60802 Time Sync – Monte Carlo Simulations with RR & NRR Drift Tracking and Compensation – Initial Results

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Version 2

References

1 – David McCall "60802 Time Synchronisation – Monte Carlo Analysis: 100-hop Model, "Linear" Clock Drift, NRR Accumulation – Overview & Details, Including Equations – v2", contribution to IEC/IEEE 60802, September 2022

Contents

- Overview of Simulation
- Initial Results
- To Investigate

Overview of Simulation

- Simulation continues to model many “runs” of a single Sync message.
  - Each run is independent of any other run.
  - Typical number of runs is 100,000 (10mins) to 3,000,000 (well over 5 hours; does not scale entirely linearly)
- Mostly models errors, not the passage of time, but…
- Includes limited model of time for clock drift via temperature ramp
  - Hybrid Monte Carlo / Time Series at this point…but time series aspect is very limited.
- All calculations for a given hop are done in parallel for all runs.
- Each run includes limited modelling of prior Sync messages and Pdelay_Req / _Resp messages necessary to calculate errors.

Initial Results

Default Configuration

```
hops <- 100 # Minimum 1 hop
runs <- 100000
#
# Input Errors, Parameters & Correction Factors
driftType <- 4 # 1 = DO NOT USE - Historical - Uniform Probability Distribution between MIN & MAX ppm/s
        # 2 = Probability Based on Linear Temp Ramp
        # 3 = Probability Based on Half-Sinusoidal Temp Ramp
        # 4 = Probability Based on Quarter-Sinusoidal Temp Ramp
# Clock Drift Probability from Temp Curve & XO Offset/Temp Relationship
tempMax <- +85 # degC - Maximum temperature
tempMin <- -40 # degC - Minimum temperature
tempRampRate <- 1 # degC/s - Drift Rate for Linear Temp Ramp
tempRampPeriod <- 125 # s - Drift Period for Sinusoidal & Half-Sinusoidal Temp Ramps
tempHold <- 30 # s - Hold Period at MIN and MAX temps before next temp ramp down or up
GMscale <- 1 # Ratio of GM stability vs. standard XO. 1 is same. 0 is perfectly stable.
nonGMscale <- 1 # Ratio of non-GM (and non-ES) node stability vs. standard XO. 1 is same. 0 is perfectly stable.
```

Default Configuration

TSGEtx <- 4 # +/- ns - Error due to Timestamp Granularity on TX

TSGErx <- 4 # +/- ns - Error due to Timestamp Granularity on RX

DTSEtx <- 6 # +/- ns - Dynamic Timestamp Error on TX

DTSErx <- 6 # +/- ns - Dynamic Timestamp Error on RX

pDelayInterval <- 125 # ms - Nominal Interval between two pDelay measurements

PDImax <- 1.3 # Max factor for Tpdelay2pdelay (uniform linear distribution max of pDelayInterval x PDImax)

PDImin <- 0.9 # Min factor for Tpdelay2pdelay (uniform linear distribution min of pDelayInterval x PDImin)

syncInterval <- 125 # ms - Nominal Interval between two Sync messages

SImode <- 3 # Mode for generating Tsync2sync *HARD CODED to MODE 3*

1 = Gamma Distribution, defaulting to 90% of Tsync2sync falling within 10% of the nominal syncInterval. Truncated at SImax (higher values above are reduced to SImax)

No truncation of low values

2 = Gamma Distribution, defaulting to 90% of Tsync2sync falling within 10% of the nominal syncInterval. Truncated at SImax (higher values are reduced to SImax)

Truncated at SImin (lower values are increased to SImin)

3 = Uniform, linear distribution between syncInterval x SImin and syncInterval x SImax

Default Configuration

```
SIscale <- 1 # Scaling factor for Mode 1 & 2 Tsync2sync vs regular distribution.
        # Scaling factor of 3 would mean 90% of Tsync2sync falling within 30% of the nominal syncInterval
SImax <- 1.048    # For mode 1 & 2, Max truncation factor (e.g. 2x syncInterval) limit for Tsync2sync; higher values reduced to SImax
            # For mode 3, upper limit of uniform linear distribution
SImin <- 0.952    # For mode 1 & 2, Min truncation factor (e.g. 0.5 x syncInterval) limit for Tsync2sync; higher values reduced to SImin
            # For mode 3, lower limit of uniform linear distribution
pDelayTurnaround <- 15 # ms - TpdelayTurnaround maximum; higher values truncated
pathDelayMin <- 5 # ns - 1m cable = 5ns path delay
pathDelayMax <- 500 # ns - 100m cable = 500ns path delay
PDTmin <- 1 # TpdelayTurnaround minimum; lower values truncated
PDTmean <- 10 # TpdelayTurnaround mean
PDTsd <- 1.8 # TpdelayTurnaround sigma; 3.4ppm will fall outside 6-sigma either side of the mean
residenceTime <- 15 # ms - TresidenceTime maximum; higher values truncated
RTmin <- 1 # TresidenceTime minimum; lower values truncated
RTmean <- 5 # TresidenceTime mean
RTsd <- 1.8 # TresidenceTime sigma; 3.4ppm will fall outside 6-sigma either side of the mean
```

Default Configuration

mLinkDelayAverage <- 50 # Number of Path Delay calculations, from Pdelay_Req & _Resp messages

that are averaged to generate mLinkDelay

mNRRsmoothingNA <- 4 # Whole Number >=1 - Combined N & A value for "smoothing" calculated mNRR (mNRRc)

Calculate mNRR using timestamps from Nth Sync message in the past

Then take average of previous A mNRRcalculations.

mNRRcompNAP <- 4 # Whole Number >=1

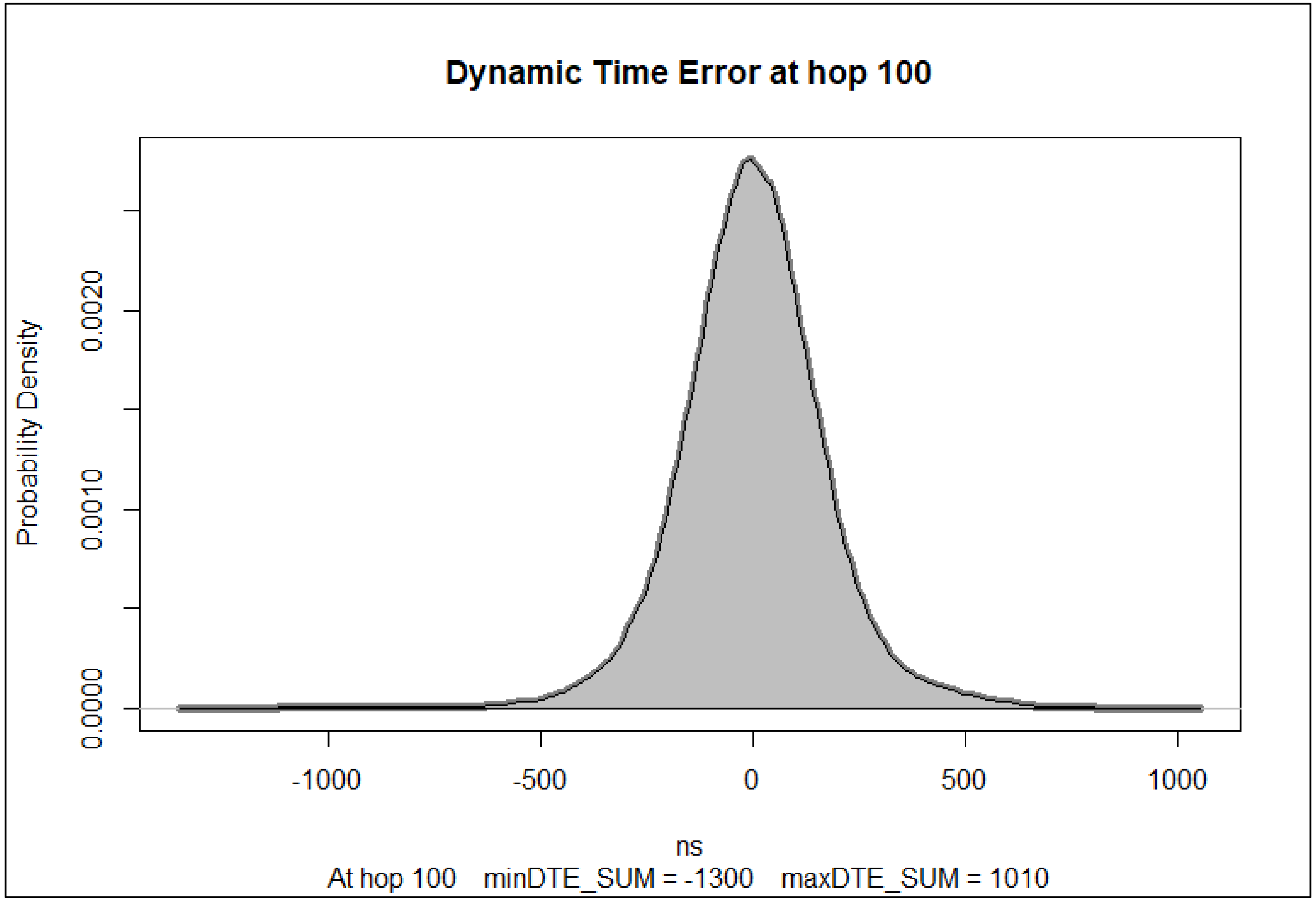
For NRR drift rate error correction calculations, take two measurements, mNRRa and mNRRb.

