JBNs1~MQ$r;X8~$7$?J,;6%7%9%F%'$N %W%m%H%?%$%W!&O!<%I%&%'%" A Prototype Hardware of a Distributed System for Efficient Execution of Parallel Applications

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Abstract

Users can run light jobs without stress on existing distributed systems. But when a user runs a heavy job on a system, it is difficult for users to use the system efficiently by using another computing resources connected by network. And other users cannot use the machine because of it.

As each computer of existing distributed systems is made to use alone, the communication mechanism of it is additional. Therefore it has much communication costs and the scheduling for the multi-user environment of it is not enough. They are serious problems. To solve these problems, we must construct the system which are made of the hardware with a high speed communication method and the software with efficient scheduling method.

Then we propose a computer system named "computer colony", which solves problems of distributed systems, much communication costs and insufficient scheduling for the multi-user environment. The Goals are (1) reasonable price for easy use or maintenance, (2) ease to use, and(3) efficient use of computing resources by parallel processing. Users can use the whole system as if it were a parallel computer. A computer colony is made of the hardware with a high speed communication method and the operating system with efficient scheduling method specialized for it.

We develop the prototype-hardware of computer colony, which is made of existing workstations with high speed communication boards for the example of "computer colony".Requirements of the high speed communication boards are following three functions, (1) direct connection to the system bus,(2) hardware flow control in lower level protocol, and (3) the programmable hardware structure.

The latency of existing communication methods are almost the software overhead of system calls. This board let users use the communication system safety without system calls, by connecting the board to the system bus and make a map for a virtual address space. That is, the board enables communication system protect by the map management by the operating system, and by making communication system for each physical address. Thus, the board can communicate for any memory access at the physical address, safety.

And, because we connect the board to the system bus with a cache-coherence control protocol, the board can invalidate a processor cache or can snoop a invalidation signal, and it can keep the cache-coherence.

In the general network system existing, the flow control is done by the software only in higher level protocol. So there are much protocol overheads. We use the network device which supports lower level flow control, and we use the flow control by a hardware for the reduction of software overhead.

It is important that how the communication model of a computer colony use. To evaluate various communication models, the board must be programmable. Therefore, the board has a protocol-processor and a cache which can access to main memory. And, the board has also a FPGA which makes up other elements on the board for flexibility.

The above proves that we can make the efficient prototype-hardware for a computer colony that can support high speed communication and keep prototype-flexibility.

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3N%W%m%H%?%$%W!&%O!<%I%&%'%"$rK\9F$G=R$Ykh$&$K9=@.9k3HKh$j!"=>Mh$NJ,;6%7%9%F%`GOIT2DG=

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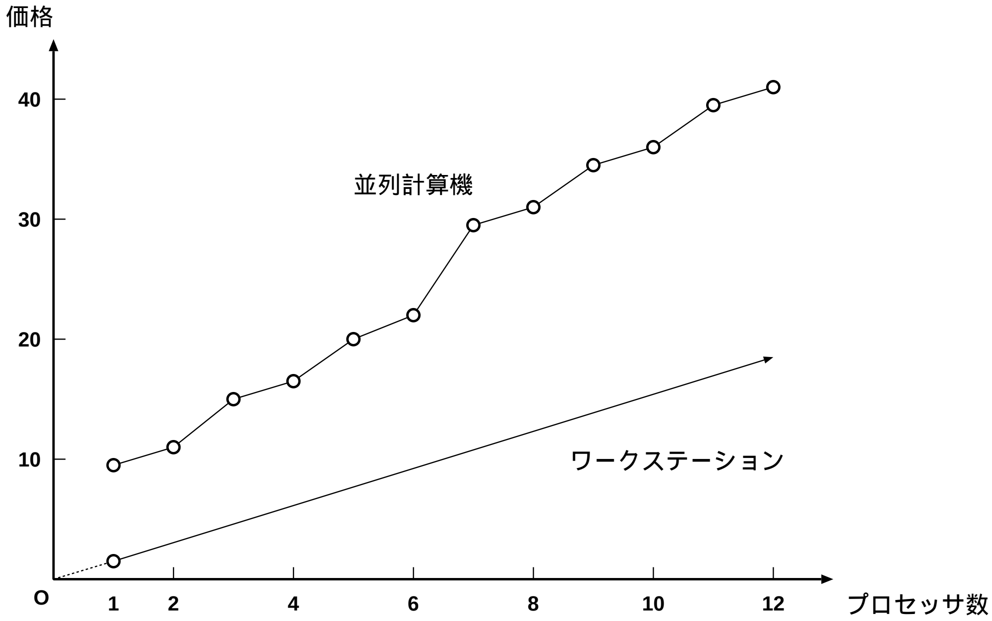
%^%k%A%W%m%;%C%55!GO!"I/O!"c~BN!"EE8;AuCVJI!"B?$/$NItIJ$r%W%m%;%C%54V$G6&MQ9k3H$,$G$-$kKb4Xoi$:!"$n$ Bf$N%W%m%;%C%5$rEk:\$9$k%^%k%A%W%m%;%C%55!$O!"F1Ey$N%W%m%;%C%5$rEk:\$9$k%7%s%0%k%W%m%;%C%55!$n$ BfJ,hj$bG\0J>e9b3[$G$"$k!#3l$ONL;:/NIHN8z2L——7W;;5!C1BNrIl@$1BgNL$K@8;:/HNGdG-k+Kh$k:90[$G$"$j!"7?$,$CF3$N798~$O5;=Q$N?JJb$JIKhCFOJQok3H$,$J$$$HM=A[5l$k!#

CJ3,E*%"%C%W%0%l!<%I2DG=@-

M=;;5,LONBg-$/$J$$Cf>.$N%o!<%/%0%k!<%W$KHCFO!"J,;6%7%9%F%`$NCJ3,E*%"%C%W%0%l!<%I2DG=@-$O!"FC$K=EMWG"$k!#

7W;;5!$O$$$:$lDDIe2=$9$k1?L?$K$"$j!"2?G/$+$K0lEYG$$BX$($;~4|$,$dCFMh$k!#=8Cf%7%9%F%`$G$b!"%W%m%;%C%5$J$I$N%b%8%e!<%k$r%"%C%W%0%l!<%I$G$-$k$b$N$b$"$k$,!"$$$:$l!"%7%9%F%`A4BN$rGc$$BX$($J1lPJiJ$$$H$-$,Mh$k!#$=NEYK!"9b2A$J%^%k



?^1: JBNs7W;;5!$H%o!<%/%9%F!<%7%g%s$N%W%m%;%C%5Bf?t$H2A3J$N4X78

%A%W%m%;%C%5$r?75,9XF~$G$-$kM5J!$J%o!<%/%0%k!<%W$O8Bil$F$$$k$@$m$&!#

J,;6%7%9%F%`G"lP!"9=@.9k5!4o$N0lIt$r!"CJ3,E*KCV-49$($F$$$/3H$,$G$-$k!#

%b%8%e%i%j%F%# 3liNJ,;6%7%9%F%`$N%a%j%C%H$O!"0l8@$G$$$($P!"J,;6%7%9%F%`$N%b%8%e%i%j%F%#$N9b5Khk!#D^$j!"=8Cf%7%9%F%`$HJ,;6%7%9%F%`$N0c$$$NK\<A$O!"%b%8%e%i%j%F%#$NEY9g$$$K$"$k$H$$$(h&!#

2.2 8=:_$NJ,;6%7%9%F%`$NLdBjE@

3Nh&$KJ,;6%7%9%F%`$O!"=8Cf%7%9%F%`Hf$Y$FM%$l$?FC<A$r;}CF$$$kbN$N!"JBNs%W%m%0%i%`$N<B9T$rA[Dj$7$?>l9g$K$O!"LdBj$,$"$k!#$=$l$O!"DL?.%3%9%H$N9b5H!"QoS(Quality of Service) $NLdBj$G$"$k!#

2.2.1 DL?.%3%9%H

8=:_$NJ,;6%7%9%F%`$G$O!"JBNs%W%m%0%i%`$r<B9T9k3H$O<B:]>e$[Hs$II,T2DG=$K6a$$!#$=$l$O<g$K!"DL?.K+$+$k%3%9%H$,Hs>o$KBg$-$$$?aG$"$k!#

:G6aGO!"1Gbps bN9b%P%s%II}$r;}$D%M%C%H%o!<%/$,MxMQ2DG=$KJjDD$"$j!"J,;6%7%9%F%`$H$$$($I$bHs>o$K9b$$%M%C%H%o!<%/!&9%k!<%W%C%H$r;}$D$h$&$K$J$C$F$-$F$$$k!#$7$+$7!"J,;6%7%9%F%`>e$GJBNs%W%m%0%i%`$r<B9T$9$k:]$KLdBj$H$J$k$N$O!"%M%C%H%o!<%/<+BN$N%9%k!<%W%C%H$G$O$J$/!"$`$7$mDL?.$K4Xok%=%U%H%&%'%"!&%*!<%P!<%X%C%IG"$k!#

3Nh&$J%*!<%P!<%X%C%I$K$O0J2<$NbN$,$"$k!'

