A look at Overtime in the NFL

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Introduction

There is debate as to how NFL overtime games should be decided. In the current system a coin toss takes place and the team that wins has the choice to either kickoff or receive the ball. They can also defer this choice and choose an end of the field to defend. The game is played with regular NFL rules and the first team to score wins. In a regular season game the teams play for fifteen minutes, and if neither team scores the game is declared a tie. In the playoffs, where there must be a winner, they keep playing until someone scores.

Ideally, the winner in overtime should be independent of which team wins the toss, but this is not the case. In the period 2004-2008 72 regular-season games went into overtime. Of those, 46 were won by the team that received the overtime kick-off, giving a success rate of 64% for the team winning the toss (with one exception, teams always opt to receive rather than kick in overtime.) Over this period the loser of the coin toss won 25 games or just 35% of the time, with one game ending tied. Thus the coin flip is important in determining the winning team. Many games are won by the team receiving the ball before the opposition's offense even gets a chance to go onto the field. Of the 72 overtime games, 28, or 39% were won without the kicking team's offense touching the ball.

Using Markov chains we can verify that, given the likelihood of a score on any given possession, this success rate for the receiving team is what we might expect. We then look at an alternative method for deciding the winner of overtime games and how it could reduce (although not eliminate) the advantage afforded by the coin toss.

Game Data

In the 2008 season there were 5461 total possessions not ended by the completion of a half. Of them, 1122 ended in touchdowns by the offense and 845 ended in field goals. Thus 1967/5461=36% of possessions resulted in the offense scoring. This fits well the numbers from 2004-08, where 39% of overtime games are won with only one team ever having the ball. The difference between the number of possessions ending in a score (36%) and those overtime game ending on one possession (39%) can be explained by the more conservative approach an offense can take close to the goal, knowing that a field goal.

Of the 5461 possessions, 2294 ended in punts, in 231 the ball was turned over on downs, 155 field goal attempts were missed, and 708 resulted in non-scoring turnovers: fumbles and interceptions that were not returned for touchdowns. A total of 21, 52, and 33 possessions ended in safeties, interceptions returned for touchdowns, and fumbles returned for touchdowns respectively. Thus in any given possession we can assume the following probabilities:

36% result in the offense winning.

$\frac{2294+231+708+155}{5461} = 0.62$ or 62% result in a change of possession.

$\frac{21+52+33}{5461} = 0.019$ or 2% result in the defense winning via a turnover or safety.

Analyzing the current system

Let us assume we have two teams, A and B and that team A receives the overtime kick-off. We can create a Markov chain matrix for our four possible states. These states listed in order are "Possession for Team A", "Possession for Team B", "Team A won" and "Team B won." Table 1 we shows the probability of going from each row state to each column state.

	Possession for A	Possession for B	A wins	B wins
Possession for A	0	0.62	0.36	0.02
Possession for B	0.62	0	0.02	0.36
A wins	0	0	1	0
B wins	0	0	0	1

Table 1

The first row of the matrix T_1 tells us the probability of being in any given situation after one possession, assuming team A starts with the ball.

$$T_1 = \begin{bmatrix} 0 & 0.62 & 0.36 & 0.02 \\ 0.62 & 0 & 0.02 & 0.36 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

To find the probabilities after n possessions we take the matrix above to the nth power and again read along the top row. For example, after three possessions,

$$T_1^3 = \begin{bmatrix} 0 & 0.24 & 0.51 & 0.25 \\ 0.24 & 0 & 0.25 & 0.51 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Which says that after three possessions the probability of team A having won is 0.51, while the probability of team B having won is 0.25. This leaves a 0.24 probability that the game is still going and as we have completed three alternating possessions, team B has the ball, hence the entry in the second column of the first row.

Now we can look at how a game should finish given our analysis. During the 2008 regular season, there were approximately six possession per quarter, so we assume that the teams play until the end of six possessions. from

$$T_1^6 = \begin{bmatrix} 0.06 & 0 & 0.57 & 0.37 \\ 0 & 0.06 & 0.37 & 0.57 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

we see that there is a 6% chance of the game not having been completed, a 57% chance the receiving team wins, and a 37% chance the kicking team wins. This appears to overestimate the probability of a game not being completed because only once in 2004-2099 did a game end in a tie. This is no doubt caused by the effect previously mentioned whereby a team close to the goal can kick a field goal, safe in the knowledge that they only need three points to win and avoid the risk of a turnover close to the endzone while going for a touchdown. If we adjust the matrix to fit the data we can reduce the probability of a possession change and increase the probability of points being scored on any given possession.
By trial and error we obtain the matrix,

$$T_2 = \begin{bmatrix} 0 & 0.5 & 0.48 & 0.02 \\ 0.5 & 0 & 0.02 & 0.48 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

which when taken to the power six gives

$$T_2^6 = \begin{bmatrix} 0.02 & 0 & 0.64 & 0.34 \\ 0 & 0.02 & 0.34 & 0.64 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

This more accurately matches the results of overtime games over the five season period. The matrix states there is a 64% chance team A has won and a 34% chance B has won, with a 2% chance of a tie, which compares to 64%, 35%, and 1% from the actual games. However the estimate says that roughly 50% of games should be won without the kicking team getting the ball, which does not agree with the actual number of 39%.

An alternative proposal

We now consider a proposal that has been made to reduce the advantage of the coin toss. As we have seen, the sudden-death method gives a significant advantage to the team that receives the ball. One proposal has been that rather than playing until one team scores, the teams play with the first to six points winning. A game can still be won on one possession, but now it requires a touchdown rather than a field goal. If no touchdown is scored the winning team can score two field goals to win the game. While this does seem likely to balance out the advantage somewhat, we will see that the team that receives the ball does still have an advantage and now the game will, in general, go longer, either resulting in potentially long playoff games, or more ties from games in which the teams haven't reached the requisite six points by the end of fifteen minutes.

