Fig. 4. State model of Contention window of S2 in steady state.

\[ P_1 = \text{Prob\{}S2 \text{ lies in "state 1" in steady state}\} \]
\[ P_2 = \text{Prob\{}S2 \text{ lies in "state 2" in steady state}\} \]
\[ \vdots \]
\[ P_N = \text{Prob\{}S2 \text{ lies in "state N" in steady state}\} \]

\[ \text{E[ Contention window size of S2]} = P_1^\star(CW) + P_2^\star(2CW) + \ldots + P_N^\star(2^{N-1}CW) \]
Fig. 2. The simplified model of the given system

The number of $S1 = m$ (2 $\leq$ m $\leq$ k)

The number of $S2 = n$ (0 $\leq$ n $\leq$ k - 2)

Note: A modified version of Stop- and- Wait could be simplified into the occupancy problem by binomial probability law. n and m out of k are determined by probabilities $P_i$, $Q_i=1-P_i$.
Fig. 3. Calculation of probability between random variables $X$, $Y$ with each different uniform distributions

$P_X(x) = 1/a$, if $x$ are in $[0,a]$ 
$= 0$, otherwise

$P_Y(y) = 1/b$, if $y$ are in $[0,b]$ 
$= 0$, otherwise

i) $a > b$

\begin{align*}
P(S1) &= P\{X < Y\} = b/2a, \\
P(S2) &= 1 - P(S1) = 1 - (b/2a)
\end{align*}

ii) $a < b$

\begin{align*}
P(S1) &= P\{X < Y\} = 1 - (a/2b), \\
P(S2) &= 1 - P(S1) = a/2b
\end{align*}
Fig. 1. Model of frame transmission in multiple access

Note:
1. We only consider two kinds of delay: transmission delay, queuing delay in analysis of delay for a packet, i.e., immediate feedback from R.
2. Assume that packets are transmitted in frames that are one time unit long, i.e., all transmission delay is 1.
3. After S1 fails to transmit a packet correctly, the next contention window size gets doubled.
4. Vacation time means two kinds of time usage: one is other’s occupation time, the other is all random back-off time.
5. Service time means the time taken for transmitting a packet by S1.
6. Looking into the above example, there are totally 3 transmits to R, two of them were done by S1, and the other by S2. (k=3, m=2, n=1 based on the binomial probability law)
Note:
7. $r_{1,S1}(t)$, $r_{1,S2}(t)$: random back-off time of each node which obeys uniform distribution $[0,CW]$
8. $t_{\text{prop},S2}(t)$: the propagation delay when $S2$ sends a packet to $R$
9. $t_{\text{proc},S2}(t)$: the processing delay when $R$ receives a packet from another
10. $t_{\text{trans},R}(t)$: the transmission time taken for $R$ to send ACK or NAK
11. 8~10 are ignored based on the assumption of immediate feedback.