Continuous Distributed Monitoring in the Evolved Packet Core

Industry Experience Report

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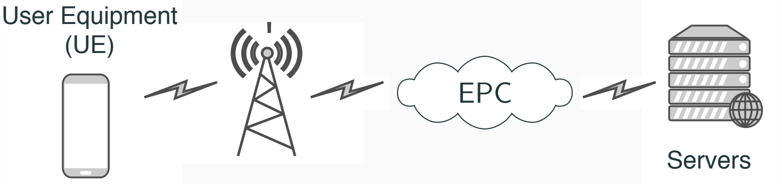
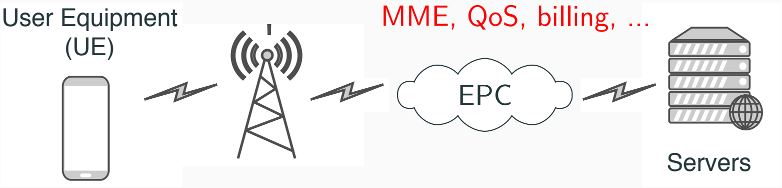
Introduction

The Evolved Packet Core



Context: Monitoring the Evolved Packet Core (EPC) in 4G

The Evolved Packet Core



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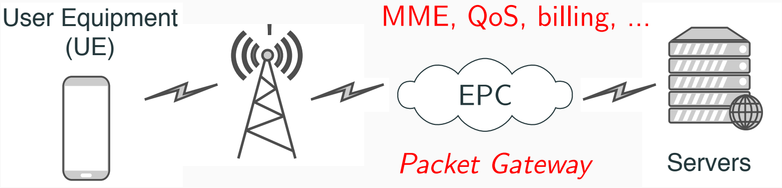
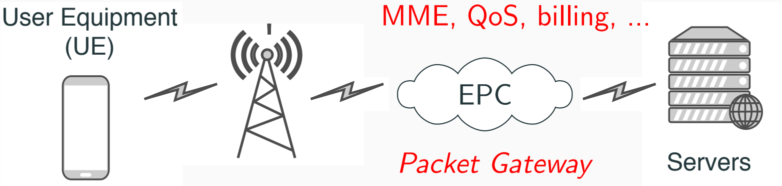


Context: Monitoring the Evolved Packet Core (EPC) in 4G

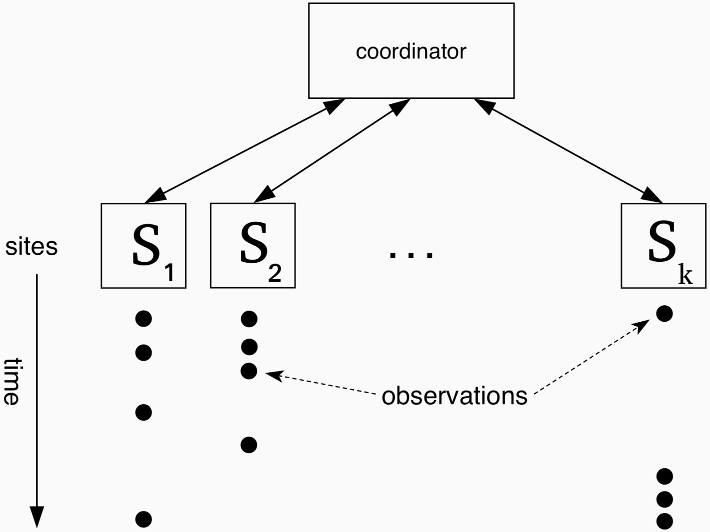
The Evolved Packet Core



- Large-Scale, Distributed, Performance-critical system.
- Strong need to continuously monitor the EPC: e.g. detection of under- or over-used subcomponents.