1. DL?.$K4X$o$k;q8;$NJ]8nN?aN%7%9%F%`!&%3!<%k
2. **TCP/IP** JI$N%W%m%H%3%k=hM}

3Nh&$J=hM}$N$?$a$K!"DL?.$NEY$Kmsec %*!<%@$N%*!<%P!<%X%C%I$,@8$8$k!#

Hf3SE*:YN3EY$NDL?.$rI,MWH9$kJBNs%W%m%0%i%`$G$O!"$\mu$sec %*!<%@$NIQEY$GDL?.$r9T$&$b$N$b$"$k!#%/%i%$%"%s%H/%5!<%P$N$h$&$JAFN3EY$NJBNs=hM}$G$"$l$P$H$b$+$/!"$=$N$h$&$JJBNs%W%m%0%i%`$r8zN(h/<B9T9k$?$aKO!"3Nh&$J%*!<%P!<%X%C%I$r$[$HsI40A4$KGS=|$9kI,MW,$"$k!#

2.2.2 QoS

QoS(Quality of Service) HO!"%f!<%6$NMW5a$KBP$7!"%7%9%F%`$,M?$($k;q8;NNLG$"$k!#8=:_$NUNIX $N%W%m%;%9$NM%@h=g0L4IM}$O!"%W%m%;%9$4HK9Tol$F$$$k!#9JoA!"Bg5,LO$J%8%g%V$N<B9TKh$j!">.5,LO$N%8%g%V$N8zN($,0-$/$JiJ$$$h$&$KBg5,LO$J%8%g%V$NM%@h=g

0L$r2<$2!">.5,LO$N%8%g%V$NM%@h=g0L$r>e$2k3HKhj!"%8%g%V$N5,LO$KhkQoS $r<B8=$7$F$$$k!#

7+$7!"%3%s%T%e!<%?!&%3%m%K!<$NL\;X$9Dc%1%$%F%s%7$NDL?.Kh$j!"%^%7%s4V$N0ICVF)2a$,<B8=$5ll$P!"$3Nh$&$J%9%1%8%e!<%j%s%0$@$1GO%7%9%F%`A4BN$,>.5,LO$N%8%g%VKhCF@jM-5lF7$^$&>uBV$,5/$3$jF@$k!#

hC$F!"%3%s%T%e!<%?!&%3%m%K!<GO!"5i$K0J2<$Nh&$J%9%1%8%e!<%j%s%0$r9T$$!"%3%s%T%e!<%?!&%3%m%K!<$rMxMQ$9$kA4$F$N%f!<%6$,2wE,$K:n6H$G$-$k4D6-$r<B8=$9$k!#

- %M%C%H%o!<%/!&%o%$%I$J%9%1%8%e!<%j%s%0

  =>Mh9Tol$F$$$?%^%7%sC10L$N%9%1%8%e!<%j%s%0$r!"%7%9%F%`A4BN$rE}3g$9$k%9%1%8%e!<%j%s%0$K3HD%9k!#

- %f!<%6C10L$N%9%1%8%e!<%j%s%0

  3F!9$N%f!<%6$NMW5a9kQoS KBP7G-k@$1BP1~$7!"$+$D!"%7%9%F%`A4BN$G3F%f!<%6$KBP7F8xJ?$J%5!<%S%9$rJ]>Z9k%9%1%8%e!<%j%s%0$r9T$&!#

3 %W%m%H%?%$%W!&%O!<%I%&%'%"

K\>OGO!"!V%3%s%T%e!<%?!&%3%m%K!<!W<B8=N?$a!"2f!9$,3+H/7F$$$k%O!<%I%&%'%"!&%W%m%H%?%$%W$r<($7!"%3%s%T%e!<%?!&%3%m%K!<$NMW7o$G$"$k9bB.DL?.5!9=<B8=N?aKM-8z$J9=@.K!$K$D$$$F=RYk!#

3.1 %W%m%H%?%$%W!&%O!<%I%&%'%"$N@_7WJ}?K

%W%m%H%?%$%W!&%O!<%I%&%'%"$O!"@h$K=R$Y$?%3%s%T%e!<%?!&%3%m%K!<$N%O!<%I%&%'%"$NFCD'$G$"$k!"9bB.DL?.5!9=$r<B8=$G$-$J1lPJiJ$$!#$=$N$?$a!"0J2<Nh$&$JMW7o$,$"$k!#

(a) %7%9%F%`%3!<%k$r2p$5$J$$DL?.

(b) %W%m%H%3%k%*!<%P%X%C%I$N7Z8:

$^$?%W%m%H%?%$%W$H7F!"0J2<$NMW7o$bI,MWG"$k!#

(c) MM!9$JDL?.J}<0$N<B8=

hC$F!"K\%W%m%H%?%$%W!&%O!<%I%&%'%"GO0J2<Nh$&$J@_7WJ}?KrH$k!#

(a) %M%C%H%o!<%/%$%s%?%U%'!<%9$N%7%9%F%`%P%9XN@\B3

(b) %O!<%I%&%'%"Kh$k%U%m!<@)8f

(c) %M%C%H%o!<%/%$%s%?%U%'!<%9$N%W%m%0%i%^%V%k$J9=@.

3.2 %W%m%H%?%$%W!&%O!<%I%&%'%"$N35MW

K\%W%m%H%?%$%W!&%O!<%I%&%'%"$N4pK\E*$J5!G=$O!"0J2<NbNG$"$k!#

1. %7%9%F%`%3!<%k$N$J$$DL?.5!9=$r<B8=$9$k$?$a!"%7%9%F%`%3!<%k$rMxMQ$;$:$K!"%f!<%6KBP7$F0BA4$K2rJ|G-$kDL?.5!9=$r<B8=$7!"%7%9%F%`%3!<%k$N%*!<%P%X%C%IrJ$/$9%O!<%I%&%'%"HJ$k!#

2. =>Mh$N%7%9%F%`$N$h$&$KHFMQ@-$O$"$k$,=E$$DL?.%W%m%H%3%k$G$O$J$/!"%7%9%F%`5,LO$KE,9g7?DL?.%W%m%H%3%k$r:NMQ$9k3HKhj!"%W%m%H%3%k%*!<%P%X%C%I$N7Z8:$r<B8=9k%O!<%I%&%'%"HJ$k!#

3. %W%m%H%?%$%W$H7F!"MM!9$JDL?.J}<0$N<B8=!&I>2A$,9T$($k%O!<%I%&%'%"$HJk!#

0J2<GO!"@h$K=R$Y$?MW7o(a),(b) N?aN%W%m%H%?%$%W!&%O!<%I%&%'%"$N9=@.K!$r=R$Y!"$=$N9=@.K!$K4p$E$$$?!"%W%m%H%?%$%W!&%O!<%I%&%'%"$N9=@.$r<($9!#

@_7WJ}?K$N!V%M%C%H%o!<%/%$%s%?%U%'!<%9$N%W%m%0%i%^%V%k$J9=@.!W$HMW7o(c) KD$$$F$O!"<!>O$G=RYk!#

3.3 3FMW7oN?aN9=@.K!

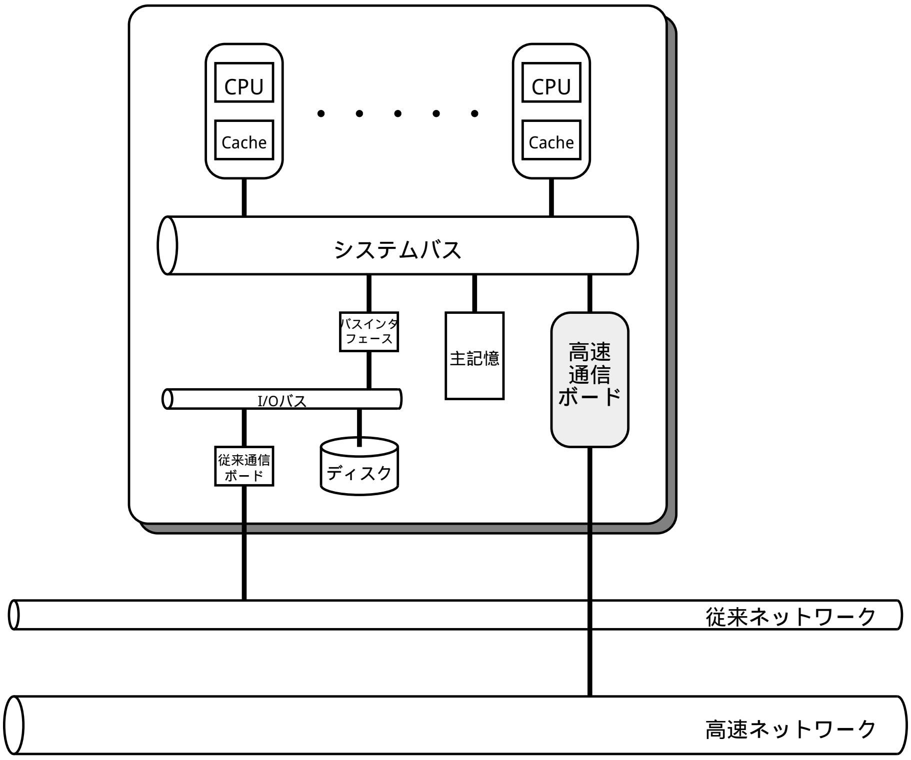
3.3.1 %M%C%H%o!<%/%$%s%?%U%'!<%9$N%7%9%F%`%P%9XN@\B3

%W%m%H%?%$%W!&%O!<%I%&%'%"$G$O!">e5-$NMW7o(a) $r<B8=$9k?$a!"%M%C%H%o!<%/%$%s%?%U%'!<%9$r!"=>Mh$N%7%9%F%`$G@\B3$5$l$F$$$?I/O %P%9$G$O$J$/!"%7%9%F%`%P%9$K@\B3$9$k!#

3N9=@.$r!"?^2$K<($9!#$3$N9=@.$Khj!"0J2<Nh$&$KMW7o$r<B8=$9$k!#

%7%9%F%`%3!<%k$r2p$5$J$$DL?.

