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Optimized On-Demand Data Streaming from Sensor Nodes

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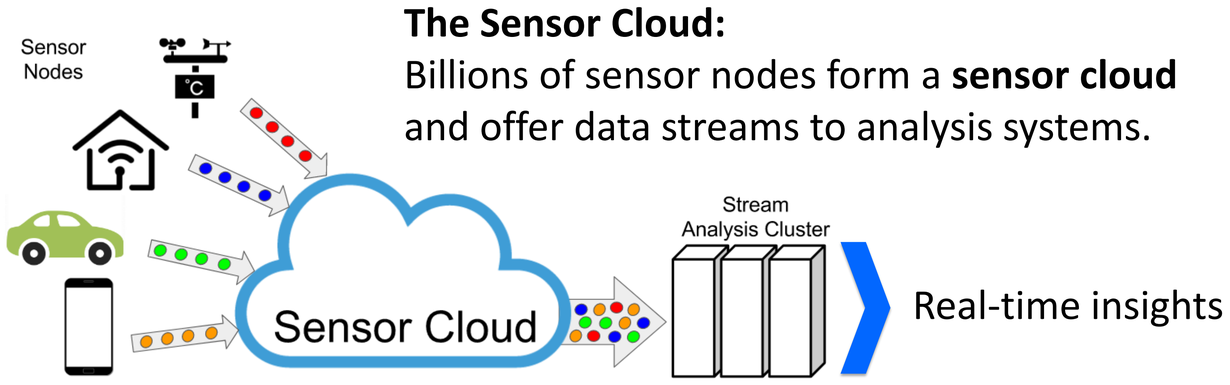
Abstract



The Sensor Cloud:
Billions of sensor nodes form a **sensor cloud** and offer data streams to analysis systems.

Problem:

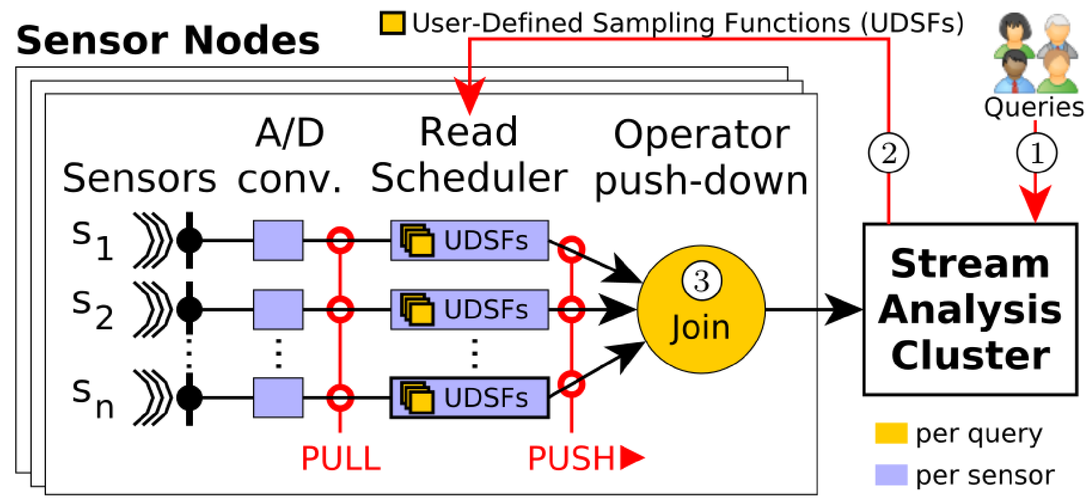
- Increasing data rates require expensive system scale-out.
- It is impossible to transfer all data from billions of sensors to all applications with maximal frequencies.

Solution:

Tailor Data Stream to the Demand of Applications

- Optimize communication costs while maintaining the result accuracy.
- Provide an abstraction to define the data demand of applications.
- Share sensor reads and data transfer among users and queries.

