DATA STREAM PROCESSING (DSP)

Overview

1. General
2. Stream
3. Aurora
4. Conclusion

1 General Overview

1. Motivation Applications
2. Definition of Data Streams
3. Data Base Management System (DBMS) vs. Data Stream Management System(DSMS)
4. Stream Projects

1.1 Motivation Applications

- interpreting of sensor information
- traffic monitoring
- environmental monitoring
- recording of telephone calls
- logging web servers
- analysing monitary flows

1.1 Social Networks, Status Feeds

- Facebook, Twitter streams
- Queries:
  - Status analysis
  - Useful for advertising
- Status feed update examples:
  - Comments added to threads at any time
  - Posts removed from threads at any time

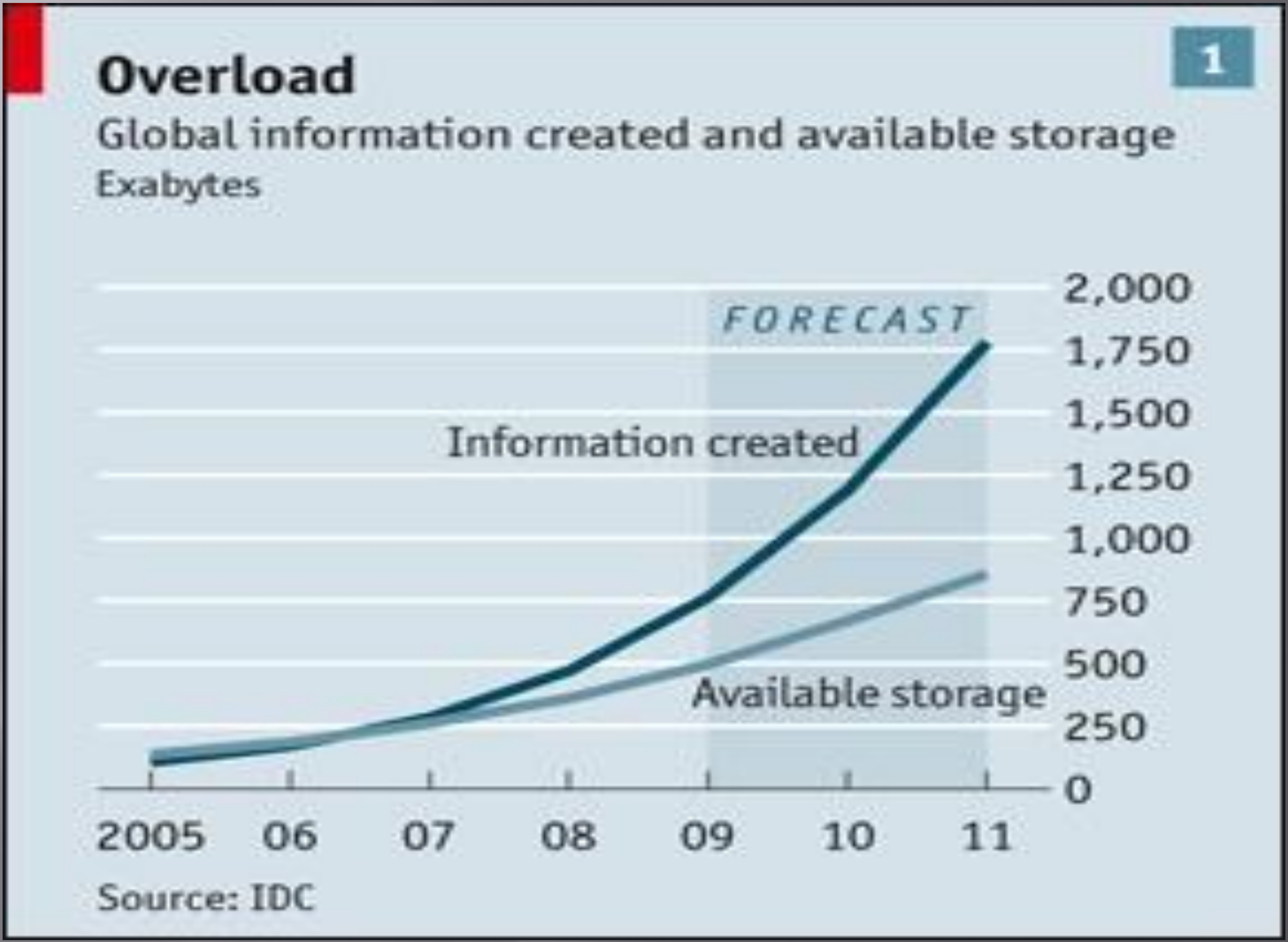


Abbildung (1), „Study Projects Nearly 45-Fold Annual Data Growth by 2020” EMC Press Release

