B46HO@J8

BjL\

%U%m!<$r9MN8$7$?7PO)@)8f5!9=

;XF365<x

=j ??M}M: 65<x

7DXf5A=NBg3X

M}9)3XIt EE5$9)3X2J

1997G/EY

69403803

>.4,8-FsO:

O@ J8 MW ;]

3X2J	EE5$9)3X	3X@RHV9f	69403803	;aL>	>.4,8-FsO:
(O@J8BjL\) %U%m!<$r9MN8$7$?7PO)@)8f5!9=					

DL?.CY1d$,%M%C%H%o!<%/;q8;$N;HMQ>u67Kh$jJQ2=$9$k:GA1EXNO7?%5!<%S%9$O!"%j%"%k%?%$%`@-$,MW5a5l$k<B;~4VDL?.$K$OE,$5$J$$!#$=$N$?$a!";OE@$+$i=*E@XN0lO"$N%G!<%?$NN.lG$"$k%U%m!<Kh$KCY1d$JIN%5!<%S%9$N<A (QoS) $rJ]>Z$9$k!"J]>Z7?%5!<%S%9$,<B;~4VDL?.$N<B8=$K$OIT2D7g$HJk!#J]>Z7?%5!<%S%9$O8D!9$N%U%m!<$NMW5a$9$k QoS $KBP1~$9Y/!"%U%m!<$rJL!9$K07$&$3HrMW5a5lk,!"7PO)@)8f$NE@$+$i9M$(kH4{B8$N7PO)@)8f5!9=$O=*E@%"%I%l%9N_$r7PO)@)8f>pJs$H7FMxMQ7F$$$k$?$a!"8D!9$N%U%m!<$K$OBP1~$G$-$J$$!#

%U%m!<$r8D!9$K07$&$3HNG-$k7PO)@)8f5!9=$N<B8=KO!"7PO)@)8f$N4pHW$HJk7PO)@)8fI=$,%U%m!<Kh$N%(%s%H%j$rJ];}$7!"%U%m!<$r8D!9$K7PO)@)8fG-k3H,IT2D7gHJ$k!#$=3GK\8&5fGO%U%m!<$r9MN8$7$?7PO)@)8fI=$N@_7W!"<BAu!"I>2A$r9T$&!"%U%m!<$r<1JL$9$k%Q%i%a!<%?$K$O!"=*E@%"%I%l%9!";OE@%"%I%l%9!"=*E@%]!<%HHV9f!";OE@%]!<%HHV9f$N4$DNCMrMQ$$$k!#<BAuKO4{B8$N7PO)@)8fI=$N<BAu$KMQ$$$ilF$$$k Radix Tree 5!9=$NFCD'$G$"$k “2DJQD9%"%I%l%9!"ITO"B3%M%C%H%^%9%/XNBP1~” $H$$$&E@$rMxMQ$7!"4{B8$N5!9=$HF)2aE*$K07$($k5!9=$r<B8=9k!#

K\8&5f$GDs0F$9$k%U%m!<$r9MN8$7$?7PO)@)8fI=Kh$j!"%k!<%?$O%Q%1%C%H$,B0$9$k%U%m!<Kh$K0[Jk7PO)$rA*Br$9k3H,G-k?$a!"J]>Z7?%5!<%S%9$K$*$$$F%U%m!<$r8D!9$K7PO)@)8f9k3H$,2DG=$HJk!#5i$K!"%U%m!<$r9MN8$9$k3H$O:GA1EXNO7?%5!<%S%9$K$*$$$F$bHs>o$K=EMWHJk?$a!"K\8&5f$OJ]>Z7?%5!<%S%9$@$1GJ$/!":GA1EXNO7?%5!<%S%9$K$*$$$F$bM-1W$G$"$k!#

!}FbMF$NMW;]$OLs 600 ;z

Summary of Bachelor's Thesis

Course	Student No.	SURNAME, Firstname
Electrical Engineering	69403803	KOMAKI Kenjiro

Title

A Routing Mechanism based on the Flow

Best-effort service, in which delay of a flow varies with the circumstance of the network resource, is not suitable to the real-time traffic which requires being in time. Therefore, guaranteed service which guarantees Quality of Service (QoS) such as delay for every **flow** which is a stream from a source to a destination is indispensable for accomplishment of real-time traffic. On guaranteed service dealing flow individually is required for granting request of QoS from each flow, but with respect to the routing mechanism existing routing mechanism uses only the destination address as routing information, so it can not deal flow individually.

Accomplishment of flow-based routing mechanism requires that the routing table, which is the basis of routing mechanism, have the entry of individual flow and so routing mechanism can route a flow individually. Therefore this research designs, implements, and evaluates a routing table based on the flow. In order to identify a flow, four parameters, destination address, source address, destination port number, and source port number, are used. In the implementation, special feature of Radix Tree Mechanism which is used for exsisting implementation is utilized, that is conrresponddence for variable length address and consecutive netmask. So routing mechanism with this routing table can be treated transparently with existing mechanism.

By a routing table based on the flow that is proposed in this research, a router can select a route for each flow that a packet belong to. So, routing flows individually on guaranteed service is accomplished. Futhermore, routing based on the flow is also very important for best-effor service. Therefore this research is useful not only for guaranteed service, but for best-effor service.

Faculty of Science and Technology, KEIO UNIVERSITY

!} The contents of English summary should be written in about 300 words.

L\ <!

?^ L\ <!

I= L\ <!

Bh **1** >O

=xO@

1.1 GX7J$*$h$SL\E*

6aG/%$%s%?!<%M%C%H$OGzH/E*$J@.D9$r?k$2!"$=$N@.D9$ON1$^$kH3mrCNiJ$$!
=Q$N?JJb$Khj%M%C%H%o!<%/$N9bB.2=!"C_@Q%a%G%#%"$NBgMFNL2=bCx7$$!#$=$l$KH<
0JA0$O8&5f<T4V$N>pJs8r49H7$FJ8;z>pJs$J$I>/NL$N%G!<%?$r07$&bN$H9M$(il$
$?%$%s%?!<%M%C%H$b!"%^%k%A%a%G%#%"DL?.$KBeI=5l$kB?MM$J%G!<%?E>AwXNMW5a$
$^$CF-F*$j!"FC$K%S%G%*2q5D$d%$%s%?!<%M%C%HEEOCJI!"2;@<!&F02h$r%$%s%?!<%
%H>e$G07$&3H$,CmL\$5lF$-$F$$$k [2]!#

%$%s%?!<%M%C%H$O%Q%1%C%H%M%C%H%o!<%/Kh$k%3%M%/%7%g%s%l%9G[Aw$,4pHWHJ$
$*$j!"%k!<%?Fb$N%P%C%U%!$d2s@~$NBS0hI}$H$$$C$?%M%C%H%o!<%/;q8;$O%k!<%?$d2s@
DL2a9k%Q%1%C%HKhCF6&M-5l$F$$$k$?$a!"%M%C%H%o!<%/;q8;$N;HMQ>u67$Kh
?.CY1d$OJQ2=$9$k!#%M%C%H%o!<%/;q8;$,;HMQ2DG=G"lP%Q%1%C%H$OB(:B$K=hM}5
1d$O>/$J$$$,!"%M%C%H%o!<%/;q8;$KM>M5$,$J$$$H$-$K$O%M%C%H%o!<%/;q8;$,;HMQ2DG
Jk$^$GBT5!7J1lPJiJ$$!#3l$r:GA1EXNO7?%5!<%S%9$H$$$&!#

0lJ}$G2;@<$dF02h$O%j%"%k%?%$%`$GAw?.$5lk>l9g!"CY1d$KHs>o$KIR46G"$j!"CY
$,>o$K$=$NDL?.$NK~B-$9$kHO0OFb$KJ]>Z5lJ1lPJi$J$$<B;~4VDL?.G"k?$
:GA1EXNO7?%5!<%S%9KOE,5J$$!#%$%s%?!<%M%C%H>e$G$N<B;~4VDL?.$N<B8=KO!":
EXNO7?%5!<%S%9KBeo$k?7$?$J%5!<%S%97ABV$H7F!"3FDL?.Kh$KMW5a$9$k%5!<%S%9$
(QoS, Quality of Service) $rJ]>Z$9$kJ]>Z7?%5!<%S%9$,I,MWHJ$k!#J]>Z7?%5!<%S%9
$G QoS $rJ]>Z$9$kC10L$O!"$"$kAw?.%[%9%H$+$i=*E@%[%9%H$^$G$N0lO"$N%Q%1%C%H72!"
Jo$A%U%m!<$G$"$k!#

J]>Z7?%5!<%S%9$N<B8=$K$O!"$=$NDL?.$,;HMQ9k7PO)>e$N3F%k!<%?$G;q8;$NM=Ls!
$k$$$O2rJ|$H$$$C$?%a%C%;!<%8$r8r49$9$k;q8;M=Ls5!9=$r;O$a!"%"%I%_%C%7%g%s%3%
%m!<%k!"%]%j%7!<%3%s%H%m!<%k!"%Q%1%C%H%9%1%8%e!<%i!"%Q%1%C%HJ,N`5!9=!"$=$7$
>Z7?%5!<%S%9$KBP1~$7$?7PO)@)8f5!9=$J$I!":GA1EXNO7?%5!<%S%9$GOI,MWH7J$+$
B?$/$N5!9=$,IT2D7g$HJk!#

$3$3$G!"7PO)@)8f5!9=$KCeL\$9$k!#J]>Z7?%5!<%S%9$G$OJ]>Z$5lk QoS $O3F%U%m!<
hC$F0[$J$j!"3F%U%m!<$,MW5a9k QoS KhCF:GE,$J7PO)$OMM!9G"k?$a!"%U%m
Kh$K0[$J$k7PO)$rA*Br9kI,MW$,$"$k!#$7$+$7!"4{B8$N7PO)@)8f5!9=$G$O=*E@%"%I%
N_$r4p$K7PO)$rA*Br$7F*$j!"=*E@%"%I%l%9$@1G$O%U%m!<$rFCDj9k3H$OIT2
G"$k!#

$=$3$GK\8&5f$G$O!"J]>Z7?%5!<%S%9$KE,7?7PO)@)8f5!9=!"D^$j%U%m!<$r8D!9$K
$&$3H,2DG=$J7PO)@)8f5!9=$N<B8=N?aN4pHWH7$F!"%U%m!<$r9MN8$7$?7PO)@)8

$N@_7W!"<BAu!"I>2A$r9TJ&!#6qBNE*KO!"%U%m!<$O=*E@%"%I%l%9!";OE@%"%I%l%9!
E@%]!<%HHV9f!";OE@%]!<%HHV9f$N 4 DN%Q%i%a!<%?KhCFDj$^k?$a!"3N 4 DN
%i%a!<%?$r%-!<$H7F;}$D7PO)@)8fI=$r<B8=9k!#

1.2 K\O@J8$N9=@.

K\O@J8GO!"K\>O$b4^$a$F 9 >O$G9=@.5l$F$$$k!#Bh 2>OGO4{B8$N7PO)@)8f5!9=
354Q$r=R$Y!"$=$N8e7PO)@)8fI=$N<BAuJ}<0$K$D$$$F=RYk!#Bh 3>OGOJ]>Z7?%5!<%S%
$D$$$F35@b$7!"J]>Z7?%5!<%S%9$N<B8=$K:]$7$F4{B8$N7PO)@)8f5!9=$NLdBjE@$r<($9!
4>OGO%U%m!<$r9MN8$7$?7PO)@)8fI=$rDs0F!"@_7W$7!"Bh 5>O$G!"?7$7$$7PO)@)8fI=$r
8=9k5!9=$N<BAuJ}K!$K$D$$$F@bL@9k!#Bh 6>OGO!"Bh 5>O$G<BAu$7$?%U%m!<$r9MN8
$?7PO)@)8fI=$NI>2A$*$h$S8!F$$r9T$$!"Bh 7>O$G:#8e$N2]Bj$r<($9!#Bh 8>OGO4XO"8&
KD$$$F35@b$7!"Bh 9>O$GK\8&5f$N7kO@$r=RYk!#

Bh **2** >O

7PO)@)8f5!9=

K\>OGO!"K\8&5f$N4pHW$HJk4{B8$N7PO)@)8f5!9=$N35MW!"5Z$S7PO)@)8fI=$N<BAu
<0KD$$$F35@b9k!#

2.1 %$%s%?!<%M%C%H%W%m%H%3%k

%$%s%?!<%M%C%H$O%M%C%H%o!<%/$,Aj8_@\B3$7$F@.$jN)CF$$$k!"$$$o$P%M%C%H%o!<
$N%M%C%H%o!<%/$G$"$j!"%$%s%?!<%M%C%H$K@\B3$7$F$$$k3F%M%C%H%o!<%/$,<+N'E*$K4
$r9T$&!#3l$O0lHLE*$J=8Cf7?%M%C%H%o!<%/G"$k%5!<%P!&%/%i%$%"%s%H7?$N%M%C%H%
%/HO0[Jj!"Cf1{$N4IM}5!9=$r;}$?$J$$$?$a!"0lE@>c32$d>pJs$N=8Cf$rKI$0MxE@$
$D!#$7$+$7F1;~$K!"=8Cf7?%M%C%H%o!<%/$G%5!<%P$,2L$?7F$$$k5!G=$r!"%$%s%?!<%M%
$K@\B3$9$k3F%[%9%H$,FH<+$KDs6!$7J1lPJi$J$$!#FC$K%G!<%?E>Aw$K:]$7%$%s%
%M%C%HGO6I=jE*$J>pJs$r4p$K%G!<%?E>Aw$r9TCF$$$k$?$a!"<!$K=R$Y$k5!9=$,I,M
Jk!#

7PO)@)8f5!9=

%$%s%?!<%M%C%H$O?tB?$/$N7W;;5!$,CXia$NAcNh$&$K8_$$$K@\B3$7$"CF7A@.5
$*$j!"%$%s%?!<%M%C%H>e$GG[Aw5l$k%Q%1%C%H$O%P%1%D%j%l!<Nh$&$K%k!<%?$+$i%
%?$X<!!9$HG[Aw5l$F$$$/!#

%$%s%?!<%M%C%H>e$G$N%G!<%?E>Aw$K$O!"%$%s%?!<%M%C%H%W%m%H%3%k **(IP, Internet**
Protocol)[18] $,MxMQ$5lk!#IP $O%3%M%/%7%g%s%l%9G[Aw$,4pHWG"$j!"%G!<%?$O%Q%1%
%H$H$$$&>.5JC10L$KJ,3d$5$lJL!9$KG[Aw5l$k!#3F%Q%1%C%H$K$O%X%C%@$,IU2C5
%X%C%@KO;OE@$N IP %"%I%l%9!"=*E@$N IP %"%I%l%9JI$,5-:\$5lk!#

%$%s%?!<%M%C%H>e$G%Q%1%C%H$r:G=*E*$J=*E@$^$G@5$7$/G[Aw9k$?$aKO!"3F%k!<
K*$$$F!"%Q%1%C%H$N%X%C%@Fb$KJ];}7F$$$k>pJs$+$i<!$K%Q%1%C%H$rAwkY$-%k!
$r7hDj$7E>Aw9k5!9=$,I,MW$HJk!#3N5!9=$r7PO)@)8f5!9=$H$$$&!#

%$%s%?!<%M%C%H>e$N3F%k!<%?$O7PO)@)8f5!9=$N$?$a$N7PO)@)8fI=$rJ];}7F$*$j!
B8$N5!9=$G$O!"G[Aw$5lk%Q%1%C%H$O=*E@%"%I%l%9$r8!:w%-!<H7$F7PO)@)8fI=$r8
$7!"<!$KG[Aw5lkY$-%k!<%?$X$N%$%s%?!<%U%'!<%9H=$N%k!<%?$N IP %"%I%l%9$r
Dj9k;EAH$_$HJC$F$$$k!#

2.2 7PO)@)8f5!9=

K\@aGO7PO)@)8f5!9=KD$$$F35@b9k!#

2.2.1 7PO)$N7hDjJ}K!

%k!<%?K*$$$F<u?.%Q%1%C%H$N7PO)$N7hDjJ}K!KO<!$N 2 <oN`$,$"$k!#

- %[%C%W%P%$%[%C%W%k!<%F%#%s%0

  7PO)@)8f5!9=$K4p$E$-!"3F%k!<%?$,J];}7F$$$k7PO)@)8fI=KhCFDj$^$k7PO)
  %Q%1%C%H$r=g!9$KG[Aw7F$$$/J}K!$r%[%C%W%P%$%[%C%W%k!<%F%#%s%0$H$$$&!#

- %=!<%9%k!<%F%#%s%0 (;OE@7PO)@)8f)

  %Q%1%C%H$rAw?.$9$k%[%9%H$,$"$i$+$8$a3FAw?.%Q%1%C%H$N%X%C%@$K!"$=$N%Q%1%C
  $,DL2a$9$k%k!<%?$N%"%I%l%9$r0l$D0l$DIU2C$7F*$/J}K!$r%=!<%9%k!<%F%#%s%0
  $$$&!#%=!<%9%k!<%F%#%s%0$rMQ$$$?%Q%1%C%H$O7PO)@)8f5!9=$rI,MWH;$:!"7PO)
  8fI=$r;2>H$;$:$K$=$N%X%C%@$KIU2C$5l?%k!<%?$N%"%I%l%9$N$_$KhC$F7PO)$,
  Dj5l$k!#

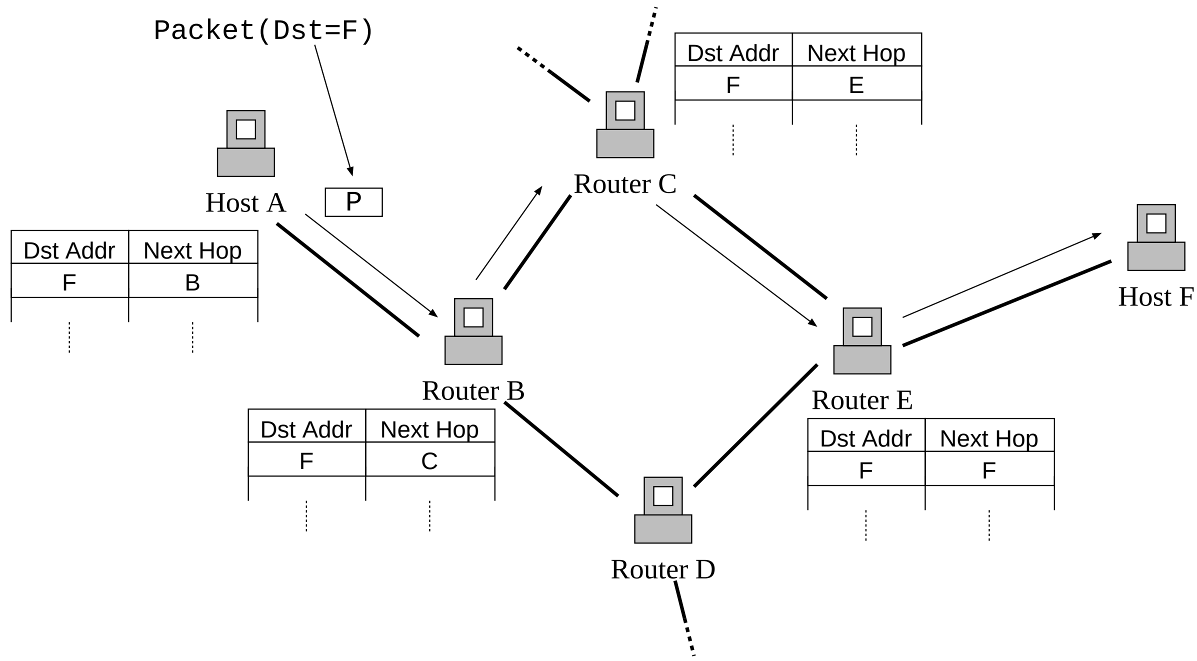
%=!<%9%k!<%F%#%s%0J}<0GO!"DL2a9k%k!<%?$rAw?.<T$,;XDjG-k?$a%Q%1%C%H
@)8f7d$9$$$,!"%Q%1%C%H$NDL2a$9$k%k!<%??t$NA}2C$K=>$C$F%Q%1%C%H%X%C%@$,Bg$
Jj!"%*!<%P!<%X%C%I$,A}Bg$9k?$a!"$3$NJ}<0$O8=<BE*GOJ/Jk!#0lJ}!"%[%C%
%$%[%C%W%k!<%F%#%s%0J}<0$G$ODL2a$9$k3F%k!<%?$G7PO)@)8fI=$r8!:w$9k?$a%*!<%
%X%C%I$,@8$8k,!"DL2a9k%k!<%?$N?t$,7PO)@)8f$N8zN($K1F6A9k3HOJ$/!"5
3HD%@-$,$"$k!#

$=$N$?$a!"7PO)@)8f5!9=GO0lHLE*$K%[%C%W%P%$%[%C%W%k!<%F%#%s%0$,MQ$$$i$l!"%
%9%k!<%F%#%s%0$O<g$K%M%C%H%o!<%/4IM}<T$N%G%P%C%0$KMQ$$$ilk!#

2.2.2 7PO)@)8fI=

7PO)@)8fI=$O<u?.%Q%1%C%H$N=*E@%"%I%l%9 (Destination Address) $H!"=*E@%"%I%l%9$r
;}$D%[%9%H$K%Q%1%C%H$rG[Aw$9k?aN<!$NCf7Q%k!<%?$N%"%I%l%9 (Next Hop Address)
$N 2 DNCM$G 1 DN%(%s%H%j$r7A@.$7F*$j!"M-8B8D$N%(%s%H%j$+$iJk!#

$3$3$G!"%$%s%?!<%M%C%H>eGN0lHLE*$J%Q%1%C%HG[Aw$NNc$r?^ 2.1$K<($9!#%[%9%H A
$i!"=*E@%"%I%l%9$,%[%9%H F G"$k%Q%1%C%H P $,Aw?.$5l?H9kH!"?^ 2.1Nh$&$
3F%k!<%?$,7PO)@)8fI=$K4p$E$$$F%P%1%D%j%l!<$G%Q%1%C%H P $rCf7Q$7$F$$$-!":G=*E
%[%9%H F $KE~Ce$9$k!#



?^ 2.1: %$%s%?!<%M%C%H>e$G$N7PO)@)8f

7PO)@)8fI=$KEPO?$5lk7PO)$N<oN`

%$%s%?!<%M%C%H>e$K$OG|Bg$J?t$N%[%9%H$,B8:_$7!"$=liA4FN%[%9%HKBP7$F7E
@)8f>pJs$r;}$D3H$O!"7W;;5!$N5-21MFNL$+$i$$$CFbIT2DG=G"$k!#$7$+$7!"%k!
$O%$%s%?!<%M%C%H>e$NA4$F$N%[%9%H$KBP7F7PO)@)8f$,2DG=$GJ1lPJi$J$$!#$
LdBj$r2r7h$9k?aK!"7PO)@)8fI=$KEPO?$5lk=*E@%"%I%l%9KO<!$N3$D$N<oN`$,
:_9k!#

- %[%9%H7PO)

  C10l%[%9%HXN7PO)!#7PO)@)8fI=KO$=$N%[%9%H$N%"%I%l%9$,EPO?5l$k!#

- %M%C%H%o!<%/7PO)

  $"$k%M%C%H%o!<%/$K@\B3$9kG0U$N%[%9%H$X$N7PO)!#7PO)@)8fI=$KO=$N%M%C
  %o!<%/$N%"%I%l%9$,EPO?5l$k!#

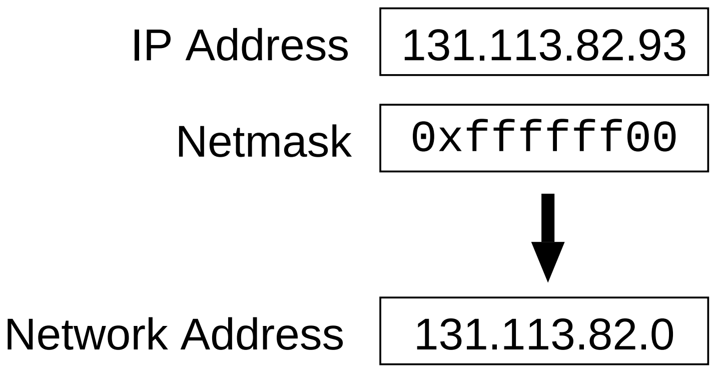
- %G%U%)%k%H7PO)

  >e5-2DN%(%s%H%j$K%R%C%H$7J+C?>l9g$N7PO)!#7PO)@)8fI=$K$OA4$F0$N%"%
  %l%9$,EPO?$5lk!#