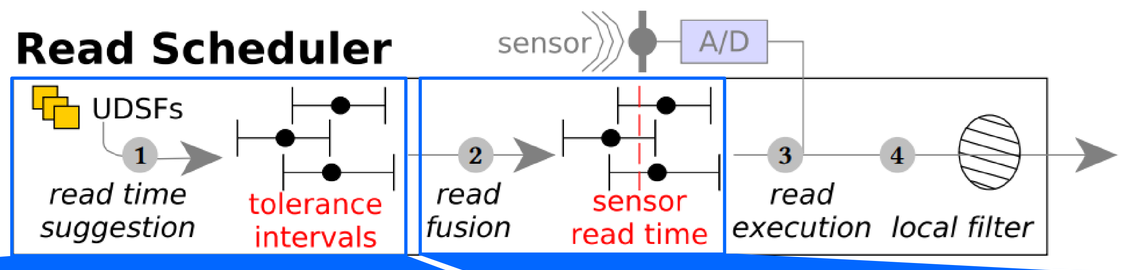
System Architecture



1. Users submit queries to a stream analysis cluster.
   - *We introduce user-defined sampling functions (UDSFs) to express the data-demand of queries.*
2. We propagate the UDSFs to the sensor nodes.
   - *Our Read Scheduler optimizes sensor read times and minimizes the data transfer based on the UDSFs.*
3. Push data to succeeding stream processing pipelines.

Multi-Query Read Scheduling

1. UDSFs propose read times with tolerance intervals.
2. We fuse proposed read times to a single sensor read if the tolerance intervals overlap.



3. We perform the actual read on the sensor.
4. We apply local filtering to further reduce data transmissions.

User-Defined Sampling Functions

An abstraction for the precise definition of each query's data demand

- Facilitate adaptive sampling techniques to reduce data transmission (e.g., Adam [Trihinas '15], FAST [Fan '14], L-SIP [Gaura '13]).
- Enable model-driven data acquisition [Deshpande '04, Raza '12].
- Diverse other application specific sampling strategies.

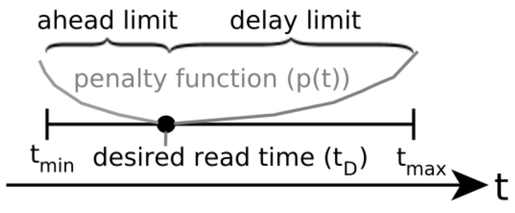
Syntax

- Upon a sensor read, propose next sensor read time.

$$s : \langle t, v \rangle \rightarrow \langle t_{min}, t_D, t_{max}, p(t) \rangle$$

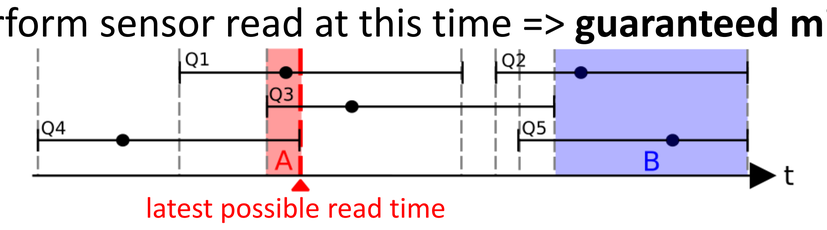
Input: Read time and sensor value

Output: Next sensor read time with tolerance interval and penalty function for read time deviations (used for optimization)

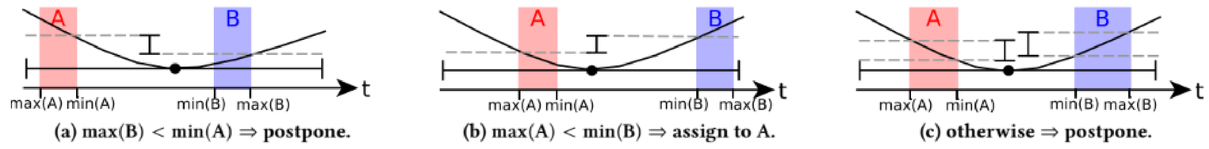


Read-Time Optimization

1. **Fuse proposed read times if tolerance intervals overlap.**
   - Find latest possible read time (first interval end).
   - Perform sensor read at this time => **guaranteed min. # of reads.**