Both use timestamps from Nth Sync message in the past, then take average of previous A calculations.

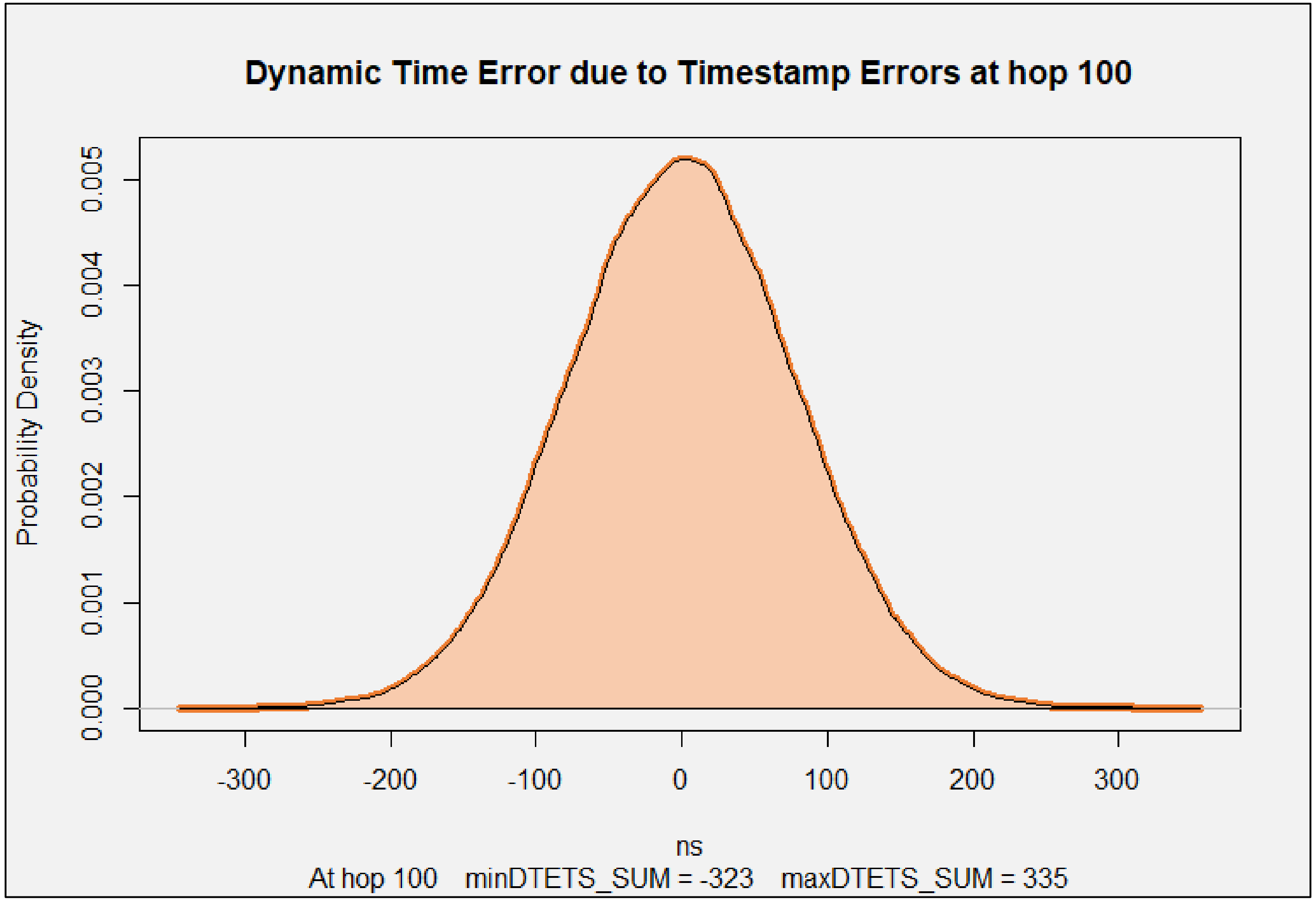
Calculation mNRRb starts P calculations in the past from mNRRa, where P = mNRRcompNAP * 2.

If 0, there is no NRR drift rate error correction.