3F%(%s%H%j$NFCD’

%$%s%?!<%M%C%H>e$G$O%Q%1%C%H$O=*E@%"%I%l%9$^$G%k!<%?$r=g!9$KG[Aw5l$F$$$/
HO4{$K@bL@$7$?!#

$3$3$G!"0[$J$k=*E@%"%I%l%9$r;}$D%Q%1%C%HF1;N$G$b!"=*E@%"%I%l%9$,F1$8%M%C%H%
%/$KB0$9kJiP$=$N%Q%1%C%H$O<!$NCf7Q%k!<%?H7$FF10l%k!<%?$rA*Br9k2DG=@
9b$$!#3N@-<A$rMxMQ$7!"%(%s%H%j$K%M%C%H%o!<%/%"%I%l%9$r;XDj9k3HKh$j!
$k%M%C%H%o!<%/>e$NG$0U$N%[%9%HXN7PO)$r 1 DN%(%s%H%j$K=8Ls$9k3H,G-$
IP GO%M%C%H%o!<%/%"%I%l%9O=$N%M%C%H%o!<%/>e$N%[%9%H$N IP %"%I%l%9$H%M%C
%^%9%/$H8F$Plk%S%C%HNs$NO@M}@Q$GI=5l$k (?^ 2.2;2>H)!#%M%C%H%o!<%/%"%I%l%9$N
<(KO%M%C%H%^%9%/$N%W%l%U%#%C%/%9$H%S%C%H?t$,9MN8$5$l!"Nc$($P?^ 2.2$N%M%C%H%
%/%"%I%l%9$O 131.113.82/24 $HI=8=$5lk!#K\O@J8GO!"0J8e%M%C%H%^%9%/$r 16 ?JI=5-
9k!#



?^ 2.2: %M%C%H%o!<%/%"%I%l%9$H%M%C%H%^%9%/

5i$K!"“$=$NB>Bg@*” $N7PO)$H7F%G%U%)%k%H7PO)$r;XDj$9k3HKhC$F!"%$%s%
%M%C%H>e$NA4$F$N%[%9%H$X$N7PO)$rJ];}$7!"$+$D7PO)@)8fI=$Khk%a%b%j;HMQNL$r>
$/J]$D3H$,2DG=$HJk!#

7PO)@)8fI=$r8!:w$9$k>l9g$KO^$:%[%9%H7PO)$,8!:w5l!"$=$N8e%M%C%H%o!<%/7
$,8!:w$5lk!#9JoA!"$"$k%"%I%l%9$,%[%9%H7PO)$H7F$b%M%C%H%o!<%/7PO)$H$
$bEPO?$5lF$$$k>l9gK=$N%[%9%H$N%"%I%l%9$r8!:w%-!<$H7F8!:w7?;~KO!"%
%H7PO)$,M%@h$5lk!#

7PO)@)8fI=NNcrI=2.1$K<($9!#I=2.1$N7PO)@)8fI=$r8!:w%-!<131.113.32.5$G8!:w$9$k
$H!"%M%C%H%o!<%/7PO) 131.113.32/24 $H%[%9%H7PO) 131.113.32.5 NIAi$b2DG=@-$,$"$k
$,!"%[%9%H7PO)$,M%@hJ?$a%[%9%H7PO) 131.113.32.5 $,A*Br$5lk!#$^$?!"131.113.29.21

$r%-!<$H7F8!:w9k$H%[%9%H7PO)!"%M%C%H%o!<%/7PO)Hb$K3:Ev$9$k%(%s%H%j$,B
7J$$$?$a!"%G%U%)%k%H7PO) 131.113.82.1 $,A*Br$5lk!#

I= 2.1: 7PO)@)8fI=$NNc

Destination Address	Next Hop Address	7PO)$N<oN`
default	131.113.82.1	%G%U%)%k%H7PO)
127.0.0.1	127.0.0.1	%[%9%H7PO)
131.113.32/24	131.113.82.33	%M%C%H%o!<%/7PO)
131.113.32.5	131.113.82.2	%[%9%H7PO)
131.113.82/24	131.113.82.35	%M%C%H%o!<%/7PO)

I= 2.1$+$ibo$+$kh&$K!"4{B8$N7PO)@)8f5!9=GO:G=*E*$J=*E@%"%I%l%9$N$_$r
:w%-!<H7$F7PO)@)8fI=$r8!:w$7!"$^$?%$%s%?!<%M%C%H$K@\B3$7$F$$$kA4%[%9%HX
%s%H%j$r!"$o$:$+$J%(%s%H%j?t (I= 2.1$G$O 5 $D) $G<B8=$7$F$$$k!#

2.2.3 7PO)@)8f%W%m%H%3%k

%$%s%?!<%M%C%H>e$G$O%Q%1%C%H$,%k!<%?$r=g!9$KCf7Q5l$F$$$/$?$a!"Aw?.%[%9%H
7PO)@)8f>pJs$,@5$7$$$H7F$b!"Cf7Q%k!<%?$N$&$A$?$@ 1 DN%k!<%?$G7PO)@)8f>pJs
8mCF$$$k>l9gKO!"@5$7$/G[Aw5l$J$$!#3N>l9g@5$7$/G[Aw5lkH$O!";OE@%
%l%9$+$i=*E@%"%I%l%9KBP7$F%Q%1%C%H$NDL2a9k%k!<%??t$,:G>.$GG[Aw5l!":GC
O)r?Ik3H$r;X$9!#

Cf7Q%k!<%?$,8m$C$?7PO)@)8f>pJs$rJ];}7F$$$k$H$$$&3H$O!"%Q%1%C%H$,B?>/>
$J7PO)$r$?$ICF=*E@%"%I%l%9$KE~C#$9k@1G$"$k$H0B0W$K9M$($F$O$$$1$J$$!#%
%H%o!<%/;q8;$,6&M-$5lF$$$k%$%s%?!<%M%C%H$G$O!"%Q%1%C%H$,>iD9$J7PO)$r$?$I$
$=$NJ,%M%C%H%o!<%/;q8;$rM>J,$KO2Hq9k$?$a!"%$%s%?!<%M%C%H$N;HMQ8zN($,Dc2<$9
5i$K>iD9$J7PO)r?IkDL?.<+?H$bL5BL$JCY1d$r@8$8k3HHJj!"E>Aw8zN($,D
9k!#

$^$?Cf7Q%k!<%?$G7PO)@)8f>pJs$,8mCF$$$k$H!"%Q%1%C%H$NG[Aw7PO)$,$"kJD8$
O)KJ$j!"%Q%1%C%H$,F1$87PO)$r<~2s$7B3$1$k2DG=@-$b$"$k!#3l$r%k!<%F%#%s%0%
%W$H8@$&!#%k!<%F%#%s%0%k!<%WO=$N%k!<%?$rDL2a$7!"$=$N=*E@%"%I%l%9$KG[Aw5
%Q%1%C%HA4F,=*E@%"%I%l%9$KE~CeIT2DG=$HJkNK2C$(!"G[Aw$5$lB3$1$k4V (Time T
Live $,M-8z$J4V) %M%C%H%o!<%/;q8;$rC%$CF7$^$&$?$a!";q8;$NO2Hq$KbDJ,$k!#

3Nh&$K!"7PO)@)8fI=$KEPO?9k>pJs$rL7=b$J$/@5$7$/J]$D$?$a$N4IM}5!9=$OHs

$K=EMW$G$"$j!">e5-$NLdBj$rHr1k$?$a$K%M%C%H%o!<%/>e$NA4FN%k!<%?K*$$$F0
@-N"$k7PO)@)8fI=$r9=C[7J1lPJiJ$$!#

F0E*7PO)@)8f

%M%C%H%o!<%/Fb$NA4$F$N%k!<%?$N7PO)@)8fI=$r@5$7$/4IM}$9$kJ}K!$H7F$O!"%M%C
%o!<%/$,>.5,LO$J>l9gKO4IM}<T$,<j:n6H$G0l$D0l$D$N%k!<%?$N7PO)@)8fI=$r4IM}$
3H$b9M$(il$k!#$7$+$7%M%C%H%o!<%/$,Bg5,LO$KJCF/kH!"$?$@0lDN%k!<%
8N>c$d2s@~$NITDL!"?7$?$J%k!<%?$NDI2C$,5/$-$kEY$K!"4IM}<T$,A4FN%k!<%?$N7PO
8fI=$r=q$-49$($k$H$$$&J}K!O-oa$F8zN($,0-$/!"8=<BE*$GOJ$$!#

$=$3$G3F%k!<%?>e$K7PO)@)8f%G!<%b%s$H8F$Plk%W%m%;%9$rF0$+$7!"3F%k!<%?>e$N%
%b%s$,<~0O$N%k!<%?$H7PO)@)8f>pJs$r8_$$$K8r49$7!"$=$N>pJs$r4p$KF0E*$K7PO)@)8
$r4IM}$9kH$$$&J}K!$,0lHLE*$G$"$k!#3N%"%k%4%j%:%`$r<B8=$9$k%W%m%H%3%k$r7
@)8f%W%m%H%3%k$H$$$&!#

7PO)@)8f%W%m%H%3%kH7$F!"BeI=E*$JbN$K RIP(Routing Information Protocol)[10]
$H OSPF(Open Shortest Path Fast)[15] $,$"$k!#

2.3 7PO)@)8fI=$N<BAu

7PO)@)8fI=$O%+!<%M%k$NFbIt$KB8:_$7!"%+!<%M%k$N30It$KBP7F7PO)@)8fI=XN%
%H%j$N8!:w!"DI2C!":o=|!"99?7$r9T$&%$%s%?!<%U%'!<%9$@$1$rDs6!$7$F$$$k!#%+!<%
FbItGN7PO)@)8fI=$N<BAu$K$OMM!9$JJ}K!$,9M$(ilk,!"Bg$-$/J,1F<!$N 3 <oN
$"$k!#

1. C1=c$JG[Ns$Khk<BAu
2. %O%C%7%e%F!<%V%k$rMxMQ$7$?<BAu
3. Radix Tree $rMxMQ$7$?<BAu [21]

Nr;KE*$K%+!<%M%kFbIt$G$N7PO)@)8fI=$O>e5-$N=g=x$G<BAu5lF-$?!#8=:_$G$O 3
L\$N Radix Tree Kh$k<BAu$,:NMQ5l$F$$$k!#

2.3.1 C1=c$JG[Ns$Khk<BAu

7PO)@)8fI=$N0lHVC1=c$J<BAuJ}K!H7$F!"C1=c$JG[NsKh$k<BAu$,$^$:9M$($ilk!
O)@)8fI=$N%(%s%H%j$r=g$KG[Ns$K3JG<$7!"8!:w$bG[NsKBP7$F=*E@%"%I%l%9$r8!:w%

H7$F9T$&!#3NJ}K!$O<BAu$OMF0W$@$,!"7PO)@)8fI=$N%(%s%H%j$r@0Nsb;$:$K=g$

YF$$$k$@$1G"$j!"%(%s%H%j?t$r n H9kH8!:wKO $O(n)$ $+$+$k!#$=N?$a!"7PC

@)8fI=$N%(%s%H%j$,B?$/$J$k>l9g$K$OE,$5$J$$!#7+$7!">.5,LO$J%M%C%H%o!<%/GG

MQG"$k!#

2.3.2 %O%C%7%e%F!<%V%kKh$k<BAu

8=:_$N%$%s%?!<%M%C%H$N5,LO$OHs>oKBg-$/!"G|Bg$J?t$N7PO)@)8f>pJs$,N.lF$$

$=$N$?$a%P%C%/%\!<%sHJkh$&$J%k!<%?GO!"7PO)@)8fI=O-oaFBg-$/$J$k!#$

$G!"C1=c$JG[NsNh$&$J8!:w8zN($N0-$$<BAuGJ$/!"7PO)@)8fI=$N5,LO$,Hs>o$KBg$

JCFb8zN($NNI$$5!9=$,5a$ail$?!#$=3G9M$($il?N,=*E@%"%I%l%9$r8!:w%

H7$?%O%C%7%e%F!<%V%k$rMQ$$$?<BAuG"$k!#

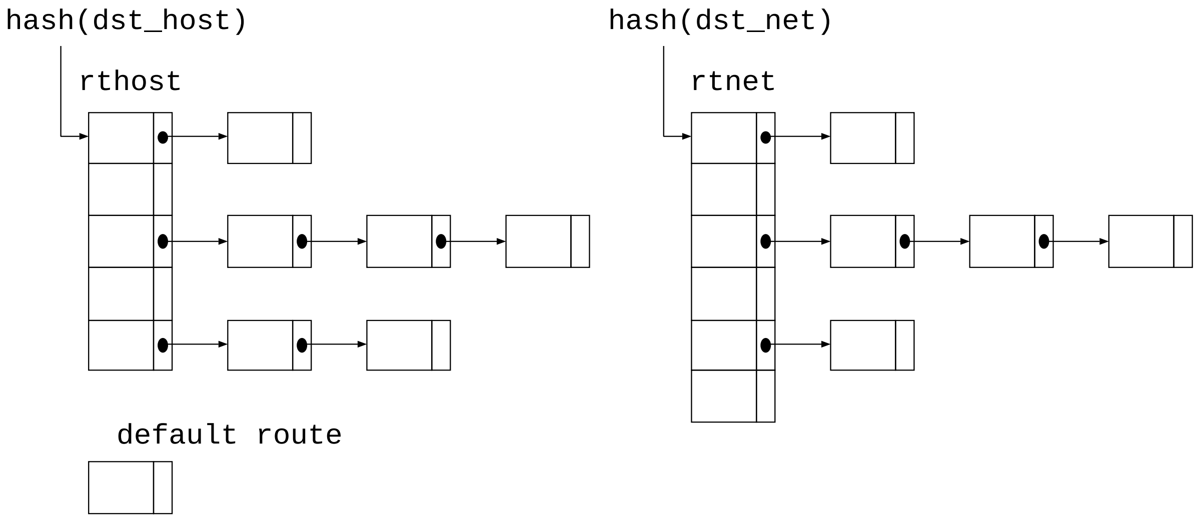
FCD'

%O%C%7%e%F!<%V%kKh$k<BAu$O!"%[%9%H7PO)MQ$N%F!<%V%k (**rthost**) $H%M%C%H%o!<%/7

O)MQ$N%F!<%V%k (**rtnet**) $N 2 DN%O%C%7%e%F!<%V%k$r;}$D3H$,Bg$-$JFCD'G"$k!#$

$?!"=*E@%"%I%l%9$+$i5a$^$k%O%C%7%eCM$,F1$87PO)@)8f>pJs$O!"$=$N%(%s%H%j$K@~7

%9%HH7$FEPO?$5lk!#3N%O%C%7%e%F!<%V%k$rMQ$$$?<BAu$N35G0?^$r?^ 2.3$K<($9



?^ 2.3: %O%C%7%e%F!<%V%kKh$k7PO)@)8fI=

3N<BAuGN8!:w$N<j=g$O<!Nh$&$KJk!#

<j=g

1. <u?.7?%Q%1%C%H$N=*E@%"%I%l%9$+$i%O%C%7%eCM$r5a$a!"**rthost** $G8!:w$r9T$&
%^%C%A7?%(%s%H%j$,@~7A%j%9%H$N>l9gKO$=$3$+$i@~7AC5:w$r9T$&!#3lKh
=*E@%"%I%l%9$H0lCW$9$k%(%s%H%j$,8+D+C?>l9g!"$=$l$rA*Br$9$k!#

2. 1 $G=*E@%"%I%l%9$H0lCW9k%(%s%H%j$,8+$D$+$iJ+C?>l9gKO!"<!$O=*E@%"
%l%9KhCFDj$^$k%M%C%H%o!<%/%"%I%l%9$+$i%O%C%7%eCM$r5a$a!"**rtnet** $G 1 $
F1MM$K8!:w$r9T$&!#$3lKhj!"%M%C%H%o!<%/%"%I%l%9$H0lCW$9$k%(%s%H%j$,8+
$+$C$?>l9g!"$=lrA*Br9k!#

3. **rthost**!"**rtnet** IAiN%F!<%V%kGb8!:w$,<:GT$7$?>l9g$K$O!"%G%U%)%k%H7PO)
$rA*Br$9$k!#%G%U%)%k%H7PO)$,$J$$>l9g$O!"E,@Z$J7PO)$,8+$D$+$i$:!"8!:w%(%i
HJ$k!#

LdBjE@

%O%C%7%e%F!<%V%k$rMxMQ$7$?<BAu$O7PO)$NDI2C!":o=|$JI,ddJ#;(KJC?bN
8!:w$O8zN(E*$G%a%b%j;HMQNL$b>/$J$$$H$$$&MxE@$,$"C?!#7+$73+H/$,?J$`$K$D
3N<BAuGOIT==J,JLL,=PF-$?!#$=lO<!$N 2 E@$G$"$k!#

- %5%V%M%C%H2=XNL$BP1~

  %O%C%7%e%F!<%V%k$rMxMQ$7$?<BAu$G$O=*E@%"%I%l%9$+$i%M%C%H%o!<%/%"%I%l%9$r
  Dj9k;~!"%M%C%H%o!<%/%"%I%l%9$O%/%i%9$N35G0$K4p$E$/I8=`E*$J%"%I%l%9G"
  $H2>Dj$7$F$$$?!#7+$7!"%5%V%M%C%H [14] $N35G0$rF3F~7?>l9g%O%C%7%e%F!<%V
  Kh$k <BAu$OM-8zGOJ/Jk!#Nc$($P!"%/%i%9 B %"%I%l%9$r 256 8D$N%/%i%9 C
  %"%I%l%9$K%5%V%M%C%H2=$7$?>l9g!"%M%C%H%o!<%/%"%I%l%9$N%O%C%7%eCM$,A4$FF1
  CMKJ$j!"256 8D$N@~7AC5:wKJCF7^$&!#
  $^$?%$%s%?!<%M%C%H$N5^B.$J3HBg$KH<$$!"VLSM(Variable Length Subnet-Mask)
  [19] $NF3F~$d CIDR(Classless Inter Domain Routing)[9] $K4p$E$/7PO)@)8f$JI,
  Ia5Z$7!"%M%C%H%^%9%/$r0U<1$7$?7PO)@)8f5!9=$,5a$ailF-$?!#FC$K!"VLSM
  CIDR $O7PO)@)8f$N:]$K:GD90lCW (logest subnet mask matching)!"D^$j:G$bD9$$
  %M%C%H%^%9%/$r;}$D7PO)$rA*Br$7J1lPJi$J$$!#

- 2DJQD9%"%I%l%9BN7O$HITO"B3%M%C%H%^%9%/$XNLBP1~

7PO)@)8fI=$O IP $KFC2=$7$?$bNGOJ$/!"B?MM$J%W%m%H%3%k$KBP1~$G$-$kY-$ $"$j!"%^%k%A%W%m%H%3%kXNBP1~$,7PO)@)8fI=$N<BAuKO5aailF$$$?!#%O %7%e%F!<%V%k$rMxMQ$7$?<BAu$N>l9gGb IP $NB>$K Xerox $N XNS[20] KbBP1~7F $$$?$,!"OSI %W%m%H%3%k$X$NBP1~$r9M$($?:]$KLdBj$HJk!#OSI %W%m%H%3%k$O IP $d XNS KO$J$$FCD' H7$F!"2DJQD9%"%I%l%9BN7O$HITO"B3%M%C%H%^%9%/$r;}$D IP $d XNS GO8GDjD9$NC;$$%"%I%l%9 (IP GO 4 %*%/%F%C%H!"XNS GO 6 %*%/%F%C %H) $rMQ$$$F$$$k$,!"OSI %W%m%H%3%k$GO-oa$FD9$$2DJQD9%"%I%l%9$rMQ$$$k %O%C%7%e%F!<%V%k$rMQ$$$?<BAu$O IP $d XNS GO%O%C%7%eCM$r5aak=*E@%"%I%l %9$,C;$+C?$?$a!"8!:wHO0O$N9J$j9~$_$d%O%C%7%eCM$N7W;;$,MF0W$KG-Hs>o$K 8zG"C?!#7+$7!"OSI %W%m%H%3%kGO8!:w9k%"%I%l%9$,D9$/$+$D2DJQD9G k?$a!"%O%C%7%e%F!<%V%k$Khk<BAu$OHs8zN(E*$HJj!"$^$?%a%b%j4IM}NLLG LdBj$,@8$8F7$^$&!#

5i$K!"OSI %W%m%H%3%k$OITO"B3%M%C%H%^%9%/$r:NMQ$7$F$$$k$?$a!"%5%V%M%C%H$ $NBP1~$HF1;~K3$NE@$r9MN8$7$J1lPJiJ$$!#

2.3.3 Radix Tree Kh$k<BAu

A09`$G=R$Y$?$h$&$K%O%C%7%e%F!<%V%k$rMxMQ$7$?<BAu$K$O!"OSI %W%m%H%3%k$H%5%V%M %HXNBP1~NLLGBg$-$JLdBj$,$"$j!"OSI %W%m%H%3%k$Nh&$K2DJQD9$GD9$$%"%I%l%9 7O$dITO"B3$J%M%C%H%^%9%/$r;}$D>l9gGb8zN(E*$K8!:w2DG=$J7PO)@)8fI=$N<BAu$,5 il$?!#

3N7k2L3+H/5l$?$N$,!"**Radix Tree** $rMxMQ$7$?<BAu [21] G"$k!#3N<BAuGO%" %I%l%9$r%S%C%HNsH_J7$F!"$=lrFsJ,LZ$K%^%C%T%s%0$7$?9=B$$r7PO)@)8fI=$KM $k!#C1=c$JFsJ,LZ$rMQ$$$k$H8!:w$N:]$K%"%I%l%9$ND9$5$NJ,$@$1Hf3S2s?t$,A}$(F $&$?$a!"=LB`$5$;$? Radix Tree $rMQ$$$k!#

K\9`GO!"Radix Tree Kh$k<BAu$r IP %"%I%l%9rNcKHC$F@bL@$9$k!#

Radix Tree $N9=B$

Radix Tree HO!"7PO)@)8fI=$N=*E@%"%I%l%9$r 32 %S%C%H$N 1 DN%S%C%HNs$H9M$(!"$= $N3F%S%C%H$, 1 $+ 0 $+$KhC$F 2 DK;^$,JLlF$$$kFsJ,LZ9=B$$N3H$r;X$9!#EPO? $k7PO)@)8f>pJs$O$=$N=*E@%"%I%l%9$KBP1~$9$k;^$KEPO?5l$k!#$7$+$7 32 %S%C%H$N %"%I%l%9$,<h$jF@$kCMA4FrLZ9=B$$K9k$H!"%a%b%j;HMQNL$,G|BgG"$k>e$K7PO)@ I=$KEPO?$9$k%(%s%H%j$N?t$,>/$J$$>l9gKO>iD9HJ$jHs8zN(E*$G$"$j!"1 DN IP %" %l%9$r8!:w$9$k:]$NHf3S2s?t$,B?$/Jj;~4VE*Kb8zN($,0-$$!#

$=$3$GJ,4t$,5/3k;^N_$rCj=P$7!"$=$N4V$r “=LB`” 5;$k!#$=N?$a!"3FJ,4t
$O 32 %S%C%H$N%S%C%HNs$N2?HVL\$GJ,4t9k$+$r>pJsH7$FJ];}$9$k!#$3lKhj!"%a
%jNLLG$b8!:w$KMW9k;~4VNLLG$b8zN($NNI$$9=B$$r<B8=G-$k!#$3$N>l9g!"DI2
:o=|JI7PO)@)8fI=$N%(%s%H%j$NA`:nKBP9$k=hM}$,J#;(KJCF7^$$!"8!:w$KH
$F8zN($,0-$/$J$k!#$7$+$7$3$NJ}K!$O!"7PO)@)8fI=$ODI2C$d:o=|$hjb8!:w$N2s?t$
$,B?$/!"DI2C!":o=|$KB?>/;~4V$,$+$+CF$b8!:w=hM}$N9bB.2=$K=EE@$r$*$/Y-G
$H$$$&K\Mh$NL\E*$r9M$($l$PBEEv$G$"$k!#

$3$3$G!"Radix Tree NNcr?^ 2.4$K!"?^ 2.4$KBP1~9k7PO)@)8fI=$rI= 2.2$K<($9!#I=
2.2GO<!%[%C%W%k!<%?%"%I%l%9$O>JN,$7!"BejK=*E@%"%I%l%9$r 2 ?J?t$GI=7?bN
E:IU9k!#3l$O Radix Tree $NF0:n$r9M$($k:]KI,MWHJk!#I= 2.2$GB@;z$KJCF
$k%S%C%H$O$=$3$GJ,4t$,5/3C$F$$$k3H$r<($7$F$$$k!#

