Processing of Mix-Sensitivity Video Surveillance Streams on Hybrid Clouds

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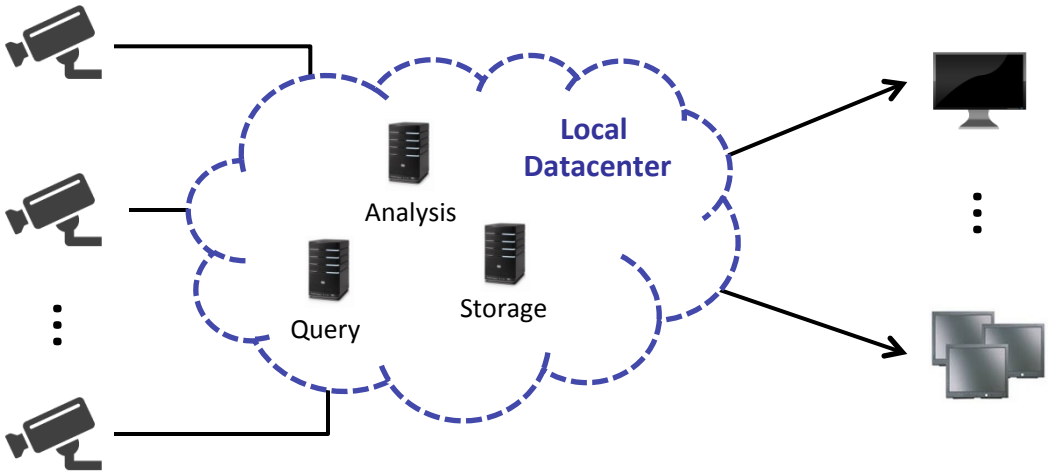
Outline

1. **Motivation**
2. Hybrid Cloud Video Surveillance Model
3. Scheduler
4. Evaluation
5. Conclusions

1. Motivation



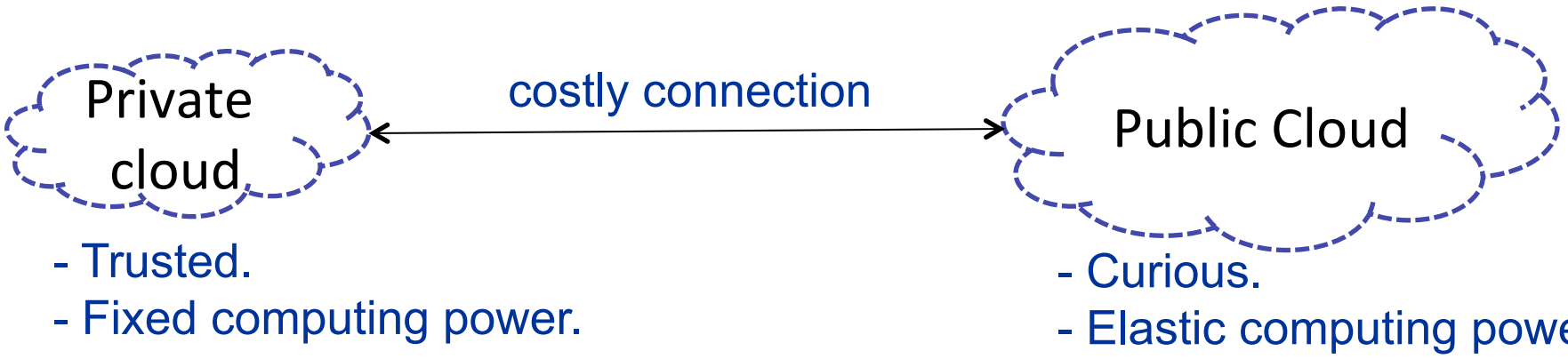
Video Surveillance Systems

- **Video surveillance systems are inherently data-intensive and often compute-intensive**
  - Transcoding, indexing, video analytics etc
  - Workload could be seasonal

1. Motivation

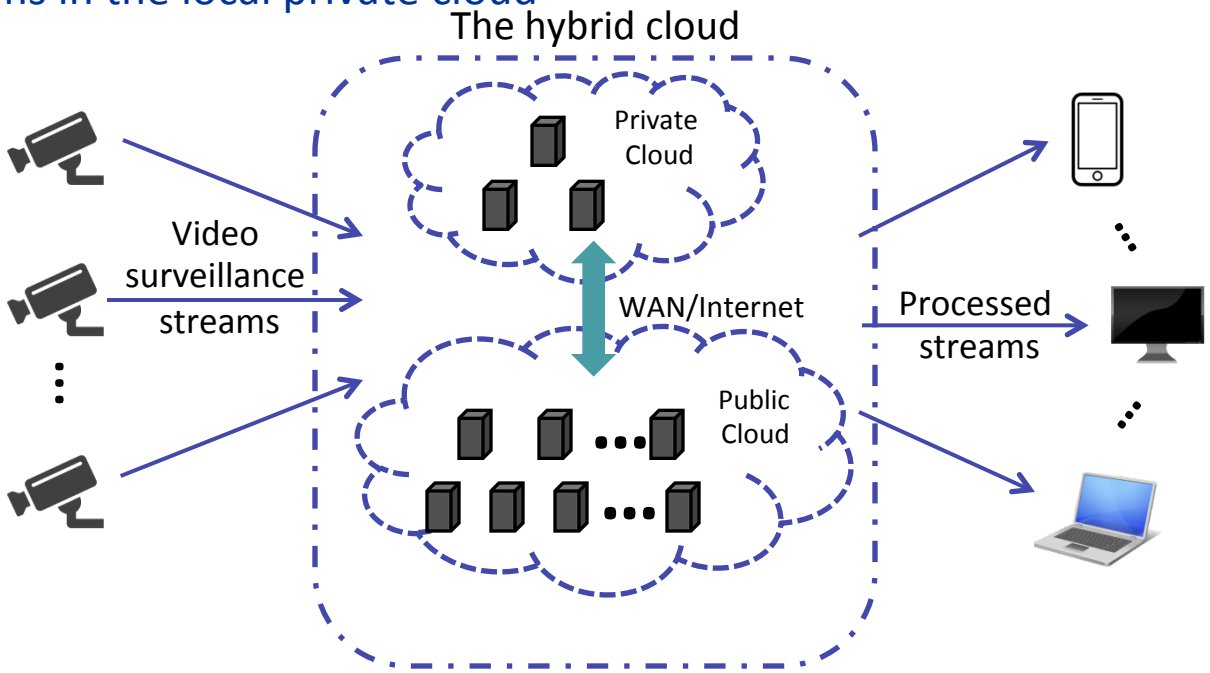
- **Outsourcing to public cloud (e.g., Amazon AWS)?**
  - Surveillance videos could contain sensitive info.
    - Various data breaches were report for different cloud provider
  - Processing in the encrypted domain is too costly for large video data.

