MODULE *Client*

EXTENDS $MQTTBase$

$ReqConnect(self) \triangleq$
$\land\ pc[self] = \text{“start”}$
$\land\ \exists\, m \in msgs :$
$\land\ m.from = self$
$\land\ m.to = broker$
$\land\ m.type = CONNECT$
$\land\ m.payload.clientId = self$
$\land\ canSendTo(broker)$
$\land\ network' = send(m,\ broker)$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“connecting”}]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $store$
$\land$ UNCHANGED $used\_num$

$RcvConnectRes(self) \triangleq$
$\land\ pc[self] = \text{“connecting”}$
$\land\ Len(network[self]) > 0$
$\land$ LET $m \triangleq Head(network[self])$ IN
$\land\ m.from = broker$
$\land\ m.to = self$
$\land\ m.type = CONACK$
$\land\ network' = rcv(m,\ self)$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“connected”}]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $store$
$\land$ UNCHANGED $used\_num$

$ReqPing(self) \triangleq$
$\land\ pc[self] = \text{“connected”}$
$\land\ \exists\, m \in msgs :$
$\land\ m.from = self$
$\land\ m.to = broker$
$\land\ m.type = PINGREQ$
$\land\ canSendTo(broker)$
$\land\ network' = send(m,\ broker)$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“ping”}]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $store$
$\land$ UNCHANGED $used\_num$

$RcvPingRes(self) \triangleq$
$\wedge\ pc[self] = \text{“ping”}$
$\wedge\ Len(network[self]) > 0$
$\wedge\ \text{LET}\ m \triangleq Head(network[self])\ \text{IN}$
$\wedge\ m.from = broker$
$\wedge\ m.to = self$
$\wedge\ m.type = PINGRESP$
$\wedge\ network' = rcv(m,\ self)$
$\wedge\ pc' = [pc\ \text{EXCEPT}\ ![self] = \text{“connected”}]$
$\wedge\ \text{UNCHANGED}\ active$
$\wedge\ \text{UNCHANGED}\ topic\_subscribers$
$\wedge\ \text{UNCHANGED}\ store$
$\wedge\ \text{UNCHANGED}\ used\_num$

$ReqPublishWithQoS0(self) \triangleq$
$\wedge\ pc[self] = \text{“connected”}$
$\wedge\ store[self] \neq \{\}$
$\wedge\ \exists\, m \in msgs :$
$\wedge\ m.from = self$
$\wedge\ m.to = broker$
$\wedge\ m.type = PUBLISH$
$\wedge\ m.qos = 0$
$\wedge\ m.packetID \notin used\_num$
$\wedge\ canSendTo(broker)$
$\wedge\ network' = send(m,\ broker)$
$\wedge\ store' = [store\ \text{EXCEPT}\ ![self] = @ \setminus \{m.packetID\}]$
$\wedge\ used\_num' = used\_num \cup \{m.packetID\}$
$\wedge\ \text{UNCHANGED}\ pc$
$\wedge\ \text{UNCHANGED}\ active$
$\wedge\ \text{UNCHANGED}\ topic\_subscribers$

$ReqPublishWithQoS1(self) \triangleq$
$\wedge\ pc[self] = \text{“connected”}$
$\wedge\ store[self] \neq \{\}$
$\wedge\ \exists\, m \in msgs :$
$\wedge\ m.from = self$
$\wedge\ m.to = broker$
$\wedge\ m.type = PUBLISH$
$\wedge\ m.qos = 1$
$\wedge\ m.packetID \notin used\_num$
$\wedge\ canSendTo(broker)$
$\wedge\ network' = send(m,\ broker)$
$\wedge\ used\_num' = used\_num \cup \{m.packetID\}$
$\wedge\ pc' = [pc\ \text{EXCEPT}\ ![self] = \text{“publishingwithqos1”}]$
$\wedge\ \text{UNCHANGED}\ active$