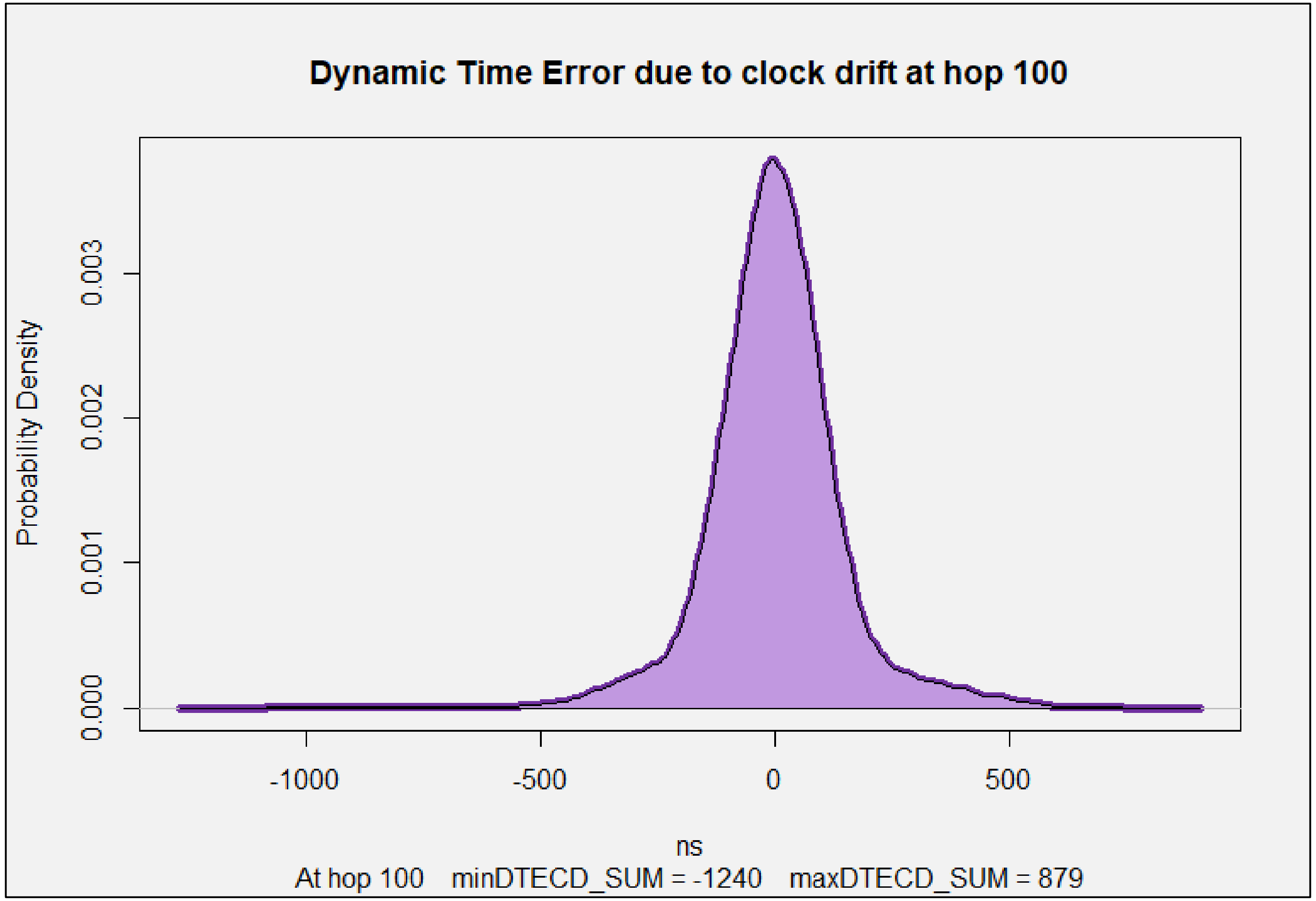
Default Configuration Results



Default Configuration Results



Default Configuration Results



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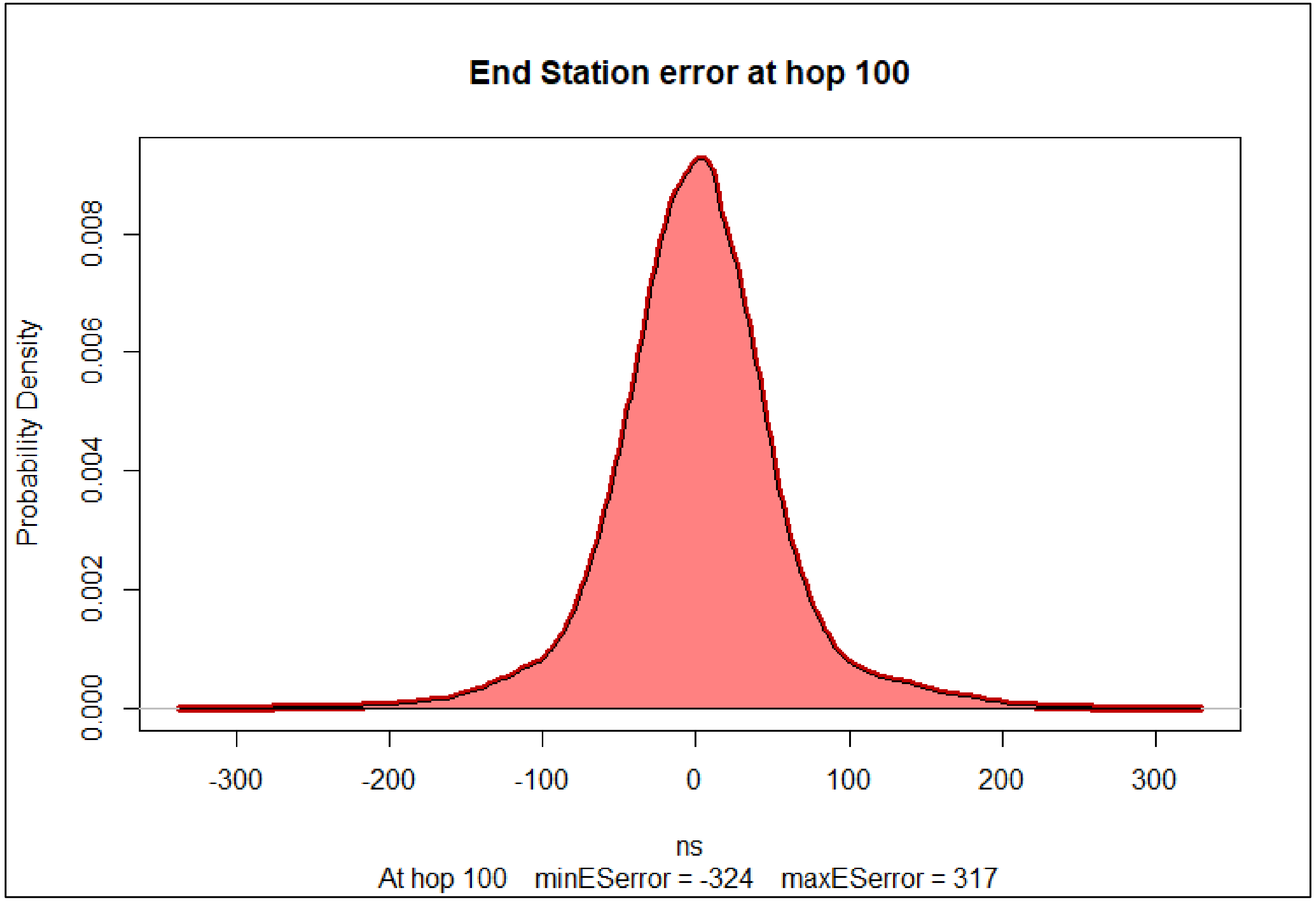