- **We consider the approach of data/computations segregation in the hybrid cloud.**



1. Motivation

- **A hybrid cloud-based video surveillance system**
  - Pushing partial video streams to public cloud while keeping sensitive video streams in the local private cloud



- **It's desired to have a middleware that unifies the two clouds and schedules the computation effectively.**

1. Motivation

- **Previous works on distributed stream processing focus on scheduling among multiple servers to balance workload among all the servers, etc.**

- **Our problem can be treated as a special case of some known general scheduling models but has its difference**
  - Conceptually consists of only two servers – a private and a public server

Our Works

- **A stream processing model specifically designed for the hybrid cloud setting**
  - Can handle ad-hoc queries and dynamic clients without rescheduling
- **Formulation of the scheduling problem**
  - Minimizes the monetary cost to be incurred on public cloud, subject to resources, security and QoS constraints
- **An efficient scheduler**
- **A proof-of-concept system**

Outline

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2. **Hybrid Cloud Video Surveillance Model**
3. Proposed Scheduler
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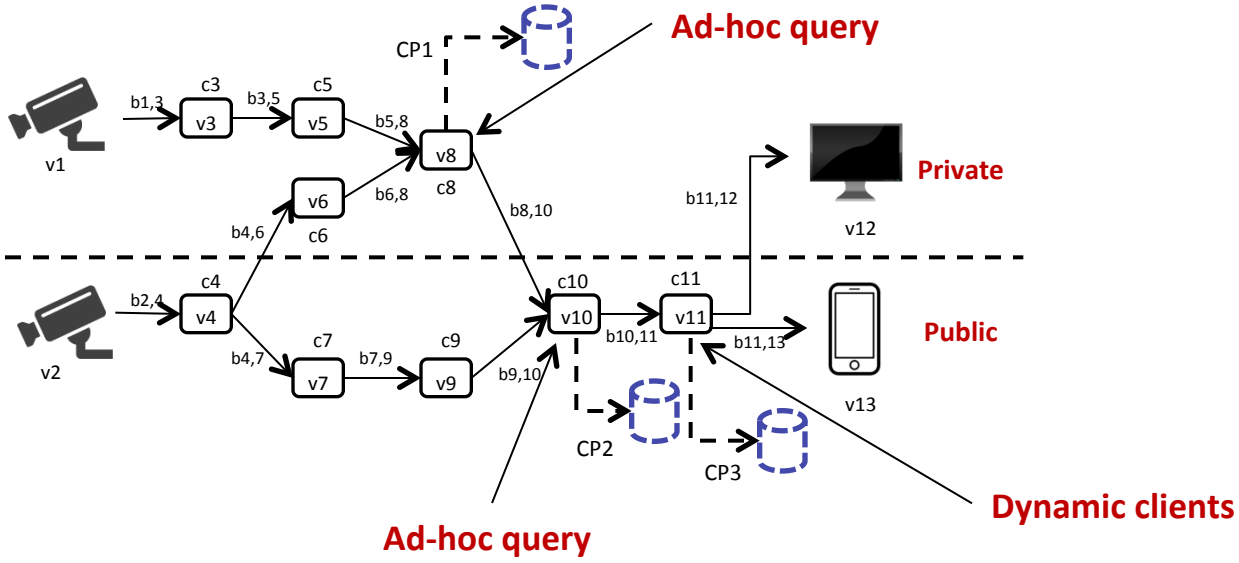
2. Hybrid Cloud Video Surveillance Model

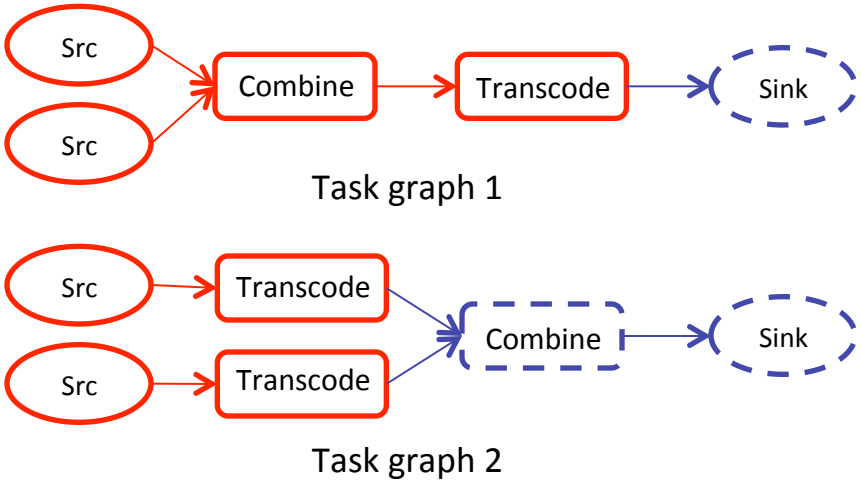
Stream Processing Model

- Each task template is modeled as a directed, acyclic and labeled graph.
  - Each template can be instantiated to multiple sources/sinks.
  - Connection Points (CPs): where ad-hoc queries and "dynamic clients" can attach

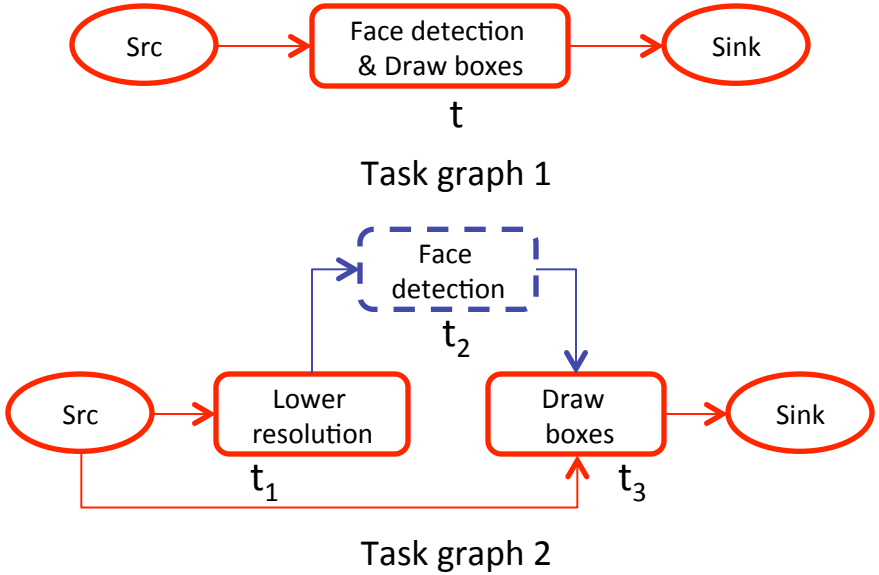


2. Hybrid Cloud Video Surveillance Model

Some tasks could be completed in multiple ways:



Example 1

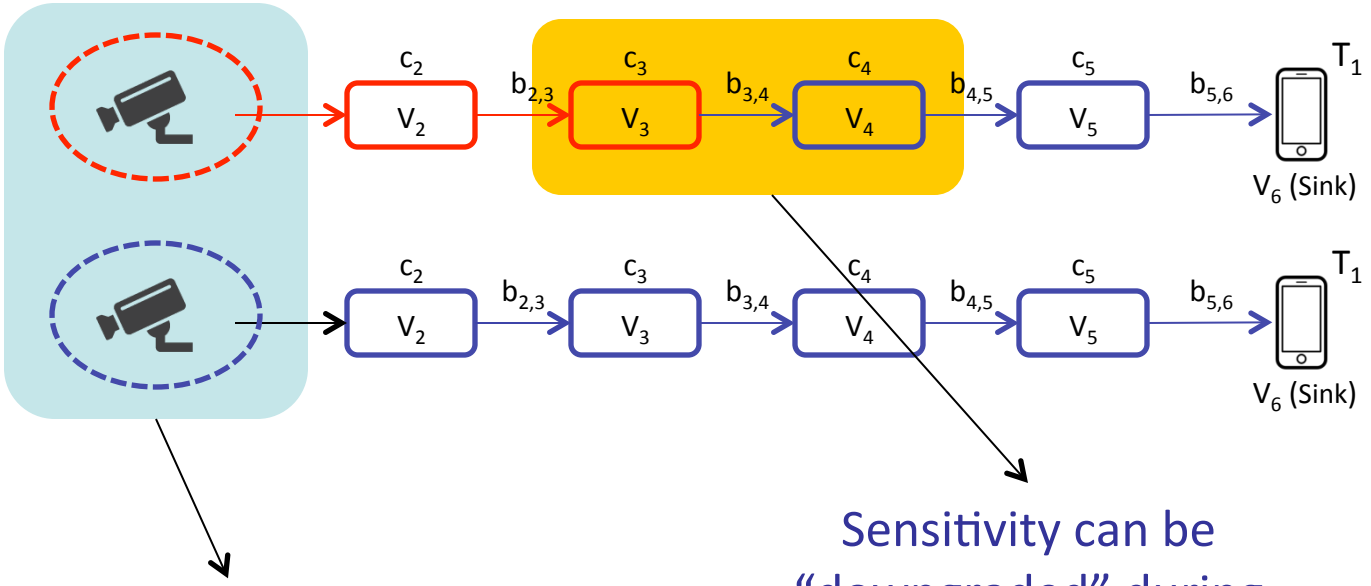


Example 2

2. Hybrid Cloud Video Surveillance Model

Security Model

- Each node in an instantiated task is tagged as *sensitive* or *non-sensitive*

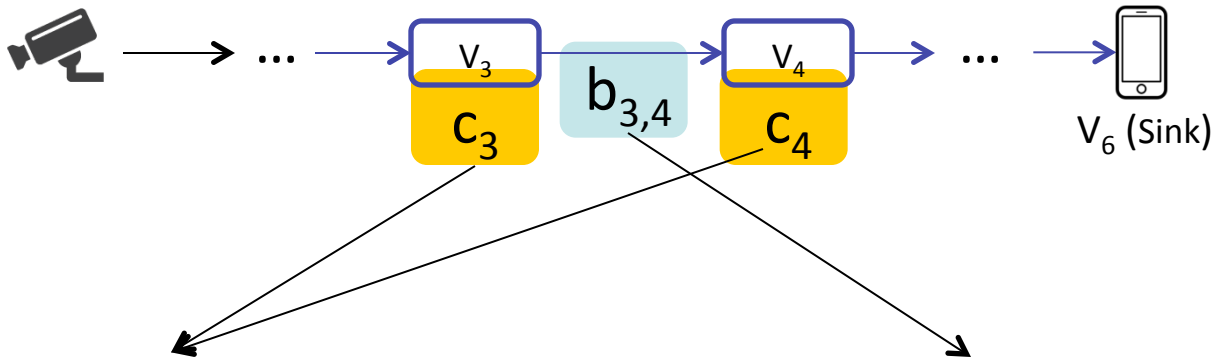


"Videos generated by cameras in the meeting room is sensitive iff time is between 2--4pm"

2. Hybrid Cloud Video Surveillance Model

Cost Model

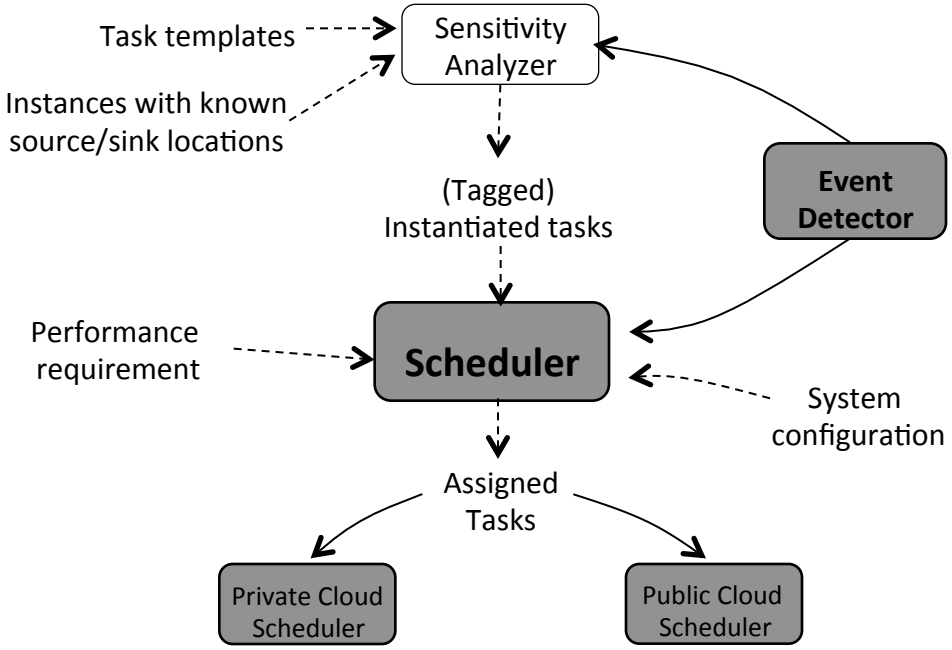
- Approximates actual monetary cost to be incurred



*Each ECU provides the equivalent CPU capacity of a 1.0–1.2 GHz 2007 Opteron or Xeon processor.

2. Hybrid Cloud Video Surveillance Model

System Architecture



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3. Scheduler – problem formulation

- **Given:** a set of task templates, and the number of time each template is to be instantiated.

- **Find:** The assignment of every operations in each instantiated task such that the cost incurred is minimized, subject to:

  (1) Private cloud cannot be overloaded;

  (2) Sensitive streams cannot flow into public cloud;

  (3) Delay constraint for each assigned task can be met.