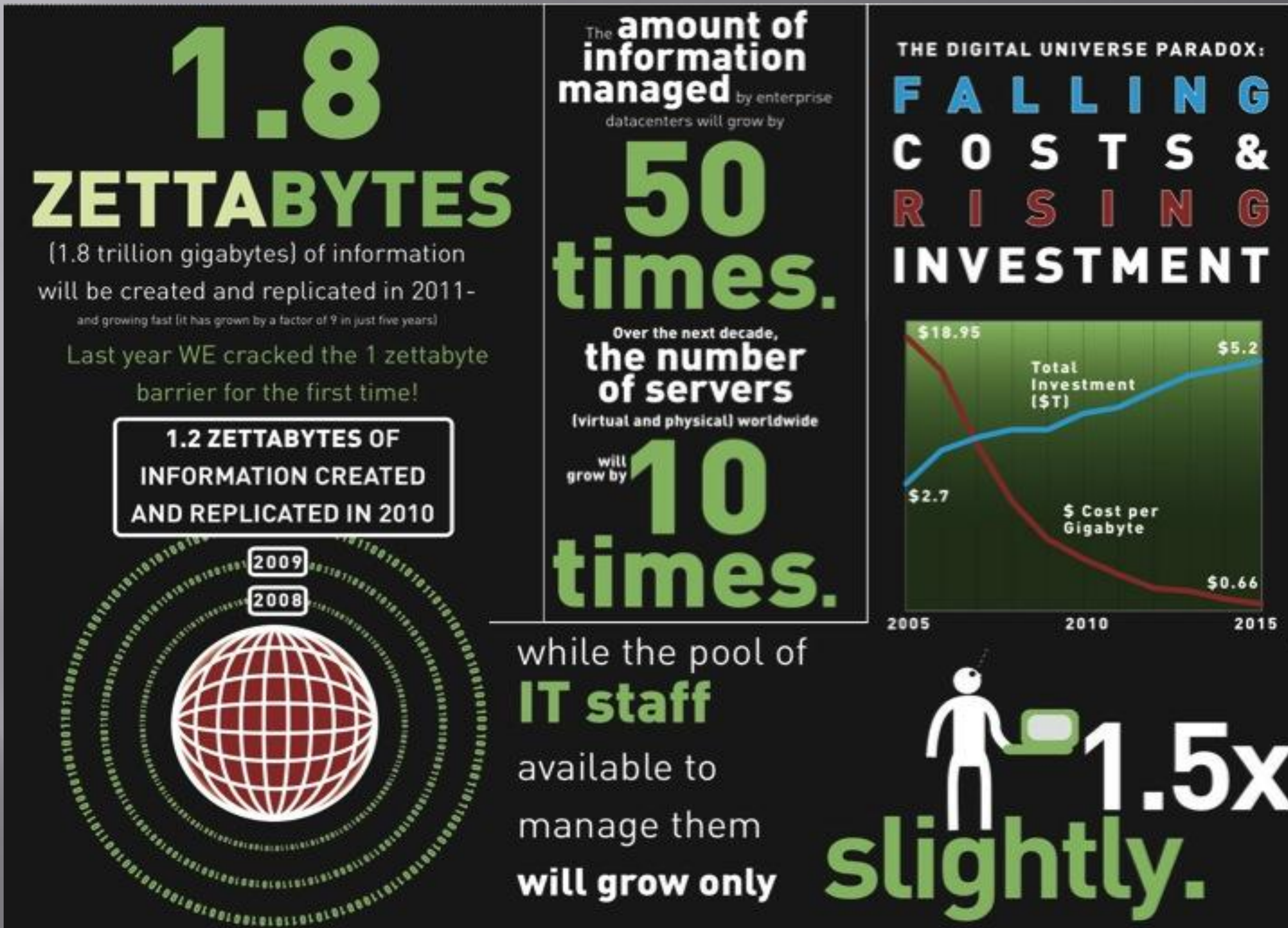


Abbildung (2), IDC 2011 Digital Universe Study

1.2 What is a Data Stream

- a sequence of digitally encoded coherent signals (packets of data or data packets) used to transmit or receive information that is in the process of being transmitted
- In a formal way, a data stream is any ordered pair (s,delta) where:
  - s is a sequence of tuples and
  - delta is a sequence of positive real time intervals.

1.3 DBMS vs. DSMS

DBMS

- Persistent data (relations)
- Random access
- One-time queries
- (theoretically) unlimited secondary storage
- Only the current state is relevant
- relatively low update rate
- Little or no time requirements
- Assumes exact data
- Plannable query processing

DSMS

- volatile data streams
- Sequential access
- Continuous queries
- limited main memory
- Consideration of the order of the input
- potentially extremely high update rate
- Real-time requirements
- Assumes outdated/inaccurate data
- Variable data arrival and data characteristics

1.4 DSMS Projects

- Amazon/Cougar (Cornell) – sensors
- Aurora (Brown/MIT) – sensor monitoring, dataflow
- Hancock (AT&T) – telecom streams
- Niagara (OGI/Wisconsin) – Internet XML databases
- OpenCQ (Georgia) – triggers, incr. view maintenance
- Stream (Stanford) – general-purpose DSMS
- Tapestry (Xerox) – pub/sub content-based filtering
- Telegraph (Berkeley) – adaptive engine for sensors
- Tribeca (Bellcore) – network monitoring

2 Stream Overview

- General
- Continuous Query Language (CQL)
- Windows
- CQL Examples
- Query Plan
- Query Approximation
- Summarize

2.1 The Stanford Data Stream Management System (STREAM)

- originally part of the homonymous research project at Stanford University
- http://infolab.stanford.edu/stream/