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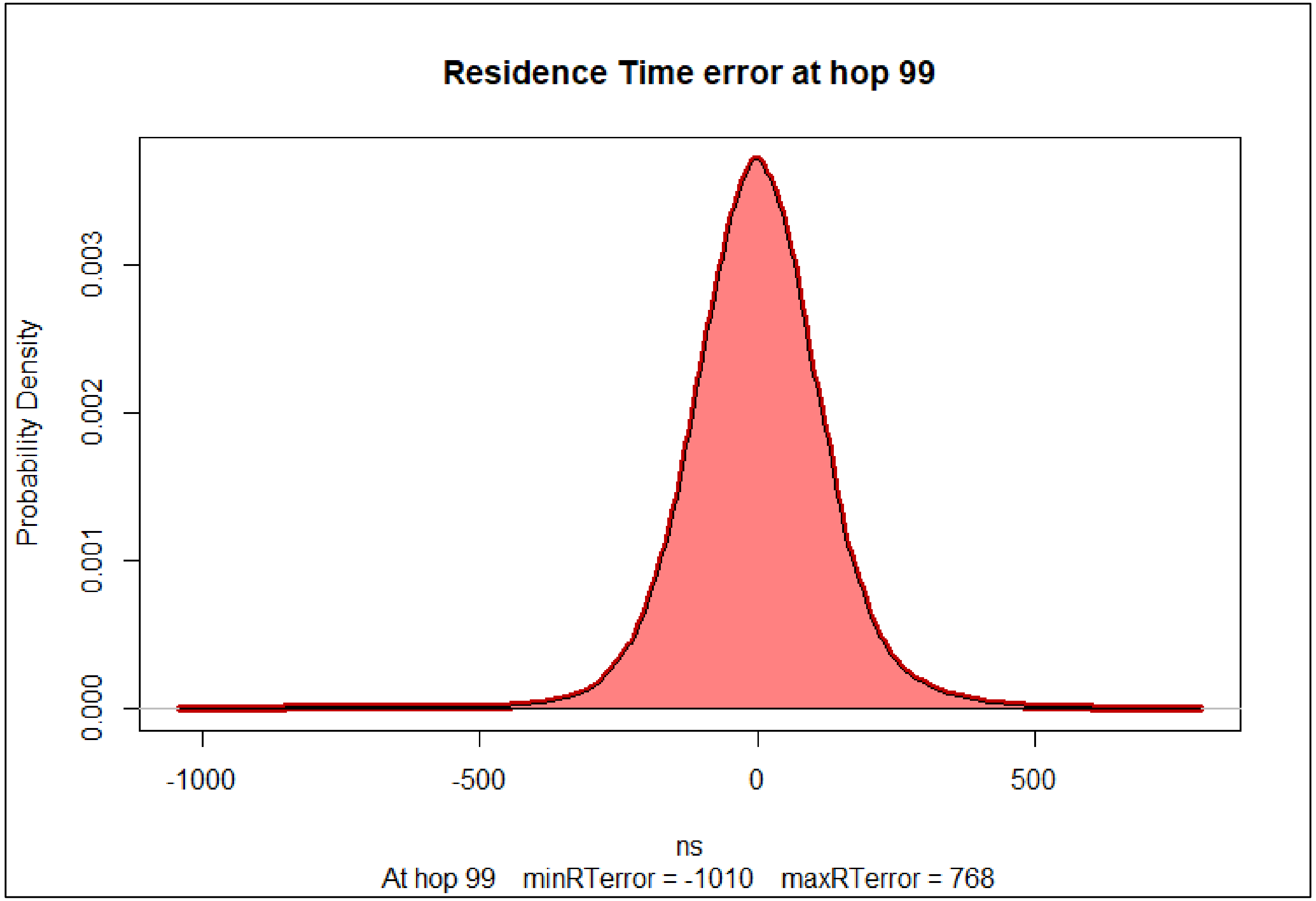
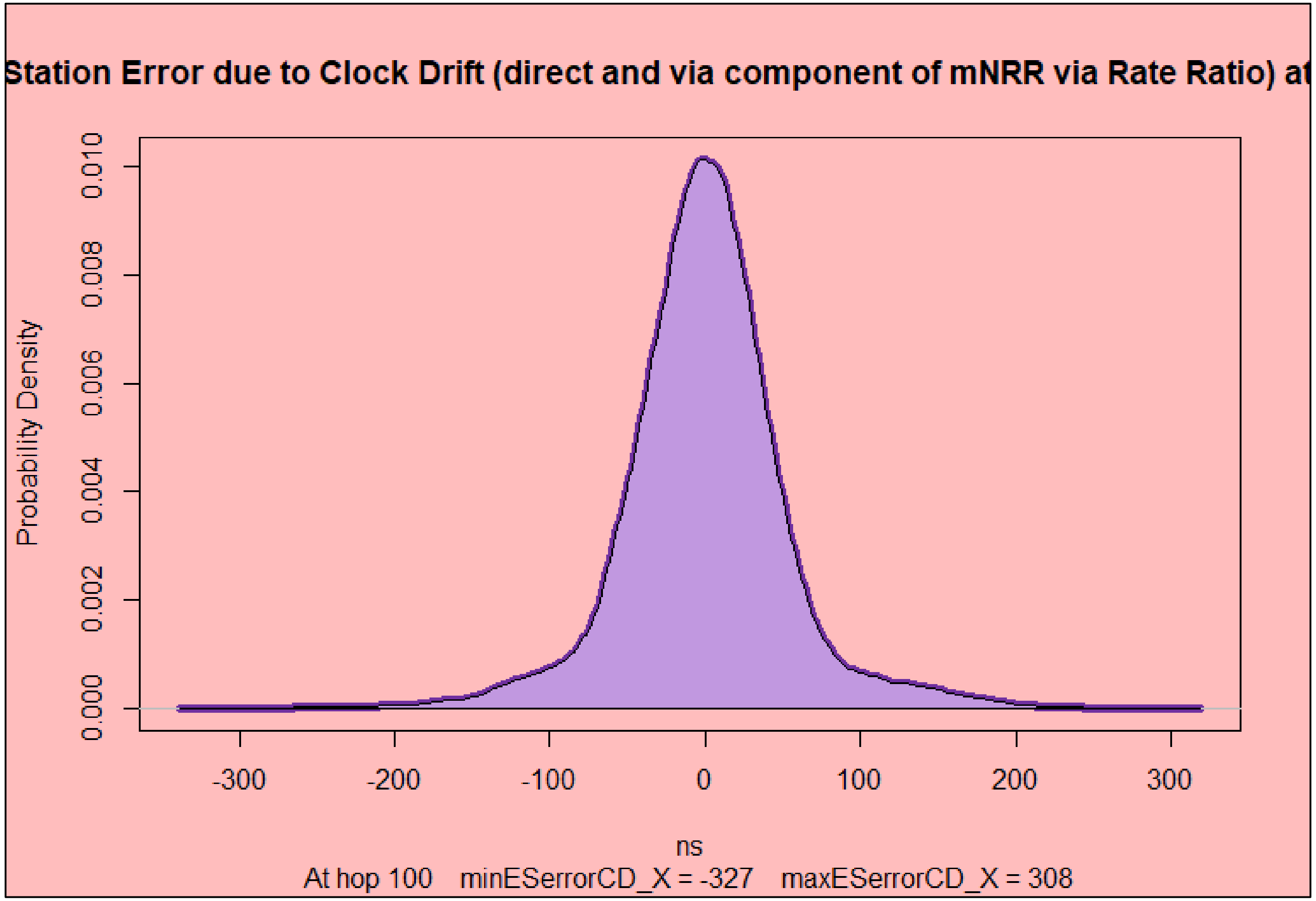
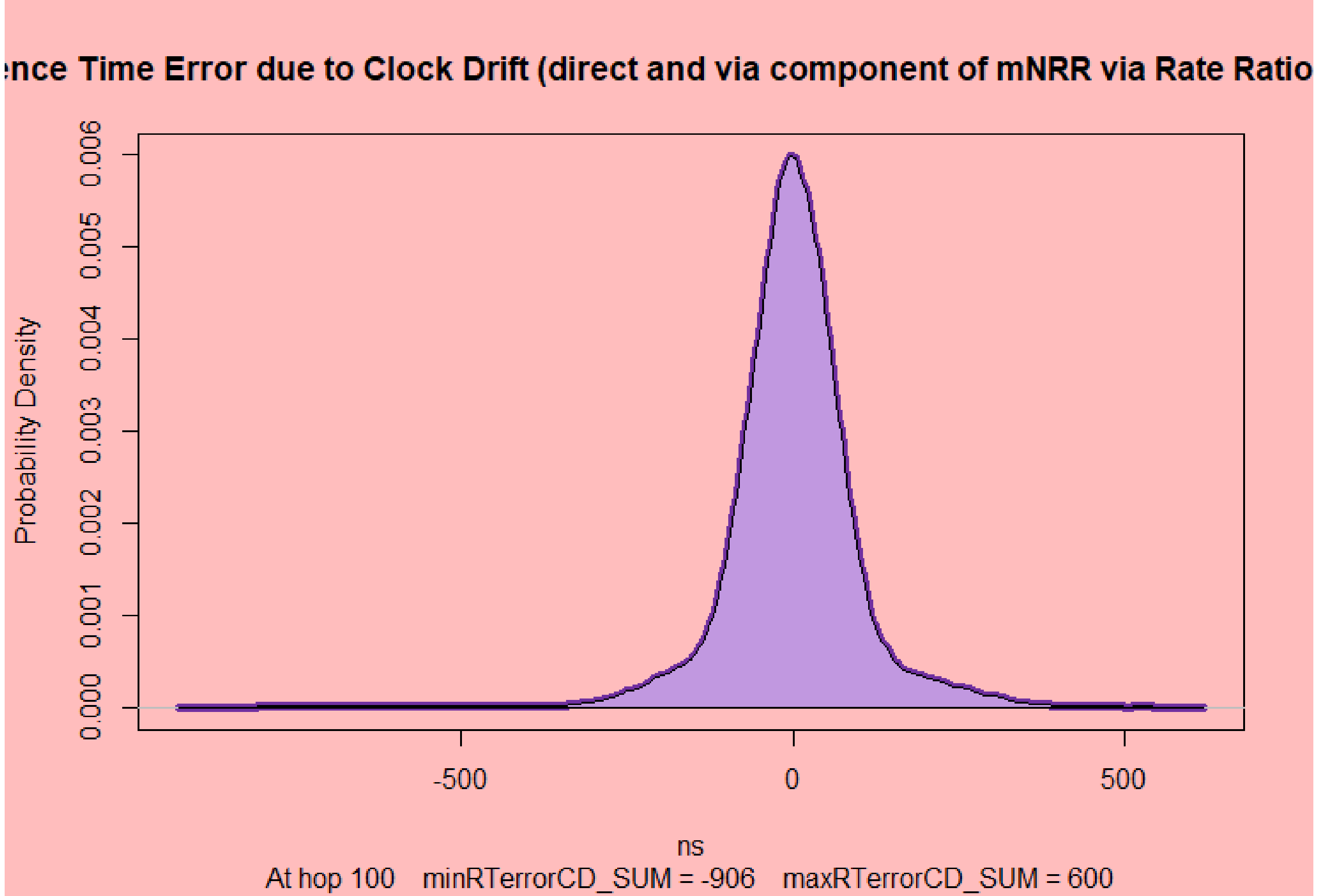