3. Scheduler – problem formulation

Cost function

parameter α and β can be determined by the cloud pricing model in use, e.g., α = 0.08 and β = 0.684 according to Amazon

$$COST = \alpha \sum_{i,j} c_j^i (1 - x_j^i) + \beta \sum_{i,j,k} b_{j,k}^i |x_j^i - x_k^i|$$

Computation cost (α * number of ECUs)

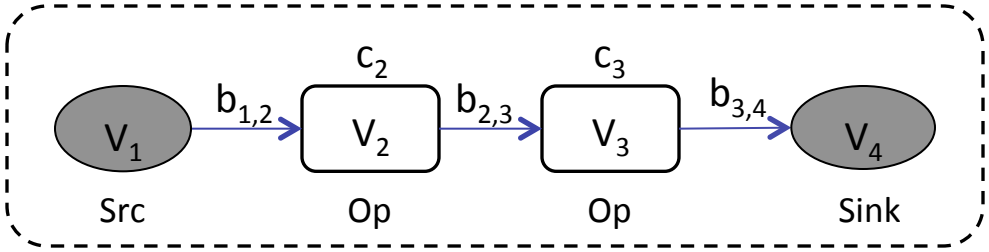
communications cost (β * inter-cloud bandwidth)

x_j^i: assignment of operation *j* in instantiated task *i*.
Value 0 if assigned to public cloud; 1 otherwise.

3. Scheduler

- **Not surprisingly, finding the optimal solution is NP-hard.**

- **Our solution:**
  - Reduce the states space to a smaller set of "minimal configurations", and then employs integer programming to select the desired configurations



in this example, there
are 4 possible configurations:
whether V_2, V_3 to be in public or private.
Not all configurations need to be considered

  - In cases where the problem size are still too large for the integer programming solver, employ a heuristic to further reduce the number of configurations.

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4. Evaluation

Conducted two groups of experiments:

- **Large-scale simulations**
- **Proof-of-concept system evaluation on Amazon EC2**

We consider 5 schedulers

1) Task-Level Water-filling (TLW): if a task contains sensitive operations, the whole task is assign private, except for sinks. Otherwise, assign it to public.

2) Task-Level Random (TLR): same as TLW but randomly assign non-sensitive task.

3) Greedy: Consider the task one by one, using the optimal assignment for each of them.

4) ProposedC: our scheduler with objective to minimize monetary cost

5) ProposedB: our scheduler with objective to minimize bandwidth usage

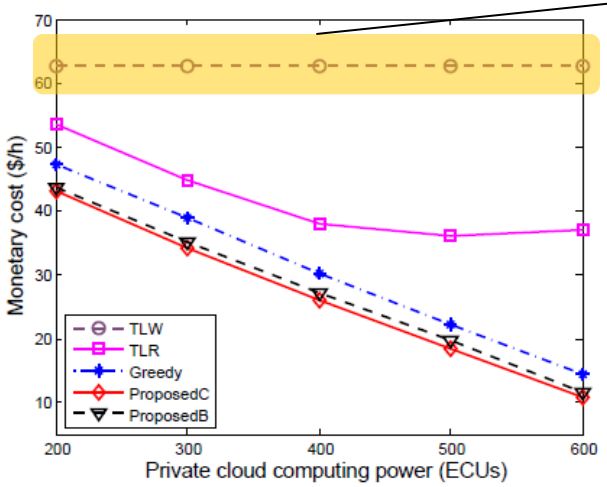
4. Evaluation: simulations

- **Simulation Setting**
  - 10 different task templates where the number of operations nodes ranging from 3 to 15
  - Choose compute cost in (0,2] ECUs and bandwidth cost in (0,1] MB/s
  - Each template is to be instantiated to 10 streams. Randomly set the sensitivity.
  - Private cloud ranges from 200 to 600 ECUs, Delay constrain: 250ms

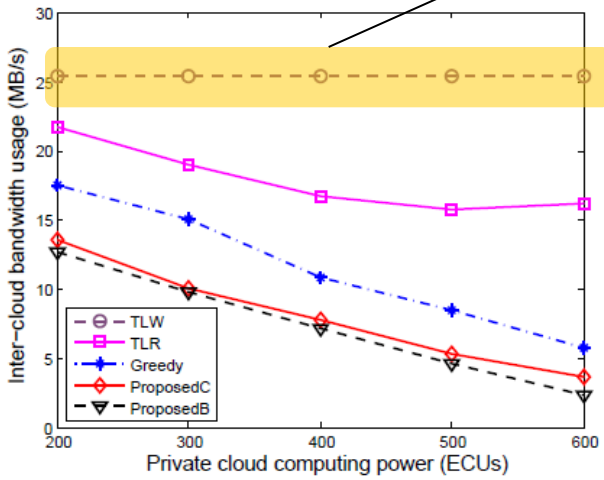
4. Evaluation: simulations

- **Without security constraint**

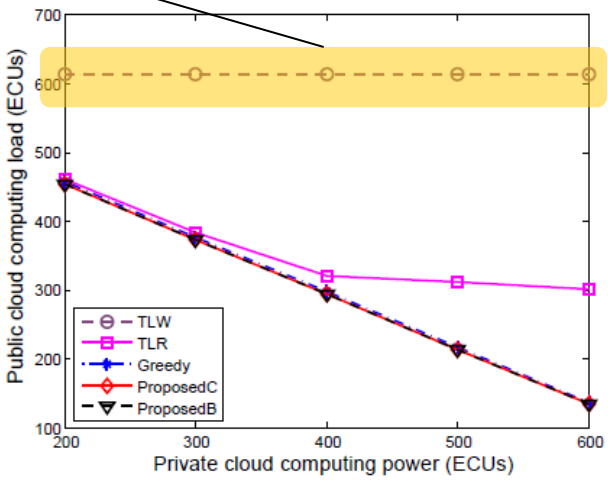
TLW pushes all streams to public cloud, giving highest monetary cost and bandwidth usage