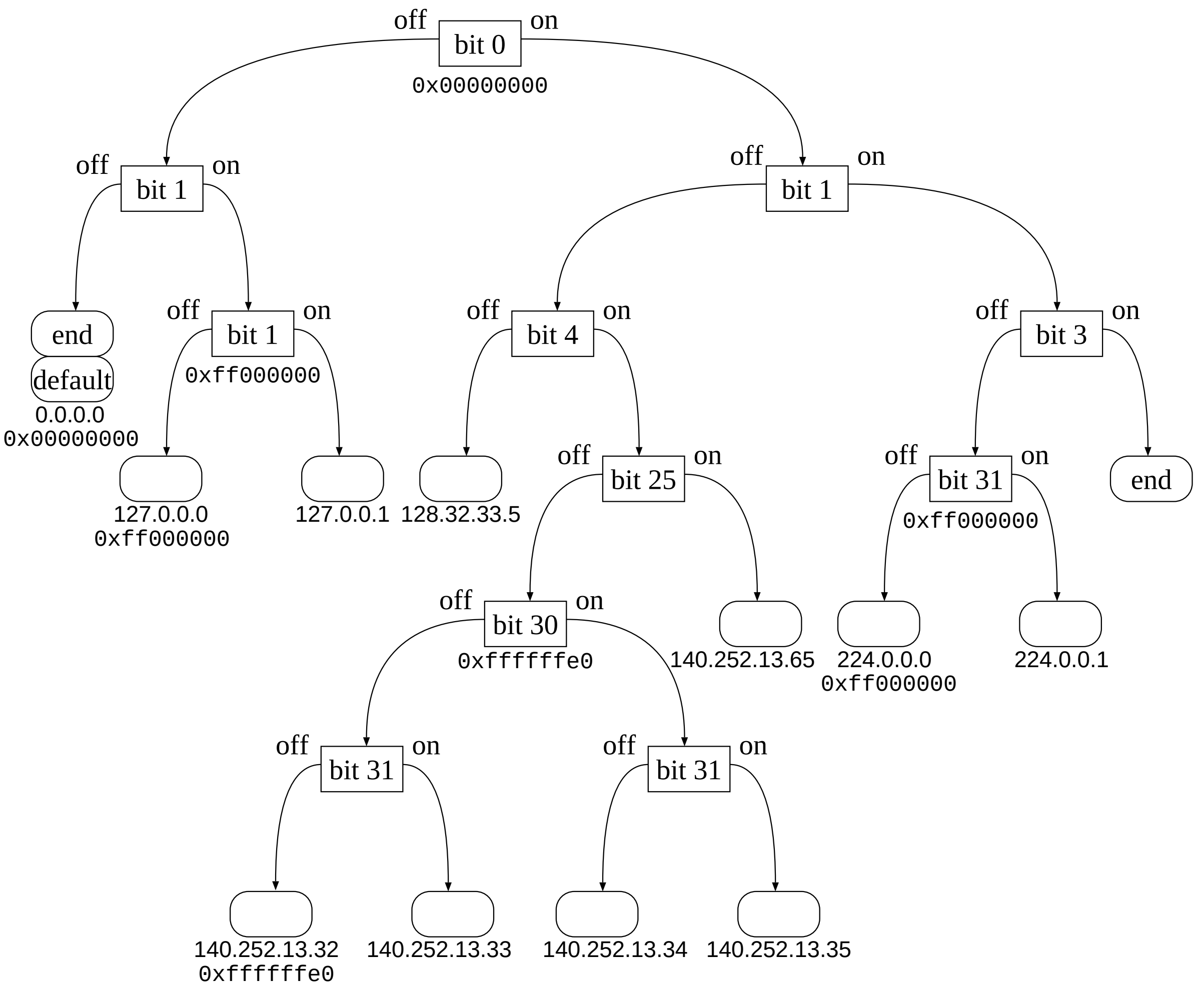
I= 2.2: ?^ 2.4 $KBP1~$9$k7PO)@)8fI=$H!"$=$N 2 ?J?tI=8=

Destination Address		32-bit IP address							
	bit:	**0000**	**0**000	0011	1111	1111	2222	2**2**22	22**33**
		0123	**4**567	8901	2345	6789	0123	4**5**67	89**01**
0.0.0.0(default)		0000	0000	0000	0000	0000	0000	0000	0000
127.0.0.0		0111	1111	0000	0000	0000	0000	0000	0000
127.0.0.1		0111	1111	0000	0000	0000	0000	0000	0001
128.32.33.5		1000	0000	0010	0000	0010	0001	0000	0101
140.252.13.32		1000	1100	1111	1100	0000	1101	0010	0000
140.252.13.33		1000	1100	1111	1100	0000	1101	0010	0001
140.252.13.34		1000	1100	1111	1100	0000	1101	0010	0010
140.252.13.35		1000	1100	1111	1100	0000	1101	0010	0011
140.252.13.65		1000	1100	1111	1100	0000	1101	0100	0001
224.0.0.0		1110	0000	0000	0000	0000	0000	0000	0000
224.0.0.1		1110	0000	0000	0000	0000	0000	0000	0001

Radix Tree Kh$k7PO)@)8fI=$N8!:w

Radix Tree Kh$k7PO)@)8fI=$N8!:wKO<!$N 3 DN<oN`$,$"$k!#

- 40A40lCW (Full Match)
- %M%C%H%^%9%/$r9MN8$7$?8!:w (Network Match)



?^ 2.4: Radix Tree Kh$k7PO)@)8fI=

- %P%C%/%H%i%C%-%s%0$NH/@8$9$k8!:w (Matching with Back Tracking)

$3$3$G?^ 2.4 !"I= 2.2$K<($97PO)@)8fI=$rJ];}9k%k!<%?$r2>Dj$7 !">e5-$N 3 <oN`$=$ $>$lKBP7$F Radix Tree 9=B$$Khk7PO)@)8f>pJs$N8!:w$N<j=g$r<($9!#

- 40A401CW (**Full Match**)

  =*E@%"%I%l%9$, 140.252.13.65 $N%Q%1%C%H$r<u?.7?H9$k!#$3lr8!:w%-!<H7 $?8!:w$N<j=g$r<($9!#

  <j=g

  1. :G=i$K 0 %S%C%HL\$r8!::9k!#140.252.13.65 $O 0 %S%C%HL\$O 1 JN$G!"1&$N ;^r?Ik!#
  2. <!$NJ,4t$G$O!"8!::%S%C%H$O 1 %S%C%HL\$G$"$j!"1 %S%C%HL\$O 0 JN$G:8$N; r?Ik!#
  3. <!$N8!::%S%C%H$O 4 %S%C%HL\$G!"140.252.13.65 $N 4 %S%C%HL\$O 1 JN$G!"1& $N;^$r$?$I$k!#
  4. <!$N8!::%S%C%H$O 25 %S%C%HL\$G!"140.252.13.65 $N 25 %S%C%HL\$O 1 JN$G!" 1&$N;^r?Ik!#
  5. :G=*E*KMUKE~C#7?>l9g!"MU$N=*E@%"%I%l%9$H8!:w%-!<$N%"%I%l%9$H$rHf 9k!#3N>l9g!"E~C#7?MU$NJ];}7F$$$k%"%I%l%9$H40A401CW (**Full Match**) 9k$?$a!"<!$NCf7Q%k!<%?$N%"%I%l%9$,Dj$^j3$N7PO)$r:NMQ9k!#

- %M%C%H%^%9%/$r9MN8$7$?8!:w (**Network Match**)

  =*E@%"%I%l%9$, 140.252.13.60 $N%Q%1%C%H$r<u?.7?H9$k!#$3lr8!:w%-!<H7 $?8!:w$N<j=g$r<($9!#

  <j=g

  1. Full Match $N;~$HF1MM$K!"0 %S%C%HL\$+$i8!::%S%C%H$r=g$KD4$Y$F$$$/!#9k $H!":G=*E*$K 140.252.13.32 $KE~C#$9$k!#
  2. Full Match $r9T$&$,<:GT$9$k!#
  3. :#EY$O%M%C%H%^%9%/$r9MN8$7$?8!:w (**Network Match**) $r9T$&!#140.252.13.32 $N%M%C%H%^%9%/$O **0xffffffe0** G"$j!"8!:w%-!<$G$"$k 140.252.13.60 $H%^%9 %/$7$?7k2L 140.252.13.32 HJ$k!#$3lOMU$NJ];}7F$$$k%"%I%l%9$H01CW$9 kNG3$N7PO)$r:NMQ9k!#

- %P%C%/%H%i%C%-%s%0$NH/@8$9$k8!:w (**Matching with Back Tracking**)

  =*E@%"%I%l%9$, 140.252.13.62 $N%Q%1%C%H$r<u?.7?H9$k!#$3lr8!:w%-!<H7 $?8!:w$N<j=g$r<($9!#

  <j=g

  1. Full Match !"Network Match $HF1MM$K 0 %S%C%HL\$+$i8!:w$7$F$$$/$H!":G=*E*$K 140.252.13.34 $KE~C#$9$k!#
  2. Full Match $r9T$&$,<:GT$9$k!#
  3. 3N>l9g!"140.252.13.34 NMUO%M%C%H%^%9%/$rJ];}$7$F$$$J$$$N$G Network Match $O9T$olJ$$ (0xffffffff $N%M%C%H%^%9%/$rJ];}7F$$$kHb8@$($k)!#
  4. Full Match $b Network Match $b<:GT$7$?>l9g$O!"Radix Tree $r:,$NJ}$^$GLa $k!#$=7F%M%C%H%^%9%/$rJ];}$7$F$$$kJ,4t$KE~C#$7$?=j$G;_$^$k!#3N> 9g!"$\boxed{\text{bit 30}}$ $NJ,4t$G$"$k!#3N=hM}$r%P%C%/%H%i%C%-%s%0$H$$$&!#
  5. $\boxed{\text{bit 30}}$ $NJ];}$7$F$$$k%M%C%H%^%9%/ 0xffffffe0 $G8!:w%-!< 140.252.13.62 $r %^%9%/$9kH!"140.252.13.32 HJ$k!#$3$N%"%I%l%9$r?7$?$J8!:w%-!<H7$F!" $\boxed{\text{bit 30}}$ $rD:E@$H7?%5%V%D%j!<$G:F$S Full Match $+$i8!:w$r3+;O$9$k!#
  6. $^$: 140.252.13.32 $N 30 HVL\$N%S%C%H$O 0 JN$G!":8$N;^r?Ik!#
  7. $\boxed{\text{bit 31}}$ GbF1MM$K:8$N;^r?Ik!#
  8. :G=*E*$K 140.252.13.32 NMUKE~C#$7!"$3lO8!:w%-!<$H40A40lCW$9k?$a!" 3N7PO)$r:NMQ$9$k!#

Radix Tree $N:,!"$9Jo$A $\boxed{\text{bit 0}}$ $NJ,4t$G$O 0x00000000 $N%M%C%H%^%9%/$rJ];}7F $$$k$?$a!"A4FN%^%C%A%s%0$K<:GT$7$F:,$KLaCF$-$?>l9g$O!"A4$F:8$N;^$r$?$I$ HKJk!#$=$7$F!"%G%U%)%k%H7PO)$,@_Dj5l$F$$$l$PI,$:$=$l$K%^%C%A$7!":G=*E %G%U%)%k%H7PO)$,:NMQ$5lk3H$,$o$+$k!#

2.4 4{B8$N7PO)@)8f5!9=$N$^$H$a

4{B8$N7PO)@)8f5!9=$G$O!"<u?.%Q%1%C%H$N=*E@%"%I%l%9N_$r4p$K7PO)@)8fI=$N8 $r9T$&!#$=$N<BAuJ}K!$O!"8=:_$N5!9=GO Radix Tree 9=B$$rMxMQ7?J}<0$rMQ$$$F$$$k

7+$78=:_$N5!9=GO7PO)@)8fI=$O%U%m!<Kh$N%(%s%H%j$rJ];}$7$J$$$?$a!"J]>Z7?% %S%9$KBP1~7?7PO)@)8f$r9T$&3H$,$G$-$J$$!#4{B8$N7PO)@)8f5!9=$NLdBjE@$O!"E >O$G@bL@9k!#

Bh **3** >O

J]>Z7?%5!<%S%9

K\>OGO!"$^$:K\8&5fK*$$$FGX7JHJ$kJ]>Z7?%5!<%S%9$K$D$$$F35@b$7!"$5iK
>Z7?%5!<%S%9$KBP1~$7$?7PO)@)8f5!9=$NI,MW@-KD$$$F=RYk!#

3.1 J]>Z7?%5!<%S%9

3.1.1 %^%k%A%a%G%#%"DL?.$NEP>l

Ev=i$O!"8&5f<T$Khk<B83%G!<%?$N>pJs8r49(EE;R%a!<%k)$d:n@.7?%W%m%0%i%`$N
IU(%U%!%$%kE>Aw)!"1s3VCO$K$"$k7W;;5!$NMxMQ(1s3V%m%0%$%s)JI$,<g$JL\E*G"$C
%$%s%?!<%M%C%H$b!"8=:_GO@$3&5,LO$N%M%C%H%o!<%/$K@.D9$70lHL$N?M!9$KMxMQ5
h&KJC?!#5i$K%M%C%H%o!<%/5;=Q$NLv?JKh$j2s@~B.EY$O7`E*$KB.$/Jj!"$
$KH<$$Ev=i$NL\E*$H$O0[$JC?MM!9$JMW5a$,=PF-$F$$$k!#$=$NCfGFCK6aG/CmL\$
$F$$$kN,!"2;@<$dF02h$r07$&%^%k%A%a%G%#%"DL?.$H8FPlkbNG$"$k!#

%^%k%A%a%G%#%"DL?.NNcH7F!"%$%s%?!<%M%C%H%3%s%5!<%H$d%S%G%*2q5DJI$,9N
il$k!#%$%s%?!<%M%C%H$G2;@<$rN.$9$3H,2DG=KJlP!"2q>l$K9T$+$:$K2H$K5o$
iK7F%3%s%5!<%H$K;22C$9k3H,G-$?$j!"F02h$rN.$9$3$H$,2DG=$KJl$P1G2
$K9T$+$:$K2H$K5o$J$,$i1G2h$r3Z$7$`$3Hb2DG=HJ$k!#$^$?!"%$%s%?!<%M%C%H$r;
$F%S%G%*2q5D%7%9%F%`$r9=C[G-lP!";22C<T$,0l%v=j$K=8$^$iJ/Fb!"3F?M$N%*%
%9$K$$$J$,$i2q5D$r9T$&3H$,$G$-$k!#

3.1.2 :GA1EXNO7?%5!<%S%9$N8B3&

%$%s%?!<%M%C%H$G2;@<$dF02h$N%j%"%k%?%$%`E>Aw$r9M$($?>l9g!"4{B8$N:GA1EXNO7?%
%S%9 (**Best-effort Service**) GOIT==J,JLL,@8$8$k3H$,=>Mh$h$j;XE&$5lF$$$k [2]!#

:GA1EXNO7?%5!<%S%9HO%$%s%?!<%M%C%H$N4pK\E*$J35G0$G$"$j!":GA1EXNO7?%5!<%S
K*$$$F%M%C%H%o!<%/;q8;(Cf7Q%k!<%?$N%P%C%U%!$d!"2s@~K*$$$FDL?.$N@j$a$kBS0h
$O!"%k!<%?$d2s@~$r;HMQ$9$kA4$F$N%Q%1%C%H$KhC$F6&M-$5lF$$$k!#$=$N$?$a%M%
%o!<%/;q8;$,;HMQ2DG=$G$J$$>l9gb"$j!"$"$k%[%9%H$,Aw?.7?%Q%1%C%H$O%M%C%H%
%/;q8;$r3NJ]$9k3H,G-$:$K=*E@%"%I%l%9$KE~C#$9$kA0$K4~5Q5l$k2DG=@-$,B
9k!#$"$k$$$O;q8;$N>u67$KhCFOF10l%U%m!<$N%Q%1%C%H$b0[Jk7PO)r?Ik$?
%Q%1%C%H$N=g=x$,F~lBXok+b7lJ$$!#$^$?F1$8%Q%1%C%H$,=EJ#7F=*E@%"%I%
$KE~Ce$9k+b7lJ$$!#7+$7!"%M%C%H%o!<%/;q8;$,;HMQ2DG=G"$k8B$j$O@5$7$
Aw7h$&$H$7!">e5-$Nh&$JLdBj$,@8$8$kNO%M%C%H%o!<%/;q8;$,3NJ]$G$-$J$$>l9
$"$k!#3Nh&KG$-$k8B$j@5$7$/G[Aw$7h&$H$$$&?6$kIq$$$,!":GA1EXNO7?%5!<%
$H$$$&L>A0$NM3Mh$G$"$k!#

2;@<$dF02h$NFC@-$r9M$(lP!"3N:GA1EXNO7?%5!<%S%9$N4pHW$N>eGO2;@<!&F02h DL?.$r9T$&KOIT==J,$JM}M3$,o+$k!#%U%!%$%kE>Aw$dEE;R%a!<%k$J$I=>Mh$NDL?.$G %M%C%H%o!<%/;q8;$r3NJ]G-$:$K6u$/$^$GBT5!$7$?$H7F$b!"$D$^$jDL?.$N=*N;;~4 B?>/CY$lFb2?$iLdBj$O$J$$!#7+$7!"2;@<$dF02h$r%j%"%k%?%$%`$KDL?.$9$k>l9g! $l$i$OC`0l<u?.<TB&$G:F@8$5lF$$$k$?$a!"%Q%1%C%H>C<:Kh$k:FAw$rBTC?$j!"= $NA08e$r<u?.<TB&$GF~$l49$($?j9$k;~4VE*M>M5$OL5$$$NG"$k!#ESCf$G2;$,ES@Z$ 2;3Z$d!"1GA|$,8+$($J$/$Jkh$&$J1G2hGO>&IJH7FN2ACM$,$J$/$JCF7^$&!

3Nh&$K!"=>Mh$N:GA1EXNO7?%5!<%S%9GOK~B-G-$J$$!"CY1dKBP7$FHs>o$KIE $JDL?.$r<B;~4VDL?.$H$$$&!#

3.1.3 J]>Z7?%5!<%S%9$NI,MW@-

<B;~4VDL?.$r%$%s%?!<%M%C%H$G<B8=$9kKOI$&$9lP$h$$$@m&$+!#%$%s%?!<% %H>eGN<B;~4VDL?.$NLdBj$O!"4{$K=R$Y$?$h$&$K%$%s%?!<%M%C%H$,:GA1EXNO7?%5!<% $r4pHW$H7F$$$kE@G"$k!#$3$3$GCmL\$9Y-$O!":GA1EXNO7?%5!<%S%9$NFCD'$O%M% %o!<%/;q8;$K6u$-$,$J$$>l9gKO;q8;$,MxMQ2DG=$KJk$^$G$NCY1d$,Bg$-$/JCF $&$,!"%M%C%H%o!<%/;q8;$,>o$K6u$$$F$$$k>uBVGOI,MW:G>.8B$NCY1d$GDL?.$,2DG=$ $kE@$G$"$k!#D^$j!"<B;~4VDL?.$,K~B-G-k@1N%M%C%H%o!<%/;q8;$r2?$i$+$NJ G"i+8aJ]>Z7F$*$1$P!"<B;~4VDL?.$OM=4|7J$$CY1d$N1F6A$r<u1:!"%$%s% %M%C%H$G$b<B8=2DG=$HJk!#3Nh&$J%5!<%S%9$r:GA1EXNO7?%5!<%S%9KBP7$F!"J 7?%5!<%S%9 **(Guaranteed Service)** $H$$$&!#J]>Z7?%5!<%S%9$O!"J]>Z7?%5!<%S%9$rMxMQ 9k3F%U%m!<KBP7$FDs6!$5lk!#%U%m!<HO!"$"$k;OE@%[%9%H$+$i=*E@%[%9%H$^$ 0lO"$N%G!<%?$NN.$l!"%Q%1%C%H72$N3H$r;X$9!#

J]>Z7?%5!<%S%9$r<B8=$9k?aN0lHLE*$J<jK!$O!"$=$N%U%m!<$,DL2a$9$k7PO)>e$N% %H%o!<%/;q8;r"i+8a3NJ]7F$*$/;q8;M=Ls **(Resource Reservation)** G"$k!#;q 8;M=Ls$r$"$i$+$8$a9T$C$?%U%m!<$OB>$NDL?.$N1F6A$r<u$1$:$K:Q$`$?$a!"<B;~4VDL? E,$7$F$$$k!#

3.2 QoS

3.1@aGOJ]>Z7?%5!<%S%9$NI,MW@-$K$D$$$F=RYk$?$a$K!"<B;~4VDL?.$K$*$1$kCY1d Nc$H7F5s2?$,!"J]>Z7?%5!<%S%9$KBP7F3F%U%m!<$,J]>Z$rMW5a9kNOCY1d$@$ OJ$$$3HKCm0U9Y$-$G$"$k!#3Nh&$J!"3F%U%m!<$,J]>Z7?%5!<%S%9K*$$$FM 9k%5!<%S%9$N<A$r **QoS(Quality of Service)** $H$$$&!#

0lHLKO QoS H7$F<!$Nh&JbN,CNil$F$$$k [23] !#

- CY1d

  A0=R7?h&$K!"DL?.$K$*$1$kCY1d$b QoS $N 1 DG$"$k!#CY1d$H$$$CFbMM!9$
  $"$j!"%"%W%j%1!<%7%g%s$dDL?.FbMF$KhCFO!"DL?.CY1d$,$"$kDxEY$NHO0OFb$K
  >Z5l$F$$$l$PB?>/$N%Q%1%C%H$NCY1d$O5vMFG-!":GBgCY1d$r9MN8$;$:$KJ]>Z$G
  $k>l9g$b$"$l$P!"1 DN%Q%1%C%H$NCY1d$b5v5lJ/!"9M$($ilk:GBg$NDL?.CY
  $r9MN8$7$FJ]>Z$9$k>l9g$b$"$k!#

- BS0h

  %$%s%?!<%M%C%H>e$GBgMFNL$N%G!<%?$rJ#?t$NAj<j$KG[IU7?$$>l9g$,$"$k!#Nc$(
  1G2h$NG[5k2q<R$,3F1G2h4[KBP7$F!"%$%s%?!<%M%C%H$r2p$7$F1G2h$N%U%#%k%`$r
  IU9k>l9g$d!"$^$?!"$"$k%"!<%F%#%9%H$N CD $rM=Ls$7$F$$$?%U%!%s$N85$K!"$=$
  CD $NH/GdF|$K0l@F$K CD %G!<%?$rG[IU9k>l9gJI$,9M$(il$k!#
  3Nh&$KBgMFNL$N%G!<%?$rG[Aw$9$k>l9g$K$O!"Aj<j@h$^GN7PO)>eG"$kDxEY
  BS0h$r3NJ]$70lEY$KG[Aw$7$?$$!#D^$j!"BS0h$KBP9kJ]>Z$,MW5a$5lk!#

- ?.Mj@-

  302J0e$HIB1!$H$r%$%s%?!<%M%C%H$r2p$7$F7k$S!"302J0eB&$,IB1!B&$N1GA|!"2;@<
  4p$K0e;UC#$K;X<(!"$^$?$O302J0eB&$GD>@\A`:n7F!"1s3V<j=Q$r9T$&%"%W%j%1
  %7%g%s$O<B83E*$J1?MQ$,9T$olF$$$k [27] !#3Nh&$J:Y?4$NCm0U$rH<$&%U%m!<$
  $O!"2hA|$d2;@<$,ES@Z$l$?$jMpl?j9k3HO5v5l$J$$!#$?$H$(CY1d$dBS0h
  J]>Z7?H7Fb!"%G!<%?%j%s%/AX$,?.Mj@-$N$J$$2s@~$r7PM3$7$F$$$k>l9g$K
  0UL#$,$J$$!#9JoA!"3Nh&$J=EMW$J%U%m!<$N>l9g$K$O?.Mj@-$N$"$k2s@~
  $_$rA*Br7FDL?.$r9T$&3H$,I,MW$HJk!#D^$j!"?.Mj@-$KBP9kJ]>Z$,MW5a
  lk!#

0J>e 3 DNE@$r5s$2$?$,!"B>Kb QoS $rMW5a$9kNcO$"$k!#

3.3 J]>Z7?%5!<%S%9$NMW5a$9$k5!9=

J]>Z7?%5!<%S%9$r<B8=$9kK$O!"3F%k!<%?>e$G<!Nh$&$JMM!9$J5!9=$,I,MWHJ$

- %"%I%_%C%7%g%s%3%s%H%m!<%k

  $"$k%U%m!<$,MW5a$9$k QoS $rDs6!$9k@1N%M%C%H%o!<%/;q8;$,B8:_$9k+I
  $+$rH=CG9k5!9=!#