Continuous Distributed Monitoring

Continuous Distributed Monitoring (CDM) Model



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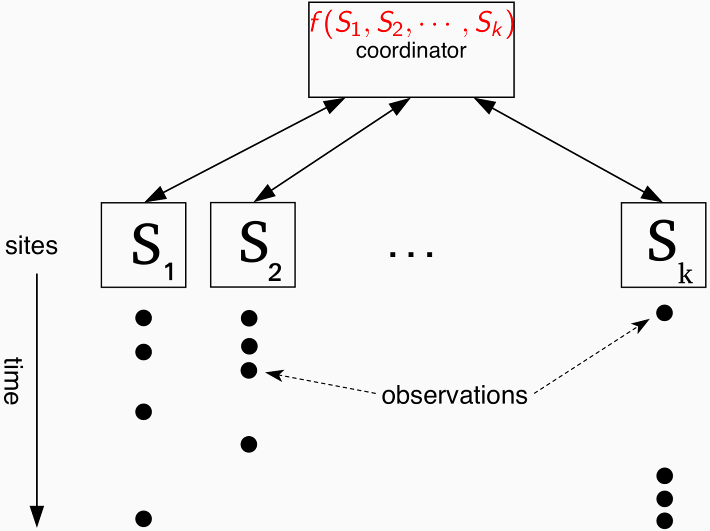

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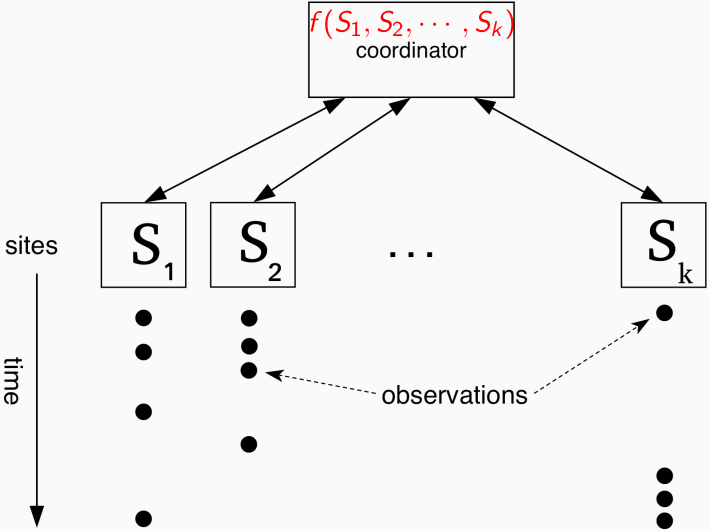
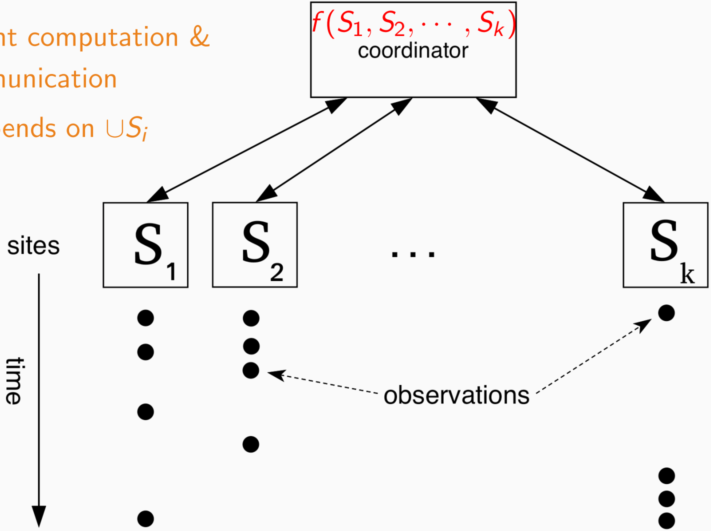


There exist variants (unidirectional, relay nodes, etc).

