EdgeDroid

An Experimental Approach to Benchmarking Human-in-the-Loop Applications

M. Olguín Muñoz[†], J. Wang[‡], M. Satyanarayanan[‡] and J. Gross[†]

[†] KTH Royal Institute of Technology
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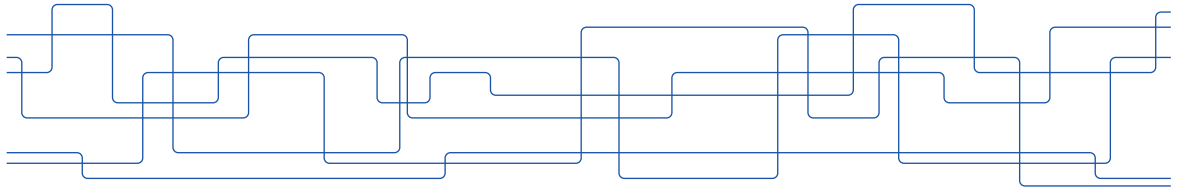
HotMobile'19 Session 5: February 28th 2019, Santa Cruz, CA



2019-02-28

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- Name all authors
- Mention Sweden

- Exciting new applications which integrate with the real world and the users.
- Put the human in a feedback loop.
- High dimensional, context-aware inputs.
- High dimensional, human-parseable outputs.

Sensory Input

Human-parseable
Feedback

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- Put the human in a feedback loop.
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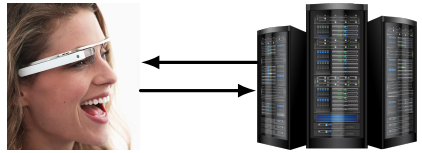
Studying Human-in-the-Loop Applications

Need to understand and optimize these applications:

- How do they interact with each other?
- How do they interact with infrastructure?
- How do they scale?

With which methodology can we study these behaviors?



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- They are interesting for developers, users, training, live assistance, etc.
- We still don't know much.

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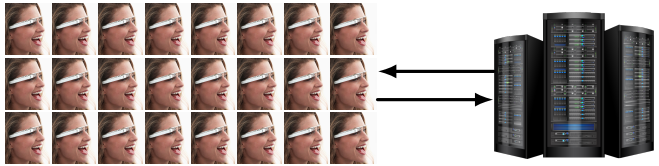

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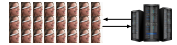

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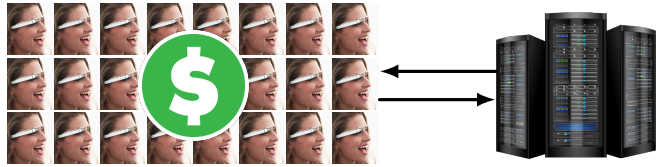

Costly

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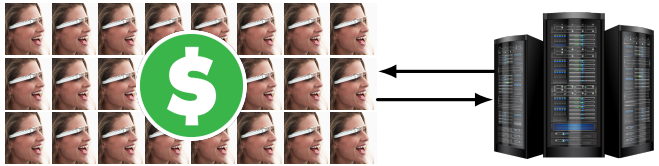

Costly, poor repeatability

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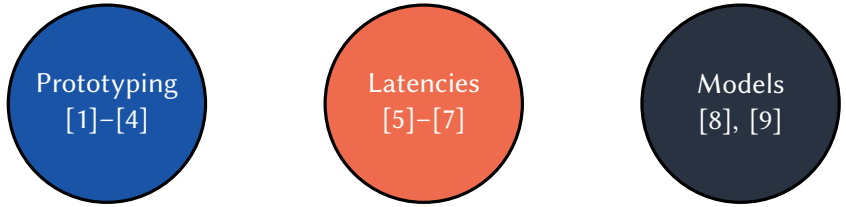
Previous & Related Work



Previous & Related Work
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[1]–[4]
Latencies
[5]–[7]
Models
[8], [9]

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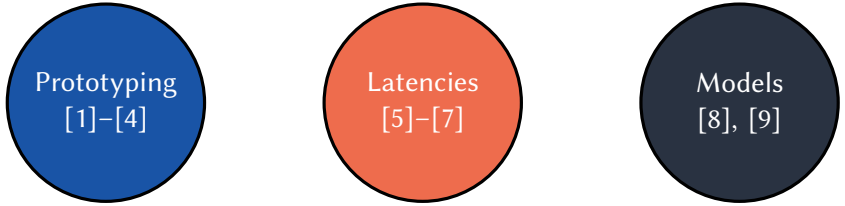

Our Contributions

- A methodology for benchmarking human-in-the-loop applications.

