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A STUDY ON THE BEHAVIOUR OF A TAGGED VEHICLE USING IRREDUCIBLE SMP MODEL

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ABSTRACT

The tagged vehicle is in idle state with probability u_b if there is no packet. After a packet is generated, the vehicle goes from state idle to state CS_1 with probability $1-u_b$, here the vehicle senses channel activity for DIFS time period. If the channel is detected not busy during this period (DIFS) (with probability $1-q_b$), the vehicle goes from idle state to TX state, which means that a packet is transmitting. Otherwise, the vehicle will defer until channel is idle for DIFS duration represented by state D_{CS}. Such deference behavior for the tagged vehicle includes two parts: waiting for the current packet in the channel finishing transmission and waiting for subsequent transmissions if any from other neighbors within its receiving range.

INTRODUCTION

The self-loop for state D_{CS} represents the phenomena in Fig (5.3) that the tagged vehicle (vehicle B) waits for the current packet (from vehicle A) in the channel finishing transmission, and then senses the channel for DIFS time, which seizes the transmission from another vehicle (vehicle C) and leads to further deference for backoff procedure of vehicle B. The probability that the tagged vehicle detects another neighbors transmission during DIFS time is denoted as r_b. If no other neighbors transmission is detected, the tagged vehicle will start backoff procedure and randomly choose a backoff counter in the range $[0, W-1]$, where $W = CW + 1$ is the backoff window size.

I. THE MODEL DESCRIPTION WITH MODIFIED SMP MODEL FOR BEACON MESSAGE DISSEMINATION

The backoff counter will be decreased by one if the channel is detected to be idle for a time slot of duration σ (with probability $1-p_b$), which is captured by the transition from state $W-i$ to state $W-i-1$.

If the channel is busy during a backoff time slot of duration σ (i.e., another vehicle starts to transmit a packet during this time slot), the backoff counter of the tagged vehicle will be suspended, which represented by the transition from state $W-i$ to D_{W-i-1} with probability p_b. Similar to state D_{CS}, state D_{W-i-1} also contains self-loop because other neighbors transmission can lead to further deference of the tagged vehicle. When the backoff counter reaches zero, the packet will directly be transmitted (an SMP transition occurs from state 0 to state TX with probability one). In TX state, a packet is transmitting. To capture the out-dated packet replacement behavior, which can happen during any state except state idle, we simplify the model by considering the total replacement probability and placing it after state TX. If the current packet has not been replaced by the next packet (with probability $1-P_f$), the SMP goes to state idle.

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Otherwise, this current packet is out-dated and replaced by the next incoming packet. Such simplification is reasonable since the packet transmission delay is usually much smaller than the packet generation interval and hence the replacement occurs extremely rare. Next, the tagged vehicle starts the service for the next packet immediately and senses the channel for DIFS time (state CS_2). A new backoff procedure is started subsequently for the new packet instead of inheriting the backoff state of the old message. This is mainly because the out-dated message may finish the backoff procedure and is replaced during its transmission. The SMP model proposed here captures more detailed DCF behavior for periodic beacon message transmission by adding more states and self-loop structure. In addition, out-dated message replacement behavior is incorporated into the model by the newly introduced model parameter P_f. The sojourn time in state j is defined as T_j. The mean and variance of T_j. in the SMP model are:

$$E\left[T_j\right]=\tau_j=\begin{cases} A_1 & j=TX \\ A_2 & j=idle \\ A_3 & j=CS_1,CS_2 \\ A_4 & j=D_{cs} \\ A_5 & j=D_0,D_1,D_2,...D_{W-2} \\ 0 & j=0 \\ \sigma & j=1,2,3,......,W-1 \end{cases}$$

$$Var\left[T_j\right]=0_j^2=\begin{cases} 0 & j\varepsilon U \ (set\,of\ states\exp ect\,idle) \\ B_1 & j=idle \end{cases}$$

Where

$$\begin{cases} A_1=\dfrac{PL}{R_d} \\ A_2=\tau-E\left[s\right] \\ A_3=DIFS \\ A_4=\dfrac{(A_1+DIFS)}{2} \\ A_5=A_1+DIFS \end{cases}$$