Continuous Distributed Monitoring (CDM) Model

- Instant computation & communication
- f depends on $\cup S_i$



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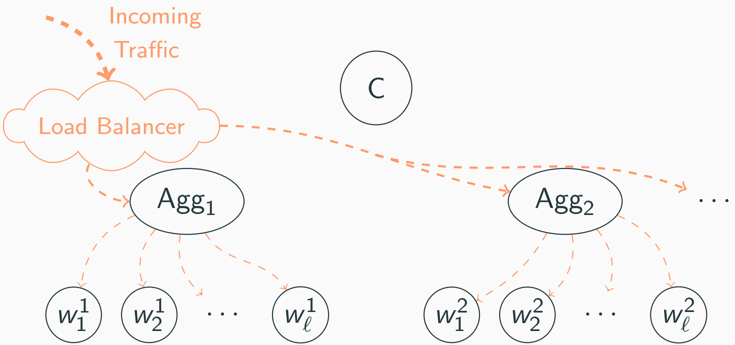
System Architecture

System Architecture Overview



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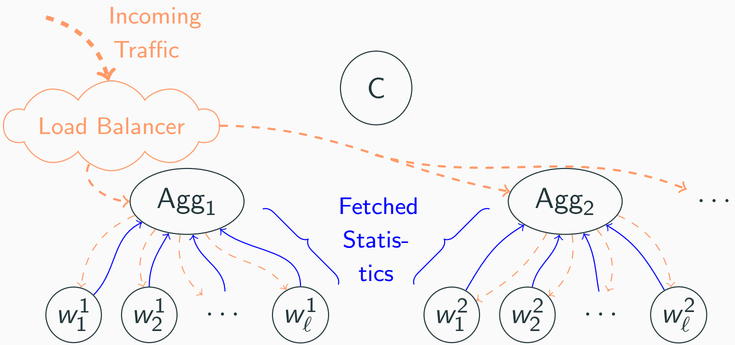

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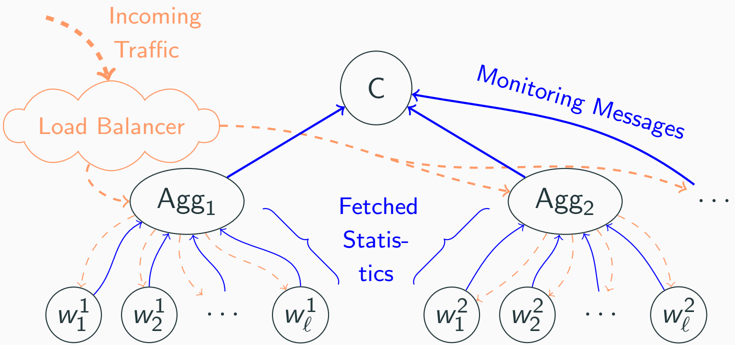

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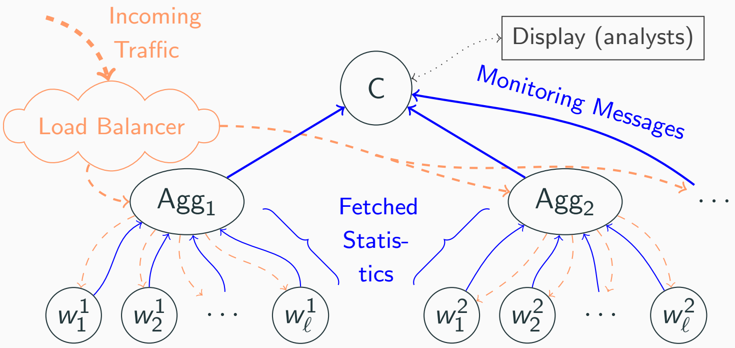

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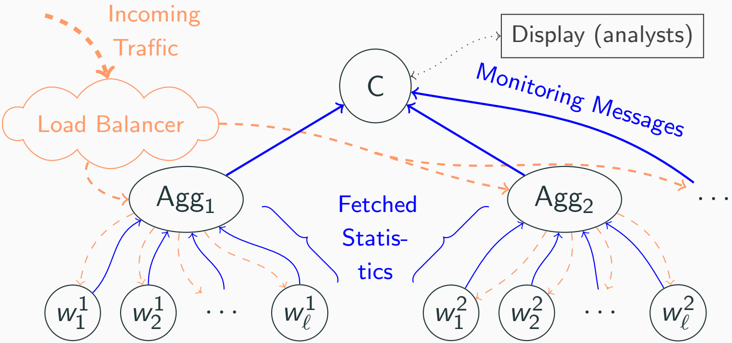

Differences with CDM models

- Sites identity matters, performance statistics $\neq$ "events", etc
- Need to account for comp. and communication delays!