%7%9%F%`%P%9$rMxMQ$7$?DL?.$G$O!"MMU(Memory Management Unit, %a%b%j4IM}%f%K%C%H) Kh$k%a%b%jJ]8n5!9=$rMxMQ9k3H$G!"DL?.5!9=$r%f!<%6KBP7$F0BA4$K2rJ|9k3H$,$G$-$k!#9JoA!"DL?.;~$K%f!<%6$,9T$&2>A[%"%I%l%9$G$N%a%b%j%"%/%;%9$r!"MMU $,J*M}%"%I%l%9$G$N%a%b%j%"%/%;%9$K



?^2: %M%C%H%o!<%/%$%s%?%U%'!<%9$r%7%9%F%`%P%9$K@\B3

JQ4 9$ 9$k!#$3$NJ*M}%"%I%l%9$X$NJQ4 9$Khj!"DL?. ;q8;$,DL>o$N%a%b%j%"%/%;%9$HF1MM$KJ]8n5l$k!#

$=$N7k2L!"%7%9%F%`%3!<%k$N2p:_$rI,MWH7$J$$DL ?.$,9T$($k!#

%j%b!<%H%a%b%j$N%-%c%C%7%s%0$N<B8=

%M%C%H%o!<%/%$%s%?%U%'!<%9$r%7%9%F%`%P%9$K@\B3 $9$k$3$H$K$h$j!">e5-$N$h$&$K%7%9%F%`%3!<%k$N2p 5J$$DL?.$,<B8=$5lk$,!"%7%9%F%`%P%9$,%-%c%C %7%e$K4X$7$F4 0A4$JA`:n$r9T$($k$?$a!"%j%b!<%H%a %b%j%"%/%;%9$N:]!"%j%b!<%H%a%b%j$NFbMF$r<+%N!< %I$K%-%c%C%7%s%0$9$k3H$b2DG=$KJj!"%a%b%j" %/%;%9$N9bB.2=$,?^lk!#

3.3.2 %O!<%I%&%'%"Kh$k%U%m!<@)8f

K\%W%m%H%?%$%W$G$O!">e5-$NMW7o(b) G"$k%W%m%H %3%k%*!<%P%X%C%I$N7Z8:N?$a!"=>Mh%=%U%H%&%'%"$G9T ol$F$$$?%U%m!<@)8f$r%O!<%I%&%'%"$G9T$&!#$=N?$a!" %N!<%I4V$N9bB.%M%C%H%o!<%/H7$FFibre Channel $r:N MQ$9$k!#

9b%P%s%II}$N%M%C%H%o!<%/$H7F$O!"Fibre Channel $NB>$K!"Gbit-Ethernet $dATM(Asynchronous Transfer Mode)!"SCI(Scalable Coherent Interface) JI$,$"$k!#

0J2<GO!">e5-$N%M%C%H%o!<%/$+$iFibre Channel $r :NMQ$7$?M}M3$r=RYk!#

1. **Gigabit Ethernet**

   Gigabit Ethernet $O=>Mh$NEthernet $HF1MM$K%U%m!< %3%s%H%m!<%k$r2<0L%l%$%d$G%5%]!<%H$7FJ$$$?$a!" %=%U%H%&%'%"$KhC$F<B8=$5lk>e0L%l%$%d$^GI, MWKJj!"%W%m%H%3%k%*!<%P%X%C%I$,Bg$-$/$J$k!#

2. **ATM**

   ATM $O%Q%1%C%H$d%;%k$NB;<:$r2sI|9k5!G=$,$J $$!#$^$?!"DL?.7F$$$kC<Kv$N?t$K%9%k!<%W%C%H$, 0MB8$9$k!#

3. **SCI**

   SCI $O%1%$%d9=@.$,%O!<%I%&%'%"$Khk2<0L%l%$%d $+$i%=%U%H%&%'%"Kh$k>e0L%l%$%d$^$G87L)$KDj5A 5l$F$$$k$?$a!"$"$kItJ,$^$G$H$$$&<BAuOG$-$J $$!#$^$?!"MM!9$J9b5i5!G=$r<B8=7F$$$k$?$a!"%W %m%H%3%k%*!<%P%X%C%I$,Bg$-$$!#

>e5-NbNKBP$7!"Fibre Channel $O%U%m!<@)8f$r2<0L %l%$%d$G%5%]!<%H7F$$$k!#0J2<GO!"Fibre Channel $G $N%U%m!<@)8f$N$?$a$N%U%l!<%`$r@bL@9k!#

Fibre Channel $N%U%m!<@)8fMQ%U%l!<%`

Fibre Channel $N%U%l!<%`%U%)!<%^%C%H$r?^ 3$K<( $9!#Fibre Channel $K$O!"0J2<$N2 <oN`$N%U%l!<%` $,B8:_$9$k[1]!#

- %j%s%/%3%s%H%m!<%k%U%l!<%`

  ACK,NACK MQ$N%G!<%?%U%#!<%k%I$N$J$$%U%l !<%`!#%U%l!<%`%X%C%@Fb$K!"ACK,NACK $N<o JL$r3JG<9k!#

- %G!<%?%U%l!<%`

  %G!<%?$r4^$`0lHL$N%U%l!<%`!#%Z%$%m!<%IIt$K!" MM!9$J%G!<%?$r3JG<9k!#

Fibre Channel GO!">e5-$N%j%s%/%3%s%H%m!<%k%U%l!< %`$r%M%C%H%o!<%/%$%s%?%U%'!<%9$GMxMQ$9k3HKhj!" %O!<%I%&%'%"GN%U%m!<@)8f$,2DG=$KJk!#

hC$F!"Fibre Channel $r:NMQ$9k3HKhj!"=>Mh %=%U%H%&%'%"$G9T$olF$$$?%U%m!<@)8f$r2<0L%l%$%d$G %O!<%I%&%'%"E*$K9T$&$3H,2DG=KJ$k!#$=$N7k2L!"%W %m%H%3%k%*!<%P%X%C%I$N0lIt$G$"$k!"%U%m!<@)8f$K4X$o $k%=%U%H%&%'%"%*!<%P%X%C%I$r7Z8:$9k3H,G-$k!#

3.4 %W%m%H%?%$%W!&O!<%I%&%'%"$N9=@.

>e5-$N9=@.K!$Khj2f!9$,@_7W$7$?%W%m%H%?%$%W!&O!< %I%&%'%"$NA4BNA|$r!"?^4$K<($9!#

0J2<GO!"@_7W7?%W%m%H%?%$%W!&O!<%I%&%'%"$N %N!<%I9=@.$H%M%C%H%o!<%/9=@.$K$D$$$F=RYk!#

3.4.1 %7%9%F%`%P%9$rMxMQ$G$-$k%N!<%I9=@.

K\%W%m%H%?%$%W!&O!<%I%&%'%"$G$O!"%N!<%I$H7F!" SPARCstation 10/20 $K%M%C%H%o!<%/%$%s%?%U%'!<%9$H Jk!"@lMQDL?.%\!<%I$rAuHw7?$bNr:NMQ9k!#$^$?!" @h$K=RY?9bB.DL?.5!9=$rK~$?9?$a!"DL?.%\!<%I$r SPARCstation 10/20 $N%7%9%F%`%P%9$G$"$kMBus $K@\ B3$9$k!#

SPARCstation 10/20 $rMWAG%^%7%s$H7F:NMQ7?M} M3$O!"0J2<$NDL$j!#

1. 3HD%MQ**MBus** %9%m%C%H$rMxMQ$G$-$k

   SPARCstation 10/20 $O!"%^%6!<%\!<%I>e$K2 DN MBus %9%m%C%H$r;}$D!#1 DNMBus %9%m%C%HKO I8=`$G%W%m%;%C%5$rEk:\$7$?MBus %b%8%e!<%k$,Au Ce$5$l$F$$$k!#$b$&1 $D$N3HD%MQMBus %9%m%C%H$K DL?.%\!<%I$r@\B3$9$k$3$H$K$h$j!"%7%9%F%`%P%9$r MxMQ$7$?DL?.$,9T$($k!#

2. **MBus** $,%-%c%C%7%e%3%R!<%l%s%9@)8fMQ?.9f$r%5%]!< %H$7$F$$$k

   SPARCstation 10/20 $O!">e5-$N3HD%MQMBus %9%m%C %H$K%W%m%;%C%5$rEk:\$7$?MBus %b%8%e!<%k$rAuCe 9k3HKh$j!"SMP(BP>N7?%^%k%A%W%m%;%C%5) $K 3HD%$9k3H,G-$k!#$=N?$a!"MBus GO%-%c%C %7%e%3%R!<%l%s%9@)8fN?aN?.9f$r%5%]!<%H$7$F $$$k!#DL?.%\!<%I$,$3$N?.9f$rMxMQ9k3HKh$j!" %-%c%C%7%e$KBP7F$N40A4$JA`:n$,2DG=$KJk!#

3.4.2 **Fibre Channel** Kh$k%N!<%I4V%M%C%H%o!<%/

J#?t$N%N!<%I$r@\B3$9$k$?$a!"Fibre Channel GO Loop %H%]%m%8!"Fabric %H%]%m%8$,A*Br$G$-$k[1]!#

- **Loop** %H%]%m%8

  Fibre Channel $NLoop %H%]%m%8$OArbitrated-Loop G"$k!#Arbitrated-Loop GO!"%k!<%WNCfGF1;~ $K1 DNNY@\%N!<%I4V$NDL?.7+G-$J$$!#$=$N$? $a!"%N!<%I?t$,A}2C7?>l9g!"1s3V%N!<%I4V$GDL?. $r9T$&:]$N%9%k!<%W%C%H$,LdBjKJ$k!#

- **Fabric** %H%]%m%8

  Fibre Channel $NFabric %H%]%m%8$O!"%M%C%H%o!<%/ >e$N?.9f$,Fibre Channel $NFraming %W%m%H%3%k$5 $(K~$?7F$$$l$P!"J#;($JAuCV4V$N@\B3!&r49$H$$ $&5!G=$O!"Fabric AuCV$,9T$CF/lk$?$a!"%N!<%I ?t$K4X$oi:0lDj$N%9%k!<%W%C%H$,4|BTG-$k!#

hC$F!"K\%W%m%H%?%$%WGO%N!<%I4V$N@\B3%H%]%m%8 H7$F!"Fabric %H%]%m%8$r:NMQ$7!"%7%9%F%`$r9=@.9k!#

4 DL?.%\!<%I

K\>OGO!"!V3%s%T%e!<%?!&3%m%K!<!W$N%W%m%H%?%$ %W!&O!<%I%&%'%"$N%M%C%H%o!<%/!&%$%s%?%U%'!<%9H7$F 2f!9$,@_7W7?DL?.%\!<%I$r<($7!"%W%m%H%?%$%W!&O!< %I%&%'%"$NMW7o$N<B8=K!$r=RYk!#

4bytes	24bytes	0 ~ 2112bytes Data Field		4bytes	4bytes
Start of Frame	Frame Header	64bytes Optional Header	2048bytes Payload	CRC Error Check	End of Frame

Data Field = 0 byte (Link Control Frame)

= 0 ~ 2112 bytes(Data Frame)

?^3: Fibre Channel $N%U%l!<%`%U%)!<%^%C%H

4.1 DL?.%\!<%I$N@_7WJ}?K

DL?.%\!<%I$NMW7o$O!"%W%m%H%?%$%W!&O!<%I%&%'%"$NMW7o$r0z$-7Q$$$@0J2<NbNHJk!#

(a) **OS** $N%7%9%F%`%3!<%k$r2p5J$$DL?.

