NetDev 0x15

PTP optimization using genetic algorithm

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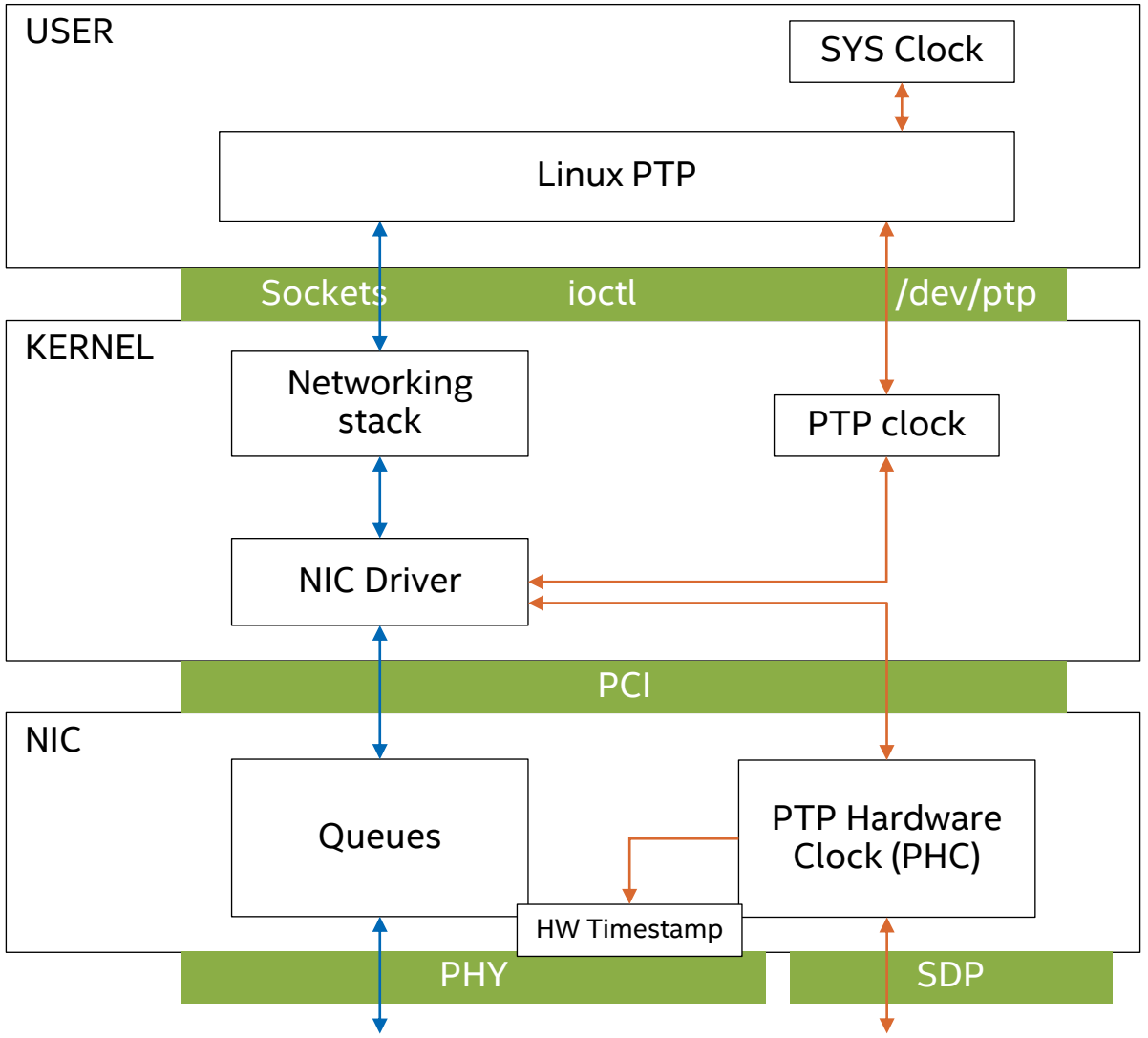
Agenda