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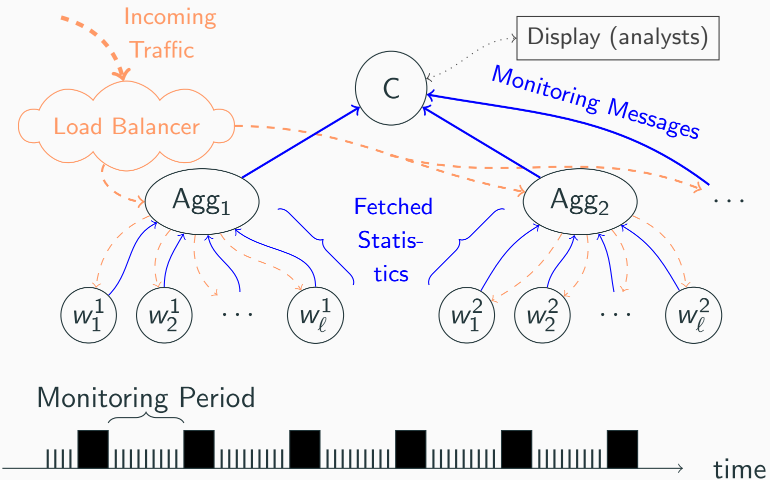

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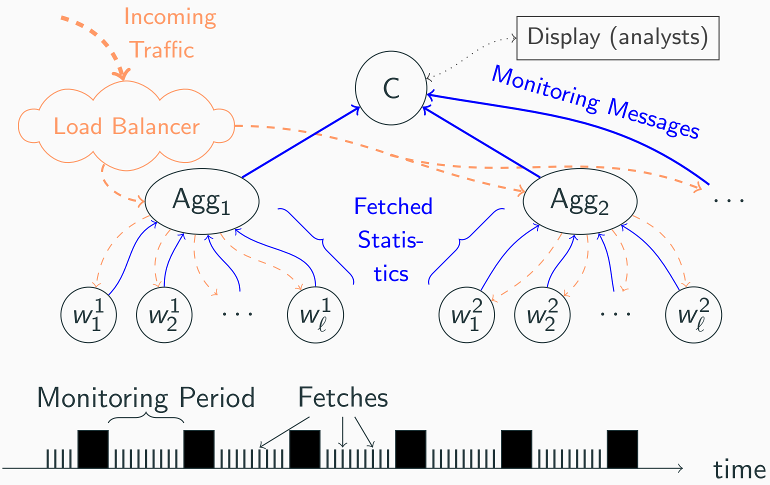

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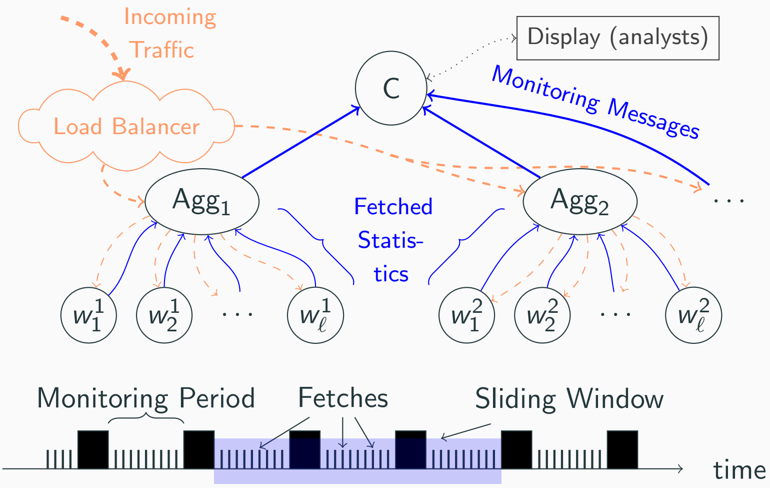