(b) %j%b!<%H%a%b%j$N%-%c%C%7%s%0$N<B8=

(c) %W%m%H%3%k%*!<%P%X%C%I$N7Z8:

(d) MM!9$JDL?.J}<0$N<B8=

3NMW7o$rK~$?9?$a!"DL?.%\!<%I$O0J2<Nh$&$J@_7WJ}?KrH$k!#

(a) DL?.;~$N;q8;J]8n$N<B8=

(b) **MBus** $N?.9f$Khk%-%c%C%7%e%3%R!<%l%s%9$N<B8=

(c) %O!<%I%&%'%"Kh$k%U%m!<@)8f

(d) %W%m%0%i%^%V%k$J9=@.

4.2 DL?.%\!<%I$N35MW

K\DL?.%\!<%I$N4pK\E*$J5!G=$O!"%m!<%+%k%^%7%s$NJ*M}%"%I%l%9$H%j%b!<%H%^%7%s$N<g5-21$rBP1~$E1k3HG"$k!#$9Jo$A!"%a%b%j%"%/%;%9L?NaH/9T;~$K%7%9%F%`%P%9$rN.lkJ*M}%"%I%l%9$r%9%L!<%W$7!"I,MW$K1~$8$F%j%b!<%H%a%b%j%"%/%;%9$H$$$&7A$NDL?.$r<B8=9kbNG"$k!#$3N?$a!"0J2<$Nh&$JF0:n$r9T$&!#

1. J*M}%"%I%l%9↔%M%C%H%o!<%/%"%I%l%9$NJQ49

   %j%b!<%H%a%b%j%"%/%;%9$,I,MW$J>l9g!"%7%9%F%`%P%9$rN.$l$kJ*M}%"%I%l%9$r2?i+$N%M%C%H%o!<%/>e$N%"%I%l%9$KJQ49$7J1lPJi$J$$!#

2. %-%c%C%7%e%3%R!<%l%s%9@)8f

   DL?.%\!<%I$O!"<+%N!<%I$N%7%9%F%`%P%9$rN.$l$kJ*M}%"%I%l%9$r4^$`MBus %H%i%s%6%/%7%g%s$r%9%L!<%W$7!"DL?.$NI,MW@-$r4XCN9kHHbK!"%-%c%C%7%e%3%R!<%l%s%9@)8f$r9T$&I,MW$,$"$k!#

3. %U%m!<@)8f

   DL?.$N@.8y!"<:GT$r<($7!"I,MW$J$i:FAw$r9TJ&%U%m!<@)8f$N5!G=$rDL?.%\!<%I$G%5%]!<%H$7J1lPJi$J$$!#

0J2<GO!"@h$K=R$Y$?MW7o$N$?$a$NDL?.%\!<%I$N9=@.$r=R$Y!"$=$N8e!"$=$N9=@.Kh$k3FMW7o$N<B8=K!$r=R$Y$k!#

4.3 DL?.%\!<%I$N9=@.

DL?.%\!<%I$N9=@.$r?^5$K<($9!#

DL?.%\!<%I>eGO!"5!G=E*$K!"MBus %$%s%?%U%'!<%9It!"Aw<u?.MQ%P%C%U%!!"%W%m%H%3%k%W%m%;%C%5!"%W%m%H%3%k%W%m%;%C%5MQ$N2<!%-%c%C%7%e!"Fibre Channel $N%A%C%W$KJ,1ilk!#

0J2<GO!"DL?.%\!<%I>e$N3FItJ,$K$D$$$F=RYk!#

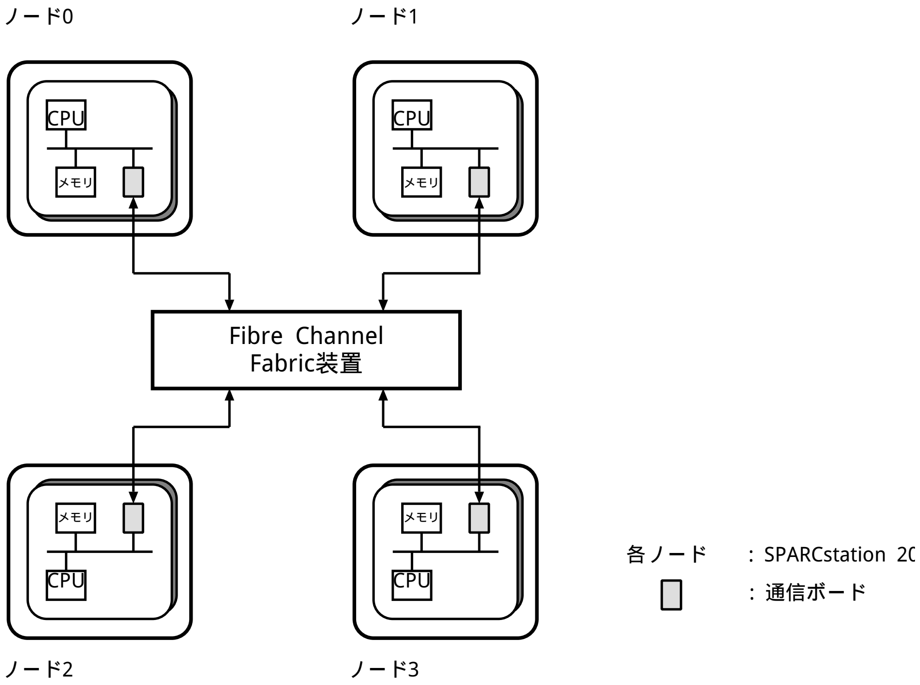
1. **MBus** %$%s%?%U%'!<%9It

   - **MBus** %$%s%?%U%'!<%9!&3%s%H%m!<%i

     MBus %$%s%?%U%'!<%9$r<B8=9k!#MBus >e$NJ*M}%"%I%l%9$r4^$`MBus %H%i%s%6%/%7%g%s$r>o$K%9%L!<%W$9$k!#

   - **B_Map**

     MBus %$%s%?%U%'!<%9!&3%s%H%m!<%kMQ%^%C%W!#<+%N!<%I$N%m!<%+%k%a%b%j$N3F%V%m%C%/$N>pJs$rJ];}9k!#



?^4: %W%m%H%?%$%W$NA4BN9=@.

$^$?!"8e=R$N E_Cache $N%P%C%/%^%C%W$H7F $bMxMQ$9$k!#

2. Aw<u?.MQ%P%C%U%!
   - **M_Buf** MBus MQ$NAw<u?.%P%C%U%!!#
   - **F_Buf** Fibre Channel Frame MQ$NAw<u?.%P%C%U%!!#
3. **Flow Ctrl.** %U%m!<@)8fMQ%m%8%C%/
4. %W%m%H%3%k%W%m%;%C%5

   %O!<%I%&%'%"$G9=@.:$Fq$JItJ,$r%W%m%H%3%k%W%m%;%C%5$G<B8=$9$k!#

   DL?.%\!<%I$K%W%m%H%3%k%W%m%;%C%5$rEk:\$9k3HKhj!"MM!9$JDL?.J}<0$rI>2AG-!"F1;~$K3+H/%3%9%H$rM^$($k3HbG$-$k!#
5. **E_Cache**

   %\!<%I>e$N%W%m%H%3%k%W%m%;%C%5MQ$N2<!%-%c%C%7%e!#<+%N!<%I$N%a%$%s%a%b%j$NFbMF$r%-%c%C%7%s%0G-$k9=@.$K$7!"%W%m%H%3%k%W%m%;%C%5$,5pBg$J%a%b%j6u4V$rMxMQG-kh$&$K9k!#
6. **Fibre Channel** MQ **Chipset**

   Fibre Channel $N%1%$%d0,1 $N=hM}$r9T$&[1]!#

   FC-0 Chip !%Q%i%1%k!?%7%j%"%kJQ49$r;\$9!#

   FC-1 Chip !Aw<u?.%U%1!<%`$KCRC%(%i!<%A%'%C%/!"8b/10b JQ49$r;\$9!#

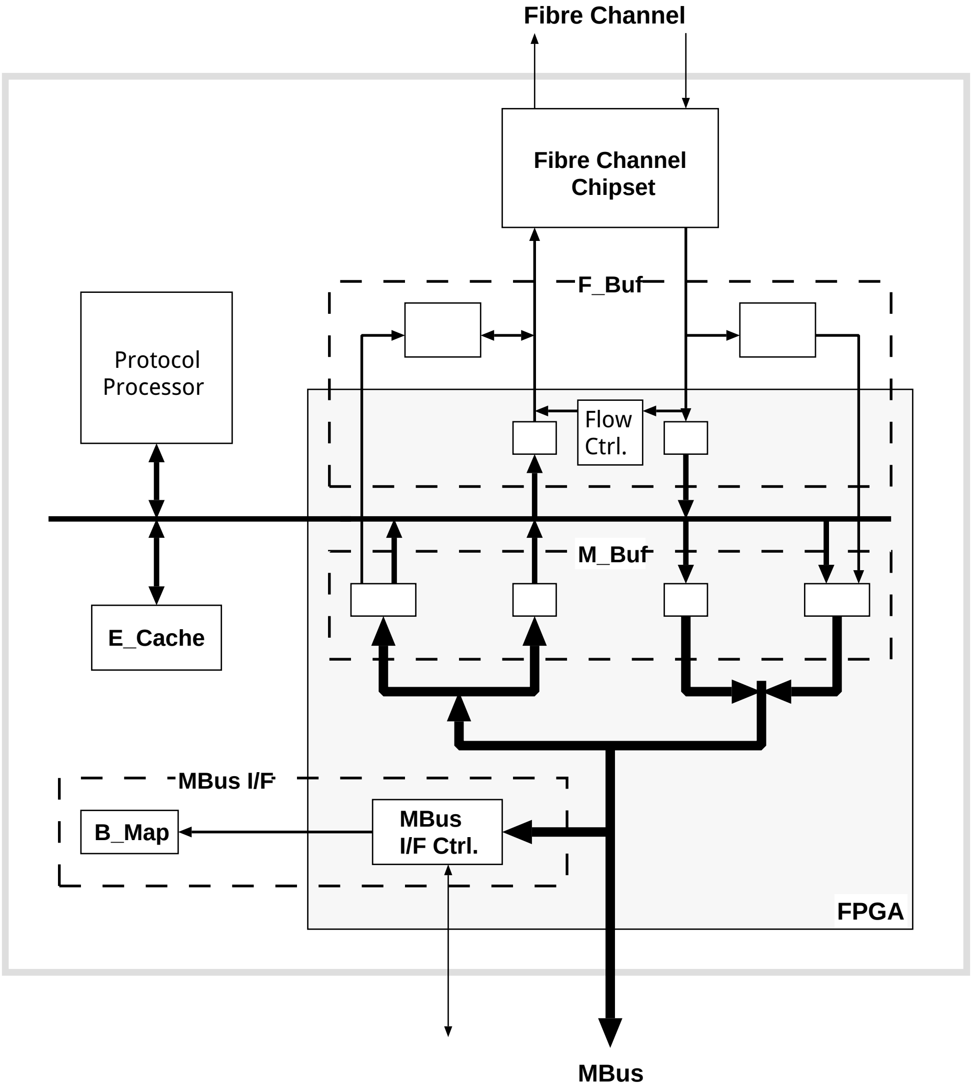
<!@a0J9_!"3liNMWAGKh$kDL?.%\!<%I$NMW7o$N<B8=K!$r=RYk!#