(a) Monetary cost



(b) Inter-cloud bandwidth

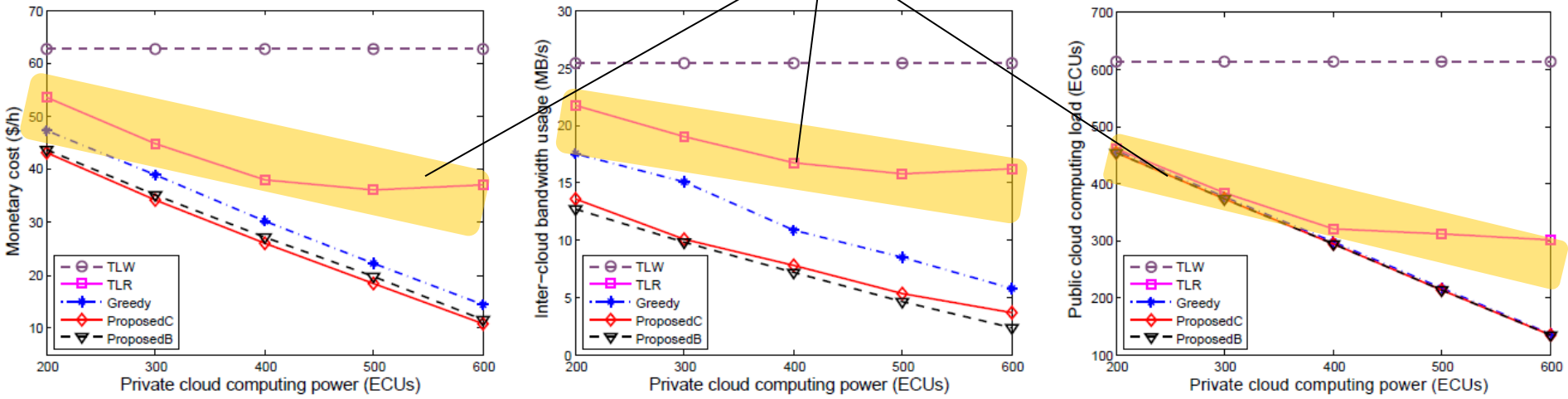


(c) Outsourced computation

4. Evaluation: simulations

- **Without security constraint**

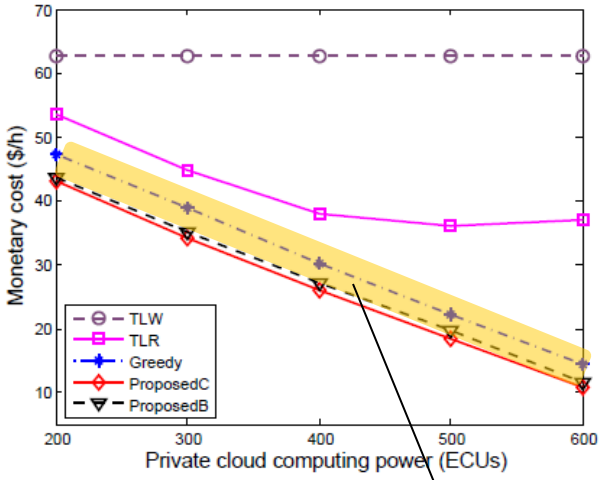
TLR keeps some streams locally but still underutilizes the private cloud



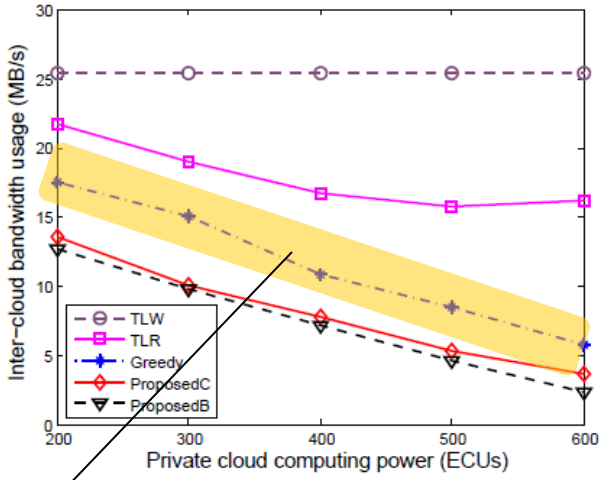
(a) Monetary cost (b) Inter-cloud bandwidth (c) Outsourced computation

4. Evaluation: simulations

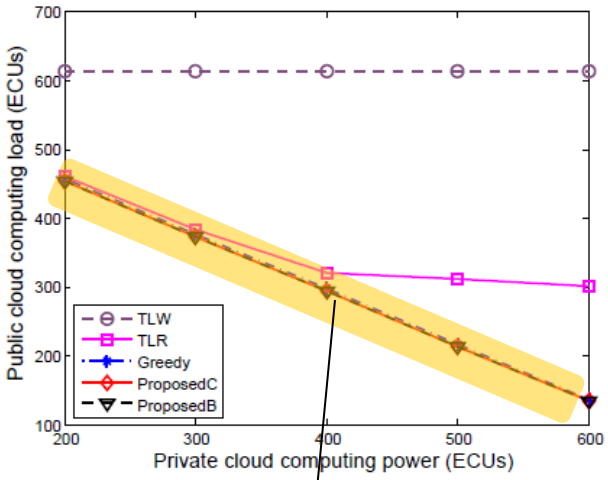
- **Without security constraint**



(a) Monetary cost



(b) Inter-cloud bandwidth



(c) Outsourced computation

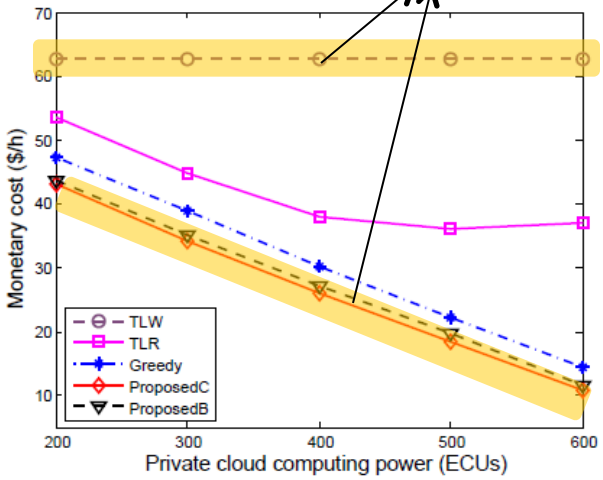
Greedy incurs higher bandwidth cost than ours, and hence higher money cost

Greedy can fully utilizes the private cloud as ours

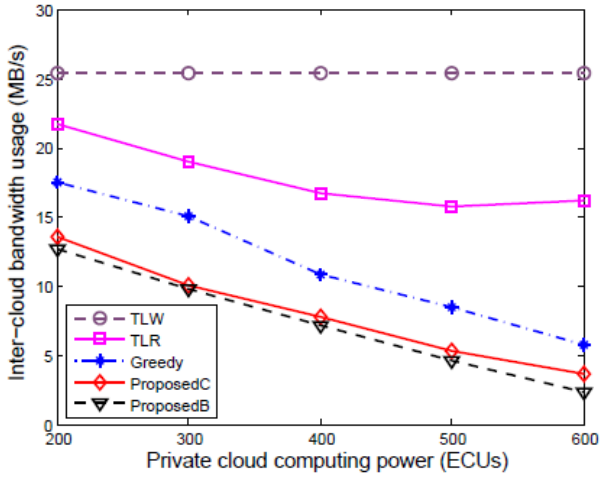
4. Evaluation: simulations

- **Without security constraint**

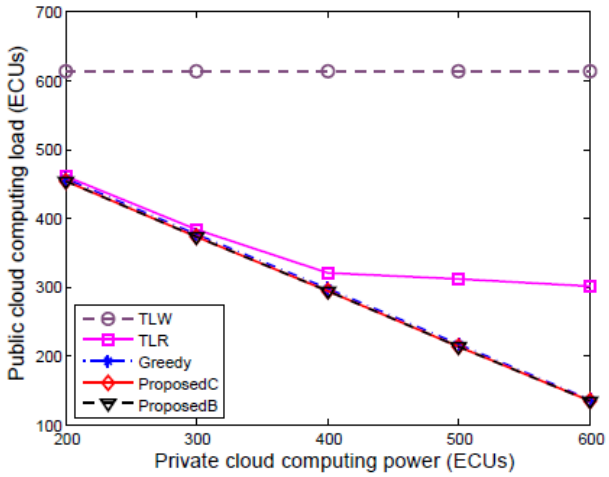
Our schedulers can reduce monetary cost by around 29%-84% compared to a pure public cloud setting