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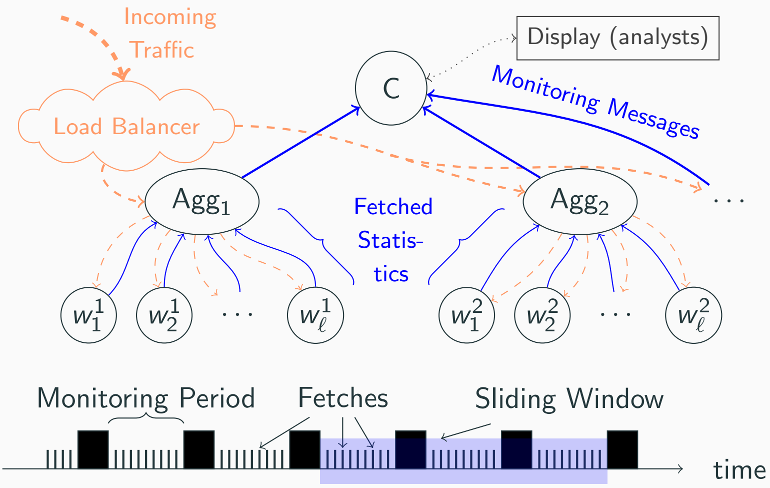

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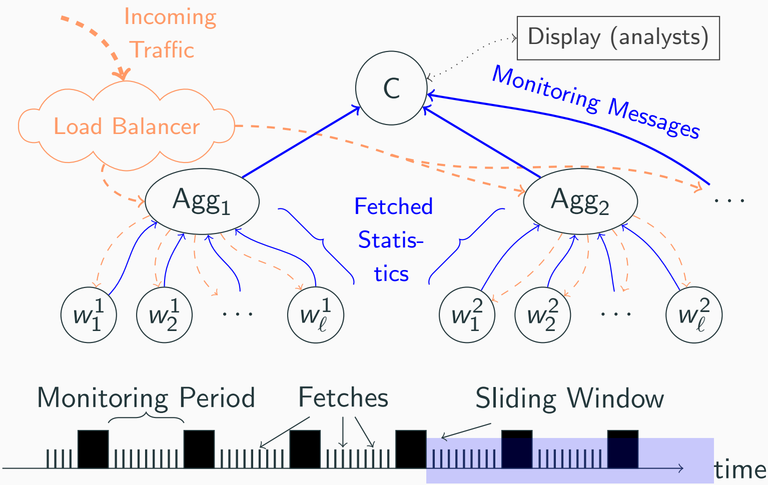

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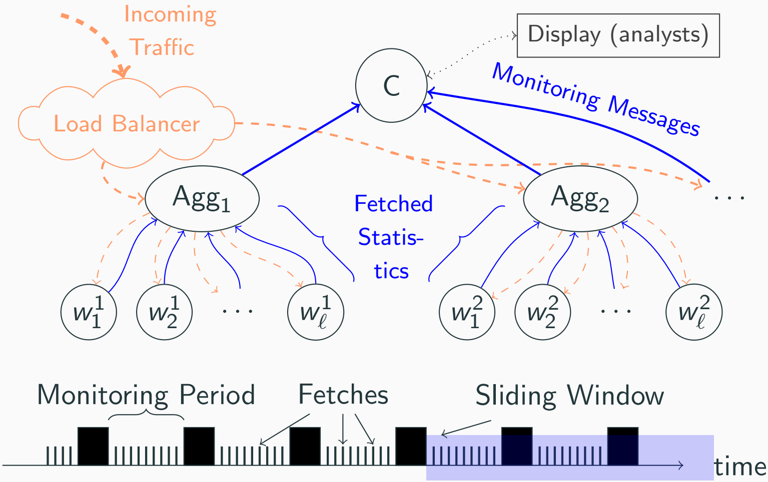
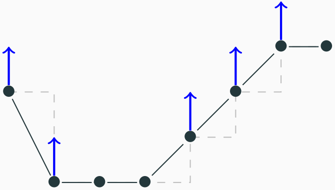


→ At the Agg: monitoring decisions then 1 monitoring message.

