Jitter and Wander Accumulation as a Function of Number of Hops for 802.1AS Synchronization Transport

Geoffrey M. Garner
SAMSUNG Electronics (Consultant)

IEEE 802.1 AVB TG
2010.11.08

gmgarner@alum.mit.edu

Outline

- Introduction
- Results
- Conclusion
- References

Introduction - 1

- The proposed resolution for comment #75 of the 802.1BA/D2.0 WG ballot includes a statement that indicates (this is in regard to jitter and wander accumulation for synchronization transport using 802.1AS):
  - Simulations have shown that jitter and wander degrade more slowly as the number of hops increases
- The actual wording of this text needs to be improved; however, the intent is to indicate that the increase in jitter and wander, as a function of the number of hops, is less than linear
  - Roughly, this means that the increase in jitter and the increase in wander from one time-aware system to the next (i.e., over one hop) decreases with increasing hop number
  - This can be indicated mathematically by saying that
    - Jitter and wander are $o(N)$, where N is the hop number

Introduction - 2

- The notation $o(N)$ ("little o")is defined as follows:
  - A function $f(N)$ is $o(N)$ if

$$\lim_{N\to\infty} \frac{f(N)}{N} = 0$$

- Note: There is a similar notation $O(N)$ ("big O"), defined as:
  - A function $f(N)$ is $O(N)$ if

$$\lim_{N\to\infty} \frac{f(N)}{N} \leq K$$

where K is an arbitrary constant

- This means that if the jitter and wander increase linearly with *N*, we would say they are $O(N)$

Introduction - 3

- Jitter and wander accumulation simulation results for synchronization transport using 802.1AS are given in [1] and [2], and references given in those references.
- However, those results all present jitter and wander accumulation in terms of MTIE as a function of observation interval, after 1 hop and after 7 hops
  - While simulation results were obtained for 1, 2, 3, 4, 5, 6, and 7 hops, the results for intermediate numbers of hops were not given in any of the references
  - In addition, the results were not plotted as a function of number of hops
  - The reason for presenting the results as a function of observation interval is that the focus in [1] and [2] was to verify that respective MTIE masks could be met with appropriate endpoint filters
    - The MTIE masks are given as a function of observation interval, and the results verified that the masks could be met after 7 hops

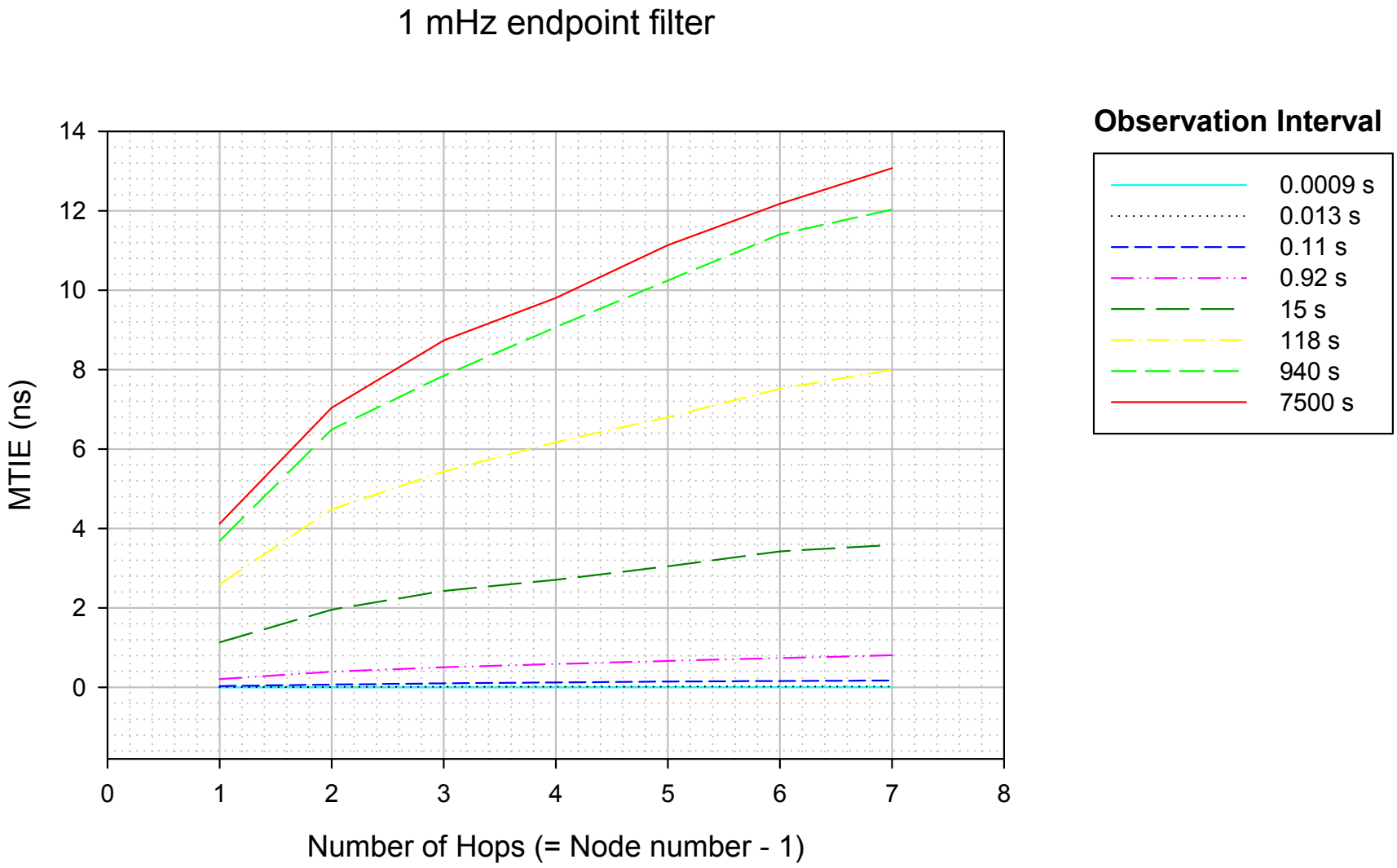
Introduction - 4

- In this presentation, the simulation results obtained in [2] are presented as a function of number of hops, for selected observation intervals
- Specifically, for each endpoint filter bandwidth considered in [2] (1 mHz, 10 mHz, 100 mHz, 1 Hz, and 10 Hz), MTIE is plotted as a function of hop number, from 1 to 7 hops, for selected observation intervals
- The observation intervals chosen are
  - 0.0009 s
  - 0.013 s
  - 0.11 s
  - 0.92 s
  - 15 s
  - 118 s
  - 940 s
  - 7500 s
- The above values were closest (of the simulation results) to 1 ms, 10 ms, 100 ms, 1 s, 10 s, 100 s, 1000 s, and 10000 s, that were available

Introduction - 5

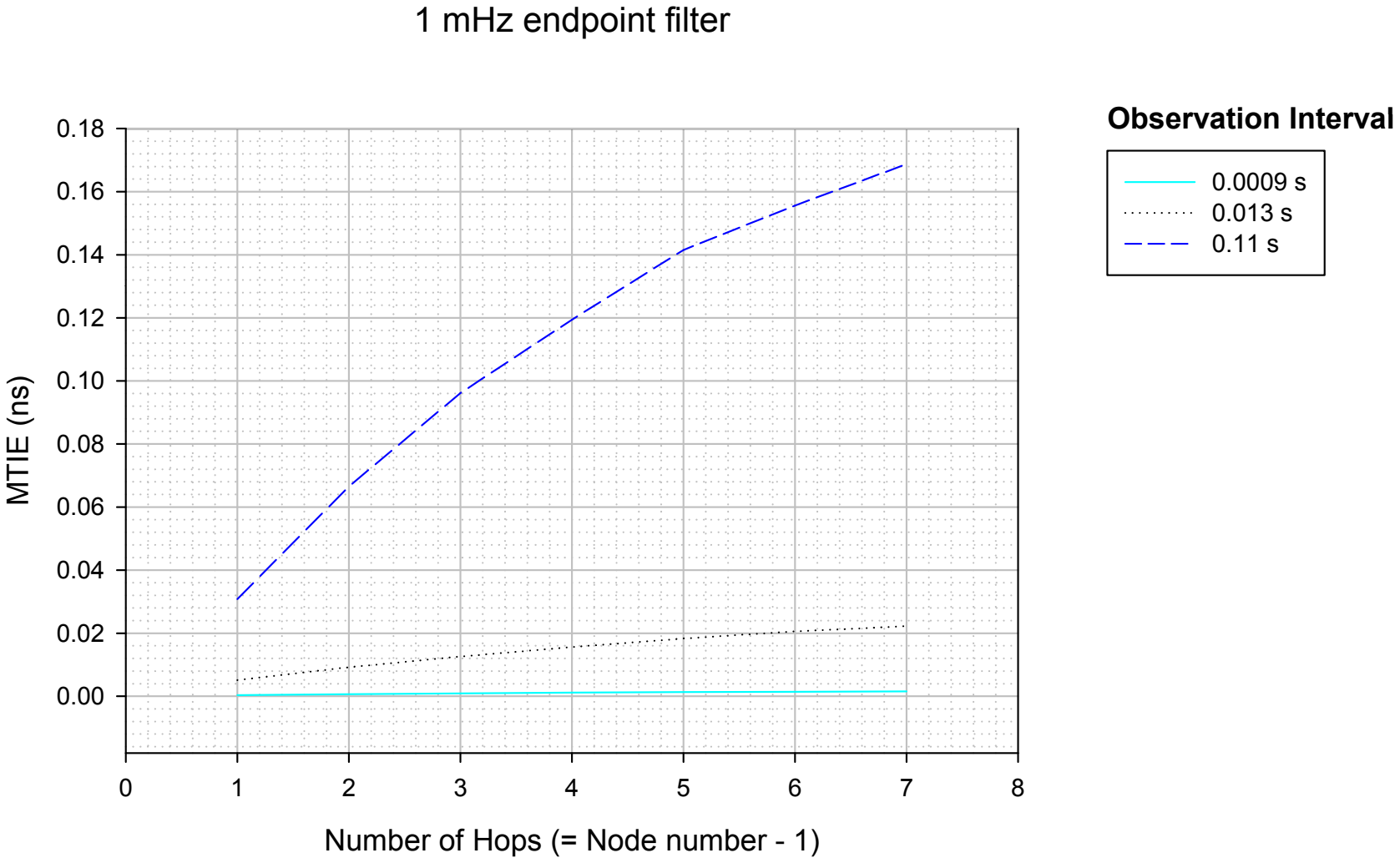
- The MTIE results here are the point-estimate results obtained in [2] for 300 multiple replications of each simulation
- All the assumptions here are the same as in [2]
- See [1], [2], and references cited there for details