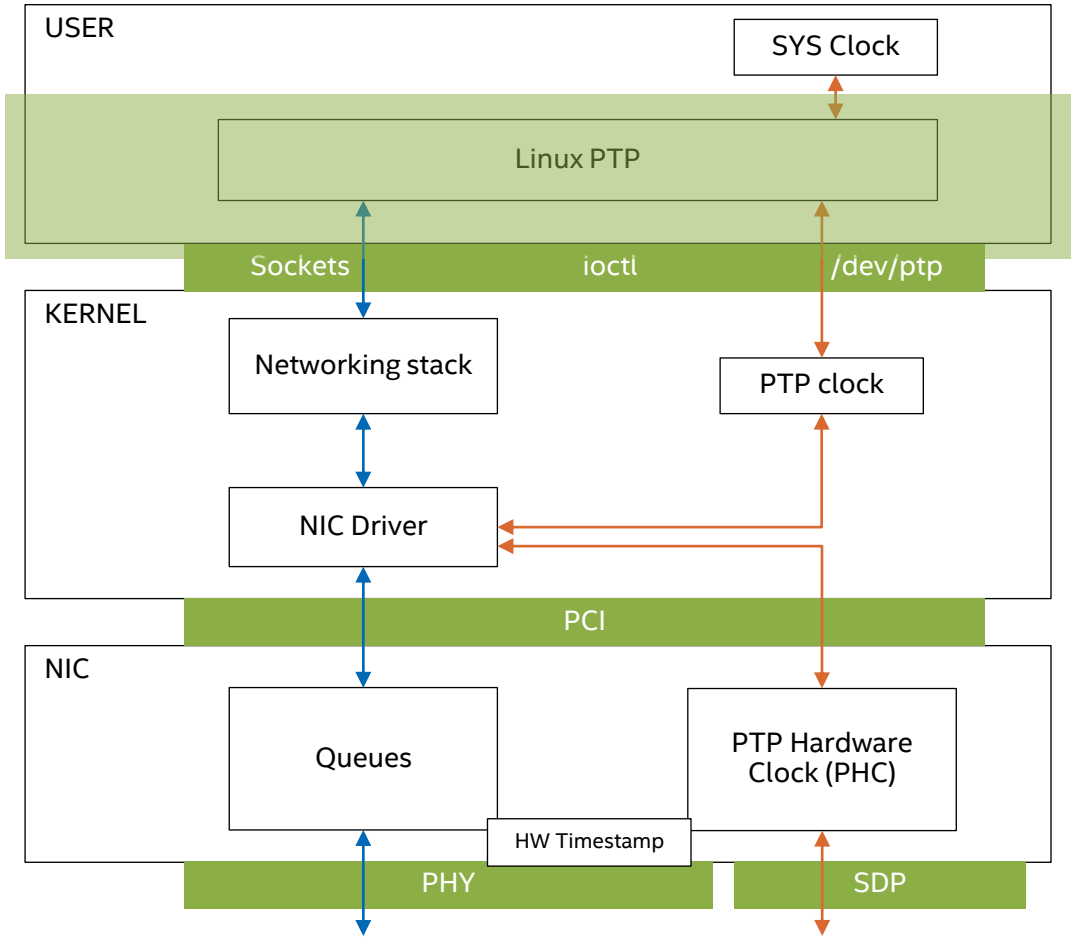
- PTP
- PID controller
  - Introduction
  - PID tuning
- Genetic Algorithms
- Data evaluation methods
- Developed framework details
- Results
- Future work

PTP on Linux

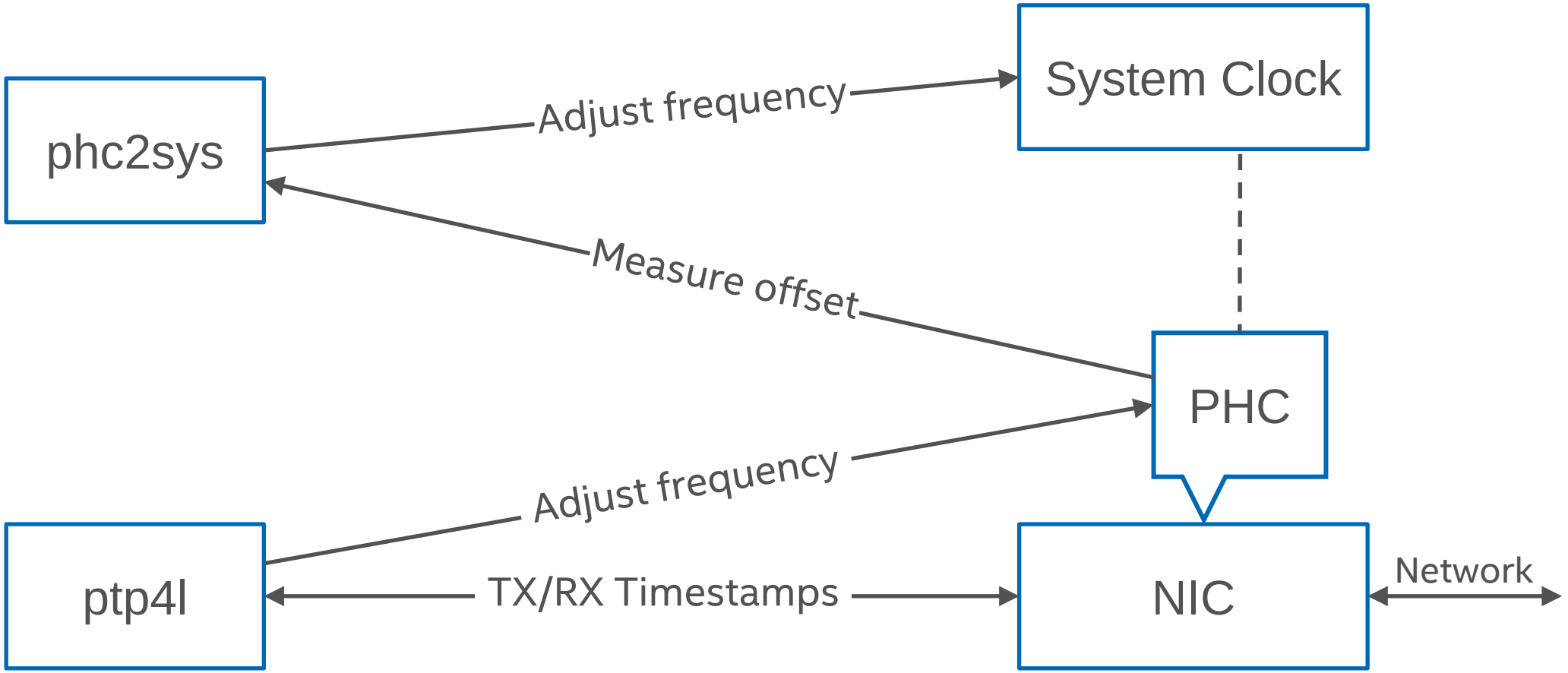

USER
SYS Clock
Linux PTP
Sockets
ioctl
/dev/ptp
KERNEL
Networking stack
PTP clock
NIC Driver
PCI
NIC
Queues
PTP Hardware Clock (PHC)
HW Timestamp
PHY
SDP