$\land$ UNCHANGED $store$
$\land$ UNCHANGED $topic\_subscribers$

$RcvPublishWithQoS1Res(self) \triangleq$
$\land\ pc[self] =$ "publishingwithqos1"
$\land\ Len(network[self]) > 0$
$\land$ LET $m \triangleq Head(network[self])$IN
$\land\ m.from = broker$
$\land\ m.to = self$
$\land\ m.type = PUBACK$
$\land\ network' = rcv(m,\ self)$
$\land\ store' = [store$ EXCEPT $![self] = @ \setminus \{m.packetID\}]$
$\land\ pc' = [pc$ EXCEPT $![self] =$ "connected"$]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $used\_num$

$ReqPublishWithQoS2(self) \triangleq$
$\land\ pc[self] =$ "connected"
$\land\ store[self] \neq \{\}$
$\land\ \exists\, m \in msgs :$
$\land\ m.from = self$
$\land\ m.to = broker$
$\land\ m.type = PUBLISH$
$\land\ m.qos = 2$
$\land\ m.packetID \notin used\_num$
$\land\ canSendTo(broker)$
$\land\ network' = send(m,\ broker)$
$\land\ used\_num' = used\_num \cup \{m.packetID\}$
$\land\ pc' =\ [pc$ EXCEPT $![self] =$ "publishingwithqos2"$]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $store$
$\land$ UNCHANGED $topic\_subscribers$

$RcvPubrecAndResPubrel(self) \triangleq$
$\land\ pc[self] =$ "publishingwithqos2"
$\land\ Len(network[self]) > 0$
$\land$ LET $m \triangleq Head(network[self])$IN
$\land\ \ m.from = broker$
$\land\ \ m.to = self$
$\land\ \ m.type = PUBREC$
$\land\ \ \exists\, rmsg \in msgs :$
$\land\ rmsg.type\ = PUBREL$
$\land\ rmsg.from = self$
$\land\ rmsg.to = broker$
$\land\ rmsg.packetID = m.packetID$

$\land$ $canSendTo(broker)$
$\land$ $network' = response(rmsg,\ rmsg.from,\ rmsg.to)$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“waitingpubcomp”}]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $store$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $used\_num$

$RcvPubComp(self) \triangleq$
$\land\ pc[self] = \text{“waitingpubcomp”}$
$\land\ Len(network[self]) > 0$
$\land$ LET $m \triangleq Head(network[self])$IN
$\land\ m.from = broker$
$\land\ m.to = self$
$\land\ m.type = PUBCOMP$
$\land\ network' = rcv(m,\ self)$
$\land\ store' = [store \text{ EXCEPT } ![self] = @ \setminus \{m.packetID\}]$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“connected”}]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $used\_num$

$ReqSubscribe(self) \triangleq$
$\land\ pc[self] = \text{“connected”}$
$\land\ \exists\, m \in msgs :$
$\land\ \exists\, t \in topics :$
$\land\ \forall\, q \in \{QoS0,\ QoS1,\ QoS2\} :$
$\land\ topic\_subscribers[t][q] \cap \{self\} = \{\}$
$\land\ m.from = self$
$\land\ m.to = broker$
$\land\ m.type = SUBSCRIBE$
$\land\ m.topic = t$
$\land\ canSendTo(broker)$
$\land\ network' = send(m,\ broker)$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“subscribing”}]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $store$
$\land$ UNCHANGED $used\_num$

$RcvSubscribeRes(self) \triangleq$
$\land\ pc[self] = \text{“subscribing”}$
$\land\ Len(network[self]) > 0$
$\land$ LET $m \triangleq Head(network[self])$IN

$\land\ m.from = broker$
$\land\ m.to = self$
$\land\ m.type = SUBACK$
$\land\ network' = rcv(m,\ self)$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“connected”}]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $store$
$\land$ UNCHANGED $used\_num$