MTIE Results for 1 mHz Endpoint Filter - 1

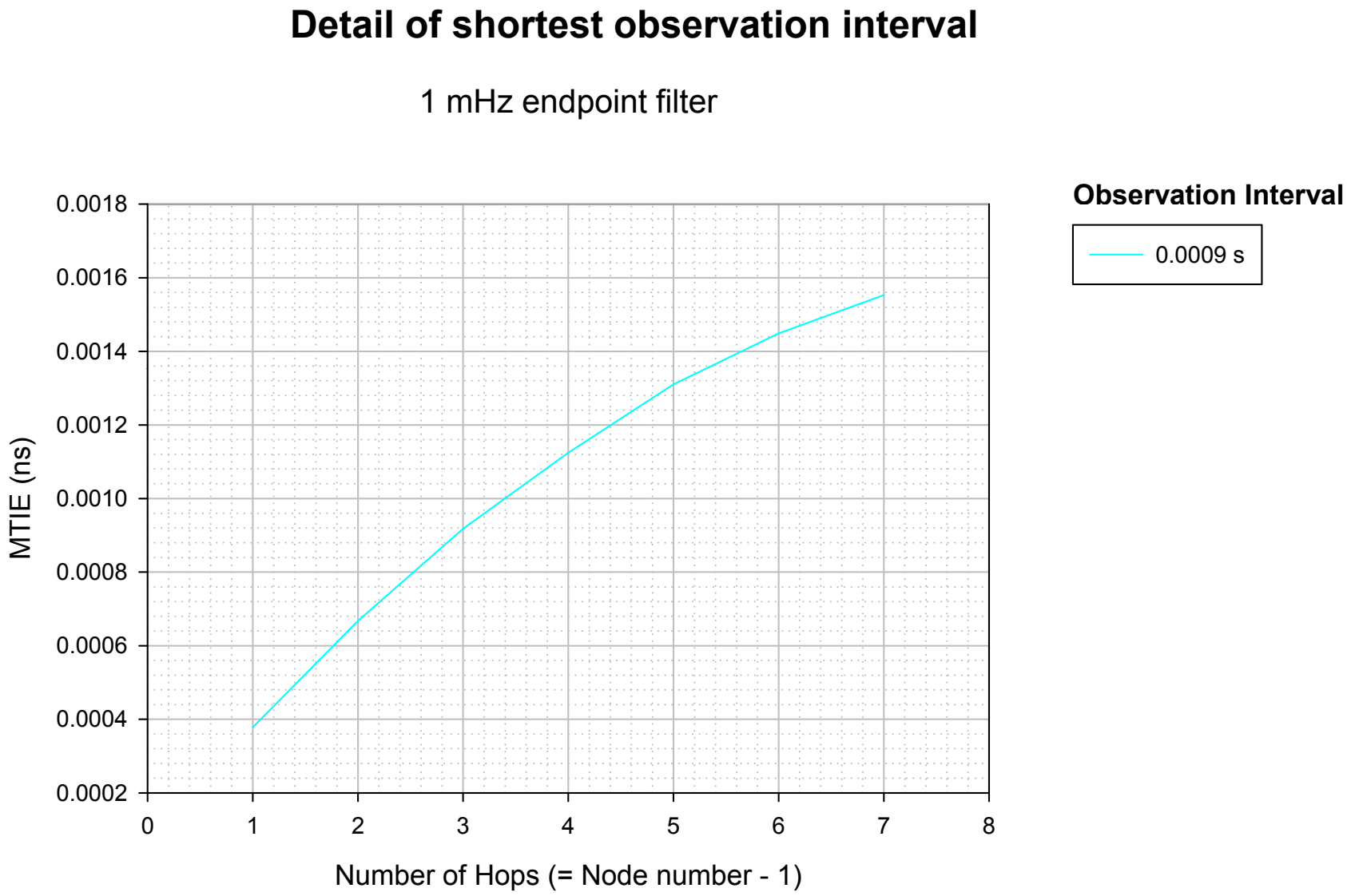


MTIE Results for 1 mHz Endpoint Filter - 2

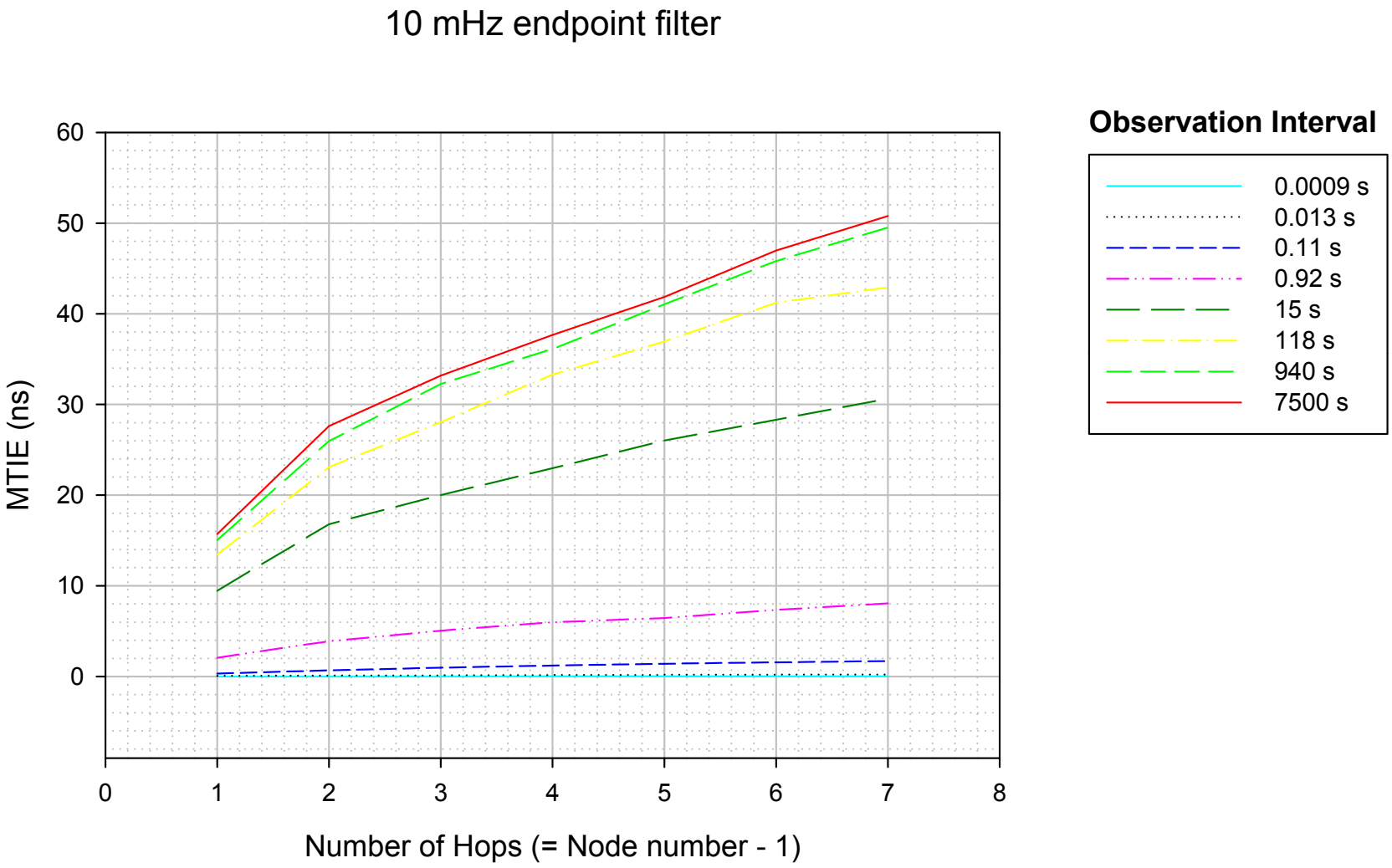
Detail of 3 shortest observation intervals