Teams act differently when they only need a field goal to win. Thus we shall assign different probabilities for scoring that depend on a team's situation. If a team has no points we shall take the probabilities from the games. The probabilities of a touchdown, field goal, change of possession, and opposition touchdown are given in the table below.

Outcome	Probability
Touchdown	$\frac{1122}{5461} = 0.21$
Field Goal	$\frac{845}{5461} = 0.15$
Turnover for touchdown	$\frac{52+33}{5461} = 0.02$
Change of possession	$\frac{2294+231+155+708+21}{5461} = 0.62$

Table 2

The change of possession includes punts, turnover on downs, missed field goals, non-scoring turnovers, and safeties. While a safety does not naturally fit into this category, a single safety essentially means only a change of possession as a team would still need two field goals or a touchdown to win, and the chance of two safeties for one team in a single overtime is negligible.

If a team already has three points, then it can switch to the conservative approach we believed they were using in the original overtime. As in matrix T_2 we now estimate that the probability of a score of any kind for the team in possession is 0.48, the probability of a change of possession is 0.5, leaving a probability of 0.02 of the defense scoring a touchdown. Summarizing the probabilities is a table, where the team in possession and the current score (with team A's points first) are listed, we get the following.

	A 0-0	B 0-0	A 3-0	B 3-0	A 0-3	B 0-3	A 3-3	B 3-3	A won	B won
A 0-0	0	0.62	0	0.15	0	0	0	0	0.21	0.02
B 0-0	0.62	0	0	0	0.15	0	0	0	0.02	0.21
A 3-0	0	0	0	0.5	0	0	0	0	0.48	0.02
B 3-0	0	0	0.62	0	0	0	0.15	0	0.02	0.21
A 0-3	0	0	0	0	0	0.62	0	0.15	0.21	0.02
B 0-3	0	0	0	0	0.5	0	0	0	0.02	0.48
A 3-3	0	0	0	0	0	0	0	0.5	0.48	0.02
B 3-3	0	0	0	0	0	0	0.5	0	0.02	0.48
A won	0	0	0	0	0	0	0	0	1	0
B won	0	0	0	0	0	0	0	0	0	1

Table 3

Putting these values into a Markov chain matrix T_3 and raising it to the sixth power we have

$$T_3^6 = \begin{bmatrix} 0.06 & 0 & 0.04 & 0 & 0.04 & 0 & 0.02 & 0 & 0.48 & 0.37 \\ 0 & 0.06 & 0 & 0.4 & 0 & 0.04 & 0 & 0.02 & 0.37 & 0.48 \\ 0 & 0 & 0.03 & 0 & 0 & 0 & 0.02 & 0 & 0.75 & 0.20 \\ 0 & 0 & 0 & 0.03 & 0 & 0 & 0 & 0.02 & 0.58 & 0.37 \\ 0 & 0 & 0 & 0 & 0.03 & 0 & 0.02 & 0 & 0.37 & 0.58 \\ 0 & 0 & 0 & 0 & 0 & 0.03 & 0 & 0.02 & 0.20 & 0.75 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.02 & 0 & 0.64 & 0.34 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.02 & 0.34 & 0.64 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Assume that A started with the ball, the top row tells us that the probability A has won after six possessions is 48% compared to 57% in the previous model. B's chance's have increased from 34% to 37%. Unfortunately, and unsurprisingly, a great deal of the drop in A's chance of winning comes not from an increase in team B winning, but from a larger chance of a game not being completed, which now has a 15% chance, compared to just 6% previously. Given our new rule, it is also more difficult for team B to win within six possessions, hence the increase in ties.

Finally we can look at how a playoff game, one with no time limit may turn out in the new system. We have

$$lim_{n\to\infty} T_3^n = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.57 & 0.43 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.43 & 0.57 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.78 & 0.22 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.60 & 0.40 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.40 & 0.60 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.22 & 0.78 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.65 & 0.35 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.35 & 0.65 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

The advantage to the receiving team is 57-43. This compares well with the 65-35 advantage we came up with in the first case (the 65-35 advantage occurs in rows 7 and 8 when we begin at 3-3, which is identical to the position we began with previously when any score will win.)

A final consideration is the length of the game. While we have said that length is irrelevant in an overtime game it is clearly of concern to the NFL for television scheduling.

The probabilities of the game being completed after a given number of possessions are in table 4.

Number of of possessions	Chance of completion
6	85%
8	93%
9	95%
10	97%
12	99%

Table 4

It takes us around twelve possessions, or one half of a football game to reach a 99% chance of the game having finished.

Conclusion

The conclusion we reach is not surprising. By requiring a total of six points be scored, the games average length of games will increase. Our T_2 matrix, in which there is a 0.5 probability of a team winning on any given possession, gives an expected number of possession of an overtime game of $\sum_{n=1}^{\infty} n(0.5^n) = 2$. In the new system the expected number of possessions is a much higher 9.3. Given the undesirability of a regular season game going beyond one quarter in overtime, and the lack of appetite among sports fans for games finishing in a tie, it seems unlikely that this new system would be beneficial for regular season games. However, one can see an appeal for a postseason playoff game. Not only is the advantage of the toss reduced which has to be good for fans who want the best team to win, but the fact that the game may go longer may not be such a bad thing for ratings-hungry television networks.

Author

Chris Jones received his BSc and PhD from the University of Salford, England having chosen the closest University to Manchester United for his study. His primary area of research is coding theory, which led him to a postdoc at the University of Virginia. He now teaches math at St. Mary's College of California in the Bay Area. He enjoys most sports and has discovered that a childhood love of cricket transfers nicely to baseball.

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