,$"$k.

%W%m%0%i%_%s%04D6-

%a%C%;!<%8%Q%C%7%s%07?$NUBNs7W;;5!$K4X7F$O,=>Mh$h$j8D!9$NUBNs7W;;5!$,,$=l>lN HW @-G=$rB8J,$KH/4x9k$?$a$NFH<+$N API $rDs6!$7$F$$$?.$=$N$?$a,API $N=$F@Ey$N=i4|%*!<%P%X%C%IBg$-$$.$^$?,$"$k7W;;5!$GNI$$%W%j%1!<%7%g%s$,3+H/$5lFb,JLN7W;;5!XN0\?"@-$,:$Fq$H$$$&LdBj$,$"C?.

3lKBP7$F7W;;5!%/%i%9%?$G$O,$=$l<+BN$,EP>l7?GX7J$K PVM $d MPI $H$$$C$?I8=`E*$J API $,,B8:_$7$?$?a$K,5!<o0MB8$N>/JJ8zN(E*$J%W%m%0%i%_%s%04D6-$,Ds6!5l$F$$$k.[y!y]

$^$?,MPP $NOS $O<+<R3+H/$7$?$bN,B?$/,01HL%f!<%6$,JBNs=hM}$X8~$1$?:G=i$N0lJb$rm4m0$99$k860x$KbJCF$$$?.3lKBP7$F7W;;5!%/%i%9%?$O!4pK\E*KO!K;THN$N OS $=$NbN$r;HMQ$9k?a,F|>dE*$K;H$C$F$$$k PC/WS $HA4$/F101$N4D6-$,;HMQG-kH$$$&MxE@$,$"$j,JBNs=hM}$NI_5o$r2<2$kNK9W8%r7$F$$$k.



?^4 API $NE}01$Khk0\?"@-$N8~>e

HW/SW $N3X=Q@-!?7]=Q@-

JBNs=hM}8&5f<T$NL\$G$_$?LLGr$5,?75,@-$NB?5NHf3SG"$k.$^$:HW $K4X$7FO,7W;;5!%/%i%9%?$OItIJ$rGcCF$-$FDJ0@1JNG6KO@H7FO3X=Q@-J7G"$k[y!y!y].L^O@,9=@.ItIJ$r:n$kHFMQItIJ%a!<%+$G$O,%3%9%H%Q%U%)!<%^%s%98~>eN?aK@ZbxBvKa$NEXNO$,J5lF$*$j,3NE@$O==J,$KI>2A9Y$-$G$"$k.

SW $K4X$7FO,7W;;5!%/%i%9%?<+BN$,SW $K0MB8$9$kItJ,$,Hs>o$KB?$$$?a,5;=QE*$J2]Bj$,Bt

[!y] %l%$%F%s%7!'HW E*$J=hM}$r0MMj$7$F<B:]$K$=$N=hM}$,3+;O$5lk$^$G$N~4V%9%k!<%W%C%H!'<B:]$K HW E*$J=hM}$r9TCF$$$k:]$N=hM}B.EY

[!y!y] :G6a$NUBNs7W;;5!$G$O,:G=i$+$i MPI $r<BAu$7$?$bN,=P2skh$&$KJC$?,,MPI $r;H$&$H MPP $N HW @-G=$,=J,$KH/4x$G$-$:$K7W;;5!%/%i%9%?$H$NM-0U5$,=P$;$J$$$H$$$&LdBj$,$"$k.

[!y!y!y] HW $G2?$+3X=QE*$J3$H$rL\O@$'$H7k2lE*$K MPP KJCF7^$&2DG=@-$,$"$k.

;3;DCF$*$j, 4hD%CF8&5f9kH=lJjN@. 2L!?@-G=$,=P$;$k2DG=@-$,$"$k. FC$K, ;EMM$N8x 3+5l$?%O!<%I%&%'%"$H%U%j!<$JOS $r%Y!<%9$K 7?8&5f$,B?$/$N@.2L$r$"$2$F$$$k. 7+7J$, $i, 3liN8&5f$NB?$/$OMPP Gb;H$($k5;=Q $,B?$$?$a, 3X=Q@-$N:9$OHW Dx$GOJ$.