MTIE Results for 1 mHz Endpoint Filter - 3



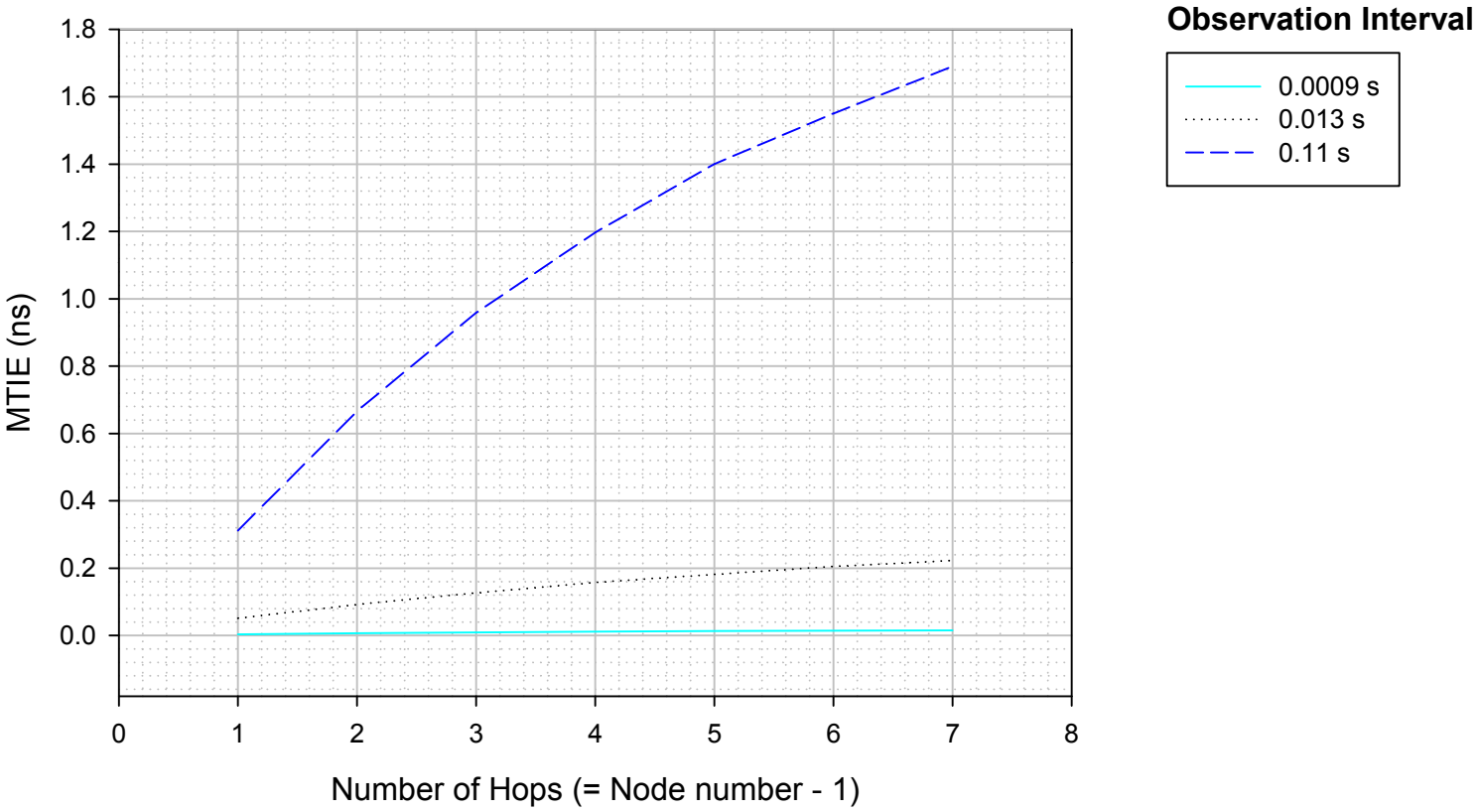
MTIE Results for 10 mHz Endpoint Filter - 1



MTIE Results for 10 mHz Endpoint Filter - 2

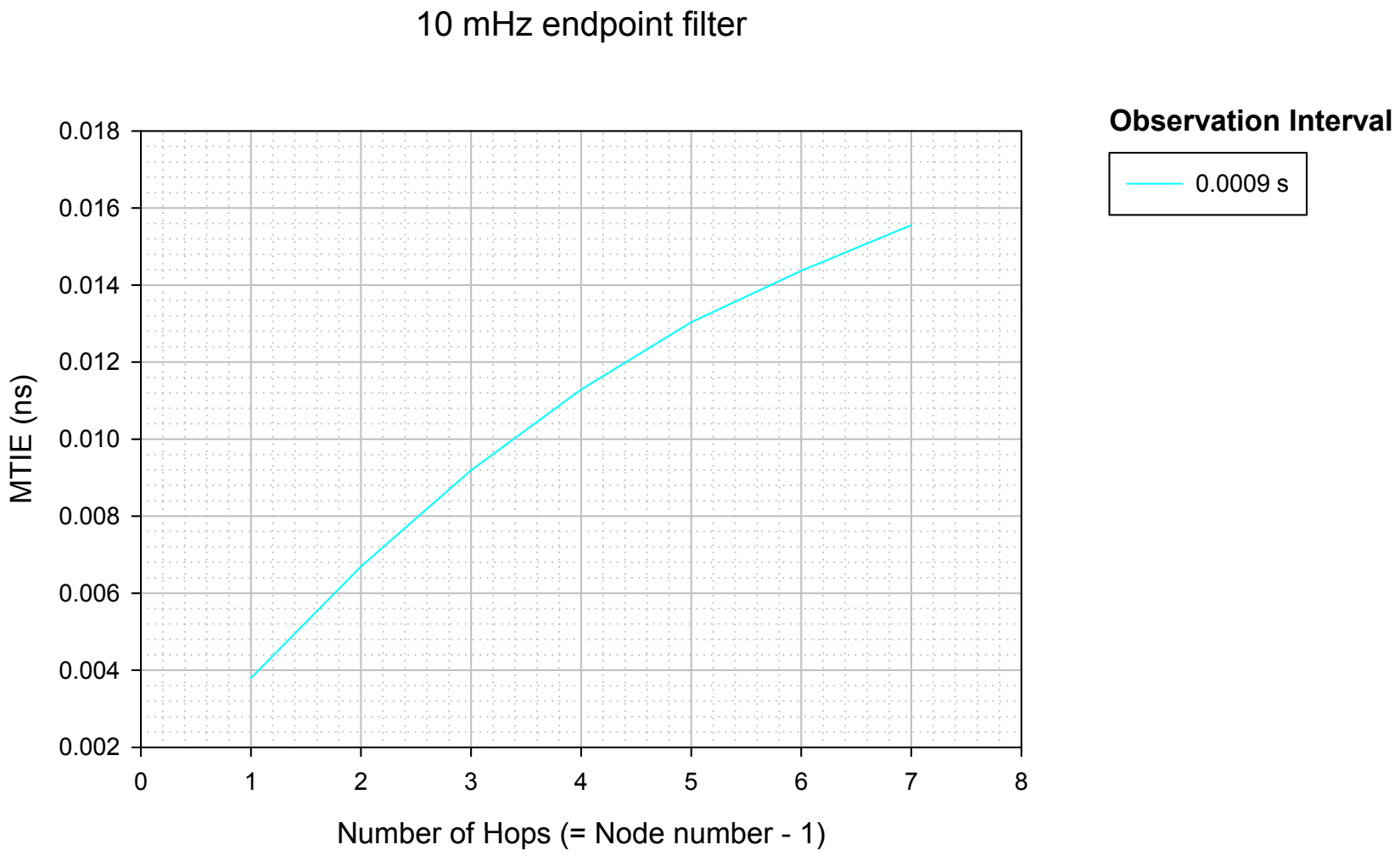
Detail of 3 shortest observation intervals