4.4 DL?.;~$N;q8;J]8n$N<B8=K!

K\DL?.%\!<%IGO!"MW7o(a)$N OS $N%7%9%F%`%3!<%k$r2p$5$J$$DL?.$r<B8=$9$k$?$a!"=>Mh OS $N%7%9%F%`%3!<%k$Khj<B8=5l$F$$$?!"DL?.;~$N;q8;J]8n$r%O!<%I%&%'%"$G9T$&!#

K\%W%m%H%?%$%W$G$O!"%7%9%F%`%P%9$rMxMQ7?DL?.$r9T$&!#3NH-@h$K=R$Y$?$h$&$K!"%f!<%6$,2>A[%"%I%l%9$rMxMQ7F%"%/%;%9$r9T$C$?$H$-!"$3lrMMU$,J*M}%"%I%l%9$KJQ49$7$F;q8;J]8n$r9T$C$F$$$k!#

7+$7!"$3$NJ*M}%"%I%l%9$r$=$N$^$^MxMQ7FDL?.$r9T$&$H!"=@Fp@-$K7g1k$?$a!"K\DL?.%\!<%IGO!"%M%C%H%o!<%/>e$rN.$l$k%"%I%l%9$H7F!"%M%C%H%o!<%/2>A[



?^5: DL?.%\!<%I$N9=@.

%"%I%l%9$r<h$jF~$l!"$3$N%M%C%H%o!<%/2>A[%"%I%l%9$rMxMQ$7$FDL?.$r9T$&!#

0J2<GO!"K\DL?.%\!<%I$GMxMQ$9$k%M%C%H%o!<%/2>A[%"%I%l%9KD$$$F=R$Y!"$3$N%M%C%H%o!<%/2>A[%"%I%l%9$rMxMQ$7$?>l9g$NDL?.%\!<%IKh$k;q8;J]8n$NJ}K!$r=R$Y$k!#

4.4.1 %M%C%H%o!<%/2>A[%"%I%l%9

K\DL?.%\!<%IGO!"%M%C%H%o!<%/>e$rN.$l$k%"%I%l%9$H7F!"%M%C%H%o!<%/2>A[%"%I%l%9$r<h$jF~lk!#

%M%C%H%o!<%/2>A[%"%I%l%9$H$$$&Cf4V7A<0$K$$$C$?$sJQ49$9$k3H$G!"%9%o%C%W%"%&%HEy$Khj%N!<%IFbK*1kJ*M}%"%I%l%9$NJQ99$,$"$C$?>l9g!"$=$N%"%I%l%9$NJQ99$rB>%N!<%I$KBP7F1#JC9k3H$,2DG=$KJk!#$=$N7k2L!"%N!<%I$NFHN)@-$,9b$^$j!"=@Fp$J%7%9%F%`9=C[$,2DG=KJ$k!#

K\DL?.%\!<%IK*$$$F!"%M%C%H%o!<%/2>A[%"%I%l%9H7FINh$&$JbN$rMxMQ$9k+KD$$$FOG0U@-$,$"$k!#0l$D$N<B8=K!$H7F!"$"$k2>A[%"%I%l%9$H!"$=$N2>A[6u4V$NID Kh$j%M%C%H%o!<%/2>A[%"%I%l%9$r9=@.$9k3H,9M$($ilk!#

4.4.2 DL?.;q8;J]8n$NJ}K!

%M%C%H%o!<%/2>A[%"%I%l%9$rMxMQ$7$?>l9g!"DL?.;~$N;q8;J]8n$r9T$&$?$aKO!"

Aw?.B&DL?.%\!<%I$O!"J*M}%"%I%l%9$+$i%M%C%H%o!<%/%"%I%l%9$X$NJQ49!"

<u?.B&DL?.%\!<%I$O!"%M%C%H%o!<%/%"%I%l%9$+$iJ*M}%"%I%l%9$X$NJQ49

$r9T$&I,MW$,$"$k!#

%"%I%l%9JQ49$NJ}K!

%"%I%l%9JQ49JQ49$N%$%a!<%8?^$r6$K<($9!#

K\DL?.%\!<%IGO!"3N%"%I%l%9JQ49$r%W%m%H%3%k%W%m%;%C%5!"E_Cache $rMQ$$$F0J2<Nh$&$K9T$&!#

1. MBus $N?.9f$NJ*M}%"%I%l%9$r!"5U0z$-%Z!<%8%F!<%V%k$G2>A[%"%I%l%9$KJQ49$7!"$=$N2>A[6u4V$NID $rF@$k!#
2. $=$N2>A[%"%I%l%9$+$iDL?.Aj<j$N%N!<%I$NID $rF@$k$?$a!"$=$liNBP1~4X78$rJ];}$9$k%^%C%W$r0z$/!#
3. 2>A[%"%I%l%9H=$N2>A[6u4V$NID Kh$j!"%M%C%H%o!<%/2>A[%"%I%l%9$r9=@.$9$k!#
4. <u?.B&$G2>A[%"%I%l%9$rF@$F!"%Z!<%8%F!<%V%k$GJ*M}%"%I%l%9$KJQ49$9$k!#

0J>eNh$&$K%"%I%l%9$NJQ49$r9T$&$3HKhj!"DL?.;~Kb%a%b%j%"%/%;%9$HF1MM$N;q8;J]8n$,<B8=$G$-$k!#

4.5 MBus $N?.9f$Khk%-%c%C%7%e%3%R!<%l%s%9$N<B8=

K\DL?.%\!<%I$O!"MW7o(b) H7$F!"%j%b!<%H%a%b%j$N%-%c%C%7%s%0$r9T$&!#$=N?$a!"%N!<%I$N%a%$%s%W%m%;%C%5$+$i8+$FDL?.%\!<%I$,$"$?$+$bB>%N!<%I$N%W%m%;%C%5%-%c%C%7%e$d%a%b%jNh$&$K8+$(kI,MW,$"$k!#$hCF3NH-!"<+%N!<%I$N%a%$%s%W%m%;%C%5$N%-%c%C%7%e$H!"B>%N!<%I$N%W%m%;%C%5%-%c%C%7%e$d%a%b%jHN4V$N%3%R!<%l%s%9$rHkI,MW$,$"$k!#$3N?$a!"DL?.%\!<%I$O0J2<Nh$&$JMW7o$rK~$?$9MBus %$%s%?%U%'!<%9$r<B8=$9kI,MW,$"$k!#

4.5.1 MBus %-%c%C%7%e%3%R!<%l%s%9$NMW7o

MBus $O!"single-ownership write-invalidate $N%-%c%C%7%e%3%R!<%l%s%9%]%j%7!<$r;}$D!#single-ownership write-invalidate HO!"M-8z$J%G!<%?$O!"$?$@0lDN%-%c%C%7%eN_$,;}$A!"%-%c%C%7%e$K=q$-9~$^$l$?$H$-!"$[$+$N%W%m%;%C%5$,;}$C$F$$$kA4FN%3%T!<$OL58z2=$5lk$H$$$&3HG"$k!#

hC$F!"DL?.%\!<%I$G%W%m%;%C%54V$N%3%R!<%l%s%9$rHk$?$aKO!"0J2<Nh$&$JMW7o$,$"$k!#

1. <+%N!<%I$N%-%c%C%7%eL58z2=

   <+%N!<%I$N%-%c%C%7%e$K!"B>$N%N!<%I$NJ*M}%a%b%j$r%-%c%C%7%e$7$F$$$k>l9g$d!"B>$N%N!<%I$N%-%c%C%7%e$HF1$8%V%m%C%/$r%-%c%C%7%e7F$$$?>l9g!"$=$liN%-%c%C%7%e$dJ*M}%a%b%j$,=q-49(il$?$H$-$K!"<+%N!<%I$N%-%c%C%7%e$rL58z2=9kI,MW$,$"$k!#

2. <+%N!<%I$N%-%c%C%7%e$dJ*M}%a%b%j$K=q$-9~s@%"%I%l%9$N8!CN

   <+%N!<%I$N%-%c%C%7%e$dJ*M}%a%b%j$K=q$-9~$^$l$?$H$-$K!"$=$N%-%c%C%7%e$HF1$8%V%m%C%/$d!"$=$NJ*M}%a%b%j$r%-%c%C%7%s%0$7$F$$$k%-%c%C%7%eKBP7$F!"$=lrL58z2=5;J1lPJi$J$$!#$=$N$?$aKO!"DL?.%\!<%I$,=q$-9~$^$l$?%"%I%l%9$rCNCF!"$=$lrI,MWH9k%N!<%I$KDL?.$9kI,MW,$"$k!#