$ReqUnsubscribe(self) \triangleq$
$\land\ pc[self] = \text{“connected”}$
$\land\ Len(network[self]) = 0$
$\land\ \exists\, m \in msgs :$
$\land\ \exists\, t \in topics :$
$\exists\, q \in \{QoS0,\ QoS1,\ QoS2\} :$
$\land\ topic\_subscribers[t][q] \cap \{self\} \neq \{\}$
$\land\ m.from = self$
$\land\ m.to = broker$
$\land\ m.type = UNSUBSCRIBE$
$\land\ m.topic = t$
$\land\ canSendTo(broker)$
$\land\ network' = send(m,\ broker)$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“unsubscribing”}]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $store$
$\land$ UNCHANGED $used\_num$

$RcvUnsubscribeRes(self) \triangleq$
$\land\ pc[self] = \text{“unsubscribing”}$
$\land\ Len(network[self]) > 0$
$\land$ LET $m \triangleq Head(network[self])$ IN
$\land\ m.from = broker$
$\land\ m.to = self$
$\land\ m.type = UNSUBACK$
$\land\ network' = rcv(m,\ self)$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“connected”}]$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $store$
$\land$ UNCHANGED $used\_num$

$GetMsgWithQoS0(self) \triangleq$
$\land\ pc[self] = \text{“connected”}$
$\land\ Len(network[self]) > 0$

$\land$ LET $msg \triangleq Head(network[self])$IN
$\land\ msg.type = PUBLISH$
$\land\ msg.qos = 0$
$\land\ network' = rcv(msg,\ self)$
$\land \quad \lor\ Len(store[self]) = 0$
$\lor \quad \land\ Len(store[self]) > 0$
$\land \exists\, i \in 1\,..\,Len(store[self]) : store[self][i] \neq msg.packetID$
$\land\ store' = [store$ EXCEPT $![self] = Append(@,\ msg.packetID)]$
$\land$ UNCHANGED pc
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $used\_num$

$GetMsgWithQoS1AndRes(self) \triangleq$
$\land\ pc[self] =$ "connected"
$\land\ Len(network[self]) > 0$
$\land$ LET $msg \triangleq Head(network[self])$IN
$\land\ msg.to = self$
$\land\ msg.type = PUBLISH$
$\land\ msg.qos = 1$
$\land\ \exists\, m \in msgs :$
$\land\ m.type\ = PUBACK$
$\land\ m.from = msg.to$
$\land\ m.to = msg.from$
$\land\ m.packetID = msg.packetID$
$\land \quad \lor\ Len(store[self]) = 0$
$\lor \quad \land\ Len(store[self]) > 0$
$\land \exists\, i \in 1\,..\,Len(store[self]) : store[self][i] \neq msg.packetID$
$\land\ network' = response(m,\ m.from,\ m.to)$
$\land\ \ store' = [store$ EXCEPT $![self] = Append(@,\ msg.packetID)]$
$\land$ UNCHANGED pc
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $used\_num$

$GetMsgWithQoS2AndRes(self) \triangleq$
$\land\ pc[self] =$ "connected"
$\land\ Len(network[self]) > 0$
$\land$ LET $msg \triangleq Head(network[self])$IN
$\land\ msg.to = self$
$\land\ msg.type = PUBLISH$
$\land\ msg.qos = 2$
$\land\ \exists\, m \in msgs :$
$\land\ m.type\ = PUBREC$
$\land\ m.from = msg.to$

$\wedge\ m.to = msg.from$
$\wedge\ m.packetID = msg.packetID$
$\wedge \quad \vee\ Len(store[self]) = 0$
$\vee \quad \wedge\ Len(store[self]) > 0$
$\wedge\ \exists\, i \in 1\,..\,Len(store[self]) : store[self][i] \neq msg.packetID$
$\wedge\ network' = response(m,\ m.from,\ m.to)$
$\wedge\ store' = [store \text{ EXCEPT } ![self] = Append(@,\ msg.packetID)]$
$\wedge\ pc' = [pc \text{ EXCEPT } ![self] = \text{“waittingpubrel”}]$
$\wedge$ UNCHANGED $active$
$\wedge$ UNCHANGED $topic\_subscribers$
$\wedge$ UNCHANGED $used\_num$