%7%9%F%'3+H/KMW9$k4|4V

0lHL$K, MPP $, 2G/$+$i3G/$+1F3+H/5l$k NKBP7F, 7W;;5!%/%i%9%?$r9=@.9kWS/PC $O3%v7n$+$iH>G/$*$-$K?7@=IJ$,EP>l$9kN$,8=>u$G$"$k. $=$N7k2LH7$F, F1;~4|$KF~<j2DG=$J MPP $H7W;;5!%/%i%9%?$G%W%m%;%C%5$N@$Be$,0c $&$H$$&8=>]$bH/@8$9$k.

%7%9%F%'J]<i$N%3%9%H

MPP $OHW/SW $N0BDj@-$,9b$/%a%s%F%J%s %9$b0QBwG-kNKBP7$F, 7W;;5!%/%i%9%?$OHW/SW $N0BDj@-$,Hf3SE*Dc$/,4pK\E*$K<+J,$G %a%s%F%J%s%9$,I,MWG"k?$aJ]<i%3%9%H$,9b$/$J$k. 7+$7, =jM-<T8D?M$,Hqd7$?;~4V$KBP9k?M7cHq$OB~G"kH9M$(kH, 7W;;5!%/%i%9%?$NJ}$,05E]E*$K%3%9%H$,0B$/Jk.

0J>e, Cx<T$N<g4Q$r8r$($F MPP $H7W;;5!%/%i%9%?$rHf3S7F$_$?$,, N><T$HbKJBNs7W;;5!G"k3HOJ6lbJ;v<BG"$k. $^$?, 0l8@$G7W;;5!%/%i%9%?$H$$CFb, J*M}E*$J<BBN$NH<oJ$$2>A[E*$J7W;;5!72$+$i, D6JBNs7W;;5!$H$N6hJL2=$,:$FqJ%7%9%F%'$^$GI}9-$/B8:_7F$*$j, >e5-$N5DO@$,9YFKBP7F@5$7$$H$O8@$$,$?$$. 7+$7, 7W;;5!%/%i%9%?$,IsJbN+Bg;(GD$J%$a!<%8$O;}$C$ED:$1$?$H;W$&. 0J2<$G$O, hj6qBNE*$J7W;;5!%/%i%9%?$N8&5f!?3+H/F08~$r>R2p9k.

4. 7W;;5!%/%i%9%?$N8&5f!?3+H/F08~

4.1 %Y%s%@;vNc![y1]

4.1.1 D6JBNs%/%i%9%?7O

IPM $NSP %7%j!<%:$d, IY;NDL$NAP3000 $OD6JBNs$N%9!<%Q!<%3%s%T%e!<%?H7F, Aa/$+$i;T>l$KEjF~$5lF$$$k7W;;5!%/%i%9%?G"$k. 7W;;%N!<%I$K$O;THN$NWS MQ$K3+H/$5l?bNr[$\$=N^$^$N7A$G:NMQ$7, J#?t%N!<%I$r@lMQ$Nc~BN$KG<$a$?$bNr@lMQ$N9bB.%M%C%H%o!<%/[y2]$G@\B3$9$k7ABVrH$k. 7W;;%N!<%I$,%b%8%e!<%k2=5l$F$$$k$?$a, 4pK\E*KO%b%8%e!<%k$N8r49$@lG:G?7CPU $N@-G=$r5}<u9k3H$,$G$-$k. 7?$,$C$F, WS MQ$N?7$7$%b%8%e!<%k$,3+H/$5lkIQEY$G, %7%9%F%'$N99?7$,2DG=$KJC$F$$$k.

4.1.2 SMP %/%i%9%?7O

B?$/$N%Y%s%@$,<!@$Be%5!<%PH7$F, 7W;;5!%/%i%9%?$r;T>l$KEjF~$7;OaF$$$k. $=$NB?$/$O, :GBg9=@.$G%7%9%F%'A4BN$N%W%m%;%C%5?t$, 256 BfDxEY$N9bJBNs7W;;5!$N0l3Q$r@jaF$$$k.

BeI=3J$N#1$D$OSUN $NEnterprise Cluster %7%j!<%:$G, Ultra Enterprise %5!<%P$r1%N!<%I$H7F:GBg4%N!<%I$G%/%i%9%?%9%F%'$G$"$k. %M%C%H%o!<%/%+!<%IH7FOSbus MQ$NSCI %+!<%I$r3+H/$7, 4%]!<%H$NSCI %9%$%C%A$G@\B3$7$F$$$k. 1999G/$^$GKO, :GBg12%N!<%I(1024CPU) $N%/%i%9%?$r3+H/9k$H$$$C$F$$$k.[y3]