10 mHz endpoint filter

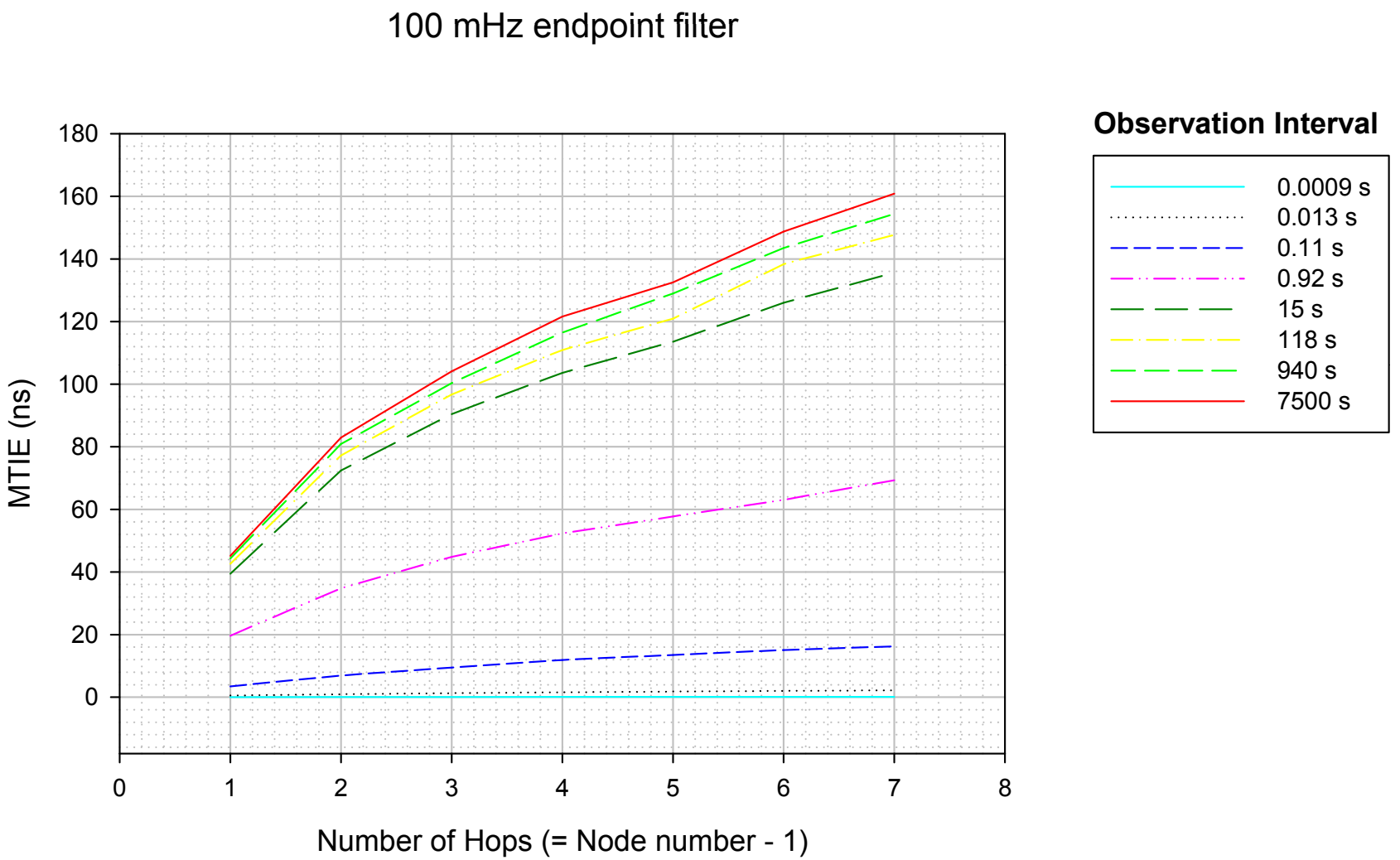


MTIE Results for 10 mHz Endpoint Filter - 3

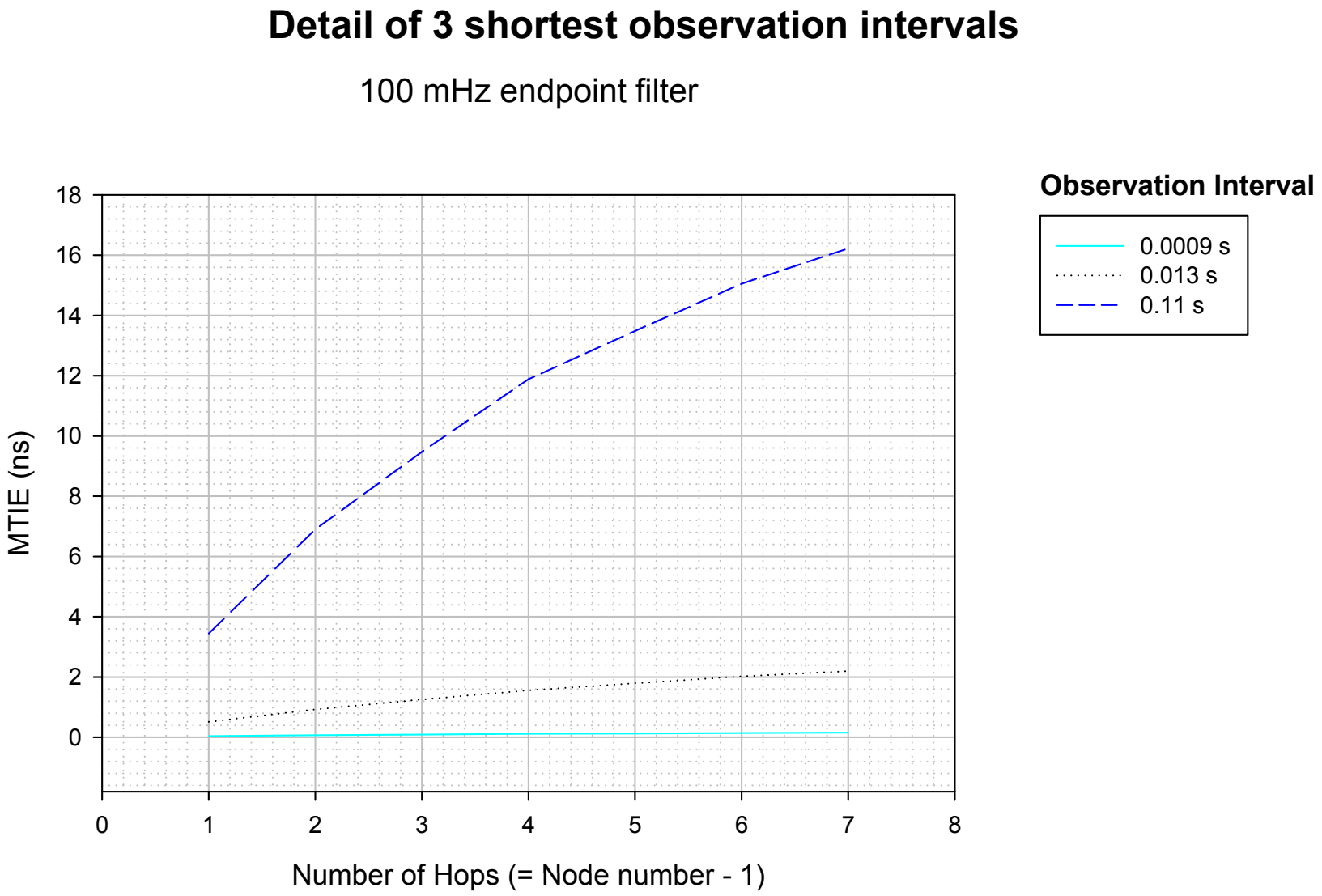
Detail of shortest observation interval



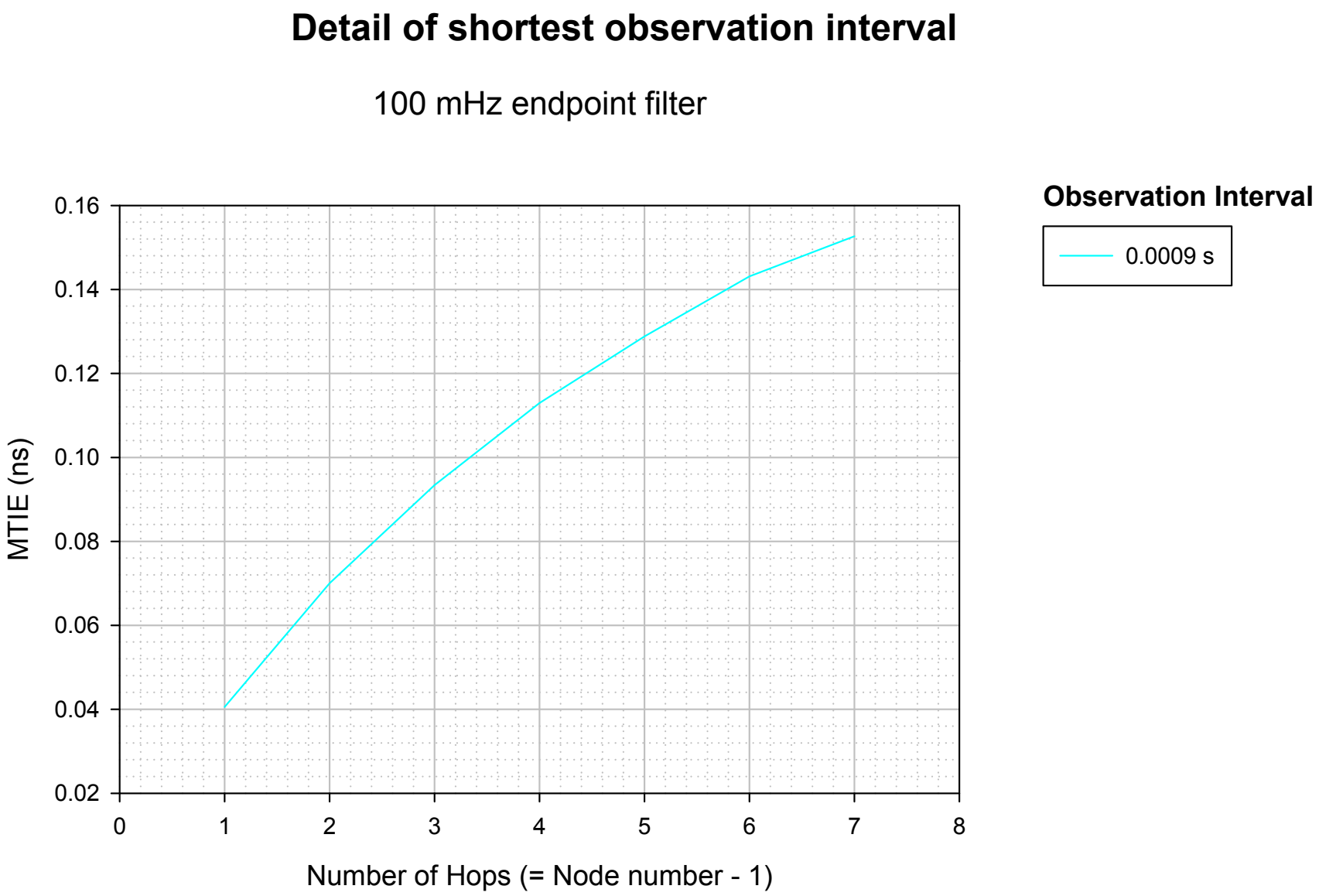
MTIE Results for 100 mHz Endpoint Filter - 1