- %]%j%7!<%3%s%H%m!<%k

  J]>Z7?%5!<%S%9$rMW5a$9$k%U%m!<$,!"J]>Z$r<u$1$k8"Mx$rJ]M-7F$$$k$+$rH=CG
  $k5!9=!#

- %Q%1%C%HJ,N`5!9=

  3FAw?.%Q%1%C%HKBP7$F!"$=l>lN%Q%1%C%H$,I,MW$H9k QoS Kh$K%/%i%9$rJ
  $1!"7PO)$r7hDj9k5!9=!#

- %Q%1%C%H%9%1%8%e!<%i

  <B:]$K3FDL?.$,MW5a9k QoS $K=>$C$F!"%Q%1%C%H$NE>Aw$r@)8f$9$k5!9=!#

- ;q8;M=Ls5!9=

  3F%k!<%?K*$$$F%U%m!<$N;q8;M=Ls$KBP9k@UG$$rIi$$!"%]%j%7%3%s%H%m!<%k$c
  $1F~$l@)8f5!9=JIXNLd$$9go;$r9T$&5!9=!#%U%m!<$,N.$l$kA0$KAw?.<T!"$b
  $/$O<u?.<T<gF3$G!"7PO)>e$N6a@\%k!<%?K"$k;q8;M=Ls5!9=$H QoS >pJs$r8_$$$
  8r49$7$F$$$-!"7PO)$N%;%C%H%"%C%W$r9TJ&!#3lKh$j%U%m!<$N7PO)>e$NA4$F
  %k!<%?$G;q8;M=Ls$,9Tol!"J]>Z7?%5!<%S%9$rDs6!$9k3H,2DG=HJ$k!#
  ;q8;M=Ls5!9=GO **RSVP(Resource ReSerVation Protocol)**[4] $,BeI=E*$J%W
  %m%H%3%kG"$j!"4{$K<BAuCJ3,$r=*$(!"8=:_$O<BMQ<B83$,9Tol$F$$$k!#

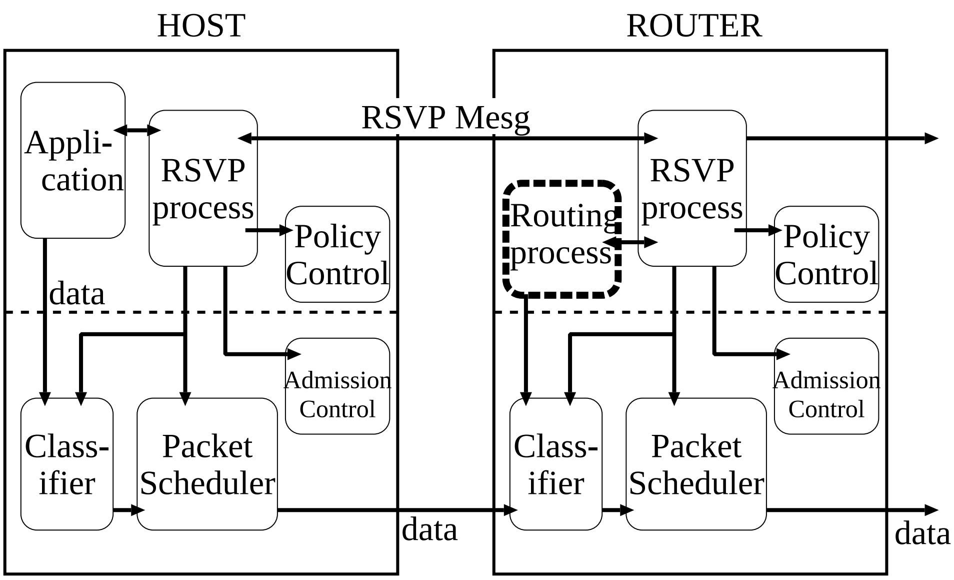
- J]>Z7?%5!<%S%9$KBP1~$7$?7PO)@)8f5!9=

  4{$K=R$Y$?$h$&$KJ]>Z7?%5!<%S%9GO%U%m!<$r8D!9$K07$&$?$a!"7PO)@)8f5!9=$K
  %U%m!<Kh$N>uBV$rJ];}G-k3H,MW5a5l$k!#>\$7$/$O 3.4@a$G=R$Y$k!#

RSVP rNcKHj!">e5-$N5!9=$N4XO"?^$r?^ 3.1$K<($9!#

3.4 J]>Z7?%5!<%S%9$KBP1~$7$?7PO)@)8f5!9=

:GA1EXNO7?%5!<%S%9$r4pHW$H9k=>Mh$N7PO)@)8f%W%m%H%3%k$G$O!"7PO)@)8fI=$KEE
9k>pJs$rA*Br$9$k4p=`$H7F:GC;7PO)$H$$$&9M$($rMQ$$$F$$$?!#7+$7@h$K=RY
$&$KJ]>Z7?%5!<%S%9GO%U%m!<$O8D!9$K07ol!"3F%U%m!<Kh$j QoS $OO[$J$j!"$=$l
$(:GE,$J7PO)$OMM!9$G$"$k!#$"$k%U%m!<$OCY1d$N>.$5$$7PO)$,:GE,$G$"$k$+$b7l$
$7!"JL$N%U%m!<$OBS0h$NBg$-$J7PO)$,:GE,$+b7lJ$$!#7?$,$C$F!"I,$:7b:GC
O)$,:GE,$J7PO)HOJi$:!":GA1EXNO7?%5!<%S%9$GMQ$$$ilF$$$k=>Mh$N7PO)@)8f%W
%H%3%kr=N^^MxMQ9k3HOG-$J$$!#



?^ 3.1: J]>Z7?%5!<%S%9$N<B8=$KI,MW$J5!9=

$^$?!"J]>Z7?%5!<%S%9$rMW5a$9$k3F%U%m!<Kh$K:GE,$J;q8;M=Ls$r9T$&$K$O!"3F2s@~
;q8;M=Ls>u67$d2s@~$NBS0hI}$N0c$$$r9MN8$7!"$=$N=V4V$N%M%C%H%o!<%/$N>u67$K1~$
:GE,$J7PO)$rA*Br9kI,MW$,$"$k!#

>e5-hj!"J]>Z7?%5!<%S%9GNDL?.$O=>Mh$NDL?.HO0[Jj!"$=$NDL?.$NMW5a$9$k Q
$=$7F=$N=V4V$N%M%C%H%o!<%/$N>u67$Khj:GE,$J7PO)$OB?MMG"k?$a!"7PO)@)8
9=b=lKBP1~7?7PO)A*Br$r9T$oJ1lPJi$J$$!#3Nh&$J7PO)@)8f5!9=$r **Q**
7PO)@)8f$H$$$&!#

QoS 7PO)@)8f$r<B8=$9kK$O%M%C%H%o!<%/Fb$N;q8;$NM=Ls>u67$d2s@~$N>uBV$r3F%k
%?$,GD0.$9kI,MW,$"$k$,!"$=N?aK$O7PO)@)8f%W%m%H%3%k$,%M%C%H%o!<%/;q8;$
BV$r>pJs$H7F07oJ1lPJiJ$$!#$^$?!"%M%C%H%o!<%/;q8;$,ITB-$7$:GE,$J7PO
A*Br$K<:GT$7$?>l9g$K$bBP1~$G$-$kh&$K!"<!A1$N7PO)(BeBX7PO))$N>pJs$bI,MWG"

5i$K!"4{B8$N7PO)@)8f5!9=GO7PO)A*Br$K=*E@%"%I%l%9$N$_$r;2>H7F$$$k$?$
07$&7PO)@)8f>pJs$b=*E@%"%I%l%9C10LG"k,!"=*E@%"%I%l%9$@$1GO%Q%1%C%H$,B
$F$$$k%U%m!<$r<1JL$G$-$J$$!#J]>Z7?%5!<%S%9$O%U%m!<Kh$KDs6!5lk?$a!"7PO)@
5!9=$b%U%m!<C10L$N>pJs$r07$oJ1lPJi$J$$!#

3Nh&$K!"J]>Z7?%5!<%S%9$r40A4$KDs6!$9k?aK$O4{B8$N7PO)@)8f5!9=GOI
J,G"$j!">e5-$N5!G=rHw($?7PO)@)8f5!9=$,I,MWHJk3H,o+$k!#

3.5 %U%m!<$r9MN8$7$?7PO)@)8fI=$NI,MW@-

J]>Z7?%5!<%S%9$rDs6!$9kK$O!"3.4@a$G=RY?h&$K4{B8$N7PO)@)8f5!9=HO0[$J 5!9=$,I,MWHJ$k!#

A0=R7?h&$KJ]>Z7?%5!<%S%9$G$O QoS $O%U%m!<Kh$K0[Jj!"$=$N<B8=KO%U%m $r8D!9$K07$&7PO)@)8f5!9=$,IT2D7gHJ$k!#%U%m!<$r8D!9$K07$&7PO)@)8f5!9=HO! %m!<$KBP1~$7$?7PO)@)8f%W%m%H%3%k$d!"%U%m!<Kh$K7PO)@)8f$G$-$kh&$J7PO)@)8fI Ir;X$9!#7+$7!"7PO)@)8f%W%m%H%3%k$,%U%m!<$KBP1~G-%U%m!<$r8D!9$K07$($?$ Fb!"7PO)@)8fI=$,%U%m!<$KBP1~7F$$$J1lP=b=$b%Q%1%C%H$r%U%m!<Kh$K7PO 8f$G$-$J$$!#D^$j!"%U%m!<Kh$K0[Jk7PO)$rA*Br$9k3H,G-$J$$!#<B:]!"8=: $($ilF$$$kJ]>Z7?%5!<%S%9GO4{B8$N7PO)@)8fI=$7$+MxMQ$G$-$J$$$?$a!"=*E@%"% %9$N$_$Khk7PO)@)8fNbHG%5!<%S%9$r9T$&$+!"7PO)@)8fI=$r;2>H7J$$;OE@7PO 8f$rMxMQ$9$k<jCJ$r<hi6kr$($J$$!#

0J>ehj!"J]>Z7?%5!<%S%9$KBP1~$7$?7PO)@)8f5!9=$r<B8=9kKO$^$:$=$N4pHW$ $k7PO)@)8fI=$r%U%m!<$KBP1~$5$;$k3H$,5^L3$G$"$k$H9M$($k!#$7$?$,CF!"K\8&5 $O%U%m!<$KBP1~7?7PO)@)8fI=$r9=C[$9k3HrL\E*H9$k!#

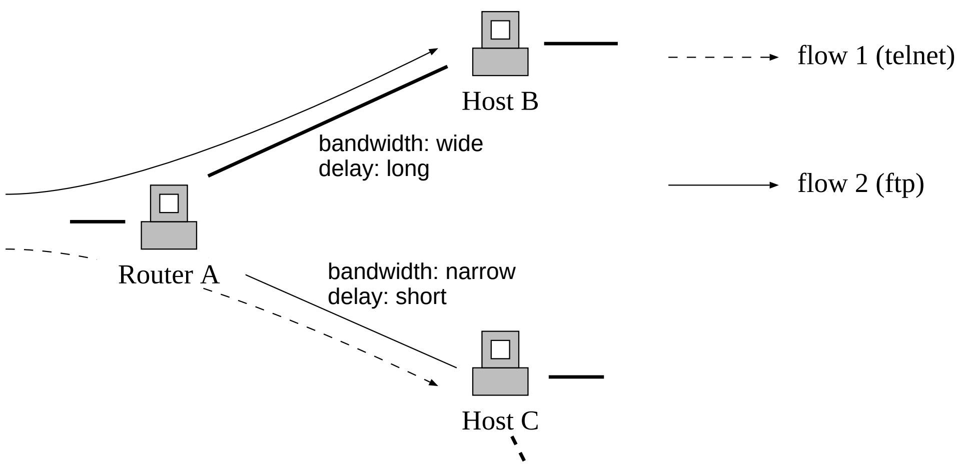
3.6 :GA1EXNO7?%5!<%S%9GNMxE@

A0=R7?h&$KK\8&5f$G$O!"J]>Z7?%5!<%S%9$N<B8=N?aK%U%m!<$r9MN8$7$?7PO) 8fI=$N<B8=$rL\E*$H9k!#7+$7K\8&5f$GDs0F9k5!9=$O!"J]>Z7?%5!<%S%9$N$_$G$:GA1EXNO7?%5!<%S%9K*$$$F$bHs>o$KM-8zG"$k!#

:GA1EXNO7?%5!<%S%9$N7PO)$K$*$$$F%Q%1%C%H$NB0$9$k%"%W%j%1!<%7%g%s$KhC$F7P $rA*Br$7$?$$>l9g$,$"$k!#Nc$($P!"BS0h$,Bg$-$$$,CY1dbBg-$$1R@17PM3$N2s@~$H! 0h$O>.$5$$$,CY1d$b>.$5$$@lMQ@~7PM3$N2s@~$,$"$k>l9g$r9M$($k (?^ 3.2;2>H)!#

0lHL$K!"ftp Nh$&$KCY1d$OB?>/Bg$-$/FbBS0h$,Bg$-$$2s@~$NJ}$,M-Mx$J%"%W%j%1 %7%g%s$O1R@17PM3$N2s@~ (A-B 4V) $r!"telnet Nh$&$K%f!<%6HNBPOC$r9T$&%"%W%j%1! %7%g%sGOBS0h$O>.5/$F9=oJ$$$,CY1d$O>.$5$/$J1lPJiJ$$$N$G@lMQ@~7PM 2s@~ (A-C 4V) $rA*Br$9k3H,K>$^$l$k!#$=3G!"K\8&5f$GDs0F$9$k5!9=$rMQ$$$k$3 Kh$j%U%m!<$r8D!9$K7PO)@)8fG-k?$a!">e5-Nh$&$J>l9g$K%"%W%j%1!<%7%g%sK 0[Jk7PO)$rA*Br9k3H$,2DG=$HJk!#

%$%s%?!<%M%C%H$NGzH/E*$J@.D9$Khj!"%M%C%H%o!<%/;HMQN($,9bF-$7B3$1$F$$$k>u $r9M$(kH!"3Nh&$K3F%"%W%j%1!<%7%g%s$NFC@-$K4p$E$-:GE,$J7PO)$rA*Br$9k $O:#8e$5iK=EMW;k5lF/kH;Wol$k!#$7$?$,CFK\8&5f$GDs0F$9$k5!9=$O!"J



?^ 3.2: %"%W%j%1!<%7%g%sKh$K0[$J$k7PO)A*Br

7?%5!<%S%9$K8B$i$::GA1EXNO7?%5!<%S%9$K$*$$$F$bHs>o$KM-MQG"$k!#

Bh **4** >O

%U%m!<$r9MN8$7$?7PO)@)8fI=$N@_7W

K\>OGO!"%U%m!<$r9MN8$7$?7PO)@)8f5!9=$N@_7W$r9T$&!#

4.1 K\8&5f$GDs0F$9$k7PO)@)8fI=$K$D$$$F

Bh 2>OGO4{B8$N7PO)@)8f5!9=$K$D$$$F=R$Y!"0J2<$NE@$r@bL@$7$?!#

- %$%s%?!<%M%C%H$OJ,;67?%M%C%H%o!<%/G"$j!"%$%s%?!<%M%C%H$K@\B3$7$F$$$k
  %M%C%H%o!<%/KhCF<+N'E*$K4IM}$5lF$$$k!#%$%s%?!<%M%C%H>e$G1s$/N%$l$?
  %9%H$X%Q%1%C%H$rAw?.9kKO!"B?$/$N%k!<%?$r7PM3$7$F%P%1%D%j%l!<$Nh&$K
  FAwjFO1k!#
- %$%s%?!<%M%C%H$G$O%[%C%W%P%$%[%C%W%k!<%F%#%s%0J}<0$r:NMQ$7F*$j!"4{B8$N
  O)@)8f5!9=GO%Q%1%C%H$rCf7Q$9$k3F%k!<%?$K$*$$$F!"%Q%1%C%H%X%C%@$NJ];}$7
  $$$k=*E@%"%I%l%9N_$r8!:w%-!<$H7F7PO)@)8fI=$r8!:w$7!"7hDj5l$?<!$NCf
  %k!<%?$X%Q%1%C%H$rAw?.9k;EAH$_$KJC$F$$$k!#
  3Nh&$K3F%k!<%?$G$O6I=jE*$J>pJs$K4p$E$$$F7PO)rDja$k!#

$^$?!"Bh 3>OGO!"0J2<$NE@$K$D$$$F3NG'7?!#

- 2;@<$dF02h$r<B;~4VDL?.H7$F%$%s%?!<%M%C%H>e$G<B8=$9kK$O:GA1EXNO7?%5!<
  %9GOIT==J,G"$j!"J]>Z7?%5!<%S%9$,IT2D7gHJ$k!#
- J]>Z7?%5!<%S%9$O%U%m!<Kh$KDs6!5lkY$-$G$"$j!"J]>Z7?%5!<%S%9$r40A4$KDs
  9kKO4{B8$N7PO)@)8f5!9=$G$OIT==J,$G$"$k!#$=$N$?$a%U%m!<$r8D!9$K07$($k
  O)@)8f%W%m%H%3%k$d7PO)@)8fI=$JI,I,MWH5lk!#

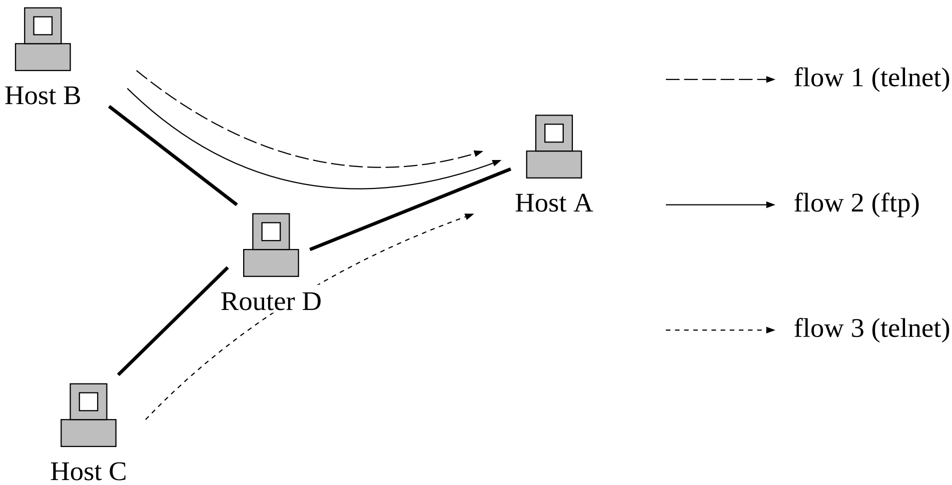
K\8&5fGO "%U%m!<$r9MN8$7$?7PO)@)8fI=" $KCeL\$7!"4{B8$N7PO)@)8fI=$Nh&$K
%1%C%H$N=*E@%"%I%l%9$+$i<!$NCf7Q%k!<%?$r7hDj$9kNGOJ/!"E>Aw9k%Q%1%C%
B0$9$k%U%m!<Kh$K%(%s%H%j$rJ];}$7!"%Q%1%C%H%X%C%@$NCf$+$i%U%m!<$r<1JL$9kCM
=P$7!"$=lK4p$E$$$F7PO)@)8f$r9T$&5!9=$rDs0F$9$k!#

4.2 K\8&5f$NL\E*$H@_7WJ}?K

K\8&5fGO!"%U%m!<$r9MN8$7$?7PO)@)8f5!9=$N<B8=N?aK "%U%m!<$r9MN8$7$?7P
@)8fI=" $N9=C[$rL\E*H9$k!#@_7W$O<!Nh$&$JJ}?K$G9T$&!#
$^$:K\8&5f$N@_7W$N3KHJ$k!"<u?.%Q%1%C%H$NB0$9$k%U%m!<$N<1JLJ}K!$K$D$$$F@
9k!#<!$KK\8&5f$GDs0F9k7PO)@)8fI=$N%+!<%M%kFb$XNAH_9~$_J}K!$K$D$$$F=R$Y

4.3 <u?.%Q%1%C%H$NB0$9$k%U%m!<$N<1JL

4{B8$N7PO)@)8f5!9=$G$O!"<u?.$7$?%Q%1%C%H$N%X%C%@$+$i=*E@%"%I%l%9$rCj=P$7!"
lr8!:w%-!<H7$F7PO)@)8fI=$r8!:w$7!"<!$NCf7Q%k!<%?$r7hDj$9k3$H!"$5iKJ
7?%5!<%S%9$r40A4$KDs6!9kKO4{B8$N7PO)@)8f5!9=$G$OIT==J,$@$H$$$&3H$O4{$
Y?!#3NM}M3$O!"4{B8$N7PO)@)8fI=GO%U%m!<Kh$N%(%s%H%j$rJ];}G-$J$$$?a
$k!#$9Jo$A=*E@%"%I%l%9$N$_$G$O%U%m!<$r<1JL9k3HOG$-$J$$!#$=$NNcH7$
?^ 4.1$r<($9!#?^ 4.1$r8+$lPo$+$kh&$K!"F1$8=*E@ (%[%9%H A) $K8~$+$&%Q%1%C%H$
$b!"%[%9%H B $+$iAw?.5l$?%Q%1%C%H$H%[%9%H C $+$iAw?.5l$?%Q%1%C%H$,B8:_9
$^$?!"F1$8%[%9%H B $+$iAw?.5l$?%Q%1%C%H$G$b!"telnet $N%Q%1%C%H$H ftp $N%Q%1%C%
$,B8:_$9$k!#



?^ 4.1: F1$808@h$X8~$+$&%Q%1%C%H$NB0$9$k%U%m!<

GO!"%Q%1%C%H$NB0$9$k%U%m!<$r<1JL9kKOI&9lPh$$$@m&$+!#$^$:?^ 4.1
$i<!$N 2 E@$,$o$+$k!#

- %U%m!<$r<1JL$9kK$O!"=*E@%"%I%l%95Z$S;OE@%"%I%l%9$,I,MW$G$"$k!#3N 2 $D
  CMKh$j!"$"$k;OE@%[%9%H$+i"$k=*E@%[%9%H$X$N%U%m!<$rFCDjG-$k!#
- F1$8=*E@%"%I%l%9!&;OE@%"%I%l%9$r;}$D%Q%1%C%HGb!"0[Jk%U%m!<$KB0$9$k2D
  @-$,$"$k!#Nc$($P?^ 4.1$G$O!"F1$8%[%9%H B $+$i%[%9%H A XN%U%m!<KO telnet $N
  %U%m!<$H ftp $N%U%m!<$,$"$k!#2>$KAPJ}$H$b telnet $N%U%m!<$G$"$C$?$H7Fb=$
  iO0[Jk%U%m!<H7$F<1JL2DG=$GJ1lPJi$J$$!#7?$,$C$F=*E@%"%I%l%

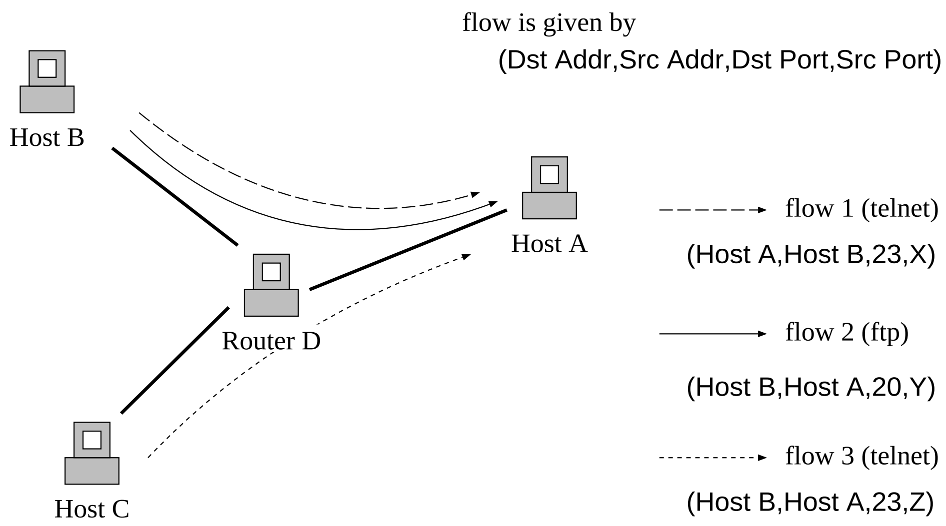
;OE@%"%I%l%9$H6&$K!"=*E@%[%9%H!&;OE@%[%9%H>e$G%U%m!<$NC<E@$rFCDj$9k3$H I,MW$HJk!#

F101%[%9%H>e$G0[$J$k%U%m!<$NC<E@$r<1JL$9k?aK!"TCP!&UDP $G;HMQ$5lF$$$ %]!<%HHV9f$rMQ$$$k!#=*E@%"%I%l%9!&;OE@%"%I%l%9$K2C$(!"=*E@%[%9%HB&$N%]!<%HHV 5Z$S;OE@%[%9%HB&$N%]!<%HHV9f$r;XDj9k3HKh$j!"$"$k0lO"$N%G!<%?$NN.$l!"$ oA%U%m!<$r<1JL$G$-$k!#

7?$,$C$F%U%m!<$r<1JL9kKO!"0J2<$N4 DN%Q%i%a!<%?$,I,MW$HJk!#

- =*E@%[%9%H$N IP %"%I%l%9 (Destination IP Address)
- ;OE@%[%9%H$N IP %"%I%l%9 (Source IP Address)
- =*E@%[%9%H>e$NC<E@$N%]!<%HHV9f (Destination Port Number)
- ;OE@%[%9%H>e$NC<E@$N%]!<%HHV9f (Source Port Number)

>e5-$K4p$E$$$F?^ 4.1$r=q$-D>7F$_$k$H!"?^ 4.2$Nh&KJ$k!#?^ 4.2$+ibo+$ h&$K!"$3$N4 DNCMKhCF%U%m!<$,40A4$K<1JLG-$k!#



?^ 4.2: 4 DN%Q%i%a!<%?Kh$k%U%m!<$N<1JL

4.4 %+!<%M%kFbXNAH$_9~$_J}K!

