ESAxioms[11,40]

$$
\begin{aligned}
&\mathrm{ESAxioms}\{\mathrm{i{:}l}\}(E;T;M;loc;kind;val;when;after;time;sends;sender;index;first;pred;causl)\\
&\equiv_{\mathrm{def}}\ (\forall e,\ e'{:}E.\ (loc(e) = loc(e')) \Rightarrow ((causl(e,e')) \vee (e = e') \vee (causl(e',e))))\\
&\qquad \&\ (\forall e{:}E.\ (\uparrow(first(e))) \Longleftrightarrow (\forall e'{:}E.\ (loc(e') = loc(e)) \Rightarrow (\neg(causl(e',e)))))\\
&\qquad \&\ (\forall e{:}E.\\
&\qquad\quad (\neg(\uparrow(first(e))))\\
&\qquad\quad \Rightarrow (loc(pred(e)) = loc(e)\ \&\ causl(pred(e),e)\\
&\qquad\qquad \&\ (\forall e'{:}E.\ (loc(e') = loc(e)) \Rightarrow (\neg(causl(pred(e),e')\ \&\ causl(e',e))))))\\
&\qquad \&\ (\forall e{:}E.\\
&\qquad\quad (\neg(\uparrow(first(e))))\\
&\qquad\quad \Rightarrow (\forall x{:}\mathrm{Id},\ t{:}\mathbb{Q}.\ when(x,e,t) = after(x,pred(e),t + ((time(e)) - (time(pred(e)))))))\\
&\qquad \&\ \mathrm{Trans}(E;e,e'.causl(e,e'))\\
&\qquad \&\ \mathrm{SWellFounded}(causl(e,e'))\\
&\qquad \&\ (\forall e{:}E.\\
&\qquad\quad (\uparrow\mathrm{isrcv}(kind(e)))\\
&\qquad\quad \Rightarrow ((sends(\mathrm{lnk}(kind(e)),sender(e)))[(index(e))]\\
&\qquad\qquad\quad =\\
&\qquad\qquad\quad \mathrm{msg}(\mathrm{lnk}(kind(e));\mathrm{tag}(kind(e));val(e))))\\
&\qquad \&\ (\forall e{:}E.\ (\uparrow\mathrm{isrcv}(kind(e))) \Rightarrow (causl(sender(e),e)))\\
&\qquad \&\ (\forall e,\ e'{:}E.\\
&\qquad\quad (causl(e,e'))\\
&\qquad\quad \Rightarrow (((\neg(\uparrow(first(e')))) \ \mathrm{c}\wedge\ ((causl(e,pred(e'))) \vee (e = pred(e'))))\\
&\qquad\qquad \vee ((\uparrow\mathrm{isrcv}(kind(e'))) \ \mathrm{c}\wedge\ ((causl(e,sender(e'))) \vee (e = sender(e'))))))\\
&\qquad \&\ (\forall e{:}E.\ (\uparrow\mathrm{isrcv}(kind(e))) \Rightarrow (loc(e) = \mathrm{destination}(\mathrm{lnk}(kind(e)))))\\
&\qquad \&\ (\forall e{:}E,\ l{:}\mathrm{IdLnk}.\ (\neg(loc(e) = \mathrm{source}(l))) \Rightarrow (sends(l,e) = []))\\
&\qquad \&\ (\forall e,\ e'{:}E.\\
&\qquad\quad (\uparrow\mathrm{isrcv}(kind(e)))\\
&\qquad\quad \Rightarrow (\uparrow\mathrm{isrcv}(kind(e')))\\
&\qquad\quad \Rightarrow (\mathrm{lnk}(kind(e)) = \mathrm{lnk}(kind(e')))\\
&\qquad\quad \Rightarrow ((causl(e,e'))\\
&\qquad\qquad \Longleftrightarrow ((causl(sender(e),sender(e')))\\
&\qquad\qquad\qquad \vee (sender(e) = sender(e')\ \&\ ((index(e)) < (index(e'))))))\\
&\qquad \&\ (\forall e{:}E,\ l{:}\mathrm{IdLnk},\ n{:}\{0..\|sends(l,e)\|^{-}\}.\\
&\qquad\quad \exists e'{:}E\\
&\qquad\qquad ((\uparrow\mathrm{isrcv}(kind(e'))) \ \mathrm{c}\wedge\ (\mathrm{lnk}(kind(e')) = l\ \&\ sender(e') = e\ \&\ index(e') = n)))
\end{aligned}
$$

clarification:

$$
\begin{aligned}
&\mathrm{ESAxioms}\{\mathrm{i{:}l}\}\\
&\qquad\qquad (E;\\
&\qquad\qquad\ T;\\
&\qquad\qquad\ M;\\
&\qquad\qquad\ loc;
\end{aligned}
$$