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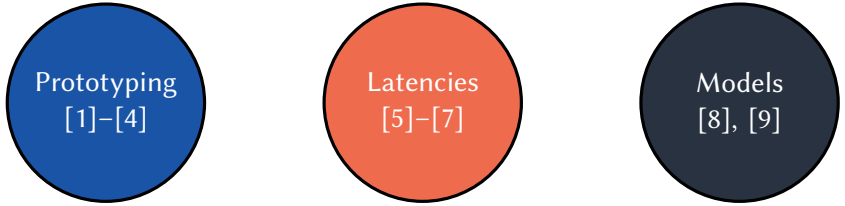

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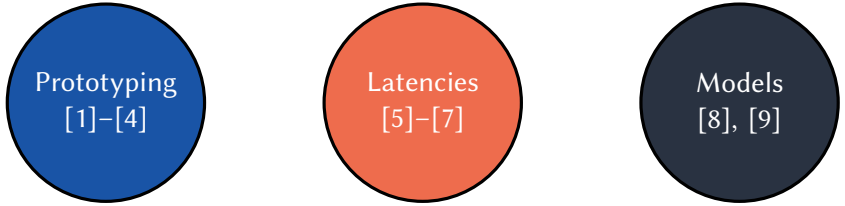

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- A methodology for benchmarking human-in-the-loop applications.
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- Experiments and measurements which show the effectiveness of the approach.

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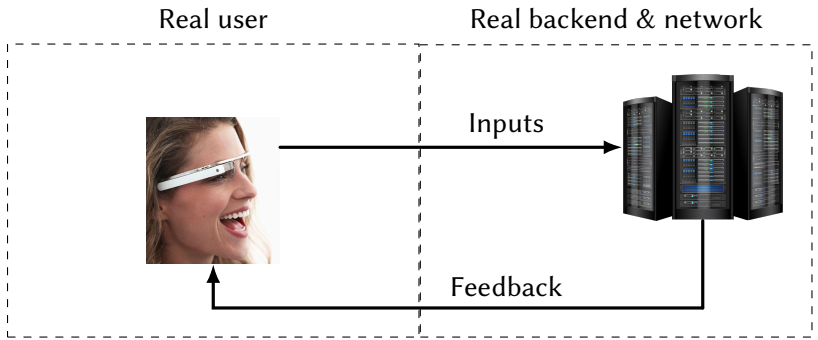
Approach

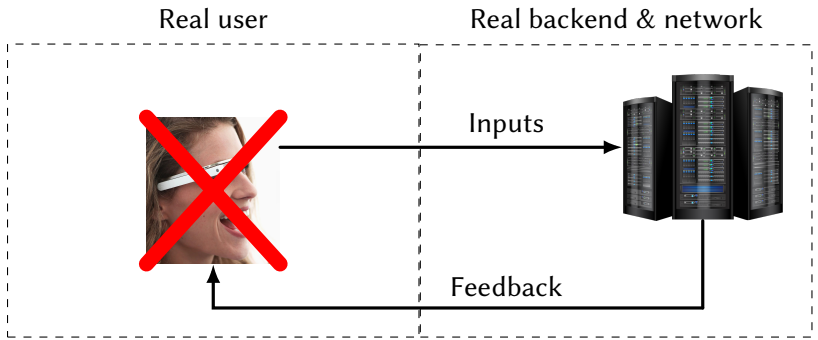


Benchmarking human-in-the-loop applications is HARD

Approach
Real user
Real backend & network
Inputs
Feedback
Benchmarking human-in-the-loop applications is HARD

- Hard because of humans.
- Trace-based approach with a “user model” which modulates the replay of the trace.
- I will explain “user model” in the next slides using an example.