Monitoring Algorithms

Basic Mode: Exact Monitoring

- Send an update if *last value sent* is different to measured value
- Keep an exact sliding window of the last n values



Selected CDM Algorithms for Counting problems

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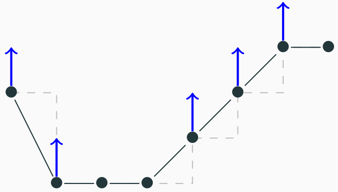
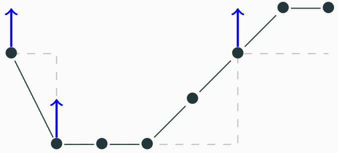


Approximation Mode: Relative Error of ε

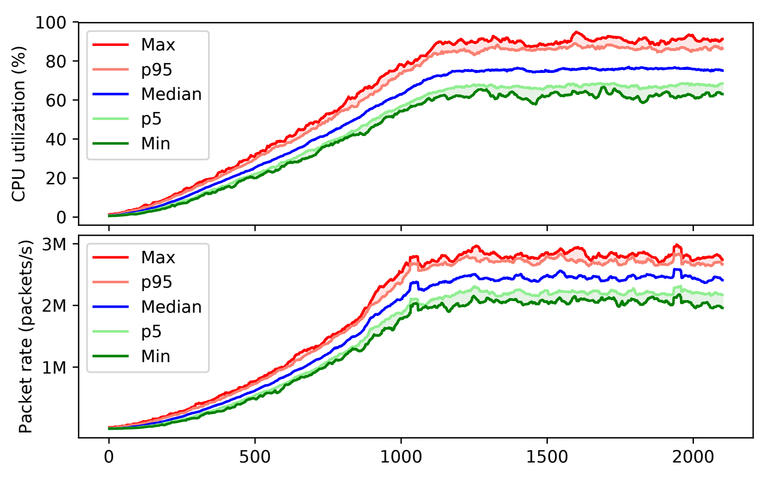
- Uses Exponential Histograms for approximate counting
- Send the *approximate count* when it is beyond some error bound from the last value sent
- Requires in all $\mathcal{O}(\log(n\varepsilon)/\varepsilon)$ words



Results

Experimental setup

- EPG setup: 2 aggregators, 72 workers per aggregator
- 2 phases: increasing load (20min) then stable load (15min)



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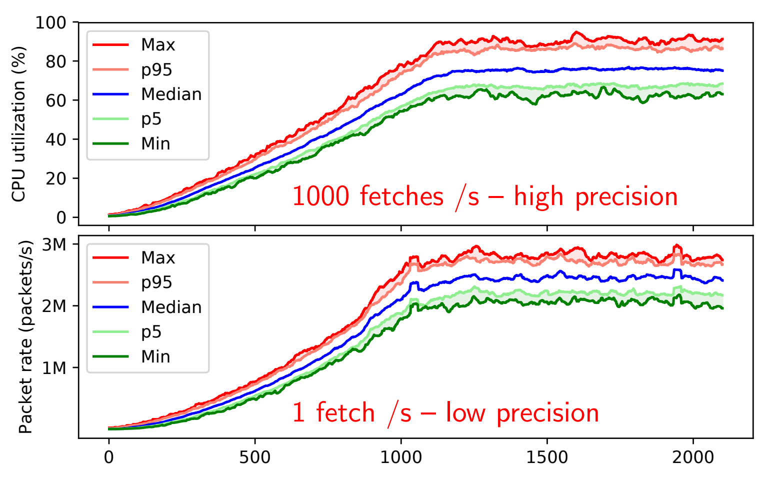
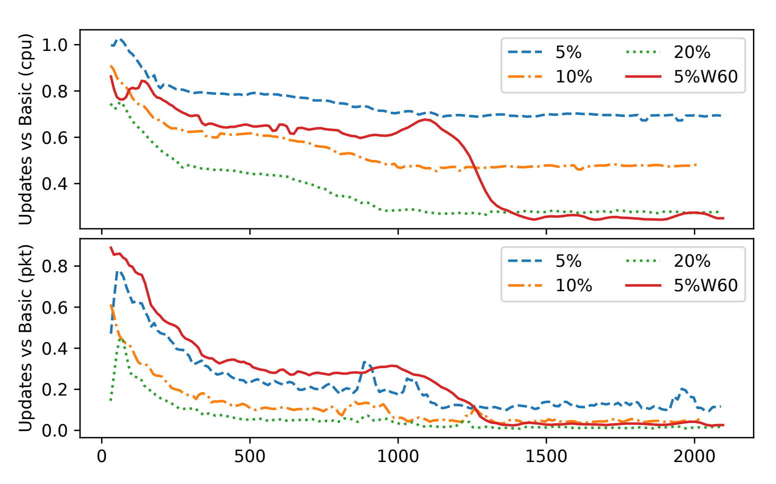