869F<9I.;~E@$G, %5!<%PItLq$NF08~$,$^$@IL@$G$"$k$,, DEC<R!8=Compaq<R!K$O, <+<R3+H/$NMemory Channel II $r;H$C$?@=IJ$N6!5k$r9T$C$F$$$k. 7W;;%N!<%IH7FO, F1<R$NAlpha %A%C%W$r:GBg120CPUEk:\$7$3$lir3,AXE*$J%/%m%9%PLV$G@\B3$7$?SMP %5!<%P$r;HMQ$9$k. Memory Channel II $N%M%C%H%o!<%/<+BN$b%/%m%9%P!<LV$G, :GBg16%N!<%I$r@\B32DG=G"$k. Memory Channel $O, 6&M-%G!<%?$N=q9~$_$K4X7F<c43FC<l$JA':n$,I,MWG"k,[y4], 6&M-%a%b%j$K='$:$k%f!<%6%$%s%?%U%'!<%9%rDs6!7F$*$j, $=$N5!G=$rMxMQ$7$F:YN3EY$NDL?.KbBP1~G-$k%=%U%&%'%"$KhkJ,;66&M-%a%b%j4D6-$N3+H/$r9TCF$$$k.

Sequent<R$OPentiumPro 4 Bf$NSMP %/%i%9%?$r SCI='5r$N%j%s%/(Link B.EY8Gbps) $G%j%s%0u$K@\B3$9$kNUMA-Q $r;T>l$K=P7F$$$k. B?$/$N7W;;5!%/%i%9%?$,, NIC $r%7%9%F%'%P%9$K@\B3$9$k9=@.rHkNKBP7$F, NUMA-Q $OCPU $d%a%b%j$,@\B3$5$l$k%W%m%;%C%5%P%9$KSCI='5r$N%M%C%H%o!<%/%"%@%W%?$r@\B3$9$k3HG, %O!<%I&%'%"Kh$k4 0A4$JJ,;66&M-%a%b%j4D6-$r<B8=$7, :YN3EYJBNs=hM}$r<B8=$9$k. NIC $,NUMA-Q K+Jj$FC2=$5lF$$k$,,%M%C%H%o!<%/<+BN$OSCI %Y!<%9$NI8='IJ$G$"$kNG%j%9%H%"%C%W$?.

4.2 8&5f=j, Bg3X4X78

4.2.1 5f6KN*<j7Z%/%i%9%?

JF9q$N%m%9%"%i%b%99qN)8&5f=j$,3+H/7?7W;;5!%/%i%9%?Avalon $O, %3%b%G%#%F%$!&O!<%I%&%'%"$H%U%j!<%=%U%H%&%'%"$@lG:nilF*j,[y5] DEC $NAl-

[y1] %Y%s%@;vNc$N%G!<%?$O, 1998G/87nKv$N;~E@$GWWW Ey$GF~<j2DG=$J%G!<%?$K4p$E$$$F$$$k.

[y2] SP %7%j!<%:MQ$N%M%C%H%o!<%/$O, 8=:_$OC1BN$G$b9XF~2DG=$G$"$k. AP3000 $N@lMQ%M%C%H%o!<%/$OF1<R$NJBNs7W;;5!AP1000 MQ$K3+H/5l$?%M%C%H%o!<%/$G$"$k.

[y3] 64 %W%m%;%C%5$NUltra HPC 10000 $r4%N!<%I@\B3$7?8=:_$N:GBg9=@.%7%9%F%'$O:#G/67n$NTOP500 Supercomputer $G430L(LINPACK 80K×80K $G100GFLOPS) $K%i%s%/$5lF$$$k.

[y4] 99?7$9Y$-6&M-%G!<%?$N%"%I%l%9=$NbNGOJ/, %7%9%F%'%P%>e$NNIC $N%G!<%?=q9~$_@lMQNN0h$X=q9~$_$r9T$&I,MW$,$"$k

[y5] 3Nh&$J%7%9%F%'$OBeowulf7?$N7W;;5!%/%i%9%?$HBFPl$F$$$k.

pha 68 Bf$K%U%j!<$JPC UNIX $N0l$DG"$kLinux $rEk:\$7, DL>o$NFastEthernet $G@\B3$7$?%7%9%F%`$G$"$k.[!y]

3l$@$1%7%s%W%k$J%7%9%F%`$G TOP500 Supercomputer $N315 0L$K%i%s%-%s%0$5$l$k7rF.$V$j$G$"$k. 0x$K, <+A0$G%7%9%F%`$rAH$_N)$F, 15 K|%I%k$G19GFLOPS $rC#@.$7F*$j, 15$/MFLOPS $N%3%9%H%Q%U%)!<%^%s%9$G$"$k. ?tCM$N>e$G$O64 %W%m%;%C%5$NOrigin 2000 KIE(9k@-G=G"$k.