Linux PTP project

- Set of userspace tools
- Implement PTP (IEEE 1588)
- Use standard kernel APIs to synchronize and manage the clocks
- Supports HW and SW time stamping
  - Best precision w/ HW time stamping
- http://linuxptp.sourceforge.net/



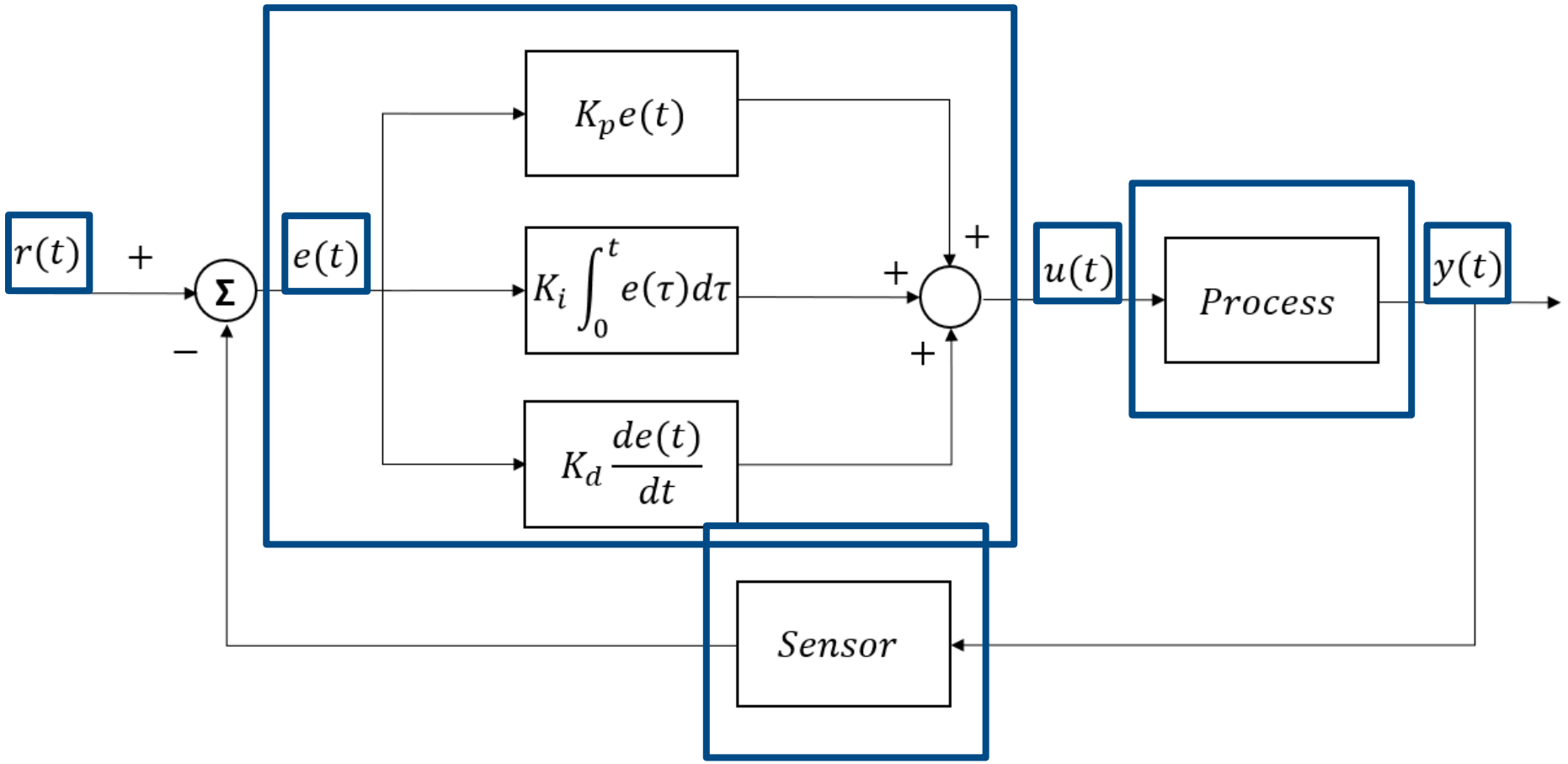
Linux PTP project



PID controller - Introduction

- Proportional-Integral-Derivative controller
- Commonly used to control feedback loops
- Uses error signal to control the object
- Three main parameters:
  - Proportional gain K_p
  - Integral gain K_i
  - Derive rate gain K_d