No. of Monitoring Updates per Round

- 5-10% of data sent for packet proc. rate; 30-70% for CPU.



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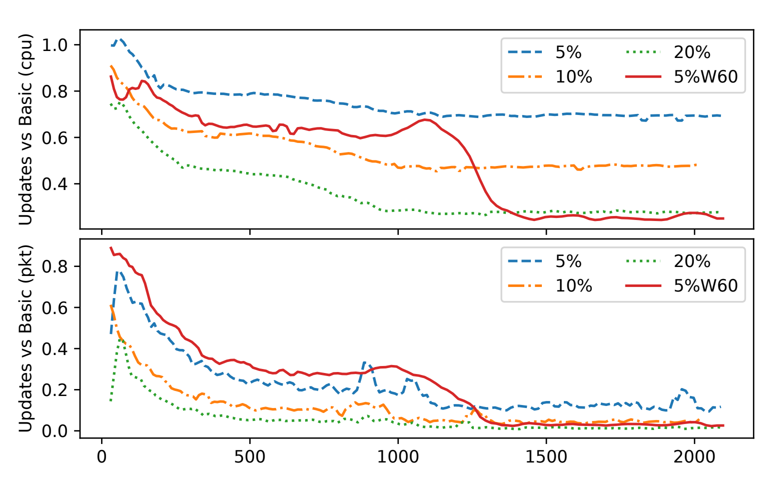
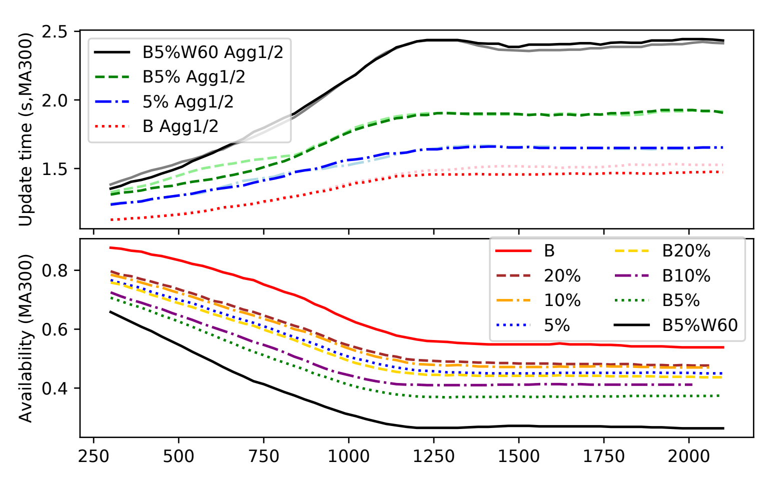


- Max relative error $< \frac{5\varepsilon}{9}$ and average $< \frac{\varepsilon}{5}$.

