Kick or Receive?

Determining Optimal NFL Playoff Overtime Strategy Via Simulation



How Does NFL Scoring Work?

- Teams can score field goals (3 points)

- Teams can score touchdowns and…
  - convert the extra point (7 points)
  - convert a 2-point attempt (8 points)
  - fail at either (6 points)

What is Overtime?

- Additional gameplay used to determine a winner if an NFL game is still tied after four quarters
  - Regular season OT capped at 10 minutes
  - Playoff OT persists until someone wins

- Overtime starts with a coin toss where the visiting team calls heads or tails

- Coin toss winner elects whether to receive the ball or kick it off

History of NFL Overtime

History of NFL OT

Sudden Death
- first team to score wins
- 60% of teams who possess ball first win

Modified Sudden Death
- Both teams possess ball
(unless first team scores TD)
- 55% of teams who possess ball first win

Modern
- Both teams possess ball
- ?? % of teams who possess ball first win

1941 ***2010*** ***2022***





2024 Super Bowl: 49ers vs. Chiefs

- First NFL game to trigger new overtime rules
- San Francisco 49ers won the coin toss and chose to receive the ball first
- 49ers scored a field goal
- Chiefs responded with a touchdown to win the game, 28-25



Reactions

49ers' bizarre OT coin flip decision comes back to bite them in Super Bowl 2024

By Ryan Dunleavy

Published Feb. 12, 2024 | Updated Feb. 12, 2024, 1:23 a.m. ET

Why the Coin Toss Cost the 49ers the Super Bowl

Kyle Shanahan not knowing the rule led directly to the 49ers losing.

GRANT COHN • FEB 17, 2024 5:03 PM EST

The Niners Should Have Thought A Little Harder About The Overtime Rules



By Luis Paez-Pumar

1:18 PM EST on February 12, 2024

Chris Jones on 49ers' decision to take ball in overtime: "They're crazy"

By Mike Florio • Published February 12, 2024 02:40 PM

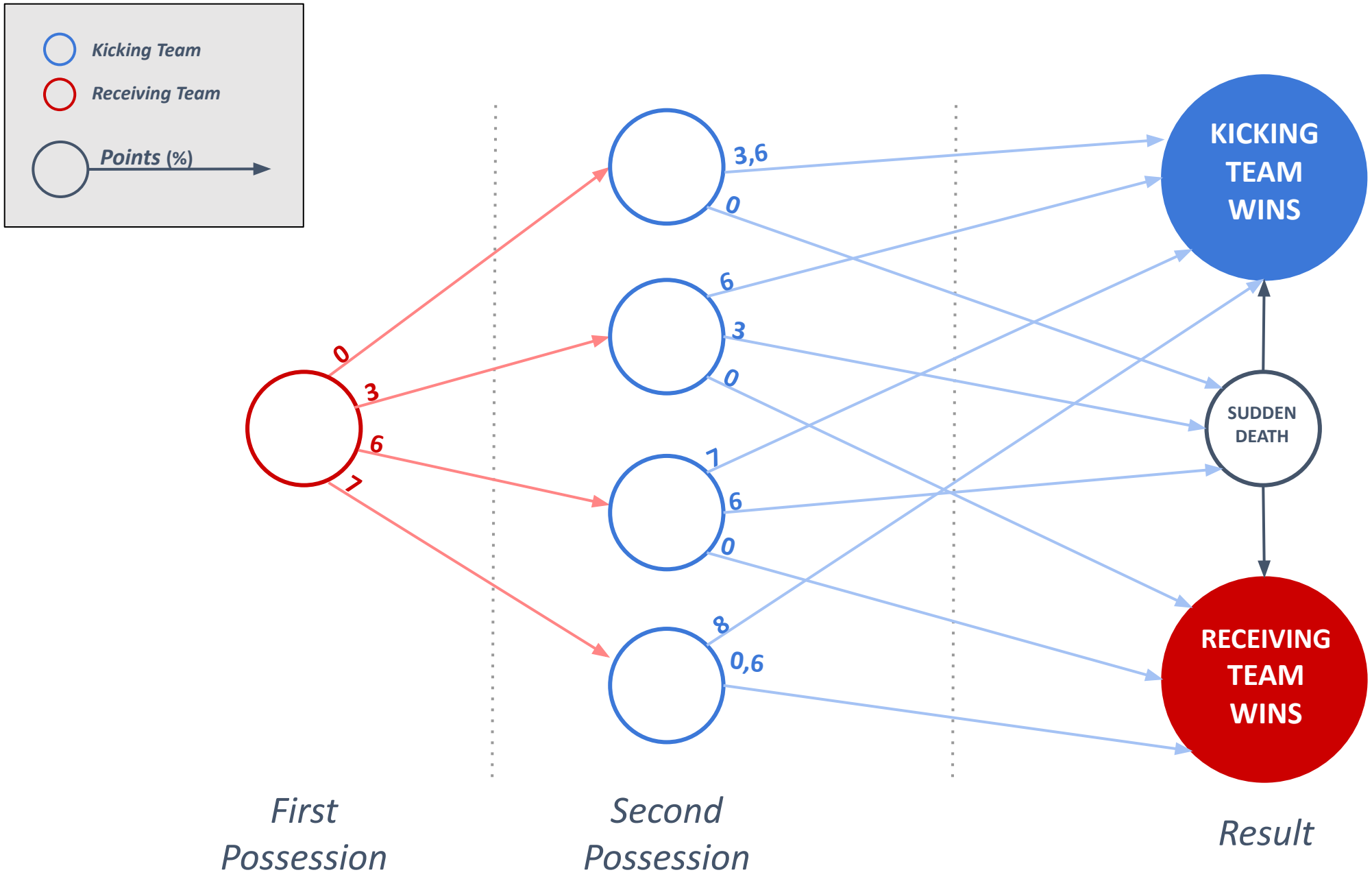
Was it actually wrong?