3. %m!<%+%k%a%b%j$NL58z$J%G!<%?NFI_9~$_$NCfCG

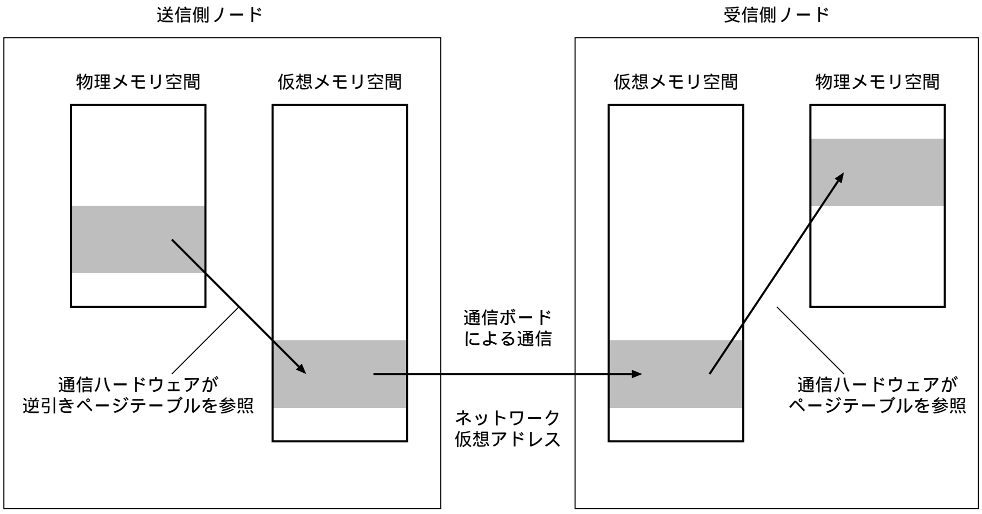
   %m!<%+%k%a%b%j$,!"B>%N!<%I$G%-%c%C%7%s%0$5$l$F$$$F!"$=$N%-%c%C%7%e$,=q$-49$($ilF$$$k>l9g!"$=$N%a%b%j$OL58z$KJk!#$=$Nh&$J%a%b%j$r!"<+%N!<%I$N%W%m%;%C%5$JI,FI$_$KMh$?>l9g!"$=NFI_9~$_$rCfCG5;k3H,$-$J1lPJiJ$$!#$=$N8e!"M-8z$J%G!<%?$r;}$D%N!<%I$+$i%G!<%?$rE>Aw7F$/$k3HKJ$k!#

4.5.2 MBus %$%s%?%U%'!<%9$NMxMQ9kMWAG

MBus K*$$$F!"%-%c%C%7%e%3%R!<%l%s%9N?$a<!$NMSH $HMIH NFsD$N?.9f$,%5%]!<%H5l$F$$$k!#

- **MSH(Memory shared)**

  $"$k%V%m%C%/$,FI$^lh$&$H7F$$$kH-!"$=$N%G!<%?$r%-%c%C%7%e$K;}CF$$$k%W%m%;%C%5KhCF%"%5!<%H5l$k!#$"$k%V%m%C%/$rFIb&H7$?%W%m%;%C%5$,3N?.9f$r4XCN$9kH!"$=$N%"%I%l%9$N%G!<%?$rJ];}7F$$$k%V%m%C%/$r6&M->uBV$K9k!#$=$N%V%m%C%/$K=q9~$_$,$"C?>l9g!"$=$N%V%m%C%/$r6&M-$7$F$$$k%-%c%C%7%eKBP7!"L58z2=rAwkI,MW$,$"$k!#



?^6: %"%I%l%9JQ49

- **MIH(Memory inhibit)**

  %b%G%#%U%!%$%I%G!<%?$r%-%&%C%7%e$K;}$C$F$$$k%W%m%;%C%5$,!"$=$N%G!<%?$N$"$k%V%m%C%/$,FI$^lh$&$H9kH-$K!"%"%5!<%H$9$k!#$3l,%"%5!<%H5lkH!"%a%b%j$O%G!<%?$rAwkN$rCfCG$9$k!#$=$N8e!"M-8z$J%G!<%?$r;}$C$F$$$k%-%&%C%7%e$+$i!"%G!<%?$,Aw$ilk!#

K\DL?.%\!<%IGO!"3NMSH,MIH $N%"%5!<%H$r9T$&$?$a!"B_Map $rMxMQ$9$k!#MBus %$%s%?%U%'!<%9!&%3%s%H%m!<%i$O!"%m!<%+%k%a%b%j%"%/%;%9$r4XCN$9kH!"$=$N%"%I%l%9$KBP1~$9$kB_Map $N9`L\$r;2>H$7!"0J2<$NB_Map $N>uBV$KhjI,MW$JF0:n$r9T$&!#

1. **Valid** $=$N%V%m%C%/$OM-8z$G$"$k3H$r<($9!#

   MBus %$%s%?%U%'!<%9!&%3%s%H%m!<%i$OF0:n$7$J$$!#

2. **Shared** $=$N%V%m%C%/$O6&M-$5lF$$$k3H$r<($9!#

   MBus %$%s%?%U%'!<%9!&%3%s%H%m!<%i$OMSH $r%"%5!<%H$9$k!#

3. **Inhibit** $=$N%V%m%C%/$OL58z$G$"$k3H$r<($9!#

   MBus %$%s%?%U%'!<%9!&%3%s%H%m!<%i$OMIH $r%"%5!<%H$9$k!#

   MIH $r%"%5!<%H$7$?>l9g!"DL?.%\!<%I$OM-8z$J%G!<%?$r;}$D%N!<%I$HDL?.$7!"%a%b%j%"%/%;%9$r9TC?%W%m%;%C%5$KM-8z$J%G!<%?$r6!5k$9$k!#

4.5.3 MBus %$%s%?%U%'!<%9$N<B8=K!

>e5-$NMW7o$rK~$?$9MBus %$%s%?%U%'!<%9$N<B8=$O!"0J2<$Nh&$K9T$&!#

1. <+%N!<%I$N%-%&%C%7%e$rL58z2=

   MBus KO!"FCDj$N%"%I%l%9$r%-%&%C%7%s%0$7$F$$$k%-%&%C%7%e$r!"L58z2=$9$k%H%i%s%6%/%7%g%s$H7F!"Coherent Invalidate(CI) $,MQ0U$5lF$$$k!#hC$FL58z2=$,I,MWJH$-$K$O!"MBus %$%s%?%U%'!<%9!&%3%s%H%m!<%i$,$3$N%H%i%s%6%/%7%g%s$rMxMQ9l$PNI$$!#

2. <+%N!<%I$N%-%&%C%7%e$dJ*M}%a%b%j$K=q$-9~s@%"%I%l%9$N8!CN

   DL?.%\!<%I$O!"%7%9%F%`%P%9$G$"$kMBus $K@\B3$5lk$?$a!"%W%m%;%C%5$,%a%b%j%"%/%;%9$9$k%"%I%l%9$r!"MF0W$K%9%L!<%W$9k3H,G-$k!#

3. %m!<%+%k%a%b%j$NL58z$J%G!<%?NFI_9~$_$rCfCG

   MBus %$%s%?%U%'!<%9!&%3%s%H%m!<%i$,!"%"%/%;%9$N$"$C$?%m!<%+%k%a%b%j$N%"%I%l%9$KBP1~$9$kB_Map $rD4$Y!"$=$N%V%m%C%/$N>uBV$,Inhibit JiMIH $r%"%5!<%H$7!"L58z$J%G!<%?$NFI$_9~$_$rCfCG$5$;$k!#

MBus $N;EMM$H7F!"%a%b%j%"%/%;%9$NH/@8$7$?%/%m%C%/$+$i2!A7%/%m%C%/0JFb$KMIH/MSH $r%"%5!<%H$9kI,MW,$"$k$?$a!"MBus %$%s%?%U%'!<%9!&%3%s%H%m!<%i$OFPGA Fb$G9=@.$7!"9bB.F0:n$5$;$k!#

0J>e$NF0:n$r9T$&MBus %$%s%?%U%'!<%9!&3%s%H%m!<%i$r@_7W$7!"MBus %$%s%?%U%'!<%9$r<B8=9k!#

4.6 %O!<%I%&%'%"Kh$k%U%m!<@)8f

%M%C%H%o!<%/>e$N%U%m!<@)8f$O!"=>Mh$N%$!<%5%M%C%HJIGOTCP/IP Nh$&$J%M%C%H%o!<%/%W%m%H%3%k$N>e0L%l%$%d$,9T$C$F$$$k!#>e0L%l%$%d$,%=%U%H%&%'%"E*$K9T$&3HKh$j=@Fp$J@)8f$,2DG=$JH?LL!"B.EY$O5>@7$KJk!#

K\%W%m%H%?%$%W$G$O!"%U%m!<@)8f$rDL?.%\!<%I$N%O!<%I%&%'%"$G9T$$!"%W%m%H%3%k%*!<%P%X%C%I$N0lIt$G$"$k!"%U%m!<@)8f$K4X$o$k%=%U%H%&%'%"%*!<%P%X%C%I$r7Z8:$9$k!#

0J2<GO!"%U%m!<@)8fN?aKI,MW$J:FAwMQ%P%C%U%!$N9=@.$H6qBNE*$JJ}K!$r=R$Y$k!#

4.6.1 :FAwMQ%P%C%U%!$N**Dual-Port-Memory** Kh$k9=@.

%U%m!<@)8f$r9T$&:]$K!":FAwMQ$N%U%l!<%`$r3JG<$7F*$/%P%C%U%!$,I,MWKJ$k!#K\DL?.%\!<%I$G$O!"$3$N:FAwMQ%P%C%U%!$r!"%G!<%?MQAw?.%P%C%U%!$H6&MQ$9$k!#$3lKhj!"%\!<%I>e$N%A%C%W?t$,8:$j!"$^$?FPGA $N%T%s?t$r@aLsG-$k!#

3N%P%C%U%!$O!"Flow Control It$,%P%C%U%!FbNG0U$N%V%m%C%/$K%a%b%j%"%/%;%9$9$kI,MW$,$"kN$G!"FIFO %a%b%j$GOJ$/!"Dual-Port-Memory $G9=@.$7!":FAwMQ%P%C%U%!H7Fb%G!<%?MQAw?.%P%C%U%!H7FbMxMQG-kh$&$K9k!#

4.6.2 %U%m!<@)8f$NJ}K!