4.2.2 D6JBNs7W;;5!$NBeBX$H7F$N7W;;5!%/%i%9%?

2f$,9q$N?7>pJs=hM}3+H/5!9=(RWC) $G3+H/$5lF$$$kMyrinet %Y!<%9$N7W;;5!%/%i%9%?[6] $O, D6JBNs7W;;5!$HHf3S7FB=?'NJ$@-G=$r=P$9$3HrL\I8H7Fk. Avalon $,4pK\E*$KHW/SW $NA4$F$r4{@=IJ$G9=@.7?NKBP7F, RWC $N%/%i%9%?$G$O, HW $OA4$F%3%b%G%#%F%#HtIJG"k,, NIC %+!<%I$N%I%i%$%P, OS, DL?.%i%$%V%i%j, 8@8l=hM}7O$H$$$C$?SW A4BN$KEOCFFH<+$K3+H/[!y!y]$7$?%7%9%F%`$G$"$k. >\:Y$OK\FC=8$N5-;vEy$r;2>H$5l?$$.

4.2.3 7W;;5!%/%i%9%?Kh$k%9%1!<%i%V%k I/O

%+%j%U%)%k%K%"Bg3X%P!<%/%l%$9;$G$O, 1990 G/Be $N=iF,$+$iNetwork of Workstations(NOW) $N8&5f$,9Tol$F$$$k. IAi+$H$$$&$H, OS $d%G%#%9%/2s$j$N8&5f$,Cf?4G"$k. 8=:_$O, 140 Bf$NWS(OS $OSolaris) $H35 Bf$NPC(OS $OPC UNIX $"$k$$$OWindowsNT) $rMyrinet %Y!<%9$N%M%C%H%o!<%/$G@\B3$7$F$$$k. %7%9%F%`Fb$K$O500-1000 Bf$N%O!<%I%G%#%9%/$,$"$j, FH<+$K3+H/$7$?5!<%P%l%9!&U%!%$%k%7%9%F%`xFS $r;HMQ$7$Fdisk-to-disk %=!<%H$N%Y%s%A%^!<%/$G1997 G/4 7n;~E@$N@$3&5-O?$rC#@.7F$$$k.

xFS $O, !¥m!<%+%k%G%#%9%/>e$N%G!<%?hj$b, System Area Network >e$NB>$N7W;;5!$N<g5-21$K$"$k%G!<%?$NJ}$,B.$/$"%/%;%9G-$k!W$H$$$&H/A[$N85$K, %G!<%?$r;HMQ$9$k%/%i%$%"%s%H$N<g5-21$r%0%m!<%P%k$J6&M-%U%!%$%k%-%&%C%7%eH7$F;HMQ$9$k cooperative caching $d, J,;66&M-%a%b%j7?JBNs7W;;5!K*1k%-%&%C%7%e0l4S@-@)8f$N<jK!$r1~MQ7F%U%!%$%kC10L$N4IM}%N!<%I$rF0E*$KJ,;6$9$k<jK!, J#?t7W;;5!$N%G%#%9%/$K8YCF%9%H%i%$%T%s%0$r9T$&%=%U%H%&%"RAID $N<jK!$JIr1~MQ9k3H$G%9%1!<%i%V%k$G2DMQ@-$N9b$$%U%!%$%k%7%9%F%`$r<B8=7F$$$k.

=>Mh$NJBNs7W;;5!$KBP9k, 7W;;5!%/%i%9%?$NI/O%7%9%F%`$N%9%1!<%i%S%j%F%#%H%3%9%H%Q%U%)!<%^%s%9$,NI$/8=lF$$$k.

[!y] %M%C%H%o!<%/$O, 36%]!<%H$NFastEthernet%%$%C%A4Bf$H, 3liN%9%$%C%A$rAj8_$K@\B3$9$k12%]!<%H$NGigabitEthernet%9%$%C%A1Bf$G9=@.5l$F$$$k.