Determining Optimal Strategy

- Should teams that win the coin toss choose to kick or receive?

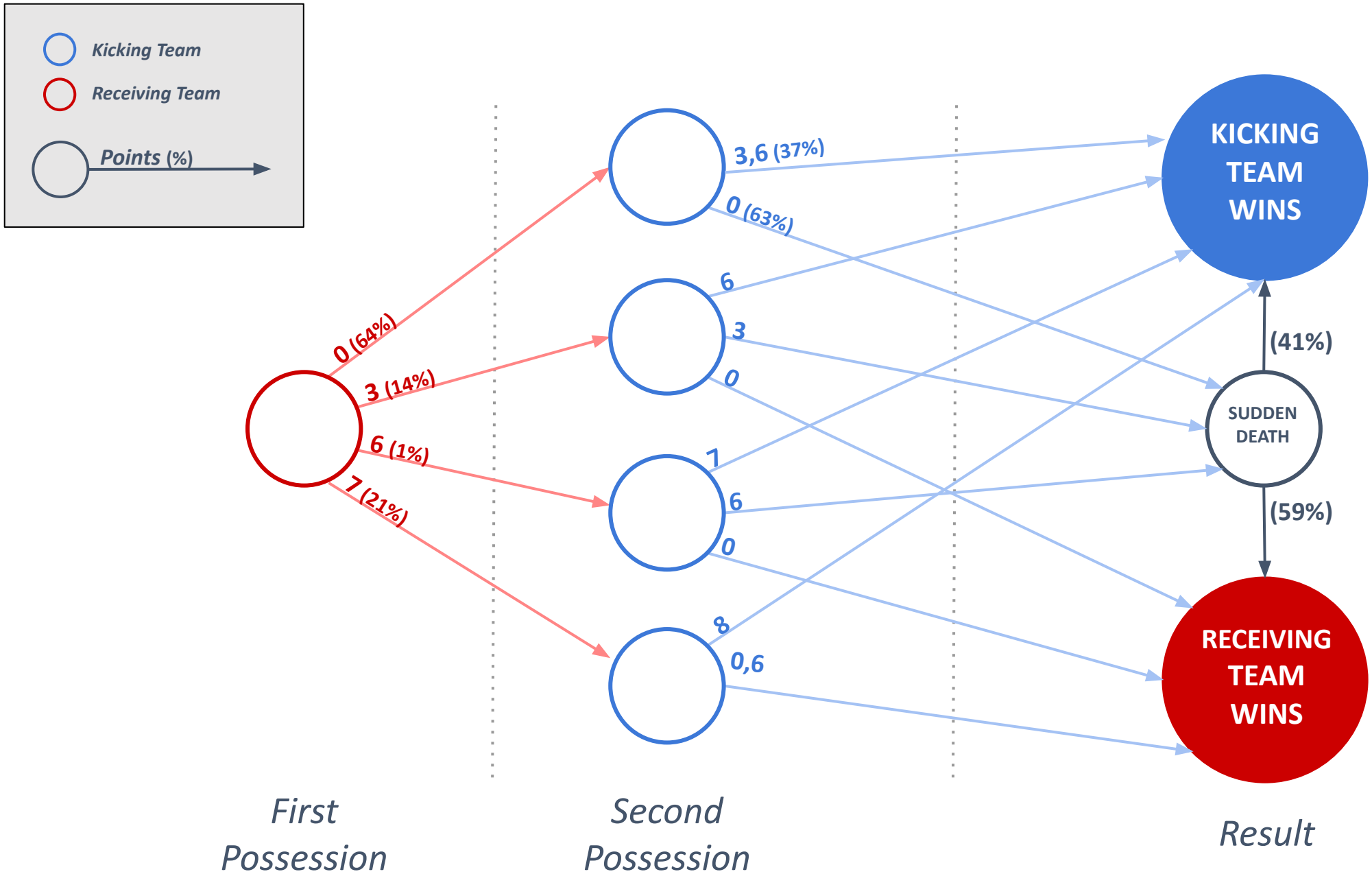
- Main debate is what advantage is greater?
  - Getting the first possession *and also the third* (when sudden death kicks in)
  - Getting the second possession and knowing how many points you need