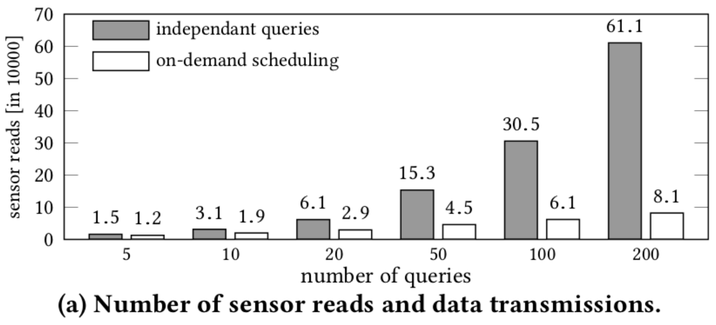


2. **Optimize read times while preserving the min. # of reads in total.**
   - Determine time intervals in which we will perform sensor reads.
   - Assign requested sensor reads to these intervals (A or B).
   - Minimize penalty to find the best sensor read time.

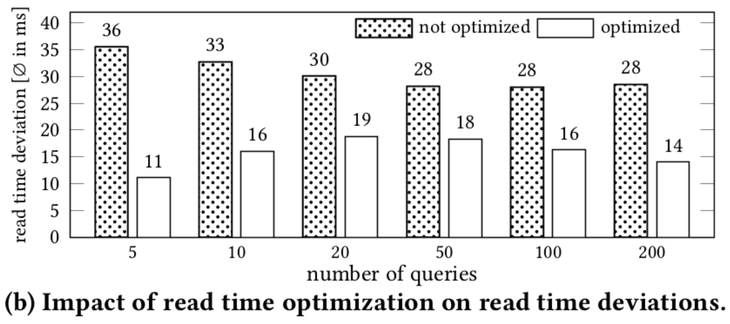


(a) max(B) < min(A) ⇒ postpone. (b) max(A) < min(B) ⇒ assign to A. (c) otherwise ⇒ postpone.

Evaluation



(a) Number of sensor reads and data transmissions.



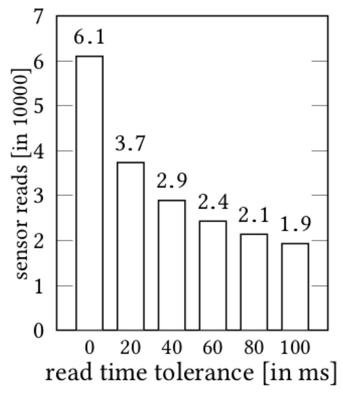
(b) Impact of read time optimization on read time deviations.

Scaling to large numbers of concurrent queries

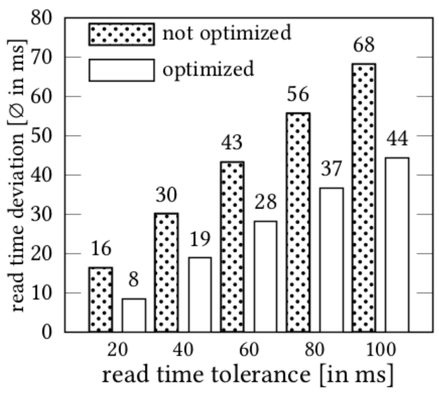
- On-Demand scheduling reduces sensor reads and data transfer by up to 87%.
- The number of reads and transfers increases sub-linearly when raising the number of queries.
- Our read-time optimizer reduces the deviation from desired read times by up to 69% (preserving the min. # of reads and transfers).

Increasing Read-Time Tolerances

- Even small tolerances enable huge savings.
- Read-time optimization is always beneficial.



(a) Sensor reads/transfers.



(b) Read time optimization.

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