2.2 Continuous Query Language (CQL)

- Expressive SQL-based declarative language

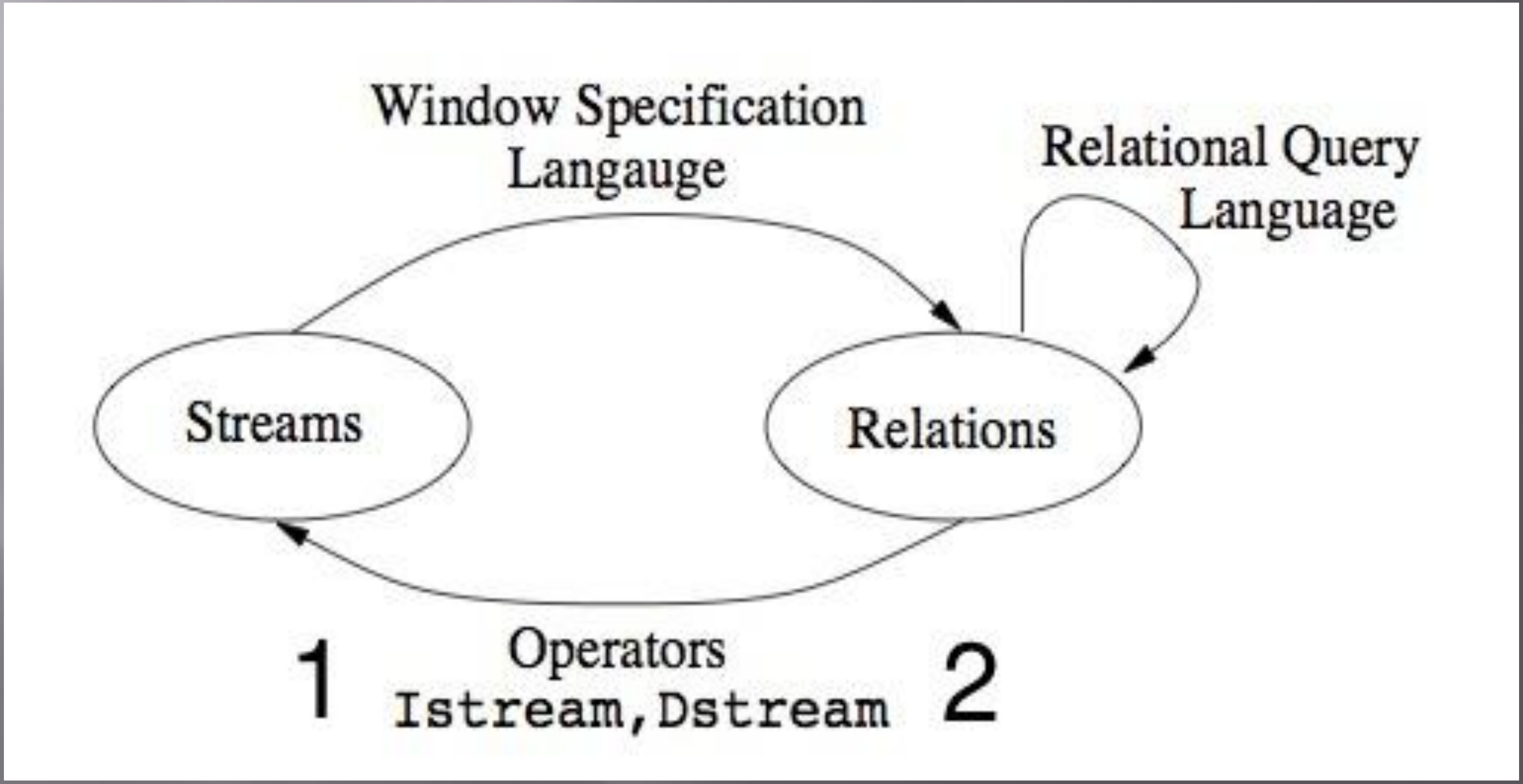


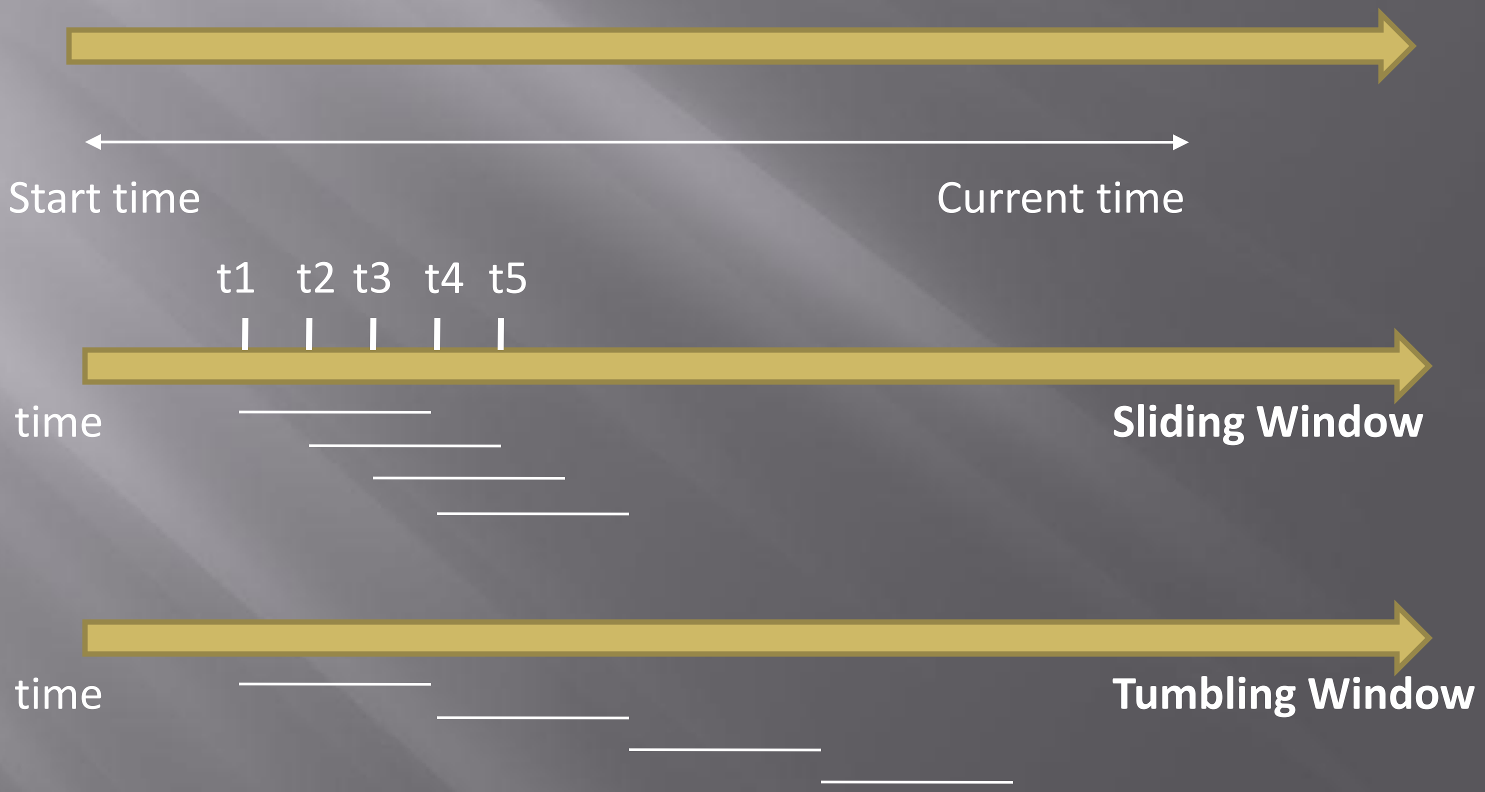
Abbildung (3), [9]

2.3 Windows

- Mechanism for extracting a finite relation from an infinite stream
- Various window proposals for restricting operator scope.
  - Windows based on ordering attribute (e.g. time)
  - Windows based on tuple counts

2.3 Windows

- Terminology



2.4 Query 1 (Window)

Find all Fotos where the name is like “foo” and they are at most 1 day old

```
Select *
From  Fotos Fo [Range 1 Day Precending]
Where Fo.name like ‘foo’
```

2.4 Query 2 (Partition)

Take the names of the 5 most recent Fotos bigger then 4000 bytes

```
Select F.name
From Fotos F
        [Partition BY F.name Rows 5]
Where F.größe < 40000
```

2.4 Query 3 (Join)

Find all Fotos and Filme where the names are equals

Select *

From Fotos Fo, Filme Fi [Range 1 Day]

Where Fo.name = Fi.name

2.4 Query 4 (Sample)

Get random 30% of the Fotos and all Films that are not older than one Day where the names are equals

```
Select *
From Fotos Fo Sample(30), Filme Fi [Range 1 Day]
Where  Fo.name = Fi.name
```

2.4 Query 5 (Istream)

Insert the name of every new foto to an Stream

```
Select  Istream(F.name)
From  F [Rows 100]
Group By F.name
```

2.4 CQL Operators

Name	Operator Type	Description
`select`	relation-to-relation	Filters elements based on predicate(s)
`project`	relation-to-relation	Duplicate-preserving projection
`binary-join`	relation-to-relation	Joins two input relations
`mjoin`	relation-to-relation	Multiway join from [22]
`union`	relation-to-relation	Bag union
`except`	relation-to-relation	Bag difference
`intersect`	relation-to-relation	Bag intersection
`antisemijoin`	relation-to-relation	Antisemijoin of two input relations
`aggregate`	relation-to-relation	Performs grouping and aggregation
`duplicate-eliminate`	relation-to-relation	Performs duplicate elimination
`seq-window`	stream-to-relation	Implements time-based, tuple-based, and partitioned windows
`i-stream`	relation-to-stream	Implements *Istream* semantics
`d-stream`	relation-to-stream	Implements *Dstream* semantics
`r-stream`	relation-to-stream	Implements *Rstream* semantics

Abbildung (4), [9]

2.5 Query Plan - Composition

- Query-Operators
- Inter-Operator-Queues
  - Connections between the operators
- Synopsis
  - summarizes the tuples seen so far, as needed for future evaluation of that operator

2.5 Query Plan (example)

Select * From S1 [Range 15 Minutes], S2 [Rows 1000]
Where S1.A = S2.A And S1.A <20