PID controller - Introduction



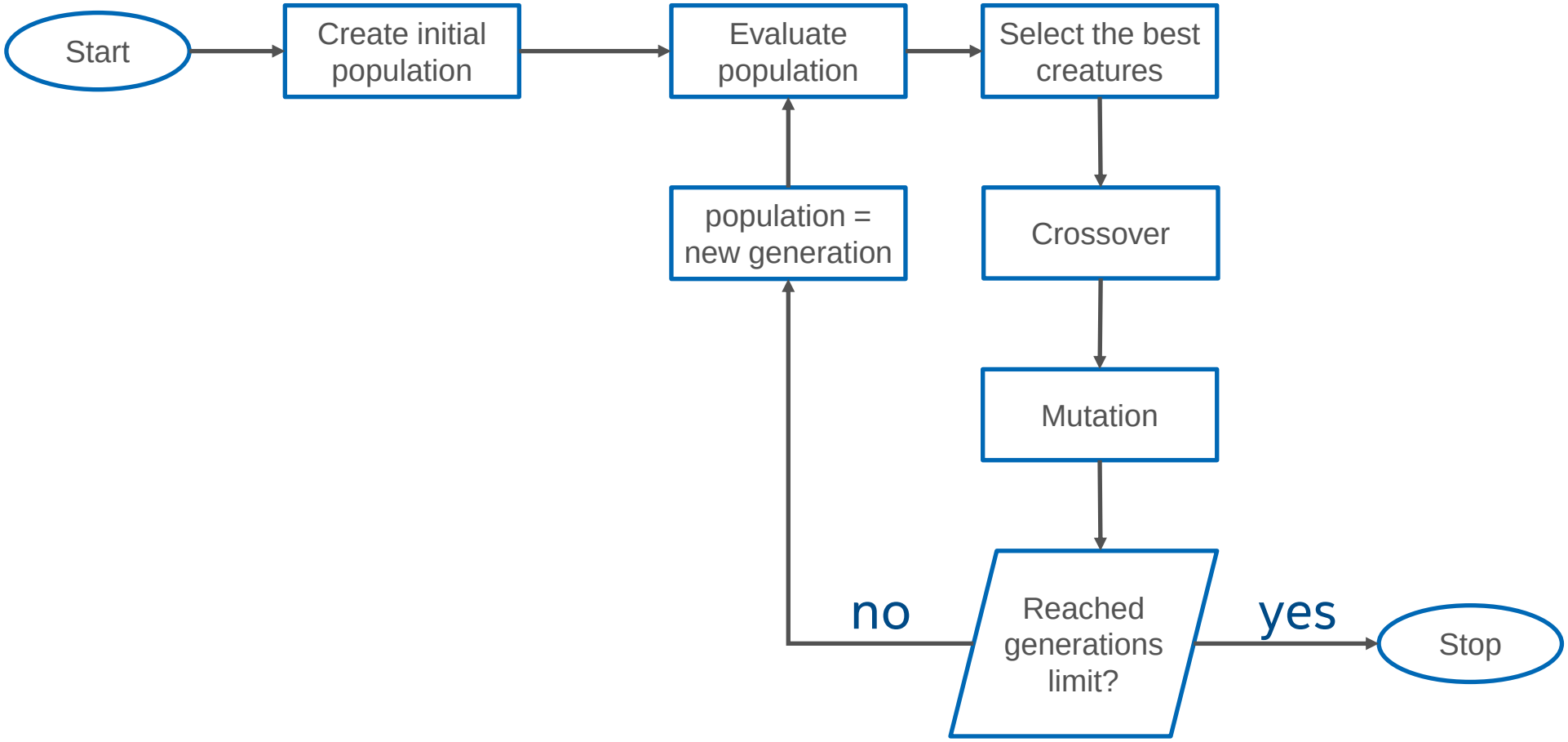
PID Controller – Tuning methods

- K_p K_i and K_d need to be carefully selected
- Behavior of the controller depends on parameters
- Incorrect parameters may destabilize the object
- Usually require manual tuning
- Difficult to find the right parameters

Genetic Algorithms

- Random search method that mimics natural evolution
- Depends on responses from the environment
- Reaches the best solution by:
  - Reproduction
  - Crossover
  - Mutation

Genetic Algorithms



Data evaluation methods

- Compare
  - expected values ($P_i, i = 1, 2, \ldots, n$)
  - observations ($O_i, i = 1, 2, \ldots, n$)
- Errors defined as:

$$e_i = P_i - O_i$$

- Model performance is based on sum of $\mathbf{e_i}$ $(i = 1,2, \ldots, n)$

Data evaluation methods

- Generic formula of average error can be represented by:

$$e_{\gamma}^{-} = [\sum_{i=1}^{n} w_i |e_i|^{\gamma} / \sum_{i=1}^{n} w_i]^{\frac{1}{\gamma}}$$

Data evaluation methods - RMSE

- $\gamma = 2$: Root Mean Square Error
- Most widely used to evaluate model performance
- Bigger errors have more significant impact on the result

$$RMSE = [n^{-1} \sum_{i=1}^{n} |e_i|^2]^{\frac{1}{2}}$$

Data evaluation methods - MAE

- $\gamma = 1$: Mean Absolute Error

$$MAE = n^{-1} \sum_{i=1}^{n} |e_i|$$

Test framework

Framework

1. Create initial random population (from a preconfigured ranges)
2. For each creature in population:
    1. Run tool under test with each creature's parameters
    2. Evaluate results
3. Select candidates for new generation
4. Crossover + mutation
5. Go back to #2 and repeat for each epoch

Framework – Data evaluation

- Match follower system's time to the leader time as closely as possible.
- Ideal scenario requires leader offset to be 0
- Calculate an error between expected values and observations

Framework – phc2sys

1. Set a fixed initial time offset
2. Synchronize system time to the PHC time
3. Use 20 reads/correction to minimize impact of bus contention
4. Use different P and I parameters for controller parameters
5. Run the tool for a fixed time
   - 80 s for short runs
   - 300 s for long runs
6. Parse tool output