4.3@a$G!"%U%m!<$r<1JL9k$?$a$K<!$N4 DN%Q%i%a!<%?$,I,MW$G$"$k3H$r=R$Y$

- Destination IP Address(0J2< Dst Addr)
- Source IP Address (0J2<!"Src Addr)
- Destination Port Number (0J2<!"Dst Port)
- Source Port Number (0J2<!"Src Port)

7PO)@)8fI=$O!"$3$N4$D$N%Q%i%a!<%?$KhCFDj^$k8D!9$N%U%m!<Kh$N%(%s%H%j$r ;}$7!"$3$N4$D$N%Q%i%a!<%?$r8!:w%-!<H7$F8!:w$r9T$$$E,@Z$J<!$NCf7Q%k!<%?$rJ 9=B$$r;}$?$MPJiJ$$!#$3$3$G!"%U%m!<$r9MN8$7$?7PO)@)8fI=NNcrI=4.1$K<($9! 4.1$+$ibo$+$kDL$j!"3F%Q%i%a!<%?A4$FKBP7FCM,;XDj5l$F$$$k%(%s%H%j(No.1)$ 1GOJ$/!"Dst Addr!"Src Addr $=$l$>$lKBP7$F%M%C%H%o!<%/7PO)$r8DJL$K;XDj$9 $k%(%s%H%j(No.3!"No.7!"No.8)bI,MWG$"$k$7!"$^$?!"$"$k%Q%i%a!<%?$@1OG$0U$NCN (*)$r;XDj$9$k%(%s%H%j(No.2!ANo.8)$bI,MWG"$k!#$5iK$O!"%G%U%)%k%H7PO)(No.9) $bM?$(ilkh$&$K7J1lPJiJ$$!#

0J>ehj!"%U%m!<$r9MN8$7$?7PO)@)8fI=$KEPO?5l$k%(%s%H%j$O0J2<$N>r7o$rK~$?$

- Dst Addr!"Src Addr %Q%i%a!<%?$O%"%I%l%9!"%M%C%H%^%9%/6&$K4{B8$N7PO)@)8fI= $N%(%s%H%j$HF1EyJCMrHj!"G$0U$N4%P%$%H?t$G$"$k!#
- Dst Port!"Src Port %Q%i%a!<%?OG0U$N2%P%$%H?tG"$k!#

>e5-$N>r7o$rK~$?$9%(%s%H%j$rJ];}$9$k7PO)@)8fI=$N<BAuKO!"4{B8$N7PO)@)8fI=$ $K9=C[$9k+!"$^$?$O?7$?$J5!9=$r9=C[9k$H$$$C$?MM!9$JJ}K!$,9M$(ilk,!"K 5fGO4{B8$N7PO)@)8fI=$N<BAuJ}K!G"$k Radix Tree $NFCD'$KCeL\$9$k!#Radix Tree $N FCD'$H7F0J2<$NE@$,5s2ilk3H$OBh2>O$G=RY?!#

- 2DJQD9%"%I%l%9XNBP1~
- ITO"B3%M%C%H%^%9%/XNBP1~

K\8&5fGO>e5-$N Radix Tree 5!9=$NFCD'Kh$j!"I=4.1$NMM!9$J%(%s%H%j$rJ];}9k 7PO)@)8fI=$r4{B8$N Radix Tree 5!9=$K<j$r2C$($k3HJ/9=C[9k!#

4.4.1 Radix Tree XNE,MQ

K\9`GO!"Dst Addr!"Src Addr!"Dst Port!"Src Port $r1AH$K7F1DN%(%s%H%j$H 7FJ];}9k7PO)@)8fI=$r!"4{B8$N Radix Tree 5!9=KO<j$r2C$($:$K<B8=9kJ}K!K $$$F@bL@9k!#

I= 4.1: %U%m!<$r9MN8$7$?7PO)@)8fI=$N%(%s%H%j

No.	7PO)@)8fI=$N%(%s%H%j				%(%s%H%j$N<oN`
	Dst Addr	Src Addr	Dst Port	Src Port	
1	131.113.82.93	131.113.82.89	22	1023	$"$kFCDj$N%U%m!<
2	131.113.82.93	131.113.82.89	*	*	%[%9%H$+$i%[%9%HXNG$0U $N%U%m!<
3	131.113.82/24	131.113.82.89	*	*	%[%9%H$+$i%M%C%H%o!<%/$X G$0U$N%U%m!<
4	131.113.82.93	131.113.82.89	23	*	%[%9%H$+$i%[%9%HXN telnet $N%U%m!<
5	131.113.82.93	*	*	*	$"$k=*E@XNG$0U$N%U%m!< (4{B8$N7PO)@)8fI=$HF1$8%(%s%H%j)
6	131.113.82.93	*	23	*	$"$k=*E@XN telnet $N%U%m!<
7	131.113.82/24	131.113.32/24	*	*	%M%C%H%o!<%/$+$i%M%C%H%o!<%/XNG$0U$N%U%m!<
8	131.113.82/24	131.113.32/24	23	*	%M%C%H%o!<%/$+$i%M%C%H%o!<%/XN telnet $N%U%m!<
9	*	*	*	*	%G%U%)%k%H7PO)

2DJQD9%"%I%l%9XNBP1~

Radix Tree $N=EMW$JFCD′G"$k “2DJQD9%"%I%l%9$X$NBP1~” $rMxMQ$9$k!#Radix Tree 5!
9=$O7PO)@)8fI=$r8!:w9k%-!<H7$F!"32%S%C%H$N8GDjD9G"$k IP %"%I%l%9$ObAm
OSI %W%m%H%3%kNh$&$J2DJQD9%"%I%l%9BN7OKbBP1~7F$$$k!#$=$3$G!"Dst Addr(32
bit)!"Src Addr(32 bit)!"Dst Port(16 bit)!"Src Port(16 bit) rJBY$F 96 %S%C%H$N 1 DN
%S%C%HNs$H9M$(!"3l$r Radix Tree 5!9=$K$*$$$F 1 DN%"%I%l%9H7$FMQ$$$k!#96 %S%
%H$O!"Radix Tree $NBP1~$7$F$$$k2DJQD9%"%I%l%9$N%"%I%l%9D9$NHO0OFbG"$k!#

ITO"B3%M%C%H%^%9%/XNBP1~

K\8&5f$G9M$($k5!9=$G$O!"Dst Addr!"Src Addr KBP7$F8D!9$K%M%C%H%^%9%/$KBP1~$7
J1lPJi$J$$!#

A0=R7?%U%m!<rDja$k 4 DN%Q%i%a!<%?rJBY$F 1 DN 96 %S%C%H$N%"%I%l%9$H$
$kJ}K!$HF1MM$K!"%M%C%H%^%9%/$rJBYF 1 DN%M%C%H%^%9%/H7$F07$&>l9gKO!"%
%H%^%9%/$,ITO"B3$KJk2DG=@-$,$"$k!#

$3$3$G Radix Tree 5!9=$Nb& 1 DNFCD′G"$k “ITO"B3%M%C%H%^%9%/$X$NBP1~” $,M-
8zKJ$k!#$3lKhj!"Dst Addr!"Src Addr Hb$K2DJQD9$N%M%C%H%^%9%/$r;}$D3H$,
2DG=KJ$j!":GD90lCW$,K~B-G-$k!#Dst Port!"Src Port $OA4$F 1 $N%M%C%H%^%9%/$rJ]
;}9k3HH9$k!#

$^$?!"$"$k%Q%i%a!<%?$,G$0UNCMr<h$k>l9g$K$b!"%M%C%H%^%9%/$r 0 H9k3HG
1~G-$k!#I= 4.1$N7PO)@)8fI=$N%(%s%H%j$r!"96 %S%C%H$N%"%I%l%9$H 96 %S%C%H$N%M%C%
%^%9%/H7$F Radix Tree 5!9=$rMxMQ7?>l9g$NI=8=$rI= 4.2$K<($9!#

0J>ehj!"@h$K=R$Y$?$h$&$K Dst Addr!"Src Addr!"Dst Port!"Src Port $r 1 DN%S%C
%HNs$H9M$(!"F1;~K=l>lN%M%C%H%^%9%/$b0lNs$KJBYF 1 DN%S%C%HNs$N%M%C%H
%9%/$H9M$(Fb!"Radix Tree $NITO"B3%M%C%H%^%9%/$X$NBP1~$Khj@5$7$/F0:n9k3
$,$o$+$k!#

4.4.2 %U%m!<$r<1JL$9$k3F%Q%i%a!<%?$NM%@h=g0L

Radix Tree O=$N9=B$>e!"@hK"kCM[$IM%@h$5lk!#Nc$($P$"$k%k!<%?$, (Dst Addr,
Src Addr, Dst Port, Src Port) $N=g=x$r:NMQ7F$*$j!"7PO)@)8fI=$,I= 4.2$G$"$kH9
$k!#$3$3$G (Dst Addr, Src Addr, Dst Port, Src Port) = (131.113.82.93, 131.113.82.89,
23, 1023) $G<1JL$5lk%U%m!<$KB0$9$k%Q%1%C%H$r<u?.7?H9kH!"I= 4.2NCfG8!:
$K%^%C%A$9$k2DG=@-$,$"$k%(%s%H%j$O!"No.2!"No.3!"No.4!"No.5!"No.6!"No.9 $N 6 DG

I= 4.2: 96 %S%C%H$N%"%I%l%9 (>eCJ) $H 96 %S%C%H$N%M%C%H%^%9%/ (2<CJ) KhCFI=8=$5 lk%U%m!<$r9MN8$7$?7PO)@)8fI=

No.	7PO)@)8fI=$N%(%s%H%j			
	Dst Addr	Src Addr	Dst Port	Src Port
1	131.113.82.93 0xffffffff	131.113.82.89 0xffffffff	22 0xffff	1023 0xffff
2	131.113.82.93 0xffffffff	131.113.82.89 0xffffffff	0 0x0000	0 0x0000
3	131.113.82.0 0xffffff00	131.113.82.89 0xffffffff	0 0x0000	0 0x0000
4	131.113.82.93 0xffffffff	131.113.82.89 0xffffffff	23 0xffff	0 0x0000
5	131.113.82.93 0xffffffff	0.0.0.0 0x00000000	0 0x0000	0 0x0000
6	131.113.82.93 0xffffffff	0.0.0.0 0x00000000	23 0xffff	0 0x0000
7	131.113.82.0 0xffffff00	131.113.32.0 0xffffff00	0 0x0000	0 0x0000
8	131.113.82.0 0xffffff00	131.113.32.0 0xffffff00	23 0xffff	0 0x0000
9	0.0.0.0 0x00000000	0.0.0.0 0x00000000	0 0x0000	0 0x0000

$"$k!#

@hK"$k%Q%i%a!<%?$NJ}$rM%@h$9kH$$$& Radix Tree $N5!9=$+$i!"Dst Addr $+$i%^%C %A$,9T$olk!#%M%C%H%^%9%/$N:GD90lCW$N86B'$+$i!"No.3 $H No.9 $N%(%s%H%j$,BP>]$+$ 30$5$l$k!#Src Addr GbF1MM$K No.5!"No.6 $,BP>]30$HJk!#5i$K Dst Port GO No.2 $N%(%s%H%j$O%M%C%H%^%9%/$,L5$/!"No.4 $N%(%s%H%j$O%M%C%H%^%9%/$,B8:_$9k?$a!" $N%Q%1%C%H$N8!:wKO No.4 $N%(%s%H%j$,:G=*E*$K%^%C%A$9kNG"$k!#

K\8&5f$GDs0F$9$k7PO)@)8fI=$N8!:wJ}<0$r0lHL2=$7!"0J2<$K<($9!#

1. 7PO)@)8fI=$NA4%(%s%H%j$r 96 %S%C%H$N8!:w%-!<$HHf3S$7!"1 %S%C%HL\$+iEy7$ %S%C%H$,:G$bD9$/B3$/%(%s%H%j$r8uJd$H9k!#
2. 1 $G8uJd$K5s$,$C$?%(%s%H%j$N%M%C%H%^%9%/$H8!:w%-!<$NO@M}@QrH$j!"$=l, %s%H%j$N%"%I%l%9$HEy$7$1lP!"$=$N%"%I%l%9$,%^%C%A$78!:w7k2LH7FJV5l
3. 2 GNHf3S$K<:GT$7$?>l9g$O 1 KLaj!"0JA0$K8uJd$K5s$,$C$?%(%s%H%j$r=|$$$F $S8!:w$r9T$&!#

3Nh&$K Radix Tree 5!9=$NMxMQKh$k%U%m!<$r9MN8$7$?7PO)@)8fI=GO!"@hK"$k% %i%a!<%?$[$IM%@h$5$l!"$+$D!"3F%Q%i%a!<%?$NCfGO:GD90lCWKh$j%M%C%H%^%9%/$ $bD9$$$bN,A*Br5l$k!#

M%@h=g0L$N1F6A

Radix Tree 5!9=Kh$k%U%m!<$r9MN8$7$?7PO)@)8fI=GO!"7PO)@)8fI=$K3JG<$9$k 4 $D $N%Q%i%a!<%?$N=g=xrI$&$9k+!"D^$j!"%U%m!<$r9MN8$7$?7PO)@)8f5!9=$r9=C[$ K"$?$j Dst Addr!"Src Addr!"Dst Port!"Src Port $N 4 DN%Q%i%a!<%?$NM%@h=g0LrI Nh$&$KD1kN$,:G$bE,Ev$+$H$$$&LdBj$,$"$k!#7PO)@)8fI=$OF1$8$G$b!"4 DN%Q %a!<%?$N=g=xKhCF%^%C%A9k%(%s%H%j$,0[Jk$?$a!"4 DN%Q%i%a!<%?$N=g=x$N Br$O=EMW$JLdBjG"$k!#0J2<GO!"Dst Addr!"Src Addr!"Dst Port!"Src Port $=$l$>$l $N%Q%i%a!<%?$K$D$$$F9M$($Ff/!#

$^$:!"7PO)@)8f5!9=$O=*E@%"%I%l%9$,L5$1$l$P7PO)@)8f$,@.$jN)$?J/!"Dst Addr $ 0lHVM%@h=g0L$,9b$$$3HO<+L@G"$k!#$^$?!"Src Port $O;OE@%[%9%H>e$NC<E@$N<1JL; G"$j!"%&%'%k%N%&%s%]!<%H$Nh&$K%"%W%j%1!<%7%g%s$K6&DLJCMGOJ$$$?$a!"B>$ $+$J$k%Q%i%a!<%?$hjbM%@h=g0L$ODc$$!#hC$F!"96 %S%C%H%"%I%l%9$K$*$$$F Dst Add $,@hF,!"Src Port $,:G8eHx$HJk!#

I= 4.3: Src Addr $H Dst Port $N=g=x$,LdBjHJ$k%(%s%H%j

No.	7PO)@)8fI=$N%(%s%H%j			
	Dst Addr	Src Addr	Dst Port	Src Port
1	131.113.82.93	131.113.82.89	*	*
2	131.113.82.93	*	23	*

LdBj$O!"Src Addr $H Dst Port $N=g=x$G$"$k!#3N 2 DNCM$N=g=x$,4XoCF/kN $O!"Nc$($PI= 4.3$Nh&$J 2 DN%(%s%H%j$,7PO)@)8fI=$K4^$^lF$$$k>l9gG"$k!#

I= 4.3Nh$&$J%(%s%H%j$r4^$`7PO)@)8fI=$rJ];}$7$F$$$k%k!<%?$,!"(Dst Addr, Src Addr, Dst Port, Src Port) = (131.113.82.93, 131.113.82.89, 23, 1023) KhCF<1JL5l $k%U%m!<$KB0$9$k%Q%1%C%H$r<u?.$7$?$H9k!#3N>l9g!"7PO)@)8fI=$N%(%s%H%j$K$ $k 4 DN%Q%i%a!<%?$N=g=x$,!"(Dst Addr, Src Addr, Dst Port, Src Port) $N=g$G$"$l$P No.1 $N%(%s%H%j$,!"5U$K (Dst Addr, Dst Port, Src Addr, Src Port) $N=g$G$"$l$P No.2 $N%(%s%H%j$,%R%C%H9k!#

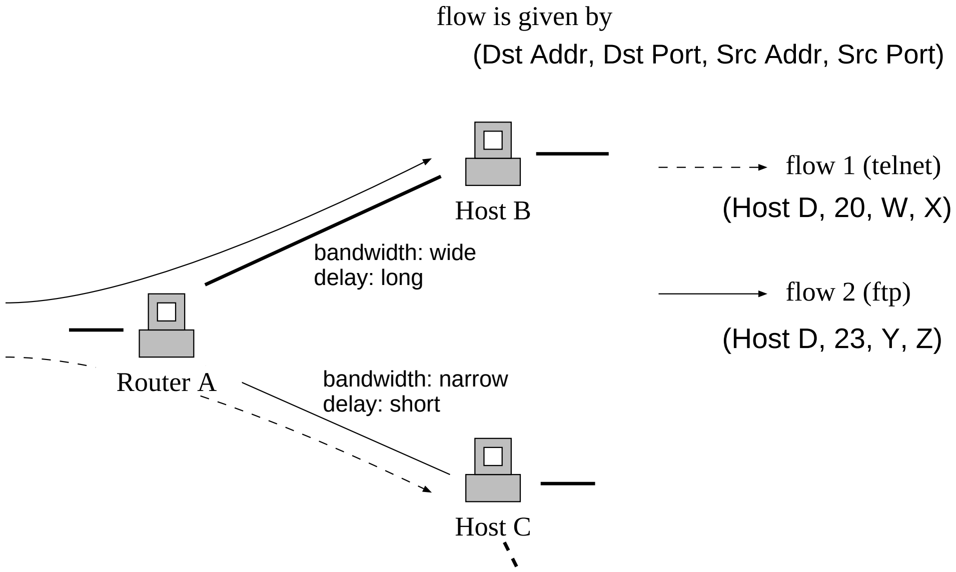
Src Addr $H **Dst Port** $NM%@h=g0L

(Dst Addr, Src Addr, Dst Port, Src Port) $N=g=x$H!"(Dst Addr, Dst Port, Src Addr, Src Port) $N=g=x$NHAi,E,@Z$+$rH=CG9k$?$a$K!"I= 4.3$N 2 DN%(%s%H%jN&$A! IAiN%(%s%H%j$,hj=EMW$+$r9M$(F_$k!#

I= 4.3$N No.1 $N%(%s%H%j$OINh&$J>l9g$KI,MWG"m&$+!#Dst Addr $H Src Addr $r;XDj$7$F Dst Port!"Src Port $, 0 $H$$$&3H$O!"$"$k;OE@%[%9%H (%M%C%H%o!<%/) $+ $i=*E@%[%9%H (%M%C%H%o!<%/) XN%U%m!<N_$rFCDj$7$F$$$F!"$=$NC<E@%[%9%H>e$N%' %j%1!<%7%g%s$OG$0U$G$"$k!#3N%(%s%H%jO"$k 1 DN%U%m!<GOJ/!"$"$k%[%9%H4 $^$?O"$k%M%C%H%o!<%/4V$NG$0U$N%U%m!<KBP9$k;q8;M=Ls$r9T$&:]$KI,MWHJ$k! >Z7?%5!<%S%9$KhC$FJ]>Z$5lkNO%U%m!<C10LG"k,!"FCDj$N%U%m!<$KBP9kJ $@$1GOJ/!"$"$k%[%9%H4V!"%M%C%H%o!<%/4VGN$"$ifkDL?.KBP7FNJ]>Z$,K lk>l9g$,$"$k!#Nc$($P%$%s%?!<%M%C%H$K@\B3$7$F$$$k$"$kAH?%4V$N2s@~$K$*$$$F! $NAH?%4V$NDL?.$@$1O"$kDxEY$NBS0h$rJ]>Z$7$?$$>l9g$,$"$j!"$=$N:]%$%s%?!<%M% %"%I%l%9$,AH?%Kh$K3djEvFil$F$$$k3H$rMxMQ$7!">e5-$N%M%C%H%o!<%/4V;q8;M $rMxMQ$9$k!#

$^$? No.2 $N%(%s%H%j$O!"Dst Addr!"Dst Port $,;XDj$5$l!"Src Addr!"SrcPort $, 0 $G $"$k!#3l$OBh 3>O$G=RY?h&$K!"J]>Z7?%5!<%S%9$N$?$a$N%(%s%H%j$H$$$&hj$

$m:GA1EXNO7?%5!<%S%9$N7PO)K*$$$F%Q%1%C%H$NB0$9$k%"%W%j%1!<%7%g%s$KhC$F7
$rA*Br$7$?$$>l9g$KMQ$$$ilk!#(?^ 4.3;2>H)!#



Router A's Routing Table:

Dst Addr	Dst Port	Src Addr	Src Port	Next Hop
D	20	*	*	B
D	23	*	*	C

?^ 4.3: %U%m!<$r9MN8$7$?7PO)@)8fI=$N:GA1EXNO7?%5!<%S%9K*1kMxE@

4 DN%Q%i%a!<%?$N:GE,$J=g=x

K\8&5fGO!"J]>Z7?%5!<%S%9$r40A4$KDs6!9k$?$a$KJ]>Z7?%5!<%S%9$KBP1~7?7
@)8f5!9=$N<B8=$r9M$(!"$=NCfG$b%U%m!<$r9MN8$7$?7PO)@)8fI=$N9=C[$rL\E*H9
L\E*O"$/$^$GJ]>Z7?%5!<%S%9$N$?$a$N5!9=$G$"$kNG!":GA1EXNO7?%5!<%S%9K*$
%"%W%j%1!<%7%g%sKh$K0[$J$k7PO)$rA*Br9k;~$KM-MQ$J>l9ghj$b!"J]>Z7?%5!<%S%
$*$$$F%[%9%H4V!"%M%C%H%o!<%/4V;q8;M=Ls$KM-MQ$G$"$k>l9g$NJ}$,hj=EMW$H9M$($

7?$,$C$F!"4 DN%Q%i%a!<%?$N=g=x$O (Dst Addr, Src Addr, Dst Port, Src Port) $N
=g$,:G$bE,@ZG"kH9M$(!"K\@_7W$Gb3$N=g=x$r:NMQ9k!#