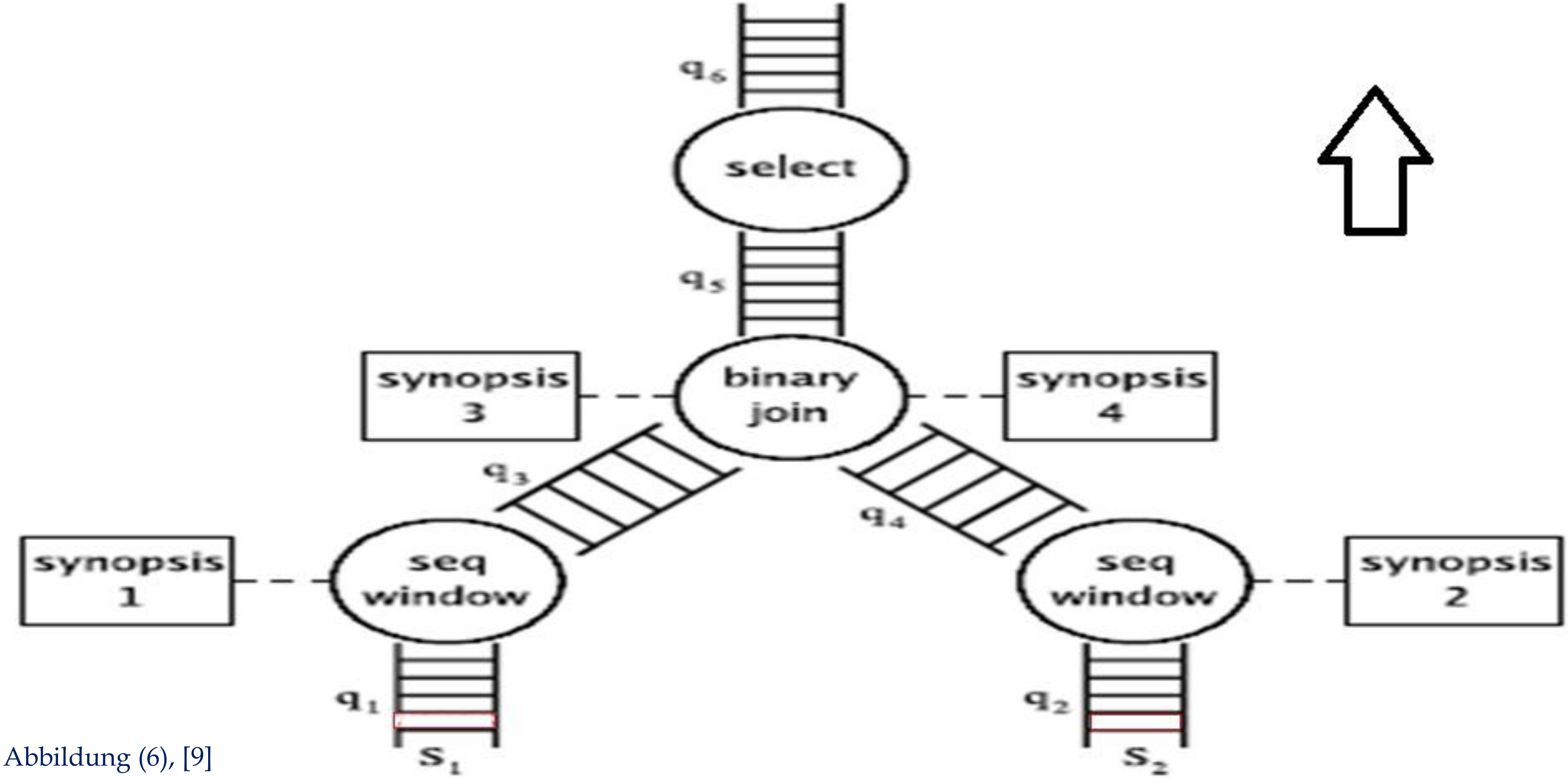


Abbildung (6), [9]

2.5 Query Plan - Optimizations

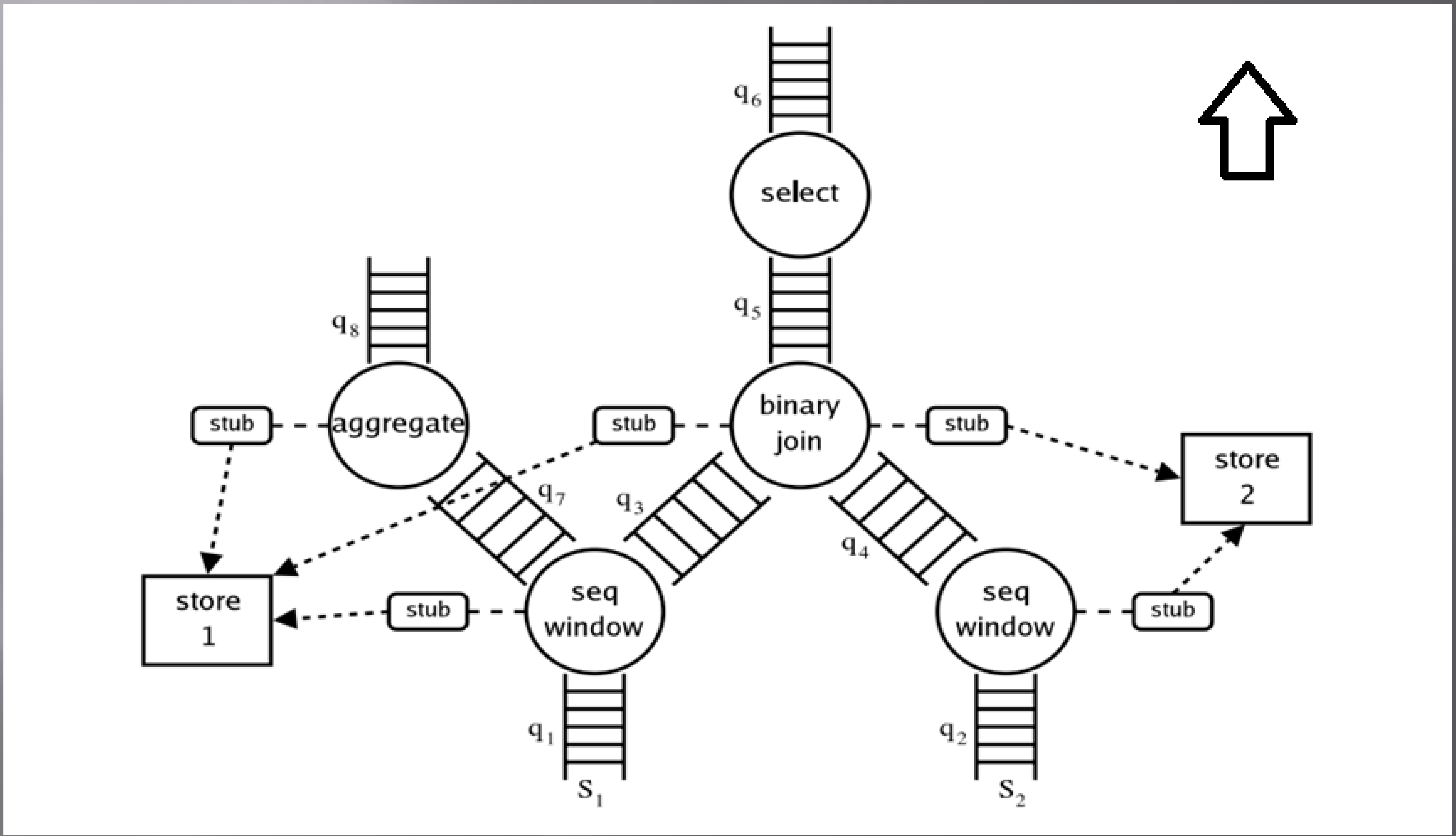


Abbildung (7), [9]