Test results

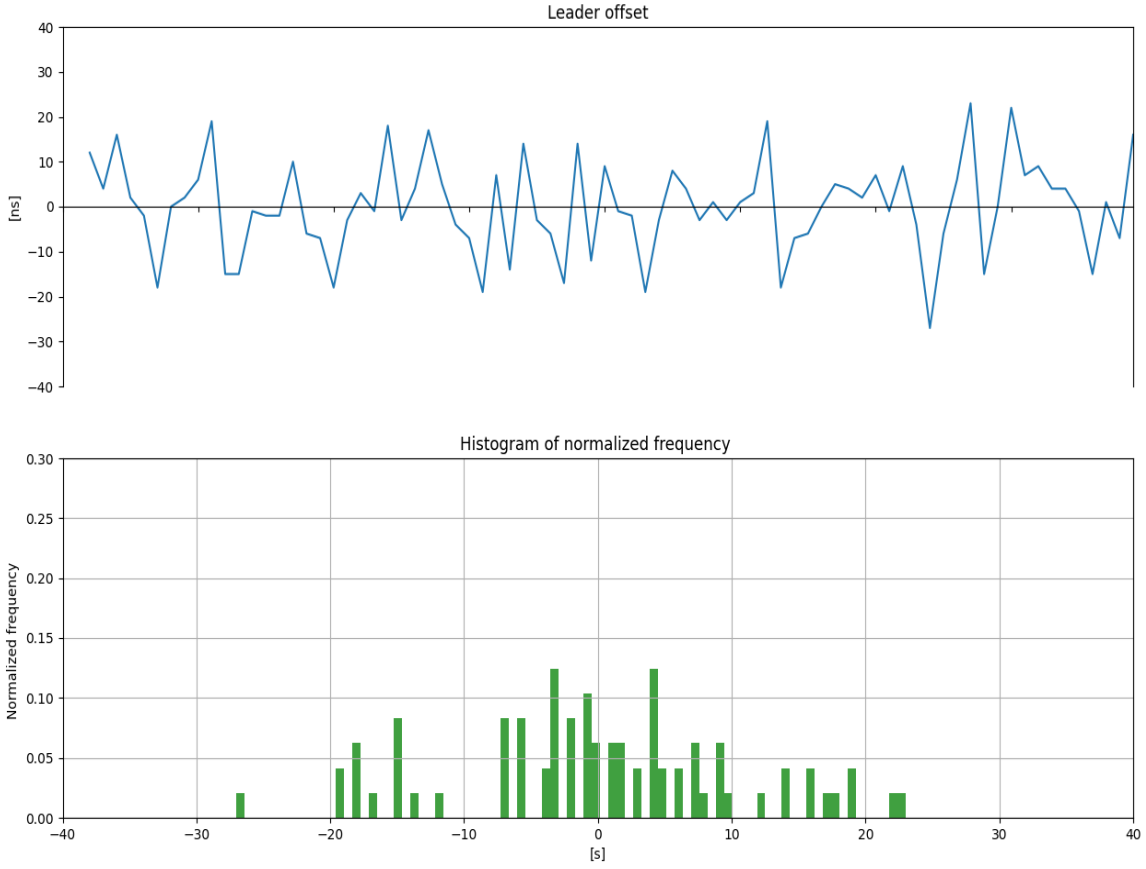
Results

1. Evaluate creatures using different metrics
   - MSE (1)
   - RMSE (2)
   - MAE (3)
2. Run algorithms with different number of epochs
   - 5
   - 10
   - 15