Approach



What if we could do away with the human users?

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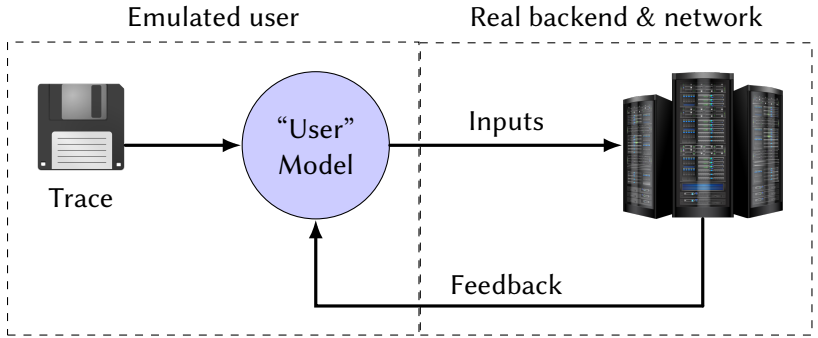

What if we could do away with the human users?
Repeatable, scalable!

Approach
Emulated user
Real backend & network
"User" Model
Trace
Inputs
Feedback
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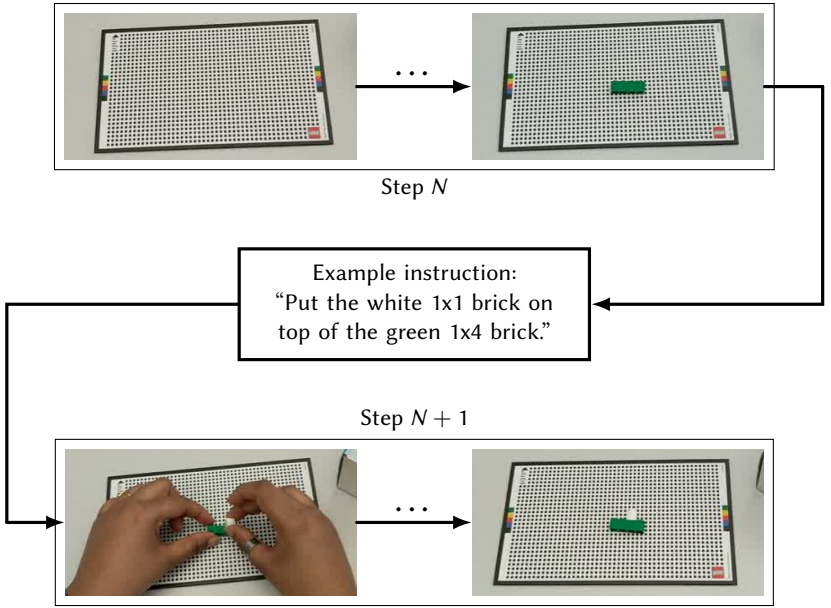
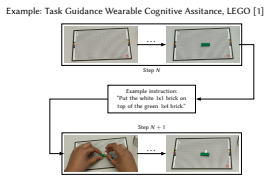
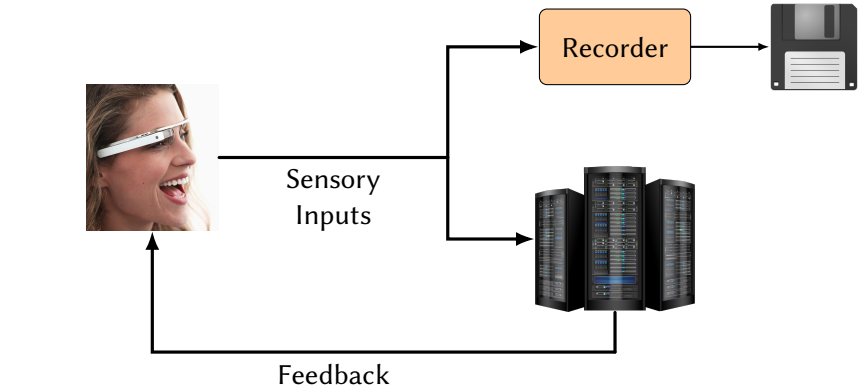
Example: Task Guidance Wearable Cognitive Assitance, LEGO [1]