4.5 K\@_7WN^Ha

K\>OGO!"%U%m!<$r9MN8$7$?7PO)@)8fI=$r9=C[9k$?$a$K0J2<$N@_7W$r9T$C$?!#

- %U%m!<$r<1JL$9kCMH7F!"0J2<$N 4 DNCM$rMQ$$$k!#3N 4 DNCM$,0l0U$KDj$ k3HKhC$F!"1 DN%U%m!<$rFCDjG-$k!#
  - =*E@%[%9%H$N IP %"%I%l%9 (Dst Addr)
  - ;OE@%[%9%H$N IP %"%I%l%9 (Src Addr)
  - =*E@%[%9%H>e$NC<E@$N%]!<%HHV9f (Dst Port)
  - ;OE@%[%9%H>e$NC<E@$N%]!<%HHV9f (Src Port)
- Radix Tree $N0J2<$NFCD'$rMQ$$$F!"4{B8$N Radix Tree 5!9=$K<j$r2C$(k3HJ$/!" %U%m!<$r9MN8$7$?7PO)@)8fI=$r9=C[$9$k!#
  - 2DJQD9%"%I%l%9XNBP1~
  - ITO"B3%M%C%H%^%9%/XNBP1~
- Dst Addr!"Src Addr!"Dst Port!"Src Port rJBY$F 1 DN 96 %S%C%H$N%"%I%l%9!" %M%C%H%^%9%/$H7F Radix Tree $rMxMQ$9$k!#
- Radix Tree $O9=B$>e!"@hK"$k%Q%i%a!<%?$[$IM%@h=g0L$,9b$/$Jk,!"K\8&5f$N L\E*$OJ]>Z7?%5!<%S%9$KBP1~$7$?7PO)@)8f5!9=$G$"$k$?$a!"(Dst Addr, Src Addr, Dst Port, Src Port) $N=g=x$,:GE,G"$k!#

Bh **5** >O

%U%m!<$r9MN8$7$?7PO)@)8fI=$N<BAu

K\>OGO!"%U%m!<$r9MN8$7$?7PO)@)8f5!9=$N<BAuJ}K!KD$$$F@bL@9k!#K\8&5f$G
<BAu$O FreeBSD 2.2.1-RELEASE >e$G!"4{B8$N%$%s%?!<%M%C%H%W%m%H%3%k$G$"$k IPv4 $K
BP7F9TC?!#

5.1 %"%I%l%99=B$BN

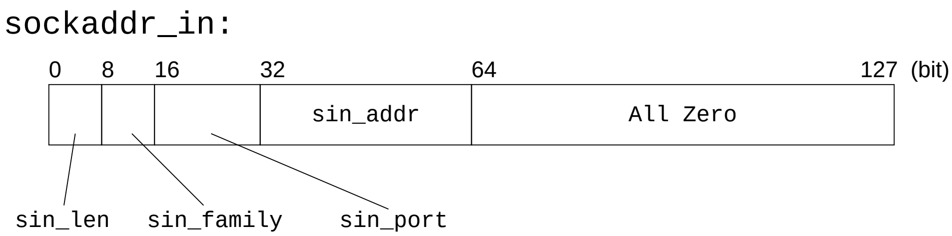
K\@aGO!"K\<BAu$G Radix Tree 5!9=$,07$&%"%I%l%99=B$BN$r<($9!#

5.1.1 %"%I%l%99=BBNN%G!<%?9=B$

4{B8$N7PO)@)8f5!9=$G$O!"Radix Tree $N%"%I%l%99=B$BNH7$F **sockaddr_in** 9=B$BN$r
MQ$$$F$$$k!#?^ 5.1$K **sockaddr_in** 9=B$BN$N%3!<%I$r!"?^ 5.2$K **sockaddr_in** 9=B$BN$N
?^$r<($9!#**sockaddr_in** 9=BBNG$O!"Dst Port H7$F **sin_port** $,%a%s%P$K4^$^$l$F$$
k,!"<B:]$N7PO)@)8f$KO3$N%a%s%P$O;HMQ5l$J$$!#

```
struct sockaddr_in {
    u_char    sin_len;            /* sizeof (struct sockaddr_in) = 16 */
    u_char    sin_family;         /* AF_INET */
    u_short   sin_port;           /* unused */
    struct    in_addr sin_addr;   /* 16-bit Destination Address */
    char      sin_zero[8];        /* All Zero */
};
```

?^ 5.1: **sockaddr_in** 9=B$BN (%3!<%I)



?^ 5.2: **sockaddr_in** 9=B$BN (?^)

Bh 4>O$G@_7W$7$?$h$&$K!"K\8&5f$NDs0F$9$k5!9=$G$O%"%I%l%99=B$BN$K0J2<$N 4 $D
%Q%i%a!<%?$r4^$`!#

- Destination Address (32 bit)

- Source Address (32 bit)
- Destination Port Number (16 bit)
- Source Port Number (16 bit)

?^ 5.1$H?^ 5.2$h$j!"**sockaddr_in** 9=B$BNKO>e5-$N 4 DN%Q%i%a!<%?N&$A Dst Addr $H Dst Port $O4^$^lF$*$j!"$+$D!"**sin_zero** $NNN0h$K Src Addr $H Src Port $rJ];}$9$k 3H$,2DG=G"kHo+$k!#D^$j!"4{B8$N **sockaddr_in** 9=BBNHF1$8Bg$-5N9=B$B $G:Q$`!#

5i$KBh 4>O$G=RY?h&$K!"4 DN%Q%i%a!<%?$N=g=x$O Dst Addr!"Src Addr!"Dst Port!"Src Port $N=g$,K>$^$7$/!"$=N?aK **sin_addr**(Dst Addr) $N0LCV$O$=$N$^$^K7 $F!"**sin_zero** $NNN0h$K Src Addr!"DstPort!"Src Port $r=g$K3JG<9k!#**sockaddr_in** 9= BBNG$N **sin_port** %a%s%P$N0LCV$O;HMQ$7$J$$!#

0J>e$NJ}?K$Khj!"K\<BAu$G%U%m!<$r07$&$?aK?7$?$KDj5A9k9=B$BN **sockaddr_fl** $rDj5A$9$k!#**sockaddr_fl** 9=B$BN$N%3!<%I$r?^ 5.3$K!"**sockaddr_fl** 9=B$BN$N?^$r?^ 5.4 $K<($9!#

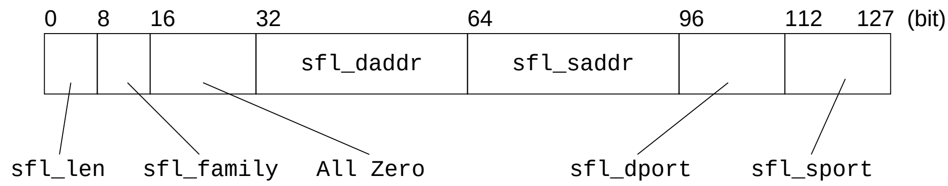
```
struct sockaddr_fl {
    u_char      sfl_len;        /* sizeof (struct sockaddr_fl) = 16 */
    u_char      sfl_family;     /* AF_INET */
    char        sfl_zero[2];    /* unused */
    struct fl_addr {
        struct in_addr  sfl_daddr,sfl_saddr;
                                         /* 32-bit src and dst addr */
        u_short  sfl_dport,sfl_sport;    /* 16-bit src and dst port */
    } sfl_addr;
};
```

?^ 5.3: **sockaddr_fl** 9=B$BN (%3!<%I)

?^ 5.2$H?^ 5.4$+ibo+kDLj!"**sockaddr_in** $H **sockaddr_fl** $O Dst Addr $N%a%s%P $,6&DL$KJj!"**sockaddr_in** 9=BBNO **sockaddr_fl** 9=BBNK%-%c%9%H9k3HKhCF F)2aE*$K07$&3H$,2DG=$G$"$k!#

0J>er^HakH<!Nh$&$KJk!#

- K\<BAuGO%U%m!<$r9MN8$7$?%"%I%l%99=B$BNH7$F!"4{B8$N7PO)@)8f5!9=$G;HMQ$ $$$k **sockaddr_in** 9=BBNrMxMQ2DG=G"$j!"$=$N7k2L$G$-$?9=BBNr **sockaddr_fl** sockaddr_fl:



?^ 5.4: **sockaddr_fl** 9=B$BN (?^)

$HL>IU$1$k!#

- **sockaddr_in** 9=BBNr8z2LE*$KMxMQ$9k3HKhj!"%U%m!<$r<1JL$9$k 4 DNCM $N:GE,$J=g=x!"Dst Addr!"Src Addr!"Dst Port!"Src Port $N=g$KJBYk3H$,$G $-$k!#
- **sockaddr_in** 9=BBNH **sockaddr_fl** 9=BBNN Dst Addr $N0LCV$OEy7/!"%-%c%9%H 9k3HKhCFF)2aE*$K07$&3H$,$G$-$k!#

5.1.2 %M%C%H%^%9%/$N;XDj

%M%C%H%^%9%/$N<h$j07$$$K$*$$$F!"4{B8$N<BAu$HK\<BAuGOBg$-$/0[Jk!#Radix Tr 5!9=GO!"%M%C%H%^%9%/$,;XDj$5lJ$$>l9g$O%M%C%H%^%9%/$OA4$F 1 $HF1$807$$$r$ $k!#$D$^$j!"%[%9%H7PO)$HG'<1$5lkNG$"$k!#

K\<BAuK*$$$F%[%9%H7PO)HO!"Bh 4>O$NI= 4.2$K$*$1$k No.1 $N%(%s%H%j!"(Dst Addr, Src Addr, Dst Port, Src Port) = (131.113.82.93, 131.113.82.89, 22, 1023) Nh$&$K!"Dst Addr!"Src Addr $,$=l>$l%[%9%H$r;XDj7F$$$F!"Dst Port!"Src Port $,$HbKM?$($i lF$$$k>l9g$r8@$&!#3N>l9gKN$_!"%M%C%H%^%9%/$,A4$F 1 KJ$k!#%G%U%)%k%H7 $OB>$NA4FN%(%s%H%j$,8!:w$K%^%C%A7J$+$C$?>l9g$KN_:NMQ5lkbNG$"$j! B8$N5!9=$HF1MM$K!"Dst Addr!"Src Addr!"Dst Port!"Src Port A4$F 0 $N>l9g$G$"$k!#

K\<BAuK*$$$F$b!"%[%9%H7PO)!"%G%U%)%k%H7PO)$N%(%s%H%j0J30$OA4$F%M%C%H%o!< 7PO)$HJk!#$=$N$?$a!"4{B8$N7PO)@)8f5!9=$N%[%9%H7PO)$KBP1~$9$k%(%s%H%j (Nc:B >O I= 4.1$N No.5 $N%(%s%H%j) $bK\<BAu$G$O%M%C%H%o!<%/7PO)$HJj!"%M%C%H%^%9%/$rJ ;}$9k3HKCm0U7J1lPJiJ$$!#7?$,$C$F!"4{B8$N7PO)@)8fI=KHfY$F%M% %o!<%/7PO)$,A}Bg$7!"$=lKH<$$%M%C%H%^%9%/$rJ];}$9$k%(%s%H%j$,A}2C9k3H$ A[5l$k!#

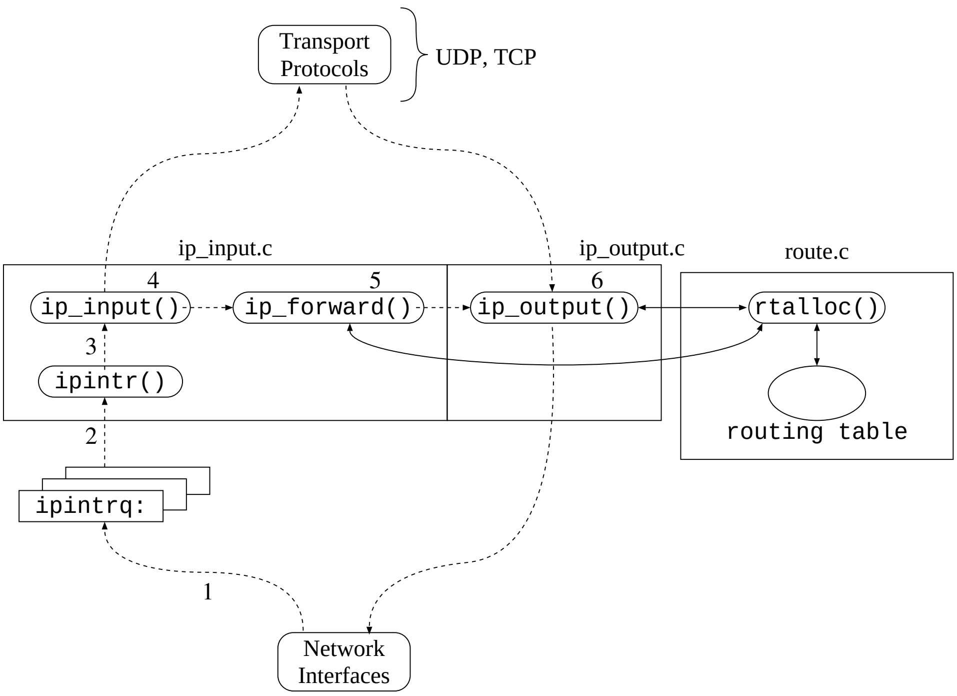
5.2 K\<BAuN?aN4{B8$N5!9=$NJQ99E@

K\@aGO!"K\<BAu$r<B8=$9k?aN4{B8$N7PO)@)8f5!9=$NJQ99E@$r@bL@$9$k!#

5.2.1 7PO)@)8fI=$N8!:w%-!<

K\9`GO4{B8$N7PO)@)8f5!9=$K$*$$$F!"%k!<%?$,%Q%1%C%H$r<u?.$7!"%M%C%H%o!<%/ %s%?!<%U%'!<%9AX$K=hM}$,0\$k$^$GKI$N4X?t$,8FPl!"K\<BAuGOI3$rJQ99$9$ MW$,$"k+$r@bL@$9$k!#

?^ 5.5$K!"%k!<%?$,%Q%1%C%H$r<u?.$7%M%C%H%o!<%/%$%s%?!<%U%'!<%9AX$K=hM}$,0\$k GNMM;R$r<($9!#



?^ 5.5: %k!<%?>eGN<u?.%Q%1%C%H$N=hM}

?^ 5.5$r4p$K!"4{B8$N7PO)@)8f5!9=$G$N<u?.%Q%1%C%H$N=hM}$r=g$K@bL@9k!#

1. %M%C%H%o!<%/%$%s%?!<%U%'!<%9$O%Q%1%C%H$r<u?.$9kH **ipintrq** $K<u?.%Q%1%C %r%-%e!<%$%s%0$9$k!#

2. 3d$j9~$_Kh$j!"**ipintrq** Fb$N%Q%1%C%H$, **ipintr()** $K0z?t$H7FEO5l$k!#

3. **ipintr()** $+$i **ip_input()** $K=hM}$,0\$k!#

4. **ip_input()** K*$$$F!"<u?.%Q%1%C%H$,<+%k!<%?08$FNbN+!"E>Aw9Y$-$bN+$r
H=CG$7!"<+%k!<%?08$FJi>e0LAX$X!"E>Aw$9Y-Ji **ip_forward()** $X=hM}$r0\$9!

5. **ip_forward()** GOE>AwKI,MWJ=hM}$r9T$$!"$=$N:] **rtalloc()** KhCF7PO)@)8f
I=$N8!:w$r9T$&!#$=7FAw?.N?$a **ip_output()** $K=hM}$r0\$9!#

6. **ip_output()** GO!">e0LAX$+$i$NAw?.%Q%1%C%H$d **ip_forward** $+$i$NE>Aw%Q%1%C%H
$NAw?.=hM}$r9T$&!#Aw?.%Q%1%C%H$N%X%C%@$+$i=*E@%"%I%l%9$rCj=P$7!"$=$l$r8!
%-!<H7$F **rtalloc()** KhCF7PO)@)8fI=$N8!:w$r9T$&!#F@$il?<!$NCf7Q%k!<
%?$K%Q%1%C%H$rE>Aw9k$?$a$K!"=hM}$r%M%C%H%o!<%/%$%s%?!<%U%'!<%9AX$K0\$

3NCf$GK\<BAu$N$?$a$NJQ99E@$r0J2<$K<($9!#

- 7PO)@)8fI=$N8!:w$r9T$& **rtalloc()** 4X?t$KEO$98!:w%-!<$O!"4{B8$N5!9=$G$O **sockadd**
9=BBNG$"$C$?$,!"K\<BAuGO%U%m!<$r<1JL$9$k **sockaddr_fl** 9=B$BNG"kN$G!
rtalloc() $r8F$S=P$9 **ip_forward()**!"**ip_output()** G=$NE@$rJQ99$9$k!#

$3$3$G!"7PO)@)8fI=$r8!:w9k **rtalloc()** 0J9_$N4X?t$K$OA4$/<j$r?($lJ/$F$$$$$
HKCm0U5l$?$$!#@hKb=RY?h&$K!"K\<BAu$G$O4{B8$N Radix Tree $N5!9=$r$=$N$
^MxMQG$-!"8!:w%-!<$rJQ99$9$k$@$1Gh$$!#

5.2.2 7PO)@)8fI=XN%(%s%H%j$NDI2C!":o=|!"JQ99

7PO)@)8fI=$N%(%s%H%j$NA`:n$b!"8!:w$HF1MM$K4X?t$KEO$99=B$BN$r **sockaddr_in** 9=B$
BN$+$i%U%m!<$r<1JL$9$k **sockaddr_fl** 9=B$BN$KJQ99$9k@1G$h$$!#7PO)@)8fI=$NA`:
$r9T$&4X?t$O **rtrequest()** G"$j!"**rtrequest()** KEO90z?tG"$k%"%I%l%9 **dst** $H%M%C
%H%^%9%/ **netmask** $r **sockaddr_fl** 9=B$BN$KJQ99$9$k!#

4{B8$N7PO)@)8f5!9=$G$O!"7PO)@)8fI=$N%(%s%H%j$rJQ99$9k?aN%$%s%?!<%U%'!<
H7$F **route** %3%^%s%I$,$"$k!#K\<BAu$KBP1~$7$?7PO)@)8fI=$NA`:n$r9T$&KO!"3
route %3%^%s%I$r%U%m!<$KBP1~7?bN$KJQ99$9kI,MW,$"$k!#

5.1.29`K*$$$F!"K\<BAu$N7PO)@)8fI=$G$O4{B8$N7PO)@)8fI=$G%[%9%H7PO)$K$"$?$
%(%s%H%jGb%M%C%H%^%9%/$rJ];}$9kI,MW,$"$k$H=R$Y$?!#0lJ}$G!"K\<BAu$GMQ$$
sockaddr_fl 9=BBNO4{B8$N5!9=$GMQ$$$ilF$$$k **sockaddr_in** 9=BBNHF)2aE*$K07$(
kH$b=R$Y$?!#$3li 2 DN3H$OAjH?$9$k!#Nc$($P4{B8$N7PO)@)8fI=$r07$&NHF1
K7$FI= 5.1$Nh&$J%(%s%H%j$r7PO)@)8fI=$KDI2C$7$?$$$>l9g!"I= 5.2$K<($9h&$K%M
%H%^%9%/$bL@<(E*$KIU2C7?>e$G7PO)@)8fI=$KDI2C7J1lPJiJ$$!#7+$7$3$

$O sockaddr_in 9=B$BN$H sockaddr_fl 9=B$BN$rF)2aE*$K07$($kh&K7$?$3H,0UL#$r J5$J$$!#

I= 5.1: 4{B8$N7PO)@)8fI=$G$N%[%9%H7PO)

Dst Addr	Src Addr	Dst Port	Src Port
131.113.82.93	0.0.0.0	0	0

I= 5.2: K\<BAuGN4{B8$N7PO)@)8fI=$N%[%9%H7PO) (%"%I%l%9: >eCJ!"%M%C%H%^%9%/: 2<C

Dst Addr	Src Addr	Dst Port	Src Port
131.113.82.93	0.0.0.0	0	0
0xffffffff	0x00000000	0x0000	0x0000

$=$3$G rtrequest() $NKAF,$G!"%M%C%H%^%9%/$,I,MW$G$"$kNK;XDj5l$F$$$J$$$b$N $r%A%'%C%/$9$k5!G=$r@_1F!"$=$N>l9gKOE,@Z$J%M%C%H%^%9%/$rIU2C9kh&K9 3lKh$j4{B8$N7PO)@)8fI=$HF)2aE*$J5!9=$,<B8=$5lk!#

5.2.3 7PO)@)8fI=$NI=<(

4{B8$N7PO)@)8f5!9=$G$O!"7PO)@)8fI=$NI=<(KO netstat %3%^%s%I$,MQ$$$ilk!#4 B8$N netstat %3%^%s%I$G$O7PO)@)8fI=$N%(%s%H%j$NI=<($, Dst Addr N_G"kN$G! %U%m!<$r<1JL9k 4 DN%Q%i%a!<%?!"Dst Addr !"Src Addr !"Dst Port !"Src Port r9$Y $FI=<($9kh$&$KJQ99$9$kI,MW$,$"$k!#

5.2.4 BeM} ARP XNBP1~

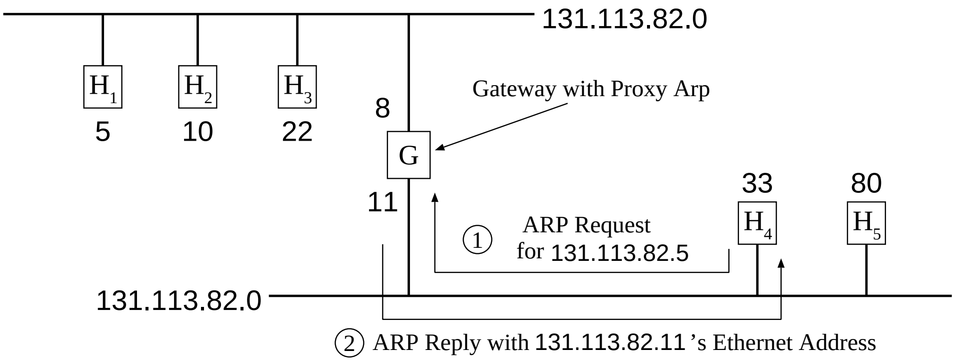
K\<BAuGO!"sockaddr_in 9=BBNHF)2aE*$K07$&3H$,$G$-$k sockaddr_fl 9=BBNr Dj5A$7!"8z2LE*$K@_7W9k3H$,$G$-$?!#7+$7!"1 D@$1LdBjE@$,B8:_9k!#$=l K\<BAuGNBeM} ARP[5] $N<h$j07$$$G$"$k!#

BeM} ARP

BeM} ARP HO!"$"$k IP %"%I%l%9$KBP1~$9$k ARP MW5a$K!"$=$N IP %"%I%l%9$r;}$D %$%s%?!<%U%'!<%9$rJ];}7F$$$J$$%[%9%H$,Be$j$K<+J,$N IP %"%I%l%9rEz($k5!9= $"$k!#3l$O!"2 DN0[Jk%M%C%H%o!<%/$rO@M}E*$K 1 DN%M%C%H%o!<%/H7$F07$&

9g$K;HMQ$5lk!#01J}$N%M%C%H%o!<%/>e$N%[%9%H$+$iH?BPB&$N%M%C%H%o!<%/>e$N%[%
KBP9$k ARP MW5a$,Aw?.5l$?>l9g$K!"$=$N 2 DN%M%C%H%o!<%/$rCf7Q$9$k%k!<%?$
BejK<+J,$N%G!<%?%j%s%/AX%"%I%l%9$rEz$($kNG$"$k!#

3NBeM} ARP NNcr?^ 5.6$K<($9!#



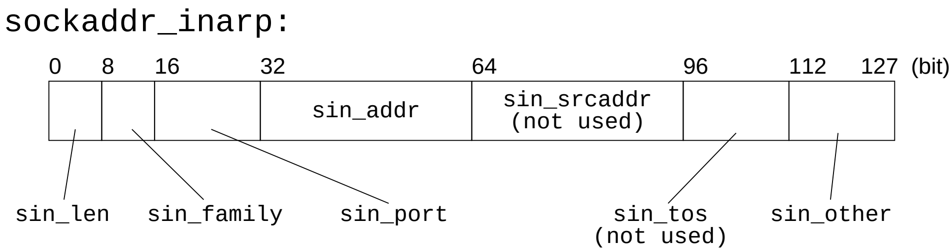
?^ 5.6: BeM} ARP

4{B8$N7PO)@)8fI=$G$NBeM} **ARP** %(%s%H%j

4{B8$N7PO)@)8fI=$G$NBeM} ARP %(%s%H%j$NO7$$J}KD$$$F@bL@9k!#BeM} ARP
%(%s%H%j$ODL>o$N7PO)@)8fI=$N%(%s%H%j$H$O0[$J$jFC<l$JbNG"k?$a!"9=B$BN
`sockaddr_in` 9=BBNH$O0[$J$k `sockaddr_inarp` 9=B$BN$rMQ$$$k!#`sockaddr_inarp` 9=B$
BN$N%3!<%I$r?^ 5.7!"`sockaddr_inarp` 9=BBNN?^$r?^ 5.8$K<($9!#

```
struct sockaddr_inarp {
    u_char     sin_len;             /* sizeof(struct sockaddr_inarp) = 16 */
    u_char     sin_family;          /* AF_INET */
    u_short    sin_port;
    struct     in_addr sin_addr;    /* IP address */
    struct     in_addr sin_srcaddr; /* not used */
    u_short    sin_tos;             /* not used */
    u_short    sin_other;           /* 0 or SIN_PROXY */
#define SIN_PROXY 1
};
```

?^ 5.7: `sockaddr_inarp` 9=B$BN (%3!<%I)



?^ 5.8: **sockaddr_inarp** 9=B$BN (?^)

?^ 5.7 !"?^ 5.8 $r8+$Fbo$+$kDL$j!"**sockaddr_in** 9=B$BN$H **sockaddr_inarp** 9=B$BN$N 0c$$$O!":G8e$N 1 %S%C%H$K$"$k!#**sockaddr_inarp** 9=BBNN **sin_other** %a%s%PKO 0 $^ $?$O 1(SIN_PROXY) $,F~$k!#3N:G8e$N 1 %S%C%H$Khj!"**sockaddr_in** 9=BBNKhkDL >o$N%(%s%H%j$H **sockaddr_inarp** 9=BBNKhkBeM} ARP $N%(%s%H%j$r6hJL9k!#

K\<BAuGNBeM} **ARP** %(%s%H%j$N<BAuJ}K!