- To compare these choices, we need to model overtime as a sequence of discrete states


Kicking Team
Receiving Team
Points (%)
0
3
6
7
3,6
0
6
3
0
7
6
0
8
0,6
KICKING TEAM WINS
SUDDEN DEATH
RECEIVING TEAM WINS
First Possession
Second Possession
Result

How do we get the transition probabilities?

- Source play-by-play data from nflfastR package (shoutout Ben Baldwin and Sebastian Carl)
- Some of the transition probabilities we can use empirical data to approximate
  - Scoring rates in tie games (opening drive or second drive after no score) can be drawn from historical distributions
  - Sudden death results from years of overtime can fill the “Sudden Death” node
- The rest we will have to simulate
  - The second possession for a team down a field goal
  - The second possession for a team down a touchdown


Kicking Team
Receiving Team
Points (%)
0 (64%)
3 (14%)
6 (1%)
7 (21%)
3,6 (37%)
0 (63%)
6
3
0
7
6
0
8
0,6
KICKING TEAM WINS
SUDDEN DEATH
(41%)
(59%)
RECEIVING TEAM WINS
First Possession
Second Possession
Result

How do we simulate a possession under unusual constraints?

- Create a sample of plays from teams in game situations where they were trying to score
  - no big score differentials, enough time left on game clock
  - buff sample by adding duplicates with slight mutations
- Initiate drive with random first play after kickoff
- Find next play by matching on down, distance, and field position
  - Example: A two-yard run on 1st-and-10 on the 25 will draw from all 2nd-and-8 plays from the 27
- Added constraints:
  - Teams can’t punt
  - Teams down 7 can’t go for field goals either
- Repeat until team scores or runs out of downs

```r
make_drive_down_TD <- function(){

  # sample first play
  first_play <- first_play_start %>%
    inner_join(play_sample, by = c("down", "ydstogo", "yardline_100", "goal_to_go")) %>%
    sample_n(1) %>%
    mutate(end = turnover | touchdown)

  # initiate drive
  drive <- first_play

  # add plays until drive ends
  while(sum(drive$end) < 1){

    # next play starts where previous one ended
    next_play_start <- drive %>%
      slice(nrow(.)) %>%
      select(yardline_100 = next_yardline_100,
             down = next_down,
             ydstogo = next_ydstogo,
             goal_to_go = next_goal_to_go)

    # join on down, distance, yardline
      next_play <- next_play_start %>%
        inner_join(play_sample, by = c("down", "ydstogo", "yardline_100", "goal_to_go")) %>%
        sample_n(1) %>%
        mutate(end = turnover | touchdown)

    }

    # increment drive
    drive <- bind_rows(drive, next_play)

  }

  drive

}
```

