Analysis of New NFL Playoff Overtime Rules Using Markov Chains

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1. Introduction

It is well known that there is an advantage to the winner of the coin toss, who almost always chooses to go on offense first, in overtime (OT) in the National Football League (NFL). Between 1994 and 2009, about 60% of the coin toss winners went on to win the game [2]. Since it was first instituted in 1974, the NFL has had three different OT systems in place, including:

- Sudden Death (1974): First team to score wins.
- Regular Season OT (2010): If winner of the coin toss scores a touchdown, that team wins. If a touchdown is not scored or a field goal is scored, the other teams gets possession to either try to win the game by scoring or tie the game to continue play.
- Playoff OT (2022): Both teams are given possession. If a team is winning after both teams have possession, that team wins. If the game is tied, play becomes sudden death.

To analyze the impact of the coin toss in each system, we can use absorbing state Markov Chains.

2. Absorbing State Markov Chains

Since a Markov Chain for NFL Overtime during the playoffs has two absorbing states, team A winning and team B winning, the transition matrix can be divided into the following sections, along with the dimensions of each section:

$$\mathbf{P} = \begin{bmatrix} \mathbf{Q}(t \times t) & \mathbf{R}(t \times r) \\ \mathbf{0}(r \times t) & \mathbf{I}(r \times r) \end{bmatrix}$$

where t is the number of transient states and r is the number of absorbing states.

The absorbing state probabilities can be found using the equation:

$$B = (I - Q)^{-1} R$$

This creates a matrix where each value represents the probability of starting in transient state i and ending in absorbing state j.This matrix can be used to find the probability that Team A has the ball first and eventually wins.

3. Previous Model Analysis

For each overtime system, we will assume that Team A wins the coin toss and decides to receive the ball. Furthermore, we will assume the following:

- The probability of a safety is negligible.
- Teams can be assumed equal since making it to overtime means the game is tied.
- Since this model will be implemented into playoff games to start, ties are not possible as one team must win.

Jones, who provided the analysis for "Sudden Death," found that the probability of team A winning given they won the coin toss is:

$$P(\text{A wins}) = (1+\gamma)^{-1}$$

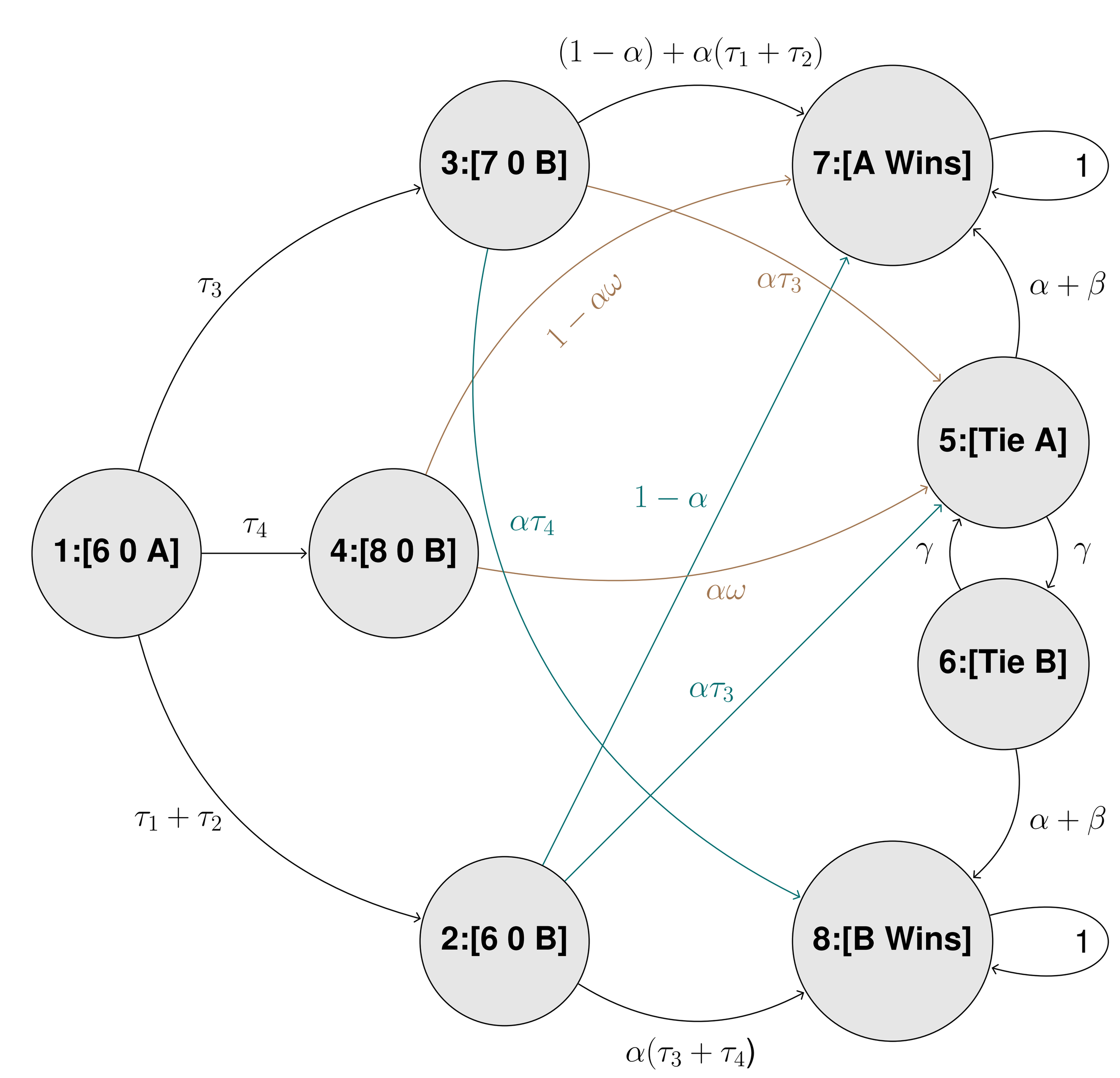
where γ is the probability of not scoring [1].