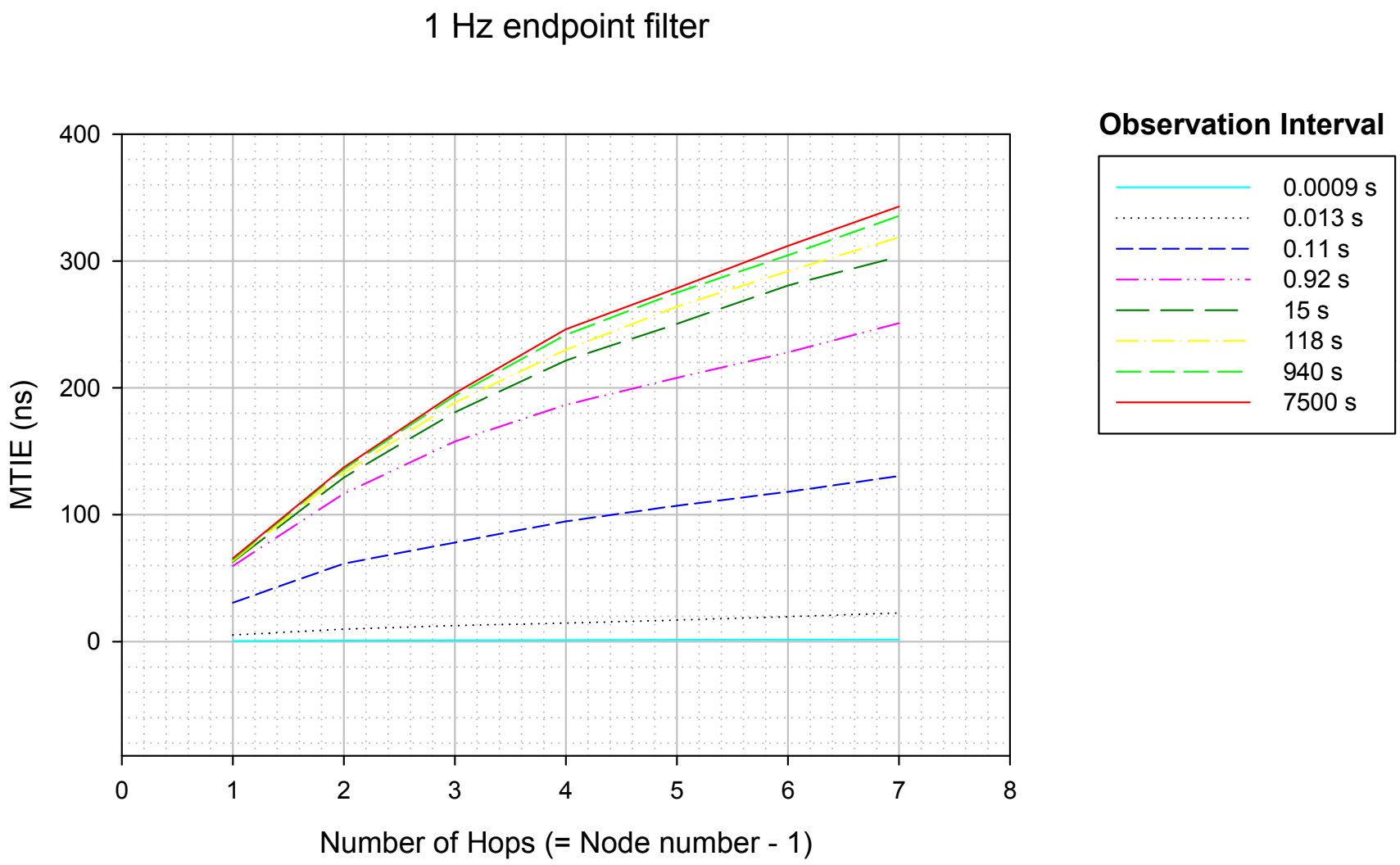
MTIE Results for 100 mHz Endpoint Filter - 2



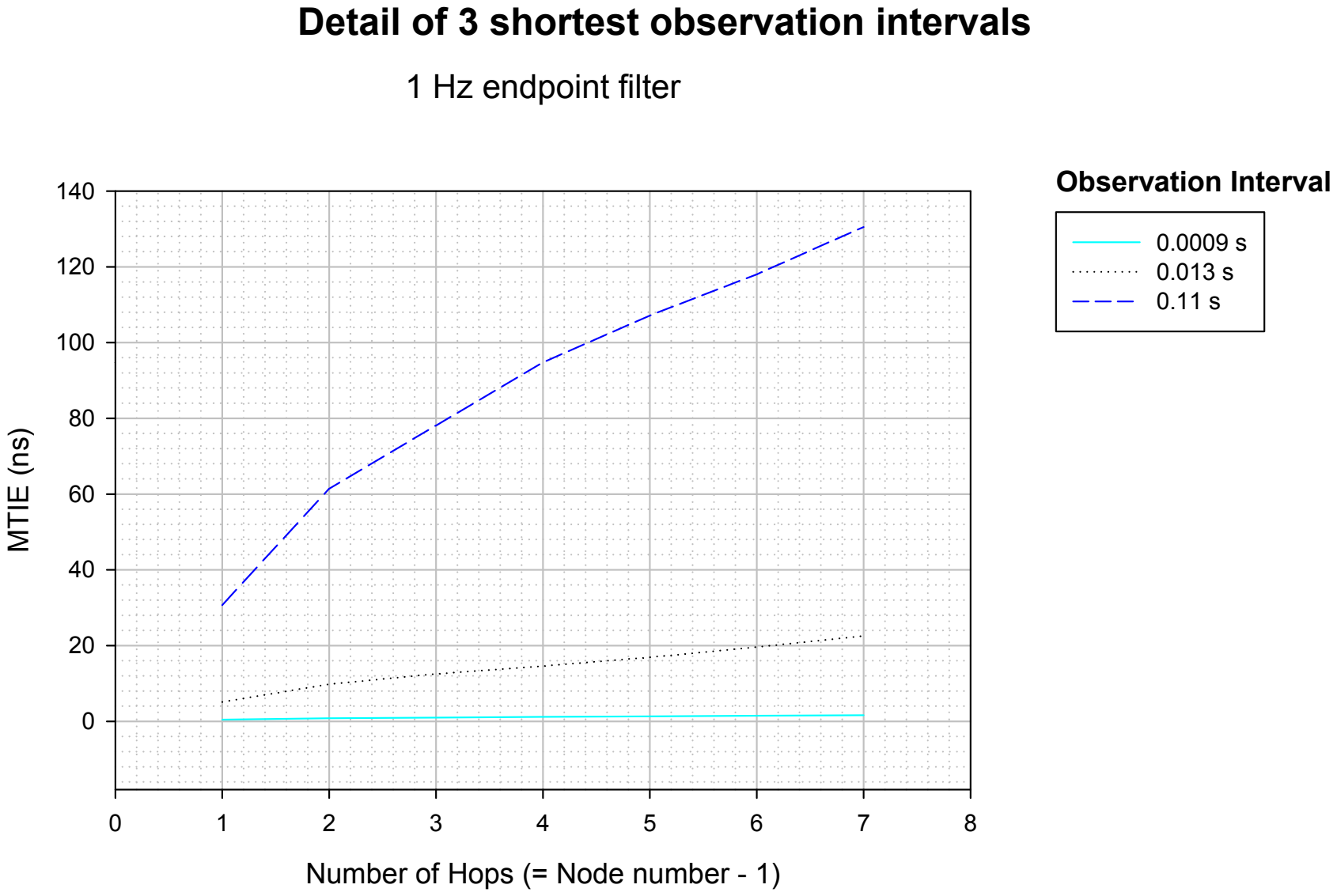
MTIE Results for 100 mHz Endpoint Filter - 3