%\!<%I>eGN%U%m!<@)8f$O!">e5-$N:FAwMQ%P%C%U%!$H!"FPGA Fb$N%U%m!<@)8fMQ%m%8%C%/G"$kFlow Control It$rMxMQ7F0J2<Nh$&$K9T$&!#(?^7)

1. Aw?.B&$G!"%X%C%@$,Fibre Channel %A%C%W%;%C%H$KAw?.$5lk$HF1;~$K!"Dual-Port-Memory $K3JG<$5lk!#
2. Aw?.B&$G!"$9GK%P%C%U%!%j%s%0$5$l$F$$$kAw?.%G!<%?$,Fibre Channel %A%C%W%;%C%H$KAw?.$5lk!#
3. <u?.B&$G!"%X%C%@!&Aw?.%G!<%?$Khk%U%l!<%`$NM-8z!?L58z$r!"Flow Control It$dFC-1 Chip $,%A%'%C%/$9$k
4. <u?.B&$G!"%U%l!<%`$,M-8z$J$i ACK $rJV$9!#%U%l!<%`$,L58z!"$^$?$O%U%l!<%`$,<u$1<h$l$J$$>l9g$O NACK rJV9!#
5. Aw?.B&$G!"ACK $^$?$O NACK $r<u$1<h$k!#
    - (a) ACK $r<u$1<hC?>l9g!"Dual-Port-Memory Fb$NEv3:%U%l!<%`$r2rJ|9k!#
    - (b) NACK $r<u$1<hC?>l9g!"Dual-Port-Memory Fb$NEv3:%U%l!<%`$r:FAw$r9T$&!#$^$?!"2s@~@ZCGJI!"I|5"IT2DG=$J>uBV$,H/@8$7$?>l9gKO!"Error $rH/9T$9$k!#

0J>eNh$&$JF0:n$r9T$&3HKh$j!"%=%U%H%&%'%"$G9Tol$F$$$?%U%m!<@)8fKh$k%*!<%P%X%C%I$r2r>C$7!"%W%m%H%3%k%*!<%P%X%C%I$r7Z8:$9$k!#

4.7 DL?.%\!<%I$N%W%m%0%i%^%V%k$J9=@.

DL?.%\!<%I$O!"%W%m%H%3%k%W%m%;%C%5$H$=$N%-%&%C%7%e!"Fibre Channel $N%$%s%?%U%'!<%9HJ$k%A%C%W%;%C%H!"FPGA $rEk:\$9$k!#$3li$N%A%C%W$O!";THNNbNrMxMQ9k!#

DL?.%\!<%I>eGN3F%A%C%W$N<BAu$r?^8$K<($9!#

>e5-%A%C%W0J30$NAw<u?.%P%C%U%!$d3F<o%3%s%H%m!<%i$O!"4pK\E*$KFPGA Fb$K@_7W$r9T$&!#

K\DL?.%\!<%IGO!"%3%s%H%m!<%iEy$NBgItJ,$N%O!<%I%&%'%"$rFPGA Fb$K@_7W9k3HKh$j!"DL?.%\!<%I$G<B8=9k5!9=$NJQ99$r9T$&$3H,2DG=KJ$k!#

$^$?!"%W%m%H%3%k%W%m%;%C%5$rEk:\$9k3HKhj!"DL?.%\!<%I>e$G!"%W%m%;%C%5$N%=%U%H%&%'%"Kh$j!"MM!9$J5!G=$,<B8=$G$-$k!#

hC$F!"$3$NDL?.%\!<%I$rAuCe7?%W%m%H%?%$%W!&%O!<%I%&%'%"$O!"MM!9$JDL?.J}<0$N<B8=!&<B83$,9T$($k!#

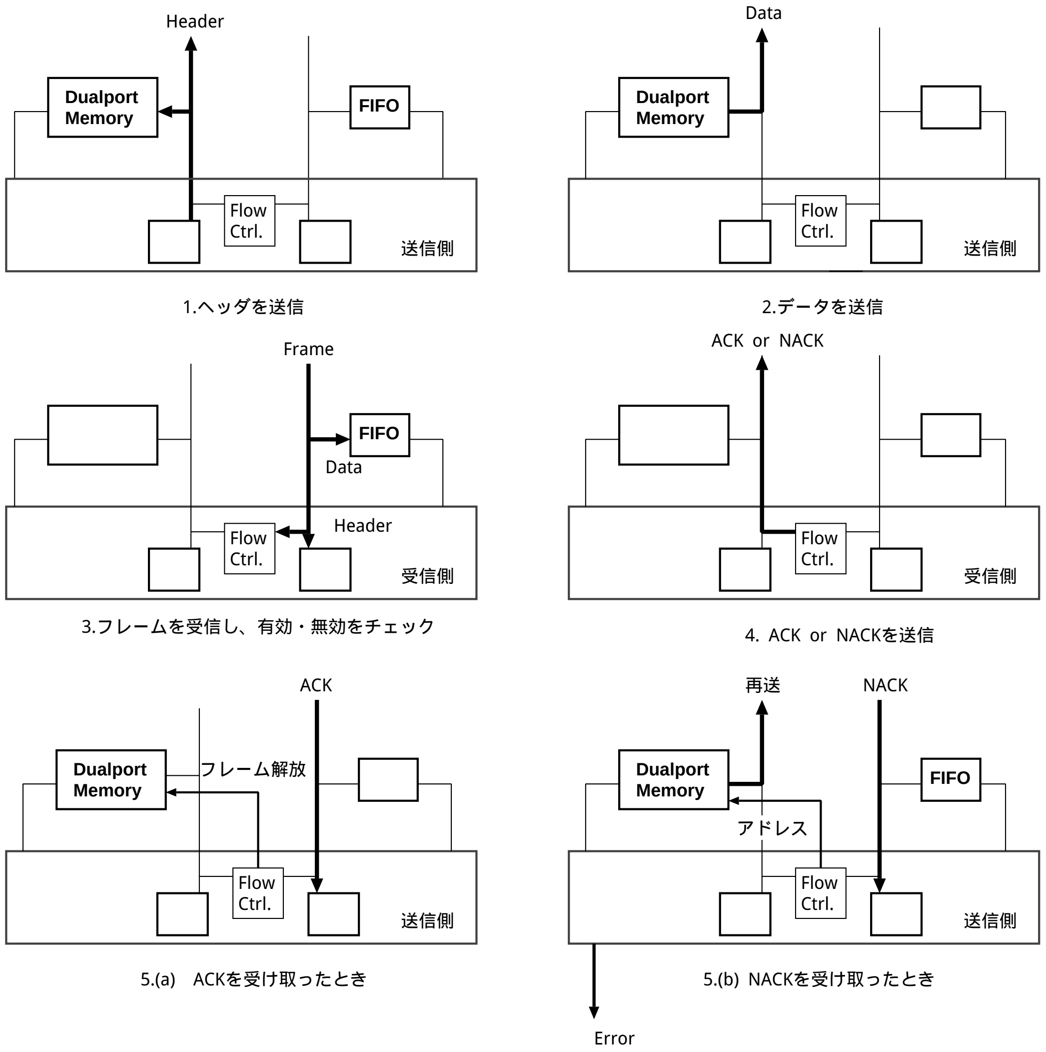
0J2<GO!"FPGA Kh$kDL?.%\!<%I$N3FItJ,$N<B8=K!$H!"%W%m%H%3%k%W%m%;%C%5H7$FK\DL?.%\!<%I$G:NMQ7?SPARClite KD$$$F=RYk!#$^$?!"FPGA!"%W%m%H%3%k%W%m%;%C%50J30$N%\!<%I>e$N%A%C%WHJ$k!"3F%a%b%j$HFibre Channel %A%C%WKD$$$F=RYk!#

1. **FPGA**

    FPGA Fb$NMWAG$O0J2<Nh$&$JbN$,$"$k!#

    - Aw<u?.%P%C%U%!

      Aw<u?.%P%C%U%!$O!"%P%9B&(M_Buf)!"%M%C%H%o!<%/B&(F_Buf) 3F!9$G%G!<%?3JG<MQ%P%C%U%!$H!"



?^7: %\!<%I>eGN%U%m!<@)8f

%P%9%3%^%s%I$^$?$O%U%l!<%`%X%C%@MQ%P%C%U%!$KJ,3d$9$k!#

$?$@$7!"%G!<%?3JG<MQ F_Buf $O!"BgMFNL$G$"$k$?$a!"FPGA Fb$K<BAu$7$J$$J}$,NI$$!#hC$F!"%G!<%?3JG<MQ F_Buf H7$F!"FPGA HOJL$N%A%C%W$rMQ$$$k!#

- %3%s%H%m!<%iN`

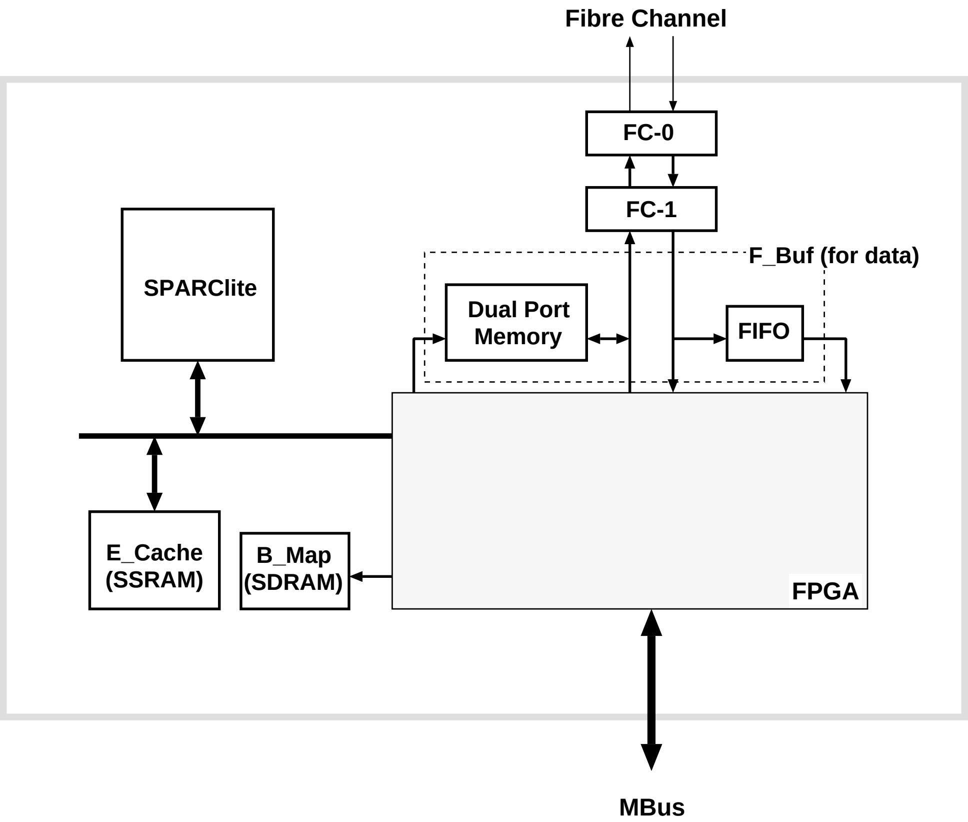
  MBus %$%s%?%U%'!<%9!&3%s%H%m!<%i$d%U%m!<%3%s%H%m!<%kMQ%m%8%C%/0J30$K!"E_Cache,FC Chipset, %P%C%U%!3F!9N?aN%3%s%H%m!<%i$rFbB"$9$k!#