2.6 Query Approximation in DSMS

- Novel notions of optimization:
  - Stream rate based [e.g. NiagaraCQ]
  - Resource based [e.g. STREAM]
  - QoS based [e.g. Aurora]

2.6 Approximation

- Why we need Approximation?
- CPU-limited Approximation
- Memory-limited Approximation
- Static Approximation
- Dynamic Approximation

2.6 Why do we need approximation

- Handling load – streams comming too fast
- Avoid unbounded storage and computation
- 2 factors can become a constraint:
  - CPU
  - Memory

2.6 CPU-limited Approximation

- Data arrived too fast
- load-shedding - dropping elements from query plans and saving the CPU time that would be required to process them to completion

2.6 Memory-Limited Approximation

- too many queries -> memory becomes a constraint -> results may partly disappear
- memory usage can be reduced at the cost of accuracy by reducing the size of synopses

2.6 Static Approximation

- Optimization during submitting a new query to the system
  - window reduction
  - sampling rate reduction

2.6 Static Approximation – window reduction

- Reduction of the size of the window
  - Saving of compution time and storage
- Exception:
  - Elimination of duplicates
  - Negations

Select *

From Fotos Fo, Filme Fi

[Range 1 Day]

Where Fo.name = Fi.name

2.6 Static Approximation – Sampling Rate Reduction

- Minimization of the Input-Stream

Select *

From Fotos Fo Sample(30), Filme Fi [Range 1 Day]

Where Fo.name = Fi.name

2.6 Dynamic Approximation

- Optimization if the system is already running
  - Synopsis Compression
  - Sampling/Load Shedding

2.6 Dynamic Approximation - Synopsis Compression

- Reduction of the Synopsis Size
- Same approach as in Memory-Limited Approximation

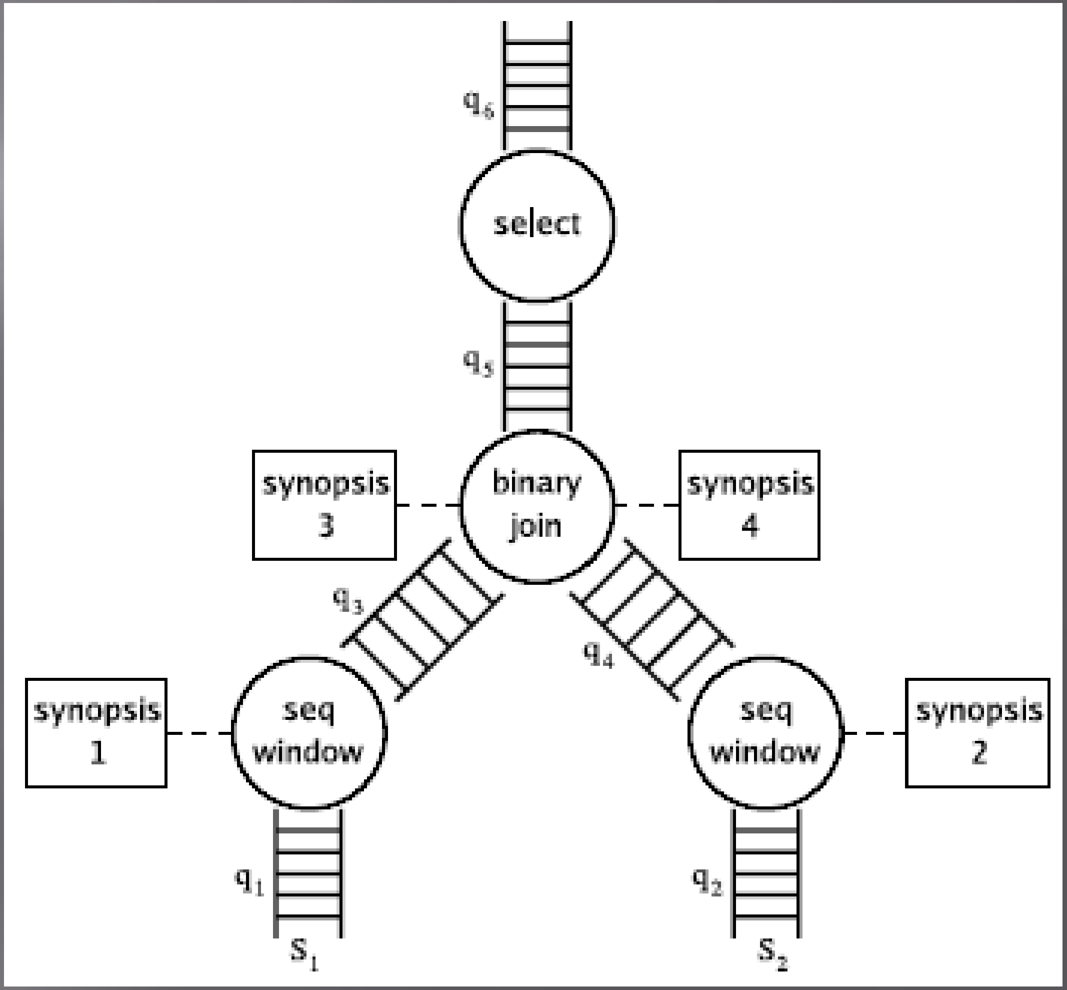


Abbildung (6), [9]

2.6 Dynamic Approximation - Sampling/Load Shedding

- Reduction of the memory usage
- Sampling:
  - Undistorted result
- Load-Shedding:
  - Easier to implement

2.7 Summarizing of STREAM

- CQL an expressive SQL-based declarative language
- Query Plan
  - One Query Plan for each Query
- Approximation
  - CPU-limited
  - Memory-limited
  - Static approximation
  - Dynamic approximation

3 Aurora Overview

- general
- Aurora vs. Stream
- Query Plan
- Optimizations
- Quality of Service

3.1 AURORA

- developed in cooperation of the M.I.T., the Brandeis University and the Brown University

3.2 STREAM vs. Aurora

STREAM

- Evey query has it own query plan
- Synopses and queues
- Direct entry of plans

AURORA

- One big query plan for all queries
- „Boxes and Arrows“ Paradigm
- Ad Hoc queries and views
- Qos for each output stream