4{B8$N7PO)@)8fI=$G$NBeM} ARP %(%s%H%j$O!":G8e$N 1 %S%C%H$NM-L5KhCF8+J,$ il$?!#$7$+$7$3$l$O **sockaddr_in** 9=B$BN$N:G8e$N 8 %P%$%H$, 0 G"k3HKhC$F<B 8=$G$-$kNG$"$k!#

K\<BAu$GMQ$$$k **sockaddr_fl** 9=BBNO:G8e$N 1 %S%C%H$^$GA4$F;HMQ9k$?$a!"K\<BAu $GBeM} ARP %(%s%H%j$r07$&:]$K!"4{B8$N7PO)@)8fI=$NJ}K!r=N^$^;H$&3HOG $J$$!#5U$K!"K\<BAu$GBeM} ARP %(%s%H%j$r4{B8$NJ}K!$HF1$8<BAur7F7$^$&$H!" 8e$N 1 %S%C%H$, 1 G"$k%(%s%H%j$rJ];}7F$$$k%k!<%?$, ARP MW5a$r<u?.7?>l9g$K 8m$C$F ARP 1~Ez$rAw?.9k62l,$"$j!"=EBg$J;vBV$r>7$$$F7^$&!#

hC$F!"K\<BAu$G$OBeM} ARP %(%s%H%j$@$17PO)@)8fI=$rJL$K:n$j!"BeM} ARP %(%s% %j$N8!:w$r9T$&>l9g$KN_!"$=$N7PO)@)8fI=$r;2>H$9kh$&$K9k!#3lKh$j!"K Au$HBeM} ARP %(%s%H%j$N6&B8$,2DG=HJ$k!#

Bh **6** >O

I>2A$*$h$S8!F$

K\8&5fGO Dst Addr N_Kh$j8!:w$r9T$&4{B8$N7PO)@)8f5!9=$rJQ99$7!"%U%m!<$
9MN8$9$k$?$a$K Src Addr!"Dst Port!"Src Port $b07$&h&K7$?!#$=N?$a!"0lO"$N=h
M}KMW9$k;~4V$OK\<BAu$NJ}$,4{B8$N5!9=$hjBg-$/$Jk3H,M=A[5l$k!#

K\>OGO!"4{B8$N7PO)@)8f5!9=$HBh 5>O$G<BAu$7$?7PO)@)8f5!9=$NI>2A$r9T$$!"3N 2
$rHf3S$9k3HKhj!"=>Mh$N5!9=$KBP9kK\<BAu$N=hM};~4V$rDjNLE*$K<($7!"K\<
$,==J,;HMQ$KBQ$(F@$k3H$r@bL@$9$k!#$^$?!"%(%s%H%j?t$NA}2CKBP9$k%*!<%P!<%
%IrB,Dj9k3HKhj!"K\<BAu$N7PO)@)8f5!9=$O!"4{B8$N7PO)@)8f5!9=$HF1MM$KG|Bg$
%s%H%j?t$,7PO)@)8f5!9=$KEPO?5l$F$$$k>l9gGb9bB.$J8!:w$r<B8=G-k3Hr<($

6.1 I>2A 1

Pentium 120MHz $N CPU!"64MB $N%a%b%j$rEk:\$7$? PC/AT 5!$G!"7PO)@)8f5!9=$K4X
9kMM!9$JF0:n$K$+$+$k;~4V$r<!$N 2 DN>l9gK*$$$F$=$l$>$lB,Dj7?!#

- K\<BAu$N7PO)@)8f5!9=$r%+!<%M%kFb$K;}$D>l9g
- 4{B8$N7PO)@)8f5!9=$r%+!<%M%kFb$K;}$D>l9g

I>2A9kNOK\<BAuK*$$$F4{B8$N<BAu$rJQ99$7$?ItJ,K*1k=hM};~4VH9$k!
<BAu$GJQ99$5l?ItJ,$O<g$K<!$N 4 DG$"$k!#

1. 7PO)@)8f5!9=$N%(%s%H%j$r8!:w9k4X?t (**rtalloc()**)
2. 7PO)@)8f5!9=$N%(%s%H%j$rA`:n9k4X?t (**rtrequest()**)
3. <u?.%Q%1%C%H$NE>Aw=hM}$r9T$&4X?t (**ip_forward()**)
4. Aw?.%Q%1%C%H$NAw?.=hM}$r9T$&4X?t (**ip_output()**)

>e5-N=l>lNF0:n$NI>2A$O!"<!$K<($9$=$l$>$l$N=hM}$KMW9k;~4VrB,Dj9$
HKhj9T$&!#7PO)@)8f5!9=$NA`:n$K4X$7FO%(%s%H%j$NDI2C!":o=|!"JQ99$JI,9M$
lk$,!"K\<BAu$G$O%(%s%H%j$NDI2C$r9T$&ItJ,$KB?$/$N5!G=$rIU2C7?$?$a!":G$b%
%P!<%X%C%I$,Bg$-$/$JkH;Wol$k "DI2C" KD$$$FB,Dj9k!#

1. **rn_match()**(<B:]$K7PO)@)8f5!9=$N8!:w$r9T$&4X?t) $N@hF,$+$i:G8e$^$G=hM}$r40N;
   9kNKM-9k;~4V *t*1
2. **rtrequest()** $K%(%s%H%jDI2CL?Na$rM?$($?:]!"**rtrequest()** $N@hF,$+$i:G8e$^$G
   =hM}$r40N;$9kN$KM-$9$k;~4V *t*2

3. **ip_forward()** $N@hF,$+$i **ip_output()** $K=hM}$,EOk^GKM-9k;~4V t_3
4. **ip_output()** $N@hF,$+$i%M%C%H%o!<%/%$%s%?!<%U%'!<%9AX$NAw?.%U%'!<%: (**ether_outp**
   $K=hM}$,EOk^GKM-9k;~4V t_4

6.1.1 I>2AJ}K!

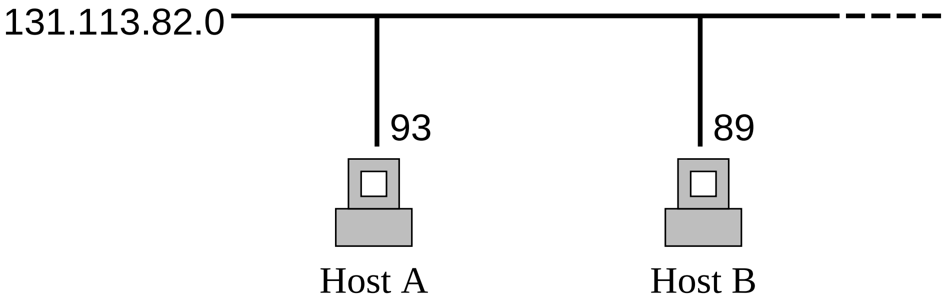
I>2AJ}K!$r0J2<$K<($9!#=c?h$KHf3S$r9T$&$?$a!"7PO)@)8fI=$N%(%s%H%j$O4{B8$N<B
$HK\8&5f$N<BAuHGA4$/F1$8bNH9$k!#$=N?$a!"CM$r;}$D%Q%i%a!<%?$O Dst Addr $
$_$G!"Src Addr!"Dst Port!"Src Port $O 0 G"$k!#

3FI>2A$r9T$C$?;~$N7PO)@)8fI=$N%(%s%H%j$rI= 6.1$K<($9!#

I= 6.1: I>2A$r9T$C$?:]$N7PO)@)8fI=$N%(%s%H%j

Dst Addr	Src Addr	Dst Port	Src Port
*	*	*	*
127.0.0.1	*	*	*
131.113.32/24	*	*	*
131.113.82/24	*	*	*
131.113.82.1	*	*	*
131.113.82.10	*	*	*
131.113.82.33	*	*	*
131.113.82.89	*	*	*
131.113.82.93	*	*	*
131.113.82.255	*	*	*

1. ?^ 6.1$K<($9I>2A4D6-K*$$$F!"%[%9%H A $+$i%[%9%H B $K **ping** $GDL?.$7$?>l9g$N
   $t_1$$rB,Dj9k!#
2. ?^ 6.1$K<($9I>2A4D6-K*$$$F!"%[%9%H A $, **route** %3%^%s%I$rMQ$$$FI= 6.2$K<($9
   %(%s%H%j$r7PO)@)8fI=$KDI2C7?>l9g$N t_2 rB,Dj9$k!#
3. ?^ 6.1$K<($9I>2A4D6-K*$$$F%[%9%H A $r%2!<%H%&%'%$$H$7!"%[%9%H B $N%G%U%)%
   %H7PO)$r%[%9%H A $K@_Dj$7$F!"%[%9%H B $+$i 131.113.29.21 $X **ping** $GDL?.$7$?>l
   9g$N%[%9%H A K*1k;~4V t_3 rB,Dj9$k!#
4. ?^ 6.1$K<($9I>2A4D6-K*$$$F!"%[%9%H A $+$i%[%9%H B $K **ping** $GDL?.$7$?>l9g$N
   $t_4$$rB,Dj9k!#



?^ 6.1: I>2A4D6-

I= 6.2: 7PO)@)8fI=$KDI2C$5lk%(%s%H%j

Dst Addr	Src Addr	Dst Port	Src Port	Next Hop
131.113.32.5	0.0.0.0	0	0	131.113.82.1

6.1.2 I>2A7k2L

I>2A$N7k2L$rI= 6.3$K<($9!#7k2L$OA4$F!"100 2s$NB,DjCM$NJ?6QG"$k!#

I= 6.3: I>2A7k2L

	4{B8$N7PO)@)8fI=	K\8&5f$GDs0F$9$k7PO)@)8fI=
8!:w:1	19	19
DI2C:2	84	104
E>Aw:3	28	29
Aw?.:4	29	31

6.2 I>2A **2**

K\8&5f$G<BAu$7$?7PO)@)8fI=$K$*$$$F!"%(%s%H%j?t$NA}2C$KH<$&8!:w;~4V$N%*!<%
%X%C%I$NJQ2=$rB,Dj7?!#

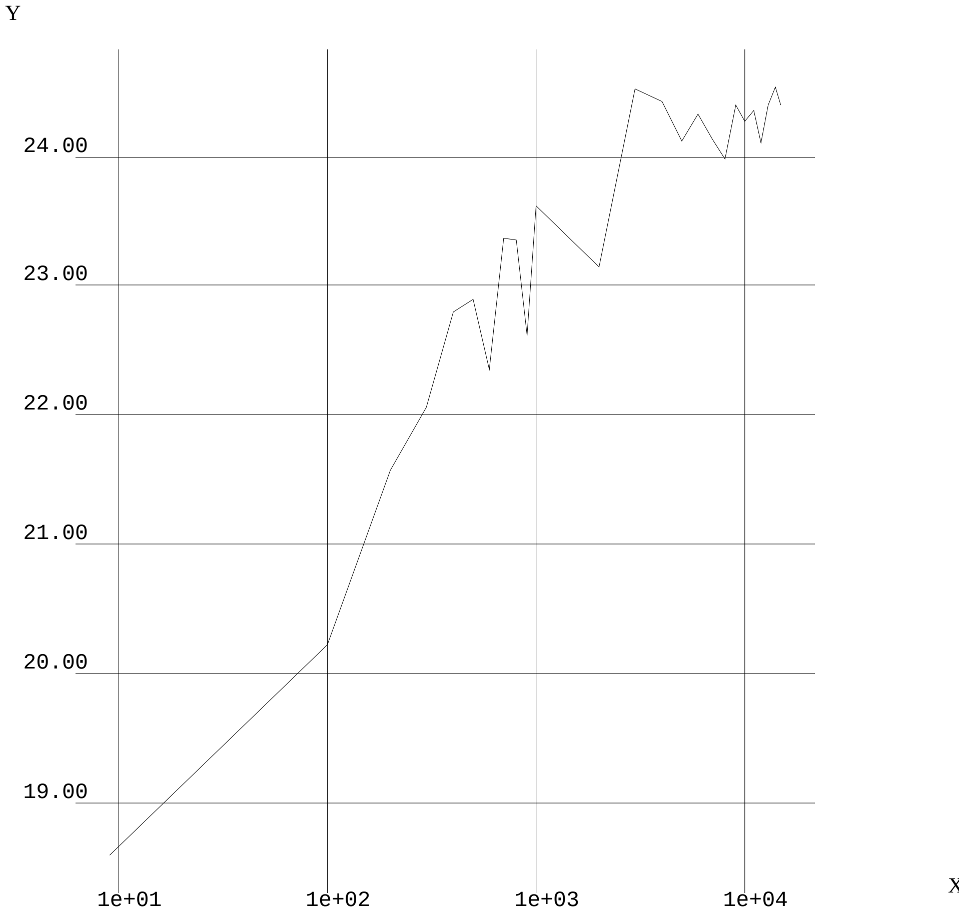
6.2.1 I>2AJ}K!

I>2A$OI>2A 1 $HF1$84D6-(?^ 6.1) $G9T$C$?!#%[%9%H A K*$$$F!"%i%s%@%`$KA*Br$5$
$?%(%s%H%j$r7PO)@)8fI=$K 15000 8DEPO?$7!"$=$N:]!"I>2A 1 GN7PO)@)8fI=$N8!:w$K

9k;~4V[1]NB,DjHF10l$NJ}K!$rMQ$$!"8!:wK+$+$k%*!<%P!<%X%C%IrB,Dj7$?!#

6.2.2 I>2A7k2L

7k2L$N%0%i%U$r?^ 6.2$K<($9!#?^ 6.2K*$$$F!"x <4$O%(%s%H%j?t$NBP?tI=<(!"y<4$O8
:wKMW7$?;~4V (C10L: μsec) G"$k!#



?^ 6.2: %(%s%H%j?t$NA}2C$KBP9k%*!<%P!<%X%C%I

6.3 8!F$

6.3.1 8!:wKBP9$k@-G=

I>2A7k2Lhj!"7PO)@)8fI=$N%(%s%H%j$,F10l$N>l9g$K$O4{B8$N<BAu$HK\<BAu$G8!:w
@-G=$OF1Ey$G$"$k$H8@$($k!#

Bh 2>OGb@bL@7?h&$K!"Radix Tree 5!9=$G$N8!:w$OFsJ,LZ$N:,$+$i3FJ,4t$KBP1~
9k%S%C%H$K=>$C$F=g$KMU$K8~$+CF?JsG$$$/!#$=$7FMUKE~C#7FO8aFMU$
;}9k%"%I%l%9$H8!:w%-!<$N%"%I%l%9$rHf3S$9$k!#$7$?$,CF!"J,4tGN%S%C%H$NH
$O4{B8$N<BAu$HK\<BAu$HGJQoiJ$$$?$a!"=hM};~4V$K:9$,8=$olkNOMU$KE~C#$
8eG"$k!#$7$+$7MU$NItJ,$G9Tol$kHf3S$N2s?t$OB?$/OJ$$$N$G!"EPO?$5lF$$$
O)@)8fI=$,J#;($G%P%C%/%H%i%C%-%s%0$,?tB?$/9Tolkh$&$J>l9gGJ1l$P!"8!:
M}KMW9$k;~4V$K:9$O=P$J$$$?$a!"$3$NI>2A7k2L$OBEEvJbNG$"$k$H8@$($k!#

6.3.2 %(%s%H%j$NA`:n$KBP9k@-G=

I=6.3$r8+$Fbo$+$kDL$j!"7PO)@)8fI=$K%(%s%H%j$rDI2C$9$k>l9g$,:G$b4{B8$N<BAu
K\<BAu$K:9$,8=ol$k!#$3lOK\<BAuGO%U%m!<$r9MN8$9k?aK!"**rtrequest()** H
$NFbIt4X?t$K$*$$$F?7$?$J5!G=$rDI2C$7$?$3HKhk!#

K\<BAuGO!"**rtrequest()** $NKAF,$GDI2C9k%(%s%H%j$,BeM} ARP %(%s%H%j$+I&$+$r
%A%'%C%/9k$?$a$N5!G=$,$"$k!#$=$7$F **rtrequest()** $NFbIt4X?t$G$"$k **rn_addroute()**
K*$$$F!"%M%C%H%^%9%/$,E,@Z$G$"$k$+$rD4$Y!"$b$7ITE,@Z$G$"$l$P%M%C%H%^%9%/$
$7$$$bNK9k5!G=$r;}$D!#

0J>e$N5!G=$NDI2C$,!"K\<BAu$G7PO)@)8fI=$N%(%s%H%j$rDI2C9k:]$N%*!<%P!<%X%C
$NM}M3$H;Wol$k!#

6.3.3 %Q%1%C%H$NE>Aw!"Aw?.$KBP9k@-G=

%Q%1%C%HE>Aw;~$NI>2A$r9TC?4X?t **ip_forward()** $H!"%Q%1%C%HAw?.;~$NI>2A$r9T$C
$?4X?t **ip_output()** $O!"$=l>$l4{B8$NbN$KF1$8JQ99$r2C$($F$$$k!#$=$l$O!"%Q%1%
%H%X%C%@$+$i%U%m!<$rFCDj$9$k 4 DN%Q%i%a!<%?$r **sockaddr_fl** 9=BBNK%3%T!<9kIt
J,G"$k!#

4{B8$N5!9=$G$O%Q%1%C%H%X%C%@$+$i Dst Addr $r%3%T!<$9k@1G$"$k$,!"K\<BAu$
$O 4 DN%Q%i%a!<%?$r07$oJ1lPJi$J$$$3Hd!"%W%m%H%3%k$N<1JL$r9kItJ,$J
$,DI2C$5lF$$$k3H!"$=$7$F **ip_forward()**!"**ip_output()** $+$i7PO)@)8fI=$N8!:w$,9T
olk3H,3N%*!<%P!<%X%C%I$N860x$G$"$k$H;W$olk!#7+7=lb?t μ sec DxEY
bNG"$j!"L5;k$G$-$k$H8@$($k!#

6.3.4 %(%s%H%j?t$NA}2C$KBP9k@-G=

Radix Tree 5!9=$,FsJ,LZ9=B$$G$"$k3H$OBh 2>O$G4{$K=R$Y$?!#0lHL$KLZ9=B$$G$NC5
:wKO!";^$N?t$r n H9kH O(log(n)) $+$+$k!#$hCF!"?^ 6.2GO%(%s%H%j?t (x <4) $r
BP?tI=<(7F$$$k$?$a!"M}O@E*KO%0%i%U$OD>@~$KJkbN$H;W$olk!#$3$3$G?^ 6.
8+kH!"$[$\M=A[DLjN%0%i%UHJCF$$$k!#3lKh$j!"%(%s%H%j?t$,A}2C7?>
Gb8!:w$N9bB.@-$,<:ol$J$$$H$$$& Radix Tree 5!9=$N5!G=$rK\<BAuGbJ];}7F$$$
3H$,$o$+$k!#

6.3.5 K\<BAu$N%*!<%P!<%X%C%I

>e5-N3H+$iK\<BAu$r<B:]$K%$%s%?!<%M%C%HK*$$$F;HMQ7?>l9g$N%*!<%P!<%
%IKD$$$F9M$($k!#4{$K<($7$?$h$&$K!"K\<BAuK*1k7PO)@)8fI=$N8!:w!"%Q%1%C%H$
Aw!"Aw?.KD$$$F$N%*!<%P!<%X%C%I$O4/6O$+$G$"$j!"7PO)@)8fI=$N%(%s%H%j$rA`:
kCfG$b:G$b%*!<%P!<%X%C%I$,Bg$-$$7PO)@)8fI=XN%(%s%H%j$NDI2C$N>l9gGb?t 1
sec G"$k!#

J]>Z7?%5!<%S%9$N>l9g$K$O!"3FDL?.$,%Q%1%C%H$rAw?.$9$kA0$K;q8;M=Ls$r9T$&!#?
$J%U%m!<$,@8$8$kEYK=$N%U%m!<$,DL2a9k3F%k!<%?$G7PO)@)8fI=$K%(%s%H%j$,DI2
$l!"=*N;;~$K$O:o=|$5lk!#$^$?K\<BAuGO!"4{B8$N5!9=$G$O%M%C%H%^%9%/$NI,MW$
$$%(%s%H%jGb%M%C%H%^%9%/$,I,MW$KJk>l9g$,$"$j!"$=N?$a%k!<%?$K$O3F%U%m!
$K%M%C%H%^%9%/$rJ];}G-$kJ,$@1N%a%b%jMFNL$bMW5a$5lk!#

7+$7!"0lHL$K%$%s%?!<%M%C%H$K$*$$$FDL?.KMW9$k;~4V$O:GDcGb 10 msec $N%*!
%@!<G"$j!"$^$?6aG/$N7W;;5!$N@-G=8~>e$KhjK\<BAu$N%*!<%P!<%X%C%I$Ohj>.$
JkbN$H;W$olk!#$=$N>l9gKOK\<BAu$r;HMQ$9k3HKhk3F%k!<%?GN%*!<%
%X%C%I$OL5;k$7F@$k!#5-21MFNL$NLdBj$b!"6aG/$N%a%b%j2A3J$NDc2<!"5;=Q$N8~>eK
%k!<%?$NEk:\$9$k%a%b%jMFNL$O:#8e$^$9$^$9A}Bg9k3H$,M=A[$5$l!"%M%C%H%^%9%
J,$NMFNL$NA}2C$OLdBj$GOJ$$$bNH;Wol$k!#

5i$KI>2A 2 Kh$j!"K\<BAu$O%(%s%H%j?t$,A}2C7?>l9gGb8!:w$N9bB.@-$O<:$o
$J$$$3H,>ZL@G-!"%$%s%?!<%M%C%H$N%P%C%/%\!<%s%k!<%?Nh$&$J7PO)@)8fI=$KG
$J?t$N%(%s%H%j$rJ];}$9$k%k!<%?$K$*$$$F$b!"M-MQ$G$"$k3H$,<($5l?!#

0J>ehj!"K\<BAu$O%$%s%?!<%M%C%H$G;HMQ$9kK$"$?$j!"==J,;HMQ$KBQ$(F@$kbN
$"$k$H8@$($k!#

Bh **7** >O

:#8e$N2]Bj

K\>OGO!"K\8&5f$N:#8e$N2]BjKD$$$F=RYk!#

7.1 IPv6 XNBP1~

K\8&5f$O4{B8$N%$%s%?!<%M%C%H%W%m%H%3%k IPv4 $rA0Ds$H7F$*$j!"IPv4 $N<!%P!<%8%
%s!"IPv6[7][11] KD$$$F$OA4$/9MN8$7$F$$$J$$!#IPv6 $O8=:_$N IPv4 $NG|Bg$JIa5ZKh
$k%"%I%l%9$N8O3i$r2r7h$9k3HJIrL\E*H7F*$j!"<!@$Be%$%s%?!<%M%C%H%W%
%3%kH7$FHs>o$KCmL\$5lF$$$k!#

IPv6 $N IPv4 HNAj0cE@$G!"K\8&5f$K4XokItJ,OBg-$/J,1F<!$N 2 D,$"$k!#

- IPv6 $N%"%I%l%9D9$O!"8=:_$N IPv4 $GMQ$$$ilF$$$k%"%I%l%9D9 32 %S%C%H$N 4 G\!
128 %S%C%HG"$k!#
- IPv6 GO!"%U%m!<$r<1JL$9$k<1JL;R$H7F "%U%m!<%i%Y%k" $H8F$Plk 24 %S%C%H
$N<1JL;R$r IP %X%C%@$KJ];}$9$k!#