Monitoring Availability

- 8 runs (ca 4h of data) with monitoring round = 1s



Conclusion

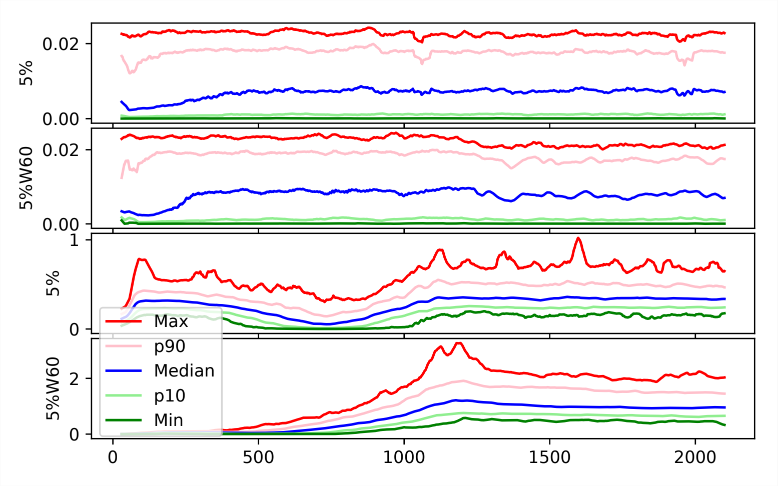
Conclusions

- Adjusted state-of-the-art CDM implementations in the EPC
- Keys to popularize CDM within a production level system
- From experiments, only 6% of data sent for 1.6% avg error
- Useful for the upcoming transition to 5G architecture

Thank you!

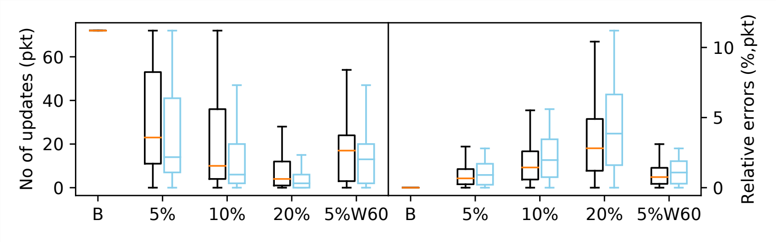
Error Analysis

- Max relative error is always close to $\frac{5\varepsilon}{9}$
- Larger window influences absolute error on CPU



Comparison with Simple Approximation

- Simple Approximation: keep an exact window and send updates when last count is beyond some predefined relative bound



- ε-Approximate algorithm presents similar tradeoffs as the simple approximation with bound $\frac{5\varepsilon}{9}$

CDM approaches

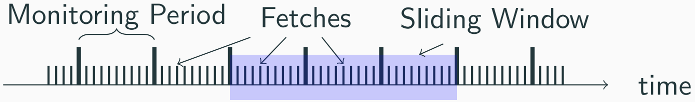
Simple approaches

- Flooding, do not scale!
- Polling, but hard to choose right polling interval!
- Sampling, do not capture scarce under/over-used components!

Solutions

- Communication-optimal algorithms
- Geometric Monitoring → efficient network-wide aggregate.
- Tailored algorithms for particular tasks → e.g. computing the frequency of items or most popular ones.
- Heuristics → e.g. adaptive filters.
- Compromises: Magpie, Dapper, Ganglia...

Proposed Monitoring Solutions



Monitoring Logic for each monitored value

- Implemented as part of the aggregator nodes
- once all fetched have been collected, a monitoring decision is taken upon propagating the update
- Aggregation of all monitoring updates: sending of (up to) a single monitoring message per aggregator

Selected CDM Algorithms

Basic Mode

- Send an update if last value sent is different
- Keep an exact sliding window of length n

ε-Approximation Mode

- Maintains an $\frac{\varepsilon}{9}$-approximate Exponential Histogram for counting approximate sum $\hat{c}$ of items over a sliding window of the last n events
- Whenever $\hat{c} > (1 + \frac{4\varepsilon}{9})c$ or $\hat{c} < (1 - \frac{4\varepsilon}{9})c$, send an update, where c is the last value sent
- Requires in all $\mathcal{O}(\log(n\varepsilon)/\varepsilon)$ words of memory

Measuring Metrics of Interests: 2 modes

With high granularity: CPU usage

1. P fetches of CPU-usage for past 1ms each within one monitoring period
2. Frequency chart (histogram of F bins) for the P fetches
3. *Sliding Windows are updated*: each bin is monitored
4. For each changed (basic) or outside of bounds (approx) value, a monitoring update is sent
5. Upon receiving an update: C updates its frequency counts for the resp. observer and CPU-bin and then may display the average CPU over the window as $\sum_{1 \leq i \leq F} i f_i / \sum_{1 \leq i \leq F} f_i$

With low granularity: Packet Processing Rate

- Only the no. of processed packets per mon. period is tracked