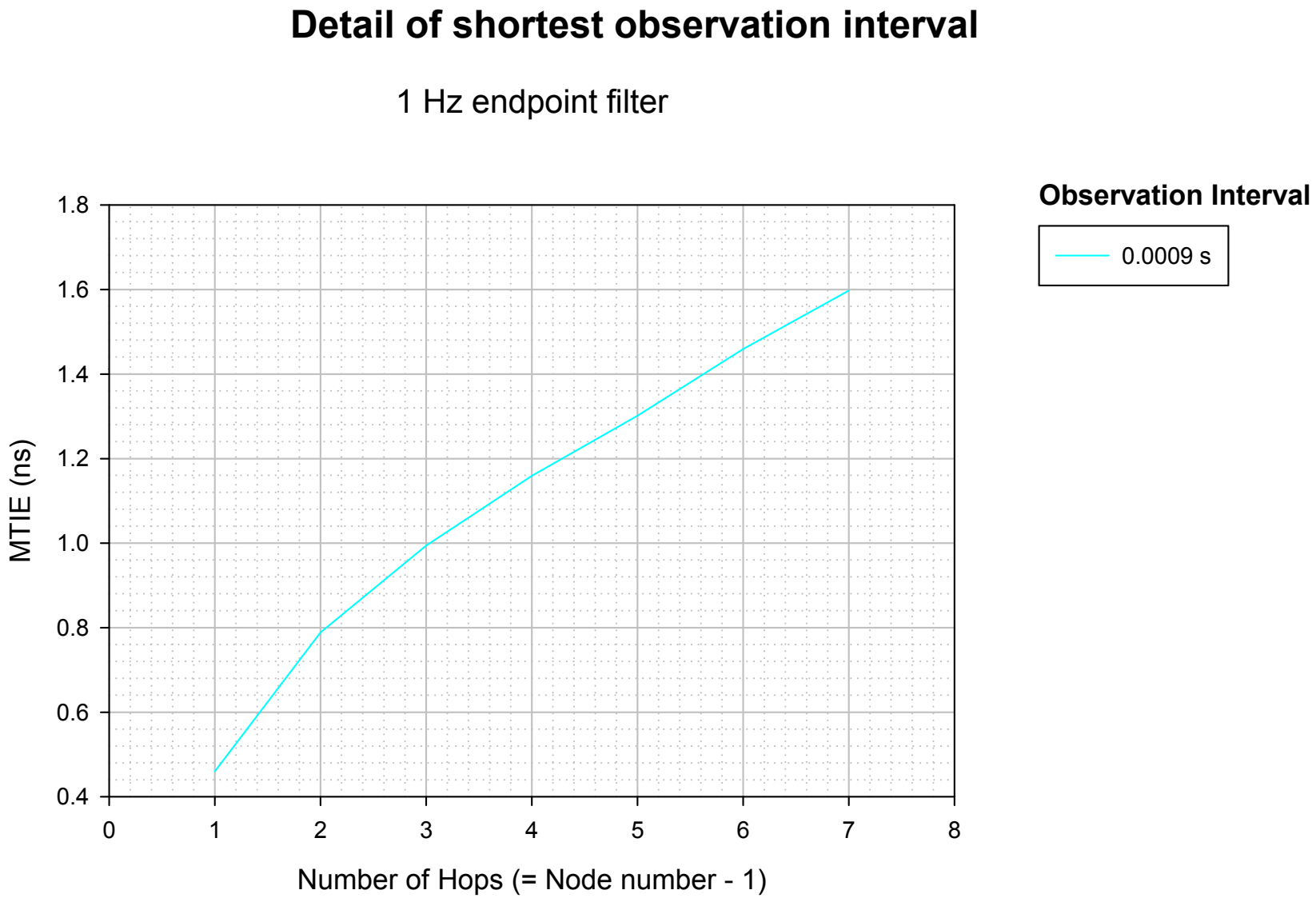
MTIE Results for 1 Hz Endpoint Filter - 1



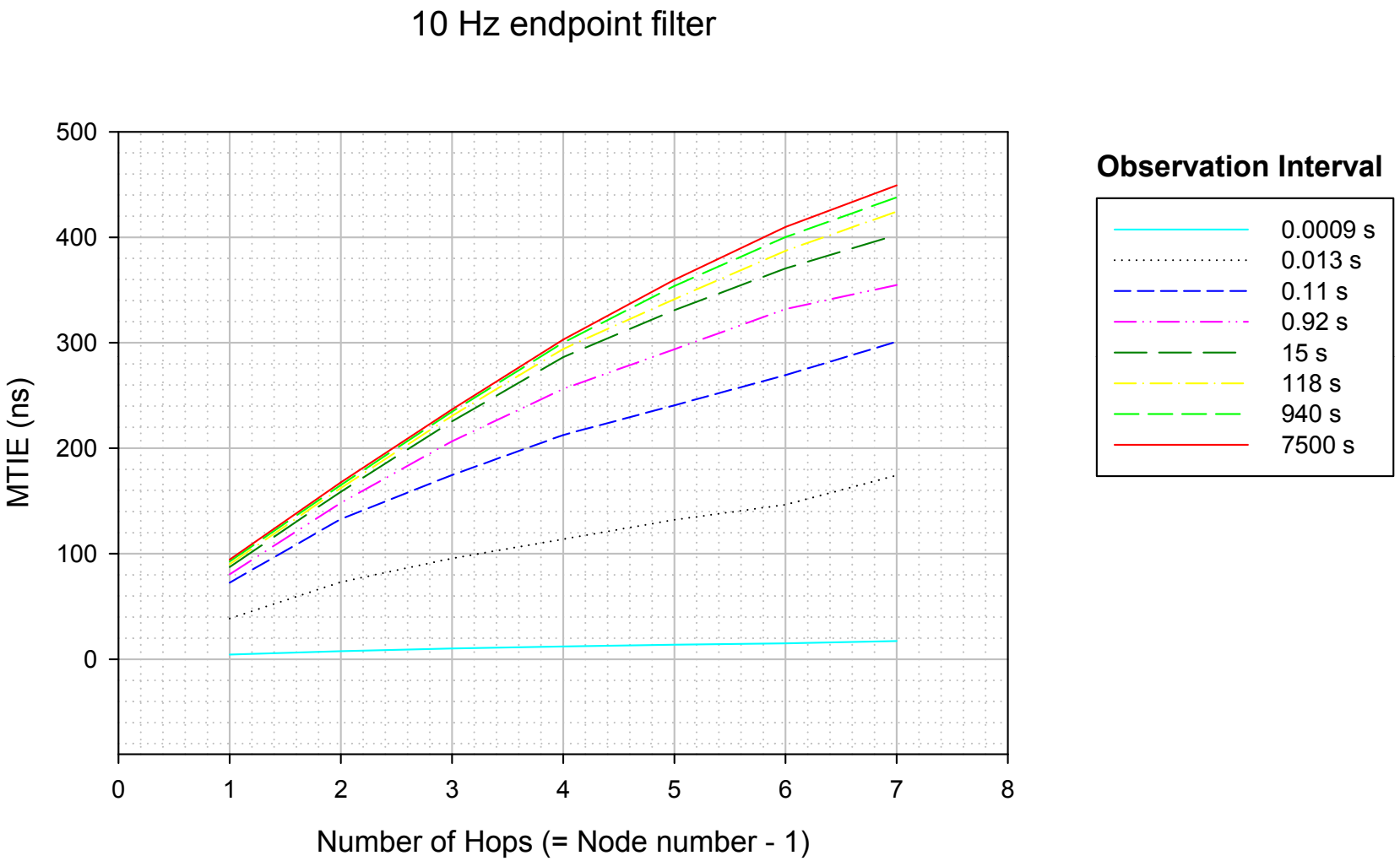
MTIE Results for 1 Hz Endpoint Filter - 2