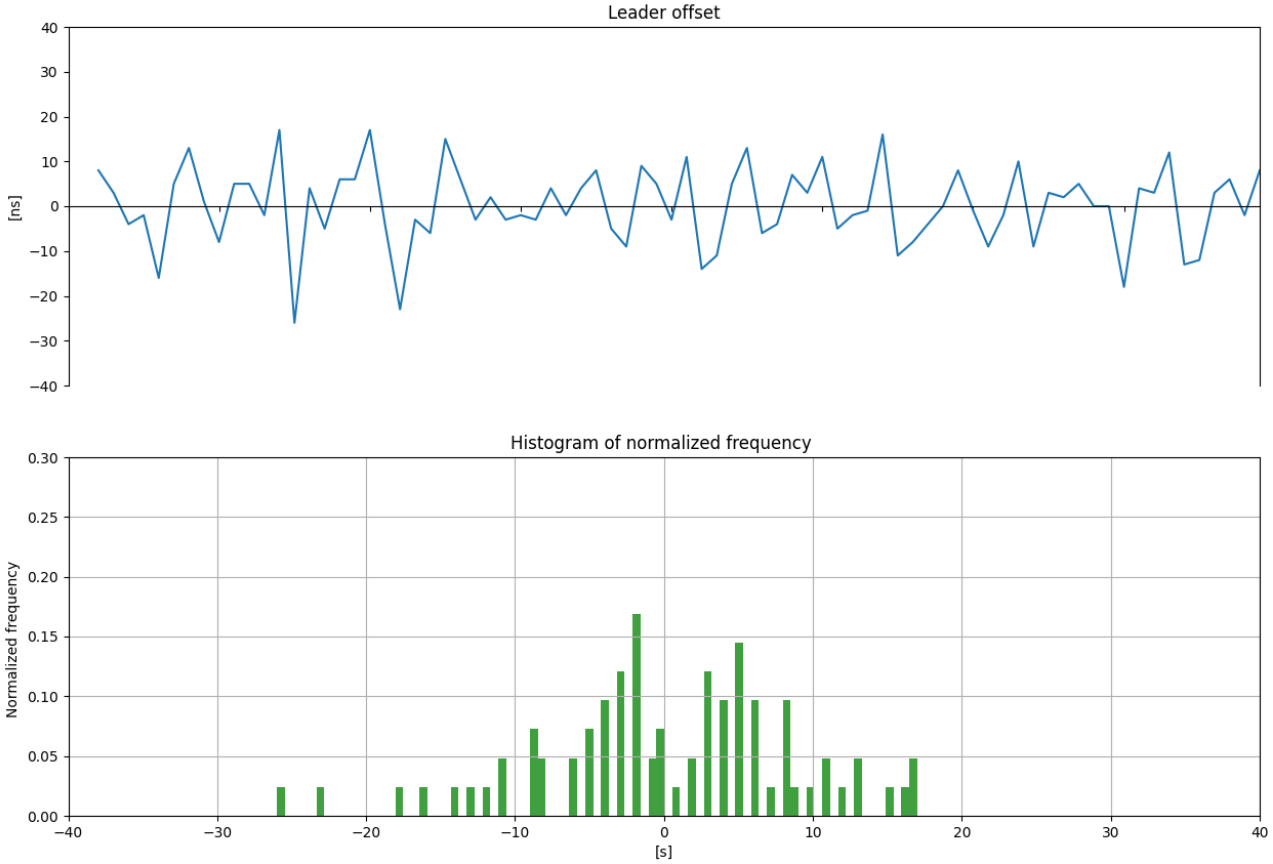
MSE

	Kp	Ki	Result
Default	0.7	0.3	110.26
Elite	0.59	0.93	75.08
		Improvement	32%

Default



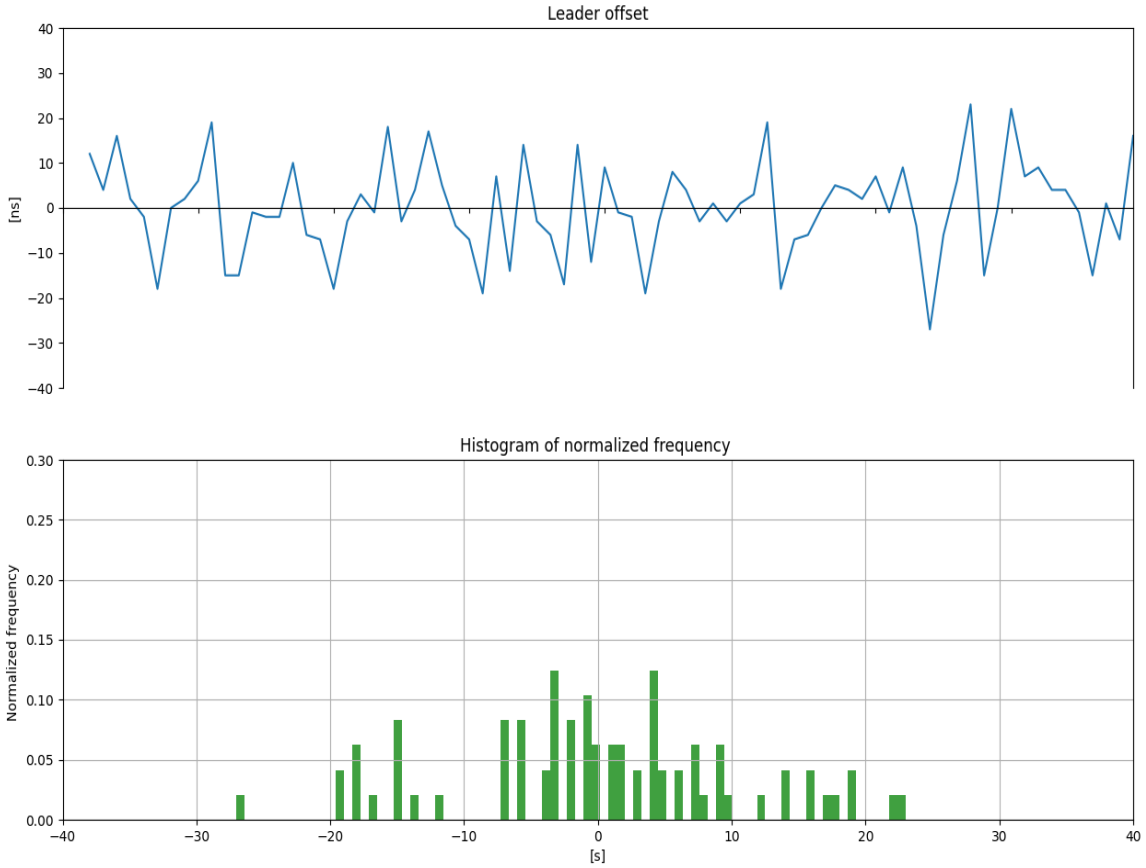