(a) Monetary cost



(b) Inter-cloud bandwidth

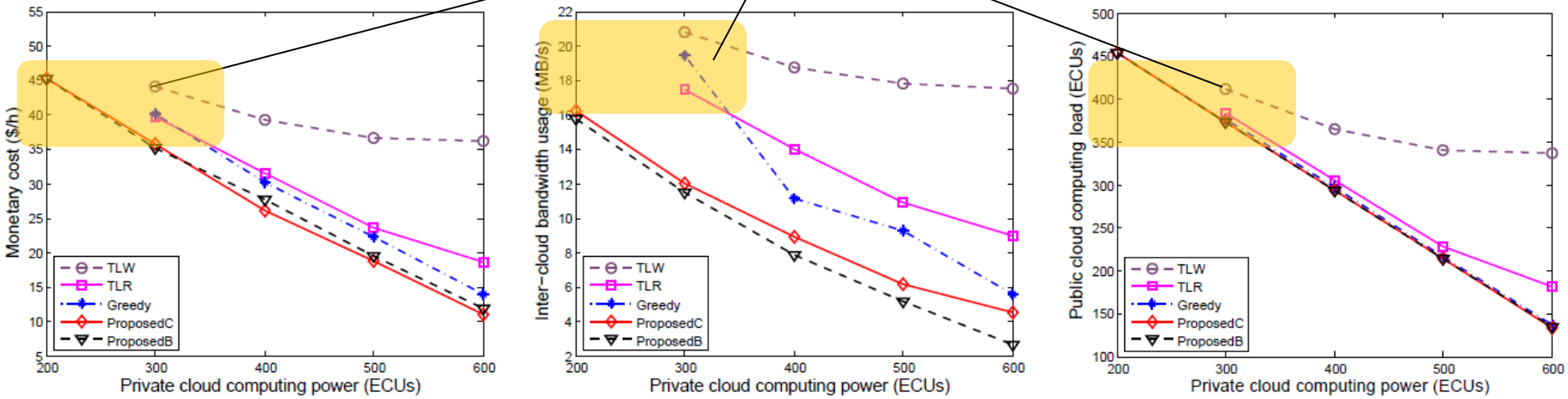


(c) Outsourced computation

4. Evaluation: simulations

- **randomly tags streams to be sensitive**

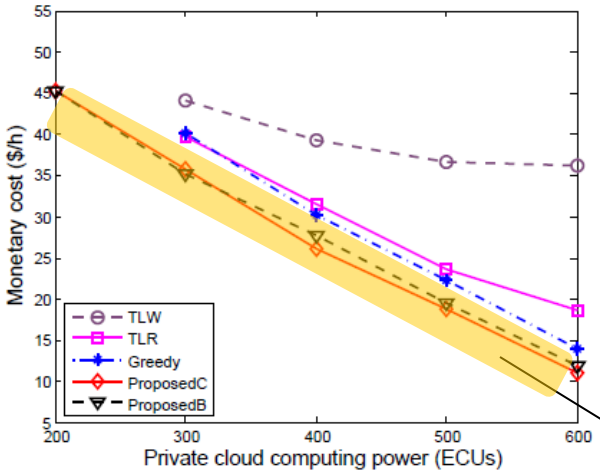
TLW, TLR and Greedy cannot schedule all the tasks when C = 200



(a) Monetary cost (b) Inter-cloud bandwidth (c) Outsourced computation

4. Evaluation: simulations

- **randomly tags streams to be sensitive**



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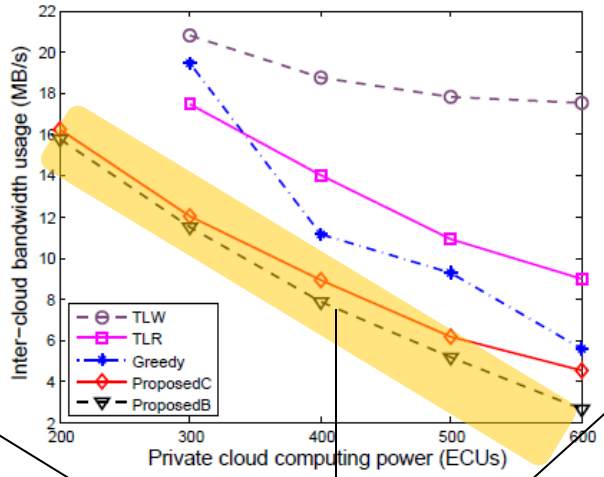
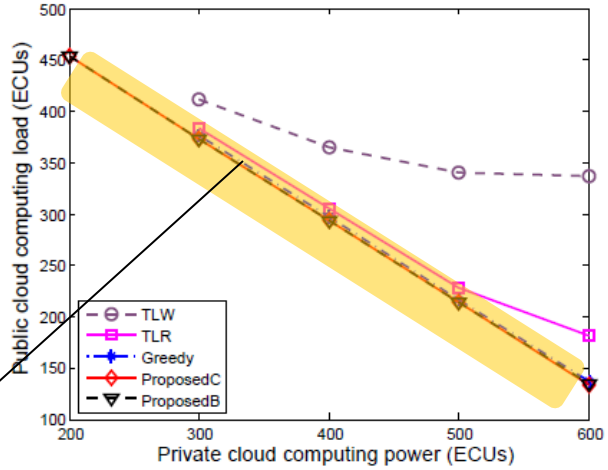