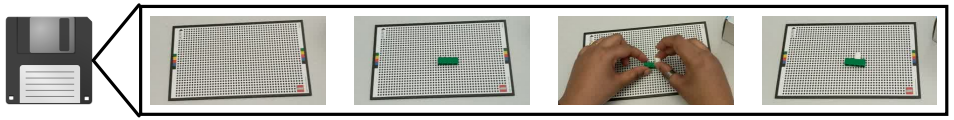


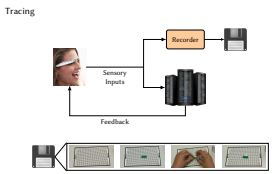


- Running example.
- Explain LEGO step by step. Captures video and gives feedback instructions.
- Don’t say it was created at CMU.
- Usable simple example for initial implementation because of Linear model.

Tracing







- First step in our approach is tracing.
- Trace raw inputs.
- Example: LEGO -> video frames.

Trace Replay

Non-trivial Challenge

- Changes in system responsiveness require adapting trace.
- System delays affect user behavior as well.

Trace Replay
Non-trivial Challenge
- Changes in system responsiveness require adapting trace.
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- Merely replaying trace is not enough.
- What happens if the responsiveness of the system changes?
- Need a way to adapt the trace to system conditions.

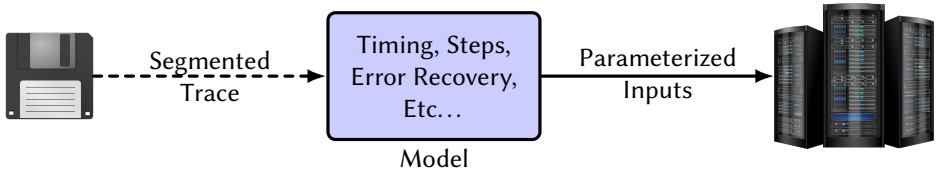
Trace Replay

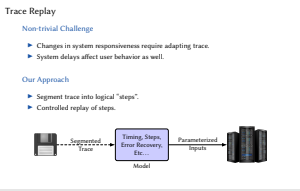
Non-trivial Challenge

- Changes in system responsiveness require adapting trace.
- System delays affect user behavior as well.

Our Approach

- Segment trace into logical “steps”.
- Controlled replay of steps.





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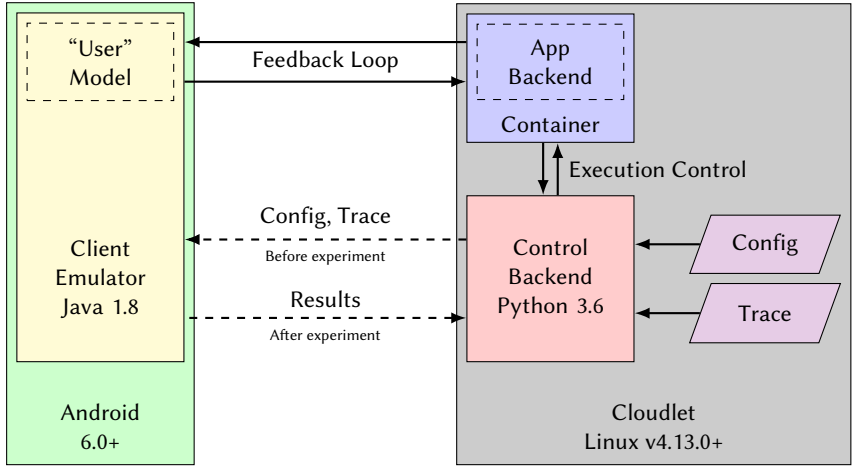
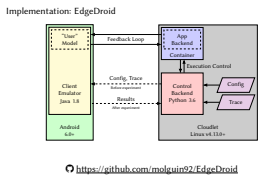
Implementation: EdgeDroid



https://github.com/molguin92/EdgeDroid



- Very short about implementation.
- Remind that we don't emulate backend or network.