A0<T$NJQ99E@$O!"Radix Tree 5!9=$,$bHb$H2DJQD9%"%I%l%9$KBP1~7F$$$k3H$r
9M$($k$H!"C1$K7PO)@)8fI=$N07$&%"%I%l%99=BBNrJQ99$7!"32 %S%C%H$N Dst Addr!"Sr
Addr $r 128 %S%C%H$NbNK9lPBP1~G-kH;Wol$k!#

8e<T$N%U%m!<%i%Y%k$O!"K\8&5fNh$&$K%U%m!<$r8D!9$K07$&$?aK IP %X%C%@$KMQ0U
l?%U%#!<%k%I$G!"$3$N>l9g%U%m!<$O (Dst Addr, Src Addr, Flow Label) KhCF0l0U$K
<1JLG-$k!#$3lh$jK\8&5f$N IPv6 XN3HD%$O!"%"%I%l%99=B$BN$r>e5-$N (Dst Addr,
Src Addr, Flow Label) H9lP2DG=G"kH9M$($ilk!#$=$N>l9g!"%"%I%l%99=BBNN
D9$5$O 280 %S%C%HHJk,!"Radix Tree 5!9=$N5vMFHO0OFb$G$"$k!#

7.2 0E9f2=XNBP1~

K\<BAuGO Dst Port!"Src Port $r%Q%1%C%H$+$iCj=P$9$k:]!"%W%m%H%3%k3,AX$r?/$7
IP %X%C%@$+$i TCP/UDP %X%C%@$rGA$$$F$$$k!#3l$O!"TCP %X%C%@$,J?J8G"lP2D
G=G"k,!"b70E9f2=5l$F$$$k$HA4$/G?iaJCMr%]!<%HHV9fH7$FA*Br$7$
$^$&!#$=$N$?$aK\<BAuGO!"0E9f2=5l$F$$$k3H$r<($9 ESP(Encapsulating Security
Payload) %X%C%@ [1] $, IP %*%W%7%g%s$K4^$^$l$F$$$?$i%]!<%HHV9f$r **sockaddr_fl** $K5-
=R$;$:$K8!:w$r9T$&$h$&$K7F$$$k!#

7+$7$3lG$O!"0E9f2=$5l?%Q%1%C%H$NB0$9$k%U%m!<$r<1JL9k3HOFq7$$!
$NLdBj$O:#8e$N2]Bj$G$"$k$,!"IPv6 GO 7.1@ahj!"%U%m!<$r<1JL$9k?aN%Q%i%a

%?$OA4$F IP %X%C%@$K4^$^lF$*$j!"%*%W%7%g%s%X%C%@rGA/I,MWOJ$/$Jk?$a!"IP
$N>l9g$K$OMF0W$K2r7h2DG=G"$k!#

Bh **8** >O

4XO"8&5f

K\>OGOK\8&5f$N4XO"8&5f$H7F!"0J2<$N 2 DK$D$$$F@bL@9k!#

- Flow Labelled IP: A Connectionless Approach to ATM[16]
- %=!<%9 IP %"%I%l%9$r9MN8$7$?7PO)@)8f%7%9%F%`$NDs0F [26]

8.1 Flow Labelled IP: A Connectionless Approach to ATM

%^%k%A%a%G%#%"DL?.$N<B8=$N$?$a$KJ]>Z7?%5!<%S%9$X$NCmL\$,9b$^$CF-$?$HF1;~

J]>Z7?%5!<%S%9$r4pHW$H7? ATM(Asynchronous Transfer Mode) $N8&5f$,6aG/@9sK

9Tol$F$$$k!#ATM $O%3%M%/%7%g%s;X8~$G$"$j!"%O!<%I%&%'%"Kh$k%9%$%C%A%s%0$r

$$!"E>AwB.EY$,B.$$$3HrFCD'H7$F$$$k!#

ATM $OL%NOE*$GO"k,!"8=:_$N;v<B>e$N6H3&I8=`G"$k%$%s%?!<%M%C%H%W%m%H%

%k IP $r4pHW$H7?%$%s%?!<%M%C%H$r<N$F!"@$3&CfA4F, ATM $r@Z$jBX$($k3HOG$

$J$$!#$=$3$G!"4{B8$N%$%s%?!<%M%C%H$H$N8_49@-$rJ]D?aK!"IP over ATM $N8&5f$

?tB?$/H/I=$5lF$$$k!#

7+$7=>Mh$N IP over ATM $O!"IP $NFCD'$G$"$k%9%F!<%H%l%9$d=@Fp@-!"4h6/@-$H ATM

$NFCD'$G$"$k%9%$%C%A%s%0!"%3%M%/%7%g%s;X8~$,3z$_9go:!"FC@-$,<:$olF7^$&

3G!"[16] GO ATM $N%3%M%/%7%g%s;X8~$NFC@-$r<N$F!"ATM %9%$%C%A>e$K IP %k!<%?

$r<BAu$7!"%3%M%/%7%g%s%l%9$N%M%C%H%o!<%/$K$*$$$FB.$$2s@~H7$F ATM $rMxMQ$9

J}K!$rDs8@$7$F$$$k!#5i$K [16] GO!"IP K*$$$F$O7PO)JQ99$OIQHKKO9Tol$J$$

HrMxMQ$7!"%Q%1%C%H$r0l$D0l$D IP AX$^$G=hM}$7%=%U%H%&%'%"$G7PO)@)8f9kNG$

$/!"%O!<%I%&%'%"$G%F!<%V%k$rJ];}$7%9%$%C%A%s%0$r9T$&$3HKhj9b$$B.EY@-G=$

$F$$$k!#

$=$N:]%O!<%I%&%'%"%9%$%C%A%s%0$N9bB.@-$rMxMQ$9k?aK!"“%U%m!<” $N35G0$rMQ

$k!#QoS $rMW5a$9$k%U%m!<$dDL?.;~4V$,D9$/Jk$HM=A[$5lk%U%m!<$N>l9g$K$O!"%9%

%A$N%F!<%V%k$K$=$N%U%m!<$N%(%s%H%j$rJ];}$7!"$=$N%U%m!<$KB0$9$k%Q%1%C%H$O%O!

%&%'%"%9%$%C%A%s%0$9$k!#Ld$$9go;%Q%1%C%HNh$&$KDL?.$,$4$/6O$+$J%U%m!<$O!

%$%C%A$K>uBV$rJ];}$;$:!"$=$NETEY%W%m%;%C%5$K=hM}5l$k!#$3$3$G!"3F%;%k$NB0$

%U%m!<$r<1JL$9k?aK [16] GOK\8&5f$HF1MM$K TCP!&UDP $N%]!<%HHV9f$rMxMQ7

$$$k!#

7+$7!"[16] GO%U%m!<$r8D!9$K07CF7PO)@)8f$r9TCF$$$ko1GO$J$$$3HK

0U5l$?$$!#[16] $G%U%m!<$r07$&$N$O IP AX$h$j2<0LAX$N%M%C%H%o!<%/%$%s%?!<%U%'!<

AXG"$j!"%U%m!<$N35G0$,MQ$$$ilkNO!"2<0LAX$G%O!<%I%&%'%"%9%$%C%A%s%0$r9
$+>e0LAX$^$G=hM}$r0\$9$+$NH=CGN_G"$k!#$9Jo$A!"7PO)@)8f$O IP AX$G9T$$=>Mh
5!9=$rMQ$$$F$$$k$?$a!"=*E@%"%I%l%9Kh$k7PO)@)8f$G$"$j!"K\8&5fNh$&$K%U%m!
$K0[$J$k7PO)$rA*Br9k3H$OIT2DG=$G$"$k!#

8.2 Source IP Address $r9MN8$7$?7PO)@)8f%7%9%F%`$N Ds0F

%$%s%?!<%M%C%H$O:r:#$NGzH/E*$JIa5ZKh$j!">&6HE*$K$bL%NOE*$J;T>lH7$FH/E8
FMhF$*$j!"ISP(Internet Service Provider) $bA}2C$N0lESr?IC$F$$$k!#3liN ISP
$,Aj8_@\B3$9$k%]%$%s%H$O IX(Internet eXchange) $H8F$P$l!"8=:_$G$O IX $OEl5~$dBg:e
JIET;TIt$K=8Cf$7$F$$$k!#3liN IX $r GIX(Global Internet eXchange) $H8F$V!#

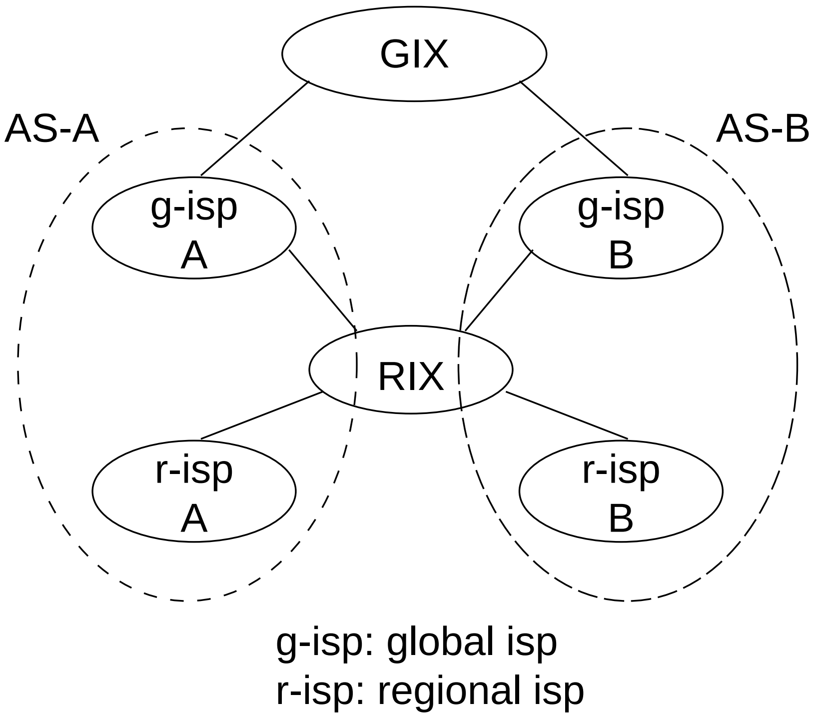
7+$7$3$&$7$?ET;TIt$X$N IX $N0l6I=8Cf$O!"COJ}ET;TK*$$$F%$%s%?!<%M%C%H$r
MQ9k:]$KM>J,$JDL?.CY1d$NH/@8$d!"BgET;TGN:R32;~$N1F6A!">pJs%3%s%F%s%D$NB
;TXN=8CfJI$NLdBj$N860xHJCF$$$k!#3NLdBj$r2r7h$9k?aK!"6aG/GOC
ET;T$KCO0h IX(RIX, Regional Internet eXchange) $r9=C[$7h&H9$kF0$-$,9-$,CFMh
$F$$$k!#CO0h IX $,9=C[$G$-$l$P!"CO0h ISP F1;N$NDL?.$r GIX KMji$:CO0hFb$GJD8
3H$,2DG=$KJk!#

CO0h IX $OBg<j ISP(global isp) $HCO0h ISP(regional isp) $K@\B3$7F*$j!"CO0h ISP $O
$=$l$>$l$,7@Ls$7$F$$$kBg<j ISP HN@\B3$rCO0h IX $r7PM3$7$F9T$& (?^ 8.1)!#$3$3$GL
Bj$,@8$8$k!#Bg<j ISP GO!"3F<+$,7@Ls7F$$$kCO0h ISP $N%Q%1%C%H$N$_$rEAAw7?$
7+$7CO0h IX Kh$jCO0h ISP $rAj8_@\B3$9kH!"=*E@%"%I%l%9N_KhCF7PO)@)8
$r9T$&4{B8$N5!9=$G$O!"CO0h IX K*$$$F3FCO0h ISP $+$i$N%Q%1%C%H$rF1Ey$K07$CF
$^$$!"Bg<j ISP GO7@Ls7F$$$J$$CO0h ISP $+$i$N%Q%1%C%H$rEAAw7F7^$$&!#3l$
2r7h9k$?$a$K [26] GO!"7PO)@)8f$N:]$K%Q%1%C%H$N=*E@%"%I%l%9$@1GJ/;OE@%"
%l%9$b9MN8$7$?7PO)@)8f5!9=$rDs0F7F$$$k!#

K\8&5f$H [26] $NAj0cE@$H7F!"<!$N 2 E@$,$"$k!#

- [26] GO=*E@%"%I%l%9!";OE@%"%I%l%9$K4p$E$$$?7PO)@)8f$r9T$&!#K\8&5fGO=*E
%"%I%l%9!";OE@%"%I%l%9$K4p$E$$$?7PO)@)8fObAm$s!"$=lK2C$($F=*E@%]!<
HV9f!";OE@%]!<%HHV9f$b9MN8$7$?7PO)@)8f$,2DG=G"$k!#

- [26] GOCO0h IX $OCO0h ISP Kh$K7PO)@)8fI=$rJ];}$7!";OE@%"%I%l%9KhCF7PO)
@)8fI=$rFCDj$7$?8e!"=>MhDL$j$N=*E@%"%I%l%9$Khk8!:w$r9T$&!#K\8&5fGO



?^ 8.1: CO0h IX $N7ABV

%m!<$rFCDj$9$k 4 DN%Q%i%a!<%?r^Ha$F 1 DN%"%I%l%9H_J7!"1 DN7PO
@)8fI=KhCF7PO)@)8f$r9T$&!#

[26] GO7PO)@)8fI=$,J#?tI,MW$G$"$j!"0lEY;OE@%"%I%l%9KhCFJ#?t$N7PO)@)8f NCf+$iE,@Z$J7PO)@)8fI=$rA*Br$7!"$=$N7PO)@)8fI=$GDL>o$N=*E@%"%I%l%9Kh$k8 $r9T$&!#K\8&5fGOA4FN7PO)$r 1 DN7PO)@)8fI=$G<B8=$7!"0lEY$N<j4V$G8!:w$r9T 3H$,$G$-$k!#5i$K!"K\8&5f$N<BAu$O [26] $N5!G=$r7sMF$$$k$?$a!"8zN(E*G"$ $+$DHFMQ@-$,9b$$$H$$$($k!#

Bh **9** >O

7kO@

4{B8$N7PO)@)8f5!9=$G$O!"%Q%1%C%H$N=*E@%"%I%l%9N_Kh$j7PO)@)8f$r9TCF$$$
%$%s%?!<%M%C%H$N4pHWG"$k:GA1EXNO7?%5!<%S%9$GO=lG==J,G"C?!#7+$7!
G/GO%$%s%?!<%M%C%H>e$G%^%k%A%a%G%#%"%"%W%j%1!<%7%g%sKh$kDL?.$r<B8=9k$
$,3iK>$5lF$-$F$$$k!#%^%k%A%a%G%#%"DL?.$O QoS $rMW5a$7!"QoS $O%U%m!<$KhC$F
Jk$?$a!"3F%U%m!<$N5a$a$k QoS $rJ]>Z$9$kJ]>Z7?%5!<%S%9$r%$%s%?!<%M%C%H$G<B8=
J1lPJi$J$$!#

J]>Z7?%5!<%S%9GO!"QoS $rMW5a$9$k3F%U%m!<Kh$K0[JC$?>uBV$rJ];}9kI,MW$,
$j!"$=N?aK7PO)@)8f5!9=Gb3F%U%m!<$r8D!9$K07oJ1lPJiJ$$!#7+$7!
B8$N=*E@%"%I%l%9$N$_$Khk7PO)@)8f5!9=GO%U%m!<$r<1JL$G$-$J$$!#

$=$N$?$aK\8&5fGO!"J]>Z7?%5!<%S%9KI,MWHJk%U%m!<$r8D!9$K07$&7PO)@)8f5
N?aK!"“%U%m!<$r9MN8$7$?7PO)@)8fI=” $N9=C[$r9TC?!#

%U%m!<$O<!$N 4 DN%Q%i%a!<%?KhCF0l0UKDj^$k!#

- =*E@%[%9%H$N IP %"%I%l%9
- ;OE@%[%9%H$N IP %"%I%l%9
- =*E@%[%9%H>e$NC<E@$N%]!<%HHV9f
- ;OE@%[%9%H>e$NC<E@$N%]!<%HHV9f

K\8&5fGO!"4{B8$N7PO)@)8f5!9=$KMQ$$$ilF$$$k Radix Tree 5!9=$rMxMQ$9k3H
hj!">e5-$N 4 DN%Q%i%a!<%?Kh$j%U%m!<Kh$N%(%s%H%j$rJ];}G-$k7PO)@)8fI=$
4{B8$N5!9=$HF)2aE*$K<B8=$7$?!#

K\<BAu$O4{B8$N7PO)@)8f5!9=hj$bB?>/$N%*!<%P!<%X%C%I$,$"k,L5;k$7F@$kbN$
$j!"J]>Z7?%5!<%S%9$KBP1~7?7PO)@)8f%W%m%H%3%kJI$,K\<BAu$r:NMQ9k3HKh
%$%s%?!<%M%C%H$K$*$1$kJ]>Z7?%5!<%S%9$NDs6!$,$h$j8=<BL#$rA}9bNH9M$($il

<U<-

K\8&5f$r9T$&5!2q$rM?$($F2<$5$j!"E,@Z$J8f;XF3$rD:$-$^$7$?7DXf5A=NBg3XM}9)3X
EE5$9)3X2J5R0w65<x =j??M}M: Gn;N$K?4$h$j46<UCW$7$^$9!#

$=$7$F!"8fB?K;$N=j$rF|:"$h$j:)@Z$J8f;XF3!"$^$?K\8&5f$N%F!<%^$r7hDj9kK"
$j8f?TNO2<$5C?K\8&5f<<Gn;N2]Dx$NJ!ED7r2p;a!"$JiS$K!"K\8&5f$N%F!<%^$rM?$
2<5j!"7ha+MF$$$?J}8~@-$rF3$$$F2<5C$?K\8&5f<<=$;N2]Dx$N;0NXBY9';a$K:
5i$N46<U$r!#

1 G/rDL7$F8&5f!"$^$?$=$NB>$NLLGb;~4VrLdo$:5.=E$J8f0U8+$rD:$-$^$7$?K\
5f<<=$;N2]Dx$N5WA>?@9(;a!"Pornchai Laohakulvathit ;a!"Lp:j7<G7;a!"KLEg510l;a!"@e
4V0l9(;a!"$=$7$F0[$J$k%0%k!<%W$G$"$kKb4Xoi$:::FI$r0z$-<u$1$F2<$5C?0KF#
?M;a$KBg$$$J$k46<U$rCW7^$9!#
FC$K@e4V0l9(;a$OEY=EJk::FI$N8f4j$$$r7y$J4i0l$D$;$:2w$/0z$-<u1F
2<5j!"46<U$NG0$O8@MU$K?T$/$;$^$;$s!#

$^$?!"K\8&5f<<$KG[B0$KJC$?;~$+$i0lG/4V?t!9$N6l3Z$r6&$K2a$4$7F-$?4G/@8
O8$a!"$*@OCKJC$?8&5f<<$N3'MM$K46<UCW$7$^$9!#K\8&5f<<$KG[B0$KJj!"3
%s%P!<$G8&5f3hF0$r9T$($?;v$rHs>o$K4r7/;W$$$^$9!#

:G8e$K!"K\8&5f<<$G8&5f@83h$r9T$J$&$K$"$?$jB?Bg$J$kM}2r$H@K7_$J$$1g=ur7
$/$l$?N>?F!"7;$K?<$/46<UCW$7$^$9!#

1998 G/ 2 7nK?F|

[1] shitama@wide.ad.jp,http://www.mt.cs.keio.ac.jp/person/shitama.html

;2 9M J8 8%

[1] R. Atkinson. IP Encapsulating Security Payload (ESP). Internet RFC1827, *IETF*, Aug. 1995.

[2] R. Braden, D. Clark, and S. Shenker. Integrated Services in the Internet Architecture: an Overview. Internet RFC1633, *IETF*, Jun. 1994.

[3] R. Braden and L. Zhang. Resource ReSerVation Protocol (RSVP) Version 1 Message Processing Rules. Internet RFC2209, *IETF*, Sep. 1997.

[4] R. Braden, L. Zhang, S. Berson, S. Herzog, and S. Jamin. Resource ReSerVation Protocol (RSVP) Version 1 Functional Specification. Internet RFC2205, *IETF*, Sep. 1997.

[5] Smoot Carl-Mitchell and John S. Quarterman. Using ARP to Implement Transparent Subnet Gateways. Internet RFC1027, *IETF*, Oct. 1987.

[6] D. Comer. *Internetworking with TCP/IP vol.I: Principles, Protocols, and Architecture 3rd Ed.* Printice Hall, 1995.

[7] S. Deering and R. Hinden. Internet Protocol, Version 6 (IPv6) Specification. Internet RFC1883, *IETF*, Dec. 1995.

[8] L. Delgrossi, R. Herrwitch, C. Vogt, and L. Wolf. Reservation Protocols for Internetworks: A Comparison of ST-II and RSVP. In *Proceedings of the 4th International Workshop on Network and Operating System Support for Digital Audio and Video*, 1993.

[9] V. Fuller, T. Li, J. Yu, and K. Varadhan. Classless Inter-Domain Routing (CIDR): an Address Assignment and Aggregation Strategy. Internet RFC1519, *IETF*, Sep. 1993.

[10] C. Hedrick. Routing Information Protocol. Internet RFC1058, *IETF*, Jun. 1988.

[11] Christian Huitema. *IPv6: The New Internet Protocol.* Prentice Hall, 1996.

[12] A. Mankin, F. Baker, B. Braden, S. Bradner, M. O'Dell, A. Romanow, A. Weinrib, and L. Zhang. Resource ReSerVation Protocol (RSVP) Version 1 Applicability Statement Some Guidelines on Deployment. Internet RFC2208, *IETF*, Sep. 1997.

[13] D. J. Mitzel, D. Estrin, S. Shenker, and Lixia Zhang. An Archtectural Comparison of ST-II and RSVP. In *Proceedings of IEEE Infocom '94*, Jun. 1994.

[14] Jeffrey Mogul. INTERNET SUBNETS. Internet RFC917, *IETF*, Oct. 1984.

[15] J. Moy. OSPF protocol analysis. Internet RFC1245, *IETF*, Jul. 1991.

[16] Peter Newman, Tom Lyon, and Greg Minshall. Flow Labelled IP: A Connectionless Approach to ATM. In *Proceedings of IEEE Infocom '96*, Mar. 1996.

[17] C. Partridge. *Gigabit Networking.* Addison-Wesley, 1994.

[18] Jon Postel. INTERNET PROTOCOL. Internet RFC791, *IETF*, Sep. 1981.

[19] T. Pummill and B. Manning. Variable Length Subnet Table For IPv4. Internet RFC1878, *IETF*, Dec. 1995.

[20] S. Senum. The PPP XNS IDP Control Protocol (XNSCP). Internet RFC1764, *IETF*, Mar. 1995.

[21] Keith Sklower. A Tree-based Packet Routing Table for Berkeley UNIX. In *Proceedings of USENIX 1991 January*, 1991.

[22] W. Richard Stevens. *UNIX NETWORK PROGRAMMING.* Prentice Hall, 1990.

[23] Z. Wang and J. Crowcroft. Quality of Service Routing for Supporting Multimedia Applications, Oct. 1995.

[24] Gary R. Wright and W. Richard Stevens. *TCP/IP Illustrated, Volume 2 The Implementation.* Addison-Wesley, 1995.

[25] L. Zhang, S. Deering, D. Estrin, S. Shenker, and D. Zappala. RSVP:A New Resource ReSerVation Protocol. *IEEE NETWORK MAGAZINE*, Sep. 1993.

[26] CCLjIp;V, >.NSOB??, ;38}1Q, Hx2HM4Fs. %=!<%9 IP %"%I%l%9$r9MN8$7$?7PO)@)8f%7% %F%`$NDs0F COOh IX $K$*$1$k7PO)@)8fLdBj$N2r7h. >pJs=hM}3X2qJ,;6%7%9%F%`1?M 5;=Q8&5f2q, 1997.

[27] Xf5A=NBg3X Bg3X1!@/:v!&%a%G%#%"8&5f2J!V0eNE2hA|$rMQ$$$?<j=Q$N7W2h%7%9%F%
%W%m%8%'%/%H. 1s3V0eNE<B83, 1996. http://pegasus.sfc.keio.ac.jp/med/simnet/.