$GetMsgWithQoS2PubRelAndRes(self) \triangleq$
$\wedge\ pc[self] = \text{“waittingpubrel”}$
$\wedge\ Len(network[self]) > 0$
$\wedge$ LET $msg \triangleq Head(network[self])$ IN
$\wedge\ msg.to = self$
$\wedge\ msg.type = PUBREL$
$\wedge\ \exists\, m \in msgs :$
$\wedge\ m.type = PUBCOMP$
$\wedge\ m.from = msg.to$
$\wedge\ m.to = msg.from$
$\wedge\ m.packetID = msg.packetID$
$\wedge\ network' = response(m,\ m.from,\ m.to)$
$\wedge\ pc' = [pc \text{ EXCEPT } ![self] = \text{“connected”}]$
$\wedge$ UNCHANGED $store$
$\wedge$ UNCHANGED $active$
$\wedge$ UNCHANGED $topic\_subscribers$
$\wedge$ UNCHANGED $used\_num$

$PublisherDone(self) \triangleq$
$\wedge\ pc[self] = \text{“connected”}$
$\wedge\ Len(network[self]) = 0$
$\wedge\ Cardinality(used\_num) = maxPubNum$
$\wedge\ \exists\, m \in msgs :$
$\wedge\ m.from = self$
$\wedge\ m.type = DISCONNECT$
$\wedge\ m.to = broker$
$\wedge\ canSendTo(broker)$
$\wedge\ network' = send(m,\ m.to)$
$\wedge\ pc' = [pc \text{ EXCEPT } ![self] = \text{“closed”}]$
$\wedge$ UNCHANGED $store$
$\wedge$ UNCHANGED $active$
$\wedge$ UNCHANGED $topic\_subscribers$
$\wedge$ UNCHANGED $used\_num$

$SubscriberDone(self) \triangleq$
$\land\ pc[self] = \text{“connected”}$
$\land\ Len(network[self]) = 0$
$\land\ \exists\, m \in msgs :$
$\land\ m.from = self$
$\land\ m.type = DISCONNECT$
$\land\ m.to = broker$
$\land\ canSendTo(broker)$
$\land\ network' = send(m,\ m.to)$
$\land\ pc' = [pc \text{ EXCEPT } ![self] = \text{“closed”}]$
$\land$ UNCHANGED $store$
$\land$ UNCHANGED $active$
$\land$ UNCHANGED $topic\_subscribers$
$\land$ UNCHANGED $used\_num$

$SubscriberAction \triangleq$
$\exists\, self \in subscribers :$
$\lor\ ReqConnect(self)$
$\lor\ RcvConnectRes(self)$
$\lor\ ReqSubscribe(self)$
$\lor\ RcvSubscribeRes(self)$
$\lor\ ReqUnsubscribe(self)$
$\lor\ RcvUnsubscribeRes(self)$
$\lor\ GetMsgWithQoS0(self)$
$\lor\ GetMsgWithQoS1AndRes(self)$
$\lor\ GetMsgWithQoS2AndRes(self)$
$\lor\ GetMsgWithQoS2PubRelAndRes(self)$
$\lor\ SubscriberDone(self)$

$PublisherAction \triangleq$
$\exists\, self \in publishers :$
$\lor\ ReqConnect(self)$
$\lor\ RcvConnectRes(self)$
$\lor\ ReqPublishWithQoS0(self)$
$\lor\ ReqPublishWithQoS1(self)$
$\lor\ RcvPublishWithQoS1Res(self)$
$\lor\ ReqPublishWithQoS2(self)$
$\lor\ RcvPubrecAndResPubrel(self)$
$\lor\ RcvPubComp(self)$
$\lor\ PublisherDone(self)$

$ClientsDone \triangleq$ whenall clients disconnneted
$\land\ \forall\, c \in clients :$
$\land\ pc[c] = \text{“closed”}$
$\land\ Len(network[c]) = 0$
$\land$ UNCHANGED $vars$