MTIE Results for 1 Hz Endpoint Filter - 3

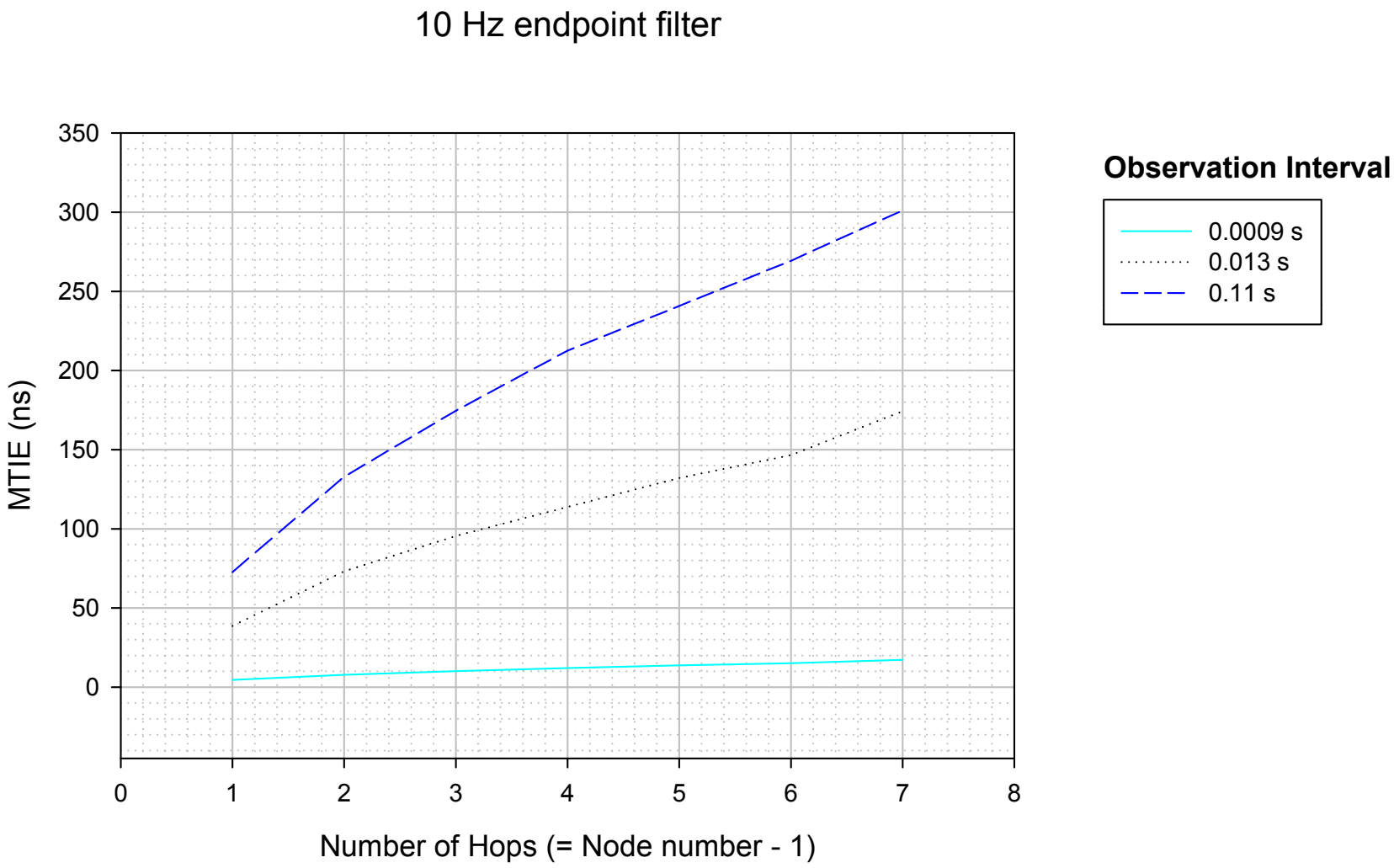


MTIE Results for 10 Hz Endpoint Filter - 1

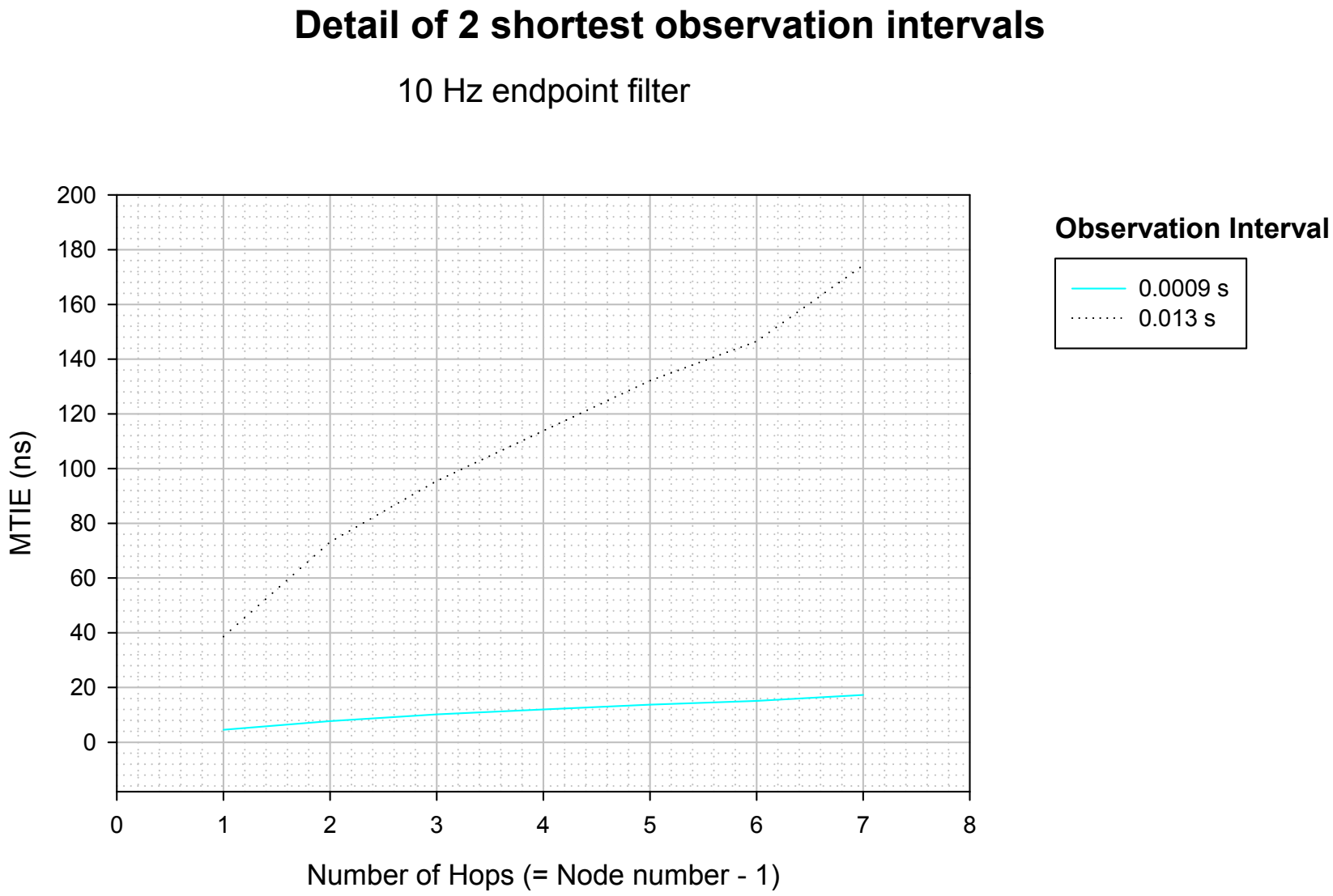


MTIE Results for 10 Hz Endpoint Filter - 2

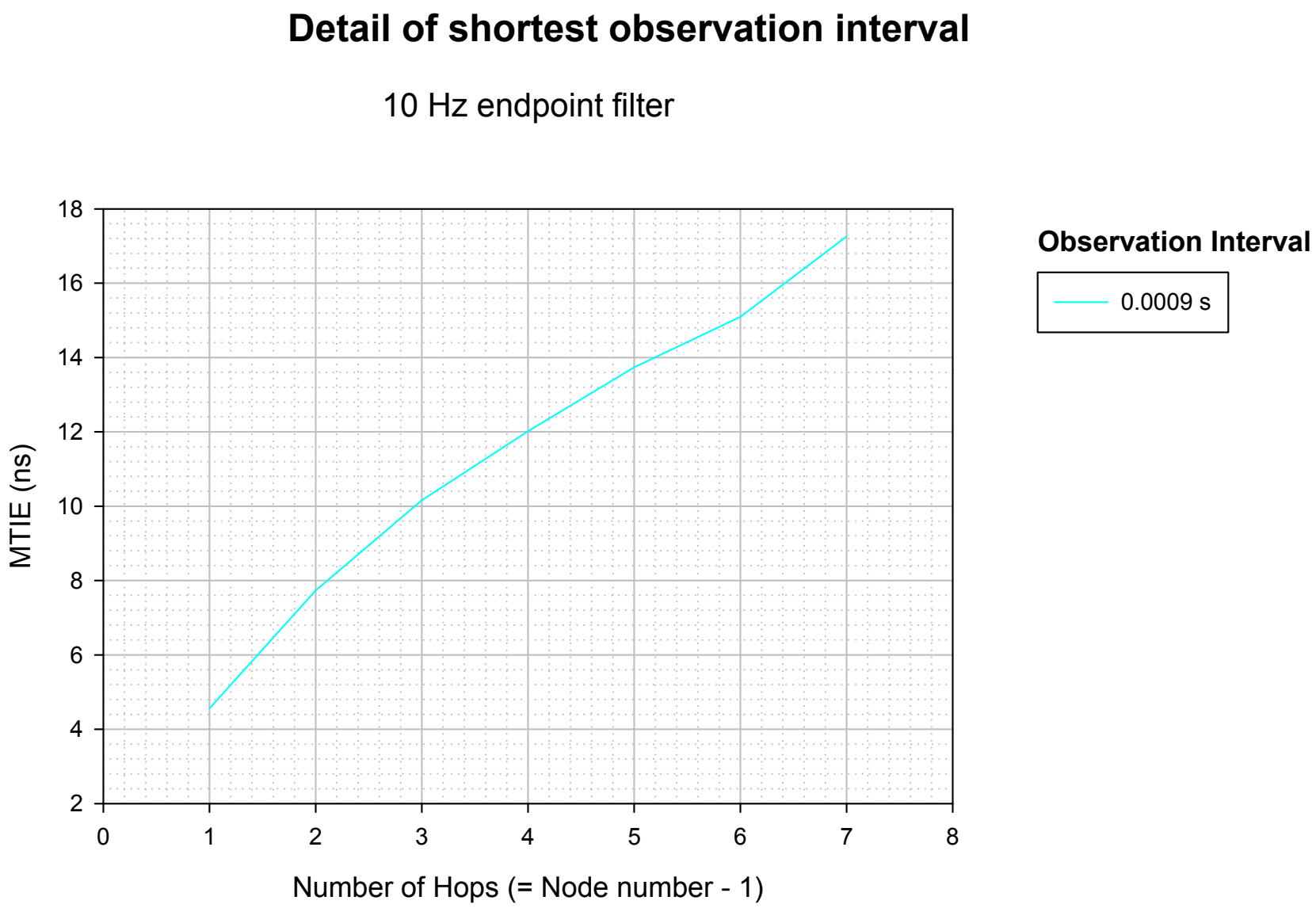
Detail of 3 shortest observation intervals