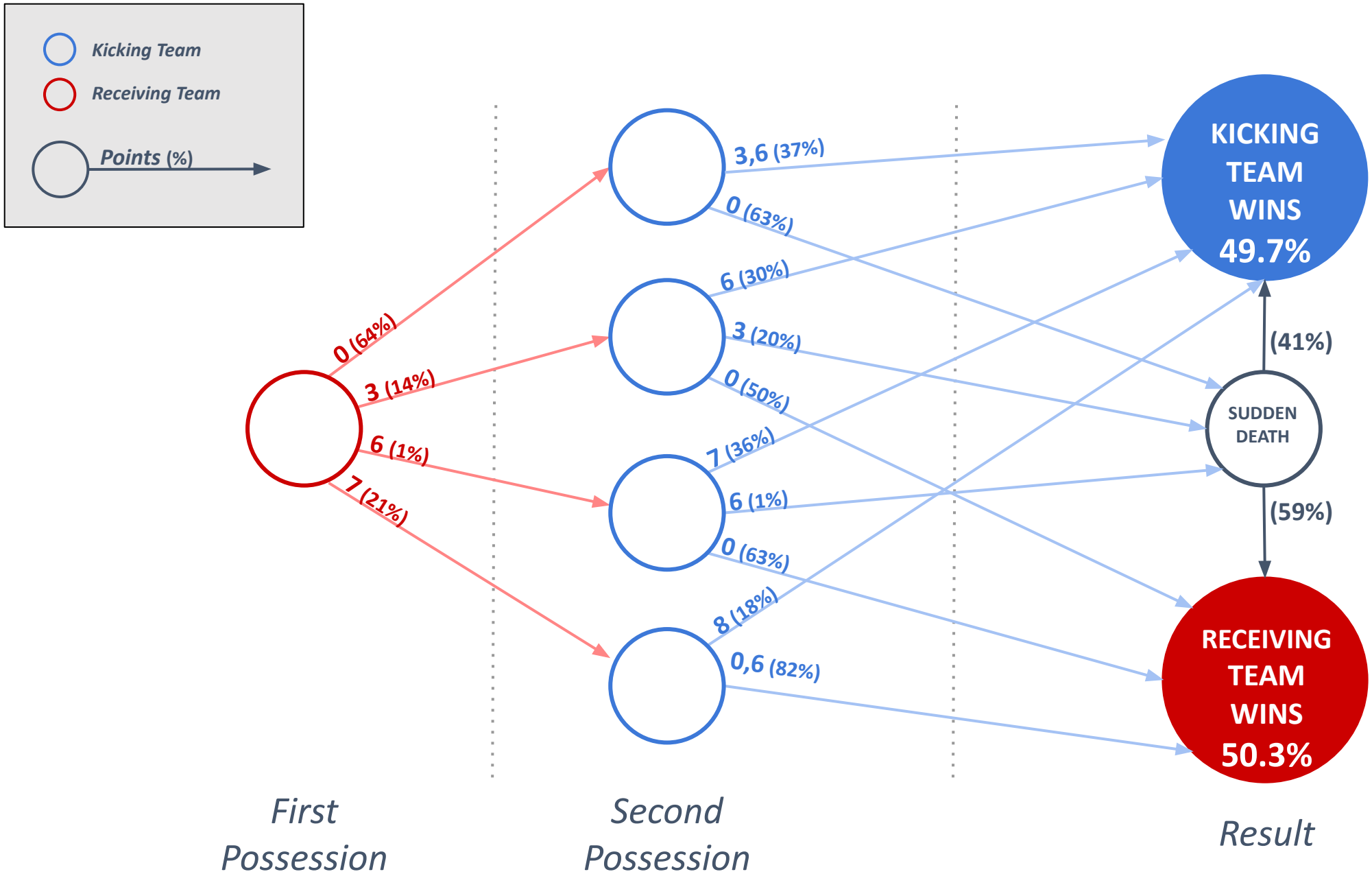
make_drive_down_TD()

yardline_100	down	ydstogo	yards_gained	touchdown	game_id	qtr	description
75	1	10	2	0	2017_13_WAS_DAL	1	(15:00) 46-A.Morris left tackle to DAL 27 for 2 yards (91-R.Ke...
73	2	8	31	0	2016_07_BAL_NYJ	3	(14:25) 14-R.Fitzpatrick pass short left to 22-M.Forte to BAL ...
42	1	10	-2	0	2023_02_MIN_PHI	2	(13:53) (No Huddle) 2-A.Mattison right guard to PHI 44 for -...
44	2	12	5	0	2018_17_CAR_NO	2	(7:09) 7-K.Allen pass short right to 40-A.Armah to NO 39 for...
39	3	7	0	0	2019_08_SEA_ATL	1	(:40) (Shotgun) PENALTY on ATL-71-W.Schweitzer, False Star...
44	3	12	0	0	2015_13_CIN_CLE	1	(8:38) (Shotgun) 7-A.Davis pass incomplete short left to 82-...
44	4	12	49	1	2017_17_CIN_BAL	4	(:53) (Shotgun) 14-A.Dalton pass deep middle to 83-T.Boyd ...

How can we speed it up?

- Replace dplyr::inner_join with collapse::join
- Replace dplyr::sample_n with dqrng::dqsample

```
Unit: milliseconds
                       expr      min       lq     mean   median       uq      max neval
 make_drive_down_TD_slow() 37.7582 243.8508 392.0060 376.5734 514.6807 1195.8033  1000
 make_drive_down_TD_fast() 20.3624 122.4919 205.9864 193.8778 266.4334  647.4269  1000
```


Kicking Team
Receiving Team
Points (%)
0 (64%)
3 (14%)
6 (1%)
7 (21%)
3,6 (37%)
0 (63%)
6 (30%)
3 (20%)
0 (50%)
7 (36%)
6 (1%)
0 (63%)
8 (18%)
0,6 (82%)
KICKING TEAM WINS 49.7%
SUDDEN DEATH
(41%)
(59%)
RECEIVING TEAM WINS 50.3%
First Possession
Second Possession
Result

Conclusions

- New overtime rules are close to being completely fair and show no obvious advantage for winning the coin toss
- The 49ers decision to receive the ball first is entirely defensible
- Some people don’t like my chart