3.2 Aurora

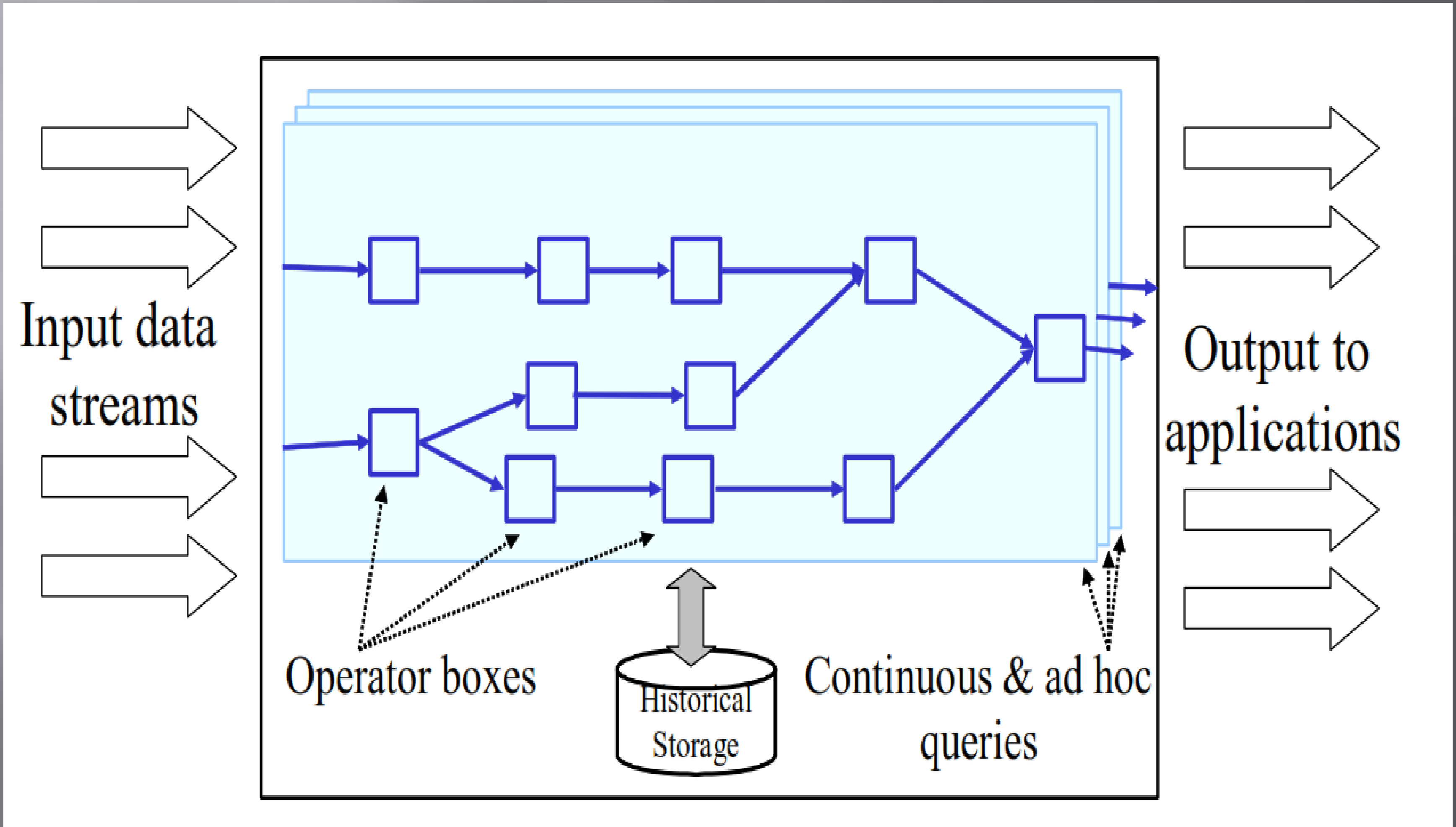


Abbildung (8), [10]

3.3 Query Language

- Based on eight primitive operations:
  - Windowed operators:
    - Slide
      - Advances a window by sliding it downstream by some tuples
    - Tumble
      - Resembles slide except that consecutive windows have no tuples in common
      - Partitions a stream into disjoint windows
    - Latch
      - Produces a partially synthetic stream by interpolating tuples between actual tuples of an input stream
  - non-windowed operators:
    - Filter
    - Drop
    - Map
    - Groupby
    - Join
  - Other Operators:
    - Resample

3.3 Query Plan

- Only one big plan (AURORA)
  - Easier to optimize
  - Adding or deleting queries always leads to bigger overhead

- One query plan for each query (STREAM)
  - Optimization is more difficult
  - Adding or deleting is quite easy