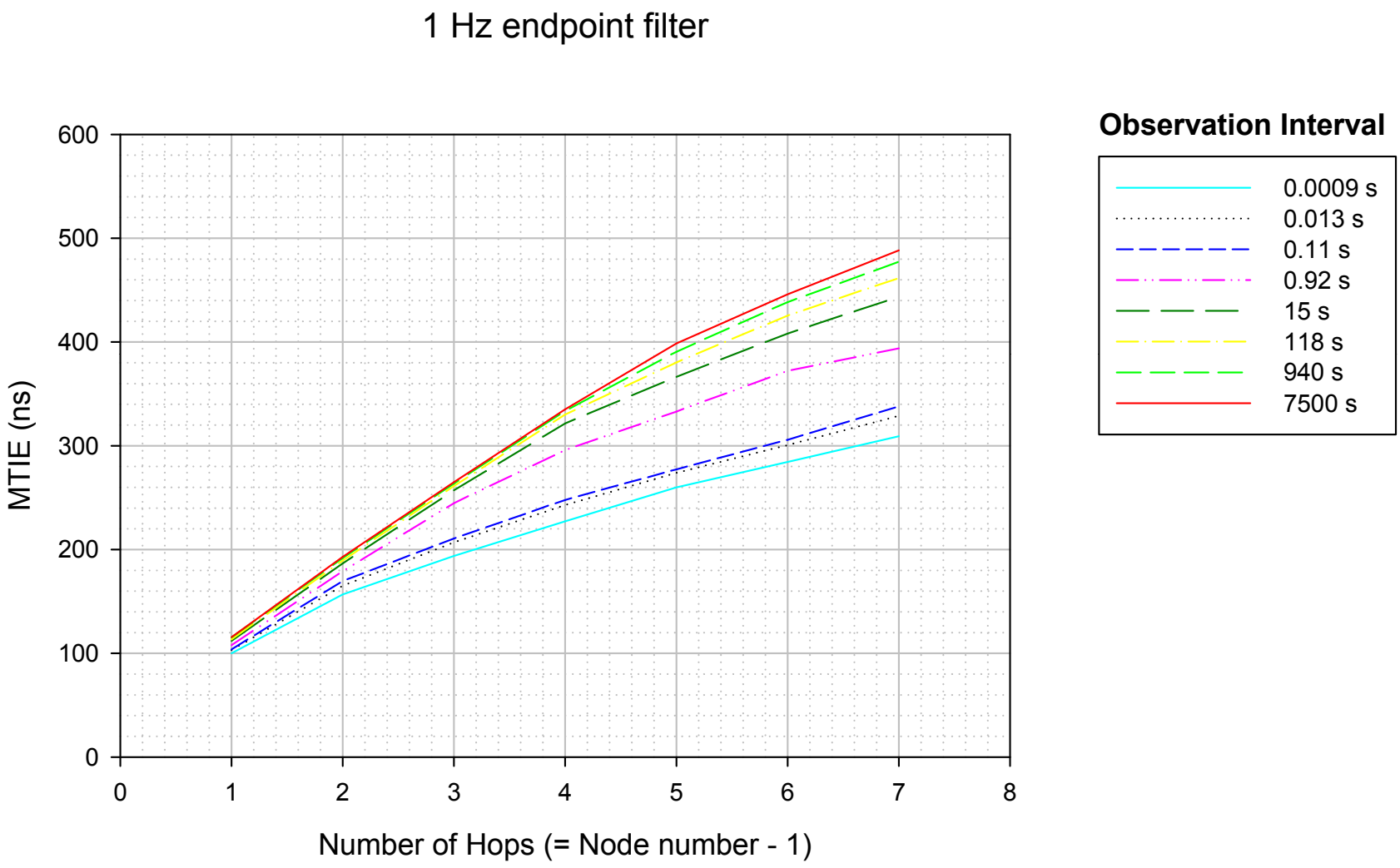
MTIE Results for 10 Hz Endpoint Filter - 3



MTIE Results for 10 Hz Endpoint Filter - 4



MTIE Results for No Endpoint Filtering



Conclusion - 1

- The results show that the increase in MTIE, for each filter bandwidth (and for the case of no endpoint filtering) and each observation interval, is generally less than linear
  - the increase in MTIE with each successive hop decreases with increasing hop number, i.e., MTIE versus hop number is concave (i.e., concave down)
  - For each filter bandwidth, additional plots showing details for shorter observation intervals are given, as the detailed results are difficult to see on the plots showing the longer observation intervals

Conclusion - 2

- However, this result is not universal
  - In the results obtained here for a 10 Hz endpoint filter, the increase in MTIE from time-aware system 7 to time-aware system 8 (hop 7) was larger than the increase in MTIE from time-aware system 6 to time-aware system 7 (hop 6), i.e., MTIE versus hop number showed an inflexion point at hop and went from being concave down to being slightly convex (i.e., concave up)
  - In addition, in many cases the increase in MTIE, while less than linear, is close to linear for a larger number of hops
- But, while the result is not universal, it did hold for the first 4 hops for the results obtained here, i.e.,
  - For all endpoint filter bandwidths (and for no endpoint filtering) the increase in MTIE with each successive hop decreases with increasing hop number over the first few (4 in the results here) hops, i.e., MTIE versus hop number is concave (i.e., concave down) over the first few hops

Conclusion - 3

- Note that:
  - MTIE for the shorter observation intervals (i.e., less than approximately 0.05 s) is a measure of jitter
  - MTIE for the longer observation intervals (i.e., greater than approximately 0.05 s) is a measure of wander
- Given that MTIE has been obtained only up to 7 hops (8 time-aware systems), a statement that jitter and wander are $o(N)$, where N is the hop number, is probably too strong
  - If MTIE were to become linear in N for larger N (i.e., $N \rightarrow \infty$), then MTIE would be $O(N)$

Conclusion - 4

- The results indicate that:
  - The increase in jitter and the increase in wander from one time-aware system to the next (i.e., over one hop) generally decrease with increasing hop number (i.e., are concave down with hop number)
  - However, this decrease itself decreases with increasing hop number, at least up to 7 hops
  - Exceptions have been observed, i.e., where the increase in MTIE over one hop is slightly larger than on the previous hop
    - i.e., MTIE showed an inflexion point after 6 hops and became slightly convex (concave up)
  - But, the general result did hold for the first few hops (4 hops in the results here), i.e.
    - For all endpoint filter bandwidths (and for no endpoint filtering) the increase in MTIE with each successive hop decreases with increasing hop number over the first few (4 in the results here) hops, i.e., MTIE versus hop number is concave (i.e., concave down) over the first few hops

References

1. Geoffrey M. Garner, *Simulation Results for 802.1AS Synchronization Transport with Clock Wander Generation and Updated Residence and Pdelay Turnaround Times*, Samsung presentation to July, 2010 IEEE 802.1 AVB TG meeting, San Diego, CA, USA, July 12, 2010. Available at http://www.ieee802.org/1/files/public/docs2010/as-garner-simulation-results-wander-gen-new-res-time-0710.pdf
2. Geoffrey M. Garner, *Multiple Replication Simulation Results for 802.1AS Synchronization Transport with Clock Wander Generation and Updated Residence and Pdelay Turnaround Times*, Samsung presentation to September, 2010 IEEE 802.1 AVB TG meeting, York, UK, September 13, 2010. Available at http://www.ieee802.org/1/files/public/docs2010/as-garner-simulation-results-mult-replic-0910.pdf