CASE B :— (HARQ–II, when chase combining is done at receiver) (Analysis of Delay limit throughput (DLT))

(We assume a slow fading time-correlated channel.)

In this case, we study the HARQ-CC protocols in which destination node decodes an information packet by combining all previously received packets from previous retransmission rounds. The source can transmit a packet maximum L no. of times. Then, if NACK is received by the transmitter and the maximum no. of transmissions L is not reached, the source retransmits the packet at a possibly different power level. Receiver tries to decode the packet by combining the all previous transmissions of the same packet using maximal-ratio-combining.

If ACK is received by the transmitter or the maximum transmission number L is reached, the transmitter begins transmission of a new packet. The total SNR of the combined packets at the receiver at the l^{th} $(1 \le l \le L)$ retransmission round in the n^{th} slot is

$$\gamma_{n,l} = \frac{\sum_{i=1}^{l} P_i |h_i|^2}{N_0} \quad \text{——— (11)}.$$

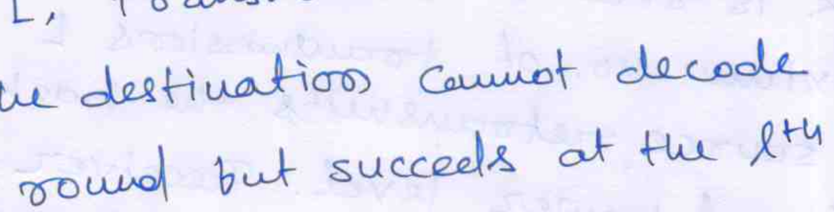
Thus for a targeted SNR γ_0, the probability of the event that the receiver fails to decode after l transmission for a Rayleigh channel with variance σ^2, is given as

$$P_{out,l} = \Pr\left[\gamma_{u,l} < \gamma_0\right] = 1 - e^{-\frac{\gamma_0 N_0}{\sigma^2 \sum_{j=1}^{l} p_j}}$$

Obviously $P_{out,l} = 1$ —— (12).

The probability that the EHWN stops at the l^{th}, $1 \leq l \leq L$, transmission round is $P_{out,l-1} - P_{out,l}$, i.e., the destination cannot decode correctly at the $(l-1)^{th}$ round but succeeds at the l^{th} round.

<u>Assumption</u>:- For eq^n (12) to be valid, we assume that channel is a slow fading time-correlated channel i.e. the channel doesn't change during retransmissions.



~~ess.~~ Essentially $L T_p << T_c$

As we need the state-space to be finite. To facilitate this, the channel is discretized into M levels, $h_1, \ldots h_M$. ~~In the correlated channel model,~~ The channel is modelled as the finite state Markov chain. ~~al so~~ The state transition probabilities for this FSMC $P_{h_k, h_{k+1}}, P_{h_k, h_{k-1}}, \forall k \in \{1, \ldots M\}$ are known.

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(12). <u>state space</u> : $\longrightarrow$ At time n, the state is given as

$$S_n = \left[B_n, H_n, S_n, E_n, P_n, l, P_1^l\right]$$

Where B_n, H_n, S_n, E_n, P_n assumes the usual meaning as described in section (7), while.

$$l \longrightarrow \text{transmission index}$$

$$\triangleq \{1, \ldots L\}$$

$$P_1^l = \sum_{m=1}^{l} P_m \quad \ldots \text{ power used till } m^{th} \text{ transmission round.}$$

(13). Transition probabilities: —

Let at time n and $(n-1)$, stages be.

$$S_n \triangleq (B_n, E_n, S_n, H_n, l, P_n, p_1^{l})$$

and $$S'_{n-1} \triangleq (B'_{n-1}, E'_{n-1}, S'_{n-1}, H'_{n-1}, l', P'_{n-1}, p_1^{l'})$$

Now, the transition probabilities $T(S_n, a, S'_{n-1})$ is given as

$$T(S_n, a, S'_{n-1}) = \delta(l', l_+) \cdot \eta\left[(B_n, E_n, S_n), a, (B'_{n-1}, E'_{n-1}, S'_{n-1})\right] \cdot P_{h_n, h'_{n-1}} \cdot \Psi\left[(P_n, p_1^{l}), a, (P'_{n-1}, p_1^{l'}); h_n, l'\right] \quad \text{—— (13).}$$

Where $$l_+ = (l \bmod L) + 1,$$

and $$\eta\left[(B_n, E_n, S_n), a, (B'_{n-1}, E'_{n-1}, S'_{n-1})\right]$$

$$= \delta(B'_{n-1}, B_n + E_n - a) \cdot p(E'_{n-1}, S'_{n-1} \mid E_n, S_n)$$

$$= \delta(B'_{n-1}, B_n + E_n - a) \cdot p(S_{n-1} \mid S_n) \cdot p(E_{n-1} \mid E_n, S_n) \quad \text{—— (14)}$$

and $\qquad \Psi\left((P_n, \beta_1^{l}), a, (P'_{n-1}, \beta_1^{l'}) ; h_n, l'\right)$ (7).

$$
= \begin{cases} \delta\left(\beta_1^{l} + \frac{a\varepsilon}{T_p}, \beta_1^{l'}\right) . P_{out,l} & l \neq L \text{ and } \cancel{P'_{n-1}} \; P'_{n-1} = P_n \\ \delta\left(\beta_1^{l'}, \frac{a\varepsilon}{T_p}\right) P_{out,l} & l = L \text{ and } P'_{n-1} = P_n \\ \delta\left(\beta_1^{l'}, \frac{a\varepsilon}{T_b}\right) \left(1 - P_{out,l}\right) & l = L \text{ and } P'_{n-1} = P_n + 1 \\ \delta\left(\beta_1^{l'}, \beta_1^{l} + \frac{a\varepsilon}{T_p}\right) \left(1 - P_{out,l}\right) & l \neq L \text{ and } P'_{n-1} = P_n + 1 \\ 0 & \text{Else.} \end{cases}
$$

$T_p \longrightarrow$ packet transmission duration.

$a\varepsilon \longrightarrow$ Energy spent when action a is taken ——— (15)

$\varepsilon =$ Minimum possible transmit energy.

<u>Rewards:</u> $\longrightarrow$ Similar to case A, we define a terminal reward.

$$R_{cc} : \mathcal{P} \rightarrow \mathbb{R}.$$

where, $\qquad R_{cc}(P+1) \geq R(P) \qquad \forall \; P \in \mathcal{P}.$

and $\qquad R(0) = 0$

At each time slot if action $a \in A$ is selected, the agent gets an immediate reward.

$$r_{cc}(\cdot) : (S_n, A, S'_{n-1}) \longrightarrow \mathbb{R}.$$

Which is specifically given as.

$$r(S_n, a, S'_{n-1}) = \begin{cases} -10, & \text{if } a > B_n \\ \dfrac{p_n |h_n|^2}{N_0 \gamma_0} & a \leq B_n . \end{cases} \qquad (16).$$

Where $p_n \longrightarrow$ power used during n'th slot.

$\gamma_0 \longrightarrow$ targeted SNR.