2. %W%m%H%3%k%W%m%;%C%5

K\DL?.%\!<%IGO!"%W%m%H%3%k%W%m%;%C%5H7$F!"SPARClite $rMxMQ$9$k!#M}M3$O0J2<NDLjG"$k!#

- SPARC %"!<%-%F%/%A%c$K=`5r$7$F$$$k$?$a!"DL?.%\!<%I$,%Z!<%8%F!<%V%k$JIr%-%c%C%7%s%0$9$k:]%a%$%s$N SuperSPARC $HF1MM$N%a%b%j%"%/%;%9$,$G$-ET9g$,NI$$!#
- %3%s%H%m!<%iMQES$N%W%m%;%C%5$G$"$k$?$a!"HQ;($J5!G=$r;}$?$J$$!#
- 9bB.F0:n(100MHz) 2DG=G"$k!#
- %"%I%l%9%P%928bit!"%G!<%?%P%932bit N?$a!"FPGA $N%T%s?t$N@)8B$rHf3SE*0 5Gw$7$J$$!#

3. %a%b%j



?^8: DL? .%\! <% I>e$N<BAu

- **B_Map**

  %m! <% +%k%a%b% j$N% ^%C%T% s% 0$r9T$ &$?$a! "$ "$k DxEYBg$-$JMFNL$,I,MWG "$k! #$ ^$?! "$=1 [$I 9bB .$GJ /$FNI$$! #hC$F! "SDRAM $G9=@ .$9 $k! #$3$1$Khj! "FPGA $+$i$N% "%I%1%9@~$r8: i9$3$H$,$G$-$k! #

- **E_Cache**

  $=$1$ [$IBgMFNL$G$ "kI ,MWO$J$$$,! "9bB .F0:n $,I ,MW$J$?$a! "SSRAM $G9=@ .$9$k! #FPGA Fb $N% -%&C% 7%e% 3% s%H%m! <% i$G@)8f$ 5$1$k! #

- %G! <% ?3JG<MQ **F_Buf**

  %G! <% ?3JG<MQAw<u? .%P%C%U% !$O! "MFNL$,Bg$-$$ NG! "FPGA HOJL$K9=@ .$9$k! #

  - Aw? .B&

    %U%m! <@)8f$N@a$G=RY ?h&$K! "Dual-Port-Memory $G9=@ .$9$k! #

  - <u? .B&

    <u? .7 ?=g=xDLjKAwi1kN$G! "FIFO %a%b% j$G9=@ .9k! #

4. **Fibre Channel** MQ **Chipset**

   K\DL? .%\! <% IGO! "Fibre Channel $N%1%$%d0,1 $r %5%]! <% H$9$k; THN$N%A%C%W$ rMQ$ $$k! #

5 $*$ojK

K\9FGO! "JBNs1~MQ$r; X8~$7$?J,; 6%7%9%F% `!V3%s %T%e! <% ? ! &3%m%K! <! W$ rDs0F$7! "$=N ?aN%W%m%H% ?%$ %W ! &O! <% I%&%'% "$N9=@ .$H! "$=$N%M%C%H%o! <% / ! &$%s% ? %U%'! <% 9$HJkDL? .%\! <% IKD$$$F=RY ?! #

%3%s%T%e! <% ? ! &3%m%K! <$O! "L=>Mh$NJ,; 6%7%9%F% `$N; } $DDL? .%3%9%H$dQoS $NLdBj$r2r7h$7! "L=>Mh$N%7%9%F% `$G $O<B8=: $F q$G$ "C ?! "%M%C%H%o! <% /7k9g$5$1$?7W; ;5 !; q 8 ;$NM-8zMxMQ$rL\; X$9! #

3N%3%s%T%e! <% ? ! &3%m%K! <<B8=N ?$a! "2f! 9$,3+H/ 7 ?%W%m%H% ?%$%W ! &O! <% I%&%'% "$G$O! "4{B8$N7W; ;5 !$N

%7%9%F% `%P%9$K@lMQ%M%C%H%o!<%/!&$%s%?%U%'!<%9$H$J$kDL?.%\!<%I$r@\B3$7!"%7%9%F% `%3!<%k$N2p:_$rI,MWH7$J$$DL?.$d!"%j%b!<%H%G!<%?$N%-%&%C%7%s%0$r<B8=$9$k!#$^$?!"%O!<%I%&%'%"$Khk%U%m!<@)8f$r9T$$!"%W%m%H%3%k%*!<%P%X%C%I$N7Z8:$r?^$k!#$3lKhj!"=>Mh$NJ,;6%7%9%F% `$HHf3S7F9bB.!&DcCY1d$JDL?.5!9=$r<B8=9k3H$,$G$-$k!#

$^$?!"DL?.%\!<%I>e$K%W%m%;%C%5$rEk:\$7$?$3HKhj!"%W%m%;%C%5XN%W%m%0%i%_%s%0$,2DG=$KJj!"DL?.%\!<%I>e$N%O!<%I%&%'%"$KhkF0:n$@$1GJ$/!"%=%U%H%&%'%"$KhkF0:n$b2DG=$G$"$j!"%W%m%H%?%$%W$H7F!"MM!9$JDL?.J}<0$r<B83G-$k4D6-$rDs6!9k3H$,$G$-$k!#F1;~$K!"%O!<%I%&%'%"$G<B8=:Fq$J5!G=$r%=%U%H%&%'%"$G<B8=$G$-!"3+H/%3%9%H$ND8:$r<B8=$G$-$k!#

3N%W%m%H%?%$%W$r40@.5;$?8e!"MM!9$JDL?.J}<0GN<B83$r9T$$!"INh&$J9=@.$K9l$P!"%7%9%F% `A4BN$G:G9b$N%Q%U%)!<%^%s%9$,F@ilk+!"$H$$$&3H$K4X$7$F9M;!$r9T$&!#

0J>eNh$&$JCJ3,rF'`$3$H$G!":G=*E*$K!V3%s%T%e!<%?!&3%m%K!<!W$NL\;X$9%O%$%Q%U%)!<%^%s%9$J%7%9%F% `$,<B8=2DG=$G$"$m$&!#

:#8e$O!"%W%m%H%?%$%W$r40@.$5$;$k$?$a!"DL?.%\!<%I$N>\:Y@_7W$d!"DL?.%\!<%I>e$N%W%m%H%3%k%W%m%;%C%5$N$?$a$N%W%m%0%i%_%s%0!"!V3%s%T%e!<%?!&3%m%K!<!W$N%=%U%H%&%'%"4D6-$G$"$kJ,;6%*%Z%l!<%F%#%s%0%7%9%F% `!Colonia!W$N%W%m%H%?%$%WXN<BAuEy$,I,MW$G$"$k!#

<UK-

K\8&5f$N5!2q$rM?$($FD:$$$?!"K\8&5f<<$NIYEDbC<#65<x$K?<?S$J<U0U$rI=7^$9!#

$^$?!"K\8&5f$K4X$7$FE,5\98f;XF3!"8fJ\Z%$r;rG??9bC0lO:=u65<x!"8^Eg@5M5=u<j$K?<$/46<UCW7^$9!#

5i$K!$6&F18&5f<TG"$k;3E:Gn;K;a!"M{M#4q;a$rO8aH7F!$F|:"MM!9$J3QEY$+$i;jiL?H$K=uNO$7$F2<$5G?5~ETBg3XBg3X1!9)3X8&5f2J>pJs9)3X65<<IYED8&5f<<$N=t7;$K?4hj46<UCW7^$9!#

; 29MJ88%

[1] X3T11 Task Group of ANSI: Fibre Channel Physical and Signaling Interface (FC-PH), Rev. 4.3 June 1,(1994).

[2] SPARC Technology Business: SuperSPARC & MultiCache-Controller User's Manual,(1994).

[3] Ben Catanzaro: SPARC %^%k%A%W%m%;%C%5%"!<%-%F%/%A%c(1995).

[4] ;3E:Gn;K, EDCf?5;J, 0KC#?7:H, 8^Eg@5M5, ?9bC0lO:, IYEDbC<#!'JBNs%"%W%j%1!<%7%g%s$r;X8~$7$?J,;6%7%9%F% `%3%s%T%e!<%?!&3%m%K!<$N9=A[,>p=h8&Js97-OS-76(SWoPP 0$AI'97), pp.55-60.(1997).

[5] @DLZ=(5.!'JBNs%"%W%j%1!<%7%g%s$r;X8~$7$?J,;6%*%Z%l!<%F%#%s%0%7%9%F% `Colonia, =$;NO@J8, 5~ETBg3X9)3X8&5f2J>pJs9)3X@l96(1997).

[6] ;3E:Gn;K!'J,;6%*%Z%l!<%F%#%s%0%7%9%F% `Colonia$N6&M-%a%b%j4IM}$H$=$N%(%_%e%l!<%?, FCJL8&5fJs9p=q, 5~ETBg3X9)3XIt>pJs9)3X2J(1997).