Elite



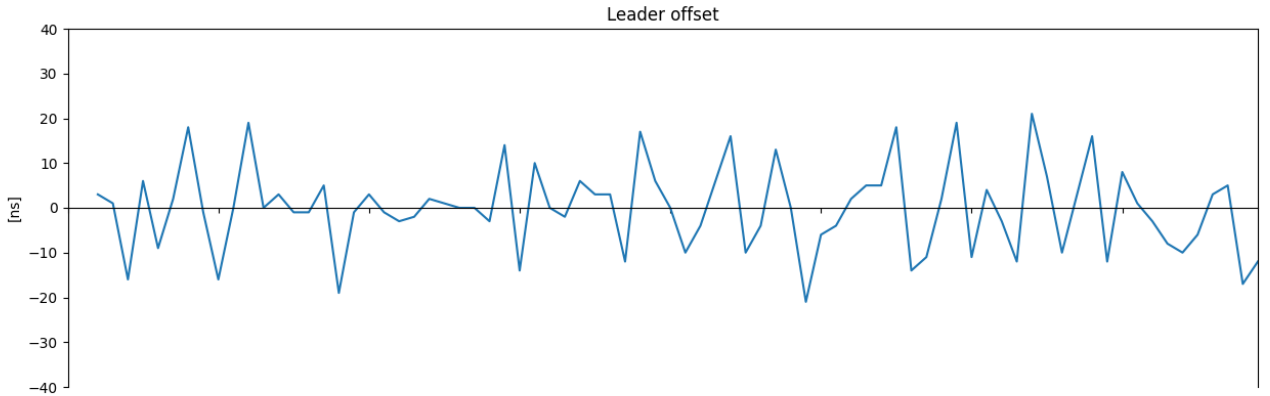
RMSE

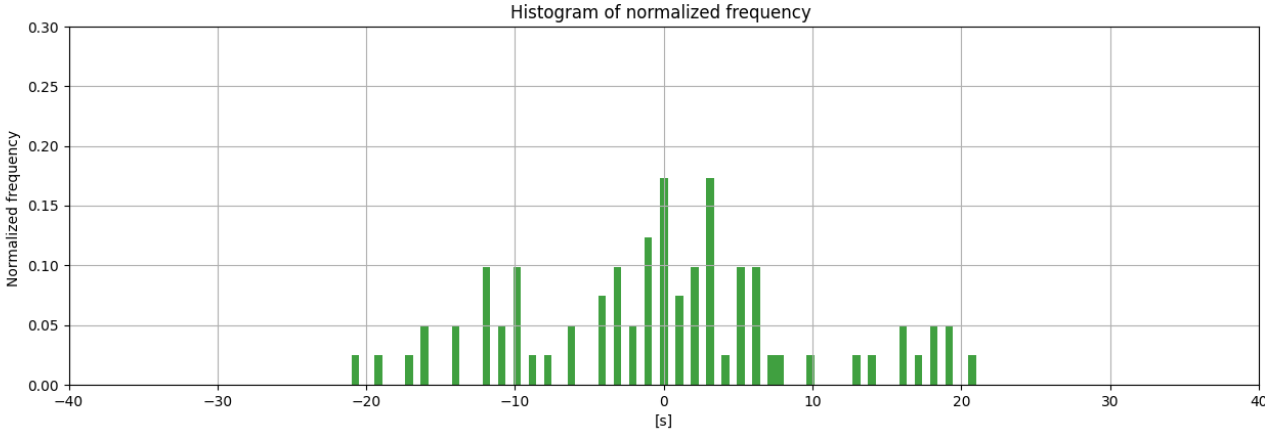
	Kp	Ki	Result
Default	0.7	0.3	11.68
Elite	0.09	0	8.98
		Improvement	23%

