Configuration Manual

MSc Research Project
Cloud Computing

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Project Submission Sheet
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Configuration Manual

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This paper provides a detailed guide for replicating the experimental setup used in the proposed Pareto-based Deep Q-Network (PDQN) load balancing framework.

1 Environment Setup

- **Operating System:** The simulation tested on macOS - Apple M1
- **Python Version:** 3.9.7 (installed via `pyenv`). Due to simulator.
- **Virtual Environment:** Created using `pyenv virtualenv yafs_env`.
- **Key Libraries:**
  - YAFS (Yet Another Fog Simulator)
  - TensorFlow 2.15 for implementing the PDQN agent.
  - Pandas, NumPy for data handling and CSV processing.
  - Matplotlib or plotting simulation results and Pareto front visualizations.
- All library are defined in `requirements.txt`

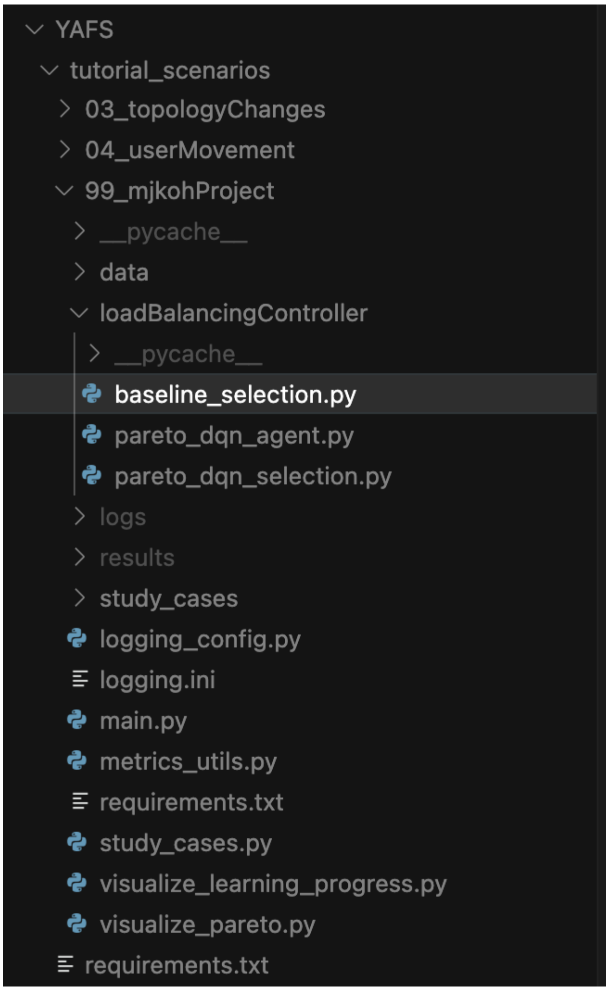
Example installation commands:

```
pyenv install 3.9.7
pyenv virtualenv 3.9.7 yafs_env
pyenv activate yafs_env
pip install -r requirements.txt
```

2 Project Structure

- YASF/tutorial_scenarios/99_mjkohProject — The proposed PDQN load balancing algorithm is built in this root directory by extending YAFS simulator's scenarios.
- loadBalancingController/ — In this directory, every load balancing approach are implemented including baseline alogithm and propoesed PDQN.
- `pareto_dqn_agent.py` — Implementation of the Pareto-based DQN agent.
- `pareto_dqn_selection.py` — Decision-making and routing logic followed the YAFS simulation's flow.

- `metrics_utils.py` — Real-time metrics collection, calculation and normalization latency and energy consumption, and common utility.
- `topologyDefinition.json` — Network topology configuration.
- `usersDefinition.json` — Source workload definitions.
- `results/` — Simulation outputs (CSV files, summary tables, visualization).
- `main.py` — control entire simulation such as setting topology, app, and deploying the simulation.



```
YAFS
  tutorial_scenarios
    03_topologyChanges
    04_userMovement
    99_mjkohProject
      __pycache__
      data
      loadBalancingController
        __pycache__
        baseline_selection.py
        pareto_dqn_agent.py
        pareto_dqn_selection.py
      logs
      results
      study_cases
      logging_config.py
      logging.ini
      main.py
      metrics_utils.py
      requirements.txt
      study_cases.py
      visualize_learning_progress.py
      visualize_pareto.py
    requirements.txt
```