3.3 Query Plan

- 3 Modes
  - Continual queries
  - Views
  - Ad-hoc queries

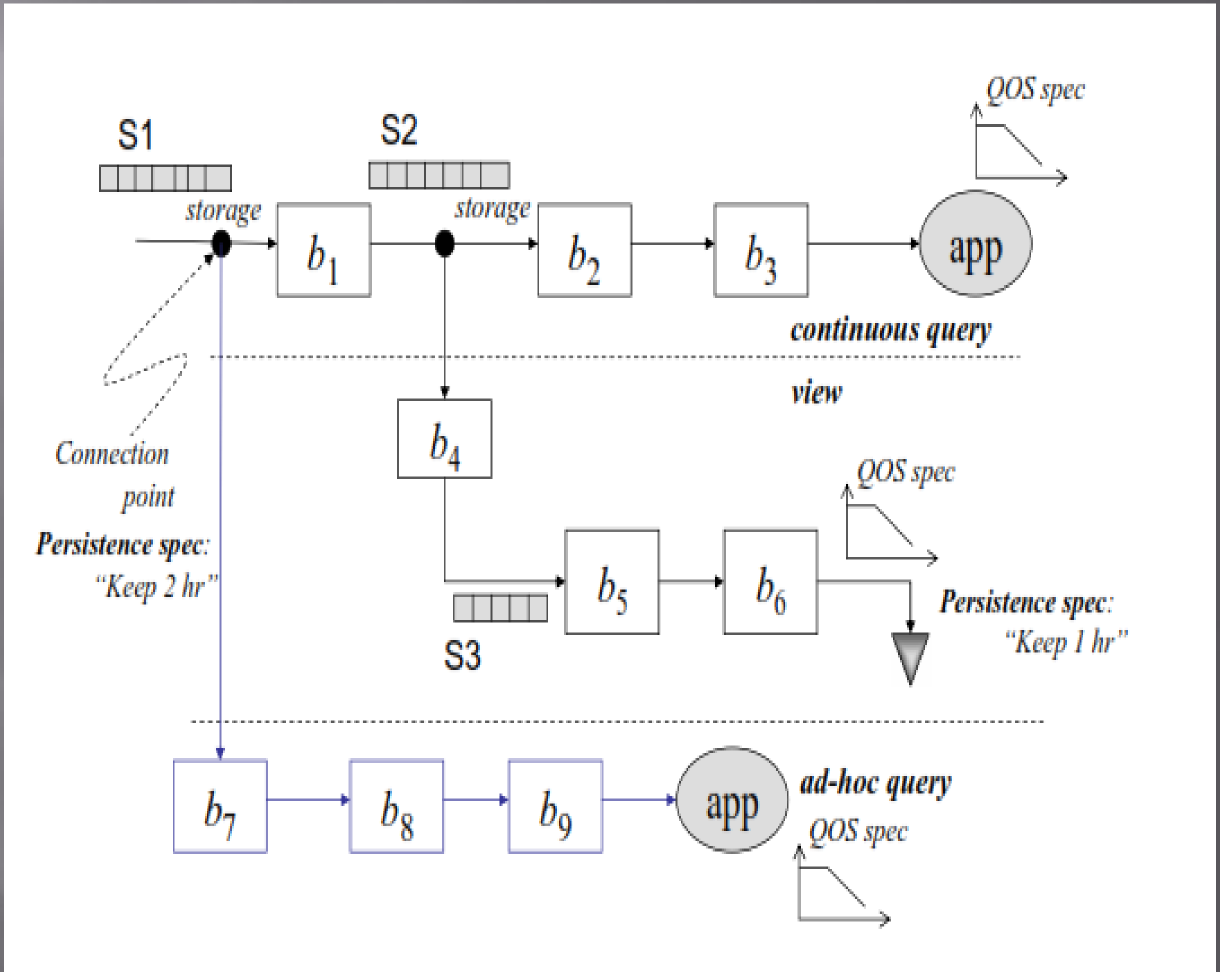


Abbildung (9) [10]

3.4 Optimization

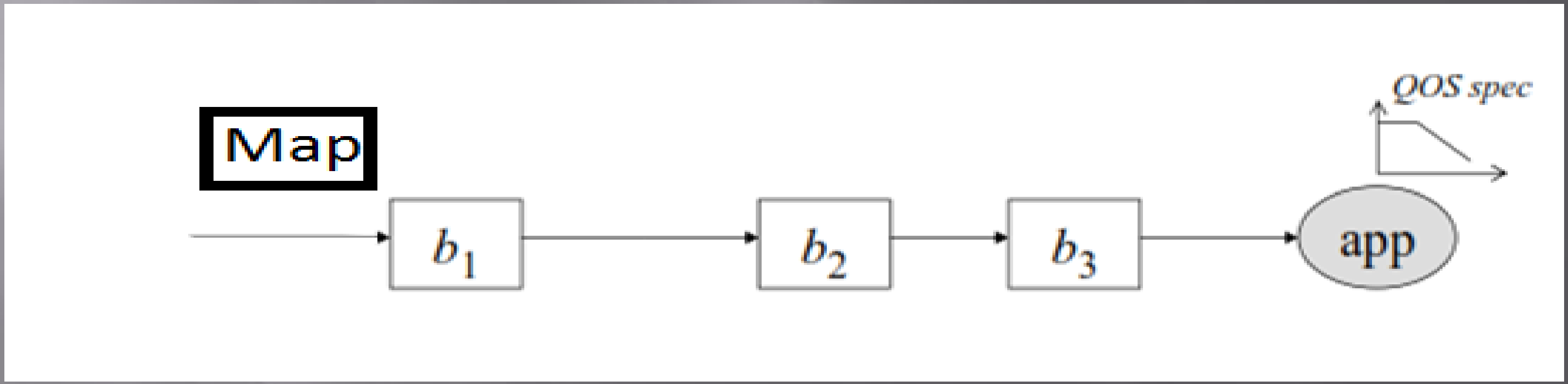
- Dynamic Continuous Query Optimization

3.4 Dynamic Continous Query Optimization

- Map-Operator
- Combination of Boxes
- Reordering of Boxes

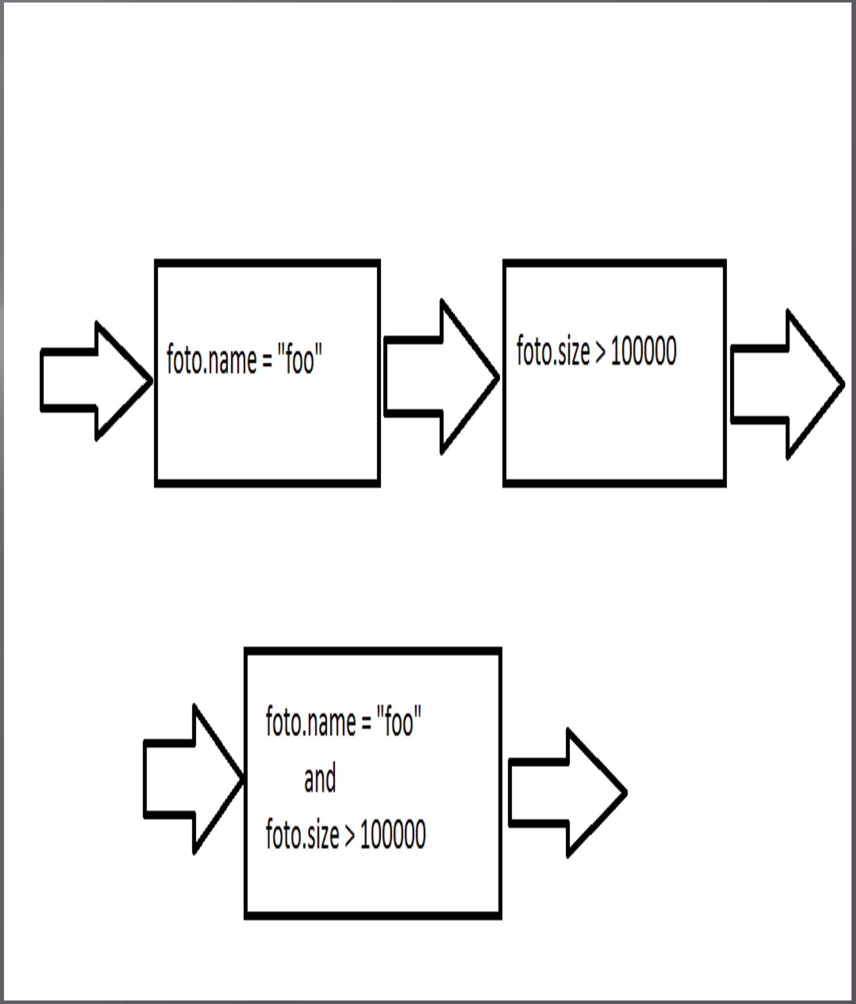
3.4 Map-Operator

- Inserting of the map Operator for eliminating uneeded tuples
- System must provide operator signatures