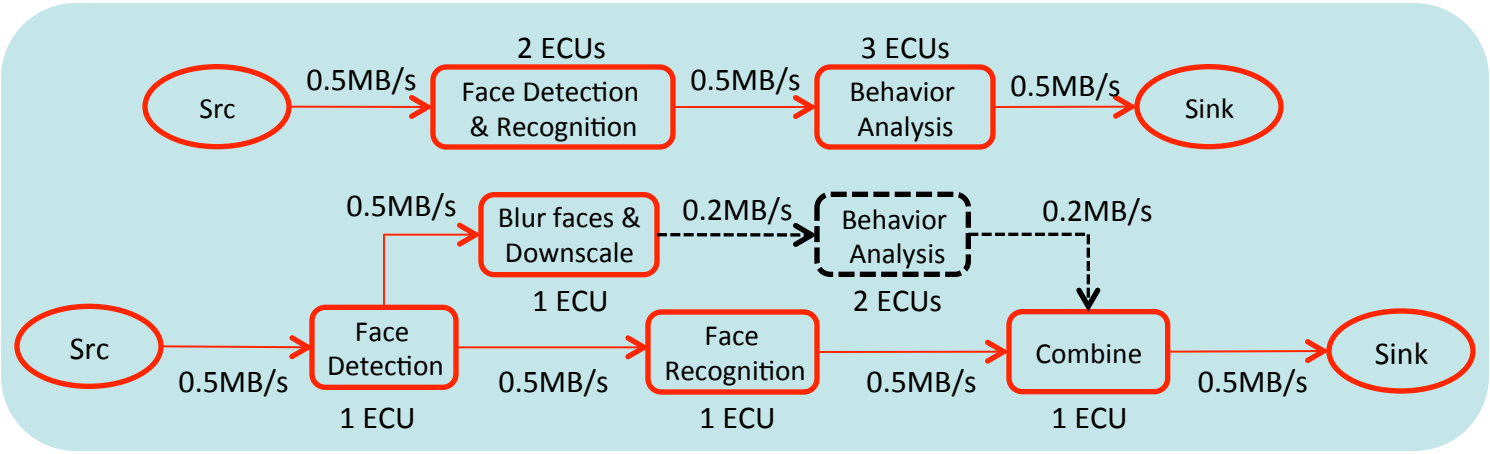
(b) Inter-cloud bandwidth



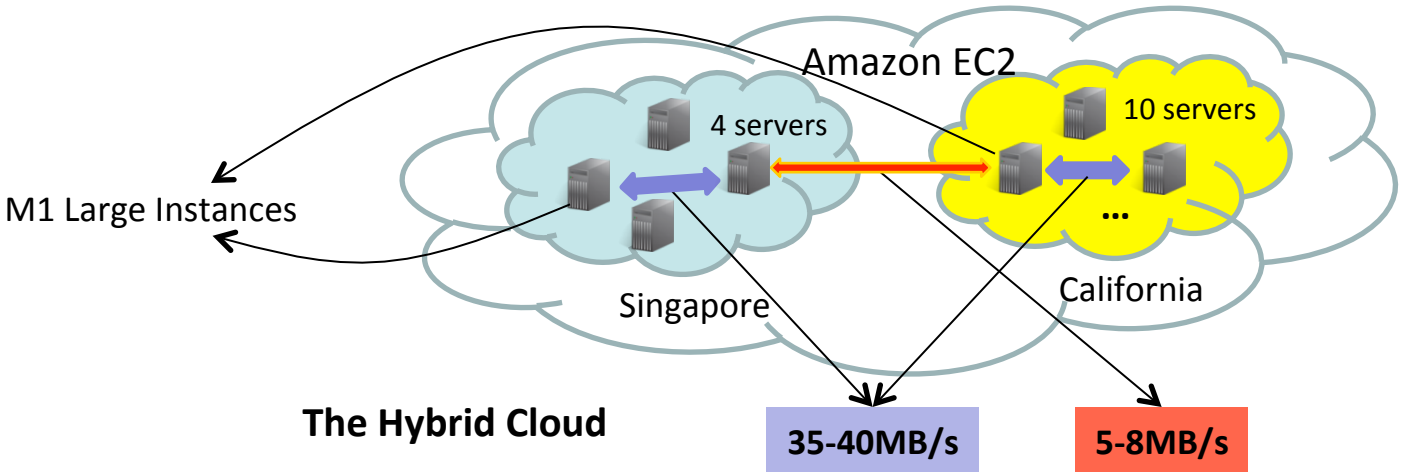
(c) Outsourced computation

Our schedulers can handle all, and constantly outperform the others

4. Evaluation: proof-of-concept system

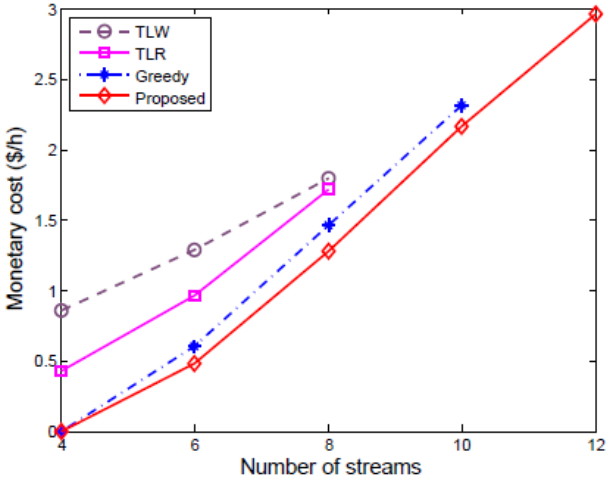


The Task Template (has 2 alternative ways to complete)



The Hybrid Cloud

4. Evaluation



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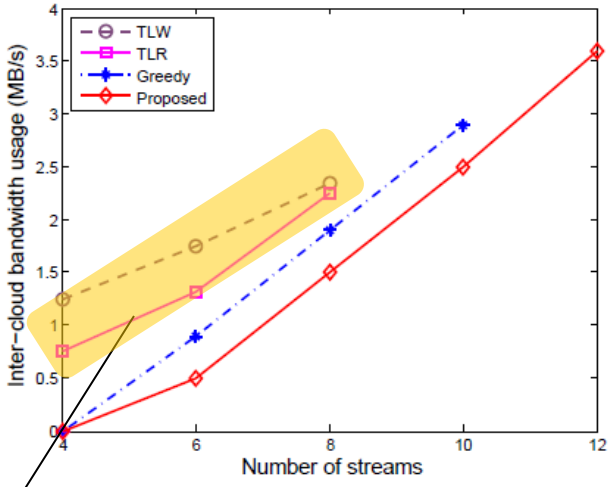
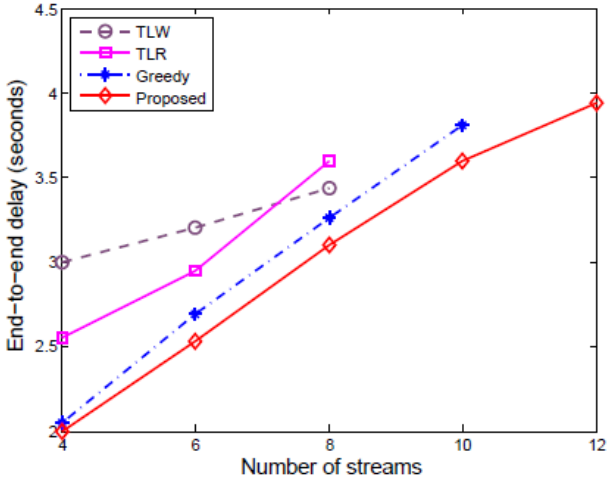