Figure 1: project structure

3 Simulation Configuration

- Three study cases are defined in `study_cases.py`.
  It creates `study_info.json`, `allocDefinition.json`, `topologyDefinition.json` for each study cases. `topologyDefinition.json` includes entity id, model (name), IPT, RAM, cost, and WATT. WATT is used for energy consumption calculation.
  - **Small Scale:** 10 fog nodes

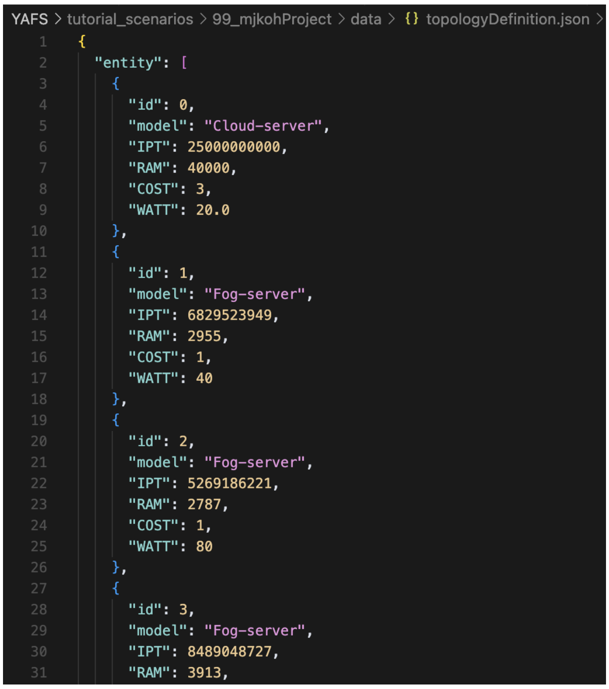
  - **Medium Scale:** 20 fog nodes
  - **Large Scale:** 30 fog nodes

- The `StudyCase` class in the configuration script allows adjusting:
  - Fog CPU range
  - Bandwidth range
  - Number of tasks per IoT device

- Simulation time can be set in the main experiment script to control the training length.

- `allocDefinition.json` includes module_name, app, id_resource. It defines modules deployment.

- `appDefinition.json` defines module, message, transmission etc.


YAFS > tutorial_scenarios > 99_mjkohProject > data > {} topologyDefinition.json >

```
{
  "entity": [
    {
      "id": 0,
      "model": "Cloud-server",
      "IPT": 25000000000,
      "RAM": 40000,
      "COST": 3,
      "WATT": 20.0
    },
    {
      "id": 1,
      "model": "Fog-server",
      "IPT": 6829523949,
      "RAM": 2955,
      "COST": 1,
      "WATT": 40
    },
    {
      "id": 2,
      "model": "Fog-server",
      "IPT": 5269186221,
      "RAM": 2787,
      "COST": 1,
      "WATT": 80
    },
    {
      "id": 3,
      "model": "Fog-server",
      "IPT": 8489048727,
      "RAM": 3913,
```

Figure 2: example of topologyDefinition.json

4 Running the Experiments

1. Ensure the virtual environment is activated:

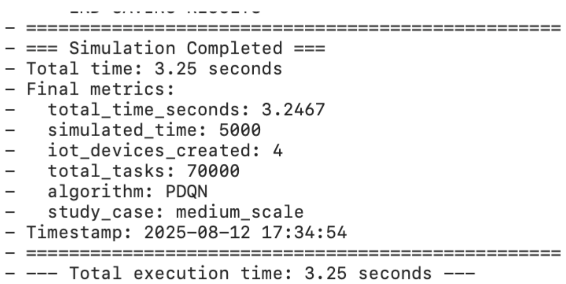
   ```
   pyenv activate yafs_env
   ```