$kind$;
val;
$when$;
$after$;
$time$;
$sends$;
$sender$;
$index$;
$first$;
$pred$;
$causl$)

$\equiv_{\text{def}}$ $(\forall e{:}E,\ e'{:}E.$
$(loc(e) = loc(e') \in \mathrm{Id}) \Rightarrow ((causl(e,e')) \vee (e = e' \in E) \vee (causl(e',e))))$
$\&\ (\forall e{:}E.\ (\uparrow(first(e))) \Longleftrightarrow (\forall e'{:}E.\ (loc(e') = loc(e) \in \mathrm{Id}) \Rightarrow (\neg(causl(e',e)))))$
$\&\ (\forall e{:}E.$
$(\neg(\uparrow(first(e))))$
$\Rightarrow (loc(pred(e)) = loc(e) \in \mathrm{Id}\ \&\ causl(pred(e),e)$
$\&\ (\forall e'{:}E.\ (loc(e') = loc(e) \in \mathrm{Id}) \Rightarrow (\neg(causl(pred(e),e')\ \&\ causl(e',e))))))$
$\&\ (\forall e{:}E.$
$(\neg(\uparrow(first(e))))$
$\Rightarrow (\forall x{:}\mathrm{Id},\ t{:}\mathbb{Q}.$
$when(x,e,t)$
$=$
$after(x,pred(e),t + ((time(e)) - (time(pred(e)))))$
$\in T(loc(e),x)))$
$\&\ \mathrm{Trans}(E;e,e'.causl(e,e'))$
$\&\ \mathrm{strongwellfounded}(E;\ e,e'.(causl(e,e')))$
$\&\ (\forall e{:}E.$
$(\uparrow\mathrm{isrcv}(kind(e)))$
$\Rightarrow ((sends(\mathrm{lnk}(kind(e)),sender(e)))[(index(e))]$
$=$
$\mathrm{msg}(\mathrm{lnk}(kind(e));\mathrm{tag}(kind(e));val(e))$
$\in \mathrm{Msg}(M)))$
$\&\ (\forall e{:}E.\ (\uparrow\mathrm{isrcv}(kind(e))) \Rightarrow (causl(sender(e),e)))$
$\&\ (\forall e{:}E,\ e'{:}E.$
$(causl(e,e'))$
$\Rightarrow (((\neg(\uparrow(first(e')))) \ \mathrm{c}\wedge\ ((causl(e,pred(e'))) \vee (e = pred(e') \in E)))$
$\vee\ ((\uparrow\mathrm{isrcv}(kind(e'))) \ \mathrm{c}\wedge\ ((causl(e,sender(e'))) \vee (e = sender(e') \in E)))))$
$\&\ (\forall e{:}E.\ (\uparrow\mathrm{isrcv}(kind(e))) \Rightarrow (loc(e) = \mathrm{destination}(\mathrm{lnk}(kind(e))) \in \mathrm{Id}))$
$\&\ (\forall e{:}E,\ l{:}\mathrm{IdLnk}.$
$(\neg(loc(e) = \mathrm{source}(l) \in \mathrm{Id})) \Rightarrow (sends(l,e) = [] \in (\mathrm{Msg_sub}(l;M)\ \mathrm{List})))$
$\&\ (\forall e{:}E,\ e'{:}E.$
$(\uparrow\mathrm{isrcv}(kind(e)))$
$\Rightarrow (\uparrow\mathrm{isrcv}(kind(e')))$
$\Rightarrow (\mathrm{lnk}(kind(e)) = \mathrm{lnk}(kind(e')) \in \mathrm{IdLnk})$
$\Rightarrow ((causl(e,e'))$

$$
\begin{aligned}
&\iff ((causl(sender(e),sender(e'))) \\
&\qquad \vee (sender(e) = sender(e') \in E \ \&\ ((index(e)) < (index(e')))))))) \\
&\& \ (\forall e{:}E,\ l{:}\mathrm{IdLnk},\ n{:}\{0..\|sends(l,e)\|^{-}\}. \\
&\quad \exists e'{:}E \\
&\quad\ ((\uparrow \mathrm{isrcv}(kind(e'))) \\
&\quad\ \mathrm{c}\wedge\ (\mathrm{lnk}(kind(e')) = l \in \mathrm{IdLnk}\ \&\ sender(e') = e \in E\ \&\ index(e') = n \in \mathbb{Z})))
\end{aligned}
$$

http://www.nuprl.org/FDLcontent/p0_963683_/p69_114359_{ESAxioms}.html