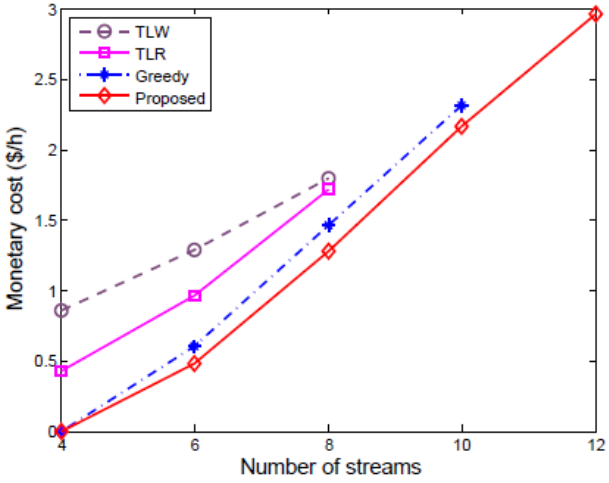
(b) Inter-cloud bandwidth



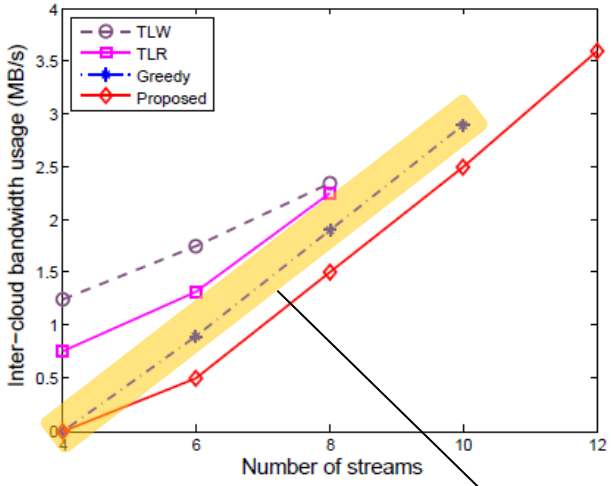
(c) Average end-to-end delay

TLW and TLR fail when
# of streams > 8

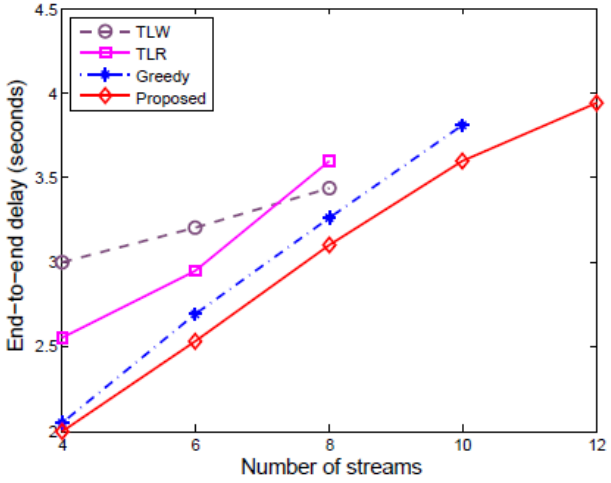
4. Evaluation



(a) Monetary cost



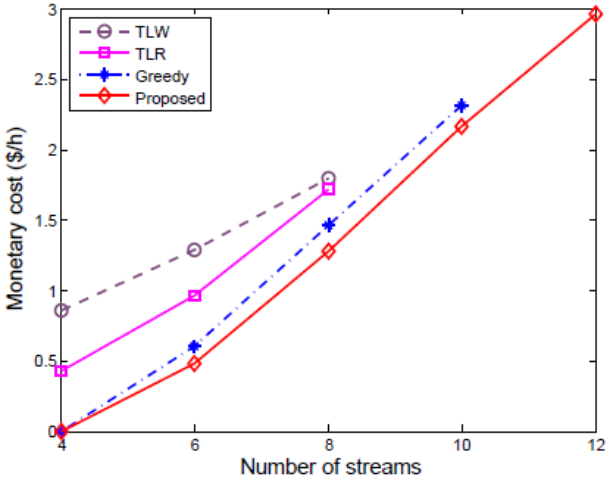
(b) Inter-cloud bandwidth



(c) Average end-to-end delay

Greedy also fails when # of streams > 10

4. Evaluation



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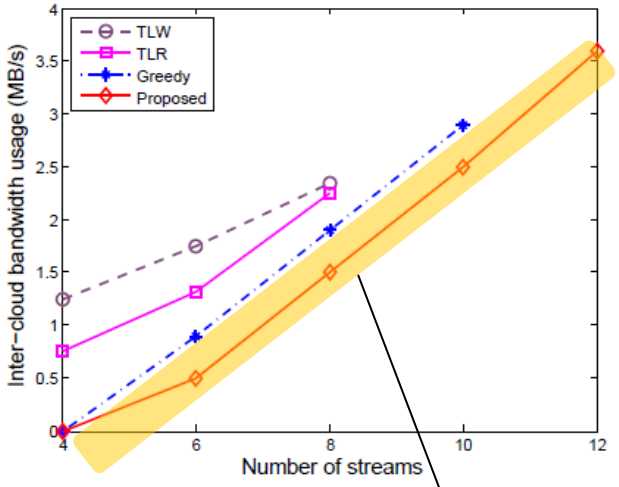

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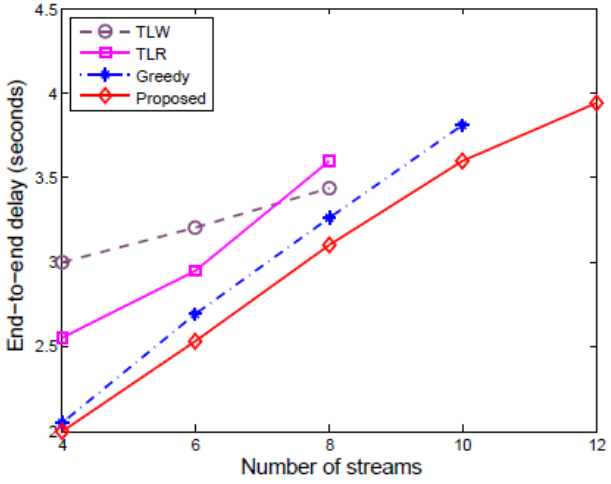

(c) Average end-to-end delay

ProposedB and ProposedC always choose the same confs, and rendered as one line

5. Conclusions

- **Practical to process large mixed-sensitivity video surveillance streams on hybrid clouds**
- **The proposed scheduler is effective in reducing monetary cost and inter-cloud bandwidth usage**
- **The monetary costs are lower than a single public cloud setting**
- **Future Work**
  - To support real-time re-scheduling
  - To implement on top of existing stream processing systems, e.g., Apache Storm[1]

[1] https://storm.incubator.apache.org/

Q & A