Evaluation

Key purpose:
Demonstrate utility of EdgeDroid.

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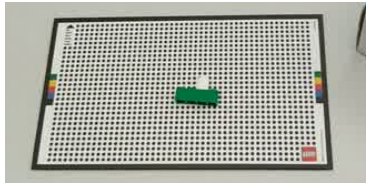
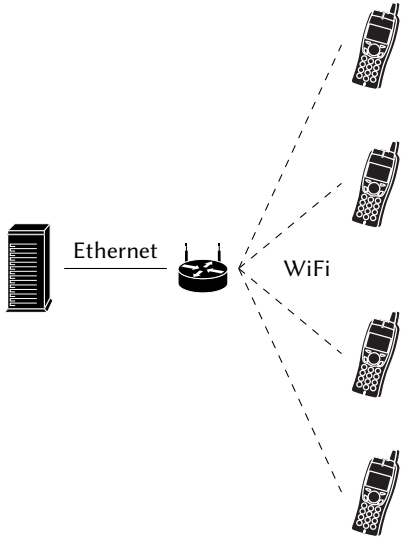
Evaluation: Setup

Application & Scenarios



LEGO Assistant



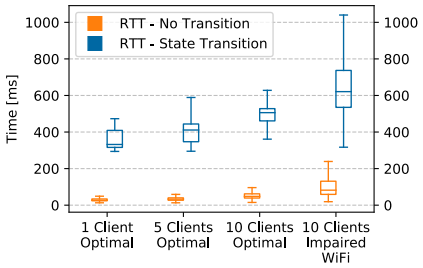
- Three *optimal* scenarios with 1, 5 and 10 devices.
- Weakened wireless link with 10 devices.
- KPI: Round-Trip Time (RTT).

Evaluation: Setup
Application & Scenarios
LEGO Assistant
Three optimal scenarios with 1, 5 and 10 devices.
Weakened wireless link with 10 devices.
KPI: Round-Trip Time (RTT).
Ethernet
WiFi

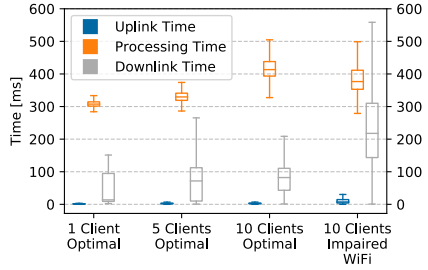
- Use example of app developer and system designer to exemplify results.

Use Cases

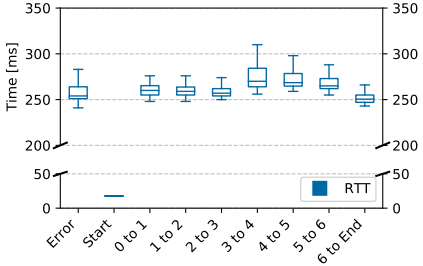
State change vs. no state change.

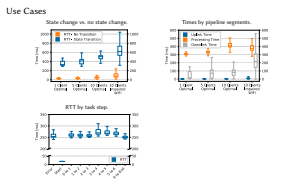


Times by pipeline segments.



RTT by task step.





- Use example of app developer and system designer to exemplify results.
- Important aspect is that these results are repeatable and automatically obtained.
- Did not have to train 10 users.

Conclusions

Future Work

- User Model.
- Other types of Applications.

Summary

- Need to study the scaling of Human-in-the-Loop applications.
  - Difficult due to human users.
- Methodology + tool suite for benchmarking:
  - **EdgeDroid**
  - Trace based.
  - Model of human behavior.
- Results which show the utility of EdgeDroid.

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- Results which show the utility of EdgeDroid.

- Talk about future model of human behavior.
- Expand to other types of applications that are not task-based.

Thank you.