Default



Elite

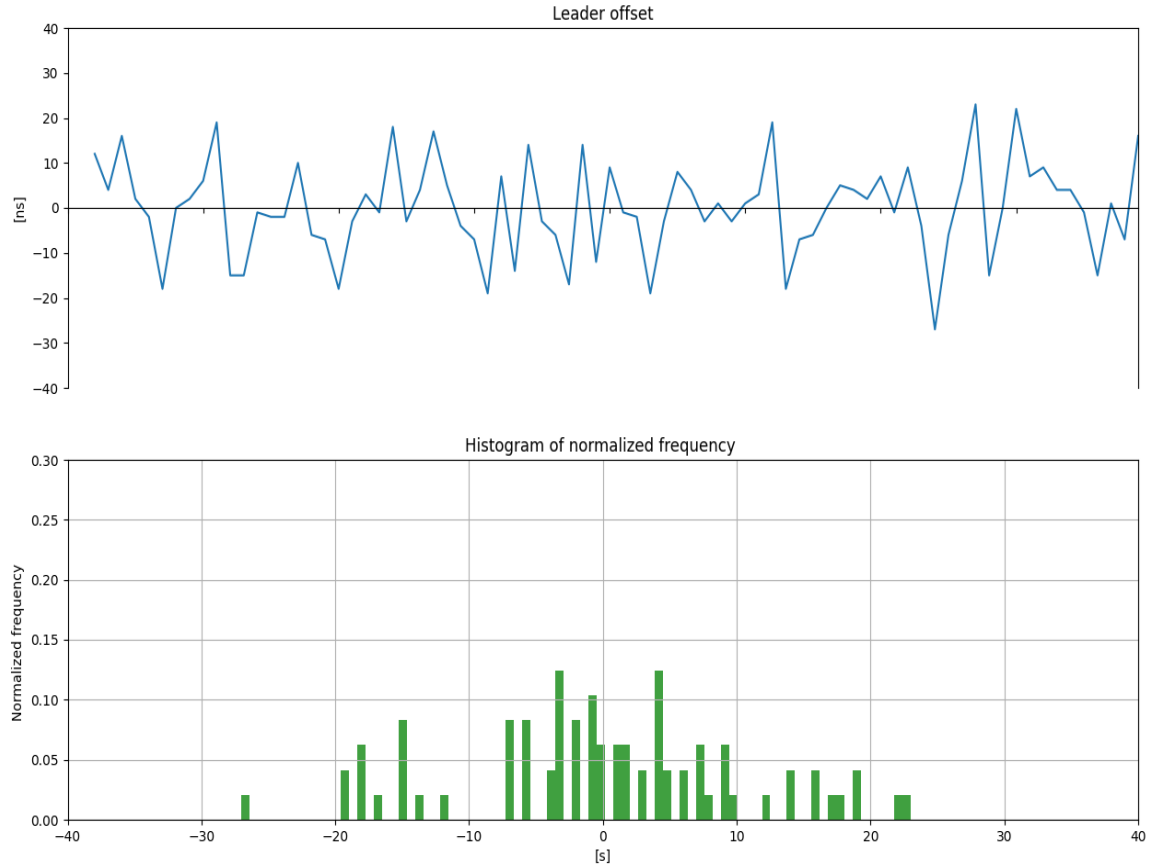




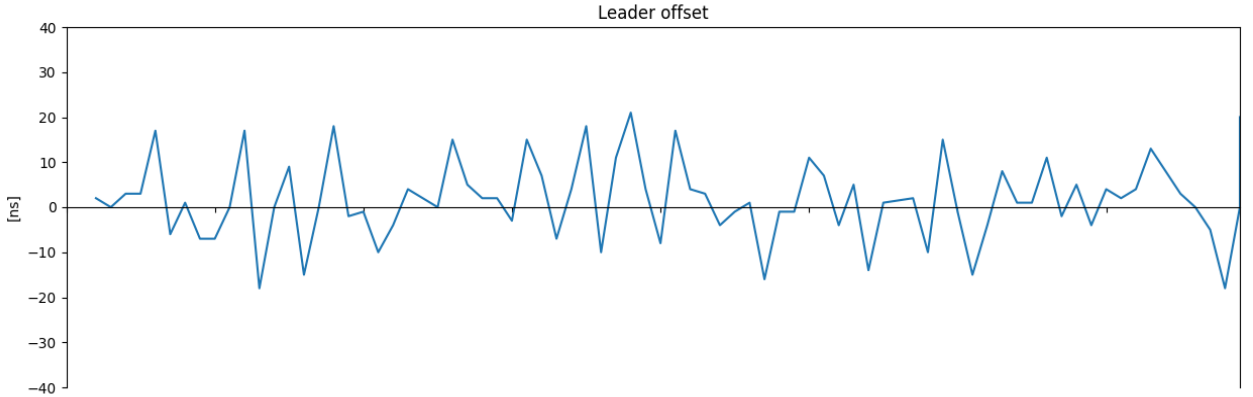
MAE

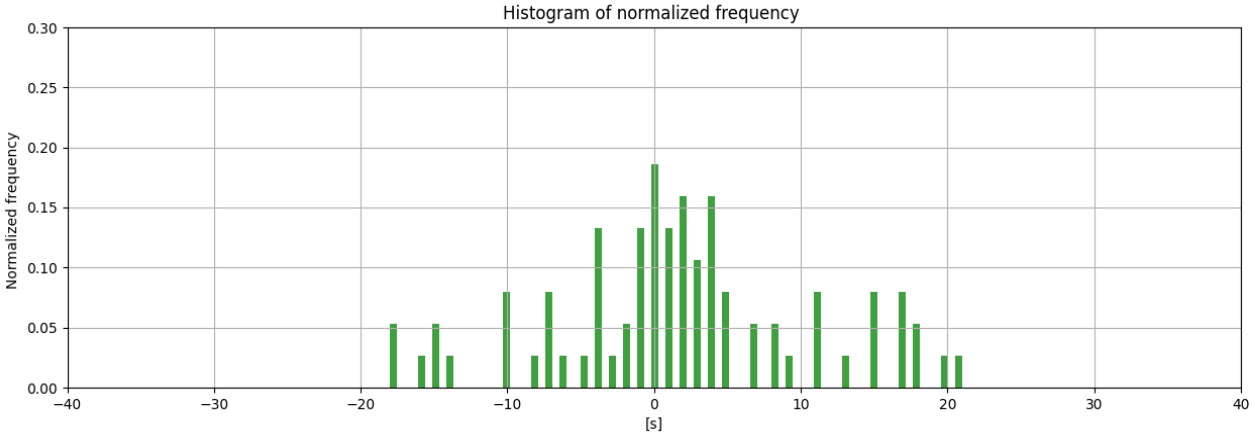
	Kp	Ki	Result
Default	0.7	0.3	8.99
Elite	0	2.51	7.32
		Improvement	19%

Default



Elite





Results (per generation)

Generation	elite Kp	elite Ki	MSE	% improvement over default
1	0.70	0.30	122.65	0%
2	10.68	0.00	112.60	8%
3	9.28	0.00	106.36	13%
4	1.30	0.00	111.71	9%
5	8.97	0.00	116.31	5%
6	9.64	0.00	107.27	13%
7	8.53	0.00	107.94	12%
8	1.99	0.00	107.34	12%
9	9.10	0.00	114.53	7%
10	9.28	0.00	106.36	13%
11	9.28	0.00	106.36	13%
12	6.89	0.00	110.94	10%
13	1.78	0.00	113.03	8%
14	1.40	0.00	105.45	14%
15	1.94	0.00	118.15	4%

Future work

Future work

- Coarse validation of stability of input parameters
  - Remove unstable configurations and replace with a different creature
- Test IEEE 1588 using ptp4l
- Longer test runs
- Find optimal number of epochs
- Find optimal elite size

Key takeaways

- PTP is crucial to meet strict Telco timing requirements
- LinuxPTP use PI controller to minimize errors
- Synchronization quality depend on PI parameters
- GA can optimize PI parameters
- Different goals can be reached using different metrics
- Tuned parameters result in 13-32% smaller errors default ones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