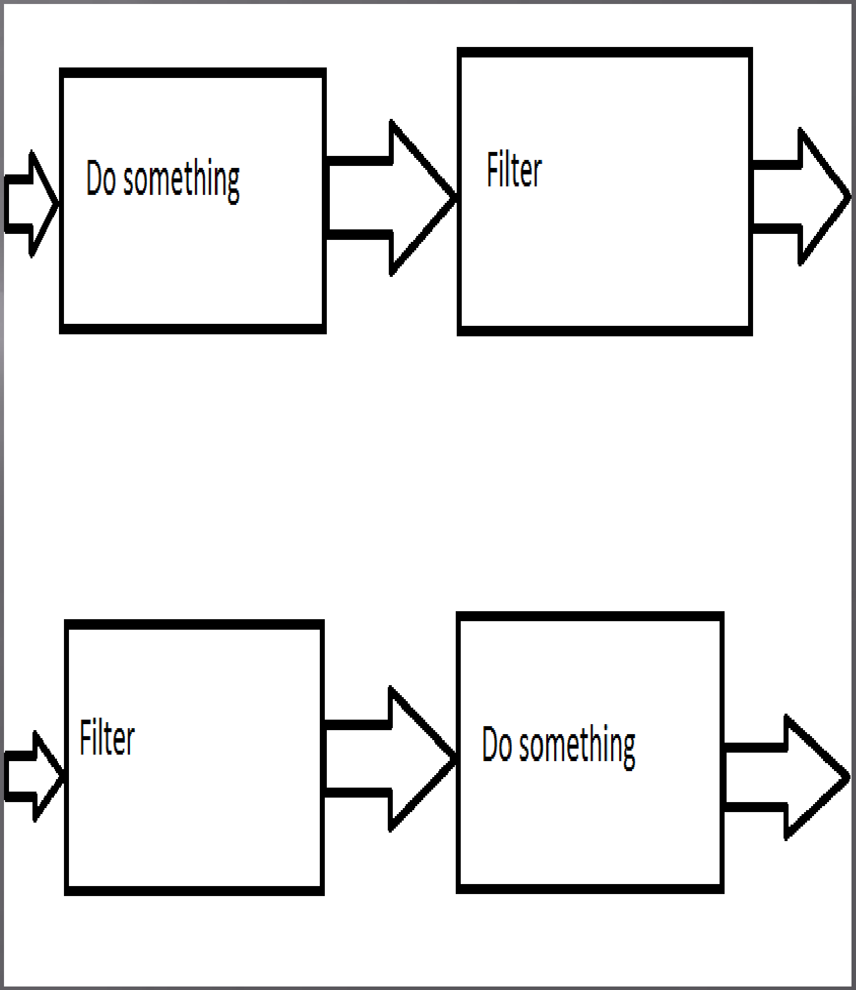
3.4 Combination of Boxes

- Combination of different boxes
- Saves overhead
- Reducing quantity of boxes



3.4 Reordering of Boxes

- For suspending tuples earlier in the query plan
- For example with pushing down a filter operator



3.5 Quality of Services (QoS)

- Aim: improve quality of the output
- Multidimensional function with 3 properities:
  - Delay
  - Tuples delivered
  - Output value

3.5 Quality of Service

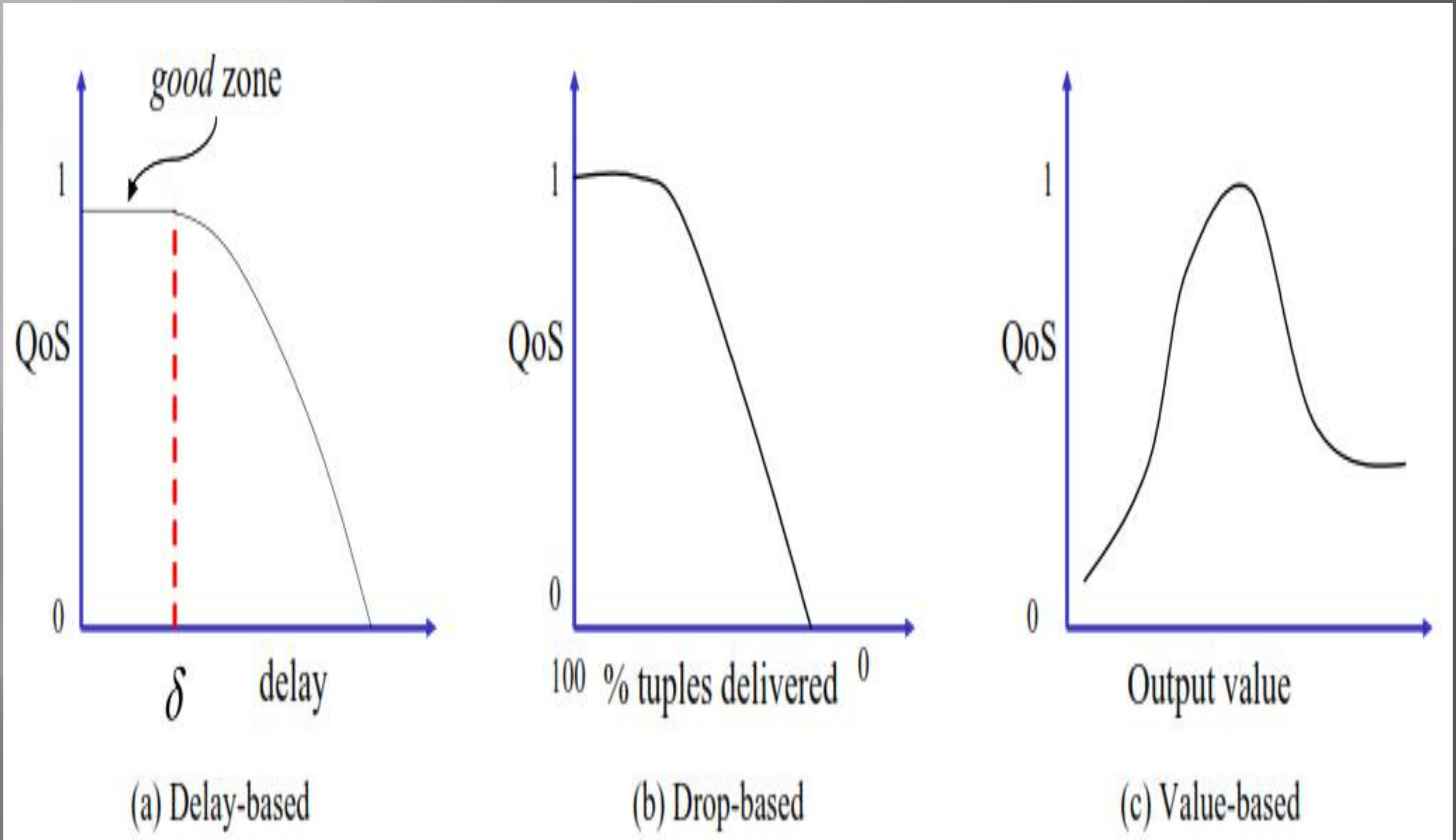


Abbildung (11),[10]

4 Conclusion

- Data Stream Processing is getting more and more important
- => so there are several projects to deal with it
- Between these projects you can find some differences
- Development is going on

THANK YOU

Any questions?