Contact

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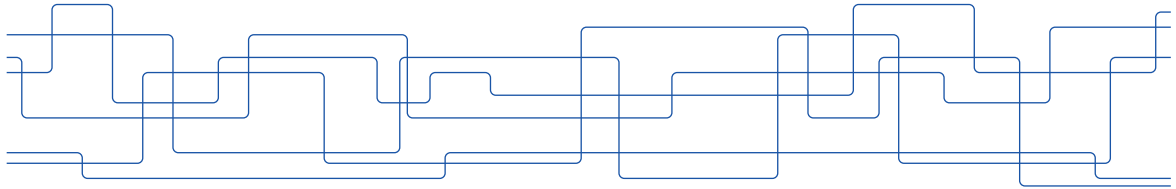
Website: https://olguin.se



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Requirements

- Generate realistic, high-dimensional, real-time inputs.
- Correctly and realistically react to feedback.
- KPI: Delays.

Trace of pre-recorded inputs & a model of user behavior

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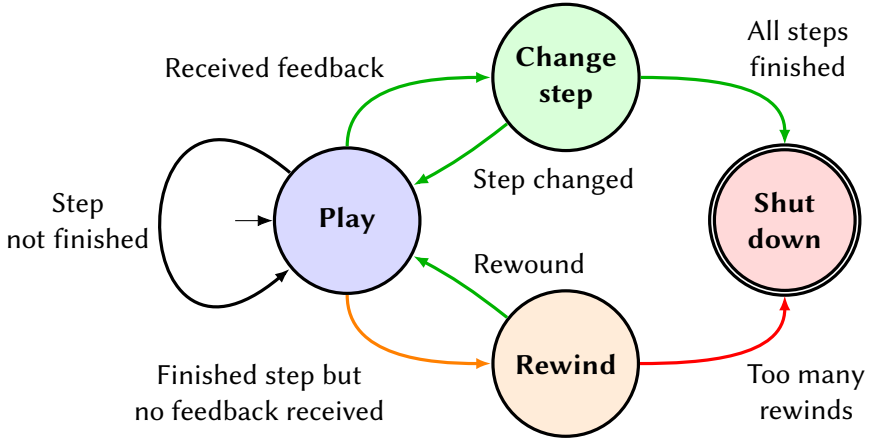
KPI: Delays.
Trace of pre-recorded inputs & a model of user behavior

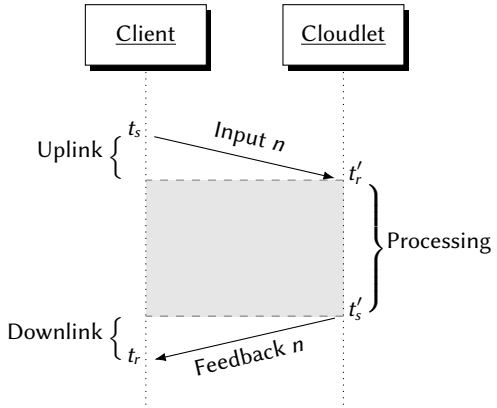
User Model



Future work: more elaborate models.

User Model
Future work: more elaborate models.

Timestamping



Clocks are synchronized previous to the experiment.

Timestamps at key points to obtain:

$$\Delta T_{\text{up}} = t'_r - t_s \quad (1)$$

$$\Delta T_{\text{proc}} = t'_s - t'_r \quad (2)$$

$$\Delta T_{\text{down}} = t_r - t'_s \quad (3)$$

$$\Delta T_{\text{total}} = \Delta T_{\text{up}} + \Delta T_{\text{proc}} + \Delta T_{\text{down}} = t_r - t_s \quad (4)$$

Timestamping
Client
Cloudlet
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References I

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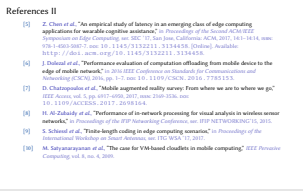

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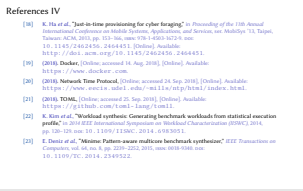
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