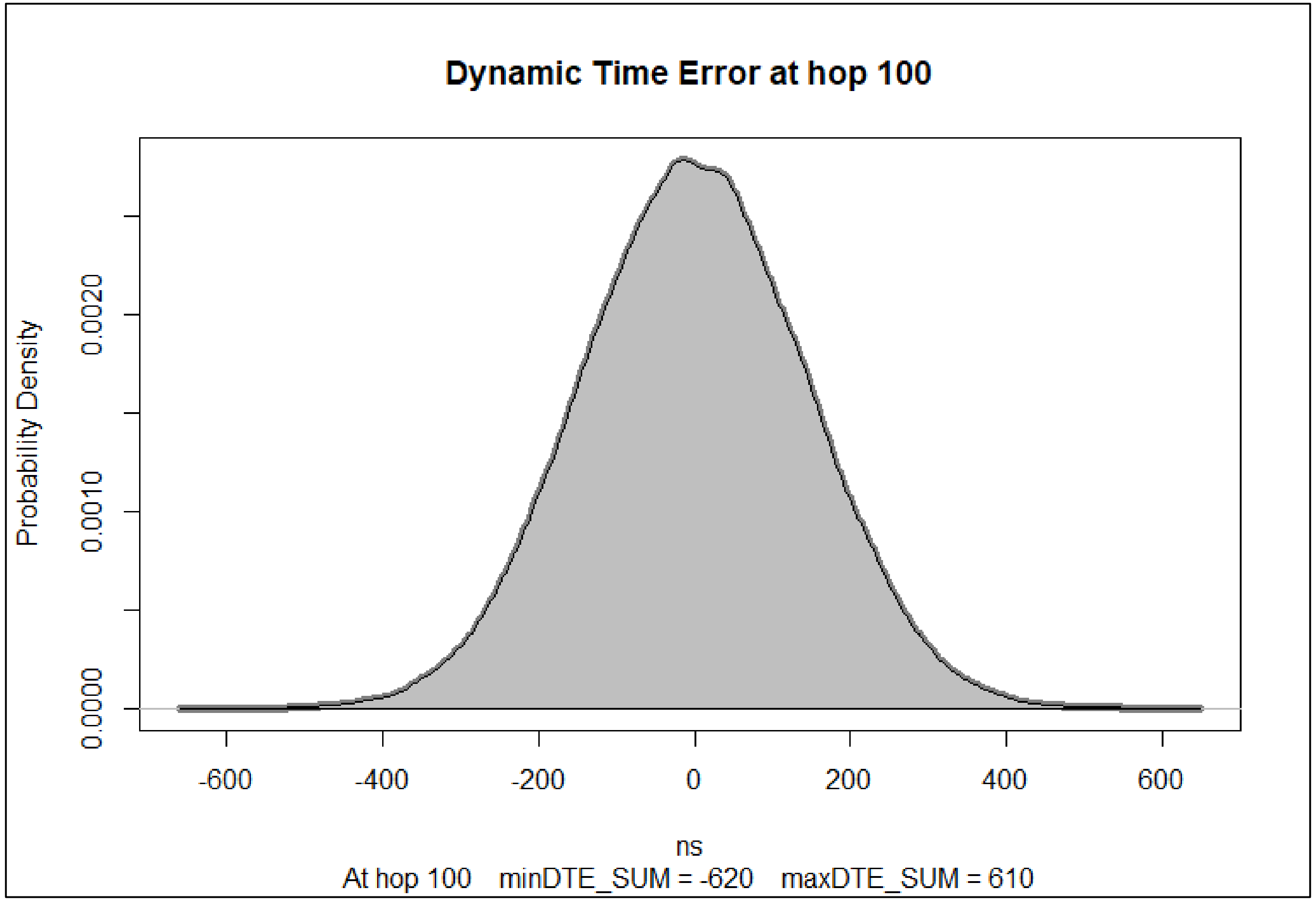
Default Configuration Results



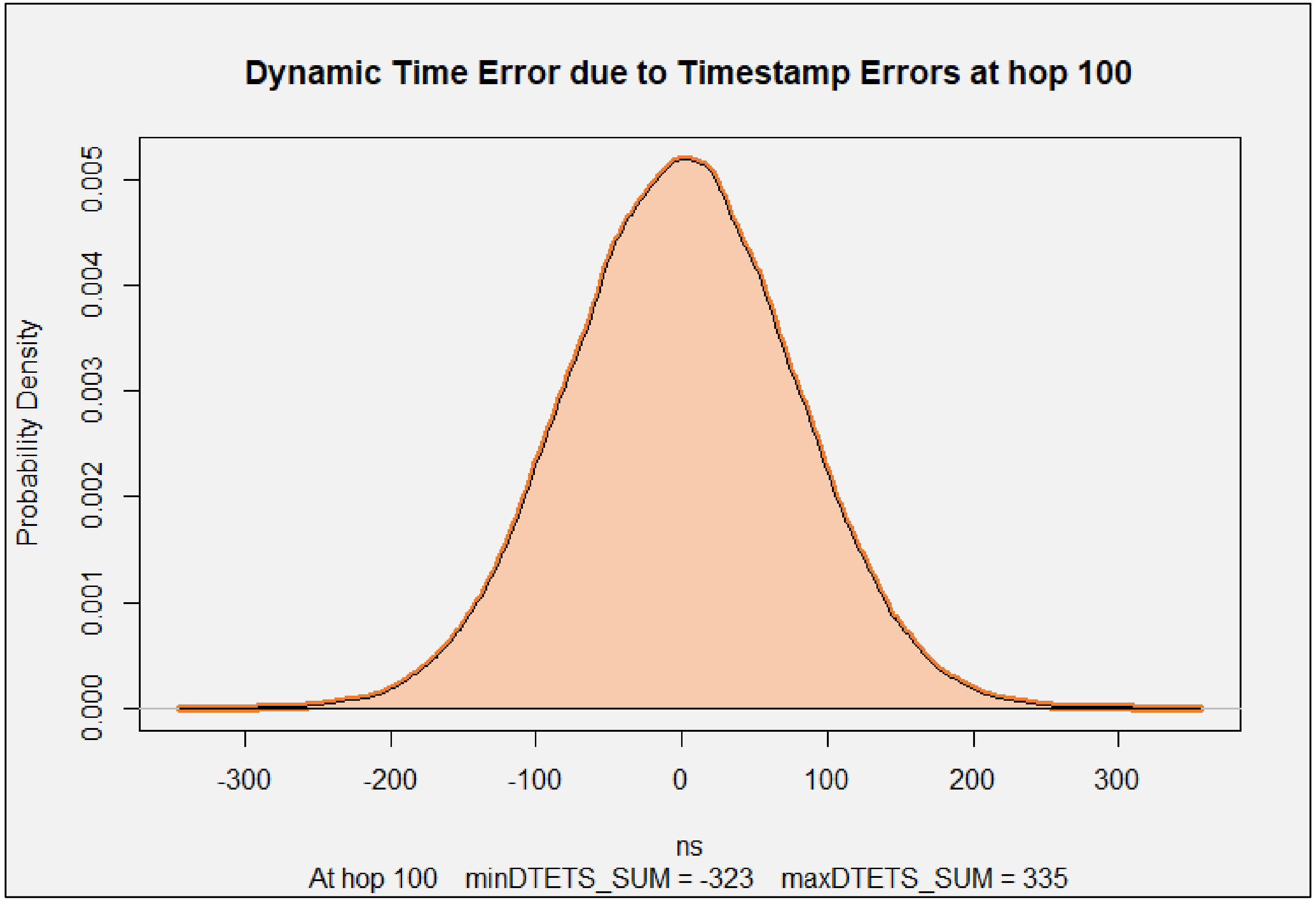
Default Configuration Results



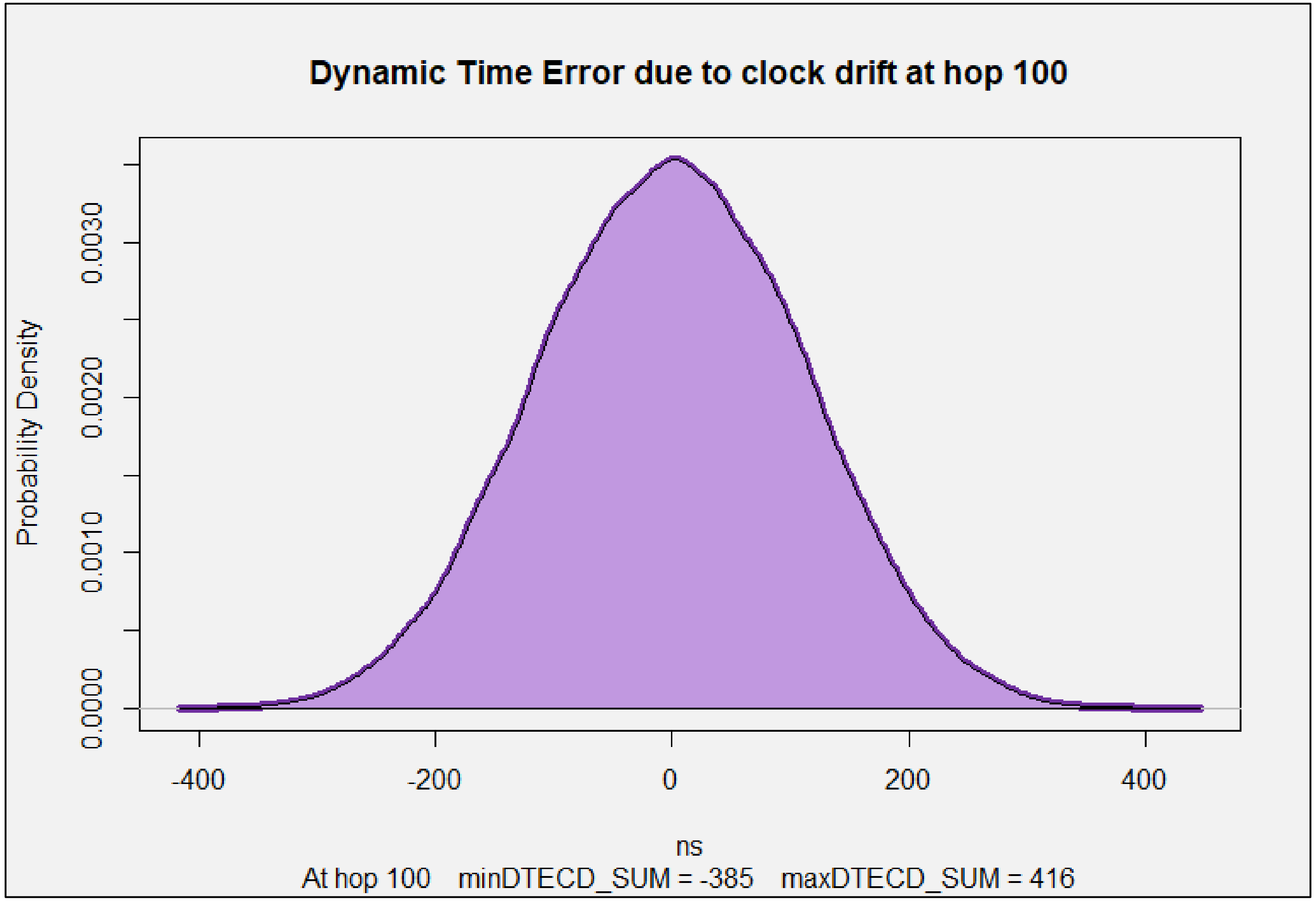
