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# Medium Access Protocol Analysis and Design: An Error-event Approach

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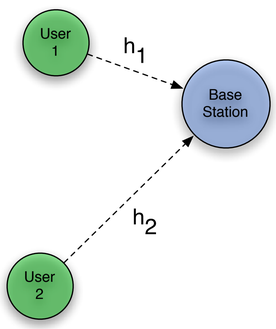
## Overview

- ***Motivation***
  - The performance of wireless multiple access systems is affected by different factors (e.g., channel, collisions, interference, etc.)
  - Current models emphasize a single factor
  - A wide variety Medium Access Control (MAC) protocols address only one factor
- ***Aim***
  - **Reverse engineer protocol performance in order to systematically forward engineer more efficient protocols for wireless multiple access systems**

## Error Event Approach

- ***Channel Model***
  - We concentrate on a 2-user system trying to communicate to a single Base Station
  - There is a fading channel between each one of the users and the base station
  - Users access the medium following different protocols

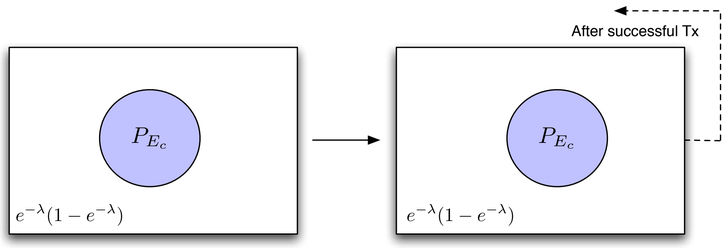



- ***Analysis Procedure***
  - In order to analyze the different MAC protocols, we propose the following procedure
    - 1) **Define** what is an error
    - 2) Identify **distinguishable** types of errors
    - 3) Find what **events** cause errors (this depends on the system model)
    - 4) Calculate the **probability** of the error-causing events
    - 5) Analyze the effects of the protocol's reaction in the **next step**

- ***Graphical Representation***
  - Our approach is suitable for graphical representation in the *space of possible events* at each *system state*
  - We introduce a diagram for each step in the protocol and it should convey the following information:
    - 1) Probability of each event
    - 2) Time required to reach that state
    - 3) Amount of information transmitted if successful
    - 4) Channel state
    - 5) Power used in transmission

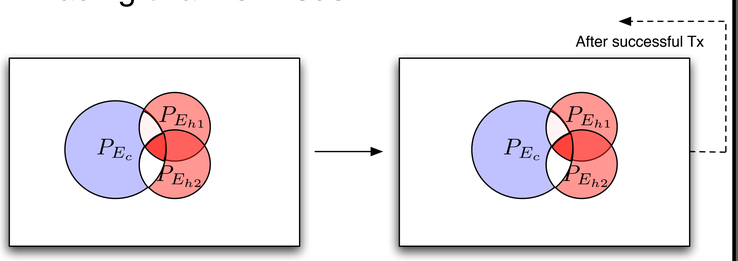
## Analysis Examples

- ***Slotted ALOHA***
  - Original model assumptions (coll. channel)




$$P_{E_c} = (1-e^{-\lambda})^2$$

  - Fading channel model




$$P'_{E_c} = (1-e^{-\lambda})^2$$

$$P'_{E_{h1}} = (1-e^{-\lambda})(1-\exp\left(\frac{-2^R-1}{SNR_1}\right))$$

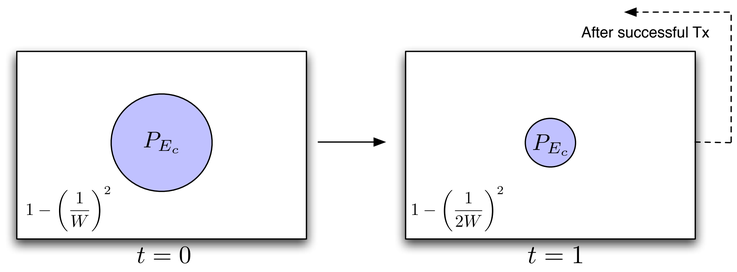
$$P'_{E_{h2}} = (1-e^{-\lambda})(1-\exp\left(\frac{-2^R-1}{SNR_2}\right))$$

$$P_{E_c} = P'_{E_c} - (P'_{E_c}P'_{E_{h1}} + P'_{E_c}P'_{E_{h2}} + 2P'_{E_c}P'_{E_{h1}}P'_{E_{h2}})$$

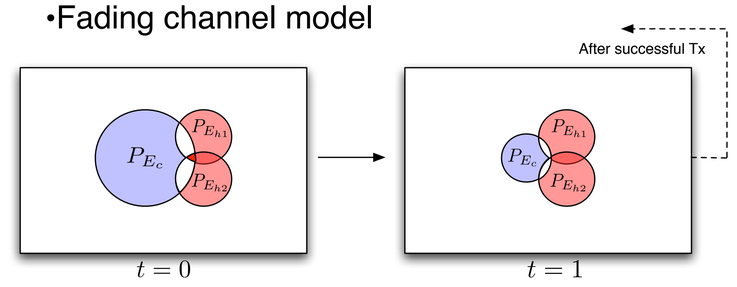
$$P_{E_{h1}} = P'_{E_{h1}} - P'_{E_c}P'_{E_{h1}}$$

$$P_{E_{h2}} = P'_{E_{h2}} - P'_{E_c}P'_{E_{h2}}$$

- ***802.11***
  - Original model assumptions (coll. channel)




  - Fading channel model




$$P'_{E_c}(t) = \left(\frac{1}{2^t W}\right)$$

$$P'_{E_{h1}} = 1-\exp\left(\frac{-2^R-1}{SNR_1}\right)$$

$$P'_{E_{h2}} = 1-\exp\left(\frac{-2^R-1}{SNR_2}\right)$$

- ***Observations***
  - The ALOHA protocol does not address any factor affecting the probability of error events
  - The 802.11 protocol reduces the possibility of back-to-back collisions, but was not designed to address the issue of fading channels
  - The approach can help identify unique situations (e.g., collision with 2 ch. in deep fade)
  - Protocols can be improved by reducing the size of the error events as part of the protocol design

## Conclusions

- **We have created a generalized analysis and design technique by evaluating protocols using error events**
- Our main contribution is the identification and aggregation of events into categories
- From this viewpoint, we can make our models and analysis reflect real-life behaviors