[!y!y] 0lIt$O%U%j!<%=%U%H$N2~NI

4.2.4 6&M-%a%b%j4D6-$rL\;X$7$F

%=%U%H%&%'%"Kh$k6&M-2>A[5-21%7%9%F%`(SVM) $rDs0F$7$?%W%j%s%9%H%sBg3X$NK.Li iN%0%k!<%W$O4-Way PentiumPro $r%Y!<%9$K$?SMP %/%i%9%?SHRIMP $r3+H/$7$F$$$k. SHRIMP GO, %M%C%H%o!<%/%$%s%?%U%'!<%9$r2>A[2=$7, %W%m%F%/%7%g%s$r4Ka:$K%f!<%6%l%Y%kDL?.$r2DG=K9$k5!9=$H7F, 2>A[%"%I%l%96u4V$K%M%C%H%o!<%/%$%s%?%U%'!<%9$N%&%$%s%I%&(Channel) $r%^%C%T%s%0$9$kVirtual Memory Mapped Channel(VMMC) $rDs0F$7, 3l$r<B8=$9k?aN@lMQ%M%C%H%o!<%/%$%s%?%U%'!<%9+!<%I$r3+H/7F$$$k. #2DN%W%m%;%94V$G0lC6, Channel $r@_Dj$9kH, $=$l0J8e$N%W%m%;%94VDL?.$OChannel $KBP1~$9$k%&%$%s%I%&$r6&M-%a%b%j$H7F;HMQ9k3H$,$G$-, DL?.$NEY$K%7%9%F%`%3!<%k%p2p$9I,MW$,$J$/$J$k.

5. $*$ojK

%9!<%Q!<%3%s%T%e!<%?$H$$($P%Y%/%H%k7W;;5!$G$"$C$?10G/A0, !¥VE2A$JHFMQ%^%$%/%m%W%m%;%C%5$rBt;3DJ$$$G, %Y%/%H%k7W;;5!KIE(9k@-G=$r=P$9!W$H$$&N,,JBNs7W;;5!$Nkp$$J86gG"$C?. $=$7$F:#F|, !¥PC $"$k$$$OWS rE,EYKDJ$$$G@lMQJBNs7W;;5!KIE(9k@-G=$r=P$9!WHkpC$F$$$kN,7W;;5!%/%i%9%?G"$k. A0<T$N>l9g, !¥V<!=hM}!W$+$i!¥JBNs=hM}!W$H$$&?$K5;=QE*$JUQ3W$,$"C?NKBP$7, 8e<T$O!¥VH$$d$9$5!W$d!¥V3%9%H%Q%U%)!<%^%s%9!W$NDI5f$H$$&, JBNs=hM}5;=Q$N!NV/E8!W$+$i!¥V.=O!W$X$NJQ3W$G$"$k$H9M$($k.

$^$?, =>Mh$NJBNs7W;;5!$N8&5f!?3+H/$,%O!<%I%&%'%"<gF37?$G$"$C$?$NKBP7F, :r:#$N7W;;5!%/%i%9%?$N8&5f!?3+H/$O%=%U%H%&%'%"$"$k$$$O%f!<%6<gF3G"kH$$&NO, FCI.9Y$-E@$G$"$m$&.

7W;;5!%/%i%9%?$NIa5Z$KhC$FJBNs=hM}$NI_5o$,Dc$/Jj, hjB?$/$/$N%W%m%0%i%^$,JBNs=hM}$rBN83$9$k5!2q$rbC$?$3HOHs>o$KM-0U5A$G$"$k. 3Nh&$J%V%l!<%/%9%k!<K$hCFJBNs=hM}$,0lIt$N8&5f<TN?aN5;=QGOJ/, 4/0lHLNEv?$jA0$N5;=QHJk3Hr4j$&<!Bh$G$"$k.

;2 9M J8 8%

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/hypertext/fpcrf/j/ap3000.html

5) @DLZ, ;3E:, 8^Eg, ?9, CfEg, IYED, "6&M-%a%b%j%Y!<%9$N%7!<%'%l%9$JJBNs7W;;5!4D6-$r<B8=$9$k%*%Z%l!<%F%#%s%0%7%9%F%`$N9=A[," >pJs=hM}3X2c@8&5f2cJs9p, 97-OS-74, pp.195–200, 1997 G/2 7n.

6) <jDM, KY, @P@n, "%o!<%/%9%F!<%7%g%s%/%i%9%MQDL?.%i%$%V%i%j PM $N@_7W$H<BAu," *JSPP'96*, pp.41-48, 1996 June. $=$NB>, 2<5-URL Eyhttp://www.rwcp.or.jp/people/mpslab/clusters/home.html

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