Half-Sinusoidal Temp Ramp



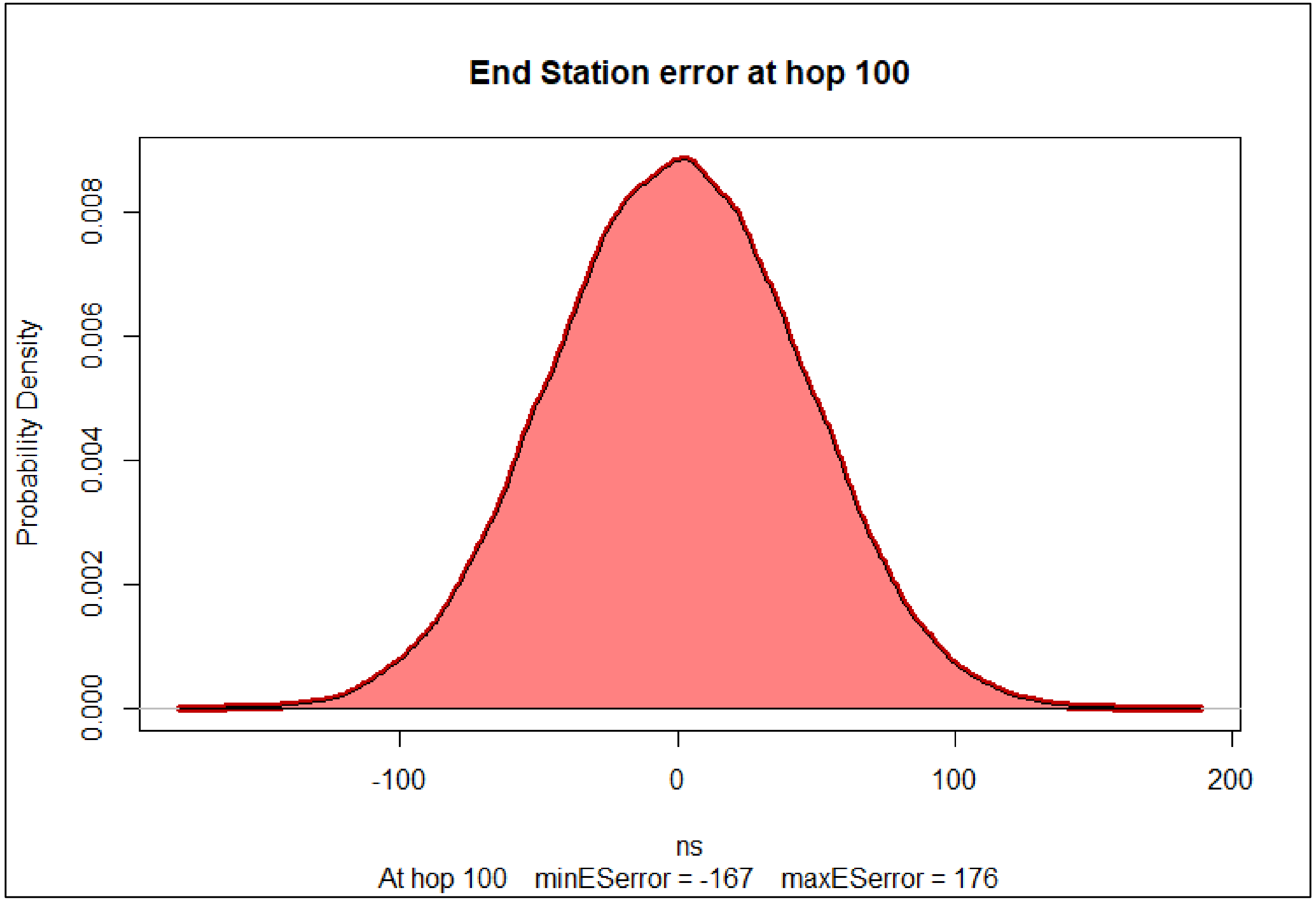
Half-Sinusoidal Temp Ramp



Half-Sinusoidal Temp Ramp



Half-Sinusoidal Temp Ramp



Half-Sinusoidal Temp Ramp