And

$$B_1=\text{var}[s]$$

T_H presents the time to transmit the packet header including physical layer header and MAC layer header. $E[S]$ and $Var[S]$ are the mean and variance of the overall message service time, which will be derived later. The sojourn time in state *idle* is the packet inter arrival time excluding the packet service time. In addition, to simplify the model, the sojourn times for channel sensing states (CS_1, CS_2, and $i=0,1,\cdots,W-1$ are modeled as deterministic using the upper bound channel sensing time (i.e., the sensing for each state only performs once). Such simplification may have impact on dense network in which channel contentions are severe. Moreover, the sojourn time in state D_{CS} is different from that in D_i ($i=0,1,\cdots,W-2$) is because the packet transmission from another vehicle may already started before the new packet is generated from the tagged vehicle. Therefore, on average, the tagged vehicle only defers for a half of the packet transmission time plus an additional idle DIFS duration in state D_{CS}. In contrast, for state D_i ($i=0,1,\cdots,W-2$), the start point of packet transmission from another vehicle is detected within the backoff time slot (state $i+1$), and hence the tagged vehicle needs to defer for the whole packet transmission time plus an additional idle DIFS duration. The embedded DTMC is solved for its steady-state probabilities for each state:

II. BALANCE EQUATION FOR THE STATES

For the State DCS

$$(1-rb)vDCS + vDVS \quad rb = vDVS \quad rb + vCS1qb$$

Therefore

$$v_{DCS} = \frac{vCS1}{(1-rp)^{v}} q \tag{1}$$

For the state CS_1

$$vCS_1 qb + vCS_1(1-qb) = v_{idle}.(1-ub)$$

Therefore

$$vCS_1 = v_{idle}.(1-ub) \tag{2}$$

For the $idle$ **state**

$$v_{idle}(1-ub) + v_{idleub} = vTX(1-pf)v_{idleub}$$

$$v - v_{idleTX} \frac{(1-pbf)}{(1-u)} \tag{3}$$

For the state TX

$$vTX = vCS_1(1-qb) + v_0$$

$$vTX = vCS_1(1-qb) + v_0$$

For the state CS_2

$$vCS2.1 = vTXpf \tag{5}$$

$$\upsilon_0.1 = \upsilon_{DCS}\left(\frac{1-r_b}{w}\right) + \upsilon_{CS_2}\frac{1}{w} + \upsilon_1(1-p_b) + \upsilon_{D_0}(1-r_b)$$

$$\upsilon_0 = \upsilon_{DCS}\left(\frac{1-r_b}{w}\right) + \upsilon_{CS_2}\frac{1}{w} + \upsilon_1(1-p_b) + \upsilon_{D_0}(1-r_b)$$

$$\upsilon_1 = \upsilon_{DCS}\left(\frac{1-r_b}{w}\right) + \upsilon_{CS_2}\frac{1}{w} + \upsilon_2(1-p_b) + \upsilon_{D_1}(1-r_b)$$

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$$\upsilon_j = \upsilon_{DCS}\left(\frac{1-r_b}{w}\right) + \upsilon_{CS_2}\frac{1}{w} + \upsilon_{j+1}(1-p_b) + \upsilon_{D_j}(1-r_b) \tag{6}$$

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$$\upsilon_{w-2} = \upsilon_{DCS}\left(\frac{1-r_b}{w}\right) + \upsilon_{CS_2}\frac{1}{w} + \upsilon_{w-1}(1-p_b) + \upsilon_{D_{w-2}}(1-r_b)$$

$$\upsilon_{w-1} = \upsilon_{DCS}\left(\frac{1-r_b}{w}\right) + \upsilon_{CS_2}\frac{1}{w} \tag{7}$$

Substituting the equation (7) in (6) we get

$$\upsilon_j = \upsilon_{w-1} + \upsilon_{j+1}(1-p_b) + \upsilon_{D_j}(1-p_b)\ ,\ j = 0,1,2......,w-2$$

$$\upsilon_j - \upsilon_{j+1} = \upsilon_{w-1} + p_b\upsilon_{j+1} + (1-r_b)\upsilon_{D_j}\ ,\ j = 0,1,2......,w-2 \qquad (8)$$

Substituting j=0, 1,2,….(w-2) in equation (8) and summing up we get

$$\upsilon_0 - \upsilon_1 = \upsilon_{w-1} - p_b\upsilon_1 + (1-r_b)\upsilon_{D_0}$$

$$\upsilon_1 - \upsilon_2 = \upsilon_{w-1} - p_b\upsilon_1 + (1-r_b)\upsilon_{D_1}$$

....

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$$\upsilon_0 - \upsilon_{w-1} = \upsilon_{w-1} - p_b\upsilon_{w-1} + (1-r_b)\upsilon_{D_{w-1}}$$

Adding the above equations we get

$$\upsilon_0 - \upsilon_{w-1} = (w-1)\upsilon_{w-1} - p_b(\upsilon_1 + ... + \upsilon_{w-1} + (1-r_b)(\upsilon_{D_0} + ... + \upsilon_{D_{w-2}}) \qquad (9)$$

CONCLUSION

In this paper the mathematical analysis for each state of the semi markov process is completely evaluated and the behaviour of the beacon message contenting for the channel resource is modeled. Also the steady state probability for the vehicle in transaction state is derived. The service time distribution using SMP model is evaluated.

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