2. Select the desired scale in the experiment configuration.

3. Run the simulation:

```
python3 main.py -t 5000 -s small_scale -a ALL
```

4. -t : simulation time
5. -s : study case (small_scale, medium_scale, large_scale)
6. -a : algorithm (RR, WRR, PDQN, ALL)
7. Results will be stored in `results/<scale>`.



```
- ==================================================
- === Simulation Completed ===
- Total time: 3.25 seconds
- Final metrics:
-   total_time_seconds: 3.2467
-   simulated_time: 5000
-   iot_devices_created: 4
-   total_tasks: 70000
-   algorithm: PDQN
-   study_case: medium_scale
- Timestamp: 2025-08-12 17:34:54
- ==================================================
- --- Total execution time: 3.25 seconds ---
```

Figure 3: simulation log example

5 Notes for Reproducibility

- The cloud server (node ID 0) is excluded from load balancing decisions.
- All routing decisions follow YAFS's `__send_message()` mechanism to simulate realistic network delays.
- Users may adjust the `lambda` parameter in `usersDefinition.json` to control the message generation rate.
- Hyperparameters such as learning rate, epsilon decay, and reward normalization are adjustable in `pareto_dqn_agent.py`.

6 Output and Visualization

- **CSV Outputs:** Every output is stored in results directory. In this directory, outputs are stored divided by study cases.
  - `result/small_scale/link_PDQN.csv`, `result/small_scale/result_RR.csv`, etc.
  - `result/medium_scale/simtrace_PDQN.csv`, etc.
  - `result/medium_scale/pareto_front_PDQN.csv` : recorded Pareto front values per episode.
  - `result/small_pareto_summary.csv`, etc.: latency/energy trade-off summary.
- **Graph:**

  - `resutl/<scale>/sim_trace_<algorithm>_grahp.gexf` — They are created by YAFS simulator defined every topology network in the graph.

- **Plots:**

  - latency, energy consumption comparison to each algorithm per scale.
  - pareto front, learning progress per episode for PDQN algoirthm. These two scatter plots did not use in the report because of ambiguous to show the improvement of learning.

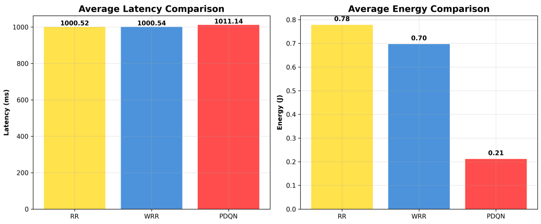
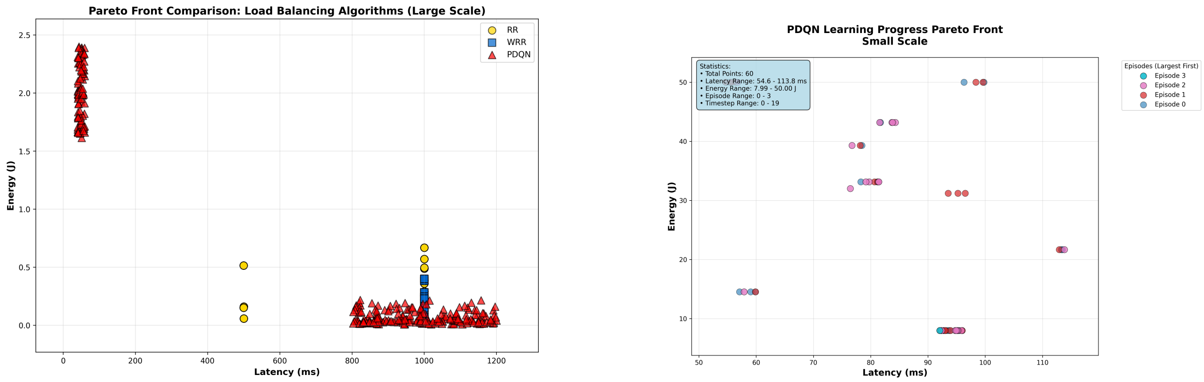


Figure 4: small scale algorithm comparison



(a) large scale pareto_front comparison

(b) pareto front learning progress

Figure 5: These plots did not use in the report