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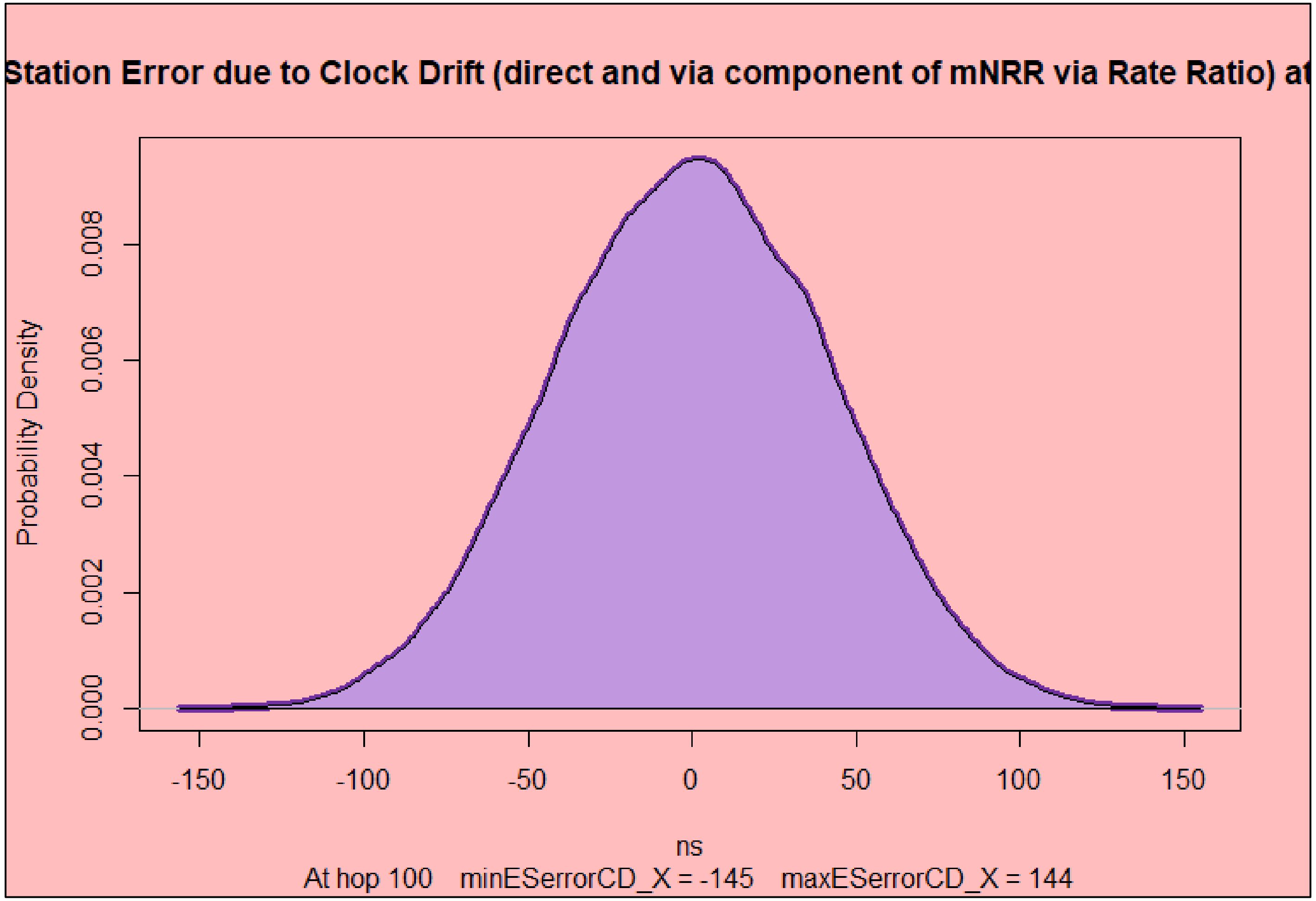
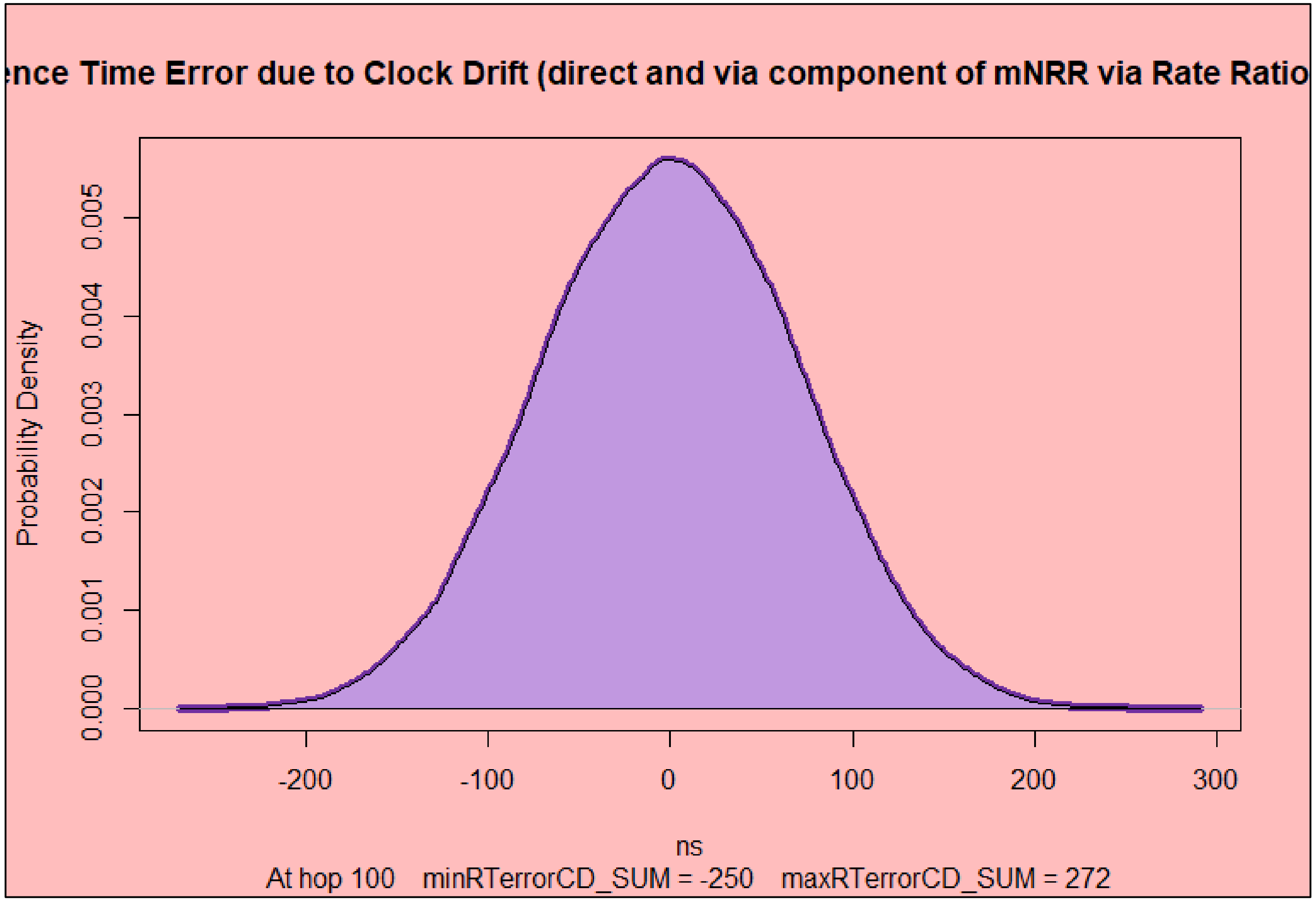
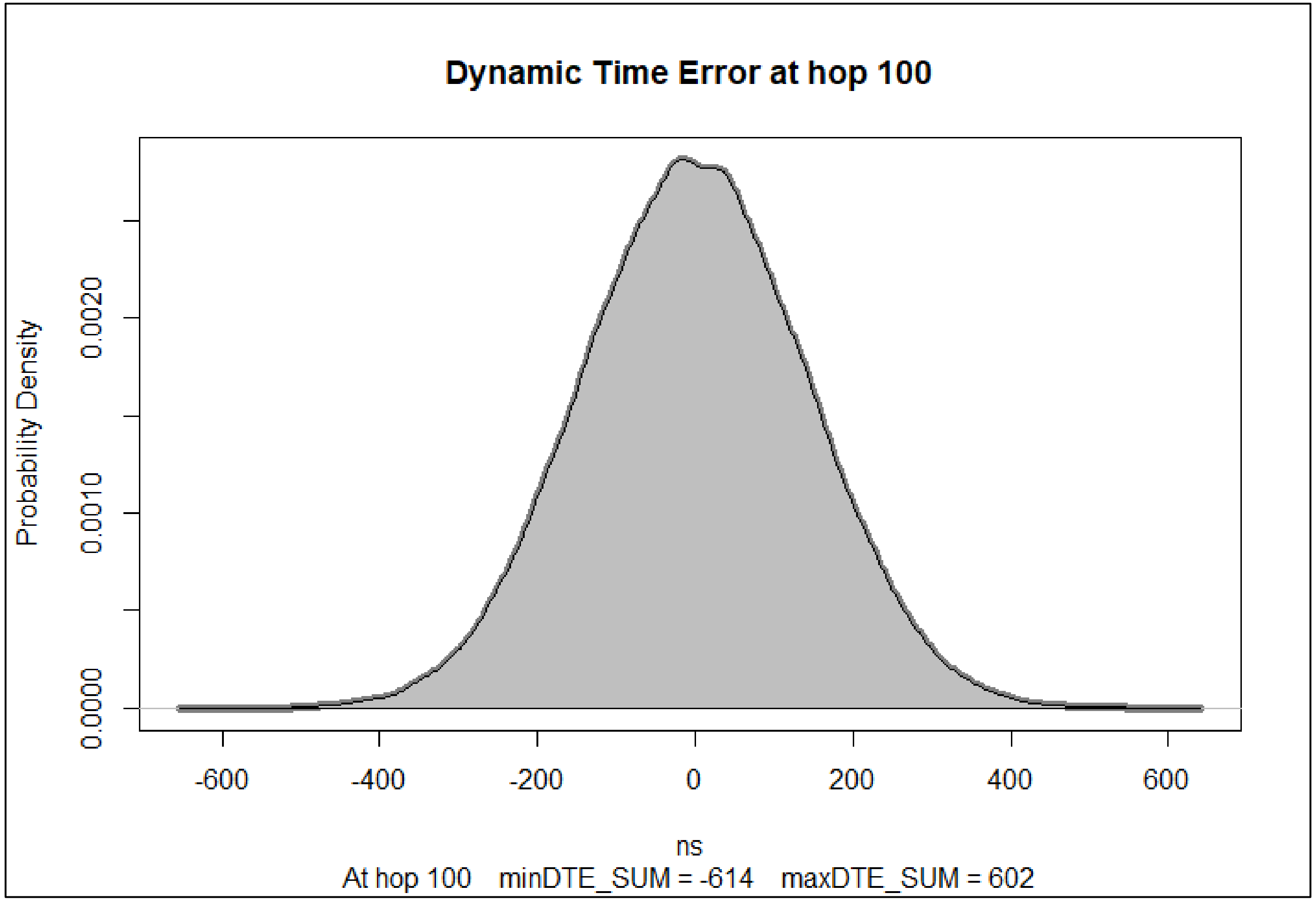