Leake and Pritchard, who provided the analysis for the "Regular Season OT," found that the probability of team A winning given they won the coin toss is:

$$\begin{aligned} P(\text{A wins}) &= P(\text{A wins}|\text{TD})P(\text{TD}) + P(\text{A wins}|\text{FG})P(\text{FG}) \\ &\quad + P(\text{A wins}|\text{NS})P(\text{NS}) \\ &= \alpha + \beta\left(\gamma + \frac{\beta}{1+\gamma}\right) + \gamma\left(\frac{\gamma}{1+\gamma}\right) \end{aligned}$$

where α is the probability of scoring a touchdown and β is the probability of scoring a field goal [2].

4. New Model Analysis



Just as with the previous models, an equation can be formed for the new model, and using an absorbing state Markov Chain, the probability of team A winning the game given they win the coin toss is found to be:

$$P(\text{A Wins}) = \alpha\lambda + \beta\left(\gamma + \frac{\beta}{1+\gamma}\right) + \gamma\left(\frac{\gamma}{1+\gamma}\right)$$

where λ is the probability of team A winning given they score a touchdown on the first drive.

The above directed graph and transition matrix can be created highlighting the probabilities of certain events occurring:

$$P = \begin{bmatrix} 0 & \tau_1+\tau_2 & \tau_3 & \tau_4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \alpha(\tau_1+\tau_2) & 0 & (1-\alpha) & \alpha(\tau_3+\tau_4) \\ 0 & 0 & 0 & 0 & \alpha\tau_3 & 0 & (1-\alpha)+\alpha(\tau_1+\tau_2) & \alpha\tau_4 \\ 0 & 0 & 0 & 0 & \alpha\omega & 0 & (1-\alpha\omega) & 0 \\ 0 & 0 & 0 & 0 & 0 & \gamma & (\alpha+\beta) & 0 \\ 0 & 0 & 0 & 0 & \gamma & 0 & 0 & (\alpha+\beta) \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

where

$$\begin{aligned} \tau_1 &= P(\text{Extra Point Not Scored}|\text{Attempted}) \\ \tau_2 &= P(\text{Two Point Conversion Not Scored}|\text{Attempted}) \\ \tau_3 &= P(\text{Extra Point Scored}|\text{Attempted}) \\ \tau_4 &= P(\text{Two Point Conversion Scored}|\text{Attempted}) \\ \omega &= P(\text{Two Point Conversion Scored}) \end{aligned}$$

We can use transition matrix P to find matrix B, and the first element of the resulting matrix would be λ from the above equation.

5. Conclusion

Using 2021 NFL data, we can compute estimates for all of the mentioned probabilities. The following table of probability comparison is formed for a team winning the coin toss and then going on to win the game:

Sudden Death	Regular Season	Playoff OT
0.616	0.574	0.551

This shows that the new model accomplishes, in theory, the goal of reducing the impact of winning the coin toss

6. References

[1] M. Jones, Win, lose, or draw: A Markov chain analysis of overtime in the National Football League, College Math. J. 35 (2004) 330–336.
[2] J. Leake and N. Pritchard, The Advantage of the Coin Toss for the New Overtime System in the National Football League, The College Mathematics Journal 46 (2015) 1-8.