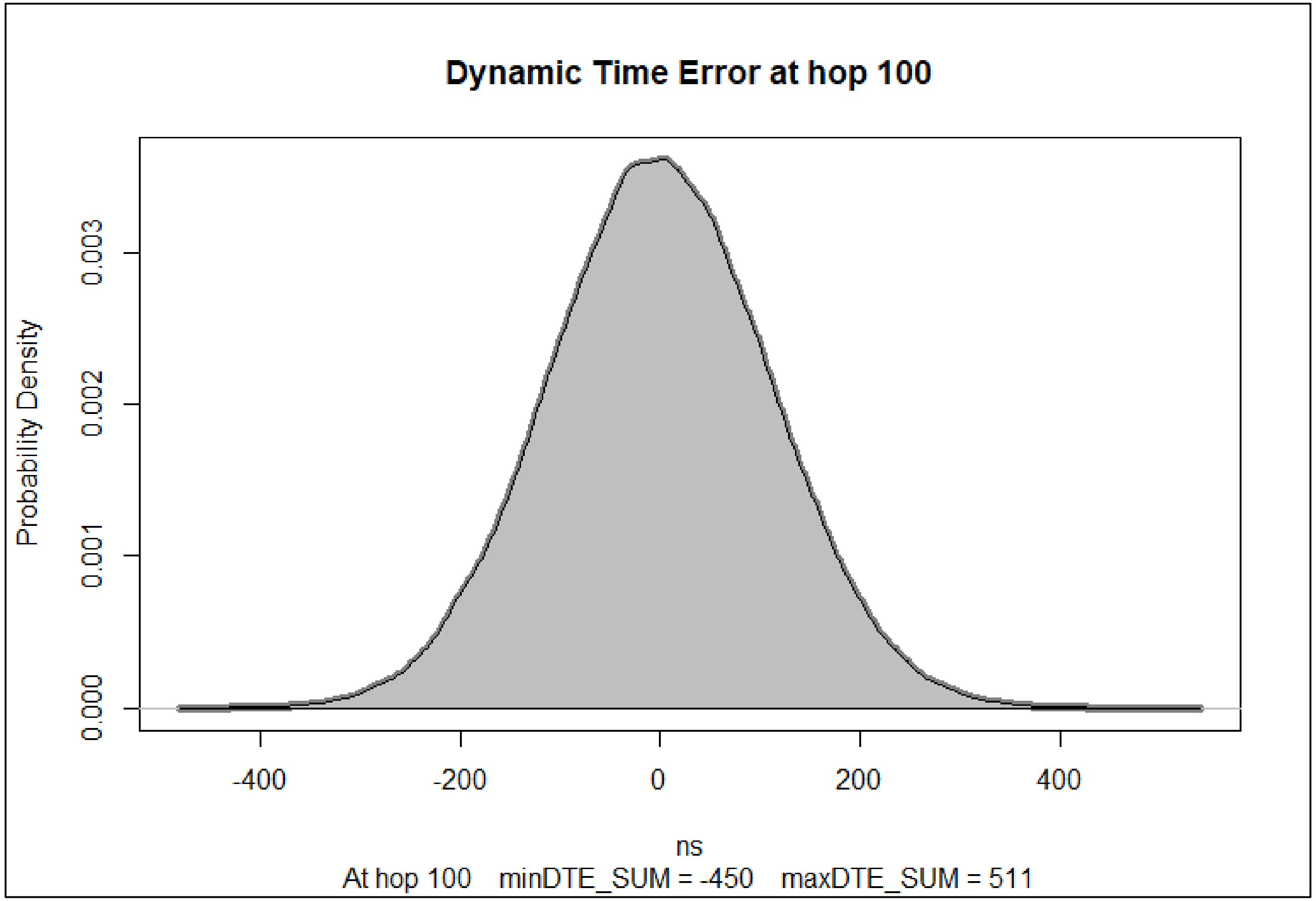
Half-Sinusoidal Temp Ramp



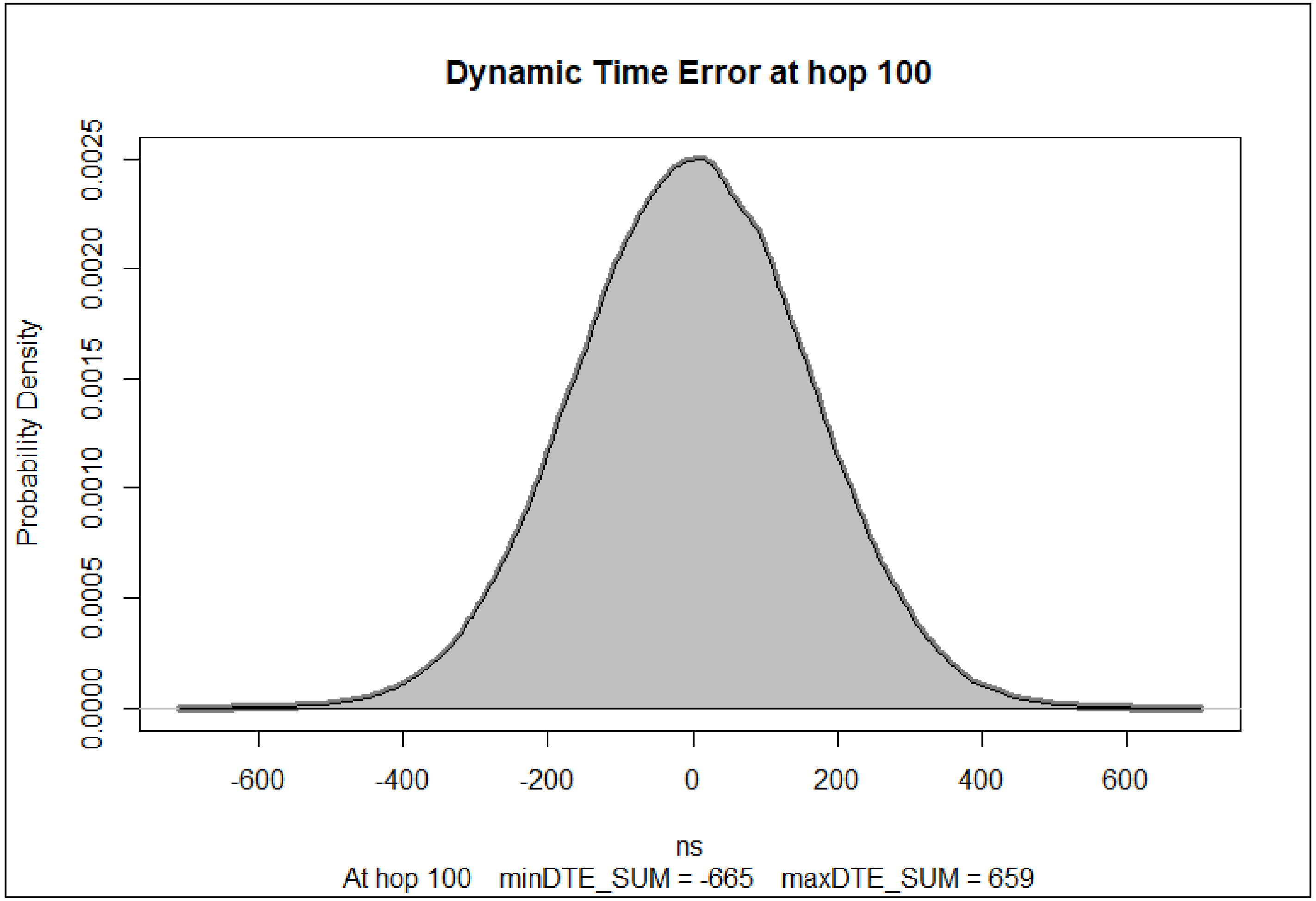
Half-Sinusoidal, (Default 125s Temp Ramp) GMscale 0.5 (±25ppm equivalent)



Half-Sinusoidal, 250s Temp Ramp GMscale 0.5 (±25ppm equivalent)



Half-Sinusoidal, (Default 125s Temp Ramp) GMscale 0.5 (±25ppm equivalent), mNRRcompNAP 3



To Investigate…

- Varying mNRRcompNAP (and mNRRsmoothingNA)
- More Stable GM
- ±1 ppm/s Drift Rate (change Temp Cycle to generate this maximum)
- Longer periods of stability (more nodes stable per run)
- Shorter residenceTime

Thank you!